Engineering Graphics
18EGDL15/25

ATME COLLEGE OF ENGINEERING

VISION

Development of academically excellent, culturally vibrant, socially responsible and globally competent human resources.

MISSION

- To keep pace with advancements in knowledge and make the students competitive and capable at the global level.
- To create an environment for the students to acquire the right physical, intellectual, emotional and moral foundations and shine as torch bearers of tomorrow's society.
- To strive to attain ever-higher benchmarks of educational excellence.

DEPARTMENT OFMECHANICAL ENGINEERING

VISION

To impart excellent technical education in mechanical engineering to develop technically competent, morally upright and socially responsible mechanical engineering professionals.

MISSION:

- To provide an ambience to impart excellent technical education in mechanical engineering.
- To ensure state of-the- art facility for learning, skill development and research in mechanical engineering.
- To engage students in co-curricular and extra-curricular activities to impart social & ethical values and imbibe leadership quality.

PROGRAM OUTCOMES (PO'S)

The Mechanical engineering program students will attain:

PO1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems

PO2. Problem analysis: Identify, formulate, research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences

PO3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations

PO4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions

PO5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations

PO6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice

PO7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development

PO8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice

PO9. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings

PO10. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions

PO11. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments

PO12. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change

COURSE MODULE

Faculty Name:				Academic Year: **2020-21**			
Department: **Mechanical Engineering**							
Course Code	Course Title	Credits	Prerequisite	Contact Hours			Total Hrs/ Sessions
				L	T	P	
18EGDL15/25	**Engineering Graphics**	**03**	**Basic Knowledge about Geometry**	**2**	**-**	**2**	**52**

Course Learning Objectives (CLO's)

This Course will enable students to

CLO1: To expose the students to standards and convections followed in preparation of engineering drawing.

CLO2: To make them understand the concepts of orthographic and isometric projections.

CLO3: Develop the ability of conveying the engineering information through drawings.

CLO4: To make them understand the relevance of engineering drawing to different engineering domains.

CLO5: To develop the ability of producing engineering drawings using drawing instruments.

CLO6: To enable them to use computer aided drafting packages for the generation of drawings.

Topics Covered as per Syllabus

MODULE - 1

Introduction to Computer Aided Sketching

Introduction, Drawing Instruments and their uses, BIS conventions, Lettering, Dimensioning and free hand practicing. Computer screen, layout of the software, standard tool bar/menus and description of most commonly used tool bars, navigational tools. Co-ordinate system and reference planes. Of HP, VP, RPP & LPP. of 2D/3D environment. Selection of drawing size and scale. Commands and creation of Lines, Co-ordinate points, axes, poly-lines, square, rectangle, polygons, splines, circles, ellipse, text, move, copy, off-set, mirror, rotate, trim, extend, break, chamfer, fillet, curves, constraints viz. tangency, parallelism, inclination and perpendicularity. Dimensioning, line conventions, material conventions and lettering.

2 Hrs

MODULE -2

Orthographic projections of Points, Straight Lines and Planes

Introduction, Definitions - Planes of projection, reference line and conventions employed, Projections of points in all the four quadrants, Projections of straight lines (located in First quadrant/first angle only), True and apparent lengths, True and apparent inclinations to reference planes (No application problems). Orthographic Projections of Plane Surfaces (First Angle Projection Only) Introduction, Definitions–projections of plane surfaces–triangle, square, rectangle, rhombus, pentagon, hexagon and circle, planes in different positions by change of position method only (No problems on punched plates and composite plates).

12 Hrs

MODULE – 3

Projections of Solids (First angle Projection only) Introduction, Definitions – Projections of right regular tetrahedron, hexahedron (cube), prisms, pyramids, cylinders and cones in different positions (No problems on octahedrons and combination solid).

16 Hrs

MODULE – 4

Development of Lateral Surfaces of Solids - Sections and Development of Lateral Surfaces of Solids Introduction, Section planes, Sections, Section views, Sectional views, Apparent shapes and True shapes of Sections of right regular prisms, pyramids, cylinders and cones resting with base on HP. (No problems on sections of solids) Development of lateral surfaces of above solids, their frustums and truncations. (No problems on lateral surfaces of trays, tetrahedrons, spheres and transition pieces).

10 Hrs

MODULE – 5 **Isometric Projection** (Using Isometric Scale Only) Introduction, Isometric scale, Isometric projection of simple plane figures, Isometric projection of tetrahedron, hexahedron(cube), right regular prisms, pyramids, cylinders, cones, spheres, cut spheres and combination of solids (Maximum of three solids). **12 Hrs**	

List of Text Books:

1) **Engineering Drawing** - N.D. Bhatt & V.M. Panchal, 48th edition, 2005- Charotar Publishing House, Gujarat.
2) **Engineering Graphics** – K R Gopalakrishna, 32nd edition, 2005 – Subash Publishers Bangalore.
3) **Computer Aided Engineering Drawing** by Dr. M H Annaiah, Dr C N Chandrappa and Dr B Sudheer Premkumar Fifth edition, New Age International Publishers.

Reference Books:

1) **Computer Aided Engineering Drawing** - S. Trymbaka Murthy, - I.K. International Publishing House Pvt. Ltd., New Delhi, 3rd revised edition- 2006.
2) **Engineering Drawing** – by N S Parthasarathy and Vela Murali, Oxford University Press, 2015
3) **Fundamentals of Engineering Drawing with an Introduction to Interactive Computer Graphics for Design and Production**- Luzadder Warren J., Duff John M., Eastern Economy Edition, 2005- Prentice-Hall of India Pvt. Ltd., New Delhi.
4) **A Primer on Computer Aided Engineering Drawing**-2006, Published by VTU, Belgaum

List of URLs, Text Books, Notes, Multimedia Content, etc

1. **Projection of Solids demo:** https://www.youtube.com/watch?v=Lx1Rurl8nVw&list=PLqivUu0_booTlAXUSRSdizoSGv9BhXZFs.
2. https://web.microsoftstream.com/channel/9dced54e-a0d4-46c5-950b-e76343faec6b (Lecture Videos)

Course Outcomes (CO's): After studying this course,	**RBT Levels**
CO1: Prepare Engineering Drawings as per BIS conventions mentioned in the relevant codes and produce computer generated drawings.	**L2, L3**
CO2: Use the knowledge of Orthographic Projection to represent Engineering information/concepts and present the same in the form of drawings.	**L2, L3**
CO3: Develop lateral surfaces of solids and also isometric drawings of simple objects by reading the orthographic projection and also converting the isometric projection to orthographic views.	**L2, L3**

Scheme Off Examination:

From Chapters	**Marks Allotted**
Module 2 [Choice between Lines & Planes)	**25**
Module 3	**45**
Module 4 or Module 5	**30**
Total	**100**

The Correlation of Course Outcomes (CO's) and Program Outcomes (PO's)

Subject Code: 18EGDL15/25				TITLE: Engineering Graphics					Faculty Name:			
Course Outcomes	Program Outcomes											
	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
CO-1	2	-	2	-	3	-	-	-	-	2	-	2
CO-2	2	2	-	-	-	-	-	-	-	2	-	-
CO-3	2	2	-	-	-	-	-	-	-	2	-	-

Note: 3 = Strong Contribution 2 = Average Contribution 1 = Weak Contribution - = No Contribution

MODULE-1

INTRODUCTION TO COMPUTER AIDED SKETCHING

OBJECTIVES:

1) To understand the basic concept of Engineering Drawing
2) To demonstrate the usage of CAD software

LESSON CONTENT:

Introduction, Drawing Instruments and their uses, BIS conventions, Lettering, Dimensioning and free hand practicing. Computer screen, layout of the software, standard tool bar/menus and description of most commonly used tool bars, navigational tools. Co-ordinate system and reference planes. Of HP, VP, RPP & LPP. of 2D/3D environment. Selection of drawing size and scale. Commands and creation of Lines, Co-ordinate points, axes, poly-lines, square, rectangle, polygons, splines, circles, ellipse, text, move, copy, off-set, mirror, rotate, trim, extend, break, chamfer, fillet, curves, constraints viz. tangency, parallelism, inclination and perpendicularity. Dimensioning, line conventions, material conventions and lettering.

1.1 Layout of a drawing sheet

Every drawing sheet is to follow a particular layout. As a standard practice sufficient margins are to be provided on all sides of the drawing sheet. The drawing sheet should have drawing space and title page. A typical layout of a drawing sheet is shown in the figure below:

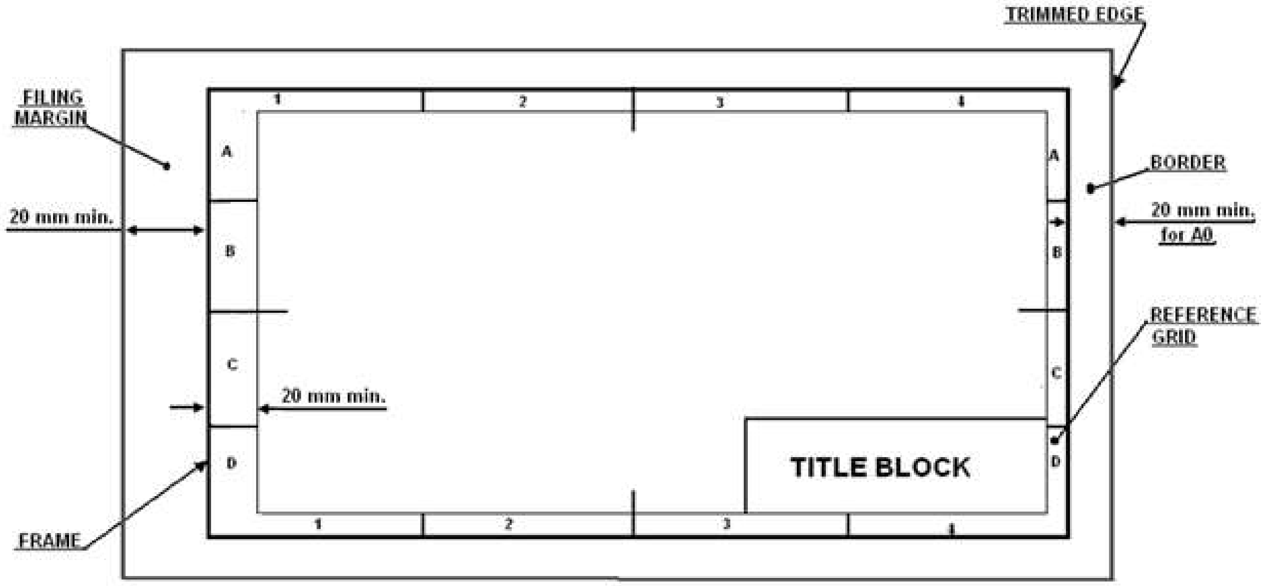


Figure 1. A typical layout of a drawing sheet.

- Borders – A minimum of 10 mm space left all around in between the trimmed edges of the sheet.
- Filing margin – Minimum 20 mm space left on the left hand side with border included. This provided for taking perforations .
- Grid reference system – This is provided on all sizes of industrial drawing sheets for easy location of drawing within the frame. The length and the width of the frames are divided into even number of divisions and labeled using numerals or capital letters. Number of divisions for a particular sheet depends on complexity of the drawing. The grids along the horizontal edges are labeled in numerals where as grids along vertical edges are labeled using capital letters. The length of each grids can be between 25 mm and 75 mm. Numbering and lettering start from the corner of the sheet opposite to the title box and are repeated on the opposite sides. they are written upright. Repetition of letters or numbers like AA, BB, etc., if they exceed that of the alphabets. For first year engineering students grid references need not be followed.
- Title box – An important feature on every drawing sheet. This is located at the bottom right hand corner of every sheet and provides the technical and administrative details of the drawing. The title box is divided into two zones

a. Identification zone : In this zone the details like the identification number or part number, Title of the drawing, legal owner of the drawing, etc. are to be mentioned.

b. Additional information zone : Here indicative items lime symbols indicting the system of projection, scale used, etc., the technical items lime method of surface texture, tolerances, etc., and other administrative items are to be mentioned.

1

Layout of the title box recommended for Engineering Drawing Course
The title box shown in figure 2 can be used for the engineering Drawing Course.

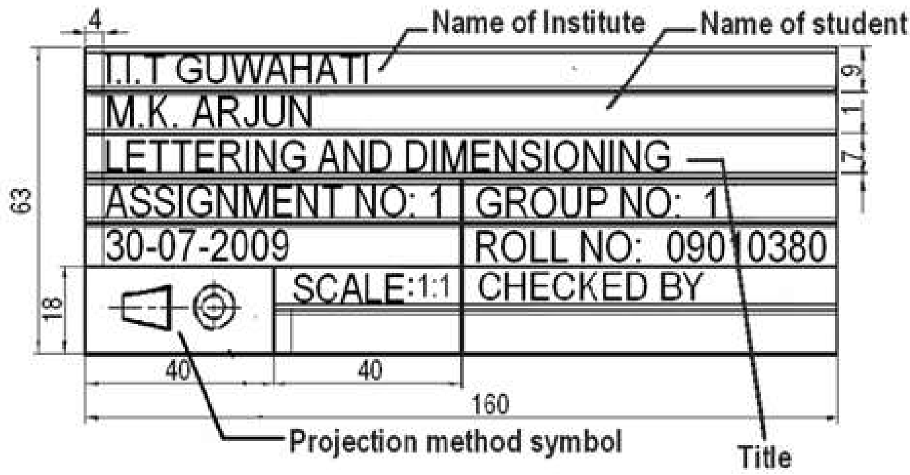


Figure 2. A typical title box recommended for Engineering students.

1.2 Lettering

Lettering is used for writing of titles, sub-titles, dimensions, scales and other details on a drawing. Typical lettering features used for engineering drawing is shown in figure 3. The following rules are to be followed in lettering. The letter sizes generally recommended for various items are shown in Table 1.

- Essential features of lettering – legibility, uniformity, ease, rapidity, and suitability for microfilming/photocopying/any other photographic processes
- No ornamental and embellishing style of letter
- Plain letters and numerals which are clearly distinguishable from each other in order to avoid any confusion even in case of slight mutilations

The Indian standard followed for lettering is BIS: 9609

- Single stroke lettering for use in engineering drawing – width of the stem of the letters and numerals will be uniformly thick equal to thickness of lines produced by the tip of the pencil.
- Single stroke does not mean – entire letter written without lifting the pencil/pen

Lettering types generally used for creating a drawing are

- Lettering A – Height of the capital letter is divided into 14 equal parts
- Lettering B – Height of the capital letter is divided into 10 equal parts

Table 2 and Table 3 indicates the specifications for Type A and Type B letters.

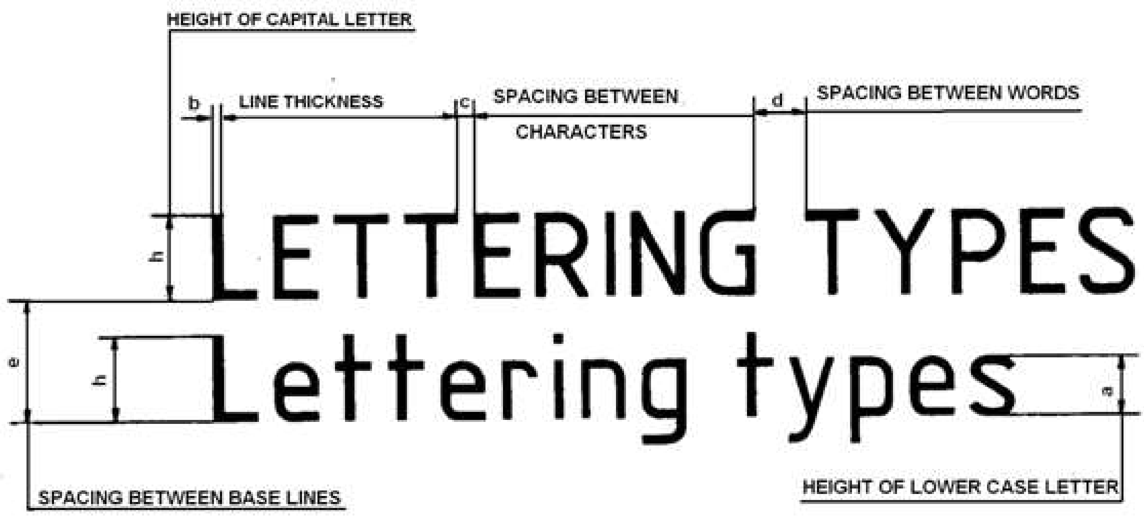


Figure 3. Typical lettering features.

Heights of Letters and Numerals

1. Height of the capital letters is equal to the height of the numerals used in dimensioning
2. Height of letters and numerals – different for different purposes

Table 1 The letter sizes recommended for various items

Sr. No.	Item	Size (mm)
1	Name of the company	10, 14,20
2	Drawing numbers, letters denoting section planes	10, 14
3	Title of the Drawing	7, 10
4	Sub-titles and heading	5, 7
5	Dimensioning, Notes, Schedules, Material list	3.5, 7
6	Alteration entries and tolerances	3.5

Table 2. Specifications of A -Type Lettering

Specifications	Value	Size (mm)						
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 b/n words	d = (3/7)h	1.05	1.5	2.1	3	4.2	6	8.4
Min. spacing b/n baselines	e = (10/7)h	3.5	5	7	10	14	20	28

Table 3. Specifications of B -Type Lettering

Specifications	Value	Size (mm)						
Capital letter height	h	2.5	3.5	5	7	10	14	20
Lowercase letter height	a = (7/10)h	-	2.5	3.5	5	7	10	14
Thickness of lines	b = (1/10)h	0.25	0.35	0.5	0.7	1	1.4	2
Spacing between characters	c = (1/5)h	0.5	0.7	1	1.4	2	2.8	4
Min. spacing b/n words	d = (3/5)h	1.5	2.1	3	4.2	6	8.4	12
Min. spacing b/n baselines	e = (7/5)h	3.5	5	7	10	14	20	28

How to begin your drawing?
To start with the preparation of a drawing the procedure mentioned below may be followed:

- Clean the drawing board and all the drawing instruments using duster.
- Fix the drawing sheet on the drawing board.
- Fix the mini-drafter in a convenient position.
- Draw border lines using HB pencil..
- Complete the title box using HB pencil .
- Plan spacing of drawings b/n two problems/views beforehand.
- Print the problem number on the left top and then commence the drawing work.

<u>Keeping the drawing clean is a must</u>

- Never sharpen pencils over drawing.
- Clean pencil point with a soft cloth after sharpening.
- Keep drawing instruments clean.
- Rest hands on drawing instruments as much as possible – to avoid smearing the graphite on the drawing.
- When darkening lines – try to work from the top of the drawing to the bottom, and from left to the right across the drawing.
- Use brush to remove eraser particles. Never use hands.
- Always use appropriate drawing pencils.

Lines

Lines is one important aspect of technical drawing. Lines are always used to construct meaningful drawings. Various types of lines are used to construct drawing, each line used in some specific sense. Lines are drawn following standard conventions mentioned in BIS (SP46:2003). A line may be curved, straight, continuous, segmented. It may be drawn as thin or thick. A few basic types of lines widely used in drawings are shown in Table 1.

Table 1. Types of letters used in engineering drawing.

Illustration	Application
Thick	Outlines, visible edges, surface boundaries of objects, margin lines
Continuous thin	Dimension lines, extension lines, section lines leader or pointer lines, construction lines, boarder lines
Continuous thin wavy	Short break lines or irregular boundary lines – drawn freehand
Continuous thin with zig-zag	Long break lines
Short dashes, gap 1, length 3 mm	Invisible or interior surfaces
Short dashes	Center lines, locus lines Alternate long and short dashes in a proportion of 6:1,
Long chain thick at end and thin elsewhere	Cutting plane lines

Line Strokes

Line strokes refer to the directions of drawing straight and curved lines. The standards for lines is given in BIS : SP-46, 2003

Vertical and inclined lines are drawn from top to bottom, horizontal lines are drawn from left to right. Curved lines are drawn from left to right or top to bottom. The direction of strokes are illustrated in figure 1.

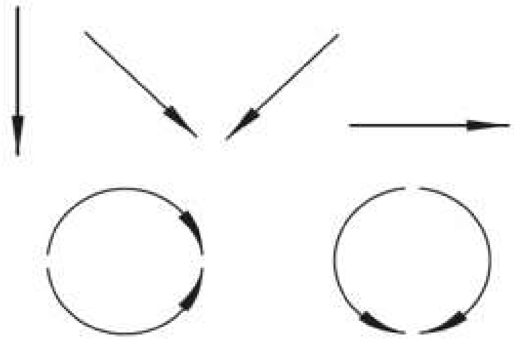


Figure 1. The line strokes for drawing straight and curved lines.

Conventions used in lines

- International systems of units (SI) – which is based on the meter.
- Millimeter (mm) - The common SI unit of measure on engineering drawing.
- Individual identification of linear units is not required if all dimensions on a drawing are in the same unit (mm).
- The drawing should contain a note: ALL DIMENSIONS ARE IN MM. (Bottom left corner outside the title box)

Typical figures showing various lines used in the construction of engineering drawing is shown in figure 2.

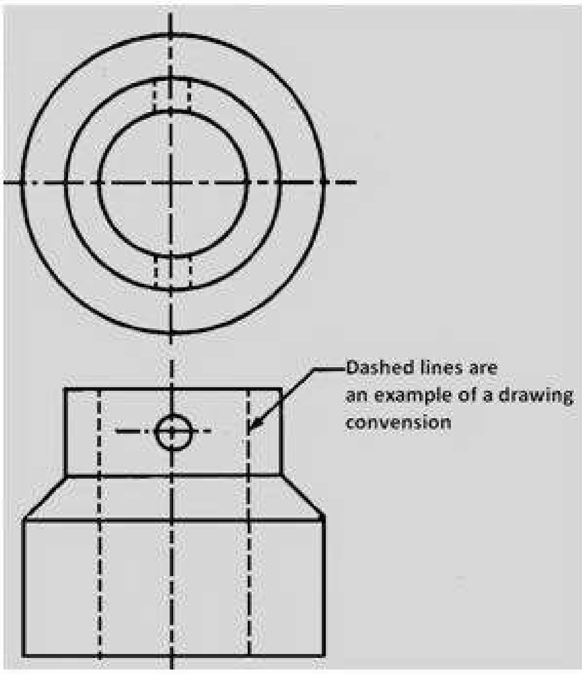
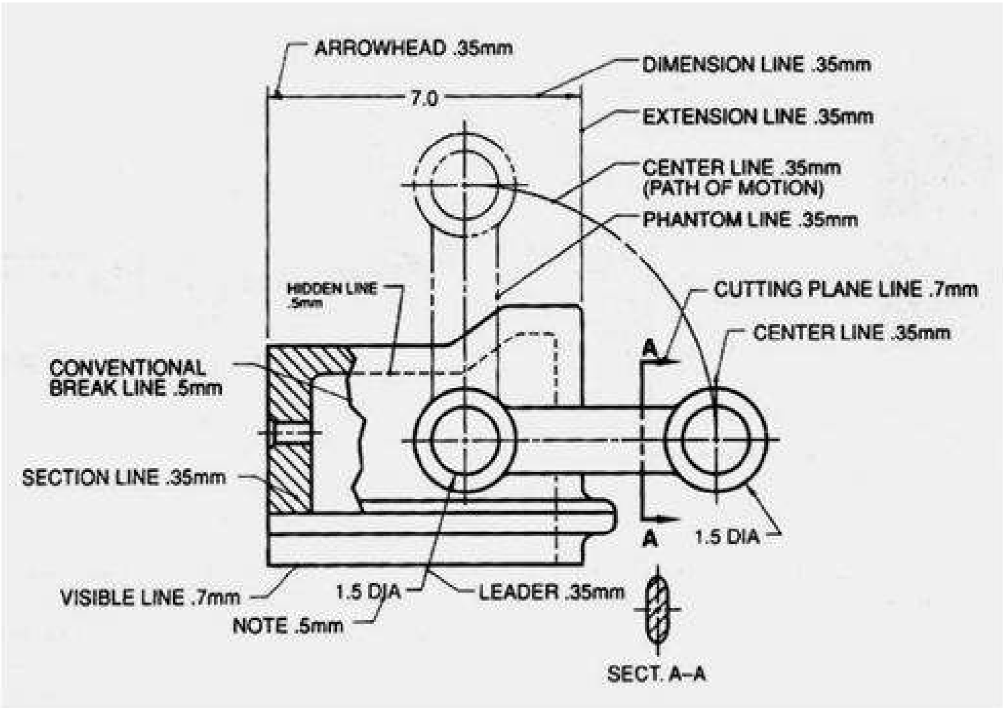


Figure 2 Typical figure showing various lines used engineering drawing

A typical use of various lines in an engineering drawing is shown in figure below:



1.3 Dimensioning

The size and other details of the object essential for its construction and function, using lines, numerals, symbols, notes, etc are required to be indicated in a drawing by proper dimensioning. These dimensions indicated should be those that are essential for the production, inspection and functioning of the object and should be mistaken as those that are required to make the drawing of an object. The dimensions are written either above the dimension lines or inserted at the middle by breaking the dimension lines.

Normally two types of dimensioning system exist. i.e. Aligned system and the unidirectional system.These are shown in figure 3.

In the aligned system the dimensions are placed perpendicular to the dimension line in such a way that it may be read from bottom edge or right hand edge of the drawing sheet. The horizontal and inclined dimension can be read from the bottom where as all the vertical dimensions can be read from the right hand side of the drawing sheet. In the unidirectional system, the dimensions are so oriented such that they can be read from the bottom of the drawing.

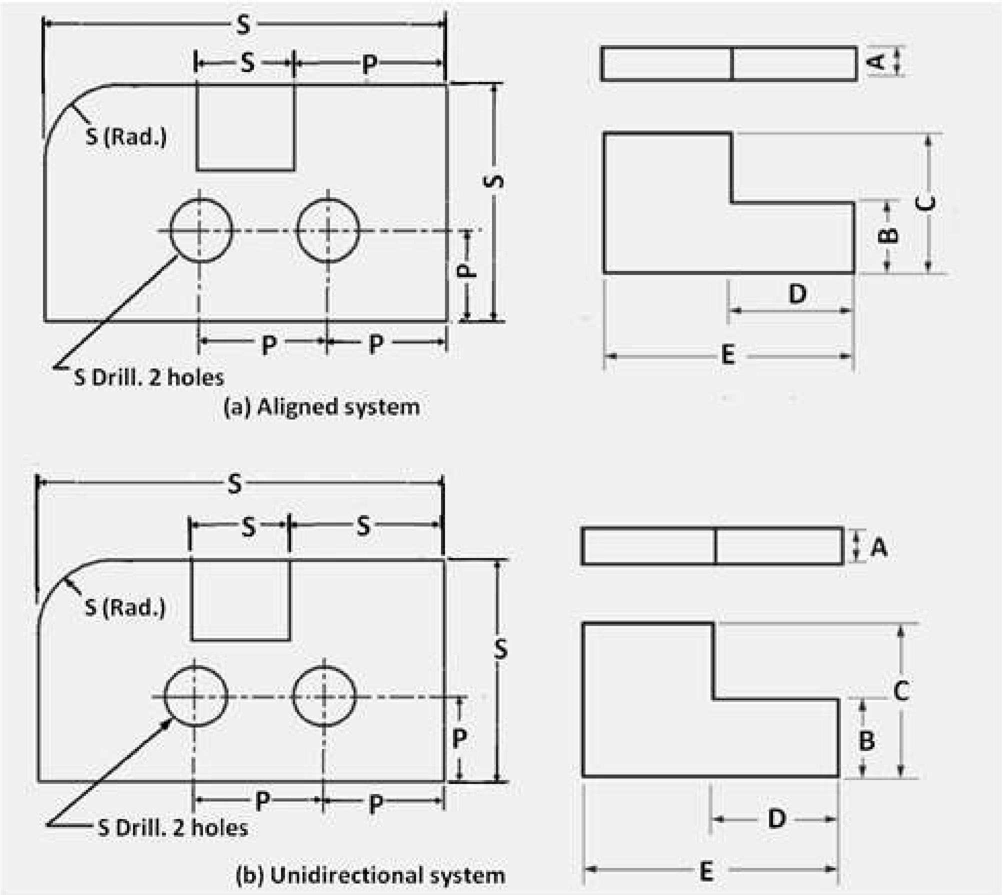


Figure 3. The aligned system and unidirectional system of dimensioning.

Rules to be followed for dimensioning. Refer figure 4.

- Each feature is dimensioned and positioned only once.
- Each feature is dimensioned and positioned where its shape shows.
- Size dimensions – give the size of the component.
- Every solid has three dimensions, each of the geometric shapes making up the object must have its height, width, and depth indicated in the dimensioning.

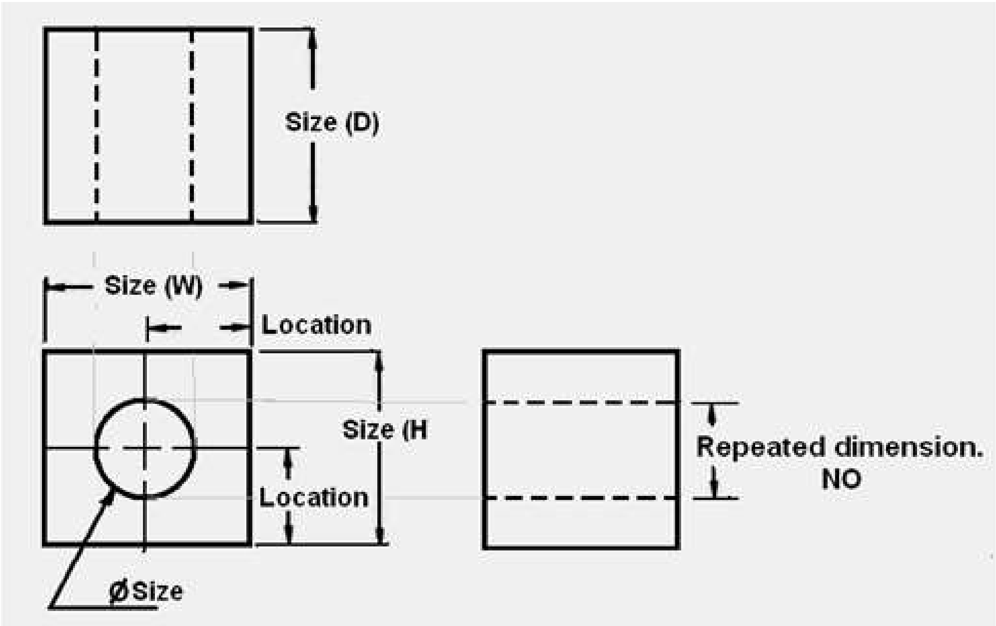


Figure 4. typical dimension lines

1.4 Scales

There is a wide variation in sizes for engineering objects. Some are very large (eg. Aero planes, rockets, etc) Some are vey small (wrist watch, MEMs components) There is a need to reduce or enlarge while drawing the objects on paper. Some objects can be drawn to their actual size. The proportion by which the drawing of aan object is enlarged or reduced is called the scale of the drawing.

Definition
A scale is defined as the ratio of the linear dimensions of the object as represented in a drawing to the actual dimensions of the same.

- Drawings drawn with the same size as the objects are called full sized drawing.
- It is not convenient, always, to draw drawings of the object to its actual size. e.g. Buildings,
- Heavy machines, Bridges, Watches, Electronic devices etc.
- Hence scales are used to prepare drawing at

  - Full size
  - Reduced size
  - Enlarged size

BIS Recommended Scales are shown in table 1.

Table 1. The common scales recommended.

Reducing scales 1:Y (Y>1)	1:2 1:20 1:200 1:2000	1:5 1:50 1:500 1:5000	1:10 1:100 1:1000 1:10000
Enlarging scales X:1 (X>1)	50:1 5:1	20:1 2:1	10:1
Full size scales			1:1

Intermediate scales can be used in exceptional cases where recommended scales can not be applied for functional reasons.

Types of Scale :-

Engineers Scale : The relation between the dimension on the drawing and the actual dimension of the object is mentioned numerically (like 10 mm = 15 m).

Graphical Scale:_ Scale is drawn on the drawing itself. This takes care of the shrinkage of the engineer's scale when the drawing becomes old.

Types of Graphical Scale :-

- Plain Scale
- Diagonal Scale
- Vernier Scale
- Comparative scale
- Scale of chords

Representative fraction (R.F.) :-

$$\text{R.F.} = \frac{\text{Length of an object on the drawing}}{\text{Actual Length of the object}}$$

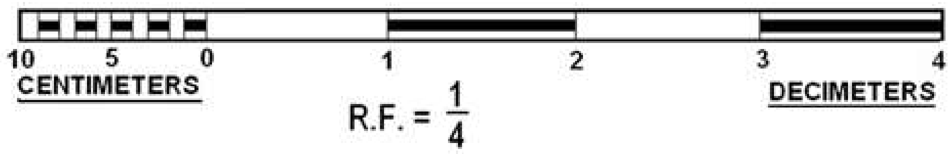
When a 1 cm long line in a drawing represents 1 meter length of the object

$$RF = \frac{1cm}{1m} = \frac{1cm}{1x\,100cm} = \frac{1}{100}$$

Length of scale = RF x Maximum distance to be represented

Plain scale :-

- A plain scale is used to indicate the distance in a unit and its nest subdivision.
- A plain scale consists of a line divided into suitable number of equal units. The first unit is subdivided into smaller parts.
- The zero should be placed at the end of the 1st main unit.
- From the zero mark, the units should be numbered to the right and the sub-divisions to the left.
- The units and the subdivisions should be labeled clearly.
- The R.F. should be mentioned below the scale.



OUTCOMES:

1) Students will be able to representation of Engineering Drawing
2) Student will be able to understand the concept of scaling
3) Students will be able to the usage of CAD software

Questionnaires

1. Define drawing.
2. What is the importance of lettering in drawing?
3. What is scaling? Explain the types of scaling.
4. Explain the concept of dimensioning.

FURTHER READING:

1) Computer Aided Engineering Drawing - S. Trymbaka Murthy, - I.K. International Publishing House Pvt. Ltd., New Delhi, 3rd revised edition- 2006.
2) Engineering Graphics - K.R. Gopalakrishna, 32nd edition, 2005- Subash Publishers Bangalore.
3) 1. Dhananjay A Jolhe, Engineering Drawing, Tata McGraw Hill, 2007.
4) 2. M.B. Shah and B.C. Rana, Engineering Drawing, pearson Education, Eds. 2, 2009.
5) 3. K. Venugopal, Engineering Drawing and Graphics, New Age International (P) Ltd., publishers, 2000.
6) 4. N.D. Bhatt and V.M. Panchal, Engineering Drawing, Charotar Publishing house, 2005

MODULE-2

ORTHOGRAPHIC PROJECTIONS

OBJECTIVES:

1) To understand the basic concept of orthographic projection
2) To understand projection of points in all quadrant
3) To understand projection of Lines and Planes in 1st quadrant

LESSON CONTENT:

Introduction, Definitions - Planes of projection, reference line and conventions employed, Projections of points in all the four quadrants, Projections of straight lines (located in First quadrant/first angle only), True and apparent lengths, True and apparent inclinations to reference planes (No application problems). Orthographic Projections of Plane Surfaces (First Angle Projection Only)

Introduction, Definitions–projections of plane surfaces–triangle, square, rectangle, rhombus, pentagon, hexagon and circle, planes in different positions by change of position method only (No problems on punched plates and composite plates).

2.1 Theory of Projections

Projection theory

In engineering, 3-dimensonal objects and structures are represented graphically on a 2-dimensional media. The act of obtaining the image of an object is termed “projection”. The image obtained by projection is known as a “view”. A simple projection system is shown in figure 1.

All projection theory are based on two variables:

- Line of sight
- Plane of projection.

Plane of Projection

A plane of projection (i.e, an image or picture plane) is an imaginary flat plane upon which the image created by the line of sight is projected. The image is produced by connecting the points where the lines of sight pierce the projection plane. In effect, 3-D object is transformed into a 2-D representation, also called projections. The paper or computer screen on which a drawing is created is a plane of projection.

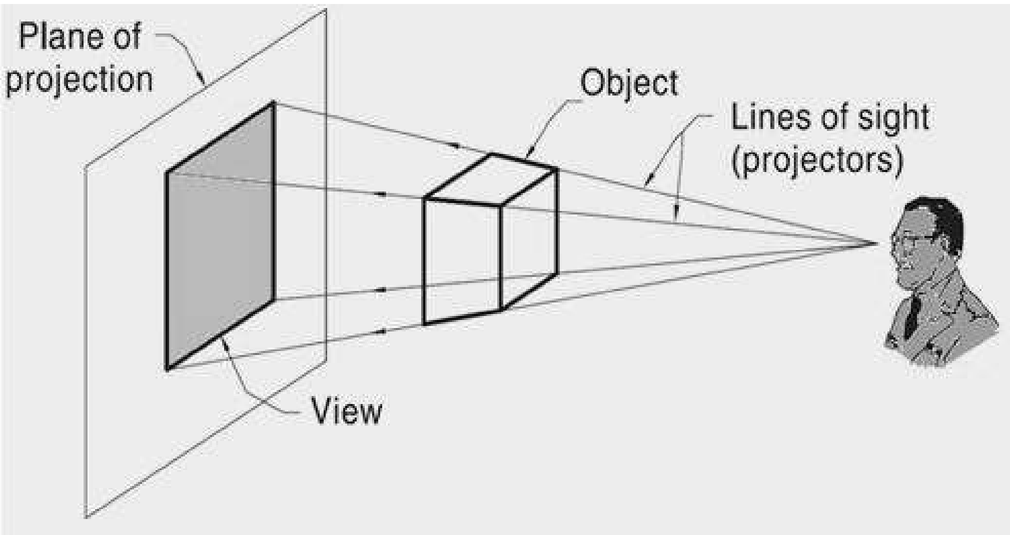


Figure 1 : A simple Projection system

Projection Methods

Projection methods are very important techniques in engineering drawing.

Two projection methods used are:

- Perspective and
- Parallel

Figure 2 shows a photograph of a series of building and this view represents a perspective projection on to the camera. The observer is assumed to be stationed at finite distance from the object. The height of the buildings appears to be reducing as we move away from the observer. In perspective projection, all lines of sight start at a single point and is schematically shown in figure 3. .

Figure 2. Photographic image of a series of buildings.

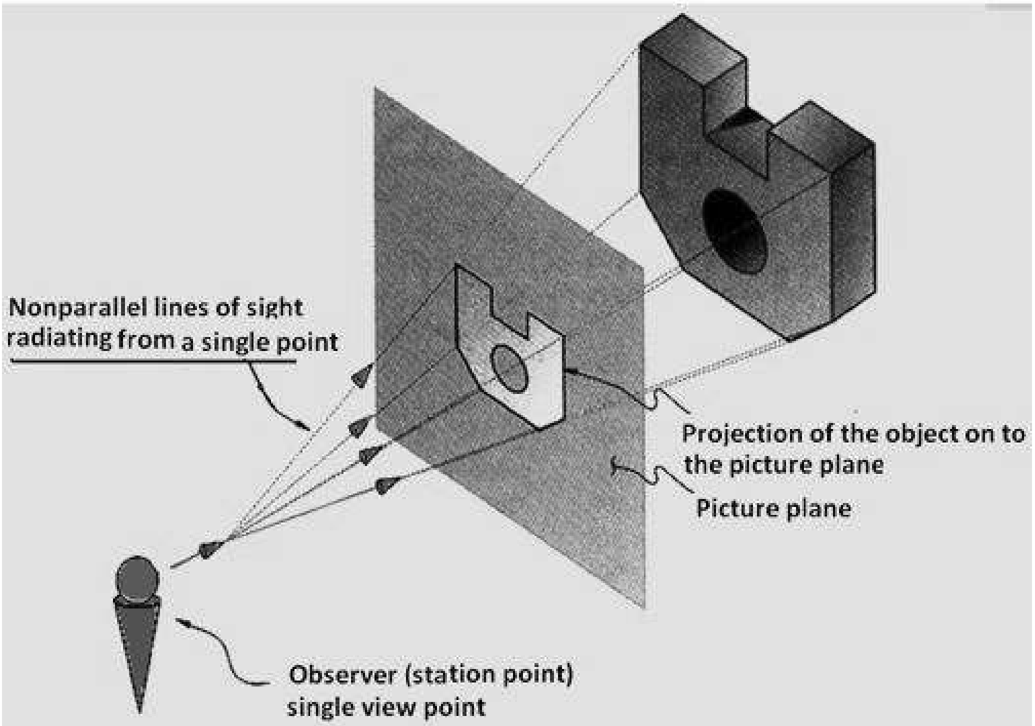


Figure 3. A schematic representation of a Perspective projection

In parallel projection, all lines of sight are parallel and is schematically represented in figure. 4. The observer is assumed to be stationed at infinite distance from the object.

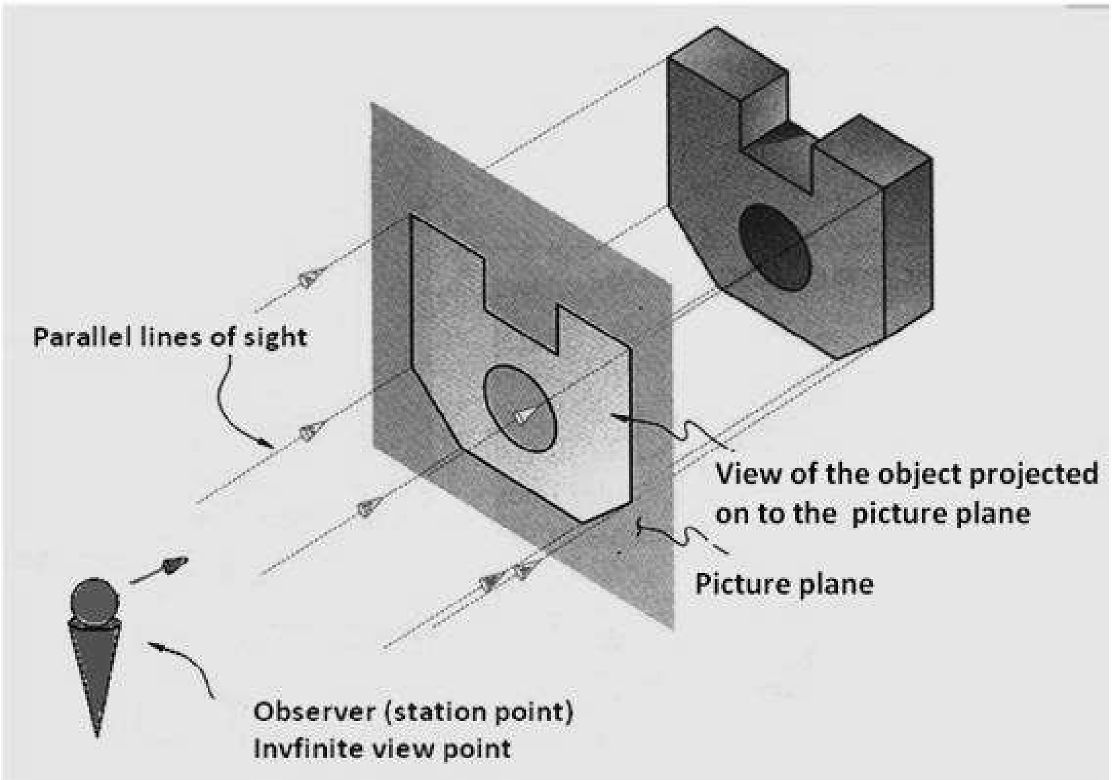


Figure 4. A schematic representation of a Parallel projection

Parallel vs Perspective Projection

Parallel projection

√ Distance from the observer to the object is infinite projection lines are parallel – object is positioned at infinity.

√ Less realistic but easier to draw.

Perspective projection

- Distance from the observer to the object is finite and the object is viewed from a single point – projectors are not parallel.
- Perspective projections mimic what the human eyes see, however, they are difficult to draw.

Orthographic Projection

Orthographic projection is a parallel projection technique in which the plane of projection is perpendicular to the parallel line of sight. Orthographic projection technique can produce either pictorial drawings that show all three dimensions of an object in one view or multi-views that show only two dimensions of an object in a single view. These views are shown in figure 5.

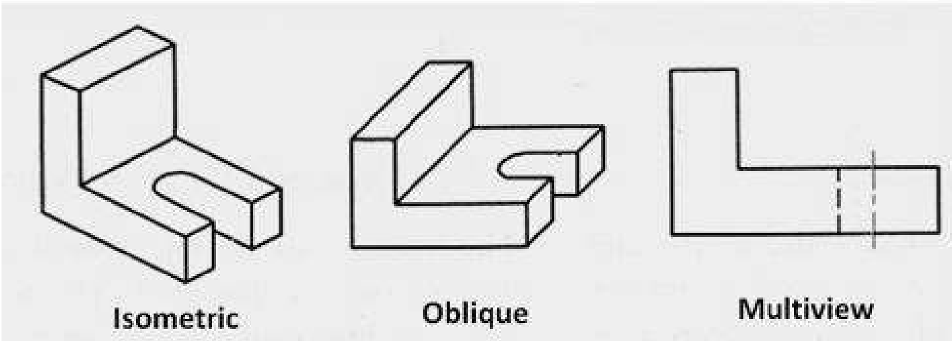


Figure 5. Orthographic projections of a solid showing isometric, oblique and multi-view drawings.

2.2 Projection Methods

Universally either the 1st angle projection or the third angle projection methods is followed for obtaining engineering drawings. The principal projection planes and quadrants used to create drawings are shown in figure 16. The object can be considered to be in any of the four quadrant.

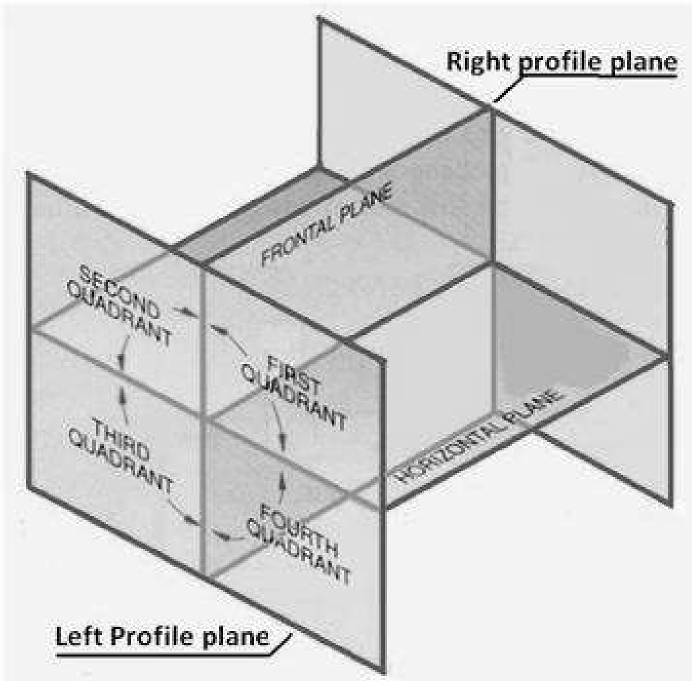


Figure 16. The principal projection planes and quadrants for creation of drawings.

First Angle Projection

In this the object in assumed to be positioned in the first quadrant and is shown in figure 17 The object is assumed to be positioned in between the projection planes and the observer. The views are obtained by projecting the images on the respective planes. Note that the right hand side view is projected on the plane placed at the left of the object. After projecting on to the respective planes, the bottom plane and left plane is unfolded on to the front view plane. i.e. the left plane is unfolded towards the left side to obtain the Right hand side view on the left side of the Front view and aligned with the Front view. The bottom plane is unfolded towards the bottom to obtain the Top view below the Front view and aligned with the Front View.

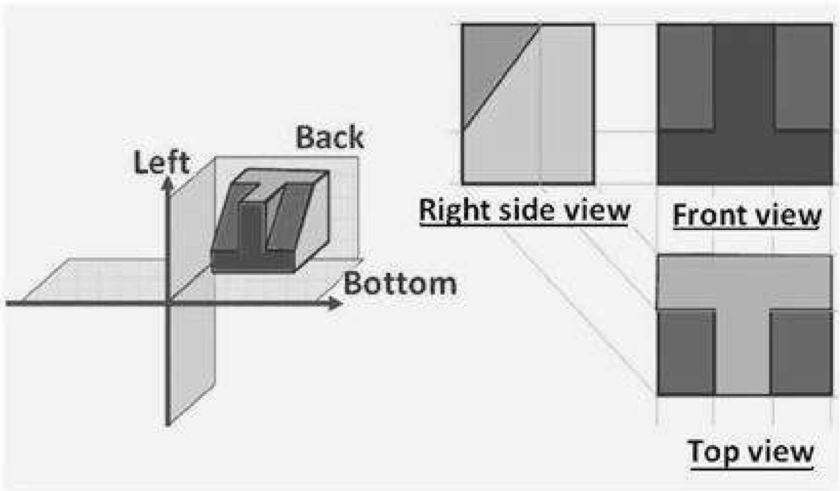


Figure 17. Illustrating the views obtained using first angle projection technique.

Third Angle Projection

In the third angle projection method, the object is assumed to be in the third quadrant. i.e. the object behind vertical plane and below the horizontal plane. In this projection technique, Placing the object in the third quadrant puts the projection planes between the viewer and the object and is shown in figure 18.

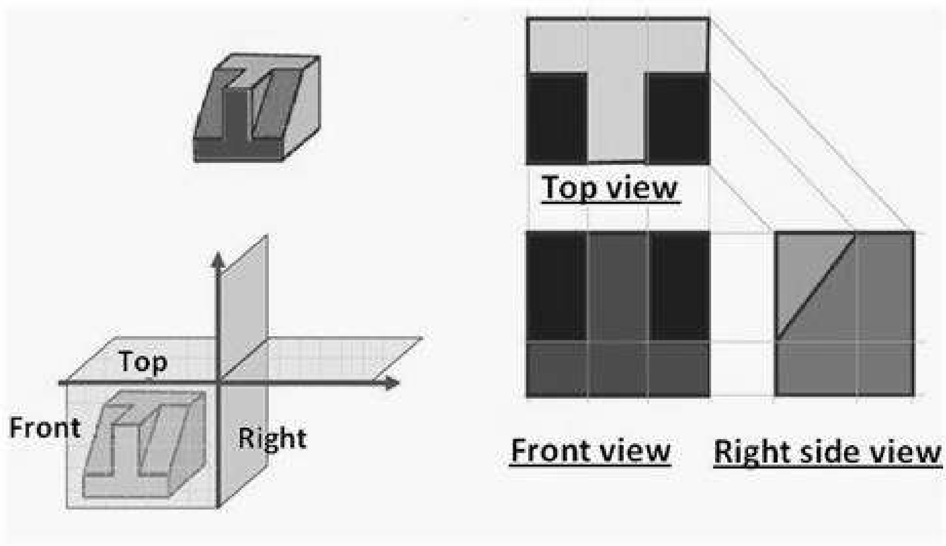


Figure 18. Illustrating the views obtained using first angle projection technique

Figure 19 illustrates the difference between the 1^{st} angle and 3^{rd} angle projection techniques. A summary of the difference between 1st and 3rd angle projections is shown if Table 1.

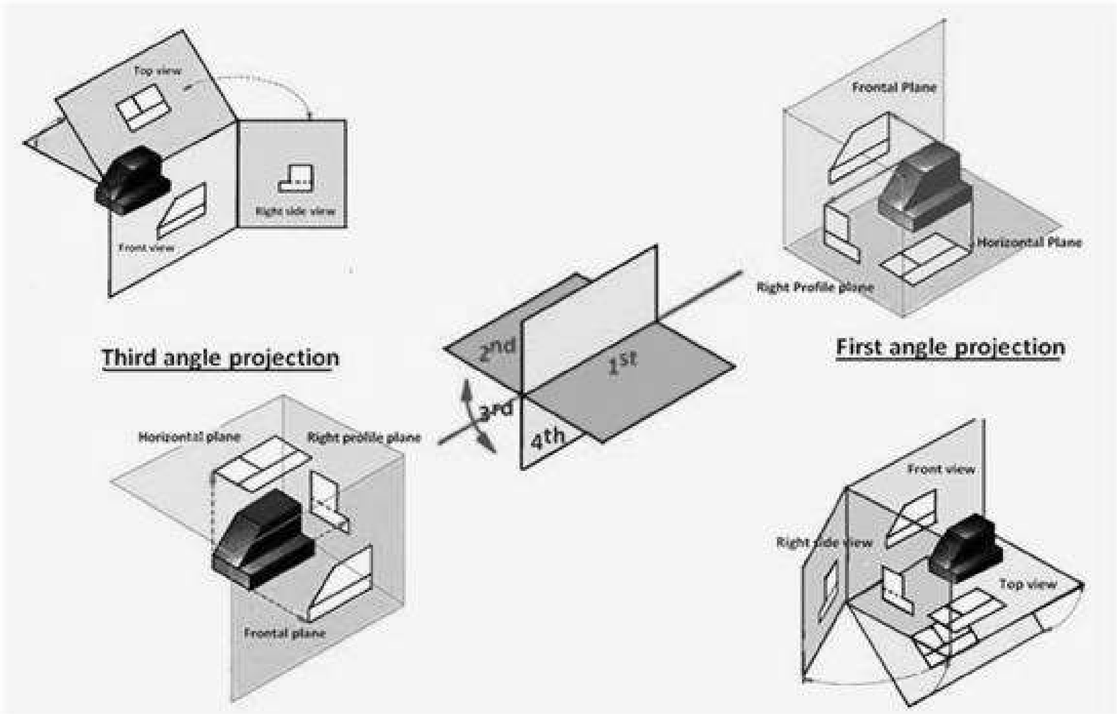


Figure 19 Differentiating between the 1^{st} angle and 3^{rd} angle projection techniques.

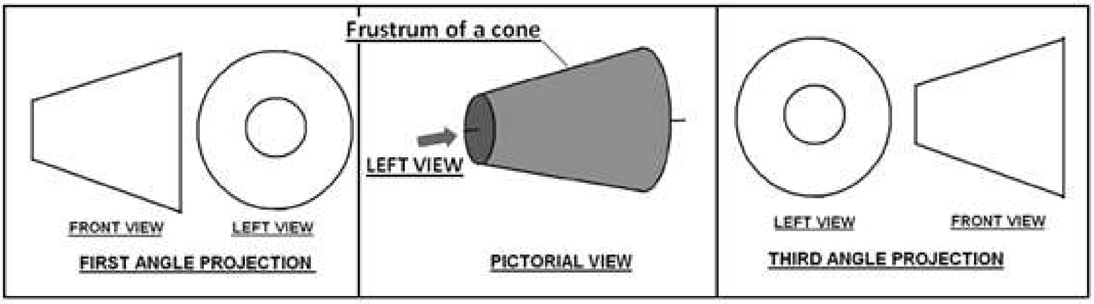
Table 1. Difference between first- and third-angle projections

First angle projection	Third-angle projection
Object is kept in the first quadrant.	Object is assumed to be kept in the third quadrant.
Object lies between observer and the plane of projection.	Plane of projection lies between the observer and the object.
The plane of projection is assumed to be non-transparent.	The plane of projection is assumed to be transparent.
Front (elevation) view is drawn above the XY line	Front (elevation) view is drawn below the XY line
Top (plan) view is drawn below the XY line	Top (plan) view is drawn above the XY line
Left view is projected on the right plane and vice versa	Left view is projected on the left plane itself.
Followed in India, European countries	Followed in USA

Either first angle projection or third angle projection are used for engineering drawing. Second angle projection and fourth angle projections are not used since the drawing becomes complicated. This is being explained with illustrations in the lecture on Projections of points (lecture 18).

Symbol of projection

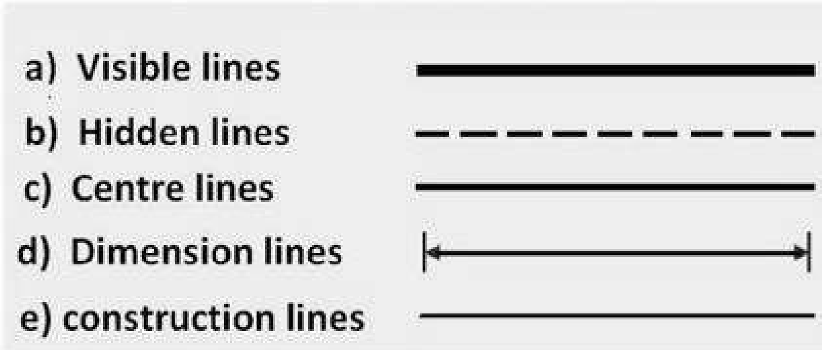
The type of projection obtained should be indicated symbolically in the space provided for the purpose in the title box of the drawing sheet. The symbol recommended by BIS is to draw the two sides of a frustum of a cone placed with its axis horizontal The left view is drawn.



2.3 Orthographic Projections

Lines are used to construct a drawing. Various type of lines are used to construct meaningful drawings. Each line in a drawing is used to convey some specific information. The types of lines generally used in engineerign drawing is shown in Table-1.

Table -1. Types of lines generally used in drawings



All visible edges are to be represented by visible lines. This includes the boundary of the object and intersection between two planes. All hidden edges and features should be represented by dashed lines. Figure 1 shows the orthographic front view (line of sight in the direction of arrow)of an object. The external boundary of the object is a rectangle and is shown by visible lines. In Figure-1(a), the step part of the object is hidden and hence shown as dashed lines while for the position of the object shown in figure-1(b) , the step part is directly visible and hence shown by the two solid lines.

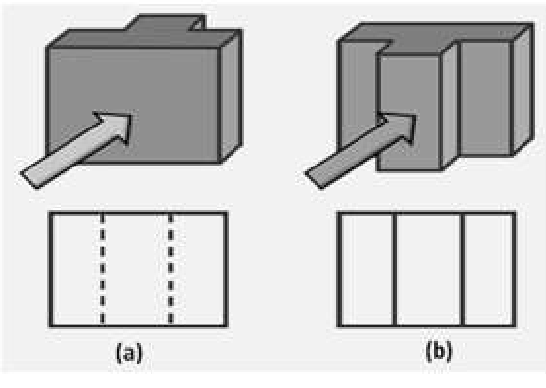


Figure 1 shows the pictorial view and front view of the object when the middle stepped region is (a) hidden and (b) visible.

Projection of Points

A POINT
The position of a point in engineering drawing is defined with respect to its distance from the three principle planes i.e., with respect to the VP, HP, & PP.
The point is assumed to be in the respective quadrant shown in figure 1(a). The point at which the line of sight (line of sight is normal to the respective plane of projection) intersects the three planes are obtained. The horizontal plane and the side planes are rotated so such that they lie on the plane containing the vertical plane. The direction of rotation of the horizontal plane is shown in figure 1 (b).

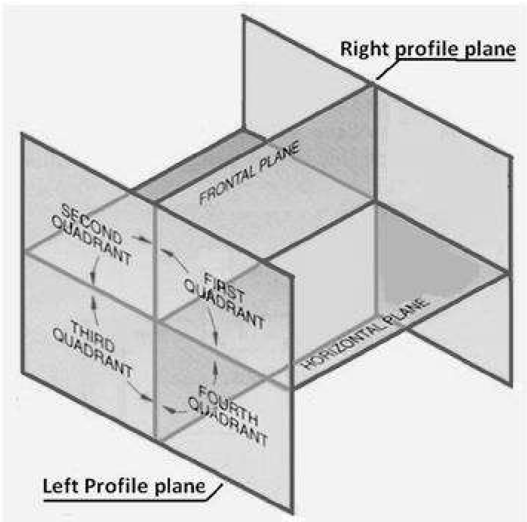


Figure 1(a). The relative positions of projection planes and the quadrants

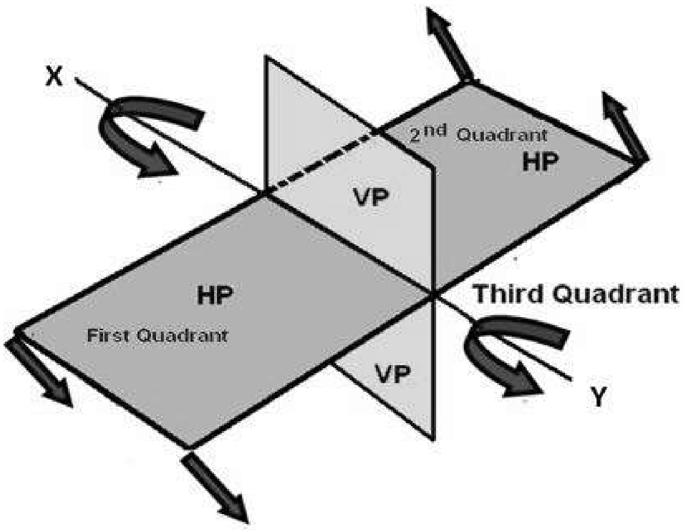


Figure 1(b). The direction of rotation of the Horizontal plane.

Conventions used while drawing the projections of points

With respect to the 1st angle projection of point "P' shown in figure 2,

- Top views are represented by only small letters eg. p .
- Their front views are conventionally represented by small letters with dashes eg. p'
- Profile or side views are represented by small letters with double dashes eg. p''
- Projectors are shown as thin lines.
- The line of intersection of HP and VP is denoted as X-Y.
- The line of intersection of VP and PP is denoted as X1-Y1

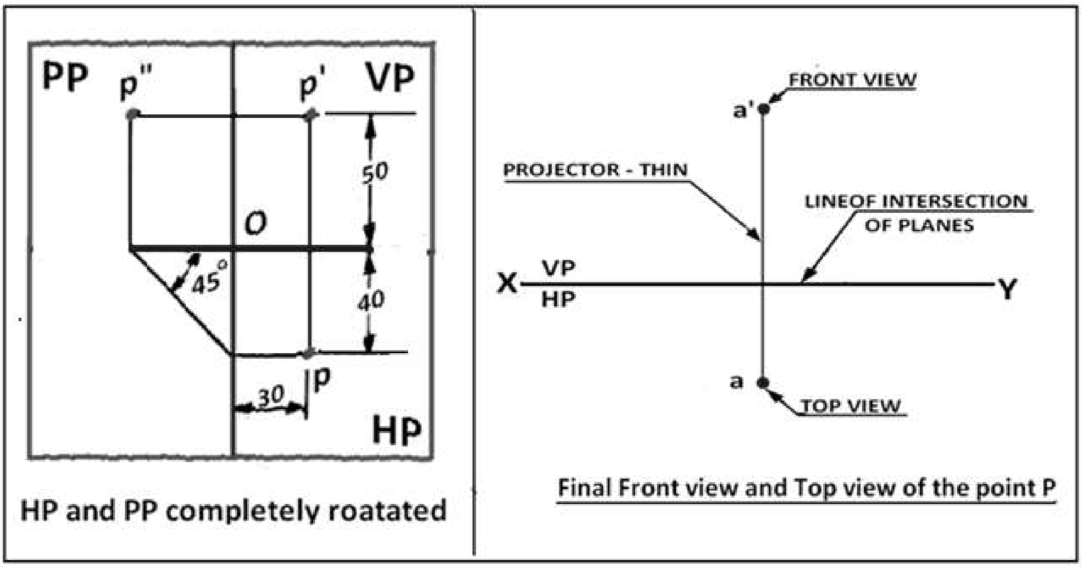


Figure 2. Showing the three planes and the projectionof the point P after the planes have been rotated on to the vertical plane.

Point in the First quadrant

Figure 3 shown the projections of a point P which is 40 mm in front of VP, 50 mm above HP, 30 mm in front of left profile plane (PP)

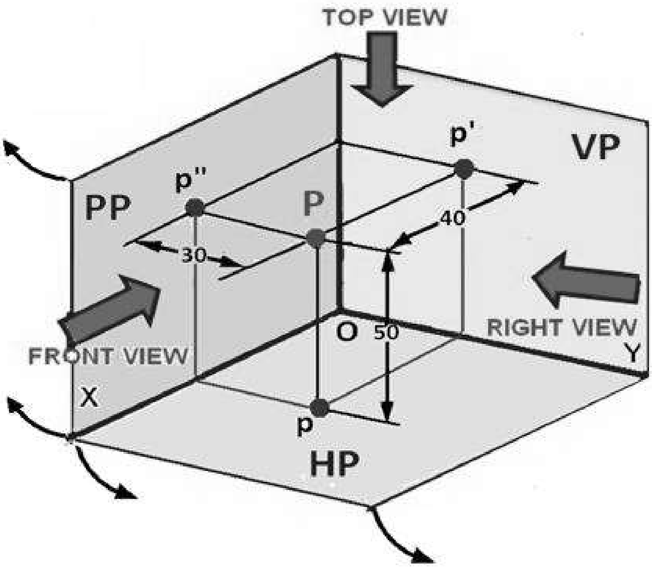


Figure 3. Projection of the point "P" on to the three projection planes before the planes are rotated.

Figure 4 shows the planes and the position of the points when the planes are partially rotated. The arrows indicate the direction of rotation of the planes. The three views after complete rotation of the planes is shown in figure 2.

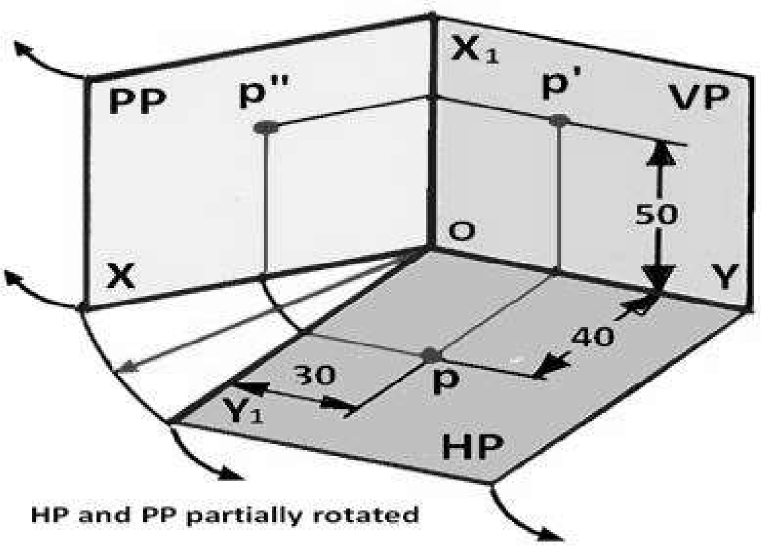


Figure 4. Projection of the point "P" on to the three projection planes after the planes are partially rotated.

The procedure of drawing the three views of the point "P" is shown in figure-4.

- Draw a thin horizontal line, XY, to represent the line of intersection of HP and VP.
- Draw X_1Y_1 line to represent the line of intersection of VP and PP.

