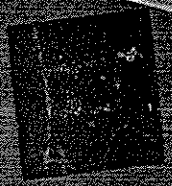
ESE 2018
Prelims Exam

MADE EASY Publications

Civil Engineering

Topicwise **Objective** Solved Papers

Volume-I



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23 Years
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ESE 2018

UPSC ENGINEERING SERVICES EXAMINATION

Preliminary Examination

Civil Engineering

Topicwise **Objective** Solved Questions

Volume-I

Topicwise Presentation	*Thoroughly Revised and Updated*

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ESE-2018 : Preliminary Examination
Civil Engineering : Volume-I
Topicwise Objective Solved Questions : (1995-2017)

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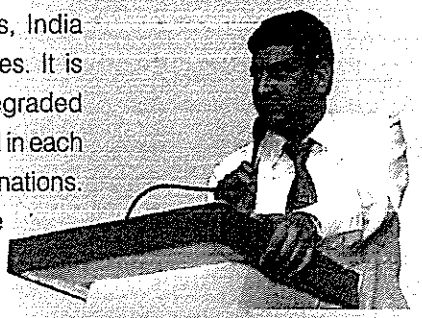
Director's Message



During the last few decades of engineering academics, India has witnessed geometric growth in engineering graduates. It is noticeable that the level of engineering knowledge has degraded gradually, while on the other hand competition has increased in each competitive examination including GATE and UPSC examinations. Under such scenario higher level efforts are required to take an edge over other competitors.

The objective of MADE EASY books is to introduce a simplified approach to the overall concepts of related stream in a single book with specific presentation. The topic-wise presentation will help the readers to study & practice the concepts and questions simultaneously.

B. Singh (Ex. IES)

The efforts have been made to provide close and illustrative solutions in lucid style to facilitate understanding and quick tricks are introduced to save time.

Following tips during the study may increase efficiency and may help in order to achieve success.

- Thorough coverage of syllabus of all subjects
- Adopting right source of knowledge, i.e. standard reading text materials
- Develop speed and accuracy in solving questions
- Balanced preparation of Paper-I and Paper-II subjects with focus on key subjects
- Practice online and offline modes of tests
- Appear on self assessment tests
- Good examination management
- Maintain self motivation
- Avoid jumbo and vague approach, which is time consuming in solving the questions
- Good planning and time management of daily routine
- Group study and discussions on a regular basis
- Extra emphasis on solving the questions
- Self introspection to find your weaknesses and strengths
- Analyze the exam pattern to understand the level of questions
- Apply shortcuts and learn standard results and formulae to save time

B. Singh (Ex. IES)
CMD, MADE EASY Group

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Civil Engineering

Volume-I

Objective Solved Questions

of UPSC Engineering Services Examination

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OOOO

UNIT

I

Building Materials

Syllabus

Stone, Lime, Glass, Plastics, Steel, FRP, Ceramics, Aluminum, Fly Ash, Basic Admixtures, Timber, Bricks and Aggregates: Classification, properties and selection criteria;

Cement: Types, Composition, Properties, Uses, Specifications and various Tests; Lime & Cement Mortars and Concrete: Properties and various Tests; Design of Concrete Mixes: Proportioning of aggregates and methods of mix design.

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OOOO

1 Cement

1.1 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Fineness of cement
B. Setting time
C. Soundness
D. Workability

List-II

1. Le-Chatelier apparatus
2. Vicat's needle
3. Air permeability apparatus
4. Slump cone

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	3	1	4	2
(c)	3	2	1	4
(d)	1	4	3	2

[ESE : 1995]

1.2 If 'p' is the standard consistency of cement, the amount of water used in conducting the initial setting time test on cement is

(a) 0.65p (b) 0.85p
(c) 0.6p (d) 0.8p

[ESE : 1995]

1.3 Assertion (A): Pozzolana is added to cement to increase early strength.

Reason (R): It offers greater resistance to the attack of aggressive waters.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

1.4 For complete hydration of cement the water-cement ratio needed is

(a) less than 0.25
(b) more than 0.25 but less than 0.35
(c) more than 0.35 but less than 0.45
(d) more than 0.45 but less than 0.60

[ESE : 1996]

1.5 Match List-I (Type of cement) with List-II (Characteristics) and select the correct answer using the codes given below the lists:

List-I

A. Air entraining portland cement
B. Low-heat portland cement
C. Hydrophobic portland cement
D. Rapid hardening portland cement

List-II

1. Suitable for very large structures
2. Unsuitable for very large masses of concrete
3. Greater resistance to frost attack
4. Safe storage under unfavourable conditions of humidity

Codes:

	A	B	C	D
(a)	4	2	1	3
(b)	3	4	1	2
(c)	3	1	4	2
(d)	4	1	2	3

[ESE : 1996]

1.6 Gypsum is used as an admixture in cement grouts for

(a) accelerating the setting time
(b) retarding the setting time
(c) increasing the plasticity
(d) reducing the grout shrinkage

[ESE : 1996]

1.7 Blast furnace slag has approximately

(a) 45% calcium oxide and about 35% silica
(b) 50% alumina and 20% calcium oxide
(c) 25% magnesia and 15% silica
(d) 25% calcium sulphate and 15% alumina

[ESE : 1996]

1.8 Which of the following pairs in respect of Ordinary Portland Cement (OPC) are correctly matched?
1. Initial setting time ... 30 minutes
2. Final setting time ... 10 hours
3. Normal consistency ... 10%
Select the correct answer using the codes given below:
(a) 1, 2 and 3 (b) 2 and 3
(c) 1 and 2 (d) 1 and 3
[ESE : 1997]

1.9 High alumina cement is produced by fusing together a mixture of
(a) limestone and bauxite
(b) limestone, bauxite and gypsum
(c) limestone, gypsum and clay
(d) limestone, gypsum, bauxite, clay and chalk
[ESE : 1997]

1.10 Consider the following statements:
High early strength of cement is obtained as a result of
1. fine grinding
2. decreasing the lime content
3. burning at higher temperatures
4. increasing the quantity of gypsum
Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2, 3 and 4 (d) 1, 3 and 4
[ESE : 1997]

1.11 Before testing setting time of cement one should test for
(a) soundness (b) strength
(c) fineness (d) consistency
[ESE : 1998]

1.12 The temperature range in a cement kiln is
(a) 500° to 1000°C (b) 1000° to 1200°C
(c) 1300° to 1500°C (d) 1600° to 2000°C
[ESE : 1998]

1.13 Consider the following statements:
1. Tests on cement paste to determine initial and final setting times are done at normal consistency condition.
2. Low heat cement has a high percentage of tricalcium aluminate.
3. High early strength portland cement contains a larger percentage of tricalcium silicate and a lower percentage of dicalcium silicate.
Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3
[ESE : 1999]

1.14 Match List-I (Property of cement) with List-II (Testing apparatus) and select the correct answer using the codes given below the lists:
List-I
A. Specific gravity
B. Setting time
C. Soundness
D. Fineness
List-II
1. Blain's apparatus
2. Le Chatelier's flask
3. Compressometer
4. Autoclave
5. Vicat's apparatus
Codes:

	A	B	C	D
(a)	3	5	1	2
(b)	2	5	1	4
(c)	2	5	4	1
(d)	5	3	4	1

[ESE : 1999]

1.15 The role of superplasticizer in a cement paste is to
(a) disperse the particles
(b) disperse the particles and to remove air bubbles
(c) disperse the particles, remove air bubbles and to retard setting
(d) retard setting
[ESE : 1999]

1.16 Consider the following oxides:
1. Al_2O_3 2. CaO 3. SiO_2
The correct sequence in increasing order of their percentage in an ordinary portland cement is
(a) 2, 1, 3 (b) 1, 3, 2
(c) 3, 1, 2 (d) 1, 2, 3
[ESE : 1999]

1.17 Increase in fineness of cement
(a) reduces the rate of strength development and leads to higher shrinkage
(b) increases the rate of strength development and reduces the rate of deterioration

(c) decreases the rate of strength development and increases the bleeding of cement
(d) increases the rate of strength development and leads to higher shrinkage

[ESE : 1999]

1.18 Match List-I (Cement) with List-II (Characteristic) and select the correct answer using the codes given below the lists:

List-I
A. High alumina cement
B. Blast furnace cement
C. Quick setting cement
D. Rapid hardening cement

List-II
1. High early strength
2. Gypsum free cement
3. Selenetic cement
4. Used in mass concrete work
5. Used in chemical factories and mines

Codes:

	A	B	C	D
(a)	5	4	2	1
(b)	4	3	2	1
(c)	5	4	3	2
(d)	4	5	1	2

[ESE : 2000]

1.19 The fineness of cement is tested by
(a) air-content method
(b) air-permeability method
(c) Le-Chatelier apparatus
(d) Vicat's apparatus

[ESE : 2000]

1.20 The test on cement designed to accelerate the slaking process of the ingredient of cement and to determine the resulting expansion in a short time is
(a) setting time test
(b) soundness test
(c) normal consistency test
(d) accelerated test

[ESE : 2000]

1.21 Consider the following statements:
High Alumina Cement (HAC)
1. has high early compressive strength and high heat of hydration than OPC-43 grade
2. is not suitable to be used in cold regions

Which of these statements is/are correct?
(a) 1 alone (b) 2 alone
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2001]

1.22 Consider the following statements:
When cement is tested for setting time; on gauging it shows quick setting. This phenomenon known as "Flash set" of cement is due to the presence of high
1. tricalcium aluminate (C_3A) in cement
2. alkalies in cement
3. tricalcium silicate (C_3S) in cement

Which of these statements are correct?
(a) 1, 2 and 3 (b) 2 and 3
(c) 1 and 2 (d) 1 and 3

[ESE : 2001]

1.23 Which one of the following statements regarding the cement fineness is NOT correct?
(a) Fine cement is more liable to suffer from shrinkage cracking than a coarse cement.
(b) Fine cement will show faster rate of hardening than coarse cement.
(c) Fine cement shows faster rate of heat evolution and total quantity of heat evolved is much large than coarse cement.
(d) Fine cement shows the same setting time as coarse cement.

[ESE : 2001]

1.24 For marine works, the best suited cement is
(a) low heat portland cement
(b) rapid hardening cement
(c) ordinary portland cement
(d) blast furnace slag cement

[ESE : 2001]

Directions: The following items consists of two statements; one labelled as **'Statement (I)'** and the other as **'Statement (II)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

1.25 **Assertion (A):** Flash set is the stiffening of the cement paste within a few minutes after mixing.
Reason (R): Flash set occurs due to insufficient gypsum to control the rapid reaction of C_3A with water.

[ESE : 2002]

1.26 **Assertion (A):** The amount of cement paste should be sufficient to cover the surface of all particles for proper workability and bond.
Reason (R): The water-cement ratio is fixed accordingly.

[ESE : 2002]

1.27 **Assertion (A):** The higher percentage of tricalcium silicate in cement results in rapid hardening with an early gain in strength at a higher heat of hydration.
Reason (R): A higher percentage of dicalcium silicate in cement results in slow hardening and less heat of hydration and greater resistance to chemical attack.

[ESE : 2002]

1.28 **Assertion (A):** For a given composition, a finer cement will develop strength and generate heat more quickly than a coarse cement.
Reason (R): The reaction between water and cement starts on the surface of the cement particles and in consequence the greater the surface area of a given volume of cement, the greater the hydration.

[ESE : 2002]

1.29 Match List-I (Type of cement) with List-II (Characteristics) and select the correct answer using the codes given below the lists:

List-I
A. Ordinary portland cement
B. Rapid hardening cement
C. Low heat cement
D. Sulphate resistant cement

List-II
1. The percentage of C_3S is maximum and is of the order of 50%
2. The percentages of C_2S and C_3S are the same and of the order of 40%
3. Reacts with silica during burning and causes particles to unite together and development of strength
4. Preserves the form of brick at high temperature and prevents shrinkage

Codes:

	A	B	C	D
(a)	2	4	1	3
(b)	3	1	4	2
(c)	2	1	4	3
(d)	3	4	1	2

[ESE : 2002]

1.30 Match List-I (Type of cement) with List-II (Property/Characteristic) and select the correct answer using the codes given below the lists:

List-I
A. High strength portland cement
B. Super sulphated cement
C. High alumina cement
D. Rapid hardening portland cement

List-II
1. Should not be used with any admixture
2. Is extremely resistant to chemical attack
3. Gives a higher rate of heat development during hydration of cement
4. Has a higher content of tricalcium silicate

Codes:

	A	B	C	D
(a)	3	2	1	4
(b)	4	1	2	3
(c)	3	1	2	4
(d)	4	2	1	3

[ESE : 2002]

1.31 Four main oxides present in ordinary portland cement are: CaO, Al_2O_3, SiO_2 and Fe_2O_3. Identify the correct ascending order of their proportions in a typical composition of OPC.
(a) Al_2O_3, Fe_2O_3, CaO, SiO_2
(b) Al_2O_3, CaO, Fe_2O_3, SiO_2
(c) Fe_2O_3, Al_2O_3, SiO_2, CaO
(d) Fe_2O_3, SiO_2, Al_2O_3, CaO

[ESE : 2002]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

1.32 **Assertion (A):** The greater the surface area of a given volume of cement the greater the hydration.
Reason (R): The reaction between the water and cement starts from the surface of the cement particles.

[ESE : 2003]

1.33 **Assertion (A):** A low C_3A cement generates less heat and develops higher ultimate strength.
Reason (R): During setting and hardening, the amount of lime liberated appears to be about 15 to 20 per cent by weight of cement.

[ESE : 2003]

1.34 The proper size of mould for testing compressive strength of cement is
(a) 7.05 cm cube (b) 10.05 cm cube
(c) 15 cm cube (d) 12.05 cm cube

[ESE : 2003]

1.35 The specific gravity of commonly available ordinary portland cement is
(a) 4.92 (b) 3.15
(c) 2.05 (d) 1.83

[ESE : 2003]

1.36 A quick-setting cement has an initial setting time of about
(a) 50 minutes (b) 40 minutes
(c) 15 minutes (d) 5 minutes

[ESE : 2003]

1.37 Consider the following statements:
Low percentage of C_3S and high percentage of C_2S in cement will result in
1. higher ultimate strength with less heat generation
2. rapid-hardening
3. better resistance to chemical attack
Which of these statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

[ESE : 2004]

1.38 Match List-I (Type of cement) with List-II (Property) and select the correct answer using the codes given below the lists:

List-I
A. Blast furnace slag cement
B. High alumina cement
C. Low heat cement
D. White cement

List-II
1. High percentage of tricalcium silicate
2. Initial setting time is approximately three and a half hours
3. Low percentage of iron oxide
4. Rate of hardening is low

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	1	3	4	2
(c)	1	2	4	3
(d)	4	2	1	3

[ESE : 2004]

1.39 Match List-I (Type of cement) with List-II (Characteristics) and select the correct answer using the codes given below the lists:

List-I
A. Rapidly hardening cement
B. Low heat portland cement
C. Portland pozzolana cement
D. Sulphate resisting cement

List-II
1. Lower C_3A content than that in OPC
2. Contains pulverised fly ash
3. Higher C_3S content than that in OPC
4. Lower C_3S and C_3A contents than that in OPC

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	3	4	2	1
(c)	1	4	2	3
(d)	3	2	4	1

[ESE : 2005]

1.40 Match List-I (Apparatus) with List-II (Purpose) and select the correct answer using the codes given below the lists:

List-I
A. Le-chatelier
B. Vicat needle with annular collar
C. Vee-Bee
D. Briquettes test machine

List-II
1. Workability of concrete
2. Soundness of cement
3. Tensile strength of cement
4. Final setting time of cement

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	2	4	1	3
(c)	1	4	2	3
(d)	2	3	1	4

[ESE : 2005]

1.41 **Assertion (A):** Low heat portland cement is used in dam construction.
Reason (R): Low heat portland cement attains higher 28 days strength than ordinary portland cements.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2006]

1.42 Match List-I (Job requirement) with List-II (Type of cement binder) and select the correct answer using the codes given below the lists:

List-I
A. High early strength
B. Lining for canals
C. Frost and acid resistance
D. Marine structure

List-II
1. Pozzolanic cement
2. Rapid hardening cement
3. Sulphate resisting cement
4. High alumina cement

Codes:

	A	B	C	D
(a)	1	4	3	2
(b)	2	3	4	1
(c)	1	3	4	2
(d)	2	4	3	1

[ESE : 2006]

1.43 As per specifications, the initial setting time of ordinary portland cement should not be less than
(a) 10 minutes (b) 20 minutes
(c) 30 minutes (d) 60 minutes

[ESE : 2006]

1.44 In cements, generally the increase in strength during a period of 14 days to 28 days is primarily due to
(a) C_3A (b) C_2S
(c) C_3S (d) C_4AF

[ESE : 2006]

1.45 Consider the following types of cements :
1. Portland pulverized fuel ash cement
2. High alumina cement
3. Ordinary portland cement
4. Rapid hardening cement

Which one of the following is the correct sequence of the above cements in terms of their increasing rate of strength gain ?
(a) 2-3-4-1 (b) 1-3-4-2
(c) 2-1-3-4 (d) 3-1-2-4

[ESE : 2007]

1.46 Ultimate strength of cement is influenced by which one of the following?
(a) Tricalcium silicate
(b) Dicalcium silicate
(c) Tricalcium aluminate
(d) Tetracalcium alumino-ferrite

[ESE : 2007]

1.47 Consider the following statements:
1. Setting and hardening of cement takes place after the addition of water.
2. Water causes hydration and hydrolysis of the constituent compounds of cement which act as binders.

Which of these statements is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2007]

1.48 Match List-I (Composition of raw material used in manufacture of cement) with List-II (Component of raw material) and select the correct answer using the codes given below the lists:

List-I	List-II
A. 25%	1. Silica
B. 65%	2. Calcium oxide
C. 5%	3. Aluminium oxide
D. 5%	4. Ferrous and magnesium oxides

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	4	3	2	1
(c)	1	3	2	4
(d)	4	2	3	1

[ESE : 2008]

1.49 Match List-I (Compound) with List-II (Proportion) in respect of ordinary Portland cement and select the correct answer using the codes given below the lists:

List-I

A. Tricalcium silicate
B. Dicalcium silicate
C. Tricalcium aluminate
D. Tetra calcium alumino ferrite

List-II

1. 25 to 30%
2. 50 to 60%
3. 6 to 8%
4. 8 to 12%

Codes:

	A	B	C	D
(a)	2	3	4	1
(b)	4	1	2	3
(c)	2	1	4	3
(d)	4	3	2	1

[ESE : 2008]

1.50 Match List-I (Equipment) with List-II (Property) and select the correct answer using the codes given below the lists:

List-I

A. Briquette testing machine
B. Le Chatelier apparatus
C. Vicat apparatus

List-II

1. Compressive strength
2. Consistency
3. Soundness
4. Tensile strength

Codes:

	A	B	C
(a)	1	3	2
(b)	1	2	3
(c)	4	2	3
(d)	4	3	2

[ESE : 2008]

1.51 **Assertion (A):** The rate of hydration is faster in finer cements.

Reason (R) : The surface area of fine cement is more in case of finer cement.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2009]

1.52 What is the requirement of water (expressed as % of cement w/w) for the completion of chemical reactions in the process of hydration of OPC ?

(a) 10 to 15% (b) 15 to 20%
(c) 20 to 25% (d) 25 to 30%

[ESE : 2009]

1.53 If P is the percentage of water required for determination of normal consistency of cement, then percentage of water to be added for determination of initial setting time is

(a) 0.70 P (b) 0.75 P
(c) 0.80 P (d) 0.85 P

[ESE : 2010]

1.54 A cement bag contains 0.035 cubic meter of cement by volume. How many bags will one tonne of cement comprise?

(a) 16 (b) 17
(c) 18 (d) 20

[ESE : 2010]

1.55 **Assertion (A):** Low heat cement is used in the construction of large dams.

Reason (R): Very high compressive strength is achieved by low heat cement in 28 days.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false
(d) A is false but R is true

[ESE : 2010]

1.56 If 'W' is the percentage of water required for normal consistency of cement, water to be added for determination of initial setting time is
(a) 0.50 W (b) 0.62 W
(c) 0.75 W (d) 0.85 W

[ESE : 2011]

1.57 Match List-I (Grade of cement and Age) with List-II (Compressive strength in N/mm^2) and select the correct answer using the code given below the lists:

List-I	List-II
A. Grade 33 (7 days)	1. 27
B. Grade 43 (28 days)	2. 43
C. Grade 53 (3 days)	3. 22
D. Grade 43 (7 days)	4. 33

Codes:

	A	B	C	D
(a)	4	2	1	3
(b)	3	2	1	4
(c)	4	1	2	3
(d)	3	1	2	4

[ESE : 2011]

1.58 Consider the following statements:
More than 6% magnesium oxide by weight in cement results in
1. high early strength and high heat generation.
2. less tendency towards volume change and formation of cracks

Which of these statements is/are correct?
(a) 1 only (b) 2 only
(c) Neither 1 nor 2 (d) Both 1 and 2

[ESE : 2012]

1.59 Fineness of cement is measured in the units of
(a) volume/mass (b) mass/volume
(c) area/mass (d) mass/area

[ESE : 2012]

1.60 The initial setting time of cement depends most on
(a) tri-calcium aluminate
(b) tri-calcium silicate
(c) tri-calcium alumino-ferrite
(d) di-calcium silicate

[ESE : 2012]

1.51 Gypsum is added into the raw materials during manufacture of cement so that the final product exhibits
(a) retarded initial setting time
(b) improved modulability for cornices, etc.
(c) increased compressive strength
(d) augmented bond strength

[ESE : 2012]

1.62 **Statement-I** : Finer grinding of cement results in early development of strength.
Statement-II : Rate of hydration of cement is increased when it is ground finer.
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

[ESE : 2012]

1.63 Soundness test of cement is carried out of determine its
(a) alumina content
(b) iron oxide content
(c) free lime content
(d) durability under sea water

[ESE : 2013]

1.64 The objectives of producing cement include
1. Incorporating industrial wastes
2. Increasing free lime
3. Increasing fineness
4. Saving energy needed in the process

(a) 1, 2, 3 and 4
(b) 1, 3 and 4 only
(c) 1, 2 and 4 only
(d) 2, 3 and 4 only

[ESE : 2013]

1.65 Which compound of cement is responsible for strength of cement?
(a) Magnesium oxide
(b) Silica
(c) Alumina
(d) Calcium sulphate

[ESE : 2014]

1.66 Which type of cement is recommended in large mass concrete works such as a dam?
(a) Ordinary Portland
(b) High Alumina
(c) Low-heat Portland
(d) Portland Pozzollona
[ESE : 2014]

1.67 Consider the following statements regarding 'setting of cement' :
1. Low-heat cement sets faster than OPC.
2. Final setting time decides the strength of cement.
3. Initial setting time of Portland Pozzollona is 30 minutes.
4. Air-induced setting is observed when stored under damp conditions.
5. Addition of gypsum retards the setting time.

Which of the above statements are correct?
(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 3, 4 and 5 (d) 2, 3 and 5
[ESE : 2014]

1.68 Consider the following statements regarding 'strength of cement' :
1. Strength test on cement is made on cubes of cement sand mix.
2. Water to be used for the paste is 0.25P, where P is the water needed for normal consistency.
3. The normal consistency is determined on Le Chatelier's apparatus.
4. Cubes are cast in two layers in leak-proof moulds further compacted in each layer by vibration on a machine.

Which of the above statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 and 4 (d) 3 and 4
[ESE : 2014]

1.69 Statement (I) : Quick-setting cement with initial setting time of 5 minutes is used in underwater constructions.

Statement (II) : Aggregate and cement are mixed dry, and the mixture is then dumped in water.
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true
[ESE : 2014]

1.70 One bag of Portland cement, 50 kg in weight, would normally have a bulk volume of
(a) 30 *l* (b) 35 *l*
(c) 40 *l* (d) 45 *l*
[ESE : 2015]

1.71 Consider the following forms of water in a hydrated cement paste:
1. Capillary water
2. Chemically combined water
3. Interlayer water
4. Adsorbed water

Which of the above forms of water will, on its/ their removal, cause shrinkage of the paste?
(a) 1, 2 and 3 (b) 1, 2 and 4
(c) 2, 3 and 4 (d) 1, 3 and 4
[ESE : 2015]

1.72 Consider the following statements:
High early strength of cement is obtained as a result of
1. Fine grinding
2. Decreasing the lime content
3. Burning at higher temperature
4. Increasing the quantity of gypsum

Which of the above statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 3 and 4
[ESE : 2015]

1.73 Assertion (A): Air-entraining cement has a higher initial setting time than o.p.c. and resists frost action better.
Reason (R): Air-entraining cement has a longer final setting time compared to o.p.c.
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 2015]

1.74 Which of the following statements is/are correct regarding the strength of cement?
1. Particle sizes less than 3 μm increase the viscous nature of the cement.
2. Finer particles in cement can be replaced by fly-ash to improve the strength.
(a) 1 only (b) 2 only
(b) Both 1 and 2 (d) Neither 1 nor 2
[ESE : 2016]

1.75 The constituent compound in Portland cement which reacts immediately with water, and also sets earliest, is
(a) Tricalcium silicate
(b) Dicalcium silicate
(c) Tricalcium aluminate
(d) Tetracalcium aluminoferrite
[ESE : 2016]

1.76 **Statement (I)** : Finer the cement, greater is the need for water for hydration and workability.
Statement (II) : Bleeding of a mix occurs due to low water-cement ratio.
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is *not* the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true
[ESE : 2016]

Answers Cement

1.1 (c)	1.2 (b)	1.3 (d)	1.4 (c)	1.5 (c)	1.6 (b)	1.7 (a)	1.8 (c)	1.9 (a)
1.10 (b)	1.11 (d)	1.12 (c)	1.13 (*)	1.14 (c)	1.15 (c)	1.16 (b)	1.17 (d)	1.18 (a)
1.19 (b)	1.20 (b)	1.21 (a)	1.22 (d)	1.23 (c, d)	1.24 (d)	1.25 (a)	1.26 (b)	1.27 (b)
1.28 (a)	1.29 (b)	1.30 (c)	1.31 (c)	1.32 (a)	1.33 (c)	1.34 (a)	1.35 (b)	1.36 (d)
1.37 (c)	1.38 (c)	1.39 (b)	1.40 (b)	1.41 (c)	1.42 (b)	1.43 (c)	1.44 (c)	1.45 (c)
1.46 (b)	1.47 (c)	1.48 (a)	1.49 (c)	1.50 (a)	1.51 (a)	1.52 (c)	1.53 (d)	1.54 (d)
1.55 (c)	1.56 (d)	1.57 (b)	1.58 (c)	1.59 (c)	1.60 (a)	1.61 (a)	1.62 (a)	1.63 (c)
1.64 (b)	1.65 (b)	1.66 (c)	1.67 (c)	1.68 (c)	1.69 (c)	1.70 (b)	1.71 (d)	1.72 (b)
1.73 (c)	1.74 (*)	1.75 (c)	1.76 (c)					

Explanations Cement

1.2 (b)
As per IS: 4031 Part 5-1988,while conducting initial setting time test on cement, a neat cement paste is prepared by gauging the cement with 0.85 times the water required to give a paste of standard consistency.

1.3 (d)
Portland-pozzolana cement produces less heat of hydration and offers greater resistance to sulphate attack and chloride-ion penetration due to impurities in water than normal portland cement. All pozzolanas need not necessarily contribute to strength at early ages.

1.4 (c)
On an average 25% of water by weight of cement is required for chemical reaction with portland cement compounds. About 17% water by weight of cement is required to fill the gel-pores. Thus 42% water by weight is required for chemical reaction and gel pores. If more than 42% of water

is used, the excess will cause undesirable cavities.

1.6 (b)

The retarder is an admixture that slow down the chemical process of hydration so that concrete remains plastic and workable for a longer time than concrete without the retarder. Gypsum is used in grouting to retard the setting time.

1.7 (a)

Blast furnace slag composition

CaO	:	42.4%
SiO_2	:	32.3%
Al_2O_3	:	13.3%
Fe_2O_3	:	0.3%
MgO	:	6.4%
SO_3	:	2.1%

1.8 (c)

According to IS code for Ordinary Portland Cement initial setting time should not be less than 30 minutes, final setting time should not be more than 600 minutes and normal consistency ranges from 20%-30% by weight of cement.

1.9 (a)

The raw materials used for manufacturing of high alumina cement are limestone and bauxite.

1.10 (b)

Gypsum is a retarder and prevents flash set. The rapid rate of development of strength is attributed to higher fineness and higher C_3S and lower C_2S content. Thus decreasing lime content will not result in rapid hardening or high early strength cement. The OPC has 63% CaO while rapid hardening cement has 64.5% CaO. A slight increase of CaO causes considerable increase in C_3S converting the OPC to a rapid hardening cement. A slight decrease in CaO and increase in SiO_2 decreases considerably the proportion of C_3S and increases proportion of C_2S thus forming low heat cement.

1.11 (d)

The test before which consistency test is required are:

(i) Initial and final setting time tests at water content 0.85P.

(ii) Compressive strength test at water content $\frac{P}{4}+3\%$ of combined weight of 1 : 3 cement and Ennore (standard) sand mix.

(iii) Sound test by Le Chatelier apparatus at 0.78P for free lime soundness.

1.13 (*)

Low heat cement has a low percentage of C_3A and C_3S, instead C_2S content is increased at the cost of C_3A and C_3S.

Test on cement paste to determine initial and final setting times are not done at normal consistency but at 85% of normal consistency.

So only third statement is correct.

1.14 (c)

Autoclave test measures soundness due to both magnesia and free lime.

Fineness is measured by:

(i) Sieve test

(ii) Air permeability method using Blaine's apparatus

1.15 (c)

Superplasticizer enhance workability of concrete by dispersing the cement particles. They impart negative charges to individual particles. Thus they confer high mobility to particles.

The setting time may be retarded due to overdose of admixture or by lowering of ambient temperature.

The superplasticizers leave very few air void and thus decrease freezing and thawing resistance.

1.16 (b)

Oxides composition			Compounds composition		
CaO	—	63	C_3S	—	40
SiO_2	—	20.6	C_2S	—	30
Al_2O_3	—	6.3	C_3A	—	11
K_2O_3	—	3.6	C_4AF	—	11

1.17 (d)

Increase in fineness of cement increases rate of strength development by expediting the hydration reactions and increases shrinkage by leading to stronger reaction with alkali reactive aggregate making it more prone to cracking.

1.18 (a)

Blast furnace cement due to its low rate of heat evolution is used in mass concrete work. Quick setting cement is gypsum free cement (gypsum is added to slow down the process of setting). Rapid hardening cement has high early strength than normal OPC. High alumina cement is used in chemical factories and mines.

1.19 (b)

Blaine's air permeability method is used to test fineness of cement.

1.20 (b)

The expansion of cement due to presence of free lime and magnesia. It is determined by the soundness test.

1.21 (a)

High Alumina Cement (HAC) is very reactive and produces very high early strength. Therefore it can be used in cold regions.

1.22 (d)

The compound tricalcium aluminate (C_3A) is fast reacting and may lead to immediate stiffening of paste, and this process is termed flash set. The role of gypsum is to prevent such a fast reaction. Similarly C_3S may also cause flash setting if present in excessive amounts.

Alkalies cause alkali-aggregate reaction which increases volume of concrete and causes spalling.

1.23 (c, d)

Total quantity of heat evolved is same far both fine as well as coarse cement. However find cement has lower setting time than, coarse cement.

1.24 (d)

Blast furnace slag cement offers high resistance to sulphate and chloride attacks.

1.25 (a)

Gypsum is added to prevent fast reaction. Insufficient gypsum lets rapid reaction of C_3A with water leading to stiffening of cement paste (i.e Flash set)

1.26 (b)

Only strength of cement depends on water cement ratio provided the mix is workable.

1.28 (a)

Fine cement has more surface area than coarse cement. Since more surface area is available for chemical reaction, finer cement has higher rate of hydration. This results in quick development of strength and generation of heat.

1.30 (c)

Super sulphated cement is manufactured by grinding together a mixture of 80-85% granulated slag, 10-15% burnt gypsum and 5% portland cement clinker. This product is ground finer than that of portland cement.

1.32 (a)

The finer the cement, the more the surface area and greater the hydration as more surface area is available for water and cement reaction. Hydration starts from the surface of cement particles.

1.33 (c)

C_3A (tricalcium aluminate) reacts with water in the start of hydration and generates heat of hydration at fast rate. So lower C_3A will generate less heat. The ultimate strength depends upon C_3S and C_2S. Lower C_3A means higher C_3S and C_2S and higher ultimate strength.

The product of hydration are calcium hydroxide $Ca(OH)_2$ and calcium silicate hydrate ($C_3S_2H_3$), a gel structure.

1.34 (a)

The mould size should be 7.06 cm cube as per IS 4031(Part-6) 1988.

1.35 (b)

Specific gravity of OPC is 3.15 and is measured using Le-chatelier's flask.

1.36 (d)

Quick setting cement is produced by adding a small percentage of aluminium sulphate and by finely grinding the cement. The percentage of gypsum or retarder for setting action is also greatly reduced. The addition of aluminium sulphate and fineness of grinding are responsible for accelerating the setting action of cement. The setting of cement starts within 5 minutes after addition of water and it becomes hard like stone in less than 30 minutes or so.

1.37 (c)

C_3S and C_2S together constitute about 70%-80% of the cement and control most of the strength giving properties. Upon hydration both give the same product called calcium silicate hydrate ($C_3S_2H_3$) and calcium hydroxide. Tricalcium silicate (C_3S) having a faster rate of reaction is accompanied by greater heat evolution develops early strength. On the other hand, dicalcium silicate (C_2S) hydrates and hardens slowly and provides much of ultimate strength. C_2S provide more resistance to chemical attack. Thus a higher C_3S percentage results in rapid hardening with early gain in strength at a higher heat of hydration. On the other hand, higher C_2S percentage results in slow hardening, less heat of hydration, higher ultimate strength and greater resistance to chemical attack.

1.38 (c)

Blast furnace slag cement has high percentage of C_3S. It is less reactive than OPC and gains strength slowly during first 28 days. Low heat cement's rate of hardening is low and has low content of C_3S and C_3A. High alumina cement has initial setting time of about 3.5 hours and final setting time of about 5 to 5.5 hours. White cement has low percentage of Iron oxide (Iron oxide gives grey colour to OPC).

1.41 (c)

The lower heat evolution is suitable for mass concreting in dam construction. However, the low heat cement attains same strength as that of OPC.

1.42 (b)

Pozzolanic cement evolves less heat during setting, therefore it is used for mass concreting like marine structures.

Rapid hardening cement attains high strength in early days.

In sulphate resisting cement the percentage of C_3A is kept below 5% and it results in the increase in resisting power against sulphate. This cement is used for structures which are likely to be damaged by severe alkaline conditions such as canal linings, culverts, syphons, etc.

High alumina cement evolves great heat during setting. It is therefore not affected by frost and resists the action of acids in a better way.

1.43 (c)

Initial setting time should not be less than 30 minutes and final setting time should not be greater than 600 minutes as per IS 12269.

1.44 (c)

14-28 day strength is mainly contributed by C_3S. Ultimately both C_3S and C_2S contribute to the strength.

1.45 (c)

The increase in strength of cement with time depends on the C_2S content of cement. C_2S is responsible for the ultimate strength of cement. Rapid hardening cement has the highest C_2S content and high alumina cement has the lowest.

1.46 (b)

Dicalcium silicate is responsible for ultimate strength while Tricalcium silicate is responsible for early strength of cement.

1.47 (c)

After water is added, setting and hardening of cement takes place due to hydration and hydrolysis of constituent compounds of cement.

1.48 (a)

Approximate oxide composition of raw materials used in manufacture of cement

Oxide	Percent content	Average
CaO	60-67	62
SiO_2	17-25	22
Al_2O_3	3.0-8.0	5
Fe_2O_3	0.5-6.0	3
MgO	0.1-3.0	2
Alkalies (K_2O_3, Na_2O)	0.4-1.3	1
SO_3	1.0-3.0	1.5

1.49 (c)

Compound	Proportion (wt%)	Average
Tricalcium Silicate	30-50	40%
Dicalcium Silicate	20-45	32%
Tricalcium aluminate	8-12	10.57%
Tetracalcium alumino ferrite	6-10	9%

1.51 (a)

Surface area is more for fine cement than coarse cement for a given weight of cement. As more surface area is available for chemical reaction, the rate of hydration in finer cement is more.

1.52 (c)

It may be noted that C_3S requires 23% of water by weight of cement and C_2S requires 21%. It means that on an average 23% of water by weight of cement is required for chemical reaction with portland cement compounds. This 23% of water chemically combines with cement and therefore, it is called bound water. A certain quantity of water (about 15% by weight of cement) is imbedded within the gel pores. This water is known as gel-water. Therefore, a total 38% of water by weight of cement is required for the complete chemical reactions and to occupy the space within gel pores.

1.53 (d)

As per IS: 4031 Part 5- 1988, initial setting time test on cement is conducted by gauging the cement with 0.85 times the water required to give a paste of standard consistency.

1.54 (d)

A bag of cement weighing 50 kg contains about 35 litres of cement.

$\therefore$ Number of bags for 1 tonne cement

$$= \frac{1 \times 1000}{50} = 20$$

1.55 (c)

The feature of low heat cement is a slow rate of gain of strength. But the ultimate strength of low heat cement is the same as that of ordinary portland cement.

1.56 (d)

Water to be added for determination of initial setting time is 0.85 W.

1.57 (b)

The compressive srength in N/mm^2 for ordinary 33 grade, 43 grade and 53 grade cement is shown below

Grade	3 days	7 days	28 days
33	16	22	33
43	22	33	43
53	27	37	53

1.58 (c)

More than 0.5% magnesium oxide by weight in cement results in large change in volume accompanying expansion resulting in disintegration and cracking.

1.59 (c)

Fineness of cement is measure of size of particles and is expressed in terms of (cm^2/kg) specific surface of cement i.e., area/mass.

1.60 (a)

The compound C_3A is characteristically fast reacting with water and may lead to an immediate stiffening of paste, and this process is termed flash set. Hence, initial setting time of cement depends most on C_3A.

1.61 (a)

The compound C_3A is fast reacting with water and leads to an immediate stiffening of paste and this process is called flash set. The role of gypsum added in the manufacture of cement is to prevent such a fast reaction.

1.62 (a)

The finer the cement, the higher is the rate of hydration, as more surface area is available for chemical reaction. This results in the early development of strength.

1.63 (c)

Free lime and magnesia content in cement is determined by the soundness test. Free lime and Magnesia are responsible for volume change in cement and thus making it unsound.

1.64 (b)

Fly ash, an industrial waste of thermal power plants is used in cement manufacturing. Free lime in cement is always tried to kept low.

Fineness of cement aids in hydration of cement.

Energy saving methods are invariably tried to keep cost of production as low as possible.

1.65 (b)

Simica is responsible for strength of cement, alumina imparts quick setting property, Calcium Sulphate delays setting of cement, Magnesium Oxide in large quantity- causes delayed expansion

1.66 (c)

Since, low heat cement has very low heat of hydration which is suitable for mass concreting such as dams, so, option (c) is correct.

1.67 (c)

Low heat cement sets slower than OPC. Setting time has no relation with strength of cement. So, option (c) is correct.

1.68 (c)

Water to be used is 0.85 P. Le chatelier's apparatus is used to determine soundness due to lime. So, option (c) is correct.

1.69 (c)

Underwater concreting is done by tremie pipe. Thus concrete slump should be 150-200 mm so that it can flow out easily under water without trapping water inside and also for its self consolidation as mechanical vibration is impractical.

1.70 (b)

Weight of cement =50 kg

Density of Portland cement $=1440\ kg/m^3$

$$\text{Bulk volume} = \frac{50}{1440}$$

$$=0.0347\ m^3\ H \simeq 35l$$

1.72 (b)

Finer the cement more is the rate of hydration which results in development of early strength. Burning at higher temperature increases tricalcium sulphate (C_3S) and hence leads to high early strength.

1.74 (*)

Statement 1 is vague whereas statement 2 is correct.

Salient advantage of using fly ash in cement concrete

- Reduction in heat of hydration and thus reduction of thermal cracks and improves soundness of concrete mass.
- Improved workability / pumpabilty of concrete
- Converting released lime from hydration of OPC into additional binding material – contributing additional strength to concrete mass.
- Pore refinement and grain refinement due to reaction between fly ash and liberated lime improves impermeability.
- Improved impermeability of concrete mass increases resistance against ingress of moisture and harmful gases results in increased durability.
- Reduced requirement of cement for same strength thus reduced cost of concrete.

Viscous nature of cement increases as the particle size decreses. Binding cementitious compounds like Calcium silicate hydrate (C-S-H) are produced when fly-ash reacts with lime and alkali in concrete which allow fly-ash to gain strength which exceeds that of finer particles in cement.

1.75 (c)

Tricalcium aluminate (C_3A) hydrates and hardens the quickest. It liberates a large amount of heat almost instantaneously and contributes somewhat to early strength.

■■■■

2 Mortar

2.1 The mortar used for masonry construction are classified based on strength in IS:2250 and IS:1905 according to their designations L_1, L_2, H_1, H_2, M_1, M_2. The correct sequence of increasing order of their strength is

(a) $L_1, L_2, H_1, H_2, M_1, M_2$
(b) $L_2, L_1, M_2, M_1, H_2, H_1$
(c) $M_1, M_2, H_1, H_2, L_1, L_2$
(d) $L_2, L_1, M_1, M_2, H_1, H_2$

[ESE : 1995]

2.2 The compressive strength of a standard good 1 : 3 portland cement-sand mortar after 3 days of curing should not be less than

(a) 70 kg/cm^2 (b) 115 kg/cm^2
(c) 175 kg/cm^2 (d) 210 kg/cm^2

[ESE : 1995]

2.3 Match List-I (Cement mortar for different work) with List-II (Proportion of cement : sand in mortar) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Normal brick work	1. 1 : 4
B. Plastering works	2. 1 : 3
C. Grouting the cavernous rocks	3. 1 : 6
D. Guniting	4. 1 : 15

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	3	1	2	4
(c)	3	1	4	2
(d)	4	3	2	1

[ESE : 1996]

2.4 The approximate proportion of dry cement mortar required for brickwork is

(a) 60% (b) 45%
(c) 30% (d) 10%

[ESE : 1997]

2.5 **Assertion (A):** In masonry, bricks are joined together by cement mortar.
Reason (R): Cement mortar adheres more effectively to brick surface than any other material.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

2.6 A gauged mortar is obtained by adding which of the following ingredient(s) to cement?

(a) Sand alone
(b) Sand and surkhi
(c) Sand and lime
(d) Surkhi alone

[ESE : 1998]

2.7 Surkhi is added to lime mortar to

(a) prevent shrinkage
(b) decrease setting time
(c) increase bulk
(d) impart hydraulicity

[ESE : 1999]

2.8 A mortar for which both cement and lime are mixed is called

(a) gauged mortar
(b) cement mortar
(c) lime mortar
(d) light weight mortar

[ESE : 2000]

2.9 Consider the following statements:

1. Addition of a small quantity of slaked lime to Portland cement in cement mortar increases the plasticity of the mortar.
2. Light weight mortar is prepared by mixing cement and finely crushed fire bricks with water.

3. Fire resistant mortar is prepared by mixing aluminous cement and finely ground china clay wares with water.

Which of these statements are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 2000]

2.10 The maximum bulking of sand is likely to occur at a moisture content of

(a) 5% (b) 8%
(c) 11% (d) 14%

[ESE : 2001]

2.11 Guniting is the application of mortar

(a) on a surface under pneumatic pressure
(b) on a vertical surface
(c) on brickwork by manual method
(d) of fluid consistency for repair works

[ESE : 2001]

2.12 Assertion (A): Addition of 5% to 6% of moisture content by weight increases the volume of dry sand from 18% to 38%.

Reason (R): Bulking of sand is caused due to surface moisture on sand particles.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2003]

2.13 Match List-I (Cement mortar for different work) with List-II (Proportion of cement and sand in mortar) and select the correct answer using the codes given below the lists:

List-I

A. Cement mortar for normal brick work
B. Cement mortar for plastering works
C. Cement mortar for grouting the cavernous rocks
D. Cement mortar for guniting

List-II

1. 1 : 4
2. 1: 3
3. 1 : 6
4. 1 : 1.5

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	1	2	3	4
(c)	3	1	4	2
(d)	1	4	2	3

[ESE : 2003]

2.14 In order to improve the workability of harsh cement mortar which of the following items is/are added?

1. Water
2. Plaster of Paris
3. Lime

Select the correct answer using the codes given below:

(a) 1 only (b) 1 and 2
(c) 3 only (d) 1 and 3

[ESE : 2003]

2.15 What is the quantity of cement (in kg) and of dry sand (in cubic metre) respectively required for preparing 1 cubic metre of wet cement mortar of 1 : 5 proportion?

(a) 270 and 1.00 (b) 290 and 1.05
(c) 290 and 1.00 (d) 310 and 1.05

[ESE : 2004]

2.16 Consider the following statements regarding cement mortar:

1. Silicate type chemical resistant mortar has good resistance to hydrofluoric acid.
2. Sulphur-type chemical resistant mortar has poor resistance to alkalis.
3. The interior surface of a building may be plastered with cement mortar containing cement and sand in the ratio 1 : 6.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE : 2004]

2.17 Consider the following statements regarding the phenomenon of bulking of sand :

1. It is due to film of water around sand particles.
2. It is due to capillary action.
3. It is more in finer sands.

Which of these statements is/are correct?

(a) 1, 2 and 3 (b) 1 and 3
(c) 2 and 3 (d) 1 and 2

[ESE : 2005]

2.18 Match List-I (cement mortar for different work) with List-II (Cement : Sand in mortar) and select the correct answer using the codes given below the lists :

List-I

A. Cement mortar for normal brickwork
B. Cement mortar for plastering work
C. Cement mortar for grouting the cavernous rocks
D. Cement mortar for guniting

List-II

1. 1 : 4
2. 1 : 3
3. 1 : 6
4. 1 : 1.5

Codes:

	A	B	C	D
(a)	3	2	4	1
(b)	4	1	3	2
(c)	3	1	4	2
(d)	4	2	3	1

[ESE : 2007]

2.19 When sand for construction work is stored at site in stacks of 61 cm height, what allowance due to sinkage and shrinkage should be provided ?

(a) 5% (b) $7\frac{1}{2}\%$

(c) 10% (d) $12\frac{1}{2}\%$

[ESE : 2008]

2.20 Which one of the following is the correct range of fineness modulus of medium sand usable in preparing cement mortar?

(a) 1.5 to 2.2 (b) 2.6 to 2.9
(c) 2.9 to 3.2 (d) 5.5 to 6.5

[ESE : 2008]

2.21 Consider the following statements:
Cement mortars richer than 1 : 3 are not used in masonry work because

1. There is no gain in strength of masonry.
2. There is high shrinkage.
3. They are prone to segregation.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

[ESE : 2011]

2.22 Which one of the following statements is correct?

(a) Adding 5% to 6% of moisture by weight increases the volume of dry sand from 18% to 38%.
(b) The bulking of fine sand is more than that of coarse sand.
(c) Volume of full saturated sand is equal to that of dry sand.
(d) All of the above

[ESE : 2011]

2.23 Consider the following statements:
Sand in cement mortar is used for

1. increasing the strength
2. reducing the shrinkage
3. decreasing the surface area of the binding material
4. decreasing the quantity of cement

Which of these statements are correct?

(a) 1, 2 and 4 (b) 1, 2 and 3
(c) 1, 3 and 4 (d) 2, 3 and 4

[ESE : 2012]

2.24 Statement-I : Attention must be extended to the results of the phenomenon of bulking of sand towards ascertaining the water demand in mortar preparation.
Statement-II : The total volume of mortar prepared per batch of mix preparation for use-in-work should be mindful of the initial settling time.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

[ESE : 2012]

2.25 Which of the following ingredients refer to binding materials of mortar?

1. Cement 2. Lime
3. Sand 4. Ashes

Select the correct answer using the code given below.

(a) 1 and 4 (b) 3 and 4
(c) 1 and 2 (d) 2 and 3

[ESE : 2014]

2.26 Consider the following statements :

1. Bricks in masonry are bound by mortar.
2. Mortars make bricks damp proof.
3. Strength of brick in masonry is improved by plastering.
4. Addition of lime improves workability.
5. Marine constructions need sulphate resistant cement mortar.

Which of the above statements are relevant for 'cement mortar'?

(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 1, 4 and 5 (d) 3, 4 and 5

[ESE : 2014]

2.27 Statement (I) : Water needed for hydration decides the quantity of the water to be used in mortar preparation.

Statement (II) : Excess water in mortar reduces its strength.

[ESE : 2014]

2.28 Statement (I) : Preparing mortar by using masonry cement improves workability as well as the finish during plastering.

Statement (II) : Masonry cement is easy to handle.

[ESE : 2014]

2.29 Consider the following statements related to 'composite mortar'.

1. Addition of lime to cement mortar improves its workability.
2. Composite mortar is obtained by adding 10% by weight of cement and mixing with water.
3. Composite mortar is not preferred in tall buildings.
4. Mechanical grinding is essential for developing composite mortar.

Which of the above statements are true in this case?

(a) 1, 2 and 3 only (b) 1, 3 and 4 only
(c) 2, 3 and 4 only (d) 1, 2, 3 and 4

[ESE : 2015]

2.30 Consider the following related to sand in mortars:

1. It increases the volume of the mortar mix.
2. It increases the strength of masonry.
3. The cost of the mortar is reduced.
4. Shrinkage of the mortar is almost prevented.
5. Surkhi can replace sand in cement mortar used in plastering and this modified mortar is more durable.

Which of the above are relevant to 'sand' in mortar?

(a) 1, 2, 4 and 5 (b) 1, 3 and 4 only
(c) 3, 4 and 5 only (d) 2, 3 and 4 only

[ESE : 2015]

2.31 Which of the following statements are correct with regard to cement mortar?

1. Workability of cement mortar can be improved by addition of lime.
2. Fly-ash cement is economical in plastering jobs.
3. Addition of saw dust improves workability.
4. Sand in mortar can be replaced by finely crushed fire bricks.

(a) 1, 2, 3 and 4 (b) 1, 2 and 3 only
(c) 3 and 4 only (d) 1, 2 and 4 only

[ESE : 2016]

2.32 Statement (I): Fire resistance of plastering can be achieved by mixing surkhi to the cement mortar.

Statement (II) : Insulation against sound and fire can be achieved by adding sufficient water in-situ just before applying the mortar.

[ESE : 2016]

■■■■

Answers Mortar

2.1 (b)	2.2 (c)	2.3 (c)	2.4 (c)	2.5 (a)	2.6 (c)	2.7 (d)	2.8 (a)	2.9 (b)	
2.10 (a)	2.11 (a)	2.12 (a)	2.13 (c)	2.14 (d)	2.15 (d)	2.16 (b)	2.17 (a)	2.18 (c)	
2.19 (d)	2.20 (b)	2.21 (b)	2.22 (d)	2.23 (d)	2.24 (b)	2.25 (c)	2.26 (c)	2.27 (d)	
2.28 (a)	2.29 (b)	2.30 (b)	2.31 (d)	2.32 (c)					

Explanations Mortar

2.1 (b)

The strength of various grades of mortars:

Grade	Strength (MPa)
L_2	0.5
L_1	0.7
M_2	2.0-3.0
M_1	3.0-5.0
H_2	6.0-7.5
H_1	10

2.2 (c)

The strength of standard mortar cube after 3 days, shall not be less than

(i) 16 MPa (160 kg/cm^2) for 33 grade OPC as per IS : 269-1989

(ii) 23 MPa (230 kg/cm^2) for 43 grade OPC as per IS : 8112-1989

(iii) 27 MPa (270 kg/cm^2) for 53 grade OPC as per IS : 12269-1987

2.3 (c)

The gunite is a mixture of 100 parts by weight of cement, 300 parts by weight of quartz sand, 35-50 parts by weight of water and 2 parts by weight approved quick compounds.

2.4 (c)

For 1 m^3 volume of brick work, the bricks required are 500. Therefore mortar needed

$= 1 - 500 \times 0.19 \times 0.09 \times 0.9 = 0.23$ m^3.

Add 15% extra for frog filling, brick bonding and wastage.

Volume of wet mortar $= 0.23 \times 1.15 = 0.265$ m^3

1 m^3 of wet mortar = 1.25 m^3 of dry mortar

$\therefore$ 0.265 m^3 wet mortar = 0.33 m^3 of dry mortar

Dry mortar as a percentage of brick work

$$= \frac{0.33}{1} \times 100 = 33\%$$

2.6 (c)

Gauged or lime-cement mortar is prepared by adding cement, sand and lime. Lower cement content in mortar leads to reduction in workability, less cohesion, and will produce porous joints with a tendency for low frost resistance. The inclusion of lime in cement mortar helps in rectifying these deficiencies by increasing the water retentivity, workability and bonding properties. In this way, early strength can also be achieved without the mature strength being too high.

2.7 (d)

Surkhi performs the same function as sand. But, in addition, it imparts strength and improve hydraulic property of mortar. As it disintegrates under the action of air and humidity, the mortar with surkhi should not be used for external plaster or pointing work.

Common functions of sand/surkhi in mortar:

(i) It acts as bulk.

(ii) It absorbs carbon dioxide from fat lime and setting of fat lime occurs effectively.

(iii) It increases resistance of mortar to crushing.

2.8 (a)

The mixture of cement, lime and sand in a particular proportion is gauged mortar.

2.9 (b)

Light weight mortar is prepared by adding materials such as saw dust, wood powder etc. to the lime mortar or cement mortar.

2.10 (a)

Maximum bulking occurs at around 5% moisture content

Bulking of sands for various moisture contents

Moisture %	% Buckling in		
	Fine sand	Medium sand	Coarse sand
1	16	8	6
2	26	16	12
3	32	22	15
4	36	27	17
5	38	29	18
6	37	28	18
8	35	26	16
10	32	22	12
12	28	19	8
15	22	12	2
17	18	7	0
20	9	0	0
27	0	0	0

2.11 (a)

Gunite is a mixture of cement, sand and water. The cement and sand shall be batched, mixed and conveyed through a hose pipe with the help of compressed air. A separate line shall bring the water under pressure. The cement, sand and water mix shall be passed through and intimately mixed in a special manifold. A cement gun is used to deposit this mixture on the concrete surface under a pressure of about 20 to 30 N/cm^2.

2.12 (a)

Assertion can be seen true from table given in solution 2.10. Surface moisture on sand particles causes capillary action which is responsible for bulking of sand.

2.15 (d)

1 m^3 of wet cement mortar = 1.25 m^3 of dry mortar.

Sum of proportions = 1 + 5 = 6

$$\text{Cement} = \frac{1.25}{6} = 0.208 \text{ m}^3 = 312.5 \text{ kg}$$

(1 m^3 cement = 1500 kg)

$$\text{Sand} = \frac{5 \times 1.25}{6} = 1.04 \text{ m}^3$$

2.16 (b)

1 : 3 to 1 : 4 ratio is used for plaster work cement mortar proportion is 1 : 6 ratio is used for stone masonry with ordinary stones, brickwork, foundations, etc.

2.17 (a)

If a dry mass of sand is moistened slightly and then shoveled or dumped loose in a heap; its volume will increase considerably relative to dry state. This phenomenon is called bulking of sand. This is because of apparent cohesion development because of interparticle adhesion due to capillary action of water. This apparent cohesion holds the particles together in clusters enclosing honey combs and occuping more volume. The finer the grain, the greater is increase in volume.

2.19 (d)

According to IS 1200, minimum height of stacks for sand is 61 cm and allowance to be deduced for sinkage and for shrinkage is 1/8th of the height of stack of 12.5%.

2.20 (b)

Sand Type	Fineness modulus
Coarse	2.2-2.6
Medium	2.6-2.9
Fine	2.9-3.2

2.22 (d)

Compared to its dry or completely saturated volume, moist fine aggregate tends to increase in volume on rehandling due to capillary effect. The capillary action between sand particles does not allow the particles to come closer to each other. This is called bulking of sand and the amount of bulking or increase in volume depends on the moisture content of the sand. In completely dry or wet state, there is no capillary action and hence, there will be no bulking when the sand is dry or completely saturated. For a moisture content of 5 to 8 per cent, the bulking can be as much as 20 to 40 per cent depending on the sand.

2.24 (b)

The increase in the volume of a given mass of fine aggregate caused by the presence of water is known as bulking. If sand is measured by volume and no allowance is made for bulking,

the mix will be richer than that specified because for a given mass, moist sand occupies a considerably larger volume than the same mass of dry mass. This results in a mix deficient in sand.

2.25 (c)

According to the kind of binding material, the mortars are classified into the following five categories:

1. Lime mortar
2. Surkhi mortar
3. Cement mortar
4. Gauged mortar
5. Gypsum mortar

2.26 (c)

Mortars contains water and don't make bricks damp proof. Plastering do not improves strength of wall. Other 3 statements are true and relevant for cement mortar.

2.29 (b)

Composite mortar is obtained by addition of water in the mixture of binding material like cement or lime and aggregates like sand.

2.30 (b)

In mortar sand helps in adjustment of strength only which is achieved by increasing or decreasing its proportion.

2.31 (d)

Saw Dust is a suitable material for use as a pozzolanic material since it satisfies the requirement for such a material by having a combined $SiO_2 + Al_2O_3 + Fe_2O_3$ of more than 70%.

Concrete becomes less workable as the Saw Dust percentage increases meaning that more water is required to make the mix more workable. This implies Saw Dust addition increases water demand for same workability.

■■■■

3 Lime

3.1 Lime mortar is generally made with
(a) quick lime (b) fat lime
(c) hydraulic lime (d) white lime

[ESE : 1995]

3.2 **Assertion (A):** Use of cement lime mortar is generally preferred to cement mortar.
Reason (R): Cement-lime mortar has higher workability and water retentivity characteristics than cement mortar.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

3.3 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. Fat lime
B. Hydraulic lime
C. Quick lime
D. Non-hydraulic lime

List-II
1. Calcined dolomitie stone
2. Calcined lime stone
3. Kankar
4. Sea shells

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	2	1
(c)	3	4	1	2
(d)	4	3	1	2

[ESE : 1996]

3.4 The modulus of rupture of hydraulic lime mortar (28 days curing) should NOT be less than
(a) 1 N/mm^2 (b) 2 N/mm^2
(c) 2.5 N/mm^2 (d) 3.0 N/mm^2

[ESE : 1997]

3.5 **Assertion (A):** For identical strength, a composite cement-lime mortar is preferred over cement mortar.
Reason (R): Composite cement-lime mortar has higher drying shrinkage than cement mortar.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

3.6 Consider the following statements:
1. Masonry in rich cement mortar though having good strength with high shrinkage is much liable for surface cracks.
2. Lime mortar possesses poor workability and poor water retentivity and also suffers high shrinkage.
3. Masonry in lime mortar has better resistance against rain penetration and is less liable to crack when compared to masonry in cement mortar.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE : 1999]

3.7 **Assertion (A):** Lime mortar is able to retain its bond with masonry unit and be free from cracks.
Reason (R): Lime mortar undergoes only negligible volume change after setting and initial shrinkage.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2000]

3.8 One of the main demerits in using the lime mortar is that it
(a) is not durable
(b) does not set quickly
(c) swells
(d) is plastic
[ESE : 2001]

3.9 Why is lime added to cement slurry for the topcoat of plastering?
(a) To improve the strength of plaster
(b) To stiffen the plaster
(c) To smoothen the plaster for ease of spread
(d) To make the plaster non-shrinkable
[ESE : 2007]

3.10 Consider the following statements about lime:
1. Calcination of limestone results in quick lime.
2. Lime produced from pure variety of chalk is hydraulic lime.
3. Hydrated lime is obtained by treating quick lime with water.
Which of the above statements are correct?
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only
[ESE : 2017]

Answers Lime

3.1 (c) 3.2 (a) 3.3 (b) 3.4 (a) 3.5 (c) 3.6 (d) 3.7 (a) 3.8 (b) 3.9 (c)
3.10 (d)

Explanations Lime

3.1 (c)
Lime used for mortar may be fat lime (quick or hydrated lime) or hydraulic lime. Slaked fat lime is used to prepare mortar for plastering, while hydraulic lime is used in preparing mortar for masonry construction.

3.2 (a)
Lime-cement mortar is also known as composite mortar or gauged mortar.

3.4 (a)
The modulus of rupture of hydraulic lime mortar (at 28 days curing) should be $\not< 1.05\ N/mm^2$.

3.5 (c)
Composite cement lime mortar has low drying shrinkage, high workability and high water retention as compared to cement mortar. So for identical strength composite cement lime mortar is preferred over cement mortar.

3.6 (d)
Lime mortar has high plasticity and it can be placed easily.
It possess good cohesiveness with other surfaces and shrinks very little and sufficiently durable.

3.7 (a)
Lime mortar possess good cohesiveness with other surfaces and shrinks very little.

3.8 (b)
One of the main demerits in using lime mortar is that it does not set quickly. Therefore the progress of work while using lime mortar is slow.

3.9 (c)
Lime posses high plasticity and sets slowly hence not used where strength is required.

3.10 (d)
1. Calcination of limestone
$CaCO_3 \xrightarrow{\Delta} CaO + CO_2$ (quick lime)
2. Lime produced from pure variety of chalk is quick lime
3. $CaO + H_2O \longrightarrow Ca(OH)_2$ (hydrated lime)

4 Concrete

4.1 The split tensile strength of M 15 grade concrete when expressed as percentage of its compressive strength is

(a) 10 to 15% (b) 15 to 20%
(c) 20 to 25% (d) 25 to 30%

[ESE : 1995]

4.2 The approximate ratio between the strengths of cement concrete at 7 days and at 28 days is

(a) 3/4 (b) 2/3
(c) 1/2 (d) 1/3

[ESE : 1995]

4.3 Modulus of elasticity of M 25 concrete as determined by formula of IS:456 is

(a) 1,24,500 MPa (b) 90,125 MPa
(c) 28,500 MPa (d) 16,667 MPa

[ESE : 1995]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.4 **Assertion (A):** For identical mix, the cube compressive strength of concrete obtained from 15 cm cube is higher than 15 cm x 30 cm cylinder compressive strength.

Reason (R): Cube compressive strength is higher than the cylinder compressive strength because of its higher contact area under the load.

[ESE : 1995]

4.5 **Assertion (A):** The specific surface of aggregate decreases with increase in size of the aggregate.

Reason (R): The workability of a mix is influenced more by the finer fractions than the coarse particles.

[ESE : 1996]

4.6 **Assertion (A):** Workability of concrete is improved by air entraining agent.

Reason (R): Air entraining agent increases concrete strength.

[ESE : 1996]

4.7 Tensile strength of concrete is measured by

(a) direct tension test in the universal testing machine
(b) applying compressive load along the diameter of the cylinder
(c) applying third point loading on a prism
(d) applying tensile load along the diameter of the cylinder

[ESE : 1996]

4.8 The approximate ratio of strength of 15 cm x 30 cm concrete cylinder to that of 15 cm cube of the same concrete is

(a) 1.25 (b) 1.00
(c) 0.85 (d) 0.50

[ESE : 1996]

4.9 If in a concrete mix the fineness modulus of coarse aggregate is 7.6, the fineness modulus of fine aggregate is 2.8 and the economical value of the fineness modulus of combined aggregate is 6.4, then the proportion of fine aggregate is

(a) 25% (b) $33\frac{1}{3}\%$
(c) 50% (d) $66\frac{2}{3}\%$

[ESE : 1996]

4.10 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Vicat's needle
B. Michaeli's compound lever apparatus

C. Le Chatelier's apparatus
D. Turbidimeter

List-II
1. Setting time
2. Specific surface
3. Tensile strength
4. Soundness

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	1	3	4	2
(c)	2	4	3	1
(d)	3	4	1	2

[ESE : 1996]

4.11 General shrinkage in cement concrete is caused by
(a) carbonation
(b) stressed due to external load
(c) drying with starting with a stiff consistency
(d) drying with starting with a wetter consistency

[ESE : 1996]

4.12 Weight-batching proceeds on
(a) the assumption of the declared weight in each bag of cement
(b) weighing the contents of each bag
(c) accurately estimating the weight of each material to be used in each batch
(d) the assumption of correct dry weight of each size range of each material and the weight of water

[ESE : 1996]

4.13 While concreting in cold weather where frosting is also likely, one uses
(a) high quality portland cement with minimum additives
(b) high alumina cement with calcium chloride additives
(c) portland cement together with calcium chloride additives
(d) a mixture of high alumina cement and portland cement

[ESE : 1996]

4.14 The modulus of elasticity (E) of concrete is given by
(a) $E = 1000\ f_{ck}$ (b) $E = 5700\sqrt{f_{ck}}$
(c) $E = 5500\sqrt{f_{ck}}$ (d) $E = 10{,}000\sqrt{f_{ck}}$

[ESE : 1997]

4.15 The optimum number of revolutions over which concrete is required to be mixed in a mixer machine is
(a) 10 (b) 20
(c) 50 (d) 100

[ESE : 1997]

4.16 Consider the following statements:
The addition of surfactants in the concrete mix results in
1. increase in the water-cement ratio
2. decrease in the water-cement ratio
3. increase in the strength of concrete
4. decrease in the curing duration
5. increase in the density of concrete

Which of these statements are correct?
(a) 1, 3 and 4 (b) 2, 3 and 5
(c) 3, 4 and 5 (d) 1, 4 and 5

[ESE : 1997]

4.17 Consider the following statements:
Higher water-cement ratio in concrete result in
1. stronger mix
2. better workable mix
3. a weak mix
4. less bleeding

Which of these statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 1 and 4

[ESE : 1997]

4.18 Match List-I (Admixtures) with List-II (Chemicals) and select the correct answer using the codes given below the lists:

List-I
A. Water-reducing admixture
B. Air-entraining agent
C. Superplasticiser
D. Accelerator

List-II
1. Sulphonated melanin formaldehyde
2. Calcium chloride
3. Lignosulphonate
4. Neutralised vinsol resin

Codes:

	A	B	C	D
(a)	2	4	1	3
(b)	1	3	4	2
(c)	3	4	1	2
(d)	3	4	2	1

[ESE : 1998]

4.19 Batching refers to
(a) controlling the total quantity at each batch
(b) weighing accurately, the quantity of each material for a job before mixing
(c) controlling the quantity of each material into each batch
(d) adjusting the water to be added in each batch according to the moisture content of the materials being mixed in the batch
[ESE : 1998]

4.20 To make one cubic meter of 1 : 2 : 4 by volume concrete, the volume of coarse aggregates required is
(a) 0.95 m^3 (b) 0.85 m^3
(c) 0.75 m^3 (d) 0.65 m^3
[ESE : 1998]

4.21 The capacity of a "28 S type" concrete mixer is 0.8 m^3. For mixing one cubic meter of concrete, the quantity of cement required is 5.5 bags. In order to avoid fractional usage of cement bags, the volume of concrete (in m^3) to be mixed per batch will be
(a) 0.79 (b) 0.55
(c) 0.73 (d) 0.44
[ESE : 1998]

4.22 A splitting tensile test is performed on cylinder of diameter D and length L. If the ultimate load is P, then splitting tensile strength of concrete is given by
(a) $\frac{P}{\pi DL}$ (b) $\frac{2P}{\pi DL}$
(c) $\frac{4PL}{\pi D^3}$ (d) $\frac{4PD}{\pi L^3}$
[ESE : 1998]

4.23 Consider the following strengths of concrete:
1. Cube strength
2. Cylinder strength
3. Split-tensile strength
4. Modulus of rupture
The correct sequence in increasing order of these strengths is
(a) 3, 4, 2, 1 (b) 3, 4, 1, 2
(c) 4, 3, 2, 1 (d) 4, 3, 1, 2
[ESE : 1999]

4.24 Consider the following statements:
Shrinkage of concrete depends upon the
1. relative humidity of the atmosphere
2. passage of time
3. applied stress
Which of these statements is/are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 alone (d) 1, 2 and 3
[ESE : 1999]

4.25 Consider the following statements:
The effect of an air entrainment in concrete is to
1. increase resistance to freezing and thawing
2. improve workability
3. decrease strength
Which of these statements is/are correct?
(a) 2 and 3 (b) 1 and 3
(c) 1 alone (d) 1, 2 and 3
[ESE : 1999]

4.26 As per IS Code of Practice, concrete should be cured at
(a) 5°C (b) 10°C
(c) 27°C (d) 40°C
[ESE : 2000]

4.27 The correct sequence of workability test(s)/ method(s) in the order of their application from low to high workability is
(a) slump test, compacting factor test and vee-bee consistometer
(b) compacting factor test, vee-bee consistometer and slump test.
(c) vee-bee consistometer, slump test and compacting factor test.
(d) vee-bee consistometer, compacting factor test and slump test
[ESE : 2000]

4.28 While testing the compressive strength of cement concrete, the correct standard conditions (viz., temperature, age, humidity and size of the specimen) to be maintained as per I.S. are
(a) 27 ± 3°C, 28 days, 90% and 15 cm^3
(b) 26 ± 2°C, 21 days, 80% and 15 cm^3
(c) 25 ± 1°C, 14 days, 75% and 15 cm^3
(d) 27 ± 3°C, 7 days, 70% and 10 cm^3
[ESE : 2000]

4.29 Which one of the following statements is correct?
(a) Bulking of sand always decreases with increase in the quantity of water.
(b) The quantity of water in ordinary concrete should be 5% by weight of cement and 25% by weight of aggregate.
(c) While mixing by weight, bulking effect of sand is not taken into account.
(d) River sand is also known as standard sand.

[ESE : 2000]

4.30 The ratio of direct tensile strength to that of modulus of rupture of concrete is
(a) 0.25 (b) 0.5
(c) 0.75 (d) 1.0

[ESE : 2000]

Directions: The following items consists of two statements, one labelled as '**Assertion (A)**' and the other as '**Reason (R)**'. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.31 **Assertion (A):** The use of fly ash as an admixture in concrete reduces segregation and bleeding.
Reason (R): The use of fly ash as a replacement of sand in a lean-mix increases the workability and has no significant effect on drying shrinkage of concrete.

[ESE : 2000]

4.32 **Assertion (A):** Calcium chloride addition in concrete proves more effective in slow-hardening portland cement than in rapid-hardening cement.
Reason (R): Calcium chloride acts as an effective accelerator thereby increasing rate of reaction.

[ESE : 2001]

4.33 Which one of the following types of concrete is most suitable in extreme cold climates?
(a) Air-entrained concrete
(b) Ready mix concrete
(c) Vacuum concrete
(d) Coarse concrete

[ESE : 2001]

4.34 Match List-I (Workability test) with List-II (Measurements) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Slump test	1. 300-500 mm
B. Compacting factor	2. 75-125 mm
C. Vee-bee test	3. 0.80 to 0.98
D. Flow test	4. 0 to 10 sec

Codes:

	A	B	C	D
(a)	2	4	3	1
(b)	1	3	4	2
(c)	1	4	3	2
(d)	2	3	4	1

[ESE : 2001]

4.35 Consider the following statements:
Curing of concrete by steam under pressure
1. increases the compressive strength of concrete
2. reduces the shear strength of concrete
3. increases the speed of chemical reaction.
Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 1 alone
(c) 2 and 3 (d) 3 alone

[ESE : 2001]

4.36 Which one of the following aggregates gives maximum strength in concrete?
(a) Rounded aggregate
(b) Elongated aggregate
(c) Flaky aggregate
(d) Cubical aggregate

[ESE : 2001]

4.37 Consider the following statements:
Ultrasonic pulse velocity test to measure the strength of concrete is
1. used to measure the strength of wet concrete
2. used to obtain estimate of concrete strength of finished concrete elements
3. a non-destructive test
Which of these statements are correct?
(a) 1, 2 and 3 (b) 2 and 3
(c) 1 and 2 (d) 1 and 3

[ESE : 2001]

4.38 Match List-I (Property) with List-II (Characteristic) and select the correct answer using the codes given below the lists:

List-I
A. Specific heat of an aggregate
B. Thermal conductivity of an aggregate
C. Thermal expansion
D. Durability of concrete

List-II
1. Breaks the bond between the aggregate and the paste
2. Is a measure of its heat capacity
3. Is affected by differences in thermal expansion of two different materials
4. Is a measure of its ability to conduct heat

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	2	4	1	3
(c)	1	4	2	3
(d)	2	3	1	4

[ESE : 2002]

4.39 The length of time for which a concrete mixture will remain plastic is usually more dependent on
(a) the setting time of cement than on the amount of mixing water and atmospheric temperature
(b) the atmospheric temperature than on the amount of mixing water and the setting time of cement
(c) the setting time of cement and the amount of mixing water than on atmospheric temperature
(d) the amount of mixing water used and atmospheric temperature than on the setting time of cement

[ESE : 2002]

4.40 Consider the following statements:
Pozzolana used as an admixture in concrete has the following advantages:
1. It improves workability with lesser amount of water.
2. It increases heat of hydration and so sets the concrete quickly.
3. It increases resistance to attack by salts and sulphates.
4. It leaches calcium hydroxide.

Select the correct answer using the codes given below:
(a) 1, 2, 3 and 4 (b) 1, 2 and 4
(c) 1 and 3 (d) 2, 3 and 4

[ESE : 2002]

4.41 Match List-I (Admixture) with List-II (Action in concrete) and select the correct answer using the codes given below the lists:

List-I
A. Calcium lignosulphonate
B. Aluminium powders
C. Tartaric Acid
D. Aluminium sulphate

List-II
1. Anti-bleeder
2. Retarder
3. Air entrainer
4. Water reducer

Codes:

	A	B	C	D
(a)	3	2	1	4
(b)	4	3	2	1
(c)	3	4	1	2
(d)	4	2	3	1

[ESE : 2003]

4.42 Bleeding of concrete leads to which of the following?
1. Drying up of concrete surface.
2. Formation of pores inside.
3. Segregation of aggregate.
4. Decrease in strength.

Select the correct answer using the codes given below:
(a) 1 only (b) 1 and 2
(c) 1 and 3 (d) 2 and 4

[ESE : 2003]

4.43 Match List-I (Material characteristics) with List-II (Property of concrete) and select the correct answer using the codes given below the lists:

List-I
A. Water cement ratio
B. Water content
C. Minimum cement content
D. Segregation

List-II
1. Durability
2. Compressive strength
3. Stability of mix
4. Workability

Codes:

	A	B	C	D
(a)	4	1	3	2
(b)	2	4	3	1
(c)	4	1	2	3
(d)	2	4	1	3

[ESE : 2003]

4.44 Stress-strain curve of concrete is
(a) a perfect straight line up to failure
(b) straight line up to 0.002% strain value and then parabolic up to failure
(c) parabolic up to 0.002% strain value and then a straight line up to failure
(d) hyperbolic up to 0.002% strain value and then a straight line up to failure

[ESE : 2003]

4.45 Consider the following statements:
Ultrasonic pulse velocity test is
1. used to measure the strength of wet concrete
2. used to obtain estimate of concrete strength of finished concrete elements
3. a destructive test
4. a non-destructive test

Which of these statements are correct?
(a) 1, 2 and 3 (b) 2 and 3
(c) 2 and 4 (d) 1 and 3

[ESE : 2003]

4.46 Match List-I (Material used in individual batching of concrete) with List-II (Tolerance when batch weight exceeds 30% of scale capacity) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Cement	1. ±0.3% of scale capacity
B. Water	2. ± 1% of scale capacity
C. Aggregates	3. ± 2% of scale capacity
D. Admixtures	4. ± 3% of scale capacity

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	1	2	4	3
(c)	3	4	1	2
(d)	4	3	1	2

[ESE : 2003]

4.47 What is the range of fineness modulus of sand which is least suitable for making a good concrete?
(a) 3.5 - 4.5 (b) 2.9 - 3.2
(c) 2.6 - 2.9 (d) 2.2 - 2.6

[ESE : 2004]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.48 **Assertion (A):** The splitting test for determining the tensile strength of concrete gives more uniform results than any other tension test.
Reason (R): The splitting test moulds can be used for casting specimens for both compression and tension tests.

[ESE : 2004]

4.49 **Assertion (A):** One year strength of continuously moist cured concrete is 40% higher than that of 28 days strength, while no-moisture-curing can lower the strength to about 40%.
Reason (R): Moist curing for the first seven to fourteen days results in a compressive strength of 70 to 80% of that of 28 days moisture curing.

[ESE : 2004]

4.50 The use of super-plasticizers as admixture
(a) increases compressive strength of concrete
(b) permits lower water cement ratio, thereby strength is increased
(c) reduces the setting time of concrete
(d) permits lower cement content, thereby strength is increased

[ESE : 2004]

4.51 Match List-I (Aggregate) with List-II (Effect) and select the correct answer using the codes given below the lists:

List-I
A. Rounded aggregates
B. Crushed aggregates
C. Flaky aggregates
D. Irregular aggregates

List-II
1. Reduce workability appreciably because of a high ratio of surface area to volume
2. Require more water than rounded aggregates and give strength lesser than crushed aggregates
3. Give concrete of higher compressive strength due to development of stronger aggregate-mortar bond
4. Require lesser amount of water and cement paste for a given workability

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	1	3	4	2
(c)	4	3	1	2
(d)	4	2	1	3

[ESE : 2004]

4.52 Consider the following statements:
For increasing the workability of concrete, it is necessary to
1. increase the quantity of cement
2. decrease the quantity of sand
3. alter the proportion of fine and coarse aggregates
4. decrease the quantity of water
5. use angular aggregate
Which of these statements are correct?
(a) 1, 2, 3, 4 and 5 (b) 2, 4 and 5
(c) 2 and 3 (d) 1 and 5
[ESE : 2004]

4.53 Slump and compaction factors are two different measures of workability of concrete. For a slump of 0 to 20 mm, what is the equivalent range of compaction factor?
(a) 0.50 – 0.70 (b) 0.70 – 0.80
(c) 0.80 – 0.85 (d) 0.85 – 0.92
[ESE : 2004]

4.54 The values of slump commonly adopted for the various concrete mixes are given below:
1. Concrete for road works: 20 to 28 mm
2. Ordinary RCC work : 50 to 100 mm
3. Columns retaining walls : 12 to 25 mm
4. Mass concrete : 75 to 175 mm
Which of the pairs given above are correctly matched?
(a) 1, 3 and 4 (b) 1 and 2
(c) 3 and 4 (d) 2 and 4
[ESE : 2004]

4.55 Consider the following pairs:
1. Hand compaction of heavily reinforced sections : Low workability (0-25 mm slump)
2. Concreting of shallow sections with vibrations : High workability (125-150 mm slump)
3. Concreting of lightly reinforced sections like pavements : Low workability (5-50 mm slump)
4. Concreting of lightly reinforced section by hand or heavily reinforced sections with vibration : Medium workability (25-75 mm slump)
Which of the pairs given above are correctly matched?
(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 1 and 3
[ESE : 2004]

4.56 The fineness modulus of fine aggregate is 2.78 and of coarse aggregate is 7.82 and the desired fineness modulus of mixed aggregate is 6.14. What is the amount of fine aggregate to be mixed with one part of coarse aggregate?
(a) 55% (b) 50%
(c) 45% (d) 40%
[ESE : 2004]

4.57 On which one of the following factors, does strength of concrete depend primarily?
(a) Quality of coarse aggregate
(b) Quality of fine aggregate
(c) Fineness of cement
(d) Water-cement ratio
[ESE : 2005]

4.58 In a shape test of aggregate, which one of the following gives the correct slot for flakiness index for a material passing 50 mm sieve and retained on 40 mm sieve?

(a) 25 mm (b) 27 mm
(c) 81 mm (d) 30 mm

[ESE : 2005]

4.59 Consider the following statements:
Cement concrete is a/an
1. elastic material
2. visco-elastic material
3. visco-plastic material
Which of these statement is/are correct?
(a) 1, 2 and 3 (b) 2 and 3
(c) 2 only (d) 1 only

[ESE : 2005]

4.60 Why is super plasticizer added to concrete?
1. To reduce the quantity of mixing water.
2. To increase the consistency.
3. To reduce the quantity of cement.
4. To increase resistance to freezing and thawing.
Select the correct answer using the codes given below:
(a) 1, 2 and 4 (b) 1, 3 and 4
(c) 2 and 4 (d) 4 only

[ESE : 2005]

4.61 On which of the following is the working principle of concrete hammer for non-destructive test based?
(a) Rebound deflections
(b) Radioactive waves
(c) Ultrasonic pulse
(d) Creep-recovery

[ESE : 2005]

4.62 Smaller size of aggregates in a concrete mix
(a) provides larger surface area for bonding with the mortar matrix which increases the compressive strength and reduces the stress concentration at the mortar-aggregate interface
(b) is economical as the concrete mix is more dense
(c) requires lesser cement for a particular water-cement ratio and hence is economical
(d) is beneficial as these aggregates can pass through the reinforcement bars more easily

[ESE : 2005]

4.63 Which one of the following correctly expresses the split tensile strength of a circular cylinder of length L and diameter D, subject to a maximum load of P?
(a) $\frac{P}{\pi DL}$ (b) $\frac{P}{2\pi DL}$
(c) $\frac{2P}{\pi DL}$ (d) $\frac{2P}{4\pi DL}$

[ESE : 2005]

4.64 **Assertion (A):** Rebound hammer (Schmidt hammer) test gives only approximate estimation of strength of the concrete specimen.
Reason (R): The test represents the hardness of the surface and provides no idea of the concrete inside.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2006]

4.65 Transportation of concrete-mix by pumps is very convenient method, particularly in case of
(a) housing complex
(b) cement concrete pavement
(c) low-rise buildings
(d) tunnel-lining

[ESE : 2006]

4.66 What is the correct sequence of operations involved in concrete production?
(a) Batching—mixing—handling—transportation
(b) Mixing—batching—handling—transportation
(c) Transportation—handling—mixing—batching
(d) Handling—transportation—mixing—batching

[ESE : 2006]

4.67 What is the approximate ratio of the strength of cement concrete at 7 days to that at 28 days curing?
(a) 0.40 (b) 0.65
(c) 0.90 (d) 1.15

[ESE : 2006]

4.68 Which one of the following properties of cement concrete is ascertained by conducting compaction factor test?

(a) Bulk density
(b) Compressive strength
(c) Modulus of rupture
(d) Workability

[ESE : 2006]

4.69 The mix design for pavement concrete is based on the
(a) flexural strength
(b) characteristic compressive strength
(c) shear strength
(d) bond strength

[ESE : 2006]

4.70 In what context is the slump test performed?
(a) Strength of concrete
(b) Workability of concrete
(c) Water-cement ratio
(d) Durability of concrete

[ESE : 2007]

4.71 Consider the following statements :
The use of superplasticizers as admixture
1. increases compressive strength of concrete
2. permits lower water-cement ratio, thereby strength is increased
3. reduces the setting time of concrete
4. permits lower cement content, thereby strength is increased?

Which of these statements is/are correct?
(a) 1 and 3 only (b) 3 and 4 only
(c) 1, 3 and 4 only (d) 2 only

[ESE : 2007]

4.72 Consider the following statements :
Curing of concrete is necessary because
1. concrete needs more water for chemical reaction
2. it is necessary to protect the water initially mixed in concrete from being lost during evaporation
3. penetration of surrounding water increases the strength of concrete

Which of these statements is/are correct ?
(a) 1, 2 and 3 (b) 1 and 3 only
(c) 2 only (d) 3 only

[ESE : 2007]

4.73 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. Absorption and surface moisture in aggregates
B. Deleterious material
C. Grading of aggregate
D. Chemical stability

List-II
1. Interferes with hydration of cement
2. Improves workability of mix
3. Ensures durability of all structures
4. Affects the mix proportions

Codes:

	A	B	C	D
(a)	3	1	2	4
(b)	4	2	1	3
(c)	3	2	1	4
(d)	4	1	2	3

[ESE : 2007]

4.74 Consider the following statements :
Modulus of elasticity of concrete is
1. tangent modulus
2. secant modulus
3. proportional to $\sqrt{f_{ck}}$
4. proportional to $1/\sqrt{f_{ck}}$

Which of these statements are correct ?
(a) 1 and 3 only (b) 1 and 4 only
(c) 2 and 3 only (d) 2 and 4 only

[ESE : 2007]

4.75 Which one of the following is employed to determine strength of hardened existing concrete structure ?
(a) Bullet test
(b) Kelly ball test
(c) Rebound hammer test
(d) Cone penetrometer

[ESE : 2007]

4.76 Which one of the following is the correct expression for the target mean strength f_t of concrete mix ?
(a) $f_t = kf_{ck} + S$ (b) $f_t = f_{ck} + kS$
(c) $f_t = f_{ck} + S$ (d) $f_t = kf_{ck} + k$
where f_{ck} is characteristic strength, k is probability factor and s is standard deviation.

[ESE : 2007]

4.77 Assertion (A): Even though vibration is the best technique of obtaining a durable and strong concrete, it cannot produce a compact concrete, if the mix is not properly graded or designed.
Reason (R): Over-vibrating of concrete with a slump of more than 10 cm may lead to honeycombing and a top surface which is not durable.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2007]

4.78 Which of the following pairs are correctly matched?
1. Particle size and texture : Affects workability
2. Absorption and surface moisture : Affects mix proportions
3. Grading : Maximizes cement content
4. Bulk density : Significant for stability

Select the correct answer using the codes given below:
(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 1 and 3

[ESE : 2008]

4.79 Consider the following statements:
1. Rise in temperature does not cause any change in the colour of cement concrete.
2. Curing minimizes the shrinkage of cement concrete when it sets.

Which of these statement is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2008]

4.80 What is the percentage of the fine aggregate of fineness modulus 2.6 to be combined with coarse aggregate of fineness modulus 6.8 for obtaining combined aggregate of fineness modulus 5.4?
(a) 30% (b) 40%
(c) 50% (d) 60%

[ESE : 2008]

4.81 Match List-I (Admixture) with List-II (Action in concrete) and select the correct answer using the codes given below the lists:

List-I
A. Calcium Lignosulphonate
B. Aluminium powders
C. Tartaric acid
D. Sodium silicate

List-II
1. Accelerators
2. Retarder
3. Air entrainer
4. Water reducer

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	4	3	2	1
(c)	4	2	3	1
(d)	1	2	3	4

[ESE : 2008]

4.82 Which factors influence the workability of concrete without sacrificing strength ?
1. Fine aggregate
2. Quantity of mixing water
3. Maximum size of coarse aggregate
4. Shape of coarse aggregate

Select the correct answer using the codes given below:
(a) 1 only (b) 2 only
(c) 1 and 2 (d) 3 and 4

[ESE : 2008]

4.83 The workability of concrete can be increased by which of the following?
1. Increasing the quantity of coarse aggregate without altering the total aggregate quantity.
2. Decreasing the quantity of coarse aggregate and at the same time correspondingly increasing the quantity of fine aggregate.
3. Using round aggregate.

Select the correct answer using the codes given below:
(a) 1 and 3 only (b) 1 and 2 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2008]

4.84 Consider the following statements regarding cement concrete:

1. Bleeding indicates deficiency of coarser materials in the mix.
2. Segregation generally indicates poor aggregate grading.

Which of these statements is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2008]

4.85 Consider the following statements:

Curing of concrete by steam under pressure

1. increases the compressive strength of concrete
2. reduces the shear strength of concrete
3. increases the speed of chemical reaction

Which of these statements is/are correct?

(a) 1, 2 and 3 (b) 1 only
(c) 2 and 3 only (d) 3 only

[ESE : 2008]

4.86 Match the sequence of determination of components of a concrete mix as per Indian Standard method of mix design and select the correct answer using the codes given below the lists:

List-I	List-II
A. Cement content	1. First step
B. Aggregate content	2. Second step
C. Water content	3. Third step
D. Water-cement ratio	4. Fourth step

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	3	2	4	1
(c)	3	4	2	1
(d)	1	4	2	3

[ESE : 2008]

Directions: The following items consists of two statements; one labelled as 'Assertion (A)' and the other as 'Reason (R)'. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.87 Assertion (A): Addition of calcium chloride while preparing concrete proves more effective with slow hardening Portland cement than with rapid hardening cement.

Reason (R): Calcium chloride is an effective accelerator in increasing the rate of relevant reaction.

[ESE : 2008]

4.88 Assertion (A): Strength of concrete is reduced due to segregation.

Reason (R): Reducing the workability of concrete mix results in segregation.

[ESE : 2009]

4.89 Assertion (A): The lower the difference between the minimum strength and the mean strength of a concrete mix, the lower the cement content to be used.

Reason (R): The method for controlling the difference between the minimum strength and the mean strength is quality control.

[ESE : 2009]

4.90 Which factors comprise maturity of concrete ?

(a) Compressive strength and flexural strength of concrete
(b) Cement content per cubic metre and compressive strength of concrete
(c) Curing age and curing temperature of concrete
(d) Age and aggregate content per cubic metre of concrete

[ESE : 2009]

4.91 What is the minimum value of individual test results (in N/mm^2) for compressive strength compliance requirement for concrete M20 as per codal provision ?

(a) $f_{ck} - 1$ (b) $f_{ck} - 3$
(c) $f_{ck} - 4$ (d) $f_{ck} - 5$

[ESE : 2009]

4.92 For what reason is it taken that the nominal maximum size of aggregate may be as large as possible?

(a) Larger the maximum size of aggregate, more the cement required and so higher the strength
(b) Larger the maximum size of aggregate, smaller is the cement requirement for a

particular water cement ratio and so more economical the mix.

(c) Larger the maximum size of aggregate, lesser are the voids in the mix and hence also lesser the cement required.

(d) Larger the maximum size of aggregate, more the surface area and better the bond between aggregates and cement, and so higher the strength.

[ESE : 2009]

4.93 What is the representative geometric mean size of an aggregate sample if its fineness modulus is 3.0 ?

(a) 150 μm (b) 300 μm

(c) 600 μm (d) 12 μm

[ESE : 2009]

4.94 What is the ratio of flexural strength (f_{cr}) to the characteristic compressive strength of concrete (f_{ck}) for M25 grade concrete ?

(a) 0.08 (b) 0.11

(c) 0.14 (d) 0.17

[ESE : 2009]

4.95 Which of the following tests compares the dynamic modulus of elasticity of samples of concrete?

(a) Compression test

(b) Ultrasonic pulse velocity test

(c) Split test

(d) Tension test

[ESE : 2009]

4.96 Which one of the following is correct regarding the most effective requirements of durability in concrete ?

(a) Providing reinforcement near the exposed concrete surface

(b) Applying a protective coating to the exposed concrete surface

(c) Restricting the minimum cement content and the maximum water cement ratio and the type of cement

(d) Compacting the concrete to a greater degree

[ESE : 2009]

4.97 Which one of the following is not required in concrete mix-design?

(a) Degree of quality control of concrete

(b) Workability of concrete

(c) Characteristic compressive strength of concrete at 28 days

(d) Initial setting time of cement

[ESE : 2010]

4.98 Consider the following statements:

Ultrasonic pulse velocity test to measure the strength of concrete is

1. used to measure the strength of wet concrete.
2. used to obtain estimate of concrete strength of finished concrete elements.
3. a destructive test.
4. a non-destructive test.

Which of these statements is/are correct?

(a) 2 only (b) 1 and 3

(c) 2 and 4 (d) 3 and 4

[ESE : 2010]

4.99 Consider the following statements about the air entraining admixture in concrete:

1. Improve workability
2. Improve durability
3. Reduce segregation during placing
4. Decrease concrete density

Which of these statements are correct?

(a) 1, 2, 3 and 4 (b) 1 and 2 only

(c) 2 and 3 only (d) 3 and 4 only

[ESE : 2010]

4.100 Consider the following statements:

Admixtures are added to concrete to

1. increase its strength.
2. reduce heat of hydration.
3. delay the setting of cement.
4. reduce water-cement ratio.

Which of these statements is/are correct?

(a) 1 only (b) 1 and 2

(c) 2 and 3 (d) 3 and 4

[ESE : 2010]

4.101 Consider the following statements:

1. Strength of concrete cube is inversely proportional to water-cement ratio.
2. A rich concrete mix gives a higher strength than a lean concrete mix since it has more cement content.
3. Shrinkage cracks on concrete surface are due to excess water in mix.

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 only (d) 2 and 3 only

[ESE : 2010]

4.102 Consider the following statements:
1. The crushing strength of concrete is fully governed by water-cement ratio.
2. Vibration has no effect on strength of concrete at high water-cement ratios.
3. Workability of concrete is affected by improper grading of aggregates.

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 2 and 3 only
(c) 2 only (d) 3 only

[ESE : 2010]

4.103 Consider the following statements:
Entrainment of air in concrete is done so as to
1. increase the workability.
2. increase the strength.
3. increase the resistance to freezing and thawing.

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 1 only
(c) 1 and 3 only (d) 3 only

[ESE : 2010]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.104 **Assertion (A):** Higher strength is achieved when superplasticizer is added to cement concrete mix.
Reason (R): By adding superplasticizer, the quantity of mixing water is reduced.

[ESE : 2010]

4.105 **Assertion (A):** In order to obtain higher degree of workability in cement concrete, both water content and proportion of cement should be increased.
Reason (R): Increase in water cement ratio decreases the strength of cement concrete; a mix with higher workability must have higher proportion of cement in it.

[ESE : 2010]

4.106 For different concrete specimens, each hydrated to the same degree, the permeability is
(a) Higher with lower water cement ratio and higher cement content.
(b) Lower with lower water cement ratio and higher cement content.
(c) Lower with higher water cement ratio and lower cement content.
(d) Lower with higher water cement ratio and higher cement content.

[ESE : 2011]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.107 **Assertion (A):** The tests for determining the setting times of cements are of little use in assessing the hardening of cement concrete.
Reason (R): Ultimate strength of concrete in-situ is not dependent upon the setting times of cement used.

[ESE : 2011]

4.108 **Assertion (A):** Centrifugal pumps are not normally usable for pumping mixed concrete even if the concrete (to be pumped) can be dropped in by a hopper system.
Reason (R): When dropping (mixed) concrete, segregation of aggregates may occur.

[ESE : 2011]

4.109 When percentage of mica present in sand is large, it
(a) Reduces the strength of mortar, or concrete.
(b) Increases the strength of mortar, or concrete.
(c) Has no effect on mortar, or concrete strength.
(d) Enhances the strength of mortar, or concrete, but only marginally.

[ESE : 2011]

4.110 Consider the following statements:
1. The compressive strength of concrete decreases with increase in water-cement ratio of the concrete mix.
2. Water is added to the concrete mix for hydration of cement and workability.
3. Creep and shrinkage of concrete are independent of the concrete mix.

Which of these statements are correct?
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2012]

4.111 According to the Indian Standard Specifications, concrete should be cured under a humidity of
(a) 90% (b) 80%
(c) 70% (d) 60%

[ESE : 2012]

4.112 Consider the following statements:
In a typical compression test with a cylindrical concrete specimen, failure is initiated by
1. crushing in compression
2. inclined shear failure
3. longitudinal tensile cracks

Which of these statements is/are correct?
(a) 1 only (b) 2 only
(c) 3 only (d) 1, 2 and 3

[ESE : 2012]

4.113 If one intends to obtain the best workability of concrete, the preferred shape of aggregate is
(a) round (b) annular
(c) triangular (d) flinty

[ESE : 2012]

4.114 Consider the following statements as regards rheology of concrete:
1. It deals with strength of concrete.
2. It deals with deformation in concrete.
3. It is the study of deformation and flow of concrete.
4. It deals with rate of shear and shear stress in concrete.

Which of these statements are correct?
(a) 1, 2, 3 and 4 (b) 3 and 4 only
(c) 2 and 3 only (d) 1 and 2 only

[ESE : 2012]

4.115 Consider the following for durability of well-graded concrete:
1. The environment
2. Cover to embedded reinforcement
3. Shape and size of concrete member

Which of these are correct?
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2012]

4.116 Consider the common methods related to testing of concrete:
1. Consistency 2. Compacting factor
3. Vee-Bee 4. Setting time
5. Slump

Which of these methods refer to measuring workability of concrete?
(a) 1, 2 and 3 (b) 1, 2 and 5
(c) 2, 3 and 4 (d) 2, 3 and 5

[ESE : 2012]

4.117 Consider the following constituents of a high performance concrete (HPC):
1. Cement
2. Fine aggregate
3. Coarse aggregate
4. Water
5. Mineral admixture
6. Chemical admixture

Which of these constituents are relevant for HPC?
(a) 1, 2, 3, 4, 5 and 6
(b) 1, 2, 3, 4 and 5 only
(c) 2, 3, 4, 5 and 6 only
(d) 1, 2, 3, 5 and 6 only

[ESE : 2012]

4.118 Which of the following factors would greatly affect the attainment of best possible strength of the concrete mix produced using the weigh-batcher?

1. Moisture content in the sand and gravel
2. Inadequate or excess use of approved admixtures
3. Speed of rotation of the drum
4. Non-emptying of the drum as fully as possible

(a) 1 and 4 (b) 1 and 2
(c) 2 and 3 (d) 3 and 4

[ESE : 2013]

4.119 The strength of concrete depends on
1. Type of mortar
2. Proportion between coarse and fine aggregates
3. Water cement ratio
4. Temperature at time of mixing

(a) 1 and 2 (b) 2 and 3
(c) 2 and 4 (d) 3 only

[ESE : 2013]

4.120 Consider the following statements:
1. Strength of structural concrete is absolutely dependent upon water cement ratio.
2. Increase in temperature during curing period improves the strength, especially for aluminous cements.
3. The concern for onset of fatigue in concrete can be overcome by increasing design loads in limit state design.
4. Even though concrete gains strength after 28 days, such increase is not considered at design stage.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 2, 3 and 4
(c) 3 and 4 only (d) 2 and 4 only

[ESE : 2013]

4.121 The workability of concrete is assessed through:
1. Slump test
2. Compaction factor test
3. Setting time of cement
4. Le-Chatelier's apparatus

(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 4 and 1

[ESE : 2013]

4.122 Consider the following statements as describing the Rheological behaviour of fresh concrete:
1. Newtonian
2. Non-Newtonian
3. Ratio of shear stress to shear rate is constant
4. Ratio of shear stress to shear rate depends upon the shear rate

Which of these statements are correct?
(a) 1, 2, 3 and 4 (b) 2 and 4 only
(c) 1, 2 and 4 only (d) 2, 3 and 4 only

[ESE : 2013]

4.123 Which of the following tests compares the dynamic modulus of elasticity of samples of concrete?
(a) Compression test
(b) Ultrasonic pulse velocity test
(c) Split test
(d) Tension test

[ESE : 2013]

4.124 UPV method in nondestructive testing for concrete is used to determine
1. Compressive strength
2. Existence of voids
3. Tensile strength
4. Static modulus of concrete
5. Dynamic modulus of concrete

(a) 1, 2, 3 and 4 (b) 1 and 3 only
(c) 2 and 5 only (d) 3 and 5 only

[ESE : 2013]

Directions: Each of the next items consists of two statements, one labeled as the **'Statements (I)'** and the other as **'Statement (II)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below :

Codes:
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

4.125 **Statement (I):** Weight batching method does not produce concrete of required strength.
Statement (II): Bulking of aggregates does not influence the weight batching method.

[ESE : 2013]

4.126 **Statement (I):** Shutter vibrators are preferred over needle vibrators for pre-stressed precast beams for bridges.
Statement (II): Needle vibrators may get choked by the leaking in of cement paste.
[ESE : 2013]

4.127 **Statement (I):** In concreting for large roof slabs, internal vibrators are preferred.
Statement (II): External vibrators consume more energy and disturb the formwork.
[ESE : 2013]

4.128 **Statement (I):** Inherent weakness of finished plain concrete is the presence of micro-cracks at the aggregate interface. It is minimized by placing fibres in the concrete mix.
Statement (II): The fibres help to transfer all incidental loads at the internal micro-cracks.
[ESE : 2013]

4.129 Consider the following statements : A good soil for making bricks should contain
1. 30% alumina
2. 10% lime nodules
3. Only small quantity of iron oxides
4. 15% magnesia

Which of the above statements are correct?
(a) 1 and 2 only (b) 1 and 3
(c) 1, 2 and 4 (d) 2, 3 and 4
[ESE : 2014]

4.130 Consider the following parameters of concrete:
1. Impermeability
2. Compactness
3. Durability
4. Desired consistency
5. Workability

Which of the above parameters are relevant for 'water-cement ratio'?
(a) 4 and 5 (b) 1 and 2
(c) 2 and 4 (d) 3 and 5
[ESE : 2014]

4.131 Consider the following statements : Presence of Na_2O and K_2O in concrete leads to
1. Expansive reaction in concrete
2. Cracking of concrete
3. Disruption of concrete
4. Shrinkage of concrete

Which of the above statements are correct?
(a) 1 and 2 only (b) 2 and 3 only
(c) 1, 2 and 3 (d) 3 and 4
[ESE : 2014]

4.132 The maximum total quantity of dry aggregate by mass per 50 kg of cement, to be taken as the sum of the individual masses of fine and coarse aggregates (kg), for M 20 grade of concrete, is
(a) 625 (b) 480
(c) 330 (d) 250
[ESE : 2014]

4.133 If aggregate size of 50–40 mm is to be tested for determining the proportion of elongated aggregates, the slot length of the gauge should be
(a) 45 mm (b) 53 mm
(c) 81 mm (d) 90 mm
[ESE : 2014]

4.134 Absorption capacity of an aggregate refers to the difference expressed in appropriate proportion in water content between
(a) a wet aggregate and a dry aggregate
(b) a dry aggregate and an oven-dry aggregate
(c) a saturated surface-dry aggregate and a dry aggregate
(d) a saturated surface-dry aggregate and an oven-dry aggregate
[ESE : 2014]

4.135 Consider the following statements concerning 'elasticity of concrete'.
1. Stress-strain behaviour of concrete is a straight line up to 10% of ultimate stress.
2. Strain determination is obtained from tangent modulus.
3. Modulus of elasticity of concrete is also called as secant modulus.

Which of the above statements are correct?
(a) 1, 2 and 3 (b) 1 and 3 only
(c) 1 and 2 only (d) 2 and 3 only
[ESE : 2014]

4.136 Consider the following statements : The addition of $CaCl_2$ in concrete results in
1. increased shrinkage
2. decreased setting time

3. decreased shrinkage
4. increased setting time

Which of the above statements is/are correct?

(a) 1 only (b) 2 and 3
(c) 3 and 4 (d) 1 and 2

[ESE : 2014]

Directions: Each of the next items consists of two statements, one labelled as **'Statement (I)'** and the other as **'Statement (II)'**. You are to examine these two statements and select the answers to these items using the code given below.

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(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true

4.137 **Statement (I)** : Grading of concrete is based on 28-days strength.

Statement (II) : Concrete does not gain any further strength after 28-days curing.

[ESE : 2014]

4.138 **Statement (I) :** Addition of admixture improves the workability of concrete.

Statement (II) : Addition of admixture increases the strength of concrete.

[ESE : 2014]

4.139 **Statement (I) :** Concrete of desired strength can be achieved by weight-batching method.

Statement (II) : Volume-batching method does not take into account bulking of aggregates, hence concrete of desired strength cannot be achieved by volume-batching.

[ESE : 2014]

4.140 Consider the following statements related to 'non-destructive testing' of concrete:

1. Indentation test is used to assess the quality of concrete.
2. Resonant Frequency Method is based on a laboratory test.
3. Compressive strength of concrete is estimated through Pulse Velocity Measurement.
4. Dynamic Modulus of Elasticity is determined by a Sonometer Test.
5. Thickness of concrete can be estimated by in-situ Rebound Hammer Test.

Which of the above statements are correct?

(a) 1, 2 and 3 only (b) 1, 2 and 5 only
(c) 1, 2, 3 and 4 only (d) 1, 2, 3, 4 and 5

[ESE : 2015]

4.141 What is the amount of water required for a workable RC of mix 1 : 2 : 4 by weight, when W/C is 0.60 and unit weight of concrete is 2400 kg/m^3?

(a) 165 *l* (b) 205 *l*
(c) 245 *l* (d) 285 *l*

[ESE : 2015]

4.142 In a concrete mix, if the maximum size of coarse aggregate is increased, the proportion of fine to coarse aggregate should be

(a) Increased
(b) Decreased
(c) Kept the same
(d) Not dependent on size of aggregates

[ESE : 2015]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.143 **Assertion (A):** Deadweight of a structure can be reduced by using light weight concrete in construction.

Reason (R): Aerated concrete, being of light weight, is used in R.C.C. multi-storied construction.

[ESE : 2015]

4.144 **Assertion (A):** Admixture in concrete is an essential constituent of concrete.

Reason (R): Admixture helps in improving or modifying specific qualities in concrete.

[ESE : 2015]

4.145 In a concrete mix of proportion 1 : 3 : 6, the actual quantity of sand, which is judged to have undergone 15% bulking, per unit volume of cement, will be

(a) 3.00 (b) 3.45
(c) 4.50 (d) 6.00

[ESE : 2016]

4.146 The Rheological behaviour of concrete, when represented by shear stress vs rate of shear, is characterized as

(a) $\tau = \tau_0 + \mu.\dot{\gamma}$ (b) $\tau_0 = \tau + \mu.\dot{\gamma}$

(c) $\frac{\tau}{\tau_0} = \mu.\dot{\gamma}$ (d) $\tau = \mu.\dot{\gamma}$

where :

τ = shear stress,

τ_0 = (initial) yield value,

μ = at-point plastic viscocity,

$\dot{\gamma}$ = at-point rate of shear.

[ESE : 2016]

4.147 Which method of curing of concrete is recommendable for rapid gain of strength of concrete?

(a) Sprinkling water
(b) Membrane curing
(c) High-pressure steam curing
(d) Infrared radiation curing

[ESE : 2016]

4.148 Which of the following is appropriate as a simple field method for assessing consistency of concrete?

(a) Compacting factor
(b) Slump test
(c) Vee-Bee test
(d) Kelly Ball test

[ESE : 2016]

4.149 Which of the following are relatable to Autoclaved Aerated Concrete?

1. Light weight 2. Strong
3. Inorganic 4. Non-toxic

(a) 1, 2 and 3 only (b) 1, 2 and 4 only
(c) 3 and 4 only (d) 1, 2, 3 and 4

[ESE : 2016]

4.150 The workability of concrete becomes more reliable depending on

1. Aggregate-cement ratio
2. Time of transit
3. Grading of the aggregate

(a) 1 only (b) 2 only
(c) 3 only (d) 1, 2 and 3

[ESE : 2016]

Directions: Each of the next items consists of two statements, one labelled as the **'Statement (I)'** and the other as **'Statement (II)'**. Examine these two statements carefully and select the answers to these items using the codes given below :

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(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is *not* the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

4.151 **Statement (I):** Water containing less than 2000 ppm of dissolved solids can generally be used satisfactorily for making concrete.

Statement (II): The presence of any of zinc, manganese, tin, copper or lead reduces the strength of concrete considerably.

[ESE : 2016]

4.152 **Statement (I):** Though a non-elastic material, yet concrete exhibits a linear relationship between stress and strain at low values of stress.

Statement (II): The modulus of elasticity of concrete is dependent on the elastic properties of aggregate and on curing.

[ESE : 2016]

4.153 Consider the following statements:

1. If more water is added to concrete for increasing its workability, it results into concrete of low strength.

2. No slump is an indication of a good workable concrete.
3. Higher the slump of concrete, lower will be its workability.
4. Workability of concrete is affected by water content as well as water cement ratio.

Which of the above statements are correct?

(a) 1 and 3 only (b) 2 and 3 only
(c) 1 and 4 only (d) 2 and 4 only

[ESE : 2017]

4.154 Pozzolana used as an admixture in concrete has the following advantages:

1. It improves workability with lesser amount of water.
2. It increases the heat of hydration and so lets the concrete set quickly.
3. It increases the resistance of concrete to attack by salts and sulphates.
4. It leaches out calcium hydroxide.

Select the correct answer using the codes given below:

(a) 1, 2 and 3 only (b) 1, 2 and 4 only
(c) 1, 3 and 4 only (d) 2, 3 and 4 only

[ESE : 2017]

4.155 Consider the following particulars in respect of a concrete mix design:

	Weight	Specific Gravity
Cement	400 kg/m^3	3.2
Fine aggregates	—	2.5
Coarse aggregates	1040 kg/m^3	2.6
Water	200 kg/m^3	1.0

What shall be the weight of the Fine aggregates?

(a) 520 kg/m^3 (b) 570 kg/m^3
(c) 690 kg/m^3 (d) 1000 kg/m^3

[ESE : 2017]

4.156 Consider the following statements regarding Cyclopean Concrete:

1. Size of aggregate is more than 150 mm.
2. Size of aggregate is less than 150 mm.
3. High slump.
4. High temperature rise due to heat of hydration.

Which of the above statements are correct?

(a) 1 and 3 only (b) 1 and 4 only
(c) 2 and 3 only (d) 2 and 4 only

[ESE : 2017]

Answers Concrete

4.1	(b)	4.2	(b)	4.3	(c)	4.4	(c)	4.5	(b)	4.6	(c)	4.7	(b)
4.8	(c)	4.9	(a)	4.10	(b)	4.11	(d)	4.12	(d)	4.13	(b)	4.14	(b)
4.15	(b)	4.16	(b)	4.17	(b)	4.18	(c)	4.19	(c)	4.20	(b)	4.21	(c)
4.22	(b)	4.23	(a)	4.24	(a)	4.25	(d)	4.26	(c)	4.27	(d)	4.28	(a)
4.29	(c)	4.30	(b)	4.31	(c)	4.32	(a)	4.33	(a)	4.34	(d)	4.35	(a)
4.36	(d)	4.37	(b)	4.38	(b)	4.39	(d)	4.40	(c)	4.41	(b)	4.42	(d)
4.43	(d)	4.44	(c)	4.45	(c)	4.46	(a)	4.47	(a)	4.48	(b)	4.49	(b)
4.50	(b)	4.51	(c)	4.52	(c)	4.53	(b)	4.54	(b)	4.55	(c)	4.56	(b)
4.57	(d)	4.58	(b)	4.59	(d)	4.60	(a)	4.61	(a)	4.62	(a)	4.63	(c)
4.64	(c)	4.65	(d)	4.66	(a)	4.67	(b)	4.68	(d)	4.69	(a)	4.70	(b)
4.71	(d)	4.72	(c)	4.73	(d)	4.74	(c)	4.75	(c)	4.76	(b)	4.77	(b)
4.78	(a)	4.79	(b)	4.80	(a)	4.81	(b)	4.82	(a)	4.83	(a)	4.84	(b)
4.85	(a)	4.86	(c)	4.87	(a)	4.88	(c)	4.89	(d)	4.90	(c)	4.91	(c)
4.92	(b)	4.93	(c)	4.94	(c)	4.95	(b)	4.96	(c)	4.97	(d)	4.98	(c)
4.99	(a)	4.100	(d)	4.101	(a)	4.102	(b)	4.103	(c)	4.104	(a)	4.105	(a)
4.106	(b)	4.107	(a)	4.108	(b)	4.109	(a)	4.110	(a)	4.111	(a)	4.112	(b)
4.113	(a)	4.114	(a)	4.115	(d)	4.116	(d)	4.117	(a)	4.118	(b)	4.119	(b)
4.120	(d)	4.121	(a)	4.122	(b)	4.123	(b)	4.124	(c)	4.125	(d)	4.126	(a)
4.127	(a)	4.128	(a)	4.29	(b)	4.130	(d)	4.131	(c)	4.132	(d)	4.133	(c)
4.134	(d)	4.135	(b)	4.136	(d)	4.137	(c)	4.138	(b)	4.139	(c)	4.140	(c)
4.141	(a)	4.142	(b)	4.143	(b)	4.144	(d)	4.145	(b)	4.146	(a)	4.147	(c)
4.148	(d)	4.149	(d)	4.150	(d)	4.151	(b)	4.152	(b)	4.153	(c)	4.154	(c)
4.155	(c)	4.156	(b)										

Explanations Concrete

4.1 (b)

Split tensile strength is 5% to 12% higher than direct tensile strength. The ratio of split tensile strength to compressive strength for different grades of concrete are given below:

M 10	10% – 15%
M 15	15% – 20%
M 20	20% – 25%
M 30	25% – 30%

For approximation purpose one can take split tensile strength as $0.7\sqrt{f_{ck}}$ which is the flexural strength given by IS : 456-2000.

The ratio of split tensile strength to compressive strength is given by

$$\frac{0.7\sqrt{f_{ck}}}{f_{ck}} \times 100$$

For M15, $f_{ck} = 15$ N/mm^2

$$\Rightarrow \quad \frac{0.7\sqrt{15}}{15} \times 100 = 18\%$$

So 15% – 20% should be the choice.

4.2 (b)

The strength of concrete at any age, can be expressed by the relation

$$f_T = \frac{T}{a + bT} f_{28}$$

The 7-day and 28 day strength are related as

$$f_{28} = k_2 (f_7)^{k_1}$$

According to IS code, the ratio f_7/f_{28} is approximately 2/3.

Grade of concrete	7 day strength (N/mm^2)
M 10	7
M 15	10
M 20	13.5
M 25	17.0
M 30	20.0
M 35	23.5
M 40	27.0

4.3 (c)

The modulus of elasticity as per IS:456-1978

$$E_c = 5700\sqrt{f_{ck}} \text{ N/mm}^2$$

The modulus of elasticity as per IS:456-2000

$$E_c = 5000\sqrt{f_{ck}} \text{ N/mm}^2$$

For *M* 25

$$E_c = 5700\sqrt{f_{ck}} = 28{,}500 \text{ MPa}$$

$$E_c = 5000\sqrt{f_{ck}} = 25{,}000 \text{ MPa}$$

4.4 (c)

The restraining effect of the platens of the testing machine extends over the entire height of the cube but leaves unaffected a part of test cylinder because of its greater height. It is therefore, the strength of cube made from identical concrete will be higher from strength of cylinder.

4.5 (b)

Specific Surface of aggregate

$$\propto \frac{1}{\text{Size of aggregate}}$$

Workability of mix is influenced more by finer fractions. Greater contribution to total surface area is made by finer particles. Both statements are true but reason does not explain assertion.

4.6 (c)

Air entraining admixtures modify the properties of concrete viz. plasticity, workability, bleeding, seggregation, permeability and frost action.

4.7 (b)

Tensile strength is generally determined indirectly. A compressive force is applied to a concrete specimen in such a way that specimen fails due to tensile stress induced in specimen. The compressive load is applied along opposite generators of concrete cylinder placed with its axis horizontal between the platens.

4.8 (c)

Ratio of cylinder strength to cube strength varies from 0.77 – 0.96. Thus 0.85 can be taken as approximate ratio.

4.9 (a)

The proportion of fine aggregate to combined aggregate,

$$R = \frac{p_2 - p}{p_2 - p_1} \times 100$$

$$\therefore \quad R = \frac{7.6 - 6.4}{7.6 - 2.8} \times 100 = 25\%$$

4.11 (d)

The drying in concrete starting from a wetter consistency causes shrinkage of concrete.

4.12 (d)

The correct dry weight of each size range of each material is calculated from their actual weight in weight batching and weight of water is measured by making adjustments for surface and absorbed water.

4.13 (b)

Calcium chloride is a rapid hardening agent. The acceleration of setting, hardening and evolution of this large quantity of heat in the early period of hydration makes the cement suitable for concreting in cold weather. The increased porosity of high alumina cement further develops more resistance to frosting.

4.14 (b)

As per IS : 456-1978, $E_c = 5700\sqrt{f_{ck}}$

As per IS : 456-2000, $E_c = 5000\sqrt{f_{ck}}$

4.15 (b)

One complete cycle of material is discharged after about 20 revolutions and it takes $2\frac{1}{2}$ to 3 minutes.

If the concrete is mixed for a comparatively longer time, it is uneconomical from the point of view of rate of production of concrete and fuel consumption. While if the speed of mixer is increased to reduce mixing time, the quality of concrete will be poor.

4.16 (b)

The addition of surfactants in concrete mix decreases water-cement ratio thereby increasing the strength. Also curing duration is increased.

4.17 (b)

High water cement ratio improves the workability of the mixture but as the water content increases the strength of the mix decreases.

4.19 (c)

The measurement of material for making concrete is called batching. It is essential to ensure uniformity of proportions and aggregate grading in successive batches.

4.20 (b)

1 m^3 freshly mixed concrete corresponds to 1.54 m^3 dry volume of concrete.

Summation of proportions = 1 + 2 + 4 = 7

$$\text{Cement} = \frac{1.54}{7} = 0.22 \text{ m}^3 = 6.6 \text{ bags}$$

(1 m^3 cement equal 30 bags of cement or 1500 kg cement)

Sand = $0.22 \times 2 = 0.44$ m^3

Coarse aggregate = $0.22 \times 4 = 0.88$ m^3

4.21 (c)

As 5.5 bags of cement can produce 0.8 m^3 of concrete .The maximum number of full bags will be 5. So 5 bags can produce $\frac{5}{5.5} \times 0.8 = 0.73$ m^3 of concrete.

4.22 (b)

Split tensile strength in the case of cylinder is obtained by $\sigma_{sp} = \frac{2P}{\pi DL}$

The test can also be performed on cubes by either

(i) along its middle parallel to the edges by applying two opposite compressive force through 15 mm square bars of sufficient length $\sigma_{sp} = 0.642\ P/S^2$ OR

(ii) along one of the diagonal planes by applying compressive forces along two opposite edges $\sigma_{sp} = 0.518\ P/S^2$

where

$P \rightarrow$ Load at failure

$S \rightarrow$ Side of the cube

$L \rightarrow$ Length of cylinder

$D \rightarrow$ Diameter of cylinder

4.23(a)

Split tensile strength - modulus of rupture - cylinder strength- cube strength, is the increasing order of strength.

4.24(a)

Shrinkage is used to describe the various aspects of volume change in concrete due to loss of moisture at different stages due to different reasons. One of the most important factors that affects shrinkage is the relative humidity of the atmosphere at which the concrete specimen is kept. Shrinkage also depends on time. Its magnitude increases with time and also with the reduction of relative humidity. Another important factor which affects shrinkage is water cement ratio and type of aggregates.

4.25 (d)

Air entrainment in concrete results in improved workability, increased plasticity, better resistance to freezing and thawing, reduction in bleeding and segregation, increased durability and easier placing and finishing. However it reduces the strength of concrete.

4.26(c)

The optimum temperature during the curing period is 15°-38°. The ambient temperature in most parts of India provide warmth required for satisfactory hydration. IS Code specifies 27°C as curing temperature.

4.27(d)

The slump test is most widely used because of the simplicity of apparatus required and the test procedure. This is suitable for concrete of medium to high workability (i.e. having slump values of 25 mm to 125 mm). The compacting factor test has been held to be more accurate than slump test, especially for medium and low workability i.e., compacting factor of 0.9 - 0.8 or slump 25-50 mm, for concrete of very low workability of the order of 0.7 or below, the test is not suitable. Vee-bee consistometer test is suitable for stiff concrete mixes having low and very low workability.

4.28 (a)

As per IS 516, while testing compressive strength of cement concrete the preferable room temperature is 27±3 °C. The size of cube for testing should be 15 cm^3.The specimen should be stored in a vibration free place, in moist air of atleast 90% relative humidity. Specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load at the failure divided by area of specimen gives the compressive strength of concrete.

4.29 (c)

When mixing is done weight bulking effect of sand is not taken into account. However when mixing is done by volume bulking effect of sand is to be considered.

4.30(b)

Tensile strength = k (compressive strength)^n

Modulus of rupture of concrete = $0.7\sqrt{f_{ck}}$ The ratio of direct tensile strength to modulus of rupture lies between 0.48-0.63. So 0.5 can be taken as average value.

4.31(c)

The fly ash is the residue from the combustion of pulverised coal collected by the mechanical dust collectors or electrostatic precipitators from the fuel gases of thermal power plants. The principal constituents of fly ash are:

SiO_2	:	30-60%
Al_2O_3	:	15-30%
Carbon	:	upto 1-7%
CaO	:	Small
MgO	:	Small
SO_3	:	30%

The fly ash may be used in concrete either as an admixture or in part replacement of cement or fine aggregate.

Use of right quality of fly ash results in reduction of water demand for desired slump. Thus it increases workability. With reduction in water content, bleeding and drying shrinkage will also be reduced.

4.32(a)

Calcium chloride accelerates the setting and hardening process. It is used in extra rapid hardening cement.

4.33 (a)

Air entrained concrete has high resistance to freezing and thawing. Vacuum concrete has been used for factory production of precast plain and RCC units.

4.35 (a)

In high pressure steam curing, higher rate of development of strength is attributed to higher temperature to which a concrete is subjected.

Due to the formation of coarser gel, the bond strength of concrete to reinforcement is reduced by about 30-50%.

4.36 (d)

The rounded aggregate has minimum voids and minimum ratio of surface area to volume, thus requiring minimum cement paste to make good concrete. However due to absence of interlocking, these aggregates are not suitable for high strength concrete and pavements.

4.37 (b)

Ultrasonic pulse velocity test is a non- destructive test which is used to estimate the strength of finished concrete.

4.39 (d)

The plasticity (workability) is lost with time mainly because of the loss of moisture due to evaporation.

4.40 (c)

A mineral additive also called a supplementary cementitious material (pozzolana) is finely ground siliceous material which does not possess cementitious property in itself, but react with calcium hydroxide (released from hydration of portland cement) to form compounds of low solubility having cementitious property. This is called pozzolanic action.

It reduces permeability, improve workability and increase resistance to chemical attack. The leaching of calcium hydroxide is avoided as $Ca(OH)_2$ is converted to cementitious product by pozzolanic action.

4.41 (b)

1. Retarders delay setting time of cement either by forming a thin coating on the cement particles and thus slowing down their dissolution in and reaction with water, or by increasing the intra-molecular distance of reacting silicates and aluminates from water molecules by forming certain transient compounds in the system. These belong to following two groups:
   (i) Soluble carbohydrate derivatives like sugar, starch, dextrin etc.
   (ii) Inorganic retarders based on hydroxides of zinc and lead, alkali-bi-carbonates, calcium borate, calcium sulphate (gypsum), skimmed milk powder (casein) etc.

   Other admixtures used as retarders are Ligno sulphonic acids and their salts, hydroxylated carboxylic acids and their salts, calcium acetate.
2. Air entrainers - natural wood resins containing abietic and pimeric acid salts, various sulphonated compounds, some animal and vegetable fats and oils such as fallow, olive oil and their fatty acids such as stearic and oleic acid.

   Various wetting agents like alkali salts or sulphated and sulphonated compounds. Sodium salts of petroleum sulphonic acids, hydrogen peroxide, and aluminium powder etc. are also used.
3. Water reducers - anionic surfactants such as lignosulphonates and their modifications and derivatives, salts of sulphonates hydrocarbons. Among these calcium, sodium and ammonium lignosulphonates are most used.

4.42 (d)

Bleeding or water gain, is a particular form of segregation in which some of the water from the concrete comes out to the surface of the concrete, being of the lowest specific gravity among all the ingredients of concrete. It causes

(i) higher shrinkage cracks at top surface
(ii) water voids and reduction of bond between the aggregates and cement paste

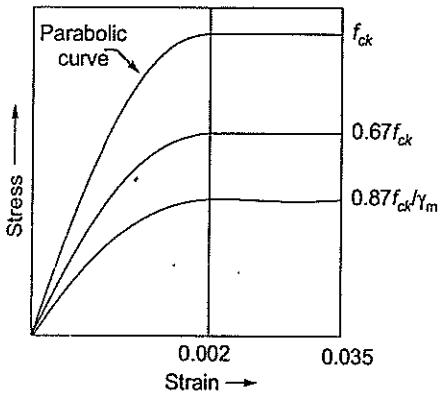
4.43 (c)

Workability increases with the water content. Is 456-2000 specifies the minimum cement content for durability of concrete. Water cement ratio

affects the compressive strength of concrete and segregation affects the stability of mix.

4.44 (c)

Parabolic up to 0.002% strain value and then a straight line up to failure



Stress-strain curve for concrete

4.45 (c)

Ultrasonic pulse velocity test is used to estimate the strength of finished concrete and not that of wet concrete. It is a non-destructive test.

4.46 (a)

The typical batching tolerances are as follows:

Cement : ± 1% of the required weight of material being weighed or ± 0.3% of scale capacity whichever is greater.

Water : ± 1% of the required weight of material being weighed or ± 0.3% of scale capacity whichever is greater.

Aggregates : ± 2% of the required weight of material being weighed or ±0.3% of scale capacity whichever is greater.

Admixtures : ± 3% of the required weight of material being weighed or ±0.3% of scale capacity whichever is greater.

4.47 (a)

Fineness modulus of different sands suitable for making concrete are:

Fine sand	- 2.2 to 2.6
Medium sand	- 2.6 to 2.9
Coarse sand	- 2.9 to 3.2

A sand having fineness modulus more than 3.2 is unsuitable for making concrete.

4.48 (b)

Split tensile test is conducted on a cylindrical specimen or cubical specimen. The same specimen can be used for compressive strength test.

Due to the applied line loading a fairly uniform tensile stress is induced over nearly two-third of the loaded diameter as obtained from an elastic analysis.

4.49 (b)

IS: 456-2000 stipulates a minimum of 7-day moist curing while **IS:7861(Part-I)-1975** stipulates a minimum of 10 days under hot weather condition. On an average, the one-year strength of continuously moist cured concrete, is 40% higher than that of 28 days moist cured concrete, while no moist curing can lower the strength to about 40%. Moist curing for the first 7 to 14 days may result in a compressive strength of 70% - 85% of that of 28 days moist curing.

4.50 (b)

The use of super-plasticizers permits lower water cement ratio by enhancing the workability and thereby increase the strength of concrete.

4.52 (c)

The factors affecting workability are:

1. The higher the water content per cubic metre of concrete, the higher will be the fluidity of concrete.
2. Higher the aggregate/cement ratio, the leaner the concrete and lesser the workability. Lower aggregate/cement ratio gives cohesive and fatty mix with better workability.
3. The bigger the size of aggregate, higher will be the workability.
4. Angular, elongated or flaky aggregate makes the concrete very harsh compared to rounded or cubical aggregates.
5. Smooth textured aggregates contribute to higher workability.
6. Well graded aggregates with less void content, gives higher workability.
7. Admixture may increase workability.

4.53 (b)

As the range of slump increases, the range of compacting factor also increases.

Slump in mm		Compacting Factor
0–25	:	0.78 – 0.80
25–75	:	0.85 – 0.87
50–100	:	0.92 – 0.935
100–150	:	0.95 – 0.96

4.54 (b)

Concrete for road work	20-30 mm
Ordinary RCC work	50-100 mm
Columns, retaining walls	75-150 mm
Vibrated concrete	12-25 mm
Mass concrete	25-50 mm

4.55 (c)

For hand compaction of heavily reinforced concrete high workability (100-150 mm) is required. For concreting of shallow sections with vibrations low workability (12-25 mm) is required.

4.56 (b)

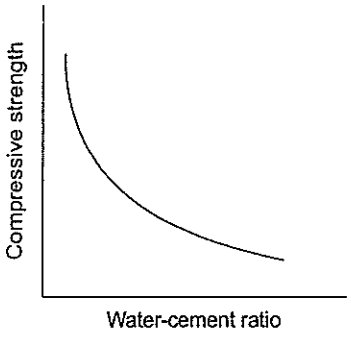
Let FA/CA ratio be x. So combined aggregate/ coarse aggregate ratio will be $(1 + x)$

$$(1 + x) \times 6.14 = 1 \times 7.82 + x \times 2.78$$

$$\therefore x = \frac{7.82 - 6.14}{6.14 - 2.78} = 0.5 \text{ or } 50\%$$

4.57 (d)

The strength of concrete has inverse relation with water-cement ratio. It reduces with increase in water-cement ratio.



4.58 (b)

$$\text{Mean dimension} = \frac{50 + 40}{2} = 45 \text{ mm}$$

$$\text{Slot for flakiness index} = \frac{3}{5} \times 45 = 27 \text{ mm}$$

4.59 (d)

Concrete is not strictly elastic in the sense that if it is unloaded after being stressed to $0.5f_o$ (f_o is the ultimate strength), a permanent set is noticed. However, the magnitude of the permanent set gradually decreases with more cycles of loading and unloading (within $0.5\ f_o$) and the stress-strain curve tends to become a straight line. The creep determination of concrete also varies linearly with the sustained stress upto $0.5f_o$. Hence for all practical purposes, the concrete should be considered to be linear elastic material when stress does not exceed $0.5f_o$.

4.60 (a)

Superplasticizers, owing to the reduction in w/c ratio, reduce the penetration of chlorides and sulphate into the concrete and, therefore, improve their resistance to the deciding effect of salt or sea water.

4.61 (a)

Rebound hammer test uses the elastic properties of concrete to determine the hardness. In rebound hammer test, hardness is determined by striking the plunger against concrete and then noting its rebound deflection.

4.62 (a)

The smaller the size of aggregates more is the surface area (inverse relation). More surface area means better bonding which increases the compressive strength and reduces stress concentration at surface. However this requires greater quantity of cement for same water-cement ratio.

4.64 (c)

The rebound hammer test measures the elastic rebound of concrete. The rebound number is correlated with compressive strength of concrete. The variation of strength of a properly calibrated hammer may lie between ± 15% and ± 20%.

4.65 (d)

Pumped concrete has largely been used in construction of multi-storey buildings, tunnels, and bridges.

4.66 (a)

The sequence of operation during concrete production is:

Batching → Mixing → Handling → Transportation → Placing, compaction and finishing Curing

4.67 (b)

7 days strength $\cong \frac{2}{3}$ of 28 days strength.

4.68 (d)

Compaction factor test is done for ascertaining workability of cement concrete. Other test for ascertaining workability is Slump Test, Vee-bee Consistometer Test and Flow Test.

4.69 (a)

The mix design for pavement concrete (Highway/ Runway) is based on the flexural strength (f_c) instead of characteristic compressive strength (f_{ck}). Because the soil beneath the concrete pavement may be scoured by flood or some other reasons and the concrete pavement will behave as a beam and the load on pavement is to be limited by flexural strength of concrete. Required flexural strength is converted into corresponding characteristic compressive strength by the expression $f_c = 0.7\sqrt{f_{ck}}$ and the concrete is designed for the required compressive strength as usual.

4.71 (d)

Superplasticizers permit the reduction of water to the extent upto 30% without affecting workability for the same amount of cement.

4.72 (c)

Due to environmental factors like evaporation the water content of concrete reduces so to replenish the water lost curing of concrete is necessary.

4.74 (c)

The modulus of elasticity most commonly used in practice is secant modulus. It decreases with increase in strength.

4.75 (c)

Rebound hammer test is a non-destructive test used to determine strength of hardened concrete by noting the rebound deflection when the concrete is hit with plunger.

4.76 (b)

Target mean strength of concrete (f_t) is :

$f_t = f_{ck} + K.S$

where

f_t = target mean strength

f_{ck} = characteristic strength

K = a statistical constant, and is derived from the mathematics of Normal Distribution

S = standard deviation

As per IS 456-2000, The value of K is equal to 1.65, where, not more than 5% of test results are expected to fall below the characteristic strength

4.77 (b)

Correct design of concrete mix and effective control in manufacture of concrete right from selection of constituent material through its correct proportioning to its placing are essential to obtain maximum benefits of vibrations.

4.78 (a)

Grading implies that a sample of aggregates contains all standard fractions of aggregate in required proportion such that the sample contains minimum voids. A sample of well graded aggregate containing minimum voids will require minimum paste to fill up the voids in the aggregate. Thus, grading minimizes the cement content.

4.79 (b)

At about 300°C, the colour of concrete changes to light pink from grey. This pink colour darkens and its intensity increases upto 600°C. It then begins to lighten.

4.80 (a)

The percentage of fine aggregate will be given as

$$R = \frac{(FM)_{coarse} - (FM)_{combined}}{(FM)_{coarse} - (FM)_{fine}} \times 100$$

$$= \frac{6.8 - 5.4}{6.8 - 2.6} \times 100 = 33\%$$

It is not given in options. So nearest answer 30% is correct.

4.81 (a)

Water cement ratio increases on mixing water and strength decreases. Increase in size of aggregate increases workability but decreases compressive strength for particular volume. Shape affects strength as round aggregates provide low to

medium strength but high workability and angular aggregates provide strength but low workability.

4.83 (a)

For the same water content, decreasing the quantity of coarse aggregate and correspondingly increasing the quantity of fine aggregate decreases workability. Coarse aggregate gives higher workability because of less friction among particles and reduction in total surface area, thus more gel paste is available, hence more workable.

4.84 (b)

Bleeding is a form of segregation in which some of the water from concrete comes out to the surface. It is observed in highly wet mix.

Bleeding: It is an autogeneous flow of mixed water within or, emergence to be surface from freshly placed concrete, usually due to excessive vibrations imparted to concrete to achieve full compaction.

Bleeding can be checked by using uniformly graded agreegates, pozzolana, air-entraining agents, finer cement, alkali cement and a rich mix.

Segregation: It is separation of ingredients of fresh concrete. It may be separation of coarse from fine aggregate, paste from coarse aggregate or water from the mix. Causes may be excess water, dropping concrete from heights, badly designed mixes, concrete carried over long distances pumping, belt conveyor system, etc. over vibration, during finishing – extrafloating and tamping.

4.85 (a)

Under pressure steam curing increases the speed of hydration of the cement. Curing of concrete by steam under pressure increases the compressive strength whereas reduces the shear stress.

4.86 (c)

The steps involved in IS method of mix design are:

1. Target mean strength for mix design is calculated by the equation.

   $\bar{f}_{ck} = f_{ck} + 1.65S$

2. Selection of water/cement ratio.
3. Estimation of entrapped air.
4. Selection of water content and fine to total aggregate ratio.
5. Calculation of cement content.
6. Calculation of aggregate content.

4.87 (a)

Calcium chloride addition in slow hardening cement is more effective than rapid hardening cement as calcium chloride acts as an accelerator and increases the rate of hydration in slow hardening cement whereas the rate of hydration is already high in rapid hardening cement.

4.88 (c)

Segregation can be defined as separating out of the ingredients of concrete mix so that the mix is no longer in a homogeneous condition. Increasing the workability of concrete by increasing water content will eventually lead to segregation and bleeding.

4.89 (d)

The cement content to be used does not depend on difference of minimum strength and mean strength. It depends on water-cement ratio, durability and strength required.

4.90 (c)

The strength development of concrete depends on both curing time and temperature. Thus it can be said that strength is a function of summation of product of time and temperature. This summation is called maturity of concrete.

Maturity = Σ(time × temperature)

4.91 (c)

As per IS : 456-2000, the characteristic compressive strength compliance requirement are:

Grade of concrete	Individual test Results (in N/mm²)
M15	$\geq f_{ck} - 3$
M20 or above	$\geq f_{ck} - 4$

4.92 (b)

For a particular water-cement ratio, larger is the size of aggregate, less is the requirement of cement. However as the aggregate size increases, the compressive strength decreases.

4.93 (c)

The fineness modulus is a numerical index of fineness, giving some idea of the mean size of the particles present in the entire body of the aggregate. The sieves used in calculating fineness modulus are arranged in the following order as per IS : 2386 (Part-I)-1963 are 80 mm, 40 mm, 20 mm, 10 mm, 4.75 mm, 2.36 mm, 1.18 mm, 600 μm, 300 μm and 150 μm. The fineness modulus can be regarded as a weighted average size of a sieve on which material is retained, and the sieves being counted from the finest.

Here the fineness modulus of the sample is 3.0. It means that the third sieve i.e. 600 μm is the average size.

4.94 (c)

$$f_{cr} = 0.7\sqrt{f_{ck}}$$

$$\therefore \quad \frac{f_{cr}}{f_{ck}} = \frac{0.7\sqrt{25}}{25} = 0.14$$

4.95 (b)

The value of modulus of elasticity found out by actual loading of concrete i.e. the static modulus of elasticity does not truly represent the elastic behaviour of concrete due to the phenomenon of creep. The value of modulus of elasticity found out by the velocity of sound or frequency of sound is referred as dynamic modulus of elasticity. The value of dynamic modulus of elasticity computed from ultrasonic pulse velocity method is somewhat higher than those determined by static method because dynamic modulus is unaffected by creep.

4.96 (c)

The most effective ways of ensuring concrete durability are:

Using right type of cement as per environment, restricting maximum water cement ratio ,restricting the minimum cement content.

4.97 (d)

According to IS: 456 - 2000 and IS : 1343 - 1980, the design of concrete mix should be based on the following factors:

(i) Characteristic compressive strength
(ii) Type of cement
(iii) Maximum nominal size of aggregates
(iv) Grading of combined aggregates
(v) Water-cement ratio
(vi) Workability
(vii) Durability
(viii) Degree of quality control

4.98 (c)

The non-destructive test may be performed directly on the in-situ concrete without the removal of a sample. These tests do not impair the intended performance of the element or member being tested. They also include methods which cause localized surface zone damage and may be called partially destructive.

The ultrasonic pulse velocity method is a non-destructive test for hardened concrete which basically involves the measurement of velocity of electronic pulses passing through concrete from a transmitting transducer to a receiving transducer. This method is based on the principle that the velocity of pulse passing through concrete is primarily dependent upon the density and the elastic properties of the materials and is independent of geometry of the component. The density and elastic properties are in turn related to the quality and strength of the material.

4.99 (a)

Air-entraining admixtures help to incorporate a controlled amount of air, in the form of millions of minute non-coalescing bubbles. These air bubbles act as flexible ball bearings and modify the properties of plastic concrete regarding workability, segregation, bleeding and finishing quality of concrete. It also modifies the properties of hardened concrete regarding its resistance to frost action, permeability and durability. For the same workability and strength, the air-entrained concrete contains approximately 5% less solid material and hence has lower density. Some of the air entraining agents are natural wood resins, various sulphonated compounds and some animal and vegetable fats and oils such as tallow, olive oil and their fatty acids such as stearic and oleic acids.

4.100 (d)

Admixtures are essentially classified as water-reducers (plasticizers), set-retarders and accelerators. The purpose of water-reducers is to achieve a higher strength by decreasing the water/cement ratio. Set-retarders are admixtures which delay the setting of concrete. Accelerators accelerate the hardening or the development of early strength of concrete. However, reducing the heat of hydration is not the main purpose of admixtures.

4.102 (b)

The crushing strength of concrete also depends upon maximum size of aggregate, gel-space ratio, etc.

4.103 (c)

Air-entrainment improves durability, workability and plasticity but it have an adverse effect on the strength of concrete. The decrease in strength is usually proportional to the amount of entrained air. For each per cent increase in air content, the compressive strength reduces approximately by 1.4 MPa.

4.104 (a)

The workability of concrete increases on use of super-plasticizers as admixture, which allows lower water-cement ratio and hence the strength is increased.

4.105 (a)

In order to obtain high workability higher water content is required but with increase in water cement ratio the strength if concrete is decreased so cement content should also be increased along with water content to maintain strength.

4.106 (b)

Permeability of concrete is directly related to the porosity of the cement paste, the distribution of capillary pores and the presence of micro-cracks (induced by shrinkage effects, tensile stresses, etc.). The main factors influencing capillary porosity are the water-cement ratio and the degree of hydration. The use of a low water-cement ratio, adequate cement and effective curing contribute significantly to reduced permeability.

4.108 (b)

Use of centrifugal pump for pumping mixed concrete leads to segregation of the concrete mix. Therefore they are not normally used for pumping concrete.

The conditions favourable for segregation are:

1. Badly proportioned mix where sufficient matrix is not there to bind and contain the aggregates.
2. Insufficiently mixed concrete with excess water content
3. Dropping of concrete from heights as in the case of placing concrete in column concreting
4. When concrete is discharged from a badly designed mixer, or from a mixer with worn out blades
5. Conveyance of concrete by conveyour belts, wheel barrow, long distance haul by dumper, long lift by skip and hoist are the other situations promoting segregation of concrete.

4.109 (a)

Mica is considered as a deleterious ingredient for preparation of mortar or concrete. The mica particles are known to change the aggregate properties with increasing mica contents. The decreased bulk density of a micaceous aggregate will mean a lower weight of aggregate will be required to make up a certain volume of water but more cement paste will be required to fill the voids and coat the particles.

The increased water absorption of the mica will mean that the water requirement of the mix will increase.

Furthermore, the increase in water requirement of the mix with mica as a result of water being used to spread the cement paste further over the increased surface area of the particles and into the increased void space, will produce a diluted cement paste and a weakened mortar.

4.110 (a)

- Compressive strength of concrete has inverse relation to water cement ratio.
- Workability increases on adding water for hydration of cement.
- Creep and shrinkage of concrete increases, with water-cement ratio.

4.111 (a)

According to IS code curing should be done under humidity of 90% at a temperature of 27±3°C.

4.113 (a)

The aggregate with rounded particles gives minimum ratio of surface area to the volume, thus requiring minimum cement paste to make good concrete. The angular shaped aggregates on the other hard provides good interlocking, hence good bond, between the particles, but it requires more cement paste to make workable concrete of high strength.

4.114 (a)

Rheology is the study of flow and deformation of materials and is used to analyze the relationship between stress, strain, rate of strain, time and also the strength of concrete.

4.115 (d)

As per IS 456-2000, the factors influencing durability are:-

- Environment
- Type and quality of constituent materials
- Cover to embedded steel
- Cement content and W/C ratio of concrete
- Workmanship
- Shape and size of member

4.118 (b)

Water content in sand and gravel will have an influence on water cement ratio of concrete thereby affecting the strength of concrete.

Admixtures are added in concrete to improve/ modify one and more property (ies) of the concrete mix.

4.119 (b)

The concrete strength depends on concrete mix proportion, water-cement ratio, compaction, temperature of curing, age, type of cement etc

4.120 (d)

Though strength of concrete depends on w/c ratio but other factors are also there which affect the strength of concrete.

Increasing the design load cannot solve the problem of fatigue.

4.121 (a)

Tests done for ascertaining workability of cement concrete are:

- Compaction factor test
- Slump test
- Vee-bee Consistometer test
- Flow test

4.122 (b)

Fresh concrete's rheological behavior is non Newtonian so the ratio of shear stress to shear rate is not constant and depends on the shear rate.

4.123 (b)

Initial tangent modulus of stress-strain curve of concrete is also called as dynamic modulus of elasticity.

4.124 (c)

The determination of compressive strength from Ultrasonic pulse velocity method is not accurate. However ultrasonic pulse velocity method is used to determine existence of voids and dynamic modulus of concrete.

4.125 (d)

Weigh batching produce concrete of desired strength.

4.129 (b)

Composition:

Magnesia ≈ 1 %

Lime ≈ 4 – 5 %

So, option (b) is correct.

4.130 (d)

Water-cement ratio is relevant to workability and durability.

Workability increases as water cement ratio increases and durability increases as water-cement ratio decreases.

4.131 (c)

Na_2O and K_2O when present in concrete cause alkali-aggregate reaction. The alkali silica reaction leads to formation of swelling type gels which results in disruption and cracking of concrete

4.132 (d)

For M20, total quantity of dry aggregate by mass per 50 kg of cement is 250 kg.

As per IS 456:2000, Table 9
Grade of Concrete Total quantity of dry aggregate by mass per 50 kg of cement (in kg)

Grade of concrete	Total quantity of dry aggregate by mass per 50 kg of cement (in kg)
M20	250
M15	330
M10	480
M7.5	625
M5	800

4.133 (c)

Slot length of guage
$= 1.8 \times$ (Mean size of agregate)

$$= 1.8 \times \frac{50 + 40}{2} = 81 \text{ mm}$$

4.135 (b)

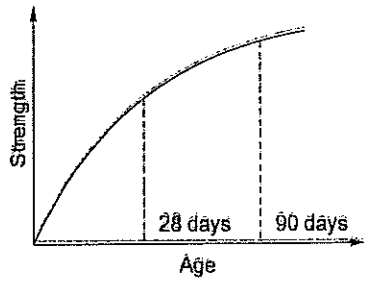
Strain determination is obtained from secant modulus. So, option (b) is correct.

4.136 (d)

$CaCl_2$ acts as a accelerator. Therefore, it decreases setting time and increase the shrinkage. So, option (d) is correct.

4.137 (c)

Grading is based on 28 days strength.
Strength of concrete increases beyond 28 days as shown in the figure.



4.138 (b)

Some admixtures when added to concrete mixture indirectly increase the strength of concrete-

- **Water-reducing admixtures** usually reduce the required water content for a concrete mixture by about 5 to 10 percent. Consequently, concrete containing a water-reducing admixture needs less water to reach a required slump than untreated concrete. The treated concrete can have a lower water-cement ratio. This usually indicates that a higher strength concrete can be produced without increasing the amount of cement.
- **Super plasticizers:** The main purpose of using super plasticizers is to produce flowing concrete with a high slump in the range of 7-9 inches to be used in heavily reinforced structures and in placements where adequate consolidation by vibration cannot be readily achieved. The other major application is the production of high strength concrete at w/c's ranging from 0.3 to 0.4.

4.139 (c)

We consider bulking of sand while using volume batching method.

4.140 (c)

Rebound hammer test gives indication about compressive strength of concrete.

4.142 (b)

When maximum size of coarse aggregate is increased then the void ratio of the volume will decreased and hence fine aggregate can be decreased.

4.143 (b)

Dead weight of a structure comprises of RCC elements like slab, beam, column and brick masonry. So, using light weight concrete like aerated concrete in RCC elements and blocks in brick masonry, dead weight can be reduced.
Though both assertion and reason is true, but R is not the explanation for A. Rather the opposite is true, i.e. assertion statement is correct explanation for reason statement.

4.144 (d)

Admixture is used only to modify specific qualities in concrete when required. It is not essential constituent of concrete.

4.145 (b)

Proportion of mix = 1 : 3 : 6
Assume volume of cement is 1 m^3
Then, Volume of sand = 3 m^3
Volume of aggregate = 6 m^3

$$\text{Actual volume of sand} = 3\left(1 + \frac{15}{100}\right) = 3.45 \text{ m}^3$$

4.146 (a)

Concrete, as a fluid, is most often assumed to behave like a Bingham Fluid. In this case, its flow is defined by two parameters, yield stress and plastic viscosity. The Bingham equation is

$\tau = \tau_0 + \mu\dot{\gamma}$.

4.147 (c)

Steam curing

This method is useful in cold weather or when early strength gain is important. There are two methods of curing:

- Low pressure steam at atmospheric pressure, and
- high-pressure steam curing in autoclaves.

High pressure steam:

This method is used for small manufactured units. The curing is done in autoclaves at temperatures in the 325°to 375°F range and pressures of 80 to 170 psi. This environment changes the chemistry of the hydration producing a concrete that has the following modified properties:

- a 24 hour strength equal to 28-day strength under ambient curing,
- less creep and shrinkage,
- better sulfate resistance,
- no efflorescence,
- lower moisture content after curing.

4.148 (d)

Kelly Ball Test is the simplest field method adopted for accessing consistency of concrete though it is not specified in Indian Standards. Slump cone test is most commonly adopted test for assessing consistency.

4.149 (d)

Autoclaved Aerated Concrete, also known as Autoclaved Cellular Concrete (ACC) or cellular concrete is a lightweight, strong, precast, inorganic and non-toxic concrete.

The lightweight is attributed to the porous nature due to air entrainment.

Advantages:

1. Improved thermal efficiency thereby reducing the heating and cooling load in buildings.
2. Porous structure allows for superior fire resistance.
3. Lightweight saves cost and energy in transportation, labour expenses.
4. There are no toxic gases or other toxic substances in ACC. Therefore it does not attract rodents or other pests nor can it be damaged by such.
5. The life of this material is extended because it is not affected by harsh climates or extreme changes in weather conditions. It will not degrade under climate changes.

4.150 (d)

As aggregate to cement ratio increases, the harsh mix is formed. As time of transit increases, workability reduces. Workability in a well graded aggregate will be greater as compared to poorly or uniformly graded aggregate.

4.153 (c)

- If water is added to concrete it increases fludity but workability remains same, however due to increase in w/c ratio, strength decreases.
- Slump ∝ workability.
- If water content is altered keeping w/c ratio constant, workability changes.

4.154 (c)

Use of Pozzolana decreases heat of hydration of delays setting.

4.155 (c)

For 1 m^3 of concrete,

$$1 = \frac{w_c}{\rho_c} + \frac{w_{ca}}{\rho_{ca}} + \frac{w_w}{\rho_w} + \frac{w_{fa}}{\rho_{fa}}$$

$$\Rightarrow 1 = \frac{400}{3.2\times1000} + \frac{1040}{2.6\times1000} + \frac{200}{1\times1000} + \frac{w_{fa}}{2.5\times1000}$$

$w_{fa} = (1 - 0.125 - 0.4 - 0.2) \times 2.5 \times 1000$

$= 687.5 \text{ kg/m}^3 \simeq 690 \text{ kg/m}^3$

4.156 (b)

Cyclopean concrete is mass concrete in which large stones each of 45.4 kg or more are placed and embedded as the concrete is deposited. They are usually more than 15 cm.

■■■■

5 Stones, Bricks and Bricks Masonry

5.1 Match List-I (Name of stone) with List-II (Use of stone) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Granite	1. Ornamental work
B. Marble	2. Ballast
C. Chalk	3. Rough stone work
D. Laterite	4. Manufacture of cement

Codes:

	A	B	C	D
(a)	3	1	2	4
(b)	2	3	1	4
(c)	2	1	4	3
(d)	1	4	2	3

[ESE : 1995]

5.2 A good brick should not absorb water by weight more than
(a) 10% (b) 20%
(c) 25% (d) 30%

[ESE : 1995]

5.3 For good bonding in bricks uniform in size
(a) all bricks need not be uniform in size
(b) bats must be used in alternate course only
(c) the vertical joints in alternate course should fall in plumb
(d) cement mortar used must have surkhi as additive

[ESE : 1995]

5.4 King closers are related to
(a) doors and windows
(b) king post truss
(c) queen post truss
(d) brick masonry

[ESE : 1996]

5.5 The texture of sandstone is
(a) porphyritic
(b) conglomerate
(c) vesicular
(d) granular crystalline

[ESE : 1996]

5.6 A good brick, when immersed in water bath for 24 hours, should not absorb more than
(a) 20% of its dry weight
(b) 30% of its saturated weight
(c) 10% of its dry weight
(d) 20% of its saturated weight

[ESE : 1996]

5.7 **Assertion (A):** The task work expected from a good mason with his team is about 7.00 sq.m (approximately 0.8 cu.m) in half -brick partition walls, whereas it is about 1.25 cu.m in one brick or thicker walls in superstructure.
Reason (R): Quantity of cement mortar in half-brick work is less than proportionate when compared to one-brick wall.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

5.8 At a Tee-junction between a 1½ brick wall and a 1 brick wall, one uses a
(a) half-queen closer in each course
(b) half-queen closer in every alternate course
(c) three-quarter bat in each course
(d) half-bat in every alternate course

[ESE : 1996]

5.9 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I	List-II
A. Pugmill	1. Blasting
B. Plug and feathers	2. Lifting

C. Lewis 3. Splitting
D. Gelignite 4. Tempering

Codes:

	A	B	C	D
(a)	2	1	3	4
(b)	2	3	4	1
(c)	4	3	2	1
(d)	2	1	4	3

[ESE : 1997]

5.10 For one cubic metre of brick masonry, the number of modular bricks needed is
(a) 400 or less (b) 400 to 450
(c) 500 to 550 (d) 600 to 650
[ESE : 1997]

5.11 **Assertion (A):** Facing bond is used when the bricks of different thicknesses are to be used in the facing and backing of the wall.
Reason (R): Facing bond is structurally good and results in uniform distribution of load.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1998]

5.12 In brick masonry,
(a) mortar strength should match brick strength
(b) mortar strength should exceed brick strength
(c) brick strength should exceed mortar strength
(d) the strengths of masonry and brick are independent
[ESE : 1998]

5.13 The crushing strength of a good building stone should be at least
(a) 50 MPa (b) 100 MPa
(c) 150 MPa (d) 200 MPa
[ESE : 1998]

5.14 The slenderness ratio for masonry walls should NOT be more than
(a) 50 (b) 40
(c) 30 (d) 20
[ESE : 1998]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

5.15 **Assertion (A):** Brick work (especially new work) sometimes develops efflorescence on the surface after wetting and drying.
Reason (R): Fired clay bricks may contain soluble salts in which sulphates of sodium, potassium, magnesium and calcium usually predominate.
[ESE : 1999]

5.16 **Assertion (A):** In double Flemish bond, each course presents the same appearance both on front face and on back face.
Reason (R): Quoin closers are used next to quoin headers in every alternate course in double Flemish bond.
[ESE : 1999]

5.17 Consider the following statements:
1. About 25% of alumina in brick earth imparts the plasticity necessary for moulding bricks into required shape.
2. Iron pyrite present in brick earth preserves the form of the bricks at high temperatures.
3. Presence of weeds in brick earth makes the bricks unsound.

Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3
[ESE : 1999]

5.18 The most important purpose of frog in a brick is to
(a) emboss manufacturer's name
(b) reduce the weight of brick
(c) form keyed joint between brick and mortar
(d) improve insulation by providing 'hollows'
[ESE : 1999]

5.19 Bricks are burnt at a temperature range of
(a) 500° to 700°C (b) 700° to 900°C
(c) 900° to 1200°C (d) 1200° to 1500°C
[ESE : 1999]

5.20 A king closer is a
(a) full brick
(b) $\frac{3}{4}$ brick
(c) longitudinally $\frac{1}{2}$ brick
(d) crosswise $\frac{1}{2}$ brick
[ESE : 2000]

5.21 Brick masonry walls and columns of a building are to be protected from earthquake. The earthquake proofing is done by providing
(a) cross walls
(b) less openings
(c) under-reamed piles
(d) a steel band at corners above windows below ceiling
[ESE : 2000]

5.22 When a beam or truss is placed on a masonry wall, it is supported on bed stone or plate. The bed stone or bed plate is necessary to
(a) add to aesthetic appearance
(b) transfer the reaction over a larger contact area
(c) increase stability of beam or truss
(d) prevent outward thrust on the wall
[ESE : 2000]

5.23 The maximum permissible slenderness ratio for masonry walls is
(a) 40 (b) 30
(c) 20 (d) 10
[ESE : 2000]

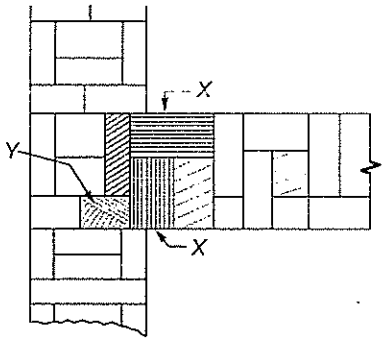
5.24 When the corner of a brick is removed along the line joining midpoints of adjoining sides, the portion left is called
(a) closer (b) squint brick
(c) queen closer (d) king closer
[ESE : 2000]

5.25 Which one of the following procedure is applied to determine the soundness of bricks?
(a) Immersing the brick under water for 16 hours and determining the quantity of water absorbed by the brick.
(b) Immersing the brick under water for 24 hours and determining its expansion using Le Chatelier apparatus.
(c) Taking two bricks, hitting one against the other and observing whether they break or not and the type of sound produced while hitting.
(d) Scratching the brick by finger nail and noting whether any impression is made or not.
[ESE : 2001]

5.26 The number of bricks required per cubic metre of brick masonry is
(a) 400 (b) 450
(c) 500 (d) 550
[ESE : 2001]

5.27 The bricks which are extensively used for basic refractories in furnaces are
(a) Chrome bricks (b) Sillimanite bricks
(c) Magnesite bricks (d) Fosterite bricks
[ESE : 2001]

5.28 The given figure shows the Tee junction in brick masonry which is known as



(a) English bond
(b) English cross-bond
(c) Flemish bond
(d) Double Flemish bond
[ESE : 2001]

5.29 The minimum compressive strength of first class bricks should be
(a) 5 N/mm^2 (b) 7.5 N/mm^2
(c) 9 N/mm^2 (d) 10 N/mm^2
[ESE : 2001]

5.30 **Assertion (A):** More uniformly burnt bricks are obtained from a downward draught kiln.
Reason (R): The bricks are laid in a circular form in this kiln.
(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2002]

5.31 Match List-I (Constituents of bricks) with List-II (Corresponding influence) and select the correct answer using the codes given below the lists:

List-I
A. Alumina
B. Silica
C. Magnesia
D. Limestone

List-II
1. Colour of brick
2. Plasticity recovery for moulding
3. Reacts with silica during burning and causes particles to unite together and development of strength
4. Preserves the form of brick at high temperature and prevents shrinkage

Codes:

	A	B	C	D
(a)	2	1	4	3
(b)	3	4	1	2
(c)	2	4	1	3
(d)	3	1	4	2

[ESE : 2002]

5.32 In some brick masonry walls, patches of whitish crystals were found on the exposed surfaces, also chipping and spalling of bricks took place from the same walls. Which among the following are the causes of these defects?
1. Settlement of foundation
2. Over-loading of the walls
3. Sulphate attack
4. Efflorescence

Select the correct answer from the codes given below:
(a) 1 and 2 (b) 2 and 3
(c) 2 and 4 (d) 3 and 4

[ESE : 2002]

5.33 Consider the following stages in the manufacturing of bricks:
1. Weathering
2. Moulding
3. Tempering

The correct sequence of these stages in the manufacturing of the bricks, is
(a) 1, 2, 3 (b) 2, 3, 1
(c) 1, 3, 2 (d) 3, 2, 1

[ESE : 2002]

5.34 Consider the following statements:
Bricks are soaked in water before use in masonry work
1. to remove dust
2. to remove air voids
3. so that they do not absorb water from cement mortar

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 1 only
(c) 2 and 3 (d) 3 only

[ESE : 2003]

5.35 Consider the following characteristics with respect to brick:
1. Minimum compressive strength = 175 (Standard units)
2. Minimum absorption in 24 hours, (in % of dry weight) = 12
3. Very little efflorescence
4. Tolerance in dimensions = ± 8%

As per Indian Standards classification, a brick with the characteristics given above is termed as
(a) H-I (b) F-II
(c) L-II (d) H-II

[ESE : 2004]

5.36 Match List-I (Test) with List-II (Procedure) and select the correct answer using the codes given below the lists:

List-I
A. Absorption
B. Hardness
C. Soundness
D. Structure

List-II
1. A brick is to be broken for the test
2. Two bricks are taken and they can be struck with each other without breaking
3. A scratch is easily made on brick surface with the help of a finger nail
4. Difference in weight between the brick immersed in water for 16 hours and its dry weight

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	4	3	2	1
(c)	4	2	3	1
(d)	1	2	3	4

[ESE : 2004]

5.37 Refractory bricks resist
(a) high temperature
(b) chemical action
(c) dampness
(d) all of the above

[ESE : 2005]

5.38 **Assertion (A):** The strength of brick masonry is purely dependent upon the type of mortar used.
Reason (R): Mortar is the binding material in masonry.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2006]

5.39 When a first class brick is immersed in cold water for 24 hours, it should not absorb water by weight more than
(a) 15% (b) 20%
(c) 25% (d) 30%

[ESE : 2006]

5.40 The temperature at which the bricks are burnt in kiln varies from
(a) 500° to 800°C (b) 800° to 1000°C
(c) 1000° to 1200°C (d) 1200° to 1500°C

[ESE : 2006]

5.41 For ornamental work, which type(s) of bricks is/are preferred ?
1. Silica bricks
2. Silica lime bricks
3. Bricks produced in autoclaves

Select the correct answer using the codes given below :
(a) 1 and 3 only (b) 2 and 3 only
(c) 1 only (d) 2 only

[ESE : 2007]

5.42 Which one of the following is the nominal size of standard modular brick ?
(a) 25 cm x 13 cm x 8 cm
(b) 25 cm x 10 cm x 8 cm
(c) 20 cm x 10 cm x 10 cm
(d) 20 cm x 15 cm x 10 cm

[ESE : 2007]

5.43 Why are bricks soaked in water before using the brick masonry?
(a) For removing dust
(b) For reducing air voids
(c) For preventing depletion of moisture from mortar
(d) For reducing efflorescence

[ESE : 2007]

5.44 Which type of brick masonry bond is provided for heavy loads on masonry?
(a) English bond
(b) Zigzag bond
(c) Single Flemish bond
(d) Double Flemish bond

[ESE : 2007]

5.45 For flatly laid single brick soling, what is the number of bricks required of nominal size 20 cm x 10 cm x 10 cm, with 1.2 cm wide cement mortar all around and with allowing up to 1% wastage for 10 m^2 area?
(a) 400 (b) 410
(c) 425 (d) 440

[ESE : 2008]

5.46 Consider the following statements:
1. Soil containing more than 30% of calcium hydroxide is used for manufacture of sand lime brick.
2. Carbon brick is made from crushed coke bonded with tar.

Which of these statements is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2008]

5.47 What is the number of traditional bricks required for 10 m^3 of brickwork with standard thickness of cement mortar (1 : 3 to 1 : 5, as the case may be)?
(a) 4750 (b) 4850
(c) 4950 (d) 5050

[ESE : 2008]

5.48 Consider the following statements on cement mortar in brick masonry :
1. Cracking in brick masonry in most of the cases is due to differential movement of the structure.
2. Rich mix cement mortar in brick masonry makes the structure unnecessarily rigid.
3. Small quantity of hydrated lime in cement mortar reduces shrinkage cracks.

Which of these statements are correct ?
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

[ESE : 2008]

5.49 For high class brick masonry, which are the proper bricks?
(a) Refractory bricks (b) Jhumb bricks
(c) Bull nose bricks (d) Modular bricks

[ESE : 2008]

5.50 Assertion (A): The volume of mortar needed for plastering on both faces of a one-brick wall is more than that for the same area on both faces together of any other thickness of brick wall.
Reason (R): More water evaporates from the wetted bricks in case of a one-brick wall and also the joints have to be more commonly raked.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2008]

5.51 Modular bricks are of nominal size 20 × 10 × 10 cm and 20% of the volume is lost in mortar between joints. Then what is the number of modular bricks required per cubic meter of brickwork ?
(a) 520 (b) 500
(c) 485 (d) 470

[ESE : 2009]

5.52 In order to achieve a safe compressive strength of 20 kg/cm^2 in a brick masonry, what should be the suitable range of crushing strength of bricks?
(a) 35 kg/cm^2 to 70 kg/cm^2
(b) 70 kg/cm^2 to 105 kg/cm^2
(c) 105 kg/cm^2 to 125 kg/cm^2
(d) More than 125 kg/cm^2

[ESE : 2009]

5.53 Consider the following statements:
1. Strength of brick masonry is influenced by type of mortar.
2. Brick masonry with lime mortar achieves full strength earlier than cement mortar masonry.
3. Mortar strength decides the strength of masonry.

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 1 only
(c) 1 and 3 only (d) 3 only

[ESE : 2010]

5.54 The average compressive strength of a burnt clay brick is less than 12.5 N/mm^2. The allowable rating of efflorescence is
(a) moderate (b) serious
(c) heavy (d) zero

[ESE : 2010]

5.55 Consider the following statements:
1. Bricks lose their strength by 25% when soaked in water.
2. Minimum crushing strength of brick in buildings should be 3.5 kg/cm^2.
3. The size of modular type bricks is 20 cm × 10 cm × 10 cm including mortar thickness.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 1 and 3 only (d) 2 and 3 only

[ESE : 2010]

5.56 When a column is supported throughout its length either by masonry walls or by construction on all the sides, then its slenderness ratio is
(a) Infinite (b) Zero
(c) Reasonably high (d) Low

[ESE : 2011]

5.57 The minimum wall thickness of any load bearing wall in case of public building built with mortar, as per IS code, should be not less than
(a) $\frac{1}{2}$ brick (b) 1 brick
(c) $1\frac{1}{2}$ brick (d) 2 brick

[ESE : 2011]

5.58 The position of the neutral axis in reinforced brick masonry is independent of the loading and is at a depth of

(a) One-third of the effective depth
(b) Half of the effective depth
(c) Full depth
(d) $\frac{1}{\sqrt{2}}$ times the effective depth

[ESE : 2011]

5.59 Maximum slenderness ratio for load-bearing masonry wall built in cement mortar, as per IS code, shall not exceed
(a) 13 (b) 20
(c) 27 (d) 30

[ESE : 2011]

5.60 As per masonry code, the stiffening coefficient for walls stiffened by piers, buttresses or intersecting walls can be
(a) 0 to 1.0 (b) 1.0 to 2.0
(c) Greater than 2.0 (d) Invariantly 1.0

[ESE : 2011]

5.61 Consider the following statements:
Maximum slenderness ratio of load-bearing masonry walls for a dwelling having more than two storeys shall not exceed
1. 12, if lime mortar is used.
2. 18, if cement-lime mortar 1 : 2 : 9 is used.
3. 24, if cement mortar 1 : 6 is used.
Which of these statements are correct?
(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

[ESE : 2011]

5.62 If the effective length, effective height and effective thickness of a masonry wall are l, h and t respectively, then the slenderness ratio of the wall shall be
(a) $\frac{l}{t}$
(b) $\frac{h}{t}$
(c) Larger of $\frac{l}{t}$ and $\frac{h}{t}$
(d) Smaller of $\frac{l}{t}$ and $\frac{h}{t}$

[ESE : 2011]

5.63 Consider the following statements:
Perforated bricks are preferred in construction since
1. they are lighter
2. they are stronger than class 1 bricks
3. they have heat-insulating properties
4. they are cheaper and need less mortar
Which of these statements are correct?
(a) 1, 2, 3 and 4 (b) 2 and 3 only
(c) 1 and 3 only (d) 3 and 4 only

[ESE : 2012]

5.64 The standard size of a brick is
(a) 20 cm × 10 cm × 10 cm
(b) 19 cm × 9 cm × 9 cm
(c) 18 cm × 9 cm × 9 cm
(d) 18 cm × 10 cm × 10 cm

[ESE : 2012]

5.65 Statement-I : Closely-graded materials are better than well -graded materials in so far as designs of concrete mixes are concerned.
Statement-II : Interparticle spaces must be well-packed densely for resulting in a good mix.
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

[ESE : 2012]

5.66 As per IS classification, the minimum compressive strength of a first class brick should be
(a) 75 kg/cm^2 (b) 100 kg/cm^2
(c) 125 kg/cm^2 (d) 150 kg/cm^2

[ESE : 2013]

5.67 When provided with alternating courses of (a) all headers and (b) all stretchers, the front elevation of such brick masonry is designated as
(a) English bond
(b) Single Flemish bond
(c) Double Flemish bond
(d) Rat-trap bond

[ESE : 2013]

5.68 I.S. Code specifies that the compressive strength of brick shall be determined by keeping the brick:
1. On edge
2. On bed

3. After soaking in water for 2 hrs
4. After soaking in water for 24 hrs

(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 2 and 4

[ESE : 2013]

5.69 Which of the following is an ODD one as regards 'requirements of good brick-earth?

(a) It must be free from lumps of lime
(b) It should not be mixed with salty water
(c) It must be non-homogeneous
(d) It should not contain vegetable and organic matter

[ESE : 2014]

5.70 The compressive strength of heavy-duty bricks, as per IS : 2980-1962, should be not less than

(a) 440 kg/cm^2 (b) 175 kg/cm^2
(c) 100 kg/cm^2 (d) 75 kg/cm^2

[ESE : 2014]

Directions: Each of the next items consists of two statements, one labelled as **'Statement (I)'** and the other as **'Statement (II)'**. You are to examine these two statements and select the answers to these items using the code given below.

Codes:

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true

5.71 **Statement (I) :** Bricks are soaked in water before using in brick masonry for removing dirt and dust.

Statement (II) : Bricks are soaked in water before using in brick masonry so that bricks do not absorb moisture from the bonding cement mortar.

[ESE : 2014]

5.72 **Statement (I) :** Brick masonry in mud mortar is weak in strength.

Statement (II) : Cement mortar enhances the strength of the bricks relative to mud mortar.

[ESE : 2014]

5.73 Consider the following statements :

1. Brickwork will have high water tightness.
2. Brickwork is preferred for monument structures.
3. Bricks resist fire better than stones.
4. Bricks of good quality shall have thin mortar bonds.

Which of the above statements are correct?

(a) 1 and 2 (b) 3 and 4
(c) 2 and 3 (d) 1 and 4

[ESE : 2014]

5.74 Consider the following statements related to autoclave bricks:

1. Less water absorption compared to other bricks.
2. Noise reduction.
3. It is cheap compared to other types of bricks.
4. Requirement of bulk volume of mortar in joints being relatively less compared to other types of brick masonry.
5. Not recommended for outer walls.

Which of the above statements are relevant to the use of 'autoclave' bricks?

(a) 1, 2 and 4 (b) 1, 3 and 5
(c) 2, 3 and 4 (d) 2, 4 and 5

[ESE : 2015]

5.75 If the actual thickness of a brick masonry wall is 19 cm, its effective length is 2.70 m, its effective height is 2.82 m and its code-specified stiffening coefficient is 1.2, then, for design considerations, the slenderness ratio of the wall will be taken as

(a) 11.8 (b) 12.4
(c) 14.2 (d) 14.8

[ESE : 2015]

5.76 The relation between the strength of brick masonry f_w, the strength of bricks f_b, and the strength of mortar f_m is given by (where K_w is a coefficient based on the layout of the bricks and the joints)

(a) $f_w = \sqrt{K_w \frac{f_b}{f_m}}$ (b) $f_w = K_w \sqrt{\frac{f_b}{f_m}}$

(c) $f_w = \sqrt{K_w f_b f_m}$ (d) $f_w = K_w \sqrt{f_b f_m}$

[ESE : 2015]

5.77 As per IS 3102-1965, for F1 class bricks, the percentage water absorption after 24 hrs of immersion in cold water shall not exceed
(a) 20% (b) 12%
(c) 25% (d) 5%
[ESE : 2015]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:
Codes:
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

5.78 **Assertion (A):** Strength of brick wall is dependent on the type of bricks and the mortar used.
Reason (R): Slenderness ratio of masonry decides the strength of the wall, and also mortar type to be used.
[ESE : 2015]

5.79 **Assertion (A):** Fly ash bricks are used in construction as alternatives to burnt clay bricks.
Reason (R): Fly ash bricks are lighter in weight and are stronger than burnt clay bricks.
[ESE : 2015]

5.80 Efflorescence of bricks is due to
(a) Excessive burning of bricks
(b) High silt content in brick clay
(c) High porosity of bricks
(d) Soluble salts present in parent clay
[ESE : 2016]

5.81 Disintegration of brick masonry walls is primarily due to
1. Efflorescence
2. Magnesium sulphate in bricks
3. Calcined clay admixtures
4. Kankar nodules

Which of the above statements are correct ?
(a) 1, 2 and 3 only (b) 1, 2 and 4 only
(c) 3 and 4 only (d) 1, 2, 3 and 4
[ESE : 2016]

Directions: Each of the next items consists of two statements, one labelled as the **'Statement (I)'** and the other as **'Statement (II)'**. Examine these two statements carefully and select the answers to these items using the codes given below :
Codes:
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is *not* the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

5.82 **Statement (I):** In general, bricks cannot be used in industrial foundations.
Statement (II): Heavy duty bricks can withstand higher temperatures.
[ESE : 2016]

5.83 **Statement (I):** In multistoried constructions, burnt clay perforated bricks are used to reduce the cost of construction.
Statement (II): Perforated bricks are economical and they also provide thermal insulation.
[ESE : 2016]

5.84 Consider the following statements:
1. IS 3583 refers to Burnt Clay Paving Bricks.
2. IS 5779 refers to Burnt Clay Soling Bricks.
3. IS 3952 refers to Burnt Clay Hollow Bricks.
4. IS 2222 refers to Burnt Clay Lay Bricks.

Which of the above statements are correct?
(a) 1, 2 and 3 only (b) 1, 2 and 4 only
(c) 3 and 4 only (d) 1, 2, 3 and 4
[ESE : 2017]

5.85 Consider the following statements:
1. A high aggregate impact value indicates strong aggregates.
2. A low aggregate crushing value indicates high crushing strength of aggregates.
3. Aggregates having elongation index values greater than 15% are generally considered suitable for pavement construction.
4. Flakiness index of aggregates should not be less than 25% for use in road construction.

Which of the above statements are correct?
(a) 2 and 3 only (b) 2 and 4 only
(c) 1 and 3 only (d) 1 and 4 only
[ESE : 2017]

5.86 Consider the following statements regarding refractory bricks in furnaces:
1. The furnace is fired at temperatures more than 1700°C.
2. Silica content in the soil should be less than 40%.
3. Water absorption of bricks should not exceed 10%.
4. Chrome bricks are known as basic bricks.
Which of the above statements are correct?
(a) 1 and 2 only (b) 2 and 4 only
(c) 1 and 3 only (d) 3 and 4 only
[ESE : 2017]

Directions: Each of the next items consists of two statements, one labeled as the **'Statements (I)'** and the other as **'Statement (II)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below :

Codes:
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

5.87 **Statement (I):** Deccan trap (basalt) is used in the foundations of blast furnaces.
Statement (II): Deccan trap has high compressive strength more than 150 N/mm^2.
[ESE : 2017]

5.88 **Statement (I):** Mud bricks can be completely replaced by Fly ash lime-Gypsum (Fal-G) bricks in building.
Statement (II): Useful fertile soil is used in manufacturing mud bricks, causing high CO_2 release in the atmosphere.
[ESE : 2017]

5.89 **Statement (I):** Contemporarily, even in high-rise buildings, ordinary brick is being replaced by glass blocks for load-bearing walls.
Statement (II): Bricks have high thermal conductivity and are not heat insulators.
[ESE : 2017]

■■■■

Answers Stones, Bricks and Bricks Masonry

5.1 (c)	5.2 (b)	5.3 (c)	5.4 (d)	5.5 (d)	5.6 (a)	5.7 (c)	5.8 (b)	5.9 (c)
5.10 (c)	5.11 (c)	5.12 (a)	5.13 (b)	5.14 (c)	5.15 (a)	5.16 (d)	5.17 (b)	5.18 (c)
5.19 (c)	5.20 (b)	5.21 (d)	5.22 (b)	5.23 (b)	5.24 (d)	5.25 (c)	5.26 (c)	5.27 (c)
5.28 (d)	5.29 (d)	5.30 (b)	5.31 (c)	5.32 (d)	5.33 (c)	5.34 (d)	5.35 (d)	5.36 (b)
5.37 (d)	5.38 (d)	5.39 (b)	5.40 (c)	5.41 (b)	5.42 (c)	5.43 (c)	5.44 (a)	5.45 (c)
5.46 (b)	5.47 (c)	5.48 (*)	5.49 (d)	5.50 (c)	5.51 (d)	5.52 (d)	5.53 (c)	5.54 (a)
5.55 (a)	5.56 (d)	5.57 (b)	5.58 (a)	5.59 (c)	5.60 (b)	5.61 (d)	5.62 (d)	5.63 (c)
5.64 (b)	5.65 (d)	5.66 (b)	5.67 (a)	5.68 (d)	5.69 (c)	5.70 (a)	5.71 (d)	5.72 (b)
5.73 (b)	5.74 (a)	5.75 (b)	5.76 (d)	5.77 (a)	5.78 (b)	5.79 (a)	5.80 (d)	5.81 (b)
5.82 (b)	5.83 (a)	5.84 (a)	5.85 (a)	5.86 (c)	5.87 (a)	5.88 (a)	5.89 (d)	

Explanations Stones, Bricks and Bricks Masonry

5.1 (c)

Chalk is used as a colouring material in the manufacture of portland cement.

Laterite is used as a road metal, in rough masonry work etc.

5.2 (b)

The brick should not absorb water more than 20% by weight for first class bricks and 22% by weight for second class bricks, when soaked in cold water for 24 hours.

5.3 (c)

For getting a good brick bond,

(i) the amount of lap should be one-fourth brick along the length of the wall and one-half brick across the thickness of wall.

(ii) the brick should be of uniform size to get uniform lap.

(iii) the stretchers should be used in the facing.

(iv) the use of brick bat should be discouraged except under special circumstances.

(v) the vertical joints in the alternate courses should be vertically above each other.

5.4 (d)

King closers are the portions of a brick obtained by cutting off the triangular piece between the centre of one end and the centre of one side.

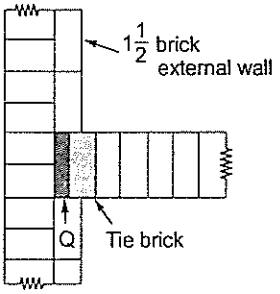
5.6 (a)

The bricks, when tested in accordance with the procedure in IS 3495 (Part 2) : 1992 after immersion in cold water for 24 hours, water absorption shall not be more than 20 percent by weight up to class 12.5 and 15 percent by weight for higher classes.

5.7 (c)

Half brick work is done in stretcher course only while other brickworks are done in both header and stretcher courses.

5.8 (b)



5.9 (c)

The process of grinding clay with water and making it plastic is known as pugging. So pugmill is used for tempering.

Gelignite is an explosive used in blasting. It is more convenient than dynamite and can be used under water.

5.10 (c)

Number of modular bricks size 20 cm x 10 cm x 10 cm with mortar

$$= \frac{1}{0.2\times0.1\times0.1} = \frac{1000}{2} = 500 \text{ bricks}$$

The nominal size of brick is taken as 20 cm x 10 cm x 10 cm while the actual size is 19 cm x 9 cm x 9 cm.

5.11 (c)

Since the number of joints in the backing and facing differ greatly, the distribution of load is not uniform.

5.12 (a)

There is no point in using a mortar with higher strength than the masonry units since the units will crush earlier than the mortar. Also it will be wasteful of money to use a very weak mortar for high strength masonry units. Thus there is an optimum relationship between masonry unit strength and mortar strength.

5.13 (b)

Crushing strength for a good building stone should be more than 100 Mpa, Hardness coefficient should be more than 14, toughness index more than 13, high durability, specific gravity more than 2.7 and low water absorption.

5.14 (c)

Slenderness ratio of masonry walls is effective length/effective thickness or effective height/ effective thickness which ever is less. As per code height of non load bearing walls shall not exceed 30 times the thickness. While for load bearing walls slenderness ratio is 27. (When Portland cement or Portland pozzolana cement is used in mortar.)

5.15 (a)

Soluble salts like potassium sulphate, sodium sulphate in fired clays develop efflorescence on brick surface after wetting and drying.

5.16 (d)

For wall of thickness equal to even number of half bricks no bats will be required and a stretcher or header will come out as a stretcher or header in the same course in front as well as back elevations. But the same is not true for wall of thickness equal to odd number of half bricks.

5.17 (b)

Silica imparts uniform shape to the bricks.

Iron pyrite causes disintegration of bricks due to oxidation of iron pyrite during burning. Vegetation makes the bricks porous as incomplete burning of these matter results in evolution of gases.

5.18 (c)

Frog is an indentation or depression on the top face of a brick made with the object of forming a key for the mortars. This also reduces the weight of the brick.

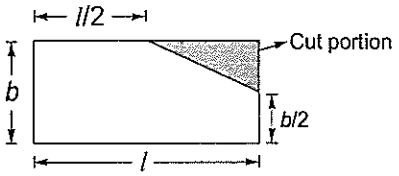
5.19 (c)

Bricks are burnt in temperature range of 900°C - 1200°C(1650°F-2190° F) in kilns or furnaces.

5.20 (b)

(i) King closer is obtained by cutting a triangular portion of brick such that half a header and half a stretcher is obtained on the adjoining cut faces.

The brick left is $\frac{1}{2}+\frac{1}{4}+\frac{1}{8}=\frac{7}{8}$



However, there is no such choice.

(ii) Queen closer is longitudinally half brick.

(iii) Half bat is crosswise $\frac{1}{2}$ brick.

5.21 (d)

To resist earthquake loads

(i) shear wall may be provided

(ii) a horizontal runner called band may be provided for bringing the walls together. They may be roof band, lintel band, gable band or plinth band depending upon the level at which it is used.

5.22 (b)

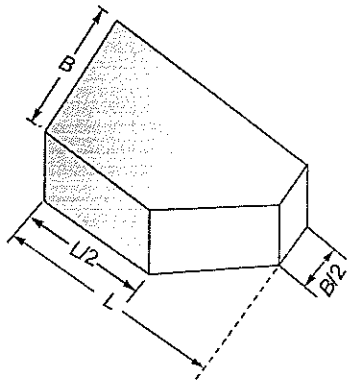
Bed plate or bed stone is used to distribute pressure upon masonry by transferring the reactions from beam or truss over large contact area.

5.23 (b)

Slenderness ratio of masonry walls is effective length/effective thickness or effective height/ effective thickness whichever is less. As per code height of wall shall not exceed 30 times the thickness. While for load bearing walls slenderness ratio is 27.

5.24 (d)

King closer



5.25 (c)

Clinging sound for soundness of bricks, while tilting agains one another.

5.26 (c)

Nominal brick size = 0.2 m x 0.1 m x 0.1 m

$$\text{No. of bricks required} = \frac{1}{0.2\times0.1\times0.1} = 500$$

5.27 (c)

Type of bricks used in basic refractories are magnesite bricks, mulite bricks, carbon bricks and basic ramming mass.

5.28 (d)

Figure shows Double Flemish bond with $1\frac{1}{2}$ brick.

In each course alternate header and stretchers are laid in both facing and backing.

5.29 (d)

The average compressive strength shall not be less than 75 kg/cm^2 (7.5 N/mm^2) for Class-II and 100 kg/cm^2 (10 N/mm^2) for Class-I.

5.30 (b)

The kilns can be rectangular or circular in shape. w/a actual reason for the bricks to be uniformly burnt lies in down wardmount of hot gases.

5.31 (c)

A small quantity of magnesia in brick earth imparts yellowish tint to the bricks and decreases shrinkage. But excess of magnesia leads to the decay of bricks.

5.32 (d)

The sulphate salts present in brick react with alumina of cement in case of cement mortar and with hydraulic lime in the case of lime mortar. Due to this reaction, there is increase in the volume of mortar and it leads to chipping and spalling of bricks and efflorescence causes patches of volatile crystals on the exposed surface.

5.33 (c)

Stages in brick manufacturing are:

- Preparation of clay

Unsoiling → Digging → Cleaning → Weathering → Blending → Tempering

- Moulding
- Drying
- Burning

5.34 (d)

Bricks are soaked in water before use in masonry work so that they do not absorb water from cement. If dry bricks are used then it will absorb water from mortar and mortar will become dry and cannot attain desired strength.

5.35 (d)

Heavy duty bricks will have two classes:

(i) Class-*A* (or Class-I) bricks with dimensional tolerance of ± 3%.

(ii) Class-*B* (or Class-II) bricks with dimensional tolerance of ± 8%.

So the brick is classified as H-II.

5.36 (b)

- Absorption is measured by taking difference in weight between the brick immersed in water for 16 hours and dry weight
- Soundness is checked by striking two bricks together without breaking them and noting the sound
- Hardness is tested by scratching the brick surface with help of finger nail
- Structure of brick is tested by breaking the brick

5.37 (d)

Refractory bricks are defined as non-metallic material suitable for construction or lining of furnaces operated at high temperatures. These are:

(i) Acid bricks
(ii) Basic bricks
(iii) Neutral bricks

The compressive strength of these bricks varies from 200 to 220 N/mm^2. The water absorption varies from 5 to 10%.

The chrome bricks can resist the corrosive action of slags and gases. They are a type of neutral bricks.

5.38 (d)

The strength of masonry depends upon strength of both mortar and brick.

5.39 (b)

Characteristics	Class-I	Class-II	Class-III
(i) Water absorption after 24 hrs	20%	22%	25%
(ii) Efflorescence	Slight	Slight	Moderate

5.40 (c)

The temperature in brick kiln varies in the range of 1000°C to 1200°C (1830°F - 2190°F).

5.41 (b)

Autoclave bricks and silica bricks are used for ornamental work like façade of a building.

5.42 (c)

Actual size of modular brick is 19 cm x 9 cm x 9 cm. With mortar thickness of *brick* becomes 20 cm x 10 cm x 10 cm and it is known as the *nominal size* of the modular bricks.

5.43 (c)

If dry bricks are used then it will absorb water from mortar and mortar will become dry and cannot attain desired strength. Bricks are soaked in water so that when used in masonry work they do not absorb water from cement.

5.44 (a)

English bond is the strongest of all bonds. Double flemish bond presents better appearance than English bond. Single flemish bond uses the strength of english bond and appearance of double flemish bond. Zigzag bond is commonly used for making ornamental panels in the brick flooring.

5.45 (c)

Though it is given that 1.2 cm wide cement mortar is provided all around the brick but considering 1.2 cm total width of cement mortar on opposite faces of brick. So number of bricks required for 10 m^2 area,

$$N = \frac{10 \times 10^4}{(21.2 \times 11.2)} = 421.16 \text{ bricks}$$

Also it is given that 1% wastage is allowed. So no. of bricks required

$$N' = N \times 1.01$$
$$= 421.16 \times 1.01$$
$$\simeq 425 \text{ bricks}$$

So option (c) is correct.

But as per question is should be

$$N' = 1.01 \times \frac{10 \times 10^4}{22.4 \times 12.4} \simeq 364 \text{ bricks}$$

5.46 (b)

Sand, lime and fly-ash are mixed in proportion of 10%, 10% and 80% respectively for manufacture of sand lime brick. Carbon bricks are made from crushed blast furnace coke bonded with tar.

5.51 (d)

Nominal size of modular bricks
= 20 cm × 10 cm × 10 cm

Actual size of modular brick
= 19 cm × 9 cm × 9 cm

Mortar required for 1 m^3 brickwork

$$= 1 - \left(\frac{1}{0.2 \times 0.1 \times 0.1} \times 0.19 \times 0.09 \times 0.09 \right)$$

$$= 1 - 0.7695 = 0.2305 \text{ m}^3$$

Volume of mortar lost between joints = 20%

∴ Volume of set mortar

$$= 0.2305 + 0.2305 \times \frac{20}{100} = 0.2766 \text{ m}^3$$

Actual volume of bricks = 1 – 0.2766

$= 0.7234 \text{ m}^3$

∴ Number of modular bricks

$$= \frac{0.7234}{0.19 \times 0.09 \times 0.09} = 470$$

5.53 (c)

Brick masonry with cement mortar achieves full strength earlier than lime mortar masonry.

5.54 (a)

According to IS:3495-1976 the rating of efflorescence should not be more than moderate up to class 12.5 bricks and slight for higher classes.

5.55 (a)

As per IS 1077, minimum crushing strength for common building bricks should be 35kg/cm^2. With mortar thickness of modular brick becomes 20 cm x 10 cm x 10 cm. Actual size of modular brick is 19 cm x 9 cm x 9 cm.

5.56 (d)

When a column is supported through its length, the effective length is taken as zero. Therefore slenderness ratio is zero.

5.57 (b)

The thickness of a load bearing wall should be sufficient at all points to ensure that the stresses due to the worst conditions of loading for which the structure is designed are within the limits prescribed for that particular type of wall. The thickness used for design calculations should be the actual thickness of the masonry and not the nominal thickness. The minimum wall thickness of a load bearing masonry is 1 brick with actual thickness of 19 cm and nominal thickness of 20 cm.

5.59 (c)

The limiting value of slenderness ratio is less for masonry built in lime mortar as compared to that built in cement mortar. Maximum slenderness ratio is 27 for cement mortar and 20 for mortar not containing cement.

5.60 (b)

Stiffening coefficient is dependent on the ratio of centre to centre spacing of the intersecting wall (s_p) and pier width in the direction of wall (w_p). It also depends on the ratio of thickness of pier (t_p) and actual thickness of wall proper (t_w). Stiffening coefficient varies from 1 to 2.

5.61 (d)

For a wall, the slenderness ratio shall be the effective height divided by the effective thickness and stiffening co-efficient (K_h) or the effective length divided by the effective thickness, whichever is less.

Thus, $S_R = \frac{l}{t \times K_h}$ or $\frac{l}{t}$, whichever is less. In case of a load bearing wall, slenderness ratio shall not exceed the values given in Table below.

Table: Maximum Slenderness rario for a load bearing wall

No. of Stories	Maximum Slenderness Ratio	
	Using Portland Cement or Portland Pozzolana Cement in Mortor	Using lime mortar
(1)	(2)	(3)
Not exceeding 2	27	30
Exceeding 2	27	12

5.62 (d)

For a wall, the slenderness ratio shall be the effective height divided by the effective thickness and stiffening co-efficient (K_h) or the effective length divided by the effective thickness, whichever is less.

Thus, $S_R = \frac{l}{t \times K_n}$ or $\frac{l}{t}$, whichever is less.

5.63 (c)

Perforated bricks are preferred over common bricks in construction as they are lighter and provide better thermal insulation.

5.64 (b)

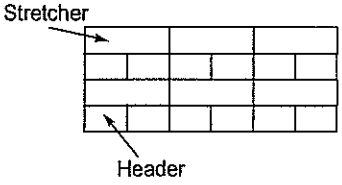
The standard dimensions of brick as recommended by Bureau of Indian Standards are

length × width × thickness = 19 × 9 × 9 cm. Including the thickness of mortar the effective size of brick becomes 20 × 10 × 10 cm.

5.66 (b)

As per IS code 1077-1992, minimum compressive strength of first class brick should be 100kg/cm^2.

5.67 (a)



5.68 (d)

As per IS code 3495(part-1) compressive strength of brick shall be determined by keeping brick immersed in water for 24 hours. Frog and all voids are filled with 1:3 mortar and brick is stored under damp jute bags for 24 hours. It is then immersed in clean water for 3 days. Then specimen is tested for compressive strength by placing it between plates and applying load of 14 MPa per minute till failure occurs.

5.69 (c)

Requirement of good earth brick are:

- Should be homogeneous
- Should not be mixed with salty water
- Must be free from lumps of lime
- Should not contain pebbles and organic matter

5.70 (a)

The code for heavy duty bricks is IS 2180 and not IS 2980. As per Cl 3.1 2180, the compressive strength should be classified as:

Classification:

Class 400: Compressive strength not less than 40.0 0 N/mm^2. (400 kgf/cm^2)

Class 450: Compressive strength not less that 45.0 N/mm^2. (450 kgf/cm^2)

5.71 (d)

If dry bricks are used then it will absorb water from mortar and mortar will become dry and cannot attain desired strength. Therefore bricks are soaked in water before use in masonry work so that they do not absorb water from mortar.

5.73 (b)

Brickwork will have low water tightness and stone work is preferred for monument structures.

So, option (b) is correct.

5.75 (b)

Slenderness ratio $S_R = \frac{L}{t}$ or $\frac{h}{t \times k_n}$ whichever is less

h = 2.82 m, k_n=1.2, t = 0.19 m

$$S_R = \frac{2.7}{0.19} = 14.21$$

$$S_R = \frac{2.82}{0.19 \times 1.2} = 12.36$$

So, S_R = 12.4

5.77 (a)

As per IS 3102-1965, the bricks were immersed in cold distilled water for 24 hours. The strength of brick also depends on its water absorption capacity. Bricks with more water absorption capacity will lose strength earlier and should not exceed 20% by weight for first class variety bricks.

5.78 (b)

Strength of brick wall is dependent on type of bricks and mortar used. Slenderness ratio of masonry decides strength of wall and also mortar type to be used. Both statements are true but statement II does not explain statement I.

5.79 (a)

Fly-ash is a waste product of cement industry and used in making fly-ash bricks which are stronger and lighter in weight than burnt clay bricks. Fly-ash bricks are good alternative to burnt clay bricks.

5.80 (d)

Efflorescence is a crystalline deposit on surfaces of masonry, concrete, bricks, etc. whitish in appearance. It is caused due to deposition of water soluble salts on their surfaces. There are many sources for these water soluble salts with some salts more soluble than others. The clay products like bricks generally show efflorescence

when soluble salts are present in the parent clay. Most common salt present in clay is calcium sulphate.

5.81 (b)

Disintegration of bricks or brickworks is due to efflorescence which may be due to presence of Magnesium Sulphate in the brick, presence of impurities such as stones, kankar nodules, etc.

Calcined clay admixture in brick preparation is used to make the bricks fire resistant upto certain extent. The bricks prepared by this method retain their shape during subsequent drying and burning.

5.84 (a)

IS 3583 refers to Burnt Clay Paving Bricks.
IS 5779 refers to Burnt Clay Soling Bricks.
IS 3952 refers to Burnt Clay Hollow Bricks.
IS 2222 refers to Burnt Clay Perforated Bricks.

5.85 (a)

$$\text{Aggregate crushing value (ACV)} \propto \frac{1}{\text{Strength}}$$

5.86 (c)

For refractory bricks furnace is fired at temperature of more than 1700°C. Silica content is more than 40%.

Water absorption of bricks should not exceed 10%.

Chrome brick are known as neutral bricks.

5.87 (a)

Blast furnace is a heavy structure, therefore it requires "high strength material" having good compressive strength at the base or foundation. Therefore deccan trap (Basalt) is having high compressive strength of about 2500 kg/cm^2 to 3000 kg/cm^2.

5.89 (d)

In a high rise building, tradiational bricks are generally used to resist load bearing wall whereas glass block is used for light structure or in partition walls/fancy walls.

■■■■

6 Timber

6.1 According to the relevant IS code, the weight of the timber is to be reckoned at a moisture content of

(a) zero (b) 4%
(c) 8% (d) 12%

[ESE : 1995]

6.2 The strength of timber is maximum when load applied is

(a) parallel to grain
(b) perpendicular to grain
(c) inclined at 45° to grain
(d) inclined at 60° to grain

[ESE : 1995]

6.3 Assertion (A): Dimensional changes in wood result due to variation in the moisture content of the wood with atmospheric condition.

Reason (R): The cell walls in wood are highly hygroscopic and when exposed to moisture, absorb large amounts of water and swell.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

6.4 The nail diameter should not be more than (t = least thickness of the wooden member to be connected)

(a) t/6 (b) t/8
(c) t/10 (d) t/12

[ESE : 1996]

6.5 The expansion and shrinkage of plywoods are comparatively very low as

(a) they are held in position by adhesives
(b) they are glued under pressure
(c) plies are placed at right angles to each other
(d) they are prepared from veneers

[ESE : 1996]

6.6 Seasoning of timber is required to

(a) soften the timber
(b) harden the timber
(c) straighten the timber
(d) remove sap from the timber

[ESE : 1996]

6.7 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I	List-II
A. Deciduous	1. Soft wood
B. Conifer	2. Hard wood
C. Endogenous	3. Eucalyptus
D. Exogenous	4. Bamboo

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	2	1	3	4
(c)	2	1	4	3
(d)	1	2	4	3

[ESE : 1997]

6.8 The modulus of elasticity of timber is about

(a) 0.5 to 1.0 $\times 10^4$ N/mm^2
(b) 1.0 to 1.5 $\times 10^4$ N/mm^2
(c) 1.5 to 2.0 $\times 10^4$ N/mm^2
(d) 2.0 to 2.5 $\times 10^4$ N/mm^2

[ESE : 1997]

6.9 During the conversion of timber by sawing, in order to obtain strong timber pieces, the cuts should be made by

(a) ordinary sawing (b) tangential sawing
(c) quarter sawing (d) radial sawing

[ESE : 1997]

6.10 A timber beam of effective span L and of cross-section $b \times d$ is said to be laterally supported if d/b and L/b are respectively

(a) less than 1 and less than 48
(b) less than 2 and less than 49
(c) less than 3 and less than 50
(d) less than 4 and less than 51

[ESE : 1997]

6.11 A timber column is made up of two individual members with longitudinal axes parallel, separated at the ends and middle points of their length by blocking, and joined at the ends by timber connectors. Such a column is called
(a) built-up column (b) composite column
(c) spaced column (d) flitched column

[ESE : 1997]

6.12 The moisture content in structural timber should be
(a) less than 5% (b) 5 to 10%
(c) 10 to 20% (d) 15 to 25%

[ESE : 1998]

6.13 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. The innermost part or core of the stem of a tree
B. The vascular tissue which encloses the pith
C. A cellular tissue and woody fibre arranged in distinct concentric circles
D. The thin layer below the bark not converted into sapwood as yet

List-II
1. Transverse septa (medullary rays)
2. Annual rings
3. The cambium layer
4. The outermost cover or skin of the stem
5. Medulla (pith)

Codes:

	A	B	C	D
(a)	2	5	3	4
(b)	5	1	2	3
(c)	4	3	2	1
(d)	5	1	4	3

[ESE : 1998]

6.14 Assertion (A): Within a given species, green timber of large moisture content dries in the same length of time as that of lower moisture content.

Reason (R): The sapwood which contains most of the moisture, dries more rapidly than the heartwood.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

6.15 Consider the following methods of preservation of timber:
1. Dipping
2. Brushing or spraying
3. Pressure impregnation

The correct sequence in decreasing order of the effectiveness of these methods of preservation is
(a) 1, 2, 3 (b) 2, 1, 3
(c) 3, 1, 2 (d) 3, 2, 1

[ESE : 1999]

6.16 Radial splits in timber originating from 'bark' and narrowing towards the 'pith' are known as
(a) heart shakes (b) star shakes
(c) cup shakes (d) knots

[ESE : 1999]

6.17 The moisture content in a properly seasoned timber will be in the range of
(a) 5% to 8% (b) 8% to 10%
(c) 10% to 12 % (d) 12% to 15%

[ESE : 2000]

6.18 The strength of timber is maximum in the direction
(a) perpendicular to the grains
(b) parallel to the grains
(c) 45° to the grains
(d) at all angles

[ESE : 2000]

6.19 On application of external stress on timbers, it behaves like
(a) an elastic material
(b) non-elastic material
(c) viscoelastic material
(d) non-viscoelastic material

[ESE : 2001]

6.20 The ratio of tangential shrinkage to radial shrinkage of wood due to reduction in moisture content is
(a) in the range from 3.1 to 5.1
(b) in the range from 2 to 3
(c) in the range from 1 to 2
(d) less than or equal to 1
[ESE : 2001]

6.21 The compressive strength in structural timber is minimum in a direction
(a) parallel to the grains
(b) perpendicular to the grains
(c) along an axis inclined at 45° to the grains
(d) along an axis inclined at 60° to the grains
[ESE : 2001]

6.22 Assertion (A): Trees which have broad leaves and shed in the autumn are classified as hard woods, while trees having needle-like leaves, broadly evergreen are classified as soft woods.
Reason (R): The term hard wood and soft wood in relation to a species of tree do not necessarily indicate relative hardness or density.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 2002]

6.23 Timber can be made reasonably fire-resistant by
(a) soaking it in ammonium sulphate
(b) coating with tar paint
(c) pumping creosote oil into timber under high pressure
(d) seasoning process
[ESE : 2002]

6.24 Which one of the following statements is the correct description of the structure of fibre board?
(a) Thin slices of superior quality of wood are glued and pressed on the surface of inferior wood.
(b) Steamed mass of wood dusts, wood wool and other vegetable fibres are pressed hard to a thickness varying from 3 mm to 12 mm.
(c) Thin and narrow wood shavings are soaked in a refractory binder material and pressed hard.
(d) Wood veneer backed by fabric mat.
[ESE : 2002]

6.25 Consider the following methods of preservation of timber:
1. Pressure application
2. Brush application
3. Dipping
4. Open tank application
The correct sequence of these methods in the increasing order of their effectiveness is
(a) 1, 3, 4, 2 (b) 3, 4, 2, 1
(c) 2, 3, 4, 1 (d) 4, 2, 1, 3
[ESE : 2002]

6.26 Match List-I (Name of defect) with List-II (Definition) and select the correct answer using the codes given below the lists:

List-I
A. Cupping
B. Bowing
C. Chucks
D. Knots

List-II
1. Caused by wood limbs encased by the wood of the free trunk
2. Caused by grain irregularities in the board and can be eliminated by proper stacking
3. Small cracks appearing at the ends of boards caused by too rapid drying
4. Unequal shrinking in the radial and tangential direction

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	4	3	2	1
(c)	1	3	2	4
(d)	4	2	3	1

[ESE : 2002]

6.27 The maximum deflection in timber beams or joints should not be greater than
(a) span/300 (b) span/325
(c) span/360 (d) span/380
[ESE : 2002]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

6.28 **Assertion (A):** Knots, one of the common features in wood, are associated with the beginning of branches.
Reason (R): Knots greatly improve the workability.
[ESE : 2002]

6.29 **Assertion (A):** Timbers used for engineering construction are derived from deciduous trees.
Reason (R): Deciduous trees yield hard wood while conifers yield soft wood.
[ESE : 2003]

6.30 **Assertion (A):** Dry rot is a disease in wood caused by spores germinating in wood cells.
Reason (R): Decomposition and putrefaction of tissues of a standing tree are indications of dry rot.
[ESE : 2003]

6.31 Dry rot in timber is caused by
(a) lack of ventilation
(b) lack of light
(c) immersion in water
(d) alternate wet and dry atmosphere
[ESE : 2003]

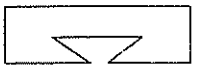
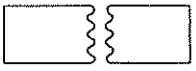
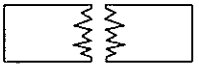
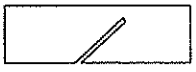
6.32 Wood is impregnated with creosote oil in order to
(a) change its colour
(b) protect against fungi
(c) protect the annular layers
(d) fill up the pores
[ESE : 2003]

6.33 A well-seasoned timber has a moisture content of about
(a) 15% to 20% (b) 10% to 12%
(c) 5% to 8% (d) 2% to 3%
[ESE : 2003]

6.34 Consider the following statements:
Hardest timber is obtained from the wood grown in
1. the moderately dry climatic regions
2. the Himalayan slopes
3. the open areas
4. the thin jungles
Which of these statements are correct?
(a) 1 and 3 (b) 1 and 4
(c) 2 and 3 (d) 2 and 4
[ESE : 2004]

6.35 Consider the following statements:
Dry rot in timber is due to
1. stacking wood in open areas
2. lack of ventilation
3. decomposition of sap
4. lack of preservatives
Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 3 and 4
[ESE : 2004]

6.36 In static bending test Match **List-I** (Type of failure) with **List-II** (Figure) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Simple tension	1. 
B. Cross grain tension	2. 
C. Splintering tension	3. 
D. Brash tension	4. 

Codes:

	A	B	C	D
(a)	1	4	3	2
(b)	4	1	3	2
(c)	4	1	2	3
(d)	1	4	2	3

[ESE : 2004]

6.37 Match **List-I** (Product) with **List-II** (Its use) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Fibre board	1. Panelling
B. Heartwood	2. Insulation
C. Laminated timber	3. Scantling
D. Plywood	4. Arches/Trusses

Codes:

	A	B	C	D
(a)	3	2	1	4
(b)	3	2	4	1
(c)	2	3	4	1
(d)	2	3	1	4

[ESE : 2004]

6.38 Match List-I (Term) with List-II (Brief description) and select the correct answer using the codes given below the lists:

List-I

A. Heart shakes
B. Knot
C. Rot
D. Sap wood

List-II

1. Disintegration caused by fungi
2. Outer layers of a log of wood
3. A branch base embedded in timber by natural growth
4. Cracks widest at centre and diminishing towards the outer circumference

Codes:

	A	B	C	D
(a)	1	3	4	2
(b)	4	2	1	3
(c)	1	2	4	3
(d)	4	3	1	2

[ESE : 2005]

6.39 Consider the following statements:
The disease of dry rot in timber is caused by
1. complete submergence in water
2. alternate wet and dry condition
3. lack of ventilation

Which of these statements is/are correct?
(a) 1 only (b) 3 only
(c) 2 only (d) 2 and 3

[ESE : 2005]

6.40 Which one of the following is the correct statement?
The strength of timber
(a) is maximum in a direction parallel to the grain
(b) is maximum in a direction perpendicular to the grain
(c) is maximum in direction 45° to the grain
(d) remain same in all directions

[ESE : 2005]

6.41 Consider the following statements:
Kiln seasoning of timber results in
1. reduced density
2. reduced life
3. dimensional stability

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 1 only
(c) 2 and 3 (d) 1 and 3

[ESE : 2005]

6.42 In a tree, the cambium layer is situated between
(a) the outer bark and inner bark
(b) the inner bark and sap wood
(c) the sap wood and heart wood
(d) the pith and heart wood

[ESE : 2005]

6.43 The timber preservative "creosote" belongs to the group of
(a) water soluble salts
(b) organic solvent type
(c) tar oil type
(d) inorganic solvent type

[ESE : 2006]

6.44 The strength of timber is maximum in a direction
(a) parallel to the grains
(b) perpendicular to the grains
(c) 45° to the grains
(d) 30° to the grains

[ESE : 2006]

6.45 Match List-I (Species) with List-II (Uses) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Babul	1. Tennis rackets
B. Benteak	2. Boats
C. Bijasal	3. Agricultural tools
D. Mulberry	4. Furniture

Codes:

	A	B	C	D
(a)	4	1	3	2
(b)	3	2	4	1
(c)	4	2	3	1
(d)	3	1	4	2

[ESE : 2006]

6.46 Which one of the following is the most preferred wood for high quality and durable furniture ?

(a) Sandalwood (b) Deodar wood
(c) Teakwood (d) Shisham wood

[ESE : 2007]

6.47 As a natural material, timber is which one of the following?
(a) Isotropic (b) Anisotropic
(c) Homogeneous (d) Heterogeneous

[ESE : 2007]

6.48 Shear strength of timber depends on which one of the following?
(a) Lignin with fibres (b) Medullary rays
(c) Heartwood (d) Sapwood

[ESE : 2007]

6.49 The defect which develops due to uncontrolled and non-uniform loss of moisture from wood is known as which one of the following ?
(a) Knot (b) Shake
(c) Warping (d) Cross grain

[ESE : 2007]

6.50 Assertion (A): Wooden window shutters should be fitted, leaving proper tolerances for dimensional changes.
Reason (R): Timber sections change in volume with change in seasons.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2007]

6.51 Match List-I (Wood element) with List-II (Description) and select the correct answer using the codes given below the lists:

List-I
A. Pith
B. Sapwood
C. Heart wood
D. Cambium layer

List-II
1. Innermost portion of the tree
2. Inner annual rings surrounding the pith
3. Outermost annual rings
4. Thin layer of sap between sapwood and inner bark

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	2	4	1	3
(c)	1	4	2	3
(d)	2	3	1	4

[ESE : 2008]

6.52 In respect of moisture content in wood, the fiber saturation point refers to which one of the following?
(a) Free water present in the cells
(b) Free water present in cell walls and cell cavities
(c) No moisture present in cell walls and cell cavities
(d) No free water exists in cell cavities but cell walls are saturated

[ESE : 2008]

6.53 The moisture content of timber used in building frames can be
(a) 2% to 5% (b) 8% to 12%
(c) 12% to 18% (d) > 20%

[ESE : 2008]

6.54 Match List-I (Disease of timber) with List-II (Effect of disease) and select the correct answer using the codes given below the lists:

List-I
A. Dry rot
B. Grey rot
C. Wet rot
D. White rot

List-II
1. Attack of sapwood by fungus
2. Damage to wood fibers due to chemical decomposition of wood
3. Destruction of cellulose of wood due to fungal attack
4. Destruction of lignin of wood due to fungal attack

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	1	4	2	3
(c)	2	3	1	4
(d)	2	4	1	3

[ESE : 2008]

6.55 What is the ratio of the elastic modulus of structural timber in longitudinal direction to that in the transverse direction?
(a) 1/2 to 1 (b) 1/10 to 1/20
(c) 1 to 2 (d) 10 to 20
[ESE : 2009]

6.56 What is the modulus of elasticity of standard timber (Group B) in (MN/cm^2) ?
(a) 0.5 to 1.0 (b) 1.0 to 1.25
(c) 1.25 to 1.5 (d) 1.5 to 1.75
[ESE : 2009]

6.57 What is the treatment for making timber fire-resistant ?
(a) ASCU treatment (b) Abel's process
(c) Creosoting (d) Tarring
[ESE : 2009]

6.58 How is the process of treatment of wood using a preservative solution and forcing air in at a pressure designated ?
(a) Rueping process
(b) Lawry process
(c) Full cell process
(d) Empty cell process
[ESE : 2009]

6.59 Consider the following statements:
1. Cambium layer is between sapwood and heartwood.
2. Heartwood is otherwise termed as deadwood.
3. Timber used for construction is obtained from heartwood.

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 2 and 3 only
(c) 1 and 2 only (d) 2 only
[ESE : 2010]

6.60 The advantage in using plywood is that the
(a) tensile strength is equal in all directions
(b) higher tensile strength in longer direction
(c) higher tensile strength in shorter direction
(d) lower tensile strength in longer direction
[ESE : 2010]

6.61 Which one of the following statements is correct as regards tensile strength of wood?
(a) Minimum in the direction parallel to the grains
(b) Maximum in the direction parallel to the grains
(c) Maximum in the direction across the grains
(d) Same in all directions
[ESE : 2010]

6.62 Consider the following characteristics regarding timber:
1. Stronger variety
2. Ability to take very smooth finish
3. Toughness
4. Difficult to season

Which of the above characteristics is/are essential for timber to be used as beams?
(a) 1 only (b) 2 and 3
(c) 3 and 4 (d) 1 and 3
[ESE : 2010]

6.63 Consider the following statements:
1. Dry rot in sap wood is caused by fungal attack.
2. Brown rot in coniferous woods is a result of fungal attack.
3. Alternate wetting and drying of unseasoned timber causes 'powdery' form of decay in wood.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only
[ESE : 2011]

6.64 Consider the following statements:
Fibre saturation point in wood is reached when
1. Free water is removed.
2. Cell water is removed.
3. Shrinkage of wood is rapid.
4. Strength gain is rapid.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 4 only (d) 1, 3 and 4
[ESE : 2011]

6.65 The radial splits which are wider on the outside of the log and narrower towards the pith are known as
(a) star shakes (b) annular rings
(c) cup shakes (d) heart shakes
[ESE : 2012]

6.66 Consider the following distinguishing characteristics of hardwood:
1. They have distinct annular rings.
2. They are not resinous.

Which of these characteristics of hardwood is/ are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2012]

6.67 Consider the following statements on the specific gravity of wood:

1. It is always greater than 2.
2. It is less than 1.
3. It is not dependent upon temperature and equilibrium moisture content.
4. It is dependent upon type of species.

Which of these statements are correct?

(a) 1, 2, 3 and 4 only (b) 1 and 3 only
(c) 2 and 3 only (d) 2 and 4 only

[ESE : 2012]

6.68 The age of a log of timber can be estimated by

(a) diameter of pith
(b) thickness of bark
(c) number of annular rings
(d) number of medullary rays

[ESE : 2012]

6.69 Consider the following statements:
Seasoning of timber results in

1. increased strength
2. increased durability
3. reduced resilience
4. increased dimensional stability

Which of these statements are correct?

(a) 1, 2 and 4 (b) 1, 2 and 3
(c) 1, 3 and 4 (d) 2, 3 and 4

[ESE : 2012]

6.70 Match List-I with List-II and select the correct answer using the code given below the lists:

List-I	List-II
A. Plywood	1. Furniture
B. Fiberboard	2. Cantilever arches
C. Laminated lumber	3. Insulation
D. Commercial block-board	4. Lining of form-work in concrete

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	4	3	2	1
(c)	1	3	2	4
(d)	4	2	3	1

[ESE : 2012]

Directions: Each of the next items consists of two statements, one labeled as the **'Statements (I)'** and the other as **'Statement (II)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below :

Codes:

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

6.71 Statement-I : Planks sawn from trees with twisted fibers are stronger than those cut from trees with normal growth.
Statement-II : Timber from trees with twisted fibers is used straightaway as poles.

[ESE : 2012]

6.72 Statement-I : Timber suitable for tension members is obtained from coniferous trees.
Statement-II : Coniferous trees have distinct annular rings and straight grains.

[ESE : 2012]

6.73 Which of the following statements are correct?

1. Knots in a tree affect the continuity of fibres.
2. Nail knots do not influence the strength of timber.
3. Druxiness of wood is not a defect.
4. Tall trees with twisted fibres give good timber of poles.

(a) 1, 2, 3 and 4 (b) 1, 2 and 4 only
(c) 1, 2 and 3 only (d) 2, 3 and 4 only

[ESE : 2013]

6.74 Excrescences in wood are

1. Defects found in trees
2. Formed due to injuries inflicted on trees when they are growing
3. Defects which render wood suitable as firewood only

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 1 and 3 only (d) 2 and 3 only

[ESE : 2013]

6.75 What treatment is adopted for making timber fire-resistant?

(a) ASCU treatment (b) Abel's process
(c) Creosoting (d) Tarring

[ESE : 2013]

6.76 Deterioration of structure of timber due to dry rot is
1. Caused by fungi
2. Due to dry-spell after heavy rains
3. Due to attack to termites
4. Indicated by surface stripes on scantlings

(a) 1 and 2 (b) 3 and 4
(c) 2 and 3 (d) 1 and 4

[ESE : 2013]

6.77 Alternate wetting and drying of timber:
1. Results in shrinkage and swelling
2. Brings about wet rot onset
3. Increases the durability
4. Causes transmission of spores from germination

(a) 1, 2, 3 and 4 (b) 1, 2 and 4 only
(c) 1, 2 and 3 only (d) 2, 3 and 4 only

[ESE : 2013]

6.78 Which IS code is used for classification of timber for seasoning purposes?

(a) IS : 4970-1973 (b) IS : 1708-1969
(c) IS : 1141-1958 (d) IS : 399-1963

[ESE : 2014]

6.79 Consider the following with regard to 'the application of preservation of timber':
1. Increase in the life span of the member
2. Increase in the strength of the timber
3. Removal of moisture
4. Prevention of growth of fungi by killing them

Which of the above are correct?

(a) 1, 2, 3 and 4 (b) 2 and 4 only
(c) 1 and 4 only (d) 2 and 3 only

[ESE : 2014]

6.80 The plies in plywood are so placed that the grains of each ply are
(a) parallel to each other
(b) at right angle to one another
(c) 45° oblique to adjacent grain
(d) not constrained by any consideration

[ESE : 2014]

6.81 AsCu, a preservative for wood, developed by the Forest Research Institute, Dehradun, comprises of chemicals:
$As_2O_5.2H_2O$, $CuSO_4.5H_2O$ and $K_2Cr_2O_7$ in the proportion of

(a) 1 : 1 : 1 (b) 1 : 2 : 3
(c) 1 : 2 : 4 (d) 1 : 3 : 4

[ESE : 2015]

6.82 The minimum number of annular rings to be seen in every 2.54 cm in the radial direction from the core for timber to be classified as 'Dense' is

(a) 10 (b) 20
(c) 25 (d) 30

[ESE : 2015]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

6.83 **Assertion (A):** Timber suitable for furniture is obtained from conifers only.
Reason (R): Woods with distinct annual rings are conifers.

[ESE : 2015]

6.84 **Assertion (A):** Seasoning of timber gives dimensional stability, safety against attack by fungi and improved workability.
Reason (R): Seasoning of timber removes moisture in the form of sap from timber.

[ESE : 2015]

6.85 Consider the following statements:
1. There will be no defects in select grade timbers.
2. The codal values for strength of grade-II timber without defects may be reduced by 37.5%.

3. For timber used as columns, the permissible stress in ungraded timbers is adopted with a multiplying factor of 0.50.
4. In case of wind force and earthquakes, a modification factor of 1.33 is adopted.

Which of the above statements are correct?

(a) 1 and 3 only (b) 1 and 4 only
(c) 2 and 4 only (d) 2 and 3 only

[ESE : 2016]

6.86 Consider the following statements regarding timber:

1. The strength of timber increases by Kiln seasoning.
2. Cutting of wood is to be done prior to treatment.
3. Water seasoning is good for prevention of warping.
4. ASCU treatment enhances the strength of wood.

Which of the above statements are correct?

(a) 1, 2 and 3 only (b) 2, 3 and 4 only
(c) 1, 3 and 4 only (d) 1, 2, 3 and 4

[ESE : 2016]

6.87 Gase(s) emitted during rotting or decomposition of timber is/are mainly

(a) Methane and Hydrogen
(b) Hydrogen Sulphide
(c) Carbonic acid and Hydrogen
(d) Ammonia

[ESE : 2016]

6.88 In the cross-section of a timber, cambium layer can occur in

(a) Inner Bark and Sap Wood
(b) Pith and Heart Wood
(c) Sap Wood and Heart Wood
(d) Outer Bark and Sap Wood

[ESE : 2016]

Directions: Each of the next items consists of two statements, one labelled as the **'Statement (I)'** and the other as **'Statement (II)'**. Examine these two statements carefully and select the answers to these items using the codes given below :

Codes:

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is ***not*** the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

6.89 **Statement (I):** Splitting of fibres is a type of seasoning defect in wood.

Statement (II) : Seasoning of timber is a general requirement for structural purposes.

[ESE : 2016]

6.90 **Statement (I) :** Hardwoods are used in special purpose heavy constructions.

Statement (II) : Hardwoods too are porous in nature.

[ESE : 2016]

6.91 **Statement (I):** 'Compreg' timbers have higher specific gravity of up to 1.30 and are stronger than other timbers.

Statement (II): Impregnation of resins and special curing methods are adopted to develop 'Compreg' timbers:

[ESE : 2017]

■■■■

Answers Timber

6.1 (d)	6.2 (a)	6.3 (a)	6.4 (a)	6.5 (c)	6.6 (d)	6.7 (c)	6.8 (a)	6.9 (d)
6.10 (c)	6.11 (c)	6.12 (c)	6.13 (b)	6.14 (d)	6.15 (c)	6.16 (b)	6.17 (c)	6.18 (b)
6.19 (a)	6.20 (a)	6.21 (b)	6.22 (b)	6.23 (a)	6.24 (b)	6.25 (c)	6.26 (d)	6.27 (c)
6.28 (c)	6.29 (a)	6.30 (c)	6.31 (a)	6.32 (b)	6.33 (b)	6.34 (a)	6.35 (c)	6.36 (a)
6.37 (c)	6.38 (d)	6.39 (b)	6.40 (a)	6.41 (d)	6.42 (b)	6.43 (c)	6.44 (a)	6.45 (b)
6.46 (c)	6.47 (b)	6.48 (a)	6.49 (c)	6.50 (a)	6.51 (a)	6.52 (d)	6.53 (b)	6.54 (a)
6.55 (d)	6.56 (b)	6.57 (b)	6.58 (a)	6.59 (b)	6.60 (a)	6.61 (b)	6.62 (d)	6.63 (a)
6.64 (d)	6.65 (a)	6.66 (b)	6.67 (d)	6.68 (c)	6.69 (a)	6.70 (c)	6.71 (d)	6.72 (a)
6.73 (b)	6.74 (b)	6.75 (b)	6.76 (a)	6.77 (b)	6.78 (c)	6.79 (a)	6.80 (b)	6.81 (d)
6.82 (*)	6.83 (d)	6.84 (a)	6.85 (b)	6.86 (a)	6.87 (c)	6.88 (a)	6.89 (b)	6.90 (b)
6.91 (a)								

Explanations Timber

6.1 (d)

Weight and strength properties of timber are greatly influenced by moisture content. Therefore the strength values and weight obtained are usually standardized at 12% moisture content.

6.2 (a)

Timber is stronger in tension along the grain but it is quite difficult to determine this because of the difficulties in conducting the test.

6.3 (a)

Variation in moisture content of wood with atmospheric condition causes dimensional change in wood. If dry piece of timber is kept in saturated atmosphere, it absorbs water from air to about15% of weight and swells up. Drying of wood below saturation point results in shrinkage.

6.4 (a)

In nailed joints in timber, it is found that where prebore is necessary, the diameter of the hole should not be greater than 4/5 of the diameter of the nail and that the diameter of the nails must lie within $\frac{1}{4}$ and $\frac{1}{6}$ of the least thickness of timbers to be connected.

6.5 (c)

The expansion and shrinkage is comparatively low when plies are placed at right angles as in the cross grained construction the longitudinal grains of the core restrain any tangential movement and vice verse.

6.6 (d)

For using timber for engineering purpose, seasoning of timber is done to remove sap in order to prevent timber from the possible fermentation.

6.7 (c)

Deciduous trees are broad leaved hardwood trees. Coniferous are needle shaped softwood trees growing in high altitudes. Endogenous trees grow inward from a hard exterior shell e.g. Bamboo. In Exogenous plants, stems are formed by successive additional layer on outside that is they grow outwards e.g. Eucalyptus.

6.8 (a)

The species of timber recommended for construction purpose are classified into three groups on the basis of their modulus of elasticity.

Group A : with modulus of elasticity above 125 t/cm^2 (12500 N/mm^2)

Group B : with modulus of elasticity between 98 t/cm^2 (9800 N/mm^2) and 125 t/cm^2 (12500 N/mm^2)

Group C : with modulus of elasticity above 56 t/cm^2 (5600 N/mm^2) and below 98 t/cm^2 (9800 N/mm^2)

6.9 (d)

The order of strength of timber section is
Radial sawing > Quarter sawing > Ordinary sawing > Tangential sawing

6.10 (c)

To prevent lateral buckling, the minimum width of the beam is kept equal to or more than $L/50$ and $d/3$. In no case width should be less than 50 mm.

6.11 (c)

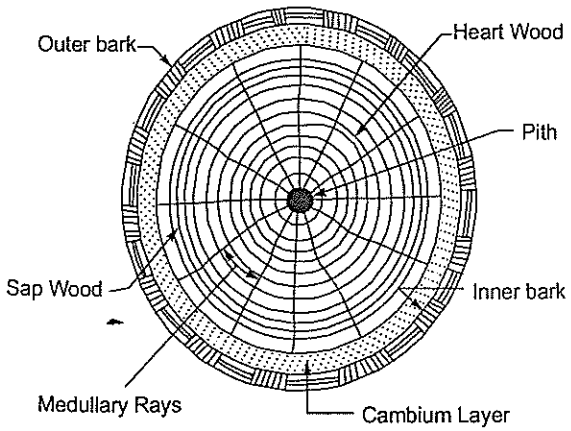
Built-up columns are made by spiking, nailing or bolting together planks or square sections.
Spaced columns are employed usually in trusses with nailed connections. They are separated from each other by means of spacer blocks.

6.12 (c)

As per IS 287-1993

- Recommended moisture content for structural elements is 12-20 percent for doors.
- The maximum permissible moisture content of structural elements for use as beam and rafter varies from 12-20 percent (depending upon the zone in which structure lies).
- The moisture content of structural elements for use as building frames like windows may vary from 8 to 16 percent (depending upon the zone in which structure lies).

6.13 (b)



6.14 (d)

Green timber of large moisture content takes more time to dry than of lower moisture content. Reason statement is true.

6.15 (c)

The most effective method is pressure impregnation in which preservative is injected under pressure in timber. In dipping method timber is dipped in preservative for a short period, proves to be more effective than preservating through brushing or spraying.

6.16 (b)

Cup shakes are caused by rupture of tissue in a circular direction. It is a curved track and separates partly one annual ring from the other.
Heart shakes occur in the centre of the cross-section and they extend from pith to sap wood in the direction of medullary rays. They occur due to shrinkage of interior part of tree which is approaching maturity. Radial shakes and star shakes extend from bark towards the sapwood. Star shakes are wider on the outside ends bark and narrower on the inside ends (sapwood). The radial shakes are fine, irregular and numerous.

6.17 (c)

As per IS 1141(1993), well seasoned timber contains moisture content in range of 10% -12%.

6.18 (b)

Strength of timber is maximum in the direction parallel to the grains and minimum perpendicular to the grains.

6.19 (a)

Timber is heterogeneous material and its strength properties are not the same along the grain and across it.

6.20 (a)

Green timber shrinks least along its length, much more along the radial direction and maximum along the circumference (tangential shrinkage). The shrinkage is above 0.1% along the length, 3 to 5% along the radius and 10 to 15% along the circumference.

6.21 (b)

Compressive strength of timber is minimum along perpendicular direction to the grains and maximum in the direction parallel to the grains.

6.22 (b)

The soft woods form a group of evergreen trees and hard woods form a group of broad leaf trees. The trees have commecial importance only some varities of soft wood may prove to be stronger than some varity of hard wood.

6.23 (a)

Wood is highly combustible but not inflammable i.e., in favourable circumstances any wood may burn to ash. Timber is not readily ignited except in small thicknesses. Timber above a particular thickness, about 12 mm cannot support self-sustained combustion and continues to burn only when external heat is supplied. Efficient fire retardant chemicals under heat help in production of more charcoal and water vapour. Some of the chemicals that can be used are ammonium phosphate, boric acid, borax, zinc chloride, sodium arsenate, etc. These can be applied to get a penetration of 2.5 to 4.0 cm by pressure treatment or soaking.

The timber surface can be coated with coal tar to make it fire resistant. However chemical treatment is more effective.

6.24 (b)

Fibre boards are rigid boards, which are prepared by processing steamed mass of wood dust or wool or other vegetable fibres and hard pressed to thickness varying from 3 mm to 12 mm.

6.25 (c)

The preservatives can be applied by:

(i) Surface treatment by brushing, spraying, and dipping (in the order of their increasing effectiveness).

(ii) Soaking.

(iii) Hot and cold open tank process ensures sterilization of timber against fungi and insects. If pressure treatment is not feasible then this method is suitable for all sapwood and easily treatable heartwood.

Thus, correct sequence of these methods is brush application-dipping-open tank application-pressure application.

6.27 (c)

In timber beams, maximum deflection specified is span/360 when the beam supports brittle coverings like AC sheets, earthenware, slates, gypsum etc. Otherwise a deflection of $\frac{1}{240}$ of span may be allowed. In case of cantilever, the deflection should not exceed $\frac{1}{180}$ of clear overhang.

6.28 (c)

Knots tend to weaken timber in tension but may improve the strength in compression. Knots make the working of wood difficult. Size, shape, quality and occurrence of knots influence the mechanical properties of timber to varying degrees.

6.29 (a)

Engineering construction requires hardwood which is derived from deciduous trees. Coniferous trees yield softwood which is used in manufacture of paper, sports equipment etc.

6.30 (c)

Decomposition and putrefaction of tissues of a standing tree can be caused by bacteria.

6.31 (a)

The dry rot occurs where there is no free circulation of air. The other causes are unseasoned wood and improper storage. The most favourable conditions for the rapid growth of fungus responsible for dry rot are absence of sunlight, dampness, presence of sap, stagnant air and warmth. Therefore lack of ventilation is the best choice.

6.32 (b)

Creosoting or Bethel's method of preservation is used for wood-attacking fungi. Creosote oil is obtained by the distillation of tar.

6.33 (b)

As per IS 1141(1993), well seasoned timber contains moisture content in range of 10% -12%.

6.34 (a)

The names hardwoods and softwoods are commercially popular but has nothing to do with the hardness of the wood of a particular group. Some softwoods, like deodar, are harder than hardwoods like papita. The softwood trees grow mainly in temperate regions and have needle shaped leaves and grow like a Christmas tree, tapering to the top e.g. deodar, chir etc.

Hardwoods grow all over the world, have broad leaves and a much heavier top or crown e.g. teak, sal etc.

6.35 (c)

Dry rot is attack on sapwood by fungus. It occurs during obsence of sunlight, dampness, presence of sap and stagnant air and warmth.

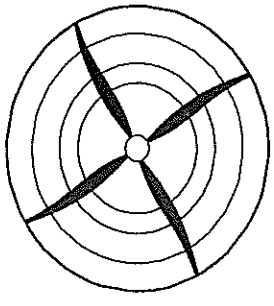
6.36 (a)

Static bending test for timber shall be made on specimens 5 cm × 5 cm × 75 cm is size. The specimen shall be absolutely free from any defect and shall not have a slope of grain more than 1 in 20 parallel to its longitudinal edges.

6.37 (c)

Fibre boards are used as insulation against heat and sound. Laminated timber is used for cantilever arches, bow, string trusses etc. Heartwood is used for scantling and Plywood is used for paneling.

6.38 (d)



Heart Shakes

Knot is branch base embedded in timber by natural growth. Rot is disintegration caused by fungi.

6.39 (b)

Lack of ventilation causes dry rot. Alternate wet and dry condition leads to wet rot.

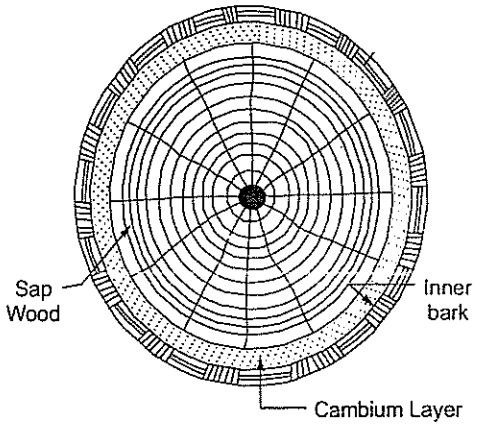
6.40 (a)

Strength of timber is maximum in the direction parallel to the grains and minimum perpendicular to the grains.

6.41 (d)

The advantage of kiln seasoning are speed, adaptability and precision. The timber obtained from kiln seasoning are weaker than that obtained from natural seasoning. There is no effect on life of the timber.

6.42 (b)



6.43 (c)

- Tar oil type : Creosote
- Organic solvent type :Gamma-Benzene hexachloride (BHC or Lindane)
- Water soluble type : Boric acid and Borax.

6.44 (a)

Strength of timber is maximum in the direction parallel to the grains and minimum perpendicular to the grains.

6.45 (b)

Babul is used for bodies and wheels of bullock carts, agricultural instruments, tool handles, etc.

Benteak is used for building construction, boat construction, furniture, etc.

Bijasal is used for ordinary building construction, cart wheel, furniture, etc.

Mulberry is used for baskets and sport goods like hockey sticks, tennis rackets, cricket bats, etc.

6.46 (c)

Deodar is the most important tree providing soft wood. It is found in Himalayas, Punjab and Uttar Pradesh. It is used for making cheap and rough furniture, railway carriages, railway sleepers, packing boxes, structural work etc.

Sandalwood is found in Assam, Nagpur and Bengal. It is used for agricultural implements, well kerbs, wheels, mallets, fancy goods, boxes, etc.

Sissoo or Shisham is dark brown in colour. It is strong, durable and tough. It is difficult to work but it takes a fine polish. It is used for high class furniture, plywoods, bridge piles, sport goods, railway carriages, etc.

Teakwood is moderately hard, durable and fire resistant. It can be easily seasoned and worked. It takes up a good polish. It is used for house construction, railway carriages, ship building, high quality and durable furniture, well kerbs, piles, etc. Its use is limited to superior work only as it is comparatively very costly.

6.47 (b)

As natural timber shows different properties in perpendicular directions, it is anisotropic.

6.48 (a)

Lignin is a class of complex organic polymers that form important structural materials in the support tissues of vascular plants giving them high shear strength.

6.49 (c)

Warping is a deviation from flatness in *timber* as a result of stresses and uneven shrinkage due to uncontrolled and non-uniform loss of moisture from wood.

6.50 (a)

Timber sections change in volume with change in season due to change of environmental factors like temperature, humidity etc., therefore while fitting wooden window shutters should be fitted leaving proper tolerance for dimensional change.

6.51 (a)

The innermost central portion or the core of the tree is called the pith or medulla. The outer annual rings between heartwood and cambium layer is known as the sapwood.

The inner annual rings surrounding the pith is called the heart wood. The thin layer of sap between sap wood and inner bark is known as the cambium layer.

6.52 (d)

Fibre saturation point is the moisture content in % of the timber when the cell walls are saturated with water and the cell cavities contain no water. Any drying below the fibre saturation point results in shrinkage.

6.53 (b)

As per IS 287-1993

- Recommended moisture content for structural elements is 12-20 percent of doors.
- The maximum permissible moisture content of structural elements for use as beam and rafter varies from 12-20 percent (depending upon the zone in which structure lies).
- The moisture content of structural elements for use as building frames like windows may vary from 8 to 16 percent (depending upon the zone in which structure lies).

6.55 (d)

In structural timber, longitudinal elastic modulus is 10 to 20 times that of radial or tangential elastic modulus.

6.56 (b)

According to IS 883 : 1970, Indian Timbers are classified into three groups, according to modulus of elasticity:

(i) Group A: Modulus of elasticity in bending above 1.26 MN/cm^2

(ii) Group B: Modulus of elasticity in bending above 0.98 MN/cm^2 and upto 1.26 MN/cm^2

(iii) Group C: Modulus of elasticity in bending above 0.56 MN/cm^2 and upto 0.98 MN/cm^2

6.57 (b)

Sir Abel's process is employed to make timber fire resistant. In this process, timber surface is coated with a dilute solution of sodium silicate-A cream-like paste of slaked fat time is then applied and finally, a concentrated solution of silicate of soda is applied on the timber surface.

6.58 (a)

Empty cell process aims at a maximum penetration of the preservative with minimum net retention. Lawry process and Rueping process are two types of Empty cell processes.

Lawry Process: In this process, the cylinder is loaded with the charge and then closed. The cylinder is then filled with the preservative and a pressure of about 3.5 to 12.5 kg/cm^2 is applied till the required absorption is obtained.

Rueping Process: In this process the charged cylinder is first subjected to an air pressure of 2.00 to 5.00 kg/cm^2 for a specified period. This pressure is maintained while the cylinder is filled with the preservative. Then an antiseptic pressure of 5.0 to 12.5 kg/cm^2 is applied till the required absorption is obtained.

6.59 (b)

Cambium layer is between inner bark and Sapwood. Heartwood is deadwood which does not take part in growth of tree and is used for construction.

6.60 (a)

The advantage of plywood is uniform tensile strength in all directions and greater resistance to cracking and splitting with change in moisture content.

6.61 (b)

Tensile strength of wood is maximum in the direction parallel to the grains and minimum perpendicular to the grains.

6.62 (d)

Timber used for beams should be easy to season. It should be tough and be of stronger variety.

6.63 (a)

In dry rot fungi attack on wood and convert it into dry powder form. Other defects in timber due to fungus attack are: Blue stain Brown rot, Heart rot, Sap stain, Wet rot.

Alternate wetting and drying of timber favour the development of wet rot in which the fungi converts timber into greyish powder form.

6.64 (d)

Fibre saturation point is the moisture content in % of the timber when the cell walls are saturated with water and the cells cavity contains no water. Any drying below the fiber saturation point results in shrinkage. Sudden and fast drying of timber results in the removal of water from cell walls and the consequent shrinkage causes cracking.

6.65 (a)

Star shakes consists of several radial splits. In some cases one or more of these splits may extend nearly to the bark. Such splits tend to open up more and more as the timber seasons. Heart shake occurs in nearly all overmature timber, being more frequent in hardwoods than in conifers. Cup or ring shake result from the pulling apart of two or more growth rings. It is one of the most serious defects to which sound timber is subjected to as it reduces the technical properties of wood.

6.66 (b)

Hardwood is generally obtained from deciduous or Broad Leaf Trees. It is generally close grained, strong, heavy, dark coloured, durable and non-resinous and are used for engineering applications. They do not show distinct annual rings.

6.67 (d)

The specific gravity of wood is dependent upon temperature and equilibrium moisture content.

6.68 (c)

Annular rings consist of closed shell of woody fibres and tissues arranged in distinct approximately concentric circles around pith. Every year one such ring is formed. Hence the total number of annular rings indicates the age of tree. The wood near the bark is the youngest.

6.69 (a)

Seasoning of timber provides superior dimensional stability. The seasoned timber have improved mechanical properties, typically the strength, which generally increases as moisture content decreases below 25 to 30 percent.

6.70 (c)

The plywood manufactured from secondary species of timber and synthetic resin is widely used for furniture and other household articles.

The fibre boards are manufactured from 100 percent raw agro-wastes such as bagasse, cotton

stacks, rice husk, jute corn etc. The boards are claimed to possess good mechanical, moisture resistant and termite resistant properties. These boards are used for thermal insulation.

6.71 (d)
Plank sawn from trees with normal fibres are stronger than those cut from trees with twisted fibre.

6.72 (a)
Coniferous trees have distinct annual rings, straight fibres and can resist tension and pull well.

6.73 (b)
Druxiness is a defect indicated by white decayed spot which are concealed by healthy wood caused by access of fungi.

6.74 (b)
Excrescences are formed when a tree has received shock or injury in its young age due to such injury, growth of tree is completely upset and irregular projections appear on body of timber.

6.75 (b)
In Sir Abel's process wood having clean and smooth surface is painted over with dilute silicate solution, then with slaked fat lime and then with stronger silicate solution for making it fire resistant.

6.76 (a)
Dry rot is a fungal defect and is caused due to wet and humid conditions.

6.77 (b)
Alternate drying and wetting of timber causes decay and decreases durability.

6.78 (c)
- IS 1141-1958 - Seasoning of timber
- IS 4970-1973-key for identification of commercial timbers
- IS 1708-1969- Tests of timber performed in laboratory
- IS 399-1963- Classification of commercial timber and their zonal distribution

6.79 (a)
In the question we are asked about preservation and not preservative. So, all are correction. If it had been preservative in the question then option 'c' would be correct because preservative neither increase the strength nor reduce the moisture content.

6.81 (d)
Ascu is mixture of hydrated arsenic pentoxide ($AS_2O_5\ 2H_2O$), copper sulphate and potassium or sodium dichromate in 1 : 3 : 4 proportion.

6.83 (d)
Timbers suitable for furniture is obtained from deciduous trees only.

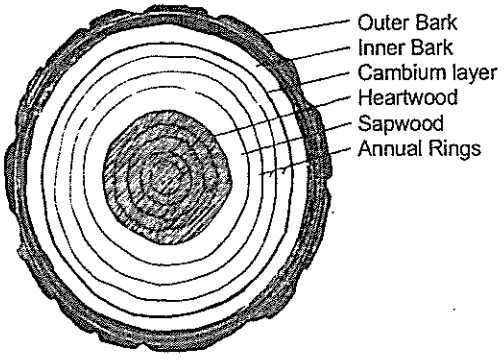
6.84 (a)
In timber, sap can be attacked by fungi leading to dimensional instability and lesser workability. Seasoning of timber removes moisture in form of sap.

6.85 (b)
Select grade is grade-I timber which is of highest quality and has no defects. Hence 1 is correct.
As per IS 1331 : 1971, the codal values for strength of grade-II timber without defects may be reduced by 25%.
As per IS 883 : 1994, in case of wind force and earthquakes, a modification factor (K_s) of 1.33 is adopted (refer table 5 IS 883 : 1994).

6.86 (a)
Application of AsCu solution increases the resistance of timber section against the action of white ants and doesn't alter the strength characteristics of timber.

6.87 (c)
Rot in timber is decomposition or putrefaction, generally results due to dampness and which is followed by the emission of gases, mainly carbonic acid and hydrogen.

6.88 (a)



6.89 (b)

Separation of fibres along the grain from one end of plank to other end is known as Splitting and is caused due to seasoning defect.

Seasoning of timber is required for structural purpose helps in increasing immunity against insect attacks, increases strength, durability, workability and resilience, reduces weight and improves transportation, reduces warping and shrinkage tendency.

6.90 (b)

Hardwoods are used in special purpose heavy construction because they are strong across and along the grains, strong in shear, tension and compression.

Hardwoods have vessels that are used in sap production. When *vessels* are sliced open, they leave tiny hollows in the wood called *pores.*

6.91 (a)

Compreg timbers are processed wood whose cells are impregnated with a resin and compressed to reduce shrinkage and swelling and to increase density and strength.

Compreg Timber has high specific gravity of 1.30 to 1.35.

- The process of manufacturing of "Compreg Timber" is same of "Impreg Timber" except that curing of resin-impregnated timber is carried out under "high temp" and high pressure under special process.
- It has high durability and high strength more than Impreg Timber.

■■■■

7 Oil, Varnishes Paint, Distempers & Miscellaneous

7.1 Match List-I (Metals or alloys) with List-II (Their common use) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Steel bars	1. Water taps
B. Zinc	2. Door Frames
C. Aluminium	3. Reinforcement in concrete
D. Brass castings	4. Corrugated roof sheet

Codes:

	A	B	C	D
(a)	3	1	4	2
(b)	3	2	4	1
(c)	1	3	4	2
(d)	3	4	2	1

[ESE : 1995]

7.2 The modulus of elasticity of high tensile steel is
(a) smaller than that of mild steel
(b) equal to that of mild steel
(c) larger than that of mild steel
(d) equal to that of aluminium

[ESE : 1995]

7.3 Yield stress of ordinary mild steel bars after twisting to a pitch of about 9 to 12 diameters
(a) increases by about 50%
(b) decreases by about 30%
(c) increases by about 20%
(d) decreases by about 10%

[ESE : 1995]

7.4 The coefficient of linear expansion of granite is in the range of that of
(a) glass (b) mild steel
(c) high carbon steel (d) bamboo

[ESE : 1996]

7.5 The ratio of Young's modulus of high tensile steel to that of mild steel is about
(a) 0.5 (b) 1.0
(c) 1.5 (d) 2.0

[ESE : 1996]

7.6 Bureau of Indian Standards classifies bitumen into grades 65/25, 85/40 etc. The first and second numbers respectively refer to
(a) softening point and penetration
(b) penetration and softening point
(c) flash point and penetration
(d) flash point and softening point

[ESE : 1996]

7.7 Polyvinyl chloride (PVC) is a
(a) thermosetting material
(b) thermoplastic material
(c) elasto-plastic material
(d) rigid plastic material

[ESE : 1996]

7.8 Assertion (A): While painting on flush doors of plywood, putty-filling is done after prime coat.
Reason (R): This reduces the quantity of paint and effort involved in the regular coats of the paints.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

7.9 Which one of the following types of steel is used in the manufacture of rails?
(a) Mild steel
(b) Manganese steel
(c) Cast steel
(d) Bessemer steel

[ESE : 1997]

7.10 The ultimate strength of cold drawn steel wires
(a) increases with the increase in the diameter of the bar
(b) increases with reduction in the diameter of the bar
(c) does not depend upon the change in the diameter of the bar
(d) depends only on the diameter of the bar
[ESE : 1997]

7.11 Match List-I (Alloy metal) with List-II (Application/ Characteristic) and select the correct answer using the codes given below the lists:

List-I
A. Aluminium alloy
B. Copper
C. Zinc
D. Lead

List-II
1. Building flashing and damp-proof course
2. Radiation shielding
3. Lightning conductors
4. Low density and high resistance to corrosion

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	4	3	2	1
(c)	3	4	1	2
(d)	4	3	1	2

[ESE : 1998]

7.12 The carbon content of structural steel is
(a) less than 0.1% (b) 0.10 to 0.25%
(c) 0.25 to 0.60% (d) 0.60 to 1.00%
[ESE : 1998]

7.13 In paints, linseed oil is used as
(a) a thinner
(b) a drier
(c) a vehicle
(d) a water-proofing base
[ESE : 1998]

7.14 Consider the following statements:
Casein glue is
1. obtained from milk
2. obtained from the blood of animals
3. used in painting of metals
4. used in the plywood industry
5. white in color
6. red in color

Which of these statements are correct?
(a) 1, 3, and 5 (b) 1, 4 and 5
(c) 2, 3 and 6 (d) 2, 4 and 6
[ESE : 1998]

7.15 Match List-I (Component of scaffolding) with List-II (Function) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Putlog	1. Diagonal member
B. Ledger	2. Vertical member
C. Brace	3. Horizontal member
D. Standard	4. Transverse member

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	4	3	2	1
(c)	3	4	1	2
(d)	3	4	2	1

[ESE : 1998]

7.16 An arrangement for temporarily supporting a structure from beneath for safety, is known as
(a) jacking (b) underpinning
(c) supporting (d) hauling
[ESE : 2000]

7.17 In building construction, the place for providing damp-proof course is at the
(a) basement level (b) window sill level
(c) lintel level (d) roof level
[ESE : 2001]

7.18 **Statement-I** : When plastering on building exteriors, more of coarser particles of sand are used in regions where seasonal rainfall is often intense and the total annual rainfall also is relatively more.
Statement-II : Such type of 'dhabbah' plastering effects the minimization of rainfall impacts resulting in less formation of mosses and less surface discoloration but may not reduce seepage to the interior.
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)

(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

[ESE : 2012]

7.19 Consider the following tests :
1. Transverse strength test
2. Water absorption test
3. Impact test
4. Breaking strength test

Which of the above are relevant to testing of tiles?
(a) 1, 2 and 3 only (b) 1, 2 and 4 only
(c) 3 and 4 only (d) 1, 2, 3 and 4

[ESE : 2016]

Directions: Each of the next items consists of two statements, one labeled as the **'Statements (I)'** and the other as **'Statement (II)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below :

Codes:
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

7.20 **Statement (I):** In recent practice, sponge iron replaces pig iron in large foundries.
Statement (II): Sponge iron can be produced in small plants using non-coking coal.

[ESE : 2017]

7.21 **Statement (I):** Foam glass is extensively used in air-conditioning units.
Statement (II): Foam glass is termite proof and noncombustible.

[ESE : 2017]

■■■■

Answers Oil, Varnishes Paint, Distempers & Miscellaneous

7.1	(d)	7.2	(b)	7.3	(c)	7.4	(a)	7.5	(b)	7.6	(a)	7.7	(b)	7.8	(d)	7.9	(b)
7.10	(b)	7.11	(d)	7.12	(b)	7.13	(c)	7.14	(b)	7.15	(a)	7.16	(b)	7.17	(a)	7.18	(a)
7.19	(d)	7.20	(b)	7.21	(a)												

Explanations Oil, Varnishes Paint, Distempers & Miscellaneous

7.2 (b)

$E = 2 \times 10^5$ N/mm^2 for both mild steel and high tensile bars.

7.3 (c)

The yield strength of mild steel plain rounded bar is 255 N/mm^2. So the increase is about 20% from a value of 250 N/mm^2.

7.4 (a)

The linear thermal coefficient range is 6×10^{-6} to 10×10^{-6} for both glass and granite.

7.5 (b)

Young's modulus of all steel types is same and hence the ratio is 1.0

7.6 (a)

Industrial bitumens are specified as per IS:73-1961 as 65/25 meaning the penetration value is 20–30 and softening point is 55 –70°C. Thus first number is softening point and second is penetration value.

Paving grade bitumens are specified as 60/70 means that penetration value is 60 to 70.

7.7 (b)

Thermoplastic or heat non-convertible group means that the plastics become soft when heated and hard when cooled.

Thermosetting or heat convertible group means that plastics become rigid when moulded at suitable pressure and temperature.

Rigid plastics have a high modulus of elasticity and they retain their shape under external stresses application at normal or moderately increased temperatures.

7.8 (d)

The wood work painting has following steps:

(i) Preparation of surface
(ii) Knotting
(iii) Priming
(iv) Stopping or putty filling
(v) Second or surface coats or under coatings
(vi) Finishing coat

So putty filling is done after prime coat.

7.10 (b)

The ultimate tensile strength of a plain hard-drawn steel wire varies with its diameter. The tensile strength decreases with increase in the diameter of the wires. Tensile strengths and elongation characteristics of cold-drawn stress relieved wires as per IS: 1785 (Part1)-1983 is as given in the following table:

Nominal Diameter (mm)	Minimum tensile strength (N/mm^2)	Elongation (%)
2.5	2010	2.5
3.0	1865	2.5
4.0	1715	3.0
5.0	1570	4.0
6.0	1470	4.0
7.0	1375	4.0

7.12 (b)

The carbon content of mildsteel is about 0.10 to 0.25%. It is used as structural steel.

7.13 (c)

Vehicle is a non-volatile fluid in which the solid body material is suspended and comprises 85%-90% drying oil plus 10%-15% drier and thinner. Examples of vehicle are:

1. **Drying oil** : Linseed oil from flax seeds, fish oil, dehydrated castor oil, tung oil, perilla oil.
2. **Drier** : Organic salts of various metals such as PbO (litharge) for lead based paints and $ZnSO_4$ and MnO for zinc based paints.
3. **Thinner** : Volatile solvents like turpentine, petroleum fractions like naphtha, benzene.

7.14 (b)

Caesin glue is obtained from coagulating skimmed milk in vats and grinding the product to a fine powder. It is used in plywood industry for gluing together veneers. It is white in colour.

7.15 (a)

Standard are vertical members of scaffolding. Ledgers are the horizontal members at right angles to standard and parallel to the wall braces are fixed diagonally on the standards. Putlogs are placed on the horizontal member (i.e. ledgers) at right angle to the walls, one end of which is held in wall.

7.16 (b)

The placing of new foundation below and existing foundation of the process of strengthening the existing foundation is known as the underpinning of foundations. The structure is held well supported in a secured manner and the footings are relieved from the load. Sometimes the structures are to be temporarily supported. This is achieved by an arrangement called shoring. It is necessary to support the super-structure when large openings are required to be made in the main walls. There are three different types of shores :

(i) Raking shores
(ii) Flying shores
(iii) Dead shores

All these types of shores support the structure from side.

7.17 (a)

DPC is provided to prevent the water rising from the subsoil or ground and getting into the different parts of the building. The best location or position of DPC is the basement of the building. In case of buildings without basement DPC lies at the plinth level or in case of structures without plinth it should be laid at least 15 cm above the ground level. In case of basements, laying of DPC is called tanking.

7.20 (b)

Direct reduced iron (DRI) is called sponge iron. It is produced from the direct reduction of iron are to iron by a reducing gas or elementary carbon produced from natural gas or coal.

The direct reduction process is comparatively energy efficiency that less fuel is required compared to traditional blast furnace. These days, direct reduction processes have bean developed to overcome difficulties of concentrational blast furnace.

7.21 (a)

"Foam glass" is porous glass foam material. Its a building material and include its light weight, high strength and it is thermal and acoustic insulating properties.

