ENGINEERING GRAPHICS

(Engineering Drawing is the language of Engineers)

UNIT 1

Conic Section (Ellipse, Parabola & Hyperbola) - Cycloids, epicycloids, hypocycloids & Involutes around circle and square – scales – diagonal – vernier scale – Free hand sketching

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Definition: Engineering graphical language for effective communication among engineers which elaborates the details of any component, structure or circuit at its initial drawing through drawing.

The following are the various drafting tools used in engineering graphics.

- Drawing Board
- Mini drafter or T- square
- Drawing Instrument box
- Drawing Pencils
- Eraser
- Templates
- Set squares
- Protractor
- Scale Set
- French curves
- Drawing clips
- Duster piece of cloth (or) brush
- Sand-paper (or) Emery sheet block
- Drawing sheet

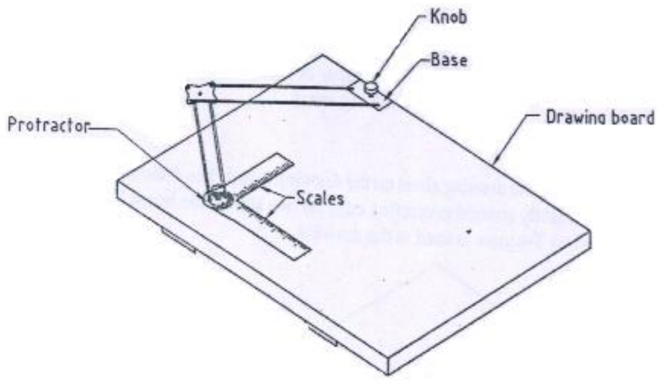
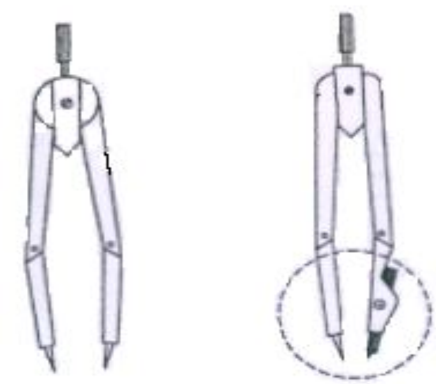


Figure Minidrafter fixed on drawing board

Drawing board and mini drafter

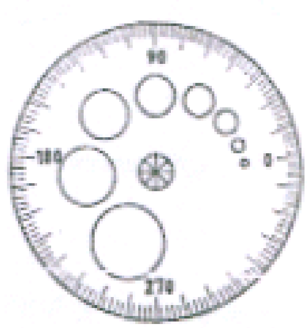
Above figure shows drawing board and mini drafter. A mini drafter is a drafting instrument which is a combination of scale, protractor and set square. It is used for drawing parallel, perpendicular and angular at any place in the drawing sheet.

Divider and compass



(i) Large size divider (ii) Large size compass

Pro-circle



Protractor with procircles

Set squares

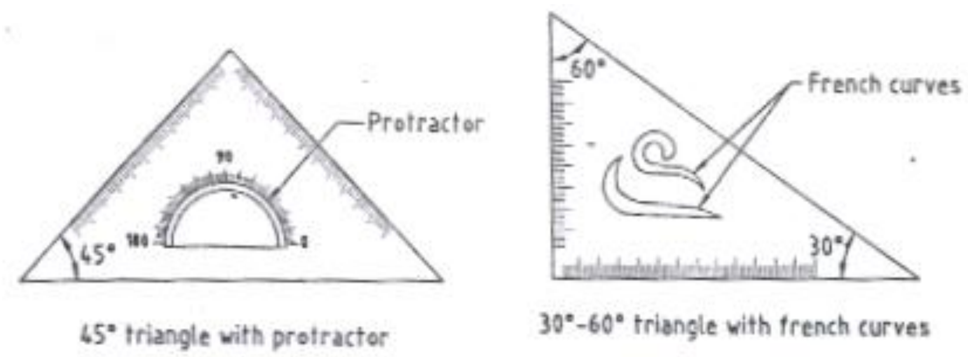


Figure Set squares

Sizes of drawing sheet

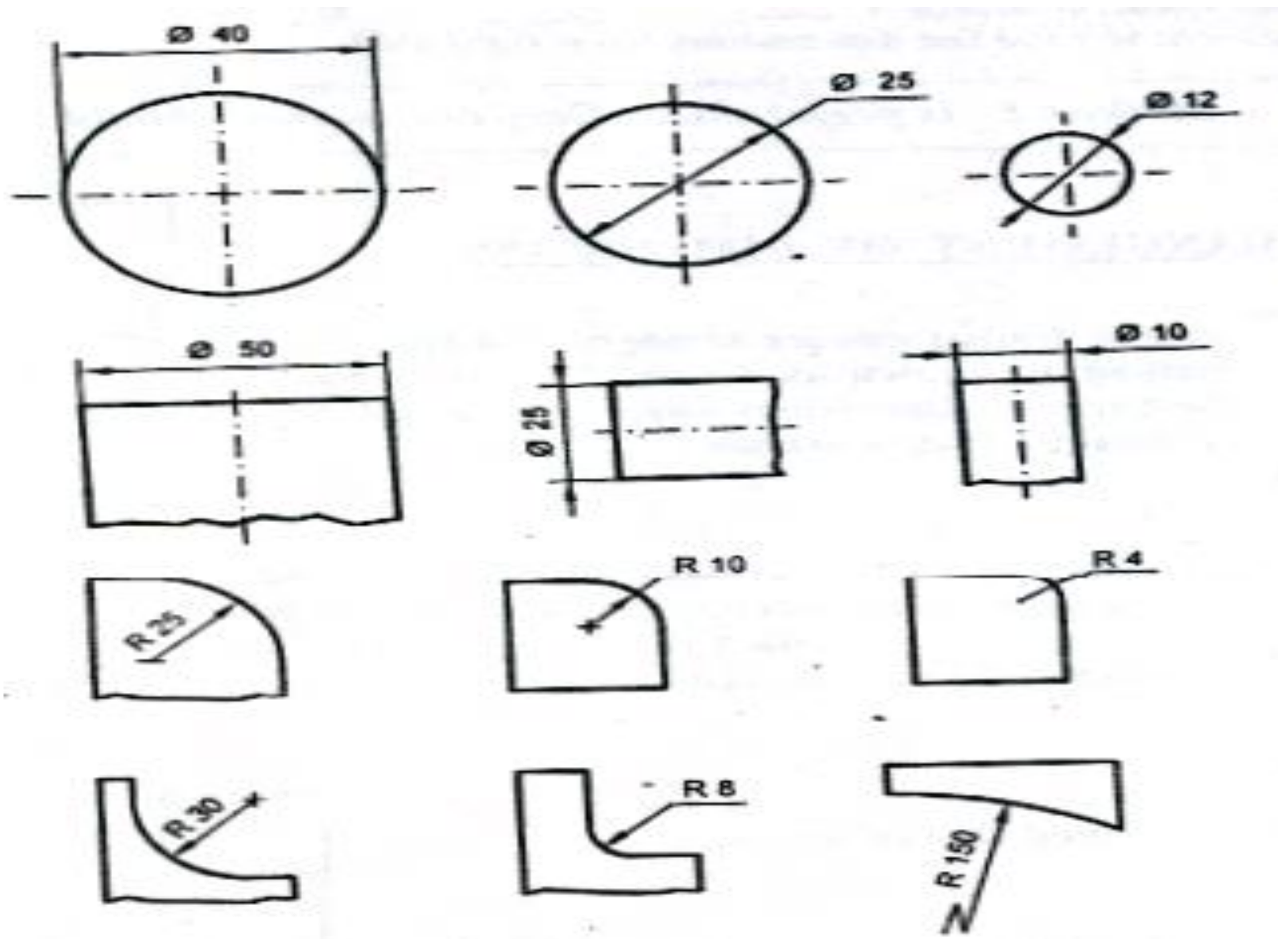
The table shows the designation of drawing sheet and its size in millimeter.

Designation	Dimension, mm Trimmed size
A0	841 x 1189
A1	594 x 841
A2	420 x 594
A3	297 x 420
A4	210 x 297

Method of dimensioning for circle, arc, semicircle:

Φ – diameter

R - radius



CONIC SECTIONS

The figure 1 shows the terminologies used in engineering graphics for a cone. Generators are the lines which are assumed that they are present on the surface of cone. These lines are called as "*generators*", because it is generated by the user.

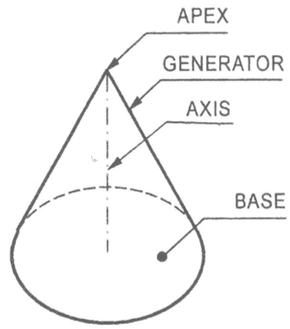
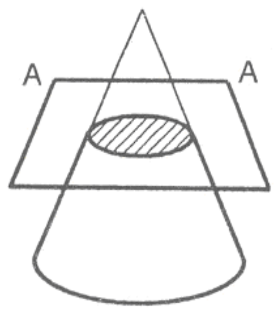
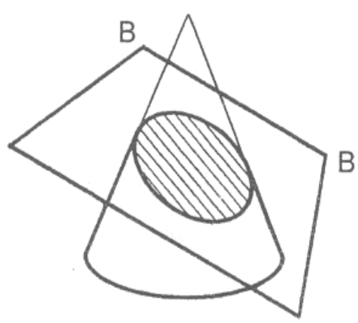


Figure 1

1. When the cutting plane cuts the cone parallel to its base then the shape obtained will be a **circle.**

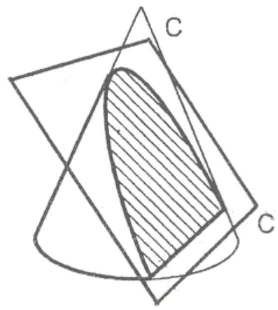


2. When the cutting plane BB is inclined to the axis of the cone and cuts all the generators on one side of the apex, the section obtained is an **Ellipse**



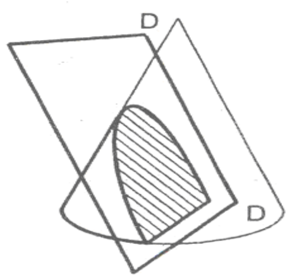
ELLIPSE

3. When the cutting plane CC is inclined to the axis of the cone and parallel to one of the generators, the section obtained is a **Parabola**



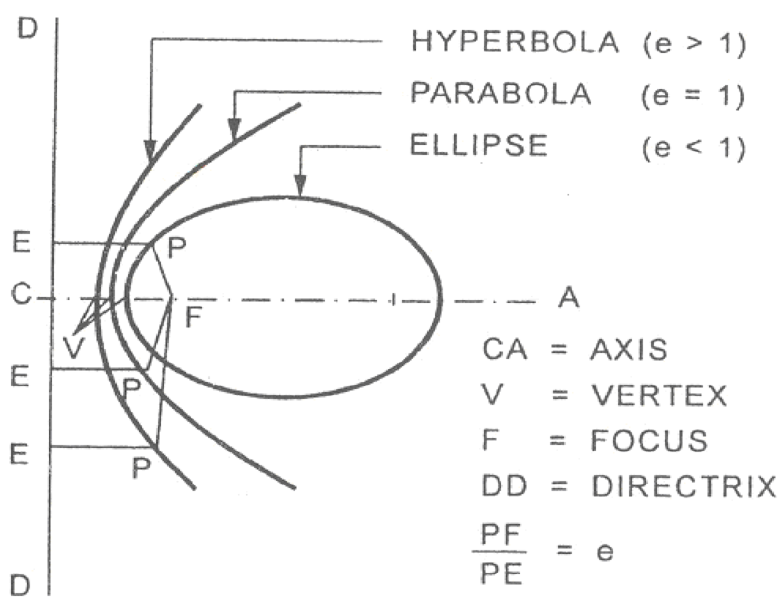
PARABOLA

4. When the cutting plane DD makes a smaller angle with the axis than that of the angle made by the generator of the cone, the section obtained is a **Hyperbola.**



HYPERBOLA

<u>Construction of conic curves by eccentricity method</u>



Eccentricity is defined as the ratio between distance of vertex from focus and distance of vertex from the directrix.

$$Eccentricity = \frac{Distance\ of\ moving\ point\ from\ focus}{Distance\ of\ moving\ point\ from\ directrix}$$

