14501–
ORiginal

1 Drawing instruments, materials and equipment

Pencils. Pencils containing special grades of graphite lead are used for engineering and technical drawing. They are graded by number and letter according to the hardness of the lead they contain. Soft pencils are graded from the softest 7B, 6B and so on, to B; medium pencils are graded HB and F; and hard pencils are graded from H, 2H and so on, to 6H, the hardest.

The point of the pencil is sharpened on a sanding block or file, or in a mechanical sharpener, to form a conical, wedged (or chiselled), or bevelled shape.

T-square. The T-square is used in conjunction with the drawing board primarily to draw horizontal lines and to support setsquares when drawing vertical and sloping lines.

While using the T-square keep the stock (the top of the T) firmly against the side of the board to ensure that the lines being drawn will be parallel. The stock will be against the left edge of the board for a right-handed user; against the right edge for a left-handed person.

In industry the parallel straight-edge and drawing machine have almost completely replaced the T-square.

Parallel straight-edge. This device is used in the same way as the T-square, except that at each end it is fastened to cords which pass over pulleys. This arrangement permits movement of the straight-edge up and down the board but keeps it in a horizontal position at all times.

Setsquares. These are used in conjunction with the T-square or parallel straight-edge to draw vertical and sloping lines. Those most commonly used are the 60° and the 45° setsquares.

Singly or in combination these setsquares can be used to draw all angles that are multiples of 15°. For other angles, the protractor is used. Angles of any size can be drawn with an adjustable setsquare.

Drawing tables and machines. Many engineers' offices are equipped with special drawing tables and machines which combine all the functions of the T-square or parallel straight-edge, setsquares, scale, and protractor. The use of a drawing machine reduces the time spent in the preparation of drawings, thus reducing costs. Left-handed drawing machines are available.

Scales. These are used for making measurements on drawings, and for measuring only, not for drawing lines. It is important for draughtsmen to draw to scale accurately, and the scale used must be indicated in the title block.

When objects are drawn to actual size, the drawing is called full-scale or full-size. However, many objects, such as buildings, ships or aircraft, are too large to be drawn full-size so they are drawn to a reduced scale. Small objects, such as wrist-watch parts, are drawn bigger to an enlarged scale. Drawings of details drawn larger than full-size should, where practical, include an undermentioned view drawn to actual size. This view may be drawn in pictorial form.

Scales are expressed as $\frac{1}{2}$ in = 1 in; 4 in = 1 in; 1 in = 1 in; 10 mm = 1 mm; 10 mm = 0.25 m, etc. The left-hand side of the equation represents a unit of length on the drawing; the right side represents a unit of length on the actual object.

Irregular curves. When drawing curved lines for which, unlike circular arcs, the radius of curvature is not constant, an instrument known as an irregular curve or French curve is used. The patterns for these curves are based on various combinations of ellipses, spirals, and other geometrical curves. Irregular or French curves are available in a variety of shapes and sizes.

Generally, the draughtsman plots a series of points of intersection along the desired path, then uses an appropriate French curve to join these points so that a smooth flowing curve results.

Dividers. These instruments are used for laying out or transferring measurements. A pair of dividers has a steel pin insert in each leg, and is available in a variety of sizes and designs, similar to a pair of compasses. A pair of compasses can be used as a pair of dividers by replacing the lead point with a steel pin.

Drawing instrument sets. Many draughtsmen have a complete set of drawing instruments that usually includes several pairs of compasses and dividers with extension attachments, ruling pens, and attachments for making inked drawings (see Fig 1 on p 3).

Templates. To save time, many draftsmen now use templates for drawing small circles and arcs. Templates are also available for drawing standard square, hexagonal, triangular and elliptical shapes, and standard electrical and architectural symbols.

Brushes. A light brush is used to keep the drawing area clean, by removing particles of eraser and any accumulated dust or dirt.

12 Orthographic projections

A projection is a drawing that represents or outlines a three-dimensional object on a two-dimensional surface.

In engineering the most commonly used type of projection is orthographic projection, which is the representation of an object on a plane of projection, when the lines of sight from the eye of the observer to the object are perpendicular to the plane of projection.

The point of sight is the real or imaginary position of the eye of the observer when viewing the object. For orthographic projection the point of sight is considered to be at an infinite distance from the object.

Lines of sight are all lines joining the eye or point of sight with points on the object. In orthographic projection the lines of sight for any view are parallel to one another and perpendicular to the plane of projection.

Plane of projection is the plane onto which the object is projected. As the lines of sight must be perpendicular to the planes in orthographic projection, it is necessary to have a different plane for each point of sight. Thus for a one-view drawing there would be one plane and one point of sight, and for a three-view drawing there would be three planes and three points of sight.

The planes most commonly used are horizontal, vertical and profile. Fig 112a shows the principal co-ordinate planes and quadrants.

Rules for drawing orthographic projections

1 Place the object in its natural position or in the position which it is to be used.
2 Place the object so that its faces will be parallel to the principal planes of projection.
3 Turn the object so that its most important or most descriptive face is parallel to the vertical plane.
4 Select the views that will show the greatest number of visible lines.

The projection is obtained by finding the points at which the lines of sight pierce the plane of projection and connecting them correctly.

Every line on the object must show as a point or a line on the projection. If the line can be seen from the point of sight, it is represented by a solid line known as a visible outline. If the line is hidden behind some other part of the object, it is represented by a dashed line known as an invisible outline or hidden line.

There are two types of orthographic projection, one being first-angle projection (which is most commonly used in Europe) and the other thir[illegible] angle projection (most commonly used in the USA).

With first-angle projection the object is considered to be in the fir[illegible] quadrant (Figs 112a and 112b) and with third-angle projection it is consider[illegible] to be in the third quadrant (Figs 112a and 112c).

Arrangement of views (first-angle projection)

The view of the top of the object (usually referred to as the plan) is plac[illegible] under the front view (usually called the elevation) and is in vertical alignm[illegible] with it, to facilitate the transfer of information from plan to elevation and vi[illegible] versa (see Figs 113 and 114).

The view of the left side of the object (profile) is placed to the right of t[illegible] elevation, and the view of the right side of the object is placed to the left of t[illegible] elevation; both side views are in horizontal alignment with the elevation [illegible] that points may be projected horizontally from one view to the other.

Arrangement of views (third-angle projection)

The view of the top of the object (plan) is placed directly above the front vi[illegible] (elevation) so that points may be projected vertically from one view to t[illegible] other (see Figs 113 and 114).

The view of the left side of the object is placed to the left of the elevation, [illegible] the view of the right side is placed to the right of the elevation; both side vi[illegible] are in horizontal alignment with the elevation so that points may be proje[illegible] horizontally from one view to the other.

Projection lines

The method shown in Figs 112b and 112c, using a 45° mitring line, is the b[illegible] as it is easier to maintain accuracy with this arrangement.

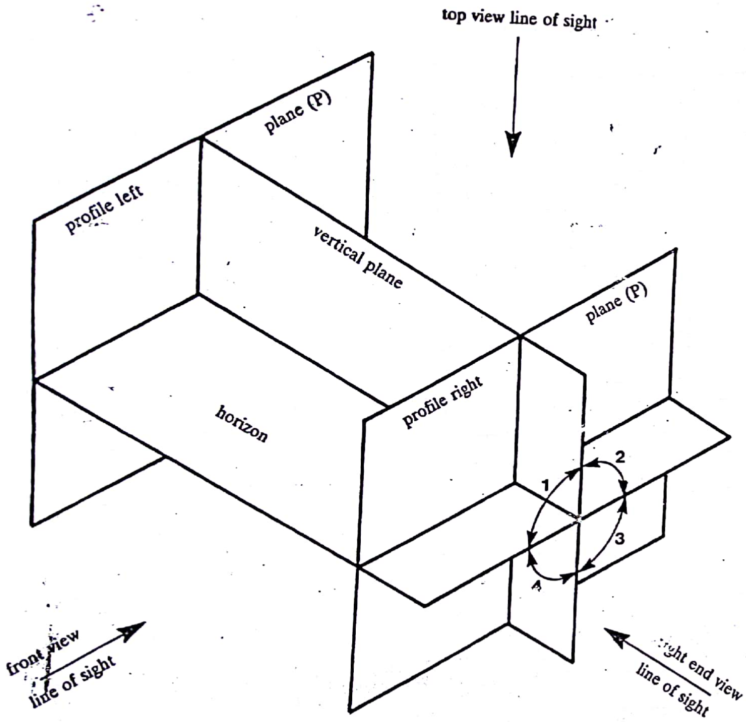

Fig 112a Principal co-ordinate planes and quadrants

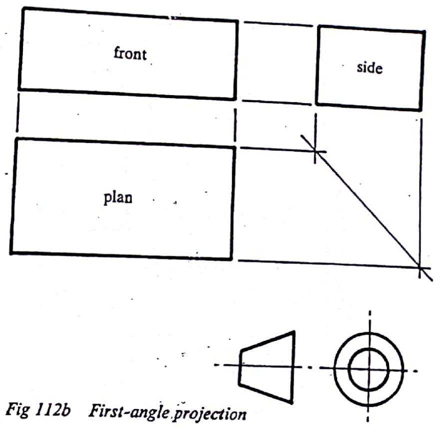

Fig 112b First-angle projection

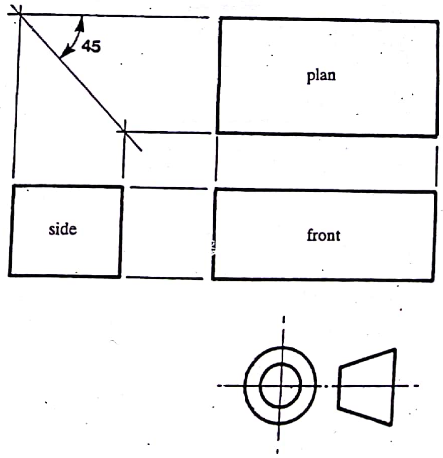

Fig 112c Third-angle projection

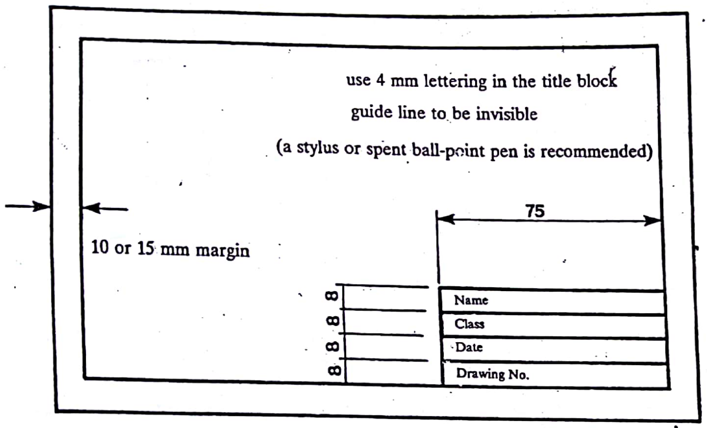

Fig 113 Preparing the drawing sheet

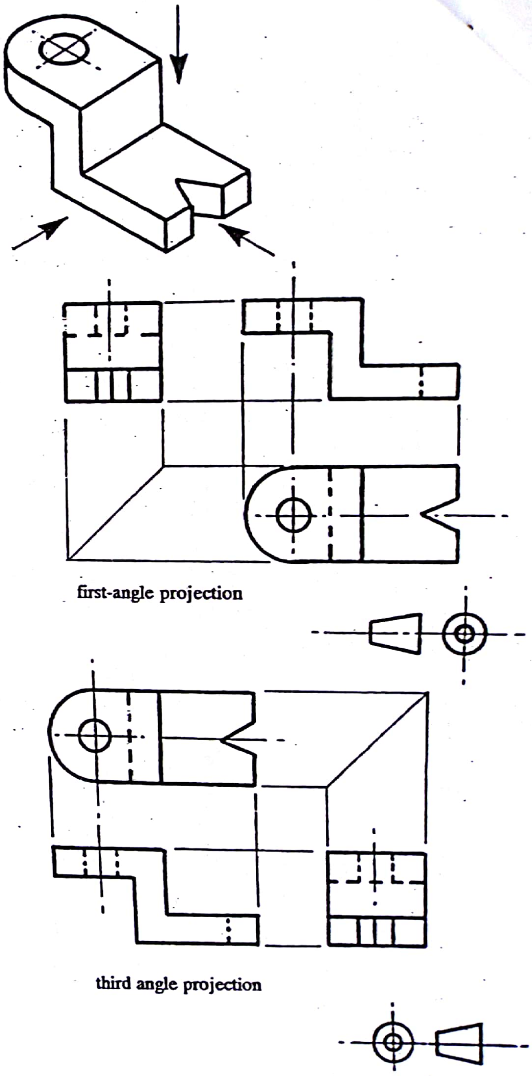

Fig 114 Comparison of first- and third-angle projection

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Solutions to orthographic projection problems