■■■■

UNIT

II

Solid Mechanics

Syllabus

Elastic constants, Stress, plane stress, Strains, plane strain, Mohr's circle of stress and strain, Elastic theories of failure, Principal Stresses, Bending, Shear and Torsion.

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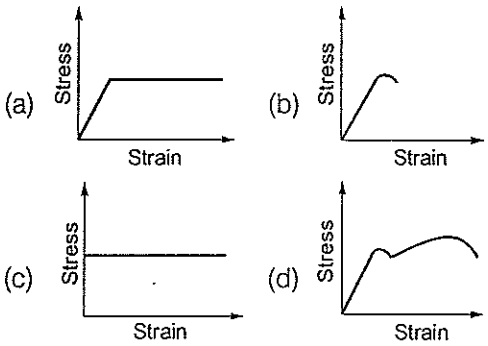
OOOO

1 Properties of Materials

1.1 The stress-strain curve for an ideally plastic material is



[ESE : 1995]

1.2 The stress level, below which a material has a high probability of not failing under reversal of stress, is known as

(a) elastic limit (b) endurance limit
(c) proportional limit (d) tolerance limit

[ESE : 1995]

1.3 The stress at which a material fractures under large number of reversals of stress is called

(a) endurance limit (b) creep
(c) ultimate strength (d) residual stress

[ESE : 1996]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

1.4 **Assertion (A):** Strain is a fundamental behaviour of the material, while the stress is a derived concept.

Reason (R): Strain does not have a unit while the stress has a unit.

[ESE : 1996]

1.5 **Assertion (A):** The amount of elastic deformation at a certain point, which an elastic body undergoes, under given stress is the same irrespective of the stresses being tensile or compressive.

Reason (R): The modulus of elasticity and Poisson's ratio are assumed to be the same in tension as well as compression.

[ESE : 1996]

1.6 **Assertion (A):** A mild steel tension specimen has a cup and cone fracture at failure.

Reason (R): Mild steel is weak in shear and failure of the specimen in shear takes place at 45° to the direction of the applied tensile force.

[ESE : 1996]

1.7 If A be the area of cross-section of a bar, the gauge length for the measurement of ductility will be

(a) $5.65 \times A^{1/2}$ (b) $5.65 \times A$
(c) $6.56 \times A^{1/2}$ (d) $6.56 \times A$

[ESE : 1998]

1.8 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Ductility
B. Brittleness
C. Tenacity
D. Toughness

List-II

1. Failure without warning
2. Drawn permanently over great changes of shape without rupture
3. Absorption of energy at high stress without rupture
4. High tensile strength

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	1	2	3	4
(c)	2	3	4	1
(d)	2	1	4	3

[ESE : 1998]

1.9 Which one of the following pairs is NOT correctly matched?

(a) Visco-elastic : *Small plastic zone material*

(b) Strain hardening material : *Stiffening effect felt at some stage*

(c) Orthotropic material : *Different properties in three perpendicular directions*

(d) Isotropic material : *Same physical property in all directions at a point*

[ESE : 1998]

1.10 Match List-I (Material) with List-II (Characteristic) and select the correct answer using the codes given below the lists:

List-I

A. Inelastic material

B. Rigid plastic material

C. Ductile material

D. Brittle material

List-II

1. No plastic zone
2. Large plastic zone
3. Strain is not recovered after unloading
4. Strain is zero upto a stress level and then stress remains constant.

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	3	4	1	2
(c)	4	3	2	1
(d)	4	3	1	2

[ESE : 1999]

1.11 Match List-I (Property) with List-II (Characteristic) and select the correct answer using the codes given below the lists:

List-I

A. Fatigue

B. Creep

C. Plasticity

D. Endurance limit

List-II

1. Material continues to deform with time under sustained loading
2. Decreased resistance of material to repeated reversals of stress
3. Material has a high probability of not failing under reversals of stress of magnitude below this level
4. Material continues to deform without any further increase in stress

Codes:

	A	B	C	D
(a)	2	1	4	3
(b)	2	1	3	4
(c)	1	2	4	3
(d)	1	2	3	4

[ESE : 1999]

1.12 **Assertion (A):** In a tensile test on a specimen, true stress in the specimen is more than the nominal stress.

Reason (R): Grip of universal testing machine introduces stress concentrations.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 1999]

1.13 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Tenacity

B. Plasticity

C. Ductility

D. Malleability

List-II

1. Continues to deform without much increase of stress
2. Ultimate strength in tension
3. Extension in a direction without rupture
4. Ability to be drawn out by tension to a small section without rupture

Codes:

	A	B	C	D
(a)	2	1	4	3
(b)	2	1	3	4
(c)	1	2	4	3
(d)	1	2	3	4

[ESE : 2000]

1.14 Match List-I (Elastic constant) with List-II (Definition) and select the correct answer using the codes given below the lists:

List-I

A. Young's modulus
B. Poisson's ratio
C. Bulk modulus
D. Rigidity modulus

List-II

1. Lateral strain to linear strain within elastic limit
2. Stress to strain within elastic limit
3. Shear stress to shear strain within elastic limit
4. Direct stress to corresponding volumetric strain

Codes:

	A	B	C	D
(a)	3	1	4	2
(b)	2	1	4	3
(c)	2	4	1	3
(d)	3	4	1	2

[ESE : 2000]

1.15 For a linear, elastic, isotropic material, the number of independent elastic constants is

(a) 1 (b) 2
(c) 3 (d) 4

[ESE : 2000]

1.16 Creep is the gradual increase of

(a) plastic strain with time at constant load
(b) elastic strain with time at constant load
(c) plastic strain with time at varying load
(d) elastic strain with time at varying load

[ESE : 2001]

1.17 Creep of a material is a property indicated by

(a) a time dependent strain of the material
(b) elongation of the material due to changes in the material properties
(c) shortening caused by shrinkage of the member
(d) the decrease in the volume of the material affected by the weather conditions

[ESE : 2002]

1.18 Resilience is

(a) maximum strain energy
(b) recoverable strain energy
(c) total potential energy
(d) shear strain energy (Beyond Hooke's Law)

[ESE : 2002]

1.19 Elastic limit is the point

(a) up to which stress is proportional to strain
(b) at which elongation takes place without application of additional load
(c) up to which if the load is removed, original volume and shape are regained
(d) at which the toughness is maximum

[ESE : 2003]

1.20 Match List-I (Material) with List-II (Properties) and select the correct answer using the codes given below the lists:

List-I

A. Isotropic
B. Homogeneous
C. Visco-elastic
D. Brittle

List-II

1. Time dependent stress-strain relation
2. No plastic zone
3. Identical properties in all directions
4. Similar properties throughout the volume

Codes:

	A	B	C	D
(a)	3	1	2	4
(b)	4	1	2	3
(c)	3	4	1	2
(d)	4	3	2	1

[ESE : 2003]

1.21 The material in which large deformation is possible before the absolute failure or rupture is termed as

(a) brittle (b) elastic
(c) ductile (d) plastic

[ESE : 2003]

1.22 Some structural members subjected to long time sustained loads deform progressively with time especially at elevated temperatures.
What is such a phenomenon called?
(a) Fatigue (b) Creep
(c) Creep relaxation (d) Fracture
[ESE : 2008]

1.23 Consider the following statements:
1. Failure occurs beyond elastic limit.
2. Rupture takes place immediately after elastic limit.
3. Permanent set occurs beyond elastic limit.
Which of these are considered in the theories of failure?
(a) 1, 2 and 3 (b) 1 and 3 only
(c) 2 and 3 only (d) 1 and 2 only
[ESE : 2011]

1.24 Consider the following salient points in a stress-strain curve of a mild steel bar:
1. Yield point
2. Breaking point
3. Yield plateau
4. Proportionality limit
5. Ultimate point
The correct sequence in which they occur while testing the mild steel bar in tension from initial zero strain to failure is
(a) 4, 1, 2, 3 and 5 (b) 1, 4, 3, 5 and 2
(c) 4, 1, 3, 5 and 2 (d) 1, 4, 2, 3 and 5
[ESE : 2011]

1.25 The material in which large deformation is possible before absolute failure by rupture takes place, is known as
(a) Ductile (b) Plastic
(c) Brittle (d) Elastic
[ESE : 2011]

1.26 If a material has identical elastic properties in all directions, it is said to be
(a) elastic (b) isotropic
(c) orthotropic (d) homogeneous
[ESE : 2012]

1.27 Which of the following statements are correct?
1. In a ductile material elastic deformation is more predominant than plastic one.
2. Brittleness is not an absolute property of a metal.
3. Rate of loading has no influence in changing the behaviour of a metal from 'ductile' to 'brittle' at low temperatures.
4. Under hydrostatic compression, a brittle metal may change into a ductile one.
(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 2 and 4
[ESE : 2013]

1.28 Which one of the following represents 'constitutive relationship'?
(a) Vertical displacements in a structure
(b) Rotational displacements in a structure
(c) System of forces in equilibrium
(d) Stress-strain behaviour of a material
[ESE : 2016]

1.29 In mild steel specimens subjected to tensile test cycle, the elastic limit in tension is raised and the elastic limit in compression is lowered. This is called
(a) Annealing effect (b) Bauschinger effect
(c) Strain rate effect (d) Fatigue effect
[ESE : 2017]

■■■■

Answers Properties of Materials

1.1 (c)	1.2 (b)	1.3 (a)	1.4 (b)	1.5 (a)	1.6 (a)	1.7 (a)	1.8 (d)	1.9 (a)	
1.10 (a)	1.11 (a)	1.12 (b)	1.13 (a)	1.14 (b)	1.15 (b)	1.16 (a)	1.17 (a)	1.18 (b)	
1.19 (c)	1.20 (c)	1.21 (c)	1.22 (b)	1.23 (b)	1.24 (c)	1.25 (a)	1.26 (b)	1.27 (d)	
1.28 (d)	1.29 (b)								

Explanations Properties of Materials

1.1 (c)

In plastic design the stress-strain curve is bi-linear as shown in figure (a). However, the stress-strain curve for ideal plastic materials is as shown in figure (c). Figure (b) shows stress-strain curve for brittle materials. Figure (d) shows stress-strain curve for ductile materials.

1.2 (b)

The stress which can be withstood for some specified number of cycles is the fatigue strength of material. The stress level which can be withstood for an infinite number of cycles, without failure is called endurance limit.

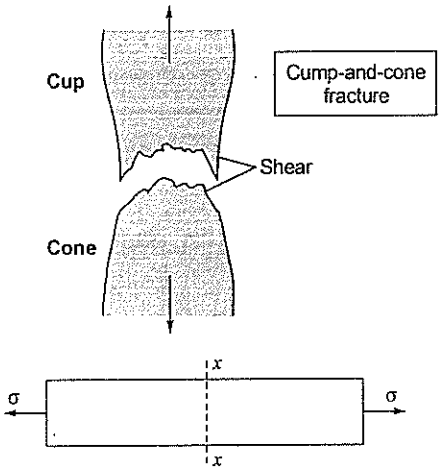
1.4 (b)

During experiment in laboratory, strain is measured that is why it is called fundamental quantity. While stress is derived from strain.

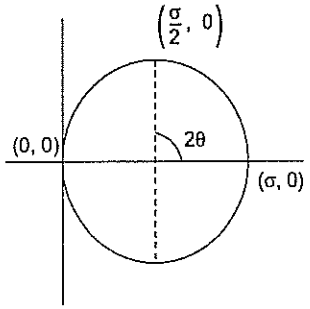
1.5 (a)

For an isotrpic homogensous material amount of elastic deformation is same irrespective of nature of stress.

1.6 (a)



Mohr circle for this stress condition as shown below:



$2\theta = 90°$

$\theta = 45°$

$2\theta = 90°$

$\theta = 45°$

Maximum shear stress is at 45° to direction of applied tensile force. Mild steel is weaker in shear.

1.7 (a)

In the tensile test of specimen, the total elongation comprises -(i) uniform extension and (ii) local extension due to necking or waisting.

Uniform extension is proportional to gauge length and local extension is proportional to $\sqrt{A_o}$ i.e., independent of gauge length.

Total extension $D_T = aL_o + b\sqrt{A_o}$ [Unwin's formula]

Therefore it is necessary to specify gauge length.

$$L_o = 5.65\sqrt{A_o}$$

1.8 (d)

- **Ductility:** Ability of a material (such as a metal or asphalt cement) to undergo permanent deformation through elongation.
- **Brittleness:** Tendency of a material to fracture or fail without significant deformation upon the application of a relatively small amount of force, impact, or shock.
- **Tenacity:** Ability of metal to resist fracture under heavy tensile load.
- **Toughness:** Ability of absorb energy at high stress without rupture.

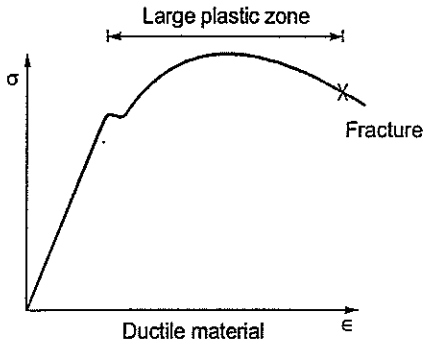
1.9 (a)

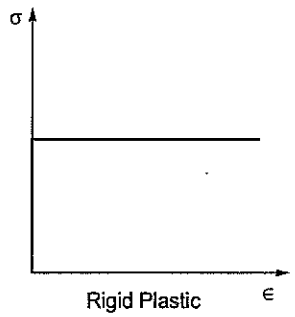
Visco-elastic material exhibit a mixture of creep and elastic after effects at room temperature. Thus their behaviour is time dependent. They do not have small plastic zone.

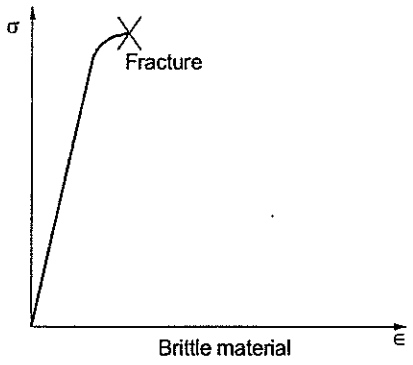
Materials with different properties in different directions are called anisotropic. Orthotropic material is a special case of an anisotropic material in three mutually perpendicular directions. However, these are symmetric about any axis.

1.10 (a)

In inelastic material, strain is not recovered after unloading.







1.12 (b)

For true stress, the actual area at any time is used. The actual area is less than original area, due to elongation in specimen therefore true stress is more than nominal stress.

1.13 (a)

Tenacity is the property of the metal to resist fracture when under the action of a tensile force.

1.14 (b)

- **Young's modulus** is ratio between stress and strain within elastic limit. It can be expressed as: E = Stress/strain
- **Poisson's ratio** is defined as the negative of the ratio of the lateral strain to the longitudinal strain within elastic limit
- **Bulk modulus:** The ratio of the change in pressure to the fractional volume compression.
- **Modulus of rigidity** or shear modulus is the rate of change of unit shear stress with respect to unit shear strain for the condition of pure shear within elastic limit

1.15 (b)

Isotropic materials have same properties in all directions. The number of independent elastic constants for such materials is 2. Out of *E*, *G*, *K* and μ, if any two constant is known for any linear elastic and isotropic material than rest two can be derived. Examples are steel, aluminium, copper, gold, etc.

Orthotropic materials refers to layered structure such as wood or plywood. The number of independent elastic constants for such materials is 9.

Non-isotropic or anisotropic materials have different properties in different directions. They show non-homogeneous behaviour. The number of independent elastic constants is 21.

1.16 (a)

Creep is the property by virtue of which a metal specimen undergoes additional deformation with the passage of time under sustained loading within elastic limit. It is permanent in nature and cannot be recovered after removal of load, hence is plastic in nature.

1.17 (a)

Creep (sometimes called cold flow) is the property of materials that results in progressive deformation when a constant load is applied over time. Deformation occurs as a result of long-term exposure to high levels of stress that are still below the yield strength of the material

1.18 (b)

Resilience is the total strain energy stored in a given volume of a material within elastic limit. On removal of load this energy is released. In other words, it is the area under load deflection curve within elastic limit.

1.19 (c)

Elastic limit is the maximum extent to which a solid may be stretched without permanent deformation of size or shape and returns to original volume and shape when load is removed.

1.21 (c)

In ductile material large deformation is possible before absolute failure or rupture whereas in plastic material strain continues to increase without much increase in stress. Brittle material fails suddenly without significant deformation.

1.22 (b)

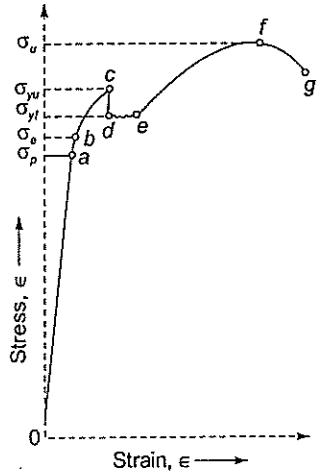
Creep results in progressive deformation when a constant load is applied over time especially at elevated temperatures. Deformation occurs as a result of long-term exposure to high levels of stress that are still below the yield strength of the material.

1.23 (b)

A material is said to have failed when it is stressed beyond the elastic limit and permanent deformation occurs. Failure of a material represents either direct separation of particles from each other (brittle fracture) or slipping of particles (ductile fracture or yielding) accompanied by considerable plastic deformations. Failure does not necessarily mean rupture.

1.24 (c)

The stres-strain curve of a mild steel bar under tension is shown below:



a : Proportionality limit: Upto this Hooke's law is valid and stress is proportional to strain.

b : Elastic limit: From a to *b* stress is not proportional to strain, while it remains elastic.

c : Upper yield point : From *b* to c material goes to plastic stage

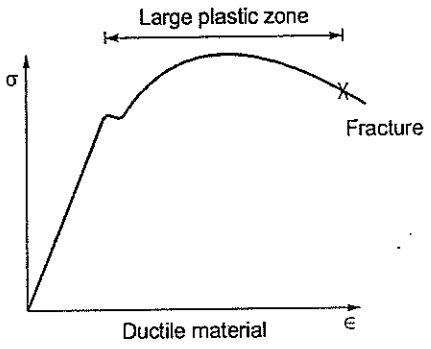
d : Lower yield point

de : Yield plateau: Yielding of material at constant stress.

f : Ultimate point: Maximum sress to which the material can be subjected in a simple tensile test.

g : Breaking point : Point where the material breaks.

1.25 (a)



1.26 (b)

An orthotropic material has different elastic property in perpendicular directions. A homogeneous material is the one with uniform composition.

1.27 (d)

Rate of loading also determines nature of metal. Ductile material can have substantial plastic deformation also.

Work by Bridgman showed that normally brittle materials can be made to behave in ductile manner if they are loaded under extremely high pressure. Practical use of this phenomenon is made in the commercial processing of extremely difficult to form metals and shapes.

1.28 (d)

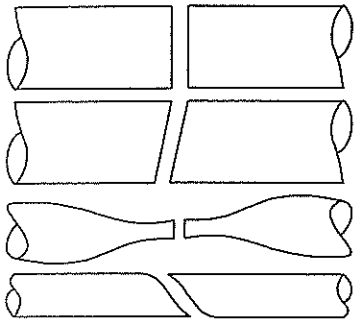
Constitutive relation is a relation between two physical quantities that is specific to a material or substance. Hooke's law is a constitutive law because it shows the relation between stress-strain behaviour.

■■■■

2 Simple Stress-Strain & Elastic Constants

2.1 When a mild-steel specimen fails in a torsion test fracture looks like

(a)
(b)
(c)
(d)



[ESE : 1995]

2.2 Given that for an element in a body of homogeneous isotropic material subjected to plane stresses, ε_x, ε_y and ε_z are normal strains in x, y and z direction respectively and μ is the Poisson's ratio, the magnitude of unit volume change of the element is given by

(a) $\varepsilon_x + \varepsilon_y + \varepsilon_z$

(b) $\varepsilon_x + \mu(\varepsilon_y + \varepsilon_z)$

(c) $\mu(\varepsilon_x + \varepsilon_y + \varepsilon_z)$

(d) $\dfrac{1}{\varepsilon_x} + \dfrac{1}{\varepsilon_y} + \dfrac{1}{\varepsilon_z}$

[ESE : 1995]

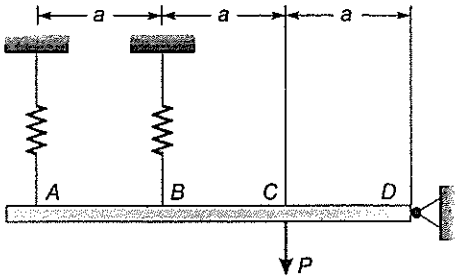
2.3 A solid metal bar of uniform diameter D and length L is hung vertically from a ceiling. If the density of the material of the bar is ρ and the modulus of elasticity is E, then the total elongation of the bar due to its own weight is

(a) $\dfrac{\rho L}{2E}$ (b) $\dfrac{\rho L^2}{2E}$

(c) $\dfrac{\rho E}{2L}$ (d) $\dfrac{\rho E}{2L^2}$

[ESE : 1995]

2.4 A rigid beam $ABCD$ is hinged at D and supported by two springs at A and B as shown in the given figure. The beam carries a vertical load P at C. The stiffness of spring at A is $2k$ and that of B is k.



The ratio of forces of spring at A and that of spring at B is

(a) 1 (b) 2

(c) 3 (d) 4

[ESE : 1995]

2.5 A steel cube of volume 8000 cc is subjected to all round stress of 1330 kg/cm^2. The bulk modulus of the material is 1.33×10^6 kg/cm^2. The volumetric change is

(a) 8 cc (b) 6 cc

(c) 0.8 cc (d) 10^{-3} cc

[ESE : 1995]

2.6 In terms of bulk modulus (K) and modulus of rigidity (G), Poisson's ratio can be expressed as

(a) $\dfrac{3K - 4G}{6K + 4G}$ (b) $\dfrac{3K + 4G}{6K - 4G}$

(c) $\dfrac{3K - 2G}{6K + 2G}$ (d) $\dfrac{3K + 2G}{6K - 2G}$

[ESE : 1995]

2.7 Two bars one of material A and the other of material B of same length are tightly secured between two unyielding walls. Coefficient of thermal expansion of bar A is more than that of B. When temperature rises the stresses induced are

(a) tension in both the materials

(b) tension in material A and compression in material B

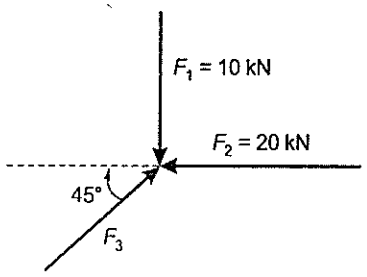
(c) compression in material A and tension in material *B*
(d) compression in both the materials

[ESE : 1995]

2.8 A bar of diameter 30 mm is subjected to a tensile load such that the measured extension on a gauge length of 200 mm is 0.09 mm and the change in diameter is 0.0045 mm. The Poisson's ratio will be
(a) 1/4 (b) 1/3
(c) 1/5 (d) 1/6

[ESE : 1995]

2.9 For the coplanar concurrent system of forces as shown in the given figure, the system will be



(a) in equilibrium if $|F_3|$ = 10 kN
(b) in equilibrium if $|F_3| = 10\sqrt{2}$ kN
(c) in equilibrium if $|F_3|$ = 20 kN
(d) will not be in equilibrium whatever be the magnitude of F_3

[ESE : 1995]

2.10 A 2 m long bar of uniform section extends 2 mm under limiting axial stress of 200 N/mm^2. What is the modulus of resilience for the bar?
(a) 0.10 units (b) 0.20 units
(c) 10000 units (d) 200000 units

[ESE : 1995]

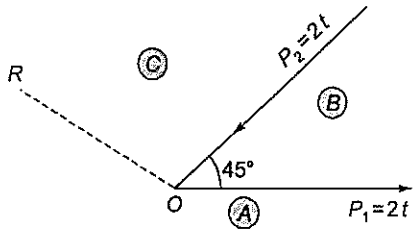
2.11 A rectangular block of size 200 mm × 100 mm × 50 mm is subjected to a shear stress of 500 kg/cm^2. If the modulus of rigidity of the material is 1×10^6 kg/cm^2, the strain energy stored will be
(a) 1000 kg-cm (b) 500 kg-cm
(c) 125 kg-cm (d) 100 kg-cm

[ESE : 1995]

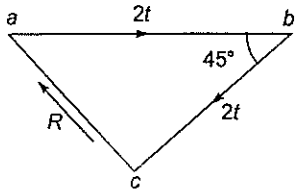
2.12 If $E = 2.06 \times 10^5$ N/mm^2, an axial pull of 60 kN suddenly applied to a steel rod 50 mm in diameter and 4 m long. It causes an instantaneous elongation of the order of
(a) 1.19 mm (b) 2.19 mm
(c) 3.19 mm (d) 11.9 mm

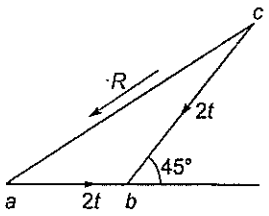
[ESE : 1995]

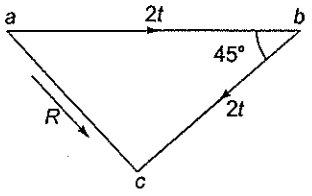
2.13 Two coplanar concurrent forces $P_1 = 2t$ and $P_2 = 2t$ meeting at *O* act on a lamina at 45° as shown in figure.

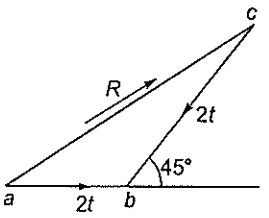


From the force diagram the force *R* to be applied at *O* in order to keep the body in equilibrium is given by

(a)


(b)


(c)


(d)


[ESE : 1995]

2.14 Parallelogram law of forces states that if two forces acting simultaneously at a point be represented in magnitude and direction by two adjacent sides of a parallelogram, their resultant may be represented in magnitude and direction by
(a) longer side of the other two sides
(b) shorter side of the other two sides

(c) diagonal of the parallelogram which does not pass through their point of intersection
(d) diagonal for the parallelogram which passes through their point of intersection

[ESE : 1995]

2.15 A bar of circular cross-section varies uniformly from a cross-section $2D$ to D. If extension of the bar is calculated treating it as a bar of average diameter, then the percentage error will be
(a) 10 (b) 25
(c) 33.33 (d) 50

[ESE : 1996]

2.16 The length, coefficient of thermal expansion and Young's modulus of bar A are twice that of bar B. If the temperature of both bars is increased by the same amount while preventing any expansion, then the ratio of stress developed in bar A to that in bar B will be
(a) 2 (b) 4
(c) 8 (d) 16

[ESE : 1996]

2.17 The lists given below refer to a bar of length L, cross sectional area A, Young's modulus E, Poisson's ratio μ and subjected to axial stress 'p'. Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. Volumetric strain
B. Strain energy per unit volume
C. Ratio of Young's modulus to bulk modulus
D. Ratio of Young's modulus to modulus of rigidity

List-II
1. $2(1+\mu)$
2. $3(1-2\mu)$
3. $\frac{p}{E}(1-2\mu)$
4. $\frac{p^2}{2E}$
5. $2(1-\mu)$

Codes:

	A	B	C	D
(a)	3	4	2	1
(b)	5	4	1	2
(c)	5	4	2	1
(d)	2	3	1	5

[ESE : 1996]

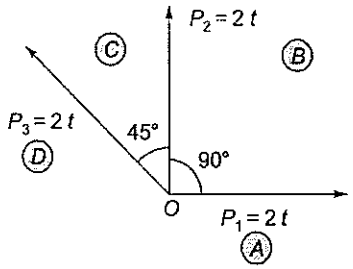
2.18 If all the dimensions of a prismatic bar of square cross-section suspended freely from the ceiling of a roof are doubled then the total elongation produced by its own weight will increase
(a) eight times (b) four times
(c) three times (d) two times

[ESE : 1996]

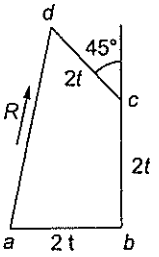
2.19 In order to find the resultant of a system of coplanar parallel system of forces, the correct sequence of the graphical procedure to be followed is
(a) force diagram, space diagram, funicular polygon and polar diagram
(b) funicular polygon, force diagram, space diagram and polar diagram
(c) space diagram, force diagram, polar diagram and funicular polygon
(d) space diagram, funicular polygon, force diagram and polar diagram

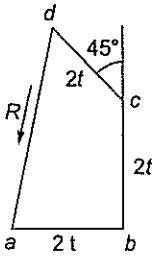
[ESE : 1996]

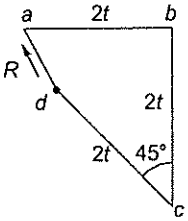
2.20 Three coplanar forces $P_1 = P_2 = P_3 = 2\,t$ act at a joint O, as shown in figure

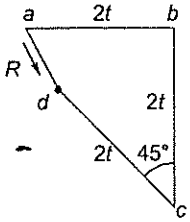


From the force diagram, the force R to be applied at O in the same plane to keep the joint O in equilibrium is given by

(a)


(b)


(c)


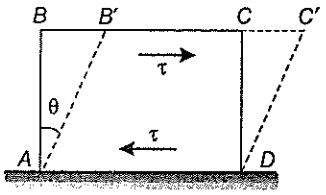
(d)


[ESE : 1996]

2.21 The side *AD* of the square block *ABCD* as shown in the given figure is fixed at the base and it is under a stage of simple shear causing shear stress τ and shear strain ϕ,

where $\phi = \dfrac{\tau}{\text{Modulus of Rigidity (G)}}$

The distorted shape is *AB'C'D*. The diagonal strain (linear) will be



(a) $\phi/2$ (b) $\phi/\sqrt{2}$

(c) $\sqrt{2}\,\phi$ (d) ϕ

[ESE : 1996]

2.22 A round steel bar of overall length 40 cm consists of two equal portions of 20 cm each having diameters of 10 cm and 8 cm respectively. Take *E* as 2×10^6 kg/cm^2. If the rod is subjected to a tensile load of 10 tonnes, the elongation in cm will be given by

(a) $\dfrac{1}{10\pi}\left(\dfrac{1}{25}+\dfrac{1}{16}\right)$ (b) $\dfrac{2}{10\pi}\left(\dfrac{1}{25}+\dfrac{1}{16}\right)$

(c) $\dfrac{3}{10\pi}\left(\dfrac{1}{25}+\dfrac{1}{16}\right)$ (d) $\dfrac{4}{10\pi}\left(\dfrac{1}{25}+\dfrac{1}{16}\right)$

[ESE : 1997]

2.23 A copper bar of 25 cm length is fixed by means of supports at its ends. Supports can yield (total) by 0.01 cm. If the temperature of the bar is raised by 100°C, then the stress induced in the bar for $\alpha_c = 20 \times 10^{-6}$ °C and $E_c = 1 \times 10^6$ kg/cm^2 will be

(a) 2×10^2 kg/cm^2 (b) 4×10^2 kg/cm^2

(c) 8×10^2 kg/cm^2 (d) 16×10^2 kg/cm^2

[ESE : 1997]

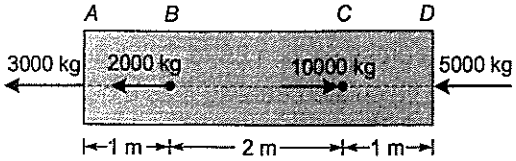
2.24 A given material has Young's modulus *E*, modulus of rigidity *G* and Poisson's ratio 0.25. The ratio of Young's modulus to modulus of rigidity of this material is

(a) 3.75 (b) 3

(c) 2.5 (d) 1.5

[ESE : 1997]

2.25 A prismatic bar of uniform cross-sectional area of 5 cm^2 is subjected to axial loads as shown in the given figure.



Portion *BC* is subjected to an axial stress of

(a) 400 kg/cm^2 tension

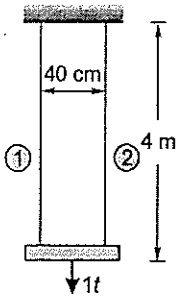
(b) 2000 kg/cm^2 compression

(c) 1000 kg/cm^2 tension

(d) 600 kg/cm^2 tension

[ESE : 1997]

2.26 Two wires of equal length are suspended vertically at a distance of 40 cm as shown in the figure below. Their upper ends are fixed to the ceiling while their lower ends support a rigid horizontal bar which carries a central load of 1t midway between the wires. Details of the two wires are given below:



Wire No.	Area (cm^2)	Material	Modulus of Elasticity (kg/cm^2)	Elongation
1	4	Copper	1×10^6	Δ_c
2	2	Steel	2×10^6	Δ_s

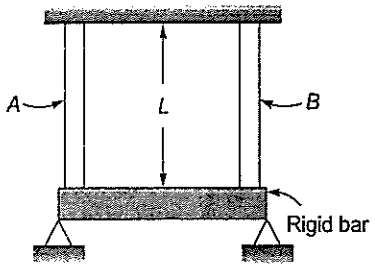
The ratio of the elongation of the two wires, Δ_c/Δ_s is

(a) 0.25 (b) 0.5

(c) 2 (d) 1

[ESE : 1997]

2.27 A composite section shown in the figure below was formed at 20°C and was made of two materials *A* and *B*. If the coefficient of thermal expansion of *A* is greater than that of *B* and the composite section is heated to 40°C, then *A* and *B* will



(a) be in tension and compression respectively
(b) both be in compression
(c) both be in tension
(d) be in compression and tension respectively

[ESE : 1998]

2.28 In an experiment it found that the bulk modulus of a material is equal to its shear modulus. The Poisson's ratio is

(a) 0.125 (b) 0.250
(c) 0.375 (d) 0.500

[ESE : 1998]

2.29 A mild steel bar is in two parts having equal lengths. The area of cross-section of Part-1 is double that of Part-2. If the bar carries an axial load P, then the ratio of elongation in Part-1 to that in Part-2 will be

(a) 2 (b) 4
(c) 1/2 (d) 1/4

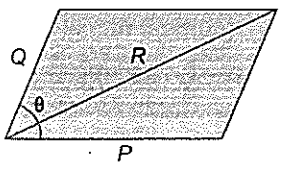
[ESE : 1998]

2.30 **Assertion (A):** A bar tapers from a diameter of 'd_1' to a diameter of 'd_2' over its length L and is subjected to a tensile force P. If extension is calculated based on treating it as a bar of average diameter, the calculated extension will be more than the actual extension.

Reason (R): The actual extension in such bars is given by, $\Delta = \dfrac{4PL}{\pi d_1 d_2 E}$.

[ESE : 1998]

2.31 In the diagram below, if Q is made equal to P and the resultant force (R) is also made equal to P, then the value of angle θ will be



(a) 120° (b) 60°
(c) 45° (d) 30°

[ESE : 1998]

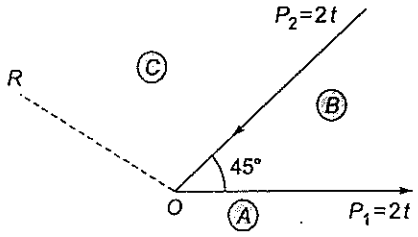
2.32 If the given forces P_1, P_2, P_3 and P_4 which are coplanar and concurrent are such that the force polygon does not close, then the system will

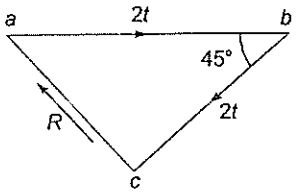
(a) be in equilibrium
(b) always reduce to a resultant force
(c) always reduce to a couple
(d) always be in equilibrium and will always reduce to a couple

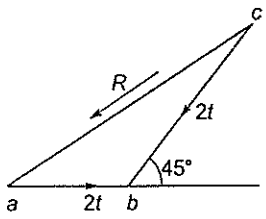
[ESE : 1998]

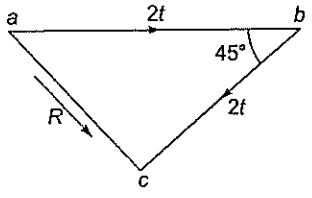
2.33 Two coplanar forces $P_1 = 2\,t$ and $P_2 = 2\,t$ meeting at O act on lamina at $\alpha = 45°$ as shown in the figure.

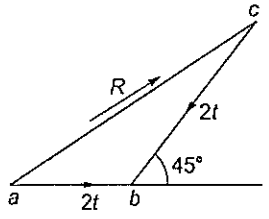
From the force diagram, force R, the resultant of P_1 and P_2, to be applied at O is given by



(a)


(b)


(c)


(d)


[ESE : 1998]

2.34 A round bar made of same material consists of 3 parts each of 100 mm length having diameters of 40 mm, 50 mm and 60 mm, respectively. If the

bar is subjected to an axial load of 10 kN, the total elongation of the bar in mm would be (E is the modulus of elasticity in kN/mm²)

(a) $\frac{0.4}{\pi E}\left(\frac{1}{16}+\frac{1}{25}+\frac{1}{36}\right)$

(b) $\frac{4}{\pi E}\left(\frac{1}{16}+\frac{1}{25}+\frac{1}{36}\right)$

(c) $\frac{4\sqrt{2}}{\pi E}\left(\frac{1}{16}+\frac{1}{25}+\frac{1}{36}\right)$

(d) $\frac{40}{\pi E}\left(\frac{1}{16}+\frac{1}{25}+\frac{1}{36}\right)$

[ESE : 1999]

2.35 If a member is subjected to tensile stress of 'p_x', compressive stress of 'p_y' and tensile stress of 'p_z', along the *X*, *Y* and *Z* directions respectively, then the resultant strain 'ϵ_x' along the *X* direction would be (*E* is Young's modulus of elasticity and 'μ' is Poisson's ratio)

(a) $\frac{1}{E}(p_x + \mu p_y - \mu p_z)$

(b) $\frac{1}{E}(p_x + \mu p_y + \mu p_z)$

(c) $\frac{1}{E}(p_x - \mu p_y + \mu p_z)$

(d) $\frac{1}{E}(p_x - \mu p_y - \mu p_z)$

[ESE : 1999]

2.36 A cylindrical bar of 20 mm diameter and 1 m length is subjected to a tensile test. Its longitudinal strain is 4 times that of its lateral strain. If the modulus of elasticity is 2×10^5 N/mm², then its modulus of rigidity will be

(a) 8×10^6 N/mm² (b) 8×10^5 N/mm²

(c) 0.8×10^4 N/mm² (d) 0.8×10^5 N/mm²

[ESE : 1999]

2.37 If forces P_1, P_2, P_3, and P_4 of a system are such that the force polygon does not close, then the system will

(a) be in equilibrium

(b) reduce to a resultant force

(c) reduce to a couple

(d) not be in equilibrium

[ESE : 1999]

2.38 Assertion (A): A mild steel tension specimen subjected to an axial load fails along a surface at 45° to its axis.

Reason (R): Mild steel is weaker in shear than in tension and the place of maximum shear is at 45° to its axis.

[ESE : 1999]

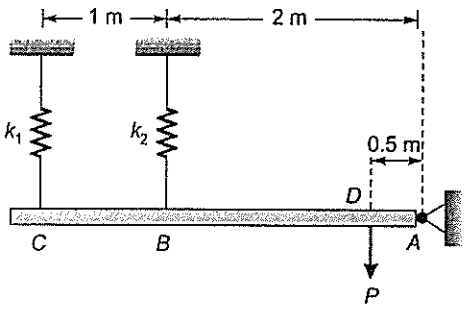
2.39 A steel bar 300 mm long and having 24 mm diameter, is turned down to 18 mm diameter for one third of its length. It is heated 30°C above room temperature, clamped at both ends and then allowed to cool to room temperature. If the distance between the clamps is unchanged, the maximum stress in the bar ($\alpha = 12.5 \times 10^{-6}$ per °C and $E = 200$ GN/m²) is

(a) 25 MN/m² (b) 50 MN/m²

(c) 75 MN/m² (d) 100 MN/m²

[ESE : 2000]

2.40 A rigid beam CBDA is hinged at *A* and supported by two springs at *C* and *B* with a vertical load '*P*' at point *D* as shown in the given figure. The ratio of stiffness (k_2/k_1) of springs at *B* and *C* is 2. The ratio of forces in spring at *C* to that at *B* is



(a) 3/4 (b) 1

(c) 4/3 (d) 2

[ESE : 2000]

2.41 A bar of uniform section is subjected to axial tensile loads such that the normal strain in the direction is 1.25 mm per m. If the Poisson's ratio of the material of the bar is 0.3, the volumetric strain would be

(a) 2×10^{-4} (b) 3×10^{-4}

(c) 4×10^{-4} (d) 5×10^{-4}

[ESE : 2000]

2.42 A square plate ($a \times a$) rigidly held at three edges is free to move along the fourth edge. If temperature of the plate is raised by temperature

't', then the free expansion at the fourth edge will be (coefficient of thermal expansion of the material = α, modulus of elasticity of the material = E and its Poisson's ratio = μ)

(a) $a\alpha t\mu$ (b) $a\alpha t(1+\mu)$

(c) $a\left(\alpha t+\frac{\alpha t\mu}{E}\right)$ (d) $a\alpha t(1-\mu)$

[ESE : 2000]

2.43 The strain energy in a member is proportional to

(a) total strain multiplied by the volume of the member

(b) product of stress and the corresponding strain

(c) product of strain and Young's modulus of the material

(d) the maximum strain multiplied by the length of the member

[ESE : 2001]

2.44 A mild steel bar of uniform cross-section A and length L is subjected to an axial load W. The strain energy stored in the bar would be

(a) $\frac{WL}{2AE}$ (b) $\frac{W^2L}{4AE}$

(c) $\frac{WL}{4AE}$ (d) $\frac{W^2L}{2AE}$

[ESE : 2001]

2.45 **Assertion (A):** The coefficient of friction is the ratio of limiting frictional force to normal reaction between two bodies in contact and one body being just sliding on the other.

Reason (R): The limiting friction is the maximum value of frictional force, which comes into play, when a body just begins to slide over the surface of the other body.

[ESE : 2002]

2.46 **Assertion (A):** The strain and stress system for a bar of length l subjected to an axial pull will be the same whether both ends of the bar are free or one end is fixed and the other end is free.

Reason (R): Rigid body displacements have no effect on the elastic deformations.

[ESE : 2002]

2.47 The bulk modulus of elasticity of a material is twice its modulus of rigidity. The Poisson's ratio of the material is

(a) 1/7 (b) 2/7

(c) 3/7 (d) 4/7

[ESE : 2002]

2.48 A free body diagram of a body shows a

(a) body isolated from all external effects without considering its own weight

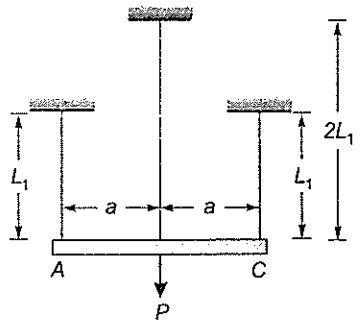
(b) body isolated from its surroundings and all external forces acting on it

(c) body isolated from its surroundings and all external actions on it

(d) body isolated from its surroundings and all internal forces on it

[ESE : 2002]

2.49 A rigid bar AC is supported by three rods of same material and of equal diameter. The bar AC is initially horizontal. A force P is applied such that the bar AC continues to remain horizontal. Forces in each of the shorter bars and in the longer bar are, respectively



(a) $0.4P, 0.2P$ (b) $0.3P, 0.4P$

(c) $0.2P, 0.6P$ (d) $0.5P$, zero

[ESE : 2003]

2.50 A member having length L, cross-sectional area A and modulus of elasticity E is subjected to an axial load W. The strain energy stored in this member is

(a) $\frac{WL^2}{AE}$ (b) $\frac{WL^2}{2AE}$

(c) $\frac{W^2L}{2AE}$ (d) $\frac{W^2L}{AE}$

[ESE : 2003]

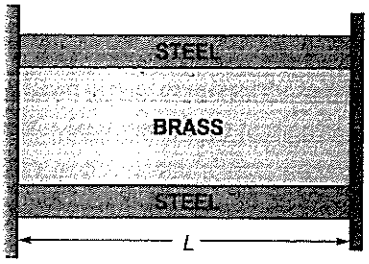
2.51 **Assertion (A):** Normal stress of one nature (compressive or tensile) acting along one of the three orthogonal axes of a member will produce strains of the same nature in its direction and strains of opposite nature along the other two directions.

Reason (R): Sum of the strains along the three orthogonal axes equals volumetric strain.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2003]

2.52 A brass bar of solid section is encased in a steel tube as shown in the diagram below



The coefficient of expansion of steel is 11.2×10^{-6} per °C and the coefficient of expansion of brass is 16.5×10^{-6} per °C. The composite bar is heated through 60°C.

Now consider the following statements:

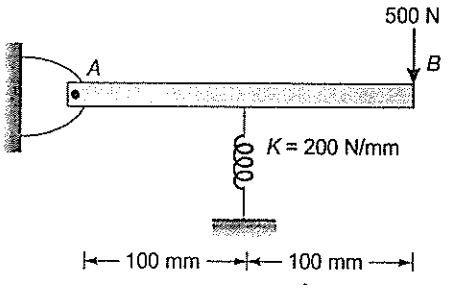
1. The stress in the brass will be tensile.
2. The stress in the steel will be tensile.
3. The stress in the steel will be compressive.
4. The stress in the brass will be compressive.

Which of these statements are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 4 (d) 2 and 3

[ESE : 2004]

2.53 A rigid bar *AB* is supported by a spring as shown in the diagram below. What is the deflection of the point *B*?



(a) 25 mm (b) 20 mm
(c) 15 mm (d) 10 mm

[ESE : 2004]

2.54 A mild steel bar of square cross-section 40 mm × 40 mm is 400 mm long. It is subjected to a longitudinal tensile stress of 440 N/mm² and lateral compressive stress of 200 N/mm² in perpendicular direction. $E = 2 \times 10^5$ N/mm², $\mu = 0.3$. What is the approximate elongation of the bar in the longitudinal direction?

(a) 0.44 mm (b) 0.88 mm
(c) 0.22 mm (d) 1 mm

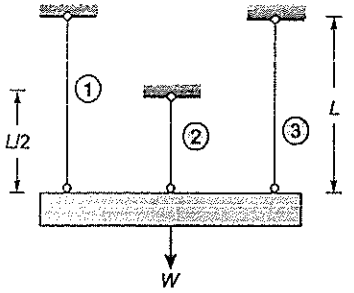
[ESE : 2005]

2.55 If the Young's modulus '*E*' is equal to the bulk modulus '*K*', then what is the value of the Poisson's ratio?

(a) 1/4 (b) 1/2
(c) 1/3 (d) 3/4

[ESE : 2005]

2.56 Three wires of steel 1, 2 and 3, each having area A support a load W as shown in the figure below. What is the ratio between collapse load and the load corresponding to yielding of one of the wires?



(a) 3 : 1 (b) 3 : 2
(c) 3 : 2.5 (d) 3 : 3

[ESE : 2006]

2.57 If *G* is the modulus of rigidity, *E* the modulus of elasticity and μ the Poisson's ratio for a material, then what is the expression for *G*?

(a) $G = \dfrac{3E}{2(1+2\mu)}$ (b) $G = \dfrac{5E}{(1+\mu)}$

(c) $G = \dfrac{E}{2(1+\mu)}$ (d) $G = \dfrac{E}{(1+2\mu)}$

[ESE : 2006]

2.58 A bar of 40 mm diameter and 400 mm length is subjected to an axial load of 100 kN. It elongates by 0.150 mm and the diameter decreases by 0.005 mm. What is the Poisson's ratio of the material of the bar?

(a) 0.25 (b) 0.28
(c) 0.33 (d) 0.37

[ESE : 2006]

2.59 What is the total strain energy of a member subjected to an axial stress f(E = Young's modulus)?

(a) $\left(\frac{f^2}{2E}\right)$ × volume of bar

(b) $\left(\frac{f}{E}\right)$ × volume of bar

(c) $\left(\frac{f^2}{E}\right)$ × volume of bar

(d) $\left(\frac{f}{2E}\right)$ × volume of bar

[ESE : 2006]

2.60 A steel rod, 100 mm long is held between two rigid supports. It is heated by 20°C. If the coefficient of thermal expansion of the material of the rod is 15×10^{-6} per °C and modulus of elasticity is 200×10^3 MN/m^2, what is the stress in the rod?

(a) 20 MN/m^2 (b) 40 MN/m^2
(c) 60 MN/m^2 (d) 80 MN/m^2

[ESE : 2007]

2.61 If modulus of elasticity of a material is 189.8 GN/m^2 and its Poisson's ratio is 0.30, what is the approximate value of shear modulus of the material?

(a) 73 GN/m^2 (b) 93.3 GN/m^2
(c) 103.9 GN/m^2 (d) 123.3 GN/m^2

[ESE : 2007]

2.62 What is the correct sequence of the following metals in the decreasing order of their Poisson's ratio?

1. Aluminium
2. Cast iron
3. Steel

Select the correct answer using the codes given below :

(a) 1-2-3 (b) 2-1-3
(c) 1-3-2 (d) 3-1-2

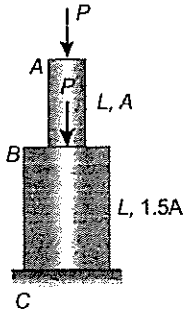
[ESE : 2007]

2.63 The value of modulus of elasticity for a material is 200 GN/m^2 and Poisson's ratio is 0.25. What is its modulus of rigidity?

(a) 250 GN/m^2 (b) 320 GN/m^2
(c) 125 GN/m^2 (d) 80 GN/m^2

[ESE : 2008]

2.64 A stepped column carries loads as shown below. What is the maximum normal stress in the column at B in the larger diameter column?



(a) $\frac{P}{1.5A}$ (b) $\frac{P}{A}$
(c) $\frac{2P}{1.5A}$ (d) $\frac{2P}{A}$

[ESE : 2008]

2.65 In a body loaded under plane stress conditions, what is the number of independent stress components in order to completely specify the state of stress at a point ?

(a) 3 (b) 4
(c) 6 (d) 9

[ESE : 2008]

2.66 A composite system where the components are of equal lengths is subjected to temperature rise. Which one of the following stresses will be developed in the component having highest coefficient of linear expansion?

(a) Compressive stress
(b) Tensile stress
(c) Shear stress
(d) Zero stress

[ESE : 2008]

2.67 A compounded bar consists of material A encased in material B. It is tightly secured at the ends. The coefficient of thermal expansion of A is more than that of B. If the temperature of the bar is increased, the stresses induced will be

(a) tensile in both materials
(b) Compressive in both materials

(c) tensile in material *B* and compressive in material *A*
(d) compressive in material *B* and tensile in material *A*

[ESE : 2008]

2.68 What is the nature of stress in a ceiling fan rod?
(a) Bending
(b) Tensile
(c) Compressive
(d) Shear

[ESE : 2008]

2.69 A square steel bar of 50 mm side and 5 m long is subjected to a load whereupon it absorbs a strain energy of 100 J. What is its modulus of resilience ?

(a) $\frac{1}{125}$ N-mm/mm^3 (b) 125 mm^3/N-mm

(c) $\frac{1}{100}$ N-mm/mm^3 (d) 100 mm^3/N-mm

[ESE : 2009]

2.70 A solid metal bar of uniform sectional area throughout its length hangs vertically from its upper end. Details of the bar are :

Length = 6 m, material density = 8×10^{-5} N/mm^3 and $E = 2 \times 10^5$ N/mm^2. What will be the total elongation of the bar in mm ?

(a) $\frac{288}{10^4}$ (b) $\frac{48}{10^4}$

(c) $\frac{144}{10^4}$ (d) $\frac{72}{10^4}$

[ESE : 2009]

2.71 A circular rod of diameter 30 mm and length 200 mm is subjected to a tensile force. The extension in rod is 0.09 mm and change in diameter is 0.0045 mm. What is the Poisson's ratio of the material of the rod ?
(a) 0.30 (b) 0.32
(c) 0.33 (d) 0.35

[ESE : 2009]

2.72 For a material having modulus of elasticity equal to 208 GPa and Poisson's ratio equal to 0.3, what is the modulus of rigidity ?
(a) 74.0 GPa (b) 80.0 GPa
(c) 100.0 GPa (d) 128.5 GPa

[ESE : 2009]

2.73 Given E as the Young's modulus of elasticity of a material, what can be the minimum value of its bulk modulus of elasticity ?

(a) $\frac{E}{2}$ (b) $\frac{E}{3}$

(c) $\frac{E}{4}$ (d) $\frac{E}{5}$

[ESE : 2009]

2.74 A mild steel bar of square cross-section 25 mm × 25 mm is 1 m long. It is subjected to bi-axial stress σ_x = 480 N/mm^2 (Tension) and σ_y = 400 N/mm^2 (Compression). $E = 2\times10^5$ N/mm^2, μ = 0.3, what is the elongation of the bar in mm in x direction ?
(a) 1.0 (b) 1.5
(c) 2.0 (d) 3.0

[ESE : 2009]

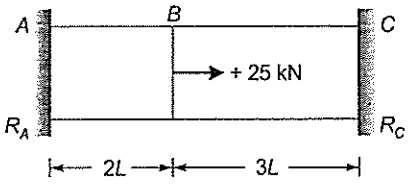
2.75 A mild steel rod tapers uniformly from 30 mm diameter to 12 mm diameter in a length of 300 mm. The rod is subjected to an axial load of 12 kN. $E = 2 \times 10^5$ N/mm^2. What is the extension of the rod in mm ?

(a) $\frac{4\pi}{5}$ (b) $\frac{2}{5\pi}$

(c) $\frac{\pi}{5}$ (d) $\frac{1}{5\pi}$

[ESE : 2009]

2.76 A prismatic bar *ABC* is subjected to an axial load of 25 kN; the reactions R_A and R_C will be



(a) R_A = – 10 kN and R_C = – 15 kN
(b) R_A = 10 kN and R_C = – 35 kN
(c) R_A = –15 kN and R_C = – 10 kN
(d) R_A = 15 kN and R_C = – 40 kN

[ESE : 2010]

2.77 Poisson's ratio is defined as the ratio of
(a) longitudinal stress and longitudinal strain
(b) lateral strain and longitudinal strain
(c) longitudinal stress and lateral stress
(d) lateral stress and longitudinal stress

[ESE : 2010]

2.78 Assertion (A): The principle of superposition is valid whenever the strain or stress to be obtained is directly proportional to the applied loads.
Reason (R): Strain energy depends on the product of stress and strain.
[ESE : 2010]

2.79 Assertion (A): A material is incompressible if its Poission's ratio is 0.5.
Reason (R): The Bulk modulus K is related to Modulus of elasticity E and to Poisson's ratio μ as per well known relationship.
[ESE : 2011]

2.80 Two circular mild steel bars A and B of equal lengths l have diameters d_A = 2 cm and d_B = 3 cm. Each is subjected to a tensile load of magnitude P. The ratio of the elongations of the bars l_A/l_B is

(a) $\frac{2}{3}$ (b) $\frac{3}{4}$

(c) $\frac{4}{9}$ (d) $\frac{9}{4}$

[ESE : 2012]

2.81 A mild steel rod tapers uniformly from 24 mm dia. to 12 mm dia. over its length of 400 mm. The rod when held vertical is subjected to an axial tensile load of 12 kN.

$E = 2 \times 10^5$ N/mm^2. The extension of the rod in mm would be

(a) $\frac{3\pi}{2}$ (b) $\frac{2}{3\pi}$

(c) $\frac{\pi}{3}$ (d) $\frac{1}{3\pi}$

[ESE : 2013]

2.82 Poisson's ratio of a material is 0.3. Then the ratio of Young's modulus to bulk modulus is

(a) 0.6 (b) 0.8
(c) 1.2 (d) 1.4

[ESE : 2013]

2.83 The relationship between Young's Modulus E, Modulus of Rigidity C and Bulk Modulus K in an elastic material is given by the relation

(a) $E = \frac{9KC}{3K+C}$ (b) $E = \frac{3KC}{3K+C}$

(c) $E = \frac{9KC}{9K+C}$ (d) $E = \frac{3KC}{9K+C}$

[ESE : 2013]

2.84 If the Poisson's ratio for a material is 0.5, then the elastic modulus for the material is

(a) three times its shear modulus
(b) four times its shear modulus
(c) equal to its shear modulus
(d) not determinable

[ESE : 2014]

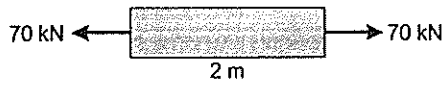
2.85 Statement (I) : There are two independent elastic constants for an isotropic material.
Statement (II) : All metals at micro-level are isotropic.
[ESE : 2014]

2.86 A metal bar of 10 mm diameter when subjected to a pull of 23.5 kN gave an elongation of 0.3 mm on a gauge length of 200 mm. The Young's modulus of elasticity of the metal will nearly be

(a) 200 kN/mm^2 (b) 300 kN/mm^2
(c) 360 kN/mm^2 (d) 400 kN/mm^2

[ESE : 2014]

2.87 A steel rod, 2 m in length, 40 mm in diameter, is subjected to a pull of 70 kN as shown in the figure

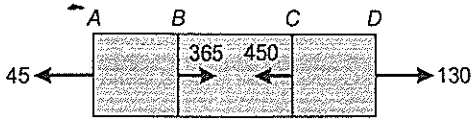


To what length should the bar be bored centrally from one end so that total extension will increase by 20% under the same force (the bore diameter is 25 mm and E is 2×10^5 N/mm^2)?

(a) 0.46 m (b) 0.55 m
(c) 0.87 m (d) 0.62 m

[ESE : 2014]

2.88 A member $ABCD$ is subjected to a force system as shown in the figure

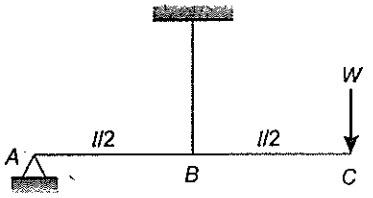


The resistive force in the part *BC* is

(a) 365 (comp.) (b) 450 (tensile)
(c) 85 (comp.) (d) 320 (comp.)

[ESE : 2014]

2.89 A rigid bar shown in the figure is hinged at *A*, is supported by a rod at *B*, and carries a load W at C.



The resistive force in the rod is

(a) 0.5 W (b) 1.0 W
(c) 1.5 W (d) 2.0 W

[ESE : 2014]

2.90 The symmetry of the stress tensor at a point in a body when at equilibrium is obtained from

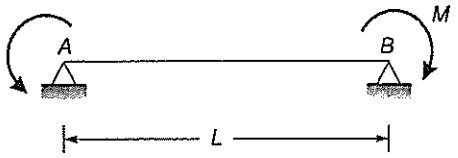
(a) conservation of mass
(b) force equilibrium equations
(c) moment equilibrium equations
(d) conservation of energy

[ESE : 2014]

2.91 **Statement (I) :** In simple bending, strain in the bent beam varies linearly across the beam depth.
Statement (II) : As per Hooke's law, within elastic limit, the stress is proportional to the strain.

[ESE : 2014]

2.92 **Statement (I) :** A simply supported beam AB of constant EI throughout, when subjected to pure terminal couples as shown in the figure, will bend into an arc of a circle.



Statement (II) : Theory of simple bending establishes relationships from among *M*, *f*, *R*, *y*, *E* and *I*.

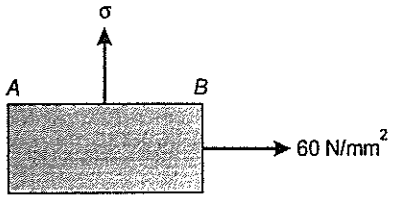
[ESE : 2014]

2.93 **Statement (I) :** The failure surface of a standard cast iron specimen of circular cross-section subjected to torsion is on a helicoidal surface at 45° to its axis.

Statement (II) : The failure occurs on a plane of the specimen subjected to maximum tensile stress, and cast iron is weak in tension.

[ESE : 2014]

2.94 Two-dimensional stress system on a block made of a material with Poisson's ratio of 0.3 is shown in the figure



The limiting magnitude of the stress so as to result in no change in length *AB* of the block is

(a) 60 N/mm² (b) 120 N/mm²
(c) 200 N/mm² (d) 240 N/mm²

[ESE : 2014]

2.95 For a given elastic material, the Elastic Modulus *E* is 210 GPa and its Poisson's Ratio is 0.27. What is the approximate value of its Modulus of Rigidity?

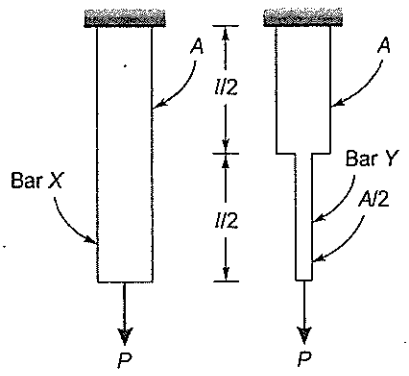
(a) 105 GPa (b) 83 GPa
(c) 159 GPa (d) 165 GPa

[ESE : 2015]

2.96 **Assertion (A):** The failure surface of an axially loaded mild steel tension specimen of circular cross-section is along a plane at 45° to the axis of the specimen.
Reason (R): The failure occurs on a plane of the specimen subjected to maximum shear stress and mild steel is relatively weak in shear.

[ESE : 2015]

2.97 What is the ratio of the strain energy in bar *X* to that in bar *Y* when the material of the two bars is the same? The cross-sectional areas are as indicated over the indicated lengths.



(a) 1/3 (b) 2/3
(c) 4/3 (d) 1/6

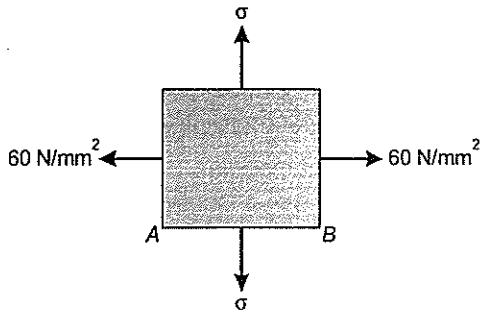
[ESE : 2015]

2.98 Lead, as a material used in construction, has $E = 15$ GPa and $K = 50$ GPa. What is its Poisson's Ratio?

(a) 0.225 (b) 0.30
(c) 0.40 (d) 0.45

[ESE : 2015]

2.99 For a block with Young's Modulus of its material being 210 GPa and its Poisson's Ratio being 0.25, when subjected to a stress system as shown in the figure, what is the magnitude of the stress σ for no strain along *AB*?



(a) 30 N/mm² (b) 60 N/mm²
(c) 120 N/mm² (d) 240 N/mm²

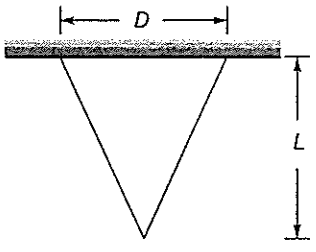
[ESE : 2015]

2.100 A circular shaft of diameter '*D*' is made of a material for which Young's Modulus of Elasticity is '*E*' and Poisson's Ratio is 'ν'. The ratio of flexural rigidity to torsional rigidity for the shaft is

(a) $4(1+\nu)$ (b) $1.5(1-2\nu)$
(c) $(1+\nu)$ (d) $0.25(1+\nu)$

[ESE : 2015]

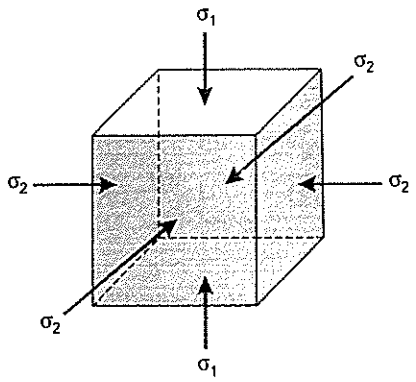
2.101 A solid conical bar of circular cross-section is suspended vertically as shown in the figure. The diameter of the bar at the base, *D*, equals 100 mm and its length, *L*, is 0.5 m. If $E = 200$ GN/m² and its weight per unit volume is 80 kN/m³, the elongation of the bar under self-weight is



(a) 1.50×10^{-6} mm (b) 1.67×10^{-5} mm
(c) 1.71×10^{-6} mm (d) 1.87×10^{-5} mm

[ESE : 2015]

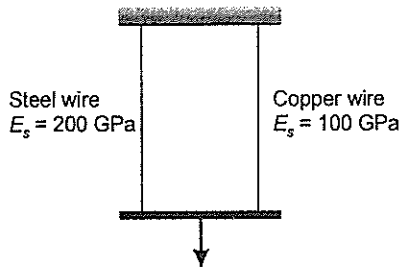
2.102 A cubical element of a structural part made of mild steel is subjected to a tri-axial compressive stress as shown in the figure. The vertical compressive stress is σ_1. The Modulus of Elasticity and Poisson's Ratio are *E* and μ, respectively. What should be the uniform lateral pressure σ_2 in terms of σ_1 and μ, so that lateral strain is prevented?



(a) $\frac{\mu}{1-\mu}\sigma_1$ (b) $\frac{\mu}{(1+\mu)(1-\mu)}\sigma_1$
(c) $\frac{\mu}{1+\mu}\sigma_1$ (d) $\frac{1+\mu}{1-\mu}\sigma_1$

[ESE : 2015]

2.103 A mechanism shown in the figure consists of equally long steel and copper wires which carry the applied load in equal shares. What shall be the ratio of the diameter of the copper wire to that of the steel wire, when both the wires undergo equal strains?



(a) $\sqrt{2}$ (b) 1.0
(c) $\frac{1}{\sqrt{2}}$ (d) $\frac{1}{2}$

[ESE : 2015]

2.104 The longitudinal strain of a cylindrical bar of 25 mm diameter and 1.5 m length is found to be 3 times its lateral strain in a tensile test. What is the value of Bulk Modulus by assuming $E = 1 \times 10^5$ N/mm²?

(a) 2×10^5 N/mm² (b) 1.1×10^5 N/mm²
(c) 1×10^5 N/mm² (d) 1×10^5 N/mm²

[ESE : 2016]

2.105 For an elastic material, Poisson's ratio is μ, Modulus of Elasticity is E, Modulus of Rigidity is C and Bulk Modulus is K. μ is expressible in terms of K and C as

(a) $\frac{6K-2C}{3K-2C}$ (b) $\frac{6K+2C}{3K-2C}$

(c) $\frac{3K-2C}{6K+2C}$ (d) $\frac{3K+2C}{6K+2C}$

[ESE : 2016]

2.106 A mild steel bar of length 450 mm tapers uniformly. The diameters at the ends are 36 mm and 18 mm, respectively. An axial load of 12 kN is applied on the bar. $E = 2 \times 10^5$ N/mm². The elongation of the bar will be

(a) $\frac{1}{3\pi}$ mm (b) $\frac{1}{6\pi}$ mm

(c) $\frac{3\pi}{2}$ mm (d) $\frac{2}{3\pi}$ mm

[ESE : 2016]

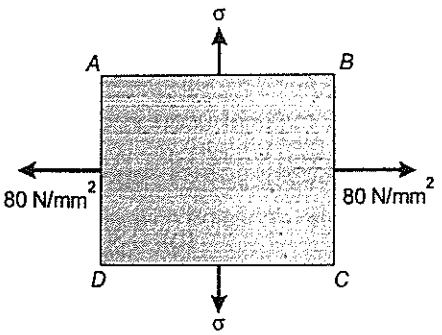
2.107 Which of the following statements are correct?

1. Strain in the direction of applied stress is known as longitudinal strain.
2. Tensile stress results in tensile strain in linear and lateral directions.
3. Strains in all directions perpendicular to the applied stress are known as lateral strain.
4. Ratio of change in volume to original volume is known as volumetric strain.

(a) 1, 2 and 3 only (b) 1, 3 and 4 only
(c) 3 and 4 only (d) 1, 2, 3 and 4

[ESE : 2016]

2.108 The state of stress on an element is as shown in the figure. If $E = 2 \times 10^5$ N/mm² and Poisson's ratio = 0.3, the magnitude of the stress σ for no strain in BC is



(a) 84 N/mm² (b) 64 N/mm²
(c) 34 N/mm² (d) 24 N/mm²

[ESE : 2016]

2.109 Consider the following statements :

1. In the infinitesimal strain theory, dilatation is taken as an invariant.
2. Dilatation is not proportional to the algebraic sum of all normal stresses.
3. The shearing modulus is always less than the elastic modulus.

Which of the above statements is/are correct?

(a) 1 only (b) 1 and 2 only
(c) 2 only (d) 1, 2 and 3

[ESE : 2016]

2.110 A mild steel bar, 1.5 m long, has a square section 40 mm × 40 mm. The bar is subjected to a two-dimensional stress, $\sigma_x = 310$ N/mm (tensile) and $\sigma_y = 300$ N/mm (compressive). $E = 2 \times 10^5$ N/mm², Poisson's ratio $\mu = 0.3$. The elongation of the bar in the direction of σ_x will be

(a) 1.25 mm (b) 1.75 mm
(c) 2.25 mm (d) 3 mm

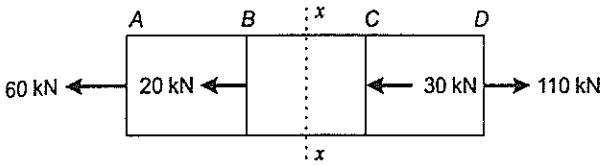
[ESE : 2016]

2.111 Two similar bars of Steel and Aluminium are heated to a same temperature. Forces are applied at the ends of the bars to maintain their lengths unaltered. If the ratio of Young's modulii of Steel and Aluminium is 3, and the ratio of the coefficients of thermal expansion of Steel to that of Aluminium is 0.5, what is the stress on the Aluminium bar if the stress on the Steel bar is 100 MPa?

(a) 16.7 MPa (b) 66.7 MPa
(c) 136.7 MPa (d) 1500 MPa

[ESE : 2016]

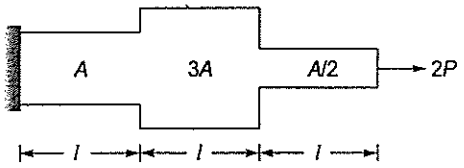
2.112 What is the stress at the section $x - x$ for the bar *ABCD* with uniform cross-section 1000 mm²?



(a) 20 N/mm² (Tensile)
(b) 30 N/mm² (Compressive)
(c) 80 N/mm² (Tensile)
(d) 50 N/mm² (Compressive)

[ESE : 2017]

2.113 The total elongation of the structural element (fixed at one end, free at the other end, and of varying cross-section) as shown in the figure, when subjected to load 2P at the free end is



(a) $6.66\frac{Pl}{AE}$ (b) $5.55\frac{Pl}{AE}$

(c) $4.44\frac{Pl}{AE}$ (d) $3.33\frac{Pl}{AE}$

[ESE : 2017]

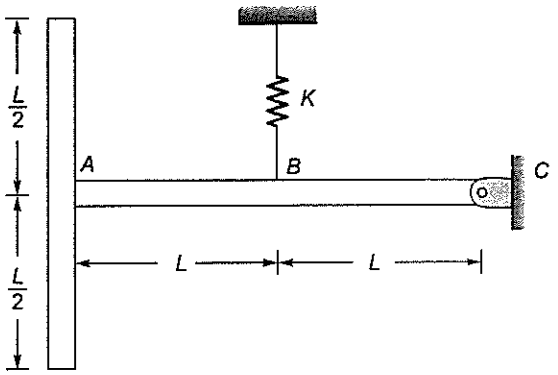
2.114 A solid uniform metal bar of diameter D mm and length l mm hangs vertically from its upper end. The density of the material is ρ N/mm³ and its modulus of elasticity is E N/mm². The total extension of the rod due to its own weight would be

(a) $\frac{\rho l^2}{2E}$ (b) $\frac{\rho l}{2E}$

(c) $\frac{\rho l}{4E}$ (d) $\frac{\rho l^2}{4E}$

[ESE : 2017]

2.115 A uniform T-shaped arm of weight W, pinned about a horizontal point C, is supported by a vertical spring of stiffness K. The extension of the spring is



(a) $\frac{3W}{4K}$ (b) $\frac{4W}{3K}$

(c) $\frac{3K}{4W}$ (d) $\frac{4K}{3W}$

[ESE : 2017]

2.116 A mild steel bar, circular in cross-section, tapers from 40 mm diameter to 20 mm diameter over its length of 800 mm. It is subjected to an axial pull of 20 kN. $E = 2 \times 10^5$ N/mm². The increase in the length of the rod will be

(a) $\frac{1}{10\pi}$mm (b) $\frac{2}{5\pi}$mm

(c) $\frac{4}{5\pi}$mm (d) $\frac{1}{5\pi}$mm

[ESE : 2017]

■■■■

Answers Simple Stress-Strain & Elastic Constants

2.1	(a)	2.2	(a)	2.3	(b)	2.4	(c)	2.5	(a)	2.6	(c)	2.7	(d)	2.8	(b)	2.9	(d)		
2.10	(a)	2.11	(c)	2.12	(a)	2.13	(a)	2.14	(d)	2.15	(a)	2.16	(b)	2.17	(a)	2.18	(b)		
2.19	(c)	2.20	(b)	2.21	(a)	2.22	(a)	2.23	(d)	2.24	(c)	2.25	(c)	2.26	(d)	2.27	(b)		
2.28	(a)	2.29	(c)	2.30	(d)	2.31	(a)	2.32	(b)	2.33	(a)	2.34	(d)	2.35	(a)	2.36	(d)		
2.37	(d)	2.38	(a)	2.39	(d)	2.40	(a)	2.41	(d)	2.42	(b)	2.43	(b)	2.44	(d)	2.45	(a)		
2.46	(b)	2.47	(b)	2.48	(b)	2.49	(a)	2.50	(c)	2.51	(b)	2.52	(c)	2.53	(d)	2.54	(d)		
2.55	(c)	2.56	(b)	2.57	(c)	2.58	(c)	2.59	(a)	2.60	(c)	2.61	(a)	2.62	(c)	2.63	(d)		
2.64	(c)	2.65	(a)	2.66	(a)	2.67	(c)	2.68	(a)	2.69	(a)	2.70	(d)	2.71	(c)	2.72	(b)		
2.73	(b)	2.74	(d)	2.75	(d)	2.76	(c)	2.77	(b)	2.78	(b)	2.79	(b)	2.80	(d)	2.81	(d)		
2.82	(c)	2.83	(a)	2.84	(a)	2.85	(c)	2.86	(a)	2.87	(d)	2.88	(d)	2.89	(d)	2.90	(c)		
2.91	(b)	2.92	(a)	2.93	(a)	2.94	(c)	2.95	(b)	2.96	(a)	2.97	(b)	2.98	(d)	2.99	(d)		
2.100	(c)	2.101	(b)	2.102	(a)	2.103	(a)	2.104	(c)	2.105	(c)	2.106	(b)	2.107	(b)	2.108	(d)		
2.109	(a)	2.110	(d)	2.111	(b)	2.112	(c)	2.113	(a)	2.114	(a)	2.115	(b)	2.116	(b)				

Explanations Simple Stress-Strain & Elastic Constants

2.1 (a)

For brittle material of low tensile strength and much larger strength in compression and shear the twisting will cause fracture along spiral line at 45° to the axis of cylinder.

For ductile material like mild steel, the plane of failure will be normal to the axis.

2.2 (a)

$$\frac{\Delta V}{V} = \frac{\text{Final volume} - \text{Initial volume}}{\text{Initial volume}}$$

$$= \varepsilon_x + \varepsilon_y + \varepsilon_z$$

2.3 (b)

The elongation of bar due to its own weight (W) is

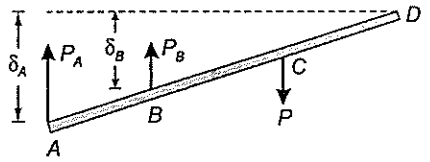
$$\Delta = \frac{WL}{2AE}$$

Now $W = \rho AL$

$$\therefore \quad \Delta = \frac{\rho L^2}{2E}$$

2.4 (c)

The rigid beam will rotate about point D, due to the load at C.



From similar triangle,

$$\frac{\delta_B}{2a} = \frac{\delta_A}{3a} \quad \text{or} \quad \frac{\delta_A}{\delta_B} = \frac{3}{2}$$

$$\frac{\text{Force in spring } A}{\text{Force in spring } B} = \frac{P_A}{P_B}$$

$$= \frac{k_A \delta_A}{k_B \delta_B} = \frac{2k}{k} \times \frac{3}{2} = 3$$

2.5 (a)

$$\text{Bulk modulus, } K = \frac{p}{\Delta V / V}$$

$$\therefore \quad \Delta V = \frac{1330 \times 8000}{1.33 \times 10^6}$$

$$= 8 \text{ cc}$$

2.6 (c)

There are four elastic constants viz.

E = Young's modulus of elasticity

G = Modulus of rigidity

K = Bulk modulus

μ = Poisson's ratio

The relations between these constants are:

(i) $G = \frac{E}{2(1+\mu)}$ (ii) $K = \frac{E}{3(1-2\mu)}$

(iii) $E = \frac{9KG}{G+3K}$ (iv) $\mu = \frac{3K-2G}{6K+2G}$

2.7 (d)

Since both the supports are fixed and both bars will try to expand, so rise in temperature will cause compressive stresses in the bars.

2.8 (b)

Longitudinal strain, $\epsilon_L = \frac{\Delta L}{L} = \frac{0.09}{200}$

Lateral strain, $\epsilon_D = \frac{\Delta D}{D} = -\frac{0.0045}{30}$

Poisson's ratio $= -\frac{\epsilon_D}{\epsilon_L} = \frac{0.0045}{30} \times \frac{200}{0.09} = \frac{1}{3}$

2.9 (d)

$F_3 \cos 45° = F_2 \quad \Rightarrow F_3 = 20\sqrt{2}$ kN

$F_3 \sin 45° = F_1 \quad \Rightarrow F_3 = 10\sqrt{2}$ kN

Therefore the forces will not be in equilibrium for any value of F_3.

For equilibrium $F_3 = \sqrt{F_1^2 + F_2^2 + 2F_1F_2\cos\theta}$

$= 10\sqrt{5}$ kN

F_3 should be at an angle $\tan\theta = \frac{1}{2}$ from horizontal.

2.10 (a)

Modulus of resilience, $u = \frac{f^2}{2E}$

where $E = \frac{fL}{\Delta L}$

$\therefore \quad u = \frac{f\Delta L}{2L} = \frac{200 \times 2}{2 \times 2000} = 0.10$ *units*

2.11 (c)

Strain energy stored $= \frac{\tau^2 V}{2G}$

$= \frac{(500)^2}{2\times10^6} \times 20 \times 10 \times 5$

$= 125$ kg-cm

2.12 (a)

Instantaneous elongation, $\Delta = \frac{2PL}{EA}$

$= \frac{2\times60\times10^3\times4000}{2.06\times10^5 \times \left(\frac{\pi\times50^2}{4}\right)}$

$= 1.19$ mm

2.13 (a)

The force R should be opposite to the resultant of $\vec{P}_1$ and $\vec{P}_2$.

Resultant of $\vec{P}_1$ and $\vec{P}_2 = \vec{P}_1 + \vec{P}_2$

$\therefore \quad R = -\vec{P}_1 - \vec{P}_2$

In other words, $\vec{R} + \vec{P}_1 + \vec{P}_2 = 0$. i.e. $\vec{R}, \vec{P}_1$ and $\vec{P}_2$ should form a closed triangle

2.15 (a)

$$\Delta_0 = \frac{4PL}{\pi E D_1 D_2}$$

Actual extension,

$$\Delta_0 = \frac{4PL}{\pi(2D^2)E} = \frac{2PL}{\pi D^2 E}$$

The average diameter of bar

$$= \frac{2D + D}{2} = 1.5\,D$$

Approximate extension,

$$\Delta = \frac{4PL}{\pi \times (1.5D)^2 E} = \frac{4PL}{2.25\pi D^2 E}$$

$\therefore$ Error in calculation $= \left(1 - \frac{\Delta}{\Delta_0}\right) \times 100$

$= \left(1 - \frac{2}{2.25}\right) \times 100 = 11.11\% \approx 10\%$

2.16 (b)

Temperature Stress $= E\alpha\Delta T$

$\frac{\text{Stress in bar } A}{\text{Stress in bar } B} = \left(\frac{E_A}{E_B}\right)\left(\frac{\alpha_A}{\alpha_B}\right) = 2 \times 2 = 4$

2.18(b)

The area of bar will become 4 times, and the volume as well as weight will increase 8 times. So increase in elongation

$$\left(\Delta = \frac{WL}{2EA}\right) \text{will be} \frac{8\times 2}{4} = 4 \text{ times}$$

2.19 (c)

First draw space diagram showing the system, point of application and line of action of the forces. Now force polygon can be drawn. Further polar diagram and funicular polygon can be drawn. Thus correct sequence is given in (c).

2.20 (b)

Equilibrant should close the force polygon. So (b) is the correct answer.

2.21(a)

At 45°,

$$\sigma_1, \sigma_2 = \pm\tau$$

$$\text{Strain} = \frac{\sigma_1}{E} - \frac{\mu\sigma_2}{E} \quad [E = 2G(1+\mu)]$$

$$= \frac{\tau}{E}(1+\mu) = \frac{\phi}{2}$$

2.22 (a)

$$\text{Elongation} = \frac{PL}{EA_1} + \frac{PL}{EA_2}$$

$$= \frac{PL}{E}\times\frac{4}{\pi}\left(\frac{1}{d_1^2} + \frac{1}{d_2^2}\right)$$

$$= \frac{10\times 1000\times 20}{2\times 10^6}\times\frac{4}{\pi}\left(\frac{1}{100} + \frac{1}{64}\right)$$

$$= \frac{1}{10\pi}\left(\frac{1}{25} + \frac{1}{16}\right)\text{cm}$$

2.23 (d)

The elongation in the bar due to increase in temperature = $L\alpha\Delta T$

Yield of support reduces strain in the bar by δ.

$$\therefore \quad \sigma = \left(\frac{L\alpha\Delta T - \delta}{L}\right)E = E\left(\alpha\Delta T - \frac{\delta}{L}\right)$$

$$= 1\times 10^6 \times \left(20\times 10^{-6}\times 100 - \frac{0.01}{25}\right)$$

$$= 1600 \text{ kg/cm}^2$$

2.24 (c)

$$\text{Modulus of rigidity, } G = \frac{E}{2(1+\mu)}$$

$$\therefore \quad \frac{E}{G} = 2\times(1+0.25) = 2.5$$

2.25 (c)

Axial load on portion BC = 3000 + 2000

= 5000 kg (tensile)

$$\text{Tensile stress} = \frac{5000}{5} = 1000 \text{ kg/cm}^2$$

2.26 (d)

Since load of 1t is applied mid-way so force in both wires will be same and equals to 0.5 t.

$$\Delta_c = \frac{500\times 4}{1\times 10^6\times 4} = 5\times 10^{-4} \text{ m} = 0.5 \text{ mm}$$

$$\Delta_s = \frac{500\times 4}{2\times 10^6\times 2} = 5\times 10^{-4} \text{ m} = 0.5 \text{ mm}$$

$$\therefore \frac{\Delta_c}{\Delta_s} = 1.0$$

2.27 (b)

Since both the ends of the bar are unyielding. With increase in temperature, both bars will be in compression and the load will be transferred to the supports.

2.28 (a)

$$\text{We know that, } \mu = \frac{3K - 2G}{6K + 2G}$$

But here, $K = G$

$$\therefore \quad \mu = \frac{3-2}{6+2} = 0.125$$

2.29 (c)

$$\frac{\Delta_1}{\Delta_2} = \frac{L_1}{L_2}\times\frac{A_2}{A_1}$$

Since $L_1 = L_2$ and $A_1 = 2A_2$

$$\therefore \quad \frac{\Delta_1}{\Delta_2} = 1\times\frac{1}{2} = \frac{1}{2}$$

2.30 (d)

Actual extension

$$\Delta_1 = \frac{4PL}{\pi d_1 d_2 E}$$

Extension base don average diameter

$$\Delta_2 = \frac{4PL}{\pi\left(\frac{d_1+d_2}{2}\right)^2 E}$$

Assuming $\Delta_1 > \Delta_2$

So, $$\frac{4PL}{\pi d_1 d_2 E} > \frac{4PL}{\pi\left(\frac{d_1+d_2}{2}\right)^2 E}$$

$$\Rightarrow \left(\frac{d_1+d_2}{2}\right)^2 > d_1 d_2$$

$$\Rightarrow \frac{d_1^2+d_2^2+2d_1d_2}{4} - d_1d_2 = 0$$

$$\Rightarrow (d_1-d_2)^2 > 0$$

Which is true.

2.31 (a)

$$R = \sqrt{P^2+Q^2+2PQ\cos\theta}$$

for $R = Q = P$

$$P^2 = 2P^2 + 2P^2\cos\theta$$

$$\Rightarrow \cos\theta = -\frac{1}{2}$$

$$\therefore \theta = 120°$$

2.32 (b)

For a system to be in equilibrium force polygon and funicular polygon must close. If force polygon does not close then the forces will reduce to a resultant force. If funicular polygon does not close, then there is resultant moment on the system.

2.34 (d)

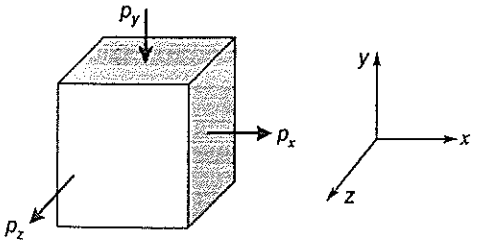
Total elongation

$$= \frac{4PL}{\pi E}\left(\frac{1}{d_1^2}+\frac{1}{d_2^2}+\frac{1}{d_3^2}\right)$$

$$= \frac{4\times10\times100}{\pi E\times100}\left[\frac{1}{16}+\frac{1}{25}+\frac{1}{36}\right]\text{mm}$$

$$= \frac{40}{\pi E}\left(\frac{1}{16}+\frac{1}{25}+\frac{1}{36}\right)\text{mm}$$

2.35 (a)



$$\epsilon_x = \frac{p_x}{E} - \mu\left(-\frac{p_y}{E}\right) - \mu\left(\frac{p_z}{E}\right)$$

$$= \frac{1}{E}\left(p_x + \mu p_y - \mu p_z\right)$$

2.36 (d)

$$\text{Poisson's ratio} = \frac{\text{Lateral strain}}{\text{Longitudinal strain}} = 0.25$$

$$G = \frac{E}{2(1+\mu)} = \frac{2\times10^5}{2.5}$$

$$= 0.8\times10^5\ \text{N/mm}^2$$

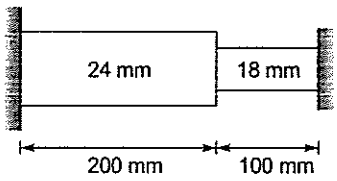
2.37 (d)

The forces are not concurrent so the resultant force and couple both may be present. Thus the best choice is that forces are not in equilibrium.

2.38 (a)

Mild steel is equally strong in tension and compression but it is weak in shear. Therefore cup and cone type failure of mild steel specimen occurs during tension test.

2.39 (d)



Change due to temperature

$$\Delta L = L_1\alpha_1\Delta T + L_2\alpha_2\Delta T$$

$$\Delta L' = \frac{PL_1}{A_1E} + \frac{PL_2}{A_2E}$$

$\Delta L + \Delta L' = 0$ (Because both ends fixed)

$$P = 2.69\ \text{kN}$$

$$\sigma_{max} = \frac{P}{A} = \frac{2.69\times10^3}{\frac{\pi}{4}(18)^2}$$

$$\simeq 105\ \text{MPa}$$

2.40 (a)

Let the deformation in spring at B be δ_B and the deformation in spring at C be δ_C.

$$\frac{\delta_B}{\delta_C} = \frac{2}{3}$$

$$\frac{F_C}{F_B} = \left(\frac{k_1}{k_2}\right)\frac{\delta_C}{\delta_B} = \frac{1}{2}\times\frac{3}{2} = \frac{3}{4}$$

2.41 (d)

ϵ_N = 1.25 mm per m

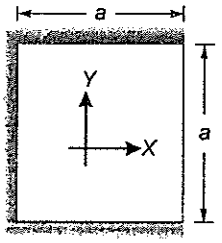
Lateral strain, ϵ_L = – Poisson's ratio × longitudinal strain

= – 0.3 × 1.25 mm per m

Volumetric strain,

$$\epsilon_V = \epsilon_N + \epsilon_L + \epsilon_L$$
$$= 1.25 - 0.3 \times 1.25 - 0.3 \times 1.25$$
$$= 0.4 \times 1.25 = 0.5 \text{ mm per m}$$
$$= 5 \times 10^{-4}$$

2.42 (b)



Free expansion in X-direction = $L\alpha t = a\alpha t$

The square plate is fixed in Y-direction. When temperature in increased, the plate will be in compression along Y-axis. Therefore lateral expansion in X-direction due to compressive stress σ in Y-direction

$$= \mu \times \frac{\sigma}{E} \times a = \mu \times \frac{\alpha t E}{E} \times a$$
$$= \mu\alpha ta$$

$\therefore$ Total elongation = $a\alpha t + \mu\alpha ta = a\alpha t(1 + \mu)$

2.44 (d)

Deformation in the bar, $\Delta = \frac{WL}{AE}$

Strain energy = $\frac{1}{2}W\Delta = \frac{W^2L}{2AE}$

2.46 (b)

Stress and strain system for bar of length l subjected to axial pull will be same whether both ends are free or one end is fixed and other end is free. Rigid body displacements without any acceleration do not have any effect on elastic deformation.

2.47 (b)

$$\mu = \frac{3K - 2G}{6K + 2G}$$

Given $K = 2G$

$$\therefore \quad \mu = \frac{6G - 2G}{12G + 2G} = \frac{4}{14} = \frac{2}{7}$$

2.48 (b)

A diagram of the body in which the body under consideration is freed from all the contact surfaces (surroundings) and all the forces acting on it (including reactions at contact surfaces) are drawn, is called a Free Body Diagram.

2.49 (a)

The elongation of all the bars will be same.

$$\Delta = \frac{P_1L_1}{EA} = \frac{P_2(2L_1)}{EA}$$

$\therefore \quad P_2 = 0.5\,P_1$

$P_2 + P_1 + P_1 = P$

$P_1 = 0.4P$ (shorter bar)

$P_2 = 0.2P$ (longer bar)

2.50 (c)

Strain energy = $\frac{1}{2}W\Delta = \frac{W^2L}{2AE}$

2.52 (c)

As both brass and steel should move together by same amount and coefficient of expansion of brass is more than that of steel. So brass will have compressive stress and steel will be under tension.

2.53 (d)

Force in the spring = $\frac{500 \times 200}{100}$ = 1000 N

Deflection in the spring = $\frac{1000}{200}$ = 5 mm

So deflection at point B = 10 mm

2.54 (d)

The lateral compressive stress is applied on perpendicular direction (not directions). So considering 200 N/mm^2 lateral stress in one direction. Therefore, strain in longitudinal direction

$$\epsilon_i = \frac{1}{E}(\sigma_1 - \mu\sigma_2)$$

$$= \frac{1}{2\times10^5} \times (440 + 0.3 \times 200)$$

$$= \frac{1}{400}$$

$\therefore$ Elongation of bar in longitudinal direction

$$= \varepsilon_l \times 400$$

$$= 1 \text{ mm}$$

2.55 (c)

$$K = \frac{E}{3(1-2\mu)}$$

$\because$ $K = E$

$\therefore$ $(1-2\mu) = \frac{1}{3}$

$\Rightarrow$ $\mu = \frac{1}{3}$

2.56 (b)

The elongation in all wires will remain same.

$$\therefore \quad \Delta = \frac{P_1 L}{AE} = \frac{P_2 L}{2AE} = \frac{P_3 L}{AE}$$

$$P_1 = P_3 = \frac{P_2}{2}$$

Thus wire having higher axial load will yield first.

$$P_2 = \sigma_y A$$

$$P_1 = P_3 = \frac{\sigma_y A}{2}$$

$$W_1 = P_1 + P_2 + P_3 = 2\sigma_y A$$

At collapse, the stress in all wires will be σ_y.

So $W_2 = 3\sigma_y A$

$$\frac{W_2}{W_1} = \frac{3}{2}$$

2.57 (c)

$$E = 2G(1+\mu)$$

$$\Rightarrow \quad G = \frac{E}{2(1+\mu)}$$

2.58 (c)

$$\text{Longitudinal strain} = \frac{\Delta L}{L} = \frac{0.150}{400} = 3.75 \times 10^{-4}$$

$$\text{Lateral strain} = \frac{\Delta d}{d} = -\frac{0.005}{40} = -1.25 \times 10^{-4}$$

$$\text{Poisson's ratio} = -\frac{\text{Lateral strain}}{\text{Longitudinal strain}} = 0.33$$

2.59 (a)

Strain energy,

$$U = \frac{1}{2} \times \text{Stress} \times \text{Strain} \times \text{Volume of bar}$$

$$= \frac{1}{2} \times f \times \varepsilon \times \text{Volume of bar}$$

$$\text{Since } \varepsilon = \frac{f}{E}$$

$$\therefore U = \frac{f^2}{2E} \times \text{Volume of bar}$$

2.60 (c)

The stress developed in the rod is given as

$$\sigma = \alpha \Delta T E$$

$$= 15 \times 10^{-6} \times 20 \times 200 \times 10^3$$

$$= 60 \text{ MN/m}^2$$

It is to be noted that temperature stress depends upon properties of material and not upon properties of cross section like length and area.

2.61 (a)

The relationship between E, G and μ is given as

$$E = 2G(1+\mu)$$

$$\Rightarrow \quad G = \frac{E}{2(1+\mu)} = \frac{189.8}{2(1+0.30)}$$

$$\Rightarrow \quad G = 73 \text{ GN/m}^2$$

2.62 (c)

The values of Poisson's ratio of various materials are tabulated below:

Material	Poisson's ratio
Aluminium	0.33
Brass	0.34
Bronze	0.34
Cast iron	0.2-0.3
Concrete	0.1-0.2
Copper	0.33-0.36
Glass	0.02-0.03
Nylon	0.40
Rubber	0.45-0.50
Steel	0.27-0.30
Wrought iron	0.3

2.63 (d)

The relationship between, E, G and μ is

$$E = 2G(1+\mu)$$

$$\Rightarrow \quad G = \frac{E}{2(1+\mu)} = \frac{200}{2(1+0.25)}$$

$$\Rightarrow \quad = 80 \text{ GN/m}^2$$

2.64 (c)

Normal stress at B

$$= \frac{\text{Total load acting at } B}{\text{Area of cross-section at } B}$$

$$= \frac{P + P}{1.5A} = \frac{2P}{1.5A}$$

2.65 (a)

In a body loaded under plane stress conditions ($2D$), the number of independent stress components is 3 i.e. two normal components and one shear components. However in a $3D$ stress condition, there will be 6 independent stress components i.e 3 normal components and 3 shear stress components.

2.66 (a)

The component having higher coefficient of linear expansion will have tendency to expand but its movement will be restricted by component having lower coefficient of linear expansion and thus will be in compression.

2.67 (c)

Since $\alpha_A > \alpha_B$, therefore the free expansion of A will be more than that of B when temperature is increased. But the compound bar tightly secured at the ends, hence the free expansion is prevented. Thus compressive stresses will be induced in A and tensile stresses will be induced in B.

2.69 (a)

Modulus of resilience is the strain energy stored in the material per unit volume.

$$u = \frac{U}{V} = \frac{100 \times 10^3}{50 \times 50 \times 5 \times 1000}$$

$$= \frac{1}{125} \text{ N-mm/mm}^3$$

2.70 (d)

Total elongation of the bar will be

$$\Delta L = \frac{\gamma L^2}{2E} = \frac{8 \times 10^{-5} \times (6 \times 1000)^2}{2 \times 2 \times 10^5}$$

$$= \frac{72}{10^4} \text{mm}$$

2.71 (c)

Poisson's ratio is given by

$$\mu = \frac{\text{lateral strain}}{\text{longitudinal strain}}$$

$$= \frac{\Delta D / D}{\Delta L / L} = \frac{\Delta D}{\Delta L} \times \frac{L}{D}$$

$$= \frac{0.0045}{30} \times \frac{200}{0.09} = 0.33$$

2.72 (b)

$$E = 2G(1 + \mu)$$

$$\Rightarrow \quad G = \frac{E}{2(1+\mu)} = \frac{208}{2(1+0.3)}$$

$$= 80 \text{ GPa}$$

2.73 (b)

We know that

$$E = 3K(1 - 2\mu)$$

The minimum value of $\mu = 0$

$$\therefore \quad E = 3K(1 - 2 \times 0)$$

$$\Rightarrow \quad K = \frac{E}{3}$$

2.74 (d)

The elongation of the bar in x-direction will be

$$\frac{\Delta L}{L} = \frac{\sigma_x}{E} - \mu \frac{\sigma_y}{E}$$

$$\Rightarrow \quad \Delta L = \frac{L}{E}[\sigma_x - \mu\sigma_y]$$

$$\Rightarrow \quad \Delta L = \frac{1000}{2 \times 10^5}[480 - 0.3 \times (-400)]$$

$$\Rightarrow \quad \Delta L = 3 \text{ mm}$$

2.75 (d)

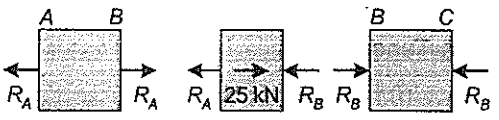
Total extension in the rod will be

$$\Delta L = \frac{4PL}{\pi E D_1 D_2}$$

$$= \frac{4 \times 12 \times 10^3 \times 300}{\pi \times 2 \times 10^5 \times 12 \times 30} = \frac{1}{5\pi}$$

2.76 (c)

The free body diagram of the given figure is shown below.



$\therefore$ Equilibrium condition for the bar is given by

$$R_A + R_B = 25 \quad \text{...(i)}$$

Compatibility condition for the bar is given by

$$\Delta_{AB} + \Delta_{BC} = 0 \quad \text{...(ii)}$$

But $\Delta_{AB} = \dfrac{R_A \times 2L}{AE}$ (tensile)

$$\Delta_{BC} = \frac{R_B \times 3L}{AE} \text{ (compressive)}$$

Substituting values of Δ_{AB} and Δ_{BC} in (ii), we get

$$\frac{R_A \times 2L}{AE} - \frac{R_B \times 3L}{AE} = 0 \quad \text{[from (i)]}$$

$\Rightarrow R_A \times 2L - (25 - R_A) \times 3L = 0$

$\Rightarrow 2R_A - 75 + 3R_A = 0$

$\Rightarrow R_A = 15$ kN

Also, $R_B = 25 - 15 = 10$ kN

Since the forces left to right directions are taken as positive, therefore, the reactions which are acting from right to left are negative.

2.79 (b)

Most materials have Poisson's ratio values ranging between 0 and 0.5. A perfectly incompressible material deformed elastically at small strains would have Poisson's ratio of exactly 0.5. The relationship between Bulk modulus K, modulus of elasticity E and Poisson's ratio μ is

$$K = \frac{E}{3(1-2\mu)}$$

for $\mu = 0.5$, $K = \infty$

It means material is incompressible.

2.80 (d)

The elongation of a bar subjected to a tensile load P is given by

$$\Delta = \frac{PL}{AE}$$

Now for bar A,

$$\Delta_A = \frac{PL}{\frac{\pi d_A^2}{4} \times E}$$

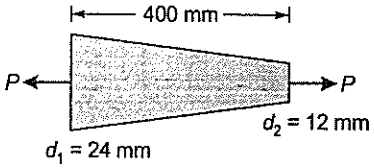
Similarly for bar B,

$$\Delta_B = \frac{PL}{\frac{\pi d_B^2}{4} \times E}$$

$$\therefore \quad \frac{\Delta_A}{\Delta_B} = \frac{d_B^2}{d_A^2}$$

$$\therefore \quad \frac{\Delta_A}{\Delta_B} = \frac{(3)^2}{(2)^2} = \frac{9}{4}$$

2.81 (d)



$$\Delta = \frac{4PL}{\pi E d_1 d_2} = \frac{4(12000)400}{\pi(2\times10^5)24(12)} = \frac{1}{3\pi}$$

2.82 (c)

$$E = 3k(1-2\mu)$$

Where Poisson's ratio

$$\mu = 0.3$$

$$\Rightarrow \quad \frac{E}{K} = 3(1-2\mu) = 3(1-2\times0.3) = 1.2$$

2.83 (a)

$$E = 2C(1+\mu) \quad \text{...(i)}$$

$$E = 3K(1-2\mu) \quad \text{...(ii)}$$

Using (i) and (ii)

$$E = \frac{9kC}{3k+C}$$

2.84 (a)

Elastic modulus = E

Shear modulus = G

$$E = 2G(1+\mu)$$

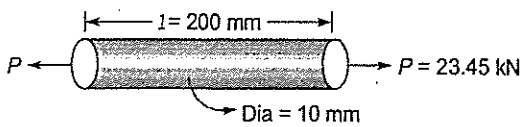
Given, $\mu = 0.5$, $E = 2 \times 1.5 \times G$

$$E = 3G$$

2.85 (c)

Two independent elastic constants are Poisson's ratio and Young's modulus. Alternatively, Bulk modulus and Shear modulus can also be used. All metals at micro level are anisotropic.

2.86 (a)



$$\Delta l = 0.3 \text{ mm}$$

$$\Rightarrow \quad \varepsilon = \frac{\Delta l}{l} = \frac{0.3}{200}$$

$$\Rightarrow \quad \sigma = \frac{P}{A} = \varepsilon E$$

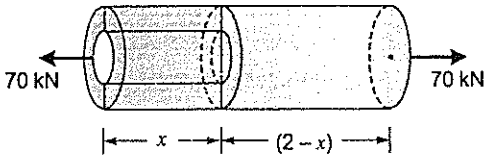
$$\Rightarrow \frac{23.5\times10^3}{\pi/4\times10^2} = \frac{2.3}{200}\times E$$

$$\Rightarrow \quad E = \frac{235}{0.785}\times\frac{200}{0.3}$$

$$\simeq 200\times10^3 \text{ N/mm}^2$$

$$\Rightarrow \quad E = 200 \text{ kN/mm}^2$$

2.87 (d)



$$\Delta l = \frac{Pl}{AE}$$

Initially when no boring,

$$\Delta l_1 = \frac{70\times10^3\times2\times10^3}{\pi/4\times40^2\times2\times10^5}$$

After boring,

$$\Delta l_2 = \frac{70\times10^3\times X\times10^3}{\pi/4\times(40^2-25^2)\times2\times10^5} + \frac{70\times10^3\times(2-X)\times10^3}{\pi/4\times40^2\times2\times10^5}$$

Given,

$$\Delta l_2 = 1.2\,\Delta l_1$$

$$\Rightarrow \frac{350x}{\pi/4\times65\times15} + \frac{350(2-x)}{\pi/4\times1600} = \frac{1.2\times400}{\pi\times1600}$$

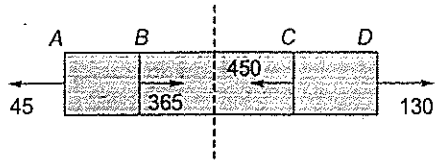
$$\Rightarrow \frac{x}{3\times13} + \frac{2-x}{64} = \frac{1.2\times2}{64}$$

$$\Rightarrow \frac{64x+78-39x}{39\times64} = \frac{2.4}{6.4}$$

$$\Rightarrow 25x = 39\times2.4 - 78$$

$$\Rightarrow x = 0.624 \text{ m}$$

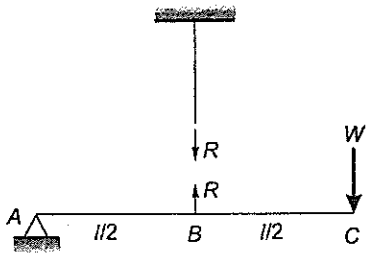
2.88 (d)



For part $BC \rightarrow (365) - 45\,(\leftarrow)$

$= 320$ comvpressive

2.89 (d)



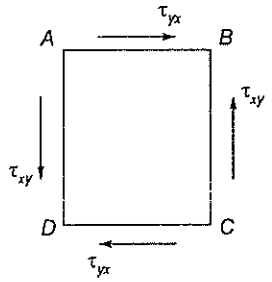
$$\Sigma M_A = 0$$

$$\Rightarrow \quad W\times l - R\times\frac{l}{2} = 0$$

$$\Rightarrow \quad R = 2\,W$$

2.90 (c)

Consider rectangular block of unit thickness



Taking moment about D

$$\tau_{xy}\,.dy.1.dx = \tau_{xy}.dx.1.dy$$

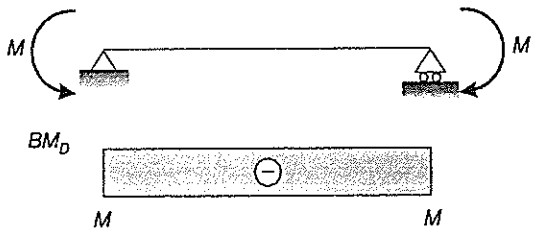
$$\tau_{xy} = \tau_{yx}$$

2.92 (a)

Now, bending equation;

$$\frac{M}{I} = \frac{E}{R} = \frac{f}{y}$$

$$\therefore \quad R = \frac{EI}{M}$$



Now, M, E and I are constant

$\therefore \quad R \rightarrow$ constant

which is true only in the case of circle,

So, answer is (a).

2.94 (c)

For no change in length

$$\varepsilon_L = 0$$

i.e. $\frac{\sigma_x}{E} - \mu\frac{\sigma_y}{E} = 0$

$$\sigma_y = \frac{\sigma_x}{\mu} = \frac{60}{0.3} = 200\text{MPa}$$

So, option (c) is correct.

2.95 (b)

As we know that,

$$G = \frac{E}{2(1+\mu)} = \frac{210}{2(1+0.27)} = 82.67\text{ GPa}$$

2.97 (b)

Strain energy in bar X,

$$U_x = \frac{P^2L}{2AE}$$

Strain energy in bar Y,

$$U_y = \frac{P^2(L/2)}{2\left(\frac{A}{2}\right)E} + \frac{P^2(L/2)}{2AE} = \frac{3}{4}\frac{P^2L}{AE}$$

$$\therefore \frac{U_x}{U_y} = \frac{\frac{P^2L}{2AE}}{\frac{3P^2L}{4AE}} = \frac{2}{3}$$

2.98 (d)

$$E = 3k(1-2\mu)$$

$$\Rightarrow \quad 15 = 3\times 50(1-2\mu)$$

$$\therefore \quad \mu = 0.45$$

2.99 (d)

For no strain along AB

$$\in_{AB} = \frac{60}{E} - \frac{\mu\sigma}{E} = 0$$

$$\Rightarrow \quad \sigma = \frac{60}{\mu} = \frac{60}{0.25} = 240\text{N/mm}^2$$

2.100 (c)

$$\because \quad \frac{\text{Flexural rigidity}}{\text{Torsional rigidity}} = \frac{EI}{GJ} = \frac{E\cdot\frac{\pi}{64}D^4}{G\cdot\frac{\pi}{32}D^4} = \frac{E}{2G}$$

$$\because \quad G = \frac{E}{2(1+\nu)}$$

$$\therefore \quad \frac{\text{Flexural rigidity}}{\text{Torsional rigidity}} = \frac{E}{2\times\frac{E}{2(1+\nu)}}$$

$$= 1+\nu$$

2.101 (b)

$$\because \text{ Elongation due to self wt. } (\delta) = \frac{\gamma L^2}{6E}$$

$$\delta = \frac{\left(\frac{80\times10^3}{10^9}\right)\left(0.5\times10^3\right)^2}{6\times\left(\frac{200\times10^9}{10^6}\right)}$$

$$\delta = \frac{80\times10^{-6}\times0.5^2\times10^6}{6\times200\times10^3}$$

$$= 1.67\times10^{-5}\text{ mm}$$

2.102 (a)

$$\because \quad \frac{\sigma_2}{E} - \frac{\mu\sigma_1}{E} - \frac{\mu\sigma_2}{E} = 0$$

$$\Rightarrow \quad \frac{\sigma_2}{E}(1-\mu) = \frac{\mu\sigma_1}{E}$$

$$\Rightarrow \quad \sigma_2 = \frac{\mu\sigma_1}{1-\mu}$$

2.103 (a)

Strain in both the wires are same.

$$\therefore \quad \frac{P_s}{A_sE_s} = \frac{P_c}{A_cE_c}$$

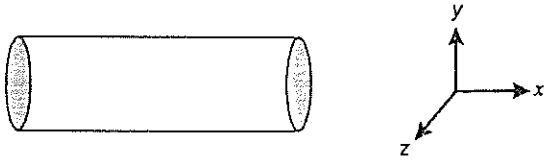
$$\Rightarrow \quad \frac{1}{A_sE_s} = \frac{1}{A_cE_c} \qquad (\because P_s = P_c)$$

$$\Rightarrow \quad \frac{A_c}{A_s} = \frac{E_s}{E_c}$$

$$\Rightarrow \quad \frac{D_c^2}{D_s^2} = \frac{E_s}{E_c} = \frac{200}{100} = 2$$

$$\therefore \quad \frac{D_c}{D_s} = \sqrt{2}$$

2.104 (c)



$$\varepsilon_x = 3\varepsilon_y$$

$$\therefore \quad \frac{\varepsilon_y}{\varepsilon_x} = \frac{1}{3} = \mu$$

Now, $E = 3K(1 - 2\mu)$

$$K = \frac{E}{3(1-2\mu)} = 1\times10^5 \text{ N/mm}^2$$

2.105 (c)

$$\mu = \frac{3K - 2C}{6K + 2C}$$

2.106 (b)

Elongation,

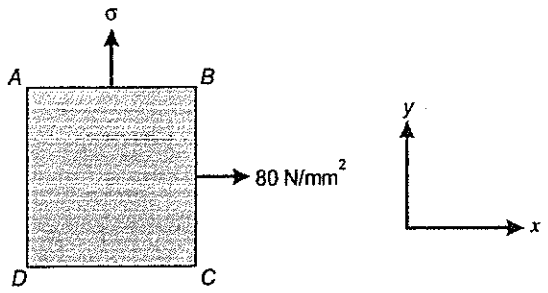
$$\Delta = \frac{4PL}{\pi d_1 d_2 E}$$

$$= \frac{4\times12\times10^3\times450}{\pi\times36\times18\times2\times10^5} = \frac{1}{6\pi} \text{ mm}$$

2.107 (b)

- Longitudinal direction is that direction in which force or stress is acting.
- Due to tensile stress, longitudinal strain will be tensile but the lateral strain will be compressive.

2.108 (d)



Strain in BC,

$$\epsilon_y = \frac{\sigma_y}{E} - \mu\frac{\sigma_x}{E}$$

$$0 = \frac{\sigma}{E} - \frac{0.3\times80}{E}$$

$$\therefore \quad \sigma = 24 \text{ N/mm}^2$$

2.109 (a)

Dilatation (Volumetric change)

$$\epsilon_V = \frac{\sigma_x + \sigma_y + \sigma_z}{E}(1 - 2\mu)$$

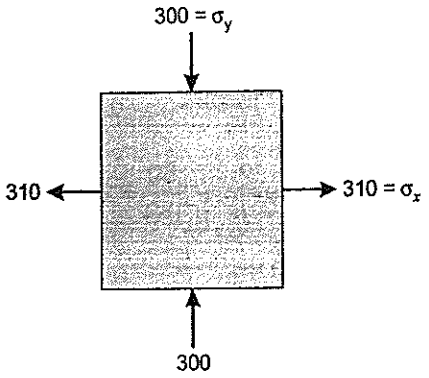
Hence directly proportional to sum of all normal stress.

Shearing modulus,

$G < E$ if $\mu > -0.5$

$G > E$, if $\mu < -0.5$

2.110 (d)



$$\epsilon_x = \frac{\sigma_x}{E} - \frac{\mu\sigma_y}{E}$$

$$= \frac{1}{2\times10^5}[310 - (0.3)(-300)]$$

$$\frac{\Delta L}{L} = \epsilon_x$$

$$\Delta L = \epsilon_x(L) = \epsilon_x\left(1.5\times10^3\right) = 3 \text{ mm}$$

2.111 (b)

$$\frac{E_S}{E_{Al}} = 3; \quad \frac{\alpha_s}{\alpha_{Al}} = 0.5$$

$$\frac{\sigma_{Steel}}{\sigma_{Al}} = \frac{(E\alpha\Delta T)_{Steel}}{(E\alpha\Delta T)_{Al}}$$

$$\sigma_{Al} = \frac{2}{3}\times100 = 66.67 \text{ MPa}$$

2.112 (c)

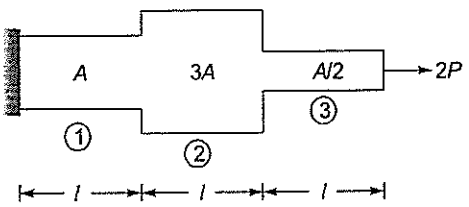
Force at section x-x

$= 60 + 20 = 80$ kN (T)

$\therefore$Stress at section x-x

$$= \frac{F}{A} = \frac{80\times10^3\text{N}}{1000 \text{ mm}^2}(T) = 80 \text{ N/mm}^2 (T)$$

2.113 (a)



Total elongation Δ

$= \Delta_1 + \Delta_2 + \Delta_3$

$$= \frac{2PI}{AE} + \frac{2PI}{3AE} + \frac{2PI}{\frac{A}{2}E}$$

$$= \frac{2PI}{AE} + \frac{2PI}{3AE} + \frac{4PI}{AE} = 6.66\frac{PI}{AE}$$

2.114 (a)

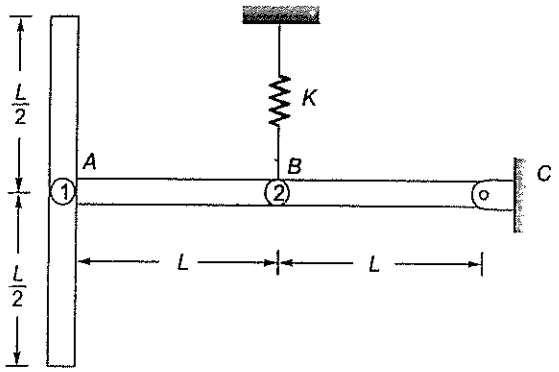
The expansion of a prismatic bar due to self,

$$\Delta = \frac{\rho l^2}{2E} = \frac{Wl}{2AE}$$

ρ = Specific weight of material

W = Total weight of bar

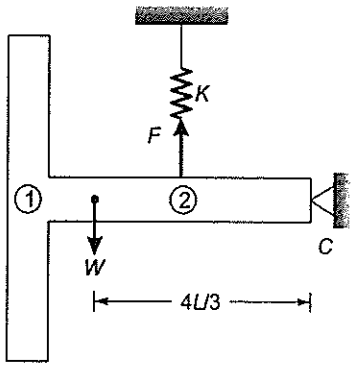
2.115 (b)



Center of gravity of T-shape is at $\bar{x}$ distance from C, calculated as

$$\bar{x} = \frac{A_1\bar{x}_1 + A_2\bar{x}_2}{A_1 + A_2}$$

$$= \frac{\left(\frac{L}{2}+\frac{L}{2}\right)\times 2L + 2L\times L}{L+2L} = \frac{4}{3}L$$



Taking moment about C

$$\Rightarrow W\times\frac{4}{3}L = F\times L$$

$$\Rightarrow F = Kx = \frac{4}{3}W$$

$$\Rightarrow x = \frac{4}{3}\frac{W}{K}$$

2.116 (b)

$$\Delta = \frac{4PL}{\pi d_1 d_2 E}$$

$$= \frac{4\times 20\times 10^3\times 800}{\pi\times 20\times 40\times 2\times 10^5} = \frac{2}{5\pi}$$

3 Shear Force & Bending Moment

3.1 **Assertion (A):** Bending moment in a beam is maximum at a section where shear force is zero.
Reason (R): Shear force at a section is given by the rate of change of bending moment.

[ESE : 1995]

3.2 Match List-I (Type and position of load on cantilever) with List-II (Shape of moment diagram for cantilever) and select the correct answer using the codes given below the lists:

List-I

A. Carrying linearly varying load from zero at its free end and maximum at the fixed end
B. Subjected to uniformly distributed load
C. Carrying concentrated load at its free end
D. Whose free end is subjected to bending moment

List-II

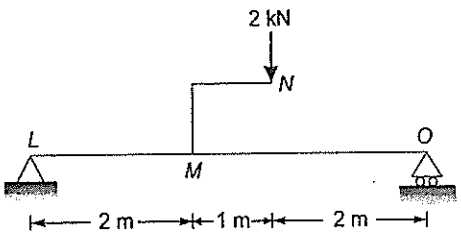
1. Parabola
2. Rectangle
3. Cubic parabola
4. Triangle

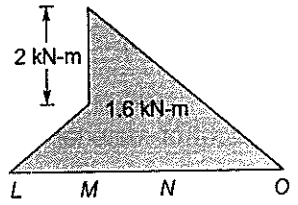
Codes:

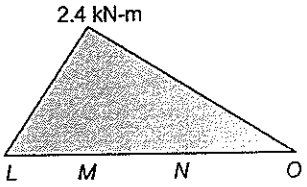
	A	B	C	D
(a)	3	2	1	4
(b)	4	3	2	1
(c)	3	1	4	2
(d)	2	4	1	3

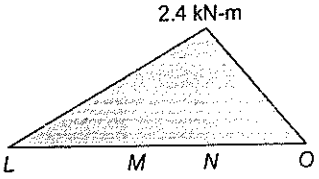
[ESE : 1995]

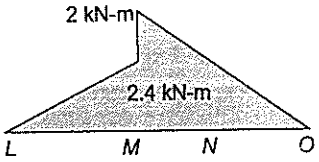
3.3 The bending moment diagram of the beam shown figure is



(a)


(b)


(c)


(d)


[ESE : 1995]

3.4 The SFD and BMD for a beam are shown in the given figures I and II. The corresponding loading diagram would be

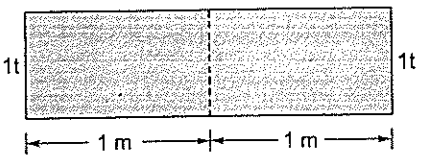


Figure-i

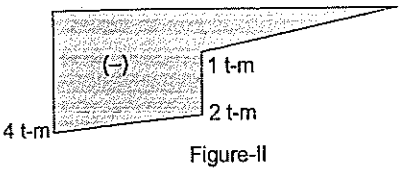
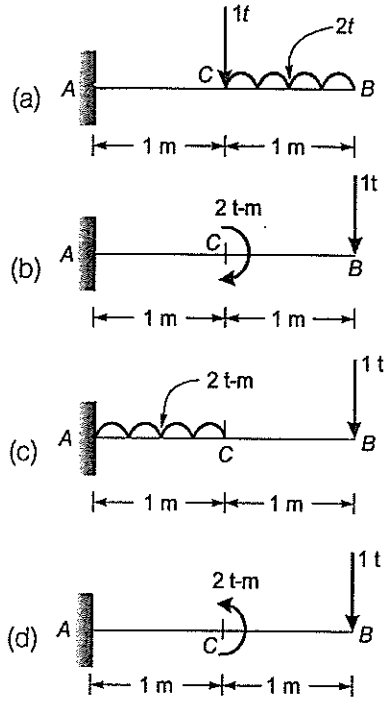
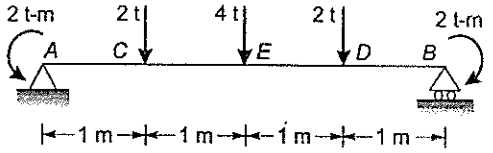


Figure-II



[ESE : 1995]

3.5 A simply supported beam is loaded as shown in the given figure. The bending moment at *E* would be



(a) 6 t-m (Sagging)
(b) 4 t-m (Hogging)
(c) 6 t-m (Hogging)
(d) 4 t-m (Sagging)

[ESE : 1995]

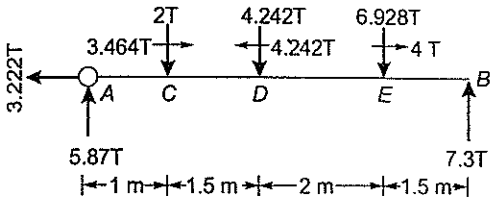
3.6 Which one of the following statements is correct?
(a) Shear force is the first derivative of bending moment.
(b) Shear force is the first derivative of intensity of load.
(c) Load intensity on a beam is the first derivative of bending moment.
(d) Bending moment is the first derivative of shear force.

[ESE : 1995]

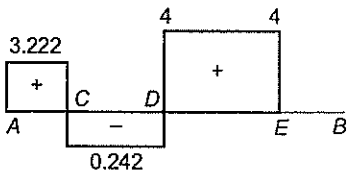
3.7 **Assertion (A):** The maximum bending moment occurs where the shear force is either zero or changes sign.
Reason (R): If the shear force diagram line between the two points in horizontal, the BM diagram line is inclined. But if the SF diagram is inclined, the BM diagram is a parabola of second degree.

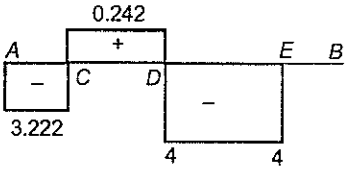
[ESE : 1996]

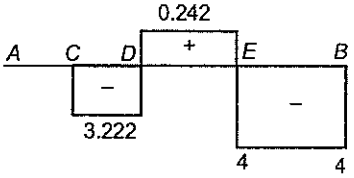
3.8 If the loads and reactions of the beam shown are as given in the following figure,

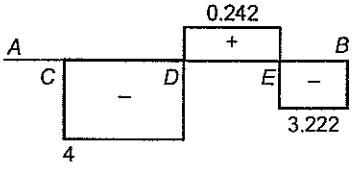


The thrust diagram on the section of the beam, taking tension positive, will be

(a)


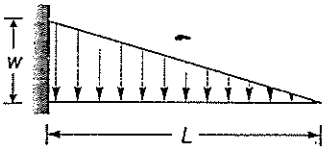
(b)


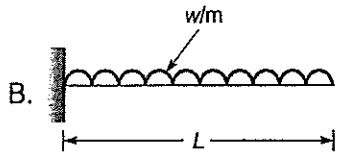
(c)


(d)


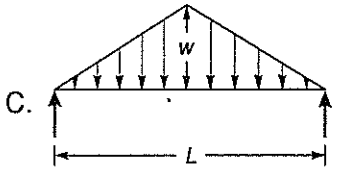
[ESE : 1996]

3.9 Match List-I (Type of beam with loading) with List-II (Maximum bending moment value) and select the correct answer given below the lists:

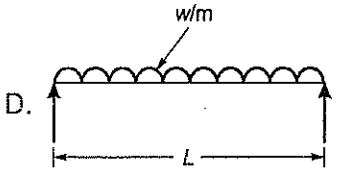
List-I	List-II
A. 	1. $\frac{wL^2}{12}$



B. 2. $\frac{wL^2}{6}$



C. 3. $\frac{wL^2}{2}$



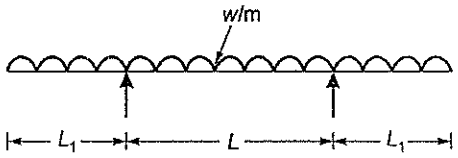
D. 4. $\frac{wL^2}{8}$

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	1	3	2	4
(c)	2	3	1	4
(d)	2	4	1	3

[ESE : 1996]

3.10 For the beam shown in the given figure, the maximum positive bending moment is equal to negative bending moment. The value of L_1 is

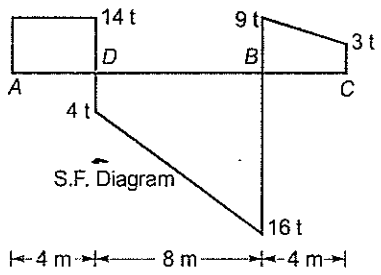


(a) $\frac{L}{\sqrt{2}}$ (b) $\frac{L}{\sqrt{3}}$

(c) $\frac{L}{2}$ (d) $\frac{L}{2\sqrt{2}}$

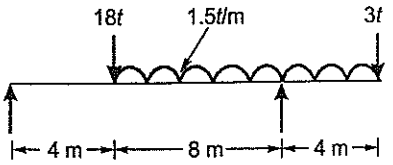
[ESE : 1996]

3.11 Consider the shear force diagram shown in given figure

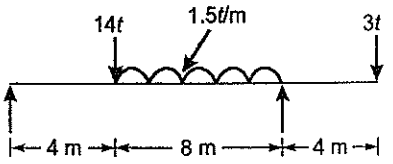


The loaded beam will be

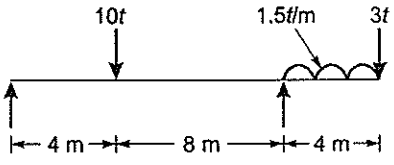
(a)



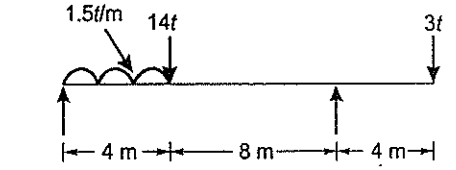
(b)



(c)



(d)



[ESE : 1996]

3.12 Match List-I (Type and position of force on cantilever) with List-II (Shape of bending moment diagram for a cantilever) and select the correct answer using the codes given below the lists:

List-I

A. Carrying linearly varying load from zero at its free end and maximum at the fixed end
B. Subjected to uniformly distributed load
C. Carrying concentrated load at its free end
D. Whose free end is subjected to a couple

List-II

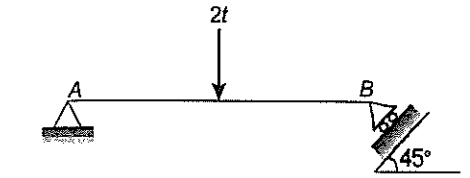
1. Parabola
2. Rectangle
3. Cubic Parabola
4. Triangle

Codes:

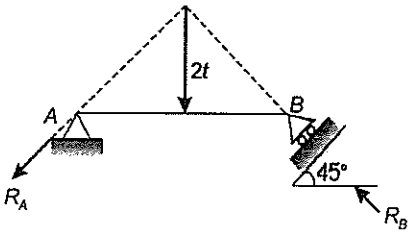
	A	B	C	D
(a)	1	2	3	4
(b)	4	3	2	1
(c)	3	1	4	2
(d)	1	3	4	2

[ESE : 1996]

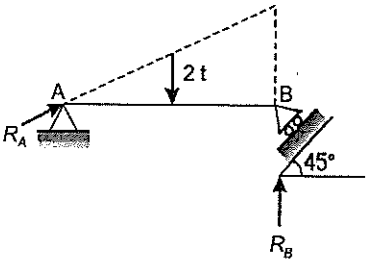
3.13 In a beam AB, support A is hinged and support B is on rollers as shown below. The directions of the reactions at A and B will be as in



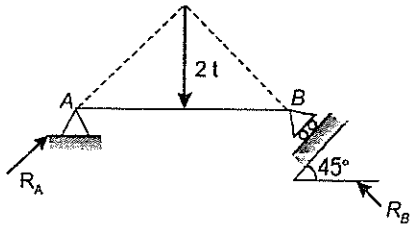
(a)



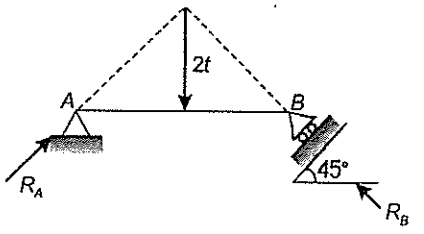
(b)



(c)



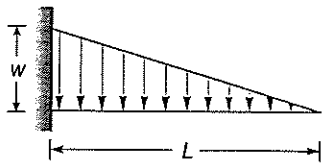
(d)



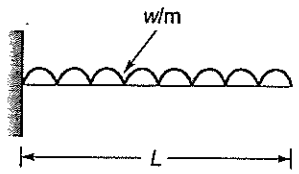
[ESE : 1997]

3.14 Match List-I (Type of beam with type of loading) with List-II (Max. BM Formula) and select the correct answer using the codes given below the lists:

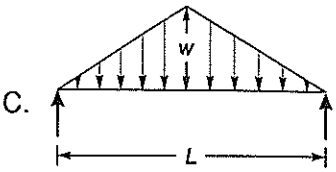
List-I List-II

A. 

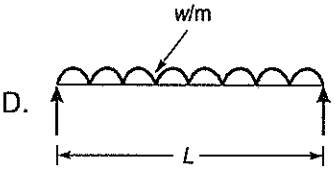
1. $\frac{wL^2}{12}$

B. 

2. $\frac{wL^2}{6}$

C. 

3. $\frac{wL^2}{2}$

D. 

4. $\frac{wL^2}{8}$

Codes:

	A	B	C	D
(a)	2	3	1	4
(b)	1	2	3	4
(c)	4	3	1	2
(d)	2	1	4	3

[ESE : 1997]

3.15 If the area under the shear curve for a beam between the two points X_1 and X_2 is k, then the difference between the moments at the two points X_1 and X_2 will be equal to

(a) k (b) $2k$

(c) $k/2$ (d) k^2

[ESE : 1997]

3.16 **Assertion (A):** Bending moment may be defined as the algebraic sum of the moments of all forces on either side of the section.

Reason (R): The rate of change of bending moment is equal to shear force at the section.

[ESE : 1998]

3.17 Which one of the following statements is NOT correct?

(a) A bending moment diagram can have a change of slope only under a transverse load.

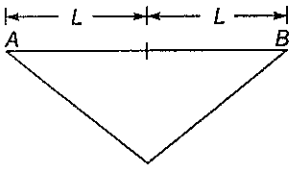
(b) The bending moment is maximum where the shear force is zero.

(c) A non-linear bending moment diagram is possible only in the distributed load regions.

(d) At every support of a continuous beam, the maximum values of negative bending moment in the span are experienced.

[ESE : 1998]

3.18 For a cantilever AB with clamped end A and subjected to concentrated loads, the shape of the bending moment diagram is shown in the adjacent figure. This diagram is



(a) an absurdity
(b) possible only if the free end *B* has an additional couple
(c) possible only if the left half of the beam has twice the moment of inertia as compared to that of the right half
(d) none of the above

[ESE : 1998]

3.19 Consider the following statements:
A simply-supported beam is subjected to a couple somewhere in the span. It would produce
1. a rectangular *SF* diagram
2. parabolic *BM* diagrams
3. both +ve and –ve BMs which are maximum at the point of application of the couple.

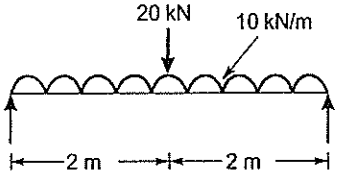
Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE : 1998]

3.20 A beam of length 10 m carries a UDL of 20 kN/m over its entire length and rests on two simple supports. In order that the maximum *BM* produced in the beam is the least possible, the supports must be placed from the ends at a distance of
(a) 5.86 m (b) 4.14 m
(c) 2.93 m (d) 2.07 m

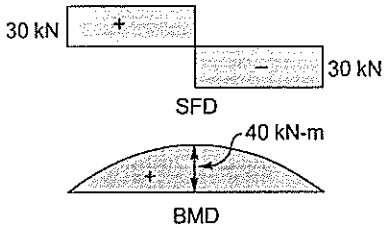
[ESE : 1998]

3.21 A simply supported beam is shown in the given figure

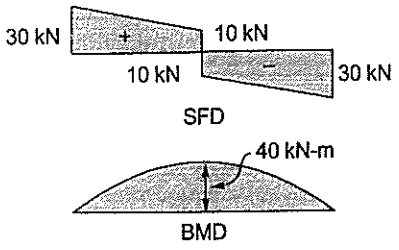


The corresponding SFD and BMD would be

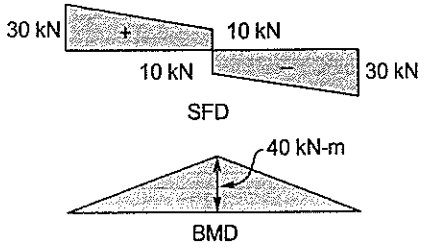
(a)



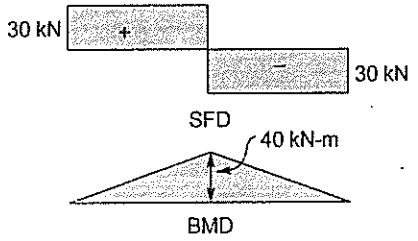
(b)



(c)

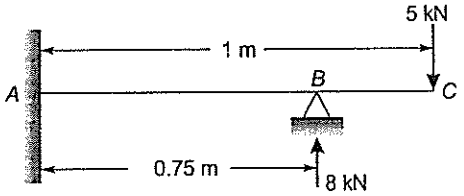


(d)



[ESE : 1999]

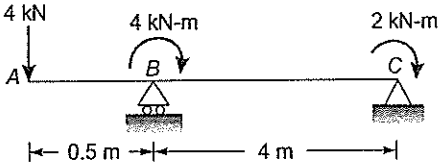
3.22 The beam *ABC* shown in the given figure is horizontal. The distance to the point of contraflexure from the fixed end *A* is



(a) 0.333 m (b) 0.666 m
(c) 0.25 m (d) 0.75 m

[ESE : 1999]

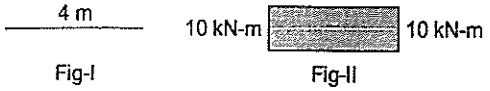
3.23 The beam shown in the given figure has a design bending moment value of



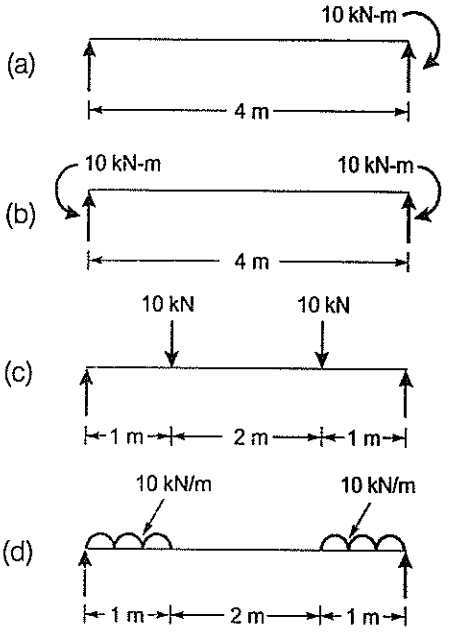
(a) 8 kN-m (b) 6 kN-m
(c) 4 kN-m (d) 2 kN-m

[ESE : 1999]

3.24 A beam's SFD and BMD are shown in Fig-I and Fig-II

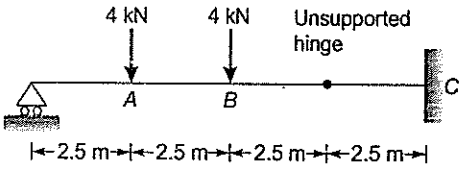


The corresponding load diagram will be



[ESE : 1999]

3.25 The bending moments at point A, B and C of the beam shown in the given figure will be



(a) 10 kN-m, 10 kN-m and 10 kN-m
(b) 10 kN-m, 10 kN-m and – 10 kN-m
(c) 20 kN-m, 10 kN-m and – 10 kN-m
(d) 10 kN-m, – 10 kN-m and 20 kN-m

[ESE : 1999]

3.26 The bending moment diagram of the beam shown in the figure-I is

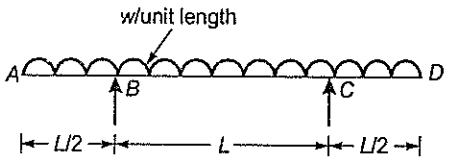
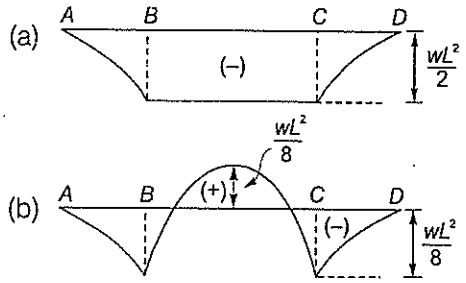
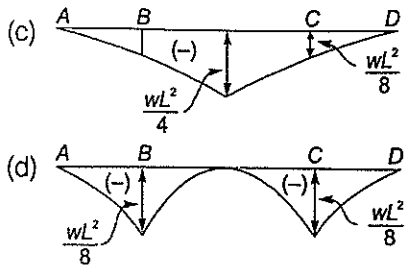


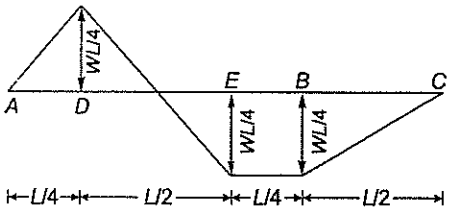
Figure-I



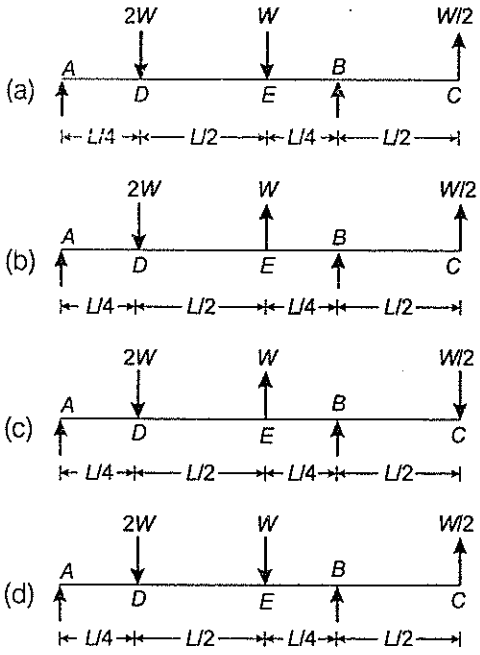


[ESE : 1999]

3.27 A beam *ABC* has simply supported span *AB* and overhanging span *BC*. The bending moment diagram for the beam is given in the following figure:

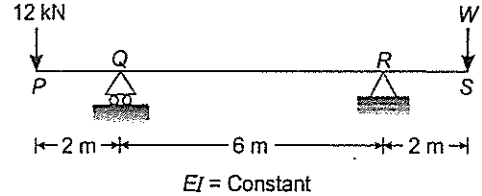


The loading for the beam would correspond to



[ESE : 2000]

3.28 A loaded beam *PQRS* is shown in the given figure.



EI = Constant

The magnitude of reaction at *R* will be zero if the value of load *W* is

(a) 2 kN (b) 2.5 kN
(c) 3 kN (d) 6 kN

[ESE : 2000]

3.29 Assertion (A): The bending moment at a section of a simply supported beam is maximum
(i) in the case of a concentrated load, where the SF changes sign.
(ii) in the case of UDL where shearing force is zero.

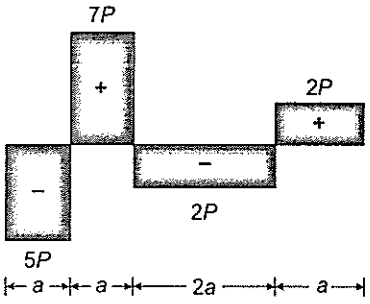
Reason (R): Actually in both the above cases shearing force should be zero at the section of maximum bending moment, because $\frac{dM}{dx} = F = 0$, satisfy the maxima condition.

[ESE : 2002]

3.30 Neglecting self weight, which of the following beams will have points of contraflexure?
(a) A simply supported beam with uniformly distributed load over part of the structure
(b) An overhanging beam with loading only over supported span and not on overhangs
(c) Fixed beam subjected to concentrated load
(d) Cantilever beam subjected to uniformly varying load with zero load at free end

[ESE : 2002]

3.31 The shear force diagram of a beam is shown in the figure.



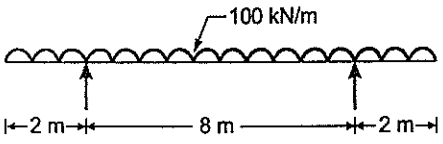
The absolute maximum bending moment in the beam is
(a) $(2P \times a)$ (b) $(5P \times a)$
(c) $(4P \times a)$ (d) $(7P \times a)$

[ESE : 2002]

3.32 If the shear force diagram of a simply supported beam is parabolic, then the load on the beam is
(a) uniformly distributed load
(b) concentrated load at mid span
(c) external moment acting at mid span
(d) linearly varying distributed load

[ESE : 2003]

3.33 The bending moment for which the beam shown below is to be designed is



(a) 200 kN-m (b) 800 kN-m
(c) 600 kN-m (d) 640 kN-m

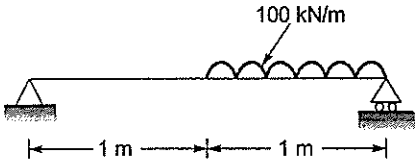
[ESE : 2003]

3.34 Assertion (A): A horizontal beam hinged at one end and freely supported at the other end will be in static equilibrium under inclined load applied on it.

Reason (R): The hinged end will offer resistance to the horizontal component of the applied force.

[ESE : 2003]

3.35 The diagram below shows a simply supported beam with load.



Which one of the following diagrams is the shear force diagram for this beam?

(a)

(b)

(c)

(d)

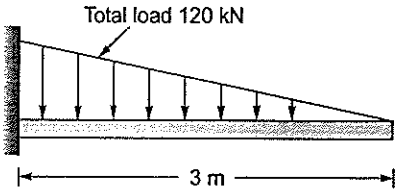
[ESE : 2004]

3.36 In which one of the following, the point of contraflexure will NOT occur?

(a) A two span continuous beam of equal spans, simply supported and loaded by UDL over both spans
(b) A simply supported beam loaded by UDL
(c) A fixed beam loaded by UDL
(d) A propped cantilever loaded by UDL

[ESE : 2004]

3.37 What are the support reactions at the fixed end of the cantilever beam shown in the diagram below?



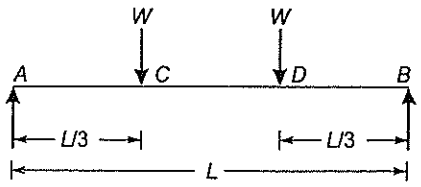
(a) 120 kN, 120 kN-m
(b) 120 kN, 240 kN-m
(c) 240 kN, 120 kN-m
(d) 120 kN, 60 kN-m

[ESE : 2004]

3.38 For shear force to be uniform throughout the span of a simply supported beam, which of the following loads should be applied on to the beam?
(a) Two equally spaced concentric loads
(b) A couple at midspan only
(c) A couple anywhere in the span
(d) UDL over the entire span

[ESE : 2004]

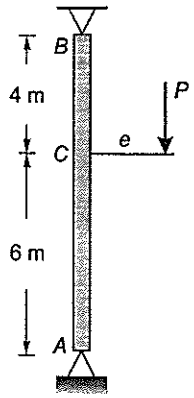
3.39 Consider the simply supported beam *AB* subjected to the point loads of equal magnitude shown in the diagram below:



The portion *CD* of the beam is
(a) in pure bending
(b) in pure shear
(c) having maximum bending moment
(d) having maximum shear force

[ESE : 2004]

3.40 Consider the following statements for the column with a bracket as shown in the figure given below:

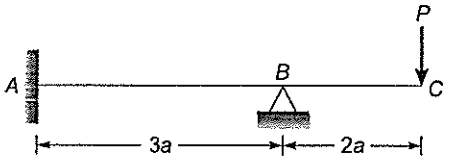


1. Shear force is constant throughout
2. Maximum moment in the column is Pe
3. The compressive axial force in the column is 0.4 P

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 1 only
(c) 1 and 3 (d) 2 only

[ESE : 2005]

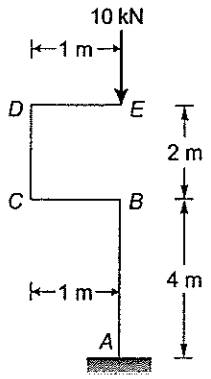
3.41 In the propped cantilever shown in the figure given below, what are the values of the bending moment and shear force at the support A?



(a) 2 Pa, *P*/3 (b) Pa, *P*
(c) Pa, *P*/3 (d) 2 Pa, 4*P*/3

[ESE : 2005]

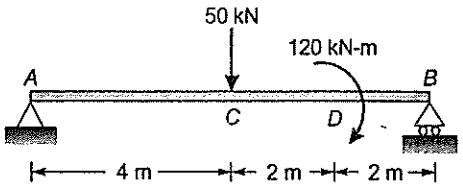
3.42 What is the bending moment at *A* for the bent column shown in the figure given below?



(a) 40 kN-m (b) 20 kN-m
(c) 10 kN-m (d) Zero

[ESE : 2005]

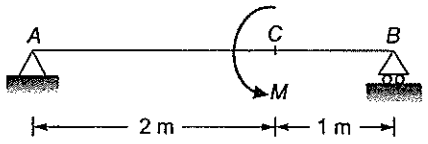
3.43 The beam shown in the figure given below is subjected to concentrated load and clockwise couple. What is the vertical reaction at *A*?



(a) 10 kN (b) 40 kN
(c) 50 kN (d) 30 kN

[ESE : 2005]

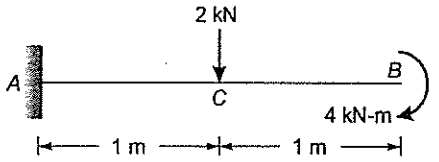
3.44 Couple *M* is applied at *C* on a simply supported beam *AB*. What is the maximum shear force for the beam?



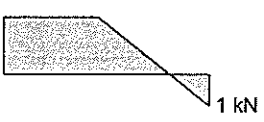
(a) Zero (b) M
(c) 2M/3 (d) M/3

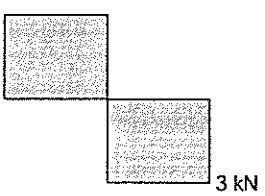
[ESE : 2005]

3.45 A cantilever beam *AB* carries loading as shown in the figure below. Which one of the following is the SFD for the beam?



(a)

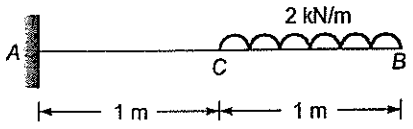
(b)


(c)


(d)

[ESE : 2005]

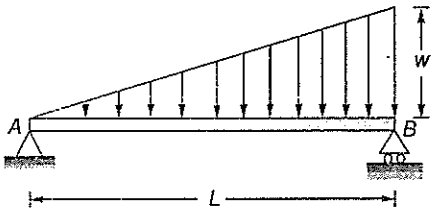
3.46 A cantilever *AB* is loaded as shown in the figure given below. What is the shape of the bending moment diagram for portion *AC*?



(a) Parabolic
(b) Linearly varying with maximum value of bending moment at *C*
(c) Linear with constant bending moment value from *C* to *A*
(d) Linearly varying with maximum value at *A*

[ESE : 2005]

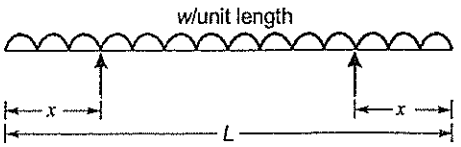
3.47 For the simply supported beam, shown in the figure given below, at what distance from the support *A*, is the shear force zero?



(a) $\frac{L}{4}$ (b) $\frac{L}{3}$
(c) $\frac{L}{2}$ (d) $\frac{L}{\sqrt{3}}$

[ESE : 2005]

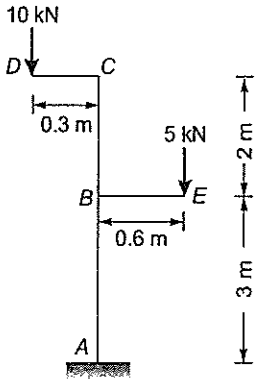
3.48 A uniform beam of span *L* carries a uniformly distributed load '*w*' per unit length as shown in the figure given below. The supports are at a distance of '*x*' from either end. What is the condition for the maximum bending moment in the beam to be as small as possible?

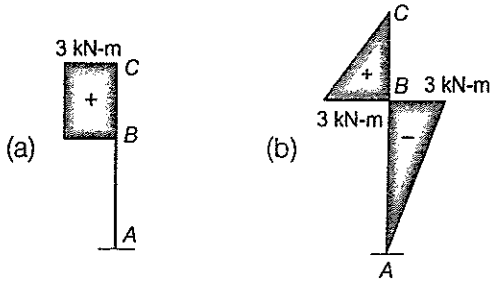


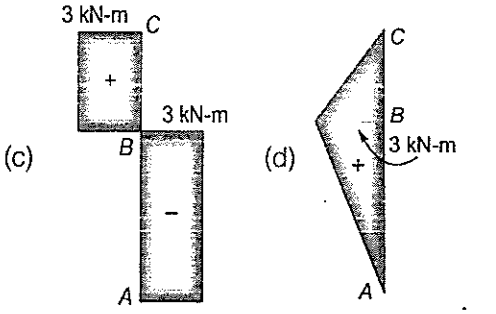
(a) $x = 0.107\,L$ (b) $x = 0.207\,L$
(c) $x = 0.237\,L$ (d) $x = 0.25\,L$

[ESE : 2005]

3.49 Which one of the following is the bending moment diagram for the vertical cantilever beam loaded as shown in the figure below?

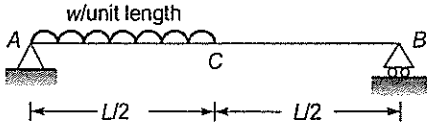


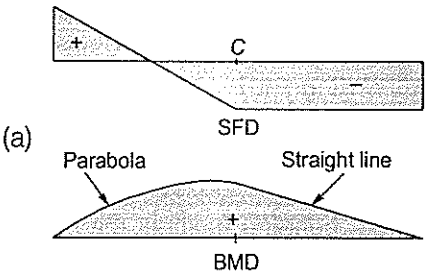


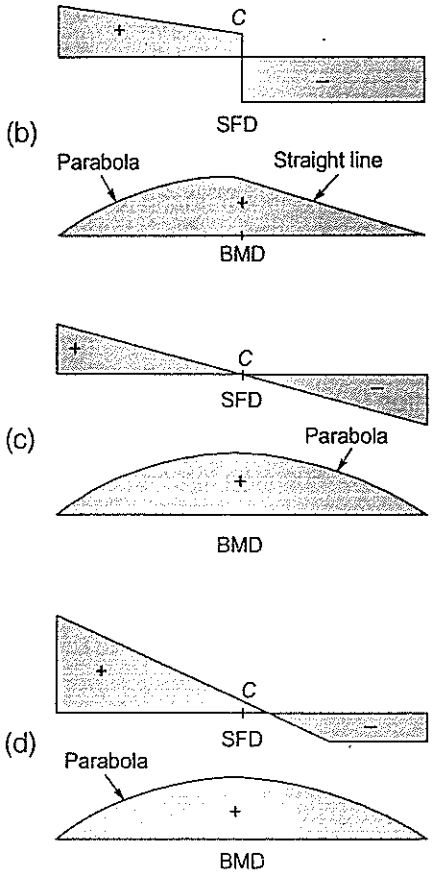


[ESE : 2006]

3.50 A simply supported beam *AB* has span *L* as shown in the figure below, Point *C* is the midspan of the beam. It is subjected to UDL w/unit length, in the portion *A* to *C*. Which of the following are the SFD and BMD for the beam?

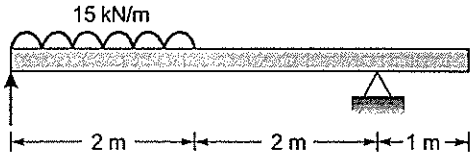






[ESE : 2006]

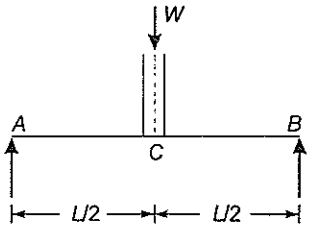
3.51 At what distance from left support of the beam shown below, is the shear force zero?



(a) 1 m (b) 1.25 m
(c) 1.5 m (d) 2.5 m

[ESE : 2007]

3.52 For the simply supported beam in the figure below, *C* is the centre of the span, *C* is also the point through which the resultant of the column load W passes. The column rests on the beam over a small length δl, symmetrically on either side of *C*. What is the shearing force at *C*?



(a) $W/2$ (b) $W/4$
(c) W (d) zero

[ESE : 2007]

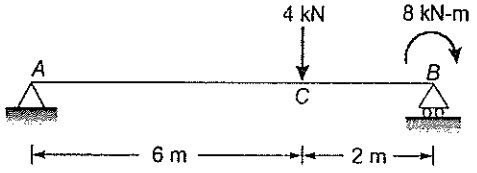
3.53 A simply supported beam AB of span L carries two concentrated loads W each at points $L/3$ from A and B. What is the SF in the middle one-third portion of the beam?
(a) $W/2$ (b) $2W$
(c) W (d) Zero

[ESE : 2008]

3.54 **Assertion (A):** Shearing force may be defined as the rate of change of loading moment.
Reason (R): Shearing force at a section is the algebraic sum of the forces to the left of the section.

[ESE : 2009]

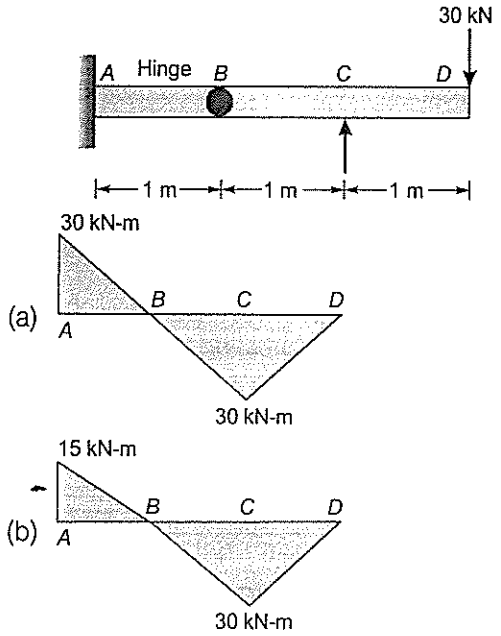
3.55 A simply supported beam AB is loaded as shown in the figure below.



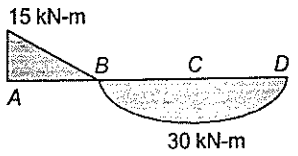
What is the SF in kN in the portion AC of the beam?
(a) 2 (b) 4
(c) 0 (d) 6

[ESE : 2009]

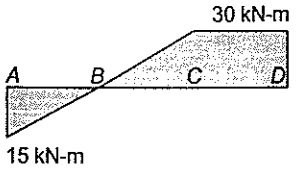
3.56 Which one of the following is the correct bending moment diagram for a propped cantilever beam shown in figure below?



(c)

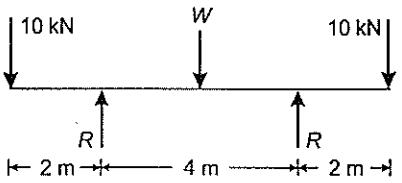


(d)



[ESE : 2009]

3.57 A beam of uniform flexural rigidity supports a set of loads as shown in figure below.



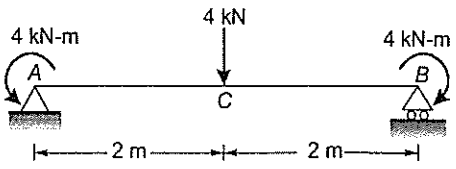
What is the value of W if the magnitudes of bending moment at midspan and at support of the beam are numerically equal ?
(a) 20 kN (b) 40 kN
(c) 60 kN (d) 80 kN

[ESE : 2009]

3.58 Shear span is defined as the zone where
(a) bending moment is zero
(b) shear force is zero
(c) shear force is constant
(d) bending moment is constant

[ESE : 2010]

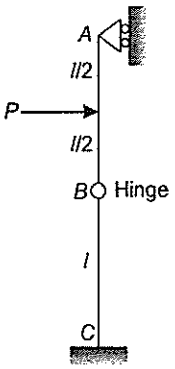
3.59 A simply supported beam is loaded as shown in figure below. The bending moment at C is



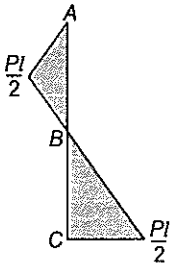
(a) 4 kN-m (Sagging)
(b) 4 kN-m (Hogging)
(c) 8 kN-m (Sagging)
(d) zero

[ESE : 2010]

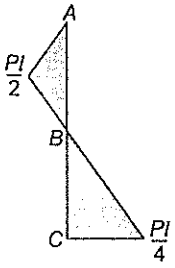
3.60 The correct bending moment diagram for the column is



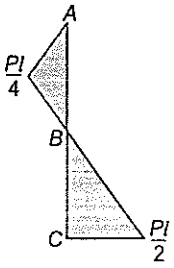
(a)



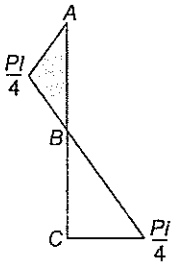
(b)



(c)

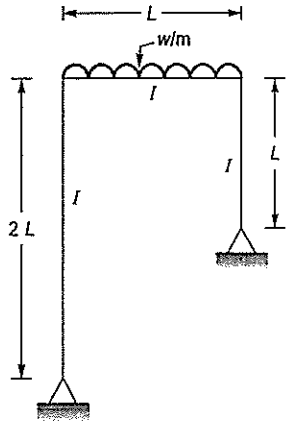


(d)

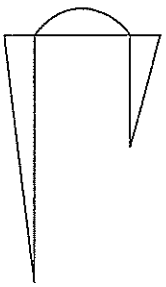


[ESE : 2011]

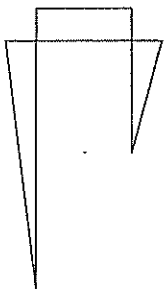
3.61 The bending moment diagram for the below shown portal frame is



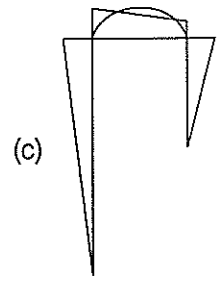
(a)



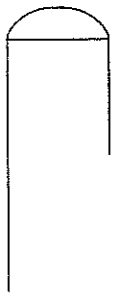
(b)



(c)

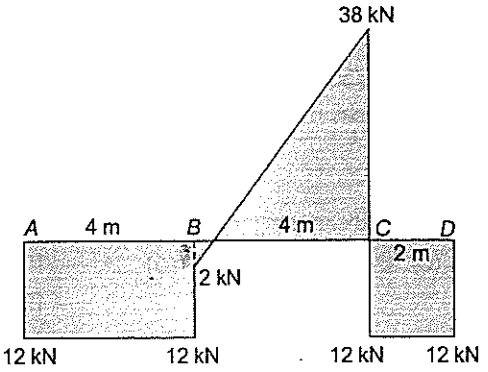


(d)



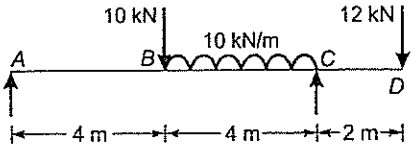
[ESE : 2011]

3.62 The shear force diagram is as shown below:

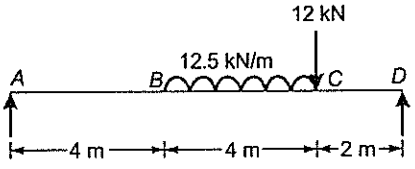


The loading diagram for the above shear force diagram is

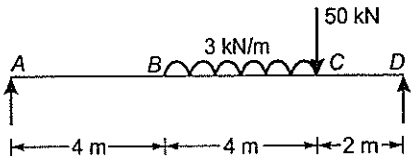
(a)



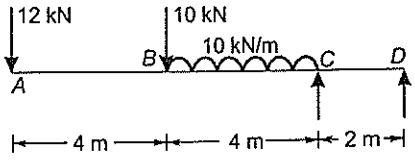
(b)



(c)



(d)



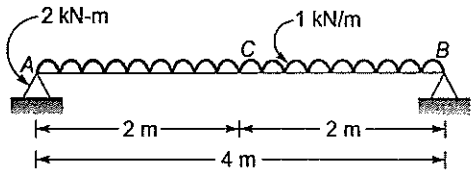
[ESE : 2011]

3.63 A simply supported beam *AB* is subjected to a concentrated load at *C*, the centre of the span. The area of the *SF* diagram from *A* to *C* will give

(a) *BM* at *C*
(b) Load at *S*
(c) *SF* at *C*
(d) Difference between *BM* values at *A* and *C*

[ESE : 2011]

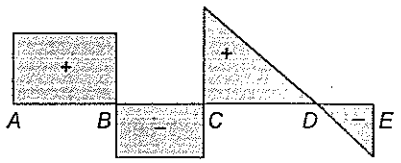
3.64 A freely supported beam *AB* of span 4 m is subjected to a UDL of 1 kN/m over the full span and a moment of 2kN-m at support *A* as shown in the figure. The resulting *BM* at mid-span *C* of the beam will be



(a) 1 kN-m (sagging) (b) 1 kN-m (hogging)
(c) 2 kN-m (sagging) (d) 2 kN-m (hogging)

[ESE : 2012]

3.65 Consider the following statements with reference to a continuous beam supported at *A*, *C* and *E* for which shear force diagram is shown in the below figure.



There is
1. *A* concentrated load acting at point *B*.
2. *A* concentrated load acting at point *D*.
3. *A* uniformly distributed load acting on the portion *CE*.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

[ESE : 2013]

3.66 Which of the following loads should be applied on a simply supported beam, so that the shear force is constant throughout its span?
(a) UDL over the entire span
(b) Two concentrated loads equally spaced in the span
(c) A central concentrated load and a UDL over the entire span
(d) A couple anywhere in the span

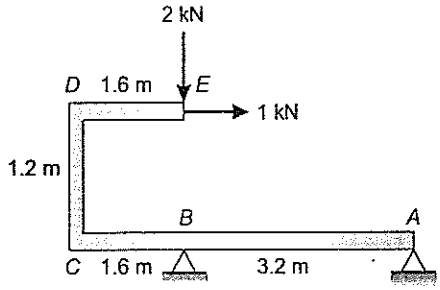
[ESE : 2013]

3.67 Which of the following statements are correct?
1. All load carrying members transmit load through basic modes of tension, compression, torsion and shear only.
2. Beams carry transverse loads.
3. Combined loading is a complicated loading.
4. Nature of internal forces decides the aspect of combined loading.

(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 2 and 4

[ESE : 2013]

3.68 The bending moment at *C* for the beam shown in the figure



is
(a) –3.2 kN-m (b) –4.4 kN-m
(c) –6.2 kN-m (d) –7.2 kN-m

[ESE : 2014]

3.69 A simply supported beam is subjected to a couple at a section within its span. It will produce
1. SF diagram of zero magnitude.
2. Uniformly varying triangular BM diagram.
3. Sudden change in sign of BM at the point of application of the couple.
4. Equal and opposite reactions at supports.

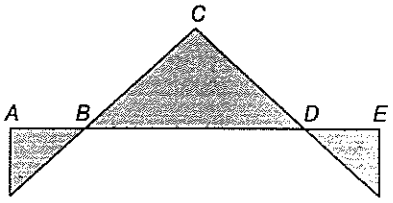
Which of the above statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 1 and 4

[ESE : 2015]

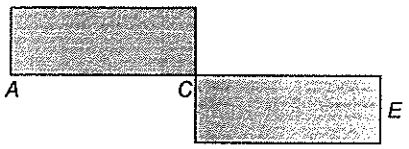
3.70 A beam of overall length *l*, with equal overhangs on both sides, carries a uniformly distributed load over the entire length. To have numerically equal bending moments at the centre of the beam and at its supports, the distance between the supports should be
(a) 0.277 *l* (b) 0.403 *l*
(c) 0.586 *l* (d) 0.707 *l*

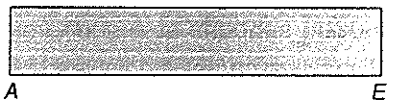
[ESE : 2015]

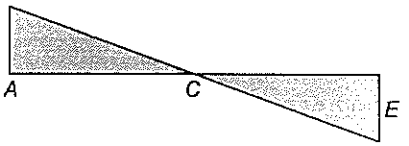
3.71 The bending moment diagram of a beam is shown in the figure.

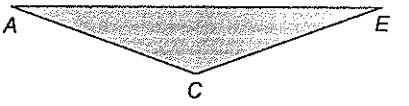


The shear force diagram of the beam is represented by

(a)


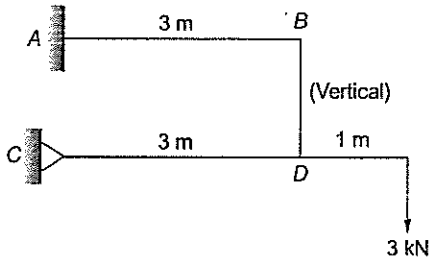
(b)


(c)


(d)


[ESE : 2015]

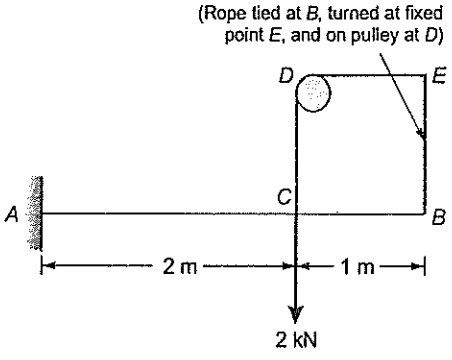
3.72 The bending moment at A for the beam shown below (with BD being a rigid bar) is

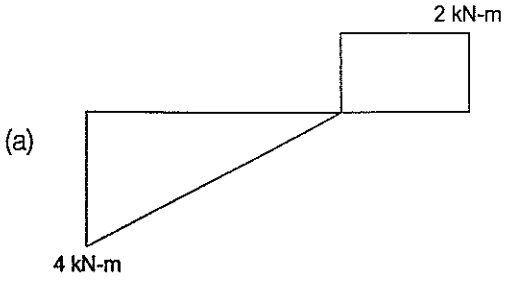


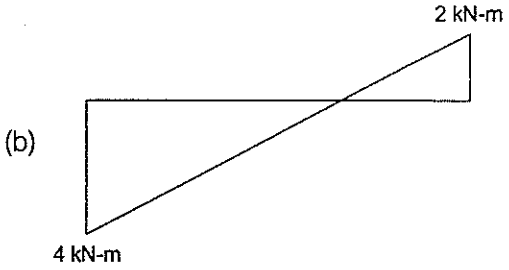
(a) Zero (b) 12 kN-m
(c) 8 kN-m (d) 6 kN-m

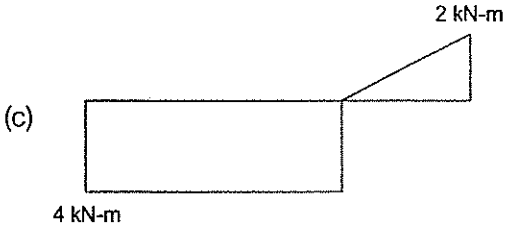
[ESE : 2016]

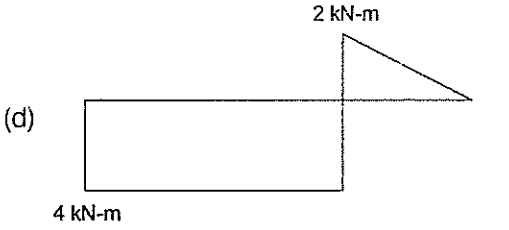
3.73 The bending moment diagram for the beam shown below is



(a)


(b)


(c)


(d)


[ESE : 2016]

3.74 In the analysis of beams subjected to loads, the point with Nil Bending Moment can be a

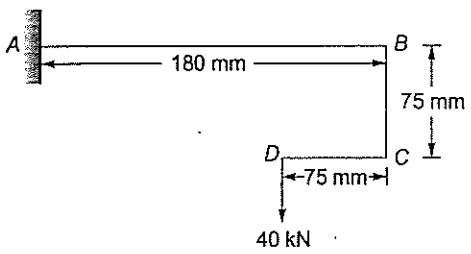
1. Point of Contraflexure
2. Point of Maximum Shear Force
3. Point of Inflection

Which of the above statements is/are correct?

(a) 1 only (b) only
(c) 3 only (d) 1, 2 and 3

[ESE : 2016]

3.75 The bending moment at A for the beam shown below (not to scale) is



(a) 3200 kN.mm (b) 3600 kN.mm
(c) 4200 kN.mm (d) 4800 kN.mm

[ESE : 2016]

3.76 Consider the following statements in respect of arched construction made of voussoirs:

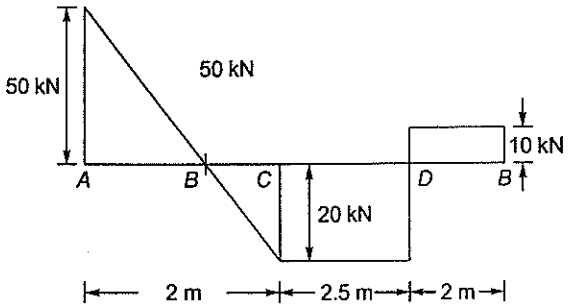
1. The superimposed load is transferred to the sidewalls only be the strength of cohesion of the mortar between the voussoirs.
2. The arch may fail under crushing when the compressive stress or thrust in it exceeds the safe crushing strength of the voussoir material.
3. Every element in the arch is subjected to compression only.
4. Failure of the arch due to the sliding of any voussoir past the adjacent one due to transverse shear can be avoided by reducing the height of the voussoirs.

Which of the above statements are correct?

(a) 1 and 4 only (b) 1 and 3 only
(c) 2 and 4 only (d) 2 and 3 only

[ESE : 2017]

3.77 Consider the following statements with regards to the shear force diagram for the beam ABCD:



1. The beam ABCD is an overhanging beam having supports at A and D only.
2. The beam carries a point load of 20 kN at C.
3. The beam carries a concentrated load of 10 kN at the end B.
4. The beam is an overhanging beam having supports at C and D only.
5. The beam carries a uniformly distributed load of 70 kN over the left hand portion AC only.

Which of the above statements are correct?

(a) 1, 2 and 3 (b) 1, 3 and 5
(c) 2, 3 and 4 (d) 2, 4 and 5

[ESE : 2017]

Answers Shear Force and Bending Moment

3.1 (a)	3.2 (c)	3.3 (a)	3.4 (b)	3.5 (d)	3.6 (a)	3.7 (b)	3.8 (a)	3.9 (c)	
3.10 (d)	3.11 (a)	3.12 (c)	3.13 (c)	3.14 (a)	3.15 (a)	3.16 (b)	3.17 (a)	3.18 (a)	
3.19 (d)	3.20 (d)	3.21 (b)	3.22 (a)	3.23 (d)	3.24 (b)	3.25 (b)	3.26 (d)	3.27 (c)	
3.28 (c)	3.29 (c)	3.30 (c)	3.31 (b)	3.32 (d)	3.33 (c)	3.34 (a)	3.35 (c)	3.36 (b)	
3.37 (a)	3.38 (c)	3.39 (a)	3.40 (c)	3.41 (b)	3.42 (d)	3.43 (a)	3.44 (d)	3.45 (a)	
3.46 (d)	3.47 (d)	3.48 (b)	3.49 (a)	3.50 (a)	3.51 (c)	3.52 (d)	3.53 (d)	3.54 (b)	
3.55 (c)	3.56 (a)	3.57 (b)	3.58 (c)	3.59 (d)	3.60 (c)	3.61 (c)	3.62 (a)	3.63 (a, d)	
3.64 (a)	3.65 (d)	3.66 (d)	3.67 (a)	3.68 (b)	3.69 (c)	3.70 (c)	3.71 (a)	3.72 (b)	
3.73 (*)	3.74 (a)	3.75 (c)	3.76 (d)	3.77 (b)					

Explanations Shear Force and Bending Moment

3.1 (a)

We know that, $\frac{dM}{dx} = V$

So *BM* is maximum where shear force is zero or changes sign.

3.2 (c)

Bending moment

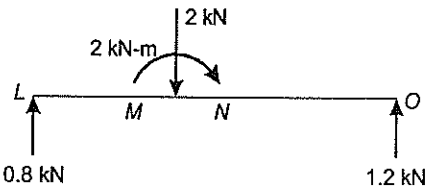
$$M = \int V dx$$

$$V = \int w dx$$

If loading is of n^{th} degree, then bending moment is of (n+2) degree

Shear force diagram is of (n+1) degree

3.3 (a)



The reaction at end *L*,

$$R_L = \frac{1}{5}(2 \times 3 - 2) = 0.8 \text{ kN}$$

The reaction at end *O*,

$$R_O = \frac{1}{5}(2 \times 2 + 2) = 1.2 \text{ kN}$$

The beam will have FBD as

So the BMD will be as shown in figure (a)

3.4 (b)

The SFD does not change, while the sudden change in BMD denotes a concentrated moment at the point *C*. The triangular shape of BMD shows concentrated load is applied at free end.

3.5 (d)

Reaction at *A*,

$$R_A = \frac{2\times1+4\times2+2\times3}{4} = 4\text{t}$$

$R_B = 4$ t

∴ Bending moment at *E*,

$M_E = -2 + 4 \times 2 - 2 \times 1$

$= 4$ t-m (sagging)

3.6 (a)

$\frac{dV}{dx} = -w$ and $\frac{dM}{dx} = V$

3.8 (a)

Section	Thrust (*T*)
AC	3.222
CD	3.222 – 3.464 = – 0.242
DE	– 0.242 + 4.242 = 4.0
EB	4 – 4 = 0

So correct thrust diagram is given in figure (a).

3.9 (c)

For cantilever beam maximum bending moment will occur at support while for simply supported beam maximum bending moment will occur at

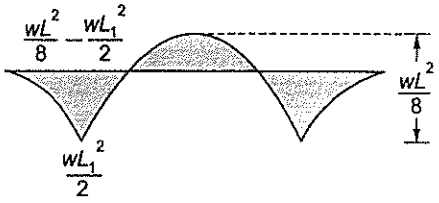
mid point.

Fig.	Maximum BM
A	$\left(\frac{wL}{2}\right)\times\frac{L}{3}=\frac{wL^2}{6}$
B	$(wL)\times\frac{L}{2}=\frac{wL^2}{2}$
C	$\frac{wL^2}{12}$
D	$\frac{wL^2}{8}$

3.10 (d)

The BM can be found from the area of SFD

The shear force diagram is



BMD of the above beam is

Maximum negative, bending moment,

$$M_1=\frac{wL_1^2}{2}$$

Maximum positive, bending moment,

$$M_2=\frac{wL^2}{8}-\frac{wL_1^2}{2}$$

For $M_1=M_2$

$$L_1=\frac{L}{2\sqrt{2}}$$

3.11 (a)

The slope of shear force diagram can be used to find load intensity.

$$\frac{dV}{dx}=-w$$

For point loads and reaction, there is sudden change in shear force at point of application.

Support reaction at A = 14 t

There is no load between A and D as SFD does not change. At D there is sudden change in value of SF from 14 t to – 4 t. So there is point load of 18 t at point D. Between D and B the shape of SFD is linearly decreasing so there is uniformly distributed load between B and D. The intensity of UDL is

$$w=\frac{16-4}{8}=\frac{12}{8}=1.5\ \text{t/m}$$

At B there is sudden change in the SF so there is reaction at B, R_B = 16 + 9 = 25 t

Again between B and C the SFD decreases linearly from 9 t to 3 t. So load intensity

$$w=\frac{9-3}{4}=1.5\ \text{t/m}$$

Finally the SFD decreases to zero suddenly at C. So a point load of 3 t is applied at C.

3.13 (c)

The vertical component of reaction at A and B will be in the upward direction and horizontal component should be equal to each other.

3.15 (a)

$$\frac{dM}{dx}=V$$

$$\therefore M_2-M_1=\int V dx=\text{Area under shear curve}$$

3.16 (b)

$$M=\Sigma M_i$$

$$\frac{dM}{dx}=V$$

But reason is not the correct explanation of Assertion.

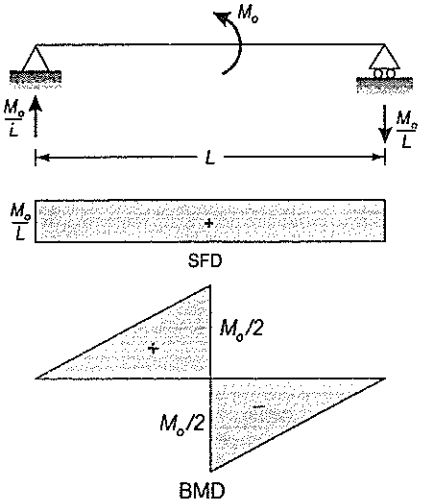
3.17 (a)

The change in slope of BMD occurs when the sign of shear force changes due to concentrated load.

3.18 (a)

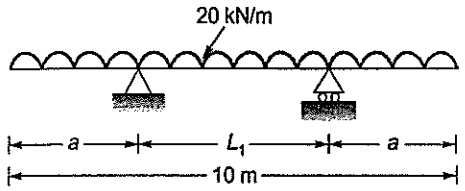
There is no moment at fixed end shown in the diagram so the figure is an absurdity.

3.19 (d)



Thus 1 and 3 are correct.

3.20 (d)



Given $L_1 + 2a = 10$ m

The bending moment will be least when maximum negative moment is equal to maximum positive moment.

$$a = 0.207\,L = 2.07 \text{ m}$$

$$\text{Minimum negative moment} = \frac{wa^2}{2}$$

$$= \frac{20 \times (2.07)^2}{2} = 42.8 \text{ kN-m}$$

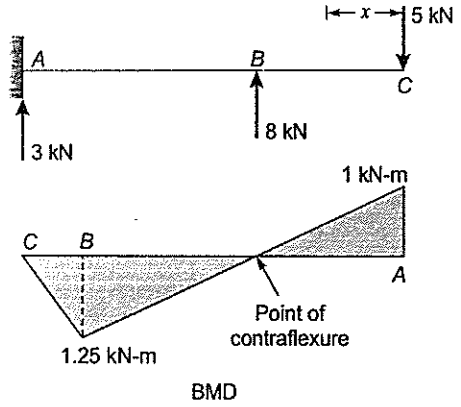
3.21 (b)

Support reaction = 10 + 10 × 2 = 30 kN

The shape of SFD will be linear with sudden drop at point of concentrated load. The shape of BMD will be parabolic.

3.22 (a)

The point where *BM* is zero and changes sign, is called point of contraflexure.



BMD

Distance of point of contraflexure from *A* is *x*,

$5(1 - x) - 8(0.75 - x) = 0$

$$x = 0.333 \text{ m}$$

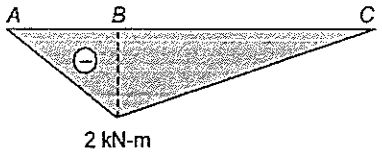
3.23 (d)

4 kN-m moment is sagging

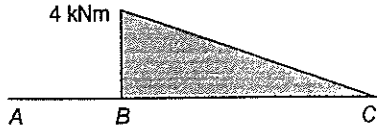
2 kN-m moment is hogging

BMDs

(i) Due to 4 kN load



(ii) Due to 4 kN-m moment



(iii) Due to 2 kN-m moment

BM at $A = 0$

BM at $B = 4 - 2 = 2$ kN-m sagging

BM at $C = -2$ kN-m hogging

So design *BM* is 2 kN-m

3.24 (b)

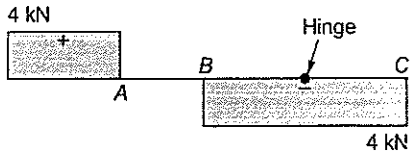
SFD is zero along the span so only opposite couple equal in magnitude are acting on member. The bending moment is hogging in nature.

3.25 (b)

Let *R* is vertical reaction and taking moment about hinge = 0

$\Rightarrow R \times 7.5 - 4 \times 5 - 4 \times 2.5 = 0$

$\therefore R = 4$



$\therefore$ *BM* at $A = 4 \times 2.5 = 10$ kN-m

BM at $B = 10 + 0 = 10$ kN-m

BM at $C = 10 - 4 \times 5 = -10$ kN-m

3.26 (d)

$$BM \text{ at } B = -\frac{1}{2}\frac{wL}{2} \times \frac{L}{2} = -\frac{wL^2}{8}$$

$$BM \text{ at } E = -\frac{wL^2}{8} + \frac{wL^2}{8} = 0$$

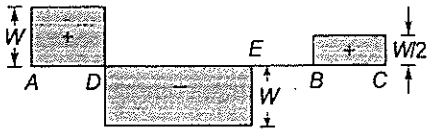
$$BM \text{ at } C = -\frac{wL^2}{8}$$

BM at $D = 0$

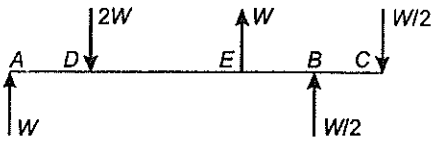
So the correct BMD is (d)

3.27 (c)

$$\text{Shear force diagram, } V = \frac{dM}{dx}$$



Loading diagram



3.28 (c)

For reaction at R to be zero, take moment about Q.

$12 \times 2 = W \times 8$

$\therefore \quad W = 3$ kN

3.29 (c)

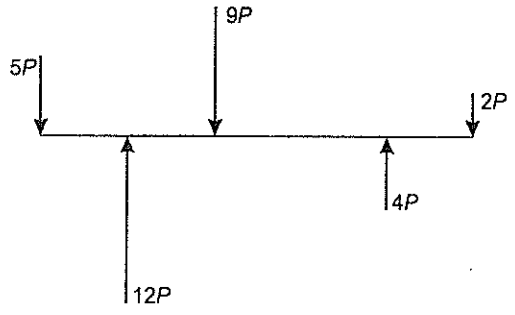
$\frac{dM}{dx} = V = 0$ is applicable for UDL, not concentrated load. Assertion is correct but reason is wrong.

3.30 (c)

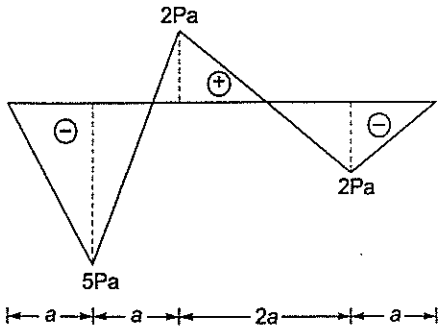
	Beam and loading	Points of contraflexure
(i)	Simply supported beam with UDL over part of the structure.	Zero
(ii)	An overhanging beam with loading only over supported span not on overhangs.	Zero
(iii)	Fixed beam subjected to concentrated load.	Two
(iv)	Cantilever beam subjected to UDL with zero load intensity at free end.	Zero

3.31 (b)

Loading diagram is



So, bending moment diagram is



3.32 (d)

$\frac{dV}{dx} = -w$

If the shear force diagram is parabolic then its slope or load will be linearly varying.

3.33 (c)

The maximum moment can be either at support or at mid span of beam portion between supports.

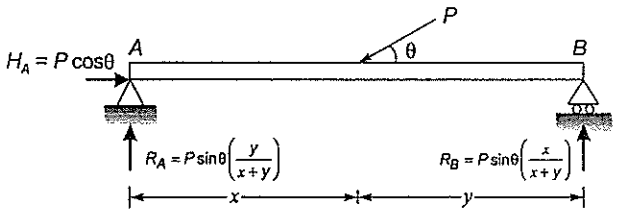
Moment at support

$$= \frac{wa^2}{2} = \frac{100 \times (2)^2}{2} = 200 \text{ kN-m}$$

Moment in mid span $= \frac{wl^2}{8} - \frac{wa^2}{2}$

$$= \frac{100 \times 8^2}{8} - 200 = 600 \text{ kN-m}$$

3.34 (a)



3.35 (c)

On left support, $R_L = \frac{100 \times 0.5}{2} = 25$ kN

On right support, $R_R = 100 - 25 = 75$ kN

Thus (c) represents correct SFD

3.36 (b)

Two span continuous beam with UDL over both spans will have two points of contraflexure. Fixed beam with UDL will have two points of contraflexure.

A propped cantilever beam with UDL will have one point of contraflexure.

3.37 (a)

Vertical reaction, $R = 120$ kN

The centroid of the load is at 1m from the support and therefore the moment

= load × centroid distance from support

Moment = 120 × 1 = 120 kN-m

3.38 (c)

A couple any where in the beam will cause equal and opposite support reactions in the beam. So the SFD will be rectangular or uniform throughout the beam.

3.39 (a)

The SFD and BMD of the beam will show that portion CD has $\frac{WL}{3}$ moment but zero shear force and so it is subjected to pure bending.

3.40 (c)

The deformation of point C in the downward direction will cause tensile stresses in part BC and compressive stress in part CA. Using strain compatibility at C.

$$\frac{P_{BC}L_{BC}}{EA} = \frac{P_{CA}L_{CA}}{EA}$$

$$\therefore \quad P_{BC} \times 4 = P_{CA} \times 6$$

$$\Rightarrow \quad P_{BC} = 1.5\,P_{CA}$$

$$P_{BC} + P_{CA} = P$$

$$P_{CA} = 0.4\,P$$

$$P_{BC} = 0.6\,P$$

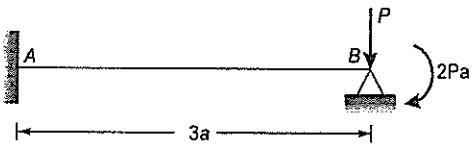
The horizontal reaction at supports

$$V = \frac{Pe}{10}$$

Thus shear force is constant throughout the column.

Maximum bending moment is 0.6 Pe.

3.41 (b)



The load P is replaced by load P and moment 2 Pa at point B. The carry over factor is $\frac{1}{2}$. So the moment at end A is Pa.

$$\Sigma M_B = 0$$

Then reaction at A is $\frac{2Pa + Pa}{3a} = P$.

3.42 (d)

The line of action of 10 kN load coincides with the point A, so there is no moment at A.

3.43 (a)

Taking moment about B, we get

$$R_A = \frac{50 \times 4 - 120}{8} = 10 \text{ kN}$$

3.44 (d)

The reaction at any support is same in magnitude and opposite in direction. The uniform shear force in the beam is $M/3$.

3.45 (a)

The reaction at support will be 2 kN upwards. So the SFD is given by figure (a).

3.46 (d)

There is no load on portion AC, so shear force remains constant throughout AC. Therefore the shape of BMD between AC will be linearly varying with maximum value at A.

3.47 (d)

$$\text{Reaction at } A = \left(\frac{WL}{2}\right) \times \frac{1}{3} = \frac{WL}{6}$$

Let the point of zero shear force occurs at section x from left support A. The load in the same portion is $\left(\frac{Wx}{L}\right) \times \frac{x}{2}$. So the position of zero shear force is $x^2 = \frac{L^2}{3}$ or $x = \frac{L}{\sqrt{3}}$.

3.48 (b)

Maximum positive BM occurs at the centre of beam and it is given as

$$= \frac{WL}{8}\left(L^2 - 4xL\right)$$

Maximum negative BM occurs at the supports and it is given as

$$= \frac{wx^2}{2}$$

For the maximum bending moment in the beam to be as small as possible, the maximum positive and negative BM should be equal i.e.

$$\frac{w}{8}(L^2 - 4xL) = \frac{wx^2}{2}$$

$$\Rightarrow 4x^2 + 4xL - L^2 = 0$$

$$\Rightarrow x = \frac{\sqrt{2}L - L}{2} \text{ and } \frac{-\sqrt{2}L - L}{2}$$

$$\Rightarrow x = 0.207\,L \text{ and } -1.207\,L$$

3.49 (a)

Moment at $C = 10 \times 0.3$ kN-m anti-clockwise.
There is no change of moment from C to B.
The moment at $B = 5 \times 0.6 = 3$ kN-m clockwise
Net moment at in $AB = 3 - 3 = 0$.

3.50 (a)

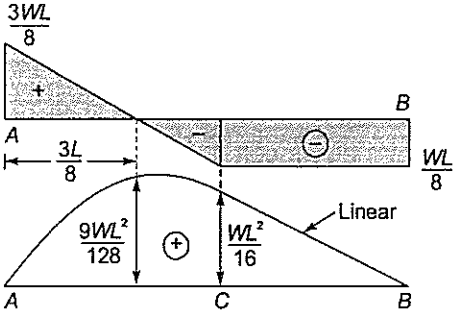
The reaction at support A,

$$R_A = \frac{3wL}{8}$$

The reaction at support B,

$$R_B = \frac{wL}{8}$$

The SFD will be linearly reducing from A to C due to UDL and constant from C to B due to no loading.
The SFD and BMD are shown below.



The BMD is parabolic from A to C and linear from C to B.

3.51 (c)

Let reaction at the left hand support be V in upward direction.
Now, we have

ΣM at right hand support $= 0$

$$\Rightarrow V \times 4 - 15 \times 2 \times (2 + 1) = 0$$

$$\Rightarrow V = 22.5 \text{ kN}$$

Let shear force is zero at a distance x from left hand support, then

$$22.5 - 15x = 0$$

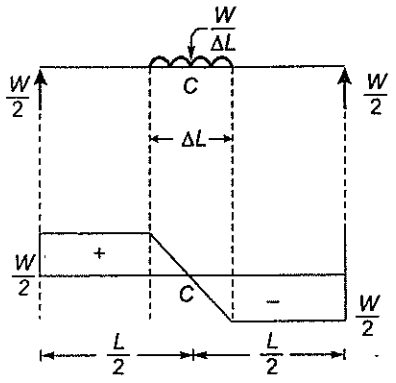
$$\Rightarrow x = \frac{22.5}{15} = 1.5 \text{ m}$$

3.52 (d)

The load W will act as a uniformly distributed load in the length ΔL.

$\therefore$ Intensity of the UDL $= \frac{W}{\Delta L}$

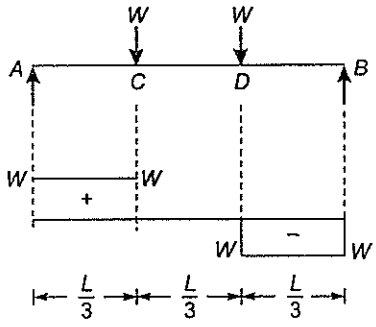
The SFD can be shown as given below:



$\therefore$ Shear force at $C = \frac{W}{2} - \frac{W}{\Delta L} \times \frac{\Delta L}{2} = 0$

3.53 (d)

Shear Force Diagram for the beam is given below.



Since the beam is loaded symmetrically, the reactions at A and B will be equal.

$$S_{C,\text{ right}} = W - W = 0$$

$$S_{D,\text{ left}} = W - W = 0$$

Hence, the middle one-third portion will carry zero shear force.

3.54 (b)

$\frac{dM}{dx} = V$ where M is the loading or bending

moment and V is the shear force.

Shear force is the algebraic sum of forces to the left or to the right of section.

3.55 (c)

Let the vertical reaction at A be V_A upwards. Taking moments about B, we get

$$\Sigma M_B = 0$$
$$\Rightarrow V_A \times 8 - 4 \times 2 + 8 = 0$$
$$\Rightarrow V_A = 0$$

Since there is no transverse force in the portion AC of the beam AB, hence the shear force in the portion AC of the beam will be zero.

3.56 (a)

Let vertical reaction at C be V_C.

$$\therefore \quad \Sigma M_B = 0$$
$$\Rightarrow V_C \times 1 - 30 \times 2 = 0$$
$$\Rightarrow V_C = 60 \text{ kN}$$

If reaction at A be V_A downwards. Then

$$\Sigma F_y = 0$$
$$\Rightarrow -V_A + 60 - 30 = 0$$
$$\Rightarrow V_A = 30 \text{ kN}$$
$$M_A = 60 \times 2 - 30 \times 3$$
$$= 30 \text{ kN-m}$$

For portion AC

$$M_x = 30 - 30x \quad [0 \le x \le 2]$$
$$M_A = 30 \text{ kN-m}$$
$$M_B = 30 - 30 \times 1 = 0$$
$$M_C = 30 - 30 \times 2$$
$$= -30 \text{ kN-m}$$

3.57 (b)

Since the beam is symmetrically loaded, hence the vertical reaction

$$R = \frac{W}{2} + 10$$

Bending moment at mid span

$$= \left(\frac{W}{2} + 10\right) \times 2 - 10 \times 4$$
$$= W + 20 - 40 = -20$$

Bending moment at support

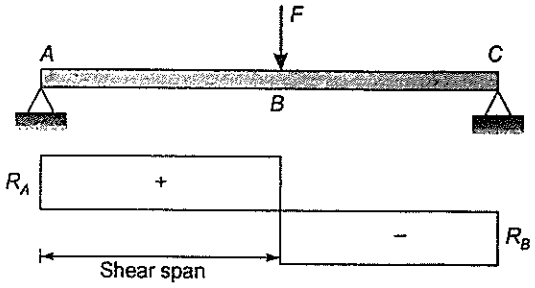
$$= -10 \times 2 = 20 \text{ kN-m}$$

But bending moment at mid span and at support are numerically equal.

$$\therefore \quad W - 20 = 20 = 40 \text{ kN}$$

3.58 (c)

Shear span is defined as the zone where shear force is constant. It is the distance between a reaction and the nearest load point.



3.59 (d)

Let the reaction at B be V_B upwards.

Taking moments about A, we get

$$V_B \times 4 - 4 - 4 \times 2 + 4 = 0$$
$$\Rightarrow V_B = 2 \text{ kN (upwards)}$$

Bending moment at C is given by

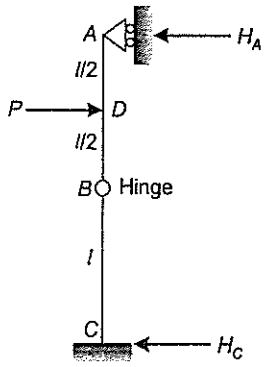
$$M_C = V_B \times 2 - 4 = 2 \times 2 - 4 = 0$$

3.60 (c)

$$\Sigma M_B = 0 \text{ for span } AB$$
$$\Rightarrow H_A \times l = \frac{Pl}{2}$$
$$\Rightarrow H_A = \frac{Pl}{2}$$

Also, $H_A + H_C = P$

$$\Rightarrow H_C = \frac{P}{2}$$



BM at mid span of AB i.e. at D

$$\Rightarrow H_A \times \frac{l}{2} = \frac{Pl}{4} \text{ (Hogging)}$$

Let moment at end C be M_C

$$\Sigma M_B = 0 \quad \text{For span } BC$$

$$\Rightarrow M_C - H_C \times l = 0$$

$$\Rightarrow \quad M_C = H_C \times l$$

$$= \frac{Pl}{2} \text{ (Anticlockwise)}$$

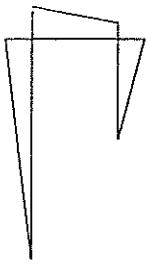
3.61 (c)

The final bending moment diagram will be obtained after the superposition of BMD due to live load and BMD due to end moments.

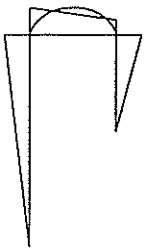
Moment at hinged support = 0

BMD due to LL: $wL^2/8$

BMD due to end moment



Final BMD =



3.62 (a)

Note: In the question given is the shear force diagram and the answer key has loading diagram.

Section *CD*: SFD is constant with magnitude of 12 kN. This shows a downward acting concentrated load at end *D*.

Section *BC*: A sloping SFD denotes a UDL on the span *BC*, with magnitude

$$\frac{38-(-2)}{4} = 10 \text{ kN/m}$$

Section *AB*: Abrupt change in value of *SF* from −2 kN to −12 kN denotes the presence of a concentrated load at *B* acting downward. Its magnitude = 12 − 2 = 10 kN.

3.63 (a, d)

$\frac{dM}{dx}$ = shear force at any section = S_x

on integrating from point *A* to *C*.

$$\Rightarrow \quad \int_A^C dM = \int_A^C S_x \cdot dx$$

or $\quad M_C - M_A =$ Area of S.F.D.

between *A* and *C* ...(i)

Now in a simply supported beam *AB*, bending moment at supports *A* and *B* = 0

i.e. $\quad M_A = M_B = 0$

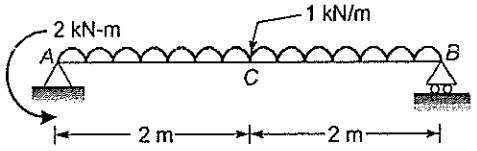
$\therefore$ from (i),

$$M_C - 0 = M_C$$

= Area of SFD between *A* and *C*

$\therefore$ Answer (a) and (d) are correct options

3.64 (a)



The reaction at end *A*

$$\Rightarrow \quad R_A \times 4 = 1 \times 4 \times 2 + 2$$

$$\Rightarrow \quad R_A = 2.5 \text{ kN}$$

$\therefore$ *BM* at mid-span *C* is

$$M_C = 2.5 \times 2 - 1 \times 2 \times 1 - 2$$

$$= 1 \text{ kNm (sagging)}$$

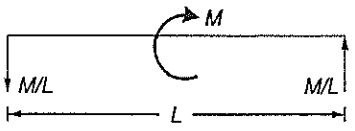
3.65 (d)

$$\frac{dV}{dx} = w$$

Slope of SFD= load intensity

There is sudden change in SFD at point B so there is concentrated load. Slope of SFD is constant in portion CE shows that UDL is acting there.

3.66 (d)

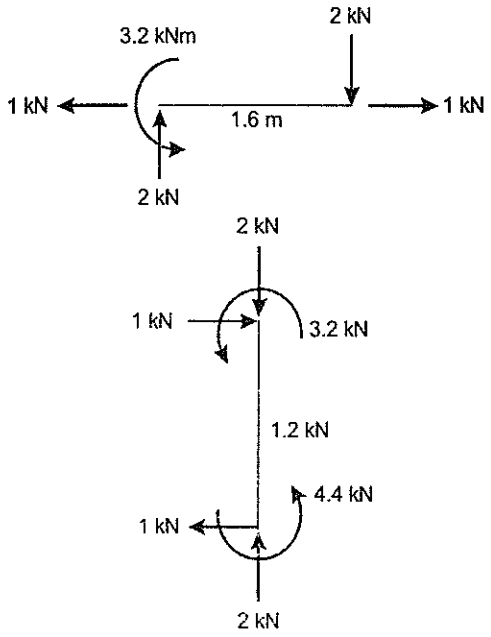


$\therefore \quad SF = \frac{M}{L}$ throughout the beam

3.67 (a)

Combined loading is not a complicated loading.

3.68 (b)



Alternatively

BM at C = Moment from either left end or right end at that section

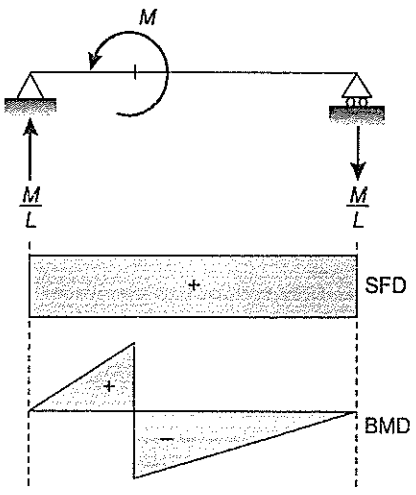
Moment from left end at C

$= 2 \times 1.6 + 1 \times 1.2$

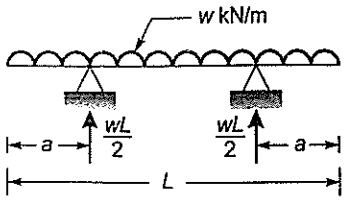
$= 4.4$ kNm (hogging)

Thus BM at $C = 4.4$ kNm

3.69 (c)



3.70 (c)



BM at mid span $= \frac{wL}{2}\left(\frac{L}{2} - a\right) - \frac{wL^2}{8}$ (sagging)

BM at supports $= -\frac{wa^2}{2}$ (hogging)

For numerically equal neglecting the negative sign of hogging BM.

$$\therefore \quad \frac{wa^2}{2} = \frac{wL}{2}\left(\frac{L}{2} - a\right) - \frac{wL^2}{8}$$

$$\Rightarrow \quad a^2 = \frac{L^2}{2} - La - \frac{L^2}{4}$$

$$\Rightarrow \quad a^2 + La - \frac{L^2}{4} = 0$$

$$\therefore \quad a = 0.2071\,L$$

$\therefore$ Distance between supports $= L - 2a$

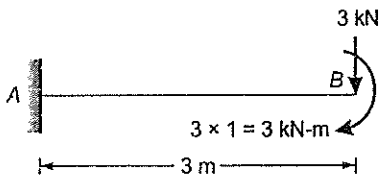
$= 0.586\,L$

3.71 (a)

$$\text{Shear force} = \frac{d}{dx}(\text{Bending moment})$$

As BMD is linear, therefore shear force must be constant and slope of BMD change its sign at mid-span therefore shear force also changes its sign at mid span.

3.72 (b)



$$(3 \times 3) + (3) + (-M_A) = 0$$

$$M_A = 12 \text{ kN-m}$$

3.73 (*)

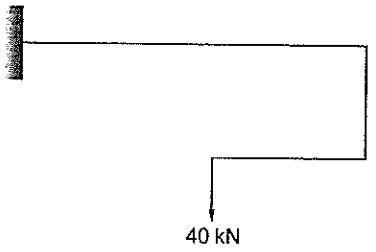
Data given is vague and under the condition of data mentioned none of the option is correct.

3.74 (a)

Point of Contraflexure: Point where BMD changes sign.

Point of inflection: Point of curve (on deflected shape) changes being concave to convex or vice versa.

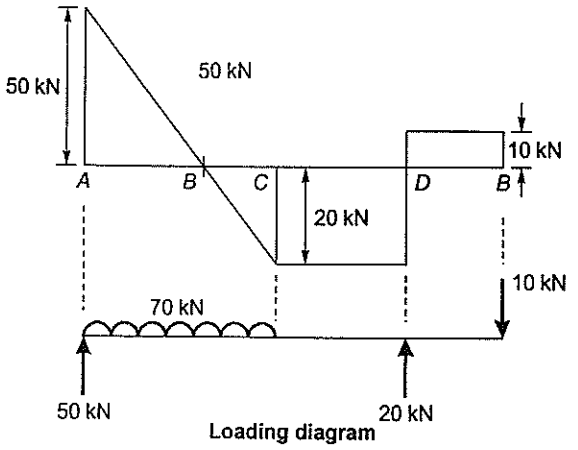
3.75 (c)



$M_A = (40)\,[180 - 75]$

$= 4200$ kN-mm

3.77 (b)



4 Principal Stress-Strain & Theories of Failure

4.1 The cross-section of a bar is subjected to a uniaxial tensile stress 'p'. The tangential stress on a plane inclined at θ to the cross-section of the bar would be

(a) $\frac{p\sin 2\theta}{2}$ (b) $p\sin 2\theta$

(c) $\frac{p\cos 2\theta}{2}$ (d) $p\cos 2\theta$

[ESE : 1995]

4.2 Consider the following statements:

1. On planes having maximum and minimum principal stresses, there will be no tangential stress.
2. Shear stresses on mutually perpendicular planes are numerically equal.
3. Maximum shear stress is equal to half the sum of the maximum and minimum principal stresses.

Which of these statements is/are correct?

(a) Only 1 is (b) 1 and 2

(c) 2 and 3 (d) 1 and 3

[ESE : 1995]

4.3 In a stressed body, an elementary cube of material is taken at a point with its faces perpendicular to X and Y reference axes. Tensile stresses equal to 15 kN/cm^2 and 9 kN/cm^2 are observed on these respective faces. They are also accompanied by shear equal to 4 kN/cm^2. The magnitude of the principal stresses at the point are

(a) 12 kN/cm^2 tensile and 3 kN/cm^2 tensile

(b) 17 kN/cm^2 tensile and 7 kN/cm^2 tensile

(c) 9.5 kN/cm^2 compressive and 6.5 kN/cm^2 compressive

(d) 12 kN/cm^2 tensile and 13 kN/cm^2 tensile

[ESE : 1995]

4.4 In a rectangular element subjected to like principal tensile stresses 'p_1' and 'p_2' in two mutually perpendicular directions X and Y, the maximum shear would occur along the

(a) plane normal to X-axis

(b) plane normal to Y-axis

(c) plane at 45° to Y-direction

(d) planes at 45° and 135° to the Y-direction

[ESE : 1995]

4.5 At a point in a structure, there are two mutually perpendicular tensile stresses of 800 kg/cm^2 and 400 kg/cm^2. If the Poisson's ratio $\mu = 0.25$, what would be the equivalent stress in simple tension according to maximum principal strain theory?

(a) 1200 kg/cm^2 (b) 900 kg/cm^2

(c) 700 kg/cm^2 (d) 400 kg/cm^2

[ESE : 1995]

4.6 According to maximum shear stress failure criterion, yielding in material occurs when

(a) maximum shear stress = $\frac{1}{2}$ yield stress

(b) maximum shear stress = $\sqrt{2}\times$ yield stress

(c) maximum shear stress = $\sqrt{3}\times$ yield stress

(d) maximum shear stress = $2\times$ yield stress

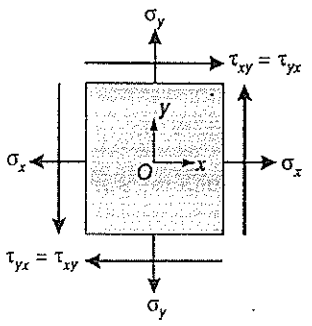
[ESE : 1995]

4.7 On an element shown in the given figure, the stresses are:

$\sigma_x = 110$ MPa

$\sigma_y = 30$ MPa

$\tau_{xy} = \tau_{yx} = 30$ MPa



The radius of Mohr's circle and the principal stresses σ_1, σ_2 are (in MPa)

	Radius = r	σ_1	σ_2
(a)	50	120	20
(b)	55	30	110
(c)	60	140	20
(d)	70	140	20

[ESE : 1996]

4.8 Consider the following statements:

1. In a member subjected to uniaxial tensile force the maximum normal stress is the external load divided by the maximum cross-sectional area.
2. When the structural member is subjected to uniaxial loading, the shear stress is zero on a plane where the normal stress is maximum.
3. In a member subjected to uniaxial loading, the normal stress on the planes of maximum shear stress is less than the maximum.

Which of these statements are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 1996]

4.9 A certain steel has proportionality limit of 3000 kg/cm^2 in simple tension. It is subjected to principal stresses of 1200 kg/cm^2 (tensile), 600 kg/cm^2 (tensile) and 300 kg/cm^2 (compressive). The factor of safety according to maximum shear stress theory is

(a) 1.50 (b) 1.75
(c) 1.80 (d) 2.00

[ESE : 1996]

4.10 In a two dimensional stress system, it is assumed that the principal stress σ_1 and σ_2 are such that $\sigma_1 > \sigma_2$; then according to the maximum shear stress theory, the failure occurs when (where σ_y is the yield stress, μ is the Poisson's ratio and E is the modulus of elasticity)

(a) $\frac{1}{E}(\sigma_1 - \mu\sigma_2) \geq \frac{\sigma_y}{E}$

(b) $\sigma_1^2 + \sigma_2^2 + 2\mu\sigma_1\sigma_2 \geq \sigma_y^2$

(c) $\sigma_1 - \sigma_2 \geq \sigma_y$

(d) $\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2 \geq \sigma_y$

[ESE : 1996]

4.11 **Assertion (A):** The inclination of the line joining any point P on the Mohr's circle and the origin O with X-axis equals twice the angle between the resultant stress and the normal of the plane for which P stands.

Reason (R): The inclination of the line joining any point P on the Mohr's circle and the centre of the circle C with X-axis equals twice the angle between the plane for which P stands and zero degree plane.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

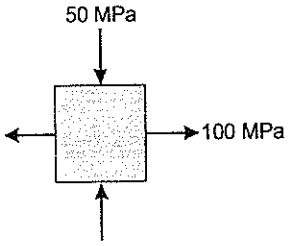
[ESE : 1996]

4.12 At a point in a strained material, if two mutually perpendicular tensile stresses of 2000 kg/cm^2 and 1000 kg/cm^2 are acting, then the intensity of tangential stress on a plane inclined at 15° to the axis of the minor stress will be

(a) 125 kg/cm^2 (b) 250 kg/cm^2
(c) 500 kg/cm^2 (d) 1000 kg/cm^2

[ESE : 1997]

4.13 For the state of stress shown in the below figure, normal stress acting on the plane of maximum shear stress is



(a) 25 MPa compression
(b) 75 MPa compression
(c) 25 MPa tension
(d) 75 MPa tension

[ESE : 1997]

4.14 According to the distortion energy theory, failure will NOT occur when (symbols have the usual meaning)

(a) $\left[\frac{(\sigma_1-\sigma_2)^2 + (\sigma_2-\sigma_3)^2 + (\sigma_3-\sigma_1)^2}{2}\right]^{\frac{1}{2}} \leq \sigma_0$

(b) $\left[(\sigma_1-\sigma_2)^2 + 4\tau^2\right]^{\frac{1}{2}} \leq \sigma_0$

(c) $\left[(\sigma_1^2+\sigma_2^2+\sigma_3^2)-\frac{1}{m}(\sigma_1\sigma_2+\sigma_2\sigma_3+\sigma_3\sigma_1)\right]^{\frac{1}{2}} \le \sigma_0$

(d) $\left[\frac{(\sigma_1-\sigma_2)+(\sigma_1-\sigma_2)^2+4\tau^2}{2}\right]^{\frac{1}{2}} \le \sigma_0$

[ESE : 1997]

4.15 In a strained body, the three principal stresses at a point are denoted by σ_1, σ_2 and σ_3 such that $\sigma_1 > \sigma_2 > \sigma_3$. If σ_0 denoted yield stress, then according to the maximum shear stress theory

(a) $\sigma_1 - \sigma_2 = \sigma_0$ (b) $\sigma_1 - \sigma_3 = \sigma_0$

(c) $\sigma_2 - \sigma_3 = \sigma_0$ (d) $\frac{\sigma_1+\sigma_3}{2} = \sigma_0$

[ESE : 1997]

4.16 All the failure theories gives nearly the same result

(a) when one of the principal stresses at a point is large in comparison to the other

(b) when shear stresses act

(c) when both the principal stresses are numerically equal

(d) for all situations of stress

[ESE : 1997]

4.17 A cube is subjected to equal tensile stress on all the three faces. If the yield stress of the material is 'σ_y' then based on the strain energy theory, the maximum tensile stress will be

(a) $\frac{\sigma_y}{\sqrt{3(1-2\mu)}}$ (b) $\frac{\sigma_y}{\sqrt{3(2-\mu)}}$

(c) $\frac{\sigma_y}{\sqrt{3(1-\mu)}}$ (d) $\frac{\sigma_y}{\sqrt{3(1+\mu)}}$

[ESE : 1997]

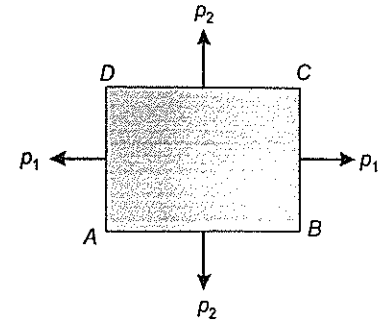
4.18 In a plane stress problem there are normal tensile stresses σ_x and σ_y accompanied by shear stress τ_{xy} at a point along orthogonal Cartesian co-ordinates x and y respectively. If it is observed that the minimum principal stress on a certain plane is zero then

(a) $\tau_{xy} = \sqrt{\sigma_x + \sigma_y}$ (b) $\tau_{xy} = \sqrt{\sigma_x - \sigma_y}$

(c) $\tau_{xy} = \sqrt{\sigma_x \sigma_y}$ (d) $\tau_{xy} = \sqrt{\frac{\sigma_x}{\sigma_y}}$

[ESE : 1998]

4.19 A plane rectangular element is subjected to two normal stresses 'p_1' and 'p_2' on two mutually perpendicular planes ($p_1 > p_2$) as shown in the figure.



Which one of the following statements is NOT true in this regard?

(a) The planes *BC* and *CD* are principal planes.

(b) Shear stress will act on planes inclined to planes *AB* and *CB*.

(c) There will not be any normal stress on planes having maximum shear stress.

(d) There will not be any shear stress on planes *AB* and *BC*.

[ESE : 1998]

4.20 At a point in a steel member, the major principal stress is 200 MPa (tensile) and the minor principal stress is compressive. If the uniaxial tensile yield stress is 250 MPa, then according to the maximum shear stress theory, the magnitude of the minor principal stress (compressive) at which yielding will commence is

(a) 200 MPa (b) 100 MPa

(c) 50 MPa (d) 25 MPa

[ESE : 1998]

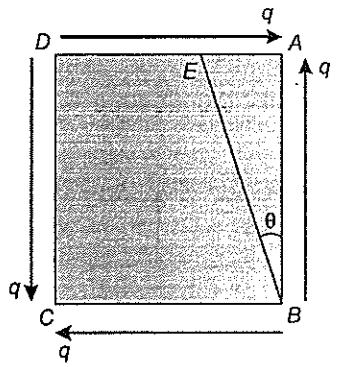
4.21 The limit of proportionality of a certain steel sample is 300 MPa in simple tension. It is subjected to principal stresses of 150 MPa (tensile), 60 MPa (tensile) and 30 MPa (tensile). According to the maximum principal stress theory, the factor of safety in this case would be

(a) 10 (b) 5

(c) 4 (d) 2

[ESE : 1998]

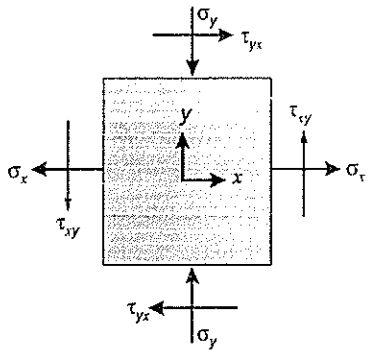
4.22 The rectangular block shown in the given figure is subjected to pure shear of intensity 'q'. If *BE* represents the principal plane and the principal stresses are σ_1, σ_2; then the values of θ, σ_1 and σ_2 will be respectively



(a) 0°, 90°; + q and – q
(b) 30°, 120°; + q and – q
(c) 45°, 135°; + $\frac{q}{2}$ and $-\frac{q}{2}$
(d) 45°, 135°; + q and – q

[ESE : 1999]

4.23 The state of stresses on an element is shown in the given figure. The values of stresses are σ_x (= 32 MPa); σ_y (= – 10 MPa) and major principal stress σ_1 (= 40 MPa). The minor principal stress σ_2 is



(a) – 22 MPa
(b) – 18 MPa
(c) 22 MPa
(d) indeterminable due to insufficient data

[ESE : 1999]

4.24 The radius of Mohr's circle of stress of a strained element is 20 N/mm^2 and minor principal tensile stress is 10 N/mm^2. The major principal stress is
(a) 30 N/mm^2 (b) 50 N/mm^2
(c) 60 N/mm^2 (d) 100 N/mm^2

[ESE : 1999]

4.25 A material of Young's modulus E and Poisson's ratio μ is subjected to two principal stresses σ_1 and σ_2 at a point in a two-dimensional stress system. The strain energy per unit volume of the material is

(a) $\frac{1}{2E}\left(\sigma_1^2+\sigma_2^2-2\mu\sigma_1\sigma_2\right)$
(b) $\frac{1}{2E}\left(\sigma_1^2+\sigma_2^2+2\mu\sigma_1\sigma_2\right)$
(c) $\frac{1}{2E}\left(\sigma_1^2-\sigma_2^2+2\mu\sigma_1\sigma_2\right)$
(d) $\frac{1}{2E}\left(\sigma_1^2-\sigma_2^2-2\mu\sigma_1\sigma_2\right)$

[ESE : 1999]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.26 **Assertion (A):** In a two dimensional stress system, the direct stresses on two planes at 45° and 135° to the principal planes have the same magnitude and nature and shear stress.
Reason (R): Points representing these stresses are on the ends of vertical diameter of the Mohr's circle.

[ESE : 2000]

4.27 **Assertion (A):** In the analysis of two dimensional stresses, the normal stress on a plane will be greater than the average principal stress, if the inclination of that plane with the plane of maximum principal stress is less than 45°.
Reason (R): The horizontal coordinate of the point on the Mohr's circle represents the stresses on the given plane which is greater than the coordinate of the centre of Mohr's circle.

[ESE : 2000]

4.28 Match **List-I** (Theory of failures) with **List-II** (Scientists) and select the correct answer using the codes given below the lists:

List-I
A. Maximum principal stress theory
B. Maximum shear stress theory

C. Maximum principal strain theory
D. Maximum distortion energy theory

List-II
1. St. Venant
2. Beltrami and Haigh
3. Tresca
4. Von-Mises
5. Rankine

Codes:

	A	B	C	D
(a)	5	3	1	4
(b)	5	1	2	4
(c)	3	5	1	2
(d)	3	1	2	5

[ESE : 2000]

4.29 A member is made of structural steel. When it is subjected to simple tension, the limit of proportionality is 280 N/mm^2. If the principal stresses p_1 and p_2 developed in the member are 100 N/mm^2 (tensile) and 40 N/mm^2 (compressive) respectively and Poisson's ratio is 0.30, then the factor of safety according to maximum shear stress theory would be
(a) 2.75 (b) 2.5
(c) 2.25 (d) 2.0

[ESE : 2000]

4.30 The principal stresses at a point in a strained material are 'p_1' and 'p_2'. The resultant stress 'p_r' on the plane carrying the maximum shear stress would be

(a) $\frac{(p_1^2 + p_2^2)^{1/2}}{2}$ (b) $\left[\frac{p_1^2 + p_2^2}{2}\right]^{1/2}$

(c) $\left[2\left(p_1^2 + p_2^2\right)\right]^{1/2}$ (d) $2\left[p_1^2 + p_2^2\right]^{1/2}$

[ESE : 2000]

4.31 If a prismatic member having area of cross-section A is subjected to a tensile load P, then the maximum shear stress and its inclination with the direction of load will be

(a) $\frac{P}{A}$ and 45° (b) $\frac{2P}{A}$ and 45°

(c) $\frac{P}{2A}$ and 45° (d) $\frac{P}{A}$ and 60°

[ESE : 2000]

4.32 In a two dimensional stress system, the two principal stresses are σ_1 of 180 N/mm^2 (tensile) and σ_2 (compressive). For the material, yield stress in simple tension and compression is 240 N/mm^2 and Poisson's ratio is 0.25. According to maximum normal strain theory, the value of σ_2 at which yielding will commence, is
(a) 240 N/mm^2 (b) 180 N/mm^2
(c) 195 N/mm^2 (d) 200 N/mm^2

[ESE : 2001]

4.33 **Assertion (A):** The failure surface of a mild steel torsion specimen subject to a torque about its axis is along a surface perpendicular to its axis.
Reason (R): Mild steel is relatively weaker in shear than in tension and the plane of maximum shear is perpendicular to its axis.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

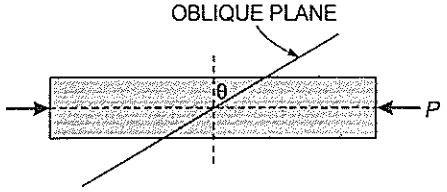
[ESE : 2001]

4.34 Consider the following statements:
Mohr's Circle is used to determine the stress on an oblique section of a body subjected to
1. direct tensile stress on one plane accompanied by a shear stress.
2. direct tensile stresses in two mutually perpendicular directions accompanied by a simple shear stress.
3. direct tensile stress in two mutually perpendicular directions.
4. a simple shear stress

Select the correct answer using the codes given below:
(a) 1 and 4 (b) 2 and 3
(c) 1, 2, 3 and 4 (d) 1, 2 and 3

[ESE : 2002]

4.35 A bar of square cross-section, having an area of cross-section A is subjected to a compressive force P as shown in the figure



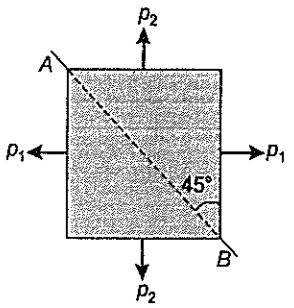
The intensity of the tangential stress on the oblique plane is given by

(a) $\frac{P}{A}\sin 2\theta$ (b) $\frac{P}{A}\cos 2\theta$

(c) $\frac{P}{2A}\sin 2\theta$ (d) $\frac{P}{2A}\cos 2\theta$

[ESE : 2002]

4.36 'p_1' and 'p_2' are two equal tensile principal stresses. On the plane AB inclined at 45° to the plane of 'p_1' as shown in the figure below



(a) the shear stress is maximum
(b) the normal stress is zero
(c) the shear stress is zero
(d) the normal stress is maximum

[ESE : 2002]

4.37 The principal strains at a point are $+800 \times 10^{-6}$ cm/cm, $+400 \times 10^{-6}$ cm/cm and -1200×10^{-6} cm/cm. The volumetric strain is equal to

(a) $+1200 \times 10^{-6}$ cm/cm
(b) $+800 \times 10^{-6}$ cm/cm
(c) -1200×10^{-6} cm/cm
(d) zero

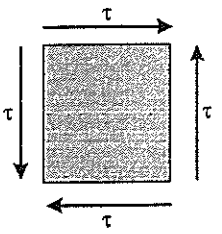
[ESE : 2003]

4.38 The radius of Mohr's circle is zero when the state of stress is such that

(a) shear stress is zero
(b) there is pure shear
(c) there is no shear stress but identical direct stresses in two mutually perpendicular directions
(d) there is no shear stress but equal direct stresses, opposite in nature, in two mutually perpendicular directions

[ESE : 2003]

4.39 The given figure shows the stress condition of an element. The principal stresses are



(a) $\pm 2\tau$ (b) $\pm\frac{\tau}{2}$

(c) $\pm\tau$ (d) $\pm\frac{2\tau}{3}$

[ESE : 2003]

4.40 If the principal stresses at a point in a stressed body are 150 kN/m^2 tensile and 50 kN/m^2 compressive, then maximum shear stress at this point will be

(a) 100 kN/m^2 (b) 150 kN/m^2
(c) 200 kN/m^2 (d) 250 kN/m^2

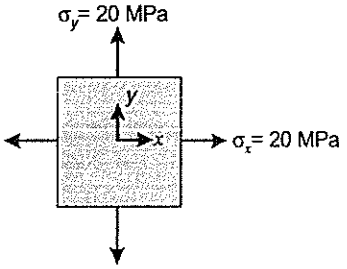
[ESE : 2003]

4.41 In the Mohr's circle for strains, radius of Mohr's circle gives the

(a) minimum value of normal strain
(b) maximum value of normal strain
(c) maximum value of shear strain
(d) half of maximum value of shear strain

[ESE : 2003]

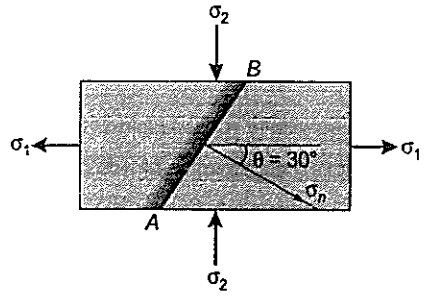
4.42 For the plane stress situation shown in the diagram below, what is the maximum shear stress?



(a) Zero, when X and Y axes are rotated 45° clockwise
(b) Zero, at all positions of orientation of X and Y axes
(c) 20 MPa, at all positions of orientation of X and Y axes
(d) –20 MPa, when X and Y axes are rotated 45° anticlockwise

[ESE : 2004]

4.43 In a piece of stressed material, the principal stress are σ_1 = 3.0 kN/m^2 tensile and σ_2 = 7.0 kN/m^2 compressive as shown in the diagram below.

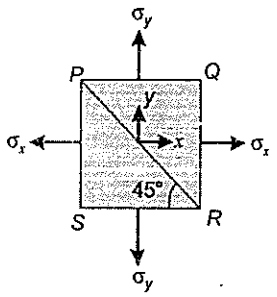


The line of action of the tensile stress makes an angle θ = 30° to the normal to the plane *AB*. What is the normal stress σ_n?

(a) +0.5 kN/m² (b) –1.5 kN/m²
(c) +2.0 kN/m² (d) –2.5 kN/m²

[ESE : 2004]

4.44 A thin wooden plate *PQRS* is made by gluing two pieces of wood along *PR* as shown in the diagram below.



If σ_x = –30 MPa, σ_y = 10 MPa and τ_{xy} = 0, then what is the normal stress on the surface PR?

(a) –10 MPa (b) –20 MPa
(c) 10 MPa (d) 20 MPa

[ESE : 2004]

4.45 In a plane strain condition in the *XY* plane, the strain components associated with *XY* axes are $\varepsilon_x = 800 \times 10^{-6}$, $\varepsilon_y = 100 \times 10^{-6}$, $\phi_{xy} = -800 \times 10^{-6}$. What are the principal strains for these strain values?

(a) $981 \times 10^{-6}, -81 \times 10^{-6}$
(b) $891 \times 10^{-6}, -18 \times 10^{-6}$
(c) $881 \times 10^{-6}, -71 \times 10^{-6}$
(d) $839 \times 10^{-6}, -81 \times 10^{-6}$

[ESE : 2004]

4.46 In a plane strain case in the *XY* plane, normal strain in *X* and *Y* directions are equal to zero and shear strain is equal to 3×10^{-6}. What is the value of diameter of Mohr's circle of strain for these strain values?

(a) 6×10^{-6} (b) 3×10^{-6}
(c) 1.5×10^{-6} (d) Zero

[ESE : 2004]

4.47 For a case of plane stress, σ_x = 40 MN/m², σ_y = 0, τ_{xy} = 80 MN/m². What are the principal stresses (in MN/m²) and their orientation with *x* and *y* axes?

(a) $\sigma_1 = 80$, $\sigma_2 = 40$, $\theta_1 = 30°$
(b) $\sigma_1 = 100$, $\sigma_2 = -60$, $\theta_1 = 32°$
(c) $\sigma_1 = 102.5$, $\sigma_2 = -62.5$, $\theta_1 = 36°$
(d) $\sigma_1 = 105$, $\sigma_2 = 62$, $\theta_1 = 36°$

[ESE : 2004]

4.48 A thin rod of 10 mm diameter is subjected to a tensile force of 7850 N. What are the principal stresses and maximum shear stress?

(a) 70 MPa, 50 MPa, 10 MPa
(b) 100 MPa, zero, 50 MPa
(c) 100 MPa, 50 MPa, 25 MPa
(d) 100 MPa, zero, zero

[ESE : 2004]

4.49 σ_x, σ_y and τ_{xy} are normal and shear stresses on the *x* and *y* faces. What is the radius of Mohr's circle in terms of these stresses?

(a) $\dfrac{\sigma_x - \sigma_y}{2}$

(b) $\dfrac{\sigma_x - \sigma_y}{2} + \tau_{xy}$

(c) $\sqrt{\left(\dfrac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$

(d) $\sqrt{\left(\dfrac{\sigma_x + \sigma_y}{2}\right)^2 - \tau_{xy}^2}$

[ESE : 2004]

4.50 **Assertion (A):** A plane stress system consists of two principal stresses σ_1 and σ_2 and a plane strain system consists of two principal strains $\varepsilon_1 = \sigma_1/E$ and $\varepsilon_2 = \sigma_2/E$. Both the systems are identical.

Reason (R): Stress is proportional to strain.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false
(d) A is false but R is true

[ESE : 2004]

4.51 At a certain point in a structural member, there are perpendicular stresses 80 N/mm^2 and 20 N/mm^2, both tensile. What is the equivalent stress in simple tension, according to the maximum principal strain theory?
(Poisson's ratio = 0.25)
(a) Zero (b) 20 N/mm^2
(c) 60 N/mm^2 (d) 75 N/mm^2

[ESE : 2005]

4.52 In a plane strain problem in XY plane, the shear strain = 12×10^{-6}, and the normal strain in X and Y direction = 0. For this state of strain, what is the diameter of the Mohr's circle of strain?
(a) 6×10^{-6} (b) 8×10^{-6}
(c) 12×10^{-6} (d) 24×10^{-6}

[ESE : 2005]

4.53 At a certain point in a strained material, there are two mutually perpendicular stresses σ_x = 100 N/mm^2 (tensile) and σ_y = 50 N/mm^2 (compressive).
[Notation : tension (+); compression (–)]
What are the values of the principal stresses in N/mm^2 at that point?
(a) 100, –50 (b) –100, 50
(c) 75, –25 (d) –75, 25

[ESE : 2005]

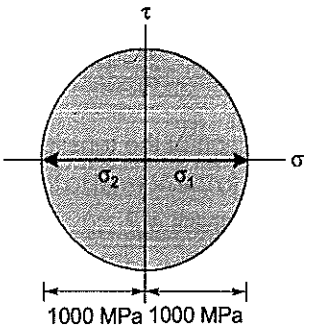
4.54 For a state of plane stress $\sigma_1 = \sigma_x$ = 40 MPa and $\sigma_2 = \sigma_y$ = 20 MPa. What are the values of the maximum inplane shearing stress and absolute maximum shearing stress?
(a) (± 10, 20) MPa (b) (± 10, 10) MPa
(c) (± 20, 10) MPa (d) (± 20, 20) MPa

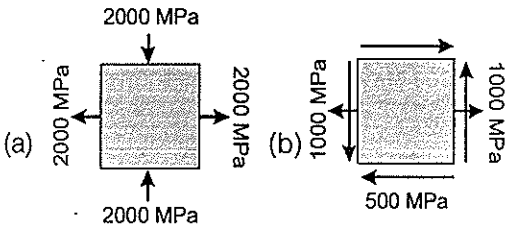
[ESE : 2005]

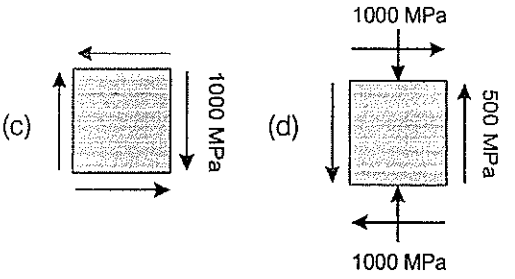
4.55 **Assertion (A):** For a ductile material the maximum shear distortion theory is most suitable.
Reason (R): The maximum shear distortion theory of failure assumes that yielding can occur in a general three-dimensional state of stress.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2006]

4.56 The Mohr's circle given below corresponds to which one of the following stress conditions







[ESE : 2006]

4.57 In a two-dimensional stress system, the two principal stresses are p_1 = 180 N/mm^2 (tensile), and p_2 which is compressive. For the material, yield stress in simple tension and compression is 240 N/mm^2 and Poisson's ratio is 0.25. According to maximum normal strain theory, for what values of p_2, shall yielding commence?
(a) 240 N/mm^2 (b) 180 N/mm^2
(c) 195 N/mm^2 (d) 200 N/mm^2

[ESE : 2006]

4.58 If the maximum principal stress for an element under bi-axial stress situation is 100 MPa (tensile) and the maximum shear stress is also 100 MPa, then what is the other principal stress?
(a) 200 MPa (tensile)
(b) 200 MPa (compressive)

(c) 100 MPa (compressive)
(d) zero

[ESE : 2006]

4.59 According to maximum shear stress criterion, at what ratio of maximum shear stress to yield stress of material does the yielding of material take place?

(a) 2 (b) $2/\sqrt{3}$
(c) $1/\sqrt{3}$ (d) 1/2

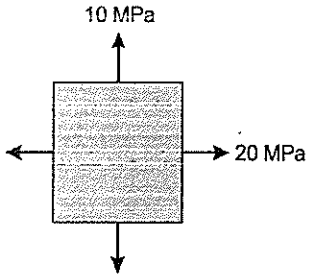
[ESE : 2007]

4.60 If p_1 and p_2 are the principal stress at a point in a strained material with Young's modulus E and Poisson's ratio 1/m, then what is the principal strain?

(a) $\frac{p_1 + p_2}{mE}$ (b) $\frac{p_1 - p_2}{mE}$
(c) $\frac{p_1}{E} - \frac{p_2}{mE}$ (d) $\frac{p_1}{m} + \frac{p_2}{mE}$

[ESE : 2006]

4.61 An element is subjected to stress as given below



For this state of stress, what is the maximum shear stress?

(a) 2.5 MPa (b) 5 MPa
(c) 10 MPa (d) 15 MPa

[ESE : 2007]

4.62 Mohr's stress circle helps in determining which of the following?

1. Normal stresses on one plane.
2. Normal and tangential stresses on two planes.
3. Principal stresses in all three directions.
4. Inclination of principal planes.

Select the correct answer using the codes given below:

(a) 1 and 2 only (b) 2 and 3 only
(c) 3 and 4 only (d) 2 and 4 only

[ESE : 2007]

4.63 Consider the following statements:
Mohr's strain circle can be drawn

1. for plane stress conditions
2. if strains in three directions are known
3. if strains on two mutually perpendicular planes are known

Which of these statements are correct?

(a) 1, 2 and 3 (b) 2 and 3 only
(c) 1 and 2 only (d) 1 and 3 only

[ESE : 2007]

4.64 What is the angle between principal strain axis and maximum shear strain axis ?

(a) 0° (b) 30°
(c) 45° (d) 90°

[ESE : 2007]

4.65 In a strained material, the principal stresses in the x and y directions are 100 N/mm^2 (tensile) and 60 N/mm^2 (compressive). On an inclined plane, the normal to which makes an angle 30° to the x-axis, what is the tangential stress in N/mm^2?

(a) $30\sqrt{3}$ (b) $40\sqrt{3}$
(c) 60 (d) 40

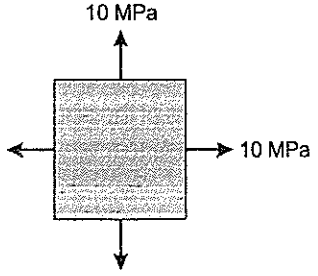
[ESE : 2007]

4.66 At what value of the ultimate shear strength, shall the material under the action of uniform axial tension fail due to shear?

(a) < 0.5 times the ultimate tensile strength
(b) < 0.7 times the ultimate tensile strength
(c) = ultimate tensile strength
(d) > the ultimate tensile strength

[ESE : 2007]

4.67 What is the diameter of Mohr's circle of stress for the state of stress shown below?



(a) 20 (b) $10\sqrt{2}$
(c) 10 (d) Zero

[ESE : 2008]

4.68 In a plane strain situation in xy plane, the displacements at a point are given as:
$u = (-2x + 8y) \times 10^{-6}$ unit
$v = (-3x + 5y) \times 10^{-6}$ unit
What is the shearing strain?
(a) 9×10^{-6} (b) 7×10^{-6}
(c) 5×10^{-6} (d) 3×10^{-6}
[ESE : 2008]

4.69 If a body carries two unlike principal stresses, what is the maximum shear stress?
(a) Half the difference of magnitude of the principal stresses
(b) Half the sum of the magnitude of principal stresses
(c) Difference of the magnitude of principal stresses
(d) Sum of the magnitude of principal stresses
[ESE : 2008]

4.70 In a biaxial strain system ε_x and ε_y, what is the maximum engineering shearing strain?
(a) $\varepsilon_x + \varepsilon_y$ (b) $\varepsilon_x - \varepsilon_y$
(c) $\frac{\varepsilon_x + \varepsilon_y}{2}$ (d) $\frac{\varepsilon_x - \varepsilon_y}{2}$
[ESE : 2008]

Directions: The following items consists of two statements; one labelled as 'Assertion (A)' and the other as 'Reason (R)'. You are to examine these two statements carefully and select the answers to these items using the codes given below:
Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.71 Assertion (A): In a tension test on a cast iron specimen, the failure of the specimen is on a cross section perpendicular to the axis of the specimen.
Reason (R): The failure of the specimen is on a plane subjected to maximum tensile stress and cast iron is relatively weak in tension.
[ESE : 2008]

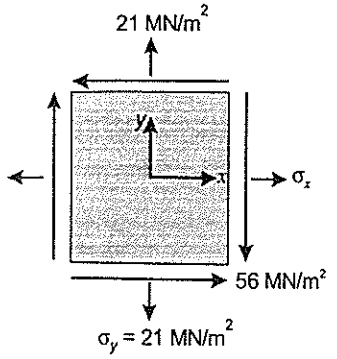
4.72 Assertion (A): In a tension test on a mild steel specimen, the failure of the specimen is along a plane at 45° to the cross section.
Reason (R): The failure of the specimen is on a plane subjected to maximum shear stress and mild steel is relatively weak in shear.
[ESE : 2008]

4.73 What would be the shape of the failure surface of a standard cast iron specimen subjected to torque ?
(a) Cup and cone shape at the centre
(b) Plane surface perpendicular to the axis of the specimen
(c) Pyramid type wedge-shaped surface perpendicular to the axis of the specimen.
(d) Helicoidal surface at 45° to the axis of the specimen.
[ESE : 2009]

4.74 At a point in a piece of stressed material the stresses are :
$\sigma_x = \alpha$ kN/m^2 tensile (normal)
$\tau_{xy} = \tau_{yx} = \beta$ kN/m^2 (shearing)
Although the values of α and β are not known yet the principal stresses are equal to each other being (5 kN/m^2). What is the radius of Mohr's circle ?
(a) $2.5 + (\alpha + \beta)$ (b) $2.5 + \frac{(\alpha + \beta)}{2}$
(c) zero (d) 2.5
[ESE : 2009]

4.75 What is the radius of Mohr's circle in case of bi-axial state of stress?
(a) Half the sum of the two principal stresses
(b) Half the difference of the two principal stresses
(c) Difference of the two principal stresses
(d) Sum of the two principal stresses
[ESE : 2009]

4.76 Figure below shows a state of plane stress.



If the minimum principal stress is – 7 MN/m^2 then what is the value of σ_x ?

(a) 30 MN/m^2 (b) 68 MN/m^2
(c) 98 MN/m^2 (d) 105 MN/m^2

[ESE : 2009]

4.77 The details of the principal stresses at a certain point in a steel member are as follows :
Major principal stress σ_1 = 180 N/mm^2 (Tensile)
Minor principal stress σ_2 is Compressive.
If the uniaxial tensile yield stress is 240 N/mm^2, according to maximum shear stress theory, what would be the value of σ_2 in N/mm^2 at which yielding will commence ?

(a) 120 tension (b) 90 tension
(c) 80 compression (d) 60 compression

[ESE : 2009]

4.78 An element of a structure is subjected to two principal stresses σ_1 and σ_2.
σ_1 = 200 N/mm^2 (Tensile)
σ_2 is Compressive
The yield stress both in simple tension and compression for the material is 240 N/mm^2. Poisson's ratio μ = 0.25; what is the value of σ_2 in N/mm^2 as per maximum normal strain theory at which the yield of material will commence ?

(a) 240 (b) 200
(c) 180 (d) 160

[ESE : 2009]

4.79 A two-dimensional stress system has like stresses σ_x = 100 N/mm^2 and σ_y = 200 N/mm^2 in two mutually perpendicular directions. The x, y, co-ordinates of the centre of the Mohr's circle are

(a) (0, 150) (b) (150, 0)
(c) (–50 , 0) (d) (50, 0)

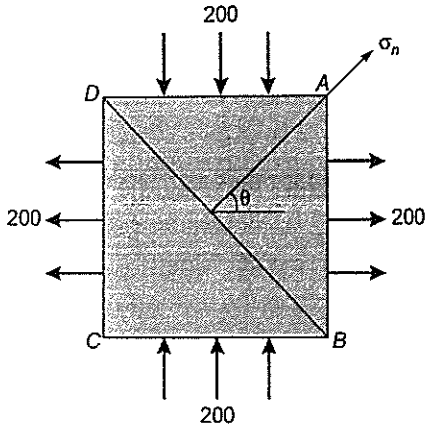
[ESE : 2010]

4.80 The limit of proportionality in the material of a structural steel member, when subjected to simple tension, is 280 N/mm^2. The principal stresses in the member are σ_1 = 122 N/mm^2 (Tensile) and σ_2 = 60 N/mm^2 (Compressive). μ = 0.3. According to maximum strain theory, the factor of safety is

(a) 2.5 (b) 1.5
(c) 2 (d) 3

[ESE : 2010]

4.81 A square element is subjected to principal stresses in N/mm^2 as shown in figure below. The intensity of normal stress σ_n on plane *BD* is



(a) $200\sqrt{2}$ (b) 100
(c) 200 (d) 0

[ESE : 2010]

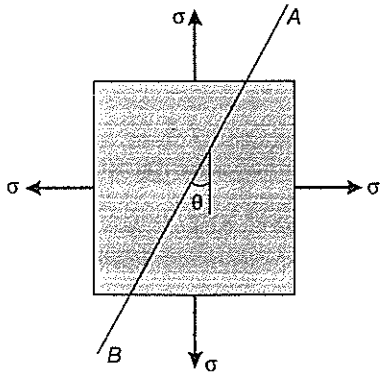
4.82 Consider the following statements:
If there is a state of pure shear τ at a point then
1. The Mohr's circle is tangential to the y-axis.
2. The centre of the Mohr's circle coincides with the origin.
3. Unlike principal stresses are each numerically equal to τ.
4. Principal stresses are like.

Which of these statements is/are correct?

(a) 1 only (b) 1 and 2
(c) 2 and 3 (d) 3 and 4

[ESE : 2010]

4.83 A point in two-dimensional stress state subjected to biaxial stress is shown in figure below. What is the normal stress acting on the plane *AB*?



(a) Zero (b) σ
(c) $\sigma \cos^2 \theta$ (d) $\sigma \sin \theta . \cos \theta$

[ESE : 2010]

4.84 Which of the following theories of failure is most appropriate for a brittle material?
(a) Maximum principal strain theory
(b) Maximum principal stress theory
(c) Maximum shear stress theory
(d) Maximum strain energy theory

[ESE : 2011]

4.85 In a strained material, the principal stresses in the *X* and *Y* directions respectively are 100 N/mm^2 (Tensile) and 60 N/mm^2 (Compressive). On an inclined plane, the normal to which makes an angle of 30° to the *X*-axis, the major principal stress, in N/mm^2, would be
(a) 60 (b) 80
(c) 20 (d) 40

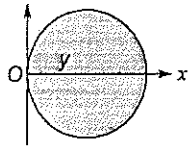
[ESE : 2011]

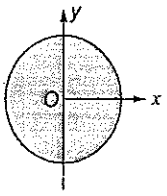
4.86 Which one of the following statements is correct?
(a) Principal stress is defined as the shear stresses on planes on which the normal stress is maximum or minimum.
(b) The centre of Mohr's circle for a two-dimensional stress system always lies in the y-axis (adopting conventional axes notation).
(c) The plane of maximum shear stress is inclined to the plane of principal stress at an angle of 45°.
(d) In case of biaxial state of normal stresses, the normal stress on 45° plane is equal to the sum of normal stresses.

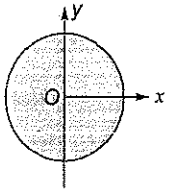
[ESE : 2011]

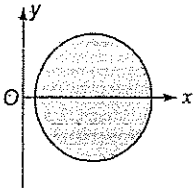
4.87 Match List-I with List-II and select the correct answer using the code given below the lists:

List-I

A. 

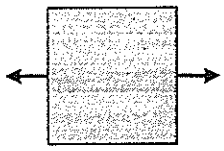
B. 

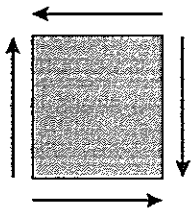
C. 

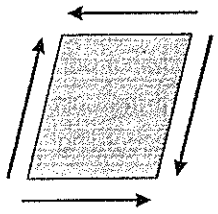
D. 

List-II

1.

2. 

3. 

4. 

Codes:

	A	B	C	D
(a)	2	4	1	3
(b)	3	4	1	2
(c)	2	1	4	3
(d)	3	1	4	2

[ESE : 2011]

4.88 In a two-dimensional stress system, the radius of the Mohr's circle represents
(a) maximum normal stress
(b) minimum normal stress
(c) minimum shear stress
(d) maximum shear stress

[ESE : 2012]

4.89 In a plane stress problem, there are normal tensile stresses σ_x and σ_y, with $\sigma_x > \sigma_y$, accompanied by shear stress τ_{xy} at a point in the *x*-*y* plane. If it is observed that the minimum principal stress on a certain section is zero, then

(a) $\tau_{xy} = \sqrt{\sigma_x \cdot \sigma_y}$ (b) $\tau_{xy} = \sqrt{\frac{\sigma_x}{\sigma_y}}$

(c) $\tau_{xy} = \sqrt{\sigma_x - \sigma_y}$ (d) $\tau_{xy} = \sqrt{\sigma_x + \sigma_y}$

[ESE : 2012]

4.90 Steel has proportionality limit of 300 MPa in simple tension. It is subjected to principal stresses of 120 MPa (tensile), 60 MPa (tensile) and 30 MPa (compressive). What is the factor of safety according to maximum shear stress theory?
(a) 1.5 (b) 1.75
(c) 1.8 (d) 2.0

[ESE : 2012]

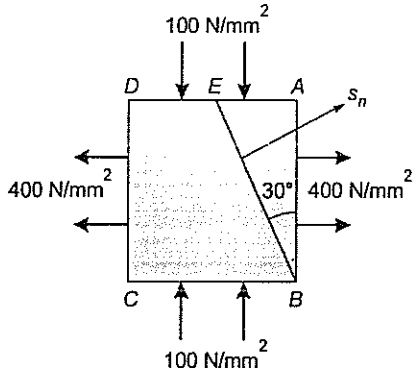
4.91 According to maximum shear stress failure theory, yielding occurs in the material when
(a) max. shear stress = yield stress
(b) max. shear stress = 2 times yield stress
(c) max. shear stress = 1/2 of yield stress
(d) max. shear stress = $\sqrt{2}$ times yield stress

[ESE : 2012]

4.92 For the design of a cast iron member, the most appropriate theory of failure is
(a) Mohr's theory
(b) Rankine's theory
(c) Maximum stress theory
(d) Maximum shear energy theory

[ESE : 2012]

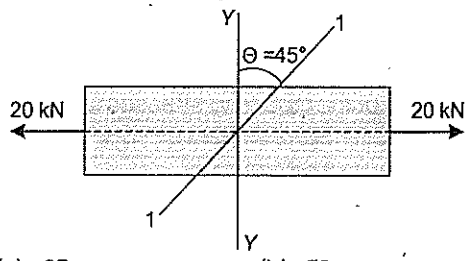
4.93 The principal stresses in N/mm^2 on a rectangular element are shown in the below figure. The intensity of normal stress σ_n on the oblique plane *BE* is



(a) 125 N/mm^2 (b) 425 N/mm^2
(c) 375 N/mm^2 (d) 250 N/mm^2

[ESE : 2013]

4.94 A mild steel bar of square cross-section has a sectional area 200 mm^2. It is subjected to an axial force of 20 kN as shown in the below figure. The intensity of the normal tensile stress is N/mm^2 on the oblique plane 1-1 at 45° with the YY-axis which is normal to the longitudinal axis will be



(a) 25 (b) 50
(c) 75 (d) 100

[ESE : 2013]

4.95 A rectangular bar of cross-sectional area *A* is subjected to an axial tensile load *P*. The maximum shear stress will occur on a plane at *X*° to any normal cross-section where *X*° is
(a) 90° (b) 270°
(c) 180° (d) 45°

[ESE : 2013]

4.96 Which of the following statements are correct?
1. Experimental results on thin-walled tubes show that maximum normal stress theory is valid.
2. Normal stress theory is valid in case of brittle materials.
3. In case of pure shear, St. Venant's theory is more valid than other theories.
4. Tresca's theory is very closely sub-stantiated by experimental results.
5. In maximum stress theory, the yield locus is a hexagon.

(a) 1, 2 and 3 (b) 2, 4 and 5
(c) 1, 2 and 4 (d) 2, 3 and 4

[ESE : 2013]

Directions: Each of the following items consists of two statements, one labelled as '**Statement (I)**' and the other as '**Statement (II)**'. You are to examine these two statements and select the answers to these items using the code given below.

Codes:
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true

4.97 **Statement (I) :** Mohr's theory is based on logical arrangement of experimental results.

Statement (II) : Mohr's theory generalizes Coulomb's theory.

[ESE : 2014]

4.98 **Statement (I) :** The most-suited failure theory for concrete is maximum shear strength theory.

Statement (II) : Ductile materials are limited by their shear strength.

