

# **DEPARTMENT OF MECHANICAL ENGINEERING**

## **B.Tech I Year I Semester ENGINEERING GRAPHICS**

**Subject Code: 23HES0301**

**Regulation: HM23**



**ANNAMACHARYA INSTITUTE OF TECHNOLOGY AND SCIENCES**

**(AUTONOMOUS)**

(Affiliated to J.N.T.U.A, Anantapur, Approved by A.I.C.T.E, New Delhi)

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Accredited by NAAC with 'A' Grade, Bangalore.

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## **ENGINEERING GRAPHICS**

(Common to All branches of Engineering)

### **Course Objectives:**

- To enable the students with various concepts like dimensioning, conventions and standards related to Engineering Drawing
- To impart knowledge on the projection of points, lines and plane surfaces
- To improve the visualization skills for better understanding of projection of solids
- To develop the imaginative skills of the students required to understand Section of solids and Developments of surfaces.
- To make the students understand the viewing perception of a solid object in Isometric and Perspective projections.

### **Course Outcomes:**

CO1: Understand the principles of engineering drawing, including engineering curves, scales, orthographic and isometric projections.

CO2: Draw and interpret orthographic projections of points, lines, planes and solids in front, top and side views.

CO3: Understand and draw projection of solids in various positions in first quadrant.

CO4: Explain principles behind development of surfaces.

CO5: Prepare isometric and perspective sections of simple solids.

## **UNIT I**

**Introduction:** Lines, Lettering and Dimensioning, Geometrical Constructions and Constructing regular polygons by general methods.

**Curves:** construction of ellipse, parabola and hyperbola by general, Cycloids, Involutess, Normal and tangent to Curves.

## **UNIT II**

**Orthographic Projections:** Reference plane, importance of reference lines or Plane, Projections of a point situated in any one of the four quadrants.

**Projections of Straight Lines:** Projections of straight lines parallel to both reference planes, perpendicular to one reference plane and parallel to other reference plane, inclined to one reference plane and parallel to the other reference plane. Projections of Straight Line Inclined to both the reference planes

**Projections of Planes:** regular planes Perpendicular to both reference planes, parallel to one reference plane and inclined to the other reference plane; plane inclined to both the reference planes.

### UNIT III

**Projections of Solids:** Types of solids: Polyhedra and Solids of revolution. Projections of solids in simple positions: Axis perpendicular to horizontal plane, Axis perpendicular to vertical plane and Axis parallel to both the reference planes, Projection of Solids with axis inclined to one reference plane and parallel to another plane.

### UNIT IV

**Sections of Solids:** Perpendicular and inclined section planes, Sectional views and True shape of section, Sections of solids in simple position only.

**Development of Surfaces:** Methods of Development: Parallel line development and radial line development. Development of a cube, prism, cylinder, pyramid and cone.

### UNIT V

**Conversion of Views:** Conversion of isometric views to orthographic views; Conversion of orthographic views to isometric views.

**Computer graphics:** Creating 2D&3D drawings of objects including PCB and Transformations using Auto CAD (*Not for end examination*).

### Textbook:

1. N.D. Bhatt, Engineering Drawing, Charotar Publishing House, 2016.

### Reference Books:

1. Engineering Drawing, K.L. Narayana and P.Kannaiah, Tata McGraw Hill, 2013.
2. Engineering Drawing, M.B.Shah and B.C. Rana, Pearson Education Inc, 2009.
3. Engineering Drawing with an Introduction to AutoCAD, Dhananjay Jolhe, Tata McGraw Hill, 2017.

# UNIT-1

## INTRODUCTION TO ENGINEERING DRAWING

Engineering drawing is a two dimensional representation of three dimensional objects. In general, it provides necessary information about the shape, size, surface quality, material, manufacturing process, etc., of the object. It is the graphic language from which a trained person can visualize objects.

### Drawing Instruments and aids:

The Instruments and other aids used in drafting work are listed below:

- Drawing board
- Setsquares
- French curves
- Templates
- Mini drafter
- Instrument box
- Protractor
- Set of scales
- Drawing sheets
- Pencils

### Drawing Board:

Until recently drawing boards used are made of well seasoned softwood of about 25 mm thick with a working edge for T-square. Nowadays mini-drafters are used instead of T-squares which can be fixed on any board. The standard size of board depends on the size of drawing sheet size required.

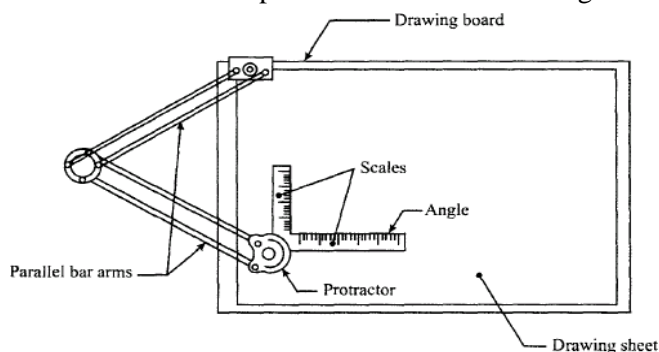


Fig. 1.1 Mini-drafter

### Mini-Drafter:

Mini-drafter consists of an angle formed by two arms with scales marked and rigidly hinged to each other. It combines the functions of T-square, set-squares, scales and protractor. It is used for drawing horizontal, vertical and inclined lines, parallel and perpendicular lines and for measuring lines and angles.

**Instrument Box**

Instrument box contains 1. Compasses, 2. Dividers and 3. Inking pens.

What is important is the position of the pencil lead with respect to the tip of the compass. It should be at least 1 mm above as shown in the fig. because the tip goes into the board for grip by 1 mm.

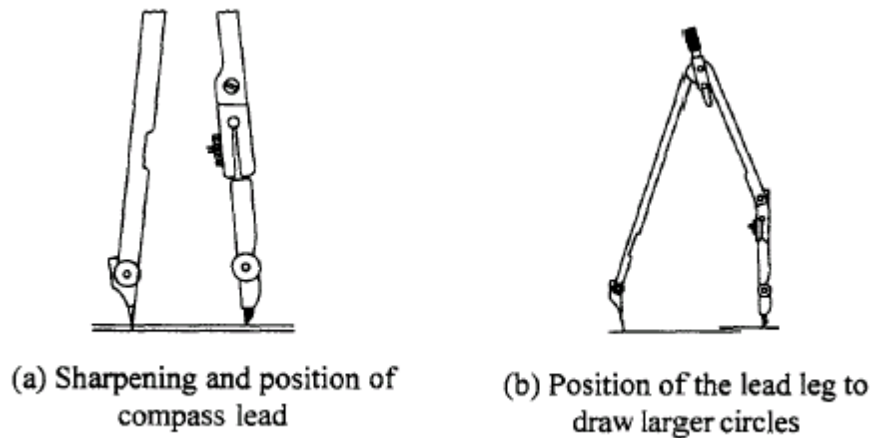


Figure.1.2

**Pencils:**

Pencils with leads of different degrees of hardness or grades are available in the market. The hardness or softness of the lead is indicated by 3H, 2H, H, HB, B, 2B, 3B etc. The grade HB denotes medium hardness of lead used for general purpose. The hardness increases as the value of the numeral before the letter H increases. The lead becomes softer, as the value of the numeral before B increases.

- HB of grade for Border lines, lettering and free sketching
- H Medium grade for Visible out lines, visible edges and boundary lines
- 2H Hard grade for construction lines, Dimension lines, Leader lines, Extension lines, Centre lines, Hatching lines and Hidden lines.

**Drawing Sheet:**

The standard drawing sheet sizes are arrived at on the basic Principal of  $x:y=1:2^{1/2}$  and  $xy=1$  where x and y are the sides of the sheet. For example A0, having a surface area of 1 Sq. m;  $x = 841$  mm and  $y = 1189$  mm. The successive sizes are obtained by either by halving along the length or doubling the width, the area being in the ratio 1: 2. Designation of sizes is given in the fig. For class work use of A2 size drawing sheet is preferred.

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

Table.1.1

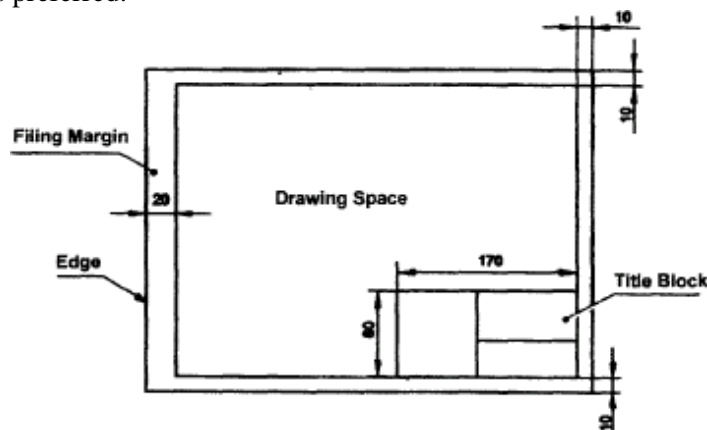


Figure.1.3

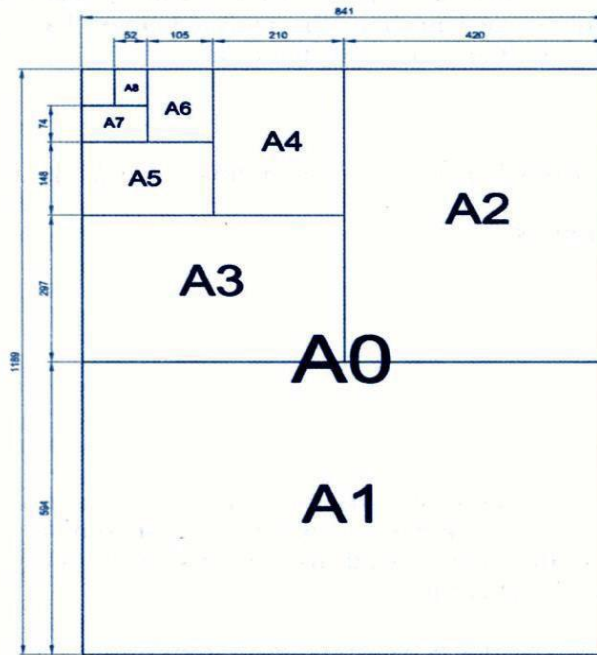


Figure.1.4

**Title Block:**

The title block should lie within the drawing space at the bottom right hand corner of the sheet. The title block can have a maximum length of 170 mm and width of 65mm providing the following information.

- Title of the drawing.
- Drawing number.
- Scale.
- Symbol denoting the method of projection.
- Name of the firm, and
- Initials of staff, who have designed, checked and approved.

**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.

- **Visible Outlines, Visible Edges:** (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 (Continuous narrow Lines):** Dimension Lines are drawn to mark dimension.
- **Extension Lines (Continuous narrow Lines):** These are extended slightly beyond the respective dimension lines.
- **Construction Lines (Continuous narrow Lines):** These are drawn for constructing drawings and should not be erased after completion of the drawing.
- **Hatching / Section Lines (Continuous Narrow Lines):** These are drawn for the sectioned portion of an object. These are drawn inclined at an angle of  $45^\circ$  to the axis or to the main outline of the section.

## ENGINEERING GRAPHICS(23HES0301)

- **Guide Lines (Continuous Narrow Lines):** These are drawn for lettering and should not be erased after lettering.
- **Break Lines (Continuous Narrow Freehand Lines):** Wavy continuous narrow line drawn freehand is used to represent break of an object.
- **Break Lines (Continuous Narrow Lines With Zigzags):** Straight continuous narrow line with zigzags is used to represent break of an object.
- **Dashed Narrow Lines (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 (Long-Dashed Dotted Narrow Lines):** These 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:** 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 0.7mm.



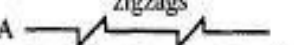


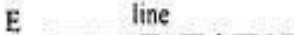

No.	Line description and Representation	Applications
01.1	Continuous narrow line 	Dimension lines, Extension lines
		Leader lines, Reference lines
		Short centre lines
		Projection lines
		Hatching
		Construction lines, Guide lines
		Outlines of revolved sections
		Imaginary lines of intersection
01.1	Continuous narrow freehand line 	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 <sup>1</sup> .
01.1	Continuous narrow line with zigzags 	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 <sup>2</sup> .
01.2	Continuous wide line 	Visible edges, visible outlines
		Main representations in diagrams, maps, flow charts
02.1	Dashed narrow line 	Hidden edges
		Hidden outlines
04.1	Long-dashed dotted narrow line 	Center lines / Axes, Lines of symmetry
		Cutting planes (Line 04.2 at ends and changes of direction)
04.2	Long-dashed dotted wide line 	Cutting planes at the ends and changes of direction outlines of visible parts situated in front of cutting plane

Table.1.2



## CONVENTIONAL REPRESENTATION OF MATERIALS

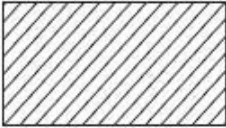
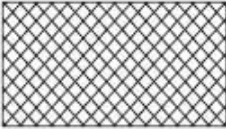


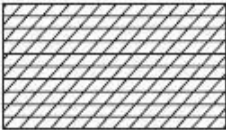
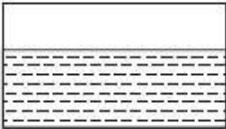

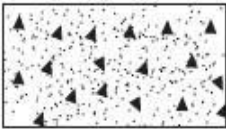
Type	Convention	Material
Metals		Steel, Cast Iron, Copper and its Alloys, Aluminium and its Alloys, etc.
		Lead, Zinc, Tin, White-metal, etc.
Glass		Glass
Packing and Insulating material		Porcelain, Stoneware, Marble, Slate, etc.
		Asbestos, Fibre, Felt, Synthetic resin products, Paper, Cork, Linoleum, Rubber, Leather, Wax, Insulating and Filling materials, etc.
Liquids		Water, Oil, Petrol, Kerosene, etc.
Wood		Wood, Plywood, etc.
Concrete		A mixture of Cement, Sand and Gravel

Table.1.3



## LETTERING

Lettering is defined as writing of titles, sub-titles, dimensions, etc., on a drawing.

### Importance of Lettering:

To undertake production work of an engineering component as per the drawing, the size and other details are indicated on the drawing. This is done in the form of notes and dimensions. Main Features of Lettering are legibility, uniformity and rapidity of execution. Use of drawing instruments for lettering consumes more time. Lettering should be done freehand with speed. Practice accompanied by continuous efforts would improve the lettering skill and style. Poor lettering mars the appearance of an otherwise good drawing.

### Size of Letters:

- Size of Letters is measured by the height of the CAPITAL letters as well as numerals.
- Standard heights for CAPITAL letters and numerals recommended by BIS are given below:  
1.8, 2.5, 3.5, 5, 6, 10, 14 and 20 mm

**Note:** Size of the letters may be selected based upon the size of drawing.

### Guide Lines:

In order to obtain correct and uniform height of letters and numerals, guidelines are drawn, using 2H pencil with light pressure. HB grade conical end pencil is used for lettering.

The following are some of the guidelines for lettering

- Drawing numbers, title block and letters denoting cutting planes, sections are written in 10 mm size.
- Drawing title is written in 7 mm size.
- Hatching, sub-titles, materials, dimensions, notes, etc., are written in 3.5 mm size.
- Space between lines =  $3/4h$
- Space between words may be equal to the width of alphabet  $3/5h$ .

### Procedure for Lettering:

1. Thin horizontal guidelines are drawn first at a distance 'h' apart.
2. Lettering Technique: Horizontal lines of the letters are drawn from left to right. Vertical, Inclined and curved lines are drawn from top to bottom.
3. After lettering has been completed, the guidelines are not erased.

Specifications	Value	Size							
Capital Letter Height	h	2.5	3.5	5	7	10	14	20	
Lowercase Letter Height	$a = (5/7) h$	-	2.5	3.5	5	7	10	14	
Thickness of Lines	$b = (1/14) h$	0.18	0.25	0.35	0.5	0.7	1	1.4	
Spacing between Characters	$c = (1/7) h$	0.35	0.5	0.7	1	1.4	2	2.8	
Min. Spacing between words	$d = (3/7) h$	1.05	1.5	2.1	3	4.2	6	8.4	
Min. Spacing between Base Lines	$e = (10/7) h$	3.5	5	7	10	14	20	28	

Table.1.4



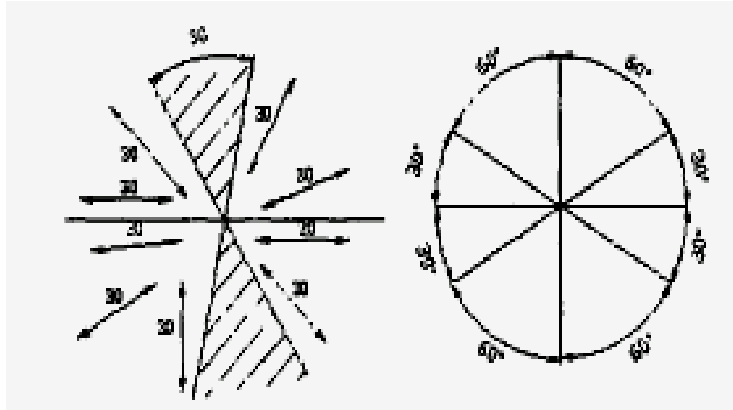


Figure.1.6(b)

**Method- 2(Uni-directional):**

Dimensions should be indicated so that they can be read from the bottom of the drawing only. Non-horizontal dimension lines are interrupted, preferably in the middle for insertion of the dimension. Note: Horizontal dimensional lines are not broken to place the dimension in both cases.

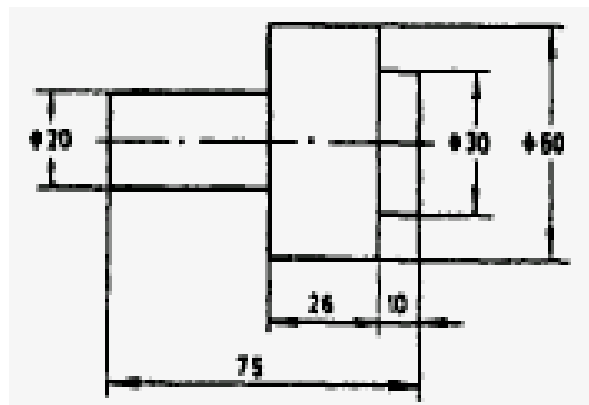


Figure.1.7

# GEOMETRICAL CONSTRUCTIONS

## Introduction:

Engineering drawing consists of a number of geometrical constructions. A few methods are illustrated here without mathematical proofs.

### 1. a) To divide a straight line into a given number of equal parts say 5.

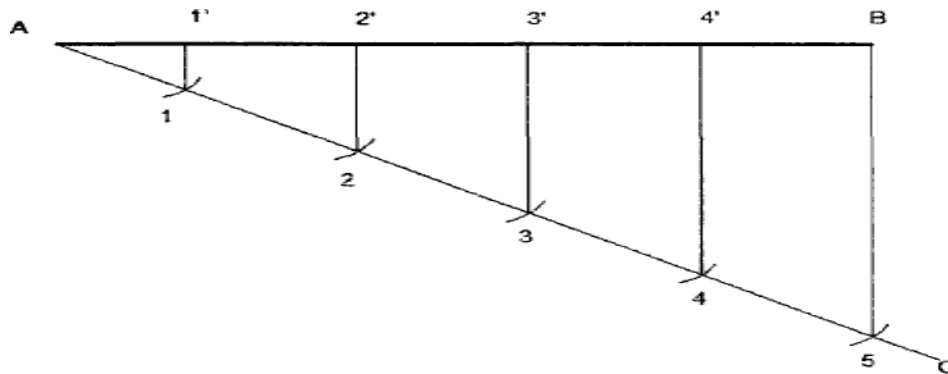


Figure.1.8

#### Construction:

1. Draw AC at any angle to AB
2. Construct the required number of equal parts of convenient length on AC like 1,2,3.
3. Join the last point 5 to B
4. Through 4,3,2,1 draw lines parallel to 5B to intersect AB at 4',3',2' and 1'.

### B )To bisect a given angle.

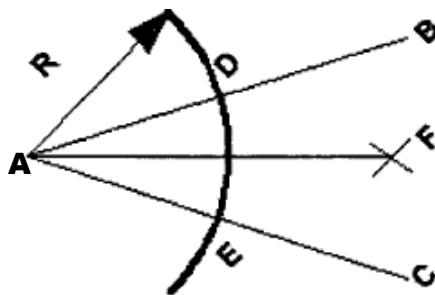


Figure.1.9

#### Construction:

1. Draw a line AB and AC making the given angle.
2. With centre A and any convenient radius R draw an arc intersecting the sides at D and E.
3. With centre's D and E and radius larger than half the chord length DE, draw arcs intersecting at F
4. Join AF,  $\angle BAF = \angle FAC$ .

### 2. To inscribe a regular polygon of any number of sides in a given circle.

#### Construction:

1. Draw the given circle with AB as diameter.
2. Divide the diameter AB into N equal parts say 5.
3. With AB as radius and A & B as centers, draw arcs intersecting each other at C.
4. Join C-P and extend to intersect the circle at D.

5. Join A-D which is the length of the side of the required polygon.
6. Set the compass to the length AD and starting from D mark off on the circumference of the circles, obtaining the points E,F, etc. The figure obtained by joining the points A,D,E etc., is the required polygon.

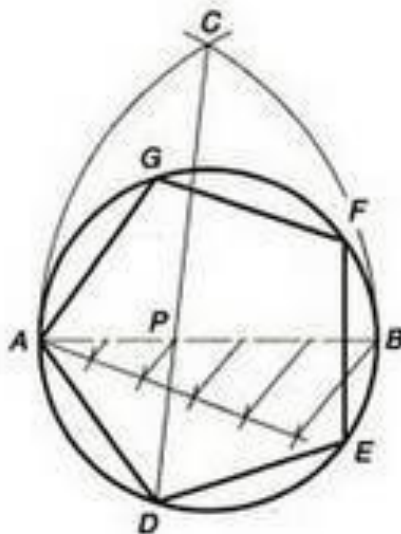


Figure.1.10

**3. To inscribe a hexagon in a given circle.**

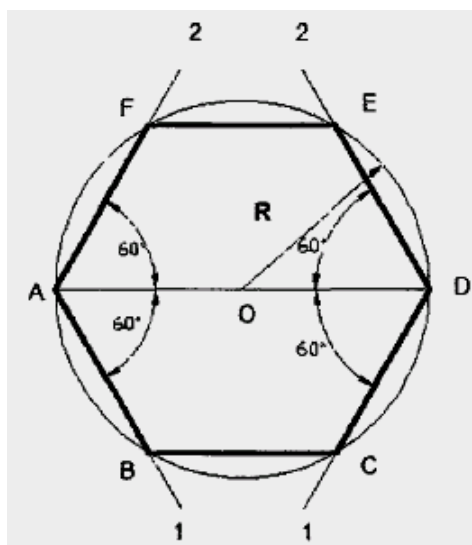


Figure.1.11

**Construction:**

1. With centre O and radius R draw the given circle.
2. Draw any diameter AD to the circle.
3. Using 30° - 60° set-square and through the point A draw lines A1, A2 at an angle 60° with AD, intersecting the circle at B and F respectively.
4. Using 30° - 60° set-square and through the point D draw lines D1, D2 at an angle 60° with DA, intersecting the circle at C and E respectively.
5. By joining A,B,C,D,E,F and A, the required hexagon is obtained.

**4. To construct a regular polygon (say a pentagon) given the length of the side.**

**Construction:**

1. Draw a line AB equal to the side and extend to P such that AB=BP

2. Draw a semi circle on AP and divide it into 5 equal parts by trial and error.
3. Join B to second division Irrespective of the number of sides of the polygon B is always joined to the second division.
4. Draw the perpendicular bisectors of AB and B2 to intersect at O.
5. Draw a circle with O as centre and OB as radius.
6. With AB as radius intersect the circle successively at D and E. Then join CD, DE and EA.

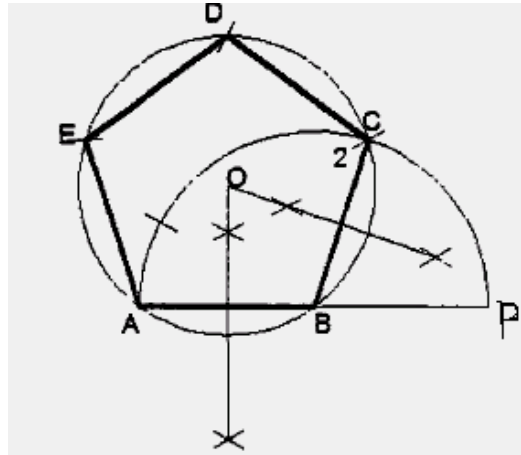


Figure.1.12

5. *To construct a regular polygon (say a hexagon) given the side AB.*

**Construction:**

1. Draw a line AB equal to the side and extend to P such that  $AB = BP$
2. Draw a semicircle on AP and divide it into 6 equal parts by trial and error.
3. Join B to second division
4. Join B-3, B-4, B-5 and produce them.
5. With 2 as centre and radius AB intersect the line B,3 produced at D. Similarly get the point E and F.
6. Join 2-D, D-E, E-F and F-A to get the required hexagon.

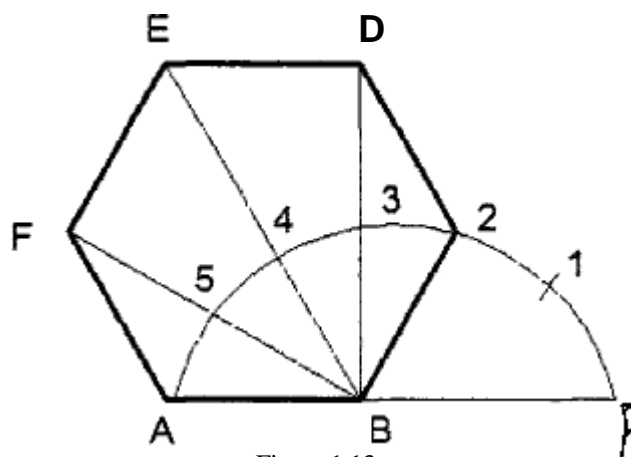


Figure.1.13

7. *To construct a regular figure of given side length and of N sides on a straightline.*

**Construction:**

1. Draw the given straight line AB.

2. At B erect a perpendicular BC equal in length to AB.
3. Join AC and where it cuts the perpendicular bisector of AB, number the point 4.
4. Complete the square ABCD of which AC is the diagonal.
5. With radius AB and centre B describe arc AC as shown.
6. Where this arc cuts the vertical centre line numbers the point 6.
7. This is the centre of a circle inside which a hexagon of side AB can now be drawn.
8. Bisect the distance 4-6 on the vertical centreline.
9. Mark this bisection 5. This is the centre in which a regular pentagon of side AB can now be drawn.
10. On the vertical centre line step off from point 6 a distance equal in length to the distance 5-6. this is the centre of a circle in which a regular heptagon of side AB can now be drawn.
11. If further distances 5-6 are now stepped off along the vertical centre line and are numbered consecutively, each will be the centre of a circle in which a regular polygon can be inscribed with side of length AB and with a number of sides denoted by the number against the centre.

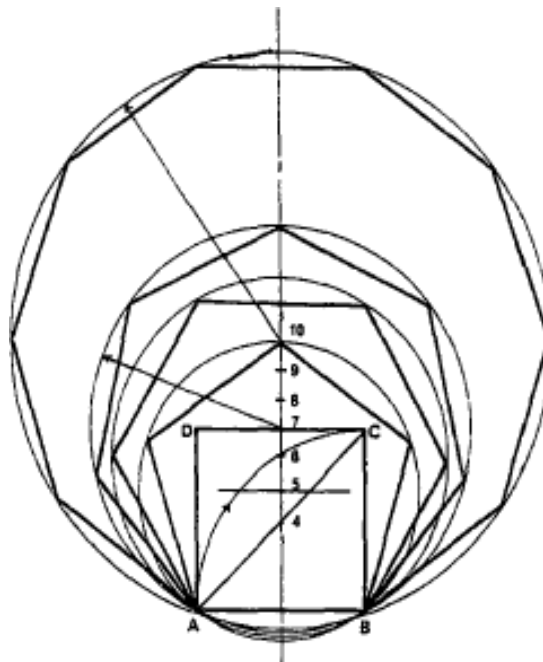


Figure.1.14



## CONICSECTIONS

Cone is formed when a right angled triangle with an apex and angle  $\Theta$  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  $2\Theta$ . When a cone is cut by a plane, the curve formed along the section is known as a conic.

### a) CIRCLE:

When a cone is cut by a section plane A-A making an angle  $\alpha = 90^\circ$  with the axis, the section obtained is a circle.

### b) ELLIPSE:

When a cone is cut by a section plane B-B at an angle,  $\alpha$  more than half of the apex angle i.e.,  $\Theta$  and less than  $90^\circ$ , the curve of the section is an ellipse. Its size depends on the angle  $\alpha$  and the distance of the section plane from the apex of the cone.

### c) PARABOLA:

If the angle  $\alpha$  is equal to  $\Theta$  i.e., when the section plane C-C 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.

### d) HYPERBOLA:

If the angle  $\alpha$  is less than  $\Theta$  (section plane D-D), the curve at the section is hyperbola. The curve of intersection is hyperbola, even if  $\alpha = \Theta$ , 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.