<u>Important Hints</u>

If e < 1, curve obtained is Ellipse

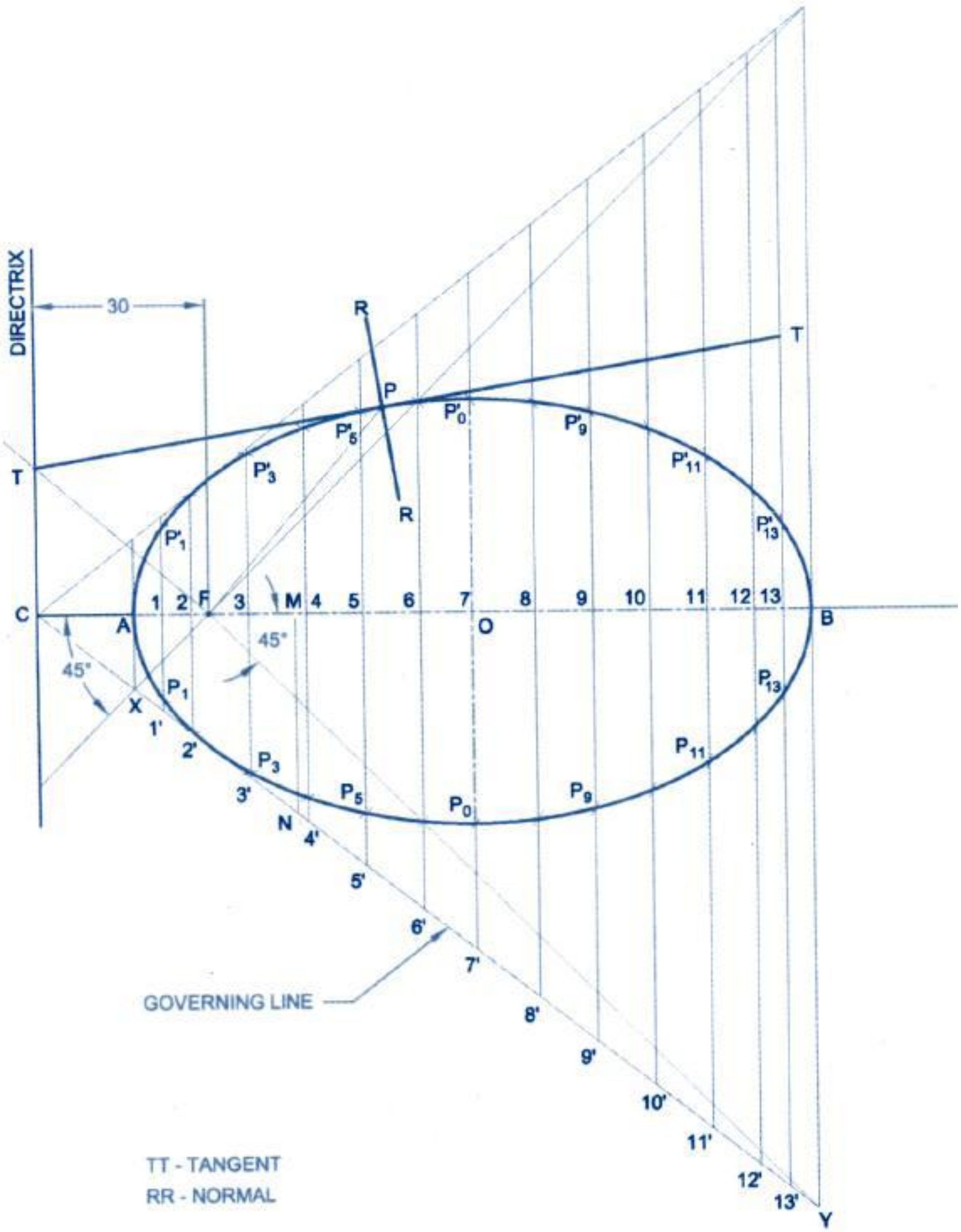
If e = 1, curve obtained is Parabola

If e > 1, curve obtained is Hyperbola

<u>**SOLVED EXAMPLES**</u>

CONIC SECTIONS

1. The focus of a conic is 30 mm from directrix. Draw the locus of a point P moving in such a way that eccentricity is 2/3. Also draw a tangent and normal at any point on the curve.



<u>Procedure to find number of divisions and size of each division</u>

Given,

$$\text{Eccentricity} = \frac{2}{3}$$

$$\text{Number of division} = \text{Numerator value} + \text{Denominator Value}$$

$$= 2 + 3$$

$$= 5 \text{ divisions}$$

$$\text{Size of each divison} = \frac{30}{5} = 6 \text{ mm}$$

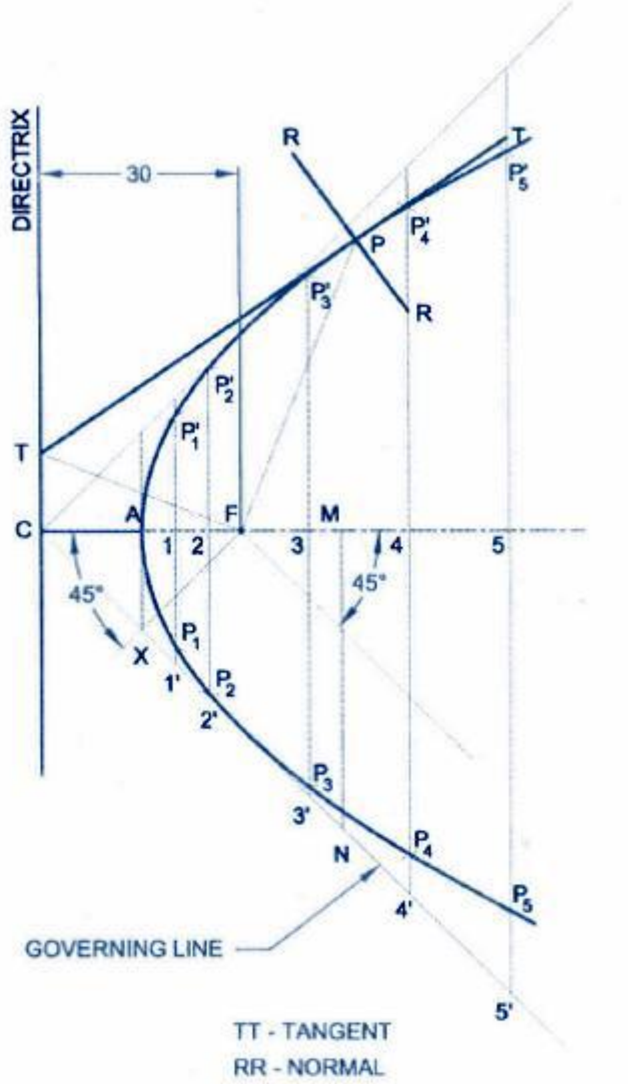
<u>Procedure :</u>

1. Draw the directrix.
2. Draw a horizontal (axis) line perpendicular from a point C on directrix.
3. Mark a point F (Focus) at a distance on the horizontal line at a distance of 30 mm from directrix.
4. Mark a point A (Vertex) by leaving two divisions from focus (each of size 6 mm) and the name the divisions as 1 and 2. Mark the remaining three divisions from A.
5. Draw a vertical line from A, so that AX is equal to FA.
6. Draw a line joining C and X and extend it in the same angle and direction.
7. After focus mark the points 3,4,5 etc. so that each division is of 6 mm.
8. Draw vertical lines crossing the points 1,2,3,4,5 etc.
9. Mark the points 1', 2', 3' etc., on the inclined line.
10. With 1-1' as radius F as centre draw the arcs above below the horizontal line on the line 1-1' and name the points as P_1' and P_1 respectively.
11. Follow the same procedure and mark the points P_2' and P_2 and so on.
12. Join all the points with a single stroke smooth curve to get an ellipse.

Procedure to draw tangent and normal

1. Mark a point P on the ellipse.
2. Join P and F.
3. Draw a perpendicular to the line PF till the line meets the directrix at the point T
4. Join the points T and P for getting a tangent for the ellipse.
5. Keep the protractor parallel to the line TP and draw the perpendicular line from P for getting a normal.

2. The distance of focus for a conic curve from directrix is 30 mm. Draw the locus of a point P so that the distance moving point from directrix and focus is unity.



<u>Procedure to find number of divisions and size of each division</u>

$$\text{Eccentricity} = \frac{1}{1}$$

$$\text{Number of division} = \text{Numerator value} + \text{Denominator Value}$$

$$= 1 + 1$$

$$= 2 \text{ divisions}$$

$$\text{Size of each divison} = \frac{30}{2} = 15 \text{ mm}$$

Procedure :

1. Draw the directrix d-d'.
2. Draw a horizontal (axis) line perpendicular from a point C on directrix.
3. Mark a point F (Focus) at a distance on the horizontal line at a distance of 30 mm from directrix.
4. Mark a point A (Vertex) by leaving two divisions from focus (each of size 6 mm) and the name the divisions as 1 and 2. Mark the remaining three divisions from A.
5. Draw a vertical line from A, so that AX is equal to FA.
6. Draw a line joining C and X and extend it in the same angle and direction.
7. After focus mark the points 3,4,5 etc. so that each division is of 6 mm.
8. Draw vertical lines crossing the points 1,2,3,4,5 etc.
9. Mark the points 1', 2', 3' etc., on the inclined line.
10. With 1-1' as radius F as centre draw the arcs above below the horizontal line on the line 1-1' and name the points as P_1' and P_1 respectively.
11. Follow the same procedure and mark the points P_2' and P_2 and so on.
12. Join all the points with a single stroke smooth curve to get a parabola.

Procedure to draw tangent and normal

1. Mark a point P on the ellipse.
2. Join P and F.
3. Draw a perpendicular to the line PF till the line meets the directrix at the point T
4. Join the points T and P for getting a tangent for the ellipse.
5. Keep the protractor parallel to the line TP and draw the perpendicular line from P for getting a normal.

3. Draw a hyperbola whose distance of focus from directrix is 60 mm. The eccentricity is 3/2. Also draw a tangent and normal at any point P on the curve.

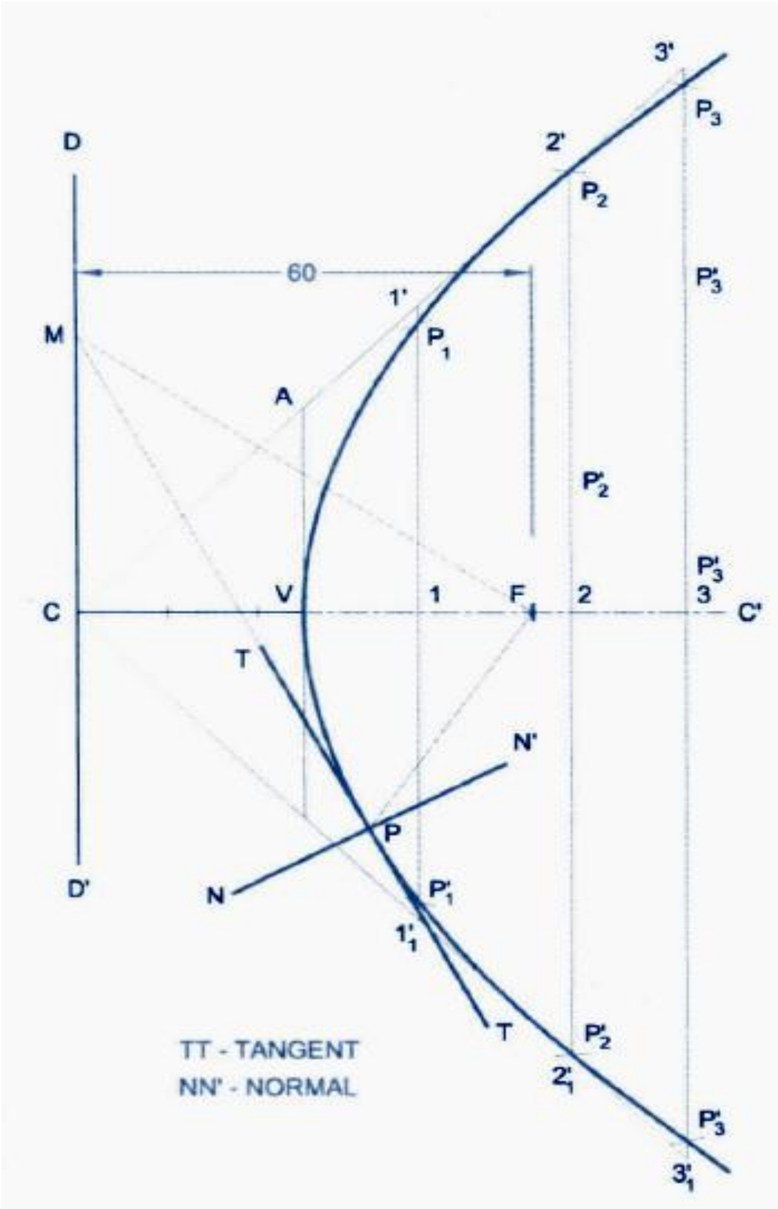
$$\text{Eccentricity} = \frac{3}{2}$$

$$\text{Number of division} = \text{Numerator value} + \text{Denominator Value}$$

$$= 3 + 2$$

$$= 5 \text{ divisions}$$

$$\text{Size of each divison} = \frac{30}{5} = 6 \text{ mm}$$



Procedure:

1. Draw the directrix d-d'.
2. Draw a horizontal (axis) line perpendicular from a point C on directrix.
3. Mark a point F (Focus) at a distance on the horizontal line at a distance of 30 mm from directrix.
4. Mark a point V (Vertex) by leaving two divisions from focus (each of size 6 mm) and the name the divisions as 1 and 2. Mark the remaining three divisions fromV.
5. Draw a vertical line from V, so that VA is equal to FV.
6. Draw a line joining C and A and extend it in the same angle and direction.
7. After focus mark the points 3,4,5 etc. so that each division is of 6 mm.
8. Draw vertical lines crossing the points 1,2,3,4,5 etc.

