Program : **B.Tech**

Subject Name: **Engineering Graphics**

Subject Code: **BT-105**

Semester: **1st**

Engineering Graphics (BT 105)

Module – I

Scales: Introduction to Engineering Drawing covering, Principles of Engineering Graphics and their significance, usage of Drawing instruments, lettering, Conic sections including the Rectangular Hyperbola (General method only); Cycloid, Epicycloid, Hypocycloid and Involute; Scales – Plain, Diagonal and Vernier Scales

Projections of Points, Straight Lines and Planes: Various types of projection System, Projection of Points in different quadrants, projections of lines and planes for parallel, perpendicular & inclined to horizontal and vertical reference planes.

Types of Lines:

Just as in English textbook the correct words are used for making correct sentences; in Engineering Graphics, the details of various objects are drawn by different types of lines. Each line has a definite meaning and sense to convey.

IS 10714 (Pint 20): 2001 (General principles of presentation on technical drawings) and SP 46:2003 specify the following types of lines and their applications:

- **Visible Outlines, Visible Edges:** Type 01.2 (Continuous wide lines). The lines drawn to represent the visible outlines/ visible edges / surface boundary lines of objects should be outstanding in appearance.
- **Dimension Lines:** Type 01.1 (Continuous narrow Lines) Dimension Lines are drawn to mark dimension.
- **Extension Lines:** Type 01.1 (Continuous narrow Lines)
- There are extended slightly beyond the respective dimension lines.
- **Construction Lines:** Type 01.1 **(Continuous narrow Lines)** Construction Lines are drawn for constructing drawings and should not be erased after completion of the drawing.
- **Hatching / Section Lines:** Type 01.1 **(Continuous Narrow Lines)** Hatching Lines are drawn for the sectioned portion of an object. These are drawn inclined at an angle of 45° to the axis or to the main outline of the section.
- **Guide Lines:** Type 01.1 **(Continuous Narrow Lines)** Guide Lines are drawn for lettering and should not be erased after lettering.
- **Break Lines:** Type 01.1 **(Continuous Narrow Freehand Lines)** Wavy continuous narrow line drawn freehand is used to represent break of an object.
- **Break Lines**: Type 01.1 **(Continuous Narrow Lines with Zigzags)** Straight continuous ~arrow line with zigzags is used to represent break of an object.
- **Dashed Narrow Lines:** Type 02.1 **(Dashed Narrow Lines)** Hidden edges / Hidden outlines of objects are shown by dashed lines of short dashes of equal lengths of about 3 mm, spaced at equal distances of about 1 mm. the points of intersection of these lines with the outlines / another hidden line should be clearly shown.
- **Center Lines:** Type 04.1 **(Long-Dashed Dotted Narrow Lines)** Center Lines are drawn at the center of the drawings symmetrical about an axis or both the axes. These are extended by a short distance beyond the outline of the drawing.
- **Cutting Plane Lines:** Type 04.1 and Type 04.2 Cutting Plane Line is drawn to show the location of a cutting plane. It is long-dashed dotted narrow line, made wide at the ends, bends and change of direction. The direction of viewing is shown by means of arrows resting on the cutting plane line.
- **Border Lines** Border Lines are continuous wide lines of minimum thickness 0.7 mm

Use of Lines:

Types of Lines and their applications (IS 10714 (Part 20): 2001) and BIS: SP46: 2003

S. No.	Line description and Representation	Applications
1.1	Continuous narrow line **B**	Dimension lines, Extension lines
		Leader lines, Reference lines
		Short centre lines
		Projection lines
		Hatching
		Construction lines, Guide lines
		Outlines of revolved sections
		Imaginary lines of intersection
1.1	Continuous narrow freehand line C	Preferably manually represented termination of partial or interrupted views, cuts and sections, if the limit is not a line of symmetry or a center line·
1.1	Continuous narrow line with zigzags **A**	Preferably mechanically represented termination of partial or interrupted views. cuts and sections, if the limit is not a line of symmetry or a center line
1.2	Continuous wide line	Visible edges, visible outlines
		Main representations in diagrams, maps. flow charts
2.1	Dashed narrow line **D** - - - - - - - - - - - - - - - -	Hidden edges
		Hidden outlines
4.1	Long-dashed dotted narrow line **E**	Center lines / Axes. Lines of symmetry
		Cutting planes (Line 04.2 at ends and changes of direction)
4.2	Long-dashed dotted wide line **F**	Cutting planes at the ends and changes of direction outlines of visible parts situated m front of cutting plane

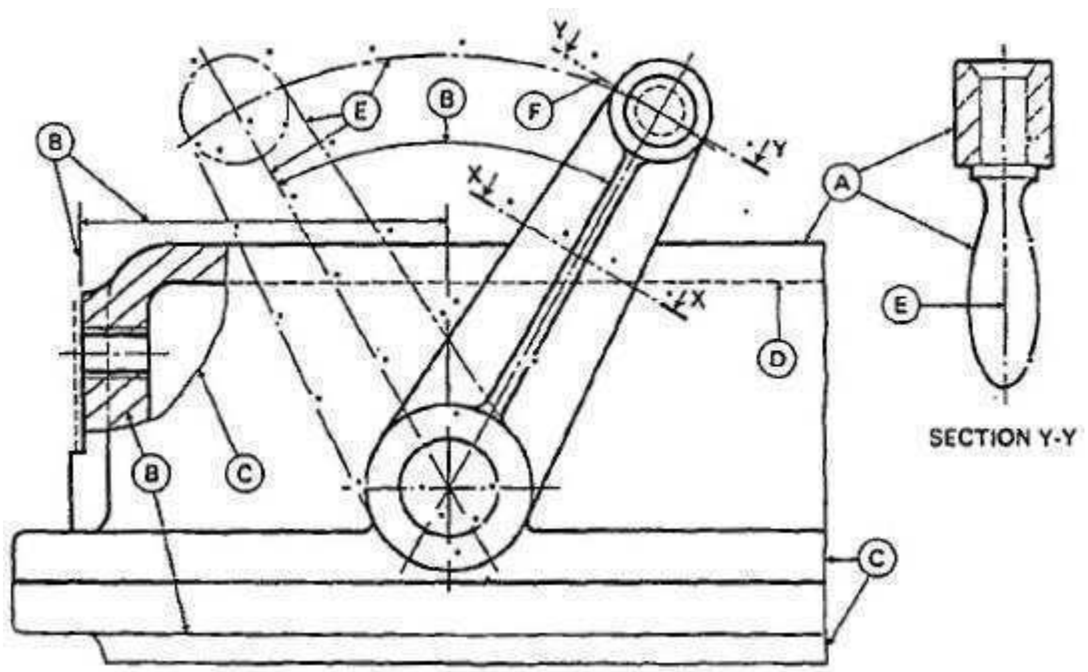


Fig. 1.1 Types of Lines

Lettering:

The essential features of lettering on technical drawings are legibility, uniformity and suitability for microfilming and other photographic reproductions. In order to meet these requirements, the characters are to be clearly distinguishable from each other in order to avoid any confusion between them, even in the case of slight mutilations. The reproductions require the distance between two adjacent lines or the space between letters to be at least equal to twice the line thickness. The line thickness for lower case and capital letters shall be the same in order to facilitate lettering.

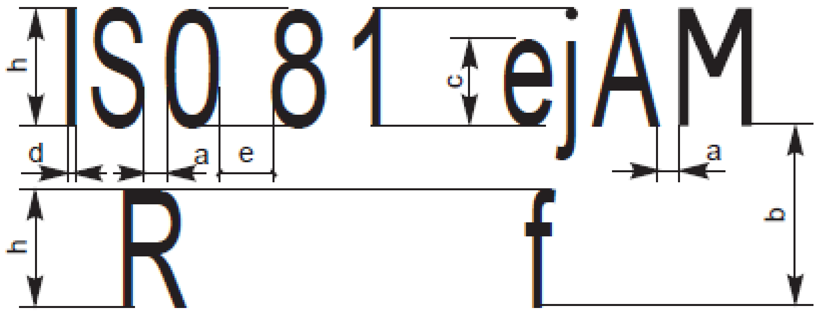


Fig. 1.2 Dimensions of lettering

Dimension of Lettering:

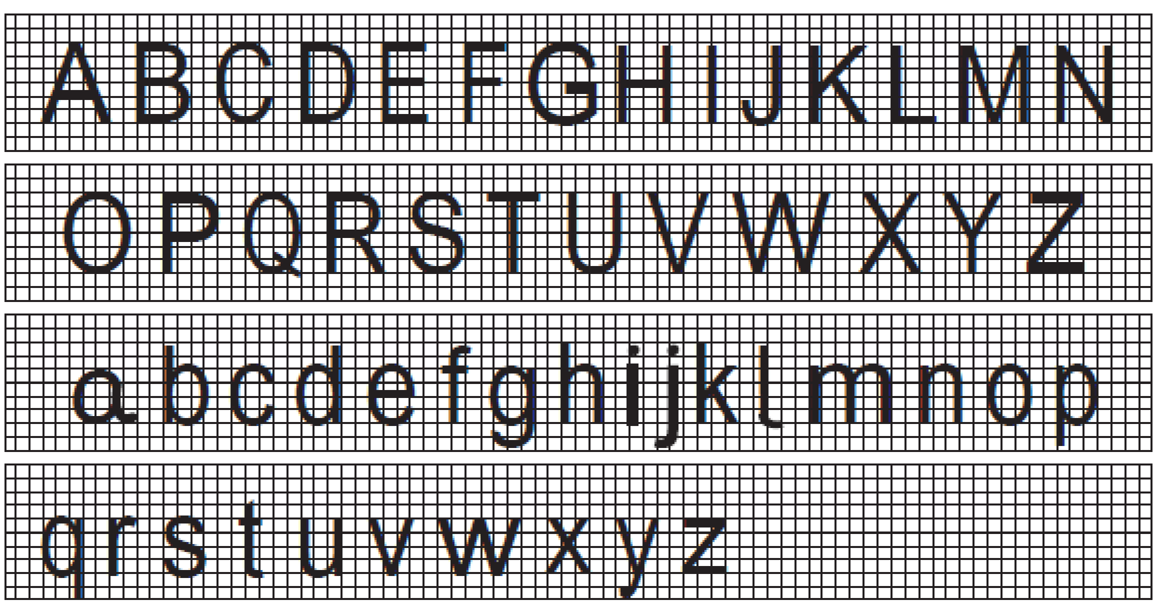
The following specifications are given for the dimensions of letters and numerals:

(i) The height of capital letters is taken as the base of dimensioning (Tables 2.6 and 2.7).

(ii) The two standard ratios for d/h, 1/14 and 1/10 are the most economical, as they result in a minimum number of line thicknesses.

(iii) The lettering may be inclined at 15° to the right, or may be vertical.