- Draw the Top View (p).
- Draw the projector line
- Draw the Front View (p') .
- To project the right view on the left PP, draw a horizontal projector through p to intersect the 45 degree line at m. Through m draw a vertical projector to intersect the horizontal projector drawn through p' at p''.
- p '' is the right view of point P

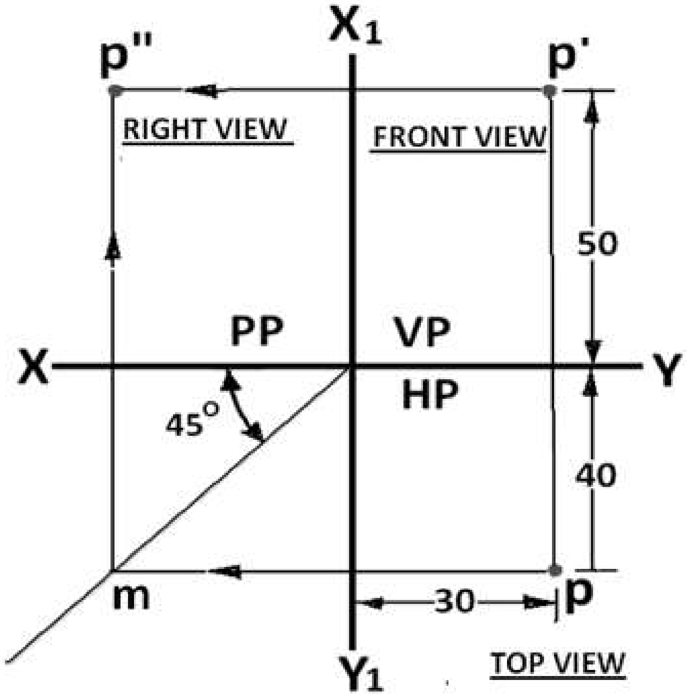


Figure 5 First angle multi-view drawing of the point "P"

Point in the Second quadrant

Point P is 30 mm above HP, 50 mm behind VP and 45 mm in front of left PP. Since point P is located behind VP, the VP is assumed transparent. The position of the point w.r.t the three planes are shown in Figure 1. The direction of viewing are shown by arrows. After projecting the point on to the three planes, the HP and PP are rotated such that they lie along the VP. The direction of rotation of the HP and PP is shown in figure 2. As shown in figure 3, after rotation of the PP and HP, it is found that the VP and HP is overlapping. The multiview drawing for the point P lying in the second quadrant is shown in figure 4. Though for the projection of a single point, this may not be a problem, the multiview drawing of solids, where a number of lines are to be drawn, will be very complicated. Hence second angle projection technic is not followed anywhere for engineering drawing.

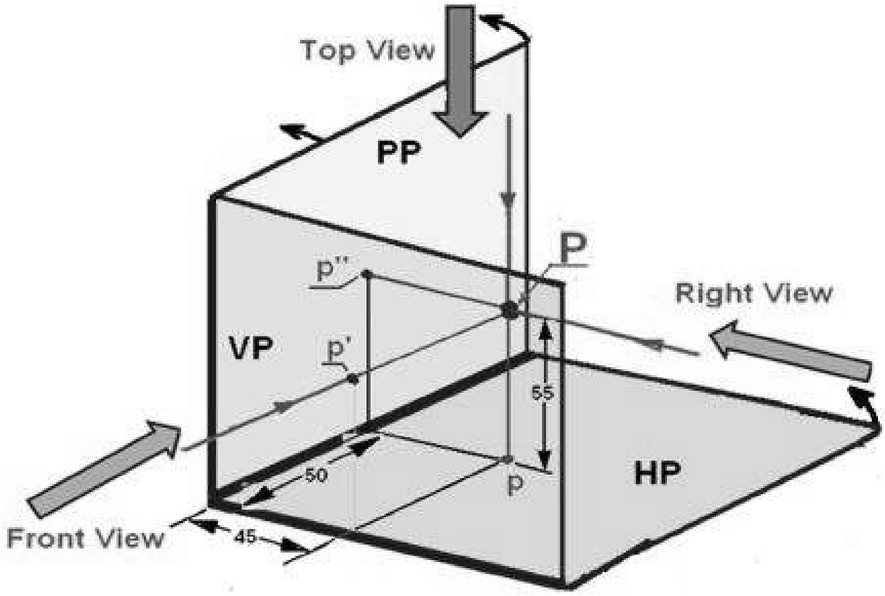


Figure 1. The projection of point P on to the three projection planes.

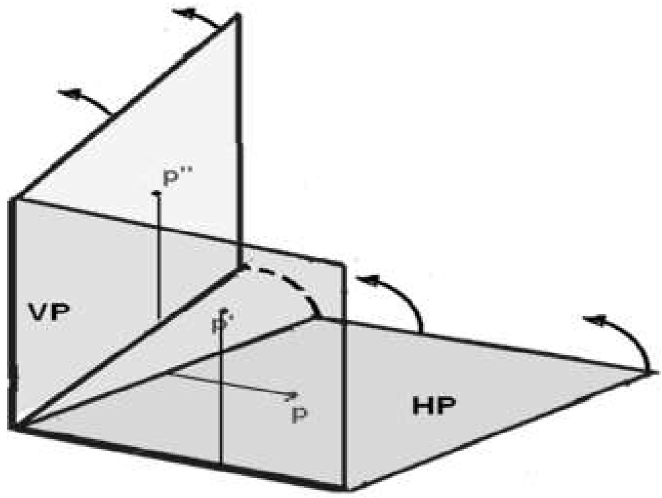


Figure 2. The direction of rotation of HP.

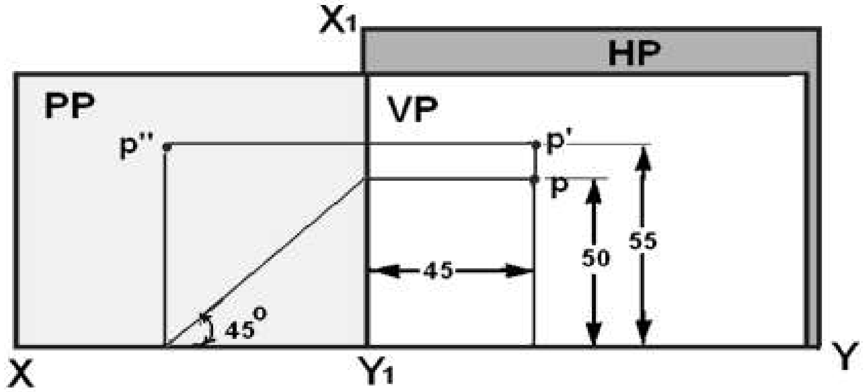


Figure 3. The projection of point P after complete rotation of the HP and PP.

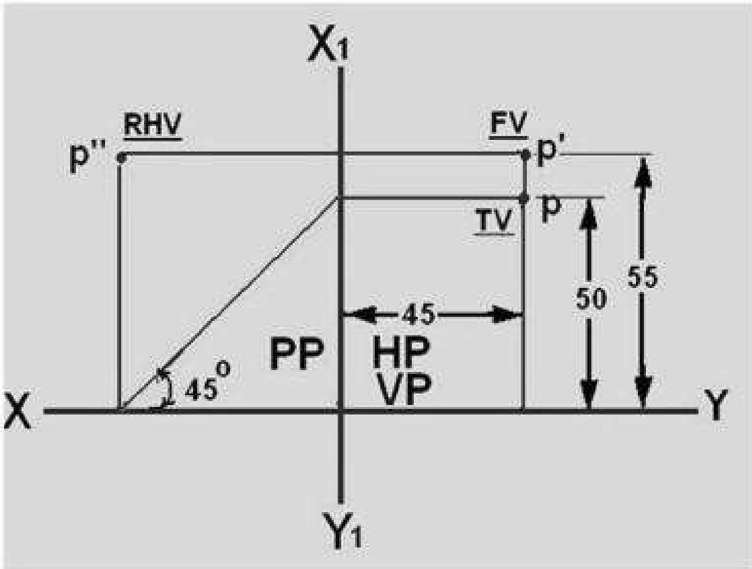


Figure 4. The multiview drawing of the point P lying in the second quadrant.

Point in the Third quadrant

Projection of a point P in the third quadrant where P is 40 mm behind VP, 50 mm below HP and 30 mm behind the right PP is shown in figure 5.

Since the three planes of projections lie in between the observer and the point P, they are assumed as transparent planes. After the point P is projected on to the three planes, the HP and VP are rotated along the direction shown in figure 6, such that the HP and PP is in plane with the VP. The orthographic projection of the point P lying in the third quadrant is shown in figure 7.

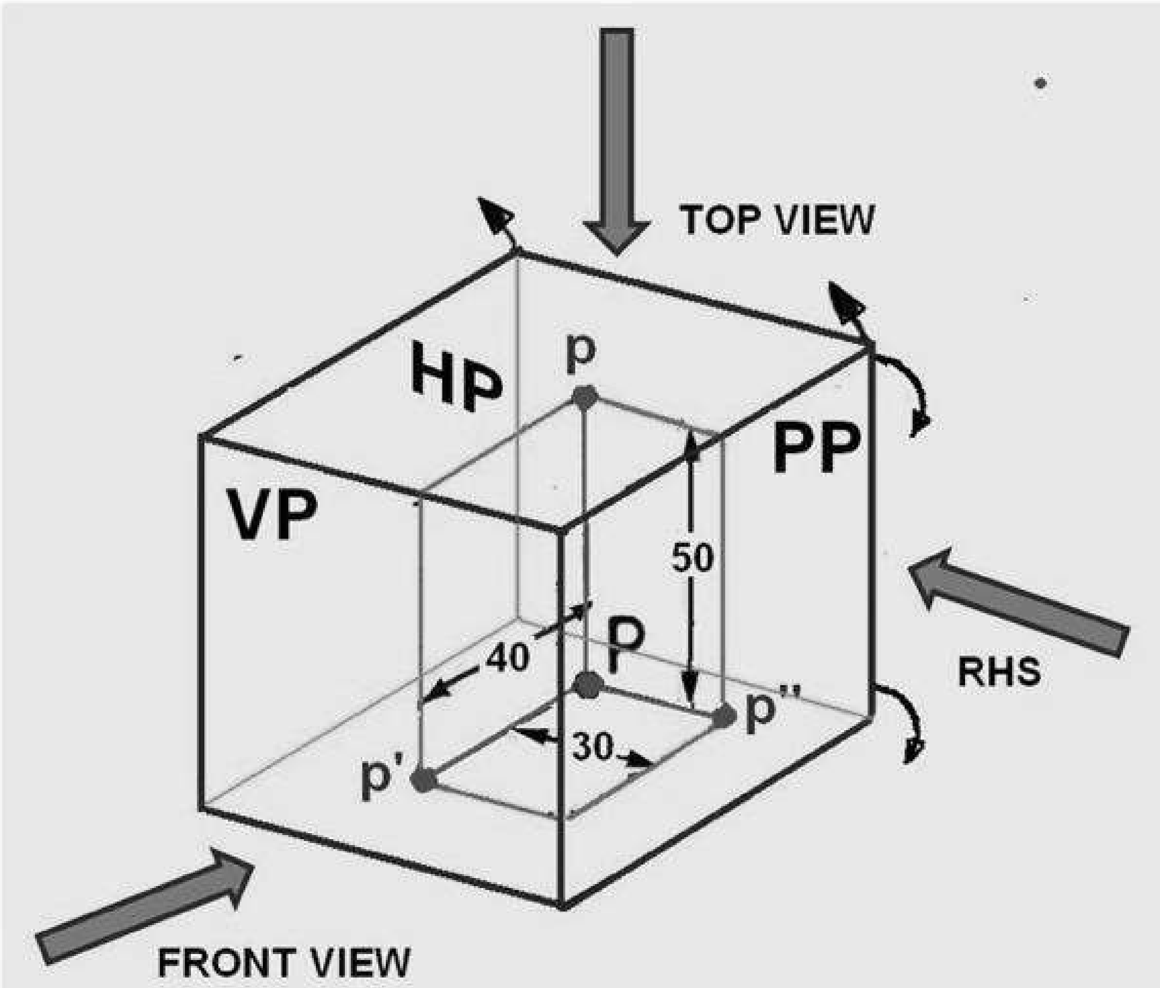


Figure 5. Projection of a point P placed in the third quadrant

In the third angle projection, the Top view is always above the front view and the Right side view will be towards the right of the Front view.

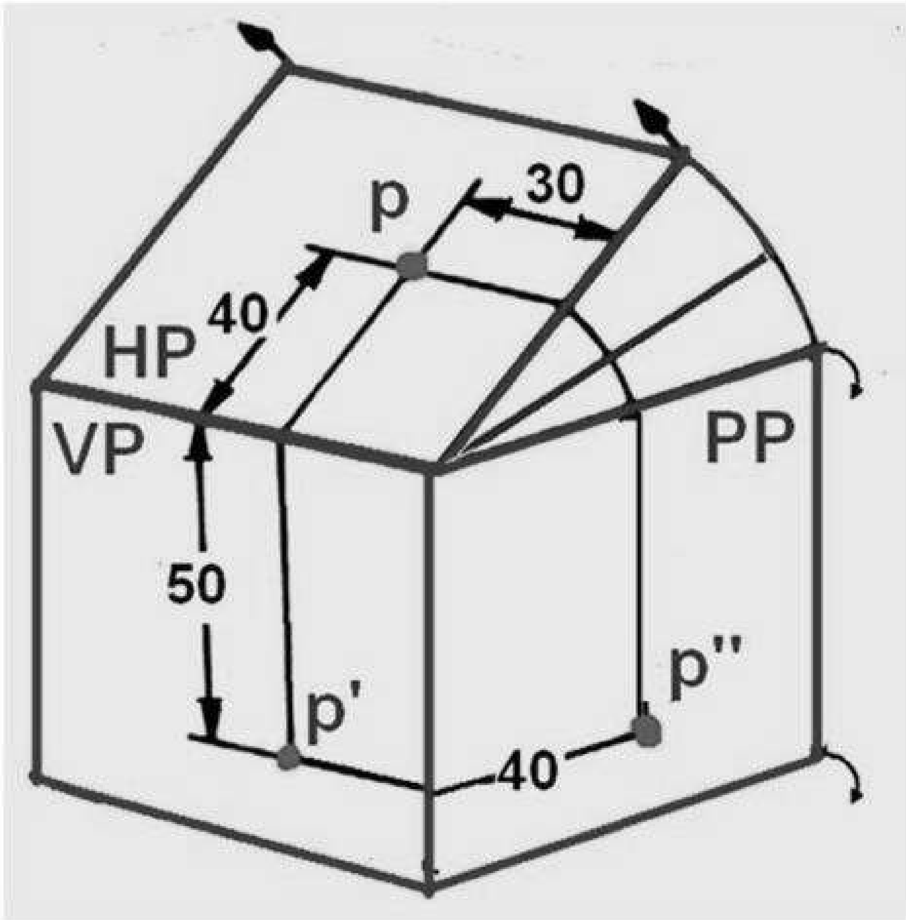


Figure 6. shows the sense of direction of rotation of PP and HP.

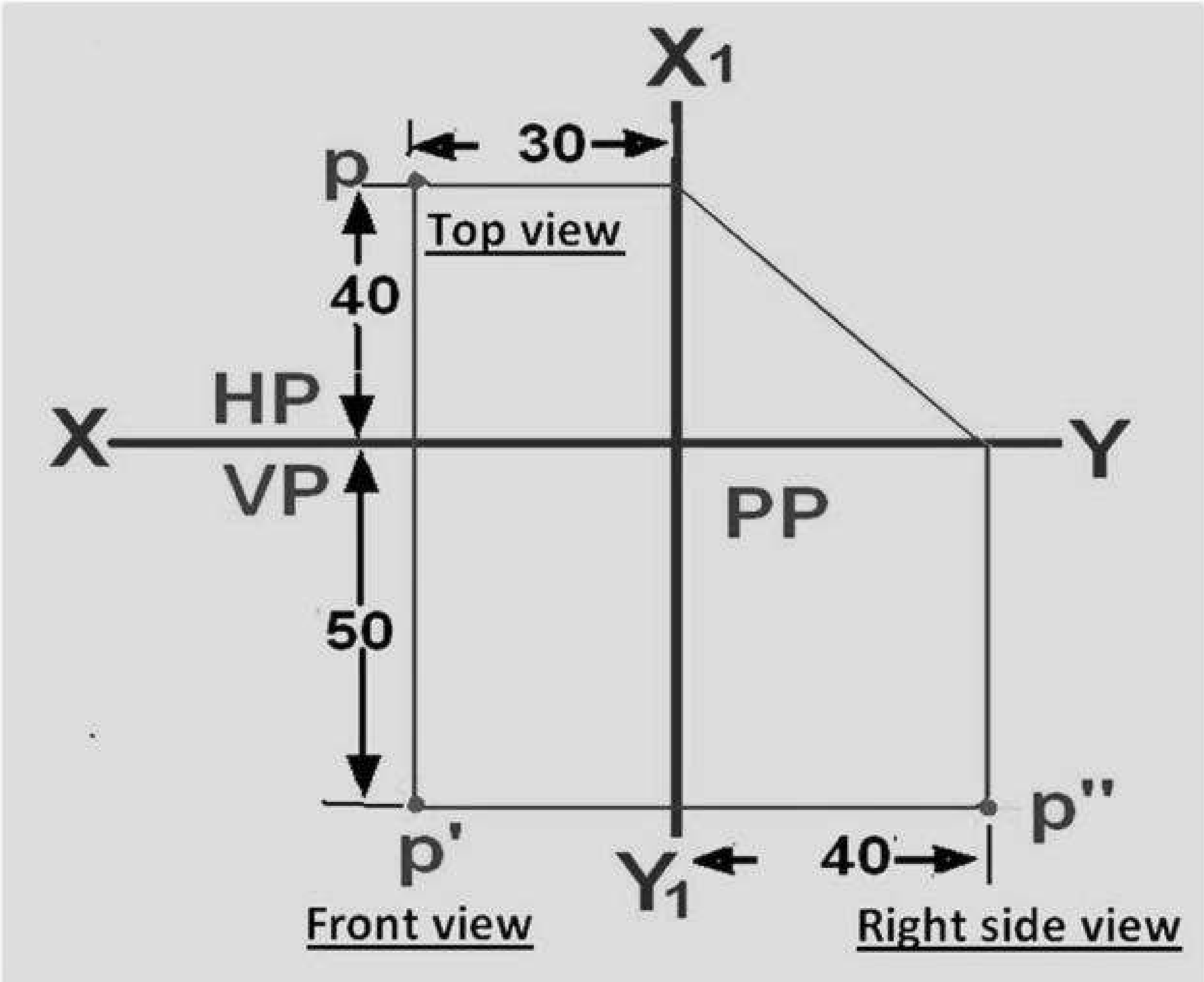


Figure 7. Multi-view drawing of the point lying in the third quadrant.

In the third angle projection, the Top view is always above the front view and the Right side view will be towards the right of the Front view.

Point in the Fourth quadrant

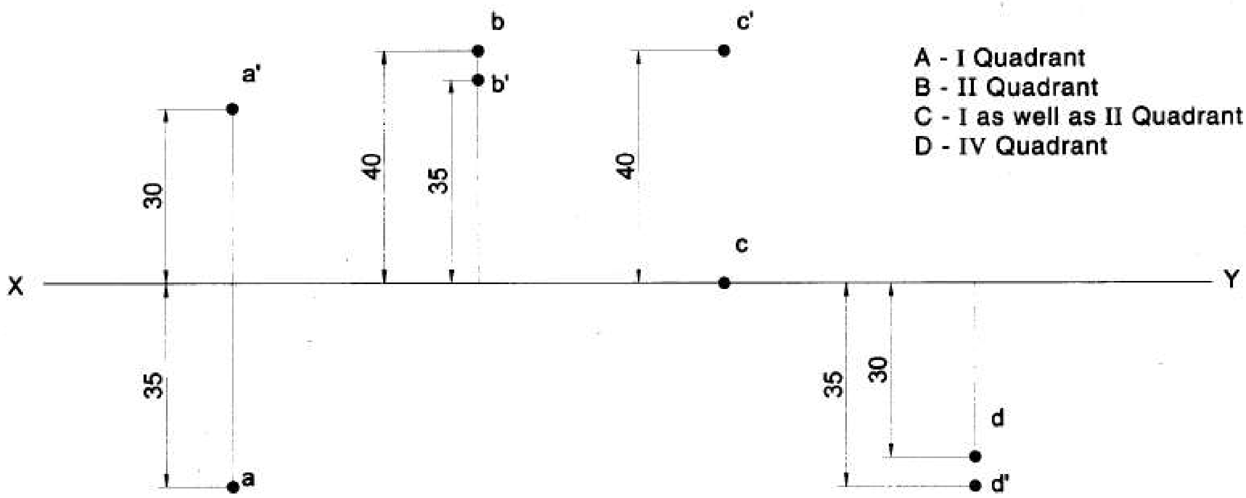
If A point is lying in the fourth quadrant, the point will be below the HP and infront of the VP. The point is projected on to the respective projection planes. After rotation of the HP and PP on to the VP, it will be observed that that the HP and VP are overlapping, similar to the second angle projection. The multi-view drawing of objects in such case would be very confusing and hence fourth angle projection technique is not followed by engineers.

Worked Examples- Projection of Points

Problem 1 Draw the projections of the following Points on the same XY line, keeping convenient distance between each projectors. Name the Quadrants in which they lie.

A – 30 mm above HP & 35 mm in front of VP.
B – 35 mm above HP & 40 mm behind VP.
C – 40 mm above HP & on VP.
D – 35 mm below HP & 30 mm in front of VP.

Solution

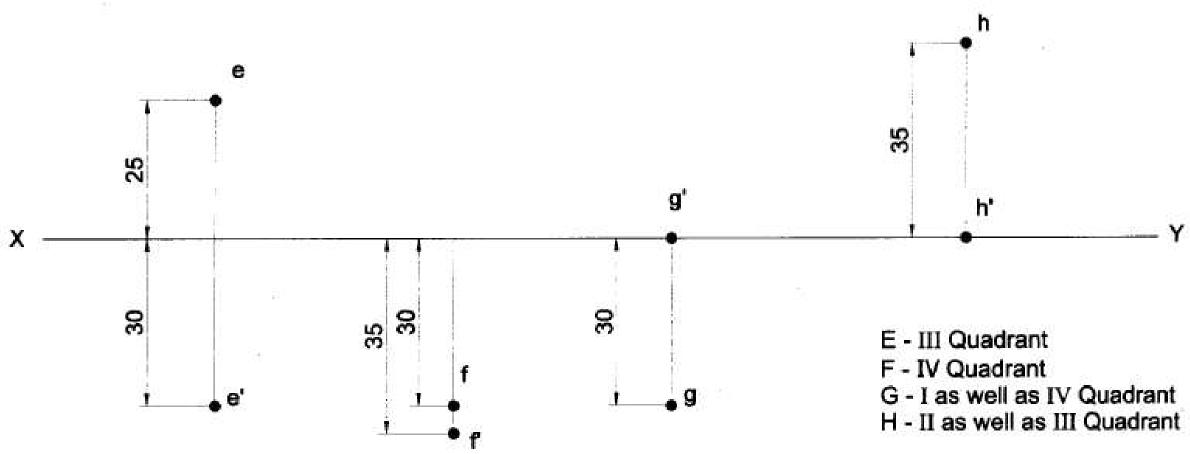


A - I Quadrant
B - II Quadrant
C - I as well as II Quadrant
D - IV Quadrant

Problem 2 Draw the projections of the following Points on the same XY line,Keeping convenient distance between each projectors. Name the Quadrants in which they lie.

E – 30 mm below HP & 25 mm behind VP.
F – 35 mm below HP & 30 mm in front of VP.
G – On HP & 30 mm in front of VP.
H - On HP & 35 mm behind VP.

Solution

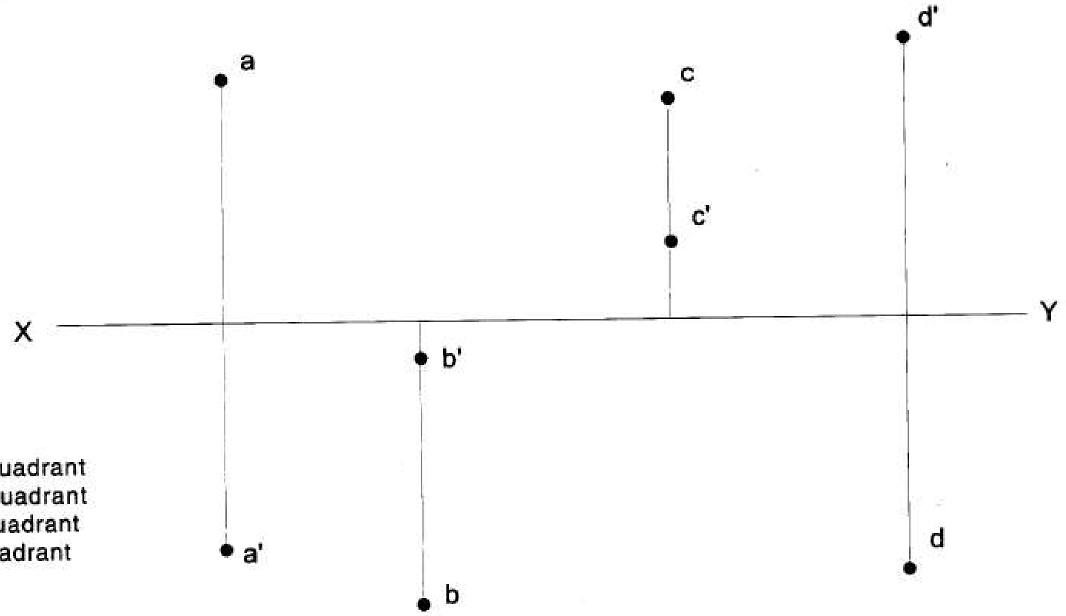


E - III Quadrant
F - IV Quadrant
G - I as well as IV Quadrant
H - II as well as III Quadrant

Problem 3 Draw and state the quadrants in which the following Points are located. Assume any distances.

A – Front view below XY line & Top view above XY line.
B – Front and Top views are below XY line.
C – Front and top views are above XY line.
D – Front view above XY line & top view below XY line.

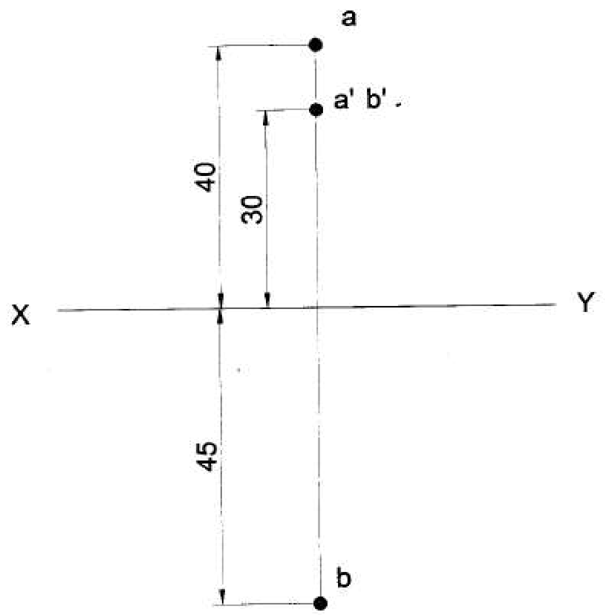
Solution



A - III Quadrant
B - IV Quadrant
C - II Quadrant
D - I Quadrant

Problem 4 A point 30mm above XY line is the front view of two points A&B .The top view of A is 40 mm behind VP & The top view of B is 45 mmin front of VP. Draw The projections of the points & state the quadrants in which the points are situated.

Solution

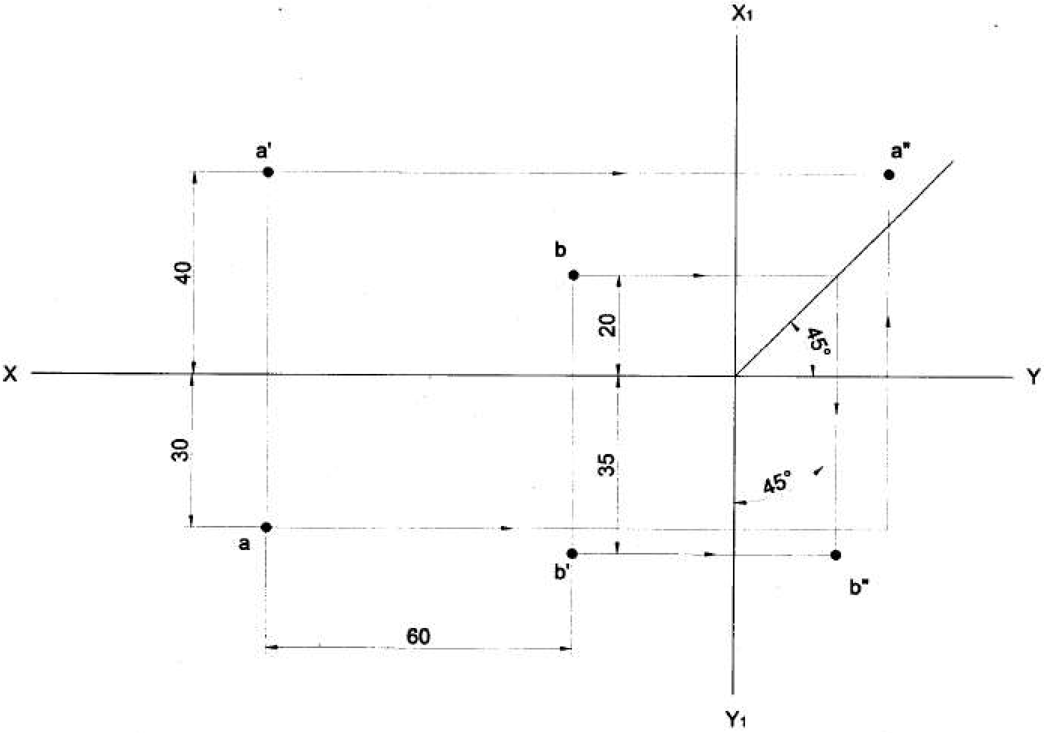


ANSWERS : **A is in II Q**

B is in I Q

Problem 5 A point 'A' is 30 mm in front of VP and 40mm above HP. Another point B is 20 mm behind VP & 35 mm below HP. The horizontal distance between the points measured parallel to XY line is 60 mm . Draw the three projections of the points. Join their front and top views.

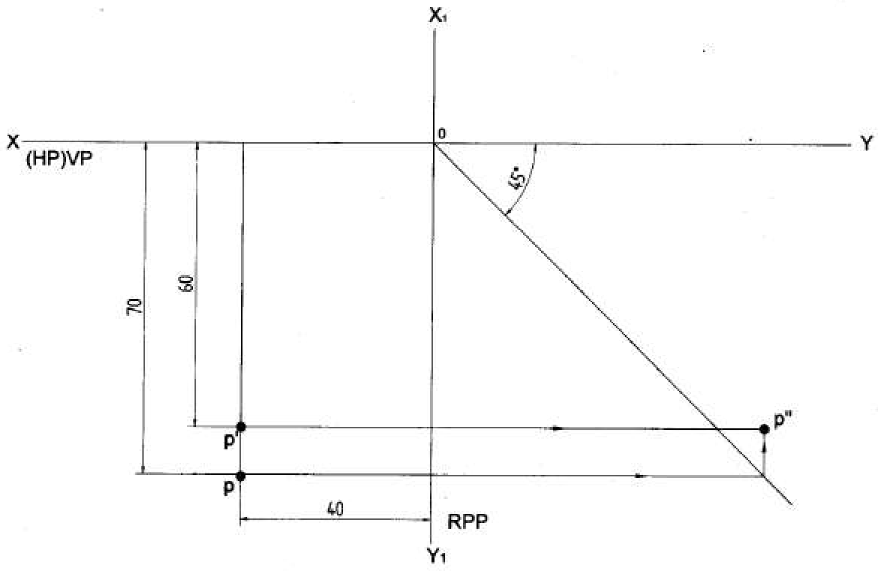
Solution



Y1

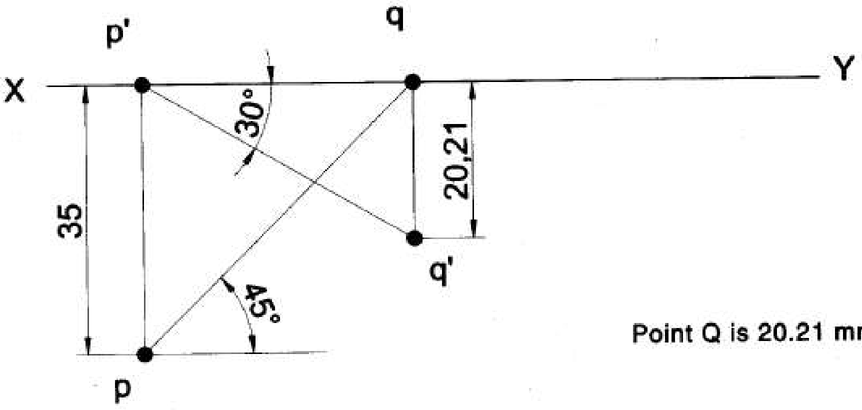
Problem 6 Draw all the three views of a point P lying 60 mm below HP, 70 mm infront of VP and 40 mm from the RPP. Also state the quadrant in which it lies.

Solution



Problem 7 A point P is on HP and 35 mm in front of VP. Another Point Q is on VP and below HP. The line Joining their front views makes an angle of 30 deg to XY line , while the line joining their top views makes an angle of 45 deg with XY line.Find the distance of the point Q from HP.

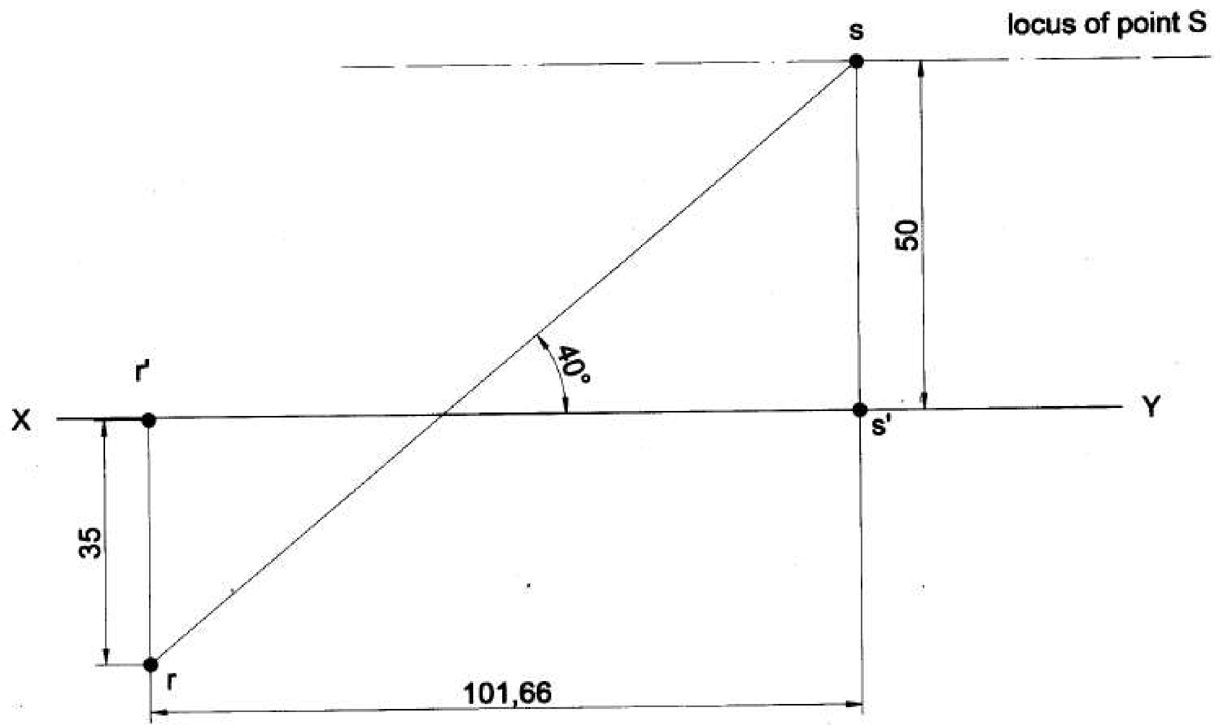
Solution



Point Q is 20.21 mm below HP

Problem 8 Two Points R and S are on HP. The point R is 35 mm in front of VP, while S is 50mm behind VP .The line joining their top views makes an angle of 40deg with XY. Find the horizontal distance between the two projectors.

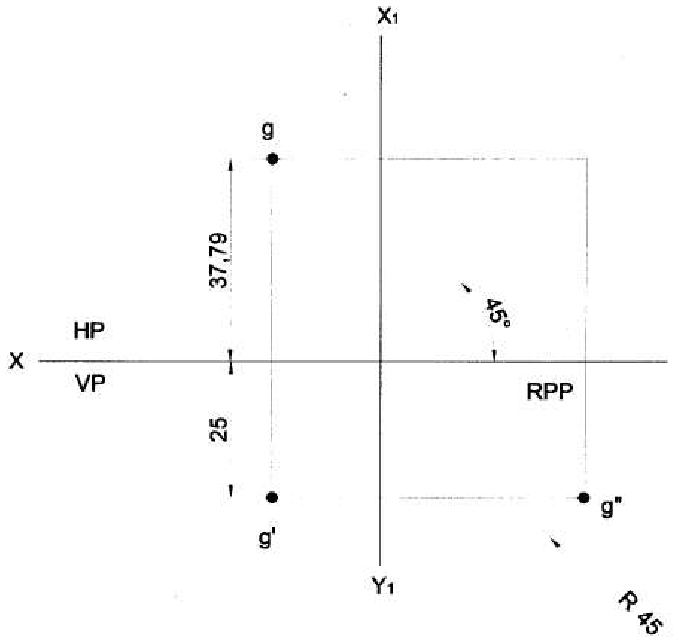
Solution



ANSWER : Distance b/w two projectors is 101.66 mm.

Problem 9 A point G is 25 mm below HP & is situated in the third quadrant. Its shortest distance from the intersection of XY and X1Y1 is 45 mm . Draw its projections and find its distance from VP.

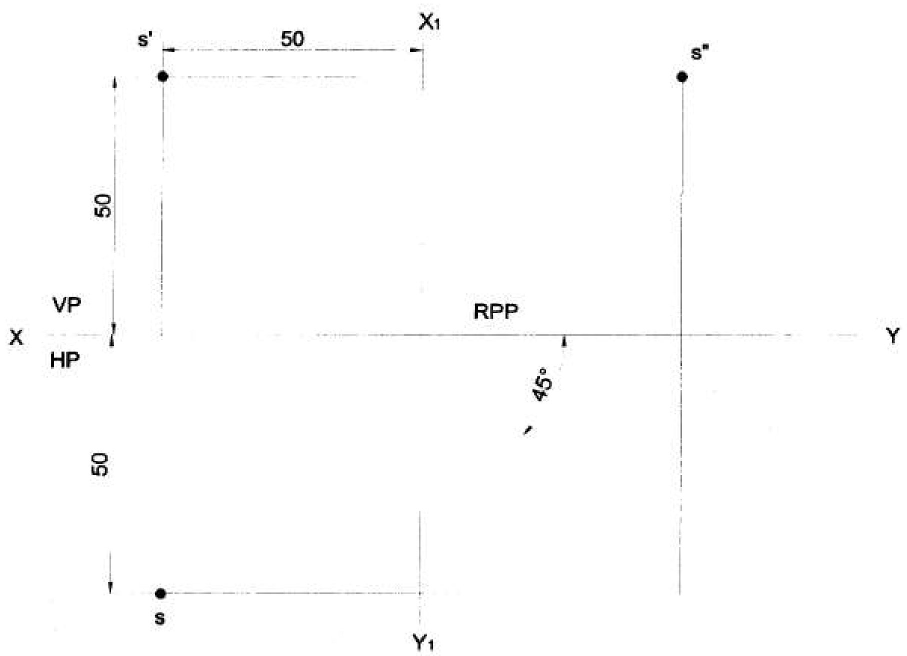
Solution



Point G is 37.79 mm behind VP

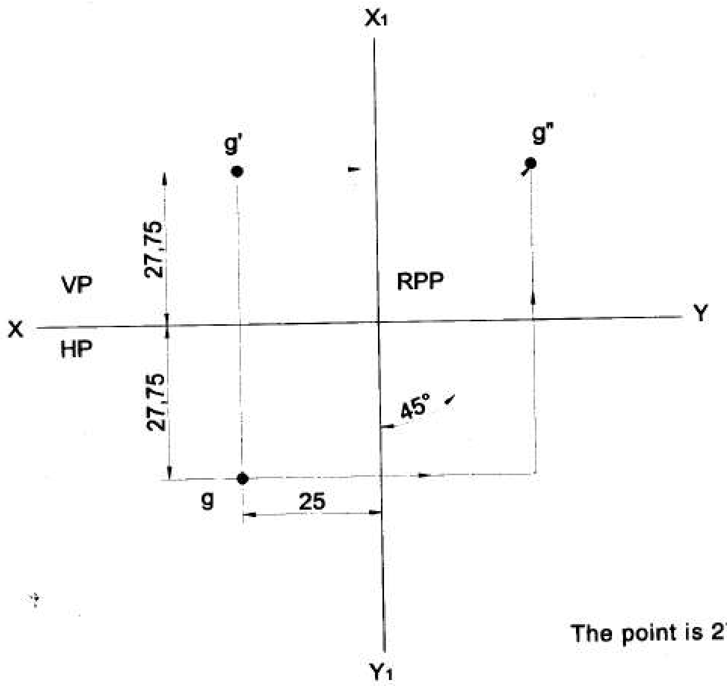
Problem 10 A point S is in the first quadrant and equidistant of 50 mm from all the three principal planes. Draw the projections of the point. Draw all the three views of the point.

Solution



Problem 11 Draw the projections of point G which is in first quadrant such that it is equidistant from HP & VP. The point is 25 mm from RPP. Determine its distances from HP&VP.

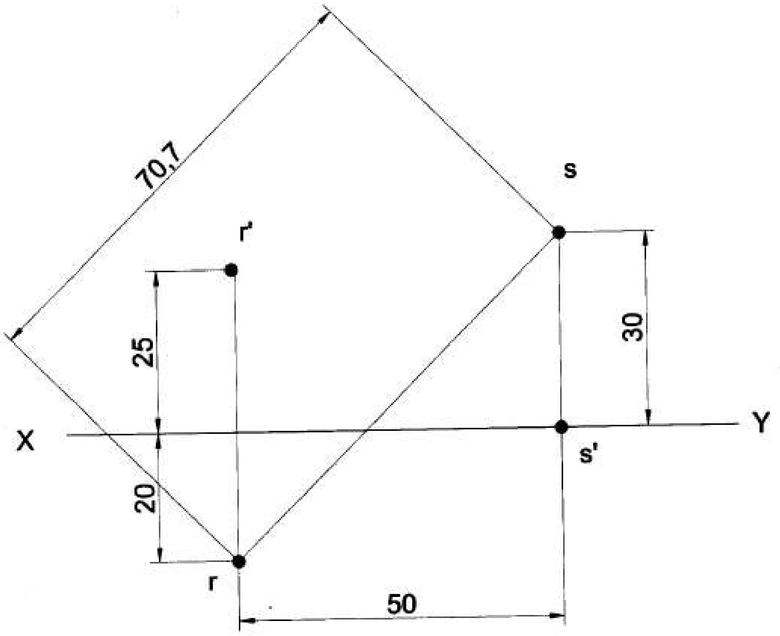
Solution



The point is 27.75 mm from VP and HP

Problem 12 A point R is 25 mm above HP & 20 mm in front of VP. Another point S is on HP and 30 mm behind VP. The distance between their projectors measured parallel to the line of intersection of VP and HP is 50mm. Find the distance between the top views of points R and S.

Solution



The Distance Between TVs of R and S is 70.7 mm

Projections of lines

Straight line

A line is a geometric primitive that has length and direction, but no thickness. Straight line is the Locus of a point, which moves linearly. Straight line is also the shortest distance between any two given points.

The location of a line in projection quadrants is described by specifying the distances of its end points from the VP, HP and PP. A line may be:

- Parallel to both the planes.
- Parallel to one plane and perpendicular to the other.
- Parallel to one plane and inclined to the other.
- Inclined to both the planes.

Projection of a line

The projection of a line can be obtained by projecting its end points on planes of projections and then connecting the points of projections. The projected length and inclination of a line, can be different compared to its true length and inclination.

Case 1. Line parallel to a plane

When a line is parallel to a plane, the projection of the line on to that plane will be its true length. The projection of line **AB** lying parallel to the Vertical plane (VP) is shown in figure 1 as **a'b'.**

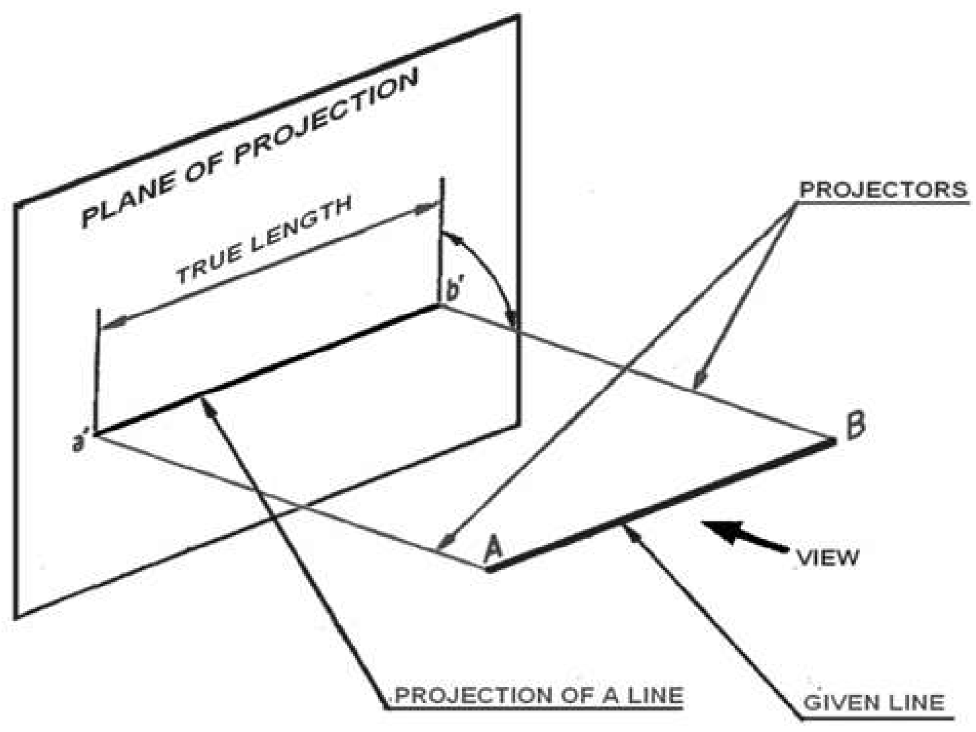


Figure 1. Projection of line on VP. Line AB is parallel to VP.

Case 2. Line inclined to a plane

When a line is parallel to one plane and inclined to the other, The projection of the line on the plane to which it is parallel will show its true length. The projected length on the plane to which it is inclined will always be shorter than the true length. In figure 2, the line AB is parallel to VP and is inclined to HP. The angle of inclination of AB with HP is being θ degrees. Projection of line AB on VP is a'b' and is the true length of AB. The projection of line AB on HP is indicated as line ab. Length ab is shorter than the true length AB of the line.

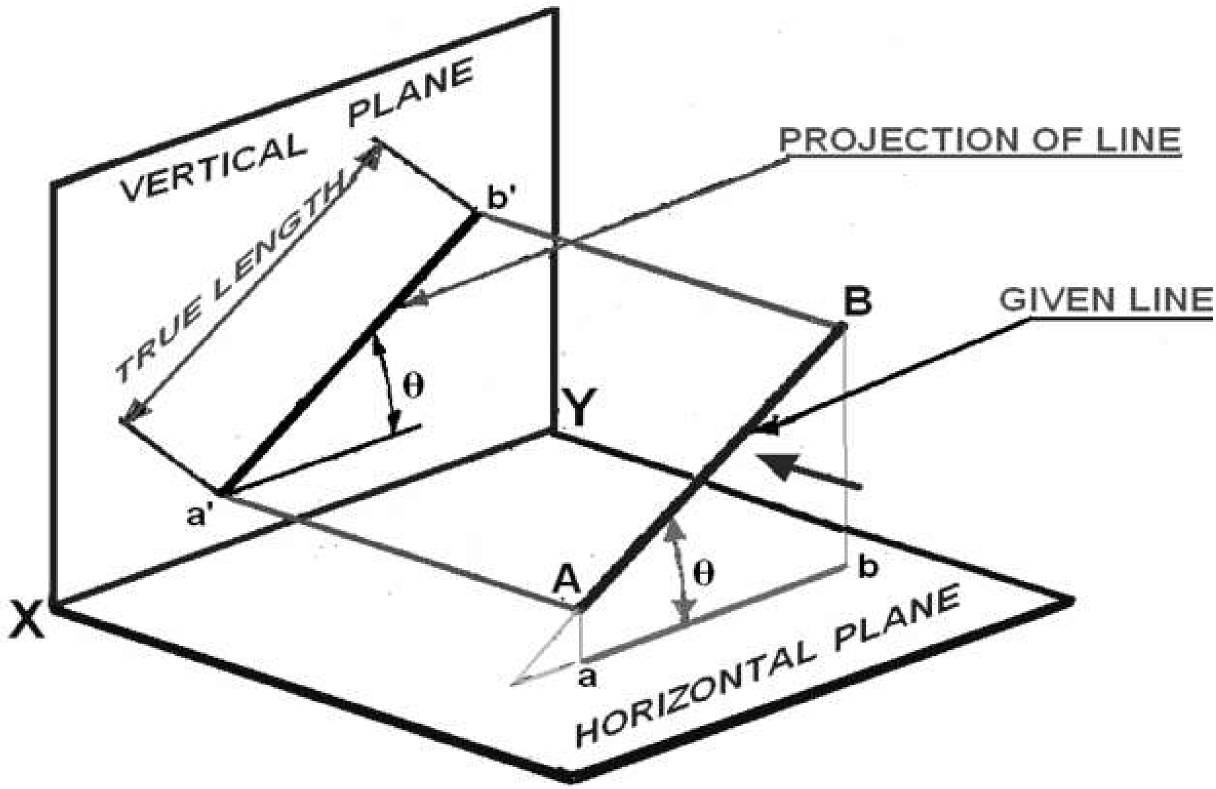


Figure 2. Projection of line AB parallel to VO and inclined to HP.

Case 3. Projection of a line parallel to both HP and VP

A line AB having length 80 mm is parallel to both HP and VP. The line is 70 mm above HP, 60 mm in front of VP. End B is 30 mm in front of right PP. To draw the projection of line AB, assume the line in the first quadrant. The projection points of AB on the vertical plane VP, horizontal plane HP and Right Profile plane PP is shown in figure 3(a). Since the line is parallel to both HP and VP, both the front view a'b' and the top view ab are in true lengths. Since the line is perpendicular to the right PP, the left side view of the line will be a point a''(b''). After projection on to the projection planes, the planes are rotated such that all the three projection planes lie in the same planes. The multi-view drawing of line AB is shown in Figure 3(b).

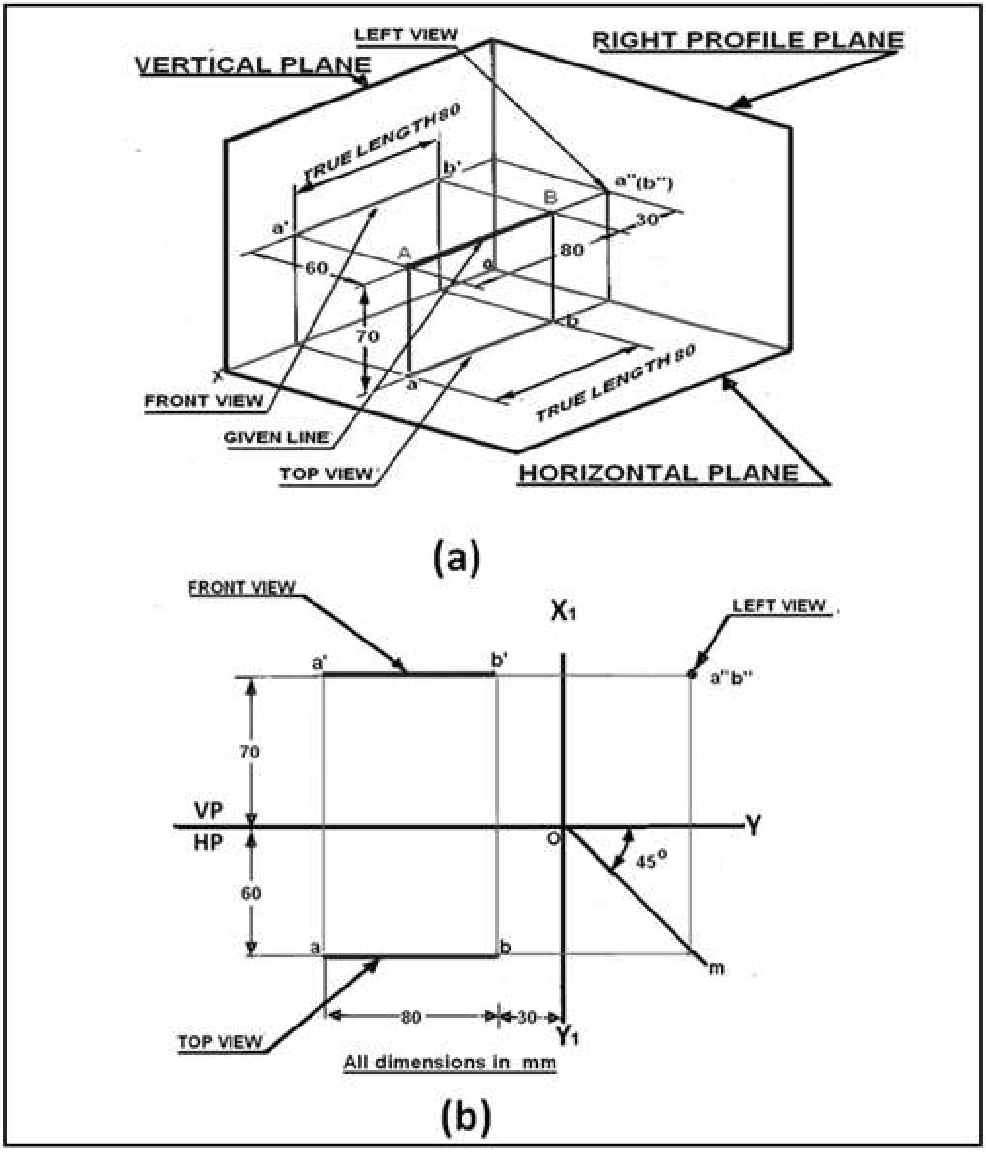


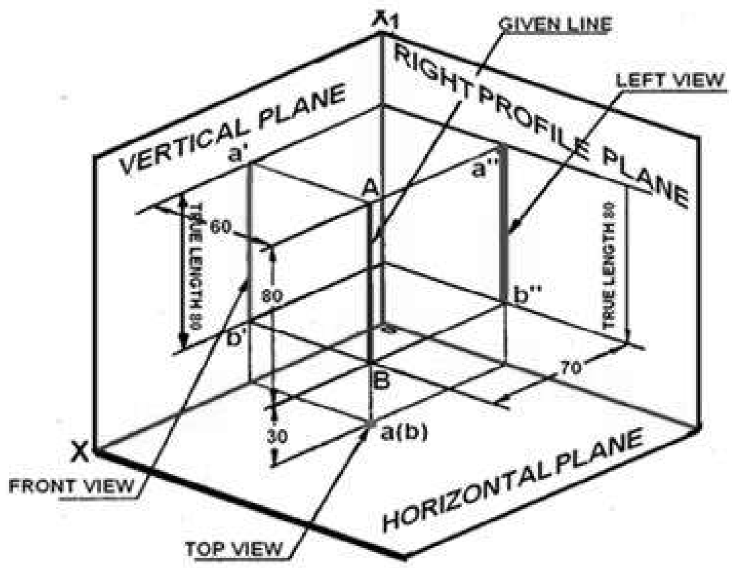
Figure 3. Projection of line parallel to both HP and VP.

Case 4. Line perpendicular to HP & parallel to VP

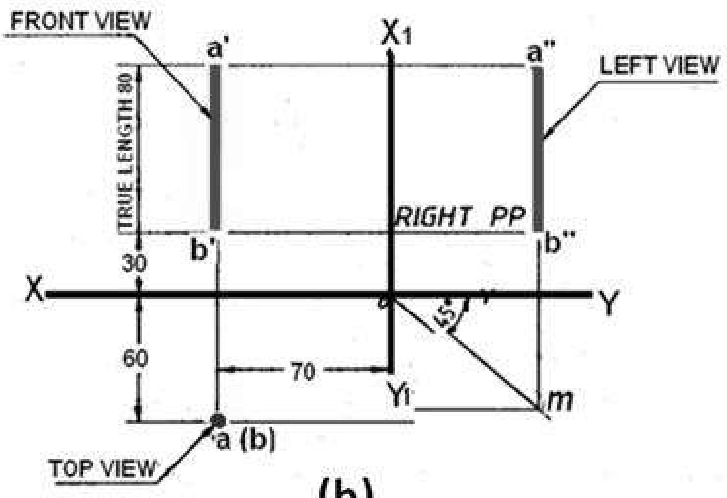
A line AB of length 80 mm is parallel to VP and perpendicular to HP. The line is 80 mm in front of VP and 80 mm in front of right PP. The lower end of the line is 30 mm above HP. The projections of line AB shown in figure 4 can be obtained by the following method.

Draw a line XY which is the intersection between VP and HP. Draw the front view a'b' = 80 mm perpendicular to the XY line, with the lower end b' lying 30 mm above the XY line. Project the top view of the line which will be a point a(b) at a distance of 60 mm below XY line. Since the line is 70 mm in front of the right PP draw the X_1Y_1 line at a distance of 70 mm on the right- side of the front view.

Through O the point of intersection of XY and X_1Y_1, lines draw a 45° line. Draw the horizontal projector through a(b) to cut the 45 degree line at m. Draw the horizontal projectors through a' and b' to intersect the vertical projector drawn through m at a′′ and b′′. a′′b′′ is the left view of the line AB.



(a)



(b)

Figure 4. Projections of a line AB perpendicular to HP and parallel to VP.

Line parallel to one plane and inclined to the other

Case 5. Line parallel to VP and inclined to HP

A line AB, 90 mm long is inclined at 30° to HP and parallel to VP. The line is 80 mm in front of VP. The lower end A is 30 mm above HP. The upper end B is 50 mm in front of the right PP. The projections of line AB shown in figure 5 can be obtained in the following manner. Mark a', the front view of the end A, 30 mm above HP. Draw the front view a'b' = 90 mm inclined at 30° to XY line.

Project the top view **ab** parallel to XY line. The top view is 80 mm in front of VP. Draw the X_1Y_1 line at a distance of 50 mm from **b'**. Draw a 45° line through **O**. Draw the horizontal projector through the top view **ab** to cut the 45 ° line at **m**. Draw a vertical projector through **m**. Draw the horizontal projectors through **a'** and **b'** to intersect the vertical projector drawn through m at **a"** and **b"**. Connect a′′b′′which is the left side view.

Case 6. Line inclined to HP and VP

When a line is inclined to both HP and VP, the apparent inclination of the line to both the projection planes will be different from the actual inclinations. Similarly the projected length of the lines on to the planes will not be the same as the true length f the line. The following notation will be used for the inclinations and length of the lines for this entire lecture series:

Actual inclinations are θ degrees to HP and φ degrees to VP.
Apparent Inclinations are a and b to HP and VP respectively.
The Apparent Lengths of line AB are ab and a'b' in the top view and front view respectively.

Example: Draw the projections of a line AB inclined to both HP and VP, whose true length and true inclinations and locations of one of the end points, say A are given.

The projections of the line AB are illustrated in figure 1. Since the line AB is inclined at θ to HP and φ to VP – its top view ab and the front view a'b' are not in true lengths and they are also not inclined at angles θ to HP and φ to VP in the Front view and top view respectively. Figure 2 illustrates the projections of the line AB when the line is rotated about A and made parallel to VP and HP respectively. A clear understanding of these can be understood if the procedure followed in the subsequent sub-sections are followed:

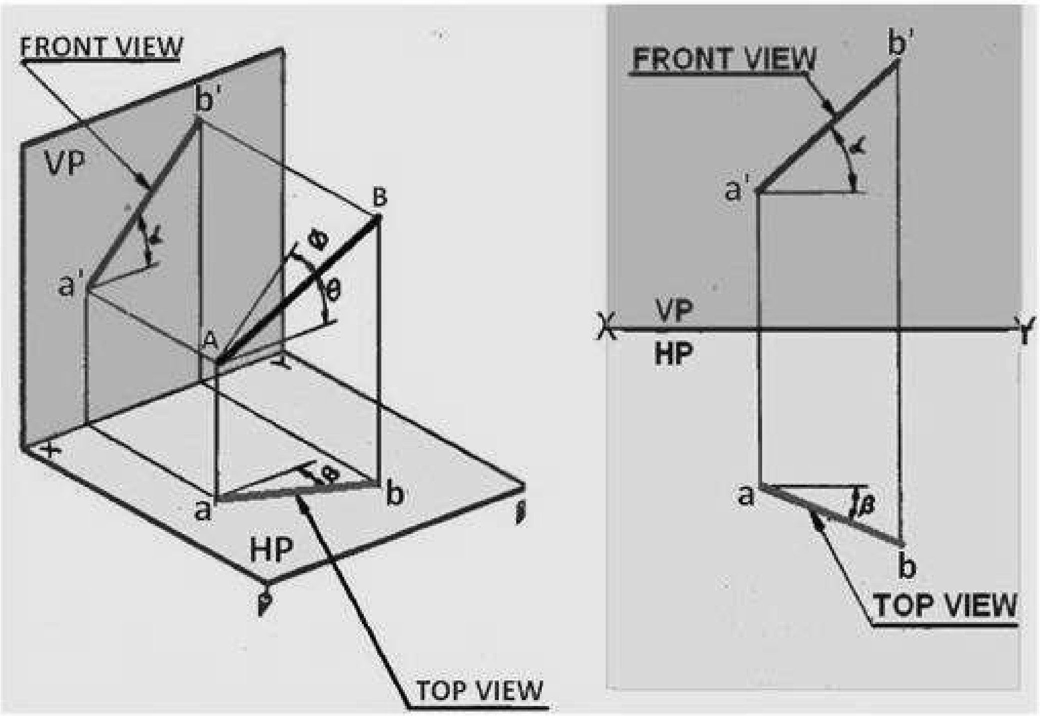
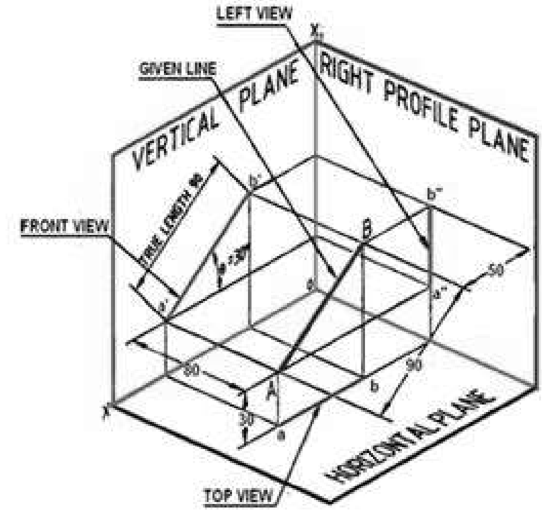
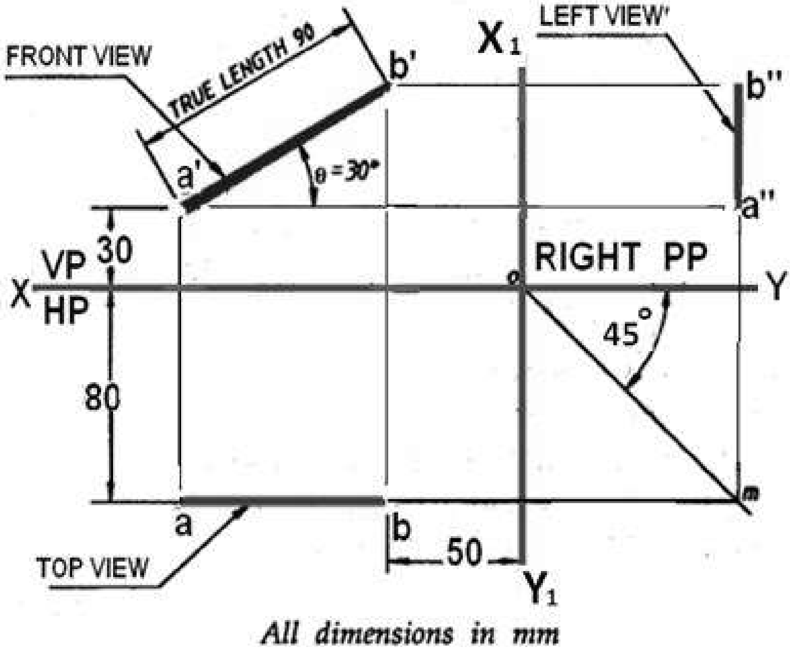


Figure 1: The projections of a line inclined to both HP and VP



(a)



(b)

Figure 5. Projections of line AB parallel to VP and inclined to HP.

Step 1: Rotate the line AB to make it parallel to VP.

Rotate the line AB about the end A, keeping θ, the inclination of AB with HP constant till it becomes parallel to VP. This rotation of the line will bring the end B to the new position B1. AB_1 is the new position of the line AB when it is inclined at q to HP and parallel to VP. Project AB_1 on VP and HP. Since AB_1 is parallel to VP, $a'b_1'$, the projection of AB1 on VP is in true length inclined at q to the XY line, and ab1, the projection of AB_1 on HP is parallel to the XY line. Now the line is rotated back to its original position AB.

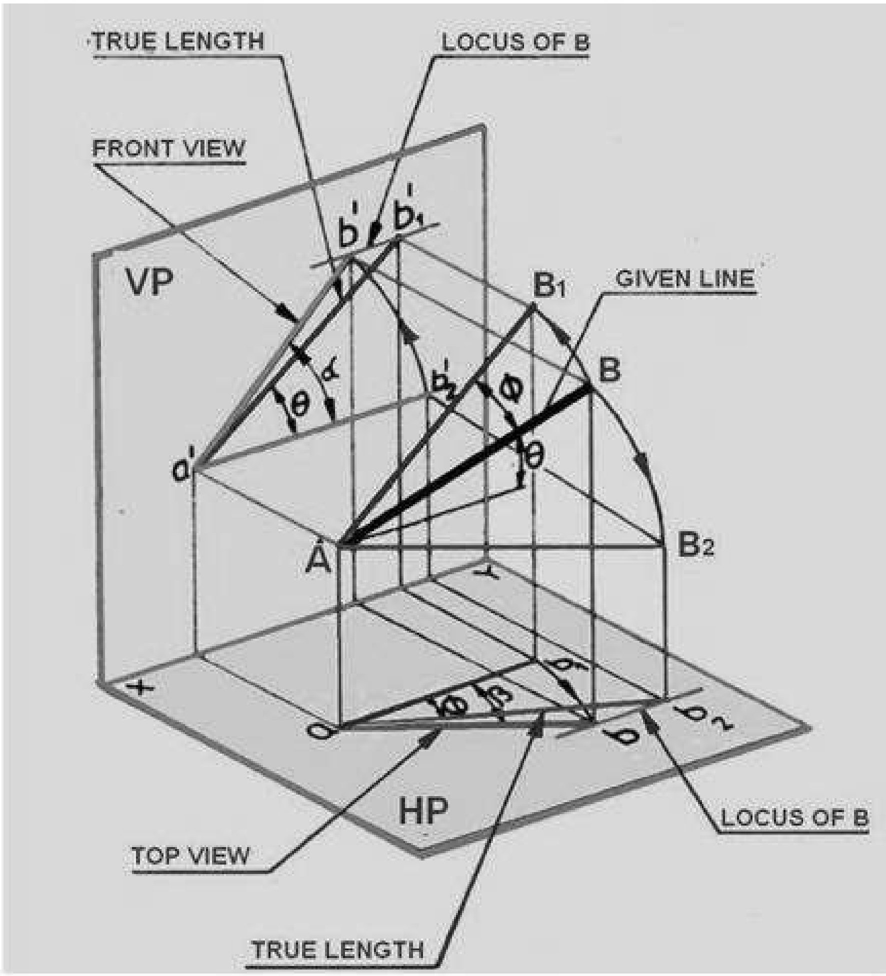


Figure 2. Illustrates the locus of end B of the line AB when the line is rotated about end A

Step 2: Rotate the line AB to make it parallel to HP.

