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DRAWING OFFICE PRACTICE

STRUCTURE

Learning Objectives

- Introduction: Important of Engineering Drawing and their Use
- Introduction: Geometrical Constructions, Conic Sections and Special Curves
- Summary
- Keywords
- Answers to Check Your Progress
- Exercises

LEARNING OBJECTIVES

After reading this unit you will be able to

Drawing Office practice

- List out drawing instruments and accessories
- Explain about drafting procedure
- Have some idea of layout of drawing sheet
- State the types of lines
- Determine the styles and size of lettering
- Get the concept of role of stability
- Define dimensioning
- List out types of scales

Geometrical Constructions, Conic and Spiral Curves

- Explain the directrix method and concentric method of ellipse
- Describe the oblong method of drawing conical curves
- State the concept of special curves
- Draw the cycloidal curves
- Draw the involute
- Mention the application of conical and special curves
- Draw spiral curves
- Define Helix and its application.

1.1 INTRODUCTION: IMPORTANCE OF ENGINEERING DRAWINGS AND THEIR USES

Engineering drawing is a graphic language. A variety of instruments and materials (Refer Fig. 1.1) are needed to record information on the drawing sheet. These are the necessary tools for laying down lines on a drawing in an accurate manner. It is essential to learn the correct technique of handling the instruments in order to promote economy and produce clean and readable drawings. For a work of professional grade, a set of superior instruments is a boon. Generally a beginner is tempted to purchase cheap instruments for learning, whereas poor ones will be an annoyance from the start and worthless after a short use. Good instruments will last a lifetime with reasonable care. Therefore, in selecting instruments and materials for drawing, one has to select the best. Since poor instruments can be difficult to distinguish from good ones, it is preferable to seek trustworthy advice before beginning. The student should mark all instruments and materials plainly with initials as soon as they are purchased.


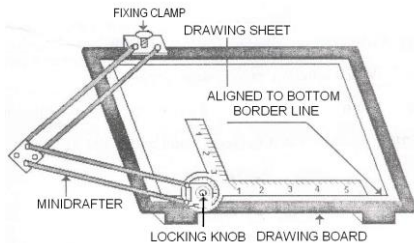

1.1.1 (a) BIS Codes

Indian Standards Institution (ISI) was in existence for framing the standards for products. Later in April 1987, Government of India formed a body of National Standards. This body for standardization is named as Bureau of Indian Standards - 'BIS'. The main objective of BIS is to foster the commercial and industrial growth of the country. BIS develops globally acceptable standard for various products. BIS involves in coordination with similar standards developing organizations, throughout the world, especially with International Standard Organization (ISO). BIS has implemented various standards especially for technical drawings. The students are strongly advised to adopt these recommended standards in practice. For our discussion in engineering graphics we will be following Indian Standards.

IS	3221	: 1966	SETS FOR DRAWING INSTRUMENTS
IS	10713	: 1983	SCALES
IS	10714	: 1983	SECTIONS AND OTHER CONVENTIONS
IS	11669	: 1986	GENERAL PRINCIPLES OF DIMENSIONING ON TECHNICAL DRAWINGS
IS	9609	: 2001	LETTERING
IS	10714	: 2001	LINES
IS	15021	: 2001	PROJECTION METHODS

1.1.1 (b) Drawing Instruments



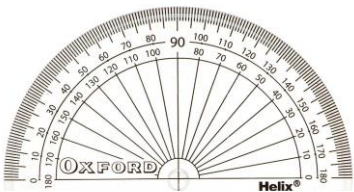
The uses, directions for use, precautions for keeping them in proper working order and specifications are presented in Fig. 1.1.



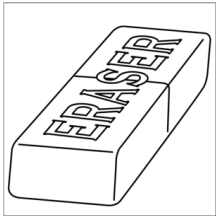


S. No.	Instrument	Remarks										
1	<div>Drawing Board</div> <div></div>	<div>It supports the drawing sheet. Handle the board carefully so that no dents or holes are made on its surface. Affix a sheet of paper on drawing board to keep it clean. It should not be used as a platform to place the drawing instruments - sharpner, pencil- pointer, duster etc. In emergency a table top or card board plank may be used in place of board. Remember the surface should be free from cracks. Drawing board is available in the following sizes:</div> <table><tr><th>Designation</th><th>Size (mm)</th></tr><tr><td>B0</td><td>1000 × 1500</td></tr><tr><td>B1</td><td>700 × 1000</td></tr><tr><td>B2</td><td>500 × 700</td></tr><tr><td>B3</td><td>350 × 500</td></tr></table>	Designation	Size (mm)	B0	1000 × 1500	B1	700 × 1000	B2	500 × 700	B3	350 × 500
Designation	Size (mm)											
B0	1000 × 1500											
B1	700 × 1000											
B2	500 × 700											
B3	350 × 500											
2	<div>Minidrafter</div> <div></div>	<div>It is used to draw horizontal, vertical and inclined lines. Drafter arms (graduated scales) should not be used for transferring dimensions to a drawing as this will damage the scale in due course. Hinges of the drafter should not have any play. Play, if any, in the rivets may be rectified by tightly tapping the rivets with a tapered pin. Drafter is specified by length of arms. Usual size is 225 mm × 150 mm.</div>										
3	<div>Compass (2 Nos)</div> <div></div>	<div>It is used to draw circles and arcs. Compass needle point must be at Big and Small least 1 mm longer than the lead point. Lead hardness should be at least one grade softer than that used in the pencil work of the drawing. Lead should be sharpened to a wedge edge for better results. Compass should be inclined slightly in the direction of sweep. Tension in the compass must be constant throughout the motion and just sufficient to enable easy setting of the distance</div>										

		between the points. This can be adjusted by adjusting the screw. Never oil the joints of compass. Compass is specified by the length of the leg. Available sizes are 150 mm, 77 mm.
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CHECK YOUR PROGRESS

1. What is meant by engineering drawing?

4	<p>Divider (2 Nos)</p> 	<p>It is used to transfer measurements from one view to another. It is used to divide curved or straight line into any number of equal parts. It is used to set-off distances from the scale to drawing. It should be kept in the appropriate velvet-seat inside the box when not in use. Never jab the divider into the drawing board. Never use the divider as a reamer, pincer or pick. It is specified by length of the leg. Available sizes are 150 mm and 77 mm.</p>
5.	<p>Scales</p> 	<p>They are used to make drawings of large objects and to transfer the dimensions of an object to the drawing. Never use the scale as a ruler for drawing lines. Commercially available scales are eight in number with designations M1, M2, M3, and so on; with graduations to measure reduction in length, i.e., 1:2, 1:5 etc.; and increase in length, i.e., 2:1, 5:1 etc.</p>
6	<p>Protractor</p> 	<p>It is used to mark or measure accurately such angles that cannot be precisely drawn or measured with the minidrafter. Some times it is combined with a set square. It is specified by the outer diameter. Available size is 150 mm with degree accuracy.</p>

7	<p>French curves</p> 	<p>They are used to draw curved lines which cannot be drawn with compass. Sometimes one or two French curves are provided in the middle of a set square. They are designated by numerals or letters and available in elliptical, parabolic, hyperbolic, logarithmic spiral, rail road and ship shapes.</p>
8	<p>Pencils (3 Nos)</p> 	<p>Soft grade (B) pencils have to be used primarily for sketching and rendering drawings and hard grade (H) pencils for instrument drawing. A pencil should always be kept sharp. It should be rotated while drawing for longer life. For better grip use hexagonal pencil. Never sharpen a pencil over the drawing. They are graded by numbers and letters from 6B, very soft and black, through 5B, 4B, 3B, 2B, B and HB to F, the medium grade, then H, 2H, 3H, 4H, 5H, 6H, 7H and 8H to 9H, the hardest.</p>
9	<p>Eraser</p> 	<p>It is used to remove pencil lines and for cleaning finger marks and smears on the sheet. Soft grade eraser should be used for better results. Never scrub a drawing all over with an eraser after finishing. It takes the life out of the lines.</p>
10	<p>Sheet fasteners (Tapes, Clips or Pins)</p> 	<p>They are used to hold the drawing sheet on board properly. As pins leave holes on the working surface of the drawing board, they should be avoided.</p>
11	<p>Pencil-Pointer pad</p> 	<p>It is used to form a long conical lead point. Pad should be kept in a paper envelope when not in use. Knock- off excess graphite from the pad outside the drawing table. Replace sand paper when it is worn out.</p>

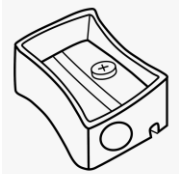

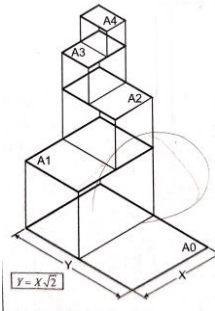
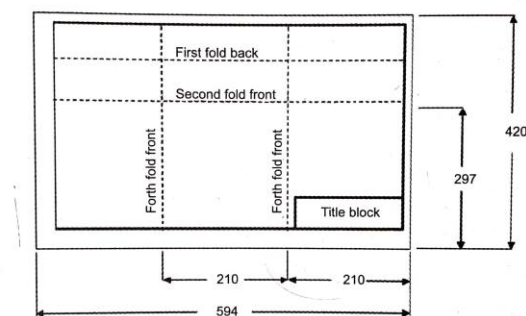
12	Sharpner 	It is used to shave off the pencil wood.
13	Duster 	It is used for removing eraser shavings and graphite particles. Use duster instead of hand to remove crumbs of pencil and eraser.
14	Box of leads	It is used to keep leads and spare needles.
15	Sketch book (2 Nos)	200 page long note book.
16	Drawing Sheet 	It should have sufficient grains or tooth to take the pencil and have a hard surface, not easily grooved by the pencil, with good erasing qualities. It should be cream coloured for easy viewing. Keep the hands off the drawing sheet as they leave oily stains. Avoid frequent sliding of drafter on drawing sheet. Move it with upward lift. Drawing sheets are available in the following standard sizes.
17	Graph paper (10 Nos)	They are used to practice lettering.
18	Hand bag	It is used to hold the above materials and instrumnets.

Fig. 1.1. Engineering drawing materials and instruments.

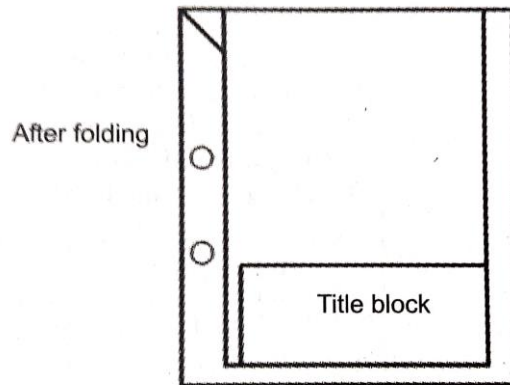
Folding of Drawing sheet (IS: 11664-1986)

Drawing sheets are folded for filing and binding purposes. The recommended folding for A2 drawing sheet is shown in figure.

BEFORE FOLDING



AFTER FOLDING



The basic principles in folding of drawing sheets are

- (i) All larger size drawing sheets i.e., A0, A1, A2 and A3 are folded to A4 size sheet.
- (ii) The title block of the folded sheets must be the bottom most position.
- (iii) The bottom right corner should be the outer visible section and should be a width of not less than 190 mm.

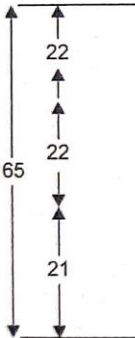
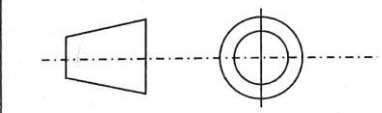
TITLE BLOCK

It is an important feature of drawing. It should be placed at the bottom right corner of the drawing sheet. The recommended specifications as per IS: 11665-1985 provides the following information.

- 1. Name of the student preparing drawing
- 2. Roll No.
- 3. Section
- 4. Title of drawing
- 5. Drawing sheet number
- 6. Scales
- 7. Name of the institution of firm
- 8. Date
- 9. Symbol denoting the method of projection
- 10. Name of the office checking the drawing

A typical recommended title-block is shown in figure.

TITLE BLOCK
ALL DIMENSIONS ARE IN MM

	Name of the college	Student name	11
		Roll No:	11
	Title of drawing	Section:	11
		Checked by:	11
		Scales:	11
		Drg. No:	Date
90		95	
185			

1.1.1 (e) General Instructions

Clean the drawing board and instruments with duster and place them in a neat place. Lukewarm soap water may be used to wash the instruments, if necessary. Always clean hands and pencil point with duster after sharpening so that the drawing sheet is not blackened.

Working on a flat board is very tiring and it is convenient to work on a tilted (20-30°) board. Drawing board can be easily tilted at the desired angle by fixing it on trestle. Working on a board improperly placed with regard to light is equally tiring. Therefore, ensure proper lighting. Standing or sitting posture of the student must be appropriate to suit the drawing board position such that he/she must be able to access all the four corners easily.

Fix the drawing sheet at bottom right hand corner of the board. Align the 0 (zero) of protractor on the drafter with the index mark and fix the arms in this position. Now clamp the drafter keeping the horizontal arm aligned with the top edge of the drawing sheet. Check that

- the arms of the drafter are reaching the areas where drawings are to be prepared on the sheet and
- the levers of the drafter are not projecting too much towards the left obstructing the passage.

A perfect rectangular working space is determined by drawing border lines (thin continuous) as shown in figure 1.2 at a distance of 25 mm to 30 mm from the left hand edge and an equal distance of 10 mm to 15 mm from top, bottom and right hand edges of the sheet. More space is required on left hand side to bind or file the sheets.

Place the title block on the right hand bottom portion of the drawing sheet. Figure 1.3 shows a typical title block suitable for engineering colleges. Name of the institution, title of the drawing, name of the student, drawing sheet number, scale, date, symbol denoting the angle of projection etc, are the features to be indicated in the title block.

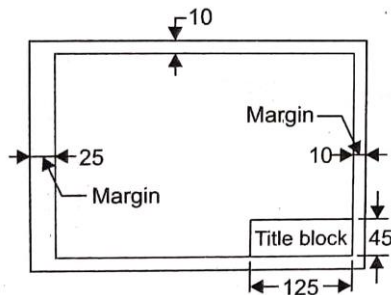


Fig. 1.2. Border lines

KONERU LAKSHMAIAH COLLEGE OF ENGINEERING		
NAME:	KATTOJU A. RAO	SCALE:
CLASS:	DATE:	
ROLL NO:	MARKS:	SHEET NO:

Fig. 1.3. Title block.

When only one drawing is to be drawn, it should be drawn in the middle. For more figures small blocks of space for each figure are to be provided at equidistance. Print problem number in a circle of diameter 10 mm on left hand top corner of drawing. If two sheets are to be used for one exercise, tie or staple them together. Fold the drawing sheet such that the title block comes to top (Refer Fig. 1.4). File the sheets neatly for submission.

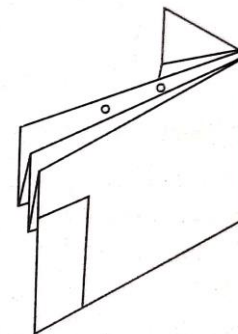
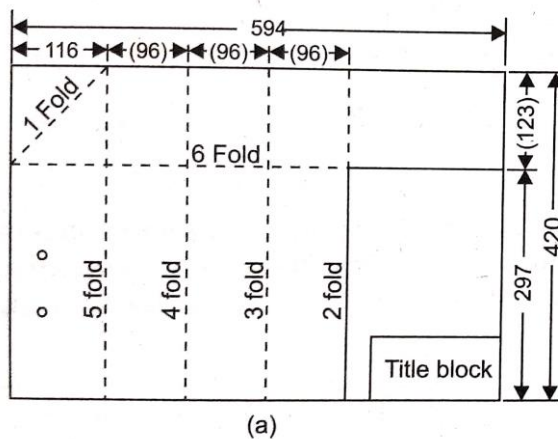


Fig. 1.4. Folding the drawing sheet.

CHECK YOUR PROGRESS

2. What is the standard size of the drawing board?

1.1.2 Lettering and Numbering

Lettering is used to convey additional information on engineering drawings. Writing of titles, subtitles, dimensions, scale and other details on a drawing is known as lettering. Lettering is used on engineering drawings because it is more uniform and more easily read than script. If one word or one dimension is misinterpreted on an engineering drawing, the entire part might be ruined.

CHECK YOUR PROGRESS

3. What is meant by lettering?

The ability to letter freehand with speed, neatness, ease, beauty of form, uniformity and legibility is a skill to be mastered by every student. Use of instruments for lettering should be avoided as it consumes more time. Lettering should be done on the drawing in such a manner that it may be read, when the drawing is viewed from the bottom edge, except when it is used for dimensioning.

All subtitles should be placed below but not too close to the respective views. Lettering should not normally be underlined. All letters and numerals should be kept clear off the lines. Efficiency in the art of lettering can be achieved by careful and continuous practice. It is conventional in engineering drawing to print any letter as plainly as possible.

Lettering should always be done with guidelines. These guidelines consist of four parallel lines, one for the top of capital letters and ascenders of lower case letters, one for the top of the lower case letters, one for the bottom of upper and lower case letters and one for bottom of the descenders of lower case letters as shown in Fig. 1.5. All the letters may or may not extend to all four lines. The guide lines should be made thin. They can be erased in such a way that they will not appear in print.

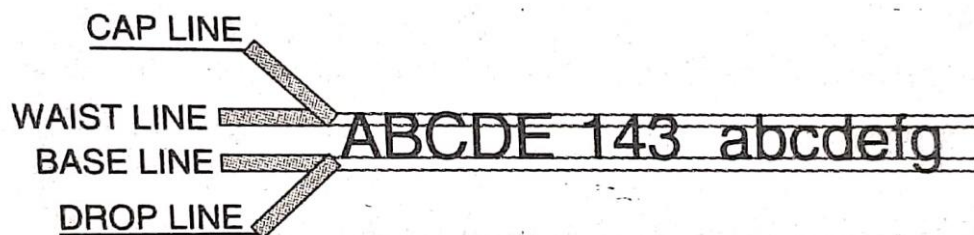


Fig. 1.5. Guidelines for lettering

Uniformity of spacing is the basis of good composition and requires that the letters in the words and the words in the sentences be properly spaced so that they can be easily read (Refer Fig. 1.6). As a general rule it

is good to make the letters broad and leave a little gap between them. The spacing left between the words should be sufficient to insert the letter N.

Because of the great variety in the shape of the letters, no actual spacing can be recommended. If the white spaces between the letters appear equal and the white spaces between the words are made to appear equal, the lettering will read well.

This results in making letters with straight sides farther apart and letters with included space closer together (Refer Fig. 1.6).

COMPOSITION IN LETTERING REQUIRES CAREFUL SPACING, NOT ONLY OF LETTERS BUT OF WORDS AND LINES

Fig. 1.6. Spacing of letters and words.



Fig. 1.7. Spacing of letters.

A sharp 2 pencil should be used for drawing guidelines. For lettering sharpen the pencil to a long, conical point and then round the lead slightly on the end so that it is not so sharp as a point used for drawing.

Position of the Hand

For good lettering the hand must hold the pencil firmly, but there should be no tension caused by gripping too tightly.

The following guidelines will give a good foundation for improving the ability to letter:

- The forearm should rest on the desk.
- The index finger should be kept as straight as possible along the pencil. This will help to avoid tension in the hand.
- The strokes should be made with as little bending of the finger as possible.
- The forearm should be at an angle of 75 to 80 with the line of lettering.
- All strokes should be made from top to bottom and left to right.

Style in Lettering

The following characteristics designate the style of lettering:

- Form (Original or Basic such as Gothic, Roman, Old English, German, Bradley etc.).
- Character of stroke (Single, Double or Filled in).
- Direction (Vertical or Slant).
- Case (Upper or Lower).

Form (Original or Basic)

There are various forms of alphabets used in the art of lettering and each is appropriate for some particular purpose.

Gothic capital letters are used by the majority of engineers when making drawings.

The civil engineer is more likely to use the slant, single stroke, Gothic upper and lower case letters. On maps the more decorative style known as Modern Roman is sometimes used. The architect uses a variation of the single stroke Gothic that is distinguished by the addition of curves and seraphs. The most decorative and the most difficult to make is the Old English.

Gothic, Roman and Old English letters should not be mixed in the same piece of lettering. It is sufficient if the young engineer learns the single stroke Gothic.

Character of Stroke

The word single stroke should not be taken to mean that the letter should be made in one stroke without lifting the pencil. It means that the thickness of the letters should be such as obtained in one stroke of the pencil. They are the simplest form of letters generally used in engineering drawings.

In double stroke lettering the letters are drawn by drawing double stroke of the pencil with a uniform thickness between the strokes. The ratio of thickness and height of letters is 1:10. For signs, inscriptions, diplomas and the like, the double stroke or filled in letters are frequently used.

Direction (Vertical or Slant)

The letters are subdivided into two types: Vertical (upright) and Slant (inclined).

Both the upright/inclined letters and numerals are used for general purpose. In vertical lettering the direction of alphabets is vertical whereas in inclined lettering the direction of the alphabets is inclined to the horizontal line.

All slanting letters are classified as italic. Inclined letters lean to the right, the slope being $67\frac{1}{2}^{\circ}$ to 75° with the horizontal. The inclined lettering

is preferred as the slight errors in inclination of letters or spacing does not show much as in vertical lettering.

The stems and the axes of all letters must be parallel, whether they are vertical or inclined. Light slope guidelines may be drawn across the horizontal guidelines at the proper angle to keep the letters at the proper slope.

Case (Upper or Lower)

The single stroke is sub-divided into two types: Upper case (Capital and Lower case (Small))

All letters should be upper case (capitals) except where lower case letters are accepted internationally for abbreviations. Capitals and small letters should not be mixed except for the purpose of capitalization of proper nouns. Figs. 1.8(a) and Fig. 1.8(b) show the Commercial Gothic upper case single stroke vertical and slant styles respectively.



Fig. 1.8. (a) Single stroke Vertical Gothic letters and numerals.

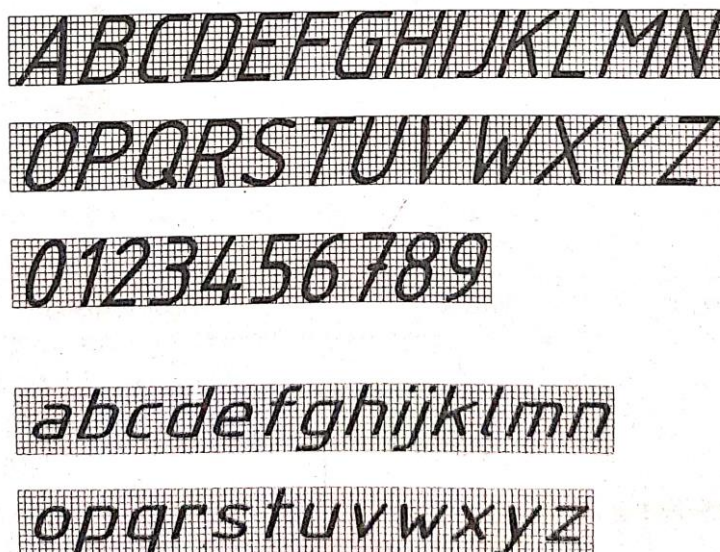


Fig. 1.8. (b) Single stroke Slant Gothic letter and numerals

Size of the letter

Size of the letter is the height of the capital letters. The small letters have their bodies two-thirds the height of the capitals. Small letters such as *b*, *d*, *h* have stems called ascenders, which are made of the same height as the capitals. Letters such as *g*, *j*, *p* have descenders that extend to one-third the height of the capital letters below the lower guidelines.

Numerals have the same height as the capital letters. Fractions frequently occur when dimensioning a drawing. They should be made large. The most common error is making them too small to be easily read. The fraction should extend above and below the capitals and integers. They should be at least one and one-half of the height of the numeral or capital letter. The numerator and denominator must each be at least two-thirds as high as the capital letter. The line between them is horizontal and neither the numerator nor the denominator may touch this line.

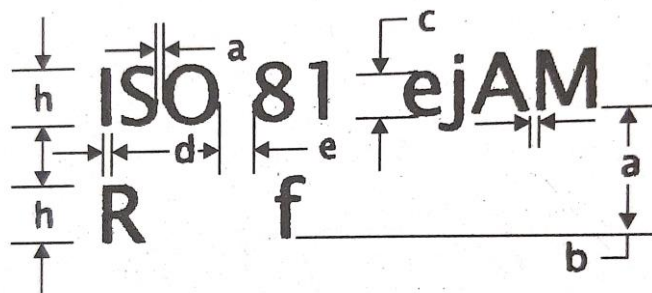
Dimensions

The height of the capital letters is taken as the base dimensioning. The range of standard heights *h* for lettering is as follows:

2.5 mm - 3.5 mm - 5 mm - 7 mm - 10 mm - 14 mm and 20 mm

The ratio of $\sqrt{2}$ in the range of heights for lettering is derived from the standardized progression of dimensions for paper sizes (A series according to ISO/R 216, Trimmed Sizes of thickness of writing paper and certain classes of printed matter).

The two standard ratios for $\frac{d}{h}$, $\frac{1}{14}$ and $\frac{1}{10}$ are most economical as they result in a minimum number of line thicknesses as is illustrated in tables (Table 1.1 and Table 1.2).



Letter of figure

Lettering A ($d = h/14$)

Table 1.1

Characteristics	Ratio	Dimensions						
Lettering height								
Height of capital h	$\left(\frac{14}{14}\right)h$	2.5	3.5	5	7	10	14	20
Height of lower case letters (without stem or tail) c	$\left(\frac{10}{14}\right)h$	-	2.5	3.5	5	7	10	14
Spacing between character a	$\left(\frac{2}{14}\right)h$	0.35	0.5	0.7	1	1.4	2	2.8
Min. spacing of base line b	$\left(\frac{20}{14}\right)h$	3.5	5	7	10	14	20	28
Min. spacing between words e	$\left(\frac{6}{14}\right)h$	1.05	1.5	2.1	3	4.2	6	8.4
Thickness of lines d	$\left(\frac{1}{14}\right)h$	0.18	0.25	0.35	0.5	0.7	1	1.4

Note: - The spacing two characters may be reduced by half if this gives a better visual effect, as for example I.A, TV; it then equals the line thickness d .

Table 1.2

Characteristics	Ratio	Dimensions						
Lettering height								
Height of capital h	$\left(\frac{10}{14}\right)h$	2.5	3.5	5	7	10	14	20
Height of lower case letters (without stem or tail) c	$\left(\frac{7}{14}\right)h$	-	2.5	3.5	5	7	10	14
Spacing between character a	$\left(\frac{2}{14}\right)h$	0.5	0.7	1	1.4	2	2.8	4
Min. spacing of base line b	$\left(\frac{14}{14}\right)h$	3.5	5	7	10	14	20	28
Min. spacing between words e	$\left(\frac{6}{14}\right)h$	1.5	2.1	3	4.2	6	8.4	12
Thickness of lines d	$\left(\frac{1}{14}\right)h$	0.25	0.35	0.5	0.7	1	1.4	2

1.1.3 Dimensioning

A drawing of an object is prepared to describe its shape and to specify its size. A complete drawing gives its shape description and also size description. The shape description is based on theory of projection. Size description is based on theory of dimensioning. Thus dimensioning is the

expression of details in terms of numerical values regarding distances between surfaces etc. Unnecessary dimensions should be avoided as they may confuse the drawing. The drawing student must learn the techniques of dimensioning, the rules of placement of dimensions on the drawing and the choice of dimensions.

The dimensions should be quoted once only. Overall dimension should be placed outside the intermediate dimension. Where overall dimension is shown, one of the intermediate distances is redundant and should not be dimensioned. Dimensions should be placed on the view which shows the relevant features most clearly.

Lines used in Dimensioning

A dimension line (Refer Fig. 1) is a thin, dark, solid line terminated by arrowheads, which indicate the direction and extent of a dimension. As shown in Fig. 1.9(b) the dimension line nearest to the object outline should be spaced at least 10 mm away. All other parallel dimension lines should be at least 6 mm apart. The spacing of dimension lines should be uniform throughout the drawing.

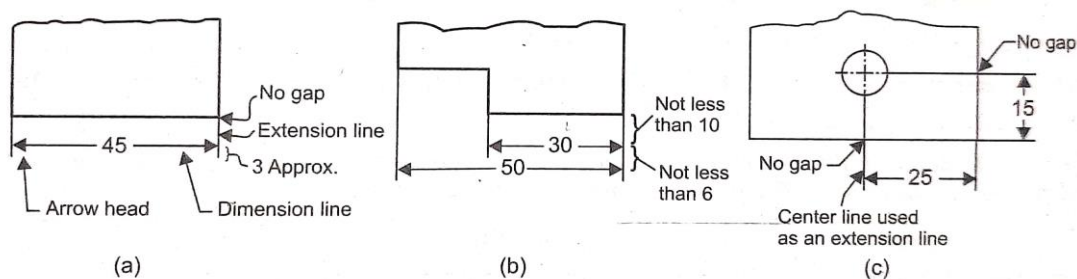


Fig. 1.9. Dimensioning technique

An extension line is a thin, dark, solid line that extends from a point on the drawing to which a dimension refers. The dimension line meets the extension lines at right angles except in special cases. No gap should be left where the extension line would join the object outline. The extension line should extend about 3 mm beyond the outermost arrowhead. Centerlines (Refer Fig. 1.9(e)) are commonly used as extension lines in locating holes and other features. When so used, the center line crosses over other lines of the drawing without gaps.

Placement of Dimension and Extension Lines

A correct example of the placement of dimension lines and extension lines is shown in Fig. 1.10(a). The shorter dimensions are nearest to the object outline. Dimension lines should not cross extension lines as at (b), which results from placing the shorter dimensions outside. Note that it is perfectly satisfactory to cross extension lines, as shown at (a). They should never be shortened, as at (e). A dimension line should never coincide with

or form a continuation of any line of the drawing as shown at (d). Avoid crossing dimensions wherever possible.

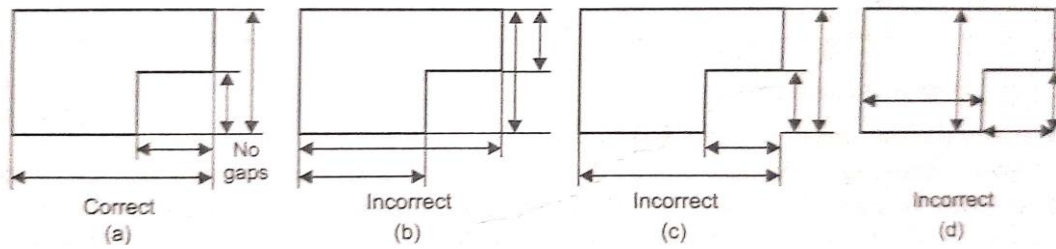


Fig. 1.10. Placement of dimensions and extension lines.

Dimensions should be lined up and grouped together as much as possible, as shown in Fig. 1.11(a) and not as at (b).

In many cases extension lines and center lines must cross visible lines of the object (Refer Fig. 1.12(a)). When this occurs, gaps should not be left in the lines, as at (b).

CHECK YOUR PROGRESS

4. What is meant by dimensioning?

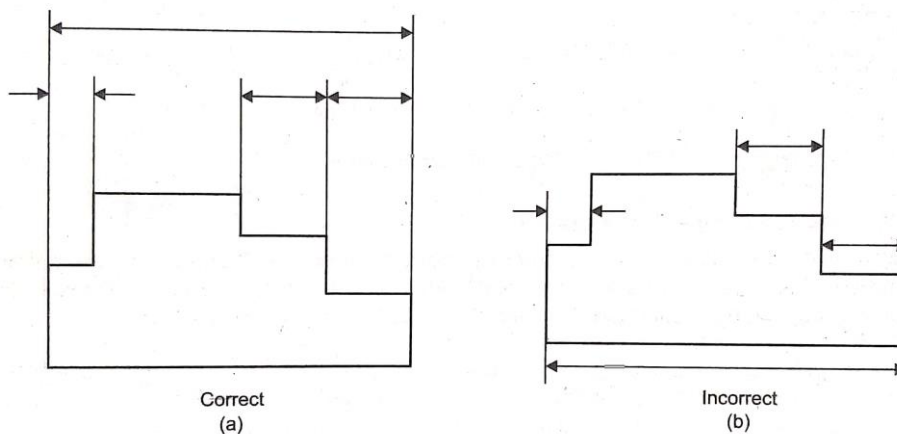


Fig. 1.11. Groped dimensions.

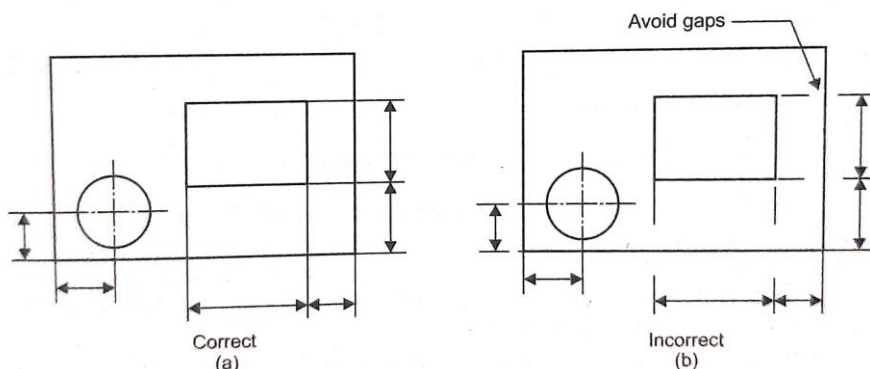


Fig. 1.12. Crossing lines

In crowded, gaps in extension lines near arrowheads may be left in order to clarify the dimensions as shown at Fig. 1.13(b). In general, avoid dimensioning to hidden lines, as shown at (c).

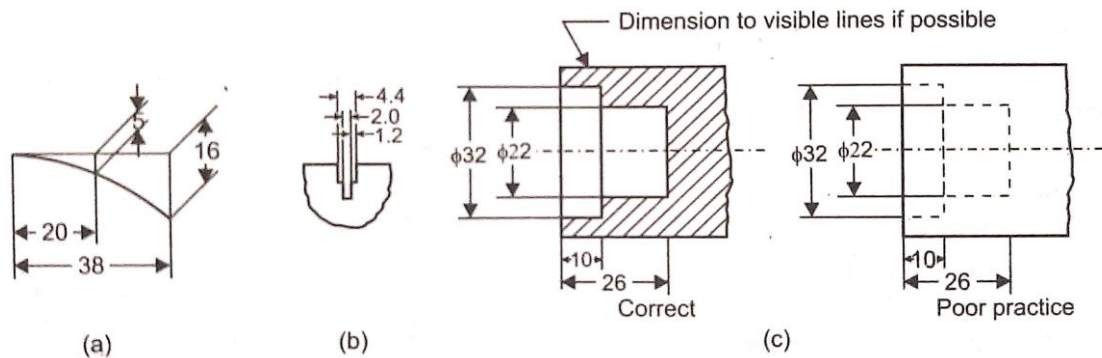


Fig. 1.13. Placement of dimensions.

Arrowheads

Arrowheads Fig. 1.14, indicates the extent of dimension. They should be drawn freehand. Use strokes towards the pointer or away from the pointer desired (b) and (c). For the best appearance, fill in the arrowheads as at (d).



Fig. 1.14. Arrow heads.

Direction of Dimension Figures

Two systems of reading direction for dimension figures are available. In the preferred unidirectional system (Refer Fig. 1.15(a)), all dimension figures and notes are lettered horizontally on the sheet and are read from the bottom of the drawing.

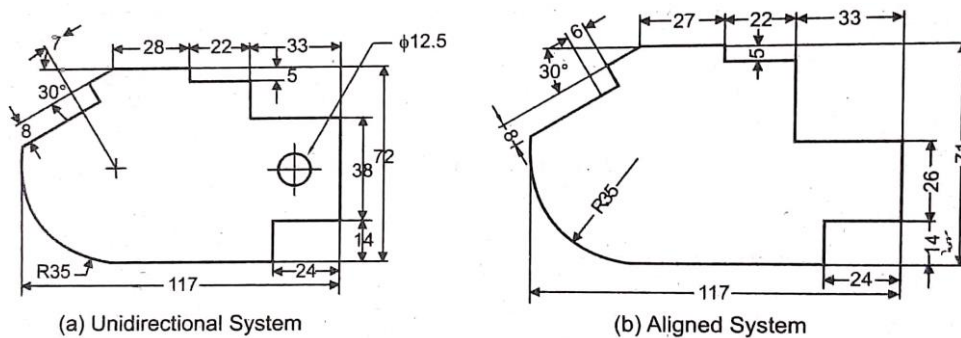


Fig. 1.15. Direction of dimensions figures

The dimension lines may be interrupted preferably near the middle for the insertion of dimensions. This system is easier to use and read, especially, on large drawings. In the aligned system (Refer Fig. 1.15(b)), all dimension figures are aligned with the dimension lines so that they may be read from the right side of the drawing sheet. The figure is placed in the middle.

