ENGINEERING GRAPHICS

(Engineering Drawing is the language of Engineers)

UNIT-I

Geometrical Constructions, Conic Section (Ellipse, Parabola & Hyperbola) - Cycloids, epicycloids, hypocycloids & Involutes

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
- Compass
- Set squares
- Protractor
- Scale Set
- French curves
- Drawing clips
- Duster piece of cloth (or) brush
- Sand-paper (or) Emery sheet block
- Drawing sheet

Drawing board and mini drafter

Below 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.

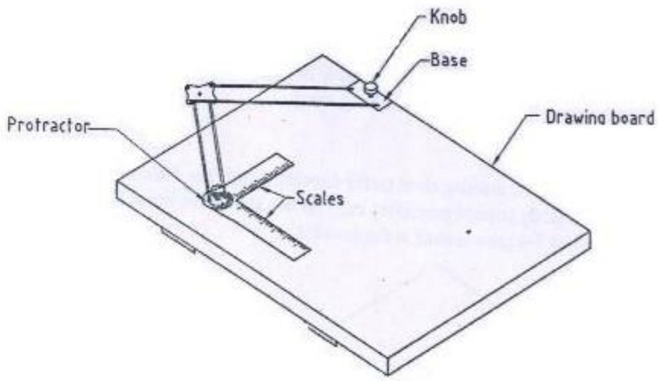
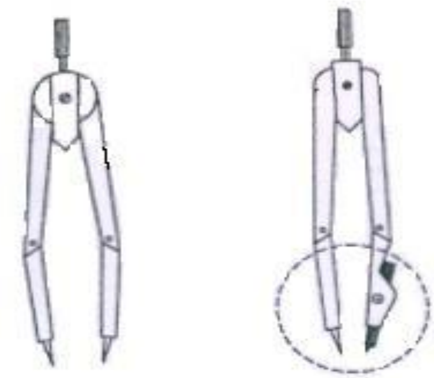


Figure Minidrafter fixed on drawing board

Divider and compass



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

Pro-circle

Protractor with procircles

Set squares

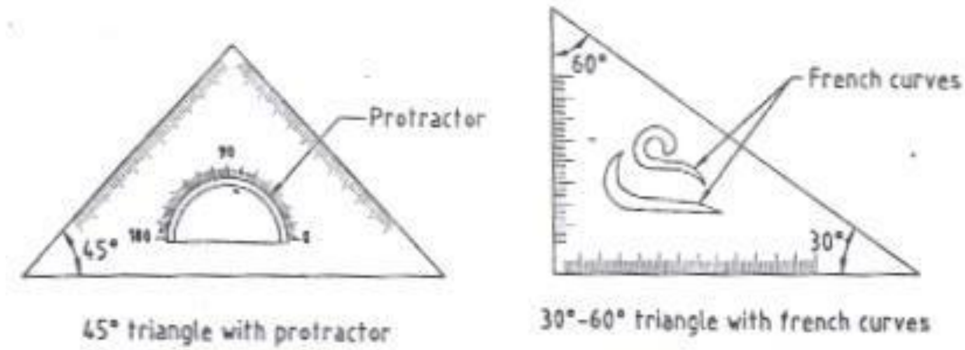


Figure *Set squares*

Sizes of drawing sheet

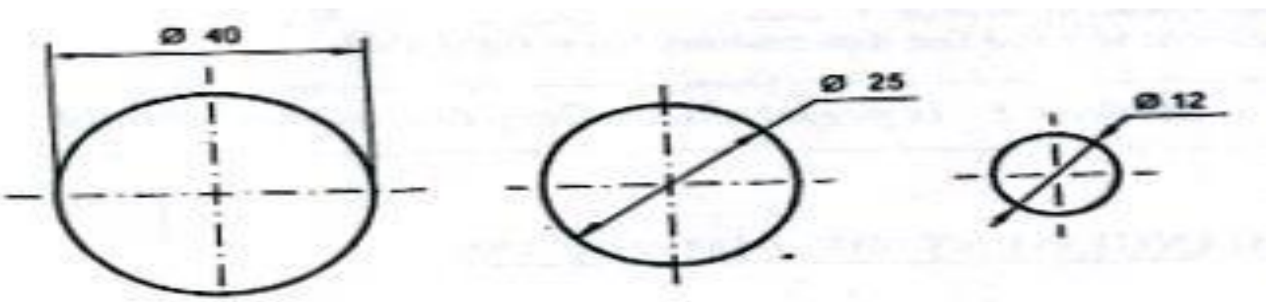
The table shows the designation of drawing sheet and its size in millimeter.

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:

Φ – diameter

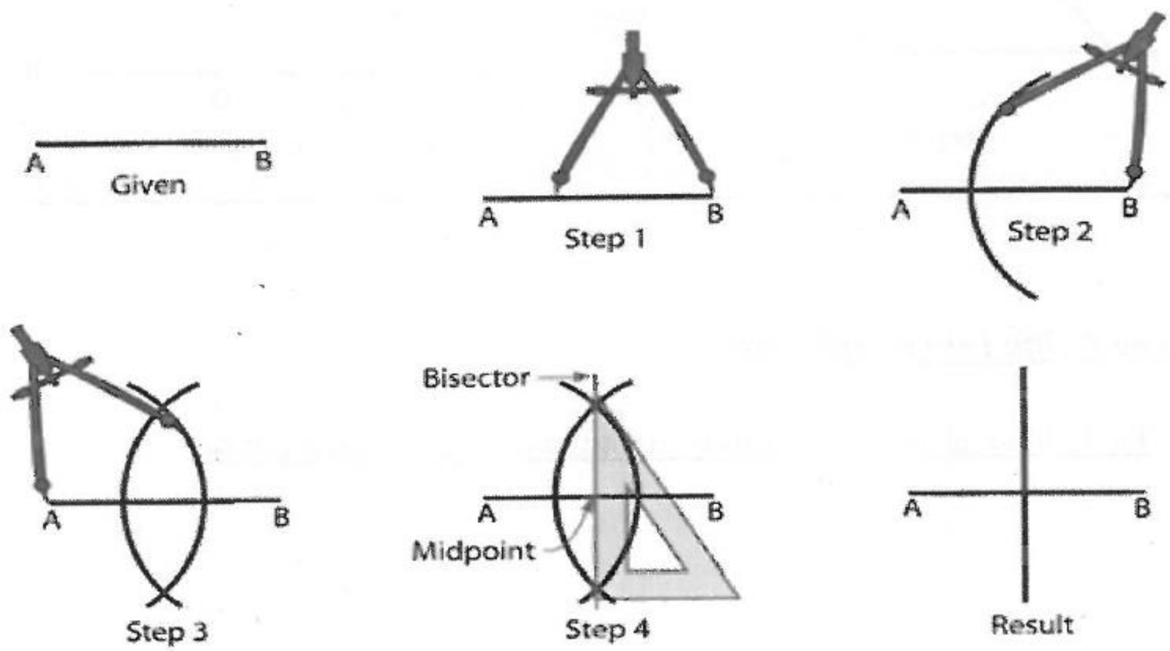
R - radius



Bisecting a line

The procedure of bisecting a given line AB is illustrated in below figure.