[ESE : 2014]

4.99 Consider the following statements:
If the planes at right angles carry only shear stress of magnitude q in a certain instance, then the
1. diameter of Mohr's circle would be equal to $2q$.
2. centre of Mohr's circle would lie at the origin
3. principal stresses are unlike and are of magnitude q each
4. angle between the principal plane and the plane of maximum shear would be 45°

Which of the above statements are correct?
(a) 1, 2 and 3 only (b) 1, 2 and 4 only
(c) 3 and 4 only (d) 1, 2, 3 and 4

[ESE : 2014]

4.100 The state of two-dimensional stresses acting on a concrete lamina consists of a direct tensile stress $\sigma_x = 1.5$ N/mm^2 and shear stress $\tau = 1.20$ N/mm^2, when cracking of concrete is just impending. The permissible tensile strength of the concrete is
(a) 1.50 N/mm^2 (b) 2.17 N/mm^2
(c) 2.08 N/mm^2 (d) 2.29 N/mm^2

[ESE : 2014]

4.101 The principal stresses at a point in a bar are 160 N/mm^2 (tensile) and 80 N/mm^2 (compr.). The accompanying maximum shear stress intensity is
(a) 100 N/mm^2 (b) 110 N/mm^2
(c) 120 N/mm^2 (d) 140 N/mm^2

[ESE : 2014]

4.102 An element of a certain material in plane strain has

$\varepsilon_x = 800 \times 10^{-6}$
$\varepsilon_y = 400 \times 10^{-6}$
$\gamma_{xy} = 300 \times 10^{-6}$

What is the maximum shearing strain?
(a) 150×10^{-6} (b) 355×10^{-6}
(c) 250×10^{-6} (d) 500×10^{-6}

[ESE : 2014]

4.103 At a point in the web of a girder, the bending and the shearing stresses are 90 N/mm^2 (tensile) and 45 N/mm^2 respectively. The principal stresses are
(a) 108.64 N/mm^2 (tensile) and 18.64 N/mm^2 (compressive)
(b) 107.60 N/mm^2 (compressive) and 18.64 N/ mm^2 (tensile)
(c) 108.64 N/m^2 (compressive) and 18.64 N/ mm^2 (tensile)
(d) 0.64 N/mm^2 (tensile) and 0.78 N/mm^2 (compressive)

[ESE : 2014]

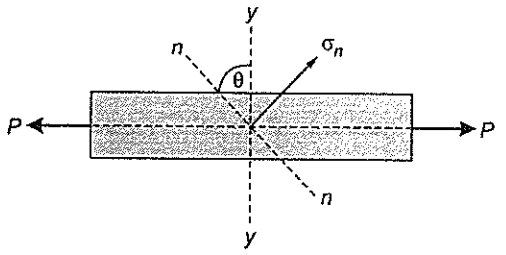
4.104 In a two-dimensional stress system, the principal stresses are $\sigma_1 = 200$ N/mm^2 (tensile) and σ_2 (compressive). The yield stress in both simple tension and compression is 250 N/mm^2, with $\mu = 0.25$. What will be the value of σ_2 according to the maximum normal strain theory?
(a) 160 N/mm^2 (b) 100 N/mm^2
(c) 200 N/mm^2 (d) 250 N/mm^2

[ESE : 2014]

4.105 A specimen is subjected to a pure shear stress regime of intensity τ. The resulting tensile and compressive stresses σ, which occur on planes inclined at 45° to the direction of the shear stresses, would be
(a) τ (b) $\frac{\tau}{2}$
(c) $\sqrt{2}\tau$ (d) $\frac{\tau}{\sqrt{2}}$

[ESE : 2015]

4.106 A mild steel bar is subjected to an axial force P, resulting in an axial stress $\sigma_x = 100$ N/mm^2. What would be the normal stress σ_n on a plane n-n making an angle $\theta = 45°$ with its axis?



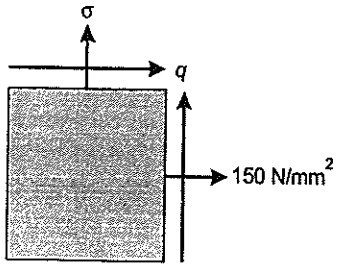
(a) 25 N/mm^2 (b) 40 N/mm^2
(c) 50 N/mm^2 (d) 100 N/mm^2

[ESE : 2015]

4.107 Which of the following stresses is measured on inclined surface in Mohr's Circle Method?
(a) Principal stress
(b) Normal stress
(c) Tangential stress
(d) Maximum stress

[ESE : 2015]

4.108 The state of stress on an element in plane stress is shown as in the figure.



What is the value of σ if the values of the principal stresses are 164 N/mm² and 36 N/mm², both tensile?

(a) 100 N/mm² (b) 75 N/mm²
(c) 62.5 N/mm² (d) 50 N/mm²

[ESE : 2015]

4.109 The state of stress at a point in 2-D stress system is characterized by direct stresses of 40 MPa compressive and 80 MPa tensile, on mutually perpendicular planes. Shear stress is absent on these planes. The maximum shear stress at this point (along a duly identified plane) is

(a) 20 MPa (b) 40 MPa
(c) 60 MPa (d) 80 MPa

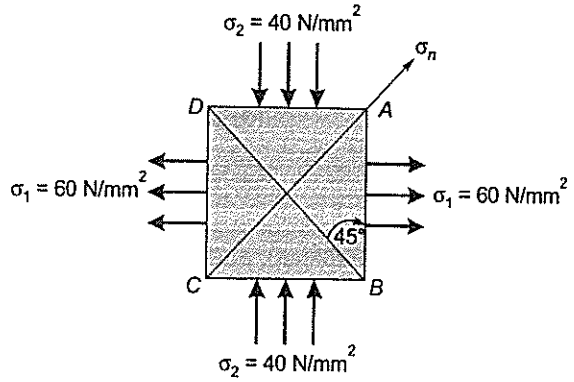
[ESE : 2015]

4.110 An electrical resistance strain rosette indicates strains of –400, +800 and +500 along the x, y and 45° axes. What is the shearing strain γ_{xy}?

(a) 100 (b) 800
(c) 600 (d) –200

[ESE : 2015]

4.111 The biaxial stress system in an element is shown in the figure. Which of the following will give the normal stress in N/mm² in the plane *BD* making an angle of 45° with the plane *BA*?



(a) 25 (b) 20
(c) 15 (d) 10

[ESE : 2015]

4.112 A cylindrical pressure vessel is 1200 mm in diameter. It is made of rolled mild steel plate. The vessel is subjected to an internal pressure of 2 N/mm². If the material yields at 200 N/mm², what should be the minimum safe thickness of the plate, based on Maximum Principal Stress Theory?

(a) 18 mm (b) 15 mm
(c) 12 mm (d) 9 mm

[ESE : 2015]

4.113 A machine element develops principal stresses of magnitudes $2P$ and P. What is the maximum magnitude of P before the material reaches the yield stress f_y as per Distortion Shear Energy Theory?

(a) f_y (b) $\frac{f_y}{2}$
(c) $\frac{f_y}{2\sqrt{3}}$ (d) $\frac{f_y}{\sqrt{3}}$

[ESE : 2015]

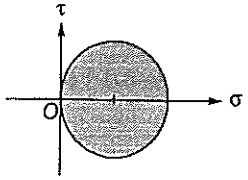
4.114 A structural element is subjected to a two-dimensional stress system, wherein σ_1 = 225 N/mm² (tensile) with σ_2 being compressive. The yield stress in both simple tension $(\sigma_y)_t$ and simple compression $(\sigma_y)_c$ is 250 N/mm² and μ = 0.25. What is the value of σ_2, according to Maximum Strain Theory?

(a) 200 N/mm² (b) 150 N/mm²
(c) 125 N/mm² (d) 100 N/mm²

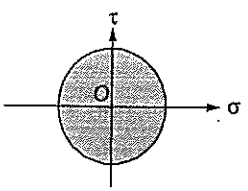
[ESE : 2015]

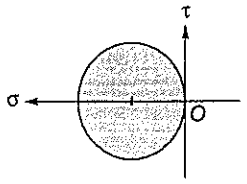
4.115 Which one of the following Mohr's Circles represents the state of pure shear?

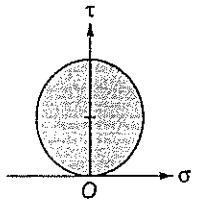
(a)



(b)



(c) 

(d) 

[ESE : 2015]

4.116 Statement (I): The failure of a mild steel specimen of circular cross-section, subjected to a torque occurs along its cross-section.

Statement (II): The failure occurs on a plane of the specimen subjected to maximum shear stress; and mild steel is relatively weak in shear.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true

[ESE : 2016]

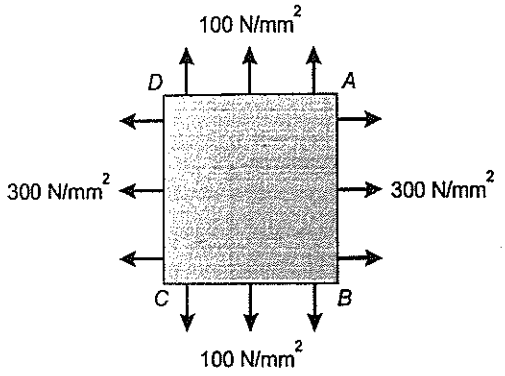
4.117 Which of the following statements are correct for stresses acting on mutually perpendicular faces of a plane element?

1. The sum of the normal stresses in mutually perpendicular planes is equal to the sum of the principal stresses.
2. The shearing stresses in two mutually perpendicular planes are equal in magnitude and direction.
3. Maximum shear stress is half of the difference between principal stresses.

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

[ESE : 2016]

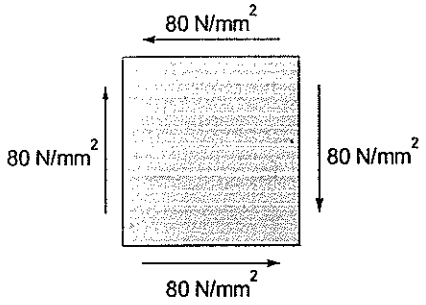
4.118 A square element of a structural part is subjected to biaxial stresses as shown in the figure. On a plane along BD, the intensity of the resultant stress due to these conditions will be



(a) $25\sqrt{5}$ N/mm² (b) $50\sqrt{5}$ N/mm²
(c) $75\sqrt{5}$ N/mm² (d) $100\sqrt{5}$ N/mm²

[ESE : 2016]

4.119 A structural element is subjected to pure shear of 80 N/mm², as shown in the figure. The yield stresses both in tension and in compression are 240 N/mm². According to the maximum normal stress theory, the factors of safety in tension and compression are, respectively,



(a) 2 and 2 (b) 2.5 and 2.5
(c) 3 and 3 (d) 4 and 4

[ESE : 2016]

4.120 Principal stresses at a point are 80 N/mm² and 40 N/mm², both tensile. The yield stress in simple tension for this material is 200 N/mm². The values of factors of safety according to maximum principal stress theory and maximum shear stress theory, respectively, are

(a) 2.5 and 2.5 (b) 2.5 and 5
(c) 5 and 5 (d) 5 and 1.67

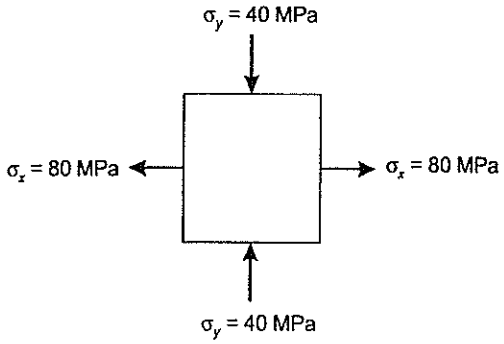
[ESE : 2016]

4.121 The principal stresses at a point are 2σ (tensile) and σ (compressive), and the stress at elastic limit for the material in simple tension is 210 N/mm². According to maximum shear strain theory, the value of σ at failure is

(a) 70 N/mm² (b) 105 N/mm²
(c) 140 N/mm² (d) 210 N/mm²

[ESE : 2016]

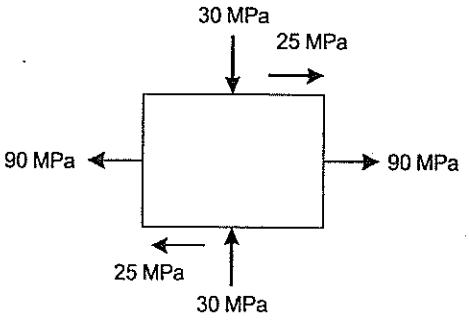
4.122 The state of stress at a certain point in a stressed body is as shown in the figure. Normal stress in x-direction is 80 MPa (Tensile) and in y-direction is 40 MPa (Compressive). The radius of the Mohr's circle for this state of stress will be



(a) 60 MPa (b) 40 MPa
(c) 20 MPa (d) 10 MPa

[ESE : 2017]

4.123 For the state of stress shown in the figure, the maximum and minimum principal stresses (taking tensile stress +, and compressive stress as –) will be



(a) 95 MPa and (– 35) MPa
(b) 60 MPa and 30 MPa
(c) 95 MPa and (– 30) MPa
(d) 60 MPa and 35 MPa

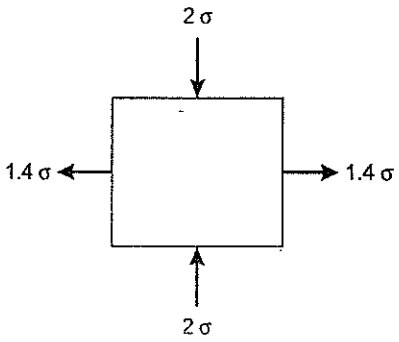
[ESE : 2017]

4.124 The principal stresses at a point in a stressed material are σ_1 = 200 N/mm², σ_2 = 150 N/mm², and σ_3 = 200 N/mm². E = 210 kN/mm² and μ = 0.3. The volumetric strain will be

(a) 8.945×10^{-4} (b) 8.945×10^{-2}
(c) 6.54×10^{-3} (d) 6.54×10^{-4}

[ESE : 2017]

4.125 The state of stress at a point in an elastic material, with yield stress of 200 MPa in simple tension, and Poisson's ratio 0.3, is as shown in the figure.



The permissible value of σ by maximum strain theory is

(a) 75 MPa (b) 100 MPa
(c) 150 MPa (d) 200 MPa

[ESE : 2017]

4.126 Consider the following statements?

1. The maximum shear stress is one half of the normal stress in the case of uniaxial stress field.
2. In biaxial stress field, acted upon by normal stresses unaccompanied by shear stresses, the maximum shear stress is any one of the normal stresses.
3. The Mohr's stress circle will be tangential to the vertical axis in the case of uniaxial stress field.

Which of the above statements are correct?

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

[ESE : 2017]

Answers Principal Stress-Strain & Theories of Failure

4.1	(a)	4.2	(b)	4.3	(b)	4.4	(d)	4.5	(c)	4.6	(a)	4.7	(a)	4.8	(c)	4.9	(d)
4.10	(c)	4.11	(d)	4.12	(b)	4.13	(c)	4.14	(a)	4.15	(b)	4.16	(a)	4.17	(a)	4.18	(c)
4.19	(c)	4.20	(c)	4.21	(d)	4.22	(d)	4.23	(b)	4.24	(b)	4.25	(a)	4.26	(a)	4.27	(a)
4.28	(a)	4.29	(d)	4.30	(b)	4.31	(c)	4.32	(c)	4.33	(a)	4.34	(c)	4.35	(c)	4.36	(c)
4.37	(d)	4.38	(c)	4.39	(c)	4.40	(a)	4.41	(d)	4.42	(b)	4.43	(a)	4.44	(a)	4.45	(a)
4.46	(b)	4.47	(c)	4.48	(b)	4.49	(c)	4.50	(d)	4.51	(d)	4.52	(c)	4.53	(a)	4.54	(a)
4.55	(b)	4.56	(c)	4.57	(c)	4.58	(c)	4.59	(d)	4.60	(c)	4.61	(b)	4.62	(d)	4.63	(a)
4.64	(c)	4.65	(b)	4.66	(a)	4.67	(d)	4.68	(c)	4.69	(b)	4.70	(b)	4.71	(a)	4.72	(a)
4.73	(d)	4.74	(c)	4.75	(b)	4.76	(d)	4.77	(d)	4.78	(d)	4.79	(b)	4.80	(c)	4.81	(d)
4.82	(c)	4.83	(b)	4.84	(b)	4.85	(a)	4.86	(c)	4.87	(*)	4.88	(d)	4.89	(a)	4.90	(d)
4.91	(c)	4.92	(b)	4.93	(*)	4.94	(b)	4.95	(d)	4.96	(b)	4.98	(c)	4.99	(d)	4.100	(b)
4.101	(c)	4.102	(d)	4.103	(a)	4.104	(c)	4.105	(c)	4.106	(b,c)	4.107	(d)	4.108	(c)	4.109	(c)
4.110	(d)	4.111	(d)	4.112	(d)	4.113	(d)	4.14	(d)	4.115	(b)	4.116	(a)	4.117	(d)	4.118	(d)
4.119	(c)	4.120	(a)	4.121	(a)	4.122	(a)	4.123	(a)	4.124	(a)	4.125	(b)	4.126	(d)		

Explanations Principal Stress-Strain & Theories of Failure

4.1 (a)

Normal stress = $p\cos^2\theta$

Tangential stress = $p\sin\theta\cos\theta = p\dfrac{\sin 2\theta}{2}$

4.2 (b)

Maximum shear stress is half of the difference of the maximum and minimum principal stresses.

4.3 (b)

Principal stresses,

$$\sigma_{1,2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

Given $\sigma_x = 15\ \text{kN/cm}^2$

$\sigma_y = 9\ \text{kN/cm}^2$

$\tau_{xy} = 4\ \text{kN/cm}^2$

$\therefore \quad \sigma_{1,2} = 12 \pm \sqrt{(3)^2 + (4)^2}$

$= 12 \pm 5\ \text{kN/cm}^2$

$\sigma_1 = 17\ \text{kN/cm}^2$

$\sigma_2 = 7\ \text{kN/cm}^2$

Both of these are tensile in nature.

4.4 (d)

The shear stress $\tau = -\left(\dfrac{\sigma_1 - \sigma_2}{2}\right)\sin 2\theta$

where, θ is the angle of inclination of the plane of major principal stress.

For shear stresses to be maximum,

$\sin 2\theta = 1$

$\therefore \quad \theta = 45°$ and $135°$

with y-direction (plane of p_1)

4.5 (c)

According to maximum principal strain theory

$$\frac{f}{E} = \frac{(\sigma_1 - \mu\sigma_2)}{E}$$

The equivalent tensile stress

$f = 800 - 0.25 \times 400$

$= 700\ \text{kg/cm}^2$

4.6 (a)

The Maximum Shear Stress theory states that failure occurs when the maximum shear stress from a combination of principal stresses equals or exceeds the value obtained for the shear stress

at yielding in the uniaxial tensile test.
For yielding in material,
Maximum shear stress = yield stress/ 2

4.7 (a)

Centre of Mohr's circle,

$$C = \frac{\sigma_x + \sigma_y}{2} = 70 \text{ MPa}$$

Radius of Mohr's circle,

$$r = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} = 50 \text{ MPa}$$

Major principal stress

$$\sigma_1 = C + r = 70 + 50 = 120 \text{ MPa}$$

Minor principal stress

$$\sigma_2 = C - r = 70 - 50 = 20 \text{ MPa}$$

4.8 (c)

When a member is subjected to uniaxial tensile force, the maximum normal stress is the external load divided by the minimum cross sectional area. Also, on the plane of maximum normal stress shear stress is zero.

4.9 (d)

Proportionality limit shear stress

$$= \frac{3000}{2} = 1500 \text{ kg/cm}^2$$

Maximum shear stress

$$= \frac{1200 - (-300)}{2} = 750 \text{ kg/cm}^2$$

$$\text{Factor of safety} = \frac{1500}{750} = 2.0$$

4.10 (c)

$(\sigma_1 - \sigma_2) \geq \sigma_y$: Maximum shear stress theory

$\frac{1}{E}(\sigma_1 - \mu\sigma_2) \geq \frac{\sigma_y}{E}$: Maximum principal strain theory

$(\sigma_1^2 + \sigma_2^2 - 2\mu\sigma_1\sigma_2) \geq f_y^2$: Maximum strain energy theory

$(\sigma_1^2 + \sigma_2^2 - \sigma_1\sigma_2) \geq f_y^2$: Distortion energy theory

4.11 (d)

The inclination of the line joining any point P on the Mohr's circle and the origin O with x-axis equals the angle between the resultant stress and the normal of the plane for which P stands.

4.12 (b)

$$\text{Tangential stress} = \left(\frac{\sigma_1 - \sigma_2}{2}\right) \times \sin 2\theta$$

$$= \left(\frac{1000 - 2000}{2}\right) \times \sin 30^\circ$$

$$= -250 \text{ kg/cm}^2$$

4.13 (c)

Normal stress on the plane of maximum shear stress

$$= \frac{\sigma_1 + \sigma_2}{2} = \frac{100 - 50}{2}$$

$$= 25 \text{ MPa (tensile)}$$

4.14 (a)

As per maximum distortion theory, maximum shear strain energy in a body should be less than or equal to maximum shear strain energy under uniaxial loading.

$$\left[\frac{(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2}{2}\right]^{1/2} \leq 0$$

4.15 (b)

As per maximum shear stress theory, for no failure maximum shear stress should be less than half of yield stress.

$$\text{Max}\left[\left(\frac{\sigma_1 - \sigma_2}{2}\right), \left(\frac{\sigma_2 - \sigma_3}{2}\right), \left(\frac{\sigma_3 - \sigma_1}{2}\right)\right] \leq \frac{\sigma_0}{2}$$

Given that $\sigma_1 > \sigma_2 > \sigma_3$

$$\frac{\sigma_1 - \sigma_3}{2} = \frac{\sigma_0}{2}$$

4.16 (a)

When one of the principal stresses at a point is large in comparison to the other, the situation resembles uniaxial tension test. Therefore all theories give nearly same result.

4.17 (a)

For equal tensile stress on all the faces,

$$\sigma^2 + \sigma^2 + \sigma^2 - 6\sigma^2\mu = \sigma_y^2$$

$$3\sigma^2(1 - 2\mu) = \sigma_y^2$$

$$\therefore \quad \sigma = \frac{\sigma_y}{\sqrt{3(1 - 2\mu)}}$$

4.18 (c)

Principal stresses,

$$\sigma_1/\sigma_2 = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

Since minimum principal stress is zero, therefore

$$\left(\frac{\sigma_x + \sigma_y}{2}\right)^2 = \left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2$$

$$\tau_{xy} = \sqrt{\sigma_x \sigma_y}$$

4.19 (c)

The normal stress on planes having maximum shear stress $= \frac{p_1 + p_2}{2}$

4.20 (c)

Let minor principal stress is σ_3.

$\therefore$ Maximum shear stress $= \left(\frac{200 + \sigma_3}{2}\right)$

$\therefore \quad \left(\frac{200 + \sigma_3}{2}\right) = \frac{250}{2}$ at yielding

$\Rightarrow \quad \sigma_3 = 50$ MPa

4.21 (d)

Maximum principal stress = 150 MPa

Factor of safety $= \frac{300}{150} = 2$

4.22 (d)

The principal stresses will act on planes at 45° and 135°.

The values of principal stresses will be q and $-q$.

4.23 (b)

Centre of Mohr's circle,

$$C = \frac{\sigma_x + \sigma_y}{2} = \frac{32 - 10}{2} = 11 \text{ MPa}$$

Major principal stress = $C + r = 40$

$\because \quad r = 29$ MPa

Minor principal stress = $C - r$

$= 11 - 29 = -18$ MPa

4.24 (b)

Minor principal stress = $C - r = 10$

Centre of circle (C) = 10 + 20 = 30 N/mm^2

Major principal stress = $C + r = 30 + 20$

= 50 N/mm^2

4.25 (a)

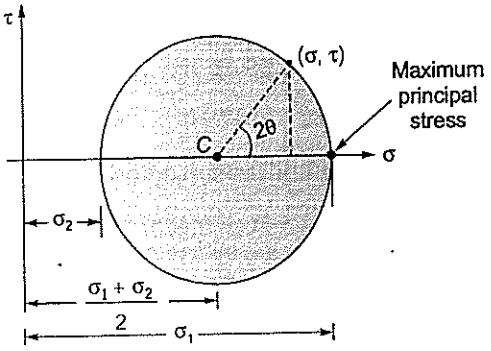
Strain energy $= \frac{1}{2}(\sigma_1 \epsilon_1 + \sigma_2 \epsilon_2)$

$$= \frac{1}{2E}(\sigma_1^2 + \sigma_2^2 - 2\mu\sigma_1\sigma_2)$$

4.26 (a)

Although direct stresses on planes at 45° and 135° has the same magnitude and direction, but the shear stresses are equal only in magnitude and not in direction.

4.27 (a)



The point (σ, τ) represents the stress condition on a plane making less than 45° from the plane of maximum principal stress.

$$\sigma > \left(\frac{\sigma_1 + \sigma_2}{2}\right)$$

4.29 (d)

Maximum shear stress,

$$\tau_{max} = \frac{100 - (-40)}{2} = 70 \text{ N/mm}^2$$

$$\text{Factor of safety} = \frac{(\sigma_y/2)}{\tau_{max}} = \frac{(280/2)}{70} = 2$$

4.30 (b)

On the maximum shear stress plane

Normal stress, $\sigma = \left(\frac{p_1 + p_2}{2}\right)$

Shear stress, $\tau = \left(\frac{p_1 - p_2}{2}\right)$

The resultant stress, $p_r = \sqrt{\sigma^2 + \tau^2}$

The other method is

$$p_r = \sqrt{p_1^2 \cos^2\theta + p_2^2 \sin^2\theta}$$

For maximum shear stress plane $\theta = 45°$

$$p_r = \sqrt{\frac{p_1^2 + p_2^2}{2}}$$

4.31 (c)

$$\text{Maximum shear stress} = \frac{(P/A) + 0}{2} = \frac{P}{2A}$$

4.32 (c)

For yielding

(i) Maximum normal tensile strain

$$= \frac{240}{E} = \frac{(180 + 0.25 \times \sigma_2)}{E}$$

(ii) Maximum normal compressive strain

$$\frac{240}{E} = \left(\frac{0.25 \times 180 + \sigma_2}{E}\right)$$

$\therefore$ From condition (i) $\sigma_2 = 240$ N/mm^2

From condition (ii) $\sigma_2 = 195$ N/mm^2

So the value of σ_2 at which yielding will start is 195 N/mm^2

4.34 (c)

If the state of stress on two planes and angle between those planes is known, then with the help of Mohr's circle we can determine stresses on oblique section.

4.35 (c)

The intensity of tangential stress

$$= \left(\frac{P}{A}\right)\sin\theta\cos\theta = \frac{P}{2A}\sin 2\theta$$

4.36 (c)

$$\text{Shear stress} = \frac{p_1 - p_2}{2} = 0 \text{ as } p_1 = p_2$$

4.37 (d)

$$\epsilon_v = 800 \times 10^{-6} + 400 \times 10^{-6} - 1200 \times 10^{-6}$$
$$= 0$$

4.38 (c)

$$R = \sqrt{\left(\frac{\sigma_1 - \sigma_2}{2}\right)^2 + \tau^2}$$

If R is zero

$$\tau^2 = 0$$
$$\tau = 0$$

and $\left(\frac{\sigma_1 - \sigma_2}{2}\right) = 0$

$$\sigma_1 = \sigma_2$$

4.39 (c)

In the case of pure shear, the principal stresses are $\pm\tau$. This can be ascertained from Mohr's circle.

4.40 (a)

Maximum shear stress,

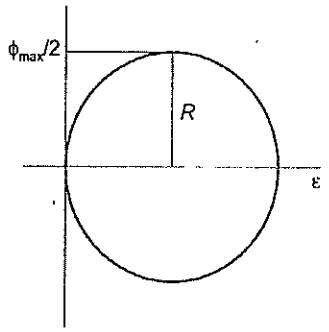
$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2}$$

Given $\sigma_1 = 150$ kN/m^2

$\sigma_2 = -50$ kN/m^2

$$\tau_{max} = \frac{150 + 50}{2} = 100 \text{ kN/m}^2$$

4.41 (d)



$$\text{Radius} = \frac{\phi_{max}}{2}$$

4.42 (b)

The Mohr's circle will be a point as $\sigma_x = \sigma_y = 20$ MPa. Therefore, shear stress will be zero for all the positions of orientation of x and y axes.

4.43 (a)

$$\sigma_n = \sigma_1 \cos^2\theta - \sigma_2 \sin^2\theta$$

$$= 3 \times \left(\frac{\sqrt{3}}{2}\right)^2 - 7 \times \left(\frac{1}{2}\right)^2 = 0.5 \text{ kN/m}^2$$

4.44 (a)

Normal stress on surface PR

$$= \frac{\sigma_x + \sigma_y}{2} = \frac{-30 + 10}{2} = -10 \text{ MPa}$$

4.45 (a)

Radius of Mohr's circle of strain,

$$r = \sqrt{\left(\frac{\varepsilon_x - \varepsilon_y}{2}\right)^2 + \left(\frac{\phi_{xy}}{2}\right)^2}$$

$$= \sqrt{(350)^2 + (400)^2} \times 10^{-6}$$

$$= 531.5 \times 10^{-6}$$

The centre of Mohr's circle,

$$C = \frac{\varepsilon_x + \varepsilon_y}{2} = 450 \times 10^{-6}$$

$\therefore$ Major principal strain $= C + r$

$$= 981.5 \times 10^{-6}$$

Minor principal strain $= C - r$

$$= -80.5 \times 10^{-6}$$

4.46 (b)

Diameter of Mohr's circle, $d = 2r$

$$r = \sqrt{\left(\frac{\varepsilon_x - \varepsilon_y}{2}\right)^2 + \left(\frac{\phi_{xy}}{2}\right)^2}$$

For $\varepsilon_x = \varepsilon_y = 0$, $r = \frac{\phi_{xy}}{2}$

$\therefore$ $d = \phi_{xy} = 3 \times 10^{-6}$

4.47 (c)

Radius of Mohr's circle of stress,

$$r = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= \sqrt{(20)^2 + (80)^2}$$

$$= 20\sqrt{17} \text{ MN/m}^2$$

The centre of Mohr's circle,

$$C = \frac{\sigma_x + \sigma_y}{2} = \frac{40 + 0}{2} = 20 \text{ MN/m}^2$$

Major principal stress $= C + r = 20\left(1 + \sqrt{17}\right)$

$$= 102.5 \text{ MN/m}^2$$

Minor principal stress $= C - r = 20\left(1 - \sqrt{17}\right)$

$$= -62.5 \text{ MN/m}^2$$

Orientation, $\theta = \frac{1}{2}\tan^{-1}\left(\frac{2\tau_{xy}}{\sigma_x - \sigma_y}\right) = 38°$

Although the orientation given in the options is wrong, however the best choice will be (c).

4.48 (b)

Major principal stress $= \frac{7850 \times 4}{\frac{\pi \times 10^2}{4}} = 100$ MPa

Minor principal stress = 0

Maximum shear stress $= \frac{100 - 0}{2} = 50$ MPa

4.49 (c)

Radius of Mohr's circle

$$= \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \left(-\tau_{xy}\right)^2}$$

$$= \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

4.50 (d)

Plane strain system is not identical with plane stress system, because

$\sigma_3 = 0$ in plane stress system

$\epsilon_3 = 0$ in plane stress system

in general,

$$\epsilon_3 = \frac{1}{E}[\sigma_3 - \mu(\sigma_1 + \sigma_2)]$$

Thus for plane strain σ_3 may be non-zero.

However in the given problem the strain is given as σ_1/E and effect of stress in lateral dimension is neglected.

4.51 (d)

Equivalent stress $= \sigma_1 - \mu\sigma_2$

$$= 80 - 0.25 \times 20$$

$$= 75 \text{ N/mm}^2$$

4.52 (c)

Radius of Mohr's circle in plane strain condition

$$R = \sqrt{\left(\frac{\varepsilon_x - \varepsilon_y}{2}\right)^2 + \left(\frac{\phi_{xy}}{2}\right)^2}$$

$$= \sqrt{\left(\frac{0}{2}\right)^2 + \left(\frac{12 \times 10^{-6}}{2}\right)^2}$$

$$R = 6 \times 10^{-6}$$

Diameter $= 2R = 12x \times 10^{-6}$

4.53 (a)

The given stresses are principal stresses as they are given on two mutually perpendicular planes and associated shear stress on these planes is zero.

4.54 (a)

Maximum in-plane shearing stress

$$= \pm\frac{\sigma_1-\sigma_2}{2} = \pm 10 \text{ MPa}$$

Absolute maximum shearing stress is based on major principle stress

$$= \frac{\sigma_1}{2} = \frac{40}{2} = 20 \text{ MPa}$$

Absolute maximum shearing stress is obtained from major principal stress applied without minor principal stress.

4.55 (b)

The maximum shear distortion energy theory of Mises and Henky is in good agreement with various combinations for ductile materials.

4.56 (c)

Principal stresses are 1000 MPa and –1000 MPa. The case is of pure shear in which shear stress is equal to radius of Mohr's circle which is equal to magnitude of principal stress i.e. radius of Mohr's circle = 1000 MPa which is represented by option (c).

4.57 (c)

Yielding may occur either in tension or compression.

For yielding in tension

$p_1 + \mu p_2 = f_y$ (Maximum normal strain theory)

$\therefore \quad p_2 = (240 - 180)/0.25 = 240 \text{ N/mm}^2$

For yielding in compression

$p_2 + \mu p_1 = f_y$

$\therefore \quad p_2 = 240 - 0.25 \times 180 = 195 \text{ N/mm}^2$

So the yielding will commence at

$p_2 = 195 \text{ N/mm}^2$

4.58 (c)

If the other principal stress is tensile

$$\frac{p_1 - 100}{2} = 100$$

$\therefore \quad p_1 = 300 \text{ N/mm}^2$

If the other principal stress is compressive

$$\frac{p + 100}{2} = 100$$

$$p = 100 \text{ N/mm}^2$$

4.59 (d)

As per maximum shear stress theory

$$\tau_{max} \le \frac{\sigma_y}{2}$$

$$\Rightarrow \frac{\tau_{max}}{\sigma_y} \le \frac{1}{2}$$

4.60 (c)

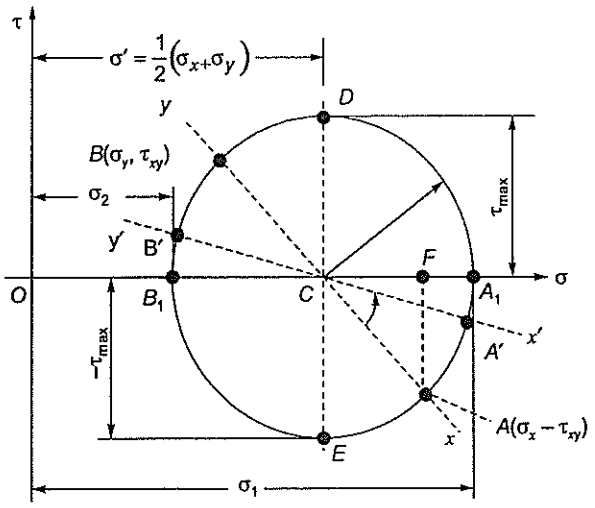
$$\text{Principal strain} = \frac{p_1}{E} - \frac{p_2}{mE}$$

4.61 (b)

The magnitude of maximum shear stress is given by

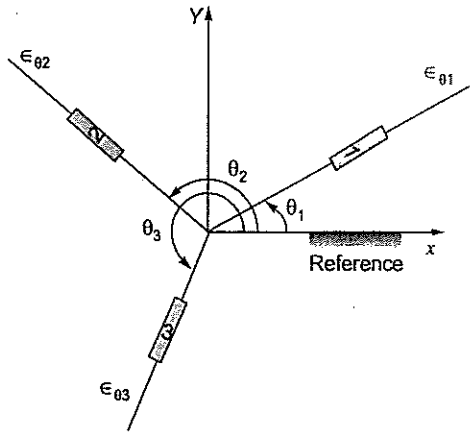
$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} = \frac{20 - 10}{2} = 5 \text{ MPa}$$

4.62 (d)



4.63 (a)

Mohr's strain circle can be drawn if strains in three directions are known. To define a general two dimensional state of strain, values of ε_x, ε_y and ϕ_{xy} are required. Thus the measurements from three strain gauges must be obtained. These three gages must be arranged at different orientations on the surface to from a strain rosette. A group of three gauges arranged in a particular fashion is called a strain rosette.



$\epsilon_{\theta 1} = \cos^2\theta_1 + \epsilon_y \sin^2\theta_1 + \phi_{xy} \sin\theta_1 \cos\theta_1$

$\epsilon_{\theta 2} = \epsilon_x \cos^2\theta_2 + \epsilon_y \sin^2\theta_2 + \phi_{xy} \sin\theta_2 \cos\theta_2$

$\epsilon_{\theta 3} = \epsilon_x \cos^2\theta_3 + \epsilon_y \sin^2\theta_3 + \phi_{xy} \sin\theta_3 \cos\theta_3$

Knowing the orientation of the three gages forming a rosette, together with the in - plane normal strains they record, the state of strain at the region of the surface concerned can be found.

4.64 (c)

$$\tan 2\theta_p = \frac{\phi_{xy}}{\epsilon_x - \epsilon_y}$$

$$\tan 2\theta_s = -\left(\frac{\epsilon_x - \epsilon_y}{\phi_{xy}}\right)$$

Thus angle between principal strain axis and maximum shear strain axis is 45°.

4.65 (b)

The magnitude of tangential stress is given by

$$\tau_{x'y'} = \frac{(\sigma_1 - \sigma_2)}{2}\sin 2\theta$$

$$= \frac{(100 + 60)}{2}\sin 60° = 40\sqrt{3}$$

4.67 (d)

Radius of Mohr's circle

$$= \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= \sqrt{\left(\frac{10 - 10}{2}\right)^2 + 0}$$

$$= 0$$

4.68 (c)

The shearing strain in xy plane is given by

$$\phi_{xy} = \frac{\partial u}{\partial y} + \frac{\partial v}{\partial x}$$

$$u = (-2x + 8y) \times 10^{-6}$$

$$\Rightarrow \quad \frac{\partial u}{\partial y} = 8 \times 10^{-6}$$

$$v = (-3x + 5y) \times 10^{-6}$$

$$\Rightarrow \quad \frac{\partial v}{\partial x} = -3 \times 10^{-6}$$

$$\therefore \quad \phi_{xy} = 8 \times 10^{-6} - 3 \times 10^{-6}$$

$$= 5 \times 10^{-6}$$

4.69 (b)

$$\tau_{max} = \frac{\sigma_1 - \sigma_2}{2} \text{ (magnitude)}$$

The principal stress given are unlike i.e if one is tensile, other is compressive. Let σ_1 be tensile and σ_2 be compressive, then

$$\tau_{max} = \frac{\sigma_1 - (-\sigma_2)}{2} = \frac{\sigma_1 + \sigma_2}{2}$$

4.70 (b)

$$\frac{\phi_{x'y'}}{2} = -\left(\frac{\epsilon_x - \epsilon_y}{2}\right)\sin 2\theta + \frac{\phi_{xy}}{2}\cos 2\theta$$

For $\theta = 45°$ and $\phi_{xy} = 0$

$$\Rightarrow \quad \frac{\phi_{x'y'}}{2} = -\left(\frac{\epsilon_x - \epsilon_y}{2}\right)$$

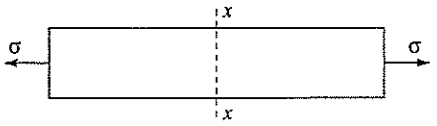
$$\Rightarrow \quad \phi_{x'y'} = -(\epsilon_x - \epsilon_y)$$

$$\Rightarrow \quad \phi_{x'y'} = \epsilon_x - \epsilon_y \quad \text{(magnitude)}$$

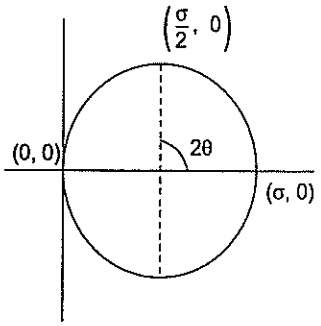
4.71 (a)

Cast iron is brittle and fails due to normal stress. It is relatively weak in tension. In a tension test maximum normal tensile stress is on cross-section perpendicular to axis of specimen, so failure will happen on this plane.

4.72 (a)



Mohr circle for this stress condition as shown below:



$2\theta = 90°$

$\theta = 45°$

Maximum shear stress in on plane at 45° to principal plane(section normal to longitudinal axis). Mild steel is weaker in shear.

4.73 (d)

Brittle materials fail in a plane at 45° from the axis when subjected to torque because they are weak in tension compare to shear. If ductile materials are subjected to torque, then the failure surface will be in a plane at 90° from the axis of shaft.

4.74 (c)

In general, the radius of Mohr's circle is given by

$$r = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + (\tau_{xy})^2}$$

In this case principal stresses are equal i.e. $\sigma_1 = \sigma_2 = 5\ kN/m^2$. The shear stress on principal planes is also zero i.e. $\tau_{xy} = 0$

$$\therefore \quad r = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + 0}$$

$$\Rightarrow \quad r = \frac{\sigma_x - \sigma_y}{2} = \frac{5-5}{2}$$

$$\Rightarrow \quad r = 0$$

It means that when $\sigma_1 = \sigma_2$, Mohr's circle degenerates into a point and no shear stresses at all develop in the xy plane.

4.75 (b)

If σ_x and σ_y are two principal stresses.

In biaxial state of stress radius of Mohr's circle =

$$\frac{\sigma_x - \sigma_y}{2}$$

4.76 (d)

Minimum principal stress is given by

$$\sigma_2 = \frac{\sigma_x + \sigma_y}{2} - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + (\tau_{xy})^2}$$

$$\Rightarrow \quad -7 = \frac{\sigma_x + 21}{2} - \sqrt{\left(\frac{\sigma_x - 21}{2}\right)^2 + (56)^2}$$

$$\Rightarrow \quad \left(\frac{\sigma_x + 35}{2}\right)^2 = \left(\frac{\sigma_x - 21}{2}\right)^2 + (56)^2$$

$$\Rightarrow \quad \frac{(\sigma_x)^2 + (35)^2 + 70\sigma_x}{4}$$

$$= \frac{(\sigma_x)^2 + (21)^2 - 42\sigma_x + 12544}{4}$$

$$\Rightarrow 112\sigma_x = 11760$$

$$\Rightarrow \quad \sigma_x = 105\ MN/m^2$$

4.77 (d)

As per maximum shear stress theory

$$\frac{\sigma_1 - \sigma_2}{2} = \frac{\sigma_y}{2}$$

$$\Rightarrow \quad \sigma_1 - \sigma_2 = \sigma_y$$

$$\Rightarrow 180 - (-\sigma_2) = 240$$

$$\Rightarrow \quad \sigma_2 = 240 - 180$$

$$\Rightarrow \quad \sigma_2 = 60\ N/mm^2$$

4.78 (d)

As per maximum principal (normal) strain theory

$$\epsilon_1 = \frac{\sigma_y}{E}$$

$$\Rightarrow \quad \frac{\sigma_1 - \mu\sigma_2}{E} = \frac{\sigma_y}{E}$$

$$\Rightarrow \quad \sigma_1 - \mu\sigma_2 = \sigma_y$$

$$\Rightarrow 200 - 0.25 \times (-\sigma_2) = 240$$

$$\Rightarrow \quad \sigma_2 = \frac{40}{0.25}$$

$$\Rightarrow \quad \sigma_2 = 160\ N/mm^2$$

4.79 (b)

The x and y co-ordinates of centre of Mohr's circle are given by

$$\left(\frac{\sigma_x + \sigma_y}{2}, 0\right) = \left(\frac{100 + 200}{2}, 0\right) = (150, 0)$$

4.80 (c)

According to maximum strain theory,

$$\sigma_1 - \mu\sigma_2 \le \frac{\sigma_y}{F}$$

$$\Rightarrow \quad 122 - 0.3 \times (-60) \le \frac{280}{F}$$

$$\Rightarrow \quad F \le \frac{280}{140}$$

$$\Rightarrow \quad F \le 2$$

4.81 (d)

For the square clement, $\theta = 45°$

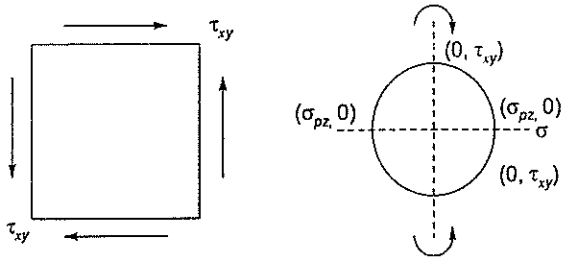
$$\therefore \ \sigma_n = \frac{\sigma_1 + \sigma_2}{2} + \left(\frac{\sigma_1 - \sigma_2}{2}\right) \times \cos 2\theta$$

$$= \frac{200 - 200}{2} + \left(\frac{200 - (-200)}{2}\right) \times \cos(2 \times 45°)$$

$$= 0$$

4.82 (c)

Principal stresses are τ_{xy} and $-\tau_{xy}$.



4.83 (b)

Normal stress acting on plane *AB* is given by

$$\sigma_n = \frac{\sigma_1 + \sigma_2}{2} + \left(\frac{\sigma_1 - \sigma_2}{2}\right) \times \cos 2\theta$$

$$= \frac{\sigma + \sigma}{2} + \left(\frac{\sigma - \sigma}{2}\right) \times \cos 2\theta$$

$$= \sigma + 0$$

$$= \sigma$$

4.84 (b)

Maximum principal stress theory (Rankine theory) is suitable for brittle material.

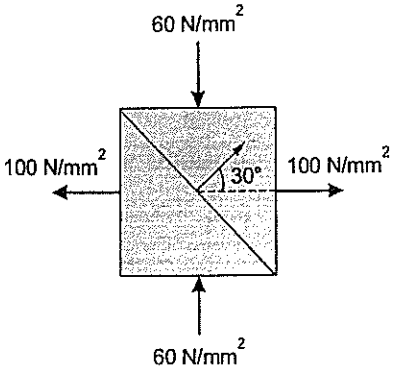
Maximum principal strain theory (St. Venants theory) is suitable for ductile and brittle material.

Maximum shear stress theory is suitable for ductile material, especially in the case of shaft.

Maximum strain energy theory is suitable for ductile material especially in the case of pressure vessel.

Maximum shear strain energy theory is suitable for ductile material and especially in the case of pure shear.

4.85 (a)



Major principal stress on the inclined plane

$$\sigma_1 = \frac{\sigma_x + \sigma_y}{2} + \frac{(\sigma_x - \sigma_y)}{2}\cos 2\theta$$

$$\theta = 30°, \ \sigma_x = 100 \text{ N/mm}^2$$

and $\quad \sigma_y = -60 \text{ N/mm}^2$

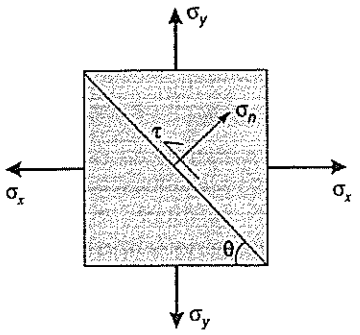
$$\sigma = \frac{100 - 60}{2} + \frac{(100 + 60)}{2}\cos 60°$$

$$= 60 \text{ N/mm}^2$$

4.86 (c)

Principal stress is the normal stress acting on the plane on which shear stress is zero.

For a body under the action of biaxial stress σ_x and σ_y shear stress acting on any plane inclined at angle θ to the x-axis.



Shear stress, τ is given by

$$\tau = \left(\frac{\sigma_x - \sigma_y}{2}\right)\sin 2\theta$$

τ will be maximum when $\theta = 45°$

Normal stress on this plane is given by

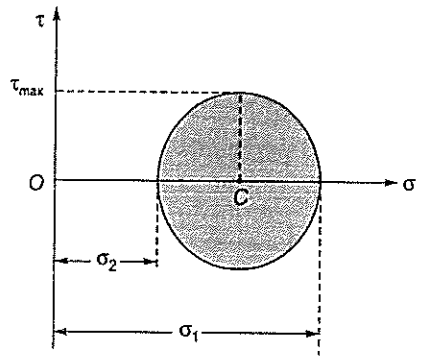
$$\sigma_n = \frac{\sigma_x + \sigma_y}{2} + \left(\frac{\sigma_x - \sigma_y}{2}\right)\cos 2\theta$$

$$= \frac{\sigma_x + \sigma_y}{2}$$

The centre of Mohr's circle for a two dimensional stress system always lies in the x-axis. In case of pure shear centre of circle coincides with origin.

4.88 (d)

Mohr's circle is the locus of normal and shear stress on an element with the changing angle of plane in 2-D case



The radius of Mohr's circle is equal to maximum shear stress.

$$r = \tau_{max} = \frac{(\sigma_1 - \sigma_2)}{2}$$

4.89 (a)

The magnitude of principal stress σ_1 and σ_2 are given by

$$\sigma_{1,2} = \left(\frac{\sigma_x + \sigma_y}{2}\right) \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

It is given that minimum principal stress on a section is zero.

Therefore, $\sigma_2 = 0$

$$\Rightarrow \left(\frac{\sigma_x + \sigma_y}{2}\right) - \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2} = 0$$

$$\Rightarrow \left(\frac{\sigma_x + \sigma_y}{2}\right) = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

Squaring both sides

$$\Rightarrow \left(\frac{\sigma_x + \sigma_y}{2}\right)^2 = \left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + (\tau_{xy})^2$$

$$\Rightarrow \tau_{xy} = \sqrt{\sigma_x . \sigma_y}$$

4.90 (d)

Maximum shear stress due to applied loading

$$\tau_{max} = \frac{\sigma_{max} - \sigma_{min}}{2} = \frac{120 - (-30)}{2}$$

$= 75$ MPa

Maximum shear stress in material at yield stress under uniaxial tension

$$\tau_y = \frac{\sigma_y}{2} = \frac{300}{2} = 150 \text{ MPa}$$

$$\therefore \text{ Factor of safety} = \frac{\tau_y}{\tau_{max}} = \frac{150}{75} = 2.0$$

4.91 (c)

According to maximum shear stress failure theory, for no failure maximum shear stress developed should be less than or equal to maximum shear stress at yield point in uniaxial loading.

$$\tau_{max} \le \frac{\sigma_y}{2}$$

$\Rightarrow$ Maximum shear stress = 1/2 of yield stress.

4.92 (b)

The maximum principal stress theory i.e., the Rankine's theory is suitable for Brittle materials such as cast iron. The maximum shear stress theory is suitable for ductile metals.

4.93 (*)

$\sigma_1 = 400$ N/mm^2

$\sigma_2 = -100$ N/mm^2 $\quad \theta = 30°$

$$\sigma_n = \left(\frac{\sigma_1 + \sigma_2}{2}\right) + \left(\frac{\sigma_1 - \sigma_2}{2}\right)\cos 2\theta$$

$$= \left(\frac{400 - 100}{2}\right) + \left(\frac{400 + 100}{2}\right)\cos 60°$$

$= 150 + 125 = 275$ N/mm^2

Option given as 375 N/mm^2

4.94 (b)

$A = 200$ mm^2

$$\sigma_1 = \frac{P}{A} = \frac{20 \times 1000}{200}\frac{N}{mm^2} = 100 \text{ N/mm}^2$$

$\theta = 45°$

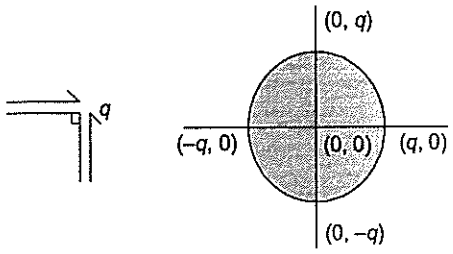
$$\sigma_n = \left(\frac{\sigma_1 + 0}{2}\right) + \left(\frac{\sigma_1 - 0}{2}\right)\cos 2\theta$$

$$= \frac{100}{2} + \frac{100}{2}\cos 90° = 50 \text{ N/mm}^2$$

4.95 (d)

Normal cross-section plane is the principal plane and plane of maximum shear is inclined at 45° to the principal plane.

4.99 (d)



Its a case of pure shear. Hence Mohr's circle is as shown

Diameter of Mohr's circle = $2q$

Centre is at origin

Principal stress are q and $-q$.

Hence they are equal in magnitude but unlike in direction.

Angle between normal to principal plane and normal to maximum shear is 90º in Mohr's circle. so it would be 45º.

4.100 (b)

$\sigma_x = 1.5$ MPa

$\sigma_y = 0$

$\tau_{xy} = 1.2$ MPa

$$\sigma_1/\sigma_2 = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$\sigma_1 = 2.17$ N/mm^2

$\sigma_2 = -0.665$ N/mm^2

Hence, option (b) is correct

4.101 (c)

Maximum shear stress

$$= \frac{\sigma_x - \sigma_y}{2} = \frac{160 - (-80)}{2}$$

$= 120$ MPa

So, option (c) is correct.

4.102 (d)

$\varepsilon_x = 800 \times 10^{-6}$

$\varepsilon_y = 400 \times 10^{-6}$

$\phi_{xy} = 300 \times 10^{-6}$

Maximum shear strain

$$\frac{\phi_{max}}{2} = \sqrt{\left(\frac{\varepsilon_x - \varepsilon_y}{2}\right)^2 + \left(\frac{\gamma_{xy}}{2}\right)^2} = 250 \times 10^{-6}$$

$$\Rightarrow \quad \gamma_{max} = 500 \times 10^{-6}$$

4.103 (a)

$\sigma_x = 90$ N/mm^2

$\sigma_y = 0$

$\tau_{xy} = 45$ N/mm^2

$$\Rightarrow \sigma_{1/2} = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right) + \tau_{xy}^2}$$

$$= \frac{90+0}{2} \pm \sqrt{\left(\frac{90-0}{2}\right)^2 + 45^2}$$

$\sigma_1 = 108.63$ N/mm^2

$\sigma_2 = -18.63$ N/mm^2

4.104 (c)

According to maximum normal strain theory,

$$\sigma_1 - \mu\sigma_2 \le \sigma_y$$

$$\Rightarrow \quad 200 - 0.25(-\sigma) \le 250$$

$$\Rightarrow \quad 200 + 0.25\,\sigma = 250$$

$$\Rightarrow \quad \sigma = \frac{50}{0.25} = 200 \text{ N/mm}^2$$

and also

$$\sigma_2 - \mu\sigma_1 > -\sigma_y$$

$$\Rightarrow \quad -\sigma - 50 > -250$$

$$\Rightarrow \quad \sigma + 50 < 250$$

$$\Rightarrow \quad \sigma < 200 \text{ N/mm}^2$$

4.105 (a)

In case of pure shear,

$$\sigma = \tau \sin 2\theta$$

At 45° $\quad \sigma = \tau \sin 90°$

$$= \tau$$

4.106 (c)

$$\sigma_n = \frac{\sigma_x + \sigma_y}{2} + \frac{\sigma_x - \sigma_y}{2}\cos 2\theta$$

$$\therefore \quad \sigma_n = \frac{100+0}{2} + \frac{100-0}{2} \times \cos 90°$$

$$\therefore \quad \sigma_n = 50 \text{ N/mm}^2$$

4.107 (b, c)

The transformation equations for plane stress can be represented in graphical form by a plot known as Mohr's Circle. This graphical representation is

extremely useful because it enables to visualize the relationships between the normal and shear stresses acting on various inclined planes at a point in a stressed body. Using Mohr's Circle the principal stresses, maximum shear stresses and stresses (normal as will as tangential) on inclined planes can also be calculated.

4.108 (d)

As we know that,

$$\sigma_x + \sigma_y = \sigma_1 + \sigma_2$$
$$150 + \sigma = 164 + 36$$
$$\sigma = 50\ \text{N/mm}^2$$

4.109 (c)

As shear stress is absent on these planes, hence normal stresses are principle stresses.

$$\sigma_1 = 80\ \text{MPa} \quad \text{(tensile)}$$
$$\sigma_2 = 40\ \text{MPa} \quad \text{(compressive)}$$
$$\tau_{max} = \left|\frac{\sigma_1 - \sigma_2}{2}\right| = \frac{80 - (-40)}{2}$$
$$= 60\ \text{MPa}$$

4.110 (c)

$$\because \quad \epsilon = \frac{\epsilon_x + \epsilon_y}{2} + \frac{\epsilon_x - \epsilon_y}{2}\cos 2\theta + \frac{\phi_{xy}}{2}\sin 2\theta$$
$$\because \quad \theta = 45^\circ$$
$$\therefore \quad \epsilon_{45^\circ} = 500 = \frac{-400 + 800}{2} + 0 + \frac{\phi_{xy}}{2}$$
$$\Rightarrow \quad \phi_{xy} = 600$$

4.111 (d)

$$\because \quad \sigma_n = \frac{\sigma_1 + \sigma_2}{2} + \frac{\sigma_1 - \sigma_2}{2}\cos 2\theta$$
$$\because \quad \theta = 45^\circ$$
$$\therefore \quad \sigma_{n45^\circ} = \frac{60 - 40}{2} + 0 = 10\ \text{N/mm}^2$$

4.112 (d)

By assuming FOS = 1.5

$$\because \quad \frac{pd}{2t} \le \frac{f_y}{\text{FOS}}$$
$$\Rightarrow \frac{2 \times 1200}{2 \times t} \le \frac{200}{1.5}$$
$$\Rightarrow \quad t \ge 9\ \text{mm}$$

4.113 (d)

As per distortion energy theory:

$$\frac{1}{2}\left[(\sigma_1 - \sigma_2)^2 + (\sigma_2 - \sigma_3)^2 + (\sigma_3 - \sigma_1)^2\right] \le f_y^2$$
$$\Rightarrow \frac{1}{2}\left[(2P - P)^2 + (P - 0)^2 + (0 - 2P)^2\right] \le f_y^2$$
$$\Rightarrow \frac{1}{2}\left[P^2 + P^2 + 4P^2\right] \le f_y^2$$
$$\Rightarrow P \le \frac{f_y}{\sqrt{3}}$$

4.114 (d)

As per maximum strain theory

$$\frac{\sigma_1}{E} - \mu\frac{\sigma_2}{E} \le \frac{\sigma_y}{E}$$

For tensile strain

$$\sigma_1 = 225\ \text{MPa}, \quad \mu = 0.25$$
$$225 - (-\sigma_2) \times 0.25 \le 250$$
$$\Rightarrow \quad \sigma_2 \le 100\ \text{MPa}$$

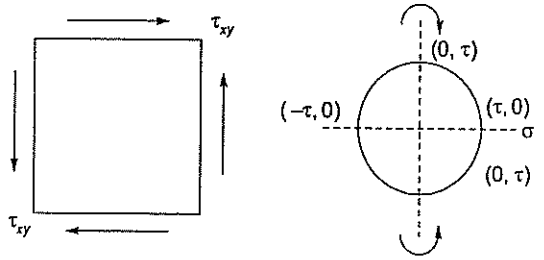
For compressive strain

$$\sigma_2 - (0.25)(-225) \le 250$$
$$\sigma_2 \le 193.75\ \text{MPa}$$

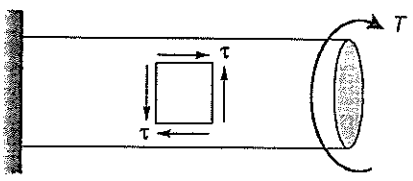
Since, σ_2 will be minimum of the above two values

$$\therefore \quad \sigma_2 = 100\ \text{MPa}$$

4.115 (b)



4.116 (a)



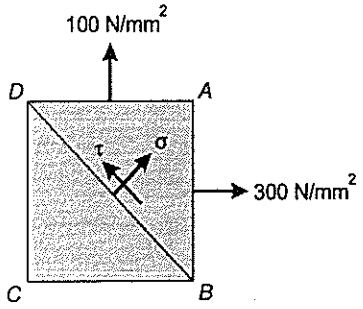
MS is ductile material which is weakest in shear so fail at τ_{max} plane.

Maximum shear stress plane will be longitudinal plane and traverse plane. (Pure shear conditions)

4.117 (d)

- The sum of normal stress on mutually perpendicular planes on any oblique plane remains constant.
- The shearing stress on two mutually perpendicular plane is same magnitude but opposite in sense of rotation.
- Maximum shear stress, $\tau_{max} = \dfrac{\sigma_1 - \sigma_2}{2}$

4.118 (d)



$$\sigma = \frac{300+100}{2} + \frac{300-100}{2}\cos 90°$$
$$= 200 \text{ N/mm}^2$$
$$\tau = \frac{300-100}{2} = 100 \text{ N/mm}^2$$

∴Resultant stress on BD
$$= \sqrt{\sigma^2 + \tau^2} = 100\sqrt{5} \text{ N/mm}^2$$

4.119 (c)

For pure shear
$$\sigma_1 = \tau = 80 \text{ N/mm}^2$$
$$\sigma_2 = -\tau = -80 \text{ N/mm}^2$$
$$\sigma_y = \pm 240 \text{ N/mm}^2$$

According to maximum normal shear theory
In tension,
$$\sigma_1 \le \frac{\sigma_y}{FOS}$$
$$\therefore \quad FOS = 3$$

In compression,
$$\sigma_2 \le -\frac{\sigma_y}{FOS}$$
$$\therefore \quad FOS = 3$$

4.120 (a)
$$\sigma_1 = 80 \text{ N/mm}^2$$
$$\sigma_2 = 40 \text{ N/mm}^2$$
$$\sigma_3 = 0$$

According to maximum principal stress theory,
$$\sigma_1 \le \frac{\sigma_y}{FOS}$$
$$FOS = \frac{200}{80} = 2.5$$

According to maximum shear stress theory
$$\tau_{max,\ absolute} \le \frac{\sigma_y}{2 \times FOS}$$
$$\therefore \quad \frac{\sigma_1 - \sigma_3}{2} \le \frac{\sigma_y}{2 \times FOS}$$
$$\frac{80-0}{2} = \frac{200}{2 \times FOS}$$
$$\therefore \quad FOS = 2.5$$

4.121 (a)

There is no theory like maximum shear strain theory. However if we use maximum shear stress theory.
$$\tau_{max,\ absolute} \le \frac{\sigma_y}{2 \times FOS}$$
Here, $\sigma_1 = 2\sigma$
$\sigma_2 = -\sigma$
$\sigma_3 = 0$
$$\therefore \tau_{max,\ absolute} = \frac{\sigma_1 - \sigma_2}{2} = 1.5\sigma$$
$$\therefore \quad 1.5\sigma \le \frac{210}{2 \times FOS}$$
$$\therefore \quad \sigma = \frac{210}{1.5 \times 2} \qquad [FOS = 1]$$
$$= 70 \text{ N/mm}^2$$

4.122 (a)

Radius of Mohr's circle
$$= \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$
$$= \sqrt{\left(\frac{80-(-40)}{2}\right)^2 + 0} = 60 \text{ MPa}$$

4.123 (a)
$$\sigma_x = 90 \text{ MPa},$$
$$\sigma_y = -30 \text{ MPa},$$
$$\tau_{xy} = 25 \text{ MPa}$$

∴Principal stress,

$$\sigma_1/\sigma_2 = \frac{\sigma_x + \sigma_y}{2} \pm \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

$$= 30 \pm \sqrt{60^2 + 25^2}$$

$$= 95 \text{ and } -35 \text{ MPa}$$

4.124 (*a)

Volumetric strain

$$\epsilon_v = \frac{\sigma_1 + \sigma_2 + \sigma_3}{E}(1 - 2\mu)$$

$$= \frac{550}{210 \times 10^3}(1 - 2 \times 0.3)$$

$$= 1.047 \times 10^{-3}$$

4.125 (b)

$$\sigma_1 = 1.4\sigma$$

$$\sigma_2 = -2\sigma$$

According to maximum strain theory,

$$\epsilon_1 \le \frac{\sigma_y}{E}$$

$$\therefore \quad \sigma_1 - \mu\sigma_2 \le \sigma_y$$

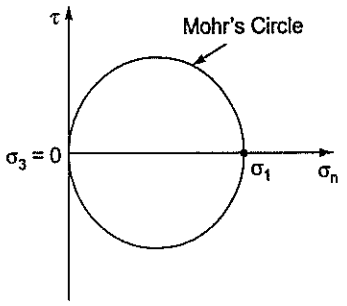
$$1.4\sigma + 0.3 \times 2\sigma \le 200$$

$$2\sigma \le 200$$

$$\therefore \quad \sigma = 100 \text{ MPa}$$

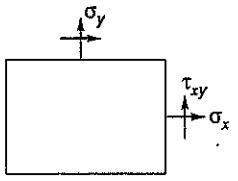
4.126 (d)

In uniaxial stress field, $\sigma_3 = 0$



$$\tau_{max} = \frac{\sigma_{12} - \sigma_3}{2} = \frac{\sigma_1 - 0}{2} = \frac{\sigma_1}{2}$$

In biaxial stress field,



$$\tau_{max} = \sqrt{\left(\frac{\sigma_x - \sigma_y}{2}\right)^2 + \tau_{xy}^2}$$

5 Deflection of Beams

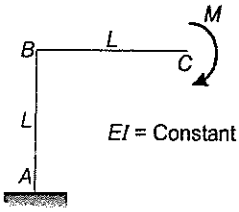
5.1 A beam simply supported at both the ends, of length L carries two equal unlike couples M at the two ends. If the flexural rigidity EI = constant, then central deflection of the beam is given by

(a) $\frac{ML^2}{4EI}$ (b) $\frac{ML^2}{16EI}$

(c) $\frac{ML^2}{64EI}$ (d) $\frac{ML^2}{8EI}$

[ESE : 1995]

5.2 What is the horizontal deflection at free end C of the frame shown in the given figure?



(a) $\frac{ML^2}{2EI}$ (b) $\frac{ML^2}{EI}$

(c) $\frac{3ML^2}{2EI}$ (d) $\frac{2ML^2}{EI}$

[ESE : 1995]

5.3 A simply supported beam of span L and flexural rigidity EI, carries a unit point load at its centre. The strain energy in the beam due to bending is

(a) $\frac{L^3}{48\,EI}$ (b) $\frac{L^3}{192\,EI}$

(c) $\frac{L^3}{96\,EI}$ (d) $\frac{L^3}{16\,EI}$

[ESE : 1996]

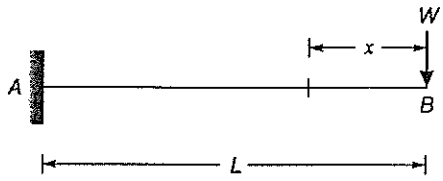
5.4 The maximum deflection of a fixed beam carrying a central load W is equal to

(a) $\frac{WL^3}{484EI}$ (b) $\frac{WL^3}{96EI}$

(c) $\frac{WL^3}{192EI}$ (d) $\frac{5}{384}\frac{WL^3}{EI}$

[ESE : 1996]

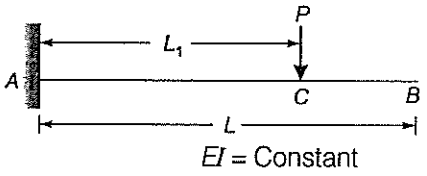
5.5 For the cantilever beam shown in the given figure, which one of the following pairs is not correctly matched?



Theorem	(EI)times deflection at B
(a) Mohr's Theorem	: Area of BMD x Distance of centroid of BMD from B
(b) Castigliano's Theorem	: $\int_0^L W x^2\,dx$
(c) Conjugate beam	: Shear force at the fixed end of conjugate beam
(d) Successive integration	: $\iint -W x\,dx$

[ESE : 1996]

5.6 A cantilever carries a load P at C as shown in the given figure.



EI = Constant

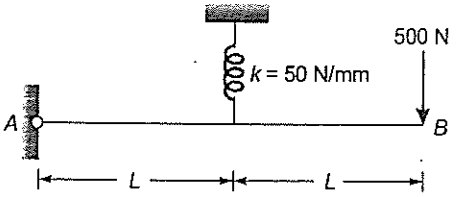
The deflection at B is

(a) $\frac{PL_1^2}{2EI}(L-L_1)$ (b) $\frac{PL_1^2}{3EI}(L-L_1)$

(c) $\frac{PL_1^2}{2EI}\left(L-\frac{L_1}{3}\right)$ (d) $\frac{PL_1^2}{3EI}\left(L-\frac{L_1}{3}\right)$

[ESE : 1996]

5.7 A rigid bar is supported by a spring as shown in the given figure.



The deflection of the point B will be
(a) 10 mm upward
(b) 20 mm downward
(c) 5 mm upward
(d) 40 mm downward

[ESE : 1996]

5.8 If the strain energy absorbed in a cantilever beam in bending under its own weight is K times greater than the strain energy absorbed in an identical simply supported beam in bending under its own weight, then the magnitude of K is
(a) 2 (b) 4
(c) 6 (d) 8

[ESE : 1997]

5.9 Consider the following statements regarding a beam of uniform cross-section simply supported at its ends and carrying a concentrated load at one of its middle third points:
1. Its deflection under the load will be maximum.
2. The bending moment under the load will be maximum.
3. The deflection at the midpoint of the span will be maximum.
4. The slope at the nearest support will be maximum.

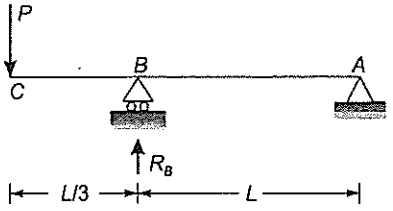
Which of these statements are correct?
(a) 1 and 3 (b) 2 and 4
(c) 1 and 2 (d) 3 and 4

[ESE : 1997]

5.10 A simply supported rectangular beam of span L and depth 'd' carries a central load W. The ratio of maximum deflection to maximum bending stress is
(a) $\frac{L^2}{6Ed}$ (b) $\frac{L^2}{8Ed}$
(c) $\frac{L^2}{48Ed}$ (d) $\frac{L^2}{12Ed}$

[ESE : 1997]

5.11 An overhang beam of uniform EI is loaded as shown in the figure below. The deflection at the free end will be



(a) $\frac{PL^3}{81EI}$ (b) $\frac{PL^3}{27EI}$
(c) $\frac{4PL^3}{81EI}$ (d) $\frac{2PL^3}{27EI}$

[ESE : 1998]

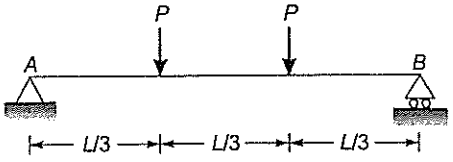
5.12 Assertion (A): Macaulay's method to determine the slope and deflection at a point in a beam is suitable for beams subjected to concentrated loads and can be extended to uniformly distributed loads.
Reason (R): Macaulay's method is based upon the modification of moment area method. This is applicable to a simple beam carrying a single concentrated load but by superposition, this method can be extended to cover any kind of loading.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

5.13 In a cantilever of span L subjected to a concentrated load of W acting at a distance of $\frac{L}{3}$ from the free end, the deflection under load will be
(a) $\frac{WL^3}{3EI}$ (b) $\frac{WL^3}{81EI}$
(c) $\frac{14WL^3}{81EI}$ (d) $\frac{8WL^3}{81EI}$

[ESE : 2000]

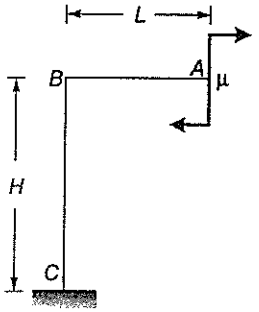
5.14 A simply supported beam of uniform flexural rigidity is loaded as shown in the given figure. The rotation of the end A is



(a) $\frac{PL^2}{9EI}$ (b) $\frac{PL^2}{6EI}$
(c) $\frac{PL^2}{18EI}$ (d) $\frac{PL^2}{12EI}$

[ESE : 2000]

5.15 A rigid cantilever frame *ABC* is fixed at *C* and carries a couple μ at the free end *A* as shown in the given figure below. Neglecting axial deformation and assuming the flexural rigidity *EI* to be constant throughout the frame, the vertical deflection of A is



(a) $\frac{\mu L}{EI}\left(H+\frac{L}{2}\right)$ (b) $\frac{\mu L^2}{EI}\left(H+\frac{L}{2}\right)$

(c) $\frac{\mu H^2}{2EI}\left(\frac{H}{2}+L\right)$ (d) $\frac{\mu H}{EI}\left(\frac{H}{2}+L\right)$

[ESE : 2000]

5.16 Match List-I (Actual beam) with List-II (Conjugate beam) on the basis of analogy and select the correct answer using the codes given below the lists:

List-I	List-II
A. Curvature	1. Shear
B. Deflection	2. Load
C. Slope	3. Moment

Codes:

	A	B	C
(a)	2	1	3
(b)	2	3	1
(c)	3	1	2
(d)	1	3	2

[ESE : 2000]

5.17 A simply supported beam '*A*' carries a point load at its mid span. Another identical beam '*B*' carries the same magnitude of load but it is uniformly distributed over the entire span. The ratio of the maximum deflections of beams '*A*' and '*B*' will be

(a) 8/3 (b) 2/3

(c) 3/5 (d) 8/5

[ESE : 2001]

5.18 The maximum deflection of simply supported beam occurs at zero

(a) bending moment location

(b) shear force location

(c) slope location

(d) shear force location and also zero bending moment location

[ESE : 2001]

5.19 Which of the following is/are determined at a point of a given beam by moment area method?

1. Shear force
2. Bending moment
3. Slope
4. Deflection

Select the correct answer using the codes given below:

(a) 1 and 2 (b) 3 alone

(c) 4 alone (d) 3 and 4

[ESE : 2001]

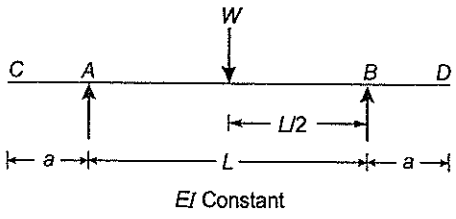
5.20 A simply supported beam of span L is subjected to a concentrated load W at midspan. The strain energy due to bending in the beam would be

(a) $\frac{W^2L^3}{48EI}$ (b) $\frac{W^2L^3}{96EI}$

(c) $\frac{W^2L^3}{24EI}$ (d) $\frac{WL^3}{96EI}$

[ESE : 2001]

5.21 Consider the loaded beam shown in the given figure:



EI Constant

Assertion (A): The deflection at the free end *C* is 'a' times the slope at *A*.

Reason (R): The elastic curve for the overhang portion *AC* or *BD* is a straight line tangential to the elastic curve at *A* and *B*.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 2001]

5.22 Consider the following statements:
A cantilever beam of length L is loaded with uniformly distributed load 'w' on the span. The beam is propped at the free end having its level same as that of the fixed end (EI is constant).

1. The prop reaction is $\frac{wL}{2}$.
2. The prop reaction is $\frac{3}{8}wL$.
3. The bending moment at the prop is $\frac{wL^2}{2}$.
4. SF is zero at $x = \frac{3}{8}L$ from the propped end.

Which of these statements are correct?
(a) 1 and 3 (b) 2 and 3
(c) 1 and 4 (d) 2 and 4

[ESE : 2001]

5.23 A unique relation between bending moment (M) and intensity of load (w) acting continuously on a beam of span (L) at a distance (x) along the axis (The flexural rigidity of beam is EI) is given by

(a) $M = \frac{wL^2}{8}$ (b) $w = \frac{d^2M}{dx^2}$

(c) $M = EI\frac{d^2w}{dx^2}$ (d) $M = \frac{wL^2}{12}$

[ESE : 2001]

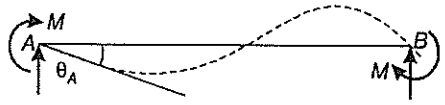
5.24 A straight cantilever of uniform cross-section carries a total load W distributed evenly over its entire length. If the free end of the cantilever is now propped upto the level of the fixed end, the vertical force required at the prop is

(a) $\frac{3}{8}W$ (b) $\frac{5}{8}W$

(c) $\frac{3}{4}W$ (d) W

[ESE : 2001]

5.25 A beam (EI = constant) of span L is subjected to clockwise moments M at both the ends A and B. The rotation of end A works out to be



(a) $\frac{ML}{2EI}$ (b) $\frac{ML}{3EI}$

(c) $\frac{ML}{4EI}$ (d) $\frac{ML}{6EI}$

[ESE : 2002]

5.26 A propped cantilever of span 4 m is fixed at A and propped at B. The beam carries a UDL of 1 t/m over the entire span. The reaction at B is
(a) 2.5 t (b) 2 t
(c) 1 t (d) 1.5 t

[ESE : 2002]

5.27 In a system two weightless rigid bars AB and BC of length 'a' each having hinge supports at the ends A and C, respectively, are connected to each other at B by a frictionless hinge (internal hinge). The rotation at the hinge is restrained by a rotational spring of stiffness 'k' and system assumes a straight line configuration ABC. The rotation at the supports due to vertical load P acting at joint B is

(a) $\frac{Pa}{2k}$ (b) $\frac{Pa}{4k}$

(c) $\frac{Pa}{k}$ (d) $\frac{2Pa}{k}$

[ESE : 2002]

5.28 For determining the deflection 'y' of a loaded beam at a distance 'x' by Macaulay's method, which one or more of the following is/are used?

1. The basic differential equation for deflection
$$EI\frac{d^2y}{dx^2} = -M;$$ where EI is the flexural rigidity of the beam, M is the bending moment.
2. Successive integration of the differential equation given in 1.
3. Known positions of zero deflection in the beam.

Select the correct answer using the codes given below:
(a) 1 only (b) 1 and 2
(c) 3 only (d) 1, 2 and 3

[ESE : 2003]

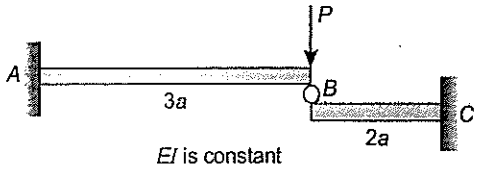
5.29 Moments of the same sense are applied to both the ends of a simply supported beam. The ratio

of the rotation of the two ends is 2. What is the ratio of the applied moments?

(a) 3/2 (b) 4/3
(c) 5/4 (d) 6/5

[ESE : 2004]

5.30 The free end of a cantilever beam is supported by the free end of another cantilever beam using a roller as shown in the figure given below. What is the deflection at the roller support *B*?

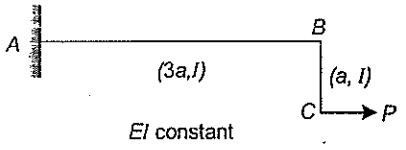


(a) $\frac{8Pa^3}{3EI}$ (b) $\frac{9Pa^3}{3EI}$

(c) $\frac{64Pa^3}{35EI}$ (d) $\frac{216Pa^3}{35EI}$

[ESE : 2005]

5.31 What is the vertical displacement at the point *C* of the structure shown in the figure given below?



(a) $\frac{9Pa^3}{2EI}$ (b) $\frac{27Pa^3}{2EI}$

(c) $\frac{27Pa^3}{8EI}$ (d) $\frac{3Pa^3}{8EI}$

[ESE : 2005]

5.32 The deflection at the free end of a uniformly loaded cantilever of length 1m is 7.5 mm. What is the slope at the free end?

(a) 0.01 radian (b) 0.015 radian
(c) 0.02 radian (d) 0.025 radian

[ESE : 2005]

5.33 Match List-I (Loading Condition) with List-II (Maximum Slope) and select the correct answer using the codes given below the lists (E = Modulus of elasticity, I = Area moment of inertia):

List-I

A. Cantilever with concentrated load W at free end
B. Cantilever with *udl* (*w*/unit length) across the complete span ($W = wL$)
C. Simply supported beam with concentrated load W at the centre
D. Simply supported beam with *udl* (*w*/unit length) across complete span ($W = wL$)

List-II

1. $\frac{WL^2}{16EI}$ 2. $\frac{WL^2}{24EI}$
3. $\frac{WL^2}{2EI}$ 4. $\frac{WL^2}{6EI}$

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	3	4	1	2
(c)	1	4	3	2
(d)	3	2	1	4

[ESE : 2006]

5.34 Match List-I (Load Case) with List-II (Expression for slope/Deflection) and select the correct answer using the codes given below the lists (Flexural rigidity = EI) :

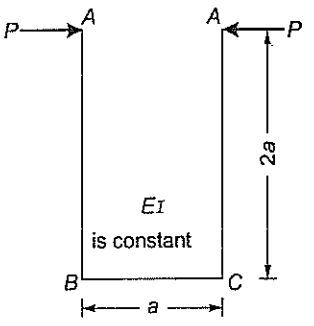
List-I	List-II
A. Slope for tip load of W	1. $WL^3/8EI$
B. Deflection for tip load of W	2. $WL^3/6EI$
C. Slope for total *UDL* of W	3. $WL^3/3EI$
D. Deflection for total *UDL* of W	4. $WL^2/2EI$

Codes:

	A	B	C	D
(a)	4	2	3	1
(b)	1	3	2	4
(c)	4	3	2	1
(d)	1	2	3	4

[ESE : 2007]

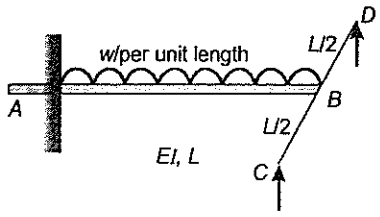
5.35 In the structure shown in the figure below, what is the distance through which the points A move towards each other?



(a) $4Pa^3/EI$ (b) $16Pa^3/3EI$
(c) $28Pa^3/3EI$ (d) $6Pa^3/EI$

[ESE : 2007]

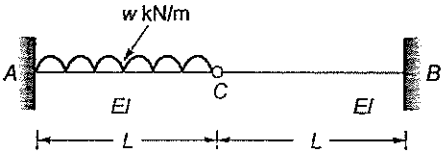
5.36 Which one of the following is the reaction of the cantilever at *B* as shown in the figure below?



(a) $\frac{3}{8}wL$ (b) $\frac{5}{8}wL$
(c) $\frac{6}{17}wL$ (d) $\frac{3}{21}wL$

[ESE : 2007]

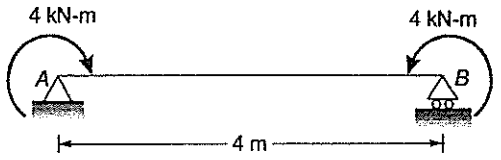
5.37 What is the reaction on the pin *C* for a beam as shown in the figure below ?



(a) $\frac{3}{8}wL$ kN (b) $\frac{1}{2}wL$ kN
(c) $\frac{1}{4}wL$ kN (d) $\frac{3}{16}wL$ kN

[ESE : 2009]

5.38 A simply supported beam *AB* of span 4 m is subjected to terminal couples as shown in the figure below.

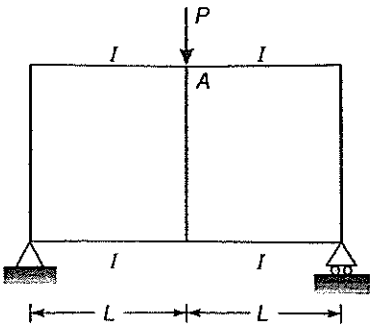


If *EI* is in kN-m^2, what is the magnitude of the central deflection of the beam in metres ?

(a) $\frac{4}{EI}$ (b) $\frac{8}{EI}$
(c) $\frac{2}{EI}$ (d) $\frac{16}{EI}$

[ESE : 2009]

5.39 What is the moment at *A* for a frame as shown in figure below ?



Each member indicated in dark lines has very large moment of inertia.

(a) $\frac{PL}{2}$ (b) $\frac{PL}{4}$
(c) $\frac{PL}{8}$ (d) $\frac{PL}{16}$

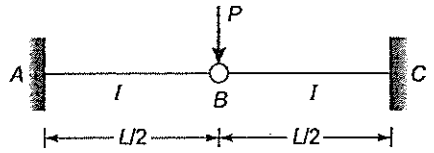
[ESE : 2009]

5.40 If the hinged end of a propped cantilever of span *L* settles by an amount δ, then the rotation of the hinged end will be

(a) $\frac{\delta}{L}$ (b) $\frac{2\delta}{L}$
(c) $\frac{3\delta}{2L}$ (d) $\frac{4\delta}{3L}$

[ESE : 2010]

5.41 What is the deflection at the hinge for the beam shown below?



(a) 0 (b) $\frac{PL^3}{3EI}$
(c) $\frac{PL^3}{24EI}$ (d) $\frac{PL^3}{48EI}$

[ESE : 2010]

5.42 The compatibility conditions in terms of strain in a two-dimensional problem are associated with
(a) Stresses
(b) Forces
(c) Properties of materials
(d) Deformations

[ESE : 2011]

5.43 A cantilever carries a uniformly distributed total load *W* over its whole length and a concentrated

upward load W at its free end. The net vertical deflection at the free end is

(a) zero

(b) $\frac{5}{24}\cdot\frac{Wl^3}{EI}$ downwards

(c) $\frac{5}{24}\cdot\frac{Wl^3}{EI}$ upwards

(d) $\frac{5}{48}\cdot\frac{Wl^3}{EI}$ upwards

[ESE : 2012]

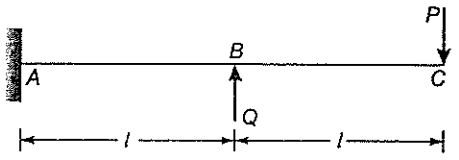
5.44 If a cantilever beam of span L and flexural rigidity EI carries a moment M at the free end, the deflection at that end is

(a) $\frac{ML}{24EI}$ (b) $\frac{ML^2}{12EI}$

(c) $\frac{ML}{6EI}$ (d) $\frac{ML^2}{2EI}$

[ESE : 2012]

5.45 For the beam-system as shown, if the deflection at C is zero, then the ratio $\frac{P}{Q}$ is

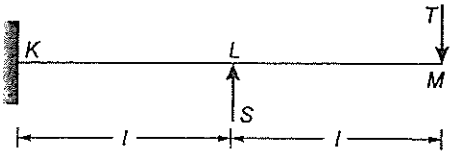


(a) $\frac{3}{8}$ (b) $\frac{5}{8}$

(c) $\frac{3}{16}$ (d) $\frac{5}{16}$

[ESE : 2012]

5.46 For the beam-system as shown, if the slope at M is zero, then the ratio $\frac{T}{S}$ is



(a) $\frac{1}{2}$ (b) $\frac{1}{3}$

(c) $\frac{1}{4}$ (d) $\frac{1}{8}$

[ESE : 2012]

5.47 Deflection limitations over beams are imposed because excessive deflection may cause

(a) undesirable twisting and distortion of end connections

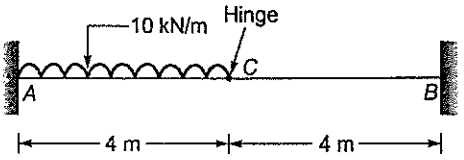
(b) problems in drainage system

(c) psychological effect on users

(d) all of the above

[ESE : 2012]

5.48 The reaction of the beam at C is

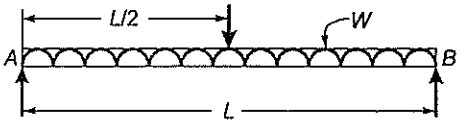


(a) 5.5 kN (b) 6.5 kN

(c) 6.5 kN (d) 7.5 kN

[ESE : 2012]

5.49 A simply supported beam of span L shown in the below figure is subjected to a concentrated load W at its mid-span and also to a uniformly distributed load equivalent to W. It has a flexural rigidity of EI. What is the total deflection at its mid-point?

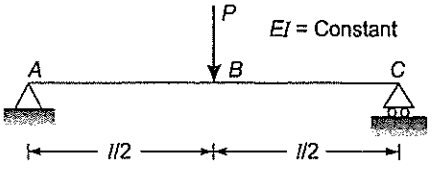


(a) $\frac{5}{384}\frac{WL^3}{EI}$ (b) $\frac{9}{384}\frac{WL^3}{EI}$

(c) $\frac{13}{384}\frac{WL^3}{EI}$ (d) $\frac{18}{384}\frac{WL^3}{EI}$

[ESE : 2013]

5.50 Mid-span deflection for the beam load system shown below can be obtained by



1. Area moment method
2. Energy method
3. Generalized three moment equation
4. Conjugate beam method

(a) 1, 2 and 3 only (b) 1, 2 and 4 only

(c) 2, 3 and 4 only (d) 1, 2, 3 and 4

[ESE : 2013]

5.51 The total deflection of a structure when subjected simultaneously to different sets of loading is equal to the sum of the deflections under each such set of loads as if acting separately on the structure. Which one of the following justifies this statement?
(a) Elastic limits is not exceeded
(b) Elastic limit including buckling is not exceeded
(c) Limit state is not exceeded
(d) Proportional limit without buckling is not exceeded

[ESE : 2013]

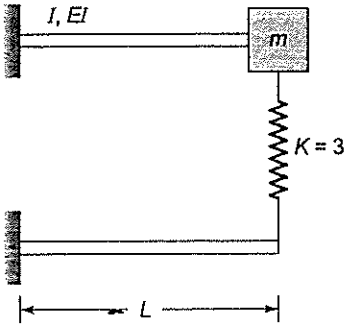
5.52 A hinged support in a real beam
(a) becomes an internal hinge in a conjugate beam
(b) changes to a free support in a conjugate beam
(c) changes to a fixed support in a conjugate beam
(d) remains as a hinged support in a conjugate beam

[ESE : 2014]

5.53 Two simply supported beams are made up of the same material and are of the same cross-section. Both beams carry uniformly distributed loads of equal intensities. One beam is 2 m long and the other is 4 m long. The 2 m long beam shows a central deflection of 1 mm. What is the central deflection of the 4 m long beam?
(a) 16 mm (b) 2 mm
(c) 8 mm (d) 1 mm

[ESE : 2015]

5.54 For the structure shown in the figure, all of I, EI and L are of respective unit values. The equivalent stiffness constant for the structure is



(a) 1 (b) 1.5
(c) 4.5 (d) 9

[ESE : 2015]

5.55 If the deflection at the free end of a uniformly loaded cantilever beam is 15 mm and the slope of the deflection curve at the free end is 0.02 radian, then the length of the beam is
(a) 0.8 m (b) 1.0 m
(c) 1.2 m (d) 1.5 m

[ESE : 2015]

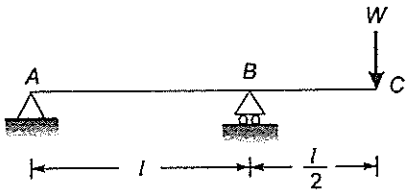
5.56 A chain, working a crane, has sectional area of 625 mm^2 and transmits a load of 10 kN. When the load is being lowered at a uniform rate of 40 m/min, the chain gets jammed suddenly at which time the length of the chain unwound is 10 m. Assuming $E = 200$ GPa, the stress induced in the chain due to this sudden jamming is
(a) 100.6 N/mm^2 (b) 120.4 N/mm^2
(c) 140.2 N/mm^2 (d) 160.0 N/mm^2

[ESE : 2017]

5.57 A simply supported beam of span l and flexural rigidity EI carries a unit load at its mid-span. The strain energy at this condition in the beam due to bending is
(a) $\frac{l^3}{48EI}$ (b) $\frac{l^3}{96EI}$
(c) $\frac{l^3}{192EI}$ (d) $\frac{l^3}{16EI}$

[ESE : 2017]

5.58 An overhanging beam of uniform EI is loaded as shown below. The deflection at the free end is



(a) $\frac{Wl^3}{81EI}$ (b) $\frac{Wl^3}{8EI}$
(c) $\frac{Wl^3}{27EI}$ (d) $\frac{2Wl^3}{27EI}$

[ESE : 2017]

5.59 A cantilever beam, 3 m long, carries a uniformly distributed load over the entire length. If the slope at the free end is 1°, the deflection at the free end is
(a) 49.27 mm (b) 39.27 mm
(c) 30.27 mm (d) 20.27 mm

[ESE : 2017]

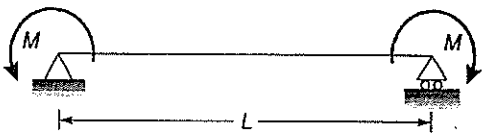
Answers Deflection of Beams

5.1 (d)	5.2 (a)	5.3 (c)	5.4 (c)	5.5 (c)	5.6 (c)	5.7 (d)	5.8 (c)	5.9 (b)	
5.10 (a)	5.11 (c)	5.12 (c)	5.13 (d)	5.14 (a)	5.15 (a)	5.16 (b)	5.17 (d)	5.18 (c)	
5.19 (d)	5.20 (b)	5.21 (a)	5.22 (d)	5.23 (b)	5.24 (a)	5.25 (d)	5.26 (d)	5.27 (b)	
5.28 (d)	5.29 (c)	5.30 (c)	5.31 (a)	5.32 (a)	5.33 (b)	5.34 (c)	5.35 (c)	5.36 (c)	
5.37 (d)	5.38 (b)	5.39 (b)	5.40 (c)	5.41 (d)	5.42 (d)	5.43 (c)	5.44 (d)	5.45 (d)	
5.46 (c)	5.47 (d)	5.48 (d)	5.49 (c)	5.50 (b)	5.51 (d)	5.52 (d)	5.53 (a)	5.54 (c)	
5.55 (b)	5.56 (b)	5.57 (b)	5.58 (b)	5.59 (b)					

Explanations Deflection of Beams

5.1 (d)

The bending moment throughout the beam is M.



The beam deforms in the form of a circular arc with radius $R = \frac{EI}{M}$. The central deflection

$$= \frac{L^2}{8R} = \frac{ML^2}{8EI}$$

5.2 (a)

The beam BC is subjected to moment M throughout its length. So vertical deflection of point C.

$$\delta_v = \frac{ML^2}{2EI} + \theta_B \times L = \frac{3ML^2}{2EI}$$

Vertical deflection of point B will be zero.

The slope at B, $\theta_B = \frac{ML}{EI}$

The slope of end C, $\theta_C = \frac{ML}{EI} + \theta_B = \frac{2ML}{EI}$

The horizontal deflection at point C will be equal to horizontal deflection at point B in column AB. The column AB is subjected to moment M throughout its length.

$$\therefore \quad \delta_h = \frac{ML^2}{2EI}$$

5.3 (c)

Strain energy due to bending

$$= \int \frac{M_x^2 dx}{2EI} = \frac{1}{2} W\delta$$

The deflection under the load,

$$\delta = \frac{WL^3}{48EI} = \frac{L^3}{48EI}$$

$\therefore$ Strain energy due to unit load

$$= \frac{1}{2} \times 1 \times \frac{L^3}{48EI} = \frac{L^3}{96EI}$$

5.4 (c)

The centre point deflection of fixed beam carrying central load is one-fourth of the centre point deflection of simply supported beam carrying point load.

$$\therefore \delta = \frac{1}{4}\left(\frac{WL^3}{48EI}\right) = \frac{WL^3}{192EI}$$

5.5 (c)

From Castigliano's theorem deflection at B

$$\delta_B = \int_0^L \frac{M}{EI}\left(\frac{\partial M}{\partial W}\right) dx$$

But $M = Wx$

$$\therefore \quad \delta_B = \int_0^L \frac{Wx^2}{EI} dx$$

In conjugate beam, shear force at the fixed end is the slope at B and BM at fixed end is the deflection at B.

5.6 (c)

$$\delta_B = \delta_C + \theta_C \times (L - L_1)$$

$$\delta_C = \frac{PL_1^3}{3EI}$$

$$\theta_C = \frac{PL_1^2}{2EI}$$

$$\therefore \quad \delta_B = \frac{PL_1^3}{3EI} + \frac{PL_1^2}{2EI}(L - L_1)$$

$$= \frac{PL_1^2}{2EI}\left[L - L_1 + \frac{2}{3}L_1\right]$$

$$= \frac{PL_1^2}{2EI}\left(L - \frac{L_1}{3}\right)$$

5.7 (d)

The force in spring,

$$F = \frac{500 \times 2L}{L} = 1000 \text{ N}$$

Deflection in the spring,

$$\delta = \frac{F}{k} = \frac{1000}{50} = 20 \text{ mm}$$

Deflection at point B

$= 2\delta = 40$ mm downward

5.8 (c)

For simply supported beam strain energy,

$$E_1 = \frac{W^2L^3}{240EI}$$

For cantilever beam strain energy,

$$E_2 = \frac{W^2L^3}{40EI}$$

$$\therefore \quad \frac{E_2}{E_1} = 6$$

5.9 (b)

The deflection is maximum at a point between load and mid span. The bending moment under the load is maximum and slope at nearest support is maximum.

5.10 (a)

Maximum bending moment, $M = \frac{WL}{4}$

Maximum deflection, $\delta = \frac{WL^3}{48EI}$

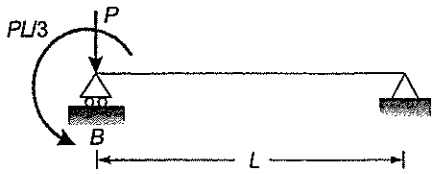
Maximum bending stress, $f = \frac{M}{Z}$

$$\therefore \quad \frac{\delta}{f} = \frac{L^2Z}{12EI} = \frac{L^2}{6Ed} \left(as \frac{I}{Z} = \frac{d}{2}\right)$$

5.11 (c)

The over hanging part of the beam can be replaced by moment $\frac{PL}{3}$ and load P at point B. Slope at B

$$\theta_B = \left(\frac{PL}{3}\right)\frac{L}{3EI} = \frac{PL^2}{9EI}$$



If there was no load on overhanging part the deflection of load point would have been $\theta_B \times \frac{L}{3}$. However due to load the additional deflection $\frac{P(L/3)^3}{3EI} = \frac{PL^3}{81EI}$ is caused.

∴ Deflection under load,

$$\Delta_{Load} = \frac{PL^2}{9EI} \times \frac{L}{3} + \frac{PL^3}{81EI} = \frac{4PL^3}{81EI}$$

5.12 (c)

Macaulay's method is based on singularity function. It is applicable for prismatic beams only. While Mohr's moment area method can be used for prismatic and non prismatic beams.

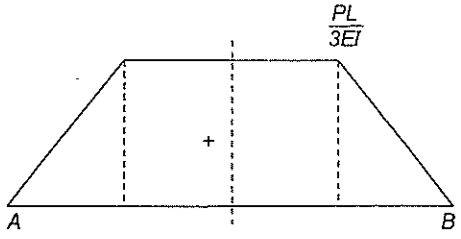
5.13 (d)

Deflection under the load,

$$= \frac{W \times (2L/3)^3}{3EI} = \frac{8WL^3}{81EI}$$

5.14 (a)

The M/EI diagram of beam is



The slope at mid point is zero. The difference between the slope at two points is M/EI area between those points. So slope at A

$$\theta_A = \frac{PL}{3EI} \times \left(\frac{1}{2} \times \frac{L}{3} + \frac{L}{6}\right) = \frac{PL^2}{9EI}$$

5.15 (a)

Slope at B, $\theta_B = \frac{\mu H}{EI}$

Considering zero slope at B, the vertical deflection at A,

$$\Delta_{1A} = \frac{\mu L^2}{2EI}$$

Total deflection at A,

$$\Delta_A = \theta_B \times L + \Delta_{1A} = \frac{\mu L}{EI}\left(H + \frac{L}{2}\right)$$

5.16 (b)

Curvature $\frac{d^2y}{dx^2}$ in the beam is analogous to load in the conjugate beam.

5.17 (d)

At the centre of simply supported beam,

(i) deflection due to point load is

$$\delta_A = \frac{WL^3}{48EI}$$

(ii) Deflection due to UDL is

$$\delta_B = \frac{5}{384} \times \frac{wL^4}{EI}$$

where $wL = W$

$$\therefore \quad \delta_B = \frac{5}{384} \times \frac{WL^3}{EI}$$

Hence, $\frac{\delta_A}{\delta_B} = \frac{8}{5}$

5.18 (c)

If y is the deflection then

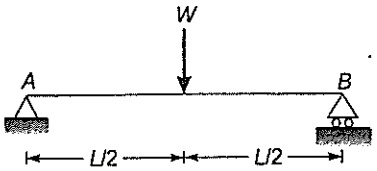
For maximum deflection, $\frac{dy}{dx} = 0$

$\frac{dy}{dx}$ represents the slope.

5.19 (d)

In moment area method $\frac{M}{EI}$ diagram is plotted and slope and deflection at a point are determined.

5.20 (b)



The strain energy due to bending in beam is given as

$$E = 2 \times \int_0^{L/2} \frac{M_x^2 dx}{2EI}$$

where, $M_x = \frac{w}{2}x$

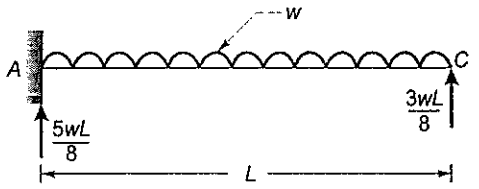
$$\Rightarrow \quad E = \frac{1}{EI}\int_0^{L/2}\left(\frac{w}{2}x\right)^2 dx = \frac{w^2}{4EI}\int_0^{L/2} x^2 dx$$

$$= \frac{w^2}{4EI}\left[\frac{x^3}{3}\right]_0^{L/2} = \frac{w^2L^3}{96EI}$$

5.21 (a)

Since there is no load on portion CA so the elastic curve is a straight line and deflection at free end is 'a' times the slope at A.

5.22 (d)



Prop reaction $= \frac{3wL}{8}$

BM at prop is zero.

The point of zero shear force will be at $\frac{5L}{8}$ from fixed end and $\frac{3L}{8}$ from prop end.

5.23 (b)

$$\frac{dV}{dx} = -w \quad \text{and} \quad \frac{dM}{dx} = V$$

$$\therefore \quad w = -\frac{d^2M}{dx^2}$$

Thus (b) represents the relation between load and BM at any section.

5.24 (a)

Vertical downward deflection due to UDL = Upward deflection due to reaction at prop

$$\frac{wL^4}{8EI} = \frac{R_B L^3}{3EI}$$

$$R_B = \frac{3}{8}wL = \frac{3}{8}W$$

5.25 (d)

Rotation at A due to moment at $A = \frac{ML}{3EI}$

Rotation at A due to moment at $B = -\frac{ML}{6EI}$

$\therefore$ Rotation at $A = \frac{ML}{6EI}$

5.26 (d)

Vertical downward deflection due to UDL = Upward deflection due to reaction at B

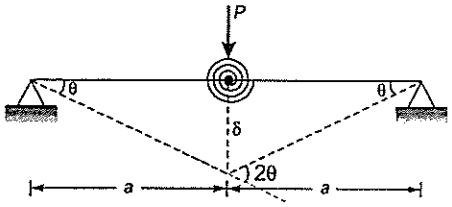
$$\frac{wL^4}{8EI} = \frac{R_B L^3}{3EI}$$

$$R_B = \frac{3}{8}wL$$

$$= \frac{3}{8} \times 1 \times 4 = 1.5t$$

5.27 (b)

Rotation in spring is double than that of rotation at the ends.



Strain energy stored in spring,

$$U = \frac{1}{2} \times T \times 2\theta \qquad [\because T = k2\theta]$$

$$= 2k\theta^2$$

Work done by load,

$$W = \frac{1}{2} \times P \times \delta$$

But from the figure above we have $\theta = \frac{\delta}{a}$

Also, strain energy stored in the spring is equal to the work done by the load.

$\therefore \quad U = W$

$$2k\theta^2 = \frac{1}{2} \times P \times \delta$$

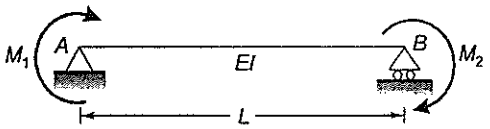
$$\Rightarrow \quad 2k\theta^2 = \frac{1}{2} \times P \times a\theta$$

$$\Rightarrow \quad \theta = \frac{Pa}{4k}$$

5.28 (d)

To find out the deflection using Macaulay's method, basic differential equation $EI\frac{d^2y}{dx^2} = -M$ is integrated successively and known boundary conditions such as zero slope etc. are used to find out constant of integration.

5.29 (c)



Rotation at end A due to M_1

$$= \frac{M_1 L}{3EI} \text{ clockwise}$$

Rotation at end B due to M_1

$$= \frac{M_1 L}{6EI} \text{ anticlockwise}$$

Rotation at end A due to M_2

$$= \frac{M_2 L}{6EI} \text{ anticlockwise}$$

Rotation at end B due to M_2

$$= \frac{M_2 L}{3EI} \text{ clockwise}$$

Rotation at A,

$$\theta_A = \frac{M_1 L}{3EI} - \frac{M_2 L}{6EI}$$

Rotation at B,

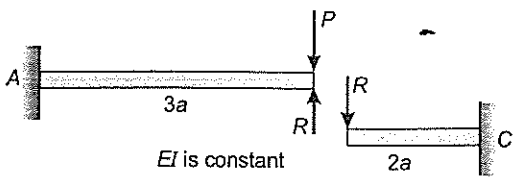
$$\theta_B = \frac{M_2 L}{3EI} - \frac{M_1 L}{6EI}$$

$$\therefore \quad \frac{\theta_A}{\theta_B} = \frac{2M_1 - M_2}{2M_2 - M_1} = 2$$

$$\Rightarrow \quad 4M_1 = 5M_2$$

$$\Rightarrow \quad \frac{M_1}{M_2} = \frac{5}{4}$$

5.30 (c)



$$\frac{P(3a)^3}{3EI} - \frac{R(3a)^3}{3EI} = \frac{R(2a)^3}{3EI}$$

$$P \times 27 - R \times 27 = R \times 8$$

$$R = \frac{27}{35}P$$

$$\therefore \quad \Delta = \frac{R(2a)^3}{3EI} = \frac{64Pa^3}{35EI}$$

5.31 (a)

The vertical displacement at C will be due to deflection of point B. The beam AB is subjected to a moment Pa and axial force P. So the deflection of point C will be $\frac{Pa(3a)^2}{2EI} = \frac{9Pa^3}{2EI}$ in the vertically upward direction.

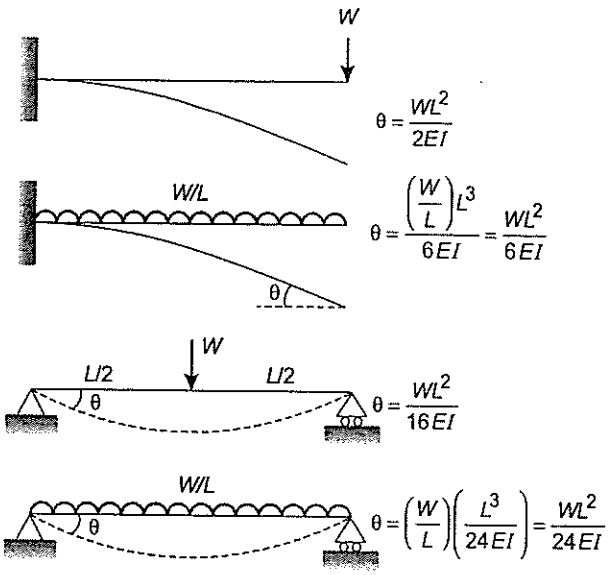
5.32 (a)

For uniformly loaded cantilever,

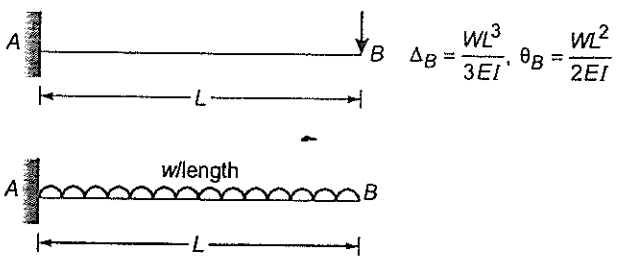
$$\Delta = \frac{wL^4}{8EI} \text{ and } \theta = \frac{wL^3}{6EI}$$

$$\therefore \theta = \frac{8\Delta}{6L} = \frac{4\Delta}{3L} = \frac{4 \times 7.5}{1000 \times 3} = 0.01 \text{ radian}$$

5.33 (b)



5.34 (c)



Given: $wL = W$

$$\Delta_B = \frac{wL^4}{8EI} = \frac{WL^3}{8EI}$$

$$\theta_B = \frac{wL^3}{6EI} = \frac{WL^2}{6EI}$$

5.35 (c)

Joints B and C are rigid, hence can act as fixed supports. Hence BA will act as a cantilever with point load at A.

$$\therefore \quad \delta_P = \frac{P(2a)^3}{3EI} = \frac{8Pa^3}{3EI}$$

Now at ends B and C, moments of magnitude 2 Pa will act respectively.

$$\therefore \quad \theta_B = \theta_C = \frac{2Pa \times a}{2EI} = \frac{Pa^2}{EI}$$

$$\text{and } \delta_M = \theta_B \times 2a = \frac{Pa^2}{EI} \times 2a = \frac{2Pa^3}{EI}$$

$$\therefore \text{ Total deflection} = 2(\delta_P + \delta_M)$$

$$= 2\left(\frac{8Pa^3}{3EI} + \frac{2Pa^3}{EI}\right) = \frac{28Pa^3}{3EI}$$

5.36 (c)

Let the reaction at B on the cantilever be R.

Deflection at B for the cantilever = Deflection at B for simply supported beam

$$\Rightarrow \quad \frac{wL^4}{8EI} - \frac{RL^3}{3EI} = \frac{RL^3}{48EI}$$

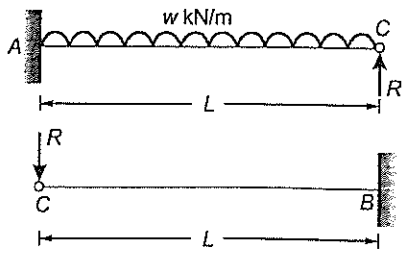
$$\Rightarrow \quad \frac{wL}{8} - \frac{R}{3} = \frac{R}{48}$$

$$\Rightarrow \quad \frac{17R}{48} = \frac{wL}{8}$$

$$\Rightarrow \quad R = \frac{6}{17}wL$$

5.37 (d)

Free body diagram of the given beam is shown below:



$$\frac{wL^4}{8EI} - \frac{RL^3}{3EI} = \frac{RL^3}{3EI}$$

$$\Rightarrow \quad \frac{2RL^3}{3EI} = \frac{wL^4}{8EI}$$

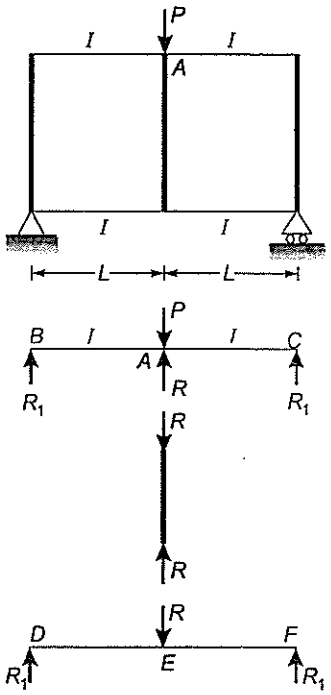
$$\Rightarrow \quad R = \frac{3}{16}wL$$

5.38 (b)

It is a case of pure bending and the deflected shape of the beam will be an arc of a circle. The central deflection in this case is given by

$$\delta_c = \frac{ML^2}{8EI} = \frac{4\times(4)^2}{8EI} = \frac{8}{EI}$$

5.39 (b)



Compatibility condition

$$\Delta_E = \Delta_A$$

$$\frac{R(2L)^3}{48EI} = \frac{(P-R)(2L)^3}{48EI}$$

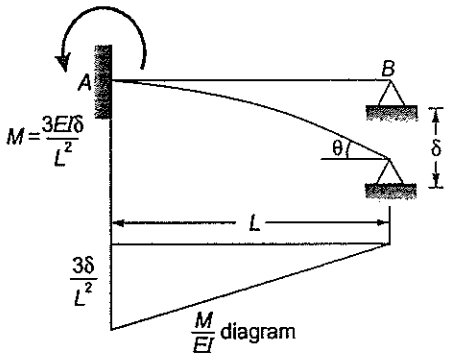
$$R = \frac{P}{2}$$

$$\Sigma V = 0$$

$$2R_1 = \frac{P}{2}; \qquad R_1 = \frac{P}{4}$$

$$M_A = \frac{PL}{4}$$

5.40 (c)

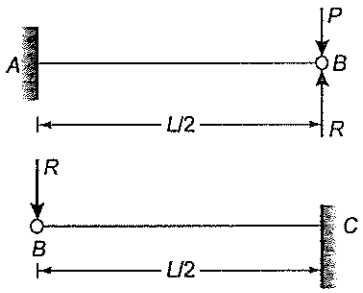


Using moment area method, we get

$$\theta = \frac{1}{2}\times\frac{3\delta}{L^2}\times L = \frac{3\delta}{2L}$$

5.41 (d)

Free body diagram of the given beam is shown below.



$$\therefore \quad \frac{P\times(L/2)^3}{3EI} - \frac{R\times(L/2)^3}{3EI} = \frac{R\times(L/2)^3}{3EI}$$

$$\Rightarrow \quad \frac{PL^3}{24EI} = \frac{RL^3}{12EI}$$

$$\Rightarrow \quad R = \frac{P}{2}$$

Deflection at the hinge is given by

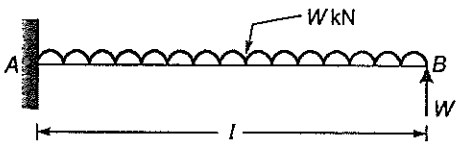
$$\delta_c = \frac{R(L/2)^3}{3EI}$$

$$= \frac{P}{2}\times\frac{L^3}{24EI} = \frac{PL^3}{48EI}$$

5.42 (d)

Compatibility conditions in terms of strain in two-dimensional problem ensure that when material particles in component deform, translate and rotate they must stay together after deformation.

5.43 (c)



The vertical deflection at end B due to point load W is given by

$$\Delta_{B_1} = \frac{Wl^3}{3EI}\text{(upward)}$$

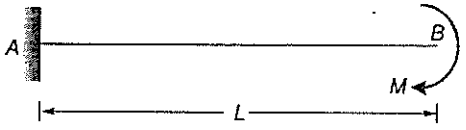
The vertical deflection at end B due to total load W over its whole length is

$$\Delta_{B_2} = \frac{Wl^3}{8EI}\text{(downward)}$$

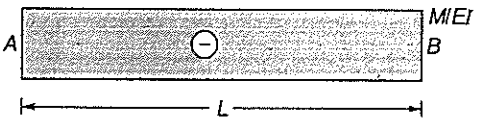
$$\therefore \quad \Delta_{net} = \Delta_{B_1} - \Delta_{B_2} = \frac{Wl^3}{3EI} - \frac{Wl^3}{8EI}$$

$$= \frac{5}{24}\cdot\frac{Wl^3}{EI}\text{(upward)}$$

5.44 (d)



BMD is given by

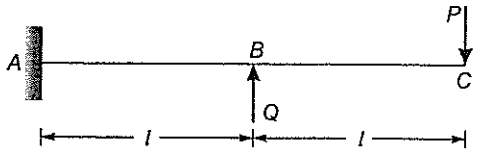


Using moment area method

$$\Delta_{B/A} = \frac{1}{2}\cdot\frac{ML}{EI}\times L$$

$$\Delta_{B/A} = \frac{ML^2}{2EI}$$

5.45 (d)



Deflection at C due to load Q at B

$$\Delta_{C/Q} = \frac{Ql^3}{3EI} + \frac{Ql^2}{2EI}\times l \text{ ...upwards}$$

Deflection at C due to load P

$$\Delta_{C/P} = \frac{P(2l)^3}{3EI} \text{ ...downwards}$$

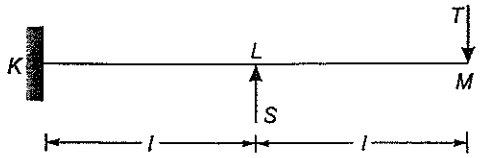
$\therefore$ For deflection at C to be zero

$$\Rightarrow \quad \Delta_{C/Q} = \Delta_{C/P}$$

$$\Rightarrow \quad P = \frac{5}{16}Q$$

$$\therefore \quad \frac{P}{Q} = \frac{5}{16}$$

5.46 (c)



Slope at M due to load S at L

$$Q_M^S = \frac{Sl^2}{2EI}\text{(anti-clockwise)}$$

Slope at M due to load T at M

$$Q_M^T = \frac{T(2l)^2}{2EI} = \frac{2Tl^2}{EI}\text{(clockwise)}$$

$\therefore$ For slope at M to be zero

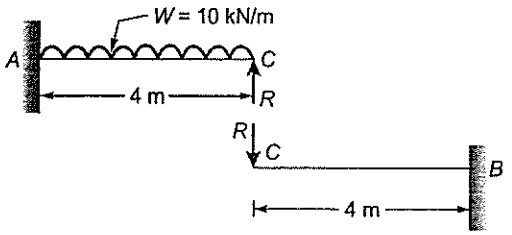
$$Q_M^S = Q_M^T$$

$$\Rightarrow \quad \frac{Sl^2}{2EI} = \frac{2Tl^2}{EI}$$

$$\Rightarrow \quad \frac{T}{S} = \frac{1}{4}$$

5.47 (d)

Let the reaction at the hinge be R



Now the deflections at C will be equal

i.e., $\frac{WL^4}{8EI} - \frac{RL^3}{3EI} = \frac{RL^3}{3EI}$

$$\therefore \quad \frac{10\times(4)^4}{8} - \frac{R\times 4^3}{3} = \frac{R\times 4^3}{3}$$

$$\Rightarrow \quad \frac{2\times R\times 64}{3} = \frac{10\times 4^4}{8}$$

$$\because \quad R = \frac{3\times 10\times 4^4}{8\times 2\times 64} = 7.5 \text{ kN}$$

5.48 (c)

$$\frac{5}{384}\frac{(wL)l^3}{EI} + \frac{WL^3}{48EI} = \frac{13}{384}\frac{WL^3}{EI}$$

5.49 (b)

Three moment equation is used to determine moments.

5.50 (d)

Real beam	Conjugate beam
Hinged support	Hinged support
Fixed support	Free support
Free support	Fixed support
Internal hinge	Internal roller
Internal roller	Internal hinge

5.51 (d)

Hook's law is applicable within the limit of proportionality and superposition principle is applicable only for small deformations.

5.53 (a)

As we know that,

$$\delta = \frac{5}{384}\frac{wL^4}{EI}$$

Both the beams have same load intensity (w), material (E) and cross-section (I).

Beam 1: $L = 2\text{ m}, \quad \delta_1 = 1\text{ mm}$

$$\delta_1 = \frac{5}{384}\times\frac{w}{EI}\times(2)^4$$

$$\therefore \quad 1 = C\times(2)^4 \Rightarrow C = \frac{1}{(2)^4}$$

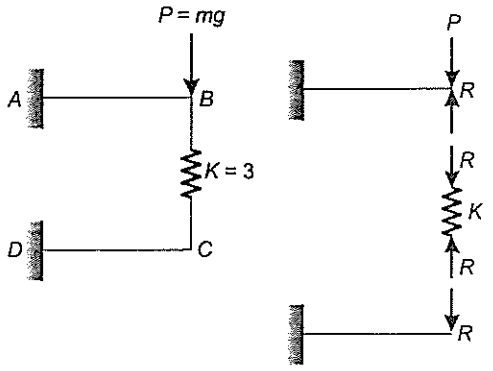
Beam-2: $L = 4\text{ m}$

$$\delta_2 = \frac{5}{384}\times\frac{w}{EI}\times(4)^4$$

$$\Rightarrow \quad \delta_2 = C\times(4)^4$$

$$\therefore \quad \delta_2 = \frac{1}{2^4}\times 4^4 = 16\text{mm}$$

5.54 (c)



Compression in spring = $\Delta_B - \Delta_C$

$$\frac{R}{K} = \frac{(P-R)L^3}{3EI} - \frac{RL^3}{3EI}$$

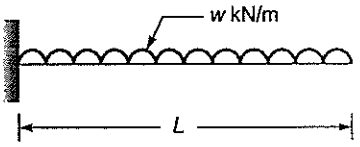
Given, $I = EI = L = 1$ unit

$$\therefore \quad R = \frac{P}{3}$$

Equivalent stiffness of structure

$$= \frac{P}{\frac{(P-R)L^3}{3EI}} = \frac{3P}{P-\frac{P}{3}} = 4.5$$

5.55 (b)



Deflection at free end

$$= \frac{wL^4}{8EI} = 15\times10^{-3}\text{ m} \qquad ...(i)$$

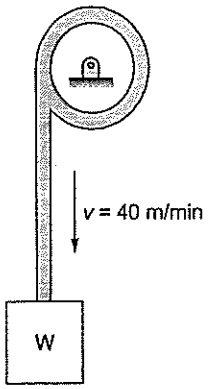
$$\text{Slope at free end} = \frac{wL^3}{6EI} = 0.02\text{ radian} \qquad ...(ii)$$

Dividing equation (i) by (ii)

$$\frac{6}{8}\times L = \frac{15\times10^{-3}}{0.02}$$

$$\therefore \quad L = 1\text{ m}$$

5.56 (b)



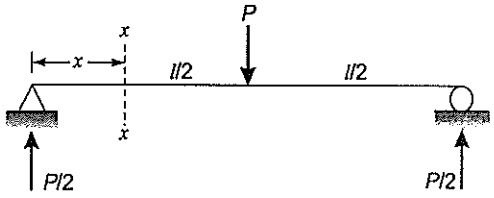
$$\frac{1}{2}mv^2 = \frac{\sigma^2}{2E}(A\times L)$$

$$\frac{1}{2}\left(\frac{10\times10^3}{9.81}\right)\times\left(\frac{40\times10^3}{60}\frac{\text{mm}}{\text{sec}}\right)^2$$

$$= \frac{\sigma^2}{2\times(200\times10^3)}\left[(625)\times(10\times10^3)\right]$$

σ = 120.2 N/mm^2

5.57 (b)



$$M_x = \frac{Px}{2}$$

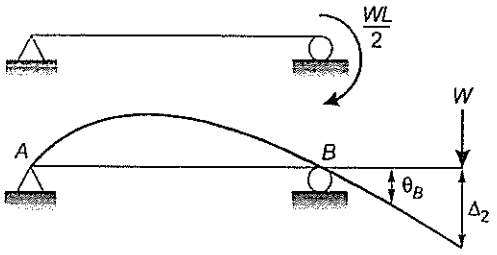
∴SE stored in the beam =

$$2\int_0^{l/2}\frac{M_x^2dx}{2EI} = 2\int_0^{l/2}\frac{(Px/2)^2dx}{2EI} = \frac{P^2l^3}{96EI}$$

For unit load P = 1

$$SE = \frac{l^3}{96EI}$$

5.58 (b)



Deflection due to cantilever action of load in span BC.

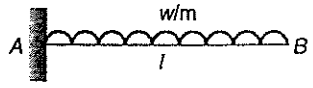
$$\Delta_1 = \frac{W(L/2)^3}{3EI} = \frac{WL^3}{24EI}$$

$$\theta_B = \frac{(WL/2)L}{3EI} = \frac{WL^2}{6EI}$$

Now $\Delta_2 = \theta_B \cdot \frac{L}{2} = \frac{WL^3}{12EI}$

$\therefore$ $\Delta = \Delta_1 + \Delta_2 = \frac{WL^3}{8EI}$

5.59 (b)



$$\theta_B = \frac{wl^3}{6EI}, \qquad \Delta_B = \frac{wl^4}{8EI}$$

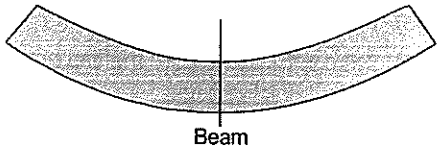
$$\Delta_B = \frac{wl^3}{6EI}\cdot\frac{6l}{8}$$

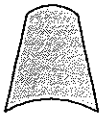
$$= \theta_B \times \frac{6l}{8} = \frac{\pi}{180}\times\frac{6\times3}{8}$$

= 0.0392 m = 39.2 mm

6 Bending & Shear Stresses in Beams

6.1 For a square-sectioned beam bent as shown in the given figure, the exaggerated view of the deformed cross-section is



(a) (b) 

(c) (d)

[ESE : 1995]

6.2 Given that $m = \frac{E_s}{E_t}$, I_t = Moment of inertia of timber portion and I_s = Moment of inertia of steel portion, the equivalent moment of inertia of a flitched beam made of steel and timber is given by

(a) $I_t + \frac{I_s}{m}$ (b) $I_s + \frac{I_t}{m}$

(c) $I_s + mI_t$ (d) $I_t + mI_s$

[ESE : 1995]

6.3 A ratio of moment carrying capacity of a circular beam of diameter D and square beam of size D is

(a) $\pi/4$ (b) $3\pi/8$

(c) $\pi/3$ (d) $3\pi/16$

[ESE : 1995]

6.4 A beam has triangular cross-section, having base 'b' and altitude 'h'. If a section of the beam is subjected to a shear force F, the shear stress at the level of neutral axis in the cross-section is given by

(a) $\frac{4F}{3bh}$ (b) $\frac{3F}{4bh}$

(c) $\frac{8F}{3bh}$ (d) $\frac{3F}{8bh}$

[ESE : 1995]

6.5 A steel wire of 20 mm diameter is bent into a circular shape of 10 m radius. If the modulus of elasticity is 2×10^6 kg/cm^2, then the maximum stress induced in the wire is

(a) 10^3 kg/cm^2

(b) 2×10^3 kg/cm^2

(c) 4×10^3 kg/cm^2

(d) 6×10^3 kg/cm^2

[ESE : 1995]

Directions: The following items consists of two statements, one labelled as the **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) Both Assertion (A) and Reason (R) are individually true and Reason (R) is the correct explanation of Assertion (A).

(b) Both Assertion (A) and Reason (R) are individually true but Reason (R) is NOT the correct explanation of Assertion (A).

(c) Assertion (A) is true but Reason (R) is false.

(d) Assertion (A) is false but Reason (R) is true.

6.6 **Assertion (A):** I-Section is preferred to rectangular section for resisting bending moment.

Reason (R): In I-Section more than 80% of bending moment is resisted by flanges only.

[ESE : 1996]

6.7 **Assertion (A):** A beam of circular cross-section in comparison to rectangular section of the same material but of equal cross-section area can resist a larger shear force.

Reason (R): The maximum intensities of shear stress in the sections of a beam of circular cross-section and of a rectangular cross-section are $1\frac{1}{3}$ times and $1\frac{1}{2}$ times the average shear stress respectively.

[ESE : 1996]

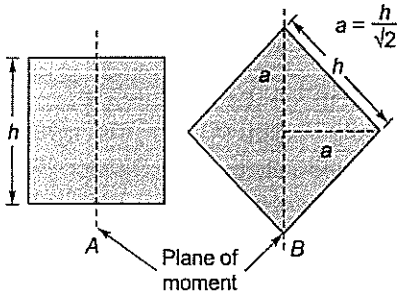
6.8 A simply supported beam of span L carries a concentrated load W at mid-span. If the width 'b' of the beam is constant and its depth is varying throughout the span, then what should be its mid-span depth, when design stress is 'f'?

(a) $\sqrt{\frac{6WL}{bf}}$ (b) $\frac{6WL}{bf}$

(c) $\sqrt{\frac{3WL}{2bf}}$ (d) $\frac{3WL}{2bf}$

[ESE : 1996]

6.9 The span and the material of the two beams A and B are the same. The area of cross section of the two beams are equal. The cross-section is square. In the case of beam A, the plane of moment is parallel to the sides of the square and in the case of beam B, the plane of moment coincides with the diagonal as shown in the given figure.



Consider the following inferences from the above data:

1. For the same loading, the deflection of the beam B is smaller than that of beam A.
2. If the load on the two beams is the same, then the maximum stress in beam B is greater than that in beam A.
3. Beam A can resist smaller load than beam B.
4. Flexural rigidity of both the beams is equal.

Which of these inferences are incorrect?

(a) 2 and 4 (b) 1 and 3

(c) 1 and 4 (d) 2, 3 and 4

[ESE : 1996]

6.10 In a simply supported wooden beam under uniformly distributed load, a hole has to be made in the direction of width at midspan to provide a pipeline. From structural strength point of view, it would be advisable to have the hole made at

(a) the bottom

(b) the top

(c) mid-depth

(d) 1/4 depth either from the top or the bottom

[ESE : 1996]

6.11 A cantilever of constant depth carries a uniformly distributed load on the whole span. To make the maximum stress at all sections the same, the breadth of the section at a distance x from the free end should proportional to

(a) x (b) $\sqrt{x}$

(c) x^2 (d) x^3

[ESE : 1996]

6.12 Consider the following statements:

A beam of channel cross-section with vertical web loaded with a concentrated load at mid-span in a plane perpendicular to the plane of symmetry passing through the centroid subjected to

1. bending moment 2. twisting moment
3. shear force 4. axial thrust

Which of these statements are correct?

(a) 2, 3 and 4 (b) 1, 2 and 3

(c) 1 and 2 (d) 1 and 3

[ESE : 1996]

6.13 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Moment of inertia
B. Elongation
C. Neutral axis
D. Top fibre

List-II

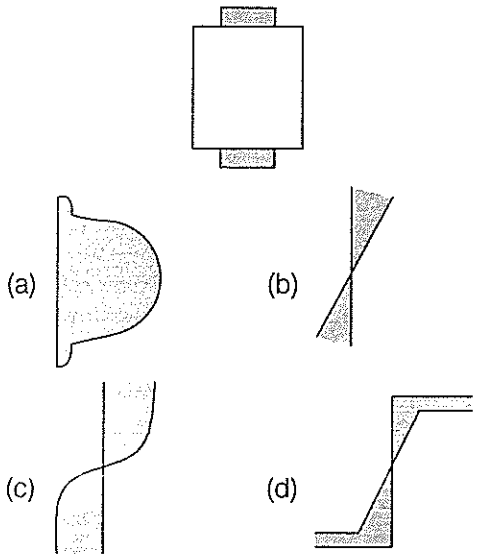
1. Tensile stress
2. Modulus of rupture
3. Zero shear stress
4. Zero longitudinal stress

Codes:

	A	B	C	D
(a)	2	1	3	4
(b)	1	2	4	3
(c)	3	4	1	2
(d)	2	1	4	3

[ESE : 1997]

6.14 A flitched beam shown in the figure below is subjected to a bending moment. The strain variation across the cross-section will be as in



[ESE : 1997]

6.15 The ratio of the flexural strength of two beams of square cross-section, the first beam being placed with its top and bottom sides horizontally and the second beam being placed with one diagonal horizontally, is

(a) $\sqrt{3}$ (b) $1/\sqrt{3}$

(c) $1/\sqrt{2}$ (d) $\sqrt{2}$

[ESE : 1997]

6.16 A simply supported beam of span L carries a point load W at midspan. The breadth 'b' of the beam along the entire span is constant. Given, f = permissible stress is bending, for a beam of uniform strength, the depth of the beam at any cross-section at a distance 'x' from the support would be

(a) $\frac{6Wx}{fb}$ (b) $\sqrt{\frac{6Wx}{fb}}$

(c) $\frac{3Wx}{fb}$ (d) $\sqrt{\frac{3Wx}{fb}}$

[ESE : 1997]

6.17 A beam of square cross-section ($B \times B$) is used as a beam with one diagonal horizontal. The location of the maximum shear stress from the neutral axis will be at distance of

(a) zero (b) $\frac{B}{4}$

(c) $\frac{B}{4\sqrt{2}}$ (d) $\frac{B}{8}$

[ESE : 1998]

6.18 **Assertion (A):** Two beams, one placed directly over the other have total moment of resistance equal to the sum of the moments of resistance of individual sections.

Reason (R): In bending, the transverse sections which were plane before bending remain plane after bending as well.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 1998]

6.19 A rectangular timber beam is cut out of a cylindrical log of diameter D. The depth of the strongest timber beam will be

(a) $\sqrt{\frac{1}{2}}D$ (b) $\sqrt{\frac{2}{3}}D$

(c) $\sqrt{\frac{5}{8}}D$ (d) $\sqrt{\frac{3}{4}}D$

[ESE : 1998]

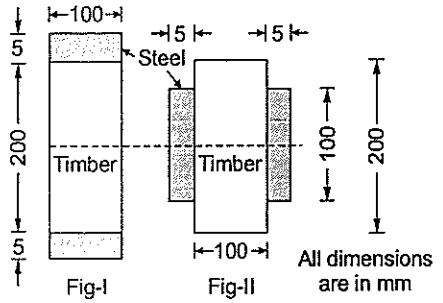
6.20 A high strength steel band-saw of 90 mm width and 0.5 mm thickness runs over a pulley of 500 mm diameter. Assuming E = 200 GPa, the maximum flexural stress developed would be

(a) 100 MPa (b) 200 MPa

(c) 400 MPa (d) 500 MPa

[ESE : 1998]

6.21 For the flitched beam shown in the below figure-I and figure-II, for the same value of maximum bending stress in timber,



(a) $MR_1 > MR_2$
(b) $MR_2 > MR_1$
(c) $MR_1 = MR_2$
(d) MR_1 and MR_2 cannot be compared

[ESE : 1998]

6.22 A simply supported beam of constant width and varying depth and uniform strength is subjected to a central concentrated load. The depth of the beam 'd_x' at a distance 'x' from one of the supports is proportional to

(a) $x^{1/2}$ (b) $x^{1/3}$
(c) x (d) x^2

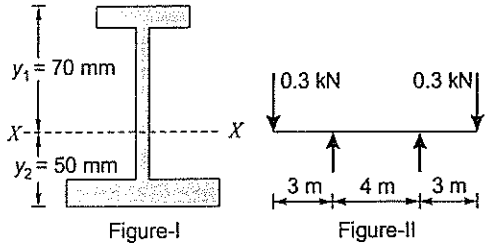
[ESE : 1999]

6.23 A mild flat of width 120 mm and thickness 10 mm is bent into an arc of a circle of radius 10 m by applying a pure moment M. If E is 2×10^5 N/mm^2, then the magnitude of the pure moment M will be

(a) 2×10^6 Nmm (b) 2×10^5 Nmm
(c) 0.2×10^5 Nmm (d) 0.2×10^4 Nmm

[ESE : 1999]

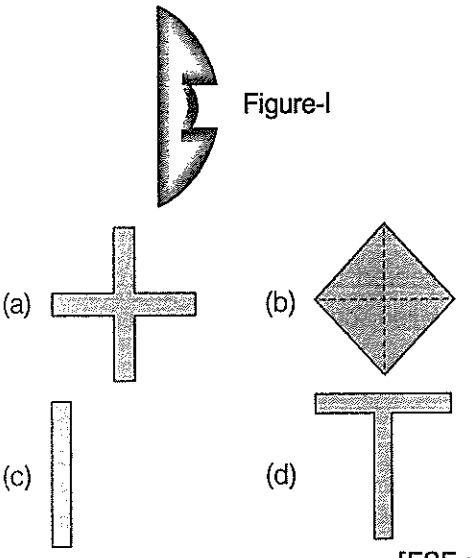
6.24 The cross-section of a beam is shown in figure-I. Its I_{xx} is equal to 3×10^6 mm^4. It is subjected to a load as shown in figure-II. The maximum tensile stress in the beam would be:



(a) indeterminable as data is insufficient
(b) 21 MN/m^2
(c) 21 kN/m^2 (d) 21 N/m^2

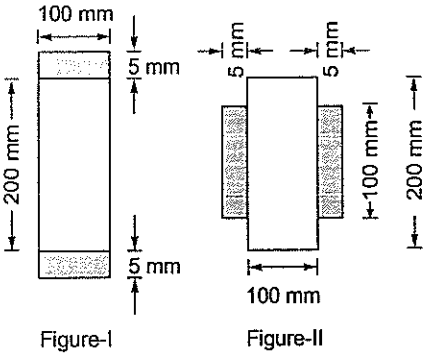
[ESE : 1999]

6.25 The shear stress distribution shown in figure-I represents a beam with cross-section



[ESE : 1999]

6.26 A timber beam of 100 mm width and 200 mm depth is reinforced with two steel plates of 100 mm width and 5 mm thickness as shown in figure-I and figure-II.

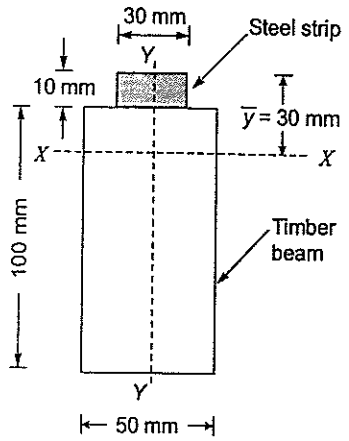


Which one of the following statements is correct for the same value of bending stress in the timber?

(a) Moment of resistance in figure-I will be more than that in figure-II.
(b) Moment of resistance in figure-II will be more than that in figure-I.
(c) Moment of resistance in figure-I will be equal to that in figure-II.
(d) No logical comparison can be made.

[ESE : 1999]

6.27 The cross-section of a timber beam with a steel strip is shown in the given figure. It is subjected to a sagging bending moment of 1000 Nm, $I_{xx} = 1250 \times 10^4$ mm^4 and modular ratio $m = 20$. The stresses at the lower surfaces of timber (σ_t) and steel (σ_s) will be respectively.

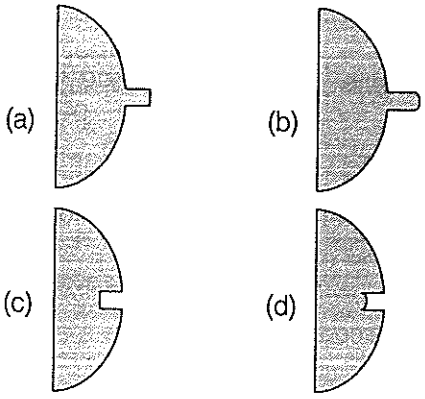


(a) + 6.4 MN/m^2 and – 6.4 MN/m^2
(b) – 6.4 MN/m^2 and – 32 MN/m^2
(c) + 6.4 MN/m^2 and – 32 MN/m^2
(d) + 32 MN/m^2 and – 6.4 MN/m^2

[ESE : 1999]

6.28 A simply supported I beam with its web horizontal is shown in the given figure. It is subjected to a vertical load.

The shape of the shear stress distribution in the cross-section of the beam under the load would be



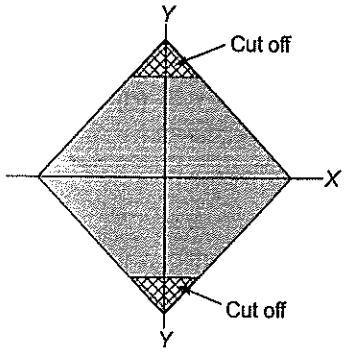
[ESE : 2000]

6.29 A cantilever beam is 2 m long. The cross-section of the beam is hollow square, with external sides 60 mm and the internal side is such that $I = 6 \times 10^5$ mm^4. If the safe bending stress for the material is 100 N/mm^2, the safe concentrated load at the free end would be

(a) 400 N (b) 500 N
(c) 600 N (d) 1000 N

[ESE : 2000]

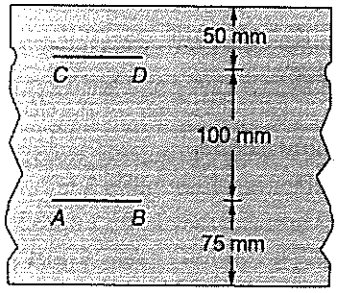
6.30 In the case of a square beam subjected to couples acting about X - X axis, it is advisable to cut off the edges and keep the section as shown in the given figure because it increases



(a) stresses in the beam
(b) stresses and reduces the weight of the beam
(c) the moment of inertia of the beam
(d) the section modulus

[ESE : 2000]

6.31 A test is conducted on a beam loaded by end couples. The fibres at layer CD are found to lengthen by 0.03 mm and fibres at layer AB shorten by 0.09 mm in 20 mm gauge length as shown in the given figure. Taking $E = 2 \times 10^5$ N/mm^2, the flexural stress at top fibres would be



(a) 900 N/mm^2 tensile
(b) 1000 N/mm^2 tensile
(c) 1200 N/mm^2 tensile
(d) 1200 N/mm^2 compressive

[ESE : 2000]

6.32 Which one of the following shear stress distribution diagrams is correct for cross-bar section shown in the Figure-I?

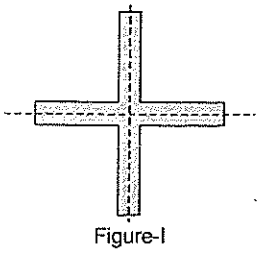


Figure-I

(a) (b)

(c) (d)

[ESE : 2001]

6.33 A rectangular beam of width 100 mm is subjected to maximum shear force of 60 kN. The corresponding maximum shear stress in the cross-section is 4 N/mm^2. The depth of the beam should be

(a) 150 mm (b) 225 mm
(c) 200 mm (d) 100 mm

[ESE : 2001]

6.34 Consider the following statements:
When a beam of square cross-section is used with a diagonal in a vertical position,
1. the shear stress distribution across the section of the beam will be maximum at the neutral axis
2. the shear stress distribution across the section of the beam will be zero both at top and bottom
3. the maximum shear stress does not occur at neutral axis

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 3
(c) 2 and 3 (d) 1 and 2

[ESE : 2001]

6.35 Which of the following points are considered while deriving the formula $\frac{M}{I} = \frac{f}{y} = \frac{E}{R}$?
1. Type of material.
2. Transverse shear force.
3. The stresses in the remaining principal direction.
4. $\sigma_y = \sigma_z = \tau_{xz} = \tau_{zx} = 0$
5. Linear variation of strain.

Select the correct answer using the codes given below:

(a) 1, 2 and 4 (b) 2, 3 and 5
(c) 4 and 5 (d) 1 and 3

[ESE : 2001]

6.36 A beam has a triangular cross-section having base 40 mm and altitude 60 mm. If this section is subjected to a shear force of 36000 N, the maximum shear stress in the cross-section would be

(a) 60 N/mm^2 (b) 36 N/mm^2
(c) 45 N/mm^2 (d) 30 N/mm^2

[ESE : 2001]

6.37 Out of the two beams of same material and same cross-sectional area one is of circular cross-section and other is of square cross-section. If these are subjected to bending moment of same magnitude, then
(a) both sections would be equally strong
(b) both sections would be equally economical
(c) square section would be more economical than circular section
(d) square section would be less economical than circular section

[ESE : 2001]

6.38 Consider the following statements:
The shear stress over a beam section of any shape for a given loading does not vary with
1. shear force at the section
2. area of the section
3. moment of inertia of the section

Which of these statements are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 2001]

Directions: The following items consists of two statements, one labelled as the **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) Both Assertion (A) and Reason (R) are individually true and Reason (R) is the correct explanation of Assertion (A).
(b) Both Assertion (A) and Reason (R) are individually true but Reason (R) is NOT the correct explanation of Assertion (A).
(c) Assertion (A) is true but Reason (R) is false.
(d) Assertion (A) is false but Reason (R) is true.

6.39 **Assertion (A):** A beam of fixed length and for given weight of material, a rectangular cross-

section provides the greatest possible moment of resistance.

Reason (R): In a beam of I cross-section, more material is positioned near the outer fibres representing regions of greatest stress and hence is stronger than beam of rectangular cross-section.

[ESE : 2002]

6.40 **Assertion (A):** The strength of a beam does not depend upon the sectional area provided.

Reason (R): It depends upon the distribution of the sectional area of the beam in relation to its neutral axis.

[ESE : 2002]

6.41 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Assumption in the theory of simple bending
B. The point at which the bending stress is maximum for any cross-section
C. The point at which the bending stress is zero for any cross-section
D. The point in the cross section through which the neutral axis passes

List-II

1. Neutral axis
2. Centroid
3. The plane sections remain plane
4. Extreme fibre
5. The cross-section is circular

Codes:

	A	B	C	D
(a)	5	4	1	2
(b)	3	1	2	4
(c)	5	1	2	4
(d)	3	4	1	2

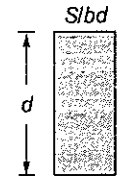
[ESE : 2002]

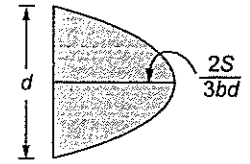
6.42 A rectangular beam of width 200 mm and depth 300 mm is subjected to a shear force of 200 kN. The maximum shear stress produced in the beam is

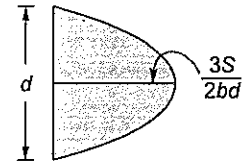
(a) 10.0 MPa (b) 7.5 MPa
(c) 5.0 MPa (d) 3.33 MPa

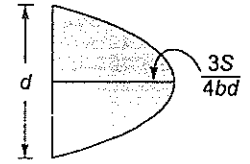
[ESE : 2002]

6.43 The shear stress distribution for a rectangular section under the action of shear force S is shown below. The rectangular section is $b \times d$. Select the correct shear stress distribution from the following:

(a) 

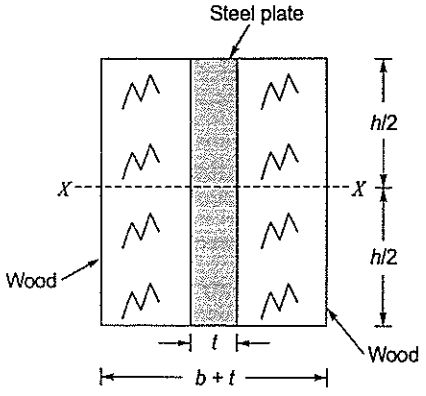
(b) 

(c) 

(d) 

[ESE : 2003]

6.44 The figure below shows the cross-section of a flitched beam consisting of a steel plate sandwiched between two wooden blocks. The second moment of area of the composite beam about the neutral axis XX is



(a) $\frac{bh^3}{12}+\frac{mth^3}{12}$ (b) $\frac{bh^3}{12}+\frac{t(mh)^3}{12}$

(c) $(b+t)\frac{h^3}{12}$ (d) $\frac{bh^3}{12}$

(where m is modular ratio of steel and wood)

[ESE : 2003]

6.45 Consider the following statements for a beam based on theory of bending:

1. Strain developed in any fibre is directly proportional to the distance of fibre from neutral surface.
2. For flexural loading and linearly elastic action the neutral axis passes through the centroid of cross-section.
3. The assumption of the plane cross-section remaining plane will not hold good during inelastic action.
4. Instances in which the neutral axis does not pass through the centroid of a cross-section include a homogenous symmetrical beam (with respect to neutral axis) and subjected to inelastic action.

Which of these statements are correct?

(a) 1, 2, 3 and 4 (b) 1, 2 and 4
(c) 3 and 4 (d) 1 and 2

[ESE : 2004]

6.46 A beam has the same section throughout its length with $I = 1 \times 10^8$ mm^4. It is subjected to a uniform $BM = 40$ kN-m, $E = 2 \times 10^5$ N/mm^2. What is the radius of curvature of the circle into which the beam will bend in the form of an arc of a circle?

(a) 1000 m (b) 500 m
(c) 400 m (d) 350 m

[ESE : 2005]

6.47 **Assertion (A):** A rectangular element is subjected to pure shear. This will result in cracks along one diagonal and crushing along the other diagonal.
Reason (R): Pure shear on a rectangular element results in tension along one diagonal and compression along the other diagonal.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

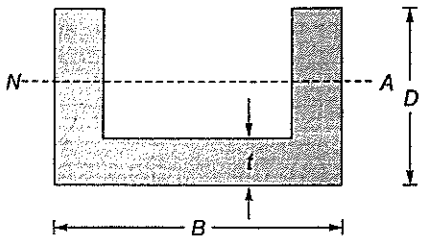
[ESE : 2005]

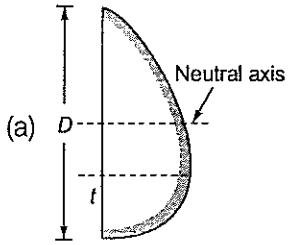
6.48 What is the ratio of maximum shear stress to average shear stress for a circular section?

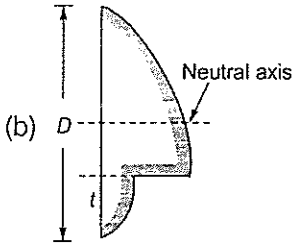
(a) 2 (b) 2/3
(c) 4/3 (d) 3/4

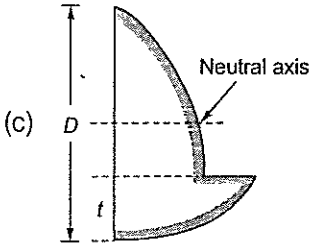
[ESE : 2005]

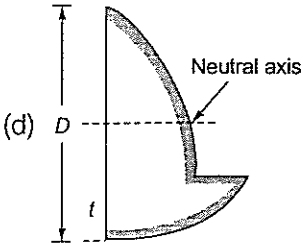
6.49 A horizontal beam shown in the figure given below is subjected to transverse loading. Which one of the following diagrams represent the distribution of shear force along the cross-section?





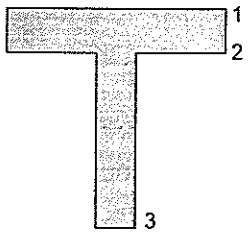


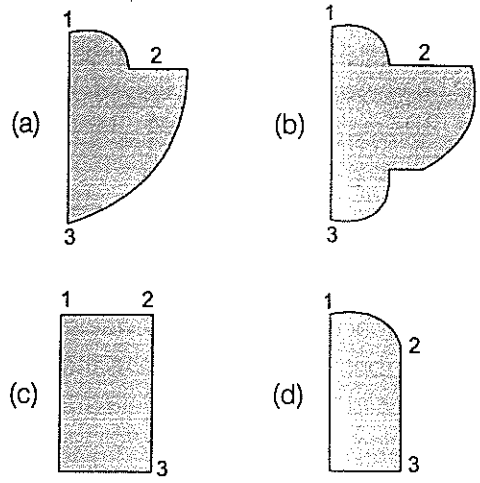




[ESE : 2006]

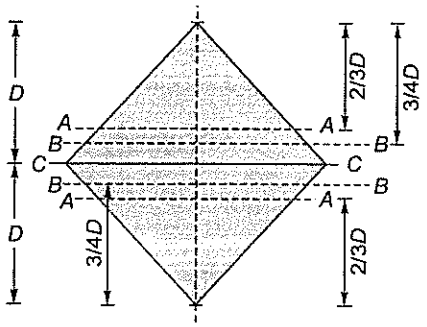
6.50 Which one of the following diagrams indicates the shear stress distribution for the beam as shown in the figure below?





[ESE : 2006]

6.51 A beam of square cross-section is placed horizontally with one diagonal horizontal as shown in the figure below. It is subjected to a vertical shear force acting along the depth of the cross section. Maximum shear stress across the depth of cross section occurs at a depth 'x' from the top. What is the value of x?



(a) $x = 0$ (b) $x = (2/3)D$
(c) $x = (3/4)D$ (d) $x = D$

[ESE : 2006]

6.52 Consider the following statements :

1. In a beam, the maximum shear stress occurs at the neutral axis of the beam cross-section.
2. The maximum shear stress in a beam of circular cross-section is 50% more than the average shear stress.
3. The maximum shear stress in a beam of triangular cross-section, with its vertex upwards occurs at $b/6$ above the neutral axis.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 2 and 3 only
(c) 1 and 2 only (d) 1 and 3 only

[ESE : 2007]

6.53 A cantilever beam of T cross-section carries uniformly distributed load. Where does the maximum magnitude of the bending stress occur?

(a) At the top of cross-section
(b) At the junction of flange and web
(c) At the mid-depth point
(d) At the bottom of the section

[ESE : 2007]

6.54 A 20 cm long rod of uniform rectangular section, 8 mm wide × 1.2 mm thick is bent into the form of a circular arc resulting in a central displacement of 0.8 cm. Neglecting second-order quantities in computations, what is the longitudinal surface strain (approximate) in the rod ?

(a) 7.2×10^{-4} (b) 8.4×10^{-4}
(c) 9.6×10^{-4} (d) 10.8×10^{-4}

[ESE : 2007]

6.55 A symmetrical I-section is subjected to shear force. The shear stress induced across the section is maximum at which location?

(a) Extreme fibers
(b) At the bottom of flanges in flanges
(c) At the bottom of flanges in web portion
(d) At the neutral axis

[ESE : 2008]

6.56 A beam is made of two identical metal flats soldered together. What is the ratio of stiffness of this beam to the stiffness of a beam in which the two flats are not soldered and which acts independently?

(a) 2 (b) 4
(c) 6 (d) 8

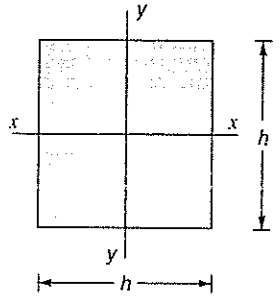
[ESE : 2008]

6.57 A structural beam subjected to sagging bending has a cross-section which is an unsymmetrical I-section. The overall depth of the beam is 300 mm. The flange stresses in the beam are :

$\sigma_{top} = 200\ N/mm^2$
$\sigma_{bottom} = 50\ N/mm^2$
What is the height in mm of the neutral axis above the bottom flange?
(a) 240 mm (b) 60 mm
(c) 180 mm (d) 120 mm
[ESE : 2009]

6.58 A timber beam is 100 mm wide and 150 mm deep. The beam is simply supported and carries a central concentrated load *W*. If the maximum stress in shear is 2 N/mm^2, what would be the corresponding load *W* on the beam ?
(a) 20 kN (b) 30 kN
(c) 40 kN (d) 25 kN
[ESE : 2009]

6.59 A square section as shown in the figure below is subjected to bending moment *M*.



What is the maximum bending stress ?
(a) $\sigma_{bc} = \sigma_{bt} = \frac{12M}{h^3}$ (b) $\sigma_{bc} = \sigma_{bt} = \frac{6M}{h^3}$
(c) $\sigma_{bc} = \sigma_{bt} = \frac{9M}{2h^3}$ (d) $\sigma_{bc} = \sigma_{bt} = \frac{9M}{h^3}$
[ESE : 2009]

6.60 A square beam laid flat is then rotated in such a way that one of its diagonal becomes horizontal. How is its moment capacity affected ?
(a) Increases by 41.4%
(b) Increases by 29.27%
(c) Decreases by 29.27%
(d) Decreases by 41.4%
[ESE : 2009]

6.61 A beam of symmetrical *I*-section, made of structural steel has an overall depth of 300 mm. If the flange stresses developed at the top and bottom of the beam are 1200 kg/cm^2 and 300 kg/cm^2 respectively, then the depth of neutral axis from the top of the beam would be
(a) 250 mm (b) 240 mm
(c) 200 mm (d) 180 mm
[ESE : 2010]

6.62 A simply supported beam of *T*-section is subjected to a uniformly distributed load acting vertically downward. Its neutral axis is located at 25 mm from the top of the flange and the total depth of the section is 100 mm. The ratio of maximum tensile stress to maximum compressive stress in the beam is
(a) 2.0 (b) 2.5
(c) 3.0 (d) 4.0
[ESE : 2010]

6.63 Consider the following statements for a beam of rectangular cross-section and uniform flexural rigidity *EI* subjected to pure bending:
1. The bending stresses have the maximum magnitude at the top and bottom of the cross-section.
2. The bending stresses vary linearly through the depth of the cross-section.
3. The bending stresses vary parabolically through the depth of the cross-section.

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 1 only
(c) 2 only (d) 1 and 2 only
[ESE : 2010]

6.64 Two beams carrying identical loads, simply supported, are having same depth but beam *A* has double the width as compared to that of beam *B*. The ratio of the strength of beam *A* to that of beam *B* is
(a) 1/2 (b) 1/4
(c) 2 (d) 4
[ESE : 2010]

6.65 A steel beam is replaced by a corresponding aluminium beam of same cross-sectional shape and dimensions, and is subjected to same loading. The maximum bending stress will
(a) be unaltered
(b) increase
(c) decrease
(d) vary in proportion to their modulus of elasticity
[ESE : 2010]

6.66 A simply supported beam of span L carries a concentrated load W at its mid-span. If the width

b of the beam is constant throughout the span, then, with permissible bending stress as σ, the depth of the beam at mid-span will be

(a) $\frac{3WL}{2b\sigma}$ (b) $\sqrt{\frac{3WL}{2b\sigma}}$

(c) $\frac{6WL}{b\sigma}$ (d) $\sqrt{\frac{6WL}{b\sigma}}$

[ESE : 2012]

6.67 Out of the two beams of the same material and same cross-sectional area, one is of circular cross-section and the other is of square cross-section. If each of these is subjected to bending moment of the same magnitude, then

(a) both sections would be equally strong
(b) both sections would be equally economical
(c) square section would be more economical than circular section
(d) square section would be less economical than circular section

[ESE : 2012]

6.68 A rectangular beam of width 100 mm is subjected to a maximum shear force of 60 kN. The corresponding maximum shear stress in the cross-section is 4 N/mm^2. The depth of the beam should be

(a) 200 mm (b) 150 mm
(c) 100 mm (d) 225 mm

[ESE : 2012]

6.69 A rectangular beam of dimensions $b \times d$ is to be cut from a circular log of wood of diameter D. For the beam to be strongest in bending, the dimensions will be

(a) $\frac{D}{\sqrt{2}}$ and $D\sqrt{\frac{2}{3}}$ (b) $\frac{D}{\sqrt{3}}$ and $D\sqrt{\frac{2}{3}}$

(c) $\frac{D}{\sqrt{2}}$ and $\sqrt{\frac{2D}{3}}$ (d) $\frac{D}{\sqrt{3}}$ and $\sqrt{\frac{2D}{3}}$

[ESE : 2013]

6.70 A simply supported rolled steel joist of I-section has flange width 250 mm and overall depth 600 mm. Its moment of inertia $I_{xx} = 12 \times 10^8$ mm^4. The steel joist is used as a beam over a simply supported span of 6 m. It carries a load of 40 kN/m including its self weight throughout the span. The maximum stress induced in the beam in N/mm^2 due to bending would be

(a) 30 (b) 90
(c) 45 (d) 60

[ESE : 2013]

6.71 A simply supported beam has uniform cross-section, b = 100 mm, d = 200 mm, throughout its length. The beam is subjected to a maximum bending moment of 6×10^7 N-mm. The corresponding bending stress developed in the beam is

(a) 30 N/mm^2 (b) 60 N/mm^2
(c) 90 N/mm^2 (d) 120 N/mm^2

[ESE : 2014]

6.72 A steel plate is bent into a circular arc of radius 10 m. If the plate section be 120 mm wide and 20 mm thick, with $E = 2\times10^5$ N/mm^2, then the maximum bending stress induced is

(a) 210 N/mm^2 (b) 205 N/mm^2
(c) 200 N/mm^2 (d) 195 N/mm^2

[ESE : 2014]

6.73 A flitched beam composed of two different pieces, each having breadth b and depth d, supports an external load. This statement implies that

1. the two different material are rigidly connected
2. there will be relative movement between the two materials
3. for transforming into an equivalent single-material, section under 'strength' considerations, the depth is kept constant and only the breadth is varied

Which of the above statements are correct?

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2014]

6.74 A simply supported beam of length 4 m is subjected to a uniformly distributed load of 2 kN/m. What is the maximum shear stress if the cross-section is rectangular, 100 mm wide and 200 mm deep?

(a) 0.2 N/mm^2 (b) 0.1 N/mm^2
(c) 0.4 N/mm^2 (d) 0.3 N/mm^2

[ESE : 2015]

6.75 A mild steel structural section is an unsymmetrical I-section, with the greater width at the top and the smaller width at the bottom. The overall depth of the beam is 300 mm, and the flange stresses at the top and the bottom of the beam are

150 N/mm^2 and 50 N/mm^2, respectively. What is the height of the neutral axis of the beam from its bottom?

(a) 125 mm (b) 100 mm
(c) 75 mm (d) 50 mm

[ESE : 2015]

6.76 What is the shear stress at the neutral axis in a beam of isosceles triangular section with a base of 40 mm and height 20 mm subjected to a shear force of 3 kN?

(a) 3 MPa (b) 6 MPa
(c) 10 MPa (d) 20 MPa

[ESE : 2015]

6.77 A beam of square cross-section is placed such that its neutral axis coincides with its diagonal, and it is subjected to a shear force *F*. What is the ratio of the maximum shear stress to the shear stress at the neutral axis?

(a) 9/8 (b) 8/9
(c) 7/8 (d) 8/7

[ESE : 2015]

6.78 The intensity of u.d.l. which, when its acts over the entire span of 1 m of a cantilever beam of rectangular cross-section of width 100 mm and depth 200 mm, would produce a maximum shear stress of 1.5 N/mm^2, is

(a) 20 kN/m (b) 30 kN/m
(c) 26.6 kN/m (d) 36.6 kN/m

[ESE : 2015]

6.79 Two planks each of 50 mm x 50 mm section are glued together along the length to form a section 50 mm x 100 mm; and used as a beam. If the shear force at a section is 1000 N, what is the maximum shear stress on the glue?

(a) 0.15 MPa (b) 0.3 MPa
(c) 0.6 MPa (d) 2.4 MPa

[ESE : 2015]

6.80 A thin steel ruler having its cross-section of 0.0625 cm x 2.5 cm is bent by couples applied at its ends so that its length *l* equal to 25 cm, when bent, as a circular arc, subtends a central angle $\theta = 60°$. Take $E = 2 \times 10^6$ kg/cm^2. The maximum stress induced in the ruler and the magnitude is

(a) 2618 kg/cm^2 (b) 2512 kg/cm^2
(c) 2406 kg/cm^2 (d) 2301 kg/cm^2

[ESE : 2016]

6.81 The bending stress in a T-beam section is maximum

1. At top fibre
2. At centroidal fibre
3. At bottom fibre

(a) 1 only
(b) 2 only
(c) 3 only
(d) At a level which is dependent on the loading condition

[ESE : 2016]

6.82 **Statement (I):** In elastic analysis of structures, the Neutral Axis is the intersection between the plane of bending and the neutral plane.

Statement (II): Neutral Axis in the context of plastic analysis of structures is always the Equal Area Axis of the cross-section.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true

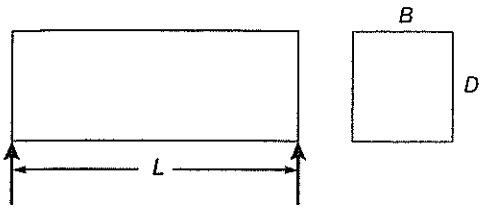
[ESE : 2016]

6.83 The span of a cantilever beam is 2 m. The cross-section of the beam is a hollow square with external sides 100 mm; and its $I = 4 \times 10^5$ mm^4. The safe bending stress for the beam material is 100 N/mm^2. The safe concentrated load at the free end would be

(a) 100 N (b) 200 N
(c) 300 N (d) 400 N

[ESE : 2017]

6.84 A homogeneous prismatic simply supported beam is subjected to a point load *F*. The load can be placed anywhere along the span of the beam. The very maximum flexural stress developed in the beam is



(a) $\frac{3FL}{2BD^2}$ (b) $\frac{3FL}{4BD^2}$

(c) $\frac{2FL}{3BD^2}$ (d) $\frac{4FL}{3BD^2}$

[ESE : 2017]

■■■■

Answers Bending & Shear Stresses in Beams

6.1 (c)	6.2 (b, d)	6.3 (d)	6.4 (c)	6.5 (b)	6.6 (a)	6.7 (a)	6.8 (c)	6.9 (a)	
6.10 (c)	6.11 (c)	6.12 (b)	6.13 (d)	6.14 (b)	6.15 (d)	6.16 (d)	6.17 (c)	6.18 (b)	
6.19 (b)	6.20 (b)	6.21 (a)	6.22 (a)	6.23 (b)	6.24 (b)	6.25 (a)	6.26 (a)	6.27 (c)	
6.28 (d)	6.29 (d)	6.30 (d)	6.31 (a)	6.32 (a)	6.33 (b)	6.34 (c)	6.35 (c)	6.36 (c)	
6.37 (c)	6.38 (c)	6.39 (d)	6.40 (a)	6.41 (d)	6.42 (c)	6.43 (c)	6.44 (a)	6.45 (b)	
6.46 (b)	6.47 (a)	6.48 (c)	6.49 (b)	6.50 (a)	6.51 (c)	6.52 (d)	6.53 (d)	6.54 (c)	
6.55 (d)	6.56 (b)	6.57 (b)	6.58 (c)	6.59 (b)	6.60 (c)	6.61 (b)	6.62 (c)	6.63 (d)	
6.64 (c)	6.65 (a)	6.66 (b)	6.67 (c)	6.68 (d)	6.69 (b)	6.70 (c)	6.71 (c)	6.72 (c)	
6.73 (b)	6.74 (d)	6.75 (c)	6.76 (c)	6.77 (a)	6.78 (a)	6.79 (b)	6.80 (a)	6.81 (c)	
6.82 (b)	6.83 (d)	6.84 (a)							

Explanations Bending & Shear Stresses in Beams

6.1 (c)

The fibres above the neutral axis will be subjected to compression and fibres below the neutral axis will be subjected to tension due to bending. These bending stresses are axial in direction.

The transverse strain will also be there at all fibres cross-section due to Poisson's effect. Thus top fibres will laterally expand and bottom fibres will get compressed. Thus the deformed section will be as shown in figure (c).

6.2 (b, d)

Transform from steel to timber

Then $I_t + m_S$

Tranfrom from timber to steel

Then $\frac{I_t}{m} + I_s$

6.3 (d)

Section modulus of square section,

$$Z_1 = \frac{D^3}{6}$$

Section modulus of circular section,

$$Z_2 = \frac{\pi D^3}{32}$$

The moment carrying capacity $M = fZ$

where f is maximum permissible bending stress

$$\therefore \quad \frac{M_2}{M_1} = \frac{Z_2}{Z_1} = \frac{6\pi}{32} = \frac{3\pi}{16}$$

6.4 (c)

Maximum shear stress occurs at mid depth and the value is $\frac{3F}{bh}$. In triangular sections. At neutral axis the shear stress is $\frac{8F}{3bh}$.

6.5 (b)

Using bending formula

$$\frac{E}{R} = \frac{M}{I} = \frac{f}{y}$$

Given, $d = 20$ mm

So, $y_{max} = \frac{d}{2} = 10$ mm

$R = 10$ m $= 10{,}000$ mm

$E = 2 \times 10^6$ kg/cm^2

$$f_{max} = \frac{2\times10^6 \times 10}{10{,}000} = 2 \times 10^3 \text{ kg/cm}^2$$

6.6 (a)

The moment of inertia of a section is more if the area lies away from neutral axis. *I*-section has higher section modulus than that of rectangular section, therefore it is preferred to rectangular section.

6.7 (a)

For rectangular section, $\tau_{max} = 1.5\tau_{av}$

For circular section, $\tau_{max} = \frac{4}{3}\tau_{av} = 1.33\tau_{av}$

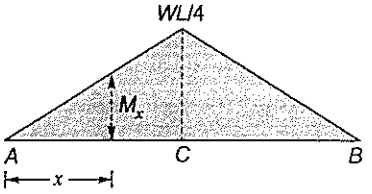
But, $\tau_{av} = \frac{V}{A}$

So for a given material, the maximum shear stress will be less in circular section when area of circular and rectangular section. Therefore circular section can resist greater shear force.

6.8 (c)

The bending moment diagram of the beam is BM at point x from simply supported end.

$$M_x = \frac{W}{2}x$$



Section modulus, $Z_x = \frac{bd_x^2}{6}$

But, $f = \frac{M_x}{Z_x}$

$\therefore \quad d_x = \sqrt{\frac{3Wx}{bf}}$

at $x = L/2 \quad d_{(L/2)} = \sqrt{\frac{3WL}{2bf}}$

6.9 (a)

The moment of inertia of both beams about their horizontal axis will be same.

i.e. $I_A = I_B = \left(\frac{h^4}{12}\right)$

Deflection $\Delta \propto \frac{1}{EI}$ and since EI of beam A and B is same so deflection will be same. Therefore (1) is incorrect.

Maximum stress in beam having more section modulus will be less.

$$Z_A = \frac{I_A}{h/2} = \frac{2I_A}{h}$$

$$Z_B = \frac{I_B}{h/\sqrt{2}} = \left(\frac{\sqrt{2}I_B}{h}\right)$$

as $Z_A > Z_B$ so $f_A < f_B$

The maximum stress in beam B is more than that in A, so (2) is correct.

The beam having higher section modulus will resist more load. So beam A can resist more load, so (3) is incorrect.

EI is called the flexural rigidity of the beam and it is same for both beams. Therefore (4) is correct.

6.10 (c)

At mid span of the beam, the beam is subjected to bending stresses only. These stress are zero at neutral axis or mid-depth so hole should be made at mid depth.

6.11 (c)

At a distance x from free end

$$M_x = \frac{wx^2}{2}$$

and $Z_x = \frac{b_x d^2}{6}$

Maximum bending stress,

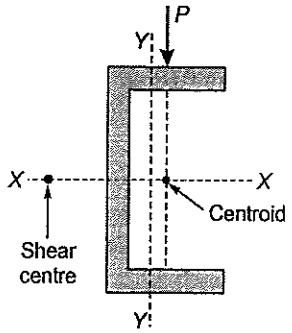
$$f = \frac{M_x}{Z_x}$$

$$\therefore \quad b_x = \frac{3wx^2}{fd^2}$$

The breadth is proportional to x^2.

6.12 (b)

Since the load does not pass through shear centre of the channel section, so the cross-section is subjected to torsion in addition to bending and shear



6.13 (d)

- In bending, maximum normal stress is known as modulus of rupture.
- Elongation ∝ Tensile stress
- Longitudinal stress is zero at neutral axis.
- At top fibre shear stress is zero as outermost surface shear stress is equal to zero.

6.14 (b)

The strain diagram is linear.

6.15 (d)

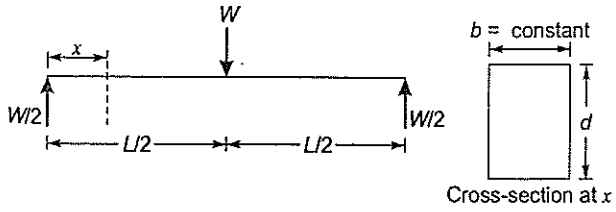
Flexural strength is proportional to sectional modulus of beams. For both beams moment of inertia will be same. Section modulus for first beam $Z_1 = \frac{2I}{a}$ (a = side of cross-section)

Section modulus for second beam,

$$Z_2 = \frac{\sqrt{2}I}{a}$$

$$\therefore \quad \frac{Z_1}{Z_2} = \sqrt{2}$$

6.16 (d)



For a beam of uniform strength

BM at distance x = Moment of resistance of beam

$$\frac{W}{2}x = \sigma z$$

$$\frac{W}{2}x = \frac{fbd^2}{6}$$

$$d = \sqrt{\frac{3Wx}{fb}}$$

6.17 (c)

The diagonal is $B\sqrt{2}$. The location of maximum shear stress from neutral axis is $\frac{1}{8}$ length of diagonal i.e. $\frac{B}{4\sqrt{2}}$.

6.18 (b)

Two beams placed one over the other will bend about their respective geometrical axes. The total moment of resistance will be equal to the sum of moments of resistance of individual sections. In analyzing such cases, the assumption of plane section remain plane after bending is valid.

6.19 (b)

For strongest beam, the section modulus should be maximum.

$$\text{Breadth of beam} = \frac{D}{\sqrt{3}}$$

$$\text{Depth of beam} = \sqrt{\frac{2}{3}}D$$

$$\text{Section modulus} = \frac{D^3}{9\sqrt{3}}$$

$$\text{Moment of inertia} = \frac{D^4}{27\sqrt{2}}$$

6.20 (b)

For pure bending,

$$\frac{M}{I} = \frac{E}{R} = \frac{f}{y}$$

$$y = \frac{0.5}{2} = 0.25 \text{ mm}$$

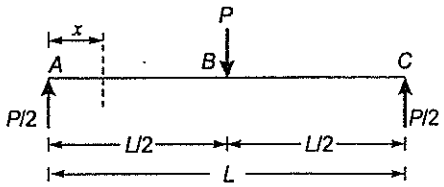
$$R = \frac{500}{2} = 250 \text{ mm}$$

$$\therefore \quad f = \frac{200 \times 0.25 \times 10^3}{250} = 200 \text{ MPa}$$

6.21 (a)

The moment capacity contributed by timber remains same in both cases. In the first case the steel plates are away from neutral axis (NA) so their contribution is more while in the second case the plate are vertical and their contribution is less. So $MR_1 > MR_2$.

6.22 (a)



Bending moment at a distance x (<L/2) from end,

$$M_x = \frac{p}{2}x$$

For a beam of uniform strength

BM at distance x = Moment of resistance of beam

$$\frac{p}{2}x = \sigma\frac{bd_x^2}{6}$$

$$d_x \propto x^{1/2}$$

6.23 (b)

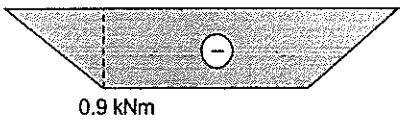
Using Bending Formula, $\frac{M}{I} = \frac{E}{R} = \frac{f}{y}$

$$M = \frac{2\times10^5 \times \left(\frac{120\times10^3}{12}\right)}{10{,}000}$$

$$= 2\times10^5 \text{ N-mm}$$

6.24 (b)

BMD of beam



Upper fibers of the beam will be under tension since the maximum *BM* of 0.9 kN-m is hogging in nature. The maximum tensile stress

$$f = \frac{My_1}{I_{xx}} = \frac{0.9\times10^6\times70}{3\times10^6}$$

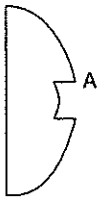
$$= \frac{9\times7}{3} = 21 \text{ N/mm}^2 = 21 \text{ MN/m}^2$$

6.25 (a)

In question figure Shear stress at point A is suddenly reduced. It shows sudden increase in width at point A, which is depicted by option (a)

6.26 (a)

For the same value of bending stress in timber, moment capacity of timber is same in both cases. In figure-I steel plates are away from the NA so more stress is generated in steel plates due to more strain. As they are away so lever arm is also large. Hence moment of resistance is more in figure-I.



6.27 (c)

The moment of inertia of timber beam equivalent is given $I_{xx} = 1250 \times 10^4$ mm^4

Stress at $y = 20$ mm

$$\sigma_{20} = \frac{1000\times10^3\times20}{1250\times10^4}$$

$= 1.6$ N/mm^2 (Compressive)

Stress at lower level of steel,

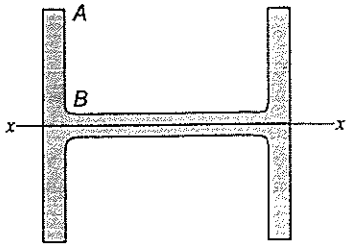
$\sigma_s = m\sigma_{20} = 1.6 \times 20 = 32$ N/mm^2

Stress at lower level of timber at $y = 80$ mm

$$\sigma_t = \frac{1000\times10^3\times80}{1250\times10^4} = 6.4 \text{ N/mm}^2$$

Stress in timber is tensile. So it is positive.

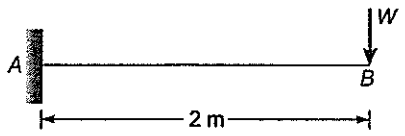
6.28 (d)



Shear stress varies in parabolic shape across a rectangular cross section. Value at top and bottom is zero and maximum at neutral axis. Shear stress will be zero at A and will increase upto B parabolically. As the width in figure increase

suddenly near B shear stress will decrease suddenly. Diagram will be symmetric about NA.

6.29 (d)



The bending moment at end $A = 2\,W$ N-m

Maximum bending stress,

$$f = \frac{2W\times10^3\times30}{6\times10^5} = 100$$

$\therefore \quad W = 1000\,\text{N}$

6.30 (d)

The increase of section modulus occurs due to the decrease in extreme fibre distance in greater proportion than it reduces the moment of inertia of the section.

6.31 (a)

The strain at layer $CD = \frac{0.03}{20} = 0.0015$

The strain at layer $AB = -\frac{0.09}{20} = -0.0045$

Let the distance of fibre CD from the neutral axis is x.

$$\frac{0.0015}{x} = \frac{0.0045}{100-x}$$

$$100 - x = 3x$$

$\therefore \quad x = 25$ mm

At top fibre, the distance from neutral axis will be

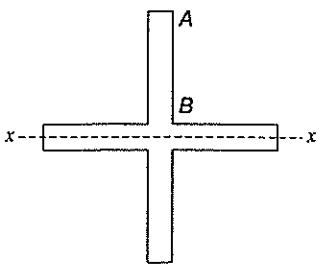
$= 25 + 50 = 75$ mm

So the strain will be $= 0.0015\times\frac{75}{25} = 0.0045$

Flexural stress $= 0.0045 \times 2 \times 10^5$

$= 900$ N/mm^2 tensile

6.32 (a)



Shear stress varies in parabolic shape across a rectangular cross section. Value at top and bottom is zero and maximum at neutral axis. Shear stress will be zero at A and will increase upto B parabolically. As the width in figure increase suddenly near B shear stress will decrease suddenly. Diagram will be symmetric about NA.

6.33 (b)

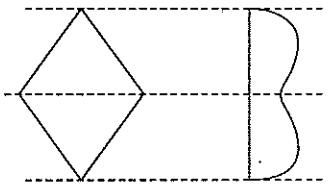
Maximum shear stress, $\tau_{max} = 1.5\,\tau_{av}$

$\therefore$ Average shear stress, $\tau_{av} = \frac{4}{1.5}$ N/mm^2

The depth of beam $= \frac{V}{b\tau_{av}} = \frac{60\times10^3\times1.5}{100\times4}$

$= 225$ mm

6.34 (c)



Maximum shear stress occurs at 3/8b from the top or bottom where b is the length of diagonal.

6.35 (c)

While deriving the formula, following considerations are made:

- Linear variation of strain
- Pure bending
- Under pure bending

$\sigma_y = \sigma_z = \tau_{xz} = \tau_{zx} = 0$

6.36 (c)

The average shear stress, $\tau_{av} = \frac{V}{(bh/2)}$

$\therefore \tau_{av} = \frac{36000}{(40\times60/2)} = 30$ N/mm^2

$\therefore$ Maximum shear stress $= 1.5\,\tau_{av}$

$= 45$ N/mm^2

6.37 (c)

Section modulus for square section,

$$Z_1 = \frac{a^3}{6}$$

Section modulus for circular section,

$$Z_2 = \frac{\pi d^3}{32}$$

Since $\frac{\pi d^2}{4} = a^2$; So $\frac{Z_1}{Z_2} = 1.18$;

Hence square section is stronger or economical.

6.38 (c)

At particular section in beam shear force is constant.

6.39 (d)

MOR = σ.z

MOR ∝ z

Z of I-section is more than that rectangular section. Therefore assertion is wrong.

6.40 (a)

The formula for determining bending stress in a beam subjected to simple bending is:

$$\sigma = \frac{My}{I}$$

Here σ is bending stress,
M is Moment about neutral axis,
y is perpendicular distance to the neutral axis,
I is second moment of area about the neutral axis

The maximum values of bending stress occurs at the topmost and bottommost fibers of the section, i.e. more is the distribution of sectional area away from neutral axis, more is the value of y which leads to more strength to the beam.

6.41 (d)

The plane sections remain plane in simple bending

Bending stress = $\frac{My}{I}$

At extreme fibre y is maximum so bending stress is also maximum.
At neutral axis $y = 0$ so bending stress is zero
Neutral axis passes through centroid of cross-section.

6.42 (c)

Average shear stress,

$$\tau_{av} = \frac{V}{bd} = \frac{200 \times 10^3}{200 \times 300} = \frac{10}{3} \text{MPa}$$

Maximum shear stress,

$$\tau_{max} = 1.5\,\tau_{av} = 5 \text{ MPa}$$

6.43 (c)

In rectangular section, shear stress varies parabolically. Shear stress at top and bottom is zero and maximum value is at the neutral axis which is equal to 3/2 times average shear stress.

6.44 (a)

Moment of inertia of composite beam

$$= I_w + mI_s = \frac{bh^3}{12} + \frac{mth^3}{12}$$

6.45 (b)

The strain distribution is linear or strain is proportional to the distance of fibre from neutral surface. The assumption of plane sections remaining plane holds good during inelastic or plastic analysis also. For plastic action the neutral axis not pass through centroid and is located at a point where area is equally divided into two halves.

6.46 (b)

$$\frac{E}{R} = \frac{M}{I}$$

$$\therefore \quad R = \frac{EI}{M} = \frac{2\times10^5 \times 1\times10^8}{40\times10^6}$$

$$= 500{,}000 \text{ mm} = 500 \text{ m}$$

6.48 (c)

Shear stress in circular section = $\frac{4V}{3A}\left(1 - \frac{y^2}{R^2}\right)$

$$\tau_{avg} = \frac{V}{A}$$

Maximum shear stress will be at y = 0

$$\tau_{max} = \frac{4}{3}\tau_{avg}$$

6.49 (b)

From the top fibre to the neutral axis the distribution is parabolic and maximum value is obtained at neutral axis. The distribution remains parabolic below the neutral axis but the values start reducing. For the bottom portion, the shear stress suddenly decreases due to increase in width of the section.

6.51 (c)

Maximum shear stress occurs at a depth from top = 3/8 × length of diagonal

$$= \frac{3}{8} \times 2D = \frac{3}{4} \times D$$

6.52 (d)

The maximum shear stress in a beam of circular cross section is $33\frac{1}{3}\%$ more than the average shear stress.

If b is the height of the triangle, then maximum shear stress will occur at $\frac{b}{2}$ from the vertex. The neutral axis lies at a distance $\frac{2b}{3}$ from vertex.

∴ Distance at which maximum shear stress occur from neutral axis $= \frac{2b}{3} - \frac{b}{2} = \frac{b}{6}$

6.53 (d)

The neutral axis shifts towards the flange of T-beam. Hence the bottom most fibre of web is more distant than the top most fibre of the flange from neutral axis. As we know that the bending stress is given by

$$f = \frac{M}{I} y$$

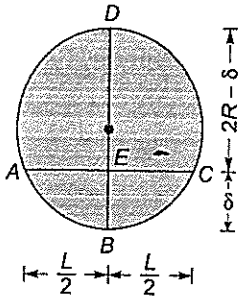
For a particular loading and beam cross section, M and I are constant.

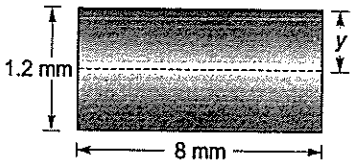
$$\therefore \quad f \propto y$$

Since y in case of bottom most fibre of T-beam is more, hence bending stress will be maximum here. It may noted that bottom most fibre of T-beam will be in compression and top most fibre will be in tension.

6.54 (c)

The arrangement can be shown as in the figure below:





The straight rod AC is bent into a circular arc ABC.

From the property of circle, we have

$$BE \times ED = AE \times EC$$

$$\Rightarrow \quad \delta \times (2R - \delta) = \frac{L}{2} \times \frac{L}{2}$$

$$\Rightarrow \quad 2\delta R - \delta^2 = \frac{L^2}{4}$$

Neglecting 2nd order quantities, we get

$$\Rightarrow \quad R = \frac{L^2}{8\delta}$$

Here $\delta = 0.8$ cm, $L = 20$ cm

$$\therefore \quad R = \frac{(20)^2}{8 \times 0.8} = 62.5 \text{ cm}$$

Also, from the theory of pure bending, we have

$$\frac{f}{y} = \frac{E}{R}$$

$$\Rightarrow \quad f = \frac{E}{R} \times y$$

$$\Rightarrow \quad \varepsilon \times E = \frac{E}{R} \times y$$

$$\Rightarrow \quad \varepsilon = \frac{y}{R}$$

$$\Rightarrow \quad \varepsilon = \frac{1.2 \times 10^{-1}}{2 \times 62.5} = 9.6 \times 10^{-4}$$

Alternatively

$$\varepsilon = \frac{4t\delta}{L^2} = \frac{4 \times 1.2 \times 0.8 \times 10}{(28 \times 10)^2}$$

$$= 9.6 \times 10^{-4}$$

6.56 (b)

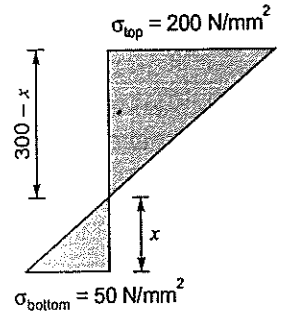
Stiffness of a beam is directly proportional to the moment of inertia of the cross section about its centroidal axis.

$$\frac{\text{Stiffness of soldered beam}}{\text{Stiffness of unsoldered beam}} = \frac{\frac{b(2d)^3}{12}}{2 \times \frac{bd^3}{12}} = 4$$

6.57 (b)

The sagging moment will cause compressive stresses above the neutral axis and tensile

stresses below the neutral axis. The variation of stresses is linear in pure bending.



$$\frac{x}{50} = \frac{300-x}{200}$$

$$\Rightarrow \quad 200x = 15000 - 50x$$

$$\Rightarrow \quad x = \frac{15000}{250} = 60 \text{ mm}$$

6.58 (c)

In case of rectangular beam, we have

$$q_{max} = 1.5\, q_{avg}$$

$$\Rightarrow \quad q_{max} = 1.5 \times \frac{S}{bd}$$

But maximum shear force at any section of the beam with a central concentrated load W is $\frac{W}{2}$

$$\therefore \quad q_{max} = 1.5 \times \frac{W}{2 \times 100 \times 150}$$

$$\Rightarrow \quad W = \frac{2 \times 2 \times 15000}{1.5 \times 10^3} \text{kN}$$

$$\Rightarrow \quad W = 40 \text{ kN}$$

6.59 (b)

From theory of pure bending

$$\frac{M}{I} = \frac{f}{y}$$

$$\Rightarrow \quad f_{max} = \frac{M}{I} \times y_{max}$$

$$\Rightarrow \quad \sigma_{bc} = \sigma_{bt} = \frac{M \times 12}{h \times h^3} \times \frac{h}{2}$$

$$\Rightarrow \quad \sigma_{bc} = \sigma_{bt} = \frac{6M}{h^3}$$

6.60 (c)

$$\frac{Z_r}{Z_{sq}} = \frac{a^3/6\sqrt{2}}{a^3/6}$$

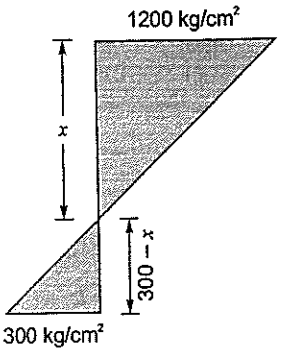
$$= \frac{1}{\sqrt{2}} = \frac{1}{1.414}$$

$$\text{Change} = \frac{Z_1 - Z_2}{Z_1}$$

So decrease by 29.27%

6.61 (b)

The variation of stresses in bending is shown below.



From rule of similar triangles, we have

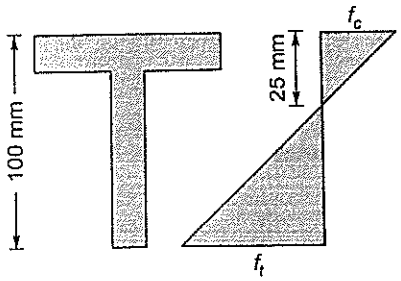
$$\frac{x}{1200} = \frac{300-x}{300}$$

$$\Rightarrow \quad x = 1200 - 4x$$

$$\Rightarrow \quad x = \frac{1200}{5} = 240 \text{ mm}$$

6.62 (c)

Let the maximum tensile stress and maximum compressive stress be f_t and f_c respectively. The distribution of stresses in the beam is shown below.



From the rule of similar triangles, we have

$$\frac{f_t}{100-25} = \frac{f_c}{25}$$

$$\Rightarrow \quad \frac{f_t}{f_c} = \frac{75}{25} = 3$$

6.63 (d)

Bending stresses vary linearly through the depth of cross section.

6.64 (c)

Strength of a beam depends on its section modulus for same loading conditions.

$$\therefore \quad \frac{Z_A}{Z_B} = \frac{b_A D^2/6}{b_B D^2/6} = \frac{b_A}{b_B} = \frac{2b_B}{b_B} = 2$$

6.65 (a)

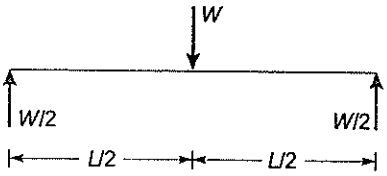
From the theory of pure bending, we have

$$\frac{f}{y} = \frac{M}{I}$$

$$\Rightarrow \quad f = \frac{M}{I} \times y$$

Now, from the above formula, it can be concluded that bending stress depends on bending moment (loading condition), moment of inertia (dimensions) and the distance of any fibre from neutral axis. Since the loading condition and cross-sectional shape and dimensions are unchanged, therefore the maximum bending stress will be unaltered.

6.66 (b)



BM at any section X distant x from the support is given by

$$M = \frac{w}{2}x$$

Let depth at the mid span be d

According to BM formula

$$\therefore \quad \frac{M}{I} = \frac{E}{R} = \frac{\sigma}{y}$$

$$\Rightarrow \quad \frac{w}{2}x = z.\sigma$$

Let depth at section X distance x from support be d_x

$$\therefore \quad \frac{w}{2}x = \frac{1}{6}\sigma b d_x^2$$

$$\Rightarrow \quad d_x = \sqrt{\frac{3wx}{\sigma b}}$$

$\therefore$ At mid span,

$$x = \frac{L}{2}$$

$$\therefore \quad d = \sqrt{\frac{3wL}{2b\sigma}}$$

6.67 (c)

The strength of a section will be proportional to its section modulus

as $\quad M \propto Z$

$\therefore$ Let diameter of circular section = D, and Side of square section = a

$$\therefore \quad \frac{\pi D^2}{4} = a^2$$

$$\Rightarrow \quad \frac{D^2}{a^2} = \frac{4}{\pi}$$

$$\therefore \quad \frac{Z_{square}}{Z_{circular}} = \frac{I_{square}}{y_{square}} \Big/ \frac{I_{circular}}{y_{circular}}$$

$$= \frac{\frac{a_4}{12}}{\frac{a/2}{}} \Big/ \frac{\frac{\pi D^4}{64}}{D/2}$$

$$= \frac{a^3}{6} \Big/ \frac{\pi D^3}{32} = \frac{32}{6\pi}\left(\frac{a^3}{D^3}\right)$$

$$= 1.18$$

$\therefore \quad Z_{square} > Z_{circular}$

Hence square section would be more economical.

6.68 (d)

For a rectangular beam

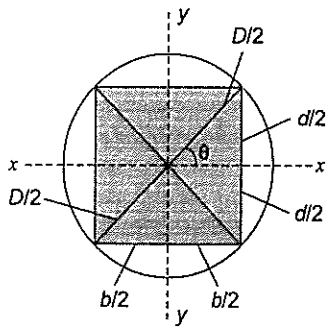
$$\tau_{max} = \frac{3}{2} \times \tau_{avg}$$

$$\Rightarrow \quad \tau_{max} = \frac{3}{2} \times \frac{P}{bd}$$

$$\Rightarrow \quad 4 = \frac{3}{2} \times \frac{60 \times 10^3}{100 \times d}$$

$$\Rightarrow \quad d = 225\,\text{mm}$$

6.69 (b)



$$\frac{d}{2} = \frac{D}{2}\sin\theta$$

$$\Rightarrow \quad d = D\sin\theta$$

$$\frac{b}{2} = \frac{D}{2}\cos\theta$$

$$\Rightarrow \quad b = D\cos\theta$$

$$Z = \frac{bd^2}{6} = \frac{D^3\cos\theta\sin^2\theta}{6}$$

$$= \frac{D^3}{6}(\cos\theta - \cos^3\theta)$$

For strongest flexural beam, $\frac{dz}{d\theta} = 0$

$$\Rightarrow \quad -\sin\theta + 3\cos^2\theta\sin\theta = 0$$

$$\Rightarrow \quad \sin\theta(3\cos^2\theta - 1) = 0$$

$$\Rightarrow \quad \cos\theta = \frac{1}{\sqrt{3}}$$

$$\therefore \quad \sin\theta = \sqrt{\frac{2}{3}}$$

$$\therefore \quad b = \frac{D}{\sqrt{3}}$$

and $\quad d = D\sqrt{\frac{2}{3}}$

6.70 (c)

$$\frac{f}{y} = \frac{M}{I}$$

$$\Rightarrow \quad f = \frac{M}{Z}$$

Where $\quad Z = I/y = \frac{12\times10^8}{300}\ \text{mm}^3$

$$= 4\times10^6\ \text{mm}^3$$

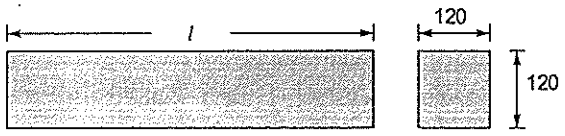
$$M = \frac{wl^2}{8} = 40\times\frac{6^2}{8} = 180\ \text{kN-m}$$

$$= \frac{180\times10^6}{4\times10^6} = 45\ \text{N/mm}^2$$

6.71 (c)

$$\sigma = \frac{M}{I}\times y = \frac{6\times10^7}{100\times\left(\frac{200^3}{12}\right)}\times\left(\frac{200}{2}\right) = 90\ \text{N/mm}^2$$

6.72 (c)



$$\frac{\sigma}{y} = \frac{M}{I} = \frac{E}{R}$$

$$\sigma = \frac{M}{I} = \frac{Ey}{R} = \frac{2\times10^5\times\frac{20}{2}}{10\times10^3}$$

$$= 200\ \text{N/mm}^2$$

6.73 (b)

In flitched beam, two different materials are rigidly connected. Thus, it prevents relative movement between two materials. So, option (b) is correct.

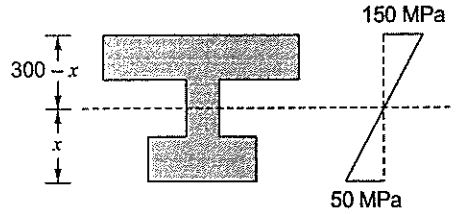
6.74 (d)

$$\because \quad V_{max} = \frac{wL}{2} = \frac{2\times4}{2} = 4\text{kN}$$

$$\because \quad \tau_{avg} = \frac{V_{max}}{bd} = \frac{4\times10^3}{100\times200} = 0.2\ \text{MPa}$$

$$\because \quad \tau_{max} = 1.5\,\tau_{avg} = 1.5\times0.2 = 0.3\ \text{MPa}$$

6.75 (c)



Stress diagram

From stress diagram,

$$\frac{50}{x} = \frac{150}{300 - x}$$

$$\Rightarrow \quad 15000 - 50x = 150x$$

$$\Rightarrow \quad x = 75\ \text{mm}$$

6.76 (c)

$$\because \quad \tau_{avg} = \frac{V}{A}$$

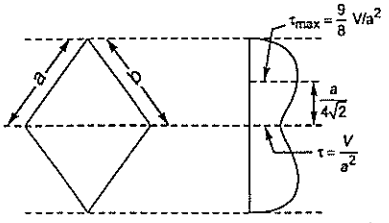
$$\because \quad A = \frac{1}{2}bh = \frac{1}{2}\times40\times20$$

$$= 400\ \text{mm}^2$$

$$\therefore \quad \tau_{avg} = \frac{3\times10^3}{400} = \frac{30}{4}\text{MPa}$$

$$\because \quad \tau_{N.A.} = \frac{4}{3}\tau_{avg} = \frac{4}{3}\times\frac{30}{4} = 10\text{MPa}$$

6.77 (a)



6.78 (a)

$$\because \quad \tau_{max} = 1.5\,\tau_{avg}$$

$$\therefore \quad 1.5 = 1.5\,\tau_{avg}$$

$$\Rightarrow \quad \tau_{avg} = 1\ \text{MPa}$$

$$\because \quad \tau_{avg} = \frac{V}{bh}$$

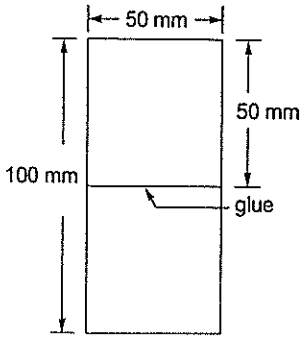
$$\Rightarrow \frac{V}{100 \times 200} = 1$$

$$\Rightarrow \quad V = 20\ \text{kN}$$

$$\because \quad w \times 1 = 20$$

$$\Rightarrow \quad w = 20\ \text{kN/m}$$

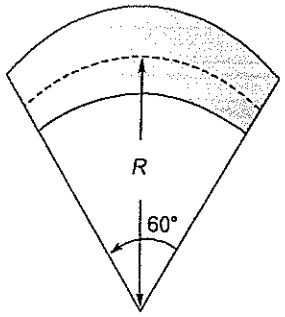
6.79 (b)



$$\text{Shear stress at glue} = \frac{3}{2} \times \tau_{avg}$$

$$= \frac{3}{2} \times \frac{1000}{50 \times 100} = 0.3\text{MPa}$$

6.80 (a)



$$L = R\theta$$

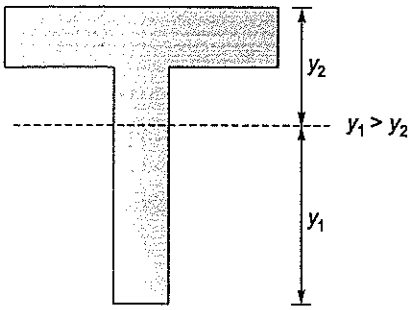
$$\therefore \quad R = \frac{L}{\theta} = \frac{25}{(\pi/3)} = 23.8732\ \text{cm}$$

Maximum bending stress,

$$\sigma_{max} = \frac{E}{R} \cdot y_{max} = \frac{2 \times 10^6}{23.8732} \times \frac{0.0625}{2}$$

$$= 2618\ \text{kg/cm}^2$$

6.81 (c)



$$\text{Since} \quad \frac{\sigma_1}{y_1} = \frac{\sigma_2}{y_2}$$

Maximum bending stress will be at maximum distance from NA so bending stress at bottom fibre will be maximum.

6.83 (d)

Max. bending stress,

$$\sigma = \frac{M}{Z} = \frac{PL}{Z}$$

$$Z = \frac{I}{y_{max}} = \frac{4 \times 10^5}{50} = 8 \times 10^3\ \text{mm}^3$$

$$\therefore \quad P = \frac{\sigma Z}{L} = \frac{100 \times 8 \times 10^3}{2 \times 1000} = 400\ \text{N}$$

6.84 (a)

Max. bending stress,

$$\sigma_{max} = \frac{M_{max}}{Z}$$

Section modulus,

$$Z = \frac{I}{y_{max}} = \frac{BD^3/12}{D/2} = \frac{BD^2}{6}$$

BM will be maximum when load is at mid-span,

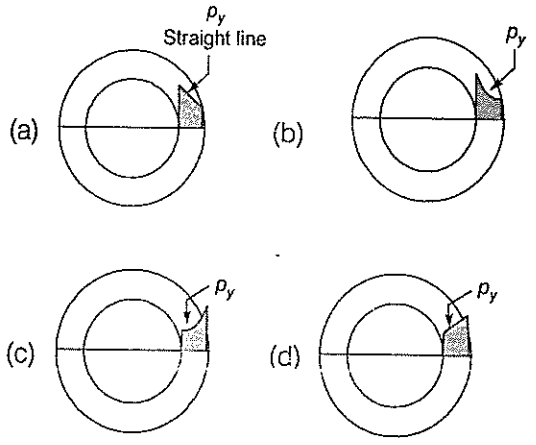
$$\therefore \quad M_{max} = \frac{FL}{4}$$

$$\therefore \quad \sigma_{max} = \frac{FL/4}{BD^2/6} = \frac{6FL}{4BD^2} = \frac{3FL}{2BD^2}$$

■■■■

7 Thick & Thin Cylinders and Spheres

7.1 A thick cylindrical pressure vessel of inner diameter D_i and outer diameter D_o is subjected to an internal fluid pressure of intensity 'p'. The variation of the circumferential tensile stress 'p_y' in the thickness of the shell will be



[ESE : 1995]

7.2 A thin cylindrical steel pressure vessel of diameter 6 cm and wall thickness 3 mm is subjected to an internal fluid pressure of intensity 'p'. If the ultimate strength of steel 3600 kg/cm^2, the bursting pressure will be

(a) 18 kg/cm^2 (b) 36 kg/cm^2
(c) 180 kg/cm^2 (d) 360 kg/cm^2

[ESE : 1995]

7.3 Two closed thin vessels, one cylindrical and the other spherical with equal internal diameter and wall thickness are subjected to equal internal fluid pressure. The ratio of hoop stresses in the cylindrical to that of spherical vessel is

(a) 4.0 (b) 2.0
(c) 1.0 (d) 0.5

[ESE : 1996]

7.4 A thin cylindrical shell of internal diameter D and thickness 't' is subjected to internal pressure 'p'. The change in diameter is given by

(a) $\frac{pD^2}{4tE}(2-\mu)$ (b) $\frac{pD^2}{4tE}(1-2\mu)$
(c) $\frac{pD^2}{2tE}(1-2\mu)$ (d) $\frac{pD^2}{2tE}(2-\mu)$

[ESE : 1997]

7.5 A cast iron pipe of 1 m diameter is required to withstand a 200 m head of water. If the limiting tensile stress of the pipe material is 20 MPa, then the thickness of the pipe will be

(a) 25 mm (b) 50 mm
(c) 75 mm (d) 100 mm

[ESE : 1998]

7.6 Consider the following statements in respect of a thick cylinder subjected to internal pressure :

1. The stress on an element on the outer wall is unidirectional.
2. The stresses on an element on the inner wall are principal stresses.
3. The constants of the Lame's equation are positive.

Which of these statements are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 1999]

7.7 The ratio of tensile stress developed in the wall of a boiler in the longitudinal direction to the tensile stress in the circumferential direction due to an internal pressure is

(a) 4 (b) 2
(c) 1/4 (d) 1/2

[ESE : 2001]

7.8 Assertion (A): The intensity of the longitudinal stress is one half of the intensity of hoop-stress or circumferential stress in a thin cylindrical shell subjected to internal pressure.

Reason (R): The stresses in the longitudinal and circumferential directions develop when a thin

cylindrical shell is subjected to internal force which tries to burst the cylinder.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2002]

7.9 The variation of the hoop stress across the thickness of a thick cylinder is

(a) linear (b) uniform
(c) parabolic (d) hyperbolic

[ESE : 2002]

7.10 A thin cylindrical tube with closed ends is subjected to:

1. Longitudinal stress $\sigma_1 = 14\ N/mm^2$
2. Hoop stress $\sigma_2 = 2\ N/mm^2$
3. Shearing stress $\tau = 8\ N/mm^2$

Then the maximum shearing stress is

(a) $14\ N/mm^2$ (b) $12\ N/mm^2$
(c) $10\ N/mm^2$ (d) $8\ N/mm^2$

[ESE : 2003]

7.11 For the analysis of thick cylinders, the theory applicable is

(a) Lame's theory (b) Rankine's theory
(c) Poisson's theory (d) Courbon's theory

[ESE : 2003]

7.12 A thin hollow cylinder of diameter 'd', length L and thickness 't' is subjected to an internal pressure 'p'. The hoop stress in the cylinder is

(a) $\frac{pd}{8t}$ (b) $\frac{pd}{4t}$
(c) $\frac{pd}{2t}$ (d) $\frac{pd}{t}$

[ESE : 2003]

7.13 A thin cylinder of thickness 't', width 'b' and internal radius 'r' is subjected to a pressure 'p' on the entire internal surface. What is the change in radius of the cylinder? (μ is the Poisson's ratio and E is the modulus of elasticity) ?

(a) $\frac{p^2r(2-\mu)}{Et}$ (b) $\frac{pr^2(2-\mu)}{Et}$
(c) $\frac{pr^2(2-\mu)}{2Et}$ (d) $\frac{p(1-\mu)}{Etr^2}$

[ESE : 2006]

7.14 A thin cylindrical tube closed at ends is subjected to internal pressure. A torque is also applied to the tube. The principal stresses p_1 and p_2 developed are 80.0 units and 20.0 units respectively. If the yield stress is 240 units, then what is the factor of safety according to maximum shear stress theory?

(a) 3.00 (b) 4.00
(c) 5.00 (d) 6.00

[ESE : 2006]

7.15 A thin cylinder of unit length, thickness 't' and radius 'r' is subjected to internal pressure 'p'. What is the circumferential stress?

(a) $pr/2Et$ (b) $pr/2t$
(c) pr/t (d) $2pr/t$

[ESE : 2008]

7.16 A cylindrical shell of 100 cm diameter made of mild steel plate is to be subjected to an internal pressure of $10\ kg/cm^2$. If the material yields at a stress of $200\ kg/cm^2$, assuming factor of safety as 4 and using maximum principal stress theory, the requisite thickness of the plate will be

(a) 8 mm (b) 10 mm
(c) 12 mm (d) 15 mm

[ESE : 2012]

7.17 A thin cylindrical shell made of mild steel plate is 1000 mm in diameter. It is to be subjected to an internal pressure of $2\ N/mm^2$. If the material yields at $200\ N/mm^2$, the thickness of the plate in mm on the basis of Rankine's theory of failure with assuming a factor of safety of 3 would be

(a) 10 (b) 12
(c) 15 (d) 18

[ESE : 2013]

7.18 A water main 160 cm dia. contains water at a pressure head of 200 m. Take weight of water to be $1000\ kg/m^3$. The thickness of the metal shell required for the water main, given that the maximum permissible stress in the metal is $400\ kg/cm^2$, will be

(a) 1 cm (b) 2 cm
(c) 3 cm (d) 4 cm

[ESE : 2013]

■■■■

Answers Thick & Thin Cylinders and Spheres

7.1	(b)	7.2	(d)	7.3	(b)	7.4	(a)	7.5	(b)	7.6	(d)	7.7	(d)	7.8	(b)	7.9	(d)
7.10	(c)	7.11	(a)	7.12	(c)	7.13	(c)	7.14	(b)	7.15	(c)	7.16	(b*)	7.17	(c)	7.18	(d)

Explanations Thick & Thin Cylinders and Spheres

7.1 (b)

Variation of hoop stress (f_x) and radial pressure (p_x) can be obtained by using Lame's equation i.e.

$$f_r - p_r = 2A$$

and $$f_r + p_r + r\frac{dp_r}{dr} = 0$$

$$\therefore \quad f_r = \frac{B}{r^2} + A, \qquad p_r = \frac{B}{r^2} - A$$

at $r = D_i$ we get $p_r = p$

$r = D_o$ we get $p_r = 0$

$$\therefore \quad p_r = p\left(\frac{D_0^2 - 4r^2}{D_0^2 - D_1^2}\right)\left(\frac{D_1^2}{4r^2}\right)$$

Radial pressure distribution is given by figure (b).

7.2 (d)

Hoop stress is more than longitudinal stress.

$$\text{Hoop stress} = \frac{pd}{2t} = \text{ultimate strength}$$

Given, $d = 6$ cm, $t = 3$ mm $= 0.3$ cm

$$\therefore \quad p = \frac{3600 \times 2 \times 0.3}{6} = 360 \text{ kg/cm}^2$$

7.3 (b)

$$\text{Hoop stress for cylindrical shell} = \frac{pd}{2t}$$

$$\text{Hoop stress for spherical shell} = \frac{pd}{4t}$$

So the ratio of hoop stress in the cylindrical to that of spherical shell is 2.

7.4 (a)

$$\frac{\text{Change in diameter}}{\text{Original diameter}} = \frac{\Delta D}{D}$$

$$= \frac{1}{E}[\sigma_1 - \mu\sigma_2]$$

$$= \frac{1}{E}\left[\frac{pD}{2t} - \frac{\mu pD}{4t}\right] = \frac{pD}{4tE}(2 - \mu)$$

$$\therefore \Delta D = \frac{pD^2}{4tE}(2 - \mu)$$

7.5 (b)

$$\text{Hoop stress} = \frac{pd}{2t} = 20 \text{ MPa}$$

$p = 200$ m head of water

$= 200$ kPa $= 2$ MPa

$$\therefore \quad t = \frac{2 \times 1}{20 \times 2} = 0.05 \text{ m} = 50 \text{ mm}$$

7.6 (d)

The inner wall is subjected to radial pressure, and hoop stress only.

The stress on the outer wall element has hoop stress only and radial stress is zero.

7.7 (d)

$$\frac{\text{Longitudinal stress}}{\text{Hoop stress}} = \frac{pd/4t}{pd/2t} = \frac{1}{2}$$

7.8 (b)

$$\text{Hoop stress, } \sigma_h = \frac{pd}{2t}$$

$$\text{Longitudinal stress, } \sigma_l = \frac{pd}{4t}$$

Stresses in longitudinal and circumferential directions develop when thin cylindrical shell is subjected to internal force which tries to burst the cylinder.

Reason is not the correct explanation of assertion

7.9 (d)

Hoop stress varies with radius R as

$$\sigma_h = \frac{B}{R^2} + A$$

So variation will be hyperbolic.

7.10 (c)

The centre of Mohr's circle

$$C = \frac{\sigma_1 + \sigma_2}{2} = \frac{14+2}{2} = 8 \text{ N/mm}^2$$

Radius of Mohr's circle

$$= \sqrt{\left(\frac{\sigma_1 - \sigma_2}{2}\right)^2 + \tau^2} = \sqrt{\left(\frac{14-2}{2}\right)^2 + 8^2}$$

$$= 10 \text{ N/mm}^2$$

Maximum shearing stress = Radius

$$= 10 \text{ N/mm}^2$$

7.11 (a)

Lame's theorem gives the solution to thick cylinder problem. The theorem is based on that the longitudinal strain is same at all points, i.e., the strain is independent of the radius.

7.12 (c)

$$\text{Hoop stress, } \sigma_h = \frac{pd}{2t}$$

Hoop stress is twice the Longitudinal stress.

7.13 (c)

$$\text{Hoop stress, } \sigma_\theta = \frac{pr}{t}$$

$$\text{Longitudinal stress, } \sigma_z = \frac{pr}{2t}$$

Strain in circumferential direction,

$$\epsilon_\theta = \frac{1}{E}(\sigma_\theta - \mu\sigma_z) = \frac{pr}{2tE}(2-\mu)$$

Change in radius = $\epsilon_\theta \times r$

$$= \frac{pr^2(2-\mu)}{2Et}$$

7.14 (b)

Maximum shear stress due to applied loading,

$$\tau_{max} = \frac{p_1 - p_2}{2} = \frac{80-20}{2} = 30 \text{ units}$$

Maximum shear stress in material at yield stress under uniaxial tension

$$\tau_y = \frac{f_y}{2} = \frac{240}{2} = 120 \text{ units}$$

$$\text{Factor of safety} = \frac{\tau_y}{\tau_{max}} = \frac{120}{30} = 4.0$$

7.15 (c)

Circumferential stress

$$\sigma = \frac{pd}{2t}$$

$$d = 2r$$

So $$\sigma = \frac{p2r}{2t}$$

$$\sigma = \frac{pr}{t}$$

7.16 (b*)

For a cylindrical shell, principal stress is given by

$$\sigma_1 = \frac{pd}{2t}$$

Given $d = 100$ cm, $p = 10$ kg/cm^2

Yield stress $\sigma_y = 200$ kg/cm^2

Now, according to maximum principals stress theory,

$$\sigma_1 \le \left(\frac{\sigma_y}{FoS}\right)$$

$$\therefore \quad \frac{pd}{2t} \le \frac{200}{4}$$

$$\Rightarrow \quad \frac{10 \times 100}{2 \times t} \le 50$$

$$\Rightarrow \quad t \ge 10 \text{ cm} = 100 \text{ mm}$$

7.17 (c)

$$\text{Factor of safety} = \frac{\text{Yield stress}}{\text{Max. normal stress}}$$

Here, maximum normal stress is Hoop stress

$$\sigma_h = \frac{pd}{2t}$$

$$t = \frac{pd}{2\sigma_h} = \frac{2 \times 1000}{2 \times 200} = 5 \text{ mm}$$

FOS = 3

Thickness required

$$= 3 \times t = 15 \text{ mm}$$

7.18 (d)

$$\frac{pd}{2t} \le 400 \text{ kg/cm}^2$$

$$\Rightarrow \quad \frac{1000 \times 200 \times 100 \times 160 \times 10}{2 \times t} \le 400 \times 10^4$$

$$\Rightarrow \quad t \ge 0.04 \text{ m}$$

So, minimum value of $t = 4$ cm

8 Torsion in Shafts & Springs

8.1 A shaft is subjected to a bending moment M and a torque T. The equivalent bending moment M_{eq} on the shaft is given by

(a) $\frac{M+\sqrt{M^2+T^2}}{4}$ (b) $\frac{M-\sqrt{M^2+T^2}}{4}$

(c) $\frac{M-\sqrt{M^2+T^2}}{2}$ (d) $\frac{M+\sqrt{M^2+T^2}}{2}$

[ESE : 1995]

8.2 A solid shaft of circular cross-section is subjected to a torque T which produces a maximum shear stress f_s in the shaft. The diameter of the shaft should be

(a) $\sqrt{\frac{\pi f_s}{16T}}$ (b) $\sqrt[3]{\frac{\pi f_s}{16T}}$

(c) $\sqrt{\frac{16T}{\pi f_s}}$ (d) $\sqrt[3]{\frac{16T}{\pi f_s}}$

[ESE : 1995]

8.3 If two springs of stiffness k_1 and k_2 are connected in series, the stiffness of the combined spring is

(a) $\frac{k_1k_2}{k_1+k_2}$ (b) $\frac{k_1+k_2}{k_1k_2}$

(c) $k_1 + k_2$ (d) k_1k_2

[ESE : 1995]

8.4 A circular shaft is subjected to a twisting moment T and bending moment M. The ratio of maximum bending stress to maximum shear stress is given by

(a) $\frac{2M}{T}$ (b) $\frac{M}{T}$

(c) $\frac{2T}{M}$ (d) $\frac{M}{2T}$

[ESE : 1996]

8.5 Two closed coil springs of stiffness k and $2k$ are arranged in series in one case and in parallel in the other case. The ratio of stiffness of springs connected in series to parallel is

(a) $\frac{1}{3}$ (b) $\frac{1}{9}$

(c) $\frac{2}{3}$ (d) $\frac{2}{9}$

[ESE : 1996]

8.6 A section of a solid circular shaft with diameter D is subjected to bending moment M and torque T. The expression for maximum principal stress at the section is

(a) $\frac{2M+T}{\pi D^3}$

(b) $\frac{16\pi}{D^3}\left(M+\sqrt{M^2+T^2}\right)$

(c) $\frac{16\pi}{D^3}\left(\sqrt{M^2+T^2}\right)$

(d) $\frac{16}{\pi D^3}\left(M+\sqrt{M^2+T^2}\right)$

[ESE : 1996]

8.7 As per the maximum principal stress theory, when a shaft is subjected to a bending moment M and torque T. And σ is the allowable stress in axial tension, then the diameter d of the shaft is given by

(a) $d^3 = \frac{16}{\pi\sigma}\left[M+\sqrt{M^2+T^2}\right]$

(b) $d^3 = \frac{4}{\pi\sigma}\left[M+\sqrt{M^2+T^2}\right]$

(c) $d^3 = \frac{32}{\pi\sigma}\left[M+\sqrt{M^2+T^2}\right]$

(d) $d^3 = \frac{8}{\pi\sigma}\left[M+\sqrt{M^2+T^2}\right]$

[ESE : 1997]

8.8 If the diameter of a shaft subjected to torque alone is doubled, then the horse power P can be increased to

(a) $16P$ (b) $8P$

(c) $4P$ (d) $2P$

[ESE : 1997]

8.9 If a circular shaft is subjected to a torque T and a bending moment M, the ratio of the maximum shear stress to the maximum bending stress is given by

(a) $\frac{2M}{T}$ (b) $\frac{T}{2M}$

(c) $\frac{2T}{M}$ (d) $\frac{M}{2T}$

[ESE : 1997]

8.10 Two shafts of solid circular cross-section are identical except for their diameter 'd_1' and 'd_2'. They are subjected to the same torque T. The ratio of the strain energies stored U_1/U_2 will be

(a) $\left(\frac{d_1}{d_2}\right)^4$ (b) $\left(\frac{d_1}{d_2}\right)^2$

(c) $\left(\frac{d_2}{d_1}\right)^2$ (d) $\left(\frac{d_2}{d_1}\right)^4$

[ESE : 1998]

8.11 Consider the following statements:

If a solid circular shaft and a hollow circular shaft have the same torsional strength, then

1. the weight of the hollow shaft will be greater than of the solid shaft
2. the external diameter of the hollow shaft will be greater than of the solid shaft
3. the stiffness of the hollow shaft will be equal to that of the solid shaft

Which of these statements is/are correct?

(a) 1, 2 and 3 (b) 2 and 3

(c) 1 alone (d) 1 and 2

[ESE : 1998]

8.12 A close-coiled helical spring shown below in Fig-I is to be cut into two equal pieces and combined as a parallel spring as shown in Fig-II. The ratio of the maximum angular twist of the situation shown in Fig-II to that of Fig-I, due to the same load W will be

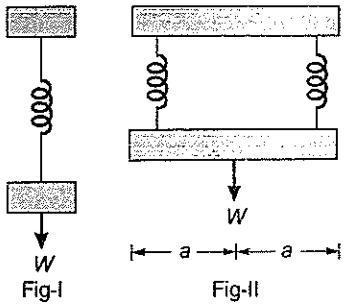


Fig-I Fig-II

(a) 1 (b) 1/2

(c) 1/4 (d) 1/8

[ESE : 1998]

8.13 A shaft turns at 150 rpm under a torque of 1500 Nm. Power transmitted is

(a) 15π kW (b) 10π kW

(c) 7.5π kW (d) 5π kW

[ESE : 1999]

8.14 A hollow steel shaft of external diameter 100 mm and internal diameter 50 mm is to be replaced by a solid alloy shaft. Assuming the same value of polar modulus for both, the diameter of the solid alloy shaft will be

(a) $10\times\sqrt[3]{9375}$ mm

(b) $10\times\sqrt[2]{9375}$ mm

(c) $10\times\sqrt[3]{\left(\frac{9375}{10}\right)}$ mm

(d) $\sqrt[3]{9375}$ mm

[ESE : 1999]

8.15 The close-coiled spring shown in Fig-I is cut into two equal pieces which are combined to form a parallel spring as shown in Fig-II. The ratio of the angular twist for the spring in Fig-II to that of spring in Fig-I due to an axial load P is

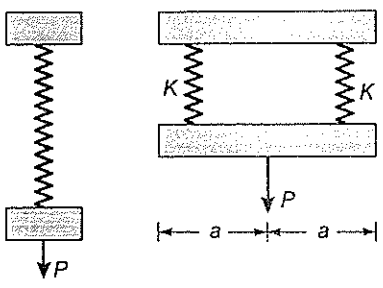


Fig-I Fig-II

(a) 1/2 (b) 1/4

(c) 1/8 (d) 1

[ESE : 1999]

8.16 A shaft of diameter 'd' is subjected to bending moment M and twisting moment T. The developed principal stress will be

(a) $\pm\frac{16}{\pi d^3}\sqrt{M^2+T^2}$

(b) $\frac{16}{\pi d^3}\left(M\pm\sqrt{M^2+T^2}\right)$

(c) $\frac{16}{\pi d^3}\left(T\pm\sqrt{M^2+T^2}\right)$

(d) $\frac{16}{\pi d^3}\sqrt{M^2+T^2}\pm M$

[ESE : 1999]

8.17 Consider a circular shaft of radius 'R' having the maximum shear stress 'f_s' developed by an applied torque.

Assertion (A): The shear stress 'q' at a point on the section having coordinate $(0, y)$ is $\frac{f_s y}{R}$

Reason (R): In the shaft, the shear stress 'q' at a point of coordinate (x, y) is $\frac{f_s}{R}\sqrt{x^2+y^2}$

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2000]

8.18 A solid shaft of 100 mm diameter in a small hydraulic turbine is subjected to an axial compressive load of 100π kN and a torque of 5π kN-m. The maximum shearing stress induced in the shaft is

(a) $20\sqrt{3}$ N/mm^2 (b) $20\sqrt{8}$ N/mm^2

(c) $20\sqrt{15}$ N/mm^2 (d) $20\sqrt{17}$ N/mm^2

[ESE : 2000]

8.19 A solid circular shaft is subjected to a torque T(in Nm), which produces a maximum shear stress of f_s(in N/mm^2) in the shaft. The required diameter of the shaft would be

(a) $10\left(\frac{16T}{\pi f_s}\right)^{1/3}$ (b) $10\left(\frac{\pi f_s}{16T}\right)^{1/3}$

(c) $10\left(\frac{16T}{\pi f_s}\right)^{1/2}$ (d) $10\left(\frac{\pi f_s}{16T}\right)^{1/2}$

[ESE : 2000]

8.20 A solid shaft has diameter 80 mm. It is subjected to a torque of 4 kN-m. The maximum shear stress induced in the shaft would be

(a) $\frac{75}{\pi}$ N/mm^2 (b) $\frac{250}{\pi}$ N/mm^2

(c) $\frac{125}{\pi}$ N/mm^2 (d) $\frac{150}{\pi}$ N/mm^2

[ESE : 2001]

8.21 Two steel shafts A and B are used for transmitting power. The ratio of revolutions of shafts i.e., $\frac{N_A}{N_B}=2$. The ratio of torques on shafts i.e., $\frac{T_A}{T_B}=\frac{1}{2}$. The ratio of the horse power transmitted by the shafts i.e. $\frac{P_A}{P_B}$ would be

(a) 1/2 (b) 1/4
(c) 1 (d) 2

[ESE : 2001]

8.22 A bar AB of diameter 40 mm and 4 m long is rigidly fixed at its ends. A torque of 600 Nm is applied at a section of the bar, 1 m from end A. The fixing couples T_A and T_B at the supports A and B, respectively, are

(a) 450 Nm and 150 N-m
(b) 200 N-m and 400 N-m
(c) 300 N-m and 150 N-m
(d) 300 N-m and 100 N-m

[ESE : 2001]

8.23 If a shaft is simultaneously subjected to a torque T and a bending moment M, the ratio of maximum bending stress and maximum shearing stress is given by

(a) $2M/T$ (b) M/T
(c) $2T/M$ (d) T/M

[ESE : 2001]

8.24 If three close-coiled and two open-coiled helical springs, each having the stiffness 'k' are connected in series than the overall stiffness is

(a) $5k$ (b) $k/5$

(c) $k/\sqrt{5}$ (d) $6k/5$

[ESE : 2001]

8.25 Strain energy in torsion of a shaft per unit volume is given by (q is maximum shear stress, E-modulus of Elasticity and G is modulus of rigidity)

(a) $\frac{q^2}{2G}$ (b) $\frac{q^2}{2E}$

(c) $\frac{q^2}{4G}$ (d) $\frac{q^2}{4E}$

[ESE : 2001]

8.26 **Assertion (A):** For a section having an axis of symmetry, there will not be twisting if the loading axis coincides with the symmetrical axis.

Reason (R): The plane of loading contains the bending axis.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 2002]

8.27 The ratio of the torsional moments of resistance of a solid circular shaft of diameter D, and a hollow circular shaft having external diameter D and internal diameter 'd' is given by

(a) $\frac{D^4}{D^4 - d^4}$ (b) $\frac{D^4 - d^4}{D^4}$

(c) $\frac{D^3 - d^3}{D^3}$ (d) $\frac{D^3}{D^3 - d^3}$

[ESE : 2002]

8.28 Match **List-I** with **List-II** and select the correct answer using the codes given below the lists:

List-I

A. Torque-twist relationship for a circular shaft

B. Strain energy of elastic torsion

C. Circumferential shear stress

D. Maximum shearing stress due to combined torsion and direct stress

List-II

1. $\frac{1}{2}\sqrt{\sigma^2 + 4\lambda^2}$ 2. $\frac{Gr\theta}{L}$

3. $\left(\frac{GJ}{2L}\right)\theta^2$ 4. $\frac{GJ}{L}\theta$

Codes:

	A	B	C	D
(a)	2	3	4	1
(b)	4	1	2	3
(c)	2	1	4	3
(d)	4	3	2	1

[ESE : 2002]

8.29 A solid circular shaft, ABC, has a total length of '$3a$'. A gear wheel positioned at B, at distance 'a' from the left hand end A, exerts a torque T. If the ends A and C are instantaneously locked in position by brakes just before the torque is applied, the torsional moments induced in both segments $T_1(AB)$ and $T_2(BC)$ are in the ratio

(a) 3 : 1 (b) 2 : 3

(c) 1 : 2 (d) 2 : 1

[ESE : 2002]

8.30 Two shafts having same length and material are joined in series and subjected to a torque of 10 kN-m. If the ratio of their diameters is 2 : 1, then the ratio of their angles of twist is

(a) 16 : 1 (b) 2 : 1

(c) 1 : 2 (d) 1 : 16

[ESE : 2002]

8.31 Two co-axial springs are subjected to a force of 1 kN. Spring constant of larger diameter spring is 80 N/mm and that of smaller diameter spring is 120 N/mm. The deformation in the spring combination will be equal to

(a) 5 mm (b) 15 mm

(c) $\frac{125}{6}$mm (d) $\frac{135}{7}$mm

[ESE : 2003]

8.32 A solid circular shaft of diameter 'd' is subjected to a twisting moment T. The maximum shear stress in the shaft is proportional to

(a) d^2 (b) d

(c) $1/d^2$ (d) $1/d^3$

[ESE : 2003]

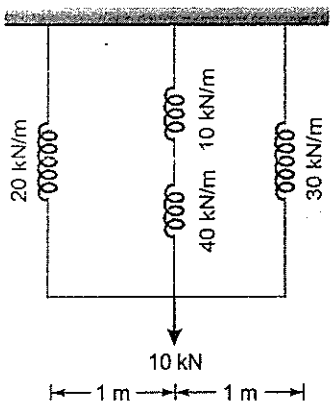
8.33 When a cantilever shaft of brittle material is subjected to a clockwise twisting moment at the free end, the possible crack propagation will be
(a) 45° clockwise with respect to the axis of shaft
(b) 45° anticlockwise with respect to the axis of shaft
(c) perpendicular to the axis
(d) parallel to the axis

[ESE : 2003]

8.34 The maximum shear stress produced in a shaft is 5 N/mm^2. The shaft is of 40 mm diameter. What is the approximate value of twisting moment?
(a) 628 N-m (b) 63 N-m
(c) 126 N-m (d) 251 N-m

[ESE : 2004]

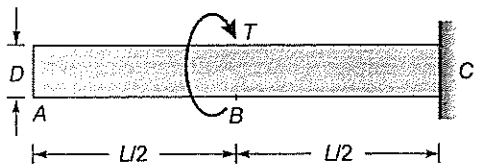
8.35 What is the equivalent spring stiffness for the system of springs shown in the figure given below?



(a) 43 kN/m (b) 50 kN/m
(c) 58 kN/m (d) 64 kN/m

[ESE : 2005]

8.36 A bar of circular cross-section of diameter D is subjected to a torque T at B as shown in the figure given below



What is the angle of twist at A?
(a) Same as that at B
(b) Zero
(c) Twice as that at B
(d) Half as that at B

[ESE : 2005]

8.37 Match List-I (Strain Energy) with List-II (Gradually applied load) and select the correct answer using the codes given below the lists (σ = direct stress, τ = shear stress, M_x = Bending moment, E = Modulus of elasticity, G = Modulus of rigidity, I = Area moment of inertia, V = Volume):

List-I	List-II
A. $\frac{\sigma^2 V}{2E}$	1. Axial load
B. $\frac{\tau^2 V}{2G}$	2. Bending load
C. $\frac{\tau^2 V}{4G}$	3. Shear load
D. $\int_0^L \frac{M_x^2 dx}{2EI}$	4. Torsional load

Codes:

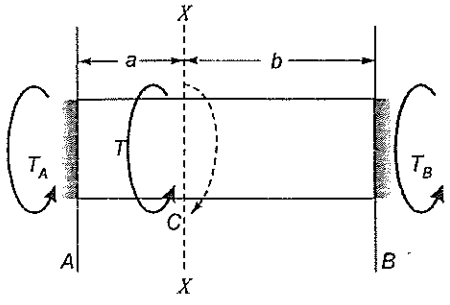
	A	B	C	D
(a)	2	3	4	1
(b)	1	4	3	2
(c)	2	4	3	1
(d)	1	3	4	2

[ESE : 2006]

8.38 The failure surface of a standard cast iron torsion specimen, subjected to a torque is along
(a) the surface helicoidal at 45° to the axis of the specimen
(b) the curved surface at the grips
(c) the plane surface perpendicular to the axis of the specimen
(d) the curved surface perpendicular to the axis of the specimen

[ESE : 2006]

8.39 For the circular shaft AB, as shown in the figure below, a torque 'T' is applied at the section XX at C, such that b/a = 1.5. The shaft is uniform in section.



What is the ratio of $\frac{T_A}{T_B}$?

(a) 2 (b) 1.5
(c) 0.67 (d) 0.5

[ESE : 2006]

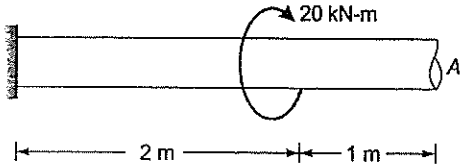
8.40 A close-coiled helical spring with n coils, mean radius R and diameter 'd' is subjected to an axial load W. What is the compression in spring?

(a) $\frac{64WR^3n}{Cd^3}$ (b) $\frac{64WR^3n}{Cd^4}$

(c) $\frac{32WR^3n}{Cd^3}$ (d) $\frac{32WR^3n}{Cd^4}$

[ESE : 2007]

8.41 A circular shaft of diameter 30 mm having shear modulus $G = 80$ GPa is subjected to moment as shown below.



What is the maximum shear stresses developed at periphery of shaft at A?

(a) 20.6 MPa (b) 15.3 MPa
(c) 7.4 MPa (d) Zero

[ESE : 2007]

8.42 Two shafts, one of solid section and the other of hollow section, of same material and weight having same length are subjected to equal torsional force. What is the torsional stiffness of hollow shaft?

(a) Equal to that of the solid shaft
(b) Less than that of the solid shaft
(c) More than that of the solid shaft
(d) Exactly half of that of the solid shaft

[ESE : 2007]

8.43 A circular shaft is subjected to a bending moment M_b and a twisting moment M_t. What is the ratio of maximum shear stress and the maximum bending stress?

(a) $\frac{2M_t}{M_b}$ (b) $\frac{M_t}{M_b}$

(c) $\frac{M_t}{2M_b}$ (d) $\frac{1.5M_t}{M_b}$

[ESE : 2008]

8.44 A 40 mm diameter shaft is subjected to a twisting moment M_t. If shear stress developed in shaft is 5 N/mm^2, what is the value of the twisting moment?

(a) 628.8 N-m (b) 328.4 N-m
(c) 62.8 N-m (d) 30.4 N-m

[ESE : 2009]

8.45 Torsion applied to a circular shaft results in a twist of 1° over a length of 1 m. The maximum shear stress induced is 120 N/mm^2 and the modulus of rigidity of the shaft material is 0.8×10^5 N/mm^2. What is the radius of the shaft?

(a) $\frac{300}{\pi}$ (b) $\frac{180}{\pi}$

(c) $\frac{90}{\pi}$ (d) $\frac{270}{\pi}$

[ESE : 2009]

8.46 A solid shaft rotating at 180 rpm is subjected to a mean torque of 5000 N-m. What is the power transmitted by the shaft in kW?

(a) 25π (b) 20π
(c) 60π (d) 30π

[ESE : 2010]

8.47 A solid shaft has length and diameter 'L_s' and D respectively. A hollow shaft of length L_h, external diameter D, and internal diameter 'd' respectively. Both are of the same material. The ratio of torsional stiffness of hollow shaft to that of solid shaft is

(a) $\left[1+\left(\frac{d}{D}\right)^4\right]\cdot\frac{L_s}{L_h}$ (b) $\left[1-\left(\frac{d}{D}\right)^4\right]\cdot\frac{L_h}{L_s}$

(c) $\left[1-\left(\frac{d}{D}\right)^4\right]\cdot\frac{L_s}{L_h}$ (d) $\left[1-\left(\frac{D}{d}\right)^4\right]\cdot\frac{L_s}{L_h}$

[ESE : 2010]

8.48 A circular shaft which has a diameter of 100 mm is subjected to a torque of 5 kN-m. The shear stress, in N/mm^2, induced in the shaft would be

(a) $\frac{160}{\pi}$ (b) $\frac{120}{\pi}$

(c) $\frac{125}{\pi}$ (d) $\frac{80}{\pi}$

[ESE : 2010]

8.49 A solid circular shaft subjected to a torque T produces maximum shear stress f_s, which is the maximum principal value in the material. The corresponding diameter of the shaft should be

(a) $\sqrt[3]{\frac{\pi \cdot f_s}{16 \cdot T}}$ (b) $\sqrt[3]{\frac{32 \cdot T}{\pi \cdot f_s}}$

(c) $\sqrt[3]{\frac{\pi}{16 \cdot T \cdot f_s}}$ (d) $\sqrt[3]{\frac{16 \cdot T}{\pi \cdot f_s}}$

[ESE : 2010]

8.50 Assertion (A): A hollow circular shaft has more power transmitting capacity than a solid shaft of same material and same weight per unit length.
Reason (R): In a circular shaft, shear stress developed at a point due to torsion is proportional to its radial distance from the centre of the shaft.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2010]

8.51 The polar moment of inertia of the cross-section of the member is required to assess the strength of the member in
(a) bending (b) torsion
(c) axial force (d) shear

[ESE : 2012]

8.52 In a circular shaft of diameter d, subjected to a torque T, the maximum shear stress inducted is
(a) proportional to d^3
(b) proportional to d^4
(c) inversely proportional to d^3
(d) inversely proportional to d^4

[ESE : 2012]

8.53 Which of the following terms represents the torque corresponding to a twist of one radian in a shaft over its unit length?
(a) Torsional stress
(b) Torsional rigidity
(c) Flexural rigidity
(d) Moment of resistance

[ESE : 2012]

8.54 If a shaft is turning at N r.p.m. and the mean torque to which the shaft is subjected is T N-m, the power transmitted by the shaft in kW would be

(a) $\frac{2\pi NT}{45000}$ (b) $\frac{2\pi NT}{60000}$

(c) $\frac{2\pi NT}{30000}$ (d) $\frac{2\pi NT}{33000}$

[ESE : 2012]

8.55 The polar modulus of a circular shaft of diameter d is

(a) $\frac{\pi}{16} \cdot d^3$ (b) $\frac{\pi}{32} \cdot d^3$

(c) $\frac{\pi}{64} \cdot d^3$ (d) $\frac{\pi}{32} \cdot d^2$

[ESE : 2012]

8.56 If a shaft rotates at 100 r.p.m and is subjected to a torque of 3000 N-m, the power transmitted in kW would be
(a) 30π (b) 15π
(c) 20π (d) 10π

[ESE : 2012]

8.57 A bar AB of diameter 40 mm and 4 m long is rigidly fixed at its ends. A torque 600 N-m is applied at a section of the bar, 1 m from end A. The fixing couples T_A and T_B at the supports A and B, respectively are
(a) 200 N-m and 400 N-m
(b) 300 N-m and 150 N-m
(c) 450 N-m and 150 N-m
(d) 300 N-m and 100 N-m

[ESE : 2012]

8.58 A solid shaft of circular cross-section is subjected to torque T which produces a maximum shear stress τ in the shaft. The diameter of the shaft will be

(a) $\sqrt[3]{\frac{16T}{\pi\tau}}$ (b) $\sqrt{\frac{\pi\tau}{16T}}$

(c) $\sqrt[3]{\frac{\pi\tau}{16T}}$ (d) $\sqrt{\frac{16T}{\pi\tau}}$

[ESE : 2012]

8.59 The ratio of torsional moments of resistance of a solid circular shaft of diameter D to that of a hollow shaft with external diameter D and internal diameter d is

(a) $\frac{D^4}{D^4 - d^4}$ (b) $\frac{D^4 - d^4}{D^4}$

(c) $\frac{D^3}{D^3 - d^3}$ (d) $\frac{D^3 - d^3}{D^3}$

Both the shafts are of the same material.

[ESE : 2012]

8.60 If A = Cross-sectional area
E = Young's modulus of elasticity
G = Modulus of rigidity
I = Moment of inertia
J = Polar moment of inertia
then torsional rigidity is given by

(a) AE (b) GE
(c) EI (d) GJ

[ESE : 2012]

8.61 A solid circular shaft has been subjected to a pure torsion moment. The ratio of maximum shear stress to maximum normal stress at any point would be

(a) 1 : 2 (b) 1 : 1
(c) 2 : 3 (d) 2 : 1

[ESE : 2013]

8.62 Which of the following terms represents the torque that produces a twist of one radian in a shaft of unit length?

(a) Torsional stress
(b) Torsional rigidity
(c) Flexural rigidity
(d) Moment of resistance

[ESE : 2013]

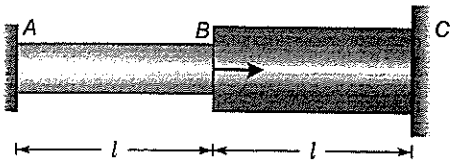
8.63 A 60 mm dia. shaft is subjected to a torque of 6 kNm. $C = 8 \times 10^4$ N/mm^2. The maximum shear stress induced in the shaft in N/mm^2 will be

(a) $\frac{8000}{9\pi}$ (b) $\frac{4000}{9\pi}$

(c) $\frac{12000}{9\pi}$ (d) $\frac{16000}{9\pi}$

[ESE : 2013]

8.64 A stepped circular shaft is fixed at A and C as shown in the below figure. The diameter of the shaft along BC is twice that of as along AB. The torsional rigidity of AB is GJ. The torque required for unit twist at B is

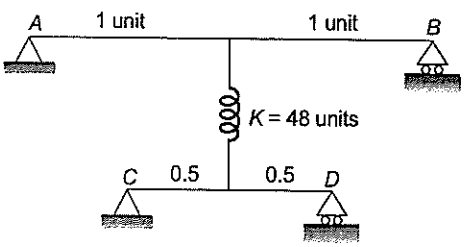


(a) $\frac{2GJ}{l}$ (b) $\frac{5GJ}{l}$

(c) $\frac{9GJ}{l}$ (d) $\frac{17GJ}{l}$

[ESE : 2013]

8.65 The equivalent spring constant for the set up shown in the below figure, where EI = unity throughout, is



(a) 30 units (b) 36 units
(c) 40 units (d) 48 units

[ESE : 2013]

8.66 A solid shaft of 80 mm diameter is transmitting 100 kW of power at 200 r.p.m. The maximum shear stress induced in the shaft will nearly be

(a) 60 N/mm^2 (b) 56 N/mm^2
(c) 52 N/mm^2 (d) 48 N/mm^2

[ESE : 2014]

8.67 The power transmitted by a 75 mm diameter shaft at 140 r.p.m., subjected to a maximum shear stress of 60 N/mm^2, is nearly

(a) 68 kW (b) 70 kW
(c) 73 kW (d) 76 kW

[ESE : 2014]

8.68 A circular shaft of diameter D is subjected to a torque T. The maximum shear stress of the shaft will be

(a) proportional to D^3
(b) proportional to D^4
(c) inversely proportional to D^3
(d) inversely proportional to D^4

[ESE : 2014]

8.69 A hollow shaft of 16 mm outside diameter and 12 mm inside diameter is subjected to a torque

of 40 N-m. The shear stresses at the outside and inside of the material of the shaft are respectively
(a) 62.75 N/mm^2 and 50.00 N/mm^2
(b) 72.75 N/mm^2 and 54.54 N/mm^2
(c) 79.75 N/mm^2 and 59.54 N/mm^2
(d) 80.00 N/mm^2 and 40.00 N/mm^2

[ESE : 2014]

8.70 A close helical spring of 100 mm mean diameter is made of 10 mm diameter rod, and has 20 turns. The spring carries an axial load of 200 kN with $G = 8.4 \times 10^4$ N/mm^2. The stiffness of the spring is nearly
(a) 5.25 N/mm (b) 6.50 N/mm
(c) 7.25 N/mm (d) 8.50 N/mm

[ESE : 2014]

8.71 A closely coiled helical spring of round steel wire 5 mm in diameter having 12 complete coils of 50 mm mean diameter is subjected to an axial load of 100 N. Modulus of Rigidity of the spring is 80 kN/mm^2. What is the deflection of the spring?
(a) 12 mm (b) 24 mm
(c) 36 mm (d) 48 mm

[ESE : 2015]

8.72 Two closely coiled helical springs *A* and *B* are respects but for the number of turns, with *A* having just half the number of turns of that *B*. What is the ratio of deflections in terms of spring *A* to spring *B*?
(a) 1/8 (b) 1/4
(c) 1/2 (d) 2/1

[ESE : 2015]

8.73 What is the diameter *d* of a solid circular shaft when subjected to a torque *T* with a corresponding maximum shear stress of magnitude f_s?
(a) $\frac{16T}{\pi f_s}$ (b) $\frac{\pi f_s}{16T}$
(c) $\sqrt{\frac{16T}{\pi f_s}}$ (d) $\sqrt[3]{\frac{16T}{\pi f_s}}$

[ESE : 2015]

8.74 A metal shaft of solid circular section rotates at 160 rpm and is subjected to a torque of 1500 Nm. What is the power, in kW, transmitted by the shaft?
(a) 32π (b) 16π
(c) 12π (d) 8π

[ESE : 2015]

8.75 What is the power transmitted by a 100 mm diameter solid shaft at 150 rpm without exceeding a maximum stress of 60 N/mm^2?
[Take $\pi^2 = 10$]
(a) 187.5 kW (b) 18.75 kW
(c) 1.875 kW (d) 1875 kW

[ESE : 2015]

8.76 What is the Polar Modulus of a solid circular metal shaft of diameter 8 cm?
(a) 64π cm^3 (b) 32π cm^3
(c) 16π cm^3 (d) 8π cm^3

[ESE : 2015]

8.77 A hollow circular shaft has the diameters 50 cm and 30 cm and is subjected to a torque. If the realized maximum shear stress is 30 N/mm^2, what is the applied torque to nearest units?
(a) 160 Nm (b) 320 Nm
(c) 80 Nm (d) 32 Nm

[ESE : 2015]

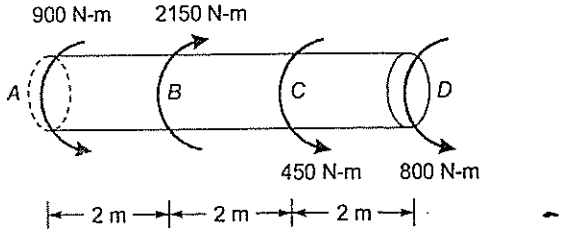
8.78 A solid shaft transmits 150 kW at a shear stress of 70 MPa running at a frequency of 3 Hz. What will be the shear stress when the frequency is 1.5 Hz?
(a) 35 MPa (b) 50 MPa
(c) 57 MPa (d) 140 MPa

[ESE : 2015]

8.79 A circular shaft rotates at 200 rpm and is subject to a torque of 1500 Nm. The power transmitted would be
(a) 10π kW (b) 15π kW
(c) 20π kW (d) 30π kW

[ESE : 2016]

8.80 Torques are transmitted to the solid circular shaft as shown in the figure below. If the corresponding permissible stress in the shaft is 60 N/mm^2, the diameter of the shaft is nearly



(a) 57.3 mm (b) 47.5 mm
(c) 37.3 mm (d) 27.3 mm

[ESE : 2016]

8.81 A solid circular shaft has a diameter d. Its polar modulus will be

(a) $\frac{\pi}{16}d^2$ (b) $\frac{\pi}{64}d^3$

(c) $\frac{\pi}{16}d^3$ (d) $\frac{\pi}{32}d^2$

[ESE : 2016]

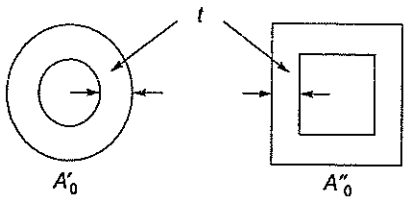
8.82 A hollow steel shaft has outside diameter d and inside diameter $d/2$. The value of d for the shaft, if it has to transmit 200 hp at 105 rpm with a working shear stress of 420 kg/cm^2, is

(a) 5.6 cm (b) 2.6 cm

(c) 12.1 cm (d) 15.5 cm

[ESE : 2016]

8.83 Two thin-walled tubular members made of the same material have the same length, same wall thickness and same total weight and are both subjected to the same torque of magnitude T. If the individual cross-section are circular and square, respectively, as in the figures, then the ratios of the shear stresses reckoned for the circular member in relation to the square member will be



(a) 0.785 (b) 0.905

(c) 0.616 (d) 0.513

[ESE : 2016]

8.84 Consider the following statements:

1. The shear stress distribution across the section of a circular shaft subjected to twisting varies parabolically.
2. The shear stress at the centre of a circular shaft under twisting moment is zero.
3. The shear stress at the extreme fibres of a circular shaft under twisting moment is maximum.

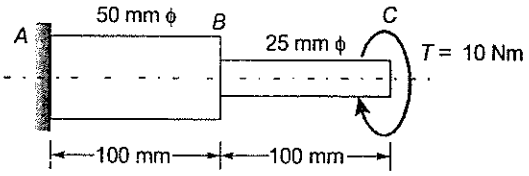
Which of the above statements is/are correct?

(a) 1, 2 and 3 (b) 1 only

(c) 2 only (d) 3 only

[ESE : 2017]

8.85 A stepped steel shaft is subjected to a clockwise torque of 10 Nm at its free end. Shear modulus of steel is 80 GPa. The strain energy stored in the shaft is



(a) 1.73 Nmm (b) 2.52 Nmm

(c) 3.46 Nmm (d) 4.12 Nmm

[ESE : 2017]

8.86 Statement (I): Hollow shafts are preferred in propeller shafts of airplanes.

Statement (II): Use of hollow shafts affords considerable reduction in the weight of the shaft for equal performance.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)

(c) Statement (I) is true but Statement (II) is false

(d) Statement (I) is false but Statement (II) is true

[ESE : 2017]

Answers Torsion in Shafts & Springs

8.1 (d)	8.2 (d)	8.3 (a)	8.4 (a)	8.5 (d)	8.6 (d)	8.7 (a)	8.8 (b)	8.9 (b)	
8.10 (d)	8.11 (b)	8.12 (c)	8.13 (c)	8.14 (c)	8.15 (b)	8.16 (b)	8.17 (a)	8.18 (d)	
8.19 (a)	8.20 (c)	8.21 (c)	8.22 (a)	8.23 (a)	8.24 (b)	8.25 (c)	8.26 (b)	8.27 (a)	
8.28 (d)	8.29 (d)	8.30 (d)	8.31 (a)	8.32 (d)	8.33 (a)	8.34 (b)	8.35 (c)	8.36 (a)	
8.37 (d)	8.38 (a)	8.39 (b)	8.40 (b)	8.41 (d)	8.42 (c)	8.43 (c)	8.44 (c)	8.44 (d)	
8.46 (d)	8.47 (c)	8.48 (d)	8.49 (d)	8.50 (b)	8.51 (b)	8.52 (c)	8.53 (b)	8.54 (b)	
8.55 (a)	8.56 (d)	8.57 (c)	8.58 (a)	8.59 (a)	8.60 (d)	8.61 (b)	8.62 (b)	8.63 (b)	
8.64 (d)	8.65 (a)	8.66 (d)	8.67 (c)	8.68 (c)	8.69 (b)	8.70 (a)	8.71 (b)	8.72 (c)	
8.73 (d)	8.74 (d)	8.75 (a)	8.76 (b)	8.77 (*)	8.78 (d)	8.79 (a)	8.80 (b)	8.81 (c)	
8.82 (c)	8.83 (a)	8.84 (c, d)	8.85 (a)	8.86 (a)					

Explanations Torsion in Shafts & Springs

8.1 (d)

Equivalent bending moment $= \dfrac{M+\sqrt{M^2+T^2}}{2}$

Equivalent torsion $= \sqrt{M^2+T^2}$

8.2 (d)

$$f_s = \frac{16}{\pi d^3}T$$

$$\therefore \quad d = \sqrt{\frac{16T}{\pi f_s}}$$

8.3 (a)

For series combination of springs,

$$\frac{1}{k} = \frac{1}{k_1}+\frac{1}{k_2}$$

$$\therefore \quad k = \frac{k_1 \times k_2}{k_1+k_2}$$

8.4 (a)

Maximum bending stress, $\sigma_b = \dfrac{32M}{\pi d^3}$

Maximum shear stress, $\tau = \dfrac{16T}{\pi d^3}$

$$\frac{\sigma_b}{\tau} = \frac{2M}{T}$$

8.5 (d)

For series connection,

$$k_e = \frac{k \times 2k}{k+3k} = \frac{2}{3}k$$

For parallel connection,

$$k_e' = k + 2k = 3k$$

$$\therefore \quad \frac{k_e}{k_e'} = \frac{2k/3}{3k} = \frac{2}{9}$$

8.6 (d)

Principal stresses,

$$\sigma_1/\sigma_2 = \frac{16}{\pi D^3}\left[M \pm \sqrt{M^2+T^2}\right]$$

Maximum principal stress is obtained by choosing '+' sign and minimum principal stress is obtained by '–' sign.