Example 1

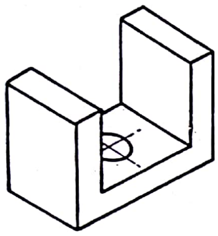


Fig 115a

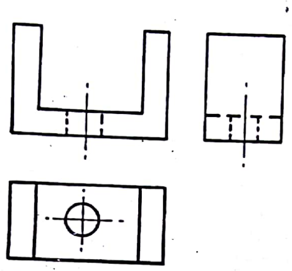


Fig 115b

Example 2

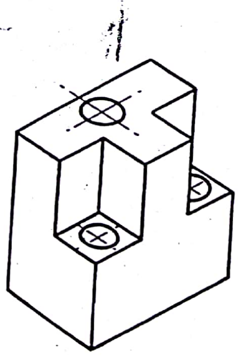


Fig 116a

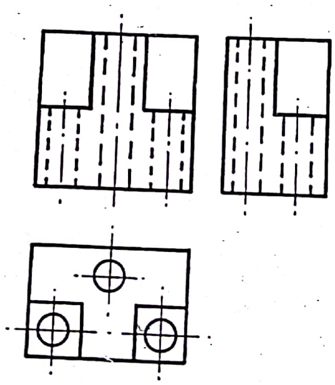


Fig 116b

Example 3

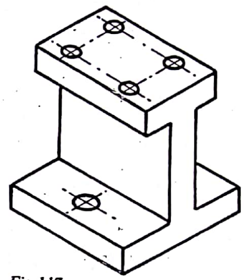


Fig 117a

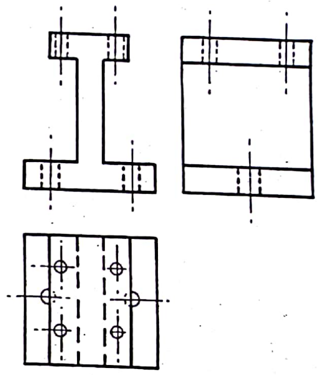


Fig 117b

Example 4

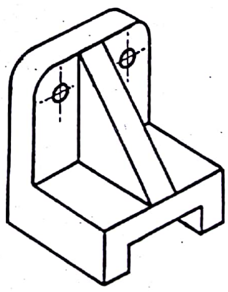


Fig 118a

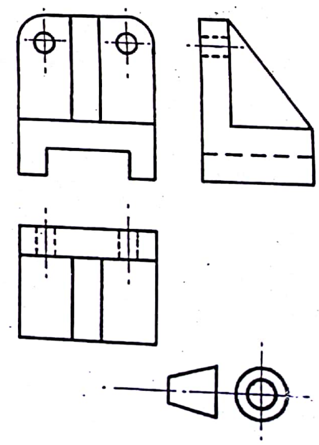


Fig 118b

Example 5

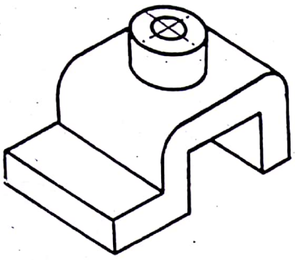


Fig 119a

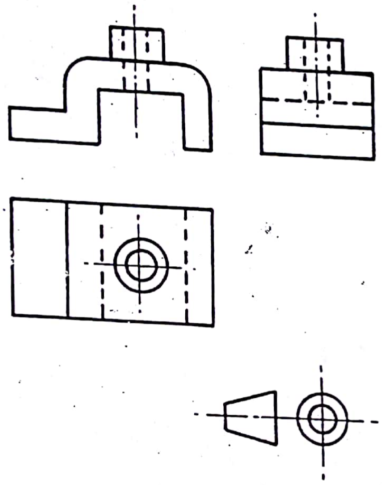


Fig 119b First-angle projection

Problems on converting isometric views ... graphic projection

Looking in the direction indicated by the arrows, and using first- and third-angle projections, draw the front elevation, side and plan views of each of the objects shown in Fig 120 below and Fig 121 opposite.

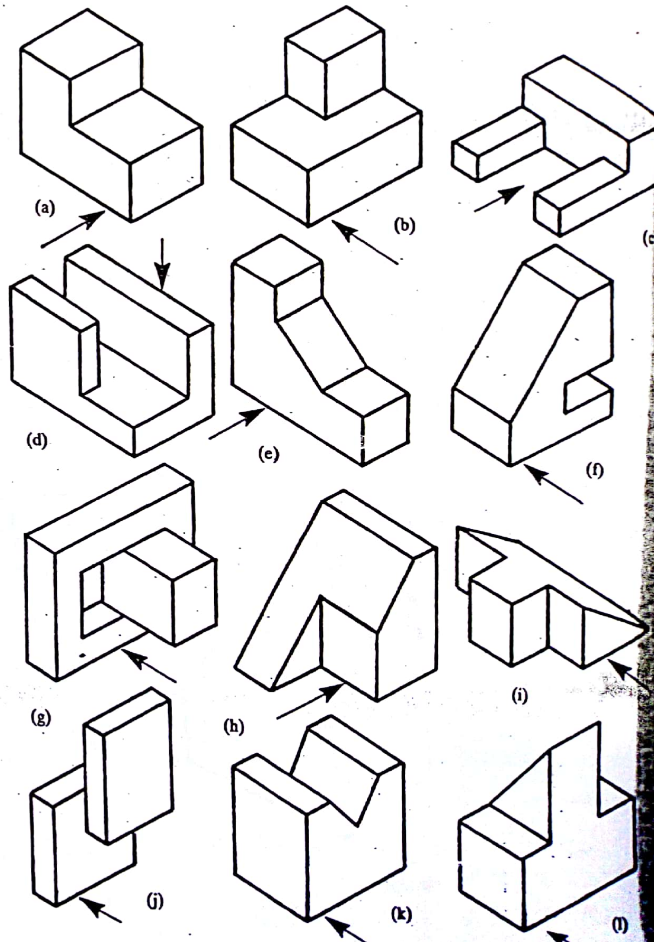


Fig 120

Problem

A cast-iron web bracket is shown in Fig 122a. Looking in the direction of arrow A, draw the front elevation, side elevation and plan view using drawing layout technique and 45° orthographic projection technique.

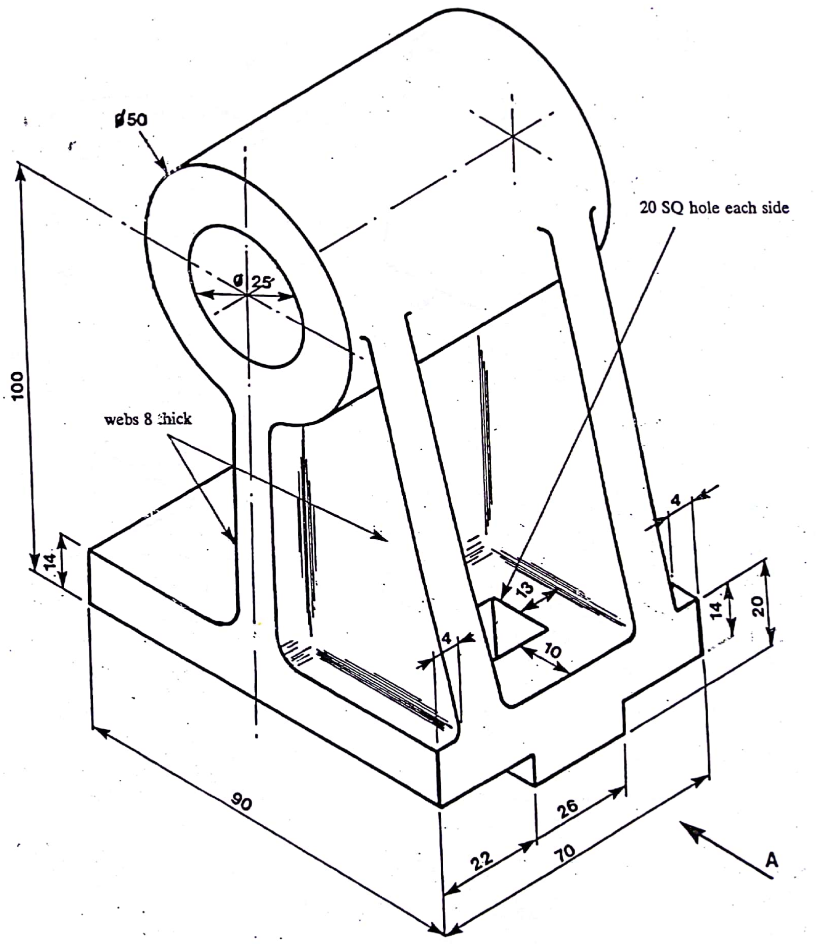


Fig 122a   Web bracket (not to scale)

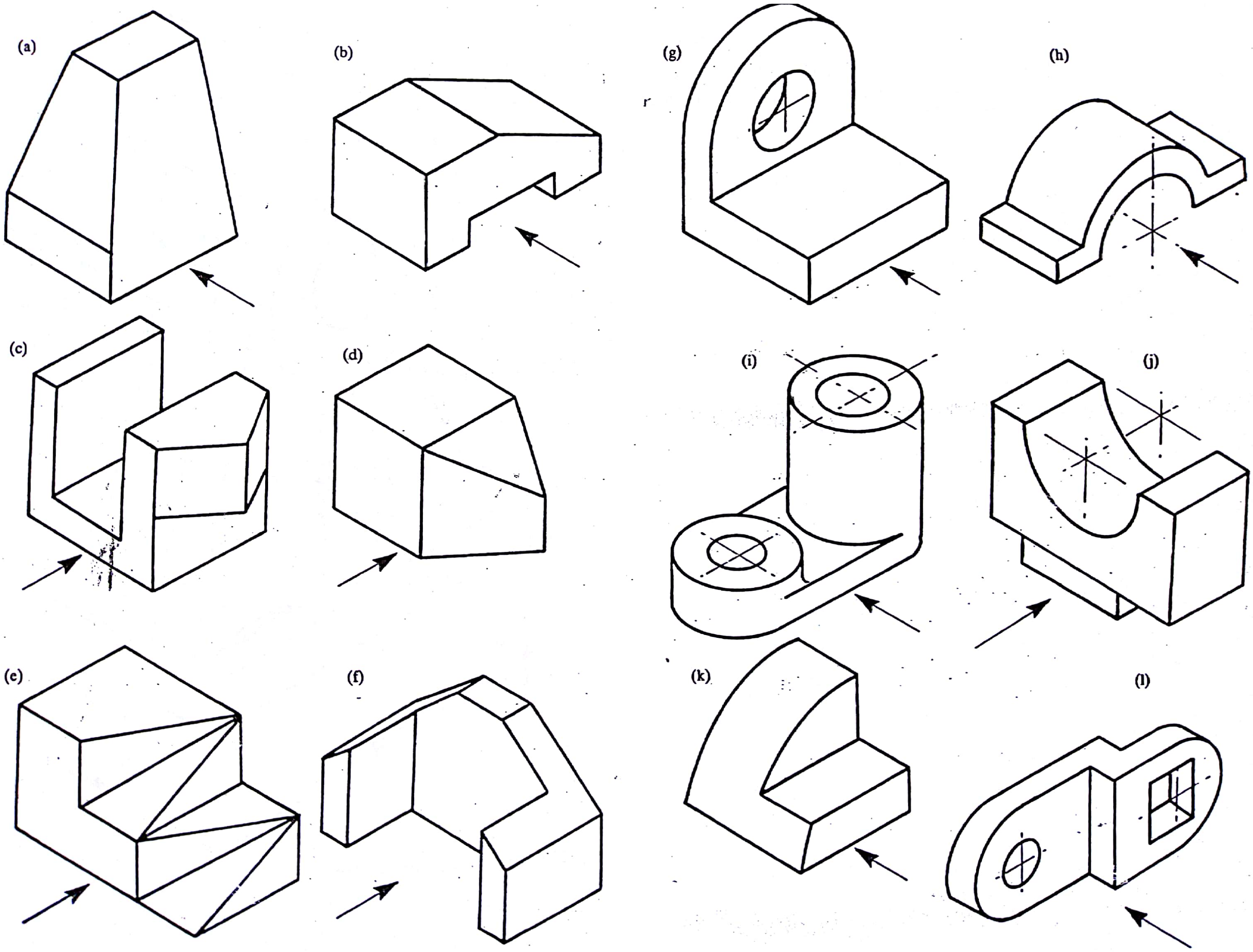
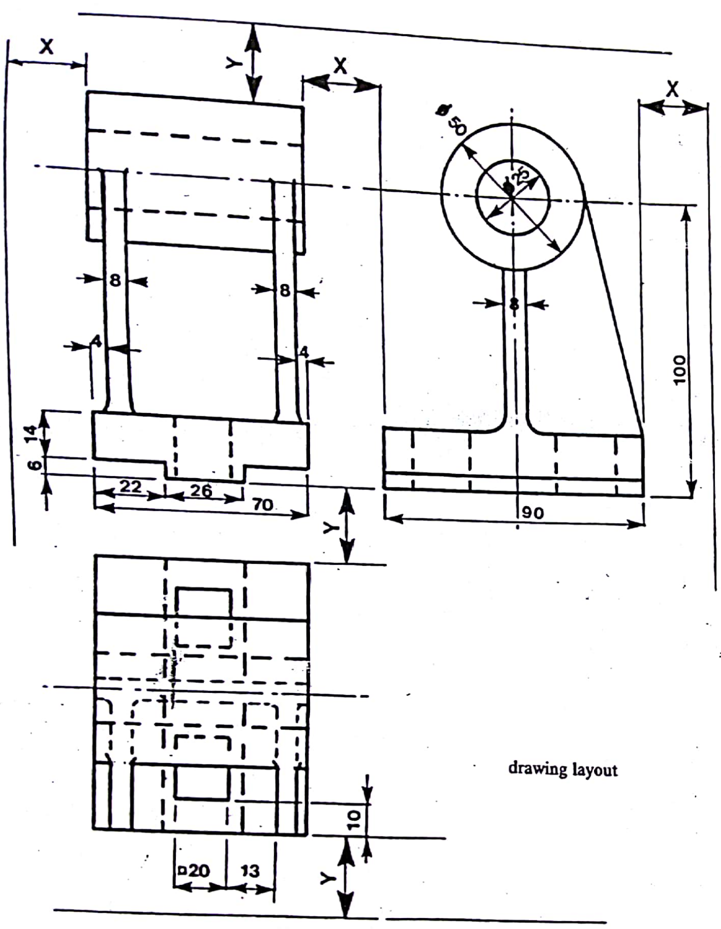
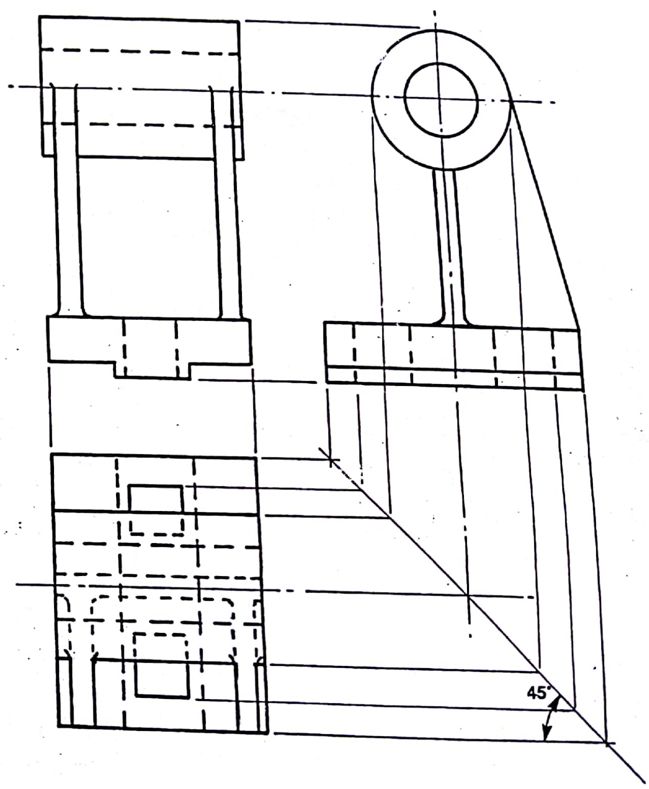


Fig 121



Note: In the drawing layout horizontal dimension X should be equal, and vertical dimension Y should be equal, throughout



Note: The use of 45° technique does not allow for a layout but allows for the transfer of information by projection.

