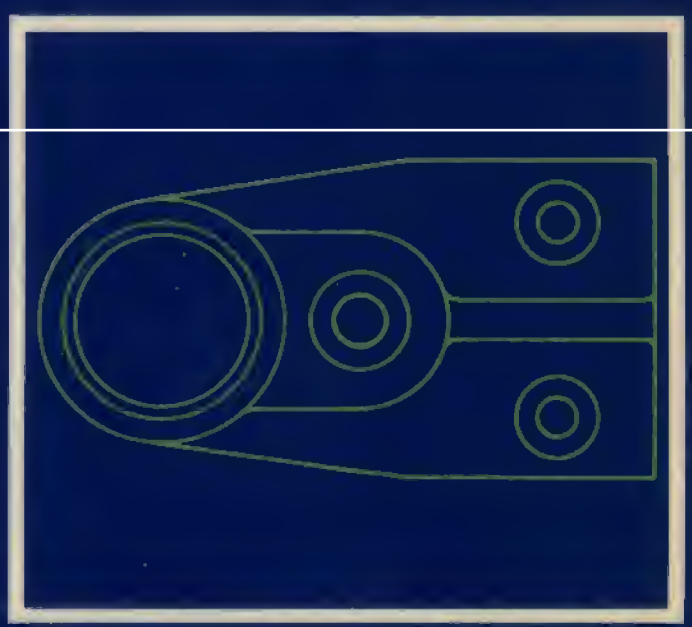
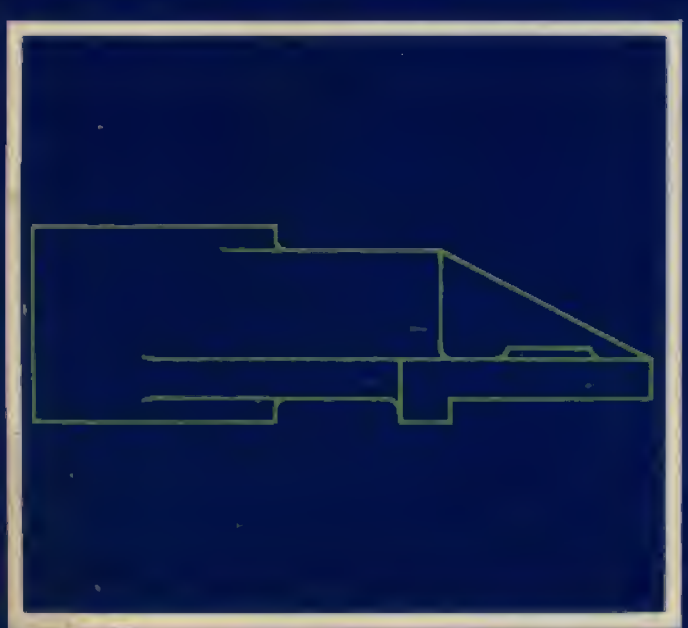
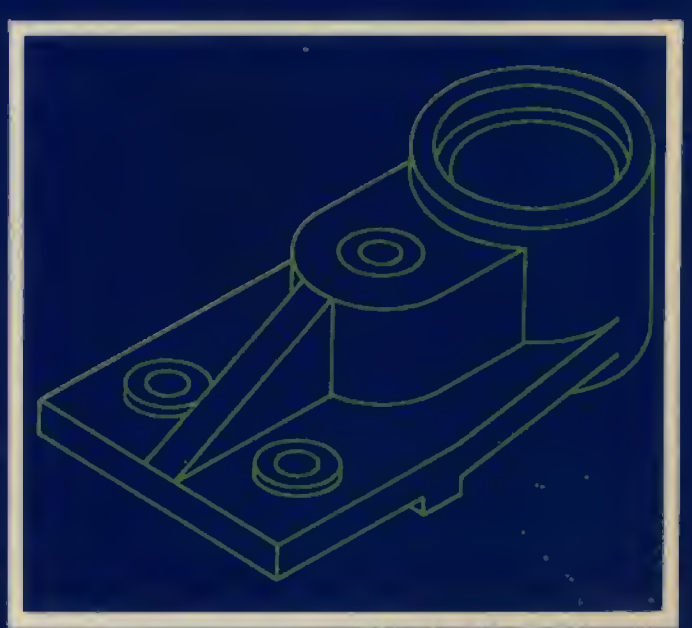
# BASIC ENGINEERING DRAWING

R S Rhodes & L B Cook







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# Preface

This book contains what we consider to be the "basics" of Engineering Drawing. Orthographic Projection, Conventions, Sectioning, Pictorial Representation and Dimensioning have been covered in detail as we feel that a thorough understanding of these topics forms a sound foundation upon which to build. All technical information, examples, exercises and solutions have been compiled in accordance with the latest "metric" drawing office standards - B.S. 308:1972.

The book has not been written for any specific course but can be profitably used both by students being introduced to Engineering Drawing and also by those who have acquired a little knowledge of the subject and wish to consolidate and increase their understanding by working through carefully graded exercises. It should prove useful for Craft, Technician (T.E.C.), O.N.D., C.S.E. and G.C.E. students and also for those H.N.D. and Degree students with little drawing experience. The book is seen primarily as a student self-educator though no doubt many teachers will find it useful as a reference source and/or exercise "bank".

Topics have been presented in a similar manner wherever possible. Generally the opening page introduces the topic, the next imparts the basic facts - visually rather than verbally wherever possible. An illustrative example is provided to aid understanding and this is followed by a series of carefully graded exercises.

We are well aware of the dangers of presenting exercises which are known to contain errors. They have been included because in our experience they are the common misconceptions among students of engineering drawing. In all cases the correct method and answers are given, sometimes immediately following the example, or in the solutions at the end of the book.

It must be emphasized that this book not only transmits information it is also a work-book. Do not be afraid of drawing and writing on the pages! If maximum benefit is to be derived from the book then the old maxim, "I do and I understand" must be the students' guide.

We thank those people whose observations and suggestions have helped us improve upon the first edition of the book. We also wish to thank the British Standards Institution for allowing us to use extracts from B.S. 308:1972.

R.S.R. & L.B.C.

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# Orthographic Projection

## Communication

There are many different ways of communicating ideas, information, instructions, requests, etc. They can be transmitted by signs or gestures, by word of mouth, in writing, or graphically. In an industrial context the graphical method is commonly used, communication being achieved by means of engineering drawings.

If oral and written communication only were used when dealing with technical matters, misunderstandings could arise, particularly in relation to shape and size. The lack of a universal spoken language makes communication and understanding even more difficult because of the necessity to translate both words and meaning from one language to another.

However, the universally accepted methods used in graphical communication through engineering drawings eliminate many of these difficulties and make it possible for drawings prepared by a British designer to be correctly interpreted or "read" by, for example, his German, French or Dutch counterpart.

Equally important, the components shown on the drawings could be made by suitably skilled craftsmen of any nationality provided they can "read" an engineering drawing.

Conventionally prepared engineering drawings provide the main means of communication between the "ideas" men (the designers and draughtsmen) and the craftsmen (machinists, fitters, assemblers, etc.). For the communication to be effective, everyone concerned must interpret the drawings in the same way. Only then will the finished product be exactly as the designer envisaged it.

To ensure uniformity of interpretation the British Standards Institution have prepared a booklet entitled BS 308:1972, *Engineering Drawing Practice*. Now in three parts, this publication recommends the methods which should be adopted for the preparation of drawings used in the engineering industry.

The standards and conventions in most common use and hence those required for a basic understanding of Engineering Drawing are illustrated and explained in this book.

## Orthographic Projection

In the engineering industry communication between the drawing office and the workshop is achieved mainly by means of engineering drawings. The principal method used to prepare these drawings is known as Orthographic Projection.

Basically, Orthographic Projection is the representation of a three-dimensional component on a flat surface (the drawing sheet) in two-dimensional form. At least two orthographic views, therefore, are required to indicate fully the shape and size of a component. If the component is a complicated one then usually more than two views are shown to aid understanding.

In this country two methods of Orthographic Projection are used. One is known as First Angle Orthographic Projection (often referred to as English Projection), the other as Third Angle Orthographic Projection (American Projection). Both methods of representation are illustrated and explained in this section.

# Orthographic Projection: First Angle

The pictorial drawing opposite indicates the shape of the component with a single view.

An orthographic drawing indicates the shape of a component by using a number of views each looking at a different face of the component.

At least two views are necessary to fully represent the component. Usually, however, three views are shown in order to clarify internal and external detail:

(1) A Front View

(2) A Plan View

(3) A Side View

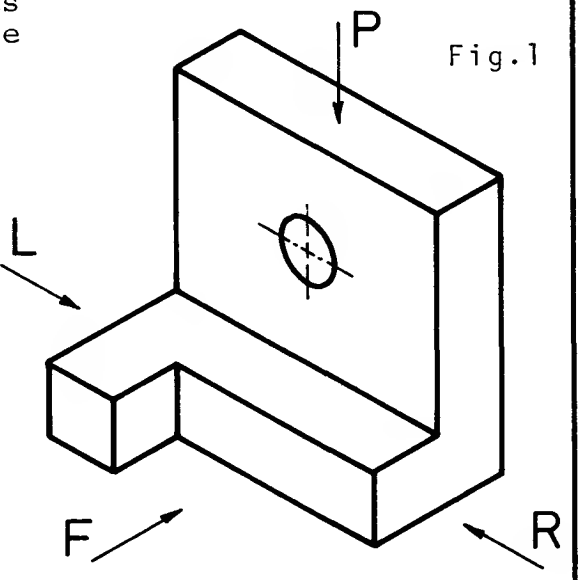
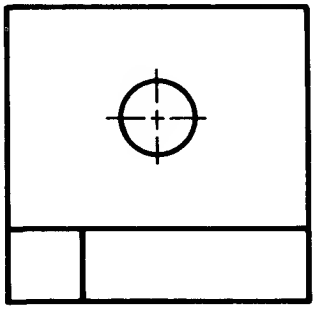



Fig.1

Fig.2



Front View (F)

(1) The front view, or front elevation, represents what is seen when looking at the front of the component in the direction of arrow F.

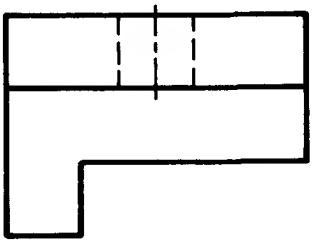


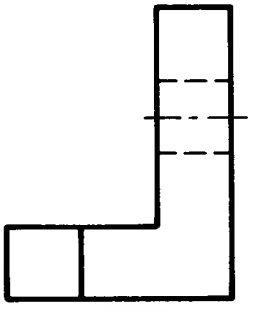
Fig.3

Plan View (P)

(2) The plan view represents what is seen when looking at the top of the component in the direction of arrow P at 90° to arrow F.

(3) A side view, or side elevation, represents what is seen when looking at the side of the component in the direction of either arrow R or arrow L. These arrows are at 90° to both arrow F and arrow P.

View looking in direction of arrow R.



Right-Hand Side View (R)

Fig.4

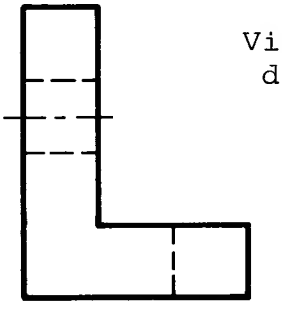


Fig.5

View looking in direction of arrow L.

Left-Hand Side View (L)

The separate views of the component are combined to form a complete orthographic drawing as shown below.

The front and side views are drawn in line with each other so that the side view may be "projected" from the front view and vice versa.

The plan view is drawn in line with and below the front view. In other words, the plan is projected from the front view.

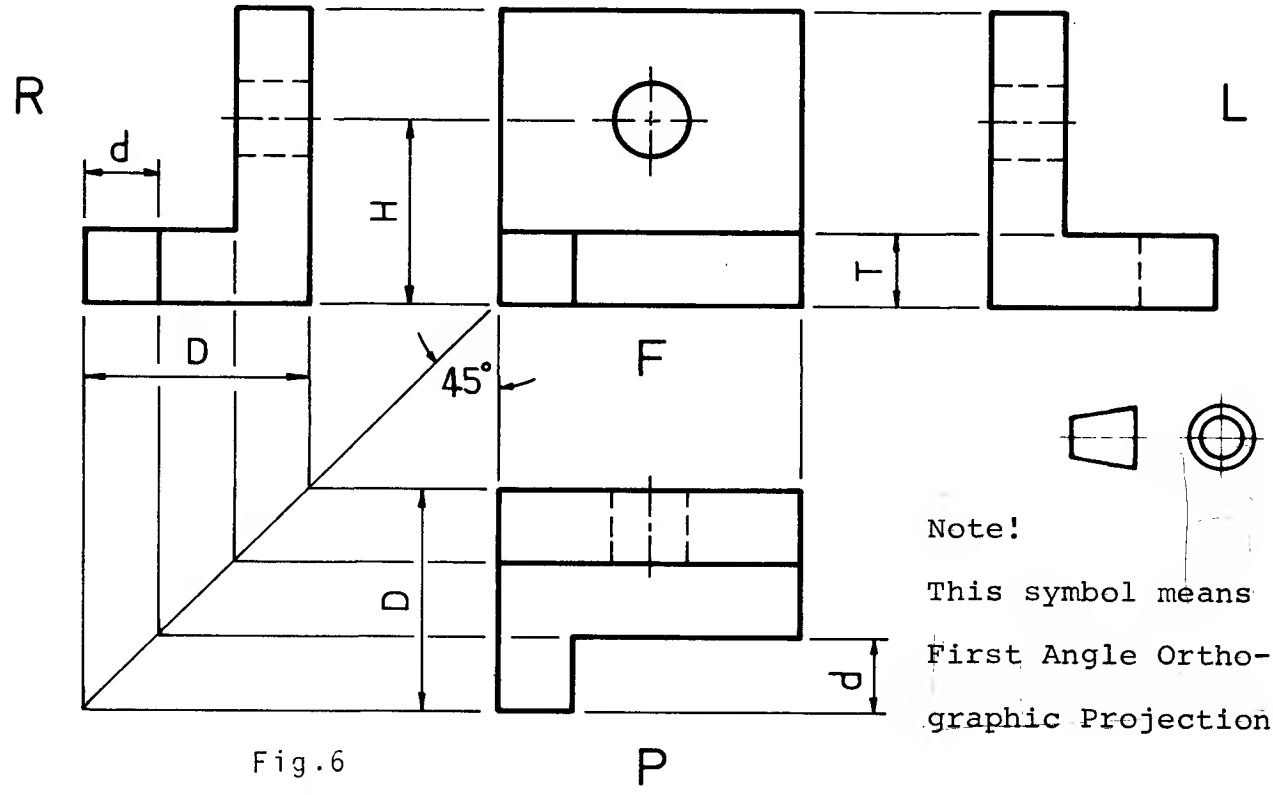



Fig.6

Note!

This symbol means First Angle Orthographic Projection.

Points to note when making a drawing using First Angle Orthographic Projection:

(1) Corresponding heights in the front view and side view are the same.
For example, the height of the hole from the base, H, is the same in both front and side views.
The thickness of the base, T, is the same in both front and side views.

(2) Widths in the side view correspond to depths in the plan.
For example, the total width, D, in the side view is the same as the total depth, D, in the plan.
The width, d, is the same in both plan and side views.

**Projection of widths from side view to plan is made easier by using the 45° swing line as shown.**

(3) The plan view is usually projected BELOW the front view.
It can be above but this would be called an "inverted" plan.

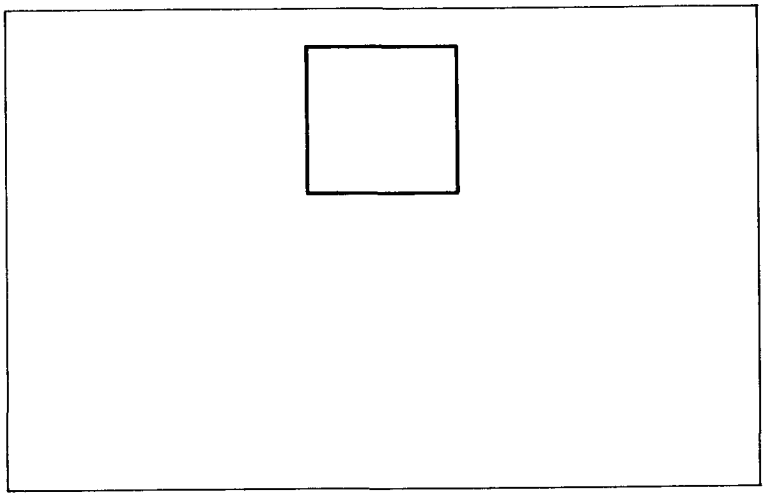
(4) The R.H. side view is shown on the L.H. side of the front view.
The L.H. side view is shown on the R.H. side of the front view.

Note: Drawings should be read (or interpreted) by viewing from the R.H. side or bottom R.H. corner of the drawing.

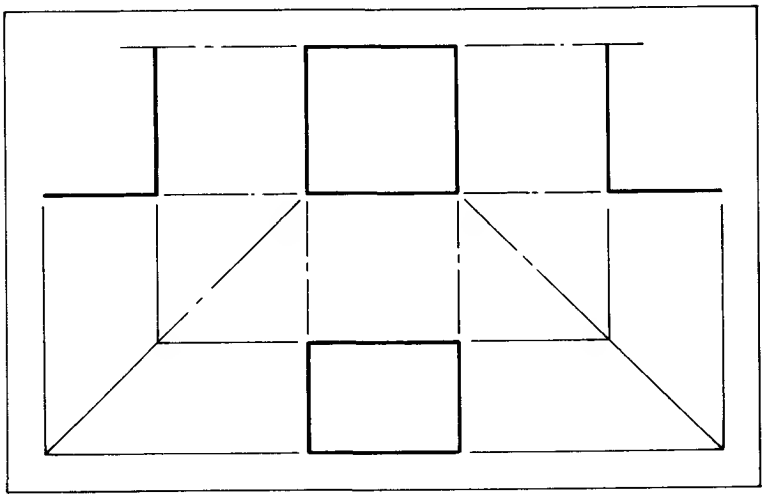
The orthographic drawing of the bracket, Fig.6, was constructed step by step as follows:

STEP 1. The face to be used as the front view of the component was chosen, in this case, looking in the direction of arrow F (Fig.1). The selection of the front view is purely arbitrary.

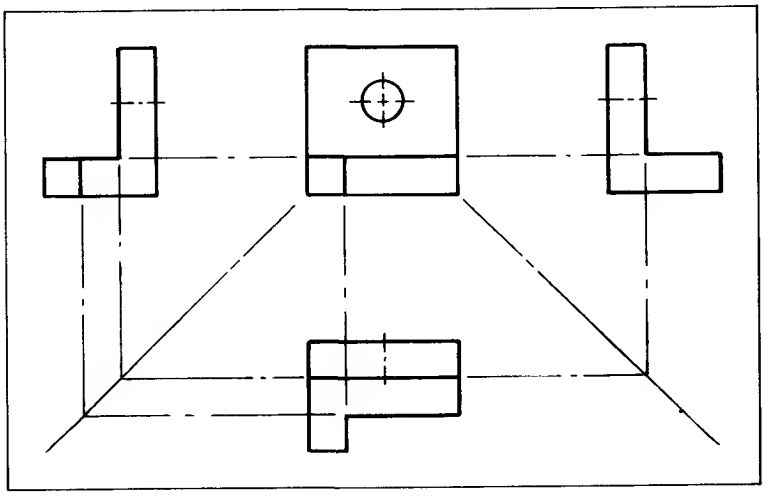
STEP 2. The outline of the front view was drawn FAINTLY in the position shown opposite leaving room on the drawing sheet for a plan view and also both end views to be added.



STEP 3. The outlines of the plan view and side views were projected FAINTLY from the front view and positioned as shown opposite.



STEP 4. All remaining external details were added and centre lines inserted as shown opposite.



STEP 5. All hidden detail, i.e. for hole and recess, was added and the outline "heavied-in" to complete the drawing as shown in Fig.6.

# Lines

For general engineering drawings, the following types of lines should be used.

1 ——— Visible outlines

2 ——— Dimension lines; Projection lines; Construction lines; Hatching or section lines; Leader lines for notes

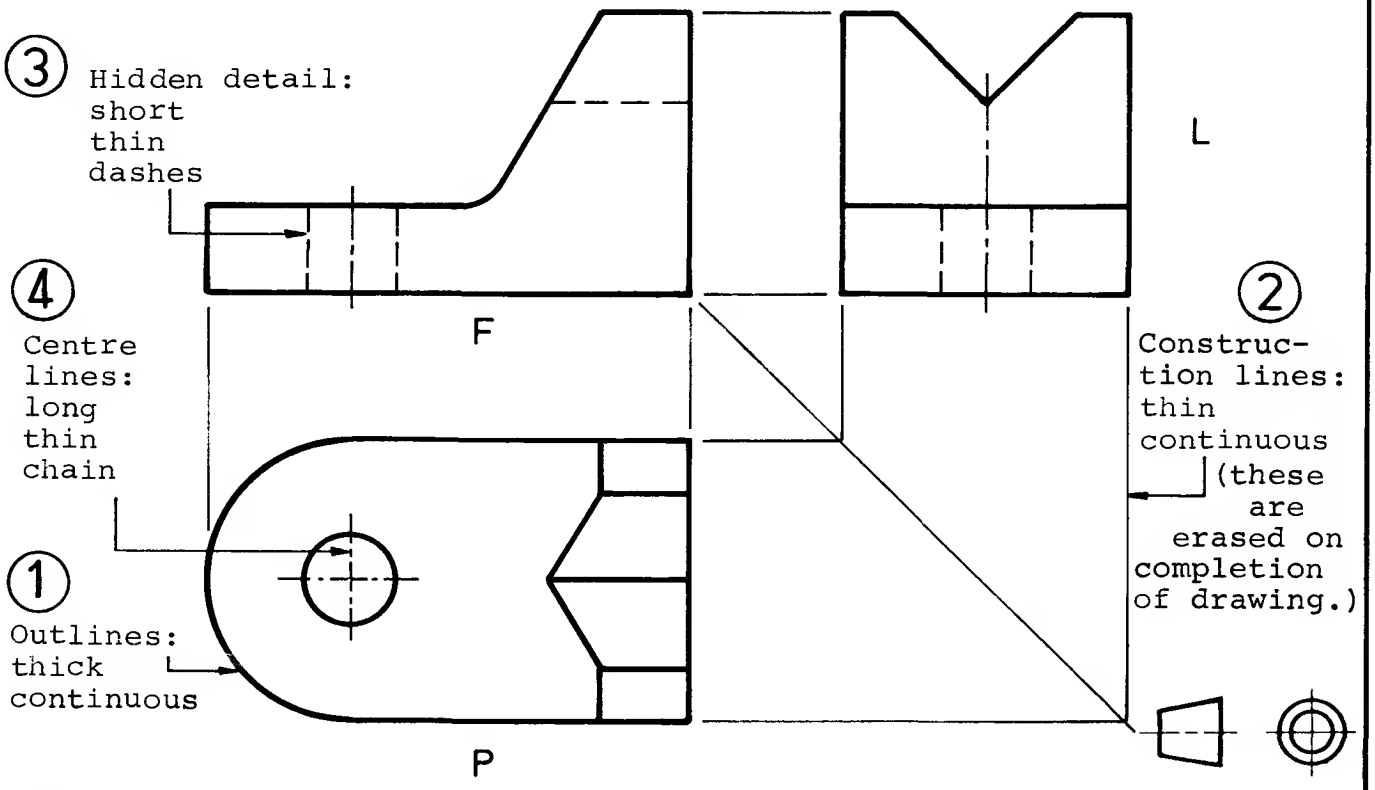
3 – – – – Hidden detail

4 ——·—— Centre lines; Pitch circles

5 ——·—— Cutting or viewing planes

6 ~~~ Short break lines; Irregular boundary lines

Typical applications of some of the recommended types of lines have been shown in previous figures and are further illustrated below.

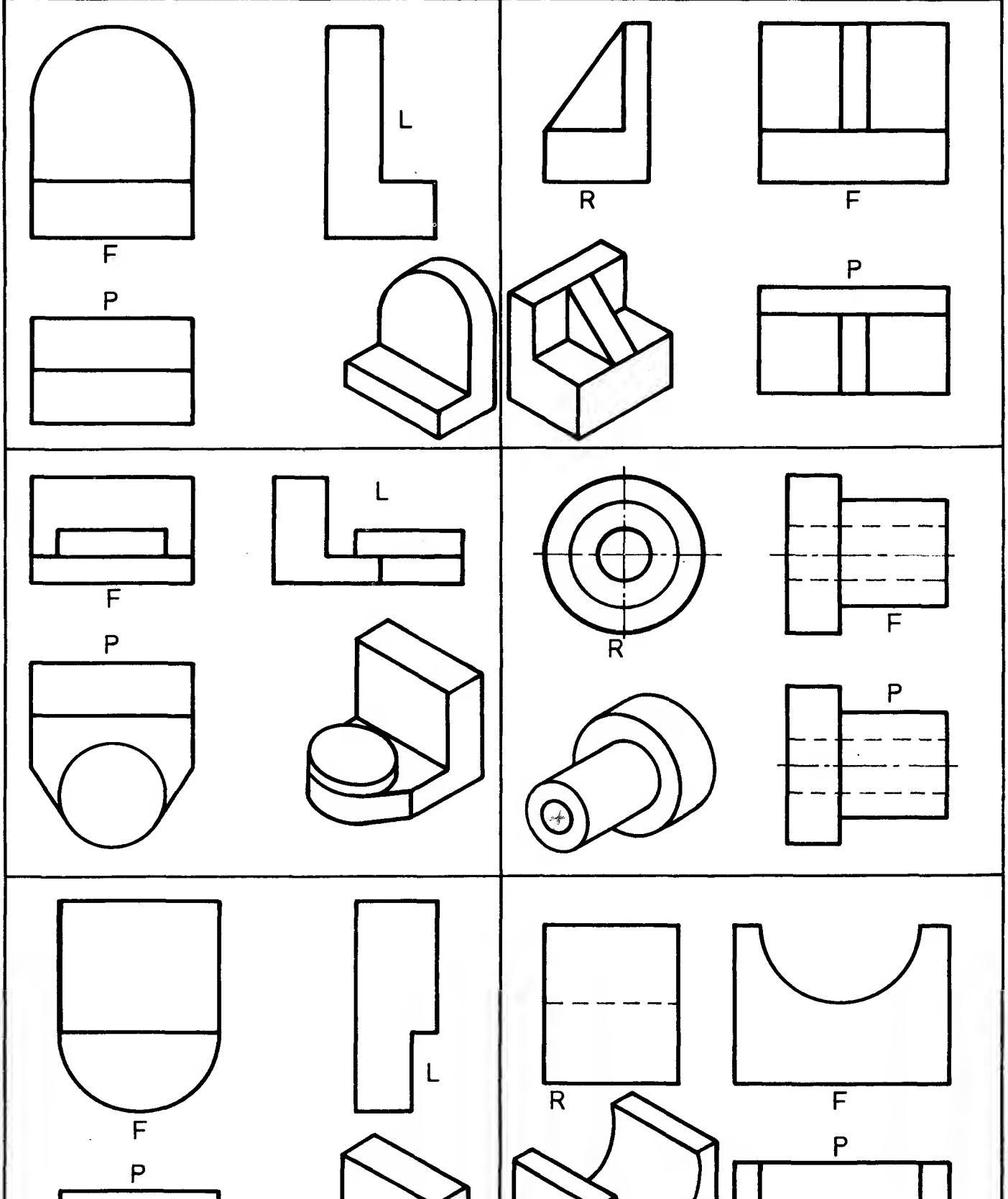



HIDDEN DETAIL

The line numbered 3 above is used to represent hidden detail, i.e. edges, holes, surfaces, etc., which are known to exist but cannot be seen when viewed from outside the component.

Note: A hidden detail line is a broken line *not* a dotted line

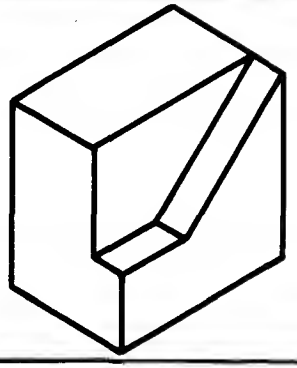
The following drawings are further examples of components drawn correctly in First Angle Orthographic Projection. Study each drawing carefully until you understand how each view is obtained.



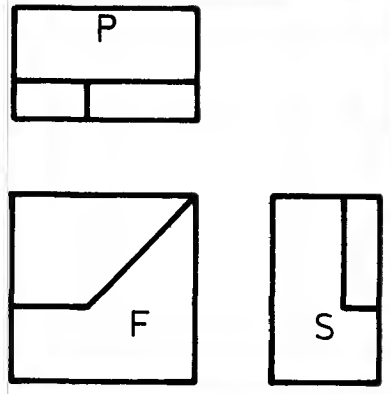
Drawings 1 to 9, shown in First Angle Orthographic Projection, represent the component below.

Examine each drawing carefully and explain briefly, either in the table below or on a separate sheet of paper, why each representation is INCORRECT.

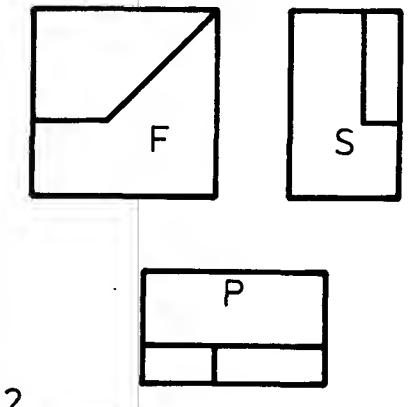
Solns. p.137



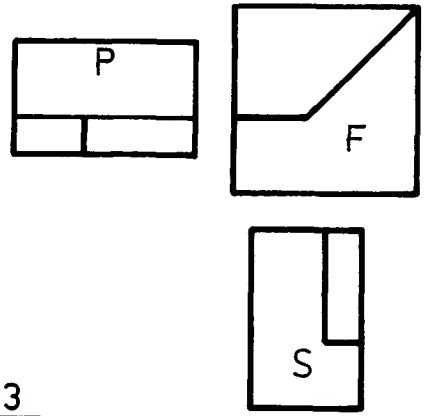
| Drg. | Reason for incorrect representation |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |



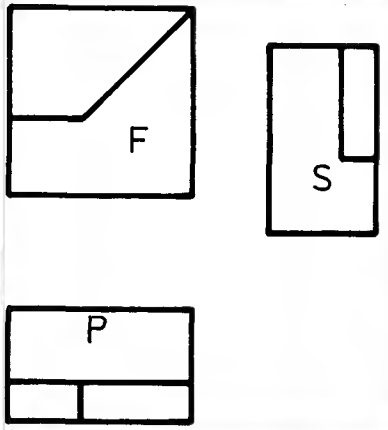
1



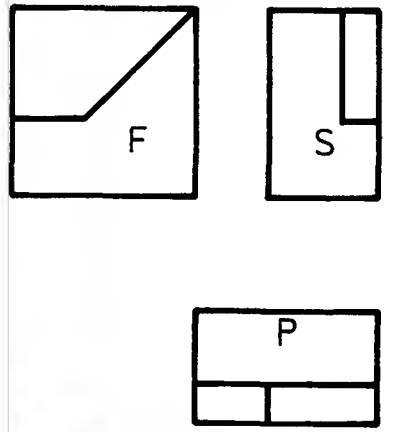
2



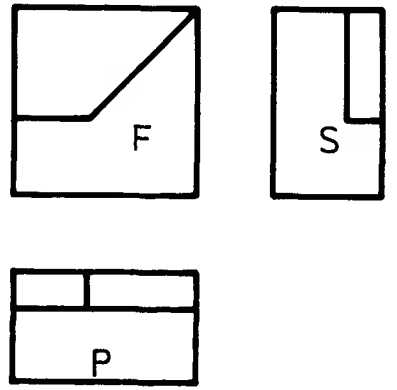
3



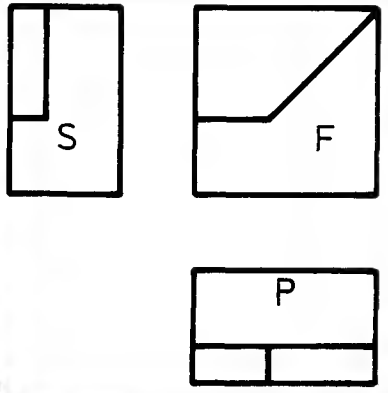
4



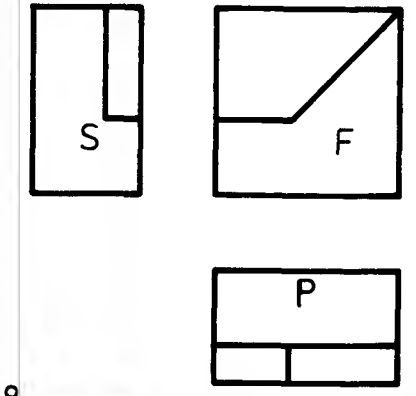
5



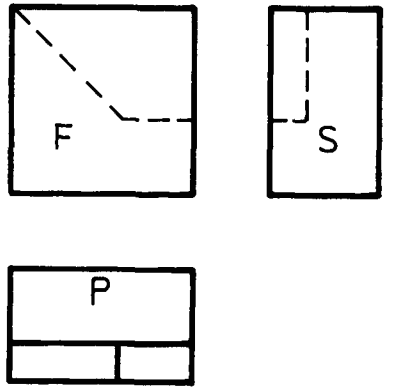
6



7



8



9

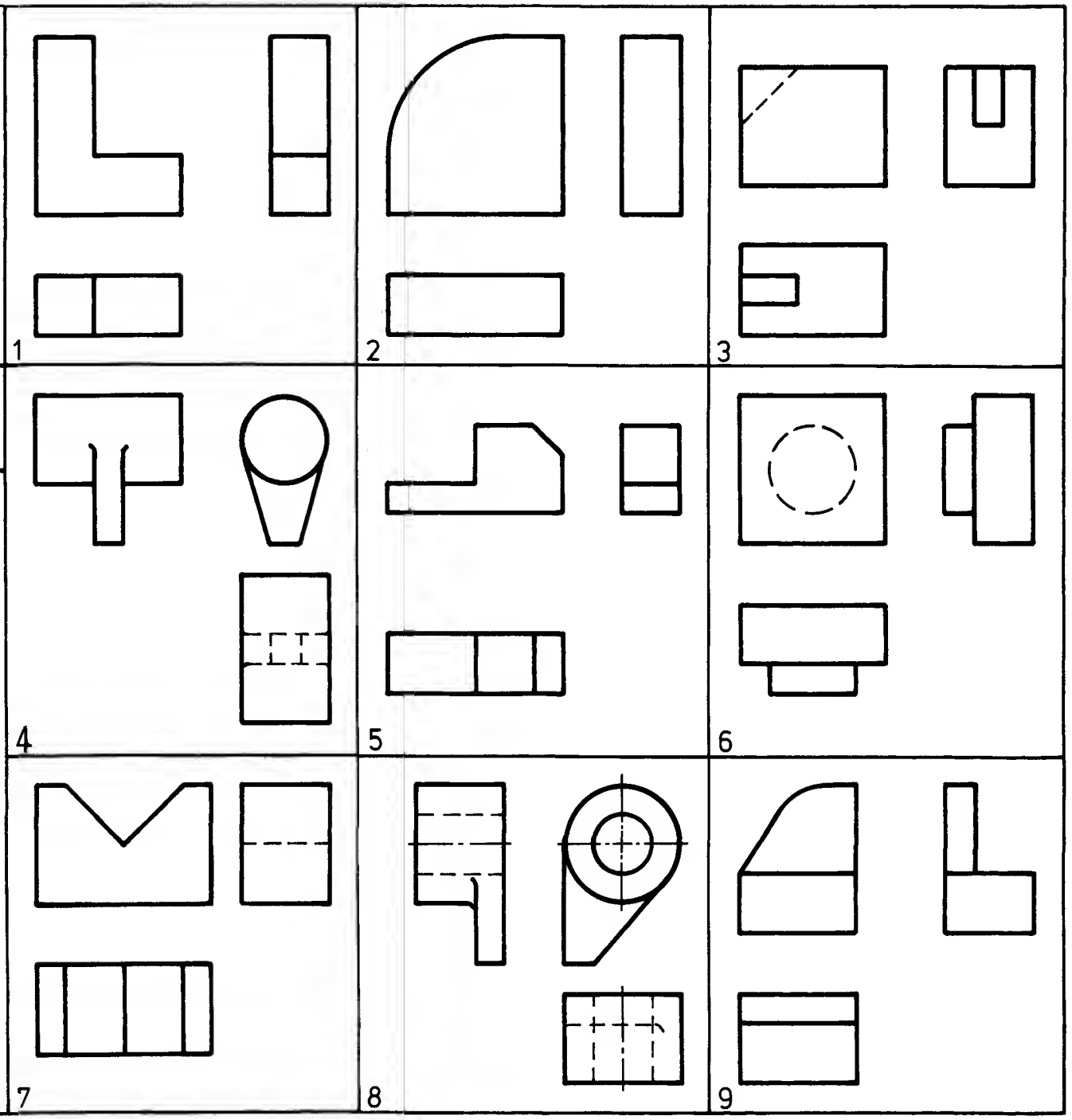
The drawings opposite are shown in First Angle Orthographic Projection.

Some show all three views drawn correctly, others show one of the views drawn incorrectly.

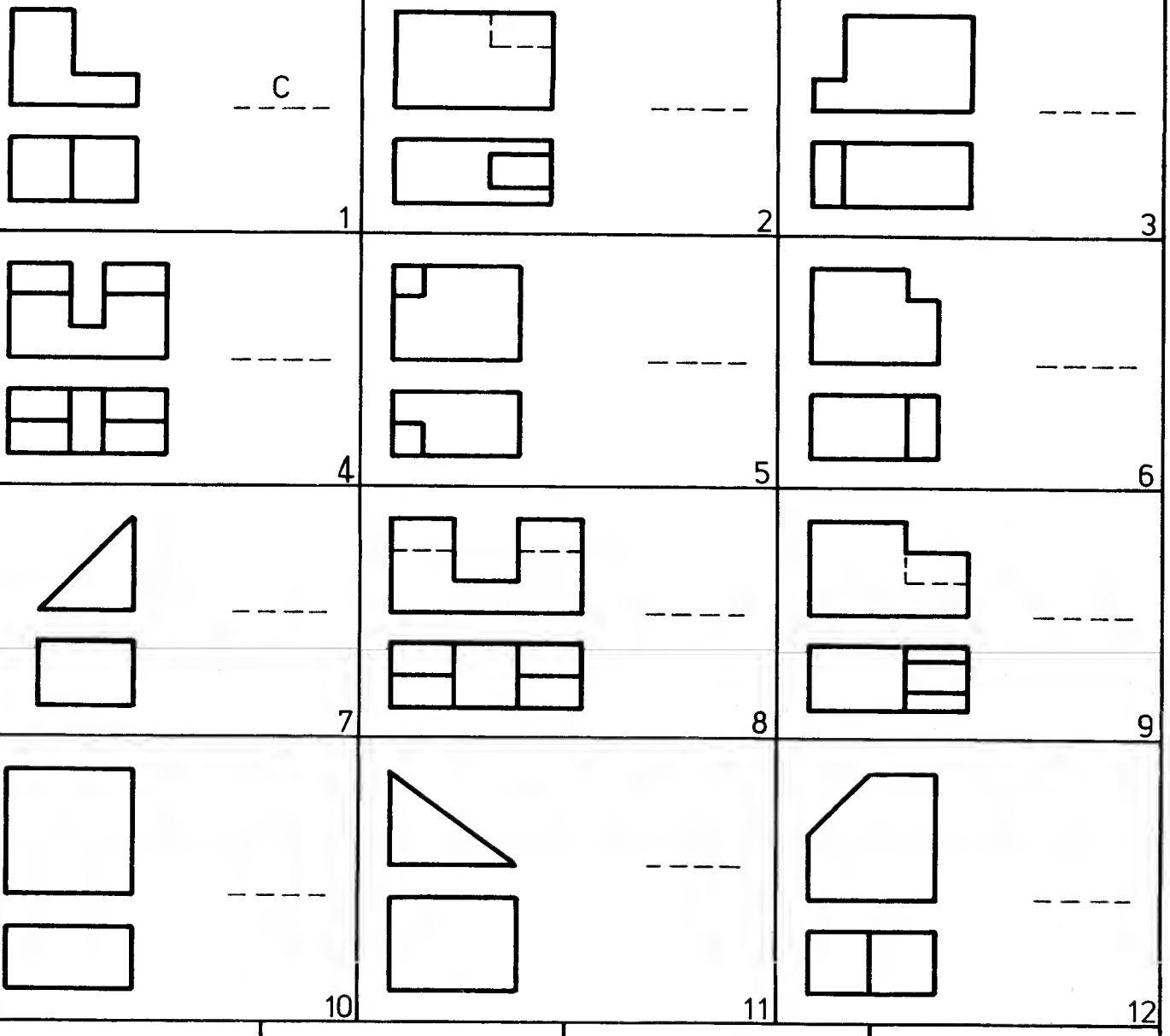
State in the table below the numbers of the drawings which are incorrectly drawn.

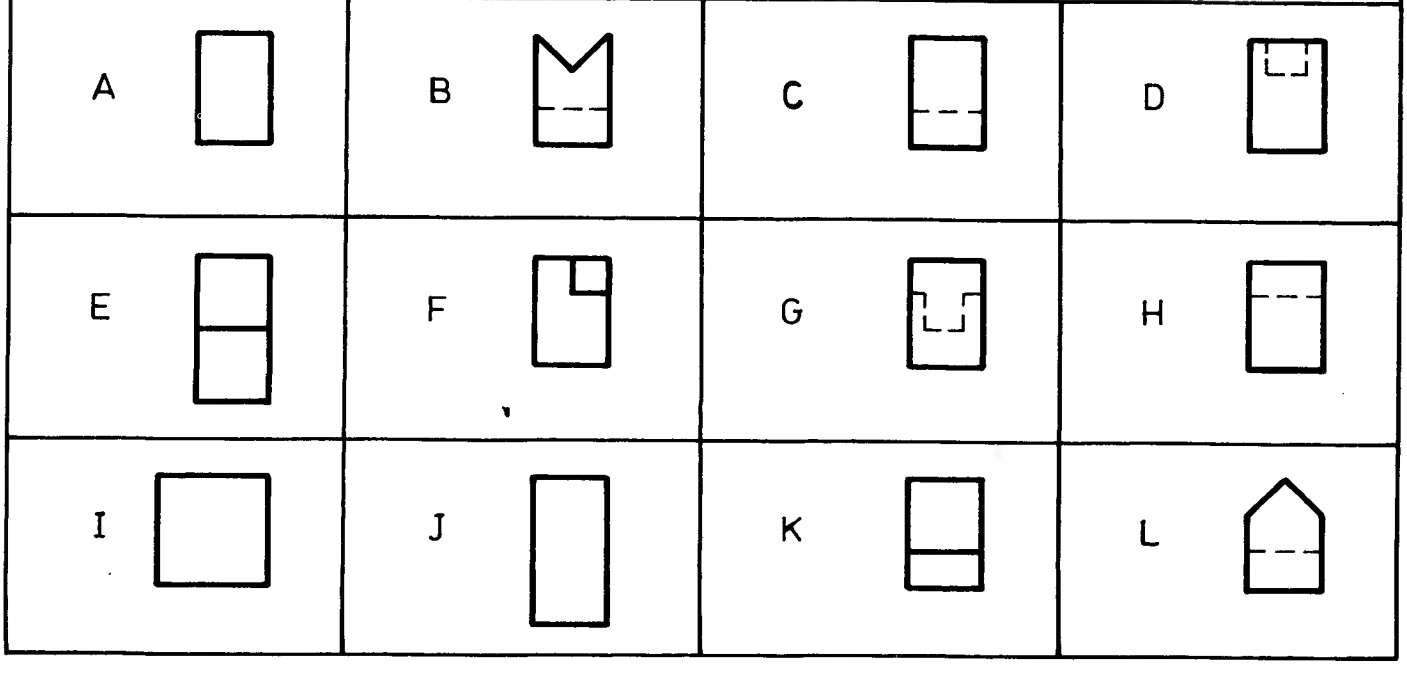
In the space provided sketch freehand the correct view in each case. Solns. p.137

| Number of drg. shown incorrectly | Sketch of correct view |
|---|---|
| | |



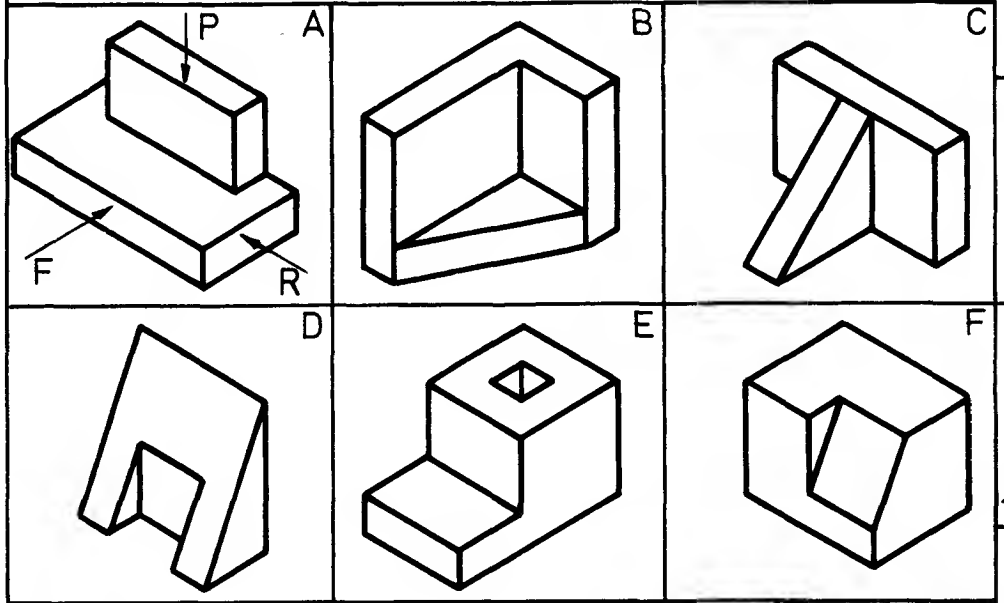
Select, from the views A to L below, the missing view from each of the drawings 1 to 12. Insert the letter in the space provided.
Example: the missing view from drawing number 1 is C. Solns. p.137



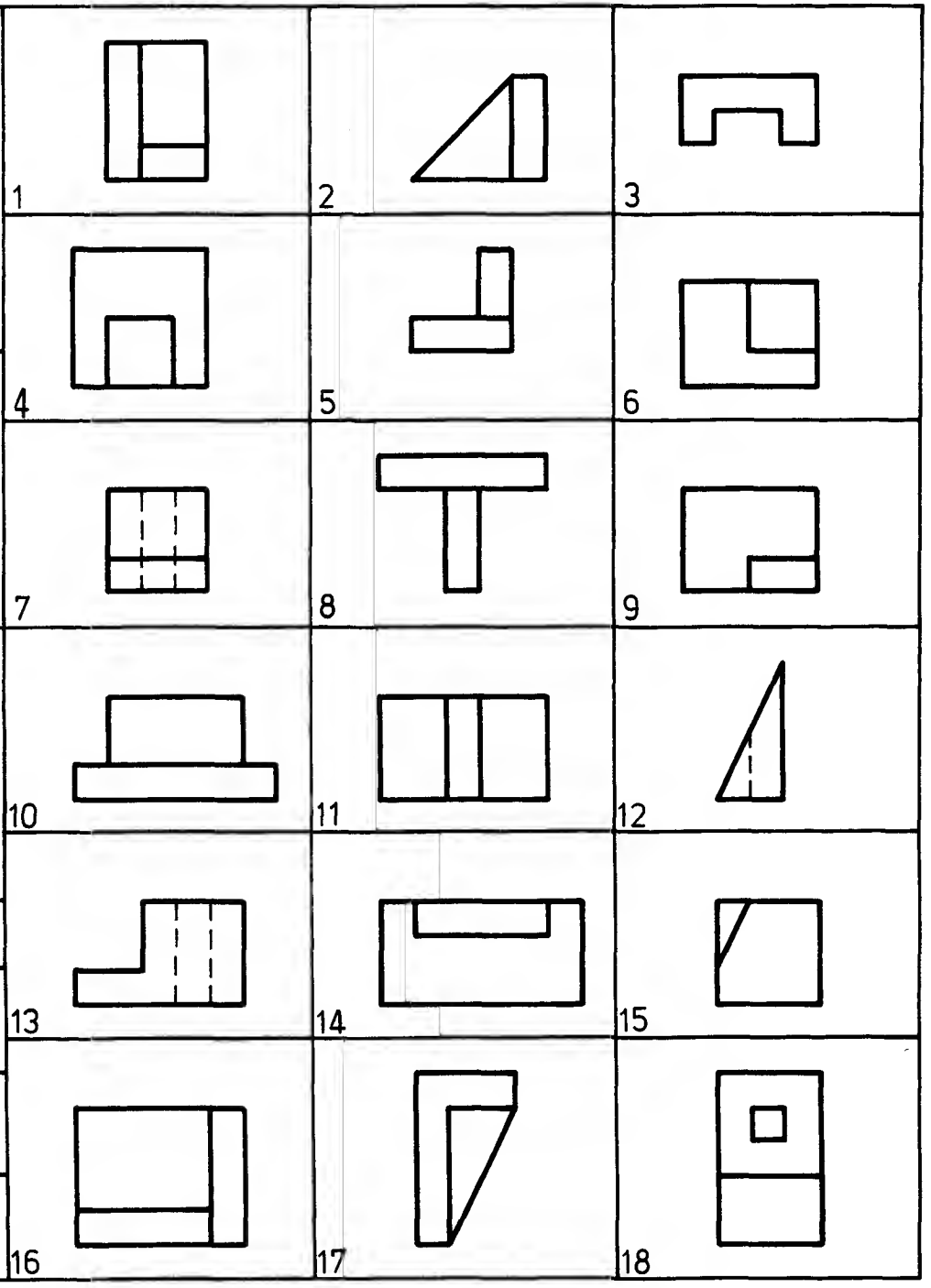



From drawings 1 to 18 opposite select the view which is requested in the table below. Place the number of this view in the appropriate position in the table.

For example, for component A, the front view, looking on F, is number 10, so 10 is placed in the answer block as shown. Solns. p.137




| Drawing | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Front view in direction of F | 10 | | | | | |
| Plan view in direction of P | | | | | | |
| Side view in direction of R | | | | | | |



# Missing detail

Drawings 1 to 9 show a front view, a plan view, and a side view in First Angle Orthographic Projection.

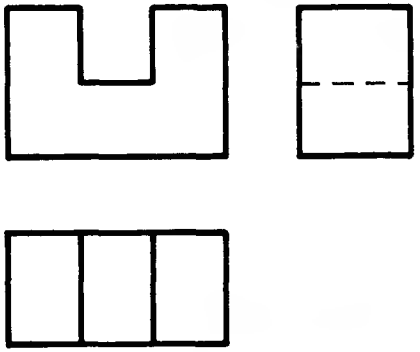
Each drawing is incomplete because detail has been omitted.

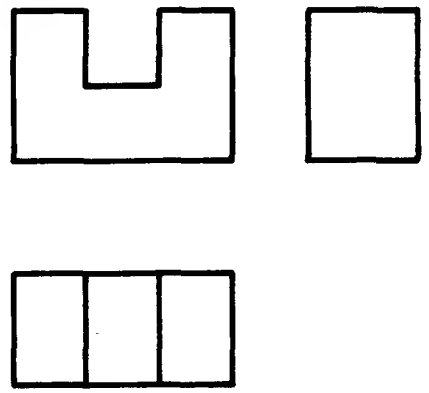
Complete each drawing by adding the missing detail.

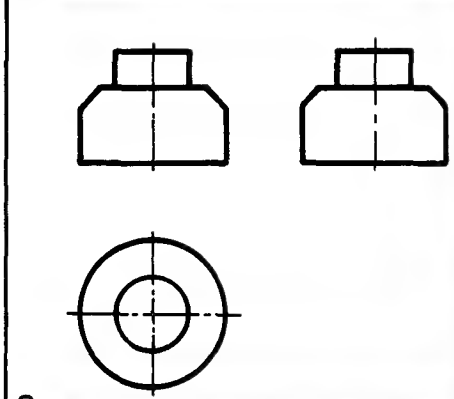
The solution to Number 1 is shown below.

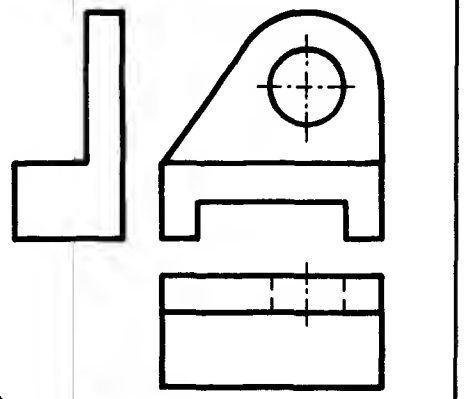
Solns. p.138

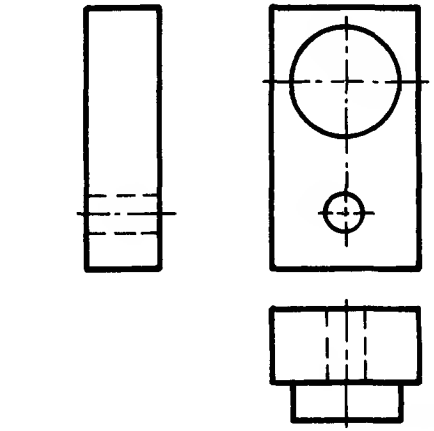
Solution

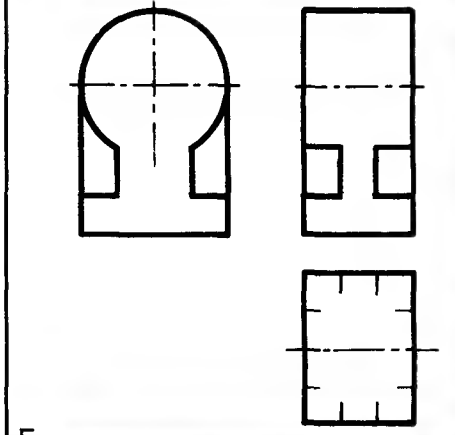


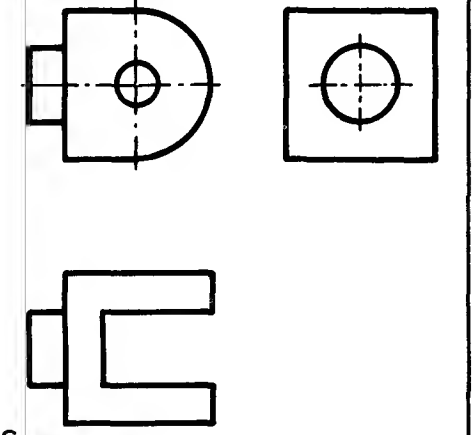


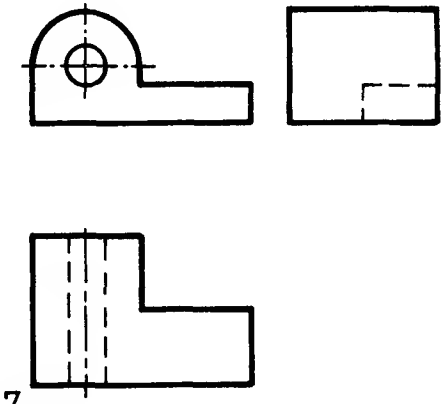



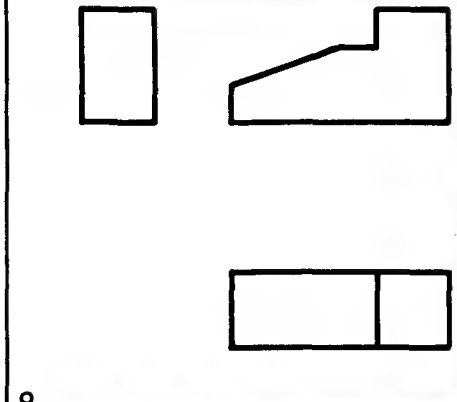



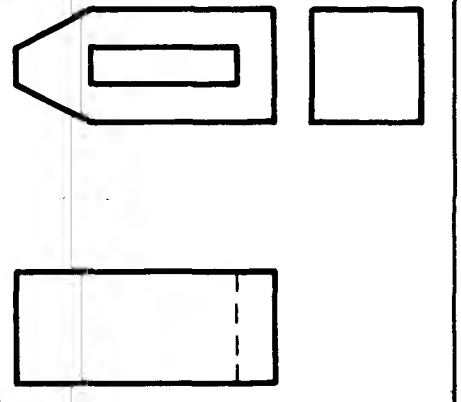



# Missing views

Drawings opposite show two views of a component in First Angle Orthographic Projection.

In the space provided sketch a third view in projection with the two views shown.

On the line provided write the name of the view which has been added.

Use F for front view
P for plan view
R for R.H. side view
L for L.H. side view.

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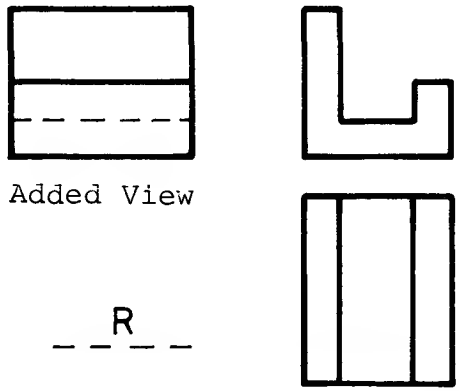
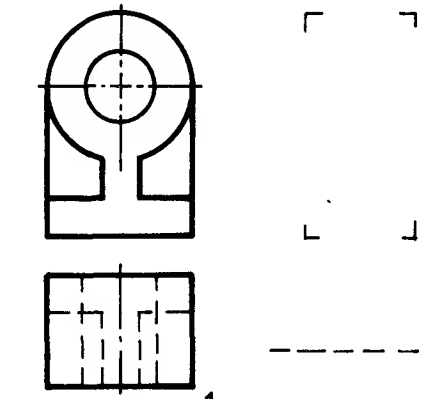
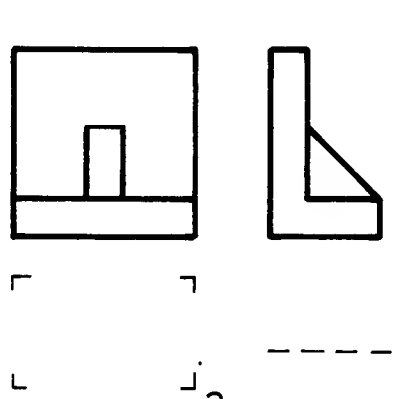
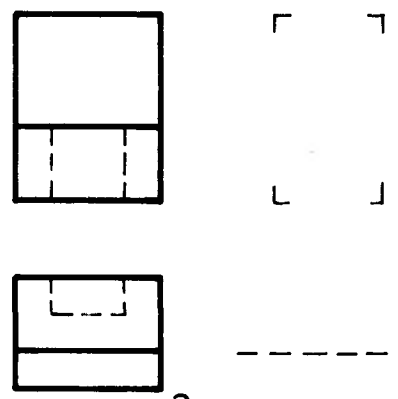
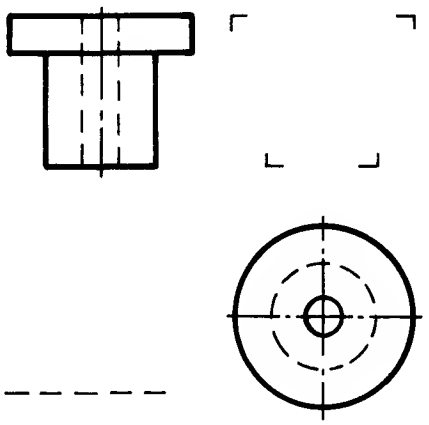
Example

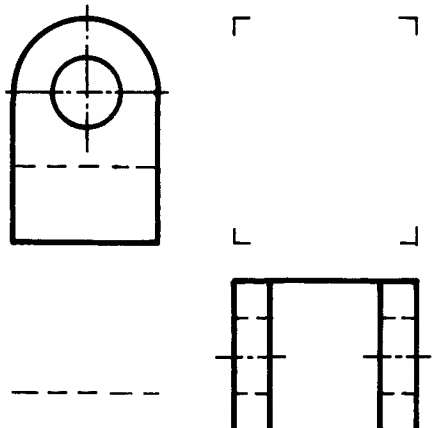


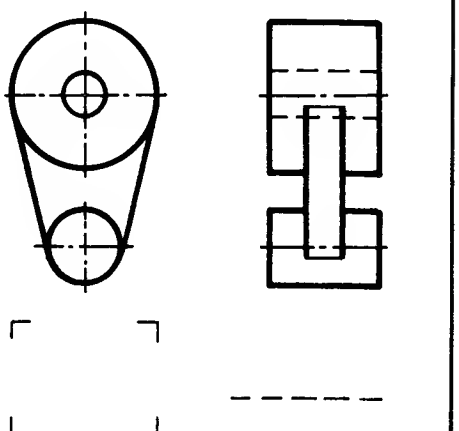



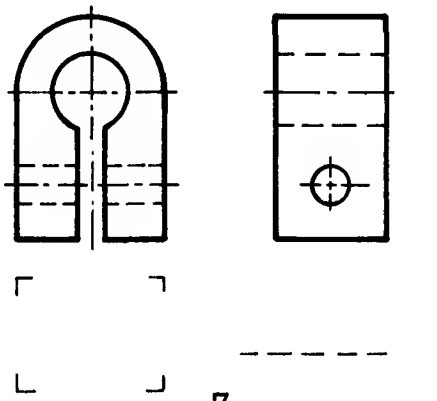



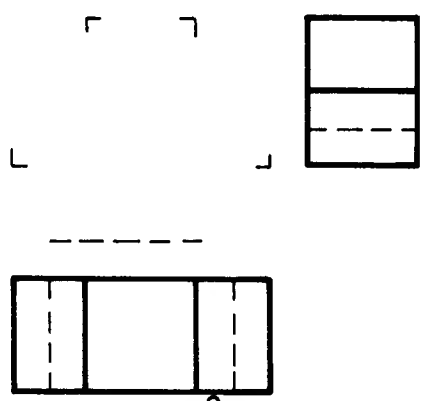



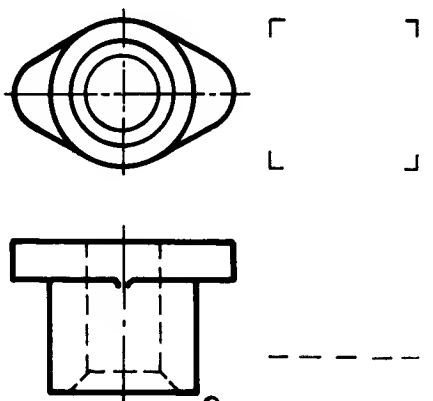



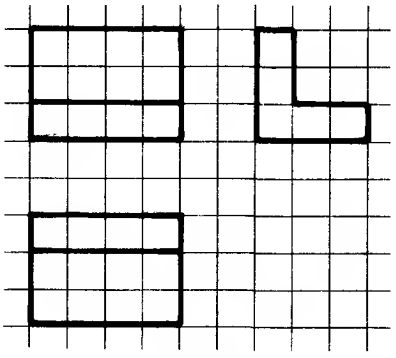



# Sketching orthographic views

The components shown below are drawn pictorially.

For each component sketch in good proportion in the space provided, a front view, a plan view and a l.h. side view.
Sketch the front view looking from F.
Show all hidden detail.
Use first angle projection as shown on the right.



Example

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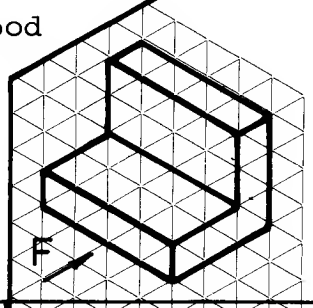
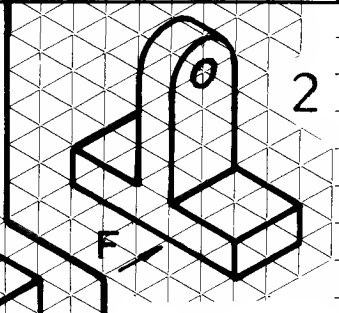
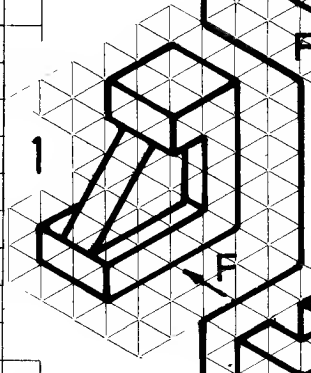
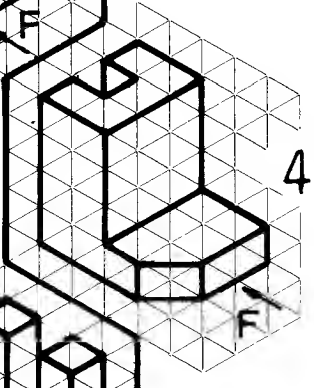
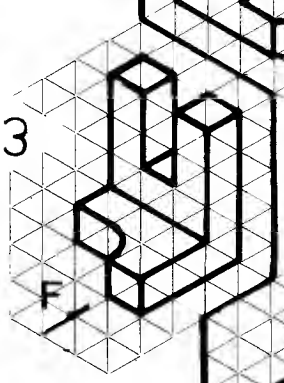
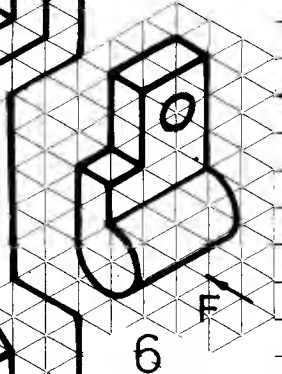


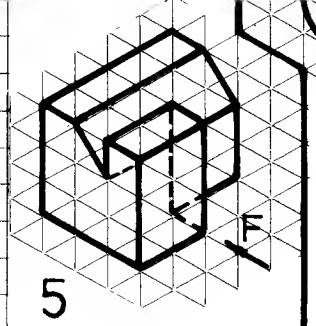



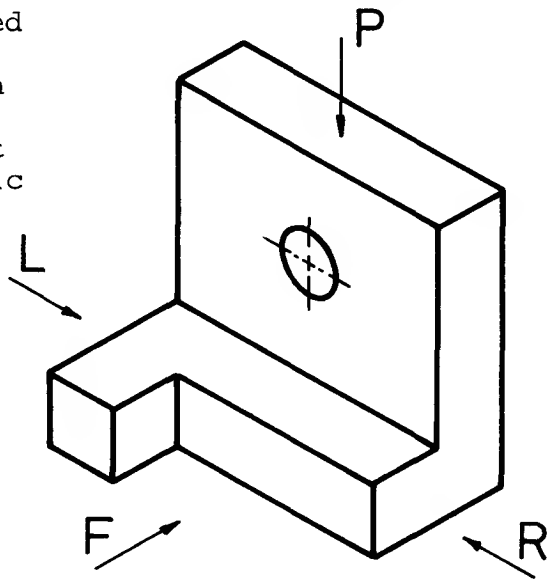



# Orthographic Projection: Third Angle

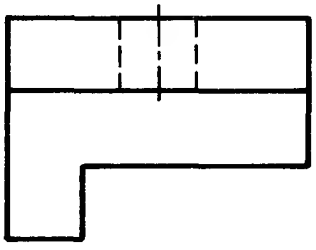
You may remember from information presented earlier in the text that there are two methods of orthographic projection used in the preparation of engineering drawings.

You should, by now, be quite conversant with one of them - First Angle Orthographic Projection. The other is known as Third Angle Orthographic Projection.

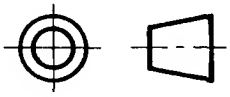



When representing a three-dimensional component in Third Angle Orthographic Projection, the basic views are exactly the same as those shown when using First Angle Orthographic Projection. The difference between First Angle and Third Angle is in the positioning of the views relative to each other.

In Third Angle Orthographic Projection the individual views are placed on the drawing sheet in projection with each other as shown:

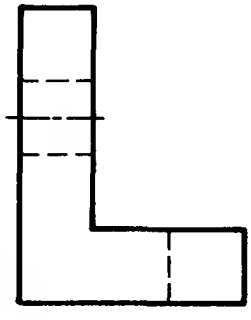


PLAN VIEW
looking from P

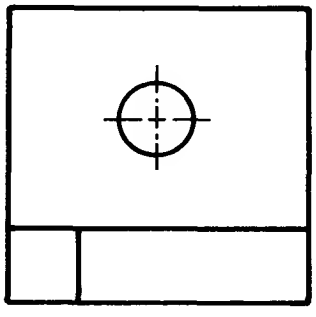


Note!

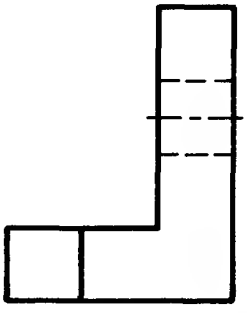
This symbol means Third Angle Orthographic Projection.



LEFT-HAND SIDE VIEW
looking from L



FRONT VIEW
looking from F



RIGHT-HAND SIDE VIEW
looking from R

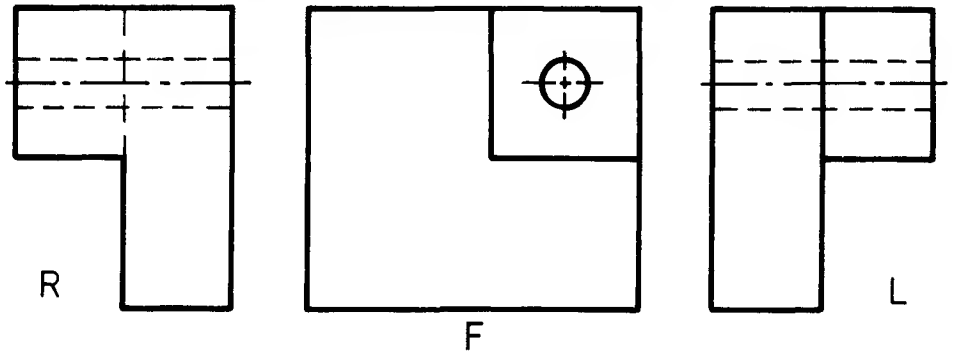
Special points to note:

(1) The plan is always projected ABOVE the front view.

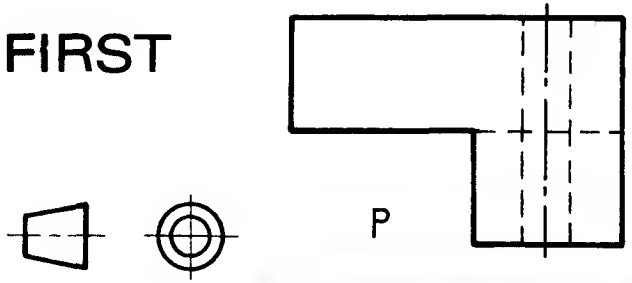
(2) The right-hand side view is shown on the RIGHT-hand side of the front view.

(3) The left-hand side view is shown on the LEFT-hand side of the front view.

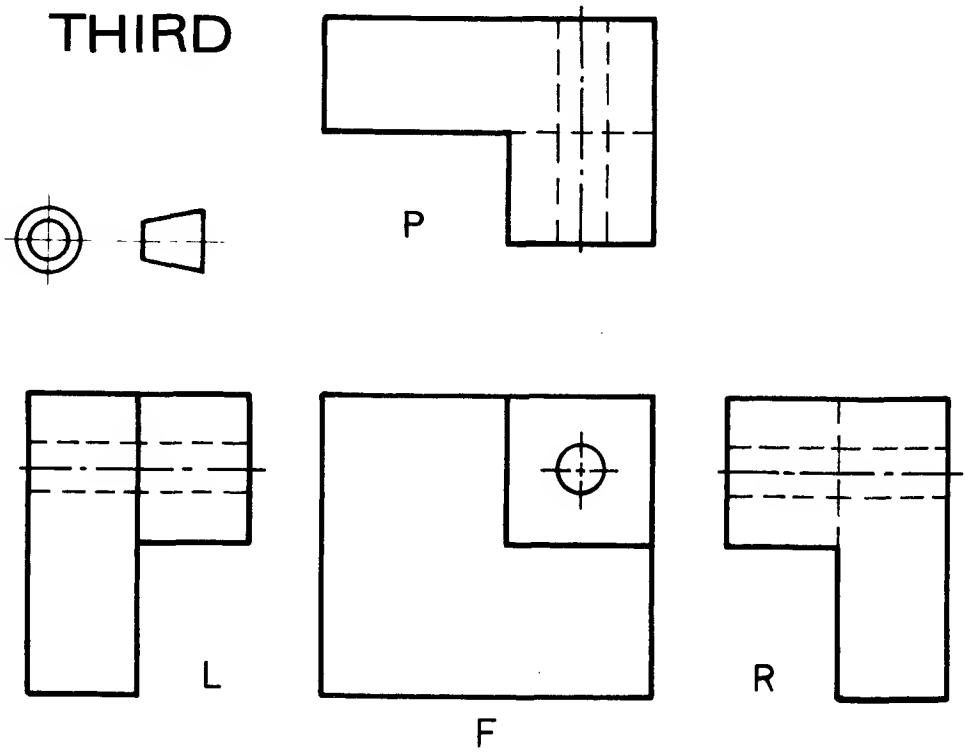
# A comparison of first angle projection and third angle projection




FIRST

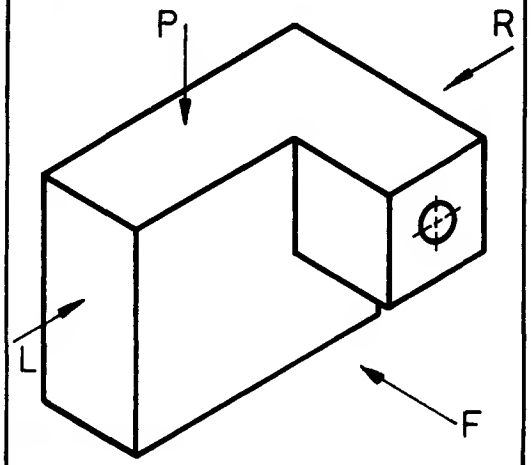



THIRD




NOTE:

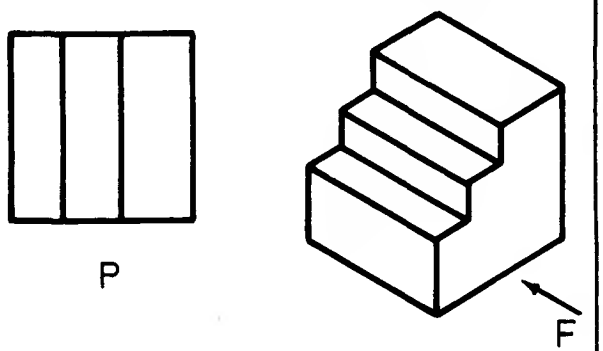
(1) The plan is BELOW the front view.
(2) The right-hand side view is on the LEFT-hand side of the front view.
(3) The left-hand side view is on the RIGHT-hand side of the front view.

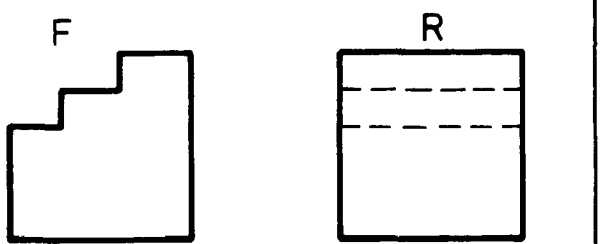



NOTE:

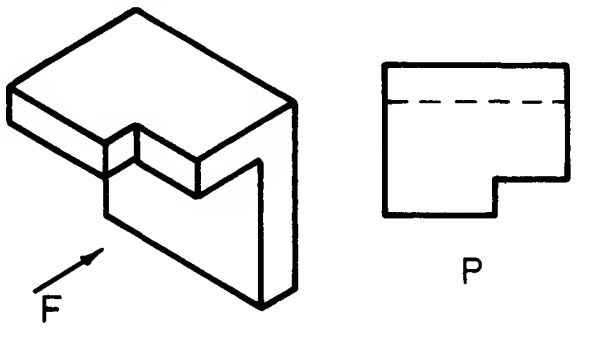
(1) The plan view is ABOVE the front view.
(2) The right-hand side view is on the RIGHT-hand side of the front view.
(3) The left-hand side view is on the LEFT-hand side of the front view.

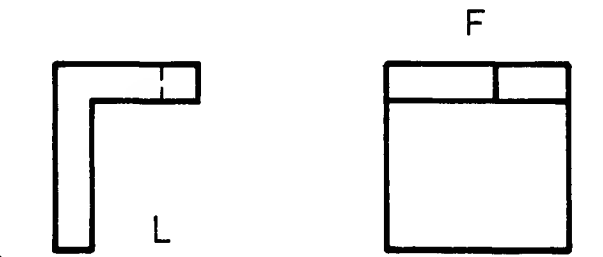
The first three drawings are further examples of components drawn correctly in Third Angle Orthographic Projection. Study each one carefully until you understand how each view is obtained.



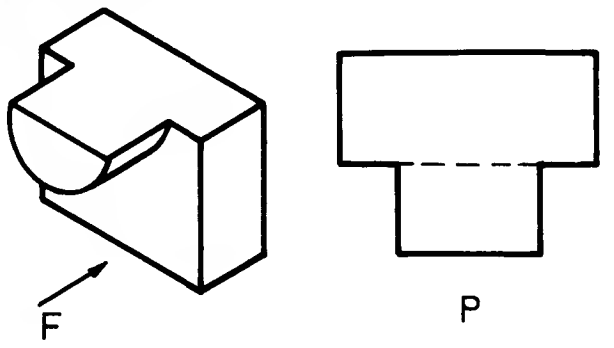



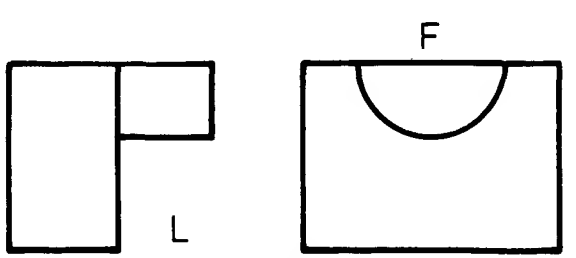

1



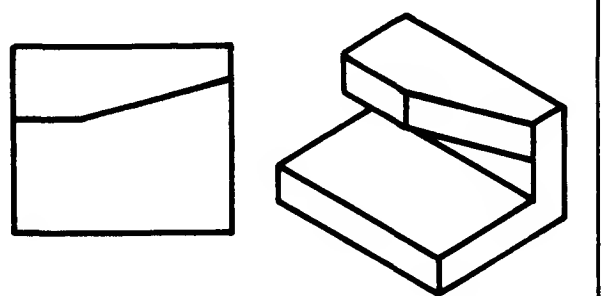

2

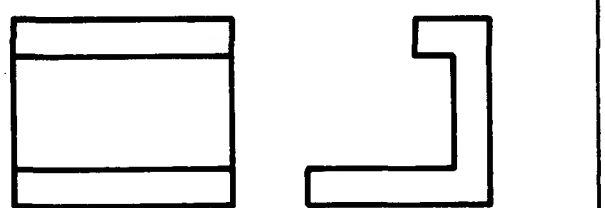


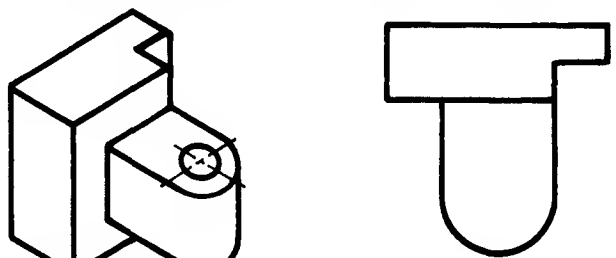

3

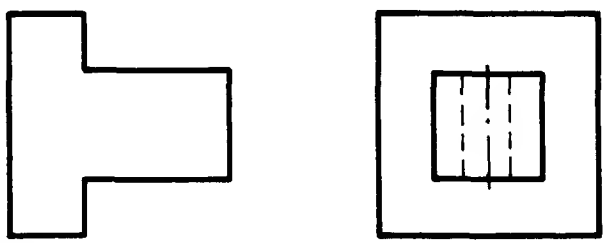
Add, to the drawings below, all missing detail and name each view shown. Solns. p.140.



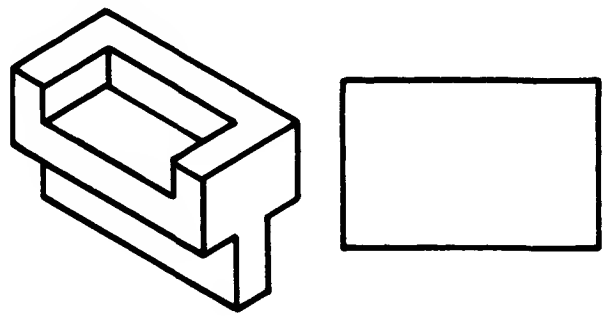


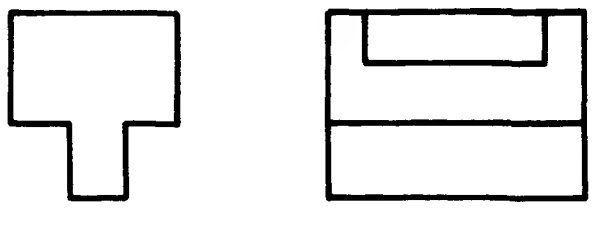
4





5



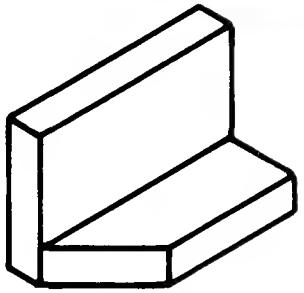


6

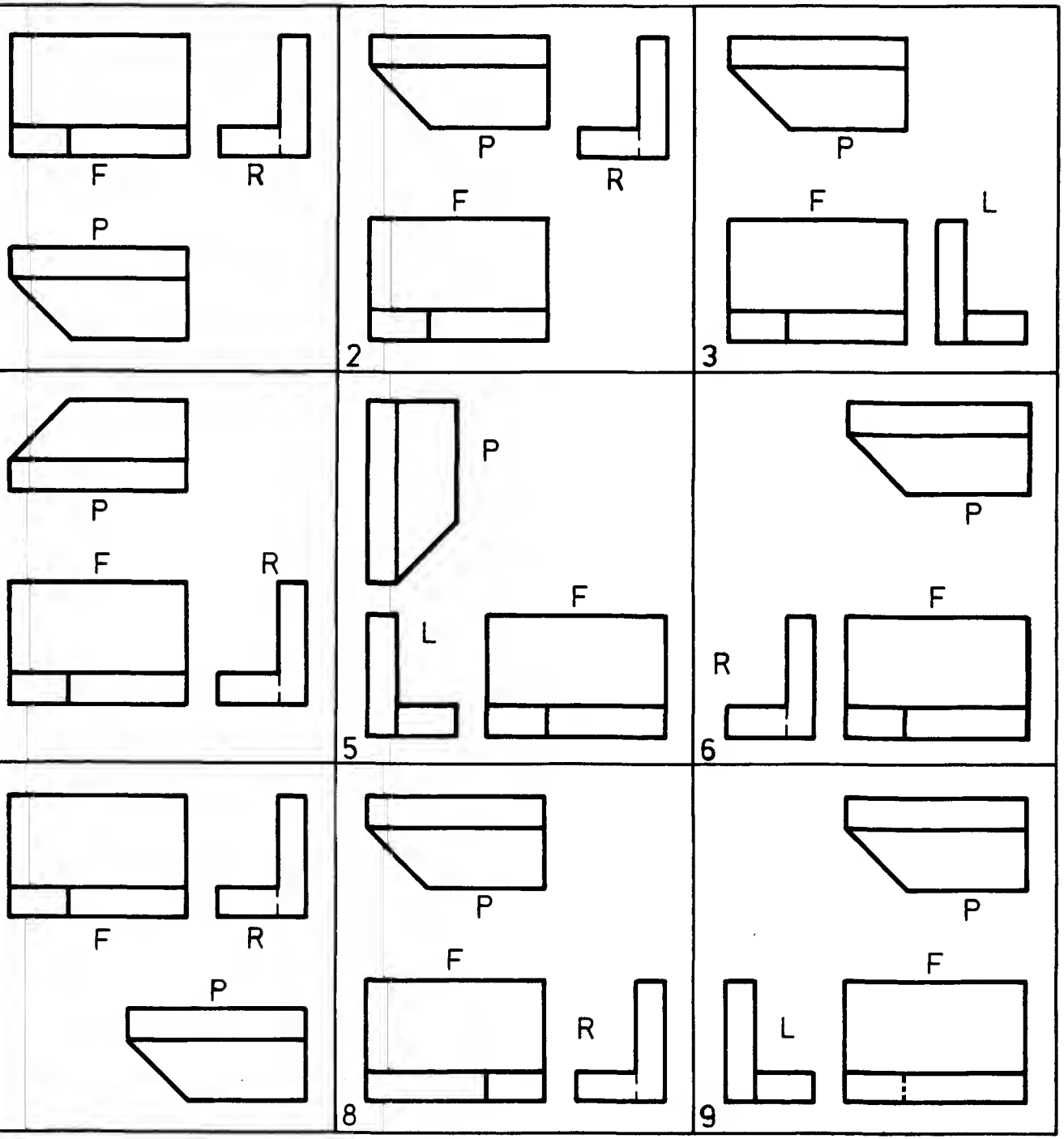
The drawings opposite, shown in Third Angle Orthographic Projection, represent the component shown below.

Examine each drawing carefully and explain briefly, either in the table below or on a separate sheet of paper, why each representation is INCORRECT.

Solns. p.140



| Drg. | Reason for incorrect representation. |
|---|---|
| 1 | |
| 2 | |
| 3 | |
| 4 | |
| 5 | |
| 6 | |
| 7 | |
| 8 | |
| 9 | |

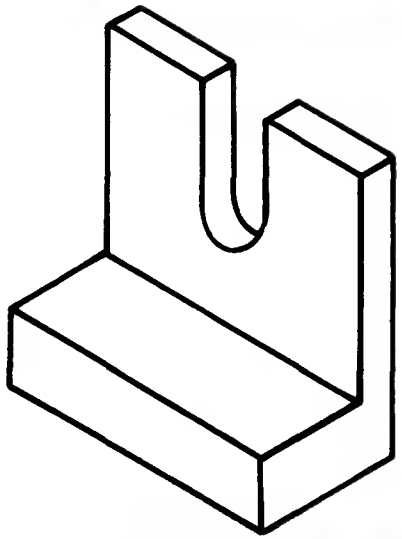


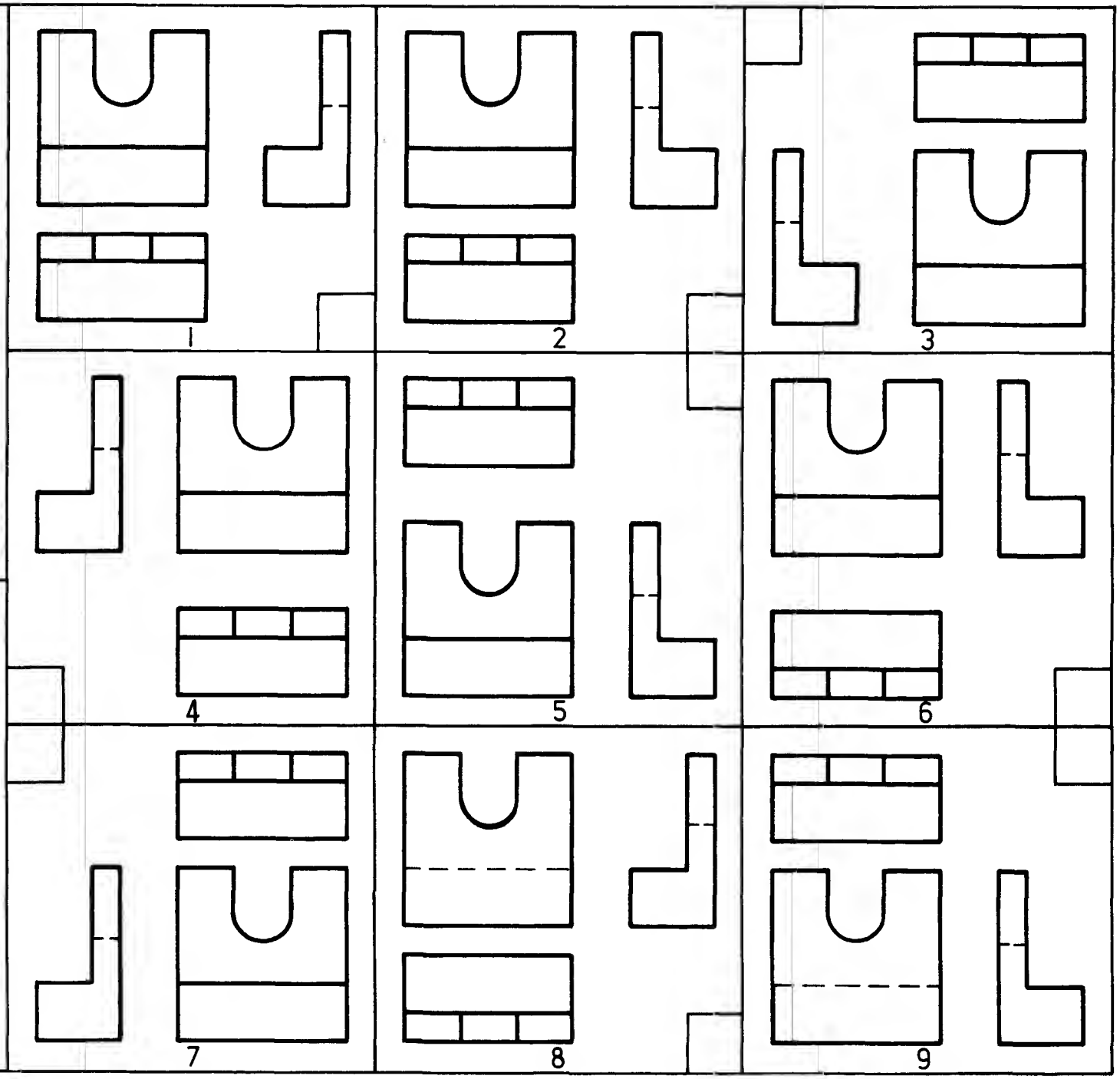
The drawings opposite represent the component shown below.

Look at the drawings carefully and decide which method of projection has been correctly used in each representation.

Insert, in the box provided, "1" for First Angle Orthographic Projection, "3" for Third Angle Orthographic Projection, "N" for neither.

Solns. p.140





The drawings opposite show two views of a component in either First Angle Orthographic Projection OR Third Angle Orthographic Projection.

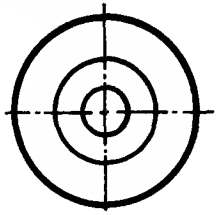
Decide which method of projection has been used and then add the missing view in the space provided.

Name the view which has been added and also the method of projection used in each drawing.

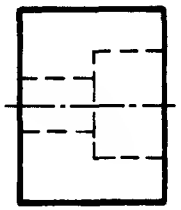
An example is shown below.

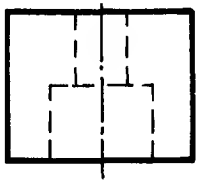
Solns. p.141

EXAMPLE



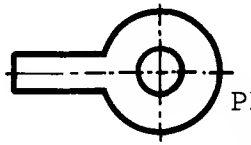
Added view





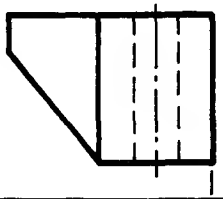
PROJ. 1st A

VIEW L



PROJ. _____

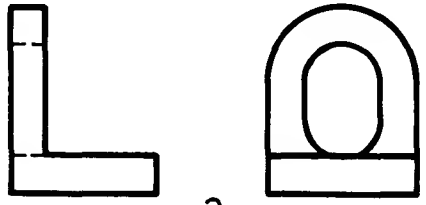
VIEW _____



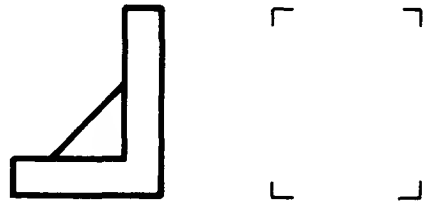
1

PROJ. _____

VIEW _____

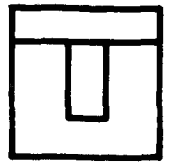


2

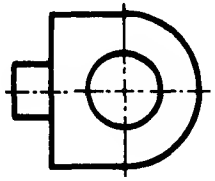


PROJ. _____

VIEW _____

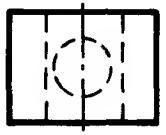


3

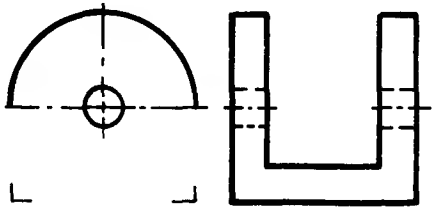


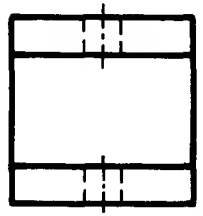
PROJ. _____

VIEW _____



4

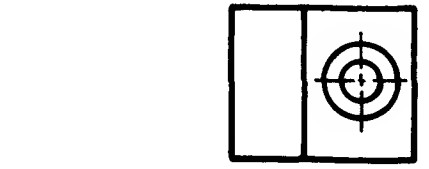




PROJ. _____

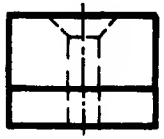
VIEW _____

5

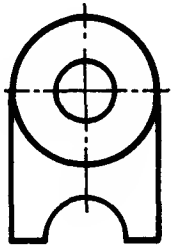


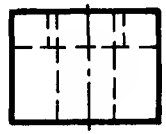
PROJ. _____

VIEW _____



6

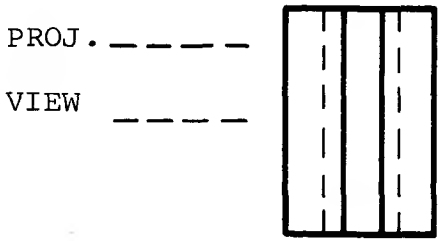


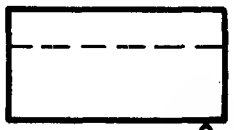


PROJ. _____

VIEW _____

7

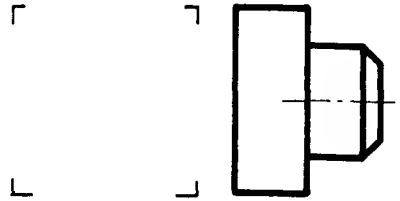


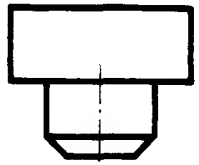


PROJ. _____

VIEW _____

8





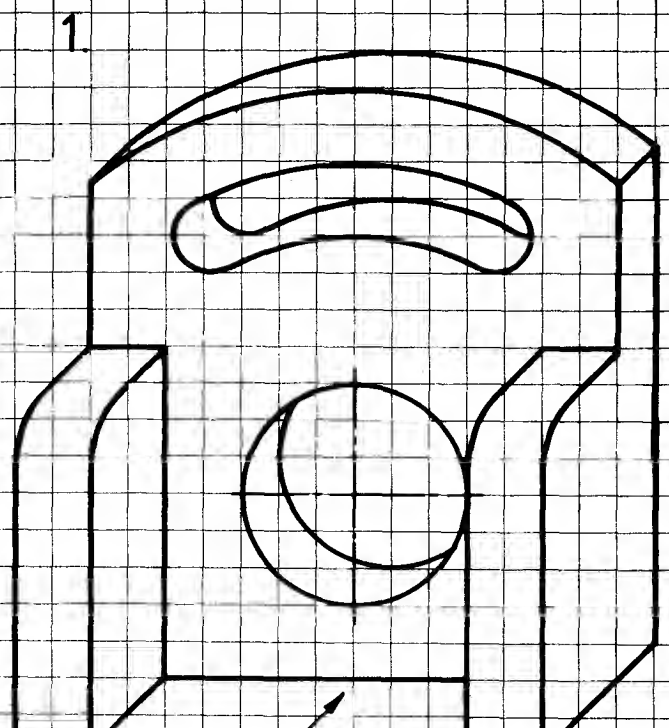
PROJ. _____

VIEW _____

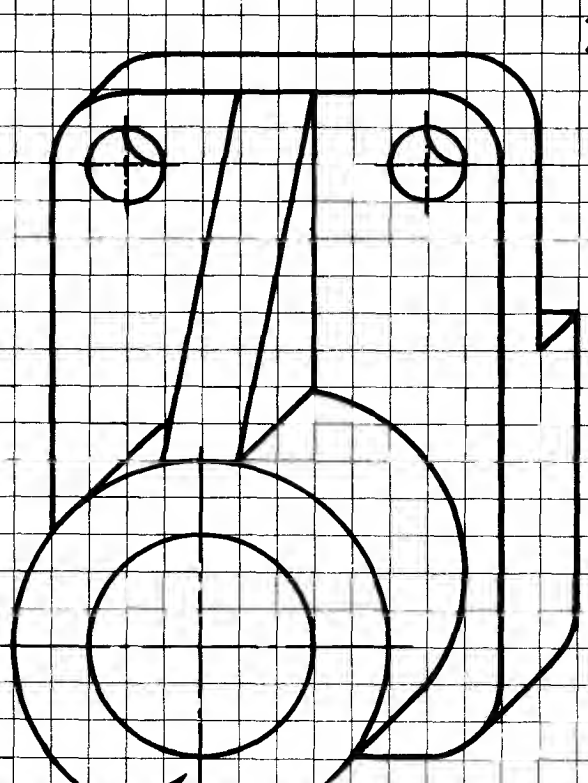
9

The components below are drawn pictorially. For each component sketch an orthographic drawing, in good proportion, using Third Angle Orthographic Projection. Sketch a front view in the direction of F, a plan view and a right-hand side view showing all hidden detail. Use the 5 mm squared grid on page 67 with tracing paper to aid sketching if you wish. Solution on p.142.