Dimension figures should be written in a vertical style. They are expressed in only one unit. All the dimensions used in this book are in mm unless or otherwise expressed explicitly. The decimal point should be bold and be in line with the middle of the figure.

Dimensioning of Angles

Angles are indicated by drawing an arc of suitable radius and putting the symbol \circ in the break. Methods of indicating various angles are shown in Fig. 1.16.

Angles are dimensioned, preferably, by means of an angle in degrees and a linear dimension, Fig. 1.16(a) or by means of coordinate dimensions of the two legs of a right triangle, (b) The coordinate method is more accurate.

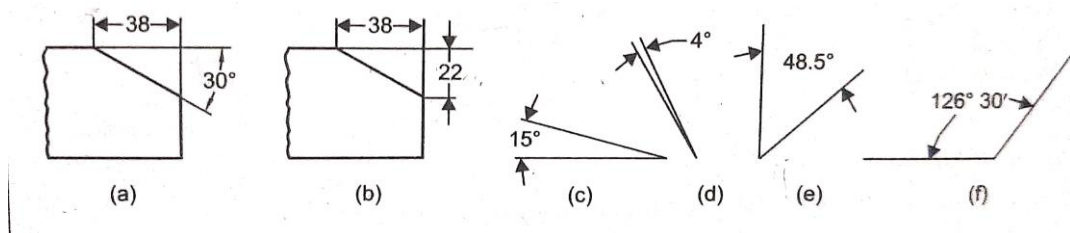


Fig. 1.16. Angles

In all cases, whether in the unidirectional system or in the aligned system, the dimension figures for angles are lettered on horizontal guidelines.

Dimension ON (or) OFF Views

Dimensions should not be placed upon a view unless doing so promote the clearness of the drawing. The ideal form is shown in Fig. 1.17(a), in which all dimensions are placed outside the view. Compare this with the evidently poor practice shown at (b).

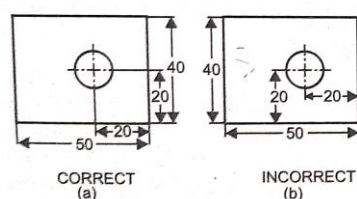


Fig. 1.17. Placement of dimensions ON or OFF views.

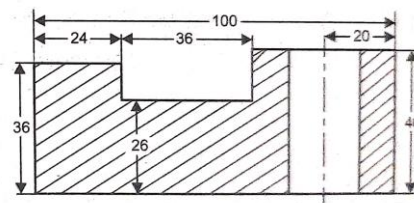


Fig. 1.18. Dimensioning inside a hatched portion.

So, place the dimensions outside of views, except where directness of application and clarity are gained by placing them on the views where they will be closer to the features dimensioned. When a dimension is placed in a sectioned area or on the view, leave an opening in the sectioned area or a break in the lines for placing the dimension figures, Fig. 1.18(b).

CHECK YOUR PROGRESS

5. What is meant by solid geometry?

1.1.3 (a) Leader Lines

Termination of leader lines

A leader line is a line referring to a feature (dimension, object, outlines, etc.). Leader lines terminate:

- With a dot, if it ends within outline of an object (Fig. 1.19 (a)).
- With an arrow, if it ends on the outline of an object (Fig. 1.19 (b)).
- With a dot or arrowhead, if it ends on a dimension line (Fig. 1.19 (c)).

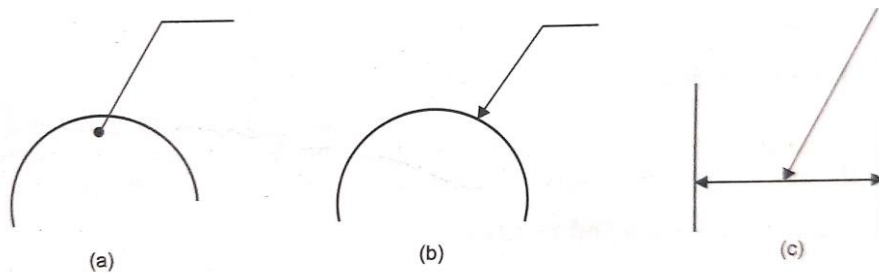


Fig. 1.19.

1.1.4 Scales

The objects of our interest vary greatly in different sizes. Such object may be a minute thing as a wristwatch gear or as big as an aeroplanes. While attempting to draw these objects on paper, a need arise to enlarge or reduce them depending on their actual sizes to have clear details, smaller objects have to be enlarged, and large size objects have to be reduced. Ofcourse, some objects may also be drawn exactly to the actual sizes. Thus the proportionate ratio by which the drawing is to be enlarged or reduced is termed as the "scale" of the drawing.

1.1.4 (a) Representative Fraction

The representative fraction (RF) or scale factor is the scale of the drawing indicated by that ratio.

i.e.,
$$RF = (\text{Length on drawing}) / (\text{Actual length}).$$

So if a 2 m long log is shown by a 20 cm long on a drawing then $RF = 20 \text{ cm} / 200 \text{ cm} = 1/10$. So in drawing if we adopt any RF, all the dimensions of the object should be drawn to the same RF. The term scale is normally expressed in the format X:Y while RF is expressed in the format X/Y. In the present example of the log mentioned above, the scale will be 1:10.

The scale must be invariably indicated on the drawing. It is written in the format: SCALE – X:Y by letters of suitable height. While the drawing objects in drawing sheet, if any scale is adapted it must be clearly indicated in the title block. Increase in that same drawing sheet, if different objects are drawn in different scales, then the scale for different objects is to be mentioned below the drawing of that particular object. In such cases, the scale is to be enclosed in a rectangle block.

1.1.4 (b) Enlarging or Enlargement Scales

While smallest object is to be drawn to note clear details, they often invariably need to be enlarged. The scales used in such drawings are called enlarging scales. Naturally, the length of the object on the drawing is more than the respective actual length/dimensions of the object. Such enlargement scales are indicated in the format X:1, X is greater than 1. in this case clearly RF greater than 1 ($RF > 1$).

Enlargement scales are normally used for drawing smaller objects like gears, screws used in wristwatch parts, electronic, gadgets, resistors, etc.,

1.1.4 (c) Reducing or Reduction Scales

When large sized objects have to be drawn, they need to be reduced in size in the drawing. The scales used for such objects or called reducing scales obviously the length of the object are the drawing is lesser than the true length of the object. Reducing scales are mentioned in the format 1:Y, where Y is greater than 1. Hence, $RF < 1$.

Some examples like huge machinery, automobiles, aeroplanes etc., are to be drawn in reducing scales.

1.1.4 (d) Full Size Scale

When drawing an object on the drawing sheet to the actual size, it is understood that the object is drawn to "Full scale". Since the length of the object in drawn is equal to the length of the object, the full scale is expressed as 1:1. Thus the full scale $RF = 1$.

1.1.4 (e) BIS Recommended Scales

Category	Format	Recommended Scales		
Enlarging scale	X : 1 ($X > 1$)	50:1	20:1	10:1
		5:1	2:1	
Full scale	1 : 1	1:1		
Reducing scale	1 : Y ($Y > 1$)	1:2	1:5	1:10
		1:20	1:50	1:100

1.1.4 (f) Units of Length Used in Drawing

There exist various units of length of any of their subdivisions. The SI unit of length is expressed in metre. But, metre is too large a unit to show the drawing sheet. Therefore the smaller divisions of metre, i.e., millimeter or centimeter are mostly conveniently used as applicable units of length on a drawing. Normally millimeter is used in a drawing unit. Millimeter can be measured precisely by an ordinary measuring scale/rule.

CHECK YOUR PROGRESS

6. What is known as scale of drawing?

7. What is called RF?

8. What is known as RF? Explain with some examples.

9. What is the format for expressing 'scale' and RF"?

1.2 INTRODUCTION: GEOMETRICAL CONSTRUCTIONS, CONIC SECTIONS AND SPECIAL

In engineering drawing, problems dealing with the construction of various curves are frequently encountered. These curves may broadly be classified into the following types:

- Conic sections
- Special curves.

Conic Sections

The curves, circle, ellipse, parabola and hyperbola are obtained by cutting a cone in different ways. The profiles of the cut surfaces form these curves, hence called *conic sections*. Fig. 1.20 shows the different possible ways of cutting a cone.

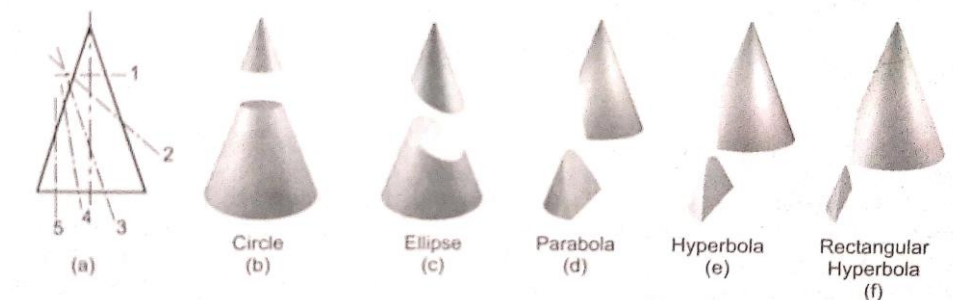


Fig. 1.20

When a cone is cut by a plane perpendicular to its axis, the resulting section will be a circle. In Fig. 1.20(a) the plane-1 cuts the cone with its surface perpendicular to its axis so as to produce a circle as shown in Fig. 1.20(b).

When a cone is cut by a plane making an angle with its axis, greater than that the generators of the cone make with the axis, the resulting section will be an *ellipse*. In Fig. 1.20(a), plane-2 cuts the same so as to produce an ellipse as shown in Fig. 1.20(c).

When a cone is cut by a plane, parallel to one of the end generators of the cone, the resulting section will be a parabola. In Fig. 1.20(a) plane-3 is parallel to the right end generator of the cone so as to produce a parabola as shown in Fig. 1.20(d).

When a cone is cut by a plane, making an angle with its axis smaller than that the generators make with the axis, the conic section will be a *hyperbola*. In Fig. 1.20(a) plane-4 cuts the cone so as to produce a hyperbola as shown in Fig. 1.20(e).

When a cone is cut by a plane parallel to its axis, the resulting section will be a rectangular hyperbola. In Fig. 1.20(a) plane-5 is parallel to the axis of the cone so as to produce a rectangular hyperbola as shown in Fig. 1.20(f). Conic section is defined, mathematically, as the curve traced by a point, which moves in a plane such that its distance from a fixed point is always in a constant ratio to its perpendicular distance from a fixed line.

CHECK YOUR PROGRESS

10. What is termed as conic section?

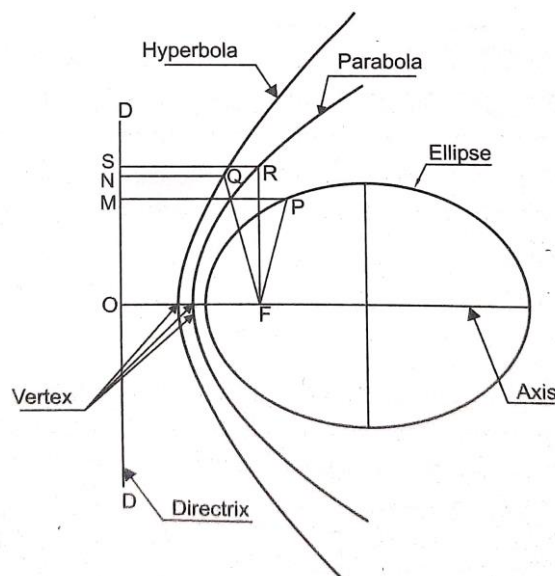


Fig. 1.21. Definition of ellipse, parabola and hyperbola

The fixed point is called focus (Refer Fig. 1.21), the fixed line is directrix and the ratio of the distance of the tracing point from the focus to its perpendicular distance from the directrix is called eccentricity. The line drawn through the focus, perpendicular to the directrix, is called axis. The point at which the curve cuts the axis is called vertex.

1.2.1 (a) Locus

If a sharp pencil point, moving in the plane of paper follows the boundary of a straight edge it traces a straight line; if it is moving point of a pair of compasses it traces a regularly curving line. Obviously, in both instances its path is regulated and is governed by some means of constraints. This path is called a locus.

In engineering where the movement of parts in mechanisms should be clearly known to facilitate provision of required space for movement, the study of the path of the points moving according to some constraints is extremely useful.

Loci of Points

(a) To draw the locus of a point equidistant from a fixed point and a fixed straight line (Figure 1.22)

Let AB be the given line and Q be the given point. It is required to draw the locus of the point that is at equidistant from this line and the point Q.

Through Q draw a perpendicular line meeting AB at P. Locate R, the midpoint of PQ. R is a point on the locus. Consider number of points between Q and R as shown in Figure 1.22.

Through these points, draw perpendicular lines to PQ as shown. With Q as center and P1 as radius cut arcs on the vertical line through 1. Similarly, with Q as center and P2, P3, P4, and P5 as radii cut arcs on the respective perpendicular lines through 2, 3, 4 and 5.

Join the intersecting points by means of a smooth curve. This curve is the locus of point that is at equidistant from the straight line AB and point Q.

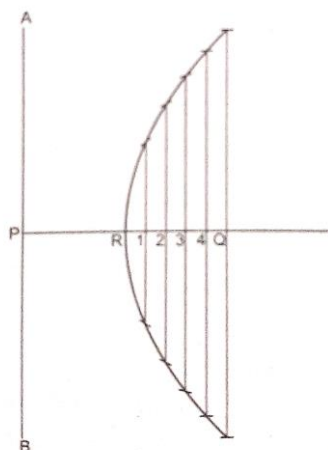


Fig. 1.22

This curve in geometry is called a parabola. As the point on the curve is equidistant from the straight line AB and point Q, the ratio of the distances is equal to 1.

i.e.,
$$\frac{PR}{PQ} = 1$$

This ratio is called the eccentricity of the curve. If the eccentricity is < 1 the curve is called as an ellipse and if the eccentricity is > 1 curve is called as a hyperbola.

The construction of these curves is dealt in detail in later sections.

1.2.1 (b) Applications for Conic Curves

Elliptical

Elliptical curved application in architectural and engineering designs, like arches, bridges, elliptical gears, fancy lamps, bullet nose, stuffing box, etc.

Parabola

The parole curves are on Light reflectors, solar concentrator, telecommunication dishes, sound reflectors, parabolic mirrors, cantilever beams, missile trajectory, etc.,

Hyperbola

Hyperbolic curves are applied in designing cooling towers, hyperbolic mirrors, flower vase, curved wooden object location of a ship in long-range navigation.

1.2.1 (e) Ellipse

Ellipse (Refer Fe 2.2) is the locus of a point P which moves such that the ratio of its distance from the fixed point to its distance from a fixed line is a constant and is always less than 1.

$$\text{Eccentricity, } \frac{PF}{PM} < 1$$

CHECK YOUR PROGRESS

11. What is a section of the cone cut by a plane parallel to the end generator?

12. What is a section of the cone cut by a plane parallel to the axis?

13. What are known as conjugate diameters?

(i) Eccentricity Method (Figure 1.23)

To draw an ellipse given the distance of the focus from the directrix and the eccentricity.

Distance of the focus from the directrix = 28 mm; eccentricity = $\frac{3}{4}$

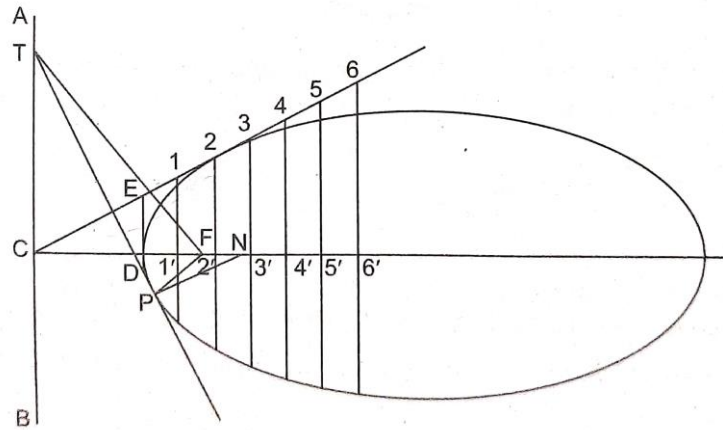


Fig. 1.23

Draw a vertical line AB. This is the directrix for the ellipse. Draw a perpendicular line (FC) to AB, the distance of F from AB is 28 mm. F is called the focus of the ellipse.

Divide FC into 7 equal parts and fix D on FC so that $\frac{FD}{CD} = \frac{3}{4}$. The ratio of the distances between the focus and any point on the ellipse and directrix and the same point is called the eccentricity, which is always a constant for an ellipse (here $\frac{3}{4}$). Through D draw a perpendicular line to CF and with D as center and radius equal to FD cut an arc on this line to locate E. Join E with C and extend the line. Consider number of points 1, 2, 3, 4, 5 and 6 on line CE as shown in Fig. 1.23(a) and through these points draw perpendiculars to CF cutting the line CF at points 1', 2', 3', 4', 5', and 6'. With F as center, 1-1' as radius cut arcs on the perpendicular through 1. Similarly with F as center 2-2', 3-3', 4-4', 5-5', and 6-6' as radii cut arcs on the respective perpendicular lines. Join these points by means of a smooth curve to obtain an ellipse. The ratio of the distance of any point on the curve from the focus and the distance of the same point from the directrix is always $\frac{3}{4}$ for this problem.

To draw tangent and normal through any point P on the ellipse

Join P with the focus F. Draw perpendicular line to this through the focus cutting the directrix at point T. Join PT and this is the tangent to the curve at P. Draw a perpendicular PN to PT and is the normal to the curve.

(ii) Concentric Circles Method (Figure 1.24)

Draw an ellipse given the major axis and minor axis

Major axis = 80 mm

Minor axis = 50 mm

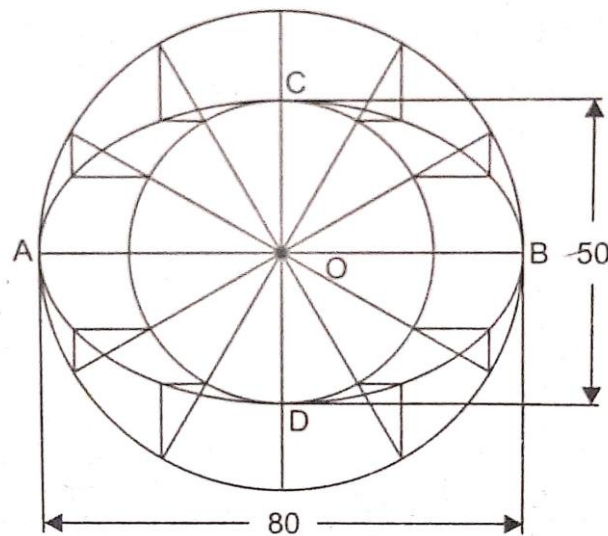


Fig. 1.24

Draw a line AB equal to 80 mm long. Through the midpoint O draw a perpendicular and cut off CD equal to 50 mm in such a way that O is the midpoint for this line also. Draw circles with O as center and diameters equal to major and minor axis of the ellipse.

Divide these circles into 12 equal parts and through the corresponding points on the circumferences on the circles draw vertical and horizontal lines as shown in Fig. 1.24. Through the meeting points of these lines draw smooth curve to obtain ellipse as shown in Fig. 1.24.

(iii) Oblong Method (Figure 1.26)

Draw an ellipse given the major axis and minor axis

Major axis = 80 mm

Minor axis = 50 mm

Draw AB and CD, being the major axis and minor axis of the ellipse. Divide AO into 4 equal parts getting points 1, 2 and 3. Similarly divide AE into 4 equal parts getting points 1', 2', and 3'.

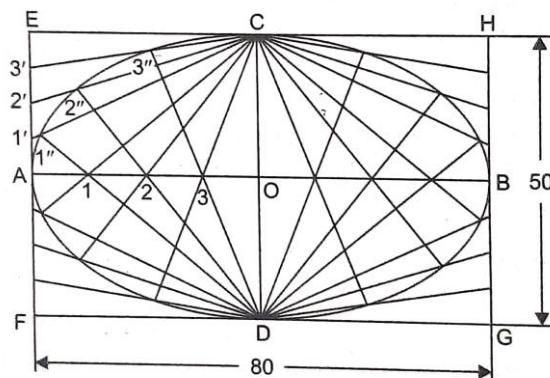


Fig. 1.25

Join $C1'$, $C2'$, and $C3'$. Join $D1$, $D2$, $D3$ and extend them to get $1''$, $2''$, and $3''$ as shown. Join these points ($1''$, $2''$, and $3''$) to obtain one portion of the curve. Similarly obtain other points in the remaining three quadrants and join them to obtain the ellipse.

1.2.1 (d) Parabola

The parabola is the locus of a point, which moves in a plane so that its distances from a fixed point (*focus*) and a fixed straight line (*directrix*) are always equal. In other words, the ratio of its distances from focus to that of directrix (*eccentricity*) is a constant and equal to one (1).

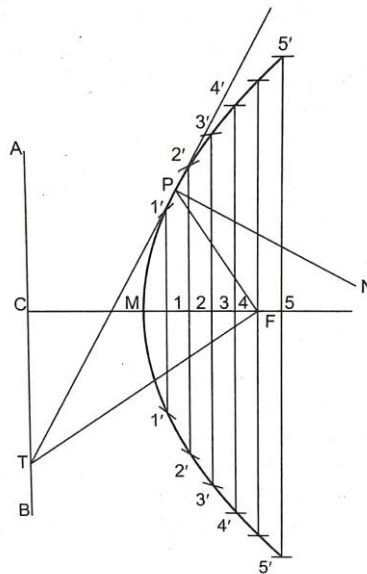


Fig. 1.26

Fig. 1.26 shows the parabola. Any line ED drawn from a point E on the parabola such that it is perpendicular to the axis CA is the ordinate. The ordinate is extended to cut the parabola at E' . EDE' is called the double ordinate i.e., $EE' = 2ED$. A parabola has unlimited number of double ordinates.

CHECK YOUR PROGRESS

14. What is the eccentricity of the parabola?

The double ordinate, which is passing through the focus, is called latus rectum. LL' is passing through the focus F and is called latus rectum. The distance along the axis (CA) between the vertex (V) and a point through which the double ordinate passes is called abscissa. DV is the abscissa corresponding to the double ordinate EE' and VF is the abscissa corresponding to the latus rectum LL' .

For a parabola, number of abscissas = number of double ordinates. Given the span/base/double ordinate and rise/axis (distance from base to vertex)/abscissa of the parabola, the same may be constructed using rectangle/parallelogram/tangent/off set method.

A parabola is used in the shape of search light/head lamp reflector, sound reflector and detector, bridges and arches, cooling towers, projectile path, solar concentrators, machine tool components, cantilever type arms and wall brackets, cables in suspension bridges, dish antenna etc.

(a) Parabola

Parabola is the locus of a point moving such a way that its distance from a fixed point, the focus, is always equal to its distance from a fixed line, the directrix.

Directrix Method

(1) To draw a parabola given the distance of the focus from the directrix (Fig. 1.27)

The distance of the focus from the directrix is equal to 50 mm, Draw AB the directrix of the parabola. At a point C draw a perpendicular to this line. On this perpendicular cut point F so that CF equal to 50 mm. Let M be the midpoint of CF.

Consider points 1, 2, 3, 4, and 5 on the line MF extended as shown in Fig. 1.27. Draw vertical lines through 1, 2, 3, 4, and 5.

With F center and C-1 as radius cut arcs on the vertical through 1 getting a pair of points 1'. 1' above and below the line CF. Similarly with F as center and C-2, C-3, C-4, and C-5 as radii, cut arcs on the perpendicular through 2, 3, 4, and 5 getting pairs of points 2', 3', 4', and 5'.

Join these points by means of smooth curve to obtain parabola.

To draw tangent and normal at a point P

Join P with F. Draw a perpendicular line through F to this line to cut the directrix at T. Join T with P and PT is the tangent. Draw PN perpendicular to this is the normal.

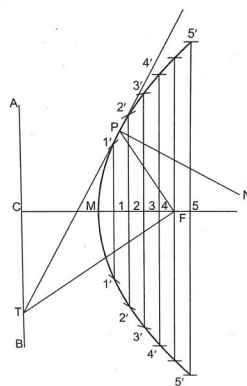


Fig. 1.27

CHECK YOUR PROGRESS

15. What is known latus return?

(ii) Parallelogram method or rectangle method (Figure 1.28)

To draw a parabola given the base and axis

Base = 60 mm

Axis = 40 mm

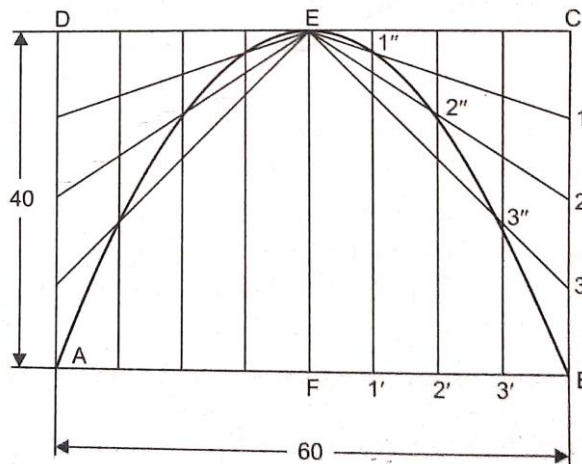
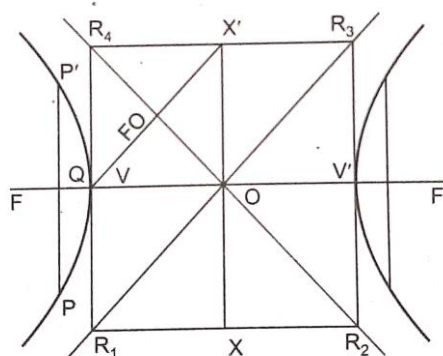


Fig. 1.28

Draw a rectangle ABCD with AB = 60 mm and BC = 40 mm. Draw the perpendicular bisector EF for the side AB. Divide FB into four equal parts and also BC into four equal parts, getting the points 1', 2', 3', and 1, 2, 3. Join E1, E2 and E3 cutting the perpendicular lines through 1', 2', and 3' at points 1'', 2'', 3''. Obtain similar points in the other half of the rectangle and join these points to get a parabola (Fig. 1.28).

1.2.1 (e) Hyperbola

The cutting plane-4 (Refer Fig. 1.20(a)) makes a smaller angle with the axis than that of the angle made by the generator of the cone and the section obtained is a hyperbola. It is an open curve.



- A,B - VERTICES
- P,P' - DOUBLE ORDINATE = PQ
- AQ - ABSCISSA
- AB - TRANSVERSE AXIS
- XX' - CONJUGATE AXIS
- R1R3, R2R4 - ASYMPTOTES

Fig. 1.29

Hyperbola is defined as the locus of a point moving in a plane in such a way that the ratio of its distance from a fixed point (F) to the fixed straight line (DD) is a constant and is greater than one. Hyperbola can also be defined as the locus of a point which moves such that the difference of its distances from two fixed points (F and F') is always a constant and is equal to the length of the transverse axis (VV'), i.e., $PF' - PF = VV'$ (Refer Fig. 1.29). When a point A is considered instead of point P on the curve $F'V-FV = VV'$ (since $FV = F'V'$).

Referring to Fig. 1.29, transverse axis (VV') is usually a horizontal axis and is equal to the distance between the two vertices of a pair of hyperbolas; foci (F and F') are two fixed points which lie on the extension of transverse axis; ordinate (PQ) is any vertical line drawn from a point P on the hyperbola such that it is perpendicular to the axis. Ordinate PQ, if extended, meets the hyperbola at P'. PP' is called double ordinate. It is twice the length of the ordinate.

Abscissa (VQ) is the distance along the axis between the vertex V and a point Q through which the double ordinate PP' passes. Conjugate axis (XX') is a line perpendicular to the transverse axis and is passing through the center of the transverse axis. When XX' is the conjugate axis, $VX = VX' = OF$; asymptotes ($R_1 R_3$ and $R_2 R_4$) are straight lines which intersect each other at the center of the transverse axis. When they are extended on either side, they never touch the curve, but approach nearer and nearer to the curve. Hyperbola is used in the channels etc.

PROBLEMS

Problem 1: Draw the curve, when the distance of the focus from the directrix is 50 mm and eccentricity is $3/2$. Name the curve and draw tangent and normal from any convenient point on it.

Solution. Refer Fig. 1.30.

1. Draw the directrix DD. At any point C on it draw a line CA perpendicular to DD to represent the axis.
2. The distance between the focus and directrix is 40 mm. So mark F, the focus, such that $CF = 50$ mm.

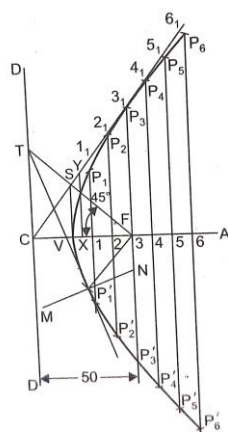


Fig. 1.30

3. Eccentricity = $3/2$. So construct the right angled triangle right angled at CXY such that $(XY/CX) = 3 \text{ units}/2 \text{ units}$ X is any point on the axis).
4. From F draw a 45° line to intersect CY at S. From S erect vertical to intersect CF at V, the vertex. Now $SV = FV$.
5. Triangle CXY is similar to triangle CVS. Therefore, $SV/CV = YX/CX = FV/CV = 3/2$.
6. Along the axis CA mark the points 1, 2, 3, 4, 5 at approximately equal intervals. Through the points 1, 2, 3, 4, 5 erect verticals to intersect CY (produced if necessary) at $1', 2' \dots 5'$ respectively.
7. With $11'$ as radius and F as center draw two arcs on either side of the axis to intersect the vertical line drawn through 1 at P_1 and P_2' .
8. Repeat the above and obtain P_2 and P_2' , P_3, P_3' P_5 , and P_5' corresponding to the points 2, 3,...5 respectively. Draw a smooth hyperbola through $P_5, P_4 \dots P_1, V, P_1', \dots P_5'$.
9. The vertex of a hyperbola is 70 mm from its focus. Draw the curve if the eccentricity is $4/3$. Draw a normal and tangent at a point on the curve, 80 mm from the directrix.

Problem 2: A point moves such that the difference of its distances from two fixed points is constant and is equal to 100 mm. The fixed points are located

200 mm apart. Draw the locus of the moving point. Name the curve. Mark on it transverse axis, foci and asymptotes.

Solution. Ares of circle method. Refer Fig. 1.31.

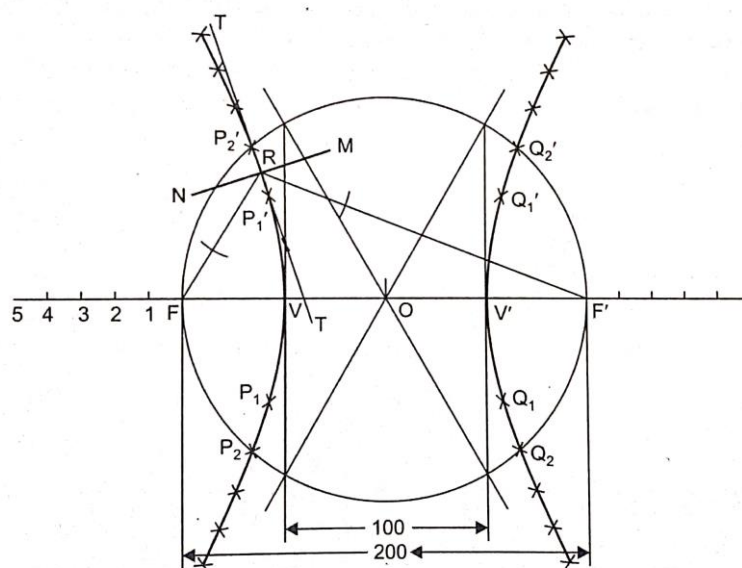


Fig. 1.31

1. Draw $FF = 200 \text{ mm}$ and bisect it at O. A point P moves such that the difference of its distances from F and $F' = 100 \text{ mm}$. But $PF' - PF = VV' =$ Transverse Axis. So mark the transverse axis $VV' = 100 \text{ mm}$ along FF' such that $OV = \left(\frac{1}{2}\right) VV' = 50 \text{ mm}$.

2. Take any number of points 1, 2, 3... (say 5) along the extension of VF.
3. V1 as radius and F as center draw first set of arcs on either side of the axis. Keep same V1 as radius and F' as center draw second set of arcs on either side.
4. Take V'1 as radius and F' as center cut the first set of arcs at P_1 and P_1' . Keep the same V'1 as radius and F as center cut the second set of arcs at Q_1 and Q_1' .
5. Repeat the above and obtain the points $P_2, P_2'; P_3, P_3'; Q_2, Q_2', Q_3, Q_3' \dots$ etc. corresponding to the points 2, 3 etc. Join $P_5, \dots P_1, V, P_1' \dots P_5$ and $Q_5, \dots Q_1, V', Q_1' \dots Q_5'$ and obtain a pair of hyperbolas.
6. Mark any point R on the hyperbola. Join RF and RF'.
7. Bisect the angle FRF'. The bisector TR is the tangent at R.
8. Draw MN perpendicular to TR through R. MN is the normal.

CHECK YOUR PROGRESS

16. What is meant by conjugate axis for a hyperbola?

(i) To draw hyperbola given the foci and the transverse axis (Figure 1.32)

Let AB be the given transverse axis and F_1 and F_2 be the foci. Consider points 1, 2, 3 and 4 on the axis outside F_1F_2 and on one side of F_1F_2 . With F_1 as center draw arcs with A-1 as radius. Similarly with F_2 as center draw arcs with the same radius. With F_1 as center and B-1 as radius draw arcs cutting the previous arcs at a pair of points $1''$.

Similarly with F_2 as center and B-1 as radius cut arcs getting another pair of points $1''$. Repeat these constructions with A-2, A-3 and A-4, and also B-2, B-3, B-4 as radius to obtain other pairs of points $2''$, $3''$, and $4''$. Join all these pairs of points by a smooth curve as shown in Fig. 1.32 to get a pair of hyperbolas of given transverse axis and foci.

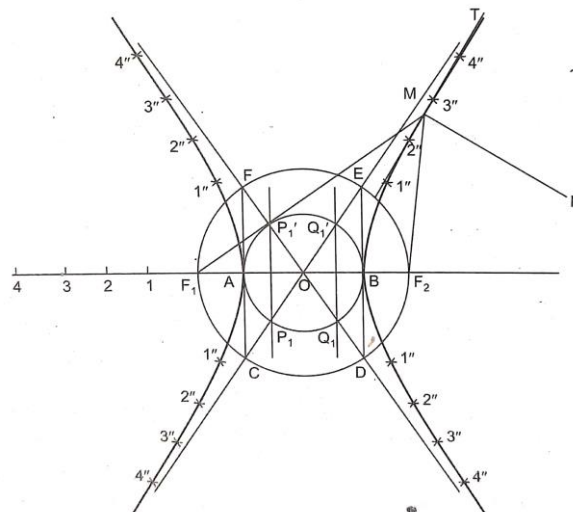


Fig. 1.32

To draw the asymptotes

Asymptote is defined as a tangent drawn at infinity to the curve.

With O as center and OF_1 as radius draw a circle cutting the perpendiculars through A and B at C, D, E and F. Through O draw a line connecting C and E. Similarly draw another line connecting D and F. This pair of straight lines is the pair of asymptotes to the hyperbolas drawn.

To draw the directorises

With O as center OA or OB as radius cut arcs on the asymptotes to get Q_1 and Q_1' . Similarly cut arcs on other side of the asymptotes to P_1 and P_1' . $P_1 P_1'$ extended and $Q_1 Q_1'$ extended are the directorises of the hyperbolas.

To draw a tangent at a given point M on the hyperbola

Join M with F_1 and F_2 . Bisect the angle $\angle F_1 M F_2$. This bisector is the tangent to the curve at M. Draw MN perpendicular to this and this is the normal at point M.

(ii) Rectangular hyperbola

Rectangular hyperbola is the locus of a point moving in such a way that the product of its distances from two fixed lines at right angles to each other is a constant. These lines are asymptotes to the rectangular hyperbola.