9. Mark the points 1', 2', 3' etc., on the inclined line.
10. With 1-1' as radius F as centre draw the arcs above below the horizontal line on the line 1-1' and name the points as P_1' and P_1 respectively.
11. Follow the same procedure and mark the points P_2' and P_2 and so on.
12. Join all the points with a single stroke smooth curve to get a hyperbola.

Procedure to draw tangent and normal

1. Mark a point P on the hyperbola.
2. Join P and F.
3. Draw a perpendicular to the line PF till the line meets the directrix at the point T
4. Join the points T and P for getting a tangent for the ellipse.
5. Keep the protractor parallel to the line TP and draw the perpendicular line from P for getting a normal.

PROBLEMS FOR PRACTICE

1. A fixed point F is 7.5 cm from a fixed straight line. Draw the locus of a point P moving in such a way that its distance from the fixed straight line is 2/3 times the distance from focus. Name the curve. Draw the tangent and normal at any point on the curve.

2. Draw the path traced by a point P moving in such a way that the distance of the focus from directrix is 40 mm. The eccentricity is unity.

3. A point moves such that its distance from a fixed straight line to its distance from a fixed point is equal. Draw the locus of the curve traced by that point. Add a normal and tangent to the curve at 40mm above the axis

4. Draw an ellipse when the distance of focus from the directrix is equal to 35 mm and eccentricity is 3/4. Draw a tangent and normal at a point P located at 30mm above the major axis.

5. Draw an ellipse whose focus distance from is 70 mm and e is 0.5. Draw the tangent and normal 40 mm above the axis.

6. Draw hyperbola whose distance of focus is 55 mm and e = 1.5. Draw the tangent and normal 50 mm from the directrix.

CYCLOIDS

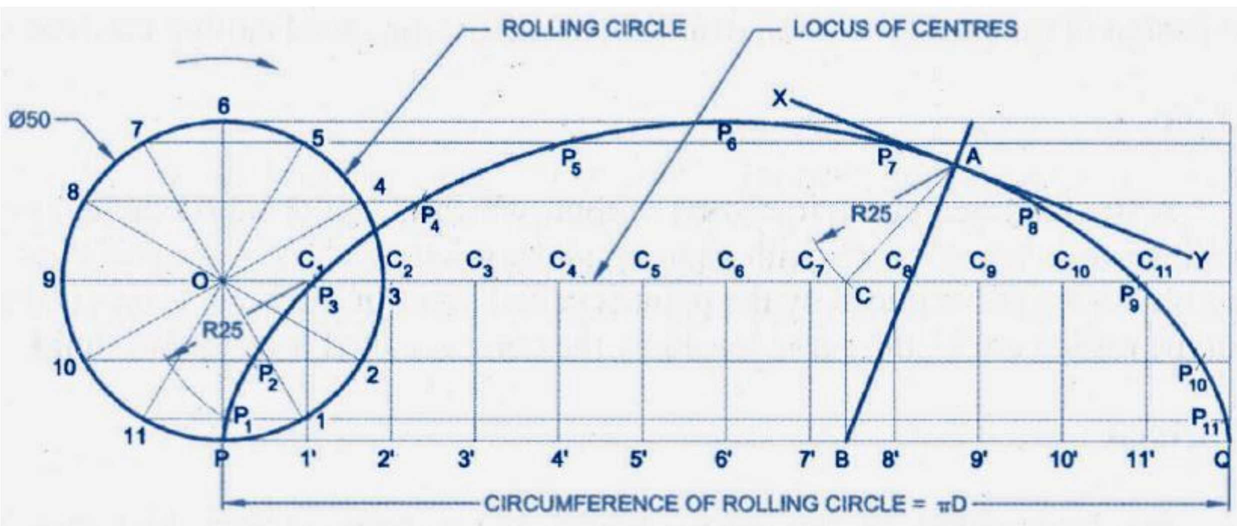
Cycloid : It is a curve traced by a point on the circumference of a circle which rolls along a straight line without slipping.

Epicycloid : It is a curve traced by a point on the circumference of a circle which rolls outside another circle**.**

Hypocycloid : It is a curve traced by a point on the circumference of a circle which rolls inside another circle.

SOLVED EXAMPLES

1. A circle of diameter 50 mm rolls on a straight line without slipping. Trace the locus of a point on the circumference of the circler rolling for one complete revolution. Name the curve, draw the tangent and normal at any point on the curve.



Procedure :

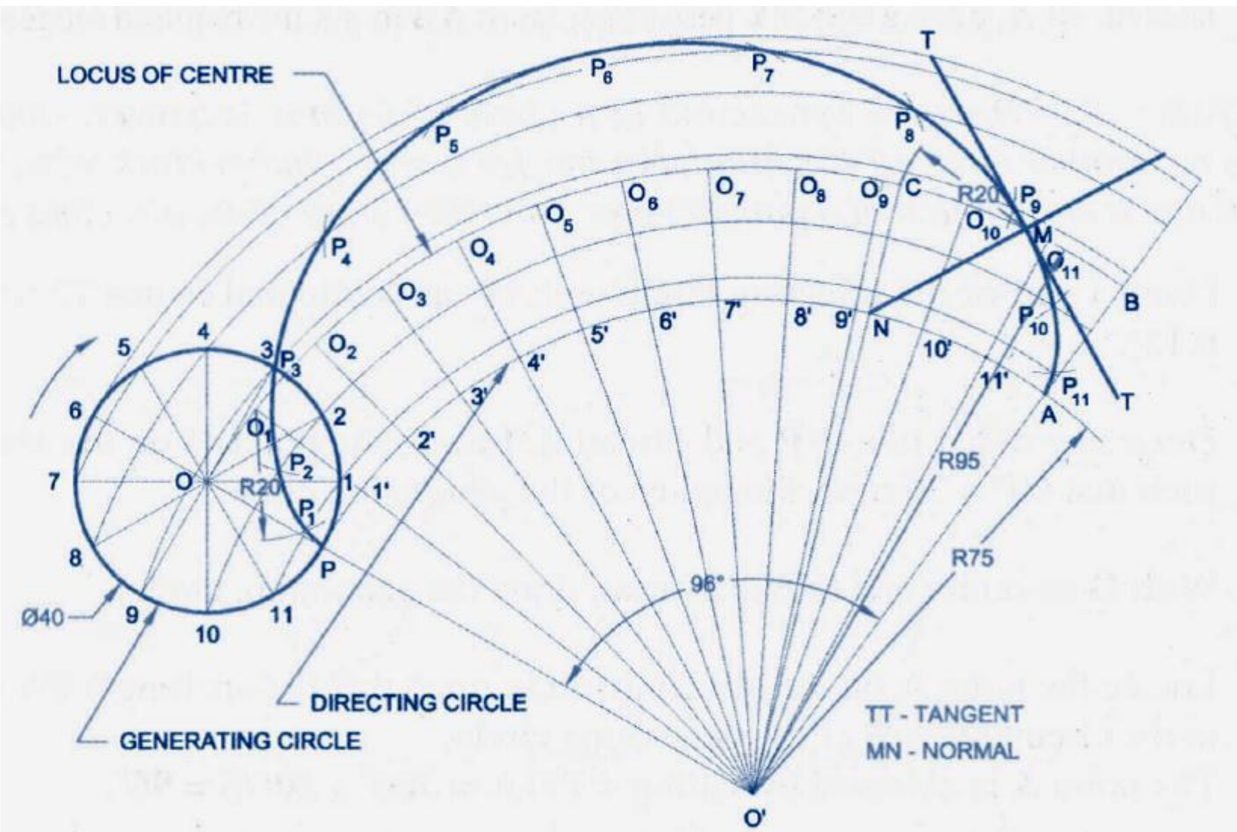
1. Draw a circle of diameter 50 mm.
2. Divide the circle into 12 equal parts, by taking an angle of 30^o each.
3. Name the divisions as 1,2,3 in anticlock wise direction from the division next to the bottom most one.
4. Name the bottom most division as P.
5. Draw a horizontal line as a tangent from P, for a length of L = πd, where d is diameter of circle.
6. Divide the horizontal line into 12 equal divisions and the name the points as 1', 2', 3', etc.
7. Draw lines passing through 11 and 1, 10 and 2, 8 and 3 and so on.
8. Draw vertical lines from 1', 2', 3', etc., so that they meet the horizontal line from 9.
9. Name the meeting points as C_1, C_2, C_3, etc.

10. With C_1 as centre 25 mm (radius of circle) as the radius, draw the arc on the horizontal line drawn from 1. Name the cutting point as P_1.
11. Follow the same procedure and get the points P_2, P_3,P_4, etc.
12. Join all the points with a single stroke smooth curve to get a cycloid.

Procedure to draw a tangent and normal to a cycloid

1. Mark a point A on the cycloid.
2. With A as centre, 25 mm as the radius draw an arc on the horizontal line drawn from 9.
3. Name the cutting point as C.
4. Draw a perpendicular line from C to the horizontal line drawn from P.
5. Name the cutting point as B.
6. Join B and A, which will be the normal to cycloid
7. Keep the protractor parallel to the line BA and draw a perpendicular line from P, which will be the tangent to cycloid.

2. Draw epicycloid of a circle of 40 mm diameter, which rolls outside on another circle of 150 mm diameter for one revolution clockwise. Draw a tangent and normal to it at a point 95 mm from the center of the directing circle.



To calculate θ:

$$\theta = \frac{r}{R} \times 360$$

where,

$r - radius\ of\ rolling\ circle$

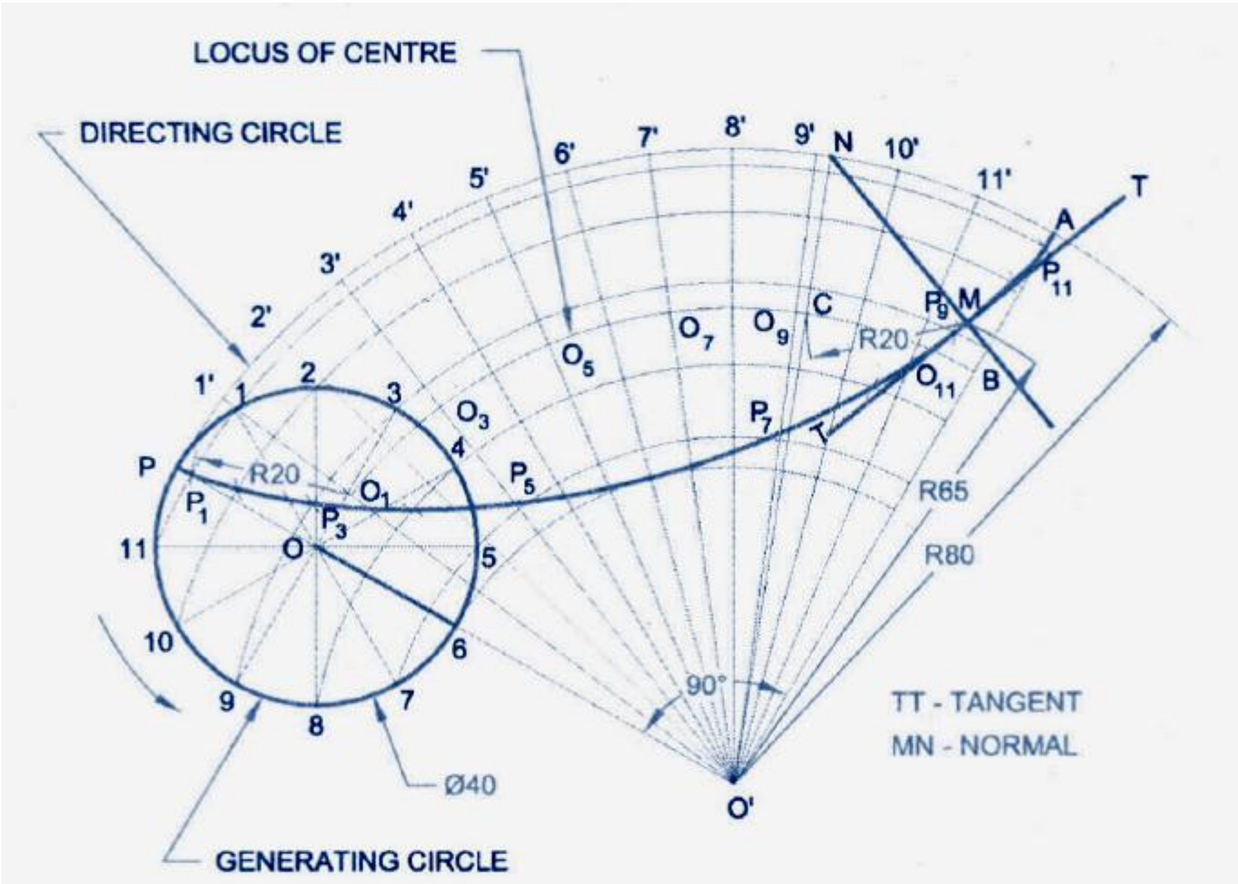
$R - radius\ of\ directing\ circle$

$$\theta = \frac{20}{75} \times 360$$
$$= 98°$$

Procedure :