8.7 (a)

Maximum stress due to bending moment

$$\sigma_1 = \frac{32M}{\pi d^3}$$

Maximum shear stress due to torsion T

$$\tau = \frac{16T}{\pi d^3}$$

Maximum normal stress due to combined action of bending moment and torque

$$\sigma_{max} = \frac{\sigma_1}{2} + \sqrt{\left(\frac{\sigma_1}{2}\right)^2 + \tau^2}$$

$$= \frac{16}{\pi d^3}\left[M + \sqrt{M^2 + \tau^2}\right]$$

According to maximum principal stress theory, for no failure

$$\sigma_{max} \le \text{Allowable stress}$$

$$d^3 \le \frac{16}{\pi\sigma}\left[M + \sqrt{(M)^2 + \tau^2}\right]$$

8.8 (b)

Torsion formula is given as

$$\frac{T}{J} = \frac{G\theta}{L} = \frac{\tau}{r}$$

Power = Torque × Rotational speed = $T\omega$

When diameter is doubled, the torque carrying capacity becomes 8 times the original. So power also increases 8 times.

8.10 (d)

Strain energy, $U = \frac{1}{2}T\theta$

and $\theta = \frac{TL}{GJ}$

$\therefore$ $U = \frac{T^2L}{2GJ}$

$J = \frac{\pi d^4}{32}$

$\therefore$ $\frac{U_1}{U_2} = \left(\frac{d_2}{d_1}\right)^4$

8.12 (c)

Angular twist in a spring is

$$\theta = \frac{32\,WRL}{\pi d^4 G}$$

where

d is diameter of wire of spring

G is modulus of rigidity

W is axial pull on spring

R is mean radius of coil

L is Length of spring

$\therefore$ $\frac{\theta_2}{\theta_1} = \frac{W_2}{W_1} \times \frac{L_2}{L_1}$

$= \frac{W/2}{W} \times \frac{L/2}{L} = \frac{1}{4}$

8.13 (c)

Power, $P = T\omega = 1500 \times \frac{2\pi \times 150}{60}$

$= 7500\pi\ W = 7.5\pi$ kW

8.14 (c)

Polar modulus is also called polar section modulus or torsional section modulus.

$\frac{I_P}{R}$ = Polar modulus

$\therefore$ $\frac{I_{P_1}}{R_1} = \frac{I_{P_2}}{R_2}$

$\Rightarrow \frac{(\pi/32) \times (D_o^4 - D_i^4)}{D_o/2} = \frac{(\pi/32) \times D^4}{D/2}$

$\Rightarrow D_o^3\left[1 - \left(\frac{D_i}{D_o}\right)^4\right] = D^3$

$\Rightarrow 100^3\left[1 - \left(\frac{50}{100}\right)^4\right] = D^3$

$\Rightarrow D = 100\ \sqrt[3]{0.9375}$

$\Rightarrow D = 10\ \sqrt[3]{\frac{9375}{10}}$

8.15 (b)

$\frac{\theta_2}{\theta_1} = \frac{W_2L_2}{W_1L_1} = \frac{1}{4}$

8.16 (b)

Maximum stress due to bending moment

$$\sigma = \frac{32M}{\pi d^3}$$

Maximum shear stress due to torsion T

$$\tau = \frac{16t}{\pi d^3}$$

Maximum normal stress due to combined action of bending moment and torque

$$\sigma_1, \sigma_3 = \frac{\sigma}{2} \pm \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$$

$$= \frac{16}{\pi d^3}\left[M \pm \sqrt{M^2 + \tau^2}\right]$$

8.17 (a)

Torsion formula,

$$\frac{G\theta}{L} = \frac{T}{J} = \frac{f}{r} = \frac{f_s}{R}$$

For point (x, y) $r = \sqrt{x^2 + y^2}$

$$\therefore \quad f = \frac{f_s\sqrt{x^2 + y^2}}{R}$$

Therefore for point (0, y)

$$f = \frac{f_s y}{R}$$

8.18 (d)

$$\text{Axial stress} = \frac{100\pi}{\frac{\pi \times 100^2}{4}} = 0.04 \text{ kN/mm}^2$$

$$= 40 \text{ N/mm}^2$$

$$\text{Shear stress} = \frac{16T}{\pi d^3} = \frac{16}{\pi \times (100)^3} \times 5\pi \times 10^6$$

$$= 80 \text{ N/mm}^2$$

Maximum shear stress is the radius of Mohr's circle.

$$\text{Maximum shear stress} = \sqrt{\left(\frac{40}{2}\right)^2 + (80)^2}$$

$$= 20\sqrt{17} \text{ N/mm}^2$$

8.19 (a)

$$f_s = \frac{16}{\pi d^3}(T \times 10^3)$$

$$\therefore \quad d = 10\left(\frac{16T}{\pi f_s}\right)^{1/3}$$

8.20 (c)

$$f_{max} = \frac{16T}{\pi d^3}$$

$$\therefore \quad f_{max} = \frac{16}{\pi \times (80)^3} \times 4 \times 10^6$$

$$= 125/\pi \text{ N/mm}^2$$

8.21 (c)

$$P = \frac{2\pi NT}{60}$$

$$\therefore \quad \frac{P_A}{P_B} = \frac{N_A}{N_B} \times \frac{T_A}{T_B} = 1.0$$

8.22 (a)

The angle of twist (θ) at the point of application of torque will be same for bar on both sides.

Thus $T_A L_A = T_B L_B$

and $T_A + T_B = T$

$$T_A = \frac{T}{\left(1 + \frac{L_A}{L_B}\right)} = \frac{600}{\left(1 + \frac{1}{3}\right)} = 450 \text{ N-m}$$

$$T_B = 600 - 450 = 150 \text{ N-m}$$

8.23 (b)

It is a series connection so

$$\frac{1}{k_{eq}} = \frac{1}{k} + \frac{1}{k} + \frac{1}{k} + \frac{1}{k} + \frac{1}{k}$$

$$\frac{1}{k_{eq}} = \frac{5}{k}$$

$$k_{eq} = \frac{k}{5}$$

8.25 (c)

Strain energy per unit volume for solid shaft

$$= \frac{q_{max}^2}{4G}$$

8.26 (b)

The shear centre lies on the axis of symmetry. So there will be no twisting when loading axis coincides with the symmetrical axis.

8.27 (a)

Torsional moment of resistance

$$= f_s \times \left(\frac{\pi D^3}{16}\right) \text{ for solid shaft}$$

$$= f_s \times \left[\frac{\pi(D^4 - d^4)}{16D}\right] \text{ for hollow shaft}$$

$\therefore$ Ratio of torsional moment of resistance

$$= \frac{D^4}{(D^4 - d^4)}$$

8.28 (d)

- For circular shaft

$$\frac{\tau}{r} = \frac{T}{J} = \frac{G\theta}{L}$$

$$T = \left(\frac{GJ}{L}\right)\theta$$

- Strain energy $= \frac{1}{2}T\theta = \frac{1}{2}\left(\frac{GJ}{L}\right)\theta^2$
- Shear stress, $\tau = \frac{Gr\theta}{L}$
- Max shear stress $= \sqrt{\left(\frac{\sigma}{2}\right)^2 + \tau^2}$

$$= \frac{1}{2}\sqrt{(\sigma)^2 + 4\tau^2}$$

8.29 (d)

$$T_1 L_{AB} = T_2 L_{BC}$$

$$\frac{T_1}{T_2} = \frac{L_{BC}}{L_{AB}} = \frac{2}{1}$$

8.30 (d)

$$\theta = \frac{TL}{GJ}$$

$$\therefore \quad \frac{\theta_1}{\theta_2} = \frac{J_2}{J_1} = \left(\frac{d_2}{d_1}\right)^4 = \frac{1}{16}$$

8.31 (a)

Coaxial springs undergo same deformation so they behave as parallel springs. The spring constant of co-axial springs is

$$k = k_1 + k_2$$

$$= 80 + 120 = 200$$

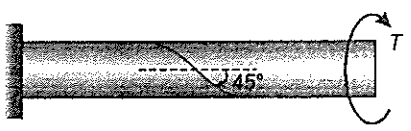
So $\Delta = \frac{1000}{200} = 5$ mm

8.32 (d)

$$f_s = \frac{16T}{\pi d^3}$$

So maximum shear stress (f_s) is proportional to $\frac{1}{d^3}$.

8.33 (a)



8.34 (b)

Twisting moment, $T = \tau_{max} J$

Torsional section modulus,

$$J = \frac{\pi d^3}{16} = \frac{\pi \times (40)^3}{16} = 12566 \text{ mm}^3$$

$\therefore T = 5 \times 12566 = 62832$ N – mm $\simeq 63$ N-m

8.35 (c)

Spring of 10 kN/m stiffness and 40 kN/m stiffness are in series. They will have equivalent stiffness of $\frac{10 \times 40}{10 + 40} = 8$ kN/m.

Now 20 kN/m, 8 kN/m and 30 kN/m stiffness springs will be in parallel so the equivalent spring stiffness will be 20 + 8 + 30 = 58 kN/m

8.36 (a)

$$\theta_B = \frac{TL}{2GJ}$$

$$\theta_A = \Sigma\frac{TL}{GJ} = \frac{TL}{2GJ} + 0 = \frac{TL}{2GJ}$$

So angle of twist at A will be equal to that at B, because there is no torque between A and B.

8.37 (d)

In the case of torsional load strain energy,

$$U = \frac{1}{2}T\theta$$

Torsional formula is $\frac{T}{J} = \frac{G\theta}{L} = \frac{\tau}{r}$

So $T = \frac{\tau J}{r}$

and $\theta = \frac{\tau L}{rG}$

$$\therefore \quad U = \frac{\tau^2}{2G} \times \left(\frac{LJ}{r^2}\right)$$

Polar moment of inertia,

$$J = \left(\frac{\pi r^4}{2}\right)$$

$$U = \frac{\tau^2}{2G} \times \frac{1}{2}\pi r^2$$

$$L = \frac{\tau^2}{4G} \times \text{volume}$$

8.38 (a)

The cast iron specimen is brittle in nature and therefore the failure surface will be helicoidal at 45° to the axis of the specimen.

8.39 (b)

$$T_A \times a = T_B \times b$$

$$\therefore \quad \frac{T_A}{T_B} = \frac{b}{a} = 1.5$$

8.40 (b)

We know that strain energy stored in the spring is given by

$$U = \frac{T^2 L}{2CI_P}$$

Here $T = WR$, $L = 2\pi Rn$,

$$I_P = \frac{\pi}{32}d^4$$

$$\therefore \quad U = \frac{W^2R^2 \times 2\pi Rn}{2C \times \left(\frac{\pi}{32}d^4\right)}$$

$$\Rightarrow \quad U = \frac{32W^2R^3n}{Cd^4}$$

Compression in the spring,

$$\delta = \frac{\partial U}{\partial W} = \frac{\partial}{\partial W}\left(\frac{32W^2R^3n}{Cd^4}\right)$$

$$= \frac{64\,WR^3n}{Cd^4}$$

8.41 (d)

Since end A is free, hence the shear stress will not develop at A.

8.42 (c)

Let the diameter of solid shaft be d_s. Let the external and internal diameter of the hollow shaft be d_o and d_i respectively. It is given that both the shafts are made of same material, have same weight and length and are subjected to equal torsional force.

∴Weight of solid shaft = Weight of hollow shaft

$$\Rightarrow \gamma \times \frac{\pi}{4}d_s^2 L = \gamma \times \frac{\pi}{4}\left(d_o^2 - d_i^2\right)L$$

$$\Rightarrow \quad d_s^2 = d_o^2 - d_i^2 \qquad \ldots(i)$$

Now, we know that, torsional stiffness is given as

$$k = \frac{T}{\theta} = \frac{GI_P}{L}$$

For same value of G and L

$$k = \frac{T}{\theta} \propto I_P$$

$$\Rightarrow \quad \frac{k_h}{k_s} = \frac{\frac{\pi}{32}\left(d_o^4 - d_i^4\right)}{\frac{\pi}{32}\left(d_s^4\right)}$$

$$\Rightarrow \quad \frac{k_h}{k_s} = \frac{\left(d_o^2\right)^2 - \left(d_i^2\right)^2}{\left(d_s^2\right)^2}$$

$$\Rightarrow \quad \frac{k_h}{k_s} = \frac{\left(d_o^2 - d_i^2\right)\left(d_o^2 + d_i^2\right)}{\left(d_s^2\right)^2} \qquad \text{[from (i)]}$$

$$\Rightarrow \quad \frac{k_h}{k_s} = \frac{d_o^2 + d_i^2}{d_o^2 - d_i^2}$$

Now, the quantity $\frac{d_o^2 + d_i^2}{d_o^2 - d_i^2}$ is always greater than 1

$$\therefore \quad k_h > k_s$$

8.43 (c)

The maximum shear stress will be

$$\tau_{max} = \frac{16M_t}{\pi D^3}$$

The maximum bending stress will be

$$\sigma_{max} = \frac{32M_b}{\pi D^3}$$

$$\therefore \quad \frac{\tau_{max}}{\sigma_{max}} = \frac{16\,M_t/\pi D^3}{32\,M_b/\pi D^3} = \frac{M_t}{2M_b}$$

8.44 (c)

Shear stress due to torsion will be

$$\tau_{max} = \frac{16\,M_t}{\pi D^3}$$

$$\Rightarrow \quad M_t = \frac{5 \times \pi \times (40)^3}{16 \times 10^3}$$

$$\Rightarrow \quad M_t = 62.8\ \text{N-m}$$

8.45 (d)

We know that

$$\frac{\tau}{R} = \frac{G\theta}{L}$$

$$\Rightarrow \quad \frac{120}{R} = \frac{0.8 \times 10^5 \times 1 \times \pi}{1 \times 10^3 \times 180}$$

$$\Rightarrow \quad R = \frac{270}{\pi}$$

8.46 (d)

The power transmitted by the shaft is given by

$$P = \frac{2\pi NT}{60}$$

$$= \frac{2\pi \times 180 \times 5000 \times 10^{-3}}{60}$$
$$= 30\pi \text{ kW}$$

8.47 (c)

The torsional stiffness of a bar is the torque required to produce a unit angle of rotation. It is denoted by k.

$$\therefore \quad \frac{T}{\theta} = k = \frac{GI_P}{L}$$

$$\Rightarrow \quad \frac{k_h}{k_s} = \frac{GI_{Ph}/L_h}{GI_{Ps}/L_s} \quad [\because \text{material is same}]$$

$$\Rightarrow \quad \frac{k_h}{k_s} = \frac{I_{Ph}}{I_{Ps}} \times \frac{L_s}{L_h}$$

$$\Rightarrow \quad \frac{k_h}{k_s} = \left[\frac{\frac{\pi}{32}\times(D^4 - d^4)}{\frac{\pi}{32}\times D^4}\right] \times \frac{L_s}{L_h}$$

$$\Rightarrow \quad \frac{k_h}{k_s} = \left[\frac{D^4 - d^4}{D^4}\right] \times \frac{L_s}{L_h}$$

$$\Rightarrow \quad \frac{k_h}{k_s} = \left[1 - \left(\frac{d}{D}\right)^4\right] \times \frac{L_s}{L_h}$$

8.48 (d)

From torsion formula, we have

$$\frac{\tau_{max}}{R} = \frac{T}{I_P}$$

$$\Rightarrow \quad \frac{\tau_{max}}{D/2} = \frac{T}{\frac{\pi}{32}\times D^4}$$

$$\Rightarrow \quad \tau_{max} = \frac{16T}{\pi D^3}$$

$$\Rightarrow \quad \tau_{max} = \frac{16 \times 5 \times 10^6}{\pi \times (100)^3}$$

$$\Rightarrow \quad \tau_{max} = \frac{80}{\pi}$$

8.49 (d)

From torsional formula, we have

$$\frac{\tau_{max}}{R} = \frac{T}{I_P}$$

$$\Rightarrow \quad \frac{\tau_{max}}{D/2} = \frac{T}{\frac{\pi}{32}\times D^4}$$

$$\Rightarrow \quad \tau_{max} = \frac{16T}{\pi D^3} \qquad [\because \tau_{max} = f_s]$$

$$\Rightarrow \quad D^3 = \frac{16T}{\pi f_s}$$

$$\Rightarrow \quad D = \sqrt[3]{\frac{16T}{\pi f_s}}$$

8.51 (b)

According to torsion formula

$$\frac{T}{J} = \frac{f_s}{R}$$

$$\Rightarrow \quad T = f_s . Z_p$$

where, $Z_p = \frac{J}{R}$

$$= \frac{\text{Polar moment of inertia}}{\text{Maximum radius}}$$

$\therefore$ The greatest twisting moment which a given shaft section can resist.

= maximum permissible shear stress x Polar modulus

$\therefore$ Polar moment of inertia asses the strength of member in torsion

8.52 (c)

For a circular shaft

$$\frac{T}{J} = \frac{f_s}{r}$$

$$\Rightarrow \quad f_s = \frac{T}{J}r = \frac{T}{\frac{\pi d^4}{32}} \times \frac{d}{2} = \frac{16T}{\pi d^3}$$

$$\therefore \quad f_s \propto \frac{1}{d^3}$$

8.53 (b)

From torsion formula

$$\frac{\tau}{r} = \frac{T}{J} = \frac{G\theta}{L}$$

$$\Rightarrow \quad T = \frac{GJ\theta}{L}$$

Twist of 1 radian implies $\theta = 1$ and unit length implies $L = 1$

$$\Rightarrow \quad T = GJ$$

T = Torsional rigidity represents torque corresponding to twist of one radian in a shaft over its unit length.

8.54 (b)

Let mean torque to which the shaft is subjected to be T Nm

$\therefore$ Power transmitted = P = mean torque × angle turned per second

$$= T \times \frac{N}{60} \times 2\pi \text{ Watts}$$

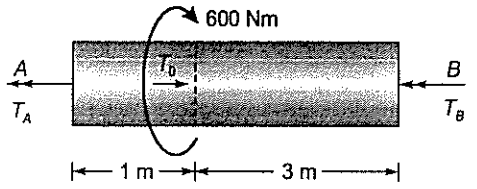
$$= \frac{2\pi NT}{60{,}000} \text{kW}$$

8.56 (d)

$$P = \frac{2\pi NT}{60{,}000} \text{kW}$$

$$= \frac{2\pi \times 100 \times 3000}{60{,}000} = 10\pi$$

8.57 (c)



The fixing couple T_A and T_B at A and B respectively is given by

$$\Rightarrow T_A = \frac{T_0 \times b}{a+b}$$

$$= \frac{600 \times 3}{1+3} = 450 \text{Nm}$$

$$\Rightarrow T_B = \frac{T_0 \times a}{a+b}$$

$$= \frac{600 \times 1}{4} = 150 \text{ Nm}$$

8.58 (a)

For a solid shaft

$$\frac{T}{J} = \frac{\tau}{R}$$

$$\Rightarrow \frac{T}{\pi D^4/32} = \frac{\tau}{D/2}$$

$$\Rightarrow \tau = \frac{16T}{\pi D^3}$$

$$D^3 = \frac{16T}{\pi\tau}$$

$$\Rightarrow D = \sqrt[3]{\frac{16T}{\pi\tau}}$$

8.59 (a)

The polar modulus for a solid circular shaft

$$Z_1 = \frac{\pi D^3}{16}$$

Polar modulus for a hollow shaft

$$Z_2 = \pi\frac{\left(D^4 - d^4\right)}{16D}$$

$$\therefore \quad \frac{Z_1}{Z_2} = \frac{\pi D^3}{16} \times \frac{16D}{\pi\left(D^4 - d^4\right)}$$

$$= \frac{D^4}{D^4 - d^4}$$

8.60 (d)

According to torsion formula

$$\frac{T}{J} = \frac{G\theta}{l} = \frac{f_s}{R}$$

Let a twisting moment T produce a twist of θ radian in a length l.

$$\frac{T}{J} = \frac{G\theta}{l}$$

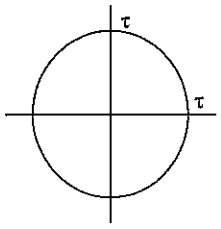
$$\Rightarrow \quad \theta = \frac{Tl}{GJ}$$

$$\Rightarrow \quad GJ = \frac{Tl}{\theta}$$

The quantity GJ stands for the torque required to produce a twist of 1 radian per unit length of the shaft.

This quantity GJ is called torsional rigidity.

8.61 (b)



Mohr's circle for pure shear

Maximum shear stress = Maximum normal stress = τ

So ratio = 1 : 1

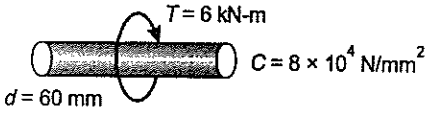
8.62 (b)

$$T = \frac{CJ}{L}\theta$$

$CJ \rightarrow$ Torsional rigidity

$\frac{CJ}{L} \rightarrow$ Torsional stiffness

8.63 (b)



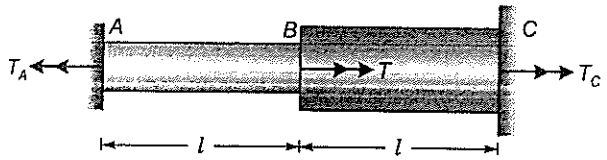
$C = 8 \times 10^4$ N/mm^2

$$f_s = \frac{T}{J}R = \frac{6\times10^6}{\frac{\pi}{32}(60)^4}\times 30$$

$$= \frac{4\times32\times30\times10^6}{\pi(36)(36)10^4}$$

$$= \frac{4000}{9\pi}\text{ N/mm}^2$$

8.64 (d)



$$\theta_{AC} = 0$$

$$\Rightarrow \quad \theta_{AB} + \theta_{BC} = 0$$

$$\Rightarrow \quad \frac{T_A l}{GJ} + \frac{(T_A - T)l}{GJ'} = 0 \qquad \ldots(i)$$

$$J' = \frac{\pi(2d)^4}{32}$$

$$= 16\cdot\frac{\pi d^4}{32} = 16J$$

From equation (i)

$$\Rightarrow \quad \frac{T_A l}{GJ} + \frac{(T_A - T)l}{16GJ} = 0$$

$$\Rightarrow \quad 16\,T_A + T_A - T = 0$$

$$\Rightarrow \quad 17\,T_A = T$$

$$\Rightarrow \quad T_A = \frac{T}{17}$$

$$\theta_{AB} = \theta_B - \theta_A$$

$$= \frac{T_A l}{GJ} = \frac{Tl}{17GJ}$$

$$\Rightarrow \quad \theta_B = \frac{Tl}{17GJ} \qquad (\text{As } \theta_A = 0)$$

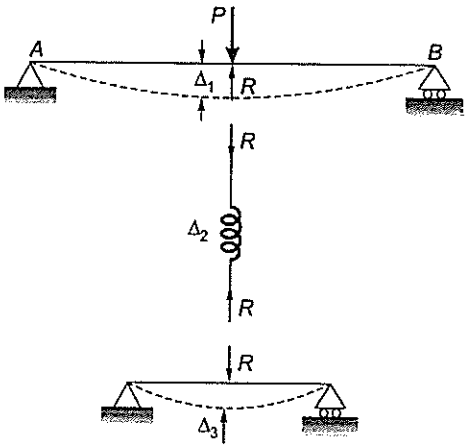
$$\Rightarrow \quad \frac{T}{\theta_B} = \frac{17GJ}{l}$$

$\therefore$ Torque required for unit twist at B

$$= \frac{17GJ}{l}$$

8.65 (a)

Let Δ_1, Δ_2 and Δ_3 is deflection of beam AB, compression of spring and deflection of beam CD respectively.



$$\Delta_2 = \Delta_1 - \Delta_3$$

$$\Rightarrow \quad \frac{R}{48} = \frac{(P-R)(2)^3}{48\times1} - \frac{R(1)^3}{48\times1}$$

$$\Rightarrow \quad R = \frac{4}{5}P$$

Now, $\Delta_1 = \frac{P}{30}$

$$k_{eq} = \frac{P}{\text{deflection in the direction of } P}$$

$$= \frac{P}{\Delta_1} = 30 \text{ units}$$

8.66 (d)

$d = 800$ mm, $P = 100$ kN

$N = 200$ rpm

$$P = \frac{2\pi NT}{60}$$

$$\Rightarrow \quad T = \frac{100\times10^3\times60}{2\pi\times200}\text{ N-m}$$

$$\tau_{max} = \frac{T}{Z_p} = \frac{\left(\frac{100\times10^3\times60}{2\pi\times200}\right)\text{N-mm}}{\frac{\pi\times80^3}{16}}$$

$$= 46.875\text{ N/mm}^2$$

8.67 (c)

$D = 75\,\text{mm}$

$N = 140\,\text{rpm}$

$\tau_{max} = 60\,\text{N/mm}^2$

$\Rightarrow \quad \tau_{max} = \frac{T}{Z_p}, P = \frac{2\pi NT}{60}$

$\Rightarrow \quad T = 60 \times \frac{\pi \times 75^3}{16}$

$\Rightarrow \quad P = \frac{2\pi \times 140 \times 60\pi \times 75^3}{16 \times 60}$

$= 73.8\,\text{kW}$

8.68 (c)

$$\tau_{max} = \frac{T}{Z_p} = \frac{T \times 16}{\pi D^3}$$

$$\Rightarrow \quad \tau_{max} \propto \frac{1}{D^3}$$

8.69 (b)

$D_0 = 16\,\text{mm}, \frac{\tau}{r} = \frac{T}{J}$

$D_i = 12\,\text{mm}$

$T = 40\,\text{N-m}$

$$\Rightarrow \quad \tau = \frac{T \times r}{J}$$

$$J = \frac{\pi(16^4 - 12^4)}{32}$$

$$\Rightarrow \quad \tau_0 = \frac{40 \times 10^3 \times \frac{16}{2}}{\pi \times \frac{(16^4 - 12^4)}{32}} = 72.75\,\text{N/mm}^2$$

$$\tau_i = \frac{72.7}{\left(\frac{16}{2}\right)} \times \left(\frac{12}{2}\right) = 54.54\,\text{N/mm}^2$$

8.70 (a)

$$k = \frac{W}{\delta} = \frac{Gd^4}{64R^3n} = \frac{8.4 \times 10^4 \times 10^4}{64 \times \left(\frac{100}{2}\right)^3 \times 20} = 5.25\,\text{N/mm}$$

8.71 (b)

$$\because \quad \Delta = \frac{64PR^3n}{Gd^4}$$

$$\therefore \quad \Delta = \frac{64 \times 100 \times \left(\frac{50}{2}\right)^3 \times 12}{80 \times 10^3 \times 5^4}$$

$= 24\,\text{mm}$

8.72 (c)

$$\because \quad \Delta = \frac{64PR^3n}{Gd^4}$$

$$\therefore \quad \Delta \propto n$$

$$\therefore \quad \frac{\Delta_A}{\Delta_B} = \frac{n_A}{n_B} = \frac{1}{2}$$

8.73 (d)

From torsion formula

$$\frac{\tau}{r} = \frac{T}{J} = \frac{G\theta}{L}$$

So $\quad \tau_{max} = \frac{Tr}{J}$

$$\Rightarrow \quad f_s = \frac{T\frac{d}{2}}{\pi d^4 / 32}$$

$$f_s = \frac{16T}{\pi d^3}$$

$$d = \sqrt[3]{\frac{16T}{\pi f_s}}$$

8.74 (d)

$$\because \quad P = T\omega$$

$$= T \times \frac{2\pi N}{60}$$

$$= 1500 \times 160 \times \frac{2\pi}{60} \times 10^{-3}\,\text{kW}$$

$= 8\pi\,\text{kW}$

8.75 (a)

$$\tau = \frac{T}{J} r$$

$$\Rightarrow \quad T = \frac{\tau J}{r}$$

$$\Rightarrow \quad T = \frac{\tau \times \frac{\pi}{32} d^4}{\frac{d}{2}} = \frac{\tau \times \pi d^3}{16}$$

$$\because \quad P = T\omega$$

$$= \tau \times \frac{\pi d^3}{16} \times \frac{2\pi N}{60} \times 10^{-3}\,\text{kW}$$

$$\therefore \quad P = \frac{60 \times \pi \times (100)^3 \times 2 \times \pi \times 150}{16 \times 60} \times 10^{-3}$$

$$\therefore \quad P = 187.5 \text{ kW}$$

8.76 (b)

$$\because \quad Z_p = \frac{\pi}{16} \times d^3$$

$$= \frac{\pi}{16} \times 8 \times 8 \times 8 = 32\pi \text{ cm}^3$$

8.77 (*)

Given:

$$d_o = 0.5 \text{ m}, \; d_i = 0.3 \text{ m}$$

$$\tau = 30 \text{ N/mm}^2 = 30 \times 10^6 \text{ N/m}^2$$

$$\because \quad \tau = \frac{T\left(\frac{d_o}{2}\right)}{\frac{\pi}{32}\left[d_o^4 - d_i^4\right]}$$

$$\therefore \quad T = \frac{30 \times 10^6 \times \frac{\pi}{32}(0.5^4 - 0.3^4)}{\frac{0.5}{2}}$$

$$= 640884.9 \text{ Nm}$$

8.78 (d)

As we know that,

$$\tau = \frac{Tr}{I_P} \qquad \ldots(i)$$

and $P = T\omega$

$$\Rightarrow \quad T = \frac{P}{\omega} = \frac{P}{2\pi v} \qquad \ldots(ii)$$

From equation (i) and (ii), we get

$$\tau = \frac{Pr}{I_P \times 2\pi v}$$

$$\Rightarrow \quad \tau \propto \frac{1}{v}$$

$$\Rightarrow \quad \frac{\tau_1}{\tau_2} \propto \frac{v_2}{v_1}$$

$$\Rightarrow \quad \frac{70}{\tau_2} \propto \frac{1.5}{3}$$

$$\therefore \quad \tau_2 = 140 \text{ MPa}$$

8.79 (a)

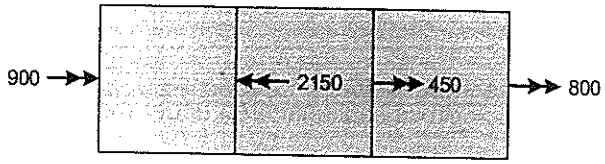
$$P = T \times \omega$$

$$= 1500 \times 2\pi \times \frac{200}{60}$$

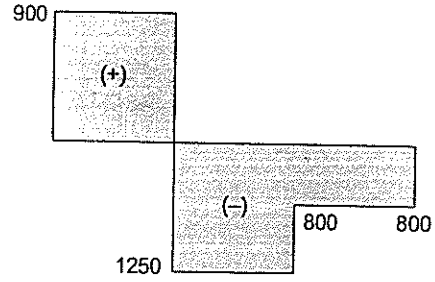
$$= 10\pi \text{ kW}$$

8.80 (b)

Applied Torque



Torsional moment diagram



(All values in Nm)

$$\tau_{max} = \frac{16T_{max}}{\pi d^3}$$

$$60 = \frac{16 \times \left(1250 \times 10^3\right)}{\pi d^3}$$

$$d = 47.5 \text{ mm}$$

8.81 (c)

Moment of inertia for circular shaft $= \frac{\pi d^4}{32}$

Polar modulus $= \frac{1}{y} = \frac{\pi d^4}{32 \times \frac{d}{2}} = \frac{\pi d^3}{16}$

y is the distance of maximum stress fibre from centre.

8.82 (c)

$$P = 200 \text{ hp} = 149.14 \text{ kW}$$

$$\text{Power, } P = \frac{2\pi NT}{60}$$

$$\therefore \quad T = 13.563 \text{ kNm} = 13563 \text{ N-m}$$

For hollow cross-section

$$\tau_{max} = \frac{16T}{\pi d_0^3\left[1 - \left(\frac{d_i}{d_0}\right)^4\right]}$$

$$420 \times 9.81 \times 10^4 = \frac{16 \times 13563}{\pi d^3\left[1 - \left(\frac{1}{2}\right)^4\right]}$$

$$\therefore \quad d = 0.121 \text{ m} = 12.1 \text{ cm}$$

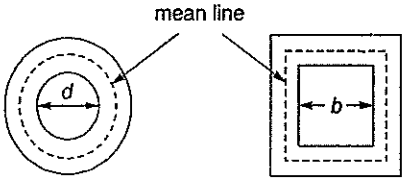
8.83 (a)

For tubular cross-section

$$\tau_{max} = \frac{T}{2A_m t}$$

A_m = Cross-sectional area under mean line.

$$\therefore \quad \frac{\tau_{max_c}}{\tau_{max_s}} = \frac{A_{m_s}}{A_{m_c}}$$



Since weight is same for both tubes

$$\therefore \quad A_C = A_S$$

$$\frac{\pi}{4}\left[d_0^2 - d_i^2\right] = b_0^2 - b_i^2$$

$$\frac{\pi}{4}\left[(d+2t)^2 - d^2\right] = (b+2t)^2 - b^2$$

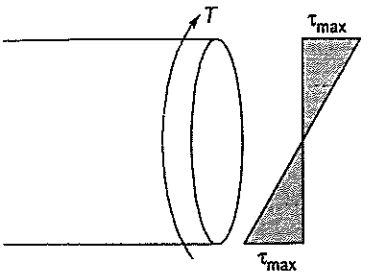
$$\frac{\pi}{4}\left[d^2 + 4t^2 + 4td - d^2\right] = b^2 + 4t^2 + 45tb - b^2$$

$$\frac{\pi}{4} \cdot 4t(t+d) = 4t\,(t+b)$$

$$\therefore \quad \frac{t+b}{t+d} = \frac{\pi}{4}$$

$$\therefore \quad \frac{A_{m_s}}{A_{m_c}} = \frac{(t+b)^2}{\frac{\pi}{4}(d+t)^2} = \frac{\pi}{4} = 0.7853$$

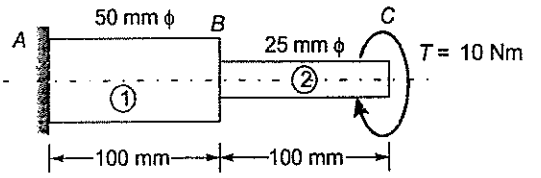
8.84 (c, d)



Shear stress distribution

Thus, shear stress distribution varies linearly and also it is zero at the centre and maximum at the extreme fibres.

8.85 (a)



$$SE = U_1 + U_2 = \int_0^{L_1} \frac{T^2 dx}{2GI_{p1}} + \int_0^{L_2} \frac{T^2 dx}{2GI_{p2}}$$

$$= \frac{T^2 L_1}{2GI_{p1}} + \frac{T^2 L_2}{2GI_{p2}} = \frac{T^2 L}{2G}\left[\frac{1}{I_{p1}} + \frac{1}{I_{p2}}\right]$$

$$= \frac{10^2 \times 0.1}{2 \times 80 \times 10^9}\left[\frac{32}{\pi(0.025)^4} + \frac{32}{\pi(0.05)^4}\right] \times 1000$$

$$= 1.73 \text{ Nmm.}$$

8.86 (a)

Hollow shaft is more strong as compared to solid shaft for same volume and same material.

9 Theory of Columns and Retaining Walls

9.1 If the crushing stress in the material of a mild steel column is 3300 kg/cm^2. Euler's Formula for crippling load is applicable for slenderness ratio equal to/greater than

(a) 40 (b) 50
(c) 60 (d) 80

[ESE : 1995]

9.2 The resultant cuts the base of a circular column of diameter 'd' with an eccentricity equal to one-fourth of 'd'. The ratio between the maximum compressive stress and the maximum tensile stress is

(a) 3 (b) 4
(c) 5 (d) infinity

[ESE : 1995]

9.3 Assertion (A): In the vertical face of triangular retaining wall of any $\frac{h}{b}$ ratio, the eccentricity is $\frac{b}{6}$ for dead storage condition.

Reason (R): For triangular retaining wall under full storage level (retained by vertical face) the eccentricity will be $\frac{b}{6}$ only if $\frac{h}{b}$ ratio is $\sqrt{S}$ (where S is specific gravity of the material of the wall).

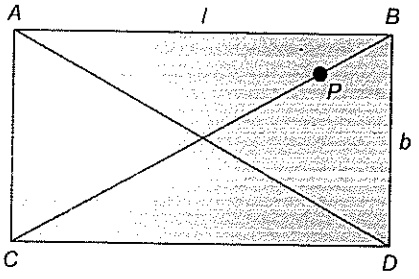
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1995]

9.4 Which one of the following pairs is not correctly matched?

Boundary condition conditions of column	Euler's buckling load
(a) Pin-Pin	$\frac{\pi^2 EI}{L^2}$
(b) Fixed-Fixed	$\frac{4\pi^2 EI}{L^2}$
(c) Fixed-Free	$\frac{0.25\pi^2 EI}{L^2}$
(d) Fixed-Pin	$\frac{\sqrt{2}\pi^2 EI}{L^2}$

9.5 Consider the following statements for a rectangular footing of length l and breadth 'b' applied with load P as shown in the given figure:



1. The stresses developed at points A and D are equal.
2. The stress developed at point B is maximum.
3. The stresses developed at point B and C are compressive.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE : 1995]

9.6 A column of height H and area at top A has the same strength throughout its length, under its own weight and applied stress p_0 at the top. Density of column material is ρ. To satisfy the above condition, the area of the column at the bottom should be

(a) $\frac{Ae^{Hp_0}}{\rho}$ (b) $\frac{Ae^{-\rho H}}{p_0}$
(c) $Ae^{(-\rho H/p_0)}$ (d) $\frac{A\rho^H}{e^{p_0}}$

[ESE : 1995]

9.7 For a circular column having its ends hinged, the slenderness ratio is 160. The l/d ratio of the column is
(a) 80 (b) 57
(c) 40 (d) 20
[ESE : 1996]

9.8 A hollow circular column of internal diameter 'd' and external diameter '$1.5d$' is subjected to compressive load. The maximum distance of the point of application of load from the centre for no tension is
(a) $d/8$ (b) $13d/48$
(c) $d/4$ (d) $13d/96$
[ESE : 1996]

9.9 Match List-I (Given sections) with List-II (Shape of the core) to ensure no tension condition and select the correct answer using the codes given below the lists:

List-I	List-II
A. Rectangular	1. Circle
B. I-section	2. Annulus
C. Hollow circular	3. Rhombus
D. Square	4. I-section
	5. Square
	6. Rectangular

Codes:

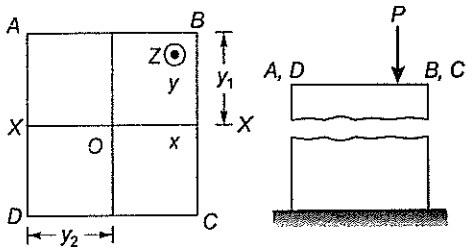
	A	B	C	D
(a)	4	6	1	2
(b)	3	3	1	5
(c)	6	4	2	5
(d)	3	4	5	1

[ESE : 1996]

9.10 Which one of the following pairs is not correctly matched?
(a) Lame's constants : Thick cylinder
(b) Macaulay's method : Deflection of beam
(c) Euler's method : Theory of column
(d) Eddy's theorem : Torsion of shafts
[ESE : 1996]

9.11 **Assertion (A):** The buckling load for a column of specified material, cross-section and end conditions calculated as per Euler's formula varies inversely with the column length.
Reason (R): Euler's formula takes into account the end conditions in determining the effective length of column.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1996]

9.12 A column $ABCD$ $(2y_1 \times 2y_2)$ of rectangular section carries a load P at Z having the coordinates (x, y) as shown in the given figure.



If the compressive stresses are taken as positive and area $A = 2y_1 \times 2y_2 = 4y_1 y_2$ and the moment of inertia about X and Y axis being I_{xx} and I_{yy} respectively, then the stress at the corner D is

(a) $\frac{P}{A}+\frac{Py}{I_{xx}}y_1+\frac{Px}{I_{yy}}y_2$ (b) $\frac{P}{A}-\frac{Py}{I_{xx}}y_1-\frac{Px}{I_{yy}}y_2$

(c) $\frac{P}{A}+\frac{Py}{I_{yy}}y_1+\frac{Px}{I_{xx}}y_2$ (d) $\frac{P}{A}-\frac{Py}{I_{yy}}y_1-\frac{Px}{I_{xx}}y_2$

[ESE : 1996]

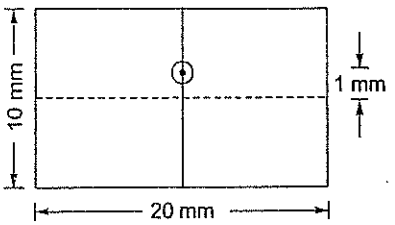
9.13 A short column of external diameter D_1 and internal diameter D_2 carries an external load W. For no-tension condition, the eccentricity will be

(a) $\frac{D_1^2-D_2^2}{8D_2}$ (b) $\frac{D_2^2-D_1^2}{8D_2}$

(c) $\frac{D_1^2+D_2^2}{8D_1}$ (d) $\frac{D_1+D_2}{8D_1}$

[ESE : 1997]

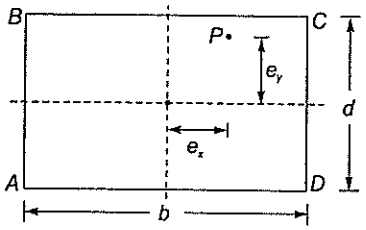
9.14 A tie bar (20 mm × 10 mm) carries a tensile load of 1 kN as shown in the figure below. Under this load, the maximum intensity of stress over the mean value will increase by



(a) 20% (b) 40%
(c) 60% (d) 80%

[ESE : 1997]

9.15 The rectangular column shown in the figure below carries a load P having eccentricities 'e_x' and 'e_y' along the X-axis and Y-axis respectively. The stress at any point (x, y) is given by



(a) $\frac{P}{bd}\left[1+\frac{12e_y \times y}{d^2}+\frac{12e_x \times x}{b^2}\right]$

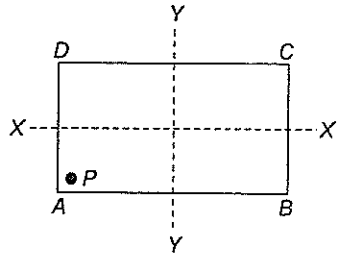
(b) $\frac{P}{bd}\left[1+\frac{12e_y \times y}{b^2}+\frac{12e_x \times x}{d^2}\right]$

(c) $\frac{P}{bd}\left[1+\frac{6e_y \times y}{d^2}+\frac{6e_x \times x}{b^2}\right]$

(d) $\frac{P}{bd}\left[1+\frac{6e_y \times y}{b^2}+\frac{6e_x \times x}{d^2}\right]$

[ESE : 1998]

9.16 A reinforced concrete footing loaded with a concentrated load P as shown in the given figure produces maximum bending stresses of 10 kN/m^2 and 15 kN/m^2 due to eccentricities about XX and YY axes respectively. If the direct stress due to load acting at P is 18 kN/m^2 (compressive), then the intensity of resultant stress at corner B will be



(a) 13 kN/m^2 tensile
(b) 13 kN/m^2 compressive
(c) 31 kN/m^2 compressive
(d) 31 kN/m^2 tensile

[ESE : 1999]

9.17 A column base is subjected to moment. If the intensity of bearing pressure due to axial load is equal to stress due to the moment, then the bearing pressure between the base and the concrete is
(a) uniform compression throughout
(b) zero at one end and compression at the other end
(c) tension at one end and compression at the other end
(d) uniform tension throughout

[ESE : 1999]

9.18 **Assertion (A):** Rankine's theory is generally used for finding out the buckling load of intermediate columns.
Reason (R): Euler's theory gives higher values for buckling loads in intermediate columns.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

9.19 Which one of the following rules ascertains the maximum permissible eccentricity of loads on circular column so that stresses will always be compressive?
(a) Middle fourth rule
(b) Middle third rule
(c) Middle half rule
(d) Middle two-third rule

[ESE : 2001]

9.20 A short hollow CI column section A is 150 cm^2 and the section modulus $Z = 10 \times 10^5$ mm^3 carries
(i) an axial load of 250 kN, and
(ii) a load of 50 kN on a bracket, the load line being 500 mm from the axis of column
The maximum and minimum stress intensities are
(a) 50 N/mm^2 tensile and 10 N/mm^2 compressive
(b) 45 N/mm^2 compressive and 5 N/mm^2 tensile
(c) 55 N/mm^2 compressive and 5 N/mm^2 tensile
(d) 60 N/mm^2 tensile and 10 N/mm^2 compressive

[ESE : 2001]

9.21 In the design of a masonry retaining wall, the
(a) vertical load should fall within the middle-third of base width

(b) horizontal thrust should act at $\frac{h}{3}$ from base

(c) resultant load should fall within a distance of one-sixth of base width on either side of its midpoint

(d) resultant load should fall within a distance of one-eighth of base width on either side of its midpoint

[ESE : 2001]

9.22 **Assertion (A):** Whenever a column section is subjected to an eccentric loading, it causes a direct stress, as well as the bending stress to come into play. Since both these stresses act normal to the cross-section, these can be algebraically added into a single resultant stress.
Reason (R): The maximum and minimum intensities of stress at the base of the column are:

$$p_{max} = \frac{W}{b}\left(1+\frac{6e}{b}\right)$$

$$p_{min} = \frac{W}{b}\left(1-\frac{6e}{b}\right)$$

where

W = weight of column per unit length

b = width of the column

e = eccentricity of the load

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 2002]

9.23 Which one of the following pairs is NOT correctly matched?

(a) Both ends hinged: $\frac{\pi^2 EI}{L^2}$

(b) Both ends fixed: $\frac{4\pi^2 EI}{L^2}$

(c) One end fixed and other end free: $\frac{\pi^2 EI}{4L^2}$

(d) One end fixed and the other hinged: $\frac{\sqrt{2}\pi^2 EI}{L^2}$

[ESE : 2002]

9.24 The slenderness ratio of a compression member in the context of Rankine's formula is defined as

(a) $\frac{\text{Length}}{\text{Least lateral dimension}}$

(b) $\frac{\text{Effective length}}{\text{Least radius of gyration}}$

(c) $\frac{\text{Effective length}}{\text{Least lateral dimension}}$

(d) $\frac{\text{Length}}{\text{Least radius of gyration}}$

[ESE : 2002]

9.25 Match List-I (End conditions of columns) with List-II (Effective length, L_e) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Both ends fixed	1. $L_e = 2L$
B. Both ends hinged	2. $L_e = L/2$
C. One end fixed, other free	3. $L_e = L/\sqrt{2}$
D. One end fixed, other hinged	4. $L_e = L$

(where L is length of the column)

Codes:

	A	B	C	D
(a)	2	4	1	3
(b)	3	1	2	4
(c)	2	4	3	1
(d)	3	1	4	2

[ESE : 2003]

9.26 For a solid circular section of diameter 'd' the stress in a column will be compressive only if the eccentricity of the line of action of the compressive force is within

(a) $d/4$ (b) $d/8$

(c) $d/6$ (d) $d/16$

[ESE : 2003]

9.27 For a masonry dam of base width b, at which location w.r.t. the central line, should the resultant loading intersect the sections to avoid tension in any horizontal section?

(a) Outside of $b/6$

(b) Within $b/6$

(c) Within $b/8$

(d) At the central line

[ESE : 2007]

9.28 A circular column of external diameter D, and internal diameter d, carries an eccentric load such that tension is developed nowhere. What shall be the diameter of the core ?

(a) $\frac{D^2+d^2}{8D}$ (b) $\frac{D^2-d^2}{8D}$

(c) $\frac{D^2+d^2}{4D}$ (d) $\frac{D^2-d^2}{4D}$

[ESE : 2009]

9.29 If the Euler load for a steel column is 1000 kN and crushing load is 1500 kN, the Rankine load is equal to

(a) 2500 kN (b) 1500 kN

(c) 1000 kN (d) 600 kN

[ESE : 2010]

9.30 A pedestal of rectangular cross-section of size $B \times D$ is subjected to a vertical load P. For the stress to be zero at the farthest point in the first quadrant of X-Y-axes of the section (with the origin at the symmetric midpoint) due to the load acting in the third quadrant is bounded by the straight line,

(a) $\frac{6X}{B}-\frac{6Y}{D}=1$ (b) $\frac{6X}{B}+\frac{6Y}{D}=-1$

(c) $\frac{6X}{B}+\frac{6Y}{D}=1$ (d) $\frac{6X}{D}+\frac{6Y}{B}=1$

[ESE : 2011]

9.31 The base of a column is subjected to moment. If the intensity of bearing pressure due to axial load is equal to stress due to moment, then the bearing pressure between the base and the concrete is

(a) Uniform compression throughout

(b) Zero at one end and compression at the other end

(c) Tension at one end and compression at the other end

(d) Compression, varying as a parabolic profile

[ESE : 2011]

9.32 Consider a circular member of diameter D subjected to a compressive load P. For a condition of no tensile stress in the cross-section, the maximum radial distance of the load from the centre of the circle is

(a) $\frac{D}{6}$ (b) $\frac{D}{8}$

(c) $\frac{D}{12}$ (d) $\frac{D}{4}$

[ESE : 2014]

Answers Theory of Columns and Retaining Walls

9.1 (d)	9.2 (a)	9.3 (b)	9.4 (d)	9.5 (c)	9.6 (c)	9.7 (c)	9.8 (b)	9.9 (b)	
9.10 (d)	9.11 (d)	9.12 (b)	9.13 (c)	9.14 (c)	9.15 (a)	9.16 (b)	9.17 (b)	9.18 (b)	
9.19 (a)	9.20 (b)	9.21 (c)	9.22 (b)	9.23 (d)	9.24 (b)	9.25 (a)	9.26 (b)	9.27 (b)	
9.28 (c)	9.29 (d)	9.30 (c)	9.31 (b)	9.32 (b)					

Explanations Theory of Columns and Retaining Walls

9.1 (d)

In order for Euler's formula to be applicable the critical stress must not exceed the proportional limit.

Now crushing stress in mild steel

$= 3300\ kg/cm^2$

$= 330\ N/mm^2$

But stress at proportional limit in mild steel

$= 250\ N/mm^2$

Euler's buckling stress $= \dfrac{\pi^2 E}{\lambda^2}$

$\Rightarrow \quad 250 = \dfrac{\pi^2 \times 2 \times 10^5}{\lambda^2}$

$\Rightarrow \quad \lambda = 88.55 \approx 89$

Thus slenderness ratio should be more than or equal to 89 ideally. Option (d) is the most close one.

9.2 (a)

For solid circular section, the maximum eccentricity for no tension is d/8.

The stress $\sigma_{c,t} = \dfrac{4P}{\pi d^2}\left[1 \pm \dfrac{8e}{d}\right]$

for $e = \dfrac{d}{4}$

$$\frac{\sigma_c}{\sigma_t} = \frac{\left(1+\frac{8e}{d}\right)}{\left(1-\frac{8e}{d}\right)} = \frac{3}{(-1)}$$

The minus sign is due to opposite nature of forces.

9.3 (b)

For no tensile stress to develop;

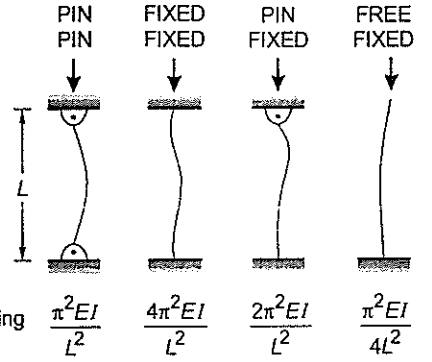
(i) For dead storage or empty condition

$$e = \frac{b}{6} \text{ for any } \frac{h}{b} \text{ ratio}$$

(ii) For full storage condition

$$e = \frac{b}{6} \text{ when } \frac{h}{b} = \sqrt{S}$$

9.4 (d)



9.5 (c)

Since the footing is rectangular and the load is eccentric about both X and Y axes respectively, the stresses at A and D are not equal.

The stress developed at point C is the combination of compressive stress due to load P, tensile stress due to eccentricity about X and Y axis respectively. So the final stress is compressive or not will depend upon the magnitude of tensile stresses. In exact terms we cannot say that the final stress at C is compressive however, option (c) is the most close among all the options.

9.6 (c)

Let area of column at the bottom be A_0.

$\therefore \quad A = A_0\, e^{\rho H/p_0}$

$A_0 = A\, e^{-\rho H/p_0}$

Also option (c) is the dimensionally correct one.

9.7 (c)

Slenderness ratio, $\lambda = \frac{l}{r}$

where r is the radius of gyration.

$$r = \frac{d}{4}$$

$$\therefore \quad \frac{l}{d} = \frac{160}{4} = 40$$

9.8 (b)

$$e_{max} = \frac{d^2 + D^2}{8D} = \frac{d^2 + (1.5d)^2}{8 \times 1.5d}$$

$$= \frac{3.25d^2}{12d} = \frac{13d}{48}$$

9.9 (b)

Kern is the region in which load can act but it does not produce tension anywhere in the cross-section.

Section	Kern
Rectangular	Rhombus
I-section	Rhombus
Hollow circular	Circle
Square	Square

9.10 (d)

Eddy's theorem is related to arches. It says that the BM at any section of an arch is proportional to the ordinate between the given arch and the linear arch.

9.11 (d)

The buckling load varies inversely with the square of effective length i.e.

$$P = \frac{\pi^2 EI}{l_e^2}$$

9.12 (b)

Moment about X-X axis = Py

Moment about Y-Y axis = Px

$$\therefore \text{ Stress at } A = \frac{P}{A} + \frac{Py}{I_{xx}} y_1 - \frac{Px}{I_{yy}} y_2$$

$$\text{Stress at } B = \frac{P}{A} + \frac{Py}{I_{xx}} y_1 + \frac{Px}{I_{yy}} y_2$$

$$\text{Stress at } C = \frac{P}{A} - \frac{Py}{I_{xx}} y_1 + \frac{Px}{I_{yy}} y_2$$

$$\text{Stress at } D = \frac{P}{A} - \frac{Py}{I_{xx}} y_1 - \frac{Px}{I_{yy}} y_2$$

9.13 (c)

For no tension, $\sigma_{min} \le 0$

$$\frac{P}{A} - \frac{My}{I} \le 0$$

$$\frac{W}{\frac{\pi}{4}\left(D_1^2 - D_2^2\right)} - \frac{We\frac{D_1}{2}}{\frac{\pi}{64}\left(D_1^4 - D_2^4\right)} \le 0$$

$$e \le \frac{\left(D_1^2 + D_2^2\right)}{8D_1}$$

9.14 (c)

Mean value of intensity of stress

$$= \frac{1000}{20 \times 10} = 5 \text{ N/mm}^2$$

Maximum value of intensity of stress

$$= 5\left[1 + \frac{6e}{d}\right] = 5\left[1 + \frac{6 \times 1}{10}\right]$$

$$= 8 \text{ N/mm}^2$$

% increase in stress

$$= \left(\frac{8-5}{5}\right) \times 100 = 60\%$$

9.15 (a)

Stress at any point

$$= \frac{P}{bd} + \frac{Pe_y \times y}{I_{xx}} + \frac{Pe_x \times x}{I_{yy}}$$

$$= \frac{P}{bd}\left[1 + \frac{12e_y \times y}{d^2} + \frac{12e_x \times x}{b^2}\right]$$

9.16 (b)

Assuming compressive stress as positive and tensile stress as negative.

Corner A and B will be in compression, whereas corner C and D will be in tension due to the eccentricity about XX-axis respectively. Corner A and D will be in compression whereas corner B and C will be in tension due to eccentricity about YY-axis respectively.

Point	Resultant stress (N/mm²)
A	18 + 10 + 15 = 43
B	18 + 10 − 15 = 13
C	18 − 10 − 15 = − 7
D	18 − 10 + 15 = 23

9.17 (b)

The uniform compressive stress throughout the base due to load P is cancelled at one end due to moment and increased at other end due to some moment. So stress intensity at one end is zero and compressive at the other end with linear variation

9.18 (b)

For intermediate columns, the effect of both crushing and buckling is to be considered as none of these alone gives the satisfactory results.

Load by Rankine's formula is given as,

$$\frac{1}{P_R} = \frac{1}{P_e} + \frac{1}{P_c}$$

where, P_R is Rankine's load

P_c is crushing load and

P_e is buckling load

So, Rankine's load considers the effect of both crushing and buckling, hence used for intermediate columns.

9.19 (a)

For no tension, $\sigma_{min} \geq 0$

$$\frac{P}{A} - \frac{My}{I} \geq 0$$

$$\frac{P}{\frac{\pi}{4}D^2} - \frac{Pe\frac{D}{2}}{\frac{\pi}{4}D^4} \leq 0$$

$$e \leq \frac{D}{8}$$

For no tension load should be within one-fourth of diameter.

9.20 (b)

$$\text{Axial stress} = \frac{(250+50)\times 10^3}{150\times 100} = 20 \text{ N/mm}^2$$

$$\text{Bending stress} = \frac{50\times 10^3 \times 500}{10\times 10} = 25 \text{ N/mm}^2$$

Maximum stress = 20 + 25 = 45 N/mm^2 (comp.)

Minimum stress = 20 – 25 = –5 N/mm^2 (tens.)

9.21 (c)

For zero tension condition $e \leq b/6$.

9.22 (b)

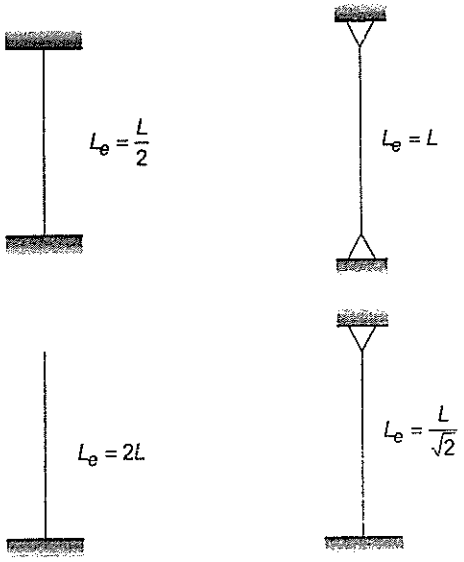
Since both direct stress and bending stress are normal stresses, they can be added algebraically. Reason is correct but does not explain Assertion.

9.23 (d)

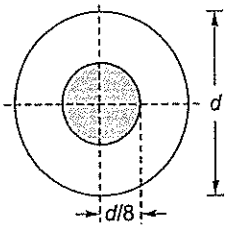
For one end fixed and other end hinged

$$P_{cr} = \frac{2\pi^2 EI}{L^2}$$

9.25 (a)



9.26 (b)



Eccentricity will lie in the hatched portion of the circle whose dia is $d/4$ i.e., $e = d/8$.

9.27 (b)

This is known as Middle Third Rule which says the maximum value of eccentricity that can be permitted on either side of the centre is equal to $b/6$ so that tension does not develop in any horizontal section.

9.28 (c)

For no tension, $\sigma_{min} \leq 0$

$$\frac{P}{A} - \frac{My}{I} \geq 0$$

$$\frac{P}{\frac{\pi}{4}\left(D^2-d^2\right)}-\frac{Pe\frac{D}{2}}{\frac{\pi}{64}\left(D^4-d^4\right)}\le 0$$

$$e \le \frac{\left(D^2-d^2\right)}{8D}$$

Diameter of core $= 2e = \frac{D^2+d^2}{4D}$

9.29 (d)

Rankine load is given by

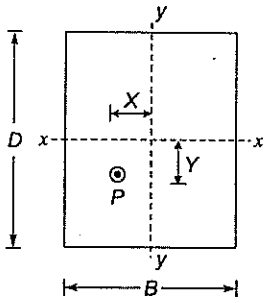
$$\frac{1}{P} = \frac{1}{P_E}+\frac{1}{P_C}$$

$$\Rightarrow \quad P = \frac{P_E P_C}{P_E+P_C}$$

$$\Rightarrow \quad P = \frac{1000\times 1500}{1000+1500}$$

$$\Rightarrow \quad P = 600\ \text{kN}$$

9.30 (c)



Stress at the farthest point in the first quadrant is

$$\sigma = \frac{P}{BD}+\frac{P(-x)}{\frac{DB^3}{12}}\times\frac{B}{2}+\frac{P(-y)}{\frac{BD^3}{12}}\times\frac{D}{2}$$

if $\sigma = 0$, then

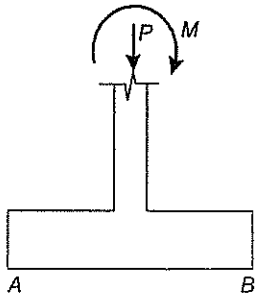
$$\frac{P}{BD}-\frac{6Px}{DB^2}-\frac{6Py}{BD^2}=0$$

or $$\frac{6x}{B}+\frac{6y}{D}=1$$

9.31 (b)

Bearing pressure at base due to axial load $= \frac{P}{A}$.

Stress at base due to moment $= \frac{M}{Z}$

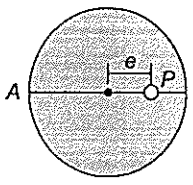


Given $\frac{P}{A} = \frac{M}{Z} = \sigma$ (say)

$$\sigma_B = \frac{P}{A}+\frac{M}{Z} = 2\sigma \text{ (Compressive)}$$

$$\sigma_A = \frac{P}{A}-\frac{M}{Z} = 0$$

9.32 (b)



$\sigma_A = 0$

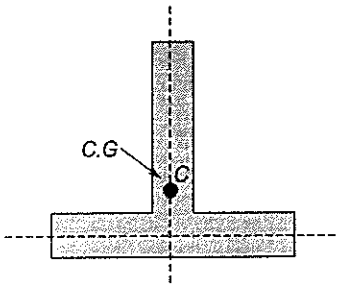
$$\Rightarrow \quad \frac{P}{A}-\frac{M}{I}y=0$$

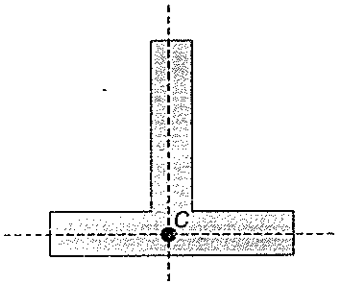
$$\Rightarrow \quad \frac{P}{\pi/4D^2}-\frac{Pe}{\frac{\pi D^4}{64}}y\times\frac{D}{2}=0$$

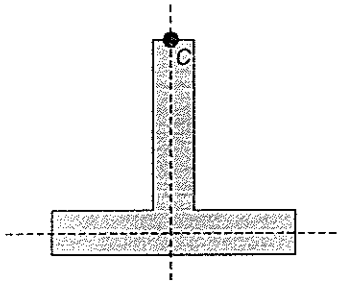
$$\Rightarrow \quad e=\frac{D}{8}$$

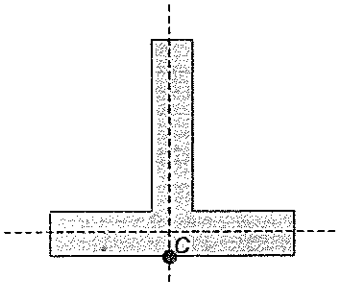
10 Shear Centre, Moment of Inertia & Principal Axes

10.1 In a thin-wall T-section, the shear centre C is located at the point shown in

(a)


(b)


(c)


(d)


[ESE : 1995]

10.2 Consider the following statements:

1. If a beam has two axes of symmetry even then shear centre does not coincide with the centroid.
2. For a section having one axis of symmetry, the shear centre does not coincide with the centroid but lies on the axis of symmetry.
3. If a load passes through the shear centre, then there will be only bending in the cross-section and no twisting.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE : 1995]

10.3 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I	List-II
A. Shear centre	1. Tension
B. Principal plane	2. Slope
C. Fixed end	3. Shear stress
D. Middle third rule	4. Twisting

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	3	1	4	2
(c)	4	1	2	3
(d)	4	2	3	1

[ESE : 1996]

10.4 The shear centre of a section is defined as that point

(a) through which the load must be applied to produce zero twisting moment on the section
(b) at which the shear force is zero
(c) at which the shear force is maximum
(d) at which the shear force is minimum

[ESE : 1997]

10.5 Shear centre of a semi-circular arc strip of radius 'r' will be at a distance of 'x' from the centre of the arc, where 'x' is equal to

(a) $\frac{\pi r}{2}$ (b) $\frac{2r}{\pi}$
(c) $\frac{4r}{\pi}$ (d) $\frac{\pi r}{4}$

[ESE : 1998]

10.6 Given that for a channel section, the width of flange = b, the depth of the web between centres of flanges = h, the thickness of flange = t, the moment of inertia of the channel about the axis of bending = I, the distance of the shear centre outside the channel section from the mid-thickness of the web is

(a) $\frac{th^2b^2}{I}$ (b) $\frac{t^2h^2b}{4I}$

(c) $\frac{th^2b^2}{4I}$ (d) $\frac{t^2hb^2}{4I}$

[ESE : 1999]

10.7 Assertion (A): There is no twisting in an open section if the point of application of the load passes through its shear centre.

Reason (R): Shear centre coincides with the centre of gravity of the open section.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

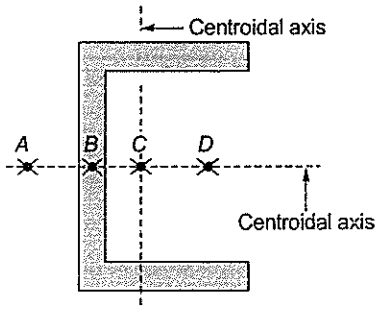
10.8 The distance of centroids of areas above and below the equal area axis in a solid circular section from its centre (R is the radius of circular section) is

(a) $\frac{4R}{3\pi}$ (b) $\frac{4\pi}{3R}$

(c) $\frac{3R}{4\pi}$ (d) $\frac{3\pi}{4R}$

[ESE : 2001]

10.9 In the symmetrical channel section shown in the figure below, which point is likely to be the shear centre?



(a) A (b) B
(c) C (d) D

[ESE : 2002]

10.10 A point load applied at shear centre induces

(a) Zero shear force (b) Zero bending
(c) Pure twisting (d) Pure bending

[ESE : 2005]

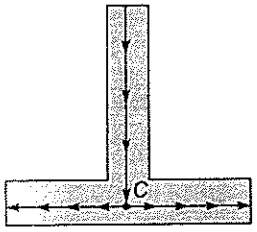
Answers Shear Centre, Moment of Inertia & Principal Axes

10.1 (b) 10.2 (c) 10.3 (a) 10.4 (a) 10.5 (c) 10.6 (c) 10.7 (c) 10.8 (a) 10.9 (a) 10.10 (d)

Explanations Shear Centre, Moment of Inertia & Principal Axes

10.1 (b)

The shear flow in the section is as shown in the figure.



The shear centre is the point about which the moment of the shear flows in all segments should be zero. So shear centre will lie at the intersection point of two axes.

10.2 (c)

For two axes of symmetry, the shear centre will coincide with the centroid.

10.3 (a)

Shear centre : The load at this point does not cause twisting.

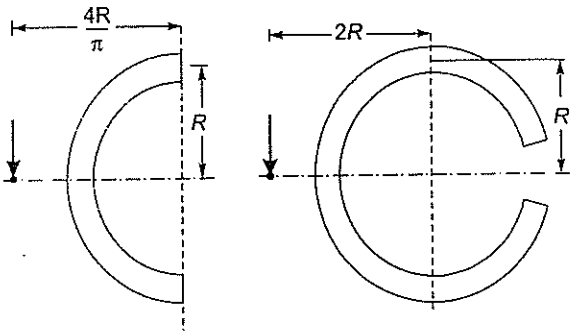
Principal plane : There is no shear stress on this plane.

Fixed end : It has zero slope

Middle third rule can be used to apply load such that there is no tension on a rectangular cross-section.

10.5 (c)

For semi circular arc the shear centre is at $\frac{4r}{\pi}$ from centre of the arc. In the case of circular tube made open by means of a cut the shear centre lies at a distance $2r$ from the centre of the circle.



10.6 (c)

$$e = \frac{b^2h^2t}{4I}$$

10.7 (c)

Shear centre coincides with Centre of gravity of open section only when section is doubly symmetric. If beam is singly symmetric then both shear centre and centroid lie on axis of symmetry but don't coincide each other.

10.9 (a)

To have balanced moment about the shear centre in this section, shear centre must lie towards left of point B i.e. at point A.

10.10 (d)

There is no twisting moment when the load is applied at shear centre. Only bending moment and shear force is induced.

UNIT

III

Structural Analysis

Syllabus

Basics of strength of materials, Types of stresses and strains, Bending moments and shear force, concept of bending and shear stresses; Analysis of determinate and indeterminate structures; Trusses, beams, plane frames; Rolling loads, Influence Lines, Unit load method & other methods; Free and Forced vibrations of single degree and multi degree freedom system; Suspended Cables; Concepts and use of Computer Aided Design.

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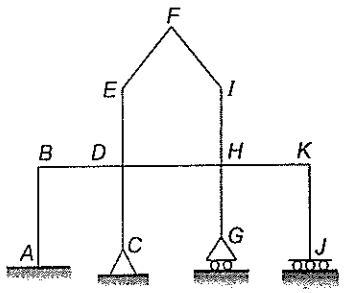
OOOO

1 Determinacy and Indeterminacy

1.1 Neglecting axial deformation, the kinematic indeterminacy of the structure shown in the figure below is



(a) 12 (b) 14
(c) 20 (d) 22

[ESE : 1998]

1.2 Match List-I (Type of structure) with List-II (Static indeterminacy) and select the correct answer using the codes given below the lists:
Number of members = m
Number of joints = n
Number of reaction elements = r

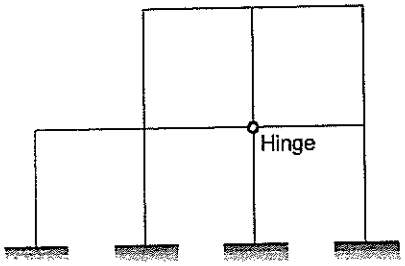
List-I	List-II
A. Plane frame	1. m + r – 3n
B. Space truss	2. 6 m + r – 6n
C. Space frame	3. 6 m + r – 3n
	4. 3 m + r – 3n

Codes:

	A	B	C
(a)	1	2	3
(b)	4	3	2
(c)	2	1	3
(d)	4	1	2

[ESE : 1999]

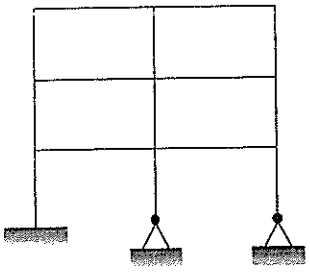
1.3 Total degree of indeterminacy (both internal and external) of the plane frame shown in the given figure is



(a) 10 (b) 11
(c) 12 (d) 15

[ESE : 1999]

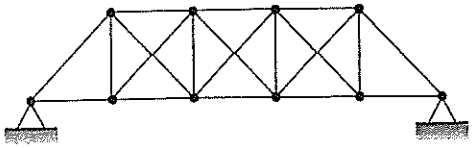
1.4 The total (both internal and external) degree of static indeterminacy of the plane frame shown in the given figure is



(a) 18 (b) 16
(c) 14 (d) 13

[ESE : 2000]

1.5 The total degree of static indeterminacy (both internal and external) for the bridge truss shown in the given figure is



(a) 4 (b) 5
(c) 6 (d) 3

[ESE : 2001]

1.6 The degree of static indeterminacy of the beam given below is

(a) zero (b) one
(c) two (d) three

[ESE : 2002]

1.7 An statically indeterminate building frame may be converted to a statically determinate one by assuming
(a) hinges at mid-height of columns
(b) hinges at the mid-span of the beams
(c) hinges at both mid-height of columns and mid-span of beams
(d) one support as fixed at base and other support on rollers

[ESE : 2004]

1.8 Consider the following statements:
1. An statically indeterminate structure is not economical from the material stand-point in comparison to a statically determinate structure.
2. If 'n' redundants in a statically indeterminate structure of 'n' degree of static indeterminacy are removed, the structure will become statically determinate but unstable.
3. In the rigid frame analysis, the axial effects are ignored as their influence is negligibly small compared to bending and shear effects.

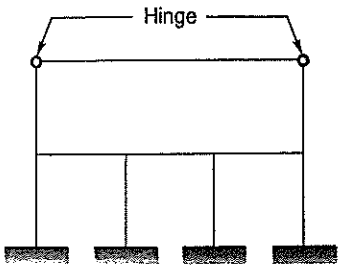
Which of these statements is/are correct?
(a) 1 only (b) 1 and 2
(c) 3 only (d) 2 and 3

[ESE : 2004]

1.9 Which one of the following is true example of a statically determinate beam?
(a) One end is fixed and the other end is simply supported
(b) Both the ends are fixed
(c) The beam overhangs over two supports
(d) The beam is supported on three supports

[ESE : 2004]

1.10 What is the total degree of static indeterminacy, both internal and external of the plane frame shown below?

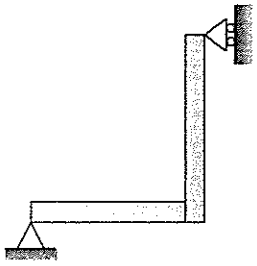


(a) 10 (b) 11
(c) 12 (d) 14

[ESE : 2005]

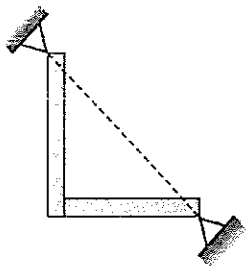
1.11 Which one of the following structures is statically determinate and stable?

(a)

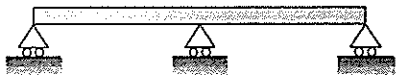


(b)

(c)



(d)



[ESE : 2005]

1.12 A prismatic beam is shown in the figure given below.

Consider the following statements:
1. The structure is unstable.
2. The bending moment is zero at supports and internal hinge.
3. It is a mechanism.

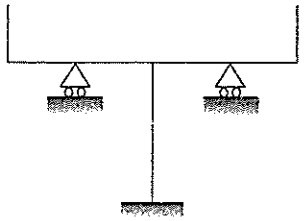
4. It is statically indeterminate.

Which of these statements are correct?

(a) 1, 2, 3 and 4 (b) 1, 2 and 3
(c) 1 and 2 (d) 3 and 4

[ESE : 2005]

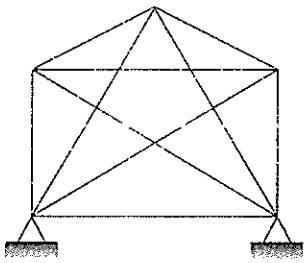
1.13 What is the degree of static indeterminacy of the frame shown in the figure given below?



(a) 4 (b) 3
(c) 2 (d) zero

[ESE : 2005]

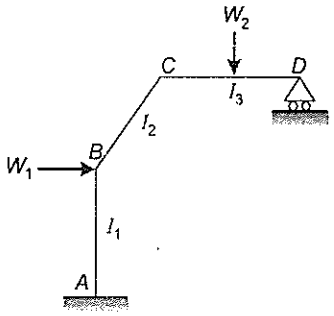
1.14 What is the degree of static indeterminacy of the plane structure as shown in the figure below?



(a) 3 (b) 4
(c) 5 (d) 6

[ESE : 2006]

1.15 The rigid plane frame *ABCD* has to be analyzed by slope deflection method. What is the number of unknown displacements/rotations for the frame as shown in the figure given below?



(a) 4 (b) 3
(c) 5 (d) 2

[ESE : 2006]

1.16 A statically determinate structure

(a) cannot be analyzed without the correct knowledge of modulus of elasticity
(b) must necessarily have roller support at one of its ends
(c) requires only statical equilibrium equations for its analysis
(d) will have zero deflection at its ends

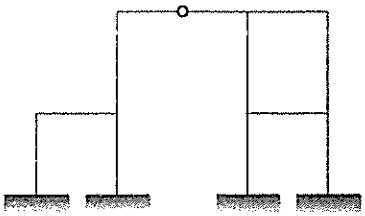
[ESE : 2008]

1.17 A statically indeterminate structure is the one which

(a) cannot be analyzed at all
(b) can be analyzed using equations of statics only
(c) can be analyzed using equations of statics and compatibility equations
(d) can be analyzed using equations of compatibility only

[ESE : 2008]

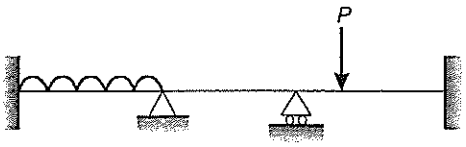
1.18 What is the statical indeterminacy for the frame shown below?



(a) 12 (b) 15
(c) 11 (d) 14

[ESE : 2008]

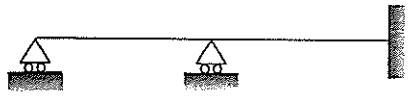
1.19 What is the total degree of indeterminacy in the continuous prismatic beam shown in the figure below?



(a) 1 (b) 2
(c) 3 (d) 4

[ESE : 2008]

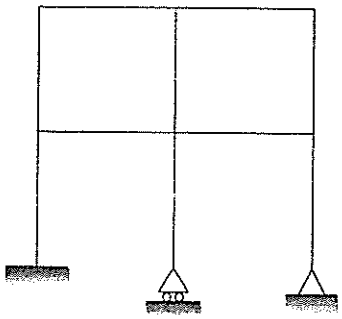
1.20 What is the number of independent degrees of freedom of the two-span continuous beam of uniform section shown in the figure below?



(a) 1 (b) 2
(c) 3 (d) 4

[ESE : 2008]

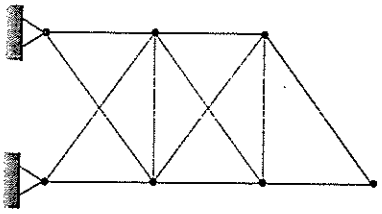
1.21 What is the kinematic indeterminacy for the frame shown below? (member inextensible)



(a) 6 (b) 11
(c) 12 (d) 21

[ESE : 2008]

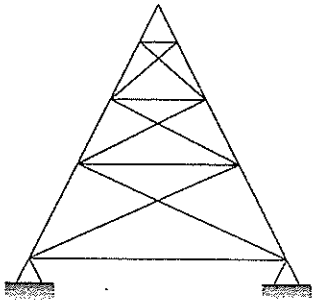
1.22 What is the total degree of static indeterminacy (both internal and external) of the cantilever plane truss shown in the figure below?



(a) 2 (b) 3
(c) 4 (d) 5

[ESE : 2008]

1.23 What is the total degree of static indeterminacy (both internal and external) of the triangular planar truss shown in the figure below?



(a) 2 (b) 4
(c) 5 (d) 6

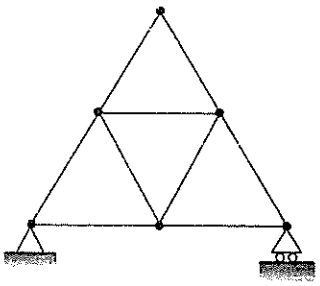
[ESE : 2008]

1.24 If the axial deformation is neglected, what is the kinematic indeterminacy of a single bay portal frame fixed at base?

(a) 2 (b) 3
(c) 4 (d) 6

[ESE : 2008]

1.25 Consider the following statements with respect to the figure below of a typical articulated frame



1. The frame is internally determinate and externally indeterminate.
2. The frame is internally indeterminate and externally determinate.
3. The frame is internally as well as externally determinate.
4. The frame is internally as well as externally indeterminate.

Which of these statements is/are correct?

(a) 1 only (b) 1 and 2
(c) 3 only (d) 3 and 4

[ESE : 2009]

1.26 The number of independent equations to be satisfied for static equilibrium in a space structure is

(a) 3 (b) 6
(c) 4 (d) 2

[ESE : 2011]

1.27 Consider the following statements:

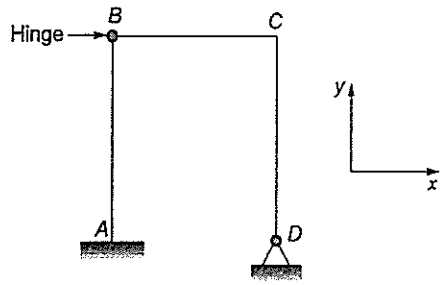
1. A properly constrained rigid system has several degrees of freedom.
2. The number of degrees of freedom of a locomotive moving on a railway track is only two.
3. A floating ship has six degrees of freedom.

Which of these statements is/are correct?

(a) 1, 2 and 3 (b) 3 only
(c) 2 only (d) 1 only

[ESE : 2012]

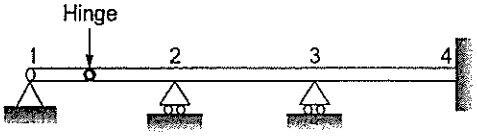
1.28 The kinematic indeterminacy of the frame is



(a) 4 (b) 6
(c) 8 (d) 10

[ESE : 2012]

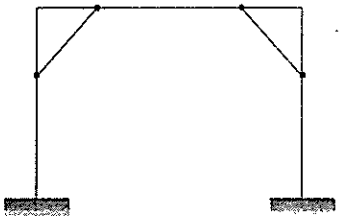
1.29 The kinematic indeterminacy of the beam is



(a) 5 (b) 9
(c) 14 (d) 15

[ESE : 2012]

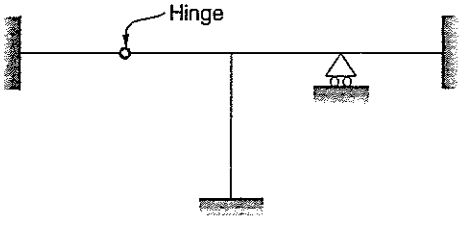
1.30 The degree of static indeterminacy for the rigid frame as shown below is



(a) 3 (b) 4
(c) 5 (d) 6

[ESE : 2013]

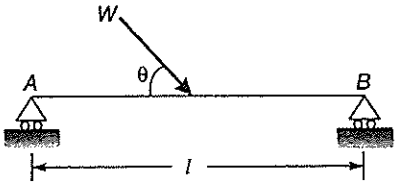
1.31 The static indeterminacy of the frame shown below is



(a) 4 (b) 6
(c) 8 (d) 10

[ESE : 2013]

1.32 The simply supported beam shown in the figure

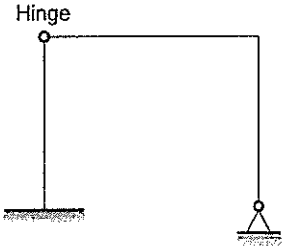


is

(a) determinate and stable
(b) determinate and unstable
(c) indeterminate and stable
(d) indeterminate and unstable

[ESE : 2014]

1.33 For the plane frame as shown in the figure

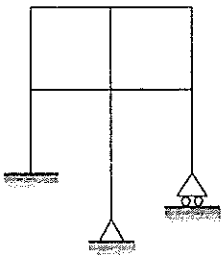


the degree of kinematic indeterminacy, neglecting axial deformation, is

(a) 3 (b) 5
(c) 7 (d) 9

[ESE : 2014]

1.34 For a skeletal frame shown in the figure

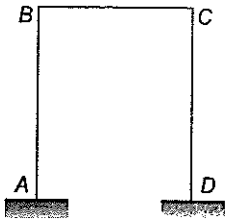


static and kinematic indeterminacies are

(a) 3 and 11 (b) 3 and 9
(c) 3 and 6 (d) 6 and 3

[ESE : 2014]

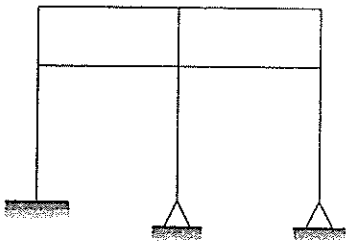
1.35 A singly-bay single-storeyed portal frame *ABCD* is fixed at *A* and *D* as shown in the figure. If axial deformation is neglected, the kinematic indeterminacy is



(a) 3 (b) 2
(c) 6 (d) 4

[ESE : 2015]

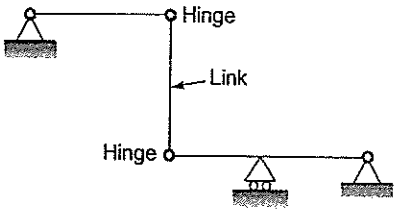
1.36 What is the number of kinematic indeterminacy for the building frame as shown in the figure when members are inextensible?



(a) 8 (b) 10
(c) 12 (d) 16

[ESE : 2015]

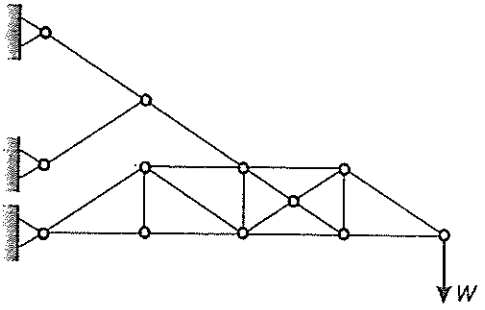
1.37 Degree of static indeterminacy of the structure as shown in the figure is



(a) 0 (b) 1
(c) 2 (d) 3

[ESE : 2015]

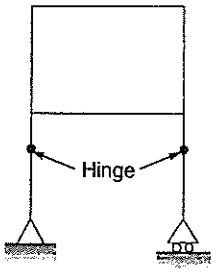
1.38 The total (both external and internal) degrees of indeterminacy of the pin-jointed structure shown in the figure is



(a) 4 (b) 3
(c) 2 (d) 1

[ESE : 2015]

1.39 The degree of static indeterminacy for a rigid frame as shown below is



(a) 0 (b) 1
(c) 2 (d) 3

[ESE : 2016]

1.40 Which of the following are examples of indeterminate structures?

1. Fixed beam
2. Continuous beam
3. Two-hinged arch
4. Beam overhanging on both sides

Select the correct answer using the codes given below:

(a) 1, 2 and 3 only (b) 1, 2 and 4 only
(c) 1, 3 and 4 only (d) 2, 3 and 4 only

[ESE : 2017]

1.41 Consider the following statements:

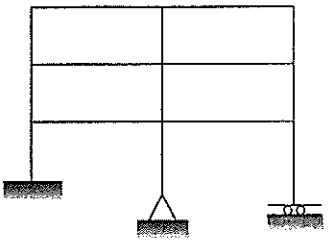
1. When the number of members (n) and joints (j) are such that the equation $n = (2j - 3)$ is satisfied, the framed structure is said to be a perfect structure.
2. In a redundant frame, the number of members is less than that required for a perfect frame.
3. If, in a framed structure, the number of members provided is more than that required for a perfect frame, it is called as a deficient frame.

Which of the above statements is/are correct?

(a) 1, 2 and 3 (b) 1 only
(c) 2 only (d) 3 only

[ESE : 2017]

1.42 The kinetic indeterminacy of the structure shown in the figure is equal to



(a) 14 (b) 15
(c) 16 (d) 17

[ESE : 2017]

Answers Determinacy and Indeterminacy

1.1 (b)	1.2 (d)	1.3 (c)	1.4 (b)	1.5 (a)	1.6 (b)	1.7 (c)	1.8 (c)	1.9 (c)	
1.10 (a)	1.11 (a)	1.12 (b)	1.13 (c)	1.14 (b)	1.15 (c)	1.16 (c)	1.17 (c)	1.18 (c)	
1.19 (d)	1.20 (d)	1.21 (b)	1.22 (a)	1.23 (b)	1.24 (b)	1.25 (c)	1.26 (b)	1.27 (b)	
1.28 (c)	1.29 (b)	1.30 (c)	1.31 (b)	1.32 (b)	1.33 (b)	1.34 (a)	1.35 (a)	1.36 (b)	
1.37 (a)	1.38 (d)	1.39 (b)	1.40 (a)	1.41 (b)	1.42 (a)				

Explanations Determinacy and Indeterminacy

1.1 (b)

Kinematic indeterminacy means degree of freedom of structure at various joints.

No rotation or translation is possible at A so degree of freedom at *A* is zero. There is a possibility of rotation at *C* but no translation so degree of freedom is one. At *G*, both rotation and translation is possible so degree of freedom is 2. At J no rotation but translation so d.o.f. is 1. At *B*, *D*, *H* and *K* there are 4 rotations and one translation so d.o.f. is 5. At *E*, *F* and *I* three rotations and two translations so d.o.f. is 5.

So kinematic indeterminacy

$= 0 + 1 + 2 + 1 + 5 + 5 = 14$

Alternate:

From direct formula

External reactions $r_e = 3 + 2 + 1 + 2 = 8$

Number of members (m) = 11

Number of rigid joints (j) = 9

Number of hinged joints (j') = 2

There are no internal hinges so number of releases is zero.

$$r_r = 0$$

Degree of kinematic indeterminacy

$$D_K = 3(j + j') - r_e + r_r - m$$
$$= 3 \times (9 + 2) - 8 - 11$$
$$= 33 - 19 = 14$$

1.2 (d)

Type of structure	No. of Unknowns	No. of equations	Degree of indeterminacy
Plane frame	3 m + r	3 n	3 m + r – 3 n
Space truss	m + r	3 n	m + r – 3 n
Space frame	6 m + r	6 n	6 m + r – 6 n

1.3 (c)

The degree of static indeterminacy

$$D_S = r_e + (3\,m - r_r) - 3(j + j')$$

Number of external reactions = r_e

$$= 3 + 3 + 3 + 3 = 12$$

Number of rigid joints,

$$j = 10$$

Number of joints at which releases are located,

$$j' = 1$$

Number of members,

$$m = 12$$

As the hinge is located at a point where 4 members meet. Hence it is equivalent to three hinges. Therefore number of releases, $r_r = 3$.

$\therefore D_S = 12 + (3 \times 12 - 3) - 3(10 + 1)$

$= 12 + 33 - 33 = 12$

1.4 (b)

$D_S = r_e + (3\,m - r_r) - 3(j + j')$

$r_e = 3 + 2 + 2 = 7$

$m = 15;\ r_r = 0;\ j = 12;\ j' = 0$

$\therefore\ D_S = 7 + 3 \times 15 - 3 \times 12 = 16$

1.5 (a)

Degree of static indeterminacy for truss

$D_S = m + r_e - 2j$

$m = 20;\ r_e = 2 + 2 = 4;\ j = 10$

$\therefore\ D_S = 20 + 4 - 2 \times 10 = 4$

1.6 (b)

$D_S = r_e + 3\,m - r_r - 3(j + j')$

$r_e = 3 + 1 + 1 = 5$

$m = 3,\ j = 3,\ j' = 1$

The hinge will create 2 members.

Number of internal reaction components released.

$r_r = 1.0$

$\therefore\ D_s = 5 + 9 - 1.0 - 3 \times (3 + 1) = 1.0$

1.7 (c)

There are two methods of approximate analysis:

(i) Portal method for low rise buildings.

(ii) Cantilever method for tall buildings.

Both methods assume an inflection point located at mid height of each column and an inflection point located at the centre of each beam.

1.8 (c)

An indeterminate structure develops less maximum bending moment over the span. So it require less cross-section to resist and more economical from material stand point. It is not necessary that removal of n redundants result in unstable structure.

1.9 (c)

$D_s = 1$: one end is fixed other is simply supported

$D_s = 2$: Both ends are fixed

$D_s = 0$: beam overhangs over two support

$D_s = 1$: beam is supported on three supports

1.10 (a)

$D_S = 3m + r_e - r_r - 3(j + j')$

Number of members $m = 10$

Number of external reactions $r_e = 12$

Number of internal reaction components released $(r_r) = 2$

Number of rigid joints $(j) = 8$

Number of joints at which releases are located $(j') = 2$

$\therefore\ D_S = 3 \times 10 + 12 - 2 - 3 \times (8 + 2) = 10$

1.11 (a)

A structure will be statically determinate if the external reactions can be determined from force-equilibrium equations. A structure is stable when the whole or part of the structure is prevented from large displacements on account of loading.

The structure in figure (b) is stable but statically indeterminate to the second degree.

The structure shown in figure (c) has both reaction components coinciding with each other, so the moment equilibrium condition will never be satisfied and the structure will not be under equilibrium. In figure (a) the structure is stable and there are three reaction components which can be determined by two force equilibrium conditions and one moment equilibrium condition.

1.12 (b)

The degree of indeterminacy $= 3 - 1 - 1 = -1$

So structure is unstable. It is a mechanism.

1.13 (c)

$D_s = 3\,m + r_e - r_r - 3(j + j')$

$m = 7;\ r_e = 3 + 1 + 1 = 5;\ r_r = 0;\ j = 8;\ j' = 0$

$\therefore\ D_s = 3 \times 7 + 5 - 3 \times 8 = 2$

1.14 (b)

For plane truss degree of static indeterminacy

$D_s = r_e + m - 2j$

$r_e = 4;\ m = 10;\ j = 5$

$D_s = 4 + 10 - 2 \times 5 = 4$

1.15 (c)

For rigid jointed plane frame, the degree of kinematic indeterminacy without neglecting axial deformations $D_k = 3j - r_e$. If axial deformations are neglected then

$D_K = 3j - r_e - m.$

$j = 4;\ m = 3;\ r_e = 3 + 1 = 4$

$\therefore\ D_K = 3 \times 4 - 4 - 3 = 5$

1.16 (c)

Structurally determinate structure may not have zero deflection at its ends, can be analyzed without correct knowledge of modulus of elasticity and can have supports other than roller support.

1.17 (c)

In order to analyze statically indeterminate structures, along with basic equations of statics additional compatibility equations equal to degree of static indeterminacy are required.

1.18 (c)

Static indeterminacy $D_S = 3m + r_e - r_r - 3(j + j')$

where m = total members = 12

r_e = total external reactions = 12

j = total number of rigid joints = 11

j' = total number of hybrid joints = 1

r_r = total number of released reactions

$= \Sigma(m_j - 1) = 2 - 1 = 1$

$\therefore \quad D_S = (3 \times 12) + 12 - 1 - 3(11 + 1)$

$= 36 + 11 - 36 = 11$

1.19 (d)

Total number of external reactions,

$r_e = 3 + 2 + 1 + 3 = 9$

Total number of equilibrium equations for inclined loading on the beam = 3

$\therefore$ Total degrees of static indeterminacy

$= r_e - 3 = 9 - 3 = 6$

Had this loading been vertical,

$r_e = 2 + 1 + 1 + 2 = 6$

Equilibrium equations = 2

$\therefore$ Total degree of indeterminacy

$= r_e - 2 = 6 - 2 = 4$

1.20 (d)

Total number of independent degrees of freedom is nothing but kinematic indeterminacy which is given by (for axially extensible members)

$D_K = 3j - r_e$

for rigid jointed plane frames or beams

Here $j = 3$

$r_e = 1 + 1 + 3 = 5$

$\therefore \quad D_K = 3 \times 3 - 5 = 4$

1.21 (b)

Degree of kinematic indeterminacy for a plane rigid frame having inextensible member is given by

$D_K = 3j - r_e - m$

where m = total number of inextensible members

Here $j = 9$, $r_e = 3 + 1 + 2 = 6$; $m = 10$

$\therefore \quad D_K = 3 \times 9 - 6 - 10 = 11$

1.22 (a)

The total degree of static indeterminacy is given by

$D_s = m + r_e - 2j$

Here $m = 12$

$r_e = 2 + 2 = 4$

$j = 7$

$\therefore \quad D_S = 12 + 4 - 2 \times 7 = 2$

1.23 (b)

The total degree of indeterminacy is given by

$D_S = m + r_e - 2j$

Where

m = number of members = 18

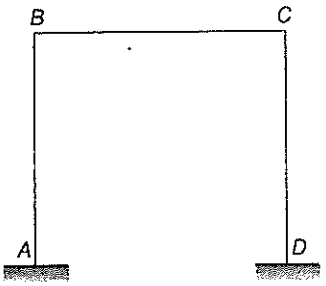
r_e = number of external reactions = 4

j = number of joints = 9

$\therefore \quad D_S = 18 + 4 - 2 \times 9 = 4$

1.24 (b)

A single bay portal frame fixed at base is shown below.



The kinematic indeterminacy is given by

$D_K = 3j - r_e - m$

Here $j = 4$; $r_e = 6$; $m = 3$

$\therefore \quad D_K = 3 \times 4 - 6 - 3 = 3$

Note: Here $DOF = 4$

$(\theta_B, \Delta_{Bx}, \theta_C, \Delta_{Cx})$

but kinematic indeterminacy is three because $\Delta_{Bx} = \Delta_{Cx}$ due to axially rigid member.

1.25 (c)

Internal indeterminacy is given as

$D_{si} = m - (2j - 3)$

$= 9 - (2 \times 6 - 3)$

$= 9 - 9 = 0$

External indeterminacy is given as

$D_{se} = r_e - 3$

$= 3 - 3 = 0$

$\therefore \quad D_s = D_{si} + D_{se} = 0 + 0 = 0$

Hence the frame is internally as well as externally determinate.

1.26 (b)

For static equilibrium in a space structure equations to be satisfied are

$$\Sigma Fx = 0,\ \Sigma F_y = 0,\ \Sigma F_z = 0$$

$$\Sigma M_x = 0,\ \Sigma M_y = 0,\ \Sigma M_z = 0$$

For plane frame:

$$\Sigma F_x = 0,\ \Sigma F_y = 0,\ \Sigma M_x = 0$$

1.27 (b)

A properly contained rigid system has finite degrees of freedom. The number of degree of freedom of a locomotive moving on a railway track is one.

1.28 (c)

The kinematic indeterminacy of the frame is

$$D_k = 3j - r_E + r_R$$

Given, $j = 4$

$r_E = 5$

$r_R = \Sigma(m' - 1)$

$= \Sigma(2 - 1) = 1$

$\therefore \quad D_k = 3 \times 4 - 5 + 1 = 8$

Note: Sometimes question maker does not mention about axial deformation of members in question. In such case calculate the answer using both, extensible member as well as inextensible member.

Here, θ_{BA}, θ_{BC}, Δ_{Bx}, Δ_{By}, θ_C, Δ_{Cx}, Δ_{Cy} and θ_D is the total kinematic indeterminacy for general frame. But in case of axially inextensible member $\Delta_{By} = \Delta_{Cy} = 0$ and $\Delta_{Bx} = \Delta_{Cx}$, so kinematic indeterminacy is 5 only. Since 5 is not in option so 8 is the answer.

1.29 (b)

The kinematic indeterminacy of the beam is

$$D_k = 3j - r_E + r_R$$

Given, $j = 5$

$r_E = 7$

$r_R = \Sigma(m' - 1)$

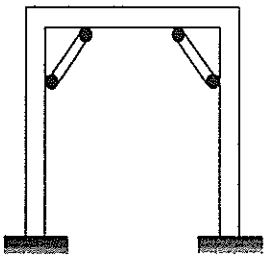
$= \Sigma(2 - 1) = 1$

$\therefore \quad D_k = 3 \times 5 - 7 + 1 = 9$

$(\theta_1, \theta_{H1}, \theta_{H2}, \Delta_{Hx}, \Delta_{Hy}, \theta_2, \Delta_{2x}, \theta_3, \Delta_{3x})$

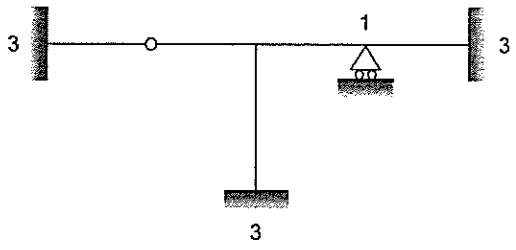
1.30 (c)

In this question internal hinge is only for inclined member as shown in figure below:



Here inclined member will behave as a truss member because it hinged at both the ends and no loading in bewteen so this member is having only one uknown.

1.31 (b)



$D_s = 3m + r_e - r_r - 3(J + J')$

$m = 5,\ r_e = 10,\ r_r = 1,\ J = 5,\ J' = 1$

$D_s = 3 \times 5 + 10 - 1 - 3(5 + 1)$

$= 6$

1.32 (b)

As per the question figure,

No. of unknowns= 2 (R_a, R_b)

No. of equilibrium equations = 3 ($M_z = 0$, $\Sigma F_x = 0$, $\Sigma F_y = 0$)

$D_s = 2 - 3$

$= -1$

The structure is determinate and unstable.

1.33 (b)

Neglecting axial deformation

$$D_k = 3j - (r + m)$$

No. of joints,

$j = 4$, reactions, $r = 4$

members, $M = 3$

$\therefore \quad D_k = 3 \times 4 - (4 + 3) = 12 - 7 = 5$

So, option (b) is correct.

1.34 (a)

$D_s = 3C - R$

$= 3 \times 4 - (1 + 2)$

$= 9$

External indeterminacy
$= 9 - (3 + 2 + 1)$
$= 3$
$D_k = 3 \times 9 - (3 + 2 + 1) - 10$
$= 11$
The closest answer is (a)

1.35 (a)

$D_k = 3j - r - m$
$= 3 \times 4 - 6 - 3 = 3$

1.36 (b)

$D_k = 3j - r - m$
$= 3 \times 9 - 7 - 10 = 10$

1.37 (a)

Degree of static indeterminacy,

$D_s = D_{s_e} + D_{s_i}$

Degree of static indeterminacy (externally),

D_{s_e} = Number of reactions – Number of equilibrium reactions.
$= 5 - 3 = 2$

Degree of static indeterminacy (internally),

$D_{s_i} = -2$

$\therefore \quad D_s = 2 - 2 = 0$

1.38 (d)

External degree of indeterminacy = No. of external reactions – No. of equilibrium reactions.

$D_{s_e} = 6 - 3 = 3$

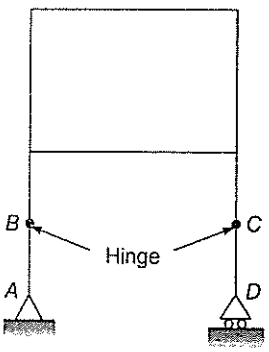
Internal degree of indeterminacy,

$D_{s_i} = m - (2j - 3)$
$= 19 - (2 \times 12 - 3) = -2$

$\therefore$ Total degree of indeterminacy,

$D_s = D_{s_e} + D_{s_i}$
$= 3 - 2 = 1$

1.39 (b)



C = 2 = No of cuts necessary to get cantilever frame

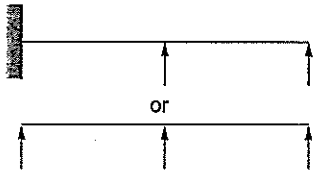
$D_s = 3 \times c - 1 - 1 - 1 - 2$
w w w w
at A at B at C at D
$= 1$

1.40 (a)

1. Fixed beam

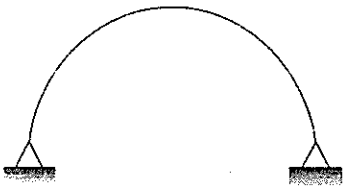
$D_s = 6$
Total equilibrium equation = 3
$D_i = D_s - r = 6 - 3 = 3$

2. Continuous beam



Minimum indeterminacy will be 1.

3. Two hinged arch.



Degree of indeterminacy = 4 – 3 = 1

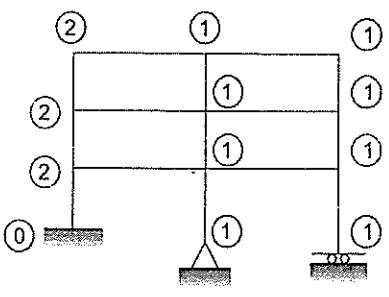
4. Beam overhanging on both side

$D_i = 3 - 3 = 0$

1.41 (b)

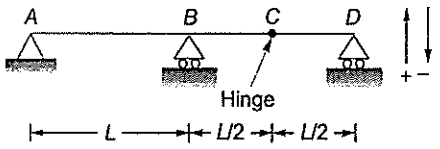
1. $n + 3 = 2j$ is a perfect frame.
2. If the number of members is less than that required than it is deficient frame.
3. If the number of provided members are more than required than frame is called redundant frame.

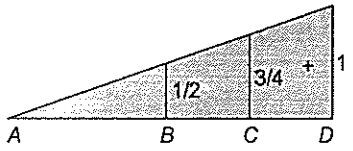
1.42 (a)

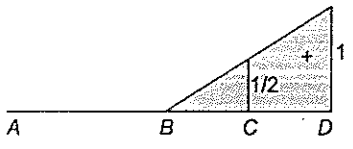


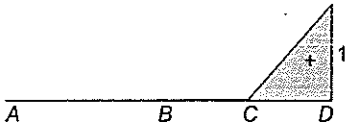
2 Influence Line Diagram and Rolling Loads

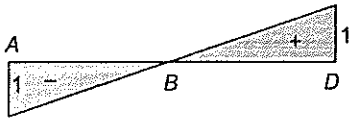
2.1 For the continuous beam shown in figure, the influence line diagram for support reaction at D is best represented as



(a)


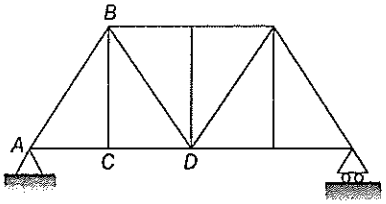
(b)


(c)


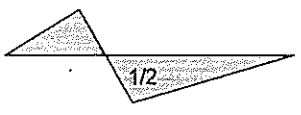
(d)


[ESE : 1995]

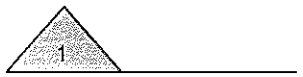
2.2 The given figure shows a portal truss:

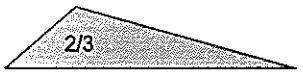


The influence line for force in member *BC* will be

(a)


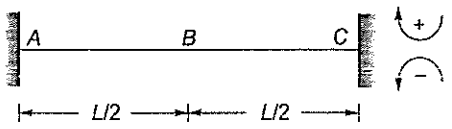
(b)

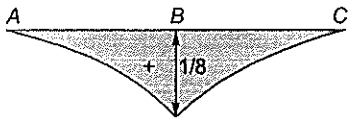
(c)


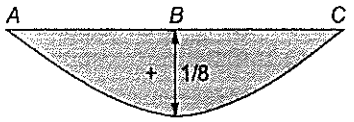
(d)


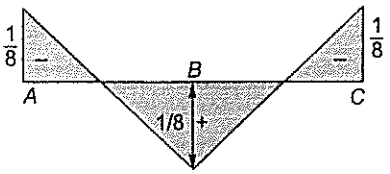
[ESE : 1995]

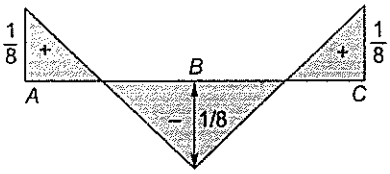
2.3 For the fixed beam shown in the figure, the influence line diagram for the bending moment at the mid-span of the beam is best represented as



(a)


(b)


(c)


(d)


[ESE : 1995]

2.4 Assertion (A): Whether it is maximum BM at a section or absolute maximum BM, the moving UDL should cover the entire span of a simple beam if span is less than load length.

Reason (R): Whether it is maximum BM at a section or absolute maximum BM, the moving UDL should be divided by the section in the same ratio in which the section divides the span, if the span is greater than load length.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

2.5 The maximum bending moment at the left quarter point of a simple beam due to crossing of UDL of length shorter than the span in the direction left to right, would occur after the load had just crossed the section by

(a) one-fourth of its length
(b) half of its length
(c) three-fourth of its length
(d) its full length

[ESE : 1997]

2.6 When a load crosses a through type Pratt truss in the direction left to right, the nature of force in any diagonal member in the left half of the span would

(a) change from compression to tension
(b) change from tension to compression
(c) always be compression
(d) always be tension

[ESE : 1997]

2.7 The influence line R_c for the beam shown in figure-I will be as in

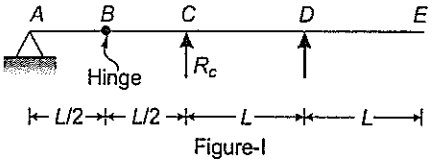
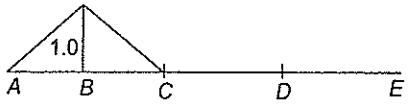
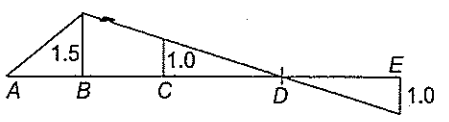
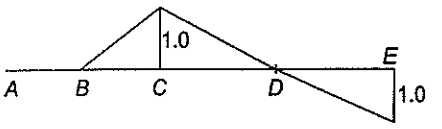
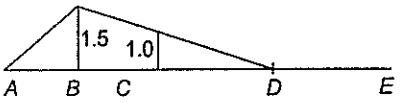


Figure-I

(a)


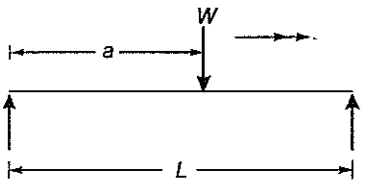
(b)


(c)


(d)


[ESE : 1998]

2.8 Assertion (A): When a single load crosses a simple span of any length, the shear force under the loads to the right for all spans is constant, so long as the load maintains the same a/L ratio (see given figure)



Reason (R): When the load maintains the same a/L ratio in all spans, the reaction at the right hand support remains the same.

[ESE : 1998]

2.9 For beam shown in figure-I, an influence line diagram is shown in figure-II. This refers to

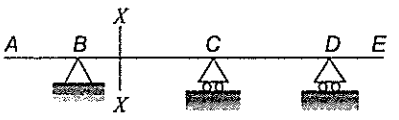


Figure-I

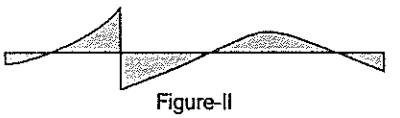


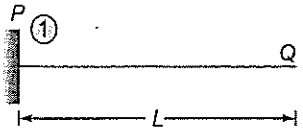
Figure-II

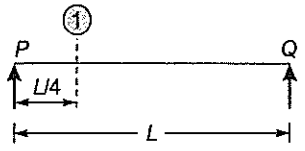
(a) reaction R_A
(b) shear force at support D
(c) BM at support B
(d) shear force at section XX

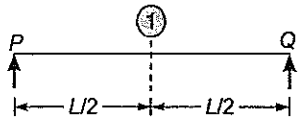
[ESE : 1999]

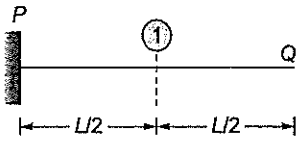
2.10 Match List-I (Beam) with List-II (Influence line for BM) and select the correct answer using the codes given below the lists:

List-I

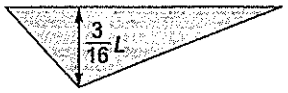
A.


B. 

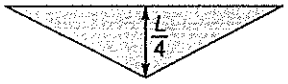
C. 

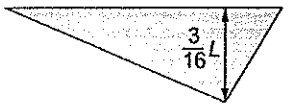
D. 

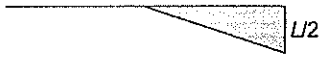
List-II

1. 

2.

3. 

4. 

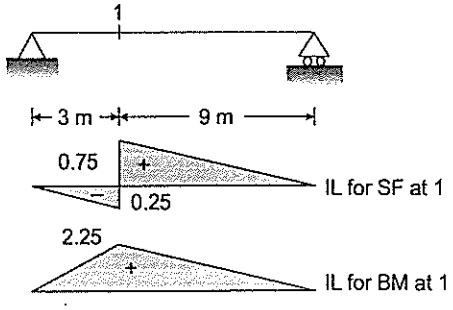
5. 

Codes:

	A	B	C	D
(a)	2	1	3	5
(b)	3	1	4	5
(c)	2	5	3	4
(d)	1	3	5	4

[ESE : 1999]

2.11 The given figures show a beam with its influence line for shear force and bending moment at section '1':

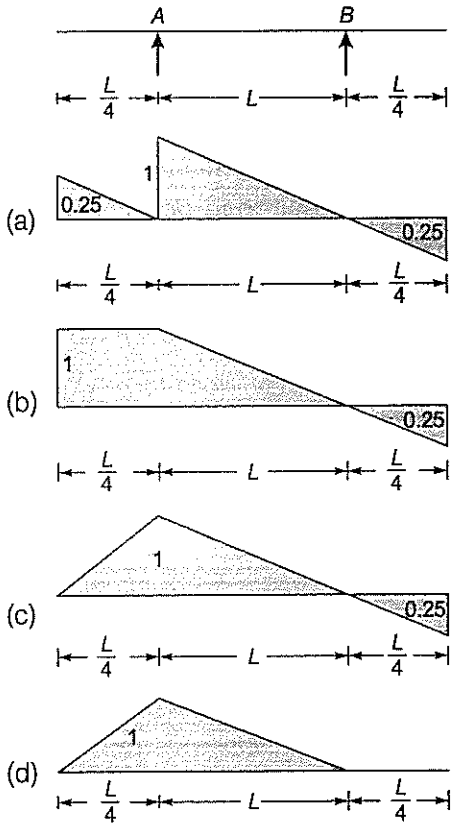


The values of the shear force and bending moment at section '1' due to a concentrated load of 20 kN placed at mid-span will be

(a) 0.75 kN and 2.25 kN-m
(b) 5 kN and 5 kN-m
(c) 7.5 kN and 10 kN-m
(d) 10 kN and 30 kN-m

[ESE : 2000]

2.12 A beam with cantilevered ends is shown in the given figure. Which one of the following diagrams represent the influence line diagram for shear force at section just to the right of the support *A*?



[ESE : 2000]

2.13 The influence line diagram for reaction *B* of the beam shown in figure-I is

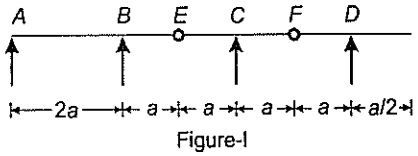
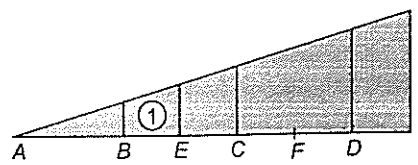
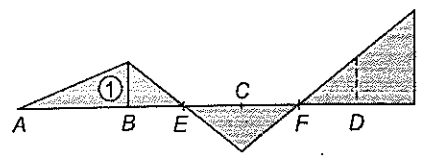
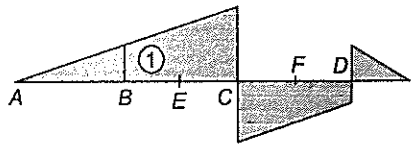
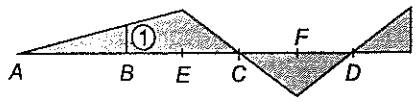


Figure-I

(a) 

(b) 

(c) 

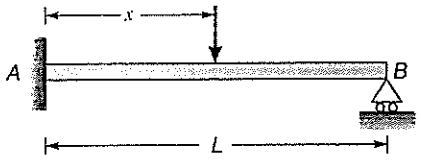
(d) 

[ESE : 2000]

2.14 **Assertion (A):** In a cantilever, the *ILD* for deflection at the free end is same as elastic curve of the beam due to unit load placed at the free end.
Reason (R): By Maxwell's Reciprocal theorem, the deflection at the free end, due to various positions of unit load on the span equals deflection at those places of unit moving load due to static unit load at the free end.

[ESE : 2001]

2.15 For the propped cantilever shown in the figure, influence line for reaction at the propped end is given by $y_1 = f(x)$.

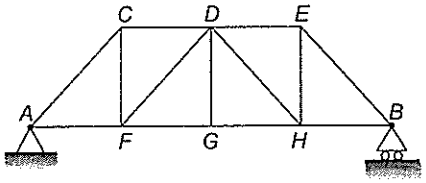


The influence line ordinate (y_2) for moment at A is given by the equation

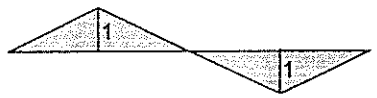
(a) $y_2 = f(x) \cdot L$ (b) $y_2 = f(x) \cdot x$
(c) $y_2 = x - f(x) \cdot x$ (d) $y_2 = x - f(x) \cdot L$

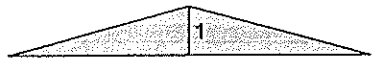
[ESE : 2002]

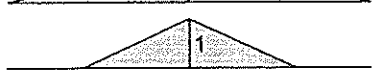
2.16 Which one of the following diagrams represents the influence line for force in the member *DG*?



(a)

(b) 

(c) 

(d) 

[ESE : 2003]

2.17 Which one of the following statements is correct? The influence line diagram (ILD) for bending moment at a section in a cantilever is a triangle extending between the section and the
(a) fixed end with maximum ordinate under the section
(b) fixed end with maximum ordinate under the fixed end
(c) unsupported end with maximum ordinate at the section
(d) unsupported end with maximum ordinate at the unsupported end

[ESE : 2004]

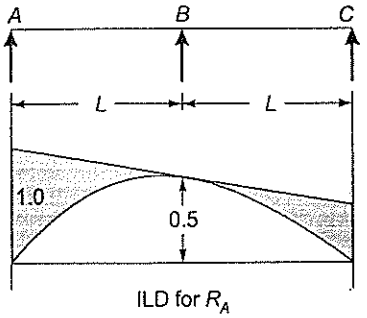
2.18 Which one of the following is correct in respect of the influence line for the bending moment at one-fourths of the span from left support of a prismatic beam simply supported at ends?
(a) It is composed of straight lines only
(b) It is composed of curved lines only
(c) It is composed of straight and curved lines
(d) It is parabolic

[ESE : 2005]

2.19 What is the shape of influence line diagram for the maximum bending moment in respect of a simply supported beam?
(a) Rectangular (b) Triangular
(c) Parabolic (d) Circular

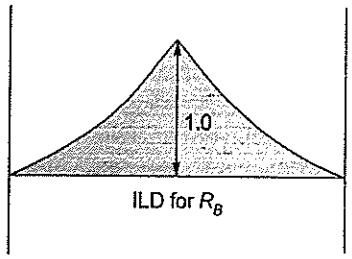
[ESE : 2005]

2.20 Consider the following statements:
1. Müller-Breslau's principle is applicable only to indeterminate structures.
2. Müller-Breslau's principle is applicable only to determinate structures.
3. Müller-Breslau's principle is applicable to determinate and indeterminate structures.
4. For a two span continuous beam *ABC*, the influence line diagrams is/are

(i) 

ILD for R_A

(ii)

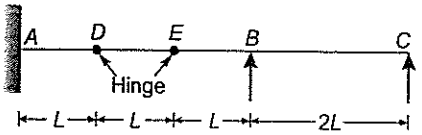


Which of these statements are correct?

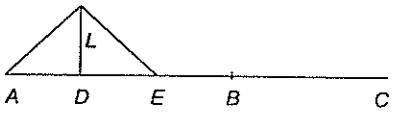
(a) 1 and 4 (ii) (b) 3 and 4 (i)
(c) 2 and 4 (i) (d) 3 and 4 (ii)

[ESE : 2006]

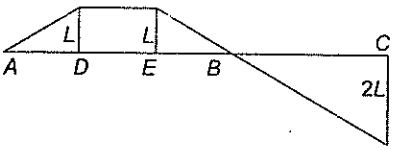
2.21 Which one of the following diagrams corresponds to the influence line diagram for moment at *A* of the beam shown below in the figure?



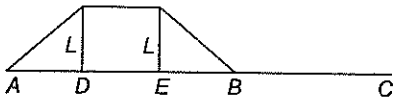
(a)



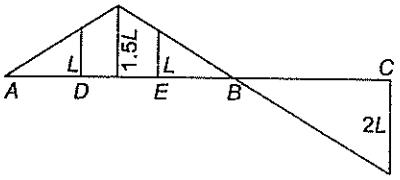
(b)



(c)



(d)



[ESE : 2006]

2.22 What is the variation of influence line for stress function in a statically determinate structure?

(a) Parabolic
(b) Bilinear
(c) Linear
(d) Uniformly rectangular

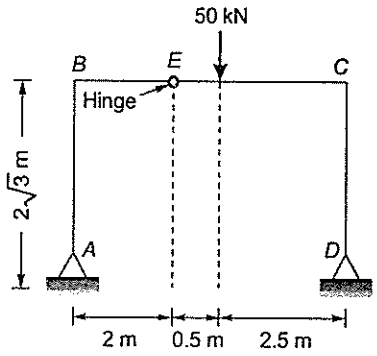
[ESE : 2007]

2.23 What is/are the use (s) of influence lines?

(a) To study the effect of moving loads on the structure
(b) To calculate the value of stress function with the critical load condition
(c) To find the position of live load for a maximum value of particular stress function
(d) Towards all the above purposes

[ESE : 2007]

2.24 What is the inclination of resultant reactions at A with the vertical for the frame shown in the figure below?



(a) 60° (b) 40°
(c) 30° (d) 50°

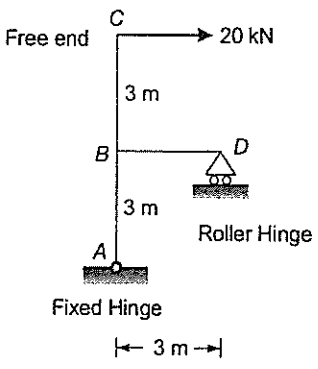
[ESE : 2007]

2.25 Muller-Breslau Principle is applicable to get influence line for which one of the following?

(a) Reaction at the ends of a simple beam
(b) Bending moment at a section
(c) Shear force at a section
(d) Forces and moments at any section

[ESE : 2008]

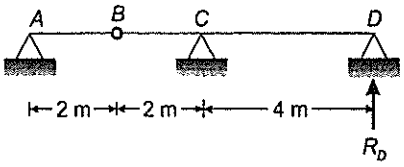
2.26 What is the reaction at the support *D* of the rigid-jointed structure shown below?



(a) 10 kN (b) 20 kN
(c) 30 kN (d) 40 kN

[ESE : 2008]

2.27 What is the ordinate of influence line at *B* for reaction R_D in figure below?



(a) 0.5 (b) 0.4
(c) 0.2 (d) Zero

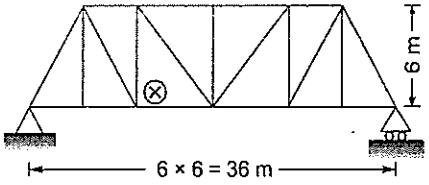
[ESE : 2009]

2.28 What is the area of influence line diagram for the reaction at the hinged end of a uniform propped cantilever beam of span *L*?

(a) $\frac{L}{8}$ (b) $\frac{L}{2}$
(c) $\frac{L}{4}$ (d) $\frac{3L}{8}$

[ESE : 2009]

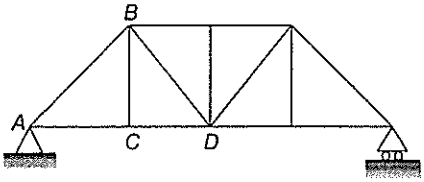
2.29 What is the maximum ordinate for influence line for the force in the member marked *X*?



(a) 1.0 (b) 1.33
(c) 1.50 (d) 2.50

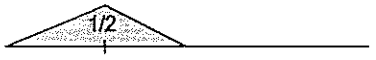
[ESE : 2009]

2.30 The influence line for force in member *BC* is



(a)

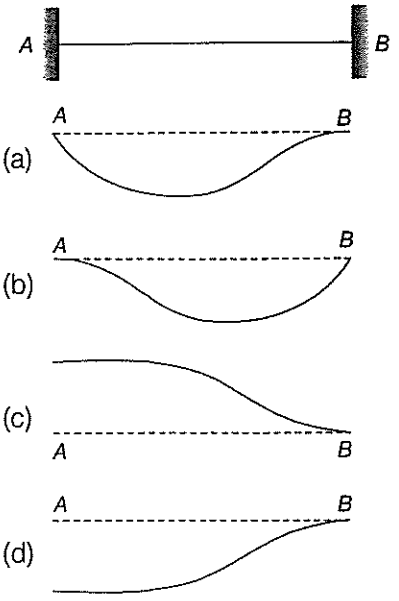
(b)

(c)


(d)

[ESE : 2010]

2.31 The influence line diagram for the support moment at *A* of the fixed beam *AB* of constant EI is



[ESE : 2010]

2.32 Assertion (A): Muller-Breslau principle is a most widely used method to determine qualitative influence lines in an indeterminate structure.
Reason (R): The determination of the qualitative influence lines is often of great value in ascertaining the most severe stresses at specified sections of a structure.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2010]

2.33 The absolute maximum bending moment that a simply supported girder of span 10 m experiences when two concentrated loads 20 kN and 30 kN spaced 2 m apart (30 kN as leading at the right) crosses the girder from left to right, is

(a) 112.2 kN-m (b) 96.6 kN-m
(c) 136.8 kN-m (d) 105.8 kN-m

[ESE : 2010]

2.34 A live load 20 kN/m, 6 m long, moves on a simply supported girder *AB* 12 m long. For maximum bending moment to occur at 4 m from left end *A*, where will the head of load be, as measured from A?

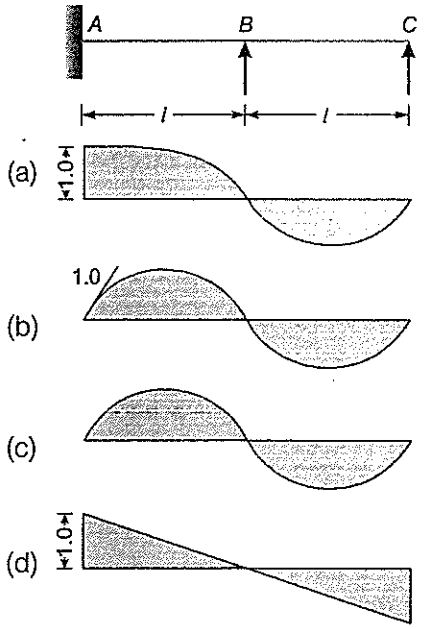
(a) 4 m (b) 6 m
(c) 8 m (d) 10 m

[ESE : 2010]

2.35 A uniformly distributed load (w) of length shorter than the span crosses a girder. The bending moment at a section in girder will be maximum when
(a) Head of the load is at the section
(b) Tail of the load is at the section
(c) Section divides the load in the same ratio as it divides the span
(d) Section divides the load in two equal lengths

[ESE : 2011]

2.36 The influence line for vertical reaction at *A* of the beam is



[ESE : 2011]

2.37 The Muller-Breslau principle in structural analysis is used for
(a) drawing influence line diagram for any force function
(b) superimposition of load effects
(c) writing virtual work equation
(d) None of above

[ESE : 2012]

2.38 The maximum bending moment under a particular point load among a train of point loads crossing a simply supported girder occurs when that load is
(a) at mid-span
(b) at one-third span
(c) at one-quarter span
(d) so placed that the load point and the point of *CG* of the train of loads are equidistant from the mid-span

[ESE : 2012]

2.39 A uniformly distributed load of length 8 m crosses a simply supported girder of span 20 m. The maximum bending moment at the left quarter-span point occurs when the distance between the point of CG of the total load and mid-span is
(a) 0 (b) 2 m
(c) 3 m (d) 4 m

[ESE : 2012]

2.40 The maximum number of unknown forces that can be determined in a concurrent coplanar force system under equilibrium is
(a) 2 (b) 3
(c) 6 (d) 1

[ESE : 2012]

2.41 For which one of the following cases is the Muller-Breslau principle applicable to get influence line?
(a) Reaction at the ends of a simple beam
(b) Bending moment at a section
(c) Shear force at a section
(d) Forces and moments at any section

[ESE : 2013]

2.42 The area of influence diagram for the reaction at the hinged end of a uniform propped cantilever beam of span *l* is
(a) $3l/8$ (b) $l/2$
(c) $l/4$ (d) $l/8$

[ESE : 2013]

2.43 The Muller-Breslau principle for influence line is applicable for
(a) simple beams (b) continuous beams
(c) redundant trusses (d) all of the above

[ESE : 2014]

2.44 The maximum bending moment caused by a set of concentrated moving loads is
(a) Always at the mid-point of span
(b) Between the mid-point and concentrated load next to the mid-point' of the span
(c) Not definable
(d) Always under a load close to the centroid of the set of loads

[ESE : 2016]

2.45 Muller-Breslau Principle for obtaining influence lines is applicable to
1. Statically determinate beams and frame
2. Statically indeterminate structures, the material of which is elastic, and follows Hooke's law
3. Any statically indeterminate structure

(a) 1 and 2 only (b) 1 only
(c) 2 only (d) 1 and 3 only

[ESE : 2016]

2.46 The maximum bending moment at a given section, in which a train of wheel loads moves, occurs when the average load on the left segment is
1. Equal to the average load on the right segment.
2. More than the average load on the right segment.
3. Less than the average load on the right segment.

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 1 only
(c) 2 only (d) 3 only

[ESE : 2017]

2.47 Two parallel rails are running on railway sleepers. The centre-to-centre distance between the rails is '*b*' with the sleepers projecting by an amount '*a*' at each end beyond the rails. When the train passes over the rails, the reaction exerted by the ground can be taken as uniformly distributed over the sleeper. The ratio $\frac{b}{a}$ for the condition that the maximum binding moment is as small as possible is

(a) 2.83 (b) 2.90
(c) 2.50 (d) 3.00

[ESE : 2017]

■■■■

Answers Influence Line Diagram and Rolling Loads

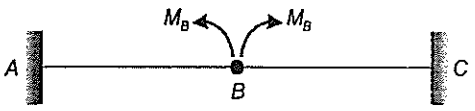
2.1 (c)	2.2 (c)	2.3 (c)	2.4 (a)	2.5 (c)	2.6 (a)	2.7 (b)	2.8 (a)	2.9 (d)	
2.10 (a)	2.11 (d)	2.12 (a)	2.13 (d)	2.14 (a)	2.15 (d)	2.16 (d)	2.17 (d)	2.18 (a)	
2.19 (c)	2.20 (*)	2.21 (a)	2.22 (c)	2.23 (d)	2.24 (c)	2.25 (d)	2.26 (d)	2.27 (a)	
2.28 (c)	2.29 (b)	2.30 (d)	2.31 (a)	2.32 (b)	2.33 (d)	2.34 (c)	2.35 (c)	2.36 (a)	
2.37 (a)	2.38 (d)	2.39 (c)	2.40 (a)	2.41 (d)	2.42 (c)	2.43 (d)	2.44 (d)	2.45 (a)	
2.46 (b)	2.47 (a)								

Explanations Influence Line Diagram and Rolling Loads

2.1 (c)
As per Muller Breslau's principle, the *ILD* for support reaction at *D* can be obtained by giving unit displacement in the positive direction of reaction. The deflected shape of beam will represent *ILD* as in figure (*c*)

2.2 (c)
Force in member *BC*, when the load is right of *D*, will be zero. When the load is between *A* and *D*, the tensile force with maximum value of 1 unit will develop. So correct diagram is as shown in figure (c).

2.3 (a)
The *ILD* for *BM* at mid span can be obtained by introducing a pinned connection at mid point and giving unit rotation at that point. The deflected shape of beam will give the *ILD*.



$$\theta_{BA} = \frac{M_B(L/2)}{EI}$$

and $$\theta_{BC} = \frac{M_B(L/2)}{EI}$$

$$\theta_{BA} + \theta_{BC} = 1.0$$

$$M_B = EI$$

Deflection at $B = \frac{M_B(L/2)^2}{2EI} = \frac{1}{8}$

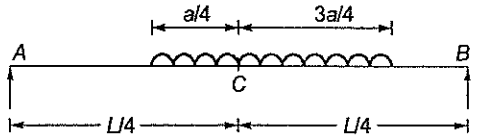
Slope at end A and end C will be zero. Therefore (a) will be the correct answer.

2.4 (a)

For the maximum BM at a section or absolute maximum BM, the moving UDL should be divided by the section in the same ratio in which the section divides the span. If length of UDL is more than the span, then for the same ratio it will cover the entire span.

2.5 (c)

Section should divide the load in the same ratio as it divides the span for maximum bending moment.



Length of UDL = a

Load crossed the section by $\frac{3a}{4}$

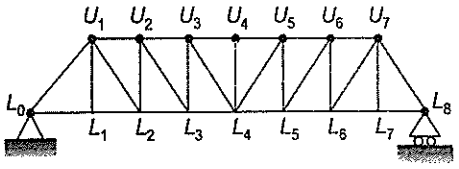
$$\Rightarrow \quad \frac{wa}{4\times\frac{L}{4}} = \frac{w\times\frac{3}{4}a}{\frac{3L}{4}}$$

$$\Rightarrow \quad \frac{wa}{L} = \frac{wa}{L}$$

So average load on both sideis equal.

2.6 (a)

The figure shows Pratt truss.



When the load is at L_1, the force in U_1L_2 will be compressive and when the load is at L_2 the force in U_1L_2 will be tensile. This will happen for all diagonal members in left half. Reverse will be the case for diagonal members of right half.

2.7 (b)

By giving unit translation in the positive direction of support reaction at R_C, the deformed shape of beam is as shown in figure (b).

2.8 (a)

Reaction at right support = $\frac{Wa}{L}$. So shear force on the right for all spans is constant.

2.9 (d)

Since the diagram shows a displacement at X–X, so the figure represents *ILD* for shear force at section X–X.

2.10 (a)

Introduce pinned connection at given section and given unit rotation at the section to find the *ILD* for *BM*.

2.11 (d)

Shear force = $0.75\times\frac{2}{3}\times 20 = 10$ kN

Bending moment = $2.25\times\frac{2}{3}\times 20 = 30$ kN-m

2.12 (a)

Introduce a vertical roller with restrained rotation just right of support A and give unit displacement in the direction of shear. The *ILD* will be as shown in (a).

2.13 (d)

Give unit displacement in the positive direction of vertical reaction at B and draw deflected shape of B. So (d) is the correct *ILD*.

2.14(a)

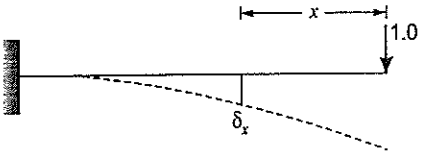


Figure-I

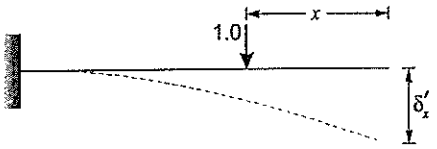


Figure-II

From Maxwell's reciprocal theorem

$$\delta_x = \delta_x'$$

Therefore the deflected shape in figure-I will be the ILD for deflection.

2.15(d)

Moment at A = Reaction at $B \times L$ – load $\times x$

$= f(x).L - x$

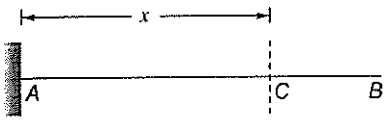
Now moment can be expressed as

$y_2 = x - f(x).L$

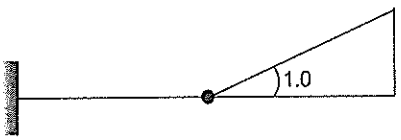
2.16(d)

Member *DG* will develop tensile force only when the load is on span *FG* and *GH*. The maximum force in the member is induced when the load is at *G*. Thus *ILD* is given by figure (d).

2.17(d)



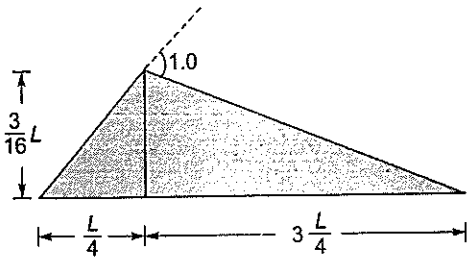
Introduce a pinned connection at *C* and give unit rotation. The *ILD* for bending moment at *C* is



So the *ILD* is the triangle between section and free end (unsupported end) with maximum ordinate at the unsupported end.

2.18(a)

Introduce a pinned connection at the section and give unit rotation. The *ILD* for the bending moment will be



The maximum ordinate of the diagram is

$$\frac{L}{4} \times \frac{3L}{4} \times \frac{1}{L} = \frac{3L}{16} \text{ units.}$$

2.19(c)

The maximum bending moment for any position of load occur under the load. So the equation for maximum bending moment is

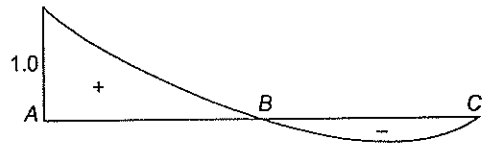
$$M_{max} = \frac{x(L - x)}{L}$$

Thus the ILD for maximum bending moment is parabolic. This is also called envelop of maximum bending moment.

2.20(*)

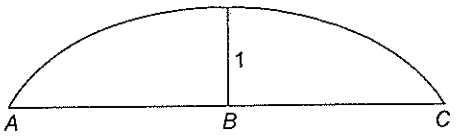
Müller Breslau's principle can be applied to both determinate and indeterminate structure. So both 1 and 2 are wrong and 3 is correct.

For *ILD* of R_A, give unit deflection in the direction of R_A and the deflected shape will given the *ILD*.



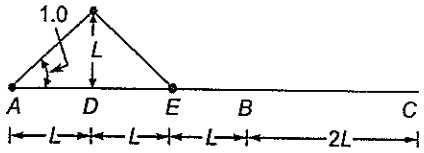
Thus there is no reaction at *A* when the load is either at *B* or *C*, while the given diagram in 4(*i*) shows some value of R_A when load is at *C*. So it is incorrect.

And *ILD* for R_B is



2.21(a)

For *ILD* of moment of *A*, introduce a pinned connection at *A* and give unit rotation, the *ILD* will be



2.22 (c)

Removing restraint makes the structure unstable as $D_s = 0$ for statistically determinate structure and therefore rigid body displacement takes place leading to linear variation of influence lines.

2.24 (c)

There is no lateral loading on the frame, hence the horizontal reactions at *A* and *D* will be equal in magnitude and opposite in nature. Let H be the magnitude of horizontal reaction and it acts from left to right at *A*. Let vertical reaction at *A* be V_A upwards.

Taking moments about the hinge at *E* from left we get

$$V_A \times 2 - H \times 2\sqrt{3} = 0$$

$$\Rightarrow \quad V_A = H\sqrt{3}$$

If the resultant makes an angle θ with the vertical, then

$$\tan\theta = \frac{H}{V_A}$$

$$\Rightarrow \quad \theta = \tan^{-1}\left(\frac{H}{\sqrt{3}H}\right)$$

$$\Rightarrow \quad \theta = 30^\circ$$

2.25 (d)

Muller Breslau principle states that the influence lines of an action (force or moment) assumes the scaled form of the deflection that the structure displays after removing the restraint on the point where the action is evaluated and applying a point load at that point which causes a unit displacement.

2.26 (d)

Taking reaction at *D* as $V_D(\uparrow)$, and moment about hinge *A* as zero respectively, we get

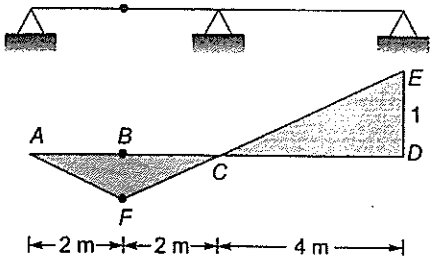
$$\Sigma M_A = 0$$

$$\Rightarrow \quad V_D \times 3 - 20 \times 6 = 0$$

$$\Rightarrow \quad V_D = 40\ \text{kN}$$

2.27 (a)

Applying Muller Breslau principle, we get *ILD* for reaction R_D.



From similar triangles *BFC* and *DEC*, we get

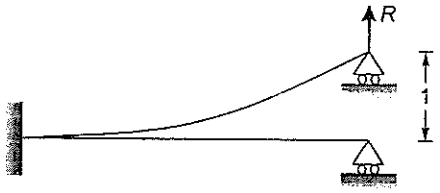
$$\frac{BF}{BC} = \frac{DE}{DC}$$

$$\frac{BF}{2} = \frac{1}{4}$$

$$BF = 0.5$$

2.28 (c)

If structure is given unit displacement at pinned support then there will be vertical reaction at pinned support.



Bending moment diagram is linear for the span.

Now, $\frac{d^2y}{dx^2} = M$

So deflected shape is cubic parabola.

2.29 (b)

maximum ordinate of influence line for force in member *X* is given as $= \frac{ab}{(a+b)h}$

where, $a = 2 \times 6 = 12$ cm

$b = 4 \times 6 = 24$ m

$h = 6$ m

So, maximum ordinate = 1.33

2.30 (d)

When the unit load is anywhere on the right side of the joint *D*, no load will be transmitted to the joint *C*. Hence for this position of the unit load, there will be no force in the member *BC*. When the unit load is exactly at *C* the force in member *BC* will be equal to 1 (tensile). When the unit load is

exactly at A, then also no load is transmitted to the joint C and hence for this position of the load also, there will be no force in the member BC.

2.31 (a)

As per Muller Breslau Principle, we have to release the moment at A and a unit rotation is given to the primary structure. Then the diagram will be as shown in option (a).

2.32 (b)

Muller Breslau is the most widely used method because of its ease of drawing ILD. After ILD for any stress function is drawn, the sections which will be subjected to critical stress can be known.

2.33(d)

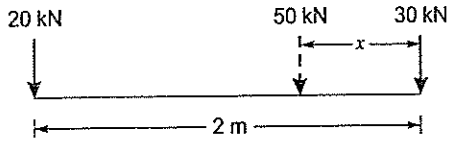
The absolute maximum bending moment will occur near the midspan and under the 30 kN load. Hence for the condition of absolute maximum bending moment the load system should be so placed on the span that the resultant of both the loads (30 + 20 = 50 kN) and the 30 kN load are equidistant from the middle point of the girder.

Let the distance of the resultant load from the leading load be x.

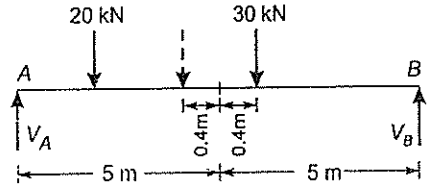
Taking moments about the leading load, we get

$$50x = 30 \times 0 + 20 \times 2$$

$$\Rightarrow \quad x = 0.8 \text{ m}$$



Hence for the condition of absolute maximum bending moment, the 30 kN load and resultant should be equidistant from the midspan of the girder.



Taking moments about A, we get

$$V_B \times 10 - 30 \times 5.4 - 20 \times (5 - 1.6) = 0$$

$$\Rightarrow \quad V_B = 23 \text{ kN}$$

$\therefore$ Absolute maximum bending moment for the girder

= Bending moment under the 30 kN load

$= 23 \times (5 - 0.4)$

= 105.8 kN-m

2.34(c)

Let C be the given section where bending moment is maximum.

$\therefore$ $AC = 4$ m and $BC = 8$ m

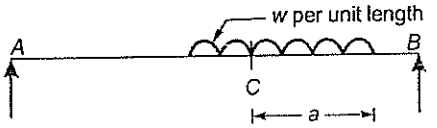
Let the head of the load after crossing the section C be at a distance 'a' from C.

For the bending moment at C to be maximum,

Average load on AC = Average load on BC

$$\Rightarrow \quad \frac{w(6-a)}{AC} = \frac{wa}{BC}$$

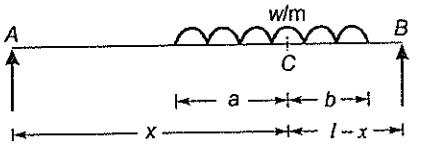
$$\Rightarrow \quad \frac{6-a}{4} = \frac{a}{8}$$



$$\Rightarrow \quad a = 4 \text{ m}$$

$\therefore$ Head of load from $A = AC + a = 8$ m

2.35 (c)

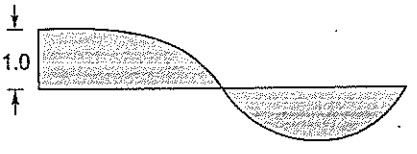


For maximum bending moment at section C

$$\frac{a}{b} = \frac{x}{l-x}$$

2.36 (a)

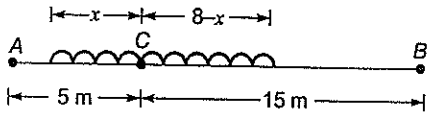
According to Muller Breslau Principle, influence line for any force is drawn by giving a unit displacement to the beam along the line of action of the force. On displacement there will be no rotation at A while rotation will be present at B and C.



2.37 (a)

The Muller-Breslau principle states that the ILD for any stress function in a structure is represented by its deflected shape obtained by removing the restrain offered by that stress function and introducing a directly related generalized unit displacement in the direction of that stress function.

2.39 (c)



The maximum bending moment at C will occur when the section divides the load in the same ratio as at divides the span

$$\therefore \quad \frac{x}{5} = \frac{8-x}{15}$$

$$\Rightarrow \quad 3x = 8 - x$$

$$\Rightarrow \quad x = 2\,\text{m}$$

Distance between point of CG of total load and mid-span is

$$\Rightarrow \quad 10 - 3 - 4 = 3\,\text{m}$$

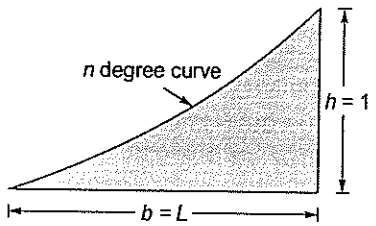
2.41 (d)

As per Muller Breslau principle, influence line for any stress function (reaction, shear or moment) at any section may be obtained by removing the restraint in that direction and by applying unit displacement in that direction. The deflected shape gives the ILD.

2.42 (c)

Area of cubic parabola

$$= \frac{bh}{n+1} = \frac{1}{4}bh = \frac{L}{4}$$



2.43 (d)

Muller- Breslau principle can be used for both statically determinate and indeterminate structures, especially for drawing ILDs.

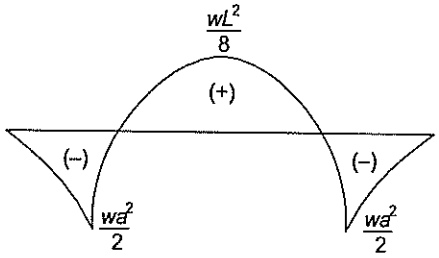
2.44 (d)

To get maximum BM under a chosen wheel load, keep the loads such that the chosen wheel load and resultant are at equal distance from centre. Then, maximum BM occurs under chosen wheel load (but not at centre). The most appropriate answer is *D*.

2.45 (a)

Muller-Breslau principle gives a qualitative sense of the influence line for any statically indeterminate structure (since we do not know what the ordinates are because the lines are not straight, they are curvilinear). We can use this principle to get a feeling of how the influence line is going to look and to get a feeling of where it is going to be positive and where it is going to be negative.

2.47 (a)



$$\frac{wa^2}{2} = \frac{wL^2}{8} - \frac{wa^2}{2} \quad (L = b + 2a)$$

$$a = \frac{L}{2\sqrt{2}} = 0.354\,L$$

$$\frac{b}{a} = \frac{1}{0.354} = 2.823$$

3 Arches and Suspension Bridges

3.1 A three-hinged parabolic arch rib of span L and crown rise 'h' carries a uniformly distributed superimposed load of intensity 'w' per unit length. The hinges are located on two abutments at the same level and the third hinge at a quarter span location from left hand abutment. The horizontal thrust on the abutment is

(a) $\frac{wL^2}{4h}$ (b) $\frac{wL^2}{6h}$

(c) $\frac{wL^2}{8h}$ (d) $\frac{wL^2}{12h}$

[ESE : 1995]

3.2 A two-hinged semicircular arch of radius R carries a concentrated load W at the crown. The horizontal thrust is

(a) $\frac{W}{2\pi}$ (b) $\frac{W}{\pi}$

(c) $\frac{2W}{3\pi}$ (d) $\frac{4W}{3\pi}$

[ESE : 1996]

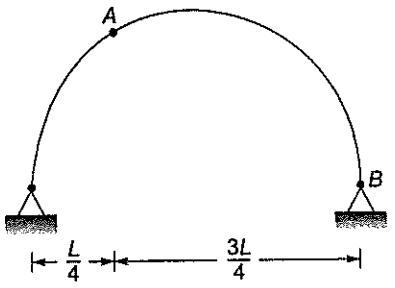
3.3 **Assertion (A):** The BM due to any load at all sections of an arch, is less than the BM at all sections of a simple beam having the same span of arch under the same load.

Reason (R): The moment due to horizontal thrust of the arch is hogging.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

3.4 For the semicircular two-hinged arch shown in the figure below, a moment of 50 t cm applied at B produces a displacement of 0.5 cm at A. If a concentrated load of 10 t is applied at A, the rotation at B in the arch will be



(a) 0.1 (b) 0.001
(c) 0.0001 (d) 0.01

[ESE : 1997]

3.5 A three-hinged semicircular arch of radius R carries a uniformly distributed load w per unit run over the whole span. The horizontal thrust is

(a) wR (b) $\frac{wR}{2}$

(c) $\frac{4wR}{3\pi}$ (d) $\frac{2wR}{3\pi}$

[ESE : 1997]

3.6 **Assertion (A):** In a parabolic symmetrical three hinged arch the bending moment at any section due to dead load is zero.

Reason (R): In influence line diagram for moment at a section of an arch, the simply supported moment diagram and 'H_{xy}' diagram have equal areas.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

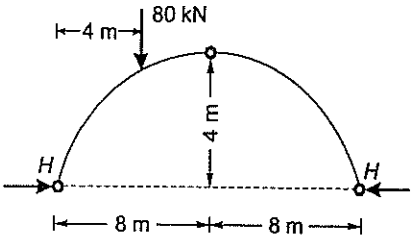
[ESE : 1997]

3.7 A circular three-pinned arch of span 40 m and a rise of 8 m is hinged at the crown and springings. It carries a horizontal load of 100 kN per vertical metre on the left side. The horizontal thrust at the right springing will be

(a) 200 kN (b) 400 kN
(c) 600 kN (d) 800 kN

[ESE : 1998]

3.8 The three-hinged arch shown in the given figure will have value of H as



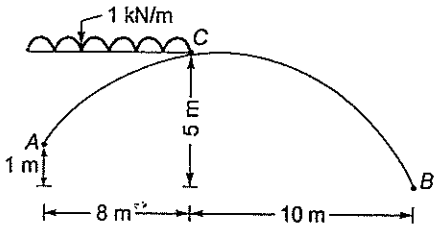
(a) 20 kN (b) 30 kN
(c) 40 kN (d) 50 kN

[ESE : 1999]

3.9 A circular segmental three-hinged arch of span 36 m and a rise of 6m hinged at the crown and springings. It carries a horizontal load of 1000 N/m covering full height of the arch on left side. The horizontal thrust on the right springing will be
(a) 6000 N (b) 4500 N
(c) 3000 N (d) 1500 N

[ESE : 2000]

3.10 The horizontal thrust at support A in a three hinged arch shown in the given figure is



(a) 2 kN (b) 4 kN
(c) 8 kN (d) 10 kN

[ESE : 2001]

3.11 A three-hinged symmetrical parabolic arch of span 20 m and rise 5 m carries a uniformly distributed load of 2 kN/m for the whole span. The bending moment at quarter point is
(a) 75 kN-m (Hogging)
(b) 75 kN-m (Sagging)
(c) 100 kN-m (Sagging)
(d) zero

[ESE : 2001]

3.12 For a two-hinged parabolic arch, V_x is sum of the vertical forces on the left hand side of the section, H is the horizontal thrust. If α is the angle of tangent at the point on arch with the horizontal, the shearing force at section from left hand side is given by
(a) $V_x \sin\alpha - H\cos\alpha$
(b) $V_x \cos\alpha - H\sin\alpha$
(c) $V_x \sin\alpha + H\cos\alpha$
(d) $V_x \cos\alpha + H\sin\alpha$

[ESE : 2002]

3.13 **Assertion (A):** Any arch cannot practically be built to the shape of the theoretical arch.
Reason (R): The shape of the theoretical arch is affected by loads moving on it.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2003]

3.14 A symmetrical parabolic arch of span L and rise 'h' is hinged at both the supports. The arch carries a uniformly distributed load of w/unit length along the entire span.
Which one of the following is correctly matched?
(a) Horizontal thrust: $\frac{wL^2}{8h}$
(b) Bending moment at crown: $\frac{wL^2}{8}$
(c) Radial shear at springing: $\left(\frac{wL}{2} - \frac{wL^2}{8h}\right)$
(d) Vertical reaction at supports: wL

[ESE : 2003]

3.15 A three-hinged semi-circular arch of radius R carries a concentrated load W at the crown. Horizontal thrust acting on the arch at the hinge would be
(a) $\frac{W}{2}$ (b) $\frac{W}{2\pi}$
(c) $\frac{2}{3}W$ (d) $\frac{4}{3}\frac{W}{\pi}$

[ESE : 2003]

3.16 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. The shape of a cable suspended between two supports is defined by
B. The cable uniformly loaded along the horizontal span takes the shape of
C. The cable uniformly loaded along its length assumes the shape of
D. The girder in a suspension bridge transmits to its supports

List-II

1. A catenary
2. A little load
3. A parabola
4. Applied loads

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	1	3	4	2
(c)	4	3	1	2
(d)	4	2	1	3

[ESE : 2004]

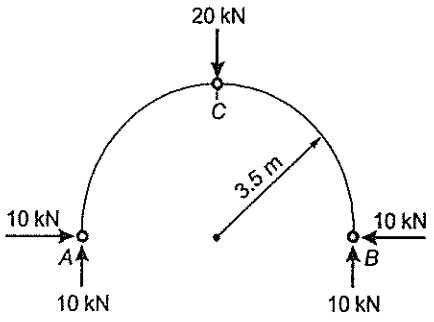
3.17 What is the horizontal thrust in a symmetric parabolic two-hinged arch of span L and central rise 'y' subjected to a uniformly distributed load of intensity 'w' per unit length over its entire span?

(a) $\frac{wL^2}{4y}$ (b) $\frac{wL^2}{8y}$

(c) $\frac{wL^2}{12y}$ (d) $\frac{wL^2}{16y}$

[ESE : 2004]

3.18 A three-hinged loaded semicircular arch ACB is shown in the figure given below. What is the shearing force at the hinge C?



(a) 20 kN (b) $20\sqrt{2}$ kN

(c) 10 kN (d) $10\sqrt{2}$ kN

[ESE : 2005]

3.19 Linear arch is one which represents

(a) centre line of an arch
(b) variation of bending moment
(c) thrust line
(d) variation of shear force

[ESE : 2005]

3.20 Consider the following statements:

1. Even though a three-hinged parabolic arch is subjected only to vertical loads, it generates horizontal reactions and axial forces.
2. A cable uniformly loaded along the horizontal span assumes the shape of a parabola, whereas a cable uniformly loaded along its length takes the shape of a catenary.
3. Cables loaded uniformly along the horizontal span are by far the types most commonly used structures in practice.

Which of these statements is/are correct?

(a) Only 1 (b) Only 2 and 3

(c) Only 1 and 2 (d) 1, 2 and 3

[ESE : 2006]

3.21 A concentrated load W moves on the span of a three-hinged arch. The horizontal thrust at the supports is maximum when the load is at which one of the following?

(a) The springing
(b) One-sixth of the span from one end
(c) Quarter span
(d) The crown

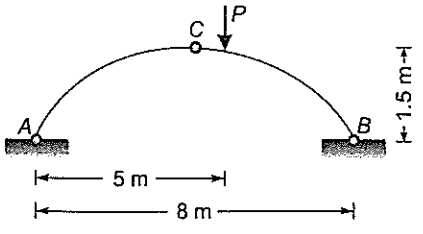
[ESE : 2007]

3.22 A suspension bridge with a two-hinged stiffening girder is

(a) statically determinate
(b) indeterminate of one degree
(c) indeterminate of two degrees
(d) a mechanism

[ESE : 2008]

3.23 A three-hinged symmetrical arch is loaded as shown in figure below. Which one of the following is the magnitude of the correct horizontal thrust?



(a) $\frac{4}{3}P$ (b) P

(c) $\frac{3}{4}P$ (d) $\frac{3}{8}P$

[ESE : 2010]

3.24 A suspension bridge with a two-hinged stiffening girder is statically
(a) determinate
(b) indeterminate to 1 degree
(c) indeterminate to 2 degrees
(d) indeterminate to 3 degrees

[ESE : 2012]

3.25 Which of the following statements is/are correct?
1. For statically determinate structures, magnitudes for maximum effects due to a series of concentrated loads can be established with the aid of influence lines.
2. Cables in suspension bridges will not take the parabolic shape if uniformly loaded along the horizontal span.
3. In a three-hinged arch structure, the normal force, shear and moment at any section are not influenced by the horizontal reaction at the support.

(a) 1, 2 and 3 (b) 1 only
(c) 2 only (d) 3 only

[ESE : 2013]

3.26 A three-hinged arch of span L and rise R is subjected to a concentrated load P at the crown-point. The horizontal thrust at the support is

(a) $\frac{PL}{4R}$ (b) $\frac{PL}{R}$

(c) $\frac{PR}{L}$ (d) $\frac{PL}{3R}$

[ESE : 2013]

3.27 A cable of negligible weight is suspended between two points spaced 300 m apart horizontally, with the right support being 12 m higher than the left support. Four vertical loads of magnitudes 400, 200, 400 and 1200 kN are applied at points A, B, C and D which are 60, 120, 180 and 240 m horizontally respectively from the left support. The largest sag of the cable will be at
(a) A (b) B
(c) C (d) D

[ESE : 2015]

3.28 A three-hinged parabolic arch of span 'l' and rise 'h' is subjected to a u.d.l. of intensity 'w', then the horizontal thrust at the supports is

(a) $\frac{wl^2}{8h}$ (b) $\frac{wl}{h}$

(c) $\frac{wl}{8h^2}$ (d) $\frac{whl}{8}$

[ESE : 2015]

3.29 When a two-hinged parabolic arch is subjected to a rise in ambient temperature, the horizontal thrust at the support will
(a) Increase
(b) Decrease
(c) Remain same
(d) Increase or decrease depending on the span

[ESE : 2016]

3.30 A three-hinged parabolic arch ABC has a span of 20 m and a central rise of 4.0 m. The arch has hinges at the ends and at the crown. A train of two point loads of 20 kN and 10 kN, 5 m apart, crosses this arch from left to right, with the 20 kN load leading. The maximum thrust induced at the supports is
(a) 25.0 kN (b) 28.13 kN
(c) 31.25 kN (d) 32.81 kN

[ESE : 2017]

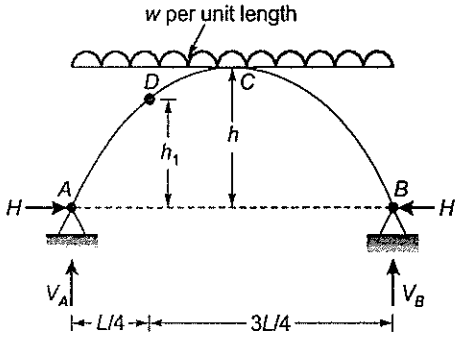
Answers Arches and Suspension Bridges

3.1	(c)	3.2	(b)	3.3	(a)	3.4	(a)	3.5	(b)	3.6	(a)	3.7	(a)	3.8	(c)	3.9	(d)
3.10	(b)	3.11	(d)	3.12	(b)	3.13	(a)	3.14	(a)	3.15	(a)	3.16	(c)	3.17	(b)	3.18	(c)
3.19	(c)	3.20	(d)	3.21	(d)	3.22	(b)	3.23	(b)	3.24	(a)	3.25	(b)	3.26	(a)	3.27	(c)
3.28	(a)	3.29	(a)	3.30	(c)												

Explanations Arches and Suspension Bridges

3.1 (c)

$$V_A = V_B = \frac{wL}{2}$$



$$\because \quad \frac{h}{(L/2)^2} = \frac{h-h_1}{(L/4)^2}$$

$$\Rightarrow \quad 4(h-h_1) = h$$

$$3h = 4h_1$$

$$h_1 = \frac{3h}{4}$$

Taking moment about hinge at D = 0

$$\Rightarrow \quad V_A \times \frac{L}{4} - H \times h_1 - \frac{wL}{4} \times \frac{L}{8} = 0$$

$$\Rightarrow \quad \frac{wL}{2} \times \frac{L}{4} - H \times \frac{3h}{4} - \frac{wL^2}{32} = 0$$

$$\therefore \quad H = \frac{wL^2}{8h}$$

3.2 (b)

For two hinged semi-circular arch with load W applied at any section, the radius vector corresponding to which makes an angle θ with the horizontal.

$$H = \frac{W}{\pi} \sin^2 \theta$$

With load at crown,

$$\theta = \frac{\pi}{2}$$

so $$H = \frac{W}{\pi}$$

3.3 (a)

Moment in an arch = BM in beam – Hy

3.4 (a)

From Maxwell-Betti theorem

$$P_A \Delta_{AB} = M_{BA} \theta_{BA}$$

$$\therefore \quad \theta_{BA} = \frac{10 \times 0.5}{50} = 0.1 \text{ radians}$$

3.5 (b)

For three-hinged semicircular arch carrying udl of w the vertical reaction at hinges.

$$V_A = V_B = WR$$

So horizontal thrust

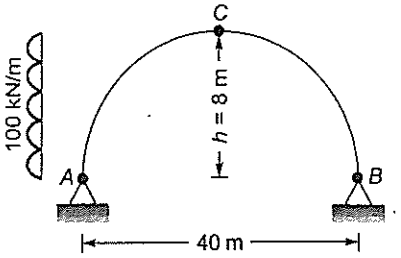
$$\therefore \quad H \times R = V_A \times R - \left(\frac{WR}{2}\right) \times \frac{R}{2}$$

$$H = V_A - \frac{WR}{2} = \frac{WR}{2}$$

3.6 (a)

A three hinged parabolic arch subjected to uniformly distributed load throughout the span, has zero bending moment everywhere because the beam bending moment and bending moment due to horizontal thrust are equal.

3.7 (a)



The vertical reaction at B is

$V_B \times 40 = 100 \times 8 \times 4$

$V_B = 80$ kN

For horizontal thrust at B taking moment of right part about crown (C)

$V_B \times 20 = H \times 8$

$\therefore \quad H = \dfrac{80 \times 20}{8} = 200$ kN

3.8 (c)

The vertical reaction at right springing

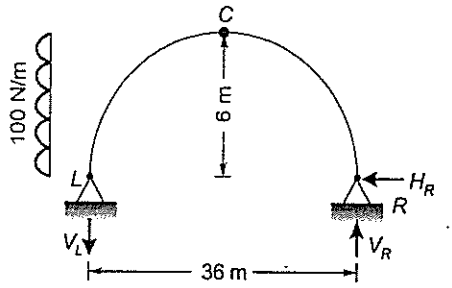
$$V_R = \frac{80 \times 4}{16} = 20 \text{ kN}$$

Horizontal thrust,

$$H = \frac{V_R \times 8}{4} = 40 \text{ kN}$$

3.9 (d)

The vertical reaction at right support



$$V_R = \frac{1000 \times 6 \times 3}{36} = 500 \text{ N}$$

Considering right segment and taking moment about crown.

$H_R \times 6 = V_R \times 18$

$H_R = 1500$ N and $H_L = 6000 - 1500 = 4500$ N

3.10 (b)

The vertical reaction at $B = V_B$ and the horizontal thrust at A and B be H.

Taking moment of forces of right segment about C

$V_B \times 10 = H \times 5$

$H = 2V_B$

$\Rightarrow \quad V_B = 0.5H$

For left segment, taking moment about C.

$V_A \times 8 - H \times 4 - 8 \times 4 = 0$

$V_A = 0.5\,H + 4$

But $\quad V_A + V_B = 8$ kN

$\therefore \quad H = 4$ kN

3.11 (d)

The bending moment throughout the span will be zero for a three hinged parabolic arch subjected to uniformly distributed load.

3.12 (b)

Shear force at a section on left side

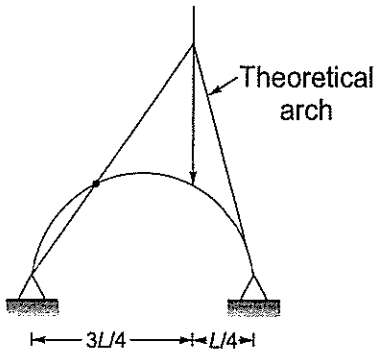
$V = V_x \cos\alpha - H \sin\alpha$

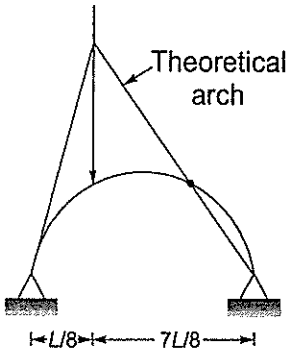
Radial thrust $N = V_x \sin\alpha + H\cos\alpha$

3.13 (a)

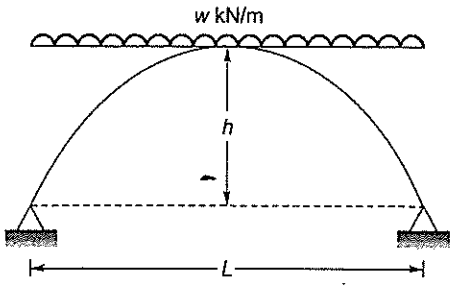
An arch cannot practically be built to the shape of the theoretical arch as the shape of the theoretical arch (funicular polygon) changes with the changing position of the load.

For ex.





3.14 (a)



Equation of parabolic arch

$$y = \frac{4h}{l^2}\left(lx - x^2\right)$$

$$H = \frac{\int \frac{My\,dx}{EI}}{\int \frac{y^2 dx}{EI}}$$

$$N_x = \left(\frac{wl}{2}x - \frac{wx^2}{2}\right)$$

$$H = \frac{\int_0^l \frac{w}{2}\left(lx - x^2\right)\frac{4h}{l^2}\left(lx - x^2\right)dx}{\int_0^l \left[\frac{4h}{l^2}\left(lx - x^2\right)\right]^2 dx}$$

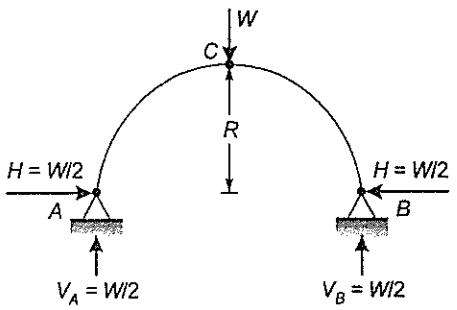
$$= \frac{\frac{w}{2}\left(\frac{4h}{l^2}\right)\int_0^l \left(lx - x^2\right)^2 dx}{\left(\frac{4h}{l^2}\right)^2 \int_0^l \left(lx - x^2\right)^2 dx}$$

$$H = \frac{wl^2}{8h}$$

Moment will be zero in the parabolic arch.

Since loading is symmetric both verticle reactions are equal so $V_A = V_B = \frac{wl}{2}$.

3.15(a)

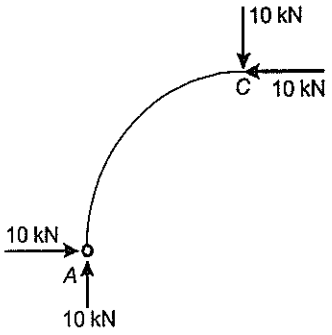


The vertical reaction at both supports is $W/2$. Taking moment about crown for any half portion of the arch.

$$H = V_A = V_B = \frac{W}{2}$$

3.18(c)

The free body diagram of part AC is



So shearing force at C is 10 kN.

3.19 (c)

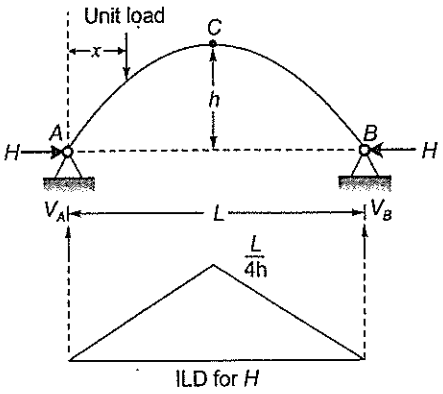
The line of thrust is the locus of the points through which forces pass in a retaining wall or an arch. Linear arch (or theoretical arch) represents the line of thrust. The members of linear arch are subjected to axial compressive forces. Shape of linear arch follows shape of free bending moment diagram.

3.20(d)

A three hinged parabolic arch develops horizontal thrust and vertical reactions. Due to these reaction components the arch is subjected to axial force (normal thrust) at every point.

Cables form an important structural component in suspension bridges and they are subjected to uniformly distributed loading throughout their horizontal span. Thus these type of loaded cables are most widely used.

3.21(d)



When a unit load moves on the span form left to right, the reactions will change at each and every

section on the span. Let the unit load be at a distance x from A, then

$$V_A = \frac{L-x}{L} \text{ and } V_B = \frac{x}{L}$$

Let H be the horizontal thrust; Taking moments about hinge C from right, we get

$$Hh = \frac{x}{L} \times \frac{L}{2} \left[0 \le x \le \frac{L}{2}\right]$$

$$\Rightarrow \quad H = \frac{x}{2h}$$

Horizontal thrust will be maximum when

$$x = \frac{L}{2} \text{ i.e., at the crown.}$$

$$\therefore \quad H_{max} = \frac{L}{4h}$$

3.22 (b)

A suspension bridge with a two-hinged stiffening girder has 4 reaction. (R_1x, R_1y & R_2x, R_2y) and there are three equation equlibrium

$4 - 3 = 1$

3.23 (b)

Let the vertical reaction at A and B be V_A and V_B respectively.

Also let the horizontal thrust be H.

Taking moment about A, we get

$$V_B \times 8 - P \times 5 = 0$$

$$\Rightarrow \quad V_B = 0.625\,P$$

$$\therefore \quad V_A = P - 0.625\,P$$

$$= 0.375\,P$$

Taking moments about C, from right, we get

$$0.625P \times 4 - P \times 1 - H \times 1.5 = 0$$

$$\Rightarrow \quad H = P$$

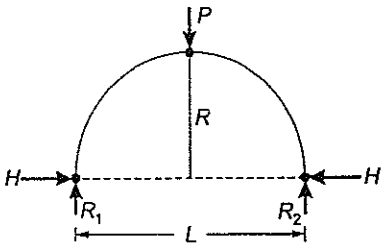
3.25 (b)

- A cable uniformly loaded along horizontal span takes the shape of parabola. The cable uniformly loaded along its length takes shape of catenary.
- The normal force, shear and moment at any section are influenced by horizontal reaction at the support in three hinged arch structure.

3.26 (a)

From symmetry

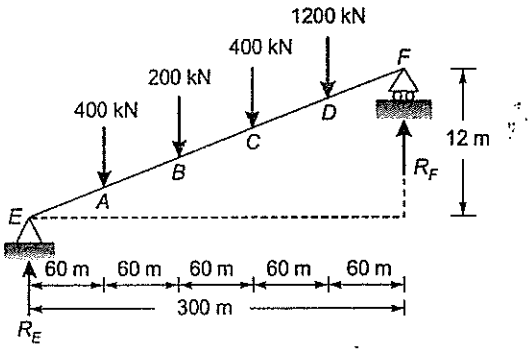
$$R_1 + R_2 = P/2$$



Taking moment about crown = 0

$$\Rightarrow \quad H = \frac{PL}{4R}$$

3.27 (c)



$$\Sigma F_y = 0$$

$$\Rightarrow \quad R_E + R_F = 2200\,\text{kN}$$

$$\Sigma M_E = 0$$

$$\Rightarrow \quad 400 \times 60 + 200 \times 120 + 400 \times 180 + 1200 \times 240 - R_F \times 300 = 0$$

$$\therefore \quad R_F = 1360\,\text{kN}$$

$$\Rightarrow \quad R_E = 840\,\text{kN}$$

Maximum sagging will occur where maximum sagging B.M. exist.

$$BM_A = 840 \times 60 = 50400\,\text{kNm}$$

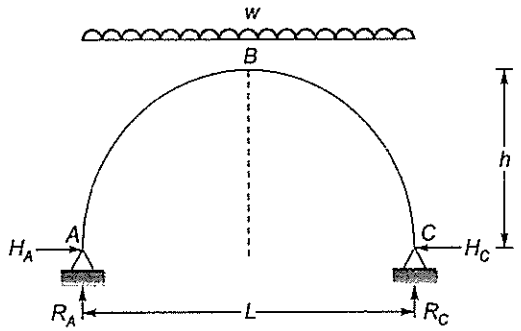
$$BM_B = 840 \times 120 - 400 \times 60 = 76800\,\text{kNm}$$

$$BM_C = 840 \times 180 - 400 \times 120 - 200 \times 60 = 91200\,\text{kNm}$$

$$BM_D = 1360 \times 60 = 81600\,\text{kNm}$$

Maximum sagging BM at point C, therefore maximum sagging will occur at point C.

3.28 (a)



$$R_C = R_A = \frac{wl}{2}$$

$$\Rightarrow \quad \Sigma M_B = 0$$

$$R_A \frac{l}{2} - H_A h - \frac{wl}{2}\frac{l}{4} = 0$$

$$H_A = \frac{wL^2}{4h} - \frac{wL^2}{8h}$$

$$= \frac{wL^2}{8h}$$

3.29 (a)

General exteriors for horizontal thrust in 2-hinged parabolic arches is

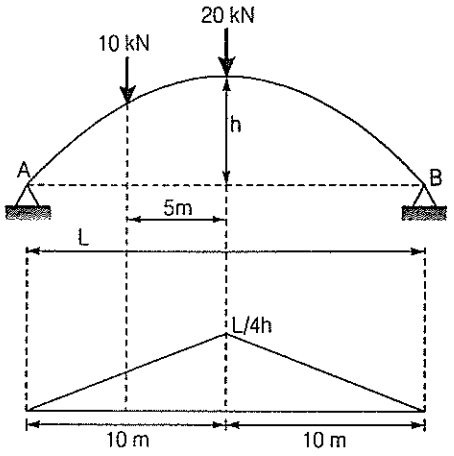
$$A = \frac{\int \frac{M_x\, y dx}{EI} + \alpha t l}{\int \frac{y^2 dx}{EI_C} + \frac{l}{AE} + k}$$

it 'α' increases, H increase

3.30 (c)

In case of a three hinged parabolic arch, the influence line diagram for horizontal thrust is linear.

Maximum thrust will be induced at the supports when 20 kN load is at the crown.



Ordinate of the ILD at a distance of 5 m from

$$A = \frac{5}{10} \times \frac{L}{4h} = \frac{1}{2} \times \left(\frac{20}{4 \times 4}\right) = 0.625 \text{ kN}$$

also $\frac{L}{4h} = \frac{20}{4 \times 4} = 1.25$ kN

Thus, horizontal thrust,

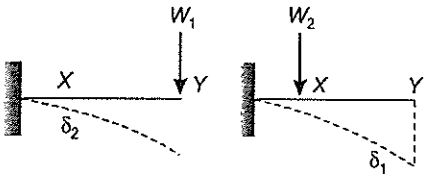
$H = 10 \times 0.625 + 20 \times 1.25$

$= 31.25$ kN

■■■■

4 Methods of Structural Analysis

4.1 In the cantilever beam shown in the given figure, δ_2 is the deflection under X due to load W_1 at Y and δ_1 is the deflection under Y due to load W_2 at X. The ratio of $\frac{\delta_1}{\delta_2}$ is

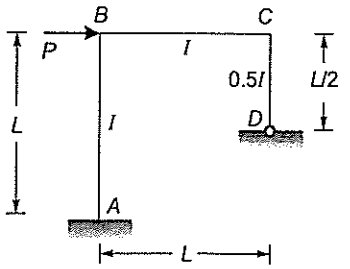


(a) $\frac{W_1}{W_2}$ (b) $\frac{W_2}{W_1 + W_2}$

(c) $\frac{W_2}{W_1}$ (d) $\frac{W_1}{W_1 + W_2}$

[ESE : 1995]

4.2 The given figure shows a portal frame with one end fixed and other hinged. The ratio of the fixed end moments $\frac{M_{BA}}{M_{CD}}$ due to side sway will be

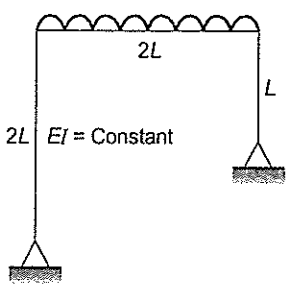


(a) 1.0 (b) 2.0

(c) 2.5 (d) 1.0

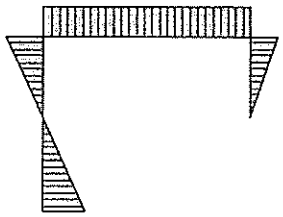
[ESE : 1995]

4.3 The given figure shows a portal frame with loads.

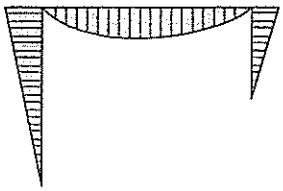


The bending moment diagram for this frame will be

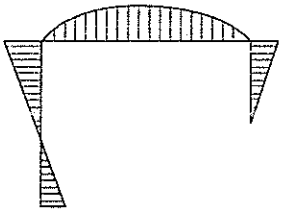
(a)



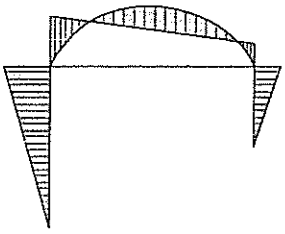
(b)



(c)

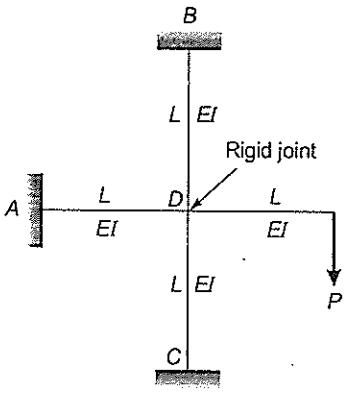


(d)



[ESE : 1995]

4.4 The given figure shows a frame loaded with a single concentrated load *P*. The fixed-end moment developed at support A will be

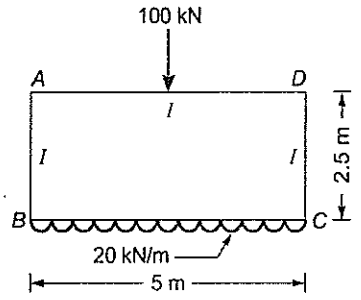


(a) $\frac{PL}{8}$ (b) $\frac{PL}{6}$

(c) $\frac{PL}{4}$ (d) $\frac{PL}{3}$

[ESE : 1995]

4.5 Which one of the following gives the distribution factors for members *AB* and *AD* of box section shown in the given figure?



(a) 0.5 and 0.5 (b) 0.33 and 0.67

(c) 0.67 and 0.33 (d) zero and 1

[ESE : 1995]

4.6 Assertion (A): The concept of strain energy can be used to analyze a statically indeterminate structure.

Reason (R): There is a direct relationship between strain energy of a structure and the slopes and deflection caused in it.

(a) both A and R are true and R is the correct explanation of A

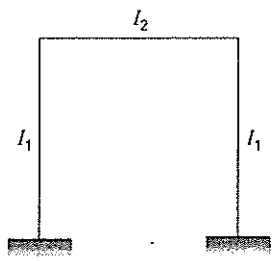
(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 1995]

4.7 The rigid portal frame shown in the given figure will not have any side sway if



I_1 = the moment of inertia of the column cross-section

I_2 = the moment of inertia of the beam cross-section

(a) it is subjected to vertical loading only

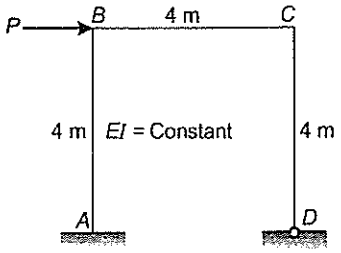
(b) $I_2 = 2I_1$

(c) the loading is symmetrical about its centre line

(d) loaded in any manner

[ESE : 1996]

4.8 For the portal frame shown in the given figure, the shear equation is



(a) $\frac{M_{BC} + M_{CB}}{4} + P = 0$

(b) $\frac{M_{BA} + M_{AB}}{4} + P = 0$

(c) $\frac{M_{BA} + M_{AB}}{4} + \frac{M_{CD}}{4} + P = 0$

(d) $\frac{M_{CD}}{4} + P = 0$

[ESE : 1996]

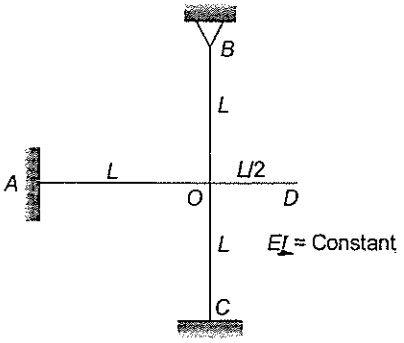
4.9 Due to some point load anywhere on a fixed beam, the maximum free bending moment is *M*. The sum of fixed end moments is

(a) M (b) 1.5M

(c) 2.0M (d) 3.0M

[ESE : 1996]

4.10 A steel frame is shown in the given figure.



If joint O of the frame is rigid, the rotational stiffness of the frame at point O is given by

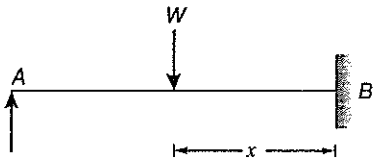
(a) $\frac{11EI}{L}$ (b) $\frac{10EI}{L}$

(c) $\frac{8EI}{L}$ (d) $\frac{6EI}{L}$

[ESE : 1996]

4.11 Consider the following statements:
In the beam shown in the given figure, for all positions of load W (except x = 0)

1. bending moment is maximum at B
2. bending moment is maximum under load
3. deflection is zero at A
4. deflection is zero at B



Which of these statements are correct?

(a) 1 and 3 (b) 2 and 4

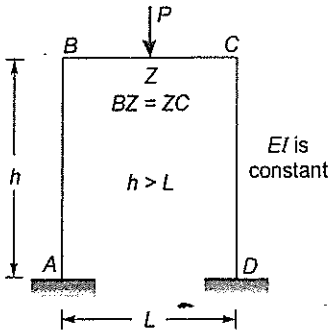
(c) 1 and 4 (d) 1, 3 and 4

[ESE : 1996]

4.12 **Assertion (A):** In the analysis of rigid frames, the usual practice is to consider the strain energy due to flexure only.
Reason (R): The strain energies due to axial and shear forces are usually quite small compared to that of flexure.

[ESE : 1996]

4.13 A symmetrical portal frame $ABCD$ fixed at A and D carries a point load P as shown in the figure below.



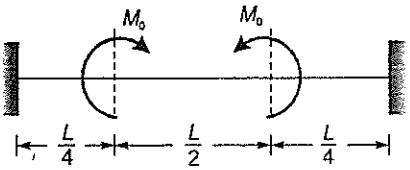
The number of points of contraflexure in the frame will be

(a) one (b) two

(c) three (d) four

[ESE : 1997]

4.14 A fixed beam is subjected to moment M_0 as shown in the figure below. The fixed end moments will be



(a) zero (b) M_0

(c) $M_0/2$ (d) $2M_0$

[ESE : 1997]

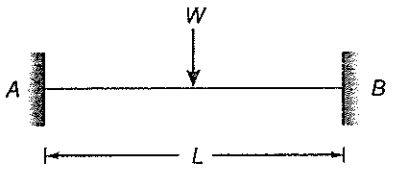
4.15 A fixed beam of uniform section is carrying a point load at its midspan. If the moment of inertia of the middle half length is now reduced to half its previous value, then the fixed end moments will

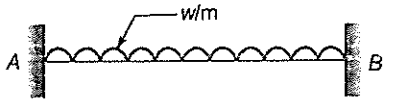
(a) increase
(b) decrease
(c) remain constant
(d) change their directions

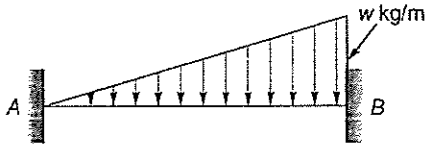
[ESE : 1997]

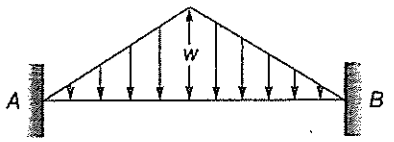
4.16 Match List-I (Fixed beam and various types of loading) with List-II (The moments at A) and select the correct answer using the codes given below the lists:

List-I

A.


B.


C.


D.


List-II

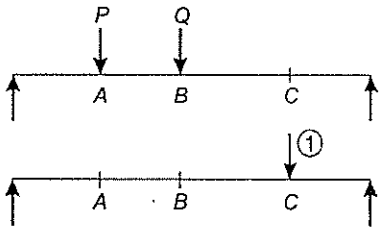
1. $\frac{5WL}{48}$
2. $\frac{WL}{15}$
3. $\frac{WL}{12}$
4. $\frac{WL}{8}$

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	3	4	1	2
(c)	4	3	2	1
(d)	3	4	2	1

[ESE : 1998]

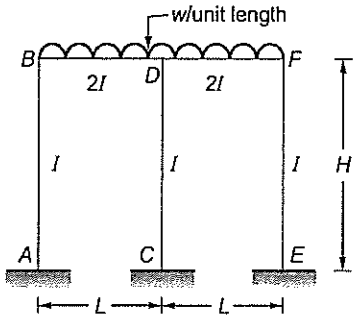
4.17 In the figures shown below x, y and z are the deflections under A, B and C due to loads P and Q. x', y' and z' are the deflection under A, B and C due to unit load at C. The deflection z would equal to



(a) $Px + Qy$ (b) $Px' + Qy'$
(c) $Py + Qx$ (d) $Py' + Qx'$

[ESE : 1998]

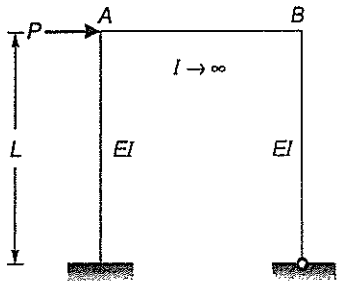
4.18 In the frame shown in the figure below, the value of M_{CD} will be



(a) $\frac{wL^2}{12}$ (b) $\frac{wL^2}{6}$
(c) $\frac{wH^2}{6}$ (d) zero

[ESE : 1998]

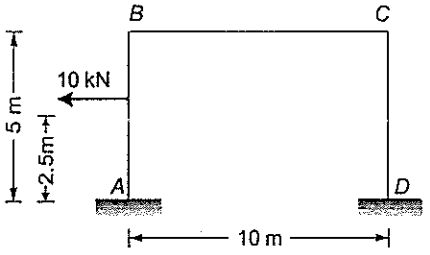
4.19 For the rigid frame shown in the figure below, the force required for moving the girder AB through a horizontal displacement Δ is given by



(a) $\frac{6EI\Delta}{L^3}$ (b) $\frac{8EI\Delta}{L^3}$
(c) $\frac{9EI\Delta}{L^3}$ (d) $\frac{15EI\Delta}{L^3}$

[ESE : 1998]

4.20 For the portal frame shown in the figure below, the final end moments are



$M_{AB} = 15$ kN-m
$M_{BA} = 10$ kN-m
$M_{CD} = 20$ kN-m
The end moment at M_{DC} will be
(a) 10 kN-m (b) 20 kN-m
(c) 30 kN-m (d) 40 kN-m

[ESE : 1998]

4.21 The moment at the indeterminate support of a two-span continuous beam of 6 m each with simple support at the ends carrying a udl of 20 kN/m over only the left span is (Flexural rigidity is the same for both the spans)
(a) 90 kN-m hogging
(b) 45 kN-m hogging
(c) 45 kN-m sagging
(d) zero

[ESE : 1998]

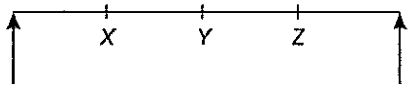
4.22 Assertion (A): In a built-in beam the area of fixed moment diagram equals the area of free moment diagram.

Reason (R): The first theorem of area-moment states that if the difference of slope between two points is zero, then the area of bending moment diagram enclosed between these points is also zero.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

4.23 The beam shown in the given figure carries loads of 20 kN and 40 kN at points *X* and *Y* respectively and produces a deflection of 6 mm at point *Z*.



To produce deflections of 8 mm and 5 mm at *X* and *Y* respectively, the load required at *Z* would be

(a) 20 kN (b) 40 kN
(c) 60 kN (d) 80 kN

[ESE : 1999]

4.24 A portal frame is shown in Figure-I. For EI constant, the deflected shape of the frame will be as in

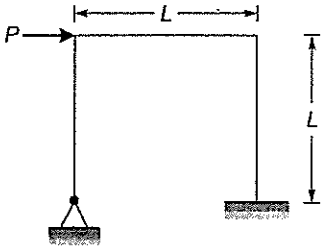
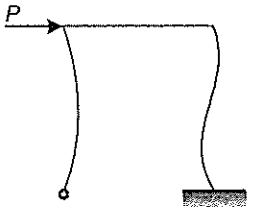
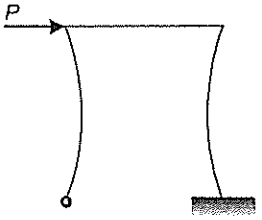


Figure-I

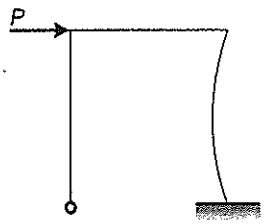
(a)



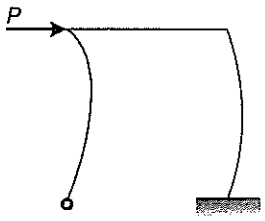
(b)



(c)

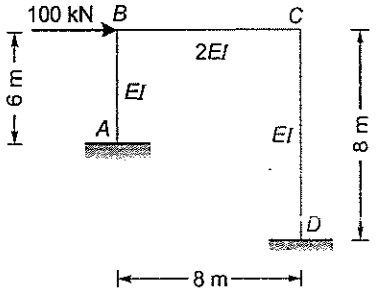


(d)



[ESE : 1999]

4.25 The slope-deflection equation at the end *B* of member *BC* for the frame shown in the given figure will be



(a) $M_{BC} = \frac{4EI}{8}(2\theta_C - \theta_B)$

(b) $M_{BC} = \frac{4EI}{8}(2\theta_B - \theta_C)$

(c) $M_{BC} = \frac{4EI}{8}(2\theta_B + \theta_C)$

(d) $M_{BC} = \frac{4EI}{8}(2\theta_C + \theta_B)$

[ESE : 1999]

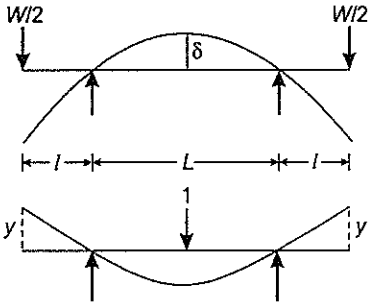
Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false
(d) A is false but R is true

4.26 **Assertion (A):** For the two systems of loads applied separately to the beam as shown in the figure below, the equation for the unknown deflection δ using reciprocal theorem is $\delta = Wy$.



Reason (R): The equation for the unknown deflection δ from influence line diagram for deflection at mid-span is $\delta = Wy$.

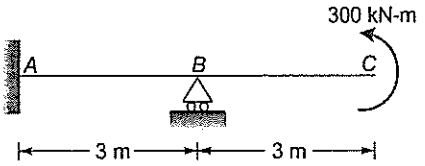
[ESE : 1999]

4.27 **Assertion (A):** In the analysis of rigid frames by the energy method, it is usually considered sufficient to calculate the total strain energy due to flexure only.

Reason (R): The strain energies due to axial force and shear are normally insignificant when compared to that for flexure.

[ESE : 2000]

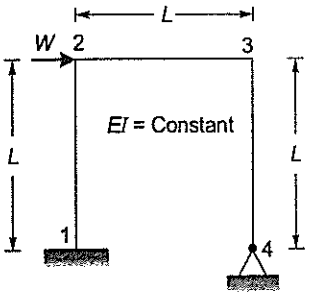
4.28 A propped cantilever of uniform flexural rigidity is loaded as shown in the given figure. The bending moment at fixed end *A* is



(a) 150 kN-m hogging
(b) 300 kN-m sagging
(c) 150 kN-m sagging
(d) 300 kN-m hogging

[ESE : 2000]

4.29 The slope deflection equation at end 2 of the member 1-2 for the frame shown in the figure is given by



(a) $M_{21} = \frac{2EI}{L}(2\theta_1 + 2\theta_2) - WL$

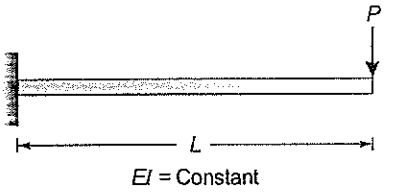
(b) $M_{21} = \frac{2EI}{L}\left(2\theta_1 - \frac{3\delta}{L}\right)$

(c) $M_{21} = \frac{2EI}{L}\left(2\theta_2 - \frac{3\delta}{L}\right)$

(d) $M_{21} = \frac{2EI}{L}\left(\theta_1 + 2\theta_2 - \frac{3\delta}{L}\right) + WL$

[ESE : 2000]

4.30 The strain energy due to bending in the cantilever beam shown in the figure is

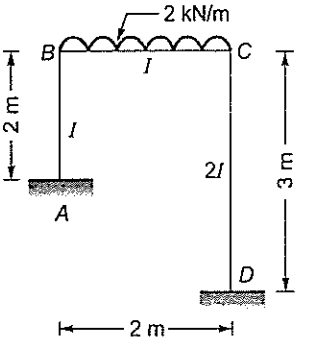


(a) $\frac{PL}{3EI}$ (b) $\frac{P^2L^3}{6EI}$

(c) $\frac{P^2L^3}{EI}$ (d) $\frac{P^2L^3}{2EI}$

[ESE : 2000]

4.31 In the portal frame shown in the given figure, the ratio of sway moments in columns *AB* and *CD* will be equal to



(a) 1/3 (b) 2/3
(c) 9/8 (d) 13/8

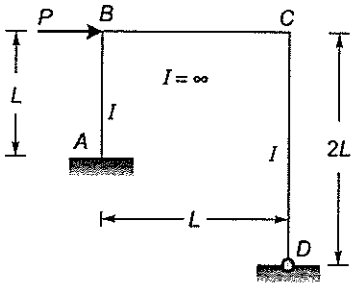
[ESE : 2000]

4.32 If a point load acting at the mid-span of a fixed beam of uniform section produces fixed end moments of 60 kN-m, then the same load spread uniformly over the entire span will produce fixed end moments equal to

(a) 20 kN-m (b) 30 kN-m
(c) 40 kN-m (d) 45 kN-m

[ESE : 2000]

4.33 If an analysis of the frame shown in the given figure indicated final moment (–) 40 kN-m at *A* and *B* of the column *AB*, then the moment M_{CD} will be



(a) –5 kN-m (b) –10 kN-m
(c) –20 kN-m (d) –40 kN-m

[ESE : 2000]

4.34 The portal frame shown in figure-I was analyzed, and the final column moments were found to be as shown in figure-II. The value of *P* is

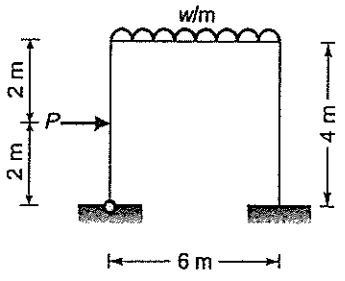


Figure-I

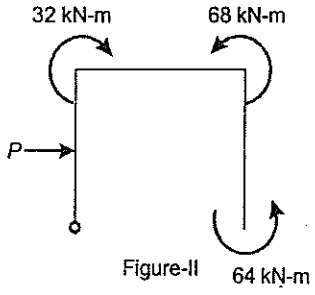
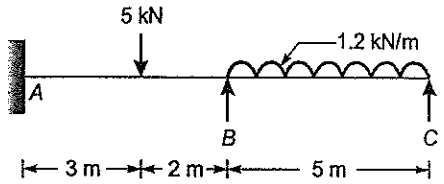


Figure-II

(a) 23 kN (b) 41 kN
(c) 45 kN (d) 50 kN

[ESE : 2000]

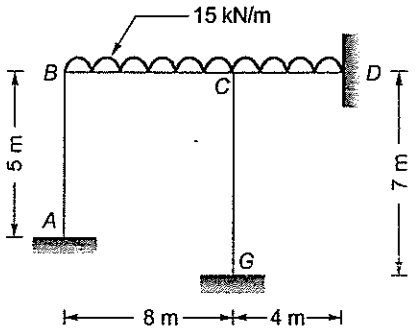
4.35 For the beam *AB* shown in the figure, the fixed end moments at ends *A* and *B* will be respectively



(a) – 3.6 kN-m and + 1.1 kN-m
(b) – 5.4 kN-m and + 4.6 kN-m
(c) – 2.4 kN-m and + 3.6 kN-m
(d) – 3.6 kN-m and + 6 kN-m

[ESE : 2000]

4.36 For the frame shown in the figure, the distribution factors for members *CB*, *CD* and *CG* are respectively (Assume *EI* as constant)

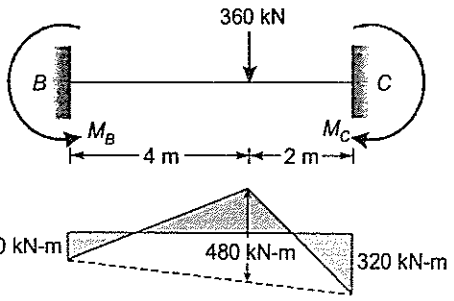


(a) $\frac{14}{29}, \frac{8}{29}$ and $\frac{7}{29}$ (b) $\frac{7}{29}, \frac{14}{29}$ and $\frac{8}{29}$

(c) $\frac{7}{29}, \frac{8}{29}$ and $\frac{14}{29}$ (d) $\frac{14}{29}, \frac{7}{29}$ and $\frac{8}{29}$

[ESE : 2000]

4.37 The load diagram and bending moment of a beam are shown in the following figures:



The shear force at *B* would be

(a) 93.33 kN (b) 120 kN
(c) 146.66 kN (d) 200 kN

[ESE : 2000]

4.38 Which one of the following steps is NOT correct in the application of moment distribution method?
(a) The distribution factors are first computed.
(b) All supports are assumed fixed or locked and fixed end moments are computed for each span, considered separate from every other span.
(c) Each support is now unlocked and the unbalanced moment is distributed to each adjacent span. Then each support is relocked.
(d) After distributing the unbalanced moment to each adjacent span, one half of this amount, with opposite sign is carried over to the other end of respective span.

[ESE : 2001]

4.39 A correct solution of a statically indeterminate structure as per the energy method
(a) is statically admissible
(b) is kinetically consistent
(c) makes the strain energy of the structure a minimum
(d) can be given by (a), (b) and (c) of the question

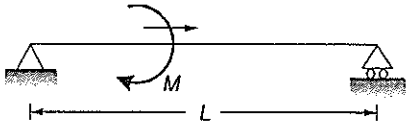
[ESE : 2001]

4.40 A uniform beam of span L is rigidly fixed at both supports. It carries a uniformly distributed load 'w' per unit length. The bending moment at mid span is

(a) $\frac{wL^2}{8}$ (b) $\frac{wL^2}{12}$
(c) $\frac{wL^2}{16}$ (d) $\frac{wL^2}{24}$

[ESE : 2001]

4.41 An applied couple 'M' is moving on a simply supported beam of span L as shown in given figure. The absolute maximum bending moment developed in the beam is



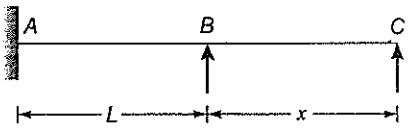
(a) $M/2$ (b) M
(c) $3M/2$ (d) $2M$

[ESE : 2001]

Directions: The following items consists of two statements; one labelled as 'Assertion (A)' and the other as 'Reason (R)'. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.42 Assertion (A): For equal distribution of moment at the support 'B' of the beam shown in the given figure the span length 'x' required $= \frac{3}{4}L$



EI = Constant

Reason (R): For equal distribution of moment for the beam shown in the figure at B, $\frac{I}{L} = \frac{3I}{4x}$.

[ESE : 2001]

4.43 Assertion (A): In a pin-jointed plane frame consisting of straight members the total strain energy U of the system may be expressed as $U = \sum \frac{S^2L}{2AE}$, where S is the axial force, A the uniform cross-sectional area and L the length of the individual member. E is the modulus of elasticity of the member material.
Reason (R): In pin-jointed plane frames only axial forces are present.

[ESE : 2001]

4.44 Assertion (A): The principle of superposition for deflection of beams subjected to a number of loads can be applied in the case of large deformations.
Reason (R): In the principle of superposition, the resultant deflection due to all the loads will be the algebraic sum of the deflections due to each load acting separately.

[ESE : 2002]

4.45 Assertion (A): In the analysis of pin-jointed plane frames, the force method is generally preferable to the displacement method.

Reason (R): The degrees of freedom for pin-jointed plane frames are generally much larger than the degrees of static indeterminacy and thus force method requires less formulation and computation than the displacement method.

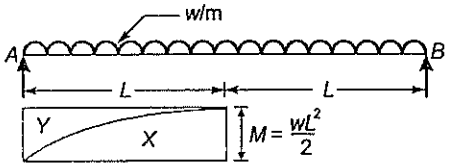
[ESE : 2002]

4.46 Assertion (A): In a built-in beam, the centroids of the fixed moment diagram and the free moment diagram will lie on the same vertical line.

Reason (R): The second theorem of area moment states that, if two points on the elastic line of the beam are at the same level, the moment of area of BMD enclosed between these points about any one of these points is zero.

[ESE : 2002]

4.47 Assertion (A): Area of BMD represented by X in the figure given above equals $\frac{2ML}{3}$.



Reason (R): Area of the figure represented by Y equals $\frac{ML}{3}$.

[ESE : 2002]

4.48 Clapeyron's theorem is applied to

(a) simply supported beam
(b) propped cantilever beam
(c) fixed and continuous beam
(d) continuous beam only

[ESE : 2002]

4.49 For which of the following conditions, the virtual work should be zero according to the Principle of virtual work?

1. A body moving with constant acceleration
2. A body rotating with constant speed
3. A body in equilibrium
4. A body moving with constant momentum

Select the correct answer using the codes given below:

(a) 1 only (b) 1 and 2
(c) 3 only (d) 4 only

[ESE : 2002]

4.50 Consider the following statements:

The principle of superposition is not applicable when

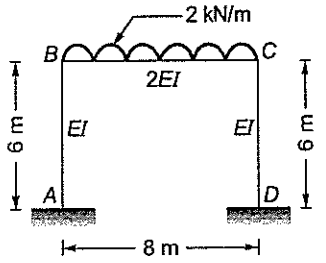
1. the material does not obey Hooke's law.
2. the effect of temperature changes are taken into consideration.
3. the structure is being analyzed for the effect of support settlement.

Which of these statements is/are correct?

(a) 1 only (b) 1 and 2
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 2002]

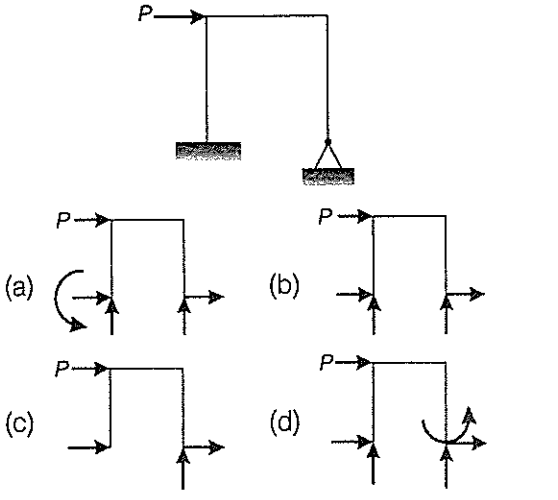
4.51 For the frame shown below, the distribution factors for members BC and BA at joint B are



(a) 0.4, 0.6 (b) 0.5, 0. 5
(c) 0.6, 0.4 (d) 0.7, 0.3

[ESE : 2002]

4.52 Which one among the following is the correct free body diagram for a portal frame shown in Figure given below?



[ESE : 2002]

4.53 Principle of minimum strain energy is

1. a particular case of Castigliano's first theorem
2. a particular case of Castigliano's second theorem

3. applicable only when the redundant supports do not yield
4. applicable even when the redundant supports yield

Select the correct answer using the codes given below:

(a) 1 and 3 (b) 1 and 4
(c) 2 and 3 (d) 2 and 4

[ESE : 2002]

4.54 Match List-I (Method of analysis) with List-II (Unknowns being evaluated) and select the correct answer using the codes given below the lists:

List-I
A. Flexibility Method
B. Stiffness Method
C. Kani's Method
D. Moment Distribution Method

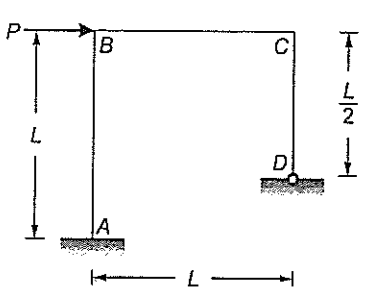
List-II
1. Degrees of freedom
2. Redundant forces
3. Rotations by incremental iteration and unknown sways of plane frames
4. Displacement, rotations and sways of plane frames

Codes:

	A	B	C	D
(a)	2	1	4	3
(b)	3	4	1	2
(c)	2	4	1	3
(d)	3	1	4	2

[ESE : 2003]

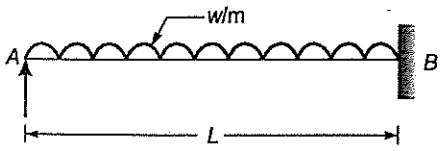
4.55 A portal frame with all the members having the same *EI*, has one end fixed and the other hinged. Due to side-sway, the ratio of fixed end moments $\frac{M_{BA}}{M_{CD}}$ would be



(a) 1 : 1 (b) 1 : 2
(c) 1 : 3 (d) 2 : 1

[ESE : 2003]

4.56 Match List-I with List-II with respect to the diagram given below and select the correct answer using the codes given below the lists:



List-I
A. Moment at *B*
B. Slope at *A*
C. Reaction at *A*
D. Stiffness of *AB*

List-II
1. $\frac{3}{8}wL$
2. $\frac{4EI}{L}$
3. 1.50 M where $M = \frac{wL^2}{12}$
4. $\frac{ML}{4EI}$ where $M = \frac{wL^2}{12}$

Codes:

	A	B	C	D
(a)	2	1	4	3
(b)	3	1	4	2
(c)	3	4	1	2
(d)	2	4	1	3

[ESE : 2004]

4.57 A beam is hinged at end *A* and fixed at *B*. A moment *M* is applied at end *A*. What is the moment developed at end B?

(a) $-M$ (b) M
(c) $M/2$ (d) $-M/2$

[ESE : 2004]

4.58 Consider the following statements:
1. The total potential energy is the sum of strain energy and potential energy due to external loading.
2. The strain energy is always positive.
3. The potential energy is always positive.
4. For equilibrium position the total potential energy is a minimum.

Which of these statements are correct?
(a) 1, 2, 3 and 4 (b) 1, 2 and 4
(c) 2, 3 and 4 (d) 1 and 3

[ESE : 2004]

4.59 A uniform beam of length $2L$ and flexural rigidity EI is fixed at both the ends. What is the moment required for unit rotation at the centre of span?

(a) $\frac{2EI}{L}$ (b) $\frac{4EI}{L}$

(c) $\frac{6EI}{L}$ (d) $\frac{8EI}{L}$

[ESE : 2004]

4.60 An elastic uniform bar of length L and cross-sectional area A is subjected, within its elastic limit, to a rapidly applied tensile force increasing from zero to a final value P. What is the final strain energy stored in the bar after vibrations have ceased? (E is the modulus of elasticity of the bar material.)

(a) $\frac{2P^2L}{AE}$ (b) $\frac{P^2L}{AE}$

(c) $\frac{P^2L}{4AE}$ (d) $\frac{P^2L}{2AE}$

[ESE : 2004]

4.61 In Kani's method hinged column is replaced by an equivalent column fixed at the base with length and stiffness as
(a) 1.5 times the original length and 3/4th stiffness of original column
(b) 1.5 times the original length and stiffness same as original column
(c) same length as original column but stiffness 3/4th of the original column stiffness
(d) twice the original column length and 1.5 times the stiffness of original column

[ESE : 2004]

Directions: The following items consists of two statements; one labelled as 'Assertion (A)' and the other as 'Reason (R)'. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.62 Assertion (A): The slope-deflection method is a stiffness method in which the joint displacements are found by applying the equilibrium conditions at each joint.
Reason (R): The displacements at a joint of a member are independent of the displacements of the member at the far end of the joint.

[ESE : 2004]

4.63 Assertion (A): In the elastic-plastic behaviour of statically indeterminate structures the ultimate load can be calculated from equilibrium considerations without any reference to the stiffness characteristics of the structure.
Reason (R): The ultimate load of a structure is influenced by settlement of supports, thermal stress and residual stresses.

[ESE : 2004]

4.64 Assertion (A): In certain special situations, omitting the shear effect deformations can lead to significant errors.
Reason (R): In general, when the bending moments vary along the length of the beam, the shearing stress resultants will be present and will influence deformation.

[ESE : 2005]

4.65 Assertion (A): The total virtual work done by a system of force acting on a rigid body in equilibrium during a virtual displacement is zero.
Reason (R): If a system of forces acting on a deformable body is in equilibrium, as the body is subjected to a small deformation, the external virtual work done by the force will also be zero.

[ESE : 2005]

4.66 Consider the following statements:
1. In a non-circular structural member subjected to torsion, plane sections before twisting remain plane after twisting.
2. The analysis of indeterminate structures by the theorem of three moments does not give the exact solutions.
3. The work done by the external loads during a virtual deformation is not equal to the increase in internal energy stored in the body.

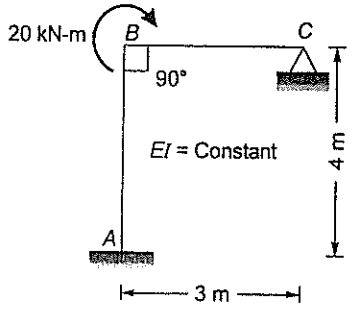
Which of these statements is/are correct?

(a) 1 and 2 (b) 2 and 3

(c) 1 and 3 (d) None

[ESE : 2005]

4.67 The figure given below shows a rigid frame fixed at *A* and hinged at *C*. If a pure moment of 20 kN-m is applied at *B* in the plane of the figure, then what is the moment at the fixed end *A*?



(a) 10 kN-m (b) 7.5 kN-m

(c) 5 kN-m (d) 2.5 kN-m

[ESE : 2005]

4.68 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Strain energy method

B. Slope deflection

C. Moment distribution

D. Kani's method

List-II

1. Successive approximation
2. Flexibility method
3. Iteration process
4. Stiffness method

Codes:

	A	B	C	D
(a)	1	4	2	3
(b)	2	3	1	4
(c)	1	3	2	4
(d)	2	4	1	3

[ESE : 2005]

4.69 Consider the following statements regarding the analysis of indeterminate structures:

1. The force method consists in applying displacement compatibility conditions at the nodes.
2. The stiffness method consists in formulating equilibrium equations at the nodes.

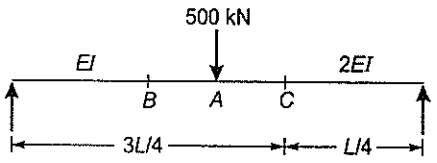
Which of these statements is/are correct?

(a) Only 1 (b) Only 2

(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2006]

4.70 A load 500 kN applied at point *A*, as shown in the figure below, produces a vertical deflection at *B* and *C* of the beam as Δ_B = 10 mm and Δ_C = 15 mm, respectively.



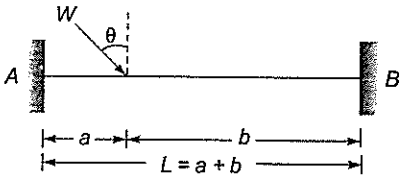
What is the deflection at *A* when loads of 100 kN and 300 kN are applied at *B* and *C*, respectively?

(a) 6 mm (b) 8 mm

(c) 11 mm (d) 12.5 mm

[ESE : 2006]

4.71 For the fixed beam as shown in the figure below, what is the fixed end moment at *A* for the given loading?

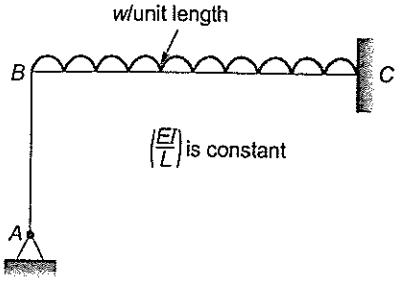


(a) $\frac{Wab^2}{L^2}\cos^2\theta$ (b) $\frac{Wa^2b}{L^2}\cos\theta$

(c) $\frac{Wab^2}{L^2}\cos\theta$ (d) $\frac{Wa^2b}{L^2}\cos^2\theta$

[ESE : 2006]

4.72 What is the ratio of magnitudes of moments in the member BC at the ends B and C in the figure given below?

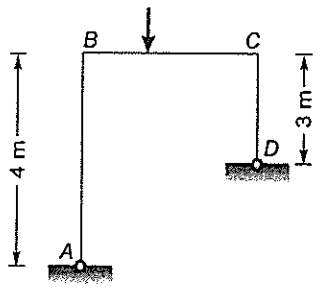


(a) 1 : 1 (b) 3 : 1

(c) 3 : 4 (d) 1 : 3

[ESE : 2006]

4.73 For the frame as shown in the figure below, the final end moment M_{BC} has been calculated as –40 kN-m. What is the end moment M_{CD}?



(a) +40 kN-m (b) –40 kN-m
(c) +30 kN-m (d) –30 kN-m

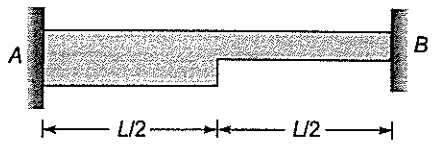
[ESE : 2006]

4.74 Consider the following statements:
Hardy Cross method of moment distribution can be applied to analyze
1. continuous beams including non-prismatic structures
2. continuous beams with prismatic elements
3. structures with intermediate hinges
4. rigid frames

Which of these statements are correct?
(a) 1, 2, 3 and 4 (b) Only 1, 2 and 3
(c) Only 1, 2 and 4 (d) Only 3 and 4

[ESE : 2006]

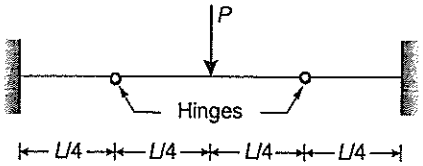
4.75 What is the carry-over factor from A to B while using moment distribution for analyzing beam as shown in the figure given below?

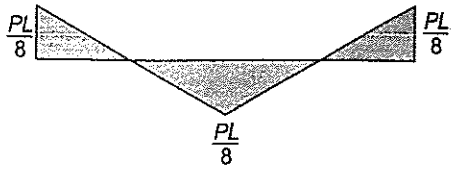


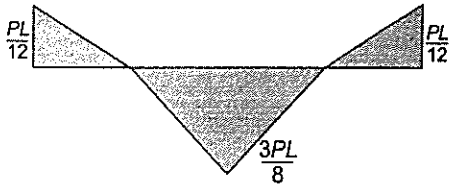
(a) 1/2 (b) 1.0
(c) <1/2 (d) >1/2

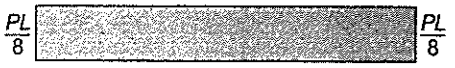
[ESE : 2006]

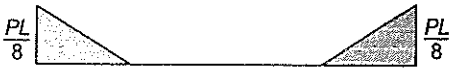
4.76 Which one of the following is the correct BMD for the loaded uniform sized beam as shown in the figure given below?



(a)


(b)


(c)


(d)


[ESE : 2006]

4.77 A fixed beam *AB* of span *L* carries a uniformly distributed load w per unit length. During loading, the support *B* sinks downwards by an amount δ.

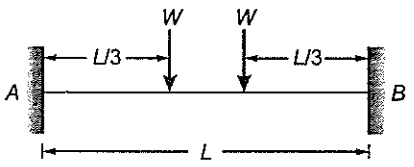
If $\delta = \frac{wL^4}{72EI}$, what is the fixing moment at B?

(a) $\frac{wL^2}{12}$ (b) $\frac{wL^2}{6}$

(c) $\frac{6EI\delta}{L^2}$ (d) Zero

[ESE : 2007]

4.78 What are the bending moments at the ends *A* and *B* of a uniform beam *AB* fixed in direction and position at *A* and *B* when acted upon by two concentrated loads at $\frac{1}{3}$rd span as shown in the figure below?



(a) $\frac{2}{9}WL$ (b) $\frac{4}{9}WL$

(c) $\frac{6}{9}WL$ (d) $\frac{8}{9}WL$

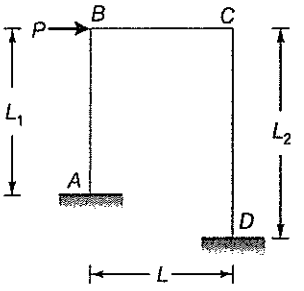
[ESE : 2007]

4.79 Which one of the following statements is correct?
(a) In slope-deflection method, the force are taken as unknowns

(b) In slope-deflection method, the joint rotations are taken as unknowns
(c) Slope-deflection method is not applicable for beams and frames having settlement at the supports
(d) Slope-deflection method is also known as force method

[ESE : 2007]

4.80 The shear equation for the portal frame shown in the figure below will be



(a) $\left(\frac{M_{AB}+M_{BA}}{L_1}\right)+\left(\frac{M_{CD}+M_{DC}}{L_2}\right)+P=0$

(b) $\left(\frac{M_{AB}+M_{BA}}{L_1}\right)+\left(\frac{M_{BC}+M_{CB}}{L}\right)+P=0$

(c) $\left(\frac{M_{BC}+M_{CB}}{L}\right)+\left(\frac{M_{CD}+M_{DC}}{L_2}\right)+P=0$

(d) $\left(\frac{M_{AB}+M_{CD}}{L_1}\right)+\left(\frac{M_{BA}+M_{DC}}{L}\right)-P=0$

[ESE : 2007]

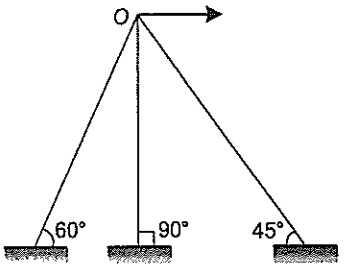
4.81 The displacement method is also referred to as which one of the following?
(a) Minimum strain energy method
(b) Maxwell-Mohr method
(c) Consistent deformation method
(d) Slope-deflection method

[ESE : 2007]

4.82 A beam carries a uniformly distributed load throughout its length. In which of the following configuration will the strain energy be maximum?
(a) Cantilever
(b) Simply supported beam
(c) Propped cantilever
(d) Fixed

[ESE : 2007]

4.83 What is the most appropriate method for analysis of a skeletal plane frame shown in the figure below?



(a) Slope-deflection method
(b) Strain energy method
(c) Moment distribution method
(d) None of the above

[ESE : 2007]

4.84 What is the ratio of load carrying capacity of a fixed beam to that of a cantilever beam of same span, having same maximum bending moment and loaded with uniformly distributed load throughout the span?
(a) 6 (b) 4
(c) 3 (d) 2

[ESE : 2008]

4.85 Consider the following statements:
1. The bending stiffness of a beam cannot be determined from the material characteristics and the dimensions of cross-section of the beam.
2. The boundary conditions of a structure are important in sketching its deflected shape qualitatively as well as for computing the displacement quantitatively.

Which of these statements is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2008]

4.86 When a load is applied to a structure with rigid joints
(a) there is no rotation or displacement of joint
(b) there is no rotation of joint
(c) there is no displacement of joint
(d) there can be rotation and displacement of joint but the angle between the members connected to the joint remains same even after application of the load

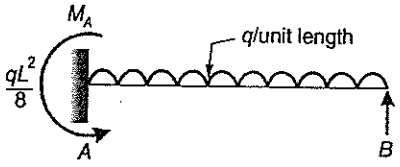
[ESE : 2008]

4.87 By which one of the following methods, an approximate quick solution possible for frames subjected to transverse loads?

(a) By cantilever or portal method
(b) By strain energy method
(c) By moment distribution method
(d) By matrix method

[ESE : 2008]

4.88 The propped cantilever AB carries a uniformly distributed load of q/unit length. In this condition the moment reaction $M_A = \frac{qL^2}{8}$.



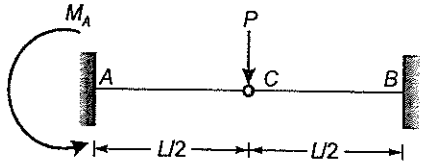
What is the clockwise moment required at B to make the slope of the deflection curve equal to zero ?

(a) $\frac{qL^2}{8}$ (b) $\frac{qL^2}{16}$

(c) $\frac{qL^2}{12}$ (d) $\frac{qL^2}{4}$

[ESE : 2008]

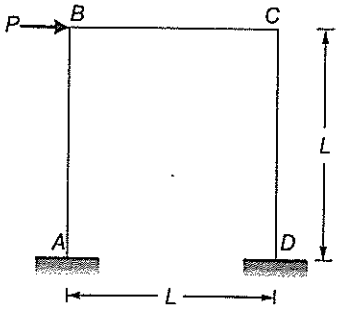
4.89 The fixed beam AB has a hinge C at mid span. A concentrated load P is applied at C. What is the fixed end moment M_A?



(a) PL (b) PL/2
(c) PL/4 (d) PL/8

[ESE : 2008]

4.90 What is the shear equation in slope deflection method for the portal frame shown below?



(a) $\frac{M_{AB}+M_{BA}}{L}+\frac{M_{CD}+M_{DC}}{L}+P=0$

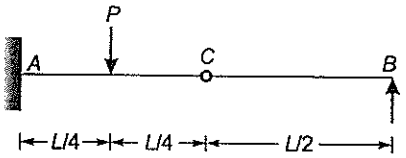
(b) $\frac{M_{AB}+M_{BA}}{L}+\frac{M_{BC}+M_{CB}}{L}+P=0$

(c) $\frac{M_{BC}+M_{CB}}{L}+\frac{M_{CD}+M_{DC}}{L}+P=0$

(d) $\frac{M_{BC}+M_{CB}}{L}+P=0$

[ESE : 2008]

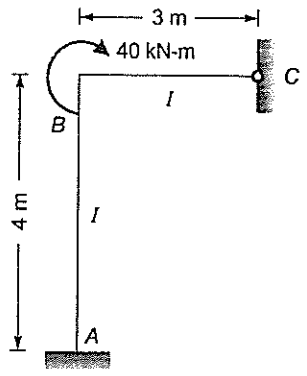
4.91 For the propped cantilever shown in the figure below, a hinge is provided at C. A and B are at the same level. What is the force reaction at the fixed end A?



(a) $4P/3$ (b) P
(c) $3P/4$ (d) $P/2$

[ESE : 2008]

4.92 For the rigid frame shown below, what is the moment reaction at A?



(a) 5 kN-m (b) 10 kN-m
(c) 12.33 kN-m (d) 15 kN-m

[ESE : 2008]

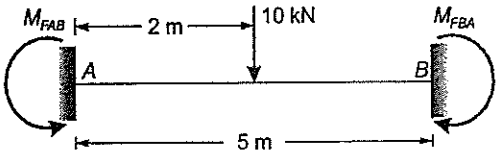
4.93 If the free end of a cantilever of span L and flexure rigidity EI undergoes a unit displacement (without rotation), what is the bending moment induced at the fixed end?

(a) $\frac{3EI}{L^2}$ (b) $\frac{4EI}{L^2}$

(c) $\frac{5EI}{L^2}$ (d) $\frac{6EI}{L^2}$

[ESE : 2008]

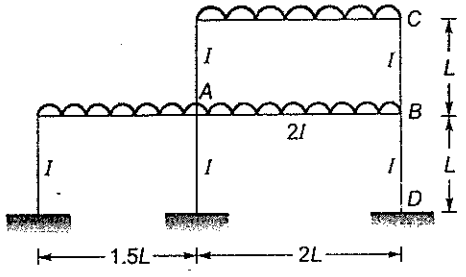
4.94 A fixed beam *AB*, of constant *EI*, shown in the figure below, supports a concentrated load of 10 kN. What is the fixed end-moment M_{FAB} at support *A*?



(a) 4.8 kN-m (b) 6.0 kN-m
(c) 7.2 kN-m (d) 9.5 kN-m

[ESE : 2008]

4.95 In the portal frame shown below, what are the distribution factors for members *BA*, *BC* and *BD* respectively?



(a) $\frac{1}{3}, \frac{1}{3}, \frac{1}{3}$ (b) $\frac{1}{2}, \frac{1}{4}, \frac{1}{4}$
(c) $\frac{2}{3}, \frac{1}{3}, 0$ (d) $\frac{1}{4}, \frac{1}{4}, \frac{1}{2}$

[ESE : 2008]

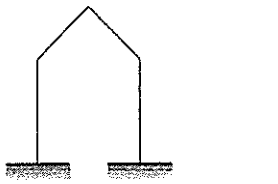
4.96 Match List-I (Analysis Method) with List-II (Structure Type) and select the correct answer using the codes given below the lists:

List-I

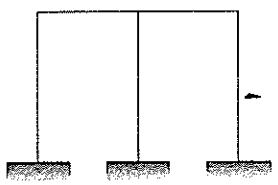
A. Kani's method
B. Force method
C. Column method
D. Displacement method

List-II

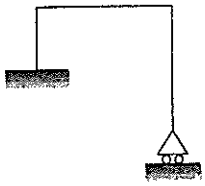
1.



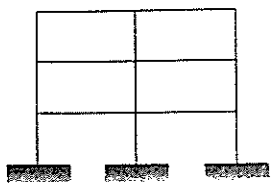
2.



3.



4.



Codes:

	A	B	C	D
(a)	4	1	3	2
(b)	4	3	1	2
(c)	2	1	3	4
(d)	2	3	1	4

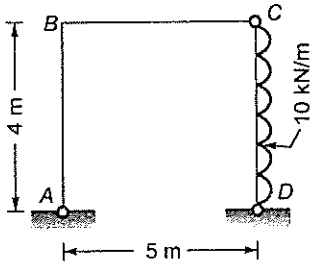
[ESE : 2008]

4.97 **Assertion (A):** Method of moment distribution is classifiable as a force method.
Reason (R): The method consists of computing end moments due to end rotation of the member.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2009]

4.98 What is the value of vertical reaction at *A* for the frame shown in figure below ?



(a) 0 (b) 10 kN
(c) 16 kN (d) 20 kN

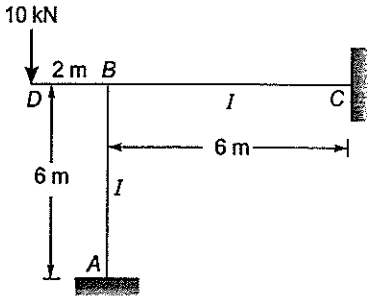
[ESE : 2009]

4.99 A fixed end beam of uniform cross-section is loaded uniformly throughout the span. What is the proportion of the bending moment at the centre to the end moment considering only elastic conditions ?

(a) 1 : 1 (b) 1 : 2
(c) 1 : 4 (d) 2 : 3

[ESE : 2009]

4.100 What is the value of θ_B for the beam shown in figure below?



(a) Zero

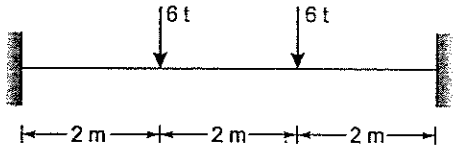
(b) $\frac{15}{EI}$ anticlockwise

(c) $\frac{30}{EI}$ anticlockwise

(d) $\frac{30}{EI}$ clockwise

[ESE : 2009]

4.101 A beam of uniform section fixed at both ends and of span 6 m is acted upon by two concentrated loads of 6 t each as shown in figure below.



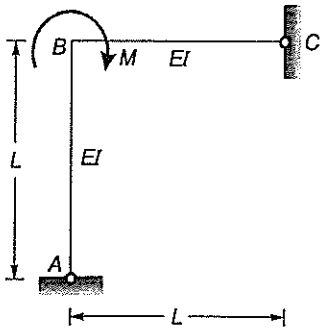
What is the fixed end moment at each end ?

(a) 6 t-m (b) 8 t-m

(c) 10 t-m (d) 12 t-m

[ESE : 2009]

4.102 What is the rotation of the member at *C* for a frame as shown in figure below?

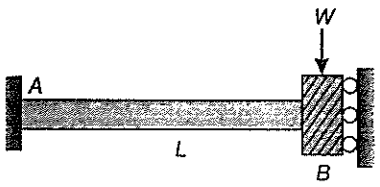


(a) $\frac{ML}{3EI}$ (b) $\frac{ML}{4EI}$

(c) $\frac{ML}{6EI}$ (d) $\frac{ML}{12EI}$

[ESE : 2009]

4.103 What is the bending moment at the end *B* for the guided beam as shown in the figure below considering the beam to be held rigidly at *B* against rotation and to support a load W ?

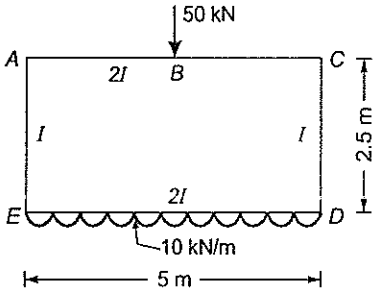


(a) Zero (b) $\frac{WL}{4}$

(c) $\frac{WL}{2}$ (d) WL

[ESE : 2009]

4.104 The distribution factors for members *AE* and *AC* of the box section are



(a) 0.5 and 0.5 (b) 0.6 and 0.4

(c) 0.25 and 0.75 (d) 1 and zero

[ESE : 2010]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

4.105 **Assertion (A):** Force method of analysis is not convenient for computer programming.

Reason (R): Band width of flexibility matrix is much larger compared to that of stiffness matrix.

[ESE : 2010]

4.106 **Assertion (A):** The moment distribution and slope-deflection methods of structural analysis are essentially stiffness methods.
Reason (R): In the moment distribution method, the slope-deflection equations are solved without writing them explicitly.
[ESE : 2010]

4.107 A fixed beam with central point load undergoes a slight settlement at one end.
Select suitable answer from the following:
(a) Moment induced at both ends will be same
(b) Moment induced at the end that has undergoes settlement will be maximum
(c) Moment induced will be maximum at the end having no settlement
(d) Zero moment at the end that has settled
[ESE : 2011]

4.108 An increase in temperature on the top fibre of a simply supported beam will cause
(a) Downward deflection
(b) Upward deflection
(c) No deflection
(d) Angular rotation about neutral axis
[ESE : 2011]

4.109 A propped cantilever beam AB of span L is subjected to a moment M at the prop end B. The moment at fixed end A is

(a) $2M$ (b) $\frac{M}{2}$

(c) M (d) $\frac{3M}{4}$

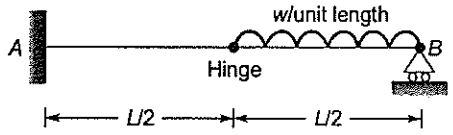
[ESE : 2011]

4.110 The moment-distribution method in structural analysis falls in the category of
(a) Displacement method
(b) Force method
(c) Flexibility method
(d) First order approximate method
[ESE : 2011]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

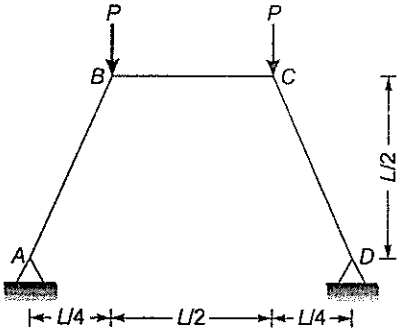
Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.111 **Assertion (A):** The propped cantilever beam shown in figure below is a determinate structure.



Reason (R): At the internal hinge shown, there exists a shear transfer and no bending moment.
[ESE : 2011]

4.112 **Assertion (A):** For the frame shown in figure below, the BM at every cross-section is zero.



Reason (R): The shape of the structure follows the funicular polygon.
[ESE : 2011]

4.113 Consider the following statements:
1. The principle of superposition will hold good for the analysis of linear structural systems only.
2. The stress in a structural member due to several applied forces is the sum of the effects due to each of such forces, applied one at a time, only if the Hooke's law holds good.
3. Internal stresses may not be caused resulting from lack of fit of a structural member.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only
[ESE : 2012]

4.114 Match List-I with List-II and select the correct answer using the code given below the lists:

List-I

A. Axel Bendixen
B. Hardy Cross
C. Winkler
D. St. Venant

List-II

1. The mathematical theory of elasticity
2. Theory of curved bars
3. Slope-deflection method
4. Moment distribution

Codes:

	A	B	C	D
(a)	1	4	2	3
(b)	3	4	2	1
(c)	1	2	4	3
(d)	3	2	4	1

[ESE : 2012]

4.115 The moment required to rotate the near end of a prismatic beam through unit angle without translation, when the far end is fixed, is

(a) $\frac{EI}{L}$ (b) $\frac{2EI}{L}$

(c) $\frac{3EI}{L}$ (d) $\frac{4EI}{L}$

[ESE : 2012]

4.116 Clockwise moments are applied to both the ends of a uniform simply supported beam. If the ratio of the rotation of two ends is 2, then the ratio of the applied moments will be

(a) $\frac{5}{4}$ (b) $\frac{7}{5}$

(c) $\frac{5}{3}$ (d) $\frac{3}{2}$

[ESE : 2013]

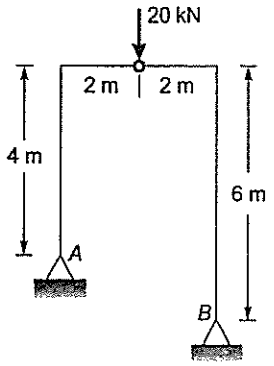
4.117 The force required to produce a unit displacement (translation without rotation) at either one-third point of a fixed beam of span l and of uniform flexural rigidity EI is

(a) $\frac{729EI}{l^3}$ (b) $\frac{724EI}{l^3}$

(c) $\frac{724EI}{3l^3}$ (d) $\frac{729EI}{2l^3}$

[ESE : 2013]

4.118 For the frame shown below, what is the horizontal thrust at A?

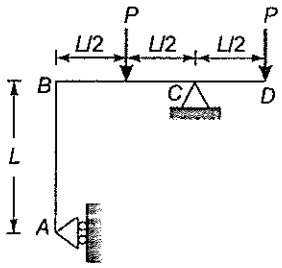


(a) 5 kN (b) 8 kN

(c) 10 kN (d) 12 kN

[ESE : 2013]

4.119 A frame *ABCD* is supported by a roller at *A* and is on a hinge at *C* as shown in the below figure. The reaction at the roller end *A* is given by

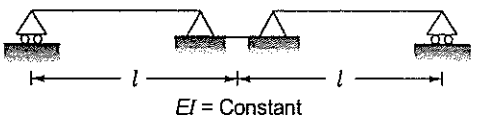


(a) *P* (b) 2*P*

(c) *P*/2 (d) Zero

[ESE : 2013]

4.120 Dead load of the beams is *w*/2 per unit run. Live load on the beams is *w*/2 per unit run. The two segments are hoisted on simple supports; and then continuity is established at the mid-support before live load is applied. The design mid-span moment is

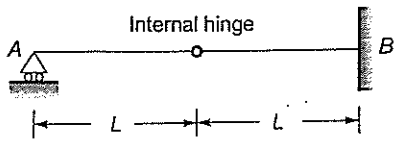


(a) $\frac{wl^2}{8}$ (b) $\frac{wl^2}{16}$

(c) $\frac{wl^2}{32}$ (d) $\frac{3wl^2}{32}$

[ESE : 2013]

4.121 The carry-over factor C_{AB} for the beam as shown in the figure



is

(a) 0.25 (b) 0.50

(c) 0.75 (d) 1.00

[ESE : 2014]

4.122 The ratio of (i) the moment required for unit rotation of the near end of a prismatic member with its far end fixed to (ii) that of a different moment required for the same effect when the far end is hinged is

(a) 1 (b) $\frac{3}{4}$

(c) $\frac{4}{3}$ (d) $\frac{1}{2}$

[ESE : 2014]

4.123 Force method in structural analysis always ensures

(a) compatibility of deformation

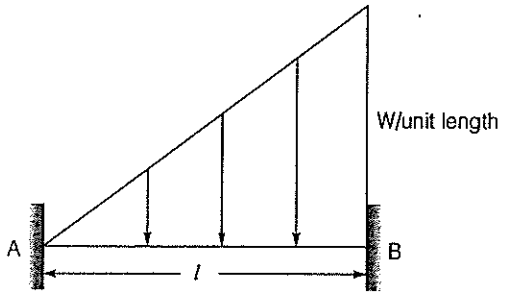
(b) equilibrium of forces

(c) kinematically admissible strains

(d) overall safety

[ESE : 2014]

4.124 Fixed end moments at A and B for the fixed beam shown in the figure, subjected to the indicated uniformly varying load, are respectively



(a) $\frac{Wl^2}{30}$ and $\frac{Wl^2}{20}$ (b) $\frac{Wl^2}{20}$ and $\frac{Wl^2}{30}$

(c) $\frac{Wl^2}{12}$ and $\frac{Wl^2}{8}$ (d) $\frac{Wl^2}{8}$ and $\frac{Wl^2}{12}$

[ESE : 2014]

4.125 Fixed end moments developed at both the ends in a fixed beam of span L and flexural rigidity. EI, when its right-side support settles down by Δ, is

(a) $\frac{6EI\Delta}{L^2}$ (sagging)

(b) $\frac{12EI\Delta}{L^2}$ (sagging)

(c) $\frac{6EI\Delta}{L^2}$ (hogging)

(d) $\frac{12EI\Delta}{L^2}$ (hogging)

[ESE : 2014]

4.126 Which one of the following methods is not classified as a Force Method?

(a) The Theorem of Three Moments

(b) The Moments Distribution Method

(c) The Method of Consistent Deformation

(d) Castigliano's Theorem

[ESE : 2015]

4.127 A single-bay portal frame of height h, fixed at the base, is subjected to a horizontal displacement δ at the top. The base moments developed are each proportional to

(a) $\frac{1}{h}$ (b) $\frac{1}{h^2}$

(c) $\frac{1}{h^3}$ (d) $\frac{1}{h^4}$

[ESE : 2015]

4.128 Carry-over factor at a support/end is defined as

(a) Modulus of Elasticity EI

(b) The ratio of moment produced at the far end to the applied moment at that support end

(c) The value of the moment to be applied to that end to cause a local slope of one radian

(d) 2 EK

[ESE : 2015]

4.129 In the slope-deflection equations, deformations are considered to be caused by

(a) Shear forces and bending moments only

(b) Axial forces, shear forces and bending moments

(c) Axial forces and bending moments only

(d) Bending moments only

[ESE : 2016]

4.130 Force method of analysis of a structure is particularly preferred when

1. The degrees of freedom of the structure become large

2. The structure has less numbers of static, and more numbers of kinematic, indeterminacies
3. The structure has more numbers of static, and less numbers of kinematic, indeterminacies

(a) 1 only (b) 2 only
(c) 3 only (d) 1, 2 and 3

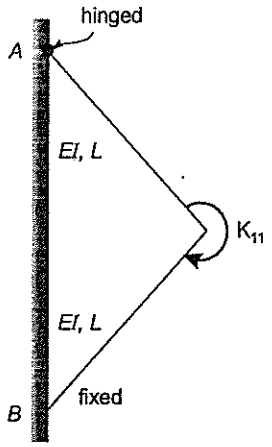
[ESE : 2016]

4.131 The ratio $\left(\frac{s}{t}\right)$ of, (s) stiffness of a beam (of constant EI) at the near end when the far end is hinged, to (t) the stiffness of the same beam at the near end when the far end is fixed, is

(a) $\frac{1}{2}$ (b) $\frac{3}{4}$
(c) $\frac{1}{1}$ (d) $\frac{4}{3}$

[ESE : 2017]

4.132 The rotational stiffness coefficient indicated as K_{11} for the frame with details as shown is



(a) $\frac{9EI}{L}$ (b) $\frac{8EI}{L}$
(c) $\frac{7EI}{L}$ (d) $\frac{6EI}{L}$

[ESE : 2017]

4.133 A single-bay portal frame of height h fixed at the base is subjected to a horizontal displacement Δ at the top. With constant EI, the base moment developed is proportional to

(a) $\frac{1}{h}$ (b) $\frac{1}{h^2}$
(c) $\frac{1}{h^3}$ (d) $\frac{1}{h^4}$

[ESE : 2017]

4.134 **Statement (I) :** Slope-deflection method is a displacement method of analysis.

Statement (II): Forces are the basic unknowns in the slope-deflection method.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

[ESE : 2017]

Answers Methods of Structural Analysis

4.1	(c)	4.2	(a)	4.3	(d)	4.4	(b)	4.5	(c)	4.6	(a)	4.7	(c)	4.8	(c)	4.9	(a)
4.10	(a)	4.11	(d)	4.12	(a)	4.13	(d)	4.14	(c)	4.15	(a)	4.16	(c)	4.17	(b)	4.18	(d)
4.19	(d)	4.20	(b)	4.21	(b)	4.22	(a)	4.23	(c)	4.24	(a)	4.25	(c)	4.26	(c)	4.27	(a)
4.28	(a)	4.29	(c)	4.30	(b)	4.31	(c)	4.32	(c)	4.33	(a)	4.34	(d)	4.35	(c)	4.36	(b)
4.37	(a)	4.38	(d)	4.39	(c)	4.40	(d)	4.41	(b)	4.42	(a)	4.43	(a)	4.44	(d)	4.45	(a)
4.46	(a)	4.47	(a)	4.48	(c)	4.49	(c)	4.50	(d)	4.51	(c)	4.52	(a)	4.53	(c)	4.54	(a)
4.55	(b)	4.56	(c)	4.57	(c)	4.58	(b)	4.59	(d)	4.60	(d)	4.61	(c)	4.62	(b)	4.63	(b)
4.64	(b)	4.65	(c)	4.66	(d)	4.67	(c)	4.68	(d)	4.69	(c)	4.70	(c)	4.71	(c)	4.72	(d)
4.73	(d)	4.74	(a)	4.75	(c)	4.76	(a)	4.77	(d)	4.78	(a)	4.79	(b)	4.80	(a)	4.81	(d)
4.82	(a)	4.83	(b)	4.84	(a)	4.85	(b)	4.86	(d)	4.87	(a)	4.88	(c)	4.89	(c)	4.90	(a)
4.91	(b)	4.92	(b)	4.93	(d)	4.94	(c)	4.95	(a)	4.96	(b)	4.97	(d)	4.98	(c)	4.99	(b)
4.100	(b)	4.101	(b)	4.102	(d)	4.103	(c)	4.104	(a)	4.105	(a)	4.106	(b)	4.107	(c)	4.108	(b)
4.109	(b)	4.110	(a)	4.111	(a)	4.112	(a)	4.113	(a)	4.114	(b)	4.115	(d)	4.116	(a)	4.117	(d)
4.118	(*)	4.119	(d)	4.120	(a)	4.121	(d)	4.122	(c)	4.123	(a, b)	4.124	(a)	4.125	(*)	4.126	(b)
4.127	(b)	4.128	(b)	4.129	(d)	4.130	(b)	4.131	(b)	4.132	(c)	4.133	(b)	4.134	(c)		

Explanations Methods of Structural Analysis

4.1 (c)

Using Betti's theorem

i.e. $P_1\Delta_{12} = P_2\Delta_{21}$

$P_1 = W_1$ and $\Delta_{12} = \delta_1$

$P_2 = W_2$ and $\Delta_{21} = \delta_2$

$$\therefore \quad \frac{\delta_1}{\delta_2} = \frac{W_2}{W_1}$$

4.2 (a)

Due to sway, the deflection of point B will be equal to that of point C.

$$M_{BA} = \frac{6EI\Delta}{L^2}$$

$$M_{CD} = \frac{3E(0.5I)\Delta}{(L/2)^2} = \frac{6EI\Delta}{L^2}$$

$$\therefore \quad \frac{M_{BA}}{M_{CD}} = 1.0$$

Note: This question is not 100% correct. If member BC is not rigid then rotation at B and C is different then equation of M_{BA} is not correct. A similar question was asked in 1998, which is correct.

4.3 (d)

Due to unsymmetrical nature of frame, the lateral translation will occur towards left. Therefore horizontal force of equal and opposite nature will develop on the supports. So correct bending moment diagram will be (d).

4.4 (b)

The eccentric load P can be replaced by a load P and moment PL at the joint D. The distribution factor for member AD, BD and CD will be $\frac{1}{3}$ for each.

$$\therefore \quad M_{DA} = \frac{PL}{3}$$

Carry over factor for the beam AD is $\frac{1}{2}$.

$$\therefore \quad M_{AD} = \frac{PL}{6}$$

4.5 (c)

Relative stiffness

$$K_{AB} = \frac{EI}{2.5};\ K_{AD} = \frac{EI}{5}$$

Distribution factors

$$D_{AB} = \frac{K_{AB}}{K_{AB}+K_{AD}} = 0.67$$

$$D_{AD} = \frac{K_{AD}}{K_{AB}+K_{AD}} = 0.33$$

4.6 (a)

For analysis of indeterminate structures, the method of least work, (a special form of **Castigliano's Second Theorem**) is useful. If R_i is the reaction component, the corresponding displacement Δ_i is zero for a rigid support, then

$$\Delta_i = \frac{\partial U}{\partial R_i} = 0$$

This holds for each of the reaction components (force or moment) in the structure. This method can be used to solve indeterminate beams, trusses, arches and frames. Thus it is based on the relation of displacement (slope or deflection) with the strain energy.

4.7 (c)

The frame is symmetrical in shape and size about a central vertical line. Therefore symmetrical loading about the centre line will not cause any side sway.

4.8 (c)

Shear in column $AB = \frac{M_{AB}+M_{BA}}{4}$

Shear in column $CD = \frac{M_{CD}}{4}$

Shear equation will be

$$\frac{M_{AB}+M_{BA}}{4} + \frac{M_{CD}}{4} + P = 0$$

4.9 (a)

Due to point load, the free bending moment diagram will be triangle.

The fixed end moments M_1 and M_2 can be imposed on it. As the slope at the ends of fixed beam is zero. So the area of total B.M.D. (fixed end moment + free moment) will be zero.

$$\left(\frac{M_1+M_2}{2}\right)L - \frac{1}{2}ML = 0$$

$$\therefore \quad M_1 + M_2 = M$$

4.10 (a)

Rotational stiffness is the ratio of moment and rotation at O. In other words rotational stiffness is the moment required for unit rotation at O.

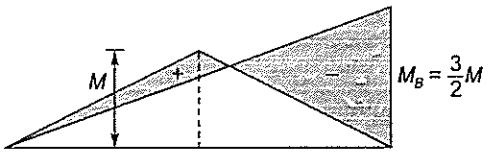
$$M = \frac{4EI}{L} + \frac{3EI}{L} + \frac{4EI}{L} = \frac{11EI}{L}$$

4.11 (d)

The propped cantilever beam shown in the figure will have zero deflection at points A and B. The slope will be zero at end B.

The bending moment will be zero at point A. The bending moment diagram of beam can be obtained by superimposing free moment diagram with fixed end moment diagram on the beam end B. Free moment under the load $M = \frac{W \times (L-x)}{L}$.

It is clear that maximum bending moment occurs at support B.



Moment under the load in the beam $= \frac{M}{4}$

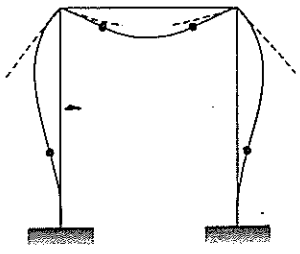
Moment at support $B = \frac{3}{2}M$

4.12 (a)

In analysis of rigid frames, strain energies due to shear and axial forces are neglected as strain energy due to flexure is much higher than strain energies due to shear and axial forces.

4.13 (d)

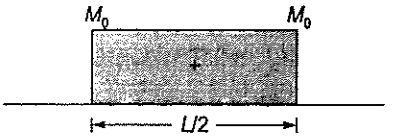
Deflected shape



There will be 1 point of contraflexure in each column and 2 points of contraflexure in beam.

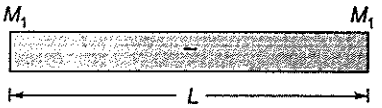
4.14(c)

The free moment diagram of the beam is



Free moment diagram

Superimposing fixed end moment diagram and considering the fact that slopes at both end of the beam is zero.



Fixed moment diagram

Area under fixed moment diagram = Area under free moment diagram

$$M_1 L = M_0 \frac{L}{2}$$

$$\therefore \quad M_1 = \frac{M_0}{2}$$

So the fixed end moments will be $M_0/2$.

4.15 (a)

Since the moment of inertia of middle half is reduced, so the redistribution of moment will occur in such a manner that less strong portion is subjected to less moment and more strong portion is subjected to more moment. From this argument, the fixed end moment will increase.

4.16(c)

For case D, $M = \frac{5}{96} wL^2 = \frac{5}{48} WL$

4.17(b)

From Maxwell Betti's reciprocal theorem

$P_1\Delta_{1,2} = P_2\Delta_{2,1}$

$P_1 \rightarrow$ load system 1 i.e. P and Q loads

$\Delta_{1,2} \rightarrow$ deflection at system 1 due to load at system 2. i.e., x′, y′ for A and B respectively.