To draw a rectangular hyperbola given one point P on the curve (Fig. 1.33)

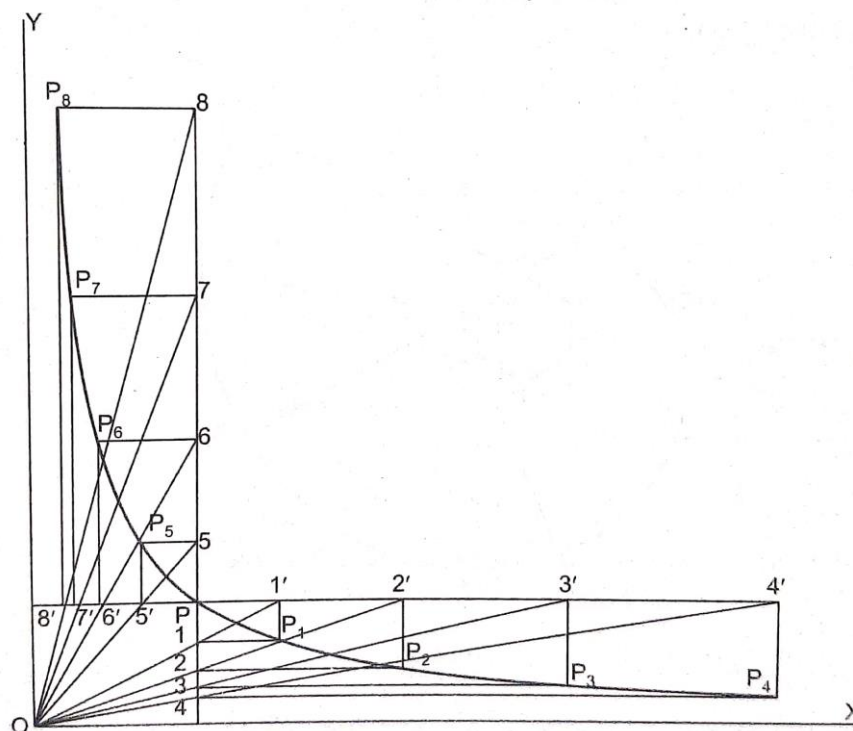


Fig. 1.33

Let OX and OY be the given pair of asymptotes and let P be the given point. Through P draw lines parallel of OX and OY. From O consider a set of radial lines cutting the vertical line through P at points 1, 2, 3, 4, 5, 6, 7 and 8 and the horizontal line through P at points 1', 2', 3', 4', 5', 6', 7', and 8'. Through 1 and 1' draw horizontal and vertical line respectively meeting at P₁. Similarly obtain P₂, P₃, P₄, P₅, P₆, P₇ and P₈. Draw a smooth curve through these points and this is the required rectangular hyperbola (Fig. 1.33)

1.2.2 - Geometric Curves

1.2.2 (a) Involute

An involute is the path traced by a point on a string, as the string unwinds itself from a line, polygon or circle, keeping the string always taut.

It can also be defined as the path traced by a point on a straight line when the line rolls along a circle without slipping.

Thus the involute will be the reverse of a cycloid to be dealt later. The normal to an involute is a tangent to the circle. In case of the polygon the involute is a series of tangential circular arcs with different radii.

This shape is used for tooth profile of gear wheels, casing of centrifugal pumps.

1.2.2 (b) Application

They find applications in designing the profiles of special purpose gears and racks, hydraulic gear pumps, cycloidal gear boxes, cycloidal cams.

Problem 3: Draw the involute of a hexagon of 30 mm side. Draw a tangent and normal to the curve from a point M on it.

Solution. Refer Fig. 134.

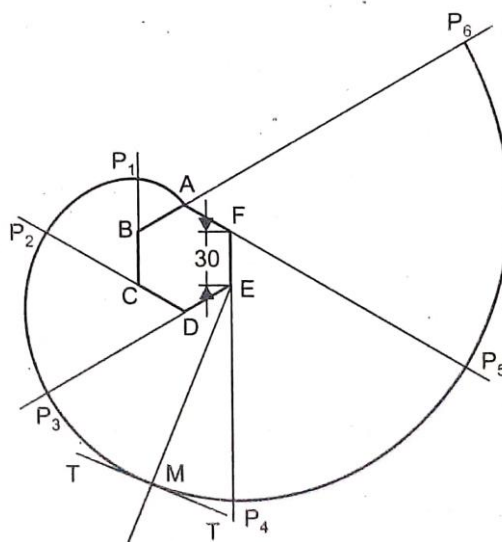


Fig. 1.34

1. Draw the given polygon (hexagon ABCDEF of side 30 mm).
2. Produce the sides CB, DC, ED, FE, AF and BA.
3. With center B and radius BA draw an arc to intersect CB produced at P₁. Now with center at C and radius CP₁, draw an arc to intersect DC produced at P₂.
4. Similarly, with the centers D, E, F and A, and radii DP₂, EP₃, FP₄, AP₅, draw arcs and complete the curve. The same procedure is followed to draw the involute of any other polygon.
5. The given point M lies in the arc P₃ P₄. The center of the arc P₃ P₄ is point E. Join E and M and extend it which is the required normal.
6. At M, draw perpendicular to the normal to obtain tangent TT.

Problem 4: Draw an involute of a circle of 40 mm diameter. Also draw a normal and tangent to it at a point 105 mm from the center of the circle.

Solution. Refer Fig. 1.35.

1. Draw a circle of given diameter D (40 mm).
2. Draw a line AB tangential to the circle at A and of appropriate length (equal to πD in this case).
3. Divide the circle and the tangential line into the same number of equal and/or equivalent divisions, i.e., circle into 12 equal parts as 1, 2, 3 ... 12. and line AB into 12 equal parts as 1', 2', 3', 12'. Let A be the starting point i.e., one end of the thread.
4. Draw tangents at points 1, 2, 3,...12 and mark P₁, P₂, P₃, ... P₁₂ such that 1P₁ = 1'B; 2P₂ = 2'B; 3P₃ = 3'B etc.
5. Draw a smooth curve through B, P₁, P₂,.....P₁₂.

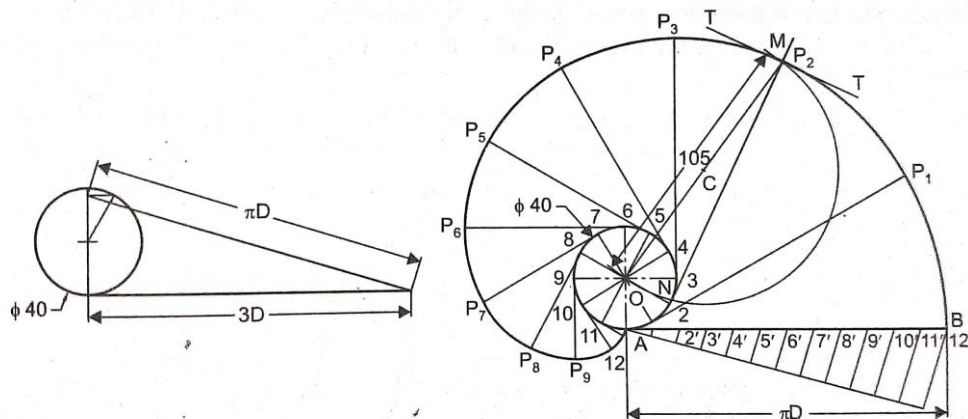


Fig. 1.35

6. Take O as center and radius equal to 105 mm, draw an arc to intersect the involute curve at M. Draw a line joining M and the center of the circle O.
Mark the mid-point C on OM. With C as center and MC as radius describe a semi-circle on the diverging side of the involute to cut the given circle at N.

7. Join NM, which is the required normal.
8. At M, draw a line perpendicular to MN to get the required tangent TT.

Problem 5: Draw a triangle and extend the sides of the triangle as shown in Fig. 1.36. With point 2 as center and 1-2 as radius cut an arc on the line obtained by extending the side 3-2, intersecting at point A. With 3 as center and 3A as radius, draw an arc intersecting the line through 3 at B. Similarly, with 1 as center and 1B as radius draw an arc intersecting the line through 1 at C. Curve 1ABC is the involute of the given triangle.

Similarly involutes of square, hexagon, etc. can also be drawn.

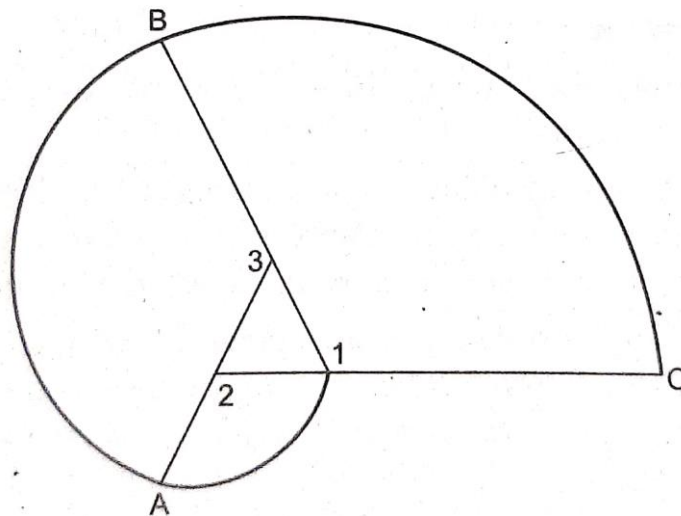


Fig. 1.36

Problem 6: Trace the path of the ends of a straight rod 80 mm long when it rolls on a semicircle of diameter 60 mm without slipping.

Draw a semicircle with O as center and 60 mm as diameter. Divide the semicircle into 6 equal parts. The rod that is going to roll along the semicircle is represented by the vertical line NM in Fig. 1.37.

On the line NM mark points 1', 2', 3', 4', by setting $N1' = \text{arc } N-1$, $1'2' = \text{arc } 1-2$, $2'3' = \text{arc } 2-3$, $3'4' = \text{arc } 3-4$, $4'5' = \text{arc } 4-5$, and $5'M = \text{arc } 5-Q$. Obtain Q on the semicircle so that $5Q = 5M$

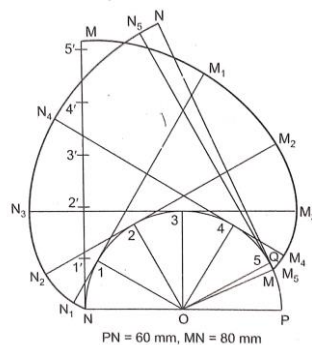


Fig. 1.37

Through points 1, 2, 3, 4, 5, and Q draw tangents. With 1 as center and N_1' as radius arc is cut on the tangent through 1 obtaining point N_1 .

Similarly N_2, N_3, \dots, N_5 and N_1 on the tangents through 1, 2, 3... Q respectively are obtained. Obtain points M_1, M_2, M_3, M_4 , and M_5 , on the tangents so that the lengths $N_1M_1, N_2M_2, \dots, N_5M_5$ are equal to the length of the rod.

Two different curves are obtained by joining N, $N_1, N_2, N_3, \dots, N_5$ and M, M_1, M_2, \dots, M_5 .

These two curves give the paths of the end points of the rod when it rolls along the semicircle without slipping. (Fig. 1.37).

1.2.2 (c) Spiral, Application

The spirals are used on the spiral springs in watches and toys, turbine casings, scroll discs of lathe chucks, spiral cams.

Spiral is the curve traced by a point A on a straight line OA, while the line under consideration rotates uniformly in a plane about a fixed point O and the point A moves continuously and regularly along the rotating line towards the point O.

The fixed point O is called the pole of the spiral. The line joining any point on the curve to the pole is called the radius vector. The angle between any radius vector and the initial radius vector is called the sectorial angle. One complete revolution of the spiral makes one convolution.

The two types of spirals are Archimedean spiral and Logarithmic spiral.

1.2.2 (d) Archimedean Spiral

It is the path traced by a point, which moves with uniform linear velocity along the radius vector while the radius vector itself rotates about the pole with uniform angular velocity.

It is also defined as the locus of a point which moves uniformly both about the center and at the same time, away or towards the center.

An archimedean spiral is used in the profile of watch/clock/toy springs, scroll plate of lathe chuck, jig or fixture clamps, cams for automation and disc cams used in sewing, weaving and printing machines.

Problem 7: Draw an archimedean spiral of one convolution. The initial and final radius vectors are 30 mm and 120 mm respectively.

Solution. Refer Fig. 1.38

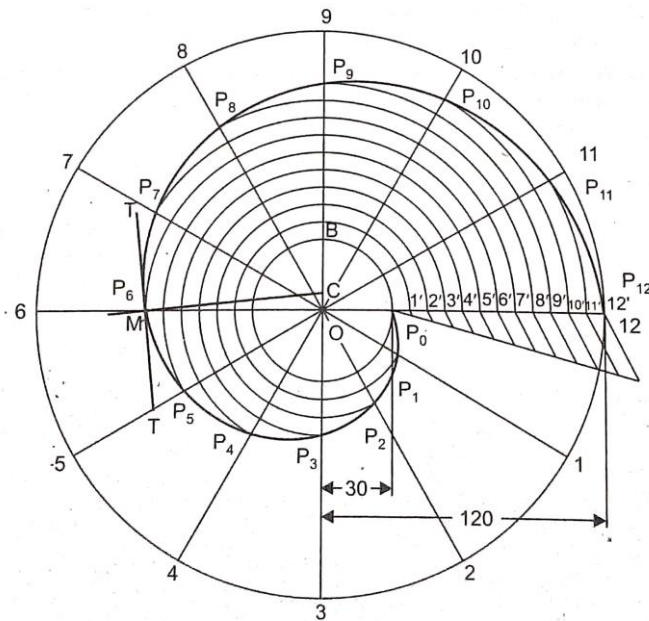


Fig. 1.38

1. With pole O as center and radii equal to R_{\max} (120 mm) and R_{\min} (30 mm), draw two circles.
2. Divide the total angular movement at pole O into suitable number of equal parts and draw radial lines O1, O2, O3....O12.
3. Divide total linear movement (difference of the two radius vectors) also into the same number of equal parts as shown in the figure.
4. On lines OO, O1, O2,...O12 mark points P₀, P₁, P₂, P₃,....P₁₂ by successively increasing the length of the radius vector by one division each time. For increasing the radius vector by one division, draw arcs, of circles with O as center and radii equal to OO, O1, O2, O3.... O12 respectively.
5. Join points P₀, P₁, P₂,...P₁₂ by a smooth curve to get the Archimedean spiral.
6. With pole O as center and the distance of the point (at which tangent and normal are to be drawn) from pole as radius draw an arc to cut the spiral at M.
7. Join MO and measure the angle MOP₀ = θ , which is equal to 180°.
8. Draw OB perpendicular to OM.
9. The polar equation of Archimedean spiral is $r = c + a\theta$, where

a = constant of the curve

r = radius vector at any point M = 75 mm

c = initial radius vector = 30 mm

θ = corresponding vector angle = 180° (measured) = π radians

$a = (r - c) / \theta = (75 - 30) / \pi = 14.318 \text{ mm}$

10. Mark C on OB such that $OC = a = 14 \text{ mm}$
11. Join MC, the normal. At M, draw a perpendicular to CM to obtain the tangent TT.

Problem 8: A mountaineering cadet slides down a rope tied to a rock at a height of 8 m above the floor. The cadet takes 10 seconds to slide down with uniform velocity. The rope oscillates in a plane through an angle of 30° on either side of the plumb line and takes 5 seconds for a complete oscillation. Draw the path traced by the cadet. Use suitable scale.

Solution. Refer Fig. 1.39.

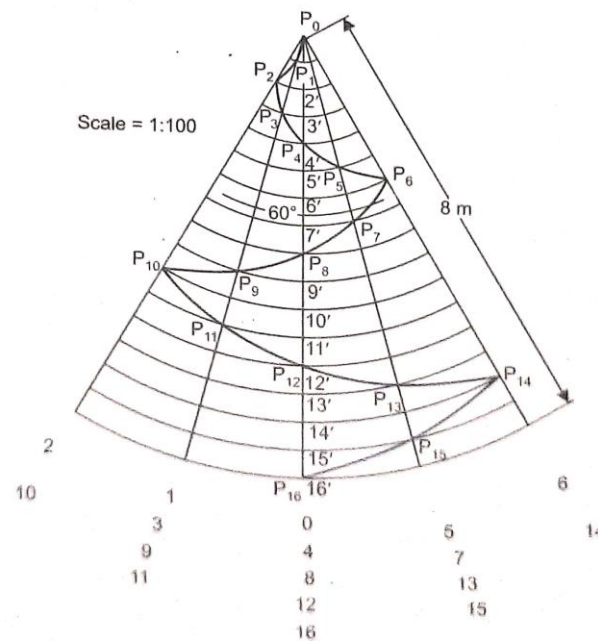


Fig. 1.39

Height of the rock = 8 m

Therefore, total linear movement = 8 m

Time taken for sliding down the rock = 10 seconds

Time taken for one oscillation = 5 seconds

No. of oscillations made during travel = $10/5 = 2$

The rope oscillates through an angle of 30° on either side of plumb line.

Therefore, total angular movement = $2 \times 60^\circ = 120^\circ$.

1.2.2 (e) Helix

If a straight line rotates uniformly around another straight line parallel to it and if a point travels along the rotating straight line at a constant speed then the curve traced by the point is called a cylindrical helix. The distance through which the point travels for one rotation of the straight line is the 'pitch' or 'lead' of the helix.

lines through these points and vertical lines from the points on the circle. Join the intersection of these vertical lines with the base of the triangle (PQ) to O' as shown in Fig. 1.41. The points on the path of helix are marked and joined by means of a smooth curve in the same way as done for circular helix. One portion of the helix is shown by means of a dotted line as this portion lies on the backside of the cone.

(iii) Helical Spring

Instead of a point in a square, normal to the surface, it moves on the surface of cylinder tracing a cylindrical helix the portion swept by the square is called square helical spring.

Draw two complete turns of helical spring made up of wire of square 10 mm side. The outside diameter of the spring is 100 mm and the pitch is 60 mm.

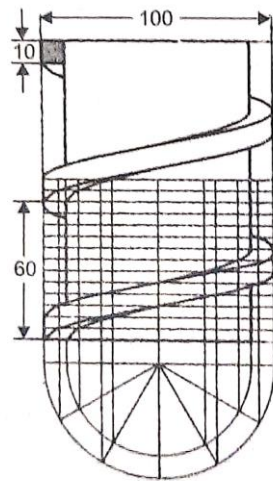


Fig. 1.42

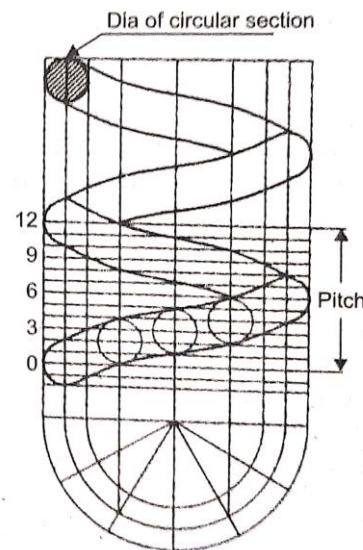


Fig. 1.43

Draw 2 semicircles of diameters 100 mm and 80 mm for the outside and inside diameters of the spring. Divide each semicircle into 12 equal parts and draw vertical lines through these points. On the vertical lines through the extreme points mark the distance, equal to twice the lead or pitch of the helix. Divide one pitch into twelve equal parts and draw horizontal lines through these twelve points. The helices of the four corner points are drawn and joined as shown in Fig. 1.42 to obtain a square helical spring.

A circular helical spring can be obtained by drawing the helix of the center of the circular cross section. With number of points, on this helix, as centers circles are drawn with radius equal to the radius of the circular cross section. Smooth tangential curves are drawn for these circles to obtain the circular helical spring as shown in Fig. 1.43.

(iv) Screw Thread

The construction of screw threads is also based on the principle of helix.

To draw two complete turns of a square thread of outside diameter 100 mm and pitch 40 mm.

The side of the square is equal to half of the pitch. The methods of construction of square thread are similar to helix. The procedure is self-explanatory (Fig. 1.44).

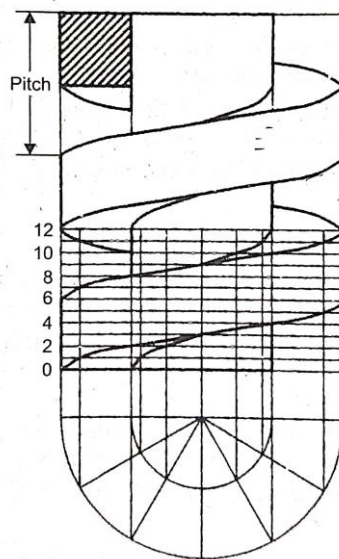


Fig. 1.44

1.2.2 (f) Cycloidal Curves

Cycloid is a special curve traced by a point on the circumference of a circle rolling on a straight line without slipping.

With O_A as center and r as radius, draw the generating circle. Draw a tangential line AA'' equal to the length of the circumference of the circle. On this line the circle is going to roll without slipping and the curve joining the positions of the point A , when the circle rolls, is called cycloid.

Divide the circle into twelve equal parts and divide the tangential line into the same number of equal parts. Through the center O_A and parallel to the tangential line, draw $O_A - O_A$, the locus of the center of the circle, when it rolls. Project the division points on the tangential line by drawing perpendiculars to cut the line drawn through the center. Let the perpendiculars cut the line drawn through the center at point O_B, O_C, \dots, O_L and O_A . With these points as centers and r as radius cut arcs on the lines, drawn parallel to the tangential line, through B, C, D, E , etc. up to L respectively to obtain the points $B'', C'', D'', \dots, L''$ and A'' . Join these points by means of smooth curve to obtain cycloid (Fig. 1.45).

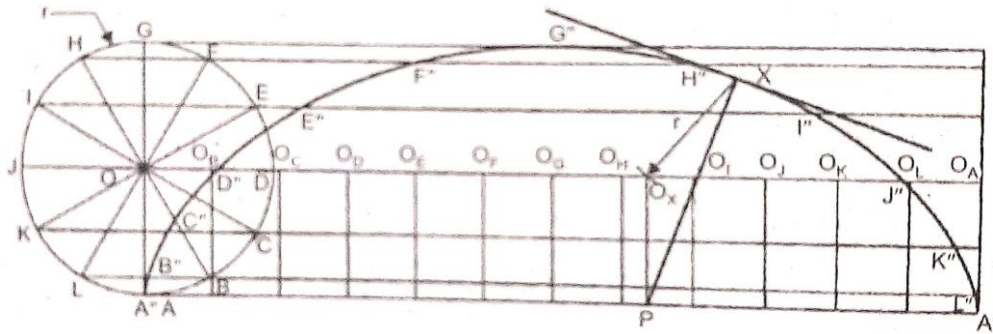


Fig. 1.45

To draw a tangent and normal to the cycloid at a point X on it.

With X as center and r as radius cut an arc on the horizontal line drawn through the center of the circle, to obtain point OX.

From OX draw a perpendicular to the tangential line AA'' cutting at point P. Join P with X and this is the normal to the cycloid at point X.

Draw another line perpendicular to this at point X and this is the tangent to the cycloid at point X.

Epicycloid

The path traced by a point on the circumference of a circle when the circle rolls without slipping on the outside of another circle.

Let r be the radius of the generating circle and R be the radius of the director circle. The generating circle is rolling outside the director circle and the path traced by the point A is called epicycloid.

If the circle rolls without slipping, the length of the arc covered by the circle is equal to the circumference of the generating circle ($2\pi r$).

Let θ subtend an angle = θ° at O

So, $2\pi r = R\theta$

$$\theta = \frac{2\pi r}{R}$$

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

where ' θ ' is the angle subtended by the arc at the center.

Divide the generating circle into twelve equal parts and draw concentric arcs through these points and through the center O_A. Divide arc AA'' also (angle) into 12 equal parts and draw radial lines through the division points of arc AA'' to fix positions of the centers of the circle when it rolls, as shown in Fig. 1.46. With these points O_A, O_B, O_C... O_L and O_A as centers and as radius, draw arcs intersecting the arcs through A, B L

obtaining points A'' , B'' , C'' L'' and A'' . Draw a smooth curve through these points and this curve is called as epicycloid.

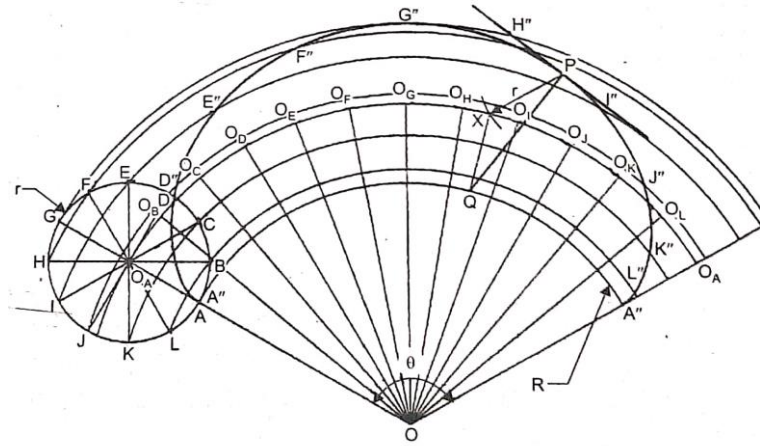


Fig. 1.46

To draw a tangent and normal to the epicycloid at any 'P' on it. With P as center and r as radius cut an arc on the arc drawn through the center O_A of the generating circle, to obtain point X.

Join X with the center of the director circle, to cut the arc on which the circle rolls at point Q. Join PQ and this is the normal to the epicycloid at point P. A perpendicular line drawn to this normal through P is the tangent to the epicycloid at point P.

Hypocycloid (Figure 1.47)

The path traced by a point on the circumference of a circle when it rolls along the inside of another circle is called hypocycloid.

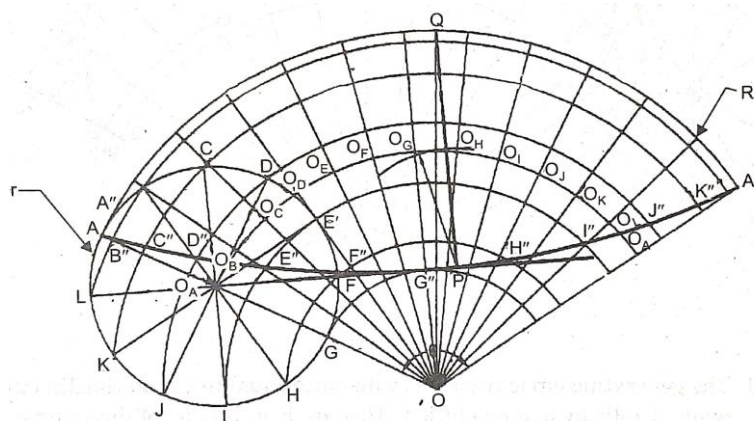


Fig. 1.47

Let r be the radius of the generating circle and R be the radius of the director circle. The generating circle is rolling inside the director circle and the path traced by the point A is called hypocycloid.

If the circle rolls without slipping, the length of the covered by the circle will be equal to the circumference of the generating circle ($2\pi r$).

So, $2\pi r = R\theta$

$$\theta = \frac{2\pi r}{R}$$

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

where ' θ ' is the angle subtended by the arc at the center.

The procedure to obtain the hypocycloid is similar to the procedure explained for epicycloid. The method of drawing tangent and normal are also the same.

CHECK YOUR PROGRESS

17. What is meant by asymptote?

Problem 9: Draw the curve traced by a point on the circumference of a rolling circle of diameter 40 mm, rolling over a circle of diameter 120 mm. Draw the tangent and normal to the curve at a point on the curve 85 mm from the center of the base circle.

Solution. Refer Fig. 1.48

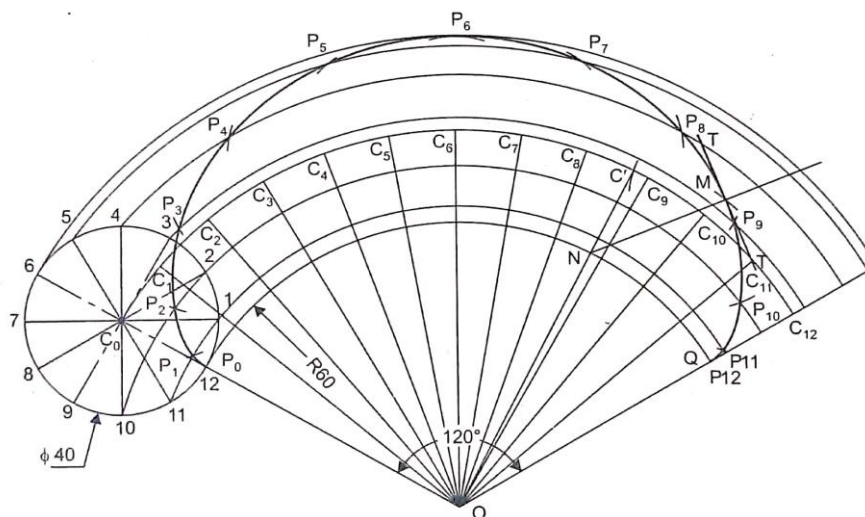


Fig. 1.48

1. The generating circle traverses a distance equal to $2\pi r$ on the directing circle while it rolls by one revolution. This arc length ($2\pi r$) of directing circle will subtend an angle at the center such that $2\pi r = R\theta$; $\theta = 360^\circ \times \frac{r}{R} =$

- $360 \times \frac{20}{60} = 120^\circ$. Draw an arc of circle ϕ (O, R = 60). At the point o draw angle of 120° .
2. On the extension of the left limb of the angle mark point C_0 at a distance 20 mm from the directing circle on outside of it. Draw the generating circle $\phi(C_0, 20)$ touching the directing circle at point P_0 , the starting position of P.
 3. Divide the rolling circle $\phi(C_0, 20)$ into 12 equal parts and mark them as 1, 2, 3,...12 in opposite direction to that of rotation.
 4. Now with O as center and radii equal to $O1, O2, O3, \dots O12$ draw arcs to intersect the extension of right limb of the angle. Also draw arc with O as center and C_0O ($60 + 20$) as radius to get the locus of the center.
 5. Divide the angle of 120° into the same number of equal parts (12) and draw radial lines through O to intersect the locus of center at $C_1, C_2, C_3, \dots C_{12}$.
 6. When the generating circle rolls through $(\frac{1}{12})^{\text{th}}$ revolution without slip, the center point C_0 will move to C_1 and the point P_0 will move to a radial distance of $O1$ represented by the arc of the circle $\phi(O, O1)$. Accordingly with C_1 as center and radius equal to $D/2$ draw an arc to cut the arc through 1 of the circle at P_1 . In a similar way get arc-arc intersection points $P_2, P_3, \dots P_{12}$.
 7. Join $P_0, P_1, P_2, \dots P_{12}$ by a smooth curve to get the epicycloid.
 8. Draw an arc of circle $\phi(O, 85)$ to intersect the curve at two points. Consider the point on the right side for drawing tangent and normal to avoid over crowding of lines.
 9. M as center and radius $r = C_0 P_0$ cut the locus of center at the point C' . Join $C'O$ which intersects the directing circle at PQ at N. Join NM, the normal and draw the tangent perpendicular to it.

Problem 10: A circle of 40 mm dia. rolls inside another fixed ring of 120 mm dia. for one complete revolution without slipping. Draw the path traced by a point on the circumference of the rolling circle for one complete revolution. Draw tangent and normal to the curve at any point on the curve.

Solution. Refer Fig. 1.49.

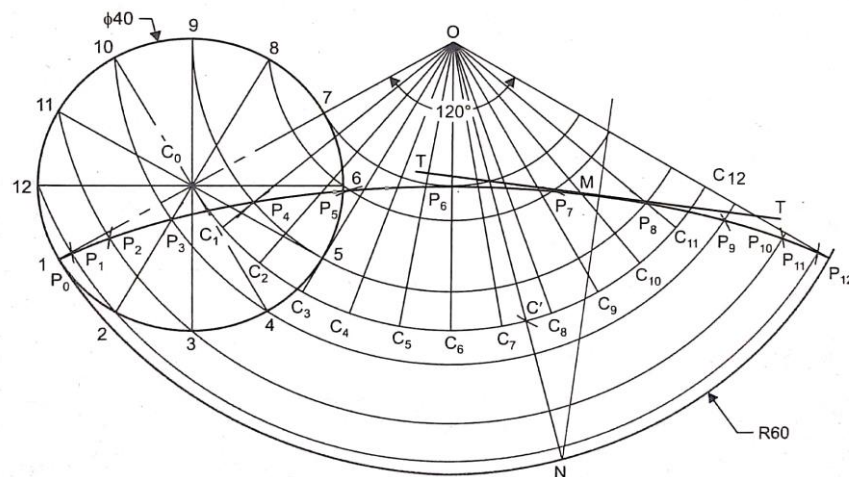


Fig. 1.49

The method of constructing hypocycloid in same is that of epicycloid. The center C_0 , for the generating circle is inside the directing circle. To draw a tangent and normal at a given point M, cut the locus of center with M as center and radius $r = C_0P_0$ at the point C'' . Join OC'' and extend it to intersect the base circle at N. Join MN, the normal At M draw a line perpendicular to MN to get the required tangent.

Problem 11: Show by means of a drawing that when the diameter of the directing circle is twice that of the generating circle, the hypocycloid is a straight line. Take the diameter of the generating circle equal to 40 mm.

Solution. Refer Fig. 1.50

$$d = 40 \text{ mm}, D = 80 \text{ mm}, \theta (20/40) \times 360 = 180^\circ.$$

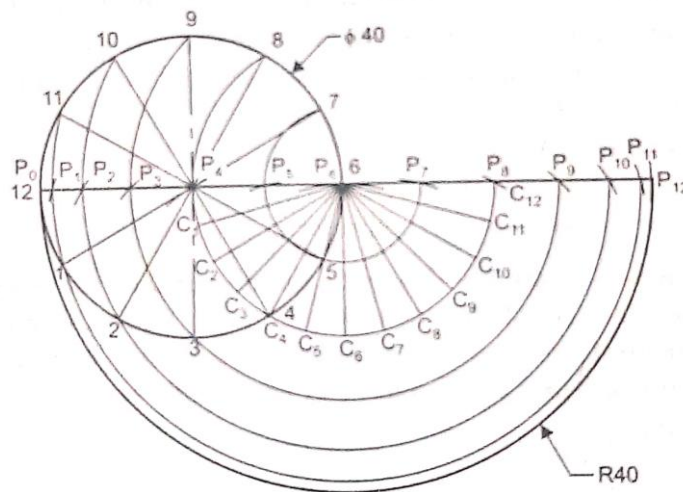


Fig. 1.50

CHECK YOUR PROGRESS

18. What is meant by asymptote?

19. What is known as hypocycloid?

20. What is an Involute?

21. What is known as Spiral?

22. Define Archimedean Spiral?

23. What known as Helix?

SUMMARY

Engineering drawing is the language expressed in graphical manner for engineers. The quality, neatness of the drawings with proper accuracy depends invariably on the quality of the instruments used. Instruments with good quality only can help the students in preparing the drawings easily, without any strain. To achieve the capacity in drafting procedures a thorough knowledge of using the instruments, materials and the appropriate drawing techniques are needed for the students.

A detailed drawing, in addition of giving the shape and size of an object should furnish the reader with information like the distance between the surfaces, type of material, type of finish, position of holes, number required and so on.

In Engineering Drawing, it is necessary to represent the sizes of the object with some written details, to convey the technical information such as the name of the company, the part details, the information regarding the part, the manufacturing process etc.

In many engineering design and drawings, use of geometrical shapes such as pentagon, hexagon, circle etc., is very essential. This chapter deals with the construction of geometrical figures which are used for the preparation of Engineering Drawings.

The curves, circle, ellipse, parabola and hyperbola are obtained by cutting a cone in different ways. The profiles of the cut surfaces form these curves, hence called conic sections.

Indian Standard Institution (I.S.I.) is recently renamed as Bureau of Indian Standards (B.I.S.) These Standards are used for the following topics in the field of Engineering Drawing.

The section plane in different inclinations produces conic sections. The application of conic sections and special curves are much used in industries, building construction and manufacturing technology. In this chapter the constructional details of conic sections and special curves are discussed at length. The foci and its locus of its movement with respect to the focus at a fixed point is described. Mainly, the directrix method is taken into consideration. Anyhow there are some more methods available like concentric circle method, parallelogram method, and rectangle method to draw such conical sections.

The special curves like cycloid and involute are much useful in building construction, arches, and gear tooth profiles. The generations of such curves are explained through step by step procedure.

1.4 KEYWORDS

1. **Polygon:** Any plane figure which is bounded by straight lines.
2. **Conic Section:** The sections obtained by the intersection of a right circular cone by a section plane in different positions relative to the axis of the cone.
3. **Locus:** Path traced by a moving point governed by some means of constraint.
4. **Eccentricity:** The ratio of the shortest distance of the tracing point from the focus to its perpendicular distance from the directrix.
5. **Axis:** The line passing through the focus and perpendicular to the directrix to draw/conceal curved.
6. **Vertex:** The point at which the curves cut the axis.
7. **Double Ordinate:** Longer line of a rectangle enclosing hyperbola.
8. **Cycloidal Curves:** A curve generated by a point on the circumference of a circle, which rolls along a straight line or another circle without slipping.
9. **Spiral:** A curve formed by the locus of a point which moves around a centre, while moving away from the centre.
10. **Involute:** A curve traced a point on a taut cord unwinding from a polygon.
11. **Helix:** A helix is a curve traced by a point moving along a line in one direction while line is revolving about another line parallel or inclined to it, such that both the motions are uniform.
12. **Scale of Drawing:** The Proportion by which the drawing of a given object is enlarged or reduced is called the scale of drawing.
13. **Enlargement Scales:** When smaller objects are to be drawn, they need to be enlarged. The scales used in such cases are called enlarging scales.
14. **Reduction Scales:** When huge objects are to be drawn, they are reduced in size on the drawing. The scales used for these objects are called reducing scales.