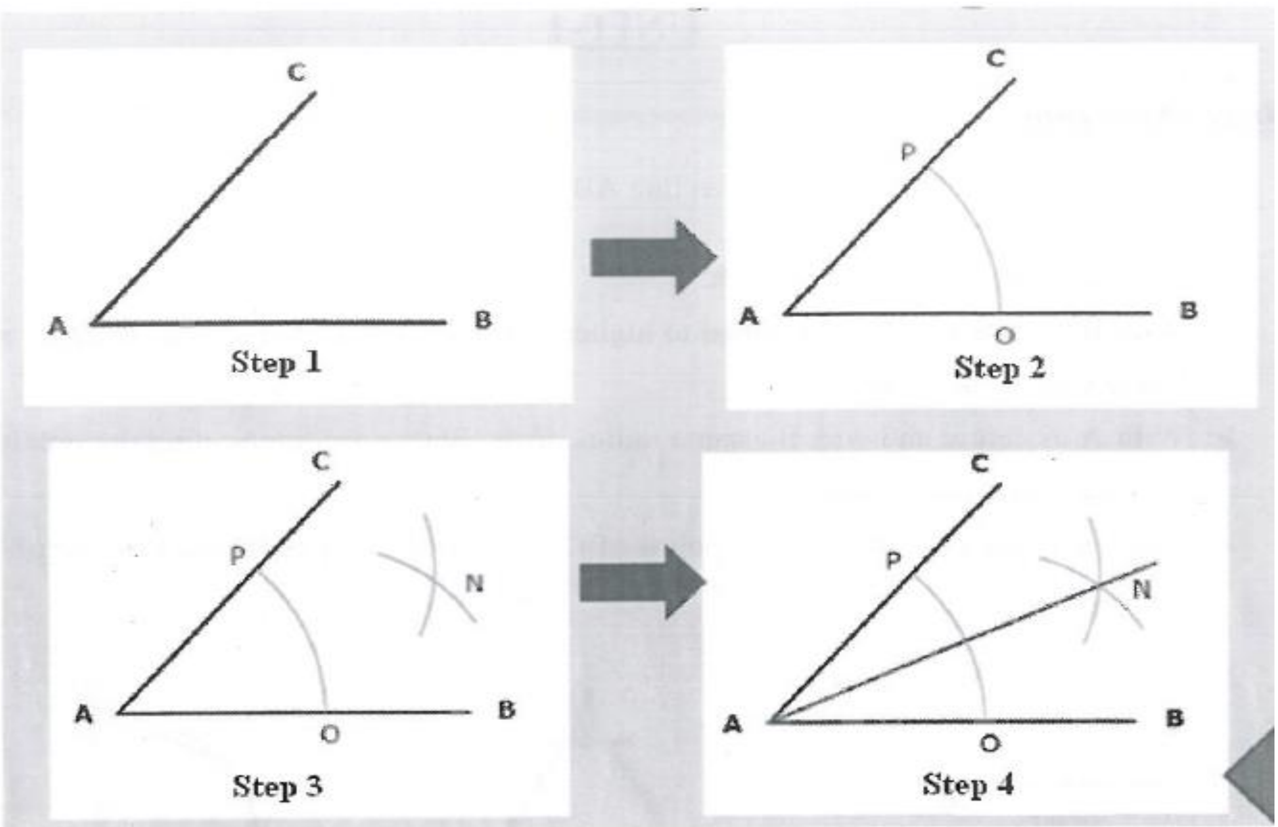
- Draw the line AB of given length.
- With B as centre and radius equal to higher than half AB, draw two arcs at upper and lower side of the given line.
- With A as centre and with the same radius draw another arc intersecting the previous arcs and name it as C and D.
- The line joining the intersection points of C and D is the perpendicular bisector of the line AB.



Bisect an angle

Let ABC be the given angle

- With A centre and any radius, draw an arc cutting AB at O and AC at P.
- With centres O and P and same radius or any convenient radius, draw arcs intersecting at each other at N.
- Draw a line joining A and N. AN bisects the angle ABC, i.e. $\llcorner CAN = \llcorner NAB$.



Dividing a line into equal parts

➢ **To divide a given straight line into any number of equal parts.**

Let *AB* be the given line to be divided into say, seven equal parts.

(i) Draw the line *AB* of given length.

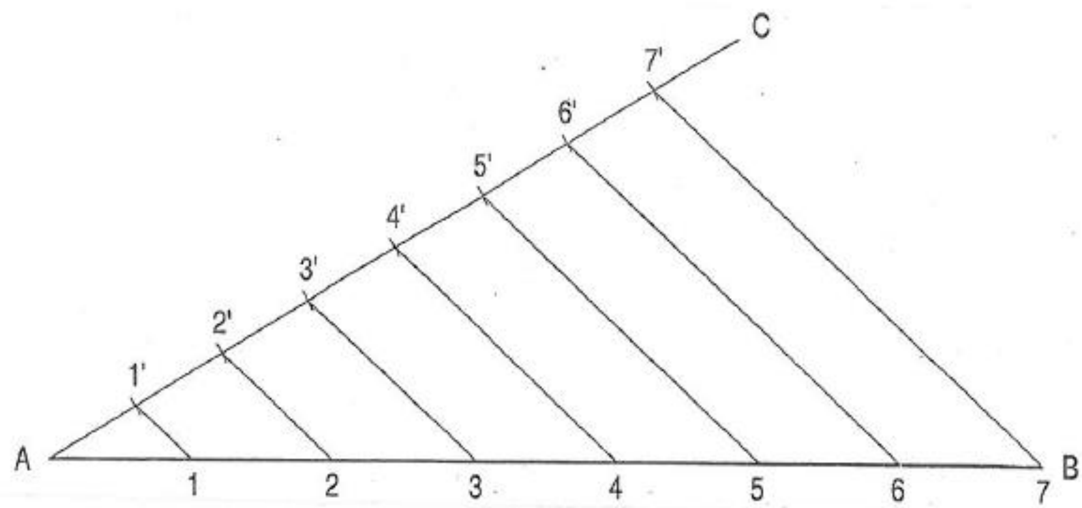
(ii) Draw another line *AC* making an angle of less than 30° with *AB*.

(iii) With the help of dividers mark 7 equal parts of any suitable length on line *AC* and mark them by points 1', 2', 3', 4', 5', 6' and 7' as shown.

(iv) Join the last point 7' with point *B* of the line *AB*.

(v) Now, from each of the other marked points 6', 5' 4', 3', 2' and 1', draw lines parallel to *7'B* cutting the line *AB* at 6, 5, 4, 3, 2 and 1 respectively.

(vi) Now the line *AB* has been divided into 7 equal parts. You can verify this by measuring the lengths.



Problems:

❖ **Draw a line AB, 150 mm long and divide it into 11 equal parts.**

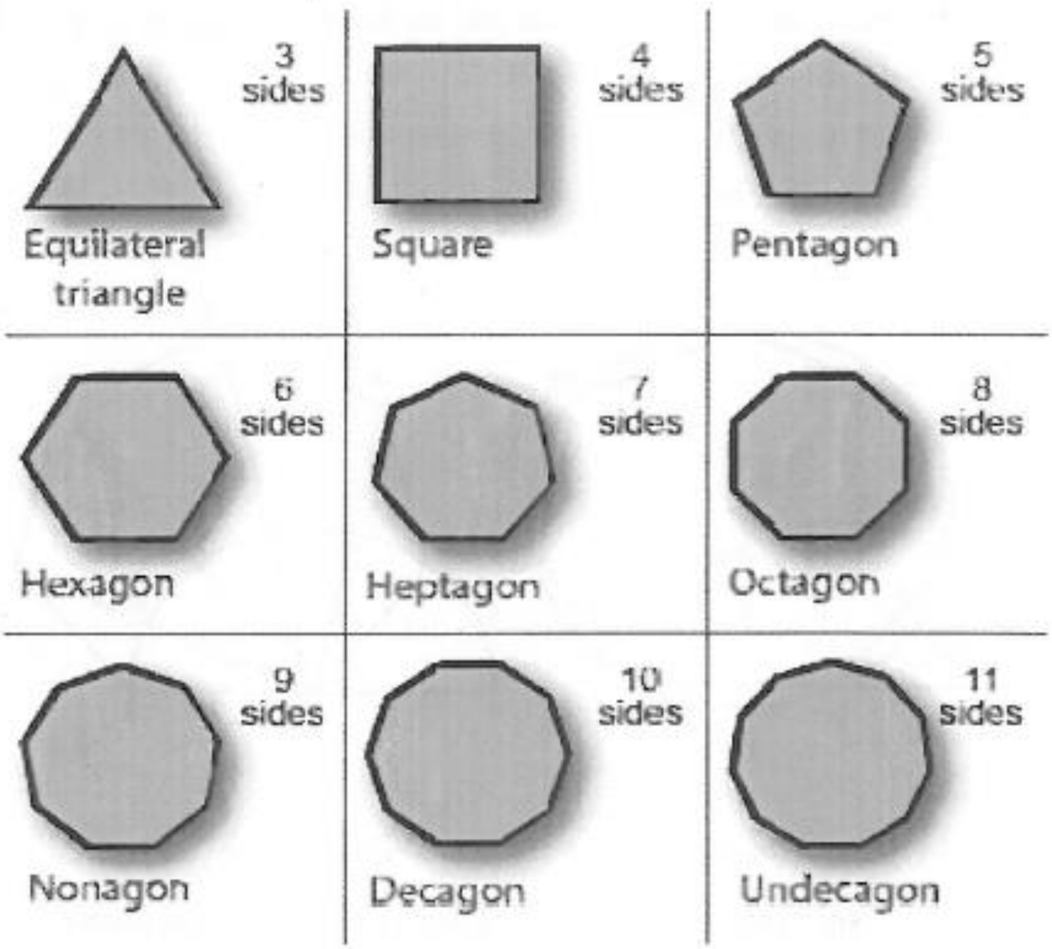
❖ **Draw a line AB, 70 mm long and divide it into 9 equal parts.**

REGULAR POLYGONS

Regular Polygon:

A **regular polygon** is a polygon that is equiangular (all angles are equal in measure) and equilateral (all sides have the same length).