$P_2 \rightarrow$ load system 2 i.e. load at C.

$\Delta_{2,1} \rightarrow$ deflection at system 2 due to load at system 1. i.e. z for point C.

$Px' + Qy' = 1 \times z$

$\therefore \quad z = Px' + Qy'$

4.18(d)

The symmetry of the loading and frame does not allow any bending moment in column CD.

4.19(d)

Both ends of left column are fixed, so shear in left column is

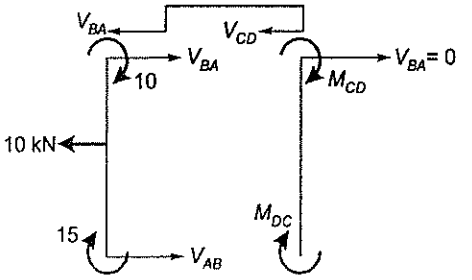
$$V_1 = \frac{12EI\Delta}{L^3}$$

For right column the top end is fixed, so shear in right column is

$$V_2 = \frac{3EI\Delta}{L^3}$$

$$P = V_1 + V_2 = \frac{15EI\Delta}{L^3}$$

4.20(b)



For column AB, taking sum of moment about B is zero.

$$V_{AB} = \frac{M_{AB} + M_{BA}}{5} + 5$$

$$= 10 \text{ kN (towards right)}$$

$\Sigma F_x = 0$ for AB

$\Rightarrow \quad V_{BA} = 0$

$\Sigma F_x = 0$ for BC

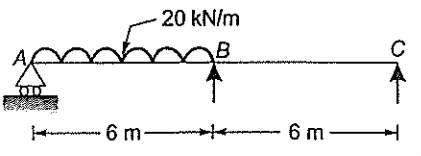
$\Rightarrow \quad V_{CD} = 0$

Now for column CD, taking sum of moment about C is zero.

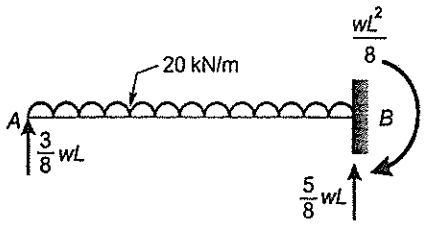
$$V_{CD} = \frac{M_{CD} + M_{DC}}{5} = 0$$

$\therefore \quad M_{DC} = -M_{CD} = -20$ kN-m

4.21(b)



A two span continuous beam as above can be considered to be a propped cantilever beam for any span. So



So hogging moment at support

$$= \frac{wL^2}{8} = \frac{20\times6^2}{8}$$

$$= 90 \text{ kN-m hogging}$$

When the load is on one span only the moment will be half i.e. 45 kN-m

4.23(c)

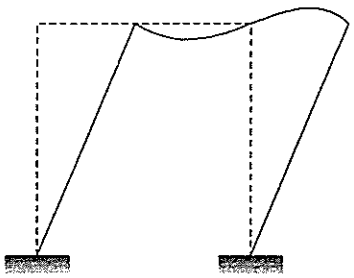
Using Maxwell-Betti's theorem

Load at $Z \times 6 = 20 \times 8 + 40 \times 5$

$$\therefore \text{Load at } Z = \frac{160+200}{6} = \frac{360}{6} = 60 \text{ kN}$$

4.24 (a)

At the fixed support, there can be no angle but in all the options given in the question, the vertical member is shown at some angle with the fixed support. Also the horizontal member will not be horizontal after deflection unless it is a rigid member but it is given that EI is constant. So this is a faulty question. The true deflected shape will be



4.25(c)

$$M_{BC} = \frac{2(2EI)}{8}(2\theta_B + \theta_C) = \frac{4EI}{8}(2\theta_B + \theta_C)$$

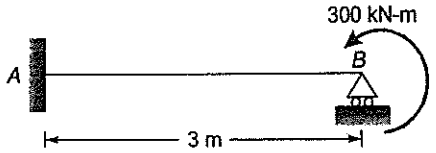
4.26(c)

Statement A is based on Maxwell-Betti's theorem and statement R is based on virtual work method.

4.27 (a)

In analysis of rigid frames, strain energies due to shear and axial forces are neglected as strain energy due to flexure is much higher than strain energies due to shear and axial forces.

4.28(a)



The moment is transferred to point B directly.

If $M_{BA} = 300$ kN-m

$M_{AB} = \frac{1}{2} \times 300 = 150$ kN-m as the carry over factor for beam is $\frac{1}{2}$. The direction of moment will be anticlockwise i.e. hogging.

4.29(c)

$\theta_1 = 0$. So $M_{21} = \frac{2EI}{L}\left(2\theta_2 - \frac{3\delta}{L}\right)$

4.30(b)

$$\text{Strain energy} = \int_0^L \frac{M_x^2 dx}{2EI} = \int_0^L \frac{(Px)^2 dx}{2EI}$$

$$= \frac{P^2L^3}{6EI}$$

4.31(c)

Sway moment in column,

$$AB = \frac{6EI\Delta}{(2)^2} = \left(\frac{3EI\Delta}{2}\right)$$

Sway moment in column,

$$CD = \frac{6E(2I)\Delta}{(3)^2} = \frac{4EI\Delta}{3}$$

4.32(c)

Fixed end moment due to central point load,

$$M_1 = \frac{PL}{8} = 60 \text{ kN-m}$$

The fixed end moment due to uniformly distributed load is $\frac{PL}{12}$. Thus it is equal to 40 kN-m.

4.33(a)

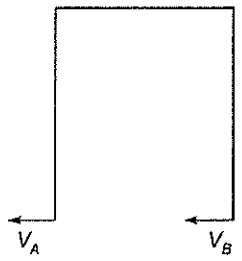
The bending moment for

$$A \text{ and } B = \frac{6EI\Delta}{L^2} = -40 \text{ kN-m}$$

The bending moment for member *CD*

$$M_{CD} = \frac{3EI\Delta}{(2L)^2} = \frac{1}{8}\frac{6EI\Delta}{L^2} = -5 \text{ kN-m}$$

4.34 (d)



Shear force in left column,

$$V_A = \frac{P}{2} - \frac{32}{4} = \left(\frac{P}{2} - 8\right) \text{ kN [Towards left]}$$

Shear force in right column

$$= \frac{64+68}{4} = 33 \text{ kN [Towards left]}$$

Now, $\Sigma F_x = 0$ for frame

$$\frac{P}{2} - 8 + 33 = P$$

$$\Rightarrow \quad P = 50 \text{ kN}$$

4.35 (c)

The fixed end moments can be given as

$$FEM_{AB} = \frac{-Wab^2}{L^2} = -\frac{5\times3\times(2)^2}{(5)^2}$$

$$= -2.4 \text{ kN-m}$$

$$FEM_{BA} = \frac{Wba^2}{L^2} = \frac{5\times2\times(3)^2}{(5)^2}$$

$$= 3.6 \text{ kN-m}$$

4.36 (b)

Member	Relative Stiffness	Distribution factor
CB	*EI*/8	7/29
CD	*EI*/4	14/29
CG	*EI*/7	8/29

4.37 (a)

Shear force at B, taking sum of moment about *C* is zero.

$$V_B = \frac{360\times2}{6} - \left(\frac{320-160}{6}\right) = 93.33 \text{ kN}$$

4.38 (d)

The carry over factor = 0.5 and the moment of same sign is carried over to the other end of respective span.

4.39 (c)

The strain energy is minimum for the structure and it gives a unique solution.

4.40 (d)

BM at fixed support = $\frac{WL^2}{12}$ (hogging)

BM at mid span = $\frac{WL^2}{24}$ (sagging)

4.41 (b)

The moment *M* will develop when the couple is on either of the end.

4.42 (a)

Stiffness of beam *AB* = $\frac{4EI}{L}$

Stiffness of beam *BC* = $\frac{3EI}{x}$

For equal distribution of moment at *B*.

$$\frac{4EI}{L} = \frac{3EI}{x}$$

or $$x = \frac{3}{4}L$$

or $$\frac{I}{L} = \frac{3I}{4x}$$

4.43 (a)

In a pin jointed frame only axial force is present and the strain energy due to axial force in a member is $\frac{S^2L}{2AE}$

Strain energy stored in frame = $U = \Sigma\frac{S^2L}{2AE}$

4.44 (d)

Principle of superposition is valid:

(i) When geometry of structure does not undergo significant change when loads are applied i.e. for Small deformations.

(ii) When response is elastic i.e. Hooke's law is valid.

4.46(a)

For fixed end beam, the area of fixed moment (A_1) diagram and free moment diagram area (A_2) will be equal because slope at both ends is zero. This is from Mohr's first theorem of moment area method. $A_1 - A_2 = 0$

Now the second theorem is about deflectance i.e. deflection of one point from slope at other point. In fixed beam deflectance will also be zero. This is represented by moment of $\frac{M}{EI}$ area. Therefore

$$A_1\bar{x}_1 - A_2\bar{x}_2 = 0 \quad \text{or} \quad \bar{x}_1 = \bar{x}_2$$

$\bar{x}_1$ and $\bar{x}_2$ are distance of centroids of areas A_1 and A_2 from any of the end.

4.47 (a)

Shape of BMD is parabolic

$$\text{Area of X} = \frac{2}{3} \times \text{base} \times \text{height}$$

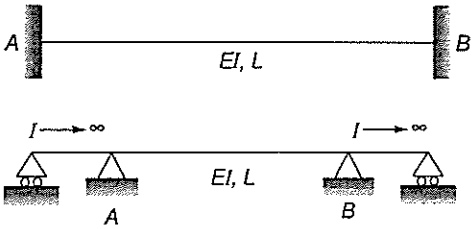
$$= \frac{2}{3} \times L \times M = \frac{2}{3}ML$$

$$\text{Area of Y} = \frac{1}{3} \times \text{base x height}$$

$$= \frac{1}{3} \times L \times M = \frac{1}{3}ML$$

4.48(c)

Clapeyron's theorem of three moment requires at least two spans. A fixed beam can be considered as follows:



Now with the modified beam in the form of continuous beam, the beam can be analyzed with three moment theorem.

4.49(c)

Some scientists like Jean Bernoulli (350 BC) and Leonardo-da-Vinci (1435) imagined a small displacement of the bodies and found out the work done by various forces in the system and stated that if the body is in equilibrium then total work done by the system should be zero. This is called Principle of virtual work. The word virtual is used since in reality there is no actual displacement.

4.50(d)

The principle of super position is applicable when

(i) the material obey Hooke's law.

(ii) the effect of temperature changes are not taken into consideration.

(iii) the supports do not yield.

4.51(c)

Member	Relative stiffness	Distribution factor
BC	$2EI/8 = 0.25EI$	0.6
BA	$EI/6$	0.4

4.52(a)

There will be three reactions (2 forces and one moment) at fixed end and two reactions at hinged support. So (a) represents the free body diagram correctly.

4.53(c)

The principle of minimum strain energy states that among the infinite sets of statically admissible values of redundant forces in a linearly elastic indeterminate structure, the one which is geometrically compatible minimizes the energy. It is a particular case of Castigliano's second theorem. In the case of structures resting on yielding supports, the displacements of the reaction components at the supports should be the same as the settlement of supports for sake of compatibility in equation.

$$\frac{\delta U}{\delta R_i} = \Delta_i$$

In this case also the right hand side of the equation can be made equal to zero if the strain energy U also includes the strain energy of the yielding supports.

4.54(a)

Force or flexibility method uses redundant forces while stiffness or displacement method of analysis uses degrees of freedom.

4.55(b)

$$M_{BA} = \frac{6EI\Delta}{L^2}$$

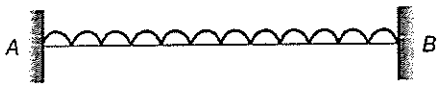
$$M_{CD} = \frac{3EI\Delta}{(L/2)^2} = \frac{12EI\Delta}{L^2}$$

$$\therefore \quad \frac{M_{BA}}{M_{CD}} = \frac{1}{2}$$

Note: Question is not fully correct. Because $M_{AB} = M_{BA} = \frac{6EI\Delta}{L^2}$, when there is no rotation at B otherwise it will be less than this. So can't be calculate easily.

4.56(c)

Consider the fixed beam with uniform loading.



Moment at both supports $(M) = \frac{wL^2}{12}$ and both are hogging in nature.

Now release the end A, the moment $\frac{M}{2}$ will be carried over to the end B. So at end B the moment will be 1.5M.

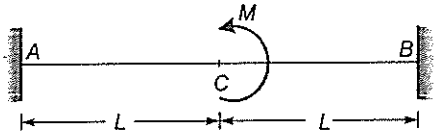
4.57(c)

The carry over factor is $\frac{1}{2}$. So moment developed is $\frac{M}{2}$.

4.58 (b)

Potential energy can be negative as it depends upon datum. E.g. gravitational potential energy is negative where it is calculated wrt datum at infinity.

4.59(d)



Due to moment at mid point there will not be any deflection of the point C, so the point C can be considered to be supported on a roller. Now the stiffness of AC and CB is $\frac{4EI}{L}$ for both. So moment required for unit rotation at C is sum of both members i.e. $\frac{8EI}{L}$.

4.60(d)

Since the load is rapidly applied so strain energy is $P.\Delta$, where

$$\Delta = \frac{PL}{EA}$$

$$\therefore \text{ Strain energy} = \frac{P^2L}{EA}$$

Answer will be (d). Because question is asking about strain energy other vibration is ceased.
Intial workdone = $P\Delta$.

Out of that, at equilibrium position i.e., $\Delta = \frac{PL}{EI}$, 50% workdone will be in the form of kinetic energy which will be converted into heat at the time of ceased virbation.

So strain energy = $\frac{1}{2}P\Delta = \frac{P^2L}{2AE}$.

4.61(c)

Kani's method is extension of slope-deflection method. It is also called rotation contribution method. Some important points are:

(i) The sum of rotation factors at a joint is $\left(-\frac{1}{2}\right)$.

(ii) If an end of a member is fixed, the rotation of that end being zero, the rotation moment is also zero.

(iii) If an end of a member is hinged or pinned, it is convenient to consider it as fixed and take the relative stiffness as $\frac{3}{4}\left(\frac{I}{L}\right)$

4.62(b)

The degree of kinematic indeterminacy or the degree of freedom of a structure is equal to the number of independent displacement components at all the joints. Thus displacement at member ends are independent but moment or reaction is

dependent on displacement components at both ends.

4.63(b)

If any part of structure collapse due to ultimate load then structure is not deteminate at that time. So support settlement and other causes also affect ultimate load.

4.64(b)

For a cantilever beam with point load P at free end

$$\Delta_{total} = \Delta_{bending}\left[1+\frac{3}{10}\frac{E}{G}\left(\frac{h}{L}\right)^2\right]$$

For short beam L/h = 1, the deflection due to shear effects is around 70% that of bending deflection. For L/h = 10, the deflection due to shear is less than 1%. Thus deflections due to shear are small in ordinary and slender beam and are usually neglected. However for short beams or deep beams the deflections due to shear are important.

4.65(c)

Bernoulli's principle of virtual work states that for a rigid body in equilibrium by a system of forces and/or couples, the total virtual work done by this system of forces and/or couples during a virtual displacement is zero.

For a deformable body under equilibrium, the external virtual work is equal to internal virtual work.

4.66(d)

For non-circular sections, the originally plane sections warp out of their own planes.

Theorem of three moments or Clapeyron's theorem is based on method of consistent displacement. It can be developed for continuous beams with or without support moments.

4.67(c)

The stiffness of AB; $K_{BA} = \frac{4EI}{4} = EI$

The stiffness of BC; $K_{BC} = \frac{3EI}{3} = EI$

So distribution factors for both members at joint B is 0.5 and 0.5. The moment at end B in member AB is 20 × 0.5 = 10 kN-m. The carry over factor for AB is $\frac{1}{2}$ so the moment at A is 5 kN-m.

4.68 (d)

Moment distribution is an successive approximation process. Interation process of rotational and displacement moment is done in Kani's method. The closest option is *d*.

4.69 (c)

(i) The **force method** considers redundant forces as unknowns. The displacement compatibility at nodes gives simul-taneous equations for these unknowns.

(ii) Similarly the **stiffness method** considers degree of freedom (independent displacement components at joints) to be unknowns. The force equilibrium equations at the nodes gives the simultaneous equations for these unknowns.

4.70(c)

Using Maxwell-Betti's theorem

$500\Delta_A = 100\Delta_B + 300\Delta_C$

$$\therefore \Delta_A = \frac{\Delta_B}{5}+\frac{3}{5}\Delta_C = \frac{10}{5}+\frac{15\times 3}{5} = 11\text{mm}$$

4.71(c)

The vertical component of load W is $W\cos\theta$.

Fixed end moment at,

$$A = FEM_{AB} = \frac{Wab^2}{L^2}\cos\theta$$

Fixed end moment at,

$$B = FEM_{BA} = \frac{Wa^2b}{L^2}\cos\theta$$

4.72(d)

At joint B:

The stiffness of member BC;

$$K_{BC} = \frac{4EI}{L}$$

The stiffness of member AB;

$$K_{BA} = \frac{3EI}{L}$$

So distribution factors

$$D_{BC} = \frac{K_{BC}}{K_{BC}+K_{BA}} = \frac{4}{7}$$

$$D_{BA} = \frac{3}{7}$$

The fixed end moments

$$FEM_{BC} = -\frac{wL^2}{12}; FEM_{CB} = \frac{wL^2}{12}$$

Releasing moment at B, the member end moment for AB at end B.

$$M_{BA} = -\frac{3}{7}\left(\frac{wL^2}{12}\right)$$

$$M_{BC} = -\frac{4}{7}\left(\frac{wL^2}{12}\right) + \frac{wL^2}{12} = \frac{wL^2}{28}$$

With carry over factor of $\frac{1}{2}$, the moment at end C of member BC is

$$M_{BC} = -\frac{2}{7}\left(\frac{wL^2}{12}\right) + \frac{wL^2}{24}$$

$$= -\frac{9}{7}\left(\frac{wL^2}{12}\right) = \frac{3wL^2}{28}$$

$$\therefore \quad \frac{M_{BC}}{M_{CB}} = \frac{1}{3}$$

4.73(d)

The shear force at end A should be equal and opposite to shear force at D. Let –40 kNm denotes the clockwise moment so moment at end B of column AB is 40 kNm anticlockwise and the shear force at A is 10 kN towards left.

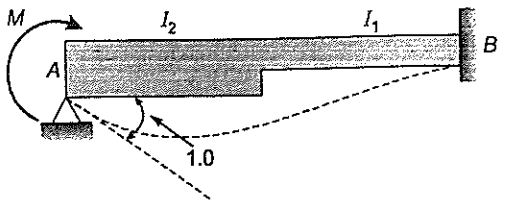
Therefore shear force at D is 10 kN towards right. Thus end moment at C is 30 kNm clockwise or –30 kNm.

4.74(a)

Hardy cross method or moment distribution method can be applied even when there is intermediate hinges.

4.75(c)

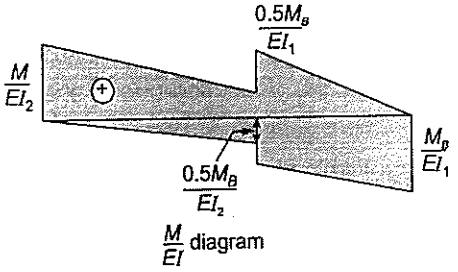
The carry-over factor for prismatic beam is $\frac{1}{2}$. When the beam is non-prismatic, the more-stiff section will be able to take more moment and it will transfer lesser moment to less stiff section. Thus carry over factor is expected to be less than $\frac{1}{2}$. To check the same, release the support A such that rotation at A is 1.0.



$$I_2 > I_1$$

From first theorem of moment area method.

The slope at end A is 1 so the M/EI area between the two will be equal to 1. The moment of M/EI area from support A should be zero because point A has zero deflection from slope at A.



$$\frac{1}{6}\left(\frac{L}{2}\right)^2 \cdot \left(\frac{M}{EI_2} + \frac{0.5M \times 2}{EI_2}\right) + \frac{1}{2} \times \frac{1}{2} \times \frac{0.5M}{EI_1} \times \left(\frac{L}{2} + \frac{L}{6}\right)$$

$$= \frac{1}{2} \times \frac{L}{2} \times \frac{0.5M_B}{EI_2} \times \frac{L}{3} + \frac{1.5M_B}{EI_1} \cdot \frac{L}{4} \times \left(\frac{5L}{18} + \frac{L}{2}\right)$$

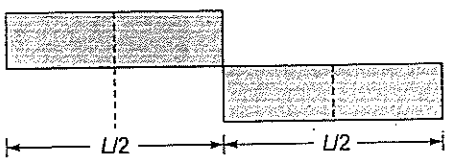
$$\frac{M}{12I_2} + \frac{M}{12I_1} = \frac{0.5M_B}{12I_2} + \frac{3.5M_B}{12I_1}$$

$$\text{COF} = \frac{M_B}{M} = \frac{\left(\frac{1}{I_2} + \frac{1}{I_1}\right)}{\frac{0.5}{I_2} + \frac{3.5}{I_1}} = \frac{(I_1 + I_2)}{(0.5I_1 + 3.5I_2)}$$

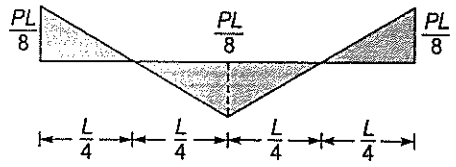
$$\text{COF} = \frac{2(I_1 + I_2)}{(I_1 + 7I_2)} < \frac{1}{2} \text{ for } I_2 > I_1$$

4.76(a)

The presence of two hinges makes the beam determinate. The shear force diagram of the beam is



The bending moment will be zero at two locations of hinges. So the BMD is



4.77 (d)

Fixed end moment at B due to

$$UDL = \frac{wL^2}{12} \text{ (clockwise)}$$

Fixed end moment at B due to sinking of support B

$$= \frac{6EI\delta}{L^2} \text{ (Anti-clockwise)}$$

$$= \frac{6EI \times wL^4}{L^2 \times 72EI}$$

$$= \frac{wL^2}{12} \text{ (Anti-clockwise)}$$

Hence final fixing moment at B

$$= \frac{wL^2}{12} - \frac{wL^2}{12} = 0$$

4.78 (a)

$$FEM_{AB} = \frac{-W \times \frac{L}{3} \times \left(\frac{2L}{3}\right)^2}{L^2} - \frac{W \times \frac{2L}{3} \times \left(\frac{L}{3}\right)^2}{L^2}$$

$$= -\frac{4WL^3}{27L^2} - \frac{2WL^3}{27L^2}$$

$$FEM_{AB} = -\frac{2WL}{9}$$

Since structure is symmetrical so

$$FEM_{AB} = FEM_{BC}$$

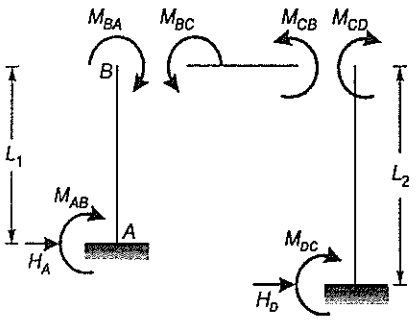
4.79 (b)

In slope deflection joints are considered rigid. It means joints rotate as a whole and the angles between the tangents to the elastic curve meeting at that joint do not change due to rotation. The basic unknowns are joint displacement (θ and δ).

4.80 (a)

Let horizontal reactions at A and D be $H_A(\rightarrow)$ and $H_D(\rightarrow)$ respectively.

Taking moment about B for column AB



$$\therefore H_A \times L_1 = M_{AB} + M_{BA}$$

$$\Rightarrow H_A = \frac{M_{AB} + M_{BA}}{L_1}$$

Similarly

$$H_D = \frac{M_{CD} + M_{DC}}{L_2}$$

For horizontal equilibrium of the structure,

$$H_A + H_D + P = 0$$

$$\Rightarrow \left(\frac{M_{CD} + M_{DC}}{L_2}\right) + \left(\frac{M_{AB} + M_{BA}}{L_1}\right) + P = 0$$

4.81 (d)

Slope deflection method, moment distribution method, Kani's method, stiffness matrix method are all displacement methods.

4.82 (a)

Strain energy stored in cantilever loaded with uniformly distributed load is $\frac{w^2L^5}{40EI}$

Strain energy stored in simply supported beam loaded with uniformly distributed load is $\frac{w^2L^5}{240EI}$

Strain energy stored in fixed propped cantilever with uniformly distributed load is $\frac{w^2L^5}{640EI}$

Strain energy stored in beam loaded with uniformly distributed load is $\frac{w^2L^5}{1440EI}$

4.83 (b)

The plane frame can be analysed by strain energy method by taking any member as redundant.

4.84(a)

Let the intensity of UDL for fixed beam and cantilever be w_1 and w_2 per unit length respectively.

But maximum BM for fixed beam

= Maximum BM for cantilever

$$\Rightarrow \quad \frac{w_1 L^2}{12} = \frac{w_2 L^2}{2}$$

$$\Rightarrow \quad \frac{w_1}{w_2} = \frac{12}{2}$$

$$\Rightarrow \quad \frac{w_1}{w_2} = 6$$

4.85 (b)

$$\text{Bending stiffness} = \frac{EI}{l}$$

Bending stiffness can be determined from material characteristics and dimensions of cross-section of beam.

4.87 (a)

Cantilever method and Portal method are approximate analysis methods.

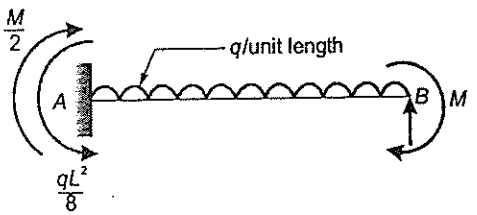
Cantilever method is used to approximately determine the effect of lateral forces experienced by tall buildings. The cantilever method uses the assumption that a tall building with a horizontal load such as wind will behave like a cantilevered beam.

Portal method is an approximate analysis used for analysing building frames subjected to lateral loading. This method is more appropriate for low rise building frames.

4.88(c)

Let the clockwise moment required to make the slope of the deflection curve equal to zero at B be M. Thus a carry over moment of magnitude $M/2$ will be induced at A in clockwise direction.

This is equivalent to fixed beam subjected to UDL.



So,

$$\Rightarrow \quad \frac{qL^2}{8} - \frac{M}{2} = \frac{qL^2}{12}$$

$$\Rightarrow \quad M = \frac{qL^2}{12}$$

4.89(c)

Since the beam is symmetrically loaded, hence the reactions at A and B will be equal.

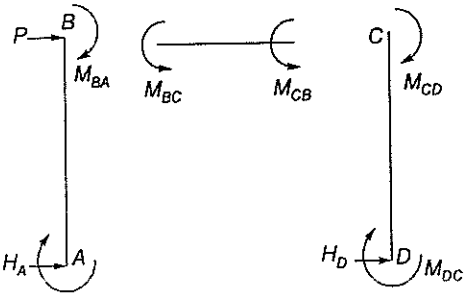
$$\therefore \quad V_B = V_A = \frac{P}{2} (\uparrow)$$

Taking moments about hinge at C from left, we get

$$\frac{P}{2} \times \frac{L}{2} - M_A = 0$$

$$\Rightarrow \quad M_A = \frac{PL}{4}$$

4.90 (a)



Shear equation

$$\overrightarrow{H_A} + \overrightarrow{H_D} + P = 0$$

$$\frac{M_{AB} + M_{BA}}{L_{AB}} + \frac{M_{CD} + M_{DC}}{L_D} + P = 0$$

$$\frac{M_{AB} + M_{BA}}{L} + \frac{M_{CD} + M_{DC}}{L} + P = 0$$

4.91(b)

Let the vertical reaction at B is $V_B (\uparrow)$

$\therefore$ Moments about hinge C from right = 0

$$\therefore \quad V_B \times \frac{L}{2} = 0$$

$$\Rightarrow \quad V_B = 0$$

If reaction at A is $V_A (\uparrow)$, then

$$\Sigma F_y = 0$$

$$\Rightarrow \quad V_A - P = 0$$

$$V_A = P$$

4.92 (b)

Distribution factor of,

$$BA = \frac{I/4}{\frac{3}{4} \times \frac{I}{3} + (I/4)} = 0.5$$

$\therefore$ $M_{BA} = 40 \times 0.5 = 20$ kN-m

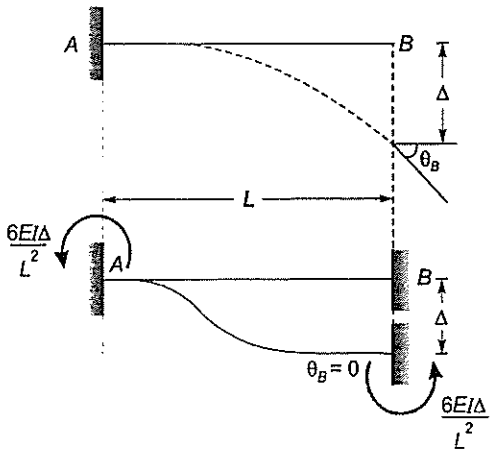
$M_{BC} = 40 \times 0.5 = 20$ kN-m

M_{AB} = Carry over moment

$= \frac{M_{BA}}{2} = \frac{20}{2} = 10$ kN-m

4.93 (d)

The free end of the cantilever will undergo a displacement Δ without any rotation only when it is made fixed. This can be visualized by the given figure



$\therefore$ Moment induced at

$A = \frac{6EI\Delta}{L^2}$ $[\because \Delta = 1]$

$= \frac{6EI}{L^2}$

4.94 (c)

$M_{FAB} = \frac{Pab^2}{L^2}$

Here $P = 10$ kN, $a = 2$ m,

$b = 3$ m, $L = 5$ m

$\therefore$ $M_{FAB} = \frac{10 \times 2 \times 3^2}{5^2} = 7.2$ kN-m

4.95 (a)

DF of $BA = \frac{\text{Relative stiffness of } BA}{\text{Total relative stiffness of members meeting at the joint}}$

$= \frac{2I/2L}{\frac{2I}{2L} + \frac{I}{L} + \frac{I}{L}}$

$= \frac{I/L}{3I/L} = 1/3$

Similarly DF of $BC = 1/3$ and

DF of $BD = 1/3$

4.96 (b)

Frame 3 can be solved by force method as it has minimum static degrees of indeterminacy. Column analogy method can be used for structures having degree of indeterminacy upto 3. Kani's method can be used for solving multilayered frame with structural symmetry.

4.97 (d)

Method of moment distribution is a displacement method.

4.98 (c)

Let the vertical reaction at A be V_A upwards. Taking moments about D, we get

$\Sigma M_D = 0$

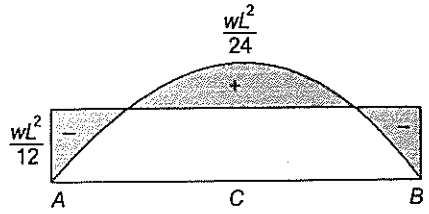
$\Rightarrow V_A \times 5 - 10 \times 4 \times 2 = 0$

$\Rightarrow$ $V_A = \frac{80}{5}$

$\Rightarrow$ $V_A = 16$ kN

4.99 (b)

Bending moment diagram of a fixed beam subjected to UDL throughout the span is given below.



$\frac{M_C}{M_A} = \frac{wL^2/24}{wL^2/12} = \frac{12}{24} = \frac{1}{2}$

4.100 (b)

Using slope deflection equations we get

$M_{BA} = M^F_{BA} + \frac{2EI}{L}(2\theta_B + \theta_A)$

$\Rightarrow$ $M_{BA} = 0 + \frac{2EI}{6}(2\theta_B + 0)$

$\Rightarrow$ $M_{BA} = \frac{2EI\theta_B}{3}$ ...(i)

$$M_{BC} = M_{BC}^F + \frac{2EI}{L}(2\theta_B + \theta_C)$$

$$\Rightarrow \quad M_{BC} = 0 + \frac{2EI}{6}(2\theta_B + 0)$$

$$\Rightarrow \quad M_{BC} = \frac{2EI\theta_B}{3} \qquad ...(ii)$$

Also, $M_{BD} = 10 \times 2 = 20$ kN-m

Equilibrium condition at B,

$M_{BA} + M_{BC} + M_{BD} = 0$

$$\Rightarrow \frac{2EI\theta_B}{3} + \frac{2EI\theta_B}{3} + 20 = 0$$

$$\Rightarrow \frac{4EI\theta_B}{3} = -20$$

$$\Rightarrow \quad \theta_B = \frac{-15}{EI}$$

Negative sign signifies that the rotation at B is anticlockwise

4.101 (b)

The value of fixed end moment at each end will be same as the beam is loaded symmetrically.

$$M = \frac{Pab^2}{L^2}$$

$$\therefore \quad M = -\frac{6 \times 2 \times 4^2}{6^2} - \frac{6 \times 4 \times 2^2}{6^2}$$

$$\Rightarrow \quad M = -\frac{16}{3} - \frac{8}{3}$$

$$\Rightarrow \quad M = -8 \text{ t-m}$$

4.102 (d)

Using slope deflection method we get

$$M_{BC} = M_{BC}^F + \frac{2EI}{L}(2\theta_B + \theta_C)$$

$$\Rightarrow \quad M_{BC} = \frac{2EI}{L}(2\theta_B + \theta_C)$$

Also, $M_{BA} = M_{BA}^F + \frac{2EI}{L}(2\theta_B + \theta_A)$

$$\Rightarrow \quad M_{BA} = \frac{2EI}{L}(2\theta_B + \theta_A)$$

From equilibrium condition, we get

$M_{BC} + M_{BA} = M$

$$\Rightarrow \frac{2EI}{L}(2\theta_B + \theta_C) + \frac{2EI}{L}(2\theta_B + \theta_A) = M$$

$$\Rightarrow \frac{2EI}{L}(4\theta_B + \theta_A + \theta_C) = M$$

$$\Rightarrow \theta_A + 4\theta_B + \theta_C = \frac{ML}{2EI} \qquad ...(i)$$

Also $M_{CB} = M_{CB}^F + \frac{2EI}{L}(2\theta_C + \theta_B) = 0$

$$\Rightarrow \frac{2EI}{L}(2\theta_C + \theta_B) = 0$$

$$\Rightarrow \quad \theta_C = -\frac{\theta_B}{2}$$

Similarly,

$$\theta_A = -\frac{\theta_B}{2}$$

$\therefore$ From (i), we get

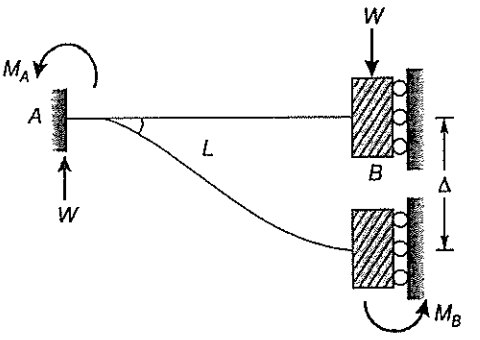
$$-\frac{\theta_B}{2} + 4\theta_B - \frac{\theta_B}{2} = \frac{ML}{2EI}$$

$$\Rightarrow \quad \theta_B = \frac{ML}{6EI}$$

$$\therefore \quad \theta_C = -\frac{\theta_B}{2} = -\frac{ML}{12EI}$$

4.103 (c)

Let deflection at the end B due to load W be Δ.



$$\therefore \quad M_A = \frac{6EI\Delta}{L^2} \text{ (anticlockwise)}$$

$$M_B = \frac{6EI\Delta}{L^2} \text{ (anticlockwise)}$$

Taking moments about B, we get

$-WL + M_A + M_B = 0$

$$\Rightarrow \quad M_A + M_B = WL \qquad [\because M_A = M_B]$$

$$\Rightarrow \quad 2M_B = WL$$

$$\Rightarrow \quad M_B = \frac{WL}{2}$$

4.104 (a)

Distribution factor of AE

$$= \frac{\text{Relative stiffness of } AE}{\text{Total relative stiffness}}$$

$$= \frac{I/2.5}{\frac{I}{2.5}+\frac{2I}{5}} = 0.5$$

Distribution factor of $AC = 1 - 0.5 = 0.5$

4.105 (a)

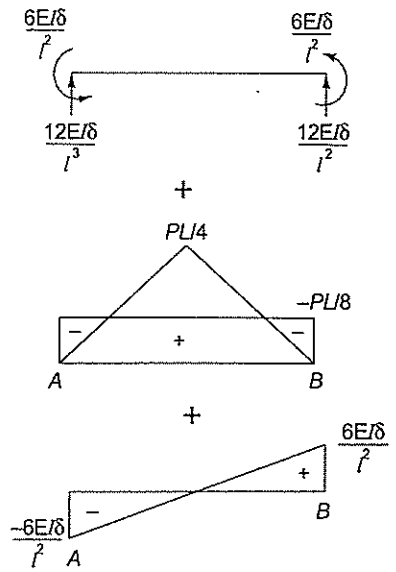
The force method of analysis is not convenient for computer programming as the choice of redundant in not unique. Further, the bandwidth of flexibility matrix in force method is much larger than the stiffness matrix. However it is very useful for hand computation.

4.106 (b)

Slope deflection and moment distribution methods are stiffness methods.

In moment distribution method iterative method for solving slope deflection equations is used to ease calculation.

4.107 (c)

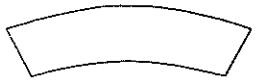


So moment at A will be more than B.

Moment induced will be maximum at end A having no settlement as at support A direction of M_1 and M_2 are same.

4.108 (b)

Top fibre will expand due to increase in temperature and beam will deflect in upward direction.



4.109 (b)

Applying compatibility condition at B

$$\frac{Rl^3}{3EI} = \frac{Ml^2}{2EI}$$

$$\Rightarrow \quad R = \frac{3}{2}\frac{M}{l}$$

at A $\quad \Sigma M = 0$

$$M_A + M - Rl = 0$$

$$\Rightarrow \quad M_A = \frac{3}{2}\frac{M}{l}\cdot l - M$$

$$M_A = \frac{M}{2}$$

4.111 (a)

Total number of unknown reactions = 3 at support A, 1 at support $B = R = 4$

Total number of equilibrium equations = $E = 3 + 1$ extra at internal hinge $= 4$

$DOI = R - E = 0$

Internal hinges are capable of transferring shear and horizontal reaction but not moment

4.112 (a)

On solving the frame by energy method, horizontal reaction is P/2. Funicular polygon for a given frame coincides with the structure and hence BM is zero.

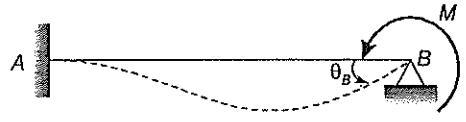
4.113 (a)

In determinate structures, internal stresses does not get developed due to lack of fit. But in indeterminate structure, internal stresses does get developed.

4.114 (b)

Axel Bendixen in 1914 offered a procedure known as slope deflection method.

4.115 (d)



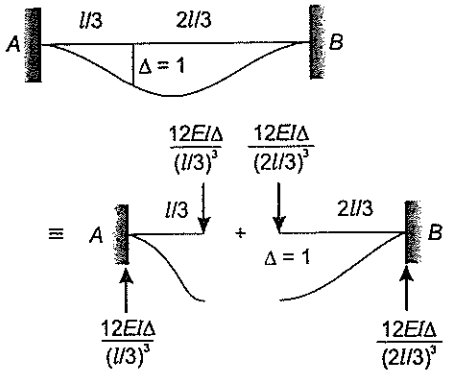
$$\theta_B = \frac{ML}{4EI}$$

$$\Rightarrow \quad M = \frac{4EI}{L}\theta_B$$

Given, $\theta_B = 1$ unit

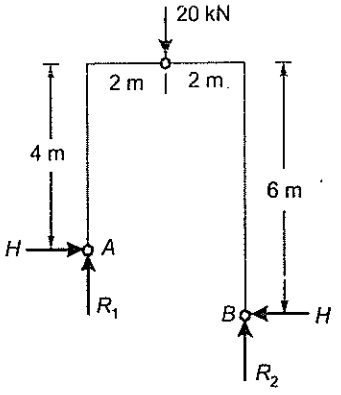
$$\therefore \quad M = \frac{4EI}{L}$$

4.117 (d)



$$P = \frac{12EI\Delta}{(l/3)^3} + \frac{12EI\Delta}{(2l/3)^3} = \frac{729EI}{2l^3} \qquad (\Delta = 1)$$

4.118 (*)



$$H(2) + R_1(4) = 20(2)$$

$$\Rightarrow \quad H + 2R_1 = 20 \qquad \text{...(i)}$$

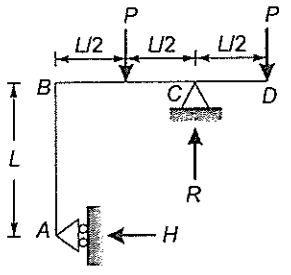
$$H(4) = R_1(2)$$

$$\Rightarrow \quad R_1 = 2H \qquad \text{...(ii)}$$

$$\therefore \quad H = 4 \text{ kN}$$

4.119 (d)

$$R = 2P$$



$$\Sigma M_C = 0$$

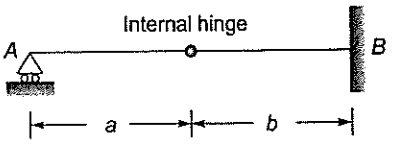
$$P\frac{L}{2} = P\frac{L}{2} + HL$$

$$\Rightarrow \quad H = 0$$

4.120 (a)

For design purposes, total load will be w and hence design moment $\frac{wl^2}{8}$.

4.121 (d)



$$\text{c.o.f.} = \frac{a}{b}$$

Hence, $a = b = L$

$\therefore$ c.o.f. = 1

4.122 (c)

$$\text{Ratio} = \frac{4EI/l}{3EI/l} = \frac{4}{3}$$

4.123 (a,b)

Every method in structural analysis always ensures equilibrium of forces. Thus, Force method in structural analysis ensures-

- Equilibrium of forces
- Compatibility of deformation

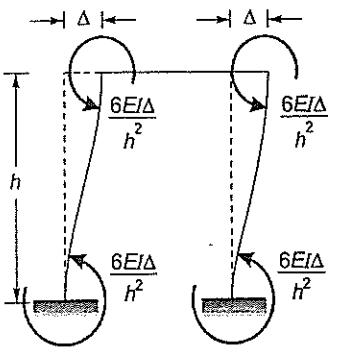
4.125 (*)

$$\frac{6EI\Delta}{L^2} \text{ (anticlockwise)}$$

4.126 (b)

The moment distribution method falls in the category of displacement method.

4.127(b)



Base moments developed are,

$$M = \frac{6EI\Delta}{h^2}$$

$$\therefore \quad M \propto \frac{1}{h^2}$$

4.129 (d)

In slope-deflection method, axial and shear deformations are neglected.

4.130 (b)

In force method, forces are taken as unknowns. If D_s is less it implies less questions. So, it is preferred method.

4.131 (b)

$$s = 3EI/L$$

$$t = 4EI/L$$

So, $$\frac{s}{t} = \frac{3}{4}$$

4.132 (c)

$$k_c = k_{CA} + k_{CB}$$

$$= \frac{3EI}{L} + \frac{4EI}{L} = \frac{7EI}{L}$$

4.133 (b)

$$\text{Base moment} = \frac{6EI\Delta}{h^2}$$

$$\propto \frac{1}{h^2}$$

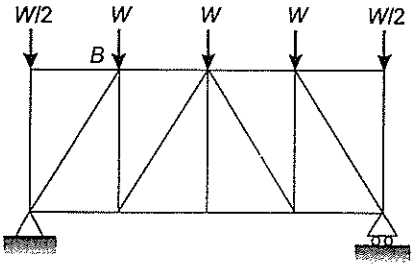
4.134 (c)

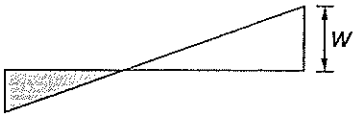
Foam glass is fire proof, rigid and excellent heat insulator. It is used in refrigeration, air conditioning industry, as a substitute for cork.

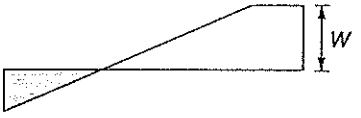
■■■■

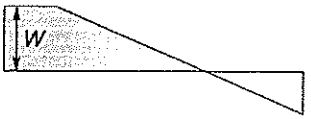
5 Trusses

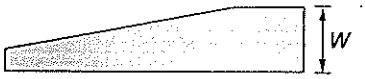
5.1 The correct shape of the force polygon for the joint *B* of the truss shown in the given figure is



(a) 

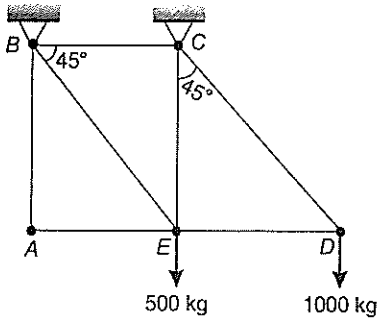
(b) 

(c) 

(d) 

[ESE : 1996]

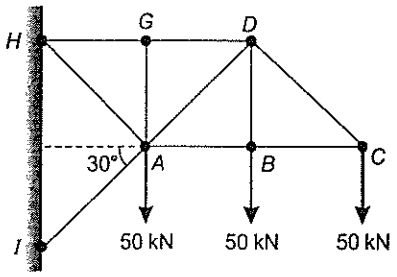
5.2 The cantilever frame shown in the given figure is supported by vertical links at *B* and *C* and carries loads as shown. The force in the bar *AE* is

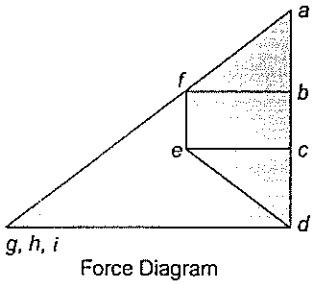


(a) 500 kg (b) 1000 kg
(c) zero (d) 2500 kg

[ESE : 1996]

5.3 In the figure below, force in member *AI* will be





Force Diagram

(a) zero
(b) 150 kN compression
(c) 300 kN compression
(d) 300 kN tension

[ESE : 1997]

5.4 What is the correct sequence of the following steps in the graphical determination of stresses in the members of a loaded plane truss?

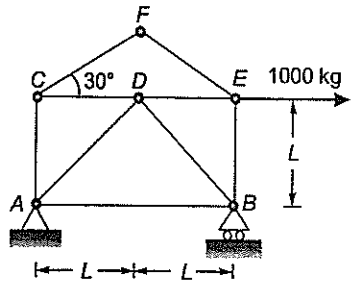
1. Vector diagram to determine the end reactions.
2. Space diagram.
3. Stress diagram.

Select the correct answer using the codes given below:

(a) 1, 2, 3 (b) 1, 3, 2
(c) 2, 1, 3 (d) 2, 3, 1

[ESE : 1997]

5.5 A plane pin-jointed truss is shown in the figure below. The force resisted by the member *AD* is



(a) zero

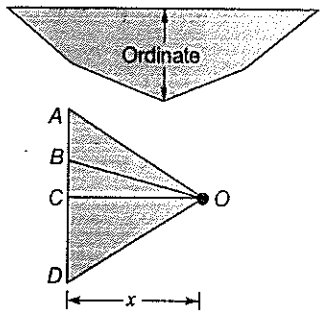
(b) $500\sqrt{2}$ kg (compression)

(c) $500\sqrt{2}$ kg (tension)

(d) $1000\sqrt{2}$ kg (tension)

[ESE : 1997]

5.6 The below figures show funicular diagram and polar diagram of a beam subjected to vertical forces 'x' is the distance of the pole from the vector line. If 'x' is doubled, then the ordinate in the funicular diagram will be

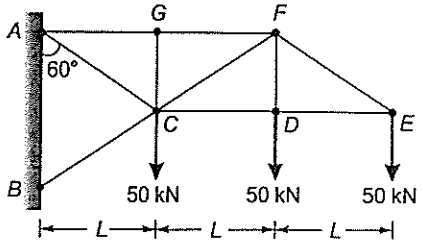


(a) doubled (b) halved

(c) unaffected (d) tripled

[ESE : 1997]

5.7 For the truss shown in the figure, the force in member AC is



(a) 50 kN compression

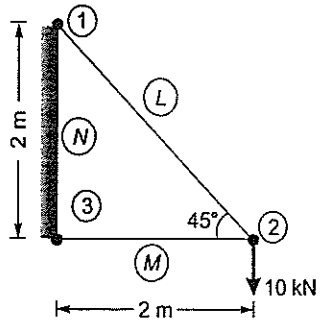
(b) 50 kN tension

(c) $50\sqrt{\frac{3}{2}}$ kN tension

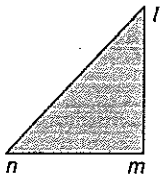
(d) zero

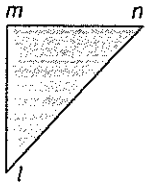
[ESE : 1998]

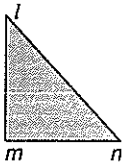
5.8 A cantilever truss with joints labelled as ①, ② and ③ is shown in the given figure. It carries a vertical load of 10 kN at joint ②

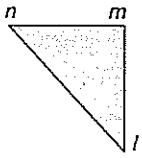


The force diagram drawn at joint ② is represented as

(a) 

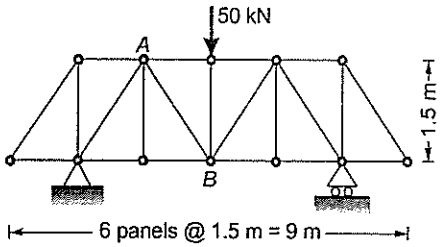
(b) 

(c) 

(d) 

[ESE : 1999]

5.9 The force in the member AB of the truss shown in the given figure is



(a) 25 kN compression

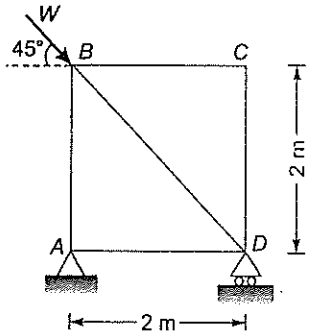
(b) $25\sqrt{2}$ kN tension

(c) $25\sqrt{2}$ kN compression

(d) 25 kN tension

[ESE : 1999]

5.10 Force in the member AB of the frame shown in the given figure will be



(a) zero (b) W

(c) $W\sqrt{2}$ (d) $\frac{W}{\sqrt{2}}$

[ESE : 1999]

5.11 Consider the following assumptions:

1. All members have same cross-sectional area.
2. The bending resistance of all the members is small in comparison with their axial force resistance.
3. All the external loads are applied directly or indirectly at the joints.
4. All joints are idealized to be frictionless hinges.

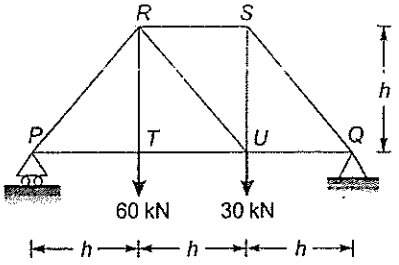
Which of these are the assumptions made in the force analysis of simple trusses?

(a) 1, 2 and 4 (b) 2, 3 and 4

(c) 1, 2 and 3 (d) 3 and 4

[ESE : 2000]

5.12 Consider a loaded truss shown in the given figure.



Match List-I (Member) with List-II (Force) and select the correct answer using the codes below the lists:

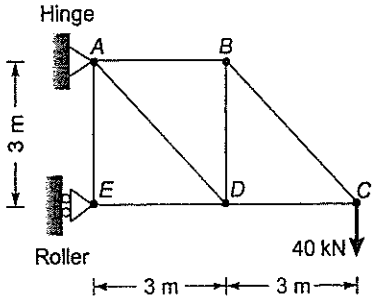
List-I	List-II
A. *PR*	1. 40 kN (Tension)
B. *RS*	2. 40 kN (Compression)
C. *SU*	3. 60 kN (Tension)
D. *RT*	4. $50\sqrt{2}$ kN (Compression)

Codes:

	A	B	C	D
(a)	3	2	1	4
(b)	3	1	2	4
(c)	4	1	2	3
(d)	4	2	1	3

[ESE : 2001]

5.13 The pin-jointed cantilever truss is loaded as shown in the given figure. The force in member *ED* is



(a) 40 kN (Compressive)

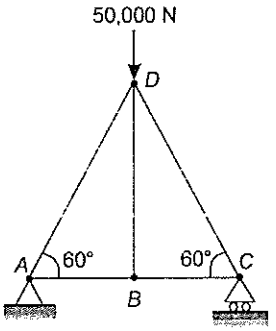
(b) 80 kN (Tensile)

(c) 80 kN (Compressive)

(d) 120 kN (Compressive)

[ESE : 2001]

5.14 In the pin-jointed plane frame shown in the given figure, the force in the member *BD* is



(a) 50000 N (Tensile)

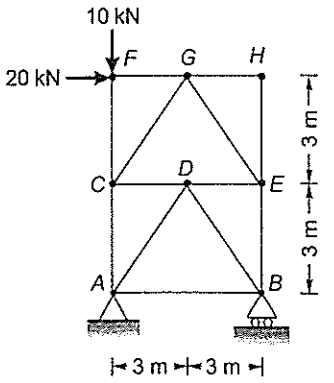
(b) 50000 N (Compressive)

(c) $50000\sqrt{2}$ N (Tensile)

(d) zero

[ESE : 2001]

5.15 A loaded pin-jointed truss is shown in the given figure. The force in member *AC* is



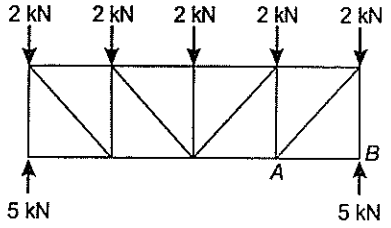
(a) $10\sqrt{2}$ kN (Tensile)

(b) $10\sqrt{2}$ kN (Compressive)

(c) zero
(d) 10 kN (Tensile)

[ESE : 2001]

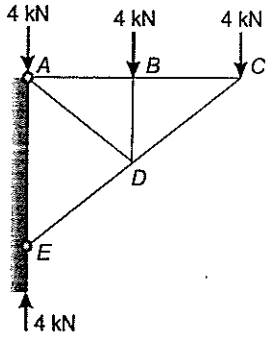
5.16 The force in member AB is



(a) 5 kN compression
(b) 2 kN compression
(c) zero
(d) 7 kN compression

[ESE : 2002]

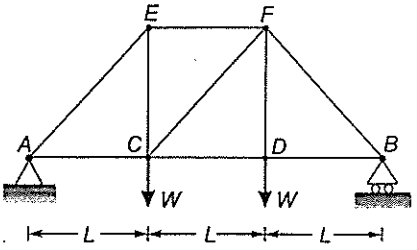
5.17 The force in the member *BD* of the truss shown in the figure given below is



(a) 4 kN tensile
(b) 4 kN compressive
(c) zero
(d) 12 kN compressive

[ESE : 2002]

5.18 In the truss shown in the figure given below, which one of the following members has no force induced in it?



(a) *CD* (b) *CE*
(c) *CF* (d) *DF*

[ESE : 2002]

5.19 A joint of a roof truss has been isolated and shown in Fig-I. The force polygon for the joint is shown in Fig-II. Member '*a*' is in compression, member '*d*' is in tension.

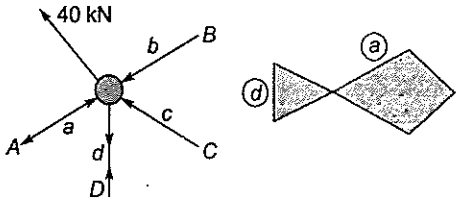
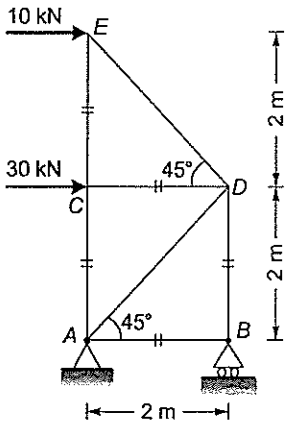


Fig-I (Free body diagram for joint) Fig-II (Force polygon)

Which one of the following is correct?
(a) Both b and c are in tension
(b) Both b and c are in compression
(c) b is in tension; c is in compression
(d) b is compression; c is in tension

[ESE : 2002]

5.20 A pin-jointed truss is loaded as shown in the figure below. Match List-I (Member) with List-II (Force Induced) and select the correct answer using the codes given below the lists:



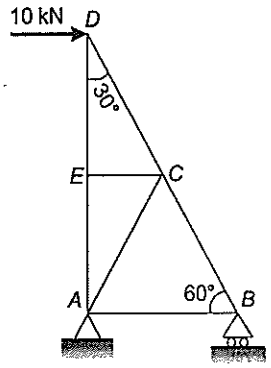
List-I	List-II
A. Member *AB*	1. 30 kN
B. Member *AC*	2. 50 kN
C. Member *BD*	3. zero
D. Member *CD*	4. 10 kN

Codes:

	A	B	C	D
(a)	3	2	1	4
(b)	4	3	2	1
(c)	3	4	2	1
(d)	4	3	1	2

[ESE : 2003]

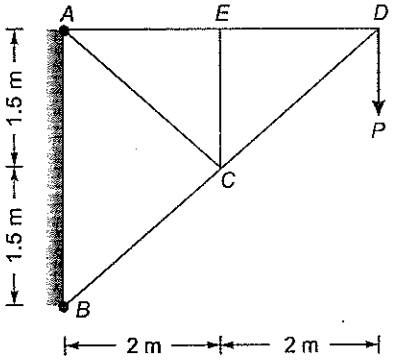
5.21 Member(s) of the frame shown below which carries/carry zero force is/are



(a) *EC* only (b) *EC* and *AB*
(c) *EC* and *AC* (d) *EC*, *AC* and *AB*

[ESE : 2003]

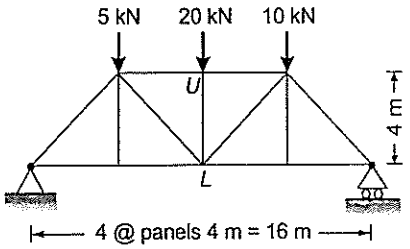
5.22 What is the force in the member *CE* of a cantilever truss shown in the adjoining figure?



(a) *P*(tensile) (b) *P*(compression)
(c) 2*P*(tensile) (d) zero

[ESE : 2003]

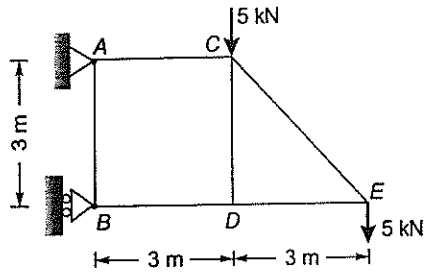
5.23 The diagram below shows a plane truss. What is the force in vertical member *UL* of the truss?



(a) 35 kN (b) 30 kN
(c) 20 kN (d) 15 kN

[ESE : 2004]

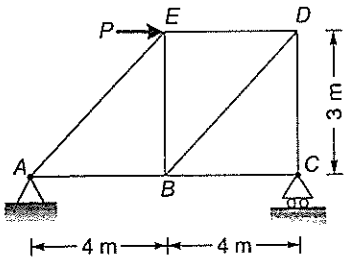
5.24 The diagram below shows a truss subjected to loading as indicated. What is the force induced in the member *AB*?



(a) 5 kN (b) 10 kN
(c) Zero (d) $5\sqrt{2}$kN

[ESE : 2004]

5.25 What is the ratio of the forces in the members AB, BE and AE of the pin-jointed truss shown in the figure given below?



(a) 5 : 4 : 3 (b) 4 : 3 : 5
(c) $\left(\frac{1}{4}\right):\left(\frac{1}{3}\right):\left(\frac{1}{5}\right)$ (d) None of these

[ESE : 2005]

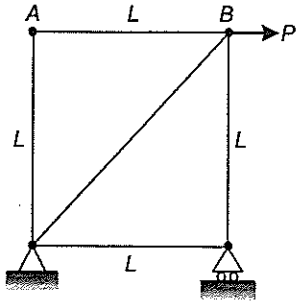
5.26 Consider the following statements:
Williot-Mohr diagram is used to determine the deflection in
1. an arch
2. a truss
3. a rigid frame
Which of these statements is/are correct?
(a) Only 1 (b) Only 2
(c) Only 3 (d) 1, 2 and 3

[ESE : 2006]

5.27 A propped cantilever *AB*, with fixed edge *A* is propped at *B* and carries uniformly distributed load over the entire span. If the prop heaves up (displaces upward), which one among the following is true if prop reaction = R_B, Moment at $A = M_A$?
(a) Both R_B and M_A will increase
(b) R_B will increase, M_A will decrease
(c) R_B will decrease, M_A will increase
(d) Both R_B and M_A will decrease

[ESE : 2006]

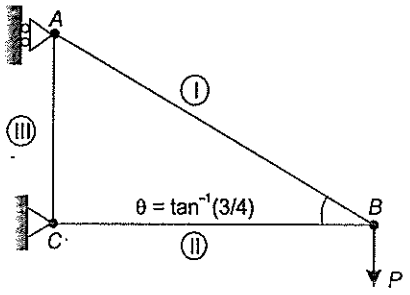
5.28 What is the force in member *AB* of the pin-jointed frame as shown below?



(a) *P* (Tension) (b) *P* (Compression)
(c) $P/\sqrt{2}$ (Compression) (d) Zero

[ESE : 2006]

5.29 A cantilever truss carries a concentrated load P as shown in the figure below:

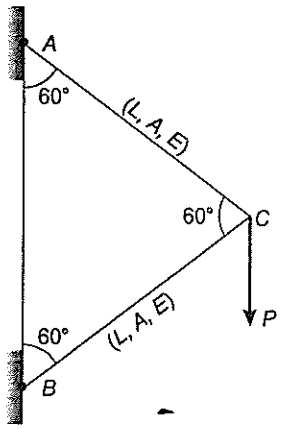


What are the magnitudes of axial forces in the members I, II, and III, respectively?

(a) 1.00P, 1.33P and 1.67P
(b) 1.67P, 1.33P and 1.00P
(c) 1.33P, 0.75P and 0.60P
(d) 0.60P, 0.75P and 1.00P

[ESE : 2006]

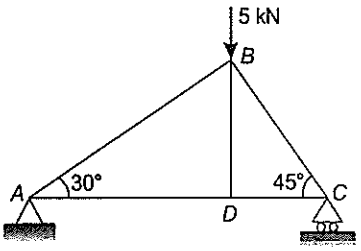
5.30 What is the vertical deflection of joint *C* of the frame shown below?



(a) *PL/AE* (b) *2PL/AE*
(c) *PL/2AE* (d) *3PL/AE*

[ESE : 2007]

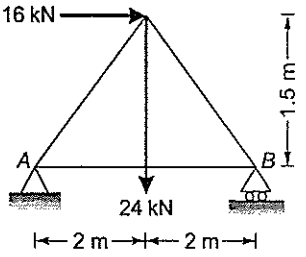
5.31 What is the magnitude of the force in the member *BD* in the figure given below?



(a) 5 kN (b) 7 kN (approx.)
(c) $4\sqrt{2}$ kN (d) Zero

[ESE : 2007]

5.32 What are the magnitudes of horizontal and vertical support reactions, respectively at support *A* of the frame shown below?



(a) 16 kN, 18 kN (b) 16 kN, 6 kN
(c) 6 kN, 16 kN (d) 8 kN, 6 kN

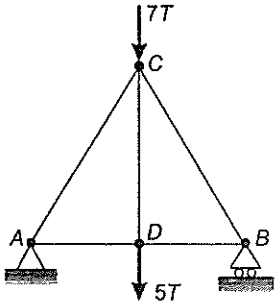
[ESE : 2007]

5.33 What does the Williot-Mohr diagram yield?

(a) Forces in members of a truss
(b) Moments in a fixed beam
(c) Reactions at the supports
(d) Joint displacement of a pin jointed plane frame

[ESE : 2007]

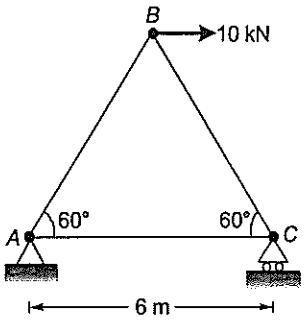
5.34 What is the force in the vertical member *CD* of the pin-jointed frame shown below?



(a) 12T (tension)
(b) 2T (compression)
(c) 7T (compression)
(d) 5T (tension)

[ESE : 2008]

5.35 What is the force in the member *BC* of the plane frame shown below?



(a) 10 kN tensile
(b) 10 kN compressive
(c) 5.76 kN compressive
(d) Zero

[ESE : 2008]

5.36 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. Maxwell's diagram
B. Henneberg's Method
C. Newmark's Method
D. Williot-Mohr diagram

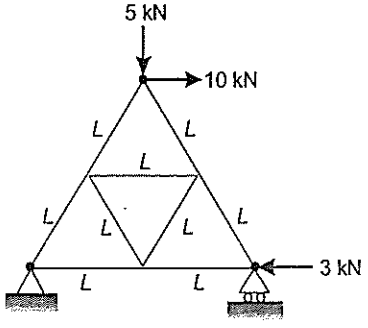
List-II
1. Displacement of joints in a truss
2. Deflection by numerical procedure
3. Forces in bar members
4. Concept of substitute member

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	3	4	2	1
(c)	3	2	4	1
(d)	1	4	2	3

[ESE : 2008]

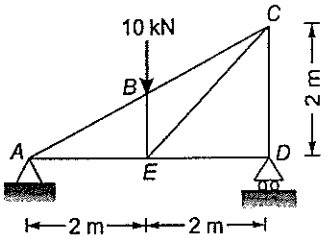
5.37 In the frame shown below, what is the horizontal reaction at left support?



(a) 15 kN (b) 13 kN
(c) 7 kN (d) 2 kN

[ESE : 2008]

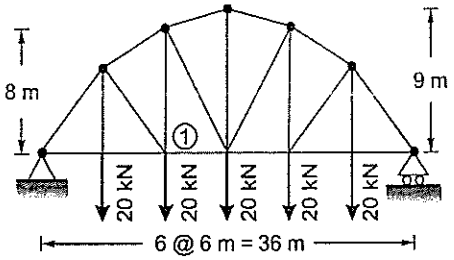
5.38 The figure below shows a pin-jointed frame.



What are the forces in members *BE*, *CD* and *ED*?
(a) 10 kN, 5 kN and 5 kN
(b) 10 kN, 5 kN and Zero
(c) 5 kN, 10 kN and Zero
(d) 5 kN, 5 kN and Zero

[ESE : 2009]

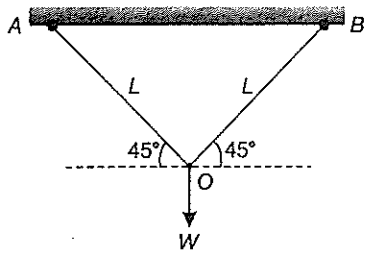
5.39 What is the force in member ① for the structure shown in figure below?



(a) 30 kN (b) 60 kN
(c) 75 kN (d) 80 kN

[ESE : 2009]

5.40 Two bars *AO* and *BO* are of uniform area *A* and are hinged at *O* as shown in figure below.



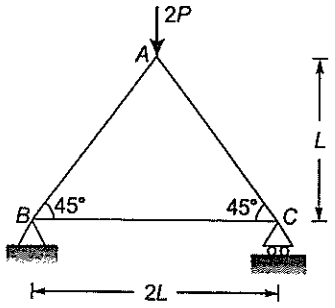
What is the vertical deflection at *O* when elastic modulus is uniformly *E*?

(a) $\frac{WL}{2AE}$ (b) $\frac{WL^2}{AE}$

(c) $\frac{WL}{AE}$ (d) $\frac{W^2L}{AE}$

[ESE : 2009]

5.41 A simple plane truss acted upon by a load $2P$ at the apex A is shown below. The axial force in the member AB is



(a) P (b) $\sqrt{2}P$

(c) $\frac{\sqrt{3}}{2}P$ (d) $\sqrt{3}P$

[ESE : 2010]

5.42 Assertion (A): In the analysis of statically determinate planar trusses by the method of joints, not more than two unknown bar forces can be determined.

Reason (R): There are only two equations of force equilibrium available for a co-planar concurrent system.

(a) both A and R are true and R is the correct explanation of A

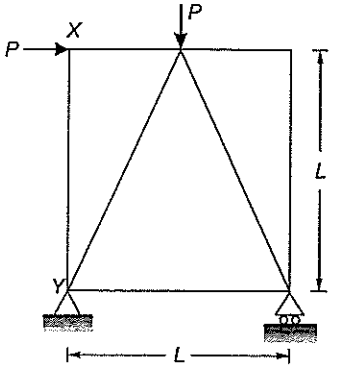
(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 2010]

5.43 The truss is shown in figure. The cross-sectional area of each member is 'A', and the modulus of elasticity of the material is uniformly E. The strain energy in the member XY is given by

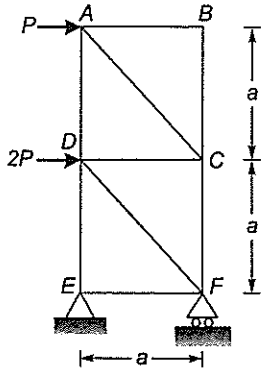


(a) $\frac{P^2L}{6AE}$ (b) $\frac{P^2L}{3AE}$

(c) Zero (d) $\frac{P^2L}{2AE}$

[ESE : 2011]

5.44 The force in the member CD is



(a) P Tensile

(b) P Compressive

(c) $2P$ Tensile

(d) $2P$ Compressive

[ESE : 2011]

5.45 Assertion (A): Method of substitution is validly employed in the analysis of member forces in certain geometries of truss structures.

Reason (R): It is always easier to analyze determinate truss forms by geometrical diagramming irrespective of conditions at the support points.

(a) Both A and R are true and R is the correct explanation of A

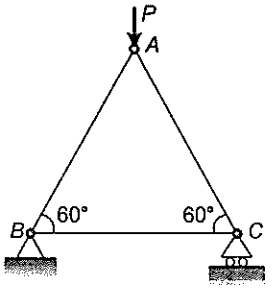
(b) Both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 2012]

5.46 The force in member BC is

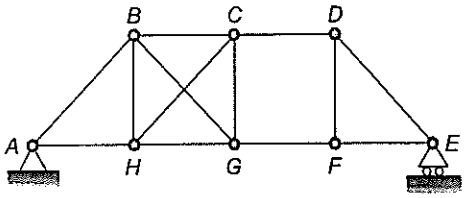


(a) $\frac{P}{2\sqrt{2}}$ (b) Zero

(c) $\frac{2P}{\sqrt{3}}$ (d) $\frac{P\sqrt{3}}{2}$

[ESE : 2013]

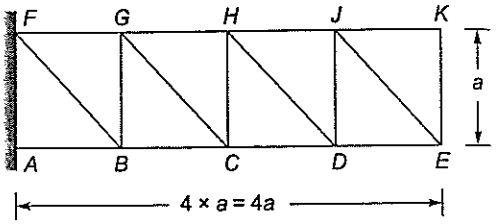
5.47 Which one of the following statements is correct for the pin-jointed truss shown in the figure?



(a) The truss is externally determinate but internally indeterminate.
(b) The truss is both externally and internally determinate.
(c) The truss is externally determinate and internally indeterminate and is unstable.
(d) The truss is externally determinate and internally indeterminate and is stable.

[ESE : 2015]

5.48 In the pin-end cantilever truss shown below, member *FG* had been fabricated 10 mm longer than required. How much will point E deflect vertically?



(a) 10 mm (b) 20 mm
(c) 30 mm (d) 40 mm

[ESE : 2016]

Answers Trusses

5.1 (a)	5.2 (c)	5.3 (c)	5.4 (c)	5.5 (c)	5.6 (b)	5.7 (d)	5.8 (d)	5.9 (b)	
5.10 (a)	5.11 (b)	5.12 (d)	5.13 (c)	5.14 (d)	5.15 (c)	5.16 (c)	5.17 (b)	5.18 (c)	
5.19 (b)	5.20 (c)	5.21 (c)	5.22 (d)	5.23 (c)	5.24 (c)	5.25 (b)	5.26 (b)	5.27 (b)	
5.28 (d)	5.29 (b)	5.30 (b)	5.31 (d)	5.32 (b)	5.33 (d)	5.34 (d)	5.35 (b)	5.36 (b)	
5.37 (c)	5.38 (b)	5.39 (b)	5.40 (c)	5.41 (b)	5.42 (a)	5.43 (c)	5.44 (a)	5.45 (a)	
5.46 (b)	5.47 (c)	5.48 (c)							

Explanations Trusses

5.1 (a)

The force polygon will represent all forces at joint *B*. There are 4 members and load *W* at joint *B*. However force in horizontal member left of *B* is zero. Thus there are 3 members having non-zero force. So (*a*) is the force polygon showing 4 forces. Other figures show 5 forces.

5.2 (c)

There is no force at joint *A*, so forces in members *AB* and *AE* will be zero.

5.3 (c)

Member *AI* is inclined at 30° from horizontal. From the force diagram, forces in members *GH* and *HI* are zero. Force in member *AI* is compressive in nature.

$F_{AI} \sin 30° = 150$

$\therefore \quad F_{AI} = 300$ kN

5.4 (c)

The first step will be space diagram and then force polygon or vector diagram should be drawn to compute end reactions. Finally stress diagram can be drawn.

5.5 (c)

There is no force at joint *F*, so forces in member *EF* and *CF* is zero. Similarly forces in member *CD* and *CA* is zero.

$$R_A = \frac{1000 \times L}{2L}$$

$= 500$ kg (downward)

Joint equilibrium at A

$F_{AD}\cos 45° = 500$

$F_{AD} = 500\sqrt{2}$ kg (tension)

5.6 (b)

It is possible to draw infinite number of funicular polygons for any system of forces.

By choosing a new pole (O') having distance $2x$ from the force polygon, the ordinates in funicular polygon will be halved.

5.7 (d)

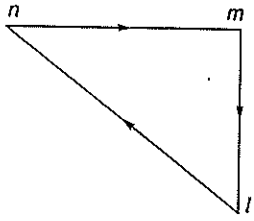
Cut a section through AG, AC and BC and take the moment of right part of the cut truss about F. The force in member AG and BC meet at point F itself so their moment is zero. The moment due to force in member AC is given by

$L\cos 30° \times F_{AC} = -50 \times L + 50 \times 0 + 50 \times L = 0$

So force in the member AC is zero.

5.8 (d)

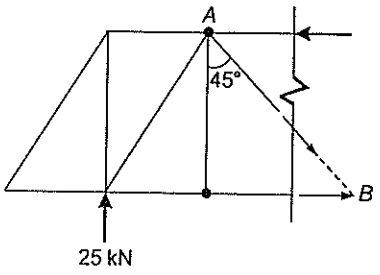
There will be tensile force in member L, N and compressive force in member N, M. Thus (d) represents the force polygon when we proceed in anticlockwise direction



5.9 (b)

The reaction at left support = 25 kN.

Cutting a section through member AB and other horizontal members of the same panel and considering left part of the cut section. The force in the member AB will be tensile.



$\Sigma F_y = 0$

$F_{AB} \times \cos 45° = 25$ kN

$\therefore \quad F_{AB} = 25\sqrt{2}$ kN (tension)

5.10 (a)

$\Sigma M_D = 0$

$R_A \times 2 = W \times 0$

$\Rightarrow \quad R_A = 0$

At A, $\quad F_{AB} - R_A = 0$

$\Rightarrow F_{AB} = 0$

Similarly all other members will have zero force except member BD which has compressive force equal to W.

5.11 (b)

Members of truss can be of different cross-section.

5.12 (d)

$$R_P = \frac{2}{3}\times 60 + \frac{1}{3}\times 30 = 50 \text{ kN}$$

$R_Q = 40$ kN

The force in PR will be compressive and will be equal to $\sqrt{2}R_P = 50\sqrt{2}$ kN.

Cutting a section through RS, RU and TU and taking moment of right part about U. The force in RS will be compressive and it will be

$$\frac{R_Q \times h}{h} = R_Q = 40 \text{ kN}.$$

Considering joint equilibrium at S, the force in member SU will be tensile and equal to R_Q i.e. 40 kN.

Considering joint equilibrium at T in the vertical direction, the force in member RT will be 60 kN tension.

5.13 (c)

Reaction at E is

$H_E \times 3 = 40 \times 6$

$\Rightarrow \quad H_E = 80$ kN

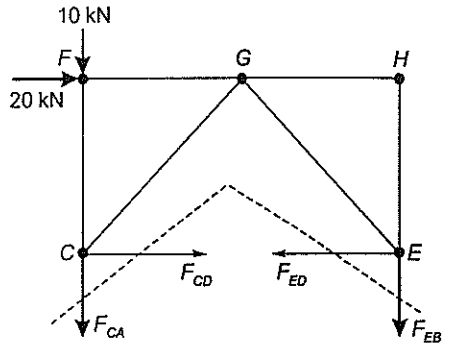
So force in member ED is 80 kN compressive.

5.14 (d)

Consider joint B and the force equilibrium equation in vertical direction will given zero force in member BD.

5.15 (c)

Cutting a section through members CA, CD, DE and EB and taking moment of the upper part about E.



$\therefore F_{CA} \times 6 + 10 \times 6 - 20 \times 3 = 0$

$\therefore F_{CA} = 0$

5.16(c)

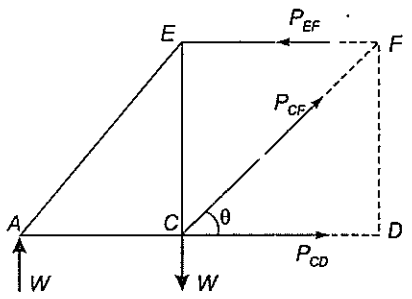
Consider joint equilibrium at *B*, the force in member *AB* will be zero.

5.17(b)

Consider joint equilibrium at *B*, the force in member *BD* will be 4 kN compressive.

5.18(c)

The loading is symmetrical and truss has only one unsymmetrical member *CF*. So this member is expected to carry no force. To verify it cut a section through *EF*, *CF*, and *CD* and consider left part of the truss.



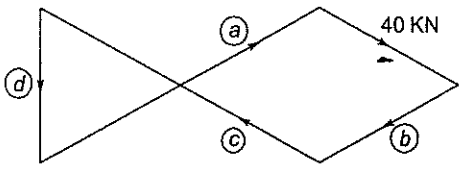
The force equilibrium in vertical direction gives

$P_{CF} \sin\theta + W - W = 0$

$\therefore \quad P_{CF} = 0$

5.19(b)

The arrows on the force polygon will be in a clockwise direction. Both *b* and *c* are in compression.



5.20(c)

The reaction at *B* will be in the vertical direction and the value of reaction is

$R_{BV} \times 2 = 30 \times 2 + 10 \times 4 = 100$ kN

$R_{BV} = 50$ kN

Considering joint equilibrium at *B*

Force in member *AB* = 0

Force in member *BD* = 50 kN (Compression).

Considering joint equilibrium at *C*, the force in member *CD* is 30 kN compressive.

For force in member *AC*, cut a section through *BD*, *AD* and *AC* and take moment of upper part about *D*. The moment due to force in *AD* and *BD*, and applied load 30 kN is zero. Force in

$CA = \frac{10 \times 2}{2} = 10$ kN (Tensile).

5.21(c)

The inspection of the truss shows that member *EC* has zero force as there is no horizontal load at joint *E*.

Now the support at *B* will have a vertical reaction. To balance the vertical reaction, the inclined member *BC* develops a compressive force and member AB will have a tensile force.

Cutting a section through *BC*, *AC* and *AE* and taking moment about point *D* for the upper part of truss, the moment due to applied load of 10 kN and moment due to forces in members *BC* and *AE* becomes zero. Thus force in member *AC* is zero.

5.22(d)

There is no force at joint *E*, so the force in member *EC* is zero.

5.23(c)

The joint equilibrium at *U* shows that force in member *UL* is 20 kN compressive.

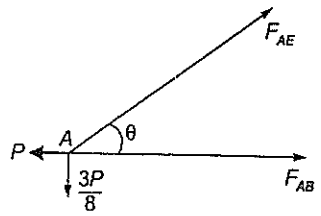
5.24(c)

At joint *B*, there is horizontal reaction only which will be balanced by force of member *BD*. So force in vertical member *AB* is zero.

5.25(b)

The vertical reaction at *A* is $\frac{3}{8}P$ in downward direction and horizontal reaction at *A* is *P* towards left.

Taking *FDB* of joint *A*,



So $\Sigma F_y = 0$

$$F_{AE}\sin\theta = \frac{3}{8}P$$

$$\therefore \quad F_{AE} = \frac{5}{8}P \text{ (tensile)}$$

$$\Sigma F_x = 0$$

$$F_{AB} = P - F_{AE}\cos\theta = 0.5\,P \text{ (tensile)}$$

$$\left(\cos\theta = \frac{4}{5}; \sin\theta = \frac{3}{5}\right)$$

At joint *E*

$$\Sigma F_y = 0$$

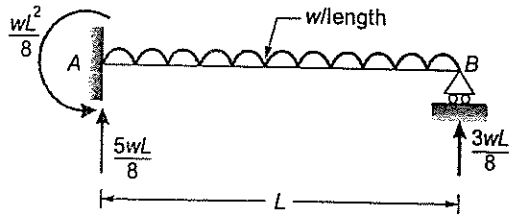
$$F_{BE} = F_{AE}\sin\theta = \frac{3}{8}P \text{ (compressive)}$$

$$F_{AB} : F_{BE} : F_{AE} = \frac{P}{2} : \frac{3}{8}P : \frac{5}{8}P = 4:3:5$$

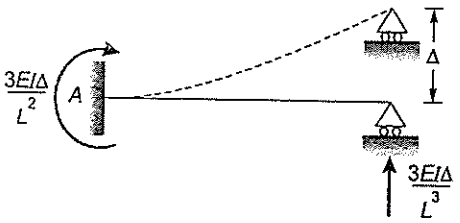
5.26 (b)

The Williot-Mohr diagram is used for deflection in trusses.

5.27 (b)



Propped cantilever with UDL



Propped cantilever with heaving

Due to heaving the prop reaction (R_B) increases while the support moment decreases.

5.28 (d)

Consider joint *A* in the truss. Since there is no external load on the point, so there is zero force in member *AB*.

5.29 (b)

$$\tan\theta = \frac{3}{4}$$

$$\therefore \quad AC = 3 \quad \text{and } BC = 4$$

$$\Rightarrow \quad \sin\theta = \frac{3}{5} \quad \text{and } \cos\theta = \frac{4}{5}$$

Horizontal reactions at *A* and *C* will be equal and opposite as there is no horizontal force acting on the truss.

Taking moment about $A = 0$

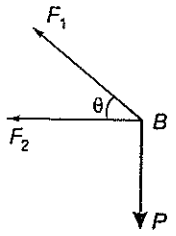
$$\Rightarrow H_C \times 3 - P \times 4 = 0$$

$$\Rightarrow \quad H_C = \frac{4}{3}P(\rightarrow)$$

$$\therefore \quad H_A = -\frac{4}{3}P(\leftarrow)$$

Vertical reaction, $V_C = P(\uparrow)$

By method of joints we have, at joint *B*



$$\Sigma F_y = 0 \quad \Rightarrow F_1\sin\theta - P = 0$$

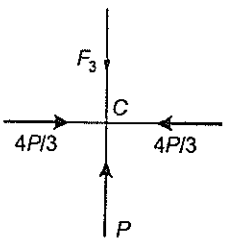
$$\Rightarrow F_1 = \frac{P}{\sin\theta} = \frac{5P}{3} = 1.67P$$

$$\Sigma F_x = 0 \quad \Rightarrow F_1\cos\theta + F_2 = 0$$

$$\Rightarrow F_2 = -\frac{5P}{3}\times\frac{4}{3}$$

$$= -\frac{4P}{3} = -1.33\,P$$

at Joint *C*



$$\Sigma F_y = 0$$

$$\Rightarrow F_3 - P = 0 \Rightarrow F_3 = P$$

5.30 (b)

Applying equilibrium equations at C.

$$\Sigma F_x = 0$$

$$\Rightarrow -P_{AC}\cos 30° + P_{BC}\cos 30° = 0$$

[Assuming AC in tension and BC in compression]

$$\Rightarrow \quad P_{AC} = P_{BC} \qquad ...(i)$$

and $\Sigma F_y = 0$

$$\Rightarrow P_{AC}\sin 30° + P_{BC}\sin 30° = P$$

[From (i) $P_{AC} = P_{BC}$]

$$\Rightarrow 2P_{AC}\sin 30° = P$$

$$\Rightarrow \quad P_{AC} = P$$

Strain energy stored in AC,

$$U_{AC} = \frac{S^2L}{2AE} = \frac{P^2L}{2AE}$$

Strain energy stored in BC,

$$U_{BC} = \frac{S^2L}{2AE} = \frac{P^2L}{2AE}$$

$$\therefore \quad U = U_{AC} + U_{BC}$$

$$\Rightarrow \quad U = \frac{P^2L}{2AE} + \frac{P^2L}{2AE}$$

$$\Rightarrow \quad U = \frac{P^2L}{AE}$$

Vertical deflection of joint C,

$$\delta_v = \frac{\partial U}{\partial P} = \frac{2PL}{AE}$$

5.31 (d)

If three members meet at a joint which carries no load, then one member will carry zero forces which is not colinear.

5.32 (b)

Horizontal reaction will be

$$H_A - 16 = 0$$

$$\Rightarrow \quad H_A = 16 \text{ kN } (\leftarrow)$$

Taking moments about B, we get

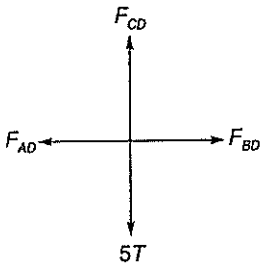
$$\Sigma M_B = 0$$

$$\Rightarrow V_A \times 4 + 16 \times 1.5 - 24 \times 2 = 0$$

$$\Rightarrow \quad V_A = 6 \text{ kN } (\uparrow)$$

5.34 (d)

Considering joint E and assuming tensile forces in members CD, AD and BD.



Now $\Sigma F_y = 0$

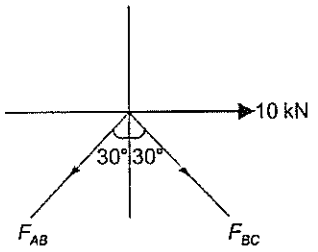
$$\Rightarrow \quad F_{CD} - 5T = 0$$

$$\Rightarrow \quad F_{CD} = 5T$$

Hence our assumption is correct.

5.35 (b)

Assuming tensile forces in AB and BC and considering joint equilibrium of B. Taking tensile force as positive.



$$\Sigma F_y = 0$$

$$\Rightarrow \quad F_{AB}\cos 30° + F_{BC}\cos 30° = 0$$

$$\Rightarrow \quad F_{AB} = -F_{BC}$$

$$\Sigma F_x = 0$$

$$\Rightarrow F_{BC}\sin 30° + 10 - F_{AB}\sin 30° = 0$$

$$\Rightarrow \quad \frac{F_{BC}}{2} + 10 + \frac{F_{BC}}{2} = 0$$

$$\Rightarrow F_{BC} = -10 \text{ kN (compression)}$$

5.36 (b)

Maxwell's Diagram: The method of joints could be used as the basis for a graphical analysis of trusses. The graphical analysis was developed by force polygons drawn to scale for each joint, and then the forces in each member were measured from one of these force polygons. The number of lines which have to be drawn can be greatly reduced, however, if the various force

polygons are superimposed. The resulting diagram of truss is known as the Maxwell's Diagram.

Henneberg's method (of bar conversions) - We replace one bar by its axial force X. Because the structure becomes unstable, we add one extra bar (at another place) to ensure mechanical stability. The axial force in the extra bar should be zero. Using this condition we can calculate the force in the removed bar.

Williot-Mohr Diagram - The Williot diagram is a graphical method to obtain an approximate value for displacement of a structure which submitted to a certain load. The method consists from a graph representation of a structural system, representing the structure's fixed vertices as a single, fixed starting point and from there sequentially adding the neighbouring vertice's relative displacements due to strain.

5.37 (c)

If the horizontal reaction at left hand support be $H(\leftarrow)$, then we have

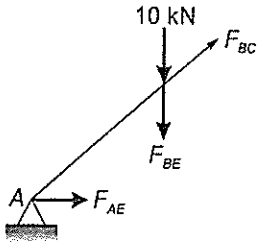
$$\Sigma F_x = 0$$

$$\Rightarrow \quad -H + 10 - 3 = 0$$

$$\Rightarrow \quad H = 7 \text{ kN}$$

5.38 (b)

Cutting a section through *BC*, *BE* and *AE* and considering left hand portion of the frame, we get



$$\Sigma M_A = 0$$

$$\Rightarrow 10 \times 2 + F_{BE} \times 2 = 0$$

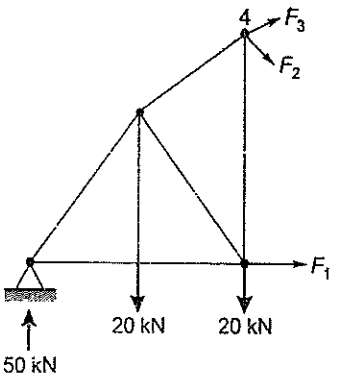
$$\Rightarrow \quad F_{BE} = -10 \text{ kN (compression)}$$

Vertical reaction at $D = 5$ kN upwards.

Since member *CD* does not have any component of force in horizontal direction hence 5 kN force will be transferred to member *CD*. It will be in compression. Member *ED* will not carry any force.

5.39 (b)

Cutting a section through the structure as shown below and considering the left hand portion.



Taking moments about 4, we get

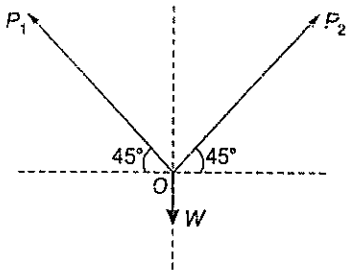
$F_1 \times 8 + 20 \times 6 - 50 \times 12 = 0$

$$\Rightarrow \quad F_1 = \frac{480}{8}$$

$$\Rightarrow \quad F_1 = 60 \text{ kN}$$

5.40 (c)

Let force in the members *AO* and BO be P_1 and P_2 respectively.



$$\Sigma F_y = 0$$

$$\Rightarrow P_1 \sin 45° + P_2 \sin 45° = W$$

$$\Rightarrow P_1 + P_2 = \sqrt{2}W \qquad \text{...(i)}$$

$$\Sigma F_x = 0$$

$$\Rightarrow P_1 \cos 45° - P_2 \cos 45° = 0$$

$$\Rightarrow \quad P_1 = P_2$$

$\therefore$ From (i), we get

$$P_1 = P_2 = \frac{W}{\sqrt{2}}$$

Strain energy stored in the bars will be

$$U = U_{AO} + U_{BO}$$

$$\Rightarrow \quad U = \frac{P_1^2 L}{3AE} + \frac{P_2^2 L}{2AE}$$

$$\Rightarrow \quad U = \frac{W^2 L}{4AE} + \frac{W^2 L}{4AE}$$

$$\Rightarrow \quad U = \frac{W^2 L}{2AE}$$

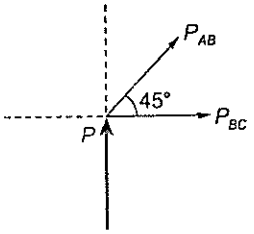
$$\therefore \quad \frac{\partial U}{\partial W} = \frac{WL}{AE}$$

$$\Rightarrow \quad \delta = \frac{WL}{AE}$$

5.41 (b)

Vertical Reaction at $B = \frac{2P}{2} = P$

Considering joint B



$$\Sigma F_y = 0$$

$$\Rightarrow P_{AB} \sin 45° + P = 0$$

$$\Rightarrow \quad P_{AB} = -\sqrt{2}P \text{ (compression)}$$

5.42 (a)

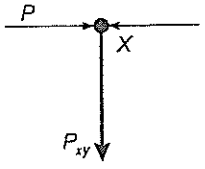
For co-planar truss we can use the two force equilibrium equations $\Sigma F_x = 0$ and $\Sigma F_y = 0$. Not more than two unknowns can be determined by using method of joints.

5.43 (c)

Strain energy in any member of a truss

$$= \frac{P^2 L}{2AE}$$

Applying method of joints at joint X of truss.



$$\Sigma V = 0$$

$$\Rightarrow \quad P_{xy} = 0$$

[$\because$ No External force in vertical direction at X]

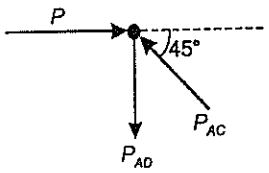
$\therefore$ Strain energy = 0

5.44 (a)

Since no external force at joint B

$$\therefore \quad P_{AB} = P_{BC} = 0$$

Joint A :

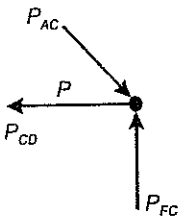


$$\Sigma H = 0$$

$$\Rightarrow \quad P = P_{AC} \cos 45°$$

$$\Rightarrow \quad P_{AC} = \sqrt{2}P \text{ (Compressive)} \quad ...(i)$$

Joint C :



$$\Sigma H = 0$$

$$P_{AC} \cos 45° = P_{CD}$$

$$\Rightarrow \quad P_{CD} = P \quad \text{(Tensile)}$$

5.45 (a)

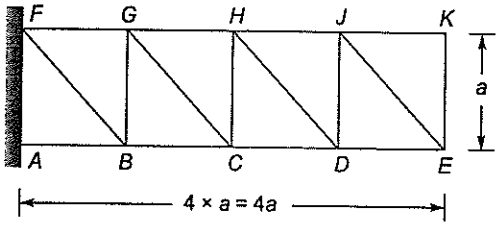
When there are three members acting at a joint, method of sections and method of joints can't be used as there will be three unknowns. Hence the method of substitution is used. In this method the redundant member is removed and another member is added if the removal makes the truss unstable. Determinate trusses can be analysed by geometrical diagramming. It can used both in case of roller and hinged support points.

5.46 (b)

Joints B and C do not move relative to each other i.e. member BC has no change in length

$\Rightarrow$ No strain $\Rightarrow$ Zero force.

5.48 (c)



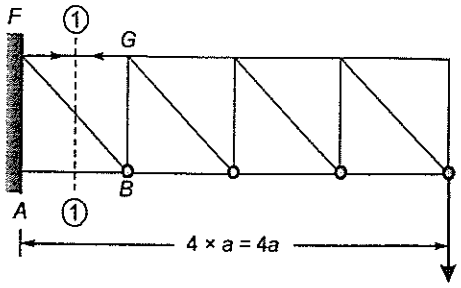
δV_E = Vertical deflection of joint E

$$= \sum \frac{PkI}{AE} = \sum k \cdot \delta$$

δ_{FG} = Elongation member FG = +10 mm

δ = 0 for all other member

k for member FG



Using method of sections

Cut F-G by (1) - (1)

Equilibrium of RHS of (1) - (1)

$\therefore \quad \Sigma M_B = 0$

$= -F_{FG} \times a + 1 \times 3a = 0$

$\Rightarrow \quad F_{FG} = 3$

So, $\quad \delta V_E = \Sigma k\delta = +3 \times (10) = 30$ mm

6 Matrix Method of Structural Analysis

6.1 Consider the following statements:
In the stiffness method of analysis,

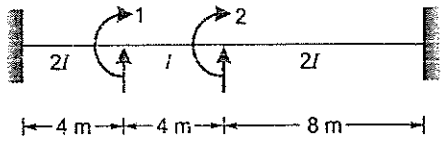
1. statically indeterminate structures alone are considered
2. both statically determinate and indeter-minate structures can be considered
3. it is necessary to identify the redundants
4. the displacements are considered as the unknowns
5. to calculate the displacements and establish the equations of equilibrium, it will be convenient to develop the stiffness matrix for the structure

Which of these statements are correct?

(a) 1, 3 and 4 (b) 1, 3 and 5
(c) 2, 4 and 5 (d) 2, 3, 4 and 5

[ESE : 2000]

6.2 Displacement coordinates for a beam are shown in the given figure. The stiffness matrix is given by



(a) $\begin{bmatrix} 3EI & EI \\ EI & 2EI \end{bmatrix}$

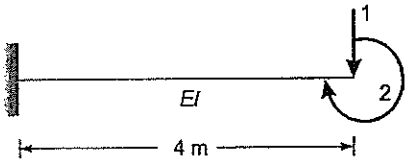
(b) $\begin{bmatrix} 3EI & -0.5EI \\ -0.5EI & 2EI \end{bmatrix}$

(c) $\begin{bmatrix} 3EI & 0 \\ 0 & 2EI \end{bmatrix}$

(d) $\begin{bmatrix} 3EI & 0.5EI \\ 0.5EI & 2EI \end{bmatrix}$

[ESE : 2000]

6.3 The flexibility matrix of the beam shown in the given figure is



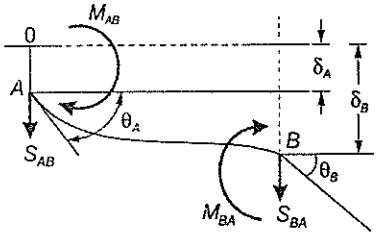
(a) $\begin{bmatrix} \frac{64}{3EI} & -\frac{8}{EI} \\ -\frac{8}{EI} & \frac{64}{3EI} \end{bmatrix}$ (b) $\begin{bmatrix} \frac{64}{3EI} & \frac{8}{EI} \\ \frac{8}{EI} & -\frac{64}{3EI} \end{bmatrix}$

(c) $\begin{bmatrix} \frac{64}{3EI} & \frac{8}{EI} \\ \frac{8}{EI} & \frac{4}{EI} \end{bmatrix}$ (d) $\begin{bmatrix} \frac{64}{3EI} & \frac{8}{EI} \\ \frac{4}{EI} & \frac{8}{EI} \end{bmatrix}$

[ESE : 2000]

6.4 A member coordinate system is shown in the given figure. The symmetric stiffness square matrix obtained for the member *AB* of length *L* with flexural rigidity '*EI*' by using the slope deflection equation and rules of matrix multiplication is as follows:

$$\begin{bmatrix} M_{AB} \\ S_{AB} \\ M_{BA} \\ S_{BA} \end{bmatrix} = \frac{2EI}{L} \begin{bmatrix} \text{Symmetric} \\ \text{Stiffness} \\ \text{Square} \\ \text{Matrix} \end{bmatrix} \begin{bmatrix} \theta_A \\ \frac{\delta_A}{L} \\ \theta_B \\ \frac{\delta_B}{L} \end{bmatrix}$$



The correct sequence of elements of the first row of the symmetric stiffness square matrix is

(a) 2, 3, 1 and 3 (b) 2, 3 – 1 and –3
(c) 2, 3, 1 and –3 (d) 1, 3, 2 and –3

[ESE : 2000]

6.5 The stiffness matrix of a beam element is

$$\left(\frac{2EI}{L}\right)\begin{bmatrix}2 & 1\\ 1 & 2\end{bmatrix}$$

Which one of the following is its flexibility matrix?

(a) $\left(\frac{L}{2EI}\right)\begin{bmatrix}2 & 1\\ 1 & 2\end{bmatrix}$

(b) $\left(\frac{L}{6EI}\right)\begin{bmatrix}2 & -1\\ -1 & 2\end{bmatrix}$

(c) $\left(\frac{L}{5EI}\right)\begin{bmatrix}1 & -2\\ -2 & 1\end{bmatrix}$

(d) $\left(\frac{L}{6EI}\right)\begin{bmatrix}1 & -2\\ -2 & 1\end{bmatrix}$

[ESE : 2005]

6.6 The number of unknowns to be determined in the stiffness method is equal to

(a) the static indeterminacy

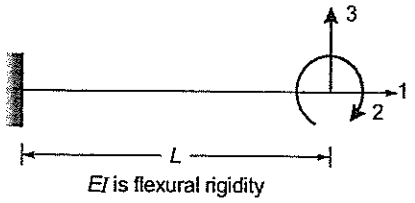
(b) the kinematic indeterminacy

(c) the sum of kinematic indeterminacy and static indeterminacy

(d) two times the number of supports

[ESE : 2005]

6.7 What is the stiffness matrix for a prismatic cantilever with coordinates as shown in figure below?



(a) $\begin{bmatrix}\frac{AE}{L} & 0 & 0\\ 0 & \frac{4EI}{L} & \frac{6EI}{L^2}\\ 0 & \frac{6EI}{L^2} & \frac{12EI}{L^3}\end{bmatrix}$

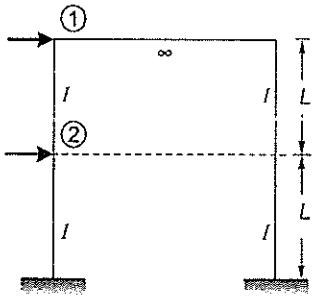
(b) $\begin{bmatrix}0 & 0 & \frac{AE}{L}\\ 0 & \frac{4EI}{L} & \frac{6EI}{L^2}\\ 0 & \frac{6EI}{L^2} & \frac{12EI}{L^3}\end{bmatrix}$

(c) $\begin{bmatrix}\frac{AE}{L} & \frac{4EI}{L} & 0\\ 0 & 0 & 0\\ 0 & \frac{6EI}{L^2} & \frac{4EI}{L}\end{bmatrix}$

(d) $\begin{bmatrix}\frac{AE}{L} & \frac{4EI}{L} & \frac{6EI}{L^2}\\ 0 & \frac{6EI}{L^2} & 0\\ 0 & \frac{6EI}{L^3} & \frac{12EI}{L^3}\end{bmatrix}$

[ESE : 2006]

6.8 The beams in the two storey frame shown in the figure below have a cross section such that the flexural rigidity may be considered infinite. Which among the following is the stiffness matrix for the structure in respect of the global coordinates 1 and 2?

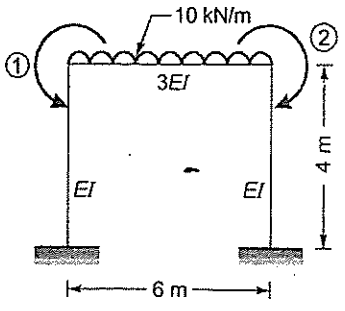


(a) $\frac{24EI}{L^3}\begin{bmatrix}1 & -1\\ -1 & 2\end{bmatrix}$ (b) $\frac{24EI}{L^3}\begin{bmatrix}1 & -1\\ -1 & 1\end{bmatrix}$

(c) $\frac{24EI}{L^3}\begin{bmatrix}2 & -1\\ -1 & 2\end{bmatrix}$ (d) $\frac{24EI}{L^3}\begin{bmatrix}1 & 1\\ 1 & 1\end{bmatrix}$

[ESE : 2006]

6.9 Considering only flexural deformations, which is the stiffness matrix for the plane frame shown in the figure given below?



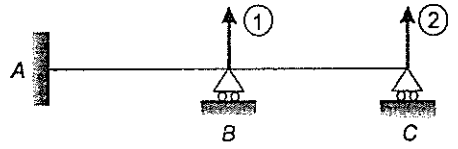
(a) $\begin{bmatrix}4 & 3\\ 3 & 4\end{bmatrix}EI$ (b) $\begin{bmatrix}3 & 1\\ 1 & 3\end{bmatrix}EI$

(c) $\begin{bmatrix}2 & 1\\ 1 & 2\end{bmatrix}EI$ (d) $\begin{bmatrix}1 & 1\\ 1 & 1\end{bmatrix}EI$

[ESE : 2006]

6.10 Flexibility matrix of the beam shown below is :

$$\delta = \frac{1}{3EI}\begin{bmatrix}1 & 2\\ 2 & 8\end{bmatrix}$$



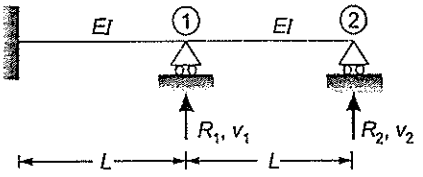
If support B settles by $\frac{\Delta}{EI}$ units, what is the reaction at B?

(a) $0.75\,\Delta$ (b) $3.0\,\Delta$

(c) $6.0\,\Delta$ (d) $24.0\,\Delta$

[ESE : 2009]

6.11 What is the value of flexibility coefficient f_{12} for the continuous beam shown in figure below?



(a) $\frac{L^3}{3EI}$ (b) $\frac{L^3}{2EI}$

(c) $\frac{L^3}{8EI}$ (d) $\frac{L^3}{1.2EI}$

[ESE : 2009]

6.12 Flexibility matrix for a beam element is written in the form:

$$[A] = \frac{L^3}{6EI}\begin{bmatrix}2 & 5\\ 5 & 16\end{bmatrix}$$

What is the corresponding stiffness matrix?

(a) $\frac{6EI}{L^3}\begin{bmatrix}16 & 5\\ 5 & 2\end{bmatrix}$ (b) $\frac{6EI}{7L^3}\begin{bmatrix}16 & 5\\ 5 & 2\end{bmatrix}$

(c) $\frac{6EI}{L^3}\begin{bmatrix}16 & -5\\ -5 & 2\end{bmatrix}$ (d) $\frac{6EI}{7L^3}\begin{bmatrix}16 & -5\\ -5 & 2\end{bmatrix}$

[ESE : 2010]

6.13 Consider the following statements relating to structural analysis:

1. Flexibility matrix and its transpose are equal.
2. Elements of main diagonal of stiffness matrix are always positive.
3. For unstable structures, coefficients in leading diagonal matrix can be negative.

Which of these statements is/are correct?

(a) 1, 2 an 3 (b) 1 and 2 only

(c) 2 and 3 only (d) 3 only

[ESE : 2010]

6.14 Flexibility matrix for a beam element is

$$[F] = \frac{1}{EI}\begin{bmatrix}36 & 9\\ 9 & 4\end{bmatrix}$$

What is the corresponding stiffness matrix $[S]$?

(a) $[S] = \frac{EI}{63}\begin{bmatrix}36 & -9\\ -9 & 4\end{bmatrix}$

(b) $[S] = \frac{EI}{63}\begin{bmatrix}36 & 9\\ 9 & 4\end{bmatrix}$

(c) $[S] = \frac{EI}{63}\begin{bmatrix}4 & -9\\ -9 & 36\end{bmatrix}$

(d) $[S] = \frac{EI}{63}\begin{bmatrix}4 & 9\\ 9 & 36\end{bmatrix}$

[ESE : 2010]

6.15 Which of the following statements are correct?

1. It is common practice to discount the influence of axial thrust on bending stiffness of members of frames.
2. In a portal frame of single bay, the columns have different thermal coefficients of expansion. If the whole frame is subjected to a same temperature, there will be a component of deformation in the vertical directions.
3. The flexibility method of analysis cannot be used to solve any kind of indeterminate structural problem.

(a) 1, 2 and 3 (b) 1 and 3 only

(c) 1 and 2 only (d) 2 and 3 only

[ESE : 2013]

6.16 Stiffness method of structural analysis starts with

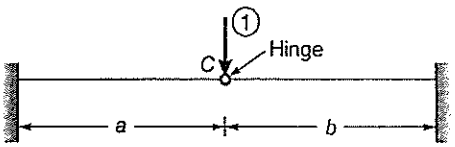
(a) force-deformation relations

(b) equilibrium condition

(c) compatible deformation
(d) equilibrium state of internal stress components

[ESE : 2013]

6.17 The stiffness coefficient k_{11} for the beam as shown below is



(a) $EI\left(\frac{1}{a^3}+\frac{1}{b^3}\right)$ (b) $2EI\left(\frac{1}{a^3}+\frac{1}{b^3}\right)$

(c) $3EI\left(\frac{1}{a^3}+\frac{1}{b^3}\right)$ (d) $4EI\left(\frac{1}{a^3}+\frac{1}{b^3}\right)$

[ESE : 2013]

6.18 Stiffness matrix method is in the category of
1. Compatibility method
2. Displacement method
3. Force method
4. Equilibrium method

(a) 1 and 3 only (b) 1 and 4 only
(c) 2 and 3 only (d) 2 and 4 only

[ESE : 2016]

■■■■

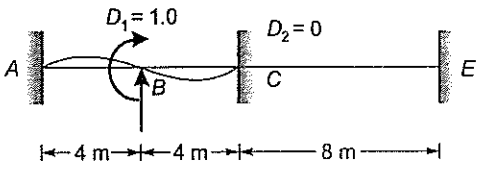
Answers Matrix Method of Structural Analysis

6.1	(c)	6.2	(d)	6.3	(c)	6.4	(c)	6.5	(b)	6.6	(b)	6.7	(a)	6.8	(a)	6.9	(b)
6.10	(c)	6.11	(d)	6.12	(d)	6.13	(b)	6.14	(c)	6.15	(c)	6.16	(b)	6.17	(c)	6.18	(d)

Explanations Matrix Method of Structural Analysis

6.2 (d)

Stiffness matrix can be obtained by making second co-ordinate i.e. rotation in the direction of 2 as zero and considering unit rotation in the direction of co-ordinate 1.



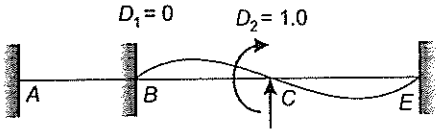
The beam AB has rotational stiffness

$\frac{4E(2I)}{4} = 2EI$ and beam BC has rotational stiffness

$\frac{4E(I)}{4} = EI$. So moment required in the direction of 1 to produce unit rotation will be $2EI + EI = 3EI$. Thus $K_{11} = 3EI$.

The moment generated at point C in the direction of co-ordinate 2 is $\frac{1}{2} \times EI = 0.5\,EI$ as the carry over factor is half. So $K_{21} = 0.5\,EI$.

Similarly make $D_1 = 0$ and $D_2 = 1.0$



$$K_{22} = \frac{4EI}{4} + \frac{4E(2I)}{8} = 2EI$$

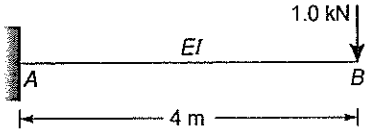
$$K_{12} = 0.5\,EI$$

$$\text{Stiffness matrix} = \begin{bmatrix} K_{11} & K_{12} \\ K_{21} & K_{22} \end{bmatrix}$$

$$= \begin{bmatrix} 3EI & 0.5EI \\ 0.5EI & 2EI \end{bmatrix}$$

6.3 (c)

Elements of flexibility matrix can be obtained by applying unit force in the direction of any one co-ordinate and calculating displacement in the direction of both co-ordinates.



Applying unit load in the direction of 1.

Deflection at B,

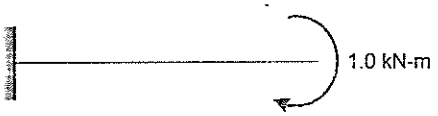
$$f_{11} = \frac{1\times 4^3}{3EI} = \frac{64}{3EI}$$

Rotation at B $f_{21} = \frac{1\times 4^2}{2EI} = \frac{8}{EI}$

The positive sign is used when the displacement is in the direction of co-ordinate, otherwise negative sign is used.

Applying unit moment in the direction of 2

Deflection at B



$$f_{12} = \frac{1\times 4^2}{2EI} = \frac{8}{EI}$$

Rotation at B,

$$f_{22} = \frac{1\times 4}{EI} = \frac{4}{EI}$$

So flexibility matrix

$$= \begin{bmatrix} f_{11} & f_{12} \\ f_{21} & f_{22} \end{bmatrix} = \begin{bmatrix} \frac{64}{3EI} & \frac{8}{EI} \\ \frac{8}{EI} & \frac{4}{EI} \end{bmatrix}$$

6.4 (c)

By first row, M_{AB} will be obtained

$$\therefore M_{AB} = \frac{2EI}{L}\left[2\theta_A + \theta_B - 3\left(\frac{\delta_B - \delta_A}{L}\right)\right]$$

$$= \frac{2EI}{L}\left[2\theta_A + \frac{3\delta_A}{L} + \theta_B - \frac{3\delta_B}{L}\right]$$

So the elements of first row are 2, 3, 1, and –3

6.5 (b)

The flexibility and stiffness matrices are inverse of each other and both are symmetrical.

The value of determinant of stiffness matrix is

$$\frac{2EI}{L}\times 3 = \frac{6EI}{L}$$

The flexibility matrix will be $= \frac{L}{6EI}\begin{bmatrix} 2 & -1 \\ -1 & 2 \end{bmatrix}$

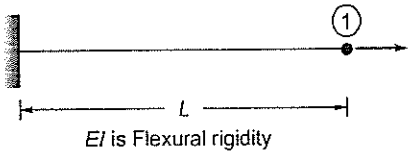
6.6 (b)

The stiffness or displacement method of analysis is based on kinematic degree of indeterminacy or independent degrees of freedom at joint.

6.7 (a)

The stiffness matrix is symmetrical in nature so (a) should be the answer.

The elements of stiffness matrix can be found as follows:



For first column of matrix consider the axial displacement only i.e.,

$D_1 = 1.0$, $D_2 = 0$ and $D_3 = 0$.

For one unit elongation of beam, the force needed

$$s_{11} = \frac{AE}{L}$$

The moment due to axial elongation,

$$s_{21} = 0$$

The vertical force due to axial elongation,

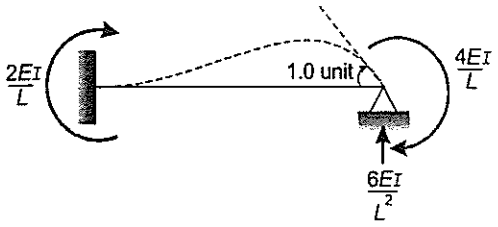
$$s_{31} = 0$$

For second column of matrix, give unit rotation at free end in the direction of displacement component (2) and calculate axial force, moment and vertical force due to the same. The other displacement components should be zero i.e.,

$$D_1 = 0,\ D_2 = 1.0 \text{ and } D_3 = 0.$$

Axial force induced,

$$s_{12} = 0$$



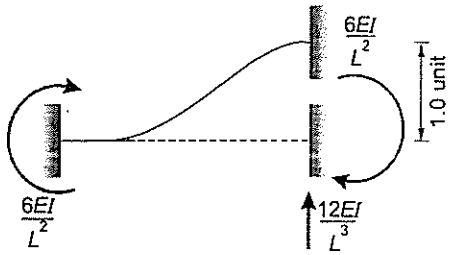
Moment required to produce unit rotation,

$$s_{22} = \frac{4EI}{L}$$

Vertical force produced,

$$s_{32} = \frac{6EI}{L^2}$$

For third column of matrix give unit deflection in the direction of displacement component (3). The other components being zero i.e. $D_1 = 0$, $D_2 = 0$ and $D_3 = 1$.



Axial force induced,

$$s_{13} = 0$$

Moment induced,

$$s_{23} = \frac{6EI}{L^2}$$

Vertical force required to cause unit deflection,

$$s_{33} = \frac{12EI}{L^3}$$

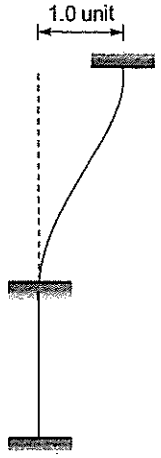
∴ The stiffness matrix is

$$\begin{bmatrix} s_{11} & s_{12} & s_{13} \\ s_{21} & s_{22} & s_{23} \\ s_{31} & s_{32} & s_{33} \end{bmatrix} = \begin{bmatrix} \frac{AE}{L} & 0 & 0 \\ 0 & \frac{4EI}{L} & \frac{6EI}{L^2} \\ 0 & \frac{6EI}{L^2} & \frac{12EI}{L^3} \end{bmatrix}$$

6.8 (a)

For first column of matrix $D_1 = 1.0$; $D_2 = 0$

The shape of columns will be



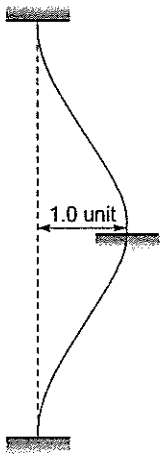
Since there are two column.

$$\therefore \quad s_{11} = \frac{12EI}{L^3} + \frac{12EI}{L^3} = \frac{24EI}{L^3}$$

$$s_{21} = -\frac{24EI}{L^3}$$

For second column of matrix

$D_1 = 0$; $D_2 = 1.0$



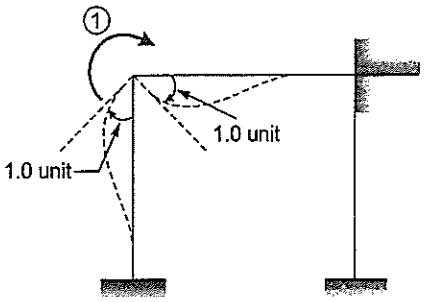
The shape of the columns will be

$$\therefore \quad s_{12} = -\frac{24EI}{L^3}$$

$$s_{22} = \frac{24EI}{L^3} + \frac{24EI}{L^3} = \frac{48EI}{L^3}$$

6.9 (b)

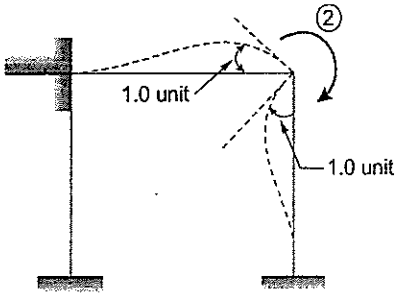
Keeping $D_1 = 1.0$ and $D_2 = 0$, the frame will be



$$s_{11} = \frac{4\times(3EI)}{6} + \frac{4EI}{4} = 3EI$$

$$s_{21} = \frac{2\times(3EI)}{6} = EI$$

Keeping $D_1 = 0$ and $D_2 = 1.0$, the frame will be



$$s_{12} = \frac{2\times 3EI}{6} = EI \text{ and } s_{22} = 3EI$$

6.10(c)

We know that

$$D_Q = D_{QS} + FQ$$

D_Q is the final displacement matrix corresponding to the redundants in the actual structure.

$$D_{QS} = D_{QL} + D_{QT} + D_{QP} + D_{QR}$$

D_{QS} includes the effects of external loads (D_{QL}), temperature (D_{QT}), prestrain effects (D_{QP}), support settlements, etc.

F is the Flexibility matrix and Q is the unknown reactions matrix.

Assuming upward displacements as positive.

$$D_{QL} = \begin{bmatrix}0\\0\end{bmatrix};\ D_{QP} = \begin{bmatrix}0\\0\end{bmatrix};$$

$$D_{QT} = \begin{bmatrix}0\\0\end{bmatrix};\ D_{QR} = \begin{bmatrix}-\frac{\Delta}{EI}\\0\end{bmatrix}$$

$$\therefore\quad D_{QS} = \begin{bmatrix}-\frac{\Delta}{EI}\\0\end{bmatrix} \quad \text{and } Q = \begin{bmatrix}V_B\\V_C\end{bmatrix}$$

Final displacement, $D_Q = 0$

$$\therefore D_{QS} + FQ = 0$$

$$\Rightarrow\quad FQ = -D_{QS}$$

$$\Rightarrow\quad Q = -F^{-1} D_{QS}$$

$$\Rightarrow\quad \begin{bmatrix}V_B\\V_C\end{bmatrix} = -\frac{3EI}{4}\begin{bmatrix}8 & -2\\-2 & 1\end{bmatrix}_{2\times2}\begin{bmatrix}-\frac{\Delta}{EI}\\0\end{bmatrix}$$

$$\begin{bmatrix}V_B\\V_C\end{bmatrix} = -\frac{3EI}{4}\times\left(-\frac{\Delta}{EI}\right)\begin{bmatrix}8 & -2\\-2 & 1\end{bmatrix}\begin{bmatrix}1\\0\end{bmatrix}$$

$$\Rightarrow\quad \begin{bmatrix}V_B\\V_C\end{bmatrix} = \frac{3\Delta}{4}\begin{bmatrix}8+(-2)\times0\\(-2)\times1+1\times0\end{bmatrix}$$

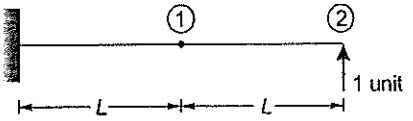
$$\Rightarrow\quad \begin{bmatrix}V_B\\V_C\end{bmatrix} = \frac{3\Delta}{4}\begin{bmatrix}8\\-2\end{bmatrix}$$

$$\therefore\quad V_B = \frac{3\Delta}{4}\times8 = 6\Delta$$

$$\text{and}\quad V_C = \frac{3\Delta}{4}\times(-2) = -1.5\Delta$$

6.11(d)

Flexibility coefficient f_{12} means displacement at (1) when a unit load is applied at (2).



$$\therefore\quad f_{12} = \frac{1\times L^3}{3EI} + \frac{1\times L}{2EI}\times L^2$$

[Maxwell's theorem)

$$= \frac{L^3}{3EI} + \frac{L^3}{2EI} = \frac{L^3}{1.2EI}$$

6.12 (d)

Stiffness matrix=inverse of flexibility matrix

$$[A] = k\begin{bmatrix}a & b\\c & d\end{bmatrix}$$

$$[A]^{-1} = \frac{1}{K|A|}\begin{bmatrix}d & -b\\-c & a\end{bmatrix}$$

Stiffness matrix = $[A]^{-1}$

$$= \frac{6EI}{L^3|A|}\begin{bmatrix}16 & -5\\ -5 & 2\end{bmatrix}$$

$$= \frac{6EI}{7L^3}\begin{bmatrix}16 & -5\\ -5 & 2\end{bmatrix}$$

6.13 (b)

Flexibility matrix is equal to its transpose as it is a square matrix and its elements are symmetrical about diagonal.

Elements of main diagonal of stiffness matrix are always positive as displacement will always occur in direction of force applied at a point.

Structure has to be stable and in equilibrium to develop flexibility matrix.

6.14 (c)

Stiffness matrix = inverse of flexibility matrix

$$= [F]^{-1}$$

$$= \frac{EI}{|F|}\begin{bmatrix}4 & -9\\ -9 & 36\end{bmatrix}$$

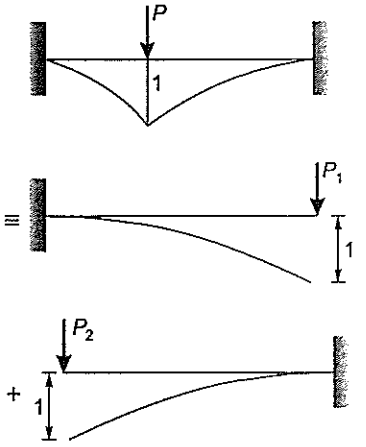
$$= \frac{EI}{(36\times 4-81)}\begin{bmatrix}4 & -9\\ -9 & 36\end{bmatrix}$$

$$= \frac{EI}{63}\begin{bmatrix}4 & -9\\ -9 & 36\end{bmatrix}$$

6.15 (c)

Flexibility method can be used for analysis of indeterminate structures by force method.

6.17 (c)



$$\therefore \quad P_1 + P_2 = 3EI\left(\frac{1}{a^3}+\frac{1}{b^3}\right)$$

6.18 (d)

Stiffness matrix method is category of slope deflection method which uses equilibrium equations to determine the displacement and force response of the structure.

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7 Structure Dynamics and Suspended Cables

7.1 A single degree of freedom system of mass 22 kg and stiffness 17 kN/m vibrates freely. If damping in the system is 2%, the cyclic frequency and the damped circular frequency, respectively, are nearly

(a) 4.4 Hz and 0.88 rad/sec
(b) 0.88 Hz and 27.8 rad/sec
(c) 4.4 Hz and 27.8 rad/sec
(d) 0.88 Hz and 0.88 rad/sec

[ESE : 2017]

7.2 A cable of insignificant weight, 18 m long, is supported at its two ends, 16 m apart, at the same level. The cable supports at its mid-reach a load of 120 N. The tension in the cable is nearly

(a) 136 N (b) 131 N
(c) 126 N (d) 121 N

[ESE : 2017]

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Answers Structure Dynamics and Suspended Cables

7.1 (c) 7.2 (b)

Explanations Structure Dynamics and Suspended Cables

7.1 (c)

$$\text{Cyclic frequency} = \frac{\omega_D}{2\pi}$$

$$= \frac{1}{2\pi}\left\{\sqrt{\frac{k}{m}}\left(\sqrt{1-\varepsilon^2}\right)\right\}$$

$$= \frac{1}{2\pi}\left\{\sqrt{\frac{17\times10^3}{22}}\left(\sqrt{1-0.02^2}\right)\right\}$$

$$= 4.4 \text{ Hz}$$

Above value must be more than 1 so answer should be 4.4 Hz.

Circular frequency,

$$\omega_D = \omega_n\sqrt{1-\varepsilon^2}$$

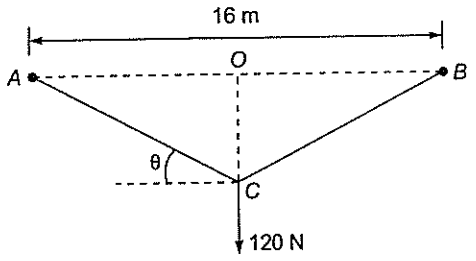
$$= \sqrt{\frac{k}{m}}\times\sqrt{1-0.02^2}$$

$$= \sqrt{\frac{17\times10^3}{22}}\times\sqrt{1-0.02^2}$$

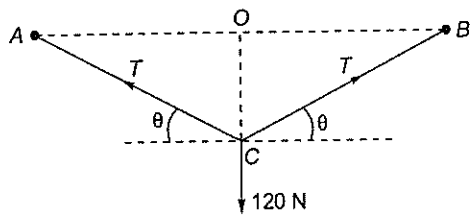
$$= 27.8 \text{ rad/sec}$$

It can't be less than 1 so answer should be 27.8 rad/sec.

7.2 (b)



FBD of joint *C*.



$$2T\sin\theta = 120$$

$$\Rightarrow \quad 2T\theta = 120$$

$$\Rightarrow \quad T = \frac{120}{2\times\frac{OC}{OA}} = \frac{120}{2\times\left(\frac{\sqrt{9^2-8^2}}{8}\right)}$$

$$\Rightarrow \quad T = 131 \text{ N}$$

■■■■

UNIT

IV

Design of Steel Structures

Syllabus

Principles of Working Stress methods, Design of tension and compression members, Design of beams and beam column connections, built-up sections, Girders, Industrial roofs, Principles of Ultimate load design.

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1 Structural Fasteners

1.1 Consider the following statements:
Aluminium is being increasingly used for structural purposes because
1. its modulus of elasticity is double that of steel
2. its coefficient of thermal expansion is half that of steel
3. it requires less maintenance
4. the strength to unit weight ratio of aluminium is high

Which of these statements are correct?
(a) 1 and 4 (b) 2 and 4
(c) 1, 2 and 3 (d) 3 and 4

[ESE : 1995]

1.2 A steel plate is 30 cm wide and 10 mm thick. A rivet of nominal diameter 18 mm is driven. The net sectional area of the plate is
(a) 18.00 cm^2 (b) 28.20 cm^2
(c) 28.05 cm^2 (d) 32.42 cm^2

[ESE : 1995]

1.3 Which one of the following is the most important consideration in the design of a riveted joint between structural members when the centroid of the rivets does not coincide with the axis of the load?
(a) Direct shear force in each rivet is proportional to its radial distance from its centroid and the resultant force in each rivet should not exceed its rivet value.
(b) Shear force caused in each rivet due to eccentricity of the load is proportional to its radial distance from its centroid and the direct shear force in each rivet should be limited to half the rivet value.
(c) The shear force caused in each rivet due to eccentricity of the load is proportional to the radial distance of the rivet from the centroid of the rivet group and the maximum resultant force in any rivet should not exceed the rivet value.
(d) The shear force caused in the rivet due to eccentricity of load as well as direct shear force caused in the rivet should not exceed rivet value individually.

[ESE : 1995]

1.4 The common assumption that, 'all rivets share equally a non-eccentric load' is valid at a load
(a) below the working load
(b) equal to the working load
(c) above the working load
(d) equal to the failure load

[ESE : 1995]

1.5 A circular plate 100 mm diameter is welded to another plate by means of 6 mm fillet weld. If the permissible shearing stress in the weld equals 10 kg/mm^2, then the greatest twisting moment that can be resisted by the weld will be
(a) 424π kg-m (b) 300π kg-m
(c) 212π kg-m (d) 60π kg-m

[ESE : 1996]

1.6 A mild steel flat subjected to tensile force of 84 tonnes is connected to a gusset plate using rivets. If the forces required to shear a single rivet, to crush the rivet and to tear the plate per pitch length are 5000 kg, 8000 kg and 6000 kg respectively, then the number of rivets required is
(a) 12 (b) 14
(c) 16 (d) 17

[ESE : 1996]

1.7 In a fillet weld the weakest section is the
(a) smaller side of the fillet
(b) throat of the fillet
(c) side perpendicular to force
(d) side parallel to force

[ESE : 1996]

1.8 Which one of the following methods of design is not suitable for structures subjected to impact and fatigue?

(a) Simple design
(b) Semi-rigid design
(c) Rigid design
(d) Plastic design

[ESE : 1996]

1.9 Assertion (A) : In structural bearing type joints, each connection is assumed to transmit its proportional share of the applied load.
Reason (R) : Applied load passes through the centroid of the connector group.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1996]

1.10 Upper yield point in the stress-strain curve in structural steel can be avoided by
(a) cold working (b) hot working
(c) quenching (d) galvanizing

[ESE : 1997]

1.11 In the design of framed connections, the rivets or bolts connecting the web of the beam with connecting angles are subject to
(a) single shearing and bearing on the web
(b) double shearing and bearing on the web
(c) double shearing and no bearing on the web
(d) no shearing but only bearing on the web

[ESE : 1997]

1.12 The effective length of the fillet weld is
(a) Total length –2 × throat size
(b) Total length –2 × weld size
(c) 0.7 × total length
(d) Total length – (weld size/$\sqrt{2}$)

[ESE : 1997]

1.13 Consider the following statements:
1. To insert a 28 mm nominal diameter rivet, 29.5 mm rivet hole is made.
2. Provision is made to allow temperature expansion of the bolt.

Which of these statements are correct?
(a) Both 1 and 2 (b) 1 only
(c) 2 only (d) Neither 1 nor 2

[ESE : 1997]

1.14 In a diamond riveting, for a plate of width 'b' and rivet diameter 'd', the efficiency of the joint is given by

(a) $\frac{(b-d)}{b}$ (b) $\frac{(b-2d)}{b}$

(c) $\frac{(b-d)}{d}$ (d) $\frac{(b-2d)}{d}$

[ESE : 1997]

1.15 For two plates of equal thickness, full strength of fillet weld can be ensured if its maximum size, for square edge, is limited to
(a) 1.5 mm less than the thickness
(b) 75% of the thickness
(c) 80% of the thickness
(d) thickness of the plate

[ESE : 1998]

1.16 In a double-riveted double-covered butt joint, the strength of the joint per pitch length in shearing the rivets is n times the shear strength of one rivet in single shear, where 'n' is equal to
(a) 1 (b) 2
(c) 3 (d) 4

[ESE : 1998]

1.17 A welded fillet joint of length L can be subjected to a maximum load of
(fs-fillet size and pss = permissible shear stress).

(a) $\frac{(fs \times L \times pss)}{3}$ (b) $fs \times L \times pss$

(c) $(0.7)(fs \times L \times pss)$ (d) $2(fs \times L \times pss)$

[ESE : 1998]

1.18 Match List-I (Use) with List-II (Type of weld) and select the correct answer using the codes given below the lists:

List-I
A. Structural members
B. Joining two surfaces
C. A hole is made in one of
D. Pressure is applied

List-II
1. Slot weld subject to direct tension or compression
2. Seam weld approximately at right angles to each other

3. Fillet weld the components and welding is done around the periphery of the hole
4. Plug weld continuously
5. Butt weld

Codes:

	A	B	C	D
(a)	5	4	1	3
(b)	4	3	2	1
(c)	5	3	1	2
(d)	4	5	3	2

[ESE : 1999]

1.19 A welding detail is shown in figure-I

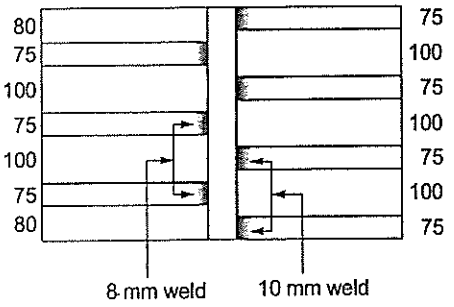
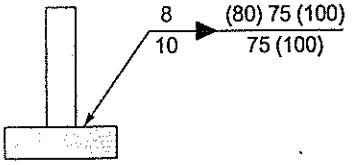
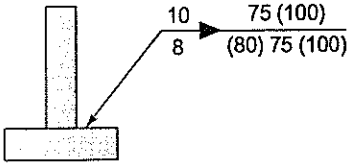
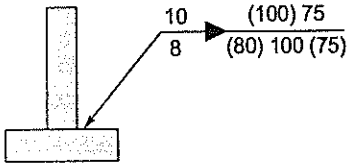


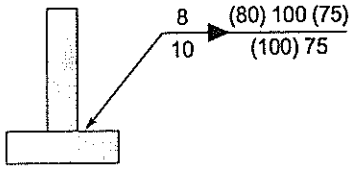
Figure-I

The welding notation for the figure is

(a) 

(b) 

(c) 

(d) 

[ESE : 1999]

1.20 A structural member carrying a pull of 700 kN is connected to a gusset plate using rivets. If the pulls required to shear the rivet, to crush the rivet and to tear the plate per pitch length are respectively 60 kN, 35 kN and 70 kN, then the number of rivets required will be

(a) 22 (b) 20
(c) 18 (d) 12

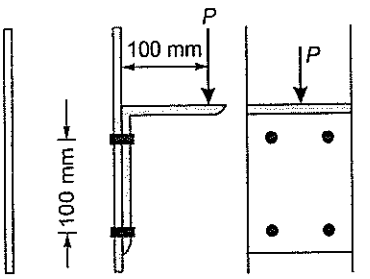
[ESE : 1999]

1.21 **Assertion (A)** : When a mild steel bar is tested in tension, the stress drops down from upper yield point to lower yield point without elongation.
Reason (R) : The boundaries of grains of mild steel are composed of brittle material.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2000]

1.22 Each bolt shown in the given figure is capable of resisting a shear force of 20 kN and tension of 15 kN. The interaction equation between the forces is



(a) $\frac{P}{40}+\frac{P}{30}=1.4$ (b) $\frac{P}{80}+\frac{P}{15}=1.4$

(c) $\frac{P}{80}+\frac{P}{30}=1.4$ (d) $\frac{P}{40}+\frac{P}{15}=1.4$

[ESE : 2000]

1.23 Consider the following statements regarding pin connections:

1. Moment at pin connection is zero.
2. Only one pin is used in a connection.
3. Secondary stresses do not occur.
4. They are rigid.

Which of these are the advantages of pin connections?

(a) 1, 3 and 4 (b) 2, 3 and 4
(c) 1, 2 and 3 (d) 1 and 2

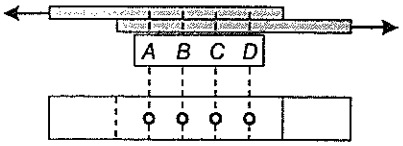
[ESE : 2000]

1.24 The permissible stresses in rivets under wind load conditions as per IS : 800 can be exceeded by about

(a) 15% (b) 25%
(c) 33% (d) 50%

[ESE : 2000]

1.25 Which one of the following statements regarding the riveted joint shown in the given figure is correct?



(a) In elastic theory all rivets carry equal forces.
(b) In plastic theory all rivets carry equal forces.
(c) Both in elastic and plastic theories all rivets carry equal forces.
(d) In plastic theory the outer rivets A and D carry greater proportion of load.

[ESE : 2000]

1.26 In an eccentrically loaded bearing type connection, P_{dx} and P_{dy} are the components of the direct load. P_{tx} and P_{ty} are the components of the torsional load. The maximum load on any connector is given by

(a) $\sqrt{(P_{dx}+P_{tx})^2+(P_{dy}+P_{ty})^2}$

(b) $\sqrt{(P_{dx}+P_{ty})^2+(P_{dy}+P_{tx})^2}$

(c) $\sqrt{(P_{dx}-P_{tx})^2+(P_{dy}-P_{ty})^2}$

(d) $\sqrt{(P_{dx}-P_{ty})^2+(P_{dy}-P_{tx})^2}$

[ESE : 2000]

1.27 Which one of the following is the mode of failure in a fillet weld material?

(a) Tension (b) Shear
(c) Bearing (d) Crushing

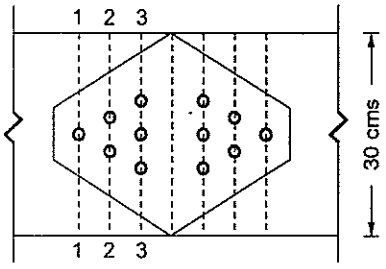
[ESE : 2001]

1.28 Load on connection is not eccentric for

(a) lap joint
(b) single cover butt joint
(c) double cover butt joint
(d) all the joints mentioned in (a), (b) and (c) of the question

[ESE : 2001]

1.29 Two steel plates each of 12 mm thickness are connected by a double cover butt joint by rivets shown in the given figure. If the rivet diameter is 22 mm with rivet force value of 53150 N and permissible stress in tension of plate is 142 N/mm^2, which one of the following section is the most critical section?



(a) Section 1 – 1
(b) Section 2 – 2
(c) Section 3 – 3
(d) Both section 1 – 1 and section 2 – 2

[ESE : 2001]

1.30 The order of elongation which a specimen of mild steel undergoes before fracture is

(a) 0.1% (b) 1%
(c) 10% (d) 100%

[ESE : 2003]

1.31 Match List-I (Failure mode) with List-II (Reason) and select the correct answer using the codes given below the lists:

List-I
A. Shear failure of plates
B. Bearing failure of plates
C. Tearing failure of plates
D. Splitting failure of plates

List-II
1. Insufficient edge distance
2. Strength of plate is less than that of the rivets

Codes:

	A	B	C	D
(a)	1	1	2	1
(b)	2	1	2	1
(c)	1	2	2	1
(d)	1	1	1	2

[ESE : 2003]

1.32 Which of the following does not describe a weld type?

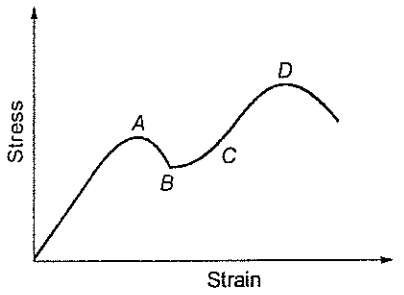
(a) Butt (b) Plug
(c) Zig-Zag (d) Lap

[ESE : 2003]

1.33 A plate used for connecting two or more structural members intersecting each other is termed as
(a) Template (b) Base plate
(c) Gusset plate (d) Shoe plate
[ESE : 2003]

1.34 In a riveted joint, failure will occur due to which one of the following?
(a) Shear failure of rivet
(b) Bearing failure of rivet
(c) Tearing failure of plate
(d) Minimum load value of shearing, bearing or tearing failure
[ESE : 2003]

1.35 The stress strain diagram for mild steel subjected to tensile load is given below. Now consider the following statements:



1. The diagram represents average stress strain diagram.
2. The diagram represents actual stress strain diagram.
3. A represents upper yield point.
4. B represents lower yield point.

Which of these statements are correct?
(a) 1, 2 and 4 (b) 1, 3 and 4
(c) 2, 3 and 4 (d) 1, 2 and 3
[ESE : 2004]

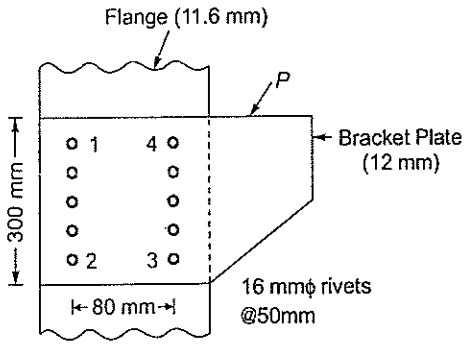
1.36 When the effect of wind or earthquake load is considered in the design of rivets and bolts for steel structures, by what percentage the permissible stresses may be exceeded?
(a) 15% (b) 25%
(c) 33.33% (d) 50%
[ESE : 2004]

1.37 A 6 mm thick mild steel plate is connected to an 8 mm thick plate by 16 mm diameter shop rivets. What is the number of rivets required to carry an 80 kN load?
(a) 2 (b) 3
(c) 4 (d) 6
[ESE : 2004]

1.38 Consider the following statements:
1. The gross area of a rivet is taken as the cross-sectional area of the rivet hole.
2. The distance between the centres of the rivets should not be less than 2.5 times the gross diameter of the rivet.
3. In no case shall fewer than two bolts or rivets be used for attaching the lug angle to the gusset.

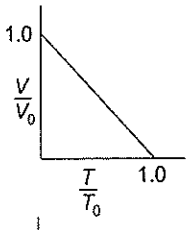
Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3
[ESE : 2004]

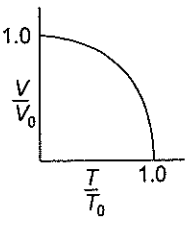
1.39 Which one of the following is the most critical rivet in the joint shown in the figure given below?

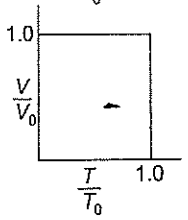


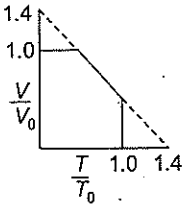
(a) No. 1 (b) No. 2
(c) No. 3 (d) No. 4
[ESE : 2005]

1.40 A bolt is subjected to shear force V and tension T. The capacity of the bolt in resisting shear and tension respectively are V_0 and T_0. Which one of the following diagrams represents interaction relations?

(a)


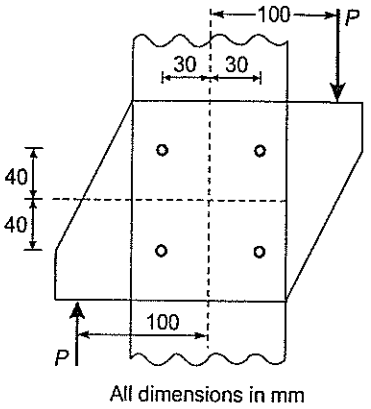
(b)


(c)


(d)


[ESE : 2006]

1.41 A bracket has been attached to flange of a column as shown in the figure. What is the maximum force in the bolt?



(a) P/4 (b) P/2
(c) P (d) 2P

[ESE : 2006]

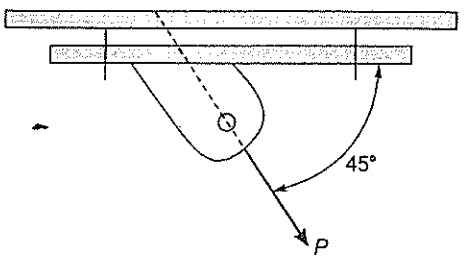
1.42 **Assertion (A):** Deflection of a beam with bolted connections is greater than that of a beam with riveted connections.
Reason (R): Bolted connections allow greater slip between components than riveted connections.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2006]

1.43 What is the ratio of the yield stress in power driven shop rivets relative to the permissible bearing stress of mild steel ?
(a) 1.0 (b) 0.8
(c) 0.6 (d) 0.4

[ESE : 2007]

1.44 Four bolts share the load P as shown in the figure below. The shear strength of bolts is 30 kN and tension strength of bolt is 40 kN.
Which one of the following is the value of *P*?



(a) 96 kN (b) 105 kN
(c) 117 kN (d) 134 kN

[ESE : 2007]

1.45 Which one of the following is correct?
Steel structures are ideally suitable for impact loads because they have high
(a) toughness value (b) elastic modulus
(c) design stress (d) plastic modulus

[ESE : 2008]

1.46 Which one of the following is correct?
The permissible stresses in a weld are usually taken as
(a) less than those of the parent body
(b) equal to those of the parent body
(c) more than those of the parent body any desired value
(d) any desired value

[ESE : 2008]

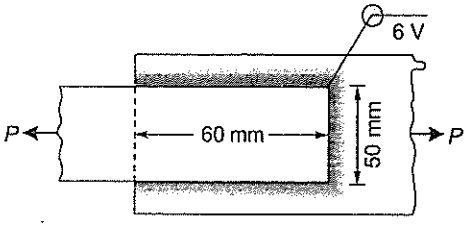
1.47 For field rivets, the permissible stresses are reduced by what percentage?
(a) 10% (b) 15%
(c) 25% (d) $33\frac{1}{3}\%$

[ESE : 2008]

1.48 A steel plate is 300 mm wide and 10 mm thick. A rivet of nominal diameter of 16 mm is driven into it. What is the net sectional area of the plate ?
(a) 2600 mm^2 (b) 2760 mm^2
(c) 2830 mm^2 (d) 2840 mm^2

[ESE : 2009]

1.49 What is the safe load P that can be transmitted by the fillet-welded joint shown in figure below if the safe allowable shear stress in the fillet-weld is 108 MPa?



(a) 60 kN (b) 66 kN
(c) 77 kN (d) 81 kN

[ESE : 2009]

1.50 Consider the following statements :
1. When wind load is the primary load, no increase in the allowable stresses is provided for in members or fasteners.
2. Due to wind load acting along with dead and live loads, increase in allowable stress upto 33·33% can be provided for.
3. Due to wind load acting along with dead load, increase in allowable stress of 25% in foundation bolts can be provided for.

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 1 only
(c) 2 and 3 (d) 3 only

[ESE : 2009]

1.51 A bolt designated as Hex bolt M 16 × 70 NL will have
(a) diameter of 16 mm
(b) diameter of 70 mm
(c) length of 16 mm
(d) cross-sectional area of 16 × 70 cm^2

[ESE : 2010]

1.52 The maximum longitudinal pitch allowed in bolted joints of tension members is
(a) 16 times the diameter of the bolt
(b) 32 times the diameter of the bolt
(c) 16 times the thickness of the plate
(d) 32 times the thickness of the plate

[ESE : 2010]

1.53 A structural member carrying a pull of 700 kN is connected to a gusset plate using rivets of 20 mm diameter. If the pull required for shearing the rivets, to crush the rivets and to tear the plate per pitch length are 60 kN, 35 kN and 70 kN respectively, then the number of rivets required is
(a) 12 (b) 18
(c) 20 (d) 22

[ESE : 2010]

1.54 The effective length of the fillet weld is
(a) Total length – 2 × throat size
(b) Total length – 2 × weld size
(c) 0.7 × total length
(d) Total length $-\left(\frac{\text{Weld size}}{\sqrt{2}}\right)$

[ESE : 2011]

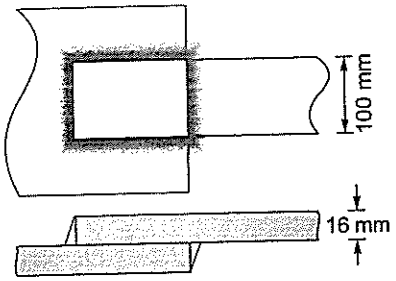
1.55 When the distance between centers of two adjacent rivets connecting the members subjected to either compression or tension exceeds the maximum pitch, then the additional rivets which are not subjected to the calculated stresses are known as
(a) Packing rivets
(b) Long-grip rivets
(c) Tacking rivets
(d) Auxiliary rivets

[ESE : 2011]

1.56 The maximum longitudinal pitch in bolted joints, subjected to tensile forces, wherein t = thickness of the plate and D = diameter of bolt, is
(a) 32 D (b) 16 D
(c) 32 t (d) 16 t

[ESE : 2011]

1.57 A tie bar 100 mm × 16 mm thick is to be welded to another plate as shown in figure using 8 mm fillet welds. If the tensile stress in plates is 150 N/mm^2 and shear stress in weld is 110.0 N/mm^2, the minimum overlap required will be



(a) 50 mm (b) 75 mm
(c) 100 mm (d) 150 mm

[ESE : 2011]

1.58 For two plates of equal thickness, full strength of square-edged fillet weld can be ensured if its maximum size is limited to
(a) 1.5 mm less than the plate thickness
(b) 67% of the plate thickness
(c) 80% of the plate thickness
(d) Thickness of the plate

[ESE : 2011]

1.59 When the effect of wind or earthquake load is taken into account in the design of a riveted connection, the permissible stresses in rivets may be exceeded by

(a) 16.66% (b) 33.33%
(c) 25% (d) 30%

[ESE : 2012]

1.60 A mild steel flat subjected to a tensile force of 840 kN is connected to a gusset plate using rivets. If the permissible forces required per pitch length (i) to shear a single rivet, (ii) to crush the rivet and (iii) to tear the plate are 50 kN, 80 kN and 60 kN respectively, then the number of rivets required is
(a) 12 (b) 14
(c) 16 (d) 17

[ESE : 2012]

1.61 The effective throat thickness of a fillet weld depends upon
(a) angle between fusion faces
(b) length of weld
(c) permissible shear stress
(d) type of weld

[ESE : 2012]

1.62 When the load line coincides with the centroid of the rivet group, the rivets are subjected to
(a) shear only
(b) tension only
(c) bending only
(d) shear as well as tension

[ESE : 2012]

1.63 Which of the following statements is/are correct?
1. A steel structure designer can guarantee the safety of the structure.
2. Working stress method of design of steel structures offers a safer and economical structure.
3. Strength and serviceability of a structure cannot be predicted on account of several unforeseen factors

(a) 1, 2 and 3 (b) 3 only
(c) 2 only (d) 1 only

[ESE : 2013]

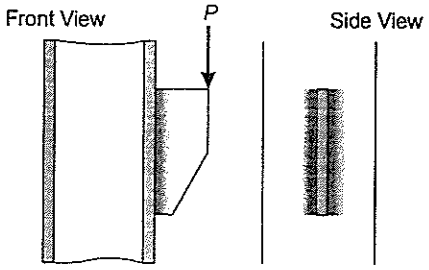
1.64 An angle ISA 50 × 50 × 6 is connected to a gusset plate 5 mm thick, with 16 mm bolts. What is the bearing strength of the bolt when the hole diameter is 16 mm and the allowable bearing stress is 250 MPa?
(a) 8 kN (b) 20 kN
(c) 22.5 kN (d) 24 kN

[ESE : 2014]

1.65 The effective length of a fillet weld is taken as the actual length
(a) plus twice the size of the weld
(b) minus twice the size of the weld
(c) plus the size of the weld
(d) minus the size of the weld

[ESE : 2014]

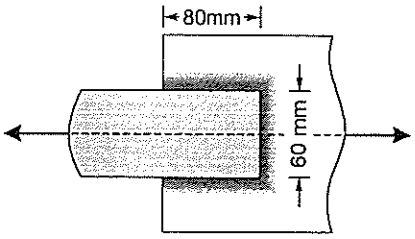
1.66 For the welded joint shown in the figure, the direct vertical shear stress on the weld is 40 MPa and the bending stress is 120 MPa. For what strength should the weld be designed?



(a) 80 MPa (b) 120 MPa
(c) 132 MPa (d) 160 MPa

[ESE : 2015]

1.67 A fillet-welded joint is shown in the figure. The size of the weld is 8 mm. Safe stress in the weld is 110 N/mm^2. What is the safe force (to the nearest magnitude) to which the weld can be subjected?



(a) 125 kN (b) 130 kN
(c) 140 kN (d) 135 kN

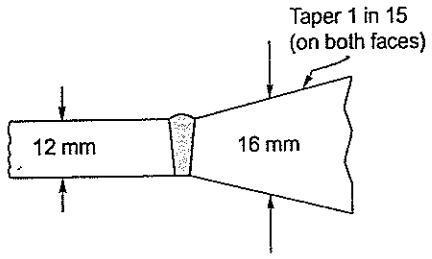
[ESE : 2015]

1.68 A circular shaft of diameter 120 mm is welded to a rigid plate by a fillet weld of size 6 mm. If a torque of 8 kNm is applied to the shaft, what is the maximum stress in the weld (to the nearest unit)?
(a) 84 N/mm^2 (b) 87 N/mm^2
(c) 90 N/mm^2 (d) 95 N/mm^2

[ESE : 2015]

1.69 Two plates of dimensions 150 mm × 16 mm and 150 mm × 12 mm at their welding edges are

joined by butt welding as shown in the figure. What is the maximum tension that this single V-butt weld joint can transmit? The permissible tensile stress in the plates is 150 MPa.



(a) 168.75 kN (b) 270 kN
(c) 218 kN (d) 1350 kN

[ESE : 2015]

1.70 What is the maximum number of 20 mm diameter bolts that can be accommodated in a single row on a 140 mm wide flat strip used as one of the structural elements involved in the process?

(a) 4 (b) 3
(c) 2 (d) 5

[ESE : 2015]

1.71 What is the nearest magnitude of strength of a 6 mm fillet weld of 100 mm length made between two flats each 10 mm thick? The allowable shear stress on the weld is 110 MPa.

(a) 23 kN (b) 33 kN
(c) 46 kN (d) 66 kN

[ESE : 2015]

1.72 Consider the following statements:

1. When analyzing by the Ultimate Load Method, the eccentrically loaded fastener group rotates about an instantaneous centre.
2. The rivet which is the farthest from the centre of gravity of the rivet group and may also be the nearest to the applied load line is the most 'critical' one.
3. The deformation at each rivet is not proportional to its distance from the centre of rotation.

Which of the above statements are correct?

(a) 1 and 3 only (b) 2 and 3 only
(c) 1 and 2 only (d) 1, 2 and 3

[ESE : 2015]

1.73 Which of the following statements are correct in respect of welded connections?

1. Strength of Butt weld is equal to the strength of components joined.
2. Fillet welds carry the loads computed based on the tensile strength characteristic of fusion material.
3. For effective transmission of load by fillet weld, the fusion faces shall subtend an angle between 60° and 120°.

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

[ESE : 2015]

1.74 The block shear failure of a bolted joint in tension occurs because of

1. Use of high shear strength bolts
2. Use of plates with higher bearing strength

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2016]

1.75 The design strength of a tension member is governed by

1. Rupture at a critical section
2. Yielding of gross area
3. Block shear of end region

Select the correct answer using the codes given below:

(a) 1 only (b) 2 only
(c) 3 only (d) 1, 2 and 3

[ESE : 2017]

Answers Structural Fasteners

1.1 (d)	1.2 (c)	1.3 (c)	1.4 (d)	1.5 (c)	1.6 (d)	1.7 (b)	1.8 (d)	1.9 (c)	
1.10 (a)	1.11 (b)	1.12 (b)	1.13 (d)	1.14 (a)	1.15 (a)	1.16 (d)	1.17 (c)	1.18 (c)	
1.19 (a)	1.20 (b)	1.21 (c)	1.22 (c)	1.23 (d)	1.24 (b)	1.25 (b)	1.26 (a)	1.27 (b)	
1.28 (c)	1.29 (a)	1.30 (c)	1.31 (a)	1.32 (c)	1.33 (c)	1.34 (d)	1.35 (b)	1.36 (b)	
1.37 (c)	1.38 (b)	1.39 (c)	1.40 (b)	1.41 (c)	1.42 (a)	1.43 (b)	1.44 (d)	1.45 (a)	
1.46 (b)	1.47 (a)	1.48 (c)	1.49 (c)	1.50 (c)	1.51 (a)	1.52 (c)	1.53 (c)	1.54 (b)	
1.55 (c)	1.56 (d)	1.57 (c)	1.58 (a)	1.59 (c)	1.60 (d)	1.61 (a)	1.62 (a)	1.63 (b)	
1.64 (b)	1.65 (b)	1.66 (c)	1.67 (d)	1.68 (a)	1.69 (a)	1.70 (c)	1.71 (c)	1.72 (c)	
1.73 (d)	1.74 (c)	1.75 (d)							

Explanations Structural Fasteners

1.1 (d)

Aluminium has greater strength to unit weight ratio compared to steel therefore they are being increasingly used for structural purposes.

The modulus of elasticity of aluminium is about one third that of steel while its coefficient of thermal expansion is double that of steel.

1.2 (c)

For a rivet with nominal diameter less than or equal to 25 mm, the hole diameter is taken 1.5 mm more than nominal diameter. For nominal diameter more than 25 mm, the hole diameter is 2 mm more than the nominal diameter. The rivet is heated uniformly from temperature 550°C to 1000°C and after placing it in the hole in the heated condition, its head is pressed on the rivet. Thus it fills the hole completely. However it can be cold driven also.

Diameter of rivet hole = 18 + 1.5 = 19.5 mm

The net cross-sectional area of plate

$= (30 - 1.95) \times 1.0 = 28.05\ cm^2$

1.3 (c)

For eccentric riveted connection,

Direct shear force,

$$R_p = \frac{P}{N}$$

$P \rightarrow$ Load with eccentricity e

$N \rightarrow$ Number of rivets

Shear force due to eccentricity,

$$R_m = \frac{Per}{\Sigma r^2}$$

$r \rightarrow$ radial distance of rivet from centroid.

Resultant $\vec{R} = \vec{R}_p + \vec{R}_m$

The magnitude of resultant should be less than rivet value.

1.4 (d)

For eccentric riveted connection,

Direct shear force,

$$R_p = \frac{P}{N}$$

$P \rightarrow$ Load with eccentricity e

$N \rightarrow$ Number of rivets

Shear force due to eccentricity,

$$R_m = \frac{Per}{\Sigma r^2}$$

$r \rightarrow$ radial distance of rivet from centroid.

Resultant $\vec{R} = \vec{R}_p + \vec{R}_m$

The magnitude of resultant should be less than rivet value.

1.5 (c)

The strength of weld (F)

$= 0.707 \times 10 \times 6 = 42.42$ kg/mm

Length of the weld, $l = \pi d = 100\pi$ mm

Twisting moment $= Fl \times \frac{d}{2}$

$= 42.42 \times 100\pi \times 50$

$= 212\ 100\pi$ kg-mm
$= 212.1\pi$ kg-m

1.6 (d)

Rivet value is minimum of 5000 kg, 8000 kg and 6000 kg.

$\therefore$ Rivet value = 5000 kg

$$\text{Number of rivets} = \frac{84\times1000}{5000} = 16.8 \simeq 17$$

1.7 (b)

Throat being the minimum section will carry maximum stress. Thus, it is weakest.

1.8 (d)

The connection, whether riveted, bolted or welded, can be designed as flexible, semi-rigid or rigid connections. Flexible connections are also known as simple connections. These connections are assumed to resist shear only. Rigid connections, also known as moment connections, can resist both shear and bending moments at the connections. Semi-rigid connections resist the bending moment in between the flexible and rigid connections.

Plastic or ultimate design considers complete mobilization of strength of material. This method does not take into consideration the effect of impact, fatigue, creep and shrinkage. The serviceability requirements of avoidance of excessive deflection and cracking are not considered.

1.9 (c)

The transmission of load in a riveted (or bolted) joint occurs either by friction between the connected plates due to large gripping forces produces by tension in the rivet (or bolt), or by shearing action on the cross-section of the rivet and bearing stresses on the faces of rivet and plates in contact with each other. In the bearing of joint friction is overcome and the joint slips. The contribution of friction is neglected and the load is fully transmitted through the rivet. All the rivets are assumed to resist the load equally.

The applied load may or may not pass through the centroid of the connector group.

1.10 (a)

Plastic deformation of metals below the re-crystallization temperature is known as cold working. In this process steel is loaded above elastic limit to have some plastic strain which in turn omits upper yield point later.

1.12 (b)

The effective length of fillet weld is taken equal to its overall length minus twice the weld size. The deduction is made to allow for craters to be formed at the ends of the welded length. The effective length of a fillet should not be less than 4 times the weld size.

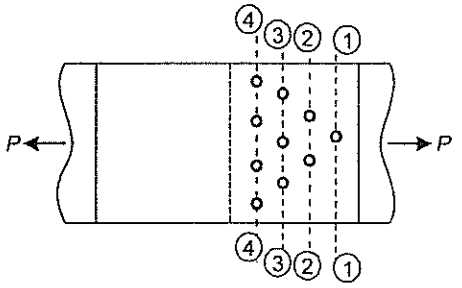
1.13 (d)

For rivets with diameter ≤ 25 mm
Diameter of the hole = (d + 1.5) mm
For rivets with diameter ≥ 25 mm
Diameter of the hole = (d + 2) mm
For 28 mm diameter, diameter of hole = (28 + 2) mm =30 mm
This provision is provided for ease of alignment of bolt.

1.14 (a)

Efficiency of riveted joint,

$$\eta = \frac{\text{Strength of riveted joint}}{\text{Strength of solid plate}}\times100$$



The section 1 – 1 is most critical. The strength of joint at section 1 – 1 is $(b-d)\,t\,\sigma_{at}$.
The strength of solid plate is $b\,t\,\sigma_{at}$.

So $$\eta = \frac{b-d}{b}\times100$$

1.15 (a)

The maximum size of a fillet weld is obtained by subtracting 1.5 mm from the thickness of the thinner member to be jointed. This specification limits the size of the fillet weld so that total

strength may be developed without overstressing the adjacent metal.

1.16 (d)

Strength of one rivet in single shear

$$= P_s = \frac{\pi}{4} d^2 \tau_{vf}$$

Strength of double riveted double cover butt joint per pitch length = P_d

$$= 2 \times 2 \times \frac{\pi}{4} d^2 \tau_{vf}$$

But $P_d = nP_s$ (given)

$\Rightarrow$ $P_d = 4P_s$

1.17 (c)

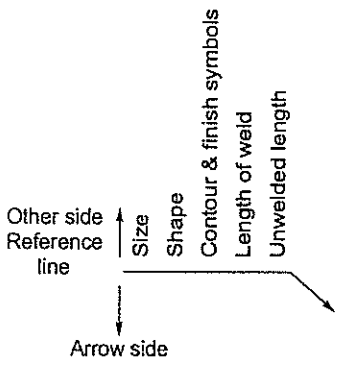
The strength fillet weld = 0.7 ($fs \times pss$) per unit length. So maximum load is strength of fillet weld × joint length (L).

1.18 (c)

In butt welds, the effective thickness is generally less than the plates connected so the joint has less than 100% efficiency. They are stronger than fillet welds and used most frequently. They are used when the members to be jointed are lined up. It is usually designed for direct tension or compression. Fillet welds are provided when two members to be jointed are in different planes.

If a sufficient length of fillet weld cannot be provided, the connection can be strengthened by the use of plug or slot welds. They are made by filling with weld metal in a circular (plug weld) or slotted (slot weld) hole cut in one of the parts to be joined.

1.19 (a)



1.20 (b)

The rivet value R = 35 kN

$$\text{Number of rivets required} = \frac{700}{35} = 20$$

1.21 (c)

The magnitude of stress corresponding to the upper yield point depends on the cross-sectional shape of the specimen and type of equipment used to perform the test.

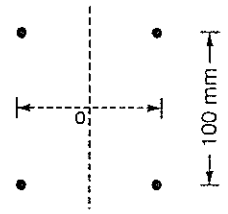
The lower yield point is observed when the rate of loading is slow whereas the upper yield point is observed when the load is applied rapidly.

1.22 (c)

The shear force in the bolt, $V = \frac{P}{4}$

The bottom bolts will be in compression, while the top bolts will be in tension.

The moment of inertia about X–X axis.



$$I = A\left(50^2 + 50^2 + 50^2 + 50^2\right)$$

$$= 10{,}000A \text{ mm}^4 \left(\sigma = \frac{My}{I}\right)$$

Tension in upper bolt

$$(T) = \frac{P \times 100 \times 50}{10{,}000A} A = \frac{P}{2}$$

Interaction equation

$$\frac{V}{V_a} + \frac{T}{T_a} \leq 1.4$$

Given V_a = 20 kN; T_a = 15 kN

$$\frac{P}{80} + \frac{P}{30} = 1.4$$

1.23 (d)

Pinned connection are provided when hinged joints are required i.e. for the connection where zero moment or free rotation is desired. Introduction of a hinge simplifies the analysis by reducing indeterminacy. These also reduce the secondary stresses but do not make them zero. A pin is subjected to shear, bearing and flexure

1.24 (b)

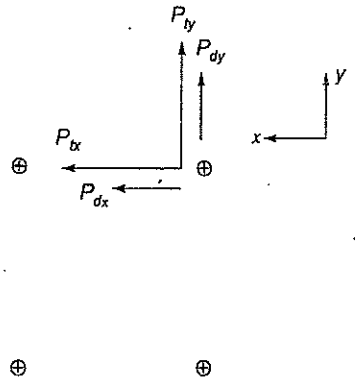
As per clause 3.9.22 IS 800 : 1984, the permissible stresses for rivets are increased by 25% when effect of wind and seismic load is taken into account.

1.25 (b)

The rivets are assumed to resist the load equally in the elastic theory. Actually the outer rivets carry more load compared to rivets in the middle rows. When the load is increased, the more highly stressed rivets start yielding earlier and there is redistribution of load among rivets. The failure will occur when all rivets have yielded and the strength of the group of rivets is equal to the strength of one rivet multiplied by the number of rivets.

1.26 (a)

Following in th type of connections



Net horizontal load= $P_{dx} + P_{tx}$

Net vertical load = $P_{dy} + P_{ty}$

Resultant load

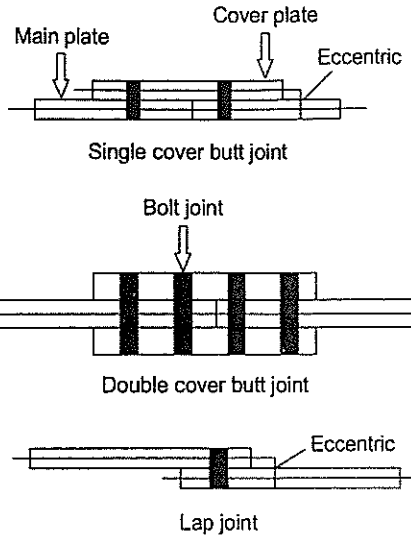
$$= \sqrt{(P_{dx} + P_{tx})^2 + (P_{dy} + P_{ty})^2}$$

1.27 (b)

Regardless of the direction in which load is applied, fillet weld fails by shear on throat.

1.28 (c)

The connection is concentric in double cover butt joint whereas in lap joint and single cover butt joint the connection is eccentric.



1.29 (a)

Gross diameter of hole = 22 + 1.5 = 23.5 mm

Strength of main plate of section 1-1

$= \sigma_{at}(B - d)t$

$= 142 \times (300 - 23.5) \times 12$

$= 471.156$ kN

At section 2-2

$= \sigma_{at} \times (B - 2d) \times t + R_v$

$= 142 \times (300 - 47) \times 12 + 53150$

$= 431.112 + 53.150 = 484.262$ kN

At section 3-3

$= \sigma_{at} \times (B - 3d) \times t + 3R_v$

$= 142 \times (300 - 70.5) \times 12 + 159450$

$= 550.518$ kN

So section 1-1 is most critical for main plate.

1.30 (c)

For mild steel

(i) Proportional limit 190 – 220 N/mm^2

(ii) Yield strength 230 – 250 N/mm^2

(iii) Ultimate strength 410 – 530 N/mm^2

(iv) Fracture strength 250 – 300 N/mm^2

(v) Elongation at fracture 23 – 35%

Thus the order of elongation is 10%

1.31 (a)

Tearing failure in plate may occur when strength of plate is less than that of rivets. A plate may fail by shear, bearing or by splitting if there is not sufficient edge distance provided in a riveted joint.

1.32 (c)

Zigzag is not a weld type. Fillet, Butt, Plug, Lap, Slot, Seam are type of welds.

1.33 (c)

Base plates are provided to distribute the load of a column on greater area.

1.34 (d)

In riveted joint, failure can occur by shear failure and bearing failure of rivet and tearing failure of plate. Strength of joint is calculated for each mode of failure and minimum value is taken as joint strength.

1.35 (b)

$$\text{Engineering stress or Average stress} = \frac{P}{A_0}$$

$$\text{True stress} = \frac{P}{A_f}$$

Engineering strain or Average strain

$$= \frac{l_f - l_0}{l_0}$$

$$\text{True strain} = ln\left(\frac{l_f}{l_0}\right)$$

The given curve represents average stress-strain diagram.

$A_0 \rightarrow$ Initial cross-sectional area of specimen

$A_f \rightarrow$ Final

$l_0 \rightarrow$ Initial length of specimen

$l_f \rightarrow$ Final length of specimen

1.36 (b)

As per IS 800-1984, In case of wind or earthquake load, allowable stresses can be increased by 25% in design of rivets and bolts for steel structures.

1.37 (c)

For shop rivets permissible stresses are

In shearing, $\tau_s = 100$ MPa

In bearing, $\sigma_b = 300$ MPa

The gross diameter of hole (D)

$= 16 + 1.5 = 17.5$ mm

Strength of rivets in bearing $= Dt\sigma_b$

$= 17.5 \times 6 \times 300 = 31.5$ kN

Strength of rivets in single shear

$$= \frac{\pi D^2}{4} \times \tau_s$$

$$= \frac{\pi}{4} \times (17.5)^2 \times 100$$

$= 24.05$ kN

$\therefore$ Rivet value $= 24.05$ kN

Hence, number of rivets required

$$= \frac{80}{24.05} = 3.33 \approx 4$$

1.38 (b)

The distance between the centres of the rivets should not be less than 2.5 time the nominal diameter of the rivets.

Less than two bolts or rivets will permit rotation about the connection. So not less than two bolts or rivets shall be used for attaching the lug angle to the gusset.

1.39 (c)

In the case of inclined loads.

A rivet nearest to the load axis will be critical. Extending the line of action of load P, it passes almost through the rivet 3. So rivet 3 is most critical.

1.40 (b)

The interaction equation for a high tension bolt subjected to shear and tension is

$$\left(\frac{V}{V_0}\right)^2 + \left(\frac{T}{T_0}\right)^2 \le 1$$

This equation is represented by diagram (b)

According to IS :800, the rivets and bolts subjected to both shear and tension shall be so proportioned that the calculated shear and axial forces do not exceed the respective allowable forces i.e.,

$$\frac{V}{V_0} \le 1 \text{ and } \frac{T}{T_0} \le 1.$$

Further $\frac{V}{V_0} + \frac{T}{T_0} \le 1.4$.

So curve(d) represents the interaction equation.

1.41 (c)

The forces on either side balance each other so force in bolts is due to moment only. The moment on the rivets

$M = P \times 100 + P \times 100 = 200P$

The distance of any rivet from centroid (r)

$$= \sqrt{(30)^2 + (40)^2} = 50 \text{ mm}$$

The maximum force in the bolt

$$= \frac{Mr}{\sum r^2} = \frac{Mr}{4r^2} = \frac{M}{4r} = \frac{200P}{4\times 50} = P$$

1.42 (a)

Greater slip between components is provided by bolted connections than by riveted connections. HSFG bolts designed as slip critical connections are used in order to overcome such slip.

1.44 (d)

According to IS : 800, the rivet and bolts subjected to both shear and tension shall follow the relation

$$\frac{V}{V_0} + \frac{T}{T_0} \le 1.4$$

Here, $V_0 = 30$ kN, $T_0 = 40$ kN

$$V = \frac{P\cos 45°}{4}$$

$$T = \frac{P\sin 45°}{4}$$

So, $$\frac{P}{\sqrt{2}\times 4\times 30} + \frac{P}{\sqrt{3}\times 4\times 40} \le 1.4$$

$$\Rightarrow \quad P \le 135.76$$

So, (d) is correct answer.

1.45 (a)

Toughness is the ability of a metal to resist fracture and it is significant for ductile materials only. Ductile materials have greater fracture strain, hence they are more tough e.g. mild steel is more tough than cast iron. Toughness, for this reason is desirable against impact loading.

1.46 (a)

As per IS Code, Permissible stresses in weld shall not exceed allowable stress for parent metal.

1.47 (a)

As per IS 800-1984, Permissible stress are reduced by 10% for the field rivets.

1.48 (c)

Net sectional area of the plate $= (B - d')t$

$= [300 - (16 + 1.5)] \times 10$

$= 282.5 \times 10$

$= 2825\ mm^2$

1.49 (c)

The safe load that can be transmitted by the fillet welded joint is given by

$$P = l \times \frac{S}{\sqrt{2}} \times 108$$

$$= (60 + 50 + 60) \times \frac{6}{\sqrt{2}} \times 108$$

$$= 77895\ N = 77.895\ kN$$

1.50 (c)

As per clause 3.9.2.1 of IS : 800-1984

1.51 (a)

Bolt designated as Hex bolt M16 × 70NL has 16 mm as nominal diameter of the bolt and 70 mm as the length of the bolt.

1.52 (c)

As per IS 800-1984, maximum longitudinal pitch allowed in bolted joints of tension members is 16 times the thickness of plate subject to maximum spacing 200 mm.

1.53 (c)

Number of rivets

$$= \frac{P}{\text{Rivet value}} = \frac{700}{35} = 20$$

1.54 (b)

Effective length is the length of the fillet weld for which the specified size and throat thickness of weld exist. It is taken equal to its overall length minus twice the weld size. The deduction is made to allow for craters to be formed at the ends of the welded length. End returns are made equal to twice the size of the weld to relieve the latter from high stress concentrations at their ends.

1.55 (c)

Tacking or stitch rivets are used to make the sections act in unison, and to prevent buckling in compression members, where two or more sections are in contact.

When the distance between the centres of two consecutive rivets in such cases exceeds the maximum specified pitch of 12t or 200 mm, whichever is less, in compression members and 16t or 200 mm, whichever is less in tension

members, additional rivets are provided. These are not subjected to calculated stresses and are called tacking or stitch rivets

1.56 (d)

The maximum longitudinal pitch in tension is 16t or 200 mm which ever is less and in compression is 12t or 200 mm whichever is less.

1.57 (c)

The overlap should not be less than5 × 16 = 80 mm

Let length of the overlap be equal to 'l' then total length of the fillet weld $= 2l + 200$.

Size of the fillet weld = 8 mm and throat thickness = 0.7s = 5.6

The joint will be designed for full strength of the plate. Strength of the fillet weld

$$= 110 \times (2l + 200) \times 5.6$$

Strength of the plate

$$= 150 \times (200 \times 16)$$
$$= 240000\ \text{N}$$

For fillet weld to carry full srength of plate

$$\Rightarrow 110 \times (2l + 200) \times 5.6 = 240000$$
$$\Rightarrow l = 94.5\ \text{mm}$$
$$\approx 100\ \text{mm}$$

1.58 (a)

As per IS 800, full strength of square-edged fillet weld can be ensured if its maximum size is limited to 1.5 mm less than the plate thickness and when fillet weld is applied to round toe of rolled steel section, maximum size of weld should not exceed ¾ of thickness of section of toe.

1.59 (c)

For rivets, bolts and tension rods, the permissible stress may be increased by 25%.

For structural steel and steel casings, the permissible stresses may be increased by $33\frac{1}{3}\%$.

1.60 (d)

Number of rivets required

$$= \frac{\text{Tensile force}}{\text{Rivet value}}$$

Now, rivet value = min of (shear, crushing tearing)

= 50 kN

$\therefore$ Number of rivets

$$= \frac{840}{50} = 16.8 = 17$$

1.61 (a)

The value of K depends upon the angle between the fusion faces as given in table

Angle b/w fusion faces	60°-90°	91°-100°	101°-106°	107°-113°	114°-120°
Constant K	0.7	0.65	0.6	0.55	0.5

1.63 (b)

No structural engineer can guarantee the safety of a structure. WSM results in uneconomical design.

To account for uncertainity in strength and serviceability of a structure FOSs are introduced.

1.64 (b)

Bearing strength = $f_b dt$

$$= 250 \times 16 \times 5$$
$$= 20\ \text{kN}$$

1.65 (b)

Effective length of fillet weld

= Actual length – 2 × weld size.

This deduction is made to compensate for craters to be formed at the end of welded length.

1.66 (c)

Shear stress = 40 MPa and bending stress = 120 MPa. Fillet welds are designed for the resultant stress. Hence strength of the weld should be greater than resultant stress.

$$\text{Resultant stress} = \sqrt{40^2 + 120^2}$$
$$= 126.49\ \text{MPa}$$

1.67 (d)

Throat thickness = 0.7 × size of weld

$$= 0.7 \times 8 = 5.6\ \text{mm}$$

$$\text{Safe force} = (80 + 60 + 80) \times 5.6 \times 110$$
$$= 135520\ \text{N}$$
$$= 135.520\ \text{kN}$$

1.68 (a)

Throat thickness,

$$t = 0.7 \times 6 = 4.2\ \text{mm}$$

Polar modulus of inertia,

$$I_P = 2\pi R^3 t$$

Shear stress,

$$\tau = \frac{T.R}{I_P} = \frac{8\times10^6\times60}{2\pi\times60^3\times4.2}$$

$$\therefore \quad \tau = 84.21\ \text{N/mm}^2$$

1.69 (a)

Generally, we assume incomplete penetration in single V-butt weld i.e. 5/8 of thickness of thinner plate.

$\therefore$ Maximum tension

$$= 150\times\frac{5}{8}\times12\times150$$

$$= 168.75\ \text{kN}$$

1.70 (c)

Nominal diameter of bolt = 20 mm

Then diameter of hole = 20 + 2 = 22 mm

Minimum pitch = 2.5 × 20 = 50 mm

Minimum end/edge distance = 1.5 × 22 = 33 mm

Let n be the number of bolts, then

$2 \times 33 + (n-1) \times 50 = 140$

$\Rightarrow \quad n = 2.48$

Therefore, maximum 2 number of bolts can be provided.

1.71 (c)

Allowable shear

$$=\frac{0.7\times6\times100\times110}{1000} = 46.2\ \text{kN}$$

1.72 (c)

In case of eccentric loading, shear in bolts due to moment is given by

$$F_i = \frac{Mr_i}{\Sigma r_i^2} \quad \text{where M = Pe}$$

Thus deformation is proportional to its distance from centre of rotation.

1.73 (d)

Fillet welds carry the loads computed based on the shear strength characteristics of fusion material.

1.74 (c)

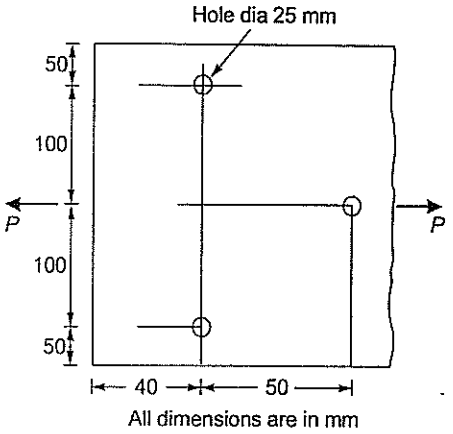
The possibility of block shear failure increases with the use of high bearing strength material and high strength bolts which results in fewer bolts and smaller connection lengths.

1.75 (d)

As per IS code 800 : 2007, Clause 6.1.

2 Tension Member

2.1 What is the effective net width of plate shown in the given sketch, for carrying tension?



(a) 212.5 mm (b) 237.5 mm
(c) 250 mm (d) 275 mm

[ESE : 1996]

2.2 A single-angle tie of a welded steel truss in an industrial shed is required to be designed for an axial tension of 50 kN. If the permissible tensile stress is 150 MPa, then the most suitable section satisfying IS : 800 codal requirements will be
(a) ISA 75 × 50 × 6
(b) ISA 60 × 40 × 5
(c) ISA 50 × 30 × 4
(d) ISA 45 × 30 × 5

[ESE : 1996]

2.3 Given that
A_e = effective area of the member and
σ_y = yield stress
In order to obtain the ultimate strength of a tension member, as per the plastic design concept, $A_e\sigma_y$ is to be multiplied by
(a) 1.1 (b) 0.95
(c) 0.85 (d) 0.75

[ESE : 1997]

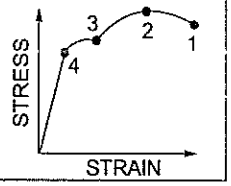
2.4 The permissible stresses for main structural steel members under dynamic loads should be increased by
(a) 20% (b) 25%
(c) 30% (d) 33.33%

[ESE : 1999]

2.5 The slenderness ratio in tension member as per BIS code where reversal of stress is due to loads other than wind or seismic shall not exceed
(a) 350 (b) 180
(c) 100 (d) 60

[ESE : 2001]

2.6 Match List-I (Properties) with List-II (Stress points labelled 1, 2, 3 and 4) in the stress-strain figure and select the correct answer using the codes given below the lists:

List-I	List-II
A. Yield point	
B. Proportional limit	
C. Rupture strength	
D. Ultimate strength	

Codes:

	A	B	C	D
(a)	3	4	1	2
(b)	4	3	1	2
(c)	3	4	2	1
(d)	4	3	2	1

[ESE : 2001]

2.7 **Assertion (A) :** In the working stress design method the internal stresses at a section of member are computed for factored loads.
Reason (R) : In the working stress design method it is ensured that the internal stresses due to working loads are less than the allowable stresses.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2002]

2.8 The working stress for structural steel in tension is of the order of
(a) 15 N/mm^2 (b) 75 N/mm^2
(c) 150 N/mm^2 (d) 750 N/mm^2
[ESE : 2003]

2.9 As per the elastic theory of design, the factor of safety is the ratio of
(a) working stress to stress at the limit of proportionality
(b) yield stress to working stress
(c) ultimate stress to working stress
(d) ultimate load to load at yield
[ESE : 2003]

2.10 In the context of the ultimate load theory for steel, the stress-strain curve for steel is idealized as
(a) a single straight line
(b) bi-linear
(c) a quadratic parabola
(d) a circular arc
[ESE : 2003]

2.11 The centre to centre maximum distance between bolts in tension member of thickness 10 mm is
(a) 200 mm (b) 160 mm
(c) 120 mm (d) 100 mm
[ESE : 2003]

2.12 Only a portion of the area of outstanding leg in an angle section serving as tension member is considered in computing the effective area of the member. This is because
(a) near the joint, the outstanding leg does not take its full stress
(b) the outstanding leg has a number of rivet holes reducing the net area
(c) the outstanding leg is susceptible to buckling
(d) additional safety is preferred in the case of tension failure
[ESE : 2004]

2.13 Some steels do not show yield plateau and show continuous curve. For such steel, how is the yield strength obtained?
(a) By drawing 0.2% offset of the strain
(b) By drawing 0.5% offset of the strain
(c) By drawing initial tangent
(d) By drawing initial secant modulus
[ESE : 2004]

2.14 Consider the following statements:
Lug angles are used to
1. increase the lengths of the end connections of angle section.
2. decrease the lengths of the end connections of angle section.
3. increase the lengths of the end connections of channel section.
4. decrease the lengths of the end connections of channel section.
Which of these statements are correct?
(a) 1 and 2 (b) 2 and 4
(c) 1, 3 and 4 (d) 1, 2 and 3
[ESE : 2004]

2.15 Lug angles
(a) are necessarily unequal angles
(b) are always equal angles
(c) increase the shear resistance of joint
(d) reduce the length of joint
[ESE : 2005]

2.16 A steel rod of 16 mm diameter has been used as a tie in a bracing system, but may be subject to possible reversal of stress due to the wind. What is the maximum permitted length of the member?
(a) 1600 mm (b) 1400 mm
(c) 1200 mm (d) 1000 mm
[ESE : 2005]

2.17 Which steel member section among the following combinations can carry maximum load?
(a) A pair of angles welded on opposite sides of a gusset plate, but not tack welded
(b) A pair of angles welded on opposite sides of a gusset plate, and tack welded along its length
(c) A pair of angles back to back on same side of a gusset plate, and tack welded
(d) A pair of angles on same side of a gusset plate, but not tack welded
[ESE : 2005]

2.18 An equal angle of area A has been attached to the support by means of a lug angle. If allowable stress in tension is f, what is the load carrying capacity of the member?
(a) 0.5fA (b) 0.85fA
(c) 0.9fA (d) 1.0fA
[ESE : 2006]

2.19 In the case of a tension member consisting of two angles back to back on the same side of gusset plate, what is k equal to? (Area of connected leg = A_1, Area of outstanding leg = A_2)

(a) $\frac{3A_1}{3A_1 + A_2}$ (b) $\frac{3A_1}{A_1 + 3A_2}$

(c) $\frac{5A_1}{A_1 + 5A_2}$ (d) $\frac{5A_1}{5A_1 + A_2}$

[ESE : 2006]

2.20 **Assertion (A):** Slenderness ratio of tension members is restricted to 250.

Reason (R): Slenderness ratio for tension members is a stiffness criterion associated with self weight.

(a) both A and R are individually true and R is the correct explanation of A

(b) both A and R are individually true but R is not the correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 2007]

2.21 For a pair of identical steel channel sections, tack-welded as a tension element, what is the net area of cross-section for design purposes?

(a) Net area of the webs only

(b) Net area of the flanges only

(c) Net area of the webs and flanges

(d) Web area plus a portion of the area of the flanges

[ESE : 2007]

2.22 What is the allowable direct tensile stress in structural steel (approximately)?

(a) $0.45f_y$ (b) $0.6f_y$

(c) $0.66f_y$ (d) $0.80f_y$

where f_y is the yield stress or proof stress.

[ESE : 2008]

2.23 How are structural members composed of two angles back to back connected throughout their length?

(a) By locking rivets

(b) By spacing rivets

(c) By gripping rivets

(d) By tacking rivets

[ESE : 2008]

2.24 Consider the following statements:

Compared to mild steel, aluminium has

1. lesser ductility
2. lesser value of Young's modulus
3. lesser tensile strength
4. no definite yield point

Which of these statements are correct?

(a) 1 and 3 only (b) 1, 2 and 3 only

(c) 1, 2, 3 and 4 (d) 1 and 4 only

[ESE : 2008]

2.25 An equal angle of area A has been welded on one side of a Gusset plate and carries tension along the axis. What is the effective area of the angle?

(a) 0.5A (b) 0.75A

(c) 0.875A (d) A

[ESE : 2008]

2.26 Steel of yield strength 400 MPa has been used in a structure. What is the value of the maximum allowable tensile strength ?

(a) 240 MPa (b) 200 MPa

(c) 120 MPa (d) 96 MPa

[ESE : 2009]

2.27 A tension member consists of two angles placed back to back. For which one of the following configurations, will the load carrying capacity of the tension member be maximum?

(a) Gusset plate is in between the two angles and tacking rivets are provided

(b) Gusset plate is in between the two angles and no tacking rivets are provided

(c) Gusset plate is on one side of the two angles and tacking rivets are provided

(d) Gusset plate is on one side of the two angles and no tacking rivets are provided

[ESE : 2009]

2.28 A steel plate is 300 mm wide and 10 mm thick. A rivet of nominal diameter 18 mm is driven. The net sectional area of the plate is

(a) 1800 mm^2 (b) 2805 mm^2

(c) 2820 mm^2 (d) 3242 mm^2

[ESE : 2010]

2.29 The capacity of a single ISA 100 × 100 × 10 mm as tension member connected by one leg only using 6 rivets of 20 mm diameter is

(a) 333 kN (b) 253 kN
(c) 238 kN (d) 210 kN

The allowable stress is 150 N/mm²

[ESE : 2010]

2.30 **Assertion (A):** In the case of mild steel, the tensile strength (expressed as per unit area) of smaller diameter bars are more than that of larger diameter bars.

Reason (R): In the case of smaller diameter mild steel bars, the ratio of outer hard core to total area (outer hard core + inner soft core) is more.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

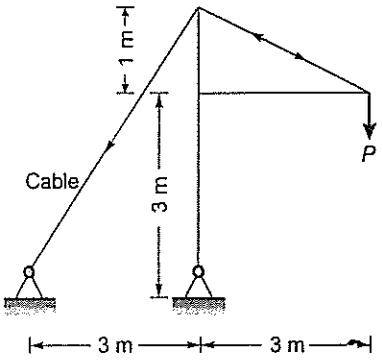
[ESE : 2010]

2.31 Two equal angles, each being ISA 100 mm × 100 mm of thickness 10 mm, are placed back-to back and connected to either side of a gusset plate through a single row of 16 mm diameter rivets in double shear. The effective areas of the connected and unconnected legs of each of these angles are 775 mm² and 950 mm² respectively. If these angles are not tack-riveted, the net effective area of this pair of angles is

(a) 3650 mm² (b) 3450 mm²
(c) 3076 mm² (d) 2899 mm²

[ESE : 2012]

2.32 In the simple system shown in the figure, the load P is equal to 4 tones. What is the tension in the cable.



(a) 4 t (b) 5 t
(c) 6 t (d) 7 t

[ESE : 2012]

2.33 Two angles of ISA 100 × 100 × 6 have been used as a tie member. The angles are welded on either side of a gusset and tag welded over its length. The maximum length of the member is: (For ISA 100 × 100 × 6, Area = 2334 mm² and r_{xx} = 30 mm)

(a) 5.4 m (b) 6.0 m
(c) 12.0 m (d) 24.0 m

[ESE : 2013]

2.34 A mild steel tube of mean diameter 20 mm and thickness 2 mm is used as an axially loaded tension member. If f_y = 300 MPa, what is the maximum load that the member can carry?

(a) 11.25 kN (b) 22.5 kN
(c) 30.0 kN (d) 37.5 kN

[ESE : 2014]

2.35 The best-suited rolled steel section for a tension member is

(a) angle section (b) T-section
(c) channel section (d) flat section

[ESE : 2014]

2.36 As per IS code, the maximum longitudinal pitch allowed in bolted joints of tension members is nominally

(a) 12 times the thickness of the plate
(b) 12 times the diameter of the bolt
(c) 16 times the thickness of the plate
(d) 16 times the diameter of the bolt

[ESE : 2016]

■■■■

Answers Tension Member

2.1	(b)	2.2	(b)	2.3	(c)	2.4	(d)	2.5	(b)	2.6	(a)	2.7	(d)	2.8	(c)	2.9	(b)
2.10	(b)	2.11	(b)	2.12	(a)	2.13	(a)	2.14	(b)	2.15	(d)	2.16	(b)	2.17	(b)	2.18	(d)
2.19	(d)	2.20	(d)	2.21	(c)	2.22	(b)	2.23	(d)	2.24	(c)	2.25	(c)	2.26	(a)	2.27	(a)
2.28	(b)	2.29	(d)	2.30	(a)	2.31	(d)	2.32	(a)	2.33	(c)	2.34	(b)	2.35	(b)	2.36	(c)

Explanations Tension Member

2.1 (b)

Effective net width of plate

$$= 300 - \left[3d - \frac{s_1^2}{4g_1} - \frac{s_2^2}{4g_2}\right]$$

$s_2 = s_1 = 50$ mm

$g_1 = g_2 = 100$ mm

$d = 25$ mm

$$\therefore \text{Net width} = 300 - \left[3\times 25 - \frac{2\times 50^2}{4\times 100}\right]$$

$$= 237.5 \text{ mm}$$

2.2 (b)

The net area required

$$= \frac{\text{Axial load}}{\text{Permissible stress}}$$

$$= \frac{50\times 10^3}{150} = 333.33 \text{ mm}^2$$

For an angle of size ISA $a \times b \times t$

The area of connected leg with dimension 'a'

$A_1 = (a - t/2)t$

The area of outstand leg with dimension 'b'

$A_2 = (b - t/2)t$

It is better to connect larger leg and leave smaller leg as outstand.

Net effective area,

$A = A_1 + kA_2$

$$k = \frac{1}{1+\frac{A_2}{3A_1}} = \frac{3A_1}{3A_1 + A_2}$$

Section	$A_1(mm^2)$	$A_2(mm^2)$	$A(mm^2)$
ISA75 × 50×6	432	282	663.60
ISA60 × 40×5	287.5	187.5	441.52
ISA 50×30×4	192	112	285.77
ISA 45×30 × 5	212.5	137.5	325.60

Thus ISA 60 × 40 × 5 is most suitable with net area 441.52 mm^2, which is more than required area of 333.33 mm^2 to resist the load.

2.3 (c)

The maximum load capacity of tension member is 0.85 $A_c f_y$

For compression member the load capacity is 1.7 $A_e \sigma_{ac}$

$\sigma_{ac} \rightarrow$ allowable compression

The maximum shear capacity of beam column is 0.55 $A_w f_y$ where A_w is the effective cross-sectional area resisting shear.

2.5 (b)

As per IS 800-1984, the maximum allowable slenderness ratio is 180 for a tension member in which a reversal of direct stress due to load other than wind or seismic force occurs.

2.4 (d)

For structural steel and steel castings, the permissible stresses may be increased by $33\frac{1}{3}\%$.

For rivets, bolts and tension rods, the permissible stress may be increased by 25%.

2.7 (d)

In the working stress design method, internal stresses are calculated at working stress (service load)

2.8 (c)

The permissible tensile stress

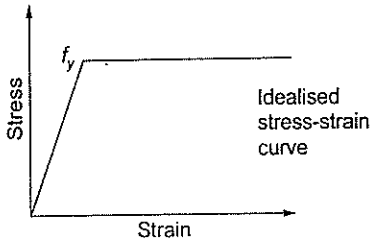
$= 0.6 f_y = 0.6 \times 250 = 150 \text{ N/mm}^2$

2.9 (b)

Usually ratio of ultimate stress to working stress is called factor of safety. In elastic theory of design the material factor of safety is only considered and the ratio of yield stress to working stress is called factor of safety.

2.10 (b)

The stress-strain relationship is idealized to consists of two straight lines as shown in the figure.



2.11 (b)

The distance between centres of two adjacent rivets, in a line lying in the direction of stress, shall not exceed $16t$ or 200 mm, whichever is less in tension members and $12t$ or 200 mm, whichever is less in compression member.

$\therefore$ c/c distance = Lesser of $(16 \times 10, 200)$

$= 160$ mm

2.12 (a)

The outstanding leg of the angle section does not take in full stress near the joint due to shear lag effect and therefore the net effective area is reduced.

$$A_n = A_1 + A_2 \left(\frac{3A_1}{3A_1 + A_2} \right) \text{ where}$$

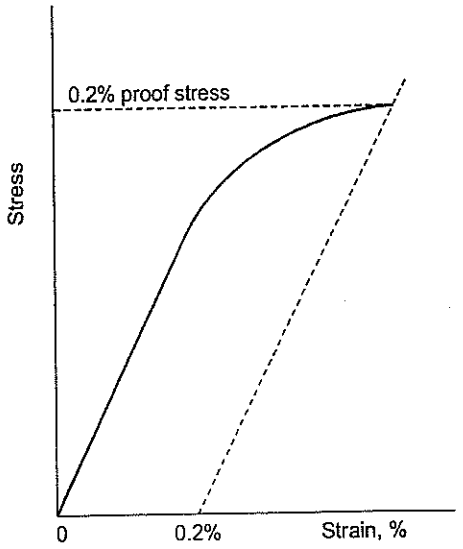
A_1= Effective cross sectional area of connected leg

A_2= Gross cross sectional area of outstanding leg.

2.13 (a)

0.2% proof stress is taken as yield strength for steels that do not show yield plateau. It is obtained by drawing offset (0.2%) of strain.

Method for determining proof stress

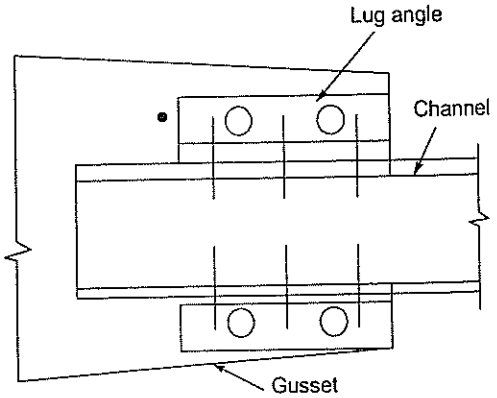


2.14 (b)

Lug angles are sometimes used to reduce the length of the connections. However their main purpose is to accommodate more number of rivets so that size of the gusset plate may be reduced.

2.15 (d)

Lug angles are used to reduce the length of connections. Figure below shows the lug angle connection with a channel type of tension member.



2.16 (b)

Radius of gyration of steel rod, r

$$= \frac{D}{4} = \frac{16}{4} = 4 \text{ mm}$$

Tie is a tension member.

For reversal of stress, the maximum permissible slenderness ratio = 350

$\therefore$ Length of member permitted $= 350 \times 4$

$= 1400$ mm

2.17 (b)

Load carrying capacity
= Net effective area × 0.6 f_y
Let (A/2) be the area of one leg of angle.
Without tack riveting as in case (a) and (d) the net effective area = 1.75 A/2 = 0.875A.
In case (c) when the angles are back to back on the same side of the gusset, the net effective area will be 0.917A.
In the case (b) where a pair of angles are on both sides of the gusset, the net effective area = A.
Therefore maximum tensile load can be carried by the angles connected in case (b).

2.18 (d)

Strength of member = allowable tensile stress × Net area of the angle
Net area = Gross Area – deduction for holes.

2.19 (d)

For single angle,

$$k = \frac{3A_1}{3A_1 + A_2}$$

For angles connected back-to-back on the same side of the gusset plate,

$$k = \frac{5A_1}{5A_1 + A_2}$$

2.20 (d)

As per IS 800-1984, slenderness ratio of tension members is restricted to 400 to fulfil stiffness requirement associated with self weight.

2.22 (b)

As per **IS : 800-1984**, the permissible stress in axial tension (σ_{at}) in MPa on the net effective area of the section shall not exceed

$$\sigma_{at} = 0.6 f_y$$

where f_y = minimum yield stress of steel in MPa.

The permissible stress in tension has been worked out after applying a factor of safety of 1.65.

2.23 (d)

Tacking or stitch rivets are used to make the sections act in unison, and to prevent buckling in compression members where two or more sections are in contact.

2.25 (c)

In the case of single angle connected through one leg, the net effective sectional area shall be taken as

$$A_{net} = A_1 + kA_2$$

where A_1 = area of connected leg = $\frac{A}{2}$

A_2 = area of unconnected leg = $\frac{A}{2}$

$$k = \frac{3A_1}{3A_1 + A_2} = \frac{\frac{3A}{2}}{\frac{3A}{2} + \frac{A}{2}} = \frac{3}{4}$$

$$\therefore \quad A_{net} = \frac{A}{2} + \frac{3}{4} \times \frac{A}{2} = 0.875A$$

2.26 (a)

Maximum allowable tensile strength
= 0.6 f_y
= 0.6 × 400
= 240 MPa

2.28 (b)

Net sectional area of the plate is given by

$$A_{net} = (B - nd') \times t$$
$$= [300 - 1 \times (18 + 1.5)] \times 10$$
$$= 2805 \text{ mm}^2$$

2.29 (d)

The net area of the tension member is given by

$$A_{net} = A_1 + kA_2$$

$$A_1 = \left(100 - \frac{10}{2}\right) \times 10 - (21.5 \times 10)$$
$$= 735 \text{ mm}^2$$

$$A_2 = \left(100 - \frac{10}{2}\right) \times 10 = 950 \text{ mm}^2$$

The angle section is connected by one leg only.

$$\therefore \quad k = \frac{3A_1}{3A_1 + A_2} = \frac{3 \times 735}{3 \times 735 + 950}$$
$$= 0.7$$

$$\therefore \quad A_{net} = 735 + 0.7 \times 950 = 1400 \text{ mm}^2$$

$$\therefore \quad P_{safe} = \sigma_{at} \times A_{net}$$
$$= 150 \times 1400 \times 10^{-3} = 210 \text{ kN}$$

2.31 (d)

When the angles are not tack-riveted, both the angles will act individually

$$\therefore \quad A_{net} = 2[A_1 + kA_2]$$

$$k = \frac{3A_1}{3A_1 + A_2}$$

$$= \frac{3 \times 775}{3 \times 775 + 950}$$

$$= 0.7099$$

$$\therefore \quad A_{net} = 2[775 + 0.7099 \times 950]$$

$$= 2899\ mm^2$$

2.32 (a)

The tension in the cable will be equal to the load $P = 4$ tonnes.

2.33 (c)

$\frac{l}{r_{min}} \leq 400$ for tension members where there is a possibility of stress reversal due to forces other than wind or earthquake

$$\Rightarrow \quad l \geq 400 \times 30\ mm$$

$$\Rightarrow \quad l \geq 12\ m$$

2.34 (b)

$$T = A \times (0.6\ f_y)$$

$$= \pi \times 20 \times 2 \times 0.6 \times 300$$

$$= 22.62\ kN$$

2.35 (b)

In T-section and flat section only, force pass through CG of section so (a) and (c) ruled out. Since flat section flutter during wind or any dynamic loading that is why we prefer T-section as best for tension member.

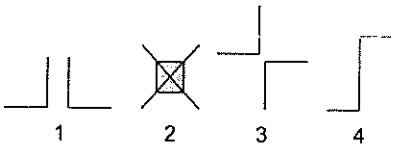
■■■■

3 Compression Member

3.1 The most critical consideration in the design of rolled steel columns carrying axial loads is the
(a) percent elongation at yield and the net cross-sectional area
(b) critical bending strength and axial yield strength of the material
(c) buckling strength based on the net area of the section and percent elongation at ultimate load
(d) compressive strength based on slenderness ratio and gross cross sectional area of the member

[ESE : 1997]

3.2 Two equal angles form a compound column cross-section as shown in figures 1, 2, 3 and 4.



Among these, those which have the same axial compression load carrying capacity would include
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 3 and 4

[ESE : 1997]

3.3 In the case of structural steel sections, the MINIMUM ratio of thickness of elements in compression, in terms of their outstanding length is specified to prevent
(a) bending failure (b) shear failure
(c) local buckling (d) tension failure

[ESE : 1998]

3.4 In the case of an axially loaded column machined for full bearing, the fasteners connecting the column to the base plates in gusseted base are designed for
(a) 100% of the column load
(b) 50% of the column load
(c) 25% of the column load
(d) erection conditions only

[ESE : 1998]

3.5 The effective length of a structural steel compression member of length L effectively held in position and restrained against rotation at one end but neither held in position nor restrained against rotation at the other end, is
(a) L (b) $1.2L$
(c) $1.5L$ (d) $2.0L$

[ESE : 1998]

3.6 Which one of the following is the most critical set of considerations in the design of rolled steel columns carrying axial loads?
(a) Percent elongation at yield and the net cross-sectional area
(b) Critical bending strength and axial yield strength of the material
(c) Buckling strength based on the net area of the section and percent elongation at ultimate load
(d) Compressive strength based on slenderness ratio and gross cross-sectional area of the member

[ESE : 1999]

3.7 Consider the following statements:
A grillage base is checked for
1. bending
2. shear
3. compression
4. web crippling

Which of these statements are correct?
(a) 1 and 4 (b) 1 and 3
(c) 2, 3 and 4 (d) 1, 2 and 4

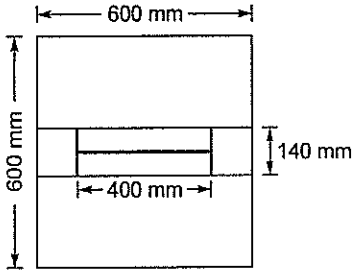
[ESE : 1999]

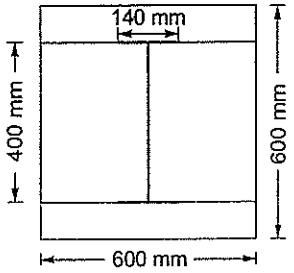
3.8 **Assertion (A) :** Battening of columns shall be done where the columns are subjected to eccentric loading in the plane of battens.
Reason (R) : Batten plates are designed to resist moments and longitudinal forces arising due to transverse shear force.
(a) both A and R are true and R is the correct explanation of A

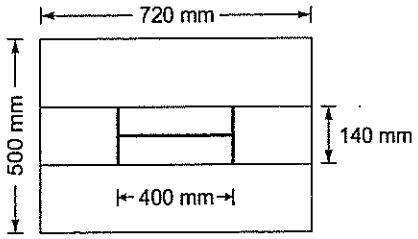
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

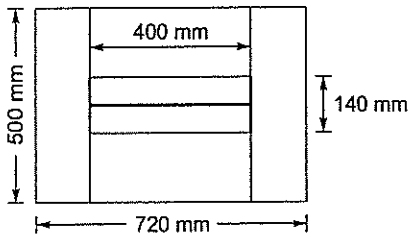
[ESE : 2000]

3.9 Which one of the following plan views of a gusseted base plate will result in minimum base plate thickness?

(a)


(b)


(c)


(d)


[ESE : 2000]

3.10 M60 structural steel tube has a radius of gyration 20 mm. The unbraced length upto which the tube can be used as a compression member, is

(a) 3.6 m (b) 5.0 m
(c) 6.0 m (d) 7.2 m

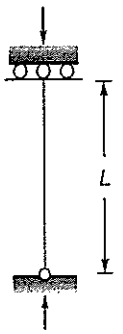
[ESE : 2001]

3.11 The elements that are normally subjected to combined bending and axial forces are

(a) struts in reinforced concrete members
(b) the members in long span bridges
(c) columns in framed structures
(d) space truss members

[ESE : 2002]

3.12 The effective length of the member shown in the figure is equal to



(a) 1.2L (b) 1.5L
(c) 2.0L (d) 3.0L

[ESE : 2002]

3.13 In a compression member, plate element may buckle locally before the entire member fails. To avoid this, which of the following recommendations are made?

1. Thickness of members is taken in terms of lengths of compression members.
2. Length of element is increased
3. Length of member is increased
4. Length of outstand is decreased

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 1, 3 and 4
(c) 2 and 3 (d) 1 and 4

[ESE : 2002]

3.14 Match List-I (Type of member) with List-II (Slenderness ratio) and select the correct answer using the codes given below the lists:

List-I

A. For compression members carrying dead and superimposed loads
B. For members carrying compressive loads due to wind or seismic forces only
C. For members carrying tension but in which the reversal of stress occurs due to wind or seismic forces

List-II
1. 350
2. 180
3. 250

Codes:

	A	B	C
(a)	1	2	3
(b)	2	3	1
(c)	3	1	2
(d)	1	3	2

[ESE : 2002]

3.15 A compression member has a centre to centre length of 4.0 m. It is fixed at one end and hinged at the other end. The effective length of the column is
(a) 4.0 m (b) 3.2 m
(c) 2.8 m (d) 2.6 m
[ESE : 2002]

3.16 An electric pole 5 m high is fixed into the foundation. It carries a wire at the top and is free to move sideways. The effective length of the pole is
(a) 3.25 m (b) 4.0 m
(c) 5.0 m (d) 10.0 m
[ESE : 2003]

3.17 Design of a simple element in steel uses one or more of the following:
1. Net area of cross-section
2. Full area of cross-section
3. Buckling criterion
4. Crushing (or yielding) criterion

Which of the above criteria are valid for the design of a column?
(a) 1 and 3 (b) 2 and 4
(c) 2, 3 and 4 (d) 1, 3 and 4
[ESE : 2003]

3.18 A steel column in a multi-storeyed building carries an axial load of 125 N. It is built up of 2 ISMC 350 channels connected by lacing. The lacing carries a load of
(a) 125 N (b) 12.5 N
(c) 3.125 N (d) Zero
[ESE : 2003]

3.19 For a compression member having the same effective length about any cross-sectional axis, the most preferred section from the point of view of strength is
(a) A box (b) An I-section
(c) A circular tube (d) A single angle
[ESE : 2003]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

3.20 **Assertion (A) :** In double-laced system of a built-up column, cross member perpendicular to the longitudinal axis of the column is not used.
Reason (R) : Lacing bars are forced to share the axial load on the strut.
[ESE : 2003]

3.21 **Assertion (A) :** Web crippling occurs at a section where heavy vertical load is applied.
Reason (R) : There is stress concentration in the vicinity of the load.
[ESE : 2003]

3.22 The type of stress induced in the foundation bolts fixing a column to its footing is
(a) pure compression (b) bearing
(c) pure tension (d) bending
[ESE : 2003]

3.23 A member is subjected to axial compression. Effective length is 3000 mm. Size of the angle used is 100 × 100 × 10 mm. What is the maximum capacity (if f_y = 250 MPa)?
(a) 101.2 kN (b) 81.7 kN
(c) 59.2 kN (d) 95.1 kN
[ESE : 2004]

3.24 What is the maximum slenderness ratio for a steel member carrying compressive loads resulting from dead loads and imposed loads?

(a) 180 (b) 250
(c) 350 (d) 400

[ESE : 2004]

3.25 Consider the following statements:
1. As far as practicable, the lacing system shall not be varied throughout the length of the strut.
2. Single laced systems on opposite sides of the components shall preferably be in mutually opposite directions, so that one is not the shadow of the other.
3. Rolled sections or tubes of equivalent strength may be used as lacing bars instead of flats.

Which of these statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

[ESE : 2004]

3.26 2-ISMB 300 × 140 sections are acting as a compound column. The height of the column is 4000 mm. Two sections are spaced 400 mm, centre to centre. In the longitudinal direction there is runner at the top of the column. What is the maximum capacity of the column in compression (f_y = 250 MPa)?
(a) 2002 kN (b) 1629 kN
(c) 1501 kN (d) 1799 kN

[ESE : 2004]

3.27 What is the maximum slenderness ratio of lacing bars in built-up columns?
(a) 120 (b) 145
(c) 180 (d) 200

[ESE : 2004]

3.28 Where should splices in the columns be provided?
(a) At the floor levels
(b) At the mid height of columns
(c) At the beam-column joints
(d) At one-fourth height of columns

[ESE : 2005]

3.29 Which one of the following stresses is independent of yield stress as a permissible stress for steel members?
(a) Axial tensile stress
(b) Maximum shear stress
(c) Bearing stress
(d) Stress in slab base

[ESE : 2005]

3.30 Why are tie plates provided in laced columns?
(a) To check the buckling of column as a whole
(b) To check the buckling of the lacing flats
(c) To check the buckling of the component columns
(d) To check the distortion of the end cross sections

[ESE : 2005]

3.31 What is the permissible tensile stress in bolts used for column bases (f_y is the yield stress of the steel)?
(a) 120 N/mm^2 (b) 150 N/mm^2
(c) $0.6f_y$ (d) $0.4f_y$

[ESE : 2005]

3.32 The slenderness ratio of lacing bars should not exceed
(a) 100 (b) 120
(c) 145 (d) 180

[ESE : 2005]

3.33 Which one of the following is a compression member?
(a) Purlin (b) Boom
(c) Girt (d) Tie

[ESE : 2005]

3.34 In a situation where torsion is dominant, which one of the following is the desirable section?
(a) Angle section
(b) Channel section
(c) I-section
(d) Box type section

[ESE : 2005]

3.35 In a gusseted base, when the end of the column is machined smooth for complete bearing, the axial load is transferred to base slab
(a) fully through fastening
(b) fully by direct bearing
(c) 50% by direct bearing and 50% through fastening
(d) 60% by direct bearing and 40% through fastening

[ESE : 2005]

3.36 Assertion (A) : Angle of inclination of lacing bars in a built-up column is constrained as $70° > \phi > 40°$, where ϕ is angle of lacing with vertical.

Reason (R) : When this limit is not maintained, the total length of the bar will be large.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2006]

3.37 A cantilever arm is to be attached to a column. Which one among the following is the best connection?

(a) Framed connection
(b) Seated connection
(c) Stiffened seated connection
(d) End plate connection

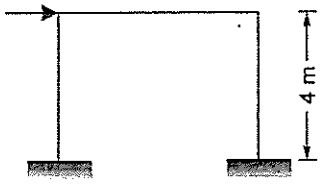
[ESE : 2006]

3.38 What is the maximum slenderness ratio permitted as per IS:800-1984 for design of a tie member subjected to reversal of stress due to earthquake?

(a) 180 (b) 250
(c) 300 (d) 350

[ESE : 2006]

3.39 An industrial portal frame shown has weak floor beams. What is the effective length of column?



(a) 3 m (b) 4 m
(c) 6 m (d) 8 m

[ESE : 2006]

3.40 What is the maximum permissible slenderness ratio of a major compression member which undergoes reversal of stress due to wind load?

(a) 180 (b) 250
(c) 300 (d) 400

[ESE : 2006]

3.41 Which one among the following is the correct ratio of effective length to actual length of a discontinuous angle strut, if ends are welded?

(a) 0.65 (b) 0.85
(c) 1.0 (d) 1.2

[ESE : 2006]

3.42 In a gusseted base, when the end of the column is machined for complete bearing on the base plate, the axial load is assumed to be transferred to the base plate

(a) fully by direct bearing
(b) fully through the fastenings
(c) 50% by direct bearing and 50% through fastenings
(d) 75% by direct bearing and 25% through fastenings

[ESE : 2007]

3.43 What is the maximum permissible longitudinal pitch in staggered riveted compression joints?

(a) 500 mm (b) 400 mm
(c) 300 mm (d) 100 mm

[ESE : 2007]

3.44 A reduction in the allowable stress in steel chimney construction is necessary if the temperature exceeds

(a) 75°C (b) 100°C
(c) 200°C (d) 300°C

[ESE : 2007]

3.45 A compound column had been fabricated with 4 angles of ISA 50 × 50 × 6 placed at corners of a square 300 mm × 300 mm. The radius of gyration of the angle is 10 mm. For the fabricated column, the overall slenderness ratio is 40. What is the maximum distance between lacing bar attachments at the fabricated columns?

(a) 500 mm (b) 400 mm
(c) 300 mm (d) 280 mm

[ESE : 2007]

3.46 What is the maximum permissible slenderness ratio for steel ties likely to be subjected to compression?

(a) 400 (b) 350
(c) 250 (d) 180

[ESE : 2008]

3.47 Which of the following parameters govern the permissible stress in compression in columns?

1. Modulus of section
2. Effective length
3. Radius of gyration

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

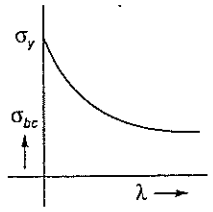
[ESE : 2008]

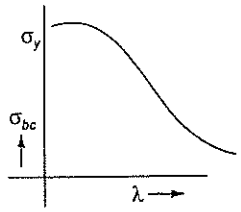
3.48 Which one of the following forces is used for the design of battens of a built-up column?

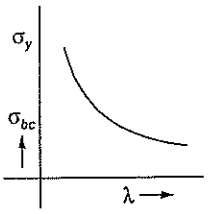
(a) Axial load
(b) Twisting moment
(c) Vertical shear
(d) Transverse shear

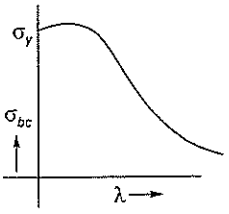
[ESE : 2008]

3.49 Which one of the following graphs represents the compressive strength (σ_{bc}) versus slenderness ratio (λ)?

(a)


(b)


(c)


(d)


[ESE : 2009]

3.50 A column bearing truss in an open industrial shed is 6 m height between its own base and the bottom of the truss. What is the effective height of the column taken for calculation of compressive strength?

(a) 4.8 m (b) 6.0 m
(c) 7.2 m (d) 9.0 m

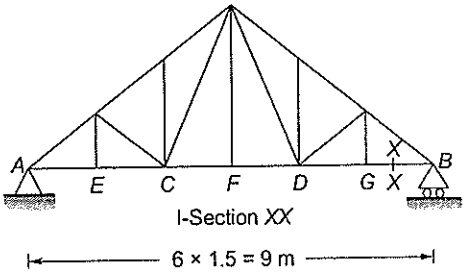
[ESE : 2009]

3.51 Which one of the following values represents the maximum slenderness ratio of any connection member which normally acts as a tie in a roof truss but can be subjected to possible reversal of stresses from the action of wind or seismic force ?

(a) 150 (b) 200
(c) 250 (d) 350

[ESE : 2009]

3.52 For the roof truss shown in figure below, bottom chord is of ISMB 200 (r_x = 83 mm, r_y = 22 mm).



Bottom chord bracings are available at *C* and *D*. Bottom member *AE* will be in compression due to wind. What is the critical slenderness ratio used for the design of member *AE*?

(a) 18 (b) 36
(c) 68 (d) 136

[ESE : 2010]

3.53 The batten plates used to connect the components of a built-up column are designed to resist.

(a) longitudinal shear only
(b) transverse shear only
(c) longitudinal shear and moment arising from transverse shear
(d) vertical shear only

[ESE : 2010]

3.54 In ISMC 400 channels placed back to back at a spacing of 26 cm carry an axial load of 160 tonnes. The lacing system should be designed to resist a transverse shear of

(a) 16 tonnes (b) 12 tonnes
(c) 8 tonnes (d) 4 tonnes

[ESE : 2010]

3.55 Match List-I (Type) with List-II (Recommended slenderness ratio) and select the correct answer using the codes given below the lists:

List-I

A. Single angle in roof trusses
B. Double angles in roof trusses
C. Single I section in columns
D. Double I section in columns

List-II

1. 80 – 150
2. 30 – 60
3. 100 – 180
4. 60 – 100

Codes:

	A	B	C	D
(a)	3	4	1	2
(b)	2	4	1	3
(c)	3	1	4	2
(d)	2	1	4	3

[ESE : 2010]

3.56 Consider the following stipulations in designing a laced column:

1. Single lacing systems on opposite planes shall preferably be in the same direction so that one is the shadow of the other.
2. Lacing bar should be a flat section.
3. The slenderness ratio of the lacing bars for compression shall not exceed 180.
4. Laced compression members are to be provided with tie plates at ends.

Which of these observations is/are correct?

(a) 1 only (b) 1 and 3
(c) 2 and 4 (d) 1 and 4

[ESE : 2010]

3.57 Which of the following steel sections should preferably be used at places where torsion occurs?

(a) Box-type section (b) Channel section
(c) Angle section (d) Any of the above

[ESE : 2011]

3.58 The most critical consideration in the design of a rolled steel column carrying axial loads is the

(a) Percentage elongation at yield and the net cross-sectional area
(b) Critical bending strength and axial yield strength of material
(c) Buckling strength based on the net area of the section and percentage elongation at ultimate load
(d) Compressive strength based on slenderness ratio and gross cross-sectional area

[ESE : 2011]

3.59 Top chord of a truss is continuous over joints l apart. Effective lengths of the member in the plane perpendicular to the truss is

(a) $0.7\,l$ (b) $0.85\,l$
(c) l (d) $1.5\,l$

[ESE : 2011]

3.60 Consider the following parameters with regards to slenderness ratio of a compression member:

1. Material
2. Sectional configuration
3. Length of member
4. Support end conditions

On which of these parameters does the slenderness ratio of a compression member depend?

(a) 1, 2 and 3 only (b) 1, 3 and 4 only
(c) 2, 3 and 4 only (d) 1, 2, 3 and 4

[ESE : 2012]

3.61 A column member of length l which cannot sway has a rigid foundation at its bottom. Its top is held with heavy beams. The effective length of the column is

(a) $1.5\,l$ (b) $1.0\,l$
(c) $0.8\,l$ (d) $0.65\,l$

[ESE : 2012]

3.62 Through which of the following responses may a steel tubular hinged strut fail?

1. Compression 2. Bending
3. Overall buckling 4. Torsion
5. Skin buckling

(a) 2, 4 and 5 (b) 1, 2 and 3
(c) 3, 4 and 5 (d) 1, 3 and 5

[ESE : 2012]

3.63 A steel column pinned at both ends has a buckling load of 200 kN. If the column is restrained against lateral movement at its mid-height, its buckling load will be

(a) 200 kN (b) 283 kN
(c) 400 kN (d) 800 kN

[ESE : 2012]

3.64 In laced columns, end tie-plates are provided to
(a) check the buckling column
(b) keep the column components in position
(c) check the distortion of column sections at ends because of unbalanced horizontal force from lacings.
(d) prevent rotation of elements
[ESE : 2012]

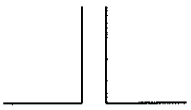
3.65 A column is effectively held in position and restrained in direction at one end but is free at the other end. If the actual length is L, the effective length is
(a) $0.67L$ (b) L
(c) $1.5L$ (d) $2L$
[ESE : 2012]

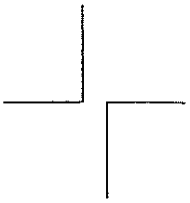
3.66 The effective width of outstand in compound steel columns for design purposes is equal to
(a) half the flange width
(b) distance of the free edge from the rivet line
(c) distance of the free edge from the stiffeners
(d) distance of the free edge to the nearest row of rivets
[ESE : 2013]

3.67 For a steel built-up column subjected to an axial force of 1200 kN, the lacing system is to be designed for resisting transverse shear of
(a) 15 kN (b) 20 kN
(c) 25 kN (d) 30 kN
[ESE : 2013]

3.68 Which of the following statements are correct?
1. In a steel compound column section, the width will be smaller when they are placed face to face than when they are placed back to back.
2. In the design of steel compound columns the length of battens are normally longer than the lacings.
3. Lacings in a steel compound column are designed as slender compression members.
(a) 1 and 3 only (b) 1 and 2 only
(c) 2 and 3 only (d) 1, 2 and 3
[ESE : 2013]

3.69 Which one of the following four shapes for a compound, column of the same effective height formed with two equal angles has the largest axial compressive load carrying capacity?

(a) 

(b) 

(c)

(d)

[ESE : 2013]

3.70 The effective length of a battened strut of actual length L, effectively held in position at both ends but not restrained in direction, is taken as
(a) L (b) $1.1L$
(c) $1.5L$ (d) $1.8L$
[ESE : 2014]

3.71 The slenderness ratio (as per IS : 800) of a member, carrying compressive loads arising from combined dead loads and imposed loads, should not exceed
(a) 180 (b) 250
(c) 350 (d) 380
[ESE : 2014]

3.72 Localized bearing stress caused by the transmission of compression from the wide flange to the narrow web causes a failure called
(a) web buckling (b) web shear flow
(c) web bearing (d) web crippling
[ESE : 2014]

3.73 Lacing of compound steel columns
(a) increases the load-carrying capacity
(b) decreases the chances of local buckling
(c) decreases overall buckling of the column
(d) assures unified behaviour
[ESE : 2014]

3.74 When designing steel structures, one must ensure that local buckling in webs does not take place. This check may not be critical when using rolled steel sections because
(a) quality control at the time of manufacture of rolled sections is very good
(b) web depths available are small

(c) web stiffness is built-in in rolled sections
(d) depth to thickness ratio of the web is always appropriately adjusted

[ESE : 2014]

3.75 For a compression member with double angle section, which of the following sections will give larger value of minimum radius of gyration?
(a) Equal angles back-to-back
(b) Unequal angles with long legs back-to-back
(c) Unequal angles with short legs back-to-back
(d) None of the above

[ESE : 2014]

3.76 Battens provided for a compression member shall be designed to carry a transverse shear equal to
(a) 2.5% of axial force in the member
(b) 5% of axial force in the member
(c) 10% of axial force in the member
(d) 20% of axial force in the member

[ESE : 2014]

3.77 In the case of an axially loaded column, machined for full bearing, the fastenings connecting the column to the base plates through gussets are to be designed for
(a) 100% of the load on the column
(b) 50% of the load on the column
(c) 25% of the load on the column
(d) Respectively erection conditions only

[ESE : 2015]

3.78 Web crippling is caused by
(a) Excessive bending moment
(b) Failure of web under point loads
(c) Width of flanges
(d) Column action of web

[ESE : 2016]

3.79 ISMB 100 (r_x = 40 mm, r_y = 10 mm) has been used as a column in an industrial shed. Along the minor axis, the column has restraints in the form of purlins at 1.0 m intervals. Effective length factor along major and minor axes are 1.2 and 1.0, respectively. If the slenderness ratio is restricted to 120, the maximum column height will be
(a) 1.0 m (b) 2.4 m
(c) 4.0 m (d) 4.8 m

[ESE : 2016]

3.80 As per IS 800 : 2007, the permitted slenderness ratio for a bracing member in case of hangers shall be
(a) 140 (b) 145
(c) 150 (d) 160

[ESE : 2016]

■■■■

Answers Compression Member

3.1 (d)	3.2 (c)	3.3 (c)	3.4 (b)	3.5 (d)	3.6 (d)	3.7 (d)	3.8 (d)	3.9 (b)	
3.10 (a)	3.11 (c)	3.12 (c)	3.13 (d)	3.14 (b)	3.15 (b)	3.16 (d)	3.17 (c)	3.18 (c)	
3.19 (a)	3.20 (b)	3.21 (a)	3.22 (c)	3.23 (b)	3.24 (a)	3.25 (c)	3.26 (a)	3.27 (b)	
3.28 (d)	3.29 (d)	3.30 (d)	3.31 (a)	3.32 (c)	3.33 (b)	3.34 (d)	3.35 (c)	3.36 (c)	
3.37 (d)	3.38 (d)	3.39 (d)	3.40 (b)	3.41 (b)	3.42 (c)	3.43 (c)	3.44 (b)	3.45 (d)	
3.46 (d)	3.47 (a)	3.48 (d)	3.49 (d)	3.50 (a)	3.51 (d)	3.52 (c)	3.53 (c)	3.54 (d)	
3.55 (b)	3.56 (d)	3.57 (a)	3.58 (d)	3.59 (c)	3.60 (c)	3.61 (d)	3.62 (d)	3.63 (d)	
3.64 (c)	3.65 (d)	3.66 (d)	3.67 (d)	3.68 (a)	3.69 (b)	3.70 (b)	3.71 (a)	3.72 (d)	
3.73 (d)	3.74 (d)	3.75 (b)	3.76 (a)	3.77 (b)	3.78 (b)	3.79 (a)	3.80 (d)		

Explanations Compression Member

3.1 (d)

For design of axially loaded compression member:

- A value of permissible compressive stress is assumed
- For this stress gross area is found.
- A trial section is chosen
- Maximum slenderness ratio for chosen section is found
- Load carrying capacity of chosen member is calculated
- The member is safe if load carrying capacity is equal or greater than the applied load.

Thus compressive strength based on slenderness ratio and cross-gross sectional area of member is most critical set of consideration.

3.2 (c)

The cruciform arrangement of double angle, in star section (figure-3) is most effective because of its approximately equal radii of gyration in two directions.

The box section (figure-2) can be formed with welded connection. The least radius of gyration of the section shown in the figure-2 and figure-3 of two angles is same and it is more than that of the sections shown in figure-1. Therefore the permissible compressive stress for figure 2 and 3 will be same and compression load carrying capacity will be same.

3.3 (c)

The minimum ratio of thickness of elements in compression in terms of their outstanding length is specified in order to prevent local buckling of the element and hence to make the entire cross section effective in compression.

3.4 (b)

When the end of the column is machined for complete bearing on the base plate, 50% of the axial column load is assumed to be transferred to the base plate by direct bearing and the remaining 50% of axial load will be transferred through the fastenings including the gusset plates, angle cleats, stiffeners etc.

Where the end of the column shaft and the gusset plates not faced for complete bearing, the fastenings connecting to the base plate are designed to transmit all forces to which the base plate is subjected.

3.5 (d)

Degree of restraint	Effective Length
(i) Effectively held in position and restrained against rotation at one end, and the other end restrained against rotation but not held in position.	1.2L
(ii) Effectively held in position and restrained against rotation at one end, and the other end is partially restrained against rotation but not held in position.	1.5L
(iii) Effectively held in position at one end but not restrained against rotation, and at the other end restrained against rotation but not held in position.	2.0L
(iv) Effectively held in position and restrained against rotation at one end but neither held in position nor restrained against rotation at the other end.	2.0L

3.6 (d)

For design of axially loaded compression member:

- A value of permissible compressive stress is assumed
- For this stress gross area is found.
- A trial section is chosen
- Maximum slenderness ratio for chosen section is found
- Load carrying capacity of chosen member is calculated
- The member is safe if load carrying capacity is equal or greater than the applied load.

Thus compressive strength based on slenderness ratio and cross-gross sectional area of member is most critical set of consideration

3.7 (d)

The grillage base essentially consists of steel beams encased in concrete. They are provided when

(i) The load on the column is very heavy

(ii) The bearing capacity of the soil on which the concrete block is to be placed may be poor.

They are designed for bending, shear and web crippling

3.8 (d)

In order to resist large forces, built up compression members are necessary. Connection between the elements is provided by lacings, battens or perforated plates.

3.9 (b)

Plate thickness in gusseted plate base,

$t = c\sqrt{3w/\sigma_{bs}}$

$c \rightarrow$ portion of the base plate acting as a cantilever

$t \rightarrow$ thickness of base plate at critical section

$w \rightarrow$ intensity of pressure from concrete under the slab

$\sigma_{bs} \rightarrow$ the permissible bending stress in slab base

Figure	Cantilever portion (c)
(a)	$\frac{600-140}{2} = 230$ mm
(b)	100 mm
(c)	180 mm
(d)	160 mm

Thus thickness of base plate shown in figure(b) will be minimum.

3.10 (a)

Maximum permissible slenderness ratio = 180

$\therefore$ Unbraced length = 180 x 20

= 3600 mm = 3.6 m

3.12 (c)

The member is effectively held in position at lower end but not restrained against rotation. At the upper end, it is restrained against rotation but not held in position.

3.13 (d)

As per Is 800, to avoid failure of plate element locally before failure of entire member in compression, the thickness of members is to be taken in terms of length and length of outstand is to be decreased.

3.15 (b)

Effective length = $0.80L = 0.80 \times 4 = 3.2$ m

3.16 (d)

It is equivalent to a compression member whose one end fixed against rotation and position end the other and neither restrained against rotation nor fixed in position in the direction perpendicular to wire. So effective length = $2L = 10$ m

In the direction of wire, the pole is hinged at wire end so effective length = $0.8L = 4.0$ m

3.17 (c)

In the case of compression, there is no need to deduct hole area from the section to compute strength.

3.18 (c)

Load carried by lacing = 2.5% of axial load.

$= \frac{2.5}{100} \times 125 = 3.125$ N

3.19 (a)

Slenderness ratio, $\lambda = \frac{l_{eff}}{r}$

Lesser the value of λ (greater radius of gyration r), the column can take more load. Maximum radius of gyration is obtained when material is farthest from centroid. Therefore box section is best.

3.20 (b)

The purpose of lacing is to hold the various parts of a column straight, parallel, at a correct distance apart and equalize the stress distribution between its various parts.

Double flat lacings with battens (cross-members) is not recommended as it gives undesirable effects.

3.23 (b)

Area of section

$= (100 - 5) \times 10 + (100 - 5) \times 10$

$= 1900$ mm^2

Radius of gyration = 19.4 mm

(From properties of sections)

$$\text{Slenderness ratio} = \frac{3000}{19.4} = 154.6$$

Allowable compressive stress = 43 MPa

Capacity of section

$= 43 \times 1900 = 81700\ \text{N} = 81.7\ \text{kN}$

3.24 (a)

As per IS 800-1984, for a steel member carrying compressive loads resulting from dead load and imposed load the maximum allowable slenderness ratio is 180.

3.25 (c)

As per IS:800-1984

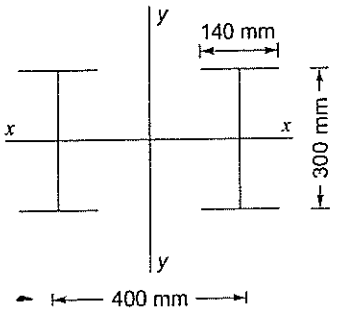
(i) Clause 5.7.1.2 As far as practicable the lacing system shall not be varied throughout the length of the strut.

(ii) Clause 5.7.1.3 Except for tie plates in double laced system and single laced system on opposite sides of the main component shall not be combined with cross-members perpendicular to the longitudinal axis of the strut unless all forces resulting from deformation of the strut members are calculated and provided for in the lacing and its fastenings.

(iii) Clause 5.7.1.4 Single laced system on opposite sides of the components shall preferably be in the same direction so that one be the shadow of the other, instead of being mutually opposite in direction.

(iv) Clause 5.7.4.1 Rolled sections or tubes of equivalent strength may be used instead of flats .

3.26 (a)



For ISMB 300 × 140

Radius of gyration

$r_{x_i} = 12.35$ cm

$r_{y_i} = 2.80$ cm

$A_i = 9227\ \text{mm}^2$

For compound section

$r_x = r_{x_i} = 123.5$ mm

$$r_y = \sqrt{r_{y_i}^2 + \left(\frac{s}{2}\right)^2} = 201.9\ \text{mm}$$

As the runner is about longitudinal direction $(x - x)$, so the column is free in the transverse direction $(y - y)$.

Effective length for bending about $x - x$ axis

$= 2 \times 4000 = 8000$ mm

$$\text{Slenderness ratio} = \frac{8000}{123.5} = 64.8$$

Allowable compressive stress = 109 MPa

$\therefore$ Capacity $= 2 \times 9227 \times 109 = 2011$ kN

3.27 (b)

As per IS:800-1984 Clause 5.7.2.3 the slenderness ratio of the lacing bars for compression members shall not exceed 145.

3.28 (d)

Splices should be provided 30 cm or 15 cm above the floor line. At this height it is convenient for the workman to add the next section of the storey above. Theoretically the splice plate should be located at the point of contraflexure of the column.

3.29 (d)

Permissible values

Axial tensile stress = $0.6f_y$

Bearing stress = $0.75f_y$

Maximum shear stress = $0.45f_y$

Stress in slab base = 185 MPa for all type of steels.

3.30 (d)

Tie plates are provided at points where lacing system is interrupted or at the ends of lacing system in laced compression member to check the distortion of end cross-section.

3.31 (a)

Permissible tensile stresses in bolts used for column bases is 120 N/mm^2.

3.32 (c)

As per IS 800-1984, the slenderness ratio of lacing bars should not exceed 145.

3.33 (b)

Strut is a compression member used in the roof truss and bracing. They are of small span and may be vertical or inclined.

The principal rafter is a top chord member in a roof truss and boom is the principal compression member in a crane.

Column, stanchion or post is a vertical compression member supporting flats or girders in a building.

3.34 (d)

For torsion resistance, the best section is solid circular shaft or hollow circular shaft. The area of section should be away from the axis of the section and it should be symmetrical about the axis. Therefore box section is most desirable.

3.35 (c)

It is assumed that 50% of axial load is transferred by direct bearing and remaining 50% through fastening when the end of column is machined smooth for complete bearing in a gusseted base.

3.36 (c)

Length will be small when ϕ is greater than 70°. Angle of inclination of lacing bars be such that they do not transmit axial column load from one component to another through secondary truss action. If the lacing is too steep then it is likely to transmit some axial load and if the inclination with axis is large, then its capacity to carry the transverse load is decreased.

3.37 (d)

The beam column connections expected to resist and transfer end reactions only are termed as shear connections or flexible connections. These permit free rotation of the beam end and do not have any moment restraint. Bracket connections, seat connections (unstiffened and stiffened) and framed connections are of flexible type.

The other type of connections which do not permit any relative rotation between the beam and column and are expected to resist moment in addition to end reactions are termed as moment connections or rigid connections. For cantilever arm both moment and end reaction is to be transferred without rotation and therefore rigid connections would be the best choice. Clip angle connection, split beam connection and bracket connection (end plate connection) are rigid connections.

3.39 (d)

Since the floor beam is weak so the top end of the column behaves like a free end. Therefore the effective length of the column is $2 \times 4 = 8$ m.

3.40 (b)

As per IS 800-1984, the maximum permissible slenderness ratio of a compression member which undergoes reversal of stresses due to wind or earthquake load is 250.

3.41 (b)

For single angle discontinuous

(i) One rivet or bolt – Effective length is the distance between the centres of end fastenings

(ii) Two or more rivets or welding – Effective length is 0.85 times the distance between node points.

3.42 (c)

If the column ends and gusset materials are not faced/machined for complete bearing, the fasteners are designed for the total forces to be transferred. If they are faced/machined for complete bearing, 50% of the forces are transferred directly by the column and 50% through the fasteners.

3.45 (d)

The maximum spacing of lacing bars should be such that the minimum slenderness ratio of the component member i.e. $\frac{C}{r_{yy}}$ is not greater than 50 or 0.7 times the slenderness ratio of the member as a whole, whichever is less, where C is the distance between the centres of connection of the lacing bars to each component.

(i) $\frac{C}{r_{yy}} \le 50$

$\Rightarrow \quad C \le 50\, r_{yy}$

$\Rightarrow \quad C \le 50 \times 10$

$\Rightarrow \quad C \le 500$ mm

(ii) $\frac{C}{r_{yy}} \le 0.7 \times$ overall slenderness ratio

$\Rightarrow \quad C \le 0.7 \times 40 \times 10$

$\Rightarrow \quad C \le 280$ mm

3.46 (d)

As per IS 800-1984, the maximum permissible slenderness ratio of a compression member which undergoes reversal of stresses due to loads other than wind or seismic force is 180.

3.47 (a)

Slenderness ratio is given by

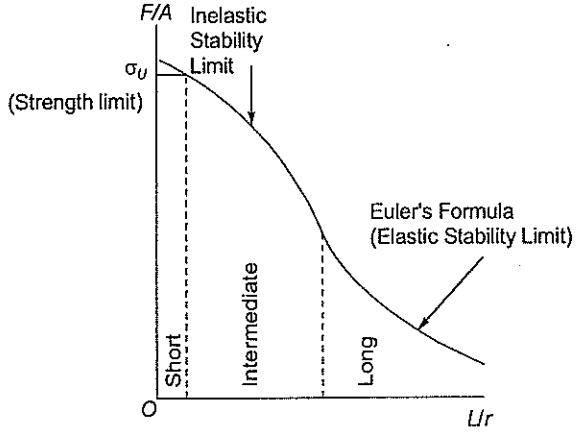
$$\lambda = \frac{l}{r_{min}}$$

where l is effective length of member and r_{min} is its radius of gyration. The permissible stress is related to the slenderness ratio.

3.48 (d)

Battens are designed to.carry bending moment and shear force arising from the transverse shear force which is 2.5% of the total axial force on the whole compression member.

3.49 (d)



3.50 (c)

Slenderness ratio is given by

$$\lambda = \frac{L_{eff}}{r_{min}} = \frac{1.5 \times 10^3}{22} = 68$$

3.53 (c)

Batten plate is horizontal rectangular plate that is used to connect pairs of steel sections by being riveted or welded connection across to form the composite section. The batten plates are designed to resist simultaneously both the longitudinal shear and moments arising from transverse shear.

3.54 (d)

The lacing system is designed for a load which is 2.5% of the axial load i.e.

$$P_{design} = \frac{2.5}{100} \times 160 = 4 \text{ tonnes}$$

3.56 (d)

The lacing bar may be a flat or angle section. The purpose of lacing is to hold the various parts of a column straight, parallel at a correct distance apart and to equalize the stress distribution between its various parts. The slenderness ratio of the lacing bars for compression shall be less than 145.

3.58 (d)

The cross-sectional shape of an axially loaded column depends largely on the length and load on the column. In its design information required will be the length of the member, the end conditions and the loads it has to support. Section which provides a large radius of gyration without providing more area and in which the average compressive stress does not exceed the allowable compressive stress is preferred. The slenderness ratio ($\lambda = l/r$) should be less than the permissible slenderness ratio. For this estimated value of slenderness ratio, the maximum allowable compressive stress, σ_{ac} is calculated.

The load carrying capacity of the member is computed by multiplying the maximum compressive stress thus obtained with the cross sectional area provided. This value of the load carrying capacity of the member should be more than the load to be supported by it.

3.59 (c)

A continuous strut is a compression member which is continuous over a number of joints, much as a top chord member of a truss bridge girder, principal rafter of a roof truss, etc. In the chord members of roof truss, double unequal angle sections with their short legs placed back to back on the opposite side of the gusset plate are used.

This provides greater overall stiffness to the truss against lateral bending. A discontinuous strut is a compression member which extends between two adjacent joints only, e.g., vertical or inclined compression members in a roof truss.

	Type	Sections	Effective Lengths	Allowable Compressive Stress
1.	Continuous	Single or double angle	0.7 L to 1.00 L	σ_{ac}
2.	Discontinuous	Single angle connected with one rivet	1.00L	0.8 σ_{ac}
3.	Discontinuous	Single angle connected with more than one rivet or with weld	0.85L	σ_{ac}
4.	Discontinuous	Double angles placed back to back on opposite sides of gusset plate	0.70 L to 0.85 L	σ_{ac}
5.	Discontinuous	Double angles placed back to back on same side of gusset plate	1.00L	σ_{ac}

3.60 (c)

The slenderness ratio, λ is given by

$$\lambda = \frac{L_{eff}}{r_{min}}$$

L_{eff} depends on length of member and support end conditions.

r_{min} depends on sectional configuration.

3.61 (d)

A column member with a rigid foundation at bottom and held by heavy beams at top will behave as a column with both ends fixed.

Hence, $L_{eff} = 0.65\,l$

3.62 (d)

The steel tabular strut depending on the slenderness ratio and thickness, can fail due to compression yielding, overall buckling or skin buckling.

3.63 (d)

The buckling load of a steel column pinned at both ends is

$$P_1 = \frac{\pi^2 EI}{l_{eff}^2} = \frac{\pi^2 EI}{l^2} = 200 \text{ kN}$$

when the column is restrained against lateral movement at its mid height

$$l_{eff} = \frac{l}{2}$$

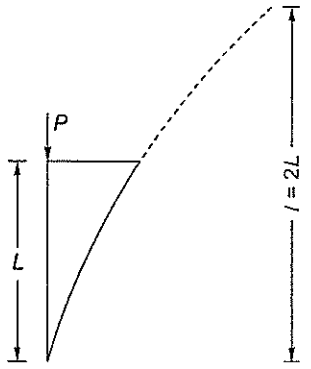
$$\therefore \quad P_2 = \frac{\pi^2 EI}{(l/2)^2} = 4 \times \frac{\pi^2 EI}{l^2} = 800 \text{ kN}$$

3.64 (c)

As per IS 800-1984, Laced compression members shall be provided with tie plates at the end of lacing systems and at the points where systems are interrupted. This is to check the distortion of column sections at the end because of unbalanced horizontal force from lacings.

3.65 (d)

As per IS 800-1984,



One end fixed and other free

3.66 (d)

As per IS 800-1984, the effective width of outstand in a compound steel column for design purpose is equal to distance of free edge to the nearest row of rivets.

3.67 (d)

Lacing system in a column is designed to resist a transverse shear of 2.5% of axial load

$$= \frac{2.5}{100} \times 1200 = 30 \text{ kN}$$

3.68 (a)

Lacings are normally longer than the length of the battens.

3.69 (b)

In shape (b) the moment of inertia is equal along both the principal axis i.e. $I_{xx} = I_{yy}$. Thus it will have the maximum compressive load carrying capacity.

3.70 (b)

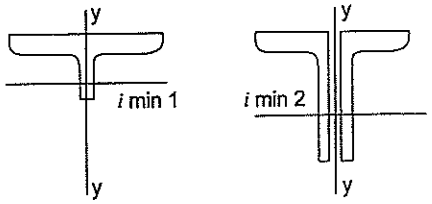
In case of battened structure, effective length is increased by 10%

$\therefore \quad L_e = 1.1\,L$

3.73 (d)

The two or more individual sections e.g. angles, channels etc of built-up columns are connected by lacing or batten and act together as one unit.

3.75 (b)



$I_{min\,2} > I_{min\,1}$

3.78 (b)

Web crippling occurs due to compression at the supports of a beam, where the bottom flange is resting on a support and top flange is holding up the concentrated load. Also, it is dependent on h/t_w ratio, not on width of flanges.

3.79 (a)

λ_{xx} = Effective slenderness ratio in x-direction

$$= \frac{1.2 \times l_{xx}}{r_{xx}} = 120$$

$$\Rightarrow \frac{1.2 \times l_{xx}}{40} = 120$$

$$\Rightarrow l_{xx} = \frac{4800}{12} = 4000 \text{ mm}$$

$$\lambda_{yy} = \frac{l_{yy}}{r_{yy}} = 120$$

$$\Rightarrow \frac{l_{yy}}{10} = 120$$

$$\Rightarrow l_{yy} = 1200 \text{ mm}$$

So, most appropriate option is (a).

3.80 (d)

As per IS 800 : 2007 Clause : 12.5.2.2, slenderness ratio of bracing member shall not exceed 160 (only hangers).

■■■■

4 Beams

4.1 A cantilever steel beam of 3 m span carries a uniformly distributed load of 20 kN/m inclusive of self weight. The beam comprises ISLB 200@198 N/mm flange100 mm × 7.3 mm, web thickness 5.4 mm

$I_{xx} = 1696.6\ cm^4$, $I_{yy} = 115.4\ cm^4$

Bending and shear stresses in the beam are respectively

(a) 530.47 N/mm^2 and 55.55 N/mm^2
(b) 3899.48 N/mm^2 and 82.19 N/mm^2
(c) 132.62 N/mm^2 and 41.1 N/mm^2
(d) 1949.74 N/mm^2 and 41.10 N/mm^2

[ESE : 1995]

4.2 The allowable shear stress in stiffened webs of mild steel beams decreases with

(a) decrease in the spacing of the stiffeners
(b) increase in the spacing of the stiffeners
(c) decrease in the effective depth
(d) increase in the effective depth

[ESE : 1997]

4.3 The rolled steel section used in a cased beam has width B mm and diameter D mm. The minimum width of the finished cased beam in mm is given by

(a) $(B + 50)$ (b) $(B + 100)$
(c) $(B + D + 100)$ (d) $2(B + D)$

[ESE : 1997]

4.4 Match List-I (Type of connection) with List-II (Type of beams) and select the correct answer using the code given below the lists:

List-I

A. Semi-rigid connection
B. Framed connection
C. Flexible connection
D. Seated connection

List-II

1. To permit large angles of rotation and to transmit negligible moment.
2. To allow small end rotation and transmit appreciable moment.
3. When a beam is connected to a beam or stanchion by means of an angle at the bottom of the beam which is shop-riveted to the beam and an angle at the top of which is field riveted.
4. When a beam is connected to a beam or stanchion by means of two angles riveted to them.

Codes:

	A	B	C	D
(a)	2	4	3	1
(b)	4	2	1	3
(c)	2	4	1	3
(d)	4	2	3	1

[ESE : 1998]

4.5 Racking force on a steel railway bridge is due to

(a) tractive effect of the driving well
(b) braking effect
(c) resistance offered by the bearing to the movement at the roller end
(d) lateral movement of the train when moving on a straight track.

[ESE : 1998]

4.6 **Assertion (A) :** Both transverse and longitudinal frames of a steel building are subjected to equal earthquake forces.

Reason (R) : Earthquake force is proportional to the mass of each floor.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.7 In a simply supported beam of span L each end is restrained against torsion, compression flange

being unrestrained. According to IS: 800, the effective length of the compression flange will be equal to

(a) L (b) 0.85 L
(c) 0.75 L (d) 0.70 L

[ESE : 1999]

4.8 A simply supported beam of 8 m effective span carries uniformly distributed load of 2 kN/m (inclusive of self load) over the effective span. If the permissible bending stress is 160 MPa, then most suitable shape and size would be a

(a) solid circular section of diameter = 110 mm, area = 9500 mm^2 and section modulus = 130660 mm^3
(b) solid rectangular section of size 60 mm × 100 mm deep, area = 6000 mm^2 and maximum section modulus = 100,000 mm^3
(c) T-section of size 200 mm × 200 mm × 10 mm thickness, area = 3900 mm^2 and maximum section modulus = 105,780 mm^3
(d) I-section of size 80 mm × 150 mm deep × 10 mm thickness, area = 2900 mm^2 and maximum section modulus = 129100 mm^3

[ESE : 2001]

4.9 Which one of the following pairs is correctly matched?

(a) Truss : Bending
(b) Beam : Twisting
(c) Column : Buckling
(d) Shaft : Shortening

[ESE : 2001]

4.10 The maximum shear force at a section is 56 kN. An ISWB of height 350 mm, breadth 200 mm, thickness of web 8 mm, with a section modulus of 887 cm^3 is used as a beam at the section. The shearing stress is

(a) 10 N/mm^2 (b) 20 N/mm^2
(c) 28.4 N/mm^2 (d) 41.6 N/mm^2

[ESE : 2001]

4.11 In selecting a rolled I-section for a simply-supported beam, along with minimum sectional modulus, a minimum, value of span/depth ratio is also ensured. This is stipulated to ensure that

(a) the buckling of beam does not take place
(b) the shear stress in beam remains within permissible limit
(c) the deflection of beam remains within permissible limit
(d) the bending stress in compression is within permissible limit.

[ESE : 2002]

4.12 Which of the following apply to 'fully rigid design' of steel structures?

1. End connections are capable of transmitting moments.
2. Angle between members at the joint does not change.
3. The structure is assumed to be pin-jointed.
4. A reduction in the maximum bending moment is permitted to provide a degree of direction fixity.

Select the correct answer using the codes given below :

(a) 1, 2 and 3 (b) 1 and 2
(c) 1, 3 and 4 (d) 2, 3 and 4

[ESE : 2002]

4.13 A symmetrical channel section is made of a material which is equally strong in tension and compression. It is used as a simply supported beam with its web horizontal to carry vertical loads. It will

(a) be strongest if the web is used as top face
(b) be strongest if the web is used as bottom face
(c) be equally strong in (a) and (b) above
(d) not be possible to state which of the above statements is correct

[ESE : 2002]

4.14 A simply supported beam of span 4000 mm is loaded with a uniformly distributed load of 30 kN/m. f_y for the material is 250 MPa. Which rolled steel section is required?