1.5 ANSWERS TO CHECK YOUR PROGRESS

1. Engineering drawing is a drawing drawn by engineer, having engineering knowledge, for the engineering purpose.
2. The standard size of a drawing board is 500*650 mm having 25mm thickness. It is made of well seasoned soft wood.
3. Writing of titles, sub titles, dimensions and other details on a drawing.

4. The expression of details in terms of numerical values regarding the distance between the surfaces on a drawing by the use of lines, symbols and units is called dimensioning.
5. It is the geometry practiced by the engineers for the graphic representation of solids of three dimensions of plane surfaces of two dimensions.
6. Proportionate ratio by which the drawing is to be enlarged or reduced is termed as "scale" of the drawing.
7. The representative fraction (RF) or scale factor is the scale of the drawing indicated by that ratio.
8. $RF = \frac{\text{Length on drawing}}{\text{Actual length}}$. So if a 2 m long log is shown by a 20 cm long on a drawing then $RF = \frac{20\text{cm}}{200\text{cm}} = 1/10$.
9. RF is expressed in the format X/Y.
10. The curves, circle, ellipse, parabola and hyperbola are obtained by cutting a cone in different ways. The profiles of the cut surfaces form these curves, hence called conic sections.
11. When a cone is cut by a plane, parallel to one of the end generators of the cone, the resulting section will be a parabola.
12. When a cone is cut by a plane parallel to its axis, the resulting section will be rectangular hyperbola..
13. Conjugate diameters are lines passing through the center of ellipse and parallel to the tangents on the curve at the points of intersection of the other diameter with the ellipse.
14. The ratio of its distances from focus to (eccentricity) is a constant and equal to one (1).
15. A parabola has unlimited number of double ordinates. The double ordinate, which is passing through the focus, is called latus rectum.
16. Conjugate axis (XX') is a line perpendicular to the transverse axis and is passing through the center of the transverse axis.
17. Asymptote is defined as a tangent drawn at infinity to the curve.
18. The path traced a point on the circumference of a circle when it rolls along the inside of another circle is called hypocycloid.
19. An involute is the path traced by a point on a string, as the string unwinds itself from a line, polygon or circle, keeping the string always taut.
20. A spiral is a curve traced by a point moving along a line in one direction. While the line is rotating in a plane about one of its ends or any point on it or on its extension.
21. When the two motions, namely, linear motion of the point and the rotary motion of the line, are uniform, the resulting curve is called an Archimedean spiral.
22. A helix is a curve traced by a point moving along a line in one direction while the line is revolving about another line parallel or inclined to it, such that both the motions are uniform.
- 23.

1.6 EXERCISES

1. What is meant by engineering drawing?
2. What is the standard size of the drawing board?
3. What is meant by lettering?
4. What is meant by dimensioning?
5. What are the two systems of dimensioning?
6. What is meant by solid geometry?
7. What is meant by projection of an object?
8. How the scale is written on a drawing sheet?
9. What is known as enlargement scale?
10. What is known as reducing scale?
11. What is known as full size scale?
12. What will be the RF for the following scales
 - (a) Enlargement scale
 - (b) Reducing scale
 - (c) Full scale.
13. What is the SI unit of length?
14. What is the normal unit of the length conveniently expressed as units of the length in the drawing?
15. The major and minor axes of an ellipse are 100 mm long and 60 mm long respectively. Locate the foci and draw the ellipse by arcs of circles method. Draw a tangent and normal to the ellipse at a point on it 20 mm above the major axis.
16. The sum of the distances of a point P from two fixed points is 120 mm and the distance between the fixed points is 60 mm. Draw the locus of the point P. Show the tangent and normal to the curve at a point on the curve 35 mm from one of the fixed points.
17. The distance between the foci of an ellipse is 120 mm and the minor axis is 80 mm long. Find the major axis and draw an ellipse by arcs of circles method. Draw its directrices and tangent and normal to the curve at any point on it other than on its major axis and minor axis. Draw also a pair of tangents from a point P outside the ellipse.
18. Construct an ellipse for a major axis equal to 100 mm and minor axis 60 mm.
19. Draw a fixed line MN of any length. The parameter of the curve is 50 mm. Trace the path of a point P moving in such a way that the ratio of its distance from the fixed point A to its distance from the fixed line MN is always unity. Name the curve. Plot at least 5 points. Draw a normal and tangent to the above curve at a point on it but 35 mm from the fixed point.
20. Draw the locus of a point P, moving equidistant from a given straight line AB and a fixed point C, Point C is on a perpendicular bisector of AB. It

is 50 mm away from AB Name the curve. Draw tangent and normal to the curve through a point P, 60 mm from the straight line.

21. Describe a parabola whose base and altitude are 80 mm and 50 mm respectively.
22. Construct parabola when its double ordinate is 150 mm and abscissa 65 mm. Find its focus and directrix Draw a pair of tangents from a point P out side the curve. Point P is 30 mm from the focus and 25 mm from the vertex.
23. Draw the curve, when the distance of the focus from the directrix is 50 mm and eccentricity is $3/2$ Name the curve and draw tangent and normal from any convenient point on it.
24. The transverse axis of a hyperbola measures 80 mm. An ordinate PM from a point on the curve measures 60 mm and the distance between M and the nearer vertex 40 mm. Draw one branch of the curve.
25. The major axis of a hyperbola is 60 mm and a point on the curve is at a distance of 75 mm from the center of the major axis and 35 mm from the vertex. Draw one branch of the hyperbola.
26. A coin of 40 mm diameter rolls over a horizontal table without slipping. A point on the circumference of the coin is in contact with the table surface in the beginning and after one complete revolution. Draw the cycloidal path traced by the point. Draw a tangent and normal at any point on the curve.
27. Draw a hyperbola when its double ordinate is 80 mm, abscissa is 15 mm and half the transverse axis is 25 mm. Find the conjugate axis, asymptotes and directrix and draw a tangent to the hyperbola from a point outside the curve.
28. Draw a hypocycloid of a circle 6 cm diameter which rolls inside another circle of 12 cm diameter for two revolutions.
29. Draw the Archimedean spiral of $1\frac{1}{2}$ convolutions with the greatest radius of 100 mm and the smallest radius of 20 mm. Draw the tangent and normal to the curve at a point 62 mm from the pole.
30. Draw the involute of a circle, 40 mm in diameter. Also draw the tangent and normal at a point on the curve at a distance of 100 mm from the centre of the circle.
31. Draw a helix for one turn upon a cylinder of 40 mm diameter and height of 80 mm. The pitch of the helix 60 mm.
32. Draw $1\frac{1}{2}$ turns of a right-handed helix of pitch 60 mm on a cylinder of diameter 70 mm.
33. An ant is moving on a vertical cylinder in a circumferential direction at a constant angular speed in the clockwise direction as seen axially from the top and with simultaneous uniform advance in the axial direction. If the diameter of the cylinder is 50 mm and the ant moves 75 mm in the axial direction during one turn, draw the path of the ant.
34. Construct two complete coils of a spring of round cross-section, external diameter 90 mm, internal diameter 70 mm and pitch 40 mm.

2

ORTHOGRAPHIC PROJECTION

STRUCTURE

- Learning Objectives
- Introduction
- Steps to be Followed in Preparing Orthographic Views
- Principle Contour of Objective
- First Angle Projection
- Illustration Example
- Summary
- Keywords
- Answers to Check Your Progress
- Exercises

LEARNING OBJECTIVES

After reading this unit you will be able to

- define the fundamentals of orthographic projection.
- illustrate what is first angle projection
- prepare the orthographic views
- state the contour of objective.

2.1 INTRODUCTION

Artists or Engineers are interested in drawing any object as it looks to him (his eye). He looks at the object for a while, and then he can simply visualize how the object may look like. By this creative idea he may draw in an artistic way. But in engineering, the artist is the observer; he views the object by keeping it in a hand or at a distance.

Then he imagines how the object looks like in the face view. He assumes Home rays passing through every corner or point of the object, and then attempts to draw the view. But actually the rays are divergent. In engineering normally we assume the rays are parallel to each other and pass through all the points of the object.

Let us assume these parallel rays fall on a screen or paper placed vertical/perpendicular to the rays. Then those parallel rays project over the paper. If we simply join all those points of projection on the paper, the object face will be obtained.

Geometrical figure are in two dimensions, they may be represented on a sheet of paper with their true shapes. But solid is a three dimensional object and it will not be possible to represent on a sheet of paper with it three dimensional true shape.

In engineering practice the face view is called the front elevation or front view. Thus in engineering practice the sort of drawing or projection is called as orthographic projection. Ortho means perpendicular view. In the orthographic projection, and all the face of the object or wall are projected on a plane.

This place on which we are drawing or projecting each and every point of the object is called as principle plan of projection, which is assumed to be normal to the rays or sight of the observer. The shape of the drawing formed by the projection of all visible and/or invisible faces of the object in consideration is called "VIEW".

In engineering practice only the front view is not enough. At least two such view/ projections are needed to express all the three dimensions.

So, it is understood that in order to get the view of the object in the same size, the rays must be parallel to each other and also perpendicular, to the plane of projection These rays are called "PROJECTORS' The view obtained as such is called "ORTHIGRAPHIC VIEW". And the method of projection is termed as "ORTHIGRAPHIC PROJECTION".

Orthographic projection and oblique projection are the type of parallel projection. In this book we concentrate only on 'orthographic projection. Here parallel projector are perpendicular to the principle of planes.

Different views of the object are obtained through viewing it from different directions. Assuming the object is fixed, the observer views and obtains only a single view. An observer can look at the object in any direction perpendicular to the plane.

Totally he can view the object from nix principle direction; *i.e.*,

- i. front
- ii. above
- iii. right side
- iv. left Side
- v. behind and
- vi. below the object

Thus,

By this, maximum ex views of the projection are possible. But in engineering practice only three view may be sufficient *i.e.*, front, top and side (right or left). In this book we adopt only first angle of projection, in which object is assumed to be in the first quadrant *i.e.*, above the horizontal

plane and in front of the vertical plane. In the first angle projection method, the object is placed between the observer and the principle plane.

Symbol for first angle projection method:



Systematic approach

In order to get the three views of an object some simple steps are advised. A picture drawn normally in isometric view will be given. To start with, let us assume a cube in an isometric view.

Let us assume the directional view as shown in the Fig. 2.1. The arrow marks indicate the direction of the view which is of course perpendicular to the principle plane. Once the direction of front view is fixed, it is easy to fix the directions of other views. This is self-explanatory in the figure in which the directions are marked as 1, 2, 3.

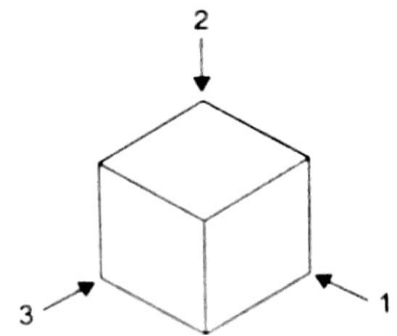


Fig. 2.1

For drawing orthographic views from the pictorial view of an object it is customary, to indicate the directions from which the object is to be viewed for the orthographic views by means of arrows. If not indicated, the arrow may be assumed parallel to a sloping axis. The other two views are obtained by looking in directions parallel to the other two axes. This explanation will be clear when Fig. 2.1 is studied carefully.

In Fig. 2.1 when the object is viewed in the direction of axis 1 for obtaining the front view, the dimension along axis 2 and axis 3 will be visible and dimensions along axis 1 will not be visible. Lines parallel to axis 1 will be viewed as point and surfaces parallel to the plane containing axis 1 will be viewed as straight lines. Careful study of the above explanation is very essential to understand the principle of drawing orthographic views from pictorial view. With this background, the method of obtaining the orthographic view from a pictorial view is explained. Examine the object carefully and then place it in a suitable position for the front view, top view, and side view.

2.1.1 Principles of Multi View Drawing

The following properties should be studied carefully and understood thoroughly before any attempt is made to prepare an orthographic drawing (first angle projection):

1. The front view and top view are always in line vertically.
2. The front view and side view are in line horizontally.
3. The front of the object in the top view is always away from the front view.
4. The front of the object in the side view is always away from the front view.
5. The depth of the object can be seen in top view and side view.
6. The width of the object can be seen in front view and top view.
7. The height of the object can be seen in front view and side view.

A stage has been reached where basic principles of orthographic and isometric projections are clear. This knowledge is used to obtain orthographic views from pictorial view of objects.

2.2 STEP TO BE FOLLOWED IN PREPARING ORTHOGRAPHIC VIEWS

When drawing orthographic working sketches a systematic order should be followed, and all the rules and conventional practices used in making working drawing should be applied. The following procedure is recommended. The object is shown in Fig. 2.2.

- i. Examine the object, giving particular attention in detail.
- ii. Determine which views are necessary.
- iii. "Block-in" the views (draw rectangles or squares according to the overall dimensions of the object), using light construction lines.
- iv. Complete the detail and darken the object lines.
- v. Sketch extension lines and dimension lines, including arrow heads.
- vi. Complete the sketch by adding dimensions, notes, title, date, sketcher's name or initials and so on.
- vii. Check the entire sketch carefully to see that no dimensions have been omitted.

Fig. 2.2 explains the steps

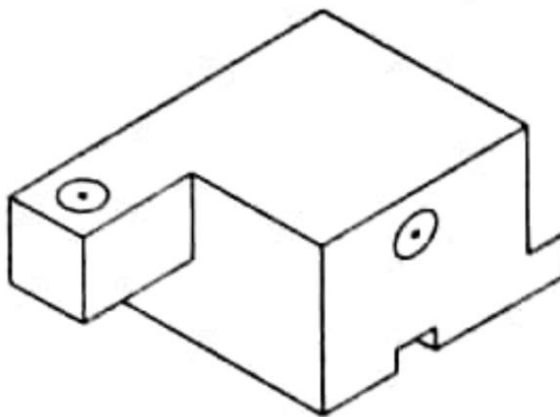


Fig. 2.2

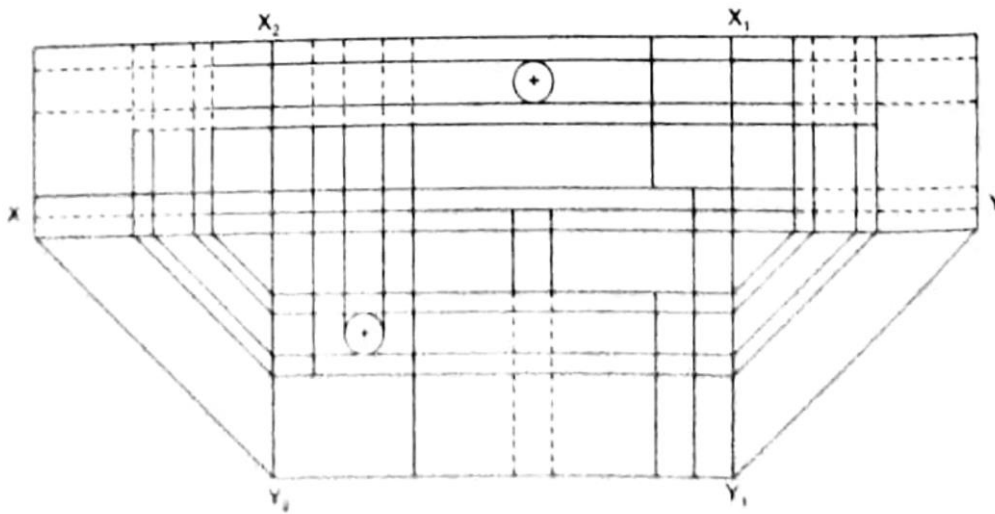


Fig. 2.3

2.3 PRINCIPLE CONTOUR OF OBJECTIVE

The front view generally shows the most distinctive outline or contour. Fig. 2.4 shows the pictorial drawings of several objects and the proper selection of front view in each case.

The side view having a minimum number of invisible lines has to be selected. Fig. 2.5 illustrates this point. The right and the left side views have the same lines, but the right side view is preferable for this object because most of the lines are visible from the right side.

After the object is placed in the proper position and the desired front view is selected, the next step is to decide upon the number of views to be drawn. This requires a careful study of the object because it is essential that all the necessary information must be given. However, for the sake of economy, it is very important that no additional view(s) be drawn.

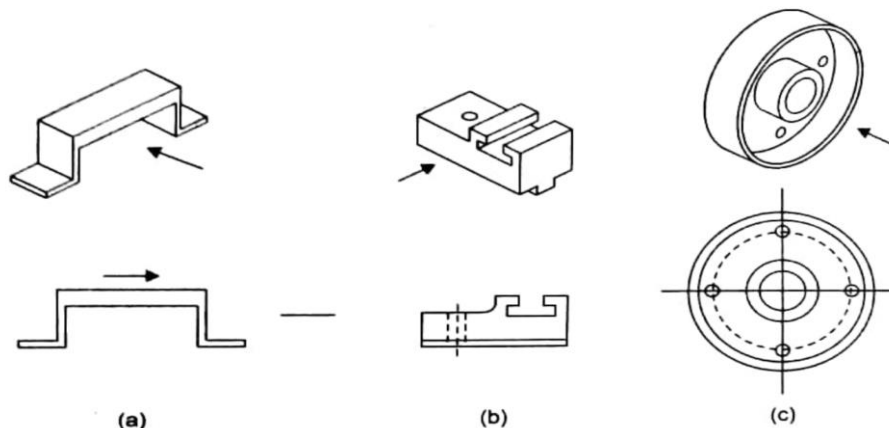


Fig. 2.4. Principle contour of object in front view.

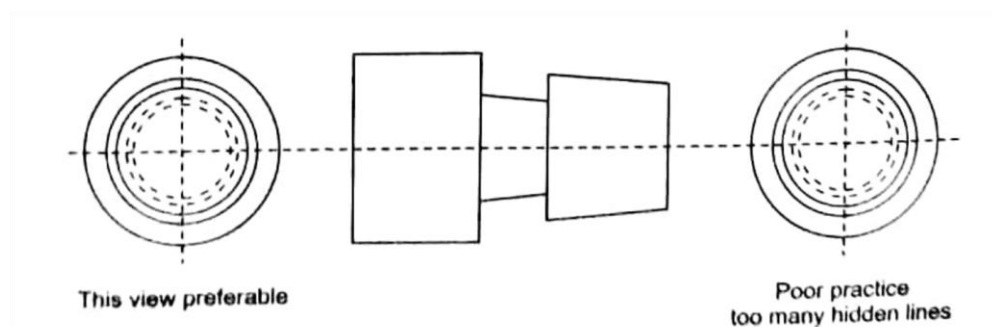


Fig. 2.5. Selection of views to avoid hidden lines.

While drawing the projections of an object, it is important to remember that every end of a line on the object must be shown in some manner in every view. Since some lines on an object are invisible from a particular direction, there must be a definite method of distinguishing the visible from the invisible. Dashed (not dotted) line is used to represent the invisible line (Refer Fig. 2.6).

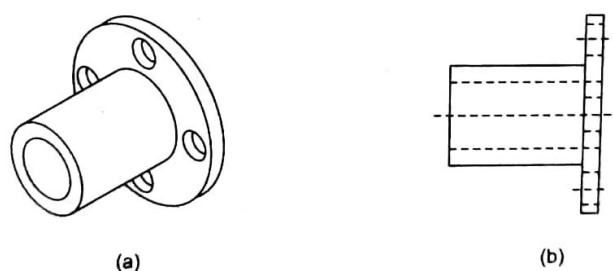


Fig. 2.6

The pictorial view of an object with the correct projections is shown in Fig 2.7. In any view there is likely to be a coincidence of lines, Hidden portions of the object may project to coincide with visible portions. In the top view, the face ABCD will be edge- wise and so only AB will be visible.

Lines CD, KN and LM, which are invisible from the top will not be shown in dashed from because they are vertically below AB.

The visible lines take precedence over the invisible lines.

The extreme generators of the holes and the edge of the face EFGH will be represented by dashed lines in the top view.

Center lines/extreme generators may occur where there is a visible or hidden outline of some part of the object. In the side view the top generator of the large hole, although invisible, will not be shown and shed line because it is behind the visible line of the notch.

The lower generator of the hole will be shown by dashed line because there is no other line between the generator and the observer.

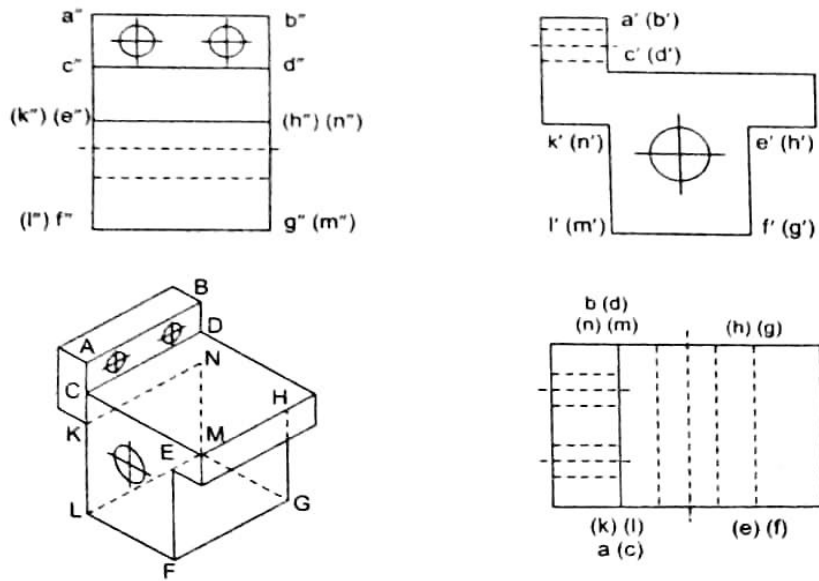


Fig .2.7. These view drawing with visibility of lines.

Since the physical features of the object must be clearly represented, full and dashed lines take precedence over all other lines. Since the visible outline is more prominent by space position, full lines have precedence over dashed lines. A full line can cover a dashed line, but a dashed line cannot cover a full line. It is evident that a dashed line cannot occur as one of the boundary lines of a view.

When a center line and cutting plane line coincide, the one that is more important for readability of the drawing take precedence over the other.

Dimension and extension lines must always be placed so as to coincide with other lines of the drawings.

The following in the order of precedence of linen: full line, dashed line, center line, cutting plane line, dimension lines, extension lines and cross hatch lines.

The rules governing the visibility in any view are the following:

- In the top view, the highest parts will be visible. These are determined from the front or side view.
- In the front view, the parts nearest to the observer will be visible. These are determined from the top or side view.
- In the right side view, the parts on the right will be visible. They are determined from the top view or front view.

2.4 FIRST ANGLE PROJECTION

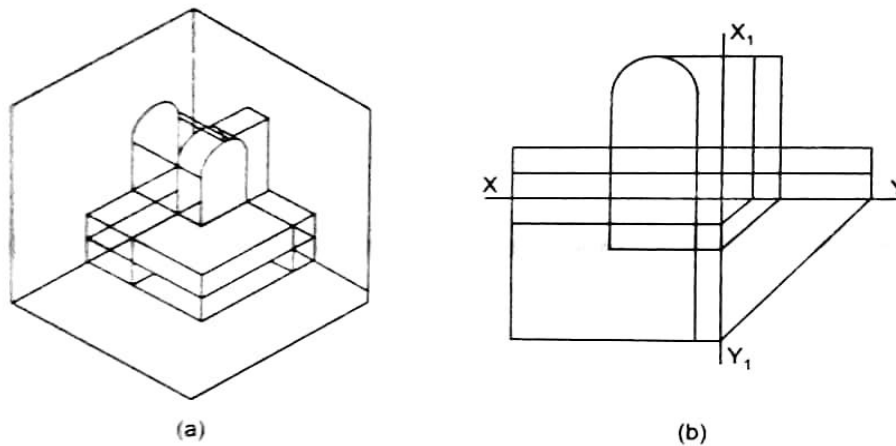


Fig. 2.8

In this view, the object is placed in the first quadrant and the projections are obtained as shown in Fig. 2.8 (a). After rotation of the planes, the three views will appear as shown in the Fig 2.8 (b). In first angle projection the object is viewed and projected on the opposite side.

2.5 ILLUSTRATIVE EXAMPLE

All orthographic projection are according to the first angle projection method. Obtain front view in X-direction, top view in Y-direction, and end view in Z-direction.

2.5.1 Examples

- Draw the orthographic views of the objects as seen from the directions marked in the Fig. 2.9.

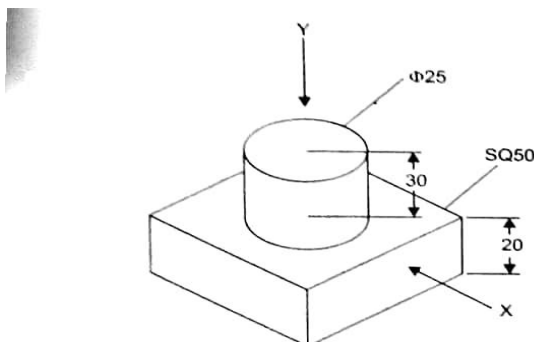


Fig. 2.9(a)

Fig. 2.9 (a)

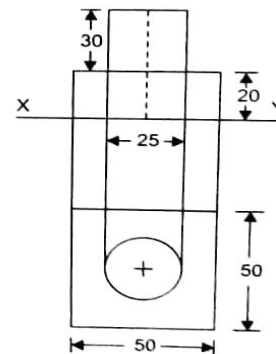
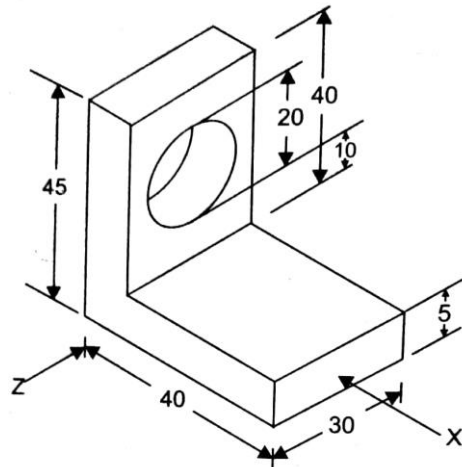


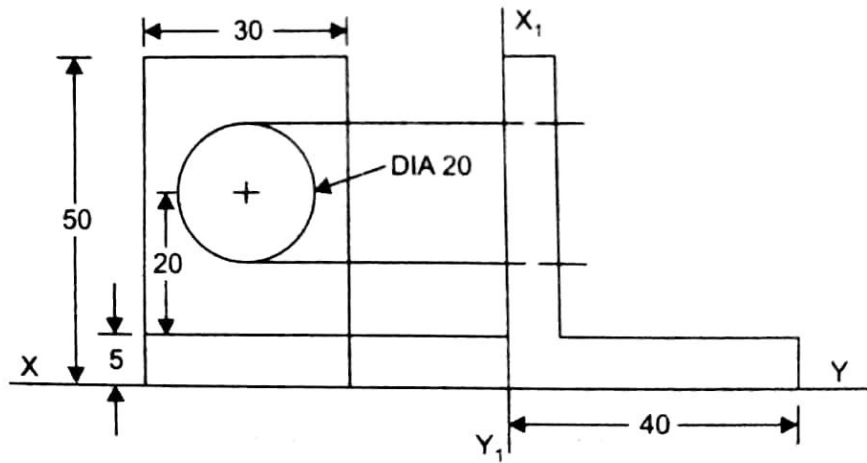
Fig. 2.9(b)

Fig. 2.9 (b)



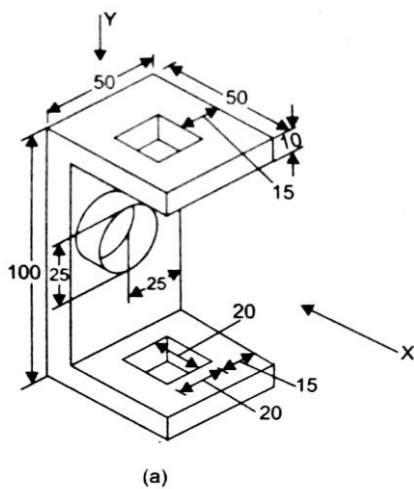
(a)

(a)

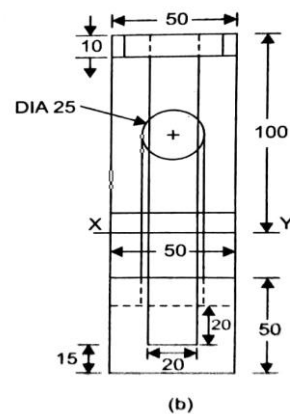


(b)

Fig. 2.10



(a)



(b)

Fig. 2.11

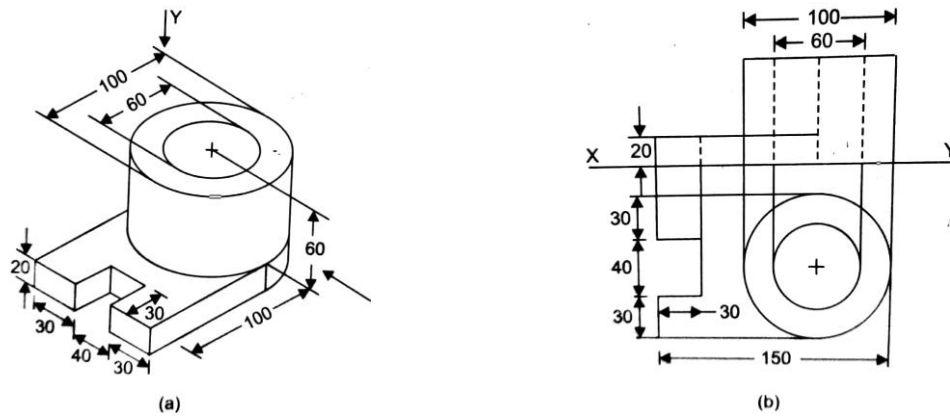


Fig. 2.12

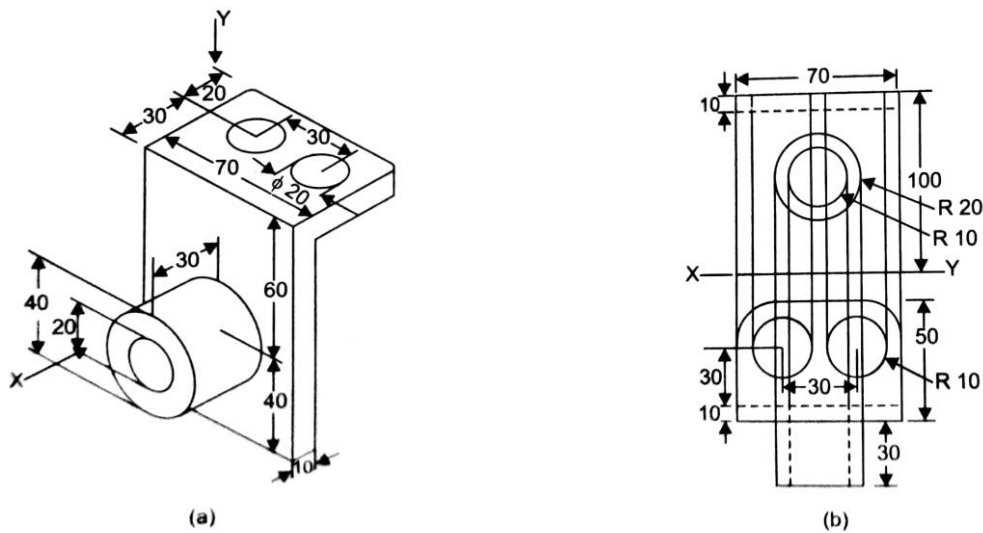


Fig. 2.13

CHECK YOUR PROGRESS

1. What is meant by projection of an object?

2. What are planes of projections?

3. What are called as principle views?

4. What is meant by first angle projection?

2.6 SUMMARY

Orthographic projection is the common and systematic method to exhibit the object. By obtaining practice through this chapter the practice obtained by this chapter, anyone can easily view the object methodologically and exhibit how the object may look like through whichever direction, they are viewed at.

Now the reader can understand the six principle direction of view and the terminologies used. In such view, to make it simple, and to simplify the ideas, only the first angle projection is preferred. The systematic approach explained and examples given will clearly indicate the guidelines how to project any object to exhibit all the three dimensions.

2.7 KEYWORDS

1. **Quardant:** Each of four parts of a circle, planes, body etc., divided by two lines or planes at right angles.
2. **Point:** A dot having position but not spatial extent magnitude, dimension or direction.
3. **Profile plane:** Principle plane of projection in a Quardant in which the profile or description of a object can be projected.
4. **First angle projection:** Projection of the point or object in the first Quardant.
5. **Third angle projection:** Projection of the point or object in the third Quardant.
6. **View:** The figure formed by the projection of al visible and invisible faces of an object is called a view.
7. **Elevation:** When the object is viewed from the front, then the orthographic view on vertical plane is called front view or elevation.
8. **Plant:** When the object is viewed from above then the orthographic view on horizontal plane in called top view (TV) or plan.
9. **Symbol:** According to the Bureau of Indian Standard, it represents two views of frustum of a cone placed with its in parallel to both the HP and VP.
10. **Projection of an object:** Outlines of the shadow or projections of an object or the image of an object.
11. **Plane of projection:** The Transparent plane on which the projections are drawn.
12. **Projectors:** The rays drawn from the extremities of the object to meet the principal planes are called projectors.
13. **Orthographic projection:** When the projectors are perpendicular to the plane on which the projection is obtained is called an orthographic projection. Orthographic projection means "right angled drawing".

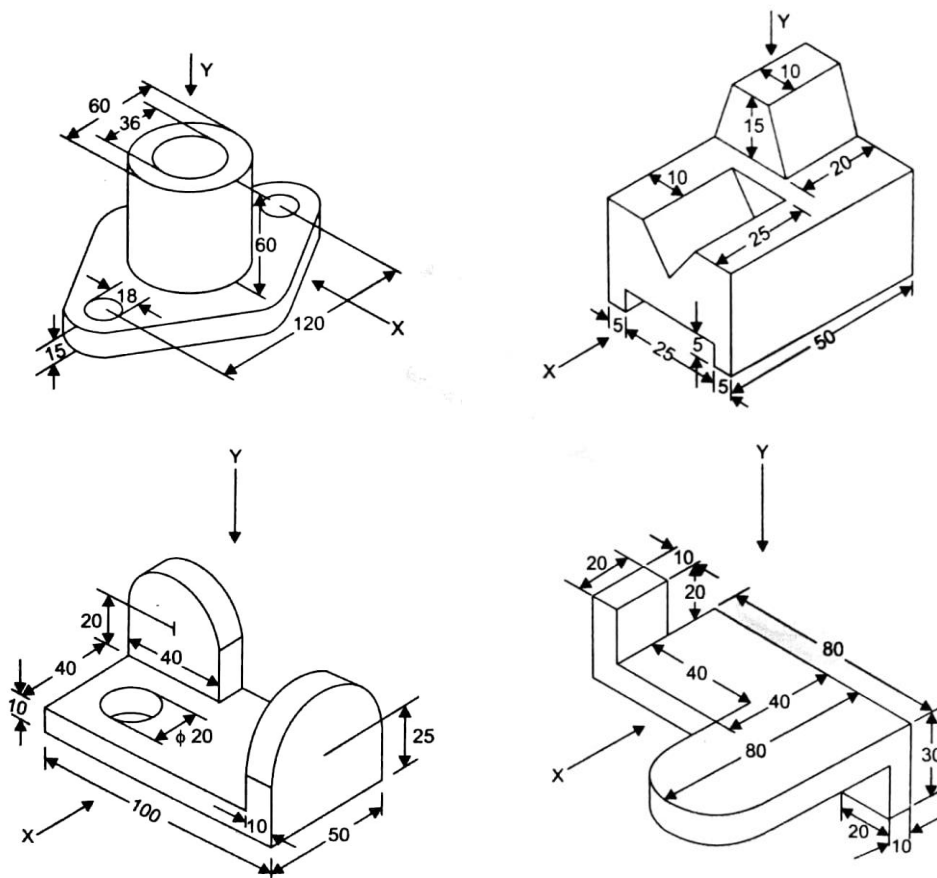
2.8 answers to check your progress

1. Outlines of the shadow are projections of an object or the image of an object.
2. The transparent plane on which the projections are drawn are called transparent plane.
3. In multiview projection, the observer is supposed to look the object from six principle direction. These views are called principle views.
4. In multiview orthographic projections, the object is placed in first quadrant. Accordingly, the method is called first angle method of production.

2.9 EXERCISES

1. How are projections classified?
2. Name few types of pictorial projection.
3. What is meant by an orthographic projection?
4. Draw the orthographic view of the following objects as seen from the directions marked.

Draw the orthographic views of the objects, whose pictorial views are given through the directions marked.



Draw the orthographic views of the objects, whose pictorial views are given through the directions marked.