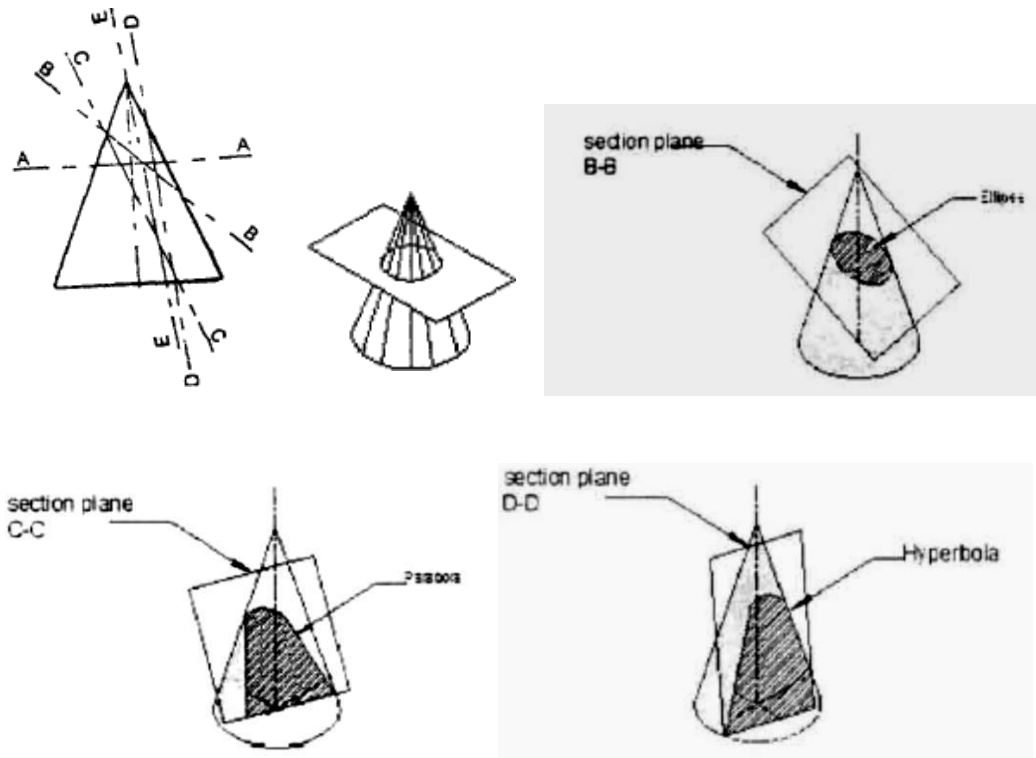


Figure.1.15

**Eccentricity( $e$ ) :**

- a. If  $e=1$ , it is parabola
- b. If  $e>1$ , it is hyperbola
- c. If  $e<1$ , it is an ellipse

*Where eccentricity  $e$  is the ratio of distance of the point from the focus to the distance of the point from the directrix.*

## PARABOLA:

In physical world, parabola are found in the main cables on simple suspension bridge, as parabolic reflectors in satellite dish antennas, vertical curves in roads, trajectory of a body, automobile head light, parabolic receivers.

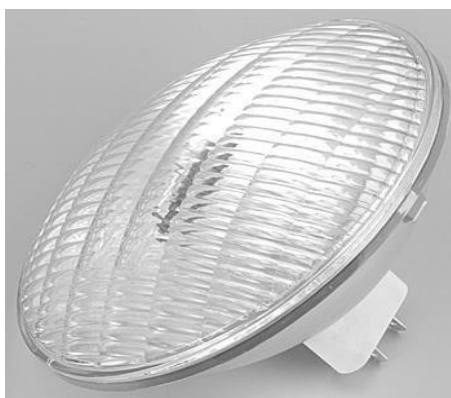
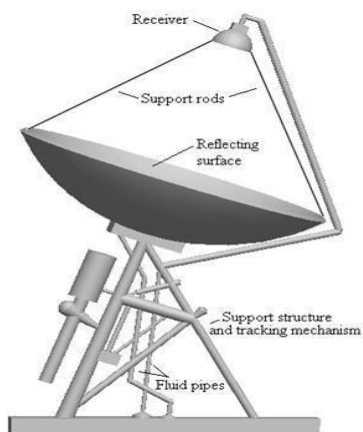


Figure.1.16

- *To draw a parabola with the distance of the focus from the directrix at 50mm (Eccentricity method)*

### Construction:

1. Draw the axis AB and the directrix CD at right angles to it:
2. Mark the focus F from 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,  $VE/VA=VF/VA=1$ , 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 1 at P1 and P'1
9. Similarly, locate the points P2, P'2, P3, P'3 etc., on either side of the axis. Join the points by smooth curve, forming the required parabola.

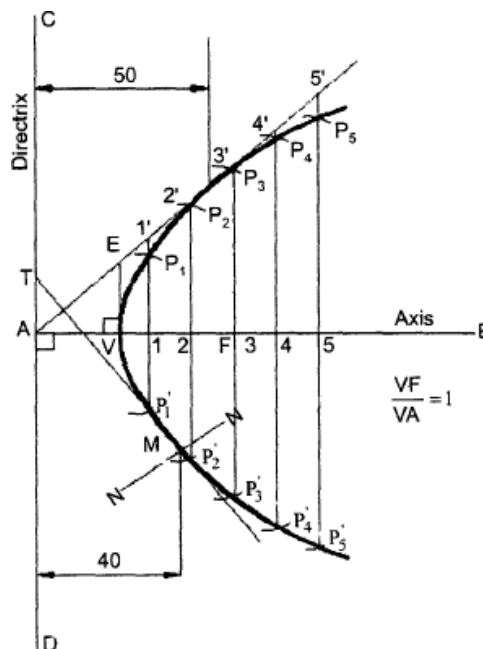


Figure.1.17

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

To draw a tangent and normal to the parabola. Locate the point M which is at 40 mm from the directrix. 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.

## ELLIPSE:

Ellipses are mostly found as harmonic oscillators, phase visualization, elliptical gears, ellipse wings.

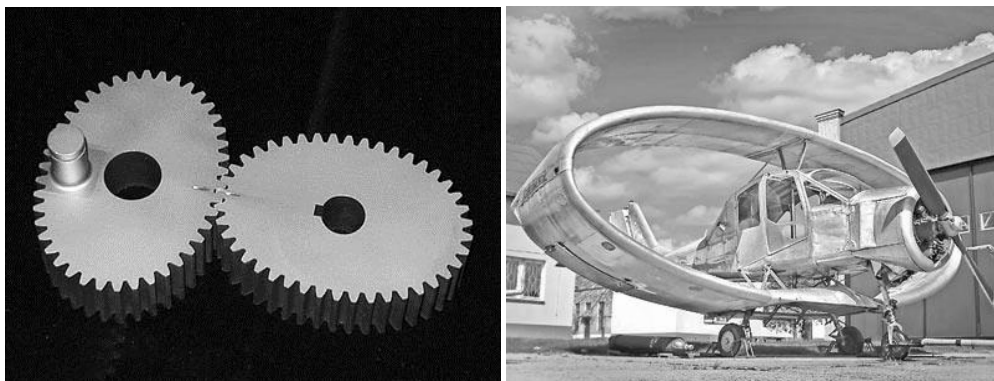


Figure.1.18

- *To draw an ellipse with the distance of the focus from the directrix at 50 mm and eccentricity = 2/3 (Eccentricity method)*

### Construction:

1. Draw any vertical line CD as directrix.
2. At any point A in it, draw the axis.
3. Mark a focus F from the axis such that  $AF_1 = 50\text{mm}$ .
4. Divide  $AF_1$  into 5 equal divisions.
5. Mark the vertex V on the third division-point from A.
6. Thus eccentricity  $e = VF_1/VA = 2/3$ .
7. A scale may now be constructed on the axis which will directly give the distances in the required ratio.
8. At V, draw a perpendicular  $VE = VF_1$ . Draw a line joining A and E.
9. Mark any point 1 on the axis and through it draw a perpendicular to meet AE produced at  $1'$ .
10. With centre F and radius equal to  $1-1'$ , draw arcs to intersect a perpendicular through 1 at points  $P_1$  and  $P'_1$ .
11. Similarly mark points 2,3 etc. on the axis and obtain points  $P_2$  and  $P'_2$ ,  $P_3$  and  $P'_3$ , etc.
12. Draw the ellipse through these points, it is a closed curve two foci and two directrices.

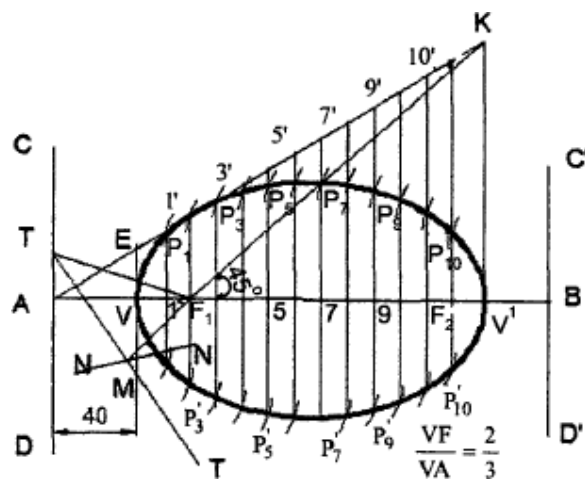


Figure.1.19

## HYPERBOLA

Lamp shades, gear transmission, cooling towers of nuclear reactors are some of the applications of Hyperbola.



Figure.1.20

- *To draw a hyperbola with the distance of the focus from the directrix at 50mm and  $e=3/2$  (Eccentricity method)*

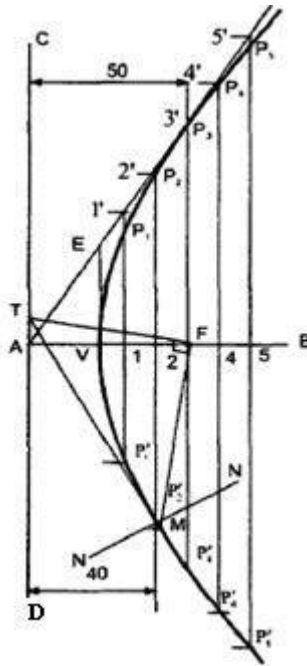


Figure.1.21

**Construction:**

1. Draw the directrix CD and the axis AB.
2. Mark the focus F on AB and 65mm from A.
3. Divide AF into 5 equal divisions and mark V the vertex, on the second division from A.
4. Draw a line VE perpendicular to AB such that  $VE=VF$ . Join A and E.
5. Mark any point 1 on the axis and through it, draw a perpendicular to meet AE produced at 1'.
6. With centre F and radius equal to 1-1', draw arcs intersecting the perpendicular through 1 at P1 and P'1.
7. Similarly mark a number of points 2,3 etc and obtain points P2 and P'2, etc.

## SPECIAL 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.

In physical world, Cycloidal curves are used as Cycloidal gears, epicyclic train dynamometer, epicyclic gear train, hypocycloid engine.

### 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.

- To draw a cycloid, given the radius  $R$  of the generating circle.

#### Construction:

1. With centre  $O$  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  $Q_1, Q_2, Q_3$  etc.
6. Through the points  $1, 2, 3$  etc., draw lines parallel to  $PA$ .
7. With centre  $O$ , 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  $Q_1$ .
8. 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.

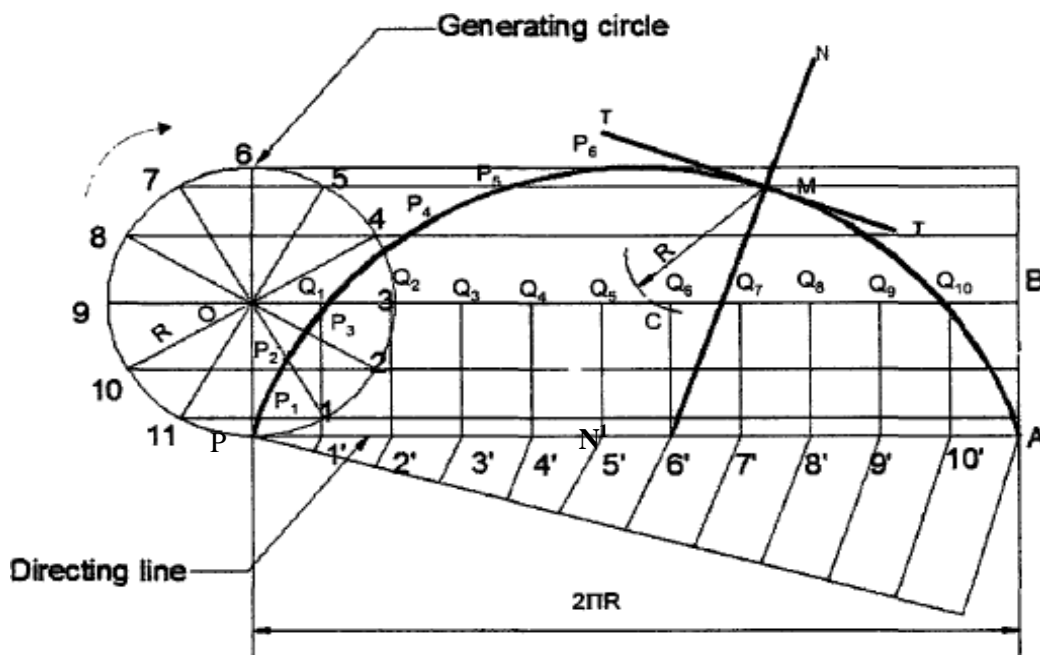


Figure.1.22



- *To draw a normal and tangent to a cycloid*

10. Mark a point M on the cycloid at a given distance from the directing line.
11. With M as a centre and the radius R, cut the centre line at point C.
12. Through point C, draw a line perpendicular to PA, Which meets PA at Point N<sup>l</sup>.
13. Join N<sup>l</sup>M and extend it to N. The line NN<sup>l</sup> is the required normal.
14. Through Point M, draw a line TT<sup>l</sup> Perpendicular to NN<sup>l</sup>. The line TT<sup>l</sup> is the required tangent.

## EPICYCLOID:

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.

- *To draw an epi-cycloid, 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 .

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  $\theta = \text{angle } PO'A = \frac{r}{R} \times 360^\circ$ . –

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.

1. Divide the arc PA and the generating circle into the same number of equal parts and number the points.
2. Join O'-1', O'-2', etc., and extend to meet the arc OB at O<sub>1</sub>, O<sub>2</sub> etc.
3. Through the points 1, 2, 3 etc., draw circular arcs with O' as centre.
4. With centre O<sub>1</sub> and radius r, draw an arc intersecting the arc through 1 at P<sub>1</sub>.
5. Similarly, locate the points P<sub>2</sub>, P<sub>3</sub> etc.
6. A smooth curve through the points P<sub>1</sub>, P<sub>2</sub>, P<sub>3</sub> etc., is the required epi-cycloid.

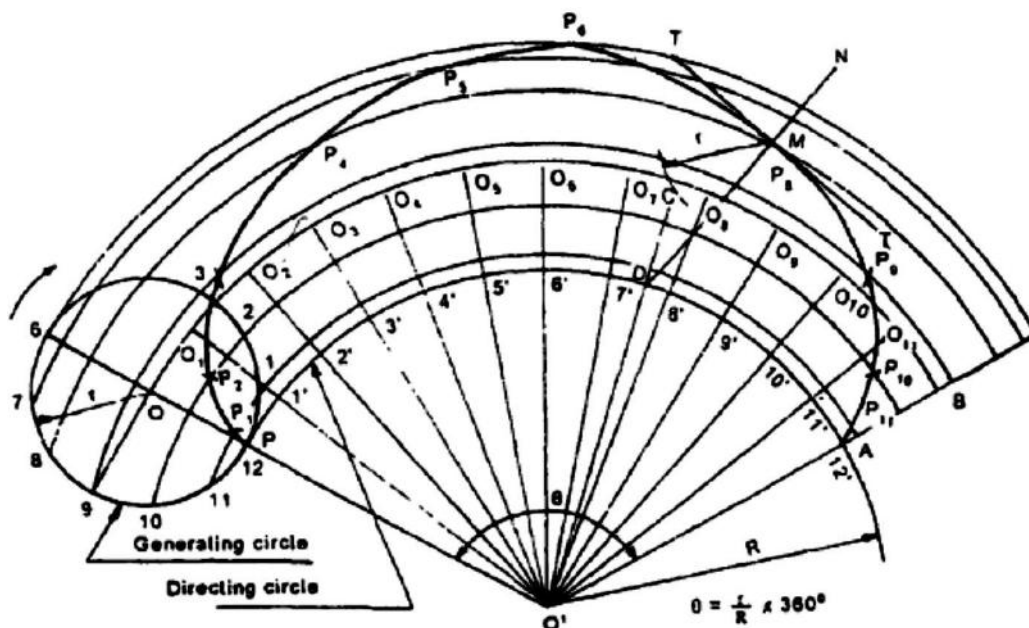


Figure.1.23



- *To draw a normal and tangent to a Epicycloid.*
7. Mark a point M on the epicycloids at a given distance from the Point O'.
  8. With M as the centre and radius r, cut the centre arc OB at point C.
  9. Join O'C to meet the arc PA at point D.
  10. Join DM and Produce it to N. The line DN is the required normal.
  11. Through Point M, Draw a line TT<sup>1</sup> Perpendicular to DN. The line TT<sup>1</sup> is the required tangent.

## **HYPOCYCLOID:**

If the generating circle rolls inside the directing circle, the curve traced by the point is called hypocycloid.

- *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 O as centre and radius (R) 100 mm draw an arc PQ which subtends an angle  $\Theta = 72^\circ$  at O.  $\theta = \text{angle } PO'Q = \frac{r}{R} \times 360^\circ$
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 (20mm) draw the rolling circle. Divide the rolling circle into 12 equal parts as 1, 2, 3 etc., in clockwise direction, since the rolling circle is assumed to roll counter clockwise.
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 intersect the locus of centre at C1 C2 C3 etc.
8. Taking centre C1 and radius r, draw an arc cutting the arc through 1 at P1. 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.

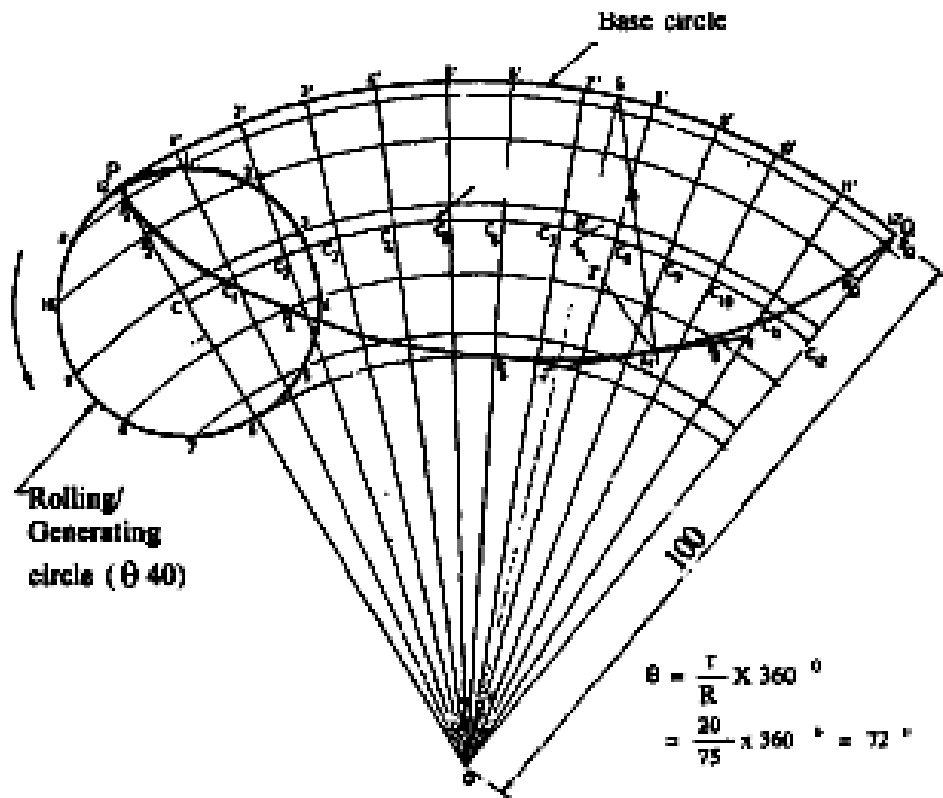


Figure.1.24

*Example: Draw an epicycloid of rolling circle of diameter 40 mm which rolls outside another circle (base circle) of 150 mm diameter for one revolution. Draw a tangent and normal at any point on the curve.*

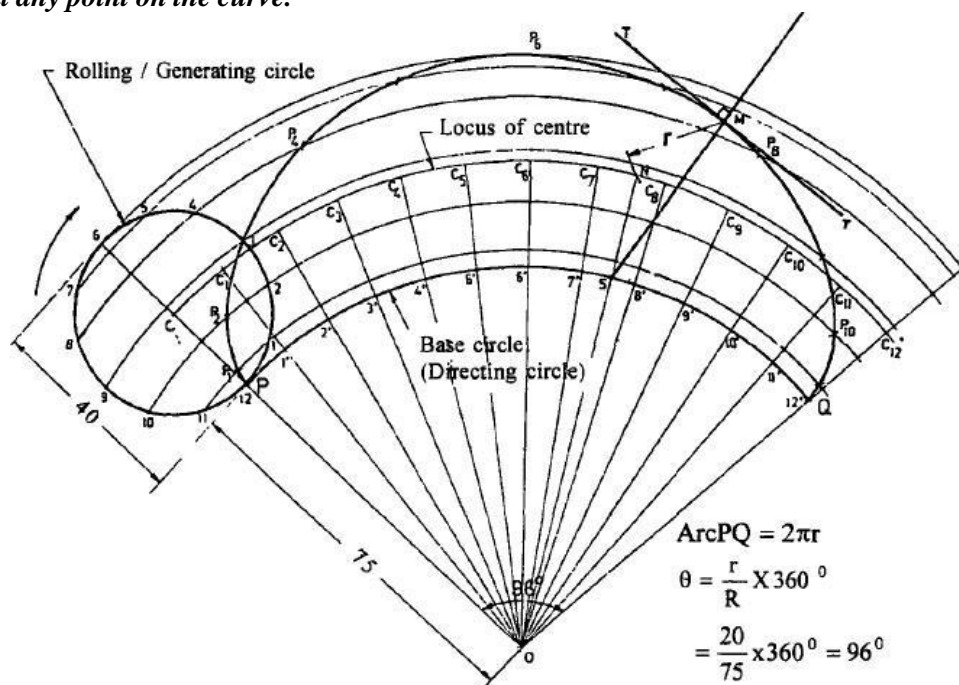
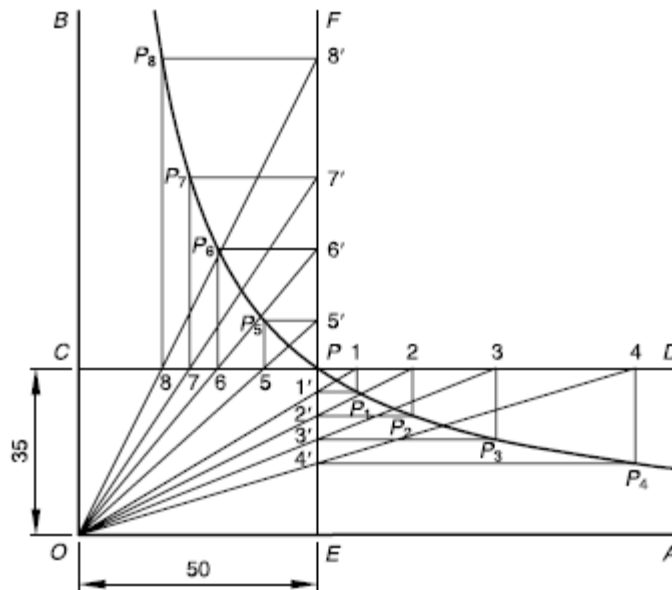


Figure.1.35

$$\theta = \text{angle } PO'Q = \frac{r}{R} \times 360^\circ$$

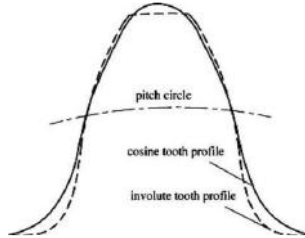
1. A point  $P$  of the hyperbola is situated at a distance of 35 mm and 50 mm from the pair of asymptotes. The asymptotes are perpendicular to each other. Draw a hyperbola using orthogonal asymptotes method.



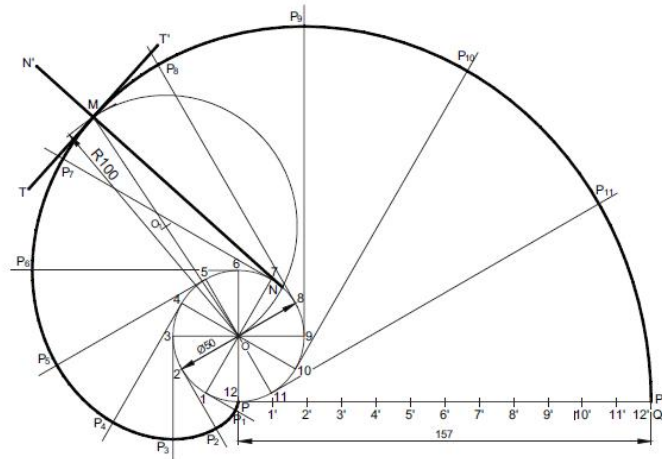
1. Draw asymptotes OA and OB perpendicular to each other.
2. Mark a point P such that its distance from OA is 35 mm and from OB is 50 mm.
3. Draw lines CD and EF parallel to OA and OB respectively, and pass through point P,
4. Mark points 1, 2, 3, etc., on line PD at any convenient distance, which need not be equal.
5. Join O1, O2, O3, etc., to intersect the line EP at points  $1^1$ ,  $2^1$ ,  $3^1$ , etc.
6. Draw lines from points 1, 2, 3, etc., parallel to OB to intersect lines drawn from points  $1^1$ ,  $2^1$ ,  $3^1$ , parallel to OA at points  $P_1$ ,  $P_2$ ,  $P_3$ , etc.
7. Mark points 5, 6, 7, etc., on line CP at any convenient distance, which need not be equal.
8. Join O5, O6, O7, etc., and produce to intersect the line PF at points  $5^1$ ,  $6^1$ ,  $7^1$ , etc.
9. Draw lines from points 5, 6, 7, etc., parallel to OB to intersect lines drawn from points  $5^1$ ,  $6^1$ ,  $7^1$ , parallel to OA at points  $P_5$ ,  $P_6$ ,  $P_7$ , etc.
10. Draw a smooth curve passing through  $P_1$ ,  $P_2$ ,  $P_3$ ,  $P_5$ ,  $P_6$ ,  $P_7$ , etc., to get the required rectangular hyperbola.

## INVOLUTES

An involute is a curve traced out by an end of a thread, when it is unwound from a circle or a polygon, the thread being kept tight. An involute of a circle is used as teeth profile of a large gear wheel and a gear reducer. In Fig., the end of the thread is at point P of the circle. When the thread is unwound keeping it always tight, it is always tangential to the circle and the point P will generate an involute. An involute of a circle is used in Payton's water meter and teeth profile of a gear.



1. Draw an involute of a circle of diameter 50 mm. Also draw normal and tangent at a point 100 mm from the centre of the circle.

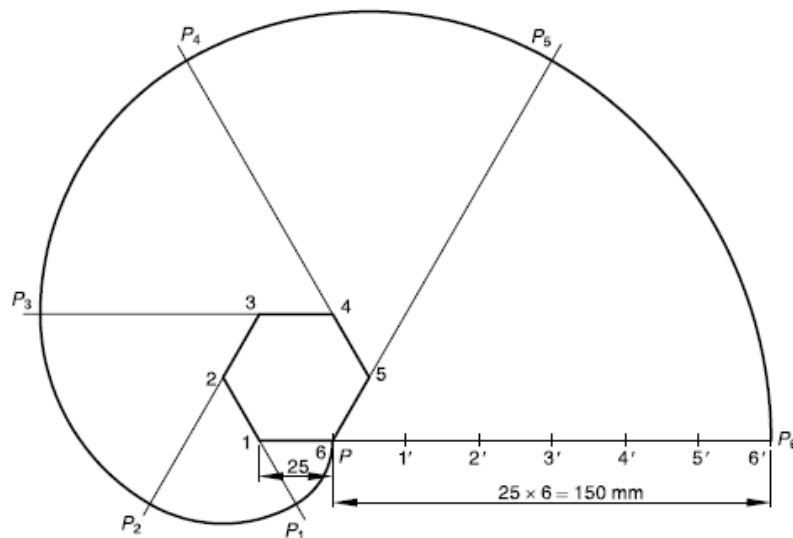


1. Draw a circle of diameter 50 mm and divide it into 12 equal parts.  
Let the end of thread before unwound is at point P of the circle. Consider the thread is unwound in the clockwise direction for one revolution. Then the length of the thread is  $\pi D$  and is tangent to the circle at point P.
2. Draw a line  $PQ = \pi D = 157$  mm and divide it into 12 equal parts. Mark its divisions as  $1\phi$ ,  $2\phi$ ,  $3\phi$ ,  $4\phi$ , etc.
3. Draw tangents to the circle at points 1, 2, 3, 4, etc., such that they represent the thread position during unwound.
4. The length of thread when unwound for  $1/12$ th revolution is equal to  $P1\phi$ . Therefore, draw an arc with centre 1 and radius  $P1\phi$  to intersect the tangent line through point 1 at point P1.
5. The length of thread when unwound for  $2/12$ th revolution is equal to  $P2\phi$ . Therefore, draw an arc with centre 2 and radius  $P2\phi$  to intersect the tangent line through point 2 at point P2.
6. Similarly, draw arcs with centres 3, 4, 5, etc., and radii  $P3\phi$ ,  $P4\phi$ ,  $P5\phi$ , etc., respectively, to intersect the tangent line through points 3, 4, 5, etc., at points P3, P4, P5, etc., respectively.
7. Draw a smooth curve to pass through P1, P2, P3, P4, etc., and obtain the required involute.