Rotate the line AB about the end A keeping φ the inclination of AB with VP constant, till it becomes parallel to HP as shown in figure 2. This rotation of the line will bring the end B to the second new Position B_2. AB_2 is the new position of the line AB, when it is inclined at f to VP and parallel to HP. Project AB_2 on HP and VP. Since AB_2 is parallel to HP, ab_2, the projection of AB_2 on HP is in true length inclined at f to XY line, and $a'b_2'$ the projection of AB_2 on VP is parallel to XY line. Now the line is rotated back to its original position AB.

Step 3: Locus of end B in the front view

Referring to figure 2, when the line AB is swept around about the end A by one complete rotation, while keeping θ the inclination of the line with the HP constant, the end B will always be at the same vertical height above HP, and the locus of the end B will be a circle which appears in the front view as a horizontal line passing through b'.

As long as the line is inclined at θ to HP, whatever may be the position of the line (i.e., whatever may be the inclination of the line with VP) the length of the top view will always be equal to ab1 and in the front view the projection of the end B lies on the locus line passing through b1'.

Thus ab_1, the top view of the line when it is inclined at θ to HP and parallel to VP will be equal to ab and b', the projection of the end B in the front view will lie on the locus line passing through b_1'.

Step 4: Locus of end B in the top view

It is evident from figure 2, that when the line AB is swept around about the end A by one complete rotation, keeping f the inclination of the line with the VP constant, the end B will always be at the same distance in front of VP and the locus of the end B will be a circle which appears in the top view as a line, parallel to XY, passing through b.

As long as the line is inclined at φ to VP, whatever may be the position of the line (i.e., whatever may be the inclination of the line with HP), the length of the front view will always be equal to $a'b_2'$ and in the top view the projection of the end B lies on the locus line passing through b_2.

Thus $a'b_2'$ the front view of the line when it is inclined at f to VP and parallel to HP, will be equal to a'b' and also b, the projection of the end B in the top view lies on the locus line passing through b_2.

Step 5: To obtain the top and front views of AB

From the above two cases of rotation it can be said that

(i)the length of the line AB in top and front views will be equal to ab_1 and $a'b_2'$ respectively and

(ii) The projections of the end B, (i.e., b and b') should lie along the locus line passing through $b_2$and b_1' respectively.
With center a, and radius ab_2 draw an arc to intersect the locus line through b_2 at b. Connect ab the top view of the line AB.
Similarly with center a', and radius $a'b_2'$ draw an arc to intersect the locus line through b_1' at b'. Connect a'b' the front view of the line AB.

Orthographic projections
As the location of one of the end points (i.e. A) with respect to HP and VP, is given, mark a anda', the top and the front views of point A.
If the line AB is assumed to be made parallel to VP and inclined at θ to HP. The front view of the line will be equal to the true length and true inclination of the line with HP. Draw $a'b_1'$ passing through a' at θ to XY line and equal to the true length of AB. $a'b_1'$ is projected down to get ab_1, the top view parallel to the XY line. This is illustrated in figure 3.

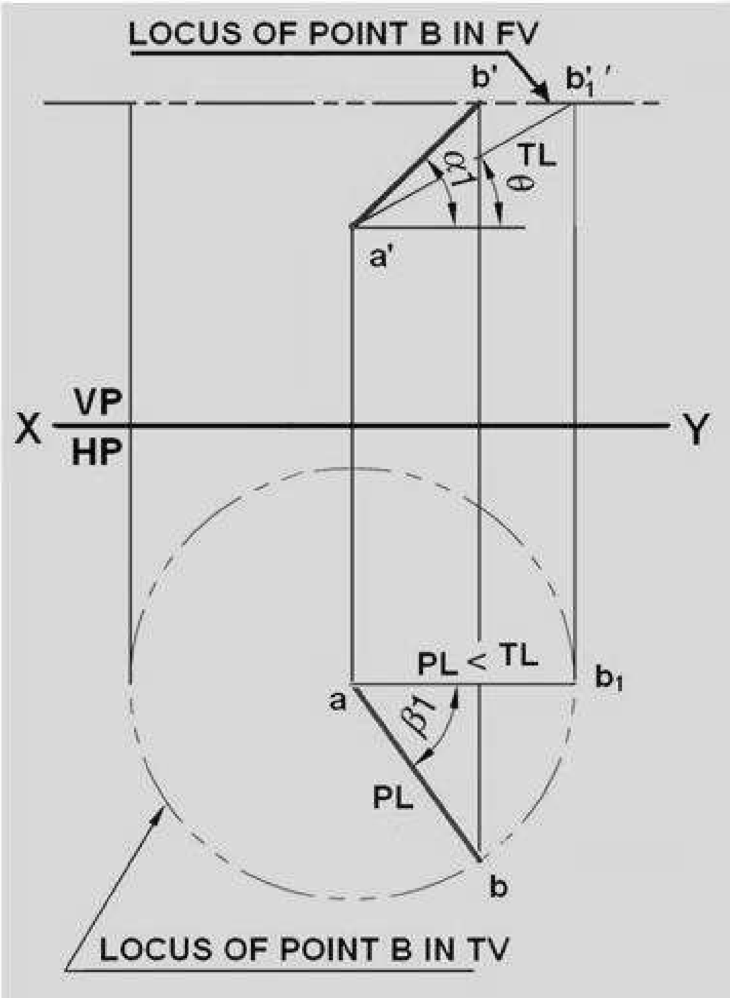


Figure 3. Illustrates the true length and true inclination of the line when it is made parallel to VP.

Now the line AB is assumed to be made parallel to HP and inclined at φ to VP. This is shown in figure 4. The top view of the line will be equal to the true length of the line and also φ, the inclination of the line with VP is seen in the top view. For this, draw ab_2 passing through a and incline at φ to the XY line. The length ab_2 is equal to the true length of AB. The end points a and b_2 are projected on to a line parallel to XY line and passing through a′ to get $a'b_2'$ which is the front view of the line when it is parallel to HP and inclined to VP. Draw the horizontal locus lines through b_2, and b_1'. With center a and radius ab1, draw an arc to cut the locus line drawn through b_2 at b. Connect ab, the top view of the line AB. With center a' and radius $a'b_2'$, draw an arc to cut the locus line drawn through b_1' at b'. Connect a'b', the front view of the line AB. Orthographic projections of line AB inclined to both VP and HP, illustrating the projected length, true lengths apparent inclinations and true inclinations are shown in figure 5.

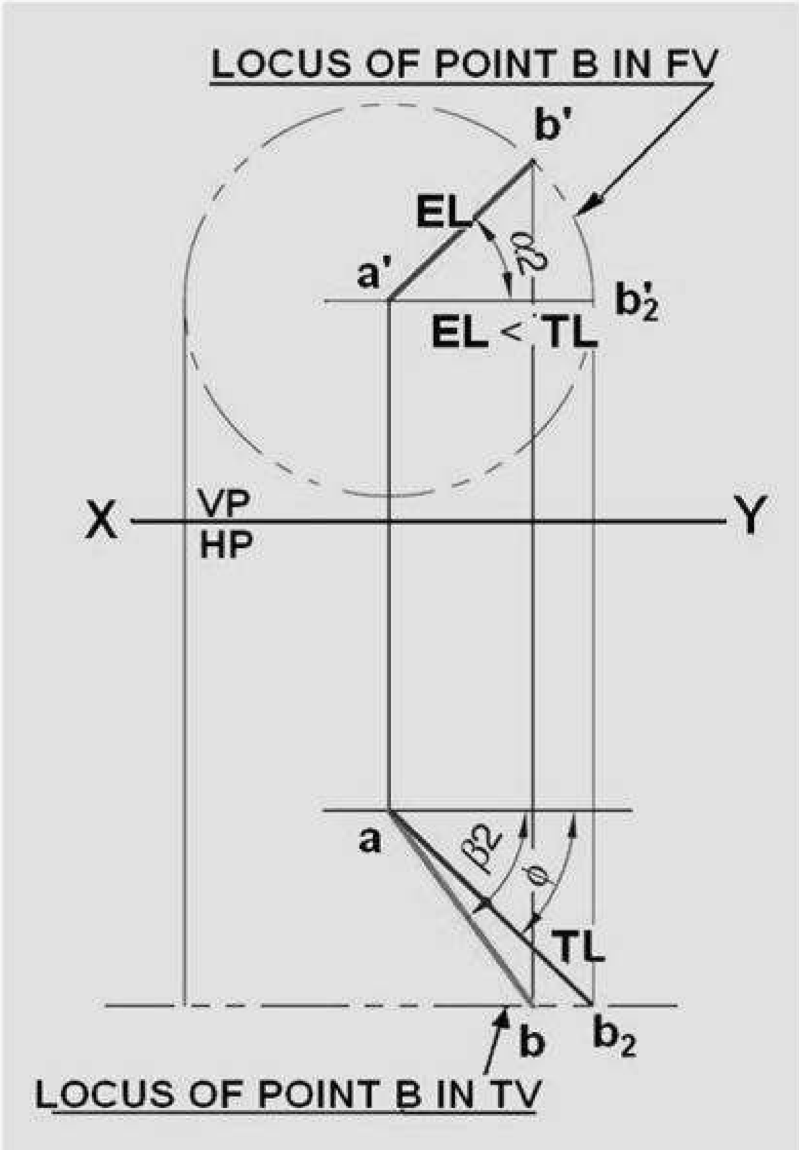


Figure 4. Illustrates the true length and true inclination of the line when it is made parallel to HP.

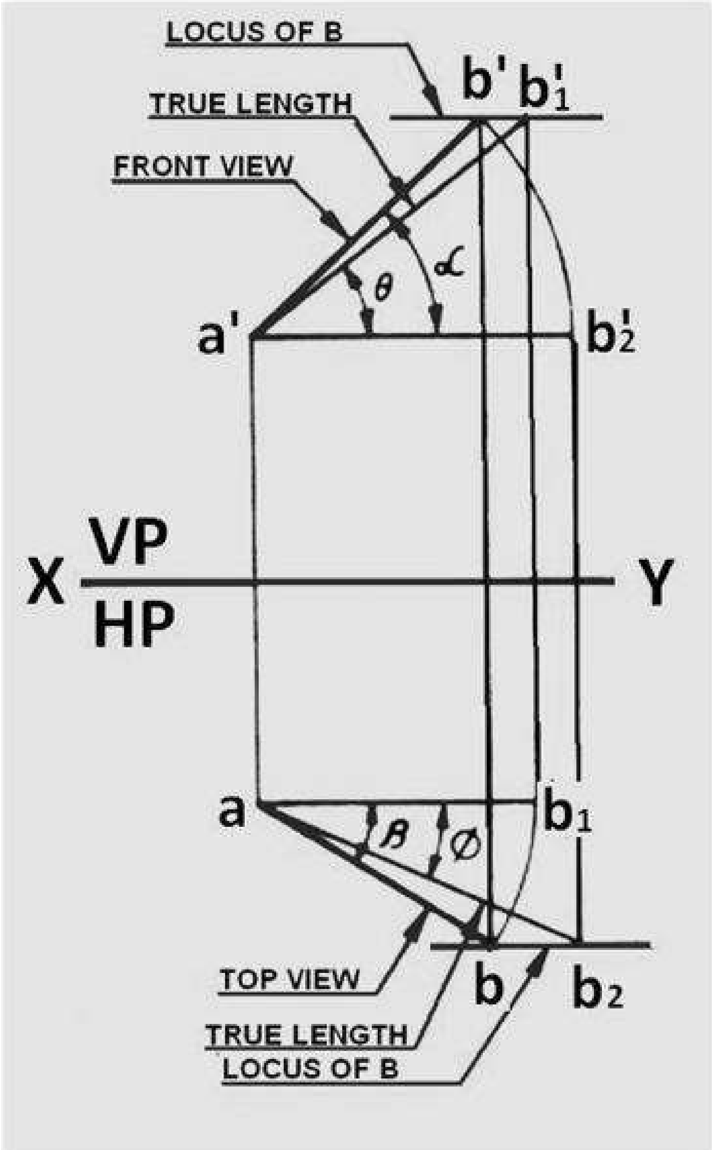


Figure 5. Illustrates the true length, apparent lengths, tue inclination and apparent inclination of the line AB inclined to HP and VP..

To Find True length and true inclinations of a line

Many times if the top and front views of a line are given, the true length and true inclinations of a line is required to be determined.

The top and front views of the object can be drawn from if any of the following data are available:

(a) Distance between the end projectors,

(b) Distance of one or both the end points from HP and VP and

(c) Apparent inclinations of the line.

The problems may be solved by

(i) Rotating line method or
(ii) Rotating trapezoidal plane method or
(iii) Auxiliary plane method.

Rotating line method

The method of obtaining the top and front views of a line, when its true length and true inclinations are given.
When a view of a line is parallel to the XY line, its other view will be in true length and at true inclination.
By following the procedure mentioned previously, in the reverse order, the true length and true inclinations of a line from the given set of top and front views can be found. The step by step procedure is shown below in figure 1.

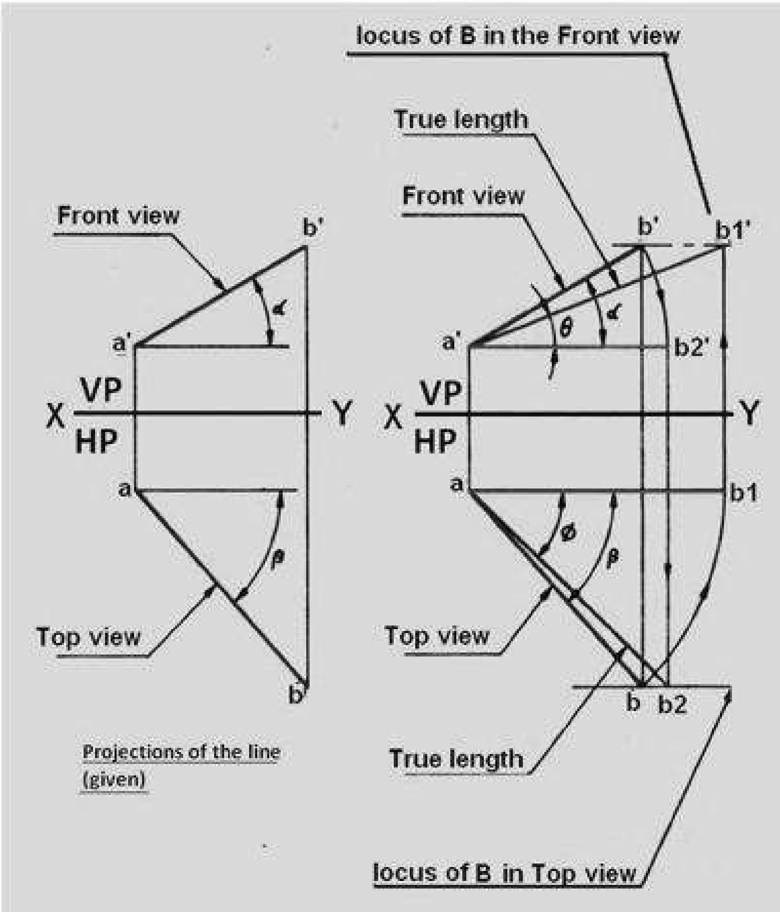


Figure 1. determinationof ture length and true inclinations of a line.

- Draw the top view ab and the front view a'b' as given
- Rotation of the top view: With center a and radius abrotate the top view to the new position ab1 to make it parallel to the XY line. Since ab1 is parallel to the XY line, its corresponding front view will be in true length and at true inclination.

- Rotation of the front view: With center a' and radius a'b' rotate the front view to the new position a'b2' parallel to the XYline. Since a'b2�to is parallel to the XY line, its corresponding top view will be in true length and at true inclination. In this position, the line will be parallel to HP and inclined at fto VP. Through b draw the locus of B in the top view. Project b2' to get b2, in the top view. Connect ab2 which will be in true length and true inclination f which the given line AB makes with VP.

Traces of a line

- The trace of a line is defined as a point at which the given line, if produced, meets or intersects a plane.
- When a line meets HP, (or if necessary on the extended portion-of HP), the point at which the line meets or intersects the horizontal plane, is called horizontal trace (HT)of the line and denoted by the letter H.
- When a line meets VP (or if necessary on the extended portion of VP), the point at which the line meets or intersects the vertical plane, is called vertical trace (VT) of the line and denoted by the letter V.
- When the line is parallel to both HP and VP, there will be no traces on the said planes. Therefore the traces of lines are determined in the following positions of the lines.

Trace of a line perpendicular to one plane and parallel to the other
Since the line is perpendicular to one plane and parallel to the other, the trace of the line is obtained only on the plane to which it is perpendicular, and no trace of the line is obtained on the other plane to which it is parallel. Figures 2 and 3 illustrates the trace of a line parallel tp0VP and perpendicular to HP and parallel to HP and perpendicular to VP respectively.

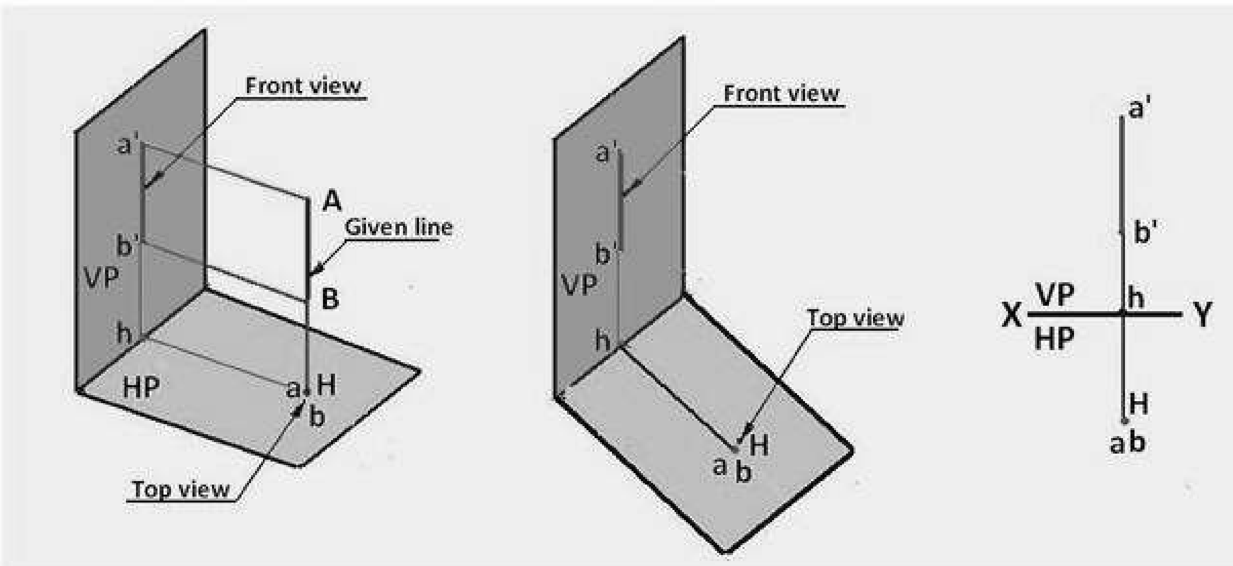


Figure 2. Trace of line parallel to VP and perpendicular to HP

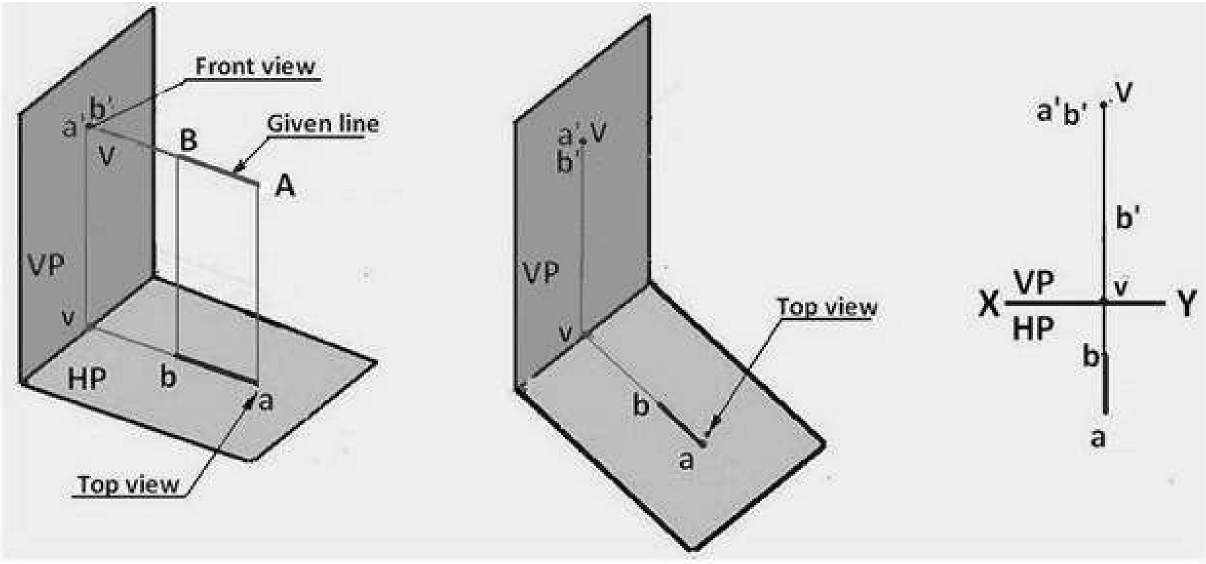


Figure 3. Trace of a line perpendicular to the VP and parallel to HP

Traces of a line inclined to one plane and parallel to the other
When the line is inclined to one plane and parallel to the other, the trace of the line is obtained only on the plane to which it is inclined, and no trace is obtained on the plane to which it is parallel. Figure 4 shows the horizontal trace of line AB which is in lined HP and parallel to VP

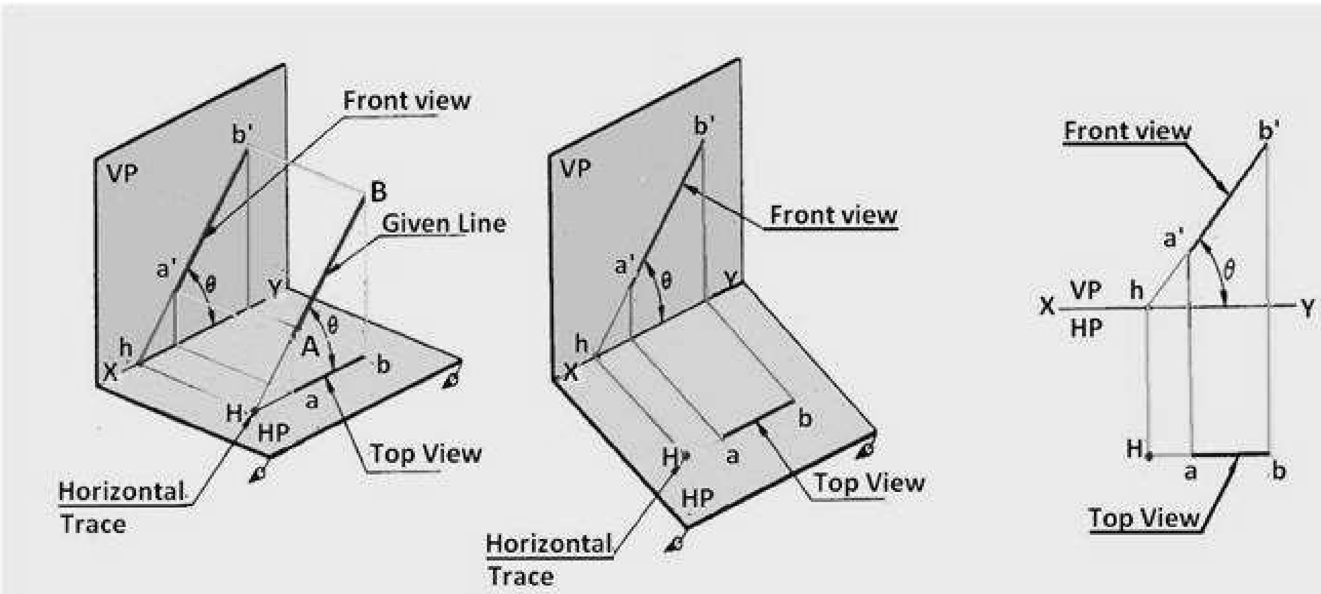


Figure 4 Horizontal trace of line AB

Figure 5 shows the vertical trace of line AB which is inclined to VP and parallel to HP

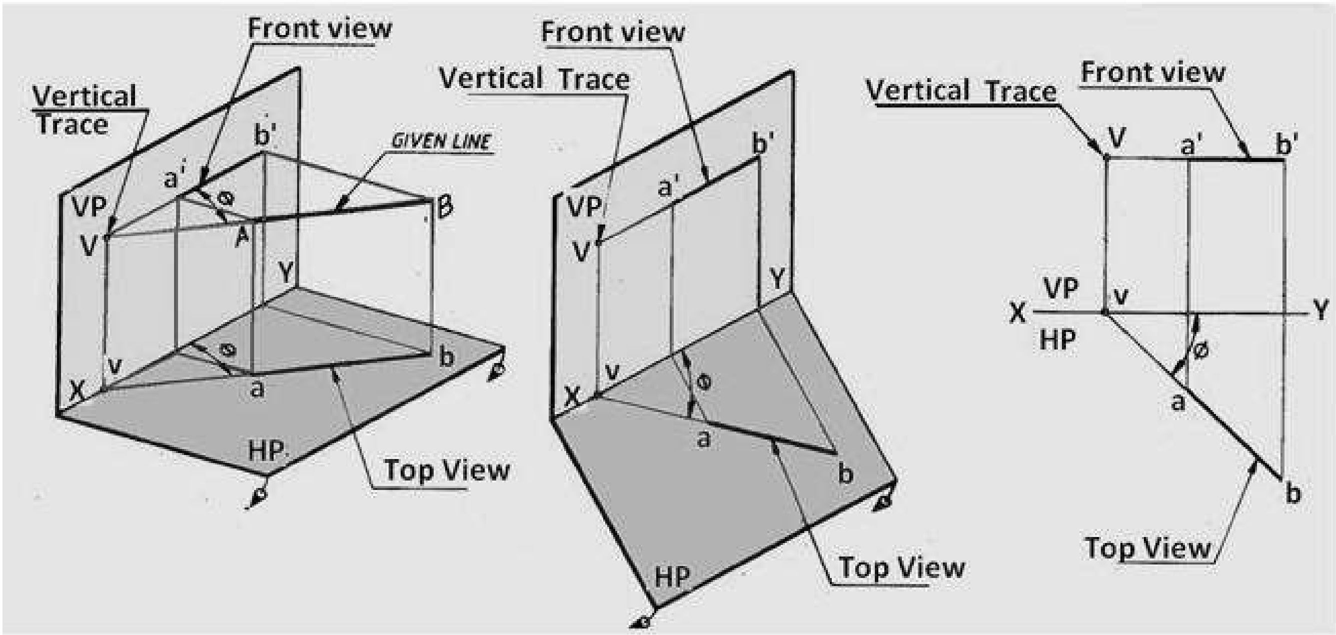


Figure 5 Vertical trace of line AB

Traces of a line inclined to both the planes

Figure 6 shows the Vertical trace (V) and Horizontal Trace (H) of Line AB inclined at q to HP and Φ to VP.

The line when extended intersects HP at H, the horizontal trace, but will never intersect the portion of VP above XY line, i.e. within the portion of the VP in the 1st quadrant. Therefore VP is extended below HP such that when the line AB is produced it will intersect in the extended portion of VP at V, the vertical trace.

In this case both horizontal trace (H) and Vertical Trace (V) of the line AB lie below XY line.

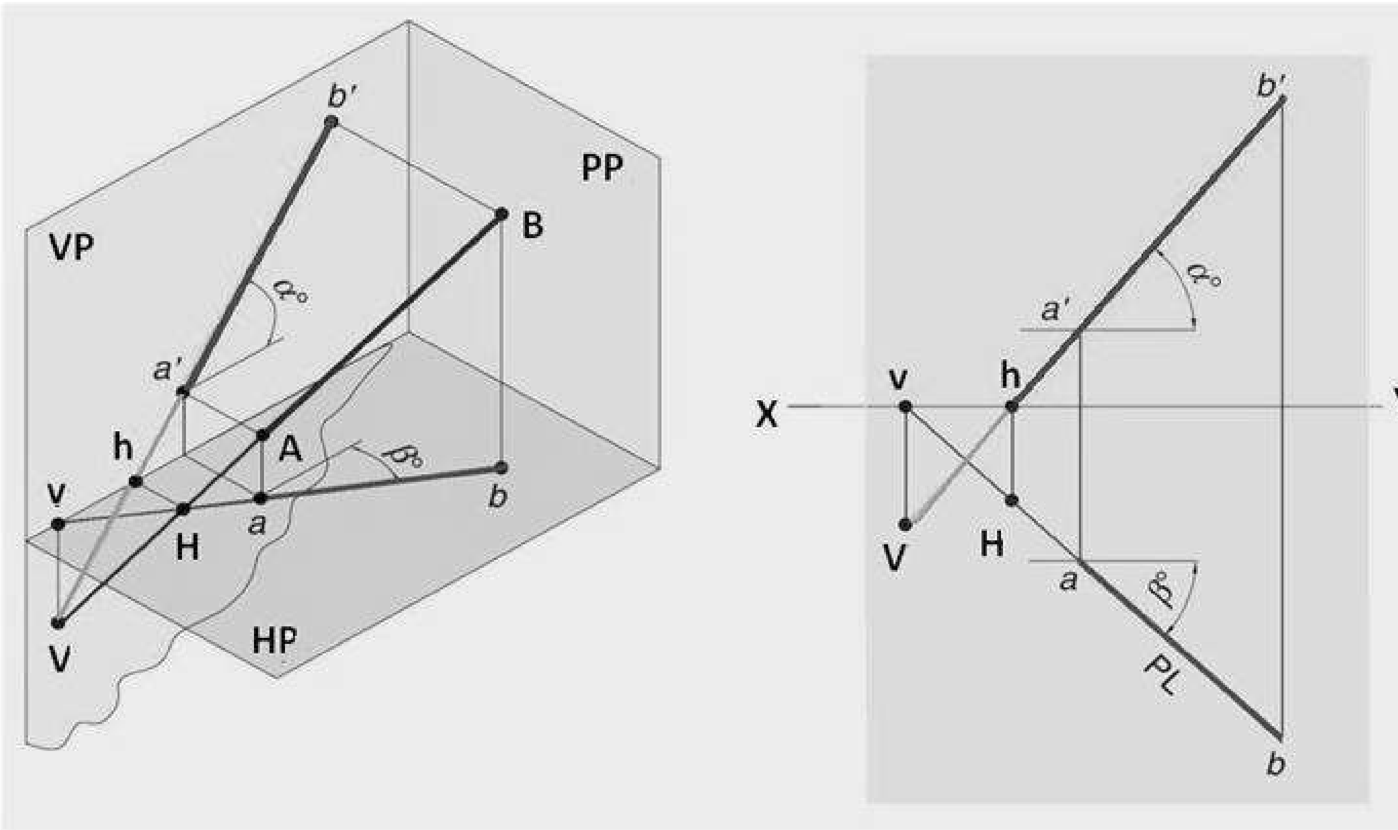


Figure 6 Vertical trace and horizontal trace of line AB which is inclined to both vertical plane and horizontal plane.

Projections of lines (Drawing practice)

Problem -1

A straight line AB of true length 100 mm has its end A 20 mm above HP and 30 mm in front of VP. The top view of the line is 80 mm and front view is 70 mm. Draw the projections (TV and FV) of the line AB and obtain the true inclinations of the line AB with HP and VP.

Solution: The solution to the problem is shown in figure 1. The step wise procedure for the solution is discussed below:

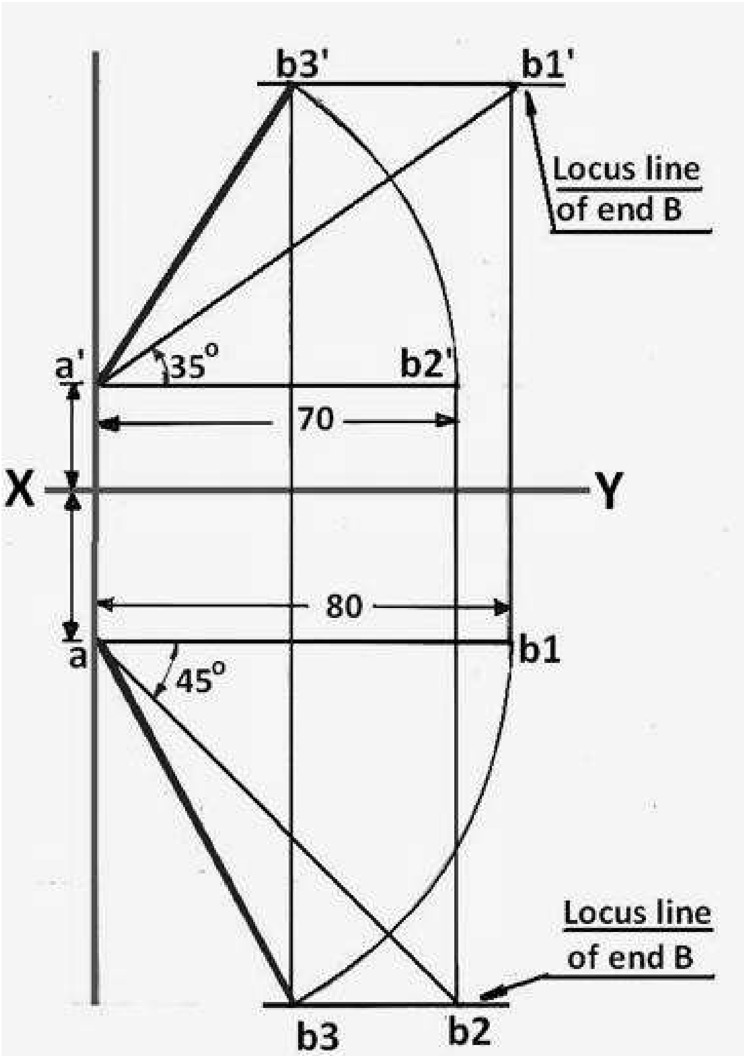


Figure 1. The projections of line AB in problem 1.

- Draw XY line and mark points **a'** (20 mm above XY line) and **a** (30mm below XY line) as given in the question.
- Let us assume that the line is parallel to HP and Inclined to VP.
- Draw a horizontal line from **a'** and mark distance equal to 70 mm on it. The end point is **b2'**. i.e., **a' b2'** = 70 mm.
- In this condition, the FV is parallel to XY line. TV can be obtained considering the following points:
  - TV of point B will be along the vertical projector drawn from B2'.
  - TV of line AB will be the true length = 100mm .
  - The true inclination of the line with VP can also be obtained.

- Draw a projector downwards from **b2'**. It is clear that if TL of AB is drawn from **a** with the required inclination with the VP, it will give the distance **a' b2'**. Therefore, with radius equal to TL= 100mm and with centre **a**, cut an arc on the downward projector from **b2'**. Let this be **ab2**. Inclination of **ab2** with horizontal will give true inclination of line AB with VP.
- Locus of point B is marked as a horizontal line at **b2**.

- Let us no assume that the line is parallel to VP and inclined to HP.
- In this condition, the TV is parallel to XY line. FV can be obtained considering the following points:
  - FV of point B will be along the vertical projector drawn from B2′.
  - FV of line AB will be the true length = 100mm .
  - The true inclination of the line with HP can also be obtained.

- Draw a horizontal line from **a** and mark distance equal to 80 mm on it. The end point is **b1**. **a b1** = 80 mm.
- Draw a projector upwards from **b1**. It is clear that if TL of AB is drawn from **a′** with the required inclination with the HP, it will give the distance **ab1**. Therefore, with radius equal to TL= 100mm and with centre **a′**, cut an arc on the upward projector from **b1**. Let this be **a′b1′**. Inclination of **a′b1′** with horizontal will give true inclination of line AB with HP.
- Locus of point B is marked as a horizontal line at **b1′**. (1)

Drawing the top view and front view of line AB

1. The plan of AB (**ab**) is obtained as follows: With a as centre and radius equal to **ab1**, cut an arc on the locus line drawn at **b2**.
2. The elevation of AB (**a′b′**) is obtained as follows: With **a′** as centre and radius equal to **a′b2′**, cut an arc on the locus line drawn at **b1′**.

The required inclinations are:
Angle of inclination with HP = 350
Angle of inclination with VP = 450

Problem -2

Straight line AB is 40 mm long. End A is 10mm above HP and 15 mm in front of VP. FV of the line is inclined at 45° and TV is inclined at 60° to XY line. Draw the projections of line AB (FV and TV) and obtain the true inclination of line AB with HP and VP.

Solution: The solution for problem 2 is shown in figure 2. The step wise procedure for the solution is discussed below:

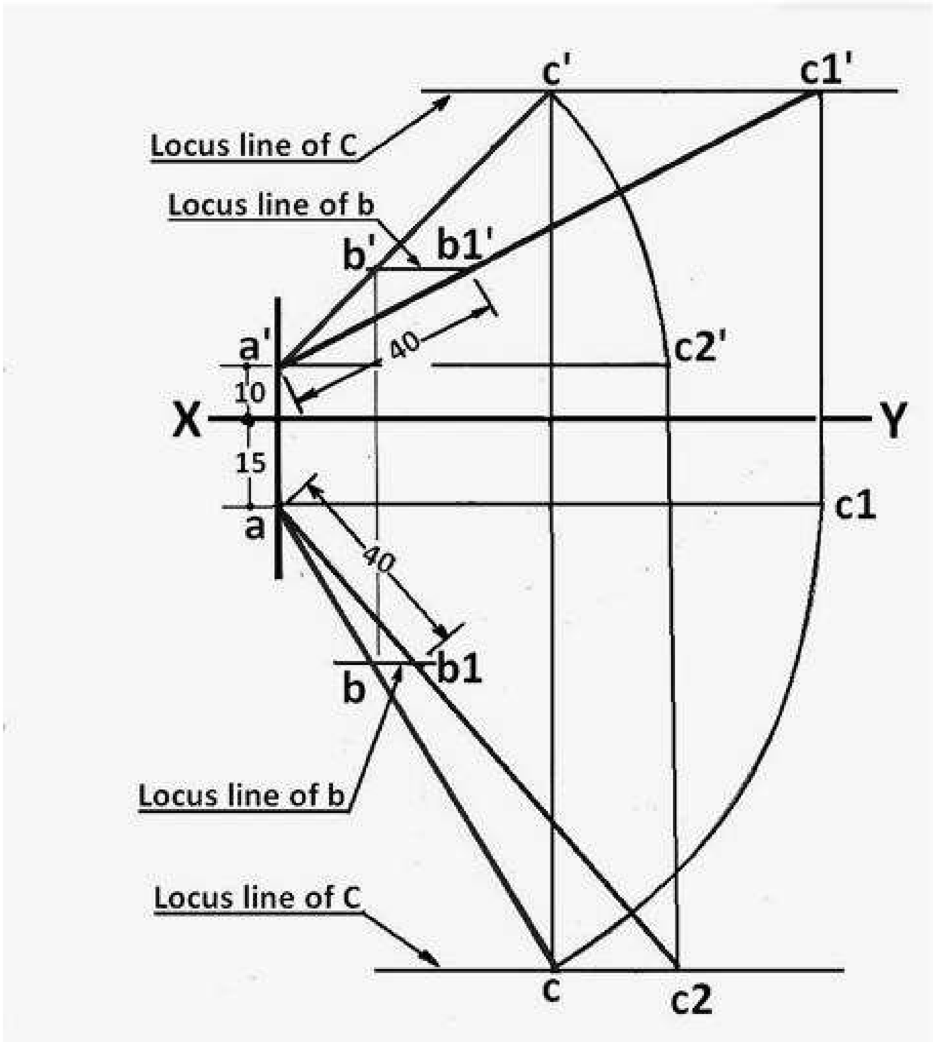


Figure 2. shows the solution of Problem 2.

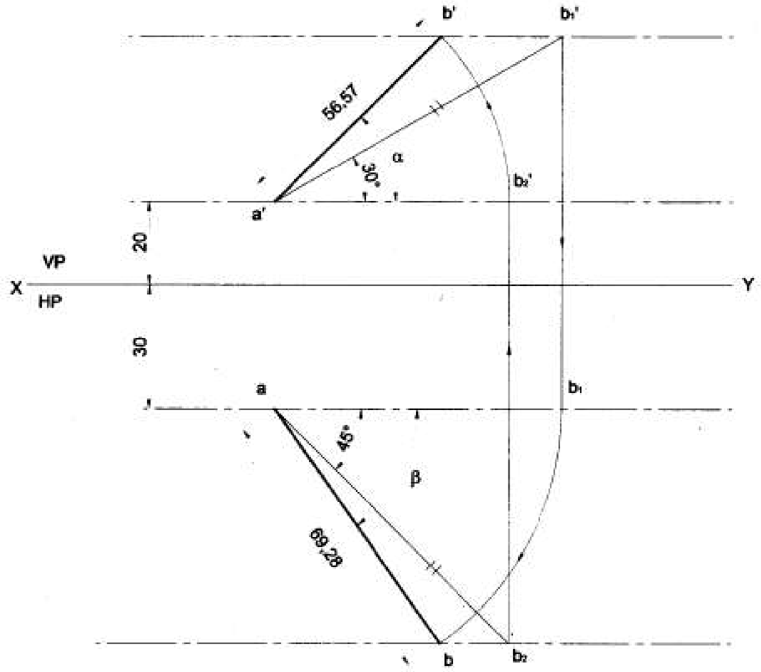
- Mark the points **a'** and **a** according to the given data (i.e., 10 mm above and 15 mm below XY line, respectively).
- Since we don't know the exact position of point B in the FV, let us arbitrarily assume a point **C** on the line **AB** extended. Then the projections of points A, B, and C should line on the same line in all orientations. i.e the point corresponding to point **b'** will lie on line **a'c'**.
  - Draw a line at 45° to horizontal from **a'** and mark any point **c'** on it.
  - Under this situation, **b'** would lie on **a'c'**.
- From **a** draw a line at 60° to horizontal from **a**.
- Drop a projector from **c'** downwards to obtain the point **c** on 60° line.
- Draw horizontal lines at **c** and **c'** to denote the locus of point C.
- With **a** as centre and radius equal to **ac**, draw an arc to meet the horizontal through **a** at **c1**.
- Draw a projector upwards from **c1** to meet the horizontal locus line at **c'**. Let this meeting point be **c1'. a'c1'** would then represent the TL and true inclination of AC with HP.
- On **a'c1'** mark **b1'** such that **a'b1'** is equal to TL of AB = 40mm.

- Draw horizontal locus line through **b1'** to meet **a'c'** at **b'**.
- **a'b'** is the required FV of AB. Drop projector downwards from **b'** and obtain TV **ab**.
- Similarly, with **a'** as centre and radius equal to **a'c'**, draw an arc to meet the horizontal through **a'** at **c2'**.
- Draw the projector downwards to meet the locus line at **c** at **c2**. **ac2** would then represent the TL and true inclination of AC with VP.
- On **ac2**, mar b1 such that TL of AB (i.e. **ab1**) = 40 mm.
- Draw the locus line passing through **b1** to line **ac** at **b**.
- **ab** is the required TV of line AB.
- The vertical projector through **b'** should pass through **b**.

The required inclinations of line AB are:
Angle of inclination with HP ≈ 270
Angle of inclination with VP ≈ 500

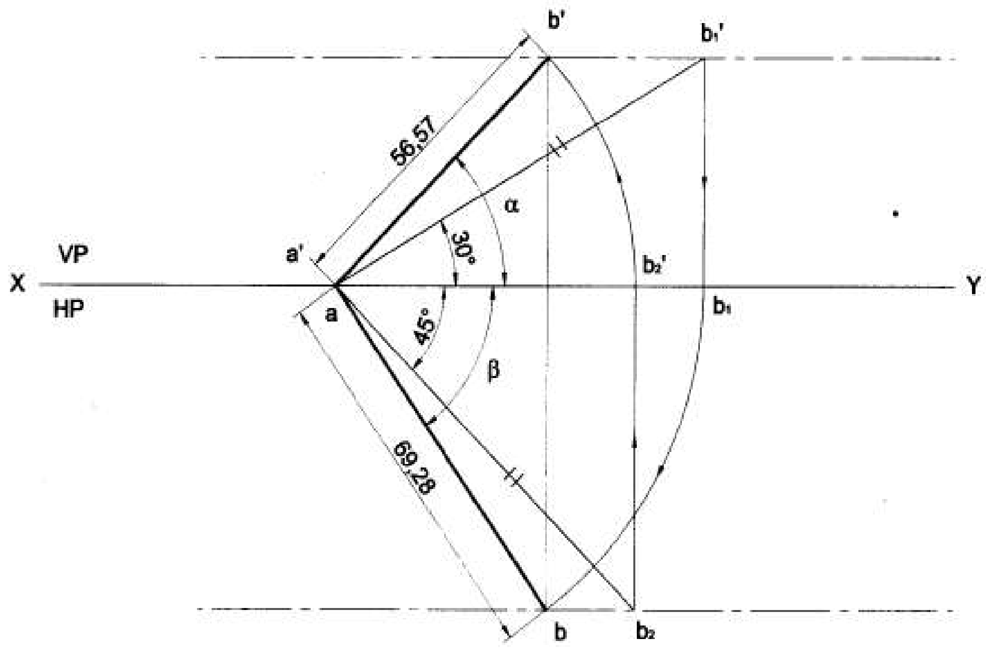
Worked Examples- Projection of Lines

Problem 1 A line AB 80 mm long has its end A 20 mm above the HP and 30 mm infront of VP. It is inclined at 30° to HP and 45° to VP. Draw the projections of the line and find apparent lengths and apparent inclinations.
Solution



ANSWERS :
$\beta = 55^0$
a'b' = 57
ab = 69

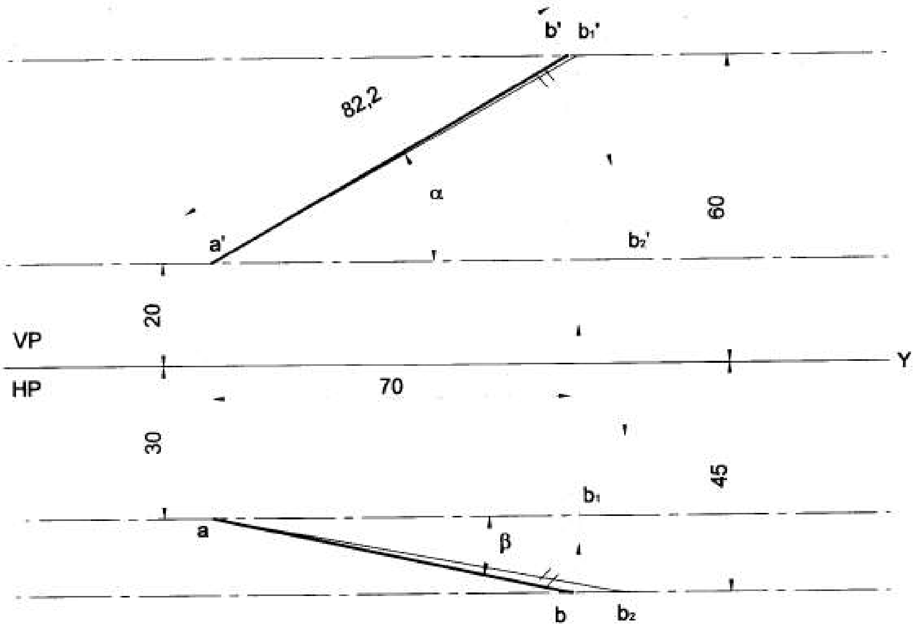
Problem 2 A line AB 80 mm long is inclined to HP at 30° and inclined to VP at 45°. Draw front and top views of line and determine their lengths. Also measure the perpendicular distance of end B from both HP and VP.
Solution



ANSWERS :
$\alpha = 45^0$
$\beta = 55^0$
a'b' = 57
ab = 69

Problem 3 A line AB has its end A 20 mm above the HP and 30 mm infront of the VP. The other end B is 60 mm above the HP. The distance between end projectors is 70 mm. draw its projections. Determine the true length and apparent inclinations.

Solution



ANSWERS :

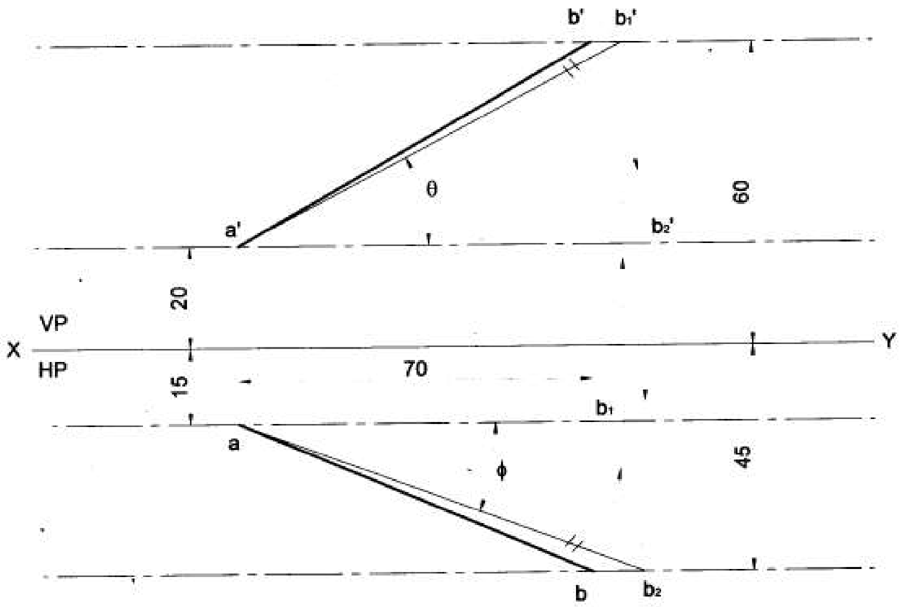
$\alpha = 30^0$

$\beta = 12^0$

a'b ' = 82

Problem 4 A line AB has its end A 20 mm above the HP and 15 mm infront of the VP. The other end B is 60 mm above the HP. The distance between end projectors is 70 mm. draw its projections. Determine the apparent lengths and true inclinations.

Solution



ANSWERS :

$\theta = 28^0$

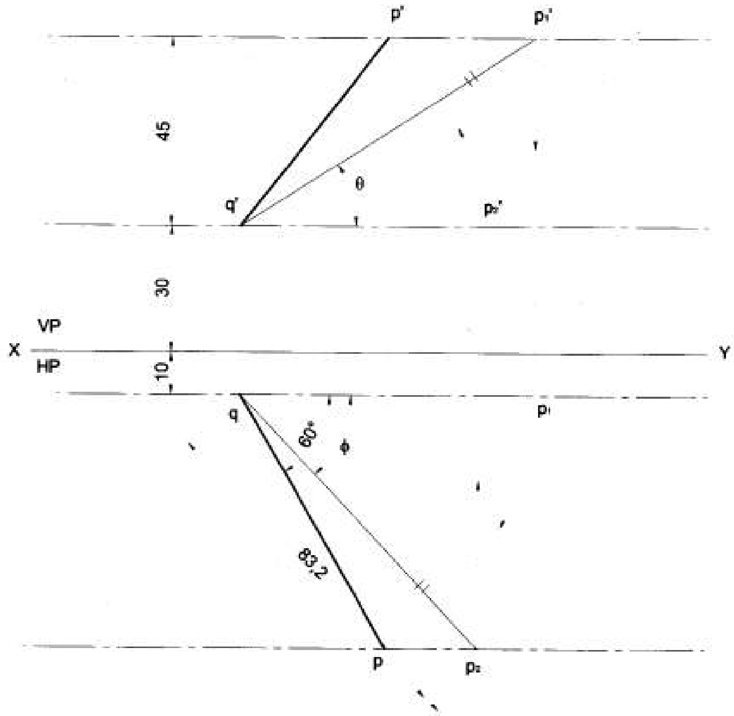
$\phi = 20^0$

a'b' = 81

ab = 76

Problem 5 The top view PQ of a straight line is 70 mm and makes an angle of 60° with XY line. The end Q is 10 mm infront of VP and 30 mm above the HP. The difference between the distances of P and Q above the HP is 45 mm. draw the projections. Determine its true length and true inclinations with HP and VP.

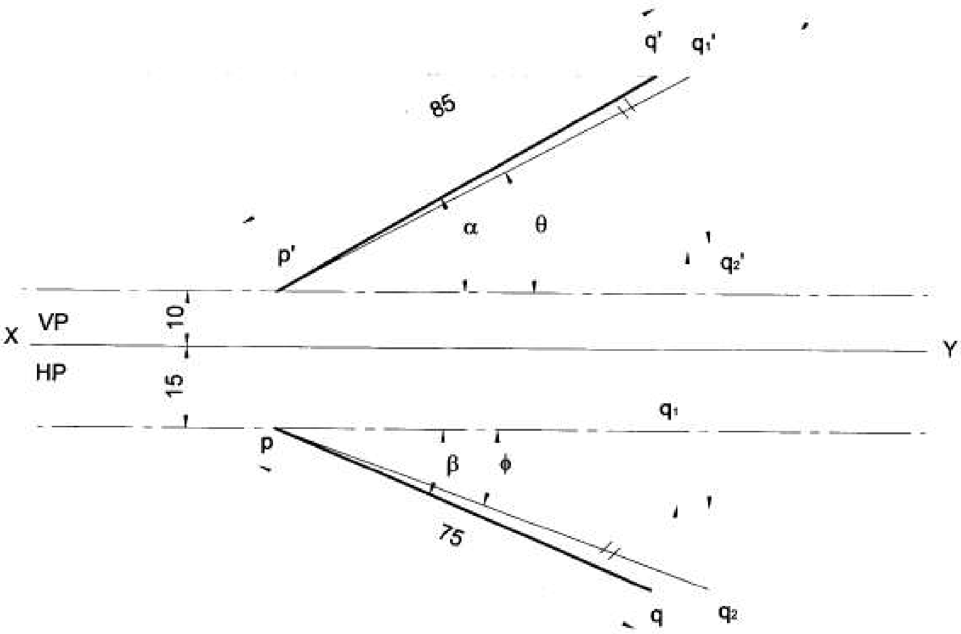
Solution



ANSWERS :
$\theta = 33^0$
$\phi = 47^0$
$qp_2 = 83$

Problem 6 A line PQ 85 mm long has its end P 10 mm above the HP and 15 mm infront of the VP. The top view and front view of line PQ are 75 mm and 80 mm respectively. Draw its projections. Also determine the true and apparent inclinations of the line.

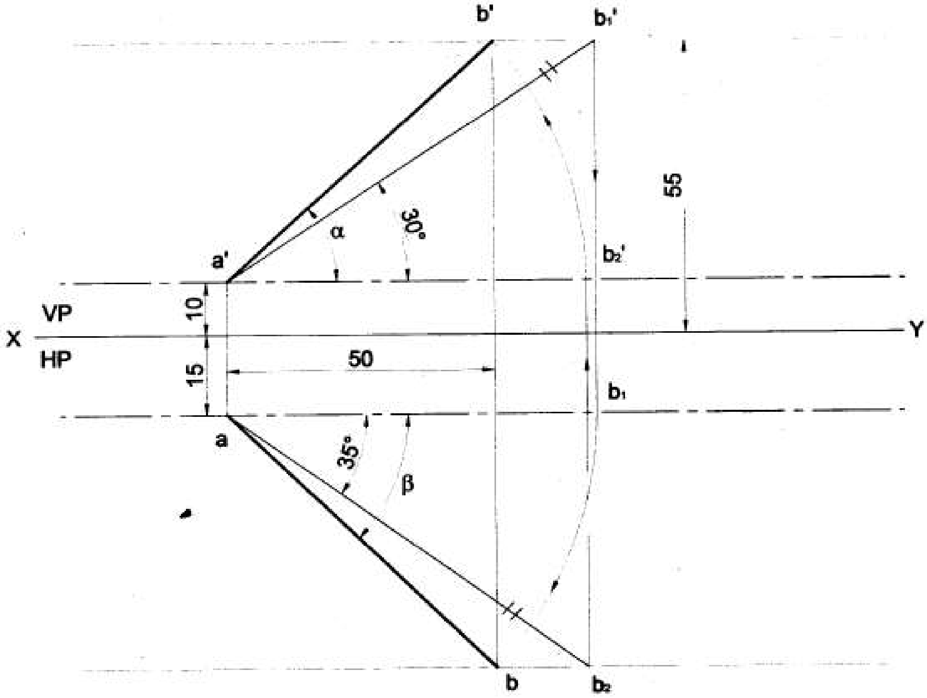
Solution



ANSWERS :
$\theta = 28^0$
$\phi = 20^0$
$\alpha = 30^0$
$\beta = 23^0$

Problem 7 A line has its end A 10 mm above HP and 15 mm infront of VP. The end B is 55 mm above HP and line is inclined at 30° to HP and 35° to VP. The distance between the end projectors is 50 mm. draw the projections of the line. Determine the true length of the line and its inclination with VP.

Solution



ANSWERS :

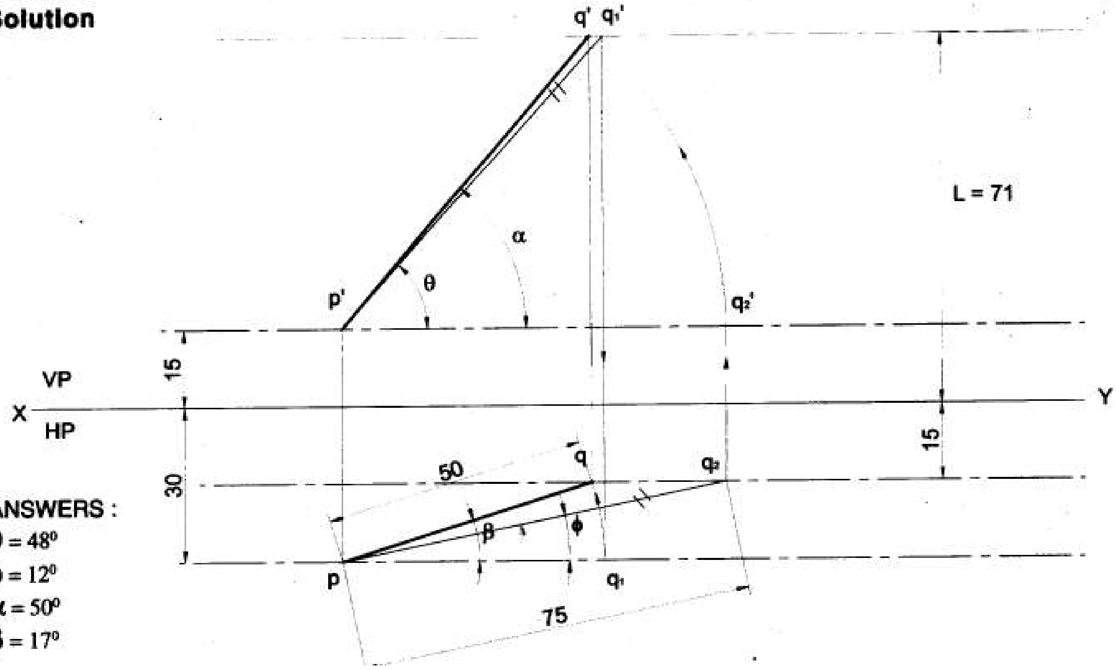
$\alpha = 42^0$

$\beta = 44^0$

TL = 80

Problem 8 The top view of a line 75 mm long measures 50 mm. the end P is 30 mm infront of VP and 15 mm above HP. The end Q is 15 mm infront of VP and above HP. Draw the projections of the line and find its true inclinations with HP and VP.

Solution



ANSWERS :

$\theta = 48^0$

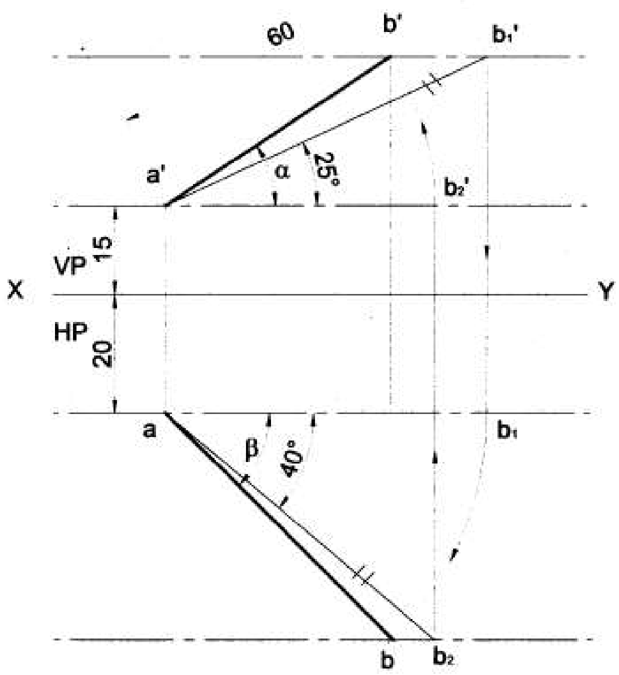
$\phi = 12^0$

$\alpha = 50^0$

$\beta = 17^0$

Problem 9 A line AB 60 mm long has one of its extremities 20 mm infornt of VP and 15 mm above HP. The lin inclined at 25° to HP and 40° to VP. Draw its top and front views.

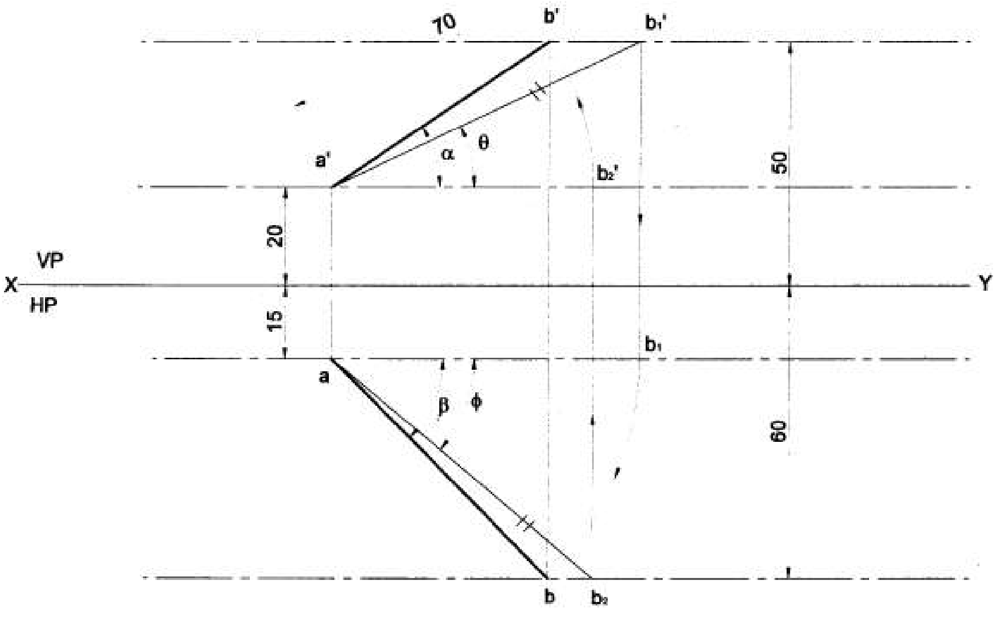
Solution



ANSWERS
$\alpha = 34^0$
$\beta = 45^0$
$a'b' = 46$
$ab = 56$

Problem 10 A line AB measuring 70 mm has its end A 15 infront of VP and 20 mm above HP and the other end B is 60 infront of VP and 50 mm above HP. Draw the projections of the line and find the inclinations of the line with both the reference planes of projection.

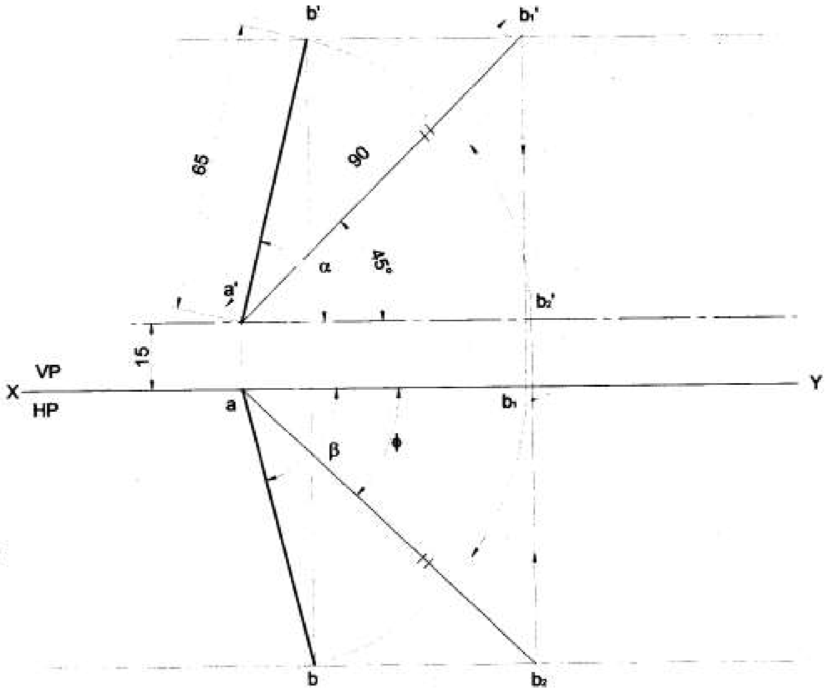
Solution



ANSWERS :
$\theta = 25^0$
$\phi = 40^0$
$\alpha = 34^0$
$\beta = 45^0$

Problem 11 The front view of a 90 mm long line which is inclined at 45° to the XY line, measures 65 mm. End A is 15 mm above the XY line and is in VP. Draw the projections of the line and find is inclinations with HP and VP.