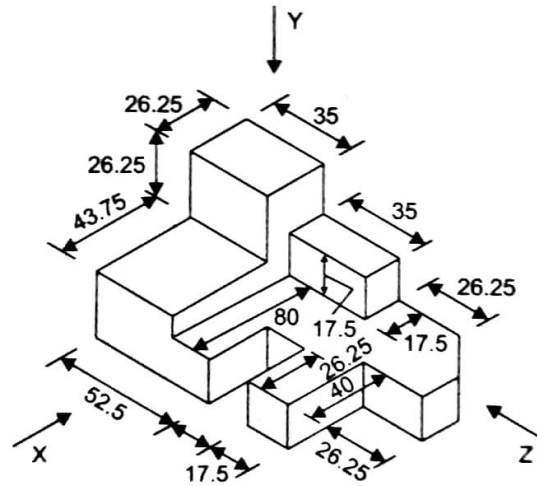


Fig. 2.14

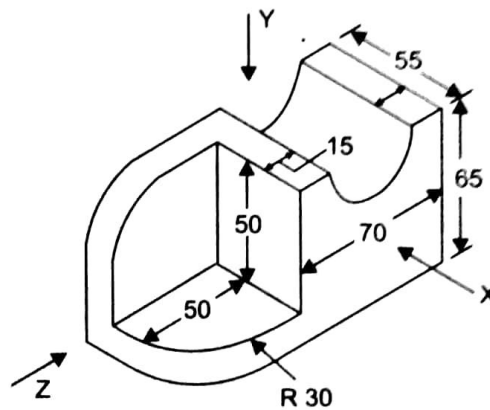


Fig. 2.15

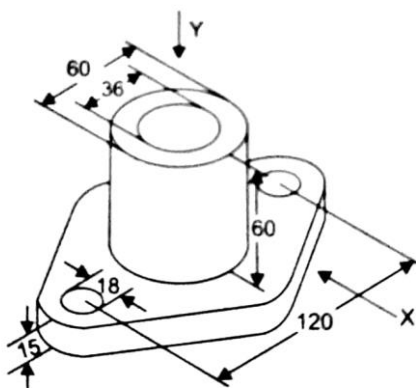


Fig. 2.15

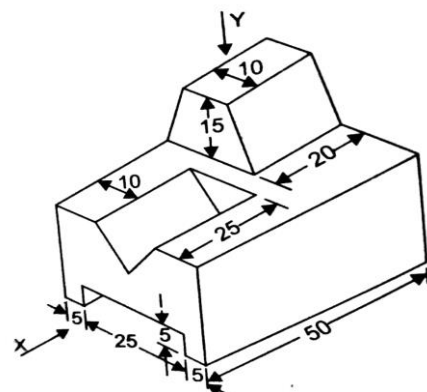


Fig. 2.17

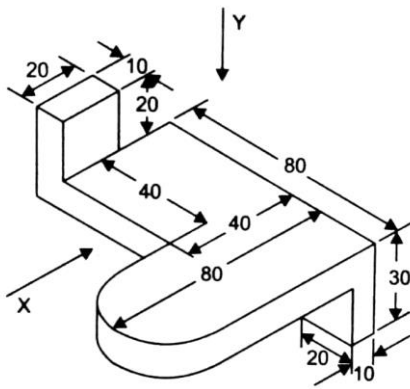


Fig. 2.18

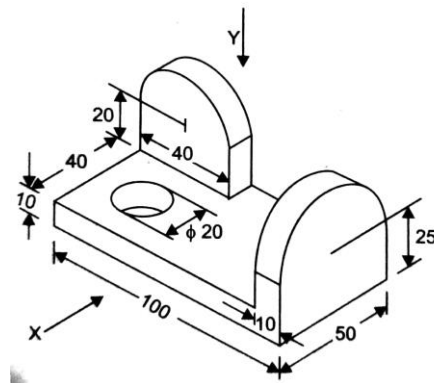


Fig. 2.19.

3

PROJECTION OF SOLIDS

STRUCTURE

Learning Objectives

- Introduction
- Steps to be Followed in Preparing Orthographic Views
- Principle Contour of Objective
- First Angle Projection
- Illustration Example
- Summary
- Keywords
- Answers to Check Your Progress
- Exercises

LEARNING OBJECTIVES

After reading this unit you will be able to

Projection of Solids

- enumerate the fundamentals of orthographic projection
- state basis of principle planes
- define the different views
- discuss the projection of planes
- draw and project simple solids in simple projection
- explain the projection of solids and solids perpendicular to HP
- draw the solids inclined to one of the reference planes only and parallel to the other
- draw the projection of the solids inclined to HP and parallel to VP
- analyse the properties of solids inclined to both the reference planes
- draw the projection of combination solids

Section of Solids

- define the principle of section of solids
- list out the guidelines for solving problems in section of solids
- discuss the purpose of sectioning and hatching procedure
- draw the true shape of section

3.1 INTRODUCTION TO PROJECTION OF STRAIGHT LINE

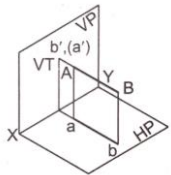
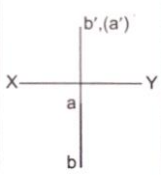
A straight line is the shortest distance between two points. The projections of a straight line are the lines obtained by joining the respective projections of the end points of the straight line. The projections of a straight line are always straight lines either of the same length or of a length shorter than its true length.

3.1.1 Projections of Lines on Principal Planes

Construction of the orthographic projections of straight lines situated in the above positions has been given in Table 3.1.

Table 3.1. Projections of straight lines

If a straight line <i>AB</i> is in space in	Pictorial view	orthographic projections	Then on the orthographic drawing	Remarks
Parallel to both the principal planes i.e., parallel to <i>HP</i> and parallel to <i>VP</i> .			Front view (<i>a' b'</i>) is parallel to <i>XY</i> top view (<i>ab</i>) is parallel to <i>XY</i> .	Length to top view (<i>ab</i>) is equal to length of front view (<i>a' b'</i>) is equal to true length <i>AB</i> . It has no trace.
On both planes, i.e., <i>HP</i> and on <i>VP</i>			<i>a' b'</i> is on <i>XY</i> <i>ab</i> is on <i>XY</i>	<i>ab</i> = <i>AB</i> <i>a' b'</i> = <i>AB</i>
On <i>HP</i> and parallel to <i>VP</i>			<i>a' b'</i> on <i>XY</i> <i>ab</i> parallel to <i>XY</i>	<i>ab</i> = <i>AB</i> <i>a' b'</i> = <i>AB</i>
Parallel to <i>HP</i> and on <i>VP</i>			<i>a' b'</i> parallel to <i>XY</i> <i>ab</i> on <i>XY</i>	<i>ab</i> = <i>AB</i> <i>a' b'</i> = <i>AB</i>
Perpendicular to <i>HP</i> and in front of <i>VP</i>			<i>a' b'</i> perpendicular to <i>XY</i> <i>a, (b)</i> below <i>XY</i>	<i>a, (b)</i> is a point <i>a' b'</i> = <i>AB</i> . Its <i>HT</i> coincides with its top view, which is a point. It has no <i>VT</i> .

Above <i>HP</i> and perpendicular to <i>VP</i>			$a', (b')$ above <i>XY</i> ab perpendicular to <i>XY</i>	$a', (b')$ is a point $ab = AB$ Its <i>VT</i> coincides with its front view, which is a point. It has no <i>HT</i> .
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3.1.2 Construction, Inscription and Circumscription of Polygons

To Draw a Regular Polygon, Given One Side

(i) Pentagon (Figure 3.1). Let *AB* be a side of the pentagon. At *B* draw $BQ = AB$ and perpendicular to *AB*. Let *P* be the midpoint of *AB*. With *P* as center and *PQ* as radius draw an arc cutting *AB* extended at *R*. *AR* is the diagonal of the pentagon. With *A* as center and *AR* as radius draw an arc and with *B* as center and side of the pentagon as radius draw an arc to cut the previous arc at *C*. Similarly obtain *D* and *E*. *ABCDE* is the required pentagon.

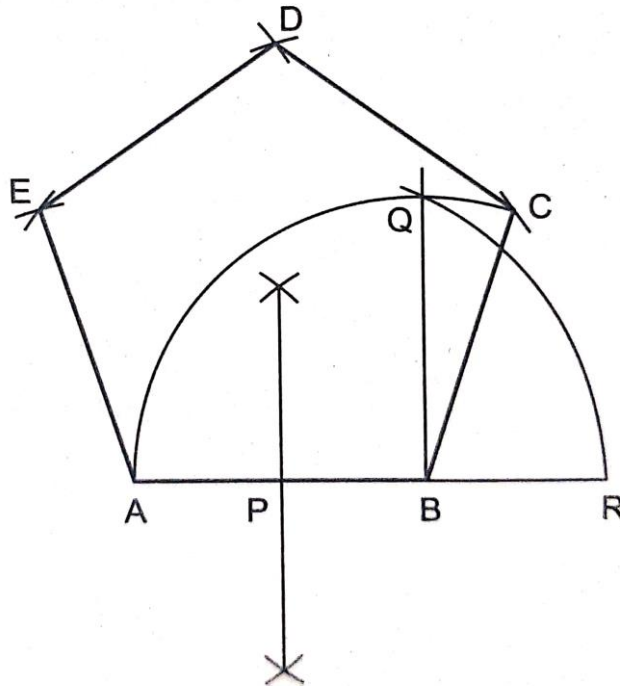


Fig. 3.1

(ii) Hexagon (Figure 3.2). Let *AB* be a side of the hexagon. Draw $AP = AB$. With *PB* as diameter draw a semicircle. Divide the semicircle into six equal parts and name them as 1, 2, 3, 4 and 5. Join *A* with 2. With 2 as center and side of the hexagon as radius draw an arc cutting the line from *A* through 3 at *E*. Similarly draw a line from *A* through 4 and 5 obtain points *D* and *C*. *ABCDEF* is the required hexagon.

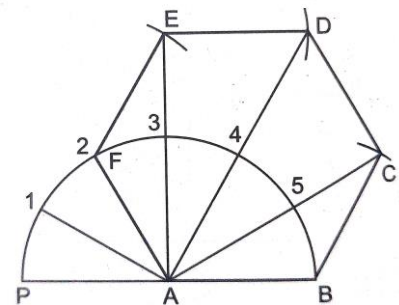


Fig. 3.2

In similar ways heptagon, octagon, etc. can be drawn. The semicircle drawn should be divided into the same number of equal parts as that of the number of sides of the polygon. Always on the line drawn through point number 2 one side of the polygon will lie.

3.1.3 Projection of Planes

A surface having length and breadth with negligible thickness is known as a plane surface or simply a plane. It is surrounded either by straight lines or curved lines. A plane in which all the sides are equal is said to be regular. When a plane is held with its surface parallel to one of the principal planes of projection, its projection on that reference plane will be of true shape.

Projection of Planes Parallel to One of the Reference Planes

If a plane is parallel to one of the reference planes its projection on that reference plane will be of true shape while its projection on the other reference plane will be a straight line parallel to the reference line.

Planes Parallel to HP

The top view shows true shape. The front view will be a straight line parallel to XY. Its VT is parallel to XY. It has no HT.

- 1. An isosceles triangle of altitude 70 and base 50 has its plane parallel to the HP and 60 above it. Draw the projections when its base is perpendicular to the VP. Find its traces.**

Data: $TV = ABC$, FV parallel to and 60 mm above XY , $ac (= AC)$ perpendicular to XY
Objs: FV , TV , HT , VT

Solution. Refer Fig. 3.3.

Consider the plane in the given position and draw the top view, satisfying the given conditions.

1. Draw XY line.
2. Draw $ac (= 50 \text{ mm})$ perpendicular to XY . Locate b on the perpendicular bisector of ac , at a distance of 70 mm. Join cb and ab to get the top view, abc . When the plane is viewed from the front, edge AB is seen in apparent length and parallel to HP .
3. Draw its front view $a'b'$ (in apparent length) parallel to and above XY . Look at the plane in the direction of arrow shown. Corner C is hidden by side AB .
4. In the front view mark C as (c') . Now $a'b'(c')$ is the FV . Extend the plane to meet VP . The extension coincides with the front view.

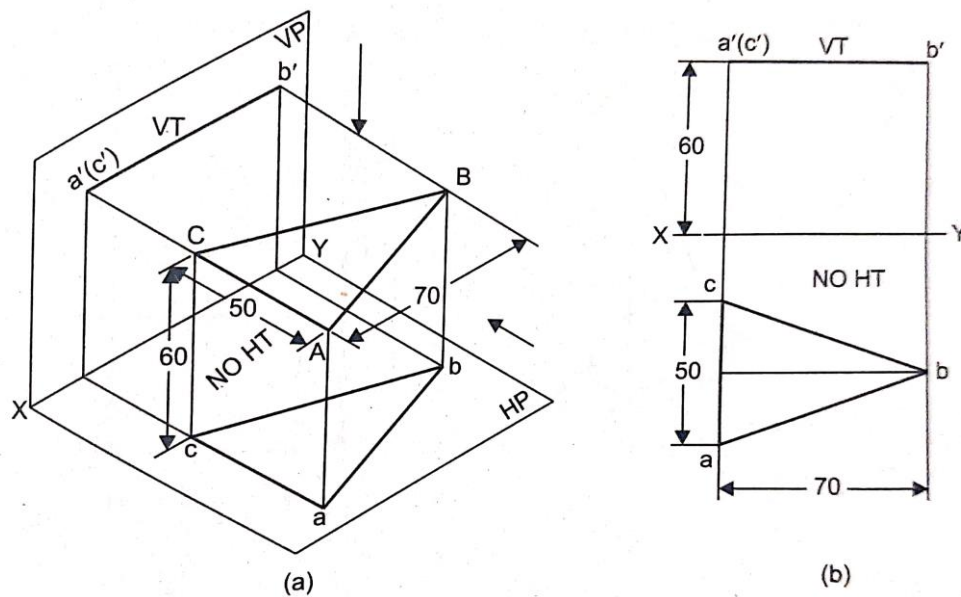


Fig. 3.3

5. So front view $a'(c')b'$ itself is the VT. Extend the plane to meet the HP. Since the plane is parallel to HP, it will not meet it.
6. Hence the plane has no HT.

Planes Parallel to VP

The front view shows true shape. The top view will be a straight line parallel to XY. Its HT is parallel to XY. It has no VT.

2. An equilateral triangle ABC of 40 mm side is parallel to and 30 mm in front of the VP. Its base AB is parallel to and 65 mm above the HP. Draw the projections of the triangle when the corner C is near to the HP.

Data:

Space Terminology	Orthographic Terminology
Plane is parallel to VP and 30 mm in front of VP	FV will be of true shape
AB is parallel to and 65 mm above XY	TV 30 mm below XY
corner C is near to the HP	$a'b'$ parallel to and 65 mm above XY
	c' near to XY

Objs: FV, TV

Solution. Refer Fig. 3.4

Consider the plane in the given position and draw the front view, satisfying the given conditions.

1. Draw XY line.

2. Draw $a'b'$ ($= 40$ mm) parallel to and 65 mm above XY . With a' and b' as centers and radius equal to 40 mm, draw arcs intersecting at c' . Join $b'd'$ and $a'c'$, to form the front view, $a'b'd'$.
3. Draw its top view ab (in true length) parallel to and 30 mm below XY . Look at the plane in the direction of arrow shown. Corner C is hidden by the side AB .

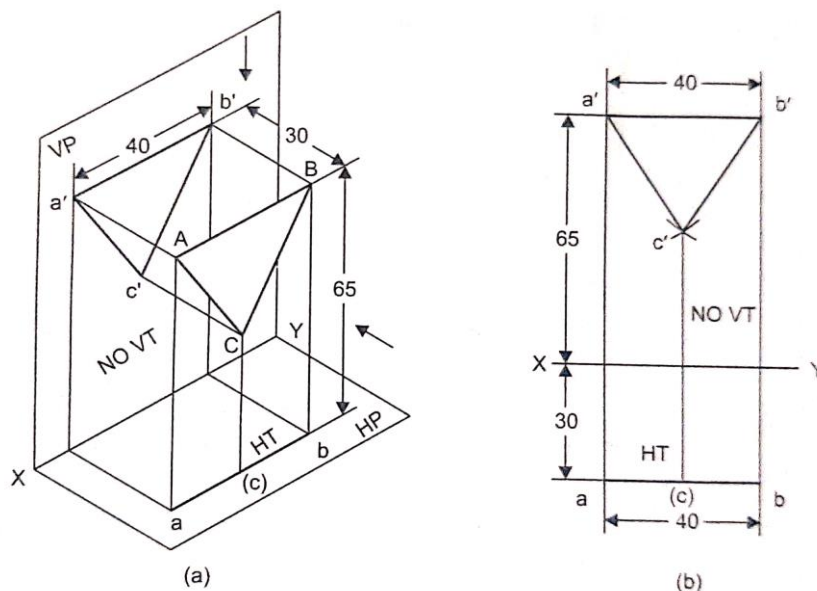


Fig. 3.4

4. In the top view mark C as (c) . Now $a(c)b$ is the top view, Extend the plane to meet the HP . The extension coincides with the top view.
5. So the top view $a(c)b$ itself is the HT . Extend the plane to meet the VP . Since the plane is parallel to VP , it will not meet it.
6. Hence, the plane has no VT .

Projection of Planes Perpendicular to Both the Reference Planes

Side view projection on the profile plane) shows true shape. Front view and top view will be straight lines perpendicular to XY .

3. A pentagonal lamina of side 30 mm is standing on one of its sides in the horizontal plane and is perpendicular to HP as well as VP . Draw its projections.

Data: $a'c'$ on XY , $ae = AE$, FV and TV straight lines perpendicular to XY , $SV = ABCDE$.

Objs: FV , TV , SV

Solution. Refer Fig. 3.5 (a) and (b).

Consider the plane in the given position.

1. Draw XY line. Also draw X_1Y_1 perpendicular to XY .
2. Construct a regular pentagon $a''b''c''d''e''$ with $a''e''$ on XY to represent the side view. When the plane is viewed from the front, the sides AB

and BC are seen in apparent lengths and perpendicular to XY (as a straight line).

3. Draw its front view $a'b'c'$ perpendicular to XY . Look at the plane in the direction and of arrow shown. The side AB hides the comers D and E .
4. In the front view mark D and E as (d'') and (e') . Now $a'b'c'(d'')(e')$ is the front view. When the plane is viewed from top, the sides BC and CD are seen in apparent lengths and perpendicular to XY .
5. Draw the top view as shown.

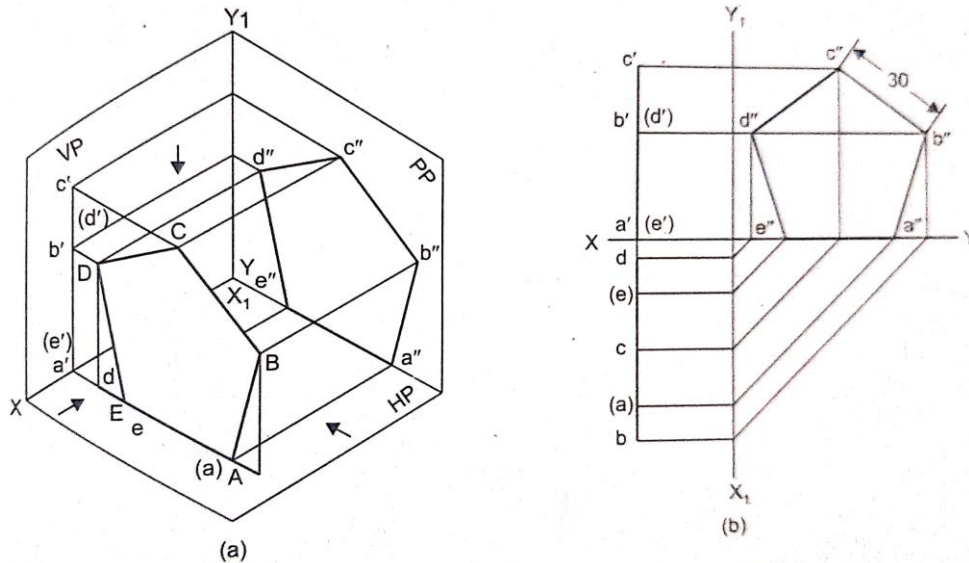


Fig. 3.5

3.1.4 Introduction of Solids

A solid is a three dimensional object having length, breadth, and thickness. It is bounded by surfaces, which may be plane, curved, or a combination of both. Solids are broadly classified into two types:

- Polyhedrons
- Solid of revolution.

A solid bounded by plane surfaces, called faces, is known as a polyhedron. A polyhedron is said to be regular if all the faces are equal and regular polygons and all the dihedral angles are equal to one another. The important regular polyhedra are

- *Tetrahedron* (Refer Fig. 3.6(a)) which has four equal equilateral triangular faces.
- *Cube or Hexahedron* (Refer Fig. 3.6(b)) which has six equal square faces.
- *Octahedron* (Refer Fig. 3.6(c)) which has eight equal equilateral triangular faces.

The polyhedra whose faces are not formed of equal and identical faces are known as irregular polyhedrons. They are classified into prisms and pyramids.

CHECK YOUR PROGRESS

1. What is a solid?

A polyhedron having two equal parallel regular polygonal end faces joined by side faces, which are parallelograms, is known as a prism. The end face on which the prism rests on *HP* is known as base. The side faces are known as lateral faces. Since the shape of the lateral faces is rectangular, they are called rectangular faces. The imaginary line joining the centers of the end faces is known as axis. The sides of the end faces are called base edges. The edges connecting the corners of the two end faces are known as lateral or longitudinal edges. The various types of prisms are named according to the shape of their end faces and are shown in Fig. 3,6 (d-g).

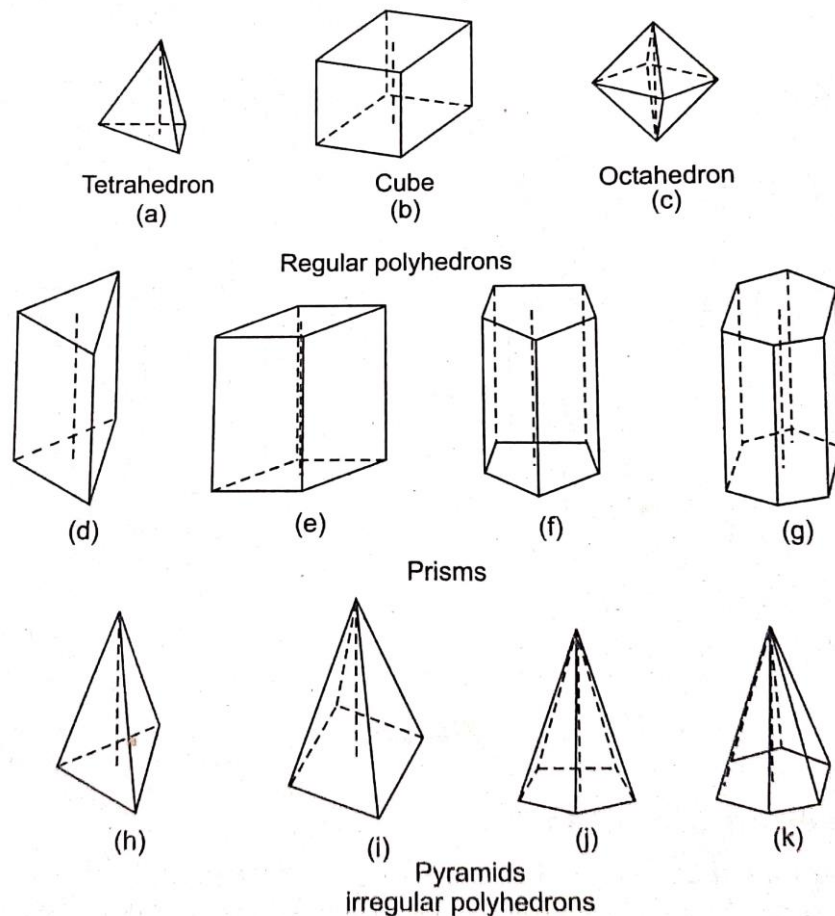


Fig. 3.6

A polyhedron having a plane figure as its base and a number of triangles meeting at a point as its side faces is known as a pyramid. The point at which the side faces meet is called apex or vertex. The imaginary line connecting the apex and the center of the base is called axis. Since the side

faces or triangular faces are inclined, they are also called inclined faces or slant faces. The edges connecting the apex and the base corners are called inclined or slant edges or longer edges. The different types of pyramids are named according to the shape of their base and are shown in Fig. 3.6 (h-k).

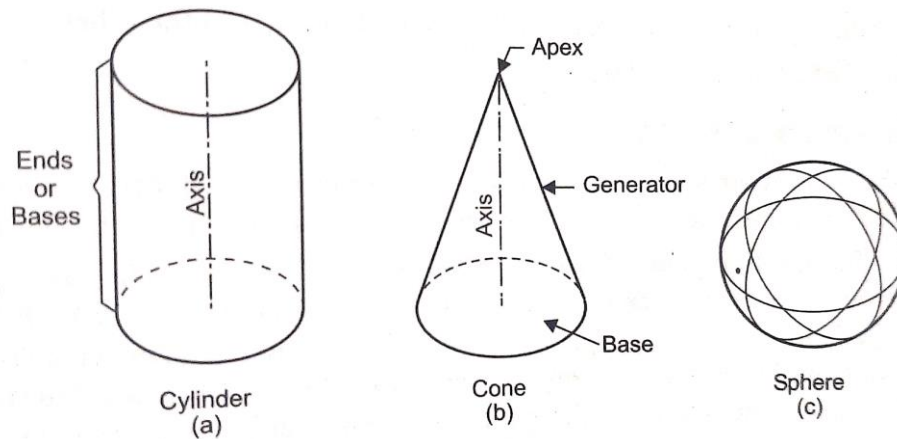


Fig. 3.7

A solid, generated when a plane figure is revolved about one of its sides, is called a solid of revolution. A cylinder is generated by the longer side of a rectangle, when the rectangle is revolved about the other longer side (Refer Fig. 3.7(a)). A sphere is generated when a semicircle is revolved about its diameter. The various types of solids of revolution are shown in Fig. 3.7.

When section planes cut solids and the top portions are removed, the remaining portions of the solids are called either frustums or truncated solids. When solids are cut such that their cut faces are parallel to the base, they are called frustums of solids (Refer Fig. 3.8). When solids are cut such that their cut faces are inclined to the base, they are called truncated solids (Refer Fig. 3.9).

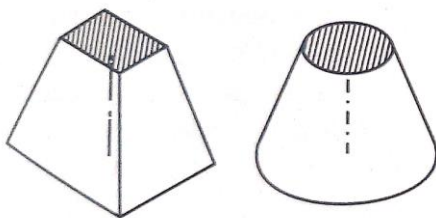


Fig. 3.8

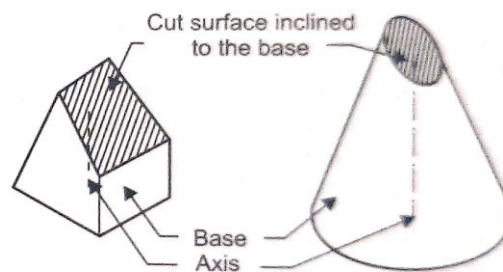


Fig. 3.9

2. What is a polyhedron?

3. What is a regular polyhedron?

Projections of a solid are always drawn starting with a view, which shows true shape of its base. It is known that true shape of the base is obtained on that reference plane to which it is parallel.

A solid in space may be located in any one of the following positions with respect to the reference planes (*HP* and *VP*):

- perpendicular to one of the reference planes
- parallel to both the reference planes
- inclined to one of the reference planes and parallel to the other
- inclined to both the planes.

3.1.5 Projection of Solids

Mostly right and regular solids are considered for projections. Hence, when a solid is named without any specification, it should be understood as being right and regular.

In all the solids explained so far with sketches, the axis of a solid, though imaginary, occupies a known position with respect to that solid. Naturally, the position of the axis will determine the two views of the solids. At times, the two views (top view, front view) may not be sufficient to give the complete details of the solid for the given position; so auxiliary views on auxiliary planes are obtained to have more details.

Positions of a solid can be broadly brought under four categories:

1. Axis parallel to one plane and perpendicular to the other plane (simple position).
2. Axis parallel to both the planes (simple position)
3. Axis parallel to one plane and inclined to the other plane (single rotation of the solid so that axis becomes inclined to one plane and remains parallel to the other plane).
4. Axis inclined to both the planes (resultant of two rotations of the solid).

Additional points to be observed while rotating the solid are, whether the solid is being rotated about (i) a side or (ii) a corner. If a solid is to be rotated about a side so that the axis becomes inclined to the *HP/VP* then that side should be viewed as a point in the front view/top view.

If a solid is to be rotated about a corner so that axis becomes inclined to the *HP/VP* then only that corner should be represented by an extreme point in the front view/op view and the two sides containing that corner should be equally inclined to *XY*. It is very important to bear this point in

mind when solving problems on solids, as this will facilitate to imagine correct position of the solid with respect to the principal planes initially.

The above points are summarized below:

1. If a solid is to be rotated about a side in the front view or top view then initially that side should be perpendicular to the VP or the HP.
2. If a solid is to be rotated about a corner point in the front view or top view then initially, only that corner should be an extreme point in the front view or top view and the two sides containing that corner should be equally inclined to XY.

Front view, top view, and end view for a solid placed in simple position are tabulated in Table 8.2.

Table 3.2

Position of the axis in simple position	Front view	Top view	End view
Perpendicular to the HP	(a) Rectangle for prisms and cylinders (b) Triangle for pyramids and cones	Base figure	(a) Rectangle for prisms and cylinders (b) Triangle for pyramids and cones
Perpendicular to the VP	Base figure	(a) Rectangle for prisms and cylinders (b) Triangle for pyramids and cones	(a) Rectangle for prisms and cylinders (b) Triangle for pyramids and cones
Parallel to both the planes	(a) Rectangle for prisms and cylinders (b) Triangle for pyramids and cones	(a) Rectangle for prisms and cylinders (b) Triangle for pyramids and cones	Base figure

Guidelines for Solving Problems in Projection of Solids:

1. In the final position if the solid is in simple position (no rotation) then draw the front view and top view as shown in Table 3.2.
2. In the final position if the axis or n face makes an angle with the VP/HP (single rotation) keep the axis perpendicular to the VP/HP satisfying condition given in the problem in connection with the rotation (whether the solid is being rotated about a side or a corner).
3. In the final position if the axis or a face makes an angle with both the VP and the HP (double rotation) keep the axis perpendicular to the VP/HP if the reference for the first rotation is made to the VP/HP.

Guidelines for Locating Invisible Edges/Generators in the Projections:

1. For prisms and cylinders one end face will be visible. Draw the projection of that end face and boundary in continuous line. The invisible portion of the other end face falling within the boundary is shown by hidden lines and all the edges/generators connected to the invisible portion are shown by hidden lines.
2. For pyramids and cones first see whether the base is visible, if so draw the projection of the base and boundary with continuous line and the edges/ generators falling behind the end face are shown in hidden lines. If the end face is not visible, draw the boundary with continuous line and show the edges/generators falling in the invisible portion of the base in hidden lines.

3.1.6 Solids Perpendicular to HP

Problem 1: Draw the projections of a triangular prism, base side 30 mm and axis 45 mm long, with the axis vertical and 20 mm in front of the VP. One side of the base is perpendicular to the VP.

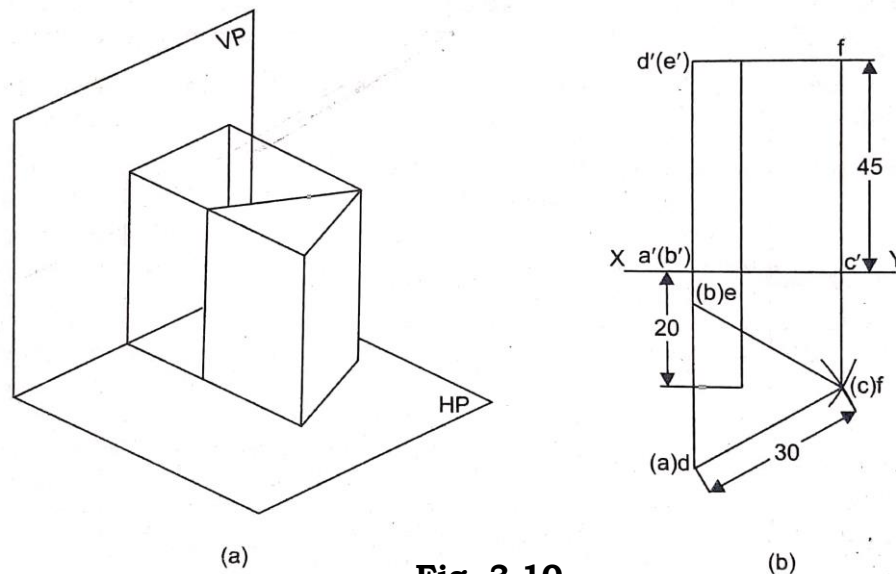


Fig. 3.10

Draw the top view of the triangular prism (a triangle) with one side of the triangle perpendicular to XY. From the top view, project the front view as shown in Fig. 3.10 (b).

CHECK YOUR PROGRESS

4. What is a pyramid?

Problem 2: Draw the projections of a square pyramid, base side 40 mm and axis 55 mm, standing on its base on the HP with all sides of the base equally inclined to the VP.

Draw the top view of the base, which is a square with all the sides of the square equally inclined to XY, and mark the top view of the apex O at the center of the square. From the top view, project the front view as shown in Fig. 3.11. (Assume reasonable values for sides and height).

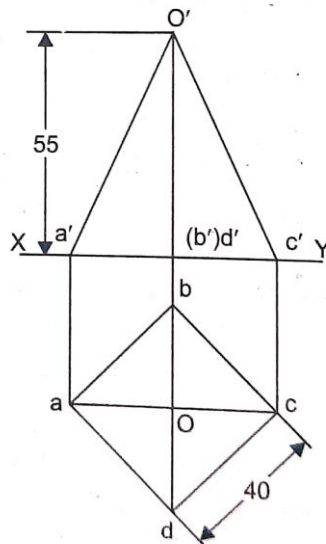


Fig. 3.11

Problem 3: Draw the projections of a vertical cylinder, base diameter 40 mm and axis 60 mm long.

Normally 12 generators are imagined on the surface of the cylinder and the projections of these generators are shown in the views (Fig. 3.12). Only one end face has been named to avoid confusion but students are advised to name both end faces and avoid selecting "O" for naming one end of a generator because "O" is normally used to indicate center.

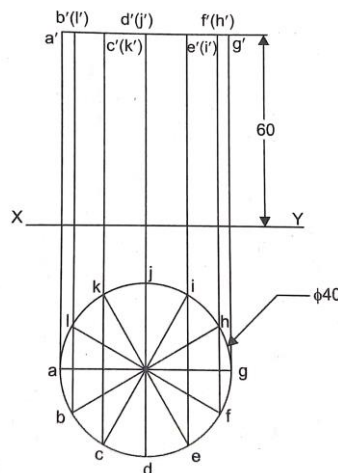


Fig. 3.12

Problem 4: Draw the projections of a right circular cone standing on the HP on its base. Base diameter 40 mm and axis 60 mm long.

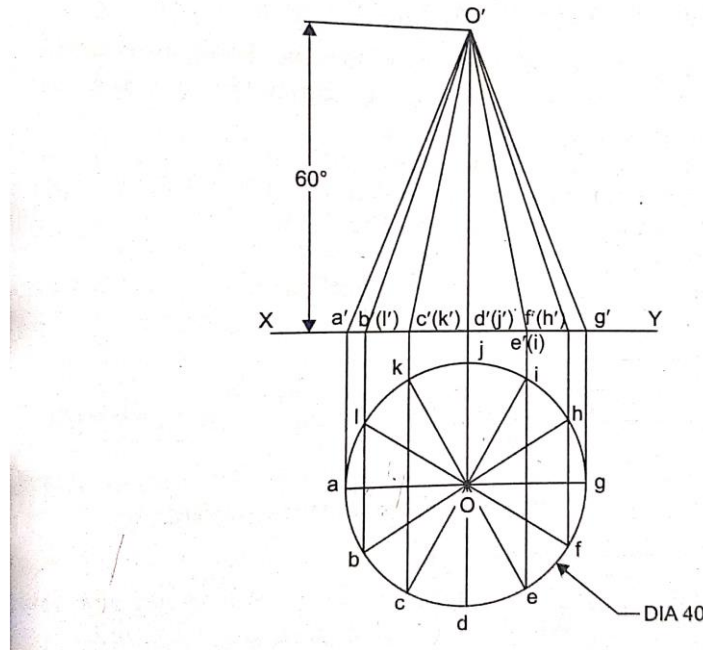


Fig. 3.13

For cone, 12 generators are imagined on the wont surface and the projections are drawn in the views (Fig. 3.13).

3.1.7 Solid Perpendicular to VP

Problem 5: Draw the projections of pentagonal pyramid with the axis at 90° to the VP and one side of the base parallel to the ITP. Base wide 35 mm and axis 50 mm long.

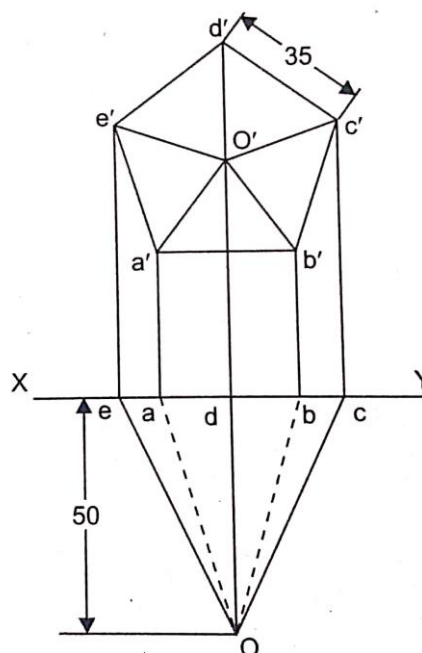


Fig. 3.14

Draw the front view with the base side AB parallel to the XY since axis in perpendicular to the VP and the side AB parallel to the HP as shown. Complete the projections as shown in Figure 3.14.