Characteristic		Dimensions, (mm)						
Lettering height (Height of capitals)	h (14/14)h	2.5	3.5	5	7	10	14	20
Height of lower-case letters (without stem or tail)	c (10/14)h	—	2.5	3.5	5	7	10	14
Spacing between characters	a (2/14)h	0.35	0.5	0.7	1	1.4	2	2.8
Minimum spacing of base lines	b (20/14)h	3.5	5	7	10	14	20	28
Minimum spacing between words	e (6/14)h	1.05	1.5	2.1	3	4.2	6	8.4
Thickness of lines	d (1/14)h	0.18	0.25	0.35	0.5	0.7	1	1.4



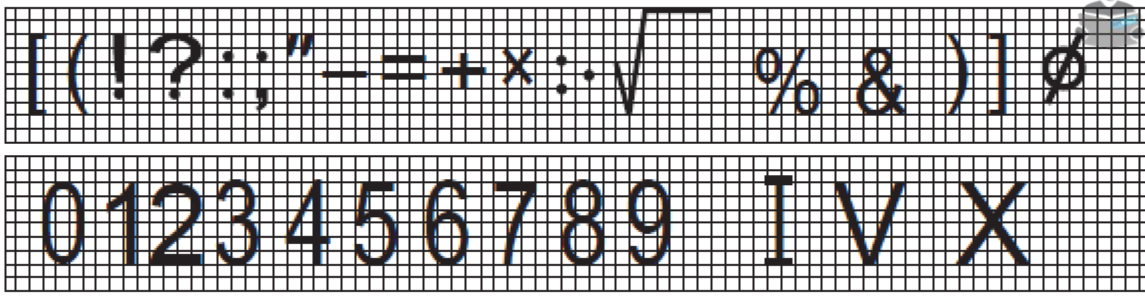


Fig. 1.3 Lettering

Dimensioning:

A drawing of a component, in addition to providing complete shape description, must also furnish information regarding the size description. These are provided through the distances between the surfaces, location of holes, nature of surface finish, type of material, etc. The expression of these features on a drawing, using lines, symbols, figures and notes is called dimensioning.

General Principles:

Dimension is a numerical value expressed in appropriate units of measurement and indicated on drawings, using lines, symbols, notes, etc., so that all features are completely defined.

1. As far as possible, dimensions should be placed outside the view.
2. Dimensions should be taken from visible outlines rather than from hidden lines.
3. Dimensioning to a centre line should be avoided except when the centre line passes through the centre of a hole.
4. Each feature should be dimensioned once only on a drawing.
5. Dimensions should be placed on the view or section that relates most clearly to the corresponding features.
6. Each drawing should use the same unit for all dimensions, but without showing the unit symbol.
7. No more dimensions than are necessary to define a part should be shown on a drawing.
8. No features of a part should be defined by more than one dimension in any one direction.

Method of Execution:

The elements of dimensioning include the projection line, dimension line, leader line, dimension line termination, the origin indication and the dimension itself. The various elements of dimensioning are shown in Fig. 1.4 a and b. The following are some of the principles to be adopted during execution of dimensioning:

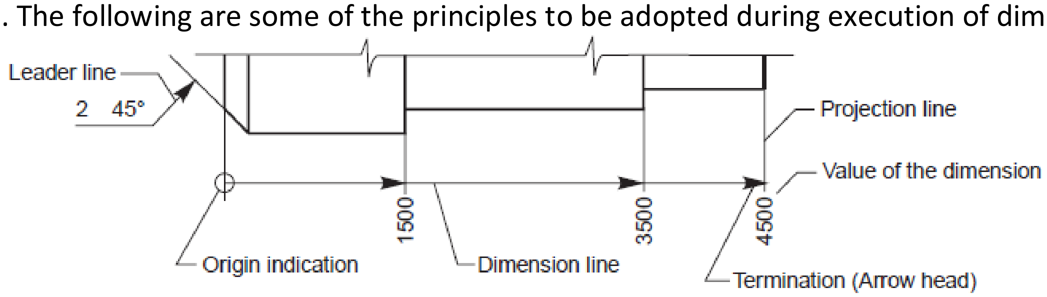


Fig. 1.4 (a) Elements of Dimensioning

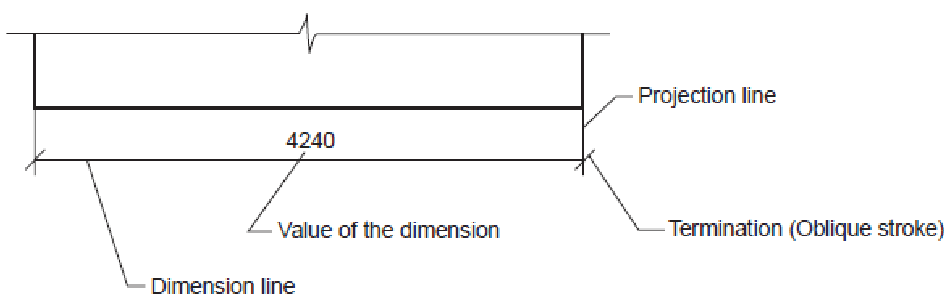
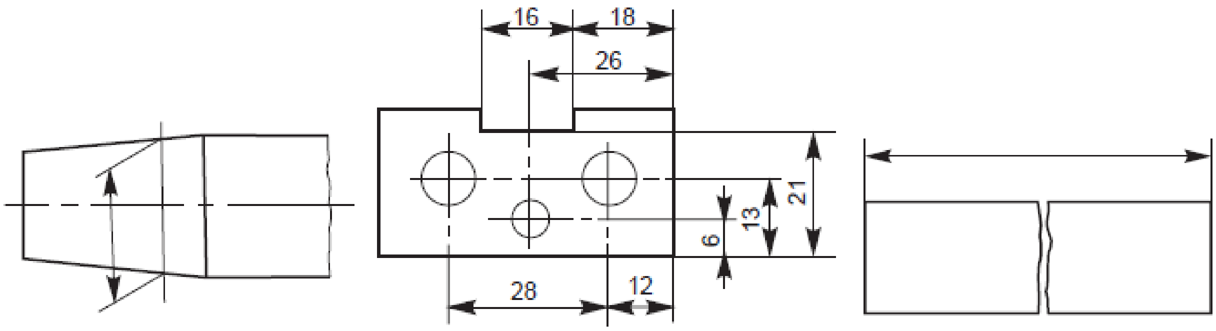


Fig. 1.4 (b) Elements of Dimensioning

1. Projection and dimension lines should be drawn as thin continuous lines.
2. Projection lines should extend slightly beyond the respective dimension lines.
3. Projection lines should be drawn perpendicular to the feature being dimensioned.

Where necessary, they may be drawn obliquely, but parallel to each other (Fig. 1.5 a). However, they must be in contact with the feature.

4. Projection lines and dimension lines should not cross each other, unless it is unavoidable (Fig. 1.5 b).
5. A dimension line should be shown unbroken, even where the feature to which it refers, is shown broken (Fig. 1.5 c).
6. A centre line or the outline of a part should not be used as a dimension line, but may be used in place of projection line (Fig. 1.5 b).



(a) (b) (b)

Fig. 1.5

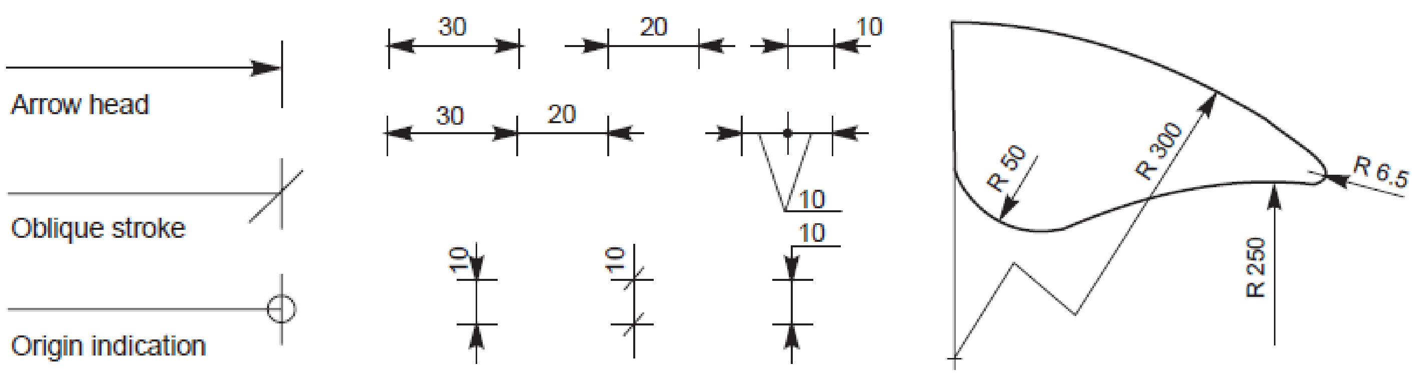
Termination and Origin Indication

Dimension lines should show distinct termination, in the form of arrow heads or oblique strokes or where applicable, an origin indication. Two dimension line terminations and an origin indication are shown in Fig. 1.6 (a). In this,

1. the arrow head is drawn as short lines, having an included angle of 15°, which is closed and filled-in.
2. the oblique stroke is drawn as a short line, inclined at 45°.
3. the origin indication is drawn as a small open circle of approximately 3 mm in diameter.

The size of the terminations should be proportionate to the size of the drawing on which they are used. Where space is limited, arrow head termination may be shown outside the intended limits of the dimension line that is extended for that purpose. In certain other cases, an oblique stroke or a dot may be substituted (Fig. 1.6 (b)).

Where a radius is dimensioned, only one arrow head termination, with its point on the arc end of the dimension line, should be used (Fig. 1.6 (c)). However, the arrow head termination may be either on the inside or outside of the feature outline, depending upon the size of feature.



(a) (b) (c)

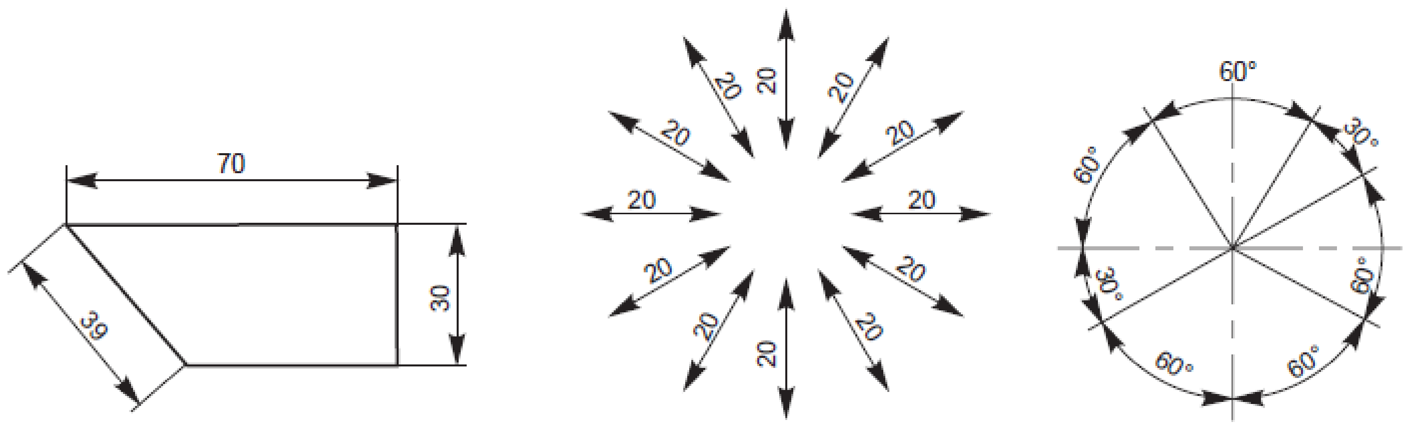
Fig. 1.6

Methods of Indicating Dimensions

Dimensions should be shown on drawings in characters of sufficient size, to ensure complete legibility. They should be placed in such a way that they are not crossed or separated by any other line on the drawing. Dimensions should be indicated on a drawing, according to one of the following two methods. However, only one method should be used on any one drawing.