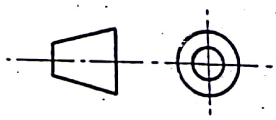


Fig 122b ***Solution to Web bracket problem (scale: half full size)***

Problems

Draw first- and third-angle projections of the objects shown below in Figs 123a–d, and measure the figures in order to dimension the drawings.

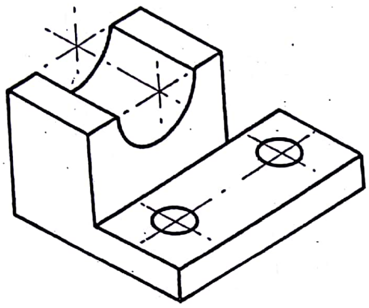


Fig 123a

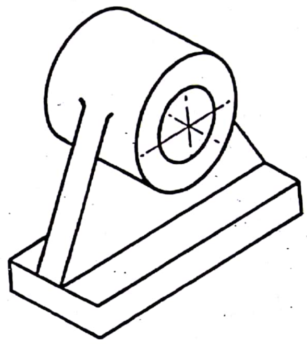


Fig 123c

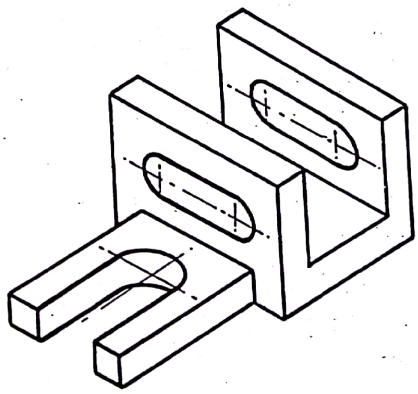


Fig 123b

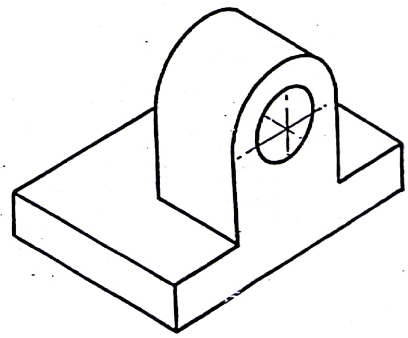
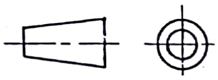
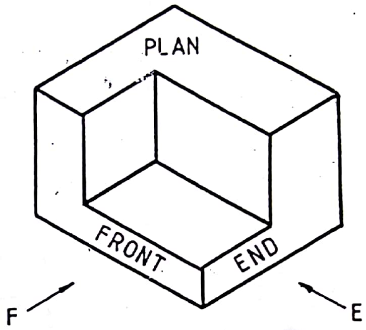


Fig 123d

First angle projection

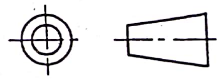
The plan is always drawn below the front elevation. Views are always projected as shown, in front of the arrows E and F. The symbol for first angle projection is shown below.

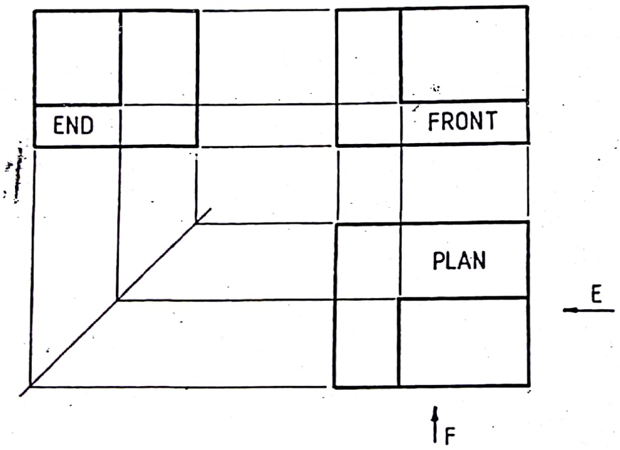


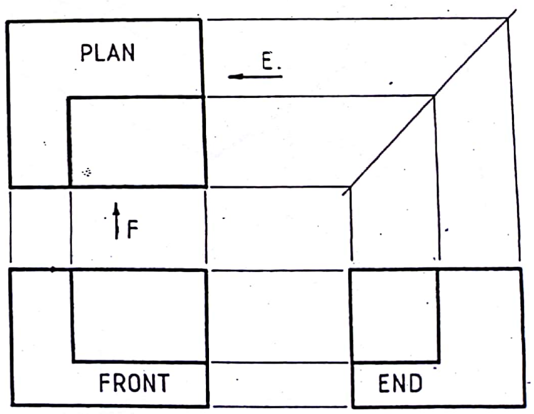


Third angle projection

The plan is always drawn above the front elevation. Views are always projected as shown, behind the arrows E and F. The symbol for third angle projection is shown below.







FIRST & THIRD ANGLE PROJECTION

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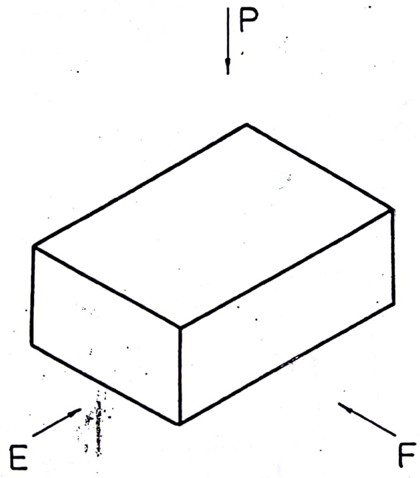
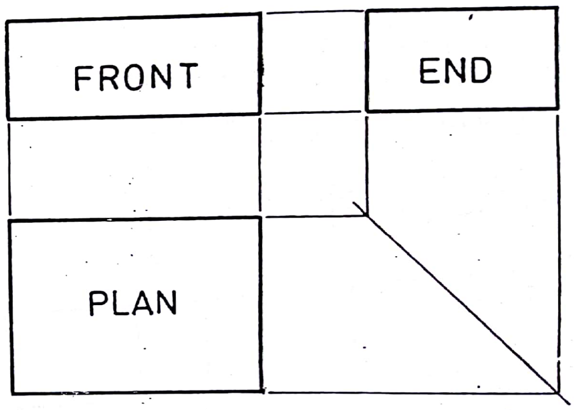
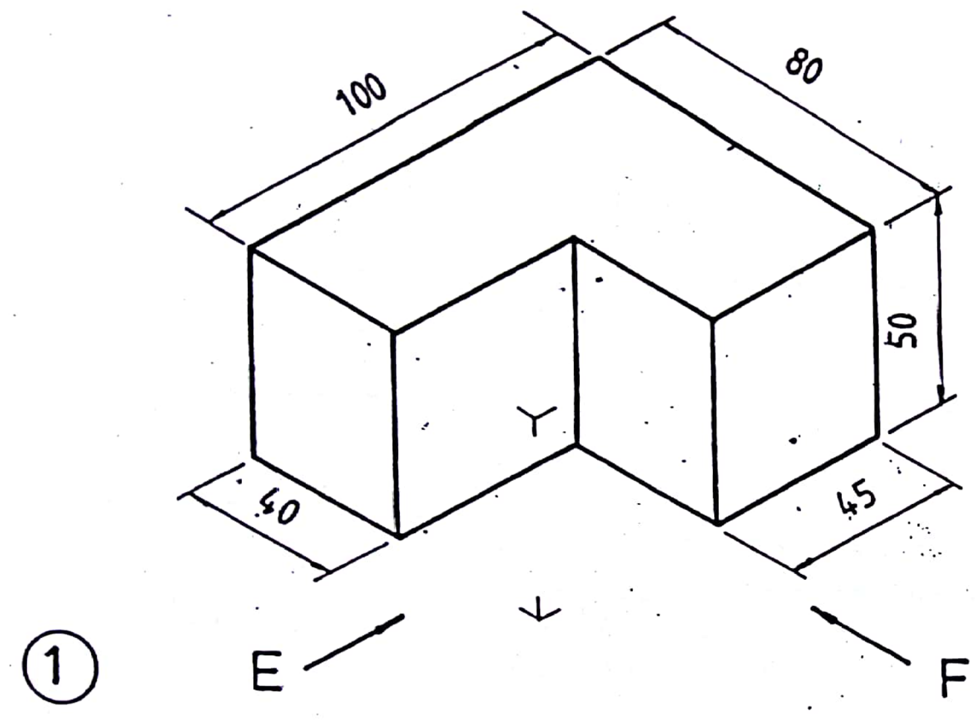




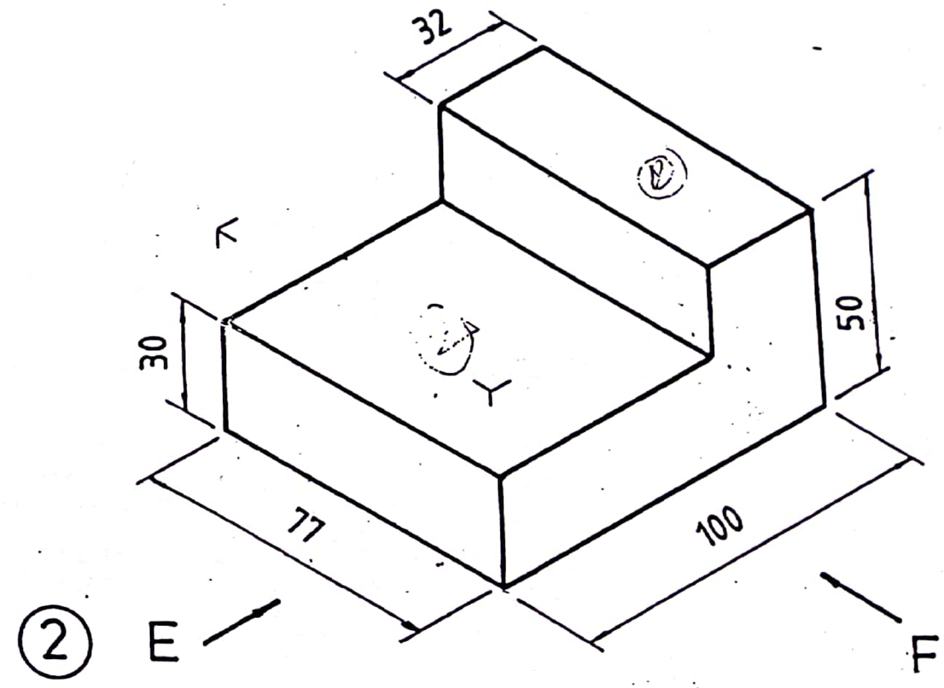
Suggested layout for questions 1-20 (A3 paper).

1. *On the left hand side of your paper, copy the given isometric drawing.*
2. *On the right hand side of your paper, draw the front elevation, end elevation and plan. The direction of the front elevation is shown by a letter F. Do not show any dimensions.*