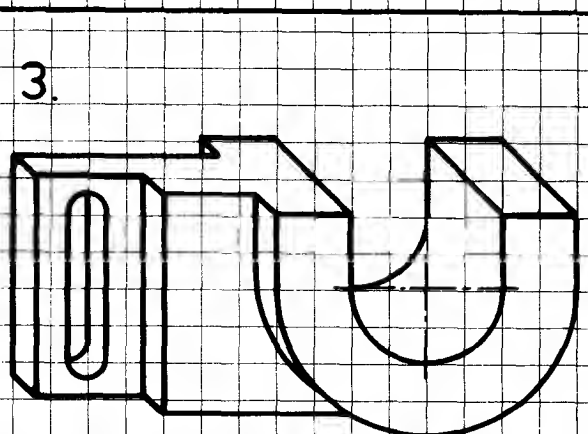
1.



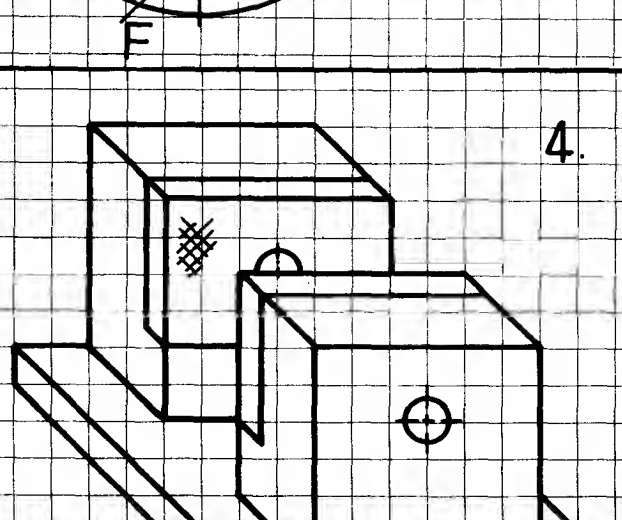

2.




3.




4.

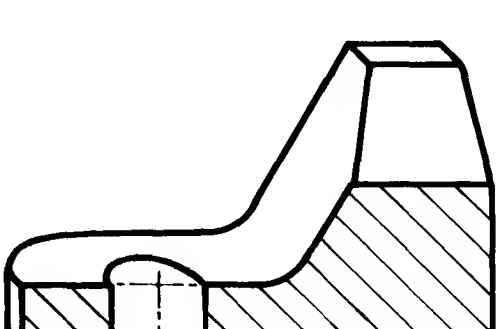



5. A partly sectioned assembly drawing in shown on page 48. Sketch, in good proportion, using 5 mm squared paper or the grid on page 67, an EXTERNAL front view, side view and plan view of the complete assembly using Third Angle Orthographic Projection. Solns. p.141 and p.142

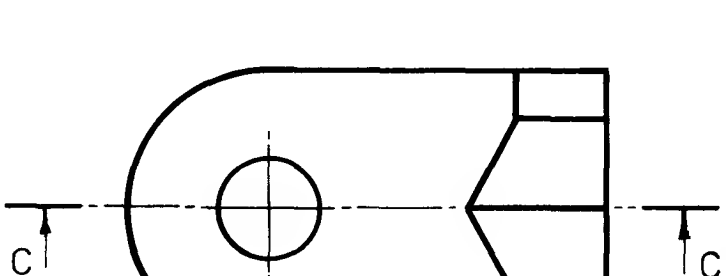
# Sectioning

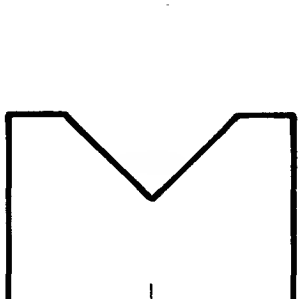
Drawings of the outside of simple components are often sufficient to convey all the information necessary to make the component. More complicated components, however, may require sectional views to clarify internal details.

A sectional view is obtained when one imagines the component to be cut through a chosen section plane - often on a centre line.

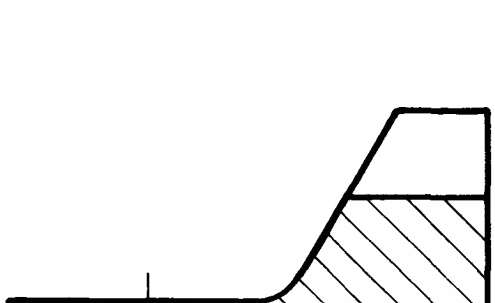


If the vee-block is cut on section plane C-C as shown above, the resulting sectional view projected from the plan replaces the usual front view of the outside of the block.



End view



Sectional Front View looking on cutting plane C-C

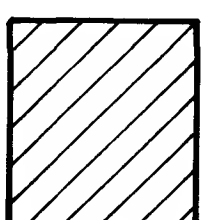


Sectional views are drawn only when it is necessary to explain the construction of a complex object or assembly. Some of the examples used in the next few pages have been chosen to illustrate the rules of sectioning although in practice, as in the case of the vee-block drawn above, a sectional view may not have been necessary

The draughtsman has to decide how a component or assembly should be sectioned in order to provide the fullest possible information. The recommendations of BS 308 enable him to do this in a way that is understood by all engineers.

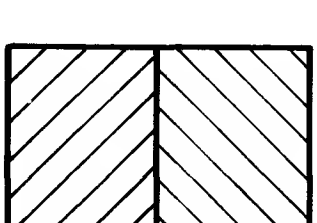
# The rules of sectioning:

1. A sectioned object is shown by lines drawn preferably at 45°. Thin lines touch the outline.



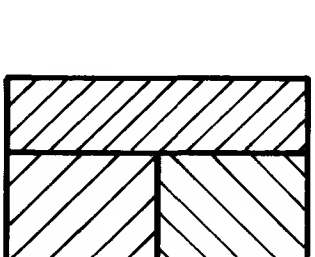
Size of sectioned part determines line spacing - preferably not less than 4 mm.

2. If two adjacent parts are sectioned, the section lines are drawn in opposite directions.



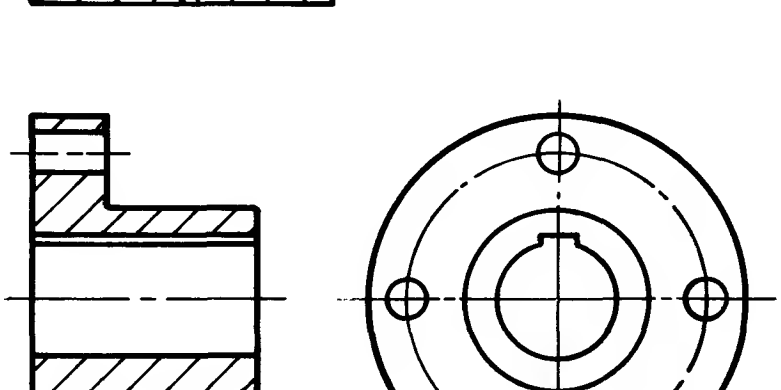
Lines are staggered where the parts are in contact.

3. Where more than two parts of an assembly are to be sectioned, the lines cannot all be opposite.



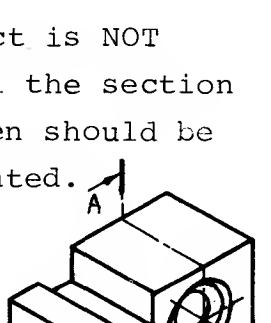
Section lines are closer together on the third area — usually the smallest

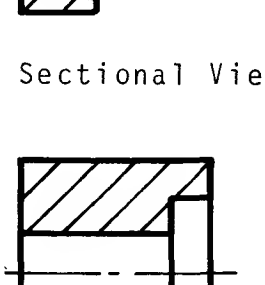
4. The sectional view of a symmetrical object is obtained when the section plane cuts through the obvious centre line. Hatching may be omitted if the meaning is clear without it.



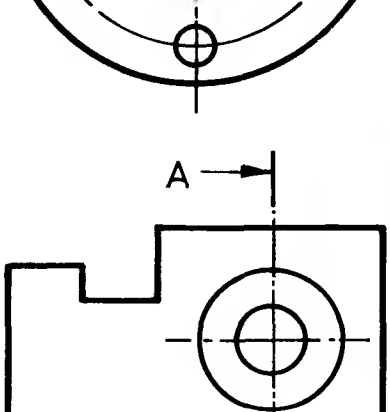
Sectional View

5. If an object is NOT symmetrical the section plane chosen should be clearly stated.



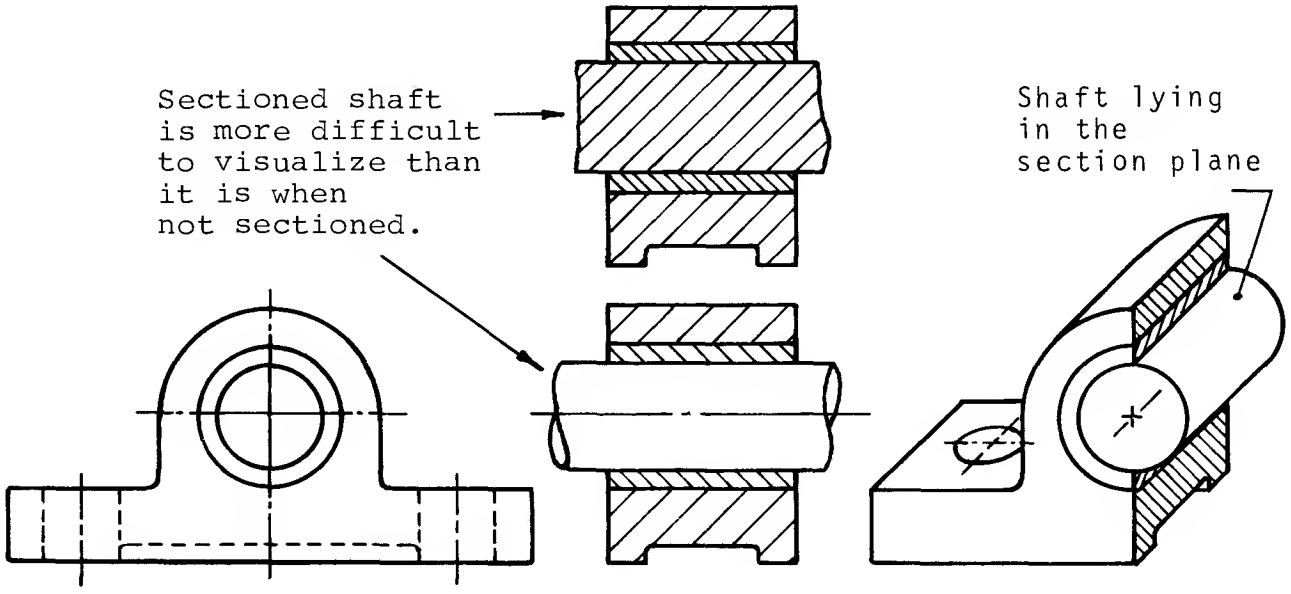



Section A-A



# Sectioning: exceptions

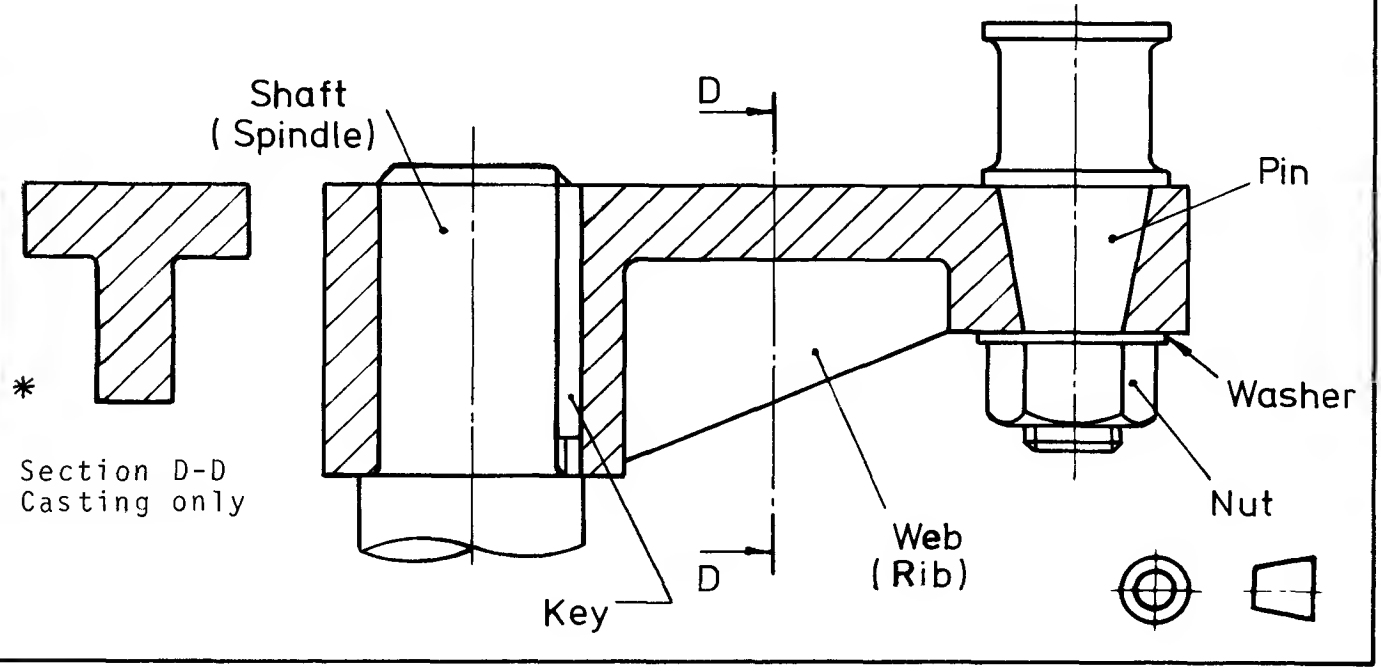
There are a number of features and parts which are NOT normally sectioned even though they may lie in the section plane. A good way to accept these exceptions to the general rule is to imagine how complicated the drawing would look if they were sectioned. They are sectioned, however, when they lie ACROSS the section plane. See section D-D. *



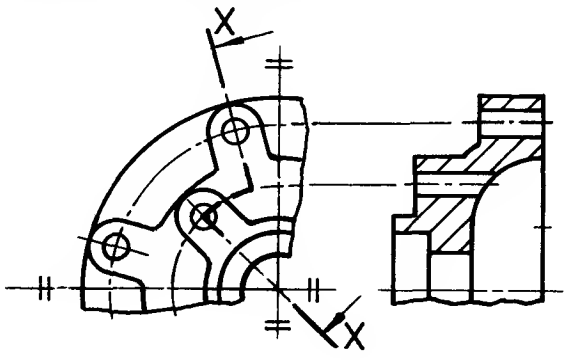

BS 308 states that the following are NOT sectioned even if they lie in a given section plane:

| | | | | | |
|---|---|---|---|---|---|
| Shafts | Keys | Rivets | Ribs | Pins | Dowels |
| Cotters | Bolts | Gear Wheels | Nuts | Webs | Washers |

Some of these are illustrated in BS 308 by this diagram:



# Staggered section planes



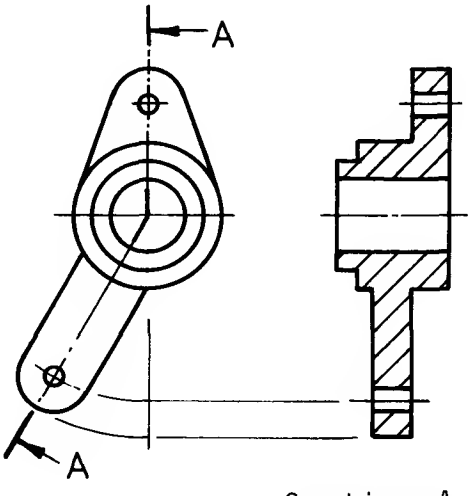

Section X-X

Each part of the section plane is swung to the vertical before projecting to the sectional End View.

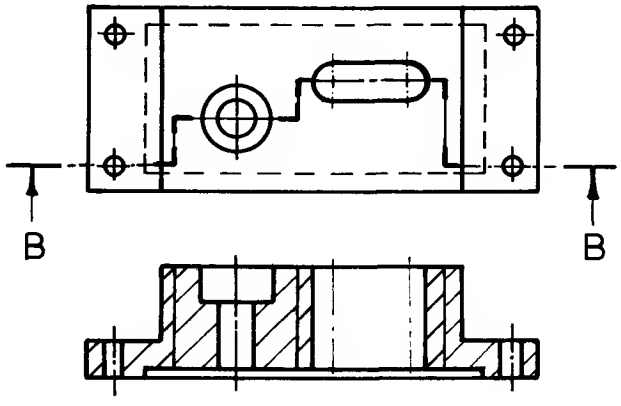
By using this convention the draughtsman avoids using too many auxiliary views.

A staggered section plane should only be used when there is a resulting gain in clarity.

Examples

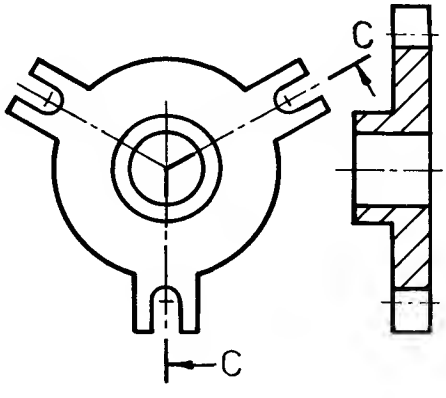



Section A-A
Re-aligned

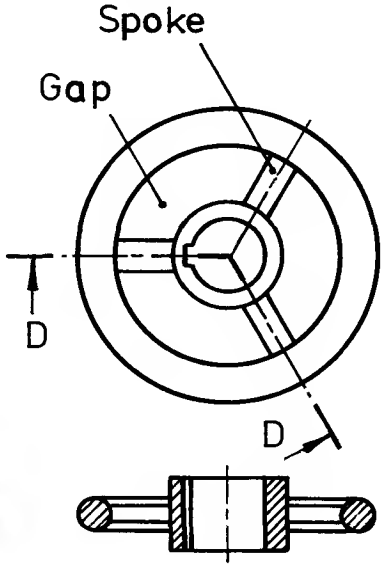



Section B-B
Staggered or offset

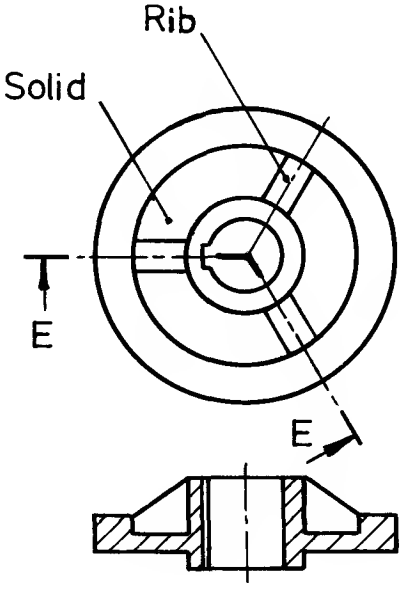
Applications of this convention to specific cases are given below.




Section C-C
Revolved



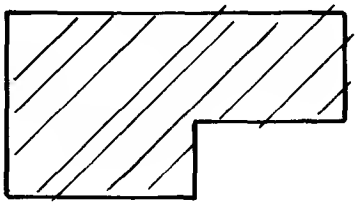

Section D-D
Revolved



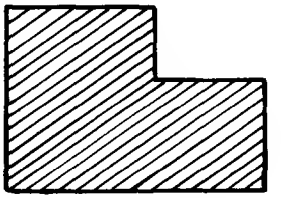

Section E-E
Revolved

Errors in sectioning occur in each of the drawings below.
Trace or re-draw a correct sectional view in each case.
State the method of projection used where applicable.

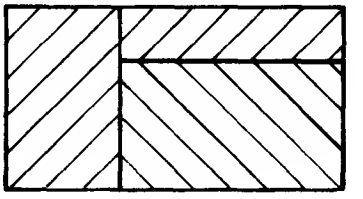
Solns. p.144



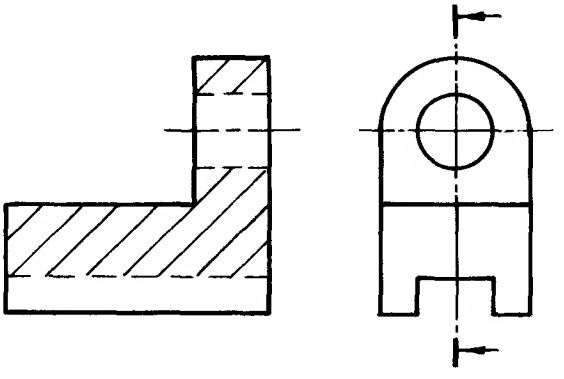
1



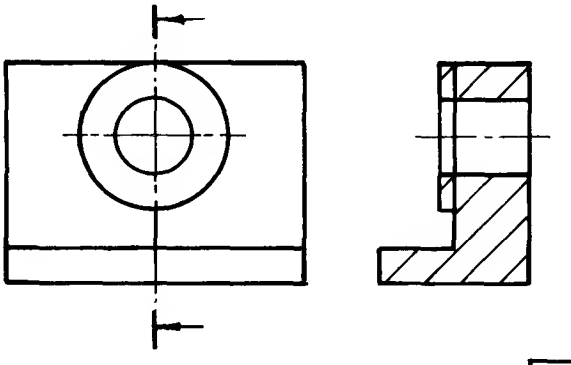
2



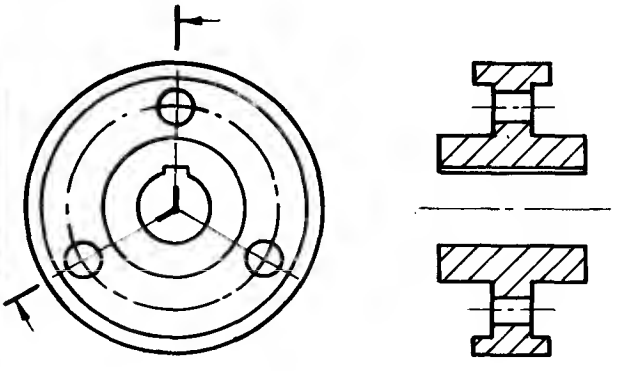
3



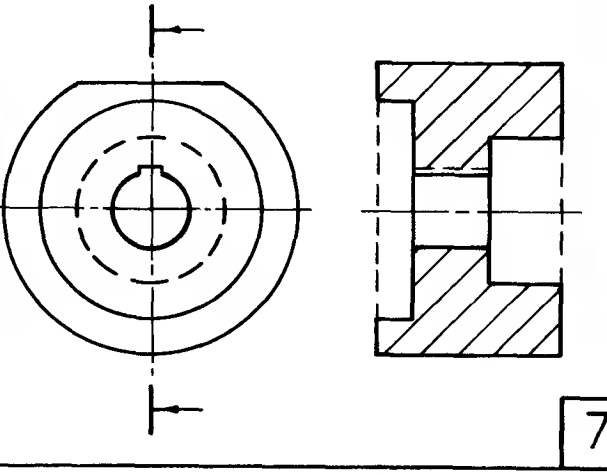
4



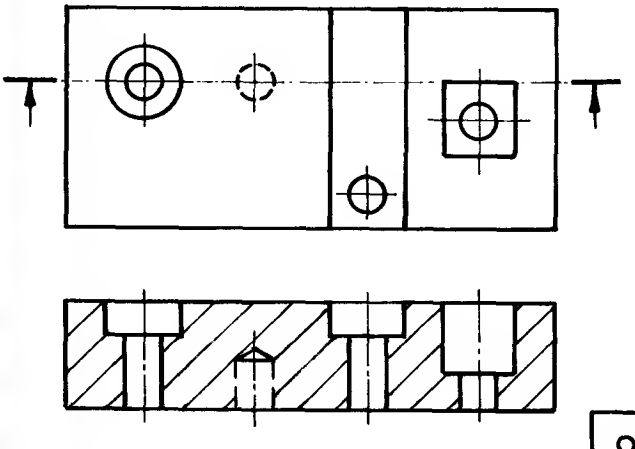
5



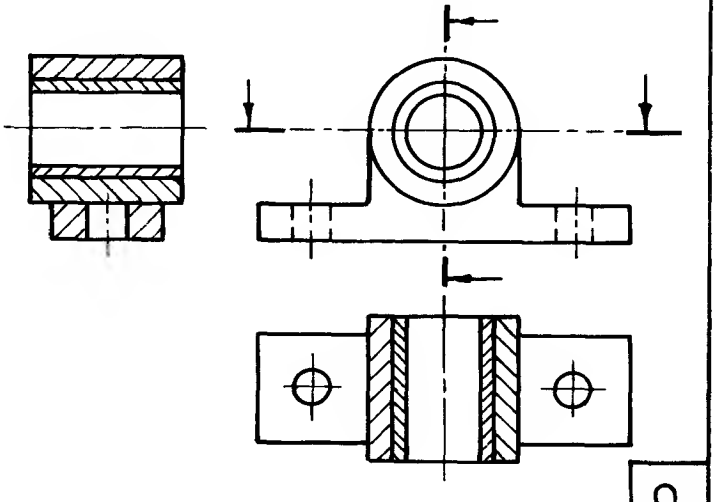
6



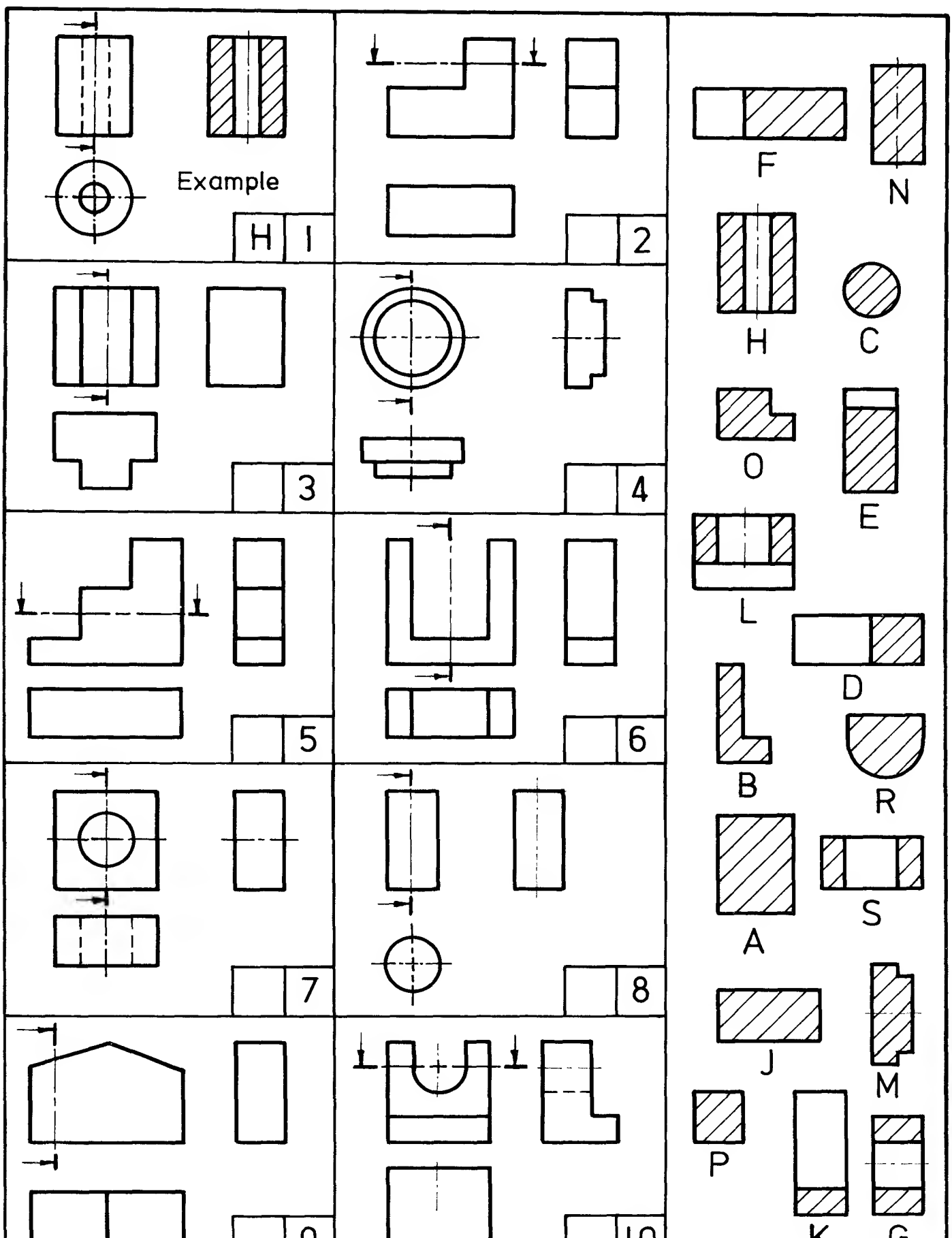
7



8

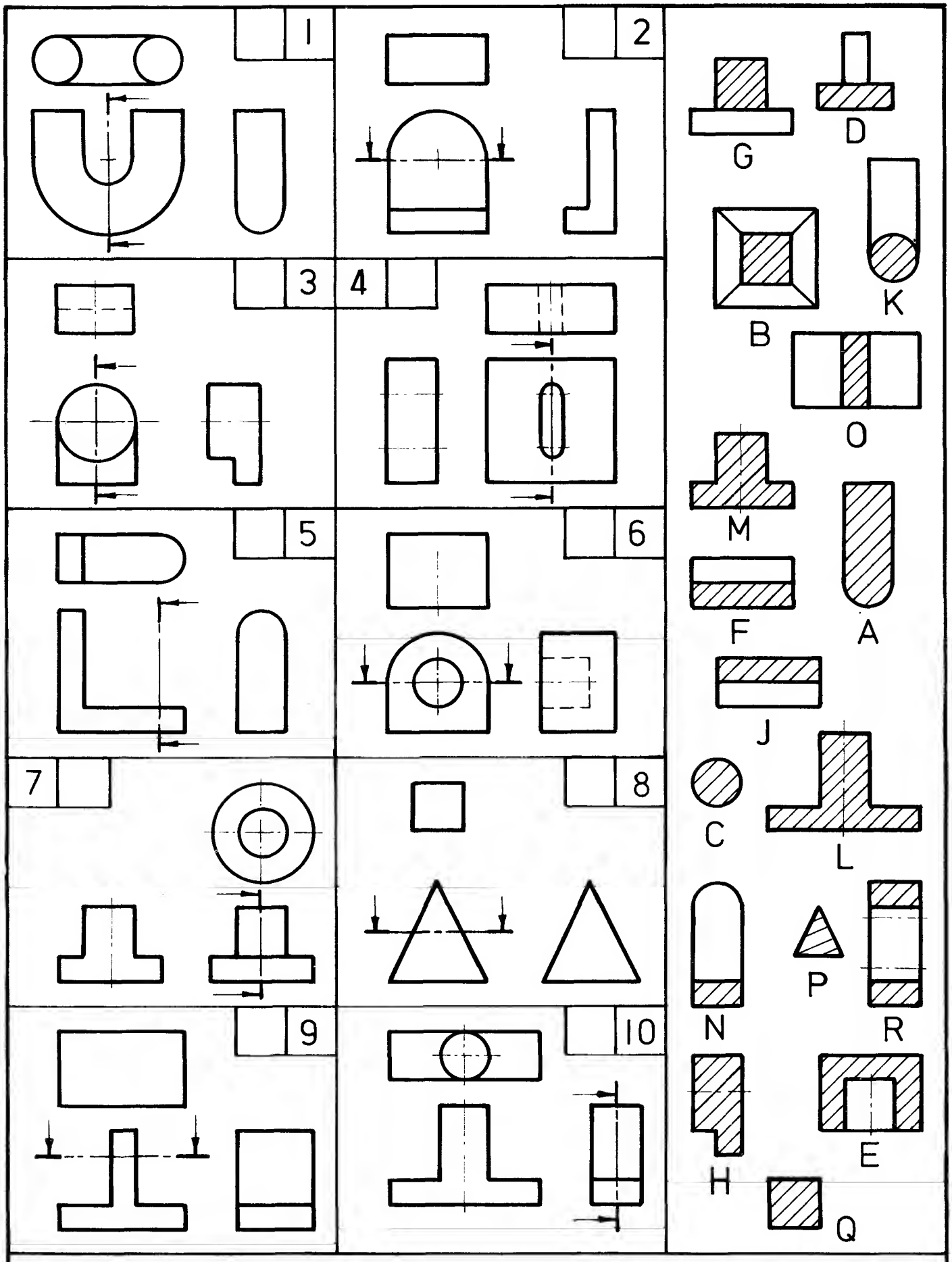


9




From the lettered drawings choose the correct sectional view for each numbered drawing.
Sketch the view in the space provided.

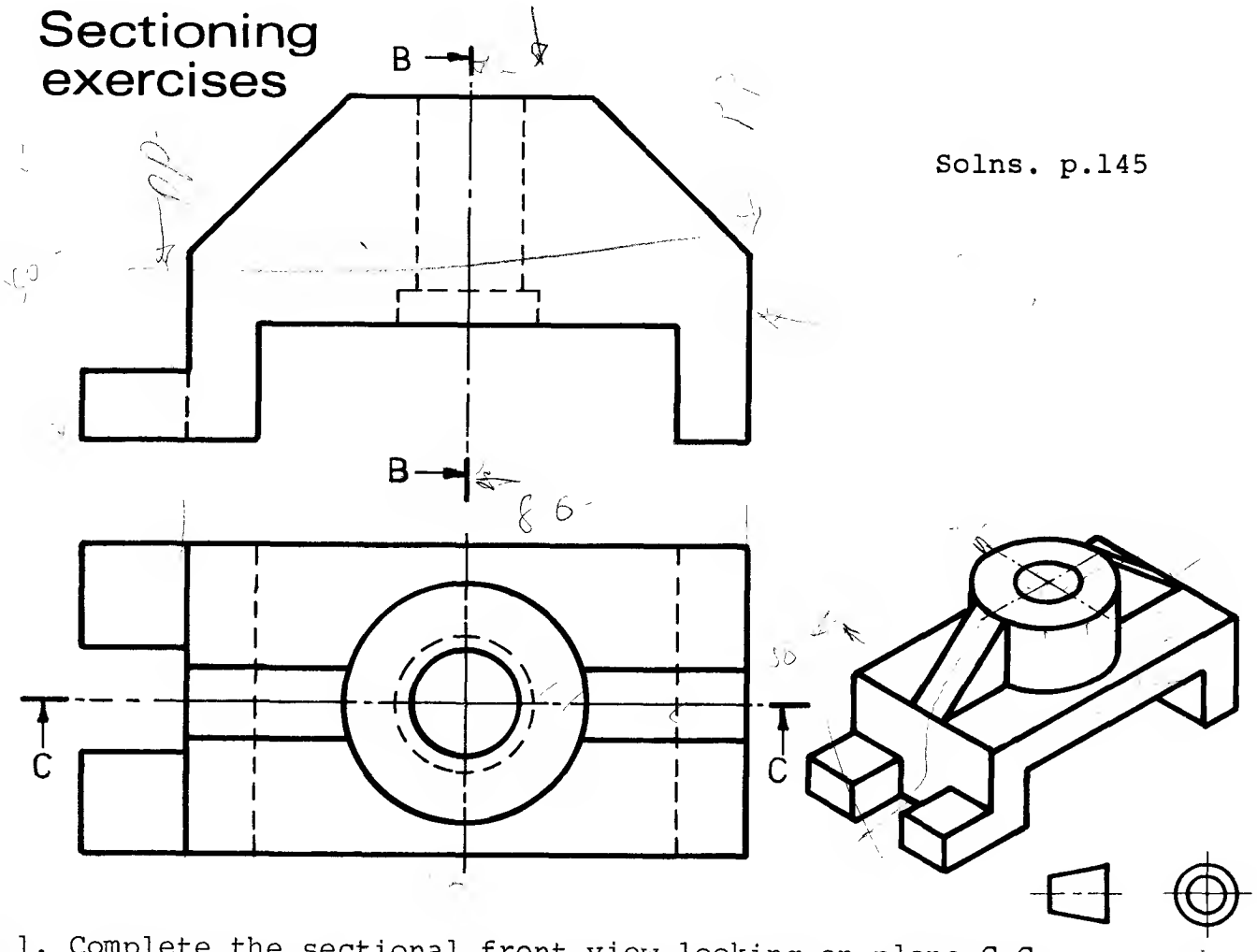
Solns. p.144



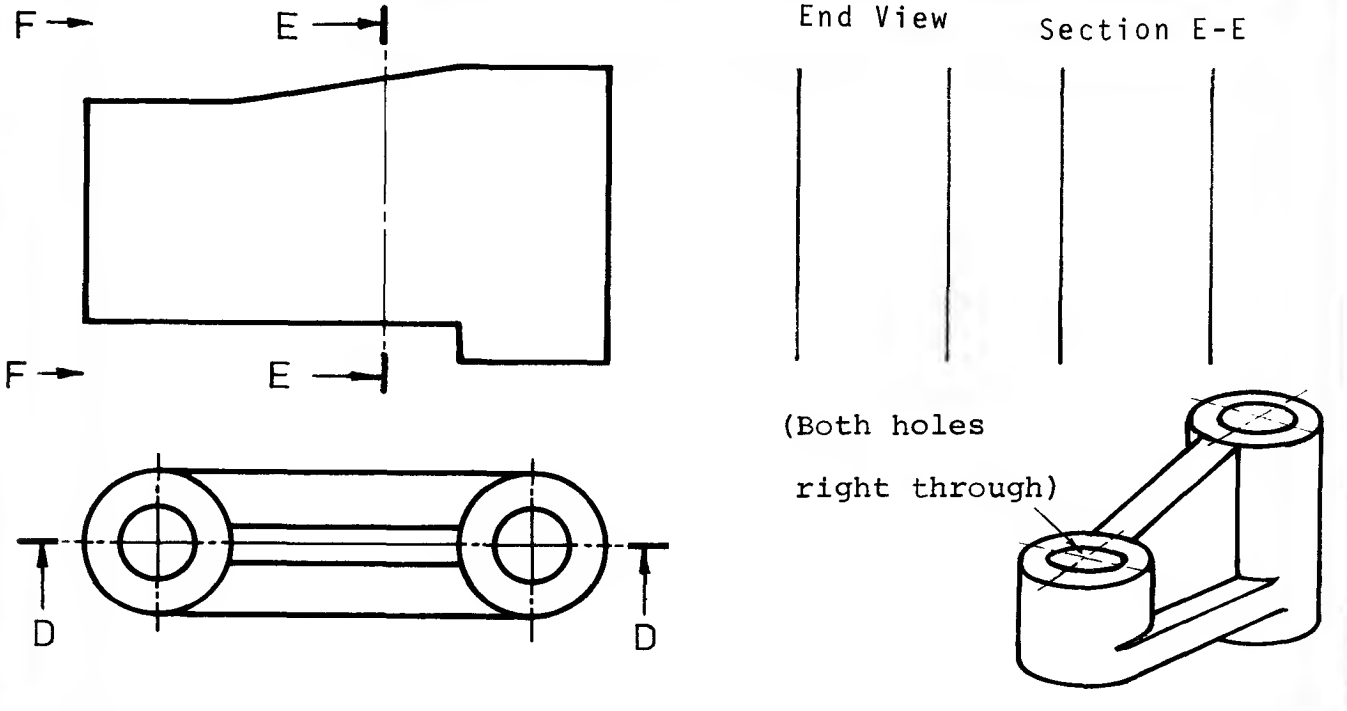

From the lettered drawings choose the correct sectional view for each numbered drawing.
Sketch the view in the space provided. Solns. p.144

# Sectioning exercises

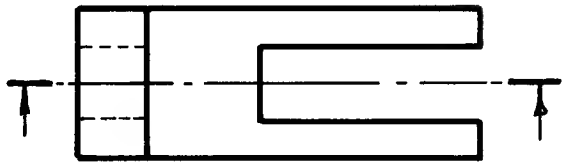
Solns. p.145



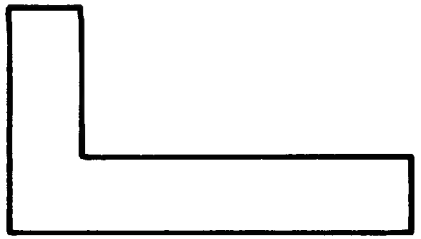

1. Complete the sectional front view looking on plane C-C.
2. Complete the sectional end view looking on plane B-B.

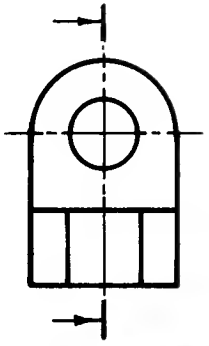



1. Draw an end view looking in the direction of arrows F-F.
2. Complete the sectional front view looking on plane D-D.
3. Complete the sectional end view looking on plane E-E.

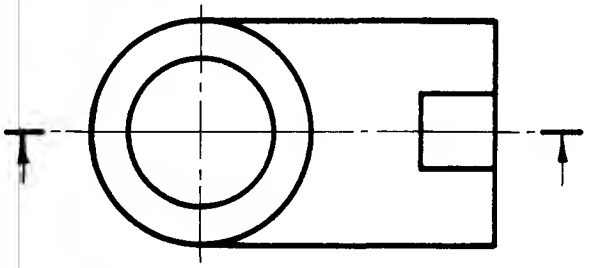


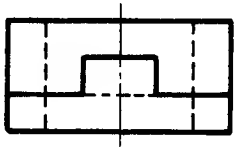
Note!
Either cutting plane will give the same sectional Front View.



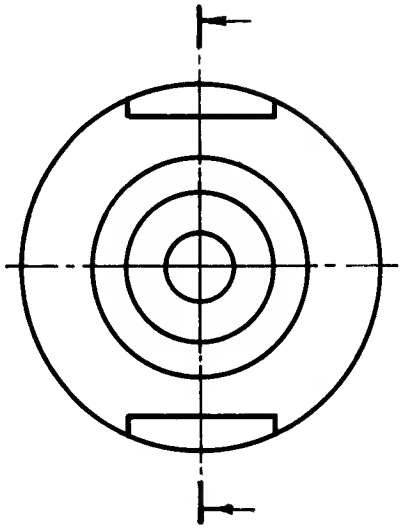


1

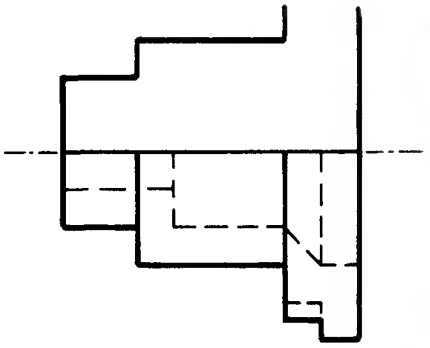




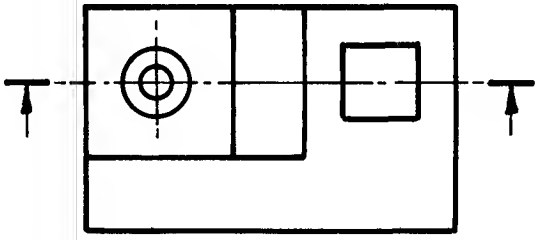
2



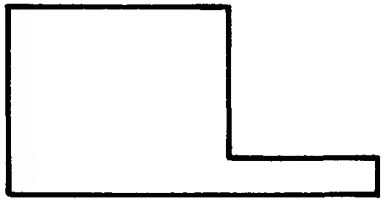
Section top half only

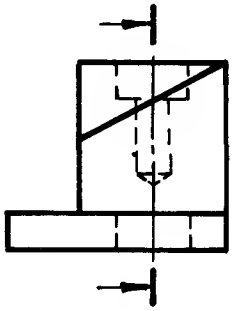


3



Note:
Either cutting plane will give the same sectional Front View.





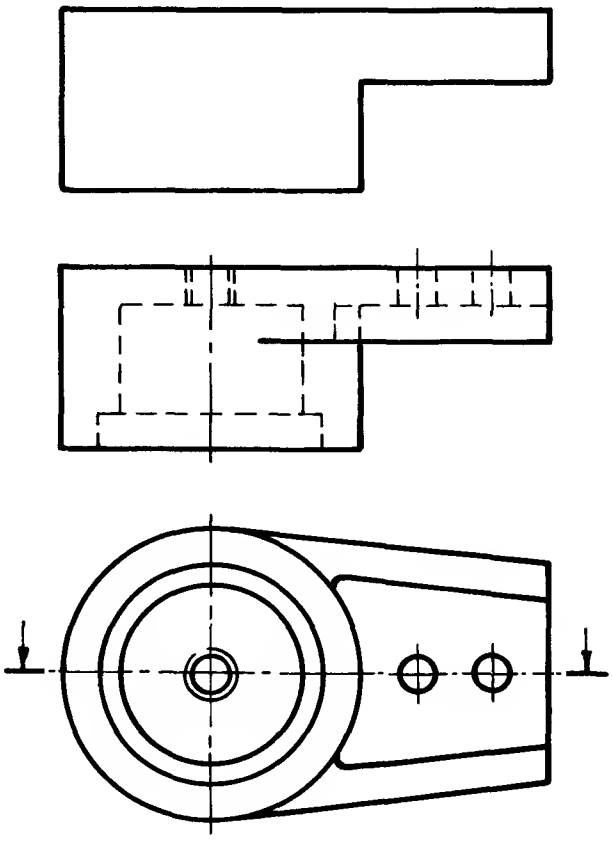
4

## Sectioning exercises

Complete the views in the above examples and also those shown on pages 30 and 31. State the method of projection used in each case. Solns. p.145.

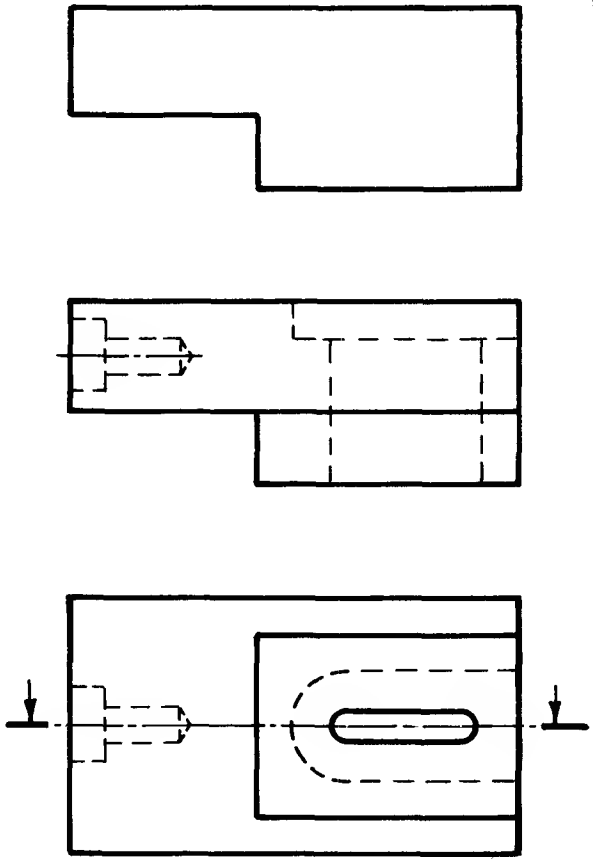
# Sectioning exercises

1

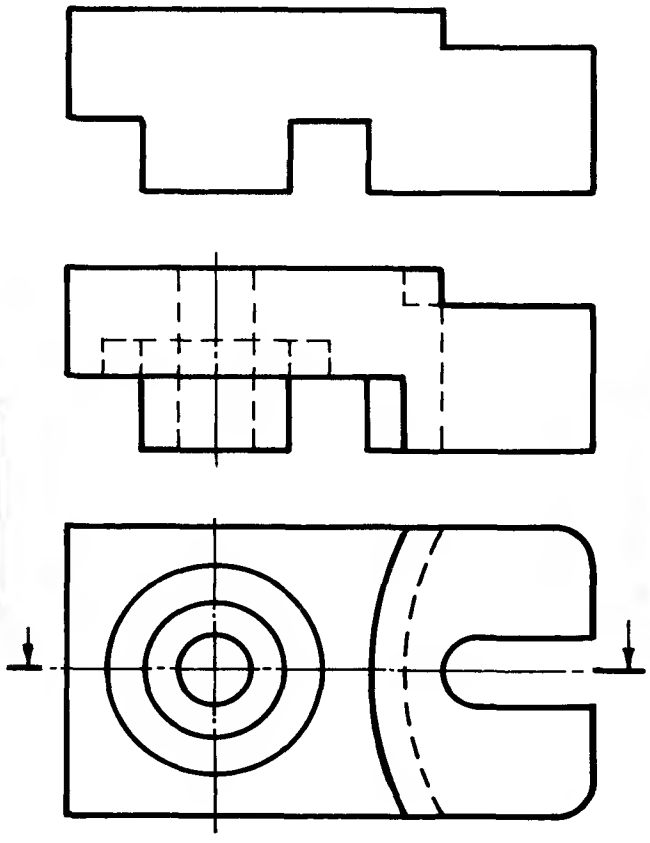


Solns. p.146

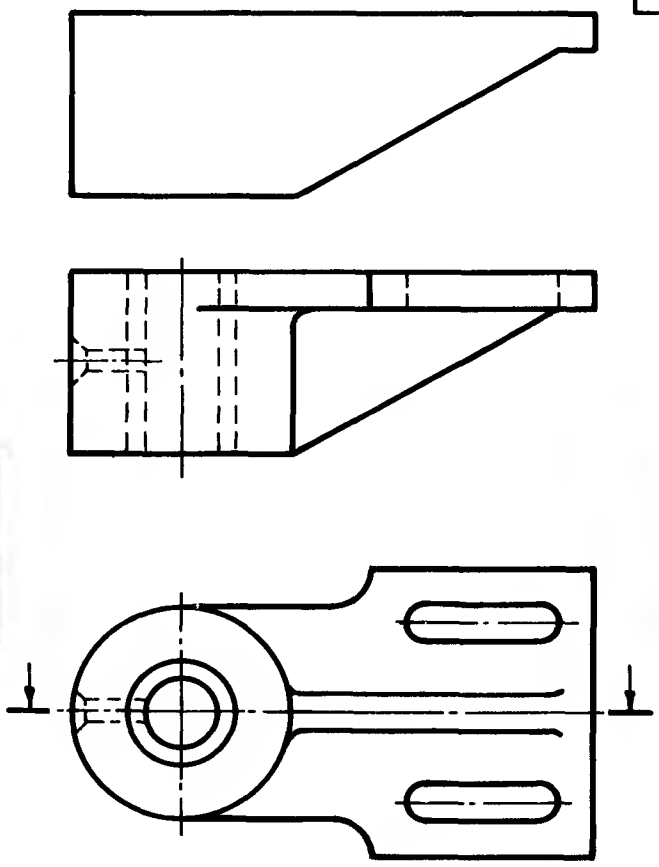
2



3

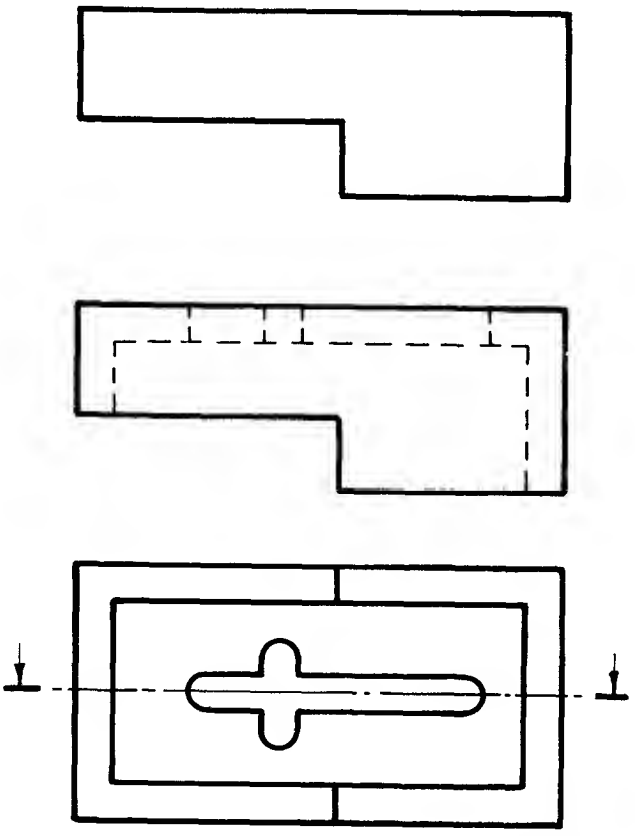


4



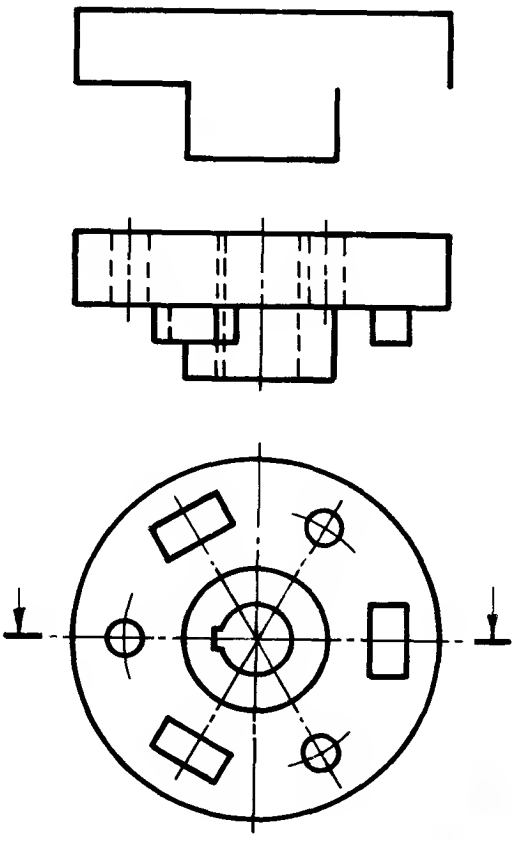
# Sectioning exercises

1

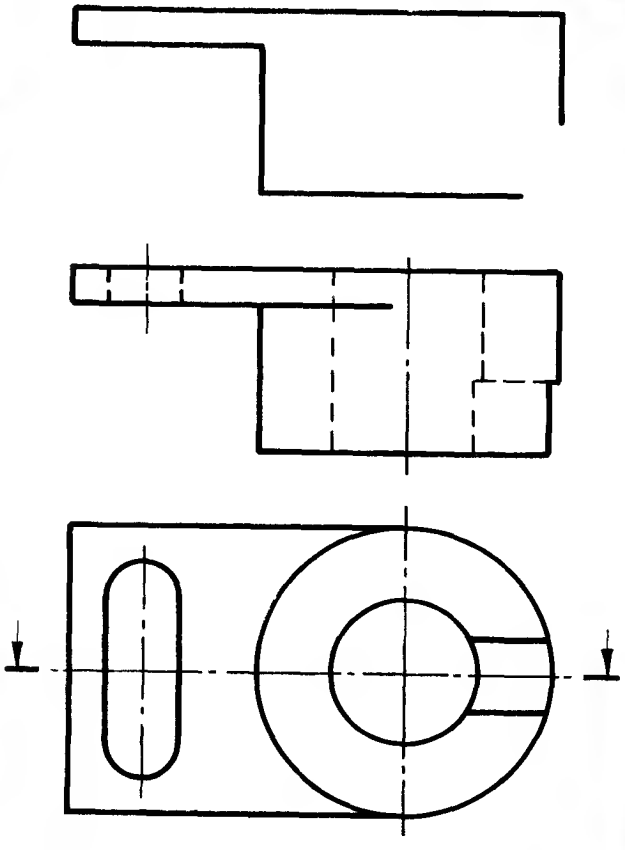


2

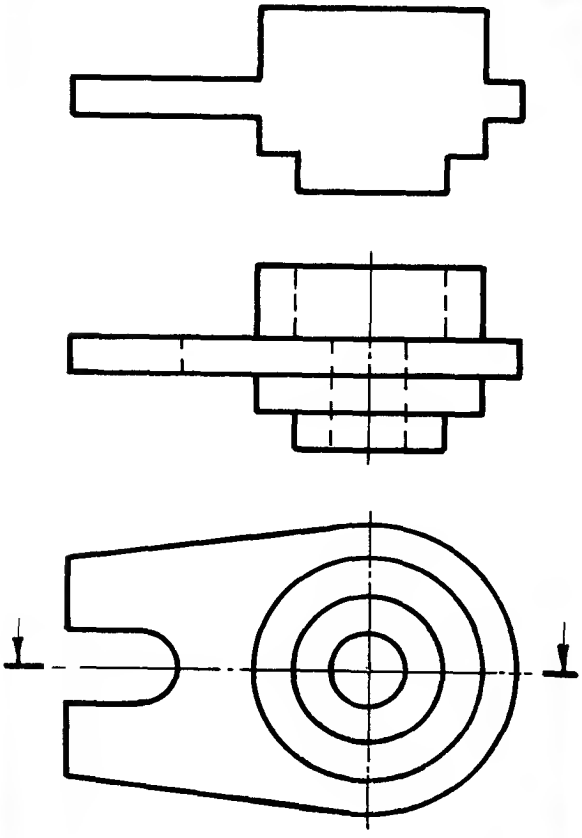
Solns. p.146



3



4

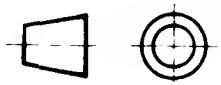


# Sectioning exercise

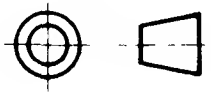
Sketch, or trace, a sectional view of the component looking on

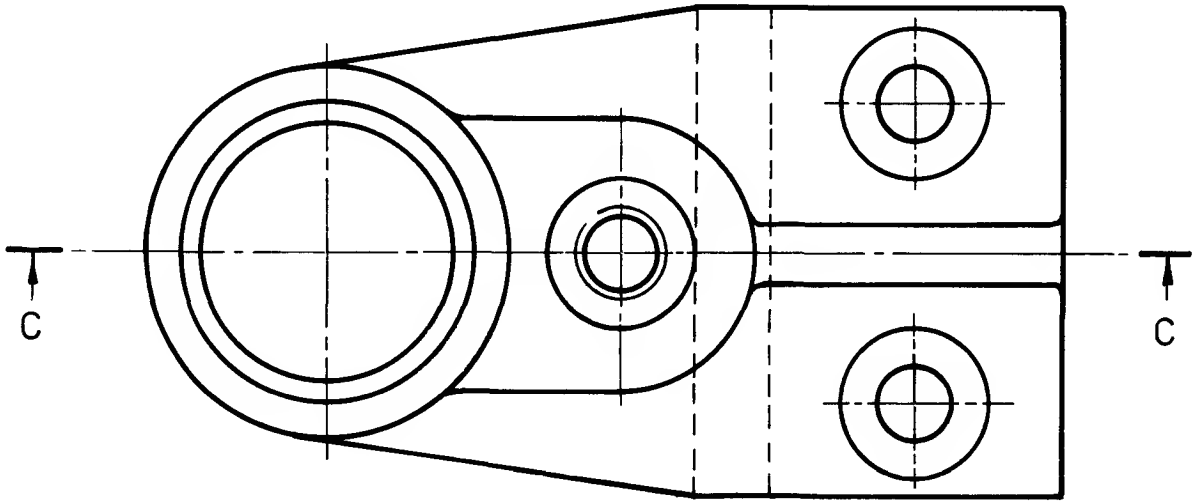
Cutting plane AA
Cutting plane BB
Cutting plane CC
Cutting plane DD

Which method of projection is used?

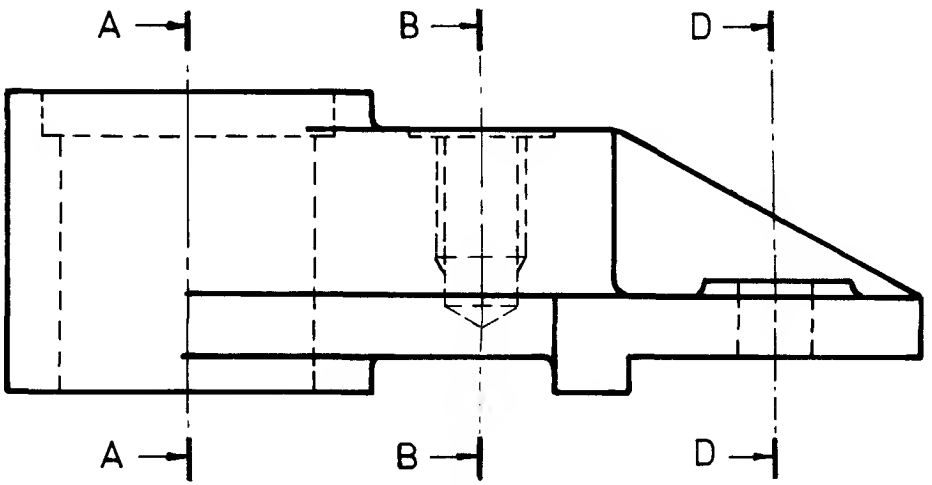


OR

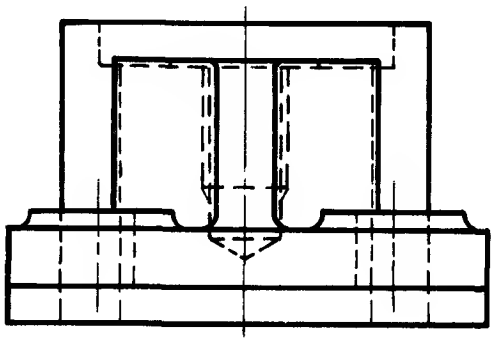





Plan




Front view



Side view

Solns. p.147

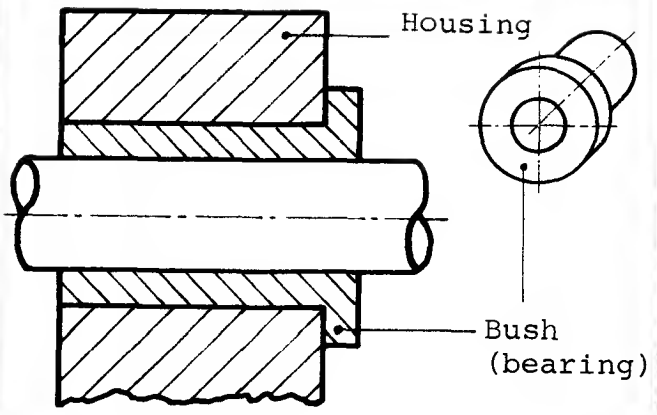
# Information on Engineering Drawings

Communication between the drawing office and the workshop is mainly achieved via the engineering drawing - orthographic and/or pictorial. In order to reduce drafting time a number of standard parts are drawn in a simplified form and many items of written information are abbreviated. In BS 308 Part 1:1972 recommendations have been made for

Conventional representation of commonly used parts & materials and Abbreviations of terms frequently used on drawings.

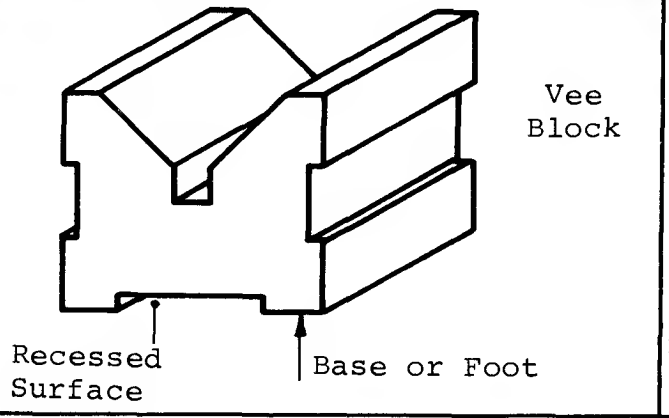
Before this engineers' "shorthand" can be used correctly it is necessary to understand the terms used to describe features of engineering components. This terminology is common to both drawing office and workshop and is often used when discussing the various manufacturing and machining processes used in engineering.

## Terminology



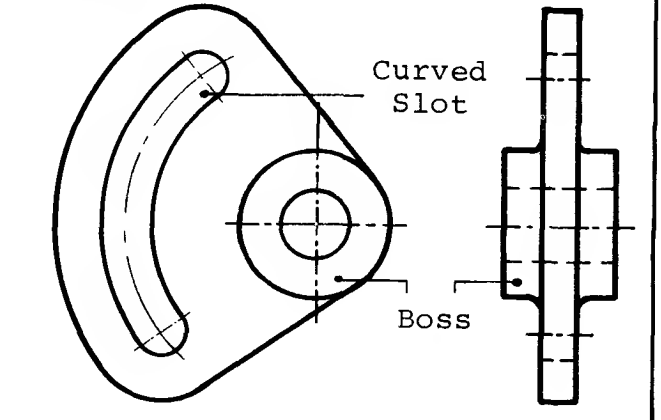

HOUSING A component into which a "male" mating part fits, sits or is "housed".

BUSH A removable sleeve or liner. Known alternatively as a simple bearing. Fig. shows a flanged bush.




BASE (or FOOT) That part upon which the component rests.

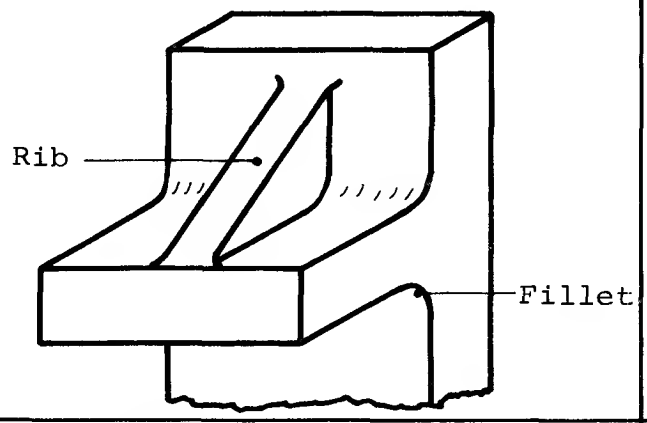
RECESSED SURFACE Ensures better seating of the base. Minimises machining of the base.




BOSS A cylindrical projection on the surface of a component - usually a casting or a forging.

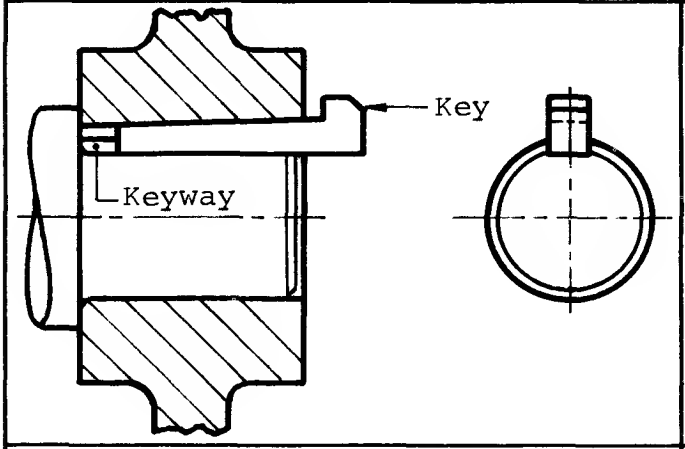
CURVED SLOT An elongated hole whose centre line lies on an arc. Usually used on components whose position has to be adjusted.

# Terminology



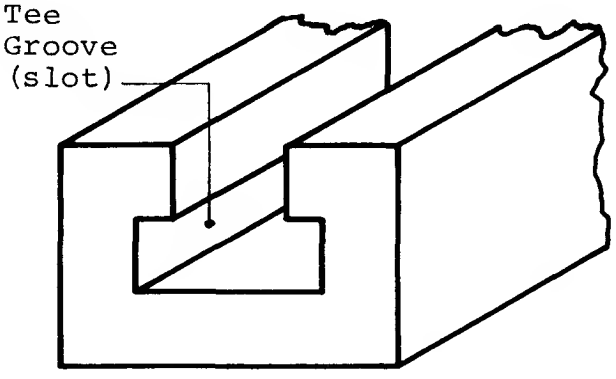

FILLET A rounded portion, or radius, suppressing a sharp internal corner.

RIB A reinforcement positioned to stiffen surfaces usually at right angles to each other

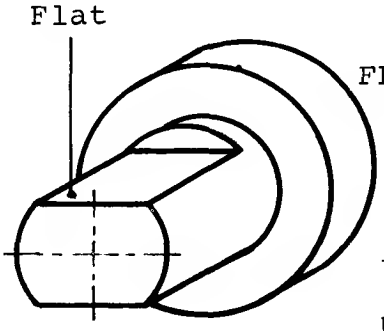



KEY A small block or wedge inserted between a shaft and mating part (a hub) to prevent circumferential movement.

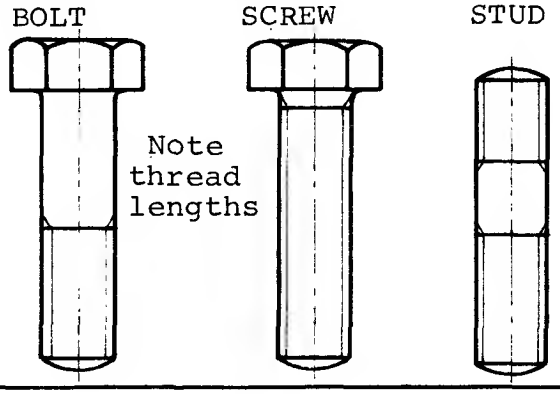
KEYWAY A parallel sided groove or slot cut in a bore or on a shaft to 'house' a mating key.

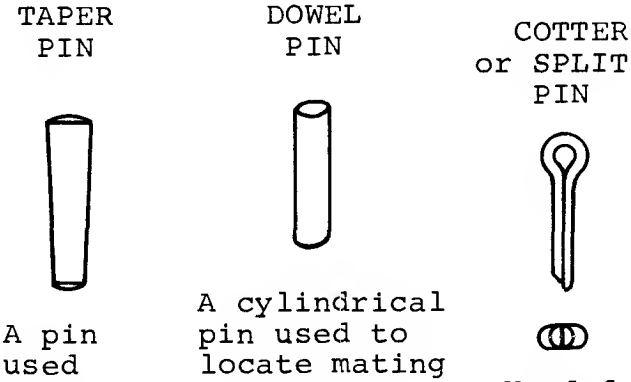



TEE SLOT Machined to "house" mating fixing bolts and prevent them turning




FLAT A surface machined parallel to the shaft axis. Usually used to locate and/or lock a mating component.




A pin used for fastening

A cylindrical pin used to locate mating parts.

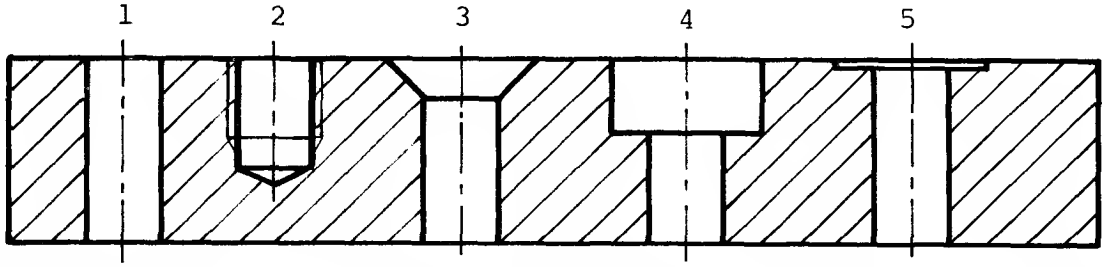
Used for fastening

# Terminology

Many different types of holes may be seen on engineering drawings. The more common ones, associated with drilling, reaming and/or tapping, are shown below in Fig.1. The name and where appropriate the application of each is indicated.

Figures 2 and 3 indicate the different terms which may be seen on drawings that are associated particularly with lathe work.

Fig.1




1. A *drilled hole* or, if greater accuracy is required, a reamed hole.
2. A *'blind' tapped hole* i.e. a threaded hole which passes only part way through the plate.
3. A *countersunk hole*. Provides a mating seat for a countersunk headed screw or rivet.
4. A *counterbore*. Provides a 'housing' for the heads of capscrews, bolts, etc.
5. A *spotface*. A much shallower circular recess. Provides a machined seat for nuts, bolt heads, washers, etc.

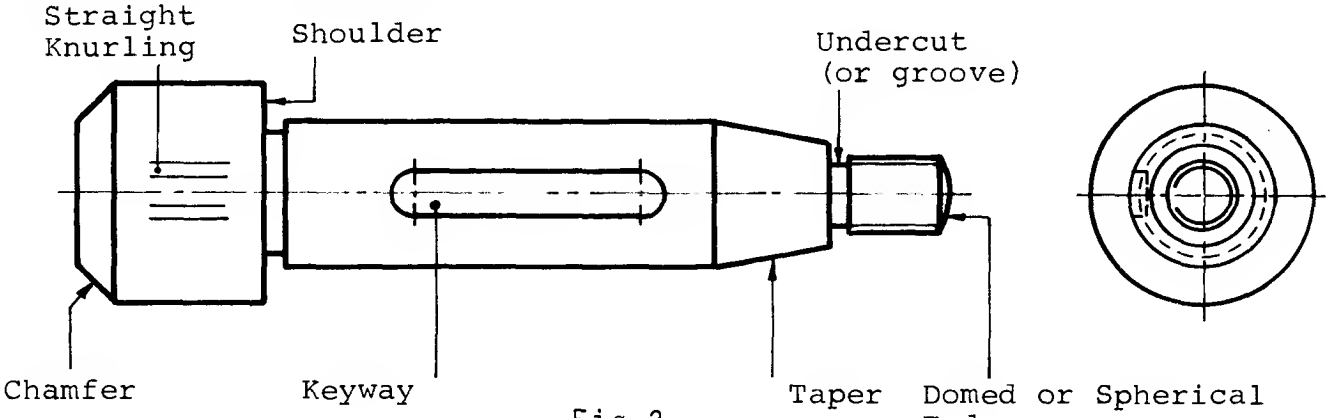



Fig.2

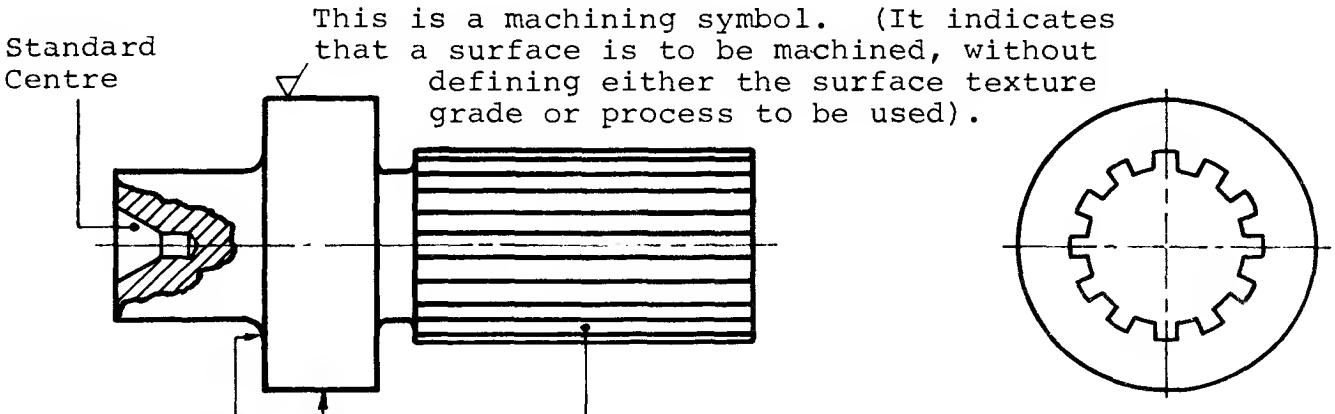
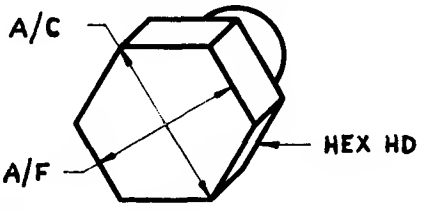
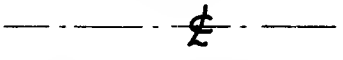
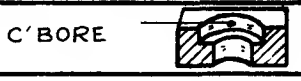
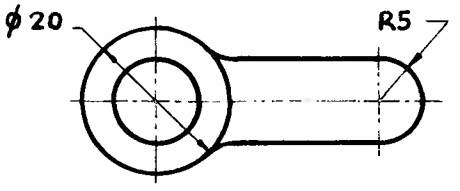
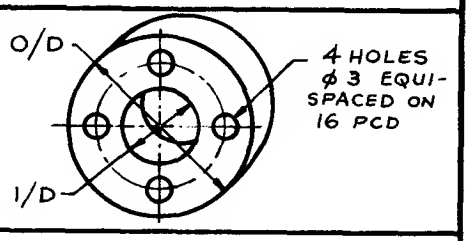
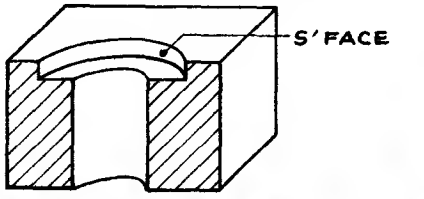
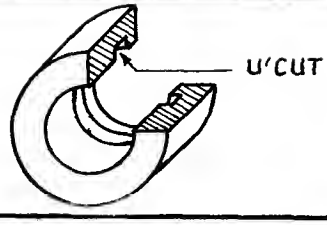



Fig.3

# Abbreviations

Many terms and expressions in engineering need to be written on drawings so frequently as to justify the use of abbreviations which help to reduce drafting time and costs. Many of these abbreviations have been standardized as can be seen in BS 308:1972:section 11. A selection of the more commonly used ones are stated and clarified in the following tables.

| | ABBREVIATION | MEANING | SKETCH/NOTES |
|---|---|---|---|
| * | A/C | Across corners |   |
| | A/F | Across flats | |
| | HEX HD | Hexagon head | |
| | ASSY | Assembly | See page 96 |
| | CRS | Centres |   |
| | ℄ or CL | Centre line |  |
| | CHAM | Chamfered |   |
| | CH HD | Cheese head |   |
| | CSK | Countersunk |   |
| | C'BORE | Counterbore |   |
| | CYL | Cylinder or cylindrical | |
| | DIA | Diameter (in a note) |   |
| | ϕ | Diameter (preceding a dimension) | |
| | R | Radius (preceding a dimension, capital only) | |
| | DRG | Drawing | |
| | FIG. | Figure | |
| | LH | Left hand | |
| | LG | Long | |
| | MATL | Material | |
| | NO. | Number | |

| | ABBREVIATION | MEANING | SKETCH/NOTES |
|---|---|---|---|
| | PATT NO. | Pattern number | |
| | PCD | Pitch circle diameter |   |
| * | I/D | Inside diameter | |
| * | O/D | Outside diameter | |
| | RH | Right hand | |
| | RD HD | Round head |   |
| | SCR | Screwed |   |
| | SPEC | Specification | |
| | S'FACE | Spotface | |
| | SQ | Square (in a note) | See page 40 for conventional representation |
| | □ | Square (preceding a dimension) | |
| | STD | Standard |   |
| | U'CUT | Undercut | |
| * | M/CD | Machined | |
| * | mm | Millimetre | |
| * | NTS | Not to scale | |
| * | RPM | Revolutions per minute | SI symbol: rev/min |
| * | SWG | Standard wire gauge | |
| * | TPI | Threads per inch | |

* Abbreviations commonly used in practice but not listed in BS 308: Part 1: 1972

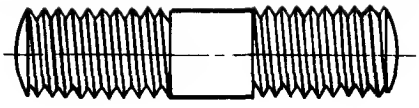
*Notes*

(1) Abbreviations are the same in the singular and plural.
(2) Capital letters are shown above, lower case letters may be used where appropriate. For other abbreviations upper or lower case letters should be used as specified by other relevant British Standards.
(3) Full stops are not used except when the abbreviation makes a word which may be confusing, e.g. NO. for 'number'.

# Conventional Representation of Common Features: Screw threads

There are many components commonly used in engineering which are complicated to draw in full. In order to save drawing time, these parts are shown in a simplified, conventional form. Some of the more frequently drawn features are shown in this section.

*Subject* - STUD

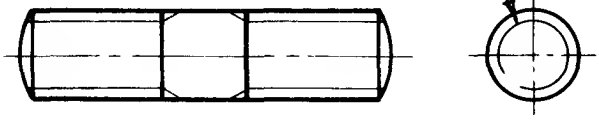


External Screw Thread
(Stud, bolt, set-screw, etc.)

*Convention*

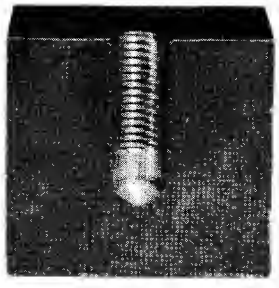
The screw thread is represented by two parallel lines. The distance between these lines is approximately equal to the depth of thread.

*Note* The inside line is THIN and the circle is *broken*



Front view Side view

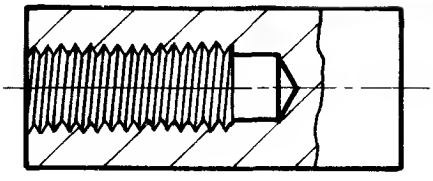
TAPPED "BLIND HOLE"

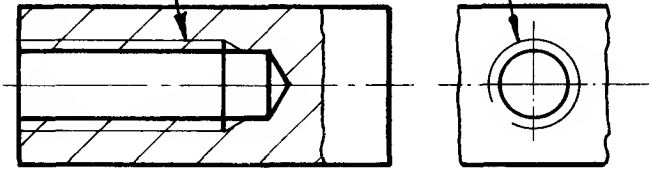


The shape of the hole formed by the tapping size drill is drawn in heavy lines.

*Note* Section lines *cross* the thread

The outside line is THIN and the circle is broken

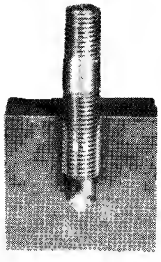




Internal Screw Thread

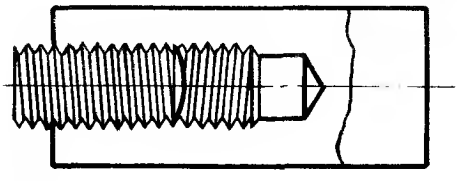
Front view Side view

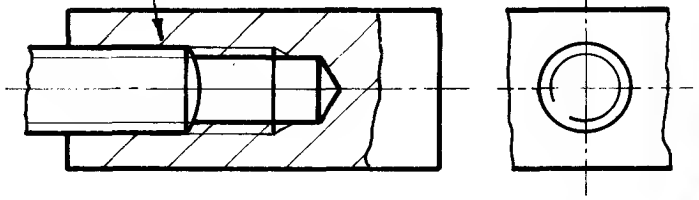
STUD INSIDE TAPPED HOLE



The external thread is superimposed over the internal thread.

*Note* Section lines are *not* drawn across the external thread.





Screw Threads
(Assembly)

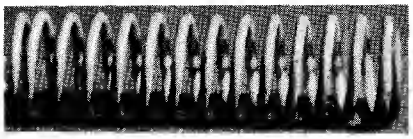
Front view Side view

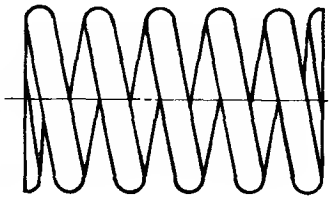
# Conventional representation: Springs

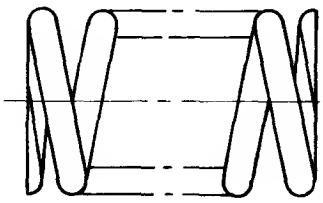
A spring is designated by stating the diameter of the wire, the coil diameter (inside or outside), the form of the spring ends, the total number of coils and its free length - See BS 1726.

In the case of the compression spring, the pitch of the coils may be deduced from its free length and number of coils.

*Subject* *Convention*



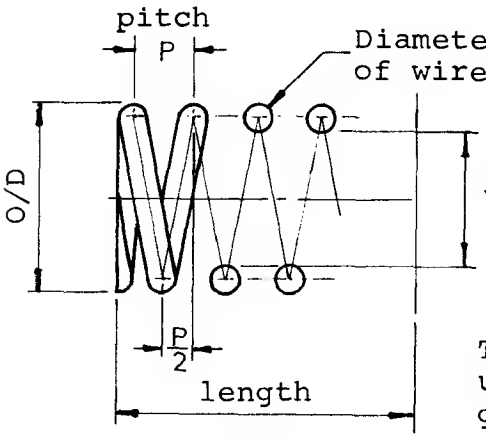


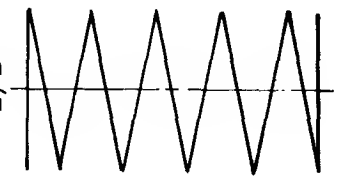


COMPRESSION SPRING

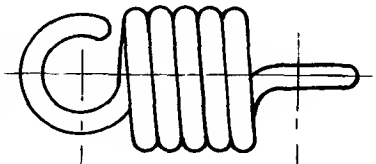
*Note*

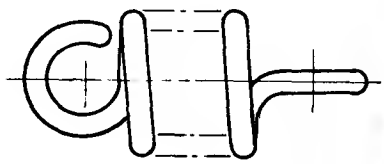
The construction on the right shows how the convention may be drawn from the spring details. Extreme accuracy is not essential; for example, a radius gauge may be used for the small radii.



This method is only used for quick diagrammatic sketches

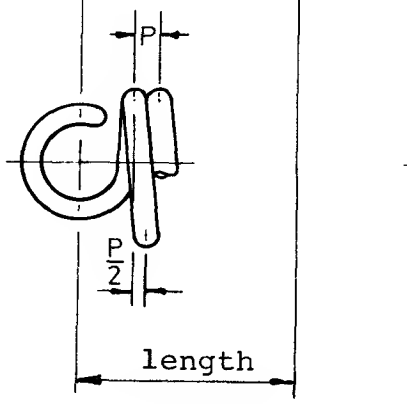




TENSION SPRING

*Note*

The construction on the right shows once again how the pitch of the coils may be used to set out the convention.

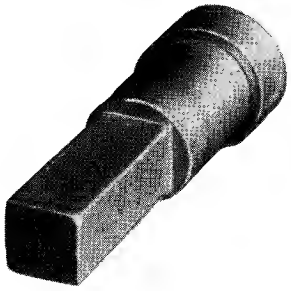



Diagrammatic representation

# Conventional representation: Shaft Details

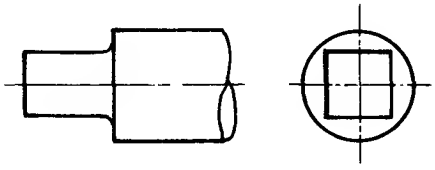
It is frequently necessary to fix a component to one end of a shaft or spindle so that a torque may be transmitted. Examples below are:

(1) Square on shaft - Machine handles, valve wheel spindle.
(2) Serrated shaft - Typical example - steering wheel to column on car.
(3) Splined shaft - Drive shaft on machine or vehicle when sliding also has to take place, e.g. in a gear box.



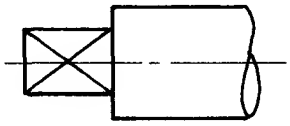
SQUARE ON the end of a long SHAFT

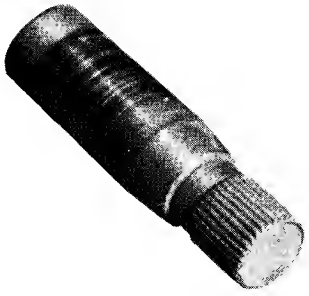
*Subject* *Convention*



Side view

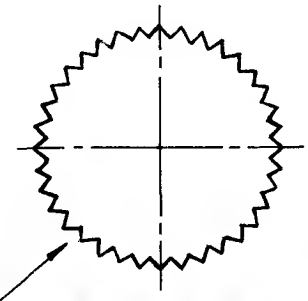
See page 96 for square on valve spindle.





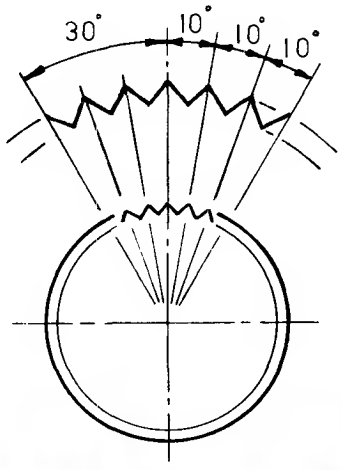
SERRATED SHAFT

The enlarged sketch shows how the serrations may be constructed

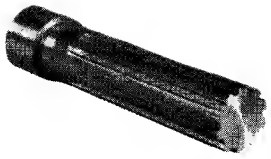


*Note*
Thirty-six serrations are shown for convenience only

View on serrated end

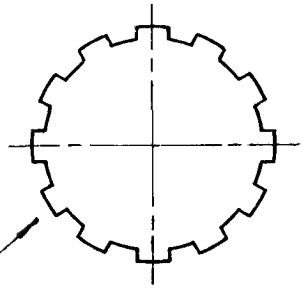



*Note*
Only a few teeth need be shown



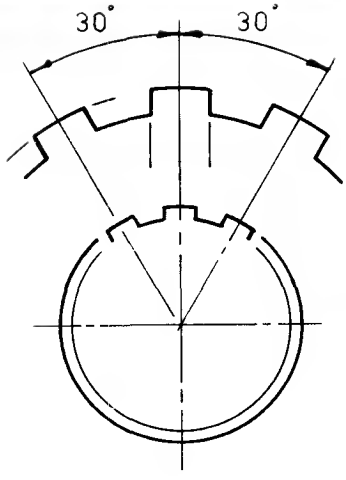
SPLINED SHAFT

Splines are usually drawn with parallel sides as emphasized in the enlarged sketch



*Note*
Twelve splines are shown for convenience only

View on splined end

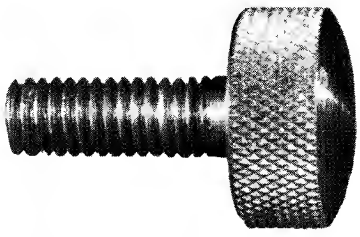


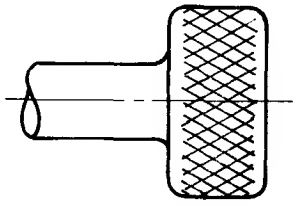

Refer to section on terminology - page 35

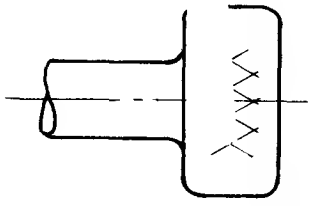
# Conventional representation: Knurling

Knurling is a common method of providing a roughened surface to aid tightening or slackening of a screw by hand. This is formed by pressing special rollers against the surface of the component whilst it revolves in a lathe. The commonly used diamond and straight knurls are shown below.

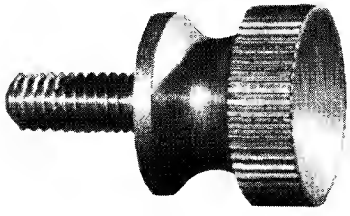
*Subject* *Convention*

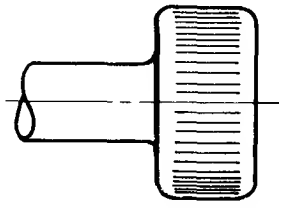


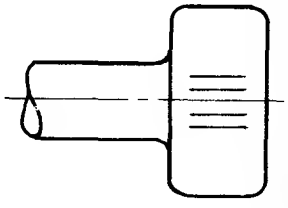




DIAMOND KNURL on
a machine screw head

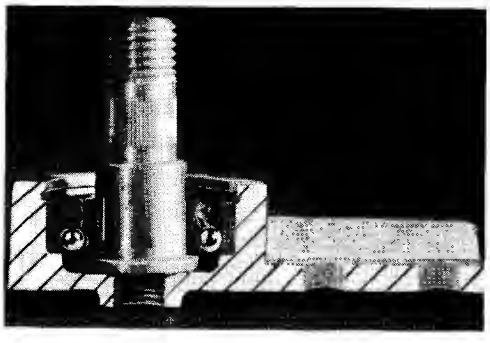






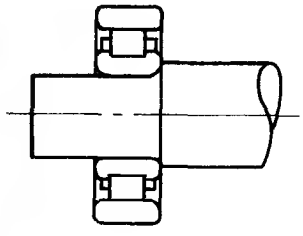
STRAIGHT KNURL on
a circuit terminal

# Bearings



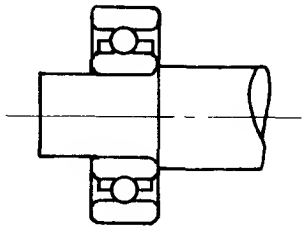
Cross-section of a
double row
self-aligning
ball bearing.

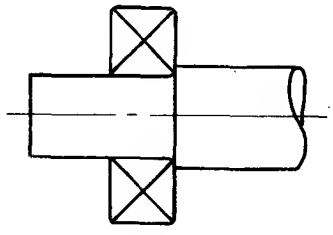
See assembly
drawing on page 103.



ROLLER

Notice how much
less drawing is
necessary in order
to represent any
ball or roller
bearing in a
conventional
manner.



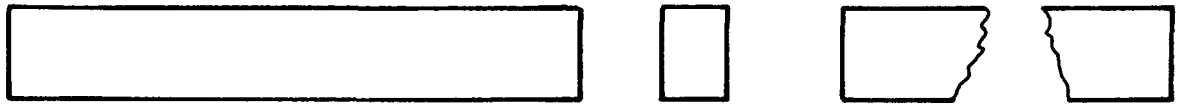


BALL

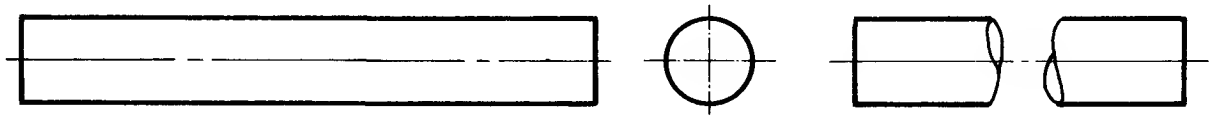
# Conventional representation: Long Components

There are occasions when bars, shafts, spindles or tubes may be too long to be drawn to a reasonable scale. In such cases the elevation may be interrupted as shown below.