**Tangent and normal to involute**

1. Mark a point M on the involute at a radial distance of 100 mm from the centre O.
2. Join OM and mark O1 as its mid-point.
3. Draw a semi-circle in clockwise direction with centre O1 and diameter OM to intersect the base circle at N.
4. Join NM and produce it to N $\phi$ . The line NN $\phi$  is the required normal.
5. Through point M, draw a line TT $\phi$  perpendicular to NN $\phi$ . The line TT $\phi$  is the required tangent.

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



Draw a hexagon of side 25 mm. Mark a point P at corner 6. The end of thread before unwound is at point P. Consider the thread is unwound in the clockwise direction for one revolution. The length of the thread is  $6 \times 25 = 150$  mm.

1. Produce sides 2-1, 3-2, 4-3, 5-4, 6-5 and 1-6 as shown.
2. Draw arcs with centres 1, 2, 3, 4, 5, 6 and radii in multiple of side length (i.e., 25 mm, 50 mm, 75 mm, 100 mm, 125 mm and 150 mm respectively) to meet sides 2-1, 3-2, 4-3, 5-4, 6-5 and 1-6 at P1, P2, P3, P4, P5 and P6 respectively.
3. Draw a smooth curve to pass through P1, P2, P3, P4, P5, P6 and obtain the required involute.

## UNIT-2

# PROJECTION OF POINTS

### Introduction

#### What is point ?

An element which has no dimensions, it can be situated in the following positions with respect to principal planes of the projections.

- Point situated above H.P and infront of V.P.
- Point situated above H.P and behind V.P
- Point situated below H.P and behind V.P.
- Point situated below H.P and infront of V.P.
- Point situated on H.P and infront of V.P.
- Point situated above H.P and on V.P.
- Point situated on H.P and behind V.P.
- Point situated below H.P and on V.P.
- Point situated on both H.P and V.P.

#### Conventional Representation:

- Actual Position of a point designated by capitals i.e. A, B, C, D...
- Front view of a point is designated by small letters with dashes i.e. a', b', c', d'....
- Top view of a point is designated by only small letters i.e .a, b, c, d....
- Side view of a point is designated by small letters with double dashes i.e. a'', b'', c'', d''...

The Intersection of reference planes is a line known as reference line denoted by x-y and the line connecting the front and top view is known as projection line; it is always perpendicular to the principal axis (x-y line).

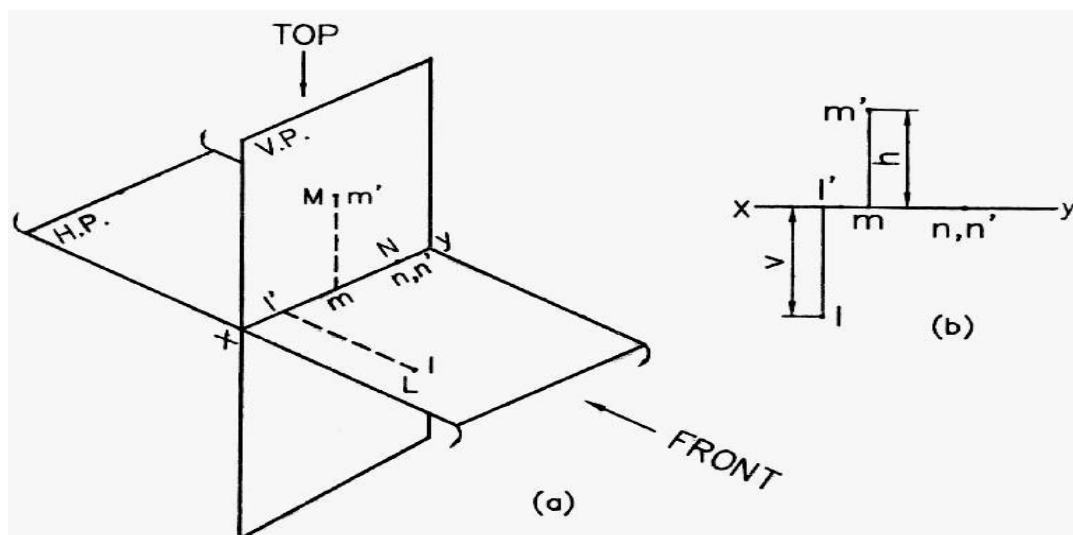


Figure2.1

**Problem:**

- Draw the orthographic projections of the following points?

- (a.) Point P is 30mm. above H.P and 40mm. in front of VP
- (b.) Point Q is 25 mm. above H.P and 35 mm. behind VP
- (c.) Point R is 32 mm. below H.P and 45 mm behind VP
- (d.) Point S is 35 mm. below H.P and 42 mm in front of VP
- (e.) Point T is in H.P and 30 mm behind VP
- (f.) Point U is in V.P and 40 mm. below HP
- (g.) Point V is in V.P and 35 mm. above H.P
- (h.) Point W is in H.P and 48 mm. in front of VP

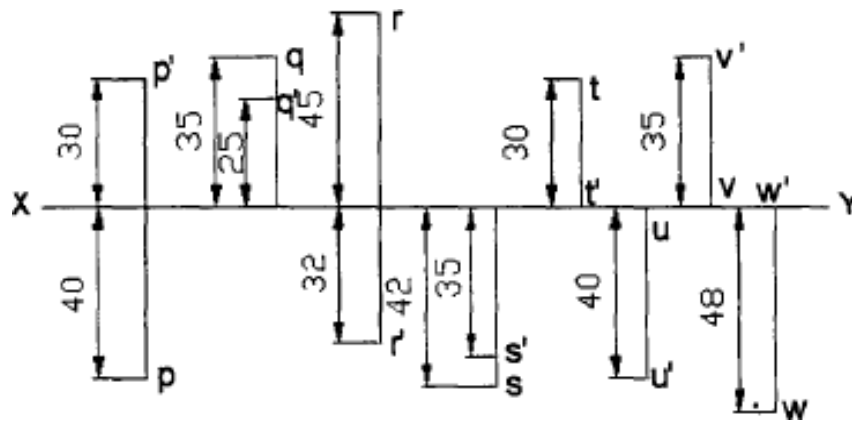
**Solution:**

Figure 2.2



# PROJECTION OF STRAIGHT LINES

## Introduction

### What is Line?

A Shortest distance between two points and the actual length of the line is known as True Length denoted by TL.

### Orientation of Straight Lines

- Line parallel to both H.P and V.P
- Line perpendicular to H.P and parallel to V.P
- Line perpendicular to V.P and parallel to H.P
- Line inclined to H.P and parallel to V.P
- Line inclined to V.P and parallel to H.P
- Line situated in H.P
- Line situated in V.P
- Line situated in both H.P and V.P
- Line inclined to both the reference planes.
  1. Line inclined to both H.P and V.P front view angle =  $90^\circ$  and top view angle =  $90^\circ$
  2. Line inclined to both H.P and V.P front view angle and top view angle =  $90^\circ$

### Problems

- **Line parallel to both H.P and V.P**

*A 50mm long line AB is parallel to both H.P and V.P. The line is 25mm in front of V.P and 60mm above H.P, draw the projections of the line.*

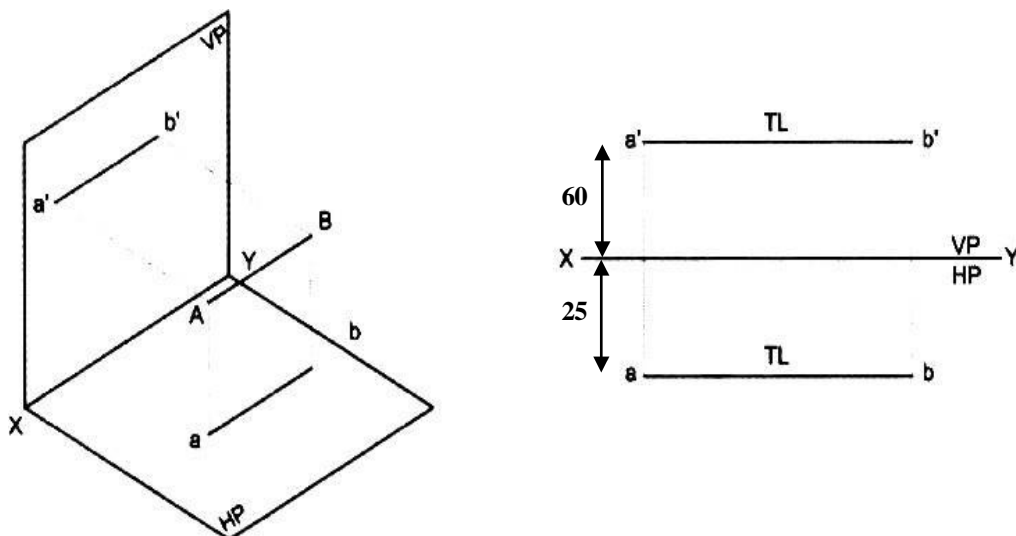


Figure 2.3

- Line perpendicular to H.P

*A 60 mm long line AB has its end A at a distance of 20 mm above the H.P. The line is perpendicular to the H.P and 40 mm in front of V.P, draw the projections of the line.*

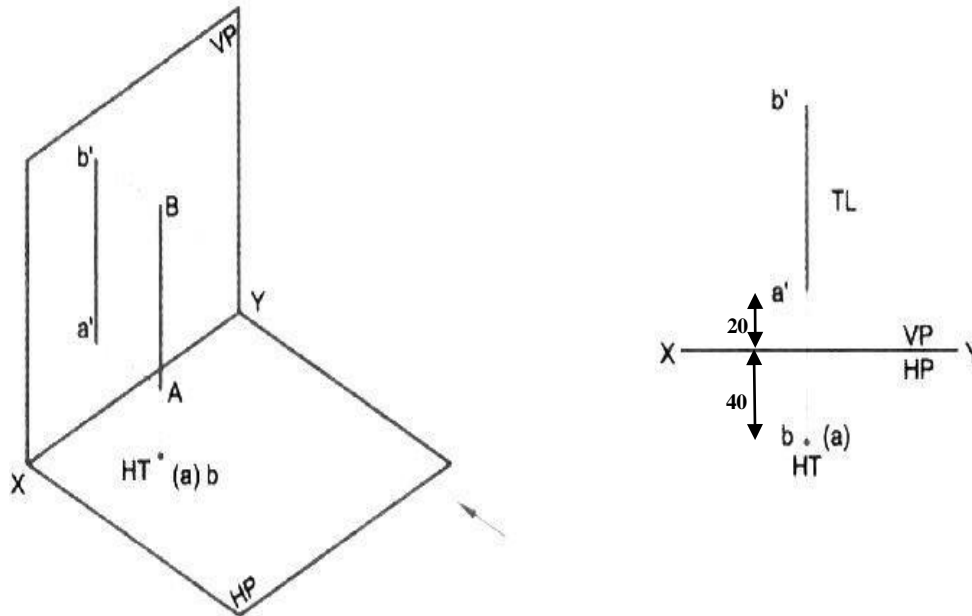


Figure 2.4

- Line perpendicular to V.P

*A 60mm long line AB, has its end A at a distance of 20mm in front of the V.P. the line is perpendicular to V.P and 40mm above H.P, draw the projection of the line.*

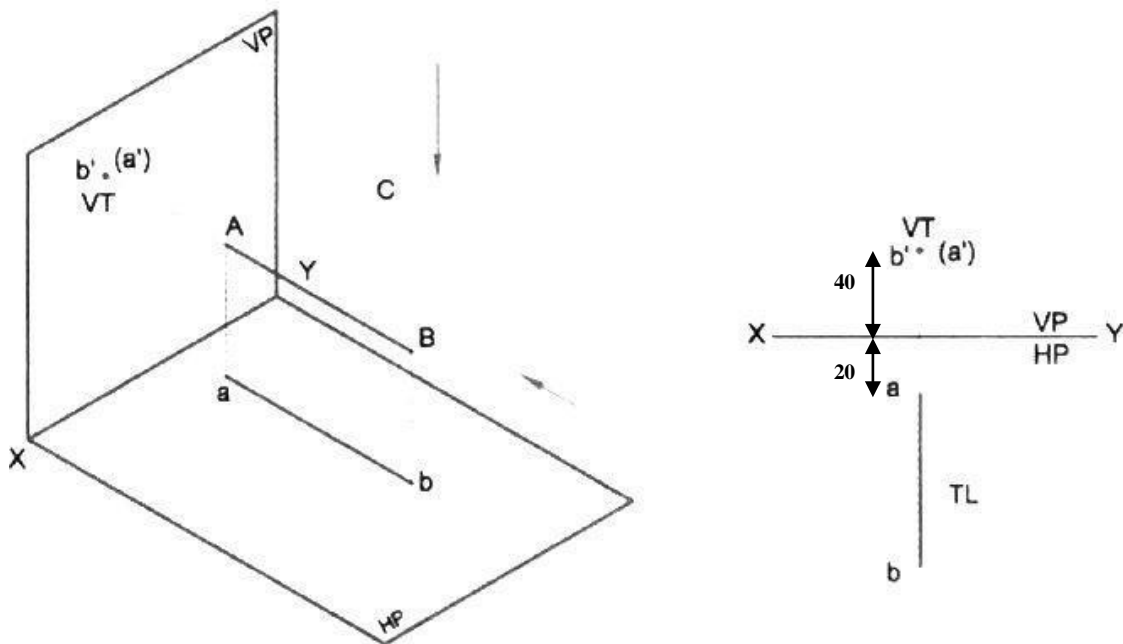


Figure 2.5

- Line inclined to H.P and parallel to V.P

*A 80mm long line AB has the end A at a distance of 20mm above HP and 40mm in front of V.P. The line is inclined at 30 deg to H.P and parallel to V.P, draw the projection of the line.*

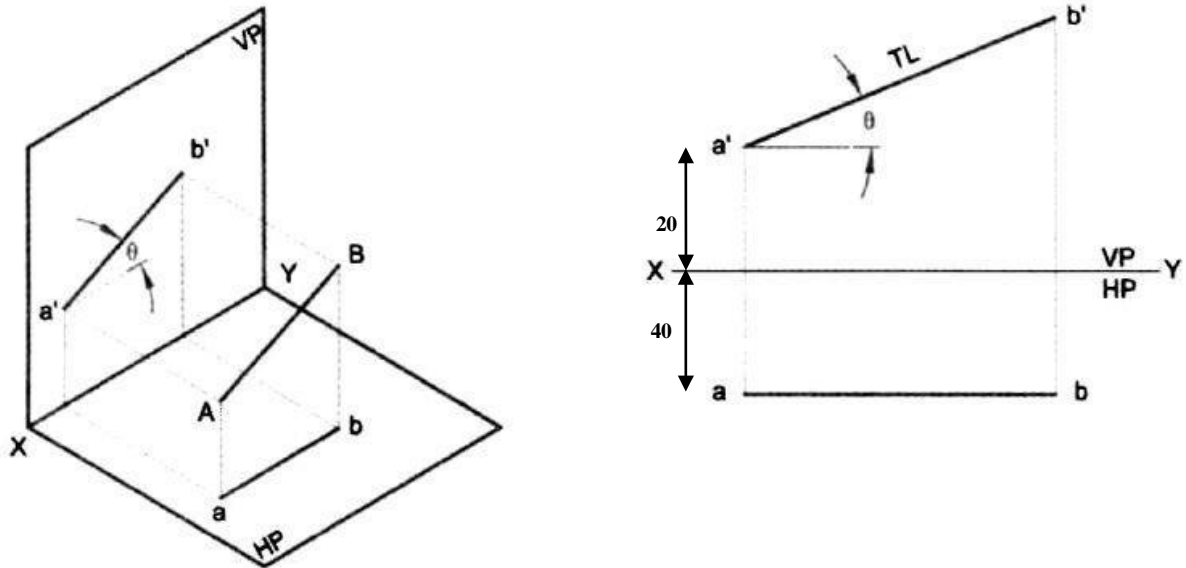


Figure2.6

- Line inclined to V.P and parallel to H.P

*An 80mm long line AB is inclined at 30 deg to V.P and is parallel to H.P. The end A is 20mm above the H.P and 20mm in front of the V.P, draw the projection of the line.*

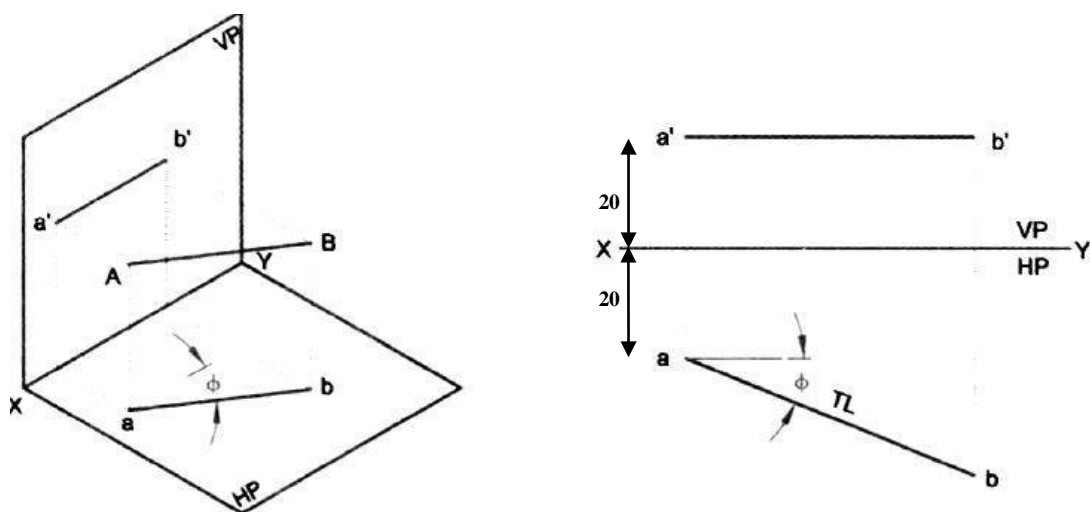


Figure2.7

- **Line situated in H.P**

*A line AB 60mm long is situated in H.P and inclined to V.P at 30 deg. The end A is 20mm in front of V.P, draw the projection of line.*

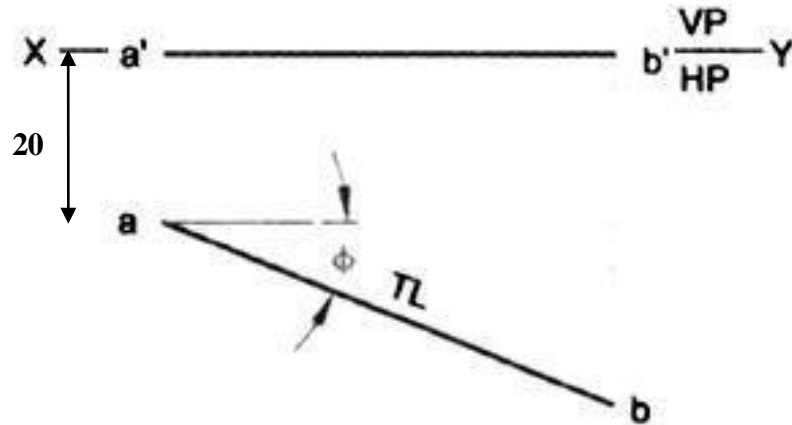


Figure2.8

- **Line situated in V.P**

*Draw the projections of 70mm long line AB situated in the V.P and inclined at 30 deg to H.P. The end A is 25mm above H.P.*

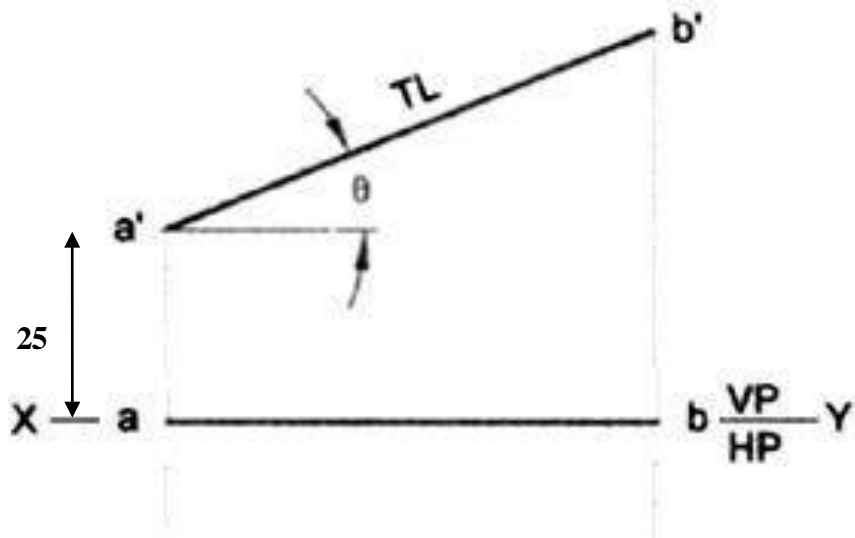


Figure2.9

- Lines inclined to both the reference planes.

*A 70mm long line AB has an end A at 20mm above H.P and 30mm in front of V.P. The line is inclined at 45 deg to the H.P and 30 deg to V.P, draw the projections.*

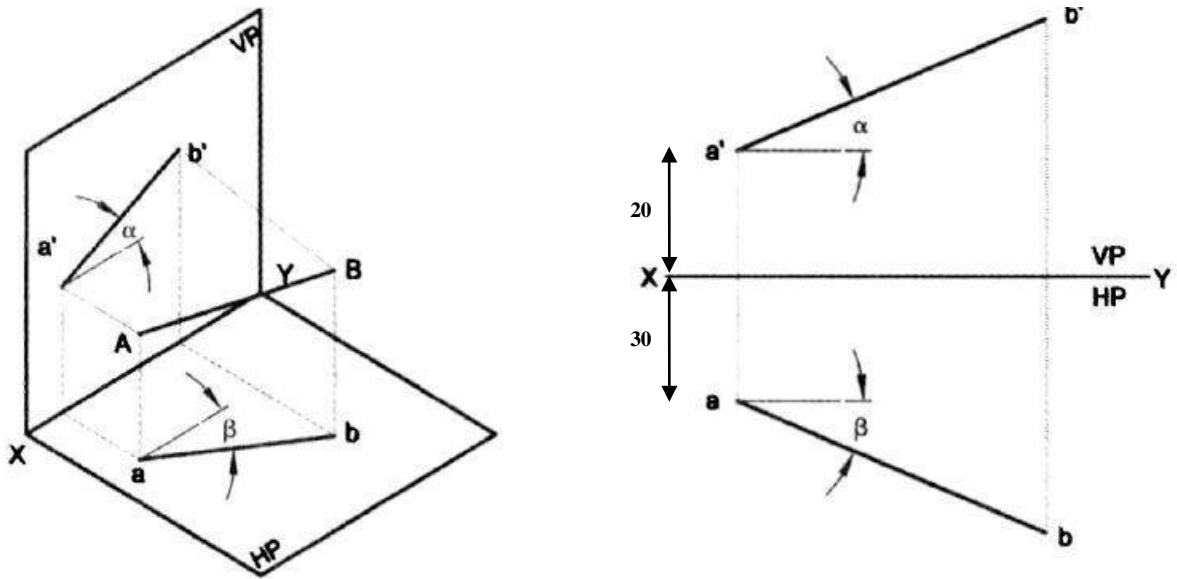


Figure2.10

### Important Questions and Previous Paper Problems:

**Problem:**

*A line AB, 70mm long, has its end A 15mm above HP and 20mm in front of VP. It is inclined at 30° to HP and 45° to VP. Draw its projections and mark its traces*

**Solution:**

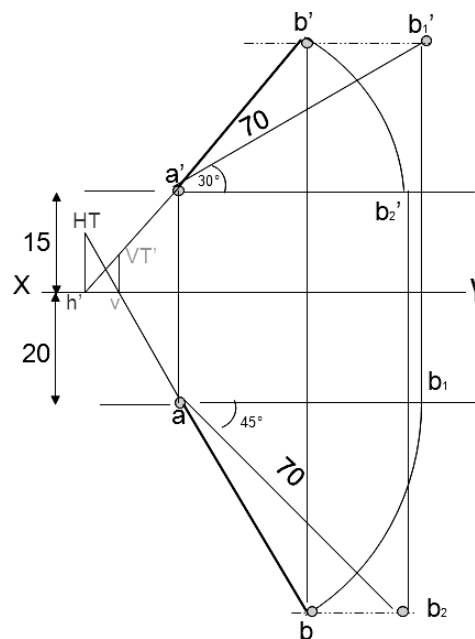


Figure2.11

**Problem:**

The top view of a 75mm long line AB measures 65mm, while its front view measures 50mm. Its one end A is in HP and 12mm in front of VP. Draw the projections of AB and determine its inclination with HP and VP

**Solution:**

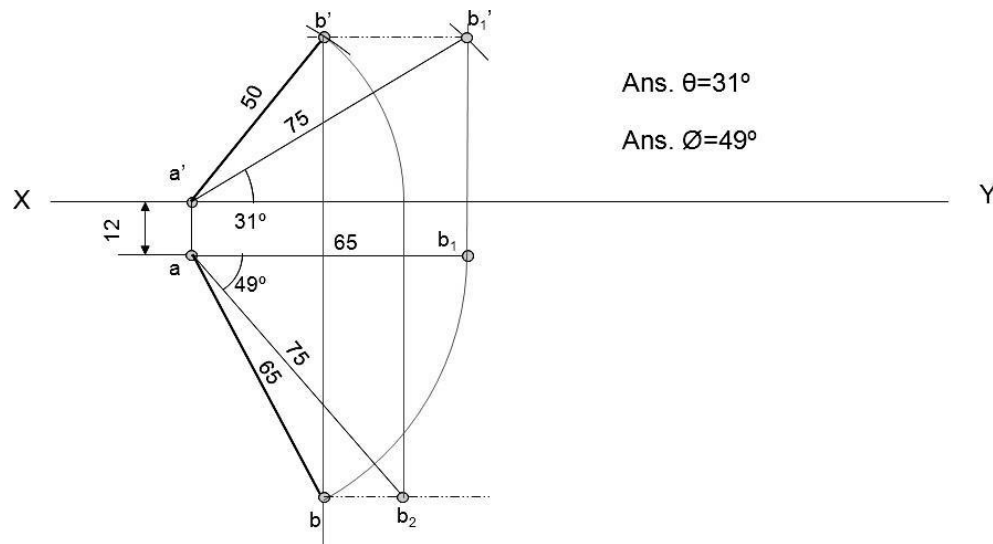


Figure2.12

**Problem:**

A line AB, 65mm long has its end A 20mm above H.P. and 25mm in front of V.P. The end B is 40mm above H.P. and 65mm in front of V.P. Draw the projections of AB and shows its inclination with H.P.

**Solution:**

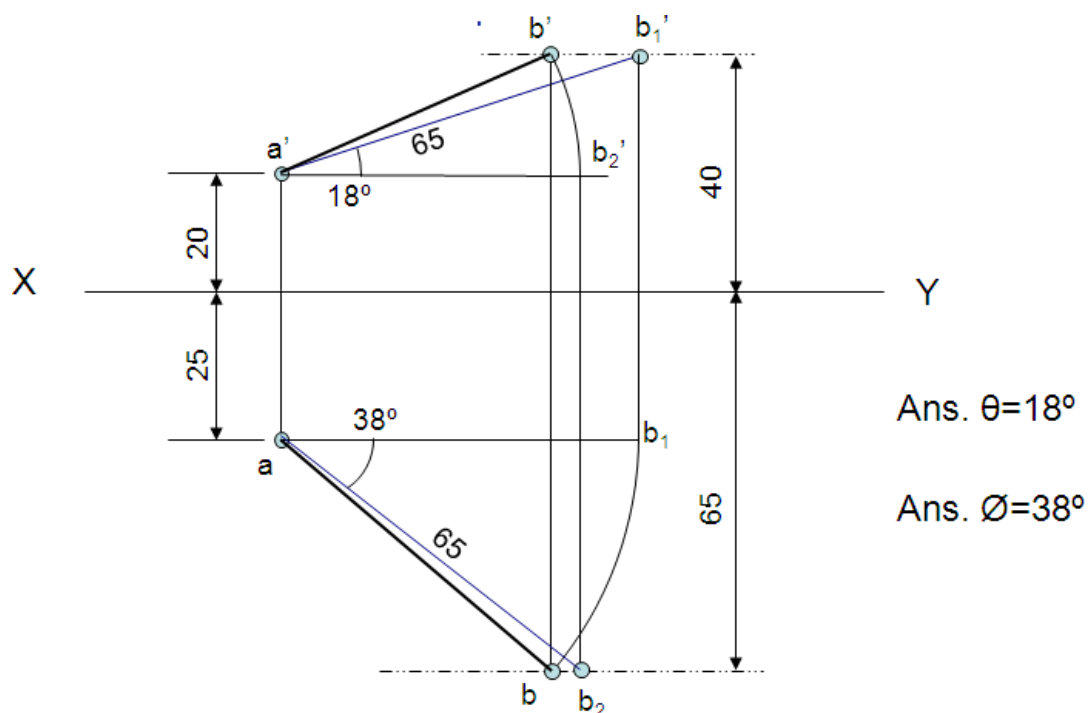


Figure2.13

**Problem:**

The projectors of the ends of a line  $AB$  are  $5\text{ cm}$  apart. The end  $A$  is  $2\text{ cm}$  above the  $H.P.$  and  $3\text{ cm}$  in front of  $V.P.$  The end  $B$  is  $1\text{ cm}$  below  $H.P.$  and  $4\text{ cm}$  behind the  $V.P.$  Determine the true length and traces of  $AB$ , and its inclination with the two planes.