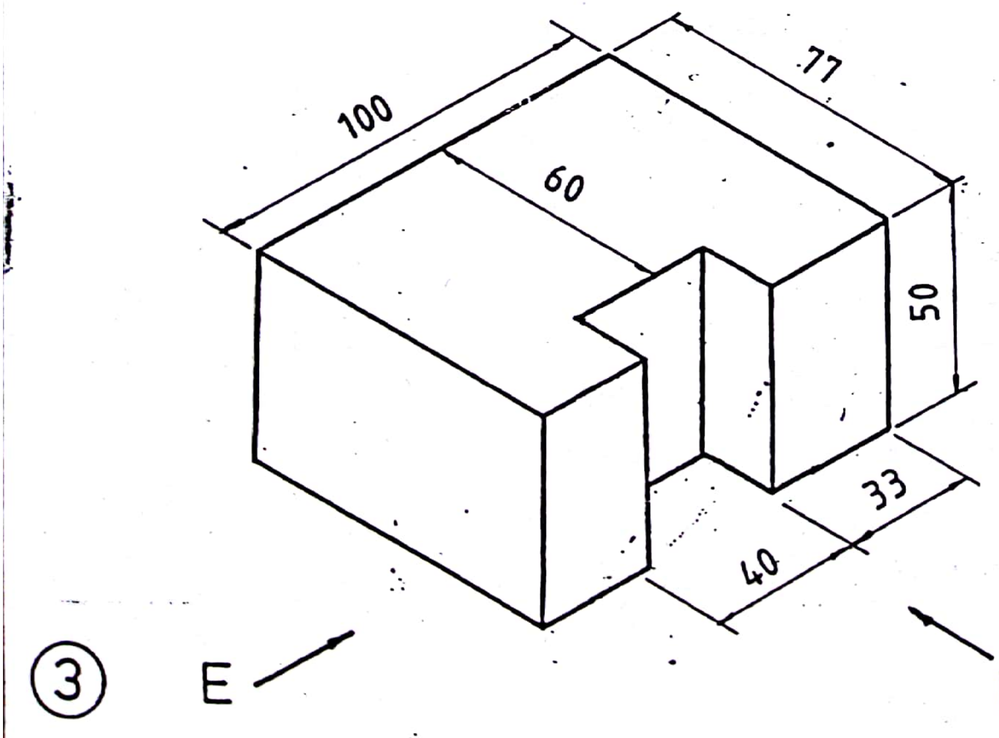
ISOMETRIC TO ORTHOGRAPHIC PROJECTION



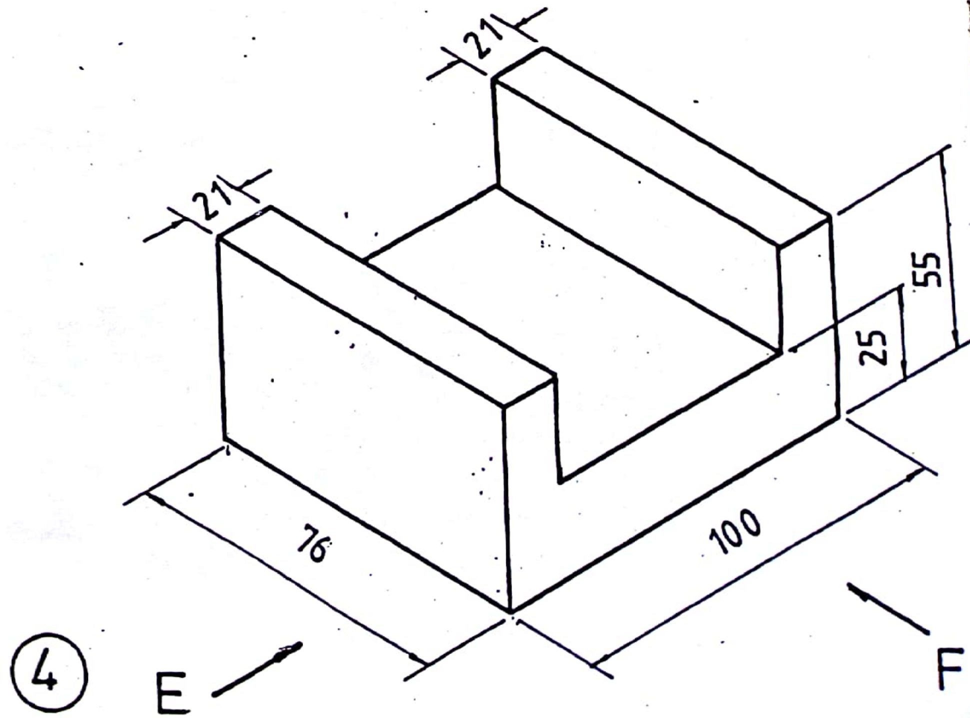
100
80
50
40
45
E
F



32
50
30
77
100
E
F



100
77
60
50
33
40
E
F



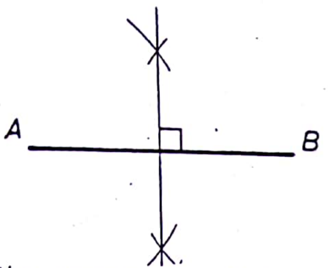
21
21
55
25
76
100
E
F

Part 2

Plane and solid geometry

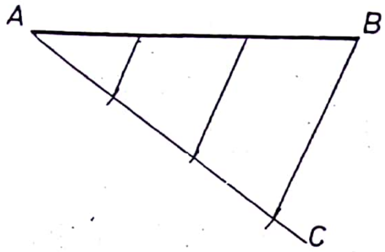
Pg 107

BISECTION OF A LINE



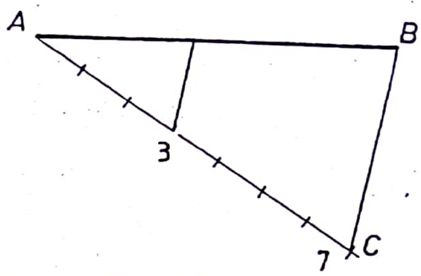
With the compass opened to a distance greater than half AB, strike arcs from A and B. A line joining the points of intersection of the arcs is the bisector.

DIVISION OF A LINE INTO EQUAL PARTS



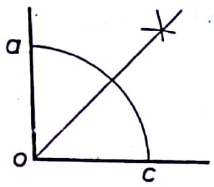
From A, draw a line AC at any angle. On line AC, make three convenient equal divisons. Join the last division with B and draw parallel lines as shown.

DIVISION OF A LINE INTO A RATIO OF PARTS



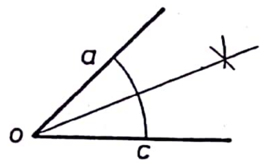
From A, draw line AC at any angle. Line AB is to be divided into the ratio of 3:4. From A, make 7 (3+4) equal divisions. Join the last division C with B and from division 3 draw a line parallel to BC.

BISECTION OF A RIGHT ANGLE



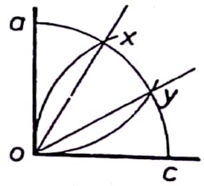
With centre 0, draw any convenient arc cutting the angle at a and c. With compass set to a suitable distance, strike arcs from a and c to intersect as shown. Each angle will now be 45°.

BISECTION OF AN ANGLE OF 45°



Proceed as for a right angle. An angle of 45° will be divided into two angles each of $22\frac{1}{2}°$. This method can be used to bisect any angle.

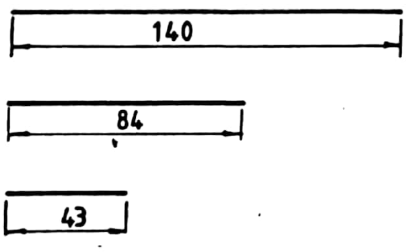
DIVISION OF AN ANGLE INTO EQUAL PARTS



To divide a right angle into 3 equal parts, draw a convenient arc with centre at 0 and touching the two sides of the right angle. With the same radius, draw arcs from a and c to cut at x and y. Each angle will be 30°.

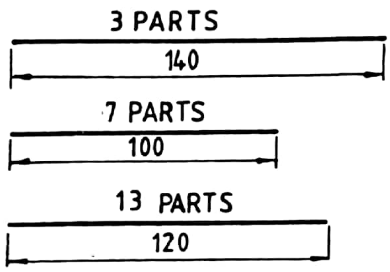
BISECTION & DIVISION OF LINES & ANGLES

200



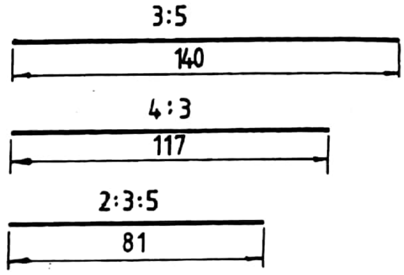
Draw each line and bisect it. Your construction should be clear but lines should be less intense.

201



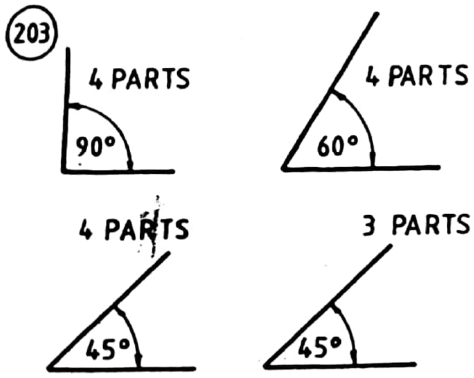
Draw each line and divide it into the number of equal parts shown using a constructional method.

202



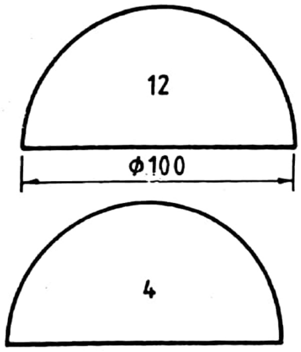
By a constructional method, divide each line into the ratio of parts indicated.

203



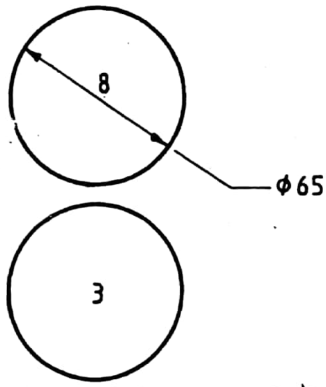
By construction, divide each angle into the number of equal parts indicated.

204



By construction, divide each semi-circle into the number of equal parts indicated.

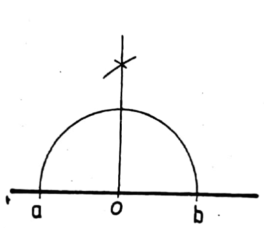
205



By construction, divide each circle into the number of equal parts indicated.

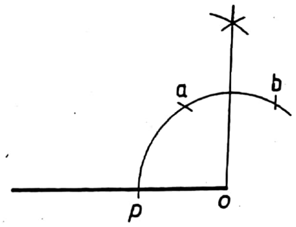
The examples shown should be drawn on two sheets of A3 paper and drawn as outlines. All construction lines should be less intense than the outlines.

... ON A LINE



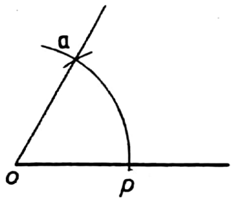
At point O, draw a semicircle of any radius to touch the line at a and b. With compass at a greater radius, strike arcs from a and b.

PERPENDICULAR AT THE END OF A LINE



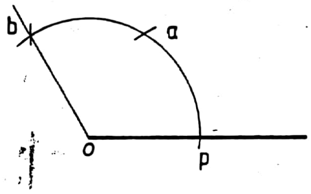
At point O, draw a convenient arc to touch the line at p. With the same radius, step off points a and b. From a and b, strike arcs of the same radius.

ANGLE OF 60°



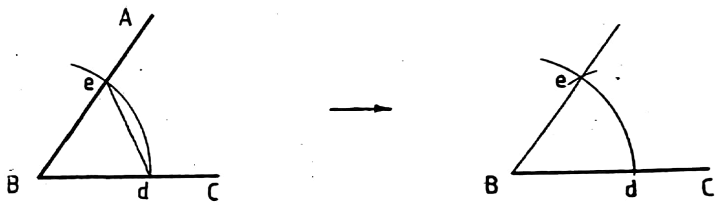
At point O, draw a convenient arc to touch the line at p. With the same radius, step off point a from p. The angle produced will be 60°.

ANGLE OF 120°



At point O, draw a convenient arc to touch the line at p. With the same radius, step off points a and b. The angle produced will be 120°.

TRANSFERENCE OF ANGLES



Draw any angle ABC and from B draw a convenient radius to touch points e and d.

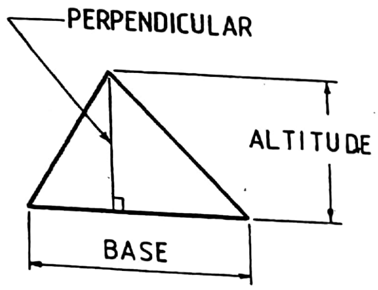
To transfer the angle, draw line B and the arc of radius Bd. Strike o distance de on the arc.

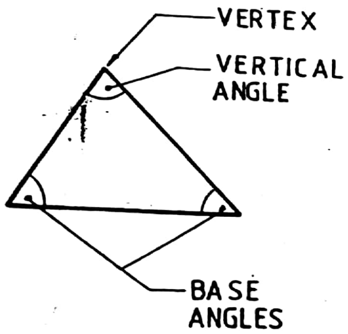
CONSTRUCTION OF ANGLES

Scanned by CamScanner

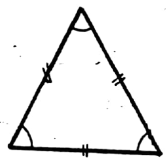
TRIANGLES

TERMINOLOGY



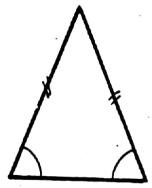


EQUILATERIAL



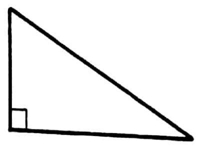
All angles 60^{G}.
All sides equal.

ISOSCELES



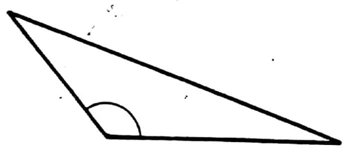
Base angles equal.
Opposite sides equal.

RIGHT ANGLED



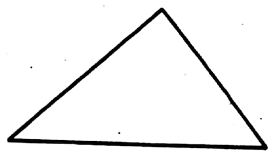
One angle is 90^{0}.
All sides of different length.

OBTUSE ANGLED



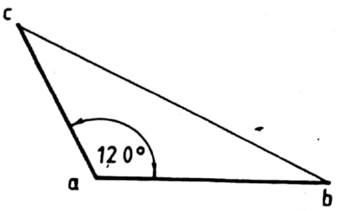
One angle is greater than 90^{0}. All sides of different length.

SCALENE



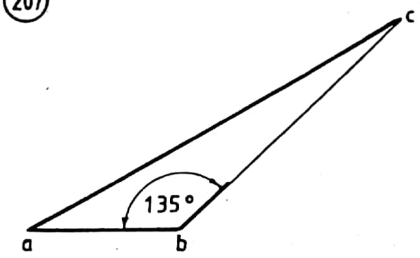
All angles different. All sides of different length.

206



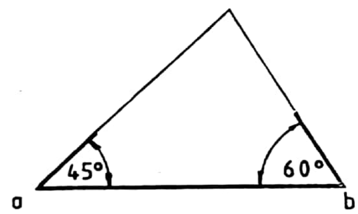
Base ab is 102.
Side ac is 71.
Angle cab 120°.

207



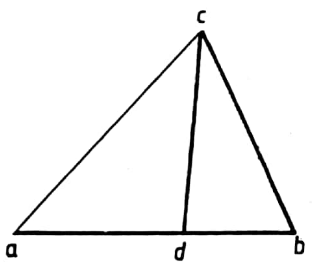
Base ab is 59.
Side ac is 177.
Angle abc 135°.

208



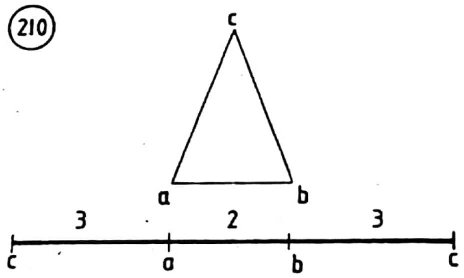
Base ab is 117.
Base angles 45°, 60°.

209



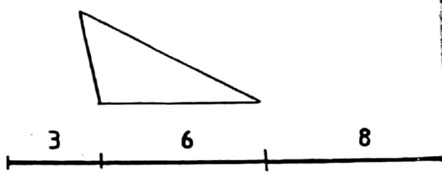
Base ab is 111.
Altitude cd is 83.
Side cb is 90.

210



Perimeter is 170.
Isosceles triangle,
ratio of sides 3:2:3.

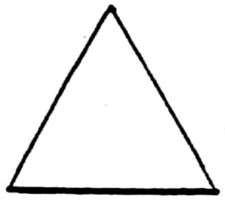
211



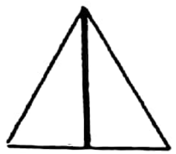
Perimeter is 178.
Ratio of sides 3:6:8.