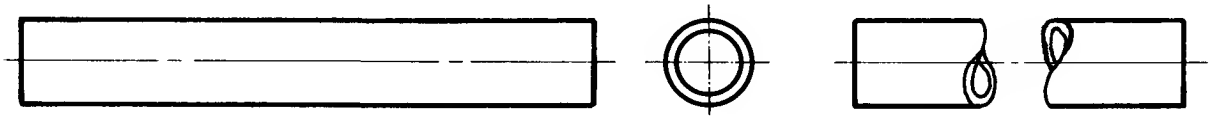
*Subject* *Convention*



RECTANGULAR BAR



CIRCULAR SHAFT OR SPINDLE

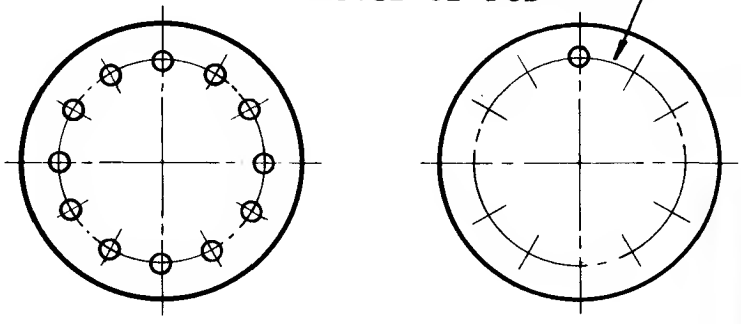


HOLLOW SHAFT OR TUBE

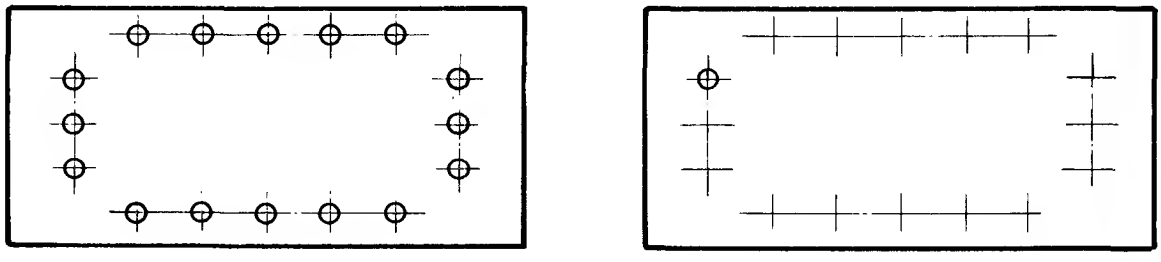
MULTIPLE HOLES

When a large number of holes of equal diameter are equi-spaced around a diameter or in line, only one hole need be drawn in full with the remainder marked with a short centre-line as shown in the drawings on the right.

Remember that this circle is called the pitch circle diameter or PCD



Holes on a *circular* pitch



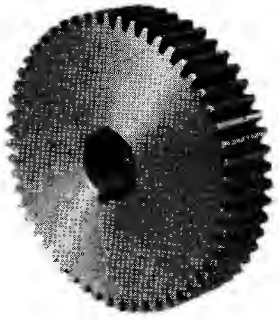
Holes on a *linear* pitch

# Conventional representation: Gears (1)

Before gears can be drawn a great deal of background knowledge about their nomenclature and construction must be acquired. The following drawings of gears are presented as conventions only.

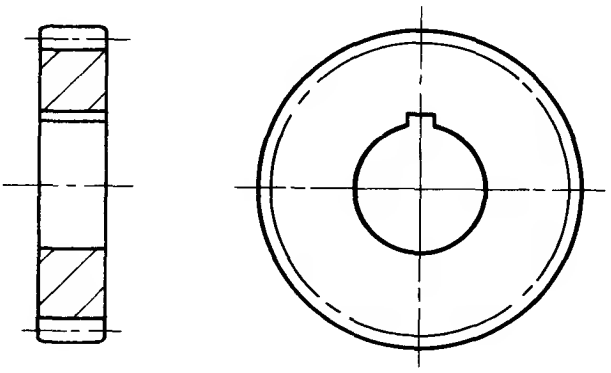
*Subject* - GEARS

*Convention*



*Note*

Side view of gear wheel is in section.



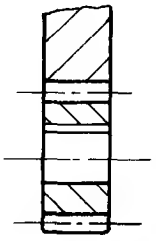
SPUR GEAR

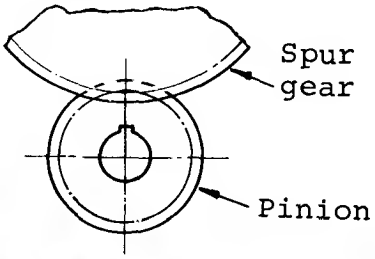
Single spur gear

*Note*

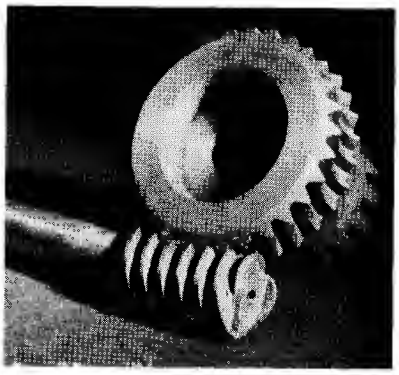
A pinion is so called when it has a relatively small number of teeth compared with its mating gear wheel.

Side view

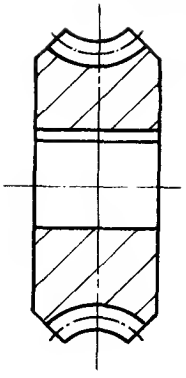




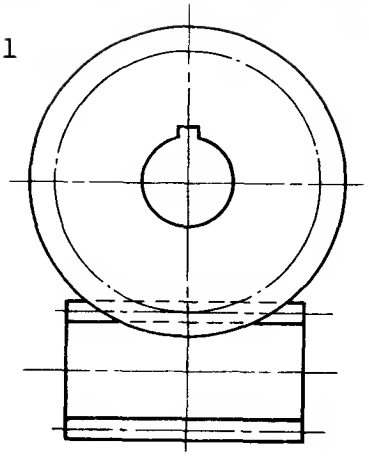

In mesh with a pinion

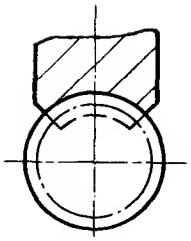


WORM AND WHEEL

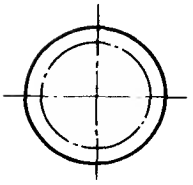


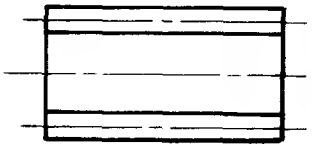
Wheel





Worm and wheel in mesh.



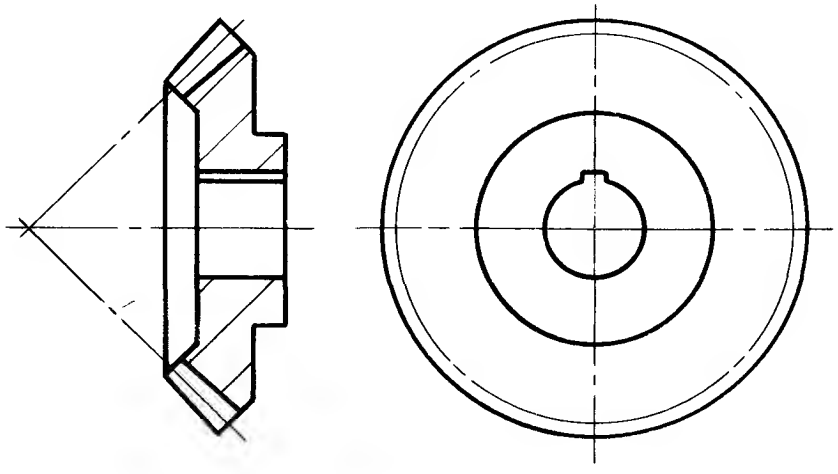


Worm

# Conventional representation: Gears (2)

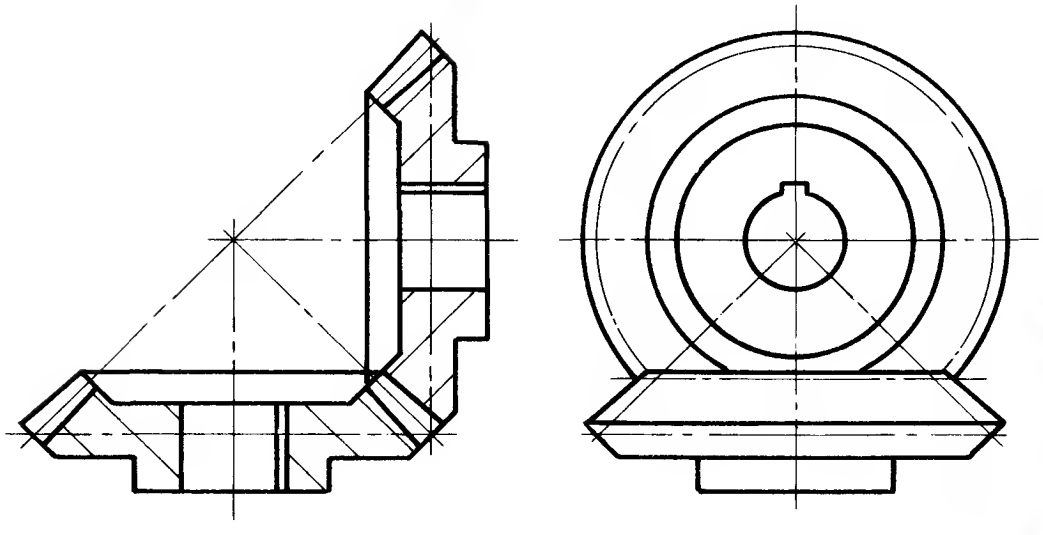
A good example of how a complex component may be drawn relatively simply is the bevel gear. The assembly shown below is of a pair of gears of equal size, the direction of motion being changed through an angle of 90°. In this arrangement, the gears are often referred to as mitre wheels.
The gears may be of differing sizes, of course, and the angle between the shafts may be other than 90°. In this latter case, the side view of the gear assembly would have to show one gear as an ellipse.

*Subject* *Convention*



BEVEL WHEEL

Assembly of a pair of bevel gears set at 90° to each other.



*Note* BS 308: Part I: 1972 deals with a number of features which require to be shown less frequently than those illustrated in this section. They are:

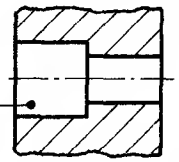
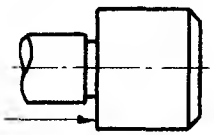
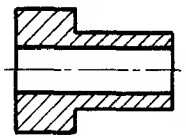
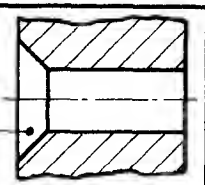
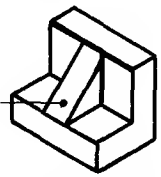
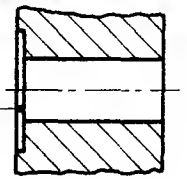
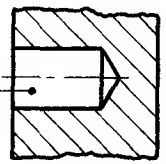
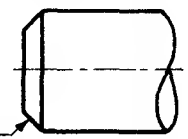
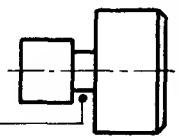
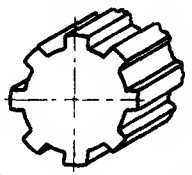
Thread inserts; repeated parts; semi-elliptic springs; conical springs; torsion springs and a rack and pinion.

*Summary* In all cases, conventional representation should only be used when it *saves drawing time*. Where it is not considered adequate, a more detailed view should be shown.

# Test for terminology

Solutions are given on page 148.

Select, from the array, the conventional engineering term for each item shown. Insert in the answer column the corresponding number and letter.

| | | ARRAY | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| Example ?  | 3C 1 | Countersunk Hole | Undercut or Groove | "Blind" Hole | Serrated Shaft |
| 1 ?  | 6 ?  | 2 | Slot | Flange | Collar | Tongue |
| 2 ?  | 7 ?  | 3 | Shoulder | Boss | Keyway | Web |
| 3 ?  | 8 ?  | 4 | Taper | "Blind" Tapped Hole | Spigot | Flanged Bush |
| 4 ?  | 9 ?  | 5 | Bore | Spotface | Splined Shaft | Counterbore |
| 5 ?  | 10 ?  | 6 | Threaded Hole | Rib | Chamfered | Tube |

# Test for abbreviations

Solutions on page 148

Select, from the array, the correct full name for which each of the following is an abbreviation. Insert in the answer column the corresponding number and letter.

| Example SPEC | 5 B |
|---|---|

| No. | Abbreviation | Answer |
|---|---|---|
| 1 | ASSY | |
| 2 | A/F | |
| 3 | ⌀ | |
| 4 | SCR | |
| 5 | STD | |
| 6 | CL | |
| 7 | R | |
| 8 | LG | |
| 9 | DRG | |
| 10 | DIA | |
| 11 | PCD | |
| 12 | CHAM | |

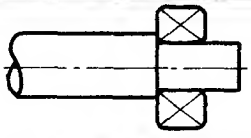
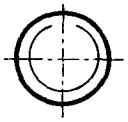
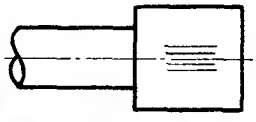
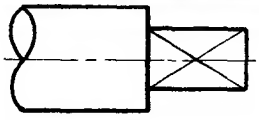
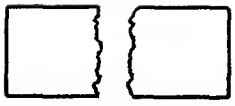
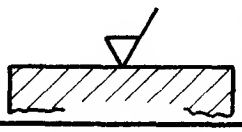
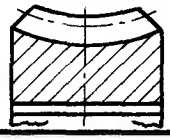
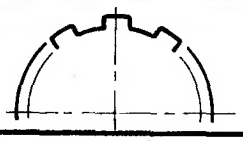
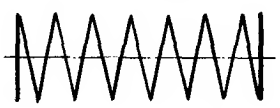
ARRAY

| | A | B | C | D |
|---|---|---|---|---|
| 1 | Across Flats | Radius | Screw | Diameter (preceding a dimension) |
| 2 | Clearance | Spherical | Long | Drawing |
| 3 | Assembled | Stated | Across Face | Right Hand |
| 4 | Diameter (in a note) | Standard | Assembly | Chamfer |
| 5 | Placed | Specification | Pitch Circle Diameter | Centre Line |
| 6 | Chamfered | Drawn | Screwed | Light Gauge |

# Test for conventional representations

Select, from the array, the names of the items for which the following diagrams are conventional representations.
Insert in the answer column the corresponding number and letter.

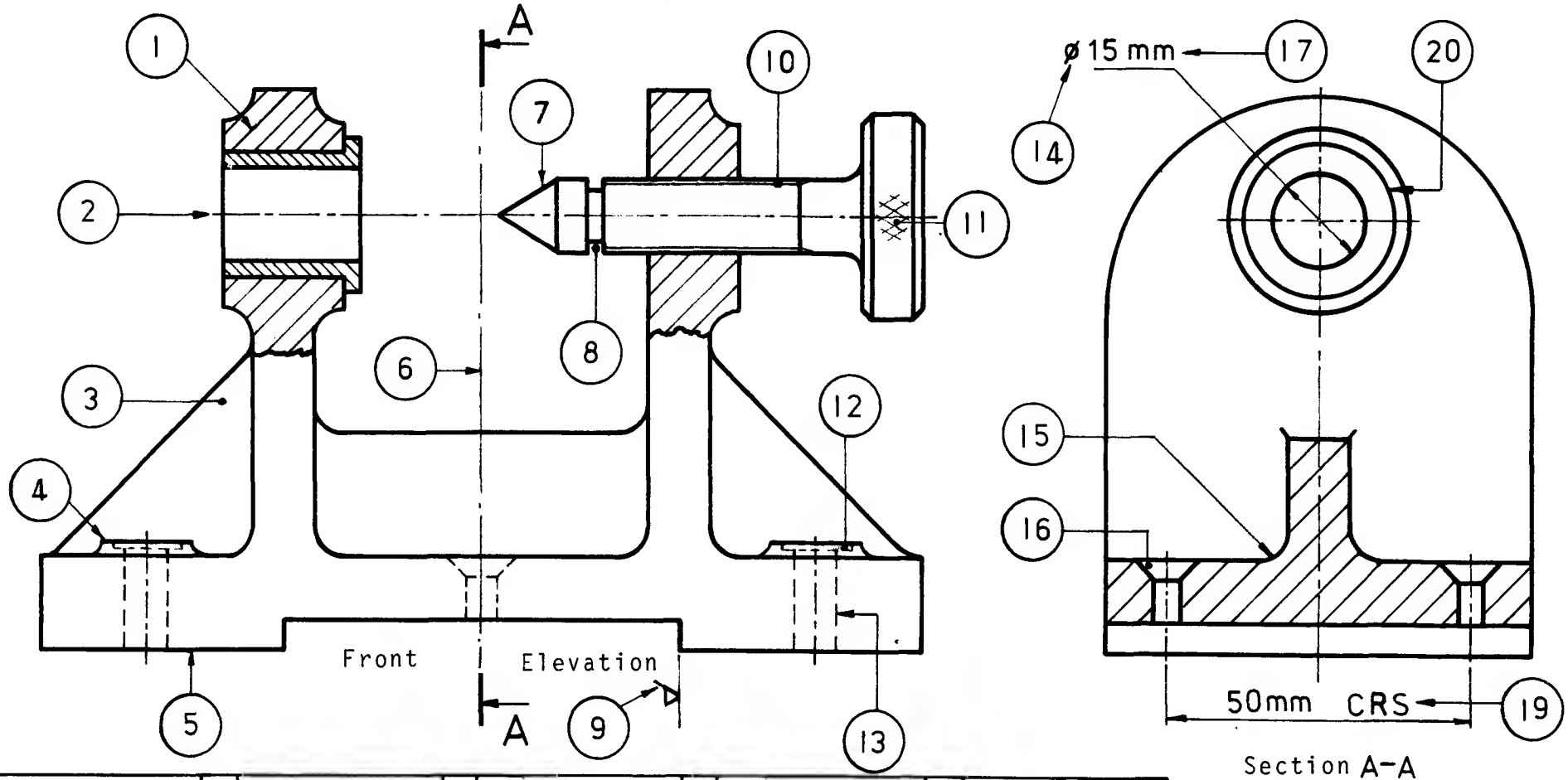
Solutions on page 148

| | Conventional reps | Answer |
|---|---|---|
| | Example  | 4C |
| 1 |  | |
| 2 |  | |
| 3 |  | |
| 4 |  | |
| 5 |  | |
| 6 |  | |
| 7 |  | |
| 8 |  | |
| 9 |  | |
| 10 |  | |

| | ARRAY | | |
|---|---|---|---|
| | A | B | C |
| 1 | Worm Wheel | Shoulder Knurling | Bevel Gear |
| 2 | Tension spring | Round Shaft | Spur Gear |
| 3 | External Screw Thread | Splined Shaft | Break in Rectangular Shaft |
| 4 | A Resistor | Worm | Break in Tubular Shaft |
| 5 | Square on Shaft | Form of Machining Symbol | Compression spring |
| 6 | Machine All Over | Internal Screw Thread | Counterbore |
| 7 | Serrated Shaft | Diamond Knurling | Bearing |
| 8 | Weld symbol | Collar | Straight Knurling |

# Test for abbreviations, terminology and conventional representations

The sectional assembly drawing below has twenty different numbered items. Insert the correct conventional name for each numbered item in the table below. For example, item 2 is a centre line: this is shown below in space 2 in the table. Solutions on page 148




| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | | 2 | Centre line | 3 | | 4 | | 5 | |
| 6 | | 7 | | 8 | | 9 | | 10 | |
| 11 | | 12 | | 13 | | 14 | | 15 | |
| 16 | | 17 | | 18 | | 19 | | 20 | |

angle
orthographic projection

# Pictorial Drawing

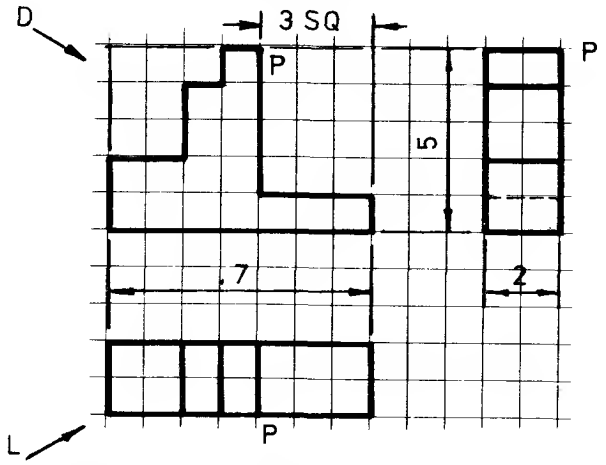
A component may be represented graphically in various ways. An Orthographic Drawing, for example, requiring a minimum of two views to fully communicate the size and shape of a component, is used in engineering mainly to convey manufacturing instructions from the designer to the craftsman. On the other hand a well executed Pictorial Drawing, adequately representing all but the most complicated components using one view only, is used mainly as an aid to visualization of the shape of a component rather than for communicating detailed instructions for manufacture.

A pictorial drawing, generally, is a quickly produced, approximately scaled representation of a component - a "picture" rather than an accurately scaled line drawing.

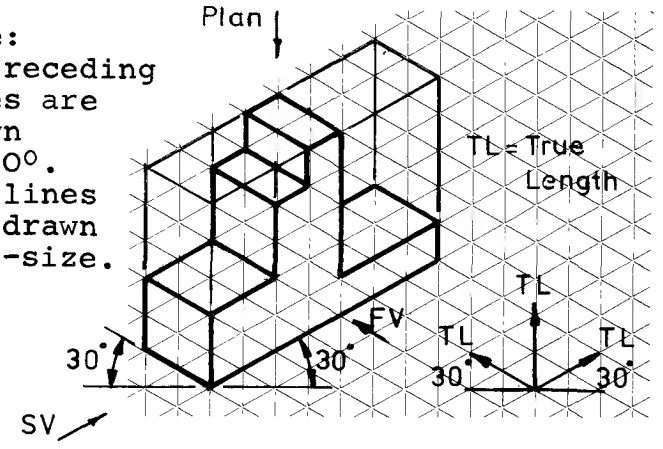
There are many different types of pictorial representation. Two of the most commonly used ones are known as Isometric Drawing and Oblique Drawing both of which are discussed in detail in this section.

*Note!* There is a method of isometric representation, more precise than the one discussed here, known as Isometric Projection. This method is much more time-consuming, and therefore less commonly used, because all sizes for the drawings have to be transferred from a specially constructed isometric scale. It is the approximate method of representation, Isometric Drawing, which is used in this section.

# Pictorial Drawing: Isometric




Note:
All receding lines are drawn at 30°.
All lines are drawn full-size.

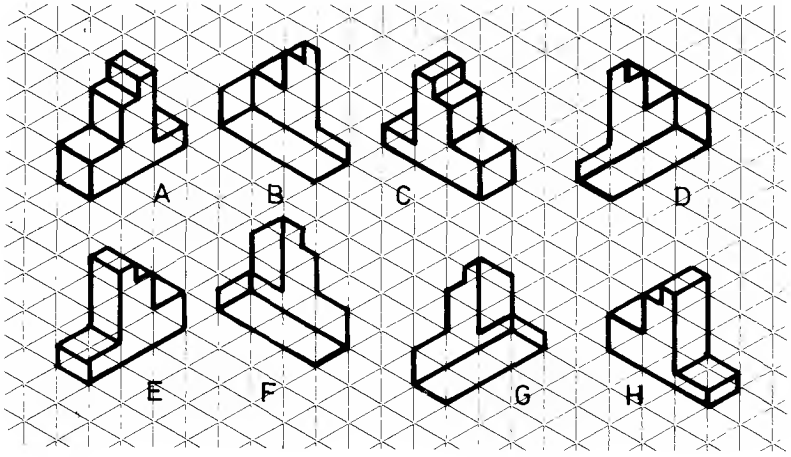



Arrow L - Looking from LEFT
Arrow D - Looking DOWN.

Isometric drawing

When making an isometric drawing from orthographic views of a component use an isometric grid at first, as shown above. Follow this simple procedure:

1. Choose the direction from which the component is to be viewed so that the resulting isometric drawing will show the most detail of the component. Compare the isometric drawings below.




Example A is drawn looking from the left and down, and is a good representation of the component.

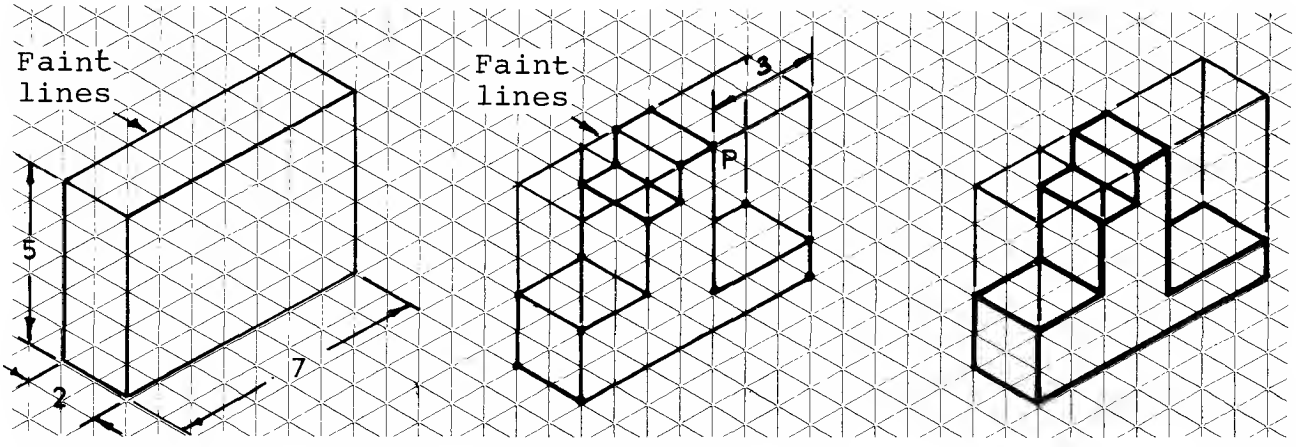
Example C shows the same detail but is drawn from a different direction.

All of the other drawings fail to show some of the details of the component.

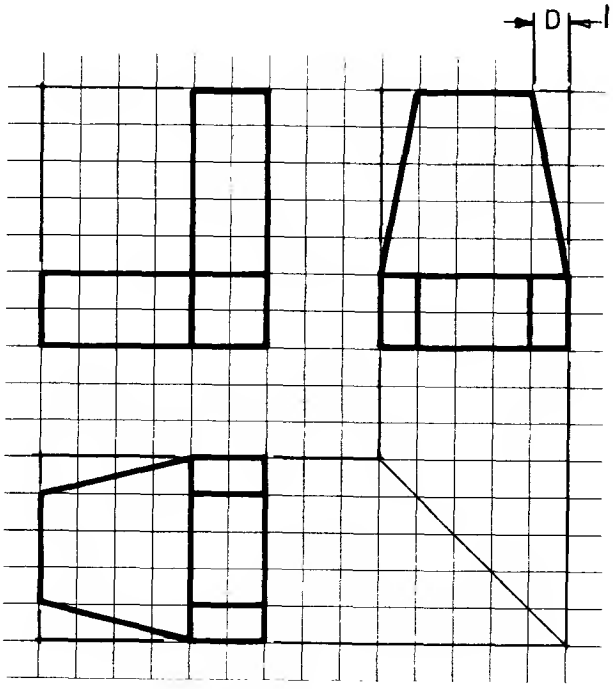
2. Draw the outline of a box into which the component will just fit.

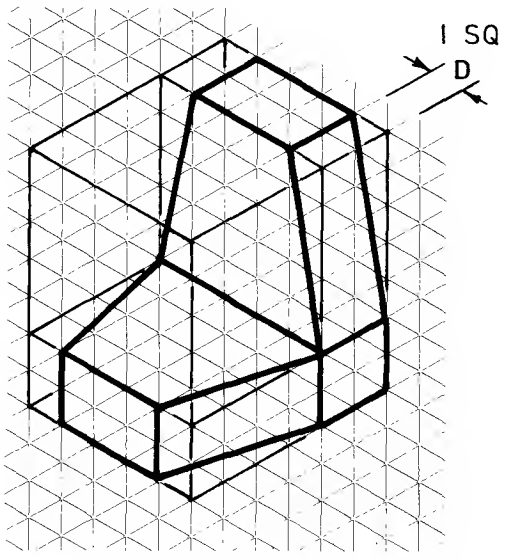
3. Use distances from the orthographic views to set out points within this box, e.g. P.

4. Heavy-in the lines when the outline is completed.



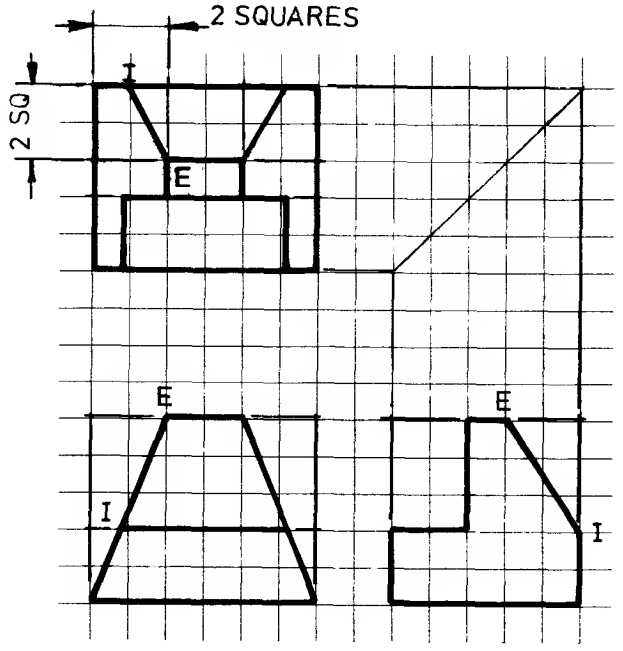
# Isometric drawing: inclined edges

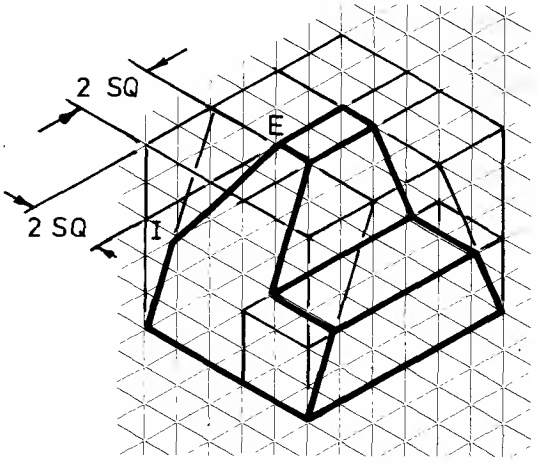



Isometric

When components have sloping surfaces, the edge distances in the orthographic views are transferred to the isometric box as shown by the dimension D in the above example.

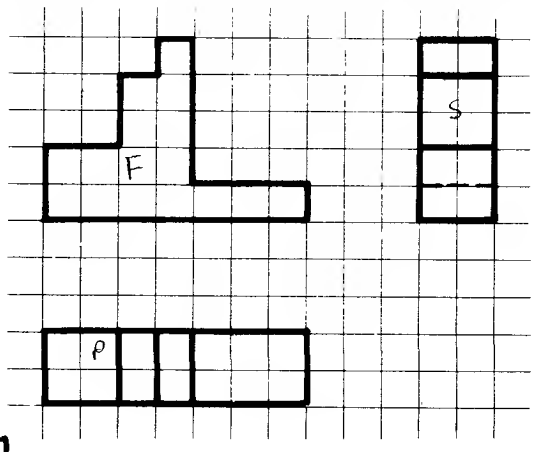


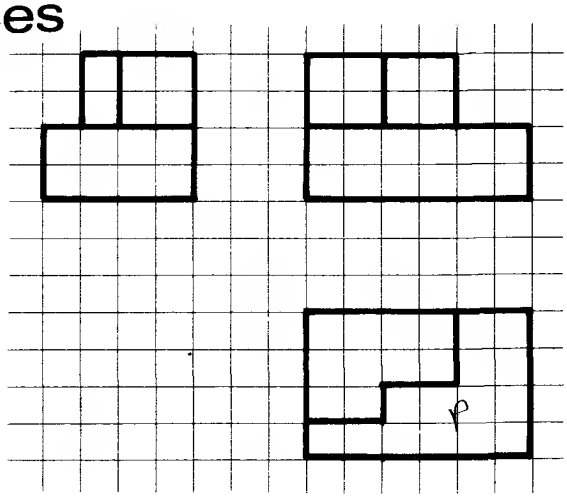

The component shown above has surfaces sloping in two directions resulting in inclined edges, for example, IE. In this case, pairs of distances from the orthographic views are used to plot points within the isometric box. Distances used in this way for location purposes are called ORDINATES.

Note:- The angles of inclination in the orthographic views are *never* transferred to the isometric box. When I and E have been located, they are joined to produce the correct slope in the isometric drawing.

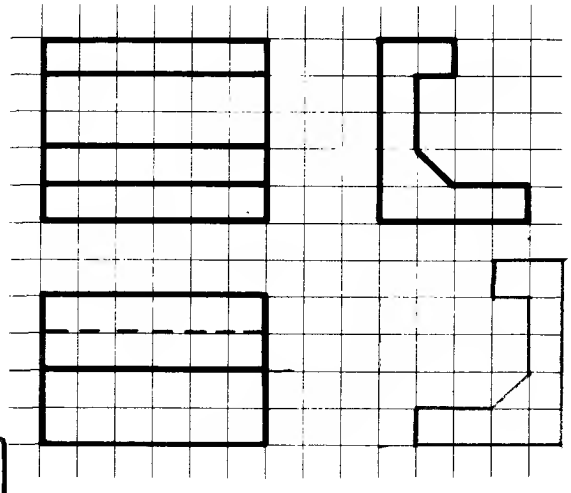
# Isometric drawing exercises



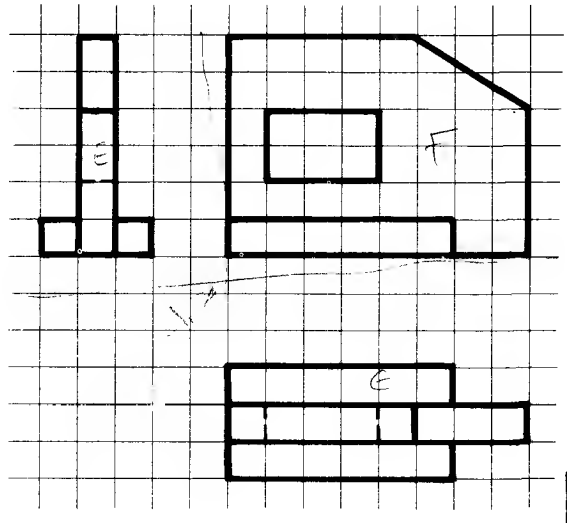

1



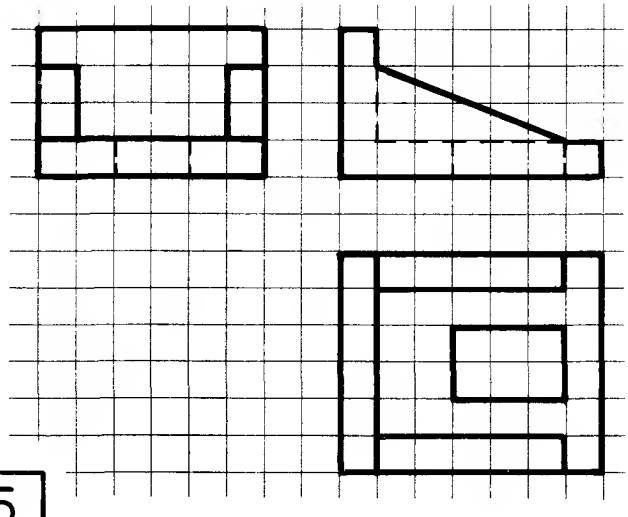

2



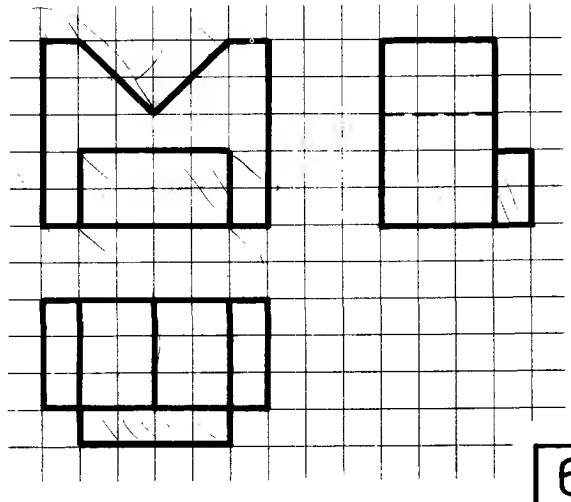
3




4

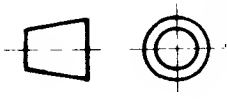


5

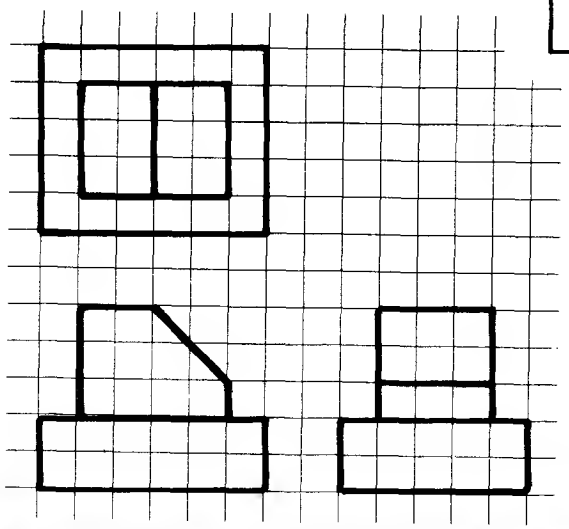


6

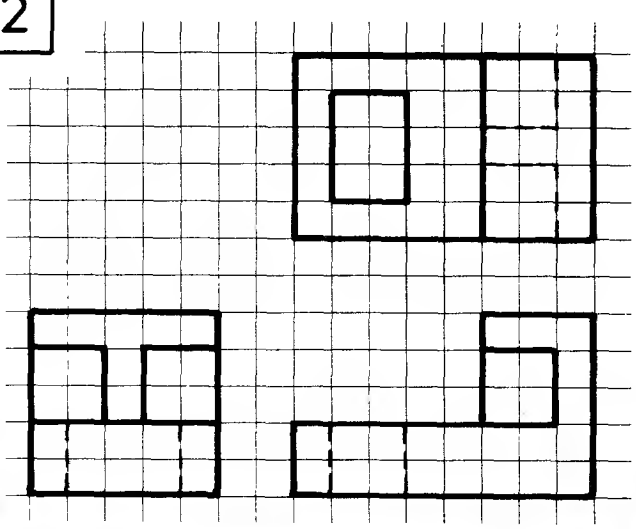
Make an isometric drawing of each component on tracing paper placed over the isometric grid on page 60. Sizes for the isometric drawing are obtained by counting the relevant number of squares in the orthographic views.
Solutions are given on p.149.



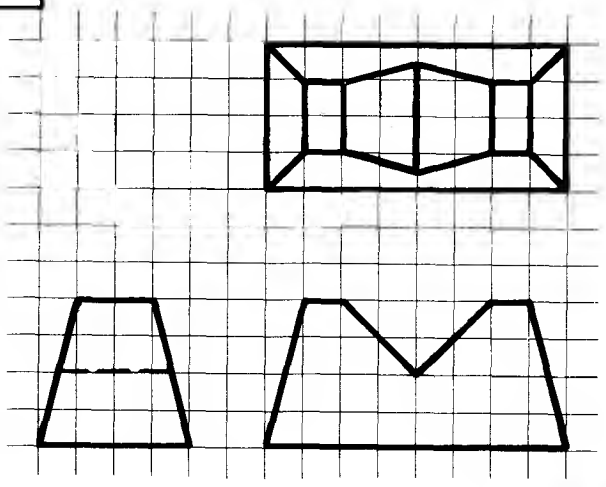
1



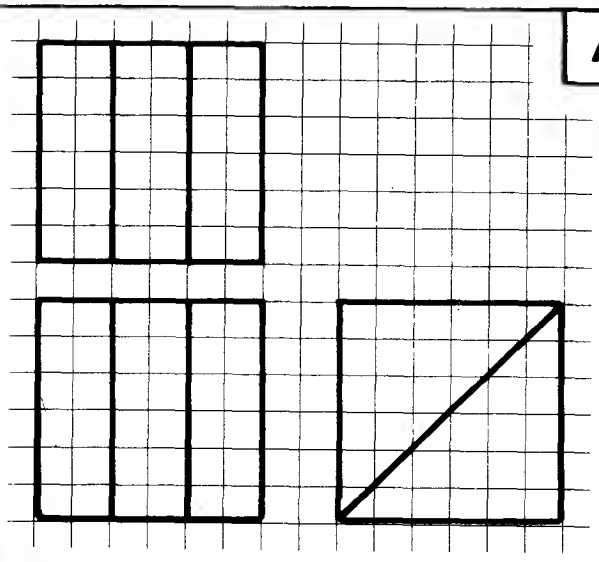
2



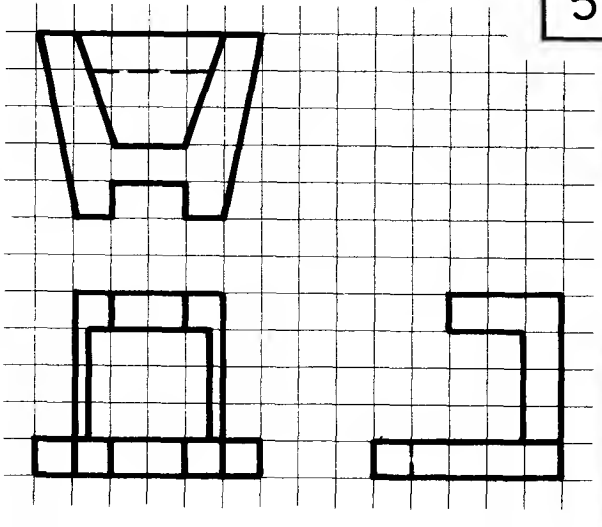
3



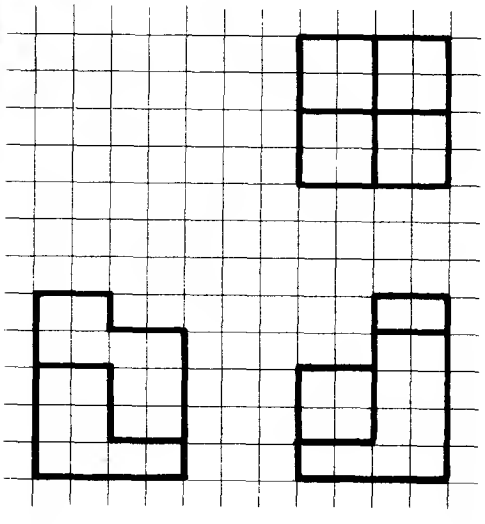
4



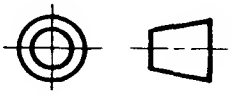
5

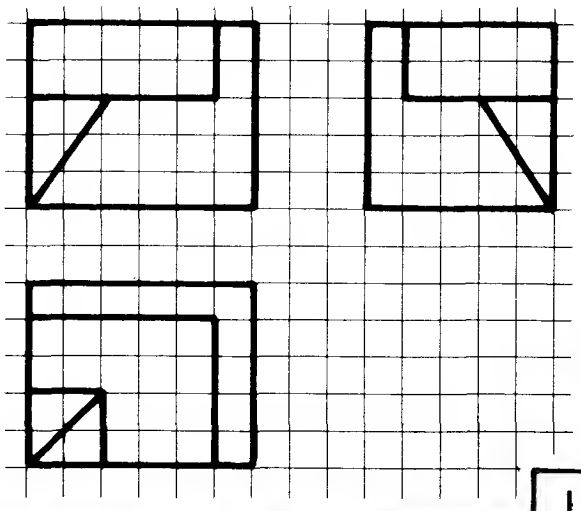


6

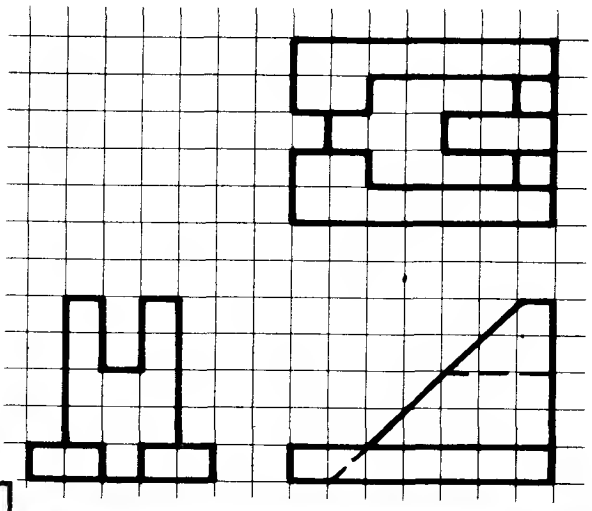


Make an isometric drawing of each component shown above using isometric paper. If the isometric grid size differs from that of the squared grid, transfer EQUAL numbers of divisions from the orthographic views to the isometric drawing. Solutions are given on page 149.

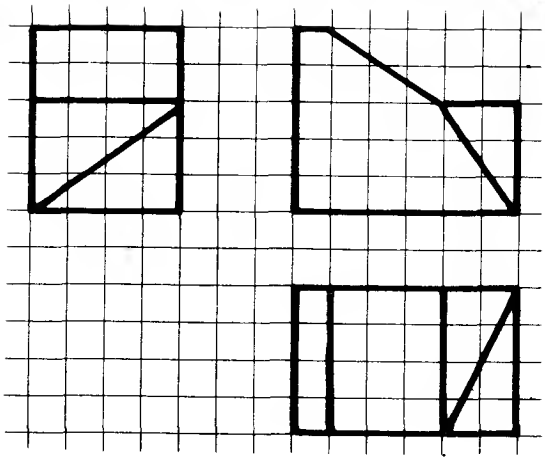




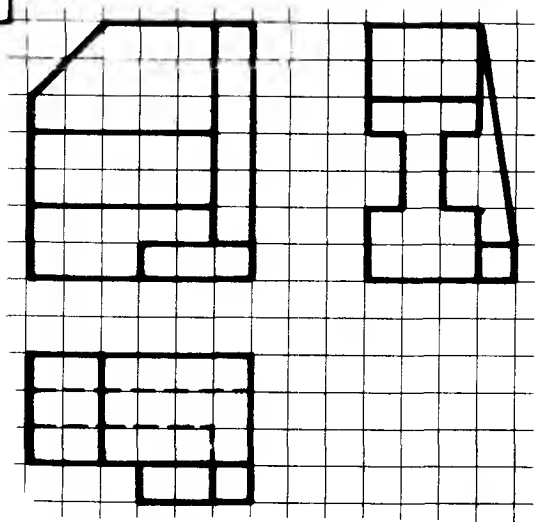
1



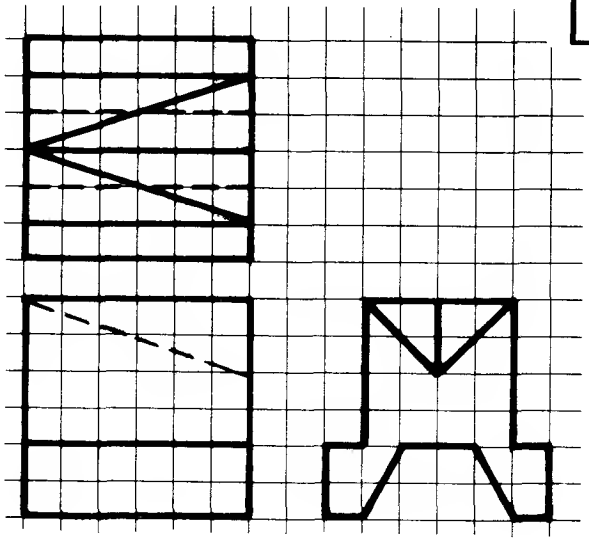
2



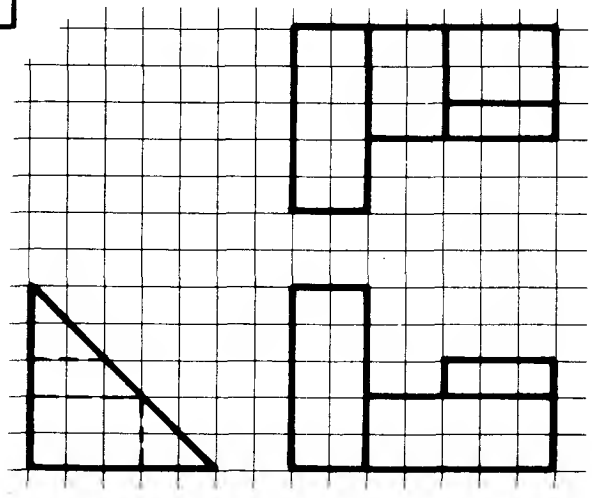
3



4



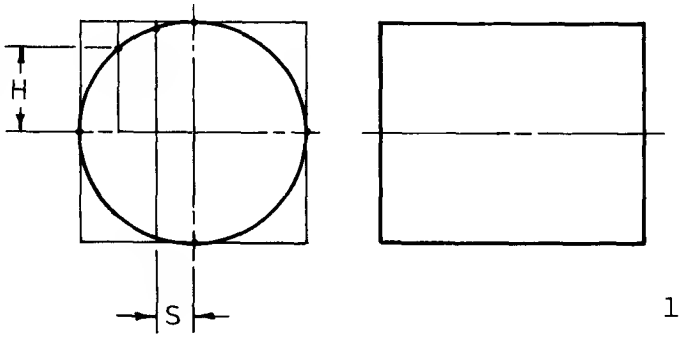
5



6

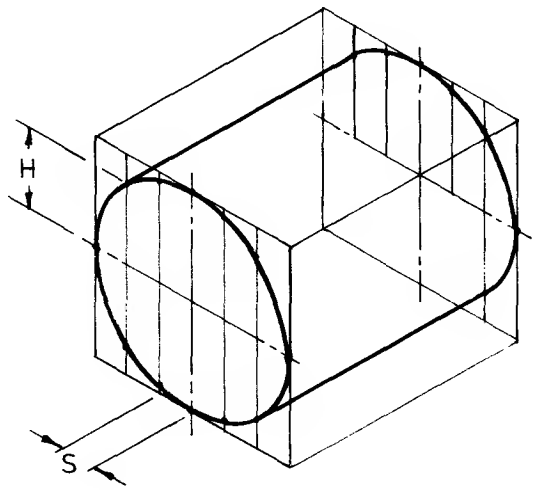
Make an isometric drawing of each component shown above using tracing paper with the isometric grid or using isometric paper. Solutions are given on page 150. Always start with a faintly drawn "isometric box" which provides three faces from which to set out ordinates.

# Isometric drawing: construction of ellipses (1)

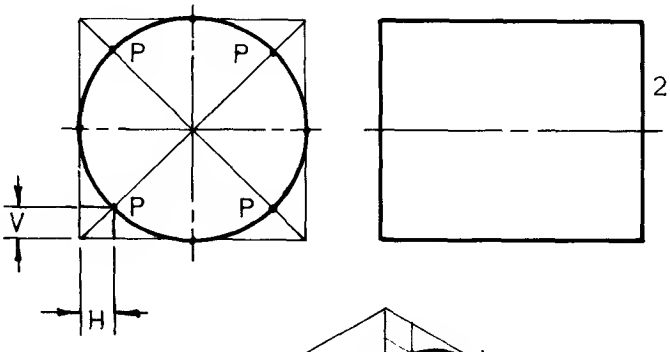



A shape which is circular on an orthographic view is shown as an ellipse on an isometric drawing.
The following constructions illustrate 3 different methods of producing the elliptical shape.

1. Lines, called ordinates, are drawn on the circle in the orthographic view as shown. Corresponding ordinates are drawn on the isometric drawing with the same spacing S. The height H of each ordinate on the true circle is transferred to the corresponding ordinate on the isometric drawing to form the outline of the ellipse. These points are joined with a neat freehand curve.
The more ordinates, the more accurate the ellipse.
As the circle and ellipse are symmetrical, the ordinates need only be constructed in a quarter-circle.




1



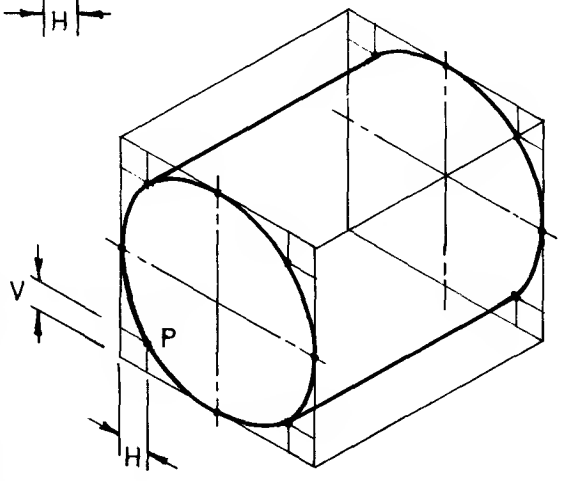

2. Diagonals are drawn on the orthographic side view as shown on the left.

Horizontal and vertical ordinates are drawn to touch the points where the circle crosses the diagonals.

The ordinates are transferred to the isometric box as shown and the resulting points of intersection P are joined with a neat freehand curve.

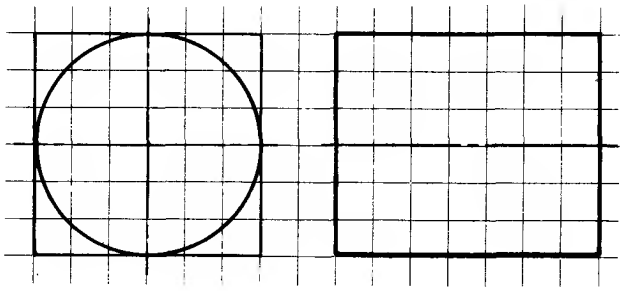
As in method 1, only a quarter-circle need be drawn to obtain the four points required.

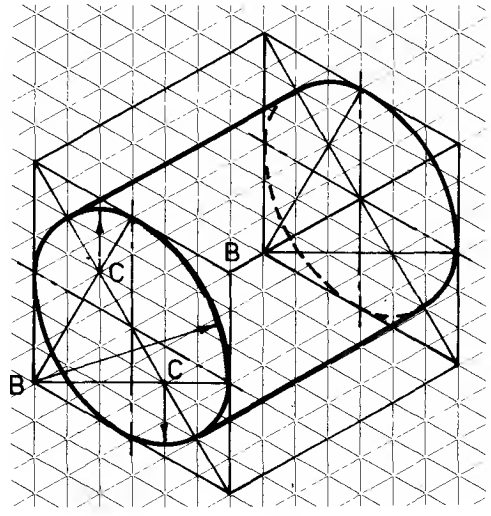
This method is useful for quick freehand sketching but is not as accurate as method 1.




2

# Isometric drawing: construction of ellipses (2)






3. In this method, the ellipse is constructed on the isometric box with compasses and several construction lines are needed to find the centres of arcs.

   Centre lines and a diagonal are drawn across the face of the isometric box as shown.

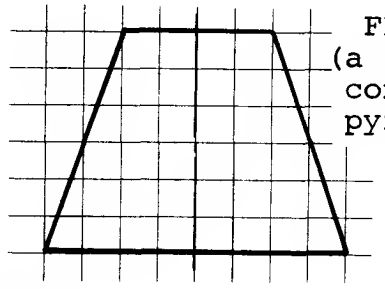
   Lines are drawn from the bottom corner of the box B to the mid-points of the opposite sides.

   The intersections C provide the centres for both minor arcs of the ellipse.

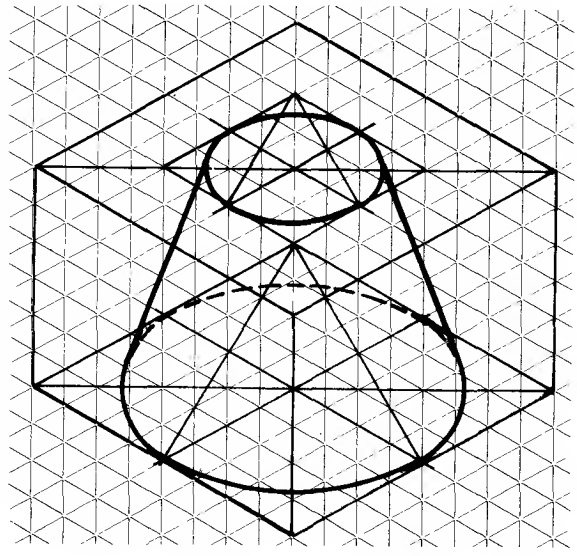
   The corners of the box B are the centres for the major arcs of the ellipse.

   If the centres have been constructed accurately, the arcs drawn with compasses will blend perfectly.

3



FRUSTUM
(a "beheaded" cone or pyramid)



4. The ellipses of the conic frustum opposite have been drawn using method 3, i.e. with compasses.

   Make further isometric drawings of the frustum using methods 1 and 2 to plot the ellipses.

   Compare the shapes and sizes of the ellipses obtained by the 3 methods.

   <u>In general</u>:

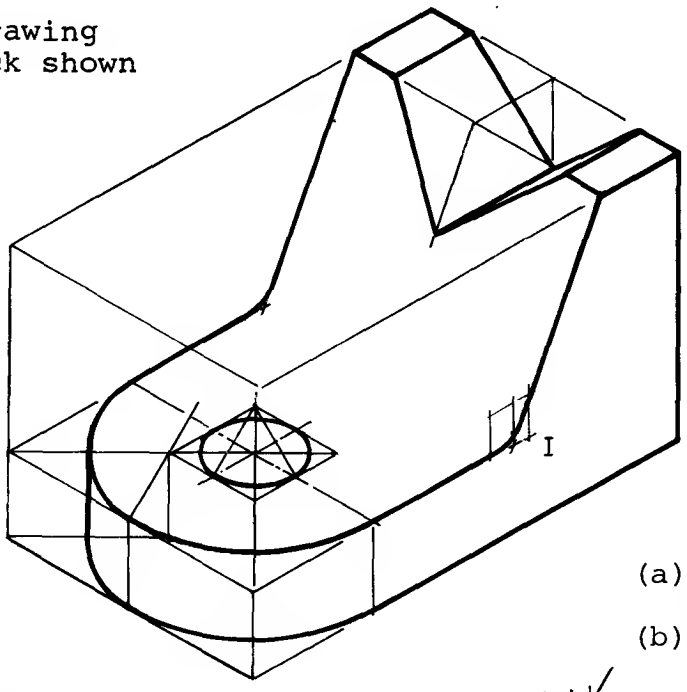
   Method 1 gives the best shaped ellipse and is very useful when there is only part of a circle to draw on the face of the isometric box.
   However, methods 2 and 3 are more rapid than 1.

4

# Isometric drawing examples

EXAMPLE 1

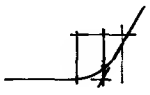
An isometric drawing of the Vee-block shown on page 21




The Vee and the sloping face have been constructed by using pairs of ordinates as shown on page 51

The small radius at the intersection of surfaces I may be drawn:

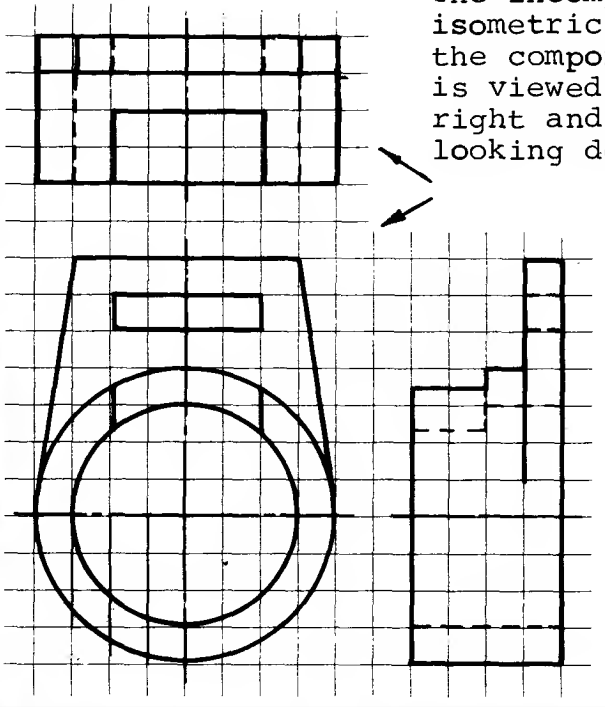
(a) using ordinates or
(b) with a radius gauge if the curve is small.

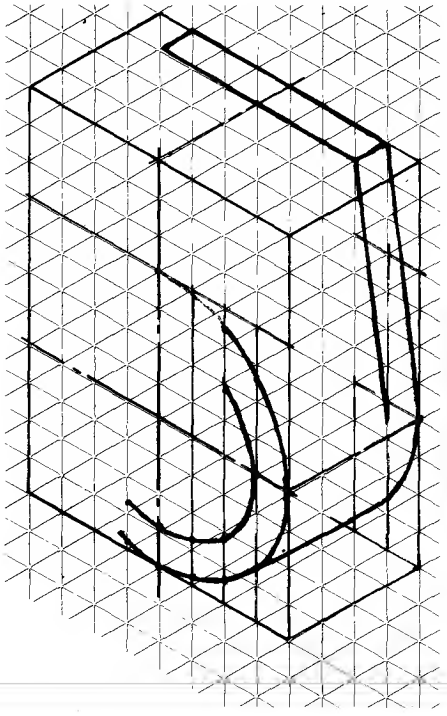


The ellipses have been constructed using method 3, i.e. with compasses.

EXAMPLE 2

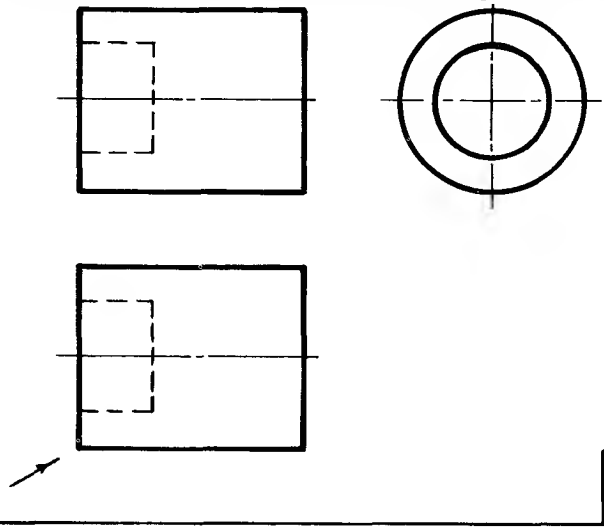
The incomplete isometric drawing of the component below is viewed from the right and looking down.



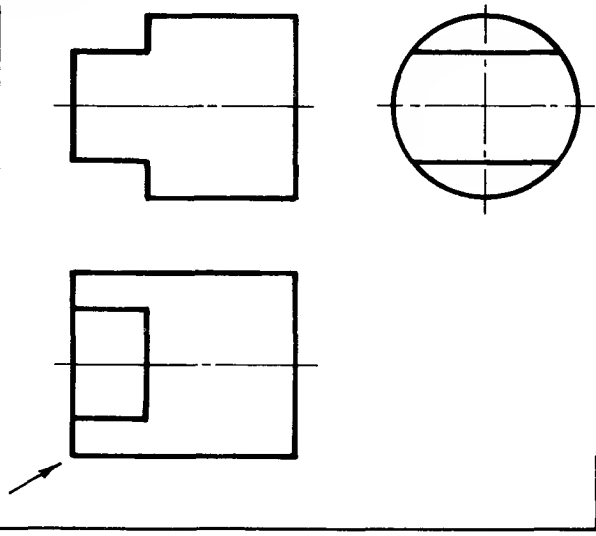


Use the procedure suggested on page 52 to complete the isometric drawing in the space provided or make a complete isometric drawing on isometric grid paper. For further examples use the drawings provided for sectioning exercises on pages 28-31 (solutions are not given).

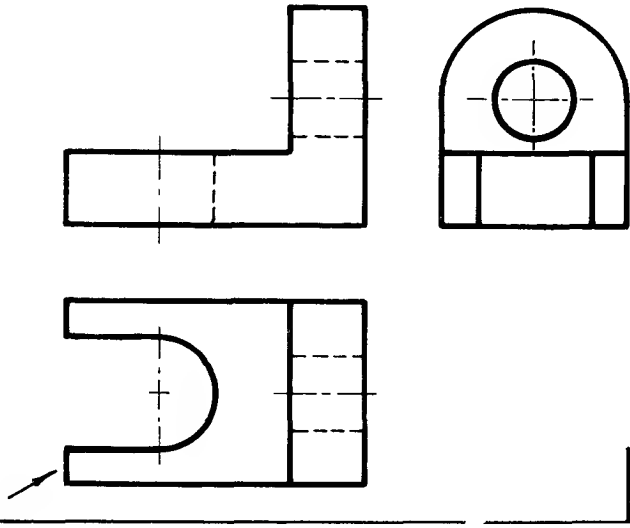
# Isometric drawing exercises



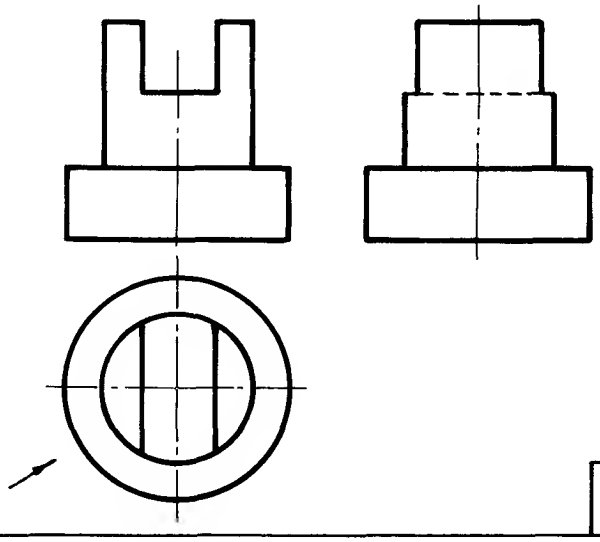
1



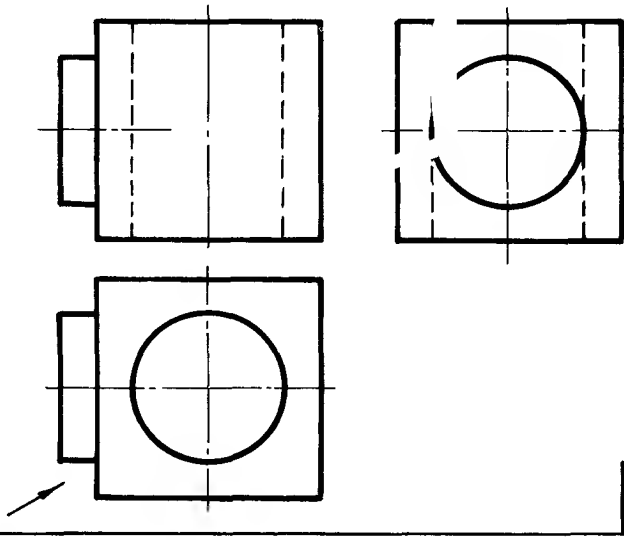
2



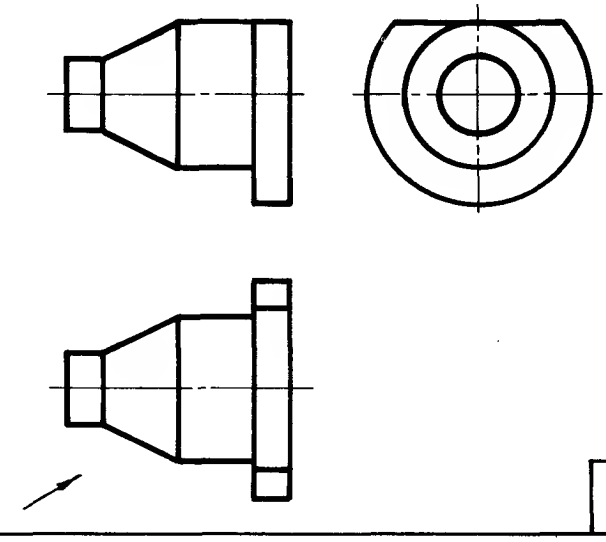
3



4

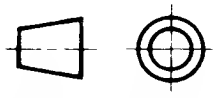


5



6

Make an isometric drawing of each component shown above.
Construct the ellipses by using one of the methods illustrated on pages 55 and 56.
In each case view the components in the direction indicated by the arrow and looking down.



Solns. p.151.

# Isometric freehand drawing

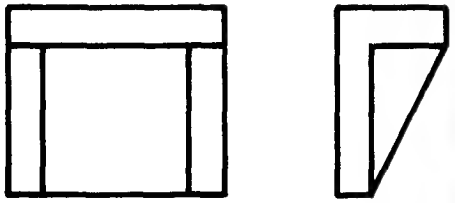
Each drawing on this page consists of two views of a component in First Angle orthographic projection.

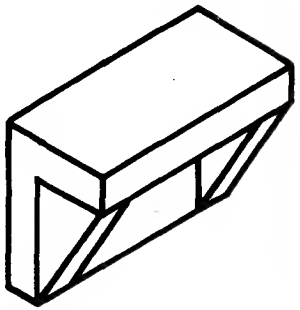
From these views, sketch an isometric view of each component in the space provided.

Hidden detail need not be shown.

An example is given below

Solns. p.152.





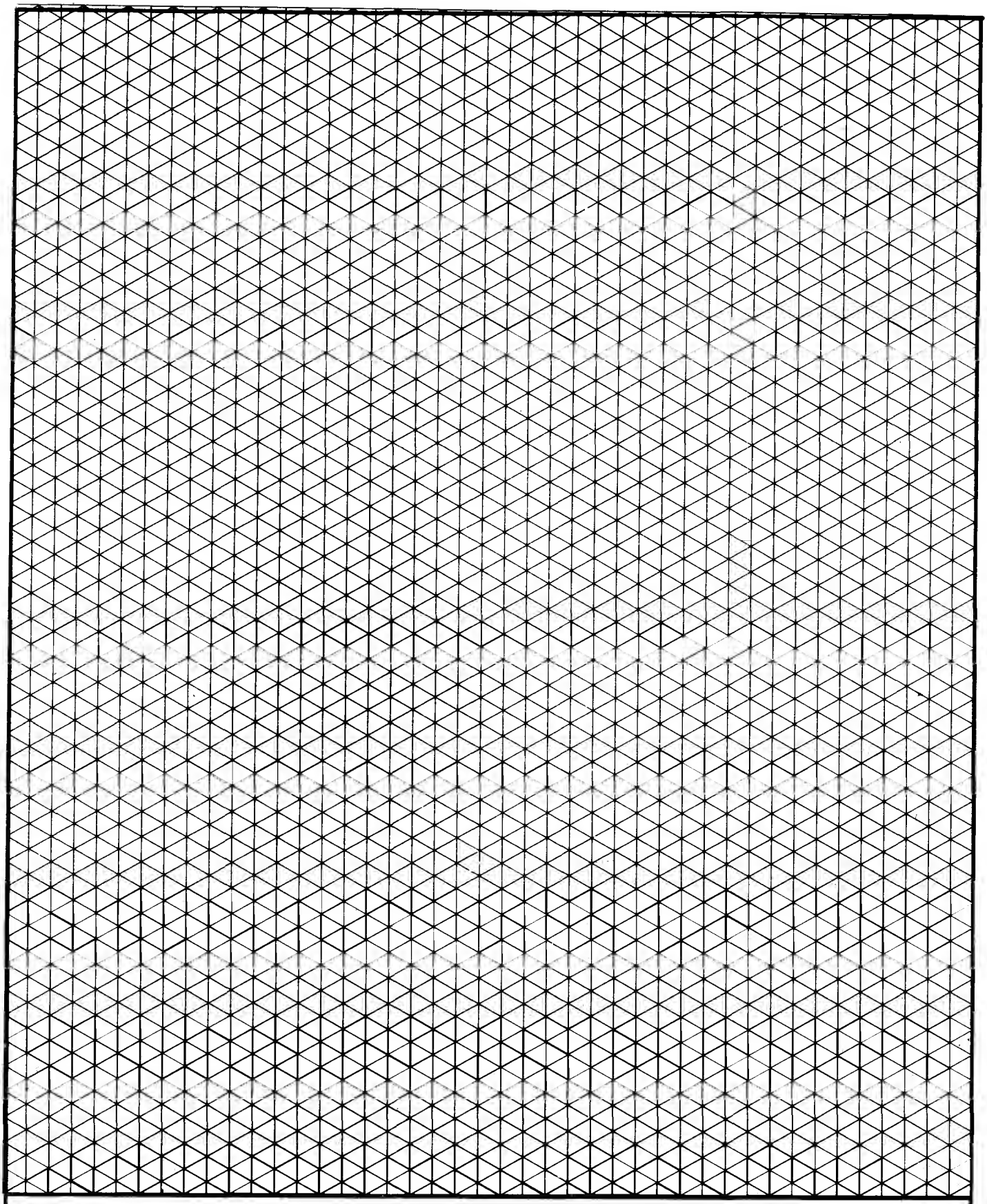
2

3

4

5

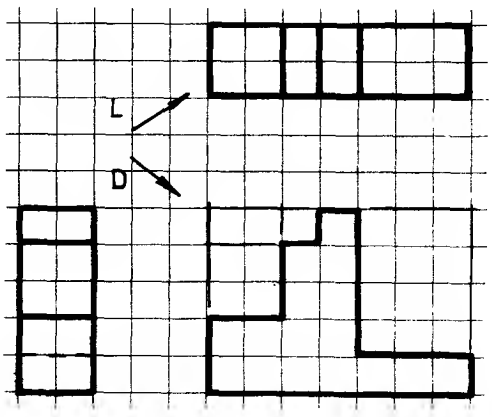
6



ISOMETRIC GRID - to be used for isometric sketches.

The above grid is composed of lines drawn at an angle of $30^{\circ}$ which intersect with vertical lines. The equilateral triangles thus formed have lengths of side equal to 5 mm.
Use the grid with tracing paper or detail paper.

# Pictorial Drawing: Oblique



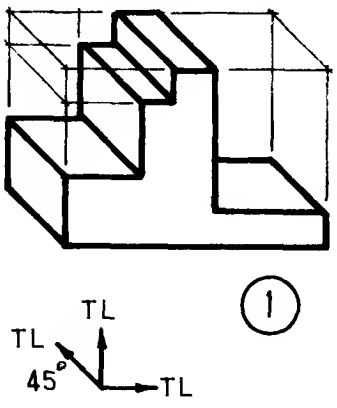

Arrow L - Looking from LEFT
Arrow D - Looking DOWN.

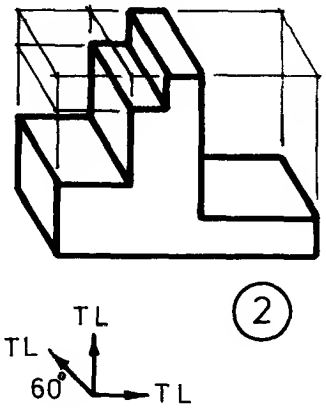
An oblique pictorial drawing presents the component with one of its faces as a true shape. This true shape is drawn on tne front face of the oblique box as shown below.

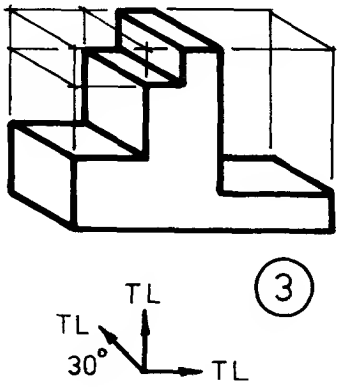
The longest face is usually drawn on the front of tne oblique box with receding lines between ½ and ¾ full size.

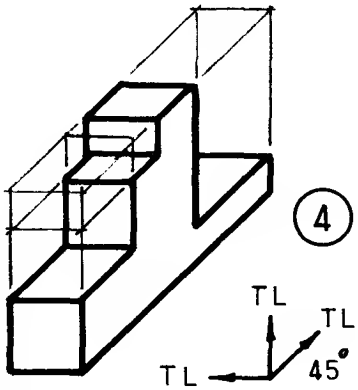
Compare these oblique drawings. Drawings 7, 8 and 9 represent the shape of the component better than the others.

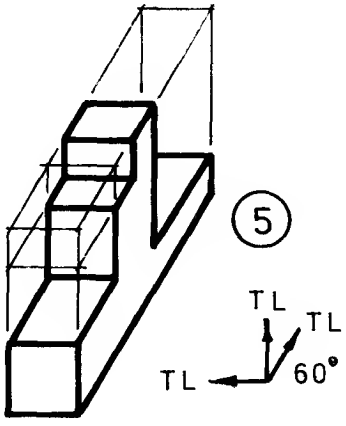
Note:- TL = TRUE LENGTH

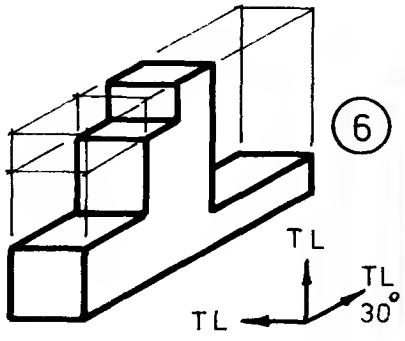


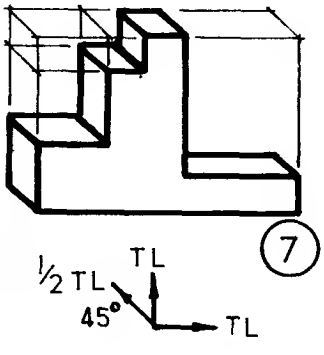



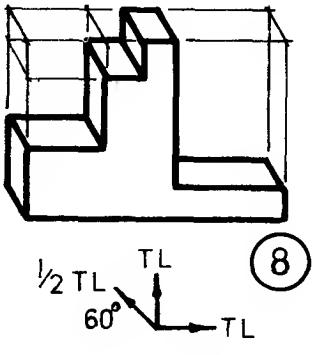



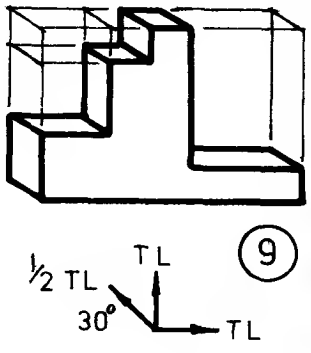



# Oblique drawing: methods of construction

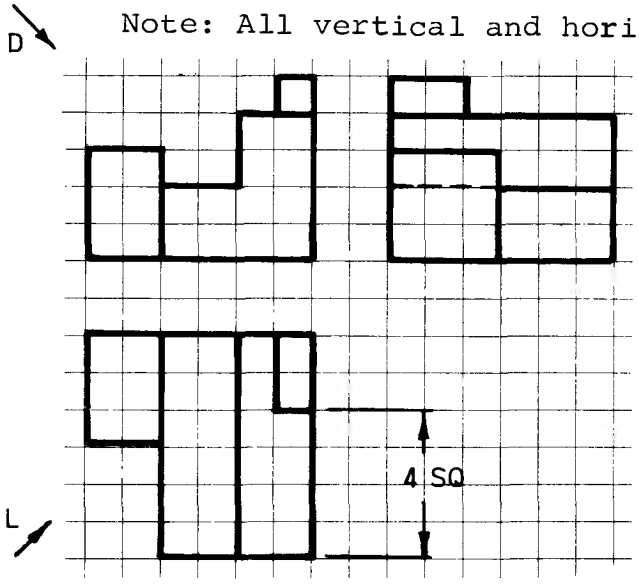
There are many variations in angle, length of receding lines, and directions from which a component may be viewed in order to produce an oblique drawing, as can be seen by the examples on the previous page. Different oblique drawings of the same component may each provide the detail required.

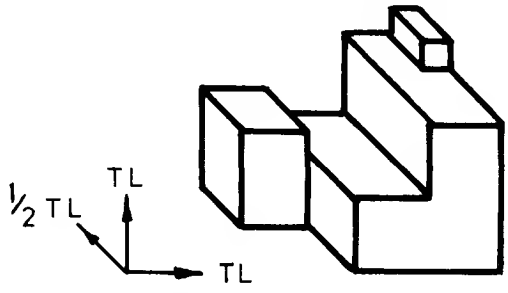
In general:

1. **The receding lines may be drawn at any angle to the horizontal but an angle of 30°, 45° or 60° is preferred as lines can be drawn with set-squares.**

2. Receding lines may be any proportion of their true length. A good pictorial representation is obtained if lengths from ½ to ¾ × actual length is used.

Note: All vertical and horizontal lines are drawn true length.

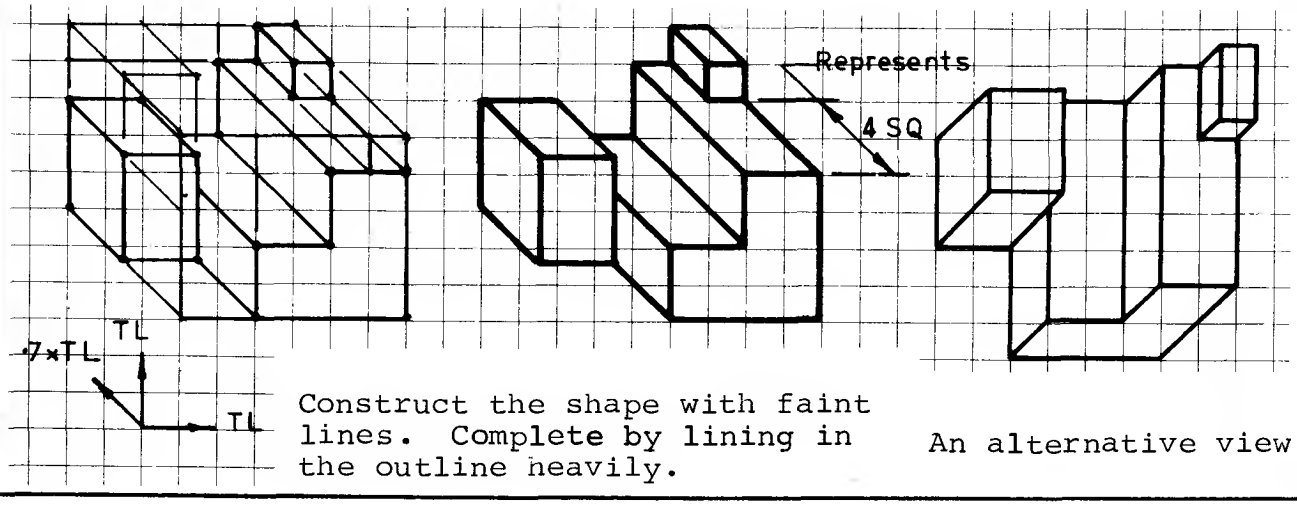



This oblique drawing is of the component viewed from the left (arrow L) and looking down (arrow D).

Receding lines are drawn at 45° and ½ true length using tee and set-squares.

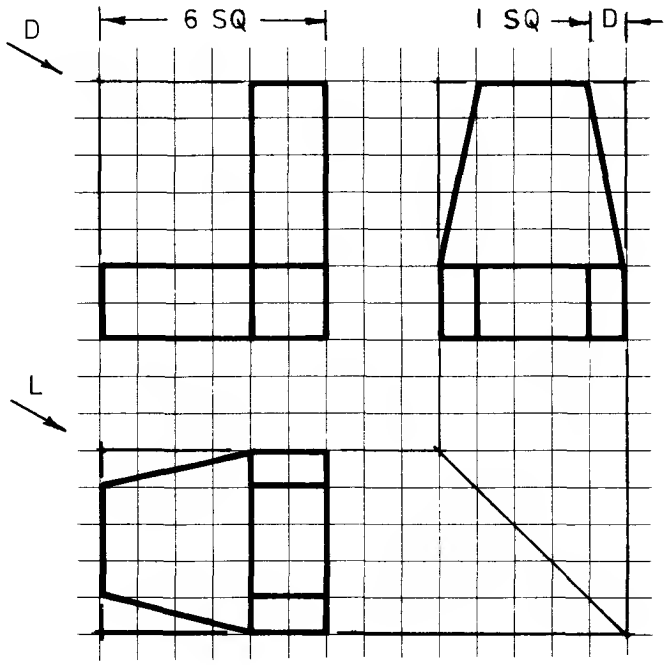
When making freehand oblique sketches it is convenient to use 5 mm squared paper and to draw the receding lines at 45° and 0·7 × true length. As the diagonal of a square is 1·4 × side of the square, then each diagonal can be used to represent two squares on the orthographic views as shown below.

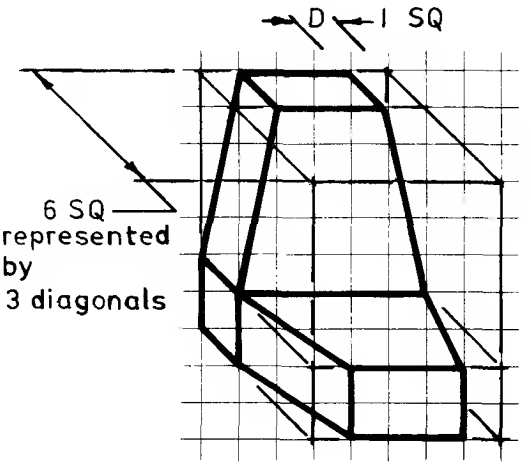



Construct the shape with faint lines. Complete by lining in the outline heavily.

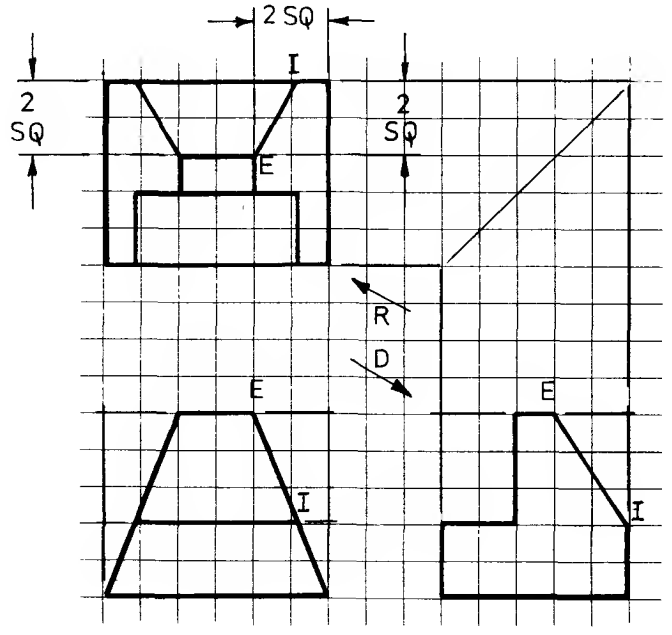
An alternative view

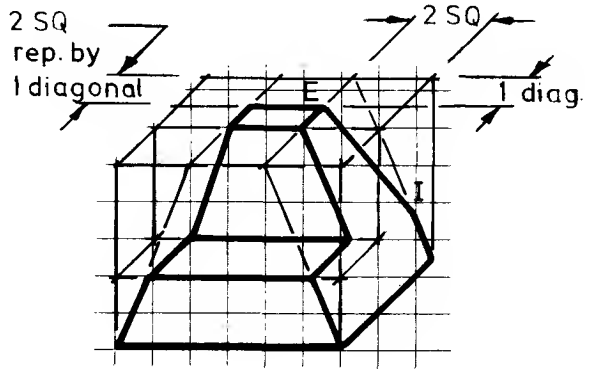
# Oblique drawing: inclined edges




When components have sloping surfaces, the edge distances in the orthographic views are transferred to the oblique box as shown by the dimension D in the above example.

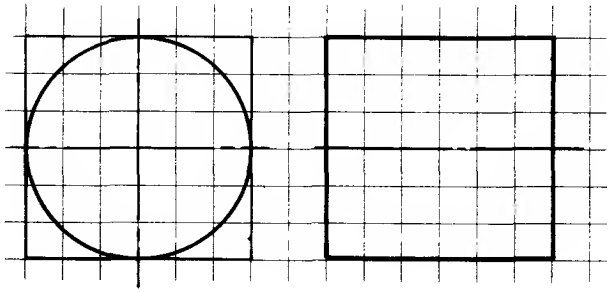



The component shown above has surfaces sloping in two directions resulting in inclined edges, for example IE. Pairs of ordinates from the orthographic views are used to plot points within the oblique box, for example point E.

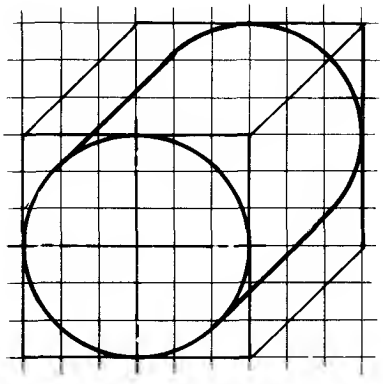
Note: The angles of inclination in the orthographic views are *never* transferred to the oblique box. When I and E have been located they are joined to produce the correct slope in the oblique drawing.

# Methods of constructing "oblique circles"



A shape which is circular in an orthographic view may be shown as a circle on the oblique drawing if the component is viewed as shown in example 1.

The end of the cylinder is a true circle which may be drawn with compasses.

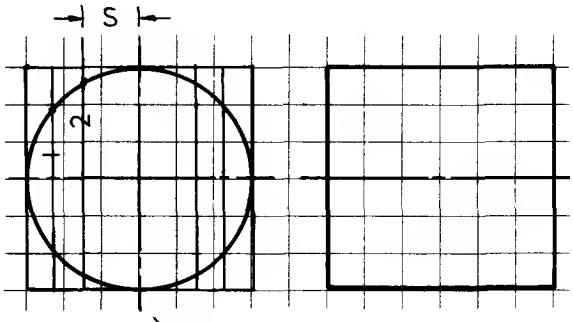



The lines of the "oblique box" have been drawn to show the size of a box into which the cylinder will just fit.

**If the circular face is receding, e.g. at 45°, it will appear elliptical and will have to be plotted. Examples 2, 3 and 4 show ways of constructing ellipses.**

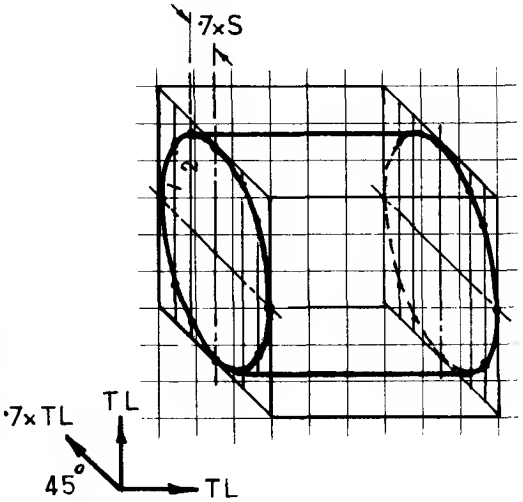
When making an oblique drawing view the component, if possible, in a direction which will allow circular and part-circular faces to be drawn with compasses.

1




The oblique ellipses on the left are plotted by using a method similar to that used for plotting an isometric ellipse.

The ordinates, however, have to be proportionately spaced along the receding lines.

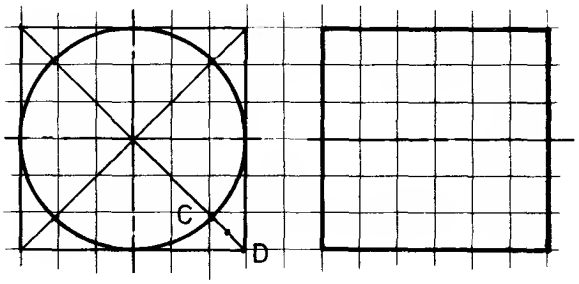



In the case of the freehand oblique drawing shown in example 2, the spacing S is 0·7 × S i.e. the length of 1 diagonal represents 2 squares on the orthographic view.

As in the construction for an isometric ellipse, the ordinates need only be constructed in a quarter-circle.

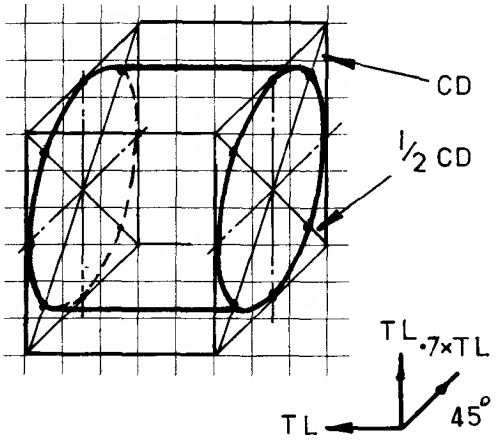
2

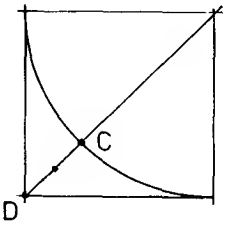
# Methods of constructing "oblique ellipses"



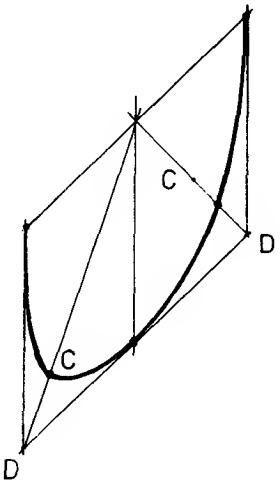

The method for constructing an oblique ellipse shown opposite is only used when the receding lines are drawn at
0·7 × true length,
mainly for quickly drawn freehand sketches.

The larger scale drawing below shows how the length CD is obtained. The length ½CD can be judged by eye.

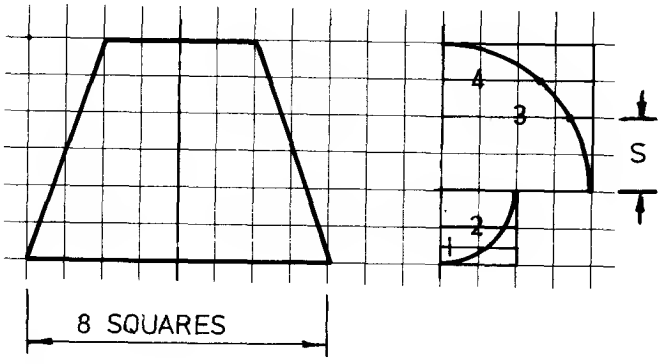



Note: The actual length of CD is transferred to the oblique box.




3




The ellipses of the conic frustum in example 4 have been drawn freehand using the ordinate method.

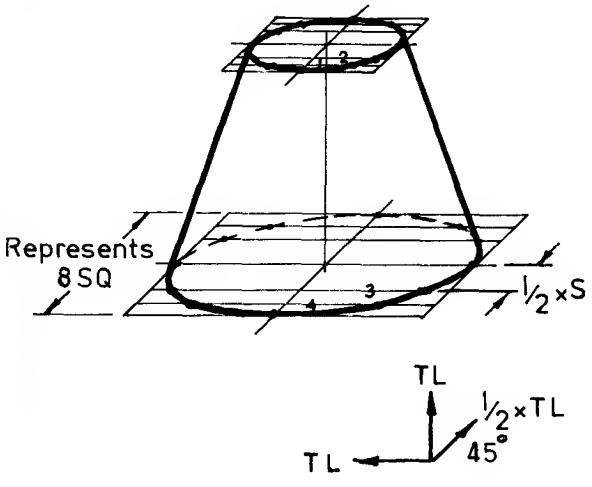
The ordinates used for plotting the points on the ellipse have been measured along horizontal lines spaced proportionately.

Ordinates are true lengths.

Spacings are ½ × true length.

The ordinate method is also useful when there is only part of a circle to be drawn in the oblique box.

Exercises: Make oblique drawings of the components shown on page 58. Solutions are not given.




4

# Oblique drawing examples

EXAMPLE 1 Two oblique drawings of the Vee-block shown orthographically on page 21. Compare these with the isometric drawing of the same component on page 57.