**Solution:**

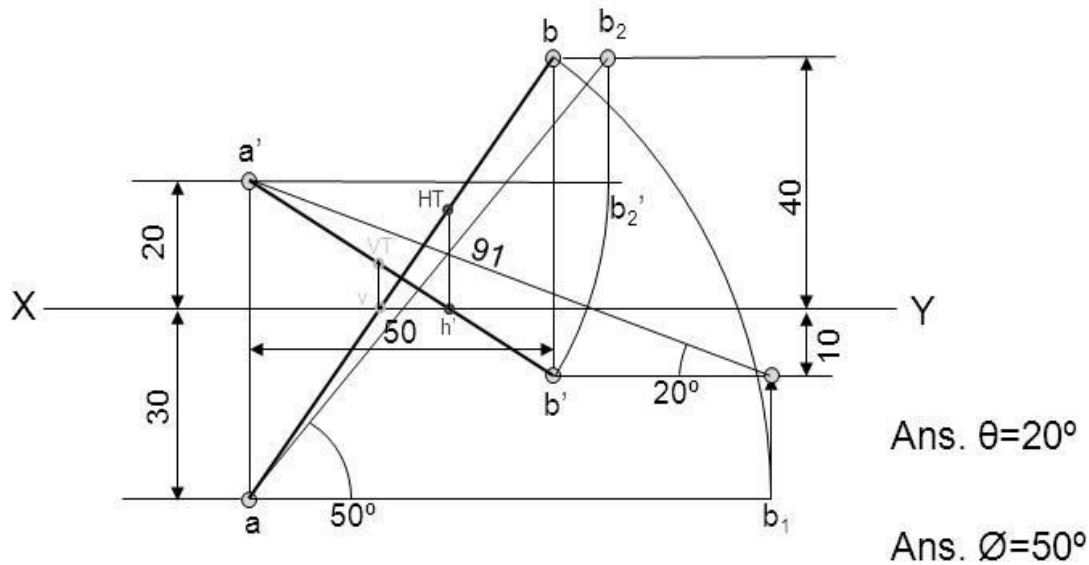


Figure 2.14

**Problem:**

A line  $AB$ ,  $90\text{ mm}$  long, is inclined at  $45^\circ$  to the  $H.P.$  and its top view makes an angle of  $60^\circ$  with the  $V.P.$  The end  $A$  is in the  $H.P.$  and  $12\text{ mm}$  in front of  $V.P.$  Draw its front view and find its true inclination with the  $V.P.$

**Solution:**

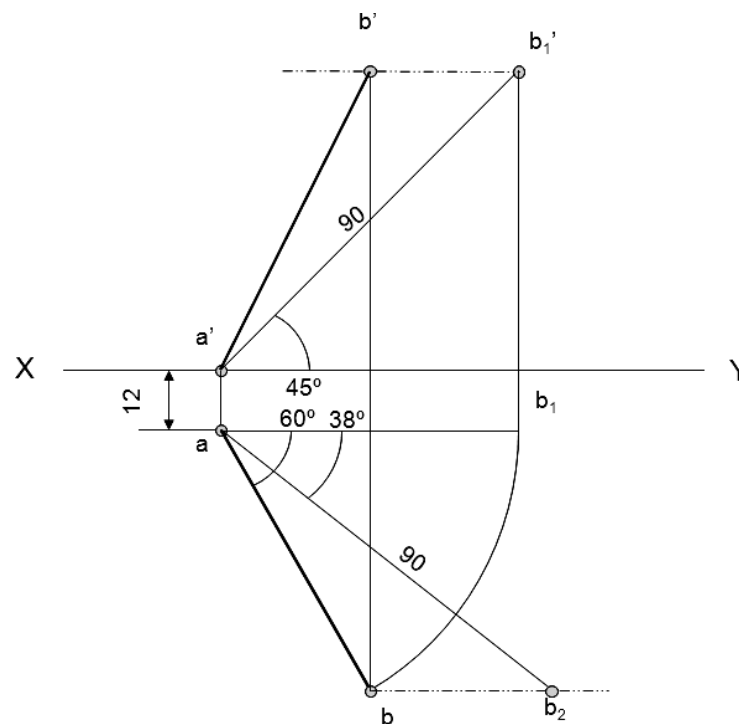


Figure 2.15

## PROJECTION OF PLANES

### Introduction:

A plane is a two dimensional object having length and breadth only. Its thickness is always neglected; various shapes of plane figures are considered such as square, rectangle, circle, pentagon, hexagon, etc

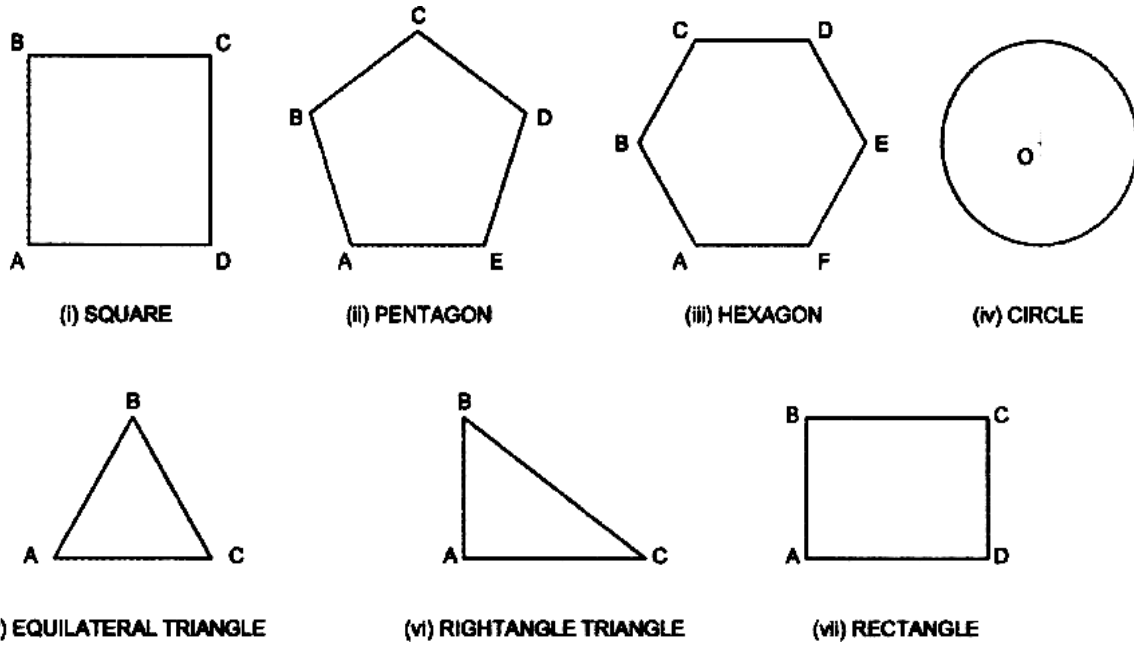


Figure 2.16

### TYPES OF PLANES:

1. Perpendicular planes which have their surface perpendicular to anyone of the reference planes and parallel or inclined to the other reference plane.
2. Oblique planes which have their surface inclined to both the reference planes.

### TRACE OF PLANE:

The trace of a plane is the line of intersection or meeting of the plane surface with the reference plane; if necessary the plane surface is extended to intersect the reference plane. The intersection line of the plane surface with **HP** is called the **Horizontal Trace (HT)** and that of **VP** is called the **Vertical Trace (VT)**.

A plane figure is positioned with reference to the reference planes by referring its surface in the following possible position.



## Projection of Different Planes position with respect to Principal planes

### 1) Surface of Plane Parallel to the HP (and perpendicular to VP)

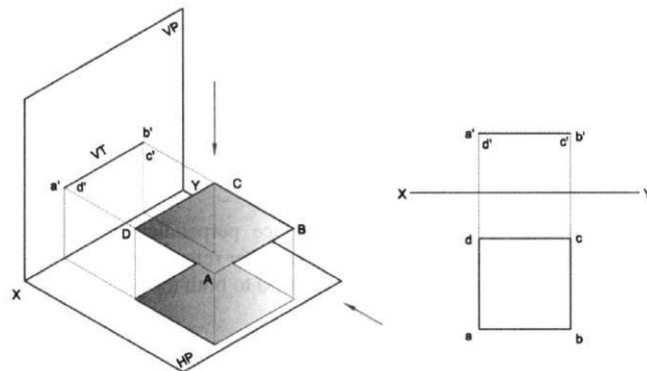


Figure 2.17

### 2) Surface of Plane Parallel to the VP (and perpendicular to HP)

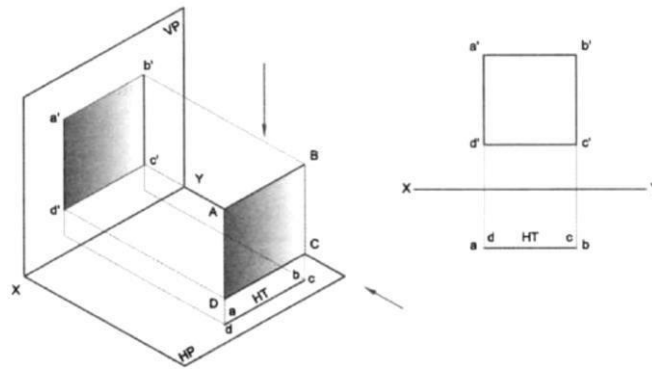


Figure 2.18

### 3) Surface of Plane Inclined to the HP and perpendicular to VP

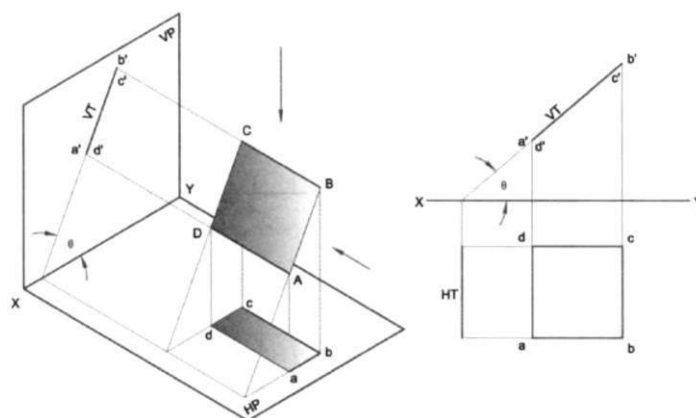


Figure 2.19

4) Surface of Plane Inclined to the VP and perpendicular to HP

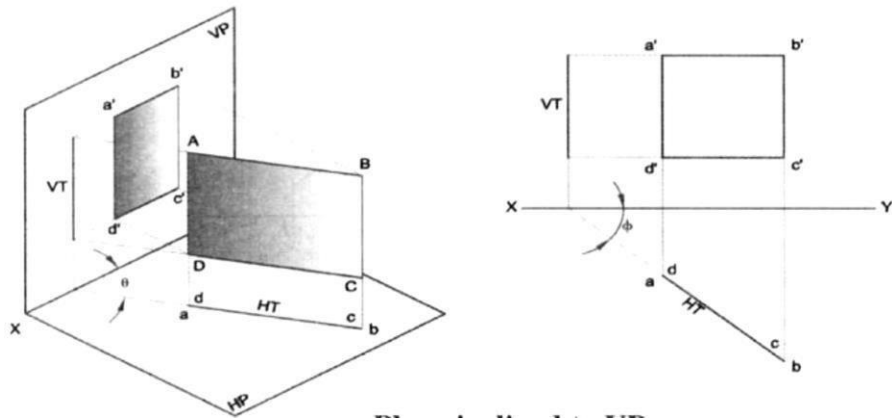


Figure 2.20

5) Surface of Plane Perpendicular to Both HP and VP

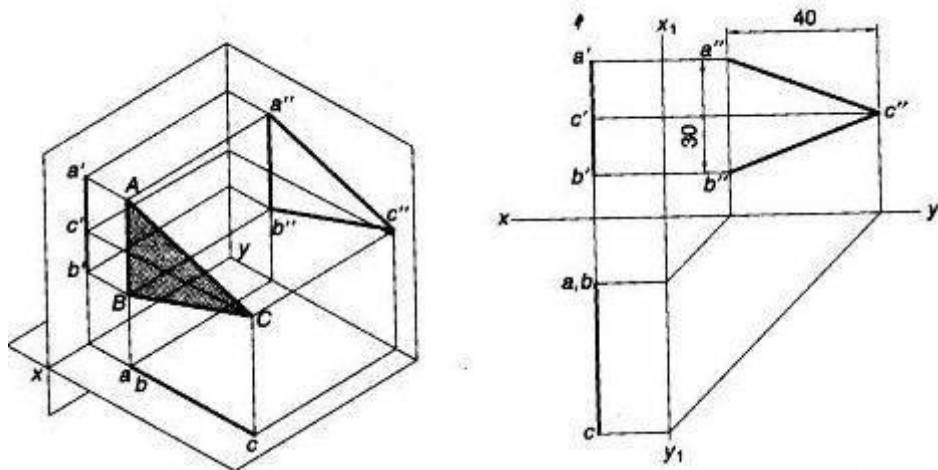


Figure 2.21

6) Surface of Plane is Inclined to Both HP and VP

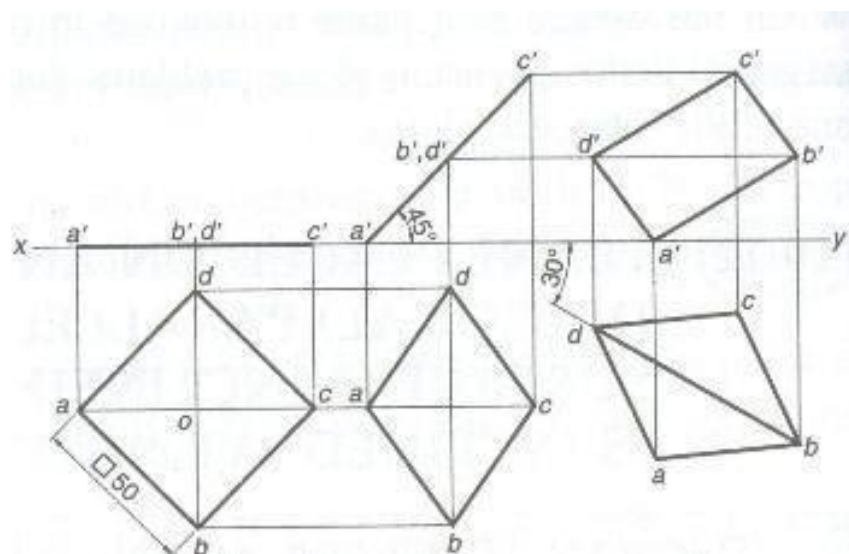


Figure 2.22

**Simple Problems:****Plane Parallel to HP**

**Problem:** A Square plane with a 40 mm side has its surface parallel to and 20 mm above the HP. Draw its Projections, when (a) A side is parallel to VP (b) A side is inclined at  $30^\circ$  to VP and (c) All sides are equally inclined to VP.

**Visualized position of surface plane Picture:**

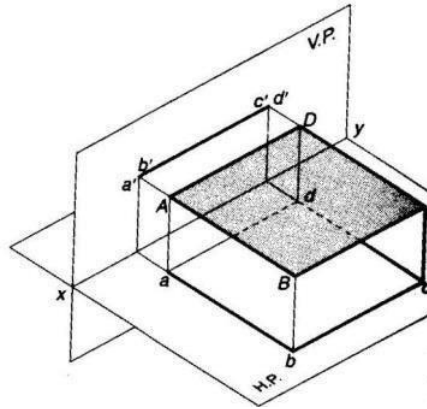


Figure 2.23a

**Solution:**

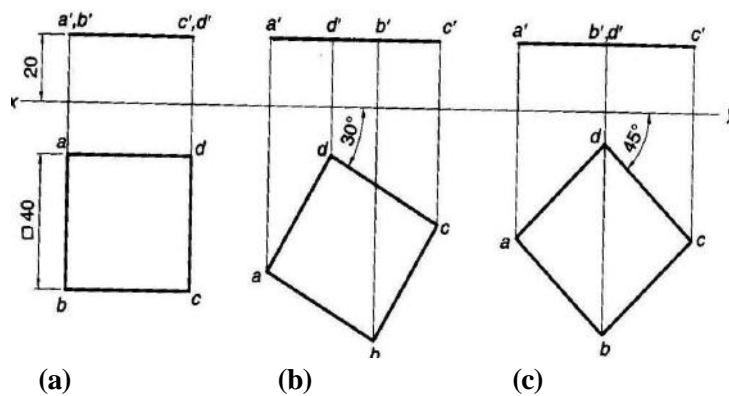


Figure 2.23b

## Plane Parallel to Plane Parallel to VP

**Problem:**

A Hexagonal plane with a 30 mm side has its surface parallel to and 20 mm in front of the VP. Draw its Projections, when (a) a side is perpendicular to HP (b) a side is parallel to the HP (c) Side is inclined at  $45^\circ$  to the HP Visualized

position of surface plane Picture:

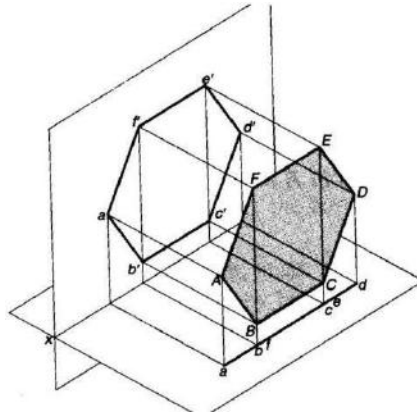


Figure 2.24 a

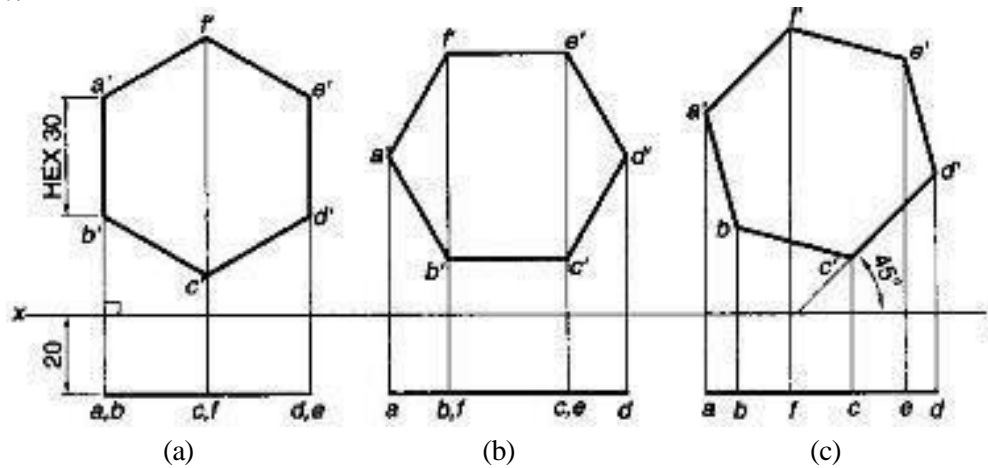
**Solution:**

Figure 2.24 b

Plane is inclined to HP and Perpendicular to VP

**Problem:**

A Pentagonal plane with a 30mm side has an edge on the HP, the surface of the Plane is inclined at  $45^\circ$  to the HP. Draw it's Projections?

*Visualized position of surface plane Picture:*

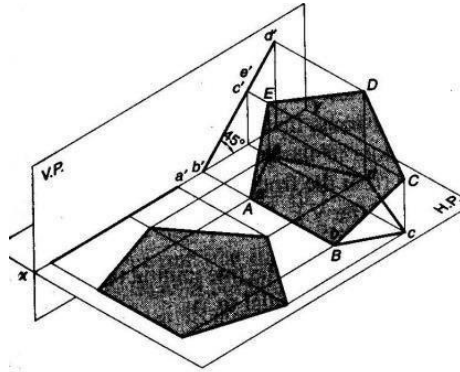


Figure 2.25a

**Solution:**

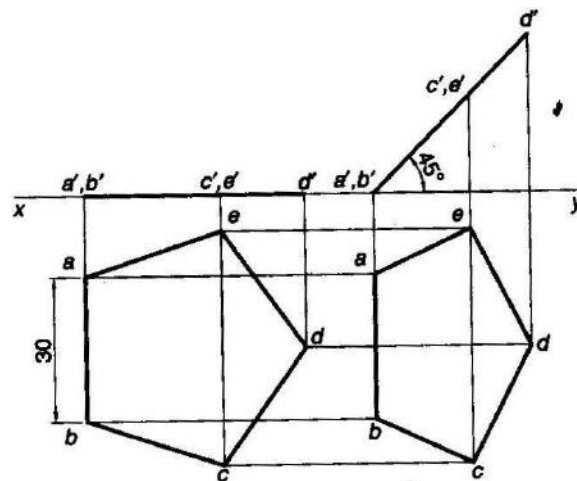


Figure 2.25b

Plane is inclined to VP and Perpendicular to HP

**Problem:**

A Hexagonal plate with a 30 mm side and negligible thickness has its surface perpendicular to the HP and inclined at  $45^\circ$  to the VP. Draw it's Projections? When one of it's sides of the Plane is Parallel to and 15 mm in front of the VP

*Visualized position of surface plane Picture:*

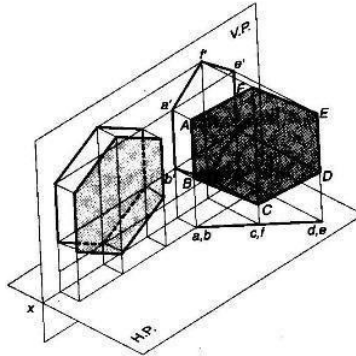


Figure 2.26a

**Solution:**

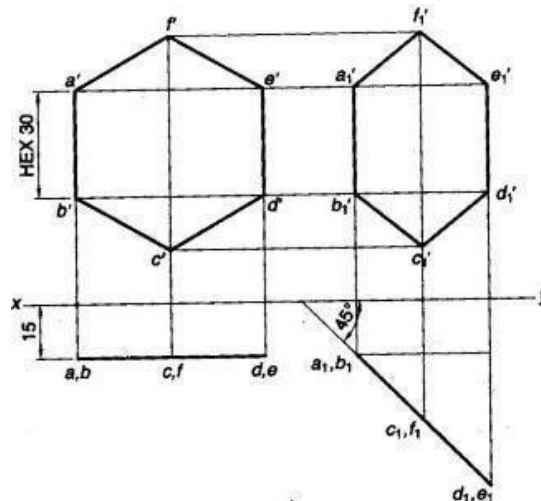


Figure 2.26b

**Problem:**

A Circular plane with a 60mm Diameter is resting on a point it's circumference on the VP. The center is 40mm above the HP , and The surface is inclined at  $45^\circ$  to the VP. And perpendicular to the HP Draw It's Projections?

**Solution:**

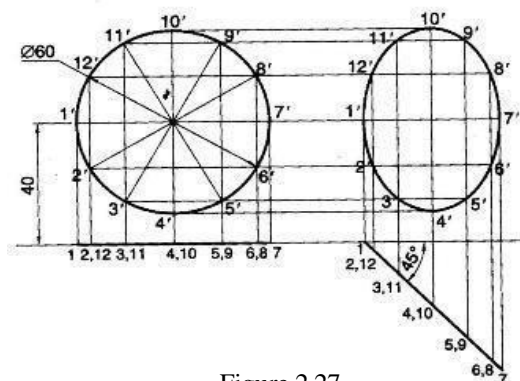


Figure 2.27

**Problem:**

Rectangle 30mm and 50mm sides is resting on HP on one of its small side which is  $30^\circ$  inclined to VP, while the surface of the plane makes  $45^\circ$  inclination with HP. Draw it's projections?

**Solution:**

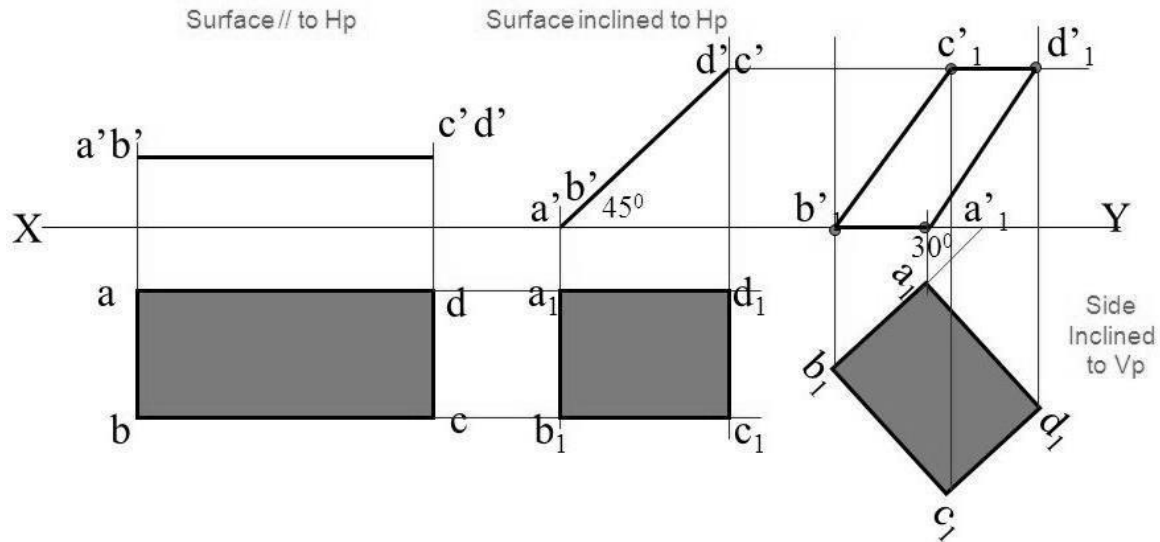


Figure 2.28

**Problem:**

A regular pentagon of 30 mm sides is resting on HP, on one of it's sides with it's surface  $45^\circ$  inclined to HP. Draw it's projections when the side in HP makes  $30^\circ$  angle with VP?

**Solution:**

**According to the given Problem**

1. Surface inclined to HP plane
2. Assumption for initial position is parallel to HP
3. So TV view will show True shape. Hence begin with TV, draw pentagon below X-Y line, taking one side vertical.

**Note:** Surface and side inclination are directly given

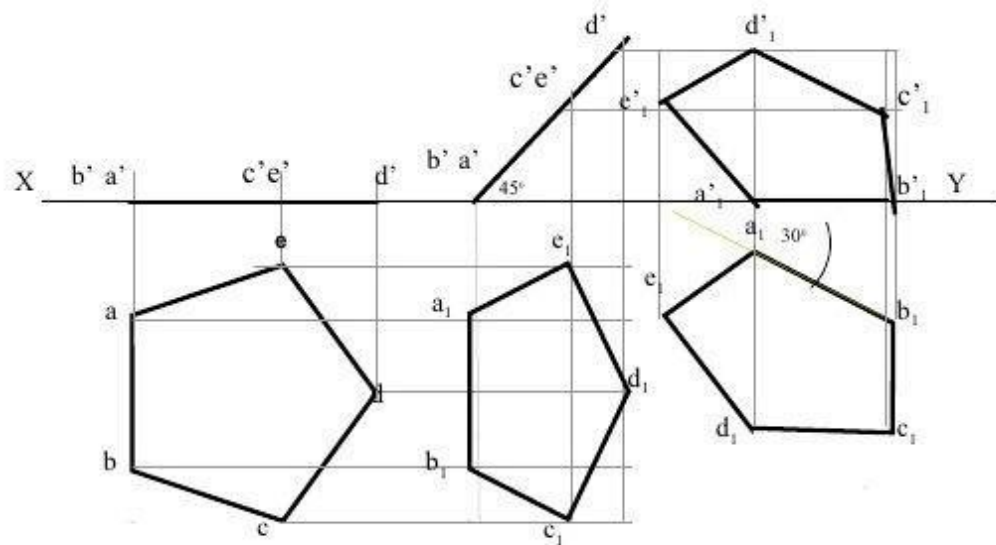


Figure 2.29



**Problem:**

A regular pentagon of 30 mm sides is resting on HP on one of its sides while its opposite vertex (corner) is 30 mm above HP. Draw projections when side in HP is  $30^\circ$  inclined to VP

**Solution:**

**According to the given Problem**

1. Surface inclined to HP plane
2. Assumption for initial position is parallel to HP
3. So TV view will show True shape. Hence begin with TV, draw pentagon below X-Y line, taking one side vertical.