METHOD–1 (Aligned System)

Dimensions should be placed parallel to their dimension lines and preferably near the middle, above and clear-off the dimension line (Fig. 1.7 a). Dimensions may be written so that they can be read from the bottom or from the right side of the drawing. Dimensions on oblique dimension lines should be oriented as shown in Fig. 1.7 b. Angular dimensions may be oriented as shown in Fig. 1.7 c.

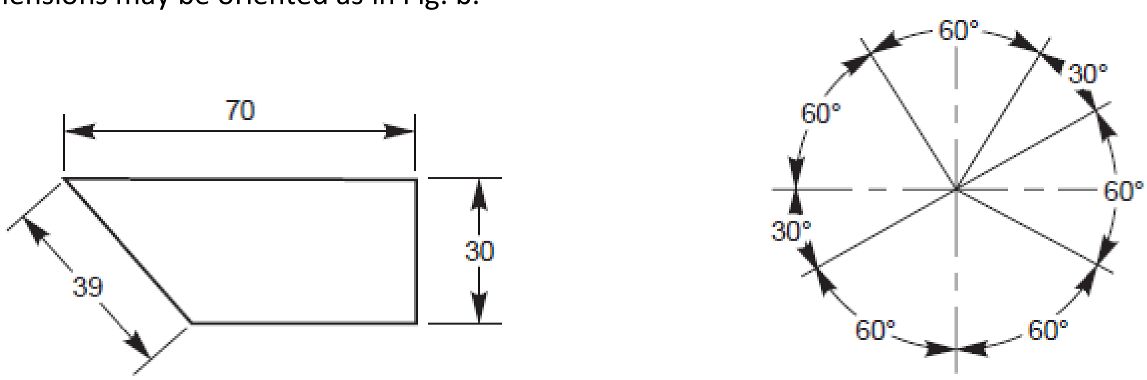


(a) (b) Oblique dimensioning (c)Angular dimensioning

Fig. 1.7

METHOD–2 (Unidirectional System)

Dimensions should be indicated so that they can be read from the bottom of the drawing only. Non-horizontal dimension lines are interrupted, preferably near the middle, for insertion of the dimension (Fig. a).
Angular dimensions may be oriented as in Fig. b.



(a) (b) Angular dimensioning

Fig. 1.8

Arrangement of Dimensioning

The arrangement of dimensions on a drawing must indicate clearly the design purpose. The following are the ways of arranging the dimensions.

i) Chain Dimensions:

Chains of single dimensions should be used only where the possible accumulation of tolerances does not endanger the functional requirement of the part.

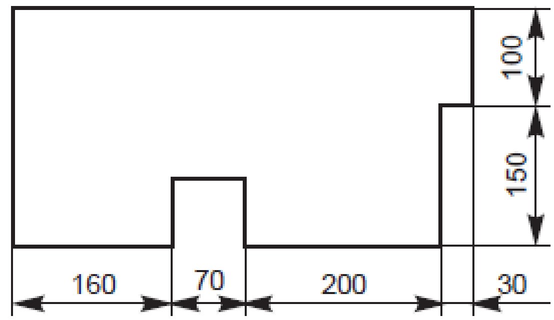


Fig. 1.9 Chain Dimensioning

ii) Parallel Dimensions:
In parallel dimensioning, a number of dimension lines, parallel to one another and spaced-out are used. This method is used where a number of dimensions have a common datum feature.

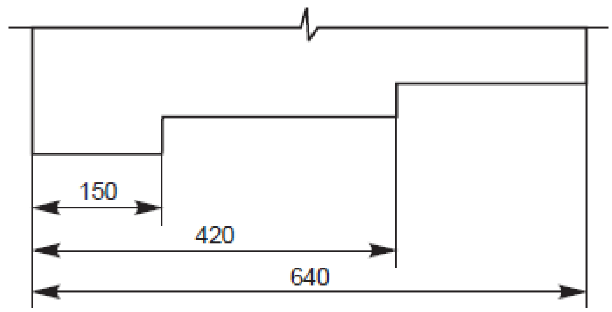


Fig. 1.10 Parallel Dimensioning

iii) Super imposed Running Dimensions:
These are simplified parallel dimensions and may be used where there are space limitations.

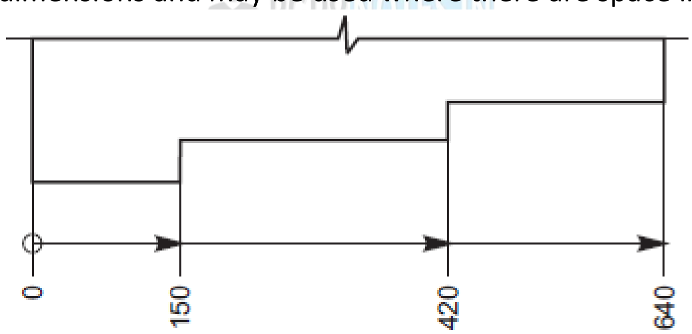


Fig. 1.11 Superimposed Running Dimensioning

iv) Combined Dimensions:
These are the result of simultaneous use of chain and parallel dimensions.

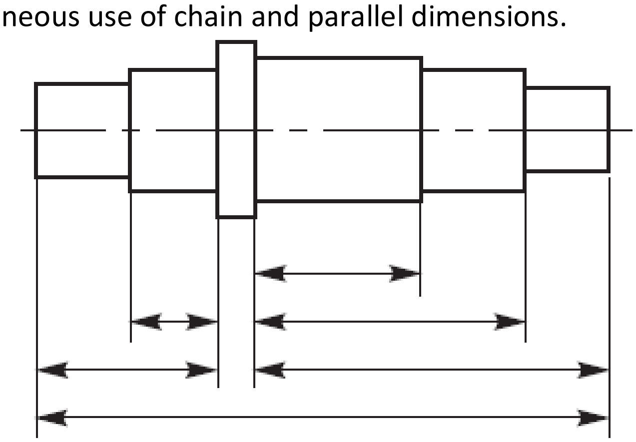
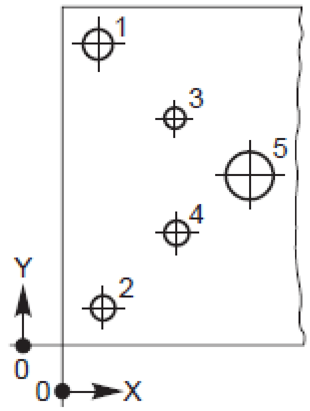


Fig. 1.12 Combined Dimensioning

v) Coordinate Dimensions:

The sizes of the holes and their co-ordinates may be indicated directly on the drawing; or they may be conveniently presented in a tabular form, as shown in Fig. 1.13.



	X	Y	ϕ
1	20	160	15.5
2	20	20	13.5
3	60	120	11
4	60	60	13.5
5	100	90	26
6			
7			
8			
9			
10			

Fig. 1.13 Coordinate Dimensioning

Scales:

It is not possible always to make drawings of an object to its actual size. If the actual linear dimensions of an object are shown in its drawing, the scale used is said to be a full size scale. Wherever possible, it is desirable to make drawings to full size.

Reducing and Enlarging Scales

Objects which are very big in size cannot be represented in drawing to full size. In such cases the object is represented in reduced size by making use of reducing scales. Reducing scales are used to represent objects such as large machine parts, buildings, town plans etc. A reducing scale, say 1: 10 means that 10 units length on the object is represented by 1 unit length on the drawing.

Similarly, for drawing small objects such as watch parts, instrument components etc., use of full scale may not be useful to represent the object clearly. In those cases enlarging scales are used.

An enlarging scale, say 10: 1 means one unit length on the object is represented by 10 units on the drawing.

The designation of a scale consists of the word SCALE, followed by the indication of its ratio as follows.

Scale 1: 1 for full size scale

Scale 1: x for reducing scales (x = 10, 20 ...... etc.)

Scale x: 1 for enlarging scales.

Note: For all drawings the scale has to be mentioned without fail.

Representative fraction (R.F.):-

$$RF = \frac{\text{Drawing size of an object}}{\text{Its actual size}} \text{ (in same units)}$$

When a 1 cm long line in a drawing represents 1 meter length of the object

$$R.F. = \frac{1cm}{1m} = \frac{1}{100}$$

LENGTH OF SCALE = R.F. MAX. LENGTH TO BE MEASURED

Units of Measurement: -

Metric System	British System
1 Kilometer (km) = 10 Hectometer (hm)	1 League = 3 Miles (mi)
1 Hectometer (hm) = 10 Decameter (Dm)	1 Mile (mi) = 8 Furlongs (fur)
1 Decameter (Dm) = 10 Meter (m)	1 Furlong (fur) = 10 Chains (ch)
1 Meter (m) = 10 Decimeter (dm)	1 Chain (ch) = 22 Yards (yd)
1 Decimeter (dm) = 10 Centimeter (cm)	1 Yard (yd) = 3 Feet (ft)
1 Centimeter (cm) = 10 Millimeter (mm)	1 Foot (ft) = 12 Inches (in)
	1 Inch (in) = 8 Eighth

Linear Conversion: -
1 Mile (mi) = 1.609 Kilometer (km)
1 Inch (in) = 2.54 Centimeter (cm) = 25.4 Millimeter (mm)

Area Conversion: -
1 are (a) = 100 Square Meter (m^2)
1 Hectare (ha) = 100 ares = 10000 Square Meter (m^2)
1 Square Mile (mi^2) = 640 Acres (ac)
1 Acre (ac) =10 Square Chain (ch^2) = 4840 Square Yards (yd^2)

1. Plain Scales (for dimensions up to single decimal)
2. Diagonal Scales (for dimensions up to two decimals)
3. Vernier Scales (for dimensions up to two decimals)
4. Comparative Scales (for comparing two different units)
5. Scale of Cords (for measuring/constructing angles)

Plain Scale

Problem No. 1: - Construct a scale of 1:4, to show centimeters and long enough to measure up to 5 decimeters.

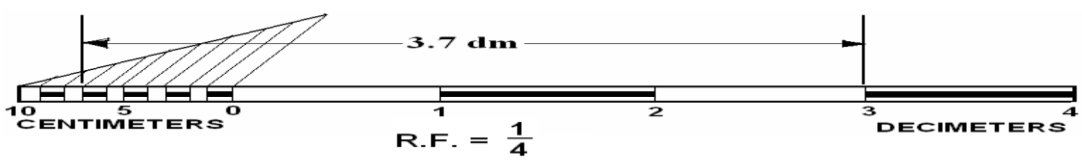


Fig. 1.14

CONSTRUCTION: -
1. R.F. = ¼
2. Length of the scale = R.F. x max. Length = ¼ ×5 dm = 12.5 cm.
3. Draw a line 12.5 cm long and divide it in to 5 equal divisions, each representing 1 dm.
4. Mark 0 at the end of the first division and 1, 2, 3 and 4 at the end of each subsequent division to its right.
5. Divide the first division into 10 equal sub-divisions, each representing 1 cm.
6. Mark cm to the left of 0 as shown.