Generally, some regular polygons are

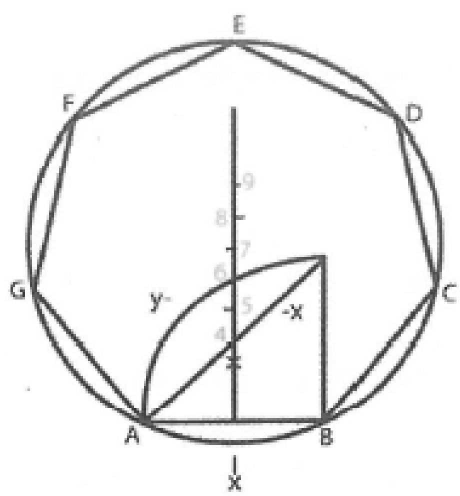


General method of drawing any polygon

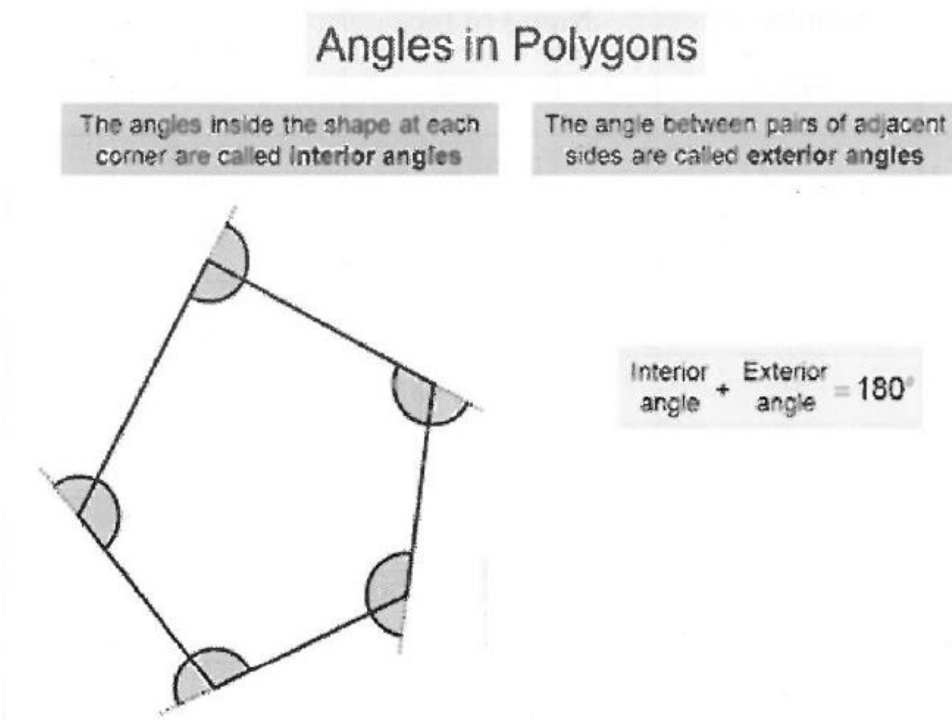
A more general method of drawing any polygon with a given length of edge.

- Draw a line AB equal to given length.
- At B, Draw a line BP perpendicular and equal to AB.
- Draw a line joining A with P.
- With centre B and radius AB, draw arc AP.
- Draw the perpendicular bisector of AB meets the line AP in 4 and arc AP in 6.
  - **(a)** A square of side equal to AB can be inscribed in the circle drawn with centre 4 and radius A4.
  - **(b)** A regular hexagon of side equal to AB can be inscribed in the circle drawn with centre 6 and radius A6.
  - **(c)** The mid-point 5 of the line 4-6 is the centre of the circle of the radius A5 in which a regular pentagon of a side equal to AB can be inscribed.
  - **(d)** To locate centre 7 for the regular heptagon of side AB, step-off a division 6-7 equal to the division 5-6.
    - (i) With centre 7 and radius equal to A7, draw a circle.
    - (ii) Starting from B, cut it in seven equal divisions with radius equal to AB.
    - (iii) Draw lines BC, CD etc. and complete the heptagon.

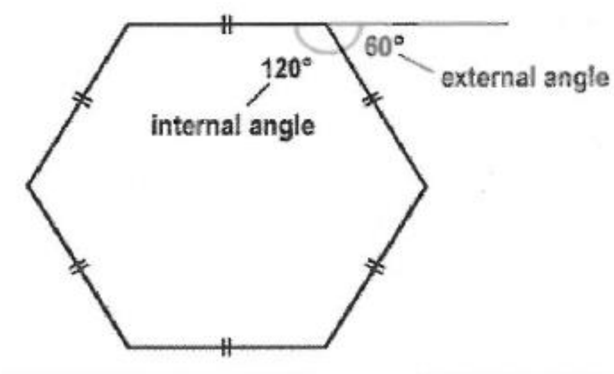
Regular polygons of any number of sides can be drawn by this method.

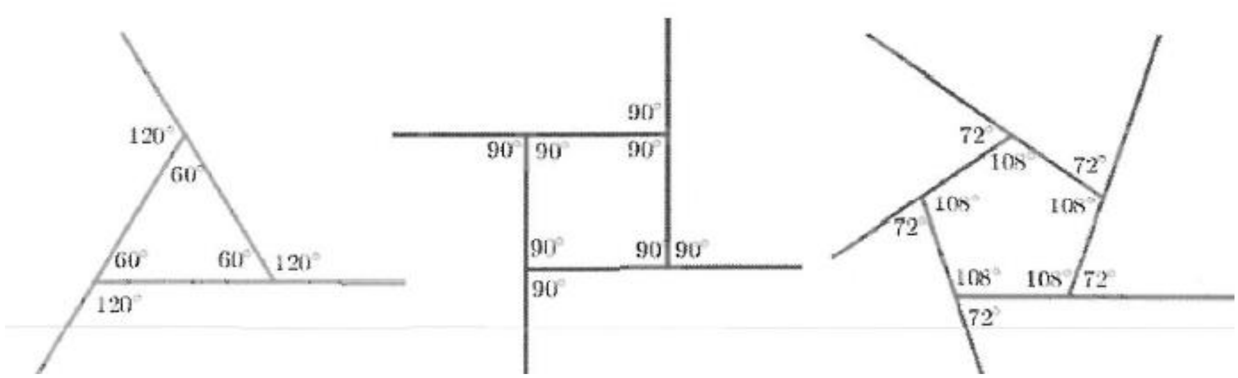


Angular method of drawing any polygon



Examples:





Exterior and Interior angles in Regular Polygons

S.No	Number of Sides	Name of the Polygon	Exterior Angle	Interior Angle
1	3	Triangle	120^0	60^0
2	4	Square	90^0	90^0
3	5	Pentagon	72^0	108^0
4	6	Hexagon	60^0	120^0
5	7	Heptagon	51.42^0	128.58^0
6	8	Octagon	45^0	135^0
7	9	Nonagon	40^0	140^0
8	10	Decagon	36^0	144^0

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.