(a) ISMB 500 (b) ISMB 400
(c) ISMB 300 (d) ISMB 600

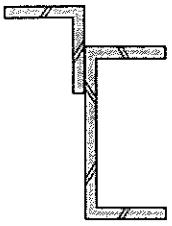
[ESE : 2004]

4.15 How are the most commonly produced and used structural elements in frames, floor beams, etc. with high moment of inertia about x-axis, are designated?

(a) ISWB-section (b) ISLB-section
(c) ISMB-section (d) ISHB-section

[ESE : 2004]

4.16 An angle is connected to the back of the flange of a channel section to be used as a beam as shown in the diagram below.



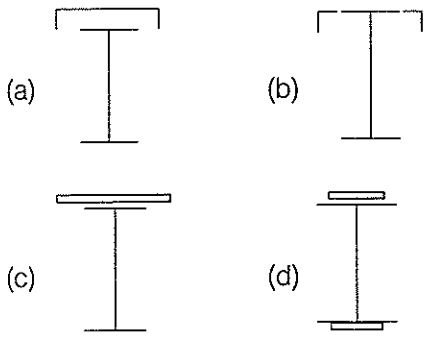
This is done to
(a) increase the compression flange area
(b) increase the moment of inertia about the major axis
(c) increase the moment of inertia about the minor axis
(d) make the load pass through the shear centre

[ESE : 2004]

4.17 In beam to column connections in steel construction, if torsion is permitted at the ends of simply supported beams by not providing the cleats, the
(a) effective length of the beam increases by 20%
(b) effective length remains same as the actual length
(c) permissible bending stresses are increased by around 10%
(d) joint has to be designed for torsion

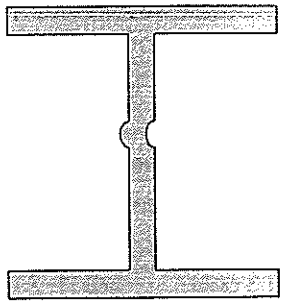
[ESE : 2005]

4.18 A laterally unsupported compression flange of beam has been strengthened by channel angle and plates as shown. Areas of all the members added are equal. Which one of the following options will yield higher allowable stress?



[ESE : 2006]

4.19 What is the failure of a section shown in the figure above called?



1. Web buckling
2. Web crippling
3. Web crimpling
4. Column buckling

Select the correct answer using the codes given below:
(a) 1 and 2 (b) 2 and 3
(c) 1 and 4 (d) 2 and 4

[ESE : 2008]

4.20 A steel beam is connected to a steel column by means of two angles placed on the two sides of the web of the beam. What is it called?
(a) Stiffened seat connection
(b) Unstiffened seat connection
(c) Framed connection
(d) Rigid connection

[ESE : 2008]

4.21 A cantilever steel beam of 3 m span carries a uniformly distributed load of 20 kN/m inclusive of self-weight. The beam comprises of ISLB200@198 N/m, flange = 100 mm × 7.3 mm; web thickness = 5.4 mm; I_{xx} = 1696.6 cm^4; I_{yy} = 115.4 cm^4. What is the maximum bending stress in the beam?
(a) 132.62 N/mm^2 (b) 530.47 N/mm^2
(c) 1949.74 N/mm^2 (d) 3899.48 N/mm^2

[ESE : 2009]

4.22 An ISMB 300 beam has modulus of section of 600 × 10^3 mm^3. Plates of 200 mm × 10 mm are added by welding them one on each flange to have total depth of section as 320 mm. What is the section modulus of the plated section?
(a) 462 × 10^3 mm^3 (b) 550 × 10^3 mm^3
(c) 710 × 10^3 mm^3 (d) 1220 × 10^3 mm^3

[ESE : 2009]

4.23 Consider the following statements :
Torsional restraint in a beam can be achieved by providing :

1. Web or flange cleats at the end connections.
2. External support to the end of the compression flange.
3. Bearing stiffness acting in conjunction with the bearing of the beam.

Which of these statements is/are correct ?

(a) 1 only (b) 1 and 2 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2009]

4.24 For an I-beam, the shape factor is 1.12; the factor of safety in bending stress is 1.5. If the allowable stress is increased by 20% for wind or earthquake loads, then the load factor is

(a) 1.10 (b) 1.25
(c) 1.35 (d) 1.40

[ESE : 2010]

4.25 The allowable shear stress in stiffened webs of mid steel beams decreases with

(a) Decrease in the spacing of the stiffeners
(b) Increase in the spacing of the stiffeners
(c) Decrease in the effective depth
(d) Increase in the effective depth

[ESE : 2011]

4.26 Consider the following statements in respect of design of web and flange splices:.

1. Flange splice shall be designed for actual BM at the section.
2. Flange splice shall be designed to resist the actual shear at the section.
3. Web splice shall be designed to resist the actual shear at the section.
4. Web splice shall be designed for actual BM.

Which of these statements are correct?

(a) 1 and 3 (b) 2 and 3
(c) 3 and 4 (d) 1 and 4

[ESE : 2011]

4.27 The allowable shear stress in the web of mild steel beams decreases with

(a) Decrease in h/t ratio
(b) Increase in h/t ratio
(c) Decrease in thickness
(d) Increase in height

[ESE : 2011]

4.28 Consider the following statements:
Web crippling due to excessive bearing stress can be avoided by

1. Increasing the web thickness.
2. Providing suitable stiffeners.
3. Increasing the length of the bearing plates.

Which of these statements are correct?

(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

[ESE : 2011]

4.29 An ISMB 500 is used as a beam in a multistorey construction. From the viewpoint of structural design, it can be considered to be 'laterally restrained' when

(a) the tension flange is laterally restrained
(b) the compression flange is laterally restrained
(c) the web is adequately stiffened
(d) the conditions in both (a) and (c) are met

[ESE : 2012]

4.30 ISMB 250 ($Ze = 410 \times 10^3$ mm^3) has been chosen as a beam cross-section to resist a bending moment. Two plates 100 mm x 10 mm are welded to each flange to enhance the moment capacity. The enhanced moment capacity is

(a) 71.5 kNm (b) 79.5 kNm
(c) 99.0 kNm (d) 148.0 kNm

[ESE : 2013]

4.31 According to IS : 875 Part 3, design wind speed is obtained by multiplying the basic wind speed by factors k_1, k_2 and k_3, where k_3 is

(a) terrain height factor
(b) structure size factor
(c) topography factor
(d) risk coefficient

[ESE : 2014]

4.32 The problems of lateral buckling can arise only in those steel beams which have

(a) moment of inertia about the bending axis larger than the other
(b) moment of inertia about the bending axis smaller than the other
(c) fully supported compression flange
(d) None of the above

[ESE : 2014]

Answers Beams

4.1 (a)	4.2 (b)	4.3 (b)	4.4 (c)	4.5 (d)	4.6 (a)	4.7 (a)	4.8 (d)	4.9 (c)	
4.10 (b)	4.11 (c)	4.12 (b)	4.13 (a)	4.14 (c)	4.15 (c)	4.16 (d)	4.17 (a)	4.18 (a)	
4.19 (b)	4.20 (c)	4.21 (b)	4.22 (d)	4.23 (d)	4.24 (d)	4.25 (b)	4.26 (a)	4.27 (b)	
4.28 (a)	4.29 (b)	4.30 (d)	4.31 (c)	4.32 (a)					

Explanations Beams

4.1 (a)

The maximum bending moment,

$$M = \frac{wl^2}{2} = \frac{20 \times 3^2}{2} = 90 \text{ kN-m}$$

Section modulus of beam,

$$Z = \frac{I_{xx}}{(200/2)} = \frac{1696.6 \times 10^4}{100}$$
$$= 1696.6 \times 10^2 \text{ mm}^3$$

Bending stress,

$$\sigma = \frac{M}{Z} = \frac{90 \times 10^6}{1696.6 \times 10^2}$$
$$= 530.47 \text{ N/mm}^2$$

Maximum shear force,

$$V = wl = 20 \times 3 = 60 \text{ kN}$$

Shear stress, $\tau = \dfrac{V}{t_w d}$

Thickness of web,

$$t_w = 5.4 \text{ mm}$$

$\therefore$ $\tau = 60 \times 10^3/(5.4 \times 200)$

$= 55.5 \text{ N/mm}^2$

4.2 (b)

For unstiffened webs the permissible shear stress, $\tau_{va} = 0.4\, f_y$

For stiffened web:

(i) For webs where distance between vertical stiffeners (c) is less than 'd'

$$\tau_{va} = 0.4 f_y \left[1.3 - \frac{\sqrt{f_y}(c/t)}{4000\left\{1 + 0.5(c/d)^2\right\}} \right]$$

(ii) for webs where distance between vertical stiffeners (c) is more than 'd'

$$\tau_{va} = 0.4 f_y \left[1.3 - \frac{\sqrt{f_y}(d/t)}{4000\left\{1 + \frac{1}{2}(d/c)^2\right\}} \right]$$

Thus with increased spacing between vertical stiffeners, τ_{va} decreases.

4.3 (b)

In multistoreyed buildings (or tier buildings) consisting of steel stanchions and beam framing, it is advisable to encase the steel frame in concrete to make it fire resistant and more pleasing to eye. It is a composite beam. The minimum width of solid casing is (B + 100). The radius of gyration about yy-axis is 0.2 (B + 100).

4.4 (c)

The framed connection is made by two angles placed on the two sides of the web of the beam. The framed connection and seated connection are classified as flexible connections.

Seated connection consist of a horizontal angle with its horizontal leg at its top to receive the beam on it.

4.5 (d)

Due to small lateral movement of trains even when moving on straight track, lateral forces are applied by the train to the track. This horizontal lateral load (raking force) is taken equal to 5.88 kN/m and treated as a moving load.

4.6 (a)

Wind and earthquake forces are reversible and may be assumed to act along each axis of the building, once at a time. Wind pressure acts on the surface of the building exposed to it. Therefore the frames in the short direction of the building are usually more affected by wind than those in the long direction. But earthquake force is proportional to the mass of each floor and its magnitude changes little from short to long direction. Therefore both transverse and

longitudinal frame may be equally affected by it and must be checked in every case.

4.7 (a)

Type of member	End Condition of Bracing	Effective length l
Simply supported beams	Restrained against torsion (i) unrestrained against lateral bending (ii) partially restrained against lateral bending (iii) fully restrained against lateral bending	 L 0.85 L 0.7 L
All Members	Effective lateral bracing at intervals along the length	Distance between intersections of bracings with member

4.8 (d)

The maximum bending moment

$$= \frac{wl^2}{8} = \frac{2\times 8^2}{8} = 16 \text{ kN-m}$$

$$Z_{req} = \frac{M_{max}}{\sigma_{bt}} = \frac{16\times 10^6}{160} = 10^5 \text{ mm}^3$$

A section with minimum area and maximum section modulus more than required section modulus will be most suitable.

4.9 (c)

The correct matching is:

Truss: shortening

Beam: bending

Column: buckling

Shaft: twisting

4.10 (b)

Shearing stress at neutral axis $= \frac{VQ}{It}$

Given $t = 8$ mm

$$I = 887\times 10^3 \times \frac{350}{2} \text{mm}^3$$

$Q = A\bar{y}$

However, the flanges of the beam take very small shear and most of it being shared by the web. Thus for I-section, the shear stress

$$f_s = \frac{V}{t_w D} = \frac{56\times 10^3}{8\times 350} = 20 \text{ N/mm}^2$$

4.11 (c)

To control deflection of beam and keep it within permissible limit, minimum value of span/depth ratio is ensured.

4.12 (b)

In fully rigid design of steel structures, end connections are capable of transmitting moments and angle between members at the joint does not change.

4.13 (a)

Web of the beam is horizontal and it is laterally unsupported. So the permissible stress in bending compression will reduce. Therefore it is better to use web as top face so that more area is on top face.

4.14 (c)

Maximum bending moment M

$$= \frac{wl^2}{8} = \frac{30\times 4^2}{8} = 60 \text{ kN-m}$$

Required section modulus

$$Z_{req} = \frac{M}{0.66 f_y} = \frac{60\times 10^6}{0.66\times 250}$$

$$= 363636.36 \text{ mm}^3 = 363.6 \text{ cm}^3$$

Beam section	Z(cm^3)
ISMB 500	1808.7
ISMB 400	1022.9
ISMB 300	573.6
ISMB 600	3060.4

Therefore ISMB 300 is suitable.

4.15 (c)

ISLB → IS Light Beam

ISMB → IS Medium Beam

ISWB → IS Wide Flange Beam

ISHB → IS Heavy Beam

ISLB are used for roof beams, vehicle frames in trucks, etc.

ISMB are used as elements in frames, floor beams, etc. They have high moment of inertia about x-axis when compared with y-axis. The lateral buckling strength is not high as the radius of gyration about y-axis is low.

ISHB are heavy beams even though they have radius of gyration close to the corresponding medium beams. The thickness of flanges and web are on the higher side.

ISWB have high radius of gyration about y-axis compared to ISMB or ISHB. Therefore they have

relatively higher lateral buckling capacity and can be efficiently used as columns in buildings.

4.16 (d)

An angle connected to the back of flange of a channel section as shown in figure will shift the shear centre towards the channel web and hence will make the load pass through the shear centre.

4.17 (a)

As per IS 800-1984, if torsion is permitted at ends of a simply supported beam by not providing cleats, the effective length of the compression flange shall be increased by 20%.

4.19 (b)

The failure of web in direct crushing under concentrated load is known as web crippling or web crimpling.

4.20 (c)

The connection when a steel beam is connected to steel column by means of two angles placed on two sides of web is a framed connection which is torsion resistant but not resistant to warping.

4.21 (b)

The maximum bending stress is given by

$$f_{max} = \frac{M_{max}}{Z}$$

But $M_{max} = \frac{Wl^2}{2} = \frac{20 \times 3^2}{2} = 90$ kN-m

$$Z = \frac{I_{xx}}{200/2} = \frac{1696.6 \times 10^4}{100}$$

$$= 169660 \text{ mm}^2$$

$$\therefore \quad f_{max} = \frac{90 \times 10^6}{169660} = 530.47 \text{ N/mm}^2$$

4.22 (d)

We know that section modulus of beam is

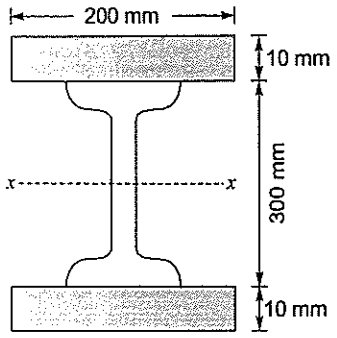
$$Z = \frac{I_{xx}}{Y_{max}}$$

$$\Rightarrow \quad I_{xx} = Z \times Y_{max}$$

$$= 600 \times 10^3 \times \frac{300}{2}$$

$$= 90000 \times 10^3 \text{ mm}^4$$

When the plates are welded to the beam, the moment of inertia of the built up section is increased



I_{xx} of plates about the centroidal axis

$$= 2 \times \left[\frac{200 \times 10^3}{12} + 200 \times 10 \times (150+5)^2 \right]$$

$= 96133.34 \times 10^3 \text{ mm}^4$

I_{xx} of built up section $= 90{,}000 \times 10^3$

$+ 96133.34 \times 10^3$

$= 186133.34 \times 10^3 \text{ mm}^4$

$\therefore$ Section modulas of the built up section

$$= \frac{186133.34 \times 10^3}{320/2}$$

$$= 1163.33 \times 10^3 \text{ mm}^3$$

The section modulus calculated above is less than $1220 \times 10^3 \text{ mm}^3$ because the moment of inertia of the welding was not incorporated in the calculations.

4.23 (d)

Torsional resistance in a beam can be achieved by web or flange cleats at the end connections, external support to the end of compression flange or bearing stiffeners and it prevents rotaion of beam about its longitudinal axis.

4.24 (d)

The factor of safety is given as

$$F_1 = \frac{\text{Yield stress}}{\text{Allowable stress}} = 1.5$$

When the allowable stress is increased by 20%, then factor of safety will be

$$F_2 = \frac{\text{Yield stress}}{1.2 \times \text{Allowable stress}}$$

$$\Rightarrow \quad F_2 = \frac{1}{1.2} \times \frac{\text{Yield stress}}{\text{Allowable stress}}$$

$$\Rightarrow \quad F_2 = \frac{1}{1.2} \times 1.5 = 1.25$$

$\therefore$ Load factor = Shape factor × Factor of safety

$= 1.12 \times F_2 = 1.12 \times 1.25$

$= 1.40$

4.25 (b)

Design of the plate girder with intermediate stiffeners, can be done by limiting their shear capacity to shear buckling strength.

Allowable shear stress in the web of a beam decreases with increase in h/t ratio and increase in distance between stiffeners.

4.27 (b)

Shear determines the design of beams.

1. When the depth of beam section is small and is loaded uniformly.
2. When large concentrated loads are placed near beam supports.
3. In plate girder where the web thickness is small.

According to I.S. 800-1984 the maximum permissible shear stress should not exceed the value of τ_{vm} given by $\tau_{vm} = 0.45 f_y$

The permissible average sher stress τ_{va} on a web whose depth does not exceed 85 times its thickness, is equal to $0.40 f_y$

Allowable shear stress in the web of a beam decreases with increase in h/t ratio and increase in distance between stiffeners.

4.28 (a)

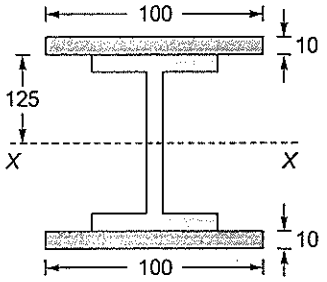
The webs of rolled steel sections are subjected to a large amount of stresses just below the concentrated loads and above the reactions from the support. Stress concentration occurs at the junction of the web and the flange. As a result, large bearing stresses are developed below the concentrated loads. The web near the portion of the stress concentration tends to fold over the flange. This type of local buckling phenomenon is called crippling or crimpling of the web.

The web of the plate girder being relatively tall and thin is a poor compression member and hence, the possibility of vertical and diagonal buckling is always there. Either the web is stiffened vertically as well as horizontally or the compressive stress in the web is kept low enough by increasing the web thickness to prevent crippling.

4.29 (b)

If the compression flange is restrained laterally against buckling or if the beam is to bend about the axis of minimum strength (y-y) axis, the beam is said to be laterally restrained.

4.30 (d)



$Z_e = 410 \times 10^3 \text{ mm}^3$

I_{xx} of plates only

$$= 2\left[100 \times \frac{10^3}{12} + 100 \times 10 \times \left(125 + \frac{10}{2}\right)^2\right] \text{mm}^4$$

$= 33.8167 \times 10^6 \text{ mm}^4$

$\therefore Z_{xx}$ of plates only

$$= \frac{33.8167 \times 10^6}{(125+10)} = 250.494 \times 10^3 \text{ mm}^3$$

$\therefore Z_{xx}$ of the whole section

$= (250.494 + 410)10^3 \text{ mm}^3$

$= 660.494 \times 10^3 \text{ mm}^3$

$\therefore$ Enhanced moment capacity

$$= \left(\frac{250}{1.1}\right) 660.494 \times 10^3 \text{ N-mm}$$

$= 150$ kN-m

4.31 (c)

According to IS 875 Part-III.

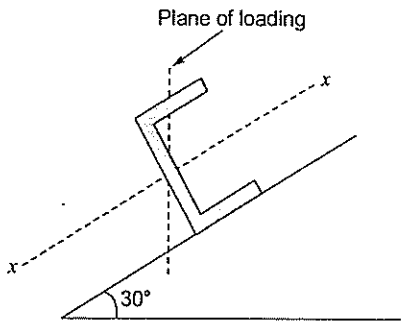
$k_1 \rightarrow$ probability factor or risk coefficient

$k_2 \rightarrow$ terrain, height and structure size factor

$k_3 \rightarrow$ topography factor

5 Plate Girders and Industrial Roofs

5.1 A channel section is placed in an inclined position carrying vertical loads as shown in the given figure. If the applied moment for the channel is 'M' due to vertical load, then M_{XX} is given by

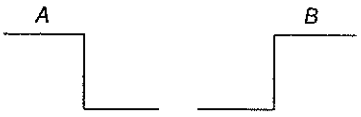


(a) $\frac{\sqrt{3}}{2}M$ (b) $\frac{1}{2}M$

(c) $\frac{1}{\sqrt{2}}M$ (d) $2M$

[ESE : 1995]

5.2 Z-purlins may be fixed in either orientation *A* or *B* as shown in the given figure. Which one of the following statements is correct in this regard?



(a) Orientation *A* is structurally more efficient than orientation *B*.
(b) Orientation *B* is structurally more efficient than orientation *A*.
(c) Both the orientations are structurally equally efficient.
(d) Neither of the two orientation is structurally efficient.

[ESE : 1995]

5.3 Intermediate vertical stiffeners are provided in plate girders to
(a) eliminate web buckling
(b) eliminate local bucking
(c) transfer concentrated loads
(d) prevent excessive deflection

[ESE : 1995]

5.4 Consider the following systems:
1. Trusses and purlins
2. Suspension system
3. Flat grid roof
4. Shells

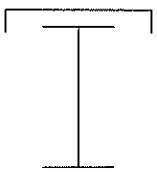
When these are used in single deck industrial structures, the correct sequence in increasing order of spans will be
(a) 3, 1, 2, 4 (b) 1, 3, 2, 4
(c) 3, 1, 4, 2 (d) 2, 4, 1, 3

[ESE : 1996]

5.5 The thickness of web for unstiffened plate girder with clear distance '*d*' between the flanges shall not be less than
(a) *d*/200 (b) *d*/85
(c) *d*/100 (d) *d*/160

[ESE : 1996]

5.6 The given figure shows a typical section of a crane girder. Consider the following statements in this regard:



The function of the top channel is to
1. increase moment of inertia about vertical axis
2. reduce moment of inertia about horizontal axis
3. increase torsional stiffness
4. increase lateral buckling strength

Which of these statements are correct?
(a) 1 and 4 (b) 2 and 3
(c) 1, 2 and 4 (d) 1, 3 and 4

[ESE : 1996]

5.7 **Assertion (A)** : Portal bracing should be used in only through bridges where cross frames cannot be used.
Reason (R) : Portal bracing causes bending moment in the end frames.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1996]

5.8 At a section along the span of a welded plate girder, where the web is spliced, the bending moment is *M*. If the girder has top flange, web and bottom flange plates of equal area, then the share of the bending moment which would be taken by the splice plates would be
(a) *M* (b) *M*/3
(c) *M*/7 (d) *M*/13
[ESE : 1997]

5.9 In the simplified design of angle iron purlins, which one of the following assumptions would NOT be valid?
(a) Load component acting normal to the slope is considered
(b) Bending moment about the minor axis is considered
(c) Allowable bending stress is not reduced
(d) Slope of the roof should not exceed 30°
[ESE : 1998]

5.10 The height at which wind force acts on a moving vehicle on a bridge deck is
(a) 1.2 m (b) 1.5 m
(c) 1.7 m (d) 2.0 m
[ESE : 1998]

5.11 If '*p*' is the basic wind pressure, for buildings with large opening design pressure on a wall is taken as
(a) 0.5*p* (b) 0.7*p*
(c) 1.0*p* (d) 1.2*p*
[ESE : 1998]

5.12 According to Indian Railway Board, in respect of steel girders of single track span for metre/broad gauge, the impact factor for a span of 6 m is
(a) 0.5 (b) 0.75
(c) 1 (d) 1.25
[ESE : 1999]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:
Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

5.13 **Assertion (A)** : Lateral bracing of adjacent trusses is necessary in industrial buildings.
Reason (R) : Wind forces acting along the ridge line are to be resisted.
[ESE : 1999]

5.14 **Assertion (A)** : The flange area method of design of plate girders is an approximate method.
Reason (R): Bending stresses in compression and tension flanges are assumed to be linearly distributed.
[ESE : 1999]

5.15 Consider the following statements regarding roofing of an industrial structure:
1. The canoidal shell is preferable to north-light steel trussed roof.
2. The ware-house flat slab construction is not suitable.
3. Loads other than self-weight have insignificant effect on the design.
4. Consideration of corrosive environment cannot be ignored as it affects the durability.
Which of these statements are correct?
(a) 1, 2, 3 and 4 (b) 2, 3 and 4
(c) 1 and 2 (d) 3 and 4
[ESE : 1999]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

5.16 **Assertion (A):** The vertical member of Howe roof truss is made of steel.
Reason (R): Ordinarily wood is not used for tension members.
[ESE : 2000]

5.17 **Assertion (A):** A through truss bridge is supported at the level of upper chord.
Reason (R): Wind has a tendency to overturn the bridge about the lower chord of leeward truss.
[ESE : 2000]

5.18 The economic spacing of a roof truss depends upon the
(a) cost of purlins and cost of roof covering
(b) cost of roof covering and dead loads
(c) dead loads and live loads
(d) live loads and cost of purlins
[ESE : 2000]

5.19 Consider the following statements:
Bearing stiffeners are provided in a plate girder
1. to avoid local bending failure of flange
2. to prevent buckling of web
3. to strengthen the web
4. under the uniformly distributed loads
Which of these statements are correct?
(a) 1, 2 and 3 (b) 2 and 3
(c) 1, 3 and 4 (d) 1, 2 and 4
[ESE : 2000]

5.20 As per IS : 800 in the case of a plate girder with vertical and horizontal stiffeners, the greater and lesser unsupported clear dimension of a web panel in terms of web thickness 't_w' should not exceed respectively
(a) $180t_w$ and $85t_w$ (b) $270t_w$ and $200t_w$
(c) $270t_w$ and $180t_w$ (d) $400t_w$ and $250t_w$
[ESE : 2000]

5.21 In a truss girder of a bridge, a diagonal consists of mild steel flat 400 ISF and carries a pull of 800 kN. If the gross diameter of the rivets is 26 mm, then the number of rivets required in the splice is
(a) 6 (b) 7
(c) 8 (d) 9
[ESE : 2000]

5.22 Which of the following loads are to be considered in designing a gantry girder in an industrial building?
1. Gravity loads
2. Lateral loads
3. Longitudinal loads
4. Wind loads
Select the correct answer using the codes given below:
(a) 1 and 2 (b) 1, 2 and 3
(c) 1 and 3 (d) 2, 3 and 4
[ESE : 2001]

5.23 In a plate girder bridge the thickness of web is less than $d'/200$ where d' is the unsupported depth of web. The web plate should be provided with
(a) vertical stiffeners
(b) horizontal stiffeners
(c) end stiffeners
(d) both vertical and horizontal stiffeners
[ESE : 2001]

5.24 In the design of steel bridges if wind or seismic forces are also considered, the allowable stresses as per BIS may be increased by
(a) 10% (b) $16\frac{2}{3}\%$
(c) 25% (d) $33\frac{1}{3}\%$
[ESE : 2001]

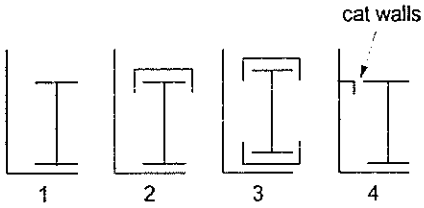
5.25 **Assertion (A):** Impact factor is used in the design of a gantry girder.
Reason (R): Loads transferred to the gantry girder are momentary.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 2001]

5.26 Which among the following assumptions are made in the design of roof trusses?
1. Roof truss is restrained by the reactions
2. Axes of the members meeting at a joint intersect at a common point
3. Riveted joints act as frictionless hinges
4. Loads act normal to roof surface

Select the correct answer using the codes given below:
(a) 1, 2 and 4 (b) 2, 3 and 4
(c) 1, 3 and 4 (d) 1, 2 and 3

[ESE : 2002]

5.27 A gantry girder has been provided with the following sections shown in the following figures



In which case(s), the allowable stresses in bending compression is equal to that in tension? Select the correct answer using the codes given below :
(a) 1 and 2 (b) 2 and 3
(c) 4 only (d) 3 only

[ESE : 2002]

5.28 Gross flange area for a riveted plate girder is to be designed considering net area as 80% of its gross area. Consider width of the flange as 500 mm while web plate as 1000 mm × 12 mm. The girder is to resist a maximum BM of 4500 kN-m. Maximum allowable bending stress in tension is 150 MPa. Gross flange area is
(a) 22000 mm^2 (b) 35500 mm^2
(c) 46000 mm^2 (d) 73000 mm^2

[ESE : 2002]

5.29 The effective flange area in tension of a plate girder is equal to

(a) A_f (b) $A_f + \frac{A_w}{2}$

(c) $A_f + \frac{A_w}{8}$ (d) $A_f + \frac{A_w}{6}$

where A_f is the area of each flange and A_w is the web area.

[ESE : 2002]

5.30 **Assertion (A) :** Compared to riveted plate girders, in welded plate girders a thicker web must be used.
Reason (R) : Omission of flange angles increases the clear depth of the web and web thickness is controlled by buckling criterion.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2003]

5.31 Consider the following statements:
Horizontal stiffener is provided when
1. the depth of webs is small.
2. tendency to web buckling is less.
3. vertical stiffeners becomes too close.
4. only thin plates are available for web.

Which of these statements are correct?
(a) 1 and 2 (b) 3 and 4
(c) 1, 2 and 4 (d) 1, 3 and 4

[ESE : 2004]

5.32 In a gabled industrial building in order to minimize the wind forces on the roof, the roof slope should be kept close to
(a) 5° (b) 15°
(c) 30° (d) 45°

[ESE : 2004]

5.33 A_f is the area of flanges and A_w is the area of web. What is the effective flange area in the design of a plate girder?
(a) $A_f + A_w/8$ (b) $A_f + A_w/6$
(c) $A_f - A_w/8$ (d) $A_f - A_w/6$

[ESE : 2004]

5.34 In a crane gantry girder, a channel is provided at the top flange girder. This accounts for bending in
(a) horizontal plane only
(b) vertical plane only
(c) horizontal and vertical planes
(d) horizontal and vertical planes and twisting

[ESE : 2004]

5.35 Consider the following statements in respect of plate girders:

1. A large number of cover plates are provided over flange angles so that curtailed flanges match the bending moment diagram exactly.
2. At least one cover plate should extend over the entire span so that rain water may not enter and corrode the connections.
3. A minimum of one-third of flange area should be provided in flange angles and balance in flange cover plates for stability.

Which of these statements are correct?

(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

[ESE : 2005]

5.36 For a vertical stiffened web of a plate girder, the lesser clear dimension of the panel should not exceed ('t' is the thickness of the web)

(a) 85t (b) 180t
(c) 200t (d) 250t

[ESE : 2005]

5.37 Purlins are provided, in industrial buildings, over roof trusses to carry dead loads, live loads and wind loads. As per IS code, what are they assumed to be?

(a) Simply supported (b) Cantilever
(c) Continuous (d) Fixed

[ESE : 2005]

5.38 Consider the following statements about provision of sag rods:

1. Sag rods reduce span length of purlin in the weak direction.
2. Sag rods are installed in the plane of the roof.
3. Ridge purlin is subject to vertical components of sag rods on either side of slope.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 2 and 3
(c) 1 and 2 (d) 1 and 3

[ESE : 2005]

5.39 Consider the following statements:
Bearing stiffeners, in plate girders, are

1. provided at supports.
2. provided under concentrated loads.
3. provided alternately on the web.

Which of these statements is/are correct?

(a) 1 only (b) 2 only
(c) 1 and 2 (d) 1, 2 and 3

[ESE : 2005]

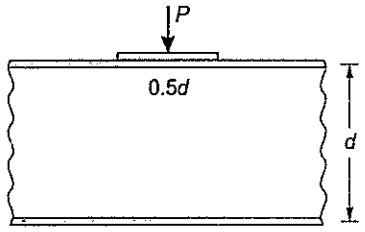
5.40 The outstand of the flange of built-up beams from the line of connection should not extend beyond

(a) $10\,T$ (b) $85\,T$
(c) $\frac{256T}{\sqrt{f_y}}$ (d) $180\,t_w$

(where T is the thickness of flange and t_w is the thickness of web)

[ESE : 2005]

5.41 A plate girder of depth d bears a concentrated load P through a distribution plate of width 0.5d as shown in the figure. If the maximum allowable critical buckling stress is calculated as 'f', what is the value of P? Web plate thickness = t



(a) 0.5 dtf (b) 1.0 dtf
(c) 1.5 dtf (d) 2.0 dtf

[ESE : 2006]

5.42 A welded plate girder has a web plate 1500 mm × 6 mm. Which one of the following is correct about stiffening the web?

(a) The web is left unstiffened
(b) The web is provided with vertical stiffeners only
(c) The web is provided with vertical stiffeners and a horizontal stiffener at 0.4 d from the top flange
(d) The web is provided with vertical stiffener and two rows of horizontal stiffeners, one at 0.4 d from the top flange and another at the mid-height of the web

[ESE : 2006]

5.43 Which one of the following sections is the most efficient for a simply supported gantry girder?

(a) I-section with equal flanges
(b) I-section with a channel attached to the top flange
(c) I-section with a wide bottom flange
(d) I-section with a heavy plate connected to the bottom flange

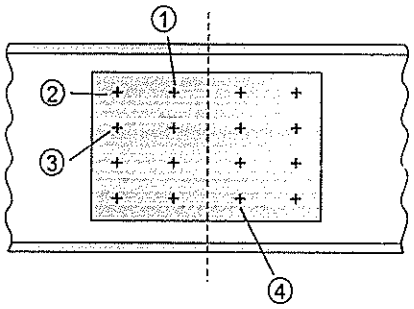
[ESE : 2006]

5.44 Conventional practice is to brace end panels of the side walls of an industrial building. Instead bracing can be provided in the bays near centre of the building. Which one of the following reasons is correct?

(a) Wind pressure at the mid length is higher compared to ends
(b) Trusses are erected starting from the ends of the building
(c) Fixing the bracings to end gables is convenient
(d) Free change of length between centre and the ends of the building is possible in mid-span bracing

[ESE : 2006]

5.45 Which one of the bolts in a web splice of a plate girder as shown in the figure is stressed maximum?



(a) Bolt - 1 (b) Bolt - 2
(c) Bolt - 3 (d) Bolt - 4

[ESE : 2006]

5.46 Why are intermediate vertical stiffeners provided in plate girders?

(a) To eliminate web buckling
(b) To eliminate local buckling
(c) To transfer concentrated loads
(d) To prevent excessive deflection

[ESE : 2007]

5.47 The portal bracing is designed for which of the following?

(a) Wind forces only
(b) Wind force + $1\frac{1}{4}$% of the compression force in two end posts
(c) Wind force + 2.5% of the compression force in two end posts
(d) Lateral shear + 2.5% of the compression force in two end posts

[ESE : 2007]

5.48 A symmetrical plate girder has been fabricated with three equal plates. If a circular hole of diameter equal to half of its height is centrally cut in the web, what is the approximate ratio of the strength of this punctured girder to that of the original girder?

(a) 93% (b) 85%
(c) 75% (d) 56%

[ESE : 2007]

5.49 Consider the following statements pertaining to intermediate stiffeners:

1. Stiffeners are provided to exclusively bear concentrated loads.
2. Stiffeners should bear tightly against top and bottom flanges.
3. Maximum spacing of stiffeners is restricted 180t, where 't' is the thickness of web.

Which of these statements is/are correct?

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 3 only (d) 2 only

[ESE : 2007]

5.50 Horizontal stiffeners are needed in plate girders if the thickness of web is

(a) <6 mm
(b) $< d/200$
(c) $< L/500$
(d) nearly equal to flange thickness

where d = distance between flanges; L = span

[ESE : 2007]

5.51 At what value (nearly) is the maximum spacing of purlins for standard asbestos roofing sheets kept?

(a) 1.0 m (b) 1.4 m
(c) 1.8 m (d) 2.0 m

[ESE : 2007]

5.52 Diagonal member of a roof truss of length L has been designed with tube of 100 mm mean diameter and 3 mm thick. The force in the member is tensile due to dead and live loads, and compressive due to occasional winds. What is the maximum permissible effective length of the member?

(a) 6.3 m (b) 8.75 m
(c) 12.25 m (d) 14.0 m

[ESE : 2007]

5.53 Consider the following statements in respect of gantry girders :

1. Gantry girders are designed for 23% extra load of crane capacity for impact.
2. Maximum deflection for dead and imposed loads without impact is limited to span/500.

Which of these statement/s is/are correct?

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2007]

5.54 Which one of the following is correct?
An intermediate vertical stiffener connected to the web is designed to withstand a shearing force of not less than

(a) $\frac{100t}{h}$ (b) $\frac{150t^2}{h}$

(c) $\frac{125h}{t^2}$ (d) $\frac{125t^2}{h}$

where t is web thickness in mm and h is the outstand of stiffener in mm.

[ESE : 2008]

5.55 The effective length of an angle member in a riveted truss is equal to which one of the following?

(a) l (b) $0.85l$
(c) $0.65l$ (d) $0.5l$

where l is the centre to centre distance between the joints.

[ESE : 2008]

5.56 Which one of the following is correct?
The purlins in the roof trusses are subjected to unsymmetrical bending because the loading

(a) is parallel to the minor principal axis, but doesn't coincide
(b) is perpendicular to the minor principal axis
(c) is inclined to the minor principal axis
(d) coincides with the minor principal axis

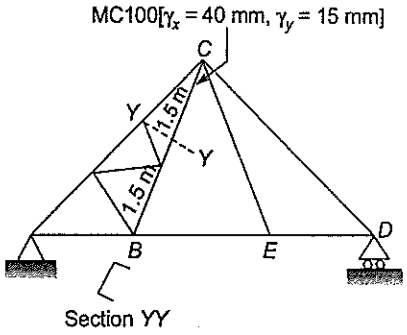
[ESE : 2008]

5.57 For a welded plate girder with vertical stiffeners, what is the maximum depth of web provisionable in design when the thickness of the web plate is 5 mm?

(a) 425 mm (b) 1000 mm
(c) 1250 mm (d) 2000 mm

[ESE : 2009]

5.58 What is the slenderness ratio to be considered in design for member BC in the structure shown below?



(a) 75 (b) 150
(c) 100 (d) 200

[ESE : 2009]

5.59 A symmetric plate girder is of I-section of depth D. The flange plates are of area A_f each and the web plate is of area A_w. What is the plastic section modulus of the above section provisionable for design?

(a) $\left(A_f + \frac{A_w}{4}\right)D$ (b) $\left(A_f + \frac{A_w}{6}\right)D$

(c) $\left(A_f + \frac{A_w}{8}\right)D$ (d) $\left(A_f + \frac{A_w}{12}\right)D$

[ESE : 2009]

5.60 The base plate of a roof truss is attached to the concrete pier with the help of 16 mm diameter mild steel anchor bolts of grade $f_y = 250$ MPa. What is the maximum pull the base can be subjected to, if the root area of bolt = 0.75 times shank area?

(a) 30 kN (b) 67.5 kN
(c) 90 kN (d) 120 kN

[ESE : 2010]

5.61 A building with a gabled roof will experience pressure on its leeward slope which is

(a) always positive
(b) always negative
(c) sometimes positive and otherwise negative
(d) zero

[ESE : 2010]

5.62 At a section along the span of a welded plate girder, in which the web is spliced, the bending moment at a section is M. The girder is comprised of top flange; web and bottom flange plates all of equal areas. The share of the bending moment taken by splice plates would be

(a) M (b) $\frac{M}{3}$

(c) $\frac{M}{7}$ (d) $\frac{M}{13}$

[ESE : 2010]

5.63 The live load for a sloping roof with slope 15°, where access is not provided to the roof, is taken as

(a) 0.65 kN/m^2 (b) 0.75 kN/m^2

(c) 1.35 kN/m^2 (d) 1.50 kN/m^2

[ESE : 2010]

5.64 A protective or decorative non-structural element placed at the level of the truss supports and column head is called.

(a) Eaves girder (b) Baluster

(c) Eaves board (d) Tie girder

[ESE : 2011]

5.65 The purlins in roof trusses are placed at the panel points essentially to avoid

(a) Axial force in rafter

(b) Shear force in rafter

(c) Deflection in rafter

(d) Bending moment in rafter

[ESE : 2011]

5.66 In a roof truss, if pitch is 1/2 and slope is 1, the angle of inclination with the horizontal would be

(a) 30° (b) 45°

(c) 60° (d) 75°

[ESE : 2011]

5.67 The thickness of web for unstiffened plate girder with clear distance 'd' between the flanges shall be not less than

(a) $\frac{d}{200}$ (b) $\frac{d}{85}$

(c) $\frac{d}{100}$ (d) $\frac{d}{160}$

[ESE : 2011]

5.68 Assertion (A): In a plate girder of uniform cross-section, intermediate vertical stiffeners are provided at closer spacing in the middle rather than at supports.

Reason (R): Intermediate vertical stiffeners are provided to prevent the web from buckling under a complex and variable stress situation resulting from combined action of shear force and bending moment.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 2011]

5.69 Consider the following provisions to possibly improve the shear capacity of a steel girder:

1. Horizontal stiffeners
2. Vertical stiffeners
3. Column splice
4. Bearing stiffeners

Which of these are correct?

(a) 1, 2, 3 and 4 (b) 3 and 4 only

(c) 1 and 2 only (d) 2 and 3 only

[ESE : 2012]

5.70 For heavy vibrating loads in industrial buildings, the roof trusses are provided with

(a) diagonal bracing in the plane of lower chord members

(b) diagonal bracing in the plane of upper chord members

(c) knee bracing

(d) sway bracing

[ESE : 2012]

5.71 Which of the following elements of a pitched roof industrial steel building primarily resists lateral load parallel to the ridge?

(a) Bracing (b) Purlin

(c) Truss (d) Column

[ESE : 2012]

5.72 Purlins are to be chosen for a roof truss of 20 m span, 4 m rise. Trusses are spaced at 4.5 m centre-to-centre. A most efficient design results from the use of

(a) angle sections

(b) channel section

(c) circular hollow sections

(d) square hollow sections

[ESE : 2012]

5.73 In a steel plate girder, the web plate is connected to the flange plates by fillet welding. The size of fillet welds is designed to safely resist.

(a) the bending stresses in the flanges
(b) the vertical shear force at the section
(c) the horizontal shear forces between the flanges and the web plate
(d) the forces causing buckling in the web.

[ESE : 2012]

5.74 A crane with two wheels per side has a capacity of 50 kN. Weight of the crane is 100 kN, weight of the trolley is 10 kN and the span is 12 m. The maximum static wheel load with hook clearance of 1.0 m from the wheel is

(a) 50 kN (b) 52.5 kN
(c) 55 kN (d) 60 kN

[ESE : 2013]

5.75 Gantry girders are designed to resist:

1. Lateral loads
2. Longitudinal loads
3. Vertical loads

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2013]

5.76 At a certain location of a plate girder of web size 1000 mm × 10 mm, a pair of bearing stiffeners 100 mm × 5 mm is welded. The effective area of bearing stiffeners is

(a) 1000 mm^2 (b) 2000 mm^2
(c) 3000 mm^2 (d) 5000 mm^2

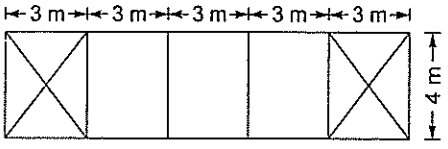
[ESE : 2013]

5.77 A monorail crane runs on an I-section of span 6 m, which is simply supported. Estimate the deflection for crane capacity of 20 kN, crab weight of 4 kN, impact factor of 25% and $EI = 10 \times 10^{12}$ Nmm^2. Deflection due to self-weight is neglected

(a) 6 mm (b) 9 mm
(c) 12 mm (d) 18 mm

[ESE : 2013]

5.78 An industrial building with 5 bays each 3 m wide has columns of height 4 m. The two end bays are braced by rods as shown in the below figure. Each column carries an axial load of 120 kN. The design force for each brace is



(a) 6 kN (b) 9 kN
(c) 15 kN (d) 30 kN

[ESE : 2013]

5.79 Bearing stiffeners in plate girders are provided to

(a) decrease the effective depth of web
(b) transfer the load from the top flange to the bottom flange
(c) prevent buckling of web
(d) increase the bearing capacity of the flange

[ESE : 2013]

5.80 In a plate girder, the web is primarily designed to resist

(a) torsional moment (b) shear force
(c) bending moment (d) diagonal buckling

[ESE : 2014]

5.81 A welded plate girder, consisting of two flange plates of 350 mm × 16 mm each and a web plate of 1000 mm × 6 mm, requires

(a) no stiffeners
(b) horizontal stiffeners
(c) intermediate vertical stiffeners
(d) vertical and horizontal stiffeners

[ESE : 2014]

5.82 Horizontal stiffener in a plate girder is provided to safeguard against web buckling due to

(a) shear
(b) compressive force in bending
(c) tensile force in bending
(d) heavy concentrated load

[ESE : 2014]

5.83 In an industrial steel building, which of the following elements of a pitched roof primarily resist loads parallel to the ridge?

(a) Bracings (b) Purlins
(c) Columns (d) Trusses

[ESE : 2014]

5.84 In which of the following cases is the compression flange most susceptible to buckle laterally?

(a) An I-section supporting a roof slab with shear connection
(b) Purlin of a roof supporting dead and live loads
(c) Encased beam
(d) A steel I-section supporting a point load when acting as a cantilever

[ESE : 2014]

5.85 The serviceability criterion for a plate girder design is based upon
(a) width of flange
(b) depth of web
(c) minimum thickness of web
(d) stiffness of web
[ESE : 2014]

5.86 Consider the following statements:
1. The thickness of the gusset plate should not be more than the thickness of the structural members being connected.
2. A plate girder is essentially a beam and its moment of resistance depends upon its section modulus.
3. The function of the flanges in a plate girder is to resist the bending moment and hence their respective areas can be reduced near the supports of a simply supported beam.

Which of the above statements are correct?
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3
[ESE : 2015]

5.87 Consider the following statements:

In a plate girder
1. Bearing stiffness are designed for bearing forces and they must also be checked for safety against compressive forces.
2. The length of any staggered intermittent fillet weld should not be less than 10 times the thickness of the stiffener.
3. Bearing stiffeners must be provided at the point of maximum bending moment.

Which of the above statements are correct?
(a) 1 and 3 only (b) 2 and 3 only
(c) 1 and 2 only (d) 1, 2 and 3
[ESE : 2015]

5.88 Consider the following statements:

Secondary stresses are induced in a roof truss due to
1. Purlins placed at intermediate points on panel lengths.
2. Rigidity of joints.
3. Eccentricity of the bolt line relative to the centroid of the member.

Which of the above statements are correct?
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3
[ESE : 2015]

5.89 Which of the following statements are correct in case of vertical intermediate stiffeners?
1. These are required only when the ratio of web depth to thickness is greater than 150.
2. They should be provided throughout the length of beam at spacing less than 1.5 times web depth.
3. These can be fitted between flanges with clear gaps at top and bottom.

(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3
[ESE : 2015]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

5.90 **Assertion (A):** In pin-jointed roof trusses, purlins are kept above nodes in the top chord.
Reason (R): The top chord is continuous through the nodes of the truss.
[ESE : 2015]

5.91 **Assertion (A):** At positions of curtailment of flange plates in a built-up structure, web stiffeners are also necessarily to be provided.
Reason (R): This improves the architectural beauty of the structure.
[ESE : 2015]

5.92 The portal bracing in a truss-bridge is used to
(a) Transfer load from top of end posts to bearings
(b) Maintain the rectangular shape of the bridge cross-section

(c) Stiffen the structure laterally
(d) Prevent the buckling of top chord under side sway

[ESE : 2016]

5.93 Gantry girders can be designed
1. As laterally supported beams.
2. As laterally unsupported beam.
3. By using channel sections.

Select the correct answer using the codes given below:
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

[ESE : 2017]

5.94 In a plate girder, the web plate is connected to the flange plates by fillet welding. The size of the fillet welds is designed to safely resist
(a) The bending stresses in the flange
(b) The vertical shear force at the section
(c) The horizontal shear force between the flanges and the web plate
(d) The forces causing buckling in the web

[ESE : 2017]

5.95 According to IS:875 Part 3, the design wind speed acting on industrial roof is estimated based on the basic wind speed by multiplying it by factors k_1, k_2 and k_3, k_1 is called
(a) Terrain height factor
(b) Structure size factor
(c) Topography factor
(d) Risk coefficient

[ESE : 2017]

5.96 Consider the following two statements regarding Bearing stiffeners provided at the location of a concentrated load:
1. Bearing stiffeners have to resist bearing and buckling loads.
2. Bearing area and the area resisting buckling load are the same.

Which of the above statements is/are correct?
(a) 2 only (b) 1 only
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2017]

■■■■

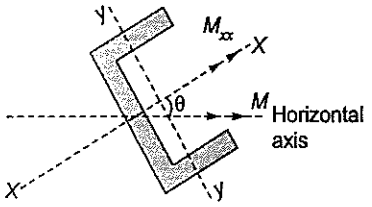
Answers Plate Girders and Industrial Roofs

5.1 (a)	5.2 (c)	5.3 (a)	5.4 (c)	5.5 (b)	5.6 (a)	5.7 (a)	5.8 (c)	5.9 (b)	
5.10 (b)	5.11 (b)	5.12 (b)	5.13 (a)	5.14 (c)	5.15 (c)	5.16 (b)	5.17 (d)	5.18 (a)	
5.19 (b)	5.20 (c)	5.21 (d)	5.22 (b)	5.23 (a)	5.24 (d)	5.25 (a)	5.26 (d)	5.27 (c)	
5.28 (d)	5.29 (c)	5.30 (a)	5.31 (b)	5.32 (c)	5.33 (b)	5.34 (a)	5.35 (d)	5.36 (b)	
5.37 (c)	5.38 (a)	5.39 (c)	5.40 (c)	5.41 (c)	5.42 (d)	5.43 (b)	5.44 (d)	5.45 (b)	
5.46 (a)	5.47 (d)	5.48 (a)	5.49 (c)	5.50 (b)	5.51 (b)	5.52 (a)	5.53 (b)	5.54 (d)	
5.55 (a)	5.56 (c)	5.57 (b)	5.58 (d)	5.59 (a)	5.60 (a)	5.61 (b)	5.62 (c)	5.63 (a)	
5.64 (c)	5.65 (d)	5.66 (b)	5.67 (b)	5.68 (d)	5.69 (c)	5.70 (a)	5.71 (b)	5.72 (b)	
5.73 (c)	5.74 (b)	5.75 (d)	5.76 (d)	5.77 (c)	5.78 (a)	5.79 (c)	5.80 (b)	5.81 (c)	
5.82 (b)	5.83 (a)	5.84 (d)	5.85 (d)	5.86 (c)	5.87 (c)	5.88 (d)	5.89 (b)	5.90 (b)	
5.91 (c)	5.92 (a)	5.93 (a)	5.94 (c)	5.95 (d)	5.96 (b)				

Explanations Plate Girders and Industrial Roofs

5.1 (a)

For vertical loading, the moment about horizontal axis is M. The angle between horizontal axis and $X-X$ axis is $\theta = 30°$.



$$\therefore \quad M_{xx} = M\cos\theta = \frac{\sqrt{3}}{2}M$$

$$M_{yy} = M\sin\theta = \frac{M}{2}$$

5.2 (c)

The location of shear centre for the Z-purlin coincide with the centroid. Therefore both the orientations are structurally equally efficient.

5.3 (a)

Web is relatively large in depth and thin. It is poor in compression and hence, the possibility of vertical and diagonal buckling is always there. Either the web is stiffened vertically as well as horizontally or the compressive stress in the web should be low enough to prevent buckling.

5.4 (c)

Flat grid roofs are used for small spans, Trusses and purlins are used for medium spans (20 m to 100 m), span length in shells is usually larger than in trusses and purlins and suspension system are used for very long spans (above 1000 m generally).

5.5 (b)

As per IS:800-1984 Clause 6.7.3.1 (a), the thickness of the web plate for unstiffened web is the greater of $\frac{d\sqrt{\tau_{va,\,cal}}}{816}$ and $\frac{d\sqrt{f_y}}{1344}$ but not less than $\frac{d}{85}$ where $\tau_{va,cal}$ is calculated average stress in the web due to shear force.

5.6 (a)

Under normal circumstances, the crane girder is designed as laterally unsupported beam carrying vertical and horizontal load at the level of the top flange. The channel at top flange

(i) increases moment of inertia about vertical axis.

(ii) improves lateral buckling strength.

The channel used below the compression flange of the wide flange beam and is supported by brackets, increases the torsional stiffness of girder.

5.7 (a)

The portal bracing is provided in a through bridge in the plane of the end posts. It is more flexible form of bracing compared to a cross frame, as it causes bending moment in the end posts. Such bracings should be used only in through bridges where cross-frame can not be used.

5.8 (c)

$$M \propto I$$

$$I_w = \frac{tB^3}{12}$$

$$I = \frac{tB^3}{12} + 2\times\left[\frac{Bt^3}{12} + \frac{Bt\times B}{2}\right]$$

$$\frac{M_w}{M} = \frac{I_w}{I}$$

$$M_w = \frac{M}{7}$$

5.9 (b)

An angle iron purlin is unsymmetrical about both the axes. IS:800-1984 permits the use of the angle section as a purlin, provided the slope of the roof truss is less than 30°. The vertical loads and wind loads are assumed to be normal to the roof truss. The bending moment about minor axis is neglected. The bending moment in a purlin may be taken as WL/10 where W is the total distributed load on the purlin including wind load. Under the calculated bending moment, the allowable bending stress is taken without lateral instability effect into account. Also, since the roof sheeting provides support against lateral buckling the allowable

bending stress is not reduced on this account. For designing purlins, limiting deflection condition for beams is not applied.

5.10 (b)

Wind on moving load (vehicle) is assumed to be acting at 1.5 m above deck and it is 300 kg/m for ordinary high bridges.

5.11 (b)

Design pressure = $(C_{pe} - C_{pi})p$

Where $C_{pe}, C_{pi} \rightarrow$ external and internal pressure coefficients respectively.

Highly permeable buildings have more than 20% openings and $C_{pi} = \pm 0.7$

The external wind pressure coefficient depends upon

(i) height to width ratio of the building
(ii) length to width ratio of the building
(iii) angle of incidence
(iv) location of wall with respect to wind, such as windward side or leeward side.

In the absence of any such information (b) is the best option.

5.12 (b)

For broad and metre gauge with single track impact factor $= 0.15 + \frac{8}{6+L}$ subjected to maximum of 1.

For, $L = 6$ m

$$\text{Impact factor} = 0.15 + \frac{8}{12}$$
$$= 0.15 + 0.67 = 0.82$$

However, there is no such option, therefore the closest answer 0.75 can be chosen.

5.13 (a)

The longitudinal wind force i.e. wind force along the ridge line is resisted by the lateral bracing. Thus lateral bracing of adjacent trusses is necessary in industrial buildings.

5.14 (c)

In the flange area method, the bending stress distribution in the tension and compression flange is assumed to be uniform.

$$M = Td_1 = A_f \sigma_{bt} d_1$$

$$\therefore \quad A_f' = \frac{M}{\sigma_{bt} d_1}$$

where $M \rightarrow$ bending moment

$A_f' \rightarrow$ net flange area

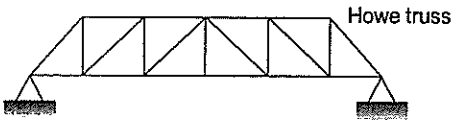
$\sigma_{bt} \rightarrow$ bending tensile stress

$d_1 \rightarrow$ effective depth of plate girder

5.15 (c)

Besides self weight; wind load, live load, impact load, snow load etc. are also considered in the design.

5.16 (b)



In the Howe roof truss, the diagonal members are in compression, while vertical members are in tension.

5.17 (d)

Truss girder bridges are of three types:

(i) deck type
(ii) through type
(iii) semi-through type

The wind load that acts on a bridge has to be transferred to the bearings by the truss members and the lateral bracings. A part of the wind load can be assumed to be acting at the panel points of the top lateral truss and the remaining on the bottom lateral truss.

A through truss bridge is supported at the level of the lower chord and the wind acts on the whole truss and the moving load. Thus the wind has a tendency to overturn the bridge about the lower chord of the leeward truss. The overturning effect will increase the load on the leeward truss.

5.18 (a)

Economic spacing of the truss is the spacing that makes the overall cost of trusses, purlins, roof coverings, columns etc. minimum. It depends upon the relative cost of trusses, purlins, roof coverings, spacing of columns, etc. For economic spacing the cost of trusses,

$t = 2p + r$

$p \rightarrow$ cost of purlins

$r \rightarrow$ cost of roof coverings

5.19 (b)

Bearing stiffeners are provided under the concentrated loads and end reactions. It serves two purposes.

(i) It prevents the web from crushing and sideways (lateral) buckling under the web.

(ii) It relieves the rivets connecting the flange angles and web from vertical force.

5.21 (d)

The rivets will be under double shear.

ISF 400 has thickness = 12 mm

Type of rivet	Permissible shear stress	Permissible bearing on rivet
(i) Power-driven rivet		
in shop	100	300
in field	90	270
(ii) Hand driven rivets	80	250

Resistance in double shear (kN)		Resistanc in bearing (kN)	Rivet value	No. of rivets 800/rivets value
(i) Power-driven				
in shop	106	93.6	106	8
in field	95.6	84.2	95.6	9
(ii) Hand driven	84.9	78.0	84.9	10

However, truss girder of a bridge is riveted by power driven rivets in field. Therefore number of rivets needed will be 9.

5.22 (b)

Loads for Gantry girder:

(i) vertical loads (gravity loads)

(ii) lateral loads

(iii) longitudinal loads

5.23 (a)

When the thickness of web is less than D'/200 vertical stiffeners should be provided.

5.24 (d)

As per IS 800-1984 Clause 3.9.2.2,in design of steel bridges the allowable stresses in steel member may be increased by $33\frac{1}{3}\%$ in case of wind or seismic force.

5.25 (a)

Impact factor for a gantry girder for various types of loads is

(A) Vertical forces transferred to the rails

(i) for electric overhead cranes additional load 25% of maximum static wheel load

(ii) for hand operated crane additional load 10% of maximum static wheel load

(B) Horizontal force transverse to rails

(i) for electric overhead train additional load 10% of weight of crab and the weight lifted on the crane.

(ii) for hand operated cranes additional load 5% of weight of crab and the weight lifted on the crane.

(C) Horizontal forces along the additional load 5% of the static wheel load rails.

5.26 (d)

Dead load and live load act downward.

5.27 (c)

When the compression flange is laterally supported by either a catwall or by additional member, then the allowable stress in bending compression is equal to that in tension.

5.28 (d)

The section modulus required,

$$Z = \frac{M}{\sigma} = \frac{4500\times10^6}{150}$$

$$= 30 \times 10^6 \text{ mm}^3$$

Net moment of inertia = $Z \times 500$

$$= 15000 \times 10^6 \text{ mm}^4$$

$$= 15 \times 10^9 \text{ mm}^4$$

Moment of inertia of web

$$= \frac{12\times1000^3}{12} = 10^9 \text{mm}^4$$

Moment of inertia of flange

$$= 15 \times 10^9 - 10^9$$

$$= 14 \times 10^9 \text{ mm}^4$$

$\therefore \quad A_f d^2 = 14 \times 10^9$ (Approximately)

$d = 500$ mm

$\therefore$ Net area of flange = 56,000 mm^2

Gross area of flange

$$= \frac{56000}{0.8} = 70{,}000 \text{mm}^2$$

5.29 (c)

The net area of the web will be 75% of the gross area. Thus, effective web area becomes

$$= \frac{A_w}{6} \times 0.75 = \frac{A_w}{8}.$$

Net area of the flange plate in tension = $A_f + \frac{A_w}{8}$.

5.30 (a)

Welded plate girders weight 5 – 15% less than riveted plate girders and are therefore economical.

In riveted plate girders, flange angles are a must whereas in welded plate girders only flange plate are provided. Therefore the effective depth for welded plate girder is increased. Due to increased effective depth, the moment of resistance of the section increases. In welded girders thick plates are provided which increase the lateral buckling strength of the compression flange.

5.31 (b)

Horizontal stiffener is provided when the vertical stiffeners become too close and only thin plates are available for web. It is provided when the depth of web is more and there is a tendency of web buckling.

5.32 (c)

According to IS 875, the pressure coefficient is minimum when the roof slope is equal to 30°.

5.33 (b)

The effective flange area for plate girder= $A_f + A_W/6$

The effective area for tension flange = $A_f + A_W/8$

In tension flange area is reduced to account for rivet holes.

5.34 (a)

The channel provided on the top flange increases the lateral resistance against the horizontal surge. Therefore it accounts for bending in horizontal plane.

5.36 (b)

For vertical stiffened web of plate girder, the lesser clear dimension of panel should not exceed 180 t. And the greater unsupported clear dimension of web panel should not exceed 270 t.

5.37 (c)

Purlins are assumed to be continuous beams.

5.38 (a)

The sag rods are round section rods and fastened to the web of the purlins. The roof coverings are not rigid and do not provide proper support. The sag rods provided between adjacent purlins to extend lateral support to the purlins in their weaker directions. The sag rods are in parallel plane of the sheeting. Purlins at the ridge are subjected to equal and opposite forces.

5.39 (c)

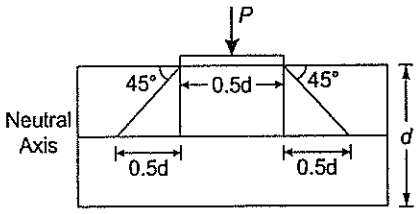
Bearing stiffeners are provided under concentrated loads and at the point of support to avoid bending failure of the flange, local crippling and crushing of the web.

5.40 (c)

As per IS: 800-1984 Clause **6.7.4.4** unless the outer edge of each stiffener is continuously stiffened, the outstand of all stiffeners from the web shall not exceed $\frac{256t}{\sqrt{f_y}}$ for sections and $12t$ for flats where 't' is the thickness of the section or flat.

5.41 (c)

The dispersion of load should be done at 45° upto the neutral axis.



The area at neutral axis = 1.5dt.

Critical buckling load, P = 1.5dtf

5.42 (d)

Web thickness (t_w) = 6 mm, d = 1500 mm

(i) No stiffener needed when $t_w \le d/85$

(ii) Transverse stiffener when $t_w \le d/200$

(iii) Transverse stiffener and one longitudinal stiffener at $d/5$ from compression flange $t_w \le d/250$

(iv) Transverse stiffener, one longitudinal stiffener at $d/5$ from compression flange and another at neutral axis when $t_w \le d/400$

$$\frac{t_w}{d} = \frac{6}{1500} = \frac{1}{250}$$

Therefore condition (iv) is applicable.

5.43 (b)

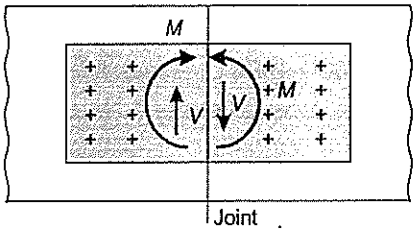
Channel at the top flange will increase the lateral resistance against the horizontal surge.

5.44 (d)

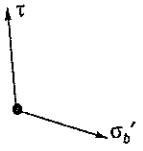
The bracings are so planned and provided that lateral forces due to wind, earthquake and crane surge are effectively transmitted to the foundation.

5.45 (b)

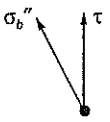
Let the distance of centroid of bolts on either side from the joining line be 'd'. The stress due to shear force, $\tau = \frac{V}{8}$



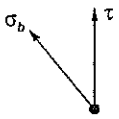
Moment on the left side = $M - Vd$
Moment on the right side = $M + Vd$
Bolt 1 has the forces



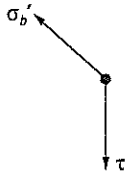
Bolt 2 is subjected to



Bolt 3 is subjected to



For bolt 4 the forces are



Here $\sigma_b' < \sigma_b < \sigma_b''$. Taking all these combination the stress in bolt 2 is maximum.

5.46 (a)

Intermediate stiffeners are also called stability stiffeners and are provided to check the diagonal buckling of the web. Such stiffeners increase the buckling resistance of the web caused by shear.

5.47 (d)

The portal bracing is designed for:

- Longitudinal shear due to forces like earthquake, wind, crane surge
- 2.5% of the compression force in two end points- to take care of eccentricity of moments and axial loads.

5.48 (a)

Effective flange area is given as,

$$A_{eff} = \frac{A_w}{6}$$

where A_F is flange area and A_w is web area.
Now for original girder, since the plates are equal,

$$A_F = A + \frac{A}{6} = \frac{7}{6}A$$

For punctured girder

$$A_F = A$$

$$A_w = \frac{A}{2}$$

So, $$A_2 = A + \frac{A}{12} = \frac{13}{12}A$$

Since strength is directly proportional so effective flange area, the ratio of strength of punctured girder to original girder,

$$\frac{\sigma_2}{\sigma_1} = \frac{A_2}{A_1} = \frac{13 \times 6}{12 \times 7} = 0.9286$$

or, $$\frac{\sigma_2}{\sigma_1} = 92.86\%$$

5.49 (c)

In intermediate stiffeners, the maximum spacing is restricted to 180t (t is the thickness of web). These are provided to avoid web buckling.

5.50 (b)

As per IS 800-1984, if the thickness of web is $< d/200$ horizontal stiffeners are needed in plate girders. Horizontal stiffener is provided at $0.4d$ from top of flange if $(d/250) < t < (d/200)$.

5.52 (c)

For the given tube,

$$I = \frac{\pi}{64}\left(d_o^4 - d_i^4\right)$$

Here, $d_o = 100$ mm, $d_i = 97$ mm

$\Rightarrow \quad I = 5.631 \times 10^5 \text{ mm}^4$

Area of section,

$$A = \frac{\pi}{4}\left(d_o^2 - d_i^2\right)$$

$$\Rightarrow \quad A = \frac{\pi}{4}\left(100^2 - 97^2\right) = 464.17 \text{ mm}$$

Radius of gyration,

$$r = \sqrt{\frac{I}{A}} = 34.83$$

So, maximum slenderness ratio for given conditions,

$$\lambda = \frac{l}{r} = 180$$

$\Rightarrow \quad l_{max} = 180 \times 34.83 = 6.270$ mm

(a) is closest answer.

5.53 (b)

Gantry girders are designed for extra load to cater for impact

- For manually operated cranes- 10% of max. Static wheel load
- For electric cranes- 25% of max. Static wheel load

5.54 (d)

As per clause 6.7.4.6 of IS: 800-1984, intermediate horizontal stiffeners not subjected to external loads shall be connected to web by rivets or welds, so as to withstand a shearing force, between each component of the stiffener and the web of not less than $\frac{125t^2}{h}$ kN/m.

5.55 (a)

As the connection is pin jointed,

Effective length = L

5.56 (c)

The plane of loading is inclined to minor principal axis in the purlins in roof trusses. Thus it is subjected to unsymmetrical bending.

5.57 (b)

Vertical stiffness are required in a welded plate girdes when

$$\frac{d}{t_w} > 85 \text{ and } \frac{d}{t_w} \le 200$$

$\therefore \quad d_{min} > 85 \times 5 = 425$ mm

$d_{max} \ge 200 \times 5 = 1000$ mm

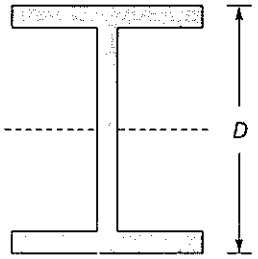
5.58 (d)

$$\lambda = \frac{l}{r_{min}}$$

$$= \frac{3000}{15} = 200$$

5.59 (a)

Symmetric plate girder (I-Section)



Plastic section modulus

$$Z_p = A_1y_1 + A_2y_2$$

$$= 2\left(A_f \frac{D}{2} + \frac{A_w}{2} \times \frac{D}{4}\right)$$

$$= \left(A_f + \frac{A_w}{4}\right)D$$

5.60 (a)

Permissible tensile stress in mild steel anchor bolts is given by

$$\sigma_{tf} = 0.4\, f_y = 0.4 \times 250 = 100 \text{ MPa}$$

Area of bolt at the root of the thread is given by

$$A_s = 0.75 \times \frac{\pi}{4} \times (16)^2 = 150.8 \text{ mm}^2$$

Assuming 2 bolts on the tension side, the maximum pull on the base will be

$$P = 2 \times \sigma_{tf} \times A_s$$

$$= 2 \times 100 \times 150.8 \times 10^{-3}$$

$$= 30 \text{ kN}$$

5.61 (b)

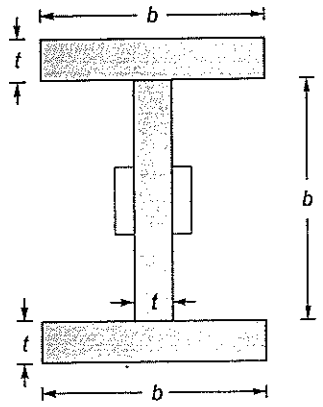
The leeward slope of a building with a gabbled roof always experiences negative pressure coefficients as it experiences suction.

5.62 (c)

The share of bending moment taken by splice plates will be the bending moment resisted by web.

The bending moment taken by web is given by

$$M_w = M \times \frac{I_w}{I}$$



Moment of inertia of web is given by

$$I_w = \frac{tb^3}{12}$$

Moment of inertia of whole section is given by

$$I = \frac{tb^3}{12} + 2 \times bt \times \left(\frac{b}{2}\right)^2$$

Neglecting the moment of inertia of flanges about their own axes.

$$\Rightarrow \quad I = \frac{7tb^3}{12}$$

$$\therefore \quad M_w = M \times \frac{tb^3/12}{7tb^3/12}$$

$$\Rightarrow \quad M_w = \frac{M}{7}$$

5.63 (a)

As per IS : 875 (P_{ac} + 2) 2008, table-2 correct option will be (a)

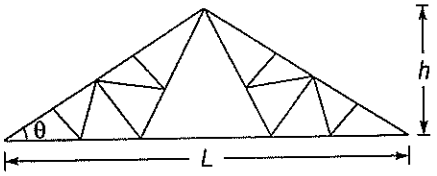
5.64 (c)

Eaves board is a thick, feather board nailed across rafters at the eaves of a building to slightly raise the first course of slates or tiles. It is a protective or decorative non-structural element.

5.65 (d)

It is desirable to place purlins only at the panel points as otherwise the principal rafter of the roof truss will be subjected to bending. When purlins are provided at intermediate points the principal rafter is designed for flexure and axial stresses.

5.66 (b)



Pitch = h/L

Slope = $\tan\theta = h/(L/2)$

= 2Pitch

$$\text{Slope} = \tan\theta = 2 \text{ pitch} = 2 \times \frac{1}{2} = 1$$

$$\Rightarrow \theta = 45°$$

5.67 (b)

IS:800-1984 recommends the provision of web stiffeners as follows.

(i) $\frac{d_1}{t_w} \leq 85$ No stiffener is required.

(ii) $\frac{d_2}{t_w} \leq 200$ Vertical stiffeners are provided.

(iii) $\frac{d_2}{t_w} \leq 250$ Vertical stiffeners and one horizontal stiffener at a distance from the compression flange equal to two-fifths of the distance from the compression flange to the neutral axis are provided.

(iv) $\frac{d_2}{t_w} \leq 400$ The requirement is the same as in (iii) plus a horizontal stiffener at the neutral axis.

where d_2 = 2 × clear distance from compression flange angles or plate or tongue plate to the neutral axis.

5.68 (d)

In a plate girder of uniform cross-section where vertical stiffeners are required, they shall be provided through the length of girder and should be spaced regularly. Because of the truss like behaviour, the capacity of plate girder is increased.

Statement II is true.

5.69 (c)

Bearing stiffeners are used to prevent local buckling and column splice has no role to play in shear capacity of steel girder. Vertical and horizontal stiffeners improve shear capacity of steel girder.

5.70 (a)

Diagonal cross bracing is used in the plane of lower chord member only when heavy vibrating loads are anticipated

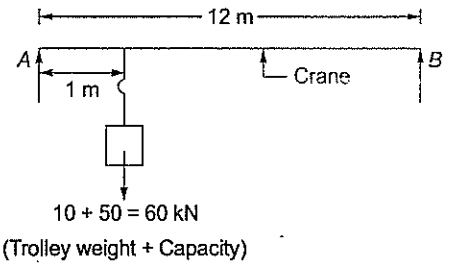
Knee bracing is provided to reduce end moments of the columns.

Sway bracing are provided to resist sway action.

5.72 (b)

Channel section is preferable for easy fastening advantage (over hollow section) and for more strength (over angle section).

5.74 (b)



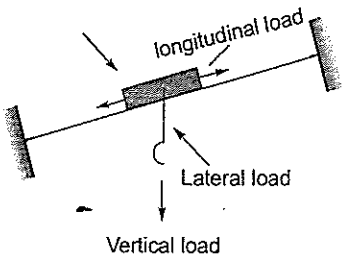
Reaction of two wheels at $A = 60 \times \frac{11}{12} = 55$ KN

Reaction per wheel = 55/2 = 27.5 KN

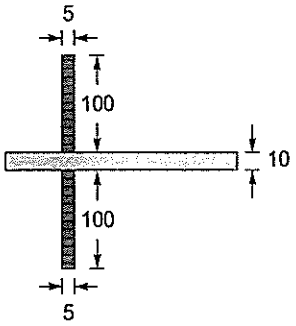
Reaction per wheel due to weight of crane = 100/4= 25 KN

Total reaction on wheel = 25 + 27.5 = 52.5 KN

5.75 (d)



5.76 (d)



Bearing area

$= (100 \times 5) + (100 \times 5) + 40 \times 10 \times 10$

$= 5000\ mm^2$

5.77 (c)

$$\delta = \frac{PL^3}{48EI}$$

$$= \frac{(1.25 \times 20) \times (6000)^3 \times 10^3}{48 \times 10 \times 10^{12}}$$

$= 11.25$ mm $= 12$ mm

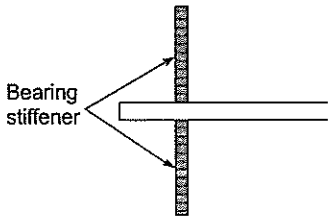
5.78 (a)

Bracings are designed for 2.5% for column load and each bracing is connected to two columns.

$$\therefore \left(\frac{2.5}{100} \times 120\right) \times 2 = 6\text{kN}$$

5.79 (c)

Bearing stiffness provide additional bearing area thereby reducing the possibility of web buckling since web in plate girder behaves like a column.



5.80 (b)

In plate girder

- Web is primarily designed to resist shear force
- Flange is primarily designed to resist bending moment

5.81 (c)

$$\lambda = \frac{1000}{6} = 166.66$$

$85 < \lambda < 200$ hence only intermediate vertical stiffners are required.

5.82 (b)

Horizontal stiffeners are provided in the compression zone of the web as they increase the buckling resistance considerably as compared to the transverse stiffeners when the web is subject to bending.

5.84 (d)

The end of the cantilever is free, hence not laterally restrained.

5.85 (d)

Depth of web fulfils deflection criteria and thickness of web fulfil corrosion so combindely we can say that stiffness is for serviceability.

5.86 (c)

Generally, thickness of the gusset plate is kept more than the thickness of the structural members being connected.

5.87 (c)

Bearing stiffeners are provided to bear the concentrated load acting on the plate girder.

5.88 (d)

The secondary stresses i.e. additional bending and shear stresses in roof truss are induced due to:

(i) Elastic deformation of structure combined with rigidity of joints.

(ii) Eccentricity of bolt line relative to the centroid of the member.

(iii) Any load placed at intermediate points on panel lengths

5.89 (b)

Vertical stiffeners are provided when ration of web depth to thickness in between 85 and 200.

5.90 (b)

Purlins are kept above nodes in the top chord in pin jointed roof trusses, to restraint principal rafter against buckling due to bending moment. The top chord is continuous through the nodes of the truss.

5.94 (c)

The horizontal shear force is generated by principle of complementary shear stress, any vertical shear stress is balanced by horizontal shear stress.

5.95 (d)

As per IS code 875 clause 5.3

k_1 = Probability factor or Risk coefficient

k_2 = Terrain, height structure size

k_3 = Topography factor

5.96 (b)

Bearing stiffness are provided to resist bearing loads and buckling loads. Bearing area is calculated according to dispersion of load.

■■■■

6 Plastic Analysis

6.1 In the plastic analysis which of the following pairs is/are correctly matched?

Geometry of steel section	Shape factor
1. Rectangle	2.0
2. Round	1.7
3. Square	1.0

Select the correct answer using the codes given below:

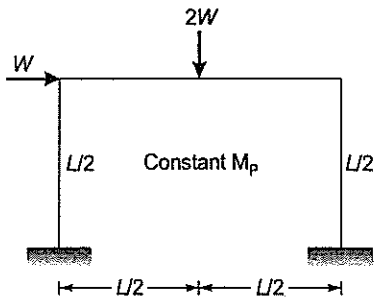
(a) 1 and 2 (b) 2 and 3
(c) 2 alone (d) 1 and 3

[ESE : 1995]

6.2 At the location of plastic hinge
(a) radius of curvature is infinite
(b) curvature is infinite
(c) moment is infinite
(d) flexural stress is infinite

[ESE : 1995]

6.3 Given figure shows a portal frame with loads. All members of frame have same plastic moment of resistance M_P. The collapse load W is



(a) $\frac{2M_P}{L}$ (b) $\frac{4M_P}{L}$
(c) $\frac{6M_P}{L}$ (d) $\frac{8M_P}{L}$

[ESE : 1995]

6.4 A rectangular steel section of width 'b' and depth 'h' has been stressed to yield point (σ_y) upto a depth of $h/4$ from both the top and bottom face under the action of a moment M. The magnitude of the moment M is

(a) $\frac{10}{24}bh^2\sigma_y$ (b) $\frac{1}{4}bh^2\sigma_y$
(c) $\frac{11}{48}bh^2\sigma_y$ (d) $\frac{13}{36}bh^2\sigma_y$

[ESE : 1995]

6.5 A simply supported beam of span L supports a concentrated load W at its midspan. If the cross-section of the beam is an I-section, then the length of elastic-plastic zone of the plastic hinge will be
(a) $L/8$ (b) $L/4$
(c) $L/2$ (d) $3L/4$

[ESE : 1995]

6.6 A continuous beam of constant M_P has three equal spans and carries total uniformly distributed load W on each span. The value of collapse load for the beam will be

(a) $\frac{12M_P}{L}$ (b) $\frac{8.65M_P}{L}$
(c) $\frac{11.656M_P}{L}$ (d) $\frac{4M_P}{L}$

[ESE : 1995]

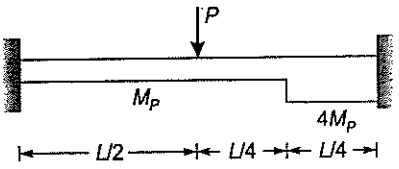
6.7 For an I-beam, shape factor is 1.12. The factor of safety in bending is 1.5. If the allowable stress is increased by 20% for wind and earthquake loads, then the load factor is
(a) 1.10 (b) 1.25
(c) 1.35 (d) 1.40

[ESE : 1995]

6.8 Yield line theory results in
(a) elastic solution
(b) lower bound solution
(c) upper bound solution
(d) unique solution

[ESE : 1995]

6.9 For the beam shown in the given figure, the collapse load P is given by



(a) $\frac{16M_P}{L}$ (b) $\frac{14M_P}{L}$

(c) $\frac{12M_P}{L}$ (d) $\frac{10M_P}{L}$

[ESE : 1996]

6.10 A fixed beam as shown in Figure 1 is loaded with a UDL over the entire span, the total load being W; when load was just increased to W_1, the deformed shape as shown in Figure 2 was seen. The value of W_1 (plastic moment of resistance = M_P) is

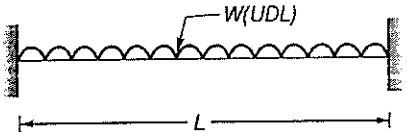


Figure 1

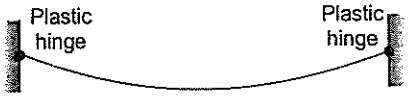


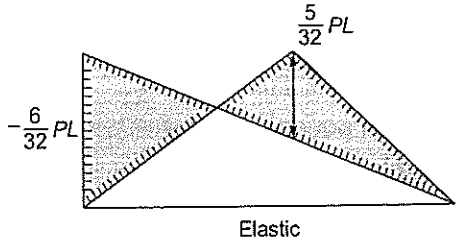
Figure 2

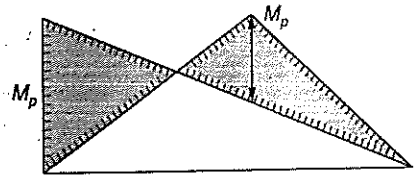
(a) $\frac{24M_P}{L}$ (b) $\frac{16M_P}{L}$

(c) $\frac{12M_P}{L}$ (d) $\frac{8M_P}{L}$

[ESE : 1996]

6.11 For a propped cantilever beam of span L with a central concentrated load P, the elastic and plastic moment diagrams are shown in the given figures:





From these diagrams, it is clear that

(a) maximum moments are distributed more advantageously in the elastic case

(b) maximum moments are distributed more advantageously in the plastic case

(c) bending moment distribution in both the cases is equally advantageous

(d) no definite conclusion can be drawn

[ESE : 1996]

6.12 Consider the following definitions:

1. collapse load/service load
2. (collapse load/service load) – 1
3. ultimate stress/permissible stress
4. (ultimate stress/permissible stress) – 1

Of these definitions, those which relate to 'margin of safety' would include

(a) 1 and 3 (b) 1 alone

(c) 2 and 4 (d) 3 alone

[ESE : 1996]

6.13 **Assertion (A) :** The shape factor of a circular section is less than that of a rectangular section.
Reason (R) : Compared to rectangular section, a circular section has more area near the neutral axis than at the extreme fibre.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 1996]

6.14 A ductile structure is defined as one for which the plastic deformation before fracture

(a) is smaller than the elastic deformation

(b) vanishes

(c) is equal to the elastic deformation

(d) is much larger than the elastic deformation

[ESE : 1996]

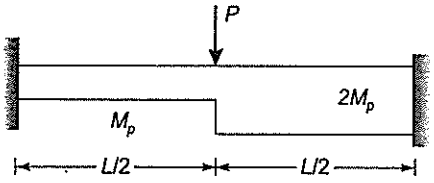
6.15 A simply supported beam of uniform cross-section has span L and is loaded by a point load P at its mid-span. The length of elastoplastic zone of the plastic hinge will be

(a) $\frac{L}{3}$ (b) $\frac{2L}{5}$

(c) $\frac{L}{2}$ (d) $\frac{3L}{4}$

[ESE : 1997]

6.16 A fixed beam made of steel is shown in the figure below. At collapse, the value of load P will be equal to

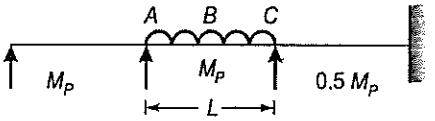


(a) $\frac{10M_P}{L}$ (b) $\frac{12M_P}{L}$

(c) $\frac{16M_P}{L}$ (d) $\frac{20M_P}{L}$

[ESE : 1997]

6.17 A continuous beam with plastic moment capacities is shown in the given figure.



The correct sequence in which the plastic hinges will form in the beam is

(a) C, A, B

(b) A and C simultaneously, followed by B

(c) B, C, A

(d) B first then A and C simultaneously

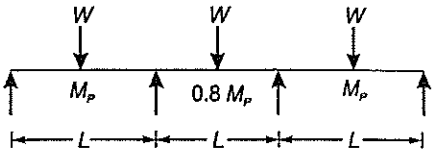
[ESE : 1997]

6.18 A thin hollow box section of 400 mm 600 mm deep (outer dimensions) with uniform plate thickness of 10 mm all-round is used for a beam. The plastic modulus of section (Z_P) and its shape factor will be

Z_P(in 10^5 mm^3)	Shape factor
(a) 36	7/6
(b) 36	6/7
(c) 42	6/7
(d) 42	7/6

[ESE : 1997]

6.19 The figure below shows a continuous beam loaded with concentrated loads W at the centre of each span. The value of W at collapse will be



(a) 3.2 M_P/L (b) 4 M_P/L

(c) 5.6 M_P/L (d) 6.4 M_P/L

[ESE : 1997]

6.20 A steel beam of rectangular cross-section is clamped at both ends. Deformation is just observed when the UDL on the beam is 10 kN/m. At the instant of collapse, the load on the beam will be

(a) 10 kN/m (b) 15 kN/m

(c) 20 kN/m (d) 30 kN/m

[ESE : 1998]

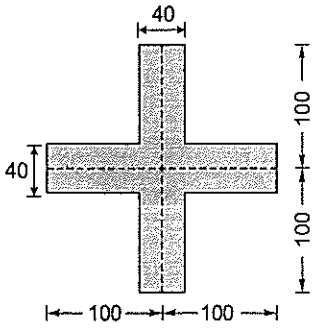
6.21 The ratio of collapse load of a propped cantilever of span L carrying a UDL throughout the span to that of a simply-supported beam carrying the same load is

(a) 1.457 (b) 1.500

(c) 2.000 (d) 3.000

[ESE : 1998]

6.22 The shape factor of the section shown in the figure below is

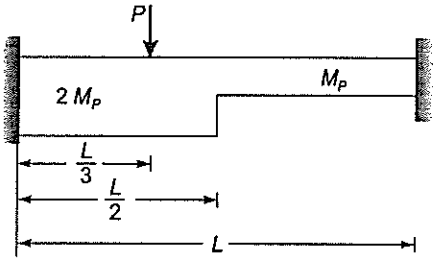


(a) $\frac{139}{82}$ (b) $\frac{145}{86}$

(c) $\frac{150}{91}$ (d) $\frac{160}{97}$

[ESE : 1998]

6.23 A fixed beam is shown in the figure below. The plastic failure load for this beam is



(a) 10 M_P/L (b) 12.5 M_P/L
(c) 15 M_P/L (d) 16.5 M_P/L

[ESE : 1998]

6.24 To transform an indeterminate frame with a degree of indeterminacy 'r' into a determinate one, the number of plastic hinges required is

(a) $r + 2$ (b) $r + 1$
(c) r (d) $r - 1$

[ESE : 1998]

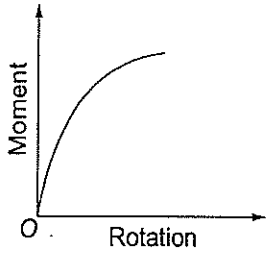
6.25 A propped cantilever of span L is subjected to a concentrated load at mid-span. If M_P is plastic moment capacity of the beam, then the value of the collapse load will be

(a) $\frac{12M_P}{L}$ (b) $\frac{8M_P}{L}$

(c) $\frac{6M_P}{L}$ (d) $\frac{4M_P}{L}$

[ESE : 1999]

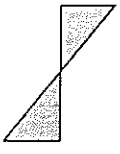
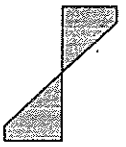
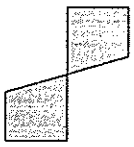
6.26 The moment rotation curve shown in the given figure is that of a



(a) rigid joint (b) flexible joint
(c) pin joint (d) semi-rigid joint

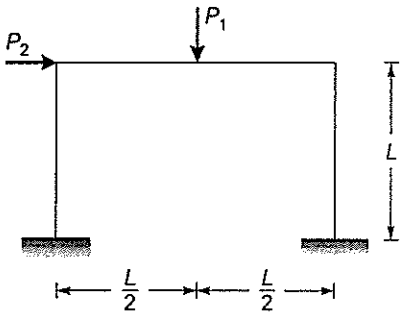
[ESE : 1999]

6.27 In a plastic hinge, the actual distribution of strain across the section will be as in

(a) 
(b)
(c) 
(d) 

[ESE : 1999]

6.28 Given figure shows a portal frame with load. All members have the same plastic moment of resistance M_P. The ratio P_1 to P_2 for beam and sway mechanism is



(a) 1 (b) 2
(c) 3 (d) 4

[ESE : 1999]

6.29 Which one of the following modes of failure is taken care of in plastic design of a steel beam?

(a) Plastic material deformation throughout the beam
(b) Lateral buckling of the beam
(c) Elastic buckling of the compression flange
(d) Hinge formation in the beam due to yielding of steel

[ESE : 1999]

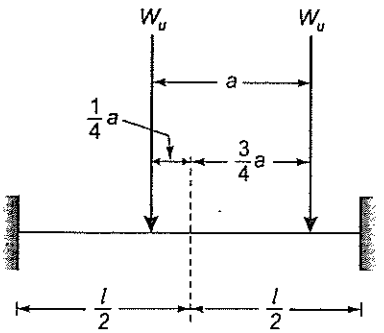
6.30 Which one of the following is the load factor?

(a) $\frac{\text{Live load}}{\text{Dead load}}$ (b) $\frac{\text{Failure load}}{\text{Working load}}$

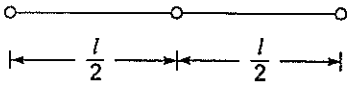
(c) $\frac{\text{Total load}}{\text{Dead load}}$ (d) $\frac{\text{Dynamic load}}{\text{Static load}}$

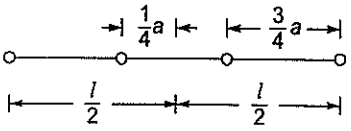
[ESE : 2000]

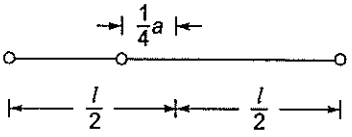
6.31 A beam of constant EI is shown in the given figure:

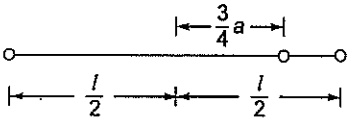


Which one of the following sketches gives a probable failure mechanism of this beam under plastic analysis?

(a)


(b)


(c)


(d)


[ESE : 2000]

6.32 Match List-I (Beam) with List-II (Collapse load) and select the correct answer using the codes given below the lists:

List I

A. Fixed beam with a central point load
B. Fixed beam with a udl of intensity 'w_u'
C. Propped cantilever with a central point load
D. Simply supported beam with a central point load

List-II

1. $\frac{8M_P}{L}$
2. $\frac{16M_P}{L}$
3. $\frac{6M_P}{L}$
4. $\frac{4M_P}{L}$

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	2	1	3	4
(c)	2	1	4	3
(d)	1	2	3	4

[ESE : 2000]

6.33 The failure mechanism for the rigid frame shown in the given figure-I (assume constant EI) is

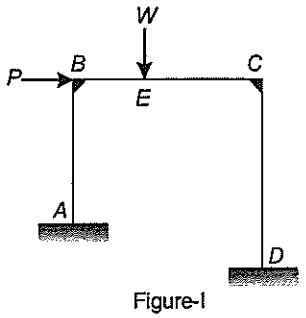
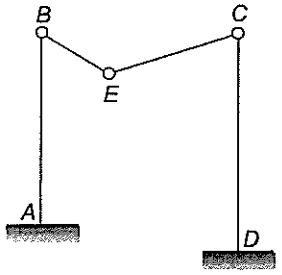
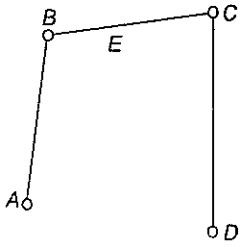
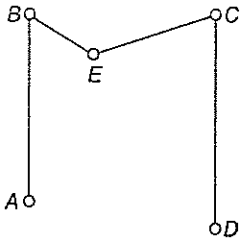


Figure-I

(a)


(b)


(c)


(d) can be (a), (b) or (c) depending upon the relative values of W, P and member dimensions.

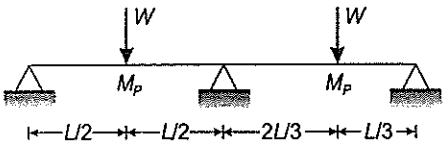
[ESE : 2000]

6.34 The yield line theory is a

(a) lower bound method of design of over-reinforced slabs
(b) lower bound method of design of under-reinforced slabs
(c) upper bound method of analysis of under-reinforced slabs
(d) upper bound method of analysis of over-reinforced slabs

[ESE : 2000]

6.35 A continuous beam with constant EI is shown in the given figure. Collapse load for this beam will be equal to



(a) $\frac{16M_P}{L}$ (b) $\frac{12M_P}{L}$

(c) $\frac{8M_P}{L}$ (d) $\frac{6M_P}{L}$

[ESE : 2001]

6.36 Which of the following statements is/are correct?

1. Plastic hinges are reached first at sections subjected to greatest curvature.
2. Formation of plastic hinges allows a subsequent redistribution of moment until fully plastic moment is reached at each critical section.
3. The maximum load is attained when a mechanism forms.

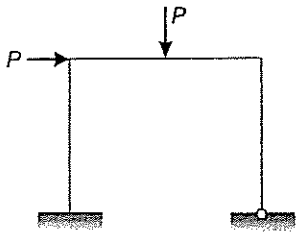
Select the correct answer using the codes given below.

(a) 1, 2 and 3 (b) 1 and 2

(c) 1 and 3 (d) 2 and 3

[ESE : 2001]

6.37 The number of possible independent mechanisms for a portal frame shown in the given figure is



(a) 2 (b) 4

(c) 1 (d) 3

[ESE : 2001]

6.38 The collapse load of a simply supported beam of span L and fully plastic moment M_P subjected to central concentrated load is given by

(a) $\frac{4M_P}{L}$ (b) $\frac{6M_P}{L}$

(c) $\frac{8M_P}{L}$ (d) $\frac{2M_P}{L}$

[ESE : 2001]

6.39 A propped cantilever beam of span L and constant plastic moment capacity M_P carries a concentrated load at mid-span, then the load at collapse will be

(a) $\frac{M_P}{L}$ (b) $\frac{6M_P}{L}$

(c) $\frac{4M_P}{L}$ (d) $\frac{2M_P}{L}$

[ESE : 2001]

6.40 Match List-I (Methods of Analysis) with List-II (Conditions satisfied) and select the correct answer using the codes given below the lists:

List-I

A. Exact plastic analysis
B. Mechanism method of plastic analysis
C. Equilibrium method of plastic analysis

List-II

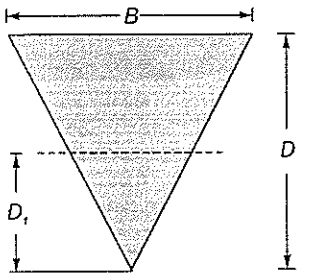
1. Equilibrium, sufficient plastic hinges and Non-violation of plastic moment capacity
2. Equilibrium and Non-violation of plastic moment capacity
3. Equilibrium, continuity and Non-violation of plastic moment capacity
4. Equilibrium and sufficient plastic hinges

Codes:

	A	B	C
(a)	3	1	2
(b)	3	4	2
(c)	1	2	4
(d)	1	4	2

[ESE : 2001]

6.41 Neutral axis distance D_1 at plastic moment condition of a triangular cross-section in given figure having similar properties in tension and compression is

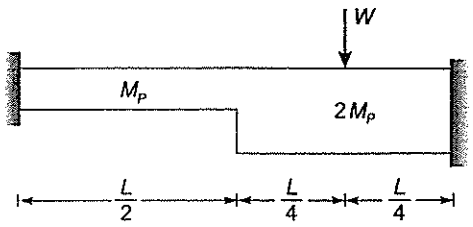


(a) $\frac{2}{3}D$ (b) $\frac{D}{2}$

(c) $\frac{D}{\sqrt{3}}$ (d) $\frac{D}{\sqrt{2}}$

[ESE : 2001]

6.42 Figure given below shows a fixed beam of steel.



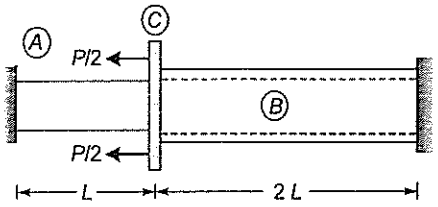
At the point of collapse, the value of load W will be

(a) $\frac{10M_P}{L}$ (b) $\frac{15M_P}{L}$

(c) $\frac{20M_P}{L}$ (d) $\frac{25M_P}{L}$

[ESE : 2002]

6.43 A rigid plate C is fastened to steel rod A of area S and to steel pipe B of area $2S$. The other ends of A and B are fastened to rigid supports. When the force P is zero, there are no stresses in A and B. The yield stresses in tension and compression is σ_y. The collapse load P under yield condition is

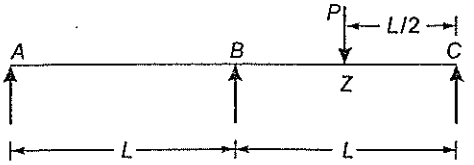


(a) $\sigma_y S$ (b) $2\sigma_y S$

(c) $3\sigma_y S$ (d) $\frac{\sigma_y S}{2}$

[ESE : 2002]

6.44 A continuous beam ABC of two equal spans AB and BC carries a load P at Z, the centre of BC. Then the magnitude of collapse load P is equal to



(a) $\frac{2M_P}{L}$ (b) $\frac{4M_P}{L}$

(c) $\frac{6M_P}{L}$ (d) $\frac{8M_P}{L}$

[ESE : 2002]

6.45 The shape factor for a solid circular section of diameter D is equal to

(a) $\frac{D}{2\pi}$ (b) $\frac{15}{2\pi}$

(c) $\frac{16}{3\pi}$ (d) $\frac{\pi D}{8}$

[ESE : 2002]

6.46 The load factor to be used for plastic design of steel structures for dead load and imposed load is

(a) 2.2 (b) 2.0

(c) 1.7 (d) 1.5

[ESE : 2002]

6.47 At the location of the plastic hinge of a deformed structure

(a) curvature is infinite

(b) radius of curvature is infinite

(c) moment is infinite

(d) flexural stress is infinite

[ESE : 2003]

6.48 Consider the following statements about shape factor:

1. It indicates the increase of strength of a section due to plastic action over elastic strength.
2. It is a ratio of plastic moment of resistance to yield point moment of resistance.
3. Beam sections which have bulk of area near neutral axis will have a low shape factor.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 3

(c) 1 and 2 (d) 2 and 3

[ESE : 2003]

6.49 Which of the following conditions are to be satisfied by an ideal plastic material?

1. It should follow Hooke's law up to the limit of proportionality.
2. Strains up to the strain hardening in tension and compression are to be the same.
3. The material property should be different in tension and compression.

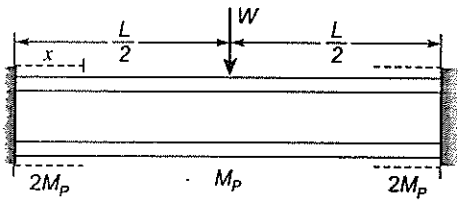
4. The values of yield stress in tension and compression should be different.

Select the correct answer using the codes given below:

(a) 1 and 2 (b) 1 and 4
(c) 2 and 3 (d) 2, 3 and 4

[ESE : 2003]

6.50 For a fixed beam shown below, it has been decided to weld cover plates at ends so that moment capacity doubles at the ends. If maximum advantage has to be derived, the length x of the plate should be



(a) $\frac{L}{2}$ (b) $\frac{L}{3}$

(c) $\frac{L}{4}$ (d) $\frac{L}{6}$

[ESE : 2003]

6.51 A structure has two degrees of indeterminacy. The number of plastic hinges that would be formed at complete collapse is

(a) 0 (b) 1
(c) 2 (d) 3

[ESE : 2003]

6.52 Match List-I (Assumption/Theorem) with List-II (Analysis and Strength) and select the correct answer using the codes given below the lists:

List-I

A. Plane section remains plane before and after bending deformations
B. Elasticity and small deformations
C. Uniqueness theorem
D. Large deformations

List-II

1. Elastic analysis and superposition
2. Strain distribution and plastic moment of resistance
3. Non-linear analysis and buckling load
4. Collapse load

Codes:

	A	B	C	D
(a)	1	2	3	4
(b)	2	1	4	3
(c)	1	2	4	3
(d)	2	1	3	4

[ESE : 2003]

6.53 For a simply supported beam of rectangular cross-section, a point load is applied at mid span. If the superimposed load alone is considered to cause the collapse, the beam is fully elastic

(a) for a distance of one third of beam length from either end
(b) at mid span
(c) for the middle third of beam length
(d) for a distance of one fourth of beam length from either end

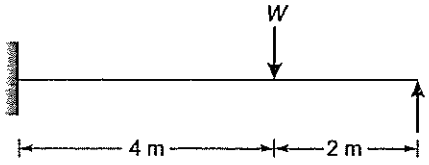
[ESE : 2004]

6.54 For steel structures proportioned using plastic design, the working load (dead load + imposed load) should be multiplied by which one of the following minimum load factor?

(a) 1.3 (b) 1.5
(c) 1.7 (d) 2.0

[ESE : 2004]

6.55 What is the collapse load for propped cantilever beam shown in the diagram below with a plastic moment capacity of M_P?



(a) $1.25M_P$ (b) $1.5M_P$
(c) M_P (d) $2M_P$

[ESE : 2004]

6.56 Consider the following statements:

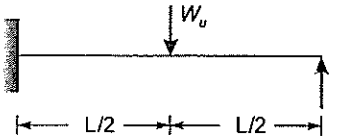
1. The development of a plastic hinge in a determinate beam results in effective destruction of the beam.
2. For fixed ended beams of rectangular section, the design by elastic theory is not conservative.
3. In the ideal plastic material, if the material is stressed to a point beyond the elastic limit and is then unstressed, there will not be any residual strain.

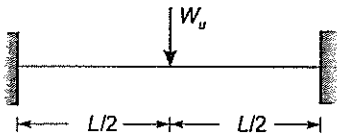
Which of these statements is/are correct?
(a) 1 only (b) 1 and 2
(c) 2 and 3 (d) 1, 2 and 3

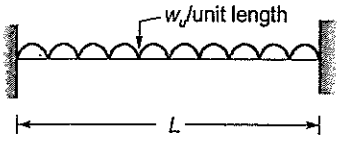
[ESE : 2004]

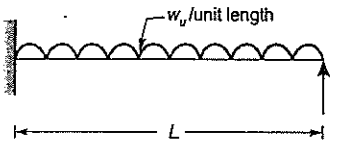
6.57 Match List-I (Type of beam) with List-II (Collapse load w_u, W_u) and select the correct answer using the codes given below the lists:

List-I

A. 

B. 

C. 

D. 

List-II

1. $\frac{8M_P}{L}$ 2. $\frac{16M_P}{L^2}$

3. $\frac{6M_P}{L}$ 4. $\frac{11.66M_P}{L^2}$

W_u and w_u per unit length denote the collapse loads and M_P denotes the plastic moment capacity of the beams corres-ponding to the collapse loads.

Codes:

	A	B	C	D
(a)	2	1	3	4
(b)	3	4	1	2
(c)	3	1	2	4
(d)	2	4	1	3

[ESE : 2004]

6.58 Assertion (A): The principle of superposition cannot be applied in plastic design and as such all the loads must be in position simultaneously for the analysis.

Reason (R): The relationship between loads and deformations in the plastic range is not linear.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2004]

6.59 A beam of rectangular section having simply supported span L, is subjected to a concentrated load at its mid-span. What is the length of elasto-plastic zone of the plastic hinge?

(a) $\frac{L}{3}$ (b) $\frac{L}{4}$

(c) $\frac{L}{5}$ (d) $\frac{L}{7}$

[ESE : 2005]

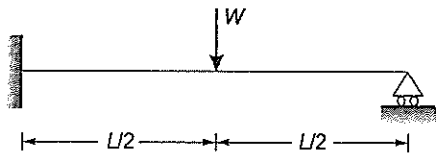
6.60 The plastic modulus of a section is 5×10^{-4} m^3. Its shape factor is 1.2 and the plastic moment capacity is 120 kNm. What is the value of the yield stress of the material?
(a) 100 N/mm^2 (b) 200 N/mm^2
(c) 240 N/mm^2 (d) 288 N/mm^2

[ESE : 2005]

6.61 In a plastic analysis of structures, the segment between any two successive plastic hinges is assumed to deform as
(a) A plastic material
(b) A rigid material
(c) An elastic material
(d) An inelastic material

[ESE : 2005]

6.62 For the propped cantilever beam shown in the figure given below, the plastic moment capacity is M_P. What is the value of its collapse load?



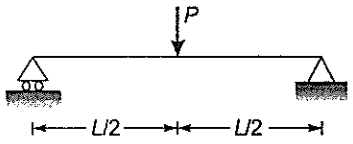
(a) $\frac{4M_P}{L}$ (b) $\frac{6M_P}{L}$

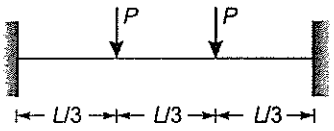
(c) $\frac{8M_P}{L}$ (d) $\frac{11.7M_P}{L}$

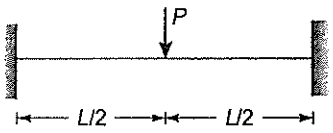
[ESE : 2005]

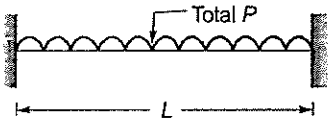
6.63 Match List-I (Loaded prismatic beam of uniform M_p) with List-II (Plastic Load) and select the correct answer using the code given below the lists:

List-I

A. 

B. 

C. 

D. 

List-II

1. $\frac{4M_P}{L}$ 2. $\frac{16M_P}{L}$

3. $\frac{6M_P}{L}$ 4. $\frac{8M_P}{L}$

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	1	2	4	3
(c)	4	2	1	3
(d)	1	3	4	2

[ESE : 2006]

6.64 A beam of square cross-section of side 'x' is composed of material whose yield stress in compression is 1.5 times the yield stress in the tension. What is the distance of the neutral axis from the centre for the fully plastic condition?

(a) $0.1x$ (b) $0.15x$

(c) $0.2x$ (d) $0.25x$

[ESE : 2006]

6.65 Which one of the following is not correct?

(a) The shape factor for any section is equal to M_p/M_y

(b) For a thin-web wide-flange beam, shape factor is close to unity

(c) For a circular section, shape factor is nearly 1.7

(d) Shape factor for an I-section sometimes may be more than that for a rectangular section.

[ESE : 2006]

6.66 What is the ratio of the shape factors for beam cross-sections having rectangular, circular and triangular shapes and of same area?

(a) 1.00 : 0.73 : 0.64

(b) 1.00 : 0.88 : 1.38

(c) 1.00 : 1.13 : 1.56

(d) 1.00 : 1.56 : 1.13

[ESE : 2006]

6.67 A fixed beam of length L has been loaded with central concentrated load. The beam has been strengthened at the supports with cover plates so that the flexural resisting yield moment capacity at the ends is thrice of that at the centre. If this capacity is to be fully effective resulting in higher collapse load, to what length from the ends should the cover plate extend?

(a) $L/3$ (b) $L/4$

(c) $L/6$ (d) $L/8$

[ESE : 2006]

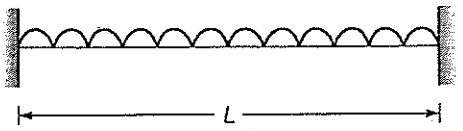
6.68 Which one of the following is the correct maximum shear capacity of a prismatic beam under plastic design of steel structures?

(a) $0.5\,A_wF_y$ (b) $0.55\,A_wF_y$

(c) $0.75\,A_wF_y$ (d) A_wF_y

[ESE : 2006]

6.69 The figure below shows a fixed beam of elastic material possessing sufficient ductility and of a uniform cross-section. It carries a uniformly distributed load which is gradually increased to its ultimate value w_u per unit length, at which the beam is transformed into a failure mechanism. What is the magnitude of w_u in terms of the ultimate moment M_u of the beam-section and span L?



(a) $\frac{8M_u}{L^2}$ (b) $\frac{12M_u}{L^2}$

(c) $\frac{16M_u}{L^2}$ (d) $\frac{24M_u}{L^2}$

[ESE : 2007]

6.70 What is the number of plastic hinges which will cause the overall total collapse of a structure?

(a) One more than the order of statical indeterminacy

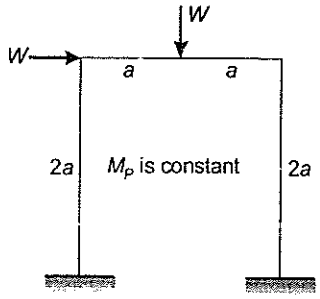
(b) Equal to order of statical indeterminacy

(c) One less than the order of statical indeterminacy

(d) Not determinable

[ESE : 2007]

6.71 What is the ultimate load for the frame shown in the figure below?



(a) M_P/a (b) $2M_P/a$

(c) $3M_P/a$ (d) $4M_P/a$

[ESE : 2007]

6.72 Match List-I (Shape of structural) with List-II (Shape factor) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Rectangular	1. 2.0
B. Circular	2. 1.1 to 1.2
C. I-section	3. 1.5
D. Diamond	4. 1.7

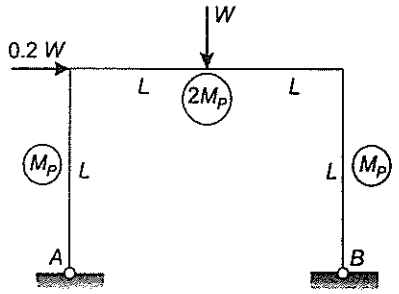
Codes:

	A	B	C	D
(a)	3	1	2	4
(b)	2	4	3	1
(c)	3	4	2	1
(d)	2	1	3	4

[ESE : 2007]

6.73 Collapse moment for the frame shown below has been worked out as $M_p = WL/5$.

What is the horizontal reaction at A at collapse conditions?

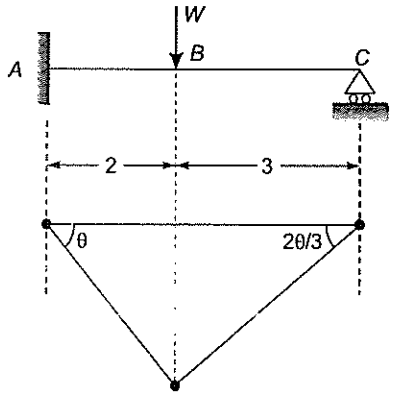


(a) 0 (b) 0.1W

(c) 0.2W (d) 0.4W

[ESE : 2007]

6.74 If a uniform beam shown in the figure below has the plastic moment capacity M_P for span AB and $0.9M_P$ for span BC, what is the correct virtual work equation?



(a) $M_P\theta + M_P\left(\theta + \frac{2\theta}{3}\right) = W.2\theta$

(b) $M_P\theta + M_P\theta + 0.9\,M_P\frac{2\theta}{3} = W.2\theta$

(c) $M_P\theta + 0.9\,M_P\left(\theta + \frac{2\theta}{3}\right) = W.2\theta$

(d) $M_P\theta + 0.9\,M_P\left(\theta + \frac{2\theta}{3} + \frac{2\theta}{3}\right) = W.2\theta$

[ESE : 2007]

6.75 Length of plastic hinge of a beam depends on which of the following?

1. Span of the beam
2. Type of loading
3. Shape of cross-section
4. Yield strength of steel

Select the correct answer using the codes given below:

(a) 1, 2, 3 and 4 (b) 1, 2 and 3 only

(c) 2 and 3 only (d) 1 and 4 only

[ESE : 2007]

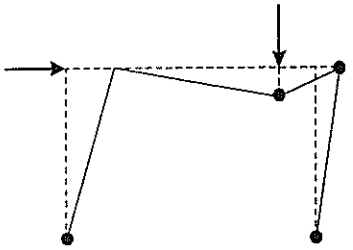
6.76 What is the number of plastic hinges formed if an indeterminate beam with redundancy R is to become determinate?

(a) $R-1$ (b) R

(c) $R+1$ (d) $R+2$

[ESE : 2008]

6.77 A portal frame has a collapse mechanism as shown below. What is the type?



(a) Pure portal mechanism

(b) Panel mechanism

(c) Combined mechanism

(d) Dual beam mechanism

[ESE : 2008]

6.78 Plastic analysis of structures is applicable to the structures made of which one of the following?

(a) Ductile and brittle materials

(b) Any structural material

(c) Brittle material only

(d) Ductile material only

[ESE : 2008]

6.79 What value of the shape factor is taken for a rectangular section in plastic design?

(a) 1.0 (b) 1.5

(c) 2.0 (d) 2.5

[ESE : 2008]

6.80 A load P is applied at the middle of a simply supported beam of span L. If the beam is made of ductile material, and M_P is the plastic moment, what is the ultimate value of P?

(a) $M_P/4L$ (b) $2M_P/L$

(c) $2.5M_P/L$ (d) $4M_P/L$

[ESE : 2008]

6.81 In the plastic analysis of a steel beam, which of the following assumptions is/are made?

1. Plane sections under bending remain plane at all stages of bending.
2. The stress-strain relation is bilinear, i.e. consisting of two straight lines.
3. Shear deformations are neglected.

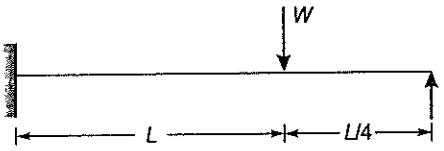
Select the correct answer using the code given below:

(a) 1 only (b) 2 only

(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2008]

6.82 A propped cantilever beam of uniform moment capacity M_0 is shown in figure below.



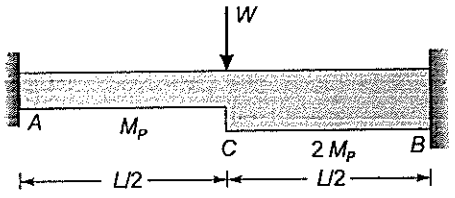
What is the collapse load W?

(a) $\frac{12}{L}M_0$ (b) $\frac{8}{L}M_0$

(c) $\frac{6}{L}M_0$ (d) $\frac{3}{L}M_0$

[ESE : 2009]

6.83 What is the collapse load in terms of M_P and L for the beam shown in figure below?



(a) $\frac{M_P}{L}$ (b) $\frac{5M_P}{L}$

(c) $\frac{10M_P}{L}$ (d) $\frac{20M_P}{L}$

[ESE : 2009]

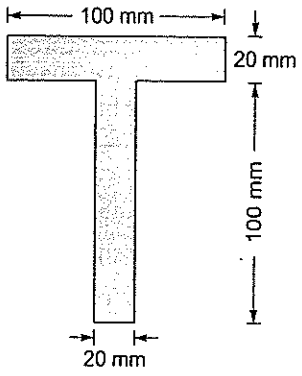
6.84 A prismatic beam (shape factor, S) fixed at both ends carries UDL throughout the span. What is the ratio of collapse load to yield load?

(a) $\frac{4}{3}S$ (b) $\frac{3}{4}S$

(c) $\frac{5}{3}S$ (d) $\frac{3}{5}S$

[ESE : 2009]

6.85 What is the distance between elastic neutral axis and plastic neutral axis for the cross-section as shown in figure below?



(a) 60 mm (b) 50 mm
(c) 40 mm (d) 20 mm

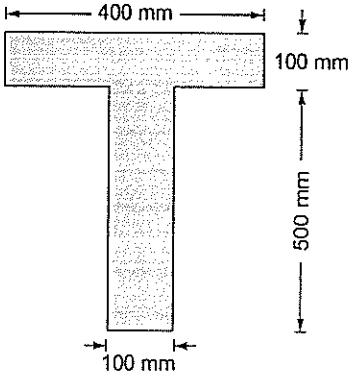
[ESE : 2009]

6.86 A simply supported beam of uniform cross-section has span L and is loaded by a point load P at its mid-span. What is the length of the elastoplastic zone of the plastic hinge ?

(a) $\frac{L}{3}$ (b) $\frac{2L}{3}$
(c) $\frac{L}{2}$ (d) $\frac{3L}{4}$

[ESE : 2009]

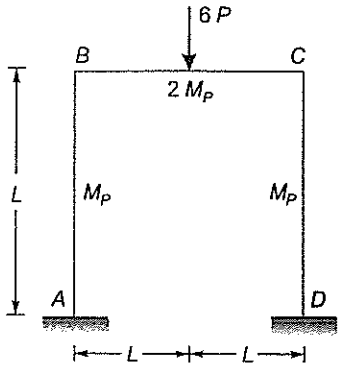
6.87 In a T-section shown in figure below, what is the distance of plastic neutral axis as measured down from top?



(a) 100 mm (b) 150 mm
(c) 200 mm (d) 300 mm

[ESE : 2009]

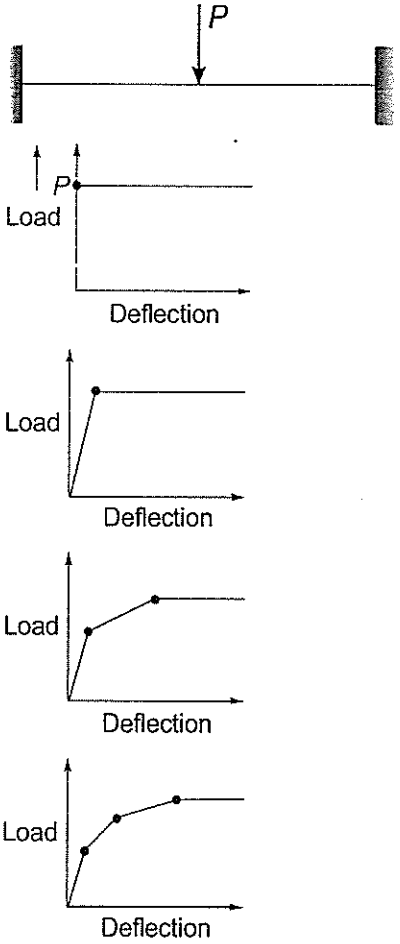
6.88 At the point of collapse, what is the value of horizontal thrust at point A in the loaded frame shown in figure below?



(a) $3P$ (b) $2P$
(c) $1.5P$ (d) P

[ESE : 2009]

6.89 Which one of the following diagrams corresponds to the load-deflection characteristics upto plastic collapse of the beam shown below?

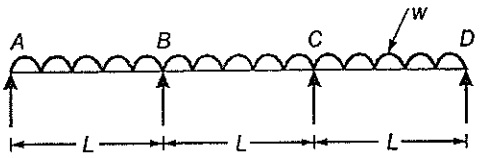


[ESE : 2010]

6.90 At the location of a plastic hinge
(a) radius of curvature is infinite
(b) curvature is infinite
(c) moment is infinite
(d) flexible stress in infinite

[ESE : 2010]

6.91 For the continuous beam shown in figure below, what is the reaction at *A* at collapse, by plastic analysis?



(a) $\frac{5wL}{12}$ (b) $\frac{wL}{2}$

(c) $\frac{7wL}{12}$ (d) $\frac{13wL}{24}$

[ESE : 2010]

6.92 Consider the following statements:

1. Shape factor
2. Length of the beam
3. Type of loading
4. Yield strength of material

Which of these affect the influence length of plastic hinge in a beam?

(a) 1 only (b) 1 and 3

(c) 2 and 3 (d) 3 and 4

[ESE : 2010]

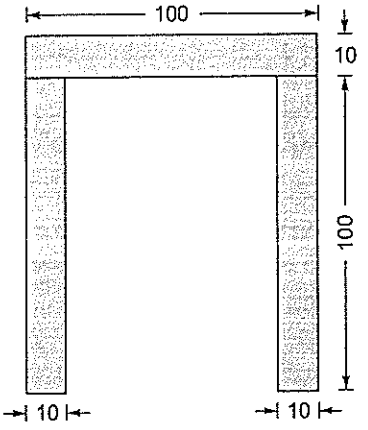
6.93 A propped cantilever of span *L* is subjected to a concentrated load at midspan. If M_P is the plastic moment capacity of the beam, the value of collapse load will be

(a) $\frac{12\,M_P}{L}$ (b) $\frac{8\,M_P}{L}$

(c) $\frac{6\,M_P}{L}$ (d) $\frac{4\,M_P}{L}$

[ESE : 2010]

6.94 The identical rectangle strips are joined to form a "hat" section. What is the plastic moment capacity?



(a) $50 \times 10^3\,\sigma_y$ (b) $100 \times 10^3\,\sigma_y$

(c) $155 \times 10^3\,\sigma_y$ (d) $300 \times 10^3\,\sigma_y$

Where σ_y is yield strength of steel

[ESE : 2010]

6.95 Consider the following conditions with respect to plastic analysis:

1. Sum of internal and external forces and moments must be equal to zero.
2. At ultimate collapse load, the number of plastic hinges must be just enough to form a mechanism.

Which of the above conditions is/are correct?

(a) 1 only (b) 2 only

(c) Neither 1 nor 2 (d) Both 1 and 2

[ESE : 2010]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

6.96 **Assertion (A):** Load deflection characteristics of a fixed beam subjected to uniformly distributed load is linear up to collapse.

Reason (R): Except at the zones of plastic hinges, rest of the components are in the elastic range.

[ESE : 2010]

6.97 **Assertion (A):** Compared to rectangular hollow section, circular hollow section possesses more plastic moment of resistance over its yield moment.

Reason (R): Circular hollow section has higher shape factor than rectangular hollow section.

[ESE : 2010]

6.98 The moment capacity of a section at plastic hinge equals

(a) Yield moment

(b) Zero

(c) Fully plastic moment
(d) Twice the yield moment

[ESE : 2011]

6.99 Which one of the following is the correct ratio of plastic moment to yield moment for a simply supported beam of uniform square cross-section throughout the span?
(a) 1.5 (b) 1.7
(c) 2.0 (d) 2.34

[ESE : 2011]

6.100 In the virtual work method of plastic analysis of steel structure, the virtual quantity is
(a) Slope (b) Moment
(c) Load (d) Displacement

[ESE : 2011]

6.101 Which of the following conditions is to be satisfied both in elastic and plastic analysis?
(a) Equilibrium condition
(b) Yield condition
(c) Plastic moment condition
(d) Mechanism condition

[ESE : 2011]

6.102 For an I beam, the shape factor is 1.12. If the allowable stress (with factor of safety in bending as 1.5) is increased by 20% for wind and earthquake loads, the modified load factor is
(a) 1.10 (b) 1.25
(c) 1.35 (d) 1.40

[ESE : 2011]

6.103 The mechanism method and the statical method guide in estimating
(a) The lower and upper bounds respectively on the strength of structure
(b) The upper and lower bounds respectively on the strength of structure
(c) The lower bound on the strength of structure
(d) The upper bound on the strength of structure

[ESE : 2011]

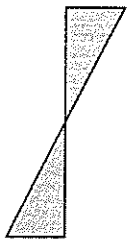
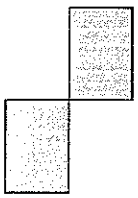
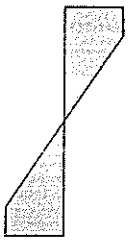
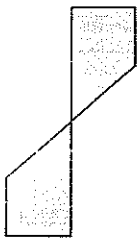
6.104 If the shape factor of a section is 1.5 and the factor of safety to be adopted is 2, then the load factor will be
(a) 3 (b) 4
(c) 1.5 (d) 2

[ESE : 2011]

6.105 A propped cantilever beam of span 'L' and constant plastic moment M_P, carries a concentrated load at midspan. The load at collapse will be
(a) $\frac{2M_P}{L}$ (b) $\frac{8M_P}{L}$
(c) $\frac{6M_P}{L}$ (d) $\frac{4M_P}{L}$

[ESE : 2011]

6.106 In a plastic hinge, the actual distribution of strain across the section is essentially as

(a) 
(b) 
(c) 
(d) 

[ESE : 2011]

6.107 The number of plastic hinges required in a structure of indeterminate status for a 'mechanism' to develop is
(a) i (b) $i + 1$
(c) $i + 2$ (d) $i - 1$

[ESE : 2011]

6.108 What is the distance away from midspan of a plastic hinge if developing in a simply supported beam of rectangular cross-section and span 6 m, subjected to a point load at the centre?
(a) Zero (b) 1 m
(c) 2 m (d) 3 m

[ESE : 2011]

6.109 Match List-I with List-II and select the correct answer using the code given below the lists:

List-I
A. Upper bound theorem
B. Lower bound theorem
C. Equilibrium of forces
D. Ductility of the material

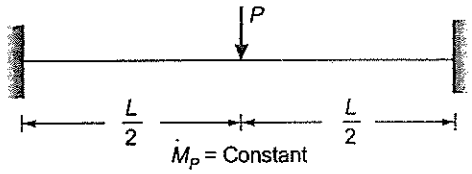
List-II
1. Undeformed state
2. Large rotation
3. Statical method
4. Mechanism method

Codes:

	A	B	C	D
(a)	2	1	3	4
(b)	4	1	3	2
(c)	2	3	1	4
(d)	4	3	1	2

[ESE : 2012]

6.110 The plastic moment at collapse is



(a) $\frac{PL}{6}$ (b) $\frac{PL}{8}$

(c) $\frac{PL}{12}$ (d) $\frac{PL}{16}$

[ESE : 2012]

6.111 Consider the following statements:
1. The virtual work method is preferred to the equilibrium method for the determination of collapse load in a structure.
2. The number of plastic hinges required for the total collapse of a statically indeterminate structure is one less than the degree of indeterminacy of the structure.
3. In a large system the uniformly distributed load can be replaced by a number of concentrated loads to simplify the plastic analysis.

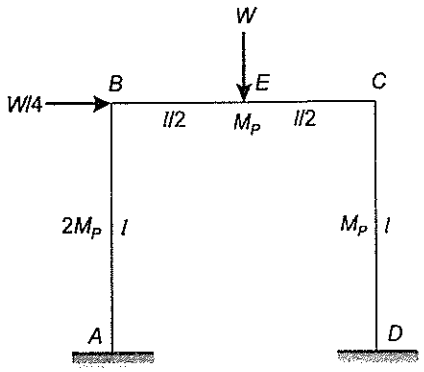
Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 1 and 3 only (d) 2 and 3 only

[ESE : 2013]

6.112 The length of beam over which the moment is greater than the yield moment is called as the plastic hinge length. What is the plastic hinge length for a simply supported beam of circular cross-section loaded at mid-span (shape factor for the section = 5/3)?
(a) 0.15l (b) 0.33l
(c) 0.4l (d) 0.5l

[ESE : 2014]

6.113 For portal frame shown in the figure, collapse load W has been calculated as per combined mechanism as $W = \frac{16M_p}{3l}$.



What is the bending moment at B at collapse conditions?

(a) $\frac{Wl}{16}$ (b) $\frac{Wl}{8}$

(c) $\frac{3Wl}{16}$ (d) $\frac{3Wl}{8}$

[ESE : 2014]

6.114 For a fixed beam with a concentrated load W at 1/4 of span from one end, the ultimate load is

(a) $\frac{16M_p}{3L}$ (b) $\frac{4M_p}{L}$

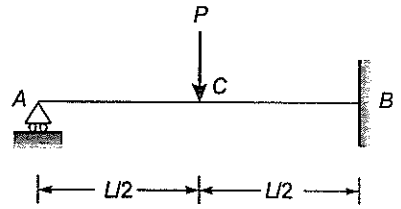
(c) $\frac{32M_p}{3L}$ (d) $\frac{6M_p}{L}$

[ESE : 2014]

6.115 The plastic modulus of a section is 4.8×10^{-4} m^3. The shape factor is 1.2. The plastic moment capacity of the section is 120 kN-m. The yield stress of the material is
(a) 100 MPa (b) 240 MPa
(c) 250 MPa (d) 300 MPa

[ESE : 2014]

6.116 A propped cantilever beam shown in the figure has a plastic moment capacity of M_0.



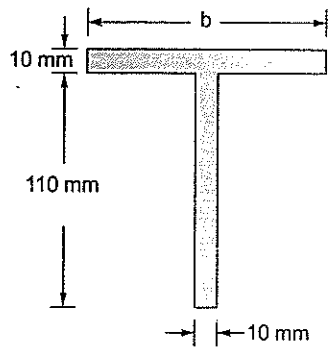
The collapse load is

(a) $\frac{4M_0}{L}$ (b) $\frac{6M_0}{L}$

(c) $\frac{8M_0}{L}$ (d) $\frac{12M_0}{L}$

[ESE : 2014]

6.117 The dimensions of a T-section are shown in the figure



For the depth of plastic neutral axis from the top of the T-section to be 9.583 mm, the flange width b must be

(a) 100 mm (b) 110 mm

(c) 120 mm (d) 130 mm

[ESE : 2014]

6.118 The shape factors of a triangle section and a diamond section are respectively

(a) 2.343 and 2.0 (b) 2.0 and 2.343

(c) 1.343 and 2.0 (d) 2.0 and 1.343

[ESE : 2014]

6.119 In considering Plastic Analysis, which of the following is a valid comprehensive statement?

(a) Shape factor is the ratio of Plastic Section Modulus to the Elastic Section Modulus.

(b) Shape factor is the ratio of Elastic Section Modulus to the Plastic Section Modulus.

(c) Shape factor is the ratio of Plastic Section Modulus to the Elastic Section Modulus and its value is always greater than 1.0.

(d) Shape factor is the ratio of Elastic Section Modulus to the Plastic Section Modulus and its value is always less than 1.0.

[ESE : 2015]

6.120 The plastic neutral axis

1. Divides the given section into two equal halves
2. Divides the given section into two unequal parts
3. Lies on the centroidal axis of the section

(a) 1 only (b) 2 only

(c) 3 only (d) 2 and 3 only

[ESE : 2016]

6.121 The plastic moment capacity M_p is

(a) Less than the yield moment

(b) Equal to the yield moment

(c) Greater than the yield moment

(d) Dependent on section dimensions

[ESE : 2016]

6.122 The ultimate moment capacity of a mild steel section is usually

(a) Equal to the plastic moment capacity

(b) More than the yield moment capacity

(c) Less than the plastic moment capacity but more than the yield moment capacity

(d) More than the plastic moment capacity

[ESE : 2016]

6.123 For a rectangular cross-section, when the extreme fibre strain was ε_y, the yield moment capacity is M_y. What would be the value of the resisting moment when the extreme fibre strain is 2 ε_y?

(a) 1.000 M_y (b) 1.250 M_y

(c) 1.375 M_y (d) 1.550 M_y

[ESE : 2017]

■■■■

Answers Plastic Analysis

6.1	(c)	6.2	(b)	6.3	(b)	6.4	(c)	6.5	(a)	6.6	(c)	6.7	(d)	6.8	(c)	6.9	(c)
6.10	(c)	6.11	(b)	6.12	(c)	6.13	(d)	6.14	(d)	6.15	(a)	6.16	(a)	6.17	(b)	6.18	(d)
6.19	(c)	6.20	(c)	6.21	(a)	6.22	(b)	6.23	(c)	6.24	(c)	6.25	(c)	6.26	(d)	6.27	(a)
6.28	(b)	6.29	(d)	6.30	(b)	6.31	(c)	6.32	(d)	6.33	(a)	6.34	(c)	6.35	(d)	6.36	(a)
6.37	(a)	6.38	(a)	6.39	(b)	6.40	(d)	6.41	(d)	6.42	(c)	6.43	(c)	6.44	(c)	6.45	(c)
6.46	(c)	6.47	(a)	6.48	(c)	6.49	(a)	6.50	(d)	6.51	(d)	6.52	(b)	6.53	(a)	6.54	(c)
6.55	(c)	6.56	(a)	6.57	(c)	6.58	(a)	6.59	(a)	6.60	(c)	6.61	(b)	6.62	(b)	6.63	(d)
6.64	(a)	6.65	(d)	6.66	(c)	6.67	(b)	6.68	(b)	6.69	(c)	6.70	(a)	6.71	(b)	6.72	(c)
6.73	(a)	6.74	(c)	6.75	(b)	6.76	(b)	6.77	(c)	6.78	(d)	6.79	(b)	6.80	(d)	6.81	(d)
6.82	(c)	6.83	(c)	6.84	(a)	6.85	(d)	6.86	(a)	6.87	(b)	6.88	(b)	6.89	(d)	6.90	(b)
6.91	(a)	6.92	(b,c)	6.93	(c)	6.94	(b)	6.95	(d)	6.96	(d)	6.97	(a)	6.98	(c)	6.99	(a)
6.100	(d)	6.101	(a)	6.102	(d)	6.103	(b)	6.104	(a)	6.105	(c)	6.106	(a)	6.107	(b)	6.108	(a)
6.109	(d)	6.110	(b)	6.111	(c)	6.112	(c)	6.113	(a)	6.114	(c)	6.115	(c)	6.116	(b)	6.117	(c)
6.118	(a)	6.119	(c)	6.120	(a)	6.121	(d)	6.122	(a)	6.123	(c)						

Explanations Plastic Analysis

6.1 (c)

Shape factor for a section is the ratio of plastic moment (plastic section modulus) and the yield moment (elastic section modulus).

	Shape	Shape factor
(i)	Rectangle or square	1.5
(ii)	Circle	1.7
(iii)	Triangle	2.34
(iv)	Diamond	2.0
(v)	I-section	1.1 to 1.2

6.2 (b)

Curvature at plastic hinge is infinite and moment is equal to plastic moment capacity. It means that infinite rotation can occur at fully plastic section.

6.3 (b)

Number of hinges needed for failure

$= r + 1$

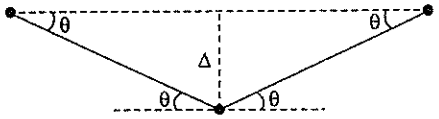
$= 3 + 1$

$= 4.$

$r \rightarrow$ degree of static indeterminacy.

The collapse load will be calculated using

(i) beam mechanism.

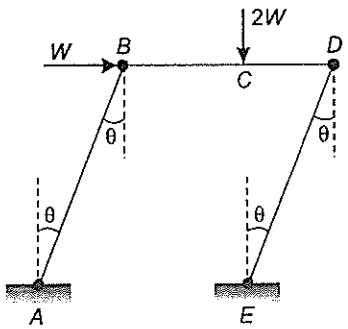


$$2W.\Delta = M_P(\theta) + M_P(2\theta) + M_P(\theta)$$

and $$\Delta = \frac{L\theta}{2}$$

$$\therefore \quad W = \frac{4M_P}{L}$$

(ii) Sway mechanism



$$W\Delta = M_P(\theta+\theta+\theta+\theta)$$

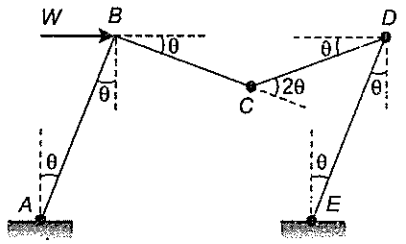
$$\Delta = \frac{L\theta}{2}$$

$$\therefore \quad W = \frac{8M_P}{L}$$

(iii) Combined mechanism

In this case hinges will form at *A*, *C*, *D* and *E*.

The other combination with hinges at *A*, *B*, *C*, *E* will give same load.



$$\therefore\ W\Delta_1 + 2W\Delta_2 = M_P(\theta + 2\theta + 2\theta + \theta)$$

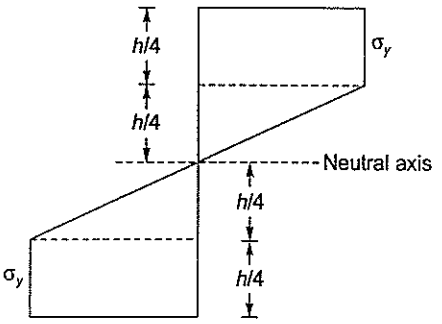
$$\Delta_2 = \Delta_1 = \frac{L\theta}{2}$$

$$\frac{3WL\theta}{2} = 6M_P\theta$$

$$W = \frac{4M_P}{L}$$

The lowest load $\frac{4M_P}{L}$ is collapse load

6.4 (c)



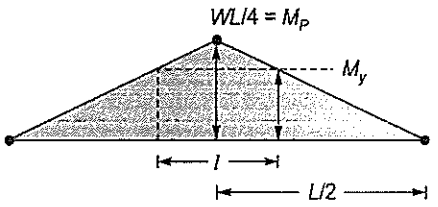
Taking moment about neutral axis,

$$M = 2b\left[\sigma_y \times \frac{h}{4} \times \left(\frac{h}{4}+\frac{h}{8}\right) + \frac{1}{2}\sigma_y \times \frac{h}{4} \times \frac{2}{3}\,\frac{h}{4}\right]$$

$$= \frac{11}{48}bh^2\sigma_y$$

6.5 (a)

For I-section shape factor $\frac{M_P}{M_y}$ = 1.1 to 1.2



From the bending moment diagram

$$\frac{W}{2}\left[\frac{L}{2}-\frac{l}{2}\right] = M_y$$

Taking $M_P = \frac{WL}{4}$

and $M_y = \frac{M_P}{1.1}$

$l = 0.09\,L = L/11$

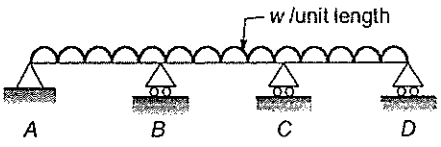
Taking $M_y = \frac{M_P}{1.2}$

$l = L/6$

So l varies between $\frac{L}{6}$ to $\frac{L}{11}$

Therefore $\frac{L}{8}$ is suitable choice

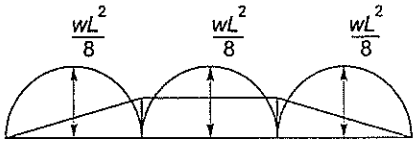
6.6 (c)



The degree of indeterminacy $r = 4 - 2 = 2$

Number of plastic hinges required for collapse $= r + 1 = 3$

Using statical method



Moment diagram due to load and redundant forces

In the span *AB*, maximum moment occurs at support *B* and at 0.414*L* away from support *A*. Thus

$$\text{collapse load} = \frac{11.656M_P}{L^2}$$

Checking for this collapse load in span *BC*, the moment does not exceeds M_P anywhere.

Note: Although number of hinges required for collapse were 3, but formation of two hinges in span *AB* or *CD* gives collapse condition.

6.7 (d)

$$\text{Factor of safety} = \frac{\text{Yield stress}}{\text{Allowable stress}}$$

With increase in allowable stress, the factor of safety will reduce to $\frac{1.5}{1.2} = 1.25$.

$\therefore$ Load Factor = FOS × shape factor
$= 1.25 \times 1.12 = 1.40$

6.8 (c)

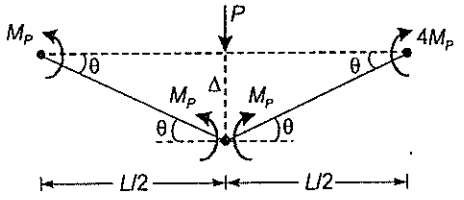
The yield line theory is the ultimate load theory. Both the virtual work method as well as equilibrium method give the upper bound solution, i.e. the computed collapse load on the basis of an assumed yield line pattern is bound to be larger than the actual collapse load.

6.9 (c)

Degree of indeterminacy, $r = 2$

Number of plastic hinges needed for collapse $= r + 1 = 3$

(i) Mechanism 1



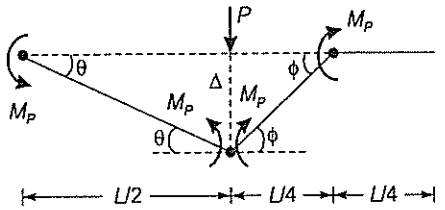
Using virtual work method, we get

$$M_P\theta + M_P(2\theta) + 4M_P\theta = P \times \frac{L}{2}\theta$$

$$\Rightarrow \quad 14M_P = PL$$

$$\Rightarrow \quad P = \frac{14M_P}{L}$$

(ii) Mechanism 2



$$\Delta = \frac{L}{2}\theta = \frac{L}{4}\phi$$

$$\therefore \quad \phi = 2\theta$$

Using virtual work method, we get

$$M_P\theta + M_P\theta + M_P\phi + M_P\phi = P \times \frac{L}{2}\theta$$

$$\Rightarrow 2M_P\theta + 2M_P\phi = P \times \frac{L}{2}\theta$$

$$\Rightarrow \quad 12\,M_P = PL$$

$$\Rightarrow \quad P = \frac{12M_P}{L}$$

Lower load among these mechanisms will be the collapse load.

$$\therefore \quad P = \frac{12M_P}{L}$$

6.10 (c)

$$\text{Fixed end moment} = \frac{w_1L^2}{12} = \frac{W_1L}{12} = M_P$$

$$\therefore \quad W_1 = \frac{12M_P}{L}$$

The plastic hinges are formed only at the ends and the beam has not collapsed yet.

At collapse, third hinge is formed in the middle and collapse load $W_2 = \frac{16M_P}{L}$

6.11 (b)

In the plastic case,

$$M_P + \frac{M_P}{2} = \frac{PL}{4}$$

$$M_P = \frac{PL}{6} = \frac{16PL}{96}$$

In the elastic case maximum moment is

$$\frac{6PL}{32} = \frac{18PL}{96}$$

Thus maximum moment in plastic case is less than elastic case. So the better distribution is obtained in plastic case.

6.12 (c)

$$\text{Margin of safety} = \frac{\text{Collapse load}}{\text{Service load}} - 1$$

$$= \frac{\text{Ultimate stress}}{\text{Permissible stress}} - 1$$

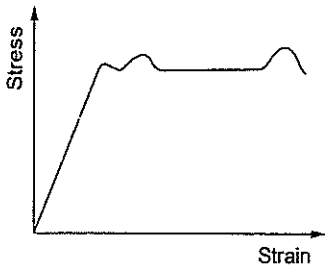
6.13 (d)

Shape factor for rectangular section = 1.5

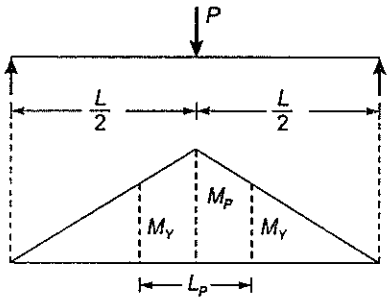
Shape factor for circular section = 1.7

6.14 (d)

Plastic deformation for a ductile structure before failure is much more than elastic deformation.



6.15 (a)



From similar triangles, we have

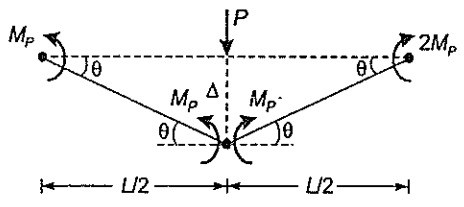
$$\frac{M_P}{M_Y} = \frac{L/2}{\frac{L}{2} - \frac{L_P}{2}}$$

$$\Rightarrow \frac{L}{L - L_P} = \frac{3}{2}$$

$$\Rightarrow \quad L_P = \frac{L}{3}$$

6.16 (a)

Number of plastic hinges needed for collapse $= r + 1 = 3$.



Using virtual work method, we get

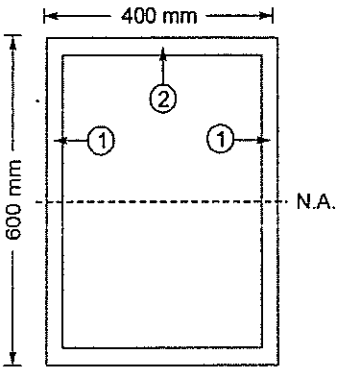
$$M_P\theta + M_P(2\theta) + 2M_P\theta = \frac{PL\theta}{2}$$

$$\therefore \quad P = \frac{10M_P}{L}$$

6.17 (b)

First the hinges will form at A and C simultaneously because the carry over factor for support A is zero while support C transfers half of the moment to fixed support on the right side. The hinge at C will form at 0.5 M_p while at A the moment M_p is required. Now due to redistribution of moments the hinge at B will form.

6.18 (d)



The area of box above neutral axis,

$A_1 = 2 \times 300 \times 10 = 6000 \text{ mm}^2$

The centroid from neutral axis is at

$y_1 = 150$ mm for A_1

$A_2 = (400 - 20) \times 10 = 3800 \text{ mm}^2$

The distance of centroid from N.A.

$y_2 = 300 - 5 = 295$ mm

Plastic section modulus,

$Z_P = 2(A_1y_1 + A_2y_2)$

$= 2 \times (6000 \times 150 + 3800 \times 295)$

However the value given in the options is based on

$A_2 = 400 \times 10 = 4000 \text{ mm}^2$

and $y_2 = 400$ mm.

Then $Z_P = 42 \times 10^5 \text{ mm}^3$

Elastic section modulus $= \frac{I_{xx}}{300}$

$$I_{xx} = \frac{400\times600^3}{12} - \frac{380\times580^3}{12}$$

$$= 1.021 \times 10^9 \text{ mm}^4$$

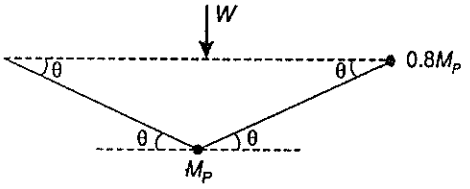
$$Z_y = 34.05 \times 10^5 \text{ mm}^3 \simeq 34 \times 10^5$$

$$\text{Shape factor} = \frac{Z_p}{Z_y} = 1.187$$

The shape factor is always greater than one.

6.19 (c)

Failure in the left/right span can be caused by formation of two hinges.



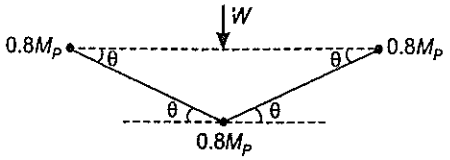
Left/Right span

Using virtual work method

$$W \times \frac{L\theta}{2} = M_P(2\theta) + 0.8M_P\theta$$

$$W = \frac{5.6M_P}{L}$$

The failure in the middle span will be caused by formation of three hinges.



$$\frac{WL\theta}{2} = 0.8M_P(\theta + 2\theta + \theta)$$

$$W = \frac{6.4M_P}{L}$$

The lower load $\frac{5.6M_P}{L}$ will be taken as the collapse load.

6.20 (c)

When the load is such that the maximum moment is equal to yield moment (M_y) at clamped ends, the beam starts deforming significantly. The load for M is given as

$$w_1 = 10 \text{ kN/m.}$$

Now hinges at clamps will be formed at a load equal to w_2 = Shape Factor × w_1

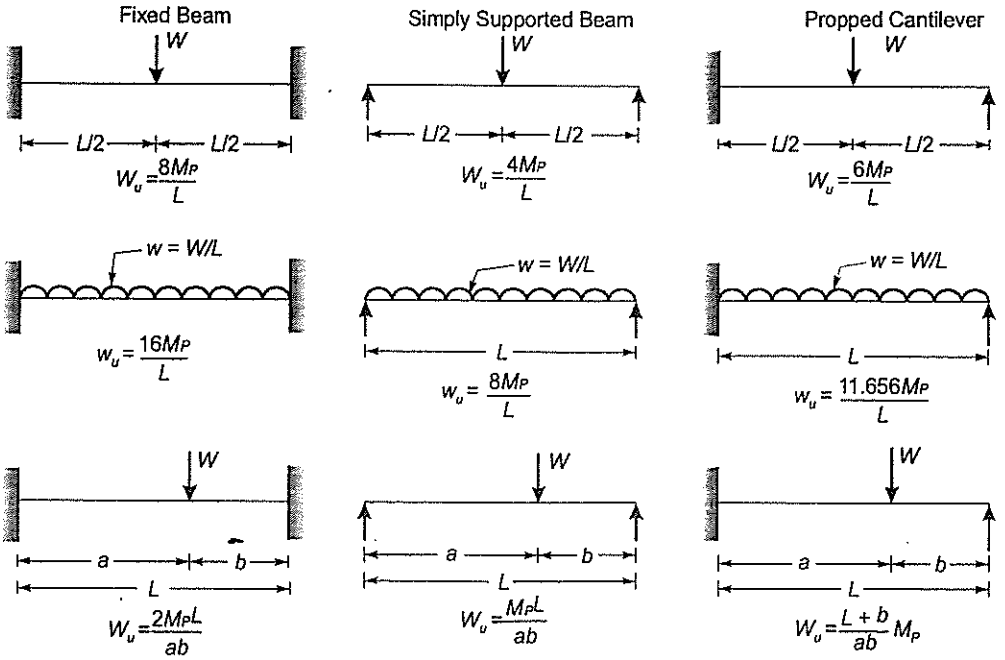
$$= 1.5 \times 10 = 15 \text{ kN/m}$$

Since beam is clamped at both the end, so it can be treated as fixed beam.

Load required to collapse the beam, after becoming two hinges at the fixed end is,

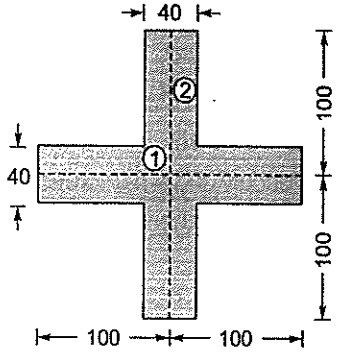
$$\text{Collapse load, } w_u = \frac{4}{3}\times 15 = 20 \text{ kN/m}$$

6.21 (a)



Ratio of collapse load of propped cantilever beam to the simply supported beam is $\frac{11.656}{8} = 1.457$

6.22 (b)



Portion above N.A.	Area (mm^2)	Centroidal distance from N.A. (mm)	Moment of inertia (mm^4)
1.	$20 \times 200 = 4000$	10	$\frac{200 \times 20^3}{3}$
2.	$40 \times 80 = 3200$	60	$\frac{40 \times 80^3}{12} + 3200 \times (60)^2$

Plastic section modulus,

$$Z_P = 2 \times (4000 \times 10 + 3200 \times 60) = 46.4 \times 10^4 \text{ mm}^3$$

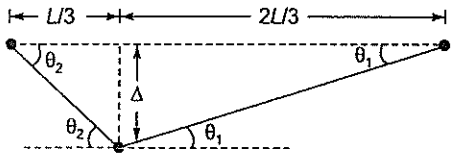
Elastic section modulus,

$$Z_y = \frac{I_{N.A}}{100} = 2 \times 13.76 \times 10^4 \text{ mm}^3$$

$$\therefore \text{Shape factor} = \frac{Z_P}{Z_y} = \frac{46.4}{13.76 \times 2} = \frac{145}{86}$$

6.23 (c)

The plastic hinges will form at both fixed ends and under the load.

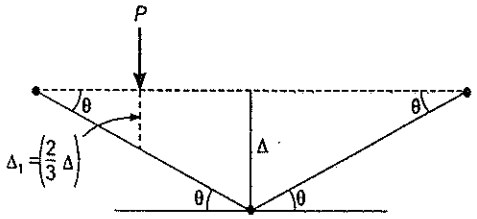


$$P\Delta = 2M_P\theta_2 + 2M_P(\theta_1 + \theta_2) + M_P\theta_1$$

$$= 2M_P\frac{3\Delta}{L} + 2M_P\left(\frac{3\Delta}{L} + \frac{3\Delta}{2L}\right) + M_P\left(\frac{3\Delta}{2L}\right)$$

$$P = \frac{16.5M_P}{L}$$

Considering hinges at both fixed ends and at section change.



$$\Delta = \theta L/2$$

$$\Delta_1 = \theta L/3$$

$$P\Delta_1 = 2M_P\theta + M_P 2\theta + M_P\theta = 5M_P\theta$$

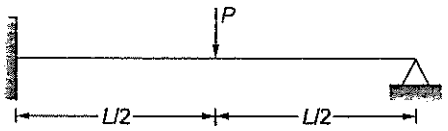
$$P = 15M_P/L$$

Lower load is the collapse load.

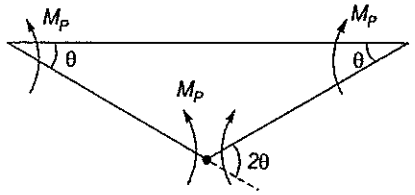
6.24 (c)

To convert indeterminate frame to determinate frame, the number of plastic hinges required is equal to the degree of static indeterminacy.

6.25 (c)



By Kinematic method



By virtue work principle:

$$\frac{PL\theta}{2} = M_p\theta + 2M_p\theta$$

$$P = \frac{6M_P}{L}$$

6.26 (d)

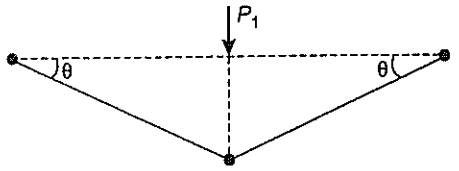
A rigid joint does not permit any rotation so moment-rotation curve will be a vertical line.

Flexible and pin joints cannot take any moment so moment-rotation curve will be a horizontal line.

6.27 (a)

Strain distribution across a section is linear is one of the basic assumption in plastic theory.

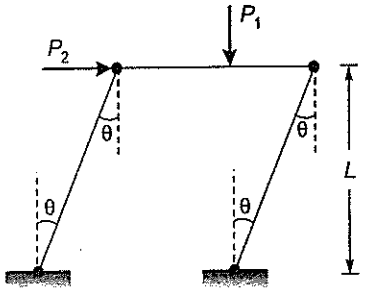
6.28 (b)



Beam mechanism

$$P_1 = \frac{8M_P}{L}$$

Sway mechanism



$$P_2 = \frac{4M_P}{L}$$

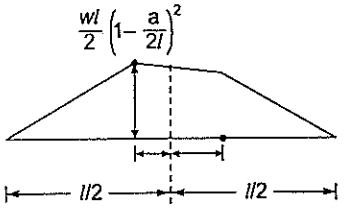
$$\therefore \quad \frac{P_1}{P_2} = 2$$

6.29 (d)

In Elastic buckling and lateral buckling the beam does not reach its yield strength and hence not considered for plastic design. A steel beam fails plastically by formation of hinges due to yielding of steel at point of maximum stress.

6.31 (c)

The fixed beam will fail by formation of three hinges. Two hinges will form at supports and one will form under either of the load. Thus (c) or (d) is the correct answer.



Free moment diagram

Since maximum moment occurs under left side load. From the loading it is clear that end moment at right support will be more as loads are close to the right support. Superimposing fixed end moment on the free moment diagram.

6.33 (a)

The degree of indeterminacy, $r = 3$

Number of plastic hinges needed $= r + 1 = 4$

Figure (a) shows beam mechanism. In other figures the mechanisms are not correctly represented.

6.34 (c)

Yield line theory is upper bound method of analysis of under-reinforced slabs. This theory accounts for only under reinforced bending failure, and effects due to shear, bond and deflection are not considered.

6.35 (d)

For left span,

$$\frac{WL}{2} = M_P(\theta + \theta + \theta)$$

$$\therefore \quad W = \frac{6M_P}{L}$$

For right span,

$$W \times \frac{L}{3} \times 2\theta = M_P\theta + M_P\theta + M_P(2\theta)$$

$$\therefore \quad W = \frac{6M_P}{L}$$

Hence $\frac{6M_P}{L}$ will be the collapse load.

6.37 (a)

There are two kinds of mechanisms, viz. DEPENDENT and INDEPENDENT mechanisms. The independent mechanisms are sometimes called as **elementary** or **basic** or **fundamental** or **primary** or **cardinal** mechanisms. The dependent mechanisms are known as **complex** or **composite** or **combined** mechanisms also.

An independent mechanism corresponds to a condition of unstable equilibrium in the structure. Associated with each independent mechanism, there is a distinct equilibrium equation. However, it is not possible to write such equilibrium equations for composite mechanism.

Number of possible locations where of plastic hinges can be formed $= n = 4$.

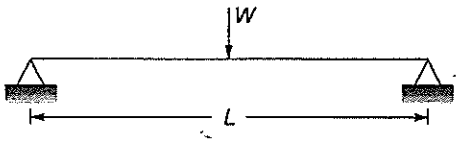
Static indeterminacy $= r = 5 - 3 = 2$.

Number of independent mechanisms,

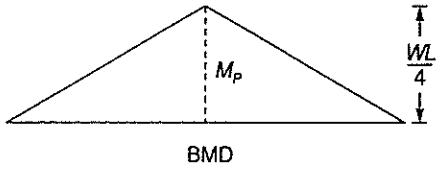
$$s = n - r$$

$$\therefore \quad s = 4 - 2 = 2$$

6.38 (a)



By Static method

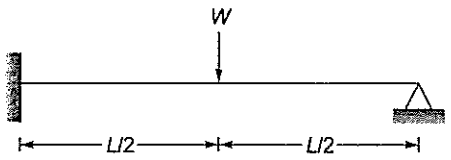


BMD

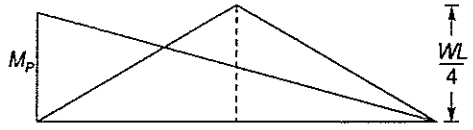
$$M_p = \frac{WL}{4} \text{ (from diagram)}$$

$$\frac{4M_P}{L} = W$$

6.39 (b)



By Static method



BMD

$$M_P + \frac{M_P}{2} = \frac{WL}{4} \text{ (from diagram)}$$

$$W = \frac{6M_P}{L}$$

6.40 (d)

There are three fundamental conditions for plastic analysis :

(i) Conditions of statical equilibrium

(ii) Plastic moment condition i.e. the plastic moment must not be exceeded anywhere

(iii) Mechanism condition – there must be just enough plastic hinges that a mechanism is obtained.

A solution satisfying the three conditions will be a unique solution of the problem.

For statical or equilibrium method of analysis equation of equilibrium and plastic moment condition are satisfied.

6.41 (d)

The area on both sides of neutral axis should be equal.

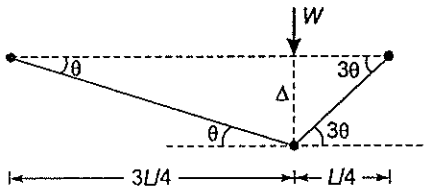
$$\frac{D_1}{B_1} = \frac{D}{B}$$

and $$\frac{1}{2}D_1B_1 = \frac{1}{4}DB$$

$$\therefore \quad D_1 = \frac{D}{\sqrt{2}}$$

6.42 (c)

Taking hinges at both fixed ends and under the load



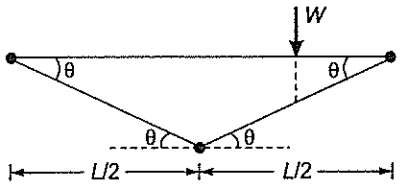
$$W\Delta = M_P\theta + 2M_P(4\theta) + 2M_P(3\theta)$$

$$\Delta = \frac{3L}{4}\theta$$

$$\frac{3LW}{4} = 15\,M_P$$

$$\Rightarrow \quad W = \frac{20M_P}{L}$$

Taking hinges at fixed ends and at point of section change.



$$W \times \frac{L}{4}\theta = M_P(\theta) + M_P(2\theta) + 2M_P(\theta)$$

$$W = \frac{20M_P}{L}$$

6.43 (c)

The load will cause compression in rod *A* and tension in rod *B*.

∴ by compatibility equation we have

$$\frac{P_A L}{SE} = \frac{P_B \times 2L}{2S \times E}$$

$$P_A = P_B \quad \text{...(i)}$$

Also, $P_A + P_B = P$ ...(ii)

∴ From (i) and (ii), we get

$P_A = P/2$ and $P_B = P/2$

Also, $\sigma_A = \frac{P}{2S}$

$$\sigma_B = \frac{P}{2 \times 2S} = \frac{P}{4S}$$

∴ $\sigma_A = 2\sigma_B$

Rod A will yield first because it carries more stress.

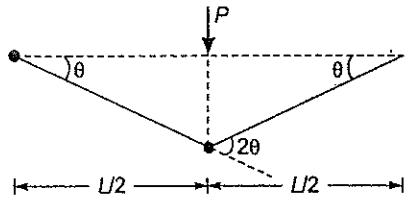
∴ $\frac{P_y}{2} = \sigma_y \times S$

⇒ $P_y = 2\sigma_y S$ (Yield load)

But collapse will occur, only when both A and B yields

∴ $P_u = \sigma_y \times S + \sigma_y \times 2S = 3\sigma_y S$

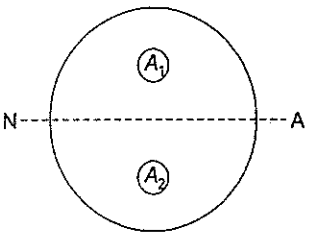
6.44 (c)



$$P \times \frac{L}{2}\theta = M_P(\theta + 2\theta)$$

∴ $P = \frac{6M_P}{L}$

6.45 (c)



Moment of area A_1 and A_2 about neutral Axis gives Z_p

Also $A_1 = A_2 = \frac{A}{2} = \frac{\pi D^2}{8}$

Hence, $Z_p = 2 \times \left(\frac{\pi D^2}{8}\right) \times \frac{4}{3\pi} \times \frac{D}{2} = \frac{D^3}{6}$

Now, Z_e about N-A is given by

$$Z_e = \frac{\pi D^3}{32}$$

Shape factor $= \frac{Z_p}{Z_e} = \frac{16}{3\pi}$

6.46 (c)

(i) For combination of Dead Load or DL + imposed load or DL + wind or seismic load, Load factor = 1.7

(ii) For DL + imposed load + wind or seismic load Load factor = 1.3

6.47 (a)

The full cross section plasticity at the location of plastic hindge associated with plastic moment capacity of a section is reached at infinite curvature.

6.48 (c)

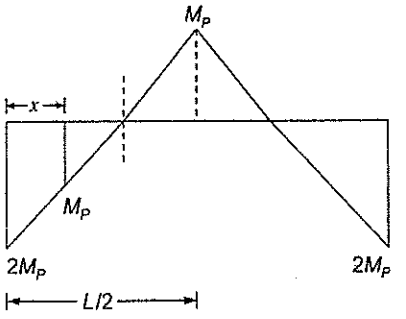
Shape factor $= \frac{M_P}{M_y} = \frac{Z_P}{Z_y}$

Beams sections which have bulk of area near neutral axis will have a high shape factor.

6.49 (a)

An ideal plastic material follows Hooke's law upto limit of proportionality. The values of young's modulus of elasticity, yield stresses in compression and tension, strains upto strain hardening in tension and compression are same.

6.50 (d)



The bending moment diagram in collapse condition is shown in the figure. The plates should extend upto point where the moment reduces to M_P.

$$\therefore\ 2M_P - \frac{3M_P}{L/2}x = M_P \Rightarrow x = \frac{L}{6}$$

6.51 (d)

Number of plastic hinges
= Degree of indeterminacy + 1
= 2 + 1 = 3

6.52 (b)

There are three theorems in plastic theory.

(i) The upper bound or kinematic theorem.

(ii) The lower bound or static theorem.

(iii) Uniqueness theorem states that if it is possible to arrive at a system of bending moments for the structure to satisfy equilibrium condition, mechanism condition and yield condition, the corresponding load system represents the true collapse load.

6.53 (a)

The plastic hinge has a length of $l/3$ in the middle portion. So beam is fully elastic for a distance of one third of beam length from either end.

6.55 (c)

$a = 4$ m

$b = 2$ m

$L = a + b = 6$ m

$$\text{Collapse load} = \left(\frac{L+b}{ab}\right)\times M_P$$

$$= \left(\frac{6+2}{4\times 2}\right)\times M_P = M_P$$

6.56 (a)

- The design by elastic theory for fixed ended beams of rectangular section is conservative.
- There will be residual strain if ideal plastic material is stressed to point beyond elastic limit and then unstressed.

6.58 (a)

The principal of superposition is valid for linear load deformation characteristic structures and for small deformations only.

6.59 (a)

Length of elasto-plastic zone

$$l_e = L\left(1-\frac{1}{f}\right)$$

f = shape factor $= \frac{3}{2}$

$$l_e = L\left(1-\frac{2}{3}\right)$$

$$l_e = \frac{L}{3}$$

6.60 (c)

$$M_P = Z_P \times f_y$$

$$\therefore\quad f_y = \frac{120\times 10^3}{5\times 10^{-4}}$$

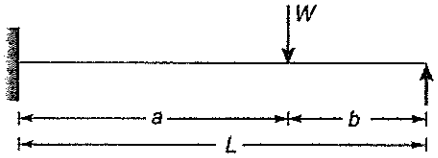
$$= 24\times 10^7\ \text{N/m}^2$$

$$= 240\ \text{N/mm}^2$$

6.61 (b)

The initial slopes and deflections of the beam do not affect the virtual work equations. Thus the displacement diagram can be simplified to consists of straight and undeflected lines i.e. rigid deformation.

6.62 (b)



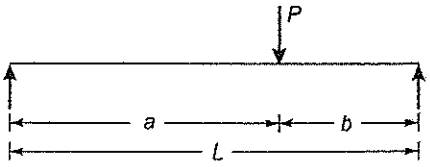
$$L = a + b$$

$$W_u = \left(\frac{L+b}{ab}\right)M_P$$

as $a = b = L/2$

$$\therefore\quad W_u = \frac{6M_P}{L}$$

6.63 (d)

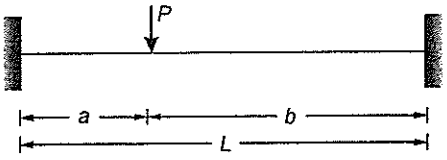


Simply supported beam

$$P = \frac{M_P L}{ab}$$

for $a = b = L/2$

$$P = \frac{4M_P}{L}$$

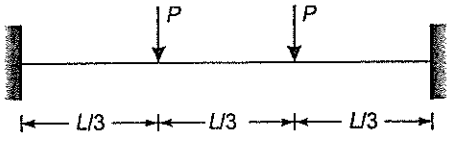


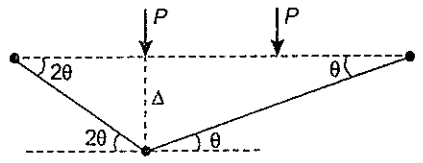
Fixed beam

$$P = \frac{2M_P L}{ab}$$

for $a = b = L/2$

$$P = \frac{8M_P}{L}$$





$$P = \frac{16M_P}{L}$$

Assuming hinges at fixed end and under the load.

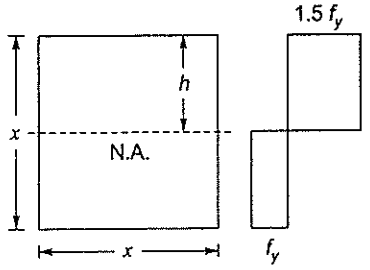
Using virtual work method.

$$M_P(2\theta + 3\theta + \theta) = P \times \frac{L}{3} \times 2\theta + P \times \frac{L}{3}\theta = PL\theta$$

$$P = \frac{6M_P}{L}$$

6.64 (a)

In fully plastic condition the stress diagram will be



The area under compression = area under tension

$$x \times h \times 1.5 f_y = (x - h) \times x \times f_y$$

$$\Rightarrow \quad 1.5\,h = x - h$$

$$\Rightarrow \quad h = \frac{x}{2.5} = 0.4x$$

The distance of neutral axis from centre

$$= 0.5x - 0.4x = 0.1x$$

6.65 (d)

Shape factor of I-section < Shape factor of rectangular section

Shape factor of I-section is in range of 1.1 to 1.2 and Shape factor of rectangular section is 1.5.

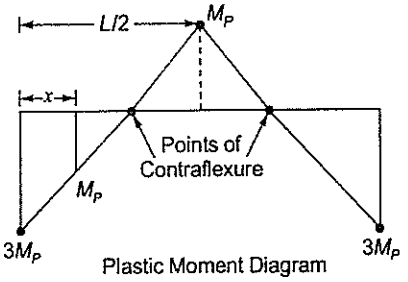
6.66 (c)

The ratio is 1.5 : 1.7 : 2.34

$$\Rightarrow \quad \frac{1.5}{1.5} : \frac{1.7}{1.5} : \frac{2.34}{1.5}$$

$$\Rightarrow \quad 1 : 1.13 : 1.56$$

6.67 (b)



Plastic Moment Diagram

To utilize the capacity effectively, the cover plates should extend from ends to the point where moment is M_P.

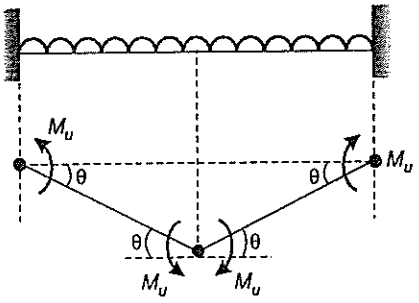
$$\therefore \quad 3M_P - \frac{4M_P}{L/2}x = M_P$$

So $$x = \frac{L}{4}$$

6.68 (b)

The maximum shear capacity is $0.55\,A_w f_y$.

6.69 (c)



By principle of virtual work, we get

$$-M_u\theta - M_u\theta - M_u\theta - M_u\theta + w_u\left(\frac{1}{2} \times L \times \frac{L}{2}\theta\right) = 0$$

$$\Rightarrow \quad w_u = \frac{16M_u}{L^2}$$

6.70 (a)

If an indeterminate structure has redundancy 'r', the insertion of 'r' plastic hinges make it statically determinate. Any further hinge converts this

statically determinate structure into mechanism. Hence, for overall collapse of the structure, the number of plastic hinges required are $(r+1)$.

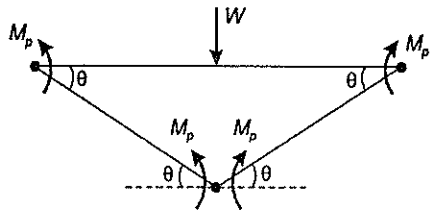
6.71 (b)

There are five possible locations at which the plastic hinges can form. Statical indeterminacy of the frame is 3.

$\therefore$ Total number of independent mechanisms,

$$i = n - r = 5 - 3 = 2$$

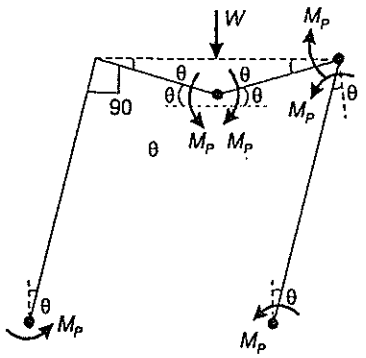
Beam mechanism



$$-M_P\theta - M_P\theta - M_P\theta - M_P\theta + Wa\theta = 0$$

$$\Rightarrow \quad W = \frac{4M_P}{a}$$

Combined mechanism



$$-M_P\theta - M_P\theta - M_P\theta - M_P\theta - M_P\theta - M_P\theta + W\times 2a\theta - Wa\theta = 0$$

$$\Rightarrow \quad 3Wa\theta = 6M_P\theta$$

$$\Rightarrow \quad W = \frac{2M_P}{a}$$

The collapse load given by combined mechanism is minimum, hence it is the ultimate load for the frame.

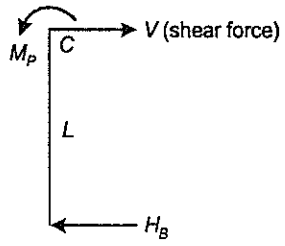
6.73 (a)

For the complete collapse of the portal frame two plastic hinges are required.

$\therefore$ Number of plastic hinges $= r + 1$

$$= (4 - 3) + 1 = 2$$

Let the two plastic hinges be formed under the load W and at the right hand rigid joint above B. Let horizontal reaction at A and B be $H_A(\leftarrow)$ and $H_B(\leftarrow)$ respectively. Considering equilibrium of right hand column at collapse, we get



$$\Sigma M_C = 0$$

$$\Rightarrow \quad H_B \times L - M_P = 0$$

$$\Rightarrow \quad H_B = \frac{M_P}{L} \qquad \left[\because M_P = \frac{WL}{5}\right]$$

$$\Rightarrow \quad H_B = \frac{WL}{5L}$$

$$\Rightarrow \quad H_B = 0.2W$$

But, we have

$$H_A + H_B = 0.2W$$

$$\Rightarrow \quad H_A = 0.2W - 0.2W$$

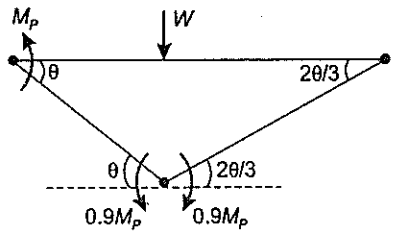
$$\Rightarrow \quad H_A = 0$$

6.74 (c)

Total number of plastic hinges needed for complete collapse of the beam may be given as

Number of plastic hinges

$$= r + 1 = (3 - 2) + 1 = 2$$



By principle of virtual work, we get

$$-M_P\theta - 0.9\,M_P\theta - 0.9\,M_P \times \frac{2\theta}{3} + W \times \theta \times 2 = 0$$

$$\Rightarrow M_P\theta + 0.9M_P\left(\theta + \frac{2\theta}{3}\right) = W \times 2\theta$$

6.75 (b)

Length of plastic hinge of beam depends upon span of beam, type of loading and shape of cross-section i.e. shape factor.

6.76 (b)

The number of plastic hinges required to make an indeterminate beam determinate is R where R is the degree of redundancy. However, for the complete collapse of the beam $(R + 1)$ plastic hinges will be required.

6.77 (c)

This is combined mechanism of beam and sway mechanism.

6.78 (d)

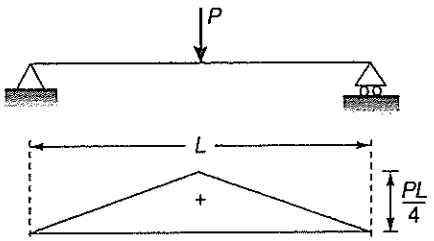
Ductility is defined as the ability of a material to deform easily upon the application of a tensile force, or as the ability of a material to withstand plastic deformation without rupture. This property enables plastic analysis of structures.

6.79 (b)

Shape factor for various sections:
Rectangular- 1.5
I-section- 1.1 to 1.2
Circular- 1.7
Diamond- 2
Triangular-2.343

6.80 (d)

The simply supported beam is a determinate one, hence one plastic hinge will be required for its complete collapse. This plastic hinge will be



formed under the load. Hence the maximum bending moment can at the most reach to the plastic moment M_P.

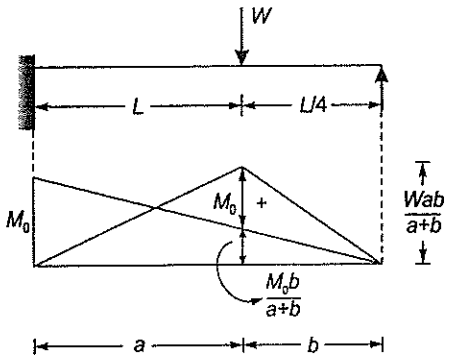
$$\therefore \quad M_P = \frac{PL}{4} \quad \Rightarrow \quad P = \frac{4M_P}{L}$$

6.82 (c)

Number of plastic hinges required for complete collapse $= r + 1$

$$= (3 - 2) + 1 = 2$$

The plastic hinges will be formed under the load and at the fixed end of the beam respectively.



But $a = L$ and $b = L/4$

$$\therefore \quad \frac{Wab}{a+b} = M_0 + \frac{M_0 b}{a+b}$$

$$\Rightarrow \quad \frac{W \times L \times L/4}{L + L/4} = M_0 + \frac{M_0 \times L/4}{L + L/4}$$

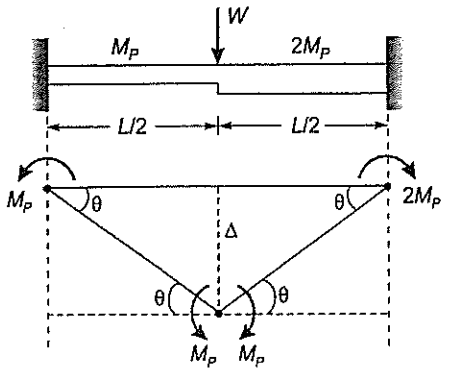
$$\Rightarrow \quad \frac{WL^2}{4} = \frac{5M_0 L}{4} + \frac{M_0 L}{4}$$

$$\Rightarrow \quad W = \frac{6M_0}{L}$$

6.83 (c)

Number of plastic hinges required for complete collapse $= r + 1$

$$= (4 - 2) + 1 = 3$$



By principle of virtual work, we have

$$-M_P\theta - M_P\theta - M_P\theta - 2M_P\theta + W \times \Delta = 0$$

$$\Rightarrow \quad W \times \frac{L}{2} \times \theta = 5M_P\theta$$

$$\Rightarrow \qquad W = \frac{10M_P}{L}$$

6.84 (a)

The collapse load for a prismatic beam fixed at both ends and caries UDL throughout the span is given by

$$W_u = \frac{16M_P}{L^2} \qquad ...(i)$$

where M_P is its plastic moment

But $$S = \frac{\text{Plastic moment}}{\text{Yield moment}}$$

$$\Rightarrow \qquad S = \frac{M_P}{M_y} \qquad ...(ii)$$

Also $$M_y = \frac{w_y L^2}{12} \qquad ...(iii)$$

Substituting value of S from (ii) in (iii), we get

$$\frac{M_P}{S} = \frac{w_y L^2}{12}$$

Substituting value of M_P from (i), we get

$$\frac{w_u L^2}{16S} = \frac{w_y L^2}{12}$$

$$\Rightarrow \qquad \frac{w_u}{w_y} = \frac{4}{3}S$$

6.85 (d)

Plastic neutral axis divides the total cross-section area into two equal parts

Total area, $A = 100 \times 20 + 100 \times 20$

$= 4000\,m^2$

$$\therefore \qquad \frac{A}{2} = \frac{4000}{2} = 2000\ mm^2$$

Thus the plastic neutral axis lies at the junction of flange and web.

Elastic neutral axis divides the cross-section in such a way that the cross-section does not have any stress at neutral axis level.

Let the depth of neutral axis from the top be y.

$$y = \frac{100\times20\times10 + 20\times100\times70}{100\times20 + 20\times100}$$

$$y = \frac{160000}{4000} = 40\ mm$$

$\therefore$ Distance between elastic neutral axis and plastic neutral axis

$= 40 - 20 = 20$ mm

6.86 (a)

Length of elasto-plastic zone

$$l_e = L\left(1-\frac{1}{f}\right)$$

f = shape factor $= \frac{3}{2}$

$$l_e = L\left(1-\frac{2}{3}\right)$$

$$l_e = \frac{L}{3}$$

6.87 (b)

Total area, $A = 400 \times 100 + 100 \times 500$

$= 90000\ mm^2$

$$\therefore \qquad \frac{A}{2} = \frac{90000}{2} = 45000 mm^2$$

Thus the plastic neutral axis lies outside the flange because the flange area is only 40000 mm^2.

Let the plastic neutral axis lies y mm below the junction of flange and web.

$\therefore \quad y \times 100 = 45000 - 40000$

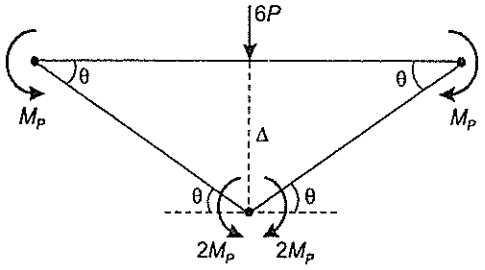
$\Rightarrow \qquad y = 50$ mm

$\therefore$ Plastic neutral axis as measured from top of flange = $100 + y$

$= 100 + 50 = 150$ mm

6.88 (b)

Beam mechanism will occur in span BC



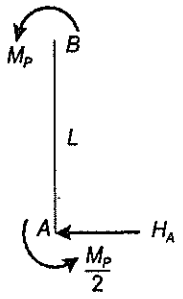
By principle of virtual work, we have

$M_P\theta + 2M_P(\theta + \theta) + M_P\theta = 6P \times L \times \theta$

$$\Rightarrow \qquad P = \frac{M_P}{L}$$

At the time of collapse, hinge will form at B, C and at centre of BC. Only 50% moment of joint B or C will transfer to A or D respectively.

FBD of column AB



Taking moments about B

$\therefore \quad H_A \times L = M_P + M_P/2 \qquad [\because M_P = PL]$

$\Rightarrow \quad H_A \times L = 3PL/2$

$\Rightarrow \quad H_A = 1.5P$

6.89 (d)

There will be three slope changes:-

(i) At nearer end of loading point

(ii) At the other support

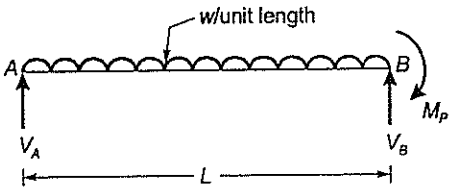
(iii) At loading point

6.90 (b)

At the location of plastic hinge the curvature is infinite as full cross section plasticity associated with plastic moment capacity of a section is reached.

6.91 (a)

Considering span AB of the continuous beam



Plastic moment capacity of the span is given by

$$M_P = \frac{wL^2}{11.656}$$

Taking moments about B, we get

$$V_A \times L - \frac{wL^2}{2} + M_P = 0$$

$$\Rightarrow \quad V_A \times L = \frac{wL^2}{2} - \frac{wL^2}{11.656}$$

$$\Rightarrow \quad V_A = \frac{0.414\, wL \times 12}{5} \times \frac{5}{12}$$

$$\Rightarrow \quad V_A = \frac{5wL}{12}$$

6.92 (b, c)

The length of plastic hinge depends on:

- Type of loading
- Length of beam
- Shape factor

Hence both option b and c are correct.

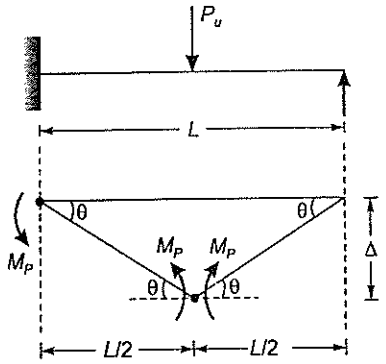
6.93 (c)

Number of possible hinges, $n = 2$

Statical indeterminacy, $r = 1$

$\therefore$ Number of independent mechanisms,

$$i = n - r = 2 - 1 = 1$$



Let the deflection under the load be Δ.

Using principle of virtual work, we get

$$P_u \times \Delta - M_P\theta - M_P\theta - M_P\theta = 0$$

$$\Rightarrow P_u \times \frac{L}{2} \times \theta = 3M_P\theta$$

$$\Rightarrow \quad P_u = \frac{6M_P}{L}$$

6.94 (b)

We know that in plastic analysis, the neutral axis divides the total area into two equal parts.

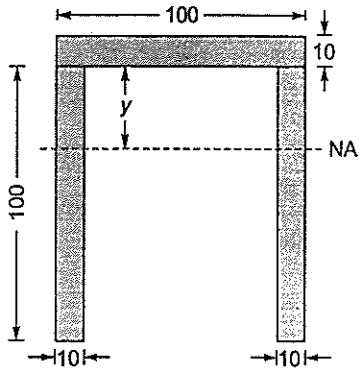
Total area of hat section is given as

$A = 100 \times 10 + 100 \times 10 + 100 \times 10 = 3000$

$\therefore$ Half of the total area i.e.

$$\frac{A}{2} = \frac{3000}{2} = 1500$$

Thus we find that half of the total area (1500) is greater than the area of horizontal strip ($100 \times 100 = 1000$). It means that the neutral axis will be somewhere in the vertical strips.



Let the neutral axis lies at a distance y from the bottom of horizontal strip, then

$$2 \times 10 \times y = 1500 - 1000$$

$$\Rightarrow \quad y = \frac{500}{20} = 25$$

But plastic section modulus is given by

$$Z_P = A_t y_t + A_c y_c$$

$$= \left[100 \times 10 \times (25+5) + 10 \times 25 \times \frac{25}{2} \times 2\right]$$

$$+ \left[10 \times (100-25) \times \frac{75}{2} \times 2\right]$$

$$= 30 \times 10^3 + 6250 + 56250$$

$$= 92.5 \times 10^3$$

Plastic moment capacity is given by

$$M_P = Z_P \times \sigma_y = 92.5 \times 10^3 \sigma_y$$

The most close option is (b)

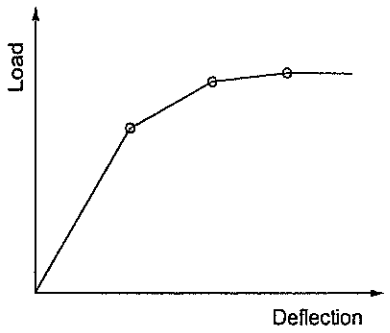
6.95 (d)

The fundamental conditions for plastic analysis:

- Equilibrium condition: Summation of moments and forces acting on structure must be zero.
- Plastic moment condition: Bending moment must not exceed fully plastic moment anywhere.
- Mechanism condition: The number of plastic hinges must be just enough to form a mechanism at ultimate collapse load.

6.96 (d)

Load deflection characteristic of a fixed beam subject to uniformly distributed load is as shown:



6.97 (a)

$$\frac{\text{Plastic moment}}{\text{Yield moment}} = \frac{Z_p}{Z_e} = \text{Shape factor}$$

Shape factor of circular hollow section(=1.27) is more than shape factor of rectangular hollow section (1.12). Thus both assertion and reason are true.

6.98 (c)

A plastic hinge is a zone of yielding due to flexure in a structural member. Although hinges do not actually form, it can be seen that large changes of slope occur over small lengths of the member at positions of maximum moments.

The strain hardening action usually occurs at these hinges so that large deflections are accompanied by a slight increase in loads. A structure can support the computed ultimate load due to the formation of plastic hinges at certain critical sections. The members remain elastic until the moment reaches a value M_p, the maximum moment of resistance of a fully yielded cross-section.

The plastic hinges are yielded zone due to flexure in a structure in which infinite rotation can take place at a constant restraining moment M_p of the section.

6.99 (a)

Section	M_P / M_y = Shape factor
Square	1.5
Rectangular	1.5
Triangle	2.3
Circle	1.7
T – section	1.8
Diamond	2

6.100 (d)

The principle of virtual work may be stated as follows:

If a system of forces in equilibrium is subjected to a **virtual displacement**, the work done by the external forces equals the work done by the internal forces, i.e.

$$W_E = W_i$$

6.101 (a)

In the elastic method of design the conditions to be satisfied are the equilibrium condition, the compatibility condition and the moment curvature relation. The conditions to be satisfied for the plastic methods of analysis are as follows:

1. Equilibrium condition: All the equilibrium conditions, i.e. summation of all the forces and moments should be equal to zero.
2. Mechanism condition: The structure at collapse must be capable of deforming as a mechanism due to the formation of plastic hinges, i.e. the ultimate load is reached when a mechanism forms. This is also called the continuity condition.
3. Yield Condition: This is also called plastic moment condition. The bending moment at any section must not exceed the full plastic moment of the section ($M \leq M_p$).

6.102 (d)

Load factor = Shape factor × FOS

$$\text{FOS} = \frac{\text{Allowable load}}{\text{Working load}}$$

FOS after increase in allowable stress

$$= \frac{1.5}{1.2} = 1.25$$

$\therefore$ Load factor = 1.12 × 1.25 = 1.4

6.103 (b)

Lower bound theorem (also called Static theorem or Safe theorem): It states that if a distribution of bending moments can be found such that the structure is in equilibrium condition under the external load and the applied moment does not exceed the plastic moment of resistance any where in the structure ($M \leq M_p$) then the structure will not collapse.

Upper bound theorem (also called Kinematic or unsafe theorem): It states that for a structure subjected to a given loading, the magnitude of the loading which is found corresponding to any assumed collapse mechanism must be either greater than or equal to, but cannot be less than, the true collapse load.

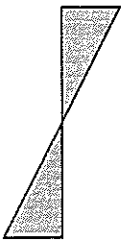
6.104 (a)

Load factor = FOS × Shape factor.

6.106 (a)

At the location of plastic hinge

Strain distribution =



Stress distribution =

6.107 (b)

The number of plastic hinges required to form a mechanism is one more than the redundancy.

6.108 (a)

The hinge length of the plasticity zone is equal to 1/3rd of the span.

The hinge length of the plasticity zone for a simple beam subjected to uniformly distributed load is $\frac{L}{\sqrt{3}}$.

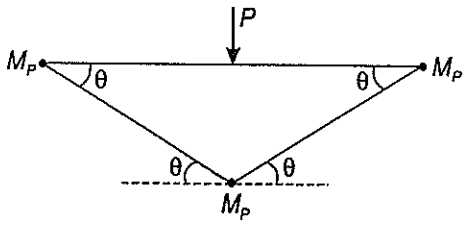
But the question has asked only about the location of the plastic hinge, that occurs under the concentrated load, therefore (a).

6.109 (d)

The upper bound theorem is based on mechanism condition according to which at ultimate collapse load the number of plastic hinges must be just enough to form a mechanism. It is also called kinematic theorem. The lower bound theorem is based on equilibrium condition also called static theorem.

6.110 (b)

Number of plastic hinges needed are $r + 1 = 3$



$$M_P\theta + M_P(2\theta) + M_P(\theta) = \frac{PL\theta}{2}$$

$$\therefore \quad P = \frac{8M_P}{L}$$

$$\Rightarrow \quad M_P = \frac{PL}{8}$$

6.111 (c)

A structure with indetermancy 'r' will become determinate by introduction of 'r' hinges. Any additional hinge will lead to collapse of structure i.e. $(r + 1)$ hinges required.

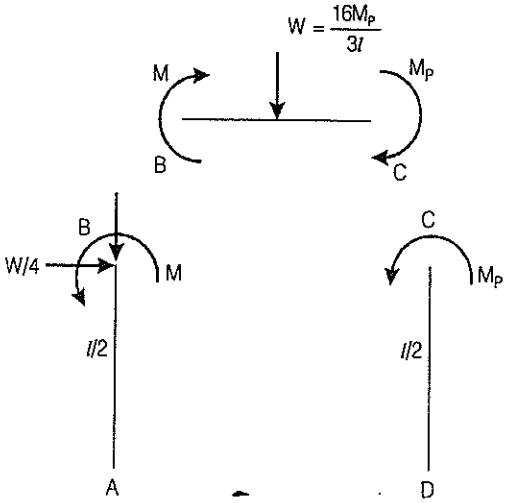
6.112 (c)

$$\text{Plastic hinge length} = l\left(1-\frac{1}{S.F.}\right)$$

For simply supported beam loaded at mid-span

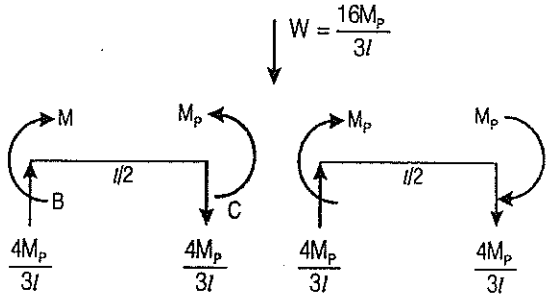
$$= l\left(1-\frac{1}{5/3}\right) = 0.4\,l$$

6.113 (a)



From FBD of BC

$$W = \frac{16M_P}{3l}$$



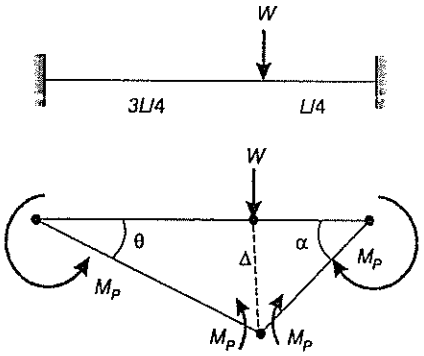
$$\Rightarrow \quad \frac{M_P - M}{l/2} = \frac{4M_P}{3l}$$

$$\Rightarrow \quad M_P - M = \frac{2M_P}{3}$$

$$\Rightarrow \quad M = M_P - \frac{2M_P}{3} = \frac{M_P}{3}$$

$$\Rightarrow \quad M = \frac{3WL}{16\times 3} = \frac{WL}{16}$$

6.114 (c)



$$\Delta = \frac{3L}{4}\theta = \frac{L}{4}\cdot\alpha$$

$$\alpha = 3\theta$$

By virtual work principle,

$$W\cdot\Delta = M_P(\theta + \theta + \alpha + \alpha)$$

$$W = \frac{32M_P}{3L}$$

6.115 (c)

$$Z_p = 4.8\times 10^{-4}\ \text{m}^3$$

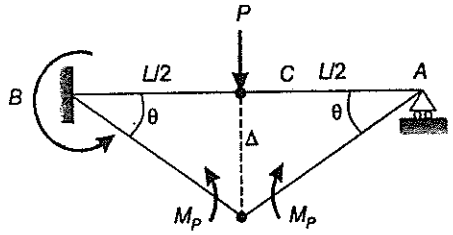
$$\text{S.F.} = 1.2$$

$$M_p = 120\ \text{kN-m}$$

$$M_p = f_y Z_p$$

$$\Rightarrow \quad f_y = \frac{120\times 10^6\ \text{N-mm}}{4.8\times 10^{-4}\times 10^9\ \text{mm}^3} = 250\ \text{MPa}$$

6.116 (b)



By principle of virtual work,

$$P \cdot \Delta = M_P(\theta + \theta + \theta)$$

$$\therefore \quad P \cdot \frac{L}{2} \cdot \theta = M_P(3\theta)$$

$$\therefore \quad P = \frac{6M_P}{L}$$

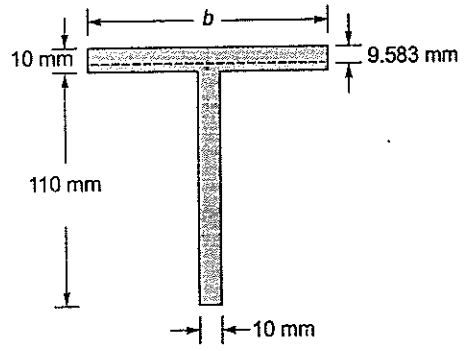
6.117 (c)

Plastic NA divides the section into equal areas.

Hence,

$$\Rightarrow 9.583 \times b = (10 - 9.583) \times b + 10 \times 110$$

$$\Rightarrow \quad b = 120 \text{ mm}$$



6.118 (a)

Shape factor for various sections:

Rectangular- 1.5

I-section- 1.1 to 1.2

Circular- 1.7

Diamond- 2

Triangular-2.343

6.119 (c)

$$\text{Shape factor} = \frac{Z_p}{Z_e}$$

Z_p = Plastic section modulus

Z_e = Elastic section modulus

Shape factor is always > 1

6.120 (a)

It is not necessary that plastic neutral axis lies on the centroidal axis of the section, for example T-section can be analysed.

6.121 (d)

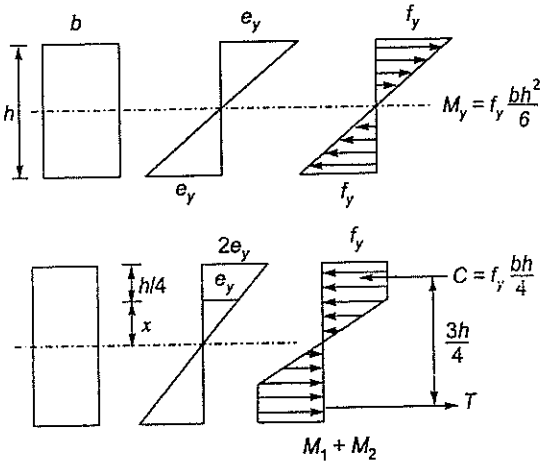
$$M_P = f_y \cdot \frac{A}{2}(\bar{y}_1 + \bar{y}_2)$$

M_P depends on area and the distribution of area of c/s.

6.122 (a)

Ultimate moment capacity and plastic moment capacity are one and the same thing.

6.123 (c)



$$\frac{x}{e_y} = \frac{h/2}{2e_y}$$

$$\Rightarrow \quad x = \frac{h}{4}$$

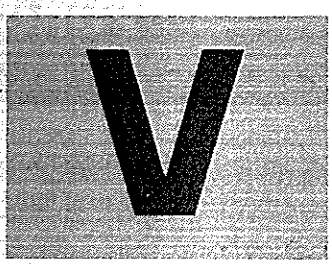
$$M_y = f_y \frac{bh^2}{6}$$

$$M = M_1 + M_2 = \left[f_y \frac{b\left(\frac{h}{2}\right)^2}{6}\right] + \left[f_y \frac{bh}{4}\left(\frac{3h}{4}\right)\right]$$

$$M = \frac{11}{48} bh^2 f_y$$

$$\text{So, } M = \frac{\frac{11bh^2}{48} f_y}{\left(f_y \frac{bh^2}{6}\right)} = \frac{11}{8} M_y = 1.375 M_y$$

UNIT



Design of Concrete & Masonry Structures

Syllabus

Limit state design for bending, shear, axial compression and combined forces; Design of beams, Slabs, Lintels, Foundations, Retaining walls, Tanks, Staircases; Principles of pre-stressed concrete design including materials and methods; Earthquake resistant design of structures; Design of Masonry Structure.

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OOOO

1 Fundamentals of RCC

1.1 Consider the following statements concerning both the working stress design and ultimate strength design of reinforced concrete:

1. Plane section before bending remains plane after bending
2. The tensile strength of concrete is ignored.

Which of these statements is/are correct?

(a) 1 alone (b) 2 alone
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 1995]

1.2 If f_{cu} and f_y are cube compressive strength of concrete and yield stress of steel respectively and E_s is the modulus of elasticity of steel for all grades of concrete, the ultimate flexural strain in concrete can be taken as

(a) 0.002 (b) $\frac{f_{cu}}{1000}$

(c) 0.0035 (d) $\frac{f_y}{1.15E_s} + 0.002$

[ESE : 1995]

1.3 Limit state of serviceability for deflection including the effects due to creep, shrinkage and temperature occurring after erection of partitions and application of finishes as applicable to floors and roofs is restricted to

(a) $\frac{\text{Span}}{150}$ (b) $\frac{\text{Span}}{200}$

(c) $\frac{\text{Span}}{250}$ (d) $\frac{\text{Span}}{350}$

[ESE : 1995]

1.4 In case of a composite construction, the effect of creep and shrinkage

(a) can be ignored even at the limit state of serviceability
(b) can be ignored at the ultimate limit state due to large inelastic strains induced
(c) can be completely eliminated if the props are removed after 28 days
(d) in the in-situ concrete has no interaction on the stresses in the pre-cast component at any stage

[ESE : 1995]

1.5 The maximum strain in concrete at the outermost compression fiber in the limit state design of flexural member is (as per IS:456-1978)

(a) 0.0020 (b) 0.0035
(c) 0.0065 (d) 0.0050

[ESE : 1996]

1.6 Deflection can be controlled by using the appropriate

(a) aspect ratio
(b) modular ratio
(c) span/depth ratio
(d) water/cement ratio

[ESE : 1996]

1.7 In limit state approach, spacing of main reinforcement controls primarily

(a) collapse (b) cracking
(c) deflection (d) durability

[ESE : 1996]

1.8 Unequal top and bottom reinforcement in a reinforced concrete section leads to

(a) creep deflection
(b) shrinkage deflection
(c) long-term deflection
(d) large deflection

[ESE : 1996]

1.9 The final deflection due to all loads including the effects of temperature, creep and shrinkage and measured from as cast level of supports of floors, roofs and all other horizontal members should NOT exceed

(a) span/350 (b) span/300
(c) span/250 (d) span/200

[ESE : 1997]

1.10 High yield deformed bars have a
(a) definite yield value
(b) chemical composition different from mild steel
(c) percentage elongation less than that of mild steel
(d) percentage elongation more than that of mild steel

[ESE : 1998]

1.11 The limiting compressive strain of concrete in bending is
(a) 0.0035 (b) 0.0015
(c) 0.0025 (d) 0.015

[ESE : 1998]

1.12 When assessing the strength of a structure as per the limit state of collapse, the value of partial safety factor for steel is taken as
(a) 2.0 (b) 1.5
(c) 1.15 (d) 1.00

[ESE : 1998]

1.13 Combination of partial safety factors for loads under limit state of collapse and limit state of serviceability will be
(a) 1.5 ($DL + LL$) or 1.5 ($DL + WL$) or 1.2 ($DL + LL + WL$) and $DL + 0.8\ (LL + WL)$
(b) 1.5 ($DL + LL$) and $DL + 0.8\ (LL + WL)$
(c) 1.5 ($DL + LL$) or 1.5 ($DL + WL$) or 1.2 ($DL + LL + WL$) and 1.0 ($DL + LL$) or 1.0 ($DL + WL$) or $DL + 0.8\ (LL + WL)$
(d) 1.2 ($DL + LL + WL$) and 1.0 ($DL + LL$) or 1.0 ($DL + WL$) or $DL + 0.8\ (LL + WL)$

[ESE : 1998]

1.14 The assumption that the plane sections normal before bending remain normal after bending is used
(a) only in the working stress method of design
(b) only in the limit-state method of design
(c) in both working stress and limit-state methods of design
(d) only in the ultimate load method of design

[ESE : 1998]

1.15 In the limit state method of design, the failure criterion for reinforced concrete beams and columns is
(a) maximum principal stress theory
(b) maximum principal strain theory
(c) maximum shear stress theory
(d) maximum strain energy theory

[ESE : 1998]

1.16 As per IS:456-1978, the ratio of stress in concrete to its characteristic strength at collapse in flexure for design purposes is taken as
(a) 0.67 (b) 0.576
(c) 0.447 (d) 0.138

[ESE : 1999]

1.17 In limit state design of reinforced concrete, deflection is computed by using
(a) initial tangent modulus
(b) secant modulus
(c) tangent modulus
(d) short-and long-term values of Young's modulus

[ESE : 1999]

1.18 If modular ratio is 'm', effective depth is D and stress ratio is 'r' $\left(r = \frac{\sigma_{st}}{\sigma_{cbc}}\right)$, the depth of neutral axis of a balanced section is

(a) $\left(\frac{m}{m-r}\right) \times D$ (b) $\left(\frac{m}{m+r}\right) \times D$

(c) $\left(\frac{m+r}{m}\right) \times D$ (d) $\left(\frac{m}{r}\right) \times D$

[ESE : 2000]

1.19 Partial safety factor for concrete and steel are 1.5 and 1.15 respectively, because
(a) concrete is heterogeneous while steel is homogeneous
(b) the control on the quality of concrete is not as good as that of steel
(c) concrete is weak in tension
(d) voids in concrete are 0.5% while those in steel are 0.15%

[ESE : 2000]

1.20 As compared to working stress method of design, limit state method takes concrete to
(a) a higher stress level
(b) a lower stress level
(c) the same stress level
(d) sometimes higher but generally lower stress level

[ESE : 2000]

1.21 The design for the limit state of collapse in flexure is based on the following assumptions:
1. Plane sections normal to the axis remain plane after bending
2. The maximum strain in concrete at the outermost tension fibre is 0.0035.
3. The relationship between the compressive stress distribution in concrete and the strain in concrete may be assumed to be rectangular, trapezoidal, parabolic or any other shape which results in prediction of strength in substantial agreement with the results of tests.

Select the correct answer using the codes given below :
(a) 1 and 3 (b) 1, 2 and 3
(c) 2 and 3 (d) 1 and 2

[ESE : 2001]

1.22 The probability of failure implied in limit state design is of the order of
(a) 10^{-2} (b) 10^{-3}
(c) 10^{-4} (d) 10^{-5}

[ESE : 2001]

1.23 If σ_{cbc} is permissible compressive stress in flexural compression in N/mm^2 in service, the modular ratio is of the order of
(a) $\frac{280}{3\sigma_{cbc}}$ (b) $\frac{280}{4\sigma_{cbc}}$
(c) 19 (d) 13

[ESE : 2002]

1.24 The stresses in concrete in a reinforced concrete element under sustained load due to creep
(a) increase with time
(b) decrease with time
(c) remain unchanged
(d) fluctuate

[ESE : 2003]

1.25 Consider the following statements:
Under-reinforced concrete flexural members
1. are deeper
2. are stiffer
3. can undergo larger deflection

Which of these statements is/are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 only (d) 1 and 3

[ESE : 2003]

1.26 Long term elastic modulus in terms of creep coefficient (θ) and 28-day characteristic strength (f_{ck}) is given by
(a) $\frac{5000\sqrt{f_{ck}}}{1+\theta}$ MPa (b) $\frac{50000\sqrt{f_{ck}}}{1+\theta}$ MPa
(c) $\frac{5000 f_{ck}}{1+\sqrt{\theta}}$ MPa (d) $\frac{5000\sqrt{f_{ck}}}{\sqrt{1+\theta}}$ MPa

[ESE : 2003]

1.27 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I	List-II
A. Serviceability	1. Sliding
B. Shear key	2. Deflection
C. Shrinkage	3. Cracking
D. Concrete spalling	4. Corrosion

Codes:

	A	B	C	D
(a)	1	3	4	2
(b)	2	1	3	4
(c)	1	3	2	4
(d)	2	1	4	3

[ESE : 2003]

1.28 The characteristic strength of concrete is
(a) higher than the average cube strength
(b) lower than the average cube strength
(c) the same as the average cube strength
(d) higher than 90% of the average cube strength

[ESE : 2004]

1.29 Assertion (A) : The stress block used in the limit state design method is obtained by testing of concrete cylinder under uniform rate of strain.
Reason (R) : If a uniform rate of strain is not adopted it is not possible to obtain the descending portion of stress and strain curve beyond maximum stress.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2004]

1.30 Consider the following statements:
1. The limit state of collapse is defined as the acceptable limit for the stresses in the materials.
2. Limit state method is one that ensures adequate safety of structure against collapse.
3. In the limit state design method, actual stresses developed at collapse differ considerably from the theoretical values.

Which of these statements is/are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) None

[ESE : 2004]

1.31 Which one of the following sections performs better on the ductility criterion?
(a) Balanced section
(b) Over-reinforced section
(c) Under-reinforced section
(d) Non-prismatic section

[ESE : 2005]

1.32 What should be the minimum grade of reinforced concrete in and around sea coast construction?
(a) M 35 (b) M 30
(c) M 25 (d) M 20

[ESE : 2005]

1.33 What is the value of flexural strength of M 25 concrete?
(a) 4.0 MPa (b) 3.5 MPa
(c) 3.0 MPa (d) 1.75 MPa

[ESE : 2005]

1.34 The maximum strain in the tension reinforcement in the section at failure when designed for the limit state of collapse should be

(a) $> \left(\frac{f_y}{1.15E_s} + 0.002\right)$

(b) $< \left(\frac{f_y}{1.15E_s} + 0.002\right)$

(c) exactly equal to $\left(\frac{f_y}{1.15E_s} + 0.002\right)$

(d) < 0.002

where, f_y = Characteristic strength of steel, and
E_s = Modulus of elasticity of steel

[ESE : 2006]

1.35 As per IS 456-2000, which one of the following correctly expresses the modulus of elasticity of concrete? (read with the relevant units)
(a) $E_c = 0.7\sqrt{f_{ck}}$ (b) $E_c = 500\sqrt{f_{ck}}$
(c) $E_c = 5000\sqrt{f_{ck}}$ (d) $E_c = 5700\sqrt{f_{ck}}$

[ESE : 2006]

1.36 Characteristic strength of M20 concrete is 20 MPa. What is the number of cubes having 28 days' compressive strength greater than 20 MPa out of 100 cubes made with this concrete?
(a) All (b) 95
(c) 80 (d) 50

[ESE : 2006]

1.37 The final deflection due to all including effects of temperature, creep and shrinkage measured from as – cast level of the supports of floors, roofs and all other horizontal members of reinforced concrete should not normally exceed
(a) Span/350
(b) Span/250
(c) (Span/350) or 20 mm whichever is less
(d) (5/348) of span

[ESE : 2006]

1.38 Which one of the following predicts the effective modulus of elasticity of concrete?

(a) $\frac{E_c}{1+\theta}$ (b) $\frac{E_c}{1+2\theta}$

(c) $\frac{E_c}{1+3\theta}$ (d) $\frac{E_c}{1+5\theta}$

where E_c is short-term elastic modulus and θ is the ultimate creep coefficient

[ESE : 2007]

1.39 Working stress method of design for reinforced concrete is
(a) not a limit state design
(b) a serviceability limit state design

(c) a limit state for crack width
(d) a collapse limit state

[ESE : 2007]

1.40 Consider the following statements:
1. In reinforced cement concrete, modular ratio is defined by the ratio (modulus of elasticity of steel)/(Modulus of elasticity of concrete).
2. Modulus of rupture of cement concrete is a function of its characteristic compressive strength.
3. The characteristic compressive strength of M 20 grade cement concrete at 7 days is $20N/mm^2$.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

[ESE : 2008]

1.41 At what stress does the first flexural crack appear in RCC beams made of M25 grade concrete?
(a) 3.0 MPa (b) 3.5 MPa
(c) 4.0 MPa (d) 4.5 MPa

[ESE : 2009]

1.42 What is the modular ratio to be used in the analysis of RC beams using working stress method if the grade of concrete is M20 ?
(a) 18.6 (b) 13.3
(c) 9.9 (d) 6.5

[ESE : 2009]

1.43 Considering modular ratio as 13, grade of concrete as M20 and grade of steel as 415, what is the ratio of balanced depth of neutral axis as per working stress method to the balanced depth of neutral axis as per limit state method ?
(a) $\frac{12}{7}$ (b) $\frac{11}{3}$
(c) $\frac{7}{12}$ (d) $\frac{3}{11}$

[ESE : 2009]

1.44 Modulus of elasticity of concrete is increased with
(a) Higher W/C ratio
(b) Shorter curing period
(c) Lesser vibration
(d) Increase in age

[ESE : 2011]

1.45 Stress-strain curve of concrete is
(a) A perfect straight line upto failure
(b) Straight line upto 0.002 strain value and then parabolic upto failure.
(c) Nearly parabolic upto 0.002 strain value and then a straight line upto failure
(d) Hyperbolic upto 0.002 strain value and then a straight line upto failure

[ESE : 2011]

1.46 Which of the following statements refer to correct purposes as regards testing of concrete by ultrasonic pulse velocity method?
1. To assess the quality of concrete in-situ.
2. To determine the dynamic modulus of elasticity of concrete.
3. To locate the presence of cracks in it.

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2011]

1.47 In limit state approach, spacing of main reinforcement controls primarily
(a) Cracking (b) Deflection
(c) Durability (d) Collapse

[ESE : 2011]

1.48 In a R.C. section under flexure, the assumption that "a plane section before bending remains plane after bending" leads to
(a) Strain distribution being linear across the depth
(b) Stress distribution being linear across the depth
(c) Both stress and strain distribution being linear across the depth
(d) Shear stress distribution being uniform along the depth

[ESE : 2011]

1.49 Consider the following statements:
1. Modulus of elasticity of concrete increases with the increase in compressive strength of concrete.
2. Shear strength of concrete increases with the increase in compressive strength of concrete.

Which of these statements is/are correct?
(a) Neither 1 nor 2 (b) Both 1 and 2
(c) 1 only (d) 2 only

[ESE : 2012]

1.50 Grade of steel is designated as Fe 415, if
(a) the upper yield stress of the steel is 415 N/mm^2
(b) the ultimate stress of the steel is 415 N/mm^2
(c) the partial safety factor is 1.15
(d) the characteristic strength is 415 N/mm^2
[ESE : 2012]

1.51 The additional cover thickness to be provided in reinforced concrete members that are totally immersed in seawater is
(a) 25 mm (b) 30 mm
(c) 35 mm (d) 40 mm
[ESE : 2012]

1.52 The minimum grade of reinforced concrete in seawater as per IS 456-2000 is
(a) M 15 (b) M 20
(c) M 30 (d) M 40
[ESE : 2012]

1.53 Which one of the following states falls under the 'Limit state of Serviceability' as per IS-456?
(a) Stability under load
(b) Loss for equilibrium of a structure
(c) Floor vibration
(d) Formation of mechanism
[ESE : 2013]

1.54 Factor of safety is the ratio of
(a) tensile stress to working stress
(b) compressive stress to working stress
(c) bending stress to working stress
(d) yield stress to working stress
[ESE : 2013]

1.55 In a reinforced concrete section, the shape of the nominal shear stress diagram is
(a) parabolic over the full depth
(b) parabolic above the neutral axis and rectangular below the neutral axis
(c) rectangular over the full depth
(d) rectangular above the neutral axis and parabolic below the neutral axis
[ESE : 2014]

1.56 For a reinforced concrete beam with M 20 concrete with Fe 415 steel, the working moment corresponding to 'balanced failure' by the Limit State Method of Design is A times of the relatable magnitude of the working moment computed by the Working Stress Method. This value of A is nearly
(a) 1.0 (b) 1.5
(c) 2.0 (d) 2.5
[ESE : 2015]

1.57 What is the pH value of potable water, as specified by IS 456 : 2000?
(a) Equal to 7 (b) Between 6 and 9
(c) Less than 6 (d) Not less than 6
[ESE : 2015]

1.58 A certain RC structure has to be constructed along a sea coast. The minimum grade of concrete to be used as per IS 456 : 2000 is
(a) More than M 20
(b) More than M 20 and less than M 30
(c) Not less than M 30
(d) Less than M 45 and more than M 30
[ESE : 2015]

1.59 What is the minimum area of tension reinforcement in beams when Fe 415 is used?
(a) 0.8% (b) 0.12%
(c) 0.15% (d) 0.2%
[ESE : 2015]

1.60 The minimum strain at failure in tension steel having yield stress f_y = 415 MPa and Young's modulus E_s = 200 GPa, as per Limit State Method of Design, is
(a) 0.0025 (b) 0.0038
(c) 0.0045 (d) 0.0050
[ESE : 2015]

1.61 Consider the following statements:
1. Modulus of Elasticity of concrete increases with increase in compressive strength of concrete.
2. Brittleness of concrete increases with decrease in compressive strength of concrete.
3. Shear strength of concrete increases with increases in compressive strength of concrete.

Which of the above statements are correct?
(a) 1 and 2 only (b) 1, 2 and 3
(c) 1 and 3 only (d) 2 and 3 only
[ESE : 2015]

1.62 Consider the following cases in the design of reinforced concrete members in flexure:
1. Over-reinforced section
2. Tension failure
3. Compression failure
4. Under-reinforced section

Which of the above cases are considered for safe design of R.C. members in flexure?
(a) 1 and 2 only (b) 2 and 4 only
(c) 3 and 4 only (d) 1 and 3 only
[ESE : 2016]

1.63 The carbonation process is demonstrated more by
(a) Atmospheric corrosion
(b) Chloride corrosion
(c) Stress corrosion
(d) Hydrogen embrittlement
[ESE : 2016]

1.64 As compared to the working stress method of design, the limit state method of design premises that the concrete can admit
(a) A lower stress level
(b) A higher stress level
(c) Occasionally higher, but usually lower, stress level
(d) Only the same stress level
[ESE : 2016]

Answers Fundamentals of RCC

1.1 (c)	1.2 (c)	1.3 (d)	1.4 (b)	1.5 (b)	1.6 (c)	1.7 (b)	1.8 (b)	1.9 (c)	
1.10 (c)	1.11 (a)	1.12 (c)	1.13 (c)	1.14 (c)	1.15 (b)	1.16 (c)	1.17 (d)	1.18 (b)	
1.19 (b)	1.20 (a)	1.21 (a)	1.22 (a)	1.23 (a)	1.24 (b)	1.25 (a)	1.26 (a)	1.27 (b)	
1.28 (b)	1.29 (d)	1.30 (c)	1.31 (c)	1.32 (b)	1.33 (b)	1.34 (a)	1.35 (c)	1.36 (b)	
1.37 (b)	1.38 (a)	1.39 (a)	1.40 (b)	1.41 (b)	1.42 (b)	1.43 (c)	1.44 (d)	1.45 (c)	
1.46 (d)	1.47 (a)	1.48 (a)	1.49 (b)	1.50 (d)	1.51 (d)	1.52 (c)	1.53 (c)	1.54 (d)	
1.55 (c)	1.56 (c)	1.57 (d)	1.58 (c)	1.59 (d)	1.60 (b)	1.61 (c)	1.62 (b)	1.63 (a)	
1.64 (b)									

Explanations Fundamentals of RCC

1.1 (c)
Tensile stresses are taken by steel only and concrete takes compression only.

1.2 (c)
The strain in steel shall not be less than $\frac{f_y}{1.15E_s} + 0.002$ to ensure ductility and ultimate flexural strain in concrete is 0.0035.

1.3 (d)
The deflection shall generally be limited to the following:
(i) The final deflection due to all loads including the effects of temperature, creep and shrinkage and measured from the as-cast level of the support of floors, roofs and all other horizontal members shall not normally exceed span/250.
(ii) The deflection including the effects of temperature, creep and shrinkage occurring after the erection of partitions and the application of finishes should not normally exceed span/350 or 20 mm whichever is less.

1.4 (b)

Creep is elastic strain and partly recoverable. However in ultimate limit state both creep and shrinkage effects can be ignored due to plastic flow.

1.5 (b)

As per Clause 38.1(b) of IS 456 : 2000, Maximum strain at outermost compression fiber is taken as 0.0035.

1.6 (c)

As per Clause 23.2.1 of IS 456 : 2000, the vertical deflection limits may be controlled by limiting the span/depth ratio.

1.7 (b)

The code specifies minimum and maximum limits for the spacing between parallel reinforcing bars in a layer. The minimum limits are necessary to ensure that the concrete can be placed easily in between and around the bars during the placement of fresh concrete. The maximum limits are specified for bars in tension for the purpose of controlling crack-widths and improving bond.

1.8 (b)

When there is unequal top and bottom reinforcement in RC section, differential strains are induced across the cross-section with the location with having reinforcement shrinking more than locations with high reinforcement, leading to shrinkage deflection.

1.9 (c)

As per IS 456 : 2000 clause 23.2, Final deflection due to loads including effect of temperature, creep, shrinkage and measured from cast level of supports of floors, roofs and all other horizontal members should not exceed span/250.

1.10 (c)

Mild steel has definite yield point and the plastic strain may extend upto a strain of 0.15. Cold worked high strength deformed bars do not have a definite yield point and the characteristic strength refers to 0.2% proof stress. Their plastic strain is less than that of mild steel bars.

1.11 (a)

As per Clause 38.1(b) of IS 456 : 2000, Maximum strain at outermost compression fiber is taken as 0.0035.

1.12 (c)

Partial material safety factor

(i) for concrete 1.5

(ii) for steel 1.15

1.13 (c)

As per clause 18.2.3.1, 36.4.1 and B 4.3

Load combinations	Limit state of collapse			Limit state of serviceability (for short term effects only)		
	DL	IL	WL	DL	IL	WL
DL + IL	1.5		1.0	1.0	1.0	–
DL + WL	1.5 or 0.9		1.5	1.0	–	1.0
DL + IL + WL	1.2		1.2	1.0	0.8	0.8

1.14 (c)

The assumption that plane sections normal before bending remain plane after bending i.e the strain variation is linear and holds good for both working stress and limit state methods of design.

1.16 (c)

The compressive strength of concrete in the structure shall be assumed to be 0.67 times the characteristic strength. The partial safety factor of 1.5 shall be applied in addition to this.

Thus stress in concrete at collapse

$$= \frac{0.67}{1.5} f_{ck} = 0.447 f_{ck}$$

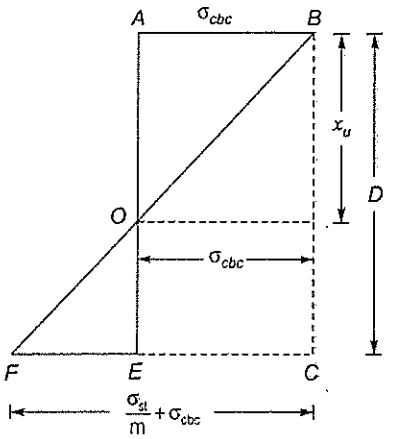
1.17 (d)

The short term deflections may be calculated using methods for elastic deflections using the short term modulus of elasticity of concrete E_c and effective moment of inertia.

For long term deflections, the long term modulus

$E_{ce} = \frac{E_c}{1+\theta}$ is used where θ is creep coefficient

1.18 (b)



From ΔOAB and ΔBFC

Depth of neutral axis,

$$x_u = \frac{\sigma_{cbc}}{\sigma_{cbc} + \frac{\sigma_{st}}{m}} D = \left(\frac{m}{m+r}\right) D$$

1.19 (b)

The partial safety factor for concrete (1.5) is higher than that of steel (1.15) because of higher variability associated with concrete i.e quality control of concrete is not as good as that of steel.

1.20 (a)

Limit state method takes concrete to higher stress level as compared to working stress method by taking into account non linear stress strain diagram.

1.21 (a)

As per limit state collapse in flexure IS 456 : 2000 (Clause 38.1). The maximum strain in concrete at outermost compression fibre is taken as 0.0035. Other two statements are true.

1.22 (a)

The structure may fail when

(i) the load exceeds the design load

(ii) the strength is less than the characteristic strength

(iii) both the load exceeds the design load and strength is less than the characteristic strength. The probability of load exceeding design load = 5%

The probability of strength less than characteristic strength = 5%.

The probability of failure is

$= 0.05 \times 0.95 + 0.05 \times 0.95 + 0.05 \times 0.05$

$= 0.0975$

Thus the order of failure is 10^{-2}.

1.24 (b)

The stresses in concrete under sustained load due to creep decrease with time because of stress relaxation.

1.25 (a)

The stiffness of a flexural member $\propto \frac{EI}{L}$.

For deeper section, the moment of inertia (I) will be more and so stiffness will also be more. Further for under reinforced sections $x_u < x_{u,max}$, means that less concrete under compression and therefore it requires deeper sections to resist a given moment.

$$M_r = Rbd^2$$

where $R < R_c$ (for balanced section)

1.26 (a)

Long term modulus of elasticity

$$= \frac{E_c}{1+\theta} = \frac{5000\sqrt{f_{ck}}}{(1+\theta)} \text{ MPa}$$

1.27 (b)

The shear key is provided in a retaining wall when it is not safe against sliding.

Spalling of concrete causes increase in volume of steel and thereby spalling of concrete.

1.28 (b)

Characteristic strength,

$$f_{ck} = f_{av} - 1.65\sigma$$

$$\therefore \quad f_{ck} < f_{av}$$

1.29 (d)

The stress-strain curve of concrete is obtained by testing of cubes under uniform rate of strain. Although it can also be conducted on cylindrical specimen.

The stress-strain curve for concrete (tested by cubes) is very complicated. The IS code has idealized it for design purposes. This is referred to as short term static design stress-strain curve of concrete.

In order to account for difference in strength indicated by a cube test and strength of concrete in structure is taken 0.67 times the characteristic strength. The partial safety factor of 1.5 is applied in addition to this.

1.30 (c)

Limit state design is based on the probabilistic concept. Thus the actual load and actual stresses may differ from the calculated load and calculated stresses. However the partial safety factor and load factor provided adequate safety to the structure against collapse.

1.31 (c)

Under reinforced section performs better on ductility criterion as the reinforcement yields prior

to failure giving sufficient warning by ensuring cracking in concrete before it fails in flexure.

1.32 (b)

Exposure	Minimum grade of plain concrete	Minimum grade of reinforced concrete
(i) Mild	–	M20
(ii) Moderate	M15	M25
(iii) Severe	M20	M30
(iv) Very severe	M20	M35
(v) Extreme	M25	M40

Concrete in sea water or exposed directly along the sea coast shall be at least *M*20 grade in the case of plain concrete and *M*30 in case of reinforced concrete. The use of slag or pozzolana cement is advantageous under such conditions.

1.33 (b)

As per **IS 456 : 2000** (clause 6.2.2)

Flexure strength of concrete

$$f_{cr} = 0.7\sqrt{f_{ck}} \text{ N/mm}^2$$
$$= 3.5 \text{ N/mm}^2$$

1.34 (a)

To ensure ductility the maximum strain in tension reinforcement in the section at failure shall not be less than $\frac{f_y}{1.15E_s} + 0.002$.

1.36 (b)

The characteristic strength is that below which not more than 5% of the test results are expected to fall. Thus 95% of cubes will have strength more than characteristic strength.

1.38 (a)

Effective modulus of concrete or long term young's modulus of elasticity

$$E_{CE} = \frac{E_c}{1+\theta}$$

1.39 (a)

WSM assumes that working stress does not exceed maximum permissible stress at any stage and concrete remains linear elastic up to collapse.

1.40 (b)

The characteristic compressive strength is measured at 28 days.

1.41 (b)

Flexural strength of concrete is given by

$$f_{cr} = 0.7\sqrt{f_{ck}} = 0.7\sqrt{25}$$
$$= 3.5 \text{ MPa}$$

1.42 (b)

As per **IS: 456-2000** modular ratio is given by

$$m = \frac{280}{3\sigma_{cbc}}$$

For *M*20 concrete $\sigma_{cbc} = 7 \text{ N/mm}^2$

$$\therefore \quad m = \frac{280}{3\times 7} = 13.3$$

1.43 (c)

As per working stress method balanced depth of neutral axis is given by

$$x_c = \left(\frac{mc}{t+mc}\right)\times d$$

For *M*20 concrete, $c = 7 \text{ N/mm}^2$ and for Fe 415, $t = 230 \text{ N/mm}^2$

$$\therefore \quad x_c = \left(\frac{13\times 7}{230+13\times 7}\right)\times d$$

$$\Rightarrow \quad x_c = 0.28\,d$$

As per limit state method, for Fe 415

$$x_{u,\text{lim}} = 0.48\,d$$

$$\therefore \quad \frac{x_c}{x_{u,\text{lim}}} = \frac{0.28d}{0.48d}$$

$$\Rightarrow \quad \frac{x_c}{x_{u,\text{lim}}} = \frac{7}{12}$$

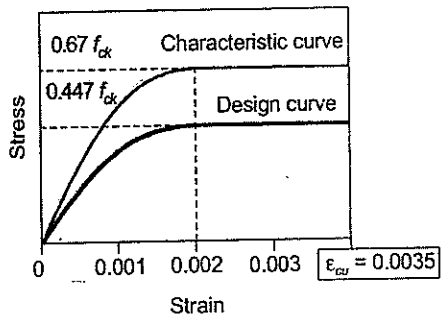
1.44 (d)

Modulus of elasticity of concrete is dependent on its compressive strength. Higher W/C ratio, shorter curing period or lesser vibration will produce concrete of lesser compressive strength. With increase in age compressive strength increases and therefore modulus of elasticity of concrete increases.

1.45 (c)

The charactristic and design stress–strain curves specified by the Code for concrete in flexural compression are depicted in Figure below. The maximum stress in the concrete in the structure is restricted to 0.67 f_{ck}. The curves consist of a

parabola in the initial region up to a strain of 0.002 (where the slope becomes zero), and a straight line thereafter, at a constant stress level up to an ultimate strain of 0.0035.



1.46 (d)

Ultrasonic pulse velocity test is an in-situ test of hardened concrete when it is already acting as a structural member.

This test is based on the principle that the velocity of sound in a solid material is a function of the square root of the ratio of its modulus of elasticity E to its density, ρ.

Higher the velocity of pulses greater is the strength of concrete.

1.47 (a)

The Code specifies minimum and maximum limits for the spacing between parallel reinforcing bars in a layer. The minimum limits are necessary to ensure that the concrete can be placed easily in between and around the bars during the placement of fresh concrete. The maximum limits are specified for bars in tension for the purpose of controlling crack-widths and improving bond.

1.48 (a)

Plane sections normal to the axis remain plane after bending, this assumption means that strain at any point on the cross-section is directly proportional to its distance from the neutral axis.

1.49 (b)

According to clause 6.2.3.1 of *IS* 456 : 2000, the modulus of elasticity of concrete is

$$E_c = 5000\sqrt{f_{ck}}$$

According to table 19 of clause 40.4, shear strength of concrete increases with the compressive strength of concrete.

1.50 (d)

415 in Fe415, represents the characteristic strength of steel. Characteristic strength is the strength below which not more than 5% test results are expected to fall.

1.51 (d)

Correct answer should be 45 mm as per Table 3 and Table 16 of IS 456 : 2000. Since, 45 mm is not in option so 40 mm is most appropriate option for concrete grade M35 and above as per note of Table 16 of IS 456 : 2000.

1.52 (c)

According to clause 8.2.8 of IS 456: 2000, minimum grade of reinforced concrete in sea water shall be M 30.

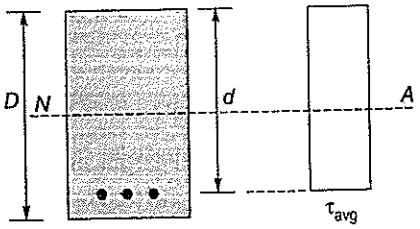
1.53 (c)

Excessive floor vibration can render a structure to be of little or no use.

1.55 (c)

Nominal shear stress $(\tau_v) = \dfrac{V}{bd}$

Nominal shear stress variation is up to tension reinforcement but there is no such option in question so most appropriate answer is (c).



1.56 (c)

Working moment by LSM

$$= \frac{0.138 f_{ck} bd^2}{1.5}$$

Working moment by WSM

$$= 0.130\,\sigma_{cbc}\, bd^2$$

$$\therefore \quad A = \frac{0.138 f_{ck} bd^2}{1.5 \times 0.13 \times \sigma_{cbc} \times bd^2}$$

$$= \frac{0.138 \times 20}{1.5 \times 0.13 \times 7} = 2.022$$

1.57 (d)

As per clause 5.4.2 of IS456:2000, pH value of potable water shall not be less than 6.

1.58 (c)

For sea water grade of concrete lower than M30 shall not be used in reinforced concrete (As per IS 456:2000).

1.59 (d)

Since, criteria for minimum area of tension reinforcement.

$$\frac{A_{st}}{bd} = \frac{0.85}{f_y}$$

$\because \quad f_y = 415\,\text{MPa}$

$$\Rightarrow \quad \frac{A_{st}}{bd} \times 100 = \frac{0.85}{415} \times 100 = 0.2\%$$

1.60 (b)

Minimum strain at failure in tension steel

$$= 0.002 + \frac{0.87 f_y}{E_s}$$

$$= 0.002 + \frac{0.87 \times 415}{2 \times 10^5}$$

$$= 0.0038$$

1.62 (b)

Design of RCC section are based on

(i) Tension failure of steel is considered safe.

(ii) Compression failure of concrete should be avoided.

(iii) Over reinforcement section are subjected to compression failure of concrete thus shall be avoided.

(iv) Under reinforcement sections are preferred due to tension failure of steel (gradual failure).

1.63 (a)

Carbonation occurs in concrete when calcium bearing phases present in concrete are attacked by CO_2 present in air, and converted to calcium carbonate.

■■■■

2 Beams and Slabs

2.1 In case of 2-way slab, the limiting deflection of the slab is
(a) primarily a function of the long span
(b) primarily a function of the short span
(c) independent of long or short spans
(d) dependent on both long and short spans
[ESE : 1995]

2.2 From limiting deflection point of view, use of high strength steel in RC beam results in
(a) reduction in depth
(b) no change in depth
(c) increase in depth
(d) increase in width
[ESE : 1995]

2.3 A slab-beam floor system may be supported on brick walls or framed into a system of RC columns. The floor thickness (slab + beam web) for the same span will be
(a) less when framed into a system of RC columns
(b) less when supported on brick walls
(c) the same in both the cases
(d) equal to the wall thickness or size of column
[ESE : 1995]

2.4 For maximum sagging bending moment at support in a continuous RC beam, live load should be placed on
(a) spans adjacent to the support plus alternate spans
(b) all the spans except the spans adjacent to the support
(c) spans next to the adjacent spans of the support plus alternate spans
(d) spans adjacent to supports only
[ESE : 1995]

2.5 Design of one-way RC slabs for concentrated load is done by
(a) using Pigeaud's moment coefficients
(b) taking slab strip of unit width containing the load
(c) taking slab strip of width effective in resisting the deflection
(d) taking orthogonal slab strips of unit width containing the load
[ESE : 1995]

2.6 The main reinforcement of a RC slab consists of 10 mm bars at 10 cm spacing. If it is desired to replace 10 mm bars by 12 mm bars, then the spacing of 12 mm bars should be
(a) 12 cm (b) 14 cm
(c) 14.40 cm (d) 16 cm
[ESE : 1995]

2.7 Shrinkage deflection in case of rectangular beams and slabs can be eliminated by putting
(a) compression steel equal to tensile steel
(b) compression steel more than tensile steel
(c) compression steel less than tensile steel
(d) compression steel 25% greater than tensile steel
[ESE : 1995]

2.8 A T-beam roof section has the following particulars:

Thickness of slab	: 100 mm
Width of rib	: 300 mm
Depth of beam	: 500 mm
Centre to centre distance of beams	: 3.0 m
Effective span of beams	: 6.0 m
Distance between points of contraflexure	: 3.60 m

The effective width of flange of the beam is
(a) 3000 mm (b) 1900 mm
(c) 1600 mm (d) 1500 mm
[ESE : 1996]

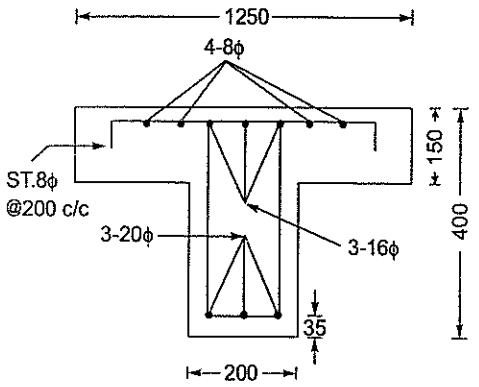
2.9 A simply supported isotropically reinforced square slab of side 4 m is subject to a service load of

6 kPa. The thickness of the slab is 120 mm. The moment of resistance required as per yield line theory is

(a) 9 kN-m (b) 9 kNm/m
(c) 13.2 kN-m (d) 13.2 kNm/m

[ESE : 1996]

2.10 For the section of the beam shown in the given figure, span of the beam = 6.0 m, concrete = *M* 20, steel = Fe 415.



If the section is checked for serviceability limit state of deflection, then it will be found that

(a) the section is unsafe
(b) the section needs revision
(c) the section is safe
(d) it cannot be judged from the given data

[ESE : 1996]

2.11 Given that d = effective depth, b = width and D = overall depth, the maximum area of compression reinforcement in a beam is

(a) 0.04 bd (b) 0.04 bD
(c) 0.12 bd (d) 0.12 bD

[ESE : 1997]

2.12 A reinforced concrete slab is 75 mm thick. The maximum size of reinforcement bar that can be used is

(a) 12 mm diameter (b) 10 mm diameter
(c) 8 mm diameter (d) 6 mm diameter

[ESE : 1997]

2.13 In the design of two-way slab restrained at all edges, torsional reinforcement required is

(a) 0.75 times the area of steel provided at midspan in the same direction
(b) 0.375 times the area of steel provided at midspan in the same direction
(c) 0.375 times the area of steel provided in the shorter span
(d) nil

[ESE : 1997]

2.14 Side face reinforcement is provided in a beam when the depth of web exceeds

(a) 300 mm (b) 450 mm
(c) 500 mm (d) 750 mm

[ESE : 1997]

2.15 Drops are provided in flats slabs to resist

(a) bending moment (b) thrust
(c) shear (d) torsion

[ESE : 1997]

2.16 **Assertion (A) :** The behaviour of an over reinforced beam is more ductile than that of an under reinforced beam.

Reason (R) : Over reinforced beam contains more steel and steel is more ductile than concrete.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

2.17 Flexural collapse in over reinforced beams is due to

(a) primary compression failure
(b) secondary compression failure
(c) primary tension failure
(d) bond failure

[ESE : 1997]

2.18 A square slab 4 m x 4 m is isotropically reinforced at the bottom. If it is subjected to a working load of 12 kPa (including self-weight), the moment capacity required as per yield line theory is

(a) 6 kN-m/m (b) 8 kN-m/m
(c) 10 kN-m/m (d) 12 kN-m/m

[ESE : 1997]

2.19 A reinforced cantilever beam of span 4 m, has a cross-section of 150 mm x 500 mm. If checked for lateral stability and deflection, the beam will

(a) fail in deflection only
(b) fail in lateral stability only

(c) fail in both deflection and lateral stability
(d) satisfy the requirements of deflection and lateral stability

[ESE : 1997]

2.20 In an RCC beam, side face reinforcement is provided if its depth exceeds
(a) 300 mm (b) 500 mm
(c) 700 mm (d) 750 mm

[ESE : 1998]

2.21 The bending moment coefficients for continuous *RC* slabs in **IS: 456-1978** code is based on
(a) Pigeaud's method
(b) Marcus's method
(c) Yield-line theory
(d) Westergaard's mathematical analysis

[ESE : 1998]

2.22 The sum of nodal forces at any yield line intersection in a slab is
(a) zero
(b) infinity
(c) independent of the reinforcement
(d) indeterminate

[ESE : 1998]

2.23 For a composite steel-beam and RCC-slab floor construction
(a) the grade of concrete has to be M20 for the composite action to be satisfactory
(b) the longitudinal reinforcement of the slab has to be welded to the beam to develop monolithicity
(c) a notch is made in the slab to house the upper flange of the beam
(d) shear connectors are provided to develop the composite action

[ESE : 1998]

2.24 The effective width 'b_f' of flange of a continuous T-beam in a floor system is given by

$$b_f = \frac{L_0}{6} + b_w + 6D_f$$

where L_0 represents the
(a) distance between points of contraflexure in a span
(b) effective span of beams
(c) clear span of beams
(d) spacing between beams

[ESE : 1999]

2.25 Beam sections of reinforced concrete designed in accordance with ultimate strength or limit state design approach, as compared to sections designed by working stress method for the same conditions of load and span, and the same width, usually have
(a) a larger depth and smaller amount of reinforcement
(b) the same depth and same reinforcement
(c) smaller depth and more reinforcement
(d) same depth as that of a deep beam

[ESE : 1999]

2.26 A doubly reinforced beam is considered less economical than a singly reinforced beam because
(a) tensile steel required is more than that for a balanced section
(b) shear reinforcement is more
(c) concrete is not stressed to its full value
(d) compressive steel is under-stressed

[ESE : 1999]

2.27 As per **IS:456-1978** the vertical deflection limit for beams may generally be assumed to be satisfied provided that the ratio of span to effective depth of a continuous beam of span up to 10 m is not be greater than
(a) 35 (b) 26
(c) 20 (d) 18

[ESE : 1999]

2.28 Negative moment in reinforced concrete beams at the location of supports is generally much higher than the positive span moment. This is primarily due to curvature at the supports being
(a) very high
(b) very low
(c) zero
(d) of reversing nature

[ESE : 1999]

2.29 In an RCC beam of breadth '*b*' and overall depth *D* exceeding 750 mm, side face reinforcement

required and the allowable area of maximum tension reinforcement shall be respectively
(a) 0.2% and 0.02 bD
(b) 0.3% and 0.03 bD
(c) 0.1% and 0.04 bD
(d) 0.4% and 0.01 bD

[ESE : 1999]

2.30 For maximum sagging bending moment in a given span of a multiple span beam,
(a) that very span as well as alternate spans are loaded
(b) adjacent spans are loaded
(c) spans adjoining this span are loaded
(d) adjacent spans are unloaded and next spans are loaded

[ESE : 2000]

2.31 Match List-I with List-II and select the correct answer using the codes given below the list:

List-I
A. Minimum percentage of tension reinforcement of *RC* beam
B. Minimum percentage of shear reinforcement of *RC* beam
C. Maximum allowable percentage of tension reinforcement of *RC* beam
D. Maximum allowable percentage of compression reinforcement of *RC* beam

List-II
1. 4
2. $\frac{85}{f_y}$
3. $\frac{40S_V}{f_y d}$

Codes:

	A	B	C	D
(a)	2	1	3	1
(b)	2	3	1	1
(c)	1	3	1	2
(d)	3	2	1	1

[ESE : 2000]

2.32 According to Whitney's theory, the maximum depth of concrete stress block in a balanced *RCC* beam section of depth '*d*' is
(a) 0.3d (b) 0.43d
(c) 0.5d (d) 0.53d

[ESE : 2000]

2.33 As per IS:456, for a singly reinforced rectangular section,
(a) $\frac{x_{u,max}}{d}$ for Fe 415 steel is 0.48
(b) the depth of the centroid of compression is $0.43\, x_{u,max}$
(c) the depth of the rectangular position of the stress block is $0.38\, x_{u,max}$
(d) the maximum value of lever arm is $d - x_{u,max}$

[ESE : 2000]

2.34 For the purpose of design as per IS:456, deflection of *RC* slab or beam is limited to
(a) 0.2% of span (b) 0.25% of span
(c) 0.4% of span (d) 0.45% of span

[ESE : 2000]

2.35 As per IS : 456, side face reinforcement, not less than 0.05% of web area, is provided on each side when the depth of web is not less than
(a) 300 mm (b) 400 mm
(c) 500 mm (d) 750 mm

[ESE : 2000]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

2.36 **Assertion (A) :** Shear capacity of a concrete beam increases with the increase in tension reinforcement.

Reason (R) : Increase in tension reinforcement increases aggregate interlocking force.

[ESE : 2000]

2.37 Assertion (A): According to BIS: 456-1978, over-reinforced sections are not permitted.
Reason (R): There is ductile failure of over-reinforced sections.
[ESE : 2001]

2.38 Assertion (A): Over-reinforced design of reinforced concrete sections is undesirable.
Reason (R): Tension failure of reinforced concrete sections is sudden.
[ESE : 2001]

2.39 For a reinforced concrete beam section the shape of the shear stress diagram is
(a) parabolic over the whole section with maximum value at the neutral axis
(b) parabolic above the neutral axis and rectangular below the neutral axis
(c) linearly varying as the distance from the neutral axis
(d) dependent on the magnitude of shear reinforcement provided
[ESE : 2001]

2.40 In a reinforced concrete T-beam (in which the flange is in compression). The position of neutral axis will
(a) be within the flange
(b) be within the web
(c) depend on the thickness of flange in relation to total depth and percentage of reinforcement
(d) at the junction of flange and web
[ESE : 2001]

2.41 Consider the following statements:
The reinforcement in reinforced concrete beam shall have concrete cover, the thickness of such cover shall be not less than
1. 25 mm
2. the diameter of bar
3. the spacing between bars
4. 5 mm
Which of these statements are correct?
(a) 3 and 4 (b) 1 and 4
(c) 2 and 3 (d) 1 and 2
[ESE : 2001]

2.42 In case of deep beam or in thin webbed RCC members, the first crack form is
(a) flexural crack
(b) diagonal crack due to compression
(c) diagonal crack due to tension
(d) shear crack
[ESE : 2001]

2.43 The specified span to depth ratios of beams satisfying the limits of vertical deflection are for spans up to 10 m.
1. For higher spans, these are to be modified by multiplying the ratios by (10/span in metres).
2. For higher spans, these are to be modified by multiplying the ratios by (span in metre/10).
3. They get further modified depending on area and type of tension reinforcement.
4. However, they do not change further with the area and type of compression reinforcement.
Select the correct answer using the codes given below:
(a) 1 and 3 (b) 2 and 3
(c) 1 and 4 (d) 2 and 4
[ESE : 2002]

2.44 Which of the following deformations are important in case of deep beams when compared to flexure alone?
(a) shear (b) axial
(c) torsional (d) bearing
[ESE : 2002]

2.45 The maximum depth of neutral axis for a beam with 'd' as the effective depth, in limit state method of design for Fe 415 steel is
(a) 0.46d (b) 0.48d
(c) 0.50d (d) 0.53d
[ESE : 2002]

2.46 A simply supported rectangular beam of span 20.0 m is subjected to *UDL*. The minimum effective depth required to check deflection of this beam, when modification factor for tension and compression are 0.9 and 1.1 respectively, will be
(a) 2.0 m (b) 1.8 m
(c) 1.3 m (d) 1.0 m
[ESE : 2002]

2.47 A continuous RC beam spans six span segments, each supporting a monolithic reinforced concrete slab. The beam will best be designed
(a) as a rectangular one throughout its span
(b) as a tee-beam throughout its span
(c) as a rectangular beam for span moments and tee-beam for support moments
(d) as a tee-beam for span moments and as a rectangular beam for support moments
[ESE : 2002]

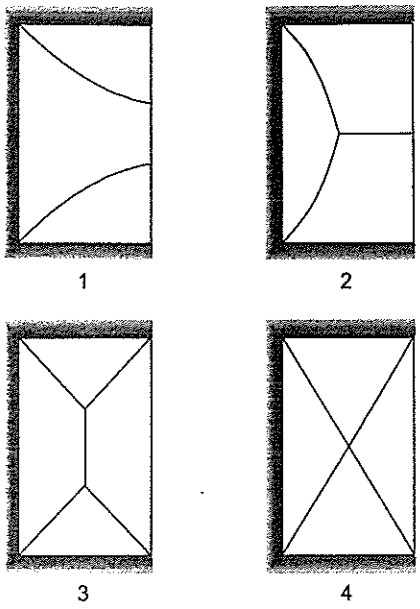
2.48 Shrinkage in a concrete slab
(a) causes shear cracks
(b) causes tension cracks
(c) causes compression cracks
(d) does not cause any cracking
[ESE : 2002]

2.49 The reinforcement for tension, when required in members, shall consist of
(a) only longitudinal reinforcement in the tension face
(b) only longitudinal reinforcement in the compression face
(c) only two legged closed loops enclosing the corner reinforcement
(d) both longitudinal and transverse reinforcement
[ESE : 2002]

2.50 In case of two-way slab, the deflection of the slab is
(a) primarily a function of the long span
(b) primarily a function of the short span
(c) independent of the span, long or short
(d) mostly long span but sometimes short span
[ESE : 2003]

2.51 A reinforced concrete beam of 10 m effective span and 1 m effective depth is supported on 500 mm × 500 mm columns. If the total uniformly distributed load on the beam is 10 MN/m, the design shear force for the beam is
(a) 50 MN (b) 47.5 MN
(c) 37.5 MN (d) 43 MN
[ESE : 2003]

2.52 A reinforced concrete rectangular slab is built-in (fixed) on three edges and the other edge is free. The possible yield line patterns for the slab subjected to a uniformly distributed load and reinforced isotropically are shown below as 1, 2, 3 and 4.



Which of these correctly exhibits the yield line pattern?
(a) 1 or 3 (b) 2 or 3
(c) 1 or 2 (d) 3 or 4
[ESE : 2003]

2.53 A reinforced concrete beam is subjected to the following bending moments:
Dead load – 20 kN-m
Live load – 30 kN-m
Seismic load – 10 kN-m
The design bending moment for limit state of collapse is
(a) 60 kN-m (b) 75 kN-m
(c) 72 kN-m (d) 80 kN-m
[ESE : 2003]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

2.54 Assertion (A) : Lateral support to a beam is provided by a concrete slab resting over the top flange of a beam.
Reason (R) : Shear connectors are needed to provide continuous lateral support.
[ESE : 2003]

2.55 Assertion (A) : Under working loads, in a reinforced concrete beam the lever arm remains unchanged.
Reason (R) : As the bending moment increases, the total compressive force and tensile force are assumed to increase in direct proportion.
[ESE : 2003]

2.56 Assertion (A) : Minimum shear reinforcement as stirrups must be provided in beams, even if the shear stress τ_v is less than the shear strength of concrete τ_c.
Reason (R) : The bending of beams creates a tendency in the particles to slide upon each other with the beam. This tendency is called shear.
[ESE : 2004]

2.57 Assertion (A) : Detailing of bars as per the requirements of maximum spacing of reinforcement in beams and slabs is sufficient to control flexural cracking.
Reason (R) : A large number of smaller diameter bars, well distributed in the tension zone, reduce the crack width more effectively than a few larger diameter bars of the same area.
[ESE : 2004]

2.58 What is the value of minimum reinforcement (in case of Fe 415) in a slab?
(a) 0.1% (b) 0.12%
(c) 0.15% (d) 0.2%
[ESE : 2004]

2.59 Minimum tension steel in RC beam needs to be provided to
(a) prevent sudden failure
(b) arrest crack width
(c) control excessive deflection
(d) prevent surface hair cracks
[ESE : 2004]

2.60 Temperature and shrinkage steel is provided in reinforced concrete slabs because
(a) it occupies larger area
(b) its thickness is less
(c) it is a main structural element
(d) it is a flexural member
[ESE : 2004]

2.61 Minimum shear reinforcement in beams is provided in the form of stirrups
(a) to resist extra shear force due to live load
(b) to resist the effect of shrinkage of concrete
(c) to resist principal tension
(d) to resist shear cracks at the bottom of beam
[ESE : 2004]

2.62 The critical section for computing design shear force in an *RC* beam where the supports exert a compressive reaction is at
(a) the centre of support
(b) the face of support
(c) a distance of half of effective depth from the face of support
(d) a distance of effective depth from the face of support
[ESE : 2004]

2.63 Doubly reinforced beams are recommended when
(a) the depth of the beam is restricted
(b) the breadth of the beam is restricted
(c) both depth and breadth are restricted
(d) the shear is high
[ESE : 2004]

2.64 In a cantilever beam carrying gravity load, main reinforcement is provided
(a) above the neutral axis
(b) as vertical stirrups
(c) as a helical reinforcement
(d) below the neutral axis
[ESE : 2004]

2.65 Match List-I (Beam variable) with List-II (Design provision) and select the correct answer using the codes given below the lists:
List-I
A. Flexure
B. Shear
C. Bond
D. Deflection

List-II

1. Minimum depth of section
2. Longitudinal steel reinforcement
3. Stirrups
4. Anchorage in support

Codes :

	A	B	C	D
(a)	3	2	1	4
(b)	2	3	1	4
(c)	3	2	4	1
(d)	2	3	4	1

[ESE : 2004]

2.66 Drop panel is a structural component in

(a) Grid floor
(b) Flat plate
(c) Flat slab
(d) Slab-beam system of floor

[ESE : 2005]

2.67 Which of the following should be employed to provide lateral support to the beams?

1. Bracing of compression flanges.
2. Shear connectors
3. Bracing of tension flanges.
4. Embedding compression flanges into RCC slab.