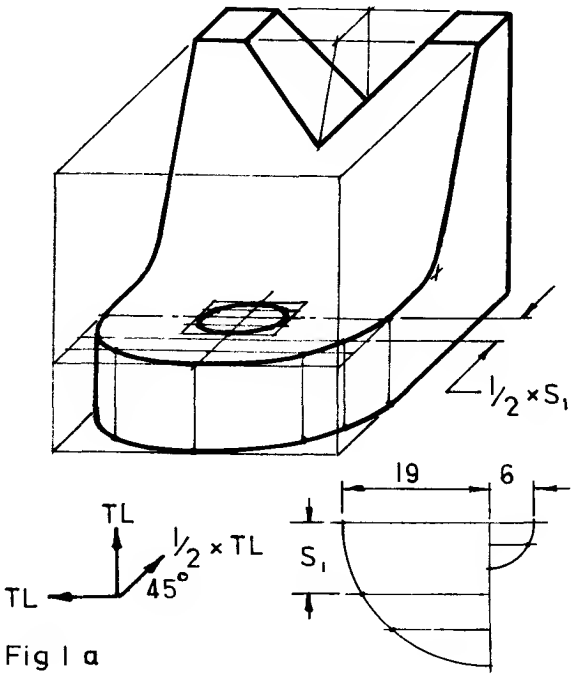



Fig 1 a

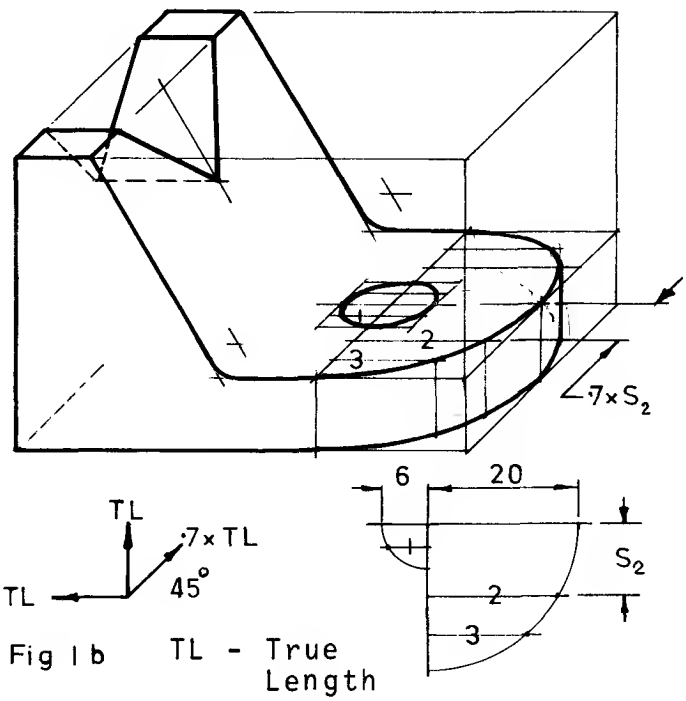


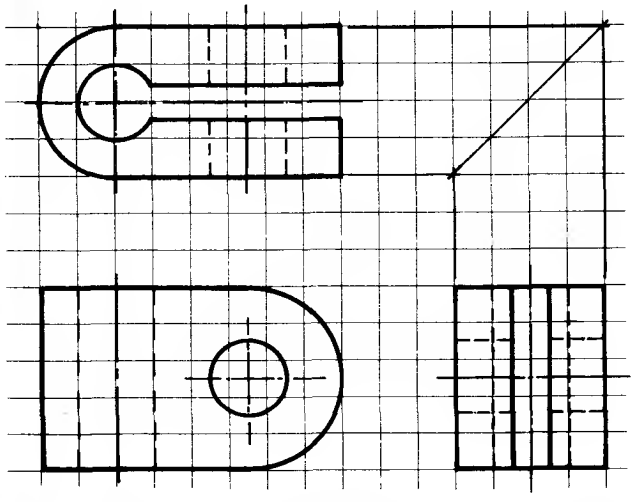

Fig 1 b TL - True Length

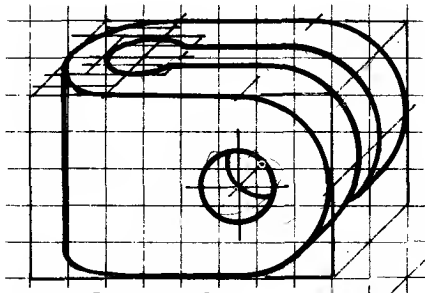
Ordinates are spaced to suit the size of ellipse being plotted and the accuracy required. More ordinates will make the drawing more accurate but it will take longer to draw. Note that ordinates set off from receding lines are spaced at proportionate distances along these lines.

Fig.1a has been drawn using the actual dimensions of the vee-block. Receding lines at 45° and ½ TL.

The length, width and height dimensions of Fig.1b have been rounded off to multiples of 5 mm so that the squares of the 5 mm grid may be used to full advantage, particularly for lines receding at 45° and 0·7 true length.

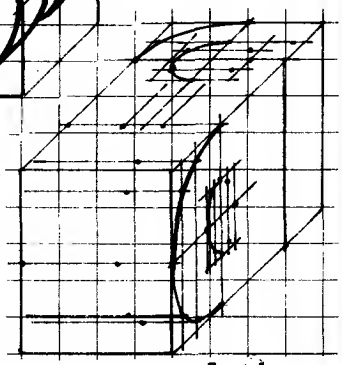
EXAMPLE 2



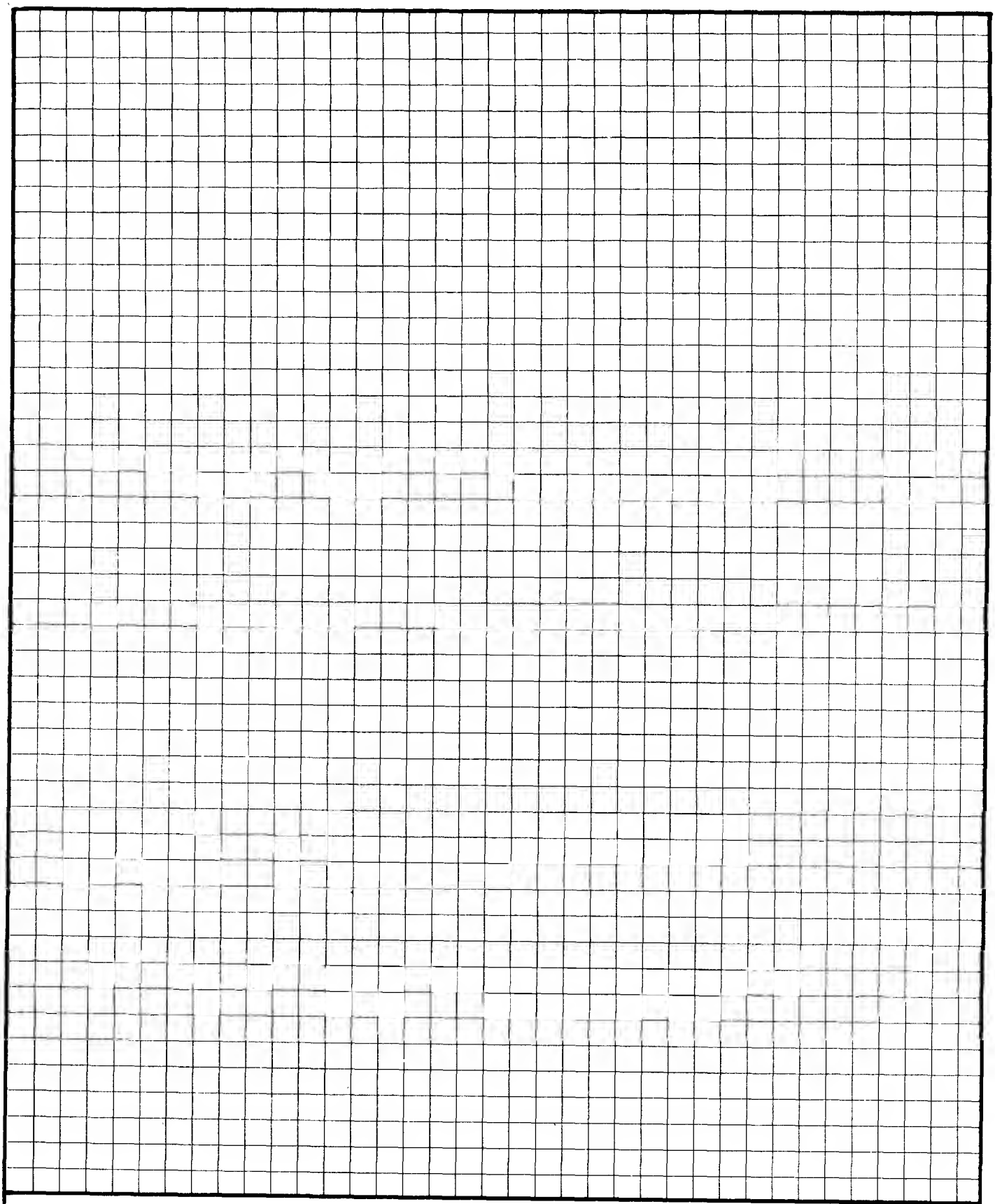


This view shows the maximum use of compasses.

Complete the oblique view on the right.→ This view involves the most construction.



For further exercises: Make oblique drawings of the components shown on pages 52, 53 and 54, using tracing paper and the 5 mm squared grid on page 67. Draw receding lines at 45° and 0·7 × TL. Solutions are given on pages 153 and 154.



SQUARED GRID - to be used for oblique pictorial drawing and orthographic drawing and sketches.

The above grid is composed of lines drawn to form squares which have lengths of side equal to 5 mm.
Use the grid with tracing paper or detail paper.

# Dimensioning

Any drawing from which a component is to be made must convey information from the designer to the craftsmen in three ways. It must

*Describe the shape of the component by using orthographic and, sometimes, pictorial views*

*Give sizes by dimensioning*

*Provide information about the workshop processes involved*

Draughtsmen and designers should understand not only methods of projection, but also dimensioning methods and processes required for the manufacture of an engineering component, so that correct instructions may be issued to the craftsman. Most of the problems of dimensioning may be solved by the application of a few simple rules. Some may be simply stated, e.g. 1, 2 and 3 below whilst others can be more easily explained by reference to diagrams (next page).

(1) Dimensions should be placed on drawings so that they may be easily "read". They must be clearly printed and placed outside the outline of the most appropriate view wherever possible.

(2) The drawing must include the minimum number of dimensions necessary to manufacture the component and a dimension should not be stated more than once unless it aids communication.

(3) It should not be necessary for dimensions to be deduced by the craftsman.

The way a draughtsman dimensions a component or assembly is influenced also by the need to consider the "type" of dimension he will use. These may be classed broadly as

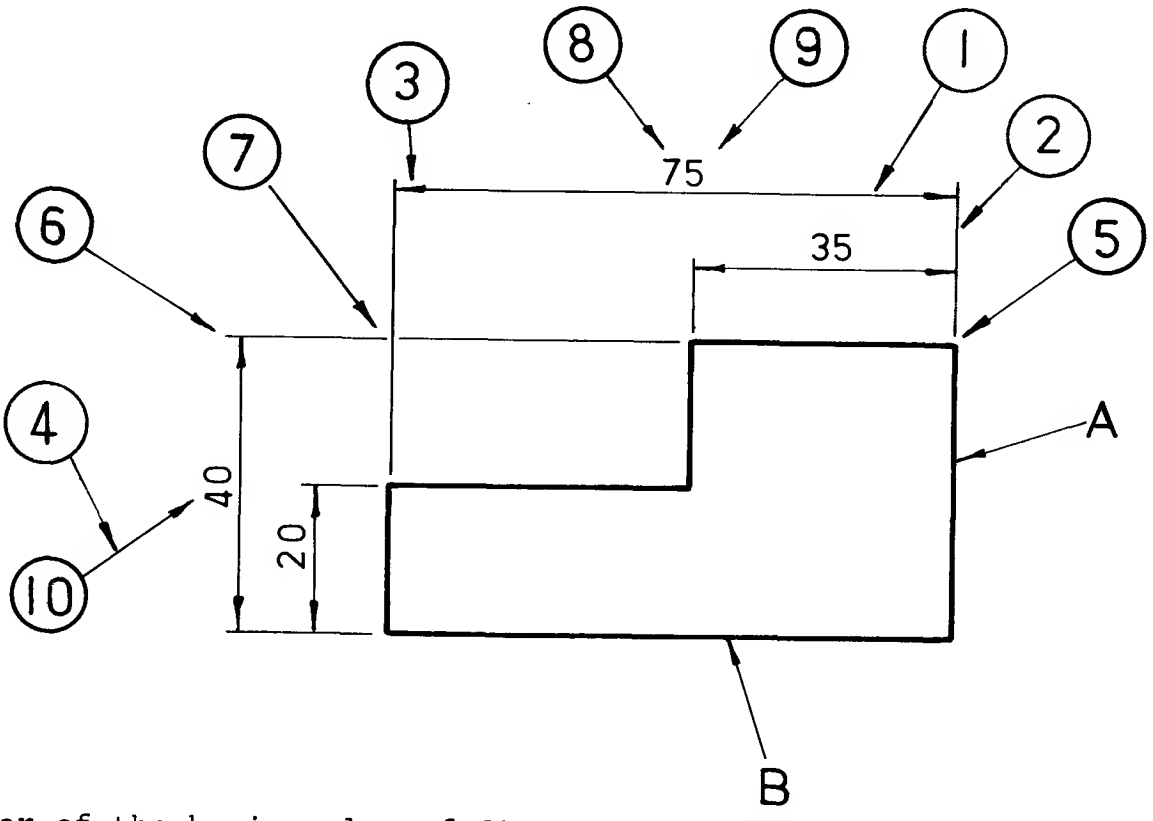
(i) SIZE DIMENSIONS - used to describe heights, widths, thicknesses, diameters, radii, etc., and, where appropriate, the shapes of the component.

(ii) LOCATION DIMENSIONS - necessary to locate the various features of a component relative to each other, to a reference surface or to a centre line, etc.

(iii) MATING DIMENSIONS - applied to parts that fit together. This implies a certain degree of accuracy, and in the case of shafts which fit into holes, the application of limits and fits will most likely be necessary. For details of limits and fits refer to pages 84-90.

All the examples in this section are intended to explain the rules of dimensioning which are set out as recommendations in BS 308:Part 2:1972. It must be stressed, however, that the dimensioning of any component depends on the draughtsman's interpretation of the recommendations. A component may be dimensioned in a number of different ways yet still be dimensioned correctly.

# Dimensioning



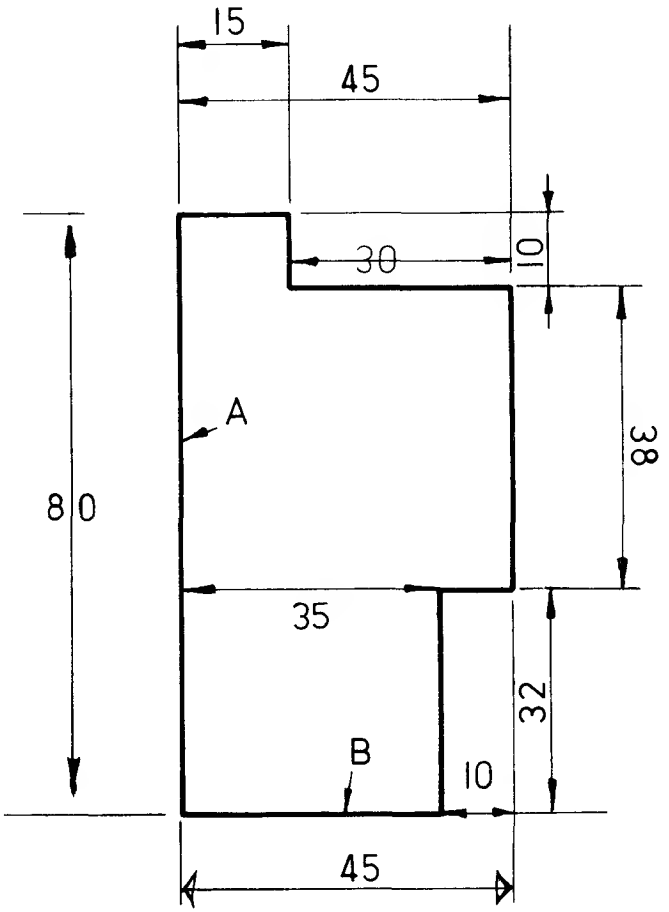

A number of the basic rules of dimensioning can be explained by reference to the above drawing of a thin plate.
The sides marked A and B are known as DATUM faces. They are used as reference edges from which dimensions are drawn. Datums may or may not be machined. Even if they are not machined it is good practice to choose reference edges in order to simplify the layout of dimensions.

Points to note:

(1) DIMENSION LINES - thin full lines placed outside the component wherever possible and spaced well away from the outlines. The longer dimension lines are placed outside shorter ones.
(2) PROJECTION LINES - thin full lines which extend from the view to provide a boundary for the dimension line. Drawn at 90° to the outline.
(3) ARROWHEADS - drawn with sharp strokes which must touch the extension lines.
(4) A LEADER LINE is a thin full line which is drawn from a note, a dimension or, in this case, a "balloon" and terminates in an arrowhead or a dot.
(5) Relatively small gap.
(6) Relatively short tail.
(7) Crossing extension lines - usually a break to ensure clarity.
(8) Dimension placed above the dimension line. This is preferred to the alternative method of placing the dimension in a gap in the line. Avoid using both methods on the same drawing if possible.
(9) Dimension placed so that it may be read from the bottom or
(10) Dimension placed so that it may be read from the right hand side of the drawing sheet.

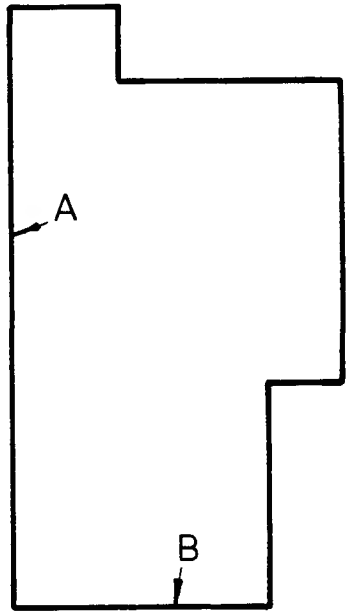
Study this information before turning to the next page.

The figure below is badly dimensioned.
How many dimensioning errors can you find?
Write your answer in the square on the right.




A and B are reference edges (datum faces).

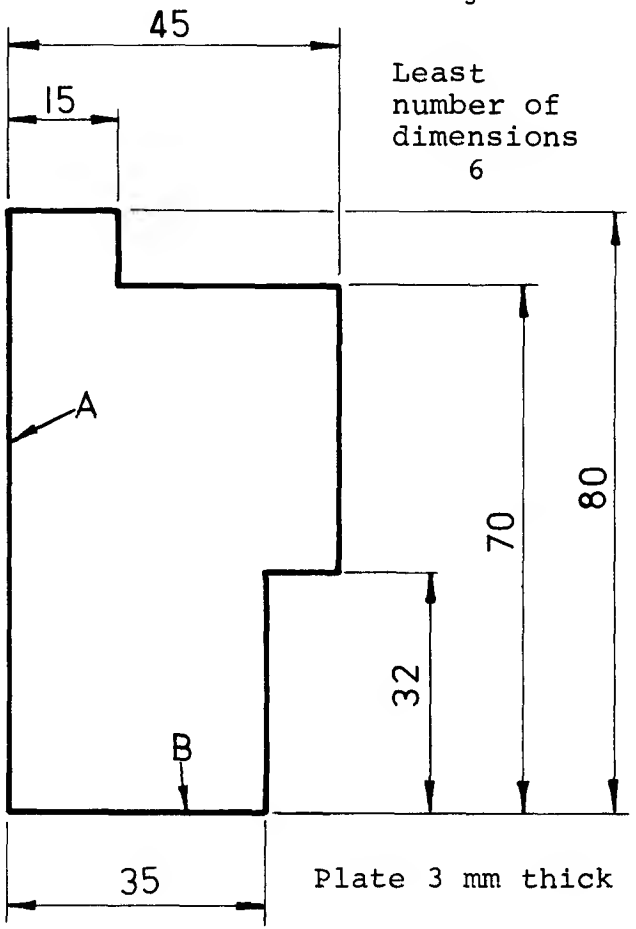
Dimension the figure below correctly.
Remember
- dimension lines are thin full black lines and should be placed outside the outline of the figure wherever possible.
- to work from reference edges (datum faces).




What is the least number of dimensions needed to dimension the plate with reference to edges A and B? (See p.71.)

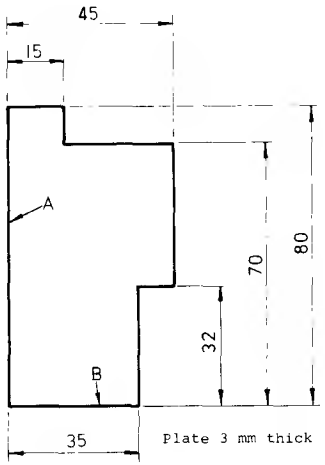
Correct solution drawn FULL SIZE

Fig.1




Drawn HALF full size

Fig.2




The solution above shows the figure drawn half full size.

The size of the figure alters but the dimensions do not.

Drawn QUARTER full size

Fig.3

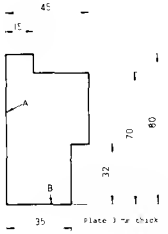


Fig.3 shows the drawing reduced to one quarter its original size, but the dimensions do not alter.

This emphasises the need for clear, bold dimensions whether the object is drawn to a smaller scale or the drawing is reduced by photographic means as in the micro-filming process.

For accurate work the shape of the object would be marked out from the reference edges A and B, so avoiding the possibility of an accumulation of errors due to continuous marking out.
In Fig.4, marking out would be done from reference edge C and any allowable error, or tolerance would be confined to each dimension.
In Fig.5, however, errors could be cumulative.

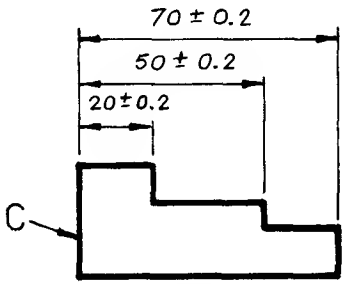



Fig. 4

Max. possible error ± 0.2

Note: Decimal marker is a point on the base line.

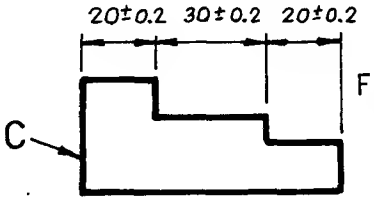
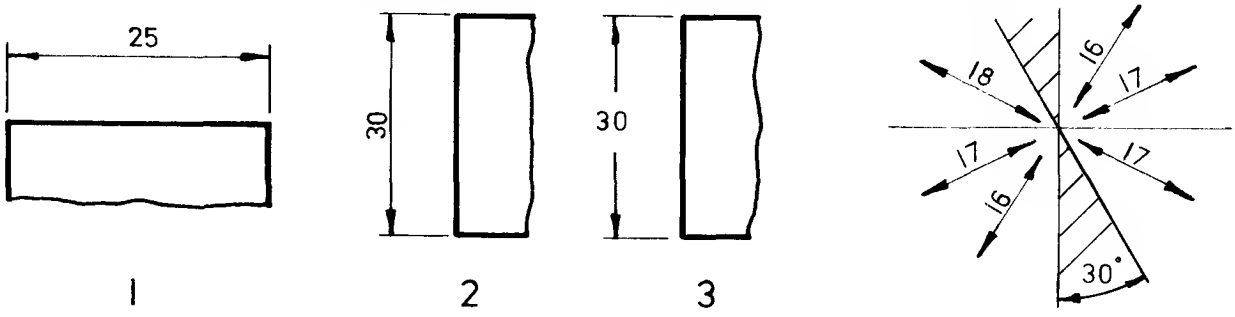



Fig. 5

Max. possible error ± 0.6

# Arrangement of dimensions

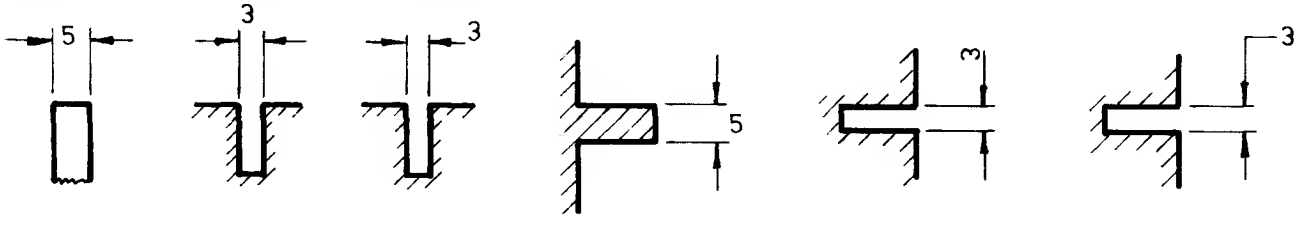
Dimensions should be placed so that they may be read from either the bottom or right-hand side of a drawing, for example:



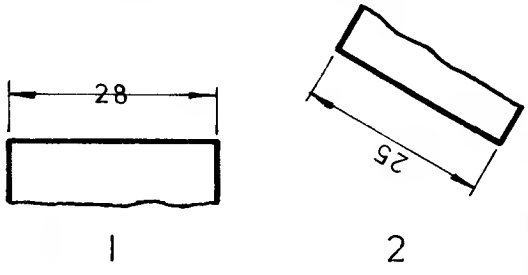

The arrangements at 1 and 2 are the most usual but there are occasions when it may be necessary to use the arrangement at 3.

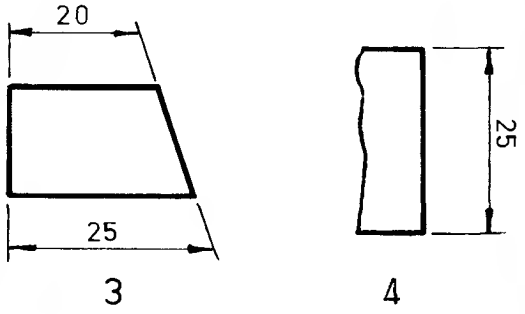
Avoid placing dimension lines in the shaded area - zones of about 30°.

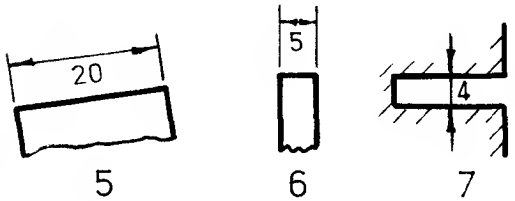
Various methods of dimensioning narrow spaces or widths are shown below. Note the placing of the arrows outside the extension lines.



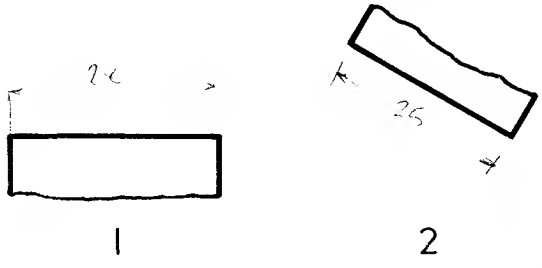

The figures shown below are dimensioned incorrectly.

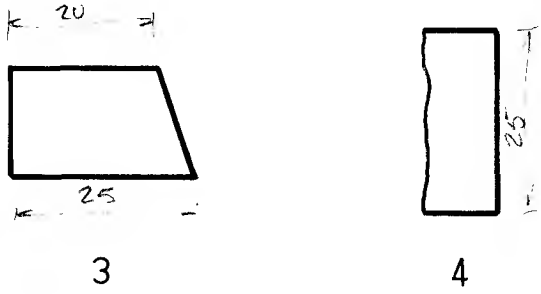


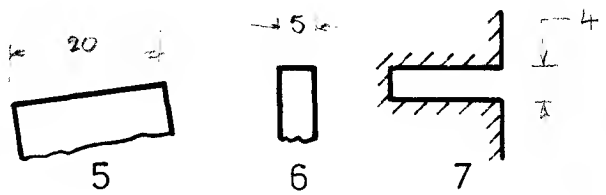




*Exercise:* Dimension the figures correctly. (Solns. p.155)

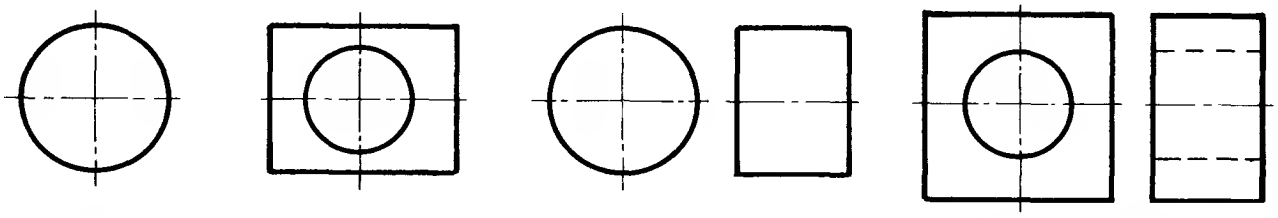


# Dimensioning circles

On an engineering drawing a circle may be one of the following:

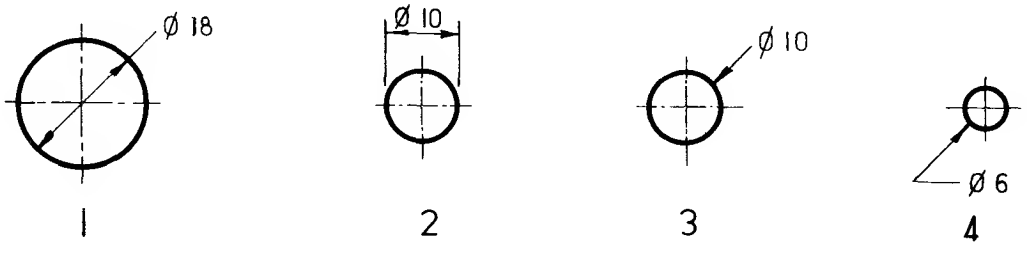


A thin disc | A hole in a thin plate | The side view of a cylinder | The side view of a cylindrical hole

The way a circle is dimensioned is influenced by the factors shown above and also by the size of the circle and the space available within the circle.

Points to note: (i) The dimension always refers to the diameter and NOT the radius
(ii) A circle is never dimensioned on a centre line.
(iii) The conventional symbol for diameter is ϕ

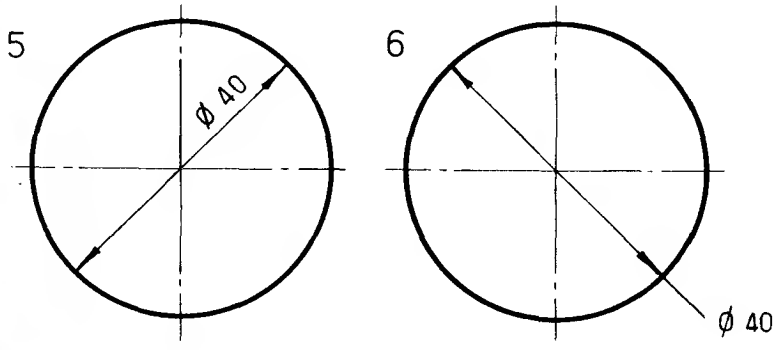
*Methods used for dimensioning relatively small circles*




1 2 3 4

In 3 and 4 the leader line must be drawn in in line with the centre of the circle

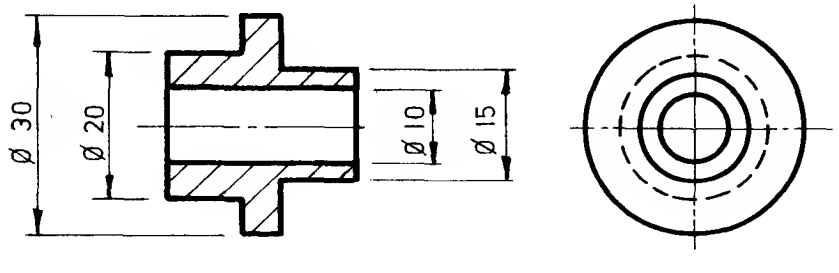
*and larger circles*




When the dimension line has to be drawn as in example 6 it is preferable to place the dimension as shown so that it may be easily read from the bottom of the sheet.

*For diameters of cylinders*

7




Side view

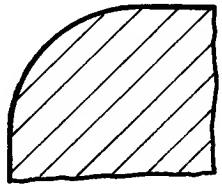


Front view

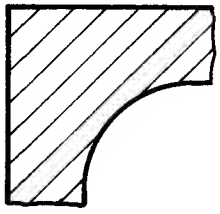
In this example it is preferable to dimension the side view even though the cylindrical shape is not apparent. Dimensions in this view, however, must always be preceded by the symbol ϕ

# Dimensioning radii

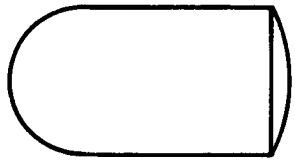
On an engineering drawing a radius usually describes the shape or contour of a component in a particular view and may be either



An external radius



An internal radius or

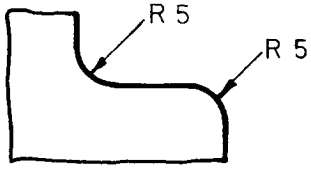


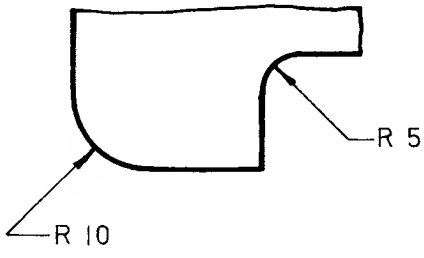
A spherical radius

A radius should be dimensioned by a dimension line which passes through, or is in line with, the centre of the arc.
The dimension line should have one arrowhead which should be placed at the point of contact with the arc.
The abbreviation R should always precede the dimension.

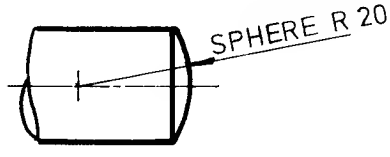
The above statements may be interpreted as follows:

For *small* radii

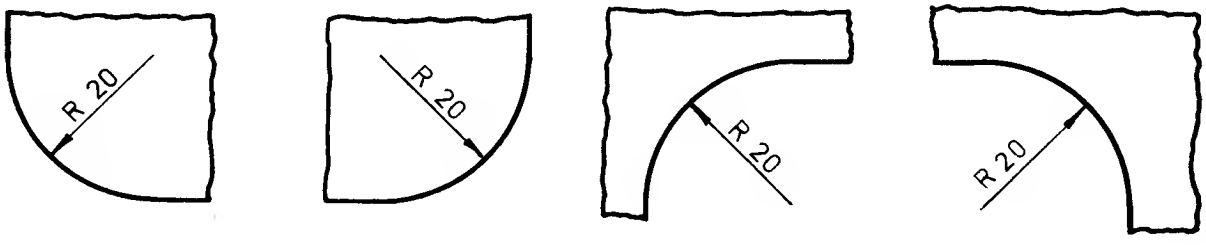


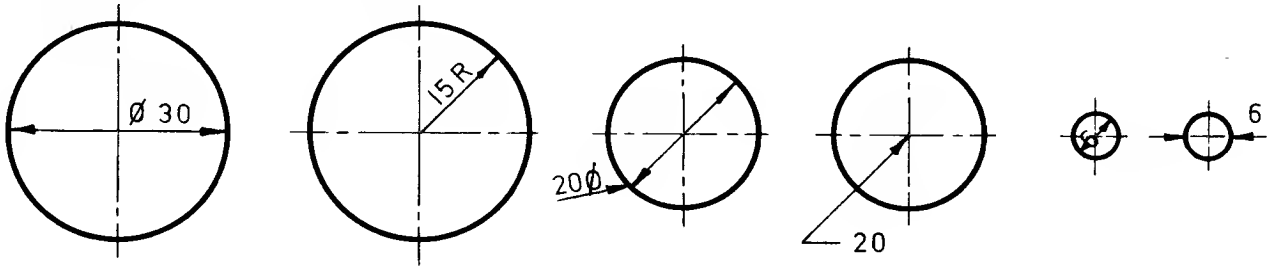

For *spherical* radii



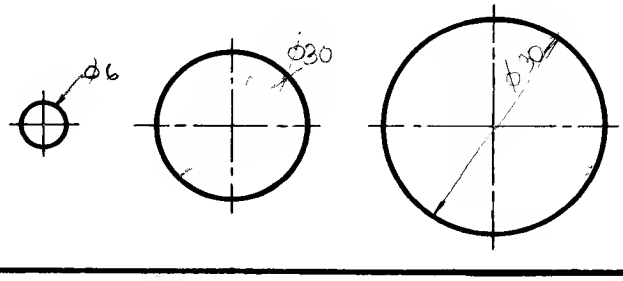

For *larger* radii




The circles shown below are incorrectly dimensioned.




*Exercise:* Dimension the circles on the right correctly using the information given on the previous page (Solns. p.155)



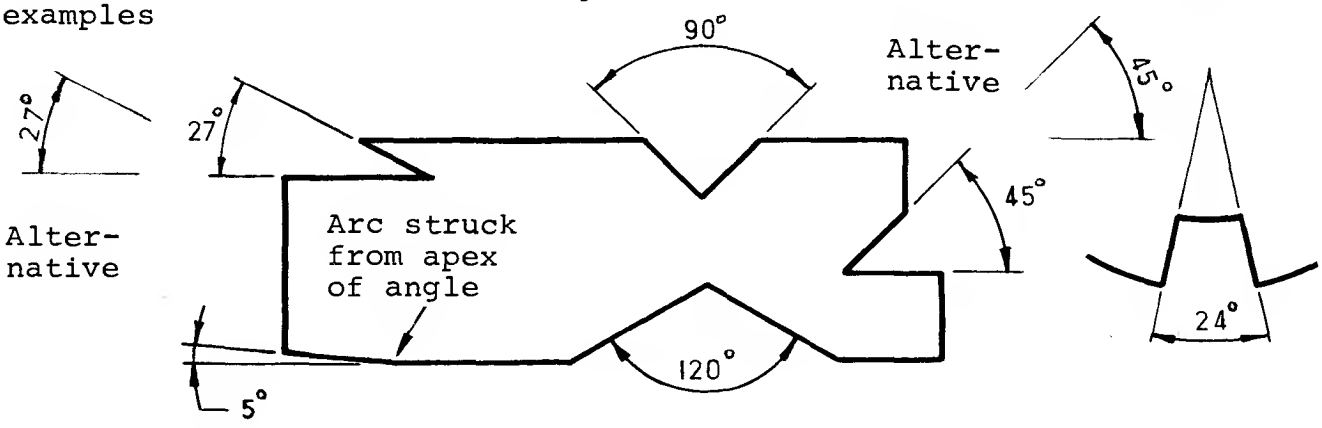
# Dimensioning angles

Angles should be expressed in: (1) degrees e.g. 90°
or (2) degrees and minutes e.g. 27° 30'
0° 15'

The placing of the angular dimension depends on:

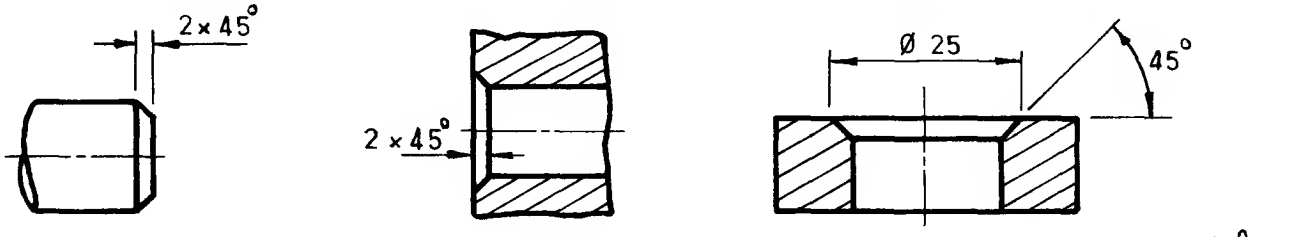
the *position* of the angle in relation to the bottom and/or the right-hand side of the drawing sheet and the *size* of the angle.

Angles may be dimensioned using one of the methods shown in these examples

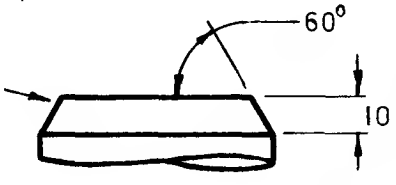



DIMENSIONING CHAMFERS

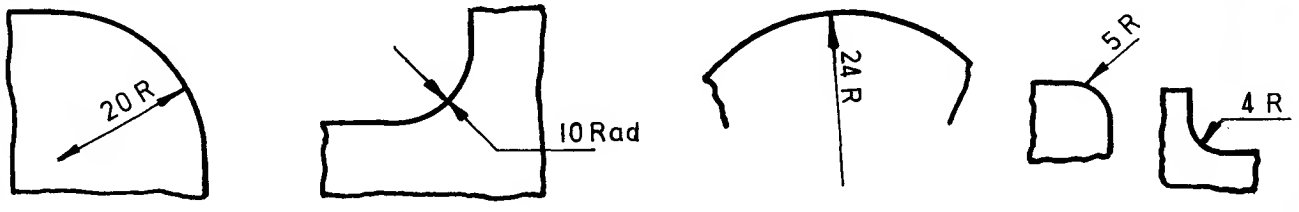
45° chamfers should be specified by one of the methods shown below:




Chamfers at angles other than 45° should be shown as a dimension and not as a note, e.g. Chamfers should not be specified by a note and a leader line.



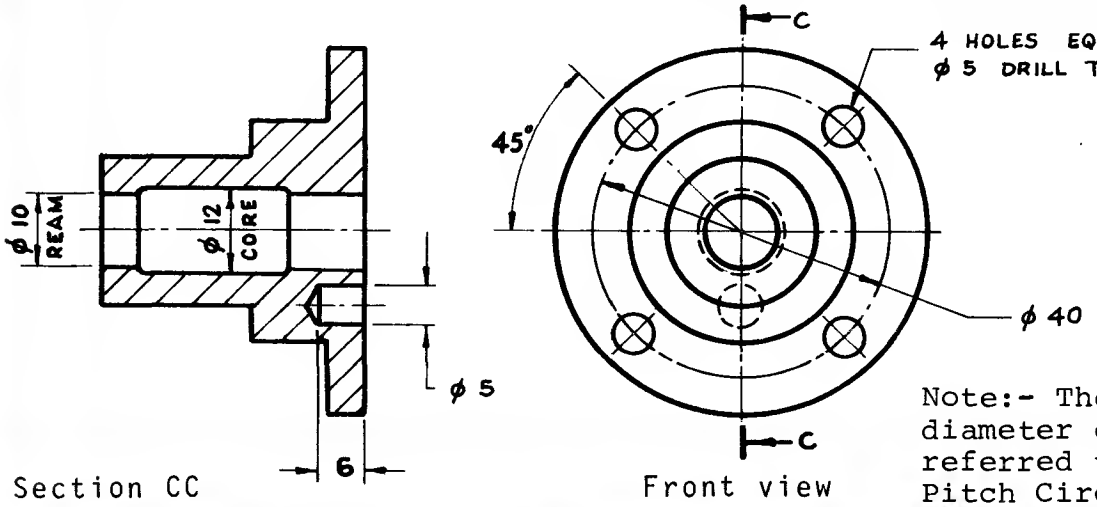

The radii below are dimensioned incorrectly.




*Exercise*:- Dimension the radii below correctly using the information given on the previous page. (Solutions on page 155)

# Designation of plain holes

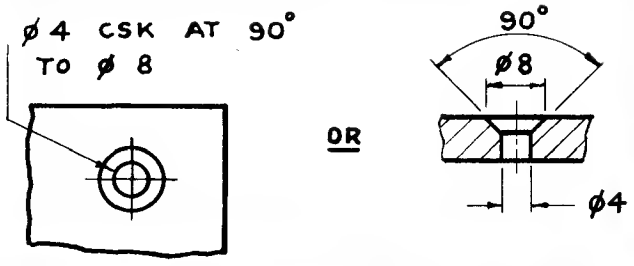
It is often necessary to specify not only the diameter of a hole but also, the way the hole is produced. Processes for forming holes include drilling, boring, reaming and coring (holes made when casting). The drawing below shows how these may be designated.



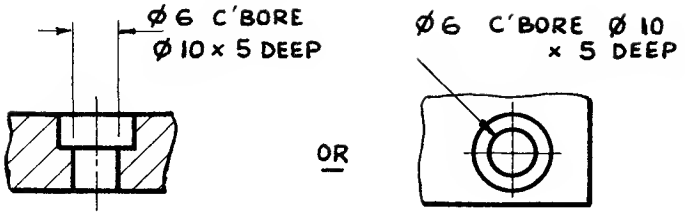

Note:- The 40 mm diameter circle is referred to as the Pitch Circle Diameter PCD

*Designation of "special" holes*

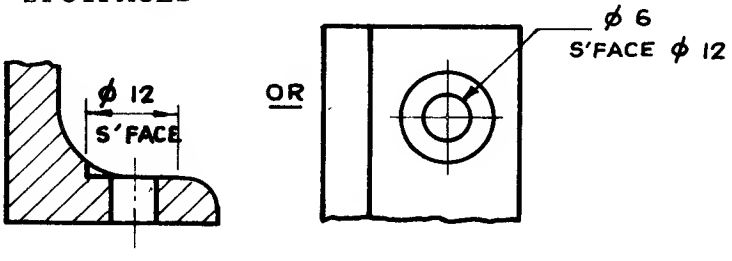
COUNTERSINKS



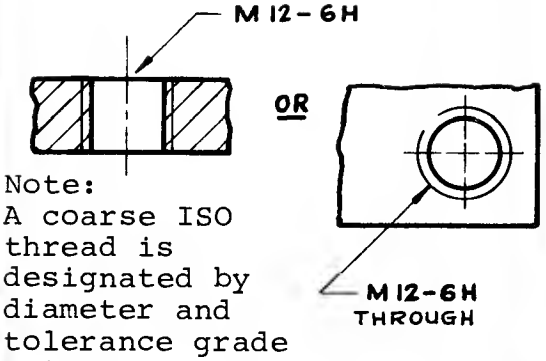

COUNTERBORES



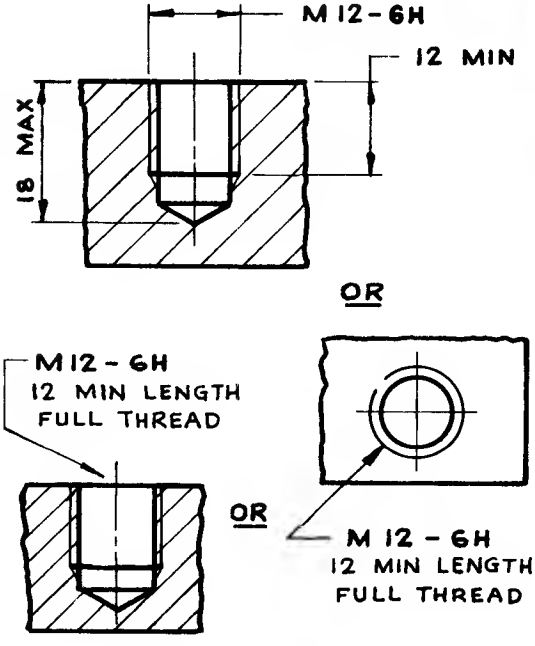

SPOTFACES




SCREW THREADS

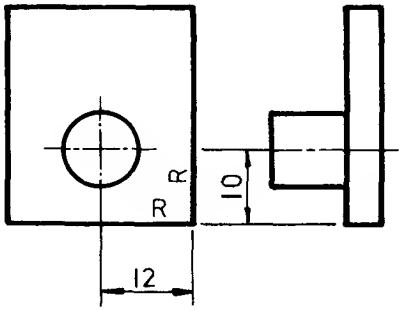



Note:
A coarse ISO thread is designated by diameter and tolerance grade only.

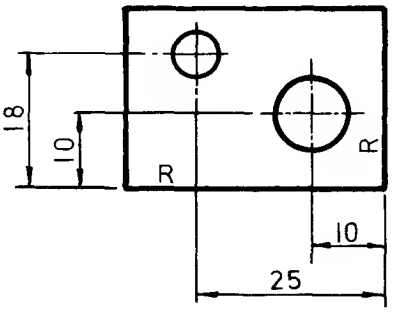


# Location dimensions

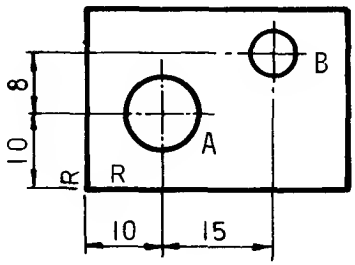
Examples on previous pages have shown how components and features may be dimensioned when size is the main consideration. Figures 1, 2 and 3 show how to dimension a component when location is necessary. The features can be located from a machined surface or centre line. Such a surface or line is known as a DATUM.




1.
Spigot located from two reference edges (R).

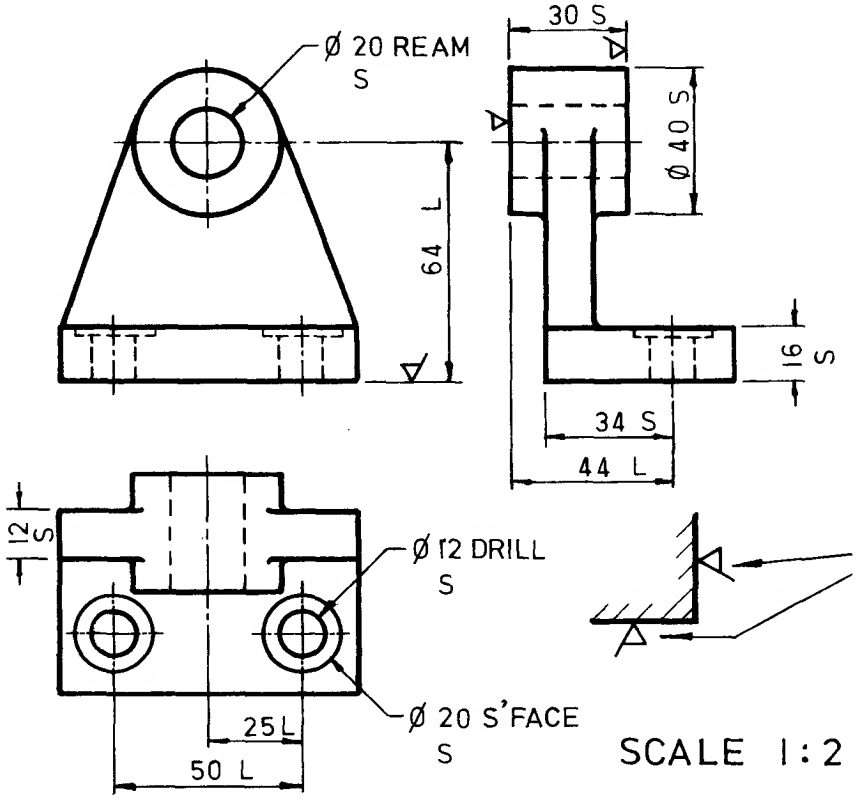



2.
Both holes located from two reference edges (R).




3.
Hole A located from two reference edges (R) then hole B related to hole A.

*Size and location dimensions and use of the machining symbol*




4.
The simple bearing bracket casting on the left shows both size and location dimensions.

Reference surfaces are marked with a machining symbol:- ∀

This is placed so that it may be read from the bottom or from the right of the sheet.

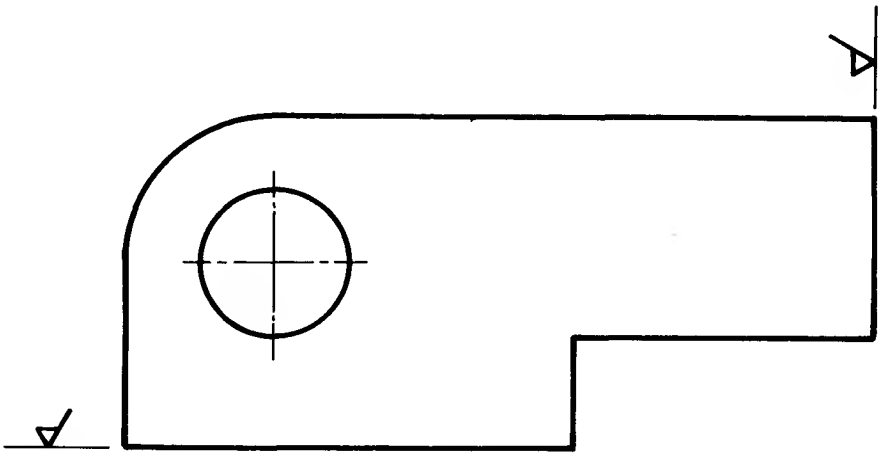
It is preferable to place the symbol on the appropriate projection line rather than as shown on the left.

No symbol is required where the machining is specified i.e. in the case of the drilled holes, the reamed holes and the spot-face.

The location dimensions are those shown with a letter L and size dimensions by a letter S. Some of the size dimensions are less accurate than others e.g. the thickness of the rib is fixed during the casting process whilst the 20 mm diameter hole is accurately reamed. The 20 mm diameter reamed hole is located by the dimension from the machined base to the centre line of the hole.

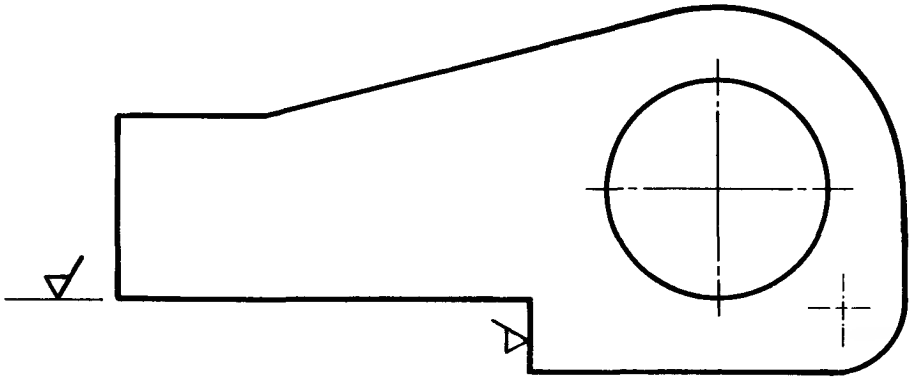
# Dimensioning exercises

Each drawing below shows a component made from mild steel plate 15 mm thick. Dimension both drawings so that accurate marking out and subsequent manufacture of the plates may be carried out. Use the machined surfaces as reference edges. The holes are to be reamed. Sizes may be obtained by measuring the drawing. All dimensions in millimetres.



Note: Each machining symbol in the following dimensioning exercises has been placed so that it appears "upright" when viewed from either the bottom right hand corner or right hand side of the drawing sheet.
The symbol is placed on the machined surface itself provided that when it is so positioned it "falls" outside the outline of the component. Alternatively, it is placed on a suitable projection line.

1



Solutions to the above exercises are given on page 156.

2

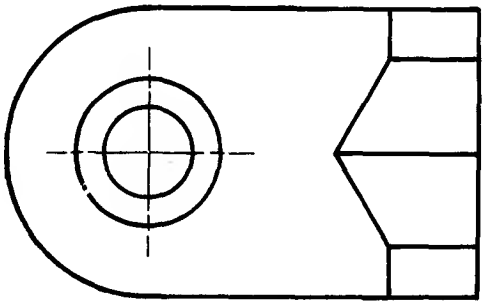
# Dimensioning exercise

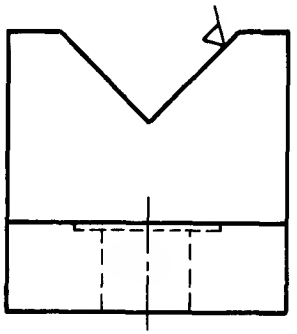
Fully dimension this drawing of a cast iron Vee-block so that it could be manufactured if required.
Add all necessary notes.

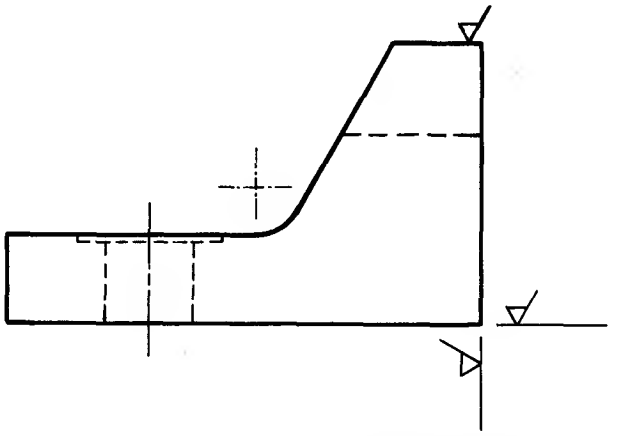
The hole in the base is to be drilled and the area around the top of the hole is to be spot-faced over a diameter of 20 mm.
The angle of the Vee is to be 90°.

Sizes may be obtained by measuring the drawing.

All dimensions in millimetres.





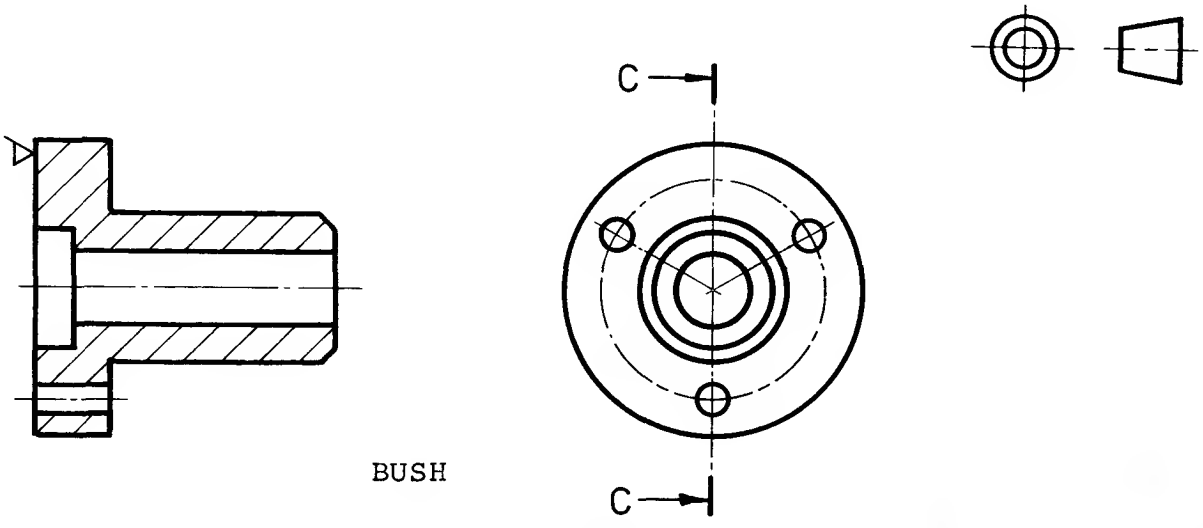




Solution on page 157

# Dimensioning exercises

Fully dimension this drawing assuming that the component is to be machined all over. Take the datum as the face of the flange marked ✓
Sizes may be obtained by measuring the drawing.
All dimensions in millimetres.
Note: Holes - 4 mm drill equi-spaced
Chamfer - 2 mm at 45°




BUSH

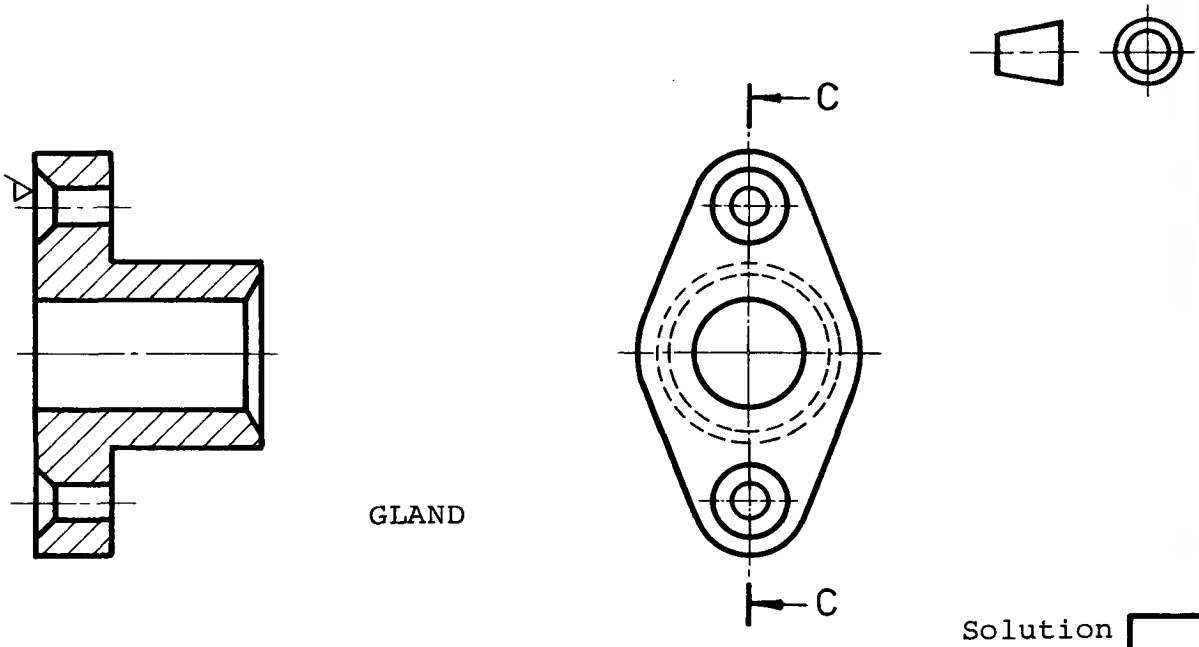
Section CC

Front view

Solution on page 158

4

Fully dimension this drawing assuming that the component is to be machined all over. Take the datum as the face of the flange marked ✓
Note: (1) Use the horizontal centre line for locating the countersunk holes in the front view
(2) The countersink is 90° and enlarges the drilled holes from 5 mm diameter to 10 mm diameter.
(3) The internal chamfer - 3 mm × 60°




GLAND

Section CC

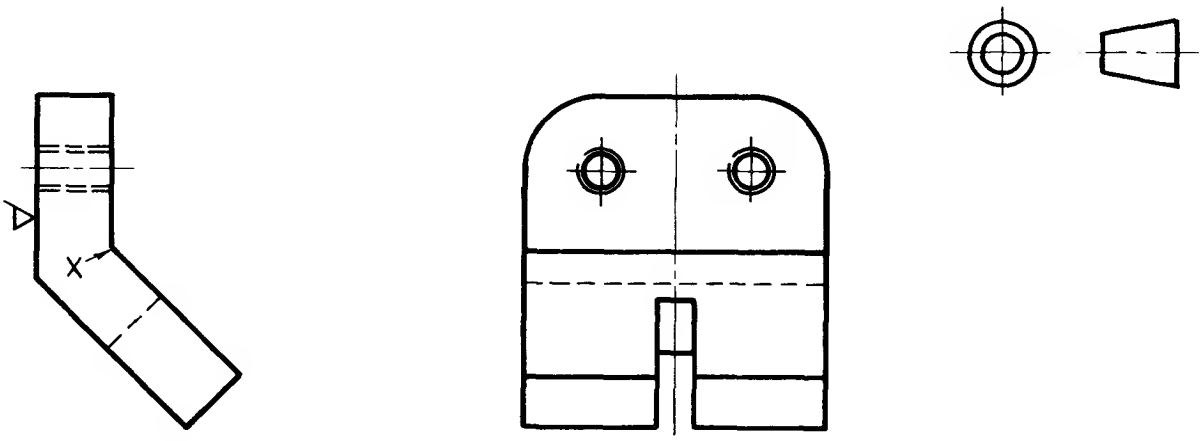
Front view

Solution on page 158

5

# Dimensioning exercises

The component below is to be made of brass. Fully dimension the drawing to enable the bracket to be manufactured.
Note:- (1) The only parts to be machined are the back face (which should be used as the datum) and the tapped holes.
(2) Locate the holes from the centre line in the front view.
(3) Locate the holes and slot from point X in the side view.




LOCATING BRACKET

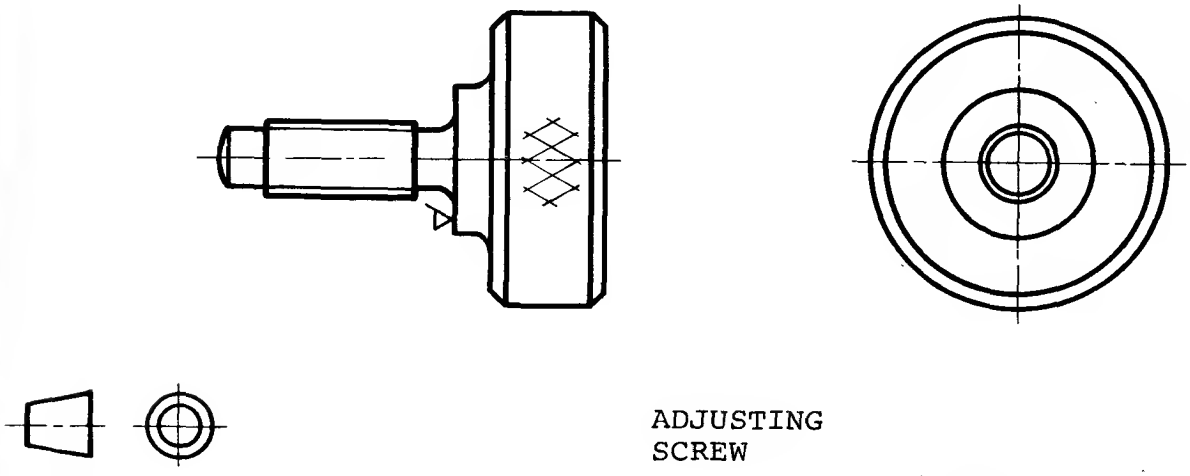
Side view

Front view

Solution on page 159

6

Fully dimension the drawing so that the adjusting screw may be manufactured. Take the shoulder marked ▽ as the datum face.
Note:- The thread is M 6. The head is knurled (fine diamond).
The chamfers - 2 mm at 45°
The radius at the end of the screw is 8 mm.



ADJUSTING SCREW

Machined all over

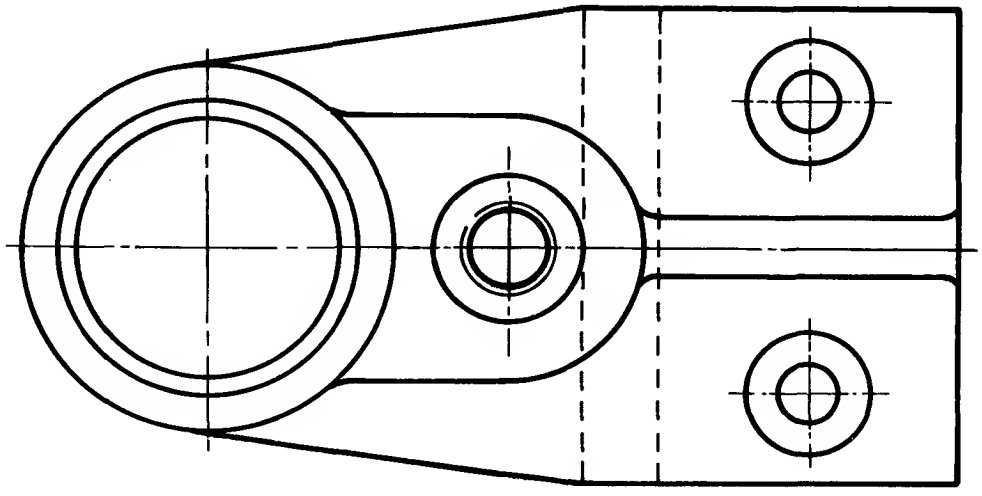
Front view

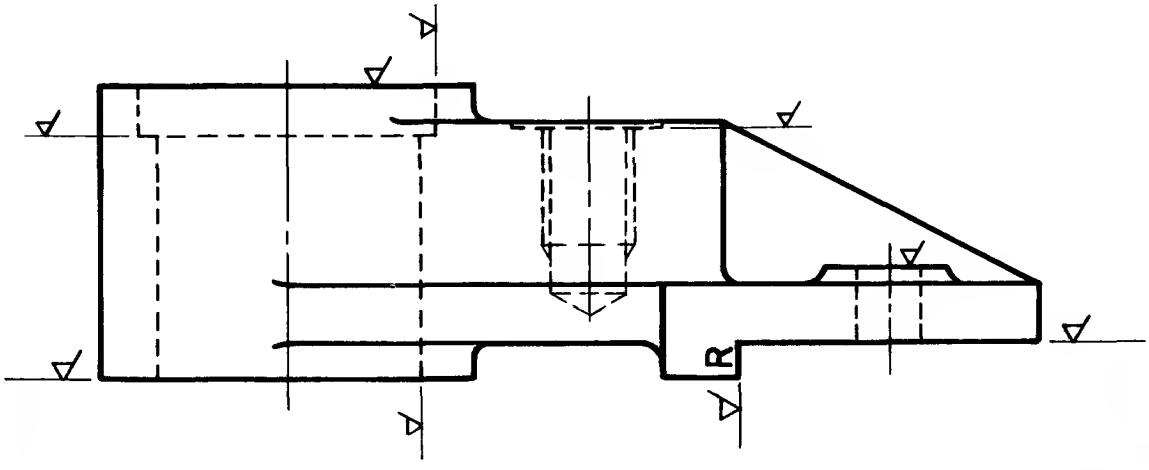
Side view

Solution on page 159

7

# Dimensioning exercise

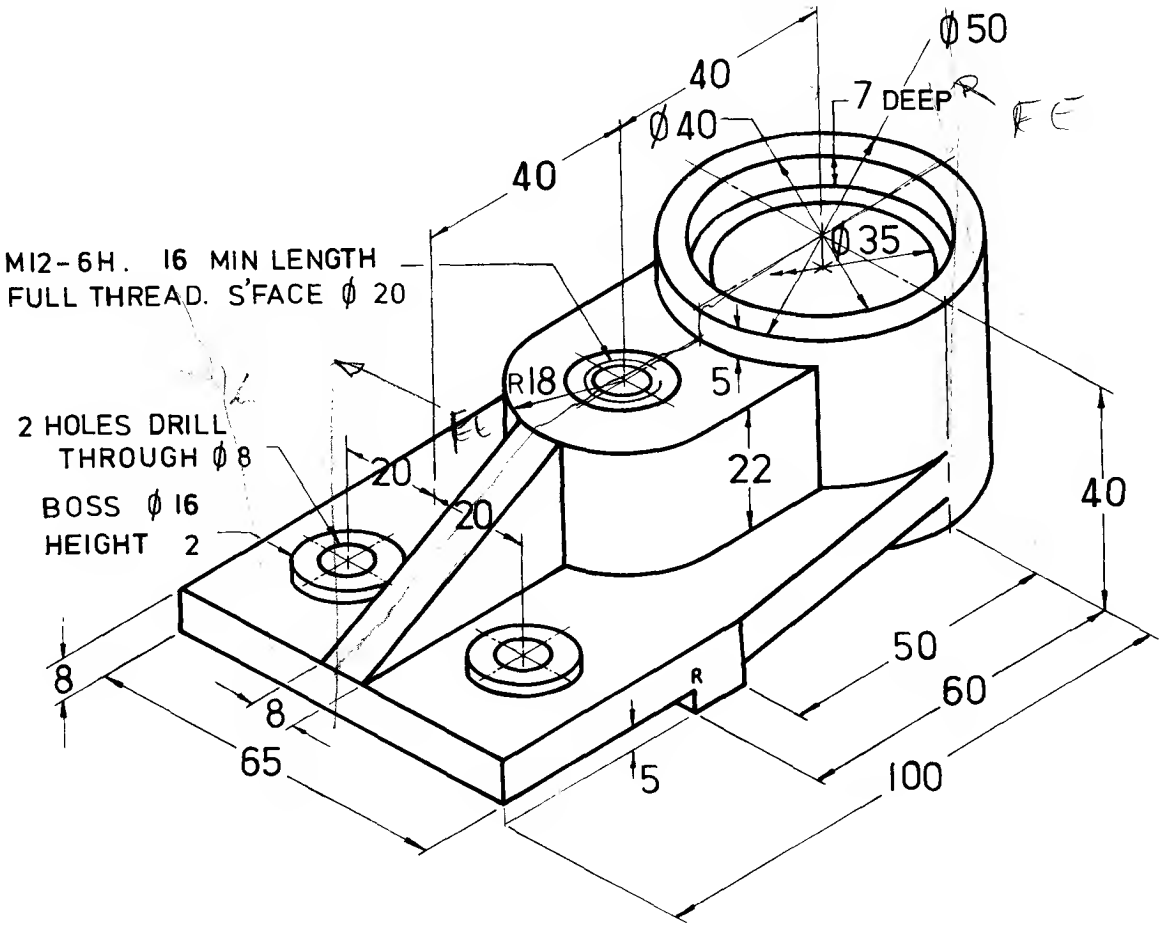





8

Fully dimension the orthographic views shown above to enable the bracket to be manufactured. Details of sizes, locations, screw threads, etc., may be taken from the pictorial view of the same component shown on the opposite page. (All dimensions millimetres) Both the 8 mm base holes and the 35 mm bore must be located from the machined face R. The tapped hole must be located from the 35 mm bore.

Note: This drawing can be fully and clearly dimensioned using two views only. The drawing of a more complicated component would possibly include a side view also to clarify both shape and dimensioning. The solution to this exercise is on page 160.




In this isometric view of the cast-iron bracket all the corner fillets (or radii) have been omitted in order to simplify the drawing.

Cast iron Bracket for Vertical Spindle.

# Limits and Fits

In the early days of engineering, "mating" parts, e.g. a shaft and the bearing in which it is housed, were manufactured individually and assembled only after laborious hand fitting by craftsmen. This method of production demanded great skill, was slow, and thus an expensive operation.

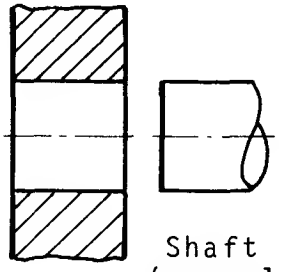
To overcome this the first system of limits and fits was introduced around the turn of the century. When the system was used correctly production costs were greatly reduced because identical mass-produced components, even those made in different places, could be readily interchanged without resorting to the time-consuming fitting operation.

The use of a suitable system of limits and fits, the latest of which (B.S. 4500) is outlined in the following text, ensures that all identical components are made to a specific size within narrow limits.

It must be stressed that when assigning limits to the dimensions of a component it is necessary to consider not only its function but also the skill of the operator and the type and condition of the machines which are used to manufacture the component.

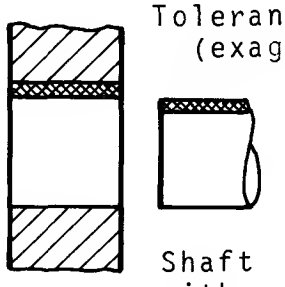
Limits should be applied to the dimensions of a component only if the resulting degree of accuracy is essential for the efficient functioning of the component. It is uneconomical to limit the accuracy of a dimension to ± 0.005 mm when ± 1 mm would prove satisfactory.

# Limits and Fits for Holes and Shafts



Hole

Shaft (normal representation)



Hole

Tolerance zones (exaggerated)

Shaft with tolerance zones

A TOLERANCE on a hole or a shaft is a permissible degree or error.
It depends on:

(1) Machining or cutting operation used.

(2) Quality of work.

(3) Type of fit between hole and shaft.

*Effect of manufacturing process on degree of accuracy obtainable*

| Tolerance number | *Process* (typical) |
|---|---|
| 1 | Slip blocks, reference gauges |
| 2 | High quality gauges |
| 3 | Good quality gauges |
| 4 | Gauges and precision fits |
| 5 | Ball bearings, fine grinding |
| 6 | Grinding, fine honing |
| 7 | High quality turning, broaching |
| 8 | Centre lathe turning and reaming |
| 9 | Horiz. and vert. boring |
| 10 | Milling, planing, extrusion |
| 11 | Drilling, rough turning, boring |
| 12 | Light press work, tube drawing |
| 13 | Press work, tube rolling |
| 14 | Die casting or moulding |
| 15 | Stamping (approx) |
| 16 | Sand casting, flame cutting |

For more detailed lists refer to BS 1916 and BS 4500

Tolerance increases with the number

*Numerical value of tolerance for sample sizes*

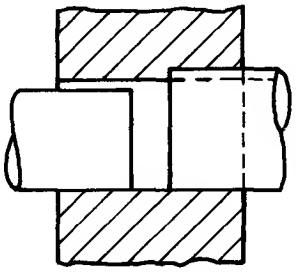
| BS 1916 inch 0.001 in | | | BS 4500 metric 0.001 mm | | |
|---|---|---|---|---|---|
| 0.119 to 0.237 | 1.969 to 3.150 | 4.725 to 7.087 | 3 mm to 6 mm | 50 mm to 80 mm | 120 mm to 180 mm |
| 0.06 | 0.08 | 0.16 | 1.0 | 2 | 3.5 |
| 0.08 | 0.12 | 0.2 | 1.5 | 3 | 5 |
| 0.12 | 0.2 | 0.32 | 2.5 | 5 | 8 |
| 0.15 | 0.3 | 0.5 | 4 | 8 | 12 |
| 0.2 | 0.5 | 0.7 | 5 | 13 | 18 |
| 0.3 | 0.7 | 1.0 | 8 | 19 | 25 |
| 0.5 | 1.2 | 1.6 | 12 | 30 | 40 |
| 0.7 | 1.8 | 2.5 | 18 | 46 | 63 |
| 1.2 | 3.0 | 4.0 | 30 | 74 | 100 |
| 1.8 | 4.5 | 6.0 | 48 | 120 | 160 |
| 3.0 | 7.0 | 10.0 | 75 | 190 | 250 |
| 5.0 | 12.0 | 16.0 | 120 | 300 | 400 |
| 7.0 | 18.0 | 25.0 | 180 | 460 | 630 |
| 12.0 | 30.0 | 40.0 | 300 | 750 | 1000 |
| 18.0 | 45.0 | 60.0 | 480 | 1200 | 1600 |
| 30.0 | 70.0 | 100.0 | 750 | 1900 | 2500 |

Tolerance increases with size of component

The tolerance number is directly related to the manufacturing process and hence to the quality of work in terms of the degree of dimensional accuracy required. The permissible degree of error increases (*a*) as the process becomes less precise and
(*b*) as the size of component increases.
Tolerance number should not be confused with the numbers which relate to surface roughness.

Refer to British Standards for further information.
Use BS 1916 for inch sizes
and BS 4500 for metric sizes.

# Limit systems

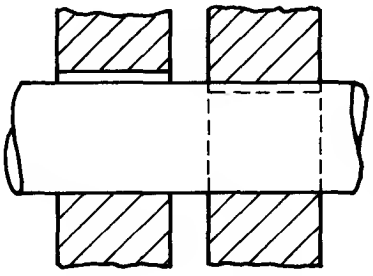


Hole size constant

Shaft size varies to provide the required fit

Clearance Interference

HOLE BASIS



Shaft size constant

Hole size varies to provide the required fit

Clearance Interference

SHAFT BASIS

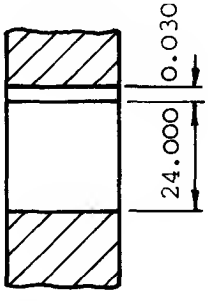
BS 1916 and BS 4500 use the hole basis but there are occasions when it is necessary to design a fit on a shaft basis.

*Basic size and disposition of tolerance*

Whenever possible, holes are designed and machined to sizes obtained with standard tools and/or to preferred sizes in millimetres (see BS 4318).

The basic size of a hole is the dimension used if no tolerances were applied. Another name used is "nominal size".

Tolerances can be applied to holes and shafts in various ways.



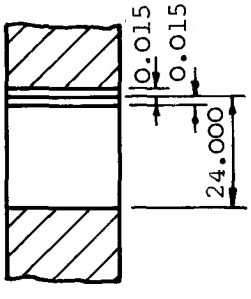

Basic size = 24.000
Tolerance = 0.030

Write $24.000^{+0.030}_{0}$

or 24.030
24.000

Unilateral disposition

Tolerance placed to ONE side of basic size




Basic size = 24.000
Tolerance = 0.030

Write $24.000^{+0.015}_{-0.015}$

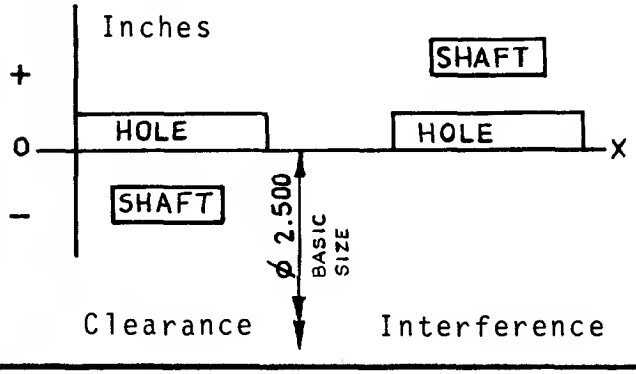
or 24.015
23.985

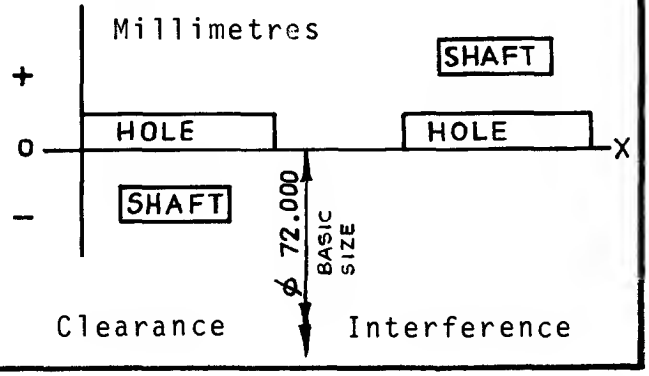
Bilateral disposition

Tolerance split above and below basic size

BS 1916 and BS 4500 generally use the unilateral method of applying limits to a size.

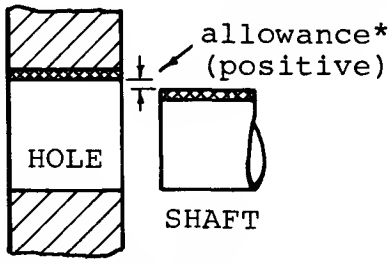
The tolerances can be represented as shapes on a graph. The OX axis is the top side of the basic size, in this case, the hole.



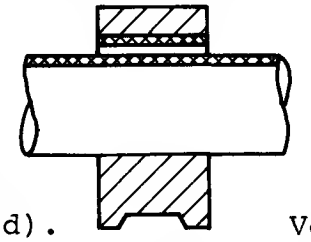
**FIT:** the relationship between hole (or internal feature) and shaft (or external feature)

ALLOWANCE - the prescribed (algebraic) difference between the low limit of size for the hole (or internal feature) and the high limit of size for the "mating" shaft (or external feature), i.e. maximum metal condition.




CLEARANCE FIT
Shaft is ALWAYS smaller than hole.

e.g. a simple bearing (exaggerated).



BEARING

The shaft is "loose" running or "easy" running or "slide".

Verbal descriptions of the fit may vary widely. Numerical differences are more important.

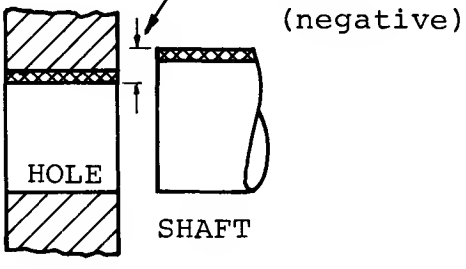
e.g. for ϕ2 inch (BS1916:53)

| | | |
|---|---|---|
| Hole sizes | | 2.0018 |
| | | 2.0000 |
| "Mating" shaft sizes | | 1.9988 |
| | | 1.9970 |
| Smallest hole | | 2.0000 |
| Largest shaft | | 1.9988 |
| ALLOWANCE | + | 0.0012 |

for ϕ24 mm (BS4500:69)

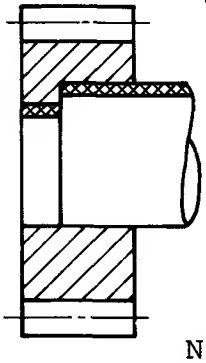
| | | |
|---|---|---|
| Hole sizes | | 24.033 |
| | | 24.000 |
| "Mating" shaft sizes | | 23.980 |
| | | 23.959 |
| Smallest hole | | 24.000 |
| Largest shaft | | 23.980 |
| ALLOWANCE | + | 0.020 |

Note! Allowance is ALWAYS positive (+) for a clearance fit.




INTERFERENCE FIT
Shaft is ALWAYS larger than hole.

e.g. a gear wheel on a shaft (exaggerated)



GEAR

The shaft is forced into the hole.

The fit can be described in such terms as:
"light press" or
"press" or
"heavy press" or
"shrink"

Numerical differences are more important.

e.g. for ϕ2 inch (BS1916:53)

| | | |
|---|---|---|
| Hole sizes | | (as above) |
| "Mating" shaft sizes | | 2.0032 |
| | | 2.0020 |
| Smallest hole | | 2.0000 |
| Largest shaft | | 2.0032 |
| ALLOWANCE | - | 0.0032 |

for ϕ24 mm (BS4500:69)

| | | |
|---|---|---|
| Hole sizes | | (as above) |
| "Mating" shaft sizes | | 24.048 |
| | | 24.035 |
| Smallest hole | | 24.000 |
| Largest shaft | | 24.048 |
| ALLOWANCE | - | 0.048 |

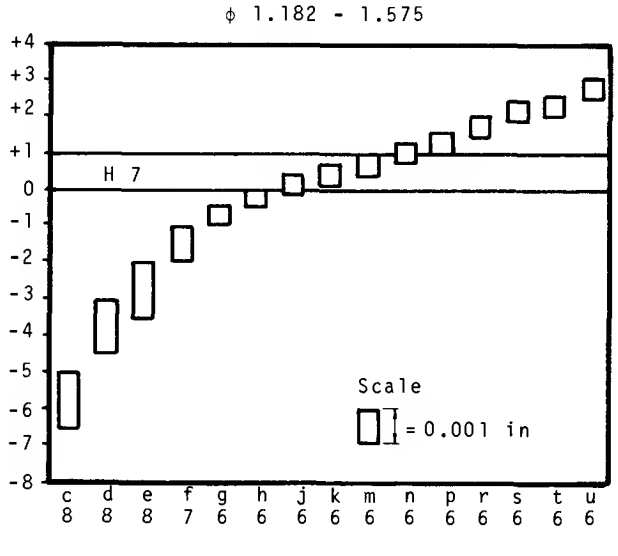
As shaft sizes are subtracted from hole sizes, the allowance will always be negative (-) for an interference fit.

* The use of the word "allowance" has been omitted from BS4500. It has been used here solely to explain the difference between clearance fit and interference fit. It is still used, of course, in BS1916:53.

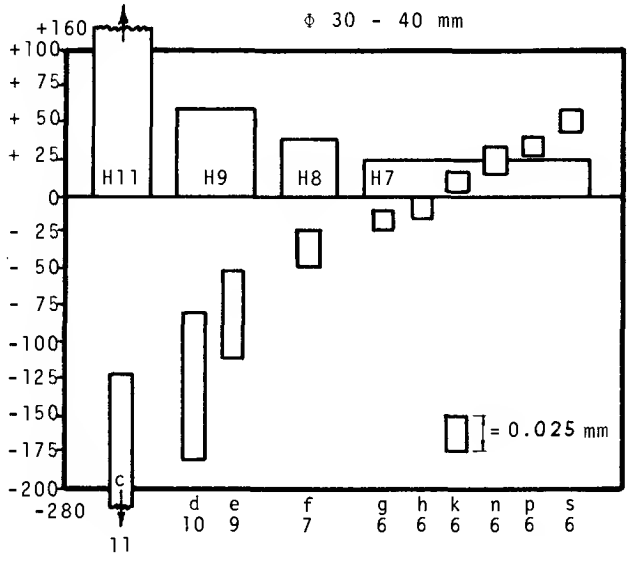
Both BS 1916 and BS 4500 recommend limits and fits for a wide range of engineering processes and activities - even horology! For most general purposes a carefully selected range of hole and shaft sizes are given in each standard.

Holes are lettered by capitals, A,B,C, etc., the limits allocated to the H-hole being recommended. The H-hole always has the basic size of the hole as one size. The letter is followed by the tolerance grade number e.g. H8. Shafts are lettered by lower case letters, a,b,c, etc., and a range of fits is provided by those given in the charts below.

BS 1916 $\phi$1.182-1.575 in




BS 4500 $\phi$30-40 mm




*Tolerance grade number*

If the tolerances on hole and shaft overlap it is possible in the random selection of components to obtain either clearance or interference. These are called TRANSITION fits e.g. H7 with k6, and are described as "push", "easy keying", "tight keying" or "drive". A fit between an H8 hole and an f7 shaft is written H8-f7 and reference to the chart above will show that this must always be a CLEARANCE fit. Further reference to BS 1916, parts 2 and 3 will show the types of fit recommended for particular types of work.

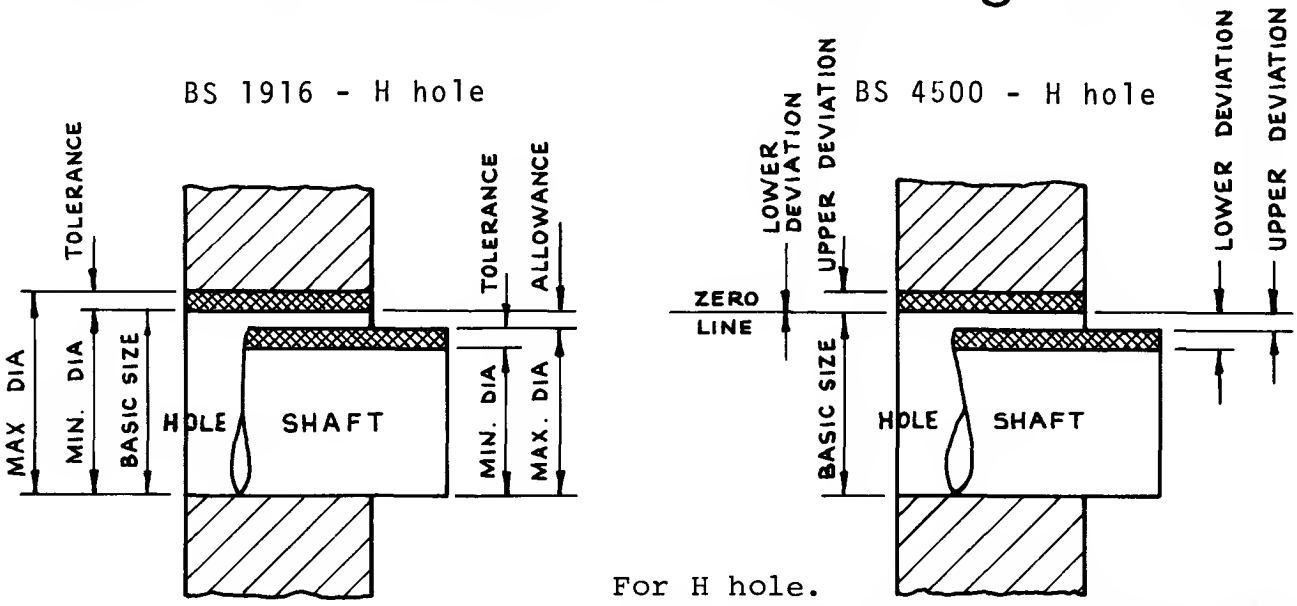
Extract from BS 1916-Limit values.

| Hole H7 0.001 in | Size of component between | | Shafts e8 - | f7 - | h6 - | j6 | s6 + |
|---|---|---|---|---|---|---|---|
| + 0.5<br>0 | in<br>0.12 | in<br>0.24 | - 0.8<br>- 1.5 | - 0.4<br>- 0.9 | 0<br>- 0.3 | + 0.2<br>- 0.1 | + 1.0<br>+ 0.7 |
| + 0.6<br>0 | 0.24 | 0.40 | - 1.0<br>- 1.9 | - 0.5<br>- 1.1 | 0<br>- 0.4 | + 0.3<br>- 0.1 | + 1.4<br>+ 1.0 |
| + 0.7<br>0 | 0.40 | 0.71 | - 1.2<br>- 2.2 | - 0.6<br>- 1.3 | 0<br>- 0.4 | + 0.3<br>- 0.1 | + 1.6<br>+ 1.2 |
| + 0.8<br>0 | 0.71 | 1.19 | - 1.6<br>- 2.8 | - 0.8<br>- 1.6 | 0<br>- 0.5 | + 0.3<br>- 0.2 | + 1.9<br>+ 1.4 |
| + 1.0<br>0 | 1.19 | 1.97 | - 2.0<br>- 3.6 | - 1.0<br>- 2.0 | 0<br>- 0.2 | + 0.4<br>- 0.2 | + 2.4<br>+ 1.8 |
| + 1.2 | 1.97 | 2.56 | - 2.5 | - 1.2 | 0 | + 0.4 | + 2.7<br>+ 2.0 |
| 0 | 2.56 | 3.15 | - 4.3 | - 2.4 | - 0.7 | - 0.3 | + 2.9<br>+ 2.2 |

Extract from BS 4500-Limit values.

| | Hole H7 0.001 mm | Size of component between | | Shafts g6 - | k6 + | n6 + | s6 + | |
|---|---|---|---|---|---|---|---|---|
| ES<br>EI | + 15<br>0 | mm<br>6 | mm<br>10 | - 5<br>- 14 | + 10<br>+ 1 | + 19<br>+ 10 | + 32<br>+ 23 | es<br>ei |
| ES<br>EI | + 18<br>0 | 10 | 18 | - 6<br>- 17 | + 12<br>+ 1 | + 23<br>+ 12 | + 39<br>+ 28 | es<br>ei |
| ES<br>EI | + 21<br>0 | 18 | 30 | - 7<br>- 20 | + 15<br>+ 2 | + 28<br>+ 15 | + 48<br>+ 35 | es<br>ei |
| ES<br>EI | + 25<br>0 | 30 | 40 | - 9<br>- 25 | + 18<br>+ 2 | + 33<br>+ 17 | + 59<br>+ 43 | es<br>ei |
| | | 40 | 50 | | | | | |
| ES | + 30 | 50 | 65 | - 10 | + 21 | + 39 | + 72<br>+ 53 | es<br>ei |
| EI | 0 | 65 | 80 | - 29 | + 2 | + 20 | + 78<br>+ 59 | es<br>ei |

# Conventional method of illustrating terms

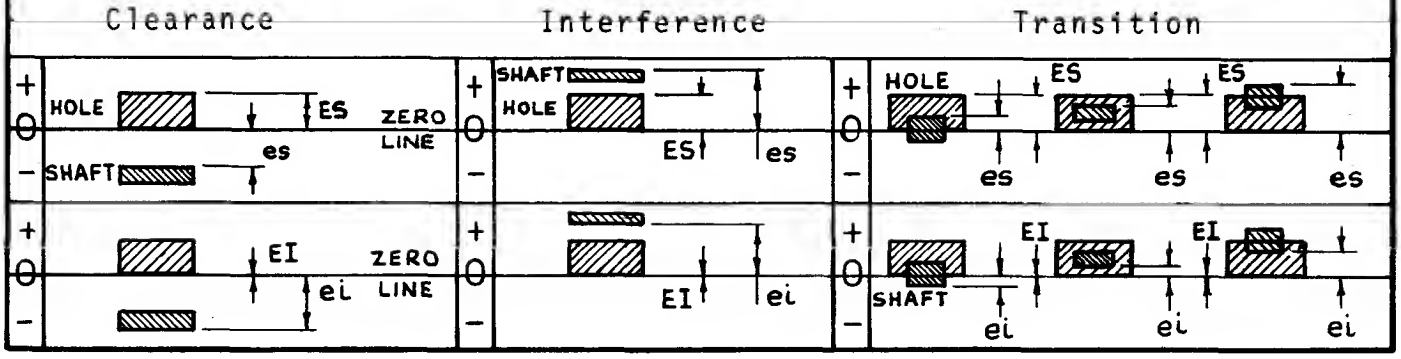



For H hole.
Zero line coincides with basic size line, hence lower deviation = 0, as shown above.