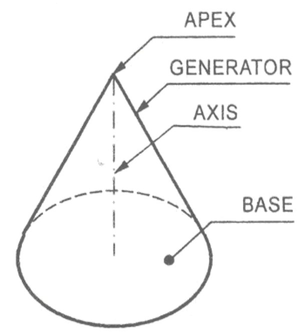


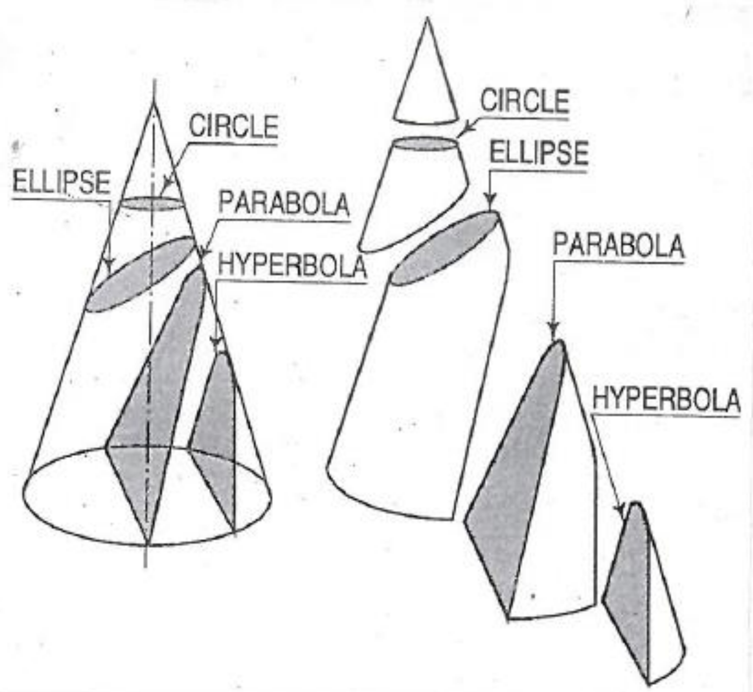
Figure 1

A figure formed by the intersection of a plane and a circular cone. Depending on the angle of the plane with respect to the cone, a conic section may be a circle, an ellipse, a parabola, or a hyperbola.

(ii) ***When a section plane is inclined to the axis and cuts all the generators on one side of the apex, the section is an ellipse.***

(iii) ***When a section plane is inclined to the axis and parallel to one of the generators, the section is parabola.***

(iv) ***When a section plane is parallel / inclined to the axis and cuts cone on one side of the axis, the section is hyperbola.***



Conic is defined as the locus of a point moving in a plane such that the ratio of its distance from a fixed point and a fixed straight line is always constant.

- **Fixed point is called Focus.**
- **Fixed line is called Directrix.**

$$\text{Eccentricity} = \frac{\text{Distance of the point from the focus}}{\text{Distance of the point from the directric}}$$

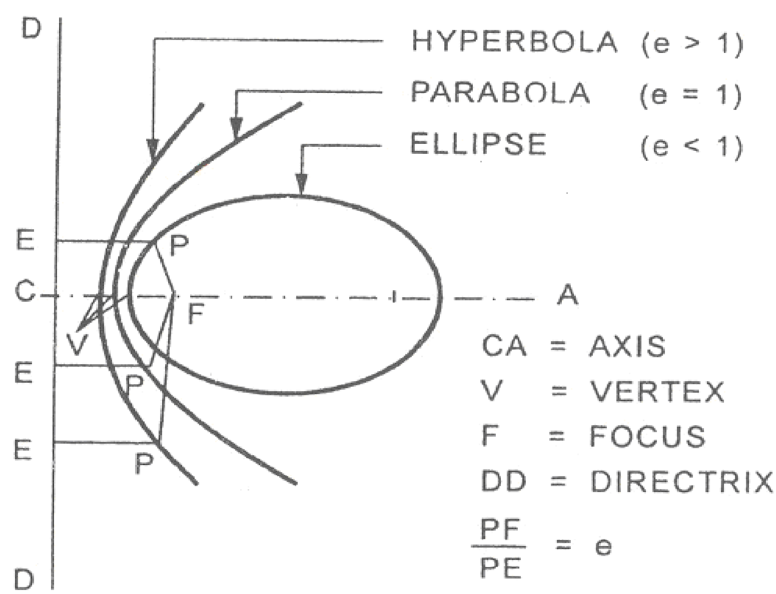
The eccentricity is denoted by "e".

For

- **Ellipse : e < 1**
- **Parabola : e = 1**
- **Hyperbola : e > 1**

The line passing through the focus and perpendicular to the Directrix is called the axis. The point at which the conic cuts its axis is called the vertex.

Construction of conic curves by eccentricity method



(a) ELLIPSE

General method:

To construct an ellipse when the distance of the focus from the Directrix is equal to 50 mm and the eccentricity is 2/3.

(i) Draw any vertical line AB as directrix.

(ii) At any point C on it, draw the axis perpendicular to the AB (directrix).

(iii) Mark a focus F on the axis such that $CF = 50$ mm.

(iv) Divide CF into 5 equal divisions (sum of numerator and denometer of the eccentricity.).

(v) Mark the vertex V on the third division-point from C.

Thus, eccentricity, $e = \frac{VF}{VC} = \frac{2}{3}$.

(vi) A scale may now be constructed on the axis (as explained below), which will directly give the distances in the required ratio.

(vii) At V, draw a perpendicular VE equal to VF. Draw a line joining C and E.

Thus, in triangle CVE, $\frac{VE}{VC} = \frac{VF}{VC} = \frac{2}{3}$.

(viii) Mark any point 1 on the axis and through it, draw a perpendicular to meet CE-produced at 1'.

(ix) With centre F and radius equal to 1-1', draw arcs to intersect the perpendicular through 1 at points P_1 and P'_1.

These are the points on the ellipse, because the distance of P_1 from AB is equal to $C1$,

$$P_1 F = 1\text{-}1'$$

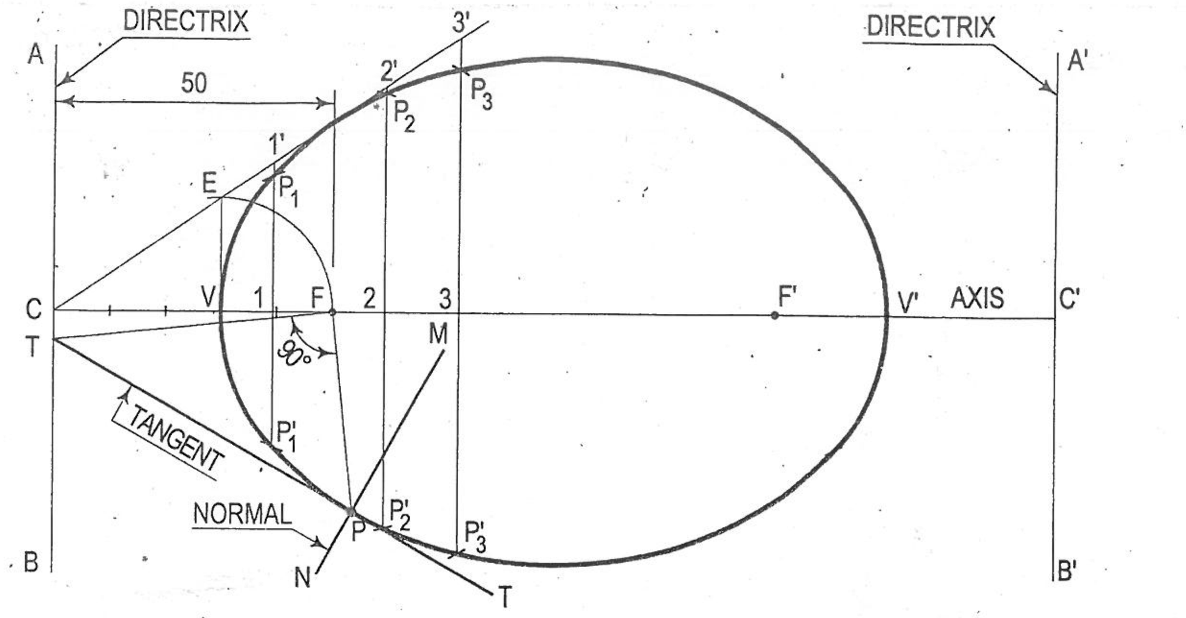
and $$\frac{1-1'}{C1} = \frac{VF}{VC} = \frac{2}{3}.$$

Similarly, mark points 2, 3 etc. on the axis and obtain points P_2 and P'_2, P_3 and P'_3 etc.

(x) Draw the ellipse through these points. It is a closed curve having two foci and two directrices.

Tangent and Normal to the curve

- Let P be a point on the curve. Join P with F.
- Draw a line perpendicular to PF will meet Directrix at T.
- Join T with P. This is the required Tangent.
- Draw a perpendicular to this tangent NM. It is the required Normal



Directrix and focus

Construction of ellipse by other methods:

Ellipse is also defined as a curve traced out by a point, moving in the same plane as and in such a way that the sum of its distances from two fixed points is always the same.

(i) The line passing through the two foci and terminated by the curve is called the major axis.

(ii) The line bisecting the major axis at right angles and terminated by the curve is called the minor axis.

The figure shows the, AB is the major axis, CD the minor axis and F_1 and F_2 are the foci. The foci are equidistant from the centre O.