Select the correct answer using the code given below :

(a) 1 only (b) 1 and 4
(c) 2 and 3 (d) 1, 2 and 4

[ESE : 2005]

2.68 A doubly reinforced concrete beam has effective cover d' to the centre of compression reinforcement. 'x_u' is the depth of neutral axis, and 'd' is the effective depth to the centre of tension reinforcement. What is the maximum strain in concrete at the level of compression reinforcement?

(a) $0.0035\,(1 - d'/d)$ (b) $0.0035\,(1 - d'/x_u)$
(c) $0.002\,(1 - d'/x_u)$ (d) $0.002\,(1 - d'/d)$

[ESE : 2005]

2.69 Consider the following statements:

In an under-reinforced concrete beam,

1. actual depth of neutral axis is less than the critical depth of neutral axis.
2. concrete reaches ultimate stress prior to steel reaching the ultimate stress.
3. moment of resistance is less than that of balanced sections.
4. lever arm of resisting couple is less than of balanced sections.

Which of these statements is/are correct?

(a) 1 and 2 (b) 1 and 3
(c) 2, 3 and 4 (d) 1 and 4

[ESE : 2005]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as 'Reason (R)'. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

2.70 Assertion (A) : The concept of locating the neutral axis in a reinforced concrete flexural member as centroidal axis is applicable in working stress design method, but not in limit state design method.

Reason (R) : The working stress design method assumes that the structural material behaves in a nonlinear elastic manner and there is strain compatibility in bond between steel and concrete.

[ESE : 2005]

2.71 Assertion (A) : Minimum shear reinforcement in all shallow beams is provided when shear stress exceeds $0.5\tau_c$ (Where τ_c is design shear stress).

Reason (R) : Minimum shear reinforcement prevents formation of inclined cracks and avoids abrupt failures and introduces ductility in shear.

[ESE : 2005]

2.72 Assertion (A) : The working stress method of R.C.C. design of beams is also known as modular ratio method.

Reason (R) : The ratio of stress in steel and concrete is the same as that of elastic modulii of steel and concrete in beam.

[ESE : 2006]

2.73 Assertion (A) : In limit state design, over-reinforced sections are not permitted.
Reason (R) : As the concrete failure is brittle, the structure fails suddenly without any warning.
[ESE : 2006]

2.74 Shear strength of concrete in a reinforced concrete beam is a function of which of the following:
1. Compressive strength of concrete
2. Percentage of shear reinforcement
3. Percentage of longitudinal reinforcement in tension in the section
4. Percentage total longitudinal reinforce-ment in the section

Select the correct answer using the codes given below:
(a) 1, 2 and 4 (b) 1, 2 and 3
(c) Only 1 and 3 (d) Only 1 and 4
[ESE : 2006]

2.75 As per codal provisions in two way slabs, the minimum mild steel reinforcement to be provided in the edge strip is
(a) On the basis of minimum bending moment
(b) Half of the area of steel provided in middle strip in the shorter span
(c) Half of the area of steel provided in middle strip in the longer span
(d) 0.15% of the cross-sectional area of concrete
[ESE : 2006]

2.76 A T-beam roof section has the following particulars:

Thickness of slab	: 100 mm
Width of rib	: 300 mm
Depth of beam	: 500 mm
Centre to centre distance of beams	: 3.0 m
Effective span of beams	: 6.0 m
Distance between points of contraflexure	: 3.6 m

What is the effective flange width of the T-beam?
(a) 3000 mm (b) 1900 mm
(c) 1600 mm (d) 1500 mm
[ESE : 2006]

2.77 A T-beam behaves as a rectangular beam of width equal to its flange if its neutral axis
(a) coincides with centroid of reinforcement
(b) coincides with centroid of T-section
(c) remains within the flange
(d) remains in the web
[ESE : 2006]

2.78 In the case of a continuous RC beam, in order to obtain the maximum positive span moment, where should the live load be placed?
(a) On all the spans
(b) On alternate spans starting from the left
(c) On spans adjacent to the spans under consideration
(d) On the span plus alternate spans
[ESE : 2007]

2.79 The cover of longitudinal reinforcing bar in a beam subjected to sea spray should not be less than which one of the following?
(a) 30 mm (b) 70 mm
(c) 75 mm (d) 80 mm
[ESE : 2007]

2.80 Which one of the following is correct in respect of the material efficiency of RCC flexural elements in rectangular beam, T-beam and two-way slab?
(a) All the three sections are equally efficient
(b) T-beam section is most uneconomical
(c) Two-way slab is most economical
(d) The efficiency of rectangular section lies between that of T-beam and two-way slab sections
[ESE : 2007]

2.81 How can shear strength be ensured in a beam?
(a) By providing binding wire on main bars
(b) By providing HYSD bars instead of mild steel bars
(c) By providing rounded aggregate
(d) By providing stirrups
[ESE : 2008]

2.82 Usually stiffness of a simply supported beam is satisfied if the ratio of its span to depth does not exceed which one of the following?
(a) 7 (b) 10
(c) 20 (d) 26
[ESE : 2008]

2.83 When is an RCC roof slab designed as a two way slab?
(a) If the slab is continuous over two opposite edges only
(b) If the slab is unsupported at one edge only
(c) If the ratio of spans in two directions is > 2
(d) If the ratio of spans in two directions is < 2
[ESE : 2008]

2.84 In a singly reinforced beam, the tensile steel reaches its maximum allowable stress earlier than concrete. What is such a section known as?
(a) Under-reinforced section
(b) Over-reinforced section
(c) Balanced section
(d) Economic section
[ESE : 2008]

2.85 Why is the design of a RC section as over-reinforced undesirable?
(a) It consumes more concrete
(b) It undergoes high strains
(c) It fails suddenly
(d) Its appearance is not good
[ESE : 2008]

2.86 What is the moment capacity of an under-reinforced rectangular RCC beam?
(a) Rbd^2 (b) Rdb^2
(c) $A_{st}\sigma_{st}jd$ (d) $A_{st}jd$
(Symbols have the usual meaning)
[ESE : 2008]

2.87 In a singly reinforced concrete beam section, maximum compressive stress in concrete and tensile stress reach their permissible stresses simultaneously. What is such a section called?
(a) Under-reinforced section
(b) Economic section
(c) Balanced section
(d) Over-reinforced section
[ESE : 2008]

2.88 For shorter storey height, cheaper form work and better lighting facilities, what is the recommended slab floor?
(a) T beam and slab
(b) Two way slab
(c) Flat slab
(d) Framed structure
[ESE : 2008]

2.89 What is the assumption in the steel beam theory of doubly reinforced beams?
(a) Only steel bars will resist tension
(b) Only concrete will resist tension
(c) Stress in tension steel equals the stress in compression steel
(d) Both concrete and steel will resist compression
[ESE : 2008]

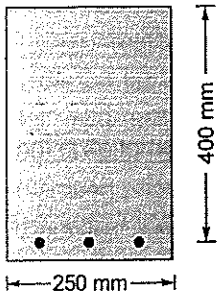
2.90 What shall be the maximum area of reinforcement (i) in compression and (ii) in tension to be provided in an RC beam, respectively, as per IS:456 ?
(a) 0·08% and 2% (b) 2% and 4%
(c) 4% and 2% (d) 4% and 4%
[ESE : 2009]

2.91 How is the deflection in RC beams controlled as per IS:456?
(a) By using large aspect ratio
(b) By using small modular ratio
(c) By controlling span/depth ratio
(d) By moderating water-cement ratio
[ESE : 2009]

2.92 In limit state design method, the moment of resistance for a balanced section using M20 grade concrete and HYSD steel of grade Fe415 is given by $M_{u,lim} = Kbd^2$, what is the value of K?
(a) 2.98 (b) 2.76
(c) 1.19 (d) 0.89
[ESE : 2009]

2.93 What is the adoptable maximum spacing between vertical stirrups in an RCC beam of rectangular cross-section having an effective depth of 300 mm ?
(a) 300 mm (b) 275 mm
(c) 250 mm (d) 225 mm
[ESE : 2009]

2.94 A simply supported RC beam having clear span 5 m and support width 300 mm has the cross-section as shown in figure below.



What is the effective span of the beam as per IS:456 ?

(a) 5300 mm (b) 5400 mm
(c) 5200 mm (d) 5150 mm

[ESE : 2009]

2.95 Match List-I with List-II and select the correct answer using the codes given below the lists :

List-I

A. Moment and shear coefficients
B. Fire resistance
C. Sliding
D. Span to depth ratio of beam

List-II

1. Durability
2. Stability
3. Analysis of structure
4. Deflection limits

Codes:

	A	B	C	D
(a)	4	2	1	3
(b)	3	2	1	4
(c)	4	1	2	3
(d)	3	1	2	4

[ESE : 2009]

2.96 Match List-I (Support) with List-II (Shear Coefficients) and select the correct answer using the codes given below the lists :

List-I

A. At end support, for imposed load (not fixed)
B. At inside support, next to end support, for imposed load (fixed)
C. At end support, for dead load and (fixed) imposed load
D. At all other interior supports (other than at 'B'), for imposed load (fixed)

List-II

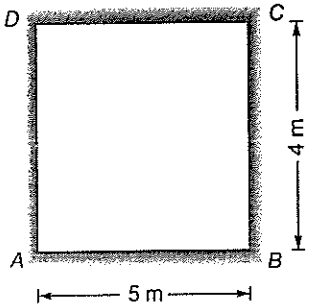
1. 0.5
2. 0.55
3. 0.60
4. 0.45
5. 0.4

Codes:

	A	B	C	D
(a)	5	3	2	4
(b)	4	2	5	1
(c)	1	2	3	4
(d)	5	3	2	1

[ESE : 2009]

2.97 The *RC* slab, simply supported on all edges as in figure below, is subjected to a total *UDL* of 12 kN/m^2. The maximum shear force/unit length along the edge '*BC*' is



(a) 16 kN (b) 12 kN
(c) 8 kN (d) 30 kN

[ESE : 2010]

2.98 In RCC beams, as the percentage areas of tensile steel increases

(a) depth of neutral axis increases
(b) depth of neutral axis decreases
(c) depth of neutral axis does not change
(d) lever arm increases

[ESE : 2010]

2.99 In the limit state method, balanced design of a reinforced concrete beam gives

(a) smallest concrete section and maximum area of reinforcement
(b) largest concrete section and maximum area of reinforcement
(c) smallest concrete section and minimum area of reinforcement
(d) largest concrete section and minimum area of reinforcement

[ESE : 2010]

2.100 The maximum per cent of moment redistribution allowed in RCC beams is

(a) 10% (b) 20%
(c) 30% (d) 40%

[ESE : 2010]

2.101 **Assertion (A):** The behaviour of an over-reinforced beam is more ductile than that of under-reinforced beam.
Reason (R): Over-reinforced beam contains more steel and steel is more ductile than concrete.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2010]

2.102 The main reinforcement of a R.C. slab consists of 10 mm bars at 100 mm spacing, if it is desired to replace the 10 mm bars by 12 mm bars, then the spacing of 12 mm bars should be
(a) 120 mm (b) 140 mm
(c) 144 mm (d) 160 mm

[ESE : 2011]

2.103 Shear resistance of concrete in a reinforcement beam is dependent on
(a) Tension reinforcement in the beam
(b) Compression reinforcement in the beam
(c) Shear reinforcement in the beam
(d) None of the reinforcement in the beam

[ESE : 2011]

2.104 In limit state design of concrete for flexure, the area of stress block is taken as
(a) $0.530\, f_{ck} \cdot X_u$ (b) $0.446\, f_{ck} \cdot X_u$
(c) $0.420\, f_{ck} \cdot X_u$ (d) $0.360\, f_{ck} \cdot X_u$

[ESE : 2011]

2.105 For a continuous slab of 3 m × 3.5 m size, the minimum overall depth of slab to satisfy vertical deflection limits is
(a) 120 mm (b) 100 mm
(c) 75 mm (d) 50 mm

[ESE : 2011]

2.106 A reinforced concrete slab is 75 mm thick. The maximum size of reinforcement bar that can be used is
(a) 6 mm diameter
(b) 8 mm diameter
(c) 10 mm diameter
(d) 12 mm diameter

[ESE : 2011]

2.107 A reinforced concrete cantilever porch has thickness t. The main reinforcement steel will be placed
(a) At mid-thickness
(b) At $t/3$ from the top
(c) Close to the bottom surface
(d) Close to the top surface

[ESE : 2011]

2.108 Consider the following statements:
Percentage of steel for balanced design of a singly reinforced rectangular section by limit state method depends on
1. Characteristic strength of concrete.
2. Yield strength of concrete.
3. Modulus of elasticity of steel.
4. Geometry of the section.
Which of these statements are correct?
(a) 2, 3 and 4 (b) 1, 3 and 4
(c) 1, 2 and 4 (d) 1, 2 and 3

[ESE : 2011]

2.109 The minimum strain at failure in the tensile reinforcement (f_y = 400 MPa) of RCC beam as per limit state method is
(a) 0.0020 (b) 0.0028
(c) 0.0037 (d) 0.0045

[ESE : 2011]

2.110 If the depth of actual neutral axis in a beam is more than the depth of critical axis, then the beam is called
(a) Over-reinforced beam
(b) Under-reinforced beam
(c) Balanced beam
(d) Deep beam

[ESE : 2011]

2.111 Match List-I with List-II and select the correct answer using the code given below the lists:

List-I
A. Doubly reinforcement section
B. Limit state design
C. Minimum cover
D. Span-depth ratio

List-II
1. Serviceability
2. Durability
3. Reduction in sectional depth
4. Ultimate moment capacity

Codes:

	A	B	C	D
(a)	1	2	4	3
(b)	3	2	4	1
(c)	1	4	2	3
(d)	3	4	2	1

[ESE : 2011]

2.112 If a two-way slab is found to be unsafe in shear, then the preferred remedy is
(a) to provide shear stirrups
(b) to increase the flexural reinforcement by 15%
(c) to increase the thickness of the slab adequately
(d) to increase the distribution reinforcement in edge strips

[ESE : 2012]

2.113 Which of the following assumption is/are implied in the table listing moment coefficients for continuous slabs?
1. Load is distributed uniformly along supports.
2. Mid-span deflections in orthogonal directions are the same.
3. Load distribution along each support is triangular.
4. Support moment is about 1.5 times span moment.

(a) 1, 2, 3 and 4 (b) 2 only
(c) 3 only (d) 4 only

[ESE : 2012]

2.114 A simply supported beam has an effective span of 16 m. What shall be the limiting ratio of span to effective depth as per IS 456- 2000?
(a) 26 (b) 20
(c) 12.5 (d) 7

[ESE : 2012]

2.115 A simply supported beam is considered as a deep beam if the ratio of effective span to overall depth is less than
(a) 1 (b) 2
(c) 3 (d) 4

[ESE : 2012]

2.116 Torsion reinforcement provided at the corners of a two-way slab
(a) distributes bending moment uniformly
(b) prevents corners from lifting
(c) controls cracking at corners
(d) does not allows any twist at corners

[ESE : 2012]

2.117 Splicing of bars in RCC beams can be done at a section where
(a) bending moment is zero
(b) bending moment is less than half of the maximum bending moment in beam
(c) bending moment is maximum
(d) shear force is zero

[ESE : 2013]

2.118 As per IS-456 : 2000, side face reinforcement in a beam is provided where depth of the web exceeds
(a) 750 mm (b) 250 mm
(c) 500 mm (d) 1000 mm

[ESE : 2013]

2.119 Consider the following statements for prediction of yield lines in a reinforced concrete slab:
1. They represent the axis of rotation.
2. They will propagate outward from a point load.
3. They are straight lines between two intersecting planes.
4. They end at the boundary of the slab or at another yield line.

Which of these statements are correct?
(a) 1, 2, 3 and 4 (b) 1, 2, and 3
(c) 1, 2 and 4 (d) 2, 3 and 4

[ESE : 2013]

2.120 Critical section for shear in case of flat slabs is
(a) at a distance of effective depth of slab from the periphery of the column the drop panel
(b) at a distance of $d/2$ from the periphery of the column/the capital/the drop panel
(c) at the drop panel of the slab
(d) at the periphery of the column [adopting standard notations]

[ESE : 2014]

2.121 The enlarged head of the supporting column of a flat slab is called

(a) capital (b) drop
(c) panel (d) block

[ESE : 2014]

2.122 If any tension reinforcement in an *RC* beam attains its yield stress during loading before the concrete in the compression zone fails due to crushing, the beam is said to be
(a) under-reinforced
(b) over-reinforced
(c) balanced
(d) non-homogeneous

[ESE : 2014]

2.123 The distance between the centroid of the area of tension reinforcement and the maximum compressive fibre in a reinforced concrete beam design is known as
(a) overall depth
(b) effective depth
(c) lever arm
(d) depth of neutral axis

[ESE : 2014]

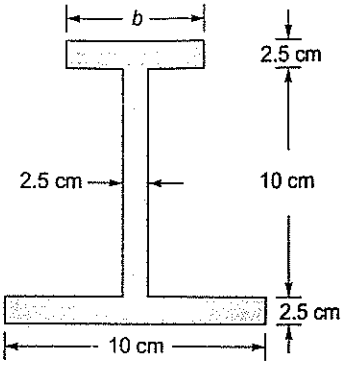
2.124 A singly reinforced rectangular concrete beam has a width of 150 mm and an effective depth of 330 mm. The characteristic compressive strength of concrete is 20 MPa and the tensile strength of steel is 415 MPa. Adopt the stress block for concrete as per IS 456-2000 and take the limiting value of depth of neutral axis as 0.48 times the effective depth of the beam for considering as a balanced section. What is the likely approximation for the limiting value of the moment of resistance of the beam?
(a) 15 kNm (b) 25 kNm
(c) 45 kNm (d) 75 kNm

[ESE : 2015]

2.125 In reinforced brickwork slabs, the diameter of main reinforcement shall, preferably not exceed
(a) 8 mm (b) 10 mm
(c) 12 mm (d) 16 mm

[ESE : 2015]

2.126 In order that the extreme fibre stresses in bending will be in the ratio 4 : 3 in the beam shown in the following figure, the width b of the upper flange (b < 10 cm) of the beam section is to be



(a) 6.1 cm (b) 6.6 cm
(c) 5.1 cm (d) 5.6 cm

[ESE : 2016]

2.127 A structural steel beam has an unsymmetrical I-cross-section. The overall depth of the beam is 200 mm. The flange stresses at the top and bottom are 120 N/mm^2 and 80 N/mm^2, respectively. The depth of the neutral axis from the top of the beam will be
(a) 120 mm (b) 100 mm
(c) 80 mm (d) 60 mm

[ESE : 2016]

2.128 A rectangular beam of depth *d* is under bending. Load has been gradually increased when the top fibre has obtained five times the strain at the first yield. What depth of the beam will still respond by elastic conditions?
(a) 0.16 d (b) 0.20 d
(c) 0.25 d (d) 0.40 d

[ESE : 2016]

2.129 Reinforced concrete slabs are designed for
1. Shear
2. Flexure
3. Positive bending moment
4. Negative bending moment

(a) 1, 2 and 3 only (b) 1 and 4 only
(c) 2, 3 and 4 only (d) 1, 2, 3 and 4

[ESE : 2016]

2.130 Flexural collapse in over-reinforced beams is due to
(a) Primary compression failure
(b) Secondary compression failure
(c) Primary tension failure
(d) Bond failure

[ESE : 2016]

2.131 A beam column is alternately bent either (1) in single curvature, or (2) in double curvature. The secondary moments induced are to be compared. These are indicated SM_1 and SM_2 as per the conditions (1) and (2) respectively

(a) $SM_1 > SM_2$

(b) $SM_1 < SM_2$

(c) $SM_1 = SM_2$

(d) Cannot be ascertained

[ESE : 2017]

2.132 Consider the following statements:

1. The minimum steel requirements of slabs are based on considerations of shrinkage and temperature effects alone, and not on strength.
2. Providing excessive reinforcement in beams can result in congestion, thereby adversely and compaction of concrete.

Which of the above statements is/are correct?

(a) 1 only (b) 2 only

(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2017]

2.133 A T-beam becomes identical to a rectangular beam with width equal to its flange width when the neutral axis is

(a) Through the geometrical centre of the beam

(b) At the junction of the rib and the flange

(c) Below the slab

(d) Within the flange

[ESE : 2017]

■■■■

Answers Beams and Slabs

2.1	(b)	2.2	(c)	2.3	(a)	2.4	(c)	2.5	(a)	2.6	(c)	2.7	(a)	2.8	(d)	2.9	(b)
2.10	(d)	2.11	(b)	2.12	(c)	2.13	(a)	2.14	(d)	2.15	(c)	2.16	(d)	2.17	(b)	2.18	(d)
2.19	(c)	2.20	(d)	2.21	(b)	2.22	(a)	2.23	(d)	2.24	(a)	2.25	(c)	2.26	(d)	2.27	(b)
2.28	(a)	2.29	(c)	2.30	(a)	2.31	(b)	2.32	(d)	2.33	(a)	2.34	(c)	2.35	(d)	2.36	(a)
2.37	(c)	2.38	(c)	2.39	(b)	2.40	(c)	2.41	(d)	2.42	(c)	2.43	(a)	2.44	(a)	2.45	(b)
2.46	(a)	2.47	(d)	2.48	(b)	2.49	(d)	2.50	(b)	2.51	(c)	2.52	(c)	2.53	(b)	2.54	(d)
2.55	(a)	2.56	(b)	2.57	(a)	2.58	(b)	2.59	(a)	2.60	(a)	2.61	(c)	2.62	(d)	2.63	(c)
2.64	(a)	2.65	(d)	2.66	(c)	2.67	(d)	2.68	(b)	2.69	(b)	2.70	(c)	2.71	(a)	2.72	(a)
2.73	(a)	2.74	(c)	2.75	(d)	2.76	(d)	2.77	(c)	2.78	(d)	2.79	(*)	2.80	(d)	2.81	(d)
2.82	(c)	2.83	(d)	2.84	(a)	2.85	(c)	2.86	(c)	2.87	(c)	2.88	(c)	2.89	(c)	2.90	(d)
2.91	(c)	2.92	(b)	2.93	(d)	2.94	(a)	2.95	(d)	2.96	(b)	2.97	(a)	2.98	(a)	2.99	(a)
2.100	(c)	2.101	(d)	2.102	(c)	2.103	(a)	2.104	(d)	2.105	(a)	2.106	(b)	2.107	(d)	2.108	(b)
2.109	(c)	2.110	(a)	2.111	(d)	2.112	(c)	2.113	(b)	2.114	(c)	2.115	(b)	2.116	(c)	2.117	(b)
2.118	(a)	2.119	(d)	2.120	(b)	2.121	(a)	2.122	(a)	2.123	(b)	2.124	(c)	2.125	(c)	2.126	(d)
2.127	(a)	2.128	(b)	2.129	(d)	2.130	(a)	2.131	(a)	2.132	(c)	2.133	(d)				

Explanations Beams and Slabs

2.1 (b)

The strip of a two way slab may be checked for deflection control against shorter span to effective depth ratios.

Span to effective depth ratio

Type of slab	Type of reinforcement	
	Mild Steel	Fe 415 grade steel
Simply supported	35	28
Continuous	40	32

2.2 (c)

The effective span to depth ratio for beam with different type of tension steel are obtained by multiplying the basic values of effective span to depth ratio with modification factor.

For high strength deformed bars, the effective span to depth ratio should be multiplied by 0.8. It means that depth should be increased.

2.3 (a)

RC columns will provide more rigidity so net design bending moment will be less.

2.4 (c)

The maximum moment or shear force at a section depends on the position of the live load.

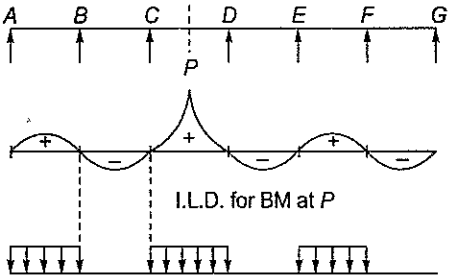
(i) For maximum positive span moment at mid point, load that span and all other alternate spans.

(ii) For maximum positive support moment, unload the spans on either side of the support and load the next spans.

(iii) For maximum negative span moment at mid point, load the adjacent spans on either side of the span and all other alternate spans.

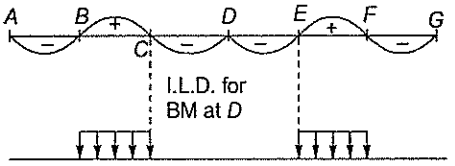
(iv) For maximum negative moment at support, load the two spans adjacent to the support and all other alternate spans.

For case (i)



Position of load for maximum positive moment at *P*.

For case (ii)



Position of load for maximum positive moment at *D*.

2.5 (a)

Pigeaud's moment coefficients can be used for computing bending moments in a panel freely supported along four edges with restrained corners and carrying symmetrically placed load distributed over small area i.e. a concreted load. Pigeaud derived these curves for thin plates, using elastic theory of flexure, and assuming Poisson's ratio of 0:15.

2.6 (c)

The horizontal distance between parallel main reinforcement bars shall not be more than three times the effective depth of solid slab or 300 mm whichever is smaller. The total reinforcement in the slab should remain same. By replacing 10 mm bars by 12 mm bars, the spacing will increase as

$$\left(\frac{d_2}{d_1}\right)^2 \times S_1 = \left(\frac{12}{10}\right)^2 \times 10 = 14.4 \text{ cm}$$

2.7 (a)

The bond between concrete and steel restrains shrinkage. Therefore, the shrinkage curvature is influenced by the area of tension and compression reinforcement equally.

The shrinkage curvature

$$\phi_{sh} = \beta e_{sh}/D$$

$e_{sh} \rightarrow$ free shrinkage = 0.0003

$D \rightarrow$ Overall depth of beam

$$\beta = 0.72\frac{P_t - P_c}{\sqrt{P_t}} \leq 1.0$$

for $0.25 \leq P_t - P_c \leq 1$

$$= 0.65\frac{P_t - P_c}{\sqrt{P_t}} \leq 1.0$$

for $P_t - P_c \geq 1$

P_c, $P_t \rightarrow$ percentage of compression and tension steel respectively

Thus shrinkage deflection can be eliminated by making compression steel equal to tension steel.

2.8 (d)

Effective width

(i) For T-beams $b_f = \frac{L_0}{6} + b_w + 6D_f \not> b$

(ii) For inverted L-beam

$$b_f = \frac{L_0}{12} + b_w + 3D_f \not> b$$

(iii) For isolated T-beam.

$$b_f = \frac{L_0}{\left(\frac{L_0}{b}\right) + 4} + b_w$$

(iv) For isolated L-beam

$$b_f = \frac{0.5L_0}{\left(\frac{L_0}{b}\right) + 4} + b_w$$

$b_f \rightarrow$ effective width of flange

$L_0 \rightarrow$ distance between points of zero moments (points of contraflexure) which may be taken as 0.7 times the effective span for continuous beams and for beams in frames

$b_w \rightarrow$ breadth of web

$D_f \rightarrow$ thickness of flange

$b \rightarrow$ actual width of flange which is equal to breadth of web plus half the sum of the clear distance between the beams on either side.

$b = 300 + 2700 = 3000$ mm

$L_0 = 3600$ mm

$b_w = 300$ mm

$D_f = 100$ mm

$$\therefore b_f = \frac{3600}{6} + 300 + 6\times100 = 1500 \text{ mm}$$

2.9 (b)

$$\text{Moment of resistance} = \frac{w_u L^2}{24}$$

Self weight of slab = $0.12 \times 25 = 3$ kN/m^2

Service load = 6 kN/m^2

Ultimate load = $1.5 \times (6 + 3) = 13.5$ kN/m^2

Ultimate moment capacity

$$= \frac{13.5\times4^2}{24} = 9 \text{ kN-m/m}$$

2.10 (d)

The final deflection is limited to span/250 or 20 mm whichever is less.

So limiting deflection = 17.1 mm

Dead load of beam

$= (0.15 \times 1.25 + 0.25 \times 0.2) \times 25 = 5.94$ kN/m

The live load is also needed to calculate short term deflection. Therefore it can not be judged from the given data.

2.11 (b)

As per IS:456-2000 maximum area of compression or tension reinforcement shall not exceed 0.04bD.

2.12 (c)

The diameter of the bars shall not exceed one eight of the total thickness of the slab.

$$\therefore \text{Maximum size} = \frac{75}{8} = 9.375 \text{ mm}$$

So the diameter will be 8 mm.

2.13 (a)

For restrained slab, the area of reinforcement in each of the four corner layers shall be three-quarters of the area required for the maximum mid span moment in the slab simply supported

on both edges meeting at that corner. If the corner contained by edges over only one of which the slab is continuous, torsion reinforcement equal to 0.375 times the area of reinforcement provided the mid-span in the same direction shall be provided. If both edges are continuous, no torsion reinforcement shall be provided.

2.14 (d)

Where the depth of web in a beam exceeds 750 mm, the side face reinforcement shall be provided along the two faces. The total area of such reinforcement shall not exceed 0.1% of the web area and shall be distributed equally on two faces at a spacing not exceeding 300 mm or web thickness whichever is less.

2.15 (c)

The slabs supported directly on columns without beams are know as flat slabs. In such slabs, large bending moments and shear forces are induced in the vicinity of columns. Therefore the columns are flared at the top called column heads or column capitals and slab are thickened around the column capitals called drops for reducing the stresses due to moments and shears. The drops primarily resist shear.

2.16 (d)

In under-reinforced beam, the reinforcement failure occurs first while in over-reinforced beam the concrete failure occurs first. Thus under-reinforced beam is ductile and over-reinforced beam shows sudden failure i.e., brittle.

2.17 (b)

Primary compression means direct compression and secondary compressive stresses are due to bending.

2.18 (d)

Ultimate load (w_u) = 1.5 × 12 = 18 kPa

$$\text{Moment capacity} = \frac{w_u L^2}{24} = \frac{18 \times 4^2}{24} = 12 \text{ kN-m/m}$$

2.19 (c)

$$\frac{\text{Span}}{\text{Effective depth}} = \frac{4000}{500} = 8 > 7$$

So the beam will fail in deflection.

For stability, the clear distance from the free end of the cantilever the lateral restraint shall not exceed $25b$ or $\frac{100b^2}{d}$ whichever is less.

Consider nominal cover = 40 mm

Effective depth = 500 – 40 = 460 mm

Clear Distance = 25 × 150 = 3750 mm

or $\frac{100 \times (150)^2}{(460)} = 4891.3$ mm

Thus clear distance between the lateral restraints shall be 3750 mm. However the span is 4 m. So the beam fails from lateral stability consideration also.

2.20 (d)

As per **IS 456 : 2000** (clause 26.5.1.3), Where depth of web in a beam exceeds 750 mm, side face reinforcement shall be provided along the two faces.

2.21 (b)

IS 456 : 1978 has adopted moment coefficients derived by Rankine-Grashoff for the analysis of simply supported rectangular slab without any provision for torsion. For continuous *RC* slabs Marcus' method is the basis.

IS 456 : 2000 has adopted moment coefficients derived by Rankine-Grashoff for the analysis of simply supported rectangular slab without any provision for torsion as in Table 27.

However, for continuous RC slab, coefficient of Table 26 is based on yield line theory.

2.22 (a)

The total force acting on segment at intersection of two adjacent straight portions of yield line is known as nodal force. The shear force acting on each side of yield line should be equal and opposite for equilibrium. Thus sum of nodal forces as junction of yield line is zero.

2.23 (d)

Shear connectors prevent separation between steel girder and in-situ concrete slab by transferring horizontal shear force along contact surface without slip. Thus they are important structural element for composite steel beam and RCC slab floor construction.

2.24 (a)

As per Clause 23.1.2. In effective width formula for T-beam L_0 represents distance between points of zero moment in beam.

2.25 (c)

LSM and ULM follow non linear stress-strain curve of steel and concrete i.e. utilize the strength in plastic zone. So sections designed have lesser depth in comparison to member designed by WSM. For the same load, bending moment is more in case of LSM compared to WSM due to provisions for partial safety factors. As depth decreases in LSM, lever arm decreases and hence larger area of reinforcement is required as compared to WSM.

2.26 (d)

The doubly reinforced beam section is needed

(i) when depth of the section is restricted and the strength available from a singly reinforced section is inadequate

(ii) at support of a continuous beam or slab where bending moment changes sign.

(iii) when members are subjected to alternate external loads and the bending moment in the sections reverses such as in concrete piles etc.

(iv) when the members are subjected to loading eccentric to either side of the axis, such as in columns subjected to wind loads.

(v) when the members are subjected to accidental lateral loads, shock or impact.

2.27 (b)

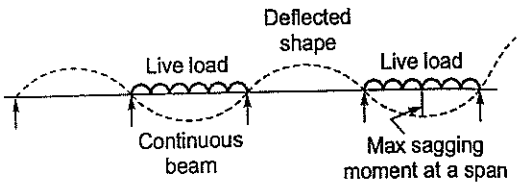
Span to effective depth ratios for spans upto 10 m.

Cantilever	–	7
Simply supported	–	20
Continuous	–	26

2.29 (c)

As per Clause 26.5.1.1 and 26.5.1.3. The maximum area of tension reinforcement should not exceed 0.04bD and total area of side reinforcement should not be less than 0.1% bD and it should be distributed equally on two faces at spacing not exceeding 300 mm or web thickness whichever is less.

2.30 (a)



From figure, load should be placed on the span as well as alternate spans for maximum sagging bending moment in given span of multiple span beam.

2.31 (b)

(i) Minimum area of tension reinforcement $\frac{0.85}{f_y}(bd)$ or $\frac{85}{f_y}\%$.

(ii) Maximum tension or compression reinforcement = 0.04 bD or 4% of gross area.

(iii) Minimum shear reinforcement $\frac{A_{sv}}{bS_v} \geq \frac{0.4}{0.87f_y}$

as per IS : 456-2000

Shear reinforcement in IS : 456-1978 was given as $\frac{A_{sv}}{bS_v} \geq \frac{0.4}{f_y}$

$\therefore$ The percentage reinforcement is

$$\frac{A_{sv}}{bd} = \frac{40S_v}{f_y d}$$

2.32 (d)

Whitney's theory is ultimate load theory. It is based on the assumption that ultimate strain in concrete is 0.3% and the compressive stress at the extreme edge of the section corresponds to this strain. Whitney replaced the actual parabolic stress diagram by a rectangular stress diagram such that the centre of gravity of both diagrams lies at the same point and their areas are also equal. He found that the average stress of the rectangular stress diagram is $K\sigma'_{cu}$. Where $K\sigma'_{cu}$ is the ultimate compressive strength of concrete cylinders at 28-day and $K = 0.85$.

The depth of rectangular stress block = $0.537d$.

2.33 (a)

(i) Maximum depth of neutral axis for $f_y = 250$ N/mm^2 is 0.53d and for $f_y = 415$ N/mm^2 is 0.48d.

(ii) The depth of centroid of compression from maximum strain fiber is $0.42\,x_{u,\max}$.

(iii) The depth of rectangular block is $\frac{3}{7}x_{u\max}$ $= 0.43\,x_{u,\max}$.

(iv) The maximum value of lever arm is $d - 0.42\,x_{u,\max}$

2.34 (c)

Deflection $\le \frac{\text{span}}{250}$ or 0.4% of the span.

2.36 (a)

The shear reinforcement contributes to the strength of the beam in the following ways.

(i) It carries a part of the shear due to the truss action.

(ii) It increases shear transfer by aggregate interlock by limiting the opening of the diagonal tension crack.

(iii) It increases the dowel action by providing support to the longitudinal bar which is being crossed by the shear crack.

(iv) It increases strength of concrete in regions particularly concrete by the closely spaced web reinforcement.

2.37 (c)

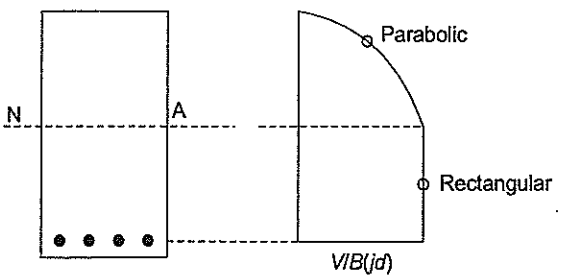
Failure of over-reinforced sections is of brittle nature.

2.38 (c)

Compression failure of reinforced concrete sections is sudden.

2.39 (b)

Shear stress varies in RCC beam as shown:



2.40 (c)

The neutral axis of T-beam may either be in the web or in the flange depending upon thickness of flange, percentage of reinforcement, amount of tensile steel, proportions of cross-section and compressive strength of materials.

2.41 (d)

For longitudinal reinforcing bar in a beam, the clear cover shall not be less than 25 mm nor less than the diameter of such bar as per **IS 456:1978.**

2.42 (c)

The deep beams are used in water tanks, bunkers, buildings etc. The basic assumption that plane section remains plane even after bending (Bernoulli's assumption) is not valid for deep beams.

Since the bending stresses are small and shear stress is large, so the principal tensile stress is nearly equal to the shear stress. Therefore diagonal tension crack are the first to start with.

2.43 (a)

The area of compression reinforcement also changes the span to depth ratio.

2.45 (b)

$$x_{u,\max} = \left[\frac{0.0035}{0.0055 + \frac{0.87 f_y}{E_s}}\right] d$$

for $f_y = 415\ \text{N/mm}^2$

and $E_s = 2 \times 10^5\ \text{N/mm}^2$

and $x_{u,\max} = 0.48d$

for $f_y = 250\ \text{N/mm}^2$

$x_{u,\max} = 0.53d$

2.46 (a)

Span to effective depth ratio

$$= 20 \times \left(\frac{10}{20}\right) = 10$$

Span to effective depth ratio with modification factors = $10 \times 0.9 \times 1.1 = 9.9$

$\therefore$ Effective depth $= \frac{20}{9.9} = 2.02$ m

2.47 (d)

The beam should be designed as rectangular beam because at support, tension will be upside and compression on downside i.e there will be

hogging moment. For span moment design the beam as T-beam as some part of slab will act as flange for beam at each of six span segments due to monolithic reinforced concrete slab.

2.48 (b)

Cracks are developed when tensile stresses and strains are caused during shrinkage due to restraint. Thus shrinkage causes tension cracks.

2.49 (d)

Transverse reinforcement is required to hold the longitudinal bars also.

2.50 (b)

For slabs spanning in two direction, the shorter of the two spans should be used for calculating the span to effective depth ratio.

2.51 (c)

The shear force should be calculated at critical section i.e. 1 m away from the face of the column. Effective span of beam is to be taken as the clear span plus effective depth of beam or centre to centre spacing of supports whichever is less. The location of critical section

$$x = 0.25 + 1 = 1.25 \text{ m}$$

$$\therefore \text{Design shear force} = \frac{10 \times 10}{2} - 10 \times 1.25$$

$$= 37.5 \text{ MN}$$

2.52 (c)

1 or 2 → For slab simply supported or fixed on three edges and free at one edge.

3 → for slab simply supported or fixed on all edges

2.53 (b)

The various load combinations are as follows:

(i) For Dead Load and Live Load the ultimate bending moment is given by,

$M_u = 1.5\,(DL + LL)$

$= 1.5 \times (20 + 30) = 75$ kN-m

(ii) For Dead Load and Earthquake (Seismic) Load the ultimate bending moment is given by,

$M_u = 1.5\,(DL + EL)$

$= 1.5 \times (20 + 10) = 45$ kN-m

(iii) For Dead Load, Live Load and Earthquake (Seismic) Load the ultimate bending moment is given by,

$M_u = 1.2\,(DL + LL + EL)$

$= 1.2 \times (20 + 30 + 10) = 72$ kN-m

So, design BM is maximum of all three combinations i.e. 75 kN-m.

2.54 (d)

For slab resting on top flange of beam, only friction force resist lateral buckling. But in design, friction is not considered and shear connectors are designed for full lateral disturbing force.

2.55 (a)

WSM assumes that concrete remains elastic up to failure i.e. stress varies linearly with strain. So compressive force and tensile force are assumed to increase in direct proportion with bending moment and thus the liver arm remains unchanged.

2.56 (b)

$\tau_v < 0.5\,\tau_c \rightarrow$ No shear reinforcement to be provided.

When $0.5\tau_c < \tau_v < \tau_c \rightarrow$ Minimum shear reinforcement.

$\tau_c < \tau_v < \tau_{c\,max} \rightarrow$ design of shear reinforcement

$\tau_v > \tau_{c,\,max} \rightarrow$ redesign the section

2.57 (a)

The increasing use of limit state method of design and high strength concrete lead to wide cracks in concrete structures. The minimum width of crack is limited on the basis of appearance of the structure, durability and corrosion resistance.

The width of flexural cracks at a particular point on the surface of the member depend primarily on the following factors:

(i) The distance from the point considered on the surface to the nearest longitudinal bar.

(ii) The distance from the point considered to the neutral axis.

(iii) Average strain at that point.

IS code has recommended maximum distance between the reinforcement bars for beams and slabs to control flexural cracks.

2.58 (b)

Minimum reinforcement in a slab

For	Fe250 (mild steel)	0.15%
	Fe415 (HYSD bars)	0.12%
	Welded wire fabric	0.12%

2.59 (a)

IS code recommends minimum percentage of tension steel in RC beams so as to prevent snapping of reinforcement before crushing and sudden failure of concrete.

2.60 (a)

Temperature & shrinkage reinforcement is invariably provided at right angles to the main longitudinal reinforcement in a slab because the surface area of slab is large.

2.61 (c)

The shear at which the inclined crack in beam without shear reinforcement is formed first, is taken as the shear strength of concrete as the difference between the loads corresponding to the first crack and the ultimate failure is very less. Formation of such crack occur when the principal tensile stress reaches the tensile strength of concrete. At the mid-span of a simply supported beam subjected to uniformly distributed load, where shear is small and bending stress is large, the direction of principal tensile stress is flat and is nearly equal to the flexural tensile stress. This will cause flexural cracks nearly vertical to the axis of the beam.

These are initiated even when $0.5\,\tau_c < \tau_v < \tau_c$.

Thus minimum reinforcement is needed to prevent flexural crack due to principal tension.

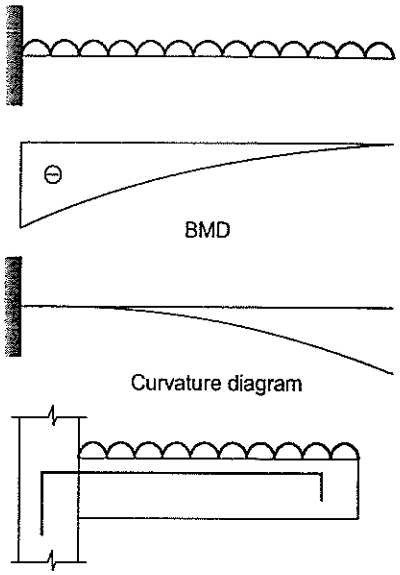
2.62 (c)

Doubly reinforced section is needed when:

- Depth and breadth of section is restricted and strength available from singly reinforced section is inadequate.
- At support of slab or continuous beam where bending moment changes sign.

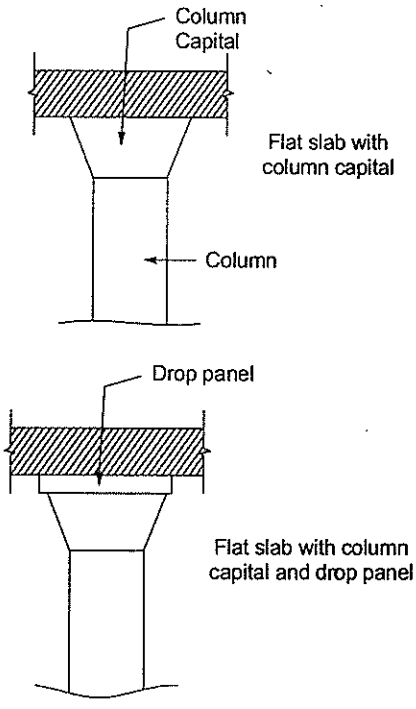
2.64 (a)

In cantilever beams carrying gravity load, top fibres above neutral axis are subjected to tensile stresses so main reinforcement is provided above the neutral axis.

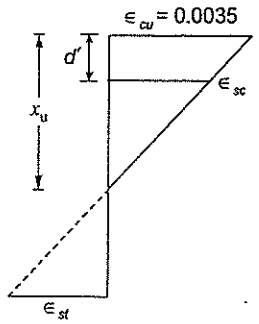


2.66 (c)

Drop Panel is structural component in flat slab



2.68 (b)



$$\frac{\epsilon_{sc}}{x_u - d'} = \frac{\epsilon_{cu}}{x_u}$$

$$\therefore \quad \epsilon_{sc} = 0.0035\left(1 - \frac{d'}{x_u}\right)$$

2.69 (b)

For under-reinforced beam

(i) $x_u < x_{u,\,lim}$ or x_c

(ii) Steel reaches ultimate stress before concrete reaching the ultimate stress

(iii) $M_u < M_{u,\,lim}$

(iv) Lever arm = $d - 0.42\,x_u$ will be more in the case of under-reinforced section.

2.70 (c)

The working stress method assumes that concrete is elastic and the stress in concrete varies linearly from zero at the neutral axis to a maximum at the extreme fibre. The bond between steel and concrete is perfect within the elastic limit of steel.

2.72 (a)

$$\text{Modular ratio } m = \frac{\sigma_{st}}{\sigma_{cbc}} = \frac{E_s}{E_c}$$

2.74 (c)

The design shear strength of concrete in *RC* beam depends upon grade of concrete i.e. compressive strength of concrete; percentage of longitudinal tension reinforcement; and axial compressive force.

2.75 (d)

The minimum reinforcement in edge strip, parallel to that edge shall be 0.15% for mild steel and 0.12% for HYSD bars, of the cross-section area of concrete.

2.76 (d)

Effective flange width,

$$b_{eff} = \frac{l_o}{6} + b_w + 6d_f$$

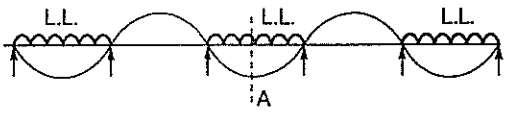
$$= \frac{3600}{6} + 300 + 6 \times 100 = 1500 \text{ mm}$$

2.77 (c)

For T-beam having neutral axis within the flange, the formulae derived for rectangular beam can be used.

2.78 (d)

In order to obtain maximum positive span moment, the live load should be placed on the span plus alternate spans



Max. span moment at A (sagging)

2.79 (*)

Note: The exposure condition comes under 'very sever' range and recommended minimum cover is 50 mm as per Table 16 of IS 456. So no answer is correct.

2.80 (d)

In two way slab,material efficiency is very high as moment redistribution occurs both in lateral and longitudinal directions, so MOR of section increases. Mostly in T beams the neutral axis lies within the web. The concrete below neutral axis does not take any stress. Thus lot of material below remains unused. Hence material efficiency of rectangular beam is less than that of two way slab but more than that of T beam.

2.82 (c)

For cantilever and continuous beam the ratio of span to depth to satisfy stiffness criterion shall not exceed 7 and 26 respectively.
(clause 23.2.1 of IS : 456-2000)

2.83 (d)

RCC roof slab is designed as two way slab if ratio of spans in two directions is less than 2 and it is supported at all four ends and if the ratio of spans in two directions is greater than 2 or is supported on only two opposite ends, it is designed as one way slab.

2.84 (a)

In under reinforced concrete, the concrete is not fully stressed to its permissible value when stress in steel reaches its maximum value.

2.85 (c)

Concrete reaches its maximum permissible value prior to yielding of steel when section is over-reinforced. The strain across section remains low

and the deflection, curvature and crack width remains low and the failure is sudden.

2.87 (c)

In balanced failure simultaneous initiation of crushing of concrete and yielding of steel occurs as compressive strain in concrete at extreme fibre reaches ultimate strain and tensile strain at level of steel reaches yield strain.

2.88 (c)

A flat slab is a typical type of construction in which a reinforced slab is built monolithically with the supporting columns and is reinforced in two or more directions without any provision of beams. Because of exclusion of beam-system in this type of construction, a plain ceiling is obtained, thus giving attractive appearance from architectural point of view. The plain ceiling diffuses the light better and is considered less vulnerable in the case of fire than the usual beam slab construction. The flat slab is easier to construct and requires cheaper formwork.

2.89 (c)

In the steel beam theory the concrete is completely neglected and the moment of resistance is taken equal to the moment of steel. Couple, taking the permissible value of stresses in compressive steel equal to permissible value in tensile steel. Thus, in the steel beam theory, the concrete serves only as a web and the compressive and tensile steels as the flanges of an imaginary steel joint having an equal area of both the flanges.

2.90 (d)

As per clause 26.5.1.1 of IS : 456-2000, the maximum area of tension reinforcement in beams shall not exceed 0.04 bD.

As per clause 26.5.1.2 of IS : 456-2000, the maximum area of compression reinforcement in beams shall not exceed 0.04 *bD*.

2.91 (c)

Deflection/vibration and cracking of R.C. member are checked by limit state of serviceability. Final deflection should be limited to maximum span/ 250 mm. Deflection limit is controlled by limiting span/depth ratio of the RC member.

2.92 (b)

Moment of resistance for a balanced section is given by

$$M_{u,\lim} = 0.36 f_{ck} \times \frac{x_{u,\lim}}{d} \times \left(1 - 0.42 \times \frac{x_{u,\lim}}{d}\right) \times bd^2$$

But for Fe 415, $x_{u,\lim} = 0.48\, d$

$$\therefore M_{u,\lim} = 0.36\, f_{ck} \times 0.48 \times (1 - 0.42 \times 0.48) \times bd^2$$

$$\Rightarrow M_{u,\lim} = 0.13796\, f_{ck} \times bd^2$$

On comparison, we get

$$K = 0.13796\, f_{ck} = 0.13796 \times 20 = 2.76$$

2.93 (d)

As per clause 26.5.1.5 of IS: 456-2000, the maximum spacing of shear reinforcement measured along the axis of member shall not exceed 0.75 *d* for vertical stirrups and '*d*' for inclined stirrups at 45°, where '*d*' is the effective depth of the section under consideration. In no case shall the spacing exceed 300 mm.

$\therefore$ Maximum spacing = 0 75 d = 0.75 × 300 = 225 mm

2.94 (a)

As per clause 22.2 of IS:456-2000, for simply supported beam or slab, the effective span of a member that is not built integrally with its supports shall be taken as clear span plus the effective depth of slab or beam or centre to centre of supports, whichever is less.

$\therefore$ Effective span = 5 × 1000 + 400 = 5400 mm

and effective span $= 5 \times 1000 + \frac{300}{2} + \frac{300}{2}$ = 5300 mm

2.96 (b)

As per table 13 of IS : 456-2000, the shear coefficients for continuous beams are as follows:

(i) At end support for dead load and imposed load (fixed) 0.4

(ii) At end support for imposed load (not fixed) 0.45

(iii) At support next to the end support on the outer side for dead load and imposed load (fixed) 0.6

(iv) At support next to the end support on the outer side for imposed load (not fixed) 0.6

(v) At support next to the end support on the inner side for dead load and imposed load (fixed) 0.55

(vi) At support next to the end support on the inner side for imposed load (not fixed) 0.6

(vii) At all other interior supports for dead load and imposed load (fixed) 0.5

(viii) At all other interior supports for imposed load (not fixed) 0.6

2.98 (a)

Moment of area below neutral axis increases as the area of reinforcement is increased. To accommodate this increase, the area of moment for concrete above neutral axis should also increase. Thus neutral axis shifts downwards and depth of neutral axis increases.

2.100 (c)

As per clause 37.1.1 of IS: 456-2000 the ultimate moment of resistance at any section should not be less than 70% of the factored moment at that section as obtained from the elastic moment envelope (considering all loading combinations).

2.101 (d)

In under reinforced beam, rate of gain of stress in steel is more than rate of concrete. So steel reaches its maximum permissible value earlier than concrete and fails first hence it is ductile in failure. In case of over- reinforced section stress in concrete reaches its maximum permissible value first so concrete fails first and it is brittle failure since concrete is brittle.

2.102 (c)

It spacing of 12 mm bars is S then

$$\left(\frac{1000}{100}\right)\times\frac{\pi\times10^2}{4}=\left(\frac{1000}{S}\right)\times\frac{\pi\times12^2}{4}$$

$\Rightarrow S = 144$ mm

2.103 (a)

In a reinforced concrete beam external shear is resisted by

1. Shear resistance 'V_{cz}' of the uncracked portion of concrete
2. Vertical component 'V_{ay}' of the 'interface shear' (aggregate interlock) force V_a
3. Dowel force V_d in the tension reinforcement (due to dowel action); and
4. Shear resistance V_s carried by the shear (transvers) reinforcement, if any.

The presence of increased longitudinal reinforcement in the flexural tension zone not only contributes to enhanced dowel action (V_d), but also serves to control the propagation of flexural cracks and contributes to increasing the depth of the neutral axis, and thereby the depth of the uncracked concrete in compression; this enhances the contributions of V_a and V_{cz}. Thus, the higher the percentage tension reinforcement, the greater the shear resistance in the concrete - up to a limit.

2.104(d)

In limit state design of concrete the design strength of concrete is 0.446 f_{ck} while the area of stress block is 0.36 $f_{ck}X_u$. Where X_u is depth of neutral axis.

2.105 (c)

As per clause 24.1, shorter of two spans spanning in two directions is used to calculate span to effective depth ratio. For two way slabs of shorter spans (up to 3.5 m) with mild steel reinforcement, span to depth ratios satisfying deflection limits are:

Simply supported slabs- 35

Continuous slabs- 40

Minimum overall depth to satisfy vertical limits= $\frac{3000}{40}$ = 75mm

2.106 (b)

The Code limits the maximum diameter of reinforcing bars in slabs to one-eight of the total thickness of the slab, and the maximum spacing of such main bars to 3d or 300 mm (whichever is less).

2.107 (d)

A cantilever porch experiences tension at the top surface while compression at the bottom, hence tensile reinforcement is provided at top.

2.108 (b)

Percentage of steel is dependent on characteristic strength of concrete (f_{ck}) rather than its yield strength.

2.109 (c)

Minimum strain is given by

$$\epsilon_s = 0.002 + \frac{0.87 f_y}{E_s}$$

$$\therefore \epsilon_s = 0.002 + \frac{0.87 \times 400}{2 \times 10^5} = 0.0037$$

2.110 (a)

Over-reinforced beam: In this type of beam, the steel area provided is more than what is required for a balanced design. Consequently, $A_{st} > A_{st,\ bal}$. Here the depth of neutral axis is more than that of balanced neutral axis, i.e. $x > x_{cr}$. It can be seen that in this case, the utilization of steel is less than its permissible vaue. The failure in this case is called compression failure and the design is referred to as over-reinforced.

2.111 (c)

In case of a slab, shear stresses are usually very low and shear reinforcement is never provided in slab. It is preferred to increase the thickness of slab and hence reduce shear stress rather than provide shear reinforcement.

2.113 (b)

Assumptions made in analysis of moment coefficient for continuous slabs:

- Mid span deflections in orthogonal directions are same
- Uniformly distributed load, where there are minimum 3 spans which do not differ in length by 15% of the longest span
- Member shall be designed to resist moment at support of $\frac{wl}{24}$ where member is built into masonry wall which develops partial restraint.

(b) is the closest option.

2.114 (c)

According to clause 23.2.1

For a simply supported beam value of span to effective depth

$$\frac{L}{D} = 20$$

For spans above 10 m, the value given above shall be multiplied by 10/span in metres i.e.,

$$\frac{10}{16} = 0.625$$

$$\therefore \quad \frac{L}{d} = 20 \times 0.625 = 12.5$$

2.115 (b)

According to clause 29.1 of IS 456 : 2000

A beam shall be deemed to be a deep beam when the ratio of effective span to overall depth l/D is less than:

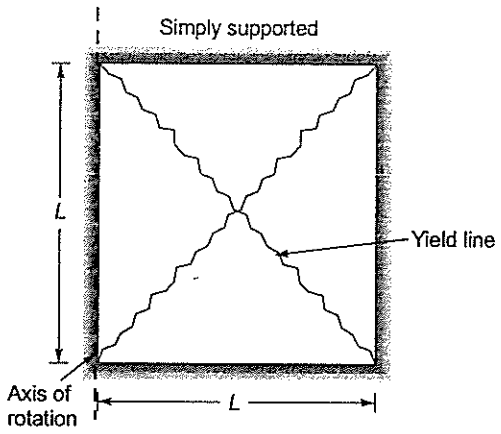
1. 2.0 for a simply supported beam; and
2. 2.5 for a continuous beam

2.117 (b)

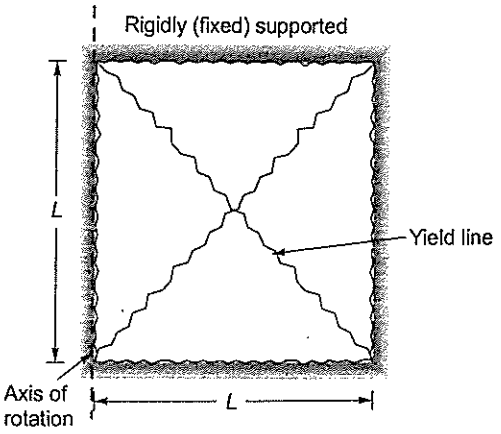
Splicing is never done at the location of maximum BM or where $BM = 0$ i.e. at maximum S.F.

2.119 (d)

Yield line may or may not be the axis of rotation.



Axis of rotation is one edge support

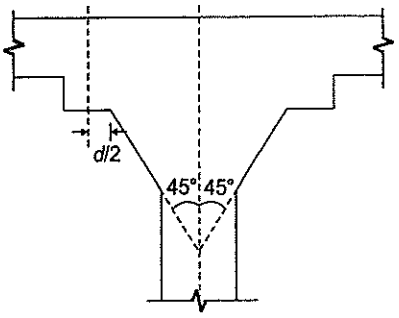


Axis of rotation is one edge support which coincides with yield line

2.120 (b)

As per IS 456: 2000 Cl. 31.6.1.

2.121 (a)



Flat slab with drop and column with column head.

The enlarge head of the supporting column of a flat slab is known as capital.

2.124 (c)

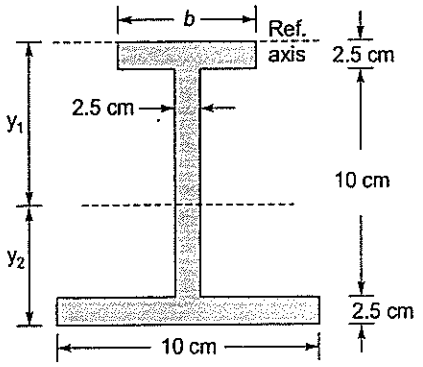
$$M_{u\lim} = 0.138\, f_{ck}\, bd^2$$
$$= 0.138 \times 20 \times 150 \times 330^2$$
$$= 45.085 \text{ kN-m}$$

2.126 (d)

Because $b < 10$ cm

So clearly $y_1 > y_2$ (Neutral axis near the bottom flange)

$$\sigma_{Top} = \sigma_1$$
$$s_{Bottom} = \sigma_2$$



$$\frac{\sigma_1}{\sigma_2} = \frac{4}{3}$$

$$\frac{\sigma_1}{y_1} = \frac{\sigma_2}{y_2} = \frac{4}{3}$$

So $$\frac{y_1}{y_2} = \frac{4}{3} \quad \text{...(i)}$$

$$y_1 + y_2 = 15 \text{ cm} \quad \text{...(ii)}$$

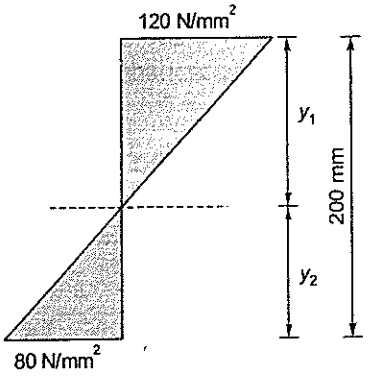
$$y_1 = 8.57 \text{ cm}$$

$$\frac{A_1 y_1' + A_2 y_2' + A_3 y_3'}{A_1 + A_2 + A_3} = 8.57$$

$$\frac{\left[\left(b \times 2.5 \times \frac{2.5}{2}\right) + (10 \times 2.5 \times 7.5) + (10 \times 2.5 \times 13.75)\right]}{(b \times 2.5) + (10 \times 2.5) + (10 \times 2.5)} = 8.57$$

On solving, we get, $b = 5.6$ cm

2.127 (a)



Stress Diagram

$$\sigma_1 = \sigma_{top} = 120 \text{ MPa}$$
$$\sigma_2 = \sigma_{bottom} = 80 \text{ MPa}$$
$$\sigma_{top} > \sigma_{bottom}$$

So, $y_1 > y_2$

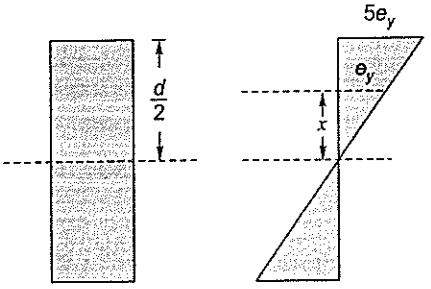
$$\frac{\sigma_1}{y_1} = \frac{\sigma_2}{y_2}$$

$$\frac{120}{y_1} = \frac{80}{y_2}$$

So, $y_1 + y_2 = 200$ ...(ii)

So, $y_1 = 120$ mm

2.128 (b)



$$\frac{x}{e_y} = \frac{d/2}{5e_y}$$

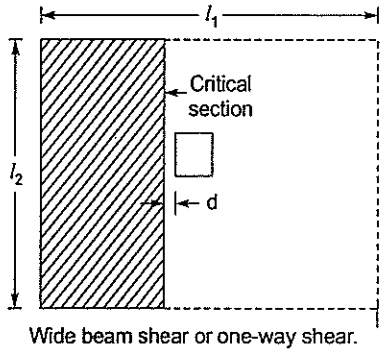
$$\Rightarrow \quad x = 0.1d$$

Depth of beam responding under elastic condition $= 2x$

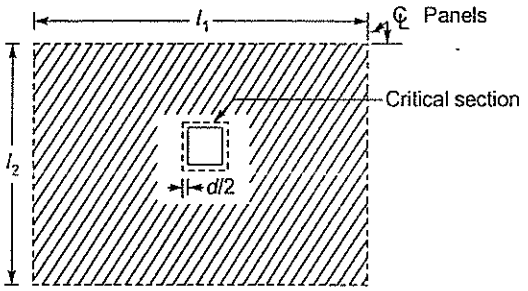
$$= 2 \times 0.1d = 0.2d$$

2.129 (d)

Slabs are mainly designed for Bending and deflection. So, Flexure, Positive Bending Moment and Negative Bending Moment are important. Slabs are designed for both One way Shear and Two-way Shear (Punching shear) also, though it does not determine the thickness or reinforcement of slab.



Wide beam shear or one-way shear.



Two-way shear or punching shear.

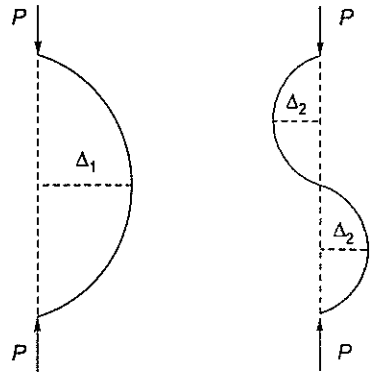
2.130 (a)

Secondary compression failure of concrete occurs in under reinforcement section, in which steel fails first and finally failure occur due to gradual increase of strain in concrete when steel starts yielding and finally concrete getting crashed (called secondary compression failure).

In over reinforcement section, failure occur due to direct failure of concrete that reach to failure strain 0.0035 first. Steel does not fail in this case.

2.131 (a)

The member of Beam Column is subjected to axial compression with bending.



Since, $\Delta_1 > \Delta_2$ so secondary moment $P\Delta_1 > P\Delta_2$. It means $SM_1 > SM_2$.

2.132 (c)

1. According to IS 456 : 2000, if load on slab is not much to provide reinforcement than also minimum reinforcement of 0.12% is provided.
2. Due to excessive reinforcement spacing between the reinforcement bars will be less which will lead to congestion and affect placement and compaction of concrete.

2.133 (d)

T-beam will be identical to rectangular beam with width equal to it's flange width when neutral axis remains below or at the level of flange.

3 Shear, Bond, Torsion and Development Length

3.1 Torsion resisting capacity of a given *RC* section
(a) decreases with decrease in stirrup spacing
(b) decreases with increase in longitudinal bars
(c) does not depend upon stirrup and longitudinal steels
(d) increases with the increase in stirrup and longitudinal steels

[ESE : 1995]

3.2 If the nominal shear stress (τ_v) at a section does not exceed the permissible shear stress (τ_c)
(a) minimum shear reinforcement is still provided
(b) shear reinforcement is provided to resist the nominal shear stress
(c) no shear reinforcement is provided
(d) shear reinforcement is provided for the difference of the two

[ESE : 1995]

3.3 In limit state design, permissible bond stress in the case of deformed bars is more than that in plain bars by
(a) 60% (b) 50%
(c) 40% (d) 25%

[ESE : 1995]

3.4 Shear span is defined as the zone where
(a) bending moment is zero
(b) shear force is zero
(c) shear force is constant
(d) bending moment is constant

[ESE : 1996]

3.5 The safe shear resistance of an anchor connector is given by (K is a coefficient and other symbols have the usual meanings)
(a) $V = Kf_{sy}A_t$ (b) $V = Kf_{sy}^2A_t$
(c) $V = Kf_{sy}^{1/2}A_t$ (d) $V = Kf_{sy}^{1/2}A_t^{1/2}$

[ESE : 1998]

3.6 Consider the following statements:
1. At a point of inflection, the embedment length need not exceed the development length L_d.
2. The condition that $L_d \le \left(\frac{M_1}{V} + L_0\right)$ need not be checked for negative reinforcement.
3. At least one-third of the total negative reinforcement provided must extend beyond the point of inflection for a distance not less than 'd' or 12ϕ or clear-span whichever is larger.

Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 1 and 3 (d) 2 and 3

[ESE : 1999]

3.7 Match List-I (Stress) with List-II (Nature) and select the correct answer using the codes given below the lists:

List-I
A. Bond stress
B. Thermal stress
C. Hoop stress
D. Torsional stress

List-II
1. Zero at centre of cross-section
2. Circumferential stress
3. Linear stress
4. Longitudinal shear stress
5. Zero on the surface

Codes:

	A	B	C	D
(a)	5	2	4	1
(b)	4	3	2	1
(c)	4	5	2	3
(d)	1	3	4	5

[ESE : 1999]

3.8 **Assertion (A):** The development length for HYSD Fe 415 bars is less than that for mild steel plain bars.

Reason (R) : The permissible bond stress for HYSD Fe 415 bars is more than that for mild steel plain bars.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

3.9 Consider the following statements:
Bars that extend into a simple support must be able to develop their full strength at a designated point L so that their moment capacity is more than the bending moment at that point. The clauses of the code require that ($\sigma_s = 0.85\sigma_{sy}$)

1. $L_d \le \dfrac{1.3M_1}{V} + L_0$

2. $\dfrac{\phi\sigma_s}{4\tau_{bd}} \le \dfrac{1.3M_1}{V} + L_0$

3. $\phi \le \dfrac{4\tau_{bd}}{\sigma_s}\left(\dfrac{1.3M_1}{V} + L_0\right)$

Which of these statements are correct?
(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 1, 2 and 3

[ESE : 2000]

3.10 While checking shear resistance of reinforced concrete beams for limit state of collapse as per IS:456, which one of the following nominal shear stress recommendations is to be adhered to?
(V_u is shear force at vertical cross-section, 'b' and 'd' are overall breadth and effective depth of beam respectively)

(a) $\dfrac{0.5V_u}{bd}$ (b) $\dfrac{2V_u}{5bd}$
(c) $\dfrac{V_u}{0.5bd}$ (d) $\dfrac{V_u}{bd}$

[ESE : 2000]

3.11 **Assertion (A) :** Tensile reinforcement bars of a rectangular beam are bent at suitable places.

Reason (R) : Bent tensile reinforcement bars in a rectangular beam resist bending moment and provide local bond stress.

[ESE : 2000]

3.12 The chances of diagonal tension cracks in R.C.C. member reduce when
(a) axial compression and shear force act simultaneously
(b) axial tension and shear force act simultaneously
(c) only shear force act
(d) flexural and shear force act

[ESE : 2001]

3.13 The maximum permissible shear stress $\tau_{c,\,max}$ given in BIS : 456-1978 is based on
(a) diagonal tension failure
(b) diagonal compression failure
(c) flexural tension failure
(d) flexural compression failure

[ESE : 2001]

3.14 The codal provisions recommend minimum shear reinforcement in the form of stirrups in the beams
1. to cater for any torsion in the beam section
2. to improve ductility of the cross section
3. to improve dowel action of longitudinal tension bars

Select the correct answer using the codes given below:
(a) 1, 2 and 3 (b) 2 and 3
(c) Only 1 (d) Only 2

[ESE : 2002]

3.15 Consider the following statements:
1. Reinforcement that is no longer required for flexure beyond a certain section, shall however be extended by d or 12ϕ, whichever is greater, before being curtailed.
2. Atleast half the bars should be bent up at the cut-off point.
3. The shear capacity at cut-off point should atleast be 1.5 times the shear force at that section.

Which of these statements are correct?
(a) 1 and 2 (b) 1 and 3
(c) 2 and 3 (d) 1, 2 and 3

[ESE : 2004]

3.16 Match List-I (Reinforcement type) with List-II (Anchorage requirement) and select the correct answer using the codes given below the lists:

List-I

A. Footing slab, tensile reinforcement
B. Cantilever beam, tensile reinforcement
C. Simply supported beam, tensile reinforcement
D. Beam, shear stirrup

List-II

1. $\frac{L_d}{3}$ into the support
2. 6ϕ for 135° bend
3. L_d into the support
4. L_d from the column face

Codes :

	A	B	C	D
(a)	1	3	4	2
(b)	1	2	4	3
(c)	4	3	1	2
(d)	4	2	1	3

[ESE : 2004]

3.17 Diagonal tension reinforcement is provided in a beam as

(a) longitudinal bars
(b) bent up bars
(c) helical reinforcement
(d) 90° bend at the bends of main bars

[ESE : 2004]

3.18 In a reinforced concrete member, the best way to ensure adequate bond is

(a) to provide minimum number of large diameter bars
(b) to provide large number of smaller diameter bars
(c) to increase the cover for reinforcement
(d) to provide additional stirrups

[ESE : 2004]

3.19 Minimum shear reinforcement is provided to

(a) resist shear force at the support
(b) resist shear on account of accidental torsion
(c) arrest the longitudinal cracks on side faces due to shrinkage and temperature variation
(d) resist shear in concrete developing on account of non-homogeneity of concrete

[ESE : 2004]

3.20 A beam of rectangular cross-section ($b \times d$) is subjected to a torque T. What is the maximum torsional stress induced in the beam ($b < d$ and α is a constant)?

(a) $\frac{T}{\alpha b^2 d}$ (b) $\frac{T}{\alpha b d^2}$

(c) $\frac{T}{\alpha b d}$ (d) $\frac{T}{bd}$

[ESE : 2005]

3.21 Consider the following statements with regard to crack formation and its control:

1. The surface width of the crack should not, in general, exceed 0.30 mm for structures not subjected to aggressive environment.
2. When depth of web in a beam exceeds 750 mm, side face reinforcement @0.1 percent of web area should be provided on each face.
3. The nominal spacing of main bars in a slab should not exceed three times the effective depth of a solid slab or 300 mm, whichever is smaller.

Which of these statements is/are correct?

(a) 1 only (b) 1 and 2
(c) 1 and 3 (d) 2 and 3

[ESE : 2005]

3.22 **Assertion (A)** : The design shear strength of axially loaded beams is increased by a factor, as per IS codes, $1+\left(\frac{3P_u}{A_g f_{ck}}\right)$ or 1.5 whichever is less.

(where P_u is axial load, A_g gross area of column and f_{ck} characteristic concrete strength)

Reason (R) : The presence of axial compressive force is to hasten the formation of both flexural and inclined cracks.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2005]

3.23 The distance between theoretical cut-off point and actual cut-off point in respect of the curtailment

of reinforcement of reinforced concrete beams should not be less than
(a) Development length
(b) 12 × diameter of bar or effective depth whichever is greater
(c) 24 × diameter of bar or effective depth whichever is greater
(d) 30 × diameter of bar or effective depth whichever is greater

[ESE : 2006]

3.24 A beam is designed for uniformly distributed loads causing compression in the supporting columns. Where is the critical section for shear? (d is effective depth of beam and L_d is development length)
(a) A distance $L_d/3$ from the face of the support
(b) A distance d from the face of the support
(c) At the centre of the support
(d) At the mid span of the beam

[ESE : 2006]

3.25 An *RC* structural member rectangular in cross section of width b and depth D is subjected to a combined action of bending moment M and torsional moment T. The longitudinal reinforcement shall be designed for a moment M_e given by

(a) $M_e = M + \dfrac{T(1+D/b)}{1.7}$

(b) $M_e = M + \dfrac{T(1-D/b)}{1.7}$

(c) $M_e = \dfrac{T(1+D/b)}{1.7}$

(d) $M_e = \dfrac{T(1-b/D)}{1.7}$

[ESE : 2006]

3.26 Assertion (A) : In working stress method of design, the values of strain in cement concrete and steel at any point are same.
Reason (R) : There is a perfect bond between steel and surrounding cement concrete.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2006]

3.27 Which one of the following is the correct expression to estimate the development length of deformed reinforcing bar as per IS code in limit state design?

(a) $\dfrac{\phi\sigma_s}{4.5\tau_{bd}}$ (b) $\dfrac{\phi\sigma_s}{5\tau_{bd}}$

(c) $\dfrac{\phi\sigma_s}{6.4\tau_{bd}}$ (d) $\dfrac{\phi\sigma_s}{8\tau_{bd}}$

where ϕ is diameter of reinforcing bar, σ_s is the stress in the bar at a section and τ_{bd} is bond stress

[ESE : 2007]

3.28 When HYSD bars are used in place of mild steel bars in a beam, the bond strength
(a) does not change (b) increases
(c) decreases (d) becomes zero

[ESE : 2008]

3.29 What is the bond stress acting parallel to the reinforcement on the interface between bar and concrete?
(a) Shear stress (b) Local stress
(c) Flexural stress (d) Bearing stress

[ESE : 2008]

3.30 Match List-I with List-II and select the correct answer using the codes given below the lists :

List-I

A. $\dfrac{V_u}{bd}$

B. $0.7\sqrt{f_{ck}}$

C. $5000\sqrt{f_{ck}}$

D. $\dfrac{\phi f_s}{4\tau_b}$

List-II
1. Modulus of rupture
2. Development length
3. Nominal shear stress
4. Hook anchorage value
5. Modulus of concrete

Codes:

	A	B	C	D
(a)	3	1	5	2
(b)	2	1	4	3
(c)	3	5	1	4
(d)	2	4	1	3

[ESE : 2009]

3.31 Consider the following statements dealing with flexural reinforcement to be terminated in the tension zone :

1. The shear at the cut-off point not to exceed two-third of the otherwise permitted value.
2. Shear reinforcement is provided along each terminated bar overlapping three-fourth of the appropriate distance from the cut-off point.
3. For 36 mm and smaller bars, the continuing bars shall provide double the area required for flexure at the cutoff and shear does not exceed three-fourth of the permitted value.

Which of these statements is/are correct?

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 3 only

[ESE : 2009]

3.32 What is the anchorage value of a standard hook of a reinforcement bar of diameter D?

(a) $4D$ (b) $8D$
(c) $12D$ (d) $16D$

[ESE : 2009]

3.33 Lap length of reinforcement in compression shall not be less than

(a) 30ϕ (b) 24ϕ
(c) 20ϕ (d) 15ϕ

where ϕ = diameter of bar.

[ESE : 2011]

3.34 The development length in compression for a 20 mm diameter deformed bar of grade Fe 415 embedded in concrete of grade $M25$ whose design bond stress is 1.40 N/mm^2, is

(a) 1489 mm (b) 1289 mm
(c) 806 mm (d) 645 mm

[ESE : 2012]

3.35 The appropriate expression in assessing development length is

(a) $L_d = \frac{\phi\sigma_s}{4\tau_{bd}}$ (b) $L_d = \frac{\phi\sigma_{bc}}{\tau_{bd}}$

(c) $L_d = \frac{\sigma_s}{4\tau_{bd}}$ (d) $L_d = \frac{\phi\sigma_s}{8\tau_{bd}}$

[ESE : 2012]

3.36 Which of the following statements are correct?

1. Splices in flexural members should not be at sections where the BM is more than 50% of the moment of resistance.
2. Normal lap splices can be used for all types of bars irrespective of the sizes.
3. Where bars of two different diameters are to be spliced, the lap length shall be calculated on the basis of the diameter of the smaller bar.

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2013]

3.37 Assuming the concrete below the neutral axis to be cracked, the shear stress across the depth of a singly reinforced rectangular beam section

(a) increases parabolically to the neutral axis and then drops abruptly to zero value
(b) increases parabolically to the neutral axis and then remains constant over the remaining depth
(c) increases linearly to the neutral axis and then remains constant up to the tension steel
(d) increases parabolically to the neutral axis and then remains constant up to the tension steel

[ESE : 2014]

3.38 If the stirrup spacing is equal to 0.75 times the effective depth of an RC beam, then the shear capacity of stirrup steel is equal to

(a) 1.25 ($f_y A_{sv}$) (b) 1.16 ($f_y A_{sv}$)
(c) 1.08 ($f_y A_{sv}$) (d) 1.00 ($f_y A_{sv}$)

where f_y is yield strength and A_{sv} is cross-sectional area of the stirrup steel.

[ESE : 2015]

3.39 If a 2-legged 8 mm diameter HYSD bar is used as shear reinforcement for a beam of width 230 mm and effective depth 300 mm, what is the nearest magnitude of the spacing of minimum shear reinforcement?

(a) 420 mm (b) 390 mm
(c) 350 mm (d) 320 mm

[ESE : 2015]

3.40 Web buckling occurs in a beam due to excessive
(a) Direct tensile stress in the web
(b) Bending tensile stress in the web
(c) Torsional shear stress in the web
(d) Compressive stress in the web

[ESE : 2015]

3.41 Consider two RCC beams, *P* and *Q*, each of width 400 mm and effective depth 750 mm, made with concrete having a τ_{cmax} = 2.0 MPa. For the reinforcement provided and the grade of concrete used, it may be assumed that τ_c = 0.75 MPa. If the design shear for the beams *P* and *Q* is 400 kN and 750 kN, respectively, which of the following statements is true considering the provisions of IS 456-2000?
(a) Shear reinforcement should be designed for 175 kN for beam *P* and the section for beam *Q* should be revised.
(b) Nominal shear reinforcement is required for beam P and the shear reinforcement should be designed for 120 kN for beam *Q*.
(c) Shear reinforcement should be designed for 175 kN for beam *P* and the section for beam *Q* should be designed for 525 kN for beam *Q*.
(d) The sections for both beams, *P* and *Q*, need to be revised.

[ESE : 2015]

3.42 A rectangular beam of width 230 mm and effective depth 300 mm is proposed to carry a BM and SF of 120 kNm and 270 kN, respectively. If M30 grade of concrete and Fe 415 steel are used for which τ_{cmax} = 3.5 MPa, which one of the following statements is correct?
(a) It can be designed as a singly reinforced, under-reinforced section.
(b) It can be designed as a doubly reinforced section.
(c) The section is unsafe from shear considerations.
(d) It can be designed as a doubly reinforced section but it is unsafe from shear considerations.

[ESE : 2015]

3.43 As per IS 456 : 2000, the maximum permissible shear stress, $\tau_{c,max}$, is based on
(a) Diagonal tension failure
(b) Diagonal compression failure
(c) Flexural tension failure
(d) Flexural compression failure

[ESE : 2016]

3.44 If a beam is likely to fail due to high bonding stresses, then its bond strength can be increased most economically by
(a) Providing vertical stirrups
(b) Increasing the depth of the beam
(c) Using smaller diameter bars in correspondingly more numbers
(d) Using higher diameter bars by reducing their numbers

[ESE : 2016]

3.45 In a reinforced concrete section, shear stress distribution is diagrammatically
(a) Wholly Parabolic
(b) Wholly Rectangular
(c) Parabolic above NA and Rectangular below NA
(d) Rectangular above NA and Parabolic below NA

[ESE : 2016]

3.46 The bond between steel and concrete is mainly due to
1. Mechanical resistance
2. Pure adhesive resistance
3. Frictional resistance

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2016]

3.47 A rectangular beam is of size 230 mm x 350 mm (effective depth). The factored shear force acting at a section is 80 kN. If the permissible shear stress in concrete is 0.25 MPa, the design shear force is nearly
(a) 100 kN (b) 80 kN
(c) 60 kN (d) 20 kN

[ESE : 2017]

3.48 Consider the following statements in the light of IS 456 : 2000:

1. There is an upper limit on the nominal shear stress in beams (even with shear reinforcement) due to the possibility of crushing of concrete in diagonal compression.
2. A rectangular concrete slab whose length is equal to its width may not be a two-way slab for certain definable support conditions.

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2017]

Answers Shear, Bond, Torsion and Development Length

3.1 (d)	3.2 (a)	3.3 (a)	3.4 (c)	3.5 (a)	3.6 (b)	3.7 (b)	3.8 (a)	3.9 (d)	
3.10 (d)	3.11 (c)	3.12 (a)	3.13 (b)	3.14 (a)	3.15 (b)	3.16 (c)	3.17 (b)	3.18 (b)	
3.19 (c)	3.20 (a)	3.21 (c)	3.22 (c)	3.23 (b)	3.24 (b)	3.25 (a)	3.26 (a)	3.27 (c)	
3.28 (b)	3.29 (a)	3.30 (a)	3.31 (a)	3.32 (d)	3.33 (b)	3.34 (d)	3.35 (a)	3.36 (b)	
3.37 (d)	3.38 (b)	3.39 (b)	3.40 (d)	3.41 (a)	3.42 (d)	3.43 (b)	3.44 (c)	3.45 (c)	
3.46 (d)	3.47 (c)	3.48 (c)							

Explanations Shear, Bond, Torsion and Development Length

3.1 (d)

The amount of torsion in a member depends upon the magnitude of the torsional stiffness of the member itself in relation to the stiffness of the interconnecting members. In reinforced concrete structures, the stiffness decreases considerably after the formation of cracks if the continuity at the joint are not considered in the design.

The presence of reinforcement in the form of longitudinal and transverse steel increases the torsional moment carrying capacity of beams.

3.2 (a)

If the calculated shear stress (τ_v) is

(i) less than allowable shear stress (τ_c) but more than $0.5\tau_c$, the minimum shear reinforcement in the form of stirrups shall be provided such that

$$\frac{A_{sv}}{bS_v} \geq \frac{0.4}{0.87f_y}$$

(ii) more than τ_c, shear reinforcement shall be provided in the form of vertical stirrups or bent up bars with stirrups or inclined stirrups to resist $V_{us} = V_u - \tau_c bd$. Here $\tau_v < \tau_{c,max}$

(iii) If $\tau_v > \tau_{c,max}$ redesign the section.

3.3 (a)

For deformed bars, the bond stress shall be increased by 60% of the values for plain bars in tension. For bars in compression, the values of bond stress for bars in tension shall be increased by 25%.

3.4 (c)

The shear strength of a beam without shear reinforcement depends upon shear span/effective depth ratio, where shear span is defined by the ratio M/V. The shear force is constant over the shear span.

3.5 (a)

$$V = K f_{sy} A_f$$

V = ultimate shear resistance of each connector

f_{sy} = ultimate tensile strength of steel of anchorage connector

A_f = cross-section area of each connector

3.6 (b)

The development length $L_d = \frac{\phi\sigma_s}{4\tau_{bd}}$

$\phi \rightarrow$ nominal diameter of the bar.

$\phi_s \rightarrow$ stress in bar at the section considered at design load.

τ_{bd} → design bond stress

At simple supports and at points of inflection, positive moment tension reinforcement shall be limited to a diameter such that

$$L_d \le \frac{M_1}{V} + L_o$$

This condition need not to be checked for negative reinforcement.

3.7 (b)

Thermal stresses are developed due to restriction of free length. These are linear with respect to change in temperature.

3.8 (a)

The development length $L_d = \frac{\phi\sigma_s}{4\tau_{bd}}$.

Design bond stress (τ_{bd}) in HYSD bars is 60% more than that for mild steel plain bars. So development length is less in HYSD bars.

3.9 (d)

Development length,

$$L_d = \frac{\phi\sigma_s}{4\tau_{bd}}$$

$$\therefore \quad \phi \le \frac{4\tau_{bd}}{\sigma_s}\left(\frac{1.3M_1}{V} + L_0\right)$$

3.10 (d)

The nominal shear stress $\tau_v = \frac{V_u}{bd}$.

3.11 (c)

The shear reinforcement can be provided by bending the longitudinal tensile reinforcement (called bent-up bars). Generally two bars are bent at a section where they are no more required for resisting bending moment.

3.12 (a)

The shear strength of concrete beam is increased due to axial compressive force.

3.13 (b)

We know that, $\tau_{c,\max} = 0.6375\sqrt{f_{ck}}$

If the area of shear reinforcement is large, failure may occur due to shear compression failure of concrete prior to the yielding of the steel. Therefore the upper limit of the area of shear reinforcement corresponds to the yielding of shear reinforcement and shear compression failure of bars simultaneously.

3.14 (a)

The equivalent shear, a function of the actual shear and torsional moment is determined from the following empirical relation:

$$V_e = V_u + 1.6(T_u/b)$$

where

V_e = equivalent shear,

V_u = actual shear,

T_u = actual torsional moment,

b = breadth of beam.

Minimum shear reinforcement is to be provided as per cl. 26.5.1.6 of IS 456, if the equivalent nominal shear stress τ_{ve} obtained from V_e calculated above, does not exceed τ_c given in Table 19 of IS 456.

3.15 (b)

As per IS : 456-2000,

(i) clause 26.2.3.1, for curtailment, reinforcement shall extend beyond the point at which it is no longer required to resist flexure for a distance equal to the effective depth of the member or 12 times the bar diameter whichever is greater except at simple supports or ends of cantilever.

(ii) clause 26.2.3.2, the shear at cut off point does not exceed two-thirds that permitted including the shear strength of web reinforcement provided.

3.16 (c)

For shear stirrup in beam anchorage length is

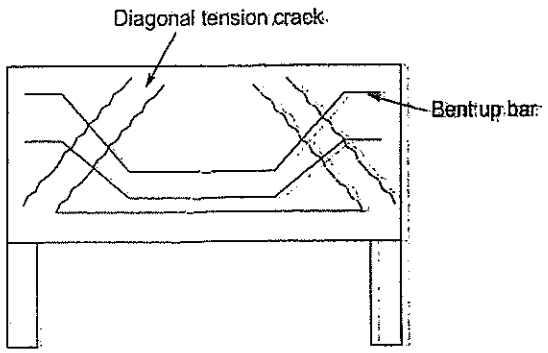
(i) 8ϕ for 90° bend

(ii) 6ϕ for 135° bend

(iii) 4ϕ for 180° bend

3.17 (b)

Diagonal tension reinforcement is provided by bent up bars.



3.20 (a)

Torsional constant of a rectangular section of width b and depth d ($b < d$) may be expressed as

$$J = b^3 d$$

For T, L and I sections torsion constant

$$J = \sum \frac{1}{3} b_i^3 d_i$$

where b_i and d_i are the dimensions of each of the component rectangles into which the section may be divided.

Torsional shear stress for rectangular section

$$\tau = \frac{T}{\alpha b^2 d}$$

For T, L and I sections torsional shear stress may be calculated for each component rectangle by considering them subjected to torsional moment

$$T_i' = T\left[\frac{b_i^3 d_i}{\sum b_i^3 d_i}\right]$$

3.21 (c)

As per IS:456-2000 clause 26.5.1.3, side face reinforcement shall be provided along the two faces where the depth of the web in a beam exceeds 750 mm. The total area of such reinforcement shall not be less than 0.1% of the web area and shall be distributed equally on two faces at a spacing not exceeding 300 mm or web thickness, whichever is less.

3.22 (c)

The axial compressive force will act against the principal tensile stress and the formation of both flexural and inclined cracks will occur at higher load.

3.23 (b)

The theoretical cut-off point is the point of contraflexure. The distance between theoretical and actual cut-off point is equal to effective depth or 12 times the diameter of bar whichever is more.

3.24 (b)

As per IS 456:2000 clause 22.6.2.1, when the reaction in the direction of applied shear introduces compression into the end region of the member, sections located at a distance less than 'd' may be designed for the same shear as that computed at distance 'd'.

3.25 (a)

The longitudinal reinforcement shall be designed to resist an equivalent bending moment

$$M_e = M + M_t$$

where $$M_t = T\left(\frac{1+D/b}{1.7}\right)$$

$$\therefore \quad M_e = M + T\left(\frac{1+D/b}{1.7}\right)$$

Equivalent shear,

$$V_e = V + 1.6\, T/b$$

3.26 (a)

In the working stress method it is assumed that concrete is elastic. Steel and concrete act together elastically, and the relationship between the loads and stresses is linear right up to the collapse of the structure i.e. bond between steel and concrete is perfect within the elastic limit of steel.

3.27 (c)

As per clause 26.2.1 of IS:456-2000, the development length L_d is given by

$$L_d = \frac{\phi \sigma_s}{4\tau_{bd}}$$

where ϕ = nominal diameter of bar

σ_s = stress in the bar at the section considered at design load

τ_{bd} = design bond stress for plain bars

The value of τ_{bd} should be increased by 60% for deformed bars.

$$\therefore \quad L_d = \frac{\phi \sigma_s}{4\left(\tau_{bd} + \frac{60}{100}\tau_{bd}\right)}$$

$$L_d = \frac{\phi \sigma_s}{6.4\, \tau_{bd}}$$

3.28 (b)

Bond strength increases when:

- HYSD bars are used instead of plain bars
- Higher grade concrete is used
- Increased length of embedment, hooks or bends are provided
- Mechanical anchorage are employed

3.29 (a)

Bond stress is defined as the shear force per unit of nominal surface area of reinforcing bar i.e the shear stress acting parallel to the bar on the interface between bars and surrounding concrete.

3.31 (a)

All these three statements are taken from clause 26.2.3.2 of IS: 456-2000.

3.32 (d)

As per clause 26.2.2.1 of IS : 456-2000, the anchorage value of a standard U-type hook shall be equal to 16 times the diameter of the bar.

3.33 (b)

Lap length in compression shall not be less than 24ϕ

Lap length in flexural tension shall be greater of L_d or 30ϕ

Lap length in direct tension shall be greater of $2L_d$ or 30ϕ.

where L_d is the development length.

3.34 (d)

According to clause 26.2.1 of IS 456: 2000

The development length L_d is given by

$$L_d = \frac{\phi\sigma_s}{4\tau_{bd}}$$

For deformed bars τ_{bd} shall be increased by 60%.

For bars in compression τ_{bd} shall be increased by 25%.

$$\therefore \quad L_d = \frac{20 \times 0.87 \times 415}{4 \times 1.4 \times 1.6 \times 1.25}$$

$$= 645 \text{ mm}$$

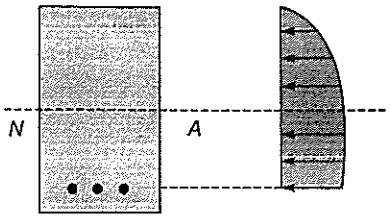
3.36(b)

Splice should be at minimum possible moment.

3.37 (d)

For cracked section,

Actual stress distribution



3.38 (b)

$\because$ Shear capacity (V_{us})

$$= \frac{0.87 f_y A_{sv} d}{S_v}$$

$$\therefore \quad V_{us} = 0.87 f_y A_{sv} \times \frac{d}{0.75d}$$

$$= 1.16 (f_y A_{sv})$$

3.39 (b)

$$\frac{A_{sv}}{S_v} = \frac{0.4B}{0.87 f_y}$$

$$\Rightarrow \quad \frac{2 \times \frac{\pi}{4} \times 8^2}{S_v} = \frac{0.4 \times 230}{0.87 \times 415}$$

$$\therefore \quad S_v = 394 \text{ mm} \simeq 390 \text{ mm}$$

3.41 (a)

Beam P:

$V_u = 400$ kN

$$\tau_v = \frac{V_u}{bd} = \frac{400 \times 10^3}{400 \times 750}$$

$$= 1.33 \text{ N/mm}^2 < \tau_{cmax} = 2.0 \text{ N/mm}^2$$

$\Rightarrow V_{us} = (1.33 - 0.75) \times 400 \times 750 = 175$ kN

Beam Q:

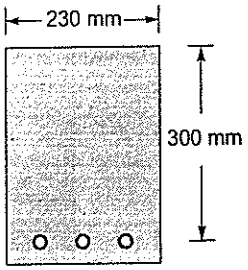
$V_u = 750$ kN

$$\tau_v = \frac{750 \times 10^3}{400 \times 750}$$

$$= 2.5 \text{ N/mm}^2 > \tau_{cmax} = 2.0 \text{ N/mm}^2$$

Not safe, hence section for beam Q should be revised.

3.42 (d)



$M_u = 1.5 \times 120 = 180$ kNm

$V_u = 1.5 \times 270 = 405$ kNm

$$\tau_v = \frac{V_u}{bd} = \frac{405}{230 \times 300}$$

$= 5.86$ N/mm^2 $> \tau_{cmax}$

(Not safe)

$$M_{ulim} = 0.36 f_{ck} b x_{ulim} (d - 0.42 x_{ulim})$$
$$= 0.36 \times 30 \times 230 \times 0.48 \times 300 \times (300 - 0.42 \times 0.48 \times 300) \times 10^{-6}$$
$= 85.67$ kNm $< M_u$

(So design as doubly reinforced beams)

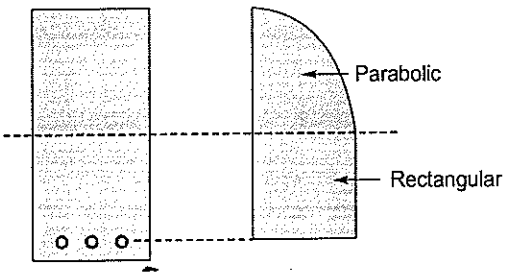
3.43 (b)

$\tau_{c,max}$ is maximum shear strength of concrete with shear reinforcement. When a large quantity of shear reinforcement is provided with main reinforcement, failure will occur due to diagonal compression failure of concrete, based on which $\tau_{c,max}$ value has been decided.

3.44 (c)

Smaller diameter bars in large numbers (such that area of steel remains the same) should be used as this effectively increases the surface area of contact between steel and concrete.

3.45 (c)



3.46 (d)

(i) Mechanical resistance is provided due to gripping of steel bars due to shrinkage of concrete.

(ii) Pure adhesive resistance is provided by adhesive of chemical (C-S-H gel) produced by concrete during setting.

(iii) Frictional resistance is when bar has tendency to slip or move.

3.47 (c)

$V_u = 80$ kN

$V_{cu} = \tau_c$ Bd

$$= 0.25 \times 230 \times 300 \times \frac{1}{10^3}$$

$= 20.125$ kN

V_{su} = Design shear force

$= 80 - 20.125$

$= 59.875$ say 60 kN

3.48 (c)

1. As per IS 456 : 2000, Nominal shear stress can not exceed a maximum value of shear otherwise it will lead to brittle failure of concrete ($\tau = 0.45 f_{ck}$).
2. One way and two way slab depends on (l/B) ratio as well as boundary conditions, as if a slab having $\frac{l}{B} < 2$ is supported at two ends (opposite) then it will lead to a one way slab.

■■■■

4 Walls, Columns and Footings

4.1 Minimum clear cover (in mm) to the main steel bars in slab, beam, column and footing respectively are

(a) 10, 15, 20, 25 (b) 15, 25, 40, 40

(c) 20, 25, 30, 40 (d) 20, 35, 40, 75

[ESE : 1995]

4.2 Which one of the following statements is correct?

(a) Maximum longitudinal reinforcement in an axially loaded short column is 6% of gross sectional area

(b) Columns with circular section are provided with transverse reinforcement of helical type only

(c) Spacing of lateral ties cannot be more than 16 times the diameter of the tie bar

(d) Longitudinal reinforcement bar need not be in contact with lateral ties

[ESE : 1995]

4.3 Match List-I (Condition of support) with List-II (Effective length of load bearing wall) and select the correct answer using the codes given below the lists (L = the length of wall between centres of piers, buttresses or cross walls):

List-I

A. Wall is continuous and supported by cross walls or buttresses and there is no opening within one eighth of the wall height

B. Wall is supported by a buttress or cross wall at one end and continues with buttress or cross wall supported at other end.

C. Wall is supported at each end by a buttress or a cross wall

D. Wall is free at one end and supported by a buttress or cross wall at the other end

List-II

1. $2.0L$
2. $0.8L$
3. $0.9L$
4. $1.0L$

Codes :

	A	B	C	D
(a)	3	2	1	4
(b)	2	3	4	1
(c)	3	2	4	1
(d)	2	3	1	4

[ESE : 1996]

4.4 The limits of percentage 'p' of the longitudinal reinforcement in a column is

(a) 0.15% to 2% (b) 0.8% to 4%

(c) 0.8% to 6% (d) 0.8% to 8%

[ESE : 1996]

4.5 Match List-I with List-II regarding the minimum concrete cover to reinforcing steel and select the correct answer using the codes given below the lists:

List-I

A. For longitudinal reinforcement in columns of size 200 mm and less, with 12 mm diameter bars as longitudinal steel.

B. For longitudinal reinforcement in beams.

C. For longitudinal bars in slabs.

D. For longitudinal bars in columns of size more than 200 mm.

List-II

1. 40 mm or diameter of bar whichever is more
2. 15 mm or diameter of bar whichever is more
3. 25 mm or diameter of bar whichever is more
4. 25 mm

Codes:

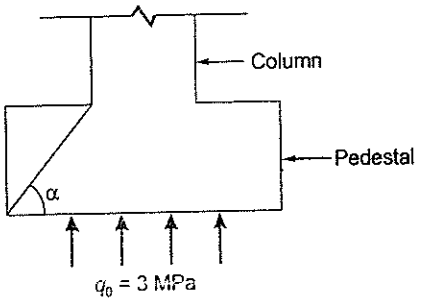
	A	B	C	D
(a)	4	3	2	1
(b)	1	2	3	4
(c)	1	3	2	4
(d)	4	2	3	1

[ESE : 1996]

4.6 The load carrying capacity of a column designed by working stress method is 500 kN. The collapse load of the column is
(a) 500.0 kN (b) 662.5 kN
(c) 750.0 kN (d) 1100.0 kN
[ESE : 1996]

4.7 Design of foundation for a large generator is guided, primarily, by
(a) frequency (b) deformation
(c) strength (d) stiffness
[ESE : 1996]

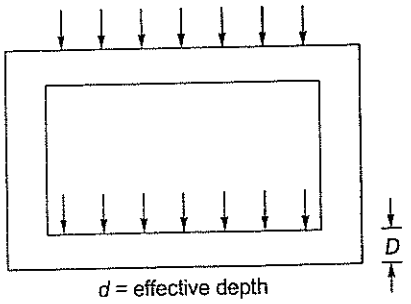
4.8 A concrete pedestal made of M20 mix is shown in the figure below. The tanα value in this case will be



(a) not less than 3.5
(b) less than or equal to 3.6
(c) greater than 3.6
(d) greater than or equal to 3.6
[ESE : 1997]

4.9 The reduction coefficient of a reinforced concrete column with an effective length of 4.8 m and size 250 mm × 300 mm is
(a) 0.80 (b) 0.85
(c) 0.90 (d) 0.95
[ESE : 1997]

4.10 A box girder section is subjected to loads as shown in the figure below. The critical section for shear in the bottom slab will occur at



(a) *D* from the face of the wall
(b) '*d*' from the face of the wall
(c) '*d*/2' from the face of the wall
(d) the face of the wall
[ESE : 1997]

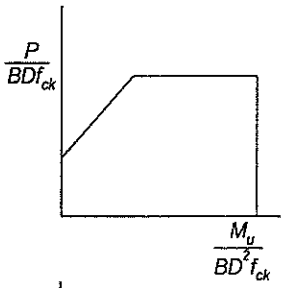
4.11 The maximum spacing of vertical reinforcement in RCC wall should NOT exceed
(a) the thickness of wall
(b) 1.5 times the thickness of wall
(c) 2 times the thickness of wall
(d) 3 times the thickness of wall
[ESE : 1998]

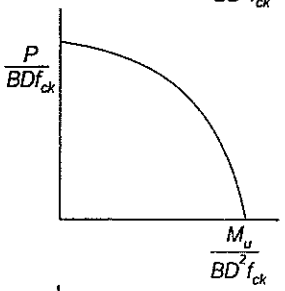
4.12 In a reinforced concrete retaining wall, a shear key is provided, if the
(a) shear stress in the vertical stem is excessive
(b) shear force in the toe slab is more than that in the heel slab
(c) retaining wall is not safe against sliding
(d) retaining wall is not safe against overturning
[ESE : 1998]

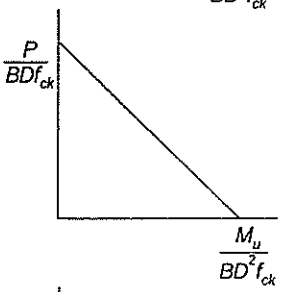
4.13 In an underground warehouse, the external walls
(a) are designed as curtain walls
(b) are designed as retaining walls with or without surcharge
(c) are designed only for vertical loads imposed by the upper floors
(d) do not share any dynamic loads caused by the movement of trucks and fork-lift vehicles.
[ESE : 1998]

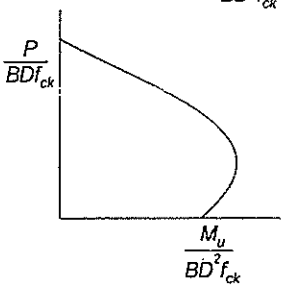
4.14 Lateral ties in *RC* columns are provided to resist
(a) bending moment
(b) shear
(c) buckling of longitudinal steel bars
(d) both bending moment and shear
[ESE : 2000]

4.15 In an axially loaded spirally reinforced short column, the concrete inside the core is subjected to
(a) bending and compression
(b) biaxial compression
(c) triaxial compression
(d) uniaxial compression
[ESE : 2001]

(a)


(b)


(c)


(d)


[ESE : 2006]

4.32 In the case of isolated square concrete footing, match the locations at which the stress resultants are to be checked, where d is effective depth of footing and select the correct answer using the codes given below the lists:

Stress Resultant		Location
A. Bending moment	1.	At face of column
B. One way shear	2.	At *d*/2 from face of column
C. Punching shear	3.	At d from face of column

Codes :

	A	B	C
(a)	1	2	3
(b)	3	1	2
(c)	1	1	3
(d)	1	3	2

[ESE : 2006]

4.33 What is the minimum nominal percentage longitudinal reinforcement to be provided in a concrete pedestal as per relevant IS code?

(a) 0.4 (b) 0.2
(c) 0.15 (d) 0.1

[ESE : 2007]

4.34 How is the depth of footing for an isolated column governed?

1. By maximum bending moment
2. By shear force
3. By punching shear

Select the correct answer using the codes given below:

(a) 2 and 3 only (b) 1 and 2 only
(c) 1 and 3 only (d) 1, 2 and 3

[ESE : 2008]

4.35 While designing combined footing, the resultant of the column loads passes through the centre of gravity of the footing slab such that the net soil pressure obtained is

(a) parabolic (b) trapezoidal
(c) uniform (d) non-uniform

[ESE : 2008]

4.36 Consider the following statements for minimum reinforcement to be provided in a wall as a ratio of vertical reinforcement to gross concrete area :

1. 0.0012 for deformed bars.
2. 0.0015 for all other types of bars.
3. 0.0012 for welded wire fabric with wires not larger than 16 mm in diameter.

Which of these statements is/are correct?

(a) 1, 2 and 3 (b) 1 only
(c) 2 and 3 only (d) 3 only

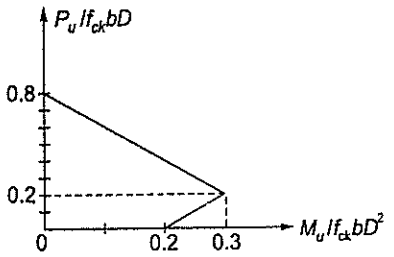
[ESE : 2009]

4.37 **Assertion (A)** : The provision of lateral reinforcement in RCC columns is not mandatory.
Reason (R) : The lateral reinforcement in RCC columns helps in preventing possible bulking of longitudinal reinforcement.

(a) both A and R are individually true and R is the correct explanation of A
(b) both A and R are individually true but R is not the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2009]

4.38 A RC column of square cross-section (400 × 400 mm^2) has its column load-moment interaction diagram as shown in figure below.



What is the maximum uniaxial eccentricity at which a factored load P_u = 640 kN can be applied safely? (Take f_{ck} = 20 MPa)

(a) 300 mm (b) 400 mm
(c) 600 mm (d) 800 mm

[ESE : 2009]

4.39 How is the base-level bending moment of a cantilever retaining wall expressed as a function of its height H?

(a) H (b) H^2
(c) H^3 (d) H^4

[ESE : 2009]

4.40 The load carrying capacity of a column designed by working stress method is 500 kN. The ultimate collapse load of the column is

(a) 500 kN (b) 662.5 kN
(c) 750 kN (d) 1100 kN

[ESE : 2010]

4.41 If the load acting on a commonly conventional sized RC column increases continuously from zero to higher magnitudes, the magnitude of the uniaxial ultimate moment that can be allowed on the column

(a) increases
(b) decreases
(c) increases and then decreases
(d) remains constant

[ESE : 2010]

4.42 **Assertion (A):** In a helically reinforced concrete column, the concrete core is subjected to triaxial state of stress.

Reason (R): Helically reinforced concrete columns are very much suitable for earthquake resistant structures.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2010]

4.43 Minimum clear over (in mm) to the main steel bars in slab, beam, column and footing respectively, are

(a) 10, 15, 20 and 25 (b) 15, 25, 40 and 75
(c) 20, 25, 30 and 40 (d) 20, 35, 40 and 75

[ESE : 2011]

4.44 In a combined footing, in the zones where the shear stresses are less than 5 kg/cm^2, stirrups to be provided are generally

(a) 2-legged (b) 4-legged
(c) 8-legged (d) 12-legged

[ESE : 2011]

4.45 The purpose of lateral ties in short R.C. columns is to

(a) Increase the load carrying capacity of column
(b) Facilitate compaction of concrete
(c) Facilitate construction
(d) Avoid buckling of longitudinal bars

[ESE : 2011]

4.46 According to IS 456 : 2000, maximum slenderness ratio for a short concrete column is

(a) Less than 12
(b) Between 12 and 18
(c) Between 18 and 24
(d) More than 24

[ESE : 2011]

4.47 The effective length of a R.C. column continuing through two storeys, properly restrained at both ends in position and direction is

(a) 0.50 L (b) 0.75 L
(c) L (d) 2 L

[ESE : 2011]

4.48 A reinforced concrete column of size $b \times D$ is carrying an axial load P and a bending moment M about an axis parallel to its width. The magnitude of bending moment is such that the neutral axis lies outside the section. Over which extent of depth from the highly compressed edge will the compressive stress have a constant value $0.45f_{ck}$?

(a) $3D/7$ (b) $4D/7$
(c) $D/2$ (d) D

[ESE : 2012]

4.49 Magnitudes of minimum reinforcement recommended for reinforced concrete using mild steel in slabs/columns are
(a) 0.15%/0.60% (b) 0.25%/0.80%
(c) 0.50%/1.00% (d) 0.15%/0.80%
[ESE : 2012]

4.50 In an isolated reinforced concrete column footing of effective depth d, the stress in punching shear is checked
(a) at the centre of the column
(b) at the face of the column
(c) at a distance $d/2$ away from the face of the column
(d) at a distance $d/2$ away from the centre of the column
[ESE : 2012]

4.51 Which one of the following represents the ratio of volume of helical reinforcement to volume of core?
(a) $0.36\left(\frac{A_g}{A_c}-1\right)\frac{f_{ck}}{f_y}$ (b) $0.36\left(\frac{A_g}{A_s}-1\right)\frac{f_{ck}}{f_y}$
(c) $0.36\left(\frac{A_s}{A_c}-1\right)\frac{f_{ck}}{f_y}$ (d) $0.36\left(\frac{A_c}{A_s}-1\right)\frac{f_{ck}}{f_y}$
where A_g, A_s and A_c are gross cross-sectional area of the member, area of steel and core area; and f_{ck} and f_y are characteristic strength of concrete and steel respectively.
[ESE : 2012]

4.52 The critical section for maximum bending moment in the footing under masonry wall is located at
(a) the middle of the wall
(b) the face of the wall
(c) mid-way between the face and the middle of the wall
(d) a distance equal to the effective depth of footing from the face of the wall
[ESE : 2014]

4.53 Consider the following statements :
The design depth of the footing for an isolated column is governed by
1. maximum bending moment
2. maximum shear force
3. punching shear
Which of the above statements are correct?
(a) 1 and 2 only (b) 1 and 3 only
(c) 1, 2 and 3 (d) 2 and 3 only
[ESE : 2014]

4.54 A concrete column carries an axial load of 450 kN and a bending moment of 60 kNm at its base. An isolated footing of size 2 m × 3 m with the 3 m side along the plane of the bending moment is provided under the column. Centres of gravity of the column and footing coincide. The net maximum and minimum pressures, in kPa, on the soil under the footing are, respectively.
(a) 95 and 75 (b) 75 and 55
(c) 95 and 55 (d) 75 and 75
[ESE : 2015]

4.55 A wall carries an axial load, 12 kN/m and also an eccentric load of 27 kN/m at 72 mm from the central axis of the wall. The equivalent eccentricity e is nearly
(a) 65 mm (b) 60 mm
(c) 55 mm (d) 50 mm
[ESE : 2015]

4.56 A shear wall of length 5 m, height 3 m and thickness 250 mm has to resist the forces due to horizontal earthquake in its plane. The relevant Section Modulus of the wall section is
(a) 3.75×10^8 mm^3 (b) 10.41×10^8 mm^3
(c) 31.25×10^6 mm^3 (d) 75×10^6 mm^3
[ESE : 2015]

4.57 When a spirally reinforced short column is loaded axially, the concrete inside the core is subjected to
(a) Bending and compression
(b) Biaxial compression
(c) Triaxial compression
(d) Uniaxial compression
[ESE : 2016]

4.58 Footings shall be designed to sustain the
1. Applied loads
2. Moments and forces under relatable loading conditions
3. Induced reactions
(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3
[ESE : 2016]

4.59 The purpose of lateral ties in a short RC column is to
(a) Avoid buckling of longitudinal bars
(b) Facilitate compaction of concrete
(c) Increase the load carrying capacity of the column
(d) Facilitate construction
[ESE : 2016]

4.60 A certain R.C. short column with 300 mm square cross-section is made of M 20 grade concrete and has 4 numbers, 20 mm diameter, longitudinal bars of Fe 415 grade steel. It is under the action of a concentric axial compressive load. Ignoring the reduction in the area of concrete due to the steel bars, the ultimate axial load carrying capacity of the column as by relevant code is

(a) 1069 kN (b) 1198 kN

(c) 1548 kN (d) 1659 kN

[ESE : 2017]

4.61 In a combined footing for two columns carrying unequal loads, the maximum hogging moment occurs at

(a) The inside face of the heavier column

(b) A section equidistant from both the columns

(c) A section subjected to maximum shear force

(d) A section subjected to zero shear force

[ESE : 2017]

■■■■

Answers Walls, Columns and Footings

4.1 (b)	4.2 (a)	4.3 (b)	4.4 (c)	4.5 (a)	4.6 (c)	4.7 (a)	4.8 (d)	4.9 (b)	
4.10 (d)	4.11 (d)	4.12 (c)	4.13 (b)	4.14 (c)	4.15 (c)	4.16 (d)	4.17 (b)	4.18 (b)	
4.19 (c)	4.20 (b)	4.21 (c)	4.22 (a)	4.23 (d)	4.24 (c)	4.25 (c)	4.26 (a)	4.27 (c)	
4.28 (c)	4.29 (c)	4.30 (d)	4.31 (d)	4.32 (d)	4.33 (c)	4.34 (a)	4.35 (c)	4.36 (a)	
4.37 (d)	4.38 (c)	4.39 (c)	4.40 (c)	4.41 (c)	4.42 (b)	4.43 (*)	4.44 (b)	4.45 (d)	
4.46 (a)	4.47 (a)	4.48 (a)	4.49 (d)	4.50 (c)	4.51 (a)	4.52 (c)	4.53 (c)	4.54 (c)	
4.55 (d)	4.56 (b)	4.57 (c)	4.58 (d)	4.59 (a)	4.60 (b)	4.61 (d)			

Explanations Walls, Columns and Footings

4.1 (b)

In IS:456-1978, the clear covers are specified as:

(i) For a longitudinal reinforcing bar in a column, not less than 40 mm, or less than the diameter of such bar.

(ii) For longitudinal reinforcing bar in a beam, not less than 25 mm, or less than the diameter of such bar.

(iii) For tensile, compressive, shear or other reinforcement in a slab, not less than 15 mm, or less than the diameter of such bar.

(iv) In other cases the clear cover to the reinforcement bars shall not be less than 40 mm or diameter of such bar whichever is more.

The minimumm clear cover should not exceed 75mm in any case.

According to IS 456:2000 nominal cover shall not be less than the diameter of bar. The nominal cover is specified to meet durability requirement in Table 16 on page 47 of the IS Code. To meet specified period of fire resistance the clear covers are given in Table 16A on page. 47.

For longitudinal reinforcing bars the nominal cover shall not be less than 40 mm.

For footings minimum cover shall be 50 mm.

4.2 (a)

In columns,

(a) the minimum longitudinal reinforcement = 0.4% of gross cross-sectional area.

(b) the maximum longitudinal reinforcement = 6% of gross cross-sectional area.

(c) the pitch of the transverse reinforcement shall not be more than the least of the following:

(i) The least lateral dimension of the compression members
(ii) 16 times the smallest diameter of the longitudinal reinforcement bar to be tied
(iii) 300 mm

4.4 (c)
As per **IS : 456-2000** the cross-sectional area of the longitudinal reinforcement in columns, shall not be less than 0.8% nor more than 6% of the gross cross-sectional area of the column.

4.5 (a)
For column, the longitudinal bar shall not have a cover less than 40 mm or the diameter of the bar whichever is more. In case of columns of minimum dimension of 200 mm or less, whose reinforcing bars do not exceed 12 mm diameter, a cover of 25 mm may be provided.

4.6 (c)
Collapse Load = Load factor x Working load
= 1.5 x 500
= 750 KN

4.7 (a)
Design of foundation for large generator is guided by frequency to avoid the occurrence of resonance (when natural frequency coincides with operating frequency).

4.8 (d)
According to **IS : 456-2000** the angle between the plane passing through the bottom edge of the pedestal and the corresponding junction edge of the column with pedestal and horizontal plane shall be governed by the expression

$$\tan\alpha \geq 0.9\sqrt{\frac{100q_0}{f_{ck}}+1}$$

Given $q_0 = 3$ MPa
$f_{ck} = 20$ MPa
$\therefore \quad \tan\alpha \geq 3.6$

4.9 (b)
In the working stress method the design of a long column is made by considering reduced stresses obtained by multiplying the permissible stresses by a coefficient,

$$C_r = 1.25 - \frac{l_{eff}}{48D} \text{ or } 1.25 - \frac{l_{eff}}{48B}$$

whichever is smaller

$$\therefore C_r = 1.25 - \frac{4800}{48\times250} \text{ or } 1.25 - \frac{4800}{48\times300}$$
$$= 0.85 \text{ or } 0.92$$

So the reduction coefficient is 0.85.

4.10 (d)
For top slab the critical section will be at a distance '*d*' from the face of the wall. For bottom slab it will be at the face of the wall.

4.11 (d)
The vertical reinforcement in walls shall be spaced not farther apart than three times the wall thickness nor 450 mm.

4.14 (c)
The role of lateral ties is to prevent premature buckling of bars, improve strength, to provide resistance against shear and torsion, to hold bars in position during construction etc.

4.15 (c)
Spirally reinforced columns have the bars and the core concrete wrapped with closely spaced helix. The spiral reinforcement is designed so as to increase the capacity of the core by an amount nearly equal to the capacity of the shell, thus maintaining the column yielding capacity when the shell spalls off.
The spiral reinforcement has confining effect of concrete in the core. Thus core is subjected to triaxial compression.

4.16 (d)
The cross sectional area of the metal core in a composite column shall not exceed 20% of the gross area of the column. A clearance of 75 mm shall be maintained between the spiral and metal core at all points, except that when the core consists of steel *H*-column, the minimum clearance should be reduced to 50 mm.

4.17 (b)
Very short columns with effective length less than three times least lateral dimension are called pedestal columns.

4.18 (b)

A buttress is a pier of masonry built as an integral part of the wall and projecting from one or both faces of the wall, decreasing in cross-sectional areas from base to top. It provides lateral support to the wall.

4.19 (c)

Combined footing supporting two columns may be used for column on property lines or sewer line. In this case load will be eccentric.

4.20 (b)

The load P should be eccentric about the centre of the footing so that it can cause a moment in reverse direction to the moment *M*. The load should be right to the centre of the footing or in other words $L_1 > L_2$.

4.21 (c)

Critical section for one way shear: The footing acting essentially as a wide beam, with a potential diagonal crack extending in a plane across the entire width, the critical section for this condition shall be assumed as a vertical section located from the face of the column, pedestal or wall at a distance equal to effective depth (d) of the footing in case of footings on soils and distance $d/2$ of the footing for footings on piles.

Critical section for two way shear: Two way action of the footing, with potential diagonal cracking along the surface of truncated cone or pyramid around the concentrated load. The distance of critical section from the periphery of the column shall be taken at $d/2$.

4.22 (a)

It is very difficult to design perfectly axially loaded column, there is generally some minimum eccentricity which may be due to material variation, inaccuracy during construction etc.

As per IS 456:2000 clause 25.4: All columns shall be designed for minimum eccentricity, equal to the unsupported length of column divided by 500 plus lateral dimensions divided by 30, subject to a minimum of 20 mm. Where bi-axial bending is considered, it is sufficient to ensure that eccentricity exceeds the minimum about one axis at a time.

4.23 (d)

The combined footing resists the load by bending in two direction. The footing in the longitudinal direction is subjected to a sagging moment in the cantilever portion and under the columns; and hogging moment in the central portion between the columns. Footing in the transverse direction develops sagging moments.

Thus maximum hogging moment occurs in the central portion where shear force is zero.

4.24 (c)

(i) Maximum tension or compression reinforcement in a beam = 0.04bD

(ii) Slenderness limits for beams to ensure lateral stability.

(a) For simply supported or continuous beam, the clear distance between lateral restrain:

$60b$ or $\frac{250b^2}{d}$ whichever is less

(b) For a cantilever, the clear distance from free end to lateral restraint: $25b$ or $\frac{100b^2}{d}$ whichever is less.

(iii) The slenderness ratio for column $K_x \frac{l_x}{D_x}$

4.25 (c)

$$M_{ax} = \frac{P_u D}{2000}\left(\frac{l_{ex}}{D}\right)^2 = \frac{P_u l_{ex}^2}{2000D}$$

$$M_{ay} = \frac{P_u b}{2000}\left(\frac{l_{ey}}{b}\right)^2 = \frac{P_u l_{ey}^2}{2000b}$$

4.26 (a)

Modular ratio, $m = \frac{280}{3\sigma_{cbc}}$

$\sigma_{cbc} \rightarrow$ permissible compressive stress due to bending in concrete.

4.27 (c)

As per IS : 456-2000 clause 26.5.3.1 (a) the minimum number of longitudinal bars provided in a column shall be four in rectangular columns and six in circular columns.

4.28 (c)

Counterforts are firmly attached to the face slab as well as the base slab. The earth pressure acting on the face slab is transferred to the counter forts which deflect as vertical cantilevers. The

back of the rear counter forts comes in tension and their front face is under compression. So the inclined (back) face of rear counter forts should be provided with main reinforcement.

In the case of front counterforts, the tension develops at the bottom face and it is provided with main reinforcement.

4.29 (c)

The diameter of transverse reinforcement shall not be less than one fourth of the diameter of the largest longitudinal bar and in no case less than 6 mm. So the diameter of the bar $\frac{25}{4} = 6.25$ mm. Choose 8 mm diameter bar.

The pitch of the transverse reinforcement shall not be more than the least of the following:

(i) The least lateral dimension of the compression members i.e. 350 mm.

(ii) Sixteen times the smallest diameter of the longitudinal reinforcement bar to be tied i.e. $16 \times 16 = 256$ mm

(iii) 300 mm

So pitch will be 250 mm c/c.

4.30 (d)

Minimum eccentricity equals to unsupported length of column/500 plus lateral dimension/30, subject to a minimum of 20 mm.

$$\frac{L}{500} + \frac{B}{30} = \frac{3000}{500} + \frac{300}{30} = 16\ mm$$

So eccentricity = 20 mm

4.32 (d)

For footings on piles the critical section for one way shear is $d/2$ from the face of the wall.

4.33 (c)

As per IS 456 : 2000 Clause 26.5.3.1. In case of pedestals in which the longitudinal reinforcement is not taken in account in strength calculations, nominal longitudinal reinforcement not less than 0.15 percent of the cross-sectional area shall be provided.

4.34 (a)

Since large soil pressures are present under footings, high shear stresses are produced and since shear reinforcement is not normally used, shear rather than moment commonly determines the minimum required depth of footing. The depth of the footing must be set such that the shear capacity of the concrete equals or exceeds the critical shear forces produced by factored loads.

4.35 (c)

While designing column footing, no eccentricity can be allowed because if tensile stresses are developed at the base of the footing the foundation will fail. Thus stress distribution below the footing must be uniform.

4.36 (a)

As per clause **32.5** of **IS : 456-2000**, the minimum ratio of vertical reinforcement to gross concrete area for walls shall be provided as below:

(i) 0.0012 for deformed bars not larger than 16 mm in diameter and with a characteristic strength of 415 N/mm^2 or greater.

(ii) 0.0015 for other types of bars

(iii) 0.0012 for welded wire fabric not larger than 16 mm in diameter.

4.38 (c)

$$\frac{P_u}{f_{ck} bD} = \frac{640 \times 10^3}{20 \times 400 \times 400} = 0.2$$

For $\frac{P_u}{f_{ck} bD} = 0.2$,

we have $\frac{M_u}{f_{ck} bD^2} = 0.3$ from the interaction diagram.

$\therefore \quad M_u = 0.3 \times 20 \times 400 \times 400^2 \times 10^{-3}$

$\Rightarrow \quad M_u = 384000$ kN-mm

But maximum uniaxial eccentricity is given by

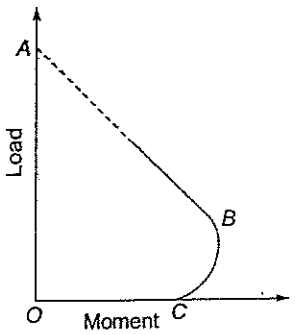
$$e = \frac{M_u}{P_u} = \frac{384000}{640} = 600 \text{ mm}$$

4.40 (c)

The ultimate collapse load on the column is given by

$W_u = W_s \times 1.5 = 500 \times 1.5 = 750$ kN

4.41 (c)



When the load on column increases, moment carrying capacity initially increases and then decreases.

4.43 (*)

Correct answer is 20, 20, 40 and 50 as per IS 456. Some designer prefer 20, 25, 40 and 50. But there is no correct option.

4.46 (a)

Short columns are those which fail primarily due to material failure. Short columns do have buckling effect, but of a limited value. Long (slender) columns are those which fail due to the material failure and also due to buckling.

According to IS : 456, a column may be considered as short when both slenderness ratios $\frac{l_{ex}}{d}$ and $\frac{l_{ey}}{b}$ are less than 12.

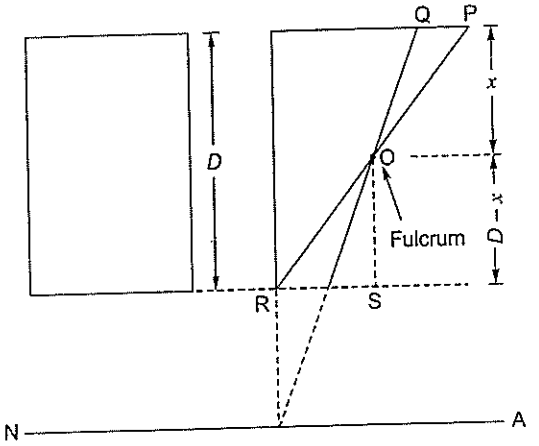
4.47 (a)

0.5L theoretical value and 0.65 L is recommeded value for design. Since 0.65 L is not given in optionso 0.5L is most appropriate answer.

4.48 (a)

Assumptions: Both axial and compressive stress are acting simultaneously. Max. compressive strain in concrete in axial compression is taken as 0.0020

Strain varies linearly and strain diagram rotates about fulcrum.



using triangle property,

$\Delta OPQ \simeq \Delta ORS$

$$\frac{x}{0.0015} = \frac{D-x}{0.0020}$$

$$4x = 3D - 3x$$

$$7x = 3D$$

$$x = 3D/7$$

4.49 (d)

According to **IS 456 : 2000**

The mild steel reinforcement in either direction in slabs shall not be less than 0.15%. In case of columns minimum reinforcement shall not be less than 0.8%.

4.50 (c)

In an isolated reinforced concrete column footing of effective depth d,

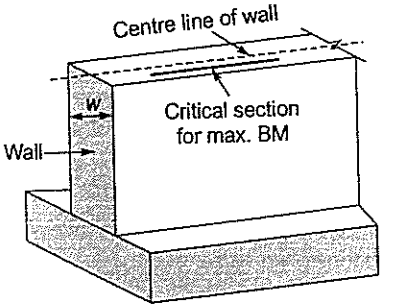
- One way shear is checked at distance d from the face of column.
- Punching shear is checked at distance $d/2$ from face of column.
- Bending moment is checked at face of column.

4.51 (a)

According to clause 39.4.1 of **IS 456 : 2000.**

The ratio of volume of helical reinforcement to the volume of core shall not be less than $0.36\left(\frac{A_g}{A_c}-1\right)\frac{f_{ck}}{f_y}$.

4.52 (c)

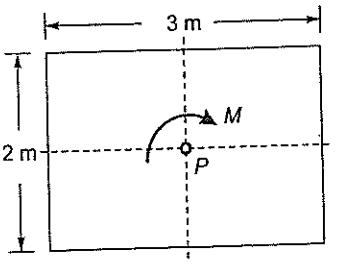


Critical section for maximum BM in the footing under masonry wall is located at mid-way between that face and the middle of the wall.

4.53 (c)

As per IS 456: 2000 Cl. 34.2.

4.54 (c)



$$\text{Extreme stresses} = \left(\frac{P}{A} \pm \frac{My}{I}\right)$$

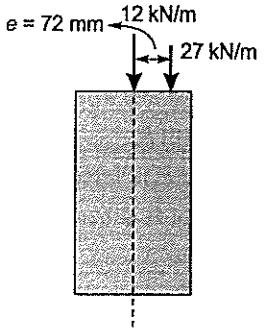
$$= \frac{450}{3\times 2} \pm \frac{60\times 1.5\times 12}{2\times 3^3}$$

$$= (75 \pm 20)\ \text{kPa}$$

$\therefore$ Maximum stress = 75 + 20 = 95 kPa

Minimum stress = 75 – 20 = 55 kPa

4.55 (d)

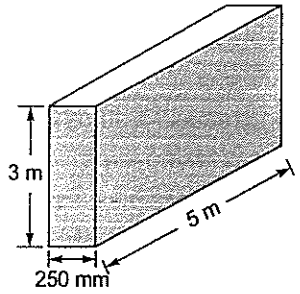


Equivalent eccentricity,

$$e' = \frac{12\times 0 + 27\times 72}{12+27}$$

$$= 49.85\ \text{mm} \simeq 50\ \text{mm}$$

4.56 (b)



For in plane bending,

$$Z = \frac{250\times(5000)^3}{12\times(2500)}$$

$$= 10.41\times 10^8\ \text{mm}^3$$

4.57 (c)

Due to hoop stress in spiral reinforcement and axial load transfer path, the concrete inside the core is subjected to triaxial compression.

4.58 (d)

Foundation structure shall be able to sustain the applied loads, moments, forces and induced reactions without exceeding the safe bearing capacity of soil.

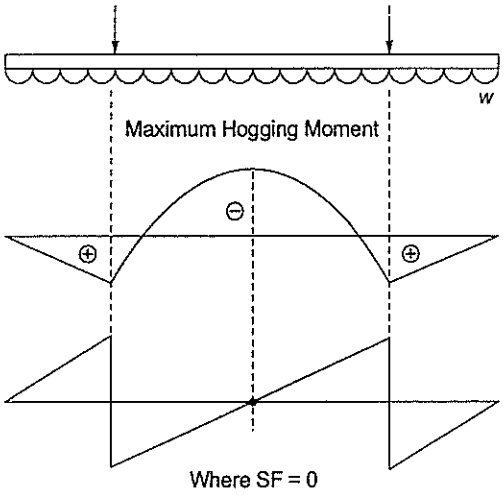
4.60 (b)

$$P_{uz} = 0.45\ f_{ck}\ A_c + 0.75\ f_y\ A_{sc}$$

$$= \left[0.45\times 20\times(300\times 300) + 0.75\times 415\times 4\times\frac{\pi}{4}(20)^2\right]\times\frac{1}{10^3}$$

$$= 1201\ \text{kN} \simeq 1198\ \text{kN}$$

4.61 (d)



5 Prestress Concrete

5.1 If a simply supported concrete beam, prestressed with a force of 2500 kN is designed by load balancing concept for an effective span of 10 m and to carry a total load of 40 kN/m, the central dip of the cable profile should be

(a) 100 mm (b) 200 mm

(c) 300 mm (d) 400 mm

[ESE : 1995]

5.2 In case of pre-tensioned RC beams

(a) shrinkage of concrete is of the order of 3×10^{-4}

(b) relaxation of steel can be ignored

(c) only one wire can be stretched at a time

(d) even mild steel can be used for prestressing

[ESE : 1995]

5.3 For prestressed structural elements, high strength concrete is used primarily because

(a) both shrinkage and creep are more

(b) shrinkage is less but creep is more

(c) modulus of elasticity and creep values are higher

(d) high modulus of elasticity and low creep

[ESE : 1995]

5.4 Prestressed concrete is more desirable in case of

(a) cylindrical pipe subjected to internal fluid pressure

(b) cylindrical pipe subjected to external fluid pressure

(c) cylindrical pipe subjected to equal internal and external fluid pressures.

(d) cylindrical pipe subject to end pressures

[ESE : 1995]

5.5 Assertion (A) : Losses in prestress of pretensioned beam are more than the losses in post-tensioned beam.

Reason (R) : This is partially due to the effect of elastic shortening.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 1995]

5.6 In a load-balanced prestressed concrete beam under self load the cross-section is subjected to

(a) axial stress

(b) bending stress

(c) axial and shear stress

(d) axial and bending stress

[ESE : 1996]

5.7 Which one of the following statements is correct?

(a) Web shear cracks start due to high diagonal tension in case of beams with their webs and high prestressing force.

(b) Shear design for a prestressed concrete beam is based on elastic theory.

(c) In the zone where bending moment is dominant and shear is insignificant, cracks occur at 20° to 30°.

(d) After diagonal cracking, the mechanism of shear transfer in a prestressed concrete member is very much different from that in reinforced concrete members.

[ESE : 1996]

5.8 A prestressed concrete beam 150 mm × 300 mm supports a live load of 5 kN/m over a simple span of 8 m. It has a parabolic cable having an eccentricity of 75 mm at mid-span and zero at the ends. The prestressing force required to maintain the net resultant stress at the bottom

fibre at mid-span as zero under the action of $DL + LL$ + prestress is

(a) 239 kN (b) 293 kN

(c) 302 kN (d) 392 kN

[ESE : 1996]

5.9 A partially prestressed member is one in which

(a) tensile stresses and cracking are permitted under service loads

(b) no tensile stresses are permitted under service loads

(c) mild steel is used in addition to prestressing steel

(d) tensile stresses are permitted but not cracking at service loads

[ESE : 1996]

5.10 For a prestressed concrete continuous beam, it is true that the concordant cable profile

(a) is not unique in any given statically indeterminate beam but it is located within a certain narrow zone

(b) may be selected so that it causes no secondary stresses ignoring economy

(c) may be chosen as a compromise between the secondary stresses and the working stress based on economy

(d) should be chosen consistent with all the statements made in (a), (b) and (c)

[ESE : 1996]

5.11 For ultimate load design of prestressed concrete girders used for bridges, combination of load factors used is (where *DL* and *LL* are dead and live loads respectively)

(a) 1.5 *DL* + 2.5 *LL* (b) 1.0 *DL* + 2.5 *LL*

(c) 1.0 *DL* + 2.0 *LL* (d) 2.0 *DL* + 2.0 *LL*

[ESE : 1996]

5.12 The prestress profile in mass-produced pretensioned slab units of 2.8 m span for normal residential buildings would generally be

(a) axial along centroidal axis

(b) parabolic below centroidal axis with zero eccentricity at ends

(c) straight along top kern

(d) straight along bottom kern

[ESE : 1996]

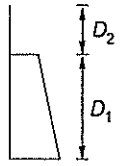
5.13 For a pretensioned rectangular plank the uplift at centre on release of wires from anchors due to pretensioning only (force P, eccentricity e) will be

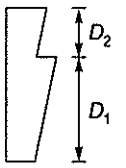
(a) $\frac{PeL^2}{6EI}$ (b) $\frac{Pe^2L}{6EI}$

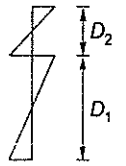
(c) $\frac{PeL^2}{8EI}$ (d) $\frac{Pe^2L}{8EI}$

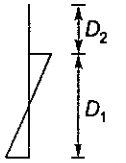
[ESE : 1996]

5.14 A pretensioned plank (depth D_1) is placed over simple supports and additional in situ concrete (depth D_2) is laid on top. What is the probable shape of stress block on hardening of in situ concrete?

(a) 

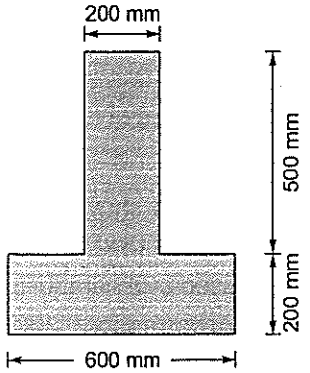
(b) 

(c) 

(d) 

[ESE : 1996]

5.15 A culvert is constructed with pretensioned inverted T section and subsequent in situ concrete. Concrete grade corresponds to $\sigma_c = 7$ MPa. For the section shown in the given figure, the maximum prestressing force will be



(a) 620 kN (b) 890 kN

(c) 970 kN (d) 1060 kN

[ESE : 1996]

5.16 At the time of initial tensioning, the maximum tensile stress in tendon immediately behind the anchorage shall NOT exceed

(a) 50% of the ultimate tensile strength of the wire or bar or strand

(b) 80% of the ultimate tensile strength of the wire or bar or strand
(c) 40% of the ultimate tensile strength of the wire or bar or strand
(d) 60% of the ultimate tensile strength of the wire or bar or strand

[ESE : 1997]

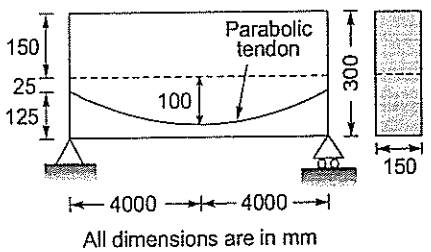
5.17 The cable for a prestressed concrete simply supported beam subjected to uniformly distributed load over the entire span should ideally be
(a) placed at the centre of cross-section over the entire span
(b) placed at some eccentricity over the entire span
(c) varying linearly from the centre of cross-section at the ends to maximum eccentricity at the middle section
(d) parabolic with zero eccentricity at the ends and maximum eccentricity at the centre of the span

[ESE : 1997]

5.18 For a prestressed concrete bridge beam, a minimum clear spacing of the cable or group of cables should be
(a) 25 mm
(b) 25 mm or 6 mm plus the largest size of the aggregate
(c) 40 mm
(d) 50 mm

[ESE : 1997]

5.19 In the PSC beam shown, f_{ck} = 45 MPa and it supports a UDL of 15 kN/m including self weight. It is prestressed by a parabolic cable carrying an effective prestress of 200 kN. The shear resistance of uncracked section at the support will be



All dimensions are in mm

(a) 93.8 kN (b) 94.5 kN
(c) 94.2 kN (d) 95.4 kN

[ESE : 1997]

5.20 In the case of a P.S.C. beam, to satisfy the Limit State of Serviceability in cracking, match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. Class 1 structure
B. Class 2 structure
C. Class 3 structure

List-II
1. No visible cracking $\sigma_t < 3$ N/mm^2
2. Concrete section uncracked; crack width to be calculated to check
3. No cracking under service loads

Codes:

	A	B	C
(a)	1	2	3
(b)	2	1	3
(c)	3	1	2
(d)	3	2	1

[ESE : 1997]

5.21 In a composite construction,
(a) interface slipping is prevented by using shear connectors
(b) differential shrinkage is overcome by using the same grade of concrete for both the components
(c) precast member is always designed to carry the weight of in-situ concrete without props
(d) the in-situ concrete cannot be prestressed

[ESE : 1997]

5.22 The magnitude of loss of prestress due to relaxation of steel is in the range of
(a) zero to 1% (b) 2 to 8%
(c) 8 to 12% (d) 12 to 14%

[ESE : 1998]

5.23 In the design of prestressed concrete structure, which of the following limit states will come under the limit states of serviceability?
1. Flexure 2. Shear
3. Deflection 4. Cracking

Select the correct answer using the codes given below :

(a) 1 and 4 (b) 3 and 4
(c) 2, 3 and 4 (d) 2 and 3

[ESE : 1998]

5.24 In pre-tensioning scheme, pre-stress load is transferred in
(a) a single stage process
(b) multi stage process
(c) either single stage or multi-stage process depending upon the magnitude of load transfer
(d) the same manner as in post-tensioning scheme

[ESE : 1999]

5.25 In the conventional prestressing, the diagonal tension in concrete
(a) increases
(b) decreases
(c) does not change
(d) may increase or decrease

[ESE : 1999]

5.26 The ultimate moment resisting capacity of a simply supported prestressed concrete beam is obtained by using
(a) force and moment equilibrium equations
(b) stress-strain relationship of concrete and steel
(c) moment equilibrium and compatibility condition
(d) force equilibrium equation alone

[ESE : 1999]

5.27 The ultimate strength of the steel used for prestressing is nearly
(a) 250 N/mm^2 (b) 415 N/mm^2
(c) 500 N/mm^2 (d) 1500 N/mm^2

[ESE : 1999]

5.28 In post-tensioned prestressed concrete beam, the end block zone is the zone between the end of the beam and the section where
(a) no lateral stresses exist
(b) only longitudinal stresses exist
(c) only shear stresses exist
(d) the shear stresses are maximum

[ESE : 2000]

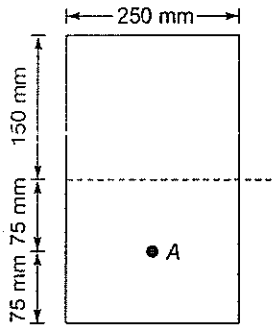
5.29 The propagation of a shear crack in prestressed concrete member depends on
(a) tensile reinforcement
(b) compression reinforcement
(c) shear reinforcement
(d) shape of the cross-section of the beam

[ESE : 2000]

5.30 If the loading on a simply supported pre-stressed concrete beam is uniformly distributed, the centroid of tendons should be preferably
(a) a straight profile along the centroidal axis
(b) a straight profile along with the lower kern
(c) a parabolic profile with convexity downward
(d) a circular profile with convexity upward

[ESE : 2001]

5.31 In the prestressed concrete beam section shown in the given figure (all dimensions in mm in the figure), if the net losses are 15% and final prestressing force applied at 'A' is 500 kN, the initial extreme fibre stresses at top and bottom will be respectively



(a) – 3.40 N/mm^2 and 16.70 N/mm^2
(b) – 3.40 N/mm^2 and 19.60 N/mm^2
(c) – 4.0 N/mm^2 and 16.70 N/mm^2
(d) – 4.0 N/mm^2 and 19.60 N/mm^2

[ESE : 2001]

5.32 The stress block in concrete for an estimate of ultimate strength in flexure of a prestressed beam
(a) should be parabolic
(b) should be parabolic-rectangular
(c) should be rectangular
(d) may be of any shape which provides agreement with the test data

[ESE : 2001]

5.33 When the tendon of a rectangular prestressed beam of cross-sectional area A is subjected to a load W through the centroidal longitudinal axis of beam, (where M = maximum bending moment and Z = section modulus) then the maximum stress in the beam section will be

(a) $\frac{W}{A}-\frac{M}{Z}$ (b) $\frac{W}{A}+\frac{M}{Z}$

(c) $\frac{A}{W}-\frac{Z}{M}$ (d) $\frac{A}{W}+\frac{Z}{M}$

[ESE : 2002]

5.34 The losses in prestress in pre-tensioning system are due to
1. elastic deformation of concrete when wires are tensioned successively
2. friction
3. shrinkage and creep of concrete

Select the correct answer using the codes given below:
(a) 1, 2 and 3 (b) 2 and 3
(c) 1 alone (d) 3 alone

[ESE : 2002]

5.35 Prestressing of indeterminate structures should take care of the following:
1. High strength concrete
2. High tensile steel
3. Load balancing
4. Partial safety factors

Select the correct answer using the codes given below :
(a) 1 and 3 (b) 2, 3 and 4
(c) 1, 2 and 4 (d) 1, 2, 3 and 4

[ESE : 2002]

5.36 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. Loss of prestress
B. End block
C. Transmission length
D. Partially pre-stressed

List-II
1. Class 3
2. Pretensioned members
3. Bursting tension
4. Elastic structures shortening

Codes :

	A	B	C	D
(a)	3	4	1	2
(b)	4	3	1	2
(c)	3	4	2	1
(d)	4	3	2	1

[ESE : 2003]

5.37 In pre-tensioning process of prestressing, the tendons are
(a) bonded to the concrete
(b) partially bonded to the concrete
(c) not bonded to the concrete
(d) generally bonded but sometimes remain unbonded to the concrete

[ESE : 2003]

5.38 A reinforced concrete beam is to be post-tensioned in such a way that no tensile stress develops at the time of post-tensioning. The distance of the tendon from the nearest face must be

(a) between $\frac{d}{5}$ and $\frac{d}{4}$ (b) $<\frac{d}{6}$

(c) between $\frac{d}{4}$ and $\frac{d}{3}$ (d) $>\frac{d}{3}$

(where d is the depth of the beam)

[ESE : 2003]

5.39 A simply supported RC beam carries UDL and is referred to as beam *A*. A similar beam is prestressed and carries the same *UDL* as the beam *A*. This beam is referred to as beam *B*. The mid-span deflection of beam *A* will be
(a) more than that of beam *B*
(b) less than that of beam *B*
(c) the same as that of beam *B*
(d) generally less but sometimes more depending upon the magnitude of UDL

[ESE : 2003]

5.40 In prestressed concrete, high grade concrete is used for
(a) controlling the prestress loss
(b) having concrete of low ductility
(c) having concrete of high brittleness
(d) having low creep

[ESE : 2003]

5.41 In the Limit state design of prestressed concrete structures, the strain distribution is assumed to be
(a) Linear
(b) Non-linear
(c) Parabolic
(d) Parabolic and rectangular

[ESE : 2003]

5.42 A simply supported post-tensioned prestressed concrete beam of span L is prestressed by a straight tendon at a uniform eccentricity 'e' below the centroidal axis. If the magnitude of prestressing force is P and flexural rigidity of beam is EI, the maximum central deflection of the beam is

(a) $\frac{PeL^2}{8EI}$ (downwards)

(b) $\frac{PeL^2}{48EI}$ (upwards)

(c) $\frac{PeL^3}{8EI}$ (upwards)

(d) $\frac{PeL^2}{8EI}$ (upwards)

[ESE : 2003]

5.43 M 40 concrete is preferred to M 20 concrete for prestressed concrete to

(a) overcome bursting stresses at the ends
(b) avoid brittle failure of concrete
(c) eliminate the effect of shrinkage
(d) economize the use of cement

[ESE : 2004]

5.44 Match List-I (Post-tensioning system) with List-II (Type of anchorage) and select the correct answer using the codes given below the lists:

List-I
A. Freyssinet
B. Gifford-Udall
C. Lee-McCall
D. Magnel Blaton

List-II
1. Flat steel wedges in sandwich plates
2. High strength nuts
3. Split conical wedges
4. Conical serrated concrete wedges

Codes :

	A	B	C	D
(a)	2	1	4	3
(b)	4	3	2	1
(c)	2	3	4	1
(d)	4	1	2	3

[ESE : 2005]

5.45 Which one of the following systems of prestressing is suitable for pretensioned members?

(a) Freyssinet system
(b) Magnel-Blaton system
(c) Hoyer system
(d) Gifford-Udall system

[ESE : 2005]

5.46 Which one of the following method is employed to manufacture prestressed concrete sleepers for the railways?

(a) Post-tensioning
(b) Pre-tensioning
(c) Pre-tensioning followed by post tensioning
(d) Partial prestressing

[ESE : 2005]

5.47 Match List-I (Post-tensioning system) with List-II (Arrangement of tendons in the duct) and select the correct answer using the codes given below the lists:

List-I
A. Freyssinet
B. Gifford-Udall
C. Lee-McCall
D. Magnel-Blaton

List-II
1. Single bars
2. Wires evenly spaced by perforated spacers
3. Horizontal rows of four wires spaced by metal grills
4. Wires spaced by helical wire core in annular spacer

Codes :

	A	B	C	D
(a)	4	1	2	3
(b)	3	2	1	4
(c)	4	2	1	3
(d)	3	1	2	4

[ESE : 2006]

5.48 A prestressed concrete beam of cross-sectional area A, moment of inertia 'I', distance of top extreme fibre from neutral axis 'y' and distance of bottom extreme fibre from neutral axis 'y_b' is subjected to a prestressing force such that stress at top fibre is zero. What is the value of eccentricity ('r' is radius of gyration)?

(a) A/y_b (b) r^2/y_b
(c) r^2/y_t (d) ry_b/y_t

[ESE : 2006]

5.49 Concordant cable profile is
(a) a cable profile that produces no support reactions due to prestressing
(b) a cable profile which is parabolic in nature
(c) a cable profile which produces no bending moment at the supports of a beam
(d) a cable profile laid corresponding to axial stress diagram

[ESE : 2006]

5.50 For a prestressed concrete continuous beam subject to different load combinations, which one of the following is correct for concordant cable profile?
(a) It is not unique, but located in a narrow zone
(b) It is unique
(c) It is selected as compromise between secondary stresses and working stresses
(d) It is selected based on deflection profile

[ESE : 2006]

5.51 The profile of the centroid of the tendon is parabolic with a central dip h. Effective prestressing force is P and the span L. What is the equivalent upward acting uniform load?

(a) $\frac{8hL}{P}$ (b) $\frac{8hP}{L^2}$
(c) $\frac{8h^2L}{P}$ (d) $\frac{8h^2P}{L}$

[ESE : 2006]

5.52 What is the uplift at centre on release of wires from anchors due to pretensioning only for force P and eccentricity e for a pre-tensioned rectangular plank?

(a) $\frac{PeL^2}{6EI}$ (b) $\frac{Pe^2L}{6EI}$
(c) $\frac{PeL^2}{8EI}$ (d) $\frac{Pe^2L}{8EI}$

[ESE : 2006]

5.53 An ordinary mild steel bar has been prestressed to a working stress of 200 MPa. Young's modulus of steel is 200 GPa. Permanent negative strain due to shrinkage and creep is 0.0008. How much is the effective stress left in steel?
(a) 184 MPa (b) 160 MPa
(c) 40 MPa (d) 16 MPa

[ESE : 2006]

5.54 Prestressing anchorage unit using multiple wire cables exists in the
(a) Freyssinet system
(b) Lee-McCall system
(c) Gifford-Udall system
(d) Hoyer system

[ESE : 2006]

5.55 What is the allowable upward deflection in a prestress concrete member under serviceability limit state condition?
(a) Span/250 (b) Span/300
(c) Span/350 (d) Span/500

[ESE : 2007]

5.56 What is the limiting principal tensile stress in prestress uncracked concrete member of M25 grade ?
(a) 1 MPa (b) 1.5 MPa
(c) 2 MPa (d) 2.5 MPa

[ESE : 2007]

5.57 At the time of initial tensioning, the maximum tensile stress immediately behind the anchorage should not exceed which one of the following?
(a) 0.50 × ultimate tensile stress
(b) 0.60 × ultimate tensile stress
(c) 0.70 × ultimate tensile stress
(d) 0.80 × ultimate tensile stress

[ESE : 2007]

5.58 Which one of the following is correct for horizontal spacing between the group of prestressing cables as per IS code?
(a) Greater of, 40 mm and 5 mm plus maximum size of coarse aggregate
(b) Greater of, 40 mm and –5 mm plus maximum size of coarse aggregate
(c) 50 mm
(d) 25 mm

[ESE : 2007]

5.59 High strength steel used in prestressed concrete can take how much maximum strain?
(a) 2% (b) 3%
(c) 4% (d) 6%

[ESE : 2007]

5.60 In pre-tensioned beams, which of the following losses is/are not considered?

1. Anchor loss
2. Shrinkage
3. Creep
4. Relaxation
5. Friction
6. Elastic shortening

Select the correct answer using the codes given below :

(a) 1, 2 and 3 only (b) 4, 5 and 6 only
(c) 5 only (d) 6 only

[ESE : 2007]

5.61 Prestressing force in a wire under thermal stressing can be estimated from which of the following ?

1. Pressure gauge with jack
2. Elongation of wire
3. Temperature rise

Select the correct answer using the codes given below :

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 2 only

[ESE : 2007]

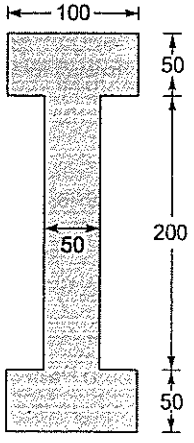
5.62 For a rectangular prestressed beam designed for operating stress conditions, what is the maximum prestressing force ?

(a) $bd\sigma_c$ (b) $\frac{1}{2}\times(bd\sigma_c)$

(c) $\frac{1}{3}\times(bd\sigma_c)$ (d) $\frac{1}{6}\times(bd\sigma_c)$

[ESE : 2007]

5.63 What is the distance between the kerns for the section given below?



(a) 100 units
(b) > 100 units, < 150 units
(c) < 100 units
(d) > 150 units

[ESE : 2007]

5.64 What is a tendon profile, in which the eccentricity is proportional to the bending moment caused by any loading on a rigidly supported indeterminate structure, at all cross-sections?

(a) Cable profile
(b) Resultant profile
(c) Concordant profile
(d) Reduced profile

[ESE : 2007]

5.65 Fully prestressed concrete beams

(a) resist all the working loads by prestress
(b) resist the full live load by prestress
(c) resist the part of the load by prestress
(d) resist only the dead loads

[ESE : 2008]

5.66 Consider the following statements :

The shear resistance of structural concrete members may be improved by :

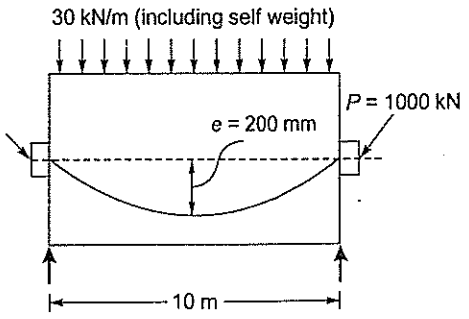
1. Axial prestressing
2. Vertical prestressing
3. Inclined prestressing

Which of these statements is/are correct?

(a) 1 only (b) 1 and 2 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2009]

5.67 What is the net downward load to be considered for the analysis of the prestressed concrete beam provided with a parabolic cable as shown in the figure below?



(a) 12 kN/m (b) 13 kN/m
(c) 14 kN/m (d) 15 kN/m

[ESE : 2009]

5.68 Match List-I with List-II and select the correct answer using the codes given below the lists :

List-I	List-II
A. IS-875	1. Earthquake resistant design
B. IS-1343	2. Loads
C. IS-1893	3. Liquid storage structure
D. IS-3370	4. Prestressed concrete

Codes:

	A	B	C	D
(a)	3	1	4	2
(b)	2	1	4	3
(c)	3	4	1	2
(d)	2	4	1	3

[ESE : 2009]

5.69 The use of 'concordant cables' in prestressed continuous beam induces
(a) initial support reactions
(b) no initial support reactions
(c) excess cracking
(d) excess deflection

[ESE : 2010]

5.70 If a simply supported concrete beam, prestressed with a force of 2500 kN, is designed by load balancing concept for an effective span of 10 m and to carry a total load of 40 kN/m, the central dip of the cable profile should be
(a) 100 mm (b) 200 mm
(c) 300 mm (d) 400 mm

[ESE : 2010]

5.71 **Assertion (A):** Losses in prestress in pre-tensioned beams are more than the losses in post-tensioned beams.
Reason (R): This is partially due to the effect of elastic shortening.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2010]

5.72 In prestressed concrete members, the shear force depends upon
(a) Distributed load
(b) Torsion
(c) Concentration load
(d) Variation in net bending moment

[ESE : 2011]

5.73 In case of Magnel-Blaton system of prestressing, each sandwich plate can generally anchor
(a) 6 wires (b) 8 wires
(c) 10 wires (d) 16 wires

[ESE : 2011]

5.74 In case of prestressed concrete members, the bursting stresses develops at
(a) Bond zone
(b) Maximum bending moment zone
(c) Maximum shear stress zone
(d) Anchorage zone

[ESE : 2011]

5.75 A prestressed concrete section is said to have failed in strength at the moment when all the material in the section has exhausted its
(a) Stress limitations
(b) Strain limitations
(c) Stress as well as strain limitations
(d) Load limitations

[ESE : 2011]

5.76 The loss due to relaxation of stress in steel in PSC member depends on
1. Applied stress level
2. Temperature
3. Type of steel
(a) 1 and 2 only (b) 2 and 3 only
(c) 1, 2 and 3 (d) 1 and 3 only

[ESE : 2011]

5.77 The 'transmission length' requirement is to be satisfied in the design of
(a) Pre-tensioned concrete beams.
(b) Post-tensioned concrete beam.
(c) Unbonded post-tensioned concrete beams.
(d) Post-tensioned continuous concrete beams.

[ESE : 2011]

5.78 Which one of the following statements is not correct with respect to PSC beams?
(a) Loss due to shrinkage is proportional to water-cement ratio used in concrete.
(b) Loss due to creep is proportional to the age of the member at the time of loading.

(c) Loss due to elastic deformation is directly proportional to the modulus of elasticity of concrete.
(d) Loss due to friction occurs in post-tensioned concrete members.

[ESE : 2011]

5.79 A simply supported rectangular beam is uniformly loaded and is prestressed. The tendon provided for prestressing should be
(a) Straight, above centroidal axis
(b) Straight, below centroidal axis
(c) Parabolic, with convexity upward
(d) Parabolic, with convexity downward

[ESE : 2011]

5.80 For a certain set of external loads, concordant profile in a prestressed beam represents to some scale the
(a) Influence line diagram
(b) Shear force diagram
(c) Bending moment diagram
(d) Williot-Mohr diagram

[ESE : 2011]

5.81 A concrete beam of rectangular cross-section of 200 mm × 400 mm is prestressed with a force of 400 kN at an eccentricity of 100 mm. The maximum compressive stress in the concrete is
(a) 12.5 N/mm^2 (b) 7.5 N/mm^2
(c) 5.0 N/mm^2 (d) 2.5 N/mm^2

[ESE : 2012]

5.82 Consider the following statements:
Prestressing in concrete can be done
1. by means of hydraulic jacks
2. by means of thermal methods
3. by means of support displacement
4. by the use of expanding cement

Which of these statements are correct?
(a) 1, 2 and 3 only (b) 1, 3 and 4 only
(c) 2, 3 and 4 only (d) 1, 2, 3 and 4

[ESE : 2012]

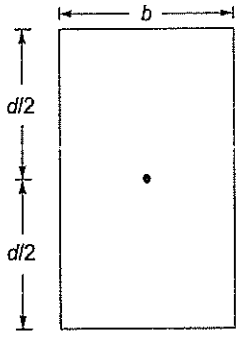
5.83 A pre-tensioned (assume no losses) concrete rectangular ($b \times d$) beam is designed on the basis of no tension. Concrete strength is σ_c. The maximum moment that the beam can carry is
(a) $\sigma_c \cdot \frac{bd^2}{2}$ (b) $\sigma_c \cdot \frac{bd^2}{3}$
(c) $\sigma_c \cdot \frac{bd^2}{4}$ (d) $\sigma_c \cdot \frac{bd^2}{6}$

[ESE : 2012]

5.84 The percentage loss of prestress due to anchorage slip of 3 mm in a concrete beam of length 30 m which is post-tensioned by a tendon with an initial stress of 1200 N/mm^2 and modulus of elasticity equal to 2.1×10^5 N/mm^2, is
(a) 0.0175 (b) 0.175
(c) 1.75 (d) 17.5

[ESE : 2012]

5.85 The below figure represents a section of a pre-stressed beam. For a no-tension design where σ_c is the permissible stress in concrete, the total moment carrying capacity is



(a) $\frac{bd^2\sigma_c}{3}$ (b) $\frac{bd^2\sigma_c}{4}$
(c) $\frac{bd^2\sigma_c}{6}$ (d) $\frac{bd^2\sigma_c}{12}$

[ESE : 2013]

5.86 Spalling stresses are produced in post-tensioned pre-stressed concrete members because of
(a) bursting force
(b) highly concentrated tendon force
(c) inadequate anchor block
(d) maximum shear zone

[ESE : 2013]

5.87 A concordant cable profile in pre-stressed concrete is
(a) parallel to the beam axis
(b) one which coincides with the centroidal axis of beam

(c) one which does not cause secondary stresses
(d) one which eliminates primary stresses

[ESE : 2013]

5.88 Spalling stresses are produced in post-tensioned pre-stressed concrete members at
(a) locations of maximum bending moment only
(b) locations of maximum shear zone
(c) anchorage zone
(d) bond-developing zone

[ESE : 2014]

5.89 In a pre-stressed member, it is advisable to use
(a) low-strength concrete
(b) high-strength concrete
(c) high-strength concrete and high-tension steel
(d) high-strength concrete and low-tension steel

[ESE : 2014]

5.90 The percentage loss of pre-stress due to anchorage slip of 3 mm in a concrete beam of length of 30 m which is post-tensioned by a tendon subjected to an initial stress of 1200 N/mm^2 and modulus of elasticity equal to 2.1×10^5 N/mm^2, is
(a) 0.0175% (b) 0.175%
(c) 1.75% (d) 17.5%

[ESE : 2014]

5.91 A post-tensioned beam of span 25 m is prestressed with 20 numbers of 40 mm diameter cables, each stressed to 1500 MPa, with eccentricity $e = 0$ at supports and $e = 500$ mm at midspan, varying parabolically. If the shear force at the support section due to externally applied load is 4500 kN, what is the nearest magnitude of the shear force resisted by the stirrups?
(a) 3060 kN (b) 4540 kN
(c) 250 kN (d) 1480 kN

[ESE : 2015]

5.92 For a pre-tensioned beam, Young's Modulus of steel and concrete are 200 GPa and 35.35 GPa, respectively. If the ultimate shrinkage strain and Ultimate Creep Coefficient are 200 microns and 1.6, respectively, what is the level of sustained stress in concrete at the level of 'steel' if the loss due to creep is three times the loss due to shrinkage?
(a) 9 MPa (b) 13 MPa
(c) 11 MPa (d) 15 MPa

[ESE : 2015]

5.93 Consider the following statements:
Correct estimation of loss of prestress is required for assessing
1. The serviceability behaviour of a PSC beam.
2. The ultimate shear resistance of a PSC beam.
3. The ultimate moment of resistance of a PSC beam.

Which of the above statements is/are correct?
(a) 1, 2 and 3 (b) 3 only
(c) 2 only (d) 1 only

[ESE : 2015]

5.94 If the loading on a simply supported prestressed concrete beam is uniformly distributed, the centroid of the prestressing tendon should be as
(a) A straight profile along the lower edge of the kern
(b) A parabolic profile with convexity downward
(c) A straight profile along the centriodal axis
(d) A circular profile with convexity upward

[ESE : 2016]

5.95 In a post-tension pre-stressed concrete beam, the end block zone is in between the end of the beam and the section where
(a) The shear stresses are maximum
(b) Only shear stresses exist
(c) No lateral stresses exist
(d) Only longitudinal stresses exist

[ESE : 2016]

5.96 In the pre-tensioning method
1. Tension in concrete is induced directly by external force
2. Tension is induced in the tendons before concreting
3. Concrete continues to be in tension after pre-stressing
(a) 1 only (b) 2 only
(c) 3 only (d) 1 and 3 only

[ESE : 2016]

5.97 In the design of pre-stressed concrete structures, which of the following limit states will qualify as the limit states of serviceability?

1. Flexural
2. Shear
3. Deflection
4. Cracking

(a) 1 and 2 only (b) 3 and 4 only
(c) 1 and 4 only (d) 2 and 3 only

[ESE : 2016]

5.98 A simply supported prestressed concrete beam is of 25 m span. The initial stress is 1000 MPa. The slip in the jack during tensioning has been 2 mm. IF E_s = 200 GPa, the loss prestress due to anchorage slip is

(a) 16% (b) 12%
(c) 10% (d) 1.6%

[ESE : 2017]

■■■■

Answers Prestress Concrete

5.1 (b)	5.2 (a)	5.3 (d)	5.4 (a)	5.5 (a)	5.6 (a)	5.7 (b)	5.8 (d)	5.9 (a)	
5.10 (b)	5.11 (d)	5.12 (d)	5.13 (c)	5.14 (b)	5.15 (c)	5.16 (b)	5.17 (d)	5.18 (c)	
5.19 (b)	5.20 (c)	5.21 (a)	5.22 (b)	5.23 (b)	5.24 (a)	5.25 (b)	5.26 (b)	5.27 (d)	
5.28 (b)	5.29 (d)	5.30 (c)	5.31 (d)	5.32 (d)	5.33 (b)	5.34 (d)	5.35 (c)	5.36 (d)	
5.37 (a)	5.38 (d)	5.39 (a)	5.40 (a)	5.41 (a)	5.42 (d)	5.43 (a)	5.44 (b)	5.45 (c)	
5.46 (b)	5.47 (c)	5.48 (c)	5.49 (a)	5.50 (a)	5.51 (b)	5.52 (c)	5.53 (c)	5.54 (a)	
5.55 (b)	5.56 (a)	5.57 (d)	5.58 (a)	5.59 (c)	5.60 (c)	5.61 (c)	5.62 (b)	5.63 (b)	
5.64 (c)	5.65 (a)	5.66 (d)	5.67 (c)	5.68 (d)	5.69 (b)	5.70 (b)	5.71 (a)	5.72 (d)	
5.73 (b)	5.74 (d)	5.75 (c)	5.76 (c)	5.77 (a)	5.78 (c)	5.79 (d)	5.80 (c)	5.81 (a)	
5.82 (d)	5.83 (d)	5.84 (c)	5.85 (d)	5.86 (b)	5.87 (c)	5.88 (c)	5.89 (c)	5.90 (c)	
5.91 (d)	5.92 (b)	5.93 (a)	5.94 (b)	5.95 (c)	5.96 (b)	5.97 (b)	5.98 (d)		

Explanations Prestress Concrete

5.1 (b)

Central dip,

$$h = \frac{wl^2}{8P} = \frac{40 \times (10)^2}{8 \times 2500} = 0.2 \text{ m} = 200 \text{ mm}$$

5.2 (a)

As per IS 1343, the shrinkage of concrete is given to be 3×10^{-4}. Shrinkage of concrete in pre-stressed members results in shortening of tension wires and contributes to loss of prestress.

5.3 (d)

High strength concrete is less liable to shrinkage cracks and has a higher modulus of elasticity and smaller ultimate creep strain, resulting in a smaller loss of prestress in steel. The use of high strength concrete results in a reduction in the cross-sectional dimensions of prestressed concrete structural elements. With a reduced dead weight of the material, longer spans become technically and economically practicable.

5.4 (a)

When cylindrical pipe is subjected to internal fluid pressure the hoop stress is tensile in nature and when cylindrical pipe is subjected to external fluid pressure the hoop stress is compressive in nature. Prestressing is required when cylindrical pipe is subjected to internal fluid pressure as the concrete is weak in tension.

5.5 (a)

	Causes	Percentage Loss Post-tensioned	Pre-tensioned
(i)	Shrinkage of concrete	6	7
(ii)	Creep of concrete	5	6
(iii)	Relaxation in steel	3	2
(iv)	Elastic shortening and bending of concrete	1	3
	Total	15	18

5.6 (a)

In load balancing method, the applied load is balanced by the cable profile. Thus bending moment and shear forces do not exist.

5.7 (b)

Due to high prestressing force, the possibility of diagonal tension crack is eliminated.

5.8 (d)

Area, $A = 45 \times 10^3 \text{ mm}^2$

Section modulus,

$$Z = \frac{Bd^2}{6} = \frac{150 \times 300^2}{6}$$

$$= 2.25 \times 10^6 \text{ mm}^2$$

$$\text{Dead load} = 0.15 \times 0.30 \times 1 \times 25$$

$$= 1.125 \text{ kN/m}$$

For bottom fibre stress to be zero

$$\frac{P}{A} + \frac{Pe}{Z} = \frac{M_{DL} + M_{LL}}{Z}$$

$$M_{DL} + M_{LL} = \frac{(1.125 + 5) \times 8^2}{8}$$

$$= 49 \text{ kN-m}$$

$$e = 75 \text{ mm}$$

$$\therefore \quad P = \frac{49 \times 10^6}{2.25 \times 10^6 \left[\frac{1}{45 \times 10^3} + \frac{75}{2.25 \times 10^6}\right]}$$

$$= 392 \text{ kN}$$

5.9 (a)

In partially prestressed members, limited tensile stresses are permitted in concrete under service loads with control on the maximum width of cracks. The untensioned reinforcement is required in the cross-section for various reasons such as to resist differential shrinkage, temperature effects and handling stresses.

5.10 (b)

Secondary moments are developed due to redundant reactions at indeterminate supports when statistically indeterminate structures are prestressed. The tendon profile which does not induce secondary moments at support is referred to as concordant profile.

5.11 (d)

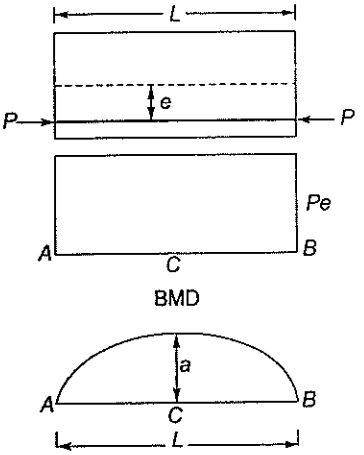
In ultimate load design concept for prestressed concrete girder used for bridges, the load factor taken for both L.L and D.L is 2.

Ultimate load = 2.0 Dead Load + 2.0 Live Load

5.12 (d)

The use of straight cable is necessary while pretensioning the slabs especially in mass production. For normal residential building we have tension at bottom. Thus cable profile used is straight.

5.13 (c)



Uplift due to pre-tensioning

= Moment of M/EI diagram about C

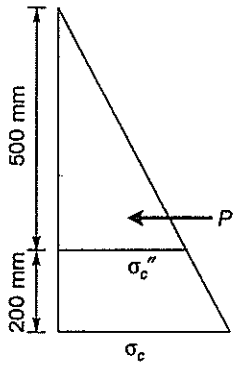
$$= \frac{Pe}{EI} \times \frac{L}{2} \times \frac{L}{4} = \frac{PeL^2}{8EI}$$

5.14 (b)

Pretensioned prestressed plank can resist both compressive and tensile stresses. However, pretensioning is done to keep the stresses compressive throughout the beam.

5.15 (c)

The stress varies from zero at one extreme fiber to σ_c at other extreme fiber.



Resultant stress diagram

$$\sigma_c'' = \frac{5}{7}\sigma_c = 5\,\text{MPa}$$

$$P_0 = \left[\frac{600\times200\times\left(\frac{5+7}{2}\right)+200\times500\times\frac{5}{2}}{1000}\right]$$

$$= 970\ \text{kN}$$

5.16 (b)

As per IS 1343:1980(clause 18.5.1) the maximum tensile stress f_{pi} immediately behind the anchorage shall not exceed 80 percent of ultimate tensile strength of wire or bar or stand at the time of initial tensioning.

5.17 (d)

The load balancing concept is used to decide the cable profile. The shape of B.M.D. forms the basis for cable profile.

In the case of udl, the BMD is parabolic so cable profile will also be parabolic.

5.18 (c)

The minimum clear spacing between groups of cables or ducts of grouped cables shall be greater of the following:

(i) 40 mm

(ii) 5 mm plus maximum size of the aggregate.

5.19 (b)

Slope of the cable at supports,

$$\theta = \frac{4(e_0 - e_s)}{L}$$

$e_0 = 100$ mm

$e_s = 25$ mm

$$\therefore \quad \theta = \frac{4\times(100-25)}{8000}$$

$$= 0.0375 \text{ radians}$$

Vertical component of prestressing force at support

$= 200 \times 0.0375 = 7.5$ kN

As per **IS:1343-1980** the ultimate resistance of a section uncracked in flexure is

$$V_{co} = 0.67bD\sqrt{f_t^2 + 0.8f_{cp}f_t}$$

Maximum principal tensile stress,

$$f_t = 0.24\sqrt{f_{ck}} = 0.24\times\sqrt{45}$$

$$= 1.61\ \text{N/mm}^2$$

$b = 150$ mm

$D = 300$ mm

Compressive stress at centroidal axis,

$$f_{cp} = \frac{P}{bD} = \frac{200\times10^3}{150\times300} = 4.44\ \text{N/mm}^2$$

$$\therefore \quad V_{co} = 0.67\times150\times300$$

$$\times\sqrt{(1.61)^2 + 0.8\times1.61\times4.44}$$

$$= 86918\ \text{N} = 86.9\ \text{kN}$$

$\therefore$ Shear resistance = 86.9 + 7.5

$= 94.4$ kN

5.20 (c)

IS 1343:1980 (clause 19.3.2) gives serviceability limit states.

Class 1 structures- no cracking under service loads

Class 2 structures- no visible cracking when $\sigma < 3$ N/mm^2

Class 3 structures- concrete section uncracked

5.21 (a)

In a composite construction, precast prestressed members are used in conjunction with the concrete cast-in situ, so that the members behave as monolithic unit under service loads. The high strength prestressed concrete is used in the tension zone, while cast-in situ concrete of relatively lower compressive strength is used in the compression zone of the composite members. The composite action between the two components is achieved by roughening the surface of prestressed unit on to which the concrete is cast in situ, thus given a better frictional resistance, or by stirrups protruding from the prestressed unit into the added concrete.

5.22 (b)

The relaxation loss in prestress depends upon the initial stress in the wires. Its magnitude is 2-8%.

5.23 (b)

Limit state of deflection and cracking comes under serviceability limits.

5.24 (a)

In the pretensioning system, the tendons are first tensioned between rigid anchor blocks prior to the casting of concrete is the moulds. The pretensioned wires are released by either cutting or releasing jacking pressure. The high tensile wires tend to shorten but are checked by the bond between concrete and steel. Thus prestress load is transferred in single stage.

5.25 (b)

The diagonal tension reduces.

5.26 (b)

The ultimate moment for prestressed members like limit state and working stress method for RCC structure is calculated from stress-strain curve for concrete and steel.

5.27 (d)

Loss in prestress is in range of 100 N/mm^2 to 250 N/mm^2. Thus high tensile steel having strength in range of 1200-1500 N/mm^2 is to be used so that even after there is loss there is sufficient prestress left in the concrete.

5.28 (b)

In the anchorage zone or the end block of a post-tensioned prestressed concrete element, the state of stress distribution is complex and three dimensional in nature. According to St. Venant's principle, the zone between the end of the beam where only longitudinal stresses exists is generally referred to as the anchorage zone or end block.

5.29 (d)

The shear cracks in prestressed concrete members are of two major types.

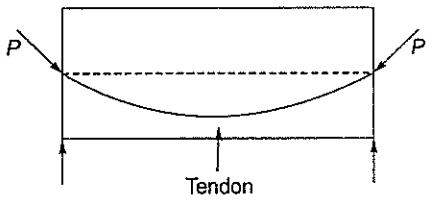
(i) Web shear cracks.

(ii) Flexure shear cracks.

Web shear cracks generally starts from an interior point, when the local principal tensile stress exceeds the tensile strength of concrete. They are likely to develop in highly prestressed beams with thin webs.

Flexure shear cracks are first initiated by flexural cracks in the inclined direction due to combined shear and flexural tensile stresses producing principal tensile stress that exceeds the tensile strength of concrete. In members without shear reinforcement, the inclined shear cracks extend to the compression face resulting in sudden explosive failures. This is sometimes referred to as the diagonal tensile mode of failure.

5.30 (c)



The profile of tendon in prestressed beam will be mirror image of the BMD. The shape of BMD is parabolic with convexivity upwards so shape of tendon will be parabola with convexivity downwards.

5.31 (d)

Initial prestressing force,

$$P = \frac{500}{0.85} = 588.24 \text{ kN}$$

$e = 75$ mm.

Area of beam,

$A = 250 \times 300 = 75000$ mm^2

Top fiber stress

$$= \frac{P}{A}\left(1 - \frac{6e}{d}\right) = -3.92 \text{ N/mm}^2$$

Bottom fiber stress

$$= \frac{P}{A}\left(1 + \frac{6e}{d}\right) = 19.6 \text{ N/mm}^2$$

5.32 (d)

As per IS 1343:1980, the method for computing flexural strength of a prestressed beam states that stress block may be of any shape which provides agreement with test data.

5.33 (b)

The maximum stress in block is compressive which occurs at mid of span and will be equal to

$$\frac{w}{A}+\frac{M}{Z}.$$

5.34 (d)

Loss of prestress in pre-tensioned members:

(i) Losses due to creep and shrinkage of concrete.

(ii) Losses due to elastic shortening of concrete.

(iii) Losses due to relaxation.

Loss of prestress in post-tensioned members:

(i) Loss due to friction (length effect, curvature effect).

(ii) Losses at anchoring stage.

(iii) Losses due to creep and shrinkage of concrete.

(iv) Losses due to successive tensioning of wires.

(v) Losses due to relaxation.

Loss of stress due to elastic shortening of concrete is maximum in pretensioned members. In the case of post-tensioned members these losses occur only when a number of cables are progressively stressed one after another.

5.35 (c)

The concept of load balancing is applied for determinate structure. Concordant cable profile is used for indeterminate structures.

5.36 (d)

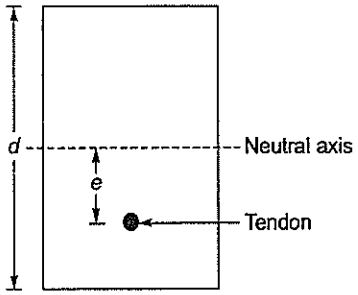
The transmission length is the length of bond anchorage of the prestressing wire from the end of a pre-tensioned member to the point of full steel stress.

5.37 (a)

The bonding of concrete with wires result in transfer of prestressing force in pretensioned members.

5.38 (d)

The eccentricity e should be less than d/6. The distance of tendons from the nearest face i.e. soffit of the beam is $\left(\frac{d}{2}-e\right)$



for $e \le \frac{d}{6}$ we have, $\frac{d}{2}-e > \frac{d}{3}$

5.39 (a)

Prestress member has less deflection and cracking than RCC member.

Other advantages of using prestress member are:-Reduction of steel corrosion, Increase in durability, Higher moment of inertia (higher stiffness), Less deformations (improved serviceability, Increase in shear capacity, Improved performance (resilience) under dynamic and fatigue loading, Larger spans possible with prestressing (bridges, buildings with large column-free spaces) etc.

5.40 (a)

High strength-concrete has greater stiffness, greater elastic modulus, less elastic deformations, low creep, and high bond strength. Hence, losses of prestress will be minimized.

5.41 (a)

It is in accordance with the assumption that a transverse plane section before bending remains plane after bending.

5.42 (d)

Maximum central deflection,

$$\delta = \frac{L^2}{8R}$$

$$\frac{1}{R} = \frac{Pe}{EI}$$

$$\therefore \quad \delta = \frac{PeL^2}{8EI} \text{ (upwards)}$$

5.43 (a)

In M40 concrete, shrinkage will be less than that in M20 concrete. M40 concrete is more brittle than M20 concrete.

5.44 (b)

In the Freyssinet system anchorage consists of cylinder of good quality concrete and is provided with corrugations on the outside. It has a central conical hole and is provided with heavy top reinforcement.

In Gifford-Udall system, the wire are stressed and anchored one by one in a separate cylinder using small wedding grip called Udall grips. Each grip consists of two split cones.

In Lee Mc Call system anchoring of bars is done by screwing special threaded nuts. The nuts bear against a distribution plate provided at the end of the beam.

In the Magnel Blaton system, the wires are anchored by wedging, two at a time into sandwich plates. The sandwich plates are provided with two wedge shaped grooves on its two faces. The wires are taken into each groove and tightened. Then a steel wedge is driven between the tightened wires to anchor them against the plate.

5.45 (c)

Hoyer system of pre-tensioning is used in mass production of pretensioned member by long line process. Freyssinet system, Magnet Blaton system and Gifford Udall system are type of post tensioning system.

5.46 (b)

Prestressing concrete sleepers in railway are manufactured by Hoyer system i.e pre-tensioning system.

5.47 (c)

In Freyssinet system, high tension steel wires 5 mm to 8 mm diameter about 12 in number are arranged to form a group into a cable with a spiral spring inside.

In the Gifford Udall system the wires are stressed and anchored one by one in a separate cylinder using small wedging grips called Udall grips.

In the Lee-Mc Call system, high tensile alloy steel bars are used as the prestressing tends.

In the Magnel Blaton system cable of rectangular section is provided. The wires are arranged with four wires per layer. The geometric pattern of the wires is maintained in the same form throughout the length of the cable by providing grills or spacers at regular intervals.

5.48 (c)

The compressive stress = $\frac{P}{A}$

The tension at top fiber = $\frac{Pe}{Z_t} = \frac{Pey_t}{I}$

For zero stress at top fiber $\frac{P}{A} = \frac{Pey_t}{I}$

$\therefore e = \frac{(I/A)}{y_t} = \frac{r^2}{y_t}$

5.49 (a)

The concordant cable profile does not produce secondary moments and there will be no reactions at the supports due to prestressing action.

5.50 (a)

The tendon profile which does not induce secondary moments at support is referred to as concordant profile. It depends upon degree of indeterminancy of structure and is not unique for all type of loading and support conditions. Thus profile satisfies a set of geometrical conditions and located in narrow zone.

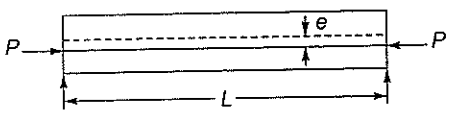
5.51 (b)

The load equivalent to the prestress in parabolic cable profile,

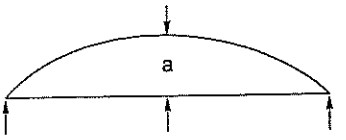
$$\frac{wL^2}{8} = Ph$$

$$w = \frac{8Ph}{L^2}$$

5.52 (c)



Camber of beam with straight tendons



Bending Moment Diagram, *Pe*

from Mohr's moment area method :

$$a = \frac{Pe \times \frac{L}{2} \times \frac{L}{4}}{EI} = \frac{PeL^2}{BEI}$$

5.53 (c)

Loss of stress due to shrinkage and creep
$= 200 \times 10^3 \times 0.0008 = 160$ MPa
Effective stress left = 200 – 160 = 40 MPa

5.54 (a)

In Freyssinet system large number of wires can be tensed simultaneously using double action hydraulic jack and anchorage units.

5.55 (b)

As per **IS:1343-1980** (code of practice for prestressed concrete), if finishes are to be applied to the prestressed concrete members, the total upward deflection should not exceed span/300, unless uniformity of camber between adjacent units can be insured.

5.56 (a)

The limiting principal tensile stress in an uncracked prestressed concrete member is given by

$$f_t = 0.24\sqrt{f_{ck}}$$
$$= 0.24\sqrt{25} = 1.2 \text{ MPa}$$

5.57 (d)

As per clause **18.5.1** of **IS:1343-1980**, at the time of initial tensioning, the maximum tensile stress immediately behind the anchorages shall not exceed 80% of the ultimate tensile strength of the wire or bar or strand.

5.58 (a)

As per clause **11.1.8.2** of **IS: 1343-1980**, in case of group of cables or ducts of grouped cables minimum clear horizontal spacing shall be greater of the following:

(i) 40 mm
(ii) 5 mm plus maximum size of aggregate

5.59 (c)

As per IS code, for prestressing maximum strain taken by high tensile steel used as tendon is 4%.

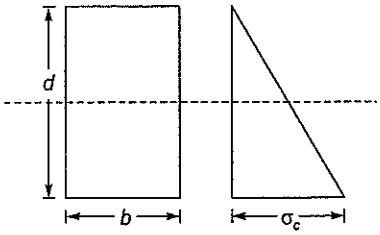
5.60 (c)

In strict terms two types of losses are not considered in pretensioned beams viz. loss due to friction and loss due to anchorage slip. Here the most close option is (c).

5.61 (c)

In thermal stressing, a member is heated upto 300°C to 400°C for 5 min. and there is about 0.5% elongation in member. After cooling it tries to shorten but is checked by fixed anchors at the ends. This induces prestressing force in range of 500-600 N/mm^2.

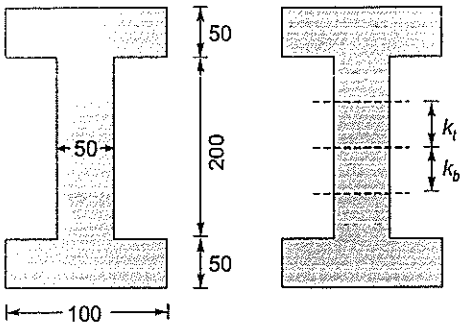
5.62 (b)



Maximum prestressing force
= area of the stress block

$$= \frac{1}{2}\sigma_c bd$$

5.63 (c)



k_b = bottom kern distance
k_t = top kern distance

$$k_t = \frac{I}{Ay_b} \text{ and } k_b = \frac{I}{Ay_t}$$

But as the I beam is symmetrical hence

$$y_t = y_b = y$$

$$\therefore \quad k_t + k_b = \frac{I}{Ay} + \frac{I}{Ay} = \frac{2I}{Ay}$$

$$= \frac{2\times\left[\frac{1}{12}\times 100\times(300)^3 - \frac{1}{12}\times(100-50)\times(200)^3\right]}{[(2\times 50\times 100)+(200\times 50)]\times 150}$$

= 127.77 units

5.64 (b)

In concordant profile eccentricity for an indeterminate structure is dependent on area of

bending moment diagram, degree of indeterminacy and flexural rigidity.

5.65 (a)

In fully prestressed concrete beams, the tensile stress is are entirely eliminated at working loads by having sufficient prestress. The entire working load will be resisted by pre-stress.

5.66 (d)

In general there are three ways of improving the shear resistance of structural concrete members by prestressing techniques viz.

(i) Horizontal or axial prestressing

(ii) Vertical or transverse prestressing

(iii) Prestressing by inclined or sloping cables

However, vertical prestressing is not generally adopted because the length of the cables being short, the loss of prestress due to anchorage slip is excessively large.

5.67 (c)

A parabolic tendon carrying a tension P will provide an upward uniformly distributed load or pressure which is given by

$$w_c = \frac{8Pe}{l^2}$$

$$= \frac{8 \times 1000 \times 200 \times 10^{-3}}{(10)^2}$$

$$= 16 \text{ kN/m}$$

$\therefore$ Net downward loading $= 30 - w_c$

$= 30 - 16 = 14$ kN/m

5.69 (b)

A concordant cable profile is a profile given for the cable such that the consequent C-line coincides with the P-line, when external loads are not applied. This means when a concordant profile is provided there will be no reactions at the supports due to prestressing alone.

5.70 (b)

Let the dip of the cable be h.

Upward pressure provided by the parabolic cable

$$= \frac{8\,Ph}{L^2}$$

In order this upward pressure may fully balance the external loading.

$$\frac{8\,Ph}{L^2} = w$$

$$\Rightarrow \frac{8 \times 2500 \times h}{(10)^2} = 40$$

$$\Rightarrow h = 0.2 \text{ m}$$

$$\Rightarrow h = 200 \text{ mm}$$

5.71 (a)

Loss in pre-tensioned member is due to elastic deformation of concrete, relaxation of steel, shrinkage and creep of concrete which is equal to almost 20% of prestress. The loss due to elastic shortening does not occur in post tensioned member so losses are limited to 15% of initial prestress.

5.72 (d)

Shear force is related to net variation in bending moment as

$$V = \frac{dM}{dx}$$

5.73 (b)

The Magnel–Blaton post-tensioning system adopts metallic sandwich plates, flat wedges, and a distribution plate for anchoring the wires. Each sandwich plate can house up to four pairs of wires. The distribution plate may be cast into the member at the desired location. The number of wires in the Magnel cable varies from 2 to 64.

5.74 (d)

The zone between the end of the beam and the section where only longitudinal stress exists is generally referred to as the anchorage zone or end block.

In the anchorage zone or the end block of a post-tensioned prestressed concrete element, the state of stress-distribution is complex and three-dimensional in nature. In most post-tensioned members, the prestressing wires are introduced in cable holes or ducts, pre-formed in the members, and then stressed and anchored at the end faces. As a result of this, large forces, concentrated over relatively small areas, are applied on the end blocks.

5.75 (c)

Member is assumed to have failed if both the stress and strain in concrete exceed their permissible limits as per the limit state criteria for the design of prestressing member.

5.77 (a)

Transmission length is the length of the bond anchorage of the prestressing wire from the end of a pre-tensioned member to the point of full steel stress.

5.78 (c)

The shrinkage of concrete in prestressed members is due to the gradual loss of moisture which results in changes in volume. The drying shrinkage depends on the aggregate type and quantity, relative humidity, water/cement ratio in the mix, and the time of exposure.

Loss due to elastic deformation of conc $= \frac{E_s}{E_c} \times f_c$

f_c = Prestress in concrete at the level of steel.

In the case of post-tensioned members, the tendons are housed in ducts preformed in concrete. On tensioning the curved tendons, loss of stress occurs in the post-tensioned members due to friction between the tendons and the surrounding concrete ducts.

The sustained prestress in the concrete of a prestressed member results in creep of concrete which effectively reduces the stress in high-tensile steel. The magnitude of the creep coefficient, ϕ, varies depending upon the humidity, concrete quality, duration of applied loading and the age of the concrete when loaded.

5.79 (d)

From the load balancing concept the shape of the tendon should correspond to the shape of the bending moment diagram.

5.80 (c)

Cable profiles are selected in a prestressed beam such that the transverse component of the cable force balances the given type of external loads. The concept of loading-balancing is useful in selecting the tendon profile, which can supply the most desirable system of forces in concrete. In general, this requirement will be satisfied if the cable profile in a prestressed member corresponds to the shape of the bending moment diagram resulting from the external loads.

5.81 (a)

The maximum compressive strength in concrete is given by

$$\sigma_{max} = \frac{P}{A} + \frac{Pey}{I}$$

$$= \frac{400 \times 10^3}{200 \times 400} + \frac{400 \times 10^3 \times 100 \times 6}{200 \times 400^2}$$

$$= 5 + 7.5 \text{ N/mm}^2 = 12.5 \text{ N/mm}^2$$

5.83 (d)

For no tension

$$\frac{P}{A} = \frac{M}{Z}$$

$$\Rightarrow \quad M = \frac{P}{A} Z = \sigma_c Z = \frac{bd^2 \sigma_c}{6}$$

5.84 (c)

Loss of prestress

$$= \frac{\Delta l}{l} \times E_s = \frac{3}{30 \times 10^3} \times 2.1 \times 10^5 = 21 \text{ N/mm}^2$$

Initial stress = 1200 N/mm^2

$$\therefore \text{ Loss of prestress} = \frac{21}{1200} \times 100 = 1.75\%$$

5.85 (d)

For maximum compression

$$\frac{P}{bd} + \frac{M}{\frac{bd^2}{6}} \le \sigma_c \qquad \text{...(i)}$$

For no tension

$$\frac{P}{bd} - \frac{M}{\frac{bd^2}{6}} = 0$$

$$\Rightarrow \quad \frac{P}{bd} = \frac{M}{\frac{bd^2}{6}} \quad \Rightarrow \quad P = \frac{6M}{d}$$

Put value of P in eq. (i)

$$\Rightarrow \quad \frac{2M}{\frac{bd^2}{6}} \le \sigma_c \quad \Rightarrow \quad \frac{12M}{bd^2} \le \sigma_c$$

$$M \le \frac{\sigma_c bd^2}{12}$$

5.86 (b)

High tensile stresses are induced in concrete when highly concentrated tendon forces are applied over anchorage zone as a result the concrete starts spalling at the anchorage zone.

5.88 (c)

Spalling stress (bursting) is occurs for post tensioned beam at anchorage zone due to heavy bearing stress.

5.89 (c)

High strength concrete has high modulus of elasticity, low ultimate creep strength and has less tendency to crack under shrinkage. High tension steel is required as normally there is loss of stress in range of 100 N/mm^2 to 250 N/mm^2.

5.90 (c)

Strain,

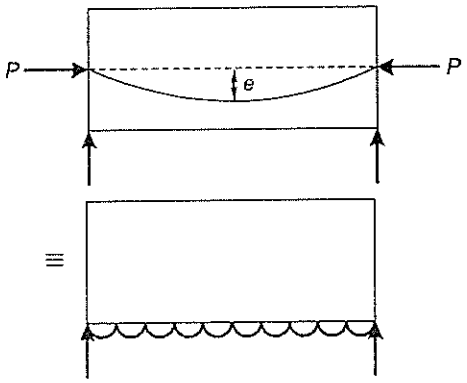
$$\epsilon = \frac{3}{30\times10^3} = 10^{-4}$$

$$\% \text{ loss} = \frac{\epsilon E}{P_0}\times 100$$

P_0 = 1200 MPa, $E = 2\times10^5$ MPa

$$\therefore \quad \%\text{loss} = \frac{10^{-4}\times2\times10^5}{1200}\times100 = 1.75\%$$

5.91 (d)



Since, $\frac{wl^2}{8} = Pe$

$$\Rightarrow \quad w = \frac{8Pe}{l^2} = \frac{8\times1500\times20\times\frac{\pi}{4}\times(40)^2\times500}{(25000)^2}$$

$$\Rightarrow \quad w = 241.152 \text{ N/mm} = 241.152 \text{ kN/m}$$

$\therefore$ upward load due to prestressing force

= 241.152 × 25 = 6028.8 kN

Reaction due to this at support = 3014.4 kN. Net shear force created at support

= 4500 – 3014.4 = 1485.6 kN

This is the shear force that has to be approximately resisted by the stirrups.

5.92 (b)

$\because$ Shrinkage loss = $\epsilon_{sc}E_s$

Creep loss = $m\phi f_c$

$$= \left(\frac{200}{35.35}\right)\times1.6\times f_c = 3\times\epsilon_{sc}\times E_s$$

$$\Rightarrow \quad f_y = 13 \text{ MPa}$$

5.94 (b)

For simply supported beam subjected to UDL, BMD is parabolic. For load balancing shape of cable shall be as per same profile (parabolic) with convexity downward.

5.95 (c)

After end zone, no lateral stresses exist. Stress direction due to P-force becomes parallel to each other in longitudinal direction.

5.96 (b)

In Pre-tensioning tendons are tensioned before the concrete is placed. In this method, the prestress is imparted to concrete by bond between steel and concrete. Tendons are temporarily anchored and tensioned and the prestress is transferred to the concrete after it is hardened.

5.97 (b)

Serviceability refers to the conditions under which a building is still considered useful. Serviceability limit state design of structures includes factors such as durability, overall stability, fire resistance, deflection, cracking and excessive vibration.

5.98 (d)

L = 25000 mm

p_0 = 1000 N/mm^2

Slip = 2 mm

$$\text{Loss} = \frac{\delta l}{l}\times E_s = \frac{2}{25000}\times200\times10^3 = 16 \text{ N/mm}^2$$

$$\% \text{ loss} = \frac{16}{1000}\times100 = 1.6\%$$

6 Masonry Structures and Earthquake Engineering

6.1 Earthquake causes horizontal and vertical accelerations in the masonry structure. The magnitude of the forces induced in the structure depend on the

(a) age of the building
(b) strength of mortar
(c) type of roof
(d) mass of the structure

[ESE : 2001]

6.2 What is the number of categories into which masonry buildings are divided on the basis of earthquake resistance features?

(a) Five (b) Four
(c) Three (d) Two

[ESE : 2005]

6.3 What is the optimum mortar mix type of maximum masonry unit strength of 5 N/mm^2?

(a) M_1 (b) M_2
(c) H_1 (d) H_2

[ESE : 2007]

6.4 For masonry built in 1:1:6 cement-lime-sand mix mortar or equivalent, the horizontal shear stress permissible on the area of a mortar bed joint is

(a) 0.15 MPa (b) 0.125 MPa
(c) 0.1 MPa (d) 0.075 MPa

[ESE : 1999]

6.5 Direct load carrying capacity of a brick masonry wall standing freely as against when it supports RC slab will be

(a) more
(b) less
(c) the same in both the cases
(d) 100% more

[ESE : 1995]

6.6 A brick masonry wall of nominal thickness 200 mm carries an axial load of 26 kN/m and another load of 19 kN/m acting at an eccentricity of 45 mm. The resultant eccentricity and eccentricity ratio are respectively

(a) 19 mm, 0.095 (b) 19 mm, 0.1
(c) 22 mm, 0.11 (d) 24 mm, 0.12

[ESE : 1996]

6.7 A 200 mm thick wall made of modular bricks is 5 m long between cross walls and 3.8 m clear height between RCC slabs at top and bottom. The slenderness ratio of the wall is

(a) 15 (b) 19
(c) 20 (d) 25

[ESE : 1997]

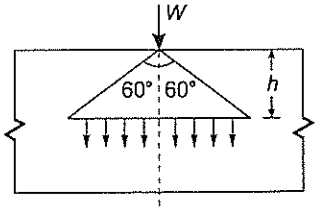
6.8 A 200 mm thick brick masonry wall made of modular bricks carries an axial load of 30 kN/m from wall above and an eccentric load of 20 kN/m from RCC floor acting at a distance of 47.5 mm from the centre line of the wall. The resultant eccentricity ratio is

(a) 0.090 (b) 0.095
(c) 0.100 (d) 0.105

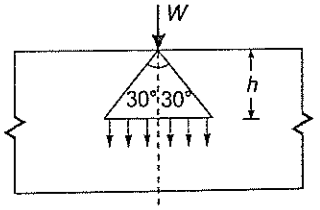
[ESE : 1997]

6.9 Which one of the following figures shows the permitted dispersion of concentrated load in masonry structures?

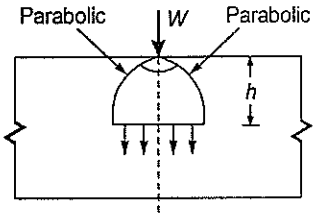
(a)



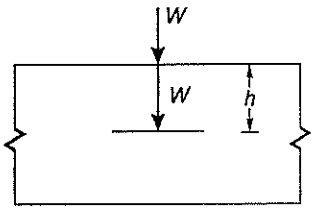
(b)



(c)



(d)



[ESE : 1997]

6.10 In brick masonry, arch action is possible only when the minimum height of wall above the top of lintel is X times the height of triangular distribution, where X is

(a) 1.00 (b) 1.25
(c) 1.50 (d) 1.75

[ESE : 1998]

6.11 The basic stress in masonry unit having height to width ratio of 1.5 may be increased by a factor of

(a) 1.2 (b) 1.4
(c) 1.6 (d) 2.0

[ESE : 1998]

6.12 Given that 'ϕ' is the angle of internal friction 'p' is the safe bearing capacity and 'γ' is the unit weight of soil, the minimum depth of foundation of a masonry footing is given by

(a) $\frac{p}{\gamma}\left(\frac{1+\sin\phi}{1-\sin\phi}\right)$ (b) $\frac{p}{\gamma}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)$

(c) $\frac{p}{\gamma}\left(\frac{1+\sin\phi}{1-\sin\phi}\right)^2$ (d) $\frac{p}{\gamma}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$

[ESE : 1999]

6.13 **Assertion (A) :** In a circular masonry column it is desirable to restrict the resultant load within the middle core of one fourth the area of the column section.

Reason (R) : It is desirable not to allow any tension in masonry structures.

Codes:

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2003]

6.14 When is a masonry wall known as a shear wall?

(a) If the earthquake load is out-of-plane
(b) If the earthquake load is in-plane
(c) If it is unreinforced
(d) If it is placed as in fill to the frame

[ESE : 2005]

6.15 Which of the following measures are resorted to for strengthening masonry wall?

1. Provide cross walls.
2. Prestressing.
3. Provide gunite slab on the surface(s) of walls.
4. Provide butresses.

Select the correct answer using the codes given below:

(a) 1, 3 and 4 (b) 1 and 2
(c) 2 and 3 (d) 1, 2, 3 and 4

[ESE : 2005]

6.16 What is the effective height of a free standing masonry wall for the purpose of computing slenderness ratio?

(a) $0.5L$ (b) $1.0L$
(c) $2.0L$ (d) $2.5L$

[ESE : 2005]

6.17 A masonry wall has height 'h', length L and thickness 't'. The allowable stress based on slenderness is calculated on the basis of

(a) h/t only
(b) L/t only
(c) lesser of L/t and h/t
(d) greater of L/t and h/t

[ESE : 2006]

6.18 The net effect of vertical and lateral forces acting on a masonry wall can be expressed as vertical load 'p'/unit length acting at an effective eccentricity 'e'. If $e > (t/6)$, tension develops in the wall. Ignoring the part of thickness 't' in tension, what is the compressive stress in extreme fibre?

(a) $p/\{(t/2)-e\}$

(b) $[2p/3\{(t/2)-e\}]$

(c) $[p/3\{(t/2)-e\}]$

(d) $[p/6\{(t/2)-e\}]$

[ESE : 2006]

6.19 Which one of the following is not a factor affecting strength of a brick masonry wall?

(a) Size and location of door in a wall

(b) Positioning of cross walls

(c) Type of roof the wall bears and its connection

(d) Type of plastering on the wall

[ESE : 2006]

6.20 In load-bearing wall, the depth of horizontal chassis should not exceed which one of the following?

(a) 1/3 thickness of masonry

(b) 1/4 thickness of masonry

(c) 1/5 thickness of masonry

(d) 1/6 thickness of masonry

[ESE : 2007]

6.21 The effective height of a masonry wall of height *H* restrained fully at its top and partially at its bottom, is

(a) 0.75 H (b) 0.85 H

(c) 1.00 H (d) 1.50 H

[ESE : 2015]

6.22 The effective length of a masonry wall stiffened by buttresses on both ends and continuing beyond these buttresses at both ends is

(a) 1.0 L (b) 2.0 L

(c) 0.9 L (d) 0.8 L

where *L* is the c/c length of the wall between successive buttresses.

[ESE : 2015]

6.23 When steel reinforcing bars are provided in masonry, the bars shall have an embedment with adequate cover in cement-sand mortar not leaner than

(a) 1 : 3 (b) 1 : 4

(c) 1 : 6 (d) 1 : 6

[ESE : 2016]

6.24 Which of the following measures are relevantly considered for earthquake loading and lateral stability of tall buildings?

1. Minimizing gravity loads
2. Adding masses at floor levels
3. Ensuring ductility at the locations of maximum moments
4. Providing shear walls
5. Providing basement

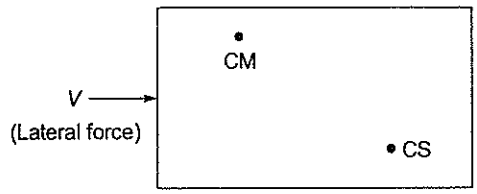
Select the correct answer using the codes given below:

(a) 1, 2 and 5 (b) 1, 2 and 4

(c) 1, 3 and 4 (d) 3, 4 and 5

[ESE : 2017]

6.25 The figure shows the plan view of a single-storey masonry shear wall building with rigid rood diaphragm. The traces of locations of the centre of mass (CM) and the centre of stiffness (CS) are as shown. Neglecting accidental eccentricity, the direction of the twisting moment on the diaphragm, the lateral force direction shown, is



(a) Clockwise

(b) Anticlockwise

(c) Opposite to the direction of lateral force

(d) None of the above

[ESE : 2017]

Answers Masonry Structures and Earthquake Engineering

6.1	(d)	6.2	(a)	6.3	(a)	6.4	(c)	6.5	(b)	6.6	(a)	6.7	(b)	6.8	(b)	6.9	(a)		
6.10	(b)	6.11	(a)	6.12	(d)	6.13	(d)	6.14	(d)	6.15	(a)	6.16	(c)	6.17	(d)	6.18	(b)		
6.19	(d)	6.20	(d)	6.21	(b)	6.22	(a)	6.23	(a)	6.24	(d)	6.25	(a)						

Explanations Masonry Structures and Earthquake Engineering

6.1 (d)

Horizontal and vertical acceleration are induced in the masonry structure due to earthquake. Inertial forces that depend on the mass of structure are developed in opposite direction for resistance.

6.2 (a)

Brick masonry is divided into five categories:

(i) Reinforced
(ii) Unreinforced
(iii) Without fill
(iv) With heavy fill
(v) Abode construction

6.3 (a)

Mortar Grade	Compressive Strength (N/mm^2)
H_1	10
H_2	7.5
M_1	5
M_2	3
L_1	1.5
L_2	0.7

6.4 (c)

For masonry built in M_1 mortar or equivalent, a horizontal shear stress f_s may be permitted on the area of mortar bed joint as given by

$f_s = 0.1 + f_d/6 \leq 0.5\ N/mm^2$

Where f_d is the actual compressive stress on the section due to dead loads.

Since the height of wall or column is not given so assume $f_d = 0$.

$\therefore \quad f_s = 0.1\ N/mm^2$

6.5 (b)

The slenderness ratio of free standing wall will be more than that when it supports RC slab. So the load carrying capacity will be less.

6.6 (a)

Resultant load = 26 + 19 = 45 kN/m

Resultant moment = 26 × 0 + 19 × 45

= 855 kN-mm/m

Resulting eccentricity, $e = \dfrac{855}{45} = 19$ mm

Eccentricity ratio = $\dfrac{e}{t} = \dfrac{19}{200} = 0.095$

Eccentricity ratio can have maximum value as 0.50.

6.7 (b)

The slenderness ratio of a wall is lesser of the $\dfrac{h}{t}$ and $\dfrac{l}{t}$

$$\frac{h}{t} = \frac{3800}{200} = 19$$

$$\therefore \quad \frac{l}{t} = \frac{5000}{200} = 25$$

6.8 (b)

Resultant eccentricity

$$e = \frac{30\times 0 + 20\times 47.5}{30+20} = 19\ mm$$

Eccentricity ratio = $\dfrac{e}{t} = \dfrac{19}{200} = 0.095$

6.9 (a)

The angle of dispersion is normally taken to be 45° for good masonry. For poor masonry it is taken to be 60°. If the height of the wall above the opening is less than 1.25 times the height of the triangle, full rectangular load over the lintel is transferred.

6.10 (b)

For the transfer of load to the sides by arch action, it is necessary that the height of the wall above the opening is 1.25 times the height of triangle of masonry load transferred on the lintel and the length of the wall on each side of the opening is equal to at least half of the effective span of the lintel.

6.11 (a)

Modifying factor for shape of masonry units.

Height to width ratio	Modification factor for shape K_u for strength of units in N/mm^2			
	5.0	7.5	10.0	15
1.0	1.2	1.1	1.1	1.0
1.5	1.5	1.3	1.2	1.1

So for height to width ratio 1.5 $K_u = 1.2$

6.12 (d)

$$\text{Minimum depth of foundation} = \frac{p}{\gamma}\left(\frac{1-\sin\phi}{1+\sin\phi}\right)^2$$

6.13 (d)

The diameter of the kern is $d/4$.

6.14 (d)

Masonry wall work as shear wall when filled within frame.

6.15 (a)

In case of masonry walls high grade concrete is not used. Hence, prestressing force is not required.

6.16 (c)

The masonry wall can be considered to be restrained at the base and free at top. So effective height will be 2 L.

6.17 (d)

The slenderness ratio of a wall or column is defined as the ratio of effective height to its effective thickness. For a wall, the effective height is replaced by the effective length if effective height happens to be less.

6.18 (b)

The effective width

$$b = 3\left(\frac{t}{2} - e\right) \qquad \therefore \frac{1}{2}\sigma_c b = p$$

$$\Rightarrow \sigma_c = \frac{2p}{b} = \frac{2p}{3\left\{\left(\frac{t}{2}\right) - e\right\}}$$

6.20 (d)

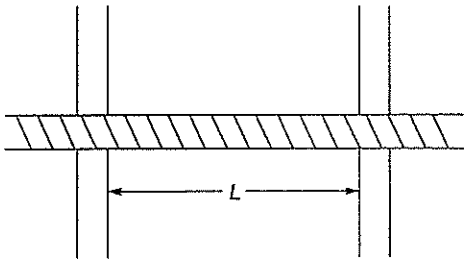
As per IS 1905:1987, in load bearing walls, the depth of vertical chases shall not exceed one third of thickness of masonry and the depth of horizontal chases shall not exceed one sixth of thickness of masonry.

6.21 (b)

Effective height of masonry wall of height H restrained fully (lateral as well as rotational) at one end and partially at the other is 0.85 H.

6.22 (a)

The effective length of masonry wall stiffened by buttresses/piers on both ends and continuing beyond buttress at both ends and is 0.8L. (the effective length is also 0.8L where a wall is continuous and is supported by cross wall and there is no opening within a distance of H/8 from the face of cross wall)



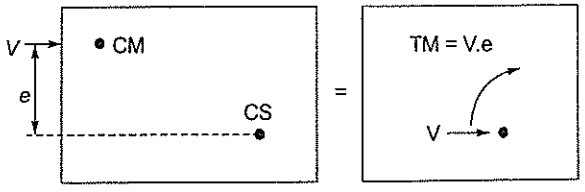
$L_{eff} = 0.8\,L$

6.24 (d)

Since problem demands lateral as well as earthquake loading stability.

1. **Minimising gravity loads:** It will provide some stability in earthquake but lateral stability will reduce (μW).
2. **Adding masses at floor level:** Addition of masses at floor level will increase earthquake load, which gives unstability.
3. **Ensuring ductility at the locations of maximum moment:** When structure will be ductile, there will not be sudden collapse.
4. **Providing shear walls:** Shear walls resist earthquake loads.
5. **Providing basement:** Basement will act as a shear key for lateral stability.

6.25 (a)



Twisting moment will be clockwise.

7 Miscellaneous

7.1 In Pigeaud's coefficient method for the analysis of an interior panel of a T-beam bridge
(a) notation for coefficients as αx_4 and αy_4 includes suffix 4 since the panel is continuous on all the four edges
(b) Poisson's ratio of concrete has no contribution
(c) the applicability is restricted to the case when the wheel load is centrally placed
(d) dispersion of load as considered through the wearing coat only.

[ESE : 1995]

7.2 The "effective width method" requires the
(a) wheel load to be dispersed through the wearing coat as well as deck slab in the transverse direction
(b) wheel load to be dispersed through the wearing coat as well as the deck slab in the longitudinal direction
(c) overlap to be considered in the transverse direction only
(d) impact factor to be considered for the dead load as well

[ESE : 1996]

7.3 Consider the following measures:
1. Keeping cement content within the range of 330 kg/m^3 to 530 kg/m^3.
2. Using well-graded aggregate with water-cement ratio less than 0.5.
3. Controlling the permissible stress in steel by the strain and crack widths rather than the strengths.
4. Providing minimum steel of any grade amounting to 0.3 per cent.

Which of these measures have been recommended by IS:3370-1970 for the design of leak-proof liquid containers of impervious concrete?

(a) 1, 2, 3 and 4 (b) 1, 2 and 3
(c) 2, 3 and 4 (d) 1 and 4

[ESE : 1999]

7.4 Consider the following statements:
The Impact factor for reinforced concrete bridges $= \frac{4.5}{(6+L)}$ (where L is the length in metres of the span).
The bridge is designed
1. for spans upto 30 m
2. for spans between 3 m and 45 m
3. either for class *A* or class *B* loading
4. for class *AA* and class 70*R*

Which of these statements are correct?
(a) 1 and 3 (b) 2 and 3
(c) 1 and 4 (d) 2 and 4

[ESE : 2001]

7.5 While designing multistorey in deep, trial structures, BIS code suggests the reduction in live loads because
(a) all the floors may not be loaded simultaneously
(b) cross-section of the columns are different at different floors
(c) thickness of roof slab is smaller than the thickness of floor slabs
(d) of the cantilevering effect of the building

[ESE : 2001]

7.6 What is the minimum width of roadway for a six-lane high-level bridge constructed for the use of road traffic only?
(a) 21.5 m (b) 22.5 m
(c) 24.0 m (d) 25.5 m

[ESE : 2007]

7.7 Consider the following types of bridges :
1. Arch bridge

2. Double cantilever bridge
3. Suspension bridge
4. Truss bridge

What is the correct sequence in the ascending order of the span ranges, generally adopted for the bridges given above ?

(a) 2 – 4 – 1– 3 (b) 1 – 3 – 2 – 4
(c) 2 – 3 – 1 – 4 (d) 1 – 4 – 2 – 3

[ESE : 2007]

7.8 Consider the following statements for longitudinal reinforcement in a *RC* member to resist earthquake force:

1. The tension steel ratio on any section shall not be less than $0.24\sqrt{\frac{f_{ck}}{f_y}}$
2. There shall be two bars at top as well as bottom of the member throughout.
3. The 'positive' steel at a joint face must be at least equal to half the 'negative' steel at that face.

Which of these statements are correct?

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2012]

7.9 Which of the following statements are correct?

1. The conventional rigid frame system of columns and beams works well for carrying both vertical and lateral loads for buildings up to 28 storeys height.
2. A shear wall does not provide stability against lateral loads.
3. Drying shrinkage is caused by the evaporation of water from concrete stored in unsaturated air.

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 1 and 3 only (d) 2 and 3 only

[ESE : 2013]

7.10 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Deck slab bridge
B. Balanced cantilever
C. Arch bridge
D. Rigid frame culvert

List-II

1. Used for long spans
2. Used for bridge medium spans
3. Statically determinate structure
4. Used for small drains

Codes :

	A	B	C	D
(a)	3	2	4	1
(b)	2	3	1	4
(c)	3	2	1	4
(d)	1	2	3	4

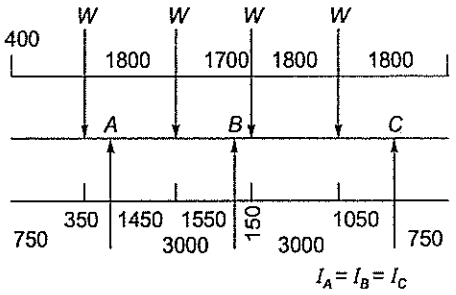
[ESE : 1995]

7.11 For a bridge-deck the most economical section shall be

(a) a double-tee section
(b) an *I*-section
(c) a box section
(d) a channel section

[ESE : 1995]

7.12 The given figure shows the position of concentrated wheel loads on a bridge deck. For determining the bending moments in the girders by Courbon's theory, the reaction factors are respectively



(a) 1.80 W, 1.33 W and 0.87 W
(b) 1.73 W, 1.28 W and 0.99 W
(c) 2.00 W, 1.50 W and 0.50 W
(d) 2.00 W, 1.25 W and 0.75 W

[ESE : 1997]

7.13 Elastomeric bearing pads are

(a) flat solid metal plates
(b) preferable to steel roller bearing since they do not require any periodical maintenance.
(c) not as satisfactory for concrete bridges as they are for steel bridges
(d) made of thermo-plastic material

[ESE : 1997]

7.14 The notching in a simply-supported timber beam of span L and depth 'd' should be restricted to the region
(a) $L/6$ from the support
(b) $L/6$ from the mid-span
(c) $L/6$ or 3d from the mid-span, whichever is less
(d) $L/6$ or 3d from the supports, whichever is less
[ESE : 1998]

7.15 To ensure adequate ductility for preventing failures during earthquakes, the percentage tension reinforcement 'p' on any face at any section in beams and girders should **NOT** exceed which one of the following values, when M15 concrete and mild steel bars are used for the construction of beams or girders (p_c is the percentage compression reinforcement and f_{ck} and f_{sy} have their usual meanings)?
(a) $p \le p_c + 0.011\frac{f_{ck}}{f_{sy}}$
(b) $p \le p_c + 0.19\frac{f_{ck}}{f_{sy}}$
(c) $p \le p_c + 0.15\frac{f_{ck}}{f_{sy}}$
(d) $p \le p_c + 0.11\frac{f_{ck}}{f_{sy}}$
[ESE : 1998]

7.16 A six-storey 4-bay *RC* frame subjected to lateral loads would structurally behave
(a) more as a cantilever than as a portal frame
(b) more as a portal frame than as a cantilever
(c) neither as a cantilever nor as a portal frame
(d) as a cantilever or as a portal frame depending upon the load intensity
[ESE : 1998]

7.17 Which one of the following components of the bridge deck is analyzed by using Courbon's method?
(a) Slabs (b) Diaphragms
(c) Cross-beams (d) Girders
[ESE : 1999]

7.18 **Assertion (A) :** Bridges designed for class-AA loading should be checked for class-A loading also.
Reason (R) : Under certain conditions, heavier stresses may be obtained for class-A loading
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 1999]

7.19 As the span of a bridge increases, the impact factor
(a) decreases
(b) increases
(c) remains constant
(d) increases up to a critical value of span and then decreases
[ESE : 2002]

7.20 In a spherical dome subjected to a uniformly distributed load the meridional force induced is
(a) compressive throughout
(b) zero at the crown
(c) tensile below the plane of rupture
(d) compressive for heavier loads, while being tensile for lower loads
[ESE : 1995]

7.21 Minimum percentage area of HYSD reinforcement in a 150 mm thick water tank wall is
(a) 0.16 (b) 0.20
(c) 0.23 (d) 0.24
[ESE : 1996]

7.22 In a deep grain container
(a) only the horizontal pressure on walls approaches a limit
(b) only the vertical pressure on the bottom approaches a limit
(c) both vertical and horizontal pressures approach the limits
(d) the vertical pressure increases continuously while the horizontal pressure approaches a limit
[ESE : 1997]

7.23 In chimneys, the allowable axial compression reduces with the ratio d/t (d being the diameter and t being the plate thickness) and NOT with

the ratio l/r as in columns. This is to take into account the action of

(a) hoop compressive strain produced by axial compression
(b) temperature gradient due to hot gases
(c) shell buckling
(d) axial strain produced by hoop tension

[ESE : 1997]

7.24 The ratio of the lateral pressure of the bulk storage material at the time of emptying to that at the time of filling is

(a) less than one
(b) equal to or less than one
(c) equal to one
(d) greater than one

[ESE : 1998]

7.25 IRC prescribes Coulomb's theory of earth pressure for the design of abutments and wing walls. The ratio of height of center of pressure above the bottom to the height of the wall is equal to

(a) 0.33 (b) 0.36
(c) 0.39 (d) 0.42

[ESE : 1998]

7.26 In chimneys, the allowable axial compression reduces with the ratio d/t, (diameter d and plate thickness t) and not with the ratio l/r as in columns. This is to recognize the

(a) hoop compressive strain produced by axial compression
(b) temperature gradient caused by hot gases
(c) shell buckling
(d) axial strain produced by hoop tension

[ESE : 1999]

7.27 Deck bridges have the main disadvantage that

(a) their compression flanges have no lateral support
(b) the traffic is exposed to winds
(c) it is not possible to provide portal bracings
(d) the road level has to be very high

[ESE : 2002]

7.28 For a portal truss column fixed at the base, the point of contraflexure is assumed at

(a) a distance mid-way between the base and the foot of the knee brace
(b) a distance mid-way between the base and top of the column
(c) the foot of the knee brace
(d) quarter distance between base and top of the column

[ESE : 2002]

7.29 From consideration of earthquake loading and lateral stability of tall buildings, which of the following measures are taken?

1. Minimize gravity loads
2. Add masses at floor levels
3. Ensure ductility at the locations of maximum moments
4. Provide shear walls
5. Provide stilt (ground) storey

Select the correct answer using the codes given below:

(a) 1 and 5 (b) 2, 3 and 5
(c) 1, 3 and 4 (d) 2, 3 and 4

[ESE : 2003]

7.30 As the span of a bridge increases, how does the impact factor vary?

(a) It decreases
(b) It increases
(c) It remains constant
(d) It increases up to a critical value of span and then decreases

[ESE : 2007]

■■■■

Answers Miscellaneous

7.1	(c)	7.2	(a)	7.3	(b)	7.4	(b)	7.5	(a)	7.6	(a)	7.7	(d)	7.8	(c)	7.9	(c)
7.10	(b)	7.11	(c)	7.12	(a)	7.13	(b)	7.14	(d)	7.15	(c)	7.16	(a)	7.17	(d)	7.18	(a)
7.19	(a)	7.20	(a)	7.21	(c)	7.22	(d)	7.23	(a)	7.24	(d)	7.25	(a)	7.26	(a)	7.27	(d)
7.28	(a)	7.29	(c)	7.30	(a)												

Explanations Miscellaneous

7.1 (c)

It can be applied for eccentric loads also.

7.2 (a)

There are three method for deck-slab design

(i) Effective width method –IRC formula

(ii) Pigeaud's coefficient method

(iii) Westergaard's method

As per effective width method, when a concrete slab is supported on two opposite edges and subjected to a point bearing load, it deflects as saucer. The wheel load is dispersed through the wearing coat as well as deck slab at 45° in the transverse direction.

7.3 (b)

IS:3370 says

Thickness of section	Mild bar reinforcement	HYSD reinforcement
≤ 100 mm	0.3%	0.24%
100-450 mm	Linearly from 0.3-0.2%	Linearly from 0.24 - 0.16%
≥ 450 mm	0.2%	0.16%

7.4 (b)

Impact allowance is expressed as a percentage or fraction of the applied live load.

(A) For *IRC* class *A* or *B* loading on concrete bridges

$$I = \frac{4.5}{6+L} \qquad 3 \le L \le 45$$

For $L < 3$ m $\quad I = 0.5$

$L > 45$ m $\quad I = 0.088$.

(B) For *IRC* Class *A* or *B* loading on steel bridges

$$I = \frac{9}{13.5+L} \qquad 3 \le L \le 45$$

For $L < 3$ m $\quad I = 0.545$

$L > 45$ m $\quad I = 0.154$

(C) For *IRC* Class AA or 70R loading

(i) For spans less than 9 m

- For tracked vehicle: 25% for spans upto 5 m and linearly reducing to 10% for spans of 9 m.
- For wheeled vehicle 25%

(ii) For spans 9 m and more

- For tracked vehicle: For *RC* bridges 10% upto 40 m span and for steel bridges 10% for all spans.
- For wheeled vehicle: For *RC* bridges 25% for spans upto 12 m

For steel bridges 25% for spans upto 23 m

7.5 (a)

The magnitude of live load depends upon the type of occupancy of the building. The live load distribution varies with time. Hence, each member is designed for worst combination of dead and live loads. A reduction in live load is allowed for a beam if it carries load from an area greater than 50 m^2. The reduction is 5% for each 50 m^2 area subjected to a maximum reduction of 25%.

Similarly, all the floors of a residential or an office building may not be loaded simultaneously. Therefore the code permits a reduction in live loads in designing columns, walls, and foundations.

Reduction in live load.

Storey below the top most storey	Reduction, % of the live load
First	0
Second	10
Third	20
Fourth	30
Fifth to tenth	40
Over tenth	50

7.8 (c)

According to clause 6.2 of *IS* 13920 : 1993

(i) The tension steel ratio on any face, at any section, shall not be less than

$$P_{min} = 0.24\frac{\sqrt{f_{ck}}}{f_y}$$

(ii) The top as well as bottom reinforcement shall consist of atleast two bars throughout the member.

(iii) The 'positive' steel at a joint face must be at least equal to half the 'negative' steel at that face.

7.9 (c)

Shear wall is infact a lateral load resisting element.

7.11 (c)

Box section has higher torsional resistance. So it is most economical.

7.12 (a)

Courbon's theory of distribution of live loads on longitudinal beams is applicable when the following conditions are satisfied:

(i) The span to width ratio is greater than 2 and less than 4.

(ii) There are at least five symmetrical cross-girders or diaphragms connecting the longitudinal girders.

(iii) The depth of the cross girders is at least $\frac{3}{4}$th of the depth of longitudinal girders.

When the live loads are eccentrically placed with respect to the axis of the bridge, then reaction factor R_x for any given girder at a distance x from the bridge axis is

$$R_x = \frac{\Sigma P}{n}\left[1+\frac{nex}{\Sigma x^2}\right]$$

Number of girder

$$n = 3$$

$$\Sigma P = W + W + W + W = 4W$$

x is measured from the bridge axis.

The bridge axis from left kerb.

$$l_c = \frac{400+1800+1700+1800+1800}{2}$$

$$= 3750 \text{ mm} = 3.75 \text{ m}$$

Girder	A	B	C
$x(m)$	3.0	0	–3

$\Sigma x^2 = (3.0)^2 + (0)^2 + (3.0)^2 = 18 \text{ m}^2$

Eccentricity,

$$e = \frac{W\times(3.35+1.55-0.15-1.95)}{4W} = 0.7$$

$$R_A = \frac{4W}{3}\left[1+\frac{3\times0.7\times3}{18}\right] = 1.80W$$

$$R_B = \frac{4W}{3}[1+0] = 1.33W$$

$$R_C = \frac{4W}{3}\left[1-\frac{3\times0.7\times3}{18}\right] = 0.87W$$

7.13 (b)

Since metallic bearings are expensive in the initial cost and required periodical oiling and greasing, the recent trend is to favour elastomeric bearing, which are easy to install, low in initial cost and require practically no maintenance. An elastomer is any member of a class of polymeric substances obtained after vulcanization and possessing characteristic similar to rubber, especially the ability to regain shape almost completely after deformation.

7.14 (d)

Where notching or cutting slots or holes are required in timber beam, the net section remaining after notching should be safe for bending and shearing stresses.

Within a length equal to $L/6$ or $3d$ whichever is less, measured from the supports, notches may be cut in the top or bottom fibers upto a maximum depth of $d/5$. Holes having diameter less than $d/4$ may be made in the middle third portion of depth and span of beam.

7.15 (c)

To ensure adequate ductility

$$p - p_c \le \left[\frac{\epsilon_u}{\epsilon_u + \mu_s \epsilon_y}\right]\frac{0.36f_{ck}}{0.87f_{sy}}$$

$$\epsilon_u = 0.0035$$

$$\epsilon_y = 0.002 + \frac{0.87f_y}{E_s} = 0.0031$$

$$\mu_s = 2.0 \text{ for M15}$$

$$\therefore \quad p - p_c \le 0.15\frac{f_{ck}}{f_{sy}}$$

$$p \le p_c + 0.15\frac{f_{ck}}{f_{sy}}$$

7.16 (a)

For cantilever action,

$$\frac{\text{Number of storey}}{\text{Number of bay}} = \frac{6}{4} = 1.5 > 1$$

So the behaviour of frame subjected to lateral loads will be more like a cantilever than as a portal frame.

For $\frac{\text{Number of storey}}{\text{Number of bay}} < 1$, the behaviour will be like a portal frame .

7.17 (d)

Courbon's theory is used for distribution of live loads on longitudinal beams (girders). The other methods for the same purpose are - Henry - Jaegar method; and Morice and Little version of Guyon and Massonet method.

7.18 (a)

IRC class *AA* loading is to be adopted within certain municipal limits in certain existing or contemplated industrial area, in other specified areas and along certain specified highways.

IRC class *A* loading is most common type of loading adopted for prominent bridges and culverts.

IRC class *B* loading is adopted for temporary structures and for bridges in specified areas. The structures with timber spans are regarded as temporary structures.

The live loadings considered are:

(i) Class AA tracked vehicles
(ii) Class AA wheeled vehicles
(iii) Class A loading

7.19 (a)

$$\text{Impact factor} = \frac{A}{B+L};$$

where A and B are constant.

So with increase in span, impact factor decreases

7.20 (a)

The primary stresses induced in the dome are (i) a compressive force acting along the meridian, called the meridional thrust and (ii) a force compressive or tensile in nature, acting along a horizontal circle on the dome called the hoop tension or hoop compression.

7.21 (c)

The minimum reinforcement for water tanks is

(i) 0.24% of the concrete section for section upto 100 mm thick.

(ii) $\left[0.24 - \frac{0.08(t-100)}{350}\right]$ % for section thickness 100-450 mm.

(iii) 16% for section thickness more than 450 mm

$\therefore$ For 150 mm, the minimum reinforcement

$$0.24 - \frac{0.08 \times 50}{350} = 0.23\%$$

7.22 (d)

Bunkers and silos are used for storage of materials like grain, cereals, coal, cement etc. The approximate methods for the analysis of these structures was suggested by Janssen and Airy. Airy's theory is based on Coulomb's wedge theory of earth pressure.

For deep bins the maximum horizontal pressure condition is to be satisfied and vertical load on the wall is $P_w = \mu' P_h$

$\mu' \rightarrow$ friction between material and wall.

Thus horizontal pressure approaches a limit and vertical pressure increases continuously.

7.23 (a)

Axial compression is induced in chimneys due to self-weight but buckling tendency becomes critical due to lateral wind pressure, which cause hoop compressive strain and buckling tendency increases with increase in d/t ratio.

7.24 (d)

$$\text{The lateral pressure during filling} = \frac{Wr}{\mu_i}$$

$$\text{The lateral pressure during emptying} = \frac{Wr}{\mu_e'}$$

$\therefore$ Ratio of lateral pressure during emptying to that at the time of filling is $= \frac{\mu_f'}{\mu_e'}$

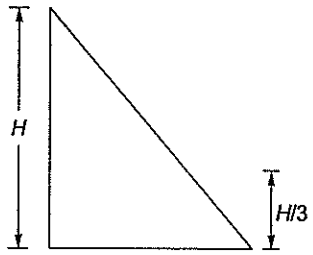
$\mu_f' \rightarrow$ friction coefficient during filling.

$\mu_e' \rightarrow$ friction coefficient during emptying

Since $\mu_e' > \mu_f'$ so ratio is greater than one

7.25 (a)

Earth pressure distribution will be as:



The centre of pressure will lie at H/3 from bottom of retaining wall.

7.26 (a)

Axial compression is induced in chimneys due to self-weight but buckling tendency becomes critical due to lateral wind pressure, which cause hoop compressive strain and buckling tendency increases with increase in d/t ratio.

7.27 (d)

T bridge also known as deck bridge is used for span of 10-20 metres. The longitudinal girders to be used depend on the road width. Slab is built monolithically with the girder because of which road level becomes very high.

7.29 (c)

During earthquake, the ground moves in all directions in nearly random motions. During ground motion, an inertia force acts on the mass of a building due to which the building tends to remain stationary while the ground moves. If the building is rigidly fixed into ground, the inertia forces will cause horizontal shears in the building, the magnitude of which depends on the ground motion and stiffness and damping characteristics of the building.

A wall which carries horizontal loads in its own plane is called shear wall. The shear walls must be present along both the axes of buildings.

Other methods of resisting earthquake are:

(i) The roof or floor elements must be tied together.

(ii) Horizontal bands may be provided for tying the walls together.

(iii) Horizontal bracing system.

(iv) Ensuring ductility at corners and other locations of maximum moments.

(v) Reducing mass of building (gravity loads).

7.30 (a)

Impact factor for RC bridges, $I = \frac{4.5}{6+L}$

where L is the length of span in meters.

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UNIT

VI

Construction Practice, Planning & Management

Syllabus

Construction-Planning, Equipment, Site investigation and Management including Estimation with latest project management tools and network analysis for different Types of works; Analysis of Rates of various types of works; Tendering Process and Contract Management, Quality Control, Productivity, Operation Cost; Land acquisition; Labour safety and welfare.

Contents

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2.	PERT and CPM	579
3.	Crashing, Resource Allocation, Updating and Engineering Economy	602
4.	Concreting Equipments	625

OOOO

1 Project Management and Network Technique

1.1 Functional organization system of working was introduced by

(a) F.W. Taylor (b) Henry Gantt

(c) M.R. Walker (d) J.E. Kelly

[ESE : 1995]

1.2 Consider the following activities in a building construction:

1. Concreting of roof slabs.
2. Brick-jelly lime concrete terracing.
3. Erection of formwork for slab.
4. Construction of parapet wall in terrace.

The correct sequence of these activities is

(a) 1, 3, 2, 4 (b) 3, 1, 4, 2

(c) 3, 1, 2, 4 (d) 1, 3, 4, 2

[ESE : 1995]

1.3 Match List-I (Indications of terms) with List-II (Terms) and select the correct answer using the codes given below the lists:

List-I

A. Used for recording instructions given by the Executive Engineer at site

B. Used widely for civil engineering construction

C. One of the principles of organization

D. One of the functions of management

List-II

1. Co-ordination
2. Unity of command
3. Line organization
4. Site order book

Codes :

	A	B	C	D
(a)	4	3	2	1
(b)	4	2	3	1
(c)	2	4	1	3
(d)	4	1	2	3

[ESE : 1996]

1.4 The profits and the associated probability of making the profits are given below in respect of four projects:

Project	Profit	Probability of making the profit
1	15%	0.5
2	10%	0.8
3	12%	0.7
4	11%	0.6

When the motive is maximization of expected profit, the correct order of preference of these projects would be

(a) 1, 3, 4, 2 (b) 2, 3, 4, 1

(c) 3, 2, 1, 4 (d) 3, 4, 2, 1

[ESE : 1997]

1.5 Gantt charts indicate

(a) comparison of actual progress with the scheduled progress

(b) balance of work to be done

(c) progressive costs of project

(d) inventory costs

[ESE : 1997]

1.6 The network rules are common to all activity-on-arrow networking systems. The use of computers for making computations may impose certain rules. Which of the following basic rules of network logic are correct?

1. Before an activity may begin, all the activities preceding it must be complete
2. Any two events may be directly connected by no more than one activity.
3. Event numbers must not be duplicated in a network.

Select the correct answer using the codes given below :

(a) 1 and 2 (b) 2 and 3

(c) 1 and 3 (d) 1, 2 and 3

[ESE : 1998]

1.7 Preliminary project report for a road project must contain
(a) the detailed estimated cost based on detailed design
(b) the several alternatives of the project that have been considered
(c) the soil survey, traffic survey, concept design and approximate cost
(d) the contract documents for inviting tenders
[ESE : 1999]

1.8 Match List-I with List-II and select the correct answer using the codes given below the lists:
List-I
A. Translates policy into a method of achieving the objective set out
B. Consists of defining the responsibilities of employees
C. Transmits all the information to the supervising staff
D. The organizational setup is aided to operate efficiently with flow of information, decisions and results in all directions
List-II
1. Co-ordinating
2. Planning
3. Organizing
4. Directing
Codes :

	A	B	C	D
(a)	3	2	1	4
(b)	2	3	1	4
(c)	3	2	4	1
(d)	2	3	4	1

[ESE : 1999]

1.9 Match List-I with List-II and select the correct answer using the codes given below the lists:
List-I
A. To allocate the resources among competing projects and to determine whether or not the returns from investment are adequate.
B. To see that adequate and timely funds are made available for investment including that for operation and maintenance
C. To analyze various aspects of a project such as process, design, size, layout, capacity, etc.
D. To find the effects of fiscal, monetary, wage, exchange rate, etc. policies
List-II
1. Technical analysis
2. Macroeconomic analysis
3. Financial analysis
4. Feasibility analysis
5. Economic analysis
Codes :

	A	B	C	D
(a)	5	4	2	1
(b)	4	3	1	2
(c)	3	5	2	1
(d)	5	3	1	2

[ESE : 1999]

1.10 Match List-I (Feasibility) with List-II (Emphasized on or calls for) and select the correct answer using the codes given below the lists:

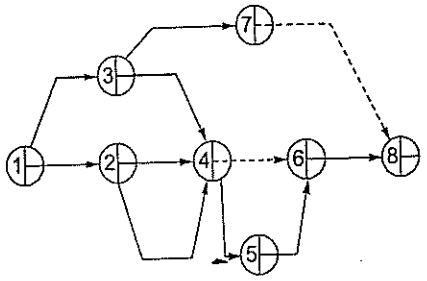
List-I	List-II
A. Social	1. Optimizing marginal costs and benefits
B. Economic	2. Forward and backward linkages
C. Input	3. Interfaces
D. Co-ordination	4. Improving wealth

Codes :

	A	B	C	D
(a)	1	4	3	2
(b)	4	1	3	2
(c)	1	4	2	3
(d)	4	1	2	3

[ESE : 2000]

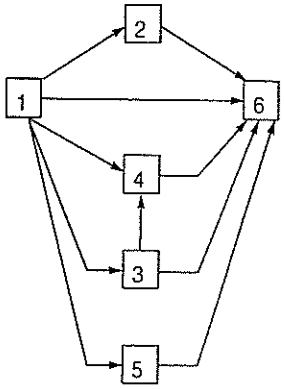
1.11 The total number of errors in the given AOA network is



(a) 1 (b) 2
(c) 3 (d) 4
[ESE : 2000]

1.12 A serious limitation of interdependencies between various activities is generally observed in
(a) bar charts (b) milestone charts
(c) network analysis (d) job layouts
[ESE : 2003]

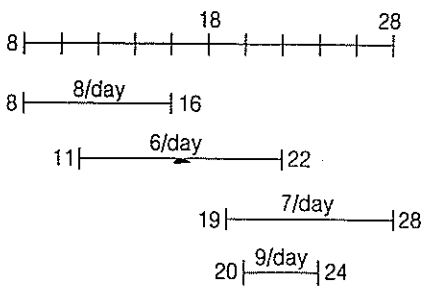
1.13 A-O-N network is suggested as shown below. The number of errors/incompatibi-lities in this network is



(a) 1 (b) 2
(c) 3 (d) 4
[ESE : 2003]

1.14 Which of the following is the correct sequence to analyze a project for implementation?
(a) Time-cost study, Network, WBS, Scheduling with resource allocation
(b) Network, Time-cost study, Scheduling with resource allocation, WBS
(c) WBS, Network, Scheduling with resource allocation, Time-cost study
(d) WBS, Time-cost study, Network, Scheduling with resource allocation
[ESE : 2004]

1.15 A bar chart of four activities indicating their scheduled start and finish "end-of-day" values and the resource requirement per day are given below. What will be the maximum and the minimum resource-need on any of the days?



(a) 22, 6 (b) 21, 6
(c) 21, 8 (d) 20, 8
[ESE : 2004]

1.16 **Assertion (A) :** In assigning activity durations in developing an AOA network, the technology to be adopted is inherently considered but not the rate of utilization (or consumption) of resources (or inputs).
Reason (R) : The adopted technology dictates the compatibly preferred consumption pattern of the inputs.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true
[ESE : 2004]

1.17 Consider the following statements:
The salient features of a bar chart over network are that
1. it is simple to draw and easy to understand.
2. it is unable to depict interdependence of activities.
3. it clearly distinguishes between critical and non-critical activities.
4. it is not possible to crash activities to get optimum and minimum duration of the project.
Which of these statements are correct?
(a) 1, 2, 3 and 4 (b) 2 and 3
(c) 1, 2 and 4 (d) 1, 3 and 4
[ESE : 2005]

1.18 Match List-I (Diagram based nomenclature) with List-II (Information capability) and select the correct answer using the codes given below the lists:
List-I
A. Work-breakdown structure
B. Bar chart
C. Linked bar chart
D. Time computations on network
List-II
1. Target dates for interface events can be stipulated
2. Can be hierarchical

3. Can include information on cost distribution over time
4. Best suited for monitoring including that for costs

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	2	1	4	3
(c)	4	1	2	3
(d)	2	3	4	1

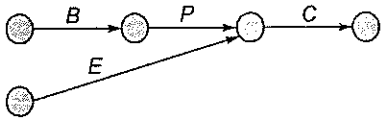
[ESE : 2005]

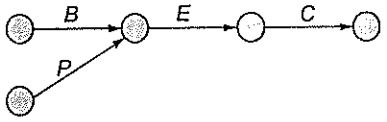
1.19 What is the significant purpose of monitoring a project through its implementation phase?
(a) To fix responsibility for delays
(b) To rerail the project with control over cost over-run
(c) To rerail the project with minimum time over-run
(d) To rerail the project with optimal time and cost over-run

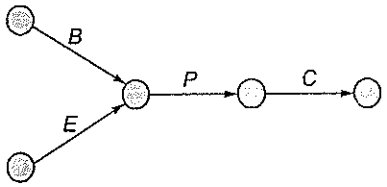
[ESE : 2005]

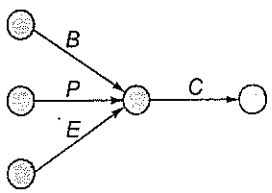
1.20 Consider the following tasks:
1. Placing of reinforcement (*P*) for roof slab cannot start before bending of reinforcement (*B*) and erection of frame work (*E*).
2. As soon as placing of reinforcement is finished, concreting (*C*) will follow.

The correct activity on arrow diagram representing for the above tasks is

(a) 

(b) 

(c) 

(d) 

[ESE : 2006]

1.21 Consider the following activities of a housing project:
1. Flooring
2. Wall-plastering
3. Conceal wiring
4. Fixing door-window frames
5. Fixing door-window shutters

What is the correct logical sequence of the above activities?
(a) 4-3-2-5-1 (b) 3-1-5-4-2
(c) 1-4-5-2-3 (d) 1-2-3-4-5

[ESE : 2006]

1.22 Match **List-I** (Chart) with **List-II** (Facilitation) and select the correct answer using the codes given below the lists:

List-I
A. Bar Chart
B. Milestone Bar Chart
C. WBS
D. Linked Bar chart

List-II
1. Activity dependencies can be implied
2. Resource requirement can be depicted
3. Higher level of authority can effect monitoring and control
4. Trade based site supervision can be assigned

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	2	1	4	3
(c)	4	1	2	3
(d)	2	3	4	1

[ESE : 2008]

1.23 **Assertion (A):** Linked bar chart cannot be developed from an AON network as easily as from an AOA network.
Reason (R): AON networks do not incorporate information corresponding to dummy arrows of AOA networks
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2008]

1.24 Consider the following statements in work breakdown structure.
1. It is a graphical representation of entire programme.
2. The top-down approach to planning is adopted.
3. The down-top approach to planning is adopted.
4. It is suitable for complex projects.

Which of these statements is/are correct?
(a) 1 only (b) 2 and 4
(c) 3 and 4 (d) 4 only

[ESE : 2010]

1.25 Consider the following statements:
1. In work-breakdown structure top-down approach is adopted.
2. Bar-chart depicts interdependencies of activities.
3. Controlling can be better achieved in milestone chart.

Which of these statements is/are correct?
(a) 1 and 3 only (b) 1 and 2 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2010]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

1.26 **Assertion (A):** A dummy' job is assigned 'zero' time to perform.
Reason (R): It is used mainly to specify precedence relationship.

[ESE : 2010]

1.27 **Assertion (A):** The time-grid diagram facilitates to readout the float for any activity by inspecting the diagram
Reason (R): In the time-grid diagram, floats are represented by broken horizontal lines as appropriate.

[ESE : 2010]

1.28 Consider the following activities:
1. Pouring of concrete
2. Erection of formwork
3. Curing of concrete
4. Removal of formwork

What is the correct sequence on a network of these activities?
(a) 1 – 2 – 3 – 4
(b) 2 – 1 – 4 – 3
(c) 2 – 1 – 3 – 4
(d) 1 – 3 – 2 – 4

[ESE : 2010]

1.29 A bar chart is commonly used because
(a) It is simple to draw and easy to understand.
(b) It indicates at a glance the overall progress of the project.
(c) It shows critical and non-critical activities.
(d) It incorporates uncertainties for delay in estimation of time required for completion of activities.

[ESE : 2011]

1.30 A linked bar chart is an improvement over a conventional bar chart, because
1. resources for individual activities can be planned
2. floats will be available for utilization as needed
3. milestone events need not be specifically monitored

Which of these is/are correct?
(a) 1, 2 and 3 (b) 3 only
(c) 2 only (d) 1 only

[ESE : 2012]

Directions: The following items consists of two statements; one labelled as **'Statement (I)'** and the other as **'Statement (II)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false
(d) A is false but R is true

1.31 **Statement (I):** Interdependence between various events is shown on a milestone chart.
Statement (II): Milestones are key events in time which occur as the project progresses.
[ESE : 2013]

1.32 **Statement (I) :** A linked-bar chart is premised on a resource-based scheduled network, and so is unique to the relevant project.
Statement (II) : A squared scheduled network drawn after allocating activity durations, with consideration of floats that have been originally available, may yet have the inputs-scheduling pending.
[ESE : 2014]

1.33 List the following processes in their correct sequence, from earliest to latest, in project implementation planning :
1. Project duration
2. Resource histogram
3. Standardized input/performance for each activity including alternatives
4. WBS
5. Resource optimization considering constraints
6. Activities and their inter-relationships

Select the correct answer using the code given below:
(a) 2, 1, 3, 5, 6 & 4 (b) 2, 6, 3, 5, 1 & 4
(c) 4, 1, 3, 5, 6 & 2 (d) 4, 6, 3, 5, 1 & 2
[ESE : 2014]

Direction: The following items consists of two statements, one labelled as **Assertion 'A'** and the other labelled as **Reason 'R'**. You are to examine these two statements carefully and select your answers to these items using the codes given below:
Codes:
(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

1.34 **Assertion (A):** In a project involving construction of several self-similar multi-storey houses, the Scheduled Bar Chart is best converted into Lines of Balance Diagram-which yet remains a 'Stacked' Bar Chart.
Reason (R): It is necessary to ensure that no set of Lines of Balance slope forward in time, from last block to first block, or top to bottom.
[ESE : 2015]

1.35 **Assertion (A):** Activity stream along a component Work-Breakdown Structure along a sub-path can refer also to an auxiliary Work-Breakdown Structure considered vertically in segments of adjacent sub-paths.
Reason (R): Work-Breakdown Structures refer to a single sub-path with a progressive duration along the activity arrows.
[ESE : 2015]

1.36 Which of the following is/are the main drawback(s) in adopting bar charts?
1. All the activities are shown as being independent of each other
2. The sequence of activities is not defined at all
3. It is difficult to judge whether an activity is completed or not

(a) 1 only (b) 2 only
(c) 3 only (d) 1, 2 and 3
[ESE : 2016]

1.37 The purpose of work-break-down structure in project planning is mainly to
1. Facilitate and improve the decision-making on procurement of resources
2. Relate activities under particular trade specializations to help in organizing for project staff
3. Co-ordinate regarding milestone events across trade specializations to improve the synergy between the trades

(a) 1 and 2 only (b) 1 and 3 only
(c) 2 and 3 only (d) 1, 2 and 3
[ESE : 2016]

1.38 Which of the following statements is/are correct?
1. An activity is in between two node numbers, which need not be in an increasing order in the activity progress sequence.
2. The length of the arrow in a network has certain significance.

3. Concurrent activities are mutually independent and can possibly be taker up simultaneously.

(a) 1 only (b) 3 only
(c) 2 only (d) 1, 2 and 3

[ESE : 2016]

1.39 **Statement (I):** Hiring and firing is a poor substitute for proper selection and proper training of labourers.

Statement (II): Bad training facilities for new employees cause them to be discharged during or at the end of the probationary period.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2017]

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Answers Project Management and Network Technique

1.1	(a)	1.2	(c)	1.3	(a)	1.4	(c)	1.5	(a)	1.6	(d)	1.7	(c)	1.8	(d)	1.9	(d)
1.10	(b)	1.11	(c)	1.12	(a)	1.13	(b)	1.14	(c)	1.15	(a)	1.16	(a)	1.17	(c)	1.18	(d)
1.19	(c)	1.20	(c)	1.21	(a)	1.22	(d)	1.23	(c)	1.24	(b)	1.25	(a)	1.26	(a)	1.27	(a)
1.28	(c)	1.29	(b)	1.30	(a)	1.31	(a)	1.32	(d)	1.33	(d)	1.34	(b)	1.35	(c)	1.36	(d)
1.37	(d)	1.38	(b)	1.39	(b)												

Explanations Project Management and Network Technique

1.1 (a)
Henry Gantt introduced Bar Chart.

1.2 (c)
First for work is erected and steel is placed over form work. Then concrete is poured and compacted in formation of slab. After that brick-jelly lime concrete is provided over casted slab for water proofing and thermal insulation. Lastly parapet wall is constructed.

1.3 (a)
Site order book is register maintained by contractor to record instructions given by executive engineer. Line organization is oldest and simplest form of organization adopted in construction projects specifying line of authority and responsibilities. Unity of command is one of the principles of organization. Co-ordination, planning, organizing etc are the function of organization.

1.4 (c)
Both the probability and profit should be considered for evaluating the preference.

The ranking should be decided by multiplying profit and probability.

Project	Profit x probability	Ranking
1.	0.075	Third
2.	0.080	Secod
3.	0.084	First
4.	0.066	Fourth

So the correct order is 3 – 2 – 1 – 4

1.5 (a)
Gantt charts give comparison of actual progress with scheduled progress i.e. it gives idea about physical progress of project but not about financial aspect.

1.7 (c)

Preliminary project report contains topographic details and soil survey along alternate alignments, consideration of geometric design and other requirements of alignment, preparation of plans and comparison of alternate routes, economic analysis and selection of final alignment.

1.8 (d)

In planning phase, strategies are set-out while considering company's policies and rules. Organizing is dividing work and assigning task to people. Directing is transferring all information to supervising staff. Coordinating is making people work together with flow of information, decisions and results in all directions.

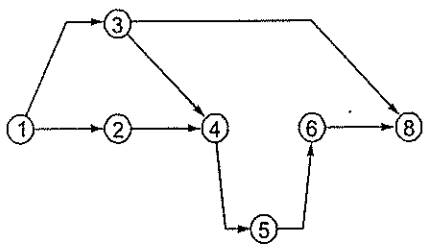
1.11 (c)

There is an extra dummy between events (7) and (8).

There are two arrows joining events (2) and (4).

There is extra dummy connecting nodes (4) and (6).

The correct diagram will be



So there are two errors.

1.12 (a)

In bar charts, inter-dependence between various activities is not shown.

1.13 (b)

In A-O-N network, there is no place for dummy activity and events.

1-6 and 3-6 is logically redudnant in the network.

1.14 (c)

In analyzing a project the first step is always Work Breakdown Structure (WBS). From WBS, network can be prepared. Thereafter scheduling with resource allocation follows. Finally time - cost study is carried out.

1.15 (a)

A table can be prepared comprising each start of finish of activity and resources needed.

Days	Resources
8 - 11	8/day
11 - 16	8 + 6 = 14/day
16 - 19	6/day
19 - 20	6 + 7 = 13/day
20 - 22	6 + 7 + 9 = 22/day
22 - 24	7 + 9 = 16/day
24 - 28	7/day

Maximum resource needed is 22 and minimum is 6.

1.16 (a)

For deciding activity duration, time and motion analysis is followed. So the technology to execute any job within a particular time is inherent in such estimation and the resources are estimated based on technology adopted.

1.17 (c)

The salient features of bar chart are :

(i) Simple to draw and easy to understand
(ii) Unable to depict interdependencies
(iii) Cannot distinguish critical and non-critical activities
(iv) Not possible to crash activities

1.18 (d)

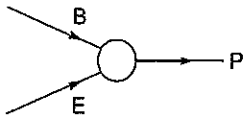
Work–breakdown structure can be Hierarchical. In multiple project scheduling, for sub-projects of a large project, there are events common to more than one sub-project. Such common events are known as interface events because they act as linking elements between the sub-project. For time computations on such networks, target dates for interface events are stipulated.