1. Mark a point O'.
2. With O' as centre draw a sector ((O'PA) with radius of generating circle 75 mm for an angle of 98^o.
3. Extend the line from P for a distance of 20 mm (radius of rolling circle) and the mark the point O at the end.
4. With O as centre, draw the rolling circle of diameter 20 mm.
5. Divide the circle into 12 equal parts and name the points as 1,2,3..etc., in the anticlockwise direction from the point next to the bottom most one.
6. With O' as centre, draw the arcs passing through the points 11-1, 10-2, 9-3 etc.
7. Divide the sector in to 12 equal angles and draw the lines starting from O'.
8. Mark the cutting points of the lines on the arc starting from 3-9, as O_1, O_2 etc.
9. O_1 as centre, 20 mm as radius draw an arc on the curve drawn from 11. Name the cutting point as P_1.
10. Similarly mark the other points P_2,P_3,P_4,.. etc.
11. Join all the points by a smooth curve to get a hypocycloid.

3. Draw hypocycloid of a circle of 40 mm diameter, which rolls inside of another circle of 160 mm diameter for one revolution counter clockwise. Draw a tangent and normal to it at a point 65 mm from the center of the directing circle.



<u>**Calculation :**</u>

$$\theta = \frac{r}{R} \times 360$$

where,

$r - radius\ of\ rolling\ circle$

$R - radius\ of\ directing\ circle$

$$\theta = \frac{20}{80} \times 360$$

$$= 90^\circ$$

Procedure :

1. Mark a point O’.
2. With O’ as centre draw a sector (O’PA) with radius of generating circle 80 mm for an angle of 98^o.
3. Mark P on the line PO’ so that OP = radius of rolling circle.
4. With O as centre, draw the rolling circle of diameter 20 mm.
5. Divide the circle into 12 equal parts and name the points as 1,2,3..etc., in the clockwise direction from the point next to the top most one.
6. With O’ as centre, draw the arcs passing through the points 11-1, 10-2, 9-3 etc.
7. Divide the sector in to 12 equal angles and draw the lines starting from O’.
8. Mark the cutting points of the lines on the arc starting from 3-9, as O_1, O_2 etc.
9. O_1 as centre, 20 mm as radius draw an arc on the curve drawn from 11. Name the cutting point as P_1.
10. Similarly mark the other points P_2,P_3,P_4,.. etc.
11. Join all the points by a smooth curve to get an epicycloid.

PROBLEMS FOR PRACTICE

1. Draw epicycloids of a circle of 40 mm diameter, which rolls outside on another circle of 150 mm diameter for one revolution clockwise. Draw a a tangent and normal to it at a point 95 mm from the center of the directing circle.

2. Draw hypocycloids of a circle of 40 mm diameter, which rolls inside of another circle of 160 mm diameter for one revolution counter clockwise. Draw a a tangent and normal to it at a point 65 mm from the center of the directing circle.

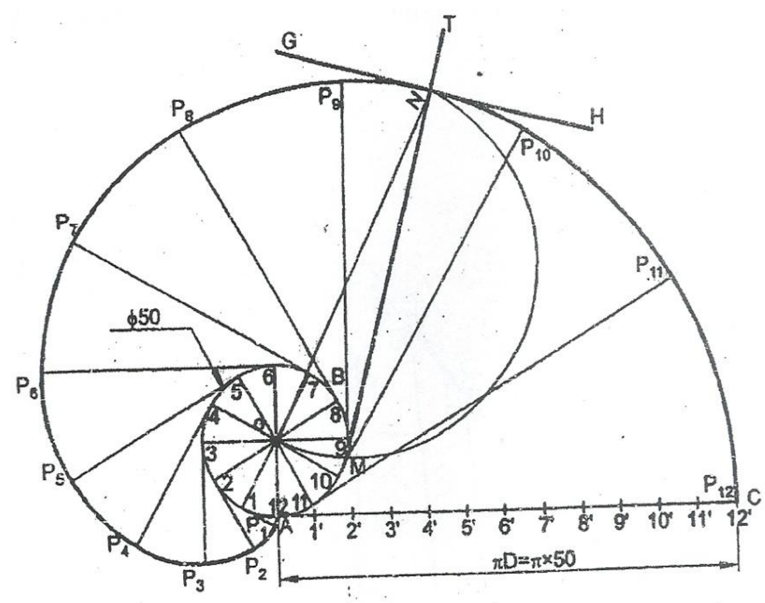
3. A roller of 40 mm diameter rolls over a horizontal table without slipping. A point on the circumference of the roller is in contact with the table surface in the beginning till one end of revolution. Draw the path traced by the point.

INVOLUTE

Definition : Involute is a path traced a point at the end of the string when it is wound or unwound from a cylindrical drum, cuboid or any tubular object.

SOLVED EXAMPLES

1. Draw an involute of a circle of 50mm diameter. Also, draw a tangent and normal at any point on the curve.



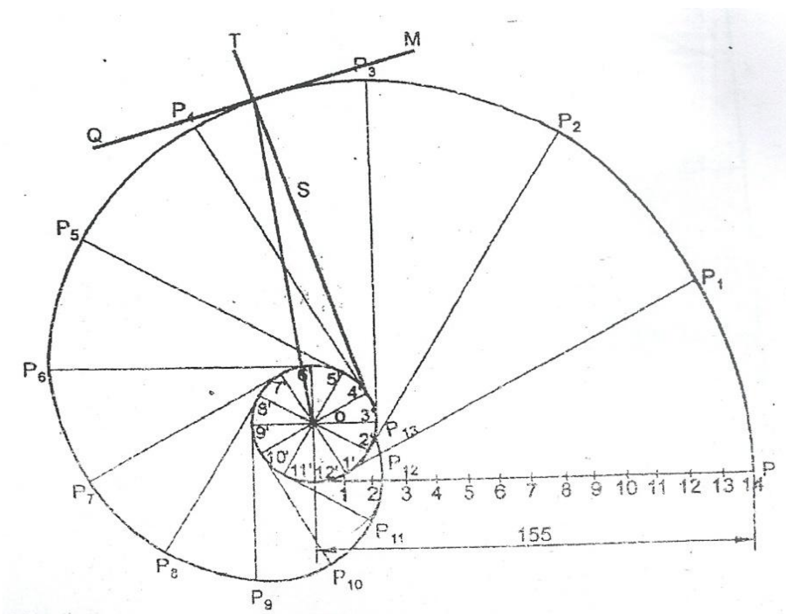
Procedure :

1. Draw a circle of diameter 50 mm.
2. Divide the circle into 12 equal parts and mark the names 1,2,3, etc., in clockwise direction starting from a point next to the bottom most one. Mark the centre point of the circle as O.
3. Draw a tangent AC from point 12 for a length of L = πd, (d – diameter of circle).
4. Divide AC into 12 equal points and the name points 1’,2’,3’..etc.,
5. Draw tangents from 1, 2, 3, etc., as shown in figure.
6. With 11-11’ as radius 11 as centre cut an arc on the tangent drawn from 11 and name the point as P_{11}.
7. Similarly obtain other points P_{10}, P_{11}, ..etc.,
8. Join all the points by a smooth curve to obtain an involute.

<u>Procedure to draw a tangent and normal to an involute :</u>

1. Mark a point N on the involute.
2. Join N and O. With the midpoint of ON as centre, half of ON as the radius, draw a semicircle on the opening side of the involute.
3. Mark the cutting point of the semicircle and circle as M.
4. Join M and N, which will be the normal.
5. Keep the protractor parallel to MN and draw a perpendicular from N, to draw the tangent.

2. An inelastic string 155 mm long has one stone end attached to the circumference of a circular disc of 40 mm diameter. Draw the curve traced out by the end of the string, when it is completely wound around the disc keeping it always tight (wound method)

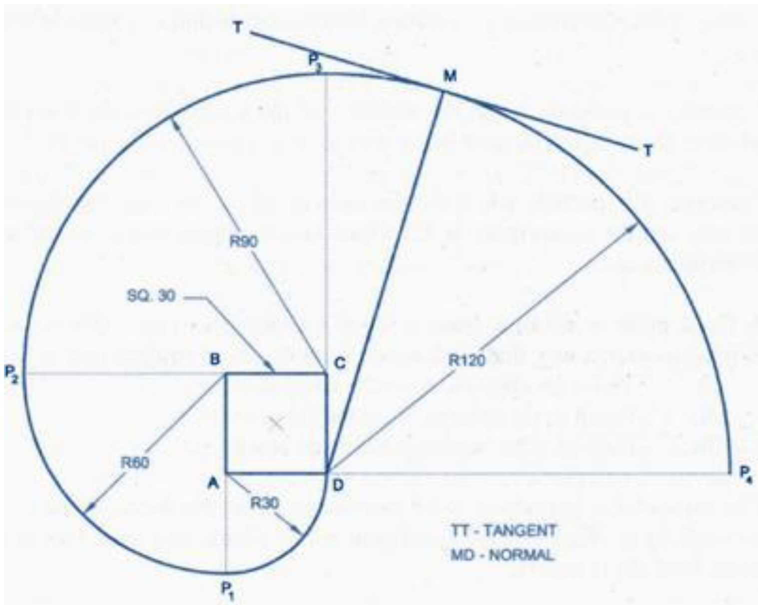


Hints :

- Draw a line 12-P tangent to 12. Divide the line 12 equal parts only for a distance of L= πd (d – diameter of circle).
- Mark the same divisions after that till p.
- Follow the same procedure with the starting radius of 12-14 with 1' as centre.
- The involute will be closed after 12', since the length of chord is more than circumference of the circle.

Tutorial: (Students are requested to refer the book and write the procedure for problem 3)