BS 4500

| | |
|---|---|
| BASIC SIZE | The size to which hole and shaft are referred. |
| DEVIATION | The algebraic difference between a size and the corresponding basic size. |
| UPPER DEVIATION | The difference between the maximum limit of size and the basic size.<br>Designated: ES for hole, es for shaft. The letters stand for the French term écart supérieur. |
| LOWER DEVIATION | The difference between the lower limit of size and the basic size.<br>Designated: EI for hole, ei for shaft. écart inférieur. |
| ZERO LINE | The line to which the deviations are referred.<br>The line of zero deviation.<br>The line which represents the basic size. |
| FUNDAMENTAL DEVIATION | For each pair of deviations, the fundamental deviation is the one nearer to the zero line. This defines the position of the tolerance zone in relation to the zero line. |

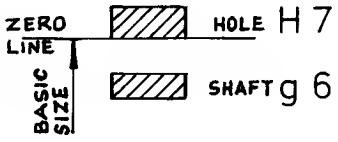
*Graphical representation of fits - H holes*



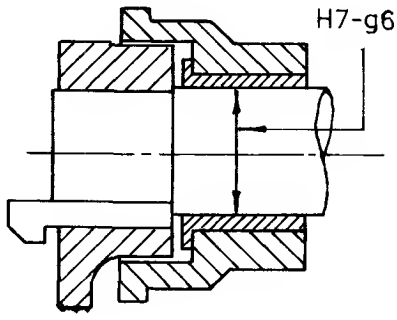
## Exercises

| Hole H 7 0.001mm | | Over | Up to and including | Shaft g 6 0.001mm | |
|---|---|---|---|---|---|
| ES + | EI | | | es - | ei - |
| 15 | 0 | 6 | 10 | 5 | 14 |
| 18 | 0 | 10 | 18 | 6 | 17 |
| 21 | 0 | 18 | 30 | 7 | 20 |
| 25 | 0 | 30 | 50 | 9 | 25 |
| 30 | 0 | 50 | 80 | 10 | 29 |

Fit




Clearance

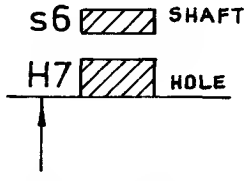



| Hole | | | | | Shaft | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Basic size | ES | EI | Max. size | Min. size | Basic size | es | ei | Max. size | Min. size |
| 10 | 0·015 | 0 | 10·015 | 10·000 | 10 | 0·005 | 0·014 | 9·995 | 9·986 |
| | | | | | | | | | |
| | | | | | | | | | |

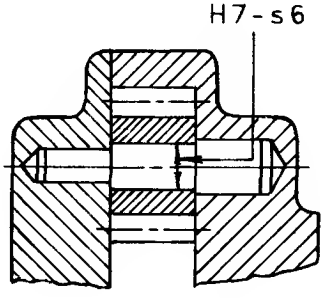
Complete the table for any other two hole and shaft sizes.

| Hole H 7 0.001mm | | Over | Up to and including | Shaft s 6 0.001mm | |
|---|---|---|---|---|---|
| ES + | EI | | | es + | ei + |
| 15 | 0 | 6 | 10 | 32 | 23 |
| 18 | 0 | 10 | 18 | 39 | 28 |
| 21 | 0 | 18 | 30 | 48 | 35 |
| 25 | 0 | 30 | 50 | 59 | 43 |
| 30 | 0 | 50 | 80 | 78 | 50 |

Fit




Interference

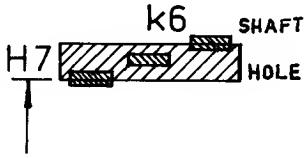



| Hole | | | | | Shaft | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Basic size | ES | EI | Max. size | Min. size | Basic size | es | ei | Max. size | Min. size |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

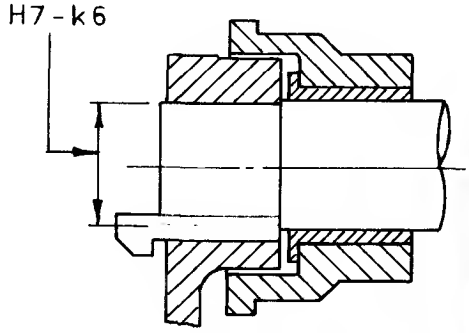
Complete the table for any three hole and shaft sizes.

| Hole H 7 0.001mm | | Over | Up to and including | Shaft k 6 0.001mm | |
|---|---|---|---|---|---|
| ES + | EI | | | es + | ei + |
| 15 | 0 | 6 | 10 | 10 | 1 |
| 18 | 0 | 10 | 18 | 12 | 1 |
| 21 | 0 | 18 | 30 | 15 | 2 |
| 25 | 0 | 30 | 50 | 18 | 2 |
| 30 | 0 | 50 | 80 | 21 | 2 |

Fit




Transition




| Hole | | | | | Shaft | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Basic size | ES | EI | Max. size | Min. size | Basic size | es | ei | Max. size | Min. size |
| | | | | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

Complete the table for any three hole and shaft sizes. Solns. p.161.

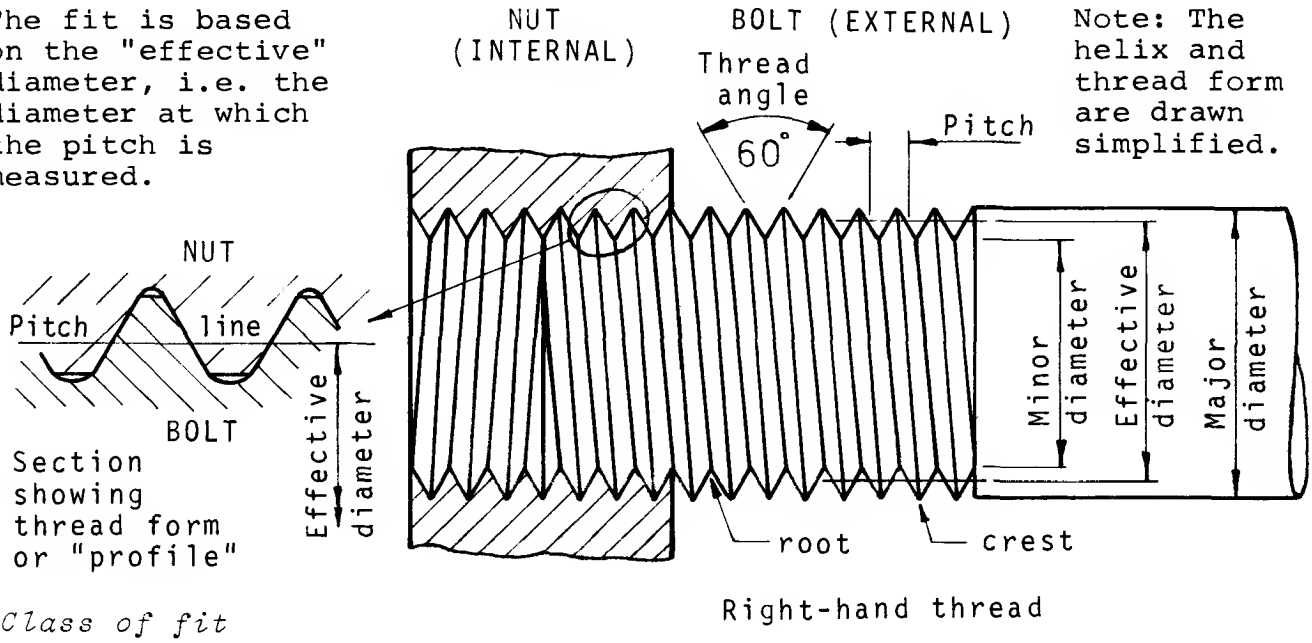
# ISO Metric Screw Threads (BS3643)

One of the most common items which needs to be clearly described on an engineering drawing is the screw thread which may be used for:

(1) Transmitting power, e.g. square thread in a vice or a lathe.
(2) Adjusting parts relative to each other (usually a Vee-thread).
(3) Fastening parts together, e.g. a nut and bolt (a Vee-thread).

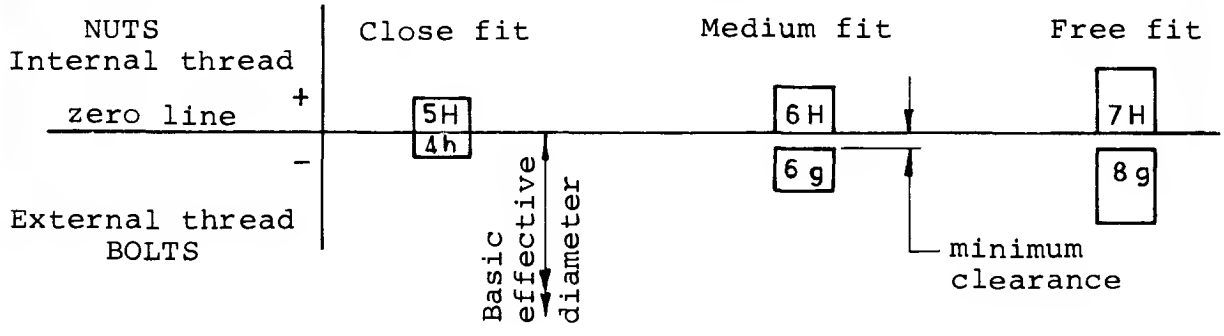
The following section deals mainly with the ISO metric thread which is recognized internationally and, over the next few years, will be used in preference to the many varied types of threads which exist in industry today. In order to specify an ISO metric thread on a drawing it is necessary to understand the basic terminology of screw threads and how the fit between internal and external threads is derived.

The fit is based on the "effective" diameter, i.e. the diameter at which the pitch is measured.




*Class of fit*

Although the thread profile is a Vee in section, the nuts are classed as "holes" and the bolts as "shafts" and tolerances are applied according to BS 4500 (Limits and Fits). They may be represented graphically like any hole and shaft combination.




Fit designated as → 5H/4h 6H/6g 7H/8g

Coarse and fine pitches are available but it is expected that the coarse pitch screw threads will suffice for most applications and that the medium fit will be the most commonly used. This may be summarized as follows:

| Class of fit | Bolts & screws | Nuts |
|---|---|---|
| medium | 6g | 6H |

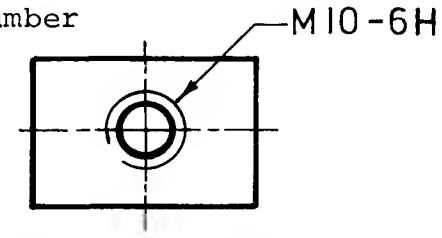
# ISO Metric screw thread designation

In production engineering it is necessary to provide information about the size of thread and the tolerance allocated to it. On a drawing, the thread would be "dimensioned" or designated by stating the information as shown in the following examples:

M 10 × 1.5 - 6H [NUT - capital H for hole or internal thread.]

M 10 × 1.5 - 6g [BOLT - small g for shaft or external thread.]

- 6g — Thread tolerance grade number
- 1.5 — Pitch in millimetres
- 10 — Nominal size in millimetres
- M — Symbol for ISO metric.




The ISO metric coarse is the thread most commonly used and a designation for this would omit the pitch, e.g. M 10-6H as shown.

| Isometric threads Preferred sizes | |
|---|---|
| Nominal diameter mm | Pitch coarse mm |
| 1.6 | 0.35 |
| 2 | 0.4 |
| 2.5 | 0.45 |
| 3 | 0.5 |
| 4 | 0.7 |
| 5 | 0.8 |
| 6 | 1 |
| 8 | 1.25 |
| 10 | 1.5 |
| 12 | 1.75 |
| 16 | 2 |
| 20 | 2.5 |
| 24 | 3 |

*Note*

In the table on the right, the inch and number sizes relate only approx-imately to the ISO metric sizes in the centre column. e.g. $\frac{5}{8}$ in actually equals

15.875 mm

13 ISO metric threads compared with 74 Imperial inch and number sizes

| UNC No. DIA | UNF No. DIA | ISO metric DIA mm | BA No. | BSW DIA | BSF DIA |
|---|---|---|---|---|---|
| | 0 | 1·6 | 10 | | |
| 1 | 1 | | | | |
| 2 | 2 | 2 | 9 | | |
| | | | 8 | | |
| 3 | 3 | 2·5 | | | |
| 4 | 4 | | 7 | $\frac{1}{8}$ | |
| 5 | 5 | 3 | | | |
| 6 | 6 | | 6 | $\frac{5}{32}$ | |
| 8 | 8 | 4 | 5 | | |
| | | | 4 | | |
| 10 | 10 | 5 | 3 | | $\frac{3}{16}$ |
| 12 | 12 | 6 | 2 | | |
| | | | 1 | | |
| $\frac{1}{4}$ | | 8 | 0 | | $\frac{1}{4}$ |
| $\frac{5}{16}$ | $\frac{3}{8}$ | 10 | | | $\frac{5}{16}$ $\frac{3}{8}$ |
| $\frac{7}{16}$ | $\frac{1}{2}$ | 12 | | | $\frac{7}{16}$ $\frac{1}{2}$ |
| $\frac{9}{16}$ | $\frac{5}{8}$ | 16 | | | $\frac{9}{16}$ $\frac{5}{8}$ |
| $\frac{3}{4}$ | $\frac{7}{8}$ | 20 | | | $\frac{3}{4}$ $\frac{7}{8}$ |
| 1 | | 24 | | | 1 |

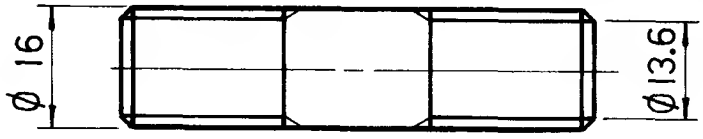
# Screw threads, nuts and bolts (ISO metric series)

A rapid, easy-to-remember method of drawing screw threads, nuts and bolts is essential if templates are not available. The drawing should look right and slight discrepancies in size are not important. The most used ISO metric bolts (up to ϕ24 mm) are:

| | M6 | M8 | M10 | M12 | M14 | M16 | M20 | M22 | M24 |
|---|---|---|---|---|---|---|---|---|---|
| Major diameter mm | 6·00 | 8·00 | 10·00 | 12·00 | 14·00 | 16·00 | 20·00 | 22·00 | 24·00 |
| Minor diameter | 4·77 | 6·47 | 8·16 | 9·85 | 11·55 | 13·55 | 16·93 | 18·93 | 20·32 |
| Minor diameter (approx.) | 4·8 | 6·5 | 8·2 | 9·8 | 11·6 | 13·6 | 17·0 | 19·0 | 20·4 |

Example of application

M 16 Stud




*Nut and bolt head sizes across the flats* (spanner sizes) in mm.

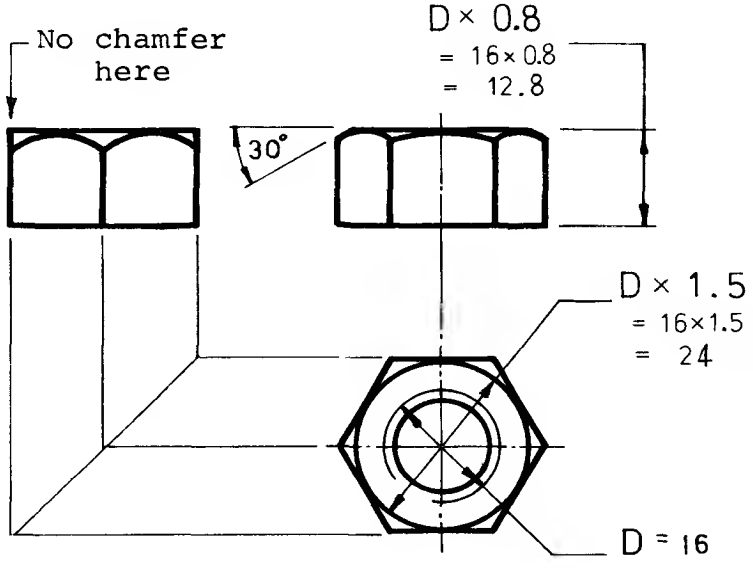
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Major diam. *D*. | 6 | 8 | 10 | 12 | 14 | 16 | 20 | 22 | 24 |
| Distance across the flats | 10 | 13 | 17 | 19 | 22 | 24 | 30 | 32 | 36 |
| *D* × 1·5 | | | | | → | 24 | 30 | 33 | 36 |
| (*D* × 1·5) + 1 mm → | 10 | 13 | 16 | 19 | 22 | | | | |
| Thickness of nut | 5·0 | 6·5 | 8·0 | 10·0 | 11·0 | 13·0 | 16·0 | 18·0 | 19·0 |
| Height of head | 4·0 | 5·5 | 7·0 | 8·0 | 9·0 | 10·0 | 13·0 | 14·0 | 15·0 |

*Approximate method*: Thickness of nut = *D* × 0·8 e.g. M10
Height of head = *D* × 0·7 e.g. M10

Example of application

M 16 Nut

Nuts are usually made from hexagonal stock bar and a 30° chamfer is machined on at least one surface.
In the plan view this appears as a circle, the diameter of which is equal to the distance across the flats.
The chamfer is drawn in the front view but not in the side view.



# Nuts and bolts exercises

The drawing below is of an M 24 nut showing how the radii in the front view and side view may be constructed. The major diameter of the bolt is the size $D$ for calculating the distance across the flats and the thickness of the nut.

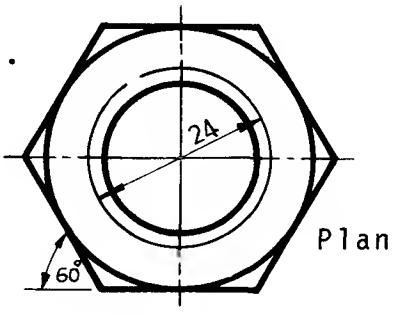
Major diameter $D$ = 24 mm
Minor diameter = 20·4 mm approx. (See p.93).

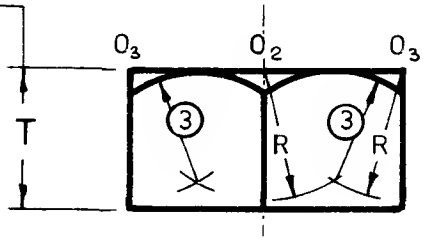
$D \times 1{\cdot}5 = 24 \times 1{\cdot}5 = 36$ mm A/F

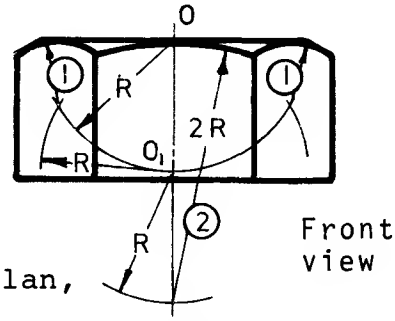
and $R$ = 18 mm - this value of $R$ is used to find the centres for radii (1), (2) and (3)

$D \times 0{\cdot}8 = 24 \times 0{\cdot}8 = 19{\cdot}2$ mm

$T$ = 19·2 mm

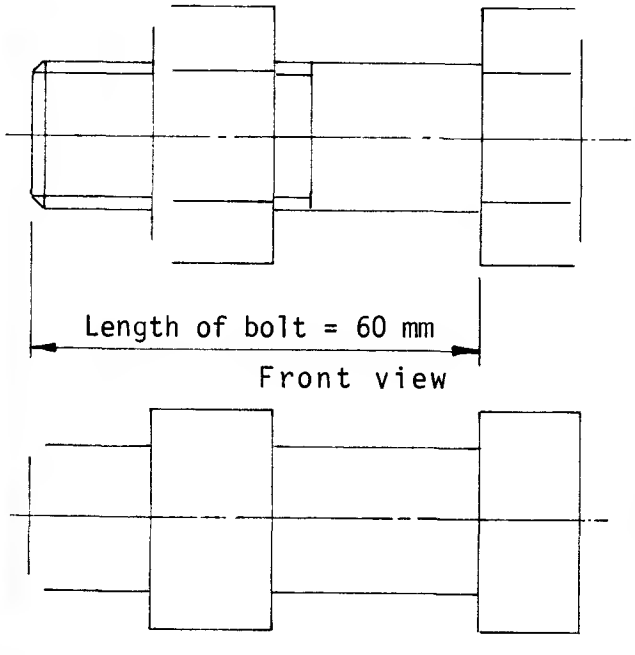


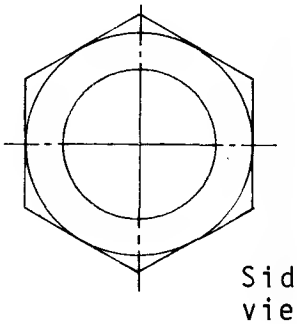

*Procedure*

(1) Draw major and minor diameter circles in plan, according to BS convention (See page 38).
(2) Set out circle in plan with radius = 18 mm, i.e. distance A/F.
(3) Construct hexagon around this circle using 60° set-square.
(4) Set out thickness of nut = 19·2 mm and project the hexagon to the front and side views.
(5) In the front view the centres for the radii marked (1) and (2) are obtained by setting out the radius $R$ = 18 mm from O and $O_1$ as shown.
(6) In the side view the centres for the radii marked (3) are obtained by setting out the radius $R$ from $O_2$ and $O_3$ as shown.




Note:

The length of a bolt is measured from under the head as shown.




*Exercise*

M 20 Bolt with nut.

1. Verify that

(*a*) minor diameter = 17·0 mm
(*b*) distance across flats = 30·0 mm
(*c*) thickness of nut = 16·0 mm
(*d*) height of bolt head = 14·0 mm (approx.)

2. Complete the drawing.

# Assembly Drawings

The purpose of an assembly drawing is to provide visual information about the way in which parts of a machine or structure fit together. There are several types of assembly drawings and the differences in presentation depend on the uses for which they are intended. They are:

(1) LAYOUT ASSEMBLIES - in which the designer places together all the various parts in order to establish overall sizes, distances, etc., and, as a result, the feasibility of his design.

(2) OUTLINE ASSEMBLIES - these give general information about a machine or a group of components, for example, main sizes and centre distances which would show how the unit would be installed. This type of assembly is often used in catalogues giving details of the range of units offered for sale.

(3) GENERAL ASSEMBLIES or ARRANGEMENT DRAWINGS - show clearly how components fit together and, more important, how the assembled unit functions. Outside views, sectional and part-sectional views may be used but dimensions are rarely needed. The various parts may be labelled by ballooning and a parts list would complete the drawing.

(4) SUB-ASSEMBLIES - are drawings which show only one unit of a multi-unit component. On more complicated or multiple part components it may first be necessary to arrange parts into sub-assemblies which are then built up into the main assembly.

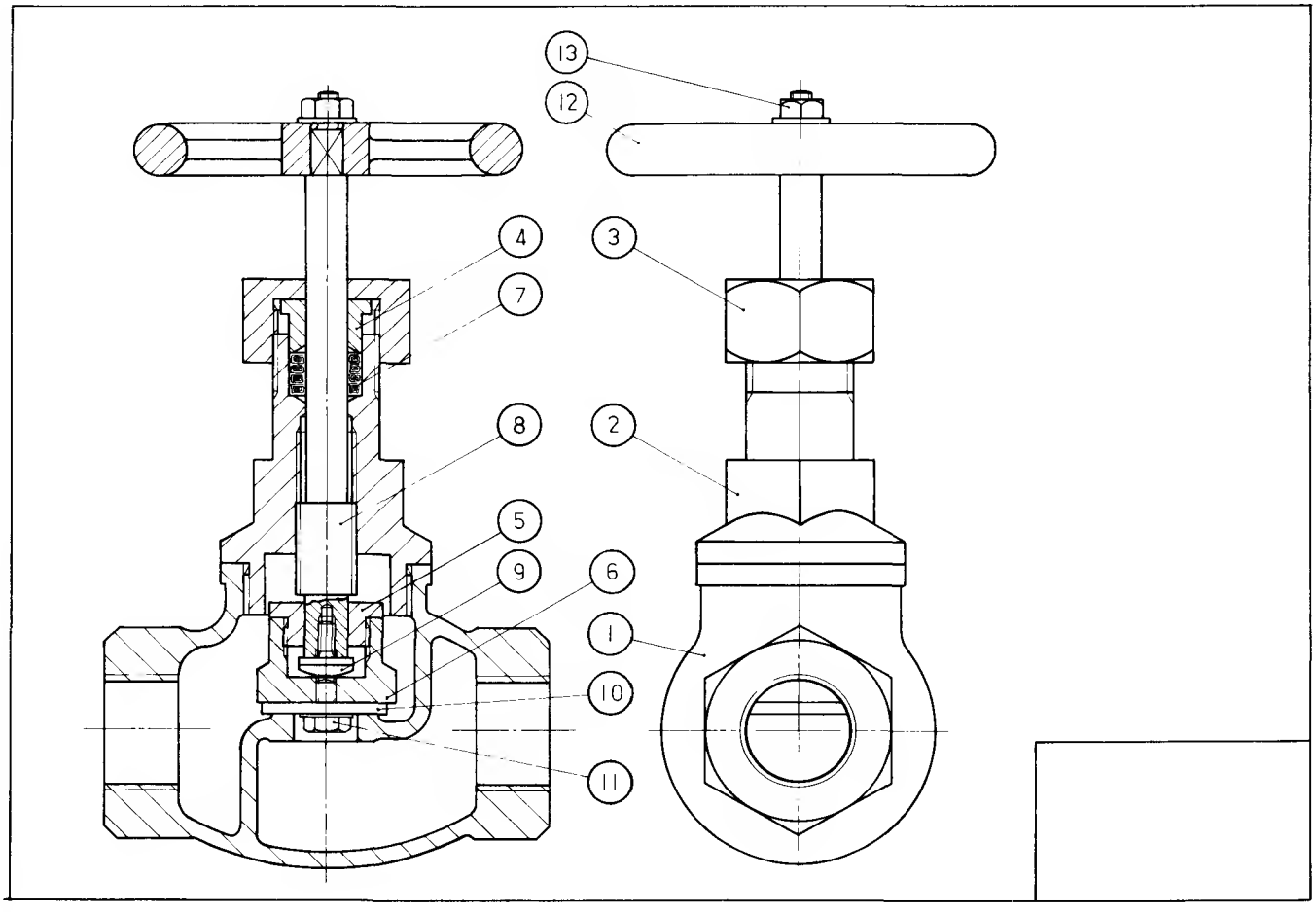
(5) SECTIONED ASSEMBLIES - a simple assembly may be drawn without the need for sectional views and be clearly understood. On more complex assembly drawings, however, too many hidden detail lines tend to confuse and a sectional view of the assembled parts conveys the information more clearly.

*Note* An assembly drawing should not be overloaded with detail. The correct place to fully dimension and describe a single part is on a detail drawing.

The drawings shown on the next page are typical of the use of a general assembly to give a general picture of a valve and a sub-assembly to show how the spindle unit is built up. A detail drawing of one of the parts is added to emphasise that the physical assembly of the valve depends on the manufacture of a large number of individual items.

The exercises which follow are of relatively simple assemblies which could be drawn with reasonable clarity without the use of sections but the resulting increase in clarity will show the advantage to be gained by their use.

The solution to the example on page 98 indicates the way in which the exercises should be carried out.

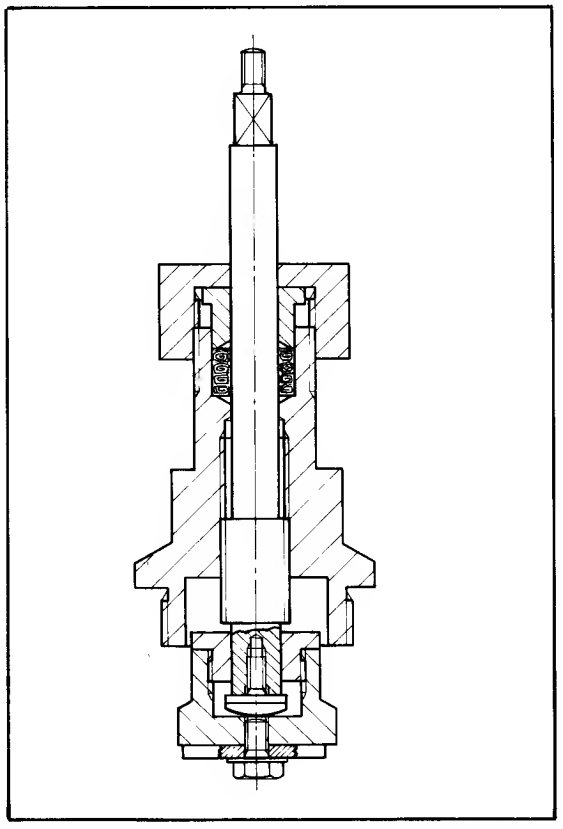


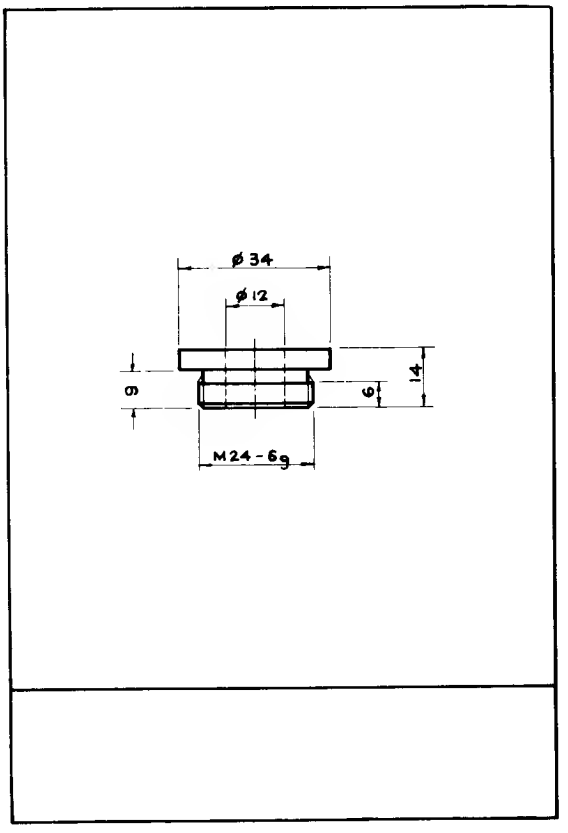

# General assembly (or General arrangement)

The above drawing is a general assembly of a screwdown valve used to control the flow of water.

The purpose of this sectional view is to label the various parts of the valve and to show how they fit together. A parts list which matches the ballooned letters is necessary and this may be either on the assembly drawing or on a separate document.

The general assembly is not dimensioned in detail although the sizes of the inlet and outlet and a few overall sizes may be shown as the drawing may be typical of a range of valves of differing sizes.





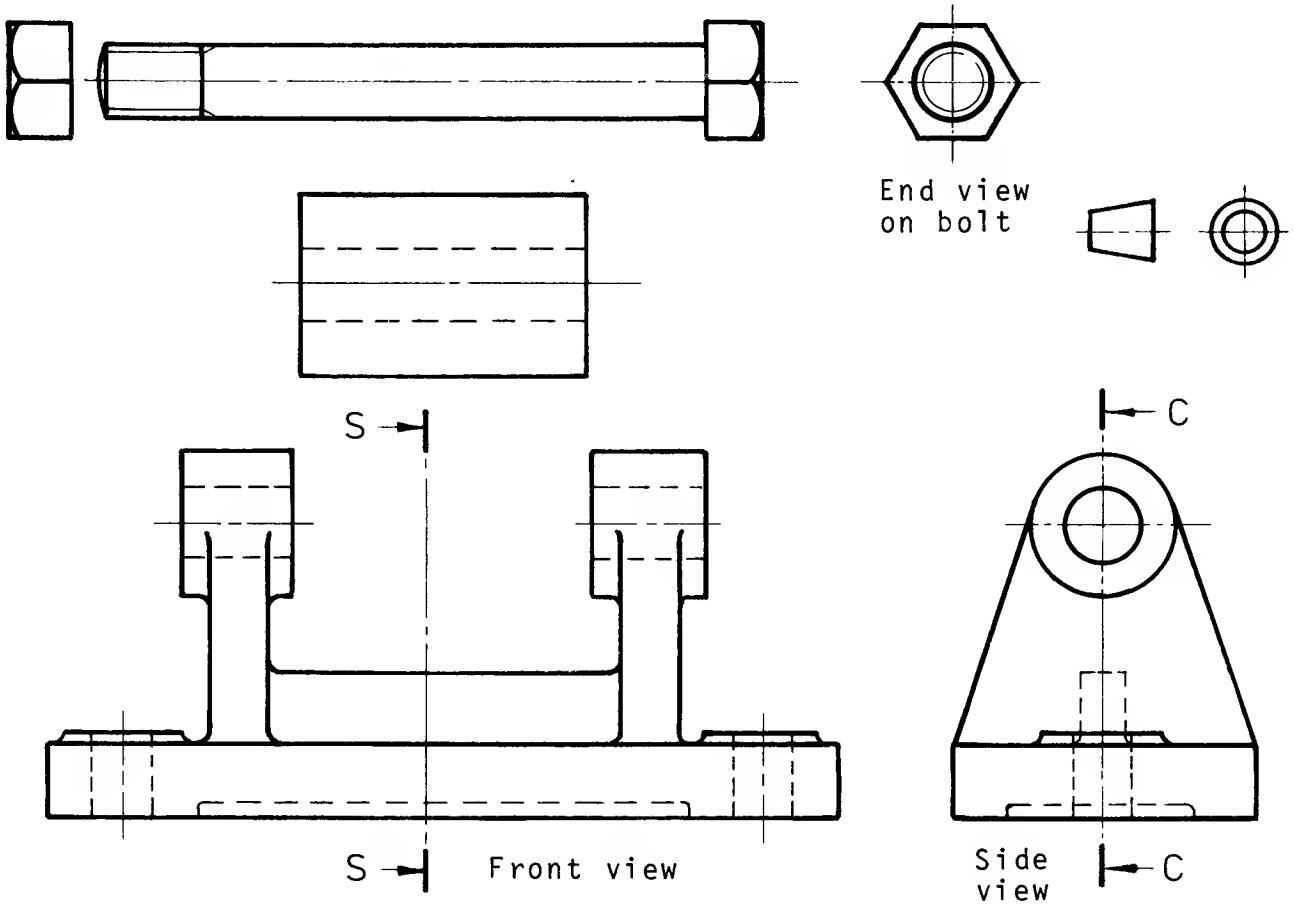

SUB-ASSEMBLY

The above sub-assembly drawing shows how several parts are assembled together before being fitted into the main body of the valve. This type of drawing is particularly useful if information more detailed than that shown on the general assembly is required, for example, by the person assembling the valve or the maintenance worker.

DETAIL DRAWING

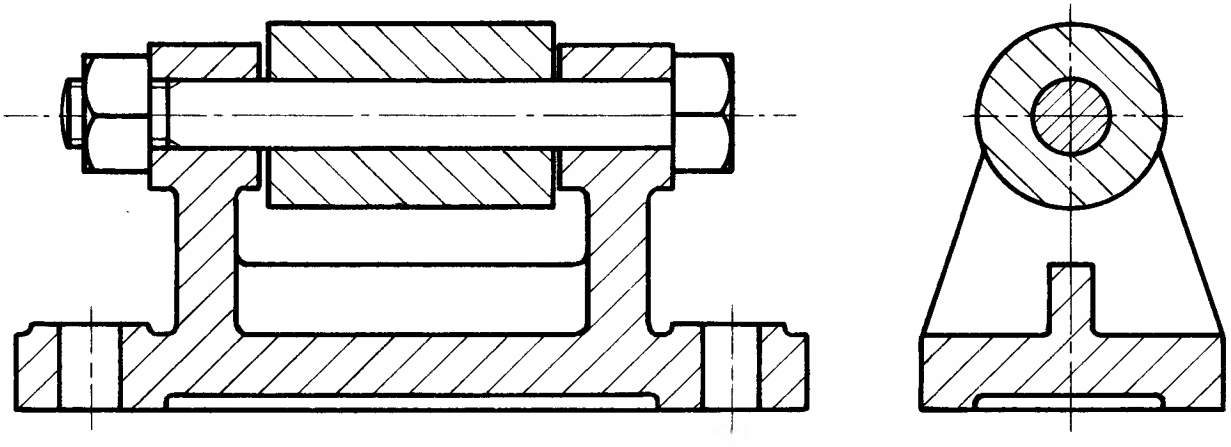
The detail drawing shown above is of one of the numerous components which make up the complete valve and in this case is a single-part drawing.
All the dimensions and processes required to manufacture the part must be shown on the drawing. It is probable that the machinist who makes this item will take no part in assembling the valve and will therefore use only this detail drawing.

# Sectioned assembly - Typical exercise




*Exercise* Build up a sectioned assembly drawing of the component parts looking on cutting plane CC to obtain a sectional front view and cutting plane SS to obtain a sectional end view, by tracing over and correctly positioning each part.

*Solution* Note that most of the outlines are unaltered.



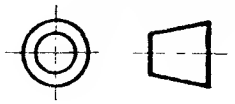
Sectional Front View looking on cutting plane CC

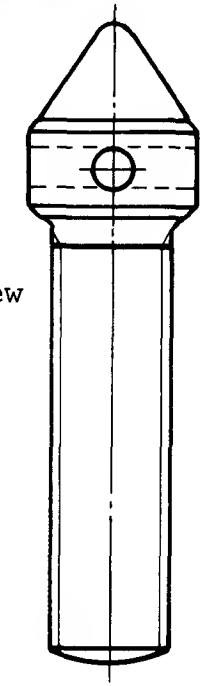
Sectional End View looking on cutting plane SS.

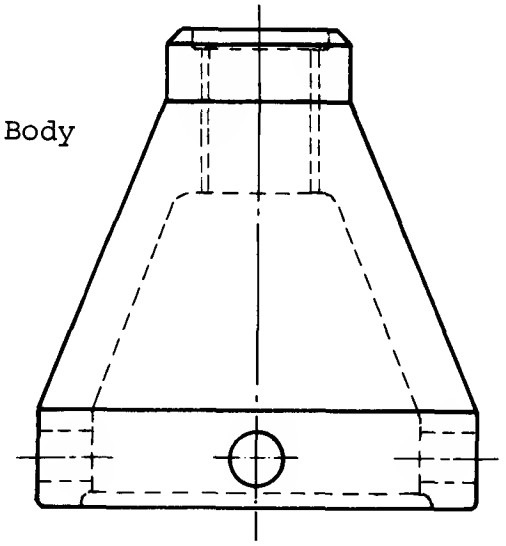
*Note* The bolt and rib are <u>not</u> sectioned in the front view, but <u>are</u> sectioned in the end view.

# Sectioned assembly exercises

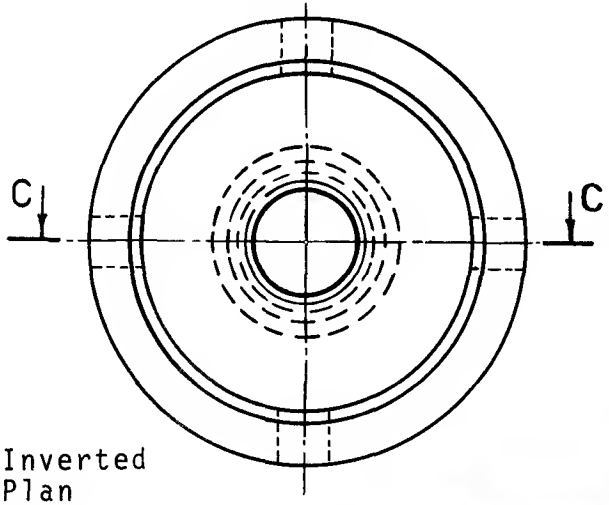
SCREW-JACK






Front View



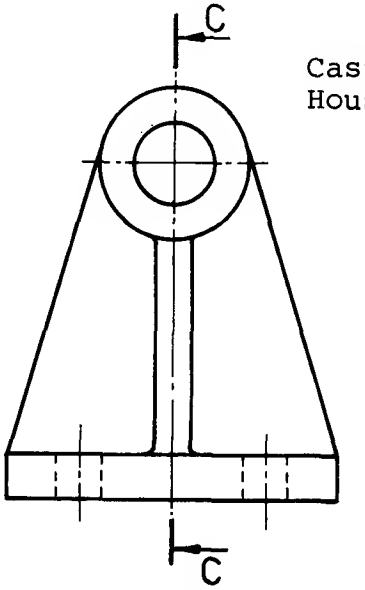

Inverted Plan

*Exercise*

Build up a sectioned assembly drawing of the component parts looking on the cutting plane CC by tracing over and correctly positioning each part.

Solution on page 162

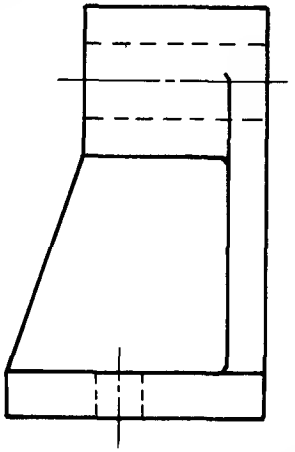
1

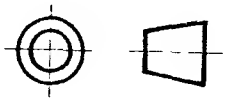



Front View

Cast Iron Housing

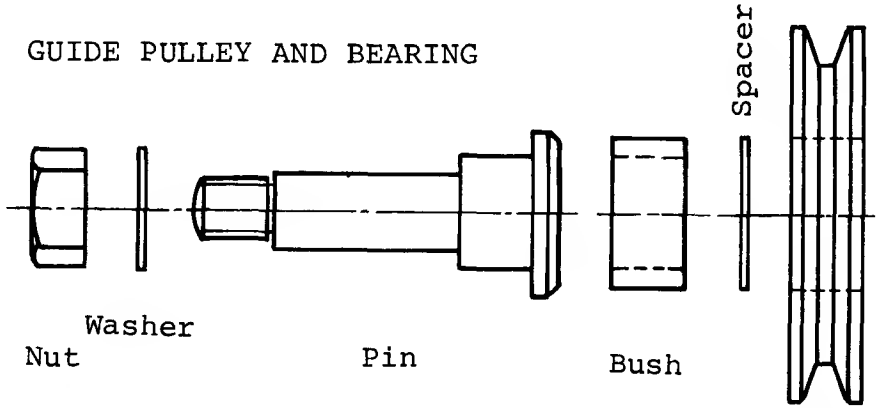
Pulley on this side





Side View

GUIDE PULLEY AND BEARING




*Exercise*

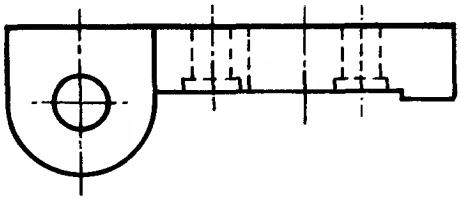
Build up a sectioned assembly drawing of the component parts looking on the cutting plane CC by tracing over and correctly positioning each part.

Solution on page 162

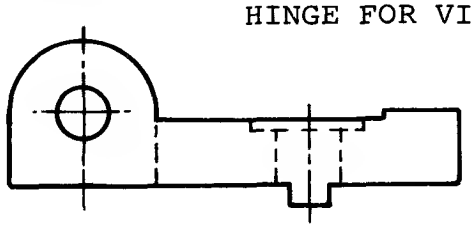
2

# Sectioned assembly exercises

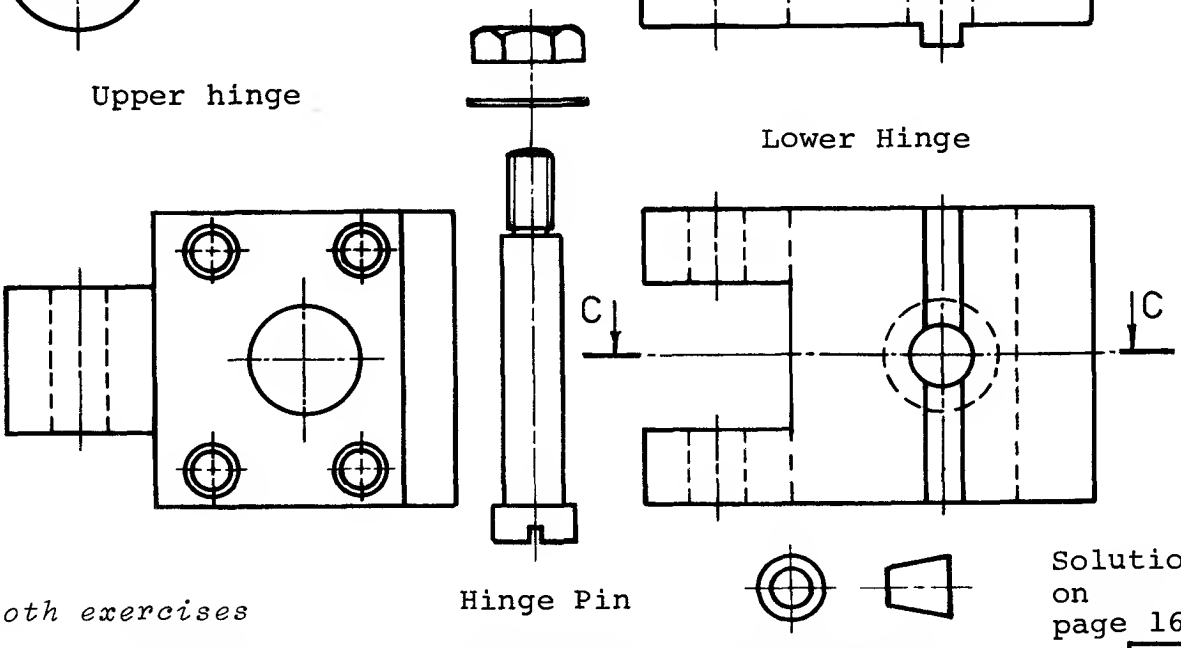
HINGE FOR VICE



Upper hinge



Lower Hinge




Hinge Pin



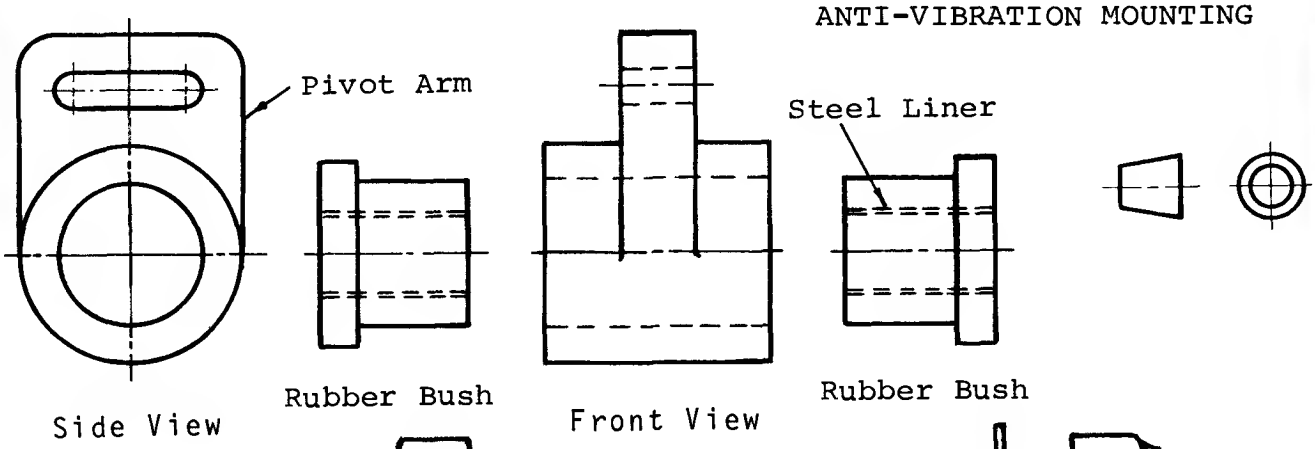
Solution on page 162

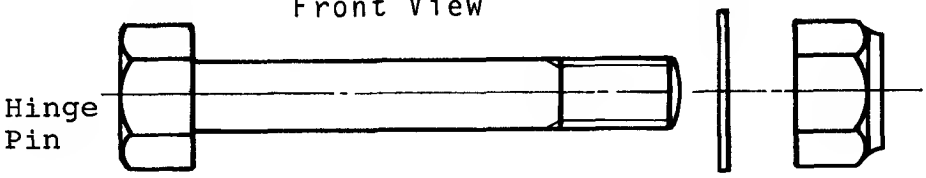
*For both exercises*

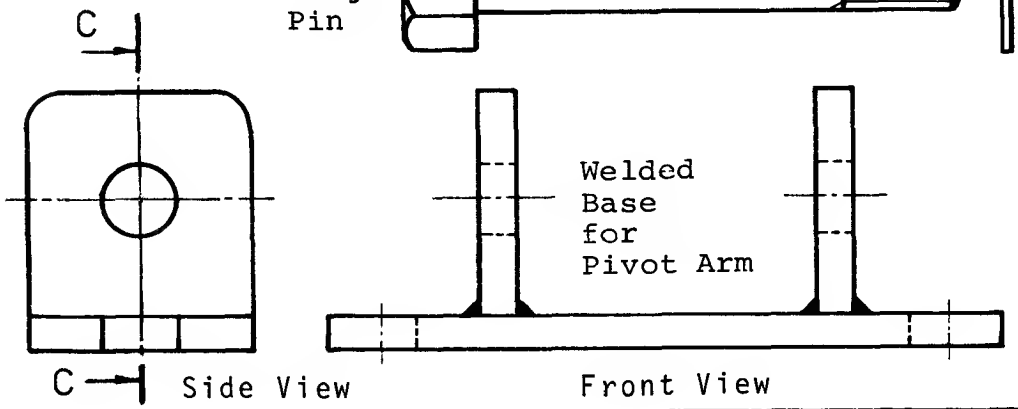
Build up a sectioned assembly drawing of the component parts looking on the cutting plane CC by tracing over and positioning each part.

3

ANTI-VIBRATION MOUNTING



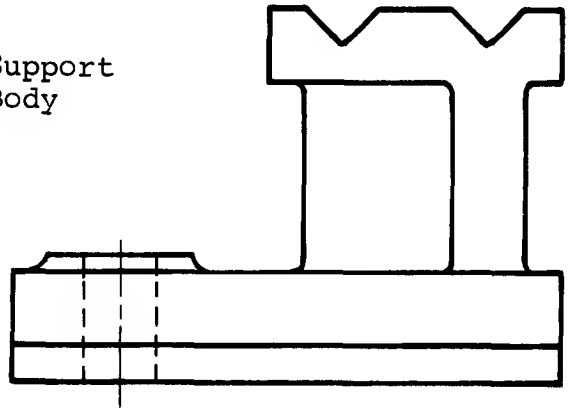




Solution on page 163

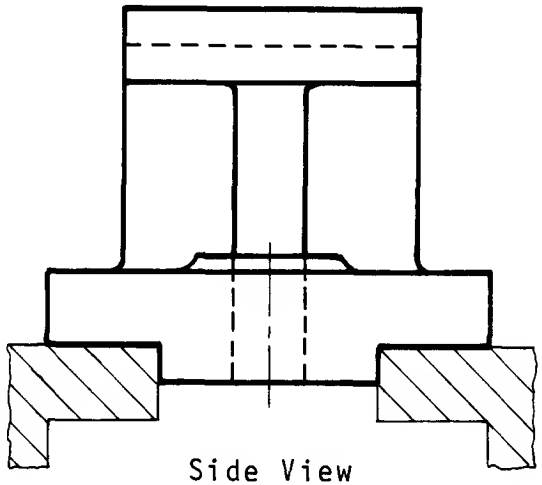
4

# Sectioned assembly exercise

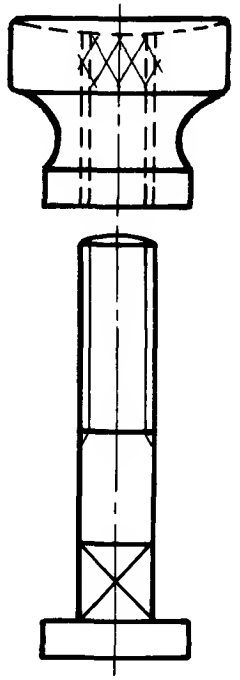
MOVABLE SUPPORT FOR
LABORATORY EQUIPMENT



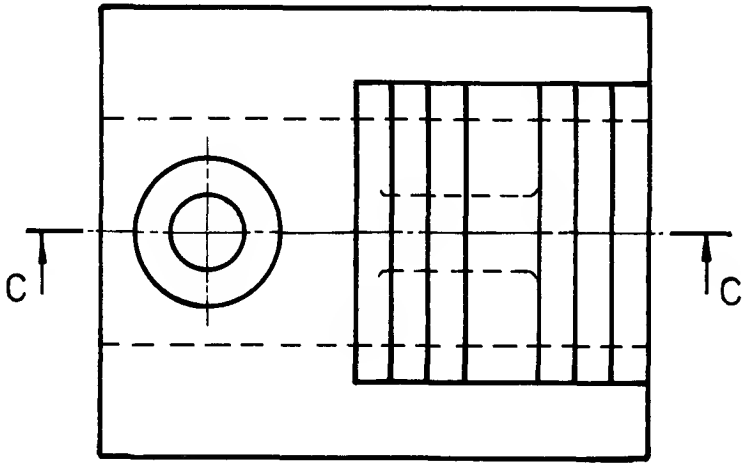

Front View



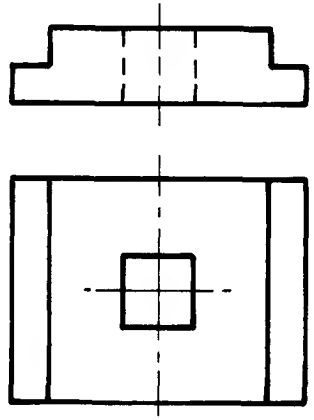
Side View




Clamp Pin




Plan

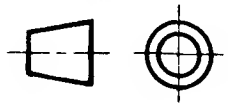


Clamp Plate

*Exercise*

Build up a sectional assembly drawing of the component parts looking on the cutting plane CC by tracing over and correctly positioning each part.

*Note* Show the hand clamp nut sectioned on the right hand of the centre line only.



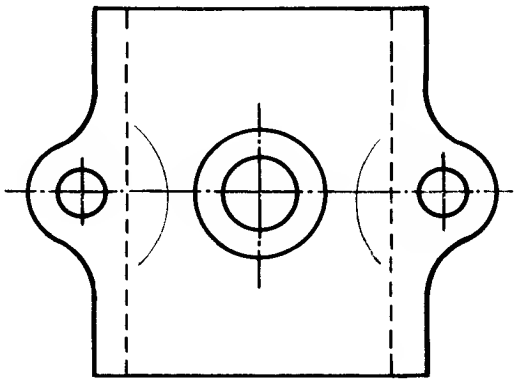
Solution
on
page 163

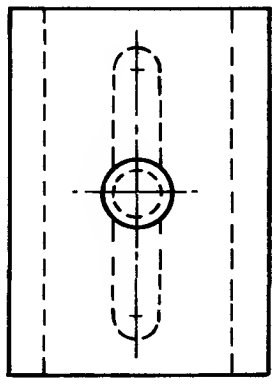
5

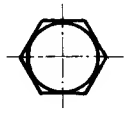
# Sectioned assembly exercise

JOURNAL BEARING

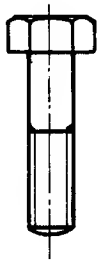
Washer
2 required

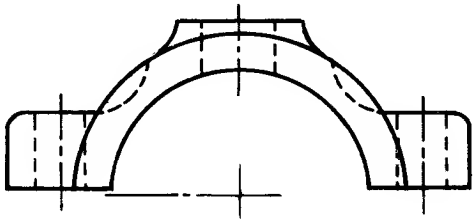




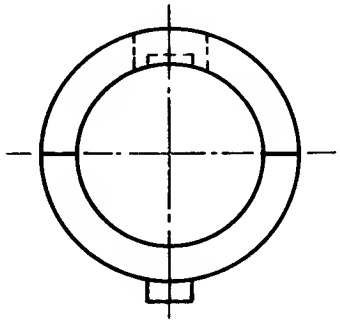


Split
bearing

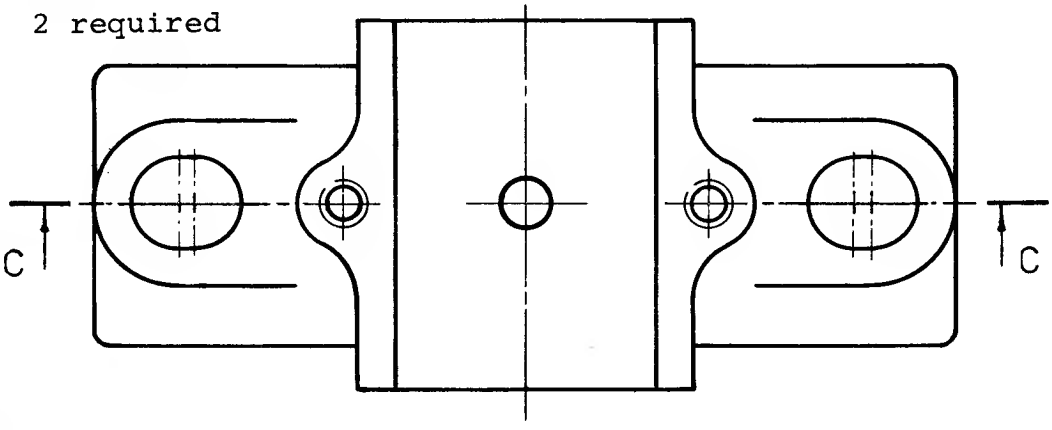




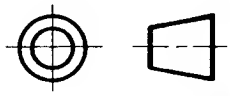
Bearing Cap

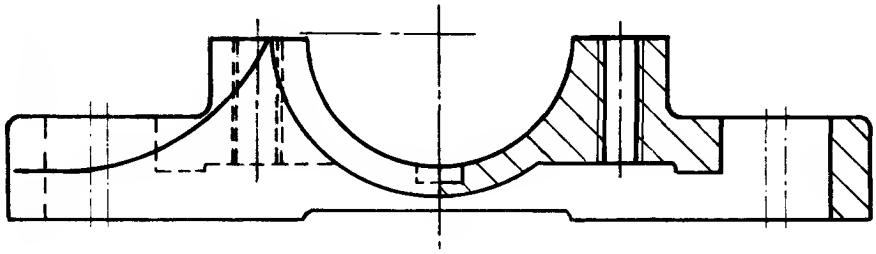


Bolt
2 required




Bearing
Housing





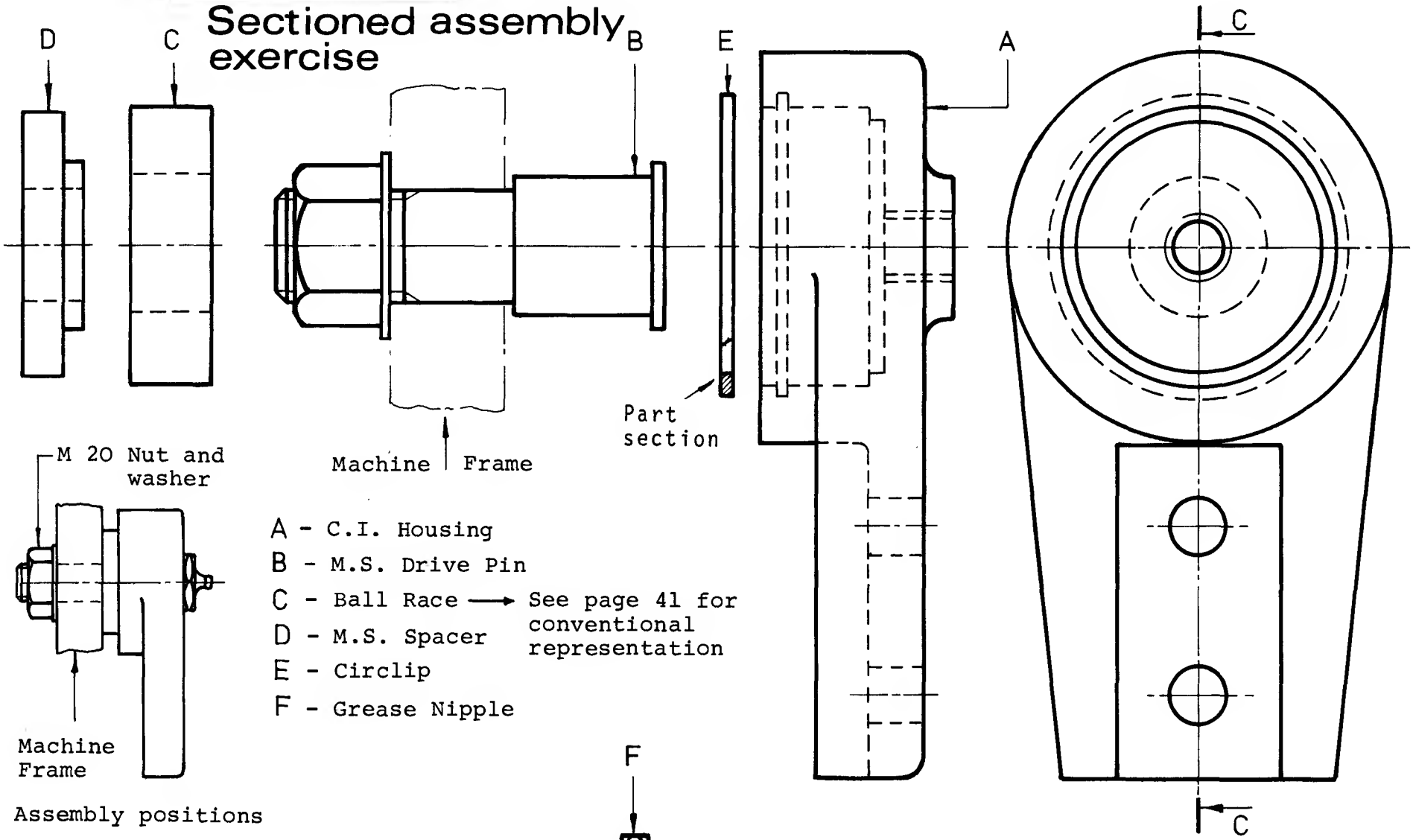
Front view with R.H. half in section

Solution
on
page 163

*Exercise* Build up a sectioned assembly drawing of the component parts looking on the cutting plane CC by tracing over and correctly positioning each part.

6

# Sectioned assembly exercise



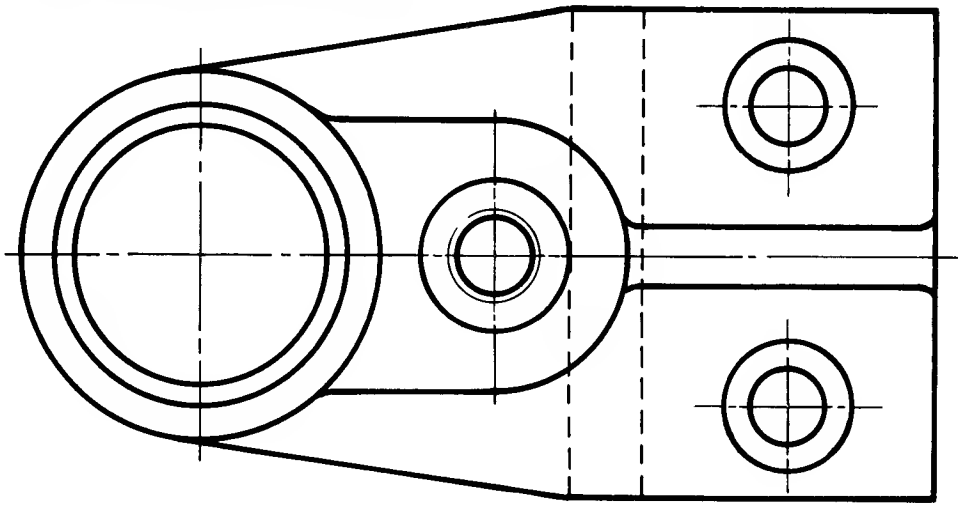

Assembly positions

*Exercise*

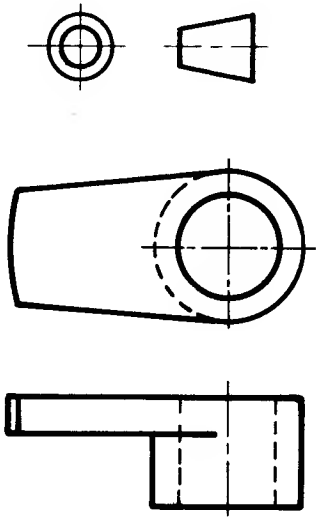
Build up a sectioned assembly drawing of the component parts looking on cutting plane CC by tracing over and correctly positioning each part.

Solution on page 164

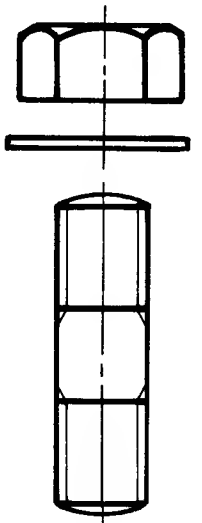
# Sectioned assembly exercise



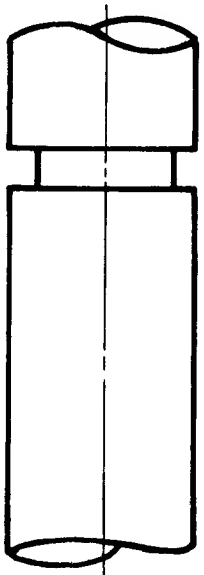
Plan



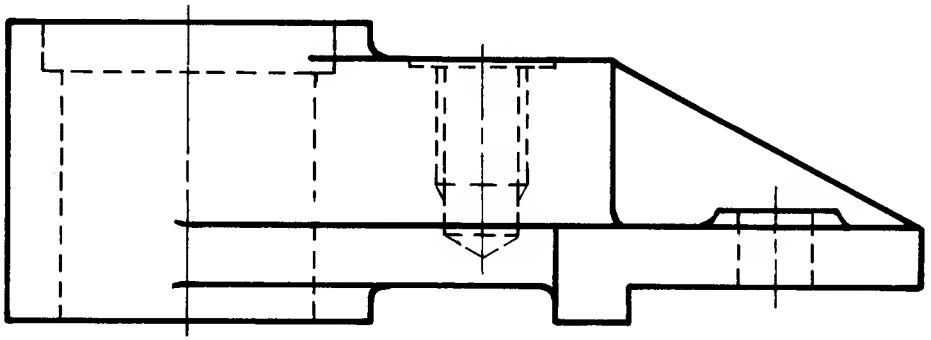
Stop Arm



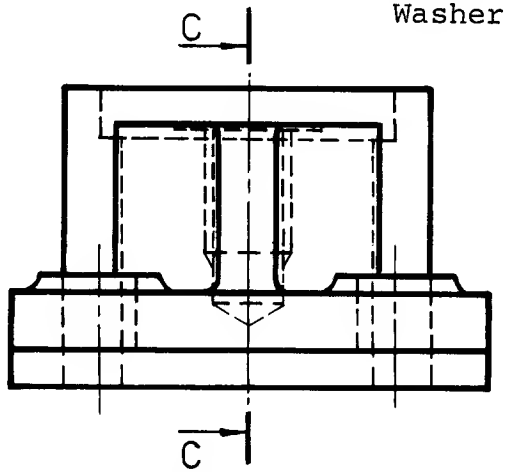
Stud,
Nut
Washer



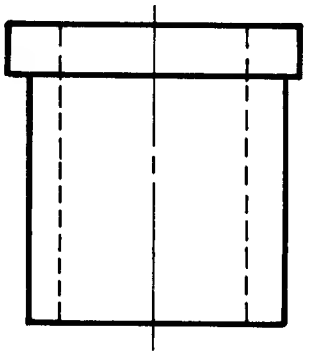
Spindle



Front View




Side View



Bush

*Exercise* Build up a sectioned assembly drawing of the component parts looking on cutting plane CC by tracing over and correctly positioning each part.

VERTICAL SPINDLE SUPPORT BRACKET

Solution on page 164

# Developments

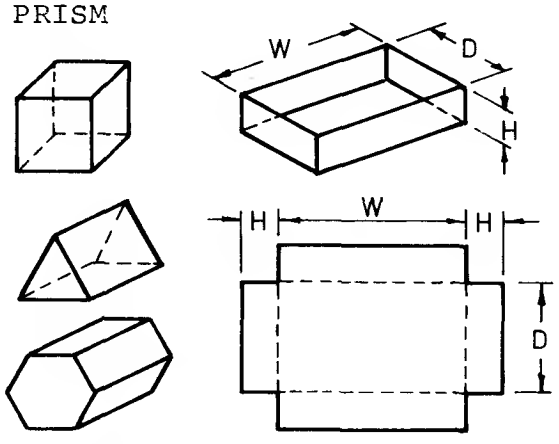
Many objects in everyday use are made from thin materials such as cardboard, plastic, aluminium, copper, brass and steel. Metals not more than about 3 mm thick are referred to as SHEET METALS.

The objects made from these materials are developed from the flat sheet. A pattern is drawn on the sheet which is then cut to the outline of the pattern. The material is bent, folded or rolled into the required shape, these processes giving the object stiffness and strength for a comparatively small weight of material.

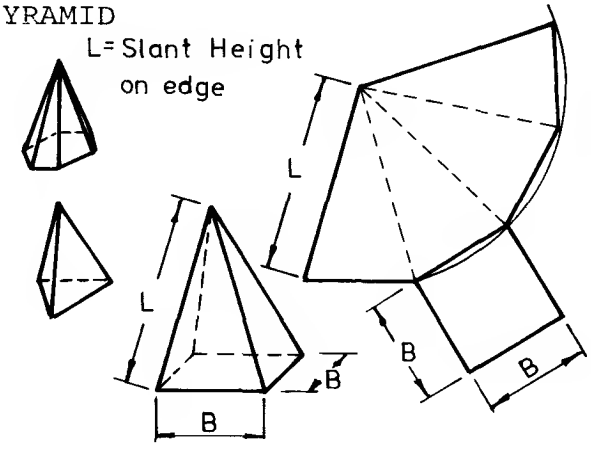
A pattern which is used to mark out further patterns is called a TEMPLATE.

There are four basic shapes in sheet metal development from which a wide variety of work is fashioned, including hoppers, bins, chutes, vessels and ducts for ventilation and dust-extraction.

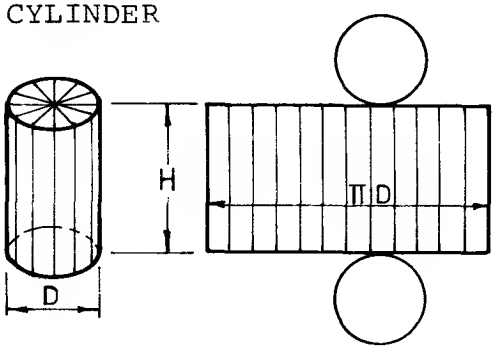
1. PRISM



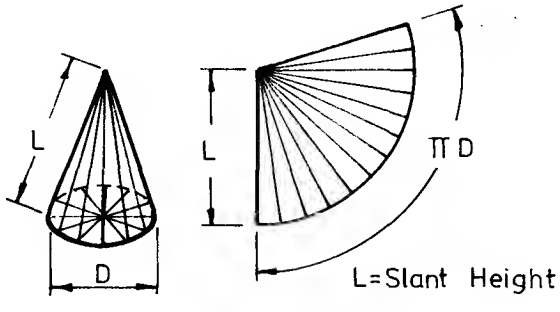

2. PYRAMID




3. CYLINDER




4. CONE




Simple shapes based on prisms, cylinders, pyramids and cones may be developed by three commonly used methods of construction. They are

1. PARALLEL LINE DEVELOPMENT: for prisms and cylinders mainly.

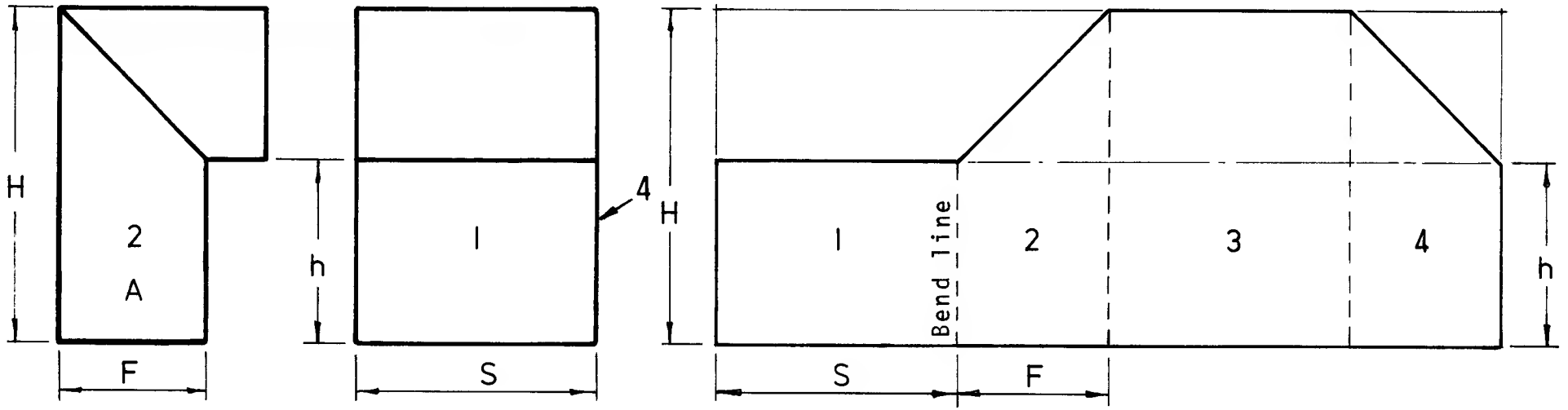
2. RADIAL LINE DEVELOPMENT: for pyramids and cones.

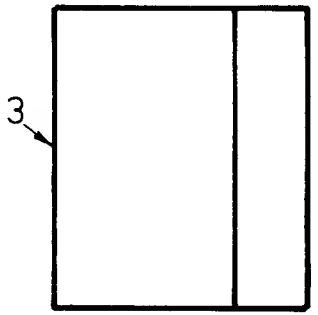
3. TRIANGULATION: for transition pieces which are used to join different shapes.

A pattern is usually folded so that the lines indicating its shape appear on the inside of the component. In practice, allowances may have to be made for extra material required for joints, stiffened edges, bends and seams.

No such allowances have been made in the exercises in the following pages so that basic principles can be emphasized.

# Parallel line development

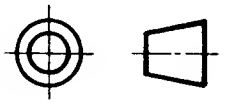



Inverted Plan

The pattern for part or "branch" A is developed as shown above. Lengths and heights are taken from the orthographic views.

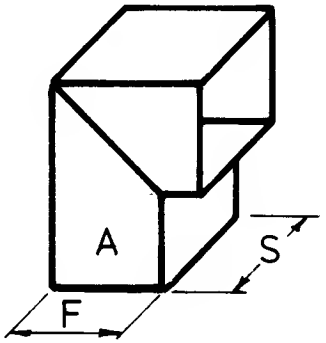
Bend lines are indicated by broken lines which are parallel to the edges from which they are projected.

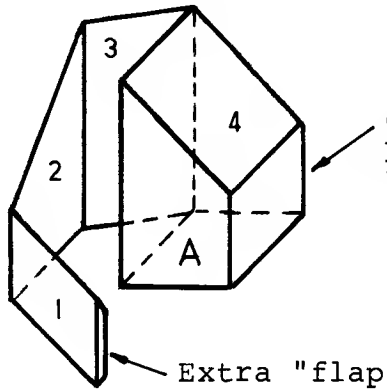


90° ELBOW

RECTANGULAR SECTION

All dimensions in millimetres.



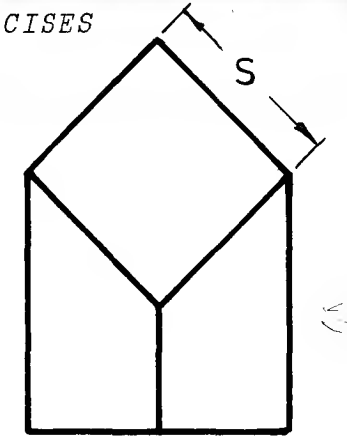

Seam at shortest edge, if possible, for economy of time and materials.

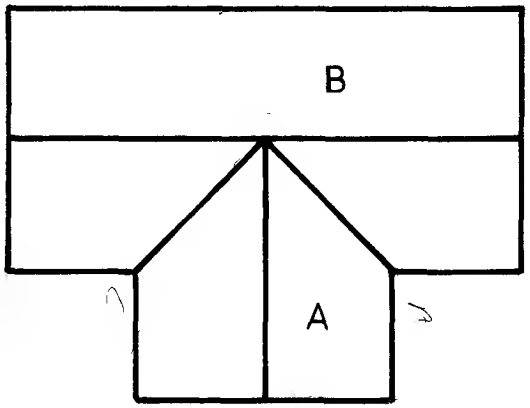
Extra "flap" for joint may be required.

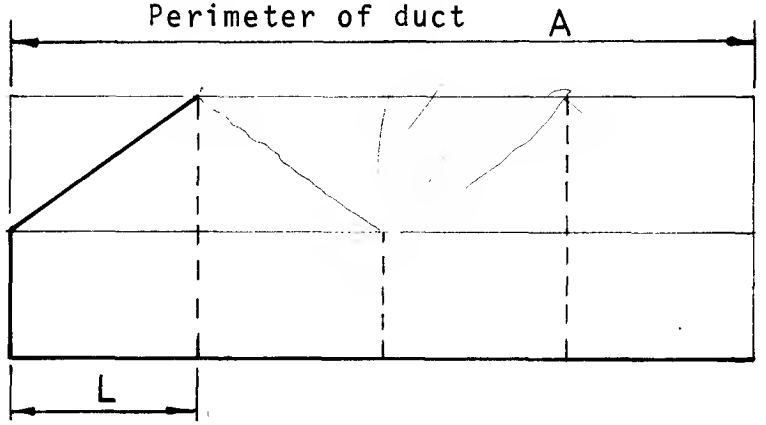
Typical example and solution.

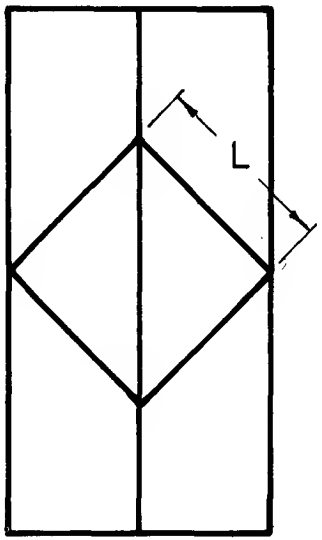
PARALLEL LINE DEVELOPMENT

*EXERCISES*

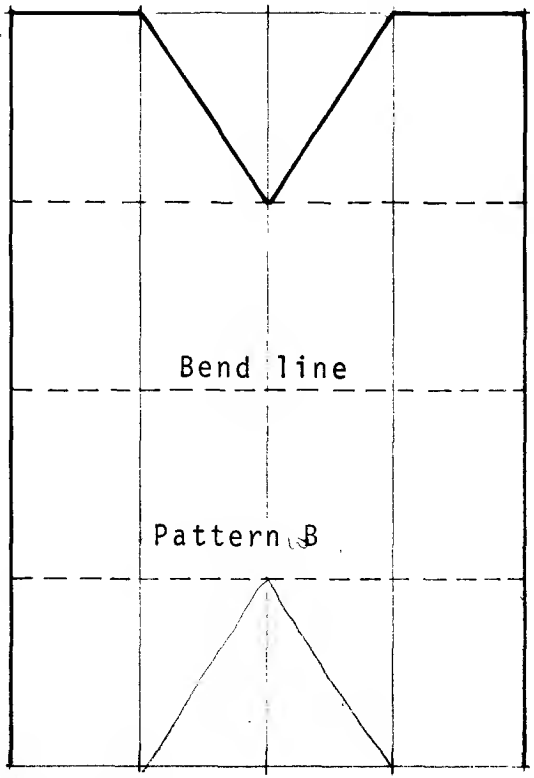



Inverted Plan

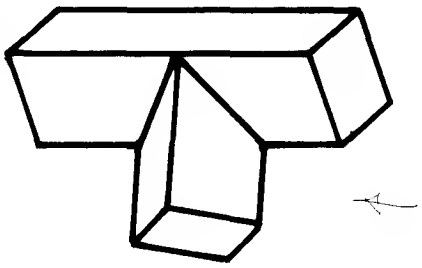



(1) Complete the pattern for part A in the space provided above.

(2) Complete the pattern for part B in order to find the shape of the hole in B.

Measure the views to obtain sizes.

Note: The cross-sections of A and B are the same, i.e. a square section inclined at 45°



All dimensions in millimetres.

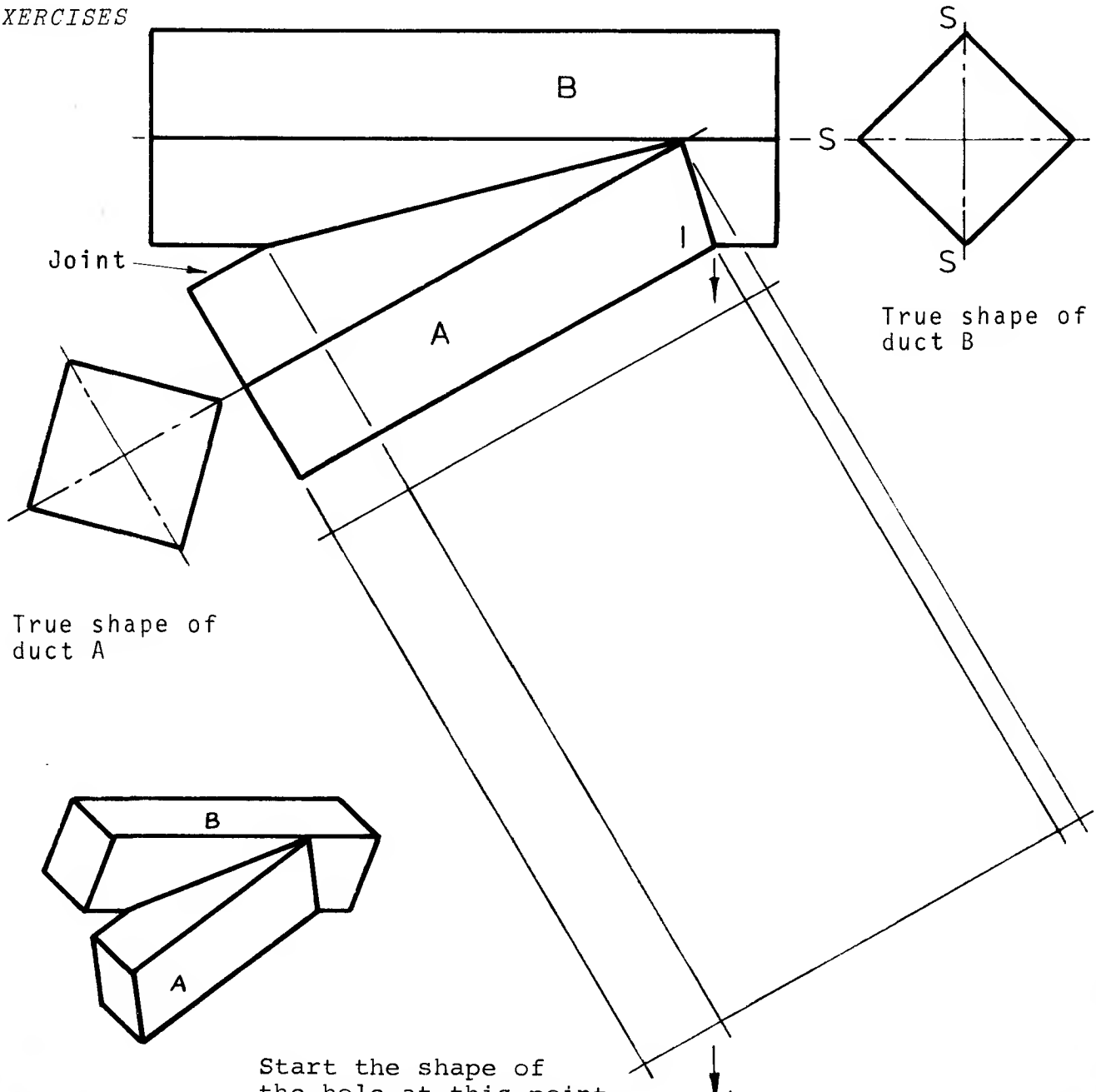
90° TEE-PIECE

DIAMOND SECTION

PARALLEL LINE DEVELOPMENT

Solutions on p.165

*EXERCISES*




Solutions on p.166

(1) Develop the pattern for branch A.

(2) Develop the pattern for one half of branch B (SSS) to find the true shape of half of the hole.

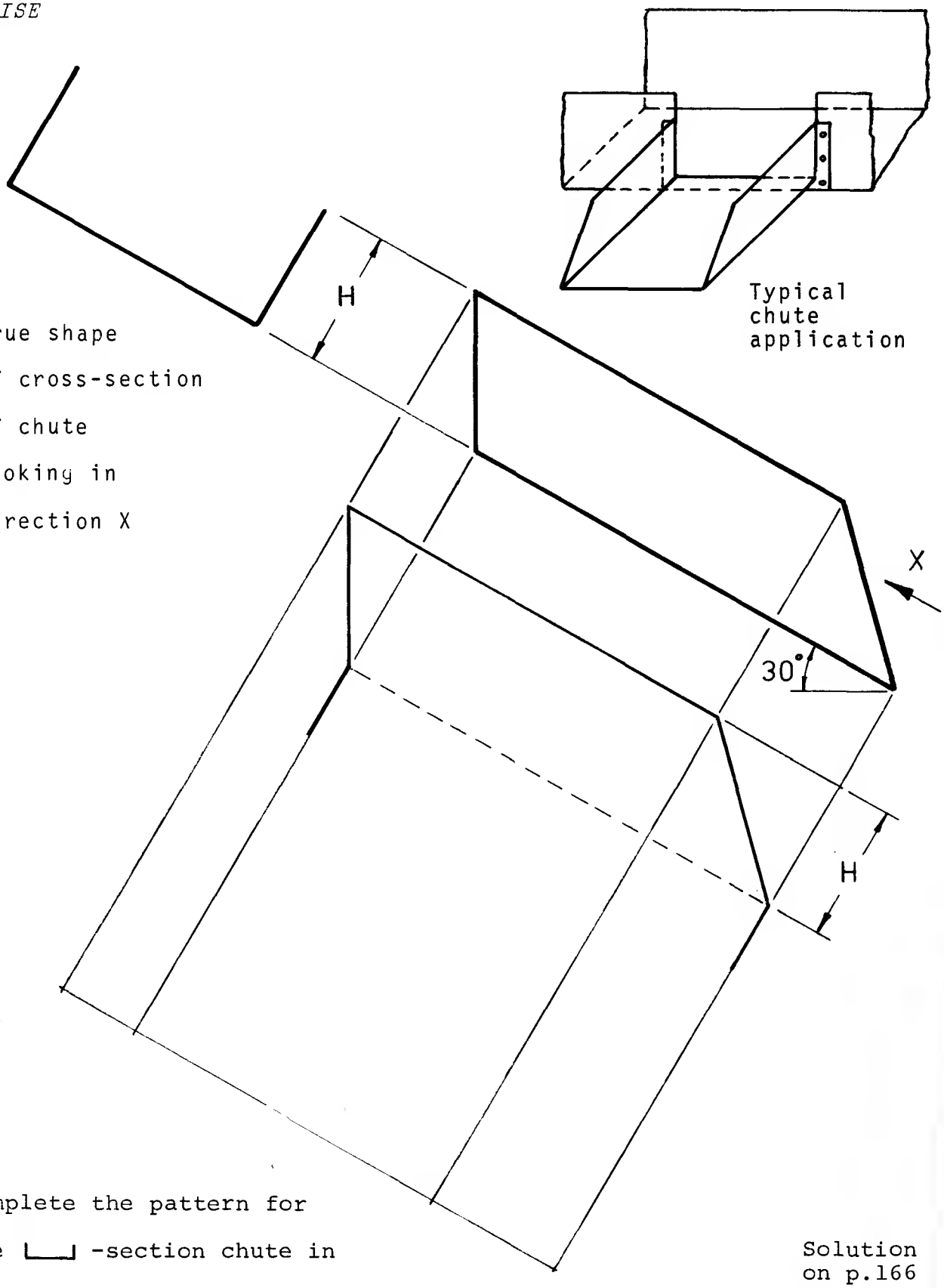
Measure the orthographic views to obtain dimensions.

All dimensions in millimetres.

30° TEE-PIECE DIAMOND SECTION

PARALLEL LINE DEVELOPMENT

*EXERCISE*




Typical chute application

True shape of cross-section of chute looking in direction X

Complete the pattern for the ⌊⎽⎽⌋-section chute in the space provided.

Measure the orthographic views to obtain dimensions.

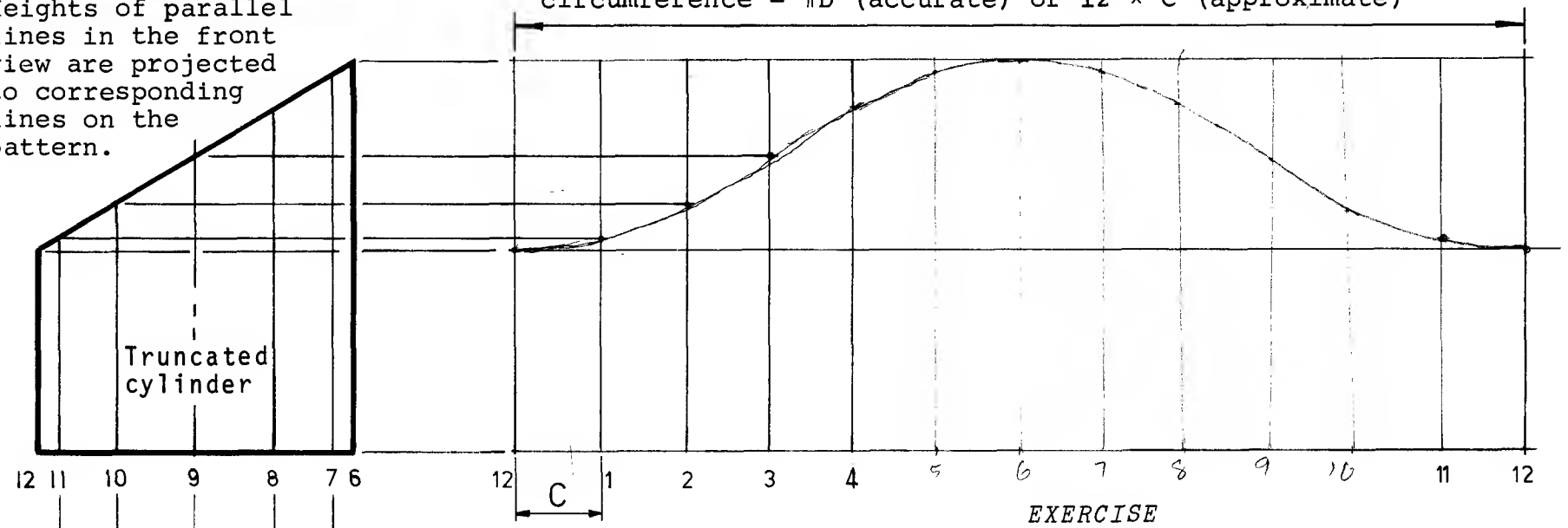
All dimensions in millimetres.

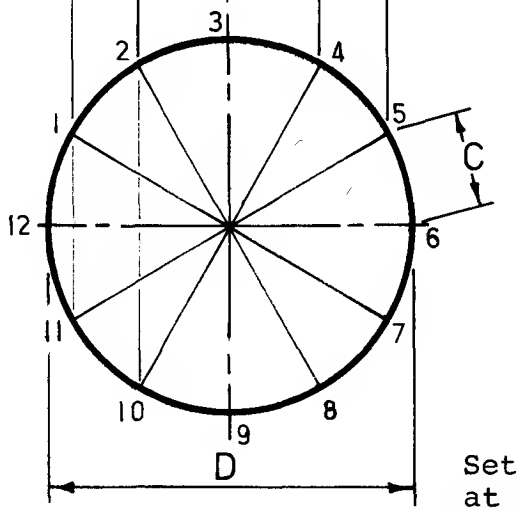
Solution on p.166

⌊⎽⎽⌋-SECTION CHUTE

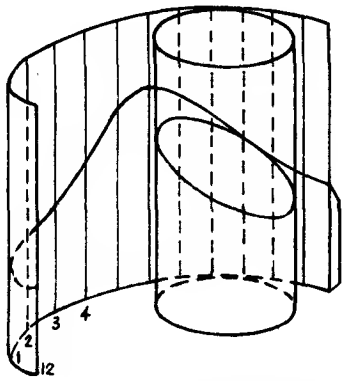
PARALLEL LINE DEVELOPMENT

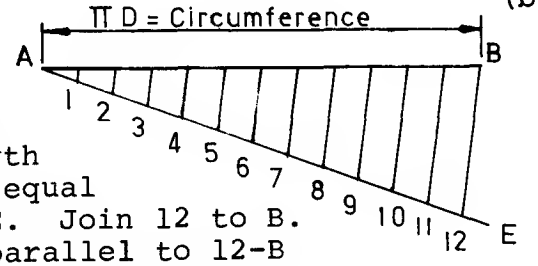
Heights of parallel lines in the front view are projected to corresponding lines on the pattern.




Divide the plan into 12 equal parts using a 30° set-square.




Set out AE at any angle and any length
Mark out 12 equal spaces on AE. Join 12 to B.
Draw lines parallel to 12-B to give 12 equal divisions on AB.

*EXERCISE*

(1) Complete the pattern for the truncated cylinder.

All dimensions in millimetres.

NOTE: Divide the pattern into 12 equal parts by:

(a) the geometrical method shown OR

(b) "stepping off" the distance C from the plan view 12 times along the base of the pattern.

Method (a) is more accurate than method (b).

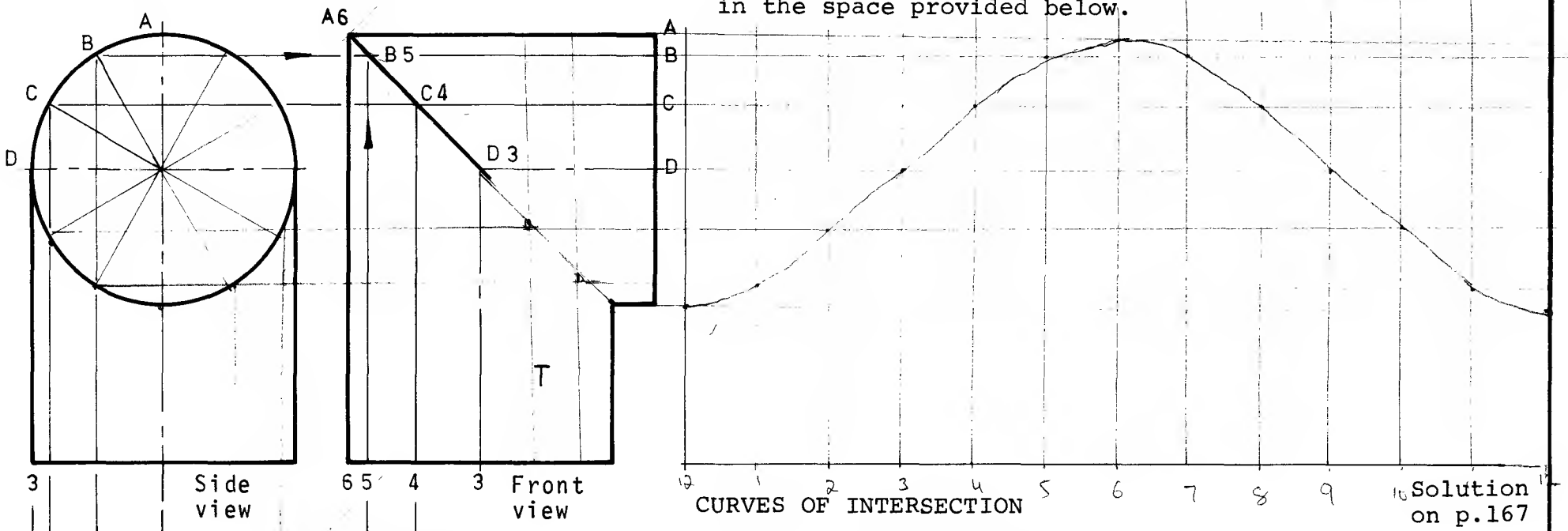
TRUNCATED RIGHT CYLINDER

PARALLEL LINE DEVELOPMENT

Soln. on p.167

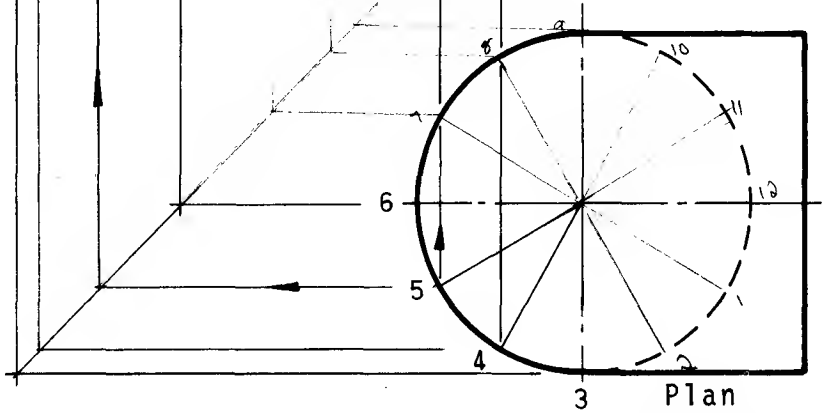
*EXERCISES*

Develop the pattern for the truncated cylinder T in the space provided below.