**Note:** Surface Inclination indirectly given and side inclination is Directly given only change is the manner in which surface inclination is described: One side on Hp & its opposite corner 30 mm above HP. Hence redraw 1<sup>st</sup> Fv as a 2<sup>nd</sup> Fv making above arrangement. Keep a'b' on xy & d' 30 mm above xy

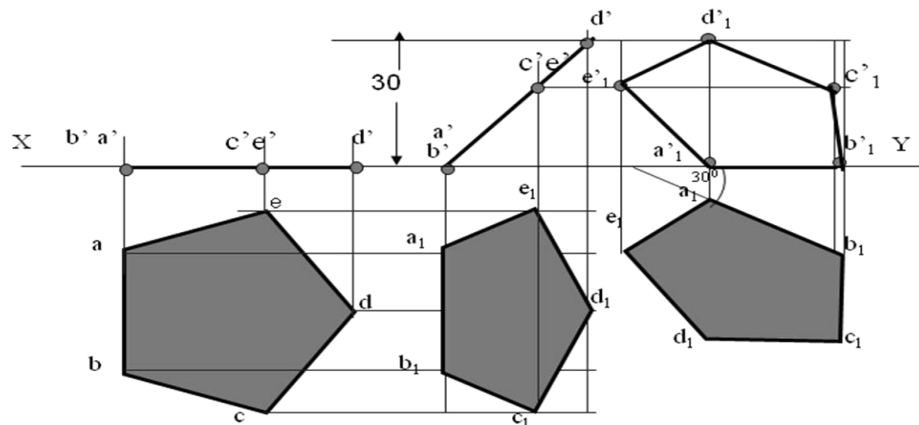


Figure 2.30

**Problem:**

A circle of 50 mm diameter is resting on HP on end A of its diameter AC which is  $30^\circ$  inclined to HP while its TV is  $45^\circ$  inclined to VP. Draw its Projections?

**Solution:**

**According to the given Problem**

1. Surface inclined to HP plane
2. Assumption for initial position parallel to HP
3. So which TV will show True shape
4. Which diameter AC horizontal Hence begin with TV, draw rhombus below X-Y line, taking longer diagonal parallel to X-Y

**Note:** In This problem inclination of TV of that AC is given, It could be drawn directly as shown in 3<sup>rd</sup> step. of that AC is given, It could be drawn directly as shown in 3<sup>rd</sup> step.

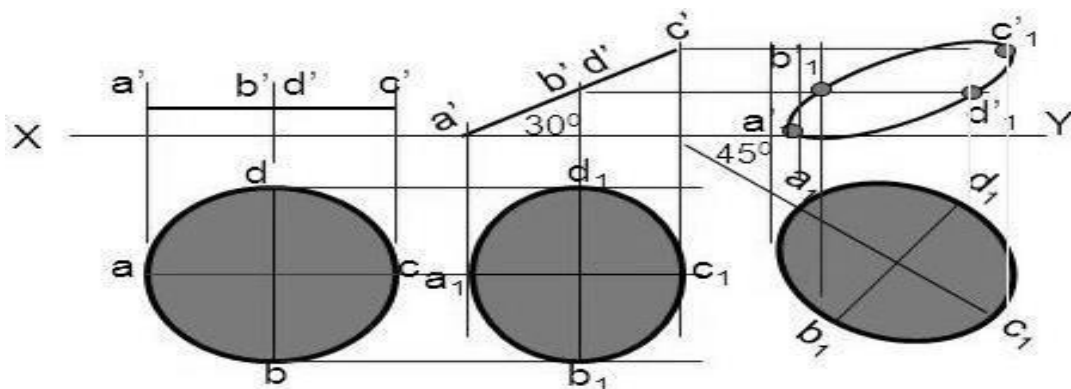


Figure 2.31



**Problem:**

A semicircle of 100 mm diameter is suspended from a point on its straight edge 30 mm from the midpoint of that edge so that the surface makes an angle of  $45^\circ$  with VP. Draw its projections.

**Solution:****According to the given Problem:**

1. In this case the plane of the figure always remains perpendicular to HP
2. It may remain parallel or inclined to VP
3. Hence TV in this case will be always a LINE view.
4. Assuming surface Parallel to VP, draw true shape in suspended position as FV. (Here keep line joining point of contact & centroid of fig. vertical )
5. Always begin with FV as a True Shape but in a suspended position. As shown in 1<sup>st</sup> FV.

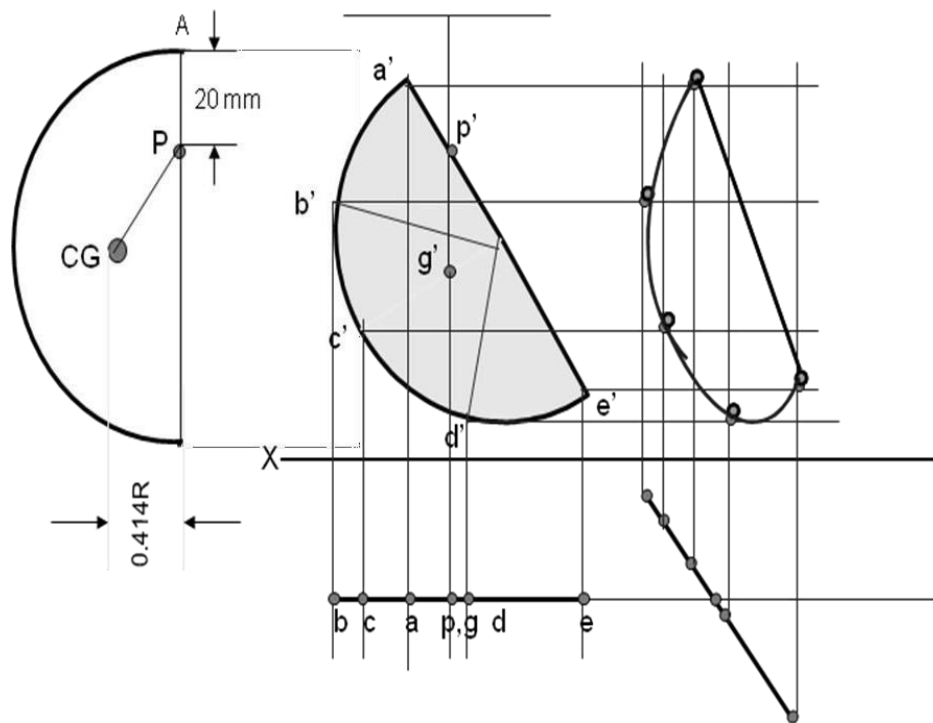


Figure 2.32

## UNIT-III

### PROJECTION OF SOLIDS

#### Introduction:

A solid has three dimensions, the length, breadth and thickness or height. A solid may be represented by orthographic views, the number of which depends on the type of solid and its orientation with respect to the planes of projection. Solids are classified into two major groups. (i) Polyhedral, and (ii) Solids of revolution

#### POLYHEDRAL

A polyhedral is defined as a solid bounded by plane surfaces called faces. They are: (i) Regular polyhedral (ii) Prisms and (iii) Pyramids

#### Regular Polyhedral

A polyhedron is said to be regular if its surfaces are regular polygons. The following are some of the regular polyhedral.

#### SOLIDS

**Prisms:** A prism is a polyhedron having two equal ends called the bases parallel to each other. The two bases are joined by faces, which are rectangular in shape. The imaginary line passing through the centers of the bases is called the axis of the prism.

A prism is named after the shape of its base. For example, a prism with square base is called a square prism, the one with a pentagonal base is called a pentagonal prism, and soon (Fig) The nomenclature of the prism is given in Fig.

To understand and remember various solids in this subject properly,  
those are classified & arranged in to two major groups.

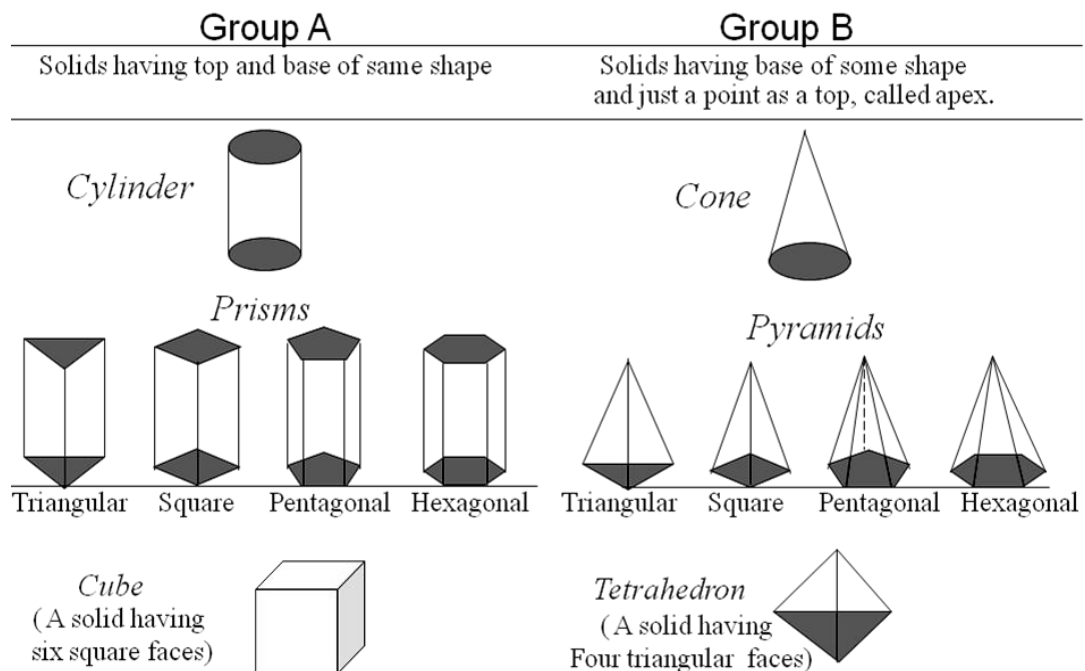


Figure 3.1

- (a) **Tetrahedron:** It consists of four equal faces, each one being an equilateral triangle.
- (b) **Hexahedron (cube):** It consists of six equal faces, each a square.
- (c) **Octahedron:** It has eight equal faces, each an equilateral triangle.

**Pyramids:** A pyramid is a polyhedron having one base, with a number of isosceles triangular faces, meeting at a point called the apex. The imaginary line passing through the centre of the base and the apex is called the axis of the pyramid.

The pyramid is named after the shape of the base. Thus, a square pyramid has a square base and pentagonal pyramid has pentagonal base and so on. The nomenclature of a pyramid is shown in Fig.

### Dimensional parameters of different solids.

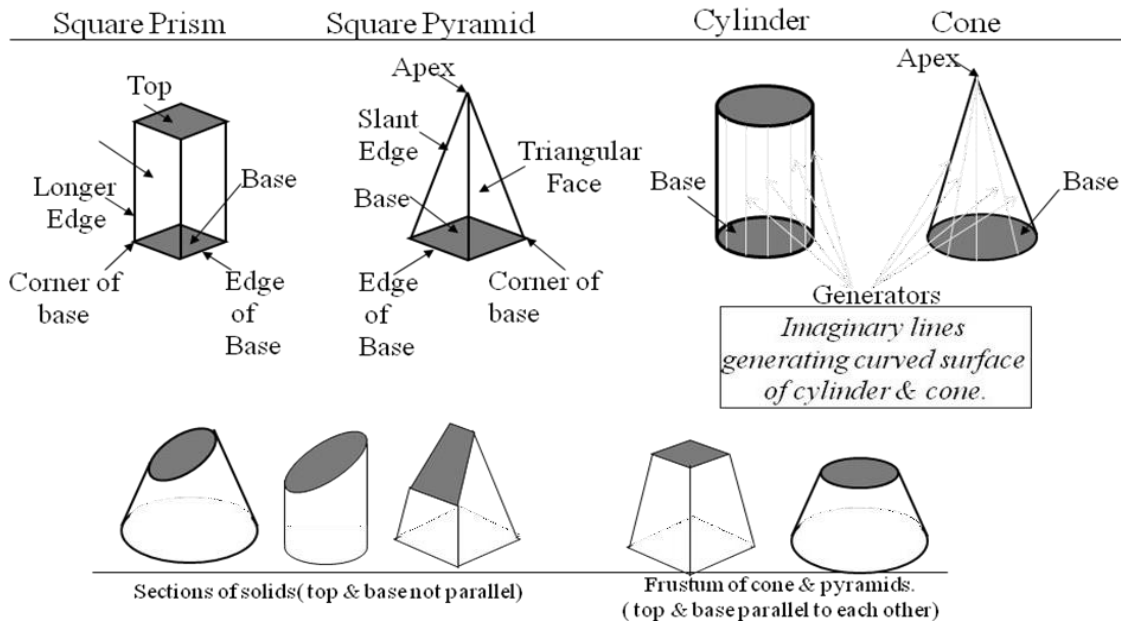


Figure 3.2

### Types of Pyramids:

There are many types of Pyramids, and they are named after the shape of their base. These are Triangular Pyramid, Square Pyramid, Pentagonal pyramid, hexagonal pyramid and tetrahedron

**Solids of Revolution:** If a plane surface is revolved about one of its edges, the solid generated is called a solid of revolution. The examples are (i) Cylinder, (ii) Cone, (iii) Sphere.

**Frustums and Truncated Solids:** If a cone or pyramid is cut by a section plane parallel to its base and the portion containing the apex or vertex is removed, the remaining portion is called frustum of a cone or pyramid

**Prisms Position of a Solid with Respect to the Reference Planes:** The position of solid in space may be specified by the location of either the axis, base, edge, diagonal or face with the principal planes of projection. The following are the positions of a solid considered.

1. Axis perpendicular to HP
2. Axis perpendicular to VP
3. Axis parallel to both the HP and VP
4. Axis inclined to HP and parallel to VP
5. Axis inclined to VP and parallel to HP
6. Axis inclined to both the Planes (VP. And HP)

The position of solid with reference to the principal planes may also be grouped as follows:

1. Solid resting on its base.
2. Solid resting on any one of its faces, edges of faces, edges of base, generators, slant edges, etc.
3. Solid suspended freely from one of its corners, etc.

#### 1. Axis perpendicular to one of the principal planes:

When the axis of a solid is perpendicular to one of the planes, it is parallel to the other. Also, the projection of the solid on that plane will show the true shape of the base.

When the axis of a solid is perpendicular to H.P, the top view must be drawn first and then the front view is projected from it. Similarly when the axis of the solid is perpendicular to V.P, the front view must be drawn first and then the top view is projected from it.

#### Simple Problems:

When the axis of solid is perpendicular to one of the planes, it is parallel to the other. Also, the projection of the solid on that plane will show the true shape of the base. When the axis of a solid is perpendicular to H.P, the top view must be drawn first and then the front view is projected from it. Similarly when the axis of the solid is perpendicular to V.P, the front view must be drawn first and then the top view is projected from it.

### 1. Axis perpendicular to HP

#### Problem:

*A Square Pyramid, having base with a 40 mm side and 60 mm axis is resting on its base on the HP. Draw its Projections when (a) a side of the base is parallel to the VP. (b) A side of the base is inclined at  $30^\circ$  to the VP and (c) All the sides of base are equally inclined to the VP.*

#### Solution:

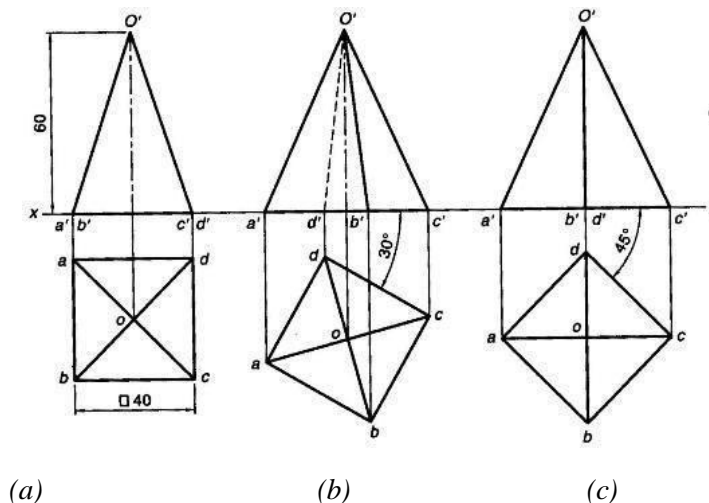


Figure 3.3

### 2. Axis perpendicular to VP

#### Problem:

*A pentagonal Prism having a base with 30 mm side and 60mm long Axis, has one of It's bases in the VP. Draw Its projections When (a)rectangular face is parallel to and 15 mm above the HP (b)*

A rectangular face perpendicular to HP and (c) a rectangular face is inclined at  $45^\circ$  to the HP  
**Solution:**

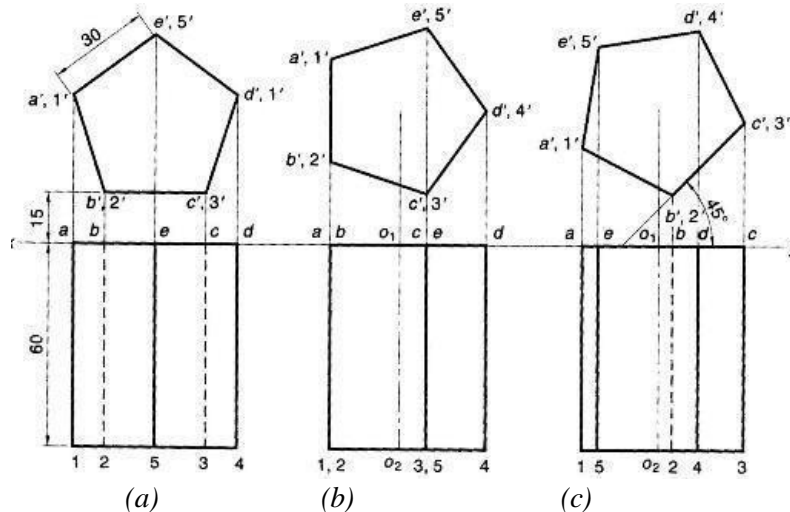


Figure3.3

### 3. Axis parallel to both the HP and VP

**Problem:**

A pentagonal Prism having a base with a 30 mm side and 60mm long axis, is resting on one of its rectangular faces on the HP. with axis parallel to the VP. Draw its projections?

**Solution:**

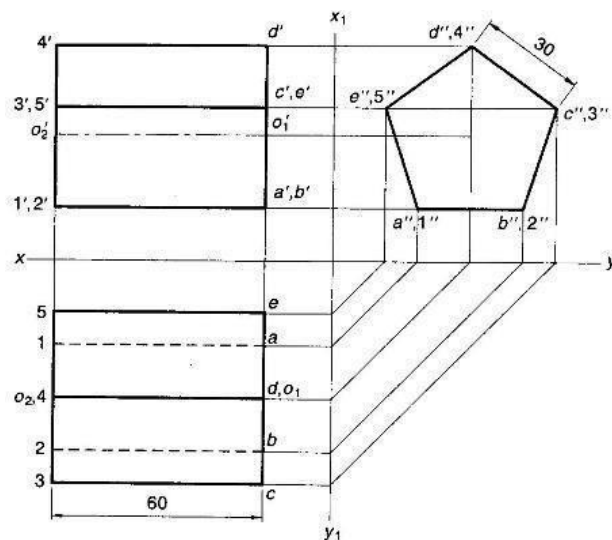


Figure3.4

### 4. Axis inclined to HP and parallel to VP

**Problem:**

A Hexagonal Prism having a base with a 30mm side and 75mm long axis, has an edge its base on the HP. Its axis is Parallel to the VP and inclined at  $45^\circ$  to the HP Draw its projections?

**Solution:**

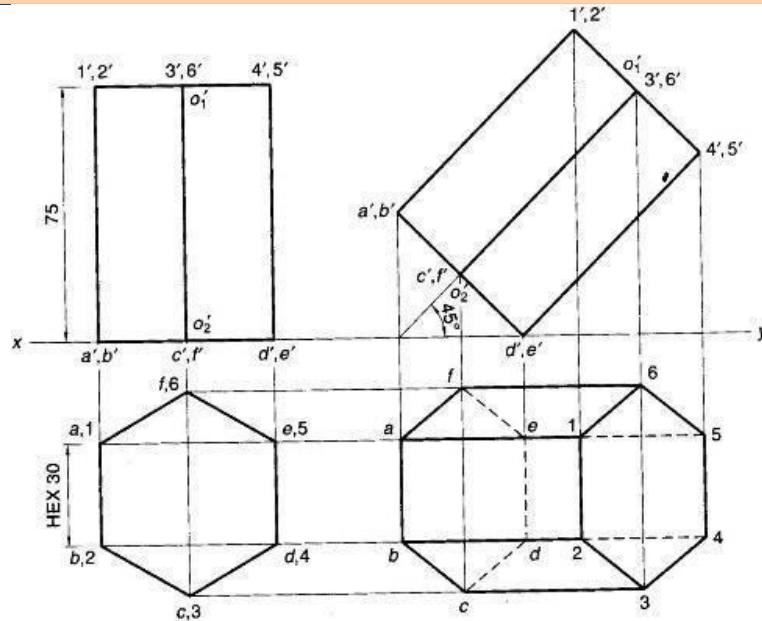


Figure 3.5

## 5. Axis inclined to VP and parallel to HP

### Problem:

An Hexagonal Prism, having a base with a 30 mm side and 65 mm long axis, has an edge of its base in the VP such that the axis is inclined at  $30^\circ$  to the VP and parallel to the HP. Draw its Projections?

### Solution:

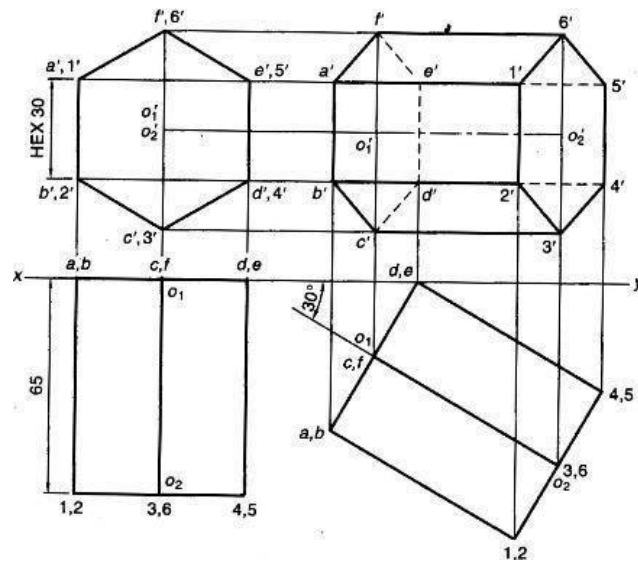


Figure 3.6

## 6. Axis inclined to both the principal planes (HP and VP)

A solid is said to be inclined to both the planes when (i) the axis is inclined to both the planes, (ii) the axis is inclined to one plane and an edge of the base is inclined to the other. In this case the projections are obtained in three stages.

Stage I: Assume that the axis is perpendicular to one of the planes and draw the projections.

Stage II: Rotate one of the projections till the axis is inclined at the given angle and project the other view from it.

Stage III: Rotate one of the projections obtained in Stage II, satisfying the remaining condition and project the other view from it.

**Problem:**

A cube of 50 mm long edges is so placed on HP on one corner that a body diagonal is Parallel to HP and perpendicular to VP. Draw it's projections.

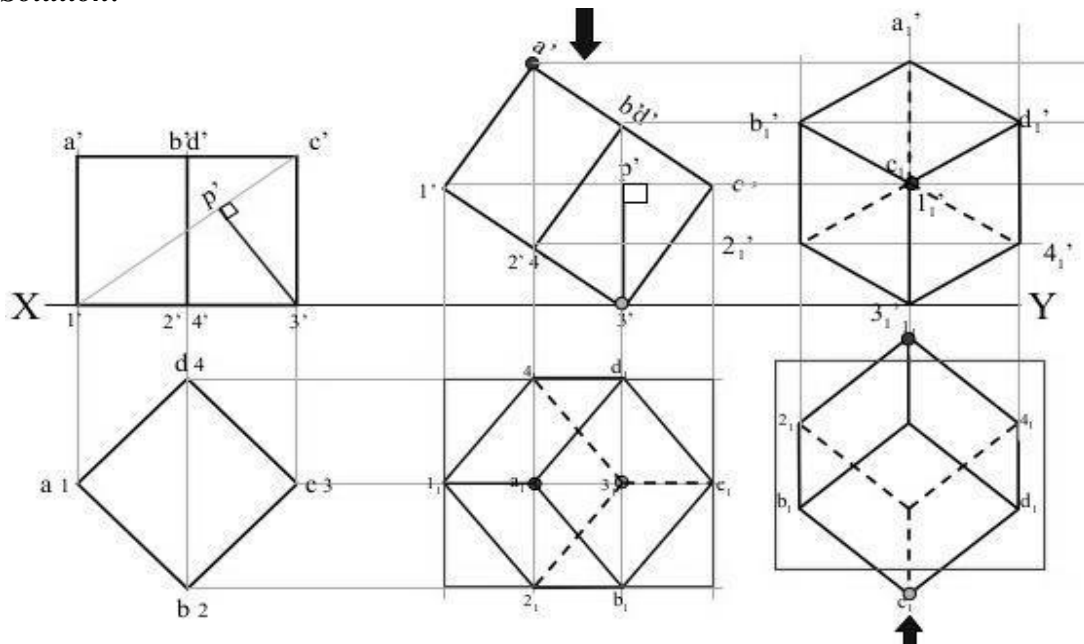
**Solution:**

Figure3.7

**Problem:**

A cone 40 mm diameter and 50 mm axis is resting on one of its generator on HP which makes  $30^\circ$  inclinations with VP. Draw it's projections?

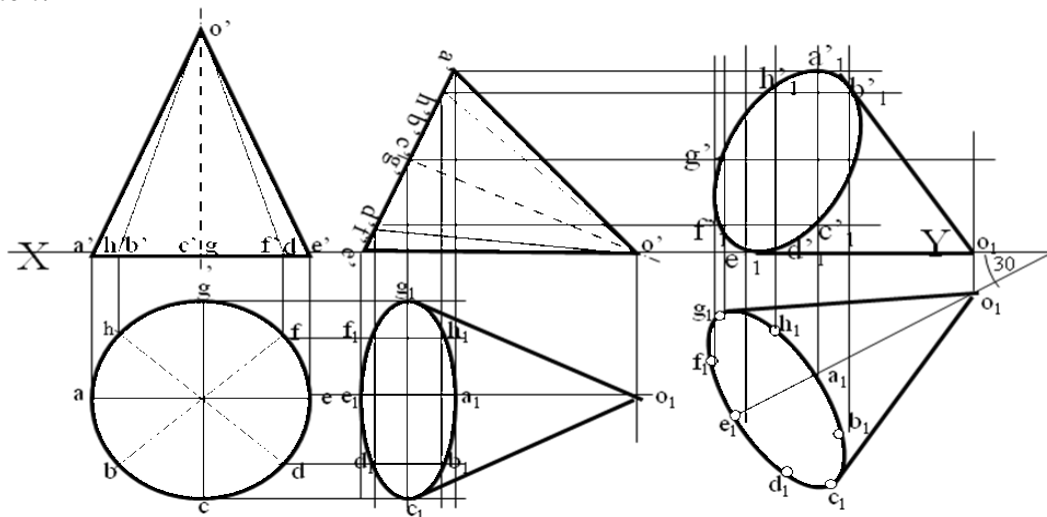
**Solution:**

Figure3.8



A cube of 50 mm long edges is so placed on HP on one corner that a body diagonal through this corner is perpendicular to HP and parallel to VP. Draw it's three views.

**Solution:**

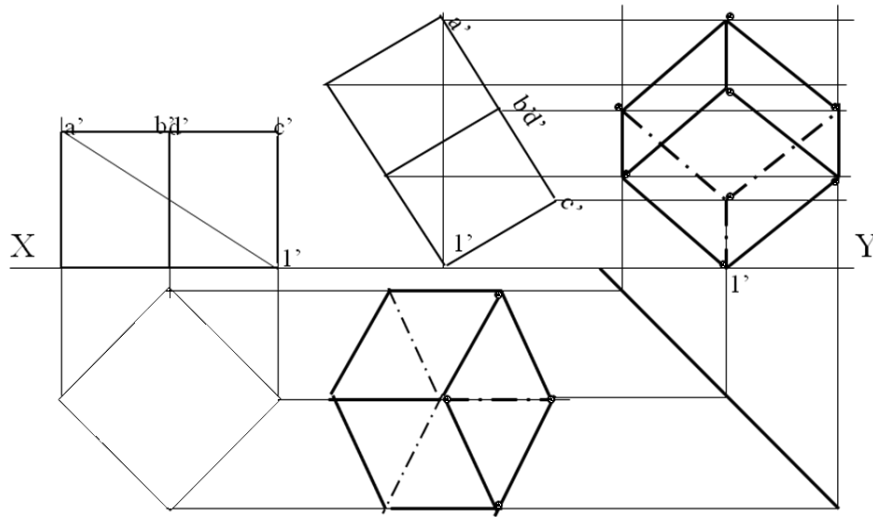


Figure3.9

**Problem:**

A circular cone, 40 mm base diameter and 60 mm long axis is resting on HP, on one point of base circle such that it's axis makes  $45^\circ$  inclination with HP and  $40^\circ$  inclination with VP. Draw it's projections.