3. Draw the path traced by a point at the end of a string, when it is wound around a square of size 40 mm.



PROBLEMS FOR PRACTICE

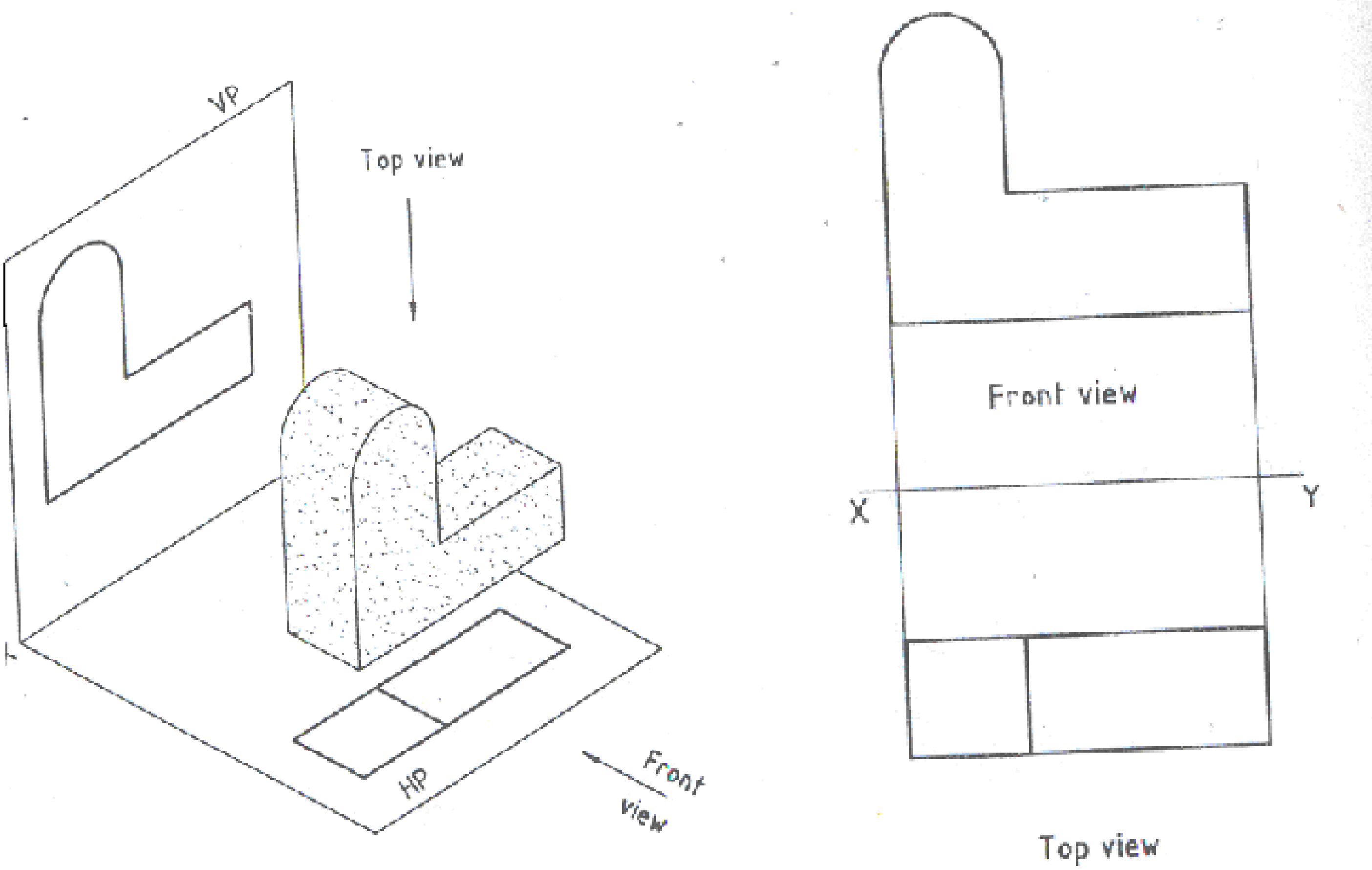
1. Draw the path traced by the end of a string when it is wound around a cylindrical drum of diameter 40 mm.

2. Draw an involute around a hexagon of side 25 mm.

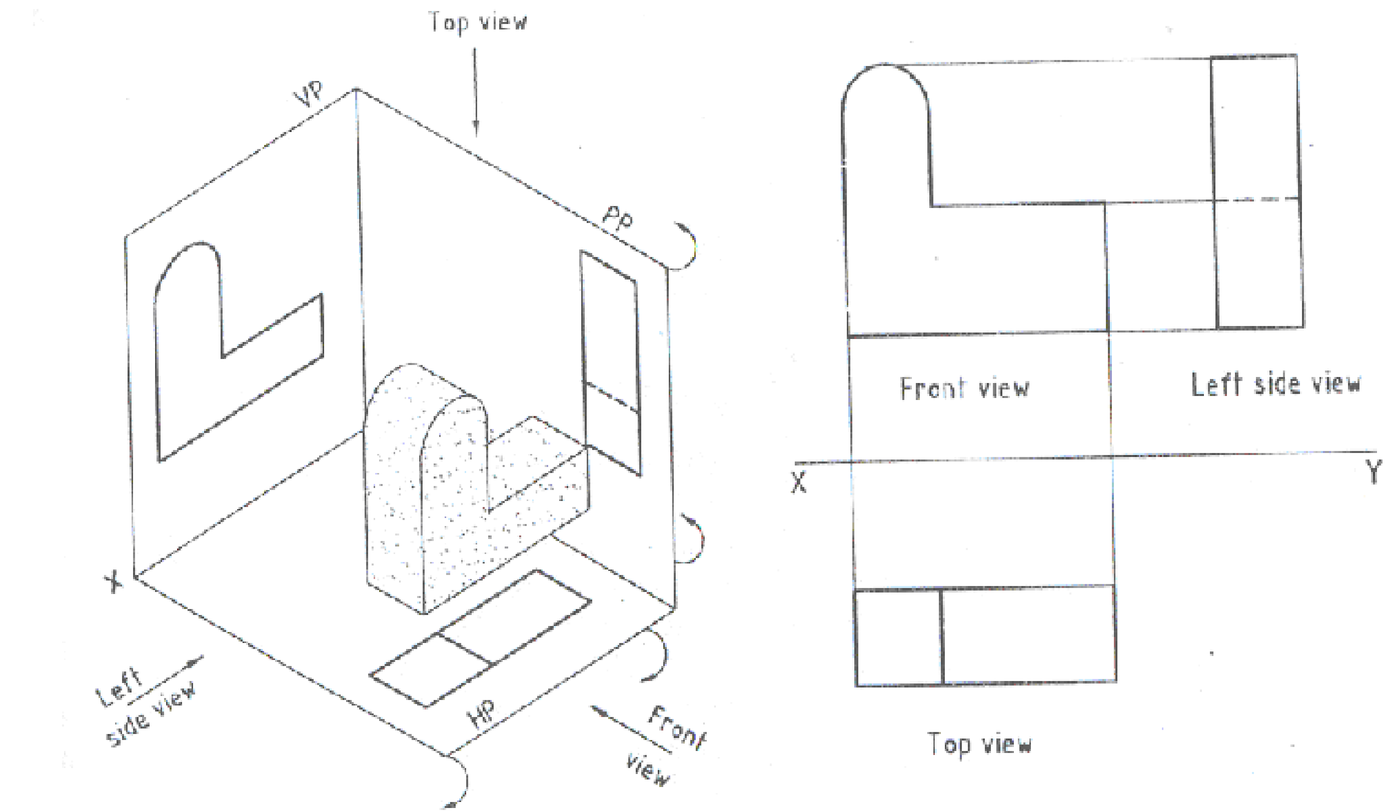
ORTHOGRAPHIC PROJECTION

- ORTHO means Right-angle.
- GRAPHIC means Drawing.
- ORTHO GRAPHIC means Right-angled Drawing.

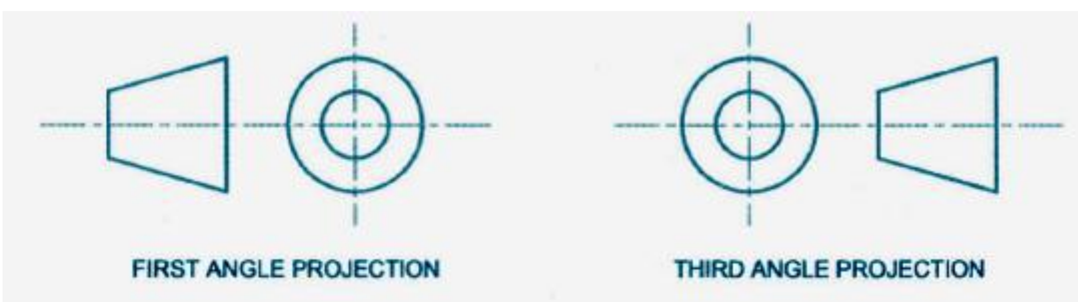
How to draw the front view (elevation) and top view (plan) in first angle projection?



Obtaining right side view on left of the object in first angle projection

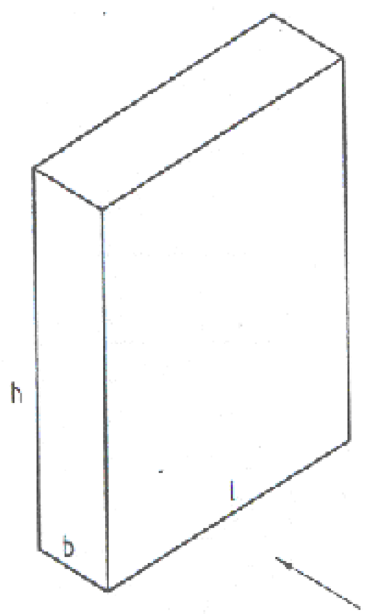


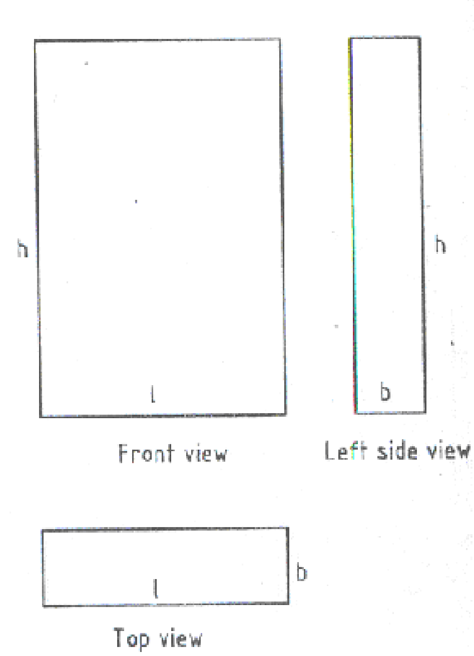
Symbol for I angle and III angle projection



Example 1 : Draw the elevation, plan and left side view of the rectangle shown in the figure.

Answer

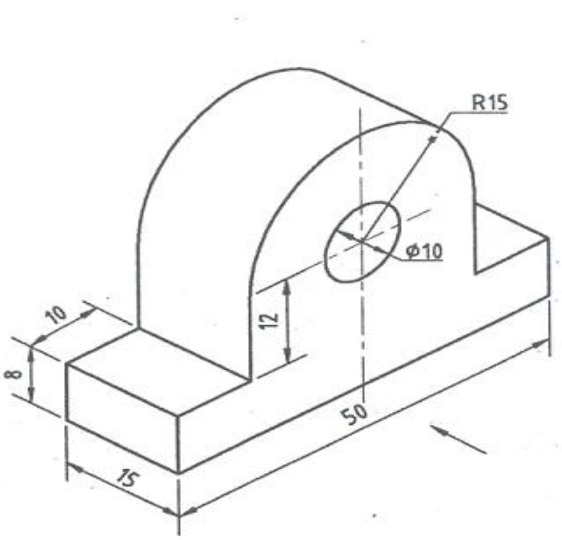


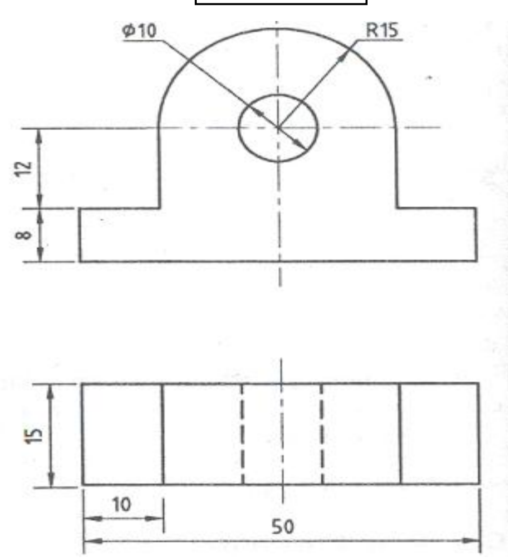


] d plan of the block given

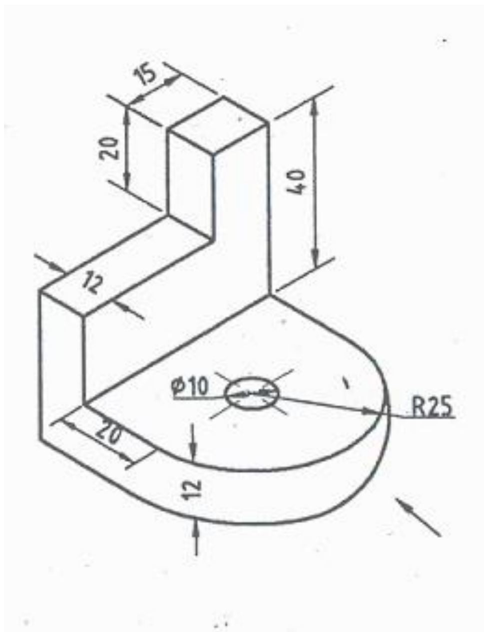
Example 2 : Draw the elevation and plan of the block shown below.