Solution



ANSWERS :

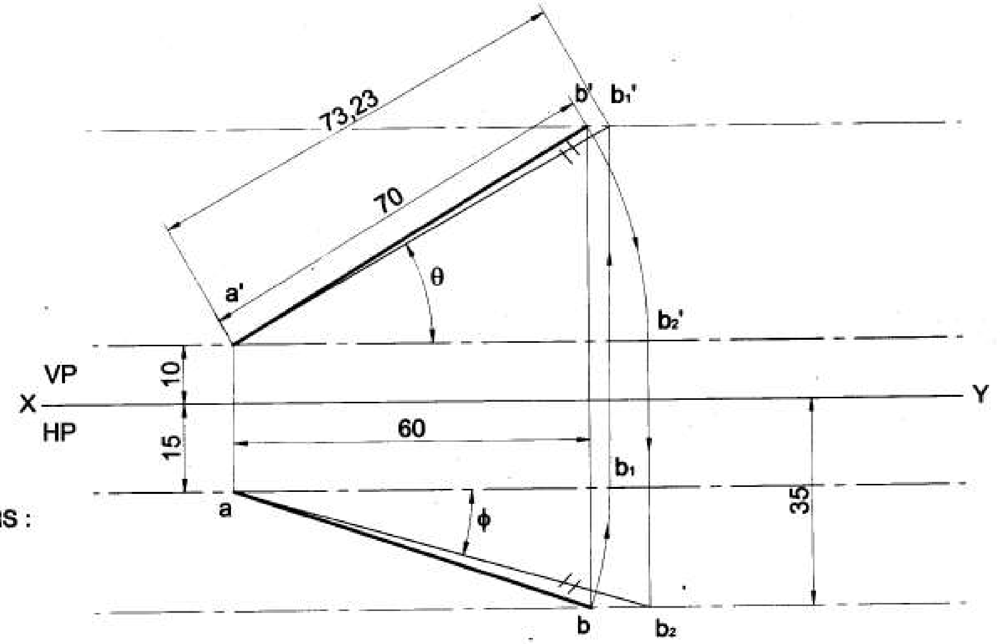
$\phi = 43^0$

$\alpha = 76^0$

$\beta = 76^0$

Problem 12 The distance between the end projectors through the end points of a line AB is 60 mm. The end A is 10 mm above HP and 15 mm infront of VP. The end B is 35 mm infront of VP. The line AB appears 70 mm long in the front view. Complete the projections. Find the true length of the line and its inclinations with HP and VP.

Solution



ANSWERS :

$\theta = 29^0$

$\phi = 16^0$

- TL = 73

Projections of Planes

Plane surface (plane/lamina/plate)

A plane is as two dimensional surface having length and breadth with negligible thickness. They are formed when any three non-collinear points are joined. Planes are bounded by straight/curved lines and may be either regular or an irregular. Regular plane surface are in which all the sides are equal. Irregular plane surface are in which the lengths of the sides are unequal.

Positioning of a Plane surface

A plane surface may be positioned in space with reference to the three principal planes of projection in any of the following positions:

- Parallel to one of the principal planes and perpendicular to the other two.
- Perpendicular to one of the principal planes and inclined to the other two.
- Inclined to all the three principal planes.

Projections of a Plane surface

A plane surface when held parallel to a plane of projection, it will be perpendicular to the other two planes of projection. The view of the plane surface projected on the plane of projection to which it will be perpendicular will be a line, called the line view of a plane surface. When the plane surface is held with its surface parallel to one of the planes of projection, the view of the plane surface projected on it will be in true shape because all the sides or the edges of the plane surface will be parallel to the plane of projection on which the plane surface is projected.
When a plane surface is inclined to any plane of projection, the view of the plane surface projected on it will be its apparent shape.
A few examples of projections of plane surfaces are illustrated below:

A: Plane surface parallel to one plane and perpendicular to the other two

Consider A triangular lamina placed in the first quadrant with its surface parallel to VP and perpendicular to both HP and left PP. The lamina and its projections on the three projection planes are shown in figure 1.
a'b'c' is the front view, *abc the* top view and *a"b"c"* the side view
Since the plane is *parallel to VP* , the front view *a'b'c'* shows the true shape of the lamina. Since the lamina is perpendicular to both HP and PP, the top view and side views are seen as lines.

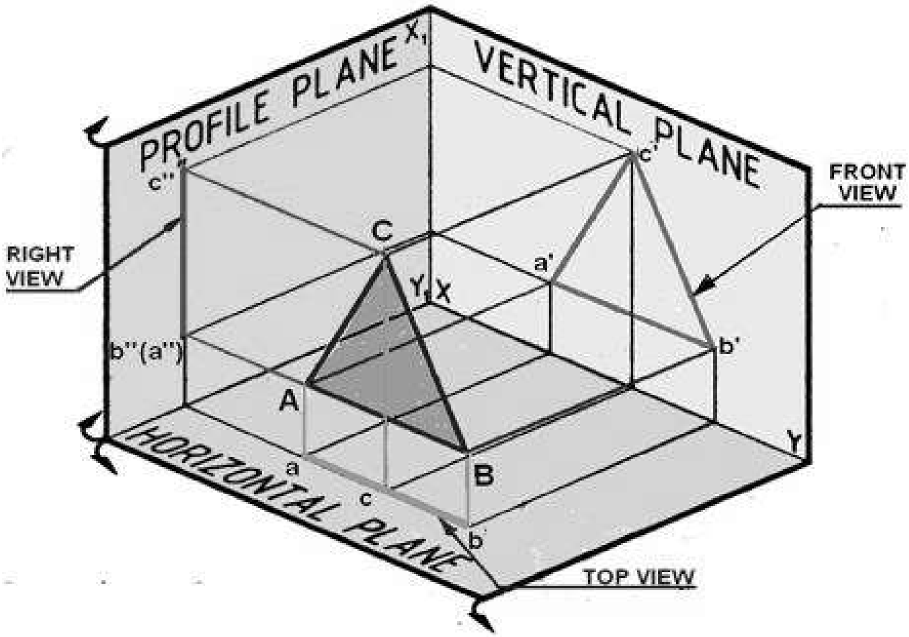


Figure 1. Projections of a triangular lamina on the projection planes

After projecting the triangular lamina on VP, HP and PP, both HP and PP are rotated about XY and X_1Y_1 lines, as shown in figure 2, till they lie in-plane with that of VP

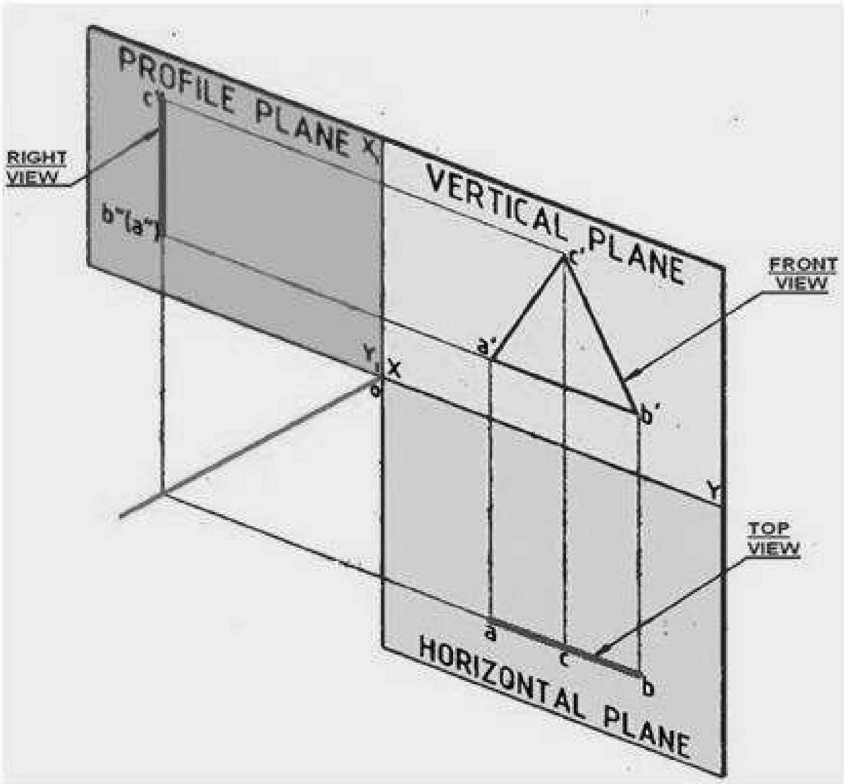


Figure 2. Rotation of PP and HP after projection.

The orthographic projections of the plane, shown in figure 3 can be obtained be the following steps.

Draw XY and X_1Y_1 lines and mark *HP, VP* and left *PP*. Draw the triangle *a'b'c'* in true shape to represent the front view at any convenient distance above the XY line. In the top view the triangular lamina appears as a lineparallel to the XY line. Obtain the top view *acb* as a line by projecting from the front view at any convenient distance below the XY line.

Since the triangular lamina is also perpendicular to left PP, the right view will be a *line* parallel to the X_1Y_1 line. To project the right view, draw a 45° line at the point of intersection of the XY and X_1Y_1lines.
Draw the horizontal projector through the corner *a* in the top view to cut the 45° line at m. Through m draw a vertical projector. From the corners c' *and* a' in the front view draw the horizontal projectors to cut the vertical projector drawn through m at c" and b". In the right view the corner A coincides with B and hence is invisible.

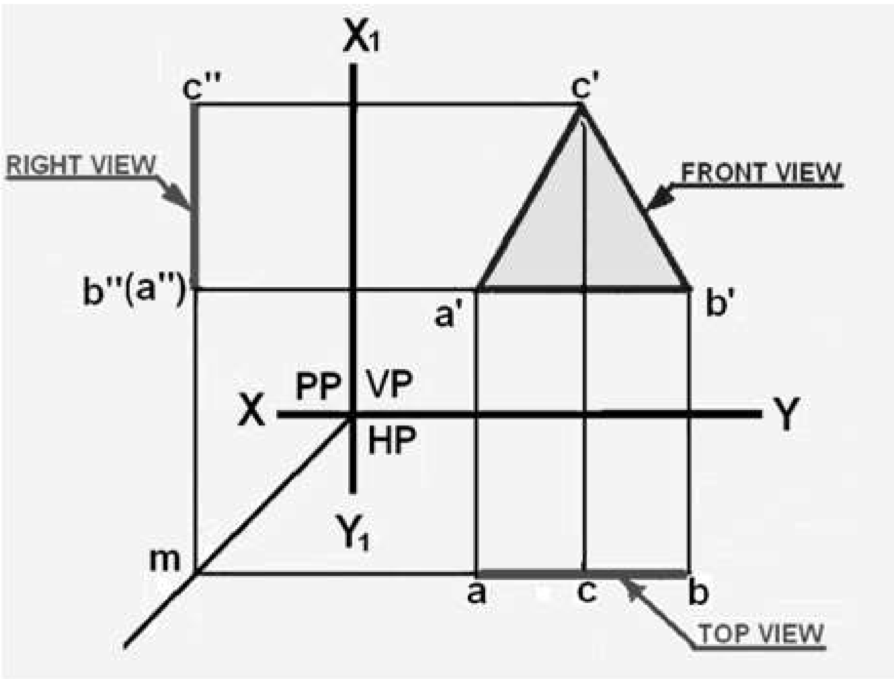


Figure 3. Orthographic projections of the lamina ABC

B) Plane parallel to HP and perpendicular to both VP and PP
A square lamina (plane surface) is placed in the first quadrant with its surface parallel to HP and perpendicular to both VP and left PP. Figure 4 (a) shows the views of the object when projected on to the three planes. Top view is shown as *abcd*, the front view as *a'(d')b'(c')* and the side view as *b"(a")c"(d")*. Since the plane is parallel to the HP, its top view *abcd* will be in its true shape. Since the plane is perpendicular to VP and PP, its front and side views will be lines *a'(d')b'(c')* and *b"(a")c"(d")* respectively.

After projecting the square lamina on VP, HP and PP, both HP and PP are rotated about XY and X_1Y_1lines , as shown in figure 4(b) , till they lie in-plane with that of VP.

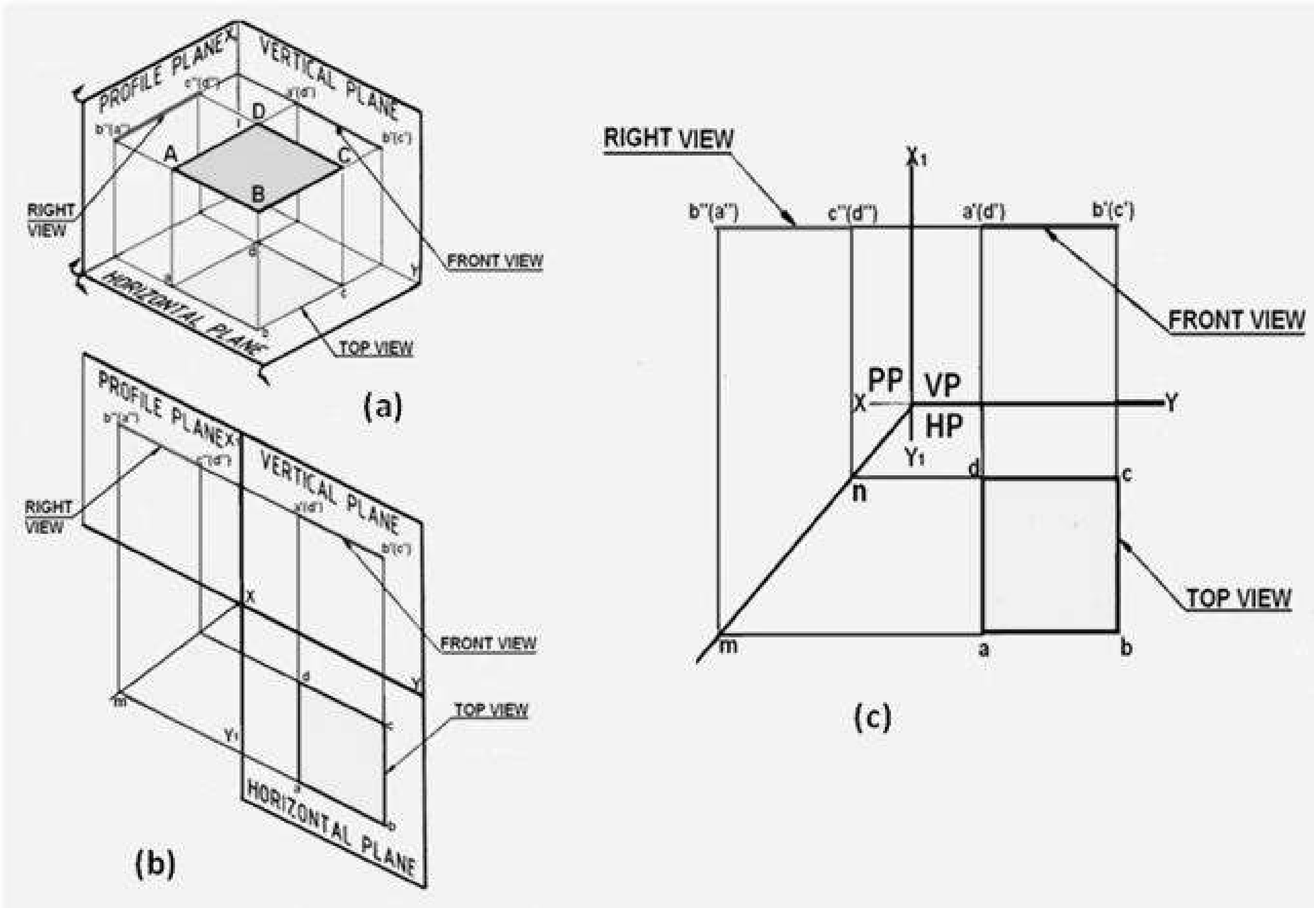


Figure 4. Projections of the lamina with its surface parallel to HO and perpendicular to both VP and PP.

The orthographic projections of the plane, shown in figure 4(c) can be obtained be the following steps.
Draw XY and X1Y1 lines and mark HP, VP and left PP.
Draw the square *abcd* in true shape to represent the top view at any convenient distance below the XY line.
In the front view, the square lamina appears as a line parallel to the XY line. Obtain the front view as a line *a'(d')b'(c')* by projecting from the top view, parallel to the XY line at any convenient distance above it. In the front view, the rear corners D and C coincide with the front corners A and B, hence *d'* and *c'* are indicated within brackets.
Since the square lamina is also perpendicular to left PP, the right view projected on it will also be a line perpendicular to X_1Y_1 line. Project the right view as explained in the previous case. In right view, the corners A and D coincide with the corners B and C respectively, hence (a') and (d'), are indicated within brackets.

C) Plane parallel to PP and perpendicular to both HP and VP
A pentagon lamina (plane surface) is placed in the first quadrant with its surface is parallel to left

PP and perpendicular to both VP and HP.
Figure 5 (a) shows the views of the object when projected on to the three planes. Side view is shown as *a″b″c″d″e″*, the front view as b′(c′)a′(d′)e′ and the top view as *a(b)e(c)d* .Since the plane is parallel to the PP, its side view *a″b″c″d″e″* will be in its true shape. Since the plane is perpendicular to VP and HP, its front and side views will be projected as lines.
After projecting the pentagon lamina on VP, HP and PP, both HP and PP are rotated about XY and X_1Y_1 lines , as shown in figure 5(b), till they lie in-plane with that of VP.

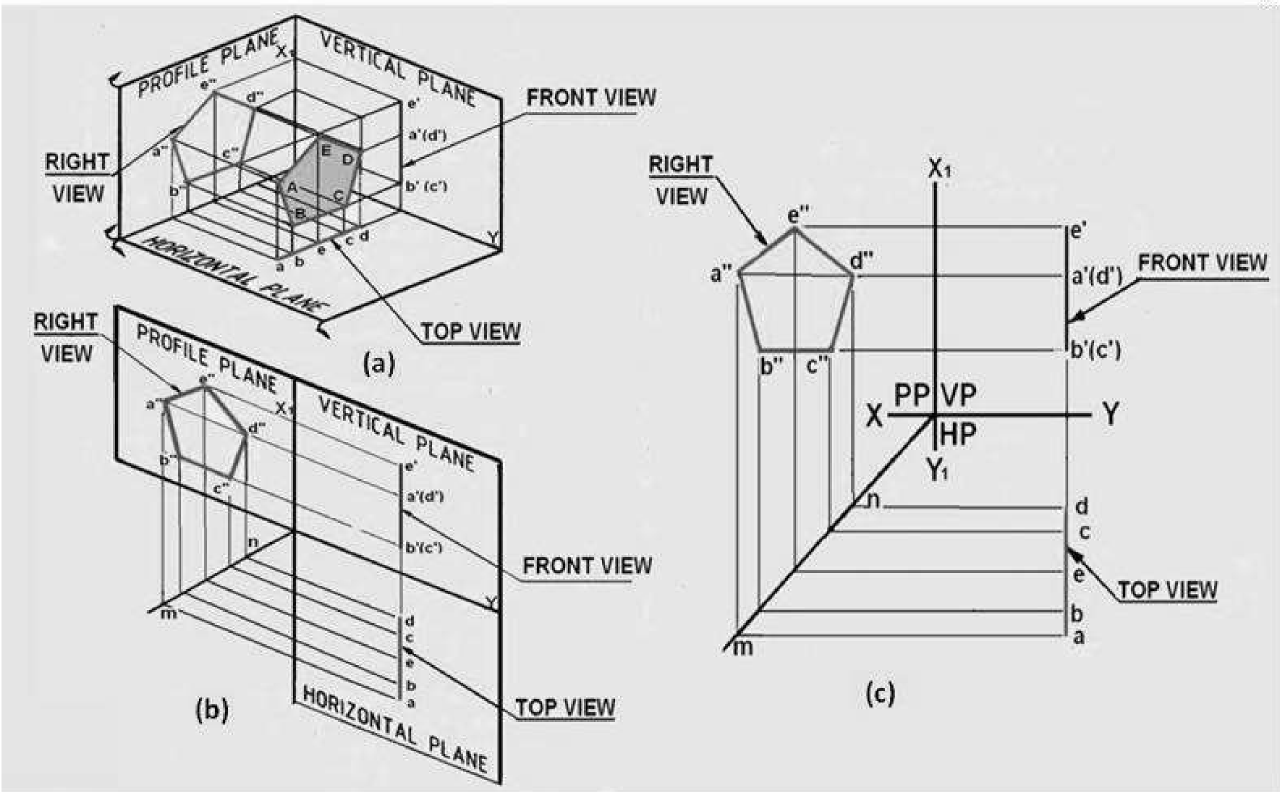


Figure 5 Projections of a pentagonal lamina with its surface parallel to PP and perpendicular to HP and VP.

The orthographic projections of the plane, shown in figure 5(c) can be obtained be the following steps. Draw XY and X1Y1 lines, and mark *HP, VP* and left *PP* .Draw the pentagon *a″b″c″d″e″* in true shape to represent the side view at any convenient distance above the XY line and left of X_1Y_1 line.
The top and front views of the lamina appear as lines perpendicular to XY line.
Obtain the front view *b′(c′)a′(d′)e′* as a line by projecting from the right view at any convenient distance from the X1Y1 line. In the front view, the rear corners D and C coincide with A and B respectively, hence d′ and c′ are indicated within brackets. The orthographic projections of the plane, shown in figure 4(c) can be obtained be the following step. Since the pentagon lamina is also perpendicular to HP, the top view also appears as a line. Project the top view from the right and front views.

D) Plane surface perpendicular to one plane and inclined to the other two

1. Plane inclined at Φ to VP and perpendicular to HP

Draw the projections of a triangular lamina (plane surface) placed in the first quadrant with its surface is inclined at f to VP and perpendicular to the HP.

Since the lamina is inclined to VP, it is also inclined to left PP at (90 - Φ).
The triangular lamina ABC is projected onto VP, HP and left PP.
a'b'c' – is the front view projected on on VP.
a"b"c" – is the right view projected on left PP.
Since lamina is inclined to VP and PP, front and side views are not in true shape.
Since lamina is perpendicular to HP, its top view is projected as a line *acb*
Figure 6 (c) shows the multiview drawing of the lamina.

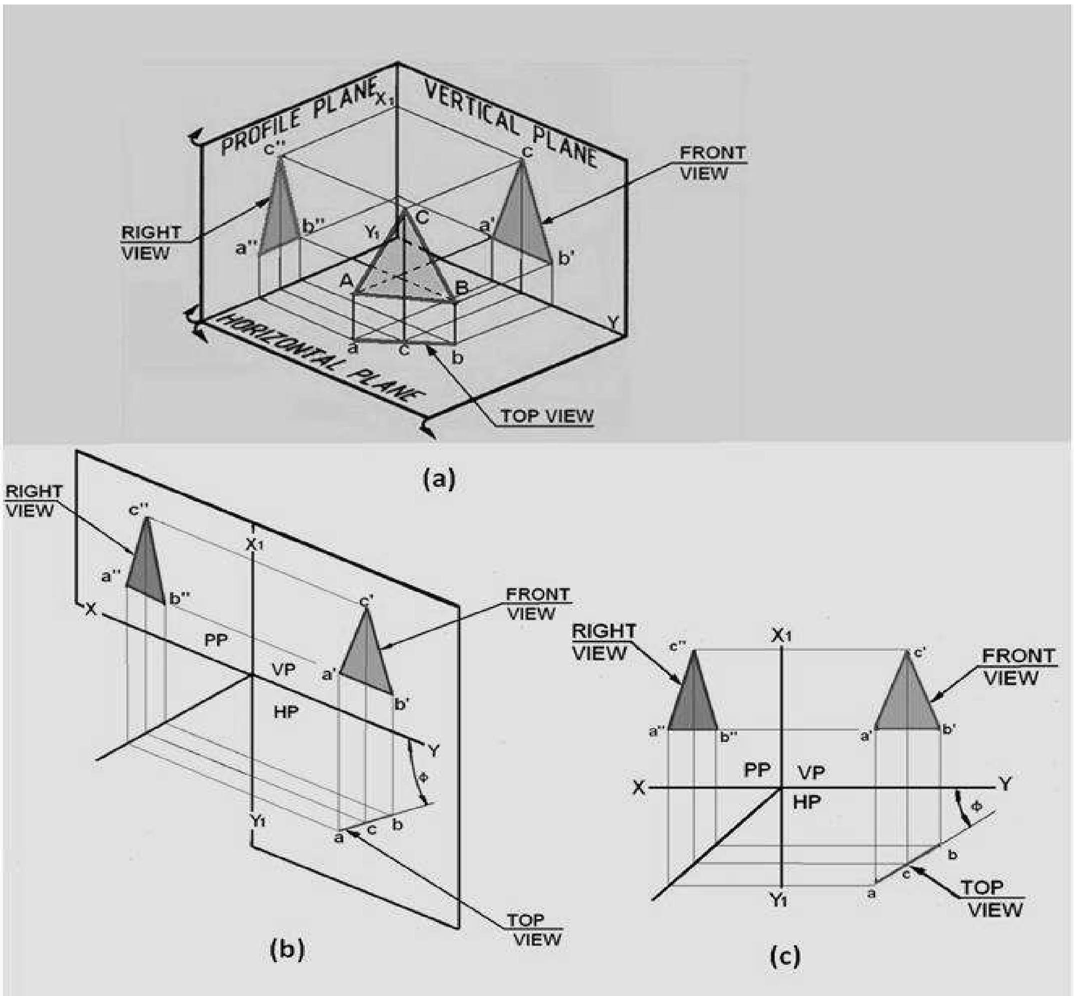


Figure 6. The projections of the triangular lamina

Problem 1:A regular pentagon lamina of 30 mm side rests on HP with its plane surface vertical and inclined at 30^0 to VP. Draw its top and front views when one of its sides is perpendicular to HP.

Solution: The projections The pentagonal lamina has its surface vertical (i.e., perpendicular to HP) and inclined at 30^0 t oVP.Since the lamina is inclined to VP, initially it is assumed to be parallel to VP. In this position one of the sides of the pentagon should be perpendicular to HP. Therefore, draw a regular pentagon a'b'c'd'e' in the VP to represent the front view with its side a'e' perpendicular to HP. Since the lamina is perpendicular to HP, the top view will be a line, a(e)b(d)c. Assume that edge a′ e′ perpendicular to HP in the final position. The top view of the lamina is now rotated about a(e) such that the line is inclined at 30° to XY line, as shown by points a_1,b_1, c_1, d_1, and e_1 in the right bottom of Figure 1. Draw vertical projectors from points a_1,b_1, c_1, d_1, and e_1. Draw horizontal projectors from points a′, b′, c′, d′, and e′. The intersection gives the respective positions of the points In the Front view. Join a_1',b_1', c_1', d_1', and e_1' to obtain the Front view of the lamina.

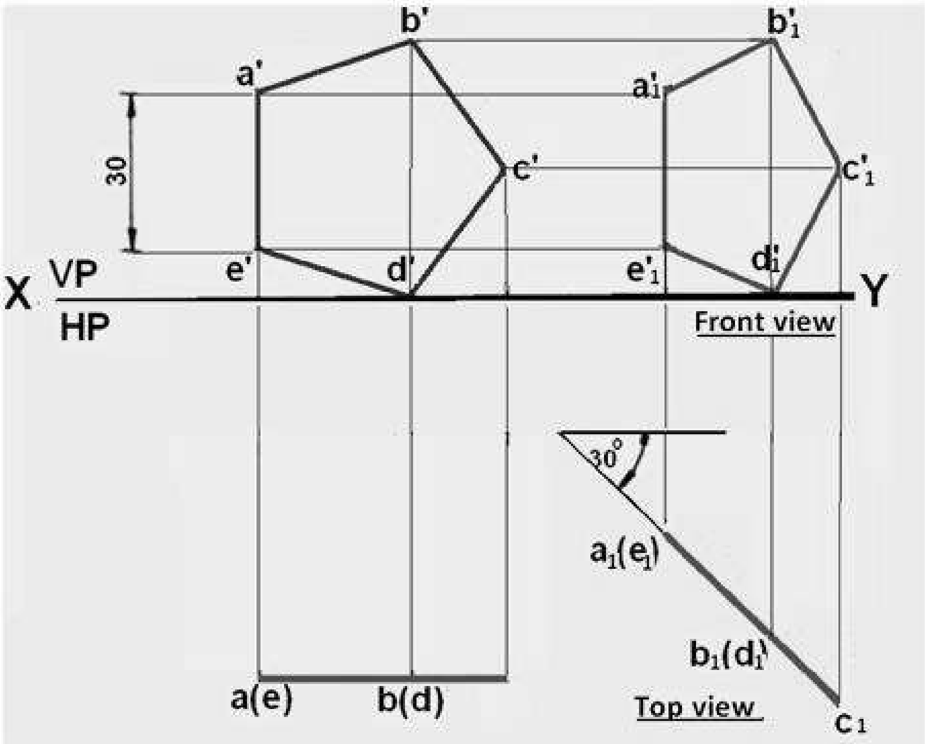


Figure 1. Orthographic projections of the pentagonal lamina.

Problem 2. Draw the front view, top view and side view of a square lamina. The surface of the lamina is inclined at θ to HP and perpendicular to VP.

Solution. The thre views of the square lamina is shown in figure 2. Since the lamina is perpendicular to VP, its front view will be a line [a′(b′) c′ (d′)] having length as the true length of the edge of the square and inclined at θ to XY line. The corners B and C coincide with A and D in the front view. Since the lamina is inclined to HP at θ, it is also inclined to the left PP at (90- θ). The square lamina is projected on to VP, HP and left PP. Draw vertical projectors from points a′, b′, c′ and d′. On any position on these lines construct the rectangle a-b-c-d such that length ab and cd are equal to the true length of the square edge. The rectangle a-b-c-d is the top view of the lamina. The side view of the lamina a″,b″,c″ and d″ can be obtained by drawing projectors from points a′,b′,c′and d′ and a, b, c, and d.

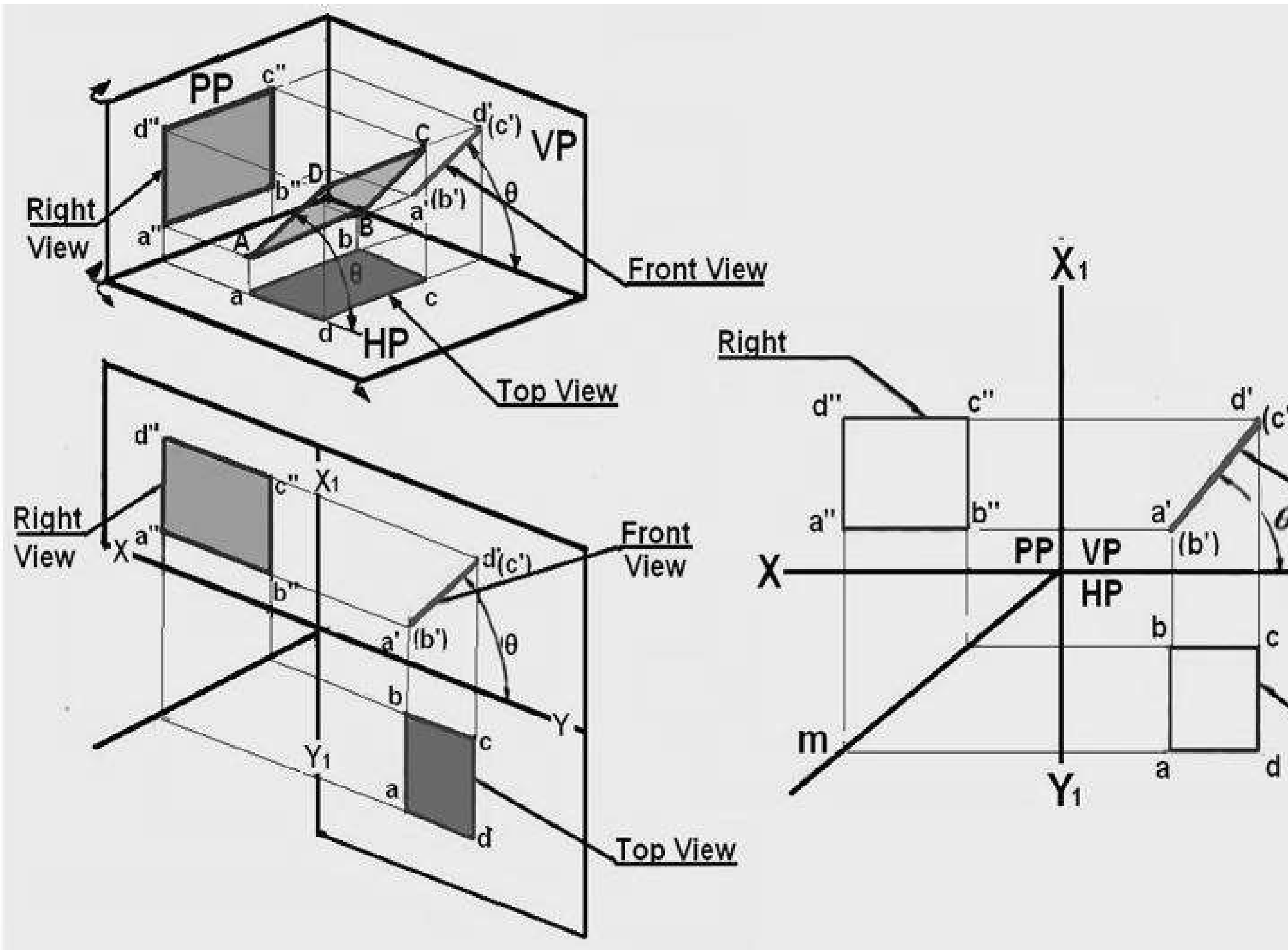


Figure 2. The projection sof the square lamina as mentioned in problem 2.

Problem 3. Draw the Top view and front view of a circular lamina if the surface of the lamina is perpendicular to HP and inclined at 30° to VP.

Solution: The projections of the circular lamina is shown in figure 3. Let us first assume that the plane is perpendicular to HP and parallel to VP. The Front view will be a circle and with diameter equal to the diameter of the lamina. Divide the circle in to 12 equal parts and label then as *1′, 2′, 3′, …., 12′*. The top view will be a straight line *1-7*, parallel to XY line and can be obtained by drawing projectors from 1′, 2′, …. and 12′. Since the circle is inclined at 30° to VP and perpendicular to HP, reconstruct the top view such that the straight line is inclined at 30° to XY line. Let the respective points be 11, 21, 31, …. 121. Draw vertical projectors from points *11, 21, 31, …. 121* to meet the horizontal projectors from points *1′, 2′, 3′, … 12′* to obtain the points *11′, 21′, 31′, …. 121′* in the Front view. Draw a smooth curve passing through points *11′, 21′, 31′, …. 121′* to obtain the Front view of the circular lamina.

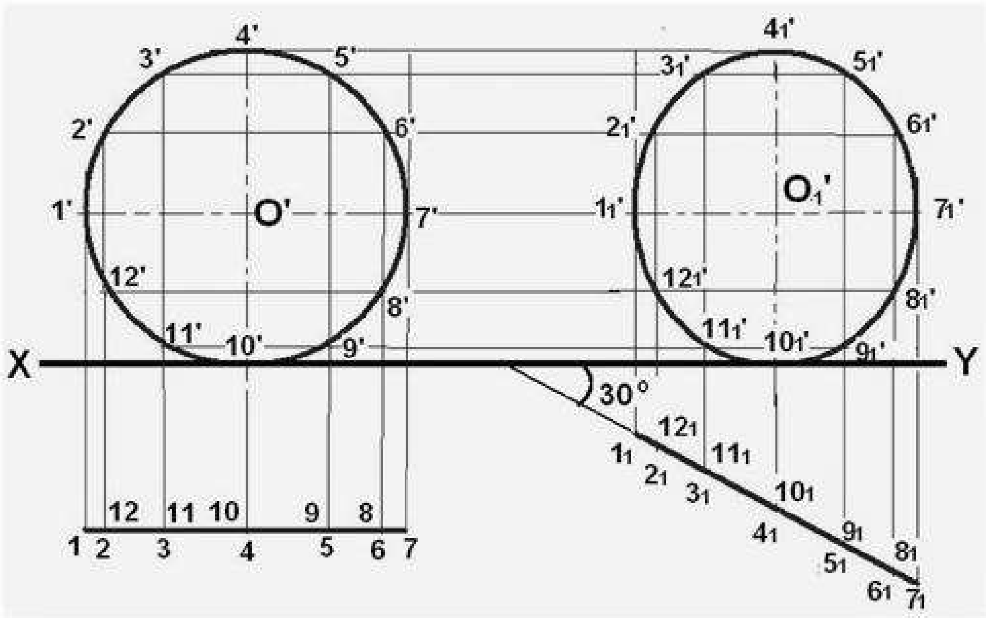


Figure 3. Projections of the circular lamina mentioned in problem 3.

To find the True shape of a plane surface
The true shape of plane surface when its top an front views are given may be determined by setting up two auxiliary planes and projecting on to these. The example below will demonstrate the method of finding the true shape of a quadrilateral.

Problem 4: The corners of a quadrilateral PQRS area as follows: P is 25 mm above HP and 50 mm in front of VP, Q is in HP and 80 mm in front of VP. R is 50 mm above HP and 40 mm in front of VP. S is 65 mm above HP and 20 mm in front of VP. The distances between the vertical projectors parallel to the XY lines are as follows: Between P and S is 20 mm, between P and Q is 35 mm, between P and R is 60 mm. Draw the top and front views of the quadrilateral and find its true shape.

Solution:
The method os obtaining the true shape of the lamina is shown in figure 4. First draw the front view and top view of the lamina as per the conditions mentioned in the problem. Through any one corner in any of the two view, say p in the top view, draw a line parallel to the XY line to intersect the edge qr at t. Project t to the top view to get t′ on q′r′. Connect p′t′. Since pt is horizontal, p′t′ is in true length. The point view of line p′t′ can be obtained by projecting on to an AIP (by drawing the reference line X1 Y1 perpendicular to p′ t′).

Project the four corner points to get the Auxiliary top view s_1 r_1 p_1 q_1 (line view). Project the auxiliary Front View on to another Auxiliary vertical plane by drawing the X_2Y_2 line, parallel to $s_1r_1p_1q_1$ line.

The Auxiliary Front view will be the true shape of the object.

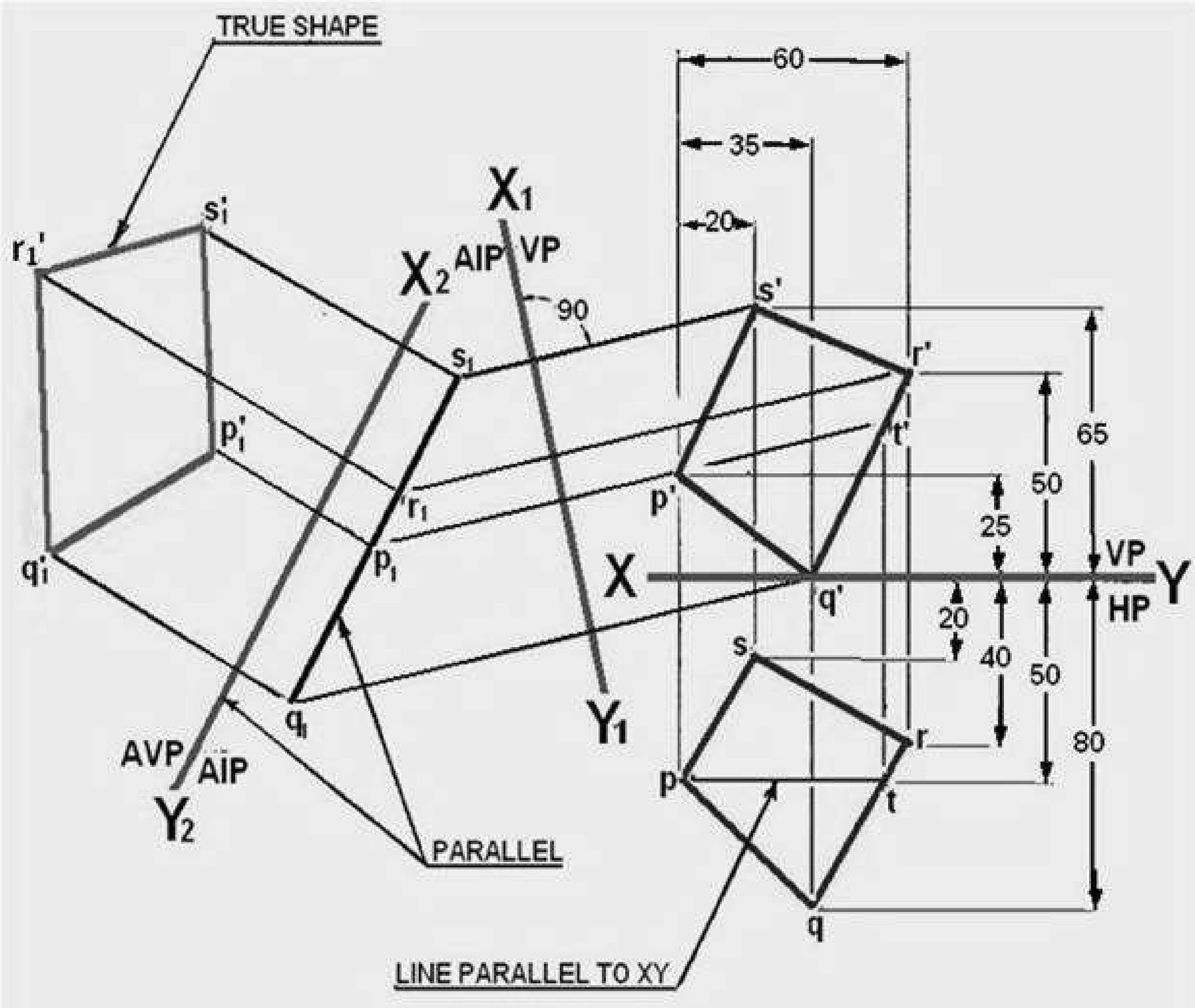
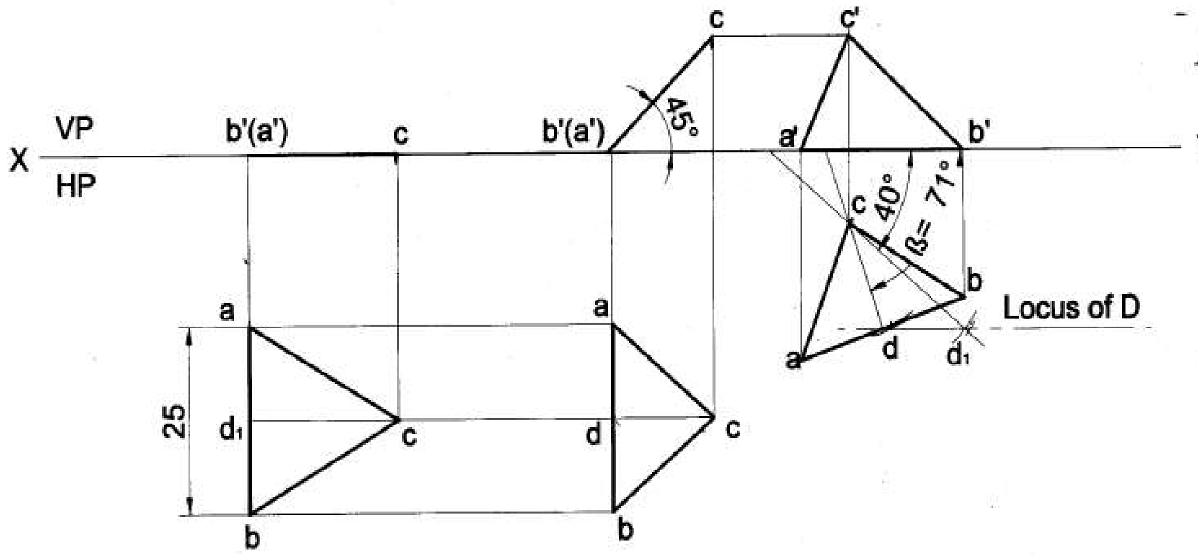


Figure 4. Solution of problem 4.

Worked Examples- Projection of Planes

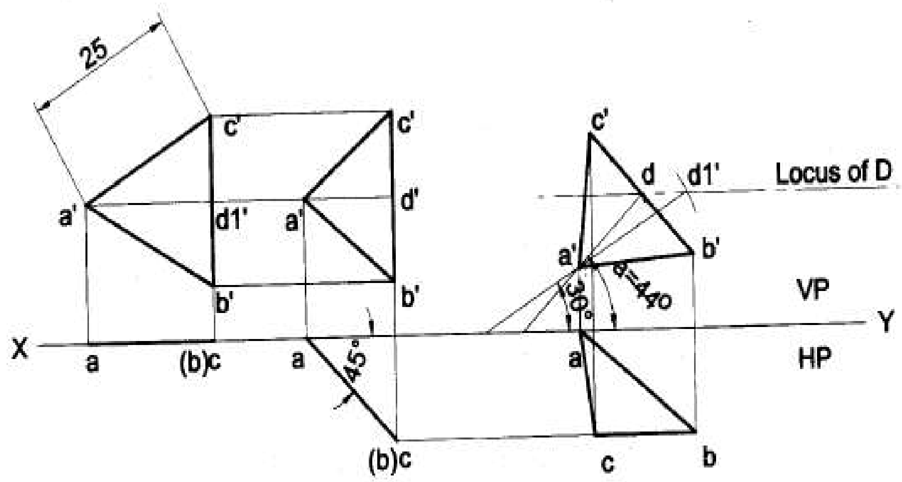
Problem 2 An equilateral triangular lamia of 25mm side lies on one of its sides on HP. The lamina makes 45° with HP and one of its medians is inclined at 40° to VP. Draw its projections.

Solution



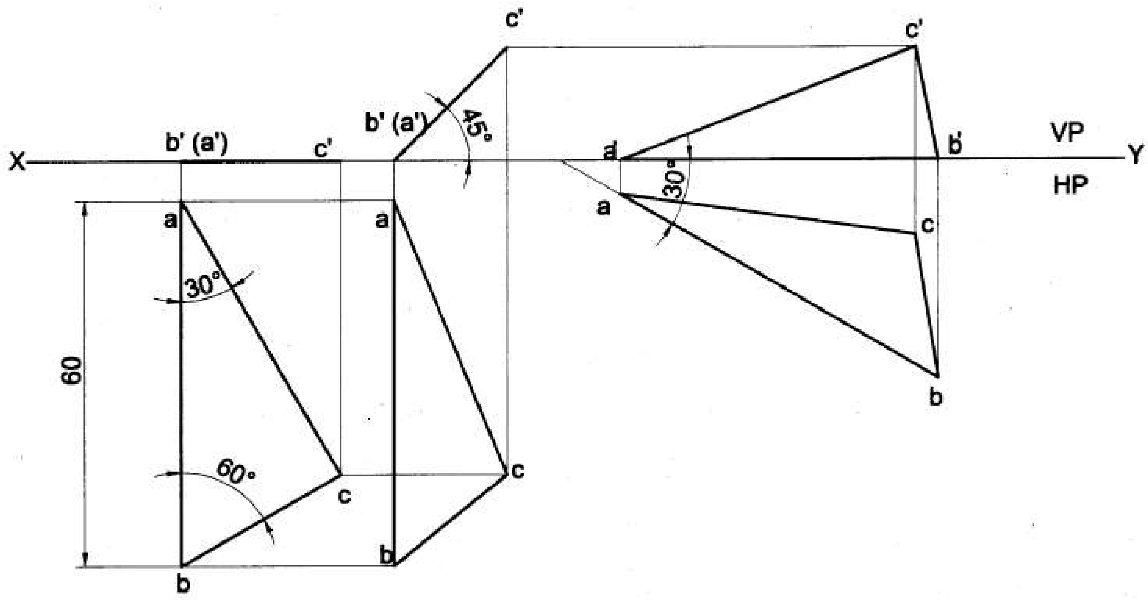
Problem 3 A triangular lamina of 25mm sides rests on one of its corners on VP such that the median passing through the corner on which it rests is inclined at 30° to HP and 45° to VP. Draw its projections.

Solution



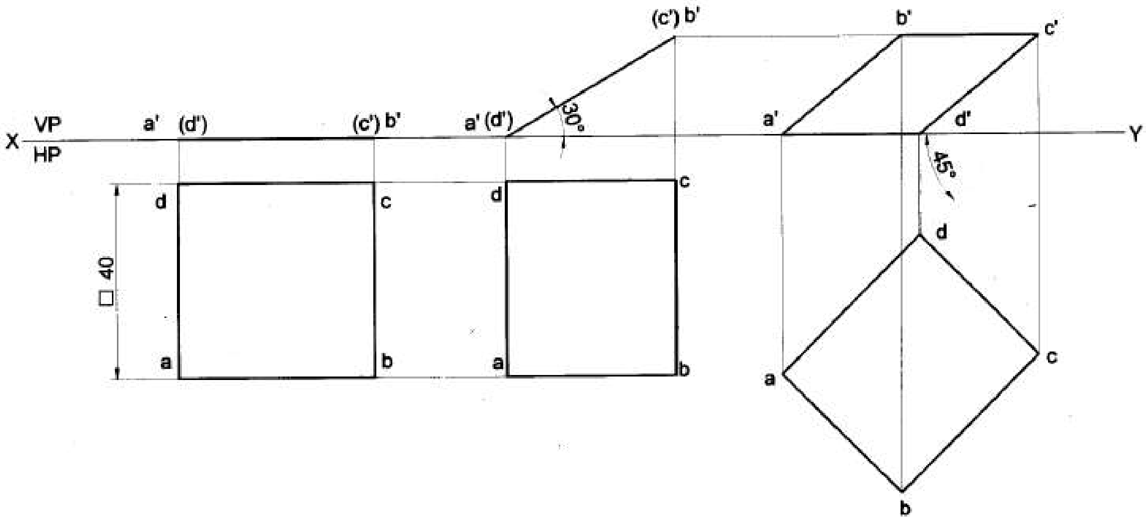
Problem 6 A 30°-60° setsquare of 60mm longest side is so kept such that the longest side is in HP, making an angle of 30° with VP. The set square itself is inclined at 45° to HP. Draw the projections of the setsquare.

Solution



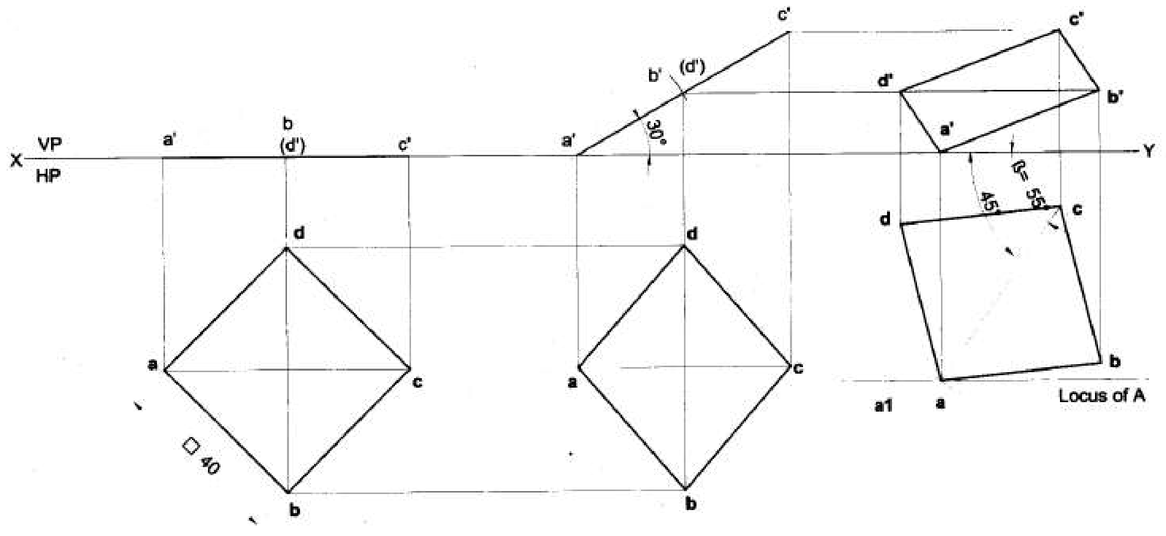
Problem 8 A square lamina of 40mm side rests on one of its sides on HP. The lamina makes 30° to HP and the side on which it rests makes 45° to VP. Draw its projections.

Solution



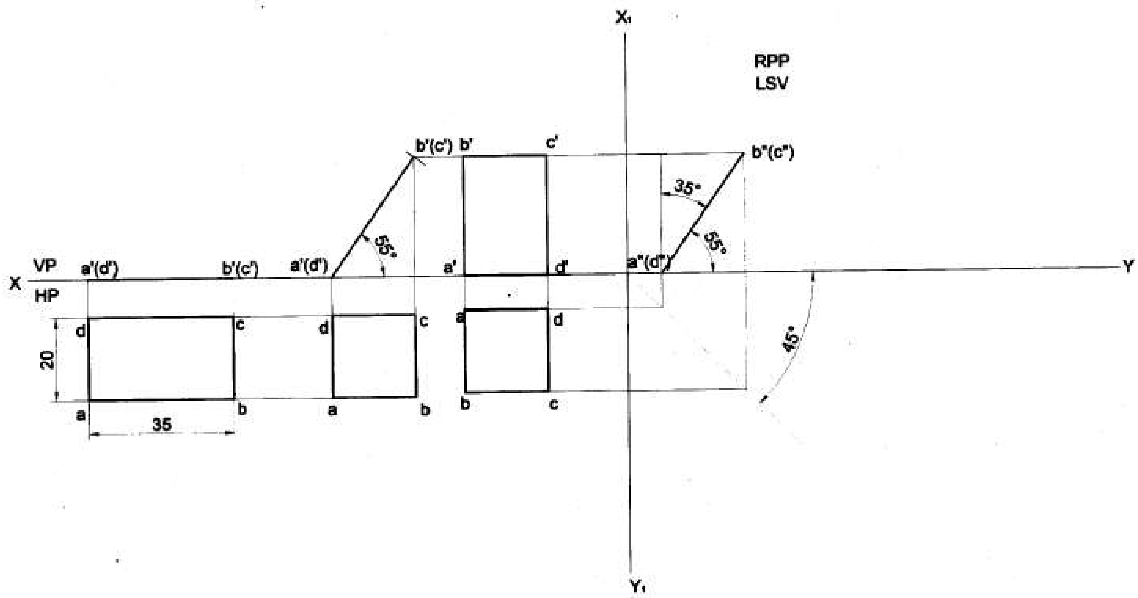
Problem 9 A square plate of 30mm sides rests on HP such that one of the diagonals is inclined at 30°to HP and 45° to VP. Draw its projections.

Solution



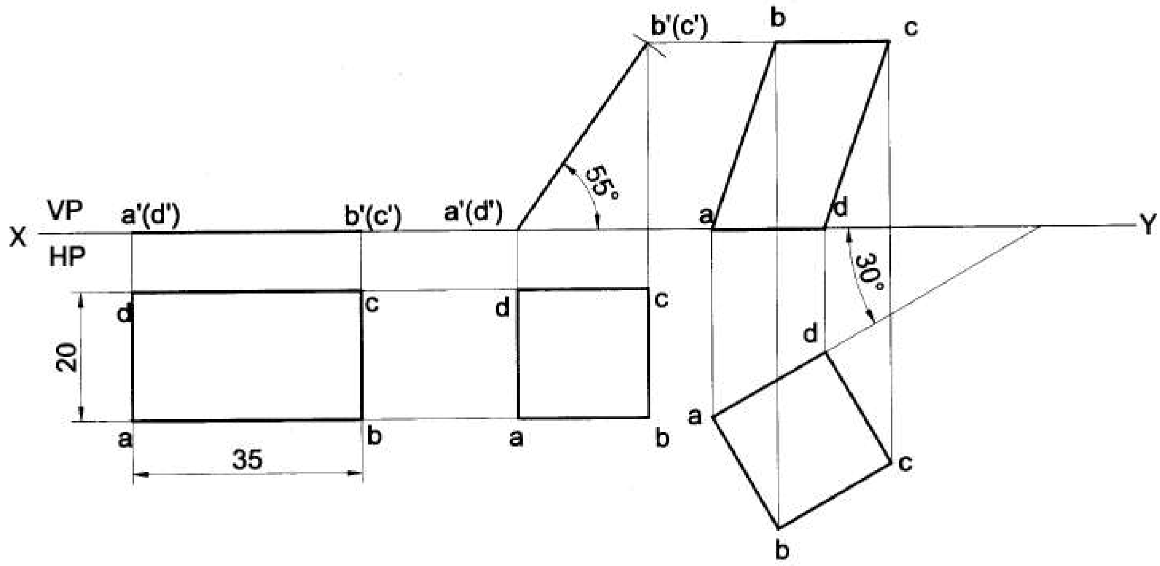
Problem 13 A rectangular lamina of 35mm x 20mm rests on HP on one of its shorter edges. The lamina is rotated about the edge on which it rests till it appears as a square in the top view. The edge on which the lamina rests being parallel to both HP and VP. Draw its projections and find its inclinations to HP and VP.

Solution



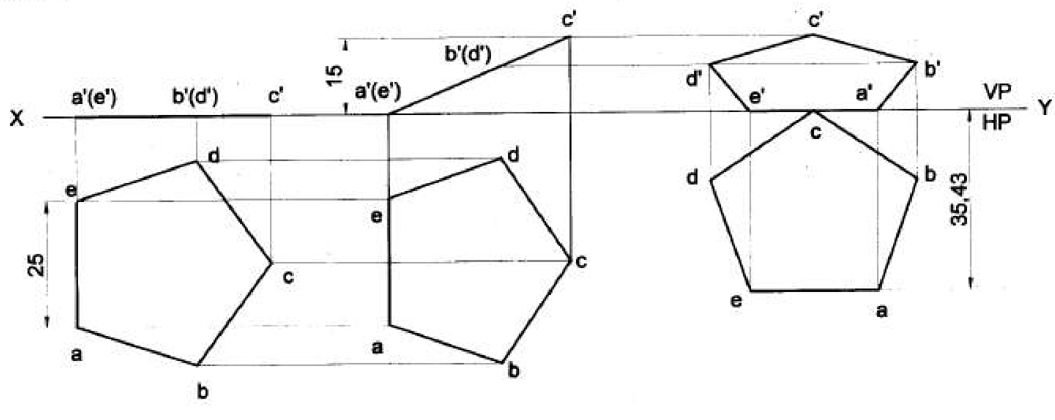
Problem 14 A rectangular lamina of 35mm x 20mm rests on HP on one of its shorter edges. The lamina is rotated about the edge on which it rests till it appears as a square in the top view. The edge on which the lamina rests is inclined 30° to VP. Draw its projections and find its inclination to HP.

Solution



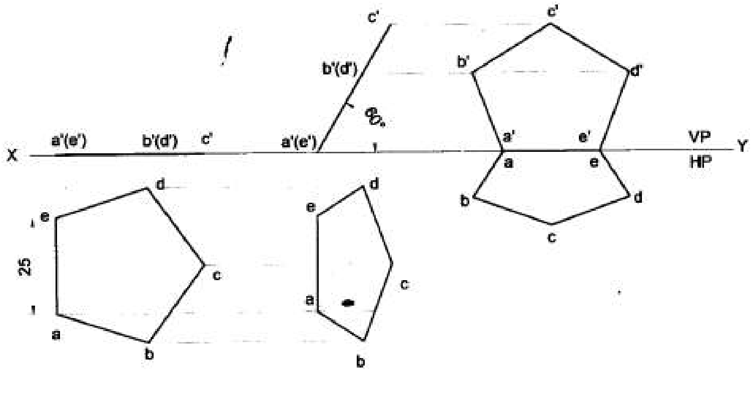
Problem 22 A pentagonal lamina of sides 25mm is resting on one of its edges on HP with the corner opposite to that edge touching VP. This edge is parallel to VP and the corner, which touches VP, is at a height of 15mm above HP. Draw the projections of the lamina and determine the inclinations of the lamina with HP and VP and the distance at which the parallel edge lies from VP.

Solution



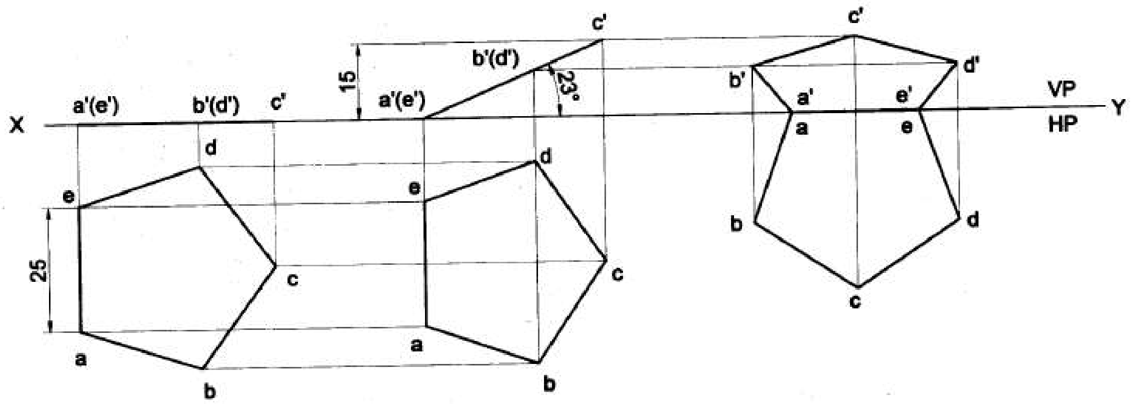
Problem 24 A pentagonal lamina of sides 25mm is having a side both on HP and VP. The corner opposite to the side on which it rests is 15mm above HP. Draw the top and front views of the lamina.

Solution



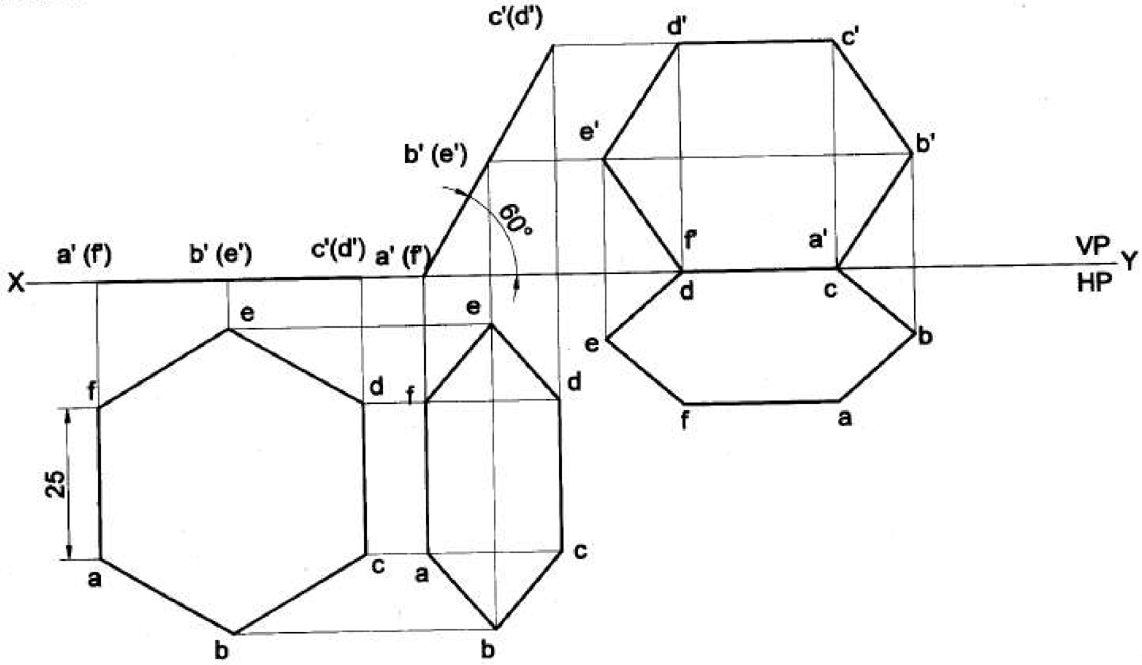
Problem 25 A pentagonal lamina of sides 25mm is having a side both on HP and VP. The surface of the lamina is inclined at an angle of 60° with HP. Draw the top and front views of the lamina.

Solution



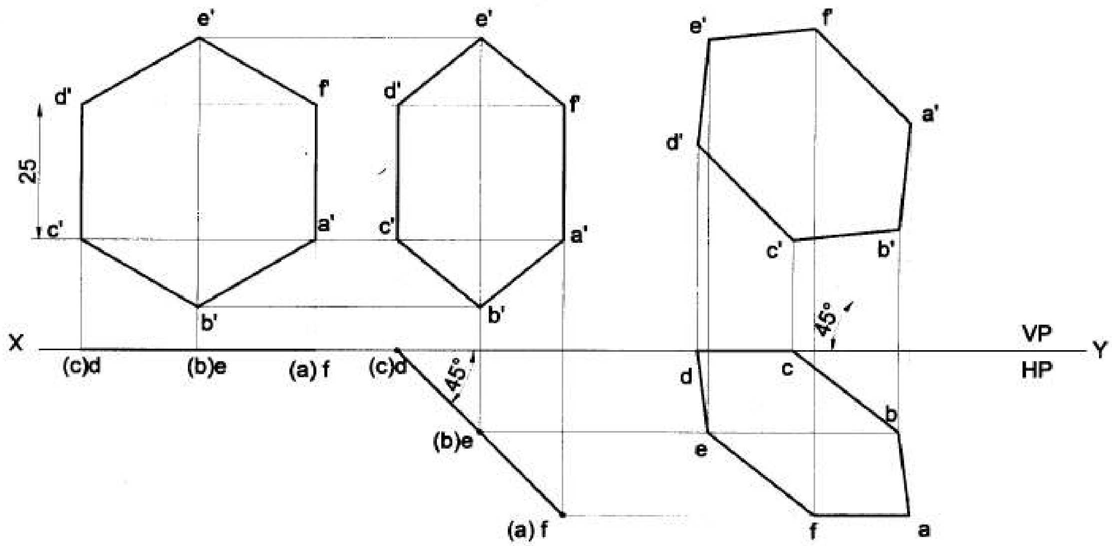
Problem 36 A regular hexagonal lamina of sides 25mm is lying in such a way that one of its sides on HP while the side opposite to the side on which it rests is on VP. If the lamina makes 60° to HP, Draw the projections of the lamina.