Diagonal Scale

Problem No. 2: - Construct a Diagonal scale of RF = 3:200 (i.e. 1:66 2/3) showing meters, decimeters and centimeters. The scale should measure up to 6 meters. Show a distance of 4.56 meters

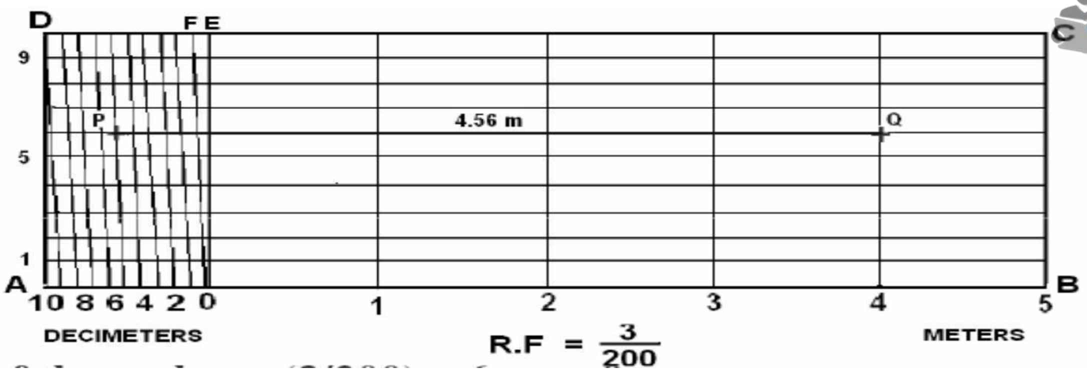


Fig. 1.15

CONSTRUCTION: -

1. Length of the scale = (3/200) x 6 m = 9 cm
2. Draw a line AB = 9 cm. Divide it in to 6 equal parts.
3. Divide the first part A0 into 10 equal divisions.
4. At A draw a perpendicular and step-off along it 10 equal divisions, ending at D.
5. Complete the rectangle ABCD.
6. Draw perpendiculars at meter-divisions i.e. 1, 2, 3, and 4.
7. Draw horizontal lines through the division points on AD. Join D with the end of the first division along A0 (i.e. 9).
8. Through the remaining points i.e. 8, 7, 6…draw lines // to D9.
9. PQ = 4.56 meters

Vernier Scale

The vernier scale is a short auxiliary scale constructed along the plain or main scale, which can read up to two decimal places.

The smallest division on the main scale and vernier scale are 1 msd or 1 vsd respectively. Generally (n+1) or (n-1) divisions on the main scale is divided into n equal parts on the Vernier scale.

Thus, 1 vsd (Vernier Scale Division) = $(n-1)/n$ msd (Main Scale Division)

When 1 vsd < 1 it is called forward or direct vernier. The vernier divisions are numbered in the same direction as those on the main scale.

When 1 vsd > 1 or (1 + l/n), It is called backward or retrograde vernier. The vernier divisions are numbered in the opposite direction compared to those on the main scale.

The least count (LC) is the smallest dimension correct to which a measurement can be made with a vernier.

For forward vernier, L C = (1 msd - 1 vsd)

For backward vernier, LC = (1 vsd - 1 msd)

Problem No. 3: - Draw a Vernier scale of R.F. = 1/25 to read up to 4 meters. On it show lengths 2.39 m and 0.91 m.

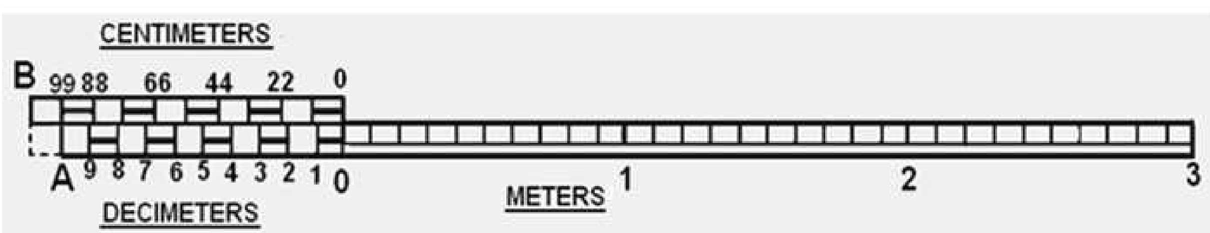


Fig. 1.16

CONSTRUCTION: -

1. Length of Scale = (1/25) × (4 × 100) = 16 cm
2. Draw a 16 cm long line and divide it into 4 equal parts. Each part is 1 meter. Divide each of these parts in to 10 equal parts to show decimeter (10 cm).
3. Take 11 parts of dm length and divide it in to 10 equal parts. Each of these parts will show a length of 1.1 dm or 11 cm.
4. To measure 2.39 m, place one leg of the divider at *A* on 99 cm mark and other leg at *B* on 1.4 mark. (0.99 + 1.4 = 2.39).
5. To measure 0.91 m, place the divider at *C* and *D* (0.8 +0.11 = 0.91).

Scale of Chord

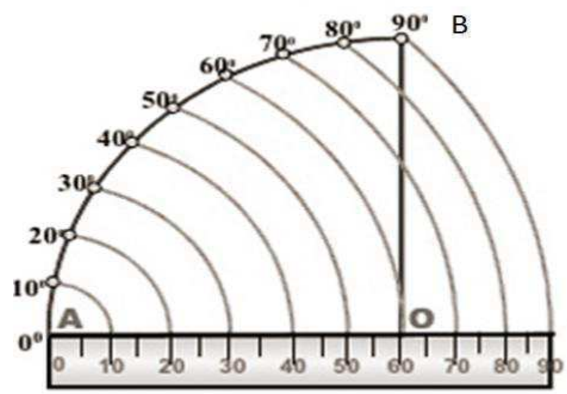


Fig. 1.17

CONSTRUCTION: -

1. Draw sector of a circle 90ºwith "OA" radius. ('OA' ANY CONVINIENT DISTANCE)
2. Divide this angle in nine equal parts of 10º each.
3. Name as shown from end 'A' upwards.
4. From 'A' as centre with cords of each angle as radius. Draw arcs downwards up to 'AO' Line OR its extension and from a scale with proper labeling as shown. As cord lengths are to measure & construct different angles it is called scale of cords.

Conic Sections:

Cone is formed when a right angled triangle with an apex and angle e is rotated about its altitude as the axis. The length or height of the cone is equal to the altitude of the triangle and the radius of the base of the cone is equal to the base of the triangle. The apex angle of the cone is 2 e.

When a cone is cut by a plane, the curve formed along the section is known as a conic. For this purpose, the cone may be cut by different section planes and the conic sections obtained are shown in Fig.

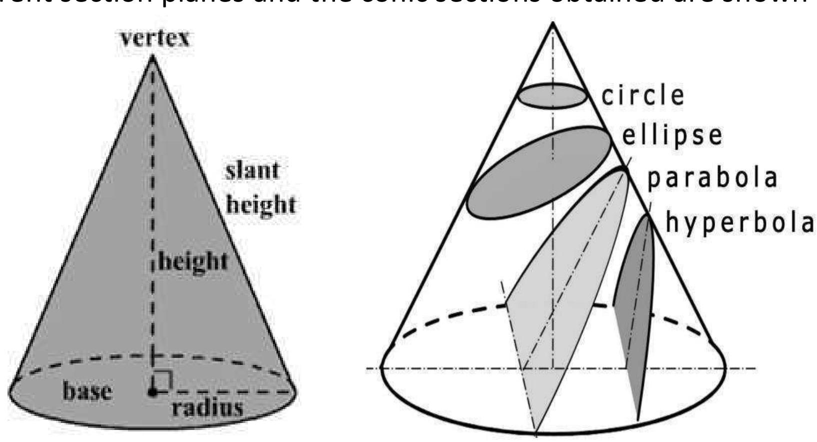


Fig. 1.18

1. Circle

When a cone is cut by a section plane making an angle α = 90° with the axis, the section obtained is a circle.

2. Ellipse

When a cone is cut by a section plane at an angle, α more than half of the apex angle i.e., e and less than 90°, the curve of the section is an ellipse. Its size depends on the angle α and the distance of the section plane from the apex of the cone.

3. Parabola

If the angle α is equal to e i.e., when the section plane is parallel to the slant side of the cone, the curve at the section is a parabola. This is not a closed figure like circle or ellipse. The size of the parabola depends upon the distance of the section plane from the slant side of the cone.

4. Hyperbola

If the angle α is less than e, the curve at the section is hyperbola. The curve of intersection is hyperbola, even if α = e, provided the section plane is not passing through the apex of the cone. However if the section plane passes through the apex, the section produced is an isosceles triangle.

Ellipse

Conic Sections as Loci of a Moving Point

A conic section may be defined as the locus of a point moving in a plane such that the ratio of its distance from a fixed point (Focus) and fixed straight line (Directrix) is always a constant. The ratio is called eccentricity. The line passing through the focus and perpendicular to the directrix is the axis of the curve. The point at which the conic section intersects the axis is called the vertex or apex of the curve.

e<1 for Ellipse, e=1 for Parabola & e>1 for Hyperbola.

Various Methods for Construction of an Ellipse

a) General method,
b) Arc of circle Method,
c) Concentric Circle Method
d) Oblong Method

a) General method:

Problem: To draw an Ellipse with eccentricity equal to 2/3 for the above problem.

Solution: Construction is similar to the one in Figure to draw an ellipse including the tangent and normal.

Following are the details of drawing different conic sections with the help of general or eccentricity method.

1. Draw the axis AB and the directrix CD at right angles to it:
2. Mark the focus F on the axis at 50mm.
3. Locate the vertex V on AB such that AV = VF
4. Draw a line VE perpendicular to AB such that VE = VF\
5. Join A, E and extend. Now, VENA = VFNA = 1, the eccentricity.
6. Locate number of points 1, 2, 3, etc., to the right of V on the axis, which need not be equidistant.
7. Through the points 1,2,3, etc., draw lines perpendicular to the axis and to meet the line AE extended at 1',2',3' etc.
8. With centre F and radius 1-1’draw arcs intersecting the line through I at P I and P’1’.
9. Similarly, locate the points P_2 etc., on either side of the axis. Join the points by smooth curve, forming the required ellipse.

To draw a normal and tangent through a point 40 mm from the directrix.

To draw a tangent and normal to the parabola, locate the point M which is at 40 mm from the direct QX. Then join M to F and draw a line through F, perpendicular to MF to meet the directrix at T. The line joining T and M and extended is the tangent and a line NN, through M and perpendicular to TM is the normal to the curve.

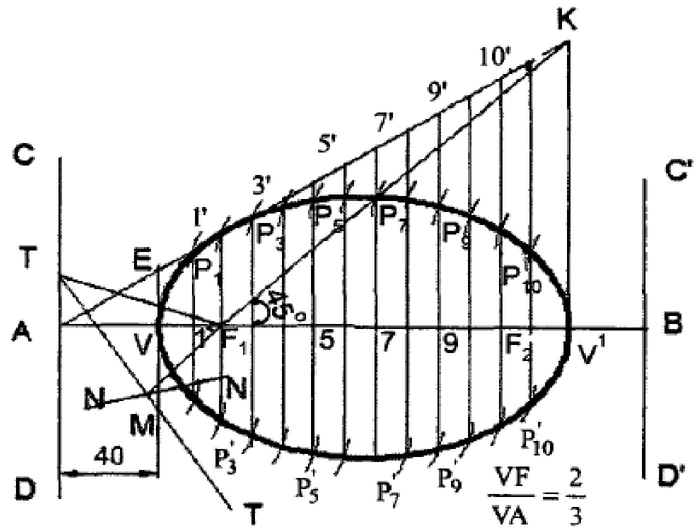


Fig. 1.19 Ellipse by General Method

b) Arc of circle Method

Problem: To draw an ellipse with major and minor axes equal to 120 mm and 80 mm respectively.