3.1.8 Solids Parallel to both the Planes

Problem 6: Draw the projections of hexagonal prism, base side 30mm and axis 100mm long, when the axis is parallel to both the planes and one rectangular side surface parallel to the VP.

To start with, draw side view of the prism with one side of the hexagon perpendicular to XY, as rectangular face is parallel to the VP. From the side view, project the front view and the top view as shown in Fig. 3.15.

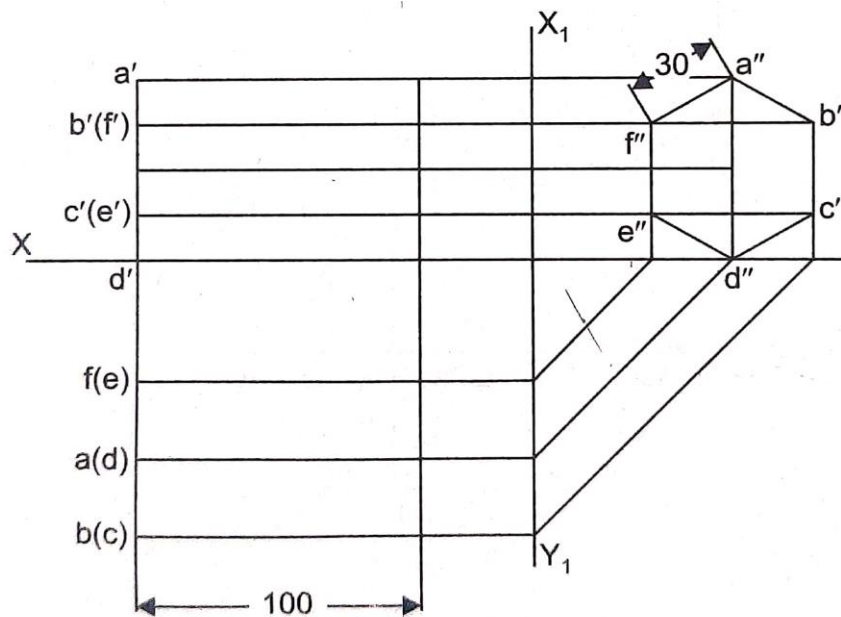


Fig. 3.15

Problem 7: Draw the projections of a tetrahedron of side 45 mm standing on the HP with one side of the base parallel to the VP.

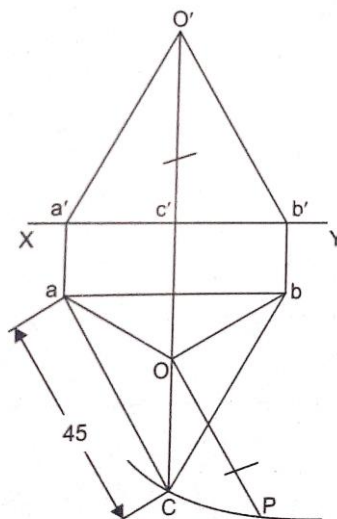


Fig. 3.16

Draw the top view of tetrahedron, an equilateral triangle with a side parallel to XY. Locate the top view of the vertex O at the center of the triangle. Join oa , ob and oc . To obtain the height of the tetrahedron draw a perpendicular line on any one of the top views of the slant edges (here on ob) at O and with the corner b as the center cut an arc of radius equal to the side of the tetrahedron on the perpendicular to obtain point P. Now Op is the height of the tetrahedron. Obtain the front view o' of the apex O by fixing the height of the apex equal to the distance obtained from the top view (op) as shown, Complete the front view $a'o'b'd'$ as shown in Fig. 3.16.

3.1.9 Projection of Solids inclined to One of the Reference Planes and Parallel to the Other

First assume the axis of the solid to be perpendicular to that reference plane to which it has to be inclined. In this position the base of the solid appears with true shape in that reference plane to which it is parallel. Draw the projections in this position.

It may be recalled, if any of base edges is parallel to or on the reference plane that particular edge has to be perpendicular to the other reference plane. On the other hand if any of the base corners/point on the base is away from or on the reference plane, the imaginary line passing through that corner/point on the base and center of the base has to be parallel to the XY line.

3.1.10 Solids inclined to HP and Parallel to VP

Problem 8: A cube of edges 40 mm is hung by a string attached to one of its corners. Draw the top and front views of the cube.

Data: views: square, rectangle

Solution: View rotation method. Refer Fig 3.17

When a solid is freely suspended from a corner, the line joining that corner with the center of gravity becomes vertical. So draw the SSFV satisfying the said condition.

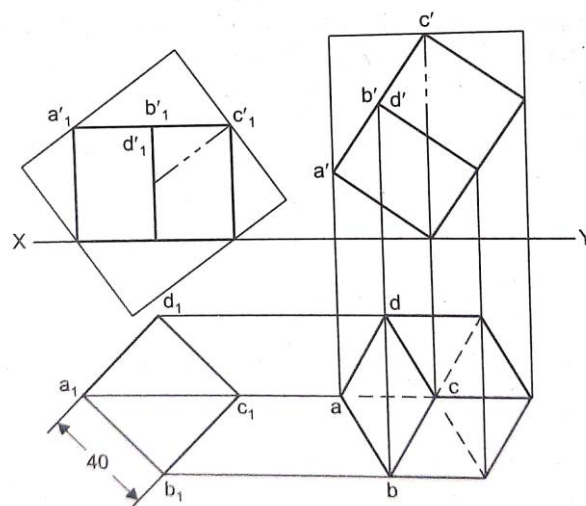


Fig. 3.17

3.1.11 Solids inclined to VP and Parallel to HP

Problem 9: A tetrahedron of 50 mm long edges has one edge parallel to the HP and inclined at 45° to the VP. Draw its projections if a triangular face containing that edge is vertical.

Data: views: triangles, $a'c$ parallel to XY , $\phi_{ABC} = 45^\circ$

Objs: FV, TV

Solution. Refer Fig. 3.18. First assume one of vertical faces of tetrahedron is parallel to VP with one side parallel to HP (axis perpendicular to VP).

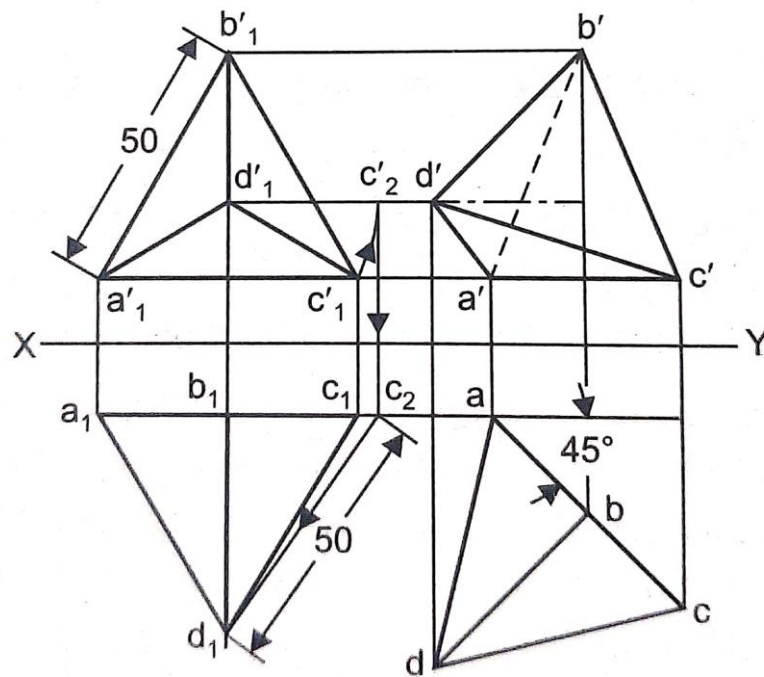


Fig. 3.18

3.1.12 Projection of Solids inclined to both the Reference Planes

Solid, with an Edge of Base parallel to or on HP, i.e. Axis, Base, Base Edge/ Diagonal, Longitudinal/Slant Edge, Generator or Specific Line/Plane of it) making θ° with HP and with VP; as the case may be

First assume the axis of the solid is perpendicular to HP with one of the base edges perpendicular to VP. In this position FSTV shows the true shape of the base and FSFV of the base will be parallel to or on XY. Now tilt the solid about the edge under consideration such that it i.e., axis, base, base edge/diagonal, longitudinal/slant edge, generator and/or specific line/plane of it makes an angle θ with HP, i.e., redraw the FV satisfying the given condition and project the corresponding TV.

Lastly reorient the solid such that it (i.e., tis, base, base edge/diagonal longitudinal/slant edge, generator or specific line/plane of it) makes an angle of ϕ with VP without disturbing former condition, i.e., redraw the TV satisfying the given condition and project the corresponding FV. If any

particular element makes θ° with HP and ϕ° with VP, its top view will make an apparent angle β ($>\phi^\circ$) with XY. In such a case reorient TV through β° .

3.1.13 Examples

Problem 1: A tetrahedron of 75 mm edge has one edge on the HP and inclined at 35° to the VP, while the face containing that edge is vertical. Draw its projections.

Data: views: triangles, $b'c'$ on XY, $\phi_{BC} = 35^\circ$

Objs: FV, TV

Solution. View rotation method. Refer Fig. 3.19

Stage 1

Assume the tetrahedron is resting on HP on one of its faces with an edge perpendicular to VP.

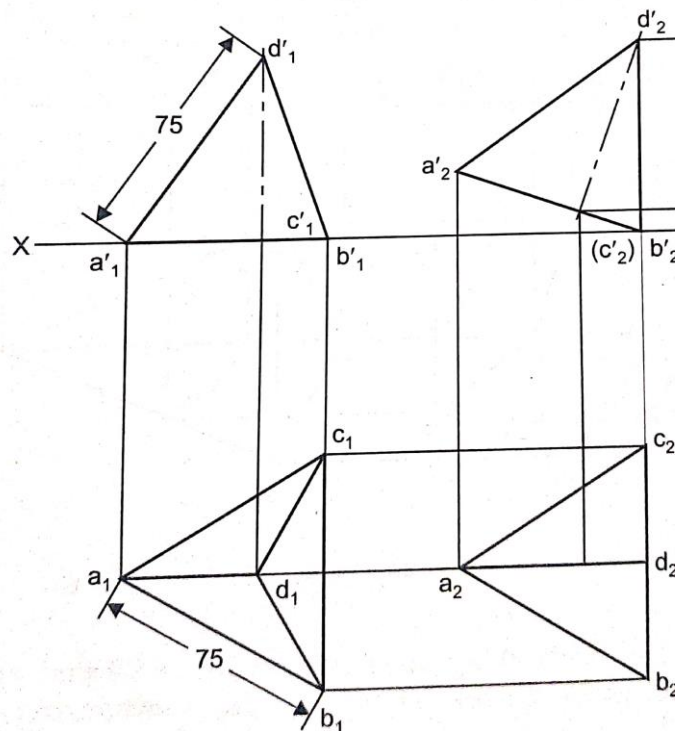


Fig. 3.19

1. Draw an equilateral triangle with one side perpendicular to XY to represent the FSTV. Locate center d_1 and join a_1d_1 , b_1d_1 , c_1d_1 to represent the slant edges.
2. Project the corresponding front view. In the FSTV $b_1'(c_1')$ d_1' represents the triangular face BCD.

Stage 2

Since the triangular face containing the base edge on HP has to be vertical, tilt the solid about the side BC to make the plane BCD vertical.

3. Redraw the front view such that $b_2' (c_2')d_2'$ is perpendicular to XY.
4. Project the corresponding top view.

Problem 2: A pentagonal pyramid, side of base 28 mm and height 70 mm is resting on HP. Its base is inclined at 40° to HP. Draw its projections.

Data: views: pentagon, triangle; $c'd'$ on XY, $\theta_{\text{base}} = 40^\circ$, $\beta_{\text{axis}} = 30^\circ$

Solution. Refer Fig. 3.20.

Since the base is inclined to HP the axis appears with apparent length in the top view.

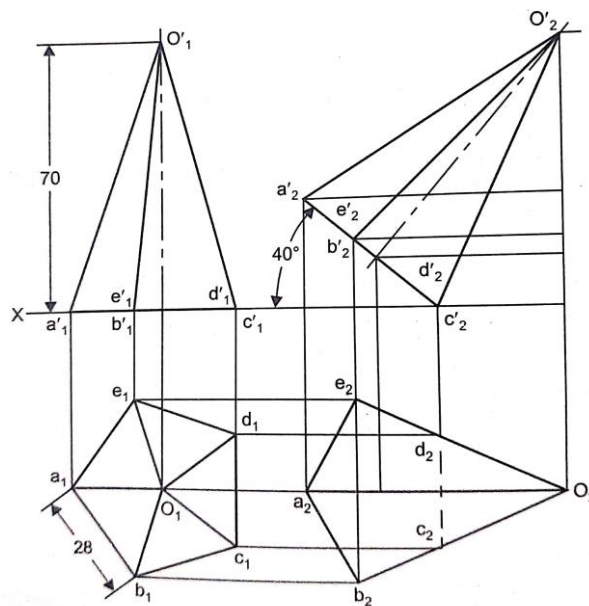


Fig. 3.20

Problem 3: One of the body diagonals of a cube of 60 mm edge is parallel to the HP and inclined at 60° to the VP. Draw the projections of the cube.

Data: views: quadrilaterals, $e'c'$ parallel to XY.

Solution. View rotation method. Refer Fig. 3.21.

Since the body diagonal is parallel to HP, redraw the front view in the second stage such that the body diagonal under consideration is parallel to XY.

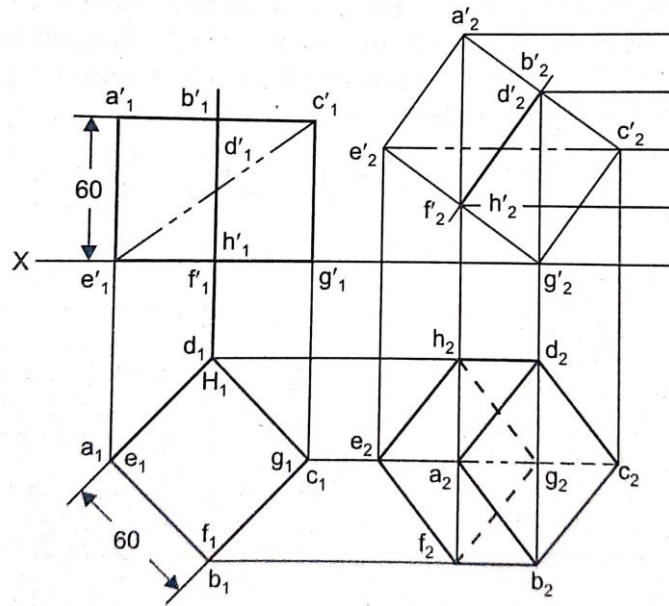


Fig. 3.21

Problem 4: A pentagonal pyramid edge of base 30 mm and height 60 mm is resting on a corner of its base in such a way that the slant edge containing the corner makes an angle of 60° , with HP. Obtain the projections.

Data: views pentagon, triangle; c' on XY, $\theta_{co} = 60^\circ$

Solution. Refer Fig. 3.22.

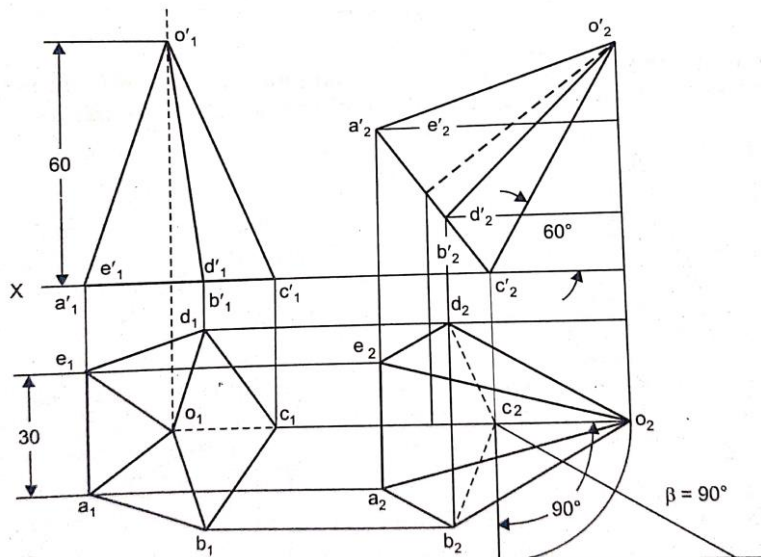


Fig. 3.22

Since the slant edge passing through the corner is inclined to both HP and VP, determine apparent angle and redraw the top view in the third stage such that the slant edge makes angle β° with XY. It may be recalled that when $\theta + \phi = 90^\circ$ apparent angle will be equal to 90° . So, simply redraw the top view after rotating it through 90° .

Problem 5: A hexagonal pyramid, base 25 mm side and axis 50 mm long has one of its slant edges on HP. A plane containing that edge and the axis is perpendicular to the HP and inclined at 45° to VP. Draw its projections when the apex is nearer to VP than the base.

Data: views: hexagon, triangle; $o'd'$ on XY, $\phi_{\text{plane}} = 45^\circ$

Solution. Refer Fig. 3.23

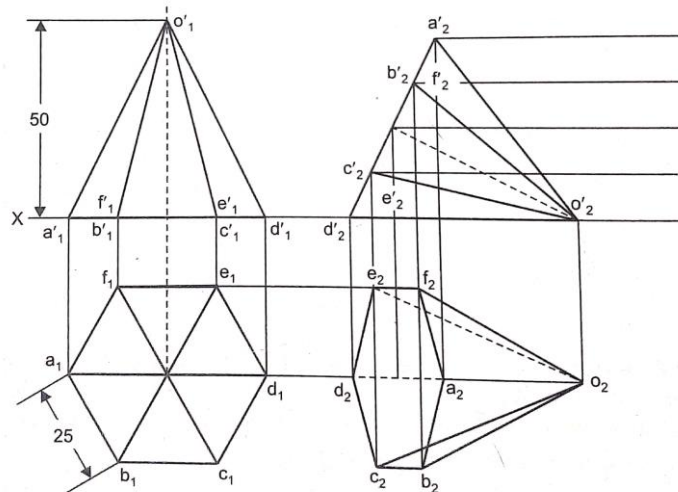


Fig. 3.23

Problem 6: A cone of diameter of base 40 mm and altitude 60 mm is lying on one of its generators with the axis parallel to the VP. Draw the projections.

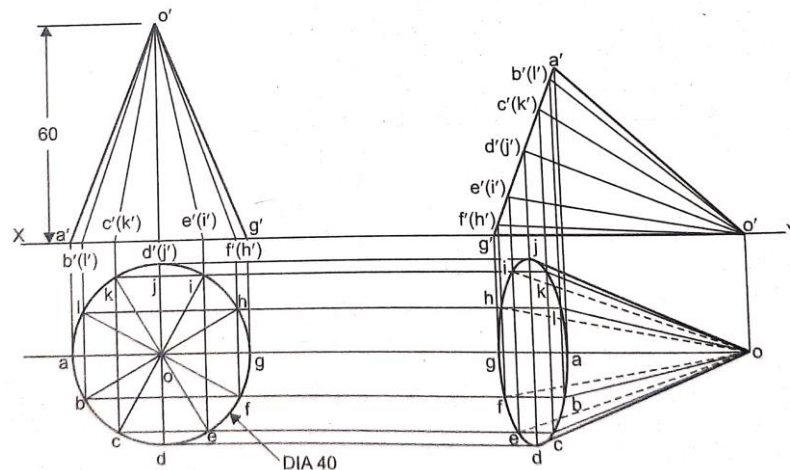


Fig. 3.24

Simple position: Assume a vertical cone standing on its base and draw the projectors.

First rotation: As the cone lies on one of its generators redraw the front view so that front view of one generator lies on XY and complete the new top view as shown in Fig. 3.24.

Problem 7: A hexagonal prism, side of base 25 mm and axis 50 mm with one of its base corners on the HP such that the base makes

an angle of 60° to the HP and its axis is parallel to the VP. Draw its projections.

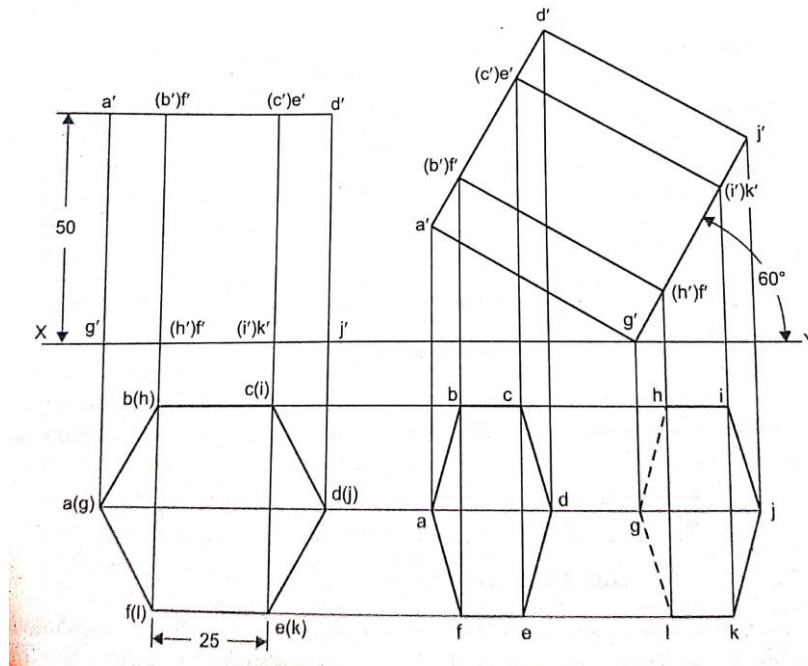


Fig. 3.25

Simple position

In the simple position a vertical hexagonal prism with a base corner at an extreme position and the sides containing that corner equally inclined to XY is assumed to satisfy the condition that the prism should stand on a base corner on HP.

3.2 SECTION OF SOLIDS

3.2.1 Introduction-Need for Sectioning

When the interior of an object is complicated or when the component parts of a machine are drawn assembled, an attempt to show hidden portions by the customary dashed lines often results in a confusing network, which is difficult to draw and almost impossible to read clearly. To overcome this difficulty a sectional view is used.

A section may be defined as an imaginary cut made through an object to expose the interior or to reveal the shape of a portion. A view in which all or substantial portion of the object is sectioned is known as a sectional view.

A sectional view or section is also used to show the exact shape of exterior parts that are rounded or curved or change shape so rapidly that the usual two or three-view drawings do not reveal their true shape. It is preferable because it shows clearly and emphasizes the solid portions, the voids and the shape. The fenders on cars, housing for revolving parts, ship propellers and aeroplane wings are of this type.

The view that is to be made in section is represented as though the portion of the object nearest to the observer were actually cut away by the section plane and removed. It should be noted that the other views are not affected in any way and always represent the entire object.

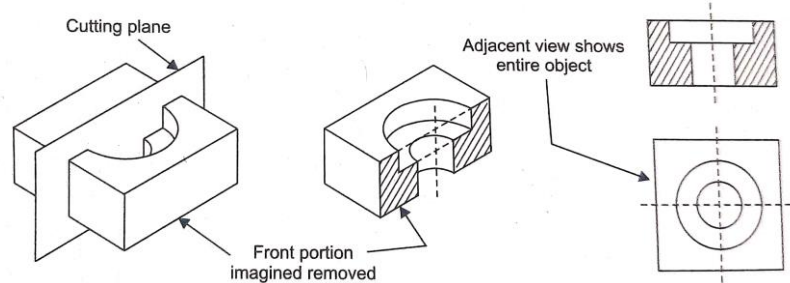


Fig. 3.26 Theory of sectional

Since the location of cutting planes must frequently be shown, a standard type of line is used for this purpose (Refer Fig. 3.27). This distinguishes it from other lines used in the drawing.



Fig. 3.27 Symbol for cutting plane line.

In order that those parts of an object that have been cut by the section plane may stand out on the drawing, a conventional scheme called crosshatching or section lining is employed. This is done by drawing light, inclined lines on those parts of the views of the object where the plane cuts the material of which the object is made.

CHECK YOUR PROGRESS

5. What is section?

The section lines may be drawn at any angle to the horizontal, but 45° lines are usually employed. The direction should be chosen so that the crosshatch lines will not be parallel or perpendicular to any of the boundary lines of the area being shaded (Refer Fig. 3.28)

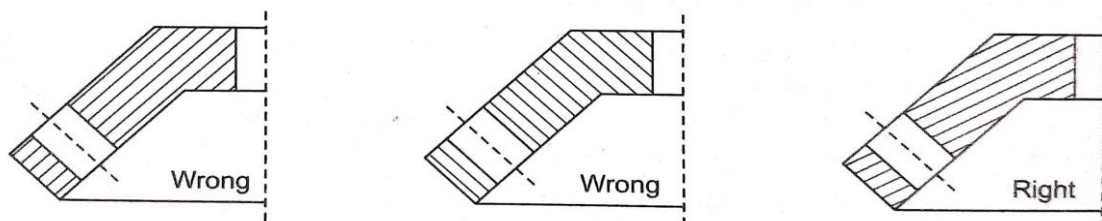


Fig. 3.28. Correct and incorrect section lining.

Section lines should be spaced uniformly (Refer Fig. 3.29).

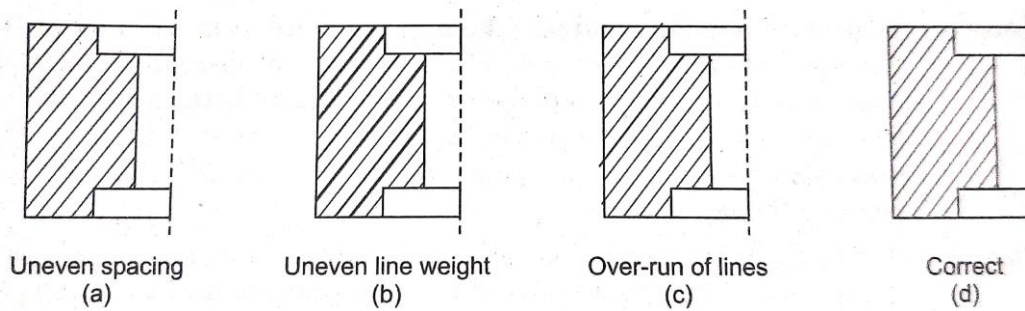


Fig. 3.29. Common errors in section lining.

The weight and thickness of section lines should be the same as those for dimension lines. In all cases they should come completely up to the outlines of the object. Fig. 3.29 shows examples of good and faulty section lining.

It is a standard practice to omit all hidden lines in the sectioned portion of a view. In making a detail of a single part, the invisible lines may be shown on the unsectioned half of the view if they are needed for dimensioning. Visible outlines appearing behind the cutting plane must always be shown in the sectioned view. The true form of the cut surface is called true shape of the section. It is obtained by viewing the object normal to the cut surface and projecting it on a plane parallel to the section plane.

With reference to the principal planes the section planes can be in the following position:

- Perpendicular to VP and parallel to HP
- Perpendicular to HP and parallel to VP
- Perpendicular to VP and inclined to HP
- Perpendicular to HP and inclined to VP
- Perpendicular to both HP and VP.

The following points should be observed in making a drawing with one view in section (Refer Fig. 3.26).

- In making the sectional view, a part of the object is imagined to be removed.
- The adjacent view shows the entire object, unless a part is shown broken away beyond the centerline to save space.

CHECK YOUR PROGRESS

6. What is known as sectional view?

- Invisible lines behind the section are omitted.
- Visible lines behind the section are shown.
- Only the parts cut by the section plane are crosshatched.

Guidelines for solving problems in section of solids

Step 1: Draw the projections of solid for the given position.

Step 2 : Locate the trace of the cutting plane i.e., if the cutting plane is an Auxiliary Vertical Plane locate its HT and if the cutting plane is an Auxiliary Inclined Plane locate its VT.

Step 3 : Locate the points of intersection of this trace with edges for the case of polyhedron (prism, pyramids, etc.) and the points of intersection of this trace with generators for solids of revolutions (cone, cylinder, etc.) in one view.

Step 4 : Project these points and join them in sequence in the other view to get the view of the cut section. Whenever the projection of an edge or generator of a solid lie in plane perpendicular to both the planes, locate the other view of the intersecting point of the trace with that edge or generator by locating that point in end view initially and project the point to the other view.

Step 5: If true shape of the cut section is required, get the auxiliary projections of this cut section on an auxiliary plane parallel to the cutting plane.

3.2.2 Section of Solids

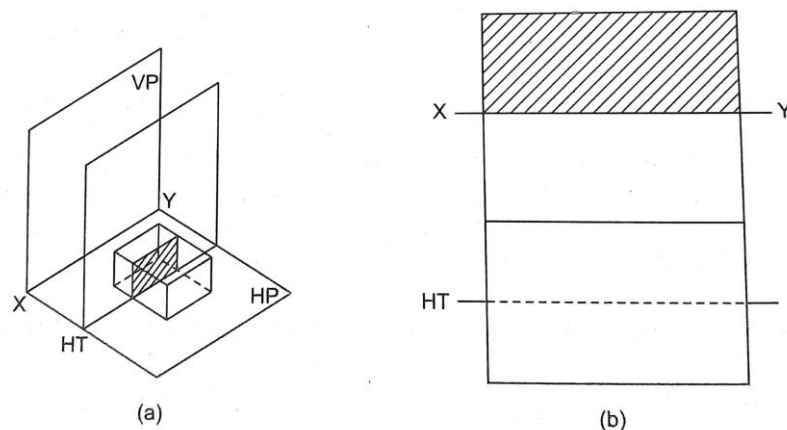


Fig. 3.30

CHECK YOUR PROGRESS

7. How to represent the section planes in a drawing?

3.2.3 Section Plane Parallel to the VP

A rectangular block standing on the HP is cut by a section plane parallel to the VP. The projections are shown in Fig. 3.30 (a) and Fig. 3.30 (b).

3.2.4 Section Plane Parallel to the HP

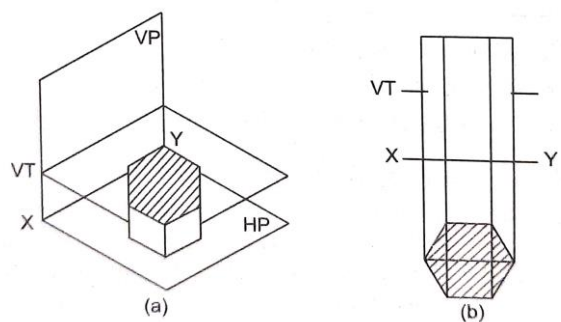


Fig. 3.31

A hexagonal prism standing on the HP is cut by a section plane parallel to the HP. The projections are shown in Fig. 3.31 (a) and Fig. 3.31 (b).

CHECK YOUR PROGRESS

8. What are section lines?

3.2.5 Section Plane Inclined to the HP and Perpendicular to the VP

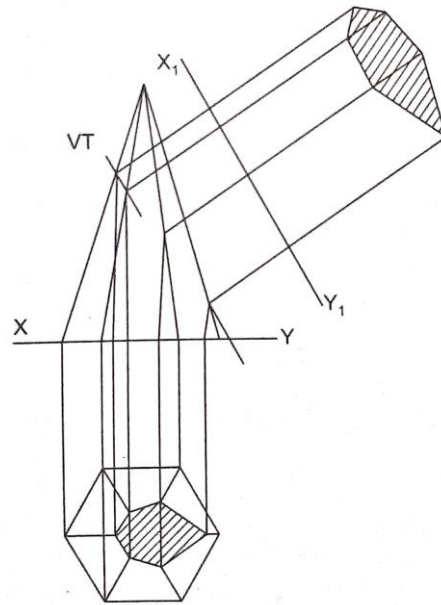


Fig. 3.32

A hexagonal pyramid standing on the HP is cut by an AIP inclined at q to the HP. The projections are shown in Fig. 3.32.

3.2.6 Section Plane Inclined to the Base

A cylinder standing on the HP is cut wholly by an AIP inclined at q to the HP. The projection and true shape of the cut section are shown in Fig. 3.33.

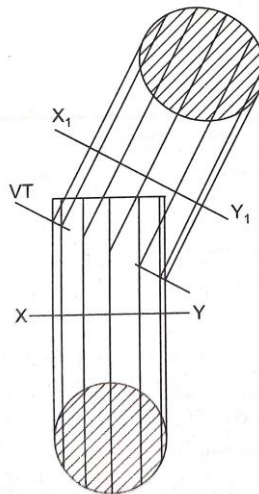


Fig. 3.33

3.2.7 Section Plane Inclined to the Axis

A cone standing on the HP is cut by an AIP inclined at q to the HP. The plane does not cut the base. The projections and true shape are shown in Fig. 3.34.

Note: It is quite interesting to observe that all conic section (circle, ellipse, parabola, hyperbola and rectangular hyperbola) can be obtained by sectioning the cone as explained here under:

1. When a plane cuts the cone parallel to the base the true shape of the cut section is a circle.
2. When a plane cuts the cone parallel to a generator the true shape of the cut section is a parabola. The plane should also cut base at the more than one point.
3. When all the generators of the cone are cut by a plane inclined to the axis the true shape of the cut section is an ellipse.
4. When the slant surface and base (at more than one point) are cut by a plane inclined to the axis (angle of inclination less than the semi cone angle) cut section is hyperbola.
5. When the cone is cut by plane parallel to the axis and not through the apex, the cut section is a rectangular hyperbola.

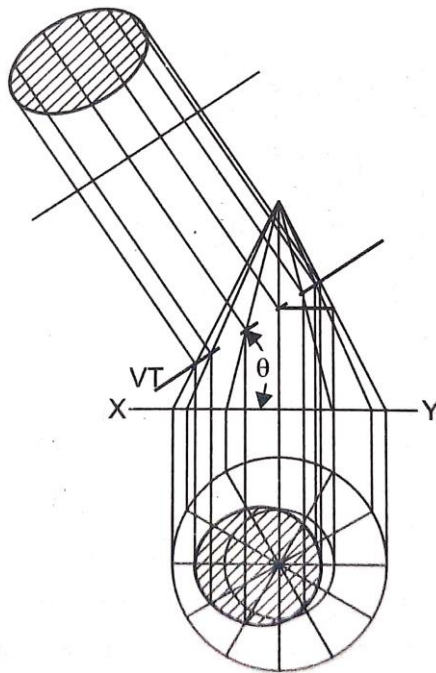


Fig. 3.34

3.3 ILLUSTRATIVE EXAMPLES

Problem 1: A cube of 30 mm long side is standing on the HP and with all side faces equally inclined to the VP. A vertical section plane

parallel to the VP cuts the solid and is located at a distance of 6 mm from the axis. Draw the sectional front view.

Draw the projections of a cube with all side faces equally inclined to the VP. Draw the HT of the vertical plane parallel to the VP and at a distance of 6 mm from the axis. Locate the points at which the HT cuts the edge of the cube in the top view and project these points on the corresponding edges in the front view. Join these points in the front view in sequence to obtain the cut section (Fig. 3.35).

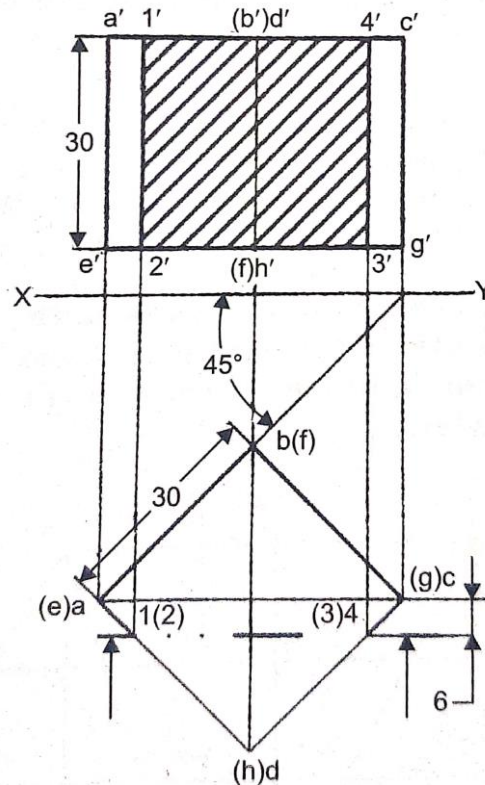


Fig. 3.35

Problem 2: A hexagonal pyramid, base 30 mm side and axis 60 mm long, stands on the HP with an edge of the base perpendicular to the VP. It is cut by a horizontal section plane passing through a point 25 mm above the base. Draw its sectional top view.