**Solution:**

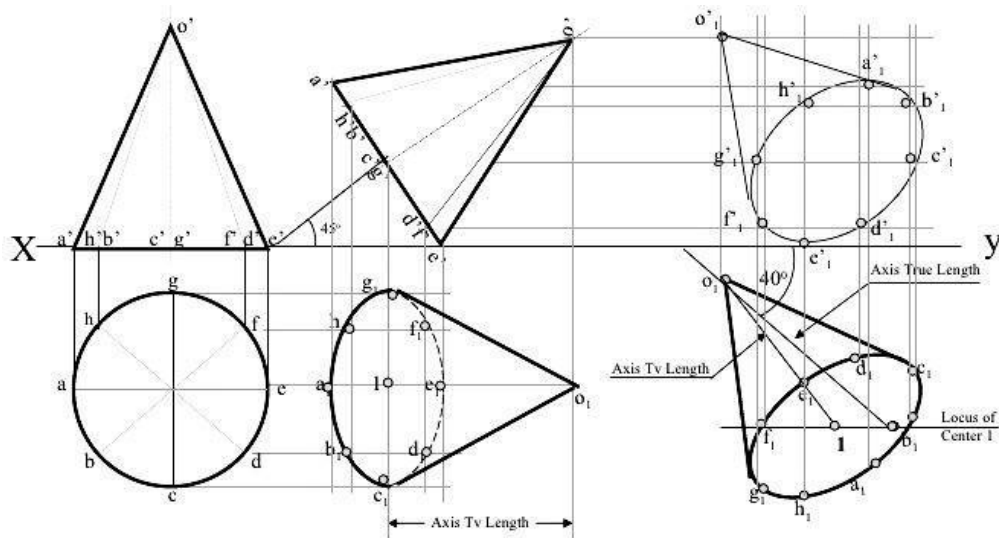


Figure3.10



A hexagonal prism, having a base with a 30mm side and an 80mm long axis, rests on one of its base edges in the H.P such that the axis is inclined at  $30^\circ$  to the HP and  $45^\circ$  to the VP. Draw its projections?

**Solution:**

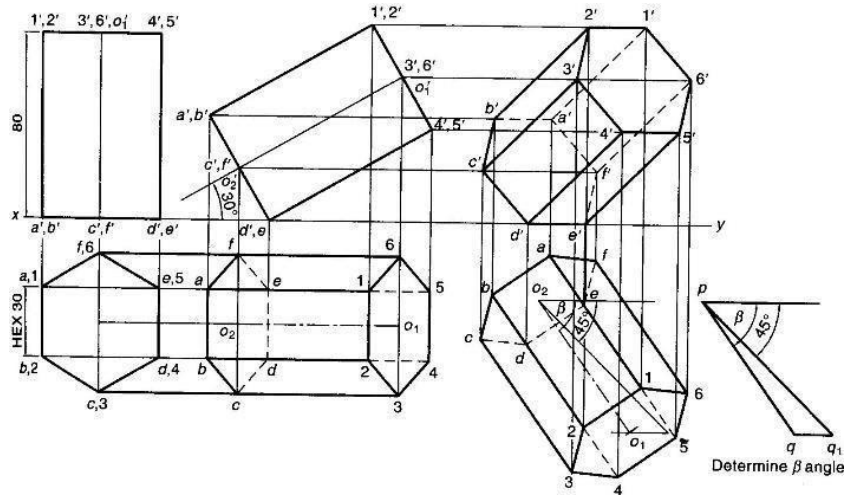


Figure3.11

**Problem:**

A Square prism, having a base with a 35mm side and an 60mm long axis, rests on one of its base edges in the HP such that the axis is inclined at  $45^\circ$  to the HP and  $45^\circ$  to the VP. Draw its projections, if the resting edge makes an angle of  $30^\circ$  with VP?

**Solution:**

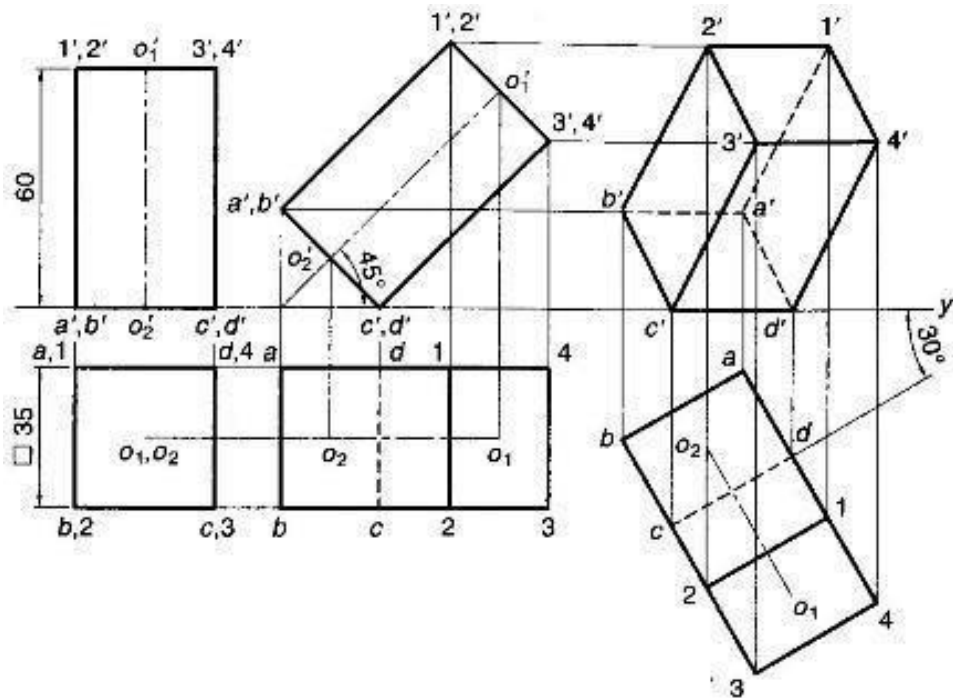


Figure3.12

A cylinder 40 mm diameter and 50 mm axis is resting on one point of a base circle on VP while its axis makes  $45^\circ$  with VP and FV of the axis  $35^\circ$  with HP. Draw its projections.

**Solution:**

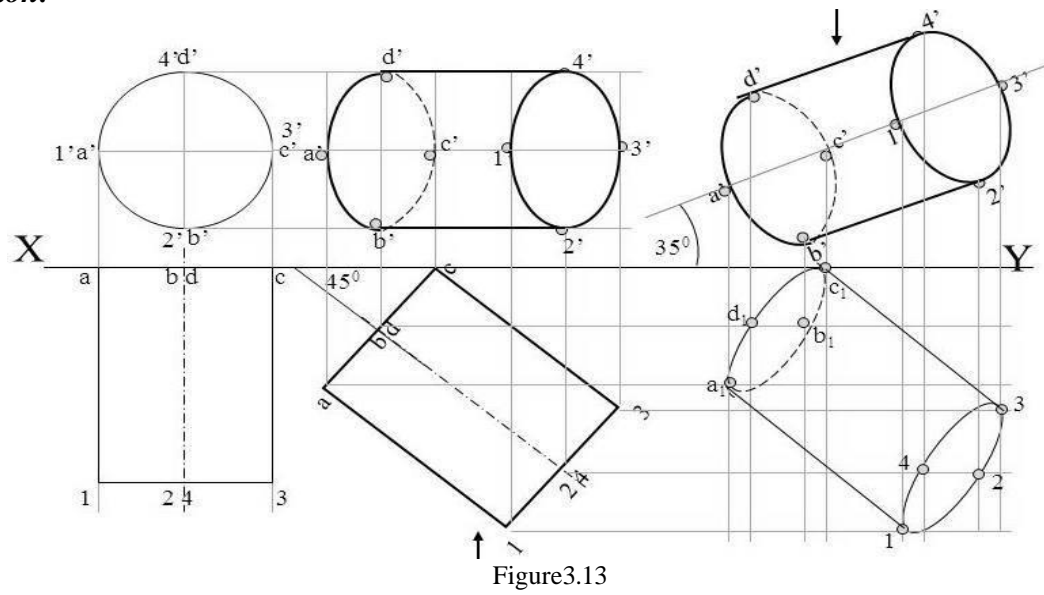


Figure3.13

# UNIT-4

## SECTIONS OF SOLIDS

### TERMINOLOGY

The following terms are frequently used in this chapter:

1. Section plane It is an imaginary plane which cuts the given object to show the internal details. This plane is represented by its trace.
2. Cut surface It is the surface created due to cutting the object by section plane. It is shown by hatching lines.
3. Hatching lines These are used to indicate the cut surface. These are represented by continuous lines drawn at  $45^\circ$  to the reference line, parallel to each other at a uniform spacing of 2 to 3 mm. For details, refer to Section 7.19.
4. Apparent section It is the projection of cut surface when the section plane is not parallel to the plane of projection.
5. True shape of section The projection of the cut surface on a plane parallel to the section plane is known as true shape of section. It shows actual shape and size of the cut surface.

### TYPES OF SECTION PLANES

Section planes are of the following types:

1. Section plane perpendicular to V.P.
  - (a) Horizontal section plane
  - (b) Auxiliary inclined plane (A.I.P.)
2. Section plane perpendicular to H.P.
  - (a) Plane parallel to V.P.
  - (b) Auxiliary vertical plane (A.V.P.)
3. Profile section plane, i.e., a plane perpendicular to both the H.P. and the V.P.
4. Oblique section plane, i.e., inclined to both H.P. and V.P. **(not considered in current study)**

### SECTION BY A PLANE PERPENDICULAR TO V.P.

#### Problem

*A triangular prism, base side 50 mm and axis 50 mm is lying on one of its rectangular faces on the H.P. with its axis perpendicular to the V.P. It is cut by a section plane parallel to and 20 mm above H.P. Draw its front view and sectional top view.*

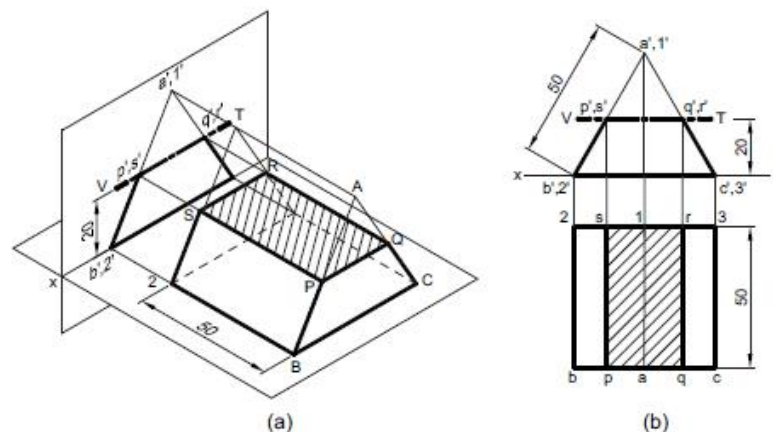


Fig. 4.1 Section of prism by horizontal plane (a) Pictorial view (b) Orthographic view

#### Problem

A triangular prism of base side 50 mm and axis 50 mm lies on one of its rectangular faces on the H.P. with its axis inclined at  $30^\circ$  to the V.P. It is cut by a horizontal section plane at a distance of 5 mm from the axis. Draw its front view and sectional top view.

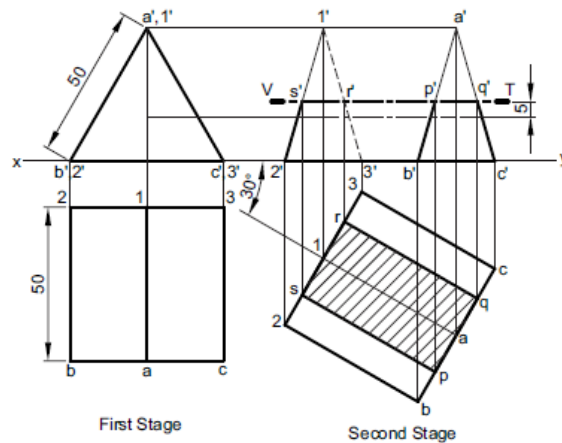


Fig 4.2

**Problem**

A square pyramid of base side 40 mm and axis 60 mm is resting on its base on the H.P. with a side of base parallel to the V.P. Draw its sectional views and true shape of the section, if it is cut by a section plane perpendicular to the V.P., bisecting the axis and is (a) parallel to the H.P., (b) inclined at  $45^\circ$  to the H.P. (c) inclined at  $60^\circ$  to the H.P.

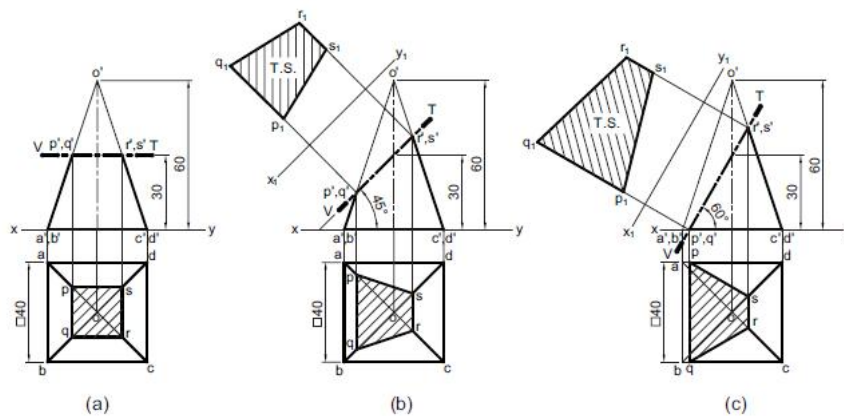


Fig 4.3

**Problem**

A square pyramid of base side 40 mm and axis 60 mm is resting on its base on the H.P. with all the sides of the base equally inclined to the V.P. Draw its sectional views and true shape of the section, if it is cut by a section plane perpendicular to the V.P., bisecting the axis and is (a) parallel to the H.P., (b) inclined at  $45^\circ$  to the H.P. and (c) inclined at  $60^\circ$  to the H.P.

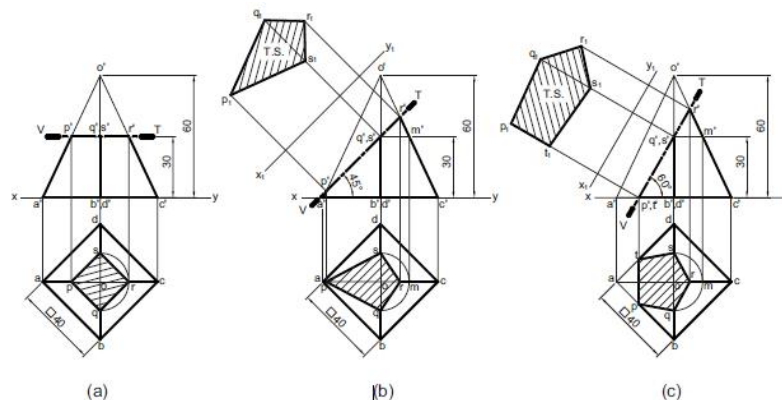


Fig 4.4

**Problem**

A pentagonal pyramid of base side 30 mm and axis 60 mm is resting on its base on the H.P. with an edge of the base parallel to the V.P. It is cut by a section plane perpendicular to the V.P., inclined at  $60^\circ$  to the H.P. and bisecting the axis. Draw its front view and sectional top view and true shape of the section.

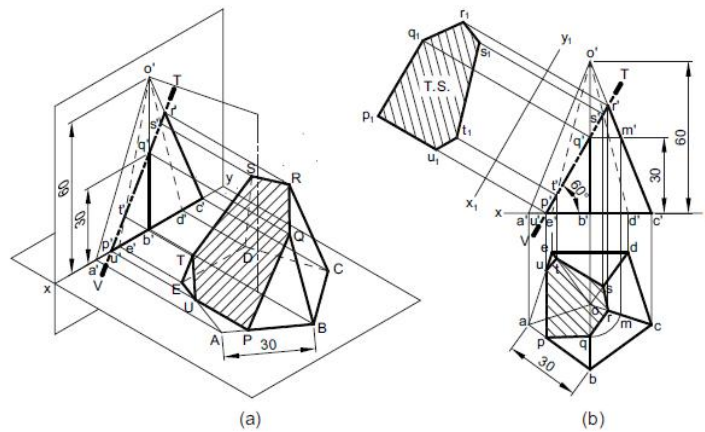


Fig 4.5

**Problem**

A cone of base diameter 50 mm and axis 60 mm is resting on its base on the H.P. It is cut by an A.I.P. inclined at  $45^\circ$  to the H.P. and passing through a point on the axis, 20 mm above the base. Draw its sectional top view and obtain true shape of the section.

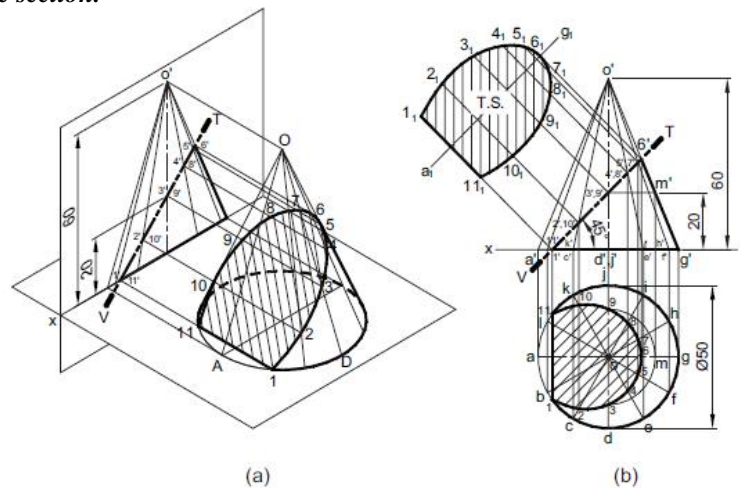


Fig 4.6

**SECTION BY A PLANE PERPENDICULAR TO H.P.**

**Problem**

A square prism of base side 40 mm and axis 60 mm rests on its base on the H.P. such that one of its rectangular faces is inclined at  $30^\circ$  to the V.P. It is cut by a section plane parallel to V.P., bisecting a face of the prism which is inclined at  $30^\circ$  to the V.P. Draw its sectional front view and top view.

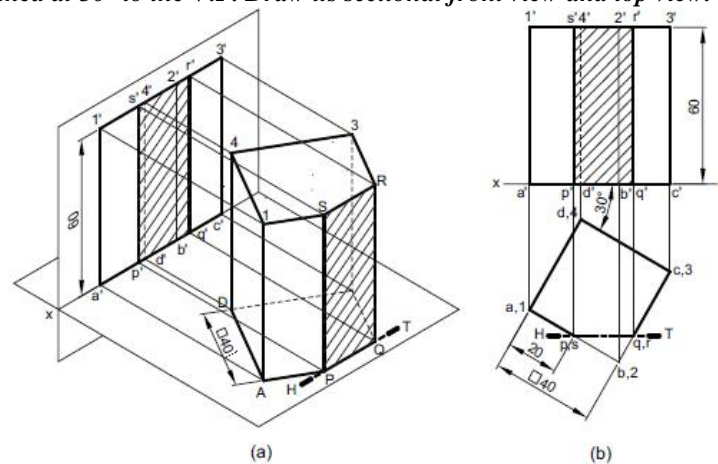


Fig 4.7



**Problem**

A square prism of base side 40 mm and axis 60 mm rests on its base on the H.P. such that one of its rectangular faces is inclined at  $30^\circ$  to the V.P. It is cut by a section plane perpendicular to H.P. and inclined at  $60^\circ$  to V.P. passing through the prism such that a face which is inclined at  $60^\circ$  to the V.P. is bisected. Draw its sectional front view, top view and true shape of section.

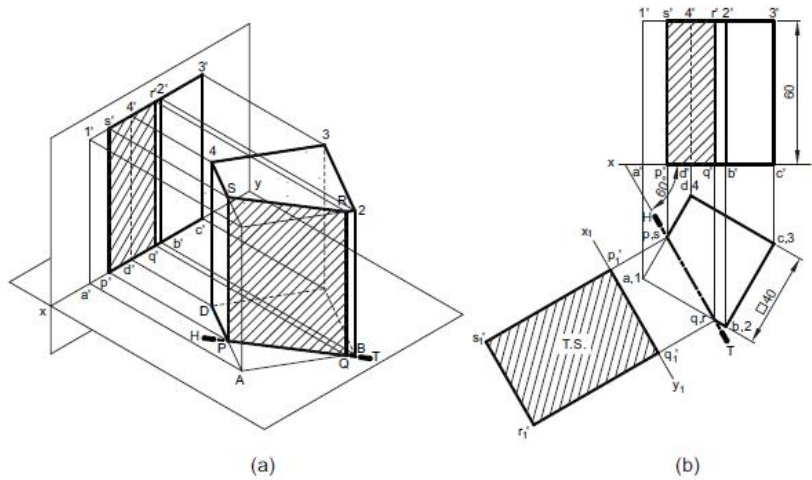


Fig 4.8

**Problem**

A pentagonal prism of base side 30 mm and axis 60 mm lies on one of its rectangular faces on the H.P. with its axis inclined at  $45^\circ$  to the V.P. A vertical section plane parallel to the V.P. cuts the prism at a distance of 20 mm from one of the end faces. Draw its sectional front view and top view.

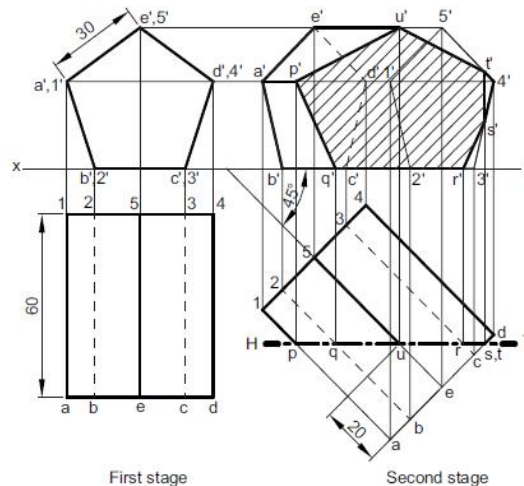


Fig 4.9

**Problem**

A pentagonal pyramid of base side 30 mm and axis 60 mm is resting on its base on the H.P. with a side of base parallel to V.P. and nearer to it. It is cut by a section plane parallel to the V.P. and 12 mm in front of the axis of the pyramid. Draw its sectional front view and top view.

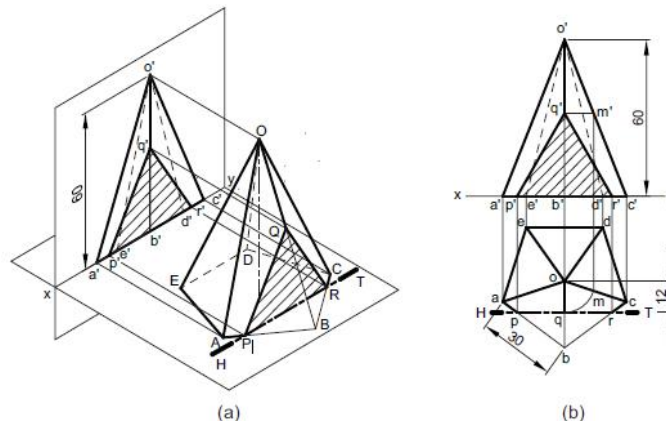


Fig 4.10



Fig 4.12

**Problem**

A pentagonal prism of base side 30 mm and axis 70 mm is resting on its base on the H.P. with a rectangular face parallel to the V.P. It is cut by an auxiliary inclined plane (A.I.P.) whose V.T. is inclined at  $45^\circ$  to the reference line and passes through the mid-point of the axis. Draw the development of the lateral surface of the truncated prism

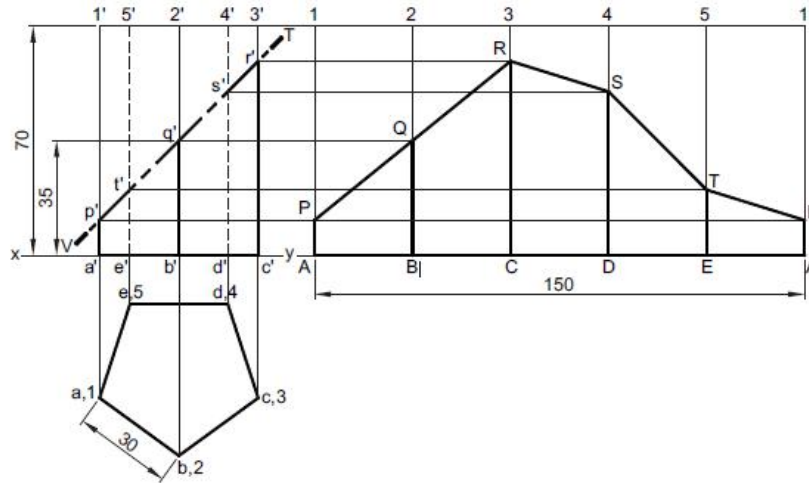


Fig 4.13

**Problem**

Figure 4.14a shows the front view of a truncated hexagonal prism of base side 30 mm and axis 90 mm. The prism is resting on the H.P. with an edge of the base parallel to the VP. Draw the development of its lateral surface.

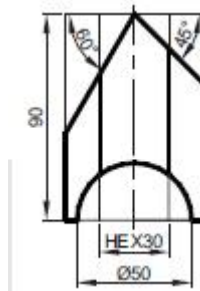


Fig 4.14a

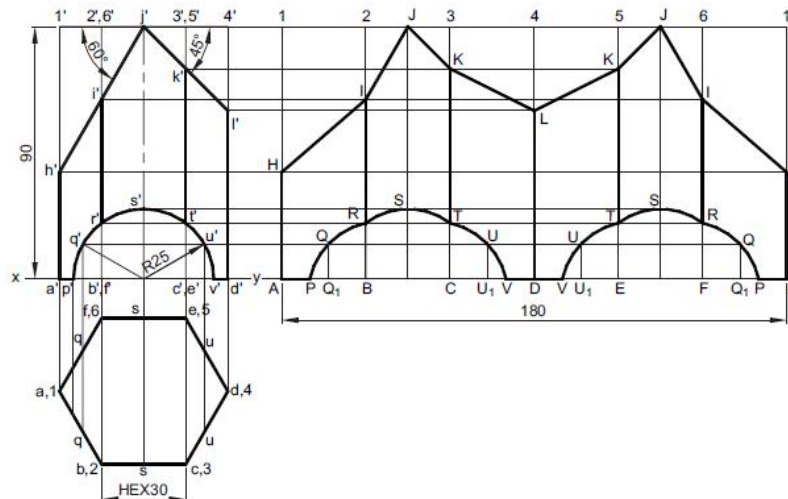


Fig 4.14b

## DEVELOPMENT OF CYLINDERS

Cylinders are also developed by parallel line method in a way similar to the prisms. Here the length of stretch line is equal to the circumference of the base circle of the cylinder.



**Problem**

A cylinder of base diameter 50 mm and axis 70 mm is resting on ground with its axis vertical. It is cut by a section plane perpendicular to the V.P., inclined at  $45^\circ$  to the H.P., passing through the top of a generator and cuts all the other generators. Draw the development of its lateral surface.

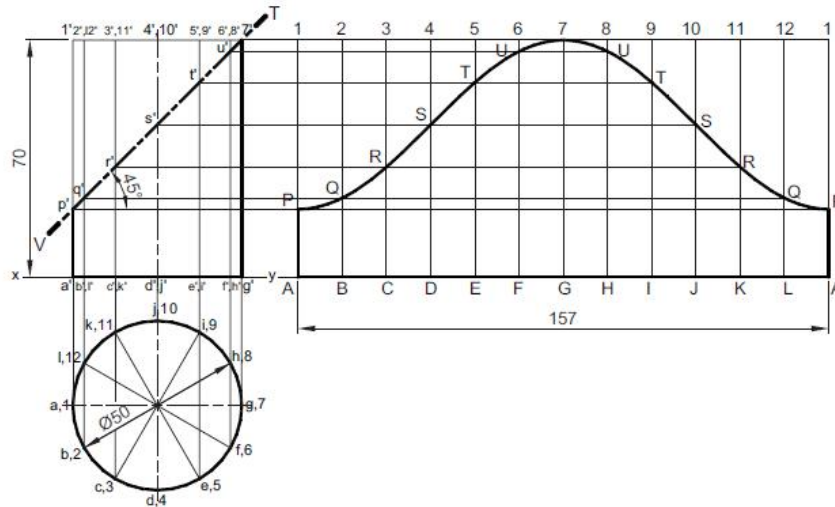


Fig 4.15

**DEVELOPMENT OF CONES**

Development of lateral surface of cone is obtained by radial line method. In this method, the development is in the form of sector of a circle, the radius of which is equal to the slant height of the cone. The subtended angle  $\theta$  of this sector is calculated as  $\theta = \frac{r}{R} \times 360^\circ$ , where  $r$  is the radius of the base circle and  $R$  is the slant height of the cone. Alternatively, the arc length of this sector can directly be transferred from the top view of the base circle. It is done by taking 1/12th of the arc length from the base circle and then marking 12 times in the development. Although approximate, it is one of the most convenient and preferred methods.