Construct each triangle using the given information. Construction lines should be less intense then the outline of the triangle.

212

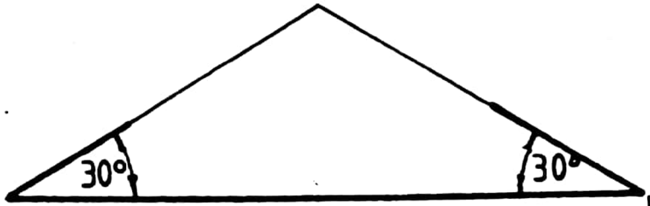


Construct the equilateral triangle given the base ab is 40.



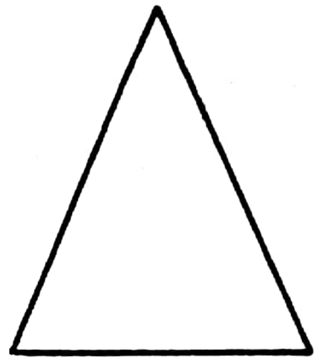
Construct the equilateral triangle given the altitude is 35.

213



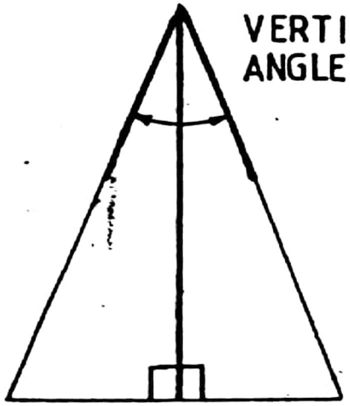
Construct the isosceles triangle given the base is 103 and the base angles are 30°.

214



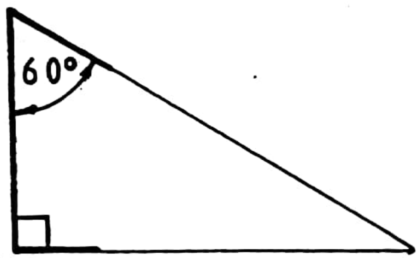
Construct the isosceles triangle given the base is 60 and the sides are 77.

215



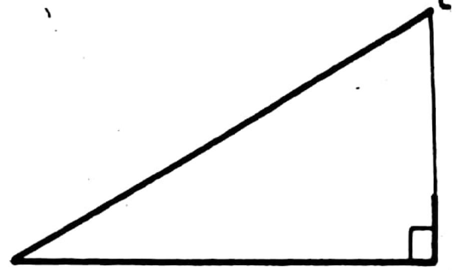
Construct the isosceles triangle given the vertical angle is 45° and the altitude is 100.

216



Construct the right-angled triangle given the base angle is 90°, the vertical angle is 60° and side ac is 68.

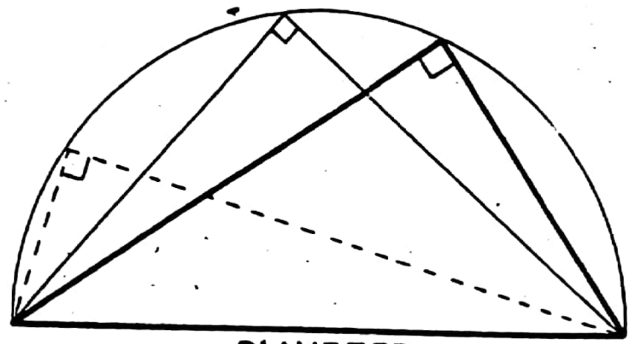
217



Construct the right-angled triangle given the base ab is 100, side ac is 120 and one base angle is 90°.

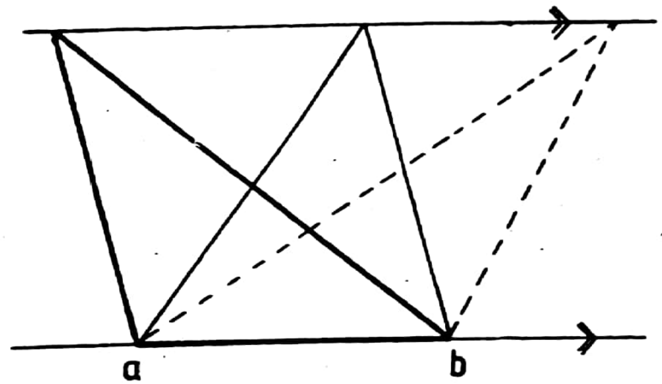
Construct each triangle using the given information. Construction lines should be less intense than the outline of the triangle.

TRIANGLE IN A SEMI-CIRCLE



A triangle whose base is the diameter of a semicircle will have a vertical angle of 90^0 when that angle touches the circumference of the semicircle.

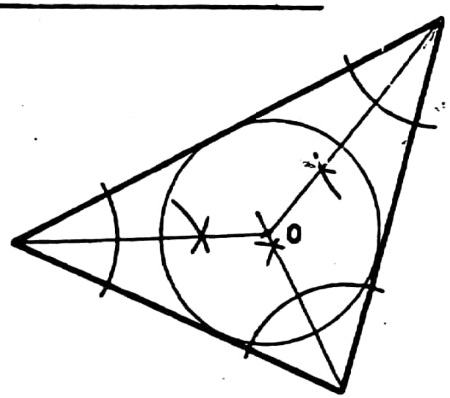
TRIANGLE BETWEEN PARALLELS



Triangles having the same base, drawn between the same parallel lines, will have the same area.

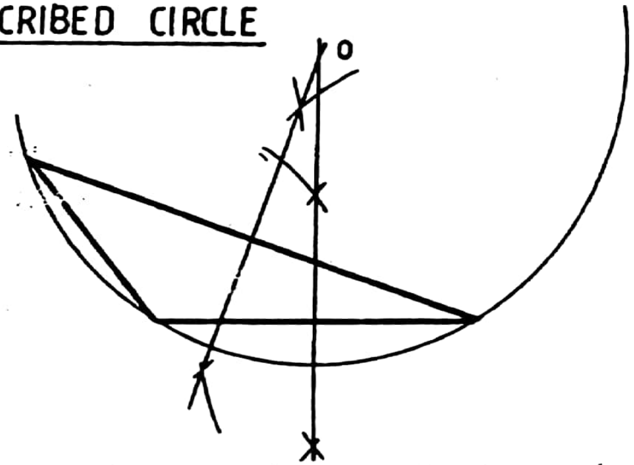
Area = $\frac{1}{2}$ base x altitude

INSCRIBED CIRCLE



An inscribed circle is one which touches the three sides of a triangle. Its centre is found by bisecting any two angles.

CIRCUMSCRIBED CIRCLE

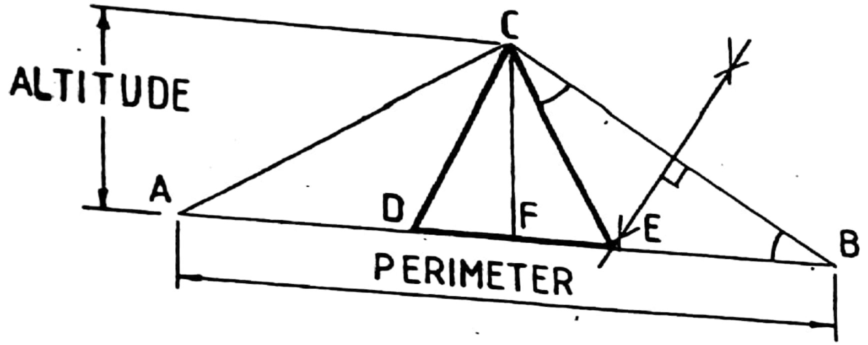


A circumscribed circle, is one which touches the three corners of a triangle. Its centre is found by bisecting any two sides of the triangle.

USEFUL PROPERTIES OF TRIANGLES

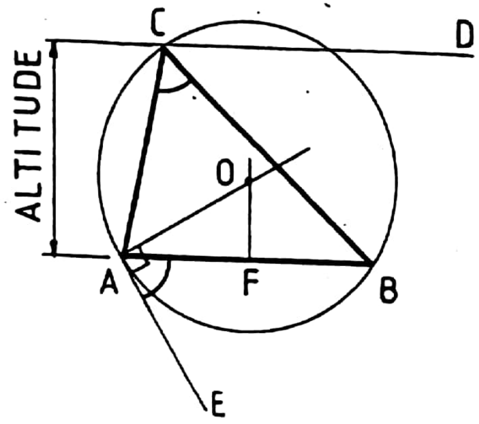
TRIANGLE CONSTRUCTIONS

ISOSCELES TRIANGLE GIVEN PERIMETER & ALTITUDE



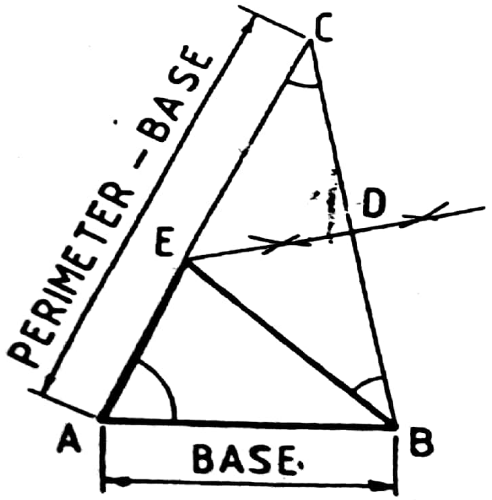
Draw the perimeter AB and erect a perpendicular at its mid-point F. CF is the altitude. Bisect CB to obtain E. EF equals half the base. Repeat the construction for AC to obtain D.

TRIANGLE GIVEN BASE, ALTITUDE & VERTICAL ANGLE



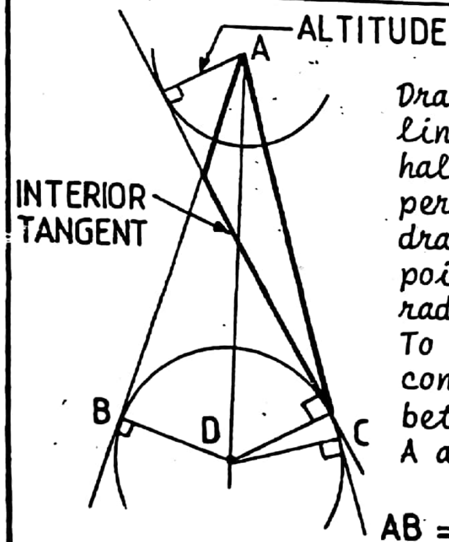
Draw the base AB and draw line CD parallel to the base. Draw angle BAE which is equal to the vertical angle. Bisect AB and construct the right angle EAO to give point O which is the centre for a circle touching the base AB and giving the angle ACB which is the vertical angle.

TRIANGLE GIVEN BASE, BASE ANGLE & PERIMETER



Draw the base AB and the base angle EAB. Line AC equals the perimeter less the base. Draw line CB and bisect it to obtain point E which is the vertex of the triangle.

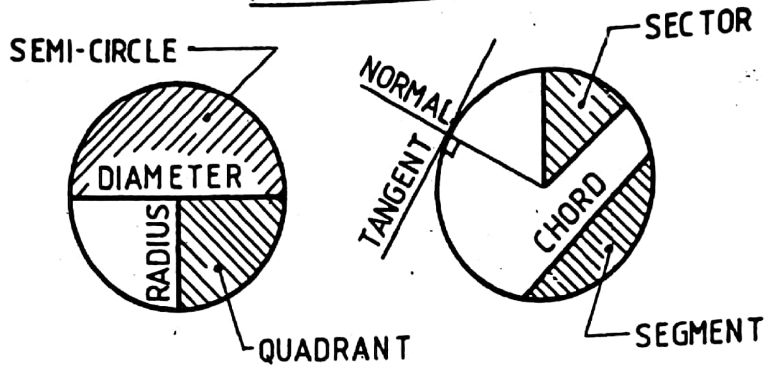
TRIANGLE GIVEN VERTICAL ANGLE, ALTITUDE & PERIMETER



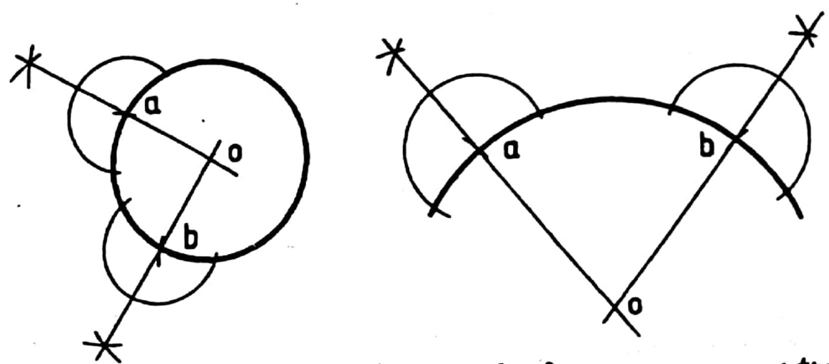
AB = AC = HALF PERIMETER

Draw the vertical angle BAC and lines AB and AC, each equal to half the perimeter. Construct perpendiculars at B and C and draw the circle centre D. At point A, draw a circle whose radius equals the given altitude. To complete the triangle, construct an internal tangent between the two circles centres A and D. (See page 132.)

PARTS OF A CIRCLE

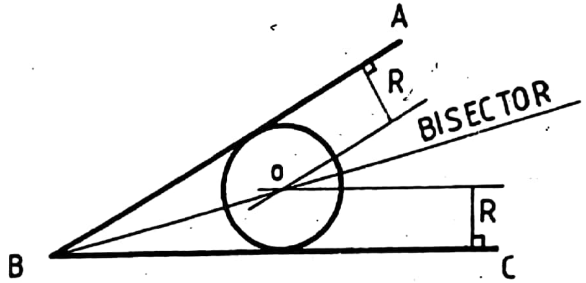


CENTRES OF CIRCLES



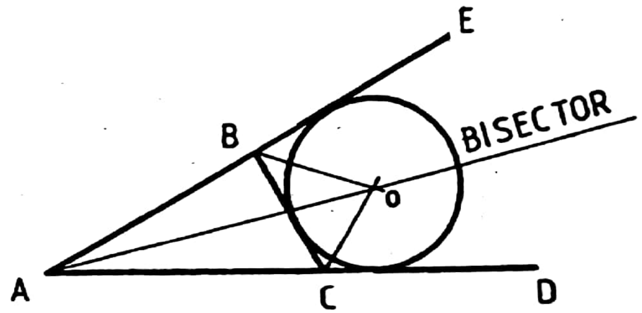
To obtain the centre O of a circle or arc, construc two normals as shown. The two constructions should b spaced by approximately 90° to obtain the most accurate result.