Answer

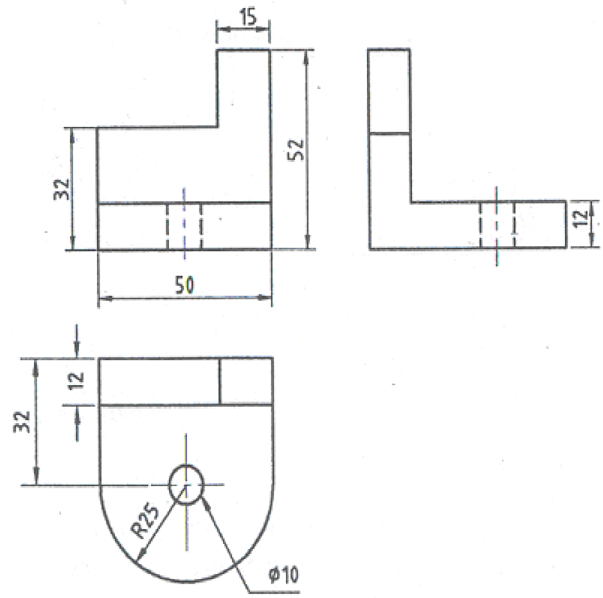




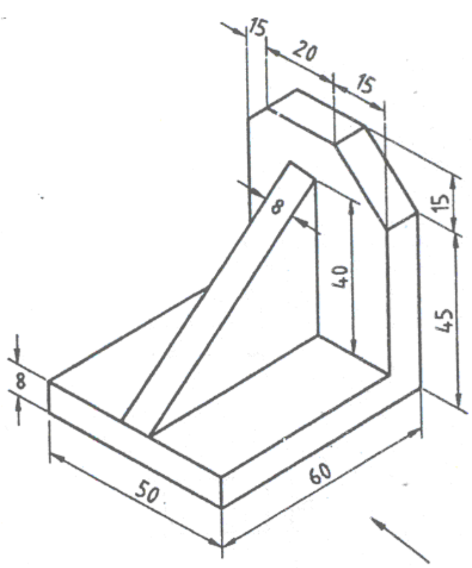
Example 3 : Draw the elevation, plan and left end view of the object shown below.



Answer

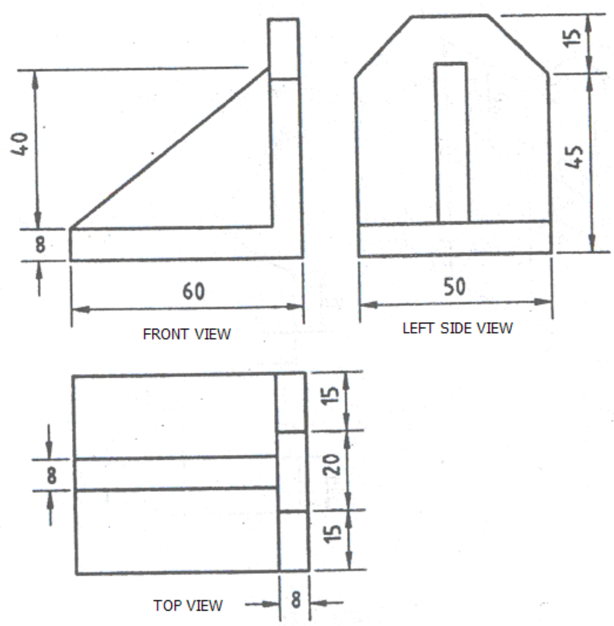


Example 4: Draw the front view, top view and left side view of the block shown below.

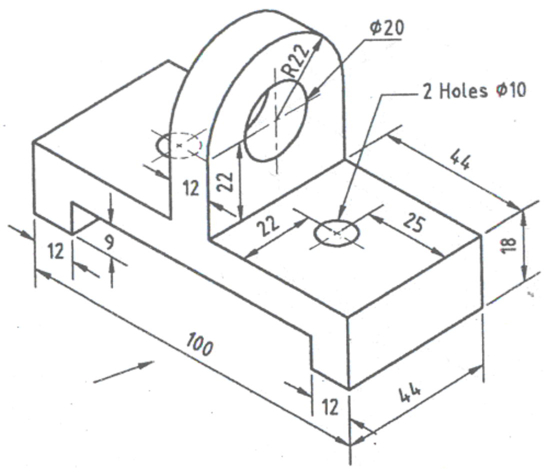


ISOMETRIC VIEW

Answer

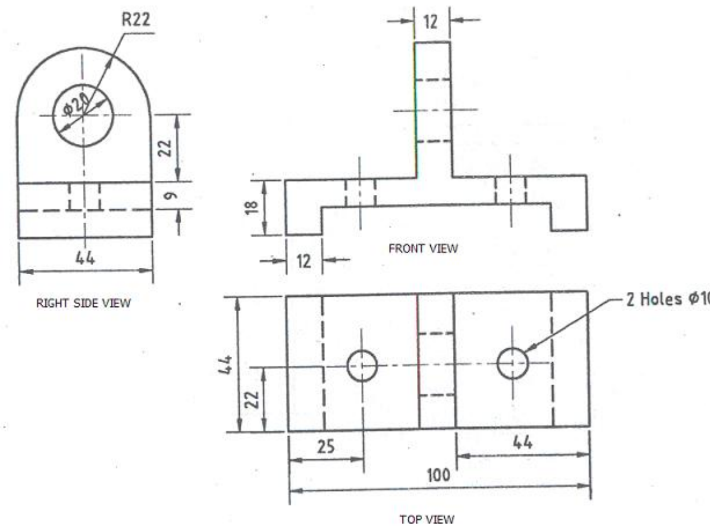


Example 5: Draw the front, top and right end view of the block shown below.



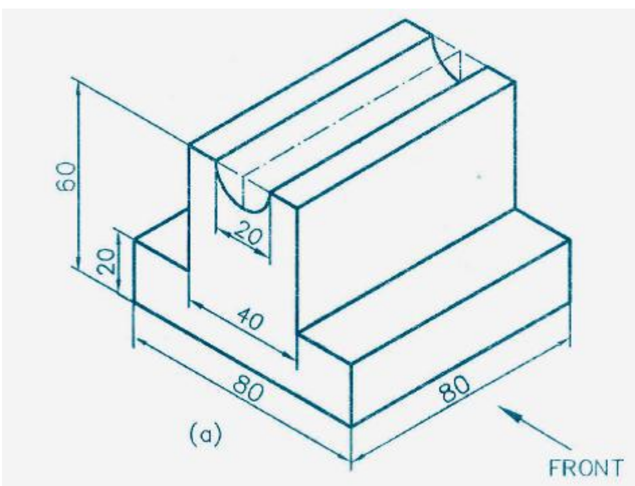
ISOMETRIC VIEW

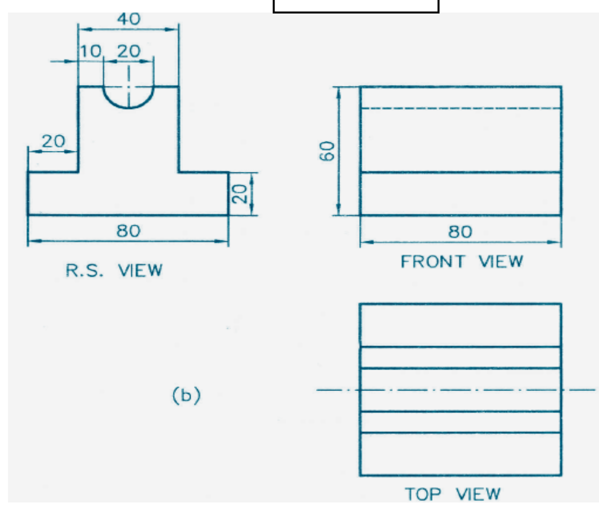
Answer



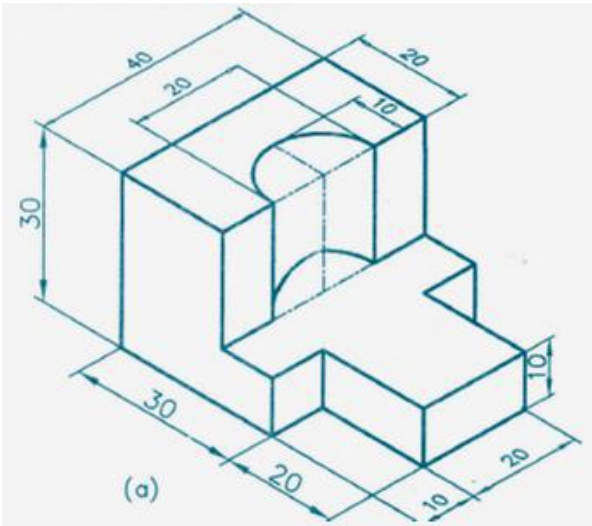
Example 6: Draw the elevation, plan and right side view of the object.

Answer

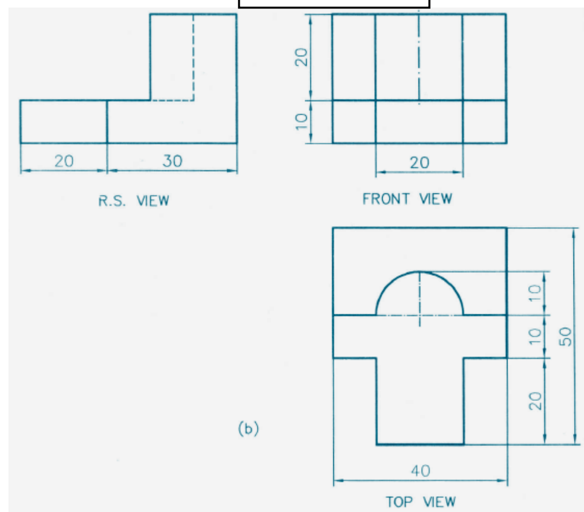




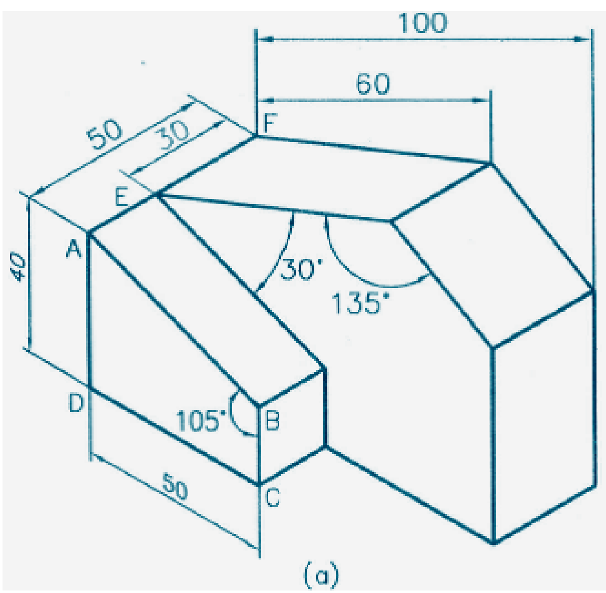
Example 7 : Draw the elevation, plan and right side view.