Solution



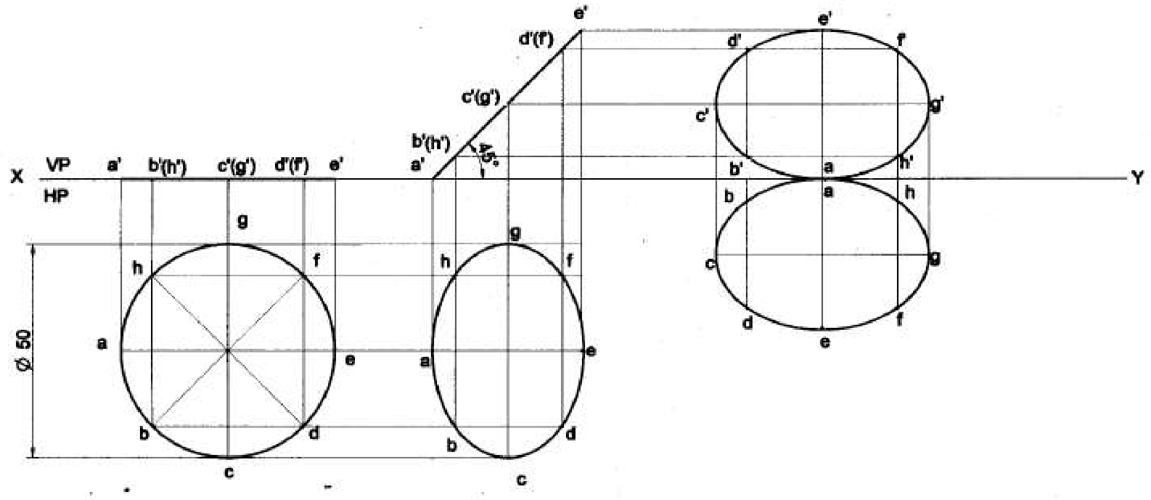
Problem 43 A hexagonal lamina of sides 25mm rests on one of its sides on VP. The lamina makes 45° to VP and the side on which it rests makes 45° to HP. Draw its projections.

Solution



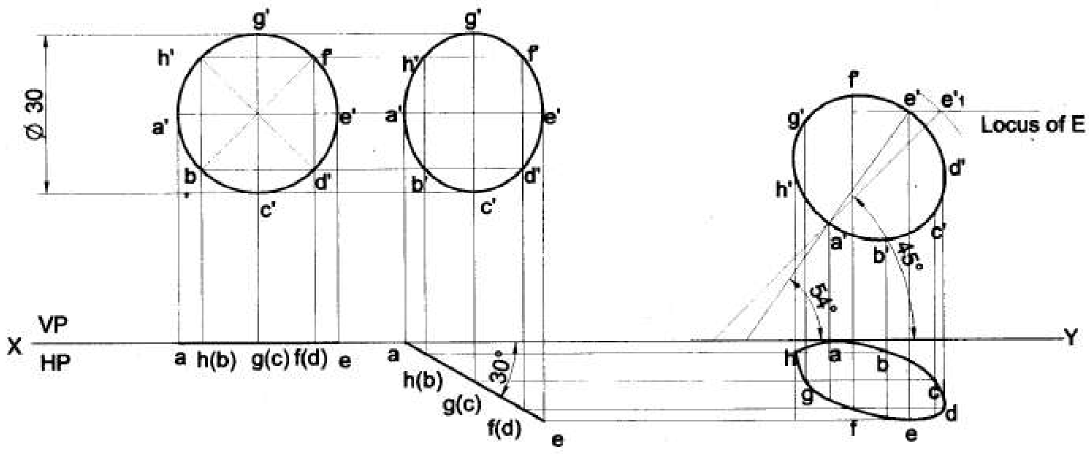
Problem 47 A circular lamina of 50mm diameter is standing with one of its points on the rim on HP and the lamina inclined at 45° to HP. The diameter at right angles to the diameter which is passing through the point on which the lamina rests is parallel to VP. Draw its projections.

Solution



Problem 50 A circular lamina of 30mm diameter rests on VP such that one of its diameters is inclined at 30° to VP and 45° to HP. Draw its top and front views in this position.

Solution



Problems on Points

1. The common point 40 mm below XY line represents not only the front views of three points A, B and C but also the top view of point C. The top view of point B is lies on XY line and top view of point A lies 50 mm above it. Draw the projections of the points and add the right side view to the point A only. Also state in which quadrants the points lie.
2. A point A is on HP and 35 mm in front of VP. Another point B is on VP and below HP. The line joining their front views makes an angle of 30 deg to XY line while the line joining their top views makes an angle of 45 deg with XY line. Find the distance of the point B from HP.
3. Two points P and Q are on HP. The point P is 30 mm behind VP, while Q is 50 mm in front of VP. The line joining their top views makes an angle of 40 deg with XY. Find the horizontal distance between their projectors parallel to XY line.
4. A point A is 40 mm in front of VP and is situated in the fourth quadrant. Its shortest distance from the intersection of XY and X! Y1 is 45 mm. draw its projections. Also find its distance from HP.
5. A point A is 20 mm above HP and in the first quadrant. Its shortest distance from the XY line is 40 mm. Draw the projections. Determine its distance from VP.
6. Draw the projections of the following points on the same XY line. Keeping convenient distance between each projectors. Name the Quadrants in which they lie.P - 10 mm above HP & 15 mm in front of VP.Q - 15 mm above HP & 25 mm behind VP.R - 25 mm below HP& in VP.S - 40 mm above HP& in VP.
7. A point P is 25 mm above HP & 20 mm in front of VP. Another point Q is on HP and 30 mm behind VP. The distance between their projectors measured parallel to the line of intersection of VP and HP is 50 mm. Find the distance between the top views of points P and Q.
8. A point A is on HP & 30 mm in front of VP. Another point B is 20 mm below HP and 20 mm in front of VP. The distance between their projectors measured parallel to XY line is 50 mm. Find the distance between the front views of the points A & B.
9. A point P is on HP and 30 mm in front of VP. Another point Q is on VP and 40 mm above HP. The distance between their projectors parallel to XY line is 50 mm. Find the distance between their front and top views of the points P and Q.
10. Draw the projections of a point A lying 30 mm above HP and first quadrant, if its shortest distance from the line of intersection of HP and VP is 50mm. Also find the distance of the point from VP.
11. 40. Draw the projections of the following points on the same reference XY line and state the quadrants in which they lie. E - 35 mm above HP & on VP. F - 30 mm below HP & on VP. G - On HP& 25 mm behind VP. H - On HP& 30 mm in front of VP.
12. A point 20 mm below the reference XY line is the top view of three points P, Q & R. P is 20 mm below HP, Q is 35 mm above HP and R is on HP. Draw the projections of the three points and state their positions & quadrants in which they situated.
13. A point is 30 mm in front of VP, 20 mm above HP & 25 mm in front / behind / from LPP. Draw the projections and name the side view.
14. A point is 40 mm behind VP, 20 mm above HP & 30 mm in front / behind / from LPP. Draw the projections and name the side view.
15. A point is 30 mm behind VP, 30 mm above HP & 25 mm in front / behind / from RPP. Draw the projections and name the side views.

Problems on Lines

1. The top view of a line PQ is 70 mm and front view is 60 mm long. The end Q is nearer to both HP and VP than the end P and is 15 above HP and 20 mm infront of VP. Draw the projections of the line if the distance between projectors is 50 mm.
2. A line AB 100 mm long measures 80 mm in front view and 70 mm in top view the mid point M of the line is 40 mm from both HP and VP. Draw its projections. Find its inclinations.
3. A line has its end A 15 mm above HP and 10 mm infront of VP. The end B is 55 mm above HP and the line is inclined at 30^0 to HP. The distance between the end projectors is 50 mm. draw the projections of the line and determine the true length of the line and its inclinations with VP.
4. A line MN 90 mm long has a point P on it which divides the line in ration 2:1,i.e.MP:PN this point P is 50 mm above HP and 60 mm in front of VP. The line is inclined at 35^0 to HP and 40 to VP. draw the projection of the line. Find the distance between end projector and the position of the ends of the with HP and VP.
5. A line AB 65 mm long, has its end A 25 mm above HP and 30 mm in front of VP. The other end is 45 mm above HP and 50 mm in front of VP. Draw the projections and determine its inclinations.
6. One end of a line is 30 mm in front of VP and 30 mm above HP. The line is inclined at 40 deg to HP and its top view measuring 60 mm, is inclined at 50 deg to XY. Draw the projections of the line and determine true length and inclination with VP.
7. The top view of the line AB 80 mm long, measures 65 mm. The mid point of the line is 60 mm in front of VP and 70 mm above HP. The point A is in the VP. Draw its projections and find its inclinations.
8. A straight line PQ is inclined at 45 deg to HP and 30 deg to VP. The point P is in HP and the point Q is in VP. The length of the straight line is 65 mm. Draw the projection of the straight line AB.
9. Draw the projections of a line AB 90 mm long and find its true and apparent inclinations with HP and VP. When its end A is on HP and 20 mm in front of VP. Its midpoint M is 20 mm above the HP and 40 mm in front of the VP.
10. A line PQ is inclined to both HP and VP by 30 deg and 45 deg respectively. One of its ends P is at a distance of 10 mm from HP and 15 mm from VP. The distance between the end projectors is 45 mm. Draw the top, front and right side views of the line. Determine the true length of the and the distances of the end Q from VP and HP.
11. Two lines AB and AC make an angle of 120 deg between them in their in front view and top view parallel to both the HP and the VP. Determine the real angle between AB and AC.
12. The elevation of a line AB 90 mm long, is inclined at 30 deg to HP and measures 70 mm. The end A is 20 mm above HP and is in VP. Draw the projections of the line and find its inclination with VP.
13. A line PQ measures 80 mm in length. The point P is above HP and in front of VP by 20 mm and 30 mm respectively. The distance between the end projectors is 50 mm the line is inclined to VP by 30 deg. Draw the projections of the line and specify its true inclination with HP.
14. The top view of a line PQ 75 mm long measures 50 mm and the front view measures 60 mm. The end P is 30 mm above HP and 15mm in front of VP. Draw the projections of the line and find its true inclinations with HP and VP. Find length of front view and distance between the end projectors.

Problems on Planes

1. A square lamia ABCD of 40mm side rests on corner C such that the diagonal AC appears to be at 45° to VP. The two sides BC and CD containing the corner C make equal inclinations with HP. The surface of the lamina makes 30° with HP. Draw its top and front views.

2. The top view of a square lamia of side 30mm is a rectangle of sides $30mm \times 20mm$ with the longer side of the rectangle being parallel to both HP and VP the top and front views of the square lamina. What is the inclination of the surface of the lamina with HP and VP?
3. A rectangular lamina of sides $20mm \times 30mm$ rests on HP on one of its longer edges. The lamina is tilted about the edge on which it rests till its plane surface is inclined HP at 45°. The edge on which it rests is inclined at 30° to VP. Draw the projection of the lamina.
4. A pentagonal lamina of edges 25mm is resting on HP with one of its corners such that the edge opposite to this corner is 20mm above HP & makes an angle of 45° with VP. Draw the top and views of the plane lamina in this position. Determine of the lamina with HP.
5. A pentagonal lamina of side 25mm is resting on one of its edges on HP with the corner opposite to that edge touching VP. This edge is parallel to VP and the corner, which touches VP, is at a height of 15mm above HP. Draw the projections of the lamina and determine the inclinations of the lamina with HP and VP and the distance at with the parallel edge lies from VP.
6. A pentagonal lamina having edges 25mm is placed on one of its corners on HP such that the perpendicular bisector of the edge passing through the corner on which the lamina rests is inclined at 30° to HP and 45° VP. Draw the top and front views of the lamina. A regular hexagonal of side 25mm is lying in such a way one of its corners on HP while the corner opposite to the corner on which it rests is on VP. If the lamina makes 60° to HP, draw the projections of the lamina.
7. A hexagonal lamina of sides 30mm is resting on HP with one its corner in VP and surface inclined at an angle of 30° with VP. The diagonal passing through that which is in VP is inclined at 45° to HP. Draw the projection of the lamina.
8. A hexagonal of sides 30mm is resting on HP with one of its corners in VP and its surface inclined at an angle of 30° with VP. The diagonal passing through that corner which is in VP appears to be inclined at 40° to HP. Draw the projection of the lamina.
9. A hexagonal lamina of sides 25mm rests on one of its sides on HP. The lamina makes 45° to HP and the side on which it rests makes 30° to VP. Draw its projections.
10. A hexagonal lamina of 25mm rests on one of its sides on HP. The lamina makes 45° to HP and the side on which it rests makes 30° to VP. Draw its projection.
11. A hexagonal lamina of sides 25mm rests on one its corners on HP. The lamina makes 45° to HP and the diagonal passing through the corner on which on it rests appears to be inclined at 30° to VP. Draw its projections.

FURTHER READING:

1) Computer Aided Engineering Drawing - S. Trymbaka Murthy, - I.K. International Publishing House Pvt. Ltd., New Delhi, 3rd revised edition- 2006.
2) Engineering Graphics - K.R. Gopalakrishna, 32nd edition, 2005- Subash Publishers Bangalore.
3) Dhananjay A Jolhe, Engineering Drawing, Tata McGraw Hill, 2007.
4) M.B. Shah and B.C. Rana, Engineering Drawing, pearson Education, Eds. 2, 2009.
5) K. Venugopal, Engineering Drawing and Graphics, New Age International (P) Ltd., publishers, 2000.
6) N.D. Bhatt and V.M. Panchal, Engineering Drawing, Charotar Publishing house, 2005.

MODULE-3

PROJECTIONS OF SOLIDS (FIRST ANGLE PROJECTION ONLY)

OBJECTIVES:

1) To understand the projection of solids in 1^{st} quadrant when the solid inclined to HP and VP.
2) To understand the projection of solids when it is suspended.

LESSON CONTENT:

Introduction, Definitions – Projections of right regular tetrahedron, hexahedron (cube), prisms, pyramids, cylinders and cones in different positions (No problems on octahedrons and combination solid).

3.1 Projections of Planes

Solid

A solid is a 3-D object having length, breadth and thickness and bounded by surfaces which may be either plane or curved, or combination of the two.
Solids are classified under two main headings

- Polyhedron
- Solids of revolution

A regular polyhedron is solid bounded only by plane surfaces (faces). Its faces are formed by regular polygons of same size and all dihedral angles are equal to one another. when faces of a polyhedron are not formed by equal identical faces, they may be classified into prisms and pyramids.

Five regular polyhedral are shown in figure 1

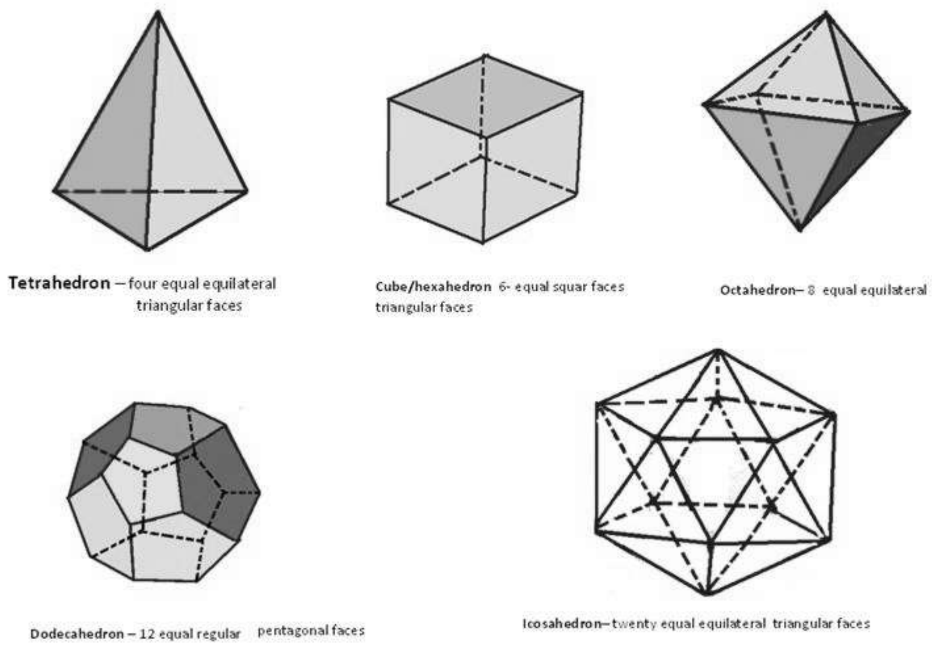


Figure 1: Five regular polyhedra

Prism

Prisms are polyhedron formed by two equal parallel regular polygon, end faces connected by side faces which are either rectangles or parallelograms.
Different types of prisms are shown in figure 2

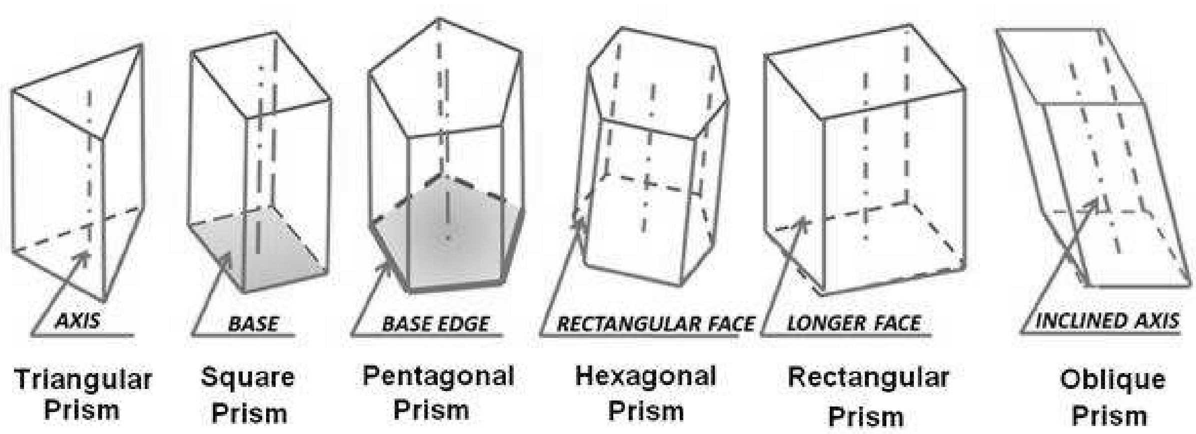


Figure 2. Various types of prisms generally encountered in engineering applications

Some definitions regarding prisms

Base and lateral faces. When the prism is placed vertically on one of its end faces, the end face on which the prism rests is called the base. The vertical side faces are the lateral faces, as shown in Figure 3.

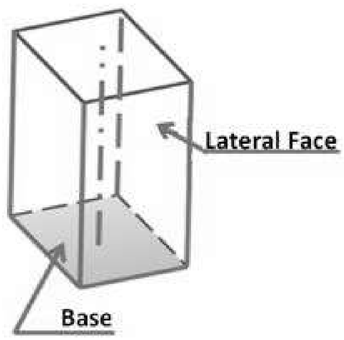


Figure 3. Shows the base and lateral face of a prism.

Base edge/Shorter edge: These are the sides of the end faces, as shown in figure 4.

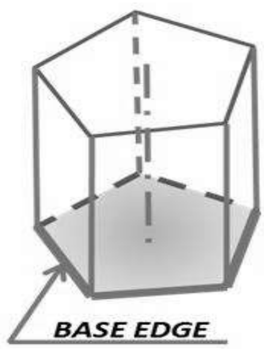


Figure 4. showing the base edge or shorter edge of a pentagonal prism.

Axis – it is the imaginary line connecting the end faces is called axis and is shown in figure 5.

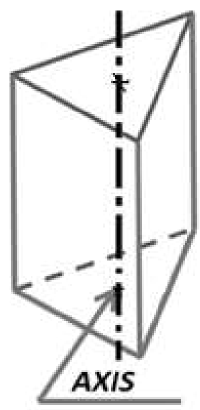


Figure 5 showing the Axis of a triangular prism.

Longer edge/lateral edges: These are the edges connecting the respective corners of the two end faces. The longer edge of a square prism is illustrated in figure 6.

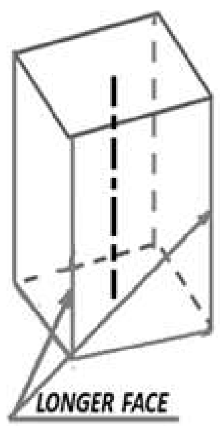


Figure 6. illustrating the longer edge of a square prism.

Right prism – A prism whose axis is perpendicular to its end face is called as a right prism .Prisms are named according to the shape of their end faces, i.e, if end faces are triangular, prism is called a triangular prism.

Oblique prism: It is the prism in which the axis is inclined to its base.

Pyramids

Pyramid is a polyhedron formed by a plane surface as its base and a number of triangles as its side faces, all meeting at a point, called vertex or apex.

Axis – the imaginary line connecting the apex and the center of the base.

Inclined/slant faces – inclined triangular side faces.

Inclined/slant/longer edges – the edges which connect the apex and the base corners.

Right pyramid – when the axis of the pyramid is perpendicular to its base.

Oblique pyramid – when the axis of the pyramid is inclined to its base.

Solids of revolution

when some of the plane figures are revolved about one of their sides – solids of revolution is generated some of the solids of revolution are:

1. Cylinder: when a rectangle is revolved about one of its sides, the other parallel side generates a cylinder.
2. Cone: when a right triangle is revolved about one of its sides, the hypotenuse of the right triangle generates a cone.
3. Oblique cylinder: when a parallelogram is revolved about one of its sides, the other parallel side generates a cylinder.
4. Sphere: when a semi-circle is revolved about one of its diameter, a sphere is generated..
5. Truncated and frustums of solids – when prisms, pyramids, cylinders are cut by cutting planes, the lower portion of the solids (without their top portions) are called, either truncated or frustum of these solids. Some examples are shown in figure 7.

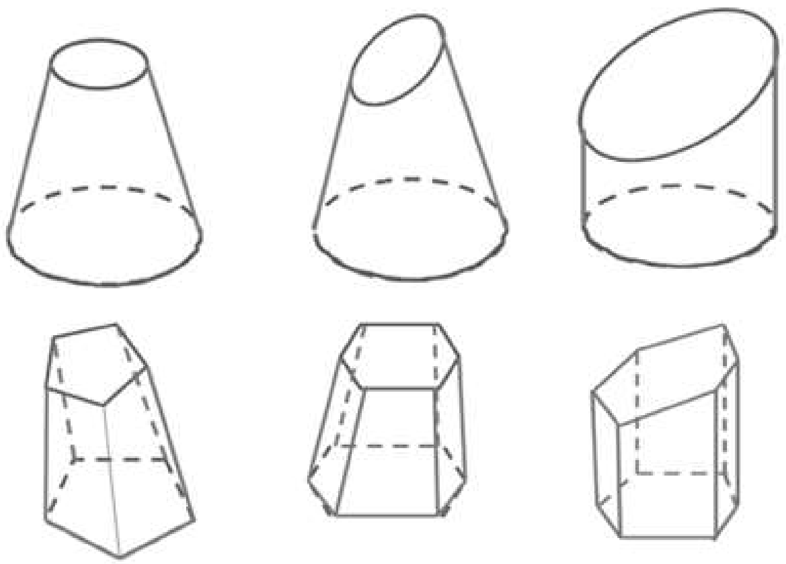


Figure 7. Illustrates some examples of truncated / frustrum of solids.

Visibility
When drawing the orthographic views of an object, it will be required to show some of the hidden details as invisible. To distinguish the invisible portions from the visible ones, the invisible edges of the object are shown on the orthographic views by dashed lines. However, in practice, these lines of dashes conveniently and colloquially, but wrongly called as dotted lines. To identify the invisible portions of the object, a careful imaginative thinking is essential.

Rules of visibility
When viewing an object, the outline of the object is visible. Hence the outlines of all the views are shown by

full lines. All the visible edges will be shown as solid lines as shown in figure 8. Figure shows the frustum of a pentagonal pyramid.

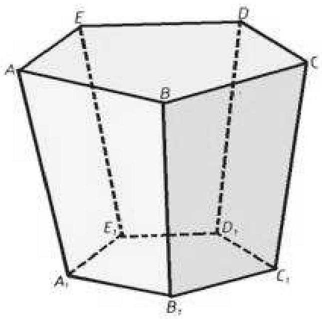


Figure 8. Front view of the object. The visible edges are shown as solid lines and the hidden edges are shown as dashed lines.

Figure 9 shows the projections of the object. In the top view, the highest portions of the object are visible. The top face ABCDE is at the top and is completely visible in the top view. In the top view, edges ab, bc, cd, de and ea are shown as full lines. The bottom pentagonal faces A1B1C1D1E1 is smaller than the top face, hence invisible. The slant edges AA_1, BB_1, CC_1, DD_1 and EE_1 are invisible in the top view, hence they are shown as lines of dashes. The line connecting a visible point and an invisible point is shown as an invisible line of dashes unless they are out lines.

In the front view, the front faces of the object are shown as visible. The faces ABB1A1 and BCC1B1 are the front faces. Hence in the front view, the corners a, b, c and a_1, b_1, c_1 are visible to the observer. Hence in the front view, the lines $a'a'_1$, $b'b'_1$ and $c'c'_1$ are shown as full lines. However the corners d, e, d_1 and e_1 are invisible in the front view. The lines, $e'e'_1$, $d'd'_1$ are invisible, hence shown as dashed lines. The top rear edges a'e', e'd' and d'c' coincide with the top front visible edges a'b' and b'c'.

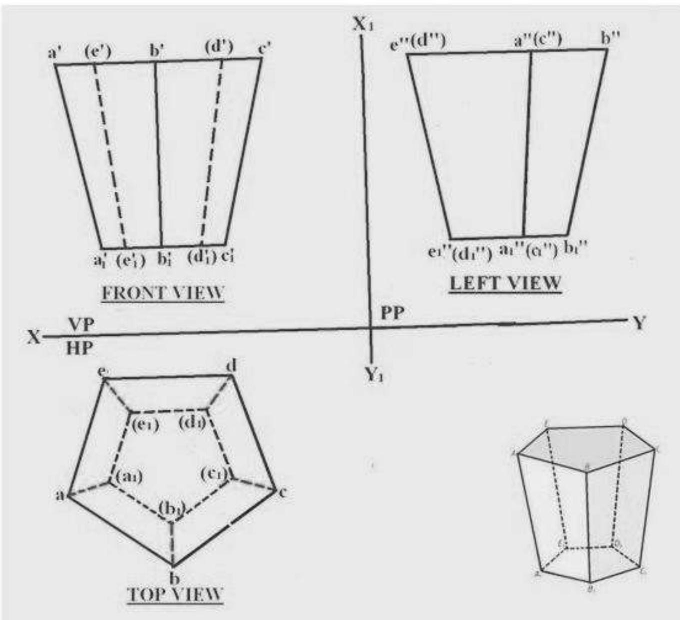


Figure 9. Projections of the frustrum of a pentagonal pyramid.

In the side view - the face lying on that side are visible. As seen in the left side view, the corners e, a, b and e_1, a_1, b_1 lie on left side and are visible in the left view. Hence the lines, e"e_1", a"a_1" and b"b_1" are shown as full lines. The edges d"d_1", c"c_1" coincide with the visible edges e"e_1" and a"a_1" respectively.

3.2 Projections of solids placed in different positions

The solids may be placed on HP in various positions

1. The way the axis of the solid is held with respect to HP or VP or both -
   - Perpendicular to HP or VP
   - Parallel to either HP or VP and inclined to the other
   - Inclined to both HP and VP
2. The portion of the solid on which it lies on HP, except when it is freely suspended position. It can lie on HP on its base edge or a corner, or a lateral face, or apex.

Axis of the solid perpendicular to HP

A solid when placed on HP with its axis perpendicular to it, then it will have its base on HP. This is the simplest position in which a solid can be placed. When the solid is placed with the base on HP position, in the top view, the base will be projected in its true shape. Hence, when the base of the solid is on HP, the top view is drawn first and then the front view and the side views are projected from it. Figure 10 shows a cylinder with its axis perpendicular to HP. There is only one position in which a cylinder or a cone may be placed with its base on HP.

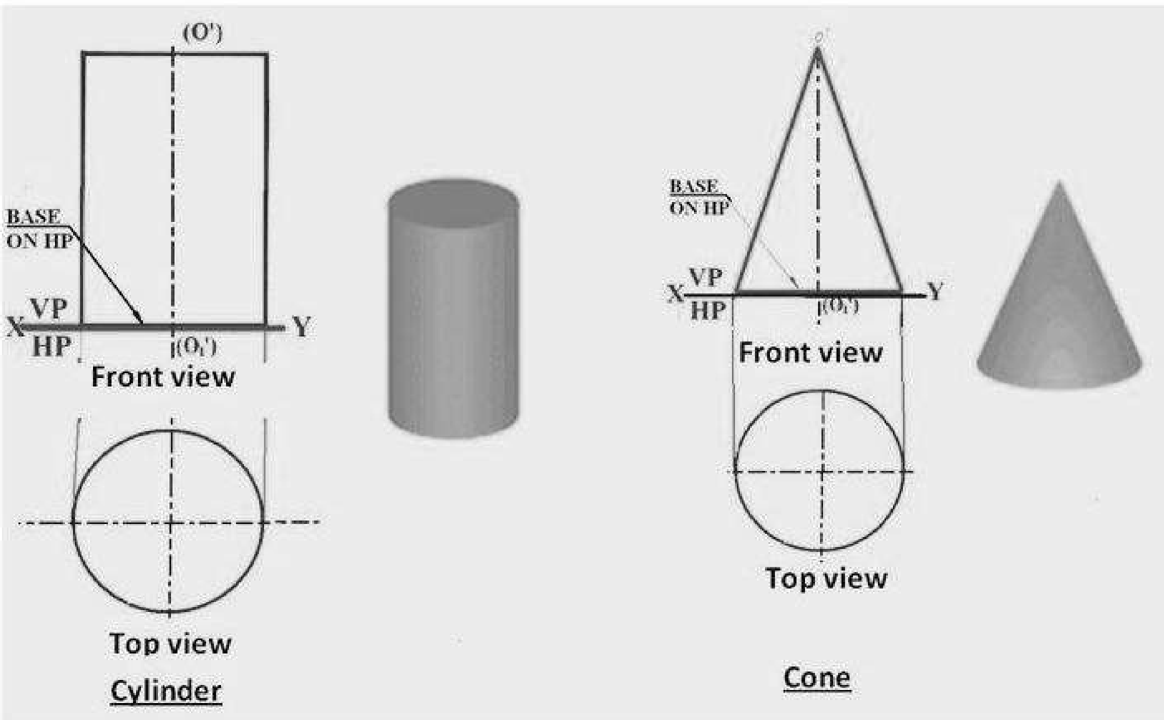


Figure 10. Front view and top view of a cylinder and cone

For prisms, there are 4 positions it may be placed with its base on HP.These positions are illustrated in figure 11.

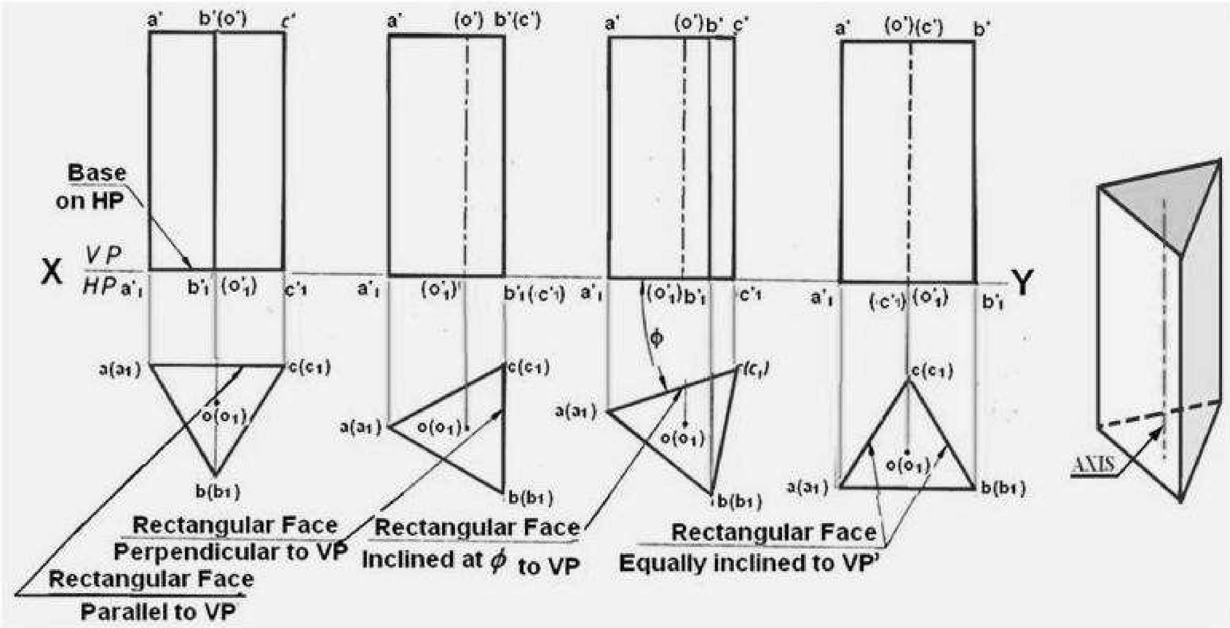


Figure 11. Projections of a triangular prism resting on its base on HP with different positions.

There are 4 positions in which pyramids may be placed with its base on HP. These positions are shown in figure 12.

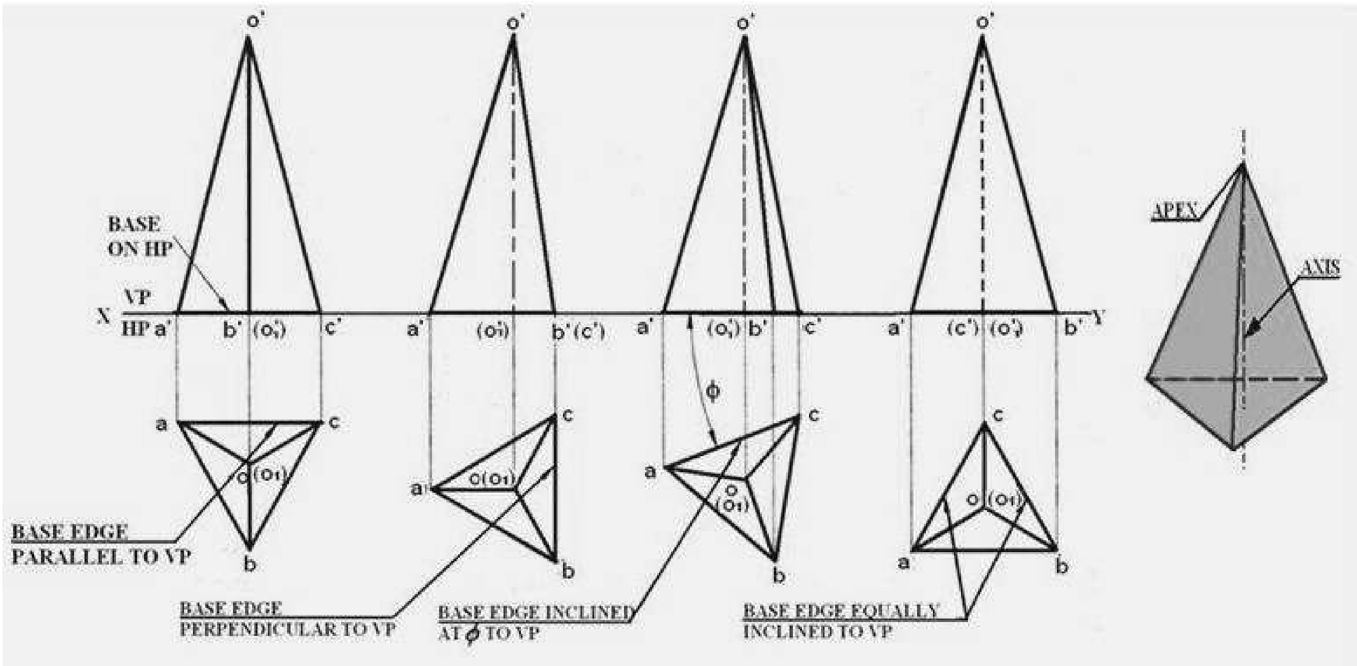


Figure 12. Projections of a triangular Pyramid resting on its base on HP with different positions.

Projections of a solid with the axis perpendicular to VP

When a solid is placed with its axis perpendicular to VP, the base of the solid will always be perpendicular to HP and parallel to VP. Hence in the front view, base will be projected in true shape. Therefore, when the axis of the solid is perpendicular to VP, the front view is drawn first and then the top and side views are drawn from it. When a cylinder rests on HP with its axis perpendicular to VP, one of its generators will be on HP. Figure 13 shows the Front view and Top view of a cylinder and cone resting on HP with their axes perpendicular to VP. In this case one of the points on the circumference of the base will be on XY.

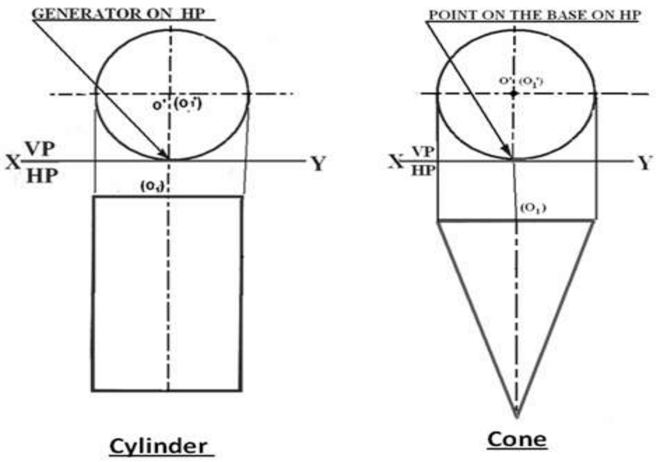


Figure 13 shows the Front view and Top view of a cylinder and cone

Prism may be placed with their axis perpendicular to VP in three different positions. The different positions are shown in figure 14.

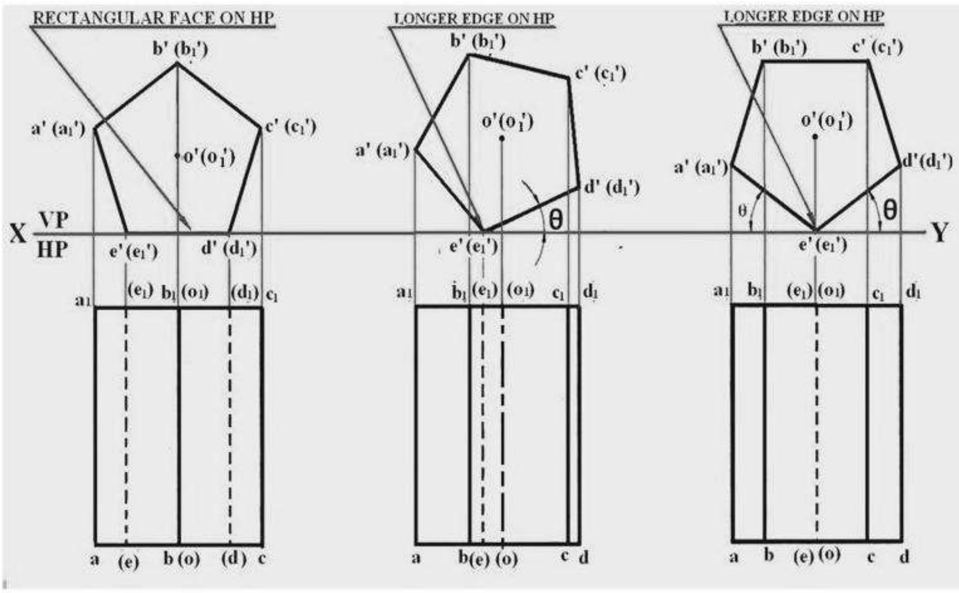


Figure 14. Projections of a pentagonal prism resting on HP and axis perpendicular to VPwith different positions.

As shown in Figure 15, pyramid may be placed with their axis perpendicular to VP in three different positions.

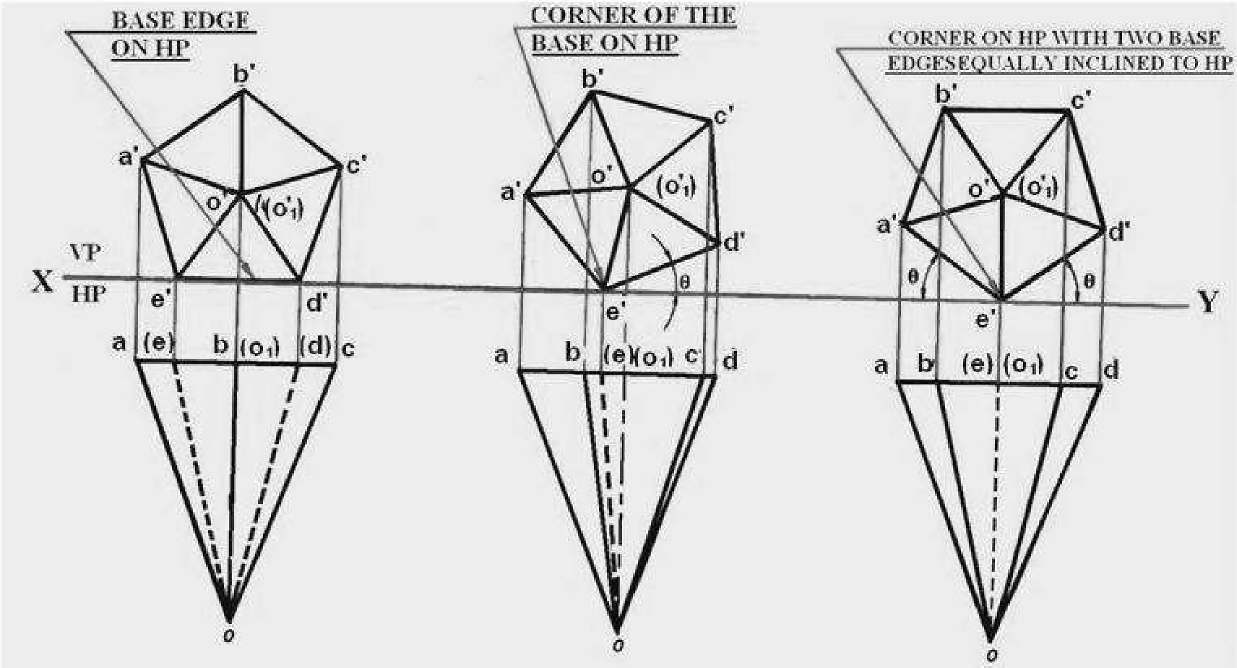


Figure 15. Projections of a pentagonal pyramid resting on HP and axis perpendicular to VP with different positions.

Axis of the solid inclined to HP and parallel to VP

When a solid is placed on HP with its axis inclined to HP, the elemental portion of the solid that lies on HP depends upon the type of the solid.
When a prism is placed on HP with its axis inclined to it, then it will lie either on one of its base edges or on one of its corners on HP.
When a pyramid is placed on HP with its axis inclined to HP, then we will have one of its base edges on HP or one of its base corners on HP or one of its slant edges on HP or one of its triangular faces on HP or an apex on HP.

3.3Methods of drawing the projections of solids

These are two methods for drawing the projections of solids:

1. Change of position method.
2. Auxiliary plane method (Change of reference-line method)

Change of position method
In this method, the solids are placed first in the simple position and then tilted successively in two or three stages to obtain the final position. The following are some of the examples.

a. Method of obtaining the top and the front views of the pyramid when it lies on HP on one of its base edges with its axis or the base inclined to HP.

If the solid is required to be placed with an edge of the base on HP, then initially the solid has to be placed with its base on HP such that an edge of the base is perpendicular to VP, i.e., to XY line in top view preferably to lie on sthe right side.

When a pentagonal prism has to be placed with an edge of base on HP such that the base or axis is inclined to HP, then initially, the prism is placed with its base on HP with an edge of the base perpendicular to VP and the lying on the right side. In this position, the first set of top and front views are drawn with the base edges $(c_1)(d_1)$ perpendicular to XY line in the top view. In the front view, this edge c_1'(d_1') appears as a point. Since the prism has to lie with an edge of the base on HP, the front view of the prism is tilted on the edge c_1'(d_1') such that the axis is inclined at q to HP.

Redraw the first front view in the tilted position. Whenever the inclination of axis q with HP is given, first the base is drawn at (90- θ) in the front view, otherwise improper selection of the position of the axis may result in the base edge c_1'(d_1') lying above or below the XY line. The second top view is projected by drawing the vertical projectors from the corners of the second front view and the horizontal projectors from the first top view. Figure 1 shows the sequence in obtaining the projection of the solid for the above case.

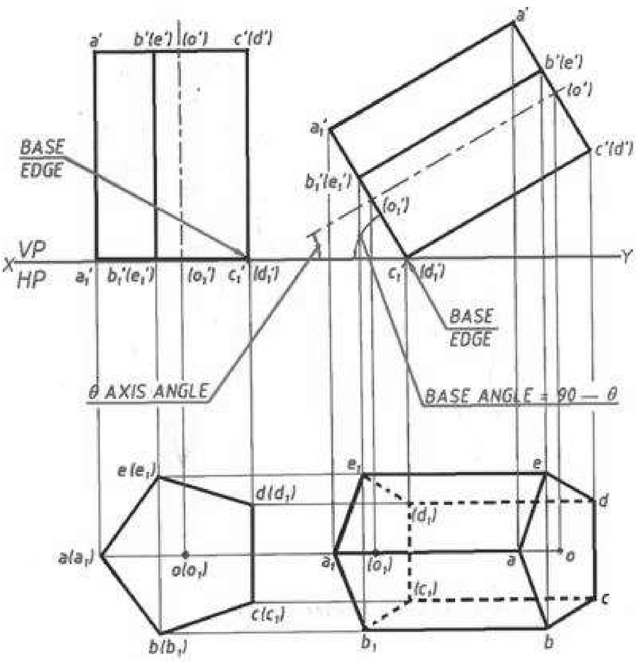


Figure 1. Illustrating the sequence for obtaining the projections of a pentagonal prism placed with an edge of base on HP such that the base or axis is inclined to HP

b.Corner of the base on HP with two base edges containing the corner on which it rests make equal inclinations with HP

When a solid lies on one of its corners of the base on HP, then the two edges of the base containing the corner on which it lies make either equal inclinations or different inclination with HP. Initially the solid should be placed with its base on HP such that an imaginary line connecting the center of the base and one of its corners is parallel to VP, i.e. to XY line in the top view, and preferably to lie on the right side. For example, when a hexagonal prism has to be placed with a corner of the base on HP such that the base or the axis is inclined to HP, then initially the prism is placed with its base on HP such that an imaginary line connecting the center of the base and a corner is parallel to VP and it lies on the right side. In this position, the first set of top and front views are drawn , as shown in step-1 of figure 2 . The line (o1)(d1) is parallel to the XY line in the top view.

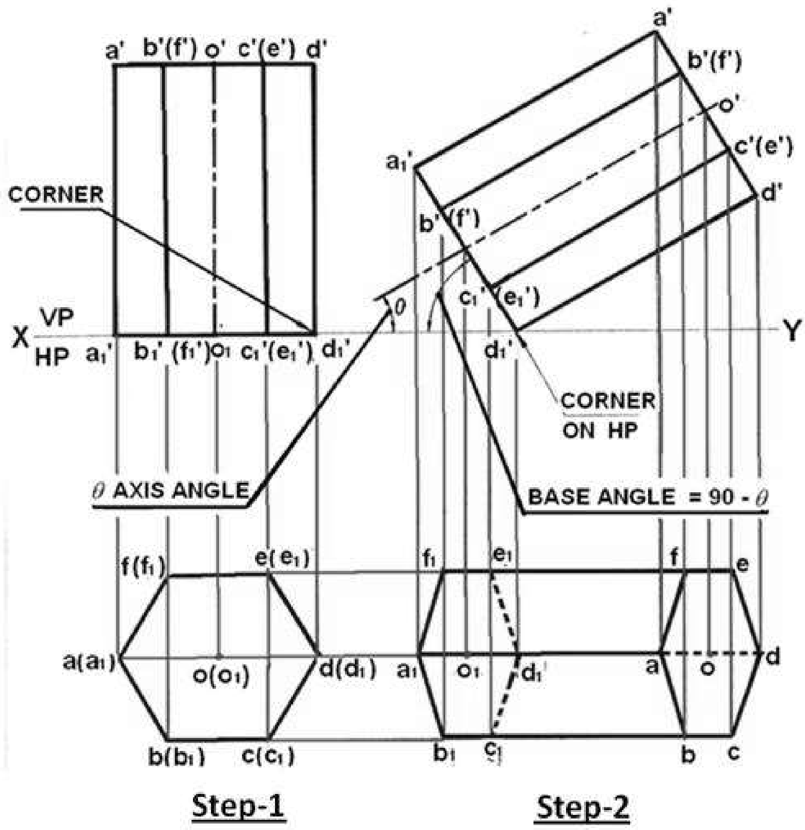


Figure 2: Projections of a prism with a corner of the base on HP and the axis is inclined to HP.

Since the prism has to lie on one of its corners of the base on HP, the front view of the prism is tilted on the corner d_1' such that the axis is inclined at q to HP. Redraw the front view in the tilted position as shown in Step-2 of figure-2. The base edge is drawn at (90- θ) in the front view. The second top view is projected by drawing the vertical projectors from the corners of the second front view and horizontal projectors from the first top view.

Following the above procedure, the top and front views of the pyramid when it rests on HP on one of its base corners such that the two base edges containing the corner on which it rests make equal inclinations with HP is shown in figure 3.

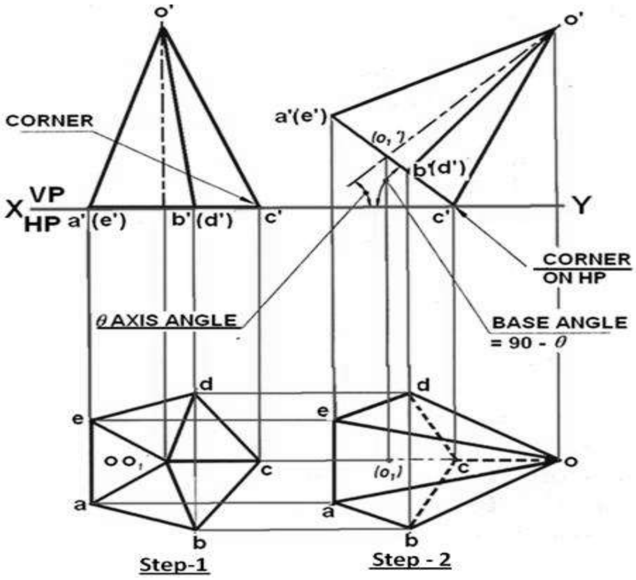


Figure 3 showing the projection of a pyramid resting on HP on one of its base corners with two base edges containing the corner on which it rests make equal inclinations with HP

c. Projections of a pyramid lying on one of its triangular faces on HP

If a pyramid has to be placed on one of its triangular faces on HP, then initially let the pyramid be placed with its base on HP such that the base edge containing that face is perpendicular to VP. (i.e. perpendicular to XY line). Figure 4 illustrates the sequence in obtaining the projections of the pyramid. In the first front view, the inclined line, **o'c'(d')** represents a triangular face. Redraw the front view such that the line representing the triangular face **o'c'(d')** lies on HP. Project the top view in this position.

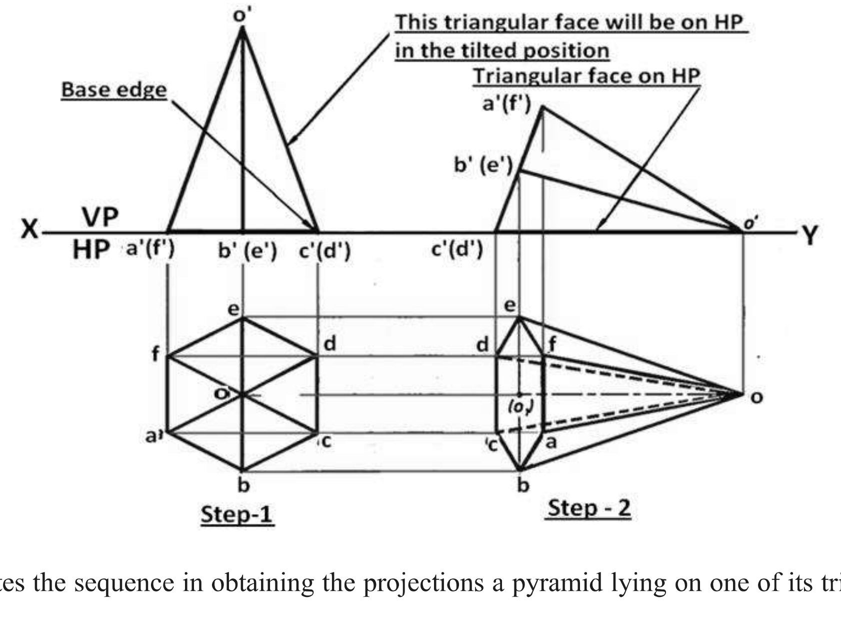


Figure 4 Illustrates the sequence in obtaining the projections a pyramid lying on one of its triangular faces on HP

d. Projections of a pyramid lying on one of its slant edge HP

The sequence of obtaining the projections of a pyramid lying on one of its slant edge on HP is shown in figure 5. In step-1, The FV and TV of the pyramid in the simple projection is drawn such that in the, top view the slant edge (line cd) on which it will rest on ground is drawn parallel to HP (parallel to XY line) in the. In the front view this edge will be line c' o'. In step-2, the object is then rotated such that the pyramid lies with its edge o'c' on HP. i.e. in the front view, o'c' lies on XY line. Project the Top view from this Front view.

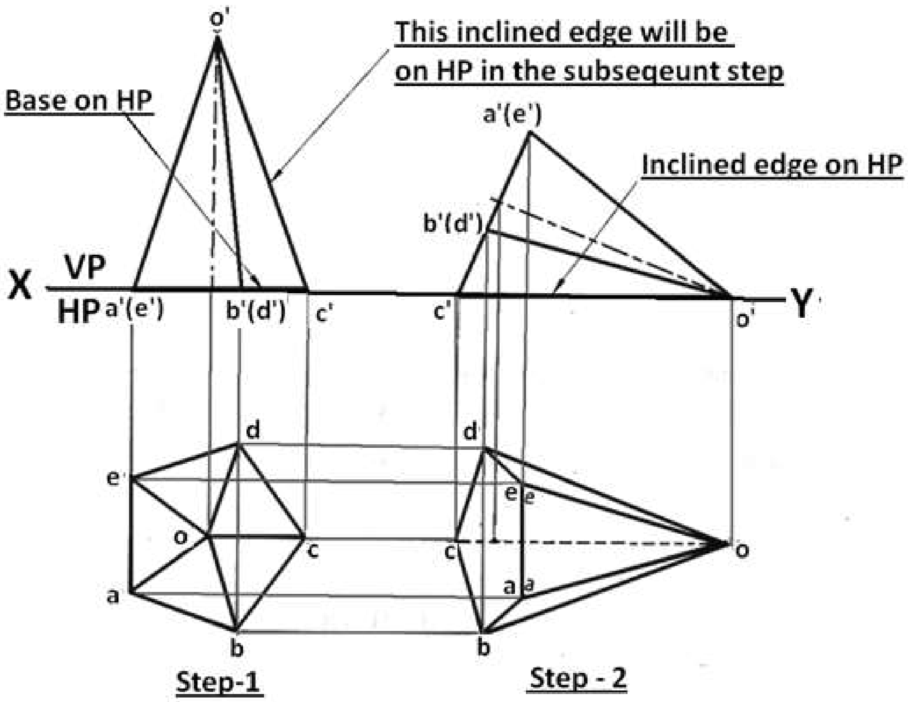


Figure 5. Projections of a pyramid lying on one of its slant edges on HP

Problem 1.
A cube of 30 mm sides is held on one of its corners on HP such that the bottom square face containing that corner is inclined at 30^0 to HP. Two of its adjacent base edges containing the corner on which it rests are equally inclined to VP. Draw the top and front views of the cube.

Solution:
The procedure of obtaining the projections is shown in figure 6. InStep-1, the projections of the cube is drawn in the simple position. The cube is assumed to lie with one of its faces completely on HP such that two vertical faces make equal inclinations with VP. Draw a square abcd to represent the top view of the cube such that two of its sides make equal inclinations with the XY line, i.e., with VP. Let (a_1), (b_1), (c_1) and (d_1) be the four corners of the bottom face of the cube which coincide in the top view with the corners a, b, c and d of the top face. Project the front view of the cube. The bottom face a_1'b_1'c_1'(d_1') in the front view coincide with the XY line. Now the cube is tilted on the bottom right corner c_1' (step-2) such that the bottom face a_1'b_1'c_1'(d_1') is inclined at 30^0 to HP. Reproduce the front view with face a_1'b_1'c_1'(d_1') inclined at 30^0 to the XY line. Draw the vertical projectors through all the corners in the reproduced front view and horizontal projectors through the corners of the first top view. These projectors intersect each other to give the corresponding corners in the top view

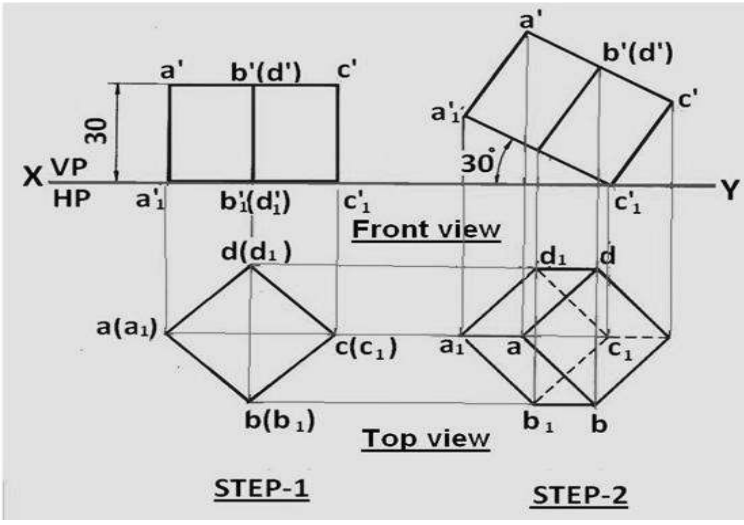


Figure 1. The projections of the cube of problem 1.

Problem-2.

A cube of 30 mm side rests with one of its edges on HP such that one of the square faces containing that edge is inclined at 30^0 to HP and the edge on which it rests being inclined to 60^0 to VP. Draw its projections.

Solution.

The procedure of obtaining the projections is shown in figure 7. First the TV and FV of the cube is drawn with the cube in the simple position. The edge bc is drawn perpendicular to the XY line. In step2, the cube is tilted such that the base of the cube is inclined at 30^0 to HP. The front view is reproduced with b1' c1'a1'd1' inclined at 30^0 to XY. The top view of the cube in step-2 is obtained by drawing projectors mentioned in problem 1. In step-3, the top view in step-2 is rotated such that line c1 b1 is inclined at 60^0 to XY line. The front view in step-2 is obtained by drawing projectors from the top view in step-3 and Front view in Step-2.

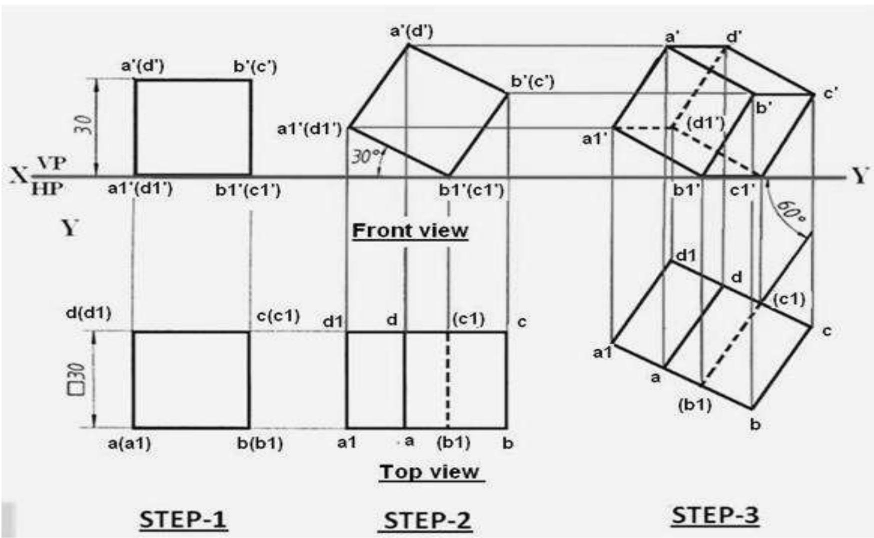


Figure 2. The projections of the cube of problem 2.

Problem 3

An equilateral triangular prism 20 mm side of base and 50 mm long rests with one of its shorter edges on HP such that the rectangular face containing the edge on which the prism rests is inclined at 30^0 to HP. The edge on which prism rests is inclined at 60^0 to VP. Draw its projections.

Solution: The procedure of obtaining the projections is shown in figure 8. The prism rests with one of its shorter edges, i.e., triangular or base edge on HP such that the rectangular face containing that edge is inclined at 30^0 to HP.

Draw the simple views of the prism when it rests with one of its triangular faces, i.e., base completely lying on HP and also with one of its shorter edges perpendicular to VP, i.e., to XY line. The shorter edge $(b_1)(c_1)$ is perpendicular to the XY line. The rectangular face containing the edge $b_1'(c_1')$ is $b_1'b'(c')(c_1')$.

Now tilt the prism on the edge $b_1'(c_1')$ such that the rectangular face $b_1'b'(c')(c_1')$ is inclined at 30^0 to the XY line. In this tilted position, project the top view.

It is seen that the edge b_1c_1 in the top view shown is perpendicular to VP, i.e, to XY line. But the edge b_1c_1 has to be inclined at 60^0 to VP, i.e, to XY line.

Therefore, reproduce the top view with the edge b_1c_1 inclined at 60^0 to the XY line as shown in the top view. Project the reproduced top view to get the front view.

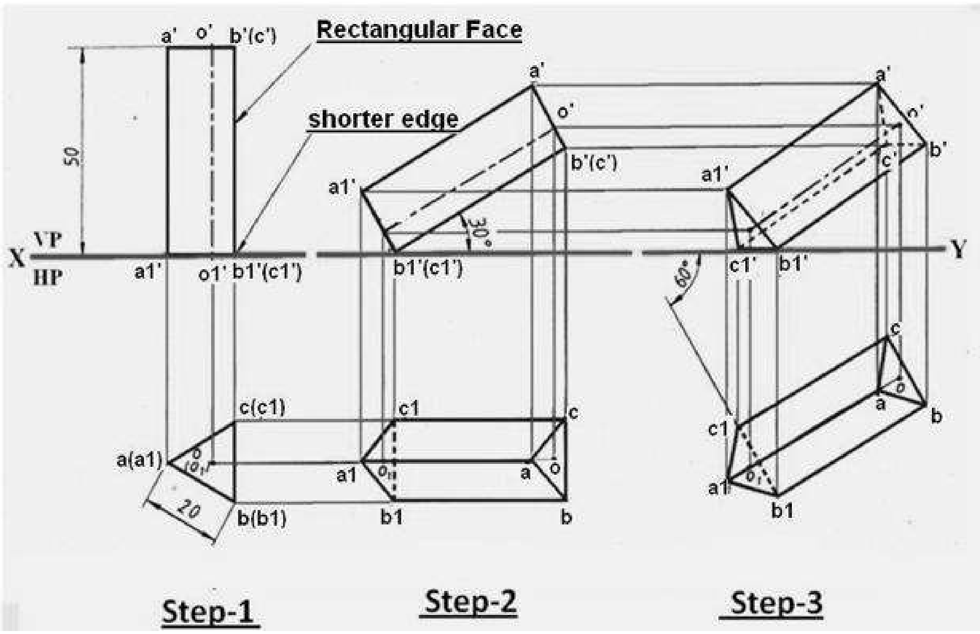


Figure 3. The projections of the triangular prism of problem-3

Problem-4
A hexagonal pyramid has an altitude of 60 mm and side base 30mm. The pyramid rests on one of its side of the base on HP such that the triangular face containing that side is perpendicular to HP. Draw the front and top views.

Solution: The solution the problem is shown in figure 9. In step-1, the pyramid is drawn in the simple position with base edge cd perpendicular to XY line. In Step-2, the Front view is tilted about cd such that line o'c'd' is made perpendicular to XY line. The top view is obtained by drawing projectors from the top view of step 1 and front view in step-2.

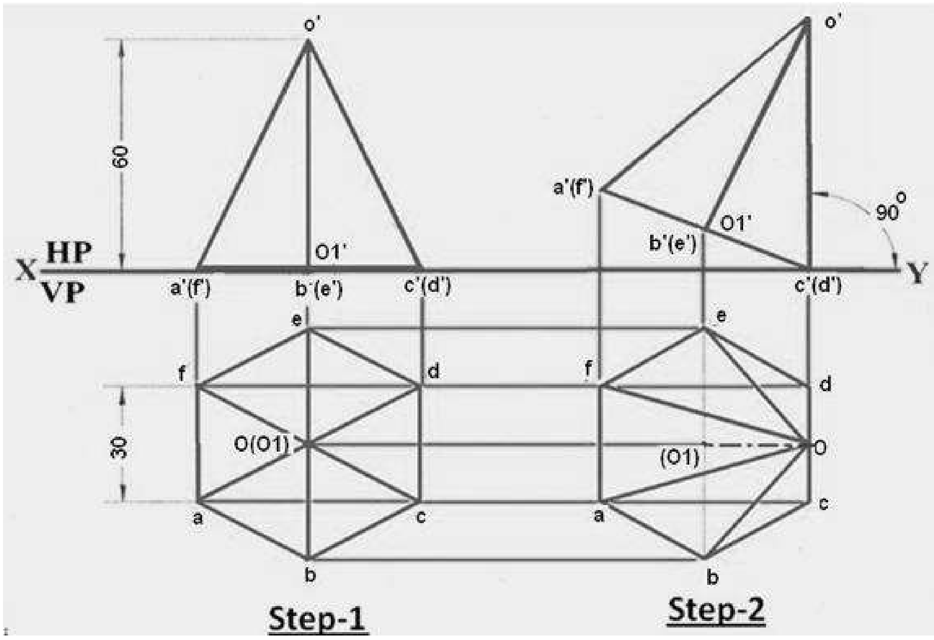


Figure 4. The projections of the hexagonal pyramid of problem-4.

Problem-5
Problem Draw the top and front views of a rectangular pyramid of sides of base 40x 50 mm and height 70 mm when it lies on one of its larger triangular faces on HP. The longer edge of the base of the triangular face lying on HP is inclined at 60° to VP in the top view with the apex of the pyramid being nearer to VP.

Solution :
The solution the problem is shown in figure 5. The projectors are obtained in 3-steps as illustrated in the figure. In the first step, the solid is projected in the simple position with base BC perpendicular to VP. In the second step, the solid is tilted about the edge BC such that the face BCO is made to lie on the ground. The front view is rotated and the top view is projected from the front view and the top view in the first step. In step-3, the top view is rotated such that edge BC is inclined at 60° to XY line . The Front view is projected using this top view and Front view of Step-2.