The points A, P, C etc. are on the curve and hence, according to the definition,

$$(AF_1 + AF_2) = (PF_1 + PF_2) = (CF_1 + CF_2) \text{ etc.}$$

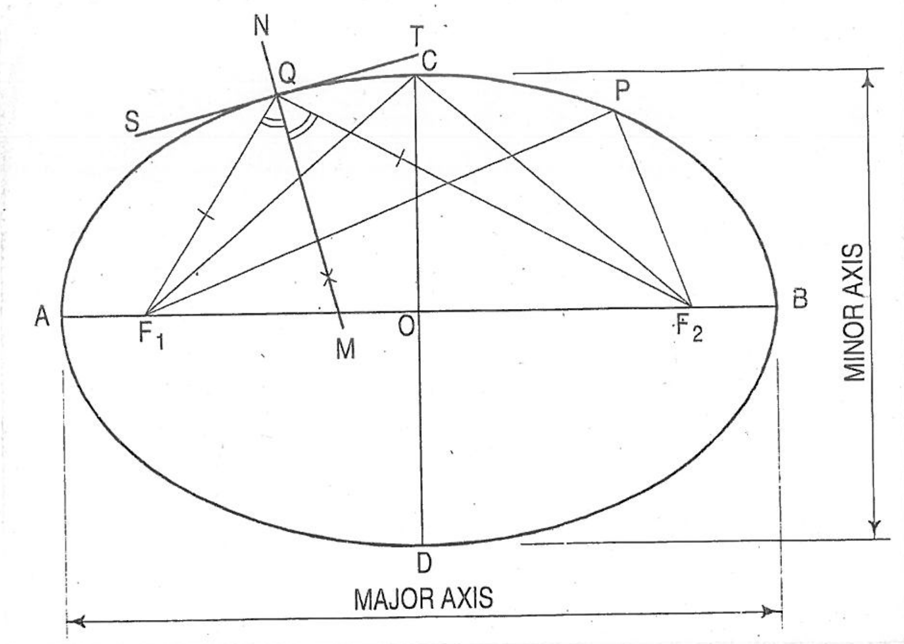
But $(AF_1 + AF_2) = AB$. $\therefore (PF_1 + PF_2) = AB$, the major axis.

Therefore, *the sum of the distances of any point on the curve from the two foci is equal to the major axis.*

Again, $(CF_1 + CF_2) = AB$.

But $CF_1 = CF_2$ $\therefore CF_1 = CF_2 = \frac{1}{2} AB$.

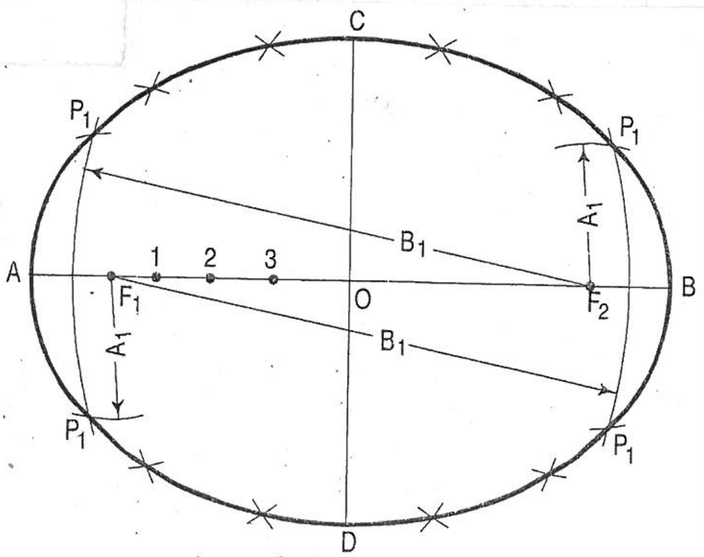
Hence, *the distance of the ends of the minor axis from the foci is equal to half the major axis.*



To construct an ellipse, given major axis and minor axis:

The ellipse is drawn by, first determining a number of points through which it is known to pass and then, drawing a smooth curve through them, by freehand. Larger the number of points, more accurate the curve will be.

Method I: Arcs of circles method



Arc of circle method

(i) Draw a line AB equal to the major axis and a line CD equal to the minor axis, bisecting each other at right angles at O.

(ii) With centre C and radius equal to half AB (i.e. AO) draw arcs cutting AB at F_1 and F_2, the foci of the ellipse.

(iii) Mark a number of points 1, 2, 3 etc. on AB.

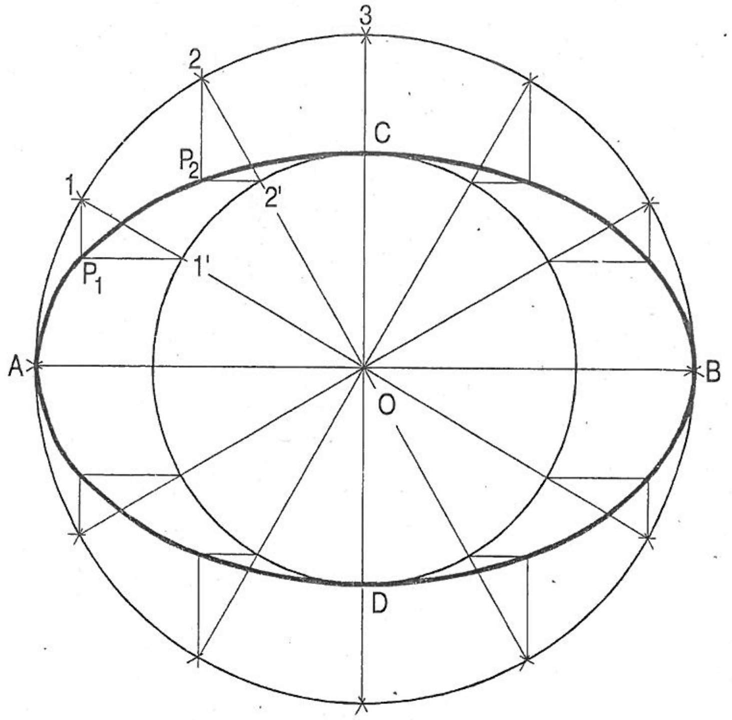
(iv) With centres F_1 and F_2 and radius equal to $A1$, draw arcs on both sides of AB.

(v) With same centres and radius equal to $B1$, draw arcs intersecting the previous arcs at four points marked P_1.

(vi) Similarly, with radii $A2$ and $B2$, $A3$ and $B3$ etc. obtain more points.

(vii) Draw a smooth curve through these points. This curve is the required ellipse.

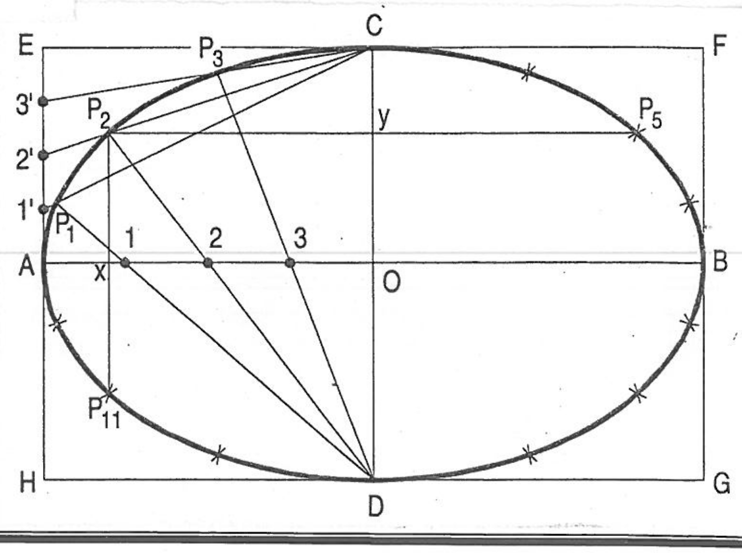
Method II: Concentric circles Method



Concentric circle method
FIG. 6-5

(i) Draw the major axis *AB* and the minor axis *CD* intersecting each other at *O*.
(ii) With centre *O* and diameters *AB* and *CD* respectively, draw two circles.
(iii) Divide the major-axis-circle into a number of equal divisions, say 12 and mark points 1, 2 etc. as shown.
(iv) Draw lines joining these points with the centre O and cutting the minor-axis-circle at points 1', 2' etc.
(v) Through point 1 on the major-axis-circle, draw a line parallel to *CD*, the minor axis.
(vi) Through point 1' on the minor-axis-circle, draw a line parallel to *AB*, the major axis. The point P_1, where these two lines intersect is on the required ellipse.
(vii) Repeat the construction through all the points. Draw the ellipse through *A*, P_1, P_2... etc.