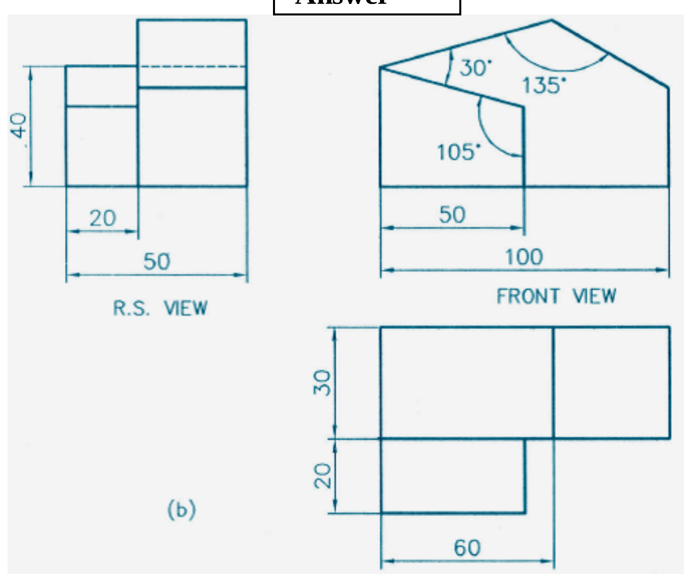
Answer



8. Draw the plan, elevation and left end view of the block shown below.

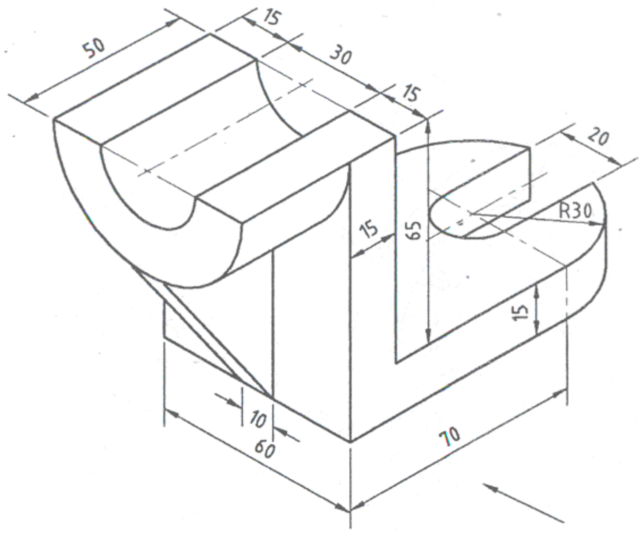


Answer



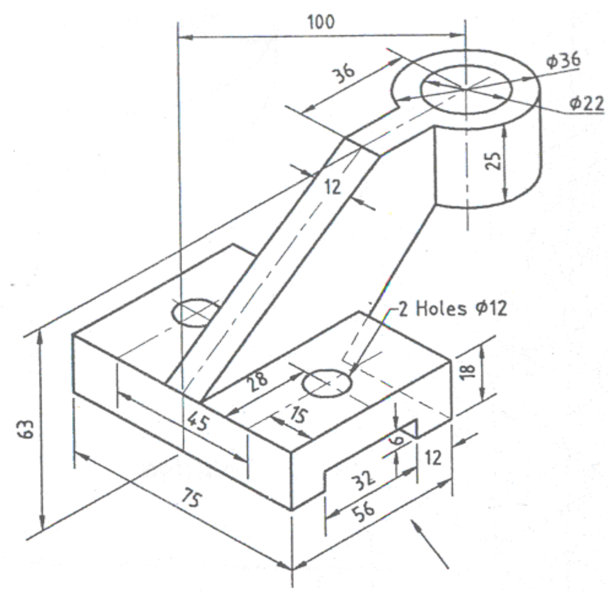
PROBLEMS FOR PRACTICE

1. Draw the elevation, plan and left end view of the block shown below.



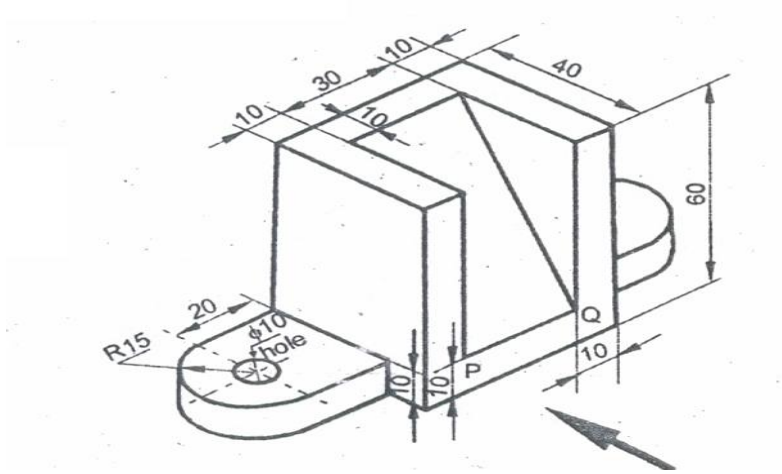
ISOMETRIC VIEW

2. Draw the elevation, plan and left side view of the object given below.

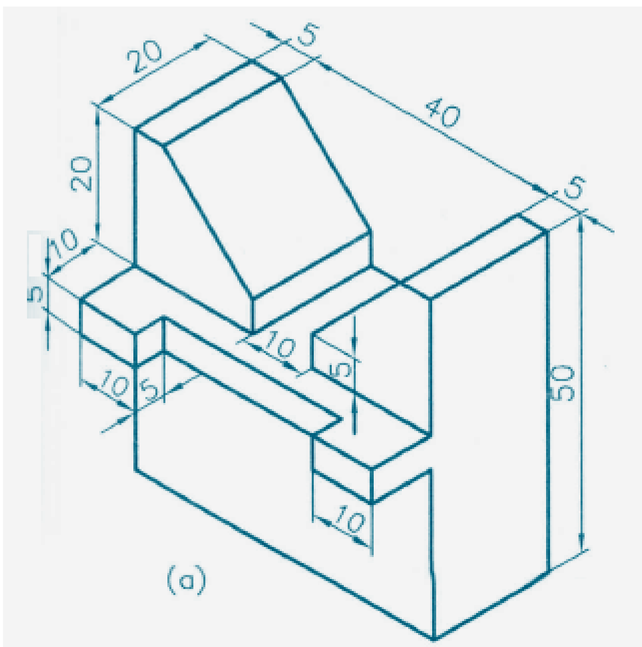


ISOMETRIC VIEW

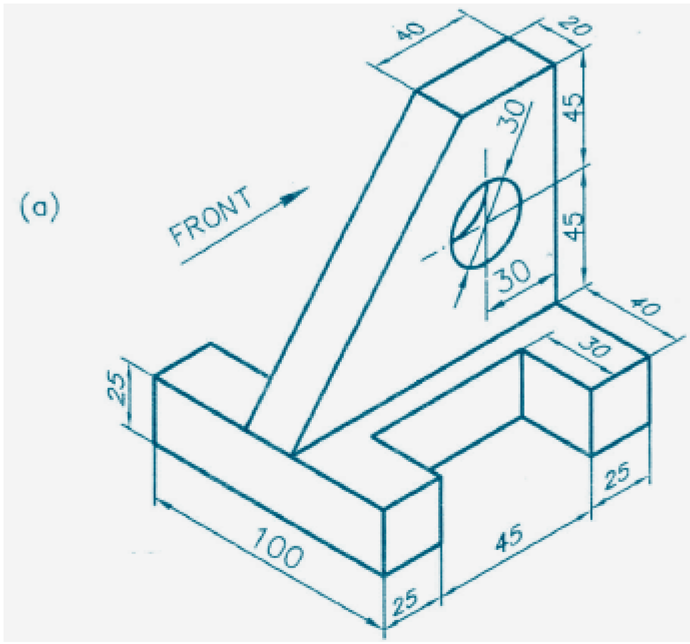
3. Draw the front, top and left side view of the block shown below.



4. Draw the plan, elevation and right end view of the object shown below.



5. Draw the front view, top view and right side view of the block shown below.



SCALES

Introduction

What is a scale?

It is not always possible or convenient to draw drawings of an object to its actual size. For instance, drawings of very big objects like buildings, machines etc., cannot be prepared in full size because they would be too big to accommodate on the drawing sheet.

Drawings of very small objects like precision instruments, namely, watches, electronic devices etc., also cannot be prepared in full size because they would be too small to draw and to read. Therefore a convenient scale is always chosen to prepare the drawings of big as well as small objects in proportional with smaller or larger sizes. So the scales are used to prepare a drawing at a full size, reduced size or enlarged size.

Definition :

Scale is defined as the ratio of the linear dimension of an element of an object as represented in the original drawing to the linear dimension of the same element of the object itself.

Full size scale

If we show the actual length of an object on a drawing, then the scale used is called full size scale.

Reducing scale

If we reduce the actual length of an object so as to accommodate that object on drawing, then scale used is called reducing scale. Such scales are used for the preparation of drawings of large machine parts, buildings, bridges, survey maps, architectural drawings etc.

Enlarging scale

Drawings of smaller machine parts, mechanical instruments, watches, etc. are made larger than their real size. These are said to be drawn in an increasing or enlarging scale.

Note: The scale of a drawing is always indicated on the drawing sheet at a suitable place either below the drawing or near the title thus “scale 1:2”. Representative Fraction (R.F)

The ratio of the drawing of an object to its actual size is called the representative fraction, usually referred to as R.F.

R.F = Drawing of an object/ Its actual size (in same units)

For reducing scale, the drawings will have R.F. values of less than unity.

For example, if 1 cm on drawing represents 1 m length of an object,

$$R.F = \frac{1cm}{(1 \times 100\,cm)}$$

$$R.F = \frac{1}{100} < 1$$

For drawings using increasing or enlarging scale, the R.F values will be greater than unity.

For example, when 1 mm length of an object is shown by a length of 1cm on the drawing, then

$$R.F = \frac{1 \times 10}{1mm} = \frac{10}{1} > 1$$

The engineering scales recommended by BIS (Bureau of Indian Standards) are as follows

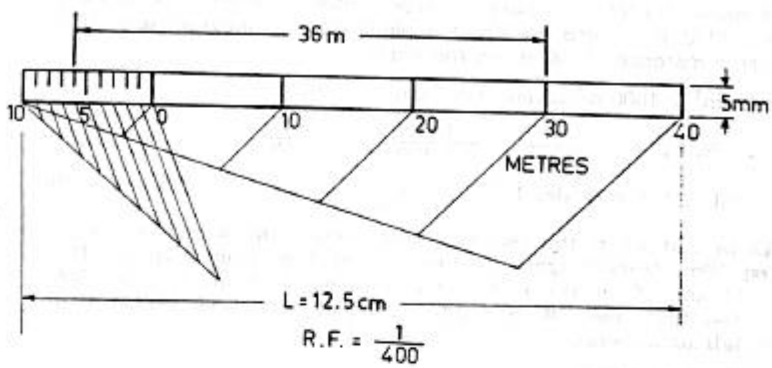
Types of Scales

1. Simple scales
2. Diagonal scales
3. Vernier scales

Plain Scale

A plain scale is simply a line, which is divided into a suitable number of equal parts, the first of which is further sub-divided into small parts. It is used to represent either two units or a unit and its fraction such as km, m and dm, etc.

Example 1: Construct a plain scale to show meters when 1cm represents 4 meters and long enough to measure up to 50 metres. Find the R.F. and mark on it a distance of 36 meters.



NOTE: Never rub-off the construction lines

PLAIN SCALE

Procedure:

$$1.\ R.F = \frac{\text{Drawing size}}{\text{Actual size (in same units)}} = \frac{1\text{cm}}{(4\times 100\text{ cm})} = \frac{1}{400}$$

2. Length of scale = R.F × Maximum length to be measured

Maximum length to be measured = 50 m.

$$\text{Therefore length of scale, } L = \left(\frac{1}{400}\right)\times 50\text{ m} = \left(\frac{1}{400}\right)\times 50\times 100\text{ cm} = 12.5\text{ cm}$$

3. Draw a horizontal line of length 12.5 (L).
4. Draw a rectangle of size 12.5×0.5 cm on the horizontal line drawn above
5. Total length to be measured is 50m.therefore divide the rectangle into 5(n) equal divisions, each division representing 10 m.

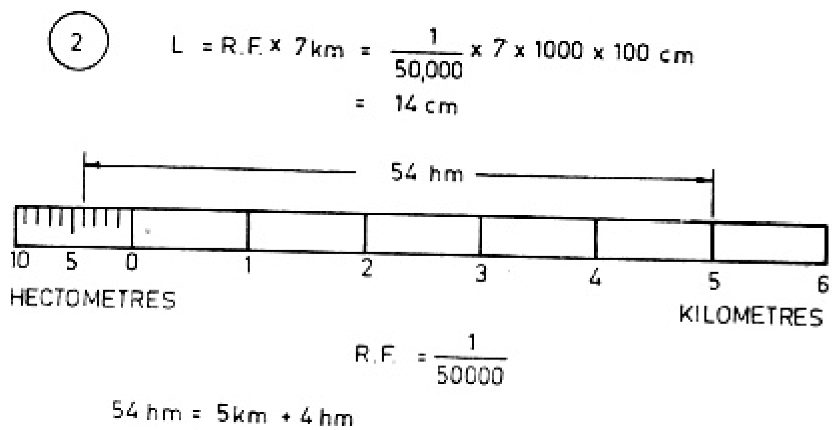
6. Mark 0 at the end of the first main division.
7. From 0, number 10, 20, 30 and 40 at the end of subsequent main divisions towards right as shown.
8. Then sub-divide the first main division into 10 subdivisions to represent metres (using geometrical construction).
9. Number the sub-divisions i.e. metres to the left of 0 as shown.
10.Write the names of main units and sub-units (METRES) below the scale. Also mention the R.F. as shown.
11. Indicate on the scale a distance of 36metres [=3main divisions to the right side of 0+6 subdivisions to the left of 0 (zero)]

Example 2 : Construct a plain scale of R.F. = 1:50,000 to show kilometers and hectometers and long enough to measure upto 7 kilometres. Measure a distance of 54 hectometers on your scale.

Procedure:

1. $\text{Length of scale} = \left(\frac{1}{50000}\right) \times 7\ \text{km} \times 7 \times 1000 \times 100\,\text{cm} = 14\,\text{cm}$

2. Draw a rectangle of size 14cmx0.5cm.divide the rectangle into 7 equal divisions, each representing 1km or 10 hm.
3. Mark 0 at the end of first main division and 1,2,3…6 at the end of subsequent main divisions towards right. Sub-divide the first division into 10 sub-divisions, each representing 1 hm. Number the sub-divisions to the left of 0 (zero).



Example 3 : A room of 1000 m^3 volume is represented by a block of 125 cm^3 volume. Find R.F. and construct a plain scale to measure upto 30 m. Measure a distance of 18 m on the scale.