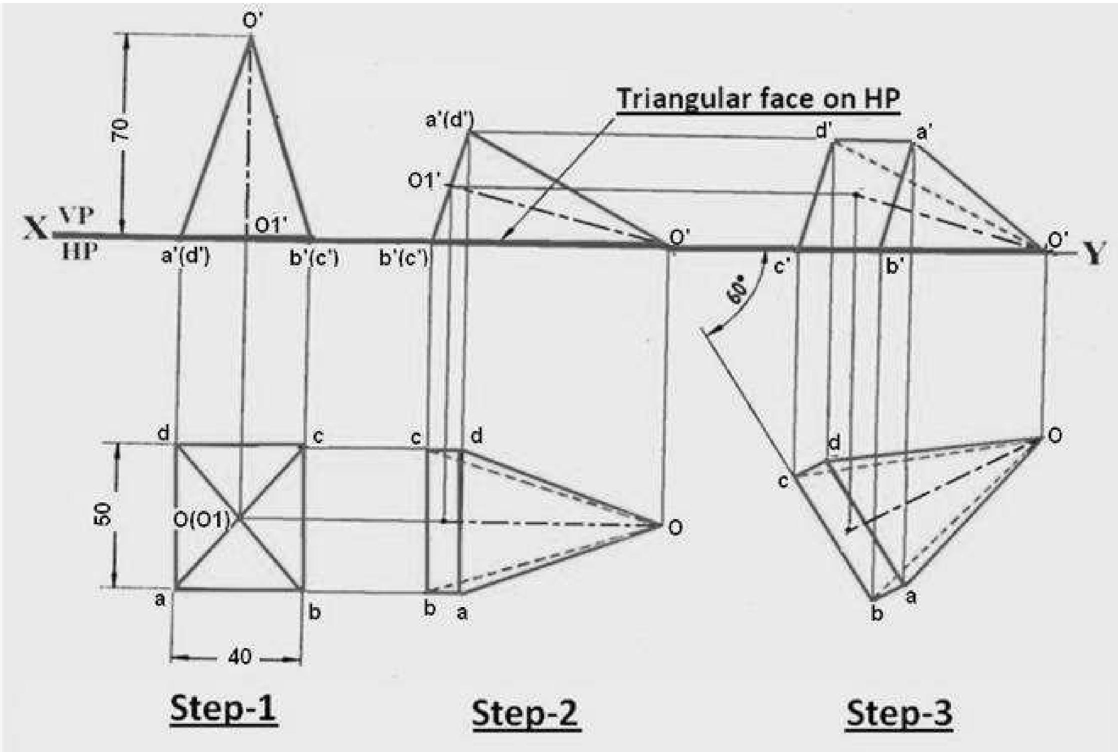


Figure 5. The projections of the rectangular pyramid of problem-5.

Problem-6

A cone of base 80 mm diameter and height 100 mm lies with one of its generators on HP and the axis appears to be inclined to VP at an angle of 40^0 in the top view. Draw its top and front views.

Solution:

Figure 6 illustrates the procedure for obtaining the projections of the cone. Three steps are involved. In step-1, the Top view and Front View of the cone is drawn in the simple position. The base circle is divided in to 12 equal parts. These points ate joined with the apex to obtain the respective generators. Instep 2, the cone is tilted such that the cone lies on one of its generator in the HP. i.e. the generator g'o' is made to coincide with the XY line. The top view of the object in this condition is drawn by drawing projectors. In step-3, the cone is titled such that in the top view the axis is inclined at 400 to the XY line. The front view of the object is obtained by projection technique.

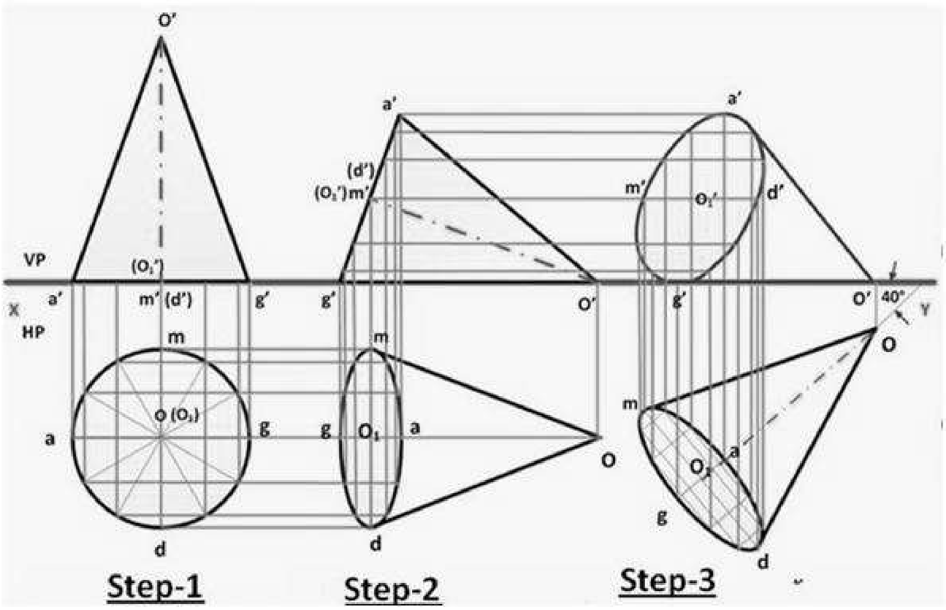


Figure 6. The projections of the cone of problem-6.

Problem-7

Draw the top and the front views of a right circular cylinder of base 45 mm diameter and 60 mm long when it lies on HP such that its axis is inclined at 35^0 to HP and the axis appears to be perpendicular to VP in the top view.

Solution:

The solution to the problem is illustrated in figure-7 . Three steps are involved as shown in the figure. In Step-1, the cylinder is drawn in the simple position (resting on the base on HP). The circle in the top view is dived in to 12 equal parts and then projected in to the front view. In step-2, The Front view is rotated about g1 such that the axis is inclined at 35° to HP (or XYline). The top view is projected from this front view with thehelp of Top view in step-1. . In step 3, the top view is rotated such that axis is perpendicular to XY line. The front view is then projected from the top view.

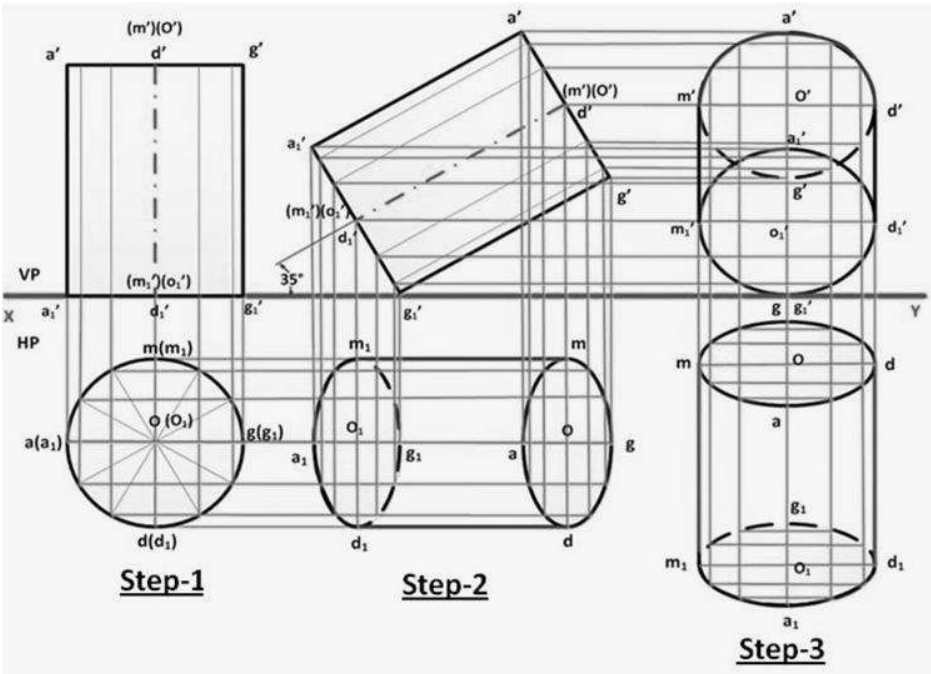
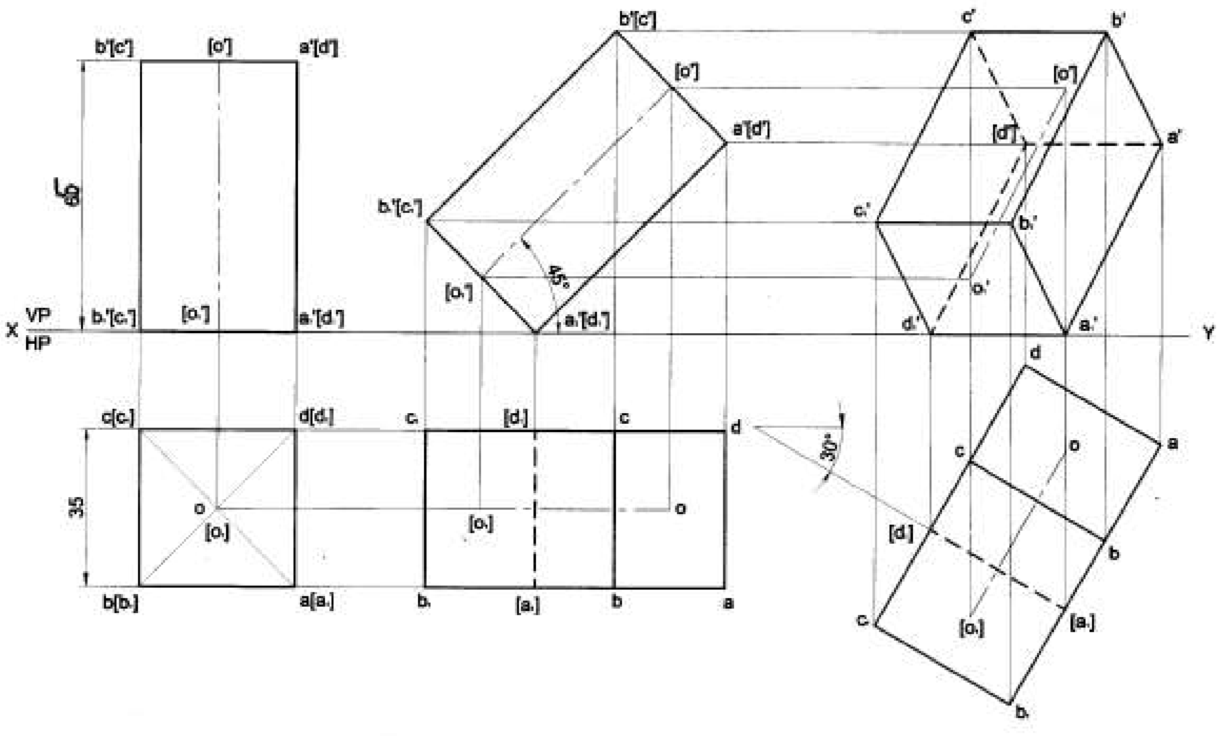


Figure 7. The projections of the cylinder as per problem-7.

Worked Examples- Projection of Solids

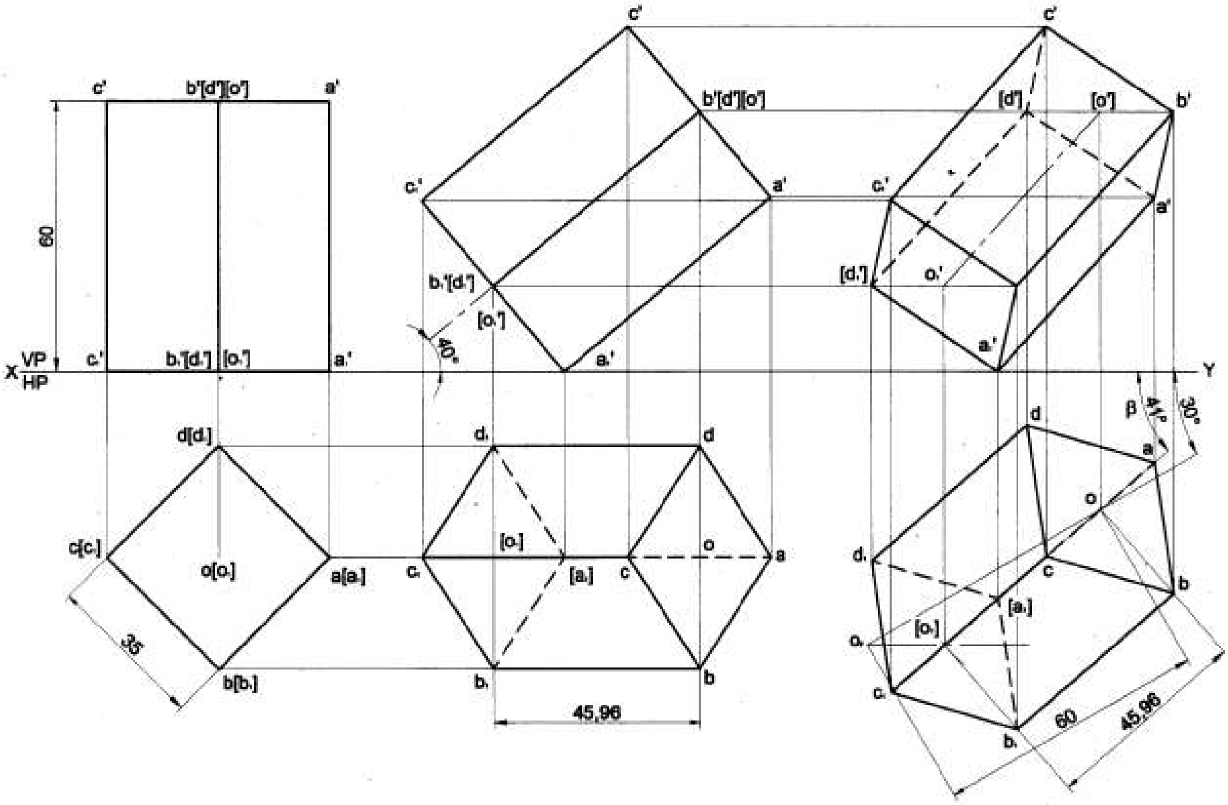
Problem 1 A square prism 35 mm sides of base and 65 mm axis length rests on HP on one of its edges of the base which is inclined to VP at 30º. Draw the projections of the prism when the axis is inclined to HP at 45º.

Solution



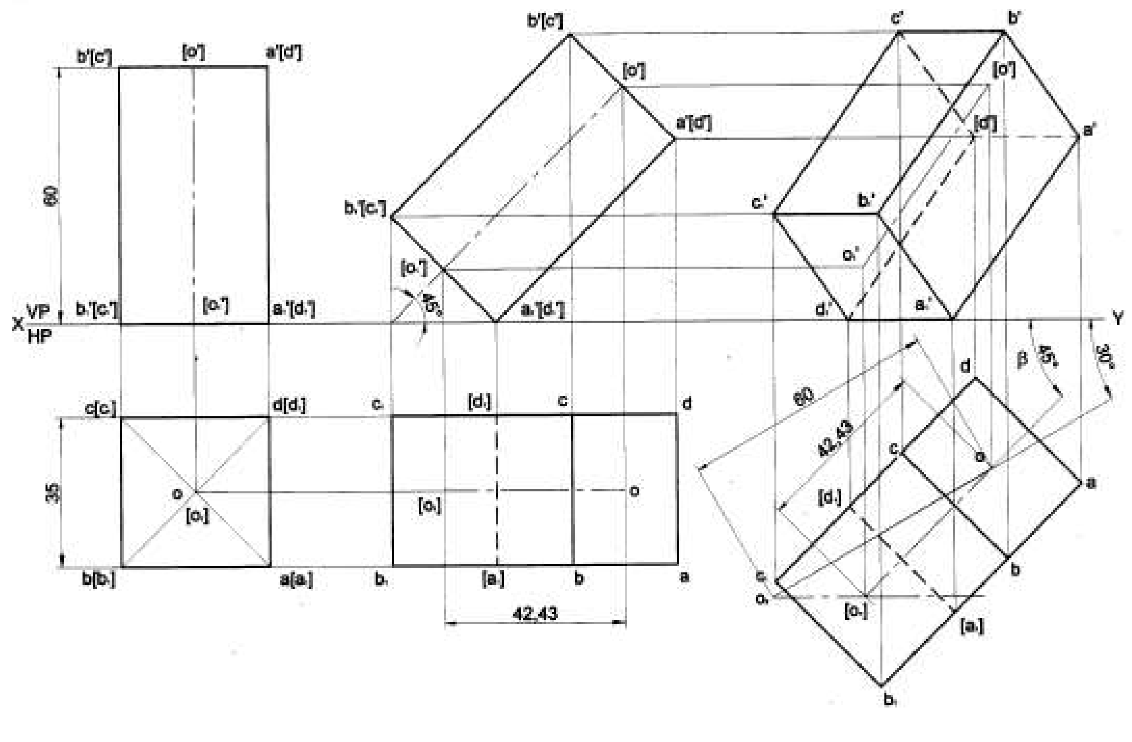
Problem 3 A square prism 35 mm sides of base and 60 mm axis length rests on HP on one of its corners of the base such that the two base edges containing the corner on which it rests make equal inclinations with HP. Draw the projections of the prism when the axis of the prism is inclined to HP at 40º and to VP at 30º.

Solution



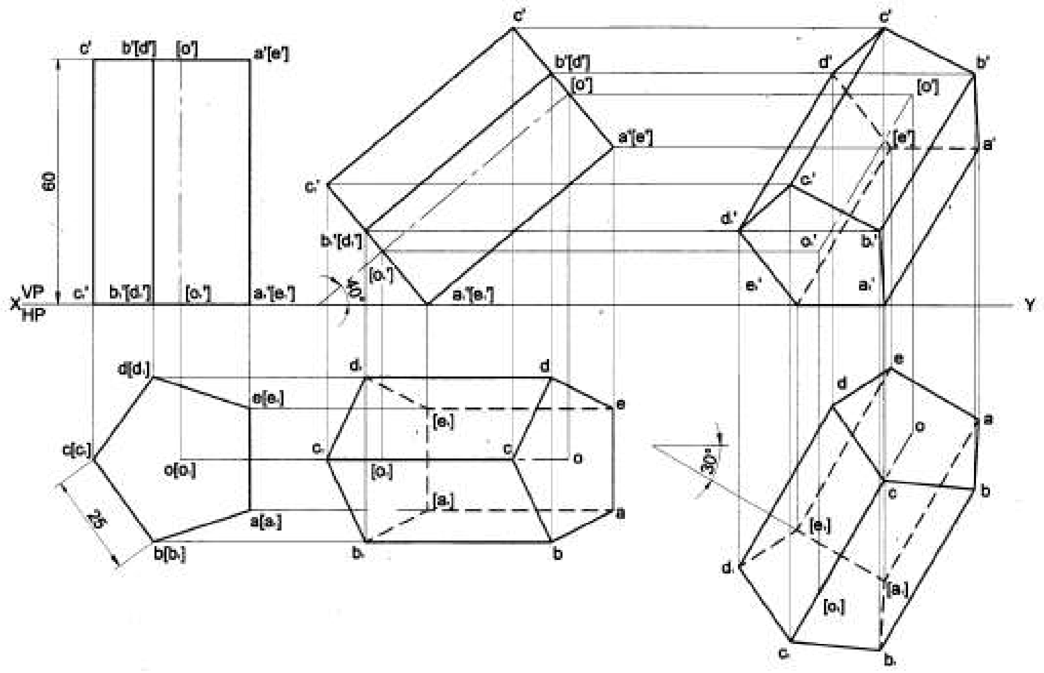
Problem 4 A square prism 35 mm sides of base and 60 mm axis length rests on HP on one of its edges of the base. Draw the projections of the prism when the axis is inclined to HP at 45º and VP at 30º.

Solution



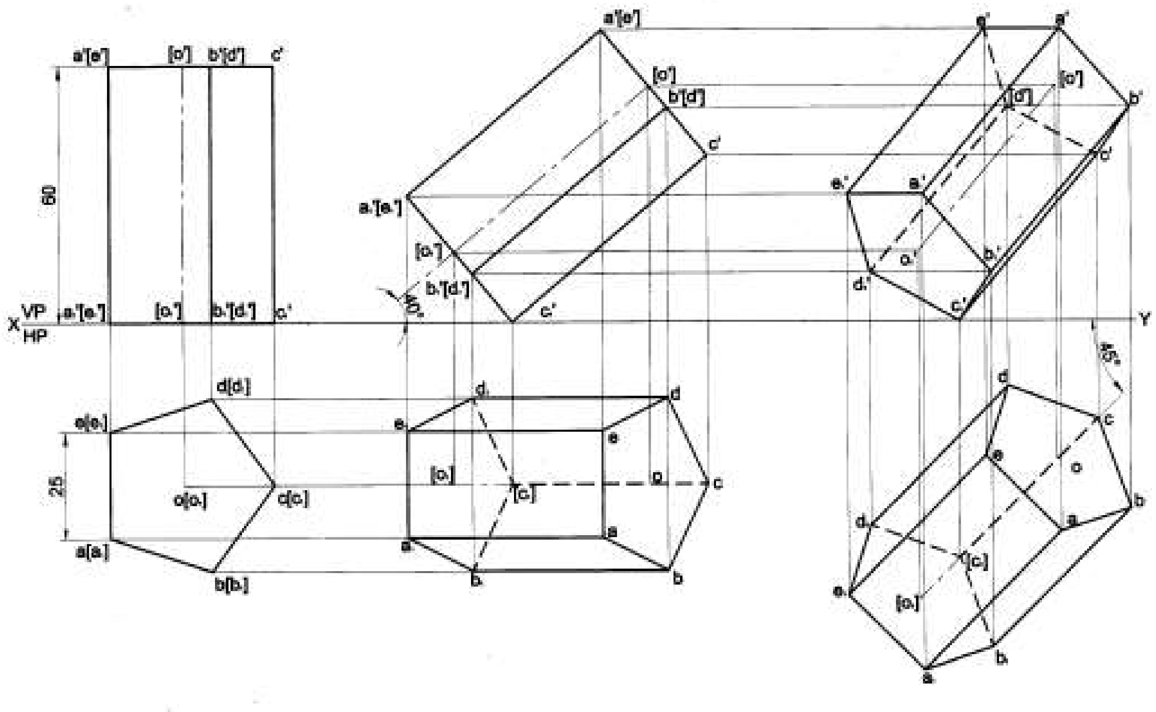
Problem 5 A pentagonal prism 25 mm sides of base and 60 mm axis length rests on HP on one of its edges of the base which is inclined to VP at 30º. Draw the projections of the prism when the axis is inclined to HP at 40º.

Solution



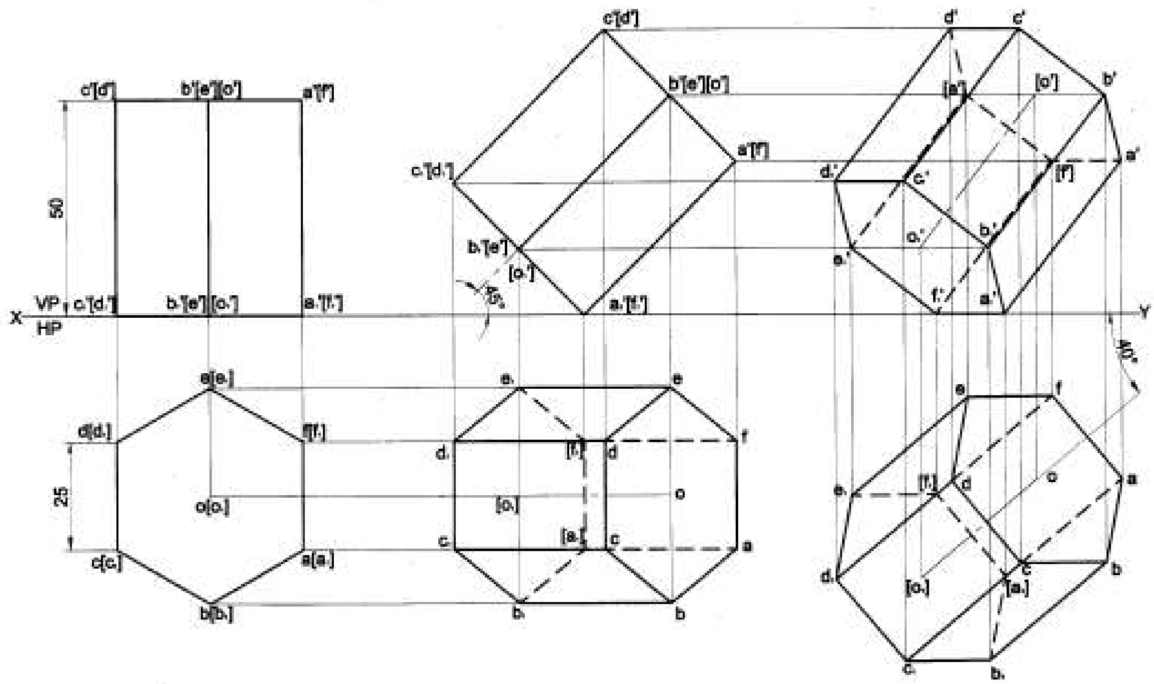
Problem 7 A pentagonal prism 25 mm sides of base and 50 mm axis length rests on HP on one of its corners of the base such that the two base edges containing the corner on which it rests make equal inclinations with HP. Draw the projections of the prism when the axis of the prism is inclined to HP at 40º and appears to be inclined to VP at 45º.

Solution



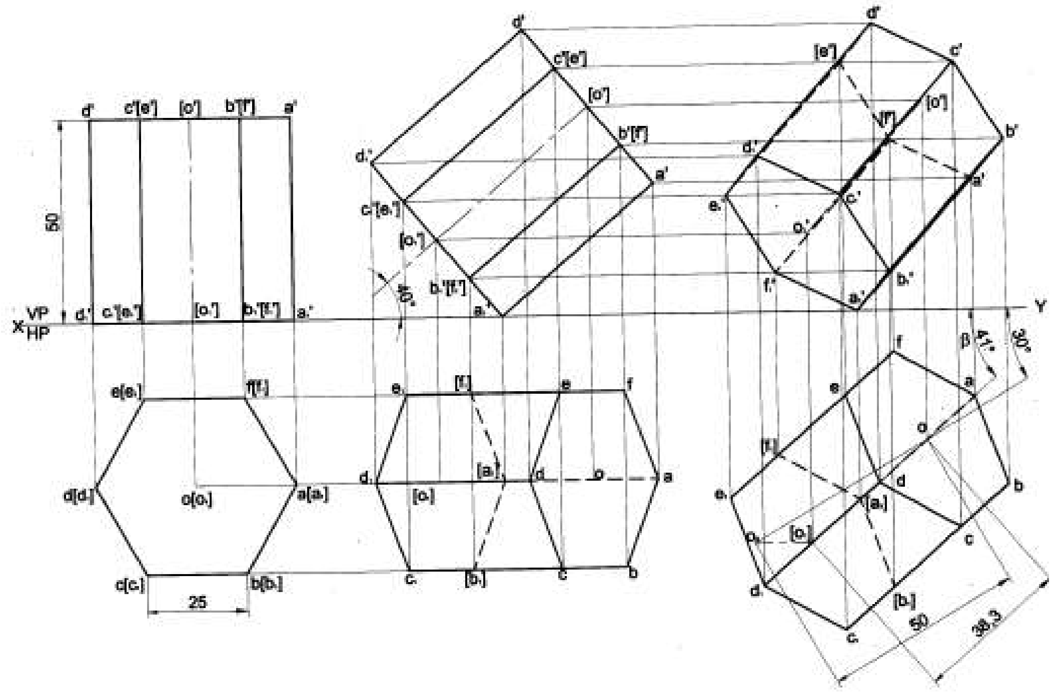
Problem 9 A hexagonal prism 25 mm sides of base and 50 mm axis length rests on HP on one of its edges. Draw the projections of the prism when the axis is inclined to HP at 45º and appears to be inclined to VP 40º.

Solution



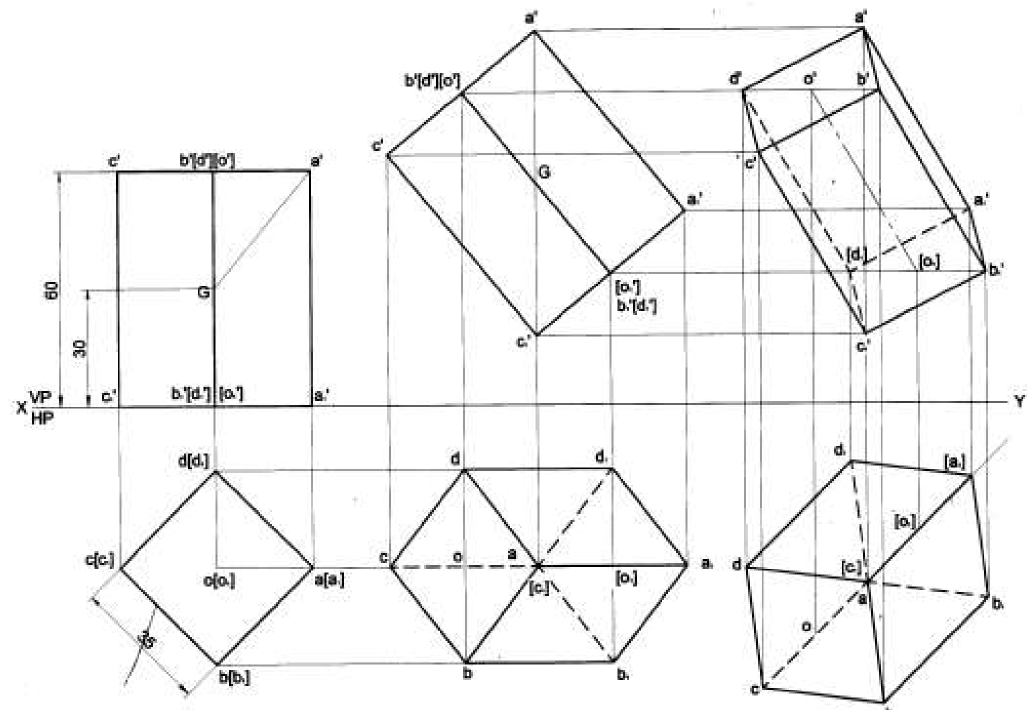
Problem 12 A hexagonal prism 25 mm sides of base and 50 mm axis length rests on HP on one of its corners of the base such that the two base edges containing the corner on which it rests make equal inclinations with HP. Draw the projections of the prism when the axis of the prism is inclined to HP at 40º and to VP at 30º.

Solution



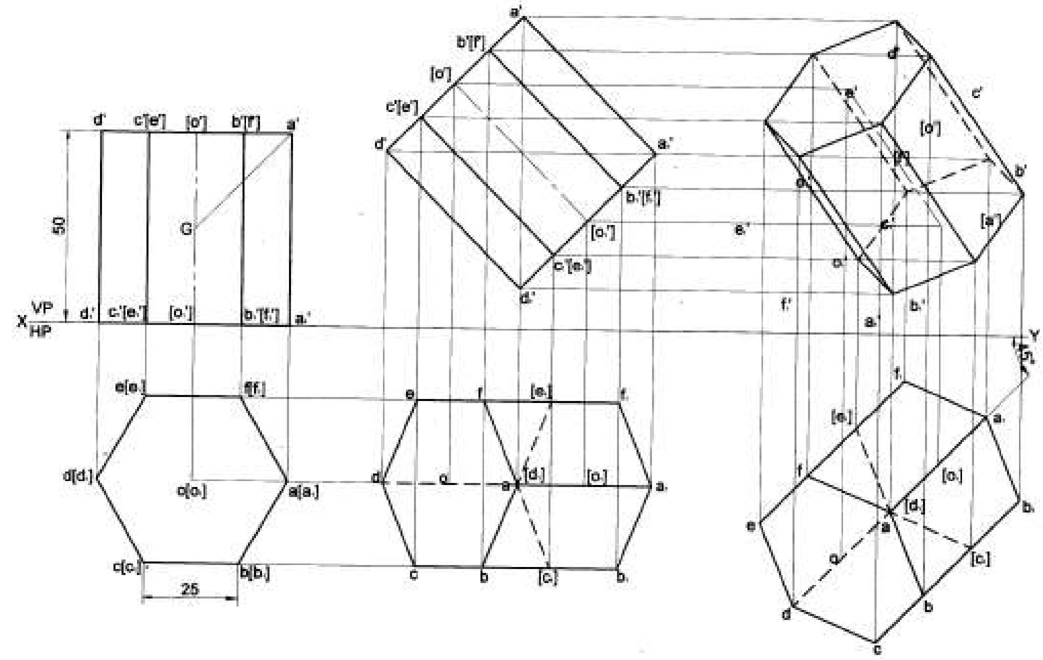
Problem 13 A square prism 35 mm sides of base and 60 mm axis length is suspended freely from a corner of its base. Draw the projections of the prism when the axis appears to be inclined to VP at 45º.

Solution



Problem 15 A hexagonal prism 25 mm sides of base and 50 mm axis length is suspended freely from a corner of its base. Draw the projections of the prism when the axis appears to be inclined to VP at 45º.

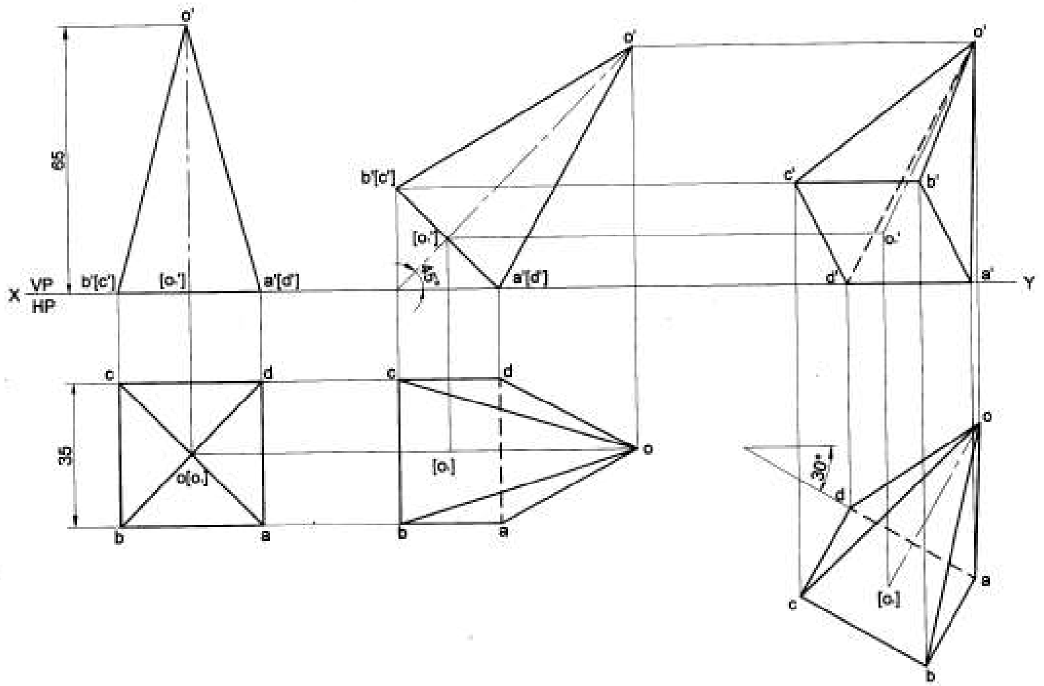
Solution



X
VP
HP
Y
50
25
G
d'
c'[e']
[o']
b'[f']
a'
d₁'
c₁'[e₁']
[o₁']
b₁'[f₁']
a₁'
e[e₁]
f[f₁]
d[d₁]
o[o₁]
a[a₁]
c[c₁]
b[b₁]

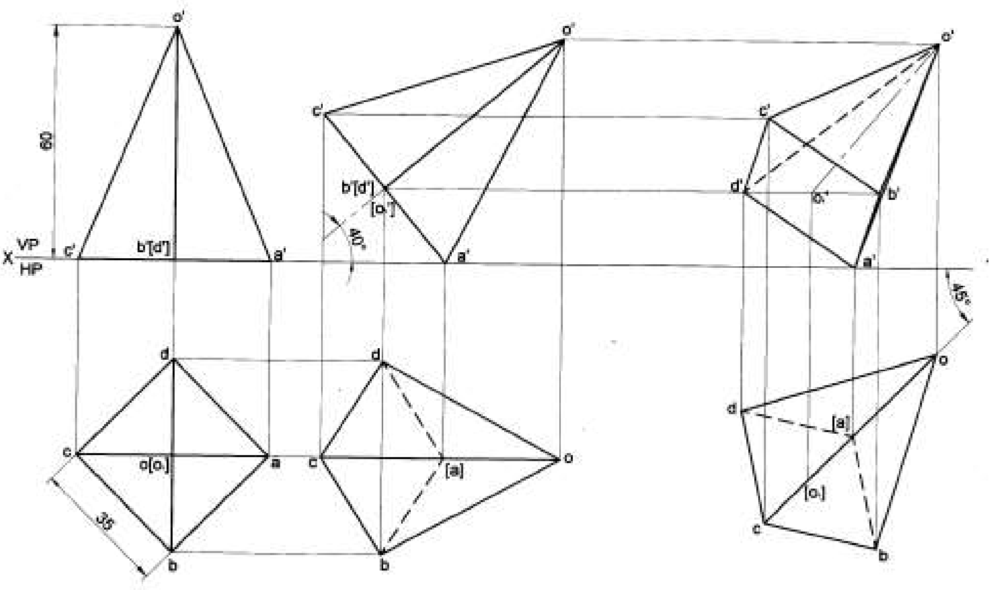
Problem 16A square pyramid 35 mm sides of base and 65 mm axis length rests on HP on one of its edges of the base which is inclined to VP at 30º. Draw the projections of the pyramid when the axis is inclined to HP at 45º.

Solution



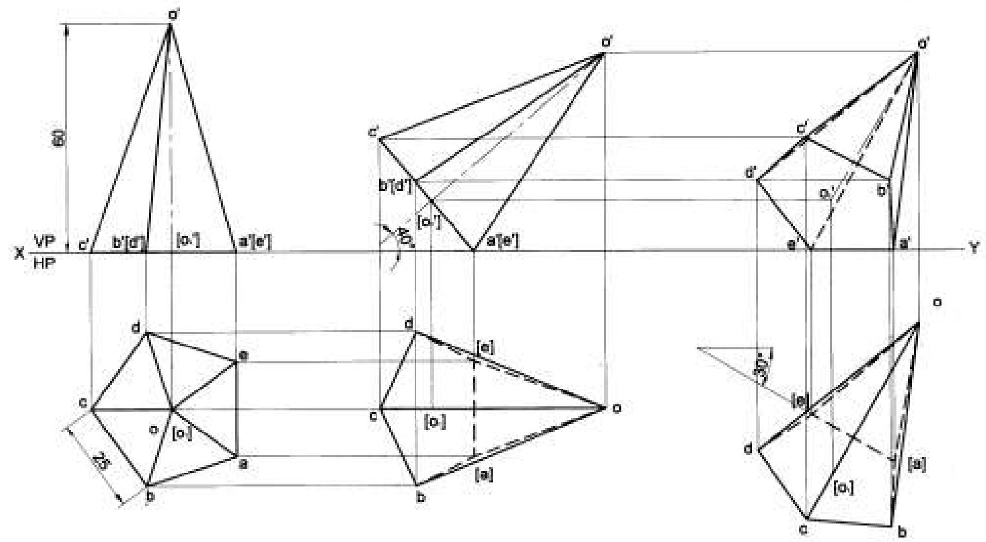
Problem 17 A square pyramid 35 mm sides of base and 60 mm axis length rests on HP on one of its corners of the base such that the two base edges containing the corner on which it rests make equal inclinations with HP. Draw the projections of the pyramid when the axis of the pyramid is inclined to HP at 40º and appears to be inclined to VP at 45º.

Solution



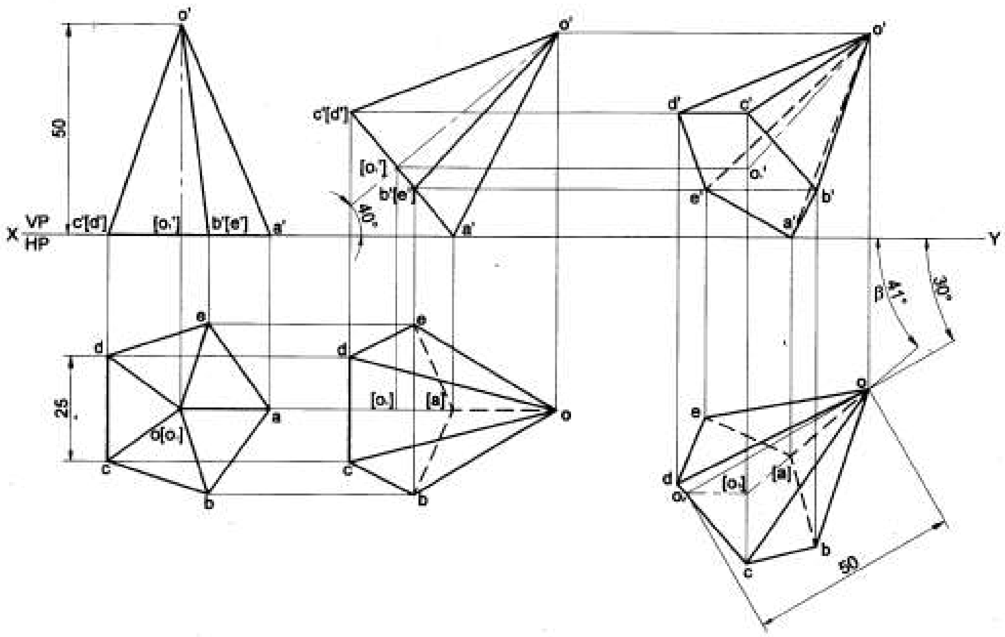
Problem 20 A pentagonal pyramid 25 mm sides of base and 60 mm axis length rests on HP on one of its edges of the base which is inclined to VP at 30º. Draw the projections of the pyramid when the axis is inclined to HP at 40º.

Solution



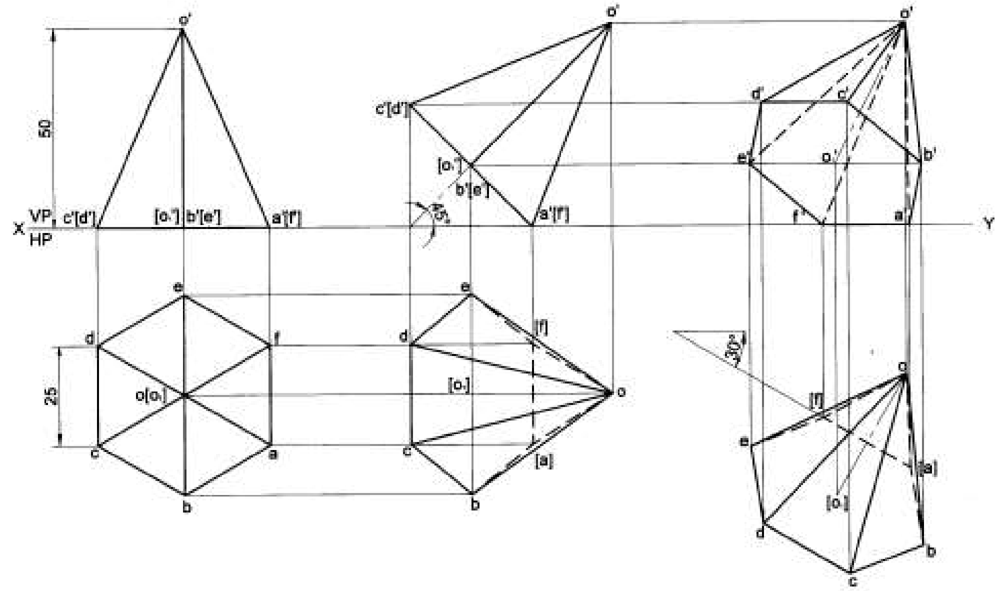
Problem 23 A pentagonal pyramid 25 mm sides of base and 50 mm axis length rests on HP on one of its corners of the base such that the two base edges containing the corner on which it rests make equal inclinations with HP. Draw the projections of the pyramid when the axis of the pyramid is inclined to HP at 40º and to VP at 30º.

Solution



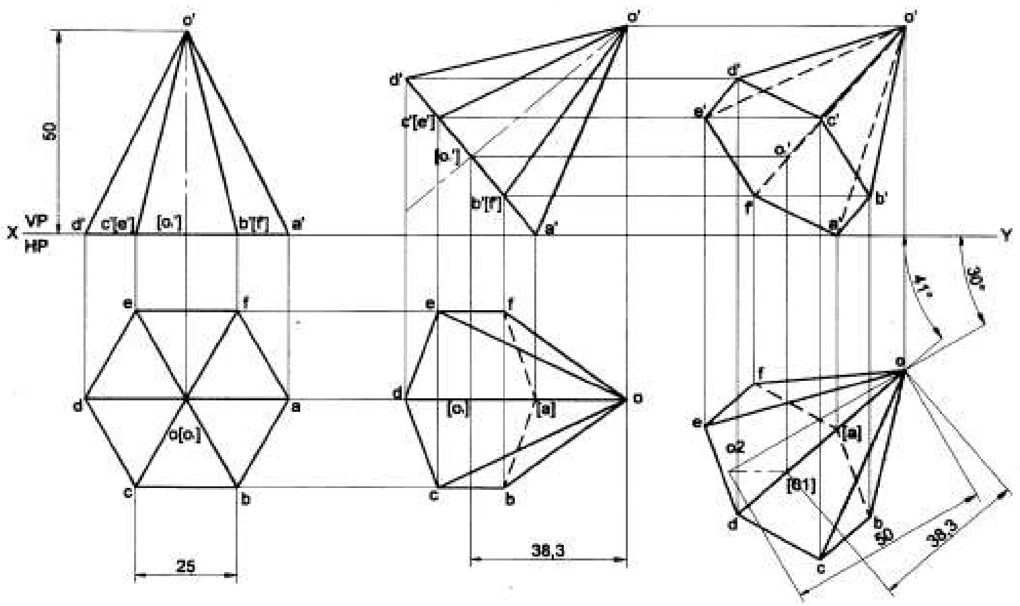
Problem 24 A hexagonal pyramid 25 mm sides of base and 50 mm axis length rests on HP on one of its edges of the base which is inclined to VP at 30º. Draw the projections of the pyramid when the axis is inclined to HP at 45º.

Solution



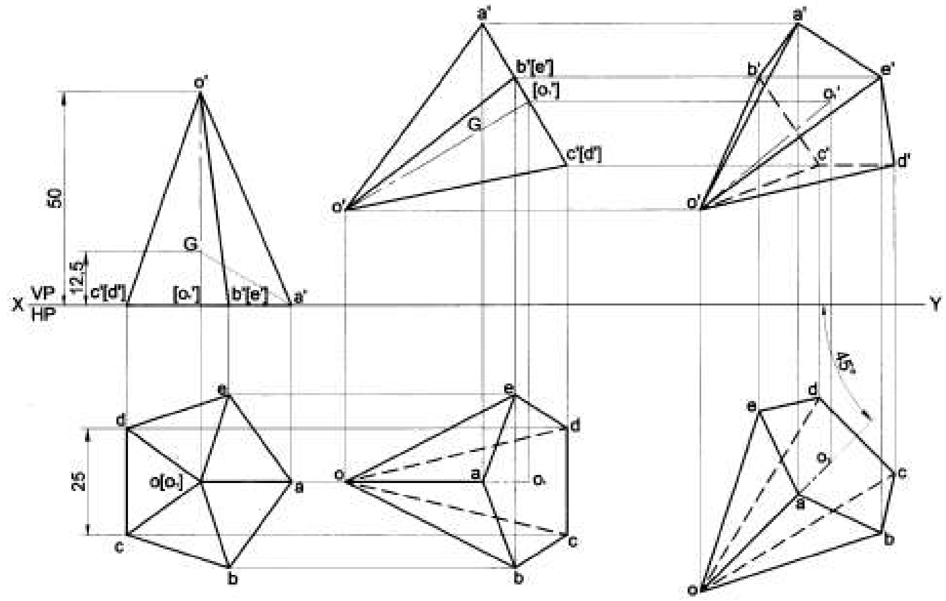
Problem 27 A hexagonal pyramid 25 mm sides of base and 50 mm axis length rests on HP on one of its corners of the base such that the two base edges containing the corner on which it rests make equal inclinations with HP. Draw the projections of the pyramid when the axis of the pyramid is inclined to HP at 40º and to VP at 30º.

Solution



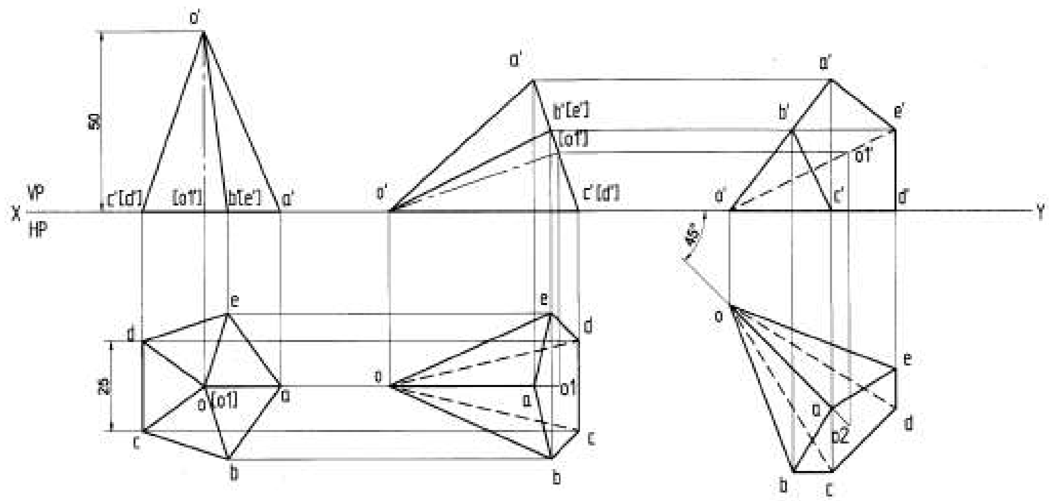
Problem 29 A pentagonal pyramid 25 mm sides of base and 50 mm axis length is suspended freely from a corner c its base. Draw the projections of the pyramid when the axis appears to be inclined to VP at 45º.

Solution



Problem 37 A pentagonal pyramid 25 mm sides of base and 50 mm axis length rests on HP on one of its slant triangular faces. Draw the projections of the pyramid when the axis appears to be inclined to VP at 45º.

Solution



Problems on Solids

1. A pentagonal pyramid 25 mm sides of base and 60 mm axis length rests on HP on one of its edges of the base which is inclined to VP at 30°. Draw the projections of the pyramid rests HP on one of its edges of the base which is inclined to VP at 30°. Draw the projections of the pyramid when the axis is inclined to HP at 40°.
2. A pentagonal pyramid 25 mm sides of base and 50 mm sides of base and 50 mm axis length rests on HP on one of its edges of the base. Draw the projections of the pyramid when the is inclined to HP at 45° and VP at 30°.
3. A pentagonal pyramid 25 mm sides of base and 50 mm axis length rests on HP on one of its corners of the base such that the two base edges containing the corner on which it rests make equal inclinations with HP. Draw the projections of the pyramid when the axis of the pyramid inclined to HP at 40° and appears to be inclined to VP at 45°.

4. A pentagonal pyramid 25 mm sides of base and 50 mm axis length rests on HP on one of its corners of the vase such that the two base edges containing the corner on which it rests make equal inclined with HP. Draw the projections of the pyramid when the axis of the pyramid is inclined to HP at 40° and to VP at 30°.
5. A hexagonal pyramid 25 mm sides of base and 50 mm axis length rests on HP on one of its edges of the base which is inclined to VP at 30°. Draw the projections of the pyramid when the axis is inclined to HP at 45°.
6. A hexagonal pyramid 25 mm sides of base and 50 mm axis length rests on HP on one of its edges of the base. Draw the projection of the pyramid when the axis is inclined to HP at 45° and VP at 30°.
7. A hexagonal pyramid 25 mm sides of base and 50 mm axis length rests on one of its corners of the base such that the two base containing the corner on which it rests make equal inclinations with HP. Draw the projections of the pyramid on when the axis of the pyramid is inclined to HP at 40° and appears to be inclined to VP at 45°.
8. A hexagonal pyramid 25 mm sides of base and 50 mm axis length rests on HP on one of its corners of the base such that the two base edges containing the corner on which it rests make equal inclinations with HP. Draw the projections of the pyramid when the axis of the pyramid is inclined to HP at 40° and to VP at 30°.
9. A square pyramid 35 mm sides of base and 60 mm axis length is suspended freely from a corner of its base. Draw the projections of the pyramid when the axis appears to be inclined to VP at 45°.
10. A pentagonal pyramid 25 mm sides of base and 50 mm axis length is suspended freely from a corner of its base. Draw the projections of the pyramid when the appears to be inclined to VP at 45°.
11. A hexagonal pyramid 25 mm sides of base and 50 mm axis length is suspended freely from a corner of its base. Draw the projections of the pyramid when the axis appears to be inclined to VP at 45°.
12. A square pyramid 35 mm sides of base and 60 mm axis length rests on HP on one of its slant edges. Draw the projections of the pyramid when the axis appears to be inclined to VP at 45°.
13. A square pyramid 35 mm sides of base and 60 mm axis length rests on HP on one of its slant5 edges. Draw the projections of the pyramid when the axis is inclined to VP at 45°.
14. A square pyramid 35 mm sides of base and 60 mm axis length rests on HP on one of its slant triangular faces. Draw the projections of the pyramid when the axis appears to be inclined to VP at 45°.

FURTHER READING:

1) Computer Aided Engineering Drawing - S. Trymbaka Murthy, - I.K. International Publishing House Pvt. Ltd., New Delhi, 3rd revised edition- 2006.
2) Engineering Graphics - K.R. Gopalakrishna, 32nd edition, 2005- Subash Publishers Bangalore.
3) Dhananjay A Jolhe, Engineering Drawing, Tata McGraw Hill, 2007.
4) M.B. Shah and B.C. Rana, Engineering Drawing, pearson Education, Eds. 2, 2009.
5) K. Venugopal, Engineering Drawing and Graphics, New Age International (P) Ltd., publishers, 2000.
6) N.D. Bhatt and V.M. Panchal, Engineering Drawing, Charotar Publishing house, 2005.

MODULE-4

SECTIONS AND DEVELOPMENT OF LATERAL SURFACES OF SOLIDS

OBJECTIVES:

1) To understand the basic concept of development
2) Development of lateral surface of prisms and cylinders when it is cut by section plane.
3) Development of lateral surface of pyramids and cone when it is cut by section plane.

LESSON CONTENT:

Introduction, Section planes, Sections, Section views, Sectional views, Apparent shapes and True shapes of Sections of right regular prisms, pyramids, cylinders and cones resting with base on HP. (No problems on sections of solids) Development of lateral surfaces of above solids, their frustums and truncations. (No problems on lateral surfaces of trays, tetrahedrons, spheres and transition pieces).

4.1 Development of surfaces

A development is the unfold / unrolled flat / plane figure of a 3-D object. It is also called a pattern where the plane may show the true size of each area of the object. When the pattern is cut, it can be rolled or folded back into the original object as shown in figure 1.

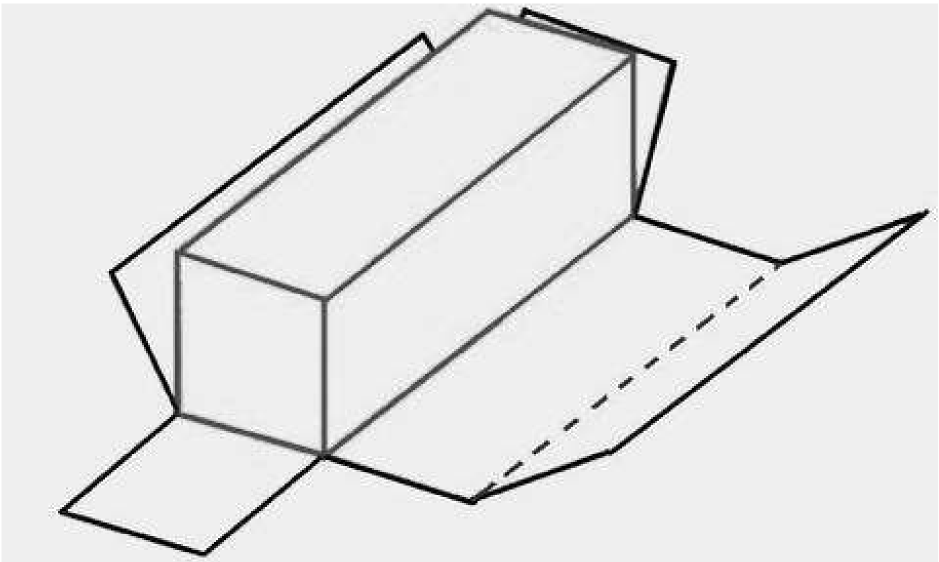


Figure 1. Typical development of the surface of a cuboid.

Types of development
There are three major types of development followed by industries. Examples are shown in figure 2.

1. **Parallel line development**: In this parallel lines are used to construct the expanded pattern of each three-dimensional shape. The method divides the surface into a series of parallel lines to determine the shape of a pattern.
2. **Radial line development**: In this, lines radiating from a central point to construct the expanded pattern of each three-dimensional shape is used. These shapes each form part of a cone and lines radiating from the vertex of the cone generate the expanded pattern of the curved surface as shown in the following explorations.
3. **Triangulation method**: This is generally used for polyhedron, single curved surfaces, and warped surfaces.
4. **Approximate development**: In this, the shapes obtained are only approximate. After joining, the part is stretched or distorted to obtain the final shape

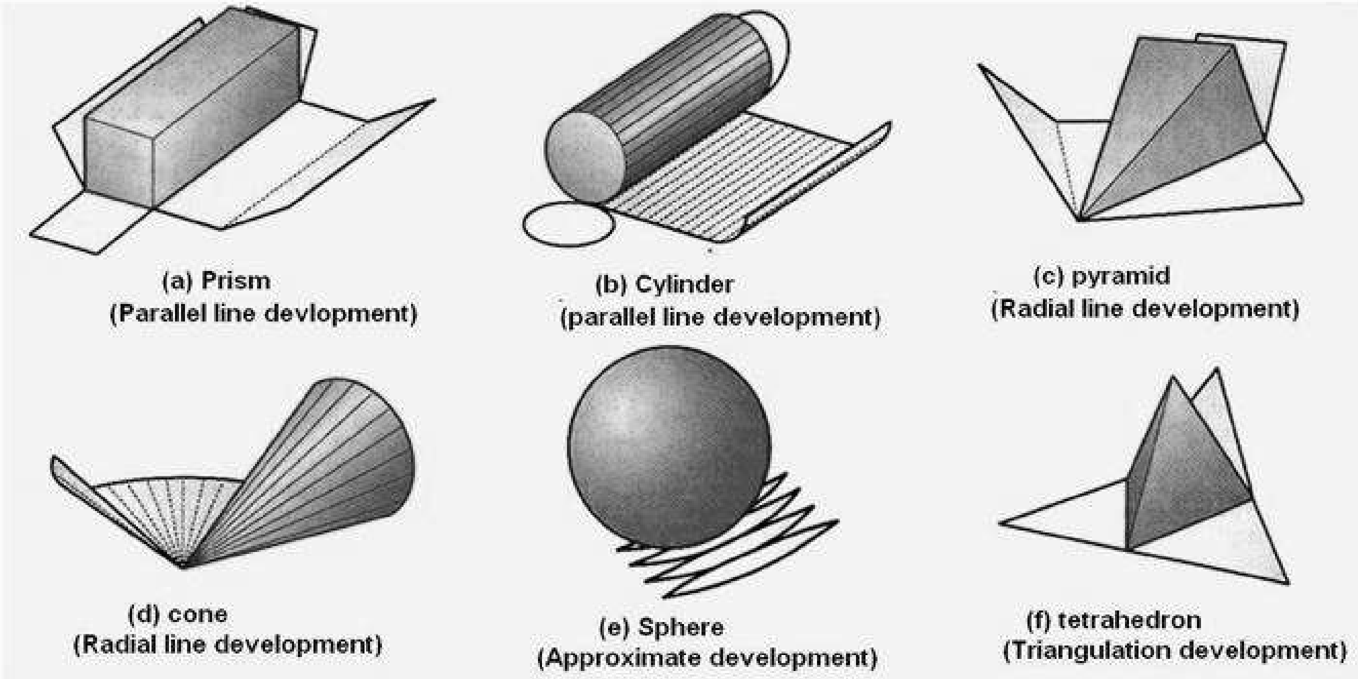


Figure 2. Typical examples of the various types of development.

A true development is one in which no stretching or distortion of the surfaces occurs and every surface of the development is the same size and shape as the corresponding surface on the 3-D object. e.g. polyhedrons and single curved surfaces. As illustrated in figure 3, polyhedrons are composed entirely of plane surfaces that can be flattened true size onto a plane in a connected sequence, where as single curved surfaces are composed of consecutive pairs of straight-line elements in the same plane which is obtained for a cone.

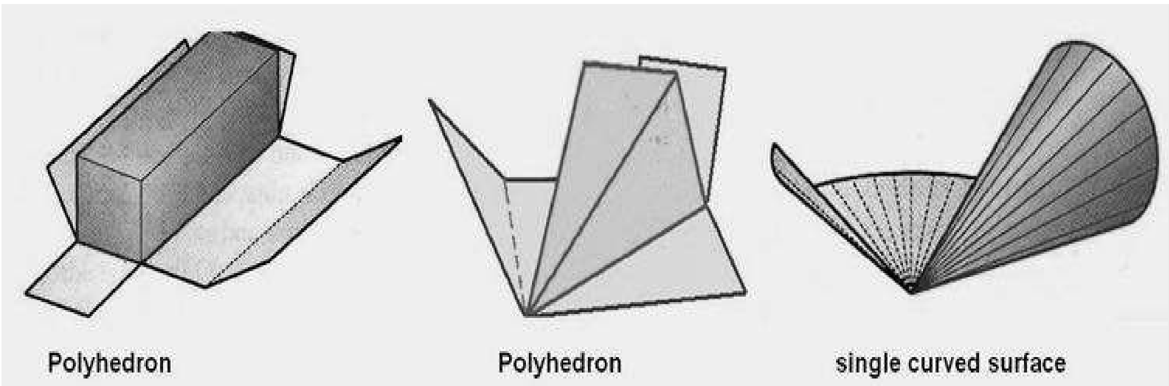


Figure 3. shows the true development obtained for polyhedrons and single curved surface

An approximate development is one in which stretching or distortion occurs in the process of creating the development. The resulting flat surfaces are not the same size and shape as the corresponding surfaces on the 3-D object. Wrapped surfaces do not produce true developments, because pairs of consecutive straight-line elements do not form a plane. Also double-curved surfaces, such as a sphere do not produce true developments, because they do not contain any straight lines. An example of the approximate development of a sphere is shown in figure 4 .

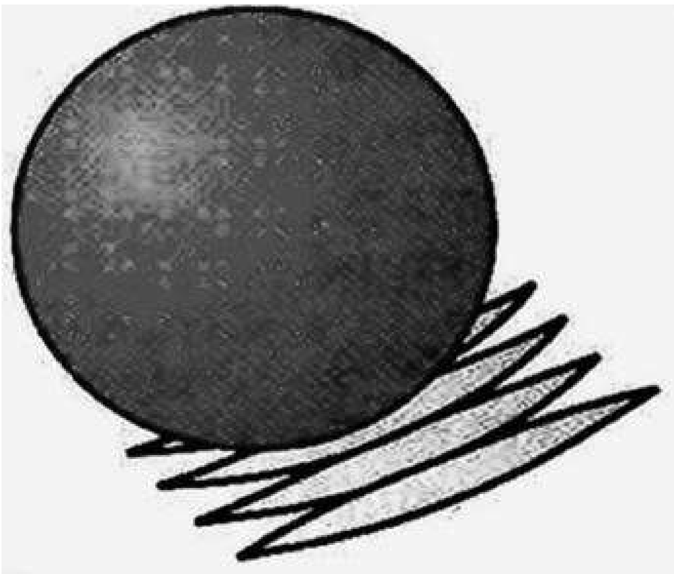


Figure 4 showing an approximate development of a sphere.

4.2 Classifications of developments

1. Parallel-line development: They are made from common solids that are composed of parallel lateral edges or elements. e.g. Prisms and cylinders as shown in figure 5. The cylinder is positioned such that one element lies on the development plane. The cylinder is then unrolled until it is flat on the development plane. The base and top of the cylinder are circles, with a circumference equal to the length of the development. All elements of the cylinder are parallel and are perpendicular to the base and the top. When cylinders are developed, all elements are parallel and any perpendicular section appears as a stretch-out line that is perpendicular to the elements.

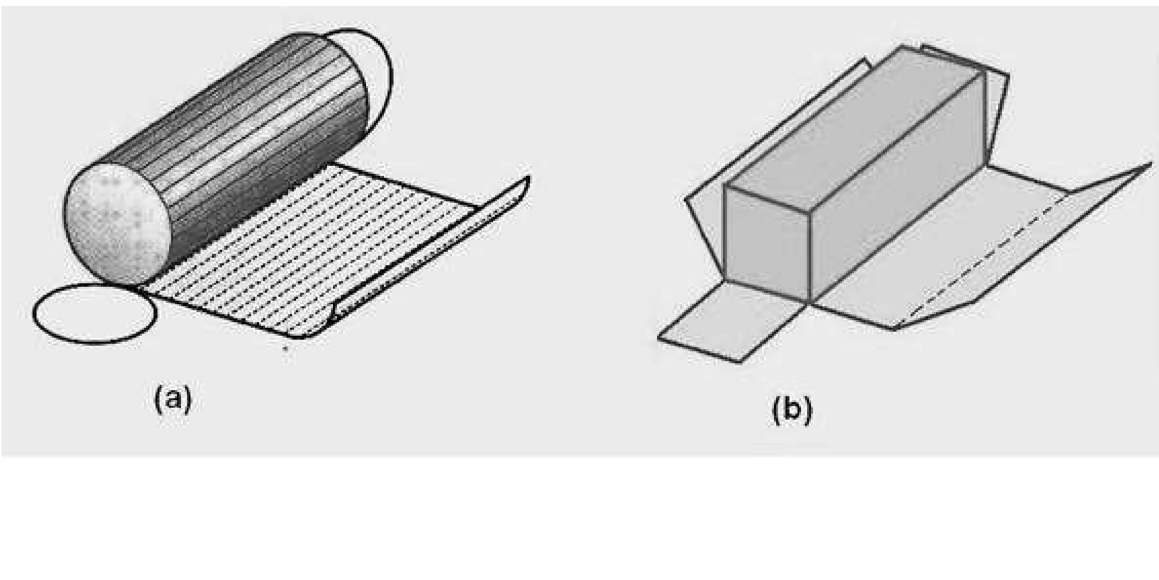


Figure 5 shows the parallel line development technique for (a) cylinder and (b) rectangular block.

2. Radial-line development
Radial-line developments are made from figures such as cones and pyramids. In the development, all the elements of the figure become radial lines that have the vertex as their origin. Figure 6 shows the radial development for a cone. The cone is positioned such that one element lies on the development plane. The cone is then unrolled until it is flat on the development plane. One end of all the elements is at the vertex of the cone. The other ends describe a curved line. The base of the cone is a circle, with a circumference equal to the length of the curved line.