Solution:

1. Draw the major (AB) and minor (CD) axes and locate the centre O.
2. Locate the foci F_1 and F_2 by taking a radius equal to 60 mm (112 of AB) and cutting AB at F_1P_1 and F_2 with C as the centre.
3. Mark a number of points 1, 2, 3 etc., between F_1 and O, which need not be equidistance.
4. With centers F_1 and F_2 and radii A_1 and B_1 respectively, draw arcs intersecting at the points PI and P;
5. Again with centers F_1 and F_2 and radii B_1 and A_1 respectively, draw arcs intersecting at the points Q_1 and Q_1'.
6. Repeat the steps 4 and 5 with the remaining points 2, 3, 4 etc., and obtain additional points on the curve. Join the points by a smooth curve, forming the required ellipse.
7. To mark a Tangent and Normal to the ellipse at any point, say M on it, join the foci F1 and F2 with M and extend FM to E and bisect the angle EMF_1. The bisector TT represents the required tangent and a line NN drawn through M and perpendicular to TT is the normal to the ellipse.

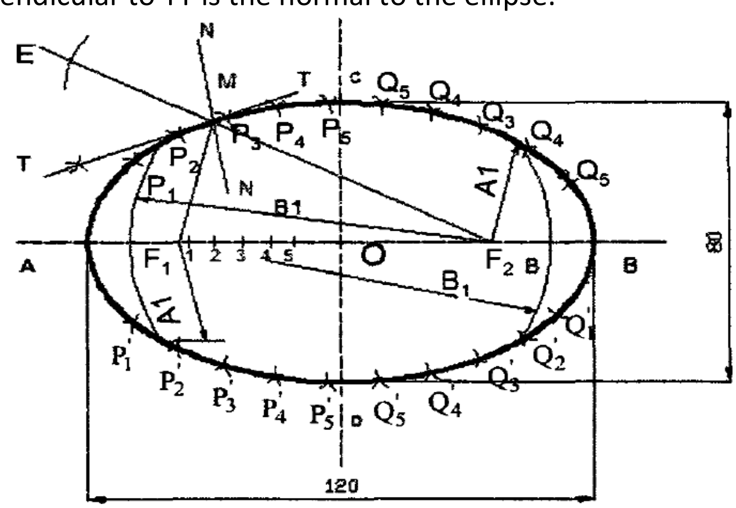


Fig. 1.20 Ellipse by Arcs of a Circle Method

c) Concentric Circle Method

Solution:

1. Draw the major and minor axes AB and CD and locate the centre O.
2. With centre 0 and major axis and minor axes as diameters, draw two concentric circles.
3. Divide both the circles into equal number of parts, say 12 and draw the radial lines.
4. Considering the radial line 0-1' -1, draw a horizontal line from I' to meet the vertical line from 1 at P_1'.
5. Repeat the steps 4 and obtain other points P_2, P_3, etc.
6. Join the points by a smooth curve forming the required ellipse.

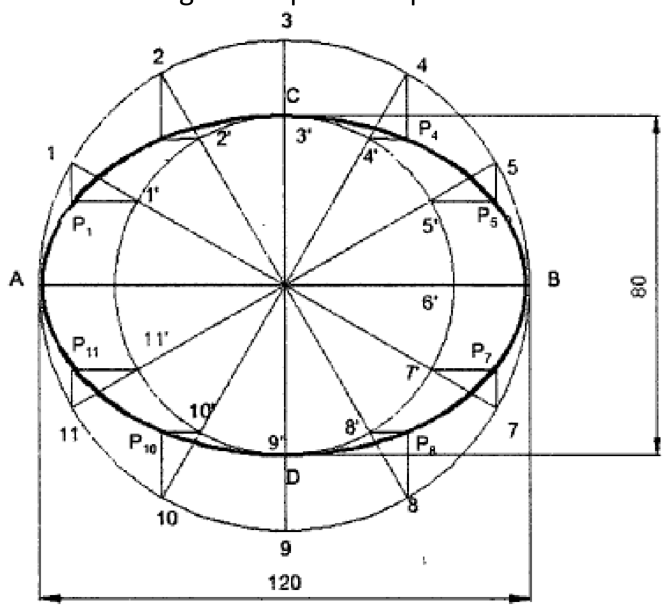


Fig. 1.21 Ellipse by Concentric Circle Method

d) Oblong Method

1. Draw the major and minor axes AB and CD and locate the centre O.
2. Draw the rectangle KLMN passing through A, D, B, C.
3. Divide AO and AN into same number of equal parts, say 4.
4. Join C with the points 1',2 ', 3' .
5. Join D with the points 1, 2, 3 and extend till they meet the lines C_1’, C_2’, C_3’ respectively at P_1, P_2 and P_3.
6. Repeat steps 3 to 5 to obtain the points in the remaining three quadrants.
7. Join the points by a smooth curve forming the required ellipse.

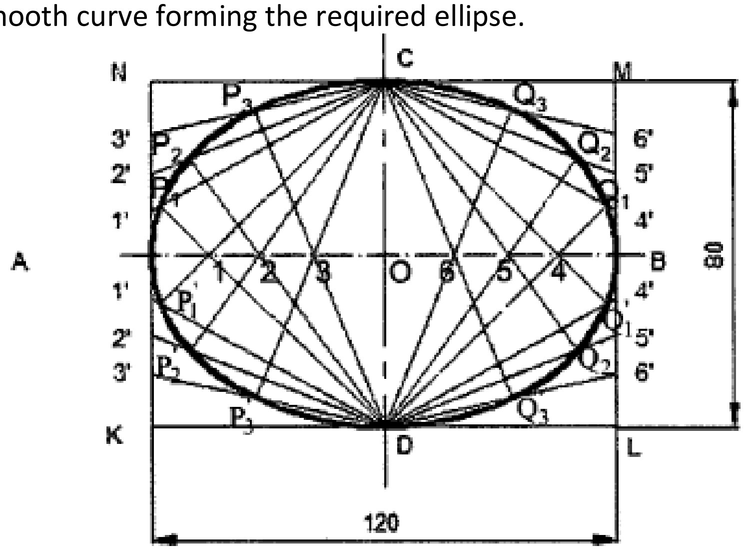


Fig. 1.22 Ellipse by Oblong Method

Parabola

Various Methods of construction of Parabola

a) General Method

b) Rectangle method

c) Tangent Method

a) General Method

Problem: To draw a normal and tangent through a point 40 mm from the directrix.
To draw a tangent and normal to the parabola, locate the point M which is at 40 mm from the direct QX. Then join M to F and draw a line through F, perpendicular to MF to meet the directrix at T. The line joining T and M and extended is the tangent and a line NN, through M and perpendicular to TM is the normal to the curve.

Following are the details of drawing different conic sections with the help of general or eccentricity method.
1. Draw the axis AB and the directrix CD at right angles to it:
2. Mark the focus F on the axis at 50mm.
3. Locate the vertex V on AB such that AV = VF
4. Draw a line VE perpendicular to AB such that VE = VF\
5. Join A, E and extend. Now, VENA = VFNA = 1, the eccentricity.
6. Locate number of points 1, 2, 3, etc., to the right of V on the axis, which need not be equidistant.
7. Through the points 1,2,3, etc., draw lines perpendicular to the axis and to meet the line AE extended at 1',2',3' etc.
8. With centre F and radius 1-1'draw arcs intersecting the line through I at P I and P'1'.
9. Similarly, locate the points P_2 etc., on either side of the axis. Join the points by smooth curve, forming the required parabola.

To draw a normal and tangent through a point 40 mm from the directrix

To draw a tangent and normal to the parabola, locate the point M which is at 40 mm from the direct QX. Then join M to F and draw a line through F, perpendicular to MF to meet the directrix at T. The line joining T and M and extended is the tangent and a line NN, through M and perpendicular to TM is the normal to the curve.

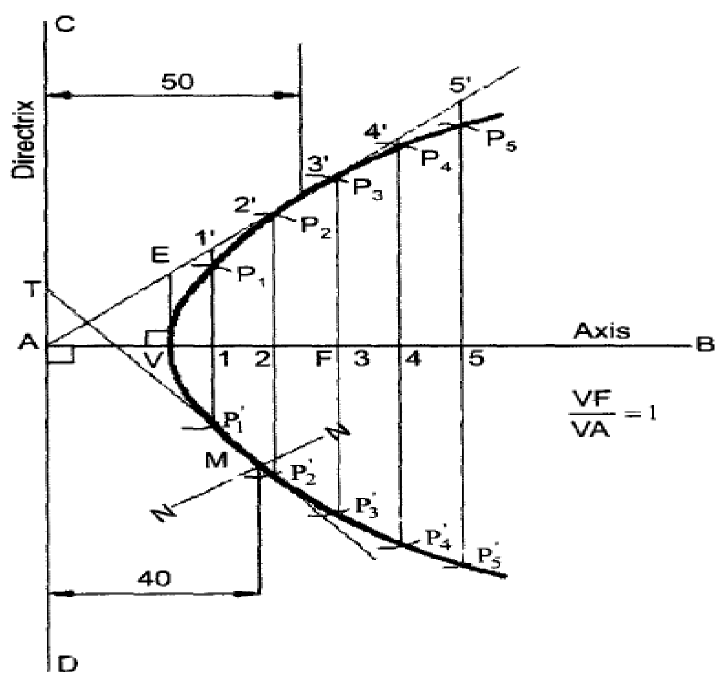


Fig. 1.23 Parabola by General Method

b) Rectangle method

Following are the steps of drawing parabola with the help of rectangle method.

1. Draw the base AB and axis CD such that CD is perpendicular bisector to AB.
2. Construct a rectangle ABEF, passing through C.
3. Divide AC and AF into the same number of equal parts and number the points 'as shown.
4. Join 1,2 and 3 to D.
5. Through 1',2' and 3', draw lines parallel to the axis, intersecting the lines ID, 2D and 3D at PI' P 2 and P3 respectively.
6. Obtain the points P;, P~ and P~, which are symmetrically placed to PI' P2 and P3 with respect to the axis CD.
7. Join the points by a smooth curve forming the required parabola.

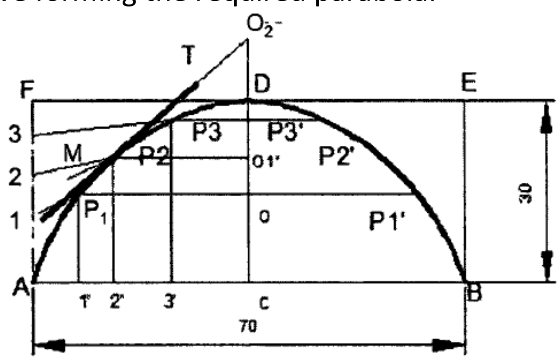


Fig. 1.24 Parabola by Rectangle Method

b) Tangent Method

Problem: To draw a parabola with 70 mm as base and 30 mm as the length of the axis.

Construction:

Following are the steps of drawing parabola with the help of tangent method.

1. Draw the base AB and locate its mid-point C.
2. Through C, draw CD perpendicular to AB forming the axis.
3. Produce CD to E such that DE = CD.
4. Join E-A and E-B. These are the tangents to the parabola at A and B.
5. Divide AE and BE into the same number of equal parts and number the points as shown.
6. Join 1-1', 2- 2', 3- 3', etc., forming the tangents to the required parabola.
7. A smooth curve passing through A, D and B and tangential to the above lines is the required parabola.
8.To draw a tangent to the curve at a point, say M on it, draw a horizontal through M, meeting the axis at F. mark G on the extension of the axis such that DG = FD. Join G, M and extend, forming the tangent to the curve at M.