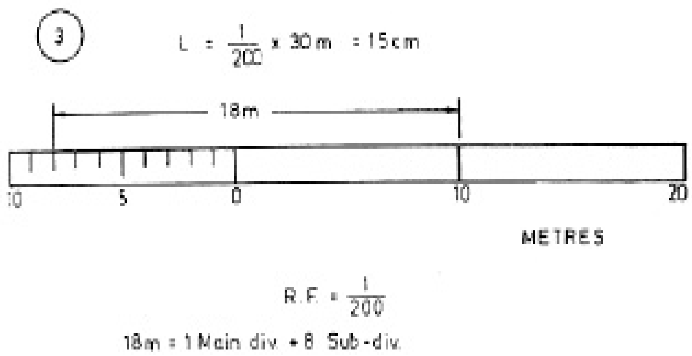
Procedure:

1. 125 cm^3 =1000 m^3 (*given*) i.e. 5 cm=10 m.

$$2.\text{Therefore R.F} = \frac{1\text{cm}}{(2\times 100\,\text{cm})} = \frac{1}{200}$$

$$3.\text{Length of the scale, } L = \frac{1}{200}\times 30\times 100 = 15\,\text{cm}$$

Note: While doing problems on volume /area, change the units of volume/area into the corresponding linear measures in order to find the length of the scale to construct the plain scale.



Diagonal Scales

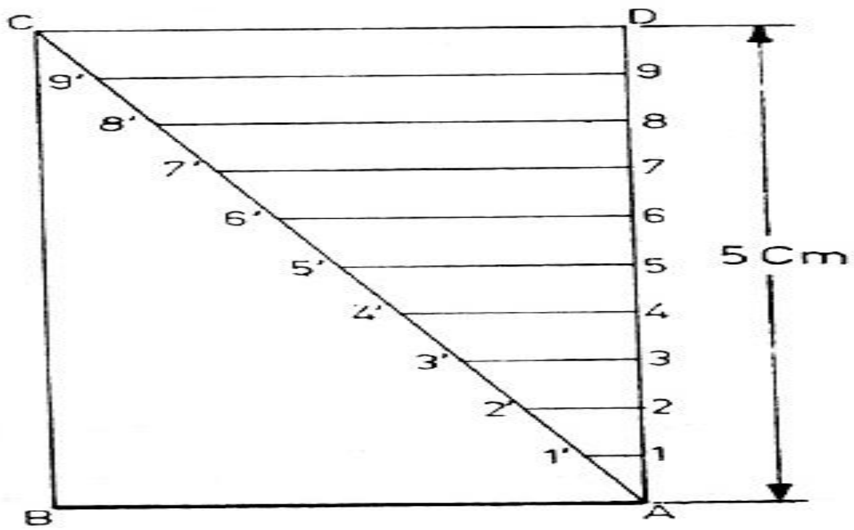
Plain scales are used to read lengths in two units such as metres and decimeters or to read the accuracy correct to first decimal. Diagonal scales are used to represent either three units of measurements such as metres, decimeters, centimeters or to read to the accuracy correct to two decimals.

Principle of Diagonal Scale

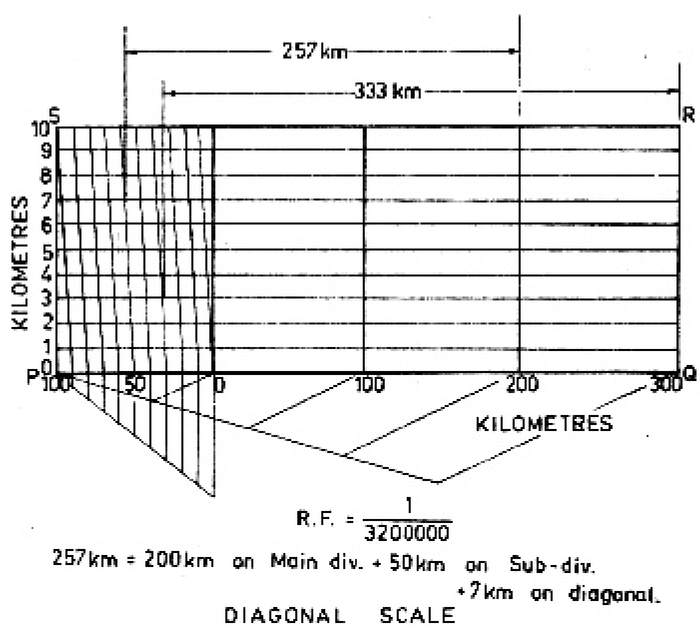
It consists of a line divided into required number of equal parts. The first part is sub-divided into smaller parts by diagonals.

1. Draw vertical lines at A and B. Divide AD into ten equal divisions of any convenient length (say 5cm) and complete the rectangle ABCD.
2. Join the diagonal AC.

3. Draw horizontal lines through the division points to meet AC at 1', 2', 3', 4', 5', & 6'.
4. Consider the similar triangles ADC and A88'. 88'/DC =A8/AD; but A8=8/10 AD. Therefore 88'/DC =8/10 i.e.. 88'=8/10 DC =0.8 DC=0.8 AB.
5. Thus the horizontal lengths 11',22', 33' etc. are equal to 0.1 AB, 0.2 AB, 0.3 AB etc. respectively, i.e. the horizontal line below CD becomes progressively shorter in length by 1/10 CD. This principle is used in constructing the diagonal scale



Example 4: Construct a diagonal scale of R.F.= 1:32,00,000 to show kilometers and long enough to measure upto 400 km. Show distances of 257 km on your scale.



Procedure :

1. R.F. =1:32,00,000 (Given).

2. $\text{Length of the scale} = \text{R.F} \times \text{Maximum distance to be measured} = \frac{1}{3200000} \times 400\,\text{km}$

$$= \frac{1}{3200000} \times 400 \times 1000 \times 100\,\text{cm} = 12.5\,\text{cm}$$

3. Draw a line PQ of 12.5 cm long.
4. Maximum length to be measured is 400 km. Minimum distance to be measured =1 km

(which is obtained from data $\frac{257}{333}$ km)

Therefore $\frac{\text{Maximum distance}}{\text{Minimum distance}} = 400.$ This can be obtained in 3 steps as $4 \times 10 \times 10$

5. Therefore by geometrical construction divide PQ into 4 main divisions, each main division representing 100 km. Mark 0 (zero) at the end of the first main division. Also mark 100, 200 and 300 towards the right of zero.

6. Using geometrical construction sub-divide the main division into 10 sub-divisions, each representing 10 km. To avoid crowding of numbers, mark only 50,100 towards the left of zero.

7. Draw a line PS of 5cm long perpendicular to PQ.

8. Complete the rectangle PQRS and draw vertical lines from each main division on PQ.

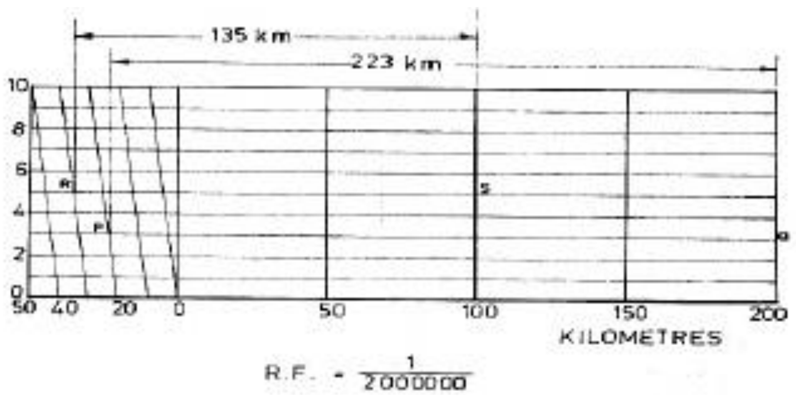
9. Divide PS into 10 equal divisions and name the divisions as 0,1,2,3…10 from P to S.

10. Draw horizontal lines from each division on PS.

11. Join S to the first sub-division from P on the main scale PQ.Thus the first diagonal line is drawn.

12. Similarly draw the remaining 9 diagonals parallel to the first diagonal. Thus each 10 km is divided into 10 equal parts by diagonals.

Example 5: The distance between Coimbatore and Madurai is 200 km and its equivalent distance on the map measures 10 cm. Draw a diagonal scale to indicate 223 km and 135 km.



Procedure:

1. $10\,\text{cm on the map represents } 200\,\text{km. So } R > F >= \frac{10\,\text{cm}}{200\,\text{km}}\, 2000000$

2. $\text{So, take the length of the scale as } 12.5\,\text{cm to represent the actual distance } \frac{12.5\,\text{cm} \times 200\,\text{km}}{10\,\text{cm}} = 250\,\text{km}$

3. $\text{Max} = 250\,\text{km}; \text{Min} = 1\,\text{km}; \frac{\text{Max}}{\text{Min}} = 250 = 5 \times 5 \times 10$

Vernier Scales

Like diagonal scales, vernier scales are used to read very small units with accuracy. They are used, when a diagonal scale is inconvenient to use due to lack of space. A vernier scale consists of two parts, i.e., Main scale and a vernier. The main scale is a Plain scale divided into minor divisions.

The vernier is also a scale used along with the main scale to read the third unit, which is the fraction of the second unit on the main scale.

Least count: Least count the smallest distance that can be measured accurately by the vernier scale and is the vernier scale and is the difference between a main scale division and a vernier scale division.

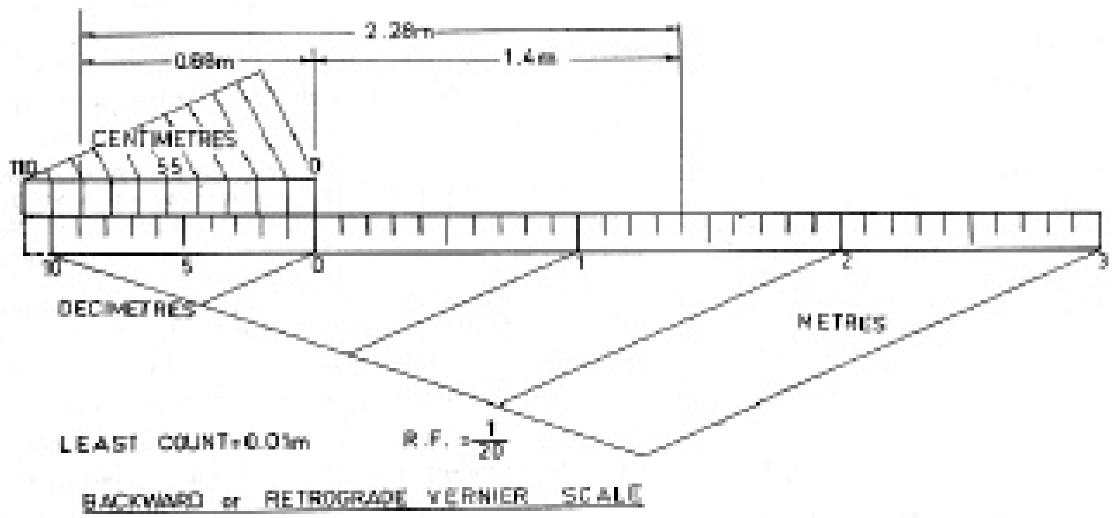
Types of Verniers:

1. Forward vernier or direct vernier
2. Backward vernier or retrograde vernier

Backward / Retrograde Vernier

In this type, the markings on the vernier are in a direction opposite to that of the main scale and (n+1) main scale divisions are divided into n vernier scale divisions.

Example 6: Construct a vernier scale to read meters, decimeters and centimeters and long enough to measure upto 4 m. R >F> of the scale is 1/20. Mark on your scale a distance of 2.28 m.



Procedure:

1. **Least count:** It is required to measure metres, decimeters and centimeters, i.e., the smallest measurement on the scale is cm. Therefore, L.C .= smallest distance to be measured = 1cm = 0.01m.

2. $\text{Length of the scale} = R > F > \text{maximum distance to be measured} = \left(\frac{1}{20}\right) \times 4\,\text{cm}$

3. $\text{Main scale: Draw a line of } 20\,\text{cm length. Complete the rectangle of } 20\,\text{cm} \times 0.5\,\text{cm}$
$\text{and divide this into 4 equal parts each representing 1 metre.}$

$\text{Sub} - \text{divide each part into 10 main scale divisions. 1 m.s.d} = \frac{1\text{m}}{10} = 1\text{dm}$

To construct the vernier to centimeter:

4. Take 1 division on the main scale and divide it into 10 equal parts on the vernier scale by geometrical construction. So 1 V.S.D $= \frac{11 M.S.D}{10} = 11 \times 1 dm$

5. Mark 0,55,1106 towards the left from 0on the vernier scale as shown.
6. Name the units of the main divisions, sub-divisions and vernier divisions on the figure as shown.
7. 2.28 m = (V.S.D x 8) + (M.S.D x14) = (0.11 m x 14) = 90.88 =1.4) m.

References

- *K.V, Natarajan, Engineering graphics, Dhanalakhshmi Publications, 2012.*
- *Venugopal, Engineering graphics, New age international, 2010.*