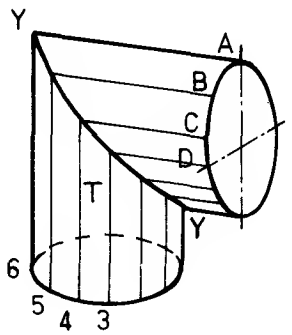



CURVES OF INTERSECTION

Solution on p.167




When two parts are joined as in the pictorial sketch opposite, their surfaces are said to intersect. The resulting joint line YY is known as the curve of intersection. In this example the curve will appear as a straight line in the front view. The method used for plotting one of the points (B5) through which the curve of intersection is drawn is explained below:



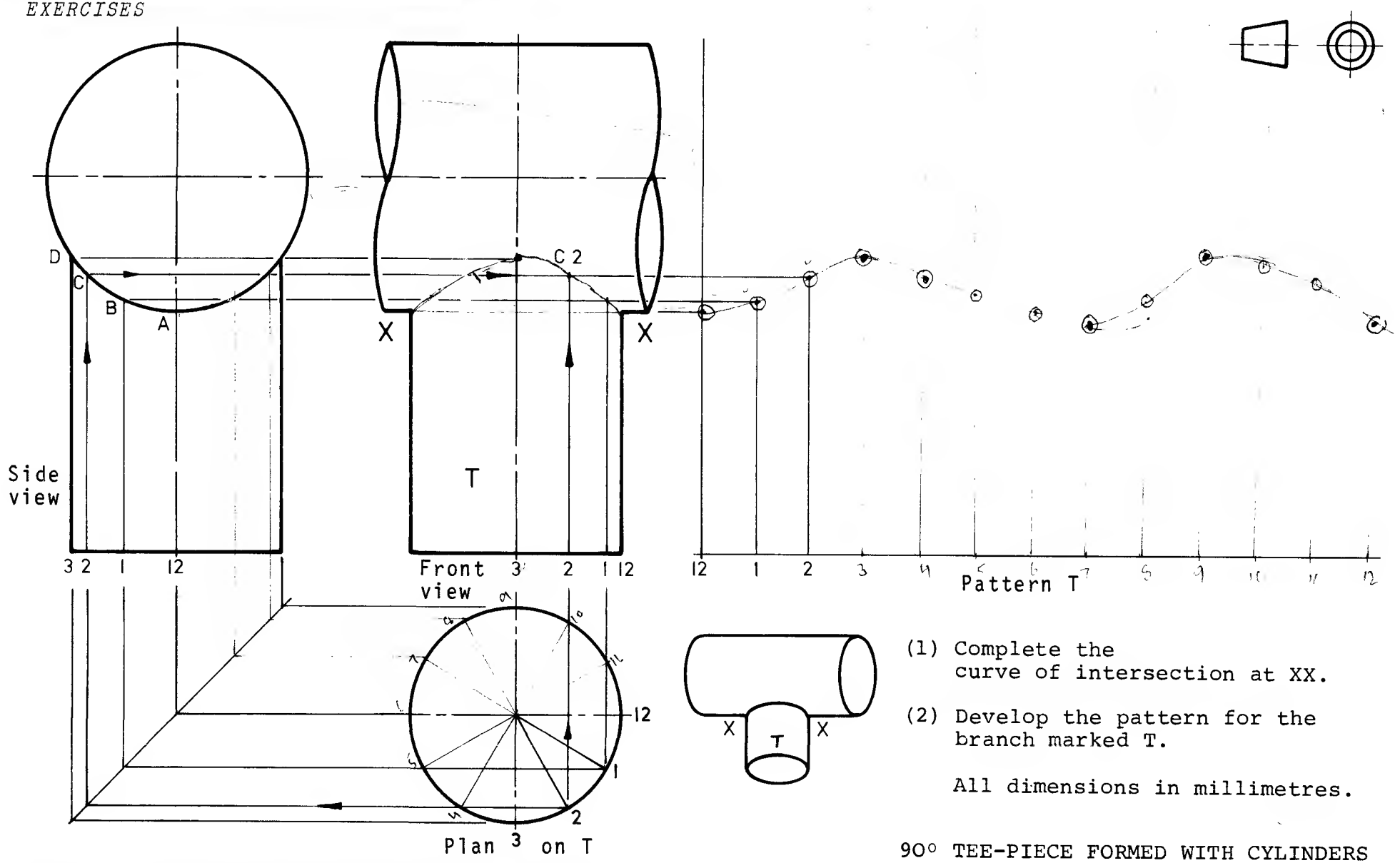

(1) A line from point 5 in plan is projected on to the top of the circle in the side view to establish point B.
(2) A horizontal line from B is then drawn across the front view.
(3) A vertical line from 5 in plan is drawn to intersect this horizontal line to give point B5 on the curve of intersection. Complete the curve of intersection in the front view.

90° ELBOW

CYLINDERS OF EQUAL DIAMETER

PARALLEL LINE DEVELOPMENT

*EXERCISES*




The construction for point C2 on the curve of intersection is carried out as shown in the previous exercise on page 111. The procedure is repeated for B1, D3 and other points.

(1) Complete the curve of intersection at XX.

(2) Develop the pattern for the branch marked T.

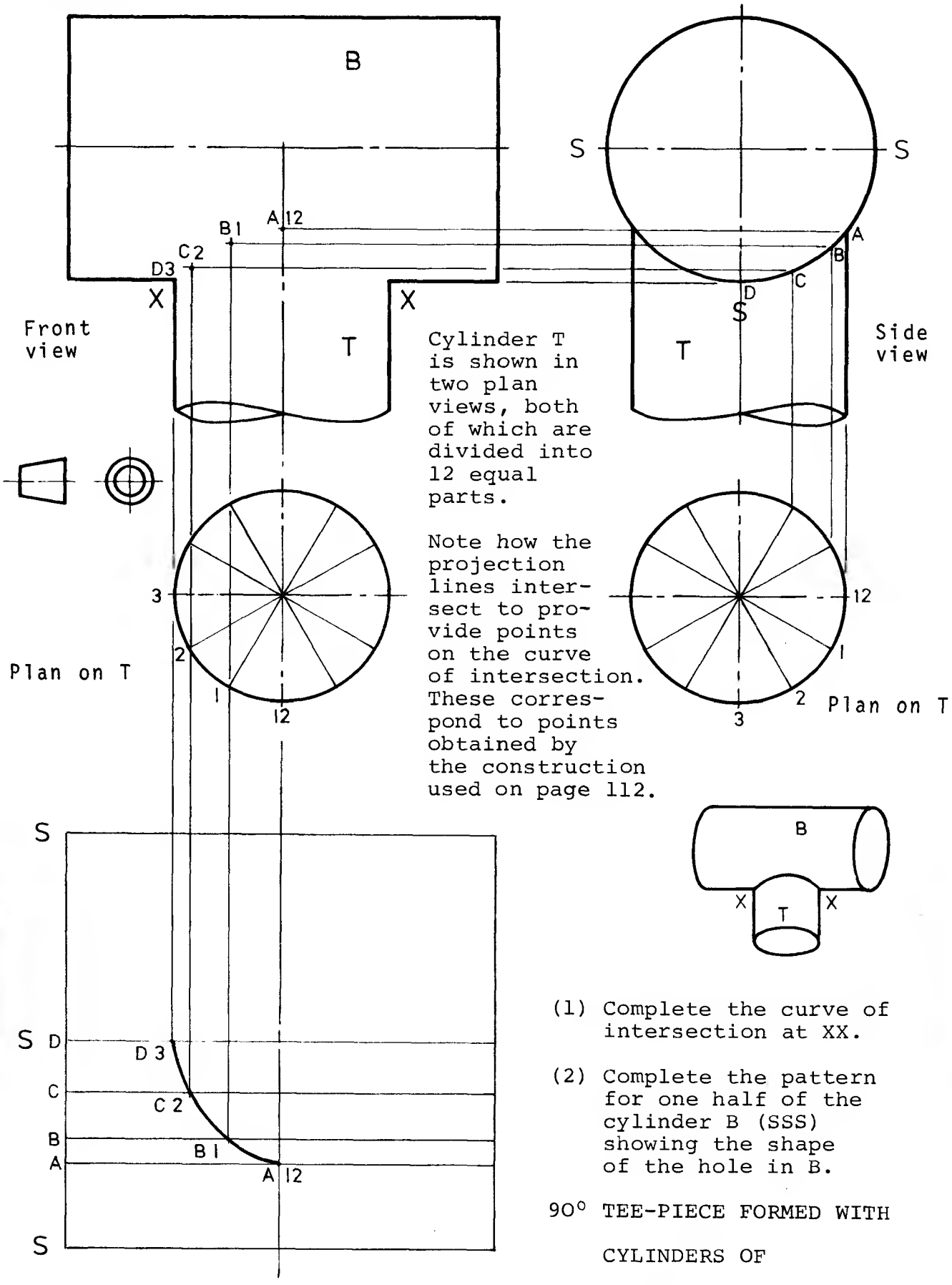
All dimensions in millimetres.

90° TEE-PIECE FORMED WITH CYLINDERS OF UNEQUAL DIAMETERS

PARALLEL LINE DEVELOPMENT

Solutions on p.167

*EXERCISES*




(1) Complete the curve of intersection at XX.

(2) Complete the pattern for one half of the cylinder B (SSS) showing the shape of the hole in B.

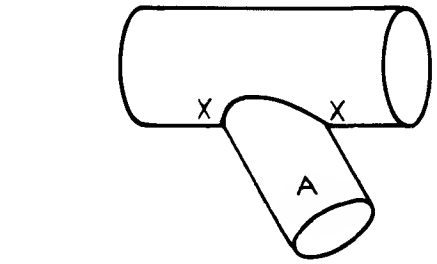
90° TEE-PIECE FORMED WITH CYLINDERS OF UNEQUAL DIAMETERS.

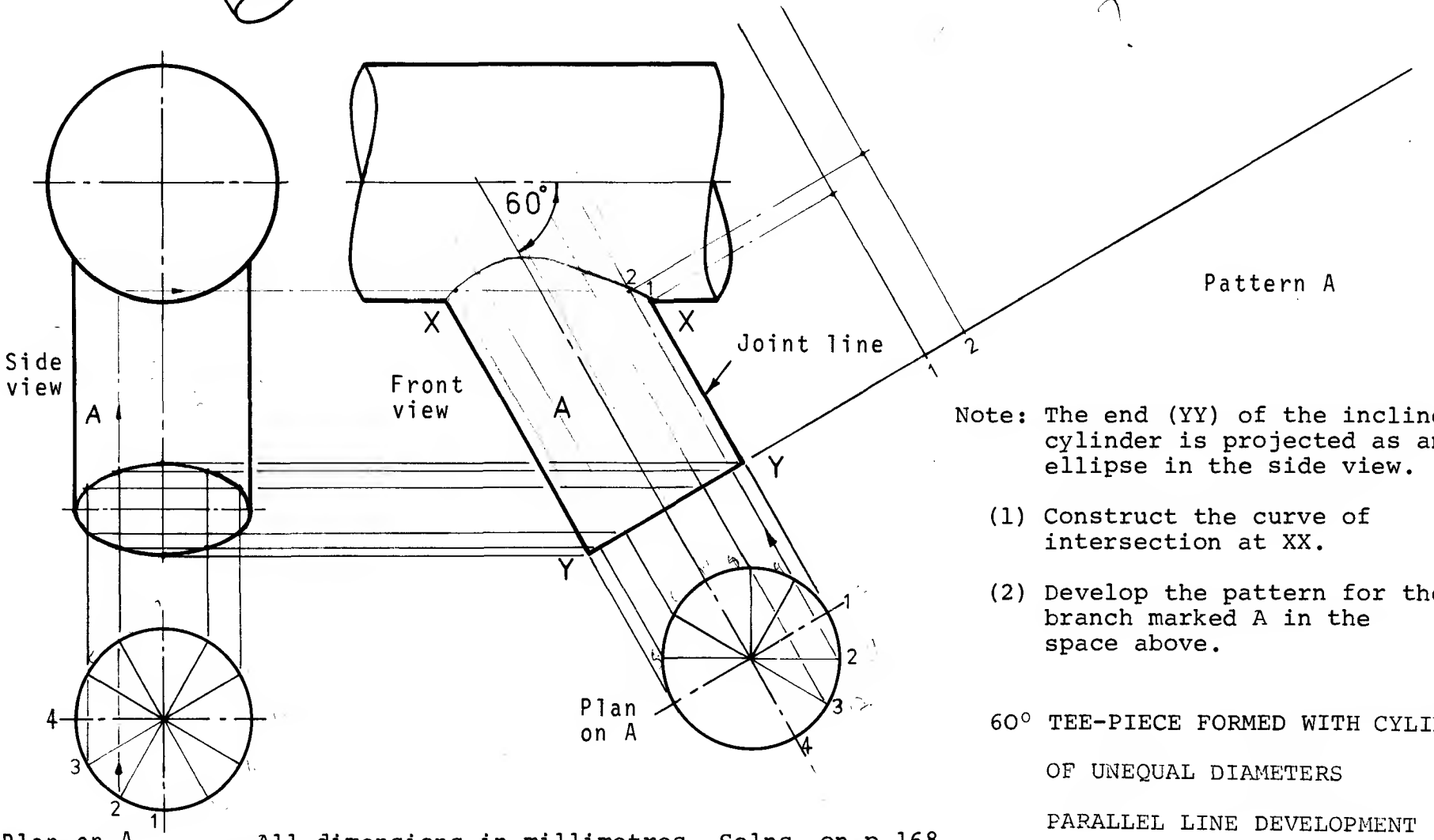
PARALLEL LINE DEVELOPMENT

Solutions on p.168

All dimensions in millimetres.

*EXERCISES*




Note: The end (YY) of the inclined cylinder is projected as an ellipse in the side view.

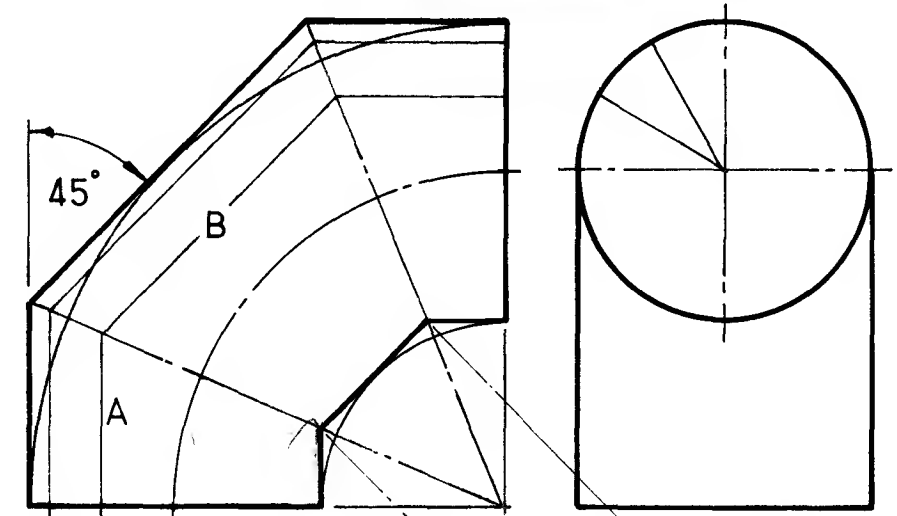
(1) Construct the curve of intersection at XX.

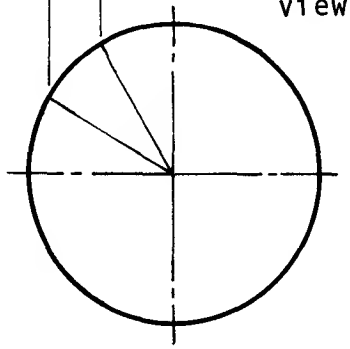
(2) Develop the pattern for the branch marked A in the space above.

60° TEE-PIECE FORMED WITH CYLINDERS OF UNEQUAL DIAMETERS

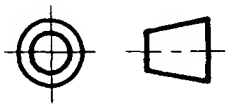
PARALLEL LINE DEVELOPMENT

All dimensions in millimetres. Solns. on p.168.

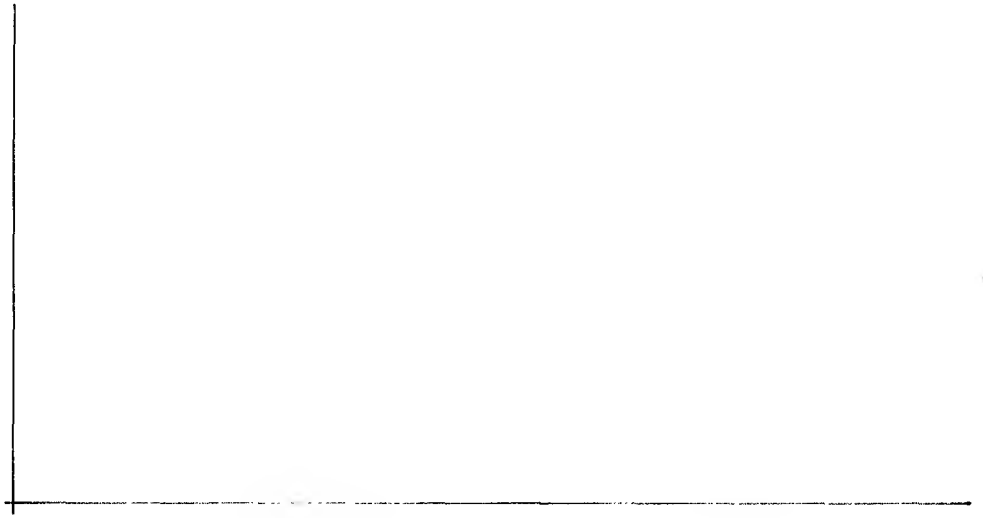


Cross-section of branch A



Pattern B



Pattern A

NOTE: A and B are right cylinders constructed from the circular bend. In this way, cylinders of equal diameters are used throughout.

(1) Develop the pattern for the part marked A in the space provided above.

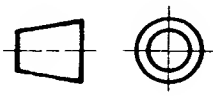
(2) Develop the pattern for the part marked B along the centre-line YY opposite.

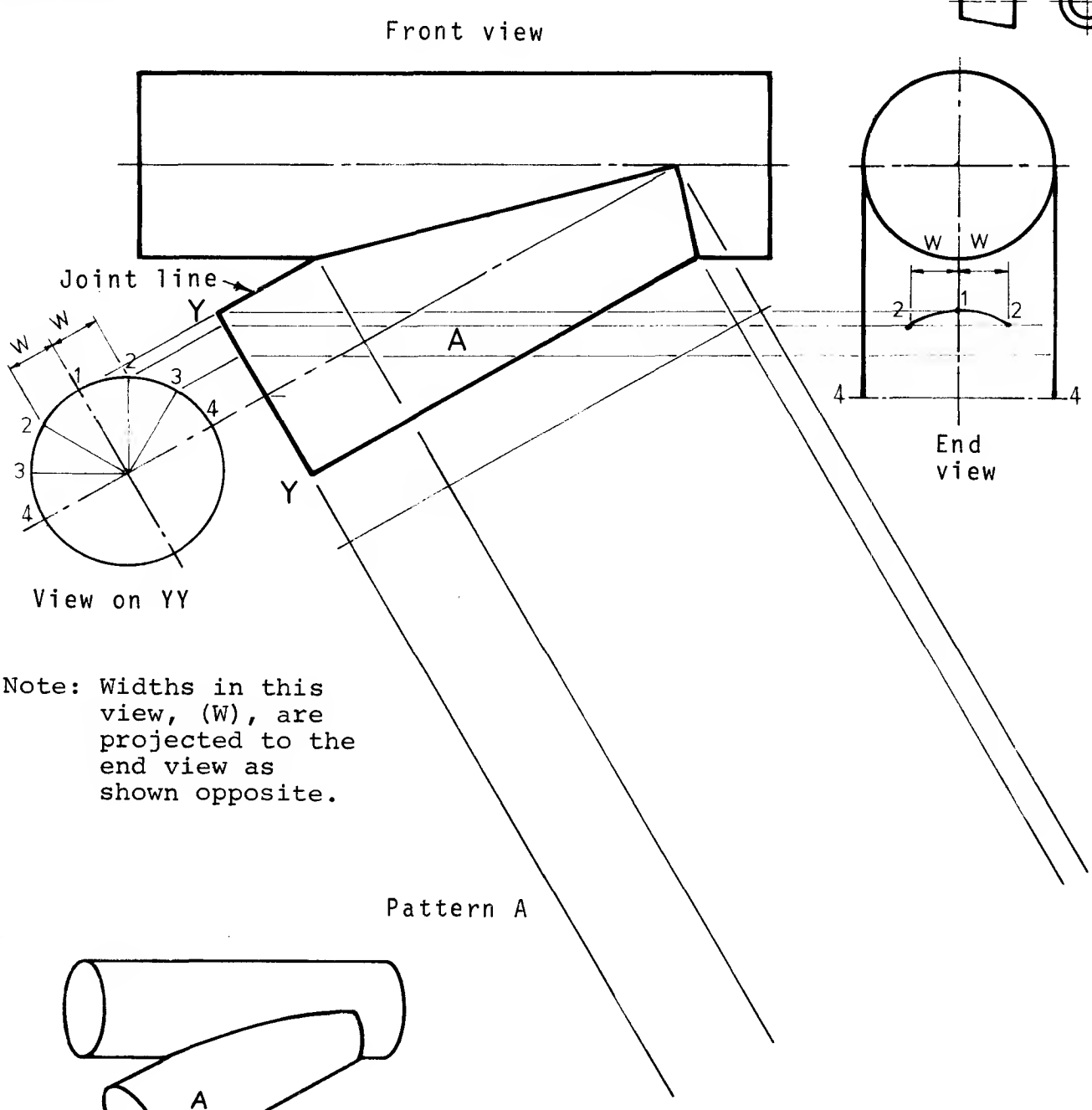
Y

90° SEGMENTAL BEND BY RIGHT CYLINDERS. 3 SEGMENTS.

PARALLEL LINE DEVELOPMENTS

All dimensions in millimetres. Solutions on p.169.






Note: Widths in this view, (W), are projected to the end view as shown opposite.




(1) Complete the end view looking on the inclined circle YY.

(2) Show that the curve of intersection is a straight line in the front view.

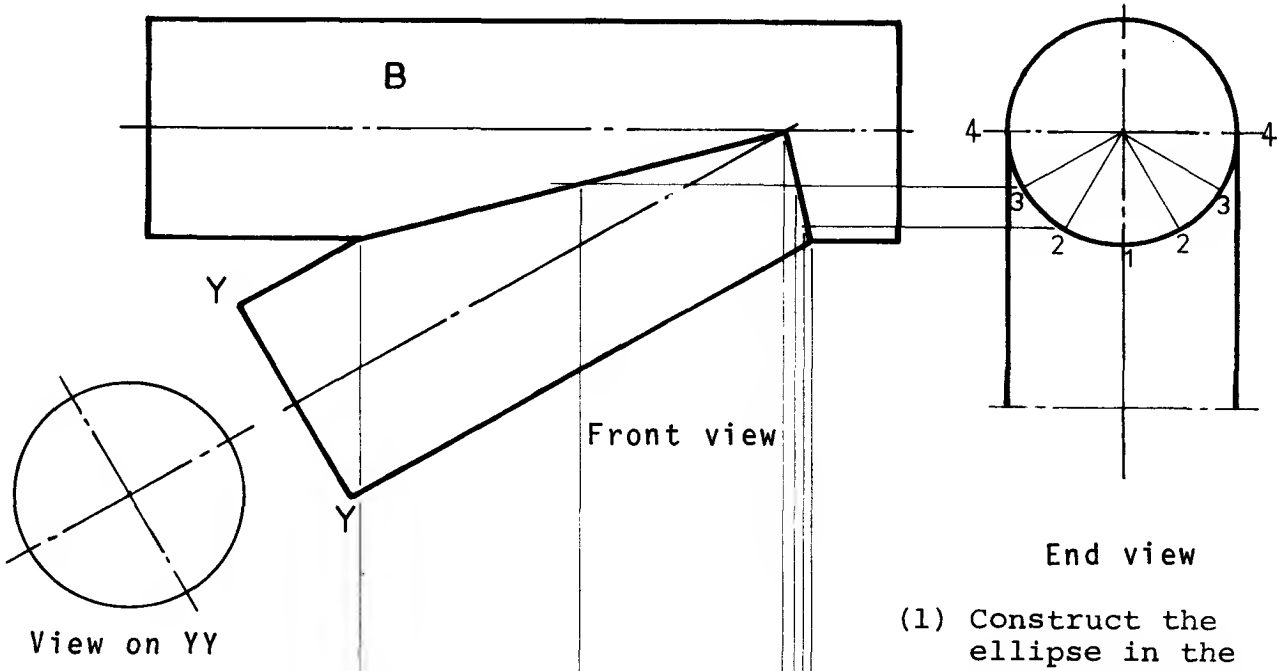
(3) Develop the pattern for the cylinder A.

Solutions on p.169

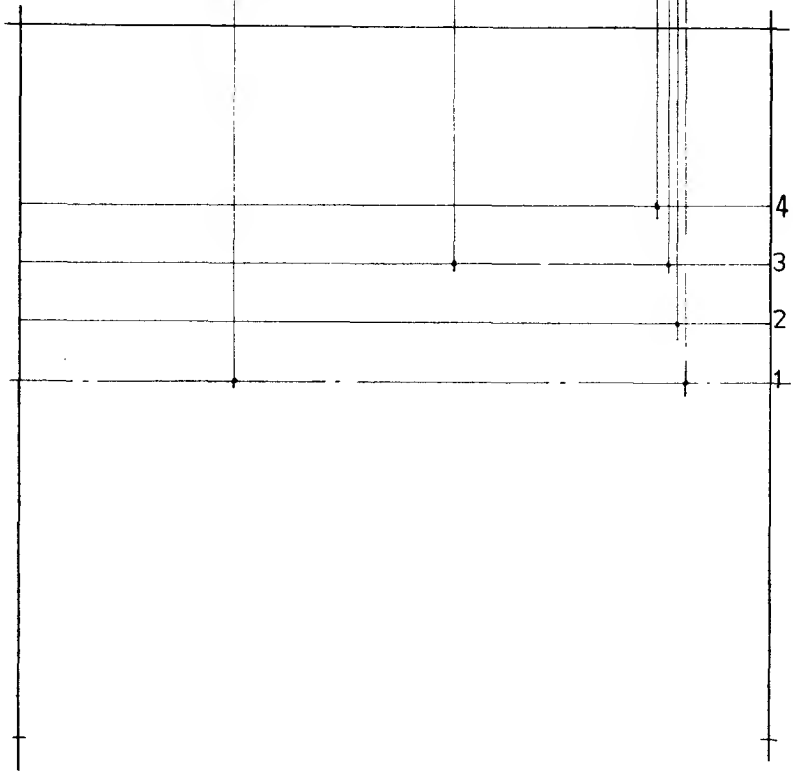
30° TEE-PIECE FORMED WITH CYLINDERS OF EQUAL DIAMETERS

PARALLEL LINE DEVELOPMENT

All dimensions in millimetres.



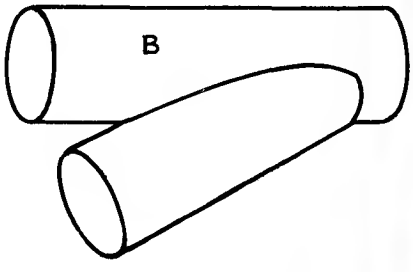

(1) Construct the ellipse in the end view which represents the inclined circle YY.




Pattern B

## 30° TEE-PIECE FORMED WITH CYLINDERS OF EQUAL DIAMETERS.

Solutions on p.170

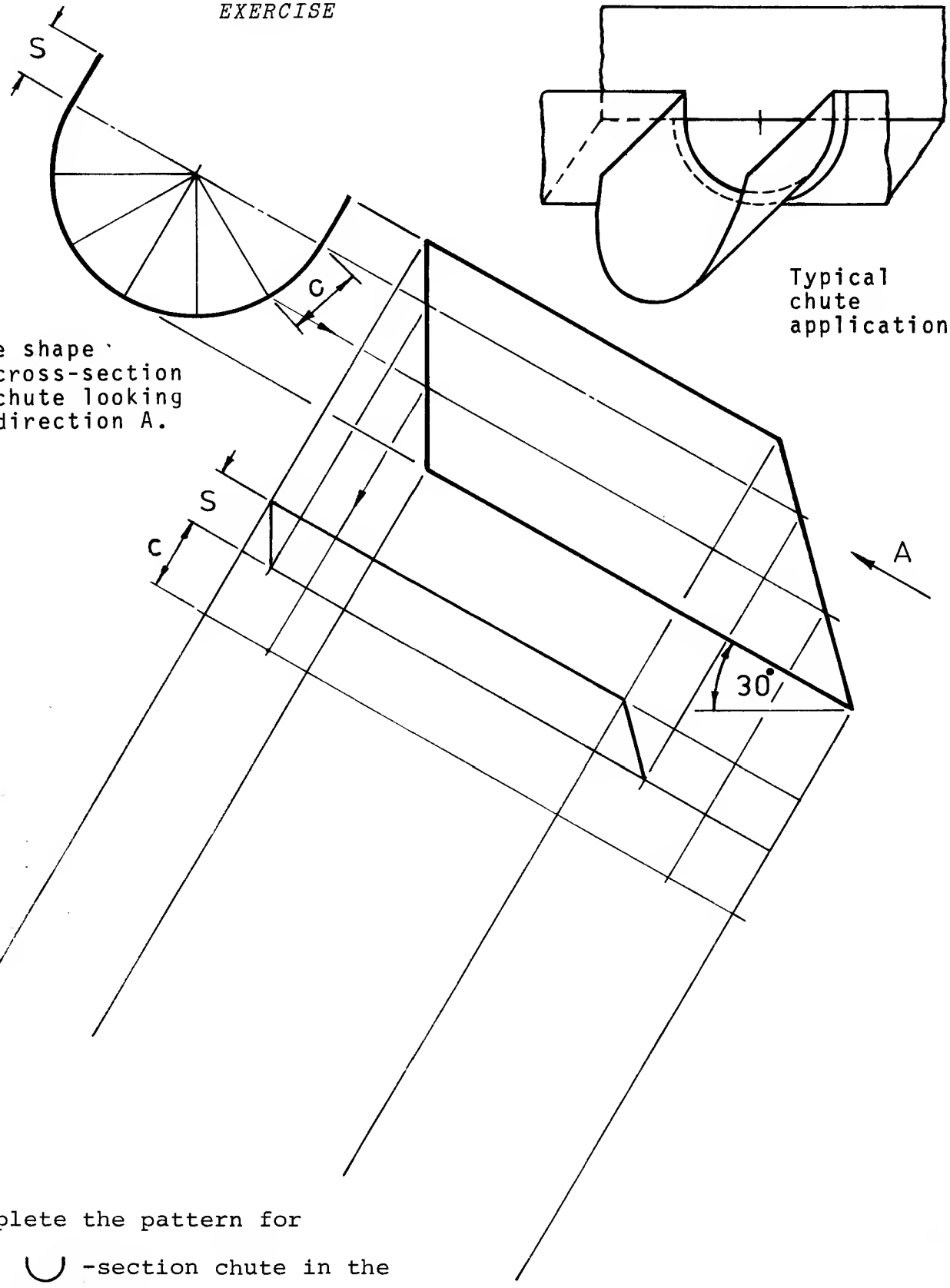



(2) Complete the pattern for the cylinder marked B showing the shape of the hole in B.

All dimensions in millimetres.

PARALLEL LINE DEVELOPMENT

*EXERCISE*

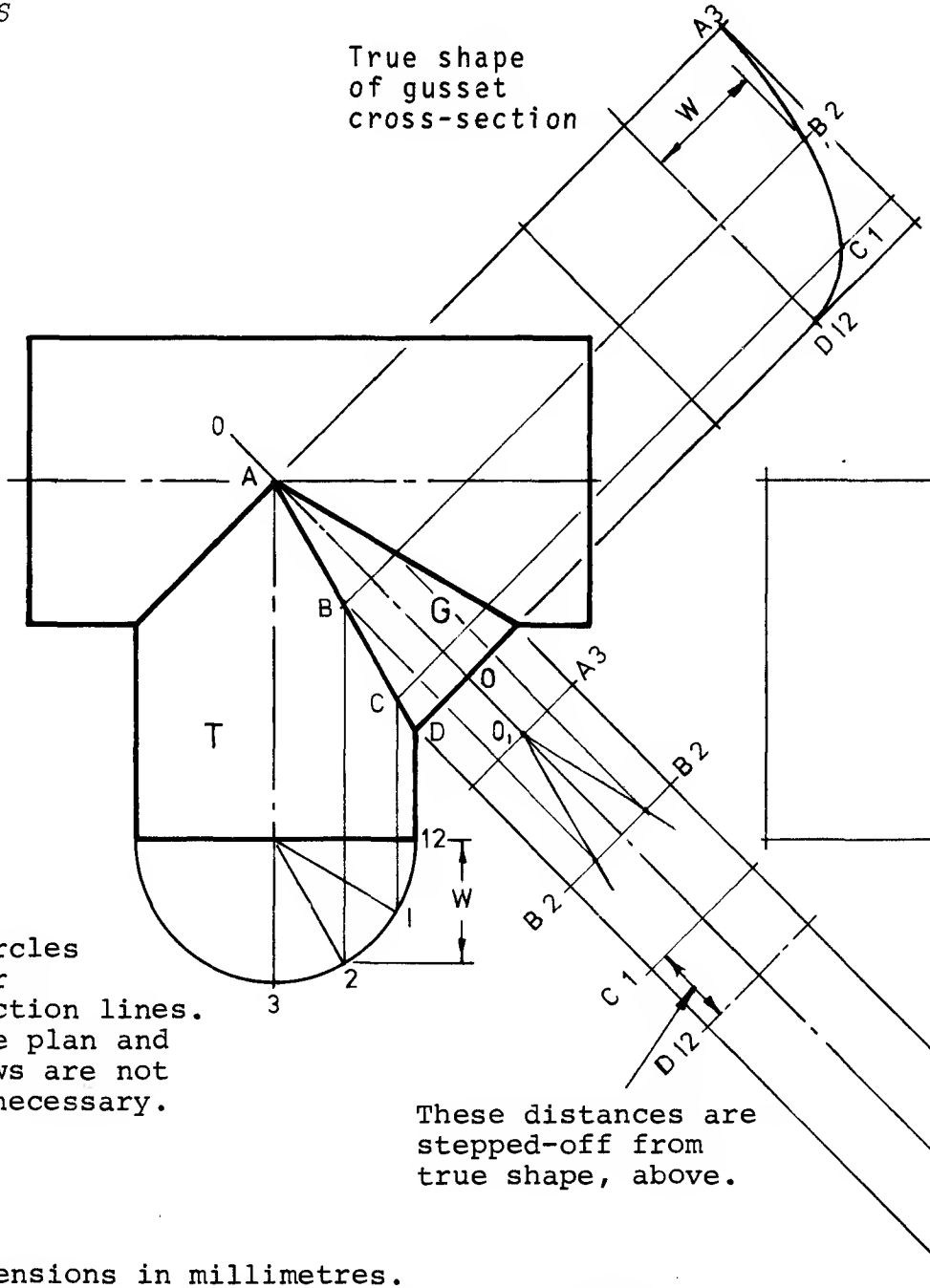



Complete the pattern for the ∪ -section chute in the space provided.

Solution on p.170

All dimensions in millimetres.

PARALLEL LINE DEVELOPMENT




(1) Develop the pattern for the branch marked T in the space provided below.

(2) Complete the true shape across the gusset G at the line OO.

(3) Complete the pattern for the gusset G along the centre-line $O_1O_1$.

Solutions on p.171.

Pattern T

Semi-circles used for construction lines. Complete plan and end views are not always necessary.

These distances are stepped-off from true shape, above.

90° TEE-PIECE FORMED FROM CYLINDERS OF EQUAL DIAMETERS, with gusset plate let in to increase the cross-sectional area of the pipe at the intersection.

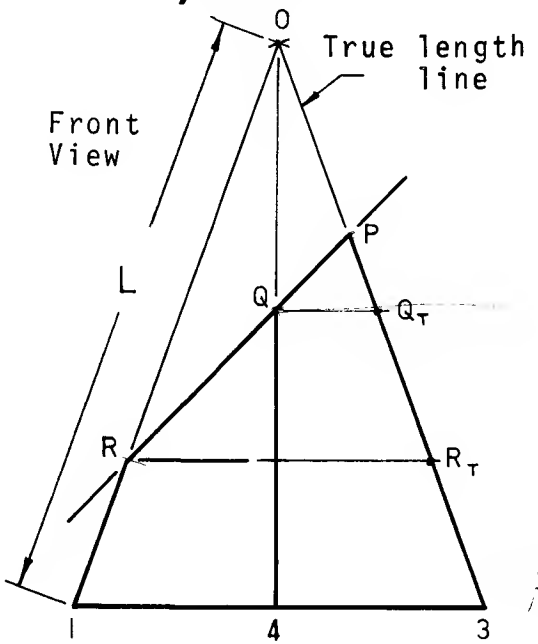
PARALLEL LINE DEVELOPMENT

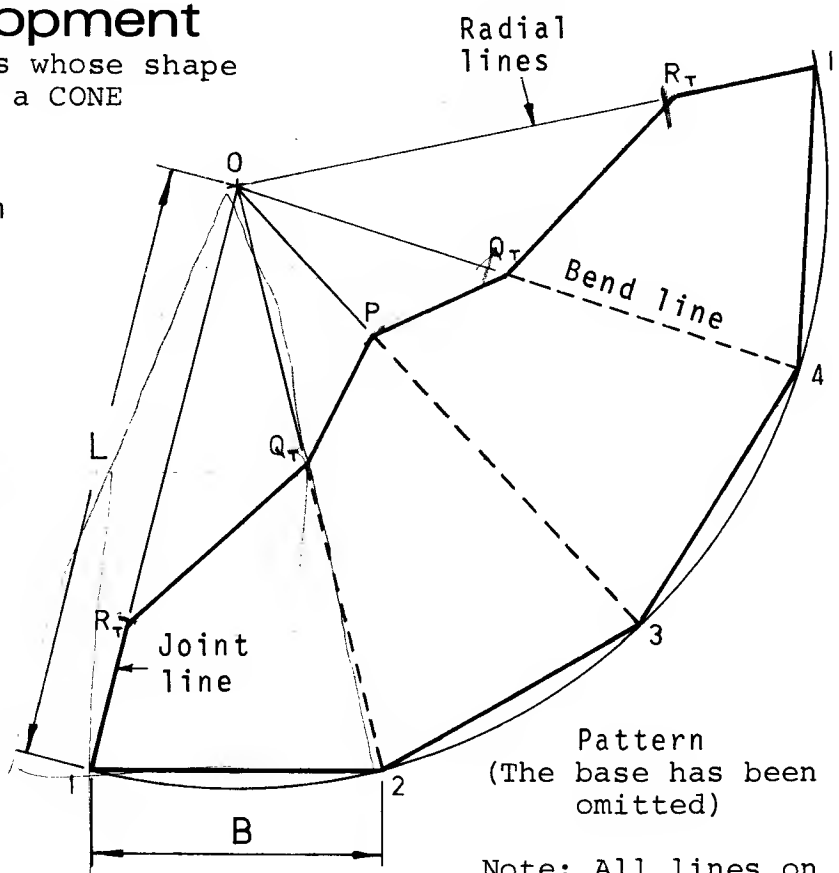
All dimensions in millimetres.

# Radial line development

Used to develop components whose shape is basically a PYRAMID or a CONE

## (a) Pyramids

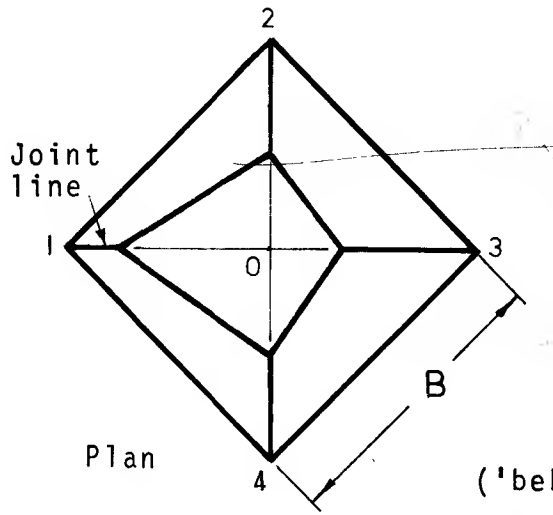


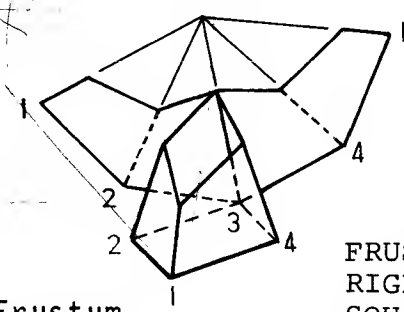




Pattern (The base has been omitted)

Note: All lines on patterns are TRUE lengths.

The shortest edge 1-$R_T$ is the joint line.




FRUSTUM OF A RIGHT SQUARE-BASED PYRAMID

METHOD OF CONSTRUCTION

(1) Determine the TRUE length of the sloping edge of the pyramid.
When the pyramid is positioned as shown here, *L* in the front view is the true length.

(2) Draw faintly an arc of radius *L* as shown opposite.

(3) Step off the true length of the base edge, *B*, four times around the arc.

(4) Draw in the radial lines faintly as shown.

(5) Step off O-P from the true length line in the front view and set it out along the radial line O-3 on the pattern.

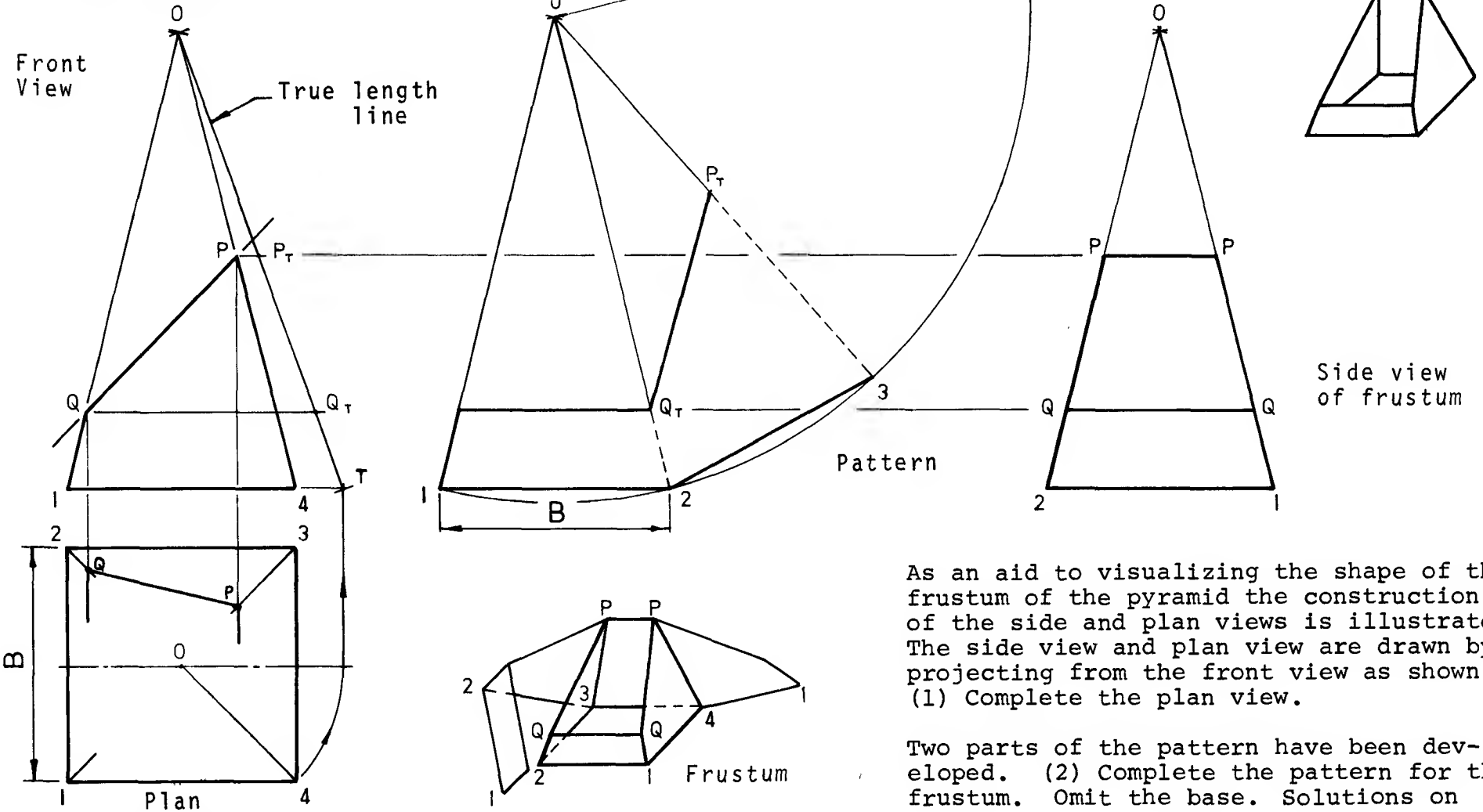
(6) Step off O-$Q_T$ along the radial lines O-2 and O-4. Note: In the front view OQ is <u>not</u> a true length.

(7) Step off O-$R_T$ along the radial lines O-1.

(8) Join up points $R_T$, $Q_T$ etc., to form the pattern of the frustum.

RADIAL LINE DEVELOPMENT

When a pyramid is positioned as shown below, length O-1 is <u>not</u> the true length of the sloping edges of the pyramid.




The true length of the sloping edge is found by swinging the plan view of one of the edges, O-4, to the horizontal and projecting to the front view as shown. O-T is the true length of all four sloping edges.

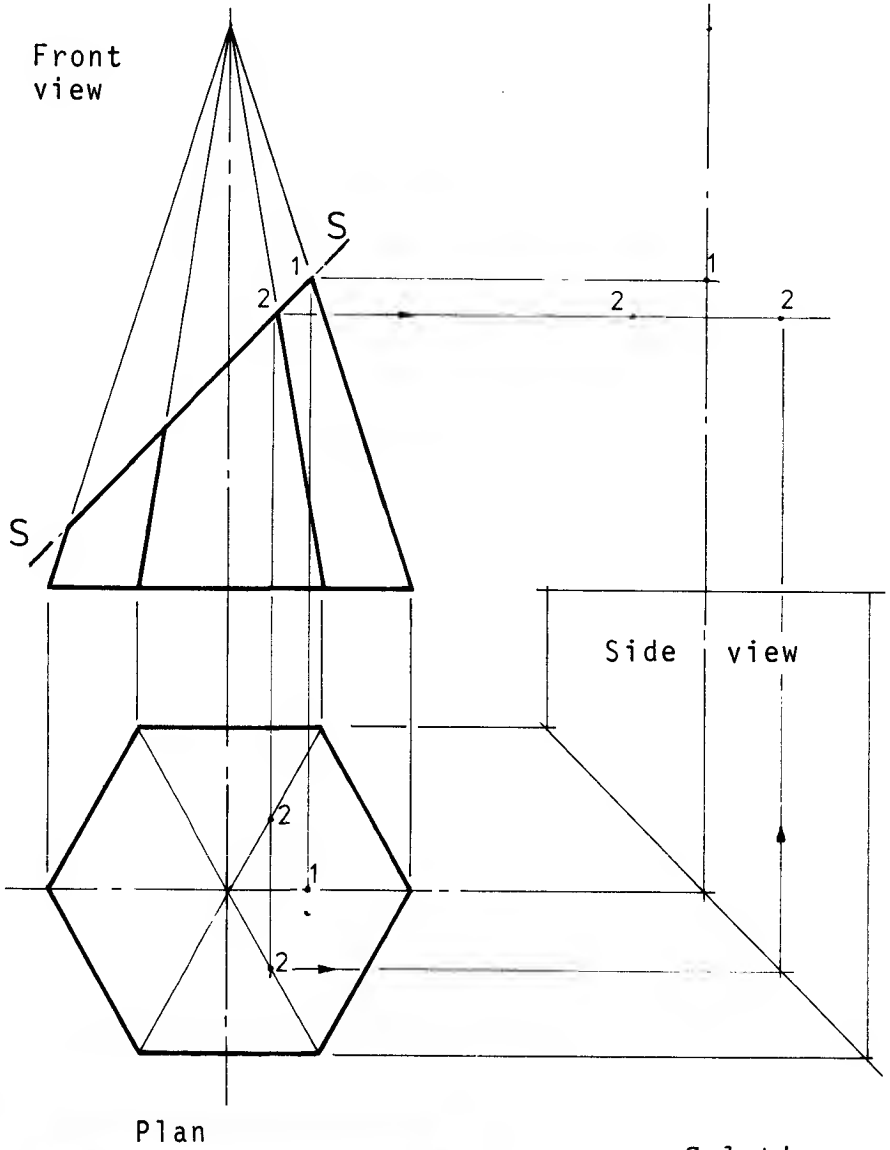
As an aid to visualizing the shape of the frustum of the pyramid the construction of the side and plan views is illustrated. The side view and plan view are drawn by projecting from the front view as shown. (1) Complete the plan view.

Two parts of the pattern have been developed. (2) Complete the pattern for the frustum. Omit the base. Solutions on p.172.

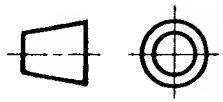
FRUSTUM of a right square-based pyramid

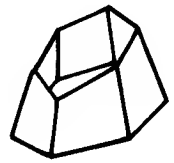
RADIAL line development.

*EXERCISES*




Pattern





Frustum

Start development here

(1) Draw the left-hand side view of the frustum in the space provided and complete the plan.

(2) Construct the pattern for the surface of the frustum below the section plane SS. Omit the base.

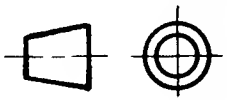
FRUSTUM OF A PYRAMID

WITH A HEXAGONAL BASE

RADIAL LINE DEVELOPMENT

Solutions on p.173

Pattern



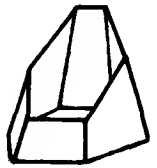
Front view

S

S

Side view

Start development here



Frustum

(1) Draw the left-hand side view of the frustum in the space provided and complete the plan.

(2) Construct the pattern for the surface of the frustum below section plane SS.
Omit the base.

Plan

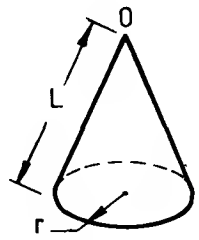
Solutions on p.174

FRUSTUM OF A PYRAMID

WITH A HEXAGONAL BASE

RADIAL LINE DEVELOPMENT

# (b) Development of right cones




There are two methods commonly used for developing patterns of conic shapes. Both are explained below.

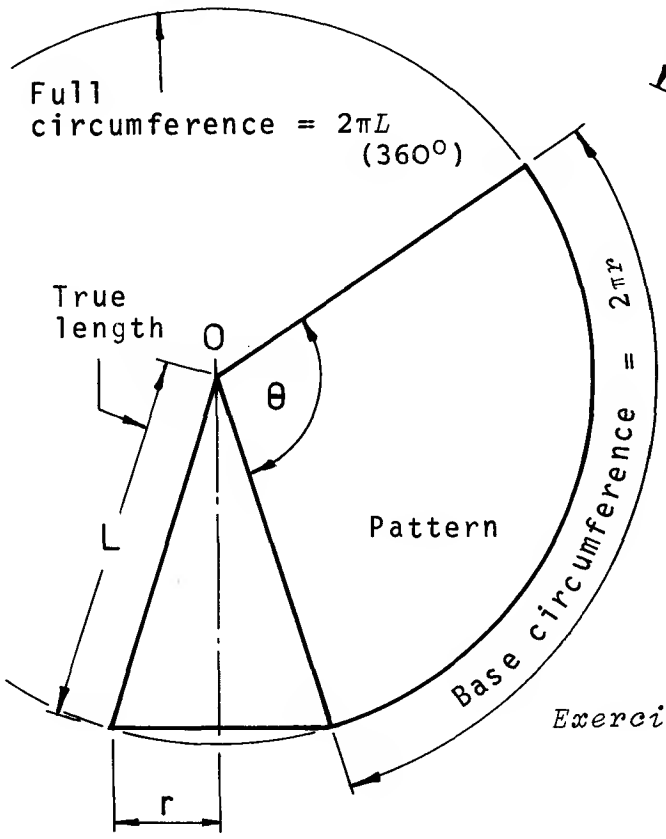



Fig.1

(1) *The accurate method* (Fig.1)

The true length of the sloping edge of the cone is $L$.
Using O as centre, an arc is drawn of radius $L$.
Before the circumference of the base of the cone can be drawn along this arc, angle θ must be calculated as follows.

$$\frac{\theta}{2\pi r} = \frac{360^\circ}{2\pi L} \qquad \theta = \frac{2\pi r \ 360^\circ}{2\pi L}$$

$$\theta = \frac{r}{L} \times 360^\circ$$

*Exercise:* Measure $r$ and $L$ (in millimetres) from fig.1, calculate angle θ, and check that the pattern is correctly drawn.

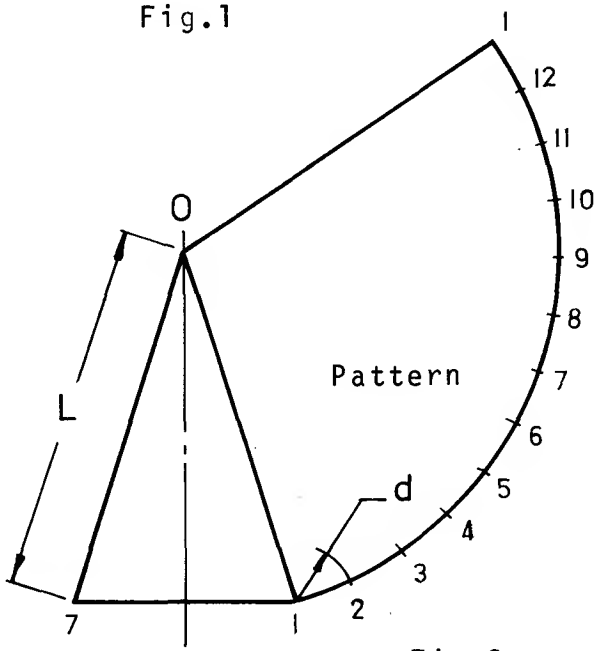
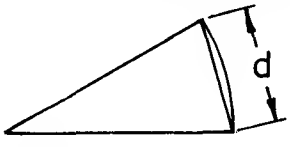
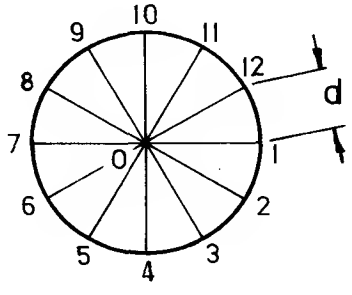



Fig.2

(2) *The approximate method* (Fig.2)

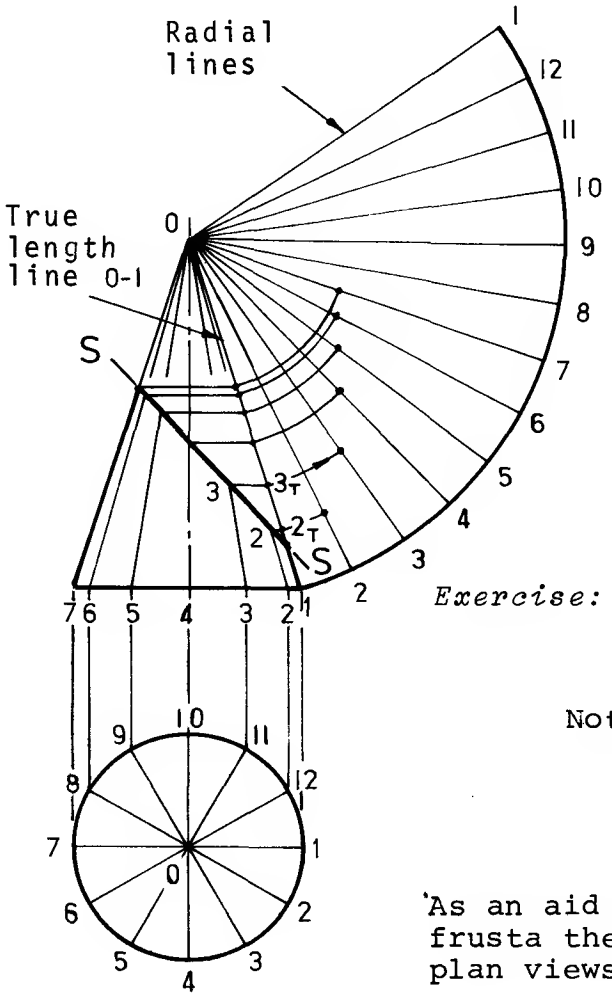
An arc is drawn with O as centre and radius $L$ as in method 1.
The plan view is divided into equal parts as shown. 12 parts are convenient, being easily obtained using a 30° set-square.
Distance $d$, which is the approx. length of the distance between pairs of points on the base circle, is stepped off around the arc 12 times to complete the development.
The sketch below shows clearly that a distance stepped off in this way is the true length of the chord between the points and not the true length of the arc.




*Exercise:* Compare the pattern constructed by this method with the one obtained using the accurate method by measuring the angles at O.

## DEVELOPMENT OF THE FRUSTUM OF A RIGHT CONE




(1) Develop the full surface area by using either the approximate method or the accurate method.

(2) Add radial lines as shown. These correspond to the radial lines drawn on the surface of the cone.

(3) From the points where the radial lines on the surface of the cone intersect the cutting plane SS, project horizontally to the true length line e.g. 2 to $2_T$, 3 to $3_T$ etc.

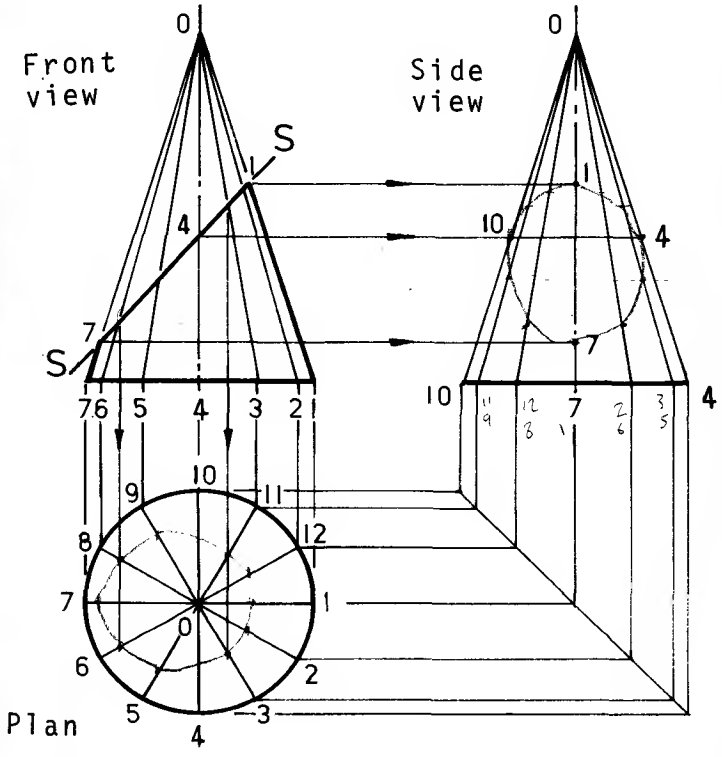
(4) Swing these true lengths from O to the corresponding radial lines on the pattern, e.g. $2_T$ to line 2, $3_T$ to line 3 etc.

*Exercise:* (5) Complete the pattern by adding the remaining points and joining with a heavy line.

Note: All lengths on the pattern must be true lengths.
The shortest edge is usually used as the joint line. In this case it is along line O-1.

As an aid to visualizing the shape of conic frusta the construction of the front and plan views is illustrated and explained below.

*Construction of plan view and side view of a conic frustum*



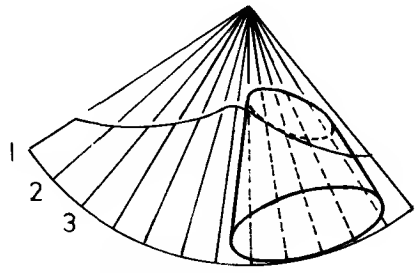

Plan view
Project the points of intersection of the radial lines and the cutting plane S-S from the front view to the corresponding radial lines in the plan as shown.
e.g. points $\begin{matrix}6\\8\end{matrix}$ to lines 6 and 8.

Side view
Project the points of intersection of the radial lines and the cutting plane S-S from the front view to the corresponding radial lines in the side view as shown.
e.g. points $\begin{matrix}4\\10\end{matrix}$ to lines 4 and 10.

*Exercises:* Complete the plan and side view.

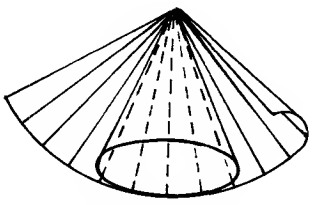
RADIAL LINE DEVELOPMENT Solns. p.175

*EXERCISES*




Frustum of cone

Pattern



Complete cone

Front view

Side view

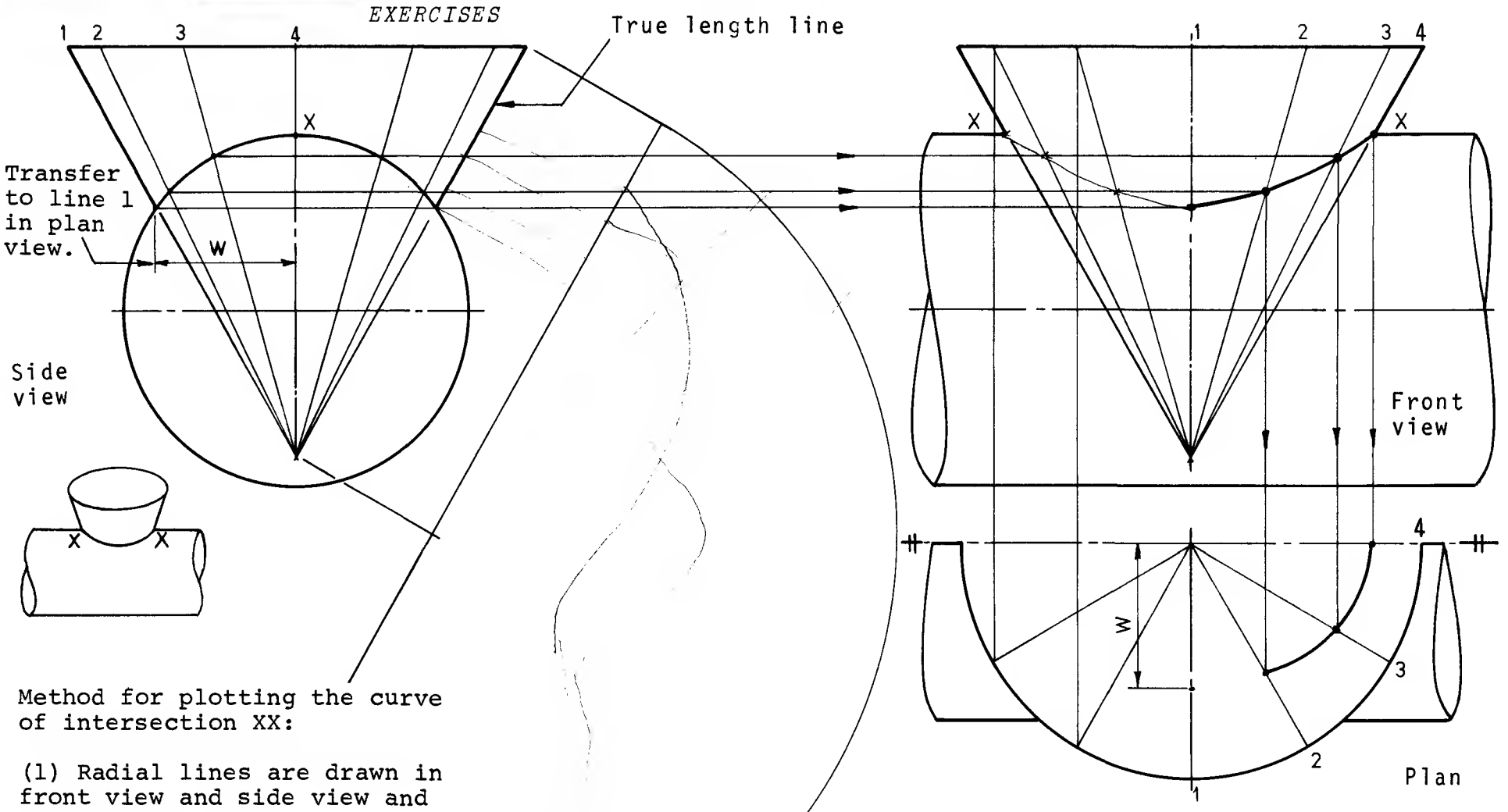
O-7 is the true length line

Plan

(1) Complete the development of the pattern of the surface area of the frustum in the space provided.
(2) Complete the plan view.
(3) Complete the side view.

Solutions on p.176.

RADIAL LINE DEVELOPMENT




Method for plotting the curve of intersection XX:

(1) Radial lines are drawn in front view and side view and numbered as shown.

(2) Horizontal lines are projected from points in side view where radial lines "cut" the circle to corresponding lines in front view e.g. 1 to 1, 2 to 2, etc.

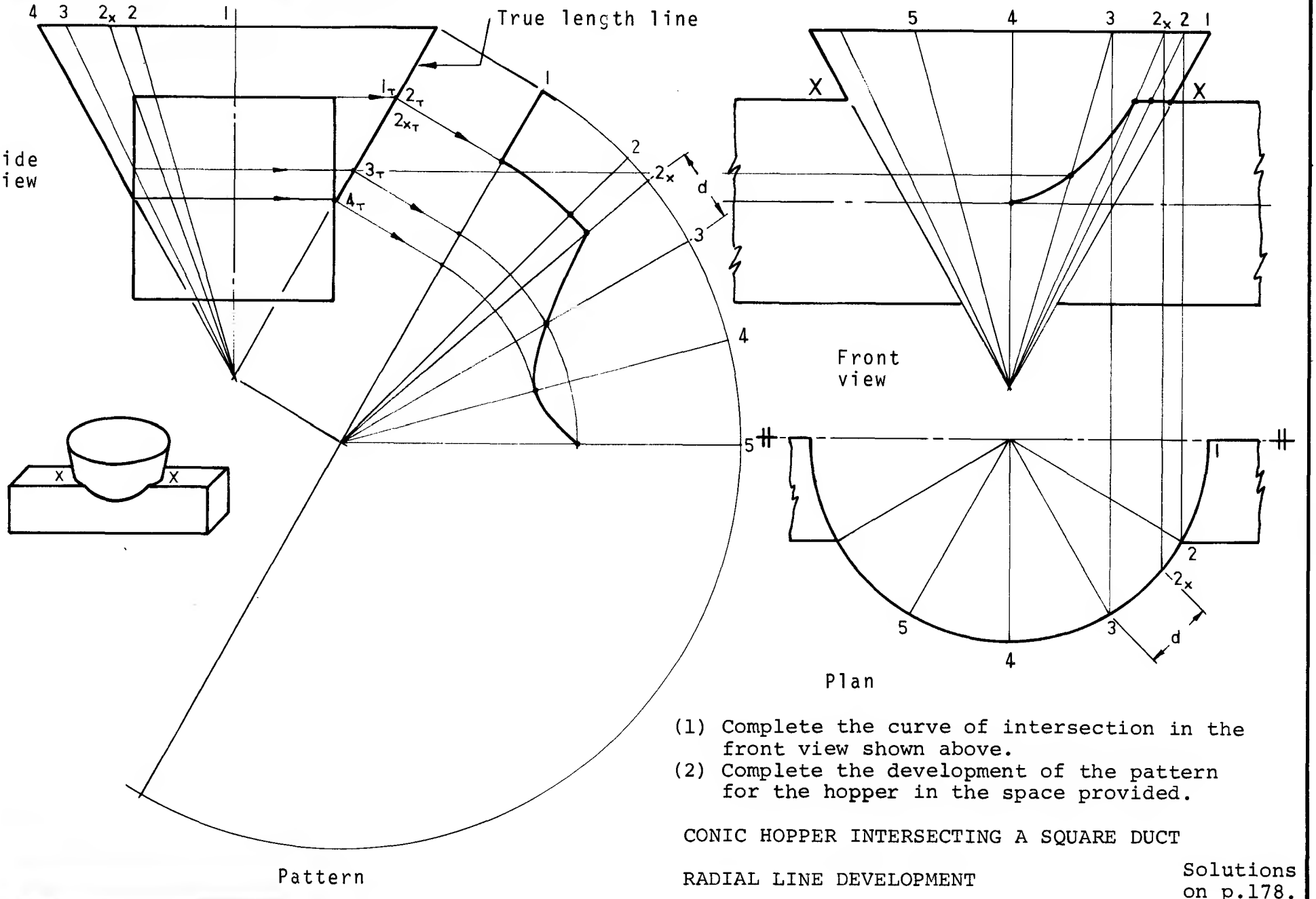
(1) Complete the curve of intersection at XX.
(2) Complete the curve in the half plan.
(3) Develop the pattern for the frustum of the conic hopper in the space provided. Use 4-X as the joint line.

CONIC HOPPER INTERSECTING A CYLINDER

RADIAL LINE DEVELOPMENT

Solutions on p.177.

*EXERCISES*



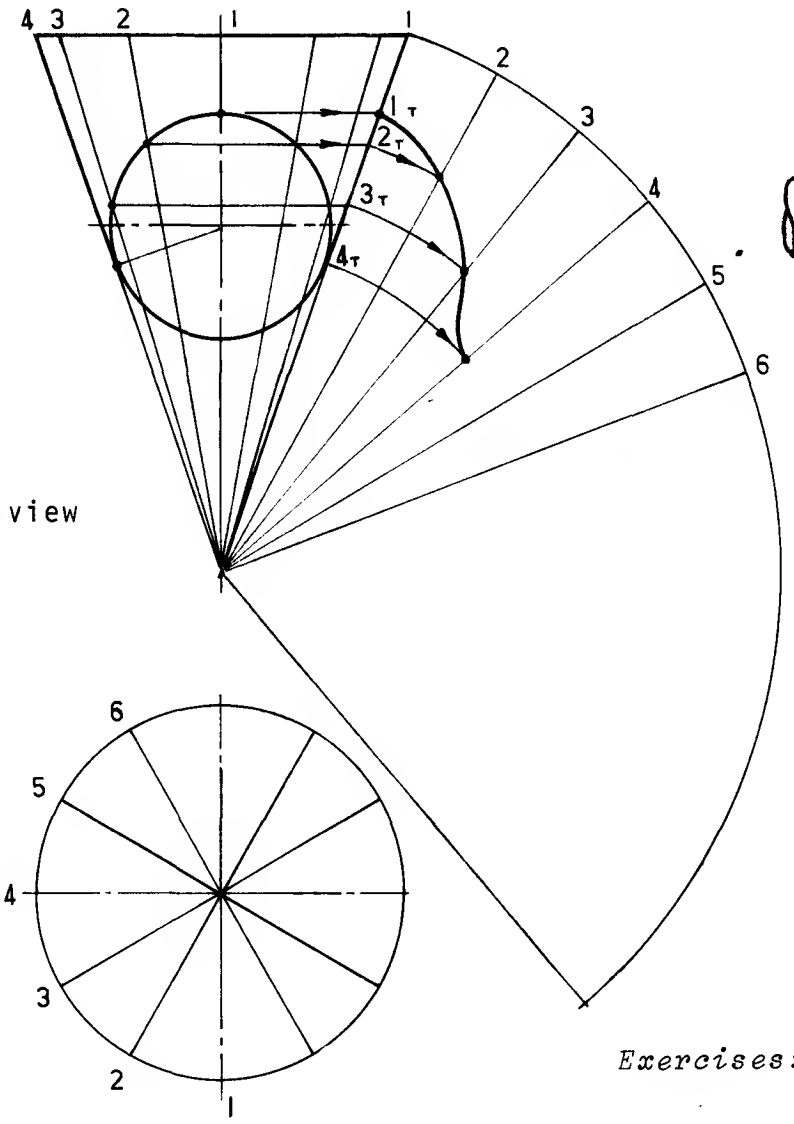

(1) Complete the curve of intersection in the front view shown above.
(2) Complete the development of the pattern for the hopper in the space provided.

CONIC HOPPER INTERSECTING A SQUARE DUCT

RADIAL LINE DEVELOPMENT

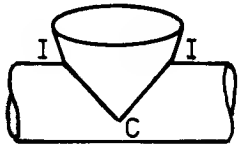
Solutions on p.178.

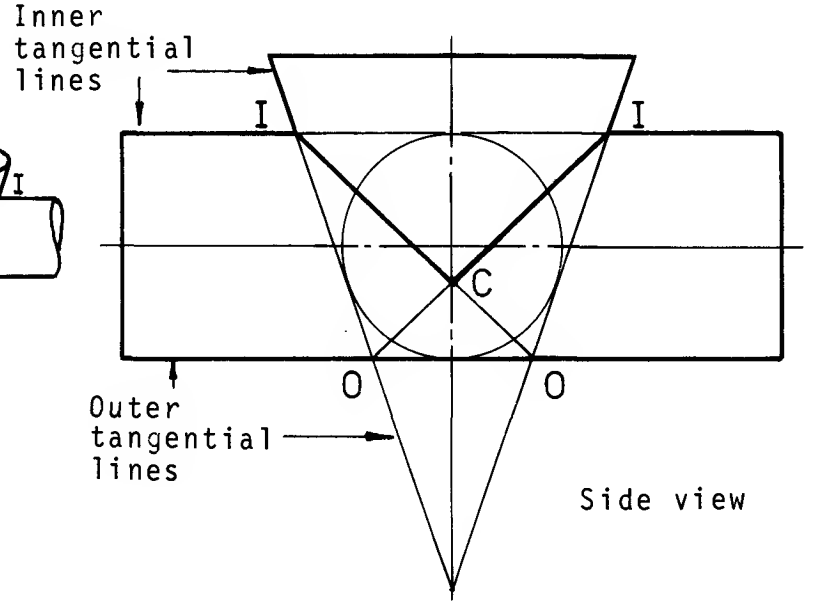
THE COMMON CENTRAL SPHERE - A SPECIAL CASE




Front view

Plan




Side view

When a circle (an imaginary sphere) can be drawn within two intersecting components so that both outside edges are tangential to the circle as shown above, a special construction may be used to determine the "curve of intersection".
Intersection points of the inner tangential lines (I) are joined to the intersection points of the outer tangential lines (O) as shown in the side view above.
The "curve" of intersection I-C-I appears as two straight lines.
Note: C is below the centre-line of the cylinder.

*Exercises:* (1) Verify this "curve" of intersection by using the radial line method shown previously.
(2) Complete the development of the pattern for the frustum of the cone in the space provided.

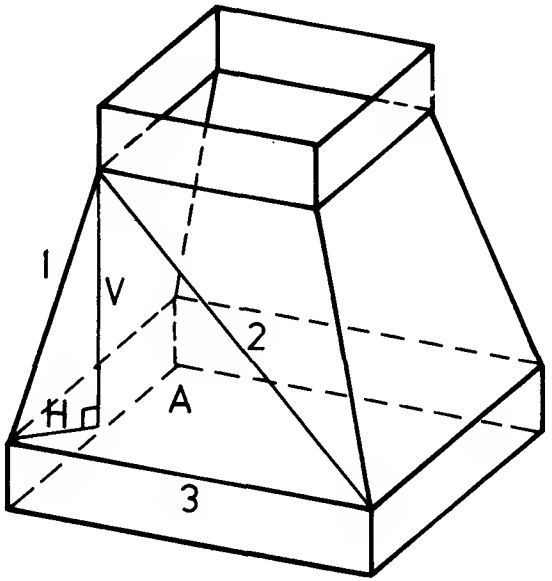
CONICAL HOPPER INTERSECTING A CYLINDER

RADIAL LINE DEVELOPMENT

Solutions on p.179

# Triangulation

This method is used to develop patterns of components which would be difficult or impossible to develop using either the parallel line or radial line methods. TRANSITION pieces, which join together ducts which have different cross-sections, may be developed using triangulation as shown in the following examples.




The pictorial view opposite shows a transition piece which connects two square sections between parallel planes. The same component is drawn orthographically in the example on the page below.

The vertical line V is the height of line 1 as seen in the front view below.
The horizontal line H is the length of line 1 as seen in the plan view below.
The angle between V and H must be $90^{o}$.

*Method*

The surface area of the component is divided into a series of triangles. Consider the triangle marked A in the plan on the page below.

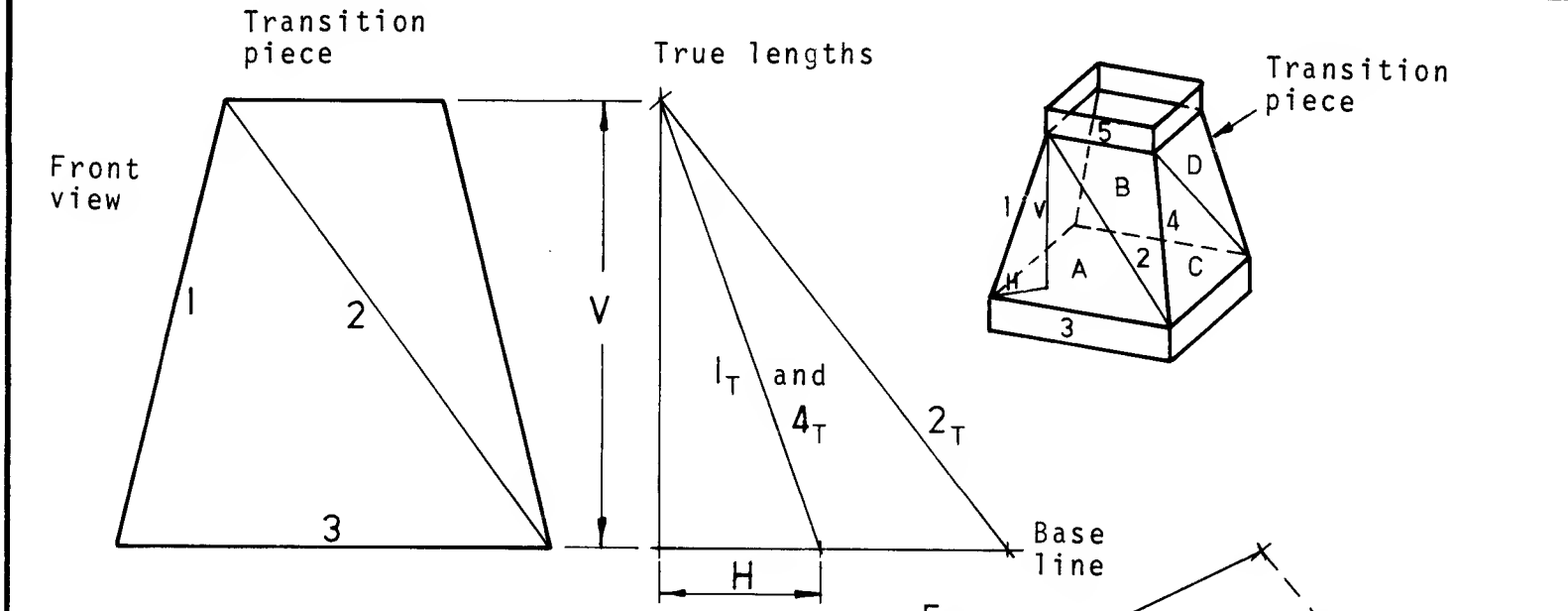
Line 3 is a true length because it is parallel to the horizontal plane.
Line 1 is not a true length in either the front view or plan because it is not parallel to the vertical plane in either the front view or the plan view.
Line 2 is not a true length in either the front view or plan for the same reason.

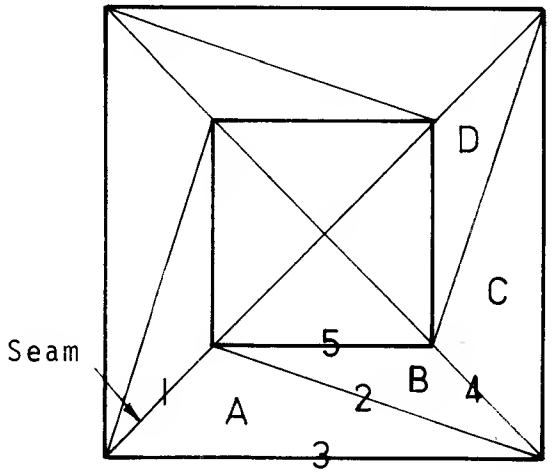
To find the true length of line 1.

Project the vertical height of line 1 (V) from the front view to the right.
Step off the length of line 1 from the plan (H) along the base line.
The hypoteneuse of the triangle thus formed is the true length (1T) of line 1.
In this example it is also the true length (4T) of line 4.
Using the same construction, verify the true length (2T) of line 2.

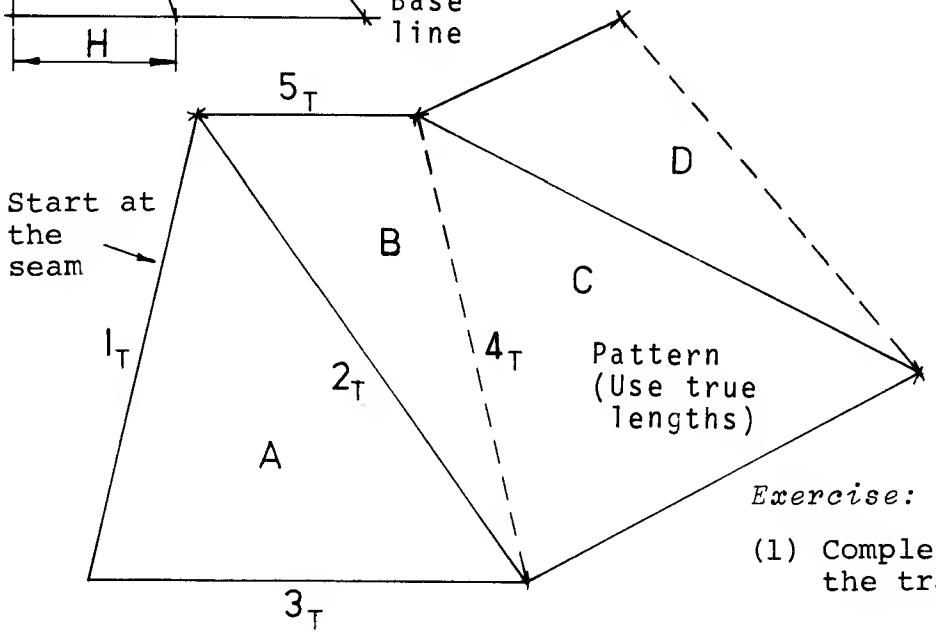
*Development*

The pattern is developed by joining together true shape triangles as shown in the example below. Starting from the seam (line 1), the triangle marked A is constructed using the true length for each edge. Triangles B, C, D, etc., are then added in the correct sequence as shown.




Plan




*Exercise:*

(1) Complete the pattern for the transition piece.

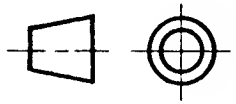
Note: Always number the lines on the line or near to the line.
Of the lines numbered only 3 and 5 are true lengths in the plan view.

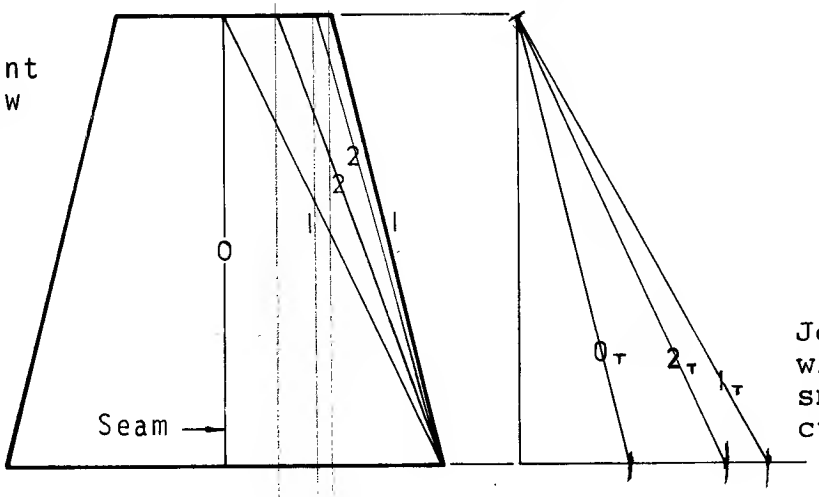
TRANSITION PIECE - SQUARE TO SQUARE BETWEEN PARALLEL PLANES

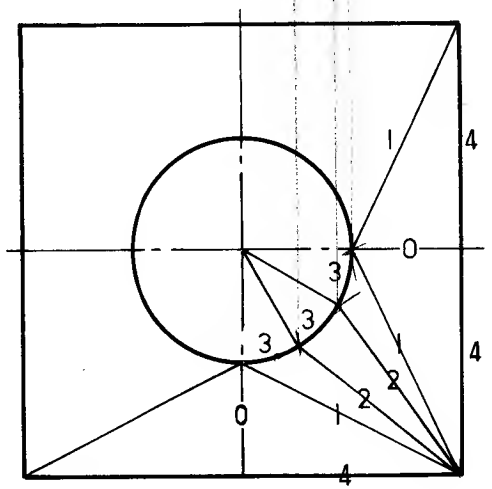
TRIANGULATION

Solution on p.180

*EXERCISES*

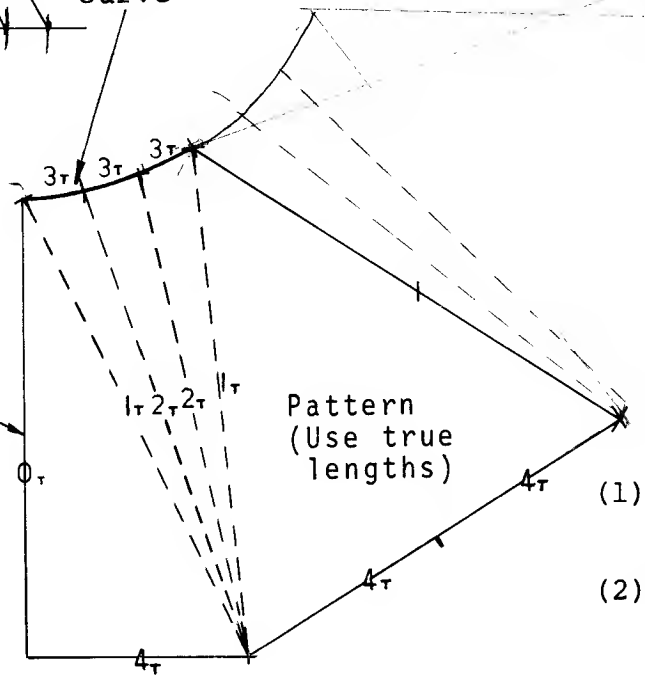


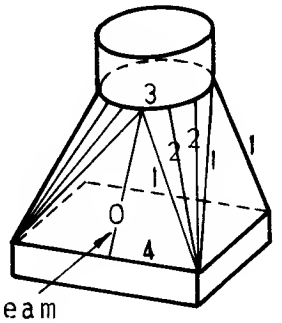



Start developing at seam

Join points with a smooth curve




(1) Verify the true length of lines 0, 1 and 2.

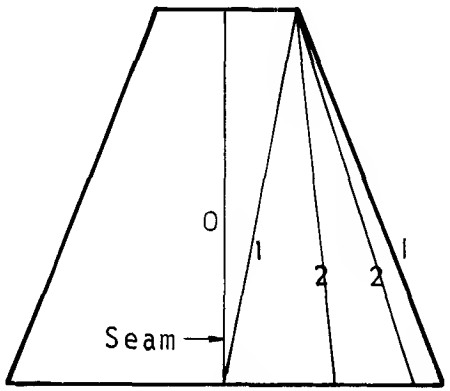
(2) Complete the pattern for the transition piece.

TRANSITION PIECE - SQUARE TO ROUND BETWEEN PARALLEL PLANES.

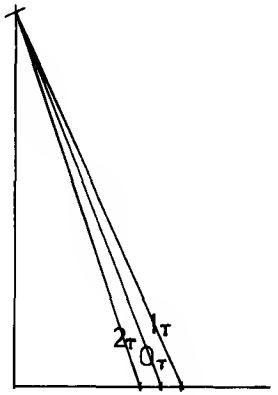
Note: Always number the lines on the line or near to the line.
Of the lines numbered only 3 and 4 are true lengths in the plan view.

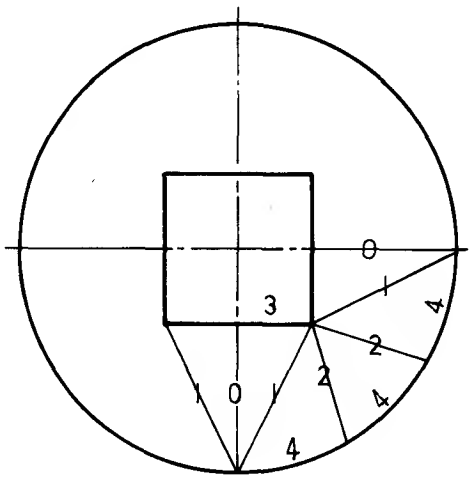
Soln. on p.181

## True lengths



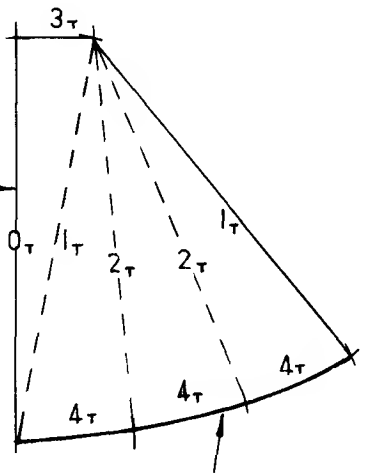

Front view



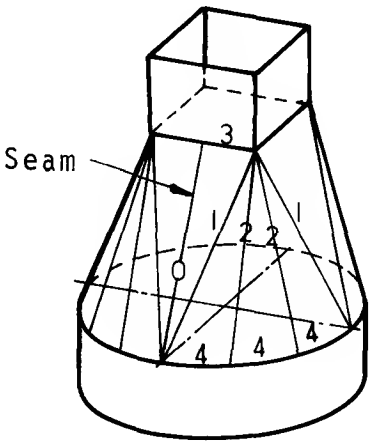

Plan

Start developing at a seam




Join points with a smooth curve

Pattern
(Use true lengths)




(1) Verify the true lengths of lines 0, 1 and 2.

(2) Complete the pattern for the transition piece.

ROUND TO SQUARE
BETWEEN PARALLEL PLANES

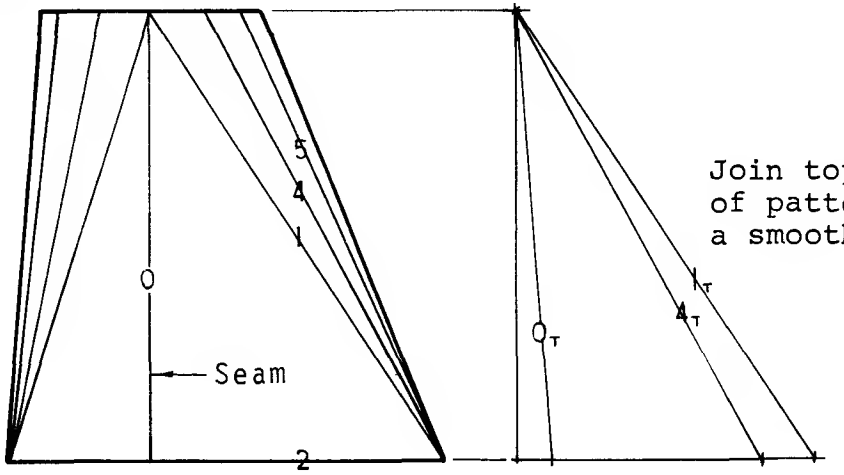
TRIANGULATION

Note: Always number the lines on the line or near to the line.
Of the lines numbered only 3 and 4 are true lengths in the plan view.

Soln. on p.181

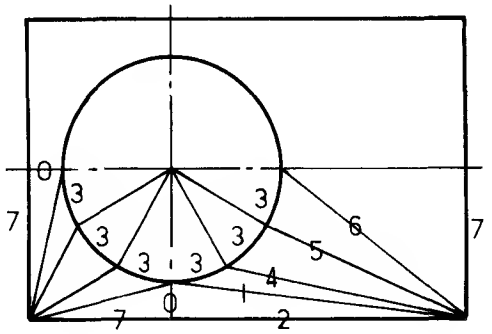
*EXERCISE*

True lengths

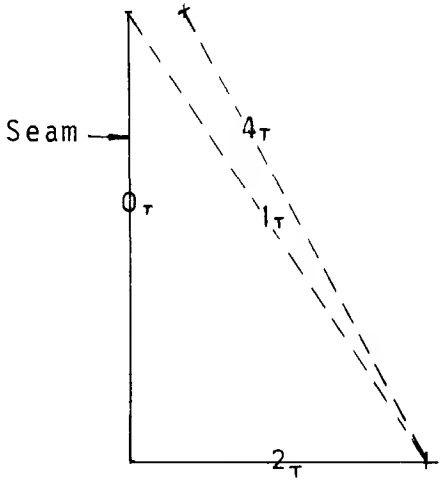



Join top points of pattern with a smooth curve

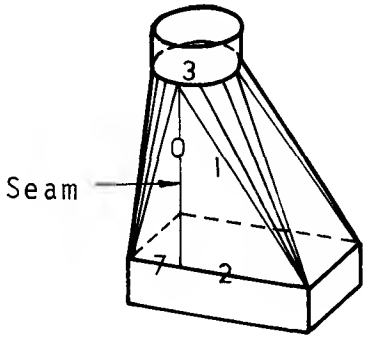
Front view




Plan




Pattern (Use true lengths)




Note: Of the lines numbered in the plan view only 2, 3 and 7 are true lengths. True lengths of other lines must be determined by the previously illustrated construction e.g. 0, 1 and 4 above.

(1) Complete the pattern for the transition piece.

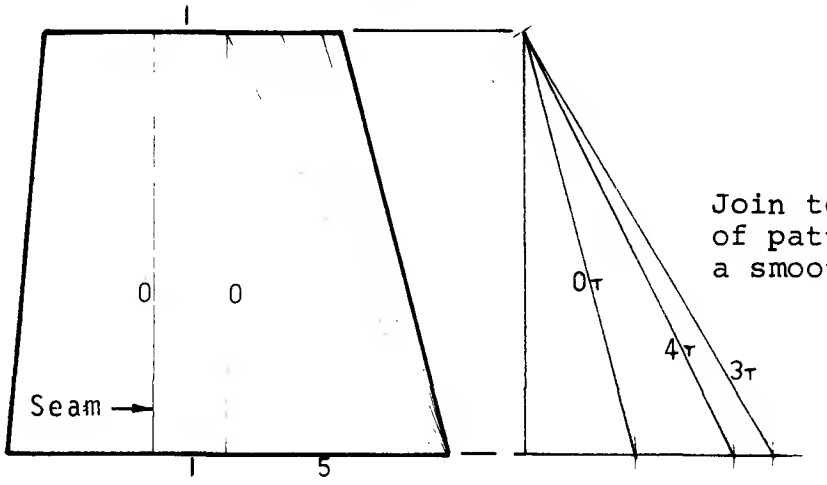
OFFSET TRANSITION PIECE - RECTANGLE TO ROUND BETWEEN PARALLEL PLANES.