**Problem**

A cone of base diameter 50 mm and axis 60 mm is resting on its base on the H.P. Draw the development of its lateral surface.

**Calculation of  $\theta$**

Slant height of cone

$$R = o'g' = \sqrt{r^2 + h^2} = \sqrt{25^2 + 60^2} = 65 \text{ mm}$$

Subtended angle

$$\theta = \frac{r}{R} \times 360^\circ = \frac{25}{65} \times 360^\circ = 138^\circ \text{ (approx.)}$$

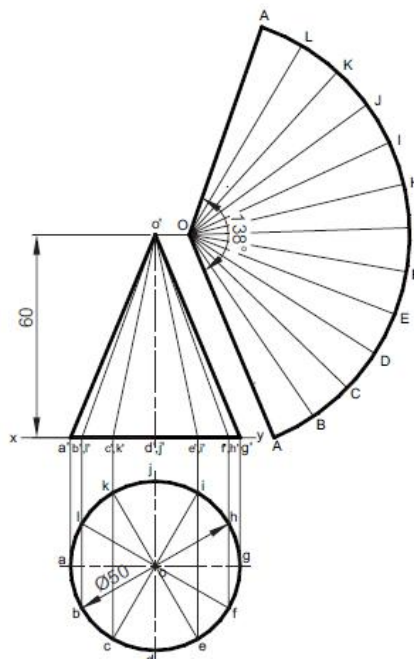


Fig 4.16

**Problem**

A cone of base diameter 50 mm and axis 60 mm is resting on its base on the H.P. Draw the development of its lateral surface when it is cut by an auxiliary inclined plane inclined at  $60^\circ$  to the H.P. and bisecting the axis.

**Calculation of  $\theta$**

Slant height of cone

$$R = o'g' = \sqrt{r^2 + h^2} = \sqrt{25^2 + 60^2} = 65 \text{ mm}$$

Subtended angle

$$\theta = \frac{r}{R} \times 360^\circ = \frac{25}{65} \times 360^\circ = 138^\circ \text{ (approx.)}$$

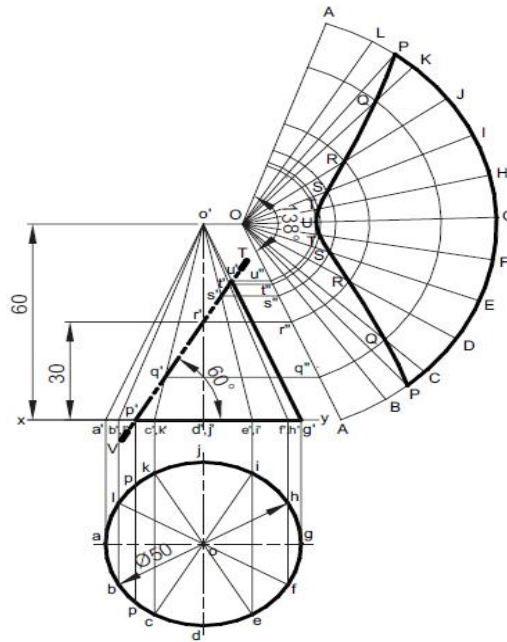


Fig 4.17

**DEVELOPMENT OF PYRAMIDS**

Development of lateral surface of a pyramid consists of a series of isosceles triangles. It is obtained by radial line method, similar to that of the cone. However, for the isosceles triangles the true length of the slant edge may or may not be available in the front view. In case true length of the slant edge is not available, one needs to first determine the true length of the slant edge. The following problems illustrate the development of the lateral surface of the pyramids.

**Problem**

Draw the development of the lateral surface of a square pyramid of base side 40 mm and axis 60 mm, resting on its base on the H.P. such that (a) all the sides of the base are equally inclined to the V.P., and (b) a side of the base is parallel to the V.P.

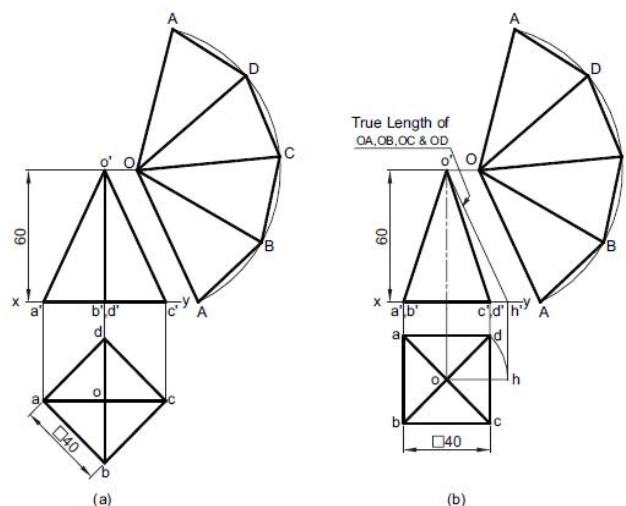
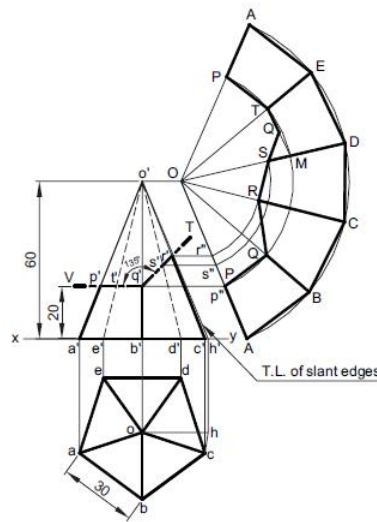


Fig 4.18

### Problem

*A pentagonal pyramid of base side 30 mm and axis 60 mm, rests on its base on the H.P. with a side of the base parallel to the V.P. It is cut by two section plane which meet at a height of 20 mm from the base. One of the section planes is horizontal, while the other is an auxiliary inclined plane whose V.T. is inclined at  $45^\circ$  to the H.P. Draw the development of the lateral surface of the solid when apex is removed.*



*Fig 4.19*

# UNIT-5

## ISOMETRIC PROJECTIONS

### Isometric projection:

Isometric projection is a type of pictorial projection in which the three dimensions of a solid are not only shown in one view but their actual sizes can be measured directly from it. The three lines AL, AD and AH, meeting at point A and making  $120^\circ$  angles with each other are termed Isometric Axes. The lines parallel to these axes are called Isometric Lines. The planes representing the faces of the cube as well as other planes parallel to these planes are called Isometric Planes.

### ISOMETRIC VIEW OF SOLIDS CONTAINING NON ISOMETRIC LINES

The inclined lines of an object are represented non isometric lines in isometric projections. These are drawn by one of the following methods

#### 1. Box Method:

In this box method, the object is assumed to be enclosed in a rectangular box and both the isometric and non-isometric lines are drawn by locating the corresponding points of contact with the surfaces and edge of the box.

#### 2. Off-Set Method:

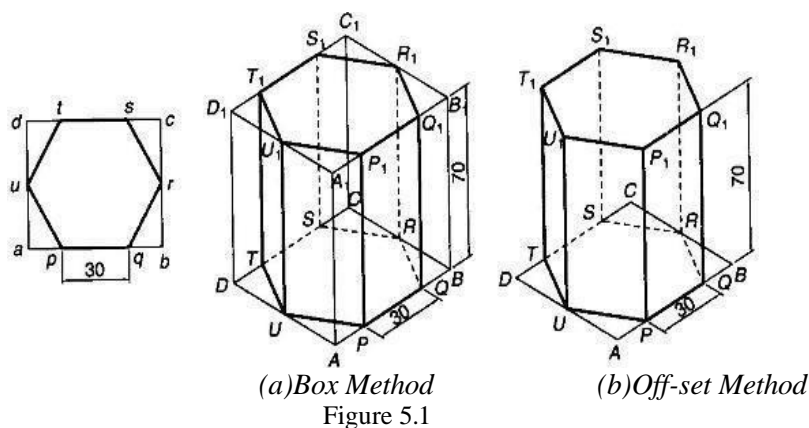
In this Off-set Method the lines parallel to isometric axes are drawn from every corner or reference of an end to obtain the corner or the reference point at the other end.

*\*The Box Method is generally convenient for solving most of the problems*

#### \*Problem:

Draw isometric view of a hexagonal prism having a base with 30 mm side and a 70 mm long axis resting on its base on the HP. With an edge of the base parallel to the VP when (a) using Box Methods (b) using Off-set Method?

#### Solution:



#### Problem:

Draw an isometric view of a cylinder, with a 50 mm base diameter and a 70 mm long axis when (a) The base is on the HP (b) when one of the generators is on the HP?

#### Solution:

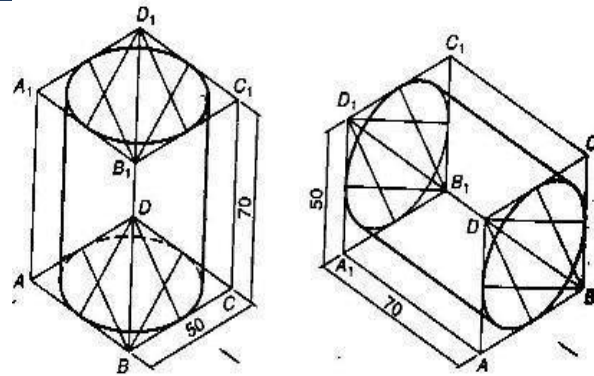
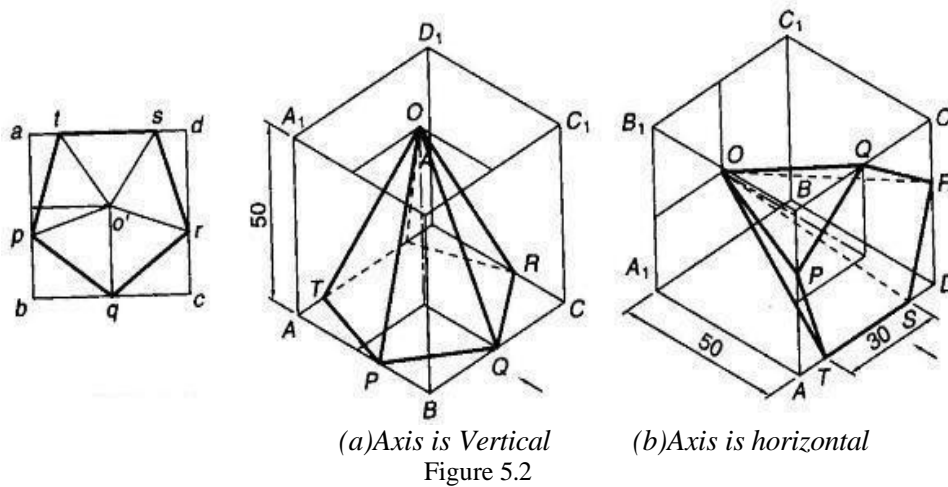


Figure 5.2

Draw an isometric view of a pentagonal pyramid having a base, with a 30 mm side and 50 mm long axis (a) when its axis is vertical (b) when its axis is horizontal?

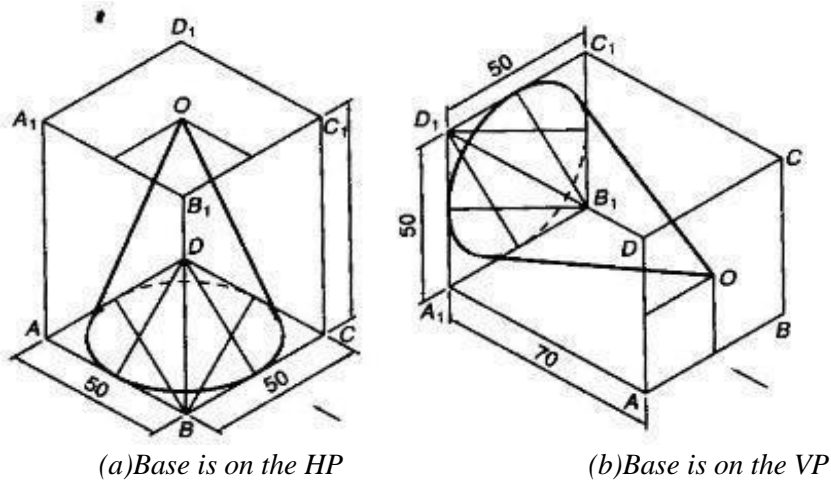
**Solution:**



**Problem:**

Draw an isometric view of Cone with a base diameter is 50 mm side and 70 mm long axis (a) when the base is on the HP (b) when the base is on the VP?

**Solution:**



## ISOMETRIC VIEW OF FRUSTUMS

**Problem:**

Draw an isometric view of Frustum of Hexagonal Pyramid having 35 mm base side 20 mm top side

and 80mm long axis, resting on its base on the HP with an Edge of the base parallel to the VP?

**Solution:**

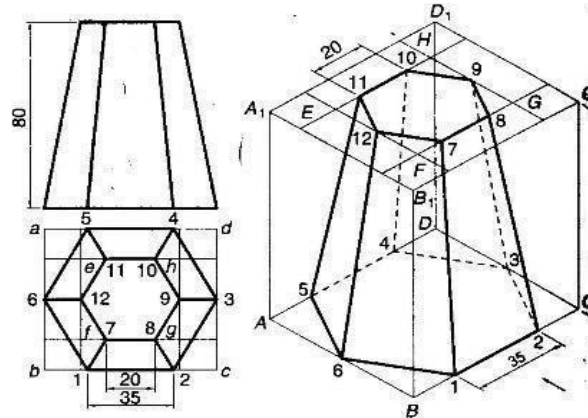


Figure 5.4

**Problem:**

Draw an isometric view of Frustum of Cone with a 60 mm base diameter, 40 mm Top diameter and 70mm long axis, resting on its base on the HP?

**Solution:**

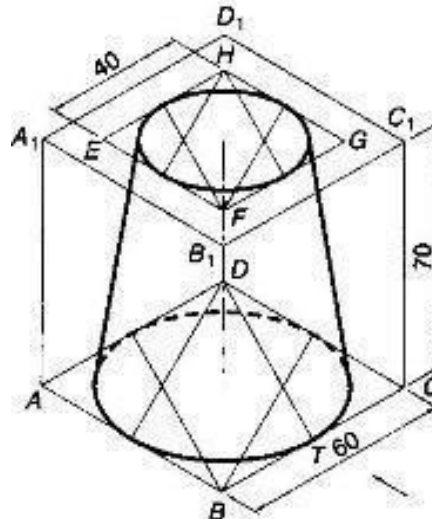


Figure 5.5

## ISOMETRIC VIEW OF COMPOSITE SOLIDS

**Problem:**

A Sphere with a 60 mm diameter is resting centrally on the Top of the Square Block with a 70 mm side 20 mm thickness. Draw an isometric view of the arrangement?

**Solution:**

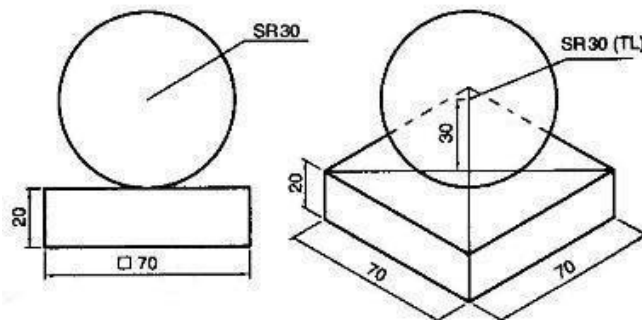


Figure 5.6



**Problem:**

A square pyramid resting centrally over a cylindrical block which is resting centrally on top of the Square block. Draw an isometric projection of the arrangement .consider the pyramid has a base of 25mm side and a 40 mm long axis, the cylinder block has a 50mm base diameter and 20mm thickness and the square block has a 70mm base side and 15mm thickness.?

**Solution:**

*Note: Solve this problem by using isometric scale (reduced length)*

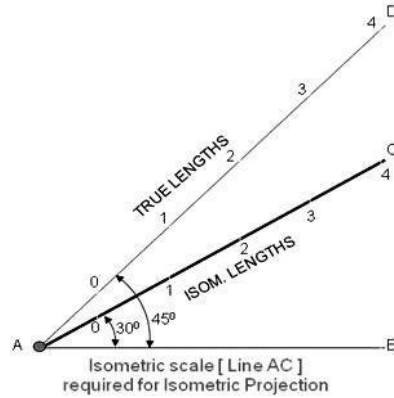


Figure 4.16(a)

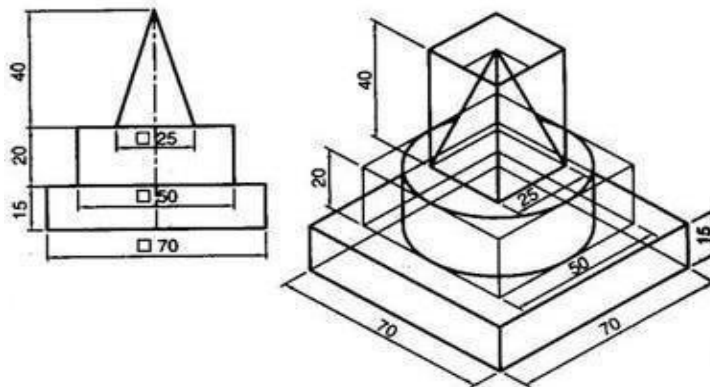


Figure 5.7

**Problem:**

Draw the isometric view of the given orthographic projection of the object?

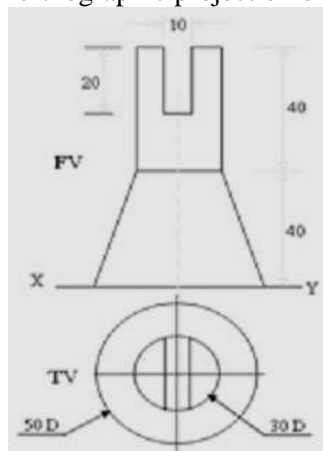


Figure 5.8a



**Solution:**

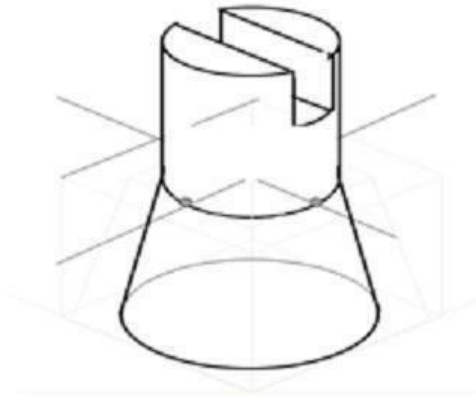


Figure 5.8b

**Problem:**

Draw the isometric view of the given orthographic projection of the object?

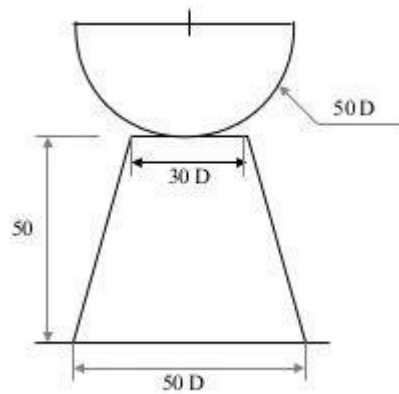


Figure 5.9a

**Solution:**

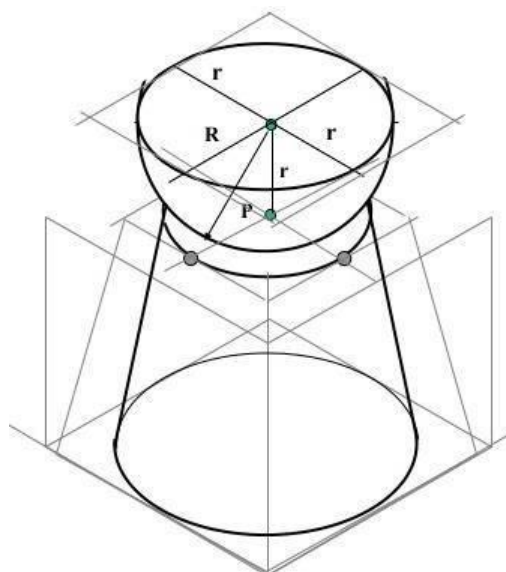


Figure 5.9b

**Problem:**

A square pyramid of 40mm base side and 60mm axis is cut by an inclined section plane through the midpoint of axis as shown. Draw isometric view of section of pyramid?

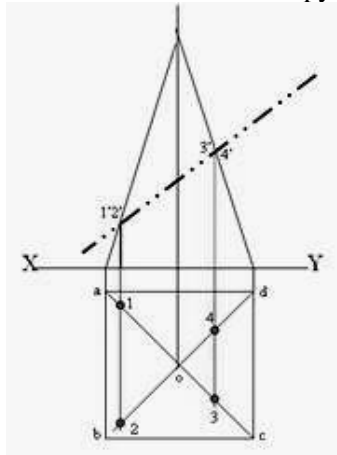


Figure 5.10a

**Solution:**

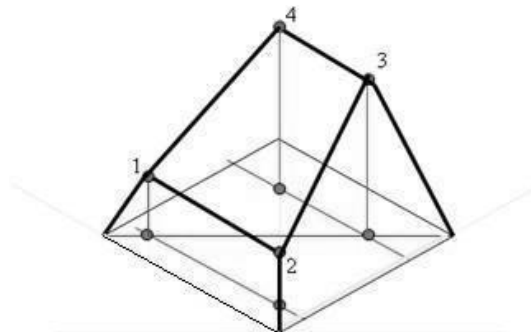


Figure 5.10b

**Problem:**

Draw the isometric view of the given orthographic projection of the object?

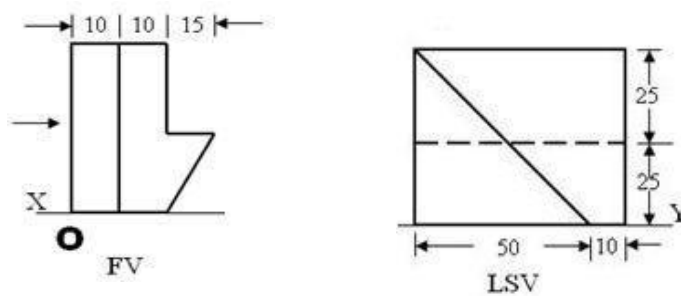


Figure 5.11a

**Solution:**

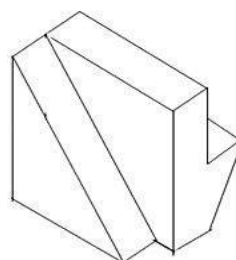


Figure 5.11b

**Problem:**

Draw the isometric view of the given orthographic projection of the object?

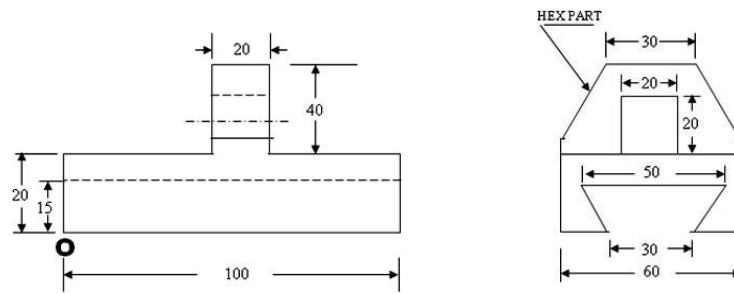


Figure 5.12a

**Solution:**

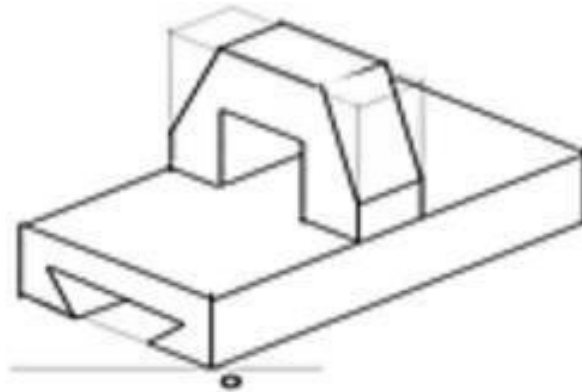


Figure 5.12b

**Problem:**

Draw the isometric view of the given orthographic projection of the object?

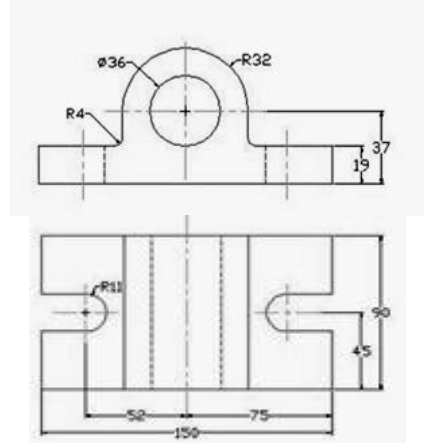


Figure 5.13a

**Solution:**

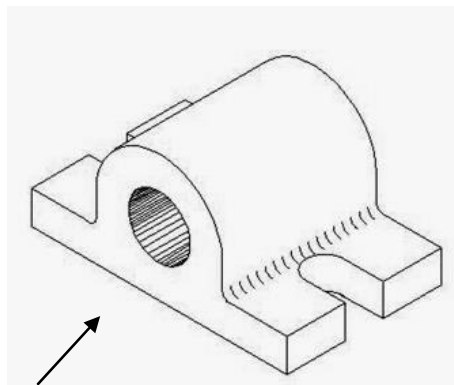


Figure 5.13b

**Problem:**

Draw the isometric view of the given orthographic projection of the object?

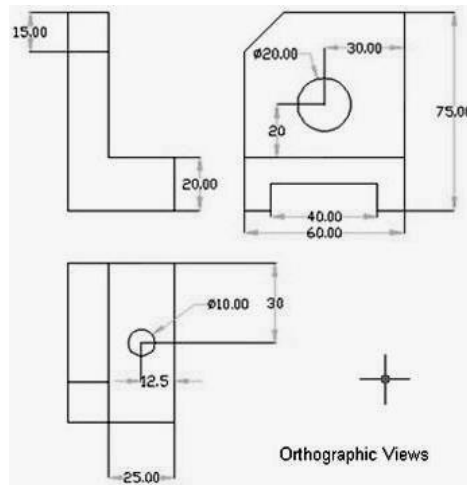


Figure 5.14a

**Solution:**

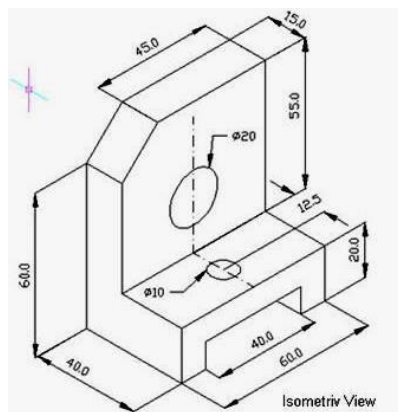


Figure 5.14b

**Problem:**

Draw the isometric view of the given orthographic projection of the object?

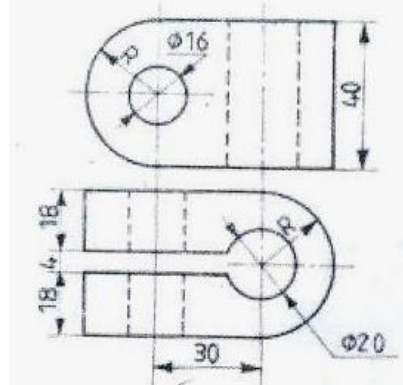


Figure 5.15a

**Solution:**

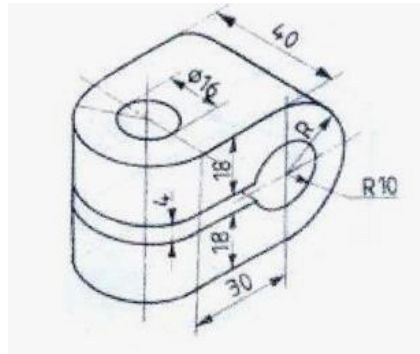


Figure 5.15b

## ORTHOGRAPHIC PROJECTION

**Projection:** Projection is defined as an Image or drawing of the object made on a plane. The lines from the object to the Plane are called projectors.

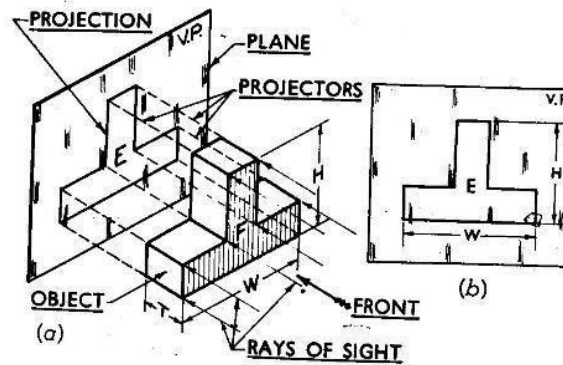


Figure 5.16

**Methods of Projections:** In Engineering drawing the following four methods of Projection are commonly used they are

- (1) Orthographic Projection
- (2) Isometric projection
- (3) Oblique projection
- (4) Perspective Projection

In orthographic projection an object is represented by two or three views on the mutual perpendicular projection planes each projection view represents two dimensions of an object.