CIRCLE IN AN ANGLE



To draw a circle of radius R in an angle, draw the bisector and a line parallel and spaced distance R from one side of the angle.

ESCRIBED CIRCLE



To draw the escribed circle to a triangle ABC, prod AB to E and AC to D. Bisect angles EAC and BCD to obtain centre O for the circle.

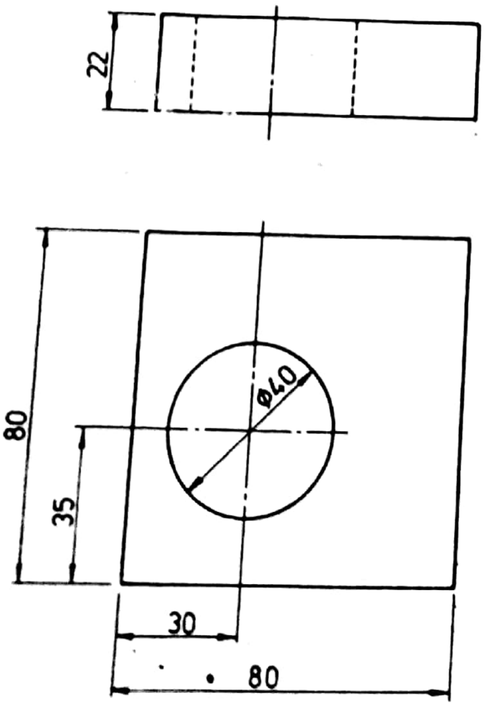
THE CIRCLE

Chapter 14
Dimensioning principles

A drawing should provide a complete set of working instructions for the craftsmen who produce the component. Dimensions define geometric characteristics such as angles, diameters, lengths, and positions; and each dimension which defines a characteristic should appear on the drawing only once, and it should not be necessary for the craftsman either to scale the drawing or to deduce dimensions by the subtraction or addition of other dimensions.

Theoretically any component can be analysed and divided into a number of standard common geometrical shapes such as cubes, prisms, cylinders, parts of cones, etc. A hole through a plate can be considered as a cylinder for this purpose. Dimensioning is a means of defining the exact amount of material remaining after a series of manufacturing operations have taken place. Manufacturing is followed by inspection and measurement is taken in both cases from functional axes or planes and these are known as datums.

A solid block with a hole in it is shown in Fig. 14.1 and to establish the exact shape of the item we require to know the dimensions which govern its length, height and thickness also the diameter and depth of the hole and its position in relation to the surface of the block.



4.1

The axis of the hole is shown at the intersection of two centre lines positioned from the left hand side and the bottom of the block and these two surfaces have been taken as datums. The length and height have also been measured from these surfaces separately and this is a very important point as errors may become cumulative and this is discussed later in the chapter.

Dimensioning therefore, should be undertaken with a view to defining the shape or form and overall size of the component carefully, also the sizes and positions of the various features, such as holes, counterbores, tappings etc., from the necessary datum planes or axes.

The completed engineering drawing should also include sufficient information for the manufacture of the part and this involves the addition of notes regarding the materials used, tolerances of size, limits and fits, surface finishes, the number of parts required and any further comments which result from a consideration of the use to which the completed component will be put. For example, the part could be used in sub-assembly and notes would then make reference to associated drawings or general assemblies.

Now there are a few rules applicable to dimensioning which are covered by British Standard 308 and, if these are adhered to, it is reasonably easy to produce a drawing to a good professional standard.

1 Dimension and projection lines are thin continuous lines 0.35 mm thick, if possible, clearly placed outside the outline of the drawing. As previously mentioned, the drawing outline should be lined in with a thickness of 0.7 mm and the drawing outline will then be clearly defined and in contrast with the dimensioning system.
2 The projection lines should not touch the drawing but a small gap should be left, about 2 to 3 mm, depending on the size of the drawing. The projection lines should then continue for the same distance past the dimension line.
3 Arrowheads should be approximately triangular, must be of uniform size and shape and in every case touch the dimension line to which they refer Arrowheads drawn manually should be filled in. Arrowheads drawn by machine need not be filled in.
4 Bearing in mind the size of the actual dimensions and the fact that there may be two numbers together where limits of size are quoted, then adequate space must be left between rows of dimensions and a spacing of about 12 mm is recommended.

5 Centre lines must never be used as dimension lines but must be left clear and distinct. They can be extended, however, when used in the role of projection lines.

6 Dimensions are quoted in millimetres to the minimum number of significant figures. For example, 19 and not 19.0. In the case of a decimal dimension, we always use a naught before the decimal marker which might not be noticed on a drawing print which has poor line definition. We write 0.4 and not .4. It should be stated here that on metric drawings the decimal marker may be either a full stop or a comma positioned on the base line between the figures, for example, 5.2 or 5,2 but never 5·2 with a decimal point midway.

7 To enable dimensions to be read clearly, figures are placed so that they can be read from the bottom of the drawing, or by turning the drawing in a clockwise direction, so that they can be read from the right hand side.

8 Leader lines are used to indicate where specific notes apply. The leader line to the hole is directed towards the centre point but terminates at the circumference in an arrow. A leader line for a part number terminates in a dot within the outline of the component. The gauge plate here is assumed to be part number six of a set of inspection gauges.

Fig. 14.2 shows a partly completed drawing of a gauge to illustrate the above aspects of dimensioning.

When components are drawn in orthographic projection, a choice often exists where to place the dimensions and the following general rules will give assistance.

1 Start by dimensioning the view which gives the clearest understanding of the profile or shape of the component.

2 If space permits, and obviously this varies with the size and degree of complexity of the subject, place the dimensions outside the profile of the component as first choice.

3 Where several dimensions are placed on the same side of the drawing, position the shortest dimension nearest to the component and this will avoid dimension lines crossing.

4 Try and ensure that similar spacings are made between dimension lines as this gives a neat appearance on the completed drawing.

5 Overall dimensions which are given for surfaces that can be seen in two projected views are generally best positioned between these two views.

Remember, that drawings are used for the manufacture of components, so ask yourself whether or not the machinist or fitter can use or work to the dimension you have quoted to make the item. Also, can the inspector check the figure, in other words, is it a measurable distance?

Fig. 14.3 shows a component which has been partly dimensioned to illustrate some of the principles involved.

Careless and untidy dimensioning can spoil an otherwise sound drawing and it should be stated that many marks are lost in examinations due to poor quality work.

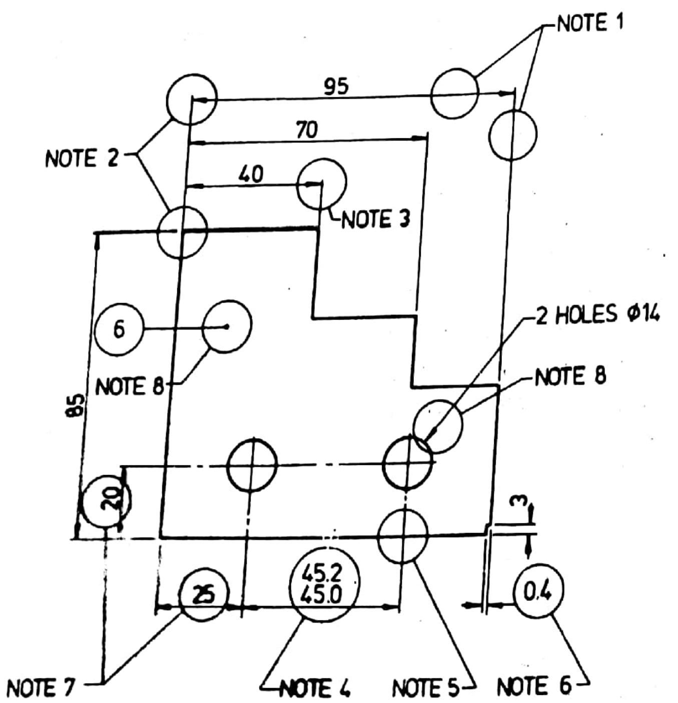


Fig. 14.2 Gauge plate

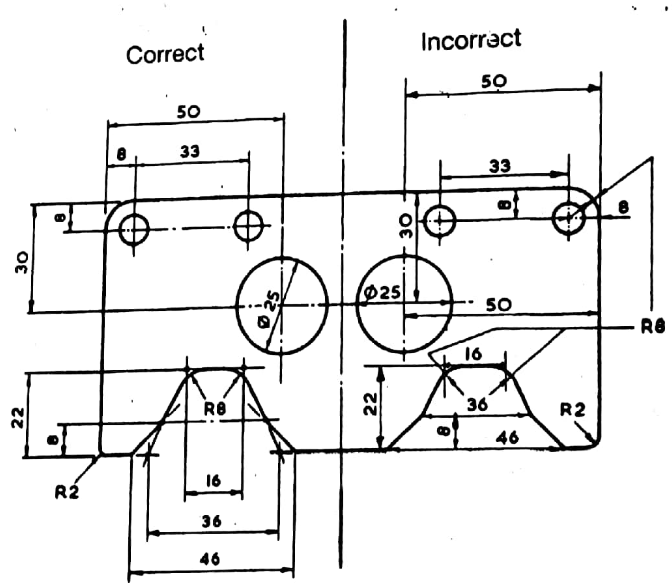


Fig. 14.3

Dimensions not to scale

Sometimes it is desirable to dimension part of a drawing which has not been drawn to the correct scale. The particular dimension is then underlined (Fig. 14.4)

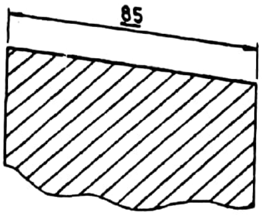


Fig. 14.4

Chain dimensioning

A plan view of a twist drill stand is given in Fig. 14.5 to illustrate chain dimensioning.

Now each of the dimensions in the chain would be subject to a manufacturing tolerance since it is not possible to mark out and drill each of the centre distances exactly. As a test of drawing accuracy, start at the left hand side and mark out the dimensions shown in turn. Measure the overall figure on your drawing and check with the auxiliary dimension given. Note the considerable variation in length which results from small errors in each of the six separate dimensions in the chain which clearly accumulate. Imagine the effect of marking out say twenty holes for rivets in each of two plates, how many holes would eventually line up? The overall length is shown in parentheses (157) and is known as an auxiliary dimension. This dimension is not one which is worked to in practice but is given purely for reference purposes. You will now appreciate that it will depend on the accuracy with which each of the pitches in the chain is marked out.

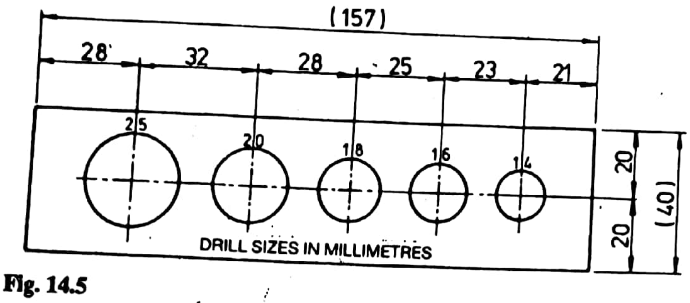


Fig. 14.5

Parallel dimensioning

Improved positional accuracy is obtainable by dimensioning from a datum and this method is shown in Fig. 14.6. The datum selected is the left hand side of the stand. Note that the overall length is not now shown as an auxiliary dimension, but as a fixed distance which

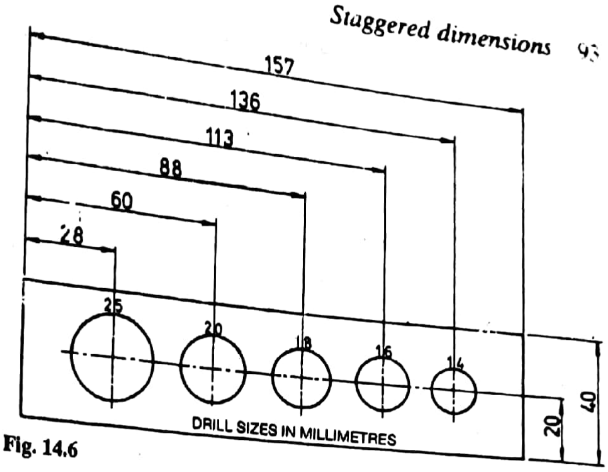


Fig. 14.6

can be separately marked out, manufactured and definitely checked.

Simplified parallel dimensioning

Note that the spacing of the six dimensions takes up considerable space and this space can be reduced if the following convention is adopted. The common origin is indicated as shown with a thin continuous circle and the dimensions placed near the arrowheads.

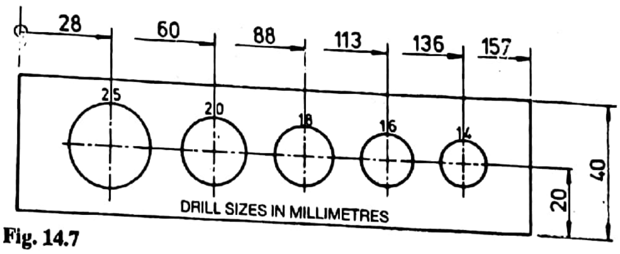


Fig. 14.7

Staggered dimensions

A number of parallel dimensions may be staggered as shown for clarity (Fig. 14.8).

The dimension lines can sometimes be omitted and leader lines used in their place, these are positioned at right angles to the outline of the component (Fig. 14.9).

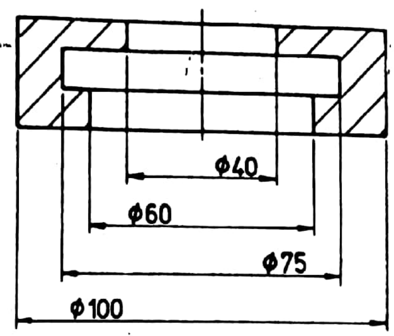


Fig. 14.8

4 Geometry of plane figures

Angles

When two straight lines meet (AB and AC below) they form an angle. Angles are measured in degrees (°). There are 360° in a circle.