Method III: Oblong method



(i) Draw the two axes AB and CD intersecting each other at O.

(ii) Construct the oblong $EFGH$ having its sides equal to the two axes.

(iii) Divide the semi-major-axis AO into a number of equal parts, say 4, and AE into the same number of equal parts, numbering them from A as shown.

(iv) Draw lines joining 1', 2' and 3' with C.

(v) From D, draw lines through 1, 2 and 3 intersecting C'_1, C'_2 and C'_3 at points P_1, P_2 and P_3 respectively.

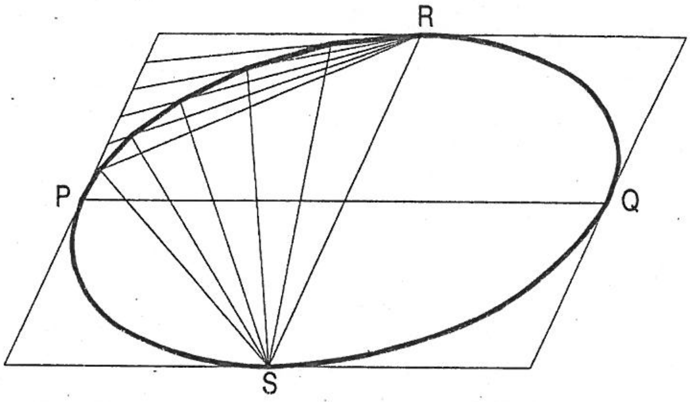
(vi) Draw the curve through A, P_1.....C. It will be one quarter of the ellipse.

(vii) Complete the curve by the same construction in each of the three remaining quadrants.

As the curve is symmetrical about the two axes, points in the remaining quadrants may be located by drawing perpendiculars and horizontals from P_1, P_2 etc. and making each of them of equal length on both the sides of the two axes.

For example, $P_2x = x\,P_{11}$ and $P_2y = yP_5$.

An ellipse can be inscribed within a parallelogram by using the above method as shown in fig. 6-8.



(b) PARABOLA

General method:

To construct a parabola, when the distance of the focus from the Directrix is 50 mm.

(i) Draw the directrix AB and the axis CD.

(ii) Mark focus F on CD, 50 mm from C.

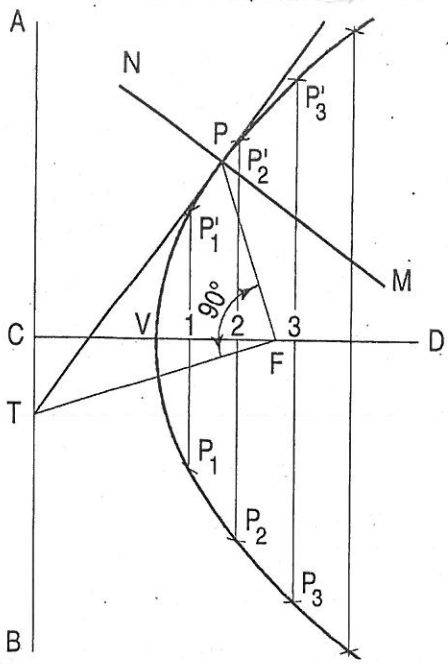
(iii) Bisect CF in V the vertex (because eccentricity = 1).

(iv) Mark a number of points 1, 2, 3 etc. on the axis and through them, draw perpendiculars to it.

(v) With centre F and radius equal to $C1$, draw arcs cutting the perpendicular through 1 at P_1 and P'_1.

(vi) Similarly, locate points P_2 and P'_2, P_3 and P'_3 etc. on both the sides of the axis.

(vii) Draw a smooth curve through these points. This curve is the required parabola. It is an open curve.



Directrix and focus

Construction of parabola by other methods

Method I: Rectangle method

To construct a parabola given the base and the axis.

(i) Draw the base AB.

(ii) At its mid-point E, draw the axis EF at right angles to AB.

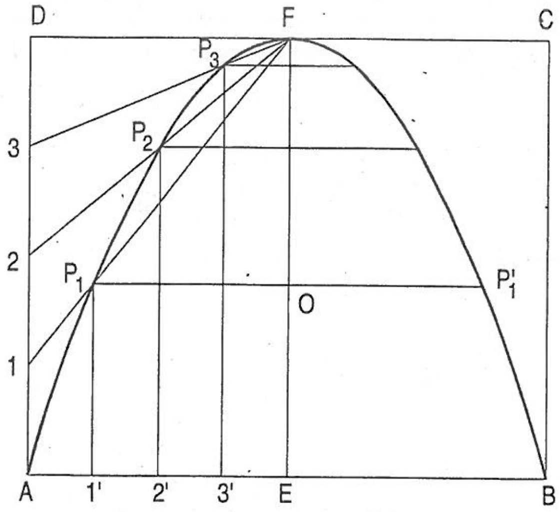
(iii) Construct a rectangle $ABCD$, making side BC equal to EF.

(iv) Divide AE and AD into the same number of equal parts and name them as shown (starting from A).

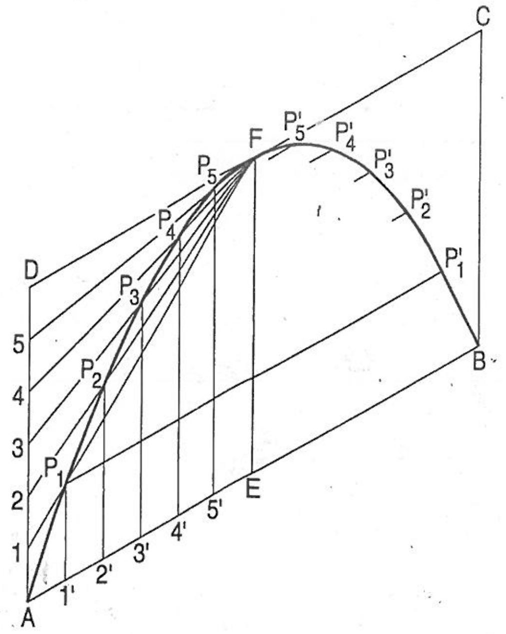
(v) Draw lines joining F with points 1, 2 and 3. Through 1', 2' and 3', draw perpendiculars to AB intersecting $F1$, $F2$ and $F3$ at points P_1, P_2 and P_3 respectively.

(vi) Draw a curve through A, P_1, P_2 etc. It will be a half parabola.

Repeat the same construction in the other half of the rectangle to complete the parabola. Or, locate the points by drawing lines through the points P_1, P_2 etc. parallel to the base and making each of them of equal length on both the sides of EF, e.g. $P_1O = OP'_1$. AB and EF are called the base and the axis respectively of the parabola.



Rectangle method



Parallelogram method

<u>Method II: Tangent method</u>

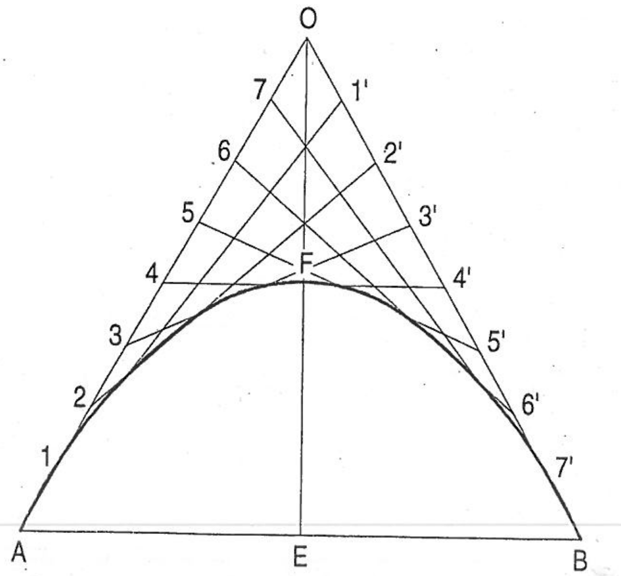
(i) Draw the base *AB* and the axis *EF*. (These are taken different from those in method I.)

(ii) Produce *EF* to *O* so that *EF* = *FO*.

(iii) Join *O* with *A* and *B*. Divide lines *OA* and *OB* into the same number of equal parts, say 8.

(iv) Mark the division-points as shown in the figure.