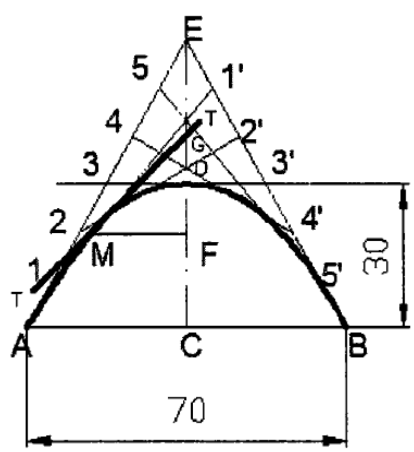


Fig. 1.25 Parabola by Tangent Method

Hyperbola

Various Method of construction of Hyperbola

a) General Method

b) Focus Vertex Method

a) General Method

Problem: Draw a hyperbola with eccentricity equal to 3/2 for the above problem**.**

Construction: Following are the details of drawing different conic sections with the help of general or eccentricity method.

1. Draw the axis AB and the directrix CD at right angles to it:
2. Mark the focus F on the axis at 50mm.
3. Locate the vertex V on AB such that AV = VF
4. Draw a line VE perpendicular to AB such that VE = VF\
5. Join A, E and extend. Now, VENA = VFNA = 1, the eccentricity.
6. Locate number of points 1, 2, 3, etc., to the right of V on the axis, which need not be equidistant.
7. Through the points 1,2,3, etc., draw lines perpendicular to the axis and to meet the line AE extended at 1',2',3' etc.
8. With centre F and radius 1-1'draw arcs intersecting the line through I at P I and P'1'.
9. Similarly, locate the points P_2 etc., on either side of the axis. Join the points by smooth curve, forming the required hyperbola.

To draw a normal and tangent through a point 40 mm from the directrix

To draw a tangent and normal to the parabola, locate the point M which is at 40 mm from the direct QX. Then join M to F and draw a line through F, perpendicular to MF to meet the directrix at T. The line joining T and M and extended is the tangent and a line NN, through M and perpendicular to TM is the normal to the curve.

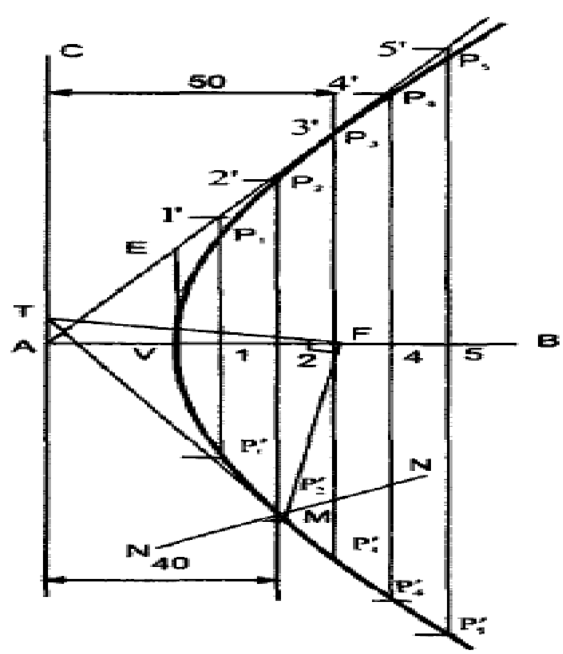


Fig. 1.26 Hyperbola by General Method

b) Focus Vertex Method---

Problem: Construct a hyperbola with its foci 70 mm apart and the major axis (distance between the vertices) as 40 mm. Draw a tangent to the curve at a point 20 mm from the focus.

Construction: Following are the steps of drawing a hyperbola.

1. Draw the transverse and conjugate axes AB and CD of the hyperbola and locate F I and F 2' the foci and V I and V Z' the vertices.
2. Mark number of points 1, 2, 3 etc., on the transverse axis, which need not be equi-distant.
3. With centre F1 and radius V_11, draw arcs on either side of the transverse a.xis.
4. With centre F2 and radius V_21, draw arcs intersecting the above arcs at P_1 and P_1'.
5. With centre F2 and radius V_11, draw arcs on either side of the transverse axis.
6. With centre F1 and radius V_21, draw arcs intersecting the above arcs at Q_1, Q_1'.
7. Repeat the steps 3 to 6 and obtain other points P_2, P_2' etc. and Q_2, Q_2' etc.
8. Join the points P_1, P_2, P_3, P_1', P_2', P_3' and Q_1, Q_2, Q_3, Q_1', Q_2', Q_3' forming the two branches of hyperbola.

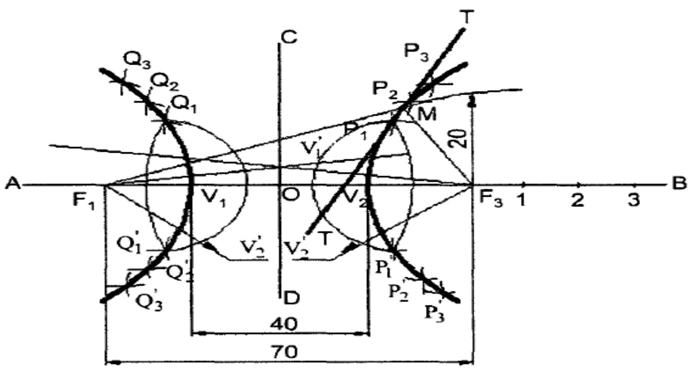


Fig. 1.27 Construction of Hyperbola

To draw the asymptotes to the given hyperbola

Lines passing through the centre and tangential to the curve at infinity are known as asymptotes.

Construction

1. Through the vertices V_1 and V_2 draw perpendiculars to the transverse axis.
2. With centre ° and radius $OF_1 = (OF_2)$, draw a circle meeting the above lines at P, Q and R, S.
3. Join the points P, O, R and S, O, Q and extend, forming the asymptotes to the hyperbola.

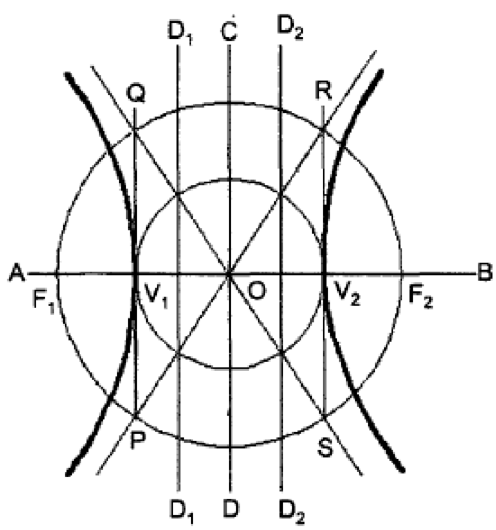


Fig. 1.28 Drawing asymptotes to a hyperbola

Rectangular Hyperbola

When the asymptotes to the hyperbola intersect each other at right angles, the curve is known as a rectangular hyperbola.

Problem: Construct a rectangular hyperbola when a point P on it is at a distance of 30 mm and 40 mm respectively from the two asymptotes.

Construction:

1. For a rectangular hyperbola, angle between the asymptotes is 90°. So, draw OR_1 and OR_2 such that the angle R_1OR_2 is 90°.
2. Mark A and B along OR_2 and OR_1 respectively such that OA = 40 mm and OB = 30 mm. From A draw AX parallel to OR_1 and from B draw BY parallel to OR_2. Both intersect at P.
3. Along BP mark 1, 2, and 3 at approximately equal intervals. Join O_1, O_2, and O_3 and extend them to meet AX at 1_1, 2_1 and 3_1 respectively.
4. From 1_1 draw a line parallel to OR_2 and from 1 draw a line parallel to OR_1. From 2 and 3 draw lines parallel to OR_1. They intersect at P_2 and P_3 respectively.
5. Then along PA mark points 4_1 and 5_1 at approximately equal intervals. Join $O4_1$ and $O5_1$ and extend them to meet BY at 4 and 5 respectively.
6. From 4_1 and 5_1 draw lines parallel to OR_2 and from 4 and 5 draw lines parallel to OR_1 to intersect at P_4 and P_5 respectively
7. Join P_1, P_2, P_3, P, P_4, and P_5 by smooth rectangular hyperbola.

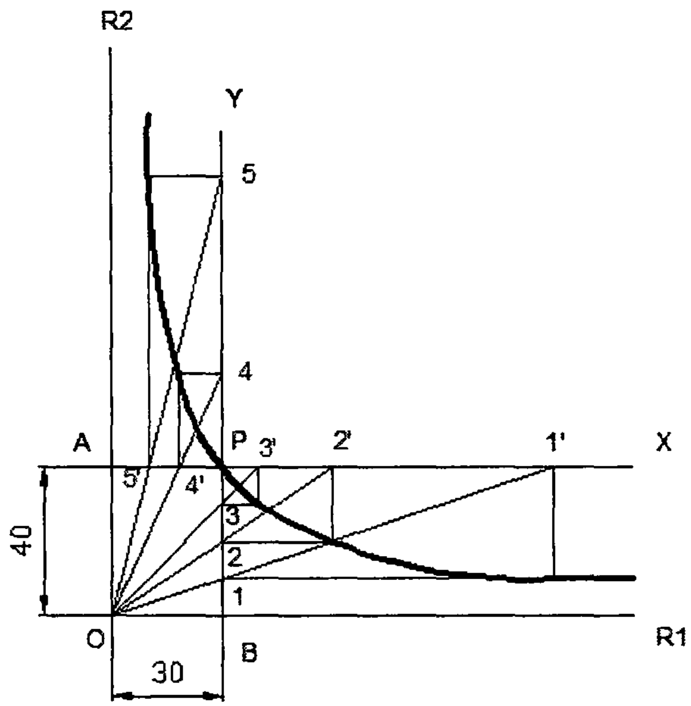


Fig. 1.29 Rectangular Hyperbola

Special Curves (Engineering Curves):

Cycloidal Curves

Cycloidal curves are generated by a fixed point in the circumference of a circle when it rolls without slipping along a fixed straight line or circular path. The rolling circle is called the generating circle, the fixed straight line, the directing line and the fixed circle, the directing circle.

1. Cycloid

A cycloid is a curve generated by a fixed point on the circumference of a circle, when it rolls without slipping along a straight line.

Problem: To draw a cycloid, given the radius R of the generating circle.

Construction

1. With centre ° and radius R, draw the given generating circle.
2. Assuming point P to be the initial position of the generating point, draw a line PA, tangential and equal to the circumference of the circle.
3. Divide the line PA and the circle into the same number of equal parts and number the points.

4. Draw the line OB, parallel and equal to PA. OB is the locus of the centre of the generating circle.
5. Erect perpendiculars at 1', 2', 3', etc., meeting OB at O_1, O_2, O_3 etc.
6. Through the points 1, 2, 3 etc., draw lines parallel to PA.
7. With centre 0, and radius R, draw an arc intersecting the line through 1 at P_1, P_1 is the position of the generating point, when the centre of the generating circle moves to °1,
S. Similarly locate the points P_2, P_3 etc.
9. A smooth curve passing through the points P, P_1, P_2, P_3 etc., is the required cycloid.