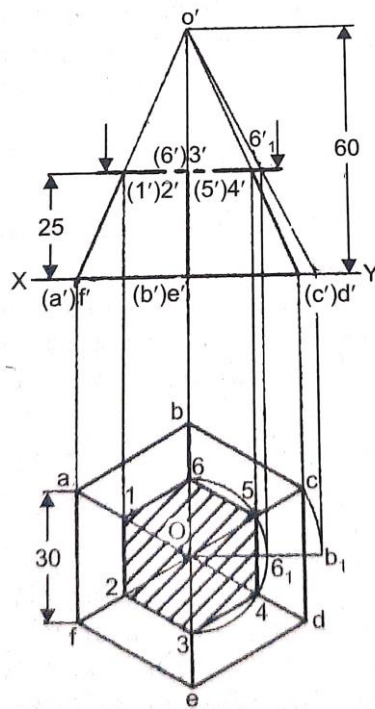


Fig. 3.36

Draw the projections of the pyramid with one side of the base perpendicular to the VP. Draw the trace of the horizontal section plane cutting the axis at a point 25 mm above the base. Locate the points at which this trace cuts edges in the front view and obtain the projection of these points in the top view. Join these points in sequence to draw the cut section.

To locate point 3 and 6 rotate ob and bring it parallel to XY . Draw a vertical line at b_1 to cut XY at b , Join $o'b_1$ and draw a horizontal line through $6'$ to cut the line $o'b_1$ at $6_1'$. Draw the vertical line through $6_1'$ to cut ob_1 at 6_1 . With o as center and $o6_1$, as radius cut an arc on ob to fix the point 6. Similarly fix the point 3 on oe (Fig. 3.36).

Problem 3: A tetrahedron, 50 mm side, stands on the HP with an edge of the base parallel to the VP. A vertical section plane cuts it parallel to the VP and the HT of the section plane is 10 mm in front of the axis of the tetrahedron. Draw its sectional front view.

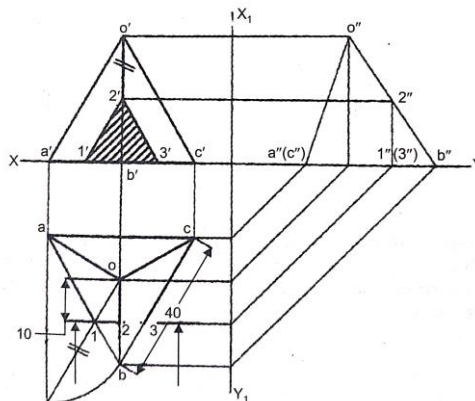


Fig. 3.37

Draw the projections of the tetrahedron with one side of the base parallel to the VP and the base on the HP.

Draw the trace of the vertical section plane parallel to the VP and located at a distance of 10 mm from the top view of the axis. Locate the points at which this trace cuts the edges of the tetrahedron in the top view and project these points on the corresponding edges in the front view.

Here the height at which the section plane cuts the slant edges OB is obtained from the end view as shown in Fig. 3.37. Join these points in sequence to draw the cut section.

Problem 4: A hexagonal pyramid, base 30 mm side and axis 60 mm long, stands on the HP with a side of a base inclined at 40° to the VP. The shortest distance of the HT of the plane, inclined at 30° to the VP, from the top view of the axis is 10 mm. Draw the sectional front view and the true shape of the section.

Draw the projections of the hexagonal pyramid with the base on the HP and one side of the base inclined at 40° to the VP.

Draw the trace of the section plane inclined at 30° to the VP and passing through point 10 mm away from the top view of the axis. To locate the point at a distance of 10 mm draw a circle at o with a radius of 10 mm as shown in the figure.

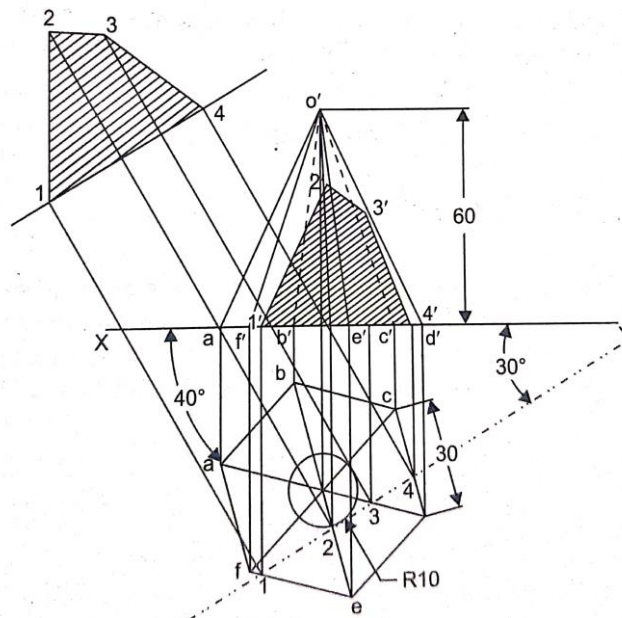


Fig. 3.38

To satisfy the condition that the section plane should be located at a distance of 10 mm from the axis, draw the trace of the cutting plane tangential to this circle. Locate the points at which the trace cuts the edges in the top view and project these points on the corresponding edges in the front view.

Draw the cut section in the front view by joining these points in sequence. Draw the true shape of the cut section by projecting it on a plane parallel to the section plane (Fig. 3.38).

Problem 5: A vertical cylinder of 50 mm diameter and 75 mm height is cut by a section plane perpendicular to the VP and inclined at 45° to the HP bisecting the axis in the front view. Draw the top view of the section on a plane parallel to the section plane.

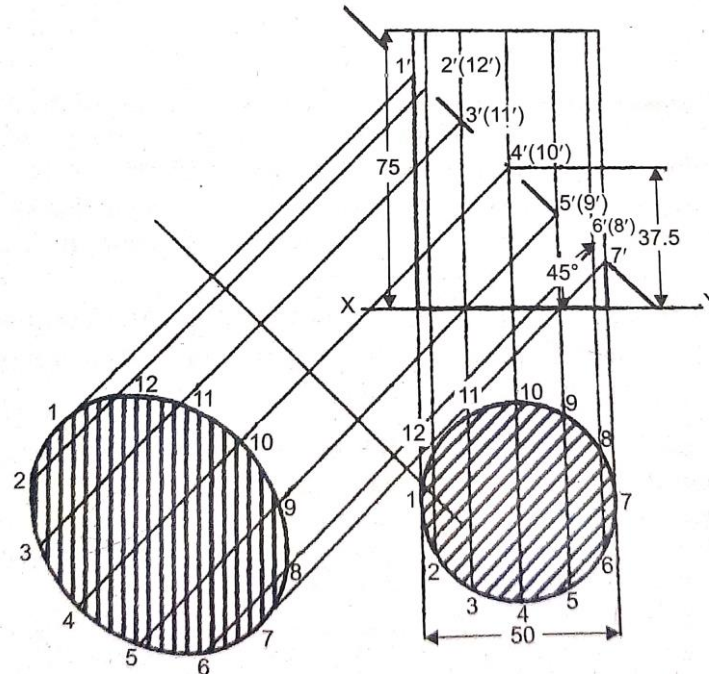


Fig. 3.39

Draw the projections of the vertical cylinder standing on the HP. Draw the trace of the section plane inclined at 45° to the HP and bisecting the axis.

Imagine twelve generators on the curved surface of the cylinder and locate the points at which the trace of the section plane cuts these generators in the front view and join the top views of these points in sequence to obtain the cut section.

Obtain the true shape of the cut section by projecting it on a plane parallel to the section plane (Fig. 3.39).

Problem 6: A cylinder, 40 mm diameter and axis 60 mm long, lies on one of its generators with the axis parallel to both planes. Draw the trace of the cutting plane inclined at 35° to the VP, so that the axis is cut at a point 25 mm from one end. Draw its sectional view and obtain the true shape of the cut section.

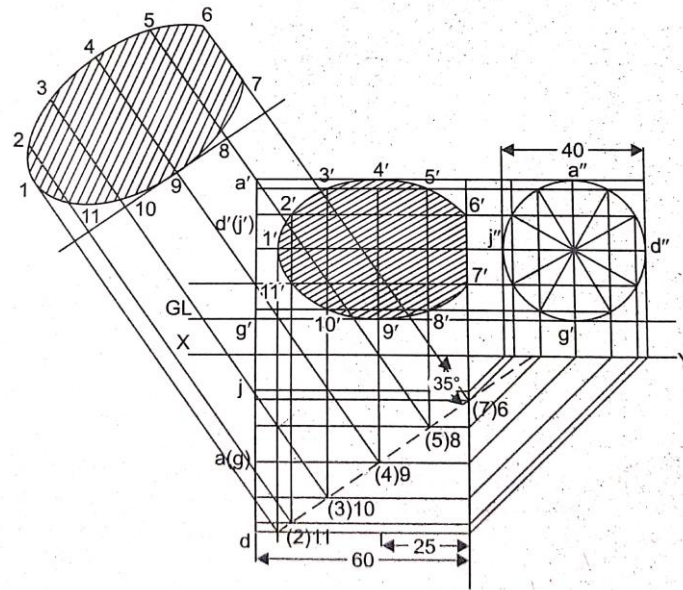


Fig. 3.40

Draw the projections of a horizontal cylinder lying on one of its generators with the axis parallel to both planes. Draw the trace of the cutting plane inclined at 35° to the VP and passing through a point 25 mm from one end face.

Imagine twelve generators on the surface of the cylinder. Locate the points at which the section plane cut these generators in the top view. Obtain 3' and 4' from the end view.

Join the front view of these points in sequence to obtain the cut section.

Draw the true shape of the cut section by projecting the cut section onto a plane parallel to the section plane as shown in Fig. 3.40.

Problem 7: A cone, diameter of base 50 mm and axis 50 mm long, is standing on its base on the HP. A section plane parallel to the base cuts it. The VT of the cutting plane passes through a point 20 mm above the base. Draw the sectional view.

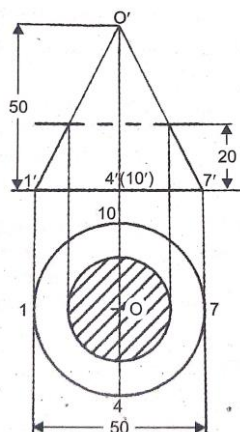


Fig. 3.41

Draw the projections of the vertical cone standing on its base on the HP.

Draw the trace of the cutting plane parallel to the base and located at 20 mm above the base. As the section plane cuts the cone parallel to its base the cut section is a circle smaller than the base circle. Find the diameter of the circle and draw the true shape as shown in Fig. 3.41.

Problem 8: A cone diameter of base 40 mm and axis 50 mm long is resting on its base on the HP. It is cut by a section plane perpendicular to VP and inclined at 80° to the HP. The section plane passes through the apex. Draw the sectional top view and obtain the true shape of the cut section.

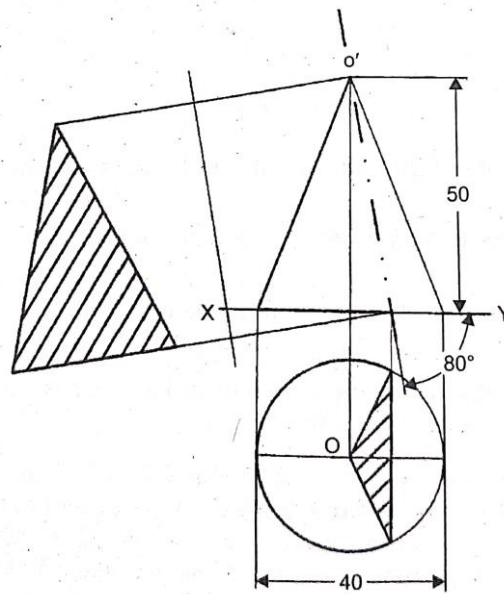


Fig. 3.42

Draw the projections of the cone standing on the HP.

Draw the trace of the cutting plane passing through the front view of the apex and inclined at 80° to the base.

As the trace of the section plane coincides with the front view of a generator obtain the top views of those two generators and join them with the top view of the apex to get the top view of the cut section. The true shape of the cut section is also an isosceles triangle as shown in Fig. 3.42.

Problem 9: A cube of 40 mm long edges is resting on the HP with one edge making an angle of 40° with the VP. It is cut by a section plane perpendicular to the VP, inclined at an angle of 30° to the HP and passing through the mid-point on the axis. Draw its sectional top view, front view and the true shape.

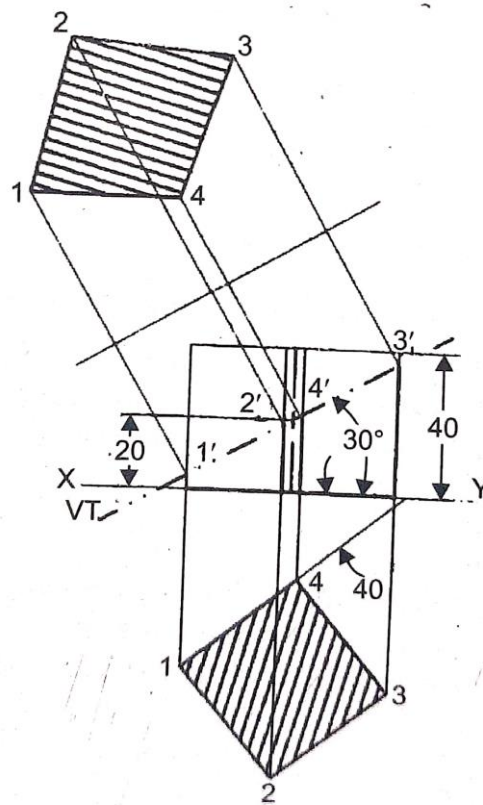


Fig. 3.43

Draw the projections of the cube resting on the HP with one base side inclined at 40° to XY.

Draw the VT of the section plane, inclined at 30° to the HP and passing through the mid-point of the axis.

Locate the points at which the section plane cuts the edges in the front view.

Join the top views of these points in sequence to get the sectional top view.

Obtain the true shape of the cut section by projecting the cut section onto a plane parallel to the section plane as shown in Fig. 3.43.

Problem 10: A cube of 60 mm side has its base edges equally inclined to the VP. A section plane perpendicular to the VP cuts it, so that the true shape of the cut section is a regular hexagon. Locate the plane and determine the angle of inclination of the VT with the reference line XY. Draw the sectional top view.

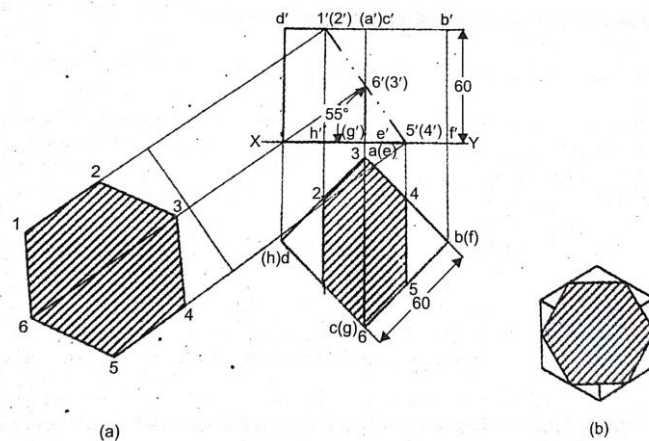


Fig. 3.44

Draw the projections of the cube with all sides equally inclined to the VP.

Only if the section plane cuts the top face, bottom face and two vertical edges, the cut section will be a hexagon (Fig. 3.44 (b)).

If such an inclined section plane cuts the solid, the top view of the cut section is also a hexagon. As the cut section is a regular hexagon, join the midpoints of two adjacent sides in the top face (1 and 2) and midpoints of two opposite adjacent sides in the bottom face (4 and 5) and section 123456 is the top view of the cut section. Here points 3 and 6 are the midpoints on the vertical edges (Fig. 3.44 (a)).

Problem 11: A cutting plane cuts a square pyramid of base side 30 mm and altitude 40 mm long so that the true shape of the cut section is trapezium with the parallel sides measuring 20 mm and 15 mm.

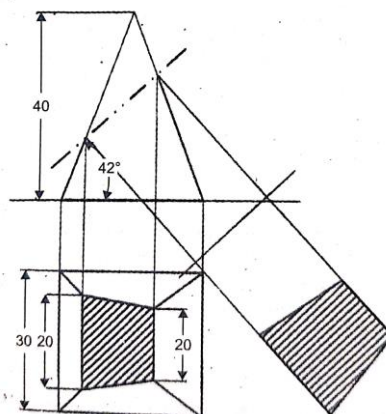


Fig. 3.45

Determine the inclination of the section plane with the HP and draw the sectional top view of the pyramid.

Draw the projections of the square pyramid with one side of the base perpendicular to the VP.

As the true shape of the cut section is to be a trapezium with parallel sides measuring 20 mm and 15 mm and assume these two parallel sides to lie on the opposite slant surfaces of the pyramid.

Draw the top view of the cut section, which is a quadrilateral with 1-2 equal to 20 mm and 3-4 equal to 15 mm. Join the front views of the points (1')2' and 3'(4') on the edges OA, OB, OC and OD respectively by means of a straight line as shown in Figure 3.45.

This line is trace of the section plane and its inclination with XY is the inclination of the section plane with the HP. The true shape of cut section is a trapezium having longer side and shorter side measuring 20 mm and 15 mm respectively as shown in Fig. 3.45.

Problem 12: A cube of 45 mm side rests with a face on HP such that one of the vertical faces is inclined at 30° to the VP. A section plane parallel to the VP cuts the cube at a distance of 15 mm from the vertical edge nearer to the observer. Draw its top and sectioned front view.

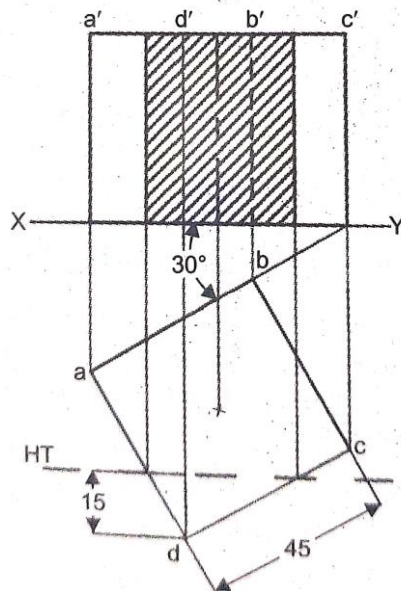


Fig. 3.46

Draw the top view of the cube with a side face inclined at 30° to VP and obtain the front view.

The trace of the section plane passes through a point 15 mm from the vertical edge nearer to the observer as shown in Fig. 3.46.

Locate the cutting points of the trace with the edges in the top view and obtain their front views and join them in sequence and obtain the sectional front view as shown in Fig. 3.46.

CHECK YOUR PROGRESS

9. When the sectional front view shows the true shape of the section?
-

SUMMARY

This chapter explains the idea and construction of solids of different polygons in simple positions and inclined positions. The solid geometry clearly educates the projection of Solids and stresses the idea and concept of different type of projection. The details explained in this chapter about the projection of solids are much useful to draw any object, component which is basically nothing but the combination of some geometrical solids. So to project any intricate objects, buildings, etc., the engineers should know the basis of the projection of geometrical solids of different shapes.

This chapter explains the solids of revolution and their relative positions in different angles with respect to the principle planes. As explained in the chapter orthographic projection of solid is a very important concept to develop engineering skills. Of course this unit serves the very purpose of imagination needed for the construction of some specific objects

Any one can easily visualize the object with one or two dimensions only, if it is a simple solid. But know about the inner detail and to visualize the interior parts of the objects in detail, it is not a simple thing. To acquire that sort of visualizing power or capacity, the engineer should know how to guess the inner details without cutting the solids. To gain such knowledge, the engineer should get a clear cut idea of sectioning, so as to explain how the solid or object may look like.

Thus this chapter clearly indicates the step by step methodology of how to obtain or visualize the inner details, shape and dimensions of the hollow solids. This chapter also explains how to get the true shape of the section. By the concept explained in this chapter, the student can visualize the idea of frustum and truncated solids. This chapter helps the students to get more ideas about the cross-section of buildings or any objects. Thus the idea of the study of section of solids paves an important way to improve and enhance visualizing power.

3.5 KEYWORDS

1. **Solid:** A Solid is a three dimensional object having length, breath, and height. It is bounded by plane surfaces or the combination of plane surfaces and curved surfaces.

- 2. Polyhedra:** A solid which is bounded by plane surfaces is called polyhedra.
- 3. Tetrahedron:** It has four equilateral triangular faces.
- 4. Octahedron:** It is bounded by eight equal equilateral triangular faces.
- 5. Dodecahedron:** It is bounded by twelve equal regular pentagonal faces.
- 6. Solids of Revolutions:** These are solids obtained by rotating a plane figure about a fixed axis.
- 7. Frustum:** When a horizontal cutting plane cuts a cone or pyramid parallel to its base and the top portion is removed, the remaining portion is termed as the frustum of a solid.
- 8. Truncated Solid:** When a cone or pyramid is cut by a plane inclined to its base and the top portion is removed, the remaining portion is termed as the truncated solid.
- 9. Section Planes:** Section plane or cutting plane is a thin and transparent plane.
- 10. Section Lines:** The cut surface of the object is shown by a series of thin, inclined and parallel lines called section lines.
- 11. Hatching:** Process of drawing section lines drawn at 45° to be Horizontal to represent the cut section.
- 12. Apparent Section:** The projection of the sectioned surface on the plane to which the cutting plane is inclined is known as the apparent section.

3.6 ANSWERS TO CHECK YOUR PROGRESS

1. A solid is a three dimensional object having length, breadth, and thickness. It is bounded by plane surfaces or curved surfaces or combination of plane and curved surfaces.
2. It is a many sides solid figure bounded by only plane surfaces. These plane surfaces are called faces.
3. If all the surfaces of the solid have same size and shape, then it called as regular polygon.
4. A polyhedron having a plane figure as its base and a number of triangles meeting at a point as its side faces is known as pyramid.
5. A section may be defined as an imaginary cut made through an object to expose the interior or to reveal the shape of a portion.
6. A view in which all or substantial portion of the object is sectioned is known as a sectional view.
7. Section planes are shown by their traces by using lines made up alternate long and short dashes, thickened at the ends.
8. The cut surface of the object is shown by a series of thin, inclined and parallel lines called section lines. This process is called 'hatching'. The section lines are usually drawn at 45° to the horizontal.
9. If the section plane is parallel to VP, then the sectional front view shows the true shape of the section.

3.7 EXERCISES

1. How much minimum number of views are required to completely describe the object? What are they?
2. Define prism.
3. Define pyramid.
4. Define solids of revolution.
5. Define frustum of a solid.
6. Define truncated solid.
7. Draw the projection of solids in the following cases:
 - (i) A pentagonal prism of side 80 mm and height 60 mm rests with one of its base edges on HP and its axis is inclined at 30° to HP.
 - (ii) A hexagonal prism of side 30 mm and height 60 mm rests with a base edge on HP and its axis is inclined at 45° to HP.
 - (iii) A hexagonal prism of side 30 mm and height 60 mm rests with one of its corners on HP and its axis inclined at 45° to HP.
 - (iv) A pentagonal pyramid of height 60 mm and side 30 mm is resting with one of its triangular faces on HP and its axis is inclined at 45° to HP and parallel to VP.
 - (v) A hexagonal pyramid of side 30 mm and height 60 mm is resting with one of its triangular faces on HP and its axis is parallel to VP.
 - (vi) A triangular pyramid of side 40 mm and height 60 mm is resting with one of its slant edges on HP and its axis is parallel to VP.
 - (vii) A cube of side 30 mm rests with one of its square faces on HP such that one of its vertical faces is inclined at 30° to VP.
 - (viii) A triangular prism of side 30 mm and height 60 mm 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° to HP.
 - (ix) A pentagonal prism of side 30 mm and height 60 mm is resting on a corner such that two base edges passing through that corner make equal inclinations with HP. Its base is inclined at 60° to HP.
 - (x) A hexagonal pyramid of side 30 mm and height 60 mm resting with one of its sides of the base on HP such that the triangular face containing that side is perpendicular to HP.

Sections of Solids

1. What is the purpose of sectioning?
2. What is meant by sectional top view and sectional front view?
3. What is meant by true shape of the section and how to obtain the true shape of the section?
4. What is meant by apparent section?
5. When the side/profile/end view show the true shape of the section?
6. A right circular cone is cut by a plane inclined to its axis and is parallel to a generator. What is the true shape of the section?
7. A right circular cone is cut by a plane which makes a smaller angle with the axis of the cone than do the generators or when the section plane is parallel to the axis. What is the true shape of the section?

8. A right circular cone is cut by a plane perpendicular to the base of the cone and passing through the apex. What is the true shape of the section?
9. A cube of 30 mm side is resting on the HP with a face vertical and inclined to the VP at angle of 60° . A vertical section plane passing through the axis and inclined at 40° to the VP cuts the solid. Draw its projections. Also, obtain the true shape of its section.
10. A pentagonal prism, side of base 50 mm length 90 mm, is lying on one of its rectangular faces on the HP with the axis parallel to the VP. A vertical section plane, the HT of which makes an angle of 35° with XY, cuts the prism bisecting the axis. Draw the sectional front view, top view and the true shape.
11. A cube, side of base 30 mm, rests with its base on HP and one of its vertical faces is inclined at 30° to VP. A section plane perpendicular to VP and inclined at 60° to HP cuts the axis of the cube at a point 15 mm from its top end. Draw sectional top view and the true shape of the section.
12. A cube stands on the HP on one of its faces so that the axis is vertical and vertical faces equally inclined to VP. It is cut by a section plane perpendicular to VP but inclined to HP such that the true shape of the section is a regular hexagon of sides 40 mm. Locate the section by its trace and obtain the sectional top view, project also the true shape from the front view.
13. A pentagonal prism of base edge 30 mm and height 70 mm is placed with one of its rectangular faces on the ground and the axis parallel to VP. It is cut by a section plane perpendicular to VP and inclined at 30° to the ground. It passes through the mid-point of the axis. Develop the remaining surface of the object.
14. A pentagonal pyramid of 30 mm base side and axis 80 mm long rests with its base on the HP with the axis perpendicular to HP. One of the base edges is parallel to VP and the corner opposite to this edge is nearer to VP. A section plane inclined to HP at 30 degrees and perpendicular to VP cuts the solid at distance of 50 mm from the base. Draw the sectional top view, side view showing the cut section and the true shape of section.
15. A vertical cylinder of 50 mm diameter and of height 60 mm resting on the HP is cut by a plane inclined at 45° to HP and perpendicular to VP. Draw the true shape of the section cut by the plane passing through the tangential point on the circular plane surface.
16. A cylinder 50 mm diameter and axis 70 mm long stands vertically on HP. A square hole of 20 mm side is cut centrally in it. Both the square hole and cylinder have the common axis. A section plane inclined at 45° to the HP and perpendicular to VP passes through the mid-point of the common axis. The two rectangular faces of the square hole make equal inclinations with VP. Draw the front view, sectional top view, sectional profile view and true shape of the section.

4

PICTORIAL DRAWING

STRUCTURE

LEARNING OBJECTIVES

- Introduction
- Isometric Axes and Line
- General Guidelines to Draw Isometric Drawings
- Isometric Projection of Plan Figures
- Isometric View of Solids and Combination of Solids
- Summary
- Keywords
- Answers to Check Your Progress
- Exercises

LEARNING OBJECTIVES

After reading this unit you will be able to

- define the isometric projection
- draw the isometric drawings
- explain the general guidelines to draw isometric drawings
- get the concept of pictorial projection of plane figure and solids
- get the drawing of combination solids in pictorial projection
- draw the pictorial drawing of objects

4.1 INTRODUCTION

The best method to study about any object is only through isometric projection. The step by step practice to draw isometric drawing improves the visualizing capacity. In this chapter we are going to learn about the systematic way to get isometric view or projection from the orthographic views (Two dimension view) given.

A thorough study on projection of simple planes and simple solids and combination of solids will help to get pictorial drawing of any object. The fundamental principle so far obtained in the previous chapters will pave the way to draw the pictorial view.

4.2 ISOMETRIC AXES AND LINE

An isometric projection shows the three principal faces of an object in equal proportion as illustrated for the cube in Fig. 4.1.

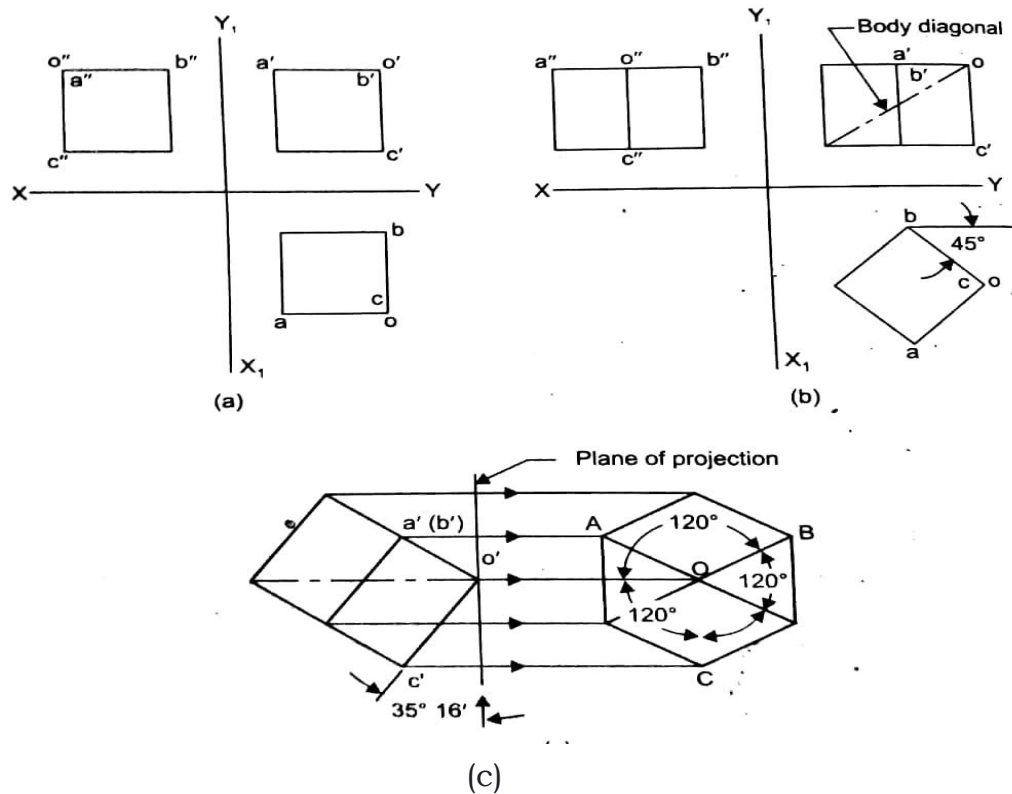


Fig. 4.1. Isometric protection by turning a cube.

The cube is in its normal position for orthographic projection in Fig. 4.1(a). In Fig. 4.1(b) it has been rotated about the vertical edge OC until the sides make 45° with the vertical plane. In Fig. 4.1(c) the cube has been tilted up until the body diagonal is perpendicular to the plane of projection, which is sometimes referred to as the *picture plane*. This places the three front edges of the cube at an angle of 35°16' with the picture plane. Thus in the isometric all edges project in equal length but not in the true length. Hence measurements can be made along these edges or axes with the same scale.

The three edges of the cube OA , OB and OC are foreshortened equally and are at equal inclinations of 120° to each other and are called *isometric axes* (Refer Fig. 4.1(c)). The lines drawn parallel to the isometric axes are called *isometric lines*. Any other line, which is not parallel to any of the isometric axes, is called *non-isometric line*. The lines AB , BC and CA are the non-isometric lines (Refer Fig. 4.1(c)). Since the non-isometric lines are not parallel to the isometric axes, they are not foreshortened in the same proportion as the isometric lines. To draw non-isometric lines first of all their ends should be located in an isometric frame and then joined. The surface ABC is an oblique surface in isometric.

It may be observed that, in isometric, vertical lines of the solid appear vertical while horizontal lines appear inclined at 30° to the horizontal. In an isometric projection the lines are foreshortened in a mathematical proportion, which can be obtained graphically (Refer Fig. 4.2). As the edges of the cube are equally foreshortened, the square faces are seen as rhombuses. The rhombus ABCD shows the isometric projection of the top square face of the cube in which BD is the true length of the diagonal.

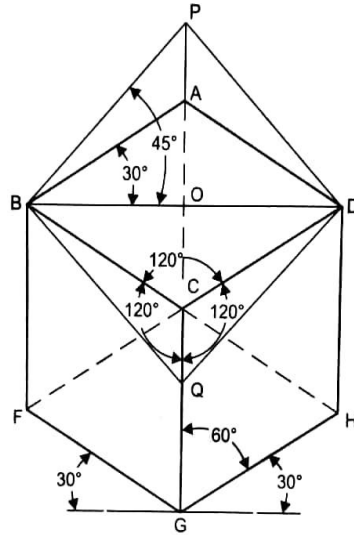


Fig. 4.2

Construct a square BQDP with BD as a diagonal. Line BP shows the true length of BA.

$$\text{In triangle BOA,} \quad \frac{BA}{BO} = \frac{1}{\cos 30^\circ} = \frac{2}{\sqrt{3}}$$

$$\text{In triangle BOP,} \quad \frac{BP}{BO} = \frac{1}{\cos 45^\circ} = \frac{\sqrt{2}}{1}$$

$$\text{Now,} \quad \frac{BA}{BP} = \frac{\text{isometric length}}{\text{true length}} = \frac{\frac{\sqrt{2}}{\sqrt{2}}}{\frac{2}{\sqrt{2}}} = \frac{1}{1.23} = 0.816$$

Thus, the isometric projection is reduced in the ratio $\frac{\sqrt{2}}{\sqrt{2}}$ i.e., the length are 0.816 of the true lengths.

Therefore, while drawing an isometric projection it is necessary to convert true lengths into isometric lengths for measuring and marking the sizes. Constructing an isometric scale as shown in Fig. 4.3 conveniently does this.

Draw a horizontal line BD of any length. At the end B, draw lines BA and BP, such that $\angle DBA = 30^\circ$ and $\angle DBP = 45^\circ$. Mark divisions of true length on the line BP and from each division, draw verticals to BD, meeting BA at respective points. The divisions thus obtained on BA give lengths on

isometric scale in almost all practical uses of the isometric system, the foreshortening of the lines is disregarded and their full length are laid off on the axes. This gives a figure of exactly the same shape but larger in proportion of 1.23 to 1, linear or in optical effect of 1.233 to 1.003.

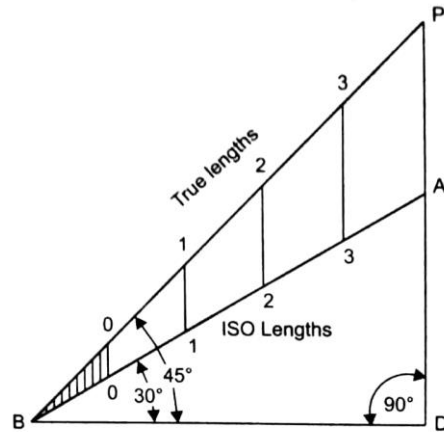


Fig. 4.3

Thus the isometric prepared ignoring the foreshortening effect is known as isometric *view/drawing*. Except when drawn beside the same piece in isometric projection, the effect of increased size is usually of no consequence (Refer Fig. 4.4). Isometric view/drawing is used almost exclusively rather than isometric projection in view of the advantage of measuring the lines directly.

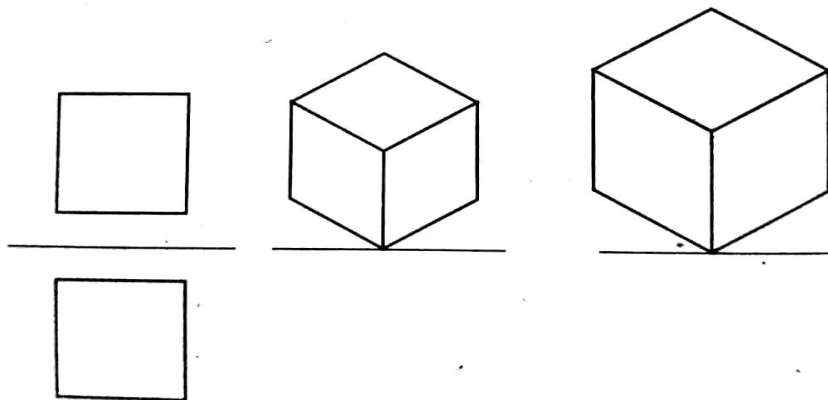


Fig. 4.4. Isometric Projection and isometric view.

As compared with multi view projections, isometric has the advantage of showing three dimensions of the object in one view, thus giving a more realistic picture of it. Compared with other forms of pictorial drawing, isometric has the advantage of being easily constructed since the same scale is used on all the sides. It can be scaled and dimensioned. It is flexible in the position in which an object may be shown but not as flexible as other types, particularly as in oblique projection. Circles can be readily approximated by the four-center method and are not distorted as in oblique projection.