Soln. on p.182

TRIANGULATION

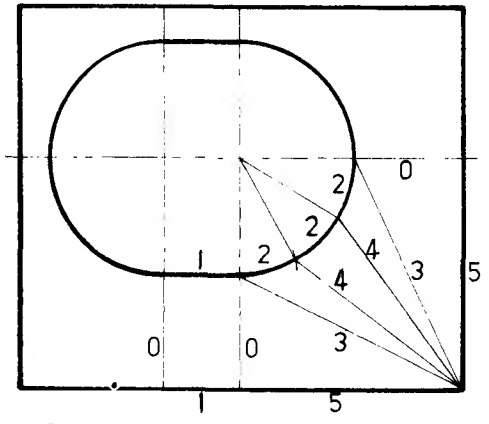
*EXERCISE*

True lengths

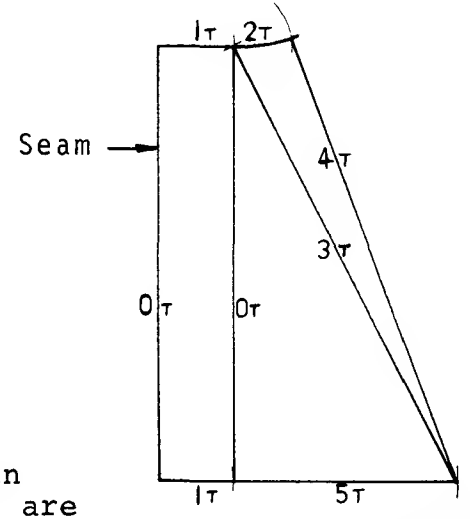



Join top points of pattern with a smooth curve

Front view

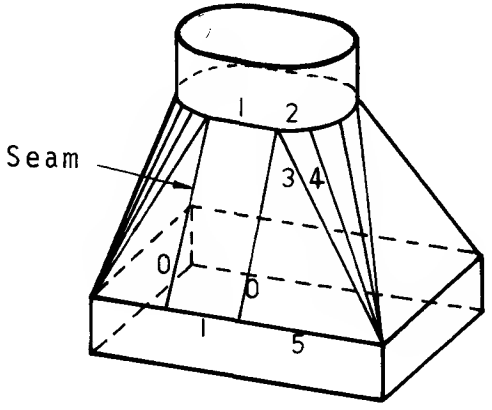



Plan




Pattern (Use true lengths)

Note: Of the lines numbered in the plan view only 1, 2 and 5 are true lengths.
True lengths of other lines must be determined by the previously illustrated construction e.g. O, 3 and 4 above.




(1) Complete the pattern for the transition piece.

OFFSET TRANSITION PIECE - RECTANGLE TO OVAL BETWEEN PARALLEL PLANES

TRIANGULATION

Soln. on p.182

# Solutions

In this section a solution is given for each of the exercises presented in the text. Each solution is identified by the page number on which the exercise appears. The solutions are arranged in the order in which the exercises are set.

Where an exercise has specifically requested a sketch or tracing the solution is sketched or traced freehand. Where it is felt, however, that an accurate representation makes it easier to understand the solutions they have been drawn to scale using instruments. On some of the more complicated solutions notes have been added in order to emphasize important points.

The Isometric and Oblique solutions shown are those thought to provide most detail. As explained in the text there is not necessarily a unique solution for each of these exercises.

Similarly the solution given for each of the dimensioning exercises may not be the only correct solution. The alternatives must, however, not only meet the requirements of the exercise but also obey the "rules" of dimensioning.

If cardboard or paper models are made of each of the development solutions and folded into the three-dimensional shape indicated in the corresponding exercise then these solutions can be easily and convincingly verified. Notice that all lines on the patterns are, as emphasized in the text, "true length" lines.

# Solutions: First Angle Orthographic Projection

On page 7

| Drg. | Reason for incorrect interpretation |
|---|---|
| 1 | Plan incorrectly positioned. It should be below F. |
| 2 | Plan incorrectly positioned. It should be projected below F. |
| 3 | Plan and side view incorrectly positioned. They should be interchanged. |
| 4 | Side view out of position. It should be projected from F. |
| 5 | Plan incorrectly positioned. It should be projected below F. |
| 6 | Plan incorrectly drawn. The cut away should be at the front of P. |
| 7 | Side view incorrectly drawn. The cut away should be hidden detail. |
| 8 | Side view positioned incorrectly. It should be drawn on the right hand side of F. |
| 9 | Plan drawn incorrectly. The cut away should be at the rear of P. |

On page 9

| | |
|---|---|
| 1 | C |
| 2 | D |
| 3 | K |
| 4 | L |
| 5 | F |
| 6 | H |
| 7 | A |
| 8 | B |
| 9 | G |
| 10 | J |
| 11 | I |
| 12 | E |

On page 8 Note These are sketched freehand.

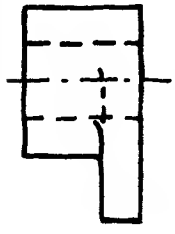
1

5



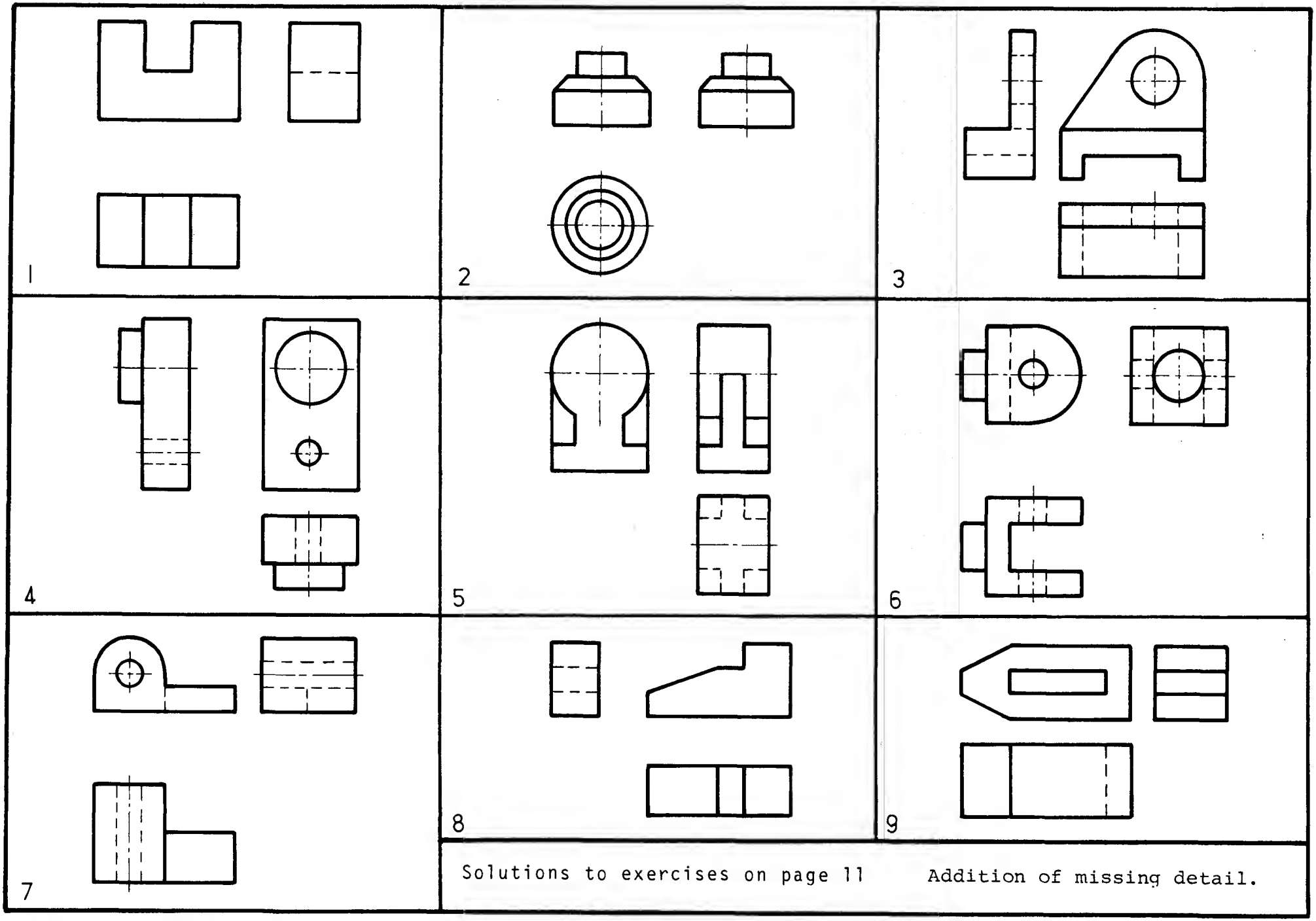
6

8



On page 10

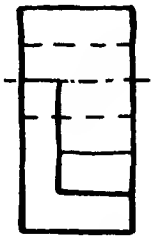
| Drawing | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| Front view in direction of F | 10 | 1 | 11 | 4 | 7 | 6 |
| Plan view in direction of P | 14 | 17 | 8 | 3 | 18 | 9 |
| Side view in direction of R | 5 | 16 | 2 | 12 | 13 | 15 |




Solutions to exercises on page 11

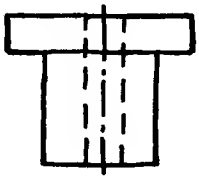
Addition of missing detail.

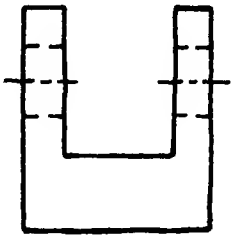
Solutions to exercises on pages 12 and 13 (sketched freehand)

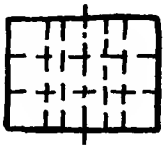

L
1

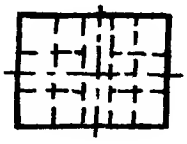

P
2

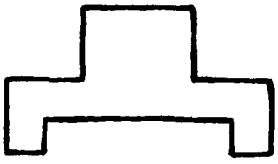

L
3

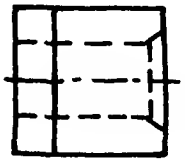

F
4

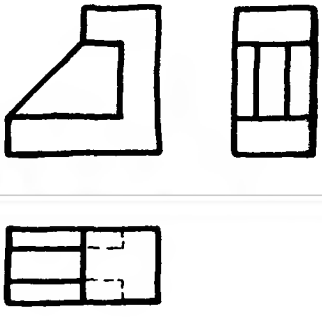

F
5

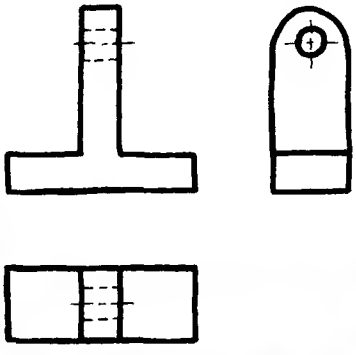

P
6

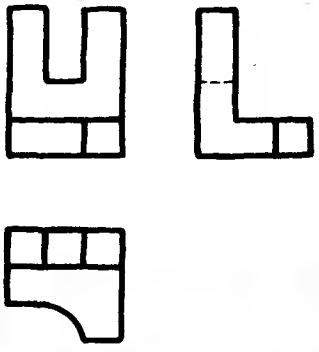

P
7

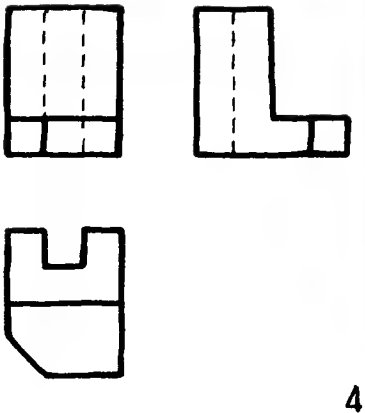

F
8

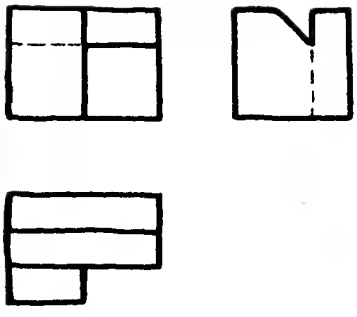

L
9

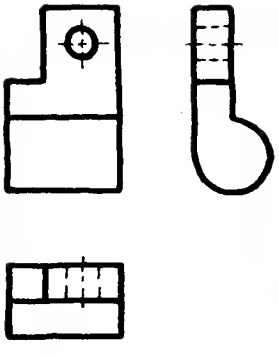

1


2

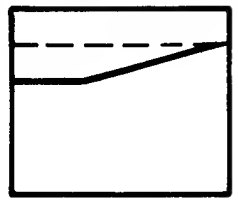

3


4

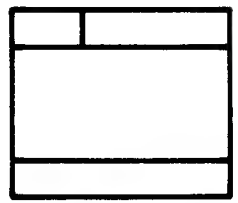

5


6

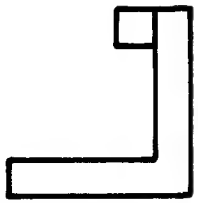
# Solutions: Third Angle Orthographic Projection



P



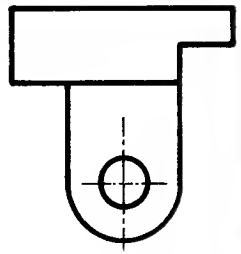
F



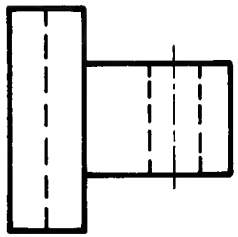
R

4

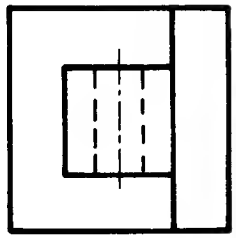
On page 16



P

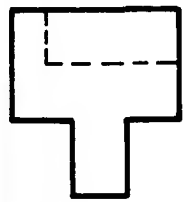


L

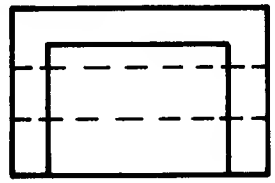


F

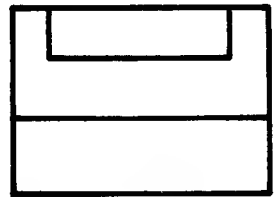
5



L



P



F

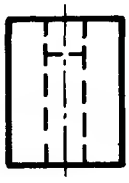
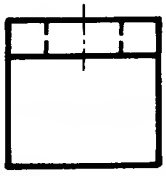
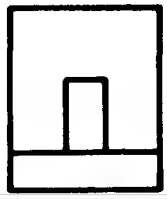
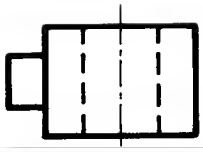
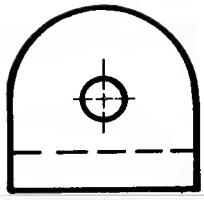
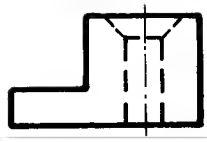
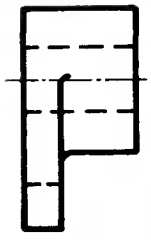
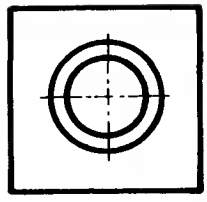
6

| | | |
|---|---|---|
| On page 17 | 1 | Plan should be projected above F - not below. |
| | 2 | R should be projected from, and placed on right of, F. |
| | 3 | Left side view should be on the left hand side of P - not as shown. |
| | 4 | The plan is drawn back to front. |
| | 5 | Plan should be projected from and placed above F - not as shown. |
| | 6 | Right side view is placed on wrong side of F - it should be on R.H. side. |
| | 7 | Plan should be placed directly above F. |
| | 8 | Front view is incorrectly drawn. Cut away should be placed on L.H. side of F. |
| | 9 | Hidden line representing cut away in F should be a full line. |

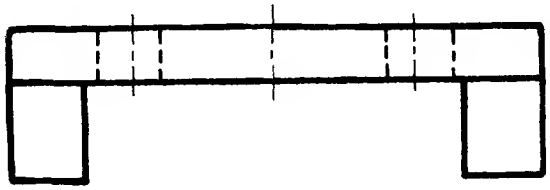
On page 18

| | |
|---|---|
| 1 | N |
| 2 | 1 |
| 3 | 3 |
| 4 | 1 |
| 5 | N |
| 6 | N |
| 7 | N |
| 8 | 1 |
| 9 | N |

Solutions to exercises on page 19 Addition of missing views.

| | | |
|---|---|---|
| Third R.H.S.  1 | Third Plan  2 | First Front  3 |
| Third Front  4 | First Front  5 | Third Front  6 |
| First L.H.S.  7 | Third Front  8 | First Front  9 |

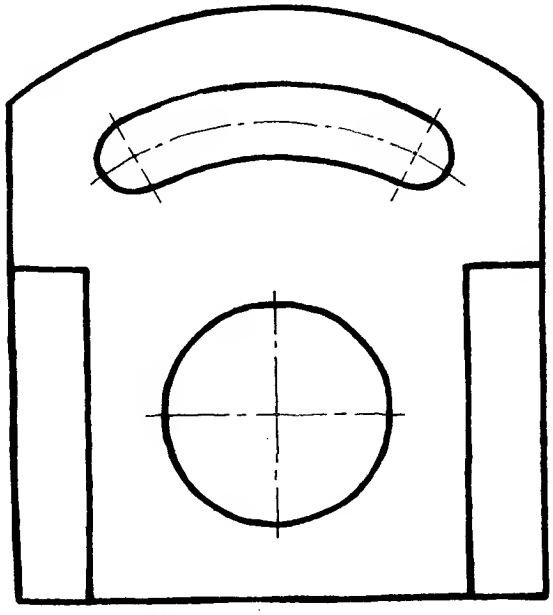
Solution to exercise 1 on page 20

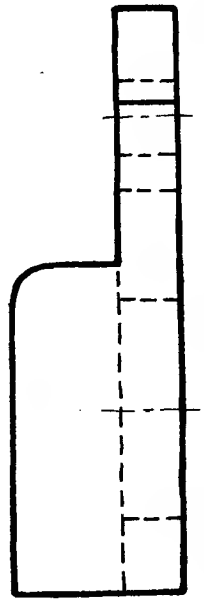


1.

Note

These views are sketched freehand

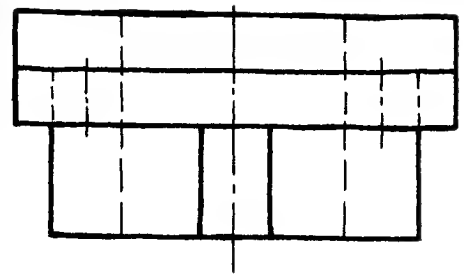


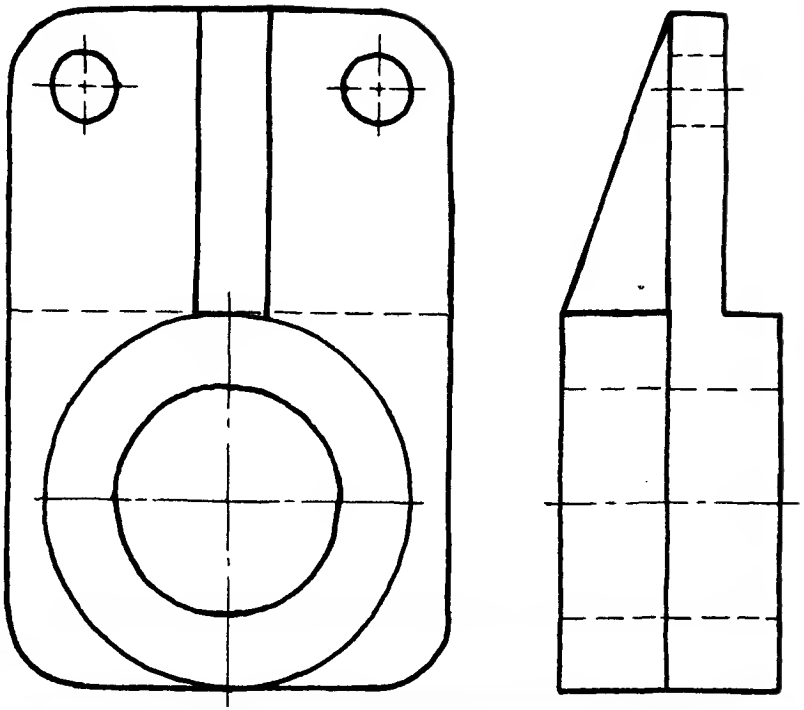


Solutions to exercises 2, 3 and 4
on page 20.

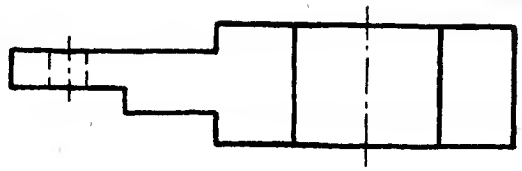
Note! These views are
sketched freehand.

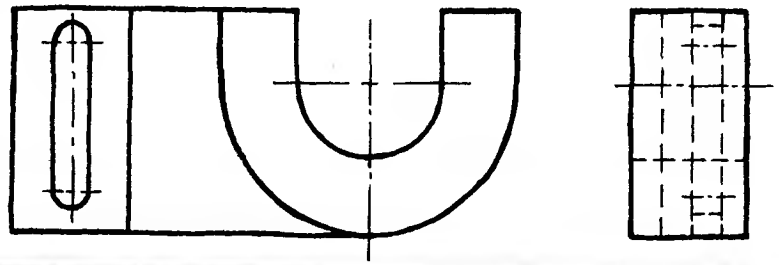
2



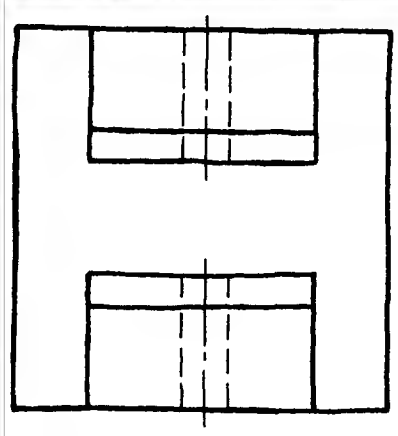


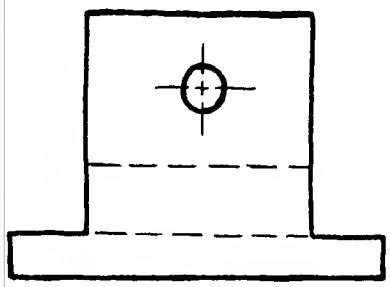
3

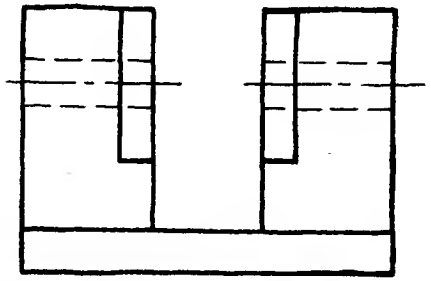


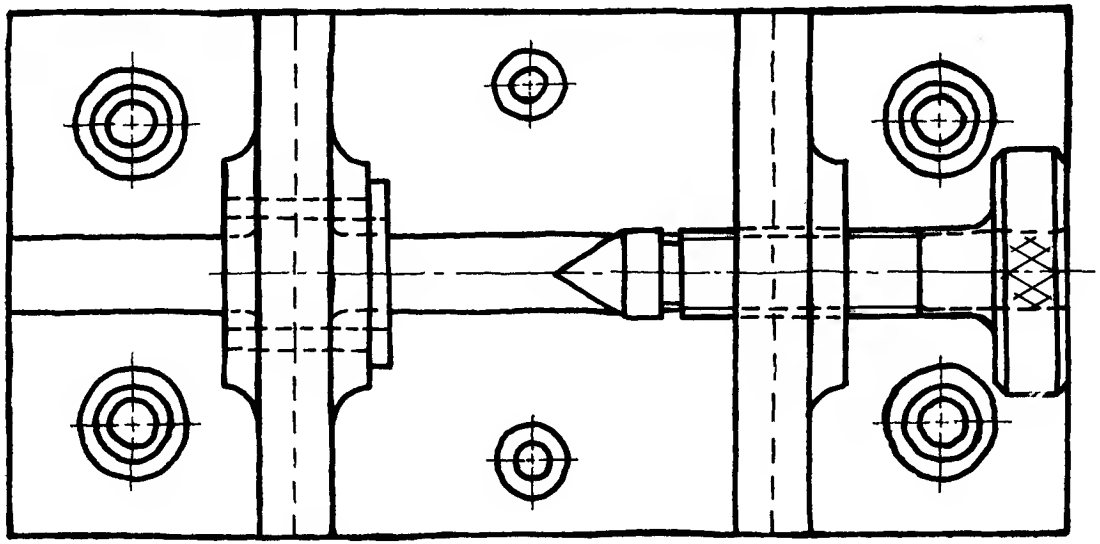


4









Solution to exercise 5

on page 20

External views using

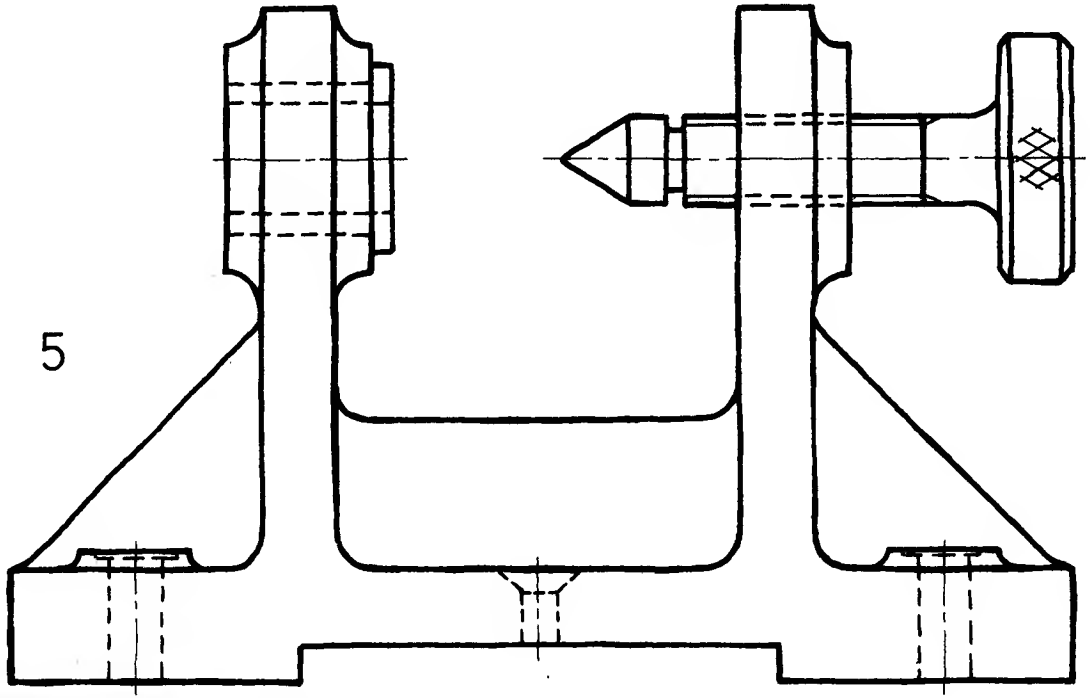
Third Angle Orthographic

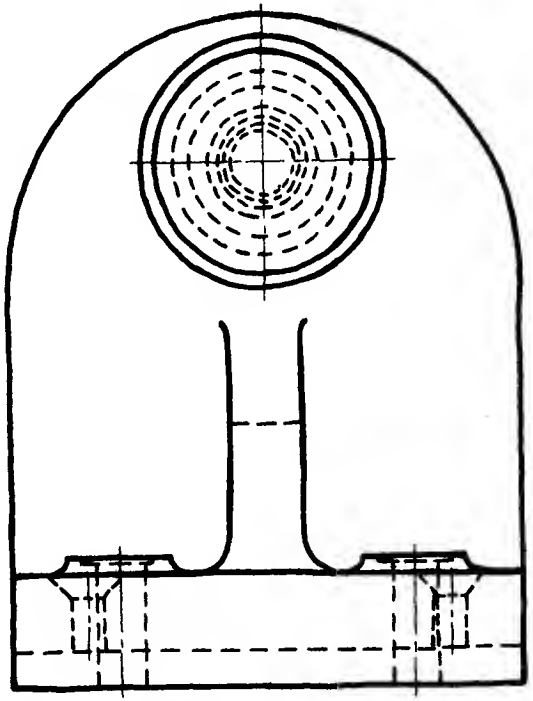
projection.

Note These views are

sketched freehand.

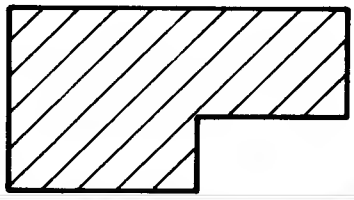
5



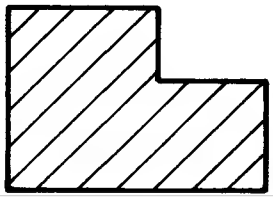


# Solutions: Sectioning

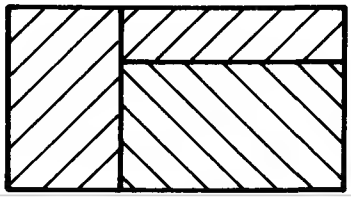
Exercises on page 25



1

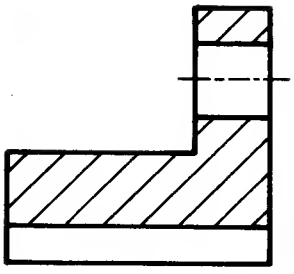


2



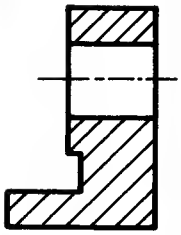
3

First angle



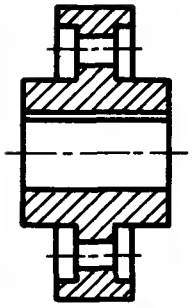
4

Third angle



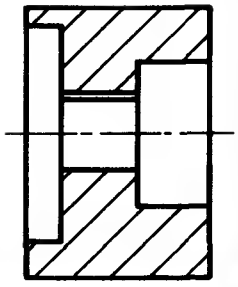
5

Third angle



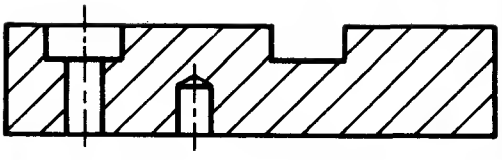
6

Third angle



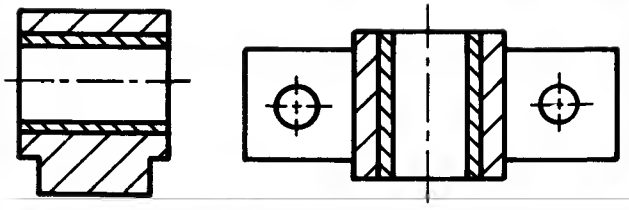
7

Third angle



8

First angle



9

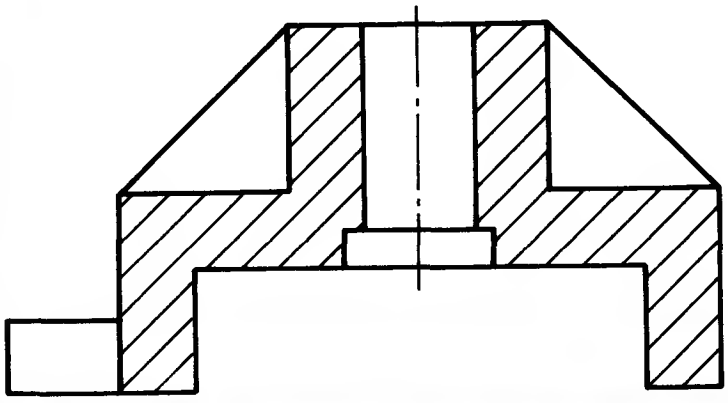
Solutions to sectioning exercises on page 26

| | | | | |
|---|---|---|---|---|
| H | 1 | | D | 2 |
| A | 3 | | M | 4 |
| F | 5 | | K | 6 |
| G | 7 | | N | 8 |
| E | 9 | | L | 10 |

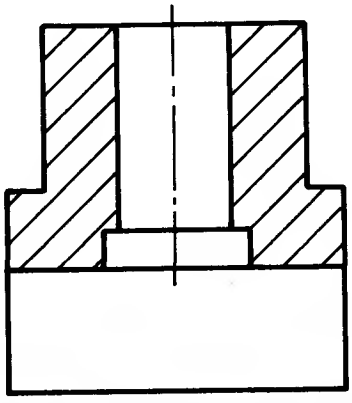
Solutions to sectioning exercises on page 27

| | | | | |
|---|---|---|---|---|
| K | 1 | | J | 2 |
| H | 3 | | R | 4 |
| N | 5 | | E | 6 |
| M | 7 | | B | 8 |
| O | 9 | | L | 10 |

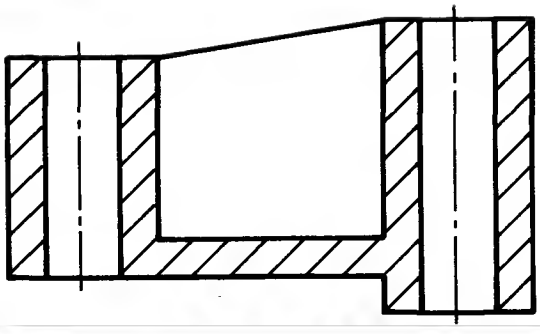
Solutions to sectioning exercises on page 28



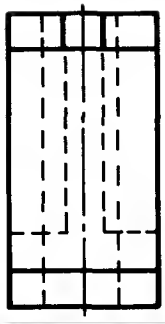
Section CC



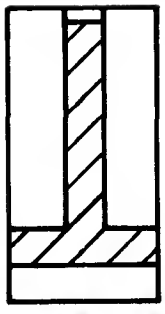
Section BB



Section DD



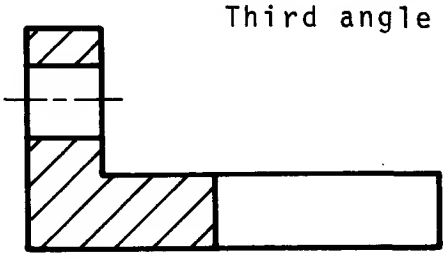
End View FF



Section EE

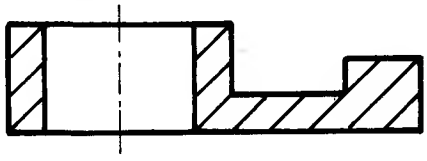
Solutions to sectioning exercises on page 29

Third angle



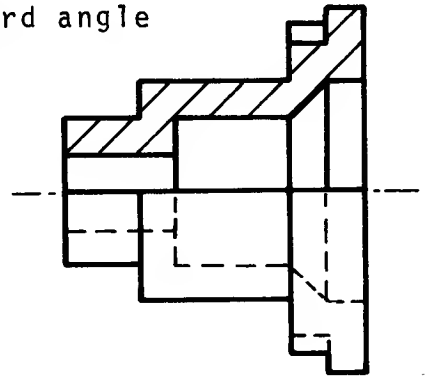
1

Third angle



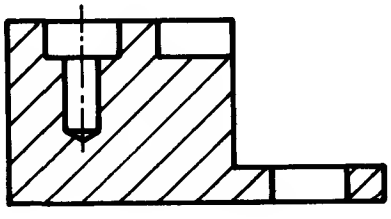
2

Third angle



3

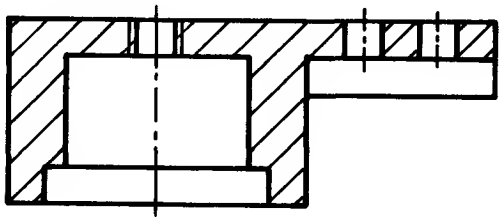
Third angle



4

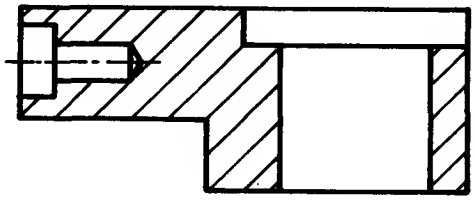
Solutions to sectioning exercises on page 30

Third angle



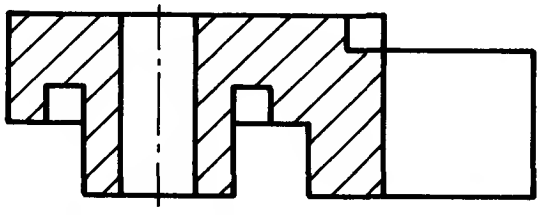
1

Third angle



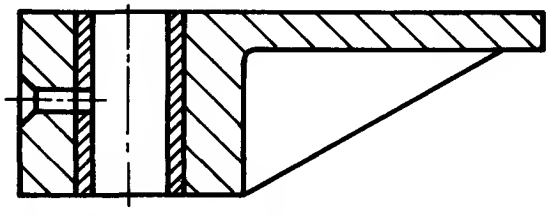
2

Third angle



3

Third angle

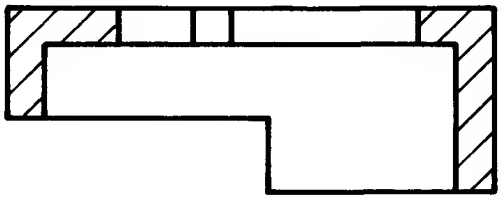


4

Note: In exercise 1 there is no bolt in the threaded hole, so the section lines cross the thread.

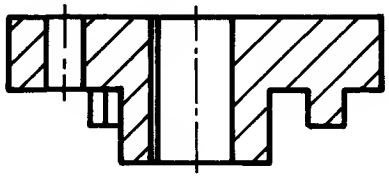
Solutions to sectioning exercises on page 31

Third angle



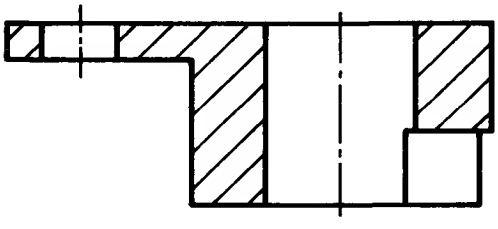
1

Third angle



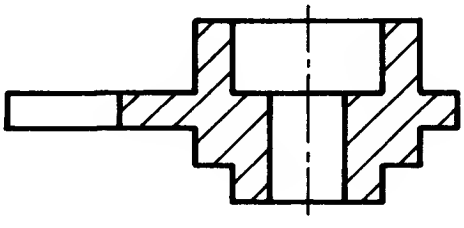
2

Third angle



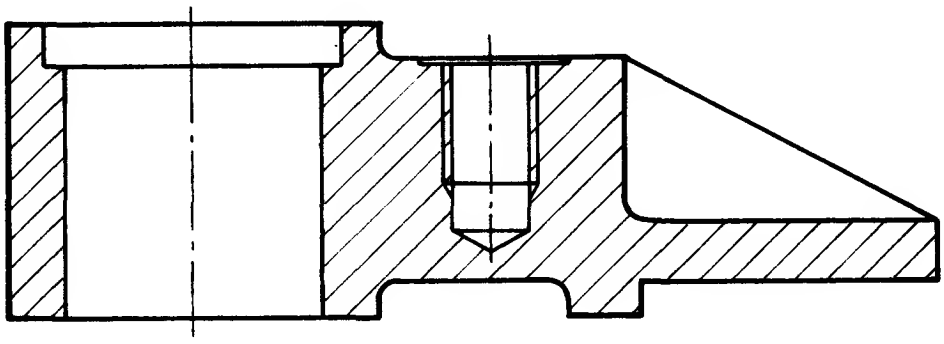
3

Third angle

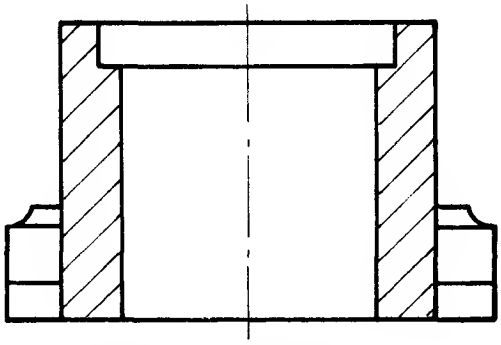


4

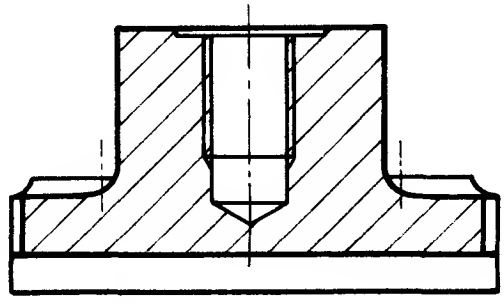
Solutions to sectioning exercises on page 32



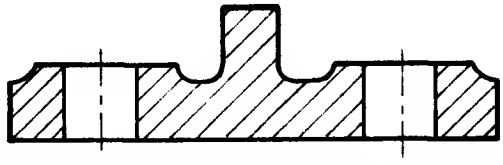
A sectional Front View looking on cutting plane CC



A sectional Side View looking on cutting plane AA

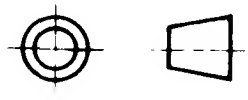


A sectional Side View looking on cutting plane BB



A sectional Side View looking on cutting plane DD

Third Angle Orthographic projection



## Solutions to exercises on page 45

### TERMINOLOGY

| | |
|---|---|
| 1 | 5D |
| 2 | 4D |
| 3 | 6B |
| 4 | 1C |
| 5 | 1B |
| 6 | 3A |
| 7 | 1A |
| 8 | 5B |
| 9 | 6C |
| 10 | 5C |

## Solutions to exercises on page 46

### ABBREVIATIONS

| | |
|---|---|
| 1 | 4C |
| 2 | 1A |
| 3 | 1D |
| 4 | 6C |
| 5 | 4B |
| 6 | 5D |
| 7 | 1B |
| 8 | 2C |
| 9 | 2D |
| 10 | 4A |
| 11 | 5C |
| 12 | 6A |

## Solutions to exercises on page 47

### CONVENTIONAL REPRESENTATION

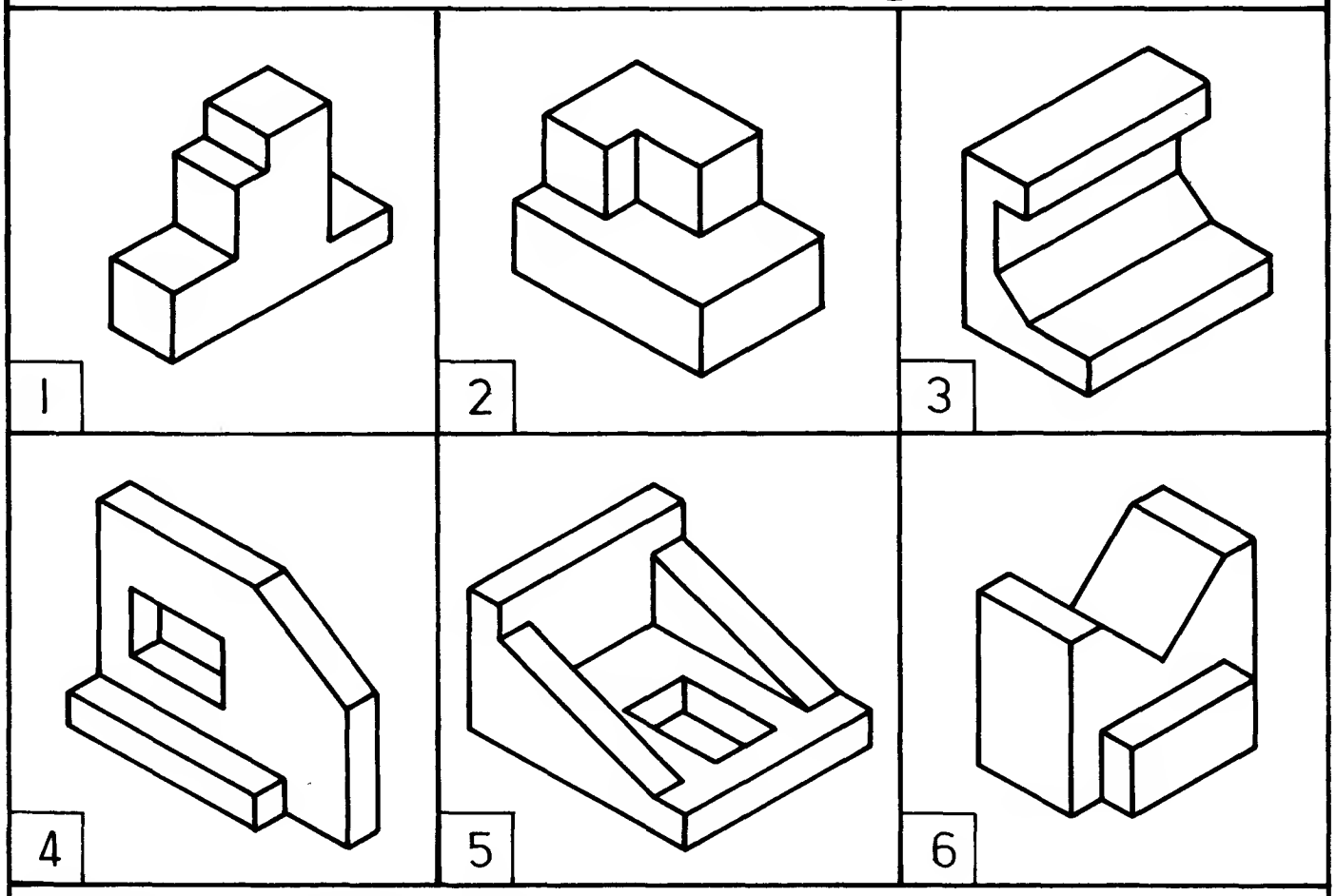
| | |
|---|---|
| 1 | 7C |
| 2 | 7A |
| 3 | 3A |
| 4 | 8C |
| 5 | 5A |
| 6 | 3C |
| 7 | 5B |
| 8 | 1A |
| 9 | 3B |
| 10 | 5C |

## Solutions to exercise on page 48

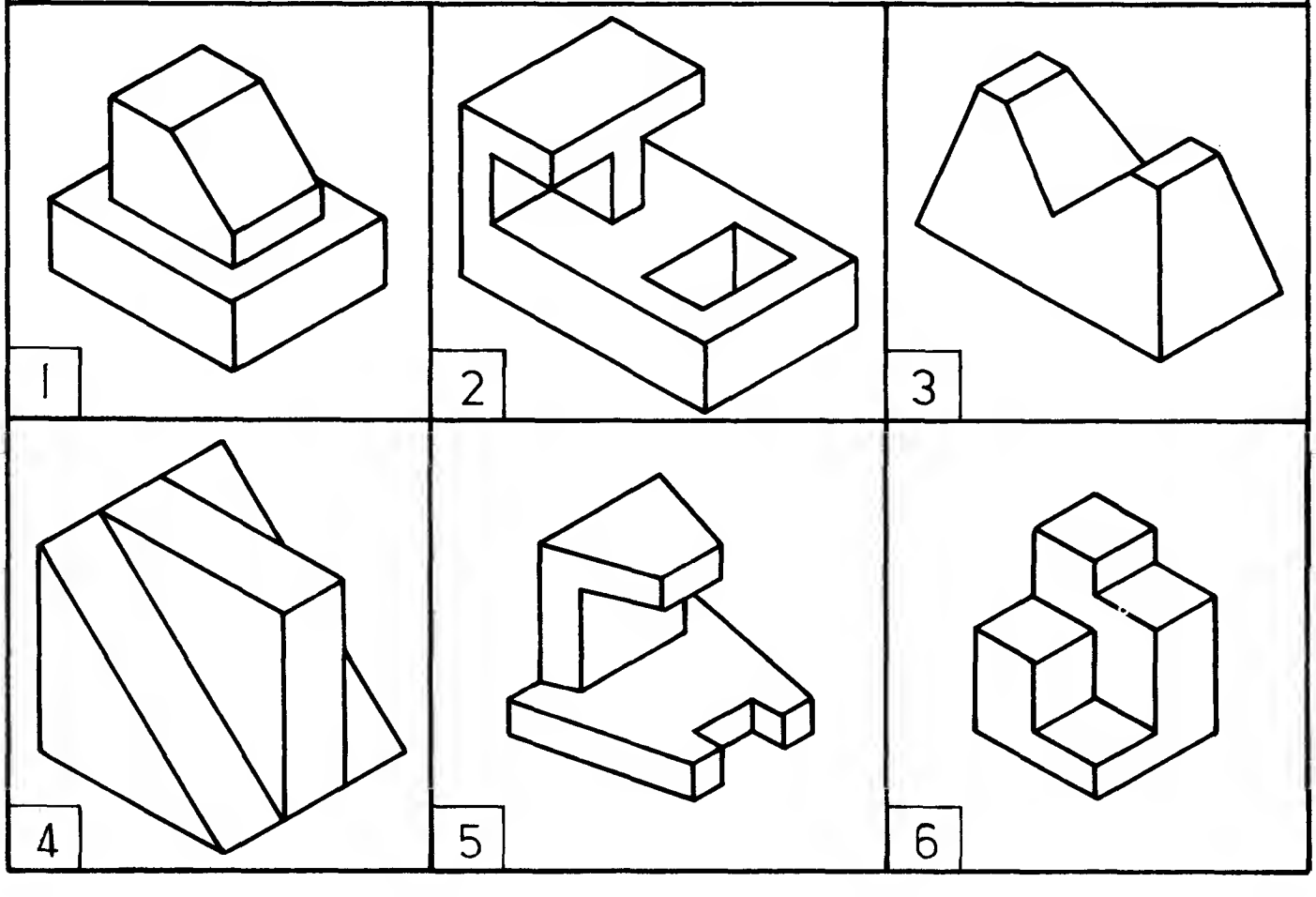
| | | | | |
|---|---|---|---|---|
| 1. Section line | 2. Centre line | 3. Rib | 4. Boss | 5. Foot (Base) |
| 6. Cutting Plane | 7. Taper | 8. Undercut | 9. M/c'ing symbol | 10. EXT thread |
| 11. Diamond knurl | 12. Spotface | 13. Hidden detail | 14. Diameter | 15. Fillet radius |
| 16. CSK hole | 17. Millimetre | 18. Third | 19. Centres | 20. A Bush |

# Solutions: Pictorial Drawing

ISOMETRIC Ex. page 52

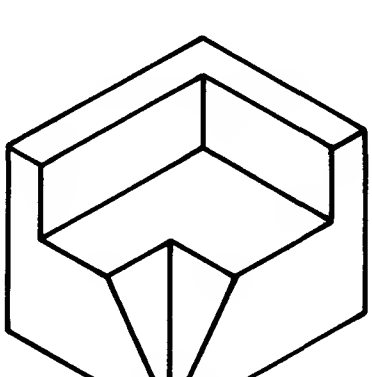



Solutions to exercises on page 53

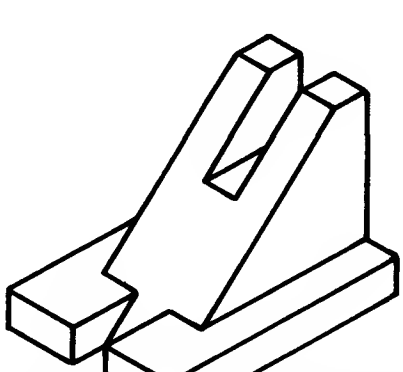


Solutions to exercises on page 54

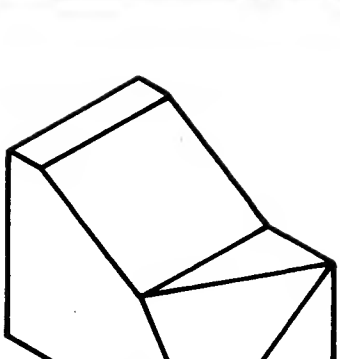
Note In these, and the preceding exercises dealing with isometric projection, each component has been viewed in the direction which shows the most detail.



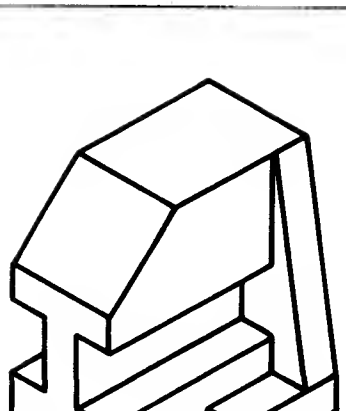
1



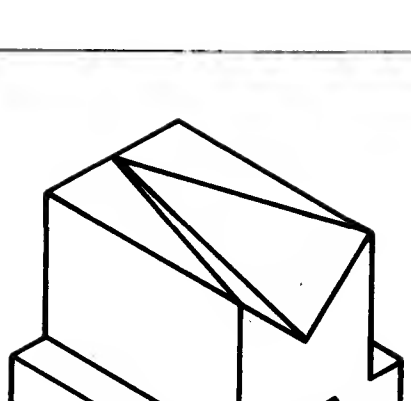
2



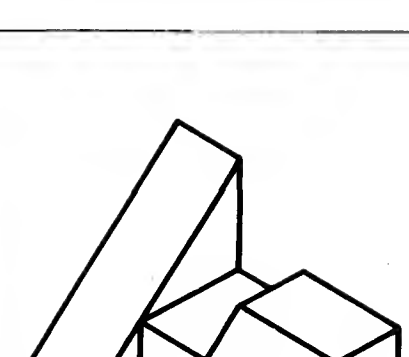
3



4



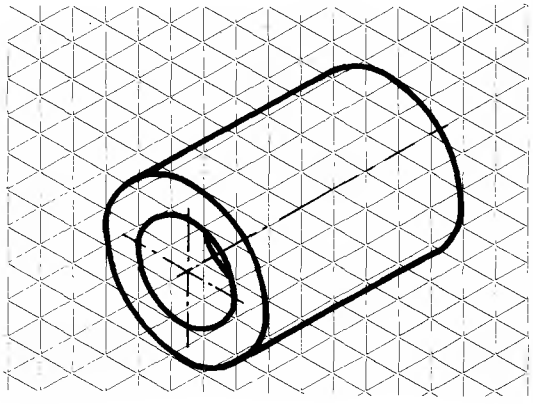
5



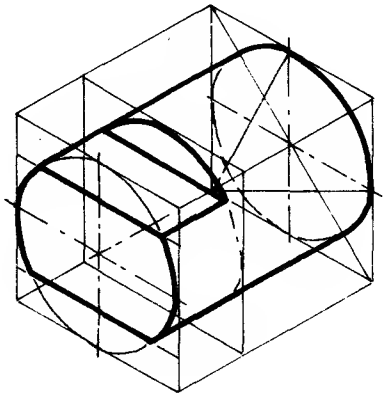
6

Solutions to exercises on page 58

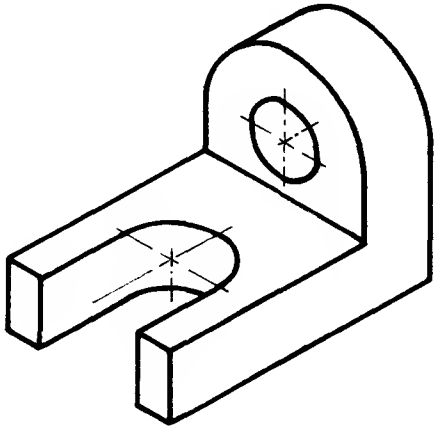
Note Each view has been drawn looking the directions indicated in the exercise. These were chosen so as to show the most detail in the pictorial view. All solutions have been drawn using either an isometric grid or a framework of lines as in 2.



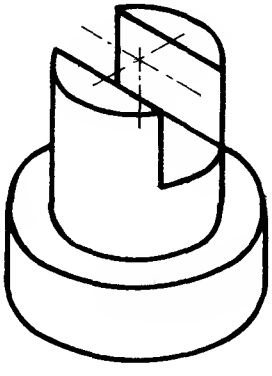
1



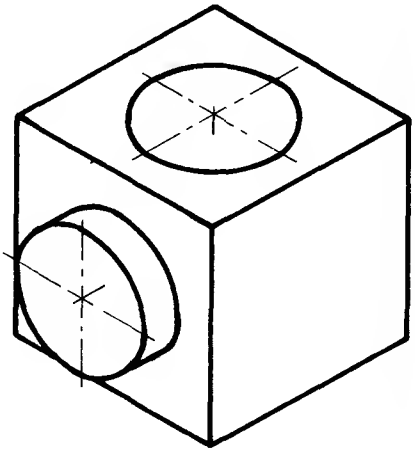
2



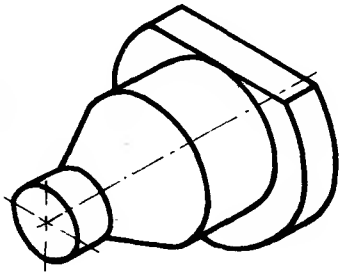
3



4



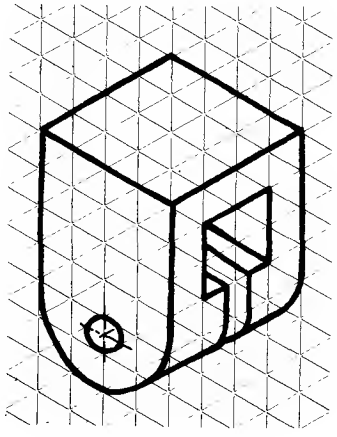
5



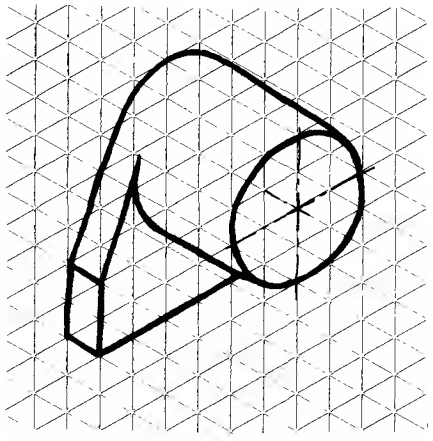
6

Solutions to exercises on page 59

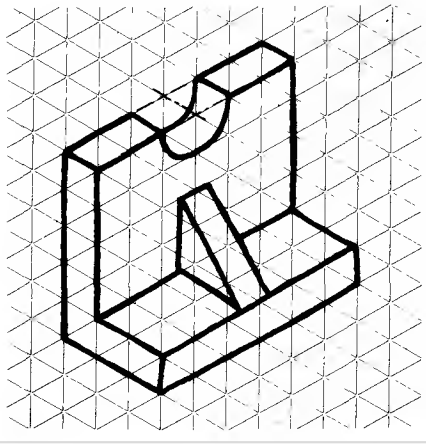
Note Each solution has been sketched freehand on an isometric grid. The resulting pictorial views are those which show the most detail of each component.



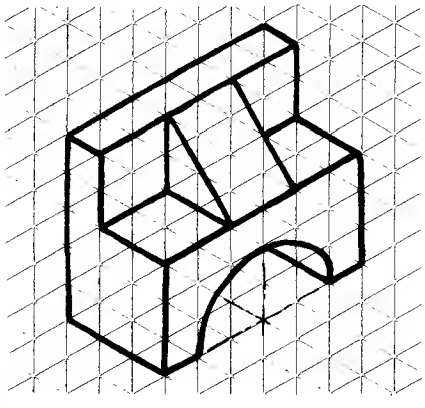
1



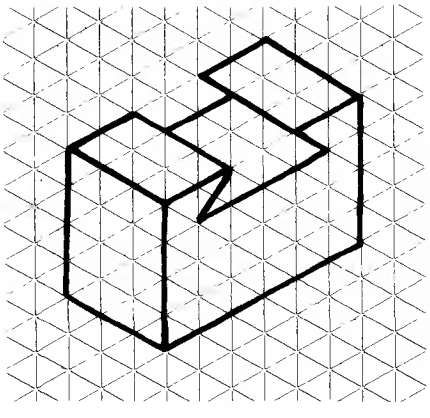
2



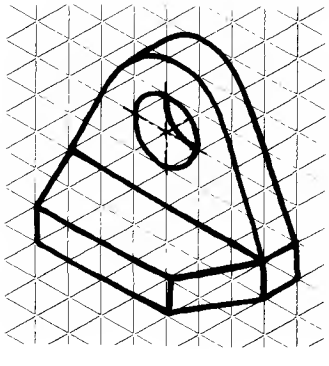
3



4

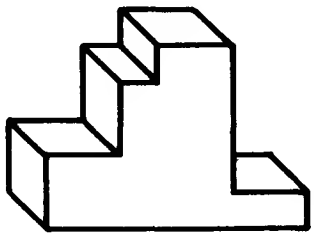


5

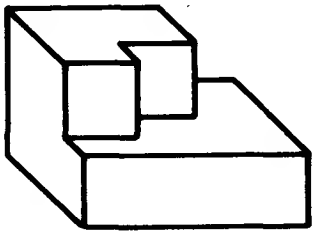


6

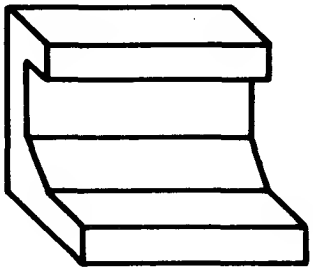
OBLIQUE Solutions to exercises on page 66 (drawings on page 52)



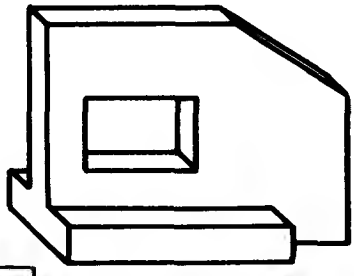
1



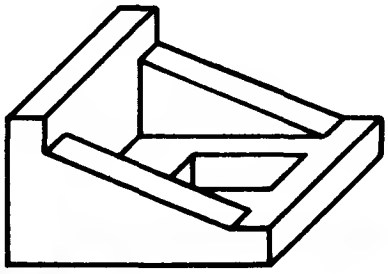
2



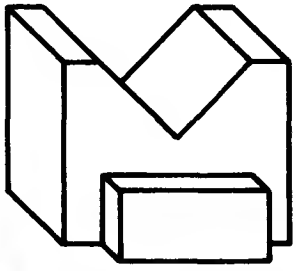
3



4

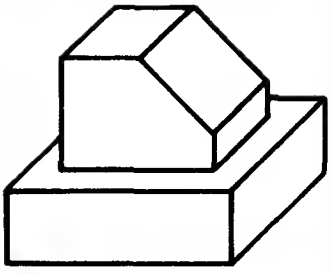


5

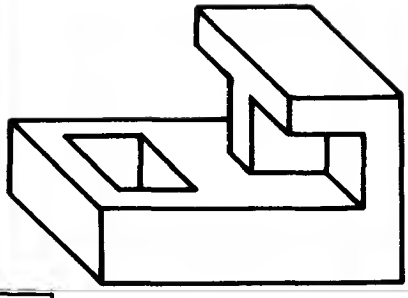


6

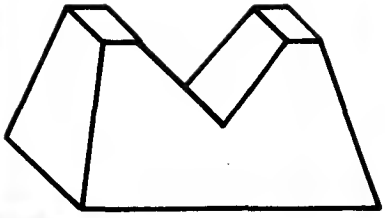
Solutions to exercises on page 66 (drawings on page 53)



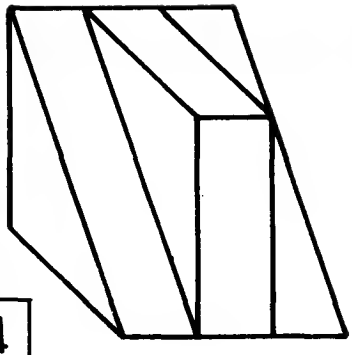
1



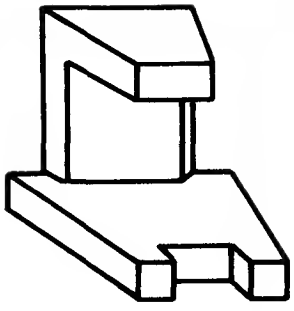
2



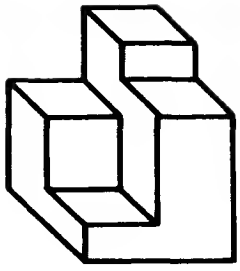
3



4



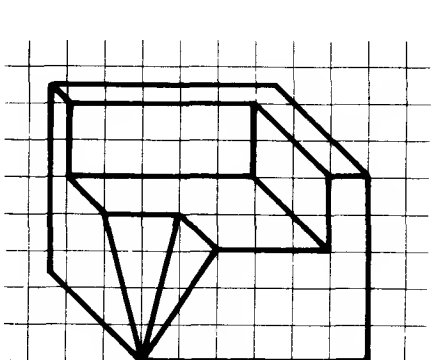
5



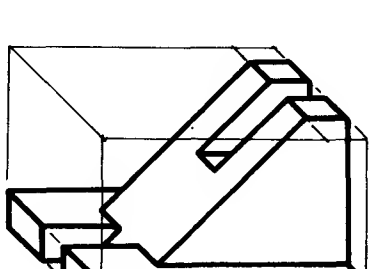
6

Solutions to exercises on page 66 (drawings on page 54)

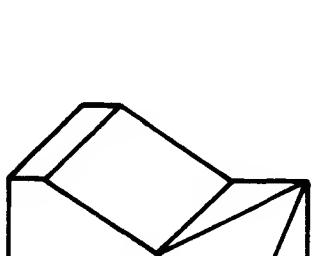
Note In these, and the preceding exercises dealing with oblique projection, each component has been viewed in the direction which shows the most detail.



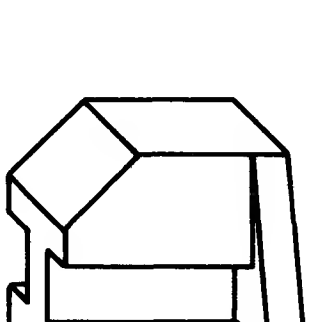
1



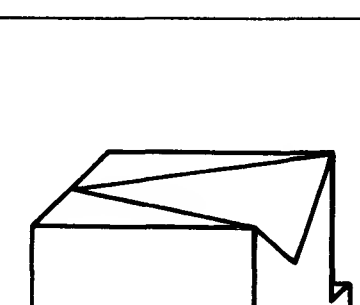
2



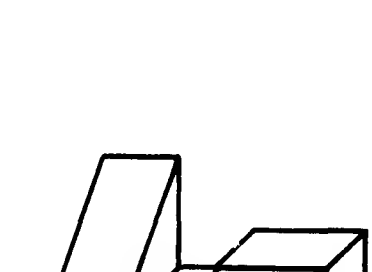
3



4



5



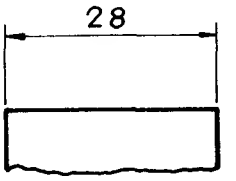
6

# Solutions: Dimensioning

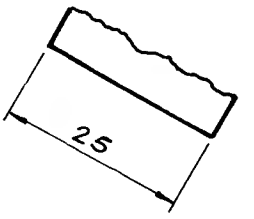
Solutions to exercises on page 72

74

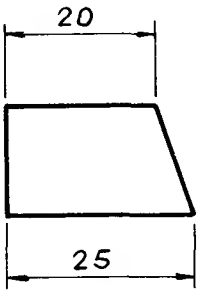
and 75



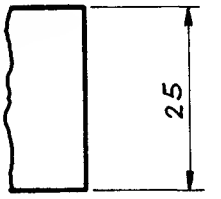

1



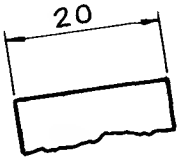

2



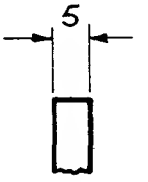

3



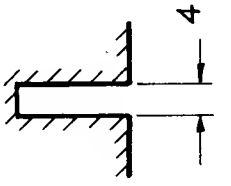

4




5




6

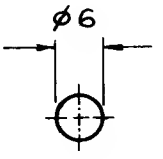


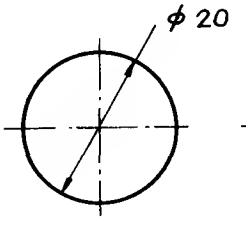

7

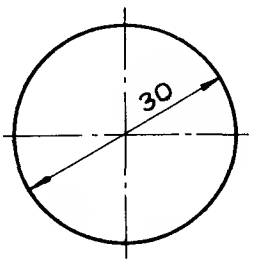
see page 72

Note

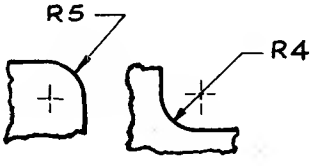
The solutions given are ideally spaced because there is adequate space for dimension lines and numbers.
On an engineering drawing, other lines may reduce the amount of space available for dimensions and care must be taken to ensure that lines and numbers are clear and do not clash with any other detail.
This is particularly the case with circles and radii when the dimension is often taken outside the circle or the radius.

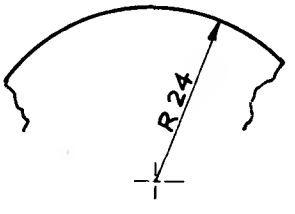


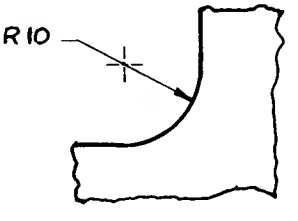



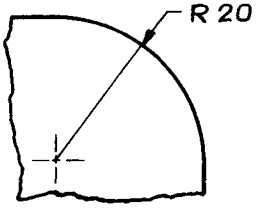




see page 74



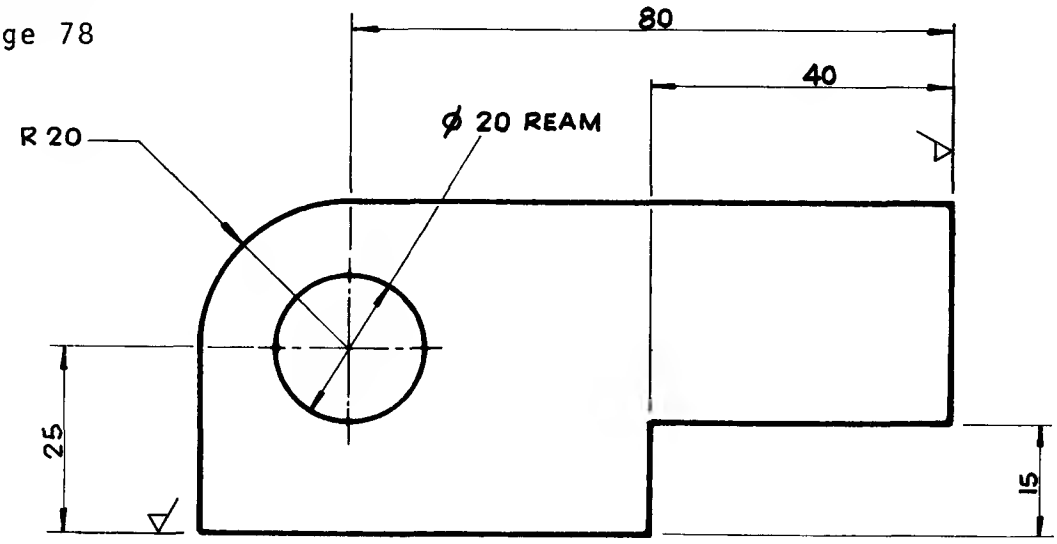



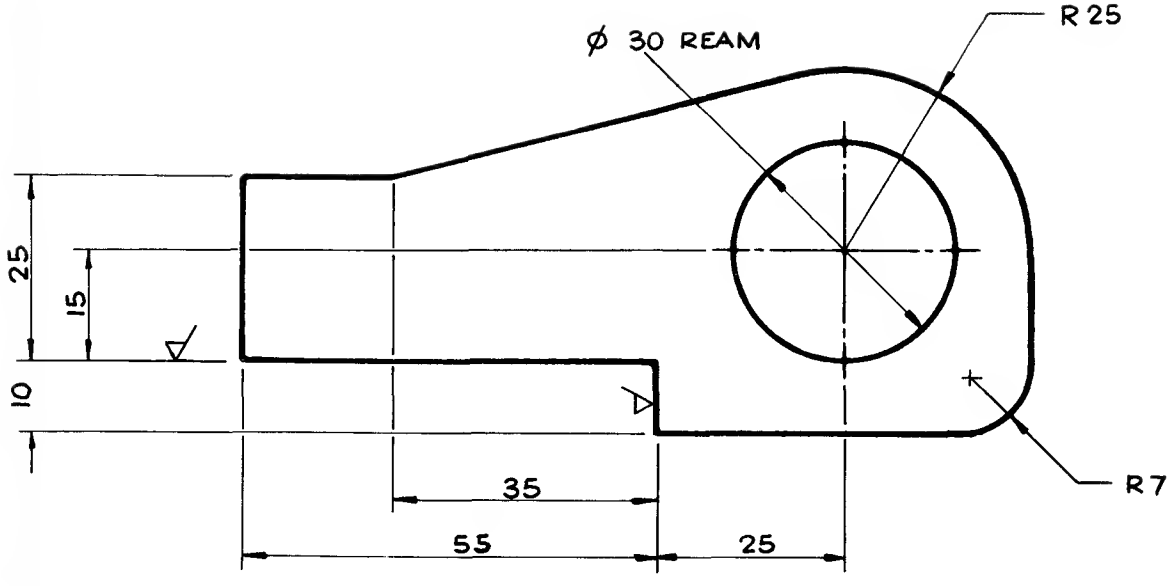

see page 75

Solutions to exercises on page 78




MATL - 15 mm MILD STEEL.

1

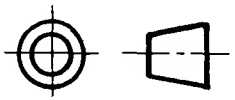


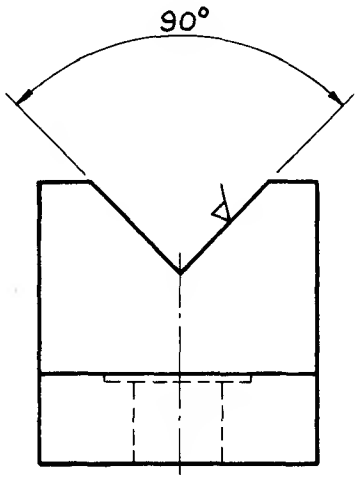

MATL - 15 mm MILD STEEL.

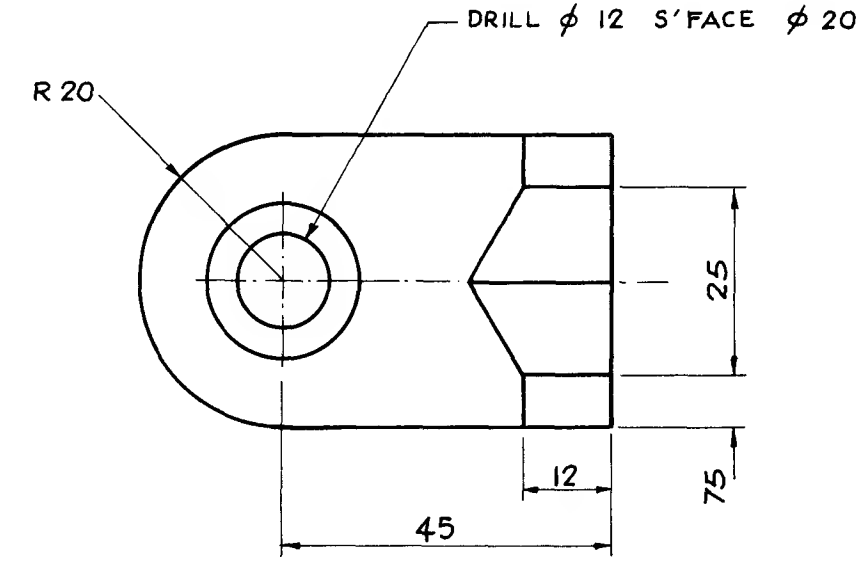
2

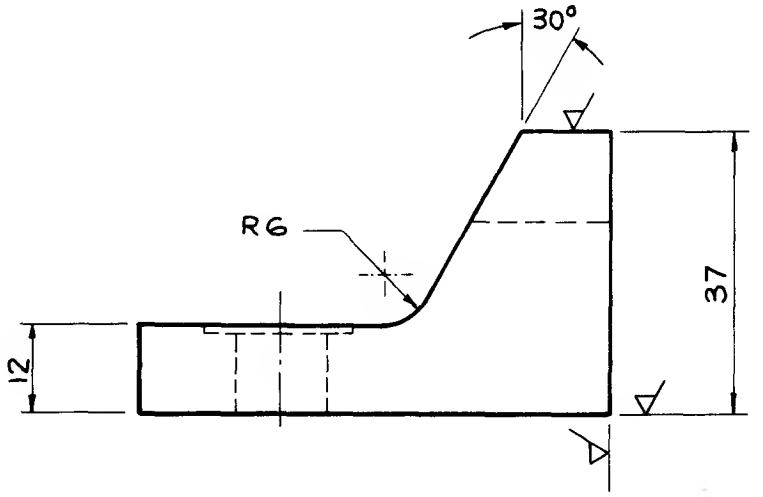
Solution to exercise
on page 79

MATL - CAST IRON

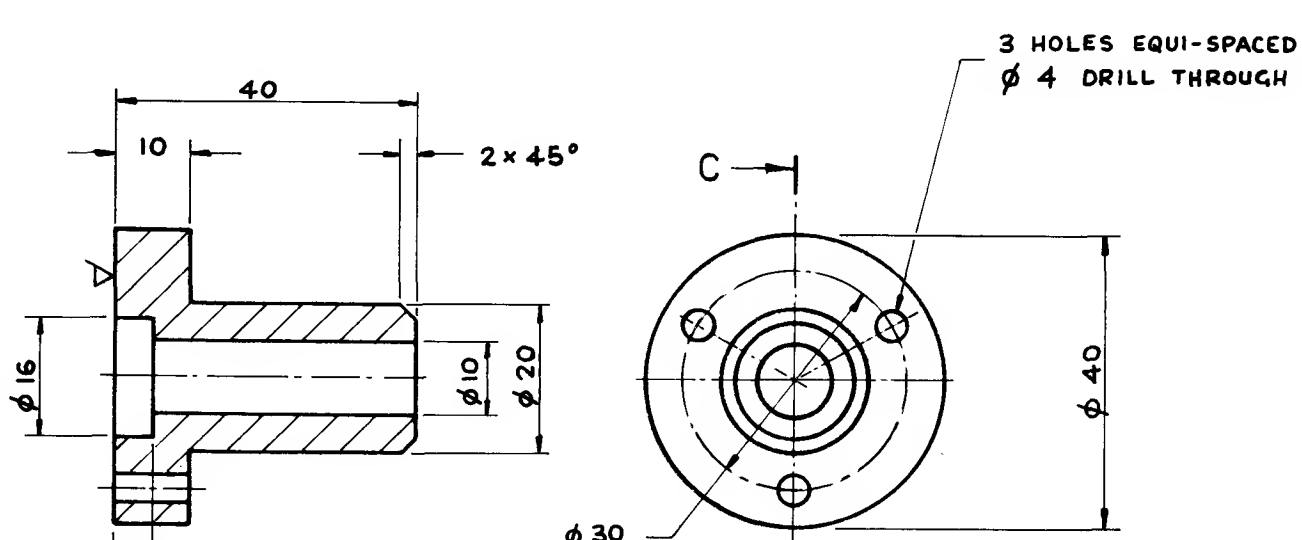




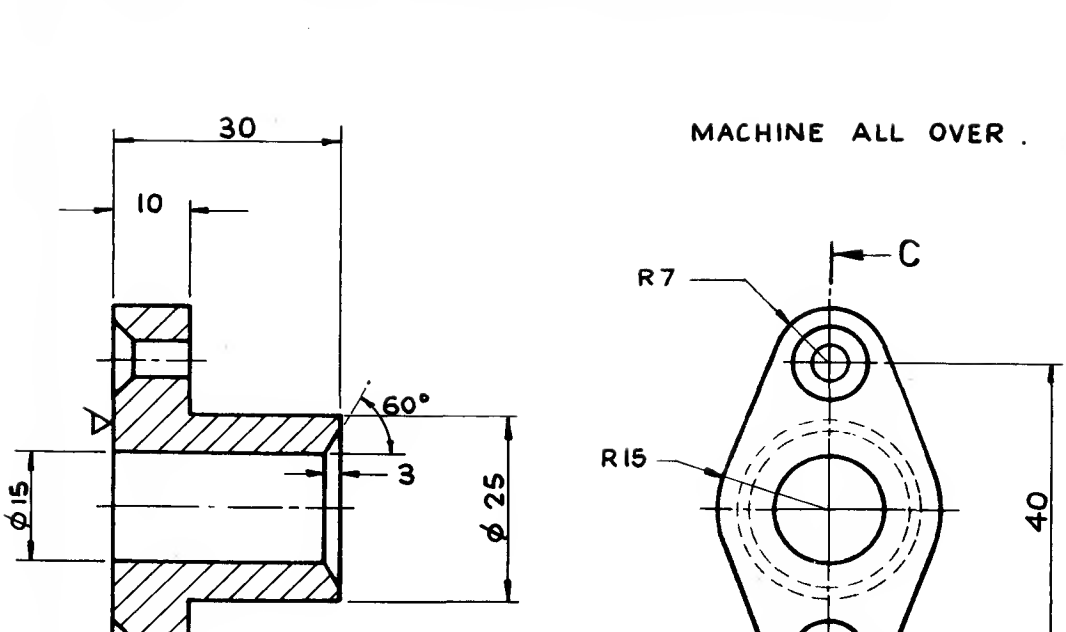



Solutions to exercises on page 80



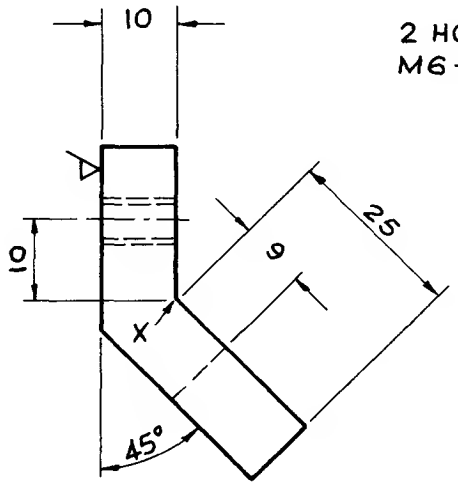

MACHINE ALL OVER.

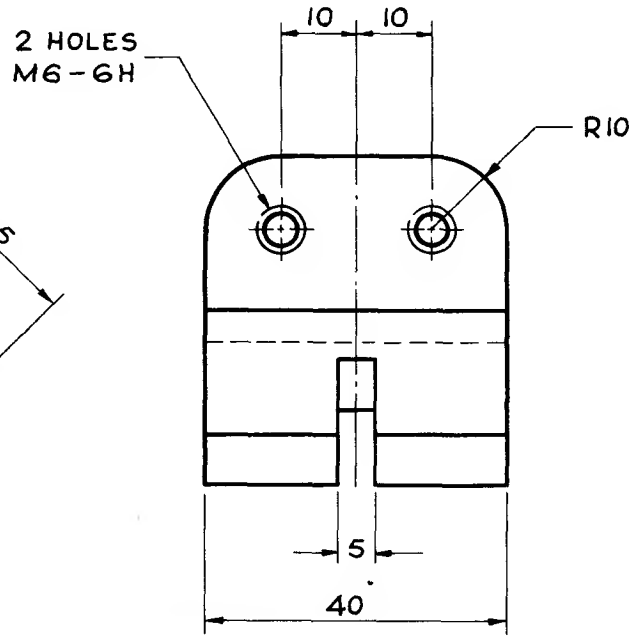
4




5

Solutions to exercises
on page 81



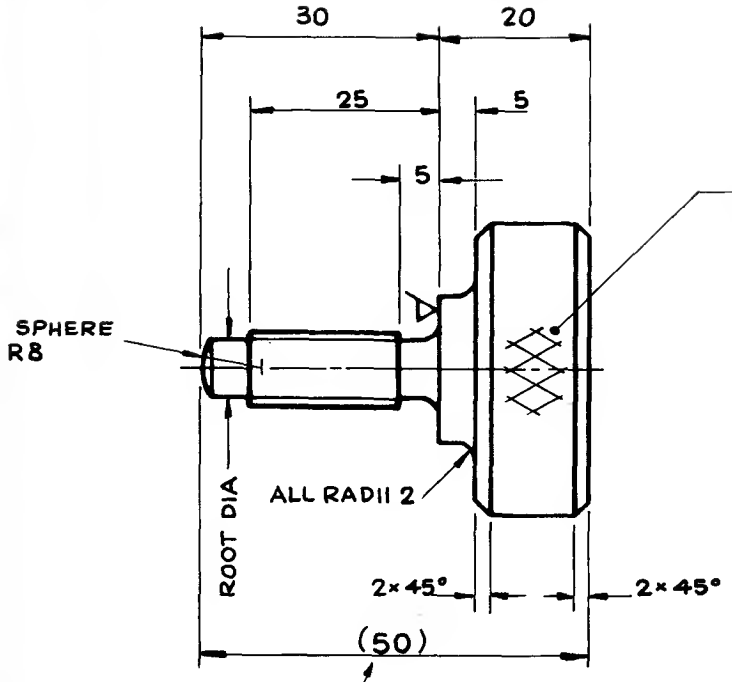



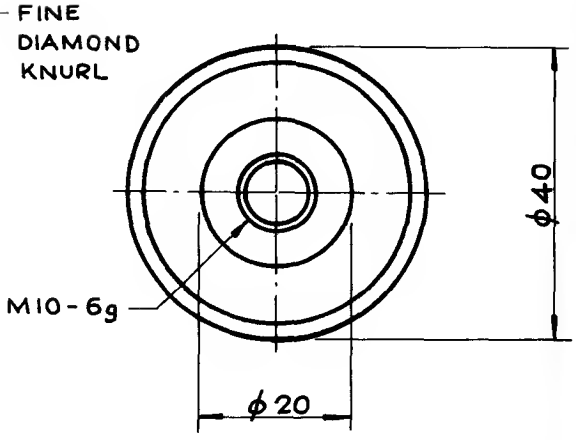

MATL - BRASS.

6

Note

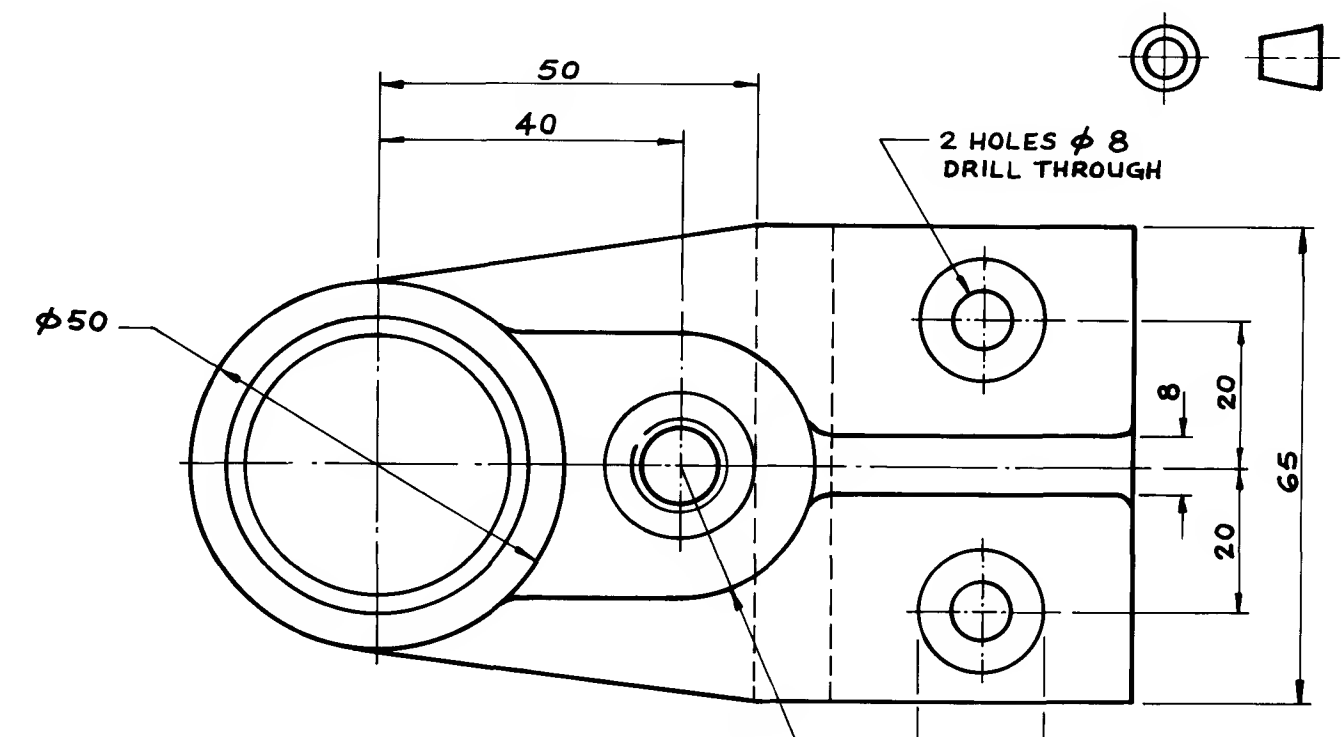
In this view, the heavy line of the root diameter is in front of the fine line circle of the thread.

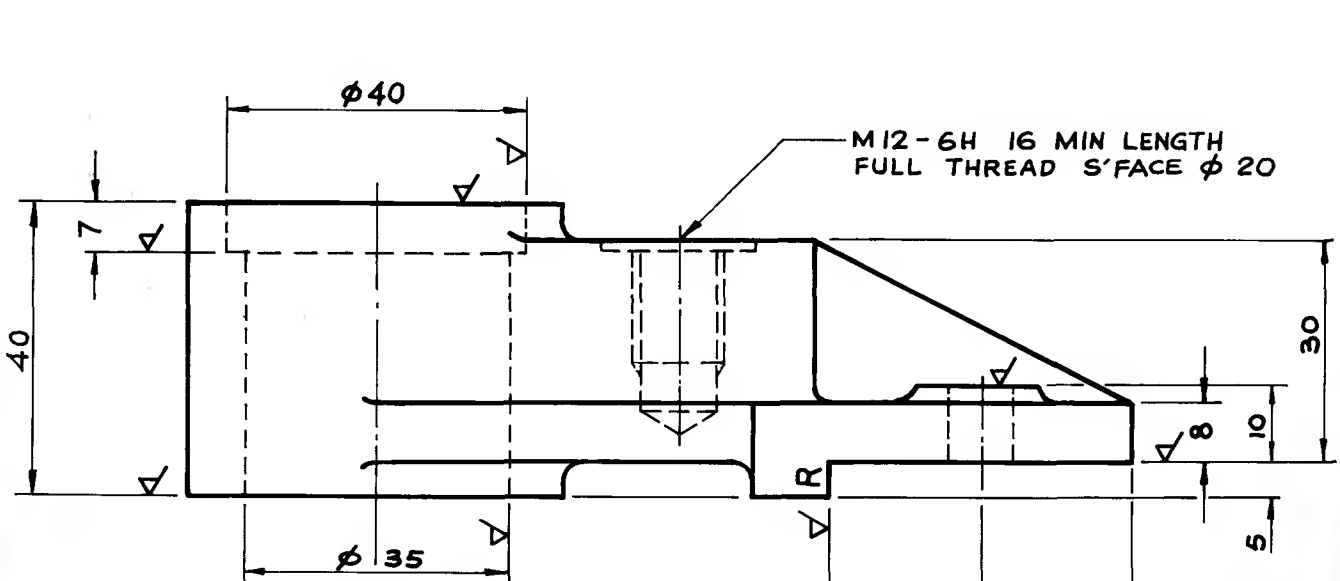



Note: The brackets indicate that this is an AUXILIARY dimension given for information only

7




8

Solution to exercise on page 82

In this exercise, an end view of the casting could have been used for indicating several of the above dimensions, but it is possible to fully dimension the component using two views only. There might well be other arrangements of the dimensions which would be quite satisfactory providing that the "rules" of dimensioning are observed and that a clear distinction is made between size and location dimensions.

# Solutions: Limits and Fits

Specimen solutions to exercises on page 90

Note: All sizes are in millimetres.
The decimal point is on the base line.

H7-g6

| Hole | | | | | Shaft | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Basic Size | ES + | EI | Max. Size | Min. Size | Basic Size | es - | ei - | Max. Size | Min. Size |
| 10 | 0.015 | 0 | 10.015 | 10.000 | 10 | 0.005 | 0.014 | 9.995 | 9.986 |
| 15 | 0.018 | 0 | 15.018 | 15.000 | 15 | 0.006 | 0.017 | 14.994 | 14.983 |
| 25 | 0.021 | 0 | 25.021 | 25.000 | 25 | 0.007 | 0.020 | 24.993 | 24.980 |
| 40 | 0.025 | 0 | 40.025 | 40.000 | 40 | 0.009 | 0.025 | 39.991 | 39.975 |
| 65 | 0.030 | 0 | 65.030 | 65.000 | 65 | 0.010 | 0.029 | 64.990 | 64.971 |

H7-s6

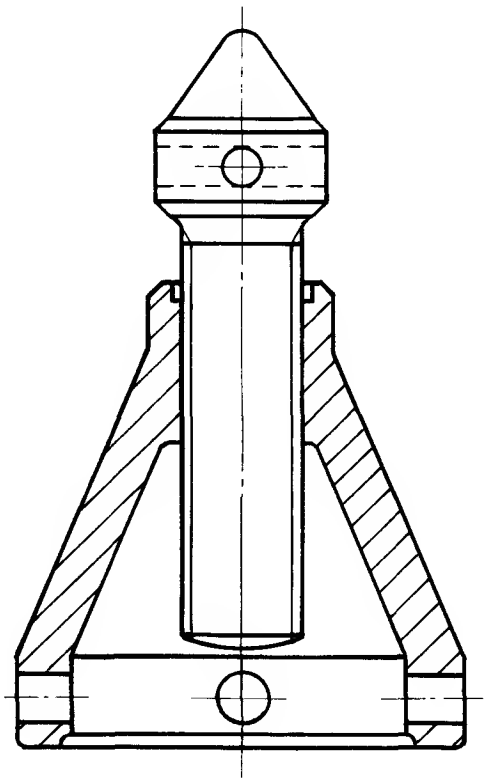
| Hole | | | | | Shaft | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Basic Size | ES + | EI | Max. Size | Min. Size | Basic Size | es + | ei + | Max. Size | Min. Size |
| 8 | 0.015 | 0 | 8.015 | 8.000 | 8 | 0.032 | 0.023 | 8.032 | 8.023 |
| 18 | 0.018 | 0 | 18.018 | 18.000 | 18 | 0.039 | 0.028 | 18.039 | 18.028 |
| 28 | 0.021 | 0 | 28.021 | 28.000 | 28 | 0.048 | 0.035 | 28.048 | 28.035 |
| 38 | 0.025 | 0 | 38.025 | 38.000 | 38 | 0.059 | 0.043 | 38.059 | 38.043 |
| 78 | 0.030 | 0 | 78.030 | 78.000 | 78 | 0.078 | 0.050 | 78.078 | 78.050 |

H7-k6

| Hole | | | | | Shaft | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Basic Size | ES + | EI | Max. Size | Min. Size | Basic Size | es + | ei + | Max. Size | Min. Size |
| 7 | 0.015 | 0 | 7.015 | 7.000 | 7 | 0.010 | 0.001 | 7.010 | 7.001 |
| 11 | 0.018 | 0 | 11.018 | 11.000 | 11 | 0.012 | 0.001 | 11.012 | 11.001 |
| 20 | 0.021 | 0 | 20.021 | 20.000 | 20 | 0.015 | 0.002 | 20.015 | 20.002 |
| 50 | 0.025 | 0 | 50.025 | 50.000 | 50 | 0.018 | 0.002 | 50.018 | 50.002 |
| 70 | 0.030 | 0 | 70.030 | 70.000 | 70 | 0.021 | 0.002 | 70.021 | 70.002 |

# Solutions: Sectioned Assemblies

Exercises on pages 99 and 100

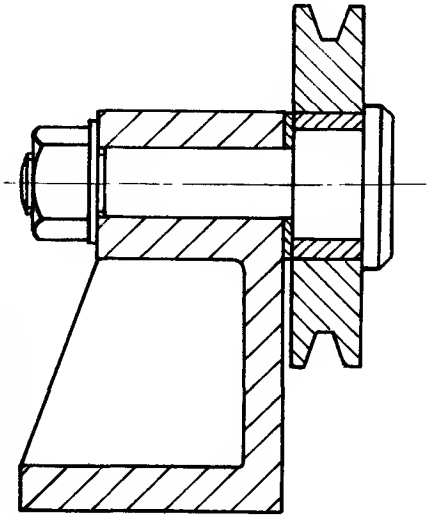


On page 99

(1) Sectioned assembly looking on cutting plane CC.