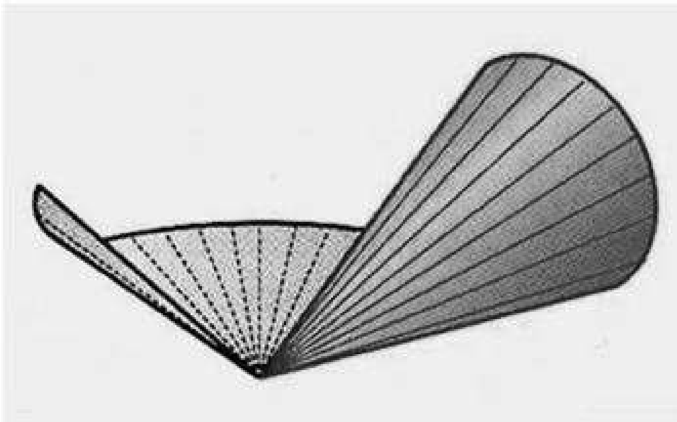


Figure 6 shows the radial development method for a cone.

3. Triangulation developments:
Made from polyhedrons, single-curved surfaces, and wrapped surfaces. The development involve subdividing any ruled surface into a series of triangular areas. If each side of every triangle is true length, any number of triangles can be connected into a flat plane to form a development. This is illustrated in figure 7 for a triangular pyramid. Triangulation for single curved surfaces increases in accuracy through the use of smaller and more numerous triangles. Triangulation developments of wrapped surfaces produces only approximate of those surfaces.

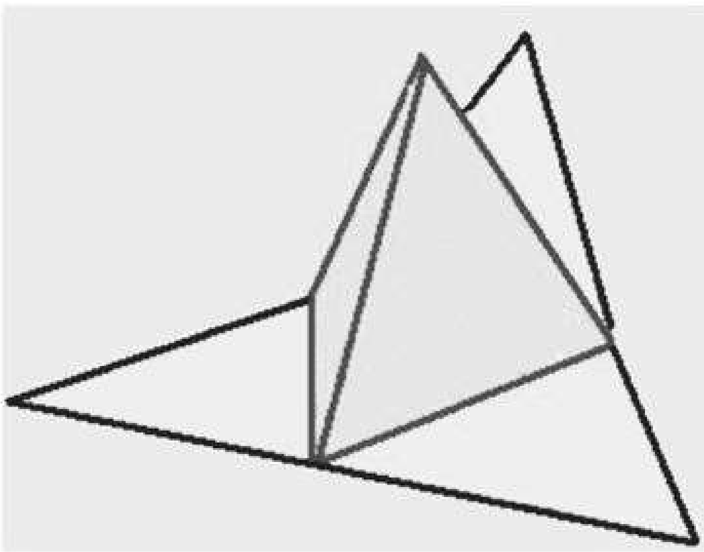


Figure 7 shows the triangulation method for obtaining the development of a triangular pyramid.

4.Approximate developments
Approximate developments are used for double curved surfaces, such as spheres. Approximate developments are constructed through the use of conical sections of the object. The material of the object is then stretched through various machine applications to produce the development of the object. This is illustrated in figure 4.

4.3 Parallel-line developments

Developments of objects with parallel elements or parallel lateral edges begins by constructing a stretch-out line that is parallel to a right section of the object and is therefore, perpendicular to the elements or lateral edges. Figure 8 illustrates the steps followed for obtaining the development of a rectangular prism by parallel line development. In the front view, all lateral edges of the prism appear parallel to each other and are true length. The lateral edges are also true length in the development. The length, or the stretch-out, of the development is equal to the true distance around a right section of the object.

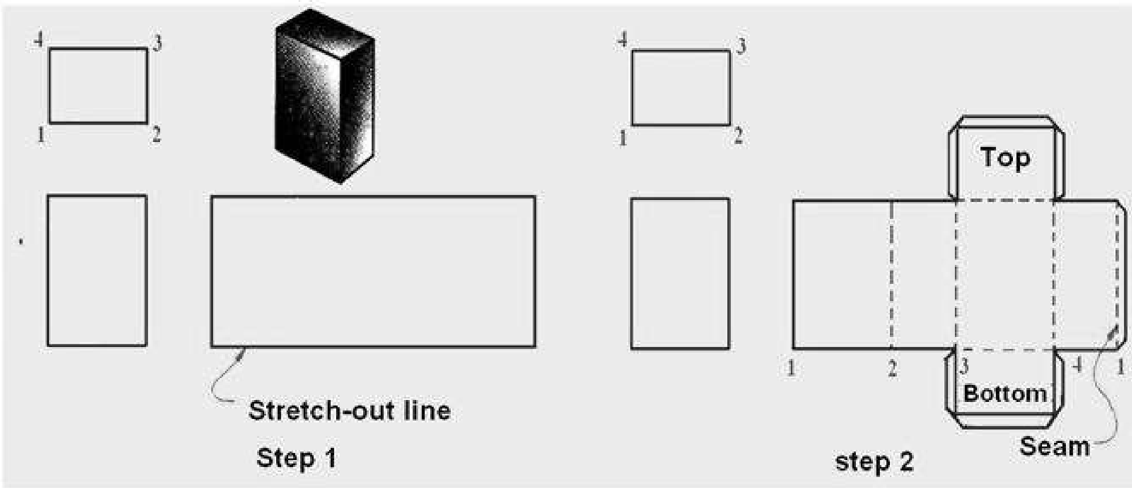


Figure 8. Stepwise procedure for obtaining the development of a rectangular prism.

***Step* 1.** To start the development, draw the stretch-out line in the front view, along the base of the prism and equal in length to the perimeter of the prism. Draw another line in the front view along the top of the prism and equal in length to the stretch-out line. Draw vertical lines between the ends of the two lines, to create the rectangular pattern of the prism.
***Step* 2.** Locate the fold line on the pattern by transferring distances along the stretch-out line in length to the sides of the prism, 1-2, 2-3, 3-4, 4-1. Draw thin, dashed vertical lines from points 2, 3, and 4 to represent the fold lines. Add the bottom and top surfaces of the prism to the development, taking measurements from the top view. Add the seam to one end of the development and the bottom and top.

1. **Development of a truncated prism**

The methoid of obtaining the development of a truncated prism is shown in figure 1.

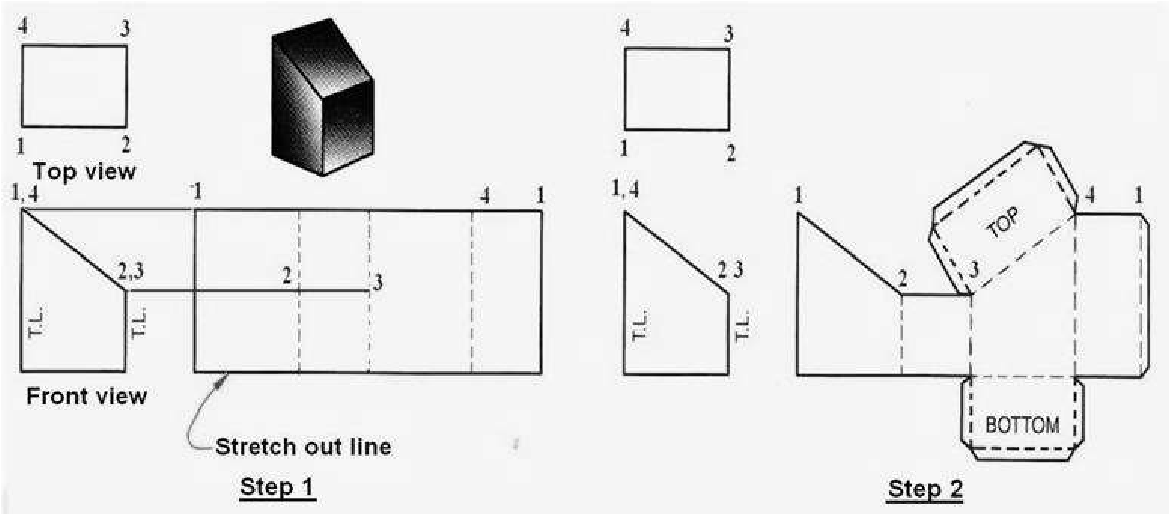


Figure1. shows the development of a truncated rectangular prism.

***Step* 1:** Draw the stretch-out line in the front view, along the base of the prism and equal in length to the perimeter of the prism.

Locate the fold lines on the pattern along the stretch-out line equal in length to the sides of the prism, 1-2, 2-3, 3-4, and 4-1.
Draw perpendicular construction lines at each of these points.
Project the points 1, 2, 3, and 4 from the front view **Step 2:** Darken lines 1-2-3 and 4-1. Construct the bottom and top, as shown and add the seam to one end of the development and the top and bottom

2. **Development of a right circular cylinder**

The Procedure for obtaining the development of a cylinder is illustrated in figure 2.

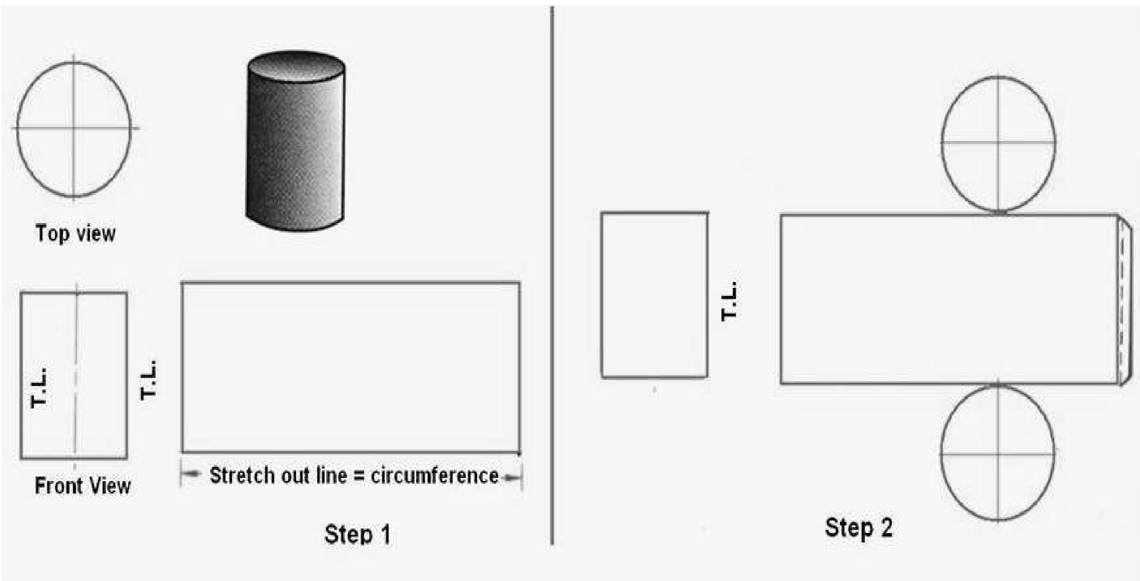


Figure 2. Shows the step wise procedure for obtaining the development of a cylinder.

***Step* 1.** In the front view, draw the stretch-out line aligned with the base of the cylinder and equal in length to the circumference of the base circle.
At each end of this line, construct vertical lines equal in length to the height of the cylinder.
***Step* 2.** Add the seam to the right end of the development, and add the bottom and top circles.

3.Development of a truncated right circular cylinder

The development of a truncated cylinder is shown in figure 3.

Step1. The top view and front view of the cylinder is drawn. The stretch out line, is aligned with the base in the F.V., is drawn with length equal to the circumference of the cylinder. Construct the rectangle with the stretch out line as one length and height of the cylinder as the width.

Step2. The top circular view of the cylinder then divided into a number of equal parts . The stretch-out line is also divided into 12 equal parts from which vertical lines 1, 2, 3, 4, …. 12 are constructed. The intersection points in the T.V. are projected into the F.V. . Draw horizontal projectors from points 1, 2, 3, …., 12 to intersect the vertical lines 1,2, 3, 4, …. 12 in the stretch out line. , where the projected lines intersect the angled edge view of the truncated surface of the cylinder. The intersections between these projections and the vertical lines constructed from the stretch-out line are points along the curve representing the top line of the truncated cylinder. Join the intersection points with a smooth curve to obtain the developmentof the lateral surface of the cylinder.

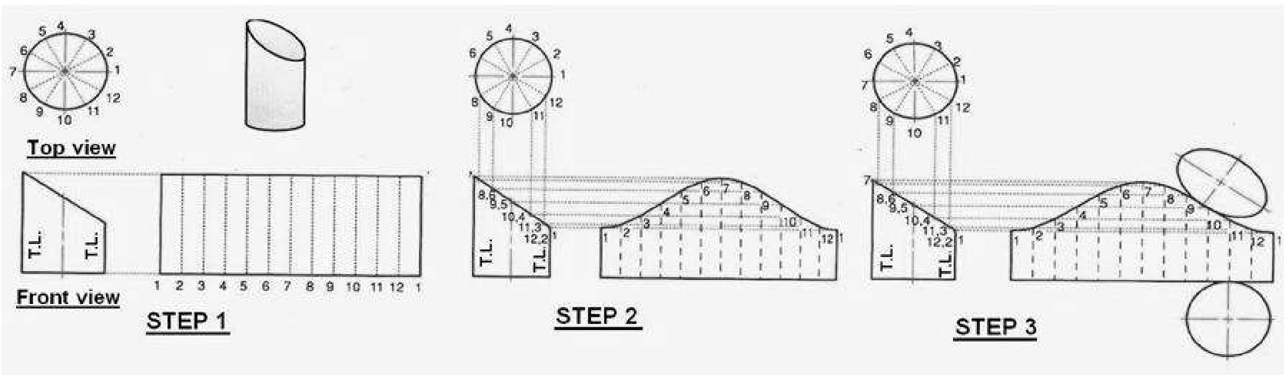


Figure 3. shows the development of a truncated cylinder.

Step 3. Draw the circle with diameter equal to the diameter of the cylinder at any point on the base of the development to obtain the development of the base surface of the cylinder. Draw an ellipse with the truncated length (length 1-7 in the step 2) as major diameter and diameter of the cylinder as the minor diameter on the top part of the development to obtain the final development of the surfaces of the truncated cylinder.

4.Development of a right circular cone

The development of a cone is shown in figure 4. For a cone, the front view will be a triangle with the slant edge showing the true length of the generator of the cone. To begin this development, use a true-length element of the cone as the radius for an arc and as one side of the development. Draw an arc whose length is equal to the circumference of the base of the cone. This can also be determined by angle $\theta = (r/l) * 360°$, where, r is the radius of the base of the cone and l is the true length of the slant edge. Draw another line from the end of the arc to the apex and draw the circular base to complete the development.

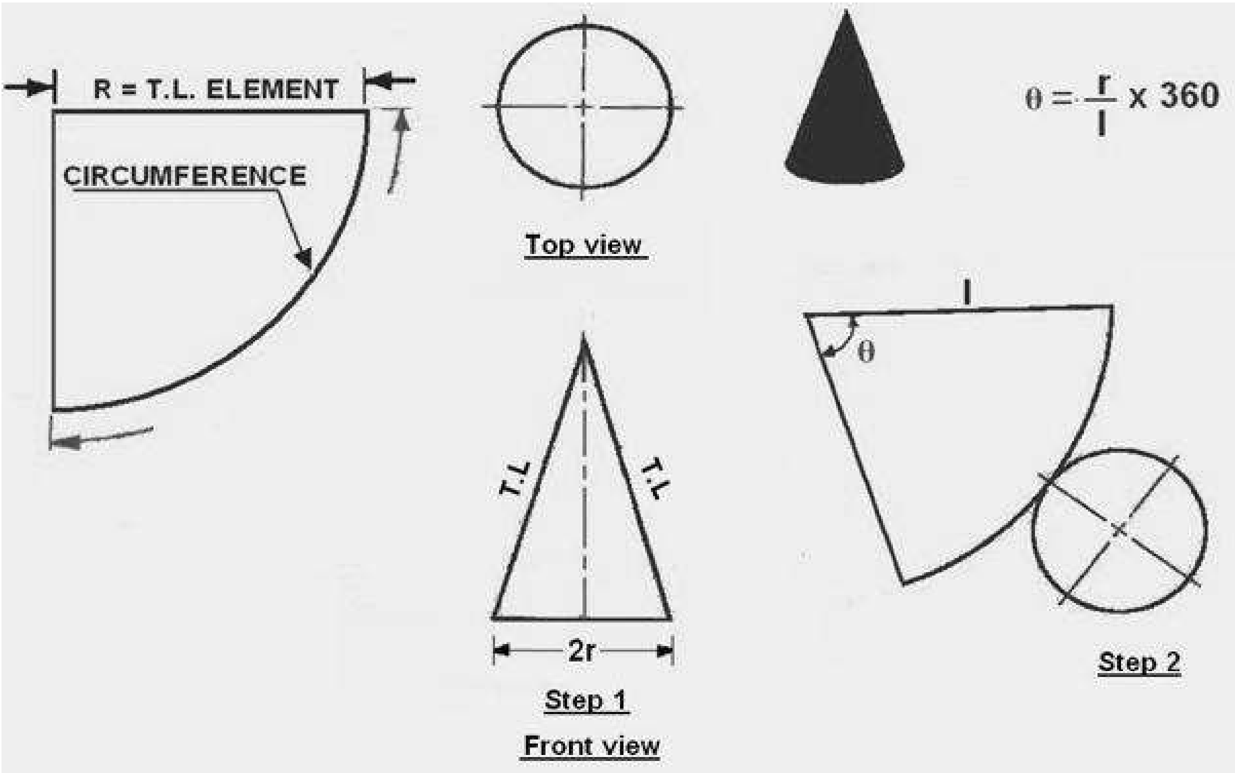


Figure 4. Development of a right cone.

5.Development of a truncated cone:

A cone of base diameter 40 mm and slant height 60 mm is kept on the ground on its base. An AIP inclined at 45° to the HP cuts the cone through the midpoint of the axis. Draw the development.

Solution:
The development of the truncated cone is shown in figure 5.

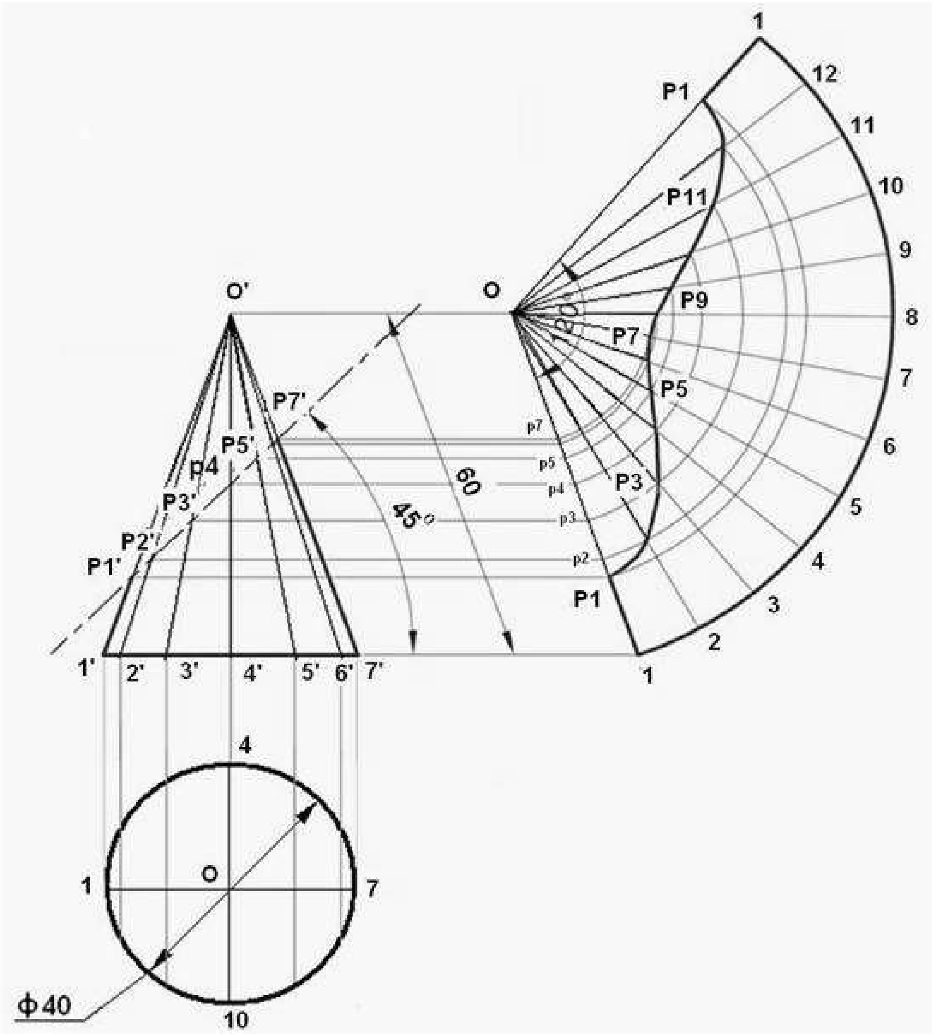


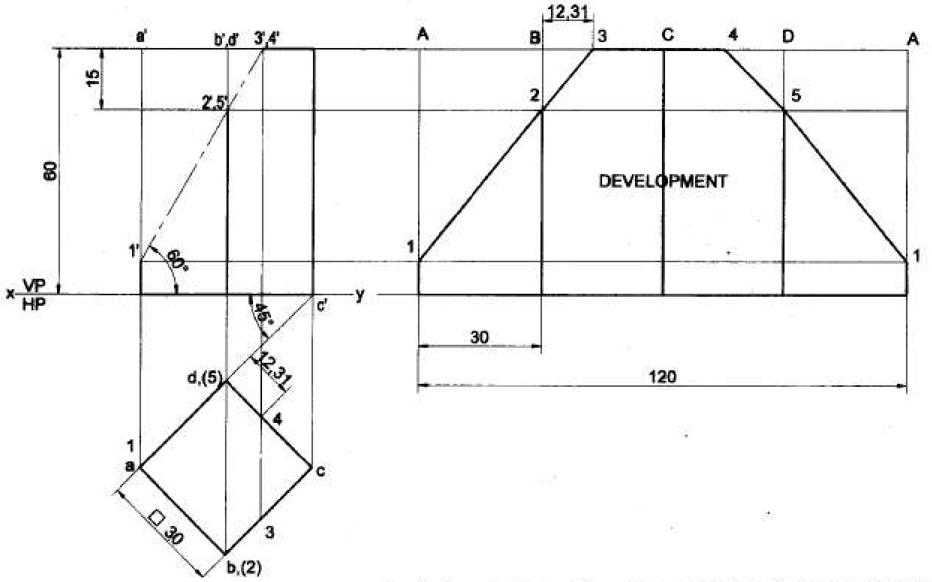
Figure 5. Development of the truncated cone (problem 5).

Draw the Front view and top view of the cone. Dive the circumference of the circle (Top View) in to 12 equal parts 1, 2, 3, 4, …., 12. Project these points on the Front view to obtain the points 1', 2', 3', …., 12'. Draw a line inclined at 45 ° to the horizontal and passing through the mid pint of the axis of the cone to represent the AIP. The locate the intersection points of the AIP with the generators O'-1', O'-2', …. O'-12' as P1', p2', p3', …. P12'. Draw the projection (figure shown on the right of the Front view) by drawing the line O1 parallel to O' 7'. Obtain the included angle of the sector. $\theta = (20/60)* 360 = 120°$ (following the procedure shown in problem 4). Then draw sector O–1–1– O with O as a centre and included angle 120°. Divide the sector into 12 equal parts (i.e., 10° each). Draw lines O–2, O–3, O–4, …, O–12. Draw horizontal projectors from P1', P2', …., P12' such that it meets the line O1 at p1, p2, p3, …, p12. With O as centre and radius O'P1', mark point P1 on line O1. With O as centre and radius equal to Op2, draw an arc to intersect the radial line O2 at point P2. Similarly obtain points P3, P4, …, P12, and P1. Join points P1, P2, P3, …., P12 and P1 to obtain the development of the truncated cone.

Worked Examples- Sections and Development of Lateral Surfaces of Solids

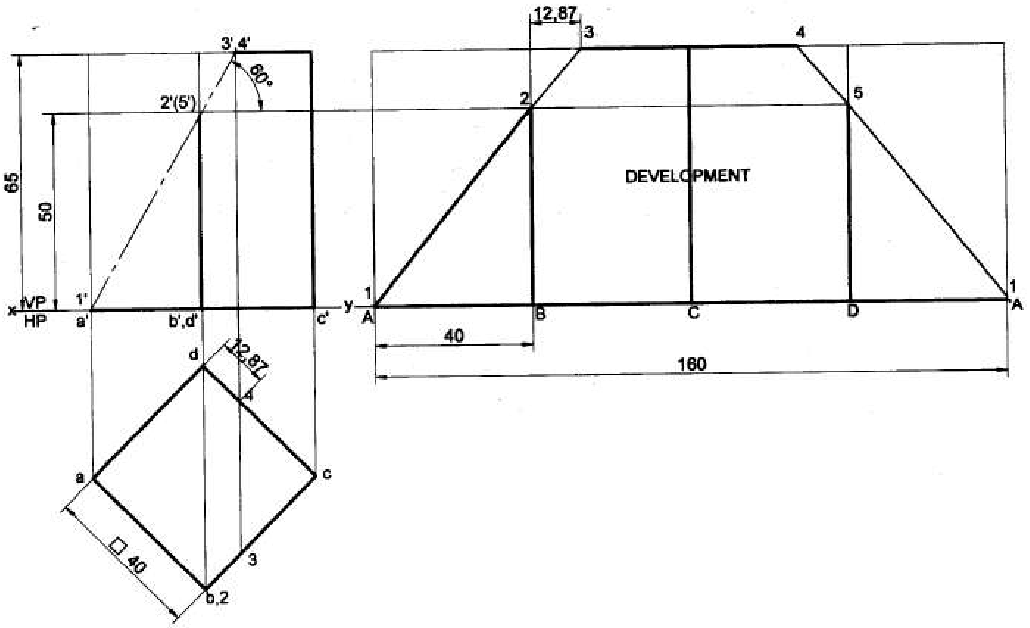
Problem 2 A square prism of base side 30 mm and axis length 60 mm is resting on HP on its base with all the vertical faces being equally inclined to VP. It is cut by an inclined plane 60° to HP and perpendicular to VP and is passing through a point on the axis at a distance 50 mm from the base. Draw the development of the lower portion of the prism.

Solution



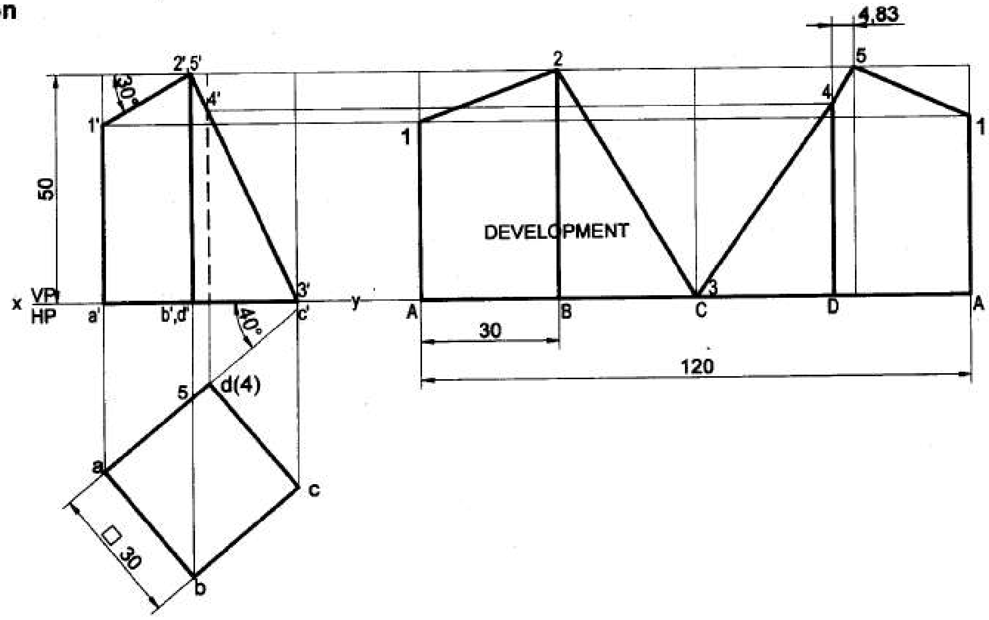
Problem 3 A square prism of base side 40mm and axis length 65mm is resting on HP on its base with all the vertical faces being equally inclined to VP. It is cut by an inclined plane 60° to HP and perpendicular to VP and is passing through a point on the axis at a distance 15mm from the top face. Draw the development of the lower portion of the prism.

Solution



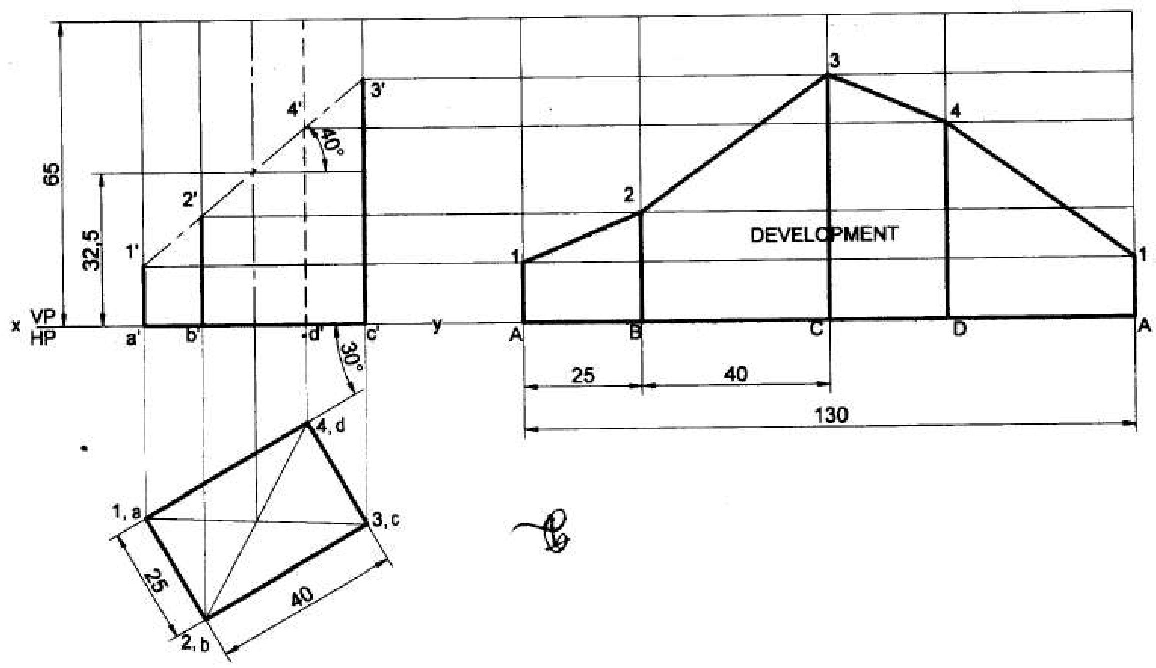
Problem 4 A square prism of 30mm side of the base and height 50mm is resting with its base on HP such that one of its vertical faces is inclined at 40° to VP. It is cut as shown in the following front view figure. Draw the development of the lateral surface of the prism.

Solution



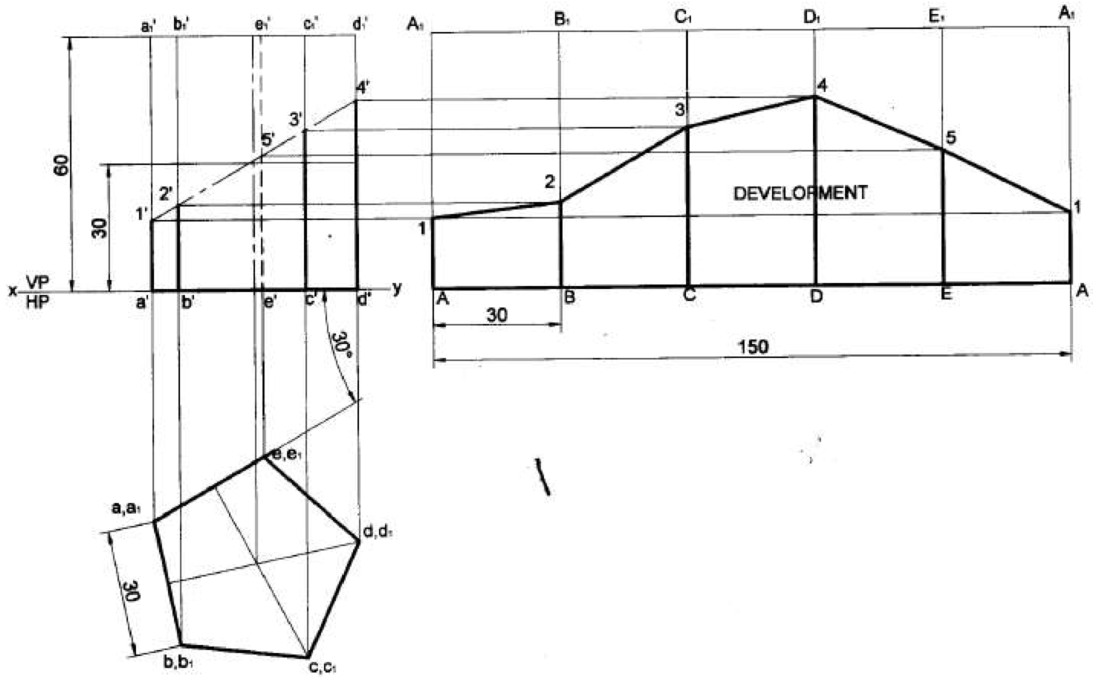
Problem 7 A rectangular prism of base 40mm x 25mm and height 65mm rests on HP on its base with the longer base side inclined at 30° to VP. It is cut by a plane inclined at 40° to HP, perpendicular to VP cuts the axis at its mid height. Draw the development of the remaining portion of the prism.

Solution



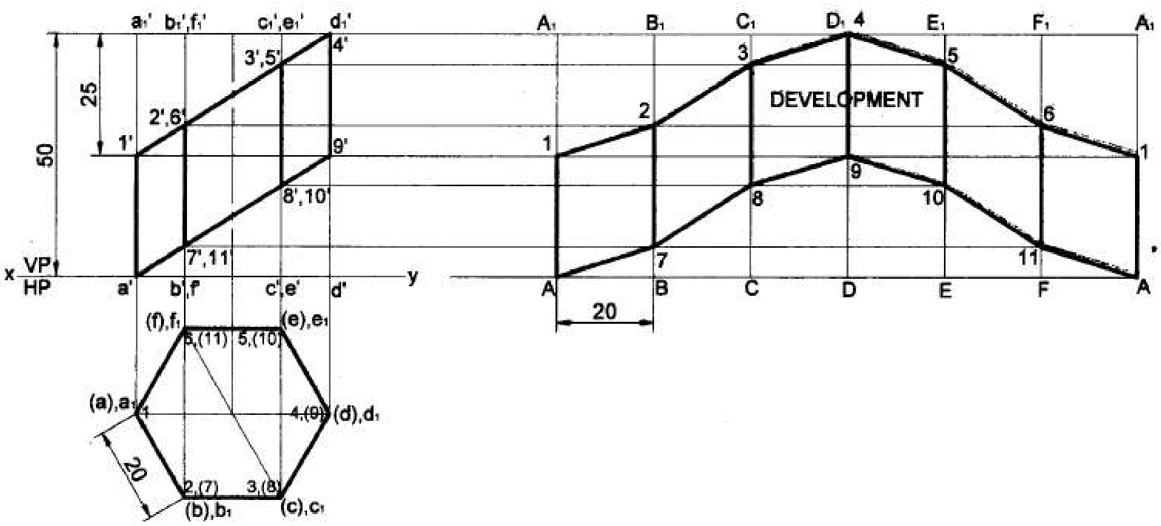
Problem 11 A regular pentagonal prism of height 60mm and base edge 30mm rests with its base on HP. The vertical face closest to VP is 30° to it. Draw the development of the truncated prism with its truncated surface inclined at 60° to its axis and bisecting it.

Solution



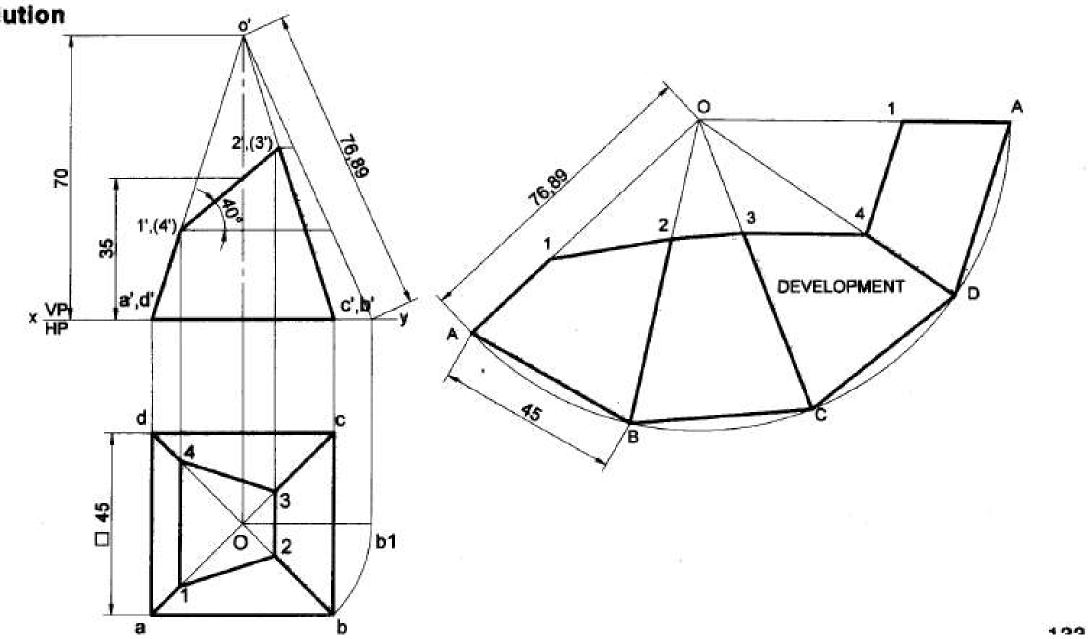
Problem 15 A hexagonal prism of base side 20mm and height 50mm is resting on HP on its base, such that one of its base edge is parallel to VP. The prism is cut in this position as shown in the following front view. Draw the development of the lateral surface of the prism.

Solution



Problem 18 A square pyramid of side of base 45mm, altitude 70mm is resting with its base on HP with two sides of the base parallel to VP. The pyramid is cut by a section plane which is perpendicular to the VP and inclined at 40° to the HP. The cutting plane bisects the axis of the pyramid. Obtain the development of the lateral surfaces the truncated pyramid.

Solution



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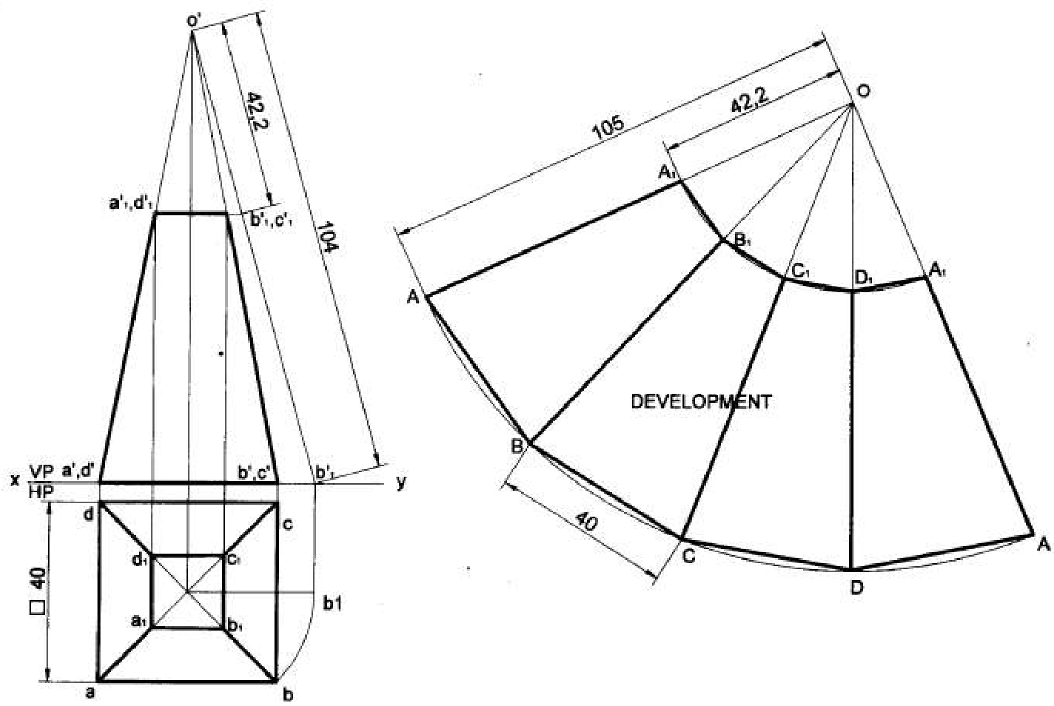
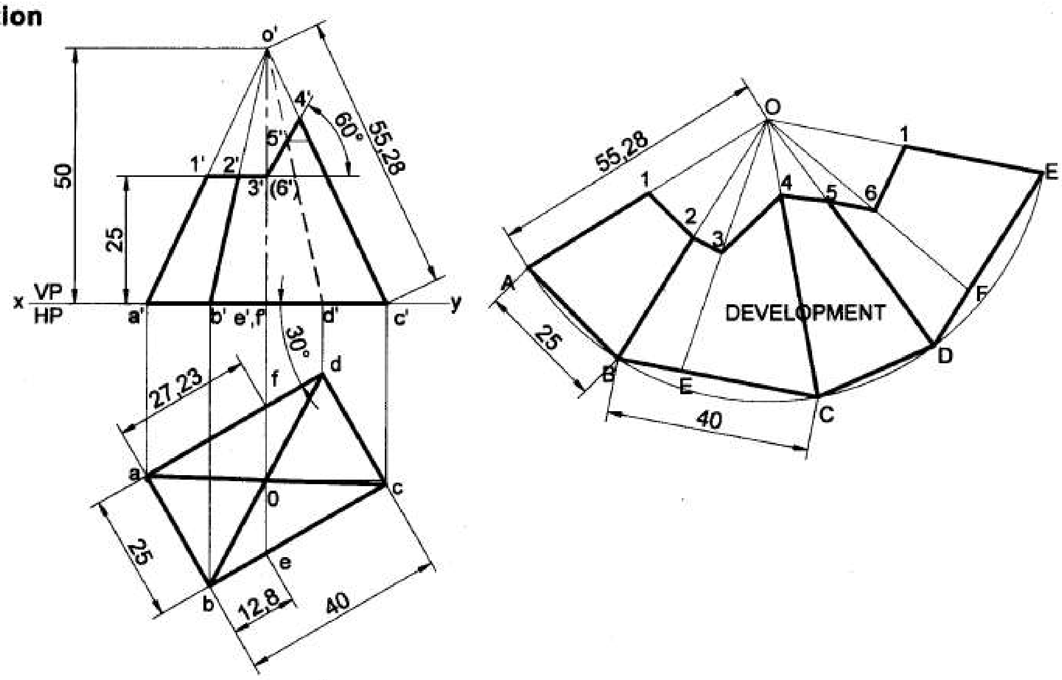
Problem 20 A frustum of a square pyramid has its base 40 mm sides, top 16 mm sides and height 60mm, its axis is vertical and a side of its base is parallel to VP. Draw the projections of the frustum and show the development of the lateral surfaces of it.

Solution



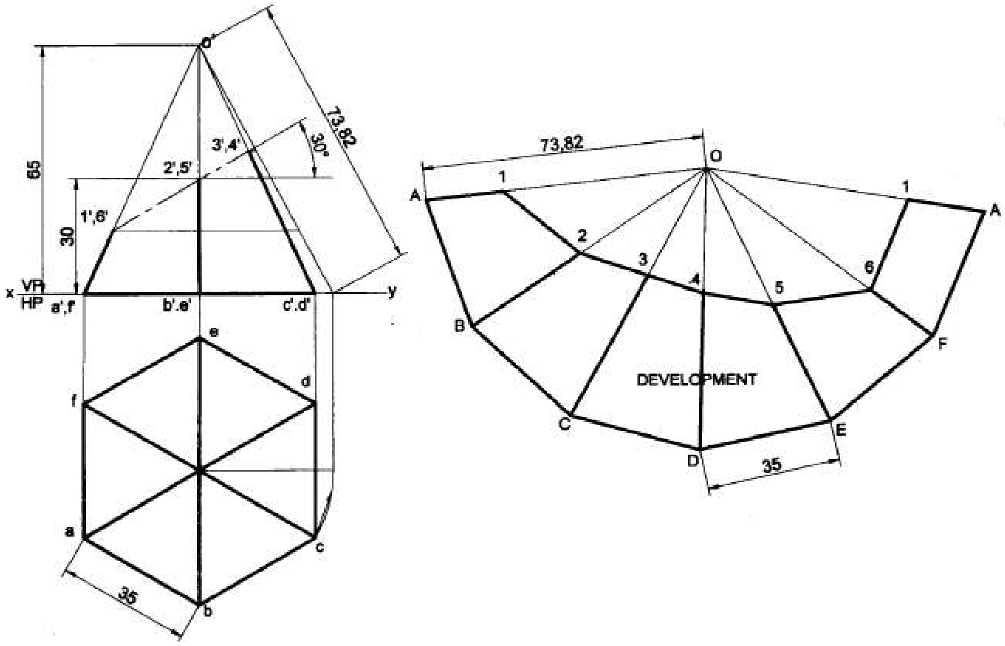
Problem 22 A rectangular pyramid, side of base 25mm x 40mm and height 50mm has one of the sides of the base is inclined at 30° to the VP. Draw the development of the lateral surface of the cut pyramid, whose front view is shown below.

Solution



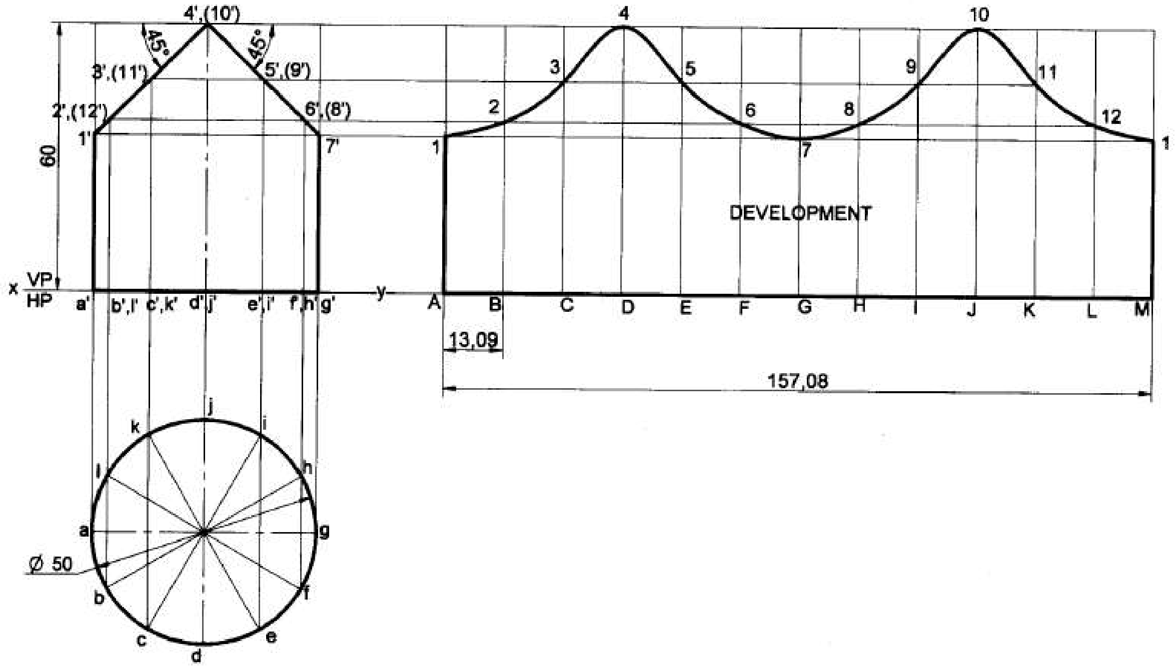
Problem 28 A hexagonal pyramid of sides 35mm and altitude 65mm is resting on HP on its base with two of the base sides perpendicular to VP. The pyramid is cut by a plane inclined at 30° to HP and perpendicular to VP and is intersecting the axis at 30mm above the base. Draw the development of the remaining portion of the pyramid.

Solution



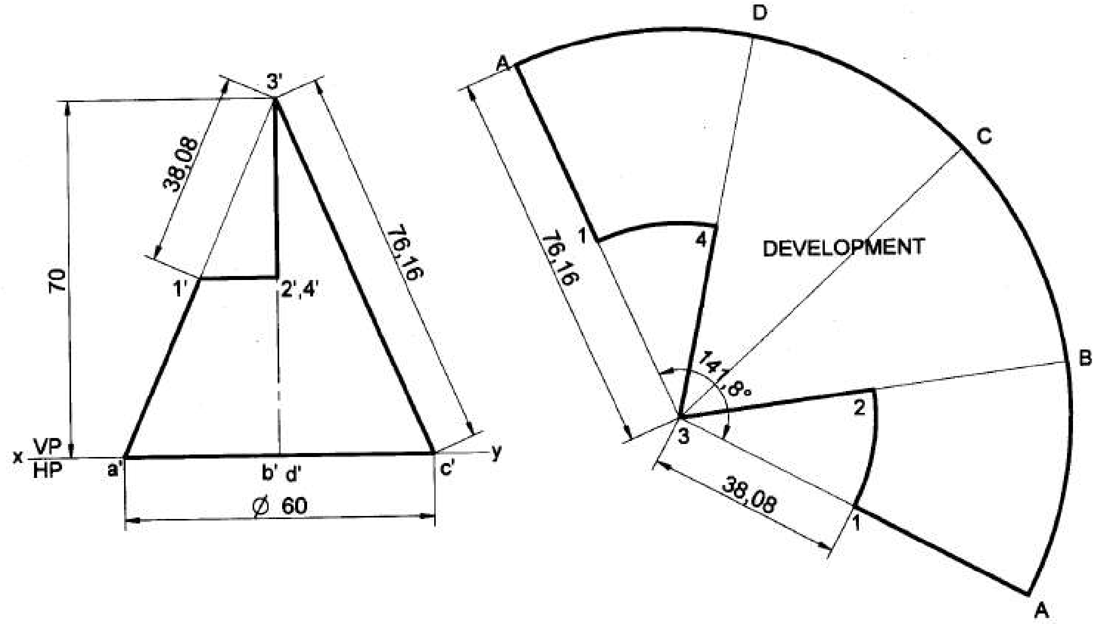
Problem 33 A vertical cylinder of base diameter 50mm and axis length 60mm is cut by a two planes which are perpendicular to VP and inclined at 45° to HP and passing through either side the centre point of the top face. Draw the development of the lateral surface of the cylinder.

Solution



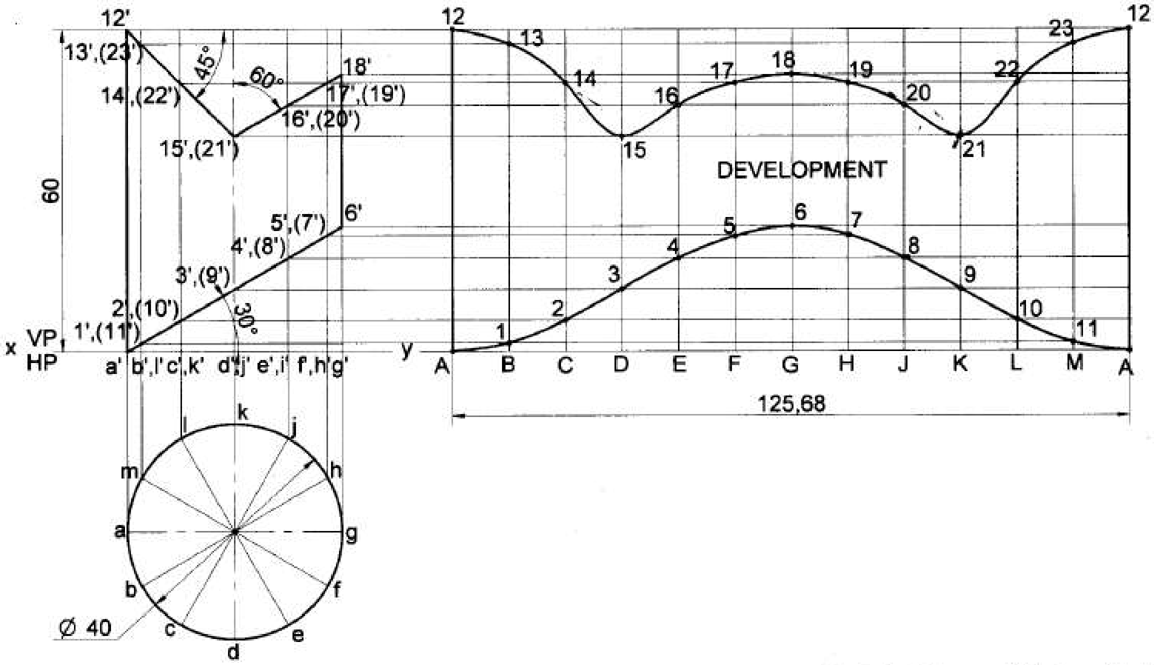
Problem 36 A cone of base diameter 60mm and height 70mm is resting on its base on HP. It is cut as shown in the following figure. Draw the development of the lateral surface of the remaining portion of the cone.

Solution



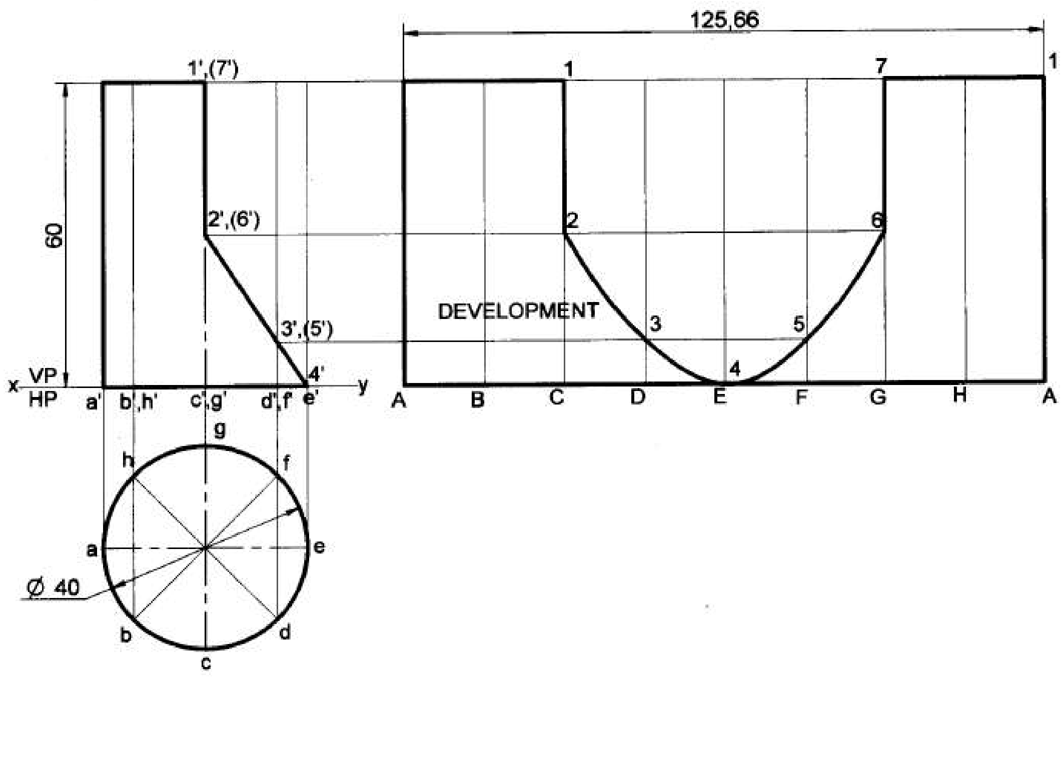
Problem 37 Develop the lateral surface of the cylinder of 40mm diameter and height 60mm which is cut in the following way.

Solution



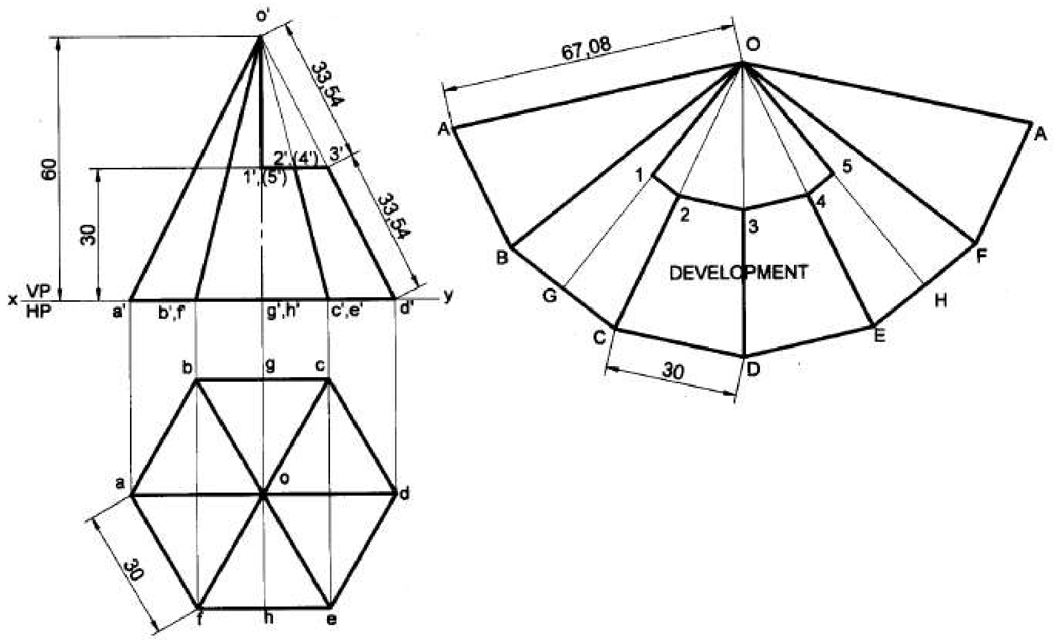
Problem 44 Develop the lateral surface of the cylinder of 40mm diameter and height 60mm which is cut in the following way.

Solution



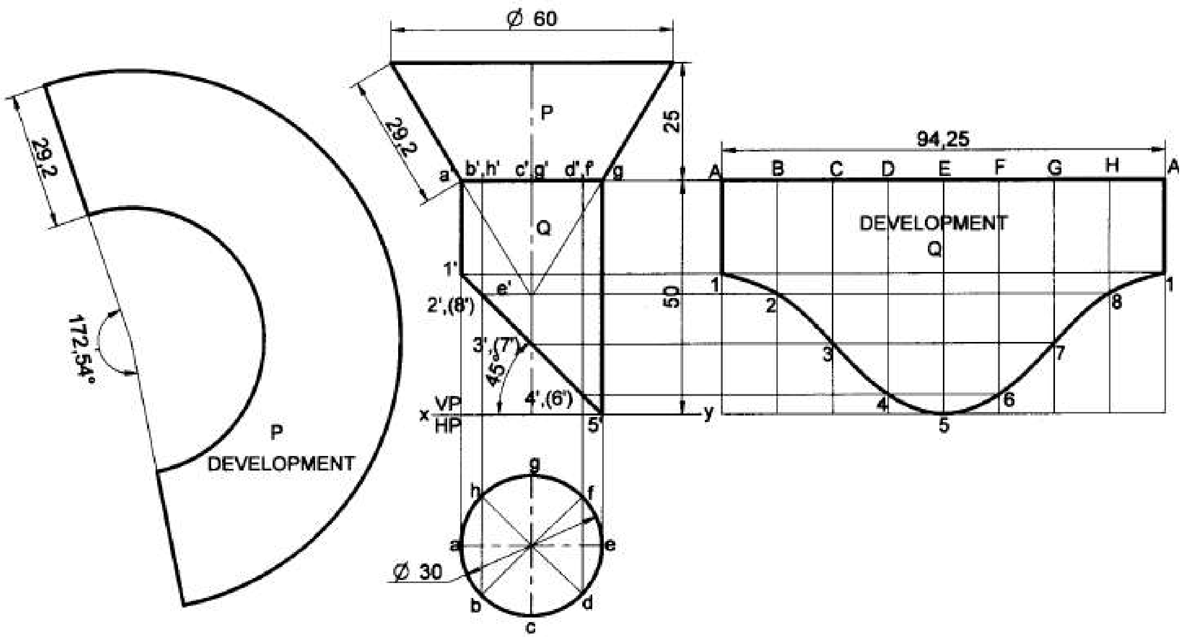
Problem 43 A hexagonal pyramid of 30mm sides of base with a side of base parallel to VP. Draw the development of the lateral surfaces of the retained portion of the pyramid which is shown by dark lines in the following figure.

Solution



Problem 50 A funnel is made of sheet metal. The funnel tapers from 60 mm. to 30 mm. diameters to a heigh mm. and then forms to a cylinder with a height of 50 mm. Bottom of funnel is beveled off completely at an angle to axis Draw the development of funnel.

Solution



Problems on Development

1. A regular pentagonal prism of height 60 mm and base edge 30 mm rests with its base on HP. The vertical face closest to VP is 30 deg to it. Draw the development of the truncated prism with its truncated surface inclined at 60 deg to its axis and bisecting it.
2. A pentagonal prism of 30 mm side of base and height 50 mm lies with its base on HP such that one of the rectangular faces is inclined at 40 deg to VP. It is cut to the shape of a truncated pyramid with the truncated surface inclined at 30 deg to the axis so as pass through a point on it 30 mm above the base. Develop the truncated portion of the prism so as to produce a one piece development.
3. A pentagonal prism of base sides 30 mm and axis length 60 mm rests with its base on HP and an edge of the base inclined at 45 deg to VP. It is cut by a plane perpendicular to VP, inclined at 40 deg to HP and passing through a point on the axis, at a distance of 30 mm from the base. Develop the remaining surface of the truncated prism.
4. A pentagonal prism of base sides 20 mm and height 40 mm is resting with its base on HP and base edge parallel to the VP. The prism is cut as shown in the following front view. Draw the development of the lateral surface of the prism.
5. A hexagonal prism of base side 20 mm and height 50 mm is resting on HP on its base, such that one of its base edge is parallel to VP. The prism is cut in this position as shown in the following front view. Draw the development of the lateral surface of the prism.
6. A hexagonal prism of base side 25 mm and height 55 mm is resting on HP on its base, such that one of its base edge is parallel to VP. The prism is cut in this position as shown in the following front view. Draw the development of the lateral surface of the prism.
7. The inside of a hopper of a flour mill is to be lined with thin sheet. The top and bottom of the hopper are regular pentagons with each side equal to 30 mm and 22.5 mm respectively. The height of the hopper is 30 mm. Draw the shape of the sheet to which it is to be cut so as to fit into the hopper.
8. A square pyramid of side of base 45 mm, altitude 70 mm is resting with its base on Hp with two sides of the base parallel to VP. The pyramid is cut by a section plane which is perpendicular to the VP and inclined at 40 deg to the HP. The cutting plane bisects the axis of the pyramid. Obtain the development of the lateral surfaces the truncated pyramid.
9. A square pyramid base 40 mm side and axis 65 mm long has its base on HP and all the edges of the base are equally inclined to VP. It is cut to with an inclined section plane so as the truncated surface at 45 deg to its axis, bisecting it. Draw the development of the truncated pyramid.
10. A frustum of a square pyramid has its base 40 mm sides, top 16 mm sides and height 60 mm, its axis is vertical and a side of its base is parallel to VP. Draw the projections of the frustum and show the development of the lateral surface of it.
11. A square pyramid of 25 mm base edge and 50 mm height rests with its base on HP with all of its base edges equally inclined to VP. It is cut by a plane perpendicular to VP and inclined to HP at 60 deg, passing through the extreme right corner of base. Draw the development of the lateral surface of the pyramid.

12. A rectangular pyramid, side of base 25 mm$\times$40 mm and height 50 mm has one of the base is inclined at 30 deg to the VP. Draw the development of the lateral surface of the cut pyramid, whose front view is shown below.
13. A frustum of a pentagonal pyramid, smaller base sides 16 mm and bigger top face sides 32 mm and height 40 mm, is resting on the HP on its smaller base. With one of its base sides parallel to the VP. Draw the projections of the frustum and develop the lateral surface it.

FURTHER READING:

1) Computer Aided Engineering Drawing - S. Trymbaka Murthy, - I.K. International Publishing House Pvt. Ltd., New Delhi, 3rd revised edition- 2006.
2) Engineering Graphics - K.R. Gopalakrishna, 32nd edition, 2005- Subash Publishers Bangalore.
3) Dhananjay A Jolhe, Engineering Drawing, Tata McGraw Hill, 2007.
4) M.B. Shah and B.C. Rana, Engineering Drawing, pearson Education, Eds. 2, 2009.
5) K. Venugopal, Engineering Drawing and Graphics, New Age International (P) Ltd., publishers, 2000.
6) N.D. Bhatt and V.M. Panchal, Engineering Drawing, Charotar Publishing house, 2005.

MODULE-5

ISOMETRIC PROJECTION (USING ISOMETRIC SCALE ONLY)

OBJECTIVES:

1) To understand the basic concept of isometric projection.
2) To understand the concepts of isometric scale.
3) Construction of isometric projections of simple solids and combination of solids.

LESSON CONTENT:

Introduction, Isometric scale, Isometric projection of simple plane figures, Isometric projection of tetrahedron, hexahedron(cube), right regular prisms, pyramids, cylinders, cones, spheres, cut spheres and combination of solids (Maximum of three solids).

5.1 Axonometric projection-

Axonometric projection is a parallel projection technique used to create a pictorial drawing of an object by rotating the object along one or more of its axes relative to the plane of projection (or the picture plane). Axonometric projection is one of the four principal projection techniques: multiview, axonometric, oblique and perspective projection (Figure-1). In multi view, axonometric, and oblique projections, the observer is theoretically infinitely far away from the projection plane. In addition, the lines of sight are parallel to each other and perpendicular to the plane of projection. The main difference between a multiview drawing and an axonometric drawing are that, in a multiview, only two dimensions of an object are visible in each view and hence more than one view is required to define the object. In an axonometric drawing, the object is rotated about an axis to show all three dimensions, and only one view is required.