(v) Draw lines joining 1 with 1', 2 with 2' etc. Draw a curve starting from *A* and tangent to lines 1-1', 2-2' etc. This curve is the required parabola.



(C) HYPERBOLA

General method:

To construct a hyperbola when the distance of the focus from the Directrix is equal to 65 mm and the eccentricity is 3/2.

(i) Draw the directrix AB and the axis CD.

(ii) Mark the focus F on CD and 65 mm from C.

(iii) Divide CF into 5 equal divisions and mark V the vertex, on *the second division from C.*

Thus, eccentricity $= \dfrac{VF}{VC} = \dfrac{3}{2}$.

To construct the scale for the ratio $\dfrac{3}{2}$ draw a line VE perpendicular to CD such that $VE = VF$. Join C with E.

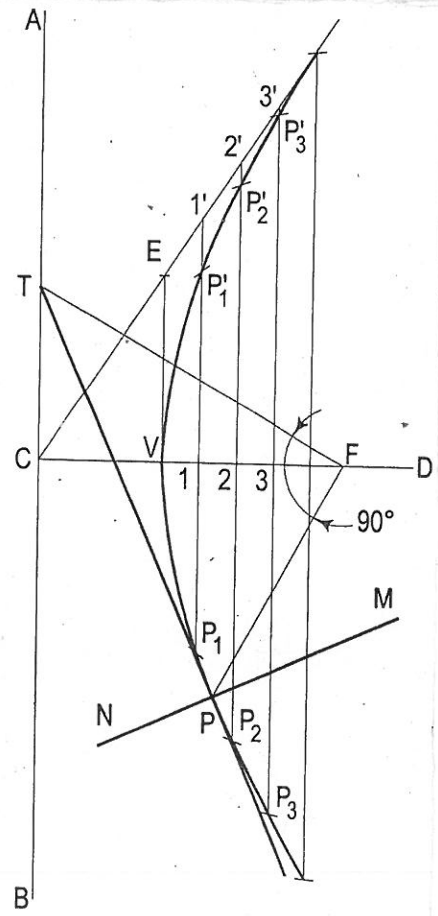
Thus, in triangle CVE, $\dfrac{VE}{VC} = \dfrac{VF}{VC} = \dfrac{3}{2}$.

(iv) Mark any point 1 on the axis and through it, draw a perpendicular to meet CE-produced at 1'.

(v) With centre F and radius equal to 1-1', draw arcs intersecting the perpendicular through 1 at P_1 and P'_1.

(vi) Similarly, mark a number of points 2, 3 etc. and obtain points P_2 and P'_2, P_3 and P'_3 etc.

(vii) Draw the hyperbola through these points.



To draw the rectangular hyperbola, given the position of a point P on it.

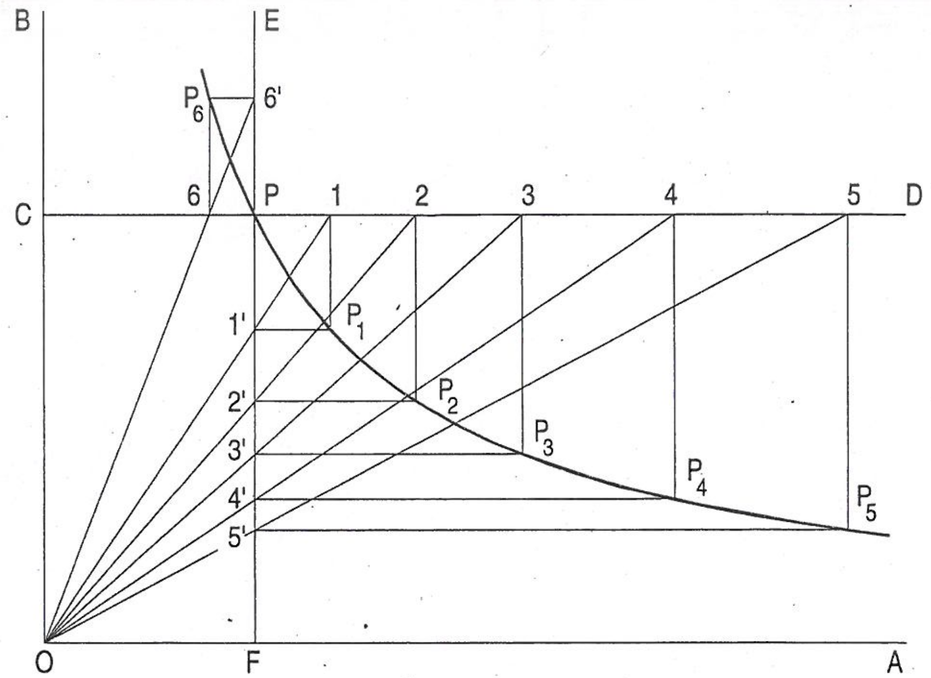


FIG. 6-23

(i) Draw lines *OA* and *OB* at right angles to each other.

(ii) Mark the position of the point *P*.

(iii) Through *P*, draw lines *CD* and *EF* parallel to *OA* and *OB* respectively.

(iv) Along *PD*, mark a number of points 1, 2, 3 etc. not necessarily equidistant.

(v) Draw lines *O*1, *O*2 etc. cutting *PF* at points 1', 2' etc.

(vi) Through point 1, draw a line parallel to *OB* and through 1', draw a line parallel to *OA*, intersecting each other at a point P_1.

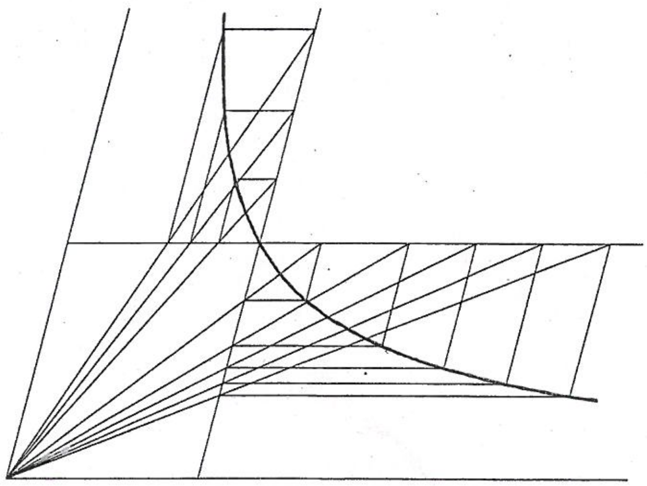


FIG. 6-24

(vii) Obtain other points in the same manner.