In ISO, oblique and perspective projections represent the object by a pictorial view as eyes see it. In these methods of projection a three-dimensional object is represented on a projection plane by one view only.

### Orthographic Projection

When the Projectors are parallel to each other and also perpendicular to the plane the projection is called orthographic Projection

**Example:** Orthographic projection of a car shown in below figure.

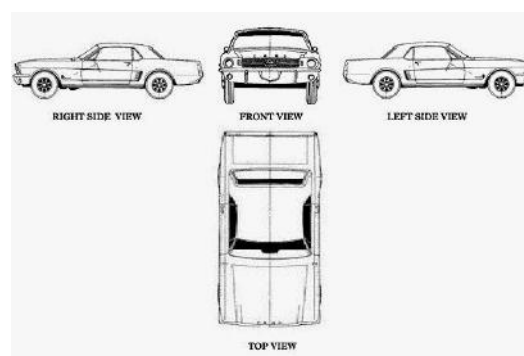


Figure 5.17

We can represent in orthographic projection two to three views enough as shown in below figures

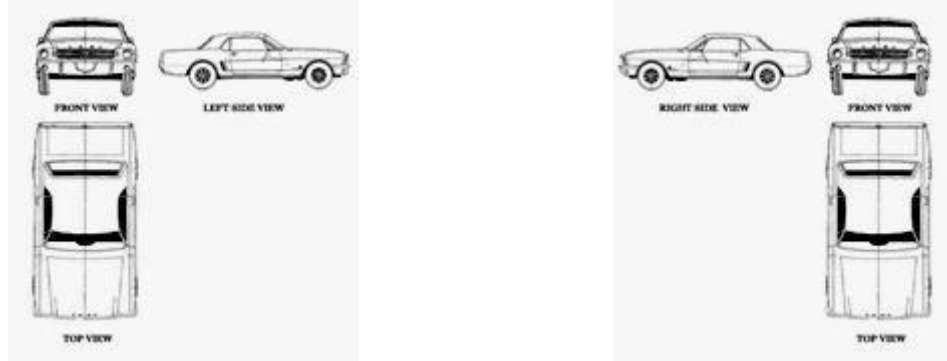


Figure5.18

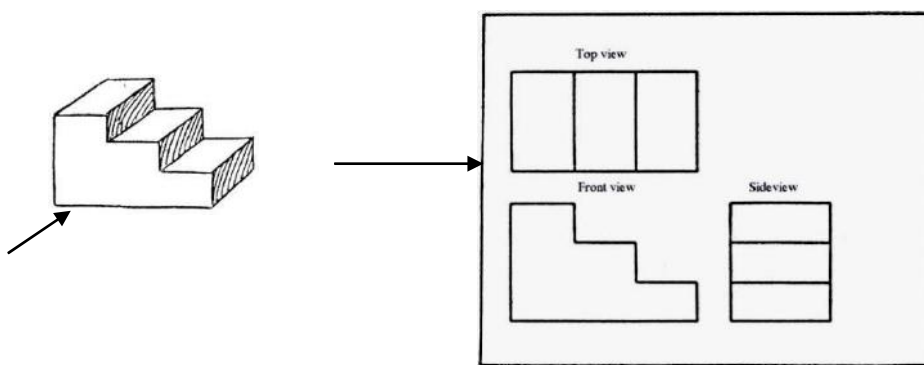


Figure5.19

### *Orthographic projection of given object*

Orthographic Projection is a way of drawing an 3D object from different directions. Usually a front, side and plan view is drawn so that a person looking at the drawing can see all the important sides. Orthographic drawings are useful especially when a design has been developed to a stage whereby it is almost ready to manufacture.

**Plane of projection:** Two planes employed for the purpose of orthographic projections are called reference planes or planes of projection. they are intersect each other at right angle to each other the vertical plane of projection is usually denoted by the letters **VP** and the other Plane is horizontal plane of Projection is denoted by **HP** .The line in which they intersect is termed as the reference line and is denoted by the letters **xy**.

### **Four quadrants:**

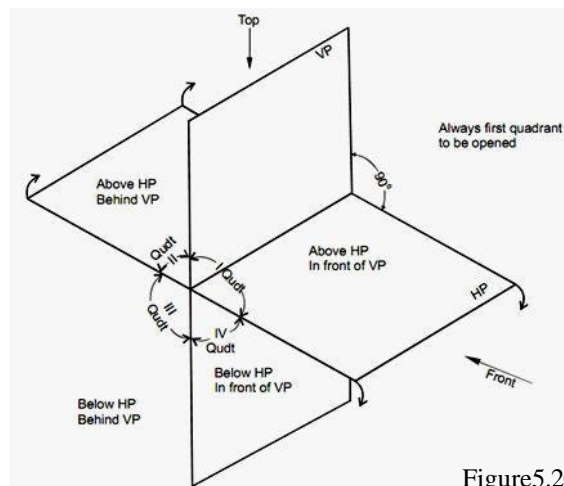


Figure5.20



The intersection of mutual perpendicular Planes i.e Vertical Plane and Horizontal Plane Form Four quadrants as shown above figure 5.5. Here planes to be assumed transparent here the object may be situated any one of four quadrants. The projections are obtained by drawing perpendiculars from the object to the planes, i.e by looking from the Front and Top. It should be remembered that the first and third quadrants always opened out while rotating the planes. The position of views with respect to the reference line will change according to quadrant in which object may be situated as shown in below figures.

### First angle Projection:

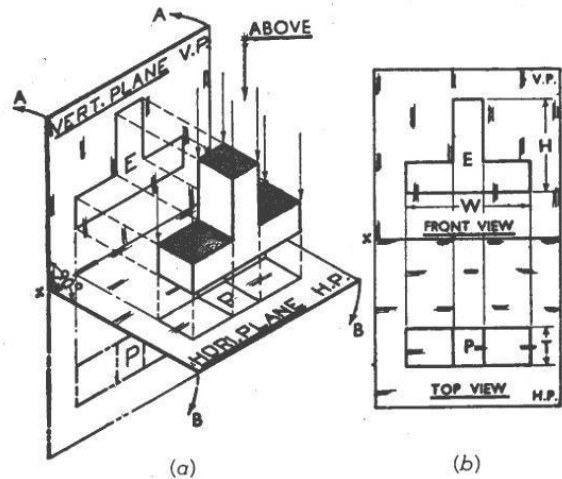


Figure 5.21

We have assumed the object to be situated in front of the VP and above the HP i.e., First quadrant and then projected it on these planes, the method of projection is known as

#### First angle projection method.

Here object lies between observer and plane of projection. In this method when the views are drawn in their relative positions the Top view comes below the front view.

### Third angle Projection:

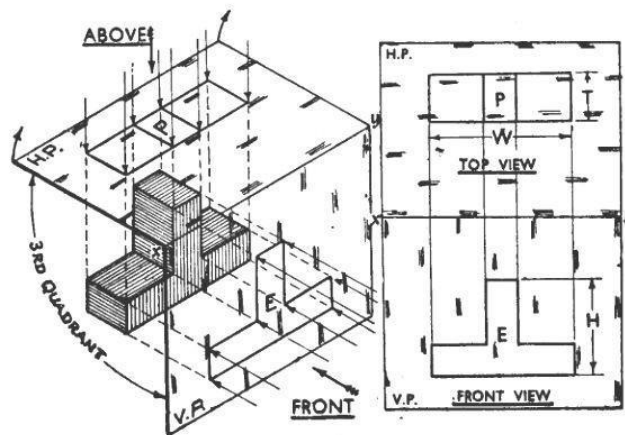


Figure 5.22

Here the object is assumed to be situated in third quadrant, here Plane of projection assumed to be transparent. It lies between Object and the observer. In this method when the views are drawn in their relative positions the Top view comes below the front view.

**Reference Line:**

While representing Projections it can be seen that while considering the front view which is seen from front the HP coincides with the line xy in their words xy represents HP.

Similarly while considering Top view which view obtained by looking from above, the same line  $xy$  represents the VP hence, when the projections are drawn in correct relationship with each other  $xy$  represents both the HP and VP this is called as Reference line.

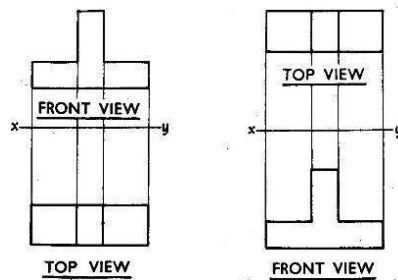


Figure 5.23

**Note:** There are two ways of drawing in orthographic- First Angle and Third Angle. They differ only in the position of the plan, front and side views.

**Problems:**

Draw the frontview, Top view and Side view of the given figure?

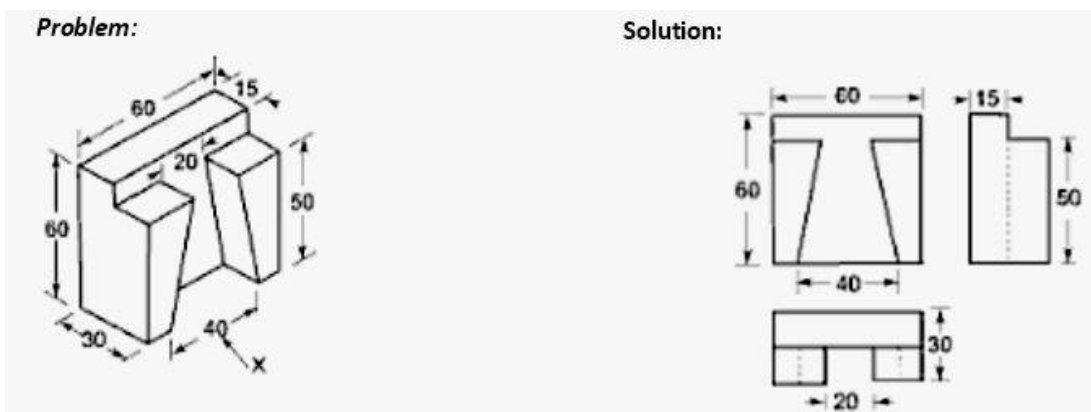


Figure 5.24

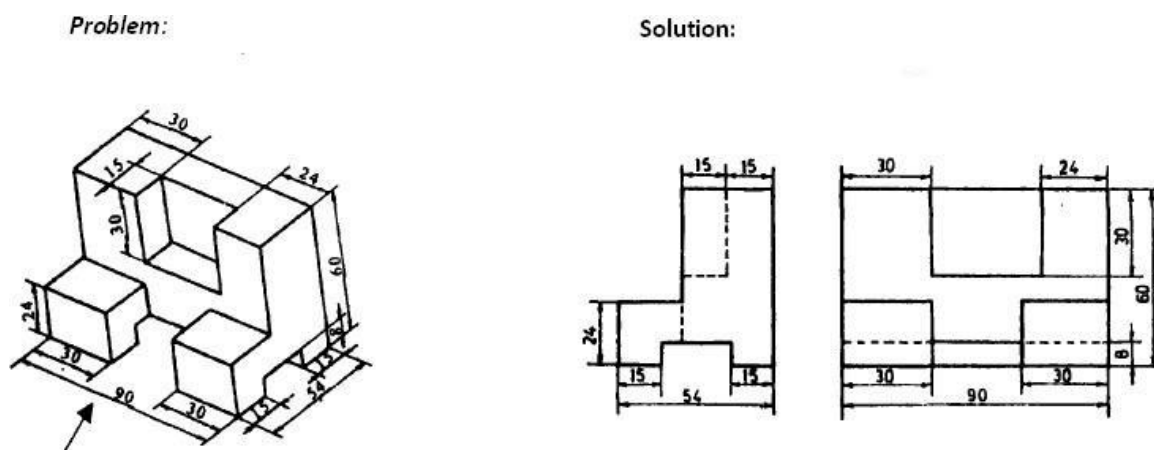
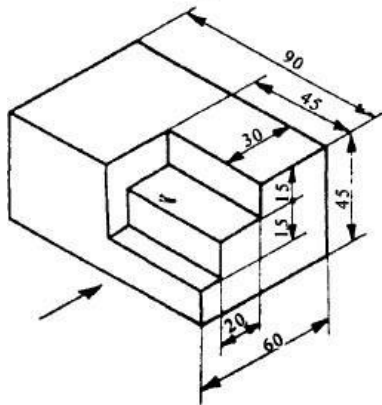


Figure 5.25

**Problem:**



**Solution:**

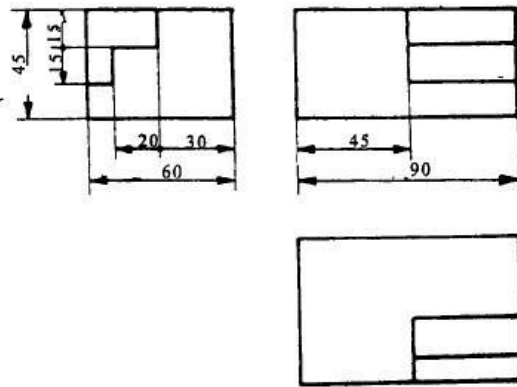
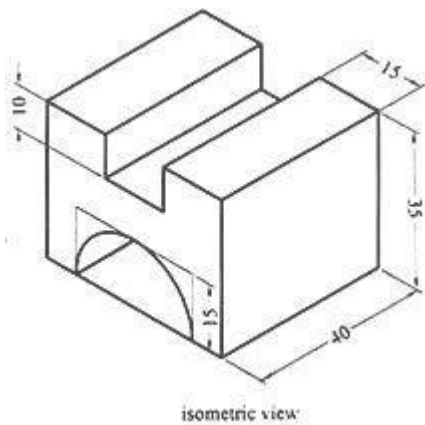


Figure5.26

**Problem**



**Solution**

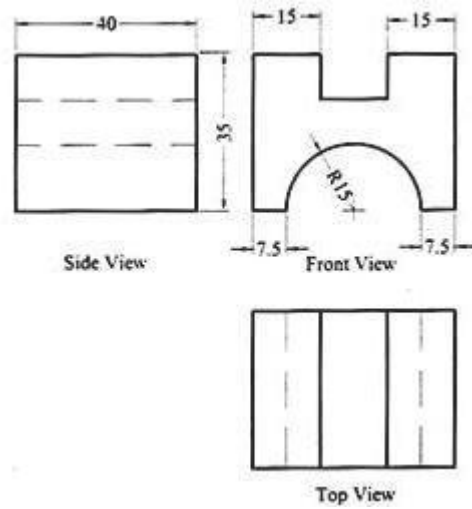
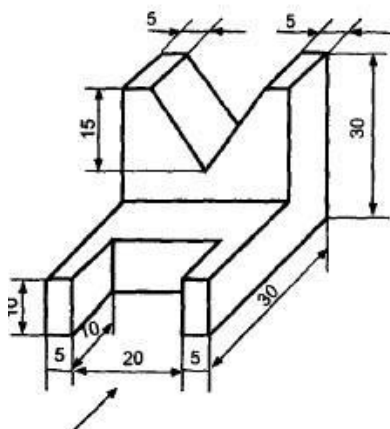


Figure5.27

**Problem:**



**Solution:**

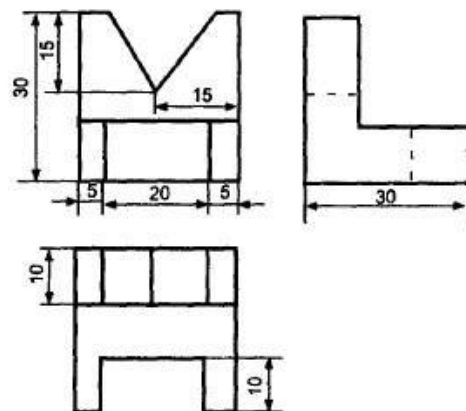
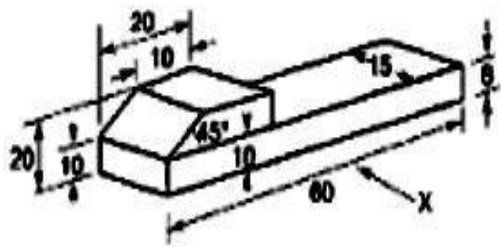


Figure5.28



*Problem:*



*Solution:*

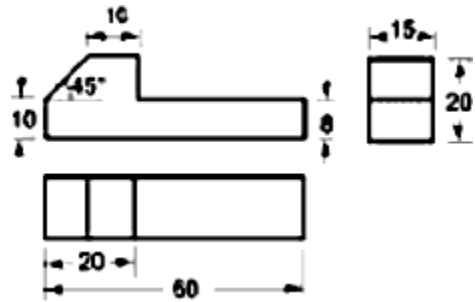
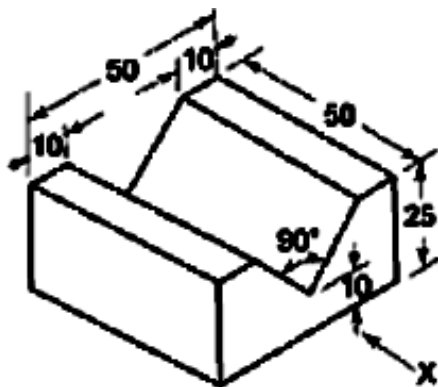


Figure 5.32

*Problem:*



*Solution:*

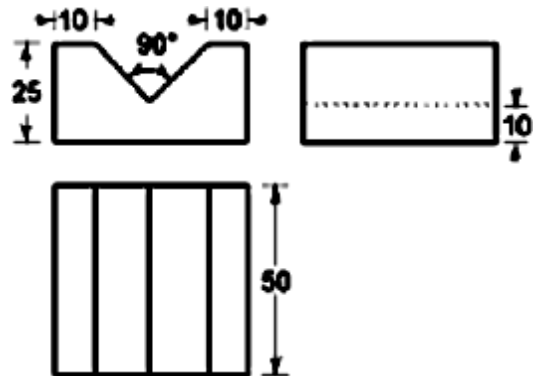
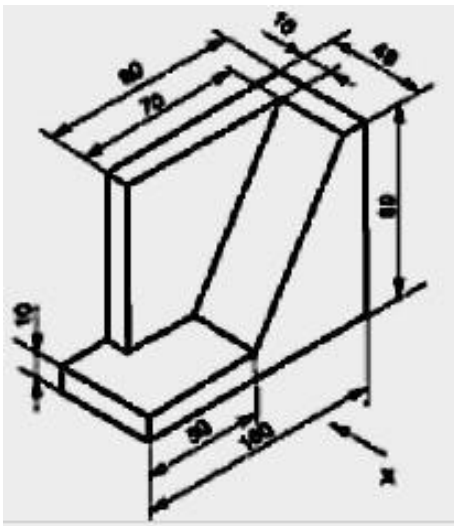


Figure 5.33

*Problem:*



*Solution*

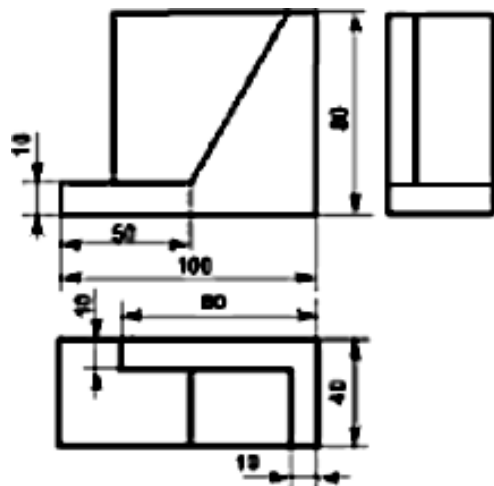
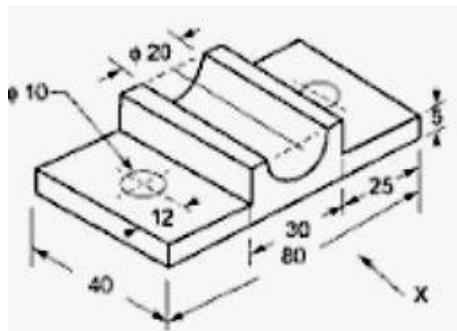


Figure 5.34

**Problem:**



**Solution:**

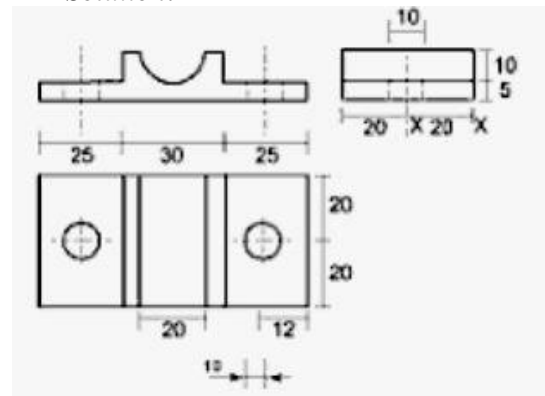
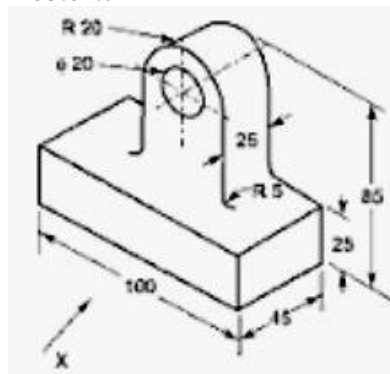


Figure5.20

**Problem:**



**Solution:**

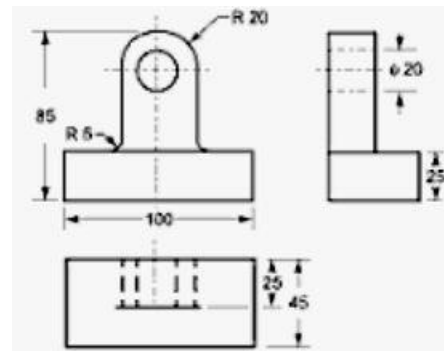
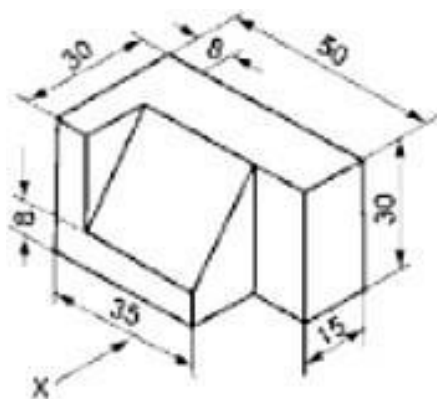


Figure5.21

**Problem:**



**Solution:**

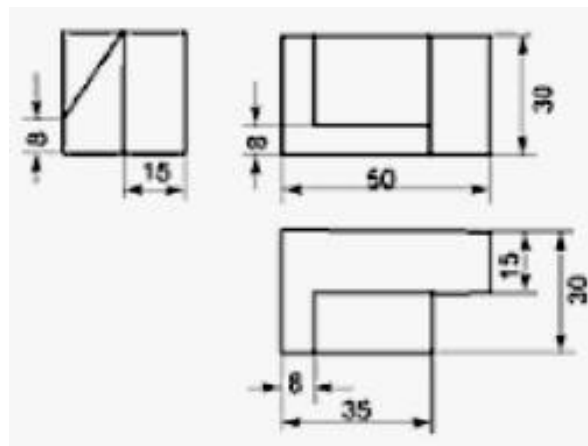
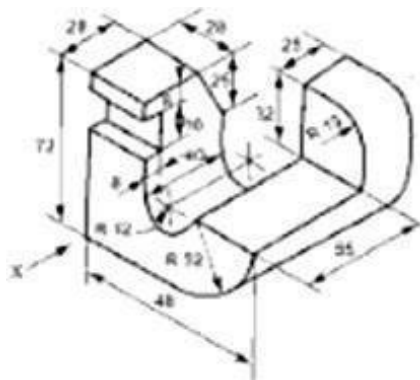


Figure5.22



**Problem:**



**Solution:**

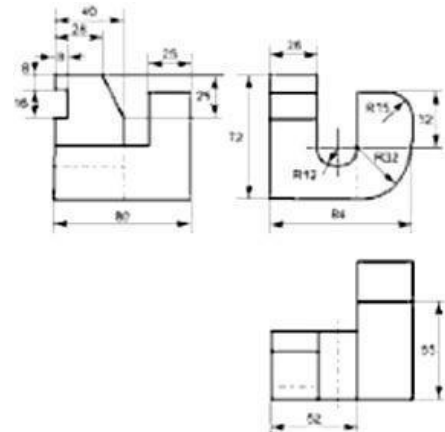
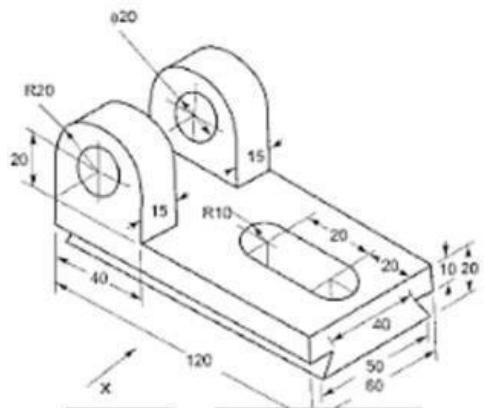


Figure5.23

**Problem:**



**Solution:**

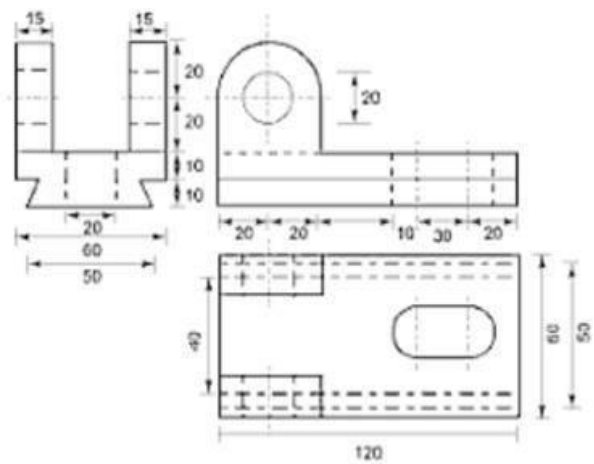
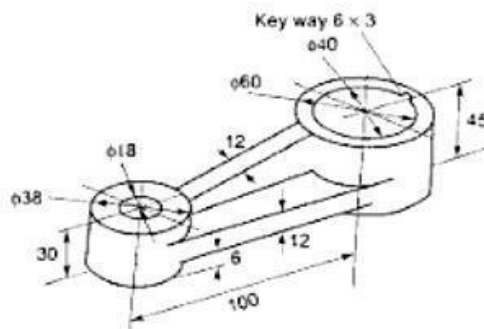


Figure5.24

**Problem:**



**Solution:**

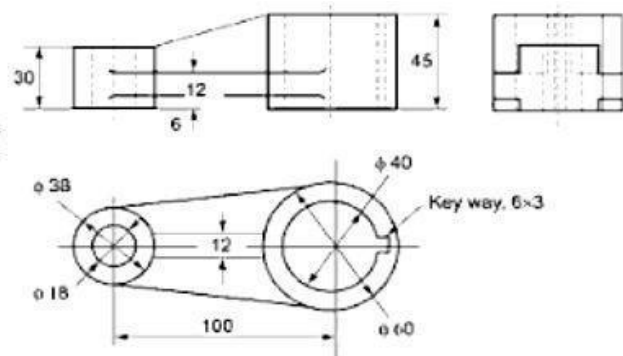


Figure5.25



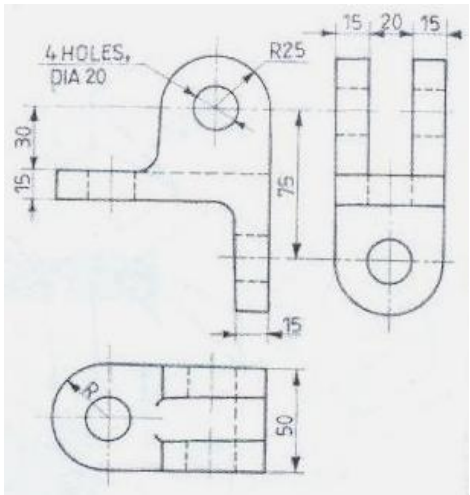


Figure 5.26

**Problem:**

***Solution:***

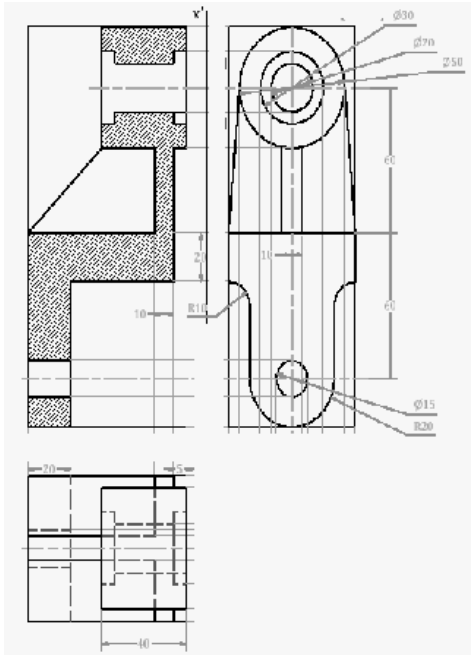


Figure 5.27