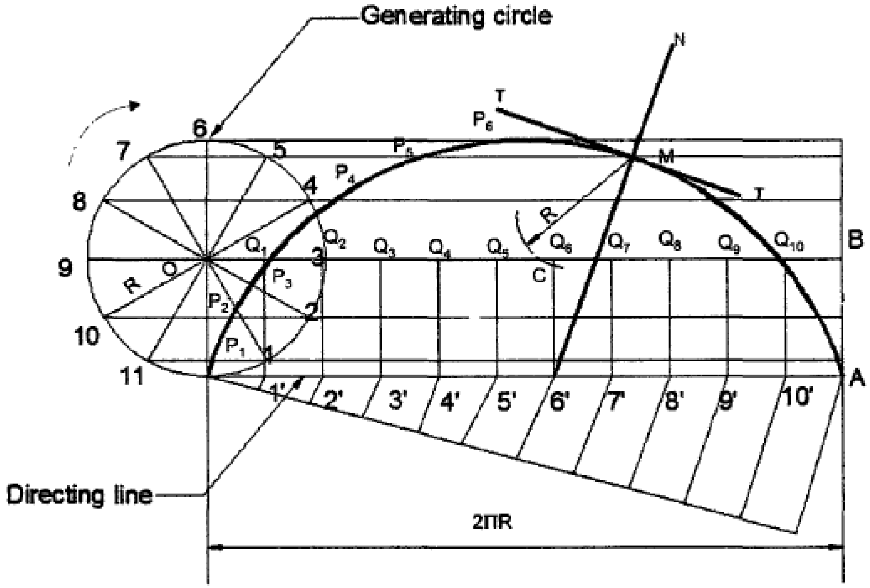


Fig. 1.30 Construction of a Cycloid

Epicycloid and Hypocycloid

An epi-cycloid is a curve traced by a point on the circumference of a generating circle, when it rolls without slipping on another circle (directing circle) outside it. If the generating circle rolls inside the directing circle, the curve traced by the point in called hypo-cycloid

Problem: To draw an epicycloid, given the radius 'r' of the generating circle and the radius 'R' of the directing circle.

Construction:

1. With centre O' and radius R, draw a part of the directing circle.
2. Draw the generating circle, by locating the centre O of it, on any radial line O'P extended such that OP = r.
3. Assuming P to be the generating point, locate the point A on the directing circle such that the arc length PA is equal to the circumference of the generating circle. The angle subtended by the arc PA at O' is given by e = angle PO'A = 360° x r/R.
4. With centre O' and radius O'O, draw an arc intersecting the line O'A produced at B. The arc OB is the locus of the centre of the generating circle.
s. Divide the arc PA and the generating circle into the same number of equal parts and number the points.
6. Join O'-1', O'-2', etc., and extend to meet the arc OB at O_1, O_2 etc.
7. Through the points 1, 2, 3 etc., draw circular arcs with O' as centre.
8. With centre 0 1 and radius r, draw an arc intersecting the arc through 1 at P_1.
9. Similarly, locate the points P_2, P_3 etc.
10. A smooth curve through the points P_1, P_2, P_3 etc., is the required epicycloid.

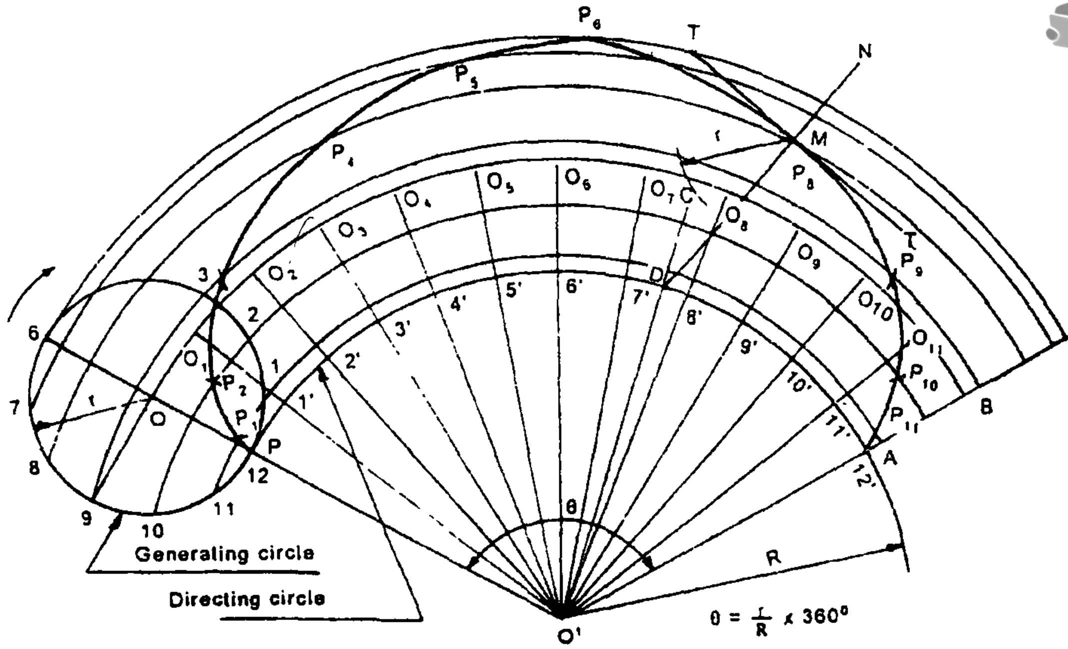


Fig. 1.31 Construction of an Epicycloid

Problem: Draw a hypocycloid of a circle of 40 mm diameter which rolls inside another circle of 200 mm diameter for one revolution. Draw a tangent and normal at any point on it.

Construction:

1. Taking any point 0 as centre and radius (R) 100 mm draw an arc PQ which subtends an angle e = 72° at O.
2. Let P be the generating point. On OP mark PC = r = 20 mm, the radius of the rolling circle.
3. With C as centre and radius r (20 mm) draw the rolling circle. Divide the rolling circle into 12 equal parts as 1, 2, 3 etc., in clock wise direction, since the rolling circle is assumed to roll counter clock wise.
4. With O as centre, draw concentric arcs passing through 1, 2, 3 etc.
5. With O as centre and OC as radius draw an arc to represent the locus of centre.
6. Divide the arc PQ into same number of equal parts (12) as 1', 2', 3' etc.
7. Join O_1', O_2' etc, which will intersect the locus of the centre at C_1, C_2, C_3 etc.
8. Taking centre C_1 and radius r, draw an arc cutting the arc through 1 at P_1. Similarly obtain the other points and draw a smooth curve through them.

To draw a tangent and normal at a given point M:

1. With M as centre and radius r = CP cut the locus of centre at the point N.
2. Join ON and extend it to intersect the base circle at S.
3. Join MS, the normal.
4. At M, draw a line perpendicular to MS to get the required tangent.

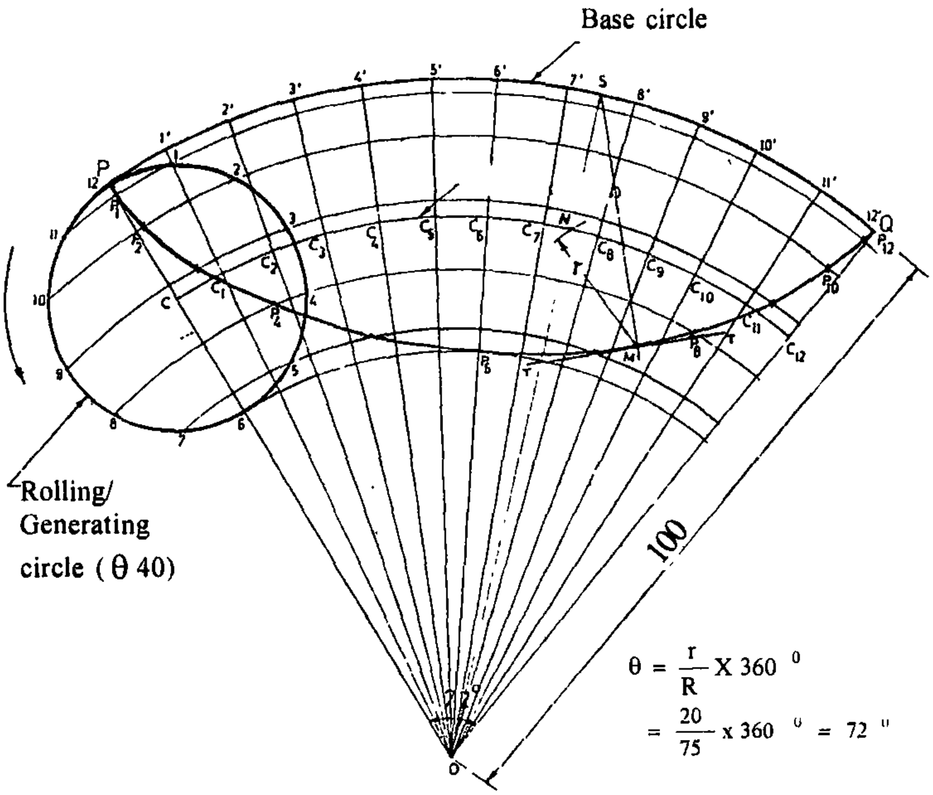


Fig. 1.32 Construction of a Hypocycloid

Involutes:

An involute is a curve traced by a point on a perfectly flexible string, while unwinding from around a circle or polygon the string being kept taut (tight). It is also a curve traced by a point on a straight line while the line is rolling around a circle or polygon without slipping.

Problem: To draw an involute of a given square.

Construction:

1. Draw the given square ABCD of side a.
2. Taking A as the starting point, with centre B and radius BA=a, draw an arc to intersect the line CB produced at P_1.
3. With Centre C and radius CP_1 =2 a, draw on arc to intersect the line DC produced at P_2.
4. Similarly, locate the points P_3 and P_4.

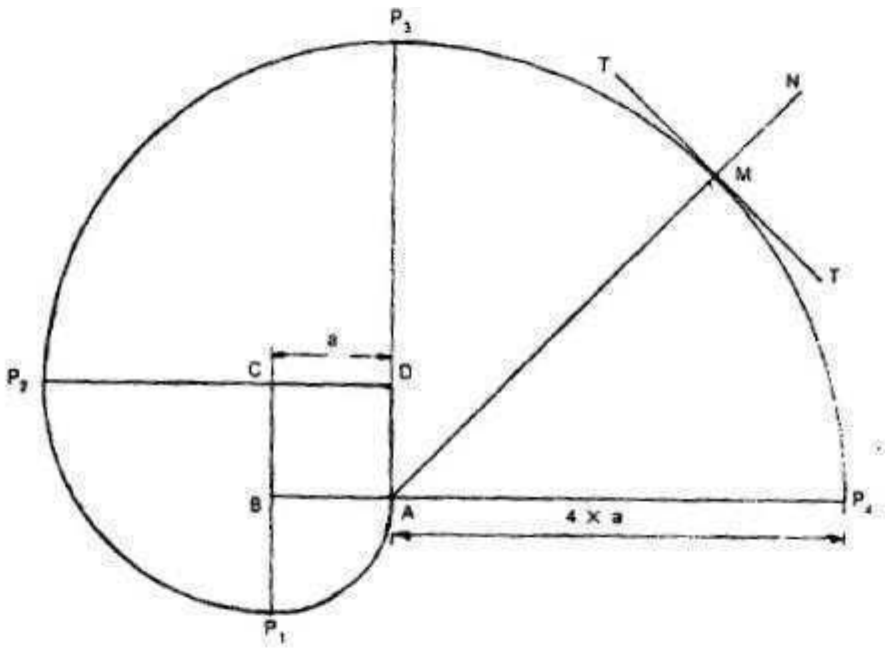


Fig. 1.33 Construction of an Involute of a Square

Problem: Draw an Involute of a circle of 50 mm diameter. Also draw Tangent and normal at a point distant 100 mm from the center of the circle.