1.19 (c)

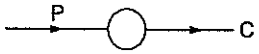
During monitoring analysis of information is done and necessary changes are done to keep project as per schedule i.e. to rerail the project with minimum time over-run.

1.20 (c)

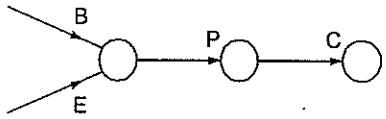
(i) Task P cannot begin until both B and E are complete.



(ii) Task C follows P.



(iii) So, correct AOA is



1.21 (a)

Door – window shutters can be fixed only after door – window frames.

Wall plastering cannot be done prior to conceal wiring.

Therefore correct sequence is 4–3–2–5–1. i.e. (Fixing door – window frames) – (Conceal wiring) – (Wall Plastering) – (Fixing door – window shutters) – (Flooring).

1.22 (d)

Bar chart gives graphical representation of activity v/s time. Resource requirement can be depicted with it. Milestone chart breaks activities into sub activities, through which controlling can be done. Work breakdown structure breaks system into identifiable major system and discreet activities, following top to down approach. Linked bar charts connect activities in sequence implying their dependency in order.

1.23 (c)

Dummy arrows show only the dependencies between two tasks and this information is incorporated in AON network as the arrows in AON represents dependencies only.

1.24 (b)

Work breakdown structure is a pictorial representation of major and minor objectives of a project. It is not a network. Instead it is a preliminary diagram of the way in which all the minor objectives go together to ensure the attainment of the major objective.

1.25 (a)

The bar chart does not show clearly the interdependencies between the various activities.

1.27 (a)

Time grid is graphical representation of network diagram on time scale. This facilitates to readout the float of activity between its end node events. Floats are shown by horizontal broken lines whereas activity duration is shown by continuous lines.

1.29 (b)

Advantage of bar chart

1. It is simple to draw, easy to understand and can be drawn quickly.
2. No trained/skilled personnel are required to make the chart.
3. The progress achieved at site is expressed in terms of percentage.
4. It may be used for depicting the resource requirements of construction project.
5. But the most important benefit of using a bar chart is that it provides a visual representation of the entire project which shows exactly when each of the above activities is supposed to start and finish.

1.30 (a)

Linked bar chart is improvement over bar chart. In this activities are linked with arrows and lines specifying sequence and order of preceding activities. Thus resources for the project and individual activities can be planned. Floats will be available for utilization as needed. Since there is inter relationship between activities, milestone events need not be specifically monitored.

1.31 (a)

Milestones are the key events which shows end of one activity and the start of another activity. Thus interdependency.

1.32 (d)

Linked bar chart depends on resource available. Thus, it is not unique for project. Statement II is true.

1.35 (c)

Work breakdown structure progresses downwards i.e. it works from pursuing general to specific

objectives. Thus it does not refer to single sub-path.

1.36 (d)

Bar charts do not show interdependency of activities. Thus their sequence is not shown and they seem independent of each other. Also bar charts do not show project progress so it is difficult to judge completion of activity.

1.38 (b)

Concurrent activities are those which either originate from a single node or terminate into single node. They are mutually independent as the starting or completion of these activities doesn't depend on each other.

The length of arrow doesn't has any significance. Length of arrow facilitates in easy visualization of the network and is adopted as per user.

Nodes are numbered as per Fulkerson's rule and it goes on increasing in the direction of project progress through every path.

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2 PERT and CPM

2.1 Consider the following features/factors:

1. Projects are the non-repetitive type.
2. Time requirement need not be known.
3. Time required is known precisely.
4. Events have been established for planning.
5. Emphasis given to activities of project.

PERT is preferred for planning because of

(a) 1, 2 and 4 (b) 3, 4 and 5

(c) 1, 3 and 4 (d) 1, 2 and 5

[ESE : 1995]

2.2 Match List-I (Description of activity floats) with List-II (Names of the floats) and select the correct answer using the codes given the lists:

List-I

A. Earliest start time of successor activity minus earliest activity in question minus the duration

B. Time available for an activity performance minus the duration of the activity

C. Excess of minimum available time over the required activity duration

D. Difference between total and free float of an activity

List-II

1. Total
2. Free
3. Interfering
4. Independent float

Codes :

	A	B	C	D
(a)	1	2	3	4
(b)	1	2	4	3
(c)	2	1	3	4
(d)	2	1	4	3

[ESE : 1995]

2.3 Given that

t = the duration of various jobs

t_m = mean time of different durations

n = number of observations

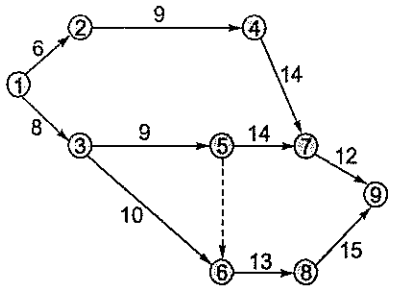
The standard deviation is given by

(a) $\frac{\Sigma t}{n}$ (b) $t - t_m$

(c) $\frac{\Sigma (t - t_m)^2}{n}$ (d) $\sqrt{\frac{\Sigma (t - t_m)^2}{n}}$

[ESE : 1995]

2.4 The flow net of activities of a project is given in the following figure. The duration of activities are indicated along the arrows.



The critical path of the activities is along

(a) 1 – 2 – 4 – 7 – 9

(b) 1 – 3 – 5 – 7 – 9

(c) 1 – 3 – 6 – 8 – 9

(d) 1 – 3 – 5 – 6 – 8 – 9

[ESE : 1995]

2.5 Match List-I (Item) with List-II (Characteristic) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Activity	1. Resourceless element
B. Event	2. Resource consuming element
C. Dummy	3. Spare time
D. Float	4. Instantaneous stage

Codes :

	A	B	C	D
(a)	1	4	3	2
(b)	2	1	4	3
(c)	2	4	1	3
(d)	3	4	1	2

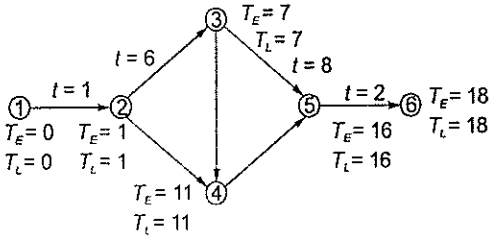
[ESE : 1995]

2.6 For a given activity, the optimistic time, pessimistic time and the most probable estimates are 5, 17 and 8 days respectively. The expected time is

(a) 8 days (b) 9 days
(c) 10 days (d) 15 days

[ESE : 1995]

2.7 The following diagram shows the details necessary for the CPM network analysis:



The critical path will be

(a) 1 – 2 – 3 – 5 – 6
(b) 1 – 2 – 3 – 4 – 5 – 6
(c) 1 – 2 – 4 – 5 – 6
(d) 1 – 2 – 4 – 3 – 5 – 6

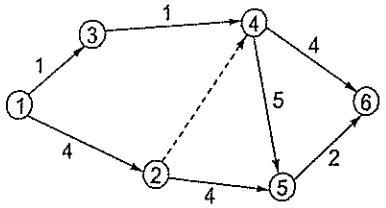
[ESE : 1995]

2.8 The optimistic, most likely, and pessimistic estimates of time for an activity are 4 days, 11 days and 12 days respectively. The expected completion time of this activity is

(a) 8 days (b) 9 days
(c) 10 days (d) 11 days

[ESE : 1997]

2.9 From the network shown in the figure below (the number on each arrow denotes the time duration of activity in days), the earliest start time, in days for activity 5–6 is



(a) 8 (b) 7
(c) 9 (d) 11

[ESE : 1997]

2.10 The time estimates obtained from four contractors *P*, *Q*, *R* and *S* for executing a particular job are as under:

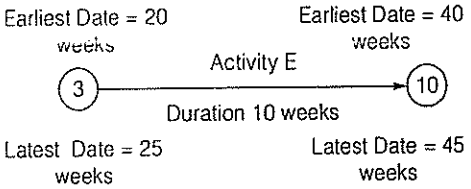
Contractor	Optimistic time, t_o	Most likely time, t_L	Pessimistic time, t_P
P	5	10	13
Q	6	9	12
R	5	10	14
S	4	10	13

Which one of these contractors is more certain about completing the job in time?

(a) *P* (b) *Q*
(c) *R* (d) *S*

[ESE : 1997]

2.11 The earliest date and the latest date of events 3 and 10 are given in the figure below. Activity E is connecting both the events and its duration is 10 weeks. The independent float of the activity is



(a) 5 weeks (b) 10 weeks
(c) 15 weeks (d) 20 weeks

[ESE : 1998]

2.12 The optimistic, the most likely duration and the pessimistic time estimates in a network are 4, 5 and 8 months respectively. The expected time is

(a) 4.00 months (b) 5.33 months
(c) 5.67 months (d) 7.00 months

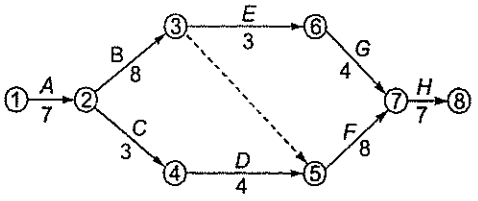
[ESE : 1998]

2.13 The probability distribution taken to represent the completion time in PERT analysis is

(a) gamma distribution
(b) normal distribution
(c) beta distribution
(d) log-normal distribution

[ESE : 1998]

2.14 The flow net of the activities of a project are shown in the network given below indicating the duration of the activities along their arrows.



The critical path of the activities is along

(a) $1 \to 2 \to 4 \to 5 \to 7 \to 8$

(b) $1 \to 2 \to 3 \to 6 \to 7 \to 8$

(c) $1 \to 2 \to 3 \to 5 \to 7 \to 8$

(d) $1 \to 2 \to 4 \to 5 \to 3 \to 6 \to 7 \to 8$

[ESE : 1998]

2.15 Two events *K* and *L* can cause delay in construction activity when occurring either each independently or both together, but the two events are not statistically independent of each other. The probability that at least one of the events occurs is 0.75 and the probability that each one occurs by itself is 0.45. The critical probability for occurrence of delay in the activity is

(a) $\dfrac{0.75}{0.45+0.75}$ (b) $\dfrac{0.75-0.45}{0.75}$

(c) $\dfrac{2\times0.45-0.75}{0.75}$ (d) $\dfrac{2\times0.45-0.75}{0.45}$

[ESE : 1999]

2.16 Consider the following pairs:

1. Difference between total float and free float : **Interfering float**
2. Sum of independent float and tail slack : **Free float**
3. Sum of independent float, tail slack and interfering float : **Total float**

Which of these pairs are correctly matched?

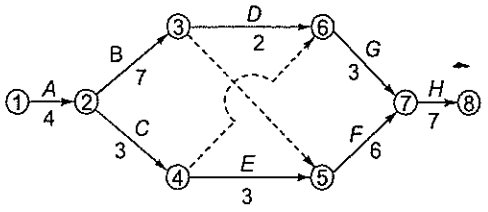
(a) 1, 2 and 3 (b) 1 and 2

(c) 2 and 3 (d) 1 and 3

[ESE : 1999]

2.17 Consider the *AOA* network of a project shown in the given figure. (Activities are designated by alphabets and durations are shown around the stem of the arrow)

The critical path will be



(a) 1-2-3-6-7-8 (b) 1-2-3-5-7-8

(c) 1-2-4-5-7-8 (d) 1-2-4-6-7-8

[ESE : 1999]

2.18 Consider the implicit details between, before and after successive steps in/within the order while doing time computations on a *CPM* network (*FP* ⇒ Forward Pass; *BP* ⇒ Backward Pass; *LET* ⇒ Late Event Time; *EET* ⇒ Early Event Time; *TF* ⇒ Total Float; *PD* ⇒ Project Duration; *AD* ⇒ Activity Duration)

The correct sequence of computation would be

(a) *EET, PD, LET, TF*

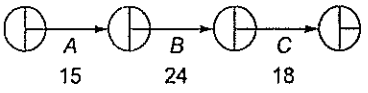
(b) *EET, PD, LET, AD*

(c) *AD, EET, BP, PD*

(d) *FP, EET, TF, PD*

[ESE : 1999]

2.19 *A*, *B* and *C* are three activities to be executed in that order. Their total durations, in days, are 15, 24 and 18 respectively. However, for better estimation of overall total duration, they are put into a ladder network with 3 equal sub-parts of each. The modified total duration for total completion of all the activities will be

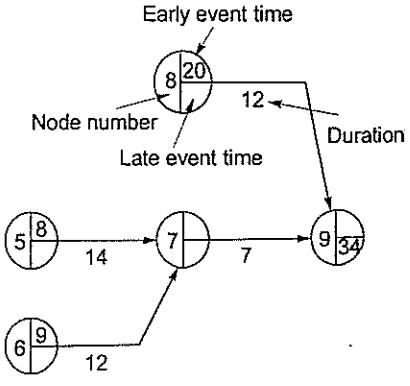


(a) 35 days (b) 37 days

(c) 39 days (d) 41 days

[ESE : 2000]

2.20 A part of the network with nomenclature of a typical legend is shown in the given figure. There can be other incoming activities on nodes, 5, 6 and 8 but there are no other incoming activities at nodes 7 and 9. There are two outgoing activities at node 9 but no other outgoing activity at any of the other nodes. The total float and free float in activity 6-7 are respectively



(a) 5 and 1 (b) 6 and zero
(c) 6 and 1 (d) zero and zero

[ESE : 2000]

2.21 There are four consecutive activities in a simple linear network, each with mean duration of T and each with 'k' as the standard deviation of its duration. The overall project duration through these activities is likely to be in the range

(a) $4T \pm k$ (b) $4T \pm 2k$
(c) $4T \pm 4k$ (d) $4T \pm 6k$

[ESE : 2000]

2.22 A certain type of resource can be deployed in a variable strength during parts of the duration of an activity. The following are the data in this context:

1. Six weeks duration with 10 units of the resource in each week, or
2. Four weeks duration with 7 units in each week followed by 5 weeks duration with 5 units in each week, or
3. Eight weeks duration with 7 units in each week, or
4. Four weeks duration with 7 units in each week followed by 3 weeks duration with 10 units in each week

For developing the CPM network involving this activity therein, the duration of this activity will be considered as

(a) 9 weeks (b) 8 weeks
(c) 7 weeks (d) 6 weeks

[ESE : 2000]

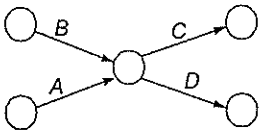
2.23 In PERT analysis, the time estimates of activities and probability of their occurrence follow

(a) Normal distribution curve
(b) β-distribution curve
(c) Poisson's distribution curve
(d) Binomial distribution curve

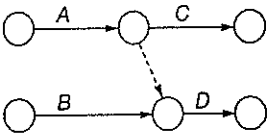
[ESE : 2001]

2.24 Activity 'C' follows activity 'A' and activity 'D' follows activities 'A' and 'B'. The correct network for the project is

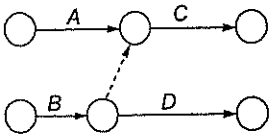
(a)



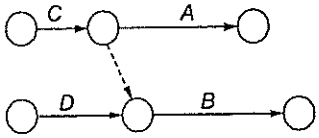
(b)



(c)

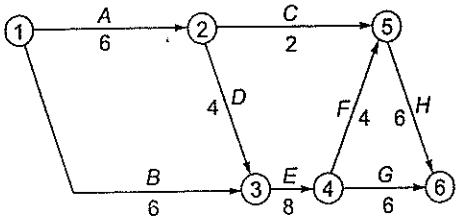


(d)



[ESE : 2001]

2.25 In the network given below, the critical path of activities is



(a) *A-C-H* (b) *B-E-F-H*
(c) *A-D-E-F-H* (d) *A-D-E-G*

[ESE : 2002]

2.26 Match List-I (Inputs into networks) with List-II (Basis) and select the correct answer using the codes given below the lists:

List-I

A. Activity Time
B. PERT durations
C. WBS
D. Interfaces

List-II

1. Availability of resources is not discussed
2. Senior management's involvement is assumed
3. Total cost of each activity is considered
4. Needed supervisory inputs are considered

Codes :

	A	B	C	D
(a)	3	1	4	2
(b)	3	1	2	4
(c)	4	2	1	3
(d)	4	2	3	1

[ESE : 2003]

2.27 Which one of the following project management techniques is deterministic in nature?

(a) CPM (b) PERT
(c) GERT (d) LCES

[ESE : 2003]

2.28 The probabilistic time is

(a) $\frac{t_o + t_p + t_n}{3}$ (b) $\frac{t_o + t_p + 4t_n}{6}$

(c) $\frac{t_o + 4t_p + t_n}{6}$ (d) $\frac{t_o + 2t_p + t_n}{4}$

where t_o = Optimistic time
t_p = Pessimistic time
t_n = Most likely time

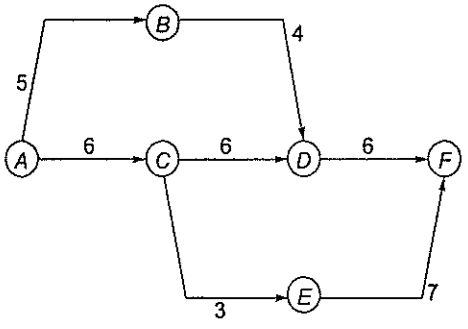
[ESE : 2003]

2.29 Three activities *F*, *G* and *H* are to be performed in the said sequence and for the whole stretch of the project need 15, 21 and 27 days respectively. If a ladder network is adopted with one-third of each activity as the laddered activity, the saving in total project time in days will be

(a) 15 (b) 18
(c) 21 (d) 24

[ESE : 2003]

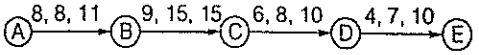
2.30 A network of seven activities is shown in the diagram given below. The respective activity durations are shown beside the arrows. Which one of the following is the total float in *AB*, the total float in *CE* and free float in *EF*, respectively?



(a) 2, 2, 3 (b) 3, 3, 2
(c) 3, 2, 2 (d) 2, 3, 2

[ESE : 2004]

2.31 The line of a PERT network is shown below in the diagram with a, m, b durations. What is the probable range of the total duration?



(a) 34.2 to 47.2 (b) 34.2 to 44.2
(c) 32.6 to 44.2 (d) 32.6 to 42.4

[ESE : 2004]

2.32 Match List-I (Reporting feature) with List-II (Implication and/or possibility) and select the correct answer using the codes given below the lists:

List-I
A. PERT study
B. Time-cost study
C. Critical path identification
D. Linked bar chart

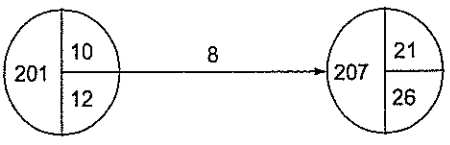
List-II
1. Cost build up on project over time can be depicted
2. Choice of technology can be concurrent
3. Choice of technology is predetermined
4. May be affected by probabilistic activity durations

Codes:

	A	B	C	D
(a)	3	2	4	1
(b)	1	4	2	3
(c)	3	4	2	1
(d)	1	2	4	3

[ESE : 2005]

2.33 For an activity 201-207 in an AOA network, the EET values, LET values and activity duration are shown in the figure given below. Between free float, interference float and independent float, which one of the following is the correct sequence in the decreasing magnitude order?

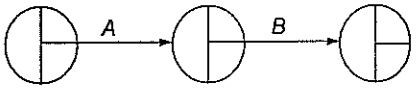


(a) Free float–Interference float–Independent float
(b) Free float–Independent float–Interference float
(c) Interference float–Free float–Independent float
(d) Interference float–Independent float–Free float

[ESE : 2005]

2.34 Two activities *A* and *B* are to be done in the given sequence. The variation of direct cost (*DC*) with possible activity duration (*T*) (in days) is indicated for each activity as follows.

T	DC	T	DC
8	12	10	15
7	14	9	17
6	17	8	19
5	21	7	21



What is the increase in total direct cost between a combined duration of 16 days and 13 days?

(a) 5 (b) 6

(c) 7 (d) 8

[ESE : 2005]

2.35 *A*, *B*, *C*, *D* and *E* are the 5 activities along the unique critical path of a AOA network of activities. Their characteristics are as under:

Activity	A	B	C	D	E
Expected duration, days	7	6	11	14	5
Standard deviation, days	2	2	3	4	1

What is the possible range of project duration (in days)?

(a) 31.2 to 54.8

(b) 28.1 to 57.9

(c) 25.5 to 60.5

(d) 24.6 to 61.4

[ESE : 2005]

2.36 **Assertion (A) :** Interference float is the event slack at the head node of an activity.

Reason (R) : Interference float cannot be shared by any other activity.

(a) both A and R are true and R is the correct explanation of A

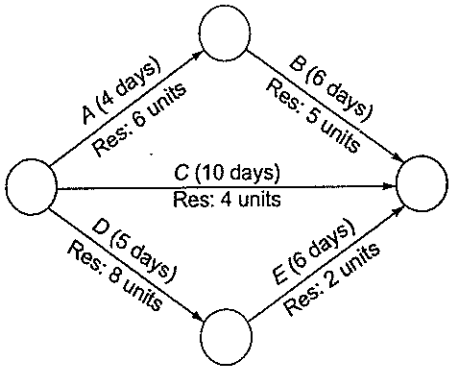
(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 2005]

2.37 The activity duration (days) and resource requirements (units) are shown in the figure below.



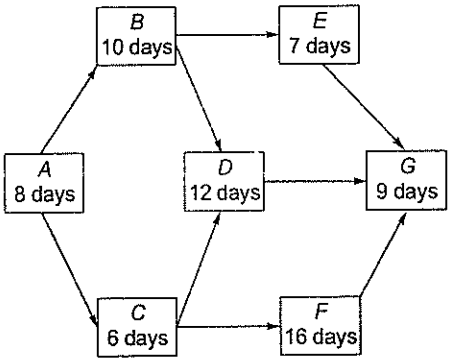
What is the maximum resource required in a day?

(a) 14 units (b) 11 units

(c) 19 units (d) 18 units

[ESE : 2006]

2.38 A small project, consists of seven activities in the activity-on-node diagram as shown in the figure below, in days and the predecessor relationships are shown.



What is the total project duration of the project?

(a) 39 days (b) 35 days

(c) 34 days (d) 41 days

[ESE : 2006]

2.39 If '*a*' is the optimistic time, '*b*' is the pessimistic time, and '*m*' is most likely time of an activity, then what is the expected time of activity?

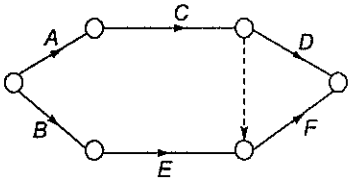
(a) $\frac{a+m+b}{3}$ (b) $\frac{a+2m+b}{5}$

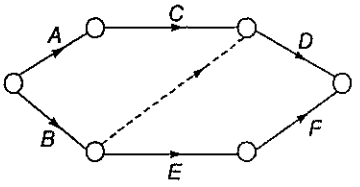
(c) $\frac{a+4m+b}{6}$ (d) $\frac{a+3m+b}{6}$

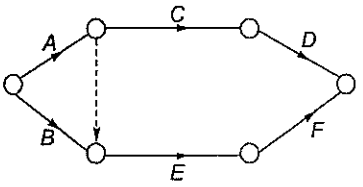
[ESE : 2006]

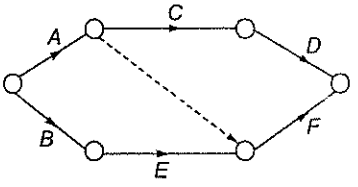
2.40 Activities *A* and *B* can be started independently. Activity *C* follows activity *A*, and activity *D* follows activities *B* and *C*. Activity *E* follows activity *B* and precedes activity *F*. The activities *D* and *F*

merge at the objective event. Which one of the following is the correct network of the project?

(a)


(b)


(c)


(d)


[ESE : 2006]

2.41 Consider the following statements associated with critical path:

1. Critical path is the most important sequence of activities which has no float and which determines the project completion period.
2. Critical path is the largest path with shortest duration within which the project can be completed.
3. The difference between early start time and late finish time must be equal to the activity duration.

Which of these statements are correct?

(a) 1, 2 and 3 (b) Only 1 and 2
(c) Only 1 and 3 (d) Only 2 and 3

[ESE : 2006]

2.42 **Assertion (A) :** Critical path can pass through dummy arrows also.

Reason (R) : Necessary additional nodes are introduced to ensure uniqueness of *i-j* notation for activities.

(a) both *A* and *R* are true and *R* is the correct explanation of *A*
(b) both *A* and *R* are true but *R* is not a correct explanation of *A*
(c) *A* is true but *R* is false
(d) *A* is false but *R* is true

[ESE : 2007]

2.43 The optimistic, most likely and pessimistic time estimates of an activity are 5, 10 and 21 days respectively. What are the expected time and standard deviation?

(a) 12, 3 (b) 11, 4
(c) 11, 2.67 (d) 10, 16

[ESE : 2007]

2.44 What is the time by which the completion of an activity can be delayed without affecting the start of succeeding activities, called ?

(a) Total float
(b) Interfering float
(c) Independent float
(d) Free float

[ESE : 2007]

2.45 Duration along the critical path defines which of the following ?

1. Shortest duration needed
2. Shortest duration permissible
3. Longest duration needed
4. Longest duration permissible

Select the correct answer the using the codes given below :

(a) 1 and 2 only (b) 1 and 4 only
(c) 2 and 3 only (d) 3 and 4 only

[ESE : 2007]

2.46 Consider the following statements regarding CPM technique of project planning:

1. The critical path consists of those activities for which the total float is zero.
2. Independent float is expressed as the difference between total float and the slack at the head event.
3. It is not possible to complete an activity earlier than the crash time.

Which of these statements are correct ?

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

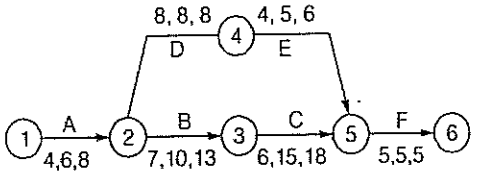
[ESE : 2008]

2.47 Which one of the following techniques is most suitable in case of research and development type of activity?
(a) Critical Path Method
(b) Project Evaluation and Review Technique
(c) Bar Chart
(d) Graphical Evaluation and Review Technique
[ESE : 2008]

2.48 What is the duration by which the completion time of any activity can be delayed without affecting the start of any of the succeeding activities?
(a) Interfering float (b) Free float
(c) Independent float (d) Total float
[ESE : 2009]

2.49 Which one of the following is associated with a critical activity in a A-O-A network?
(a) Maximum float (b) Minimum float
(c) Zero float (d) Free float
[ESE : 2009]

2.50 What is the proportional variation and what is the 'range' of project duration for the network as shown with the indicated probabilistic *a*, *m*, *b* durations of the respective activities?



(a) $\frac{1}{15}$, 28 to 42 (b) $\frac{1}{15}$, 30 to 45
(c) $\frac{1}{12}$, 28 to 42 (d) $\frac{1}{12}$, 30 to 45
[ESE : 2009]

2.51 Which one of the following relates to determination of critical path in PERT?
(a) Event oriented slack
(b) Activity oriented float
(c) Event oriented float
(d) Activity oriented slack
[ESE : 2009]

2.52 PERT calculations yield a project length of 60 weeks with a variance of 9 weeks. Probability factor corresponding to 95% probability is 1.647; then the number of weeks required to complete the project with a probability of 95% is
(a) 60.94 (b) 62.94
(c) 64.94 (d) 66.94
[ESE : 2010]

2.53 Consider the following statements:
1. PERT is activity-oriented and adopts deterministic approach.
2. CPM is event-oriented and adopts probabilistic approach.
3. PERT is event-oriented and adopts probabilistic approach.
Which of these statements is/are correct?
(a) 1 only (b) 1 and 2
(c) 2 and 3 (d) 3 only
[ESE : 2010]

2.54 In PERT analysis, the time estimates of activities correspond to
(a) normal distribution
(b) Poisson's distribution
(c) β-distribution
(d) binomial distribution
[ESE : 2010]

2.55 A father notes that when his teenage daughter uses the telephone she takes no less than 5 minutes for a call but sometimes as much as an hour. 15 minutes calls are more frequent than calls of any other duration. If the daughter's calls were to be represented as an activity in PERT project, the expected duration of each phone call is
(a) $14\frac{5}{6}$ minutes (b) $16\frac{5}{6}$ minutes
(c) $18\frac{5}{6}$ minutes (d) $20\frac{5}{6}$ minutes
[ESE : 2010]

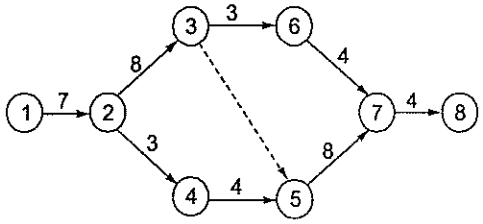
2.56 The duration of any activity in case of a PERT programme is calculated as a weighted average of three time estimates namely the optimistic time t_o, the pessimistic time t_p and the most probable time t_m, which is given as
(a) $\left(\frac{t_o + t_m + 4t_p}{6}\right)$ (b) $\left(\frac{t_o + 4t_m + t_p}{6}\right)$
(c) $\left(\frac{4t_o + t_m + t_p}{6}\right)$ (d) $\left(\frac{3t_o + 2t_m + t_p}{6}\right)$
[ESE : 2010]

2.57 Consider the following statements of network:
1. Only one time estimate is required for each activity.
2. Three time estimates for each activity.
3. Time and cost are both controlling factors.
4. It is built-up of event-oriented diagram.

Which of the above statements are correctly applicable to CPM network?
(a) 1 and 3 (b) 1 and 2
(c) 2 and 4 (d) 3 and 4

[ESE : 2010]

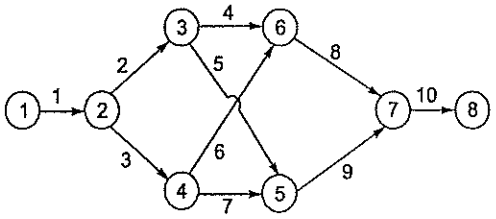
2.58 In the network shown below, the duration of activities are written along their arrows. The critical path of the activities is along



(a) 1 – 2 – 3 – 5 – 7 – 8
(b) 1 – 2 – 3 – 6 – 7 – 8
(c) 1 – 2 – 4 – 5 – 7 – 8
(d) 1 – 2 – 3 – 4 – 5 – 7 – 8

[ESE : 2010]

2.59 The figure below indicates a project network; the number at each activity represents its normal duration in days. The critical path is along



(a) 1 – 2 – 3 – 6 – 7 – 8
(b) 1 – 2 – 4 – 5 – 7 – 8
(c) 1 – 2 – 3 – 5 – 7 – 8
(d) 1 – 2 – 4 – 6 – 7 – 8

[ESE : 2010]

2.60 Consider the following statements:
1. Total float can affect all activities in the chain.
2. Free float can affect only the preceding activities.
3. Independent float affects only the particular concerned activity.

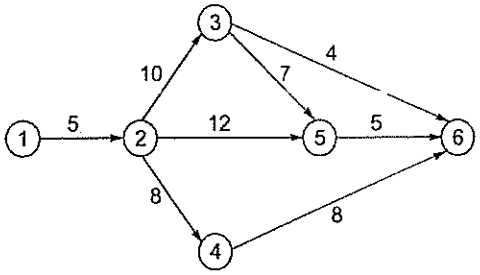
Which of these statements/are correct?
(a) 1 only (b) 1 and 2 only
(c) 2 and 3 only (d) 1, 2 and 3

[ESE : 2010]

2.61 **Assertion (A):** The probability of completion of a multi-path project at the expected project completion duration is 50%.
Reason (R): The standard deviate for the critical path duration is zero.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2010]

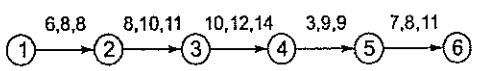
2.62 In the network shown below, the number of the arrow gives the duration of the activity. The earliest expected time for event 6 to be attained is



(a) 22 (b) 27
(c) 23 (d) 24

[ESE : 2011]

2.63 Consider a series of activities *A*, *B*, *C*, *D* and *E* comprising a project where in, *a*, *m*, *b* durations of each activity are indicated. What is the probability of completing the project in 45 days? The area under the normal probability curve is indicated in the table by adopting standard notations.

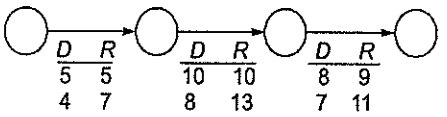


Z	1.0	0.8	0.6	0.4	0.2	0.0
A	0.841	0.788	0.726	0.655	0.579	0.500

(a) 0.20 (b) 0.23
(c) 0.26 (d) 0.29

[ESE : 2011]

2.64 Consider the three activities indicated in sequence. The possible alternatives for individual durations (D) in days, and the corresponding cost of resource consumption in units of money per day (R) respectively, are also indicated beside the activities. Overhead costs are to be added at 12 units of money per day of duration. What is the most optimal total cost including overheads, if all the activities are to be completed in either 22 or 21 days?



(a) 466 units of cost (b) 460 units of cost
(c) 453 units of cost (d) 450 units of cost

[ESE : 2011]

2.65 Critical path moves along the activities having total float as
(a) Positive (b) Negative
(c) Zero (d) Unity

[ESE : 2011]

2.66 The probability distribution taken to represent the completion of time in PERT analysis is
(a) Normal Distribution
(b) Beta Distribution
(c) Gamma Distribution
(d) Gaussian Distribution

[ESE : 2011]

2.67 Slack time is associated with
(a) A real activity
(b) An event
(c) Both event and real activity
(d) Dummy activity

[ESE : 2011]

2.68 IN PERT analysis, the time estimates of activities and probability of their occurrence follow
(a) beta distribution
(b) gamma distribution
(c) normal distribution
(d) Poisson's distribution

[ESE : 2012]

2.69 Two parallel paths A and B extending from start to finish comprise a project network. Along A, the expected duration is 40 days with a standard deviation of 8 days; along B, these are 45 days and 12 days, respectively. What is the probability of the complete project being finished in 42 days? The table of normal probability curve is given:

z	$f(z)$
0	0.500
0.1	0.540
0.2	0.579
0.3	0.618
0.4	0.655
0.5	0.691
0.6	0.726
0.7	0.758
0.8	0.788
0.9	0.816
1.0	0.841

(a) 0.6 (b) 0.4
(c) 0.5 (d) 0.24

[ESE : 2012]

2.70 Total float in a planning network is
(a) Late start time – Early start time
(b) Early start time – Late start time
(c) Late start time – Late finish time
(d) Late finish time – Early finish time

[ESE : 2012]

2.71 Which of the following statements are correct in respect of a linked-bar chart?
1. Any activity can be shown split into several sub-parts if so desirable.
2. Inter-linkages between WBS groups can be depicted.
3. Mandatory pauses between activities are also always demonstrated on the chart.
4. Scheduling of material procurement can optionally enhance the utility.

(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 1 and 4

[ESE : 2013]

2.72 Consider the following statements pertaining to CPM net work analysis:
1. It is event-oriented method.
2. It is activity-oriented method.
3. Time and cost are controlling factors.
4. Time alone is controlling factor.

Which of these statements are correct?

(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 1 and 4

[ESE : 2013]

2.73 Which of the following do not characterize the critical path?

1. Falls on a single straight line between start and end nodes.
2. Has no dummies
3. Indicates the minimum feasible duration for the complete project.
4. Indicates the maximum sensible duration in which to complete the project.
5. Has no parallel sub-paths between any two nodes on it.

(a) 2, 4 and 5 (b) 1, 2 and 5
(c) 2, 3 and 4 (d) 1, 3 and 4

[ESE : 2013]

2.74 In a critical path network, which of the following are involved?

1. A series of interconnected activities
2. Considerations for uncertainties in time estimate
3. A logical sequence of activities is provided
4. The node number at the arrow head is numerically smaller than that at tail end

(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 1 and 3

[ESE : 2013]

2.75 Which one of the following relates to determination of critical path in PERT?

(a) Event-oriented slack
(b) Activity-oriented slack
(c) Event-oriented float
(d) Activity-oriented float

[ESE : 2013]

2.76 A father notes that his teenage son uses the telephone. He takes no less than 5 minutes for a call and sometimes as much as an hour. 20 minutes calls are more frequent that calls of any other duration. Considered as a PERT activity a phone call's expected duration in minutes is

(a) $20\frac{1}{6}$ (b) $22\frac{1}{6}$
(c) $24\frac{1}{6}$ (d) $26\frac{1}{6}$

[ESE : 2013]

Directions: Each of the next items consists of two statements, one labeled as the **'Statements (I)'** and the other as **'Statement (II)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below :

Codes:

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

2.77 **Statement (I):** A bar chart may look awkward when demonstrating the works to be executed for external finishes in multi-storey constructions.
Statement (II): External scaffolding can be dismantled in a top-to-down sequence only

[ESE : 2013]

2.78 **Statement (I):** When LSS is drawn as a squared diagram, the respective total float for each sub-path will be shown in full at the head-end of that sub-path.
Statement (II): By considering LS for scheduling , the sparable time is pushed to the head-end.

[ESE : 2013]

2.79 **Statement (I):** PERT network is event-oriented and it does not reflect on time or resources.
Statement (II): Planners can decide about the uncertainties involved in time duration while planning itself.

[ESE : 2013]

2.80 Which system of network given below completely eliminates the use of dummy activities?

(a) A-O-A (Activity-on-Arrow)
(b) A-O-N (Activity-on-Node)
(c) PERT
(d) CPM

[ESE : 2014]

2.81 Free float can be associated with which of the following?

1. In one of two sub-paths between any two adjacent nodes

2. In the last activity in the sub-paths, less by at least one of the sub-paths, between any two nodes
3. Following all sub-activities in a laddered network
4. Whenever mandatory calendar dates are prescribed for major milestone events

Select the correct answer using the code given below.

(a) 1, 2 and 3 (b) 1, 3 and 4
(c) 2, 3 and 4 (d) 1, 2 and 4

[ESE : 2014]

2.82 In PERT analysis, the time estimates of activities follow
(a) normal distribution curve
(b) β-distribution curve
(c) Poisson's distribution curve
(d) binomial distribution curve

[ESE : 2014]

2.83 In an Activity-on-Arrow network, which of the following rules of network logic are mandatory?
1. Any two events can be directly connected by not more than one activity.
2. Event numbers should not be duplicated in a network.
3. Before an activity may begin, all the activities preceding it must be completed.

Select the correct answer using the code given below.

(a) 1 and 2 only (b) 2 and 3 only
(c) 1 and 3 only (d) 1, 2 and 3

[ESE : 2014]

2.84 **Statement (I) :** A dummy job takes zero time to perform.

Statement (II) : It is used solely to illustrate precedence relationship.

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is not the correct explanation of Statement (I).
(c) Statement (I) is true but Statement (II) is false.
(d) Statement (I) is false but Statement (II) is true

[ESE : 2014]

2.85 Activity A, Activity B and Activity C are cast into a ladder diagrammatic CPM network, with splitting each into three equal parts as A_1, A_2, A_3; B_1, B_2, B_3 and C_1, C_2, C_3. Typical sequencing as in a ladder diagram is adopted (like B_2 following A_2 and B_1). The optimum number of dummy arrows needed for a satisfactory and correct ladder diagram will be

(a) 1 (b) 2
(c) 3 (d) 4

[ESE : 2015]

2.86 It is estimated that an activity can be assigned an optimistic duration of 16 days, a pessimistic duration of 28 days and a most likely duration of 19 days. What is the expected duration for this activity?

(a) 20 days (b) 19 days
(c) 22 days (d) 18 days

[ESE : 2015]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) Both A and R are true and R is the correct explanation of A
(b) Both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

2.87 **Assertion (A):** A merging node will have a uniquely determinable Late Event Time.

Reason (R): A merging node is defined as a node where more than one incoming activity arrow leads in.

[ESE : 2015]

2.88 **Assertion (A):** AON networks do not generally have any dummy links.

Reason (R): Links express activity dependencies exhaustively and completely.

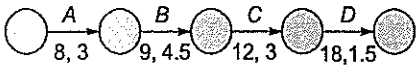
[ESE : 2015]

2.89 **Assertion (A):** In a multi-path PERT network, the project duration resulting from the critical path always has a 50% probability of completion by that duration.

Reason (R): The expected through-path duration together with 3-times the standard deviation of that expected duration must be considered for all the paths in the network.

[ESE : 2015]

2.90 Activities A, B, C and D constitute a small project; their interrelationship, expected duration and standard deviation of this expected duration are shown in the figure, respectively.



With a view to improving the speed of implementation, each of B, C and D are split into three equal segments, maintaining appropriate interrelationships between A and each of these nine segments. What will be the standard deviation of the modified project duration after segmentation (to the nearest 1/10 unit)?

(a) 6.2 (b) 5.6
(c) 5.2 (d) 4.6

[ESE : 2016]

2.91 Which of the following statements are implicit in developing the critical path network?

1. Only one time estimate is required for any activity
2. Time only is the controlling factor a this stage
3. Time and cost both are controlling factors at this stage
4. Critical events may have positive negative, or zero float

(a) 1 and 2 only (b) 1 and 3 only
(c) 1 and 4 only (d) 2 and 4 only

[ESE : 2016]

2.92 In the Critical Path Method of project planning, free float can be

(a) Greater than independent float
(b) Greater than total float
(c) Less than independent float
(d) Equal to total float

[ESE : 2016]

2.93 Slack time in PERT analysis

(a) Can never be greater than zero
(b) Is always zero for critical activities
(c) Can never be less than zero
(d) Is minimum for critical events

[ESE : 2016]

2.94 Statement (I): Critical path(s) through a CPM network can be identified even without working out the backward pass computations by a competent user.

Statement (II) : Critical path is the progressive chain of activities from start to finish (not excluding between splitting and merging nodes) through the network where Total Float is absent throughout (including through dummy arrows, if appropriate).

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is *not* the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

[ESE : 2016]

2.95 Which of the following statements is/are correct for noncritical activity?

1. It demands very special attention and action
2. One can do with normal attention to this activity with some leeway for action.

Select the correct answer using the codes given below:

(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2

[ESE : 2017]

Answers PERT and CPM

2.1 (a)	2.2 (d)	2.3 (d)	2.4 (c)	2.5 (c)	2.6 (b)	2.7 (b)	2.8 (c)	2.9 (c)
2.10 (b)	2.11 (a)	2.12 (b)	2.13 (b)	2.14 (c)	2.15 (d)	2.16 (a)	2.17 (b)	2.18 (a)
2.19 (a)	2.20 (c)	2.21 (d)	2.22 (a)	2.23 (b)	2.24 (b)	2.25 (c)	2.26 (a)	2.27 (a)
2.28 (b)	2.29 (d)	2.30 (c)	2.31 (d)	2.32 (d)	2.33 (c)	2.34 (c)	2.35 (c)	2.36 (c)
2.37 (d)	2.38 (a)	2.39 (c)	2.40 (b)	2.41 (a)	2.42 (b)	2.43 (c)	2.44 (d)	2.45 (b)
2.46 (d)	2.47 (b)	2.48 (b)	2.49 (c)	2.50 (a)	2.51 (a)	2.52 (c)	2.53 (d)	2.54 (c)
2.55 (d)	2.56 (b)	2.57 (a)	2.58 (a)	2.59 (c)	2.60 (c)	2.61 (c)	2.62 (b)	2.63 (d)
2.64 (c)	2.65 (c)	2.66 (a)	2.67 (b)	2.68 (a)	2.69 (b)	2.70 (a, d)	2.71 (a)	2.72 (b)
2.73 (b)	2.74 (d)	2.75 (a)	2.76 (c)	2.77 (b)	2.78 (a)	2.79 (d)	2.80 (b)	2.81 (c)
2.82 (b)	2.83 (d)	2.84 (a)	2.85 (d)	2.86 (a)	2.87 (b)	2.88 (a)	2.89 (c)	2.90 (a)
2.91 (b)	2.92 (a)	2.93 (d)	2.94 (d)	2.95 (b)				

Explanations PERT and CPM

2.1 (a)

PERT is probabilistic in nature and it is event based. It is used for non-repetitive type of projects. CPM is activity based and time for completion is known precisely.

2.2 (d)

Total float is the excess of maximum available time over the activity time.

$$F_T = \left(T_L^j - T_E^i\right) - t^{ij}$$
$$= LST - EST$$
$$= LFT - EFT$$

Free float is the excess of available time over the activity time when all jobs start as early as possible.

$$F_F = \left(T_E^j - T_E^i\right) - t^{ij}$$
$$= F_T - S_j$$

Independent float is the excess of minimum available time over the activity time.

$$F_{ID} = \left(T_E^j - T_L^i\right) - t^{ij}$$
$$= F_F - S_i$$

Interfering float is the difference between total float and free float

$$F_{IN} = F_T - F_F = S_j$$

2.4 (c)

The critical path should have maximum duration.

Path	Duration
1 – 2 – 4 – 7 – 9	6 + 9 + 14 + 12 = 41
1 – 3 – 5 – 7 – 9	8 + 9 + 14 + 12 = 43
1 – 3 – 5 – 6 – 8 – 9	8 + 9 + 0 + 13 + 15 = 45
1 – 3 – 6 – 8 – 9	8 + 10 + 13 + 15 = 46

Maximum duration is for path 1 – 3 – 6 – 8 – 9, so this is the critical path.

2.5 (c)

Activity: It is resource consuming element of the project

Event: It is stage or instant of time at which some milestone of project is achieved.

Dummy: Special type of activity which does not consume any resource and time.

Float: Time by which finish or start of activity can be delayed without affecting project completion time.

2.6 (b)

$$\text{Expected time, } t_e = \frac{t_o + 4t_m + t_p}{6}$$
$$= \frac{5 + 4 \times 8 + 17}{6}$$
$$= 9 \text{ days}$$

2.7 (b)

In CPM networks, critical path is the path traced by critical activities. Critical activities are those activities which have zero total float i.e.

$$F_T = \left(T_L^j - T_E^i\right) - t^{ij}$$

F_T for 1 – 2 = (1 – 0) – 1 = 0
F_T for 2 – 3 = (7 – 1) – 6 = 0
F_T for 3 – 5 = (16 – 7) – 8 = 1
F_T for 5 – 6 = (18 – 16) – 2 = 0

Thus activity 3 – 5 is not critical. The duration of activities 2 – 4, 3 – 4 and 4 – 5 are not provided. Since 3 – 5 is not critical the only available path is 1– 2 – 3 – 4 – 5 – 6.

It may be noted that in the given network slack $(T_L - T_E)$ at each event is zero. And we know that events hving zero slack are critical events. The path traced by critical events is the critical path. But, this theory applies for a PERT network. Thus if this network happens to be a PERT network then there might have been three critical paths. viz. (i) 1 – 2 – 3 – 5 – 6, (ii) 1 – 2 – 4 – 5– 6 and (iii) 1 – 2 – 3 – 4 – 5 – 6.

2.8 (c)

$$\text{Expected time, } t_e = \frac{t_o + 4t_m + t_p}{6}$$
$$= \frac{4 + 4\times 11 + 12}{6}$$
$$= 10 \text{ days}$$

2.9 (c)

Using forward pass, the earliest start time of any activity can be found. Starting with event 1 with earliest occurrence time (EOT) as zero, the EOT of other head events are assigned by adding activity times and choosing such maximum time obtained from all paths.

Event	1	2	3	4	5	6
EOT (days)	0	4	1	4	9	11

EOT of tail event = EST of activity

$\therefore$ $EST_{5-6} = 9$ days

2.10 (b)

The standard deviation,

$$\sigma = \left(\frac{t_p - t_o}{6}\right)$$

Contractor's Standard deviation in estimates
$P \rightarrow (13 - 5)/6 = 4/3 = 1.33$
$Q \rightarrow (12 - 6)/6 = 1$
$R \rightarrow (14 - 5)/6 = 1.5$
$S \rightarrow (13 - 4)/6 = 1.5$

Since the time estimates of contractor Q has least standard deviation, so work can be completed by him in most certain manner.

2.11 (a)

Independent float $= (EOT)_{10} - (LOT)_3 - t_{3\text{-}10}$
$= 40 - 25 - 10 = 5$ weeks

2.12 (b)

$$\text{Expected time, } t_e = \frac{t_o + 4t_m + t_p}{6}$$
$$= \frac{4 + 4\times 5 + 8}{6}$$
$$= 5.33 \text{ months}$$

2.13 (b)

The distribution curve for the time taken to complete each activity of a project resembles a β-distribution curve and the distribution curve for the time taken to complete entire project (consisting of several activities) in general resembles a normal distribution curve.

2.14 (c)

Path	Time taken
1 – 2 – 4 – 5 – 7 – 8	7 + 3 + 4 + 8 + 7 = 29
1 – 2 – 3 – 5 – 7 – 8	7 + 8 + 0 + 8 + 7 = 30

The path 1 – 2 – 4 – 5 – 3 – 6 – 7 – 8 is not possible. Hence, critical path is
1 – 2 – 3 – 5 – 7– 8

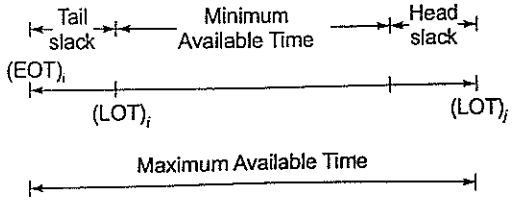
2.15 (d)

$P(K \cap L) = P(K) + P(L) - P(K \cup L)$
$\therefore P(K \cap L) = 2 \times 0.45 - 0.75$
Critical probability for delay in activity

$$\therefore P(K/L) = \frac{P(K \cap L)}{P(L)} = \frac{2\times 0.45 - 0.75}{0.45}$$

2.16 (a)

Time scale for an activity:



Independent Float (*IF*) is the excess of minimum available time over activity time.

Free Float (*FF*) is the excess of available time over the activity time when all jobs start as early as possible.

So $FF = IF$ + Tail slack.

Interfering Float = $TF - FF$ = Head slack

$\therefore TF$ = Int. $F + FF$ = Int. $F + IF$ + Tail slack

Or $TF = IF$ + Head slack + Tail slack

2.17 (b)

Path	Total duration
1 – 2 – 3 – 6 – 7 – 8	4 + 6 + 2 + 3 + 7 = 23
1 – 2 – 3 – 5 – 7 – 8	4 + 7 + 0 + 6 + 7 = 24
1 – 2 – 4 – 5 – 8	4 + 3 + 3 + 6 + 7 = 23
1 – 2 – 4 – 6 – 7 – 8	4 + 3 + 0 + 3 + 7 + 17

Critical path is the path with maximum total duration i.e. 1 – 2 – 3 – 5 – 7 – 8

2.18 (a)

The sequence is

AD – FP – EET – PD – BP – LET – TF

2.19 (a)

In ladder network, the duration will be the sum of the duration of activity having maximum duration and 1/3 of the durations of other two activities.

$\therefore$ Modified total duration

$$= 24 + \frac{1}{3}(15+18) = 35 \text{ days}$$

2.20 (c)

The forward pass is incomplete and the backward pass should also be shown.

Event	(EOT)	(LOT)
5	8	13
6	9	15
7	22	27
8	20	22
9	32	34

For activity 6 – 7

Total Float $= (LOT)_7 - (EOT)_6 - t_{6-7}$

$= 27 - 9 - 12 = 6$ units

Free Float $= (EOT)_7 - (EOT)_6 - t_{6-7}$

$= 22 - 9 - 12 = 1$ units

2.21 (d)

From central limit theorem,

Overall project duration

$$T_e = T + T + T + T = 4T$$

Variance of project

$$= k^2 + k^2 + k^2 + k^2 = 4k^2$$

Standard deviation of project

$$\sigma = \sqrt{4k^2} = 2k$$

The range of project is $T_e - 3\sigma$ to $T_e + 3\sigma$

$\therefore 4T \pm 6k$ will be the range.

2.22 (a)

The activity duration will correspond to minimum cost of resource.

Sr. No.	Duration	Resource consumption
1	6	6 × 10 = 60 units
2	4 + 5 = 9	4 × 7 + 5 × 5 = 53 units
3	8	8 × 7 = 56 units
4	4 + 3 = 7	4 × 7 + 3 × 10 = 58 units

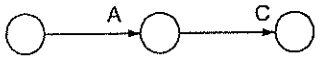
So the activity duration to be considered for the CPM network will be 9 weeks.

2.23 (b)

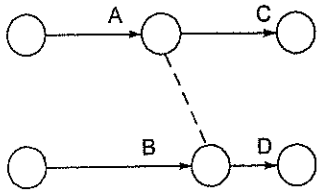
As much information is not available about the activities, three point estimate are taken which can be left skewed or right skewed. In PERT analysis time estimate follow â distribution.

2.24 (b)

Step 1:



Step 2:



2.25 (c)

Path	duration
A – C – H	6 + 2 + 6 = 14
B – E – F – H	6 + 8 + 4 + 6 = 24
A – D – E – F – H	6 + 4 + 8 + 4 + 6 = 28
A – D – E – G	6 + 4 + 8 + 6 = 24

The longest path is *A – D – E – F – H* and so that is the critical path.

2.26 (a)

For estimating PERT durations, there is no constraint on resources. For Interfaces the senior management's involvement is considered to decide the target dates for interface events in very large projects.

2.27 (a)

PERT → Programme Evaluation and Review Technique

GERT → Graphical Evaluation Review Technique.

2.28 (b)

PERT analysis follows probabilistic approach for estimation of time and estimated time is calculated by weighted average method.

$$t_e = (t_o + t_p + 4\,t_n)/6$$

2.29 (d)

The total time taken in laddered network

$$= \frac{15+21}{3} + 27 = 39 \text{ days}$$

$\therefore$ Time saved = 15 + 21 + 27 – 39 = 24 days.

2.30 (c)

Solving the network will give earliest occurrence time (T_E) and latest finish time (T_L) as below:

Event	A	B	C	D	E	F
T_E	0	5	6	12	9	18
T_L	0	8	6	12	11	18

Total float = T_L for head event
– T_E for tail event
– duration of activity

Total float AB = 8 – 0 – 5 = 3

Total float CE = 11 – 6 – 3 = 2

Free Float = T_E for head event
– T_E for tail event
– duration of activity

Free float EF = 18 – 9 – 7 = 2

2.31 (d)

$$\text{Expected time, } t_e = \frac{t_o + 4t_m + t_p}{6}$$

$$\text{Variance} = \left(\frac{t_p - t_o}{6}\right)^2$$

Probable Range $(T_e - 3\sigma)$ to $(T_e + 3\sigma)$

$T_e \rightarrow$ expected project duration

$\sigma \rightarrow$ standard deviation for project

Activity	t_e	variance
AB	8.5	0.25
BC	14	1
CD	8	2/3
DE	7	1

$$T_e = 37.5$$

$$\sigma = \sqrt{0.25 + 1 + \frac{2}{3} + 1} = 1.707$$

$$T - 3\sigma = 37.5 - 3 \times 1.708 = 32.37$$

$$T + 3\sigma = 37.5 + 3 \times 1.708 = 42.62$$

$\therefore$ The most close is option is (d)

2.32 (d)

The PERT study is used for non-repetitive type of projects. To achieve more realistic estimate of the cost of the project and to have better control against the original estimate, cumulative project cost versus time is depicted. For a research work or any new type of project technology can not be pre-decided.

In time cost study, the durations of activities on critical path can be reduced by

(i) deploying more resources for the early completion of such activities

(ii) relaxing the technical specifications for such activities i.e. choice of technology becomes concurrent with duration reduction.

In critical path identification for PERT network, the critical events may have positive/zero/ negative slack depending upon the project scheduled completion time. If there are more than one critical path of a PERT network, then find the variance along each critical path and select the greatest value. Thus the process is affected by probabilistic activity durations.

2.33 (c)

Free Float = $(EET)_{207} - (LET)_{206} - t$
= 21 – 10 – 8 = 3

Independent Float = $(EET)_{207} - (EET)_{206} - t$
= 21 – 12 – 8 = 1

Interference Float = $(LET)_{207} - (EET)_{206} - t$
= 26 – 21 = 5

So, the correct sequence will be :
Interference float – Free float – Independent float.

2.34 (c)

Normal time for both activities
for A, T_{NA} = 8 days
for B, T_{NB} = 10 days
Either of the activities can be crashed and tabular representation of crashing is as follows:

Activity		Direct costs		Total time	Total cost
A	B	A	B		
8	10	12	15	18	27
7	10	14	15	17	29
7	9	14	17	16	31
7	8	14	19	15	33
7	7	14	21	14	35
6	7	17	21	13	38
5	7	21	21	12	42

Increase in direct cost between a combined duration of 16 days and 13 days = 38 – 31 = 7

2.35 (c)

Project duration, $T = 7 + 6 + 11 + 14 + 5$
$= 43$ days
Variance = $2^2 + 2^2 + 3^2 + 4^2 + 1^2 = 34$
Standard deviation $\sigma = \sqrt{34} = 5.8$
Range of project duration = (Minimum time, Maximum time)
Minimum time = $T - 3\sigma = 25.6$ days
Maximum time = $T + 3\sigma = 60.4$ days

2.36 (c)

Interference float is the slack of head event. However only independent float cannot be shared by any other activity.

2.37 (d)

Activity	EST	Duration (Days)	EFT = EST + duration
A	0	4	4
B	4	6	10
C	0	10	10
D	0	5	5
E	5	6	11

Resource requirement:

Day	Activities	Resources
1	A + C + D	6 + 4 + 8 = 18
2	A + C + D	6 + 4 + 8 = 18
3	A + C + D	6 + 4 + 8 = 18
4	A + C + D	6 + 4 + 8 = 18
5	B + C + D	5 + 4 + 8 = 17
6	$B + C + E$	5 + 4 + 2 = 11
7	$B + C + E$	5 + 4 + 2 = 11
8	$B + C + E$	5 + 4 + 2 = 11
9	$B + C + E$	5 + 4 + 2 = 11
10	$B + C + E$	5 + 4 + 2 = 11
11	D	2

The maximum resources required are 18 on 1st, 2nd, 3rd and 4th day.

2.38 (a)

Paths	Duration (days)
$A - B - E - G$	8 + 10 + 7 + 9 = 34
$A - B - D - G$	8 + 10 + 12 + 9 = 39
$A - C - F - G$	8 + 6 + 16 + 9 = 39
$A - C - D - G$	8 + 6 + 12 + 9 = 35

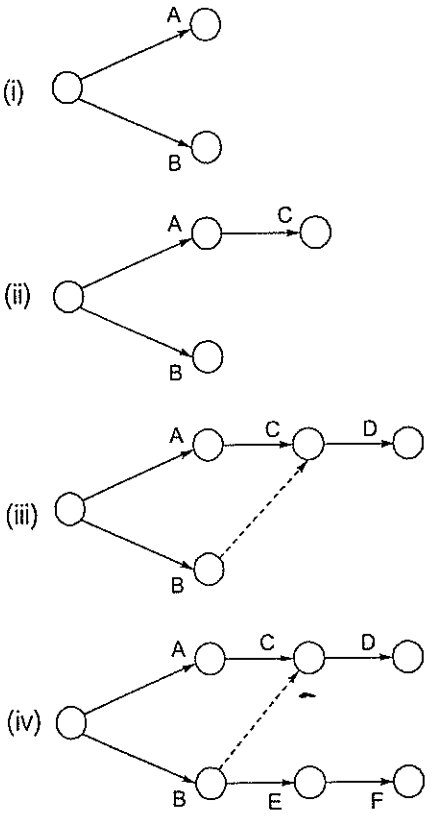
Thus project duration is 39 days and there are two critical paths $A - B - D - G$ and $A - C - F - G$.

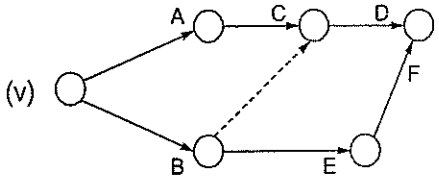
2.39 (c)

PERT analysis follows probabilistic approach for estimation of time and estimated time is calculated by weighted average method.

$$t_e = (a + 4m + b)/6$$

2.40 (b)





Dummy activities can also be critical activities which are introduced to maintain logic of the network. Thus critical path passes through dummy activities.

2.41 (a)

The duration in critical path is largest. However it is the shortest duration (minimum duration) within which the project can be completed.

Since the total float and other floats are zero on critical path. So $EST = LST$ and $LFT = EFT$ and $LFT - EST$ = activity duration.

2.43 (c)

Expected time, $t_e = \dfrac{t_0 + 4t_l + t_p}{6}$

$= \dfrac{5 + (4 \times 10) + 21}{6}$

$= 11$ days

Standard deviation, $\sigma = \dfrac{t_p - t_0}{6}$

$= \dfrac{21 - 5}{6} = 2.67$

2.44 (d)

The delay which can be performed without delaying succeeding activities and affects only preceding activities is called free float. Free float (F_F) is given by

$$F_F = \left(T_E^j - T_E^i\right) - t_{ij}$$

Total float is the time span by which starting or finishing of an activity can be delayed without delaying the completion of the project. Total float (F_T) is given by

$$F_T = \left(T_L^j - T_E^i\right) - t_{ij}$$

Independent float is the minimum excess available time which exists without affecting any of succeeding or preceding activities. It is given by

$$F_{ID} = \left(T_E^j - T_L^i\right) - t_{ij}$$

Interfering float (F_{INT}) is the difference of total and free float.

$$F_{INT} = F_T - F_F$$

2.45 (b)

Critical path defines the shortest duration needed and not permissible because we can still reduce the duration of critical path by crashing.

2.46 (d)

Independent float is equal to free float minus tail event slack, i.e.

$$F_{ID} = F_F - S_i$$

2.47 (b)

PERT technique is most suitable in case of research and development type activities since it takes into account uncertainties involved in time estimation.

2.48 (b)

Free float is the amount of time that an activity can be delayed without delaying the Early Start of its successor activity. Free float can be calculated by subtracting the Early Finish date of the activity from the Early Start date of next activity (ES of next Activity – EF of current Activity).

2.49 (c)

Critical path activities are the project tasks that must start and finish on time to ensure that the project ends on schedule. If the Early Start date and Late Start date for an activity are the same, the activity is said to have zero float. Activities that have zero float start on time and prevent the schedule from slipping.

2.50 (a)

Expected time, $t_e = \dfrac{a + 4m + b}{6}$

Standard deviation, $\sigma = \dfrac{b - a}{6}$

Activity	a	m	b	t_e	σ
A	4	6	8	6	0.67
B	7	10	13	10	1
C	6	15	18	14	2
D	8	8	8	8	0
E	4	5	6	5	0.33
F	5	5	5	5	0

The critical path will be $A - B - C - F$ and the project duration will be 35.

∴ Standard deviation of the project,

$$\sigma = \sqrt{(0.67)^2 + (1)^2 + (2)^2 + 0}$$

$$= 2.33$$

Range of project duration

$$= T_E - 3\sigma \text{ to } T_E + 3\sigma$$

$$= 35 - 3 \times 2.33 \text{ to } 35 + 3 \times 2.33$$

$$= 28 \text{ to } 42$$

Proportional variation

$$= \frac{\text{Standard deviation}}{\text{Project duration}}$$

$$= \frac{2.33}{35} = \frac{1}{15}$$

2.52 (c)

The probability factor is given by

$$Z = \frac{T_S - T_E}{\sigma}$$

where σ is standard deviation

$$\therefore \quad \sigma = \sqrt{\text{Variance}} = \sqrt{9}$$

$$= 3 \text{ weeks}$$

Given that $T_E = 60$ weeks; $Z = 1.647$

$$\therefore \quad T_S = T_E + Z\sigma$$

$$= 60 + 1.647 \times 3$$

$$= 60 + 4.941$$

$$= 64.941 \text{ weeks}$$

2.53 (d)

PERT is event-oriented and adopts probabilistic approach where as CPM is activity-oriented an adopts deterministic approach.

2.54 (c)

The distribution curve for the time taken to complete each activity of a project resembles a β-distribution curve whereas the distribution curve for the time taken to complete the entire project (consisting of several activities) in general resembles a normal distribution curve.

2.55 (d)

The expected duration of each phone call is given by

$$t_e = \frac{t_o + 4t_m + t_p}{6}$$

$$= \frac{5 + 4 \times 15 + 60}{6} = \frac{125}{6}$$

$$= 20\frac{5}{6} \text{minutes}$$

2.56 (b)

PERT analysis follows probabilistic approach for estimation of time and estimated time is calculated by weighted average method.

$$t_e = (t_o + t_p + 4\, t_n)/6$$

2.57 (a)

Three time estimates for each activity are required in PERT network. PERT is built up of event oriented diagram.

2.58 (a)

A critical path is the longest path (time wise) connecting the initial and end event.

(i) 1–2–3–5–7–8 → 7 + 8 + 0 + 8 + 4 = 27

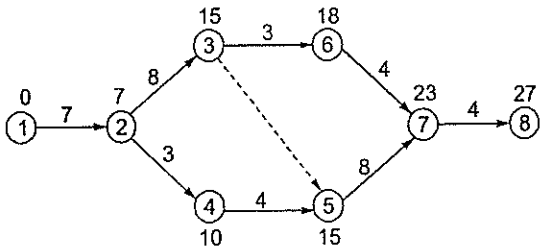
(ii) 1–2–3–6–7–8 → 7 + 8 + 3 + 4 + 4 = 26

(iii) 1–2–4–5–7–8 → 7 + 3 + 4 + 8 + 4 = 26

(iv) 1–2–3–4–5–7–8 → Redundant

2.59 (c)

Critical path is longest path time wise.



1 – 2 – 3 – 5 – 7 – 8 is the critical path.

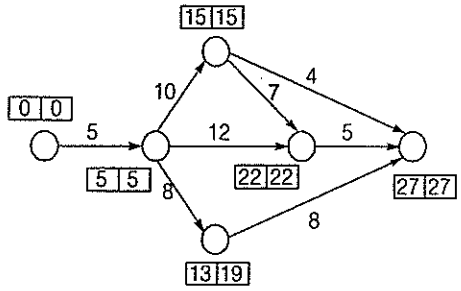
2.60 (c)

Total Float is the amount of time that an activity can be delayed from its early start date without delaying the project finish date. It affects only preceding and succeeding activities.

2.61 (c)

Standard deviation for critical path is the square root of the sum of square of standard deviation of activities along the critical path.

2.62 (b)



The Earliest occurence time and the latest occurence time of each event is calculated above

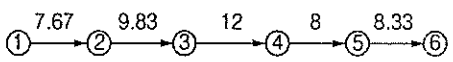
$(EOT)_j$ = max: $[(EOT)_i + t_{ij}]$

$(LOT)_i$ = min: $[(LOT)_j - t_{ij}]$

2.63 (d)

Expected time of completion (t_e) of each activity is computed below:

$$t_e = \frac{t_0 + 4t_L + t_P}{6}$$



Standand deviation for each activity is given by:

$$\sigma = \frac{t_p - t_o}{6}$$

$\sigma_{1\text{-}2} = 0.33, \quad \sigma_{2\text{-}3} = 0.5$

$\sigma_{3\text{-}4} = 0.67, \quad \sigma_{4\text{-}5} = 1$

$\sigma_{5\text{-}6} = 0.67$

Standard deviation of the project

$$\sigma = \sqrt{(\sigma_{1\text{-}2})^2 + (\sigma_{2\text{-}3})^2 + (\sigma_{3\text{-}4})^2 + (\sigma_{4\text{-}5})^2 + (\sigma_{5\text{-}6})^2}$$

$= 1.502$

Total expected completion time of project = $T_E = 7.67 + 9.83 + 12 + 8 + 8.33 = 45.83$

Now, For completion of project in 45 days

$$Z = \frac{45 - 45.83}{\sigma} = \frac{-0.83}{1.502} = -0.55$$

From table, probability for Z = 0.55

$$= 0.655 + \frac{(0.726 - 0.655)}{(0.6 - 0.4)} \times (0.55 - 0.4) = 0.708$$

$\therefore$ Probability for $Z = -0.55$: $1 - 0.708 = 0.29$

2.64 (c)

(i) Completion time : 22 days

(a) Crash I[st] activity

Direct cost = $4 \times 7 + 10 \times 10 + 8 \times 9$
= 200 units

Indirect cost = $22 \times 12 = 264$ units

Toal cost = 464 units

(b) Crash 3[rd] activity

Direct cost = $5 \times 5 + 10 \times 10 + 7 \times 11$
= 202 units

Indirect cost = $22 \times 12 = 264$ units

Total cost = 466 units

(ii) Completion time : 21 days

Direct cost = $5 \times 5 + 8 \times 13 + 8 \times 9$
= 201 units

Indirect cost = $21 \times 12 = 252$ units

Toal cost = 453 units

Optimal cost = 453 units

2.65 (c)

Total float is the amount of time that an activity can be delayed without delaying the project completion date. Total float is often known as the slack. On a critical path, the total float is zero as *critical path already gives* longest sequence of activities in a project plan which must be completed on time for the project to complete on due date.

2.66 (a)

The distribution curve for the time taken to complete each activity of a project resembles a β-distribution curve and the distribution curve for the time taken to complete entire project (consisting of several activities) in general resembles a normal distribution curve.

2.67 (b)

Slack denotes the flexibility range within which an event can occur.

Slack of an event = (LOT – EOT) of the event. In the CPM network the minimum value of slack is zero and the zero slack event is called the critical event.

2.68 (a)

In PERT time estimates follows beta distribution. In CPM it follows normal distribution.

2.69 (b)

Z is given by,

$$Z = \frac{T_S - T_E}{\sigma}$$

Now, $T_S = 42$ days

$T_E = 45$ days (critical path)

$$\therefore \quad Z = \frac{42-45}{12} = -0.2$$

By interpolation from table given

For $Z = -0.2$;

$f(Z) = 0.42 \cong 0.4$

2.70 (a,d)

Total float is calculated by subtracting the Early Start date of an activity from its Late Start date (Late Start date – Early Start date), or Early Finish date from its Late Finish date (Late Finish date – Early Finish date).

2.72 (b)

PERT → Event oriented → Time is the controlling factor.

CPM → Activity oriented → Both time and cost are considered.

2.73 (b)

Critical path need not be a straight time.

Critical path can have dummies also.

Critical path indicates the time duration earlier to which project can not be completed.

Critical path can have parallel sub-paths also between two nodes lying on it.

2.74 (d)

Critical Path Network considers deterministic approach hence there is no consideration for uncertainties in time estimate. Node number at arrows head is numerically larger than that of end tail.

2.75 (a)

In PERT analysis critical path is determined with help of slack. Slack, is the amount of *time* by which a given task within a *project* can be delayed before it impacts the deadline for the *project*

2.76 (c)

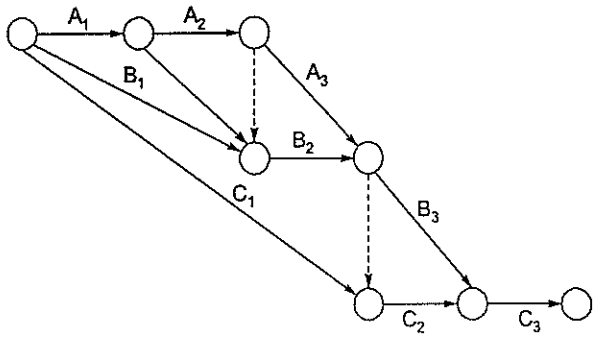
$$t = \frac{(5\text{min}) + (4 \times 20\text{min}) + (60\text{min})}{6}$$

$$= 24.16667 \text{ min} = 24\frac{1}{6}\text{ min}$$

2.79 (d)

PERT reflects on time.

2.85 (b)



From diagram, 2 is the optimum number of dummy arrow.

2.86 (a)

$t_o = 16$ days,

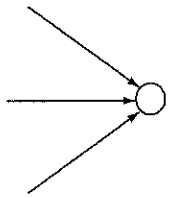
$t_m = 19$ days and $t_p = 28$ days

Expected duration,

$$t_E = \frac{16 + 4 \times 19 + 28}{6}$$

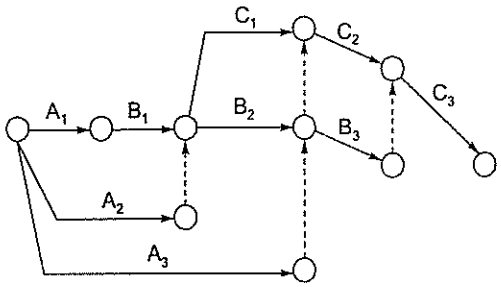
$$= 20 \text{ days}$$

2.87 (b)



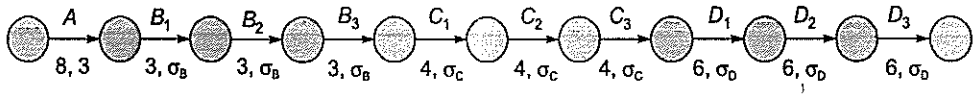
Merging Node

2.89 (c)



2.90 (a)

After splitting of activities, new network diagram will be as shown



$$4.5 = \sqrt{\sigma_B^2 + \sigma_B^2 + \sigma_B^2}$$

$$\Rightarrow \quad 4.5 = \sqrt{3\sigma_B^2}$$

$$\Rightarrow \quad \sigma_B = \sqrt{\frac{(4.5)^2}{3}}$$

Similarly, $\sigma_C = \frac{3}{\sqrt{3}}$, $\sigma_D = \frac{1.5}{\sqrt{3}}$

Standard deviation of total project,

$$\sigma = \sqrt{3^2 + 3\sigma_B^2 + 3\sigma_C^2 + 3\sigma_D^2}$$

$$= \sqrt{3^2 + 4.5^2 + 3^2 + 1.5^2}$$

$$= 6.36$$

2.91 (b)

Float is associated with activity not events. Time and cost both are controlling factors. In CPM only one time estimate is required for any activity.

2.92 (a)

$$F_T = LST - EST = LFT - EFT \quad ...(i)$$

$$F_F = F_T - S_j \quad ...(ii)$$

$$F_{ID} = F_F - S_i \quad ...(iii)$$

$$F_{IN} = S_j = F_T - F_F \quad ...(iv)$$

where,

F_T = Total float
F_F = Free float
F_{ID} = Independent float
F_{IN} = Interfering float
S_i = Tail event slack
S_j = Head event slack

From eq. (iii)

$F_F > F_{ID}$

From eq. (ii)

$F_F < F_T$

Thus free float (F_F) is greater than independent float.

2.93 (d)

Slack can be positive, negative or Zero. For critical events slack will be minimum (or zero). Slack is associated with events so statement b is wrong as it mentions activities not events.

2.95 (b)

Noncritical activities, do not demand special attention since there is a float time available to complete that activity.

■■■■

3 Crashing, Resource Allocation, Updating & Engineering Economy

3.1 In resources levelling
(a) total duration of project is reduced
(b) total duration of project is increased
(c) uniform demand of resources is achieved
(d) cost of project is controlled

[ESE : 1995]

3.2 The original cost of an equipment is Rs. 10,000. Its salvage value at the end of its total useful life of five years is Rs. 1,000. Its book value at the end of two years of its useful life (as per straight line method of evaluation of depreciation) will be
(a) Rs. 8,800 (b) Rs. 7,600
(c) Rs. 6,400 (d) Rs. 5,000

[ESE : 1995]

3.3 The following table contains data on four activities, A, B, C and D:

Activity	Starts at Week number	Ends with Week number	Resources needed per week
A	9th	16th	6
B	11th	20th	4
C	15th	22th	3
D	13th	24th	7

The maximum total resource load in any week will be
(a) 20 (b) 17
(c) 16 (d) 14

[ESE : 1995]

3.4 Three activities implementable in parallel, have the following time-cost relationships for direct cost component in each:
Activity A:
10 days-800 units; 9 days-900 units; 8 days-1000 units
Activity B:
11 days-1200 units; 10 days-1350 units; 9 days-1500 units
Activity C:
7 days-500 units; 6 days-700 units; 5 days-900 units
The feasible range of total direct cost component for the three activities together is
(a) 2500 to 3400 units
(b) 2650 to 3200 units
(c) 2500 to 2900 units
(d) 2600 to 3100 units

[ESE : 1995]

3.5 Consider the following statements:
A floating floor construction can
1. efficiently absorb impact noise
2. efficiently insulate against impact noise
3. efficiently insulate against airborne noise
Which of these statements are correct?
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE : 1996]

3.6 Cost-benefit studies are essential to
(a) assess the total cost of the work
(b) ascertain the relevant escalation in prices
(c) monitor the expenditure
(d) evaluate the viability and worthwhileness of taking up the project

[ESE : 1996]

3.7 Window sills in residential houses are normally kept at
(a) 83 to 90 cm above the floor level
(b) 80 to 90 cm above the floor level
(c) 78 to 88 cm above the floor level
(d) 75 to 85 cm above the floor level

[ESE : 1996]

3.8 Consider the following statements:
Resource levelling means
1. economical utilization of resources
2. gradual increase in resources
3. adjustment of resources to have the least variations.
4. complete revamping of resources to suit the requirements
5. validating network depending on resource constraints

Which of these statements are correct?
(a) 1 and 2 (b) 2, 3 and 4
(c) 3 and 5 (d) 1, 2, 3, 4 and 5

[ESE : 1997]

3.9 The issue rate of an item stocked in stores is
(a) permanently fixed
(b) fixed at the beginning of each year
(c) a rate less than the market rate
(d) the rate revised during the year when there is an appreciable variation in the rates of the items

[ESE : 1997]

3.10 Assertion (A) : The point of minimum total cost of equipment occurs when the inventory procurement cost is equal to the inventory holding cost.
Reason (R) : The inventory procurement cost is inversely proportional to the size of the lot, and the inventory holding cost is directly proportional to the size of the lot.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1998]

3.11 It is desired to purchase four different types of construction equipment from three different manufactures. The optimal order for the equipment and the minimal cost are to be determined. The most appropriate model for this purpose would be
(a) Waiting line model
(b) Inventory model
(c) Transportation model
(d) Assignment model

[ESE : 1998]

3.12 Consider the following statements:
Crashing a project in terms of its duration would result in
1. an increase in the indirect cost
2. a decrease in the indirect cost
3. a decrease in the direct cost
4. an increase in the direct cost

Which of these statements are correct?
(a) 1 and 4 (b) 2 and 3
(c) 1 and 3 (d) 2 and 4

[ESE : 1998]

3.13 Which of the following are the possible changes during the updating of the project network?
1. Change in the duration of an activity.
2. Addition or deletion of an activity.
3. Change in the logical relationship among the activities

Select the correct answer using the codes given below :
(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE : 1998]

3.14 Cost of owning an equipment would include
(a) cost of depreciation, maintenance and repair, and fuel
(b) cost of investment, wages of the crew, and fuel
(c) cost of fuel, lubricating oil, investment, and depreciation
(d) cost of investment, major repairs, and depreciation

[ESE : 1998]

3.15 Sensitivity analysis is a study of
(a) comparison of profit and loss
(b) comparison of assets and liabilities
(c) changes in output due to change in input
(d) economics of costs and benefits of the project

[ESE : 1998]

3.16 With the usual notations, sinking fund factor is given by

(a) $(1+i)^n$ (b) $\frac{i}{(1+i)^n-1}$

(c) $\frac{1}{(1+i)^n}$ (d) $\frac{i(1+i)^n}{(1+i)^n-1}$

[ESE : 1998]

3.17 In the time-cost optimization, using CPM method for network analysis, the crashing of the activities along the critical path is done starting with the activity having
(a) longest duration
(b) highest cost slope
(c) least cost slope
(d) shortest duration

[ESE : 1998]

3.18 **Assertion (A) :** In resource levelling, the project completion time is not extended even though there is constraint in the availability of resources.
Reason (R) : There is generally a constraint against exceeding the project duration time.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1999]

3.19 In a project, the contractor is paid on the basis of the running bill for a month. The rate contract for concerning is Rs. 1000 per m^3 of concrete. The consumption of number of cement bags of weight 50 kg is 527. The mix proportion for the concrete is 1:1.4:2.75 with w/c ratio of 0.52. The approximate billing amount of the month will be
(a) Rs. 5,27,000 (b) Rs. 1,49,404
(c) Rs. 62,252 (d) Rs. 26,350

[ESE : 1999]

3.20 Activity *P* is followed by Activity *Q* which in turn, is followed by Activity *R*. The direct cost of these activities in relation to the choice of feasible durations table is given below:

	Activity P			Activity Q			Activity R		
Duration in days	7	6	5	8	7	6	9	8	7
Direct Cost Rs. '000	12	14	15	20	23	27	40	42	45

For all the three activities taken together the minimum possible direct cost for a total duration of 21 days will be
(a) Rs. 81,000 (b) Rs. 79,000
(c) Rs. 78,000 (d) Rs. 77,000

[ESE : 1999]

3.21 Capital recovery factor at 15% p.a. discrete compounding for 4 years is 0.35. Rs. 10,000 deposited now at 15% p.a. discrete compounding will yield an amount X at the end of each 4 year period in perpetuity. The value of X is
(a) Rs. 7,500 (b) Rs. 6,666
(c) Rs. 6,000 (d) Rs. 5,000

[ESE : 1999]

3.22 A machine costs Rs. 16,000. By constant rate of declining balance method of depreciation, its salvage value after an expected life of 3 years is Rs. 2,000. The rate of depreciation is
(a) 0.25 (b) 0.30
(c) 0.40 (d) 0.50

[ESE : 1999]

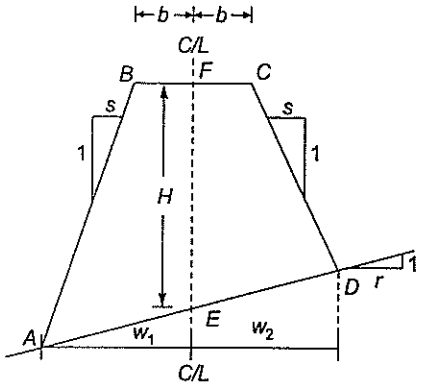
3.23 The outgo of investment in a project is estimated at 2000 units of money at year zero. The following four alternatives of revenue earning schemes are considered as possibilities, each at 6% ROR
1. 600 units of money at the end of each of the year 1st to 5th.
2. 800 units at the end of year 1, reducing at the rate of 100 units each year, ending with 400 units at the end of year 5.
3. 400 units at the end of year 1, increasing at the rate of 100 units each year, ending with 800 units at the end of year 5.
4. 400 units at the end of each of year 1 and year 2; with 600 units at the end of year 3; and with 800 units at the end of each of year 4 and year 5.

From the investor's point of view, the correct sequence in decreasing order of preference will be
(a) 2, 1, 4, 3 (b) 2, 4, 3, 1
(c) 3, 4, 2, 1 (d) 3, 1, 2, 4

[ESE : 1999]

3.24 A two-level section *ABCD* is shown in the given figure with ground slope 1 in r and formation slope 1 in s. *EF* is the centre line (C/L) of the formation.

Top width of the formation is $2b$ and widths to the toe are w_1 and w_2. The width 'w_1' will be



(a) $b+\frac{rs}{r-s}\left(H+\frac{b}{r}\right)$

(b) $b+\frac{rs}{r+s}\left(H-\frac{b}{r}\right)$

(c) $b-\frac{rs}{r-s}\left(H+\frac{b}{r}\right)$

(d) $b+\frac{rs}{r+s}\left(H+\frac{b}{r}\right)$

[ESE : 2000]

3.25 An equipment is available for Rs. 2,00,000. It has an estimated useful life of 5 years. By the double rate declining balance method of depreciation, the book value at the end of the second year will be

(a) Rs. 1,28,000 (b) Rs. 1,20,000
(c) Rs. 72,000 (d) Rs. 60,000

[ESE : 2000]

3.26 Every m^3 of excavation requires either 3 man-hours or 0.2 machine-hour. The respective rates are Rs. 8 per man-hour and Rs. 200 per machine-hour. A total quantity of 4000 m^3 of excavation is to be done. The possible minimum total cost for the complete job, by a suitable combination of manual and mechanical means of excavation will be

(a) Rs. 80,000 (b) Rs. 1,20,000
(c) Rs. 1,50,000 (d) Rs. 1,80,000

[ESE : 2000]

3.27 A project is of 4 months duration and needs expenditure of Rs. 15,000 per month uniformly, which should be available readily on hand at the beginning of each month. Bills can be raised with 15% profit over cost at the end of each month of work. The amount due on a bill raised will be reimbursed with a further months' delay without any deductions. The working capital required and the duration for which its maximum is needed are respectively

(a) Rs. 15,000 and from beginning to end of month 1
(b) Rs. 15,000 and uniformly from beginning to end of month 4
(c) Rs. 30,000 and from end of month 1 to end of month 2
(d) Rs. 45,000 and just at the end of the 2nd month

[ESE : 2000]

3.28 Five activities are scheduled between time–3 days and time – 14 days in a bar chart. Resource loading per day for these activities, along with their durations as read on the bar chart grid are:

Activity	A	B	C	D	E
Duration	3-8	4-12	10-14	7-11	11-14
Resource loading per day	5	4	8	3	2

Match List-I (Resource loading per day) with List-II (Day number) derived from above data and select the correct answer using the codes given below the lists:

List-I	List-II
A. 16	1. 12th
B. 15	2. 14th
C. 14	3. None
D. 12	4. 11th
	5. 8th

Codes :

	A	B	C	D
(a)	3	4	5	2
(b)	4	3	1	5
(c)	4	2	5	1
(d)	3	4	1	5

[ESE : 2000]

3.29 Assertion (A) : Project-time-cost schedules (inclusive of indirect costs) always show decreasing overall costs for decreasing overall project duration (so long as such compression is feasible).

Reason (R) : Generally, the incremental rate increases as consumption of a resource increases.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2000]

3.30 The probability that the load on a scaffolding will exceed 2 t is 0.15. The probability that the strength of the scaffolding will be more than 2 t is 0.8. The probability of failure of the scaffolding will be

(a) 0.68 (b) 0.17
(c) 0.12 (d) 0.03

[ESE : 2000]

3.31 Concreting at site can start on any one day, with all preparations having been done on the previous day. As per the past experience of owner, contractor and the architect, it is decided that the chance of any one being late is 0.4. The chance of starting on time on the appointed day is

(a) 0.064 (b) 0.216
(c) 0.288 (d) 0.432

[ESE : 2001]

3.32 In the time-cost analysis, the cost slope is defined as

(a) $\frac{\text{Crash cost} - \text{Normal cost}}{\text{Crash time} - \text{Normal time}}$
(b) $\frac{\text{Crash time} - \text{Normal time}}{\text{Crash cost} - \text{Normal cost}}$
(c) $\frac{\text{Crash cost} - \text{Normal cost}}{\text{Normal time} - \text{Crash time}}$
(d) $\frac{\text{Normal cost} - \text{Crash cost}}{\text{Normal time} - \text{Crash time}}$

[ESE : 2001]

3.33 Which one of the following is the base for resource levelling?

(a) Delaying the completion of critical activities
(b) Delaying the start of non-critical activities
(c) Reducing completion time of critical activities
(d) Not delaying the completion of critical activities

[ESE : 2001]

3.34 A construction equipment has a useful life of 5 years after which it is to be replaced by a new one. If the interest rate is 4%, the sinking fund factor will be

(a) 0.033 (b) 0.184
(c) 0.224 (d) 0.232

[ESE : 2001]

3.35 For supplying water to a city, two alternate design concepts are being considered with 8% p.a. discrete compounding as the criterion. A rock tunnel of indefinitely long life will cost Rs. 30 lakhs now, and will need Rs. 60,000 per year for operations. The alternative is by a pipe line system, with an expected life of 20 years, at a first cost of Rs. 20 lakhs now, and will need annual operating expenses of Rs. 92,000. In term of annualized costs, the tunnel system will have a relative disadvantage of (given C.R.F. at 8% p.a. discrete compounding for 20 years = 0.10185) nearly

(a) Rs. 14,000 (b) Rs. 11,000
(c) Rs. 8,200 (d) Rs. 4,300

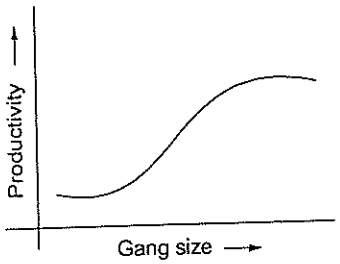
[ESE : 2001]

3.36 Payment allowance is selected keeping in mind

(a) overall cost
(b) normal profit and total time
(c) overall cost and total time
(d) overall cost, normal profit and total time

[ESE : 2001]

3.37 Consider the following statements regarding the curve shown in the given figure:



As the gang size increases,

1. the out-turn rate of the gang will always increase irrespective of the number of gang
2. the out-turn rate of the gang will decrease once it exceeds the optimal number
3. beyond the optimal number, the inefficiency of the gang will increase.

Which of these statements are correct?

(a) 1, 2 and 3 (b) 1 and 2

(c) 2 and 3 (d) 1 and 3

[ESE : 2001]

3.38 Pay-back period gives an estimate of

(a) profitability

(b) liquidity

(c) time-value of money

(d) interest rate of return

[ESE : 2001]

3.39 The optimum duration is the

(a) the summation of normal-durations of each activity in the project

(b) summation of the normal-duration of activities on critical path

(c) one, which gives the minimum total cost for completing the project

(d) summation of crash-time of activities on critical path

[ESE : 2002]

3.40 In order to investigate a method of least-cost scheduling, which of the following assumptions are made?

1. The planned duration of an activity can be any whole day value between the normal and crash durations.
2. The direct cost of an activity is linear between the normal and crash direct costs.
3. The overhead costs is linear during the entire project.

Select the correct answer using the codes given below :

(a) 1 and 2 (b) 1 and 3

(c) 2 and 3 (d) 1, 2 and 3

[ESE : 2002]

3.41 Which one of the following statements applies to the declining balance method of depreciation accounting?

(a) Uniform write-off of cost throughout the service is aimed

(b) Greater write-off in the early years is aimed

(c) Smaller write-off in early years is aimed

(d) A varying rate of depreciation is applied on the basis of market value of the asset

[ESE : 2002]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

3.42 Assertion (A) : The salvage value is less in the initial period of the equipment and increases as the equipment ages.

Reason (R) : The salvage value of an equipment is the actual amount that can be realized on a trade-in for a replacement machine.

[ESE : 2002]

3.43 Assertion (A) : When attempting resource optimization, activity-time cost trade off information could be gainfully employed.

Reason (R) : Generally, as activity time is extended beyond the minimum cost duration, splitting of the activity duration is always possible.

[ESE : 2002]

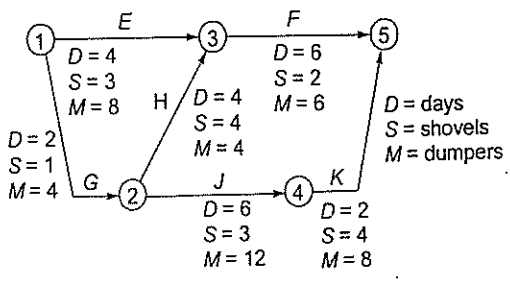
3.44 An equipment is purchased for Rs. 40,000.00 and is fully depreciated by straight line method over 8 years. Considering interest on average annual cost at 15% p.a., the charge on the company due to use of this equipment, if made uniformly over the 8 years, is

(a) Rs. 5,750 (b) Rs. 8,000

(c) Rs. 8,375 (d) Rs. 14,000

[ESE : 2002]

3.45 In the network given below, the maximum number of shovels and dumpers required are



(a) 6 shovels and 14 dumpers on days 9 and 10
(b) 24 shovels and 10 dumpers on days 3 and 4
(c) 30 shovels and 90 dumpers on all days
(d) 10 shovels and 24 dumpers on days 3 and 4

[ESE : 2002]

3.46 The probability that the load on a scaffolding will exceed the design load of 3 tonnes is 0.15. At the same time, the probability that the strength of the scaffolding will be more than 3 tonnes is 0.85. The probability that the scaffolding will fail is

(a) 0.2775 (b) 0.1275
(c) 0.0225 (d) 0.0020

[ESE : 2002]

3.47 In time-cost analysis, the cost slope C_s is

(a) $\frac{C_c - C_n}{t_c - t_n}$ (b) $\frac{C_c - C_n}{t_n - t_c}$

(c) $\frac{t_c - t_n}{C_c - C_n}$ (d) $\frac{C_n - C_c}{2(t_n - t_c)}$

where C_c = Crash cost
C_n = Normal cost
t_c = Crash time
t_n = Normal time

[ESE : 2003]

3.48 Sinking fund method is useful in

(a) depreciation (b) obsolescence
(c) liquidation (d) scrap value

[ESE : 2003]

3.49 Cost of required materials for construction has been estimated by a contractor and an extract thereof indicates: Rs. 80,000 for month-1, Rs. 1,20,000 for month-2, Rs. 1,00,000 for month-3 and Rs. 1,40,000 for month-4. He has arranged with suppliers to pay 40% immediately on purchase, 40% one month later and balance 20% two months later. His payment towards cost of materials in month-3 will exceed that in month-4 by

(a) Rs. 20,000 (b) Rs. 16,000
(c) Rs. 12,000 (d) Rs. 8,000

[ESE : 2003]

3.50 Match List-I (Cost) with List-II (Feature) and select the correct answer using the codes given below the lists:

List-I
A. Optimal cost
B. Overhead cost
C. Direct cost
D. Indirect cost

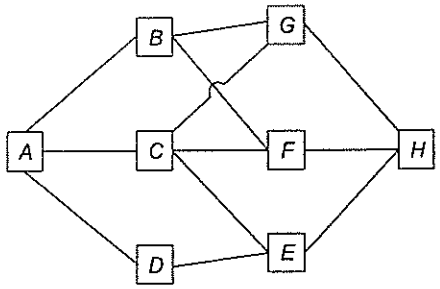
List-II
1. Activity related
2. Developed by crashing process
3. Project-related
4. Contained in, or contributing exclusively to the related product

Codes:

	A	B	C	D
(a)	4	3	2	1
(b)	2	1	4	3
(c)	4	1	2	3
(d)	2	3	4	1

[ESE : 2004]

3.51 Consider the AON diagram below:
What is the minimum number of dummy arrows required for conversion into AOA diagram?



(a) 3 (b) 4
(c) 5 (d) 6

[ESE : 2004]

3.52 Assertion (A) : In resource levelling approach of resource allocation, activity start times are scheduled such that the peak demand for a particular resource remains within available limit of the resources.
Reason (R) : In resource levelling approach of resource allocation, the total project time is not changed.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2005]

3.53 What is the process of incorporating changes and rescheduling or replanning called?
(a) Resource allocation
(b) Resource smoothing
(c) Resource levelling
(d) Updating

[ESE : 2006]

3.54 The depreciation charges for a machine are thirty paise per working hour. The machine has scrap value of Rs. 2,000 and a working hour average life of 24000 hours. What is the purchase price of the machine?
(a) Rs 1,800 (b) Rs 7,200
(c) Rs 9,200 (d) Rs 14,275

[ESE : 2007]

3.55 Assertion (A) : Time cost studies have to be firmed up before the EOQ and ABC analysis can be undertaken.
Reason (R) : Time cost studies can be premised on no bottlenecks or shortages in materials procurement.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2007]

3.56 A tunnel of length of 800 m is to be driven. Part of the total length is through granite and balance is through sandstone. Granite can be tunneled at 10 m per day and sandstone at 20 m per day. Two mutually exclusive site conditions can be (i) A probability of 0.4 for 600 m granite with 200 m sandstone; (ii) Probability of 0.6 that each is 400 m long. The probabilistic estimate of total tunneling duration is
(a) 74 days (b) 68 days
(c) 64 days (d) 60 days

[ESE : 2008]

3.57 Assertion (A): Whereas crashing considers only the negative cost slope aspects, resource allocation may need consideration of the positive cost slope aspects also.
Reason (R): Implementability is based on manageability and affordability of resource histograms.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2008]

3.58 An equipment costs Rs. 25 Lakhs with an estimated salvage value of Rs. 5 Lakhs after 5 years of useful life. What is the approximate equated annual cost for use of the equipment ?
(a) Rs. 4 Lakhs (b) Rs. 10 Lakhs
(c) Rs. 13 Lakhs (d) Rs. 17 Lakhs

[ESE : 2009]

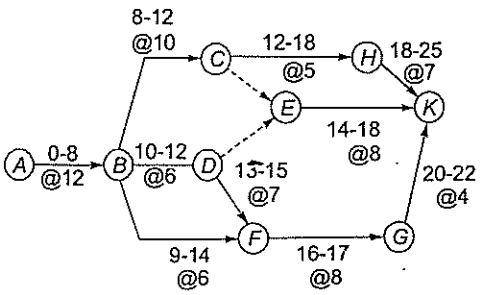
3.59 A preliminary survey indicates that 20% of the time of a gang of workers is spent idly. What is the total number of observations required to determine the proportion of idle time with 95% confidence limit ? Critical value at this level of confidence is 1.96.
(a) 236 observations (b) 246 observations
(c) 256 observations (d) 266 observations

[ESE : 2009]

3.60 A construction equipment has a useful life of 4 years after which it is to be replaced by a new one. If the interest rate is 6%, what is the nearest value of the sinking fund factor ?
(a) 0.023 (b) 0.23
(c) 0.17 (d) 0.31

[ESE : 2009]

3.61 The scheduled durations, by the convention 'after/at the end of indicated day number' and the cost per day of duration, of each activity are shown in the network below.

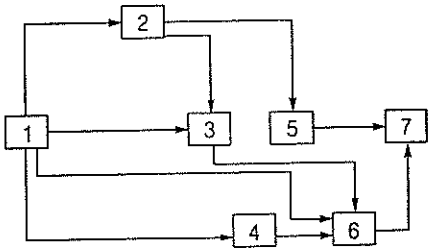


What are the costs incurred on day numbers 13 and 17?

(a) 14 and 20 (b) 11 and 18
(c) 14 and 21 (d) 11 and 21

[ESE : 2009]

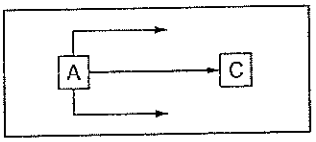
3.62 How many links are deletable in the A-O-N network shown below?

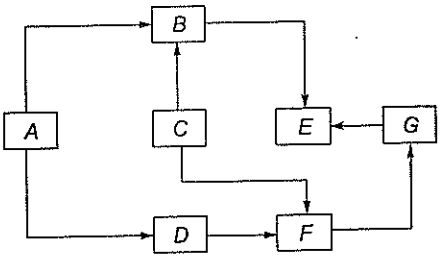


(a) None (b) One
(c) Two (d) Three

[ESE : 2009]

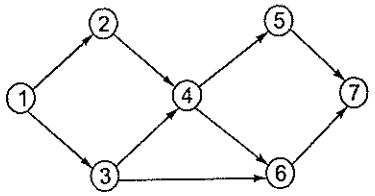
3.63 Consider the accompanying A-O-N diagram :



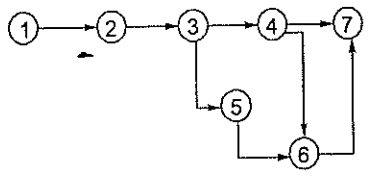


Which one of the following *A-O-A* diagrams correctly represents this *A-O-N* diagram?

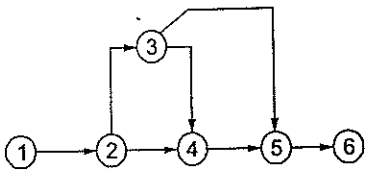
(a)



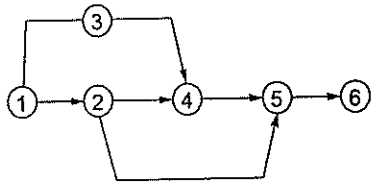
(b)



(c)



(d)



[ESE : 2009]

3.64 A uniform series of income is available in perpetuity, which will yield an amount of Rs. 4,000/-at the end of each 4-year period. Sinking fund (deposit) factor, @ 8% p.a., for discrete compounding, is 0.222. For the same interest rate, what will be the capitalized equivalent income 'now' ?

(a) Rs. 11,100 (b) Rs. 12,500
(c) Rs. 14,285 (d) Rs. 16,000

[ESE : 2009]

3.65 Which one of the following is relevant to Activity on Node (AON)?

(a) Dummy activities may be many
(b) There will be no dummy activities
(c) It is used for quite complex project
(d) It is easier to associate with time flow of activities.

[ESE : 2010]

3.66 A building contractor discovers from his record that in the last 200 slab castings his mixer machine broke down 21 times. During each breakdown, he had to pay on an average about Rs. 2,500 for idle labour. A standby mixer machine, if hired on the day of slab casting, would cost him Rs. 200 per day. The expected loss is more than the mitigation expense of hiring the mixer by

(a) Rs. 151.50 (b) Rs. 241.50
(c) Rs. 262.50 (d) Rs. 283.50

[ESE : 2010]

3.67 Consider the following statements regarding the slope of cost-time curve:

1. It is given by difference between normal cost and crash cost divided by crash time.

2. It is given by difference between crash cost and normal cost divided by difference between crash time and normal time.
3. It is given by difference of crash cost and normal cost divided by normal time.
4. It is given by crash cost divided by crash time.

Which of these statements is/are correct?

(a) 1 only (b) 2 and 3
(c) 2 only (d) 3 and 4

[ESE : 2010]

3.68 Consider the following statements:

1. The resources are considered to be unlimited.
2. The resources are considered to be limited.
3. The start times of some of the activities are so shifted within their available floats that the uniform demand is created for the resources.

Which of these statements is/are correct?

(a) 1 only (b) 1, 2 and 3
(c) 2 and 3 only (d) 1 and 3 only

[ESE : 2010]

3.69 A unit of equipment costs Rs. 25 Lakh and has a life of 5 years with no salvage value. The average annual cost of this equipment based on straight-line depreciation is

(a) Rs. 5 Lakh (b) Rs. 10 Lakh
(c) Rs. 15 Lakh (d) Rs. 20 Lakh

[ESE : 2010]

3.70 **Assertion (A):** Activity-on-node network eliminates the use of dummy activities.
Reason (R): It is self-sufficient as it contains all activity times on the nodes itself.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2010]

3.71 Which one of the following is the objective in crashing?

(a) Reduction in duration
(b) Reduction in resources
(c) Reduction in cost
(d) Reduction in project size

[ESE : 2011]

3.72 A contractor wishes to determine a suitable combination of manual labour and machine work for the excavation of a multistorey construction. For every cum of excavation, 3 man-hours are needed; or 0.2 machine-hour. Costs involved are Rs. 20 per man-hour and Rs. 500 per machine-hour. The total quantity of excavation is estimated to be 4000 cum. The optimal quantity of excavation to be done manually for minimum total cost will be

(a) 1500 cum (b) 1800 cum
(c) 2250 cum (d) 2500 cum

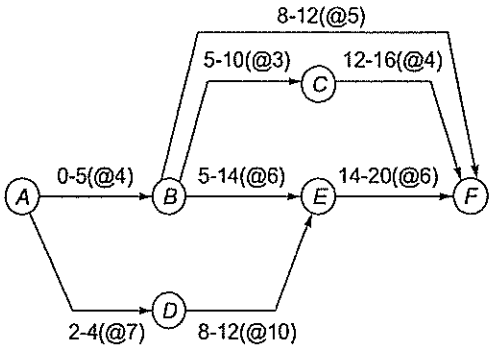
[ESE : 2011]

3.73 A crane is purchased now; its useful life is 8 years after which a new crane must be purchased. If the interest rate is 6%, the capital recovery factor (CRF) is

(a) 0.3141 (b) 0.5420
(c) 0.1610 (d) 0.1259

[ESE : 2011]

3.74 Scheduled durations (in days) of activities and their respective resource requirement (in units per day) are shown on the diagram. What is the total number of units of resource required on the 11th and the 16th days?



(a) 21 and 10 (b) 18 and 12
(c) 18 and 10 (d) 21 and 12

[ESE : 2012]

3.75 It takes 0.4 hrs to drive from the garage to the head of the route, 0.4 hrs to drive between the route head and disposal site and 0.25 hrs to return from the disposal site. It takes 0.2 hrs to off-load a truck at the disposal site. The crew is permitted two 15-minute breaks and a further 30 minutes for miscellaneous delays. If two runs are made to the deposit site each day, how much time is left

in an 8-hr nominal duty duration for refuse collection before starting to return to garage from disposal site? Take loading time as 30 minutes.

(a) 4.15 hrs (b) 4.25 hrs
(c) 4.75 hrs (d) 4.85 hrs

[ESE : 2012]

3.76 In construction project, the cost-slope of an activity is an indication of

(a) extra-time needed
(b) extra cost needed
(c) reduction of duration of critical activity
(d) crashing of an activity

[ESE : 2013]

3.77 An equipment for use in construction activity is purchased now for Rs. 15000, and is used continuously on the job. The annual OMR costs assignable as lump sum at the respective year beginning are Rs. 5000. The equipment will be used for 5 years after which its salvage value is estimated to then be Rs. 1000. The equipment annual cost as reckoned at the end of each year when MACR is 10% for which SFF for 5 years is 0.1638 is

(a) Rs. 7800 (b) Rs. 8000
(c) Rs. 8793 (d) Rs. 8957

[ESE : 2013]

3.78 A four-cycle gasoline engine when tested at temperature 35°C and pressure of 740 mm of Hg was found to develop 75 HP. Its horse power at standard condition is

(a) $75\times\frac{308}{288.5}\times\frac{740}{760}$

(b) $75\times\frac{288}{308}\times\frac{760}{740}$

(c) $75\times\sqrt{\frac{308}{288.5}}\times\sqrt{\frac{740}{760}}$

(d) $75\times\frac{760}{740}\times\sqrt{\frac{308}{288.5}}$

[ESE : 2013]

3.79 Given that SPCAF, for 10%, for 1, 2 and 3 years are respectively, 1.1000, 1.2100 and 1.3310, what is C.R.F. for 10% for 3 years?

(a) 0.7513 (b) 0.5187
(c) 0.3021 (d) 0.4021

[ESE : 2013]

3.80 An equipment costs Rs. 25000 to purchase now. It will be used continuously for 8 years. At the end, its salvage value is estimated to be Rs. 1600. Its residual book value at the beginning for the 6th year its use, by the straight line method of depreciation is

(a) Rs. 6250 (b) Rs. 9375
(c) Rs. 10375 (d) Rs. 7450

[ESE : 2013]

3.81 PERT calculations yield a project length of 70 weeks with a variance of 9 weeks. The number of weeks required to complete the project with a probability of 95% (probability factor for 95% = 1.647) is

(a) 73.94 weeks (b) 74.94 weeks
(c) 75.94 weeks (d) 76.94 weeks

[ESE : 2013]

3.82 A linear project is split into six identical activities, each having a, m and b durations of 4, 8 and 10 days, which results in the standard deviation of the duration for the complete project being X_1 days. As an alternative attempt at project planning, the earlier-split six activities are clubbed as (1st and 2nd), (3rd and 4th) and (5th and 6th), thus needing to consider only three (now-modified) activities; and the standard deviation of the duration for the complete project is now reported as X_2 days. What will be the ratio $\frac{X_2}{X_1}$?

(a) $\frac{2}{3}$ (b) $\frac{7}{6}$

(c) $\frac{5}{6}$ (d) 1

[ESE : 2013]

3.83 A project is estimated to cost Rs. 100 million inclusive of 20% thereof as cost of direct labour. However, 60% of the labour hours budgeted for is non-productive. If 15% of such wasted labour hours are intended to be curtailed by improved methods of control, then the resulting savings in labour cost would be

(a) Rs. 1.2 million (b) Rs. 1.5 million
(c) Rs. 1.8 million (d) Rs. 2.0 million

[ESE : 2013]

3.84 Consider the following statements regarding resource allocation/adjustment:

1. Economical utilization of resources.
2. Adjustment of resources to have leave variation in resource histogram.
3. Gradual increase in resources.
4. Activities are so rescheduled that maximum projected need for any resource does not cross the limit of available resources.

Which of these statements are correct?

(a) 1 and 2 (b) 2 and 3
(c) 3 and 4 (d) 2 and 4

[ESE : 2013]

3.85 There is a task involving 160 m^2 of fixing timber formwork for the roof slab of a single-storey building. The time earmarked for completion is four days, working eight hours per day. If a workers' team consisting of two skilled workers and a unskilled worker can install the formwork at the rate of 1.25 m^2/hr, then the number of teams required is

(a) 3 (b) 4
(c) 5 (d) 6

[ESE : 2013]

Directions: Each of the next items consists of two statements, one labeled as the **'Statements (I)'** and the other as **'Statement (II)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below :

Codes:

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

3.86 **Statement (I):** Probabilistic activity durations may yet be relevantly assigned even when work outputs have been standardized for labour gangs for the specified project.

Statement (II): Results of work-study are dependent on rest allowances and work ratings.

[ESE : 2013]

3.87 **Statement (I):** When developing the time-cost study of a project as a whole, the time-cost relationships of every activity therein may have necessarily to be inputted.

Statement (II): Any project is constituted by all the activities therein.

[ESE : 2013]

3.88 **Statement (I):** When an equipment is used at a reduced post of service, the ROR cannot be uniquely determined even when the log book of the equipment has been maintained regularly.

Statement (II): OMR expenditure may be very much reduced when used in reduced post of service.

[ESE : 2013]

3.89 **Statement (I) :** In resource levelling, project completion time is not extended provided there is no constraints on availability of resources.

Statement (II) : There is generally a constraint against exceeding the project duration time.

[ESE : 2014]

3.90 Three consecutive activities *A*, *B* and *E* (in that order) have their *T*-duration (in days) vs. *C*–Direct Cost (in monetary units) relationship expressed in the following table:

A		*B*		*E*	
T	C	T	C	T	C
8	15	6	7	4	11
9	14	7	6	5	12
10	16	8	7	6	13

What is the optimum duration for the corresponding minimum total direct cost for all the three activities when taken up consecutively without pause or disruption?

(a) 22 days (b) 21 days
(c) 20 days (d) 19 days

[ESE : 2014]

Directions: Each of the next items consists of two statements, one labeled as the **'Statements (I)'** and the other as **'Statement (II)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below :

Codes:
(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

3.91 Statement (I): 'Lift' and 'lead', even if wherever relevant, do not affect any activity duration during the course of implementation of a project.
Statement (II): Procurement of materials, particularly, is normally from assigned, or designated, quarry sites, which are already fixed while starting the project.
[ESE : 2015]

3.92 Statement (I): Time-Cost Study for a project must be adopted only when project duration is to be crashed.
Statement (II): When there are unmanageable restrictions in realizing a predetermined resource histogram, Time-Cost Study may have to consider extension of project duration as well.
[ESE : 2015]

3.93 Statement (I): Crashing of project duration always increases the cost of the project on its completion, no matter what the indirect, or outhead, costs are.
Statement (II): The critical path along the project activities network diagram is compressed in the process of investigating the crashing of the project duration, and not the non-critical activities, up to a certain stage of crashing.
[ESE : 2016]

3.94 Statement (I) : Resources Optimization is largely a pre-implementation pursuit whereas Resources Allocation is a through-implementation dynamic process.
Statement (II): Resources Allocation has a larger bearing on Inventory Management than Resources Optimization.
[ESE : 2016]

3.95 A small project consists of 3 activities *P*, *Q* and *R* to be executed in that sequence. The relationship between Time Duration (in 'Units' of time-*T*) and corresponding total direct cost (*C* units) for each of the activities, for alternate mutually exclusive possible durations for each activity, are tabulated herewith:

P		Q		R	
T	C	T	C	T	C
8	250	6	340	8	400
9	235	7	320	10	375
10	225	8	295	12	350
11	215	9	275		

For a total duration of 25 units of time, the least total direct cost for the complete project will be
(a) 965 units (b) 950 units
(c) 940 units (d) 925 units
[ESE : 2016]

3.96 Consider the following statements regarding tendering for a civil work:
1. Earnest money deposit (EMD) is a prerequisite to tender for a work.
2. It is not essential to call for the contractor's credentials when a tender is invited.
Which of the above statements is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2
[ESE : 2017]

3.97 Consider the following statements regarding quality control:
1. It refers to absolute conformity to specifications.
2. It may not vouch against overspending.
3. It may unknowingly resort to overdesign in the hope of risk minimization.
4. It is intended to reduce maintenance costs.
Which of the above statements are correct?
(a) 1 and 3 (b) 2 and 3
(c) 2 and 4 (d) 1 and 4
[ESE : 2017]

Answers Crashing, Resource Allocation, Updating and Engineering Economy

3.1 (c)	3.2 (c)	3.3 (a)	3.4 (a)	3.5 (d)	3.6 (d)	3.7 (b)	3.8 (c)	3.9 (d)	
3.10 (a)	3.11 (a)	3.12 (d)	3.13 (a)	3.14 (d)	3.15 (a)	3.16 (b)	3.17 (c)	3.18 (a)	
3.19 (c)	3.20 (d)	3.21 (a)	3.22 (d)	3.23 (a)	3.24 (a)	3.25 (c)	3.26 (b)	3.27 (c)	
3.28 (d)	3.29 (d)	3.30 (d)	3.31 (b)	3.32 (c)	3.33 (b)	3.34 (b)	3.35 (d)	3.36 (d)	
3.37 (c)	3.38 (b)	3.39 (c)	3.40 (d)	3.41 (b)	3.42 (d)	3.43 (b)	3.44 (c)	3.45 (d)	
3.46 (c)	3.47 (b)	3.48 (a)	3.49 (b)	3.50 (d)	3.51 (a)	3.52 (c)	3.53 (d)	3.54 (c)	
3.55 (b)	3.56 (c)	3.57 (a)	3.58 (a)	3.59 (*)	3.60 (b)	3.61 (d)	3.62 (c)	3.63 (c)	
3.64 (a)	3.65 (b)	3.66 (*)	3.67 (c)	3.68 (c)	3.69 (a)	3.70 (a)	3.71 (c)	3.72 (d)	
3.73 (c)	3.74 (a)	3.75 (b)	3.76 (b)	3.77 (c)	3.78 (d)	3.79 (d)	3.80 (c)	3.81 (b)	
3.82 (d)	3.83 (c)	3.84 (d)	3.85 (b)	3.86 (b)	3.87 (a)	3.88 (d)	3.89 (a)	3.90 (c)	
3.91 (d)	3.92 (b)	3.93 (d)	3.94 (b)	3.95 (d)	3.96 (a)	3.97 (d)			

Explanations Crashing, Resource Allocation, Updating and Engineering Economy

3.1 (c)

In resource levelling the total project duration is not changed but some of the activity start times are shifted by their available float so that more or less uniform resource demand is guaranteed.

In resource smoothening, the activity start times are so rescheduled that the peak demand does not exceed the available limit of resource. If it does not give desirable result by consideration of floats, the total project duration to minimum extent may be extended.

3.2 (c)

$$\text{Annual depreciation} = \frac{P - C_s}{n}$$

$$= \frac{10000 - 1000}{5} = 1800$$

$\therefore$ Book value at the end of two years

$$= 10{,}000 - 2 \times 1800 = 6400$$

3.3 (a)

15^{th} - 16^{th} week demands most resources because four activities A,B,C,D will run in parallel in that week.

Resource load = 6+4+3+7=20

3.4 (a)

The minimum cost for normal duration of all activities = 800 + 1200 + 500 = 2500 units.

The maximum cost for crash duration of all activities = 1000 + 1500 + 900 = 3400 units.

3.5 (d)

Impact noise or structure-borne noise is developed in solid structures and it is then transmitted as air-borne noise. The closing of doors, vibrations of machines etc. set up vibrations in solid materials of the structure which result in the transmission of noise to the receiving room.

The air-borne noise has less power, continues for a long time and is confined to places near its origin. The impact noise has more power, continues for a short duration and is often propagated over long distances.

In floating floor construction, the floor is separated from the structural floor by a layer of resilient material such as quilted mineral or glass wool. It can insulate against air-borne noise and can reduce the impact noise. So 1 and 3 are correct.

3.7 (b)
Window sills are provided to give a suitable finish to the window opening and to protect the external wall below such opening.

3.8 (c)
In resource levelling the activities are so rescheduled that the maximum or peak demand for the resources does not exceed the available resources. Thus in resource levelling the main constraint is on the resources. However, the resources cannot be less than the maximum amount needed for any activity of the project.

3.9 (d)
Issue rate denotes cost per unit fixed on the article of stock for the purpose of calculating the amount creditable to the subhead concerned of stock account when issued from stock. An issue rate is fixed for each article of stock on the basis of actual cost plus other expenses including storage charges. So this rate should be revised when there is variation in the rates of the item.

3.10 (a)

The inventory procurement cost $= \frac{DF}{Q}$

The carrying cost $= \frac{QC}{2}$

Total cost $= \frac{DF}{Q} + \frac{QC}{2}$

Where, $D \rightarrow$ Demand in units per year.
$Q \rightarrow$ Order quantity
$C \rightarrow$ Carrying or holding cost (per unit per year)
$F \rightarrow$ Fixed order cost

For minimum total cost,

$$\frac{DF}{Q} = \frac{QC}{2}$$

$\therefore$ Economic Order Quantity (EOQ)

$$Q = \sqrt{\frac{2DF}{C}}$$

3.11 (a)
Waiting line model is used for ensuring that resources required by numerous activities are adequate.

3.12 (d)
Crashing reduces duration and therefore indirect cost decreases while direct cost increase.

3.13 (a)
In updating sometimes it becomes imperative to change the original network as the work progress. Such an alteration may be due to several reasons such as the change in time schedule because of say, changes in the supply of materials, non-availability of additional labour during the project. Thus activity durations are changed and some activities may be added and those activities which are already complete may be deleted.

Due to change in the company's policy of execution the interdependence of some operations may change i.e. logical relationship among activities may change.

3.14 (d)
The most significant factors affecting ownership cost are :
(i) Purchase expense or initial cost.
(ii) Salvage value
(iii) Tax saving from depreciation
(iv) Major repairs and overhauls
(v) Property taxes
(vi) Insurance
(vii) Storage and miscellaneous
The operating cost includes fuel or energy cost and lubrication oil cost.

3.15 (a)
A sensitivity analysis involves explicit consideration of the economic impact of changes in the values of one or more parameter. The objective is to determine how sensitive the selection decision is to the values of the parameters used in the analysis. It can be done using
(i) Present worth method
(ii) Future worth method
(iii) Internal rate of return method
(iv) Annual worth method

3.16 (b)
The various factors used in calculation of depreciation are :

(i) Uniform series present worth factor

$$= \frac{(1+i)^n - 1}{i(1+i)^n}$$

(ii) Capital recovery factor $= \frac{i(1+i)^n}{(1+i)^n - 1}$

(iii) Uniform series compound amount factor

$$= \frac{(1+i)^n - 1}{i}$$

(iv) Sinking fund factor $= \frac{i}{(1+i)^n - 1}$

3.18 (a)

In resource levelling, the project completion time is not extended even though there is constraint in the availability of resources.

3.19 (c)

From Rule of Thumb:

1 bag of cement (50 kg) contains 0.035 m^3 of cement.

Yield of concrete of proportion (1:1.4:2.75)

$$= \frac{2}{3} \times 0.035 \times (1 + 1.4 + 2.75)$$

$$= 0.023 \times 5.15 = 0.12\ m^3$$

So concrete from 527 bags of cement will be

$$= 527 \times 0.12 = 63.24\ m^3$$

Therefore approximate billing

$$= 63.24 \times 1000 = 63240$$

The most close option is (c).

3.20 (d)

The activity with least cost slope is to crashed first. So for one day crash, the cost slope of activities are :

Activity	Cost slope (Rs. '000)
P	2
Q	3
R	2

So crashing *R* by one day first, and then *P* by one day. Now the direct costs of each activity and duration will be

Activity	Duration	Direct Cost Rs.'000
P	6	14
Q	8	20
R	8	42
Total	22	76

Now one day crashing is required to reach at desirable duration of 21 days. The activity P has least cost slope of Rs. 1000. So

Activity	Duration	Direct cost Rs.'000
P	5	15
Q	8	20
R	8	42
Total	21	77

3.21 (a)

Capital Recovery factor (*CRF*) = 0.35; $i = 0.15$

$$X = P\left[(1+i)^4 - 1\right]$$

$$= \frac{P \times i}{\text{Sinking Fund Factor } (SFF)}$$

$$S.F.F. = CRF - i$$

$$= 0.35 - 0.15 = 0.20$$

$$\therefore \quad X = \frac{10{,}000 \times 0.15}{0.20} = 7500$$

3.22 (d)

Rate of depreciation

$$r_D = 1 - \left(\frac{C_s}{C_i}\right)^{1/n}$$

Initial cost, $C_i = 16000$

Salvage value, $C_s = 2000$

$n = 3$

$$\therefore \quad r_D = 1 - \left(\frac{2000}{16000}\right)^{1/3} = 0.50$$

3.23 (a)

Alternative 1 : Annual earning,

$A_1 = 600$ units

Alternative 2: Equivalent annual earning,

$$A_2 = 800 - \frac{100}{i}[1 - n \times SFF]$$

Alternative 3: Equivalent annual earning,

$$A_3 = 400 + \frac{100}{i}[1 - n \times SFF]$$

Alternative 4: Equivalent annual earning,

$$A_4 = CRF \times \left[\frac{400}{(1+i)} + \frac{400}{(1+i)^2} + \frac{600}{(1+i)^3} + \frac{800}{(1+i)^4} + \frac{800}{(1+i)^5}\right.$$

For $i = 6\%$ $n = 5$

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} = 0.24$$

$\therefore$ $SFF = 0.24 - 0.06 = 0.18$

$$\therefore \quad A_2 = 800 - \frac{100}{0.06}(1 - 5 \times 0.18)$$

$$= \text{Rs. } 633.33$$

$$A_3 = 400 + \frac{100}{0.06} \times (1 - 5 \times 0.18)$$

$$= \text{Rs. } 566.67$$

$$A_4 = 0.24 \times \left[\frac{400}{1.06} + \frac{400}{(1.06)^2} + \frac{600}{(1.06)^3} + \frac{800}{(1.06)^4} + \frac{800}{(1.06)^5}\right]$$

$$= \text{Rs. } 592.47$$

The higher earning means, better choice. So correct decreasing order preference 2 – 1 – 4 – 3.

3.24 (a)

$$w_1 = b + \left(H + \frac{w_1}{r}\right) \times s$$

After rearranging, we get

$$w_1 = \frac{br}{(r-s)} + H\left(\frac{rs}{r-s}\right)$$

[After adding and subtracting $\frac{bs}{r-s}$]

$$w_1 = b + \frac{rs}{r-s}\left(H + \frac{b}{r}\right)$$

3.25 (c)

$n = 5$ years

Book value, $B_m = C_i \times (1 - FDB)^m$

Where $FDB = \frac{2}{n} = \frac{2}{5} = 0.4$

$\therefore \quad B_2 = 2{,}00{,}000 \times (1 - 0.4)^2$

$= 72{,}000$

3.26 (b)

Total cost when only man-hours are used

$C_1 = 4000 \times 3 \times 8 = 96{,}000$

Total cost when only machine-hours are used.

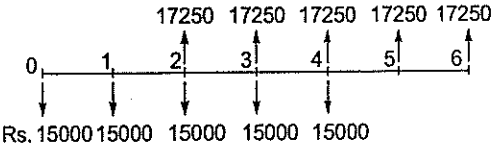
$C_2 = 4000 \times 0.2 \times 200 = 1{,}60{,}000$

The minimum cost with a combination of man and machine hours will lie between C_1 and C_2. So the cost is Rs. 1,20,000

3.27 (c)

The cash flow diagram will be developed by showing the expenditure as downward arrows and reimbursed amount as upward arrow.

Bill of any month = 15000 × 1.15 = 17250



The cash flow diagram shows that working capital required is 15000 + 15000 = 30000 to carry out the job for two months. All the payments by the contractor will be done at the end of the month 1 and month 2 without any reimbursement so maximum is needed from the end of months 1 to the end of month 2.

3.28 (d)

Day	Activities	Resource Loading
8	*A, B, D*	5 + 4 + 3 = 12
11	*B, C, D*	4 + 8 + 3 = 15
12	*B, C, E*	4 + 8 + 2 = 14
14	*C, E*	8 + 2 = 10

While calculating resource loading the activity *A* having duration 3-8 is meant to be executed on 4th, 5th, 6th, 7th and 8th day and not on 3rd day.

3.29 (d)

The total project cost v/s time curve decreases till optimum project duration after which it increases. Thus if project is shortened below or prolonged above optimum project duration the total project cost will increase. Cost is minimum at optimum project duration.

3.30 (d)

The scaffolding will fail when the load is more and strength is less.

So probability of failure

$= 0.15 \times (1 - 0.8) = 0.03$

3.31 (b)

Probability of being late = 0.4

Probability of being on or before time

$= 1 - 0.4 = 0.6$

Probability of being on time will be that all of them come on or before time.

$\therefore \quad P = 0.6 \times 0.6 \times 0.6 = 0.216$

3.32 (c)

$$\text{Cost slope} = \frac{\text{Crash cost} - \text{Normal cost}}{\text{Normal time} - \text{Crash time}}$$

3.33 (b)

In resource leveling rescheduling of activities is done such that maximum demand of resources does not exceed maximum limit. For this, start of non-critical activities is delayed i.e activities having float are rescheduled first.

3.34 (b)

Sinking fund factor

$$= \frac{i}{(1+i)^n - 1} = \frac{0.04}{(1+0.04)^5 - 1} = 0.184$$

3.35 (d)

Since rock tunnel has infinite life. So the annual equivalent cost of construction of Tunnel

= Initial cost × Rate of interest

= 3000000 × 0.08 = 240000

The operating cost of tunnel is Rs. 60,000 so total annual cost will be

= 240000 + 60000 = 300000

For pipe line system, the total annual cost

= 2000000 × CRF + 92000

= 2000000 × 0.10185 + 92000

= 295700

Thus, tunnel will have a relative disadvantage of 300000 – 295700 = 4300

3.36 (d)

Wages or payment allowance shall be made on the basis of amount and quality of work. Wage payment plans can be classified under two groups :

(a) Non incentive plans like Time or Day rate system.

(b) Incentive Wage plans like piece rate or other schemes.

3.37 (c)

The slope of curve gives out-turn rate. The out-turn rate is zero initially, then increases and becomes constant. After a certain gang size it decreases and finally become zero.

3.38 (b)

Pay back period method involves the determination of the length of time required to recover the initial investment based on a zero interest rate. The investment alternative having the smallest payback period is preferred alternative using the payback period method.

3.39 (c)

The direct cost increases with decrease in duration while the indirect cost decreases with decrease in duration. The optimum duration in the crashing of activities will correspond to minimum total cost (direct + indirect) of project completion.

3.40 (d)

The direct cost vs. time graph is generally a curve. However it can be approximated by straight line or more than one straight line, depending upon the flatness of the curve.

3.41 (b)

The straight line method of depreciation has uniform write-off of cost throughout the service is aimed.

Declining balance method, double declining balance method and sum of the 'years' digits method are accelerated type of depreciation methods. The greater write-off of cost is taken in early years. Thus, the value of asset decreases at a decreasing rate.

The sinking fund method assumes that the value of an asset decreases at an increasing rate i.e. smaller write-off of cost is aimed in early years and it increases in later years.

3.42 (d)

Salvage value is the value of the equipment at the end of the utility period without being dismantled. This may be due to its being worn out, dangerous, obsolete or inadequate. It is more in the initial period of equipment and decreases as the equipment ages.

3.43 (b)

Splitting of activity will result in reduction of the total cost.

3.44 (c)

The average cost of equipment is given by

$$P_{av} = \frac{P(n+1) + S(n-1)}{2n}$$

Here $P = 40000;\ n = 8;\ S = 0$

$$\therefore \quad P_{av} = \frac{40000 \times 9}{16} = 22500$$

Annual depreciation

$$= \frac{40000}{8} = 5000$$

∴ Total annual cost

$$= 0.15 \times P_{av} + 5000 = 8375$$

3.45 (d)

EST → Earliest Start Time

EFT → Earliest Finish Time

Activity	Duration	EST	EFT	S	M
E	4	0	4	3	8
F	6	6	12	2	6
G	2	0	2	1	4
H	4	2	6	4	4
J	6	2	8	3	12
K	2	8	10	4	8

Change in resource loading will occur on the start or finish day of any activity.

Day 1: Activities $E + G$

$S = 3 + 1 = 4$

$M = 8 + 4 = 12$

Day 3: Activities $(E + H + J)$

$S = 3 + 4 + 3 = 10$

$M = 8 + 4 + 12 = 24$

Day 5: Activities $(H + J)$

$S = 4 + 3 = 7$

$M = 4 + 12 = 16$

Day 7: Activities $(F + J)$

$S = 2 + 3 = 5$

$M = 6 + 12 = 18$

Day 9: (Activities $F + K$)

$S = 2 + 4 = 6$

$M = 6 + 8 = 14$

Day 11: Activities F

$S = 2;\ M = 6$

Resource requirement

Day	1	2	3	4	5	6	7	8
S	4	4	10	10	7	7	5	5
M	12	12	24	24	16	16	18	18

Day	9	10	11	12
S	6	6	2	2
M	14	14	6	6

Thus maximum number of shovels and dumpers are required on day 3 and day 4.

3.46 (c)

Probability of load exceeding design load,

$$p_1 = 0.15$$

Probability of load not exceeding design load,

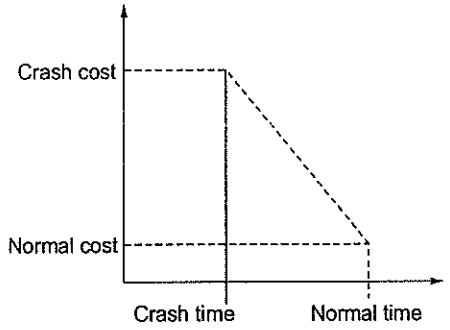
$$p_2 = 0.85$$

∴ Probability of failure

$$= p_1 \times (1 - p_2)$$
$$= 0.15 \times (1 - 0.85) = 0.0225$$

3.47 (b)

Cost slope is defined as the ratio of difference between Crash cost & Normal cost and difference between Normal Time & Crash Time.



3.48 (a)

The commonly used method for calculating depreciation are :

(i) Straight line method
(ii) Declining balance method
(iii) Double declining balance method
(iv) Sum of the year's digits method
(v) Sinking fund method

3.49 (b)

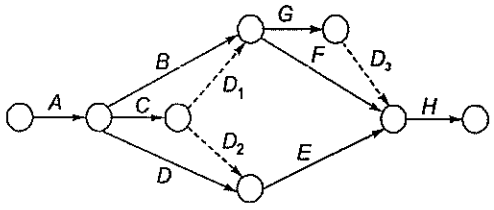
	Expenditure in month (Rs.)					
Purchase	1st	2nd	3rd	4th	5th	6th
Month 1	32000	32000	16000			
Month 2		48000	48000	24000		
Month 3			40000	40000	20000	
Month 4				56000	56000	28000
Total	32000	80000	104000	120000	76000	28000

The difference between expenditure of 3rd and 4th month is Rs. 16,000.

3.50 (d)

Fixed indirect cost is independent of the progress of project. It includes initial expenditure for purchase of equipment, installation and storage charge required for different activities.

3.51 (a)



No. of dummies = 3.

3.52 (c)

The resource levelling approach, total project time is not changed.

3.53 (d)

Updating project is necessary to keep project as per needs of situation by incorporating changes, rescheduling or re-planning. Updating varies with complexity and size of projects.

3.54 (c)

$$\text{Total depreciation} = \frac{30}{100} \times 24000 = 7200$$

Scrap value = 2000

Purchase price = Total depreciation + Scrap value

$= 7200 + 2000 = 9200$

3.56 (c)

Granite can be tunneled at 10 m per day and sandstone at 20 m per day.

Now for first site condition, tunneling duration, with 0.4 probability,

$$D_1 = \frac{600}{10} + \frac{200}{20} = 70 \text{ days}$$

For second site condition with 0.6 probability tunneling duration,

$$D_2 = \frac{400}{10} + \frac{400}{20} = 60 \text{ days}$$

So, probabilistic estimate of total tunneling duration

$D = (70 \times 0.4) + (60 \times 0.6) = 64$ days.

3.57 (a)

Positive cost slope might be considered in resource allocation as there may be scarcity of resources.

3.58 (a)

Equated annual cost or annual depreciation

$$= \frac{\text{Initial value} - \text{Salvage value}}{\text{Useful life of equipment in years}}$$

$$= \frac{2500000 - 500000}{5} = 400000$$

3.59 (*)

Number of observations required is given by the formula

$$N = \left(\frac{zX\sigma}{m}\right)^2$$

where, z = critical value = 1.96

σ is standard deviation which is not given and M is margin of error which is the value added to subtracted from the sample mean to obtain the required length of interval between the minimum and maximum value of the final result.

This value of m is also not given in the question so no solution can be obtained.

[*But still if we take σ = 20% and

$m = (100 - 95)/2 = 2.5$,

we get N = 246 observations.]

3.60 (b)

Sinking fund factor

$$= \frac{i}{(1+i)^n - 1} = \frac{0.06}{(1+0.06)^4 - 1} = 0.23$$

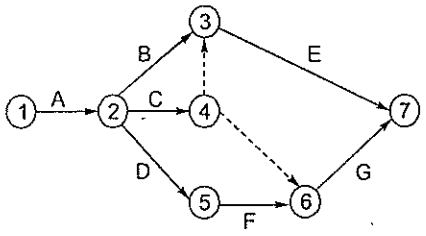
3.61 (d)

Day	Activity	Resource
13	$C \longrightarrow H$	5 + 6 = 11
	$B \longrightarrow F$	
17	$C \longrightarrow H$	5 + 8 + 8 = 21
	$E \longrightarrow K$	
	$F \longrightarrow G$	

3.62 (c)

There are two deletable links 1-3 and 1-6.

3.63 (c)



3.64 (a)

Present capitalized equivalent income

$$= \frac{X}{i} \times \left[\frac{i}{(1+i)^n - 1}\right] = \frac{X}{i} \times \text{Sinking Fund Factor}$$

$$= \frac{4000}{0.08} \times 0.222 = 11{,}100$$

3.65 (b)

Activity on Node (AON) system of the network completely eliminates the use of dummy activities.

3.67 (c)

$$\text{Cost slope} = \frac{\text{Crash cost} - \text{Normal cost}}{\text{Normal time} - \text{Crash time}}$$

3.68 (c)

It is not given that what is the method of resource allocation. For resource smoothening (d) is correct option but for resource levelling, (c) is correct option.

3.69 (a)

The average annual cost as per straight-line depreciation is given as

$$D = \frac{C_i - C_s}{n} = \frac{25 - 0}{5} = 5 \text{ lakhs}$$

3.70 (a)

The use of dummy activities is eliminated in A-O-N network and logical relations are established since the system is self sufficient as time interval between two succeeding activity is shown by times (LFT,EFT, LST,EST) present in diagram.

3.71 (c)

The objective of crushing is to reduce total project cost and to reach optimum project duration which corresponds to minimum total project cost.

3.72 (d)

Let quantity of excavation done manually be H

Let quantity of excavation done by machine be M

Then, $H + M = 4000$ cum

Total cost : $T = 3 \times 20 \times H + 0.2 \times 500 \times M$

$T = 60\ H + 100\ M$

By trial and error:

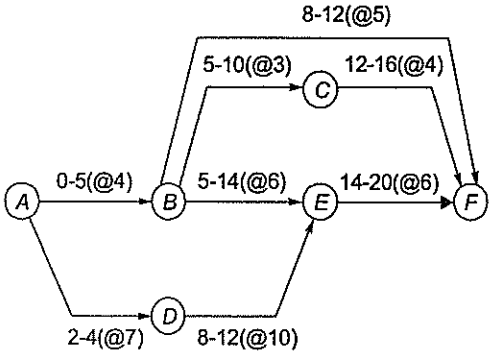
$H = 1500$; $M = 2500$	$T = 340000$
$H = 1800$; $M = 2200$	$T = 328000$
$H = 2250$; $M = 1750$	$T = 310000$
$H = 2500$; $M = 1500$	$T = 300000$

3.73 (c)

Capital recovery factor

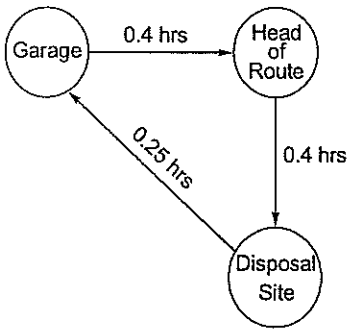
$$\text{CRF} = \frac{i(1+i)^n}{(1+i)^n - 1} = \frac{(0.06)(1+0.06)^8}{(1+0.06)^8 - 1} = 0.1610$$

3.74 (a)



Day	Activity	Requirement
11	$B \to E$	$6 + 10 + 5 = 21$
	$D \to E$	
	$B \to F$	
16	$E \to F$	$6 + 4 = 10$
	$C \to F$	

3.75 (b)



Time taken in I[st] run

Time of travel from Garage to Route Head = 0. 4 hrs

Loading time = 0.5 hrs

Time of travel from Route Head to Disposal Site = 0.4 hrs

Time of unloading = 0.2 hrs

∴ Total time = 1.5 hrs

Time taken in II[nd] run

Time of travel from Disposal Site to Route Head = 0.4 hrs

Loading time = 0.5 hrs

Time of travel from Route Head to Disposal Site = 0.4 hrs

Time of unloading = 0.2 hrs

$\therefore$ Total time = 1.5 hrs

Time for miscellaneous delays

= 0.5 hrs

Assuming that the crew takes one 15 min. break

Time taken = 0.25 hrs

$\therefore$ Total time = 1.5 + 1.5 + 0.5 + 0.25

= 3.75 hrs

$\therefore$ Time left = 8 – 3.75

= 4.25 hrs

3.76 (b)

Case of construction project

= Direct + Indirect cost

Direct cost is a function of time and indirect cost may on may not be a function of time.

$$\text{cost} - \text{slope} = \frac{\Delta C}{\Delta t} = \text{function of time}$$

= change in cost per unit change in time

≡ extra cost which will incur

3.77 (c)

Equipment annual cost

$$= 5000 + 15000\left(\frac{A}{P},i,n\right) - 1000\left(\frac{A}{F},i,n\right)$$

$$\text{SFF} = \left(\frac{A}{F},i,n\right) = 0.1638$$

$$\left(\frac{A}{P},i,n\right) = \text{SFF} + i = 0.2638$$

$\therefore$ Equipment annual cost

= 5000 + 15000 (0.2638) – 1000 (0.1638)

= Rs. 8793.2

3.78 (d)

$$\frac{P}{P_o} = \left(\frac{P}{P_o}\right)\left(\frac{T}{T_o}\right)^{1/2}$$

where p = pressure, P = power

$$\Rightarrow \left(\frac{P}{P_o}\right) = \left(\frac{P}{P_o}\right)\sqrt{\frac{T}{T_o}}$$

$$\Rightarrow P = (75\,\text{HP})\left(\frac{760}{740}\right)\sqrt{\frac{35+273}{15.5+273}}$$

$$= (75)\frac{760}{740}\sqrt{\frac{308}{288.5}}$$

3.79 (d)

SPCAF for 10% for 3 years = 1.3310

$$\text{CRF for 10\% for 3 years} = \frac{i \times SPCAF}{SPCAF - 1}$$

$$= \frac{0.1 \times 1.3310}{0.3310} = 0.40211$$

3.80 (c)

Annual depreciation

$$= \frac{\text{cost price} - \text{salvage value}}{\text{Time (in years)}}$$

$$= \frac{25000 - 1600}{8} = 2925$$

Book value is the original cost of equipment less cummulative depreciation upto the year under consideration.

= 25000 – 5 x 2925

Since beginning of 6th year $\Rightarrow$ 5 completed years

= Rs.10375

3.81 (b)

Std. deviation

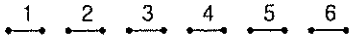
$$= \sqrt{\text{Variance}} = \sqrt{9} = 3$$

$$1.647 = \frac{T - 70}{3}$$

$$\Rightarrow \quad T = 74.941 \text{ weeks}$$

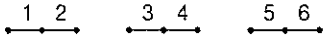
3.82 (d)

Case I:



Case II:

After clubbing the activities



Std. deviation of individual activities

$$= \frac{10 - 4}{6} = 1 \text{(before clubbing)}$$

$\therefore$ Std. deviation of whole project in case-I

$$= \sqrt{1^2 + 1^2 + 1^2 + 1^2 + 1^2 + 1^2} = \sqrt{6}$$

Std. deviation of individual activities after clubbing

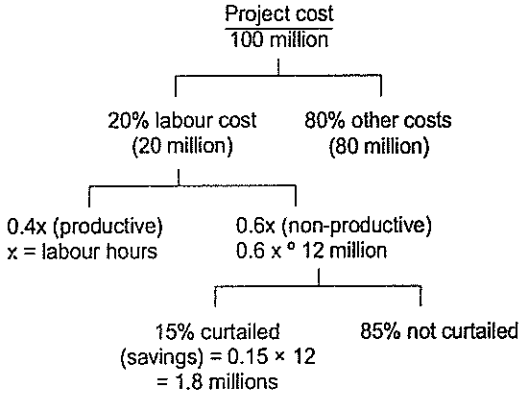
$$= \sqrt{1^2 + 1^2} = \sqrt{2}$$

∴ Std. deviation of whole project in case-II

$$(X_2) = \sqrt{(\sqrt{2})^2 + (\sqrt{2})^2 + (\sqrt{2})^2} = \sqrt{6}$$

$$\therefore \quad \frac{x_2}{x_1} = \frac{\sqrt{6}}{\sqrt{6}} = 1$$

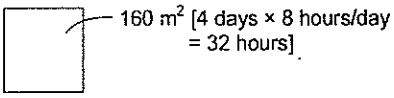
3.83 (c)



3.84 (d)

In resource allocation, it is the efficient utilization of available of resources and not the economic utilization of resources. Thus the activities are so planned so as not have any requirement of resources beyond the available resources.

3.85 (b)



Team works @ 1.25 m^2/hr

In 32 hours, 160 m^2 area is to be covered i.e. in one hour area to be covered is

$$\frac{160}{32} = 5 \text{ m}^2/\text{hr}$$

∴ Number of terms required

$$= \frac{5}{1.25} = 4 \text{ teams}$$

3.87 (a)

Time cost relationship of every activity must be known to establish total time-cost of project as project is constituted by all the activities therein.

3.88 (d)

When equipment is used at reduced post of service, the rate of return can be determined from the log book if it has been maintained.

3.89 (a)

In resource levelling, project completing time is extended only when availability of resources is less than the required resources. But if there is no constraint on availability of resources, project completion time is never extended.

So, correct answer is (a).

3.90 (c)

Minimum cost

A	14	9
B	6	7
C	11	4

∴ Total duration = 9 + 7 + 4 = 20 days

3.95 (d)

The following combinations are possible for a total duration of 25 units of time.

Combination sequence	P		Q		R		Total Cost
1.	8	250	7	320	10	375	945
2.	8	250	9	275	8	400	925
3.	9	235	6	340	10	375	950
4.	9	235	8	295	8	400	930
5.	10	225	7	320	8	400	945
6.	11	215	6	340	8	400	955

Hence least total direct cost is 925.

3.96 (a)

Earnest money deposited (EMD) is deposited with submission of tender document only. Contractor is approved by government before biding only, and credentials are given to him and it is required while tender is invited.

■■■■

***NOTE:* Conflict in Definitions**

Resource levelling and resource smoothening defined in this book are as per definitions/concepts explained in Foreign author books such or Roury Bourke, Harald Kerzer and some Indian authors also have followed the same concept like M.R. Gopalan, K. Nagranjan, Prasanna Chandra, NPTEL Lectures etc. but some of the Indian authors have given just opposite explanation of these terms which include B.C. Puramia, R. Seetharaman and U.K. Shrivastava.

4 Concreting Equipments

4.1 Consider the following operations:

1. Drilling
2. Blasting
3. Mucking
4. Placing Steel
5. Placing concrete

The correct sequence of these operations in tunnel construction is

(a) 1, 2, 4, 3, 5 (b) 1, 3, 2, 4, 5
(c) 1, 2, 3, 4, 5 (d) 1, 3, 4, 2, 5

[ESE : 1995]

4.2 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Derick
B. Claw-hammer
C. Chain-Lewis
D. Drop-hammer

List-II

1. Stone masonry work
2. Wood work
3. Steel work
4. Concrete compaction
5. Pile foundation

Codes :

	A	B	C	D
(a)	1	3	5	4
(b)	2	3	4	5
(c)	3	1	5	2
(d)	3	2	1	5

[ESE : 1996]

4.3 The maximum rimpull in the first gear of a tractor while towing a load is 6300 kg. The tractor weighs 12 tonnes and is operating along a 2 per cent upgrade and the rolling resistance is 45 kg/tonne. Pull available for towing the load is

(a) 3425 kg (b) 5515 kg
(c) 4350 kg (d) 2975 kg

[ESE : 1996]

4.4 The probable output per hour of a 34° double-drum paving mixer in cum/hour, is

(a) 1.5 to 2.5 (b) 2.0 to 2.5
(c) 2.0 to 3.25 (d) 2.5 to 3.0

[ESE : 1996]

4.5 The tipping load of a crane refers to

(a) lifted weight together with all attached handling tackle and hoist rope, with grounded attached outriggers
(b) lifted weight together with all attached handling tackle but excluding hoist rope, with specifying the radius horizontally, with grounded outriggers
(c) lifted weight alone, with specifying the radius for the lifted weight and also for the counter weight without grounding the outriggers
(d) lifted weight alone, at specified horizontal radius without grounding the outriggers

[ESE : 1996]

4.6 Consider the following statements:

A concrete mixer is specified by the

1. volume of the mixing drum
2. horse power of the prime mover
3. volume of mixed concrete discharged
4. mixer drum speed
5. feeding arrangement

Which of these statements are correct?

(a) 1, 2 and 5 (b) 1, 3 and 4
(c) 3 and 5 (d) 2 and 4

[ESE : 1997]

4.7 Reinforced concrete door and window frames can be compacted using

1. needle vibrator
2. plate vibrator
3. form vibrator
4. tamping

The correct sequence of these equipment in order of preference (from the best to the worst) is

(a) 2, 3, 4, 1 (b) 3, 2, 1, 4
(c) 2, 3, 1, 4 (d) 3, 2, 4, 1

[ESE : 1997]

4.8 Which of the following types of pumps can be used for concreting?
1. Piston operated
2. Pneumatically operated
3. Centrifugally operated, with straight blades
4. Screw type

Select the correct answer using the codes given below :
(a) 1 and 3 (b) 1 and 2
(c) 1, 3 and 4 (d) 2 and 4

[ESE : 1997]

4.9 Grader is used mainly for
(a) trimming and finishing
(b) shaping and trimming
(c) finishing and shaping
(d) finishing, shaping and trimming

[ESE : 1997]

4.10 Which one of the following is NOT an excavating and moving type of equipment?
(a) Bulldozer (b) Clamshell
(c) Scraper (d) Dump truck

[ESE : 1997]

4.11 The most suitable type of equipment for compacting of cohesive soils is
(a) smooth-wheeled rollers
(b) vibratory rollers
(c) sheep foot rollers
(d) tampers

[ESE : 1997]

4.12 For excavating utility trenches with precise control of depth, the excavation equipment used is
(a) hoe (b) shovel
(c) dragline (d) none of these

[ESE : 1997]

4.13 The basic action involved in sheep foot rolling is
(a) kneading (b) pressing
(c) tamping (d) vibration

[ESE : 1997]

4.14 Assertion (A) : Single scaffolding consists of a single framework of standards, ledgers and put-logs constructed parallel to the wall.

Reason (R) : Putlogs are placed at both ends on frames when it is difficult to provide holes in the wall.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 1997]

4.15 The function of coping is to serve as a
(a) covering to the wall to throw off water
(b) ornamental course between lintel level and roof level
(c) projection from a wall to support a structural member
(d) shade against solar radiation

[ESE : 1997]

4.16 Match List-I (Types of work) with List-II (Type of contract most appropriate) and select the correct answer using the codes given below the lists:

List-I
A. Specified architectural work
B. House construction
C. Repainting of house
D. Dewatering foundations

List-II
1. Cost plus
2. Lumpsum
3. Item rate
4. Price work

Codes :

	A	B	C	D
(a)	3	2	1	4
(b)	2	3	4	1
(c)	2	3	1	4
(d)	3	2	4	1

[ESE : 1997]

4.17 Consider the following statements:
Wheeled tractors are replacing crawler tractors because
1. wheeled tractors travel faster
2. crawler tractors are more expensive
3. track parts of a crawler tractor wear out quickly
4. crawler tractors have stick control

Which of these statements are correct?

(a) 1, 3 and 4 (b) 2, 3 and 4

(c) 1, 2 and 3 (d) 1, 2 and 4

[ESE : 1998]

4.18 Match List-I (Nature of work) with List-II (Machine required) and select the correct answer using the codes given below the lists:

List-I

A. Excavation and moving

B. Pure excavation

C. Pure transportation

D. Pure hoisting

List-II

1. Derrick
2. Dump truck
3. Power shovel
4. Drag line

Codes :

	A	B	C	D
(a)	1	3	2	4
(b)	3	4	2	1
(c)	4	3	2	1
(d)	4	3	1	2

[ESE : 1998]

4.19 The rated loads of lifting cranes, as percentage of tipping loads at specified radius, for crawler-mounted, and pneumatic tyre mounted machines would be respectively

(a) 80 and 90 (b) 90 and 80

(c) 85 and 75 (d) 75 and 85

[ESE : 1998]

4.20 **Assertion (A) :** The hoe is not very advantageous in digging trenches and basements.

Reason (R) : In a hoe, the digging action results from the drag of the bucket.

(a) both A and R are true and R is the correct explanation of A

(b) both A and R are true but R is not a correct explanation of A

(c) A is true but R is false

(d) A is false but R is true

[ESE : 1999]

4.21 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I

A. Cube specimen

B. Pavement slab

C. Heavily reinforced column

D. Mass concrete in bridge piers

List-II

1. Pin vibrator
2. Form vibrator
3. Table vibrator
4. Screed vibrator
5. Manual compaction

Codes :

	A	B	C	D
(a)	4	3	2	1
(b)	2	3	4	5
(c)	3	4	2	1
(d)	3	4	1	5

[ESE : 1999]

4.22 Consider the following statements regarding use of mechanical vibrator:

1. It can be used for small as well as large volumes of concrete.
2. The mix can have high value of slump.
3. Density of concrete can be high.

The advantages of a mechanical vibrator include

(a) 2 and 3 (b) 1 and 3

(c) 1, 2 and 3 (d) 1 and 2

[ESE : 1999]

4.23 A centrifugal pump is required to lift 2.8 m^3/s of water to a height of 7.5 m. If the total loss of head in the pipe system is 0.25 m and the efficiency of the pump is 80%, then the brake horse power will be

(a) $\frac{1000\times2.8\times7.5\times0.8}{75}$

(b) $\frac{1000\times2.8\times7.75}{0.8}$

(c) $\frac{1000\times2.8\times7.75}{0.8\times75}$

(d) $\frac{1000\times2.8\times0.8}{75}$

[ESE : 1999]

4.24 A 6 m^3 central concrete mixing plant takes in 1875 kg of cement, 5120 kg of sand and 6060 kg of coarse aggregate along with 865 kg of water per batch. There is a reduction of 1.5% in volume in the freshly mixed wet concrete from the nominal

volume. The unit weight of the freshly mixed wet concrete will be

(a) 2320 kg per m^3 (b) 2335 kg per m^3
(c) 2345 kg per m^3 (d) 2355 kg per m^3

[ESE : 2000]

4.25 IC engines usable for earthwork are calibrated under standard conditions (denoted by suffix 'o') relating its horse power H_0, standard barometric pressure P_0 and standard test temperature T_0, all in absolute scales. H, P and T refer to corresponding values when used under other than standard conditions. The ratio of $\frac{H_0}{H}$ is

(a) $\frac{P}{P_0}\sqrt{\frac{T}{T_0}}$ (b) $\frac{P_0}{P}\sqrt{\frac{T}{T_0}}$

(c) $\sqrt{\frac{P_0}{P}\frac{T}{T_0}}$ (d) $\sqrt{\frac{P_0}{P}\frac{T}{T_0}}$

[ESE : 2000]

4.26 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. Self-loading scraper
B. Narrow tread high pressure tyre
C. Supercharger
D. Gear ratios

List-II
1. Reduce loss in power
2. Rimpull management
3. Lower rolling resistance
4. Compromise between loading and hauling performances

Codes :

	A	B	C	D
(a)	4	3	2	1
(b)	4	3	1	2
(c)	3	4	1	2
(d)	3	4	2	1

[ESE : 2000]

Directions: The following items consists of two statements; one labelled as 'Assertion (A)' and the other as 'Reason (R)'. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.27 **Assertion (A) :** Crawler mounted power shovels have low speeds.
Reason (R) : Power shovels are usable with all classes of earth and rocks.

[ESE : 2000]

4.28 **Assertion (A) :** Crane and bucket arrangement is always and at all places preferable over tower and buckets arrangements for placement of concrete.
Reason (R) : With cranes, haul distances for buckets can be reduced.

[ESE : 2000]

4.29 **Assertion (A) :** In the hydraulically-controlled bulldozers, the blade can be forced into the ground more accurately than in the cable-controlled bulldozers.
Reason (R) : High friction on the blade is produced in addition to its weight in the hydraulically-controlled bulldozers.

[ESE : 2001]

4.30 A construction concrete mixer of capacity 0.8 m^3 is used and the mixer discharges the entire batch of concrete into a single hopper. The time per cycle may be taken for charging, mixing and discharging mixes as 1.6 minutes and lost time may be taken as 0.15 minutes. The number of batches per hour is equal to

(a) $\frac{60}{1.6+0.15}$ (b) $\left(\frac{60}{1.6}\right)-0.15$

(c) $\left(\frac{60-0.15}{1.6}\right)\times 0.8$ (d) $\frac{60}{1.6-0.15}$

[ESE : 2001]

4.31 Which of the following statements are the advantages of surface vibrators?
Surface vibrators are best suited
1. for one way reinforced slabs and road surfaces

2. when depth of the concrete to be vibrated exceeds 250 mm
3. where immersion vibrations are impracticable

Select the correct answer using the codes given below:

(a) 1, 2 and 3 (b) 1 and 2
(c) 2 and 3 (d) 1 and 3

[ESE : 2001]

4.32 The output Q of the earth moving equipment like excavators, shovels, loaders (where 'q' is production per cycle in m^3 and 'c' is cycle time in seconds) is

(a) $\frac{q \times 3600 \times \text{efficiency}}{c} m^3/hr$
(b) $q \times 3600 \times \text{efficiency}\ m^3/hr$
(c) $qc \times 3600 \times \text{efficiency}\ m^3/hr$
(d) $qc \times 3600\ m^3/hr$

[ESE : 2001]

4.33 For a given load rating, the operating radius of crane can be increased by

(a) increasing weight of the machine
(b) increasing engine horse power
(c) increasing the length of boom or arm
(d) operating the crane slowly

[ESE : 2001]

4.34 **Assertion (A) :** The more economical alternative of replacing an equipment is to redesign and improve the equipment.

Reason (R) : Redesigning and improving an equipment can result in labour saving.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2002]

4.35 Match List-I (Type of mixers) with List-II (Characteristics) and select the correct answer using the codes given below the lists:

List-I

A. Tilting, drum type concrete mixers
B. Pan type concrete mixers
C. Portable tilting drum type concrete mixers
D. Portable non-tilting drum type concrete mixers

List-II

1. Are very efficient especially with stiff mixes and the drum rotates about a vertical axis
2. Are meant for small, scattered jobs using small-sized aggregates
3. Are fed from one side of the drum while the mixed concrete is discharged from the other end and the drum rotates about a horizontal axis
4. Are best suited for large sized aggregates as in mass concrete

Codes :

	A	B	C	D
(a)	2	3	4	1
(b)	4	1	2	3
(c)	2	1	4	3
(d)	4	3	2	1

[ESE : 2002]

4.36 Match List-I (Vibrators) with List-II (Application) and select the correct answer using the codes given below the lists:

List-I

A. Vibrating tables
B. Screed vibrators
C. Internal vibrators
D. Form vibrators

List-II

1. For thin tunnel linings
2. For mass concrete work
3. For precasting concrete members
4. For thin slabs, pavements and floors

Codes :

	A	B	C	D
(a)	3	1	2	4
(b)	2	4	3	1
(c)	3	4	2	1
(d)	2	1	3	4

[ESE : 2002]

4.37 Which of the following are the disadvantages of non-tilting type concrete mixers?

1. They are not favoured when large sized aggregates are used.
2. Mixing of the concrete occurs through both rolling and pulling from buckets.
3. Content of fines is increased.
4. They are not easy to clean.

Select the correct answer using the codes given below :

(a) 1, 2 and 3 (b) 1, 3 and 4
(c) 1, 2 and 4 (d) 2, 3 and 4

[ESE : 2002]

4.38 Match List-I (Type of cranes) with List-II (Characteristic) and select the correct answer using the codes given below the lists:

List-I
A. Hydraulic crane
B. Electric overhead crane
C. Travelling bridge crane
D. Hammerhead crane

List-II
1. Has legs moving on tracks laid on the floor
2. Has cantilever arms on both sides
3. Has the unique advantage that the boom length and the angle can be changed during operation
4. Has three-way motion in mutually perpendicular directions

Codes :

	A	B	C	D
(a)	3	2	1	4
(b)	1	4	3	2
(c)	3	4	1	2
(d)	1	2	3	4

[ESE : 2002]

4.39 The norm for providing standby equipment for one shift operation is

(a) 5% (b) 10%
(c) 20% (d) 30%

[ESE : 2002]

4.40 For cleaning and grubbing of construction site of 15000 m^2 area, a bulldozer is used which has effective width of 2 m of the blade and an average speed of 2.5 kmph. If hiring charges of bulldozer are Rs. 500 per hr., then cost per m^2 is

(a) Rs. 10 (b) Rs. 12
(c) Rs. 15 (d) Rs. 18

[ESE : 2002]

4.41 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. A rubber tyred bulldozer gives better output
B. A bulldozer mounted on crawler tracks gives better output
C. A rubber tyred bulldozer
D. A crawler mounted bulldozer

List-II
1. While working on earth or soft ground
2. Results in lesser operator fatigue
3. Has greater use and versatility on jobs
4. When working on a hard surface

Codes :

	A	B	C	D
(a)	2	1	4	3
(b)	4	1	2	3
(c)	2	3	4	1
(d)	4	3	2	1

[ESE : 2002]

4.42 In compaction of clayey-soil using sheep-foot roller, compaction is achieved by

(a) static action (b) vibration action
(c) kneading action (d) impact action

[ESE : 2003]

4.43 The working range of a crane is limited horizontally for maximum lift only by

(a) boom length
(b) length of hoist cable
(c) length of jib
(d) counter weight

[ESE : 2003]

4.44 Which one of the following types of crane is used for high rise buildings?

(a) Traveller crane
(b) Tower crane
(c) Overhead gantry crane
(d) Derrick crane

[ESE : 2003]

4.45 A certain concreting job can be started only when all three groups, viz.

(i) measuring and loading,
(ii) operating the machine and
(iii) evacuating and transporting

are in position. These local groups can be credited each with only a chance of 0.7 being on time, and the 0.3 chance of being late, each independently of the other. What are the chances of the starting of the job getting delayed on any day due to non-arrival of any one group on time?

(a) 0.021 (b) 0.147
(c) 0.343 (d) 0.441

[ESE : 2003]

4.46 **Assertion (A)** : Rubber tyred equipment pull better on smooth, hard surfaces while crawlers work better on firm earth.
Reason (R) : Bulldozers mounted on wheels are employed on earth construction for better performance.
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2003]

4.47 The vibrators are used for
(a) compacting concrete
(b) proper mixing of concrete
(c) removing excess water from concrete
(d) obtaining smooth surface

[ESE : 2003]

4.48 Which one of the following statements is correct?
(a) Grade resistance is positive when the unit travels downgrade and negative when travelling upgrade.
(b) Grade resistance depends on the type of equipment or the haul surface and is in addition to rolling resistance.
(c) Grade resistance acts against the total weight of both wheel and track type units.
(d) Grade resistance for units moving on the road surface is greater than grade resistance for units moving on rails.

[ESE : 2003]

4.49 Match **List-I** (Type of compactor) with **List-II** (Soil best suited) and select the correct answer using the codes given below the lists:

List-I
A. Sheepsfoot compactor
B. Steel tandem compactor with 2 or 3 axles
C. Steel drum
D. Pneumatic with large tyre

List-II
1. Granular or granular plastic
2. Sandy silts, sandy clays, gravelly sand and clays with few fines
3. Clay, silty clay, gravel with clay binder
4. Sandy silts, most granular material with some clay binder

Codes:

	A	B	C	D
(a)	3	1	4	2
(b)	2	4	1	3
(c)	3	4	1	2
(d)	2	1	4	3

[ESE : 2003]

4.50 Match **List-I** (Equipment) with **List-II** (Operation) and select the correct answer using the codes given below the lists:

List-I
A. Power shovel
B. Dragline
C. Backhoe
D. Clamshell

List-II
1. Can excavate vertically
2. Can excavate underwater
3. Has better control because of the rigid dipper stick
4. Can operate while standing on firm ground and the bucket is pulled towards the machine

Codes:

	A	B	C	D
(a)	3	2	4	1
(b)	3	2	1	4
(c)	2	3	1	4
(d)	2	3	4	1

[ESE : 2003]

4.51 The number of trips of a dumper per hour is given by

(a) $\frac{60 \text{ minutes}}{\text{Actual or effective cycle time in minutes}}$

(b) $\frac{60 \text{ minutes}}{\text{Ideal cycle time in minutes}}$

(c) $\frac{60 \text{ minutes}}{\text{Ideal running time + Loss time minutes}}$

(d) $\frac{60 \text{ minutes}}{\text{Running time in minutes}}$

[ESE : 2003]

4.52 Consider the following statements:
1. The ideal output of a power shovel is achieved at 90° angle of swing.
2. Output from a power shovel is independent of size of trucks.

3. The optimum depth of cut of a power shovel is the one at which the dipper comes out with full load.
4. The optimum depth of cut does not vary with the size of the dipper of a power shovel.

Which of these statements are correct?

(a) 1 and 3 (b) 2 and 4
(c) 1, 2 and 3 (d) 1, 2 and 4

[ESE : 2004]

4.53 What is the volume of concrete mix produced if a batch type concrete mixer of 1500 litres capacity takes an effective time of 15 seconds for one batch of production?

(a) 36 m^3/hr (b) 180 m^3/hr
(c) 360 m^3/hr (d) 720 m^3/hr

[ESE : 2004]

4.54 Consider the following statements:
When acquiring a crane for a project work, the important aspects of the specifications will include information on

1. length of hoist line
2. length of boom line
3. tipping condition
4. bucket size
5. angle of swing in absolute terms
6. haul distance

Which of these statements are correct?

(a) 2, 3, 5 and 6 (b) 1, 2, 3, and 6
(c) 1 and 5 (d) 2, 4, 5 and 6

[ESE : 2004]

4.55 Match List-I (Type of jobs) with List-II (Type of equipment) and select the correct answer using the codes given below the lists:

List-I

A. Handling stiff and cohesive mixes used in the manufacturing of precast concrete
B. Road construction where space and access are limited
C. Consolidating concrete in thin slabs
D. Vibrating both the form and the concrete

List-II

1. External vibrator
2. Dual drum mixers
3. Pan mixers
4. Electric hammer
5. Vibrating roller

Codes:

	A	B	C	D
(a)	3	5	1	4
(b)	3	2	5	1
(c)	5	2	4	3
(d)	5	3	4	1

[ESE : 2004]

4.56 Which of the following are taken into consideration in determining ultimate operating factor of a typical earthmoving equipment?

(a) Rated output at flywheel (or similar power smoothing fitting), maximum power consumption time factor and fuel consumption.
(b) Maximum power consumption time factor, idle running time proportion, overall shutdown time proportion.
(c) Total load/output of earthwork delivered as a proportion of rated capacity.
(d) Maximum power consumption time factor, cycle time as proportion of running time, idle running time between sites, overall shutdown time proportion.

[ESE : 2004]

4.57 If the depth of face from which a shovel is excavating material is too shallow, then which one of the following is correct?

(a) The dipper may not be filled in one pass up the face
(b) The depth of penetration of the dipper can be increased
(c) The depth of penetration of the dipper would be decreased
(d) Excess earth will spill down to the bottom of the face

[ESE : 2004]

4.58 A scraper of self weight 27 tonnes works on sandy clay soil weighing 1800 kg/m^3 of bank measure. Haul road rolling resistance is 3.5% and grade is 2% adverse for loaded unit. The earth carried per trip is 14 m^3 (b.m.). What rim pull, in newton (approximately) is required when travelling loaded and empty, respectively?

(a) 35600, 5100 (b) 32200, 4800
(c) 30100, 4400 (d) 28700, 4050

[ESE : 2004]

4.59 A roller with 1.5 m effective width of drum moves with an average speed of 1.5 kmph. What is the output when six number of passes are used for effectiveness?

(a) 13.5 m^2/hr (b) 37.5 m^2/hr
(c) 135 m^2/hr (d) 375 m^2/hr

[ESE : 2004]

4.60 Two centrifugal pumps work in parallel at a common delivery head of 18 m. The first pump delivers 90 *l*ps at an efficiency of 60% and the second pump delivers 60 *l*ps at an efficiency of 50%. What is the overall efficiency of the system?

(a) 62.5% (b) 58%
(c) 55.5% (d) 52%

[ESE : 2004]

4.61 Match List-I (Earth excavating equipment) with List-II (Uses) and select the correct answer using the codes given below the lists:

List-I
A. Power shovel
B. Hoe
C. Clamshell
D. Bulldozer

List-II
1. Excavation of earth in confined area or pit
2. Rehauling of loose or excavated material from one place to another place
3. Clearing and scrubbing of worksite
4. Excavation of trenches

Codes:

	A	B	C	D
(a)	1	4	2	3
(b)	1	4	3	2
(c)	4	1	2	3
(d)	4	1	3	2

[ESE : 2004]

4.62 Match List-I (Working details) with List-II (Type of pumps) and select the correct answer using the codes given below the lists:

List-I
A. The water which has entered inside the pump is revolved at high speed by means of the impeller revolving in a tight casing.
B. The pump gives constant discharge even under variable heads.
C. Usable in pumping from crooked holes and for handling corrosive liquids
D. Water can be lifted to large heights using the hydraulic ram

List-II
1. Air-lift pump
2. Impulse pump
3. Reciprocating pumps
4. Diesel engine driven pumps
5. Centrifugal pumps

Codes:

	A	B	C	D
(a)	1	3	5	2
(b)	5	3	1	2
(c)	4	2	5	3
(d)	5	2	4	3

[ESE : 2004]

4.63 Match List-I (Performance parameters) with List-II (Performance pattern) and select the correct answer using the codes given below the lists:

List-I
A. RPM vs. Discharge
B. Head vs. Discharge
C. BHP vs. Discharge
D. Efficiency vs. Discharge

List-II
1. Increases with increasing head but decreases slightly with discharge
2. Increases initially, stalls and then decreases fast
3. Generally decreases continuously
4. Increases and stalls

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	1	3	4	2
(c)	1	2	4	3
(d)	4	2	1	3

[ESE : 2004]

4.64 How many litres of water will be pumped per minute by a double acting reciprocating pump with 6 cm cylinder diameter and 15 cm stroke length, driven by a crankshaft running at 90 rpm with no slippage?

(a) 84.6 (b) 81.2
(c) 78.5 (d) 76.4

[ESE : 2004]

4.65 A bulldozer operates on a 30m stretch and moves at 2.4 kmph when pushing the earth, and returns empty at 6 kmph. The time lost in loading and shifting gears per trip is 18 seconds. Its operating factor is nearly 50 min/hour. What is the number of trips made per hour?

(a) 31 (b) 33
(c) 35 (d) 37

[ESE : 2005]

4.66 What type of vibrator is used for concreting thin section as well as heavily reinforced section?

(a) Vibrating needle (b) Internal vibrator
(c) Surface vibrator (d) Form vibrator

[ESE : 2005]

4.67 Which of the following advantages accrue to the use of Articulate Dump Trucks (ADT) over Rigid Dump Trucks (RDT) for construction and earth moving work?

1. Higher manoeuverability
2. Low turning radius
3. Lower fleet costs

Select the correct answer using the codes given below :

(a) 1, 2 and 3 (b) 1 and 2
(c) 1 and 3 (d) 2 and 3

[ESE : 2005]

4.68 Match List-I (Type of roller) with List-II (Uses) and select the correct answer using the codes given below the lists:

List-I

A. Pneumatic roller
B. Vibratory roller
C. Sheep foot roller
D. Grid and mesh roller

List-II

1. Granular and silty materials, bituminous road works, etc.
2. Compaction of cohesive material like clay
3. Compaction of non-cohesive soil
4. Compaction of gravel base

Codes:

	A	B	C	D
(a)	1	3	2	4
(b)	2	4	1	3
(c)	1	4	2	3
(d)	2	3	1	4

[ESE : 2005]

4.69 Match List-I (Type of equipment) with List-II (Purpose) and select the correct answer using the codes given below the lists:

List-I	List-II
A. Agitating Truck	1. Quarrying
B. Hoe	2. Compacting
C. Derrick Pole	3. Hoisting
D. Sheep Foot roller	4. Transporting

Codes:

	A	B	C	D
(a)	4	3	1	2
(b)	2	1	3	4
(c)	4	1	3	2
(d)	2	3	1	4

[ESE : 2005]

4.70 Match List-I (Machinery) with List-II (Purpose) and select the correct answer using the code given below the lists:

List-I

A. Bulldozer
B. Power shovels
C. Dragline
D. Clamshell

List-II

1. Most suited for vertically lifting loose materials
2. The bucket in this unit digs by pulling the load towards it
3. To excavate all type of soils and dump it into trucks
4. For digging the earth at or below the operating level and loading it to hauling units
5. Largely employed for excavating and moving the earth

Codes:

	A	B	C	D
(a)	5	3	4	1
(b)	1	4	2	5
(c)	5	4	2	1
(d)	1	3	4	5

[ESE : 2005]

Directions: The following items consists of two statements; one labelled as **'Assertion (A)'** and the other as **'Reason (R)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below:

Codes:
(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

4.71 **Assertion (A) :** Smooth wheeled rollers are preferred for compacting granular soils but not cohesive soils.
Reason (R) : Cohesive soils tend to form a crust over the rolling smooth surface.
[ESE : 2006]

4.72 **Assertion (A) :** For low discharges at high heads, reciprocating pumps are not suitable.
Reason (R) : In a reciprocating pump, the liquid is pushed out of the cylinder by actual displacement of a piston or a plunger.
[ESE : 2006]

4.73 Consider the following statements:
A mixer designated 400 NT indicates that
1. it is non-tilting type mixer
2. its nominal mix batch capacity is 400 litres
3. it requires 400 revolutions for proper mixing of the batch using one bag of cement
Which of these statements are correct?
(a) Only 1 and 3 (b) Only 1 and 2
(c) Only 2 and 3 (d) 1, 2 and 3
[ESE : 2006]

4.74 Match List-I with List-II and select the correct answer using the codes given below the lists:
List-I
A. To dig trenches, footings or basement where the precise control of depth is required
B. To handle loose materials such as sand, gravel, coal, etc.
C. To excavate all classes of earth except the rock and load it into the trucks
D. To excavate the earth from a canal and to be deposited on nearby banks
List-II
1. Clam shells
2. Power shovel
3. Back hoe
4. Scraper
5. Drag line

Codes:

	A	B	C	D
(a)	3	5	2	1
(b)	2	1	4	5
(c)	3	1	2	5
(d)	2	5	4	1

[ESE : 2006]

4.75 Which of the following are the advantages of crawler mounted bulldozer over wheel mounted bulldozers?
1. Higher travel speed
2. Able to travel over very soft soil
3. Able to travel over very rough surfaces having no haul roads
Select the correct answer using the code given below :
(a) 1, 2 and 3 (b) Only 1 and 2
(c) Only 1 and 3 (d) Only 2 and 3
[ESE : 2006]

4.76 How are concrete mixers specified ?
(a) By the number of cement bags used in a batch
(b) By the nominal volume of concrete that can be mixed in a batch
(c) By the volume of water used
(d) By the volume of aggregate used
[ESE : 2007]

4.77 Match List-I (Crane) with List-II (Suitable for) and select the correct answer using the codes given below the lists :
List-I
A. Tower crane
B. Floating crane
C. Mobile crane
D. Gantry crane
List-II
1. Hydraulic structures
2. High industrial plant
3. Longitudinal and lateral movements of load
4. Railway electrification
Code :

	A	B	C	D
(a)	2	1	4	3
(b)	3	4	1	2
(c)	2	4	1	3
(d)	3	1	4	2

[ESE : 2007]

4.78 For three-dimensional movement of a weight, which one of the following is most suitable?
(a) Chain hoist (b) Winch
(c) Crane (d) Jack
[ESE : 2007]

4.79 When power shovels are operated under different site conditions (in terms of material handled), what is the correct sequence in the increasing order of the output for the following materials ?
1. Well-blasted rock
2. Hard and tough clay
3. Poorly blasted rock
4. Moist loam or sand

Select the correct answer using the codes given below :
(a) 1 – 2 – 3 – 4 (b) 1 – 4 – 3 – 2
(c) 4 – 2– 3 – 1 (d) 4 – 3 – 1 – 2
[ESE : 2007]

4.80 Vibratory rollers are more useful for compacting which of the following ?
(a) Sandy soils (b) Silty soils
(c) Clayey soils (d) Mixed soils
[ESE : 2007]

4.81 Bottom-dump wagons are suitable for handling which of the following ?
(a) Wet sticky clay
(b) Sand and gravel
(c) Quarry rocks
(d) Any type of material
[ESE : 2007]

4.82 Which one of the following shovel excavators is considered most efficient in loading carriers?
(a) Dipper shovel (b) Dragline
(c) Backhoe (d) Clamshell
[ESE : 2007]

4.83 A tractor-trailer assembly has a gross weight of 25 tonnes. When moving over a level road, its rolling resistance is 42 kg per tonne. It is moved up a road of 5% grade. What is the required tractive effort?
(a) 1050.5 kg (b) 1060.5 kg
(c) 1085 kg (d) 1102.5 kg
[ESE : 2007]

4.84 Match List-I with List-II and select the correct answer using the codes given below the lists:

List-I
A. Agitator truck
B. Needle vibrator
C. Concrete pump
D. Tremie pipe

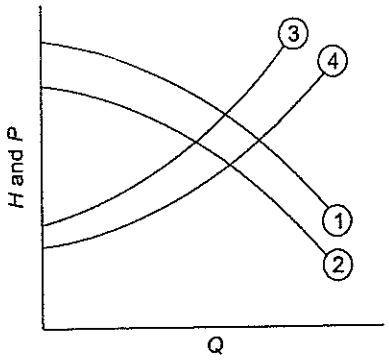
List-II
1. Placing of concrete
2. Underwater concreting
3. Compaction of concrete
4. Ready mixed concrete transport

Codes:

	A	B	C	D
(a)	1	3	4	2
(b)	4	2	1	3
(c)	1	2	4	3
(d)	4	3	1	2

[ESE : 2007]

4.85 The performance of a centrifugal pump [*H* and *P* vs. *Q*] is typically shown in the figure below with four curves numbered 1, 2, 3 and 4.



Which one of the following is correct ?
(a) 1 and 2 refer to *P*, with *P* along 1 referring to greater speed than P along 2
(b) 1 and 2 refer to *H*, with *H* along 1 referring to greater speed than *H* along 2
(c) 3 and 4 refer to *P*, with *P* along 3 referring to lesser speed than *P* along 4
(d) 3 and 4 refer to *H*, with *H* along 3 referring to greater speed than H along 4
[ESE : 2007]

4.86 Match List-I (Equipment) with List-II (Used as/ with) and select the correct answer using the codes given below the lists:

List-I
A. Clamshell
B. Designation S

C. Designation E
D. Centralized production

List-II
1. Paving mixer
2. Aggregate storage bins at batching and mixing plant
3. Transit mixer
4. Construction mixer

Codes:

	A	B	C	D
(a)	2	3	1	4
(b)	2	4	1	3
(c)	1	3	2	4
(d)	1	4	2	3

[ESE : 2008]

4.87 The strain on the boom of a hoist is minimum when it is in the
(a) vertical position
(b) horizontal position
(c) inclined position general
(d) 45° inclined position

[ESE : 2008]

4.88 Which of the following are the advantages of a crawler mounted power shovel over a rubber-tyred equipment?
1. It can operate on soft and hard soil.
2. It is less expensive than rubber-tyred equipment.
3. It works faster than rubber-tyred equipment.

Select the correct answer using the codes given below:
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 1 and 3 only

[ESE : 2008]

4.89 Fill factor range of a power shovel when used for well blasted rock is
(a) 0.9 – 1.0 (b) 0.8 – 0.9
(c) 0.6 – 0.75 (d) 0.4 – 0.5

[ESE : 2008]

4.90 Match List-I (Equipment) with List-II (Category) and select the correct answer using the codes given below the lists:

List-I
A. Derrick Crane
B. Hoe
C. Clamshell
D. Dumper truck

List-II
1. Excavating equipment
2. Hauling equipment
3. Hoisting equipment
4. Lifting equipment

Codes:

	A	B	C	D
(a)	3	1	4	2
(b)	4	2	3	1
(c)	3	2	4	1
(d)	4	1	3	2

[ESE : 2008]

4.91 The approximate hourly output of a scraper is given by $\frac{100\,C}{(D/30)+2.8}$ where C is the struck capacity of the scraper in m^3 and D is the one-way haul distance in meters. For a nominal 7 m^3 scraper hauling over 65 m, the hourly output will nearly be
(a) 170 m^3 (b) 160 m^3
(c) 150 m^3 (d) 140 m^3

[ESE : 2008]

4.92 Consider the following parameters:
1. The stability of the footing.
2. The strength of the boom.
3. The counterweight.
4. Size of aggregates.

Which of the above parameters governs the load capacity of a crane?
(a) 1 only (b) 1, 2 and 3
(c) 2 and 3 only (d) 2, 3 and 4

[ESE : 2009]

4.93 An engine was tested at local atmospheric pressure of 73 cm of mercury and local temperature of 10°C, and was found to develop X_1 units of power. If it was later worked at conditions of 75 cm of mercury as local atmospheric pressure and at local temperature of 16°C, what proportion of X_1 will it then develop?

(a) nearly $\frac{1}{60}$ times more

(b) nearly $\frac{1}{60}$ times less

(c) nearly $\frac{1}{50}$ times more

(d) nearly $\frac{1}{50}$ times less

[ESE : 2009]

4.94 Consider the following equipments :
1. Drag line
2. Power shovel
3. Hoe
4. Crawler dozer

Which of the above may be used for excavation of materials and loading them into trucks ?
(a) 1, 2 and 3 (b) 1 and 2 only
(c) 2 and 3 only (d) 2, 3 and 4

[ESE : 2009]

4.95 A power shovel is fitted with an engine of 150 f.w.h.p. It operates on full load for 6 minutes followed by 8 minutes of idling at one-third power. Its hourly utilization is for 3 cycles. What is its utilization factor?
(a) 0.398 (b) 0.433
(c) 0.467 (d) 0.528

[ESE : 2009]

4.96 Consider the following statements :
1. There is no large difference in speed between wheeled tractors and crawlers.
2. The operating cost of crawlers is generally more than for wheeled tractors.
3. Both viz, wheeled tractors as well as crawlers, need to be mounted on trailers for long distance hauls.
4. Wheeled tractors may occasionally suffer slips whereas crawlers do not.

Which of these statements is/are NOT correct ?
(a) 1 only (b) 1 and 2
(c) 1 and 3 (d) 3 and 4.

[ESE : 2009]

4.97 A 1.75 m^3 capacity tractor loader has a forward loaded speed of 240 m/min, returning unloaded speed of 300 m/min and operates at 80% of the specified speed. It hauls earth over a distance of 60 m with fixed time per trip being 25 seconds. What is its effective cycle time ?
(a) 54.25 seconds (b) 55.50 seconds
(c) 56.75 seconds (d) 58.75 seconds

[ESE : 2009]

4.98 A 1.6 m^3 capacity tractor loader works at a site with an effective per-round-trip time of 64 seconds. Effective delivery of excavated material is 90%. If utilization is 50 minutes per hour working, what will be the productivity in a 4-hour shift ?
(a) 253 m^3 (b) 262 m^3
(c) 270 m^3 (d) 282 m^3

[ESE : 2009]

4.99 Match the List-I (Equipment) with List-II (Category) and select the correct answer using the codes given below the lists :

List-I
A. Derrick crane
B. Hoe
C. Clamshell
D. Dumper Truck

List-II
1. Excavating equipment
2. Hauling equipment
3. Hoisting equipment
4. Vertical lifting equipment

Codes:

	A	B	C	D
(a)	2	1	4	3
(b)	3	1	4	2
(c)	2	4	1	3
(d)	3	4	1	2

[ESE : 2009]

4.100 A single-acting reciprocating pump has a stroke of 30 cm, speed of 115 rpm and a piston of 30 cm diameter. It discharges 39 litres per second through a height of 15 m. The slip of the pump is
(a) 2.8% (b) 3.2%
(c) 3.6% (d) 4.0%

[ESE : 2010]

4.101 The correct statement in respect of a centrifugal pump is
(a) the discharge varies in direct proportion to speed as also square of the diameter
(b) the head varies as the square of the speed as also of the square of the diameter
(c) the discharge varies in inverse proportion to speed as also the cube of the diameter
(d) the power varies as the head and square of the diameter

[ESE : 2010]

4.102 A crawler-tractor weighs 9 ton and a rubber-tyred tractor capable of exerting the same maximum drawbar pull weighs 7.5 ton. 65% of weight of the latter is carried by the two driving wheels. Tractive coefficient for crawler track and rubber tyre is respectively 0.48 and 0.90. Which tractor is more suitable for use where the running surface is concrete?

(a) Crawler-tractor (b) Rubber-tyred tractor
(c) Either (d) Neither

[ESE : 2010]

4.103 A four-wheel tractor whose operating weight is 13,000 kg is pulled along a haul road having a slope of 4% at a uniform speed with a rolling resistance of 10 kg/ton for 1% slope. The tension in the toe cable is 1105 kg. The rolling resistance of the haul road is

(a) 35 kg/ton (b) 45 kg/ton
(c) 55 kg/ton (d) 65 kg/ton

[ESE : 2010]

4.104 On a particular construction project, the contractor on an average employed 100 workers with 50 hours per week. The project lasted for 35 weeks and during this period, 14 disabling injuries occurred. The injury-frequency rate is

(a) 6 (b) 7
(c) 8 (d) 9

[ESE : 2010]

4.105 **Assertion (A):** A drag line is a suitable equipment for excavating or digging earth and depositing it on nearby bank.

Reason (R): In drag-line, there is no need of a separate hauling unit.

(a) both A and R are true and R is the correct explanation of A
(b) both A and R are true but R is not a correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2010]

4.106 Which one of the following rollers is suitable for soil cement stabilized road construction?

(a) Vibratory roller
(b) Sheepfoot roller
(c) Pneumatic roller
(d) Smooth wheel roller

[ESE : 2011]

4.107 In a group housing project, it is proposed to use pre-fabricated RCC beams and columns. The most useful construction equipment is

(a) Derrick Crane (b) Chute
(c) Weigh Batcher (d) Transit Mixer

[ESE : 2011]

4.108 Tractive coefficient of a Crawler truck in loose soil is

(a) Less than that of rubber tyre tractors
(b) More than that of rubber tyre tractors
(c) Same as that of rubber tyre tractors
(d) Nearly zero

[ESE : 2011]

4.109 A centrifugal pump 18 cm diameter, running at 1460 rpm delivers 0.096 m^3/sec water against a head of 36 m of water with an efficiency of 86%. If another pump, twice the size of this said pump, is run at the same speed, how much water would the bigger pump deliver and at what head of water? (Take $\sqrt[3]{2} = 1.26$)

(a) 0.192 m^3/sec and 46.36 m
(b) 0.192 m^3/sec and 90.72 m
(c) 0.384 m^3/sec and 45.36 m
(d) 0.384 m^3/sec and 90.72 m

[ESE : 2011]

4.110 The output from a power shovel is 144 cum/hr. The required number of trucks of 12 cum capacity each with 16 rminute cycle time and with 80% operating efficiency will be

(a) 5 (b) 4
(c) 3 (d) 2

[ESE : 2011]

4.111 A supercharger is used in the engines of earth moving machines at higher altitudes because

(a) The ambient atmospheric pressure is less at higher altitudes
(b) Four cycle engines depend on the suction of the engines for the supply of air
(c) Two cycle engines are not rugged enough for higher altitudes
(d) The ambient temperature is less as the altitude is higher

[ESE : 2011]

4.112 Match List-I with List-II and select the correct answer using the code given below the lists:

List-I
A. Concrete pumps
B. Agitating trucks
C. Transit Mixer
D. Crane Bucket

List-II
1. Ready Mix concrete
2. Multi-storey concreting works
3. Tunnel works
4. Built-up and busy area

Codes:

	A	B	C	D
(a)	3	4	1	2
(b)	2	1	4	3
(c)	3	1	4	2
(d)	2	4	1	3

[ESE : 2011]

4.113 Match List-I with List-II and select the correct answer using the code given below the lists:

List-I
A. Crawler-mounted lifting cranes
B. Rubber-tire-mounted lifting cranes
C. Drag lines with 1.34 cum bucket, digging and loading in gravel
D. Power shovel converted into hoe

List-II
1. Limiting load is within 75% of tipping load.
2. Allow use of dipper with its stick.
3. Time taken in swinging between 45° to 180° is 23 to 35 seconds
4. Limiting load is upto 85% of tipping load

Codes

	A	B	C	D
(a)	1	3	4	2
(b)	2	3	4	1
(c)	1	4	3	2
(d)	2	4	3	1

[ESE : 2011]

4.114 Assertion (A): Pumps for concreting are generally of the positive displacement category.
Reason (R): Roto-dynamic pumps may effect more crushing of the coarse aggregate.
(a) Both A and R are individually true and R is the correct explanation of A
(b) Both A and R are individually true but R is not the correct explanation of A
(c) A is true but R is false
(d) A is false but R is true

[ESE : 2011]

4.115 The most suitable type of equipment for compaction of cohesive soils is
(a) smooth-wheeled roller
(b) vibratory roller
(c) sheeps foot roller
(d) tamper

[ESE : 2012]

4.116 For excavating rocks, the most suitable equipment is
(a) dragline (b) power shovel
(c) clamshell (d) hoe

[ESE : 2012]

4.117 The initial cost of equipment is Rs. 1100, salvage value is Rs. 100 and life of equipment is 5 years. The rate of interest for sinking fund is 8%. The yearly depreciation by straight line method is
(a) Rs. 200 (b) Rs. 400
(c) Rs. 600 (d) Rs. 800

[ESE : 2013]

4.118 Which of the following statements are correct?
Tilting type concrete mixers are preferred in situ:
1. Because problem of clogging the opening is avoided.
2. For large constructions only.
3. Because they are suitable for dry mix.
4. Whenever the rated capacity is more than 200 litres.

(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 2 and 4

[ESE : 2013]

4.119 Which of the following statements are correct?
1. Drag lines are superior to hoes in excavation jobs.
2. Hoes are more rigid than power shovels.
3. For deeper excavations power shovels give lesser output than hoes.
4. Hoes exert greater tooth power as compared to draglines.

(a) 1 and 2 (b) 2 and 3
(c) 1 and 3 (d) 2 and 4

[ESE : 2013]

4.120 If the free haul distance is 200 m, the cost of borrow (including excavation and hauling) is Rs. 4/m^3 at station. Cost of haulage beyond free haul is Rs. 0.75/m^3 per station meter. The limit of economical haul distance is

(a) 160 m (b) 260 m
(c) 360 m (d) 460 m

[ESE : 2013]

4.121 A four-wheel tractor whose operating weight is 15,000 kg is pulled along a level haul road at a uniform speed by another tractor. The average tension in the toe cable is 675 kg. The rolling resistance of the haul road is

(a) 25 kg/t (b) 35 kg/t
(c) 45 kg/t (d) 55 kg/t

[ESE : 2013]

Directions: Each of following items consists of two statements, one labeled as the **'Statements (I)'** and the other as **'Statement (II)'**. You are to examine these two statements carefully and select the answers to these items using the codes given below :

Codes:

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)
(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is NOT the correct explanation of Statement (I)
(c) Statement (I) is true but Statement (II) is false
(d) Statement (I) is false but Statement (II) is true

4.122 **Statement (I):** In the erection of tall buildings, tower crane is preferred.

Statement (II): Tower crane is a combination crane and it is suitable when the area is small and congested.

[ESE : 2013]

4.123 **Statement (I):** For short distance hauls, dumpers are well suited.

Statement (II): Dumpers have the advantages of larger capacity of 5 cu m or more, and they are hauled by power units.

[ESE : 2013]

4.124 **Statement (I):** Draw-bar pull exerted in crawler-tractors overlaps between different speed ranges, which latter are achieved by operating in different gears.

Statement (II): Variations in rolling resistance of ground surfaces and the grade of the surfaces rolled on, influence the magnitude of the needed draw-bar pull.

[ESE : 2013]

4.125 **Statement (I):** A wheel type tractor with a scraper is employed to move earth for short hauls.

Statement (II): Wheel type tractor moves faster than crawler type tractor.

[ESE : 2013]

4.126 **Statement (I):** Diaphragm pump is very popular in constructions requiring dewatering of trenches.

Statement (II): Diaphragm pump is more adaptable in performance than other types of pumps.

[ESE : 2013]

4.127 **Statement (I):** Power shovels mounted on crawlers are universally used for excavating earth.

Statement (II): They have a dipper with hard teeth to break even hard rocks.

[ESE : 2013]

4.128 **Statement (I):** An air vessel on the suction side of a reciprocating pump contributes much to increase in efficiency.

Statement (II): Water gets sucked into the pump cylinder faster.

[ESE : 2013]

4.129 **Statement (I):** Negative slip is a possibility in reciprocating pumps.

Statement (II): Non-cavitations in a long suction pipe with simultaneously a short delivery pipe may cause the delivery valve to open before the discharge stroke starts.

[ESE : 2013]

4.130 **Statement (I):** Reciprocating pumps may have more severe restrictions on their suction piping system than centrifugal pumps.

Statement (II): Centrifugal pumps can have the advantage of axial balancing to alleviate possible axial thrust at the eye of the pump.

[ESE : 2013]

4.131 Engines are rated at specified conditions. Then which of the following statements are correct?

1. Power developed increases as local temperature increases.
2. Power developed increases as local temperature decreases.
3. Power developed is not dependent on local temperature.
4. Power developed increases as local atmospheric pressure increases.
5. Power developed increases as local atmospheric pressure decreases.

Select the correct answer using the code given below.

(a) 1 and 4 (b) 3 and 4
(c) 3 and 5 (d) 2 and 4

[ESE : 2014]

4.132 Consider the following statements in respect of 'mixers' :

1. Mass batch mixing of ingredients is the most desirable method.
2. Charging all materials into a drum mixer is done 'at once'.
3. The quantity of material fed into a mixer should be not more than the quantity that can be used in less than 30 minutes after completion of mixing.
4. Reversing mixers have less capacity than tilting mixers.
5. In large mixers, additional time of mixing is allowed.

Which of the above statements are correct?

(a) 1, 2 and 3 (b) 1, 3 and 5
(c) 2, 3 and 4 (d) 2, 4 and 5

[ESE : 2014]

4.133 Consider the following statements about 'cranes':

1. Mobile cranes are suitable in small operations.
2. Whirley crane is a stationary crane with a long boom.
3. Tower crane is used in lifting heavy machinery.
4. A guy-derrick can operate in a limited area only.

Which of the above statements are correct?

(a) 1 and 4 (b) 2 and 4
(c) 1 and 3 (d) 2 and 3

[ESE : 2014]

4.134 Extracts from the head-discharge characteristics of two centrifugal pumps are tabulated with respective subscripts 1 and 2; manometric head hm is given in metres; and discharge Q is given in lps:

Q	12	14	16	18	20
hm_1	50.2	50.8	51.3	50.0	30.0
hm_2	42.4	38.8	35.7	32.0	25.0

The pumps are connected in series against a static head of 80m; the estimate of the total of head losses is $Q^2/120$ m What is the delivered discharge?

(a) 15.80 lps (b) 16.35 lps
(c) 17.35 lps (d) 17.75 lps

[ESE : 2014]

Directions: Each of the following items consists of two statements, one labelled as 'Statement (I)' and the other as 'Statement (II)'. You are to examine these two statements and select the answers to these items using the code given below.

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(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I).
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(d) Statement (I) is false but Statement (II) is true

4.135 **Statement (I):** Hoe is not very advantageous in digging trenches and basements.
Statement (II) : In a hoe, the digging action results from the drag of the bucket.

[ESE : 2014]

4.136 **Statement (I):** In close-range works of excavation, power shovel is suitable.
Statement (II): Power shovel has greater rigidity and gives greater output than draglines.

[ESE : 2014]

4.137 **Statement (I) :** Reciprocating pump is self-priming.
Statement (II) : Reciprocating pump is used to pump dirty water in excavations.

[ESE : 2014]

4.138 **Assertion (A):** Repeated passes are needed with sheep-foot rollers for optimum compaction.
Reason (R): Even if optimum moisture content is ensured, repeated passes are needed to ensure right and even distribution of moisture within the soil volume.
[ESE : 2015]

4.139 **Assertion (A):** Dewatering pumps for use in shallow pits are often of nearly straight-blade centrifugal types.
Reason (R): Centrifugal pumps can lift water to high lifts.
[ESE : 2015]

4.140 **Assertion (A):** Crawler-mounted excavator is more suitable for excavation in soft ground.
Reason (R): Crawler-mounted excavator can be moved at low speeds.
[ESE : 2015]

4.141 Which of the following statements are correct?
1. Cranes are employable in moving and/or hoisting loads.
2. With the use of dipper and stick, power shovels can be used as hoes.
3. Overdrive for higher speeds is a facility often used comfortably in the working of a tractor.
4. Clam shells are less desirable than draglines if the material is water-saturated.

(a) 1 and 4 only (b) 1 and 2 only
(c) 2 and 3 only (d) 3 and 4 only
[ESE : 2016]

4.142 A tractor has a permissible loaded speed of 200 m/minute, which can increase by 25% when the load is removed/deposited. Generally, it is operated at 80% of the permissible speed (loaded or unloaded). It works at a location where haul distance is 120 m. Rest allowance per round-trip is taken as 50 seconds on an average. Fixed time per trip, for loading and unloading and turnaround, etc., is 30 seconds. What is its effective cycle time?
(a) 157 seconds (b) 161 seconds
(c) 173 seconds (d) 182 seconds
[ESE : 2016]

4.143 A single-acting reciprocating pump has a stroke of 25 cm, speed of 135 rpm, and a piston of 30 cm diameter. If its slip has been estimated as 4% at a particular operating condition, what is the corresponding realized discharge through a height of 14 m?
(a) 33.2 *l*ps (b) 35.6 *l*ps
(c) 37.0 *l*ps (d) 38.2 *l*ps
[ESE : 2016]

4.144 Consider the following statements:
1. Pumps used in series are generally of the centrifugal type.
2. Centrifugal pumps, though yielding comparatively smaller discharges than axial flow pumps, yield higher heads (at each stage) compared to axial flow pumps.

Which of the above statements is/are correct?
(a) 1 only (b) 2 only
(c) Both 1 and 2 (d) Neither 1 nor 2
[ESE : 2016]

4.145 The efficacy of pumpcrete is based primarily on
1. The capacity of pump
2. The aggregate size, which should not exceed 8 cm
3. The diameter of pipe being large, with more than 30 cm being desirable
4. The performance of the agitator

(a) 1 and 4 only (b) 1 and 2 only
(c) 3 and 4 only (d) 2 and 3 only
[ESE : 2016]

4.146 In a non-tilting type drum mixer,
1. Large size aggregate up to 20 – 25 cm can be handled
2. Mixing time is less than 2 minutes
3. Discharge is through buckets onto the platform
4. For large-size mixers, the mixing time should be slightly increased if handling more than 800 litres of the mix

Which of the above statements are correct ?
(a) 1 and 2 only (b) 2 and 3 only
(c) 1, 2 and 4 only (d) 3 and 4 only
[ESE : 2016]

4.147 How many impellers are required for a multi-stage pump to lift 4000 *l*pm against a total head of 80 m at a speed of 750 rpm; given that N_s for each impeller should be between 720 to 780 units?

(a) 6 (b) 5
(c) 4 (d) 3

[ESE : 2016]

4.148 A 15 cm centrifugal pump delivers 6 *l*ps at a head of 26 m running at a speed of 1350 rpm. A similarly designed pump of 20 cm size runs at the same speed. What are the most likely nearest magnitudes of discharge and delivery head provided by the latter pump?
(a) 11 *l*ps and 46 m (b) 14 *l*ps and 52 m
(c) 11 *l*ps and 52 m (d) 14 *l*ps and 46 m

[ESE : 2016]

4.149 Which of the following statements are correct as operating characteristics of a centrifugal pump?
1. As discharge increases from zero value, head slightly increases; then the head declines gently; and beyond a certain discharge, the head falls steeply.
2. As discharge increases, efficiency increases from zero, rising fast to a maximum value and then falls rapidly, more rapidly than the head-discharge curve.
3. BHP increases from a non-zero (positive) value at zero discharge, the increase being only moderate before it starts falling beyond a certain discharge.

(a) 1, 2 and 3 (b) 1 and 2 only
(c) 1 and 3 only (d) 2 and 3 only

[ESE : 2016]

4.150 Engines used in earthwork equipment are qualified by the power developed under specified conditions. As operating conditions change, the power developed will increase with local ambience, if
1. Ambient temperature increases
2. Ambient temperature decreases
3. Ambient pressure increases
4. Ambient pressure decreases

Which of the above statements are correct?
(a) 1 and 3 only (b) 1 and 4 only
(c) 2 and 3 only (d) 2 and 4 only

[ESE : 2016]

4.151 Manometric head developed h_m in m, and discharge Q in *l*ps in respect of two pumps, 1 and 2, are tabulated. The pumps are connected in series against a static head of 100 m. Total head losses for a discharge of $\frac{Q^2}{100}$(m). What is the delivered discharge?

Q (in *l*ps)	15	18	20	22	25
h_{m1} (in m)	60.6	61.2	62.0	55.0	48.0
h_{m2} (in m)	50.8	51.0	48.8	45.8	40.0

(a) 20.15 *l*ps (b) 21.25 *l*ps
(c) 21.95 *l*ps (d) 22.20 *l*ps

[ESE : 2016]

4.152 A reciprocating pump has a stroke of 30 cm, speed of 100 rpm, and a piston of 22.5 cm diameter. It discharges 18.9 *l*ps. What is the slip of the pump?
(a) 3.12% (b) 3.54%
(c) 4.15% (d) 4.95%

[ESE : 2016]

4.153 The following data were recorded when a centrifugal pump worked at its maximum efficiency : Q = 40 *l*ps; Manometric head developed = 25 m; Input shaft horse power = 11.9 W. What is the non-dimensional specific speed of the pump if it was running at 1500 rpm? (May adopt the following (all in S.I. units):

$g^{1/4} = 1.77$, $g^{1/2} = 3.132$, $g^{3/4} = 5.544$,

$\sqrt{2} = 1.414$, $\sqrt{5} = 2.236$ and $\sqrt{10} = 3.162$

(a) 165 (b) 155
(c) 145 (d) 135

[ESE : 2016]

4.154 The total head to be developed by a centrifugal pump is expected to be up to 50 m. The normal ratio of radii of impeller rim and impeller eye of 2 is maintained. The design is for a speed of 1300 rpm. What is the nominal diameter of the impeller? Take $\sqrt{g} = 3.13$ and $\frac{1}{\pi} = 0.318$.

(a) 53 cm (b) 57 cm
(c) 60 cm (d) 64 cm

[ESE : 2016]

Directions: Each of the next items consists of two statements, one labelled as the **'Statement (I)'** and

the other as **'Statement (II)'**. Examine these two statements carefully and select the answers to these items using the codes given below :

Codes:

(a) Both Statement (I) and Statement (II) are individually true and Statement (II) is the correct explanation of Statement (I)

(b) Both Statement (I) and Statement (II) are individually true but Statement (II) is *not* the correct explanation of Statement (I)

(c) Statement (I) is true but Statement (II) is false

(d) Statement (I) is false but Statement (II) is true

4.155 **Statement (I) :** Positive displacement pumps can be used for pumping of ready-mixed concrete.

Statement (II): The coarse aggregate in the mix is unlikely to be crushed during positive displacement.

[ESE : 2016]

4.156 **Statement (I) :** In the operation of reciprocating pumps, slip can sometimes be negative.

Statement (II) : Under conditions of high speed, long suction pipes (without capitation) and short delivery pipes, inertia pressure can be relatively rather high, causing the delivery valve to open before the discharge stroke begins.

[ESE : 2016]

4.157 **Statement (I) :** For implementing weigh-batching, separate compartments are made for storing large quantities of the aggregates. Besides lifting and loading equipments, there must be regular assessment of grading and also of moisture content.

Statement (II) : Whereas eventual strength of the mix depends also on the grading of the ingredients, the water needs too must be properly computed and implemented.

[ESE : 2016]

4.158 **Statement (I):** Hand-operated chain-hoists include differential screw-geared types within their range.

Statement (II): In case of a hoist-winch, the capacity of the hoist is increased by a number of gear reductions.

[ESE : 2016]

4.159 **Statement (I):** When employing weigh-batching for mix preparation, bulking of sand has to be accounted for.

Statement (II): Bulked sand will affect the proportional composition of the ingredients to be used in making wet concrete of the desired eventual strength.

[ESE : 2016]

4.160 **Statement (I):** Whereas shutter vibrators are preferred for use with pre-stressed beams, needle vibrators are preferred in foundation concreting.

Statement (II): Needle vibrators are susceptible to get dysfunctional with leaking-in of cement slurry — which is not the case with the shutter vibrator.

[ESE : 2016]

4.161 **Statement (I):** The forward edge of wheels or outriggers acts as a fulcrum in determining the lifting capacity of a mobile crane.

Statement (II): There is in-built security and safety against sudden dropping of load, as well as against abrupt swinging, in the working of a mobile crane.

[ESE : 2016]

■■■■

Answers Concreting Equipments

4.1	(c)	4.2	(d)	4.3	(b)	4.4	(d)	4.5	(a)	4.6	(c)	4.7	(a)
4.8	(b)	4.9	(c)	4.10	(d)	4.11	(c)	4.12	(a)	4.13	(a)	4.14	(b)
4.15	(a)	4.16	(d)	4.17	(d)	4.18	(c)	4.19	(d)	4.20	(d)	4.21	(c)
4.22	(b)	4.23	(c)	4.24	(d)	4.25	(b)	4.26	(b)	4.27	(c)	4.28	(d)
4.29	(b)	4.30	(a)	4.31	(d)	4.32	(a)	4.33	(c)	4.34	(d)	4.35	(b)
4.36	(c)	4.37	(b)	4.38	(c)	4.39	(b)	4.40	(a)	4.41	(b)	4.42	(c)
4.43	(a)	4.44	(b)	4.45	(d)	4.46	(b)	4.47	(a)	4.48	(c)	4.49	(c)
4.50	(a)	4.51	(a)	4.52	(a)	4.53	(c)	4.54	(a)	4.55	(b)	4.56	(d)
4.57	(a)	4.58	(d)	4.59	(d)	4.60	(c)	4.61	(a)	4.62	(b)	4.63	(b)
4.64	(d)	4.65	(d)	4.66	(d)	4.67	(a)	4.68	(a)	4.69	(c)	4.70	(a)
4.71	(a)	4.72	(d)	4.73	(b)	4.74	(c)	4.75	(d)	4.76	(b)	4.77	(a)
4.78	(c)	4.79	(c)	4.80	(a)	4.81	(b)	4.82	(c)	4.83	(d)	4.84	(d)
4.85	(b)	4.86	(b)	4.87	(c)	4.88	(b)	4.89	(a)	4.90	(a)	4.91	(d)
4.92	(b)	4.93	(a)	4.94	(a)	4.95	(b)	4.96	(c)	4.97	(d)	4.98	(c)
4.99	(b)	4.100	(d)	4.101	(b)	4.102	(b)	4.103	(b)	4.104	(c)	4.105	(c)
4.106	(a)	4.107	(a)	4.108	(b)	4.109	(d)	4.110	(b)	4.111	(a)	4.112	(c)
4.113	(c)	4.114	(a)	4.115	(c)	4.116	(b)	4.117	(a)	4.118	(d)	4.119	(d)
4.120	(c)	4.121	(c)	4.122	(c)	4.123	(d)	4.124	(a)	4.125	(d)	4.126	(b)
4.127	(c)	4.128	(a)	4.129	(a)	4.130	(a)	4.131	(d)	4.132	(b)	4.133	(a)
4.134	(d)	4.135	(d)	4.136	(b)	4.137	(c)	4.138	(a)	4.139	(c)	4.140	(b)
4.141	(a)	4.142	(b)	4.143	(d)	4.144	(a)	4.145	(a)	4.146	(d)	4.147	(b)
4.148	(d)	4.149	(a)	4.150	(c)	4.151	(b)	4.152	(d)	4.153	(b)	4.154	(a)
4.155	(a)	4.156	(a)	4.157	(b)	4.158	(b)	4.159	(d)	4.160	(b)	4.161	(b)

Explanations Concreting Equipments

4.2 (d)

Drop hammer is used to drive a pile.

Claw hammer is used to drive nails in wood.

Chain Lewis is used for lifting stone blocks.

4.3 (b)

Rolling resistance = 12 × 45 = 540 kg

$$\text{Grade resistance} = 12000 \times \frac{2}{100} = 240 \text{ kg}$$

∴ Pull available for towing the load

= Maximum rimpull – Rolling resistance – Grade resistance

= 6300 – 540 – 240 = 5520 kg

4.4 (d)

Double drum paving mixer is used for mixing concrete for road or pavement construction. It consists of a long drum divided into two parts by a central diaphragm. Both parts are operated in series. The concrete is initially mixed upto a certain time in the first compartment of the drum and then transferred to the section compartment for the remaining operation of mixing. Thus mixing capacity can be doubled with the same batching equipment and supervisory staff. Standard size of double compartment mixers are 16E(16°) and 34E(34°) as per ASTM specification, where E

stands for paving mixer and the number indicates nominal volume of mixed concrete in ft^3 in one batch.

Capacity of 34° double-drum mixer per batch = $34 \times (0.3048)^3 = 0.963\ m^3$

Assuming time loss per hour for cleaning drum, chutes, starting and oiling engine and taking rest for labourers = 15 min.

Actual operating time per hour = 60 – 15
= 45 min.

As per Indian standards cycle time per batch of $0.2\ m^3$ = 3 min.

∴ Cycle time for $0.963\ m^3$

$$= \frac{0.963}{0.2} \times 3 = 14.45 \text{ min.} = 15 \text{ min. (Approx.)}$$

Number of batches per hour $= \frac{45}{15} = 3$

∴ Probable output per hour
$= 0.963 \times 3 = 2.89\ m^3$

4.5 (a)

When a crane lifts a load attached to the hoist line that passes over a sheave located at the boom point of the machine, there is a tendency to tip the machine over.

The tipping load is the load that produces a tipping condition at a specified radius. The load includes the weight of the item being lifted plus the weights of hooks, hook blocks, slings and any other items used in hoisting the load, including the weight of the hoist rope located between the boom point sheave and the item being lifted.

4.6 (c)

As per IS:1791-1985, concrete mixers are designated by a number representing its nominal mixed batch capacity in litres such 85T, 100T, 200NT, 200R, etc. T, NT and R denote tilting, non-tilting and reversing respectively. Thus, these letters indicate feeding arrangement.

4.7 (a)

Plate vibrator is used for manufacture of large prefabricated elements such as electric poles, railway sleepers, prefabricated roof element, door and window frames, etc. Form vibrators can also be used, but their efficiency is low. Needle vibrators will create problem due to congested reinforcement and it is better to compact by hand otherwise reinforcement may get disturbed. So needle vibrators should be the last choice.

4.8 (b)

There are three types of concrete pumps viz. piston pumps, pneumatic pumps and squeeze pressure pumps. Most piston pumps currently contain two pistons, with one retracting during the forward stroke of the other to give a more continuous flow of concrete. The pneumatic pumps normally use a reblending discharge box at the discharge end to bleed off the air and to prevent segregation and spraying. In the case of squeeze pressure pumps, hydraulically powered rollers rotate on the flexible hose within the drum and squeeze the concrete out at the top. The vacuum keeps a steady supply of concrete in the tube from receiving hopper.

4.9 (c)

Graders are multipurpose machines used for finishing, shaping, bank sloping and ditching.

4.10 (d)

Scraper is a self sufficient machine which can dig, load, haul and discharge the material in uniformly thick layers.

Dump trucks are fitted with automatic unloading devices and they are used for moving the excavated material. The loading is normally done by loading shovels or loaders.

4.11 (c)

Material	Impact	Pressure	Vibration	Kneading
Gravel	Poor	No	Good	Very good
Sand	Poor	No	Excellent	Good
Silt	Good	Good	Poor	Excellent
Clay	Excellent with Confinement	Very good	No	Good

Sheepfoot rollers compact by tamping and kneading. Therefore they are suitable for silt and clay i.e. cohesive soils.

4.12 (a)

Hoe may be used to

(i) excavate below the natural surface of the ground on which the machine rests.

(ii) dig trenches, footings or basements and general grading work which requires precise control of depths.

(iii) penetrate easily into toughest materials to be dug.

4.13 (a)

The primary action is kneading in sheep foot roller.

4.14 (b)

When it is difficult to leave holes in the wall to provide bearing for the putlogs, then two frames of standards, ledgers and braces are used. One frame is placed close to the wall and the other at a distance of 1.5 m from the first one. Put logs are then supported on both the frames. This arrangement is called Mason's Scaffold. Thus, the Mason's Scaffold is entirely independent of the wall.

4.15 (a)

Coping is a covering placed on the exposed top of an external wall. It is essentially provided to prevent the seepage of water through the joints of the top most corner of the wall. It may be of concrete, stone, brick or terracotta.

4.16 (d)

For specified architectural work, specific items/ materials are used. Hence, item rate type of contract is most appropriate.

For construction of house, large number of quantity of materials is required, thus many a time it is lumpsum type of contract.

Price work contract is related to a particular work for which the price is to be paid like repainting of house which is done after some years of use of house.

In cost plus a fixed sum contract, the contractor will honestly endeavour to perform the work in the shortest possible time, with the best workmanship and for the least cost, in order to win high business prestige. This is ideally suited for war emergency when compensation is no consideration and also on works relating to subsoil conditions which cannot be correctly estimated for bidding.

4.17 (d)

Wheel tractor possesses speed upto 3 to 4 times higher than a crawler tractor.

A wheel tractor has steering wheel which is easy to operate and control while a crawler tractor is provided with stick control which is not easy to control.

Crawler tractors are more costly initially than wheel tractors. Operation, maintenance and repair cost is less in wheel tractor than in crawler tractor.

4.19 (d)

A partial safety factor with respect to tipping is introduced by PCSA (Power Creane and Shovel Association) rating standards that state that the rated load of a lifting crane shall not exceed the following percentages of tipping loads at specified radii.

(i) Crawler mounted cranes, 75%
(ii) Rubber-tyre-mounted machines, 85%
(iii) Machines on outriggers, 85%

4.20 (d)

Hoe is advantageous for digging trenches, footings or basements and general grading work which requires precise control of depths.

4.22 (b)

When mechanical vibrators are used, the mix should not have high slump.

4.23 (c)

Total head against which work will be done,

$H = 7.5 + 0.25 = 7.75$ m

$$\therefore BHP = \frac{wQH}{75\eta} = \frac{1000 \times 2.8 \times 7.75}{0.8 \times 75}$$

4.24 (d)

Nominal volume, $V = 6\ m^3$

Total weight of all ingredients,

$$W = 1875 + 5120 + 6060 + 865$$
$$= 13920\ kg$$

Reduction in volume = 1.5%

Volume of freshly mixed concrete,

$$V_1 = \left(\frac{100 - 1.5}{100}\right) \times V = 5.91\ m^3$$

Density or unit weight of concrete

$$= \frac{W}{V_1} = \frac{13920}{5.91} = 2355\ kg/m^3$$

4.25 (b)

The combined effect of pressure and temperature on IC engine is determined from the test carried out under conditions (P, T) different from the standard conditions (P_o, T_o).

Horse power, $H = H_0 \frac{P}{P_0}\sqrt{\frac{T_0}{T}}$

$$\Rightarrow \quad \frac{H_0}{H} = \frac{P_0}{P}\sqrt{\frac{T}{T_0}}$$

4.26 (b)

Scrapers can be used in a wide range of material types (including shot rock) and are economical over a wide range of haul lengths and haul conditions. They are a compromise between machines designed exclusively for either loading or hauling.

The rolling resistance varies with size of tyre, pressure on tyre and tread of tyre. A narrow tread gives high pressure and lower rolling resistance than a broad tread, low pressure tyre on a hard surface road due to small area of contact between the tyre and road surface.

The effect of the loss in power due to altitude can be eliminated by the installation of a supercharger. This is a mechanical unit that will increase the pressure of the air supplied to the engine, thus enabling sea-level performance at any altitude.

Rimpull designate the tractive force between the rubber tyres of driving wheels and the surface on which they travel. If the coefficient of friction is high enough to eliminate tyre slipping, the maximum rimpull is a function of the power of the engine and the gear ratios between the engine and the driving wheels.

4.27 (c)

Power shovels are capable of excavating all classes of earth except the solid rock without prior loosening.

4.28 (d)

Tower bucket arrangement has following advantages :

(i) Initial cost is less.

(ii) It requires less space; so used in congested area.

Crane bucket arrangement has following features :

(i) Cranes permit to deposit concrete at different elevations around the structure.

(ii) The crane may be used for other operation when not dealing with concrete placement.

(iii) Crane hoisting is economical in the long run although its initial cost is high.

4.29 (b)

Hydraulic controlled bulldozer is able to produce high down pressure on the blade to force them into the ground. It is able to maintain precise setting of the position of blade.

4.30 (a)

Let number of batches in an hour be n.

Lost time $= 0.15n$

$$\therefore \quad n = \frac{60 - 0.15n}{1.6}$$

$$\Rightarrow n = \frac{60}{1.6 + 0.15}$$

4.31 (d)

Surface vibrators are placed directly on the concrete mass. These are best suited for the compaction of shallow elements and should not be used when depth of concrete to be vibrated is more than 250 mm.

4.32 (a)

Output

$$= \frac{\text{Production per cycle} \times \text{Efficiency} \times 3600}{\text{Cycle time in second}} \ \text{m}^3/\text{hr}$$

4.33 (c)

The horizontal distance from axis of rotation of the crane to centre of vertical hoist line or load block is called operating radius. The operating radius of crane can be increased by increasing length of boom.

4.34 (d)

Redesigning and improving of equipment will save labour cost because of greater automation in the equipment. However, the existing equipment has to be replaced and better equipment needs to be employed to achieve economy in operation. Therefore redesigning and improving may not be economical alternative due to high initial cost.

4.35 (b)

Tilting, drum type concrete mixers can be used even if aggregate size is more than 75 mm

whereas non-tilting mixers can be used for small size aggregate only. Non-tilting mixer consists of drum rotating about horizontal axis and concrete is fed from one end and discharged from other. Pan type of mixers consist of star blades rotating about vertical axis and are very efficient. Portable non-tilting drum type mixers are used for small, scattered jobs.

4.37 (b)

The non-tilting type of mixer is suitable for small works and aggregate size not greater than 7.5 cm. With large sized aggregates, segregation may take place.

4.39 (b)

The norm for providing standby equipment for:

One shift operation: 10%

Two shift operation: 20%

Three shift operation: 30%

4.40 (a)

Area cleaned by dozer in one hour

= Effective width × Average speed

= 2 × 2500 = 5000 m^2/hr

No. of hours taken to clean 15000 m^2 area

$$= \frac{15000}{5000} = 3 \text{ hr}$$

Cost = 500 × 3 = 1500

$$\text{Cost per } m^2 = \frac{15000}{1500} = \text{Rs. } 10$$

4.41 (b)

Crawler mounted dozer has greater floatation because of low pressure under the tracks. They can deliver greater tractive effort while operating on loose or muddy soil. They are versatile for various job conditions.

The rubber tyred bulldozer has higher travel speed on hard and level surfaces. In those conditions they give better output. They result in lesser operator fatigue.

4.42 (c)

Compaction of clayey-soil using sheep-foot roller is achieved by kneading action. Sheep foot roller drum pads penetrate through the top lift and compact the lift below.

4.43 (a)

The working range of crane is limited horizontally for maximum lift by boom length. Boom length is the straight-line distance from the centerline of boom foot-pin to the centerline of the boom-point load.

4.44 (b)

Tower crane is used for erection of very tall industrial and residential buildings.

Gantry crane is used in factories and workshops.

4.45 (d)

Non-arrival of any one group on time means that the two groups arrive on time. Thus probability

= 0.3 × 0.7 × 0.7 + 0.7 × 0.3 × 0.7

+ 0.7 × 0.7 × 0.3 = 0.441

4.46 (b)

On smooth, hard surface rubber tyred equipment can achieve higher speed and will give more output. Crawler has more tractive force and suitable for rough surfaces.

4.47 (a)

Vibrators develop vibrations with help of electric motor with an unbalanced mass on its drive shaft and compact the concrete. The entrapped air and excess water is removed resulting in better finish.

4.48 (c)

Grade resistance is measured in percent slope. Uphill grades are normally referred to as adverse grade expressed as positive percentage while downhill grades are referred to as favourable grades expressed as negative percentage.

Grade resistance does not depends on the type of equipment or the condition or type of road.

4.49 (c)

Sheep's foot compactor are used to compress cohesive soils like clay, silty clay etc. Steel tandem compactor can be used on semi cohesive soil with up to 10% clay binder. Steel drums are used to compact granular plastic. Pneumatic large type compactor is used for compacting relatively graded sand.

4.51 (a)

Productive capacity of a hauling unit

= Hauler's payload per cycle in tonnes or m^3

$$\times \frac{60}{\text{Cycle time in minutes}}$$

Where payload is the maximum recommended load for a hauling unit as prescribed by the manufacturer.

Cycle time = Loading time + hauling time
+ dumping and turning time
+ return time
+ spotting and waiting time.

4.52 (a)

The output of a power shovel depends on
(i) class of material
(ii) depth of cut
(iii) angle of swing
(iv) job conditions
(v) management conditions
(vi) size of hauling units like trucks
(vii) skill of operator
(viii) physical condition of the shovel

The optimum depth of cut is that depth at which the output is greatest and dipper comes up with full load without excessive downward pressure and tension. This depth varies with the type of soil and size of the dipper.

Ideal production of a shovel is based on operating at 90° angle of swing.

4.53 (c)

Volume of concrete mix per hour

$$= 1500 \times \frac{3600}{15} \times \frac{1}{1000} = 360 \text{ m}^3/\text{hr}$$

4.54 (a)

For transporting excavated material, following are the important considerations:
1. Length of Haul
2. Nature of haul route
3. Conditions of tipping or spreading
4. Type of excavator used

Specifications of crane include:
1. Operating weight
2. Its model and serial number
3. Boom length
4. Boom angle
5. Jib length
6. Swing speed

4.55 (b)

Pan mixers with revolving star of blades are suitable for stiff and lean mixes.

External vibrators are attached to outside of the form and they vibrate the form that in turn vibrates the concrete.

4.56 (d)

Operating factor = Engine factor
× Time factor

Engine factor accounts for operating at rated HP during maximum output and below rate HP for balance of cycle time.

Time factor accounts for shut down time proportion.

4.57 (a)

If the depth of face from which a shovel is excavating material is too shallow, then it will be difficult to fill the bucket (dipper) in one pass up the face.

4.58 (d)

When loaded the grade resistance will be 5.5% and when empty the grade resistance will be 1.5%.

Total resistance = Rolling resistance
+ Grade resistance

When travelling loaded the weight

$$= 27 + \frac{1800 \times 14}{1000} = 52.2 \text{ t}$$

When travelling empty the weight = 27 t

Thus rimpull

$$\text{(i) when loaded} = \frac{5.5}{100} \times 52.2 \times 1000 \times 10$$
$$= 28710 \text{ N}$$

$$\text{(ii) when empty} = \frac{1.5}{100} \times 27 \times 1000 \times 10$$
$$= 4050 \text{ N}$$

4.59 (d)

$$\text{Output} = \frac{\text{Average speed} \times \text{effective width}}{6}$$

$$= \frac{(1.5 \times 1000) \times 1.5}{6} = 375 \text{ m}^2/\text{hr}$$

4.60 (c)

Efficiency is given by

$$\eta_o = \frac{\text{Power delivered to the fluid}}{\text{Power input into the shaft}}$$

$$= \frac{\gamma QH}{BP}$$

$$BP = \frac{\gamma QH}{\eta_o}; \text{ delivery head } H = 18 \text{ m}$$

Pump discharge (Q)	Efficiency (η_0)	BP
90 *l*ps	60%	$\frac{90\times18\gamma}{0.6}$
60 *l*ps	50%	$\frac{60\times18\gamma}{0.5}$

Total discharge delivered = 90 + 60 = 150 *l*ps at delivery head of 18 m.

The pumps work in parallel

$$\therefore \eta_{overall} = \frac{150\times18\gamma}{\frac{90\times18\gamma}{0.6}+\frac{60\times18\gamma}{0.5}}\times100 = 55.5\%$$

For pumps in series

$$\eta_{overall} = \frac{\Sigma Q}{\frac{Q_1}{\eta_1}+\frac{Q_2}{\eta_2}+.....}$$

$$\eta_{overall} = \frac{\Sigma H}{\frac{H_1}{\eta_1}+\frac{H_2}{\eta_2}+.....}$$

4.61 (a)

Power Shovel is used in excavation of earth in confined area or pit.

Hoe is used in excavation of trenches because trenches need precise control of dimensions and Hoe is suitable for this purpose.

Clamshell is used in rehauling of loose or excavated material.

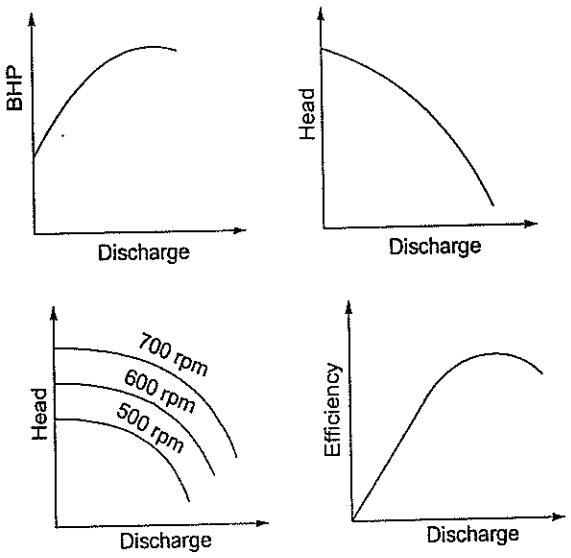
Bulldozer is used in clearing and scrubbing of worksite.

4.62 (b)

A centrifugal pump is based on forced vortex flow and water is revolved at a high speed by impeller.

Reciprocating pumps can give constant low discharge under varying head.

4.63 (b)



4.64 (d)

$Q = 2ALN = 76.4$ lit/minute

Where $A = \frac{\pi\times6^2}{4}\text{cm}^2$

$L = 15$ cm, $N = 90$ rpm

$$\therefore \quad Q = 2\times\frac{\pi}{4}\times6^2\times\frac{15\times90\times10^3}{10^6}$$

$$= 76.34 \approx 76.4 \text{ lit/minute.}$$

4.65 (d)

Cycle time = Hauling time + Return time + Lost time

$$= \frac{0.03}{2.4}\times60+\frac{0.03}{6}\times60+\frac{18}{60}$$

$$= 0.75 + 0.3 + 0.3 = 1.35 \text{ minutes}$$

$$\text{Number of trips per hour} = \frac{50}{1.35}\simeq37$$

4.66 (d)

Vibrating needle and internal vibrator are same thing. Form vibrator can be used for thin walls. They are particularly useful where reinforcement, lateral ties and spacers interfere too much with internal vibrator.

Surface vibrators can be used for thin members.

4.67 (a)

Advantages of *ADT* over *RDT* are :

(i) Higher Manoeuverability

(ii) Lower turning radius

(iii) Higher tractive effort

(iv) Better operator comfort
(v) Faster cycle times and therefore low fleet costs.

4.68 (a)

Pneumatic roller – Granular and silty materials, bituminous road works, etc.
Vibratory roller – Compaction of non-cohesive soils.
Sheepfoot roller – Compaction of cohesive material like clay.
Grid and mesh roller – Compaction of gravel base.

4.69 (c)

Agitating truck – Transporting
Hoe – Quarrying (Penetrate easily into toughest material)
Derrick Pole – Hoisting
Sheep foot roller – Compacting

4.70 (a)

Bulldozer is employed for excavating and moving the earth.
Power shovels can excavate all type of soils except solid rock without prior loosening and dump it into trucks. Power shovels can be used for digging the earth at or below the operating level and loading it into hauling units.
Dragline is designed to excavate below the level of machine. The bucket in dragline digs up by pulling the load towards it.
Clamshells are suited for vertically lifting loose materials.

4.71 (a)

Smooth wheeled rollers have main methods of compaction (i) by impact and (ii) vibration. The compacting efficiency of the smooth wheeled roller depends on the weight, width and diameter of each roller. They are suitable for a wide range of soils, preferably granular soils and pavement materials for the various layers.

4.72 (d)

Reciprocating pumps are suitable for low discharges at high head.

4.73 (b)

400 NT means that the concrete mixture is non tilting drum type mixture having nominal mix batch capacity of 400 liters.

4.74 (c)

Back hoe or hoe can be used for digging trenches where precise control of depth is needed. Power shovels can be used to excavate the earth and load it into the trucks or other hauling equipments waiting nearby. They are capable of excavating all classes of earth except the solid rocks without loosening.
A dragline is designed to excavate below the level of the machine and need not to go into a pit or hole for excavating the earth. When the excavated earth is to be deposited on nearby banks or dams, it is better to use dragline with a long boom enough to dispose of the earth in one operation, eliminating the need of hauling units thereby reducing the cost of handling the earth. A dragline is excellent for excavating trenches without shoring.

The clamshell bucket is designed to excavate material in vertical direction and it is primarily used for handling loose materials such as sand, gravel, crushed stone, coal, etc.

4.75 (d)

Wheel mounted bulldozer has higher travel speed than crawler mounted bulldozer.

4.76 (b)

As per IS 1791-1985, concrete mixtures are specified by:

- The nominal volume of concrete that can be mixed in a batch
- The feeding arrangement of concrete in the drum i.e. Reversing, tilting and non-tilting.

4.77 (a)

Tower cranes provide high lifting height and good working radius, while taking up a very limited area. These advantages are achieved at the expense of low lifting capacity and limited mobility as compared to mobile cranes. Gantry crane is specially advantageous where the load has to be moved three dimensionally.

4.78 (c)

Chain hoist, winch and jack are used for one dimensional vertical movement of weight whereas Crane is used for three-dimensional movement of weight.

4.79 (c)

Power shovels are capable of excavating all classes of earth, except the solid rock with prior loosening.

4.80 (a)

Vibratory rollers are best used for compacting granular and sandy soil. When these soil types are vibrated, particles shift positions to set more closely with adjacent particles and density is increased.

4.81 (b)

Bottom dump wagons are economic haulers when the material to be moved is free flowing such as sand, gravel, reasonably dry earth and coal. The use of bottom dump wagons will reduce the time required to unload the material.

4.82 (c)

A backhoe can function as a bulldozer for backfilling. It is most efficient in loading carriers. It is an excellent excavator for digging loosely packed moist clay or sandy clay.

4.83 (d)

Tractive effort = Rolling resistance + Grade resistance

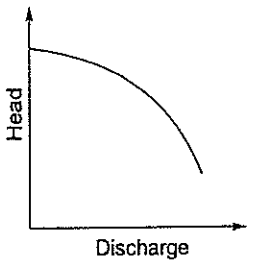
$$= 42 \times 25 + (42 \times 25) \times \frac{5}{100}$$

$$= 1050 + 52.5 = 1102.5 \text{ kg}$$

4.85 (b)

Head vs Discharge in centrifugal pump varies as:

As speed increases delivery head increases.



4.88 (b)

Generally crawler mounted is more expensive than rubber tyre mounted but (b) is the best option as it is always slower than rubber tyre mounted.

4.91 (d)

$$\text{Hourly output} = \frac{100\,C}{\frac{D}{30} + 2.8} = \frac{100 \times 7}{\frac{65}{30} + 2.8} = 140.94 \text{ m}^3$$

4.92 (b)

The parameters which govern the load capacity of a crane:

(i) The stability of the footing on which crane rest.

(ii) The strength of the boom of crane.

(iii) The counterweight which balances the tipping moment.

4.93 (a)

If the test is carried out under conditions different from the standard, the horse power may be determined by using the following formula:

$$H_s = H_o \times \frac{P_s}{P_o} \times \sqrt{\frac{T_o}{T_s}}$$

$$\Rightarrow \quad H_s = X_1 \times \frac{75}{73} \times \sqrt{\frac{273+10}{273+16}}$$

$$\Rightarrow \quad H_s = 1.01667\, X_1$$

Increase in power $= H_s - X_1$

$$= 1.01667\, X_1 - X_1 = 0.01667\, X_1$$

$$= \frac{1}{60} X_1$$

4.94 (a)

Dozers are used for dozing (pushing materials), land clearing, ripping and towing other pieces of construction equipments. They are very efficient excavating tools for short haul applications upto 100 m and as auxiliary machine to other construction equipments.

4.95 (b)

1 cycle of operation = 8 + 6 = 14 minutes

Hourly utilization for 3 cycles = 14 × 3 = 42 minutes

Operating time for 3 cycles = 6 × 3 = 18 minutes

Idling time for 3 cycles = 8 × 3 = 24 minutes

$$\therefore \text{ Engine factor} = \frac{18}{42} \times 1 + \frac{24}{42} \times \frac{1}{3} = 0.619$$

The power shovel operates for 42 minutes in an hour.

$$\therefore \text{Time factor} = \frac{42}{60} = 0.7$$

$\therefore$ Utilization factor = Engine factor × Time factor

$$= 0.619 \times 0.7 = 0.433$$

4.96 (c)

There is a considerable difference in travelling speeds of wheeled tractors and crawlers. Only crawlers need to be mounted on trailers for long distance hauls, because crawlers are suited only for short hauls of 60 to 150 m.

4.97 (d)

Actual forward loaded speed

$$= \frac{80}{100} \times 240 \times \frac{1}{60} = 3.2 \text{ m/sec}$$

Time required to travel a distance of 60 m

$$= \frac{60}{3.2} = 18.75 \text{ sec}$$

Actual returning unloaded speed

$$= \frac{80}{100} \times 300 \times \frac{1}{60} = 4 \text{ m/sec}$$

Time required to travel a distance of 60 m

$$= \frac{60}{4} = 15 \text{ sec}$$

$\therefore$ Effective cycle time

= Forward travelling time + Returning time + Fixed time per trip

$$= 18.75 + 15 + 25$$

$$= 58.75 \text{ sec}$$

4.98 (c)

$$\text{Effective capacity of loader} = \frac{90}{100} \times 1.6$$

$$= 1.44 \text{ m}^3$$

$$\text{Total productivity per hour} = \frac{50 \times 60}{64} \times 1.44$$

$$= 67.5 \text{ m}^3$$

Total productivity in 4h shift = 67.5 × 4

$$= 270 \text{ m}^3$$

4.100 (d)

Theoretical discharge (Q_{th}) of the pump is given by

$$Q_{th} = \frac{ALN}{60} = \frac{\pi \times (0.3)^2 \times 0.3 \times 115 \times 10^3}{4 \times 60}$$

$$= 40.64 \text{ litres per second}$$

$$\text{Percentage slip} = \frac{Q_{th} - Q_{ac}}{Q_{th}} \times 100$$

$$= \frac{40.64 - 39}{40.64} \times 100 = 4.0\%$$

4.101 (b)

Discharge varies in direct proportion to speed as also linearly to diameter.

Head varies as square of speed as also square of diameter.

Power varies with the third power of the diameter.

4.102 (b)

Maximum possible tractive force available to crawler tractor before slippage

$$= 0.48 \times 9 = 4.32 \text{ tonnes}$$

Maximum possible tractive force available to rubber tyred tractor before slippage

$$= 0.65 \times 0.90 \times 7.5 = 4.3875 \text{ tonnes}$$

The available tractive force in rubber tyred tractor is more than that in crawler tractor. Therefore rubber tyred tractor will be suitable in this case.

4.103 (b)

Operating weight of tractor,

$$W = \frac{13000}{1000} = 13 \text{ tonnes}$$

Total grade resistance

$$= 13 \times 10 \times 4 = 520 \text{ kg}$$

Required tractive effort, P

= Tension in toe cable − Total grade resistance

$$= 1105 - 520 = 585 \text{ kg}$$

$\therefore$ Rolling resistance,

$$R = \frac{P}{W} = \frac{585}{13} = 45 \text{ kg/tonnes}$$

4.104 (c)

Injury frequency rate is defined as the number of disabling injuries per 1,00,000 man-hrs worked. A disabling injury is an injury which causes a

loss of working time beyond the day, shift or turn during which the injury was received.

∴ Injury frequency rate

$$= \frac{\text{Number of disabling injuries} \times 10^5}{\text{Number of man-hrs worked}}$$

$$= \frac{14 \times 10^5}{100 \times 50 \times 35} = 8$$

4.105 (a)

Dragline works by dragging bucket against the material to be excavated and depositing it on banks near the excavation place hence there is no need of separate hauling unit.

4.106 (a)

Smooth wheel rollers are useful for finishing operations after compaction of fills and for compacting granular base course.

Vibratory rollers: The roller compacts the soil primarily by kneading action. These rollers are effective for compacting cohesive as well as cohesionless soils.

The sheep-foot rollers are ideally suited for compaction of cohesive soils. The rollers compact the soil by a combination of tamping and kneading action.

Soil-cement should be properly compacted. For good results, fine-grained soils should be compacted wet of optimum and coarse-grained soils, dry of optimum.

4.107 (a)

Derrick crane: Is a hoisting equipment used to lift the load, hold it in suspension during transfer from one location to the other and finally place it on the desired location.

Chutes: When concrete is to be deposited below ground level at a higher depth it can be discharged through a steel shaft called chute. Height of fall is avoided. It may be used in pile foundation.

Weight batcher: Used for batching of materials for a desired concrete mix.

Transit mixer: A transit mixer is a truck on which a concrete mixer is mounted. The aggregates and cement are charged into the mixer at a central batching plant and water is added to the mixer on route to the job. Mixing process gets completed by the time it reaches the site.

4.108 (b)

A crawler truck it is used for moving heavy units on rough surface having poor traction. The optimum pull that a crawler truck can provide depends upon its weight and is equal to the coefficient of traction (depending upon road surfaces) multiplied by the weight of unit, regard less of the power supplied by the engine.

Having more tractive effort a crawler truck can operate on soft footing such as loose or muddy soil. A wheel tractor possesses a lower coefficient of traction between rubber tyres and some soil surfaces.

4.110 (b)

Actual carrying capacity of the truck

$= 0.8 \times 12 = 9.6$ cum

$$\text{No. of trucks required} = \frac{144}{9.6 \times \left(\frac{60}{16}\right)} = 4$$

4.111 (a)

A supercharger is an air compressor that is used to inject more air into an internal combustion engine in order to increase its power output. These are most commonly found in vehicle engines. In cars, the compressor is often driven by a turbine, in which case it is called a turbocharger.

Regardless of the mechanism used to inject more air into the engine, the principle behind a supercharger is fairly simple. An internal combustion engine works by using the combustion of gasoline in a cylinder to drive a piston. By injecting more air than is present in the surrounding atmosphere, there is more oxygen. More oxygen means more fuel can be burned, increasing the amount of power delivered with each work cycle.

A supercharge compresses the air back to sea-level equivalent pressures, or even much higher, in order to make the engine produce just as much power at cruise altitude.

4.112 (c)

Crane bucket help to deposit concrete at different elevations around a structure e.g. multistorey building.

Concrete Pumps: Are commonly used on tunnel works and on locations which are not easily accessible.

Transit mixer: A transit mixer is a truck on which a concrete mixer is mounted. The aggregates and cement are charged into the mixer at a central batching plant and water is added to the mixer on route to the job. Mixing process gets completed by the time it reaches the site.

Agitating Truck: If the unit is used to haul ready mixed concrete which requires agitation on route to prevent it from segregation, the unit is called an agitator truck.

4.114 (a)

A positive displacement pump causes fluid to move by trapping a fixed amount of it then forcing (displacing) that trapped volume into the discharge pipe. These pumps are used for pumping highly viscous fluids including concrete and heavy oils, and under special applications demanding low flow rates against high resistance. Positive displacement pumps, unlike centrifugal or roto-dynamic pumps, will produce the same flow at a given speed (RPM) no matter what the discharge pressure which is helpful in concreting works. Also roto dynamic pumps causes segregation of concrete mix and crushing of the aggregates.

4.115 (c)

Sheeps foot roller because of its kneading effect is most suitable equipment for compaction of cohesive soil.

4.116 (b)

Power shovel are used for digging hard rock in quarries or ore in mines. Dragline is most suitable for excavation of channel and canals, can handle wet or foggy material, and suitable for underwater excavation. Clamshell can be used for handling of loose or soft and medium hard materials only. Hoe is commonly used in quarries which have tough digging conditions and are prone to flooding.

4.117 (a)

Initial cost of equipment: Rs. 1100

Salvage value: Rs.100

[This value is recoverable at the end of service life of the equipments.]

∴ Actual depreciation incurred

= 1100 – 100 = Rs. 100

This loss incurred in 5 years.

∴ Yearly depreciation by straight line method

= 100/5 = Rs. 200/year

4.118 (d)

In order to avoid variation in the concrete quantity within different batches, these type of concrete mixers are preferred particularly in large projects.

4.119 (d)

Because of dierect pull of dipper in hoe.

4.120 (c)

The term free haul distance means a distance over which hauling material involves no extra cost. The limit of economic haul is reached when the cost of haul and cost of excavation become equal.

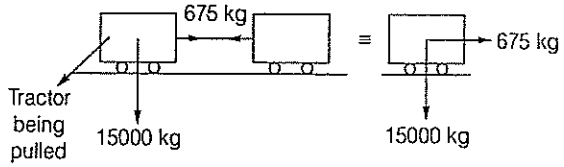
Limit of economic haul,

$$\text{LEH} = \text{Free haul distance} + \frac{\text{Excavation cost}}{\text{Overhaul cost}}$$

Now as the station distance is not given so assuming one station to be of 30 m. So,

$$\text{LEH} = 200 + \frac{4}{0.75} \times 30 = 360 \text{ m}$$

4.121 (c)



$$675 = \mu(15000)$$

$$\Rightarrow \quad \mu = \frac{675}{1500} \text{ kg/kg} = \frac{675}{15} \text{ kg/ton}$$

$$= 45 \text{ kg/ton}$$

4.122 (c)

Tower crane is actually derrick crane mounted on a steel tower. They are used in erection of tall residential and commercial buildings.

4.123 (d)

Dumpers are suitable for both short and long distance hauls.

4.125 (d)

Wheel type tractor with a scraper will move earth for a longer haul distance and at higher speed.

4.126 (b)

Diaphragm pumps are very popular in constructions requiring dewatering of trenches. They can handle chemicals, effluents, gasoline, ground water, acids, sewage, sludge etc. Diaphragm pumps use positive displacement to move liquids and are more adaptable. They are reliable as they do not include internal parts that rub against each other.

4.127 (c)

Power shovels are *used primarily* to *excavate earth* and load it into trucks or tractor–pulled wagons or onto conveyer belts. *They* are capable of *excavating all* classes of *earth, except solid rock*, without prior loosening.

4.128 (a)

When there is air vessel on the suction side of reciprocating pump, the fluctuations in velocity of flow are eliminated, water gets sucked into the pump cylinder faster and head loss due to friction is reduced which results in increase in efficiency.

4.129 (a)

The actual discharge of reciprocating pump may be more than the theoretical discharge and slip will be negative. This may happen when pumps have long suction pipe and low delivery head. The inertia pressure will be large compared to pressure outside delivery valve causing it to open before suction stroke is completed. Thus some liquid is pushed directly into delivery pipe before start of delivery stroke, making actual discharge more than theoretical discharge.

4.131 (d)

$$\frac{H}{P}\sqrt{T} = \text{constant}$$

where, $H \rightarrow$ Horse power of engine
$P \rightarrow$ Pressure in mm of H_g
$T \rightarrow$ Temperature in K

Power developed is directly propertional to local atmospheric pressure and inversely pressure to the square root of local temperature.

4.132 (b)

1. Batch mixing is always desirable as per the mass or weight of ingredients.
2. Normally initial setting time is 30 minute, hence placing of concrete should be done before it.
3. For large mixers, additional time of mixing is allowed.

4.133 (a)

1. Whirley crane is not a stationary crane.
2. Tower crane is used in lifting construction materials.

4.134 (d)

Static head= 80 m

Monometic head,

$$h_m = 80 + \frac{Q^2}{120}$$

From chart, when Q = 18 lps

$$h_m = 50 + 32 = 82 \text{ m}$$

Also, $h_m = 80 + \frac{Q^2}{120} = 82.7$ m

Thus, answer should be very near to 18 lps. So, correct answer is (d).

For $Q = 17.75$ lps

$$h_{m1} = 51.3 - \frac{51.3 - 50}{18 - 16}(17.75 - 16)$$

$$= 50.1625 \text{ m}$$

$$h_{m2} = 35.7 - \frac{35.7 - 32}{18 - 16}(17.75 - 16)$$

$$= 50.1625 \text{ m}$$

$$h_{m2} = 35.7 - \frac{35.7 - 32}{18 - 16}(17.75 - 16)$$

$$= 32.4625 \text{ m}$$

$$\therefore \quad h_m = h_{m1} + h_{m2} = 82.6275 \text{ m}$$

Also, manometric head required

$$h'_m = 80 + \frac{17.75^2}{120} = 82.6255 \text{ m}$$

So, correct answer (d).

4.135 (d)

Hoe is efficient and advantageous in digging trenches and basements.

4.136 (b)

Power shovel has greater rigidity and gives greater output than draglines. Power shovel is suitable in close range excavation due to very low travelling speeds.

4.137 (c)

To pump dirty water in excavations centrifugal pump is preferred as there is low head and high discharge.

4.138 (a)

Repeated passes by the sheep-foot rollers compacts the loose lift and bind it to previously compacted lift resulting in optimum compaction and also ensures the even distribution of moisture within soil volume.

4.139 (c)

Centrifugal pump is preferred to pump dirty water in excavations. It is used for low head and high discharge. For high heads, reciprocating pumps are used.

4.140 (b)

Crawler mounted excavator is more suitable for soft ground such as soft and muddy soil as it has high *traction* and maneuverability. It moves at low speeds (average speed is in range of 4-5 kmph).

4.141 (a)

Cranes are used for hoisting loads.

Dragline is most suitable for under water excavation.

4.142 (b)

Speed = 200 m/min.

It operates at 80% of speed.

∴When loaded, speed = 0.8 × 200 = 160 m/min.

When unloaded speed increases by 25% i.e., 1.25 × 200= 250 m/min.

With 80% operating speed, speed after unloading

$$= 0.8 \times 250 = 200 \text{ m/min.}$$

Cycle time

$$= \frac{120}{160}(60) + \frac{120}{200}(60) + 30 + 50$$

$$= 161 \text{ seconds}$$

4.143 (d)

$$Q_{theo} = \frac{ALN}{60} = \frac{\pi}{4}\frac{(0.3)^2(0.25)(135)}{60}$$

$$= 0.04 \text{ m}^3/\text{sec}$$

$$\% \text{ slip} = \frac{Q_{theo} - Q_{Act}}{Q_{theo}} \times 100$$

$$0.04 = 1 - \frac{Q_{Act}}{Q_{theo}}$$

$$\frac{Q_{Act}}{0.04} = 0.96$$

$$Q_{Act} = 38.4 \text{ } l\text{ps}$$

4.144 (a)

Centrifugal pumps gives greater discharge.

4.145 (a)

- Aggregate size should not exceed 40 mm.
- Diameter of pipe is usually in the range of 125-150 mm.

4.146 (d)

In non-tilting type drum mixture aggregate upto 7.5 cm can be handled.

Mixing time is approximately equal to 800 litre capacity (2 min. is considerably high).

4.147 (b)

Number of impeller = ?

$$N_s = \frac{N\sqrt{Q}}{H^{3/4}}$$

Take, $N_s = 750$

$$750 = \frac{750\sqrt{4000/60}}{(H)^{3/4}}$$

$$H_{mano} = 16.44$$

Number of impeller

$$= \frac{80}{16.44} = 4.866 \simeq 5$$

4.148 (d)

$$\frac{H}{D^2N^2} = \text{constant}$$

$$\frac{26}{(15)^2(1350)^2} = \frac{H}{(20)^2(1350)^2}$$

$$H = 46.22 \text{ m}$$

$$\frac{Q}{D^3N} = \text{constant}$$

$$\frac{6}{(15)^3N} = \frac{Q}{(20)^3N}$$

$$Q = 14.22 \text{ } l\text{ps}$$

4.150 (c)

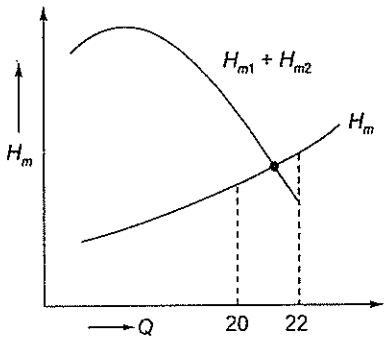
$\frac{H\sqrt{T}}{P}$ = Constant for IC engines.

4.151 (b)

Q (*lps*)	15	18	20	22	25
H_{m1}	50	61.2	62	55	48
H_{m2}	46.7	51	48.8	45.8	40
Total ($H_{m1} + H_{m2}$)	114.4	112.2	110.8	100.8	88

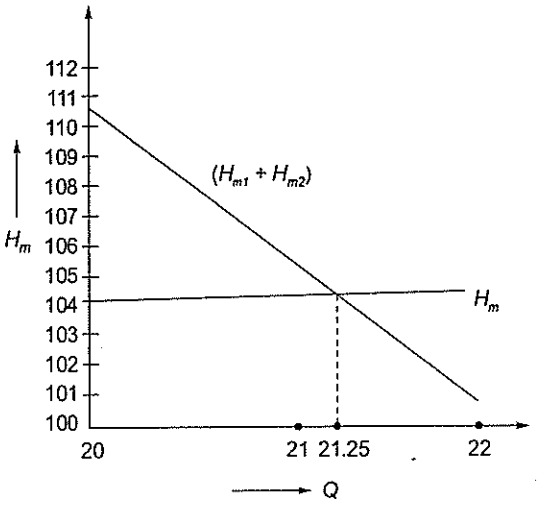
$$H_m = 100 + \frac{Q^2}{100} \qquad Q \Rightarrow lps$$

Q (*lps*)	15	18	20	22	25
H_m	102.25	103.24	104	104.84	106.25



Both the graph cut between 20 and 22.

Now,



4.152 (d)

$$Q_{theo} = \frac{ALN}{60}$$

$$= \frac{\pi}{4}\frac{(0.225)^2(0.3)(100)}{60}$$

$$= 19.88 \text{ lps}$$

$$\%\text{slip} = \frac{Q_{theo} - Q_{Act}}{Q_{theo}} \times 100$$

$$= \frac{19.88 - 18.9}{19.88} \times 100 = 4.93\%$$

4.153 (b)

$$N_s = \frac{N\sqrt{Q}}{(gH)^{3/4}}$$

$$= \frac{1500\sqrt{40}}{(9.81 \times 25)^{3/4}} = 153.07 \simeq 155$$

4.154 (a)

$$\frac{u_2^2 - u_1^2}{2g} = H_{mano}$$

$$\frac{1}{2g}\left[\left(\frac{\pi D_2 N}{60}\right)^2 - \left(\frac{\pi D_1 N}{60}\right)^2\right] = 50$$

$$\frac{1}{2g}\left[\left(\frac{\pi N}{60}\right)^2 \times D_1^2\right](4-1) = 50$$

$D_1 = 0.2656$ m $= 26.56$ cm

So, $D_2 = 53.12$ cm

4.155 (a)

Aggregates would not be crushed.

4.157 (b)

- Moisture correction is done on daily basis.
- Water cement ratio is important parameter of mix design.

4.158 (b)

- Differential screw gear is a type of chain hoist.
- Greater the gear reduction, lesser the motor has to work.

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