Angles can be drawn and measured using a protractor (see p 7).

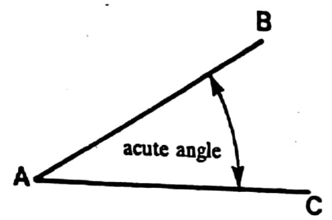


Fig 19a An acute angle (less than 90°)

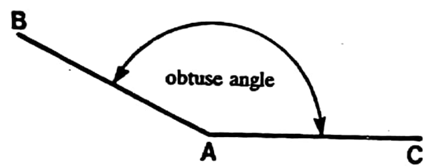


Fig 19b An obtuse angle (90°–180°)

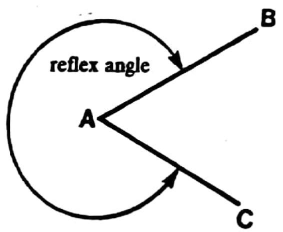


Fig 19c A reflex angle (larger than 180°)

To bisect a given angle

Draw the angle BAC (Fig 20). With centre A and any convenient radius drawn an arc to cut AB at D and AC at E. With centre D and any radius draw an arc. With centre E and the same radius draw an arc to intersect the first at F. Join AF. This is the bisector.

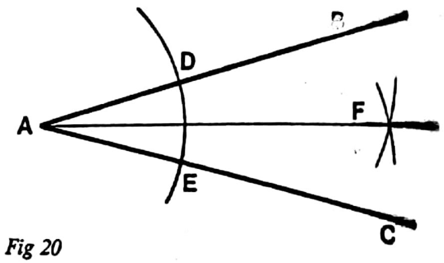


Fig 20

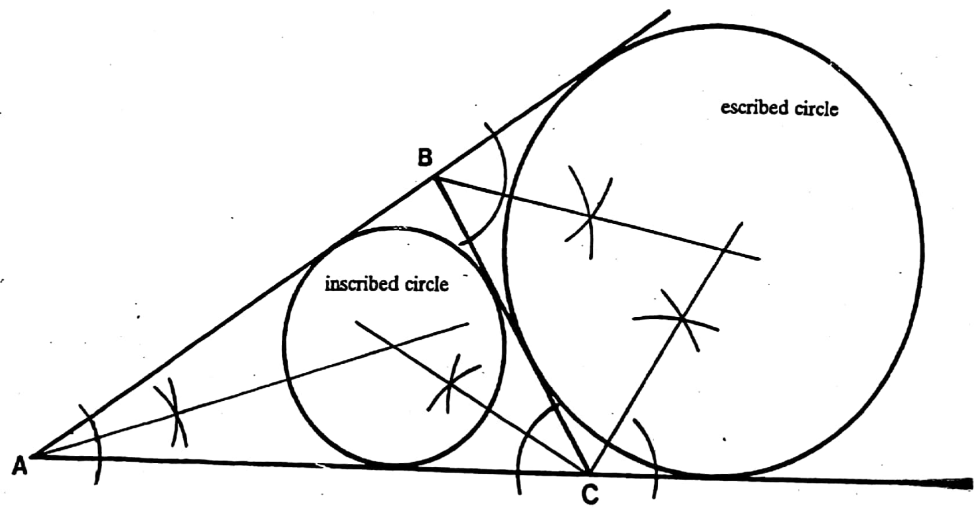


Fig 21

The construction shows how the inscribed circle and the escribed circle of triangle BAC may be drawn by using the bisectors of the internal and external angles of the triangle (see also p16).

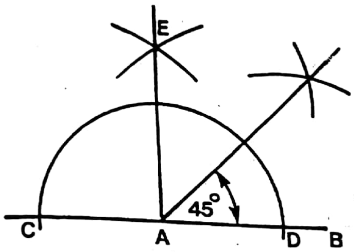


Fig 22a

To construct an angle of 45° (Fig 22a)

1 Construct a right angle BAE thus:

a) Draw given line AB.

b) Extend construction line outwards from A.

c) With centre A and any convenient radius draw semi-circle CD.

d) With centres C and D, and any convenient radius, draw arcs to intersect at E.

e) A line from A through the intersection of the arcs is the perpendicular.

2 Bisect the right angle to obtain angle of 45°.

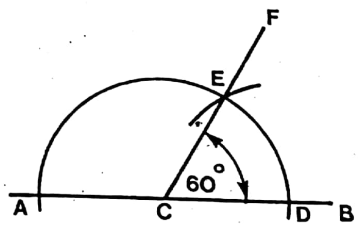


Fig 22b

To construct an angle of 60° (Fig 22b)

1 Draw line AB.

2 Indicate point C at any point on AB.

3 With centre C and any convenient radius draw arc to cut AB at D.

4 With centre D and same radius draw arc to intersect first arc at E.

5 Draw line from C through E to F. Angle FCB is required angle of 60°.

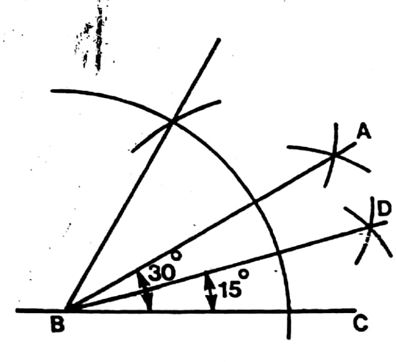


Fig 22c

To construct angles of 30° and 15° (Fig 22c)

1 Construct angle of 60°, as above.

2 Bisect angle of 60°.

3 Angle ABC is required 30° angle.

4 Construct angle of 30°, as above.

5 Bisect angle of 30°.

6 Angle DBC is required 15° angle.

Triangles

A triangle is a plane rectilinear figure sides.

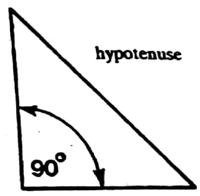
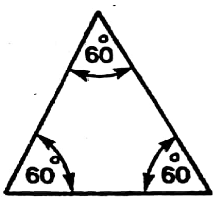


Fig 22d Right-angled triangle

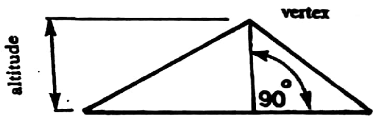


all three sides and all three angles equal

Fig 22e Equilateral triangle

two sides equal and two angles equal

Fig 22f Isosceles triangle



all three sides and all three angles unequal

Fig 22g Scalene triangle

Circles

A circle is a plane figure bounded by a line called the circumference which is always equidistant from the centre of the circle. The distance from the centre to the circumference is called the radius; the distance from one edge of the circumference to the other through the centre of the circle is called the diameter.

An arc is any part of the circumference.

A chord is any straight line drawn across the circle meeting the circumference at both ends. Any such line passing through the centre of the circle is called the diameter.

A tangent is a straight line that touches the circumference. It is always at right angles to the radius at the point of contact.

The line drawn from the point of contact to the centre of the circle is called the 'normal'.

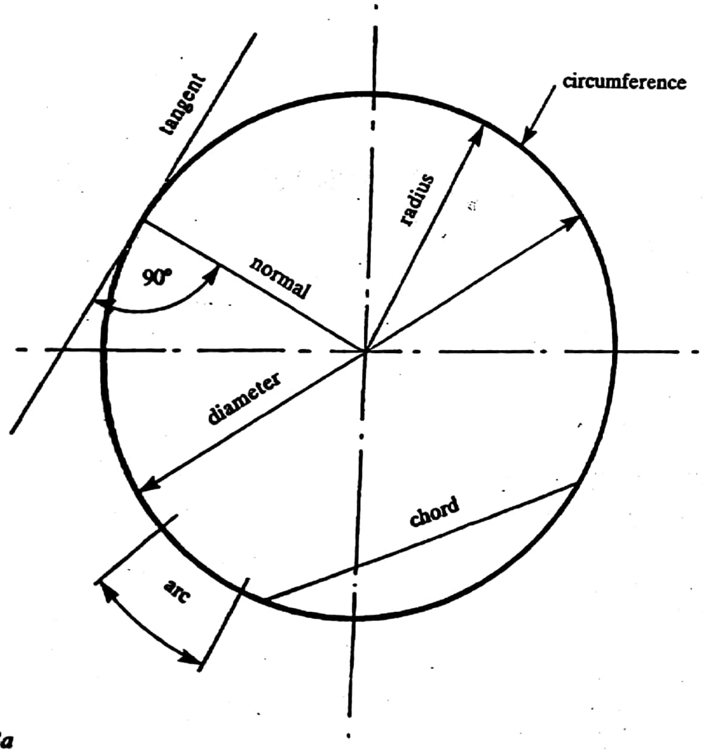


Fig 23a

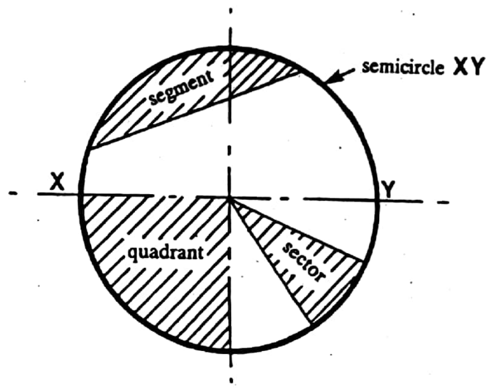


Fig 23b

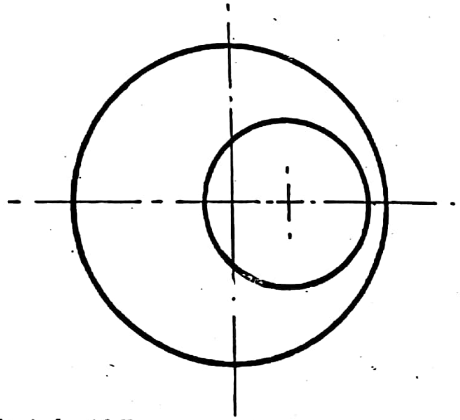


Fig 23c Eccentric circles (different centres)

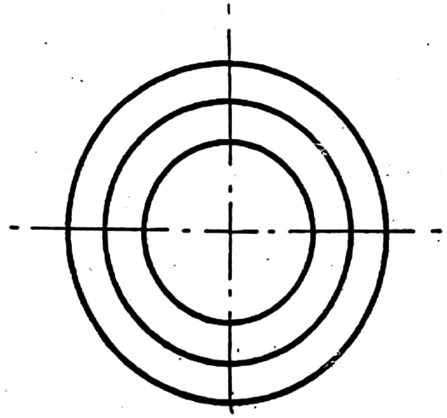


Fig 23d Concentric circles (same centre, different radii)

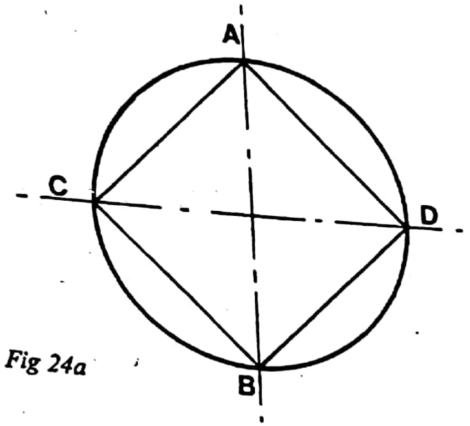


Fig 24a

To inscribe a square in a circle (Fig 24a)

1 Draw the given circle.
2 Draw diameters AB and CD at right angles to each other.
3 Draw lines AC, CB, BD and DA to complete the square.

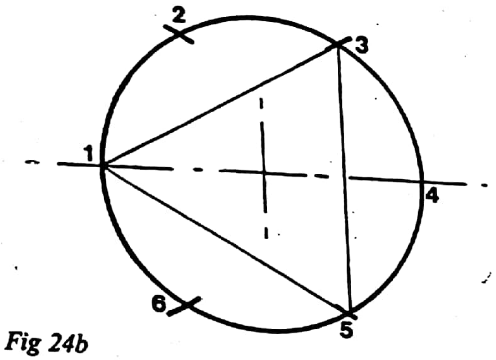


Fig 24b

To inscribe an equilateral triangle in a circle (Fig 24b)

1 Draw the given circle.
2 Take the radius of the circle and step it off six times around circumference.
3 Join every second point on the circumference (1, 3, 5) to complet equilateral triangle.

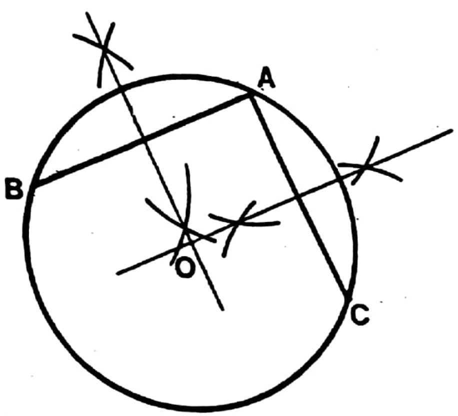


Fig 24c

To find the centre of a circle (Fig 24c)

1 Draw any two chords AB and AC.
2 Bisect AB and AC. The bisecting lines intersect at O, which is the ce the circle.

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To draw the circumscribed circle to a given triangle (Fig 24d)

1 Draw the given triangle ABC.

2 Bisect any two sides. The bisecting lines intersect at O, which is the centre of the required circle.

3 With centre O and radius OA, draw the circle, which will also pass through B and C.

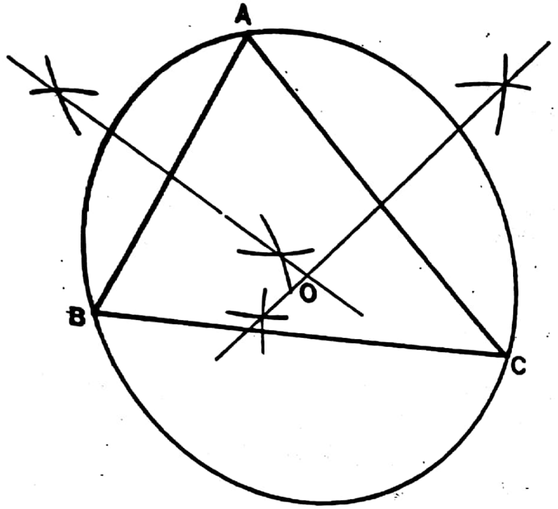

Fig 24d

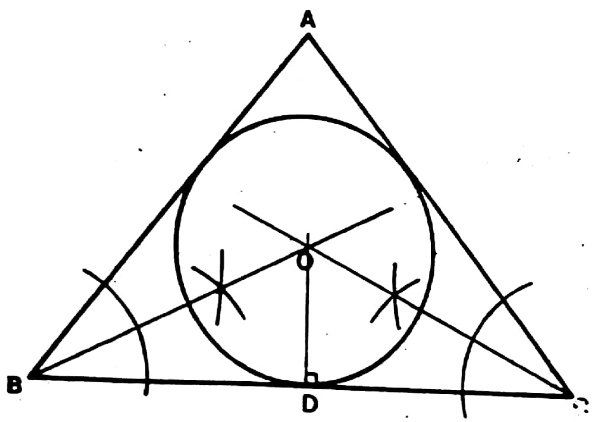

Fig 24e

To draw a circle of given radius to touch a given straight line and circle (Fig 24f)

1 Draw the given straight line AB and circle with centre O.

2 Draw a line parallel to AB at a distance equal to the radius of the required circle.

3 Add radius of required circle to radius of given circle and use this length to draw an arc, centre O, to cut the parallel line at C.