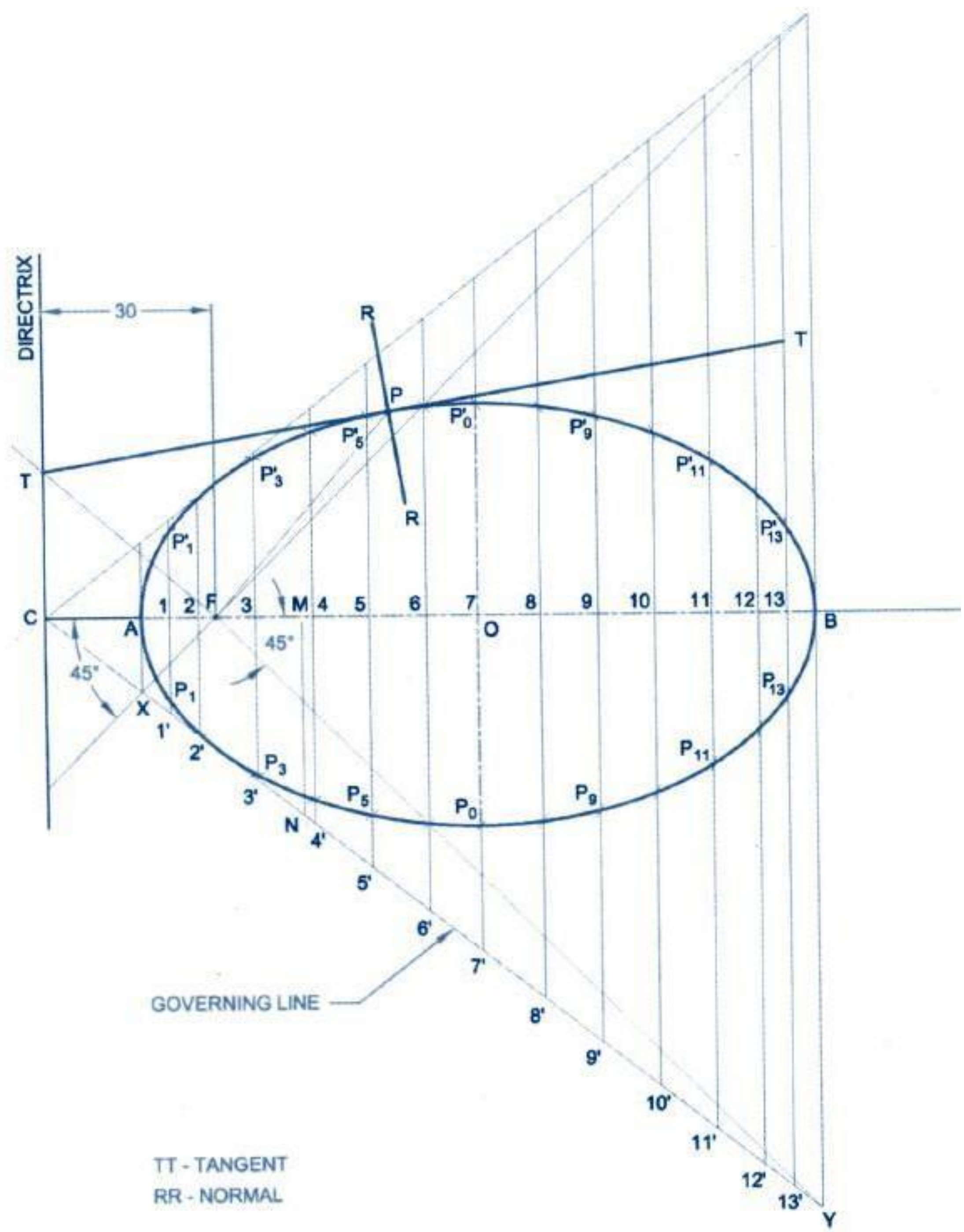
For locating the point, say P_6, to the left of *P*, the line *O*6 should be extended to meet *PE* at 6'. Draw the hyperbola through the points P_6, *P*, P_1 etc.

A hyperbola, through a given point situated between two lines making any angle between them, can similarly be drawn, as shown in fig. 6-24.

SOLVED EXAMPLES

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.



Procedure to find number of divisions and size of each division

Given,

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

$$\begin{aligned}\text{Number of division} &= \text{Numerator value} + \text{Denominator Value} \\ &= 2+3 \\ &= 5 \text{ divisions}\end{aligned}$$

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

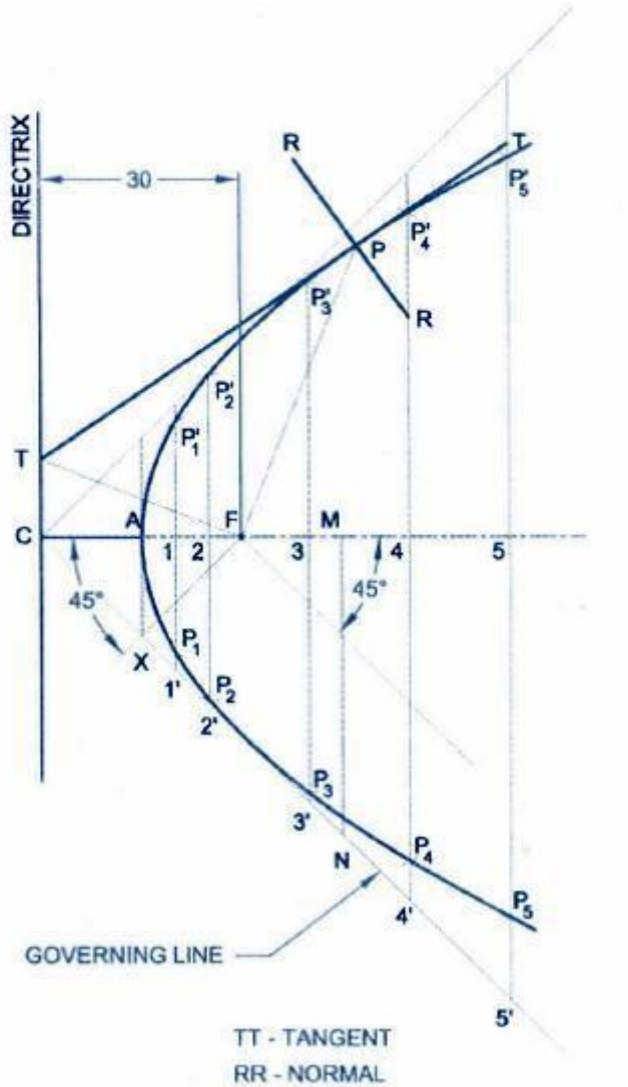
Procedure :

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>

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

$$\begin{aligned}\text{Number of division} &= \text{Numerator value} + \text{Denominator Value}\\ &= 1+1\\ &= 2 \text{ divisions}\end{aligned}$$

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

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

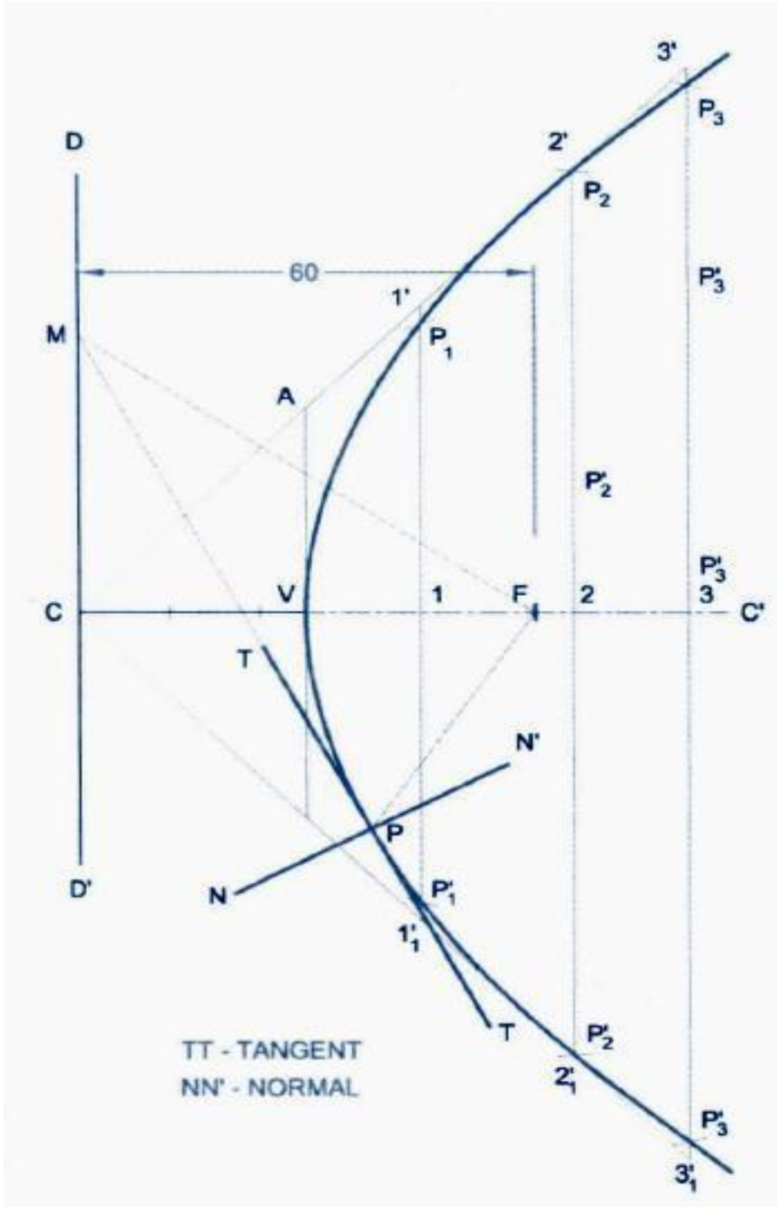
1. Mark a point P on the ellipse.
2. Join P and F.
3. Draw a perpendicular to the line PF till the line meets the directrix at the point T
4. Join the points T and P for getting a tangent for the ellipse.
5. Keep the protractor parallel to the line TP and draw the perpendicular line from P for getting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

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

$$\begin{aligned}\text{Number of division} &= \text{Numerator value} + \text{Denominator Value} \\ &= 3 + 2 \\ &= 5 \text{ divisions}\end{aligned}$$

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



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.