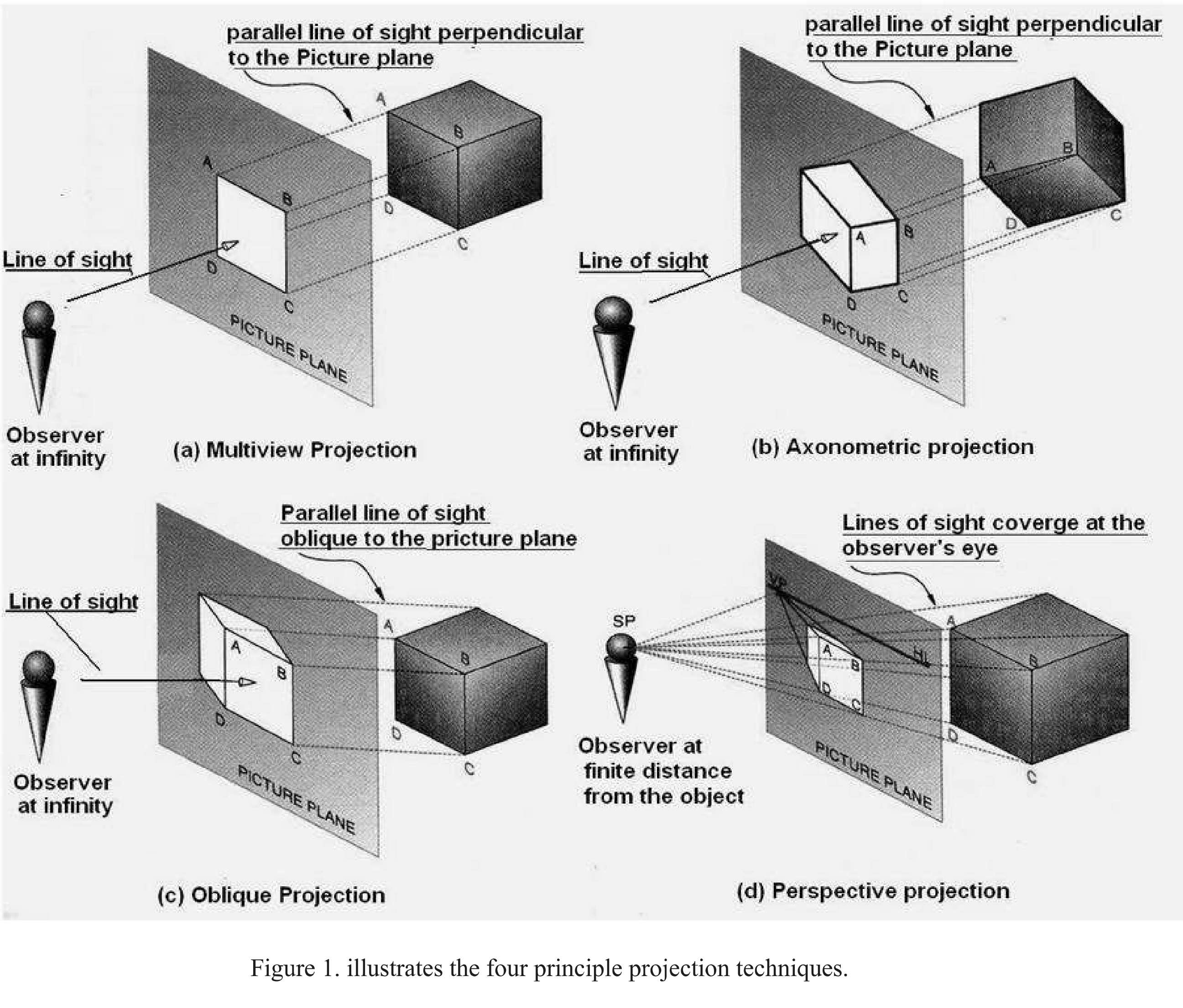


Figure 1. illustrates the four principle projection techniques.

Isometric projection is a type of pictorial projection in which the dimensions along the three axes of the solid are shown in one view. It is one of the three types of axonometric projection In axonometric drawing, one axis of space is shown vertical and depending on the exact angle at which the view deviates from the orthogonal, axonometric projections are generally three types: (a) trimetric projection, (b) dimetric projection, and (c) isometric projection.. This is illustrated in figure 2.

1. In trimetric projection, the direction of viewing is such that all of the three axes of space appear unequally foreshortened. The scale along each of the three axes and the angles among them are determined separately as dictated by the angle of viewing. Trimetric perspective is seldom used
2. In dimetric projection, the direction of viewing is such that two of the three axes of space appear equally shortened, of which the attendant scale and angles of presentation are determined according to the angle of viewing; the scale of the third direction (vertical) is determined separately. When two of the three angles are equal, the drawing is classified as a dimetric projection. Dimetric drawings are less pleasing to the eye, but are easier to produce than trimetric drawings
3. In isometric projection, the most commonly used form of axonometric projection in engineering drawing. Here all three angles are equal. The isometric is the least pleasing to the eye, but is the easiest to draw and dimension.

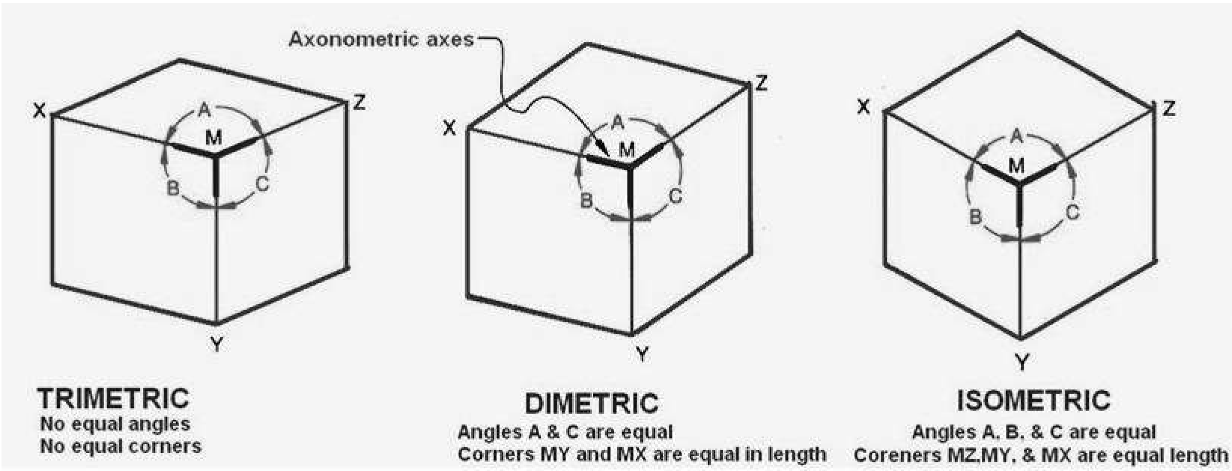


Figure 2. Shows the three types of axinometric drawing. The angles determine the type of axinometric drawing.

5.2 Isometric Axonometric Projections

An isometric projection is a true representation of the isometric view of an object. An isometric view of an object is created by rotating the object 45° about a vertical axis, then tilting the object (see figure 3, in this case, a cube) forward until the body diagonal (AB) appears as a point in the front view. The angle the cube is tilted forward is 35° 16'. The 3 axes that meet at A, B form equal angles of 120° and are called the isometric axes. Each edge of the cube is parallel to one of the isometric axes. Line parallel to one of the legs of the isometric axis is an isometric line. Planes of the cube faces & all planes parallel to them are isometric planes

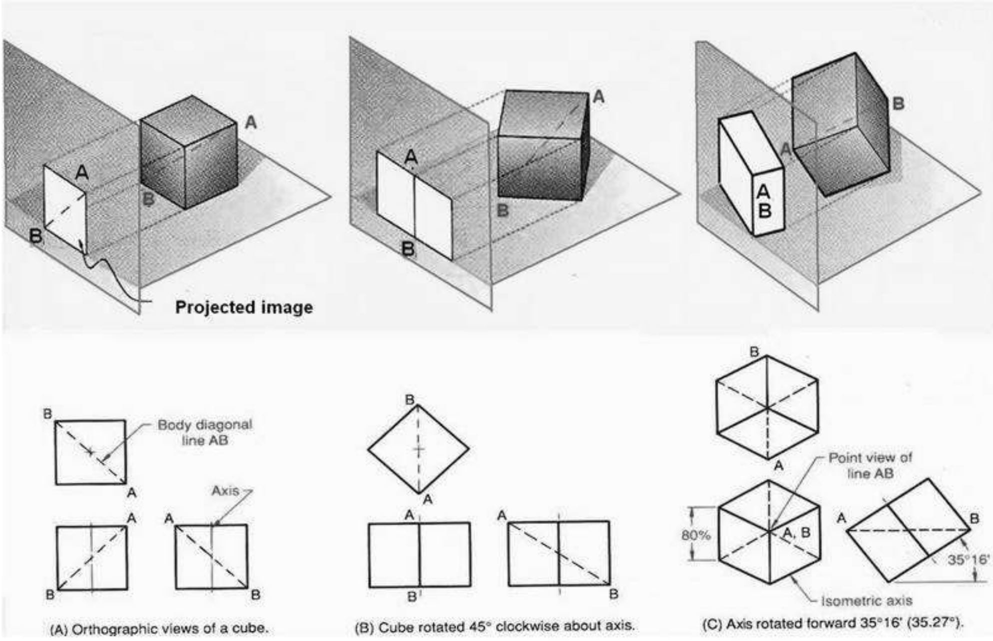


Figure 3. Rotation of the object with respect to the projection plane result in isometric projection.

The forward tilt of the cube causes the edges and planes of the cube to become shortened as it is projected onto the picture plane. The lengths of the projected lines are equal to the cosine of 35° 16', or 0.81647 times the true length. In other words, the projected lengths are approximately 80% of the true lengths. A drawing produced using a scale of 0.816 is called an *isometric projection* and is a true representation of the object. However, if the drawing is produced using full scale, it is called an isometric drawing, which is the same proportion as an isometric projection, but is larger by a factor of 1.23 to 1. Figure 4. Illustrates the isometric projection and isometric drawing. Isometric drawings are almost always preferred over isometric projection for engineering drawings, because they are easier to produce. An isometric drawing is an axonometric pictorial drawing for which the angle between each axis equals 120° and the scale used is full scale.

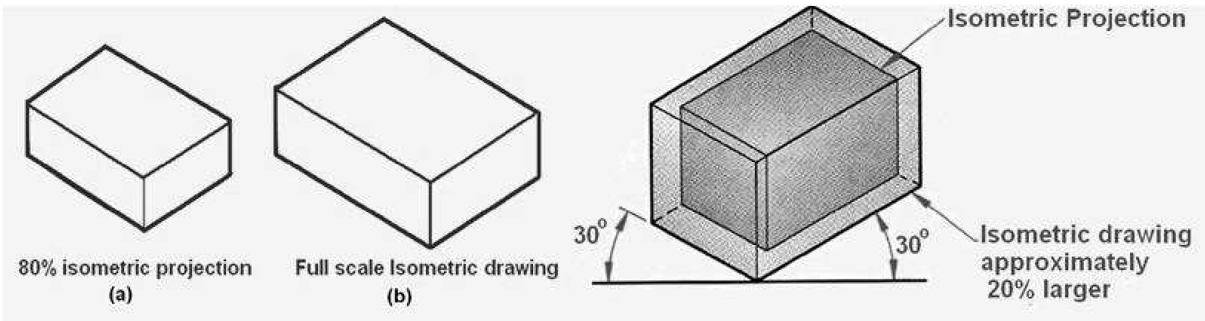


Figure 4 Shows the (a) isometric projection and (b) isometric drawing (or view) of a cuboid.

While drawing isometric projection, an Isometric scale is to be constructed for convenience and all the measurements are to be taken from this scale. As shown in figure 5, isometric scale is produced by positioning a regular scale at 45 ° to the horizontal and projecting lines vertically to a 30° line.

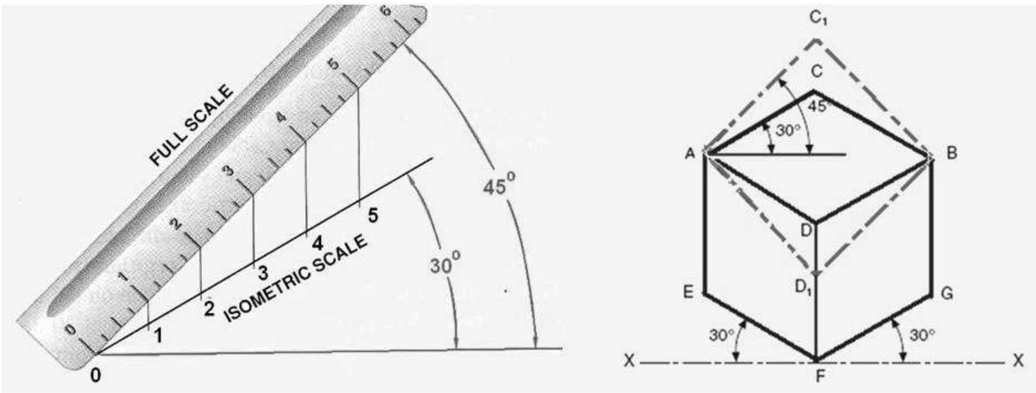


Figure 5. illustrates the construction of an isometric scale.

$$\text{Isometric scale} = \left(\frac{\text{Isometric length}}{\text{True length}}\right) = \frac{\cos 45°}{\cos 30°} = \frac{1}{\sqrt{2}} + \frac{\sqrt{3}}{2} = 0.8165$$

i.e. isometric length = 82% (approximately)

Isometric axes can be positioned in a number of ways to create different views of the same object. Figure 6(a) is a regular isometric, in which the viewpoint is looking down on the top of the object. In a regular isometric, the axes at 30° to the horizontal are drawn upward from the horizontal. In the reversed axis isometric, as shown in figure 6(b), the viewpoint is looking up on the bottom of the object, and the 30° axes are drawn downward from the horizontal. Figure 6(c)&(d) show the long axis isometric, where the viewpoint is looking from the right or from the left of the object, and one axis is drawn at 60 ° to the horizontal. While drawing the Isometric view, first the view point will have to be decided for obtaining the maximum technical information.

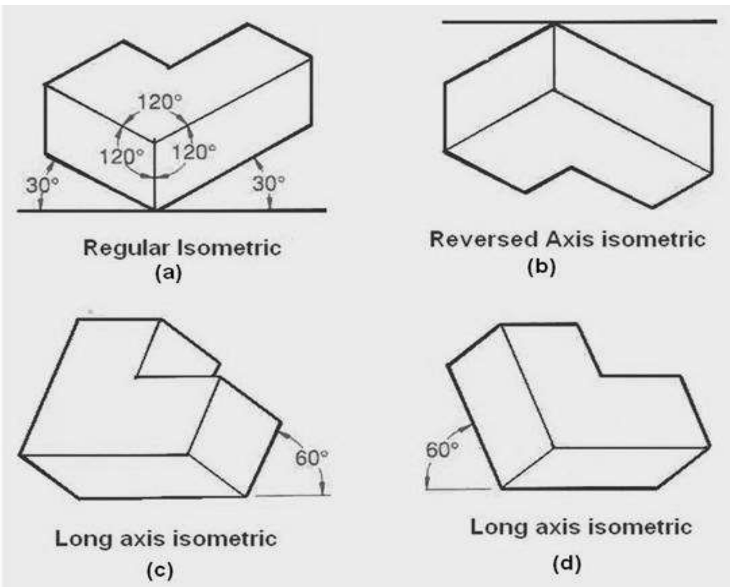


Figure 6. shows different isometric axis depending on the direction of view point.

Isometric axes and non-isometric axes

Figure 7(a) illustrates the isometric axes, non-isometric axes and isometric planes. In an isometric drawing, true length distances can only be measured along isometric lines. i.e. lines that run parallel to any of the isometric axes. Any line that does not run parallel to an isometric axis is called a non-isometric line. Non-isometric lines include inclined and oblique lines and cannot be measured directly. Instead they must be created by locating two end points. Figure 7(b) is an isometric drawing of a cube. The three faces of the isometric cube are isometric planes, because they are parallel to the isometric surfaces formed by any two adjacent isometric axes. Planes that are not parallel to any isometric plane are called non-isometric planes sa shown in figure 7(a).

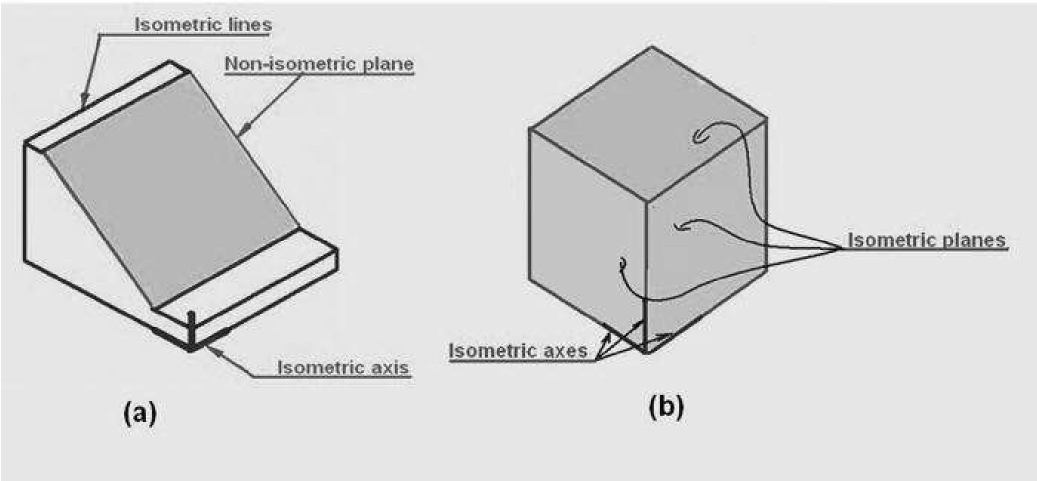


Figure 7. showing isometric axes, non-isometric axes and isometric planes.

Hidden Lines, Center Lines and Dimensions

In isometric drawings, hidden lines are omitted unless they are absolutely necessary to completely describe the object. Most isometric drawings will not have hidden lines. To avoid using hidden lines, choose the most descriptive viewpoint. However, if an isometric viewpoint cannot be found which clearly depicts all the major features, hidden lines may be used. eg. Figure 8(a). Centerlines are drawn only for showing symmetry or for dimensioning. Normally, centerlines are not shown, because many isometric drawings are used to communicate to non-technical people and not for engineering purposes.

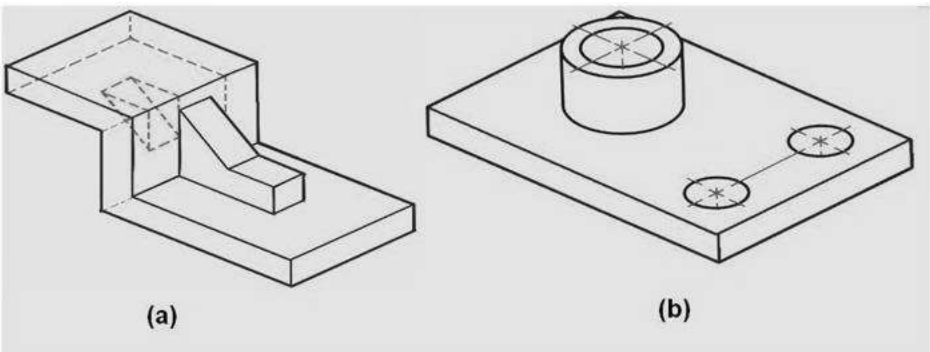


Figure 8 showing hidden lines and centre lines.

Dimension lines, extension lines, and lines being dimensioned shall lie in the same plane. All dimensions and notes should be unidirectional, reading from the bottom of the drawing upward and should be located outside the view whenever possible. The texts are read from the bottom, using horizontal guidelines as shown in Figure 9.

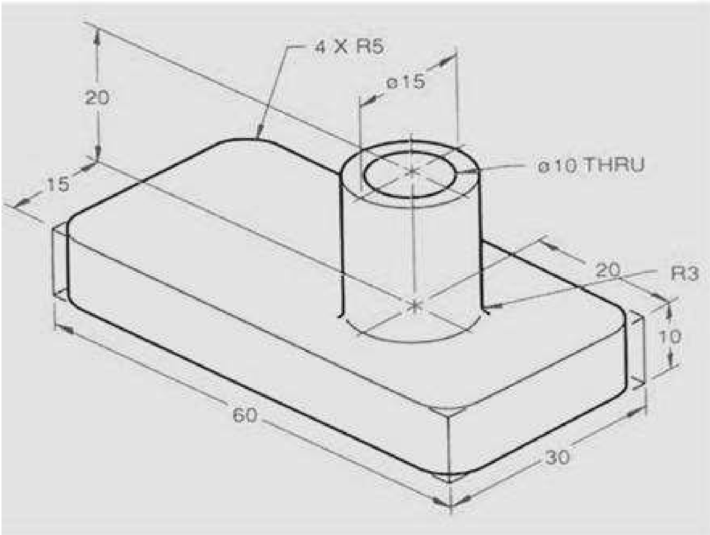


Figure 9 showing the procedure of using dimension lines, extension lines and text.

5.3 Isometric view of some standard shapes

1.Square

Consider a square ABCD with a 30 mm side shown in Fig. If the square lies in the vertical plane, it will appear as a rhombus with a 30 mm side in isometric view as shown in Fig. (a) or (b), depending on its orientation, i.e., right-hand vertical face or left-hand vertical face. If the square lies in the horizontal plane (like the top face of a cube), it will appear as in Fig.(c). The sides AB and AD, both, are inclined to the horizontal reference line at 30°.

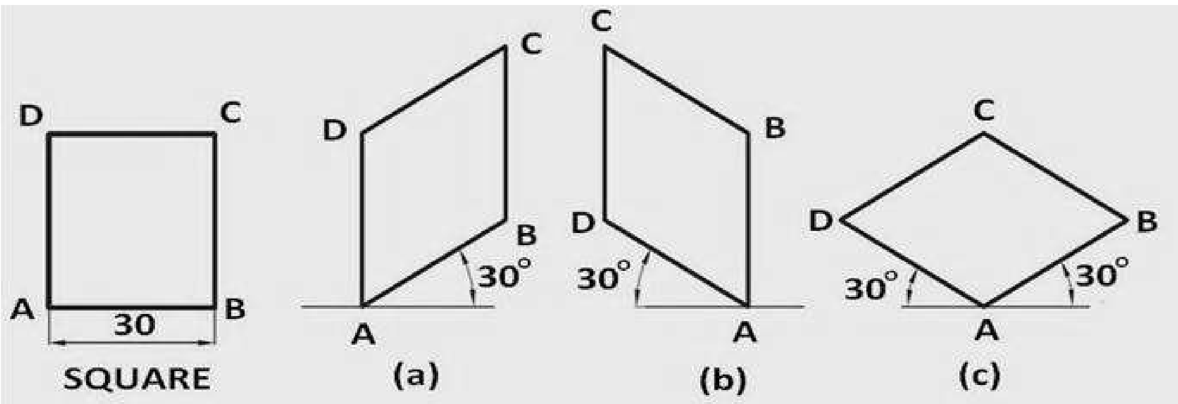


Figure 10. Isometric views of a square.

2.Rectangl*e*

A rectangle appears as a parallelogram in isometric view as shown in figure 11.. Three versions are possible depending on the orientation of the rectangle, i.e., right-hand vertical face, left-hand vertical face or horizontal face.

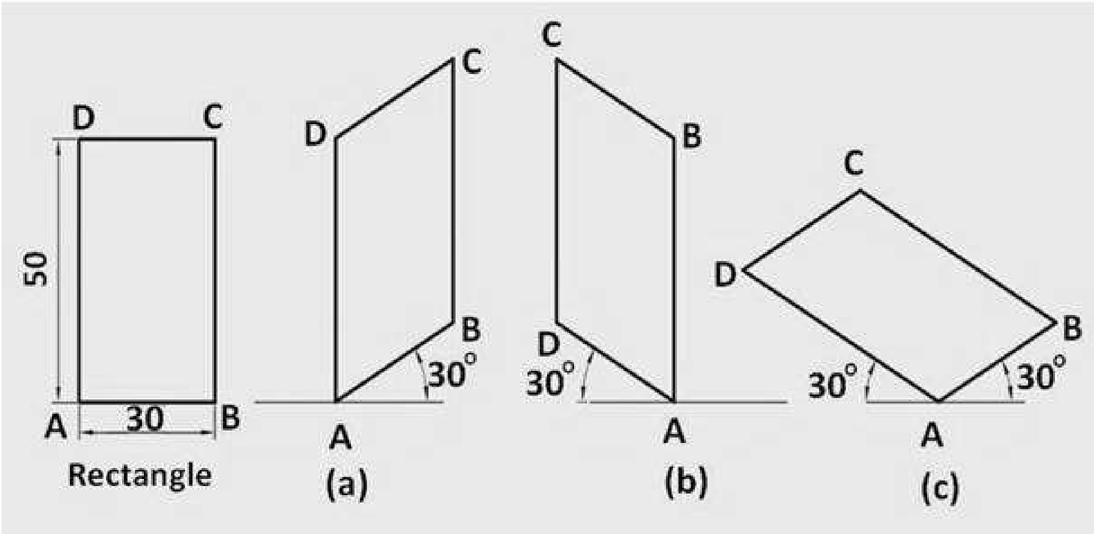


Figure 11. Isometric views of a rectangle.

3.Triangle

A triangle of any type can be easily obtained in isometric view as explained below. First enclose the triangle in rectangle *ABCD*. Obtain parallelogram *ABCD* of the rectangle as shown in Fig. 12(a) or (b) or (c). Then locate point 1 in the parallelogram such that *C*–1 in the parallelogram is equal to *C*–1 in the rectangle. *A*–*B*–1 represents the isometric view of the triangle.

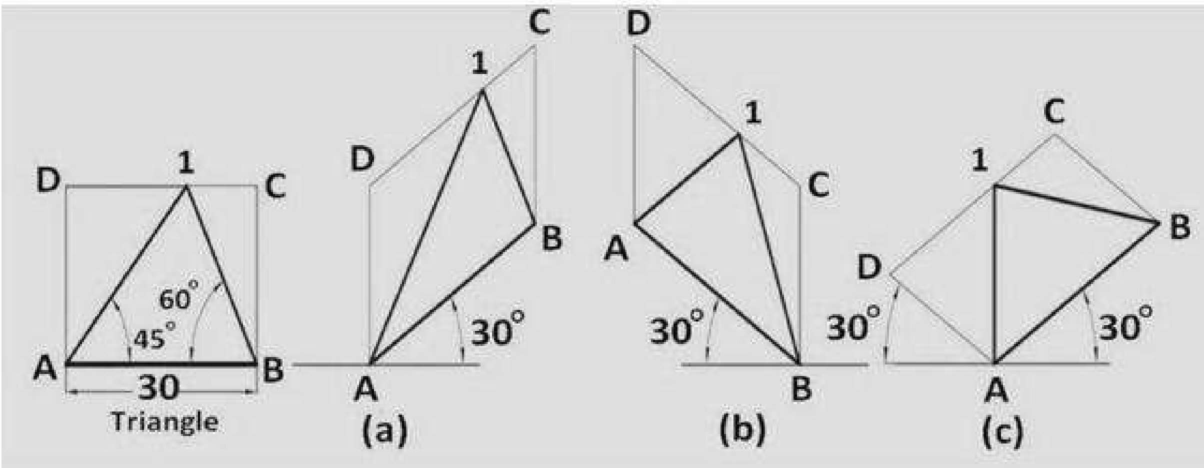


Figure 12. Method of obtaining the isometric views of a triangle.

4.Pentagon

Enclose the given pentagon in a rectangle and obtain the parallelogram as in Fig. 13 (a) or (b) or (c). Locate points 1, 2, 3, 4 and 5 on the rectangle and mark them on the parallelogram. The distances *A*–1, *B*–2, *C*–3, *C*–4 and *D*–5 in isometric drawing are same as the corresponding distances on the pentagon enclosed in the rectangle since the edges of the rectangle are isometric axes.

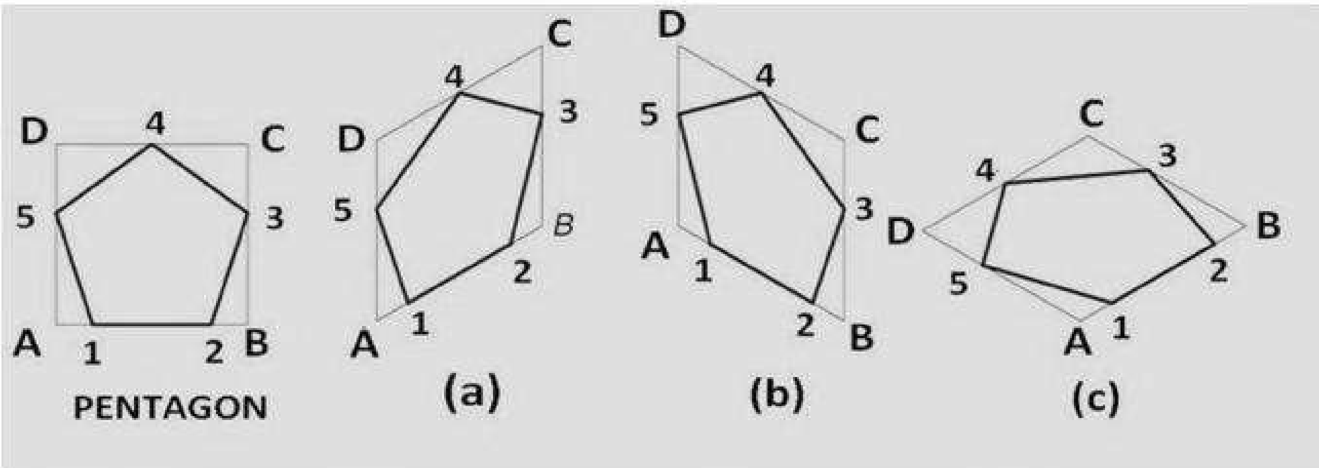


Figure 13. Method of obtaining the isometric views of a pentagon.

5.Circle

The isometric view or isometric projection of a circle is an ellipse. It is obtained by using four-centre method explained below and illustrated in Figure 14.
Four-Centre Method: First, enclose the given circle into a square *ABCD*. Draw rhombus *ABCD* as an isometric view of the square. Join the farthest corners of the rhombus, i.e., *A* and *C*. Obtain midpoints 3 and 4 of sides *CD* and *AD* respectively. Locate points 1 and 2 at the intersection of *AC* with *B*–3 and *B*–4 respectively. Now with 1 as a centre and radius 1–3, draw a small arc 3–5. Draw another arc 4–6 with same radius but 2 as a centre. With *B* as a centre and radius *B*–3, draw an arc 3–4. Draw another arc 5–6 with same radius but with *D* as a centre.

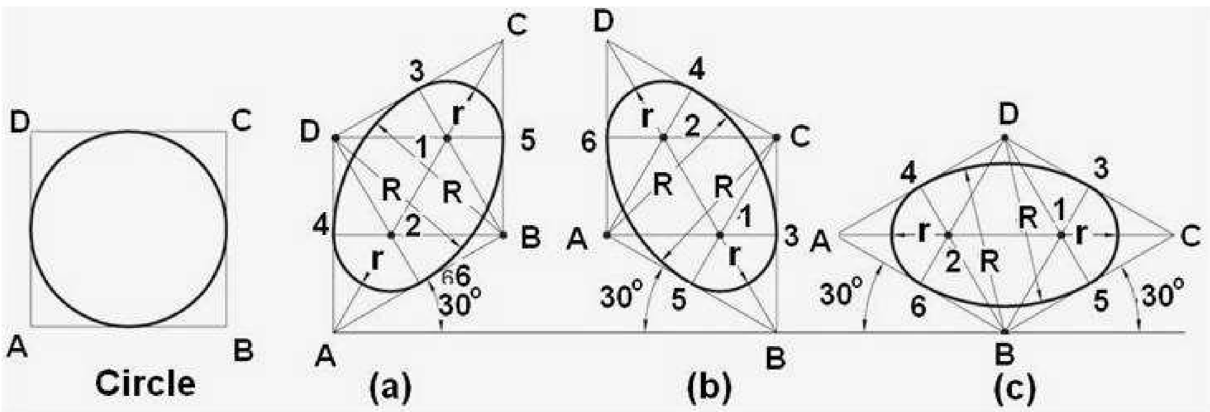


Figure 14. Method of obtaining the isometric views of a circle by four-centre method.

6.Isometric view of irregular Shape

The method of drawing the isometric view of an irregular shape 1–2–3–4–5–6–7 is illustrated in Figure 15. First the figure is enclosed in a rectangle. The parallelogram is obtained in isometric for the rectangle as shown. The distances B–2, D–2, C–3, E–3, G–4, F–4, H–5, H–6 and A–7 has the same length as in original shape since they are along the isometric axis. The points 1 to 7 are located by travelling along the isometric lines. After locating the points, the points are joined for lines which lie along non-isometric lines viz. 1-2, 2-3, 3-G, 6-5, 7-6.

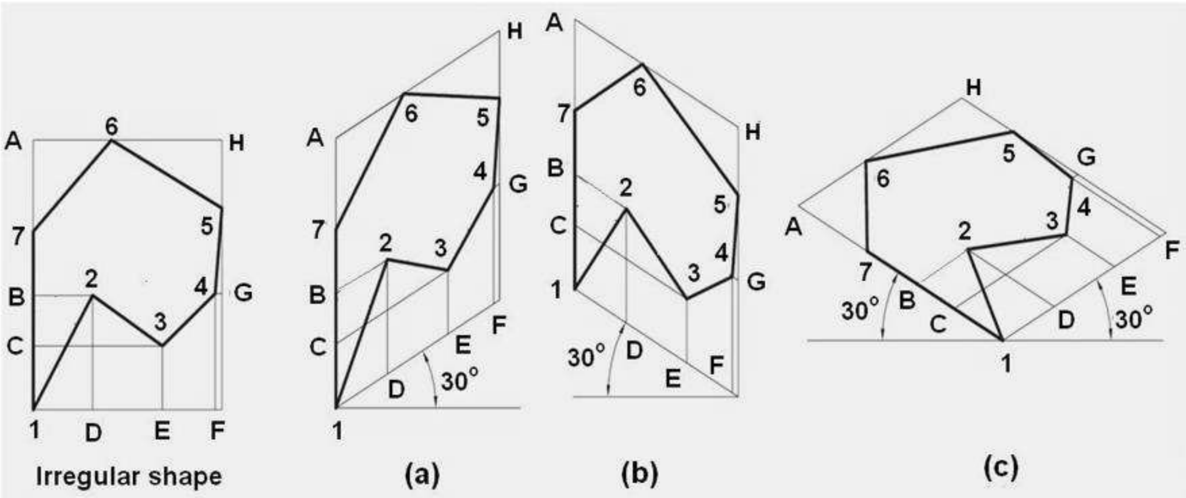
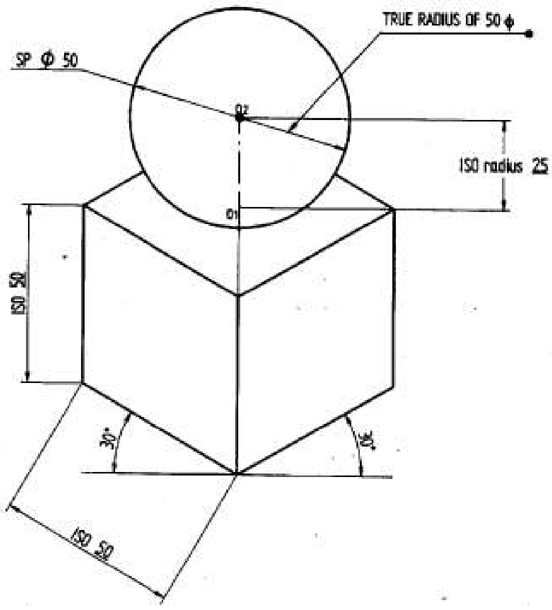


Figure 15. Method of obtaining the isometric views of an irregular shape.

Worked Examples- Isometric Projection

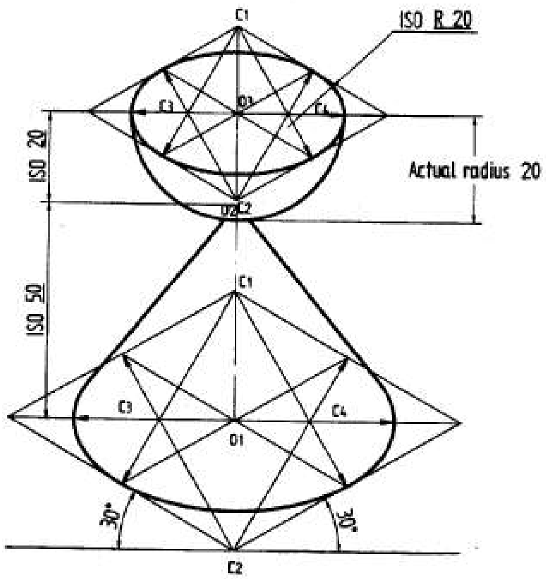
Problem 1 A sphere of diameter 50 mm rests centrally on top of a cube of sides 50 mm. Draw the Isometric projections of the combination of solids.

Solution



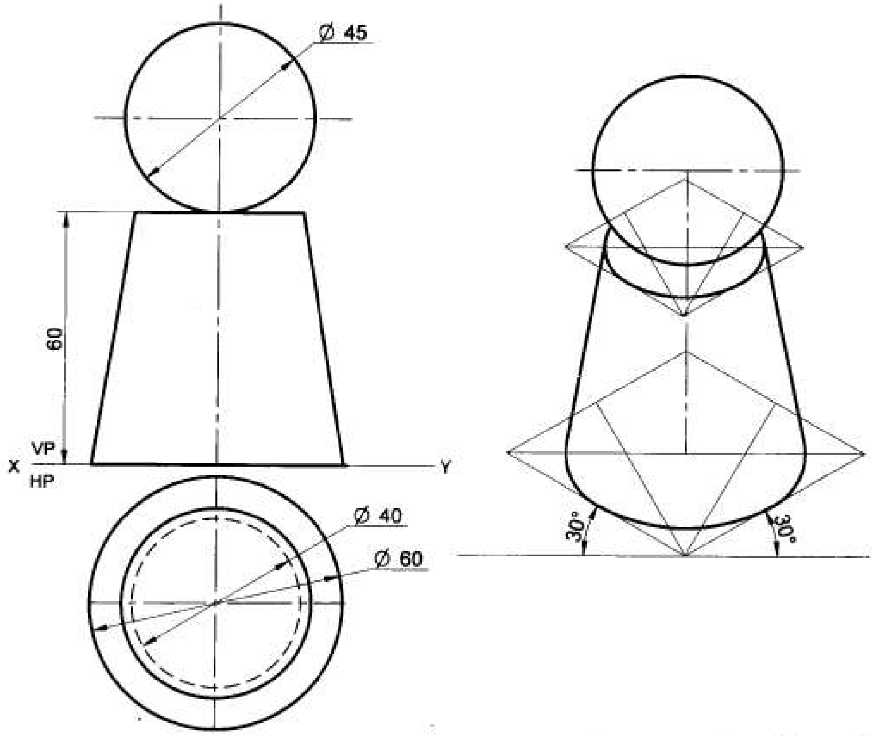
Problem 2 A hemisphere of 40 mm diameter is supported co-axially on the vertex of a cone of base dia. 60 mm and axis length 50 mm. The flat circular face of the hemisphere is facing upside. Draw the isometric projection of the combination of solids.

Solution



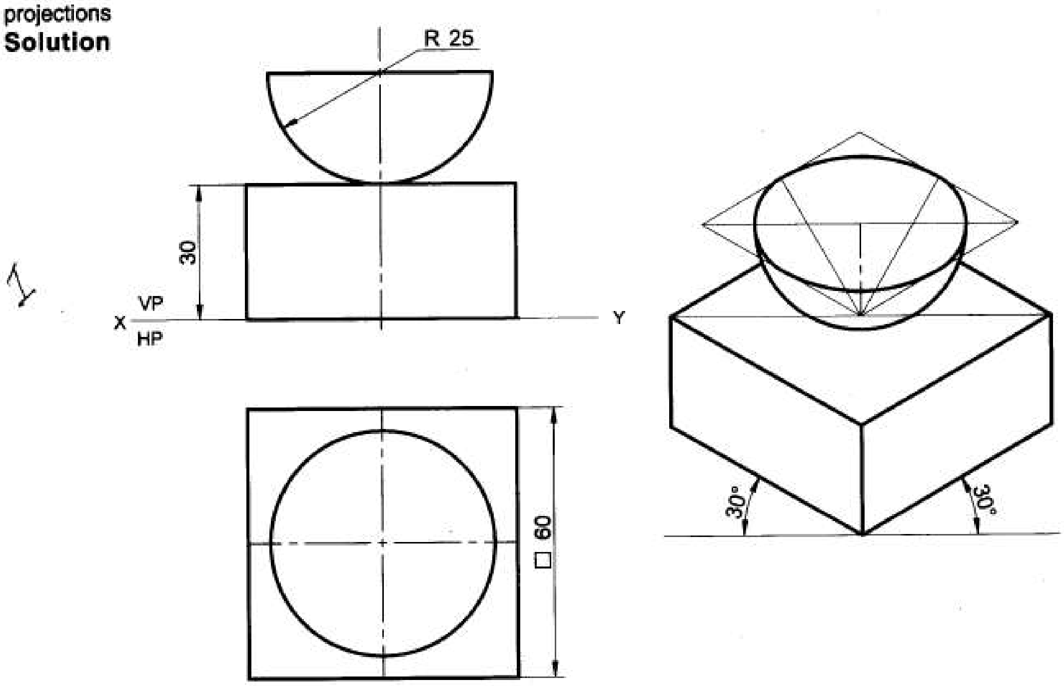
Problem 14 A sphere of diameter 45mm rests centrally over a frustum of cone of base diameter 60mm, top diameter 40mm and height 60mm. Draw its isometric projections.

Solution



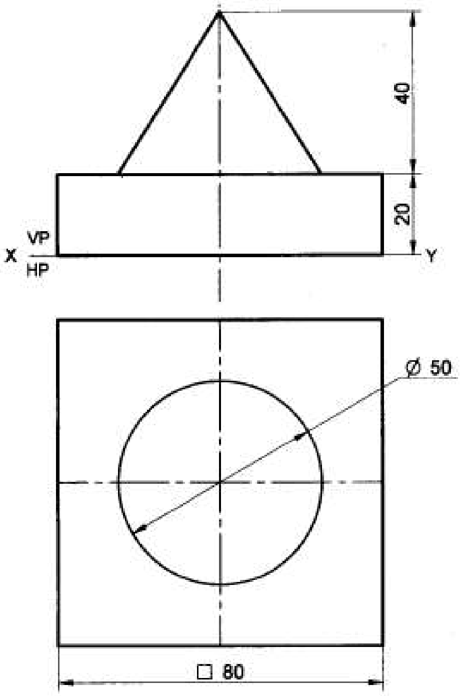
Problem 15 A hemisphere of diameter 50mm is centrally resting on top of a square prism of base side 60mm and height 30mm such that the curved surface of hemisphere is touching the top face of the prism. Draw its isometric projections

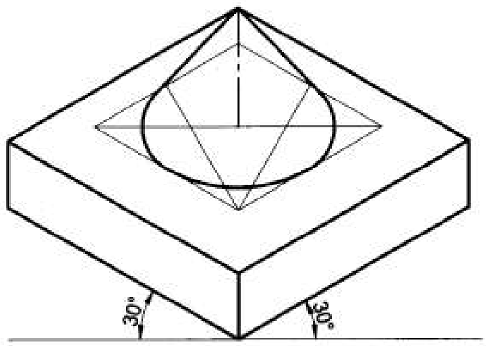
Solution



Problem 17 A cone of base diameter 50mm and height 40mm is placed centrally on the top face of a square slab side-80mm and height20mm. Draw the isometric projection of the combination

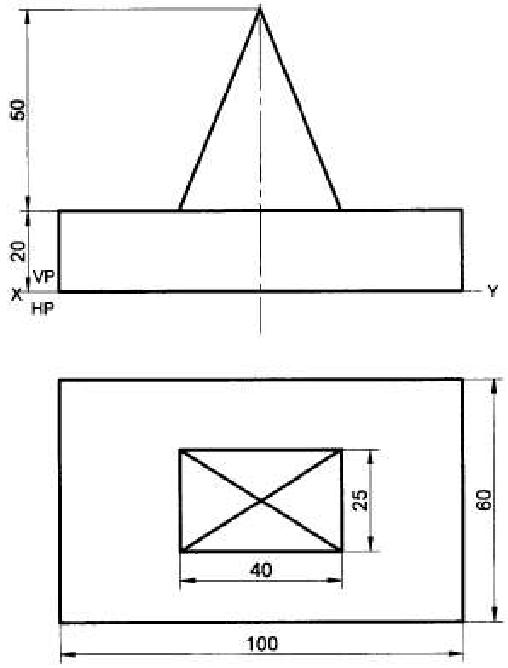
Solution

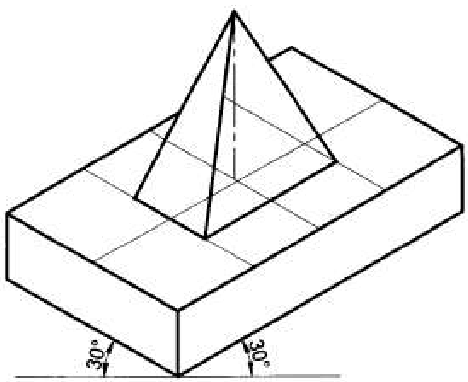




Problem 19 A rectangular pyramid of base-40mmx25mm and height50mm is placed centrally on a rectangular slab sides-100mmx60mm and thickness-20mm. Draw the isometric projection of the combination

Solution

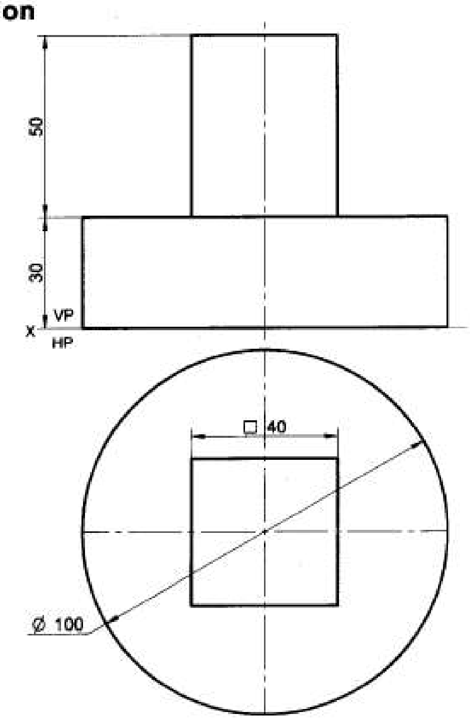


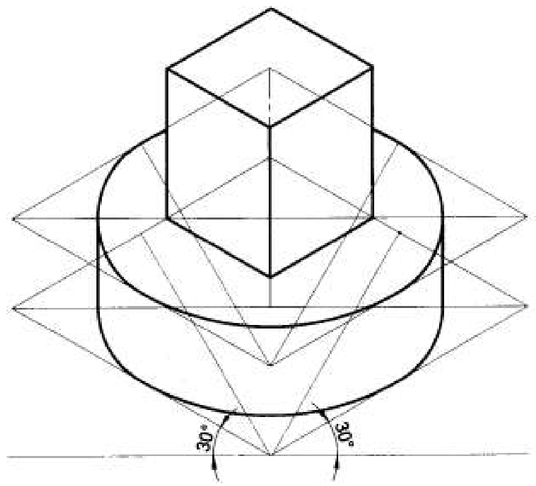


2

Problem 20 A square prism base side-40mm, height50mm is placed centrally on a cylindrical slab of diameter 100mm and thickness-30mm. Draw the isometric projection of the combination

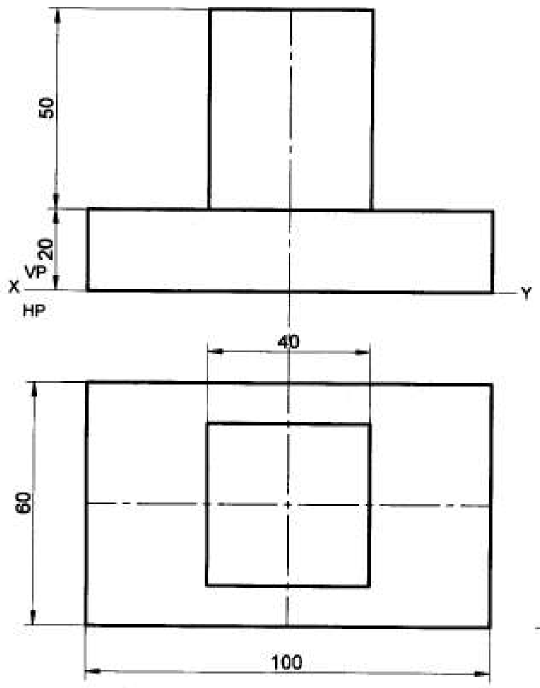
Solution

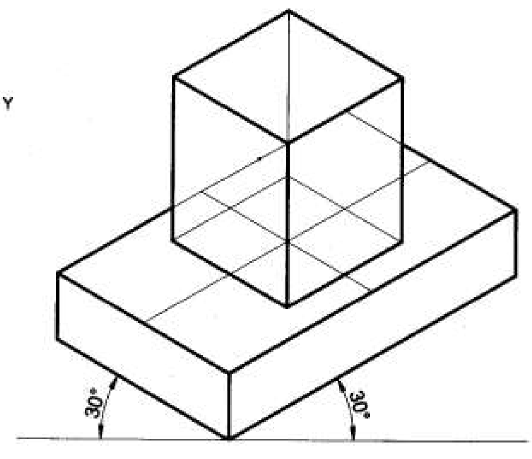




Problem 21 A square prism base side-40mm, height50mm is placed centrally on a rectangular slab sides-100mmx60mm and thickness-20mm. Draw the isometric projection of the combination

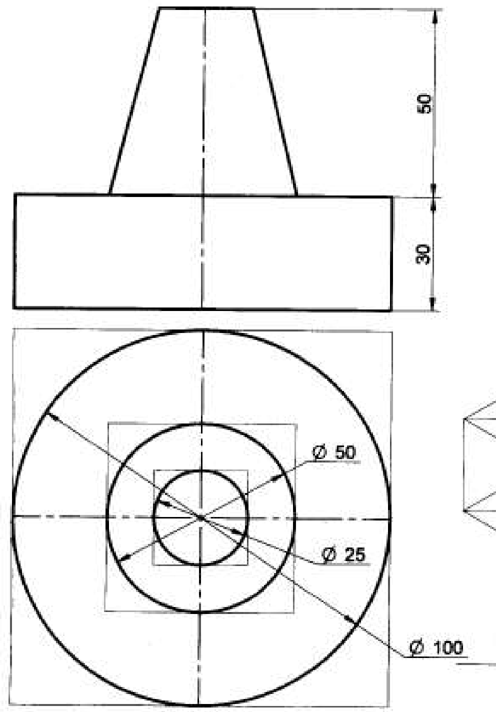
Solution

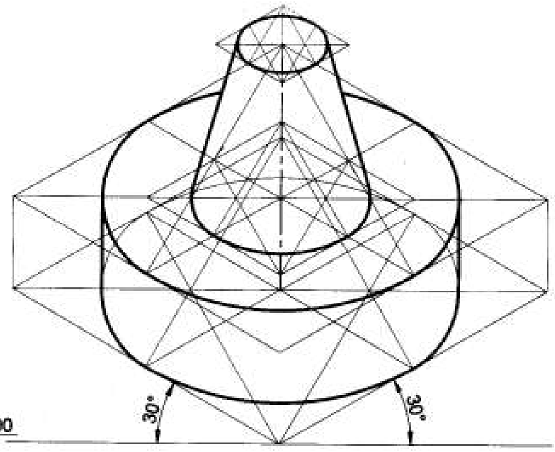




Problem 22 A frustum of cone base diameter 50mm, top diameter 25mm and height50mm is placed centrally on a cylindrical slab of diameter 100mm and thickness-30mm. Draw the isometric projection of the combination

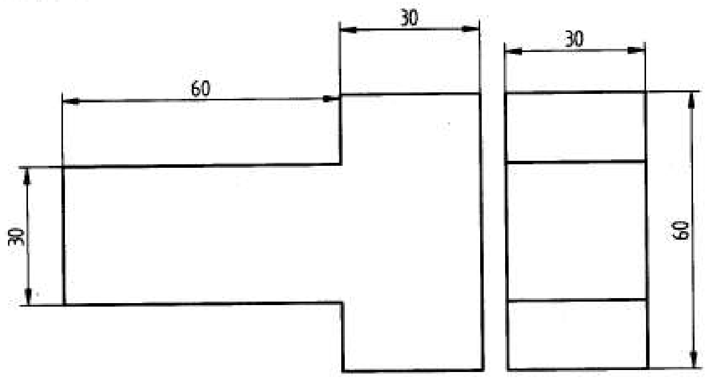
Solution

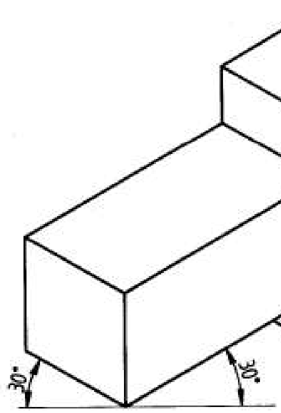




Problem 27 Following figure shows the front and side views of solid. Draw the Isometric projection of the solid.

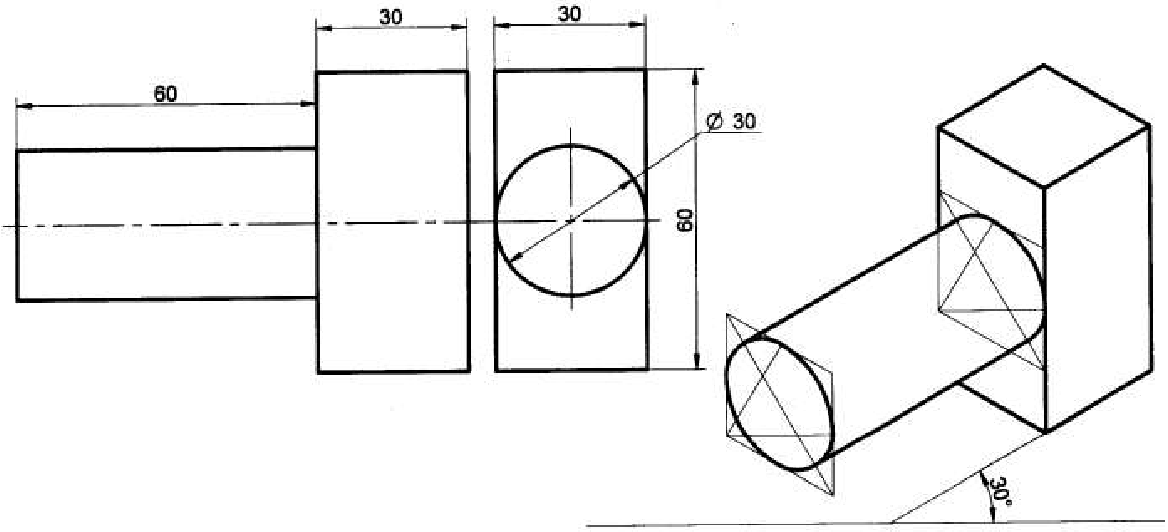
Solution





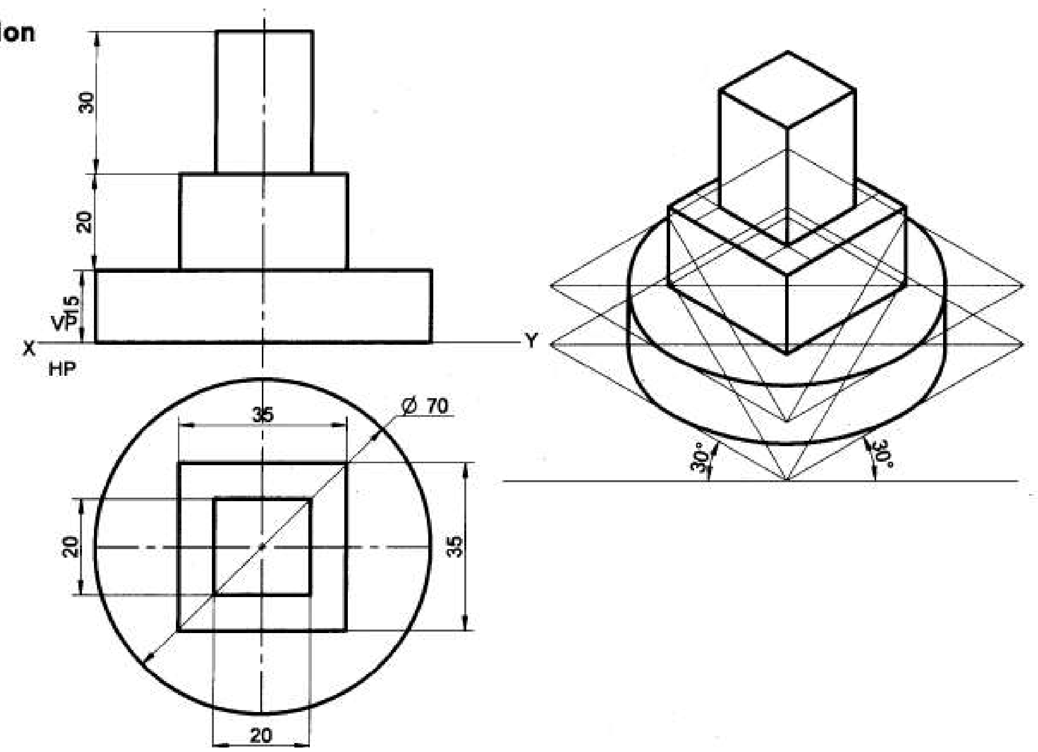
Problem 28 Following figure shows the front and side views of solid. Draw the Isometric projection of the solid.

Solution



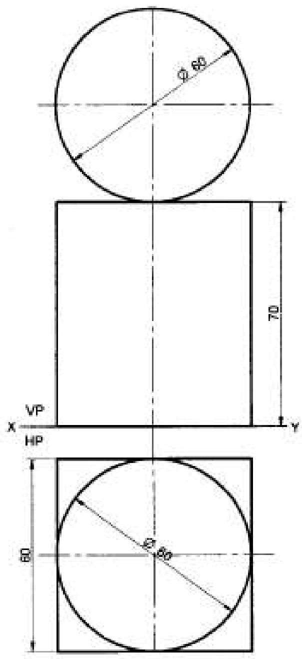
Problem 30 Following figure shows the front and top views of solid. Draw the Isometric projection of the solid.

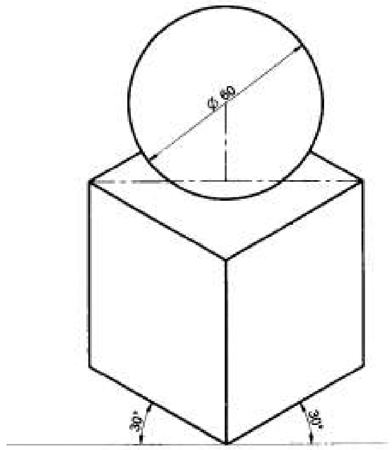
Solution



Problem 33 A sphere diameter 60mm is placed centrally on the top face of a square prism side-60mm and height 70mm. Draw the isometric projection of the combination

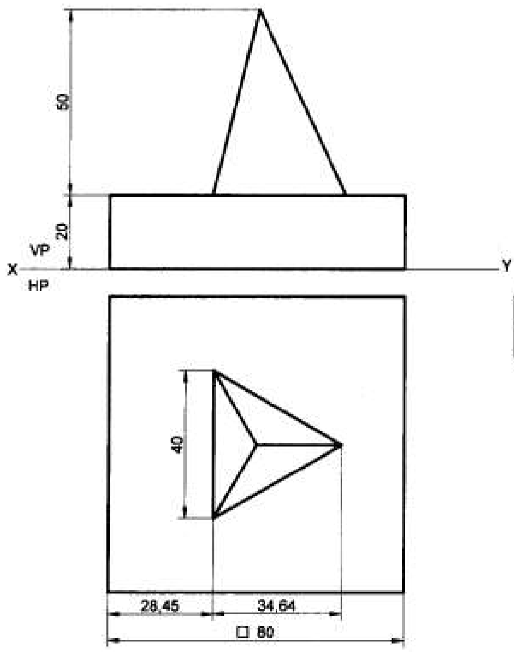
Solution

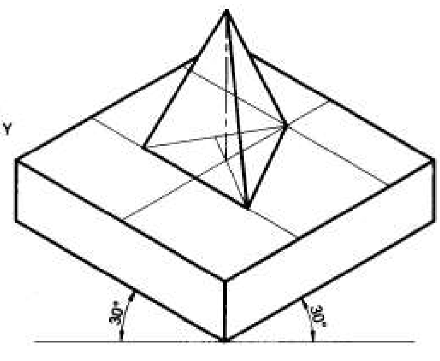




Problem 40 A triangular pyramid base side-40mm and height 50mm is placed centrally on a square slab side-80mm and 20mm-thick. Draw the isometric projection of the combination

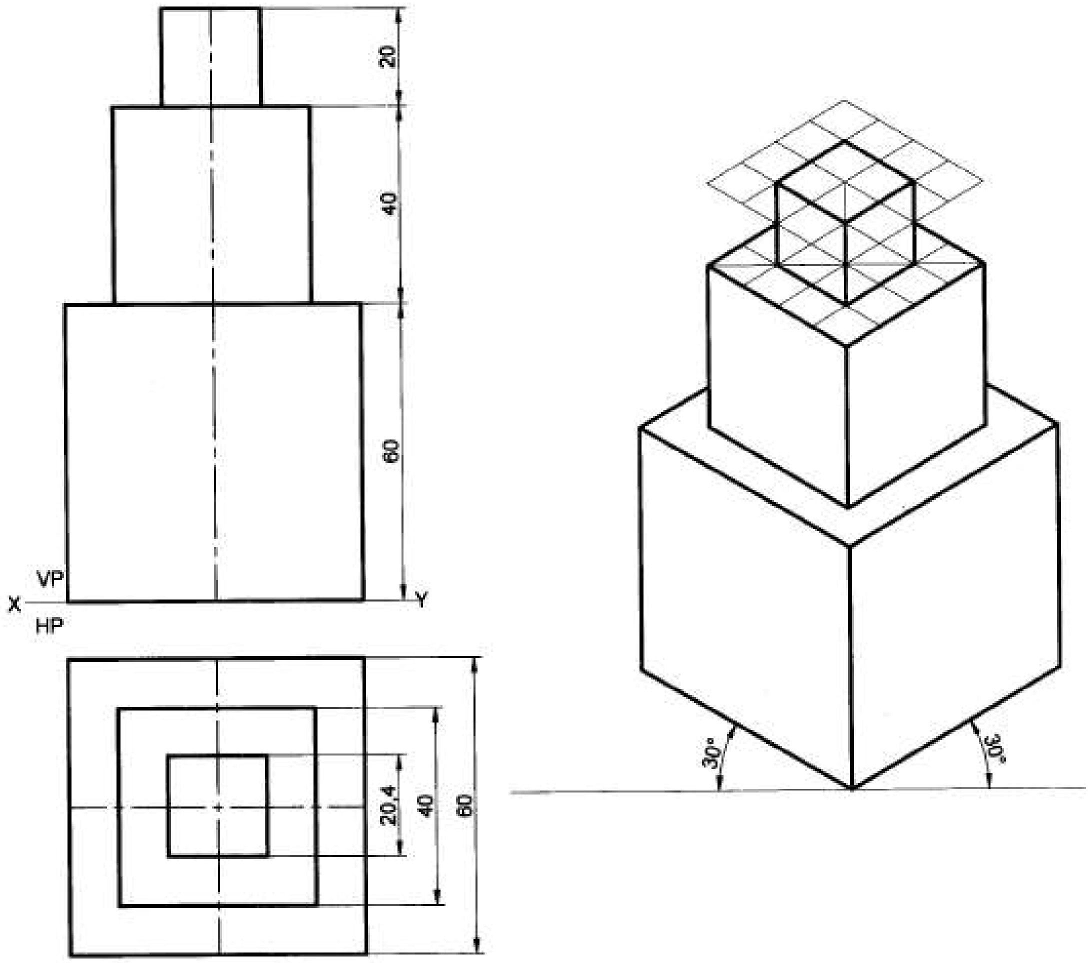
Solution





Problem 47 Three cubes of sides 60mm, 40mm and 20mm are placed centrally one above the other in the ascending order of their side. Draw the isometric projection of the combination

Solution



Problems on Isometrics

1. A rectangular pyramid of base- $40mm \times 25mm$ and height 50mm is placed centrally on a cylindrical slab of diameter 100mm and thuckness-30mm. Draw the isometric projection of the combination.
2. A rectangular pyramid of base- $40mm \times 25mm$ and height 50mm is placed centrally on a rectangular slab sides- $100mm \times 60mm$ and thickness-20mm. Draw the isometric projection of the combination.
3. A square prism base side-40mm, height 50mm is placed centrally on a cylindrical slab of diameter 100mm and thickness-30mm. Draw the isometric projection of the combination
4. A square prism base side-40mm, height50mm is placed centrally on a rectangular slab sides- $100mm \times 60mm$ and thickness-20mm. Draw the isometric projection of the combination
5. A frustum of cone base diameter 50mm, top diameter 25mm and height50mm is placed centrally on a cylindrical slab of diameter 10mm and thickness-30mm. Draw the isometric projection of the combination.
6. A frustum of cone base diameter 50mm, top diameter 25mm and height 50mm is placed centrally on a square slab side-80mm and thickness-30mm. Draw the isometric projection of the combination
7. A frustum of cone base diameter 50mm, top diameter 25mm and height 50mm is placed centrally on the top face of a cylinder diameter 60mm and height 60mm. Draw the isometric projection of the combination
8. A hemisphere diameter 50mm is resting on its curved surface centrally on the top face of a rectangular pyramid base- $80mm \times 60mm$ and top- $60mm \times 40mm$, height 55mm. Draw the isometric projection of the combination
9. A hemisphere diameter 70mm is placed on the ground on its curved surface. A cone base diameter 70mm and height 70mm is placed centrally on it. Draw the isometric projection of the combination
10. Following figure shows the front and side. Draw the Isometric projection of the solid.
11. Following figure shows the front and side views of solid. Draw the Isometric of the solid.
12. Following figure shows the front and side views of solid. Draw the Isometric projection of the solid.

FURTHER READING:

1) Computer Aided Engineering Drawing - S. Trymbaka Murthy, - I.K. International Publishing House Pvt. Ltd., New Delhi, 3rd revised edition- 2006.
2) Engineering Graphics - K.R. Gopalakrishna, 32nd edition, 2005- Subash Publishers Bangalore.
3) Dhananjay A Jolhe, Engineering Drawing, Tata McGraw Hill, 2007.
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5) K. Venugopal, Engineering Drawing and Graphics, New Age International (P) Ltd., publishers, 2000.

6) N.D. Bhatt and V.M. Panchal, Engineering Drawing, Charotar Publishing house, 2005.