4 With centre C and radius CD draw the required circle.

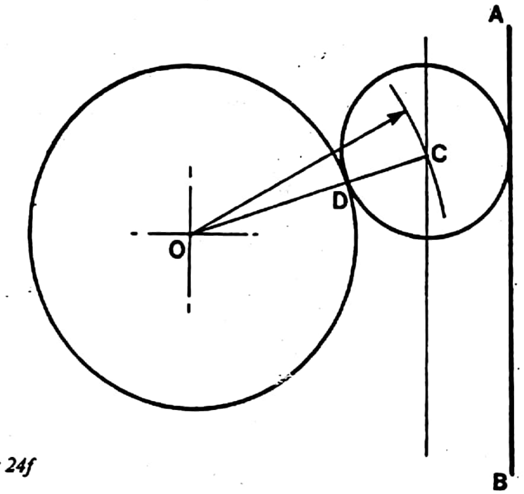

Fig 24f

To draw an inscribed circle to a given triangle (Fig 24e)

1 Draw the given triangle ABC.

2 Bisect any two angles. The bisecting lines will intersect at O, which is the centre of the circle.

3 Draw a perpendicular from any side to O (line OD).

4 With centre O and radius OD draw the required circle.

To draw a circle or arc of given radius to touch two given converging lines (Fig 24g)

1 Draw given lines AB and AC.
2 Draw lines parallel to AB and AC at a distance equal to radius of required circle, to intersect at O.
3 Draw a line perpendicular to AC from O (line OD).
4 With centre O and radius OD draw required arc or circle.

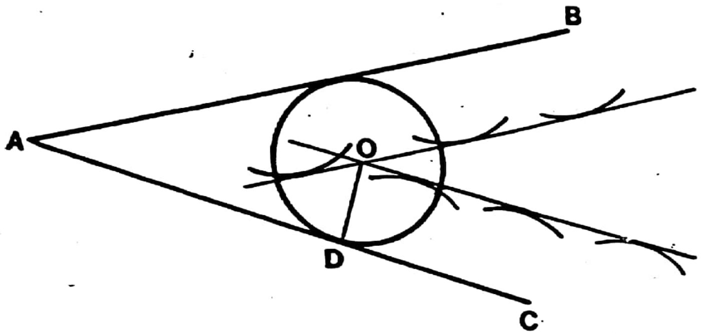

Fig 24g

To draw a circle to touch three given lines (Fig 24h)

1 Draw three given lines AB, BC, CD.
2 Bisect the two angles ABC and BCD. Bisecting lines intersect at O, the centre of required circle.
3 Draw a line OE perpendicular to any side from O.
4 With centre O and radius OE draw required circle.

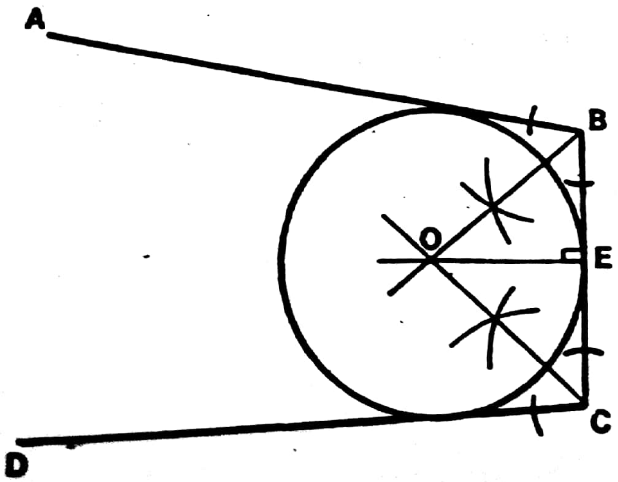

Fig 24h

To construct a tangent to a circle at a given point on the circumference (Fig 24i)

1 Draw circle with centre O. Indicate given point P.
2 Draw line OP and extend beyond circle.
3 With centre P and radius OP draw an arc to cut extended line at A.
4 Bisect OA. Bisector BC is required tangent.

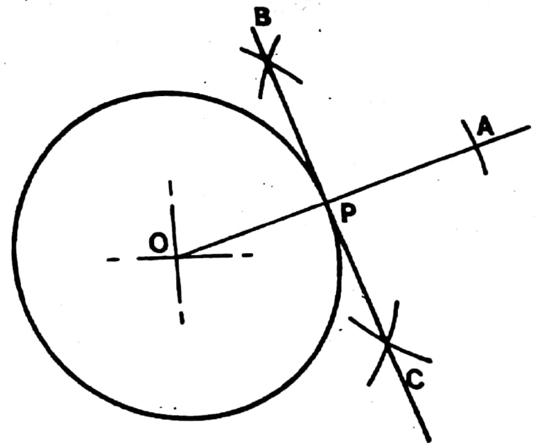

Fig 24i

To construct a tangent to a circle from a given point outside (Fig 24j)

1 Draw circle with centre O. Indicate given point P.
2 Draw line OP.
3 Construct a semi-circle on OP to cut circle at A.
4 Extend line from P through A. This is the required tangent.

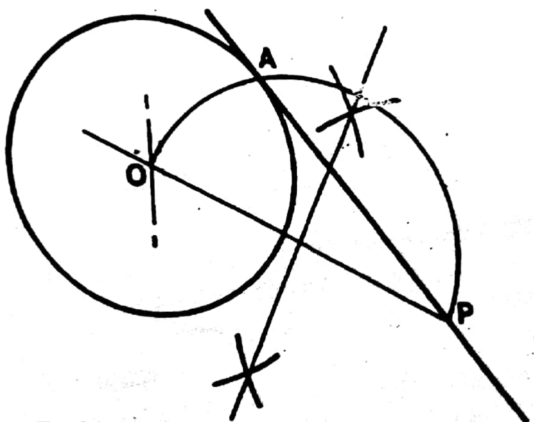

Fig 24j

Quadrilaterals

A quadrilateral is a four-sided plane figure. Special types are defined below:

Square: A quadrilateral with four equal sides and a right angle at each corner (Fig 25a).
Rectangle. A quadrilateral with opposite sides equal and a right angle at each corner (Fig 25b).
Parallelogram. A quadrilateral with opposite sides equal and parallel and angles other than right angles at each corner (Fig 25c).
Rhombus. A quadrilateral with all four sides equal and angles other than right angles at each corner (Fig 25d).
Trapezium. A quadrilateral with two opposite sides parallel (Fig 25e).
Deltoid. A quadrilateral with pairs of adjacent sides of equal length to form a kite (Fig 25f).
Trapezoid. An irregular quadrilateral with four unequal sides and angles (Fig 25g).

Polygons

A polygon is a plane rectilinear figure with more than four sides. According to the number of sides a polygon has it may be termed a pentagon (5 sides), hexagon (6), heptagon (7), octagon (8), nonagon (9) or decagon (10).

Regular polygons have sides of equal length with all included angles equal (Fig 26a). Irregular polygons are those that are not regular (Fig 26b). The sum of all the angles of a polygon should always equal 360°.

To draw a regular hexagon using a 60° setsquare, given the length of one side (Fig 26c)

1 Draw AB.
2 Draw lines at 60° from A and B in turn and mark off length AB along them to give C and D.
3 Draw lines at 60° from C and D in turn and mark off length AB along them to give E and F.
4 Join E to F. ABCDEF is required hexagon.

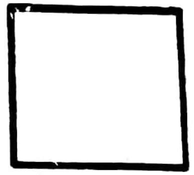

Fig 25a Square

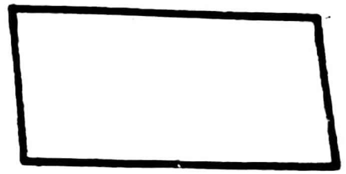

Fig 25b Rectangle

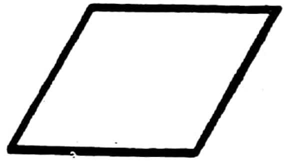

Fig 25c Parallelogram

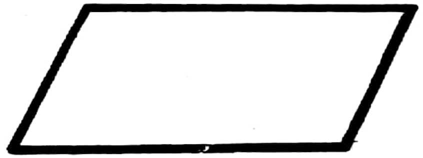

Fig 25d Rhombus

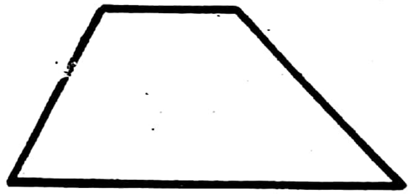

Fig 25e Trapezium

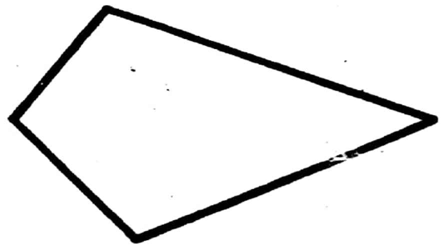

Fig 25f Deltoid (kite)

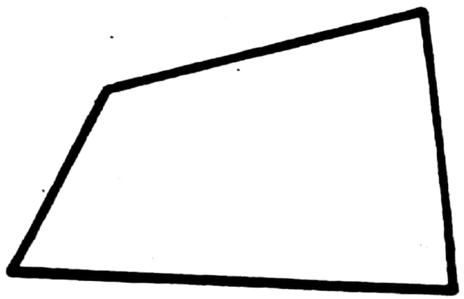

Fig 25g Trapezoid (or irregular quadrilateral)

To draw a regular polygon given the length of one side (Fig 26d)

1 Draw line AB equal in length to one of the sides of the polygon.
2 Bisect AB.
3 From B draw an angle of 45° to intersect the bisector at point 4.
4 From B draw an angle of 60° to intersect the bisector at point 6.
5 Bisect between points 4 and 6 to give point 5.

Note. Point 4 is the centre of a circle, radius 4A, containing a square.

Point 5 is the centre of a circle, radius 5A, containing a pentagon.

Point 6 is the centre of a circle, radius 6A, containing a hexagon.

By marking points at similar distances the centres and radii of circles containing any polygon can be obtained.

6 To draw a pentagon, mark off point 5 as described above.
7 With centre at point 5 draw a circle radius 5A.
8 Step off sides of figure (length=AB) round circumference of circle.

To draw a regular polygon in a given circle (or given a diagonal) (Fig 26e)

1 Draw the given circle and diameter AM.
2 Divide the diameter into the same number of divisions as the polygon has sides.
3 With centre M draw an arc radius MA. With centre A draw another arc of the same radius to intersect the first arc at N.
4 Draw N2 and produce to intersect the circle at B (for any polygon).
5 AB is the first side of polygon. Step out sides BC, CD, and so on. ABCDE is required polygon.

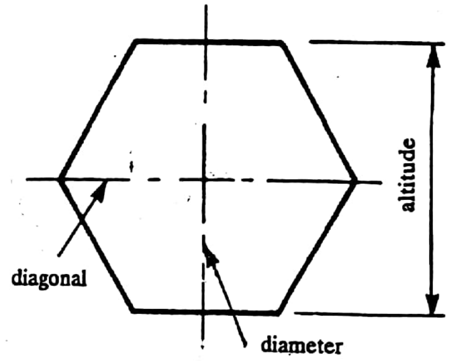

Fig 26a Regular polygon

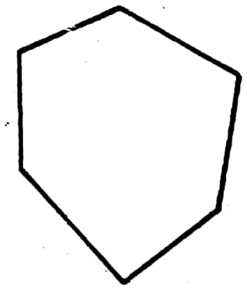

Fig 26b Irregular polygon

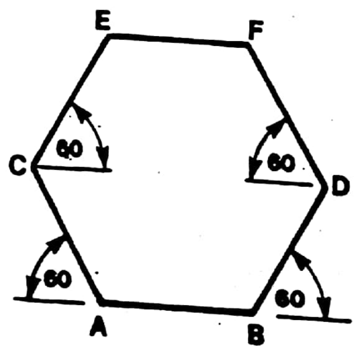

Fig 26c

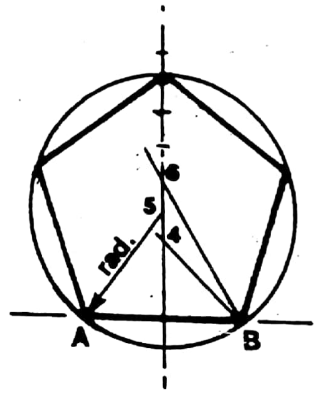

Fig 26d

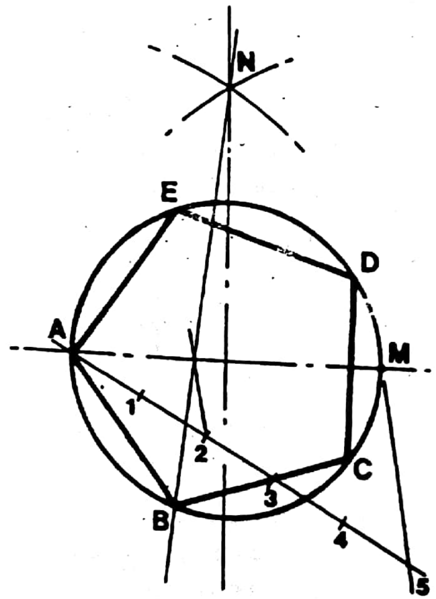

Fig 26e

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