Note:

Although the screw lies in the cutting plane it is not sectioned when cut longitudinally (i.e. along its length).



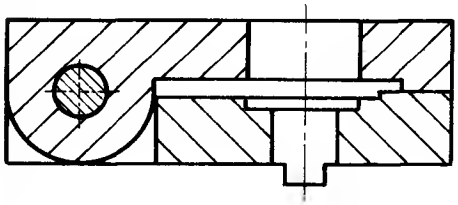
On page 99

(2) Sectioned assembly looking on cutting plane CC.

Note:

The pin, nut and washer are not sectioned.

The spacer is not considered to be the same as a washer and is sectioned in this case.



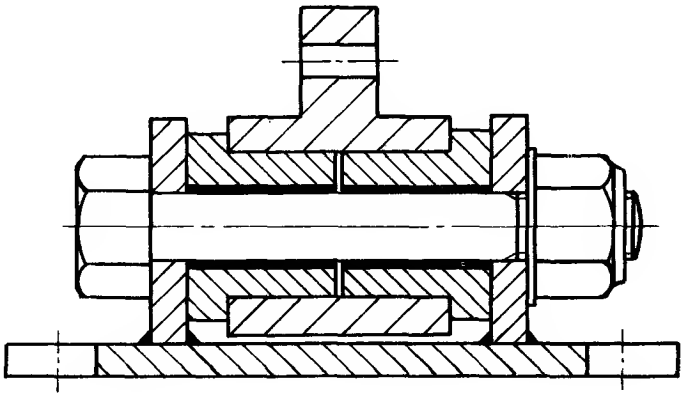
On page 100

(3) Sectioned assembly looking on cutting plane CC.

Note:

The hinge pin lies across the cutting plane and is sectioned when cut transversely.

Solutions to Sectioned Assembly Exercises on pages 100, 101 and 102

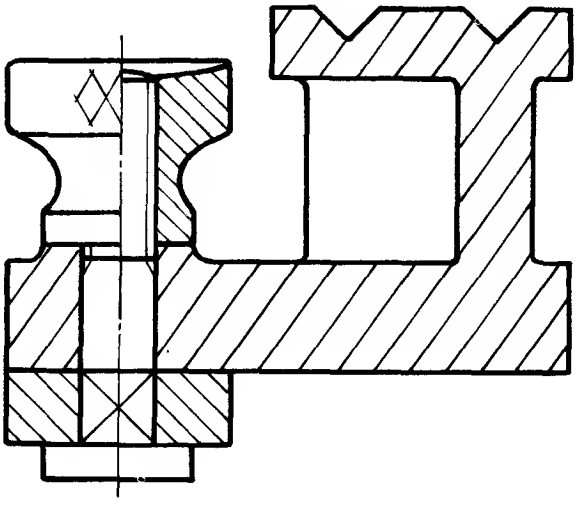


On page 100

(4) Sectioned assembly looking on cutting plane CC.

Note:

The thin steel liners are sectioned by single thick lines

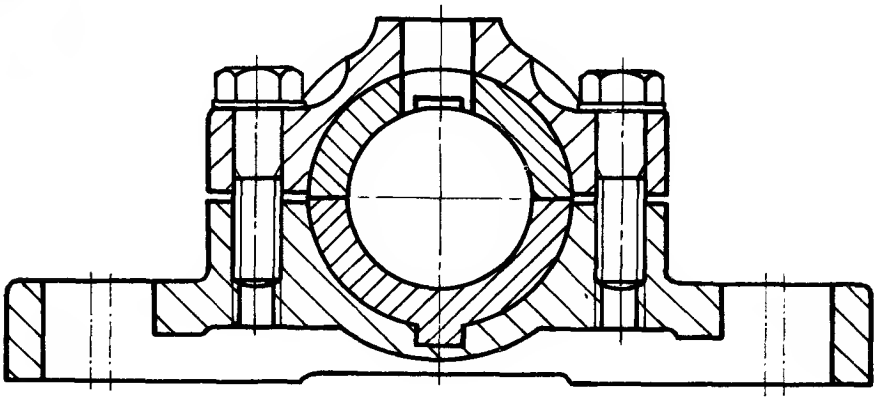


On page 101

(5) Sectioned assembly looking on cutting plane CC.

Note:

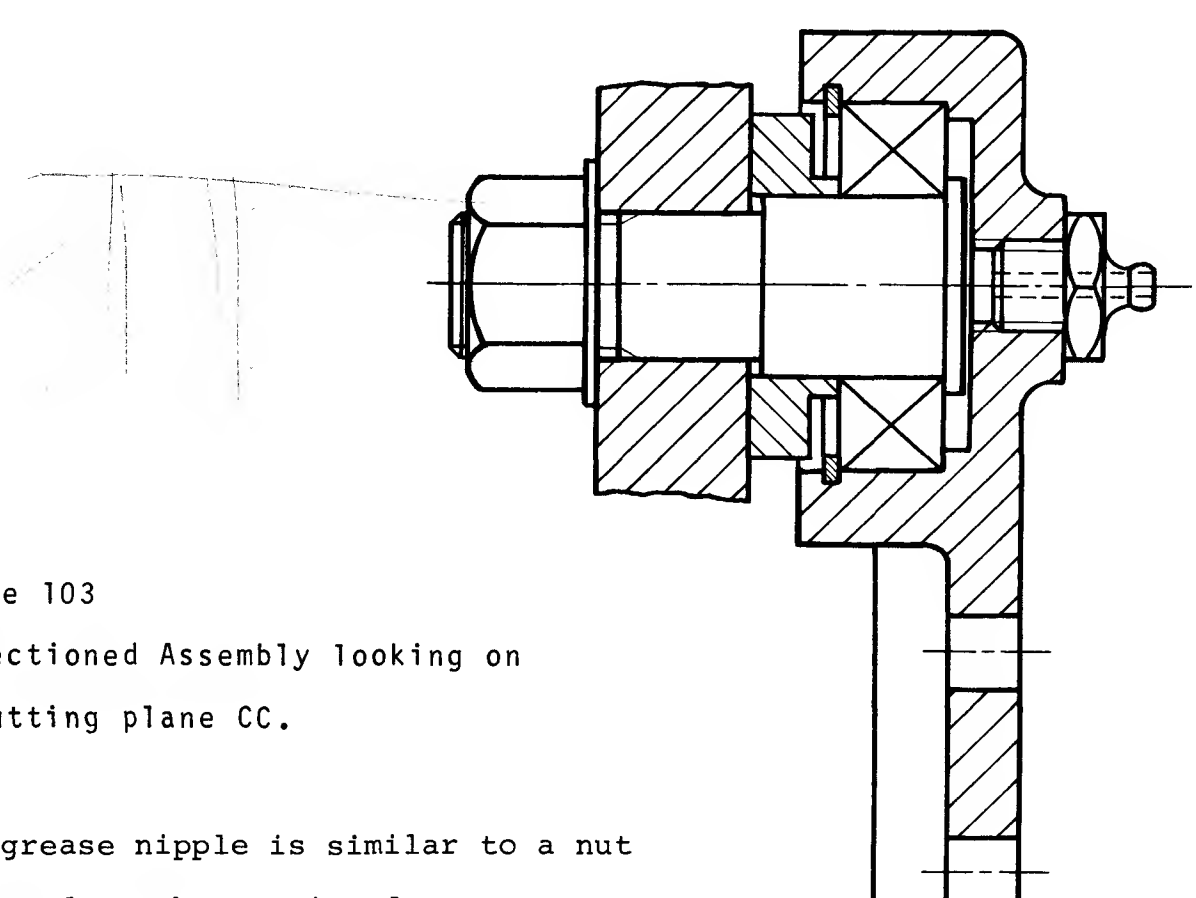
As the Vee grooves are at 45°, the section lines may be drawn at an angle other than the normal 45°.



On page 102

(6) Sectioned assembly looking on cutting plane CC.

Solutions to Sectioned Assembly Exercises on pages 103 and 104



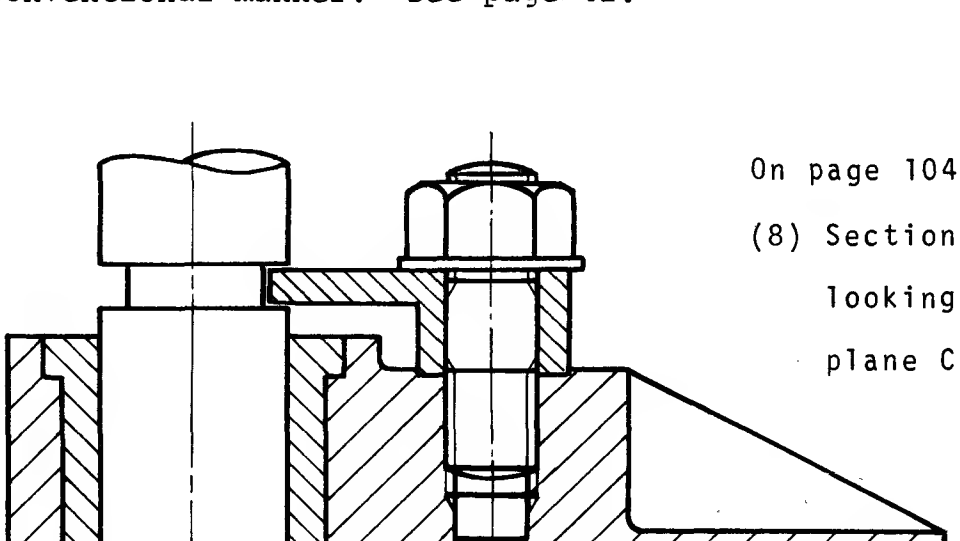
On page 103

(7) Sectioned Assembly looking on cutting plane CC.

Note:

The grease nipple is similar to a nut and need not be sectioned.

The ball race is shown in the conventional manner. See page 41.



On page 104

(8) Sectioned Assembly looking on cutting plane CC.

# Solutions: Developments: Parallel Line

In the solutions of development exercises, the following notes will be useful:

(1) Types of line.

Outlines ——————————

Bend lines – – – – – – – – – –

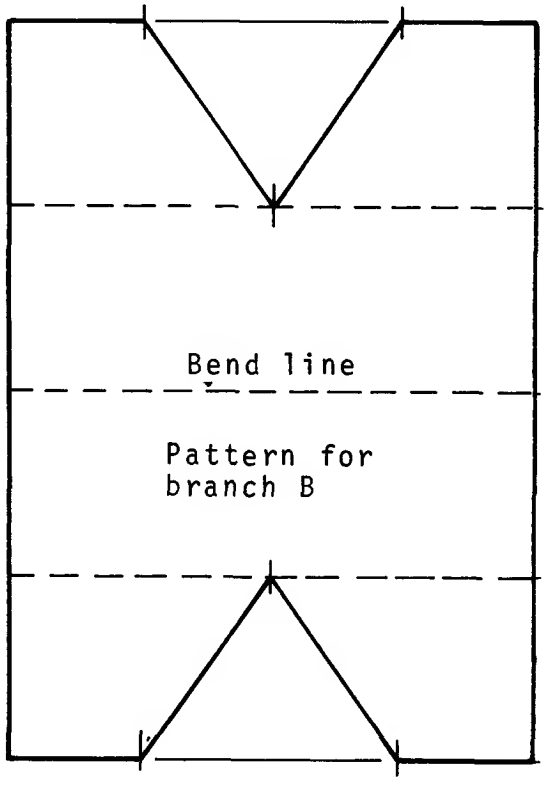
Construction lines ——————————

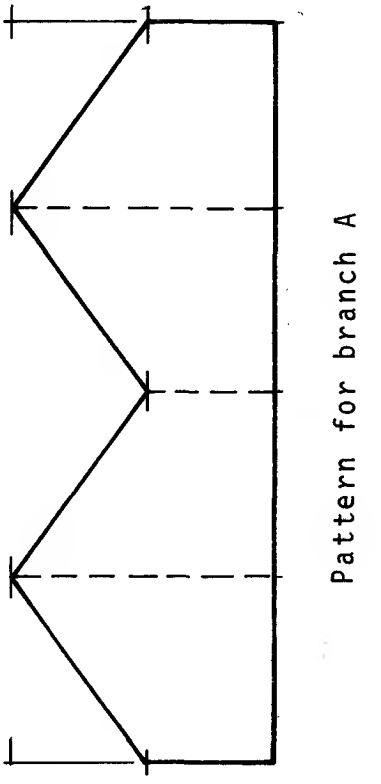
(2) All the prisms, cylinders, pyramids, cones and transition pieces are hollow, thus no section lines are required on cut surfaces.

(3) The development of a sheet metal component can be shown to be correct by forming the required shape from the pattern. A tracing can be made of each solution and transferred to thin card from which the pattern can be cut. An allowance must be made for extra material along fixing edges. See the example on page 105.
The card folds more easily if the bend lines are scored on the inside surface of the pattern with a fine ball point pen. A quick drying latex type adhesive is ideal for joints.

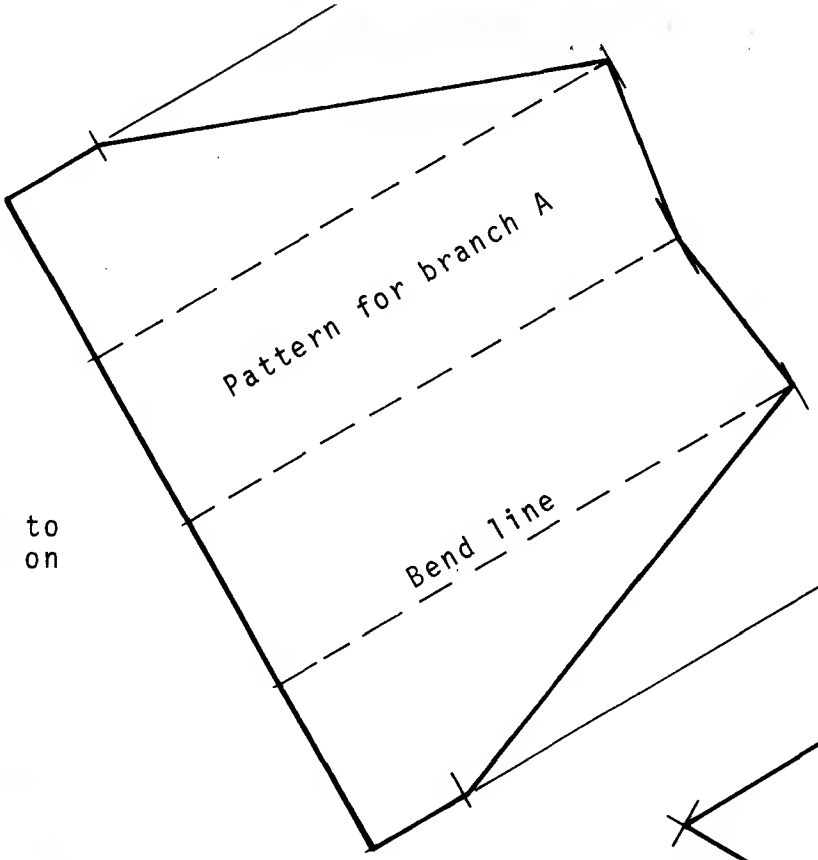
PARALLEL LINE DEVELOPMENT

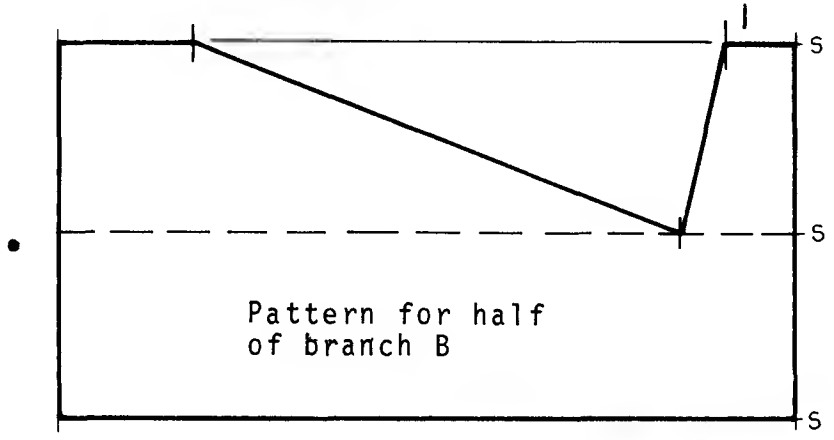
Solutions to exercises on page 107

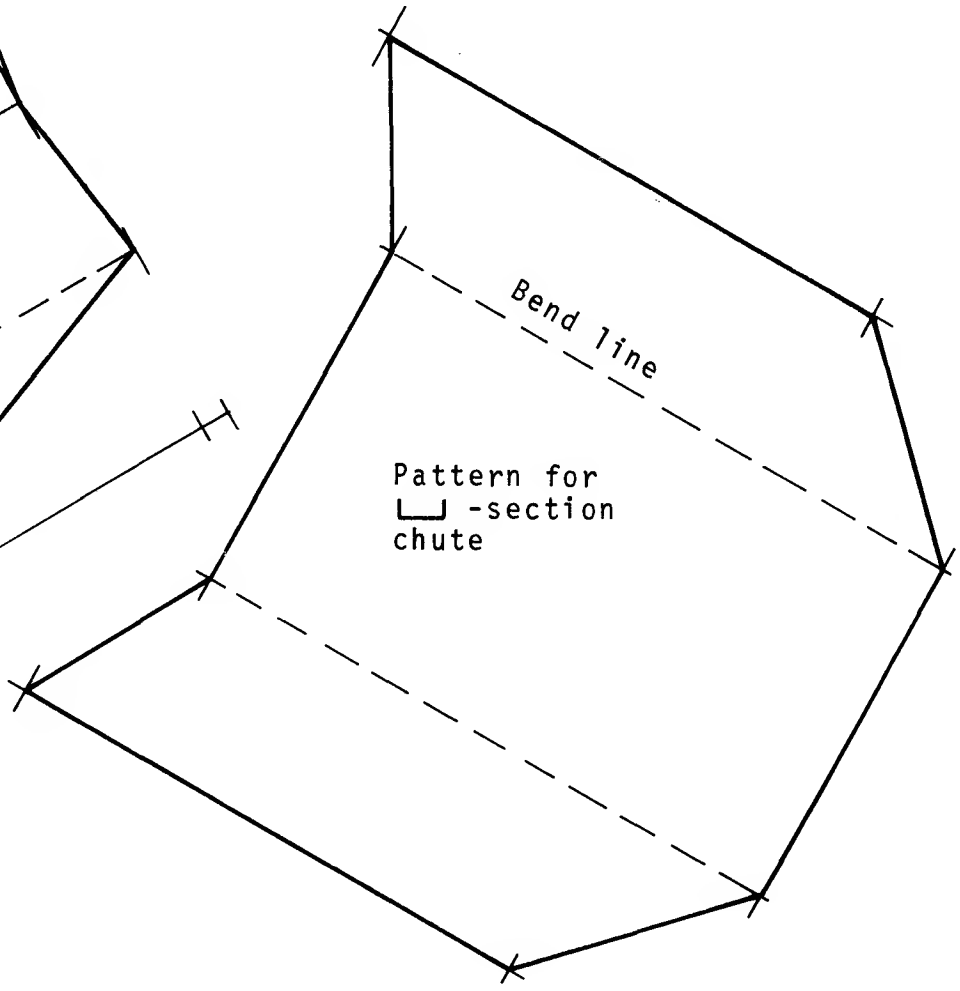


Solutions to exercises on page 108

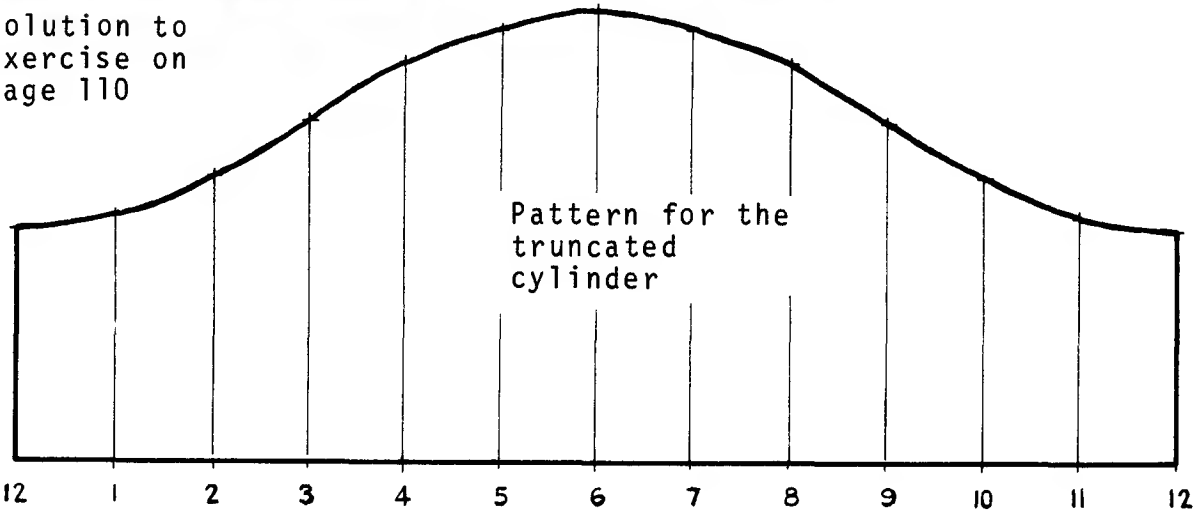


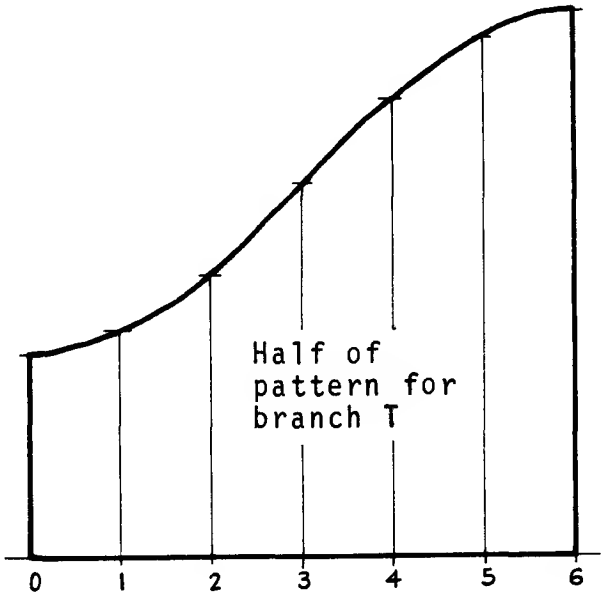



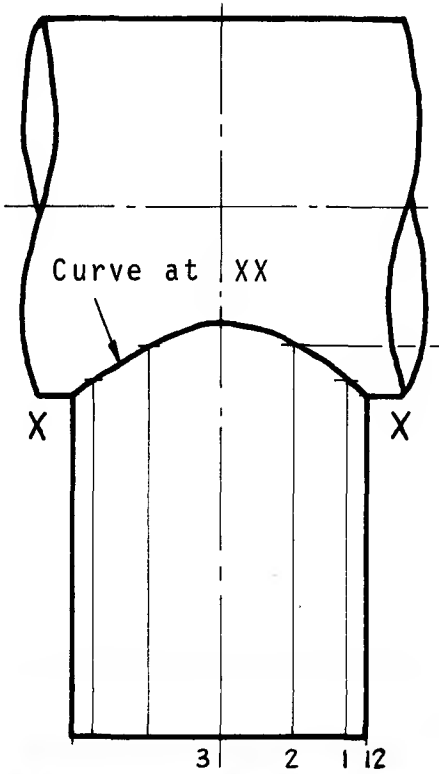

Solution to exercise on page 109

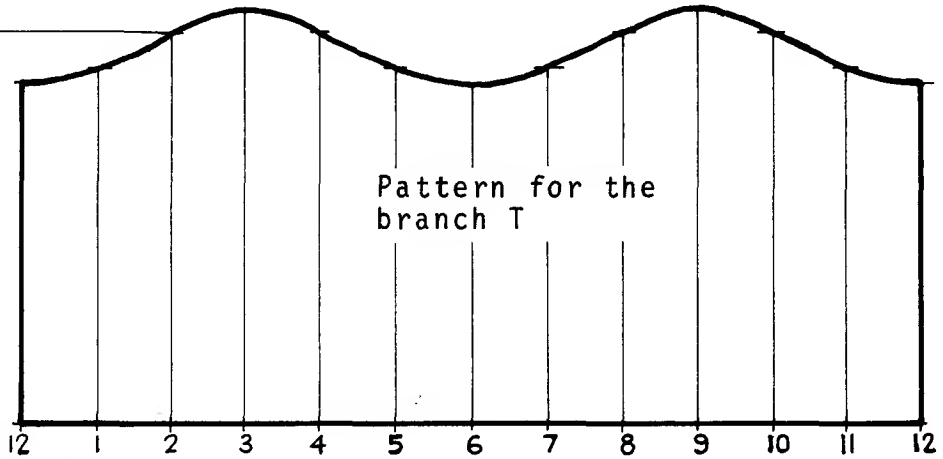
Solution to exercise on page 110




Solutions to exercises on page 112



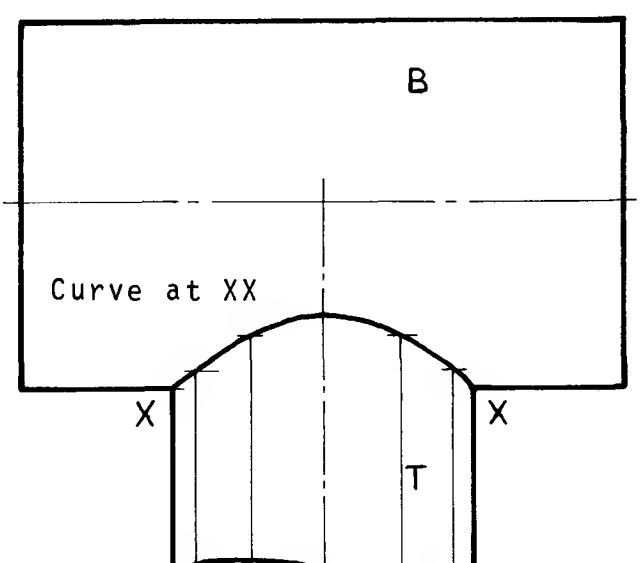




Solution to exercise on page 111

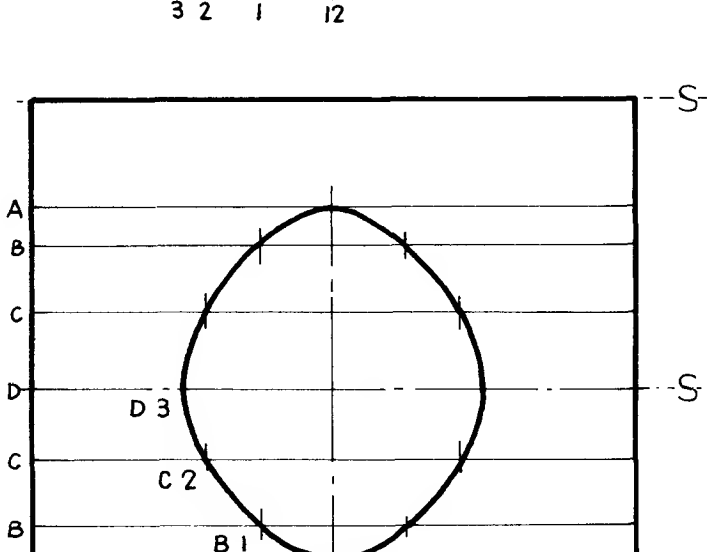
Note:

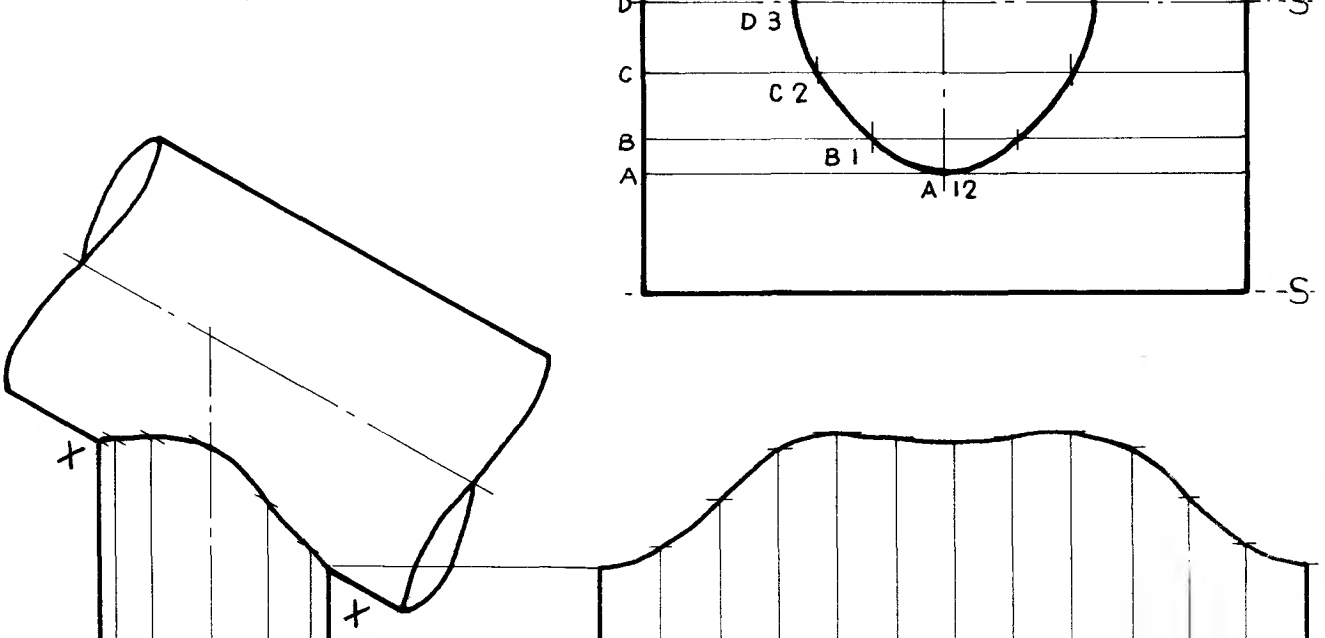
Half the pattern of the truncated cylinder T is shown. The other half is a mirror image of this.

Solutions to exercises on page 113




Pattern for one half of the cylinder B showing the shape of the hole in B.



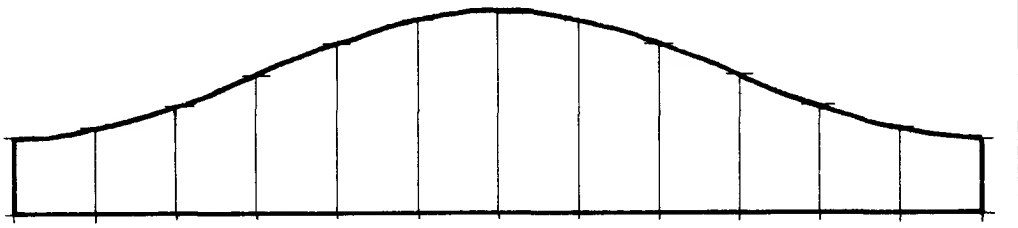




Solutions to exercises on page 114

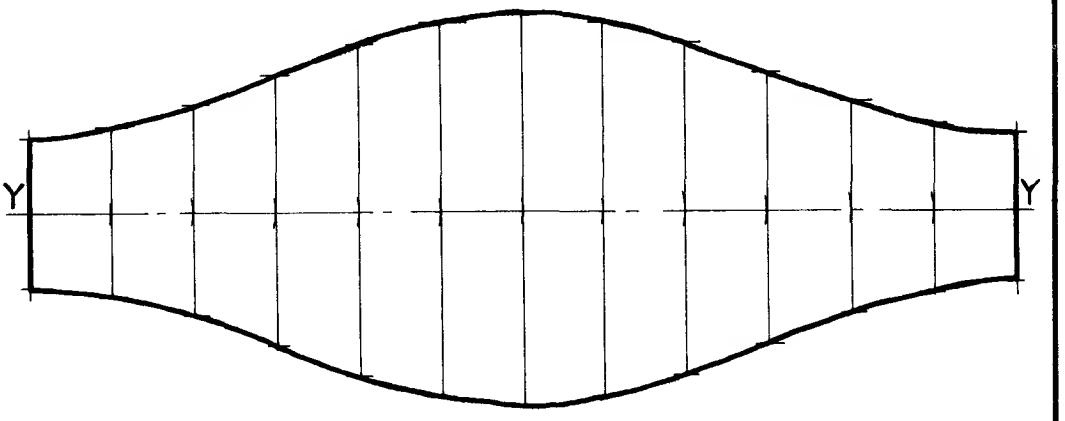
Pattern for branch A

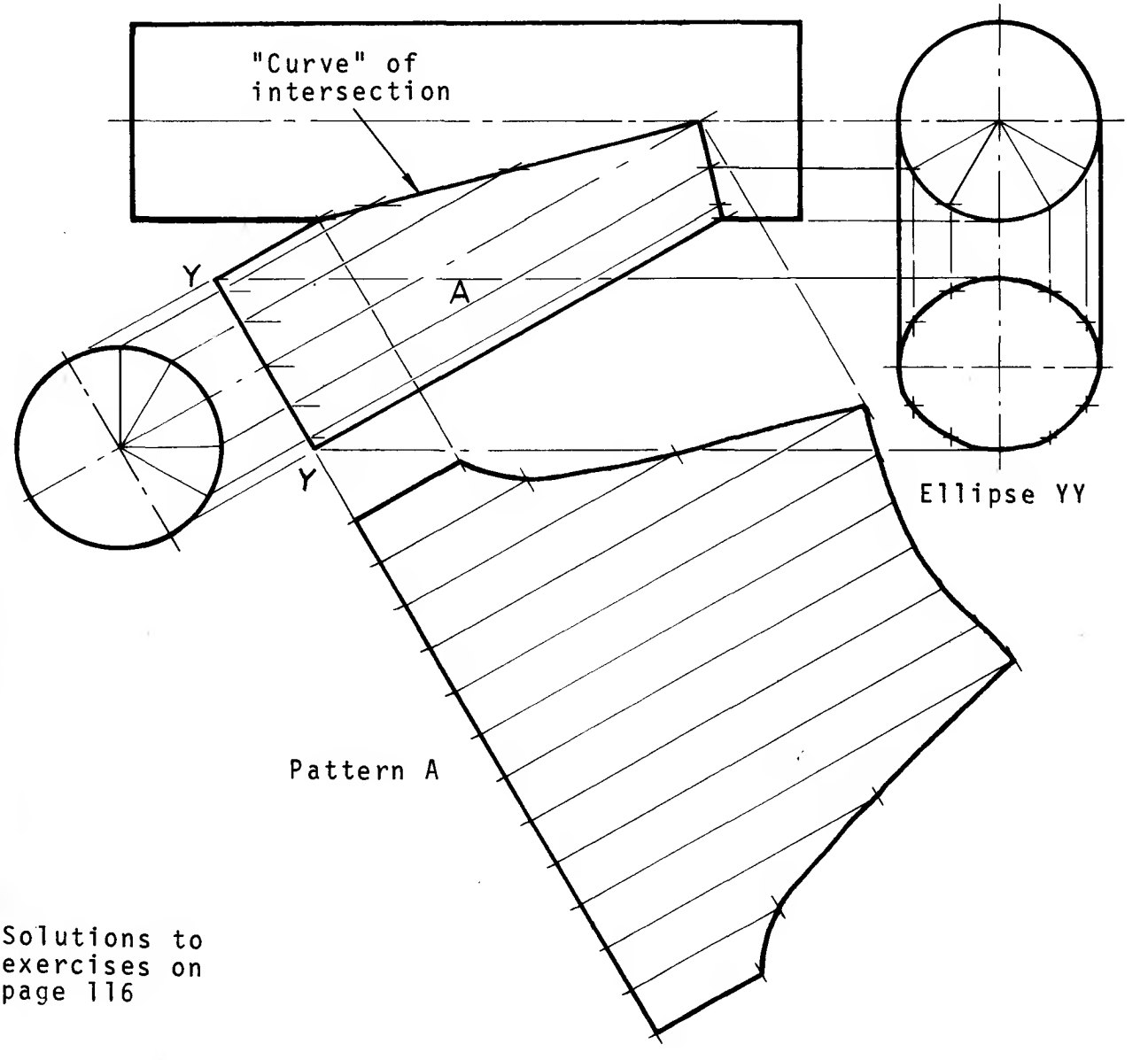
Solutions to exercises on page 115

Pattern A



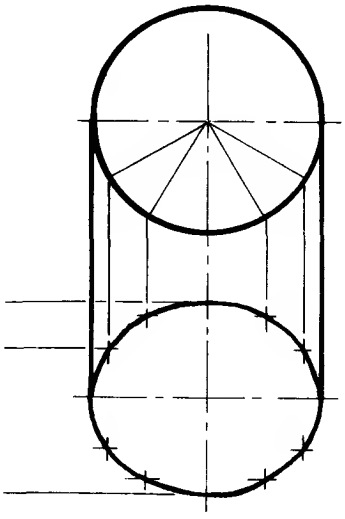
Pattern B



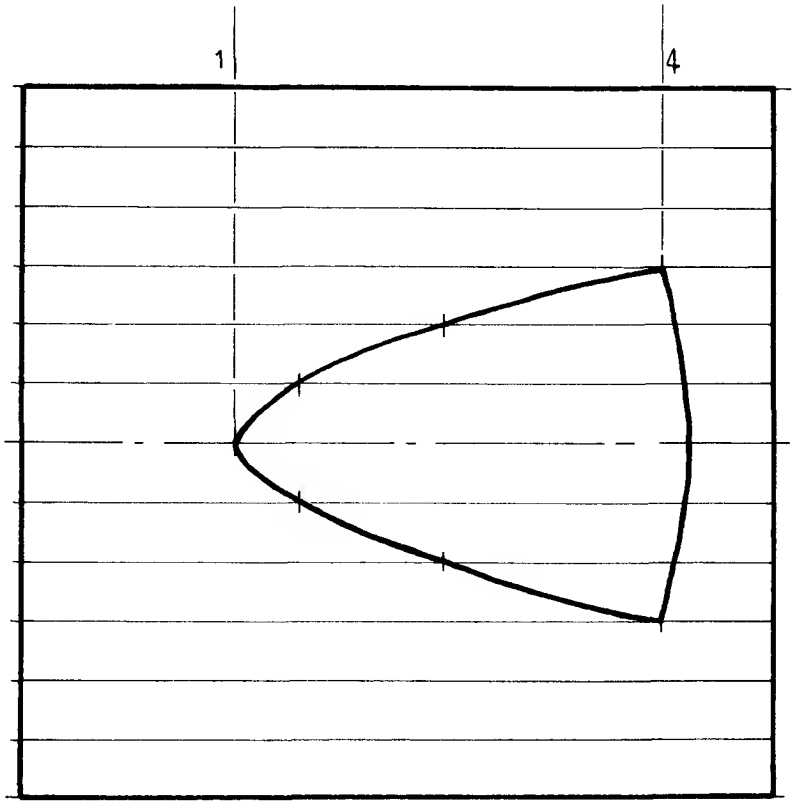




Solutions to exercises on page 116

Solutions to exercises on page 117

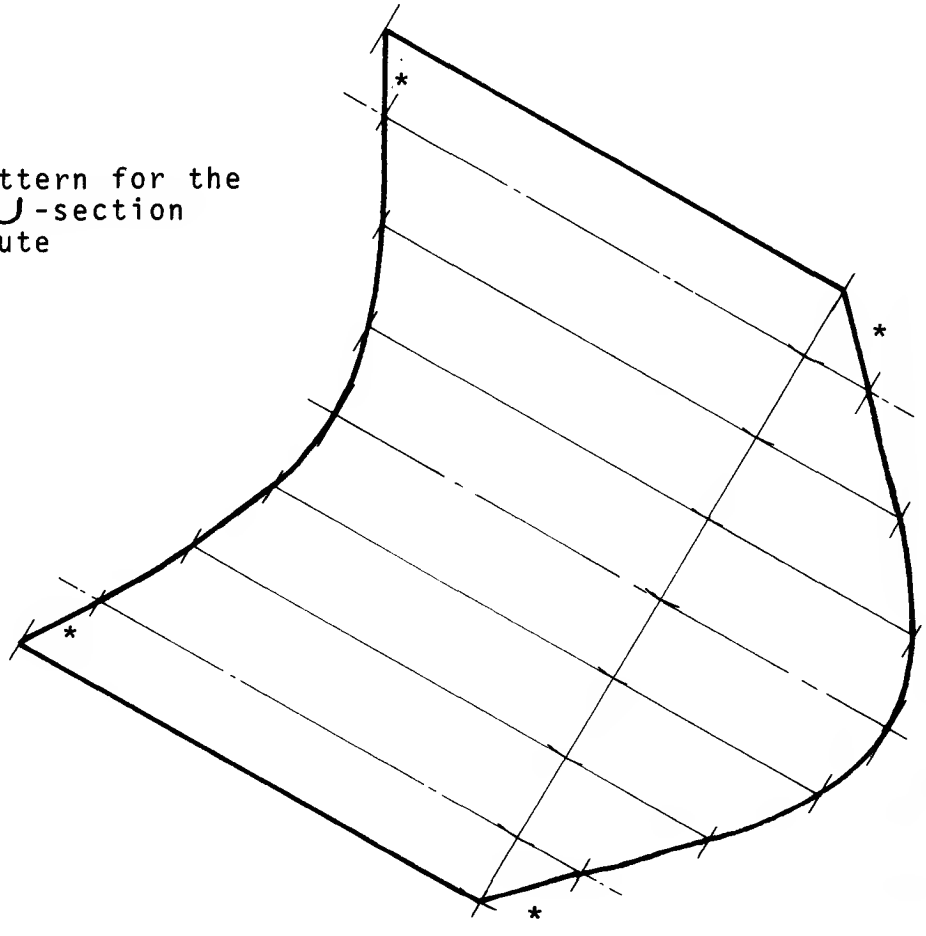


Ellipse YY




Pattern for B showing shape of hole

Pattern for the ∪-section chute

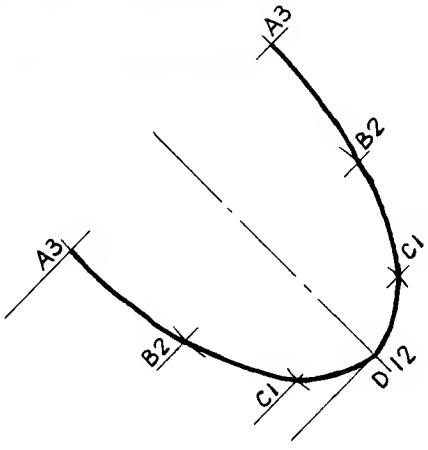



Note:

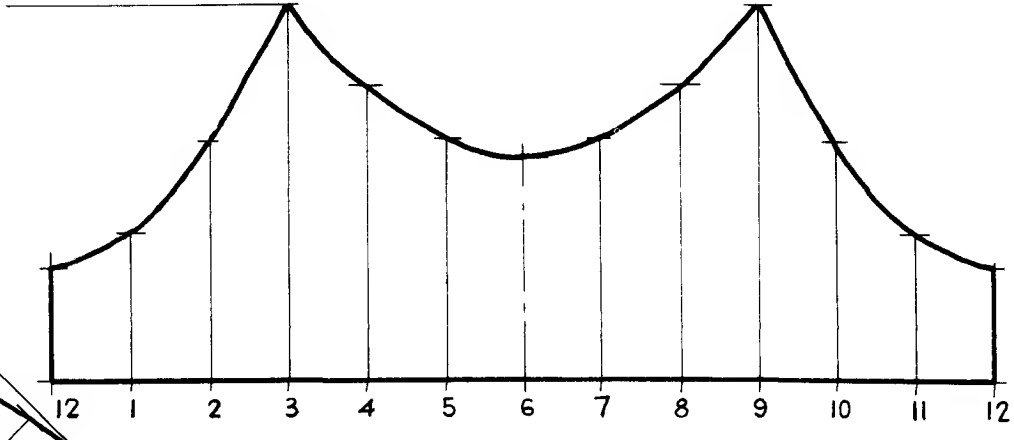
Line is straight here *

Solution to exercise on page 118

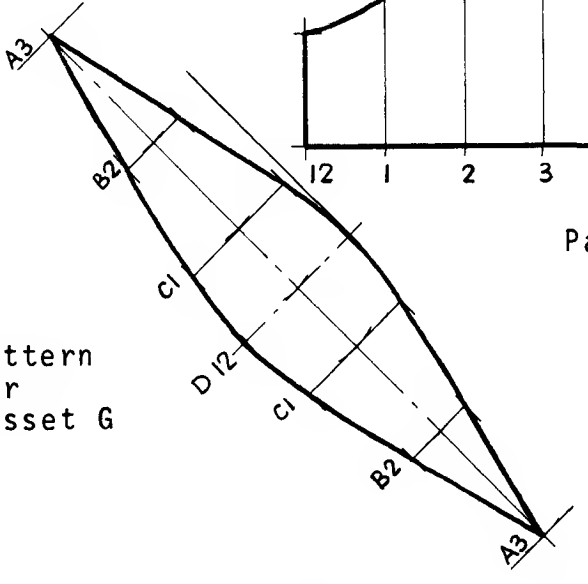
Solutions to exercises
on page 119




True shape of
gusset G
cross-section



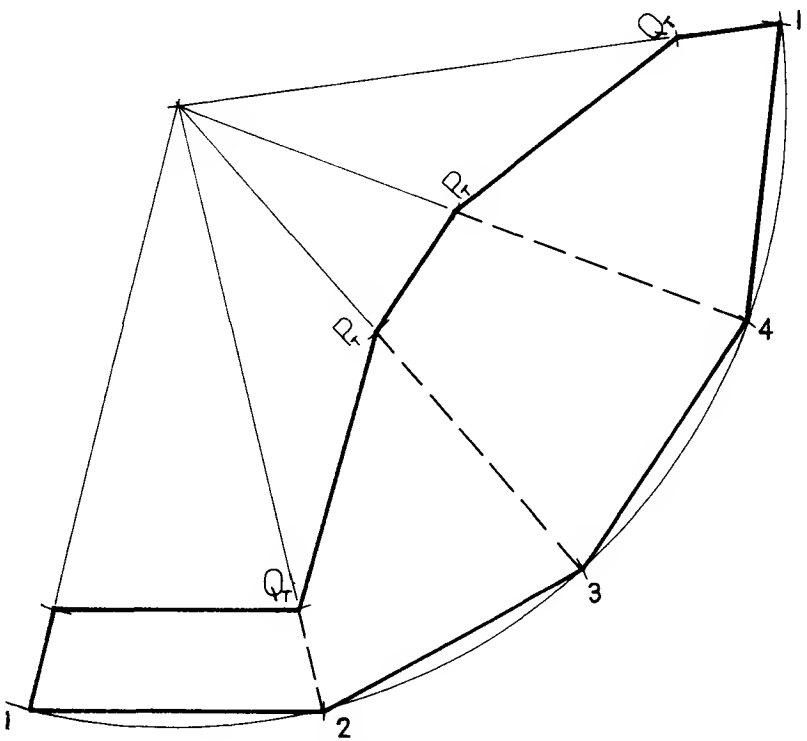

Pattern for the branch T



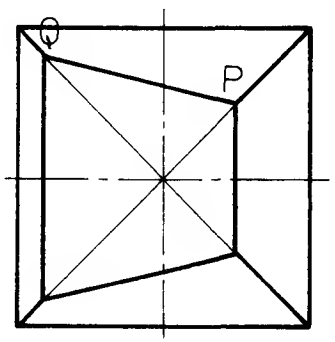

Pattern
for
gusset G

# Radial Line Development - Pyramids

Solutions to exercises on page 121

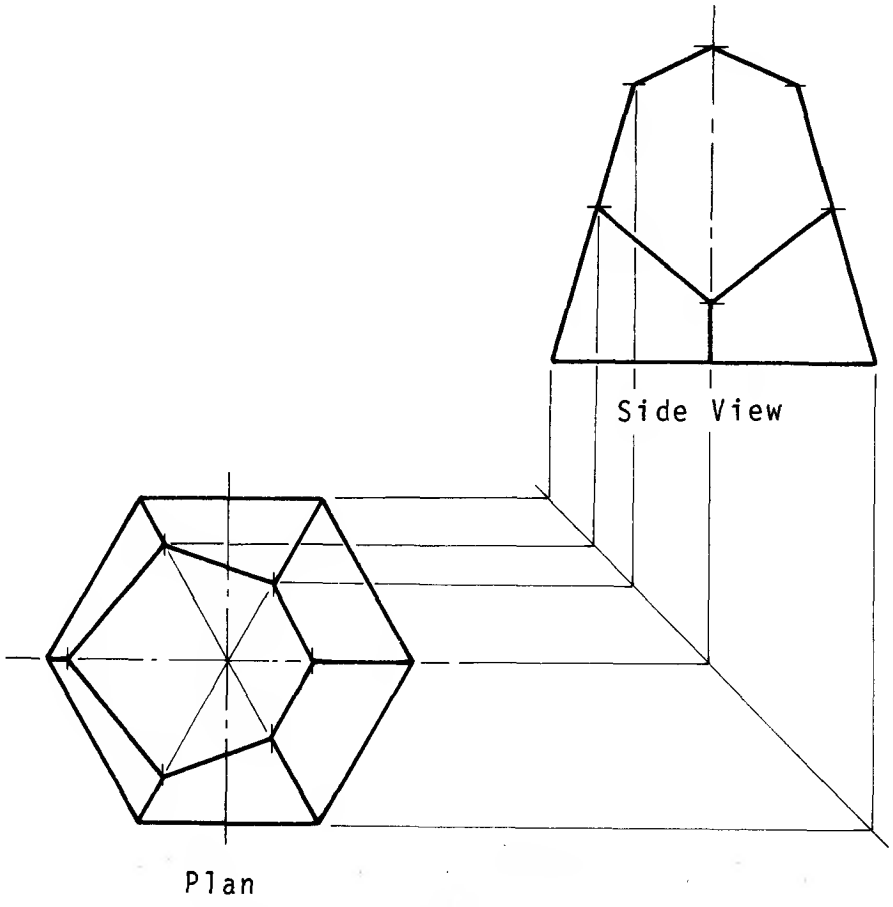



Pattern for Frustum

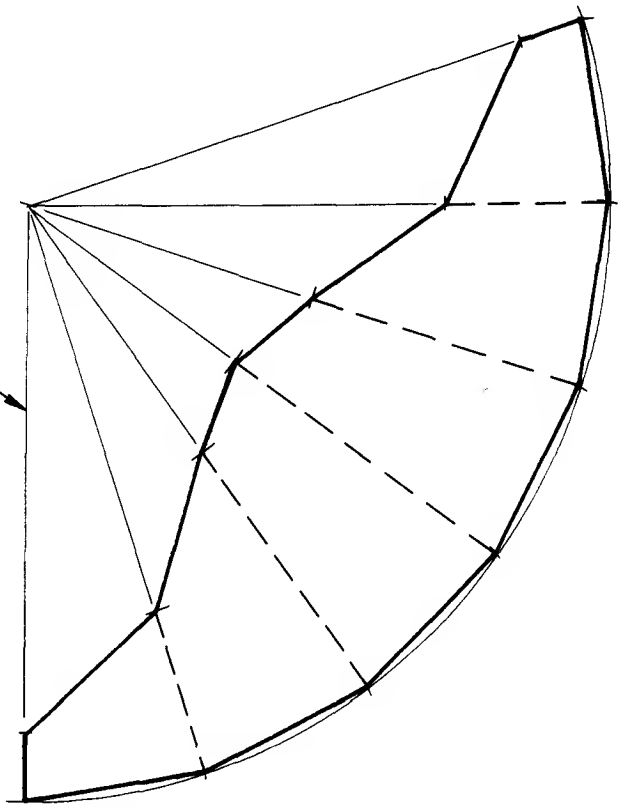



Plan

Solutions to exercises on page 122

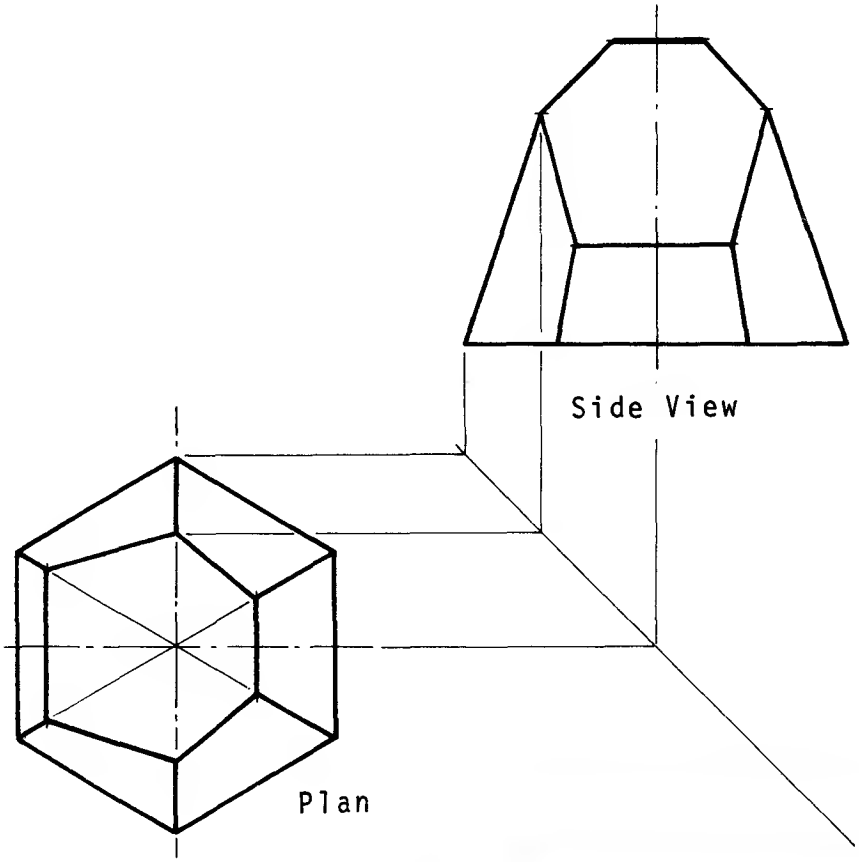



Note: These lines are true length

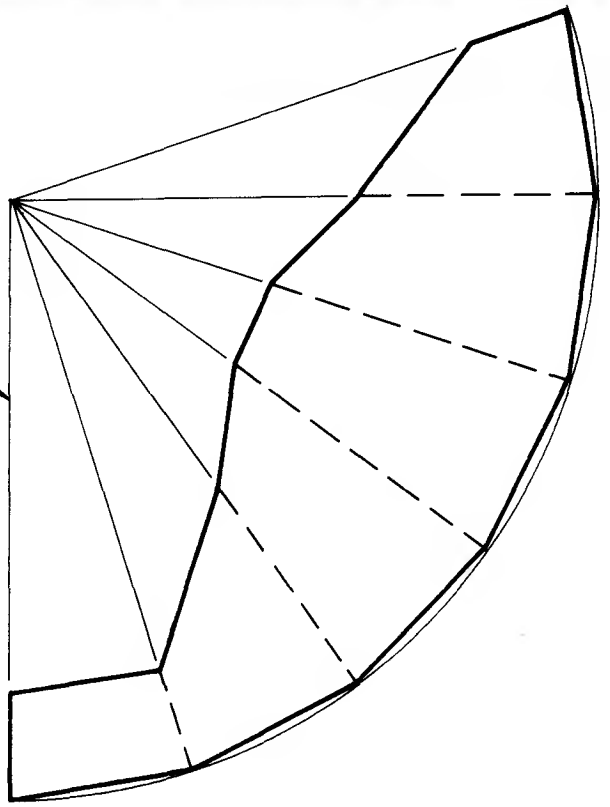


Pattern for frustum

Solutions to exercises on page 123

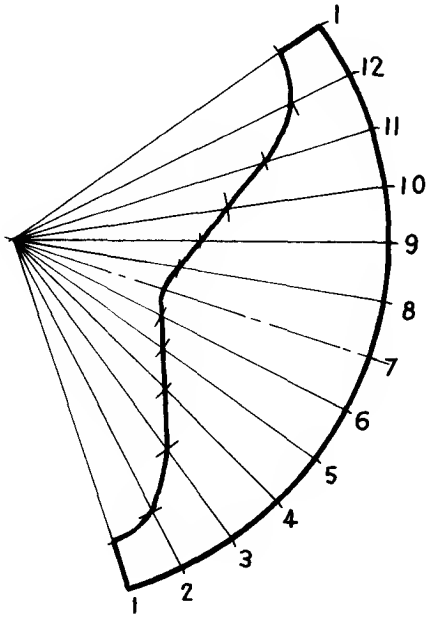



Note: These lines are true length



Pattern for frustum

# Radial Line Development - Cones

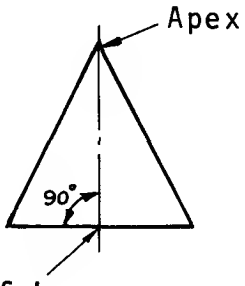



Complete pattern for surface area of frustum of a right cone

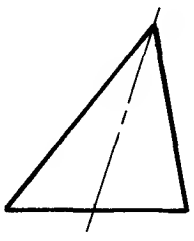
Completion of exercises started on page 125

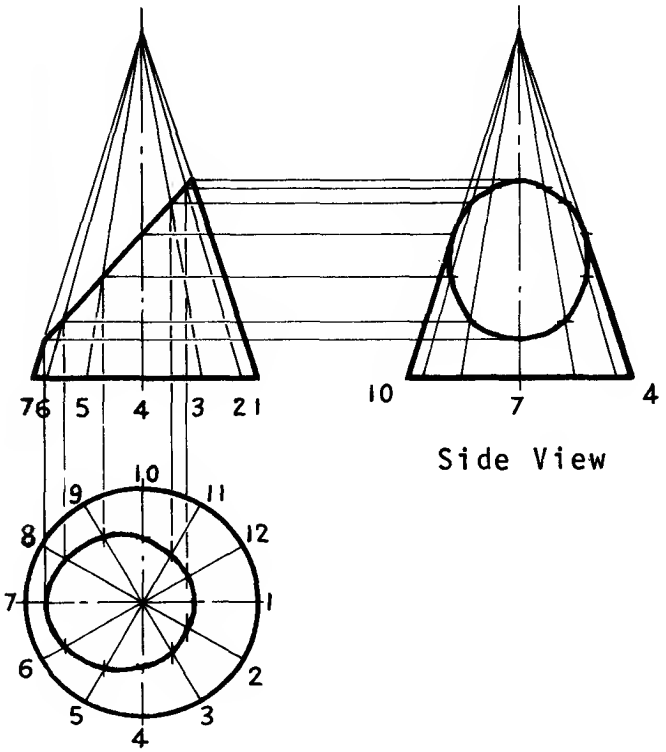
Note:

A RIGHT CONE is one in which a line drawn from the apex of the cone to the centre of the circular base is always at right angles to the base.




An OBLIQUE CONE is one in which the line from apex to the centre of the circular base is inclined at any angle other than 90° to the base.

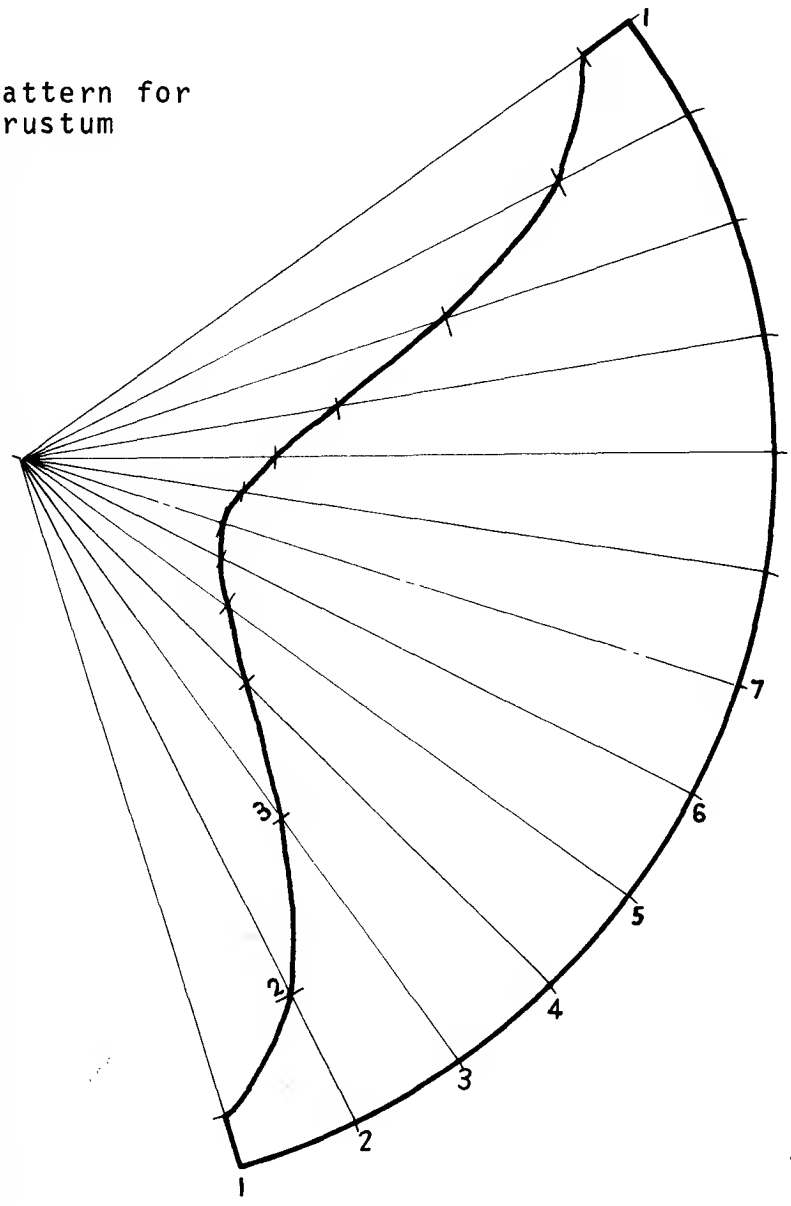


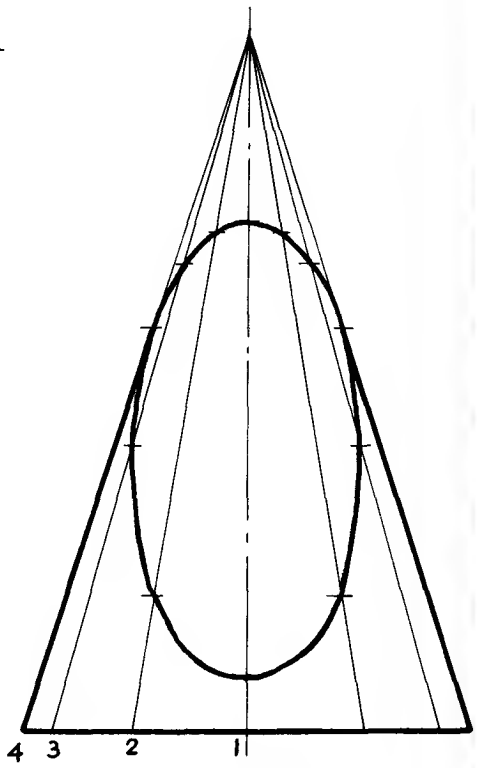



Note:

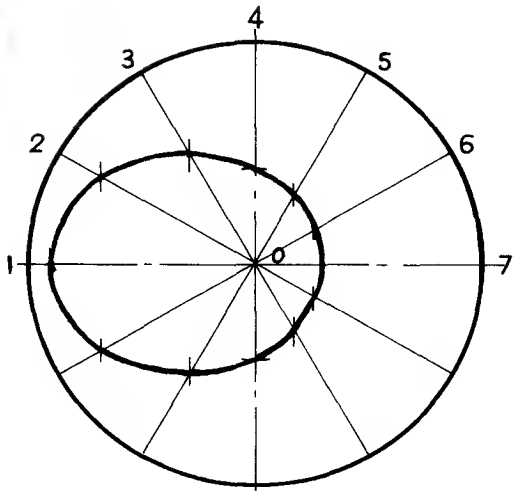
Section lines are not drawn on cut surfaces because the cone is hollow

Pattern for frustum




Side View

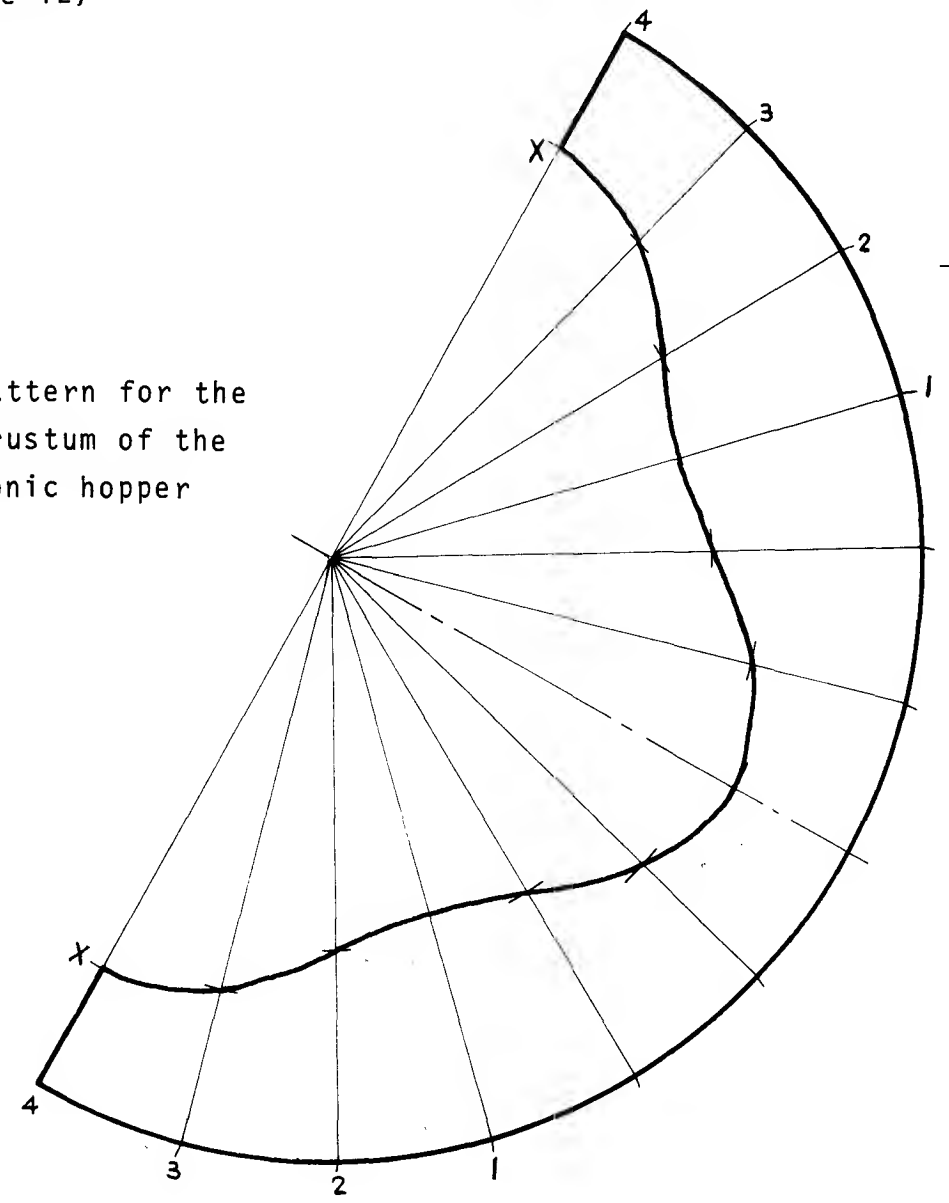


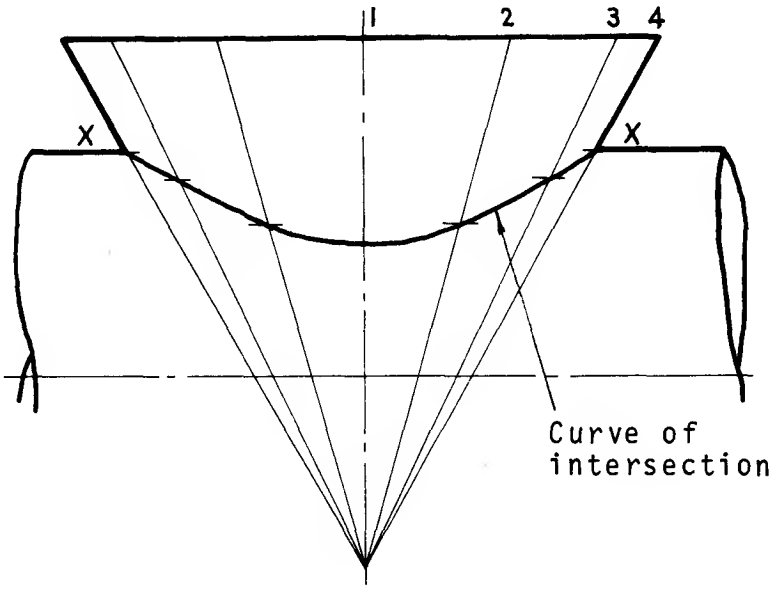

Plan

Solutions to exercises on page 126

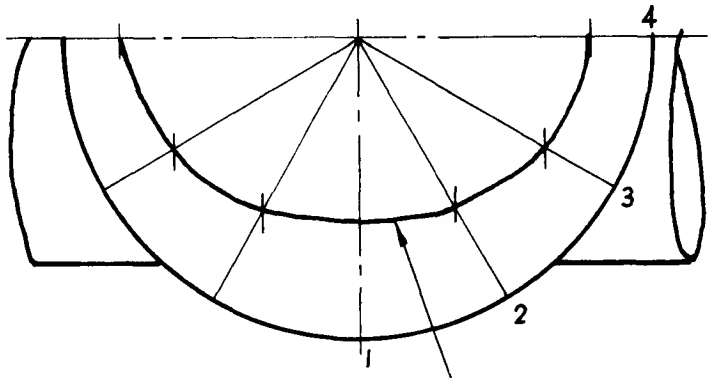
Solutions to exercises
on page 127

Pattern for the
frustum of the
conic hopper



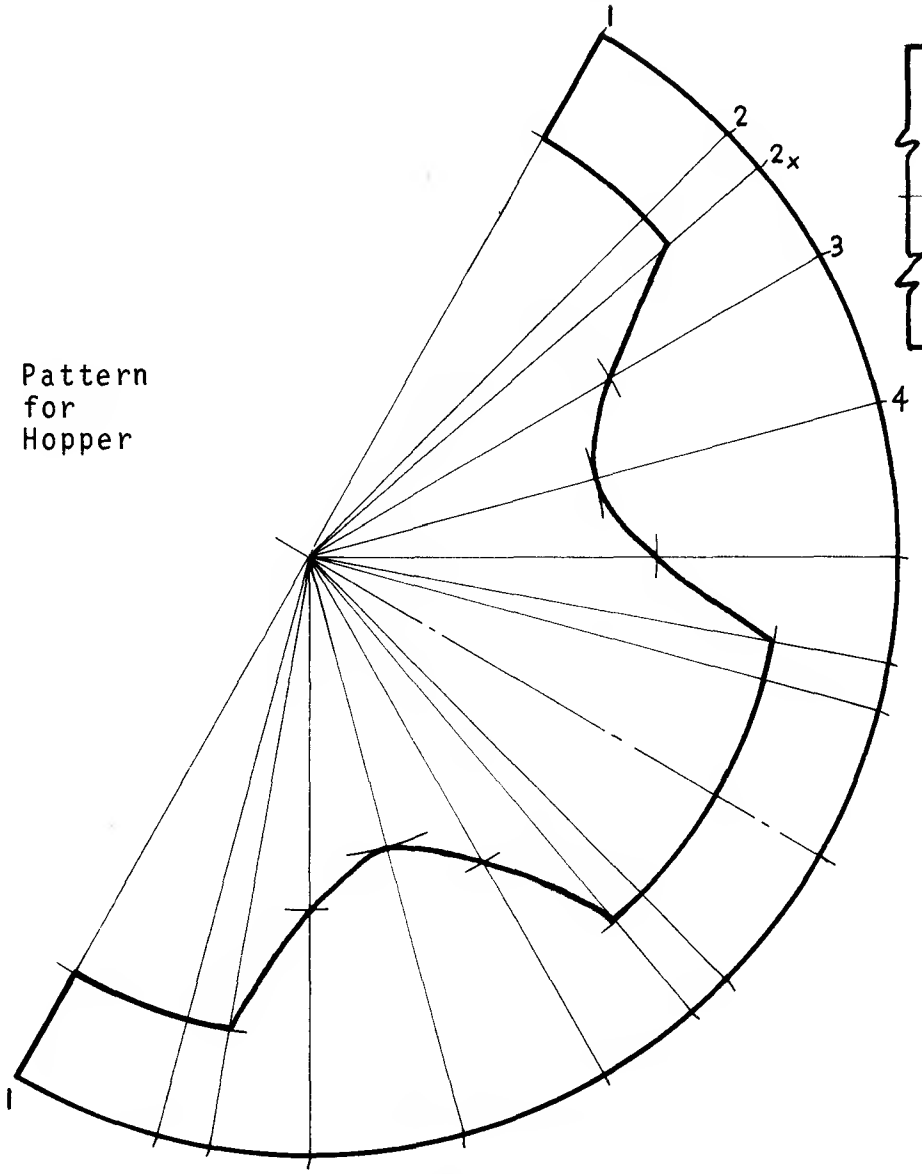




Curve of
intersection XX

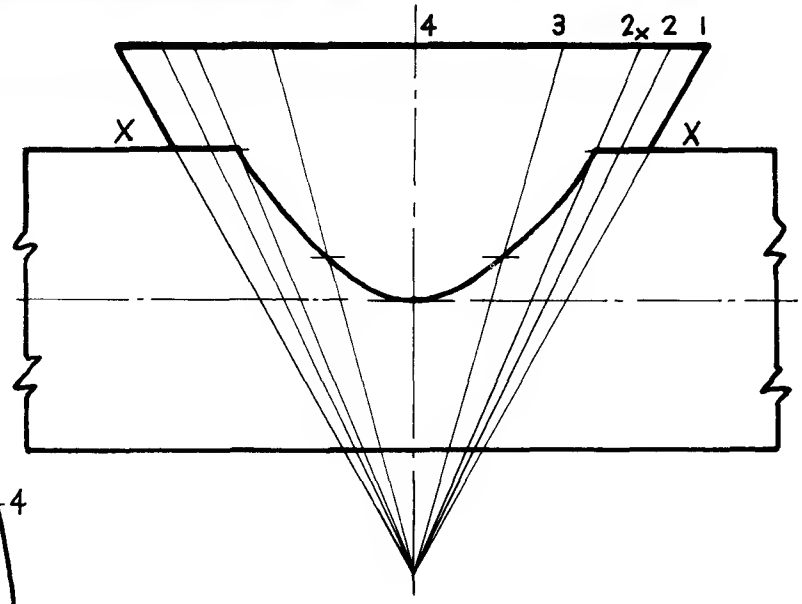



Curve of
intersection
in plan

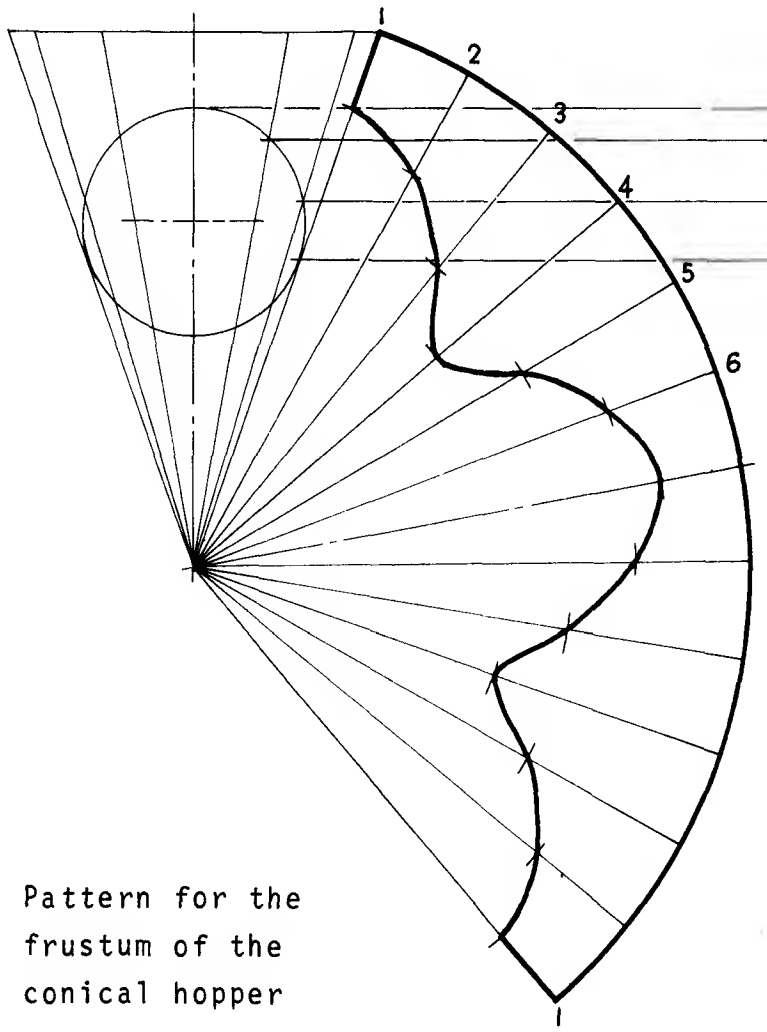
Solutions to exercises
on page 128



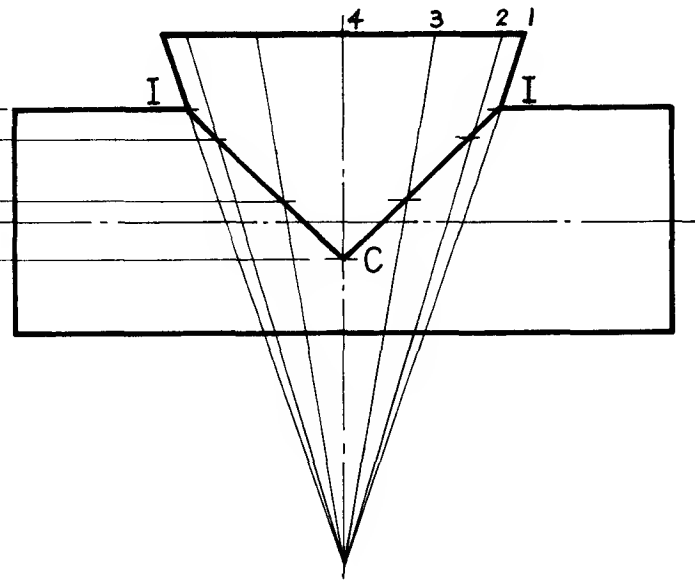

Pattern
for
Hopper




Curve of intersection XX




Pattern for the frustum of the conical hopper



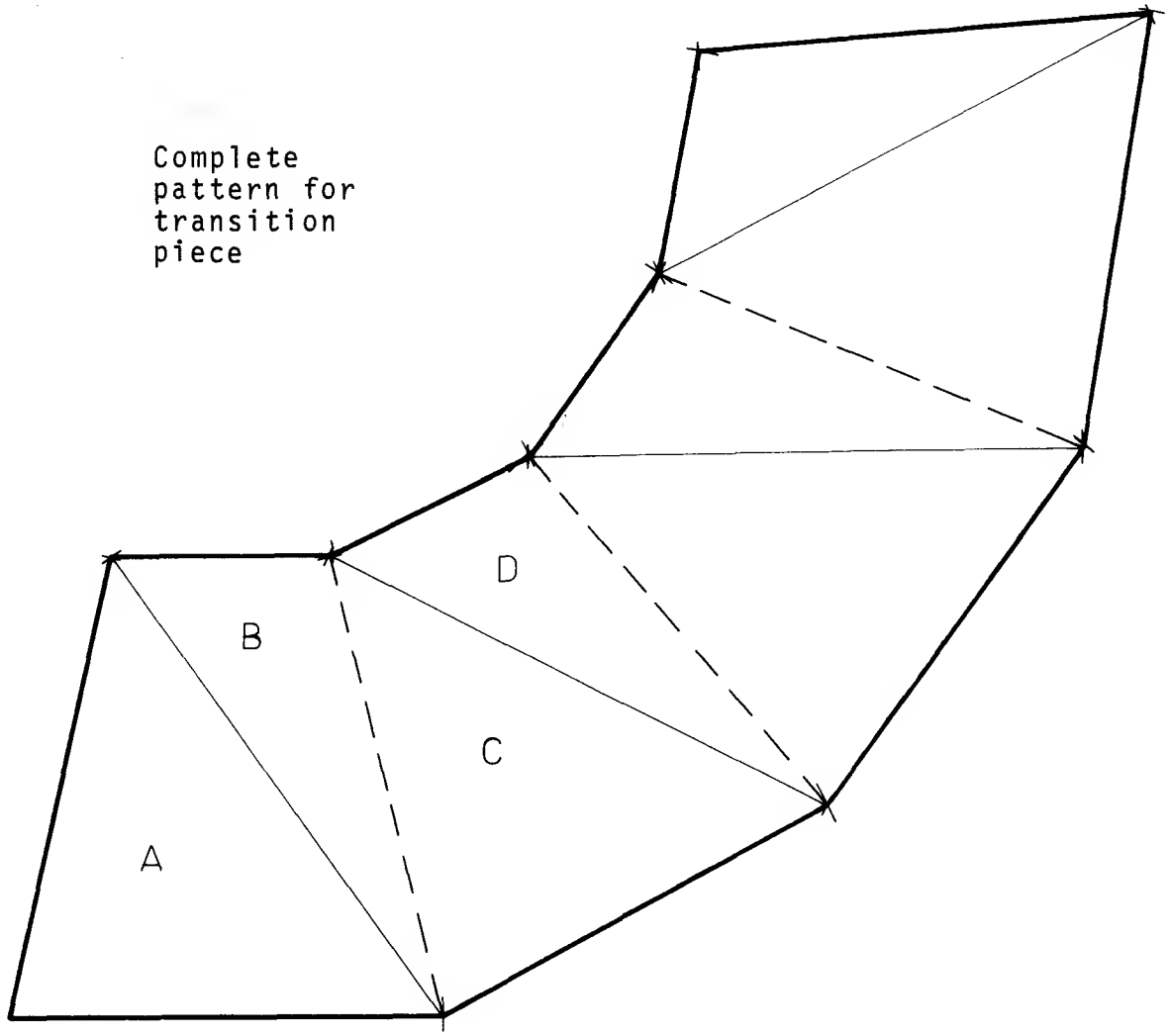

"Curve" of intersection ICI

Solutions to exercises on page 129

# Triangulation

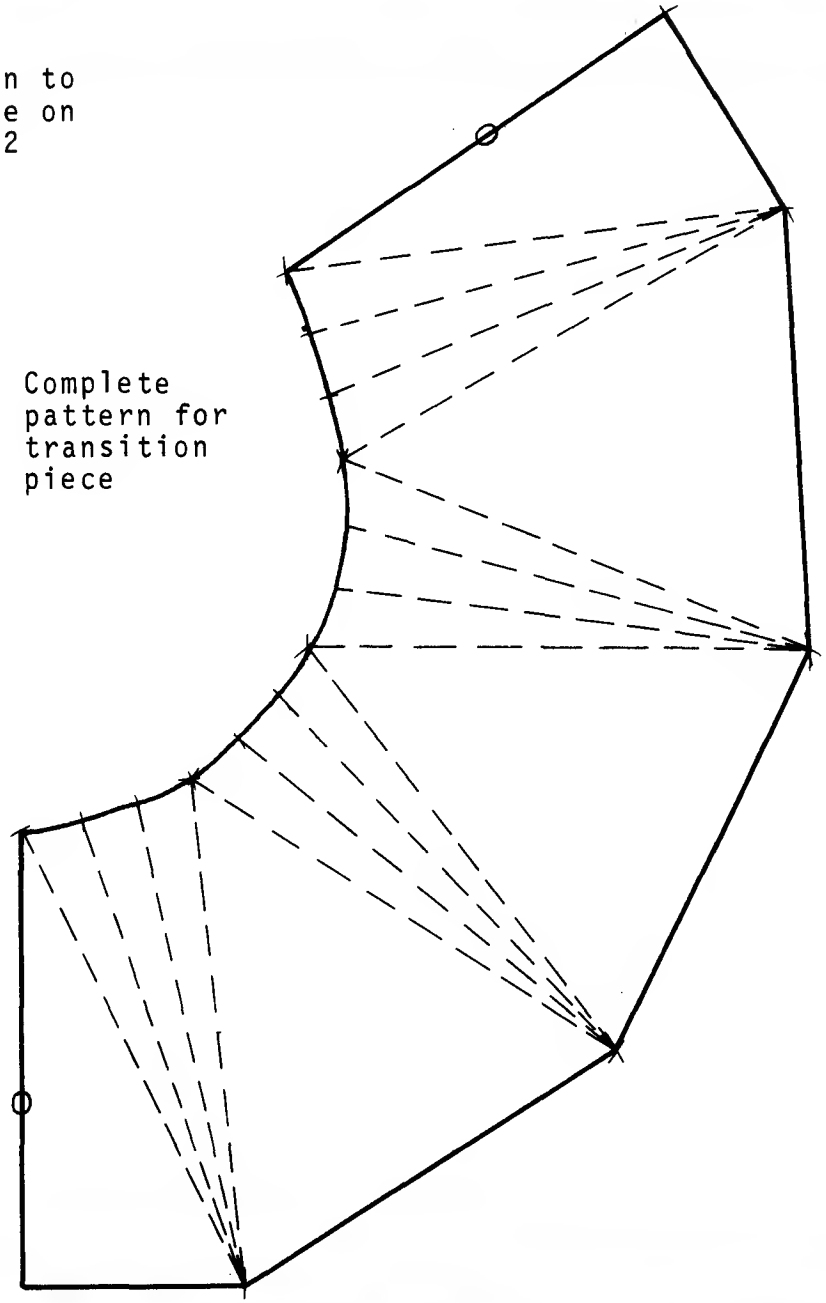
Solution to exercise on page 131

Complete pattern for transition piece

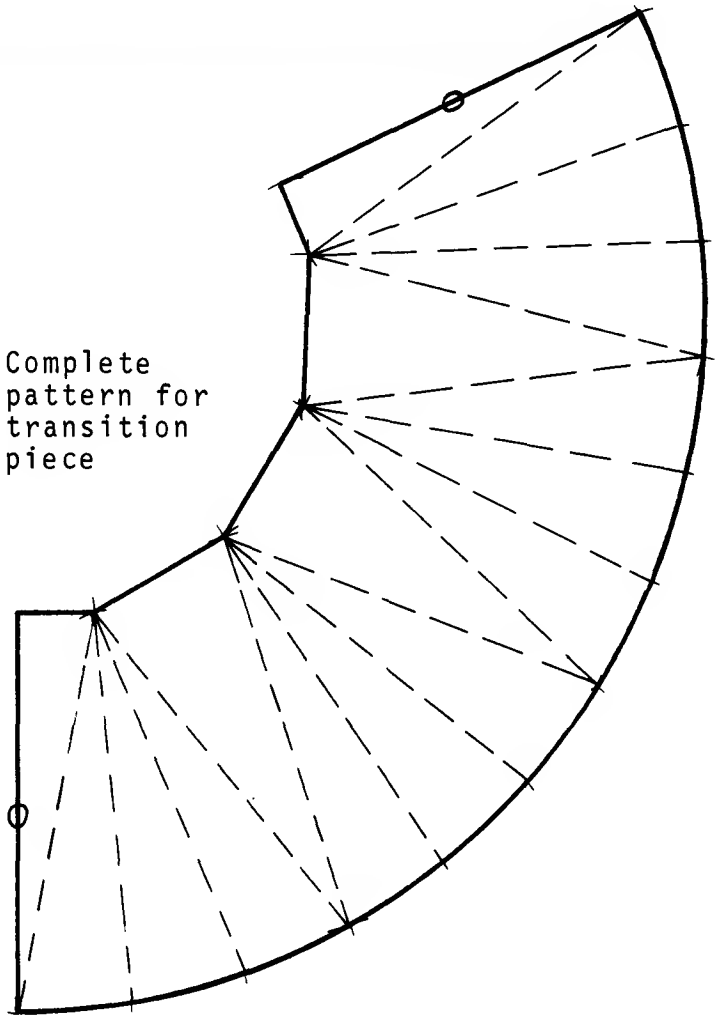


Solution to exercise on page 132

Complete pattern for transition piece

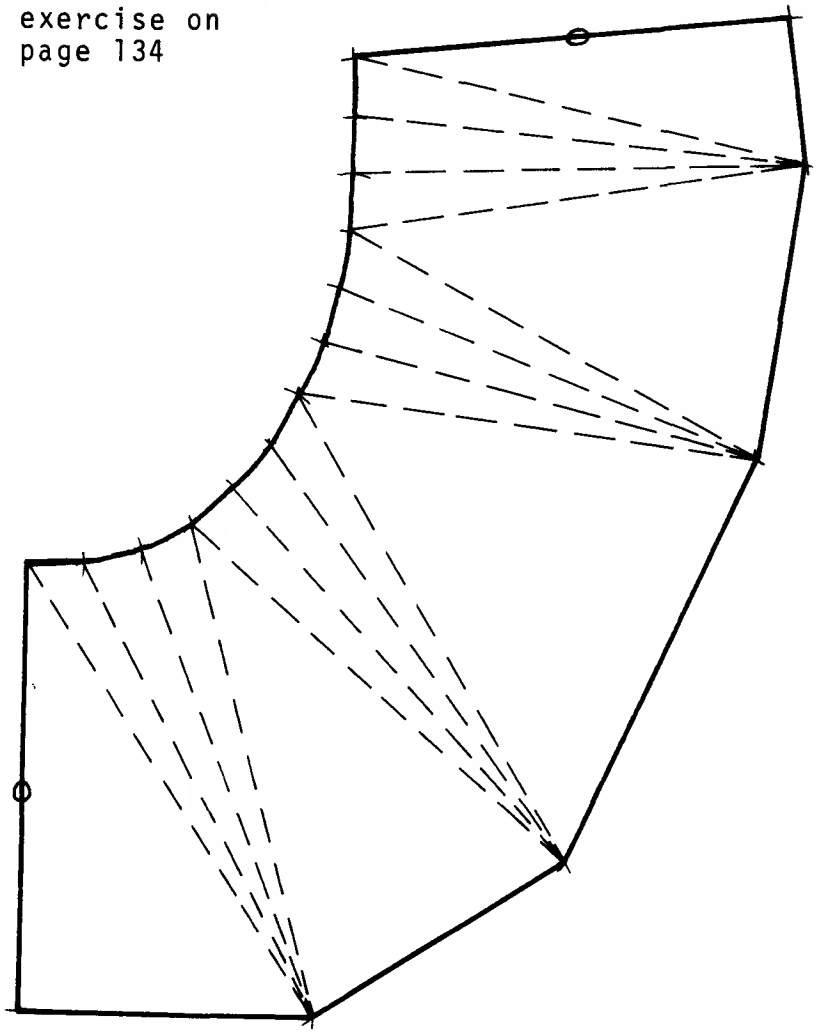


Complete pattern for transition piece



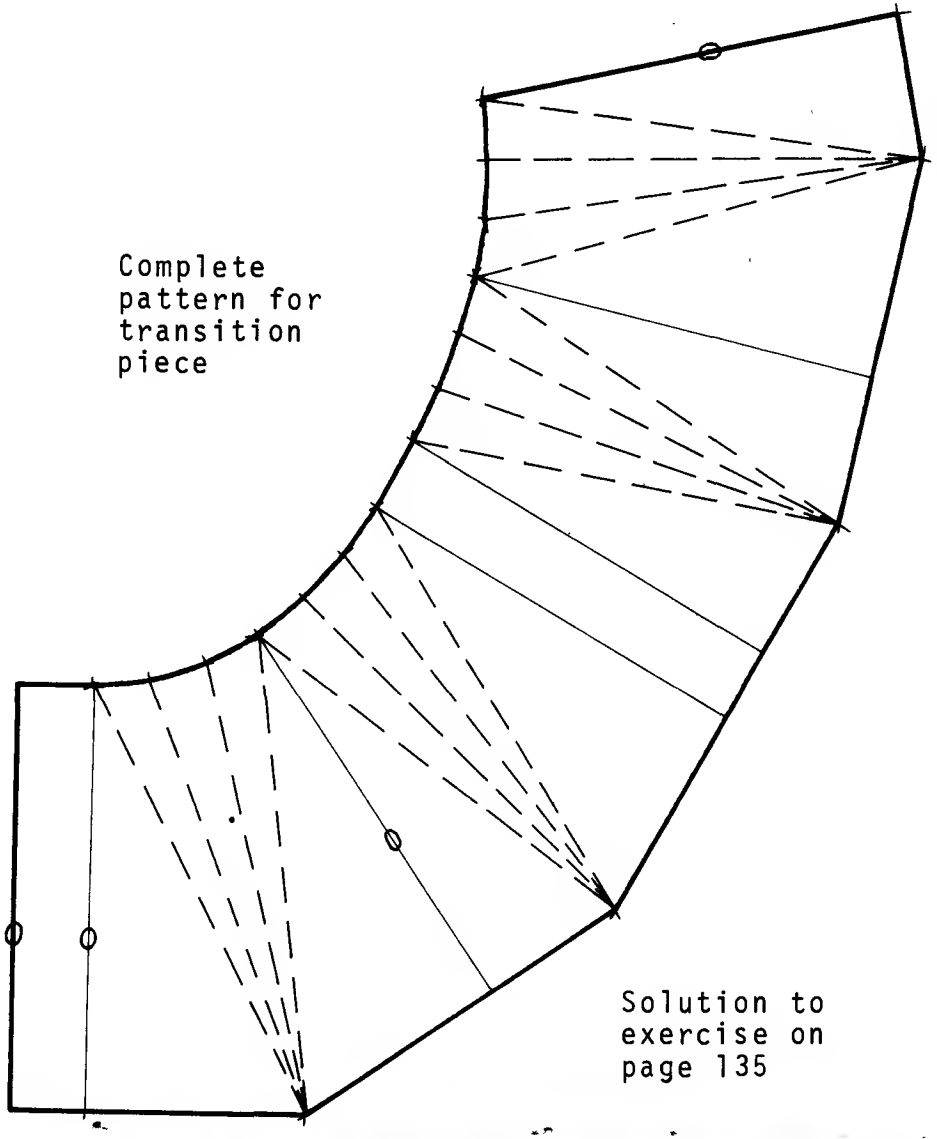
Solution to exercise on page 133

Solution to exercise on page 134



Complete pattern for transition piece

Complete pattern for transition piece



Solution to exercise on page 135

*Basic Engineering Drawing* is for any student about to begin the study of engineering or technical drawing. It is actually used throughout the whole educational spectrum – from CSE to degree students. The pace of working through the book is dictated by the ability of the student.

It is particularly suitable for craft and technician students and has found great favour with first-year engineering degree students who have done little or no engineering drawing. For CSE and O-level students it provides a firm foundation in the practicalities of engineering.

It is not oriented towards a particular syllabus but deals with the basic requirements for the preparation and the interpretation of engineering drawings. Information and exercises are presented on a one-sheet system, and attention is concentrated on particular topics by using a minimum of words and a maximum of pictorial explanation.

The approach to the subject is based largely on the interpretation of drawings as a means of communication. The student is encouraged to interpret and properly use the conventions of BS308:1972. Subjects covered are 1st and 3rd angle projection, technology, abbreviations, conventional representation, sectioning, isometric and oblique drawing, dimensioning, limits and fits, ISO metric screw threads, assemblies, and parallel line, radial line, and triangulation developments.

Each section deals with basic ideas and applications with the maximum involvement of the student. Many of the exercises are for completion in the book itself, and solutions to exercises are given at the end. For these reasons, the book is ideal for self-study.

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