Construction: 1) Point or end P of string AP is exactly πD distance away from A. Means if this string is wound round the circle, it will completely cover given circle. B will meet A after winding.

2) Divide πD (AP) distance into 8 numbers of equal parts.

3) Divide circle also into 8 numbers of equal parts.

4) Name after A, 1, 2, 3, 4, etc. up to 8 on πD line AP as well as on circle (in anticlockwise direction).

5) To radius C-1, C-2, C-3 up to C-8 draw tangents (from 1, 2, 3, 4, etc to circle).

6) Take distance 1 to P in compass and mark it on tangent from point 1 on circle (means one division less than distance AP).

7) Name this point P_1.

8) Take 2-B distance in compass and mark it on the tangent from point 2. Name it point P_2.

9) Similarly take 3 to P, 4 to P, 5 to P up to 7 to P distance in compass and mark on respective tangents and locate P_3, P_4, P_5 up to P_8 (i.e. A) points and join them in smooth curve it is an INVOLUTE of a given circle.

Involute Method of Drawing Tangent & Normal

1) Mark point q on it as directed.

2) Join q to the center of circle c. considering cq diameter, draw a semicircle as shown.

3) Mark point of intersection of this semicircle and pole circle and join it to q.

4) This will be normal to involute.

5) Draw a line at right angle to this line from q.

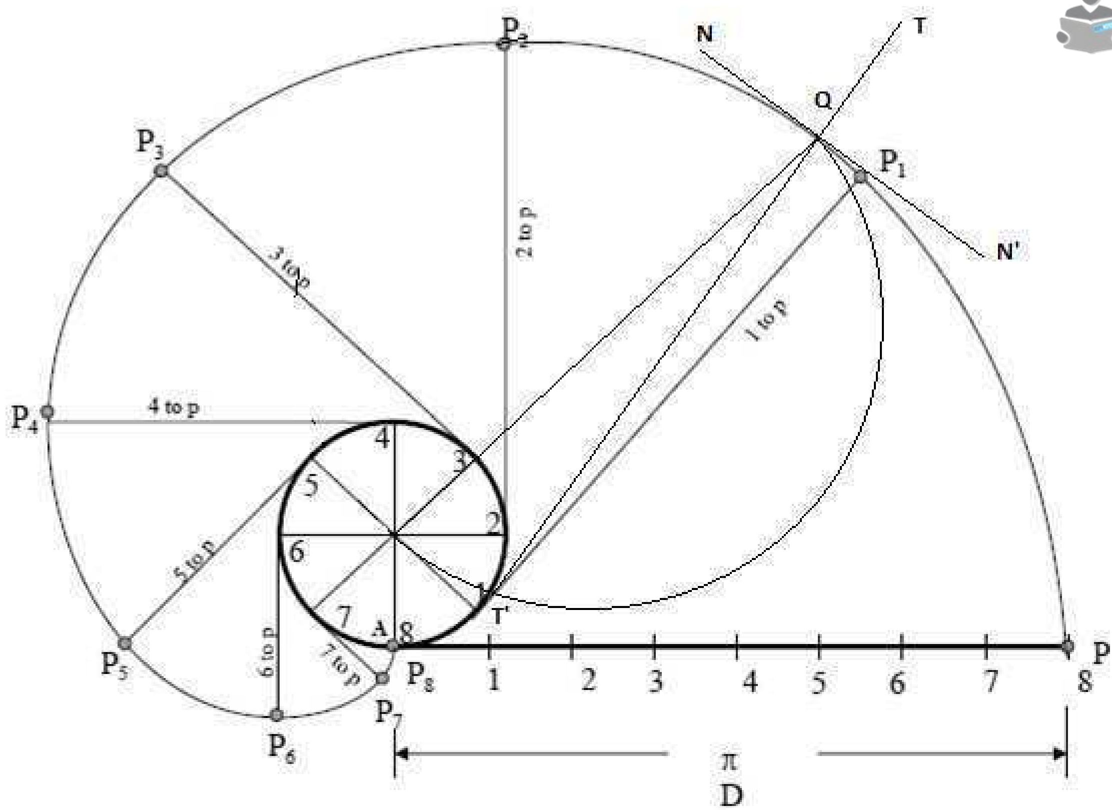


Fig. 1.34 Construction of an Involute of a Circle

Spirals:

If a line rotates in a plane about one of its end and at the same time, if a point moves along the line continuously in one direction, the curve traced out by the moving point is called Spiral.

Terminologies used in spirals are as follows:

1. Pole: Fixed end of the line about which the line rotates.

2. Radius Vector: The line joining any point of the curve with the pole.

3. Vectorial Angle: Angle between the initial position of the line and the instantaneous position of the line.

4. Convolution: Rotation of the moving line through 360 is called one convolution. A spiral make any number of convolution before it reaches the final destination.

Types of Spiral

1. Archimedean Spiral: An Archimedean Spiral is a curve traced out by a point moving uniformly along a straight line towards or away from the pole, while the line revolves about its one of the ends with uniform angular velocity.

Problem: Construct an Archimedean spiral for one and half convolution. The greatest and the least radii being 50 mm and 14 mm respectively. Draw tangent and normal to the spiral at a point 40 mm from the center.

Construction:

1) Draw a horizontal axis of the length equal to 100 mm. And mark the center point O on it.

2) Draw a vertical axis bisecting and perpendicular to the horizontal axis passing through the point O.

3) With O as center and radii equal to 50 mm and 14 mm respectively draw two circles.

4) Divide these circles into 12 equal divisions. And give the notations 0, 1, 2, 3, etc. up to 18 because of one and half convolution of the curve as shown into the figure.

5) Now divide the distance between the two circles, which is 50 mm – 14 mm = 36mm, on the horizontal axis into the same number of division as of the circle, which is 18 because of one and half convolution. So, the distance between the two consecutive divisions is 2 mm.

6) With O as center and radius equal to O1 on the horizontal axis draw an arc between the respective divisional lines of the circle OO & O1 as per the figure given above. Like in the same way draw 18 arcs.

7) Draw a smooth medium dark free hand curve from the end points of the previously drawn arcs in sequence to get Archimedean Curve.

8) To draw normal and tangent to the curve mark a point say K to the curve at the given distance which is 40 mm form the center O by a compass. Draw a line starting from this point K to the center of the circle O. With this line KO draw a perpendicular line of the length equal to value of the formula given below:

X = Distance between the two radius vectors in mm/ Difference of these two radius vectors in radians.

Here it is selected as OO – O3, which is equal to 3.81 mm. Now from the end point of this line draw a medium dark line which passes through the point K, that is normal to the curve. And draw a perpendicular line to the normal and passing through the point K which is tangent to the curve.

9) Give the dimensions by any one method of dimensions and give the name of the components by leader lines wherever necessary.

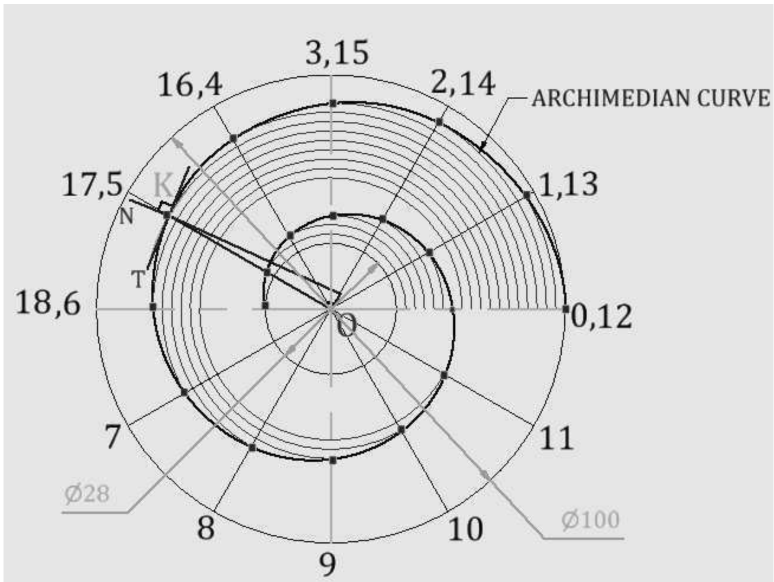


Fig. 1.35 Construction of an Archimedean Spiral

2. Logarithmic Spiral*:* The ratio of the lengths of consecutive radius vectors enclosing equal angles is always constant. I.e. the values of the vectorial angles are in arithmetic progression and the corresponding values of radius vectors are in geometric progression.

Problem: Ratio of lengths of radius vectors enclosing angle of 30° = 5:6. Final radius vector of the spiral is 90 mm. Draw the spiral.

Construction:

1. Draw line AB and AC inclined at 30°.
2. On line AB, mark A -12 = 90 mm. A as center and A12 radius draw an arc to cut AC at 12′.
3. Mark A11 (= 5/6 of A12) on AB. Join 12′ and 11.
4. Draw an arc with A as center and A11 radius to cut the line AC at 11′.
5. Draw a line through 11′ parallel to 12′-11 to cut AB at 10. Repeat the procedure to obtain points 9′, 8′, and 7′…0.

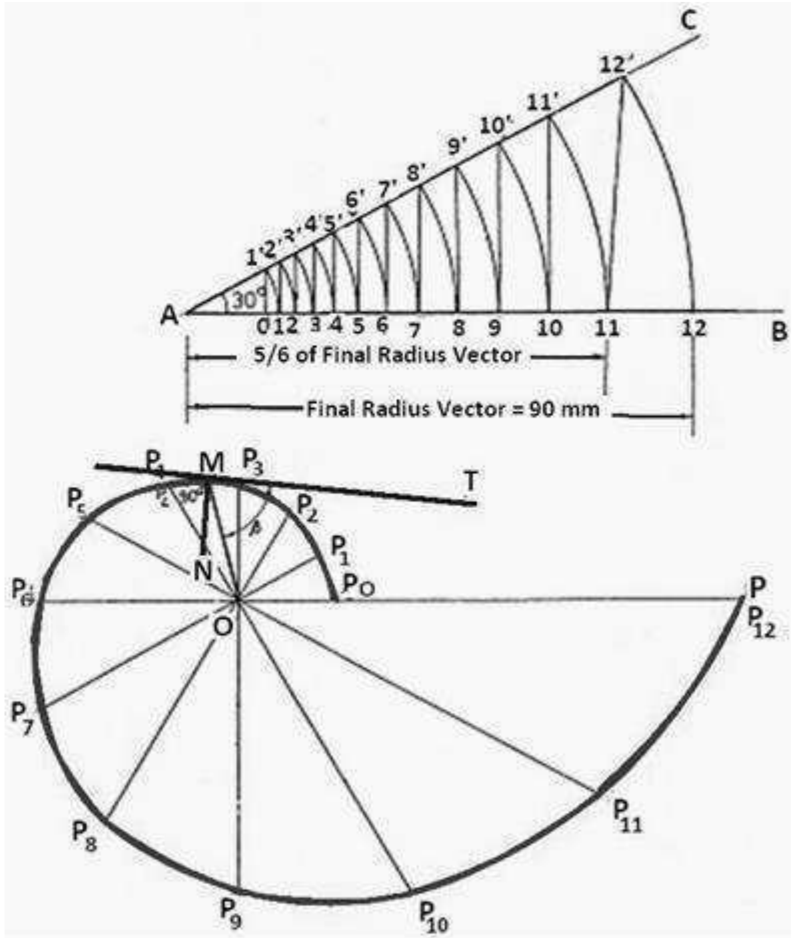


Fig. 1.36 Construction of an Logarithmic Spiral