CHECK YOUR PROGRESS

1. What is pictorial drawing?

Against these advantages may be placed definite disadvantages that limit its usefulness in certain situations. Long objects with parallel sides show a disagreeable distortion since the eye is accustomed to the *perspective effect* of long parallel lines that appear to approach each other. There is also an exactness of symmetry causing an overlaying of lines in some symmetrical objects, which makes the isometric difficult to read.

CHECK YOUR PROGRESS

2. What is isometric view or isometric projection?

4.3 GENERAL GUIDELINES TO DRAW ISOMETRIC DRAWINGS

General points to draw isometric views or projections.

1. Select the face of the object, in such a way that the maximum details of the object are visible.
2. Hidden lines or dotted lines need not be shown in isometric projection.
3. No dimensions are represented in Isometric.
4. Circles are represented as ellipses in Isometric.
5. The given orthographic views need not be repeated.
6. All the vertical edges of the object remain vertical in isometric.
7. All the construction lines must be thin and all visible edges must be thick.
8. In isometric projection all the dimensions must be reduced to Isometric lengths.

Isometric views of plane surfaces:

1. Draw a horizontal line. Locate Y.
2. Through Y, draw an isometric axis XY at an angle of 30° on the right side of Y.
3. Similarly, draw an isometric axis YZ at an angle of 30° on the left side of Y.
4. Draw a perpendicular line at Y.

To represent isometric view of a rectangle: (To Fig. 4.5a)

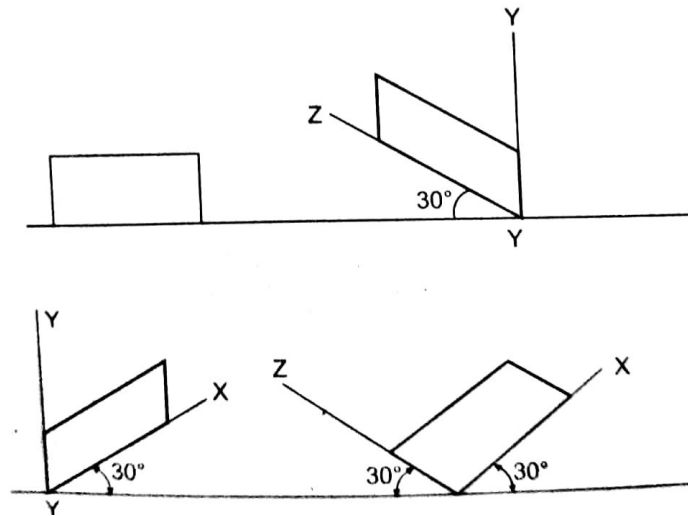


Fig. 4.5 (a)

Repeat the same procedure

Vertical position:

1. By considering XY Plane.
2. By considering XY plan.

To represent isometric view of a triangle: (To Fig. 4.5b)

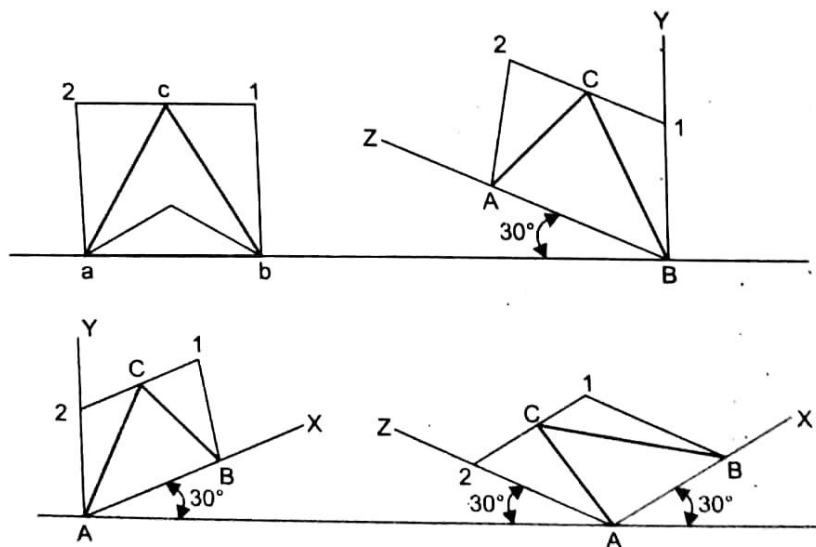


Fig. 4.5 (b)

Enclose triangle abc in a rectangle ab 12.

Draw the isometric view of rectangle ab 12. In

1. Vertical position and
2. Horizontal position

Measures 1 to c distance and mark the same distance in the isometric view. Point c is between 1 and 2.

To represent pentagon: (To Fig. 4.5c)

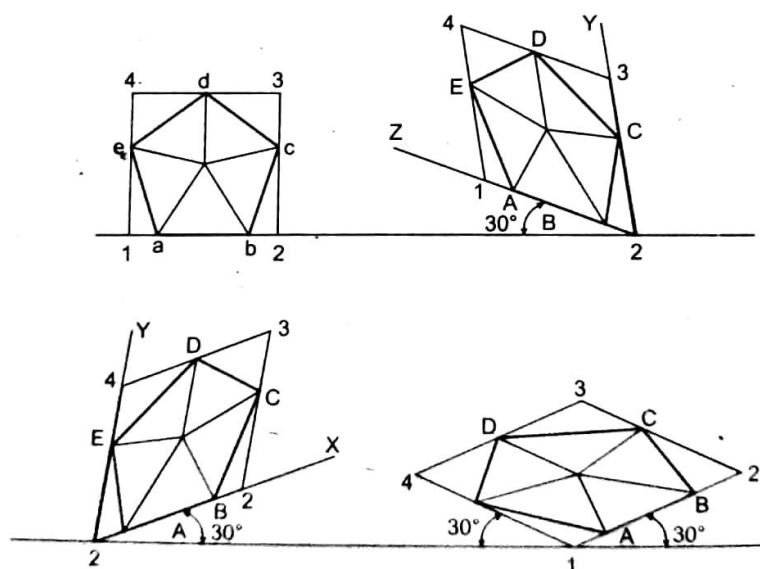


Fig. 4.5 (c)

Enclose pentagon $a b c d e$ in a rectangle 1234.

Draw the isometric view of rectangular surface in vertical and horizontal positions.

Measure 1 to a distance and locate the same distance from 1 in the isometric view.

Measure 2 to b distance and locate the same distance from 2 in the isometric view.

Locate remaining points C, D and E.

Join ABCDE which is the required pentagonal surface in isometric view.

4.4 ISOMETRIC PROJECTION OF PLAN FIGURES

4.4.1 Planes Composed of Isometric Lines

In the isometric projection, vertical lines are drawn vertical and the horizontal lines are drawn inclined at 30° to the baseline. As the sides of the square are parallel to the isometric axes they are foreshortened to approximately to 82% in the isometric projections. Therefore, construct isometric scale for determining these iso-dimensions.

Problem 1: Draw the isometric view of the square shown in Fig. 4.6(a).

Solution. Refer Fig. 4.6.

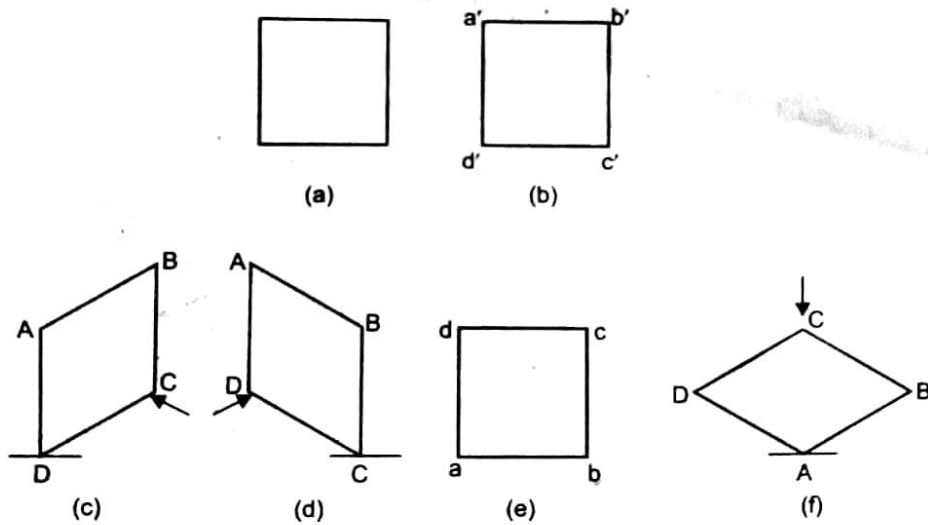


Fig. 4.6

1. If the square is vertical, draw the side DC inclined at 30° to the base line as shown in Fig. 4.6(c). Draw the verticals at D and C and mark off A and B on these verticals. Join AB, which is parallel to DC. Now ABCD is the required projection. This may also be drawn as shown in Fig. 4.6(d). Arrows in Figs. 4.6 (c) and (d) show the directions of viewing.
2. If the square is horizontal, draw the sides AD and DC inclined at 30° to the baseline and complete the isometric projection ABCD as shown in Fig. 4.6 (f). Here the arrow indicates the direction of viewing.

CHECK YOUR PROGRESS

3. What are isometric axes?

4. Define isometric lines.

Problem 2: Draw the isometric of a circular lamina of diameter 30 mm.

Solution. Coordinate method. Refer Fig. 4.7.

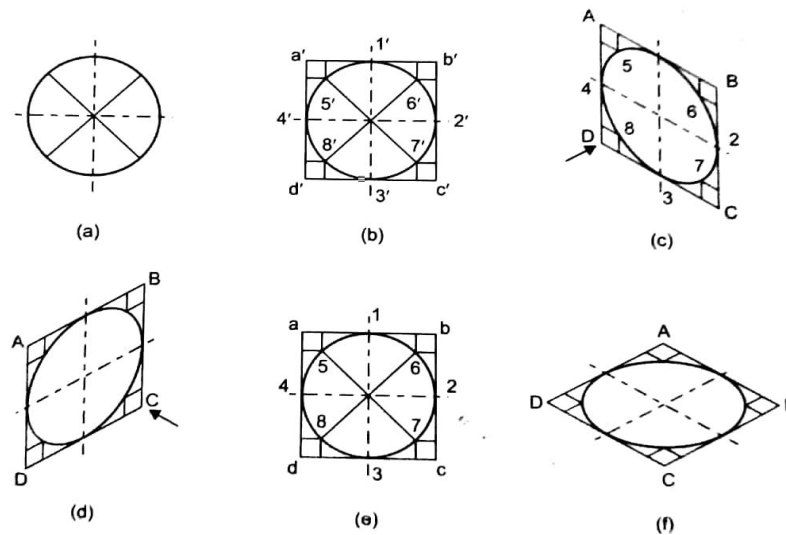


Fig. 4.7

1. Divide the circle into 8 equal parts with a drafter.
2. Enclose the circle in a square as shown in Fig. 4.7(b) and draw horizontal and vertical lines through the division points on the circle to determine the coordinates of each point.
3. Draw the isometric square as shown in Fig. 4.7(c). Draw the horizontal coordinates by transferring distances from the circle in Fig. 4.7(b) to the parallelogram as shown.
4. Draw the vertical coordinates by transferring distances from the circle in Fig. 4.7(b) to the parallelogram as shown.
5. The intersection of the coordinates locate points 5, 6, 7 etc on the ellipse.
6. Draw a smooth curve through these points.
7. Fig. 4.7(f) shows the isometric of circular lamina considering the given view as the top view.

4.5 ISOMETRIC VIEWS OF SOLIDS AND COMBINATION OF SOLIDS

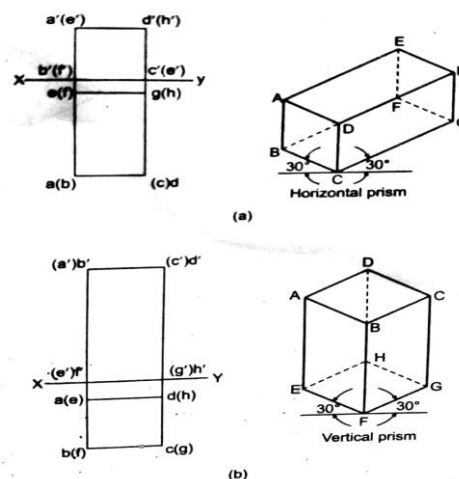


Fig. 4.8

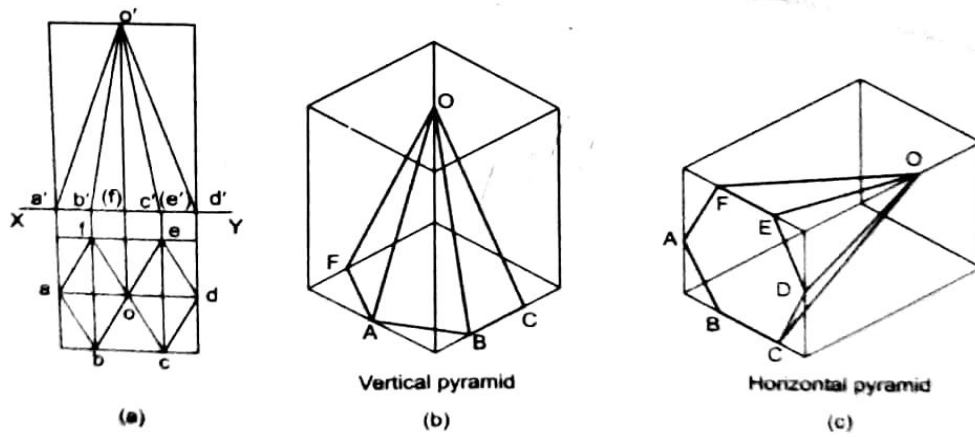


Fig. 4.9

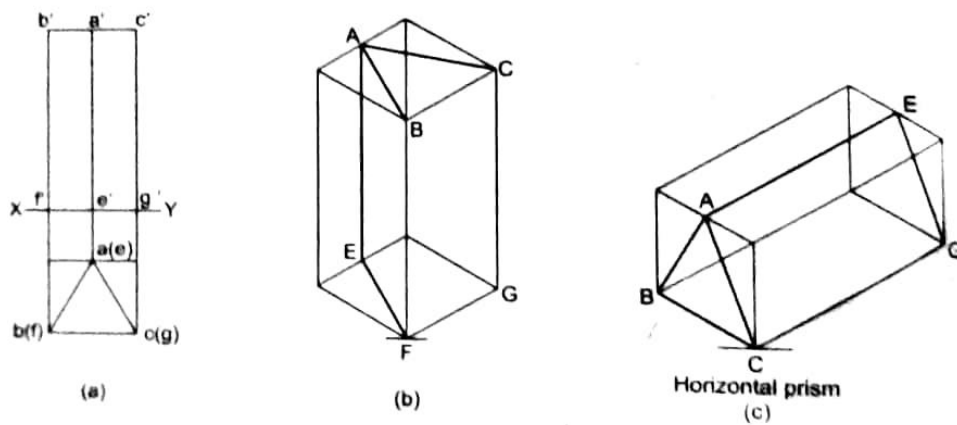


Fig. 4.10

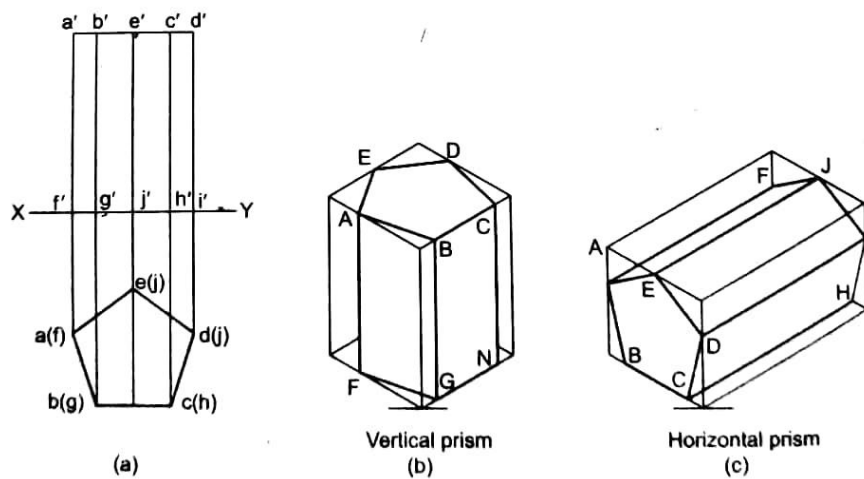


Fig. 4.11

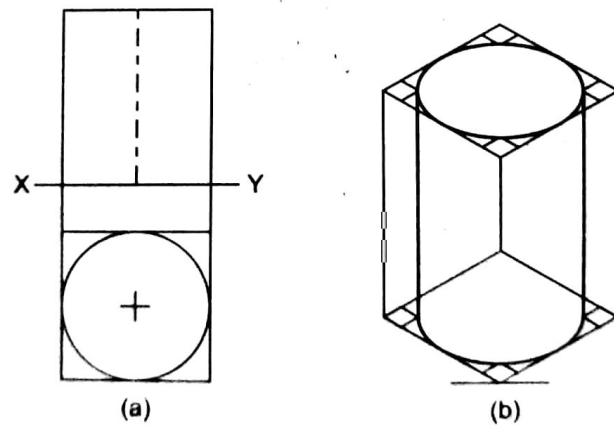


Fig. 4.12

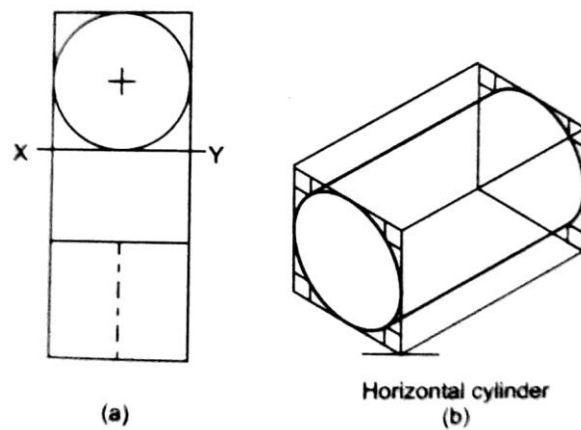


Fig 4.13

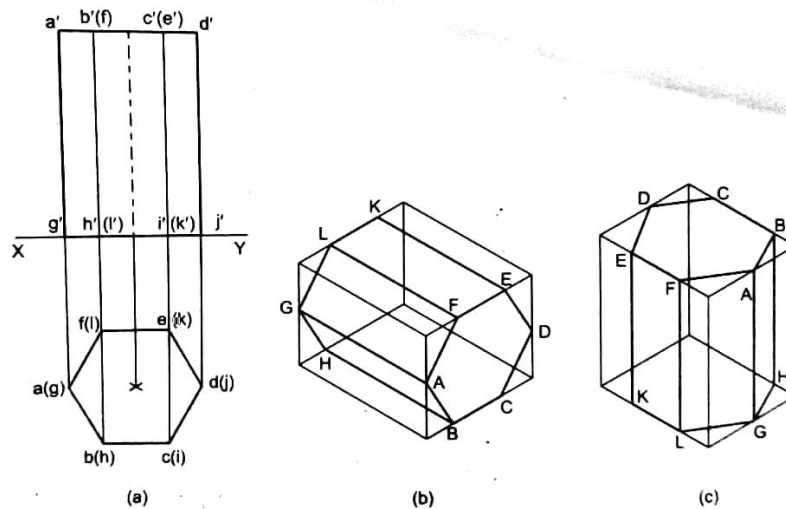


Fig. 4.14

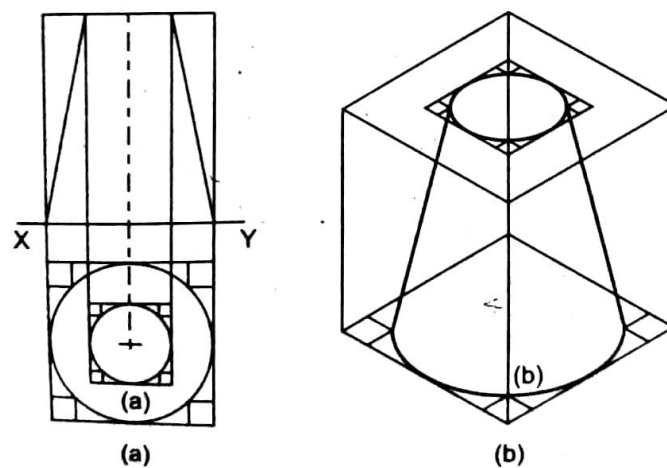


Fig. 4.15

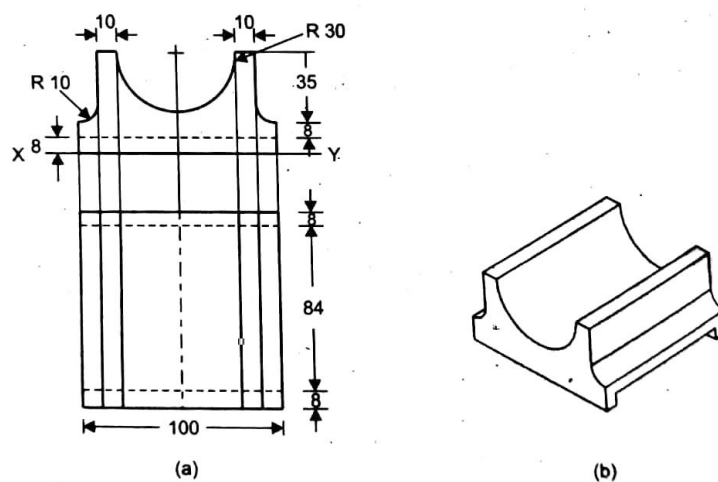


Fig. 4.16

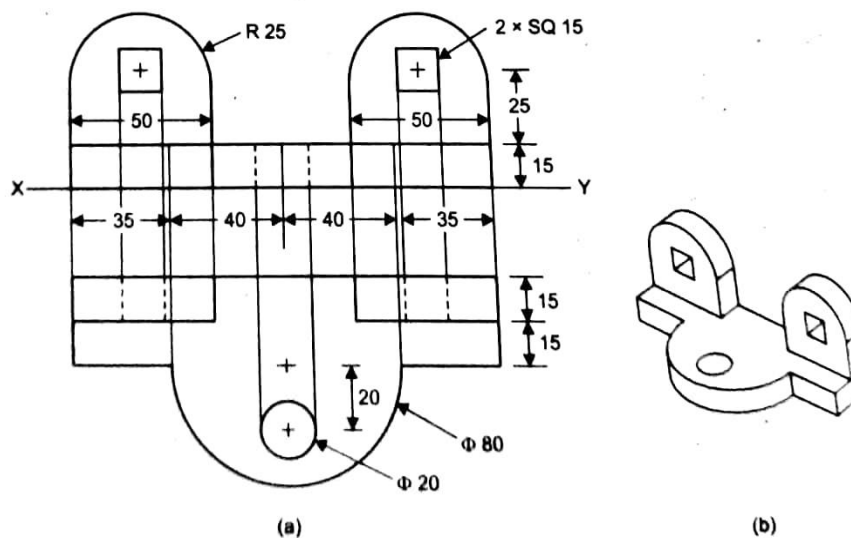


Fig. 4.17

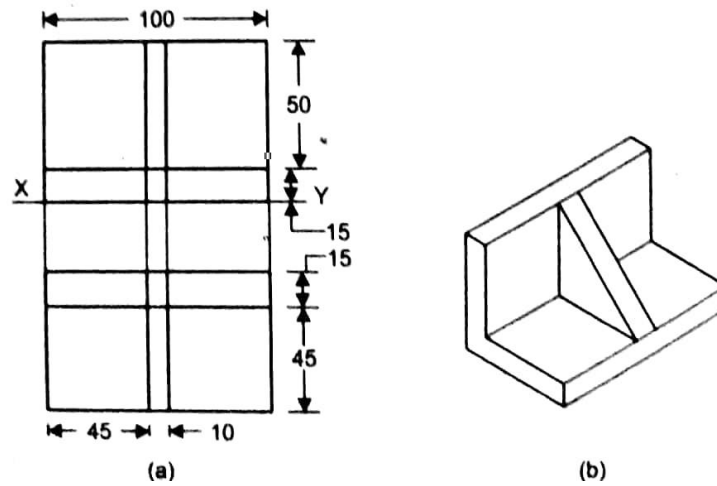


Fig. 4.18

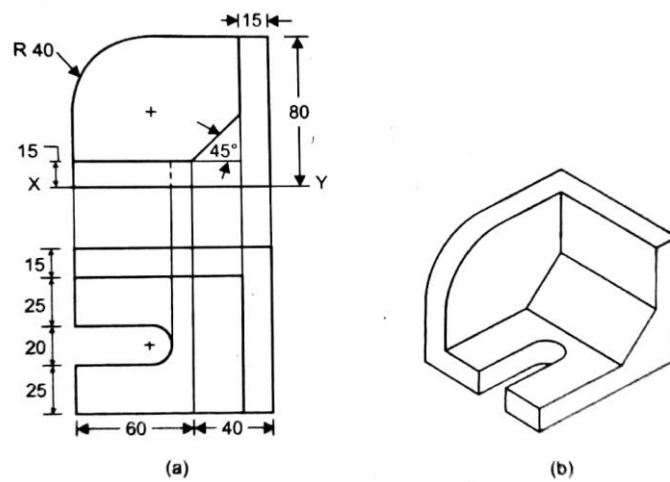


Fig. 4.19

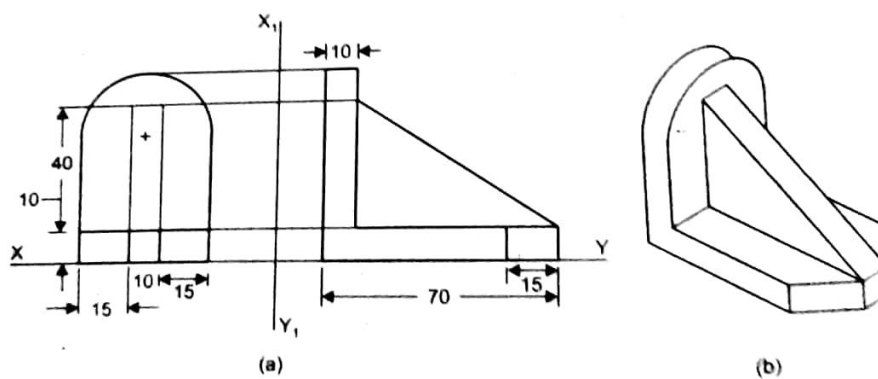


Fig. 4.20

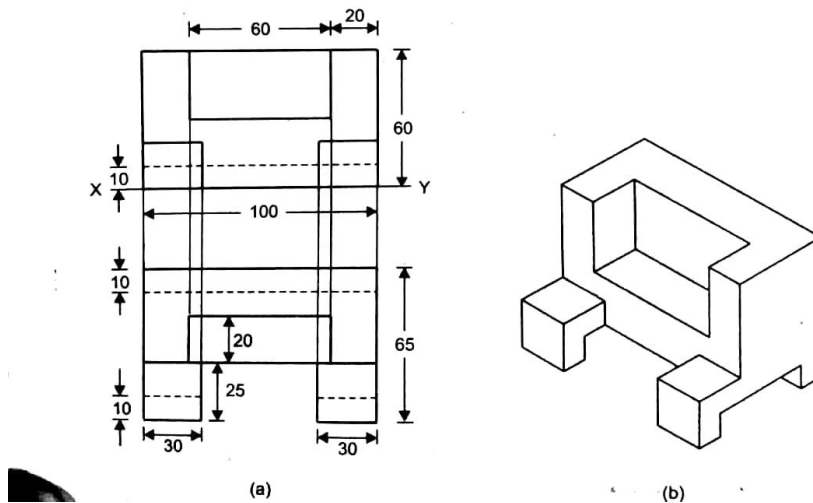


Fig 4.21

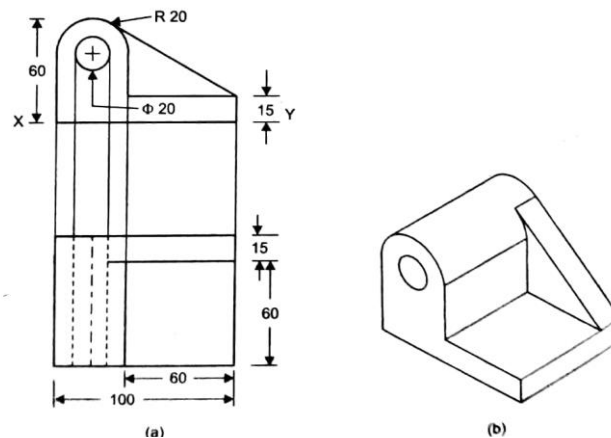


Fig. 4.22

4.6 SUMMARY

To study the isometric projection the student must have some imagining/visualizing capacity about the object. Through the training obtained in projection of solid and isometric projection can definitely improve a student's expertise in visualizing the object. In this unit, the students have studied the systematic way to obtain the isometric views, from the two dimensional views or orthographic views. Or in other words, proper training has been obtained convert orthographic views into pictorial drawings. With the help of the pictorial drawing, which is a 3D view, an engineer can explain the full details of the object of three dimensions in a single drawing. Though orthographic views give the details of the object, it needs the some expertise on principle of projection. Through pictorial

drawing even, a lay man can easily understand and get complete knowledge and details of the object in question.

4.7 KEYWORDS

1. **Pictorial Drawing:** It is one in which all the three dimensions of the object can be seen in a single view.
2. **Isometric Projection:** Iso means 'equal' Metric projection means 'a drawing to a reduced measure'.
3. **Isometric Axes:** The three principal lines making 120° with each other are called isometric axes.
4. **Isometric Lines:** Lines drawn parallel to any of the three isometric axes are called isometric lines.
5. **Isometric Planes:** Planes parallel to the planes containing the isometric axes and isometric lines are called isometric planes.
6. **Non-Isometric Line:** Lines which are not parallel to any of the isometric axes are called non-isometric lines.
7. **Isometric Scale:** A scale in which the true lengths and its corresponding isometric lengths are shown is known as isometric scale.

4.8 ANSWERS TO CHECK YOUR PROGRESS

1. It is one in which all the three dimensions of the object can be seen in a single view.
2. Iso means 'equal' Metric projections means 'a drawing to a reduced measure'. Thus isometric projection means a system of projection having equality of measure.
3. The three principal lines making 120° with each other are called isometric axes.
4. Lines drawn parallel to any of the three isometric axes and isometric lines.

4.9 EXERCISES

1. Define isometric planes.
2. What are non-isometric line?
3. State the difference between isometric view and isometric projection.
4. What is the advantage of isometric projection over orthographic projection?
5. A cone (50 mm diameter and 40 mm axis) is placed centrally over a cylindrical slab (50 mm base diameter and 35 mm axis). The axes of the solid coincide and vertically positioned. Draw the isometric projections.

6. A square pyramid of base side 30 and axis 50 is placed centrally on top of a cylindrical slab of 60 diameter and 35 thick. Draw the isometric projection.
7. A cone of base diameter 40 mm is mounted centrally on the top of a square slab of side 60 mm and thickness 15 mm. Draw the isometric projection of the solids.
8. A cylinder of dia 40 mm and height 30 mm is resting on a square block of base 50 mm and height 35 mm draw its Isometric projections.
9. A hexagonal prism, side of base 25 mm and height 70 mm rests on HP and one of the edges of its base is parallel to VP. A section plane perpendicular to VP and inclined at 40° to HP cuts the axis of the prism at 55 mm above HP. Draw the isometric view of the truncated portion of the prism, clearly showing the cut surface.
10. A cylinder 50 mm diameter and 75 mm height stands on HP. A section plane perpendicular to VP, inclined at 60° to HP cuts the cylinder and passes through a point on the axis at a height of 50 mm above the base. Draw the isometric view of the truncated portion of the cylinder, when the cut surface is clearly visible to the observer.
11. A pentagonal pyramid, 30 mm edge of base and 70 mm height, stands on HP such that an edge of the base is parallel to VP and nearer to it. A section plane perpendicular to VP and inclined at 40° to HP cuts the pyramid passing through a point on the axis at a height of 40 mm from the base. Draw the isometric view of the truncated pyramid, showing the cut surface.
12. A cone of base 50 mm diameter and axis 75 mm long, stands on HP. It is cut by a section plane perpendicular to VP, inclined at 45° to HP and passing through a point on the axis 40 mm above the base. Draw the isometric view of the truncated cone, showing the cut surface.
13. Draw the isometric view using isometric scale of the object whose projections are shown in Fig. 4.23.

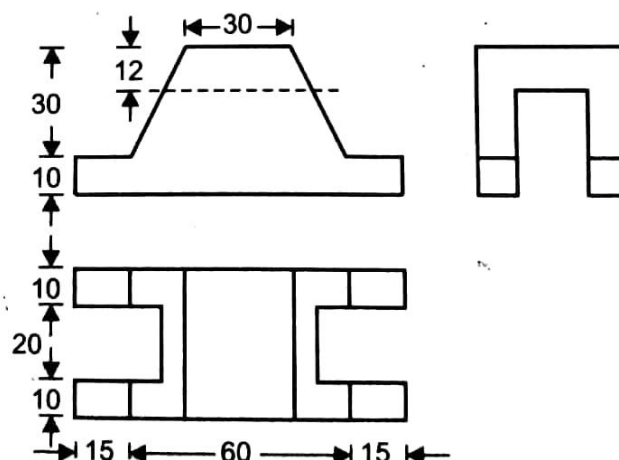


Fig. 4.23

14. Draw an isometric of the object shown in Fig. 4.24.

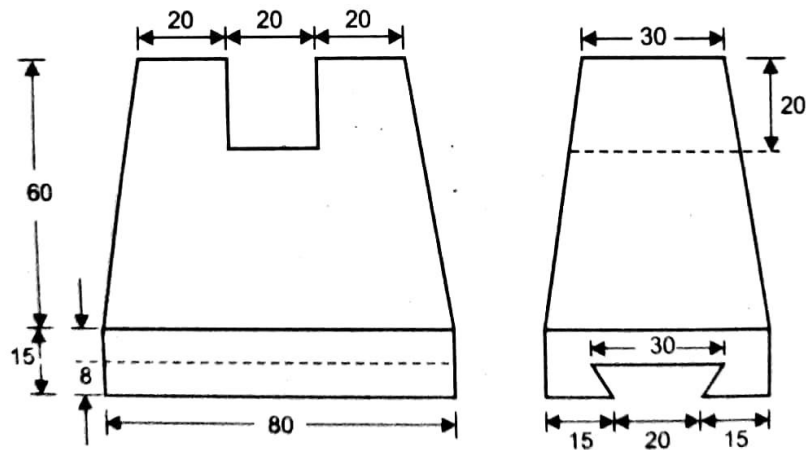


Fig. 4.24

15. Draw the isometric drawing of dovetail shop whose views are shown in Fig. 4.25.

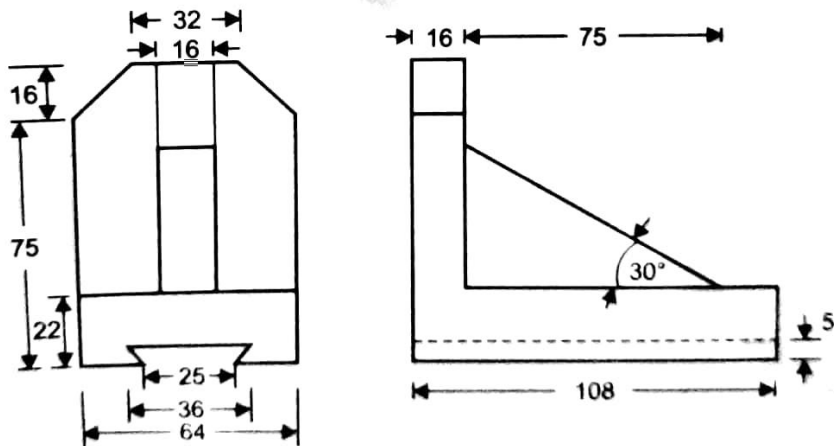


Fig. 4.25

16. Draw the isometric projection of the object whose orthographic projections are shown in Fig. 4.26.

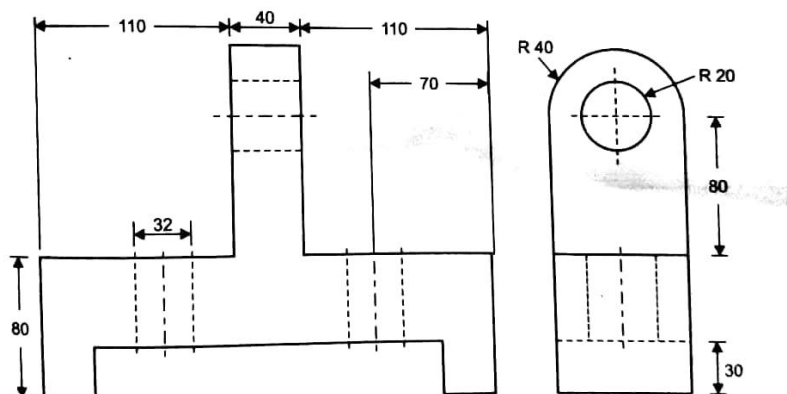


Fig. 4.26

17. Draw the isometric projection of the object shown in Fig. 4.27.

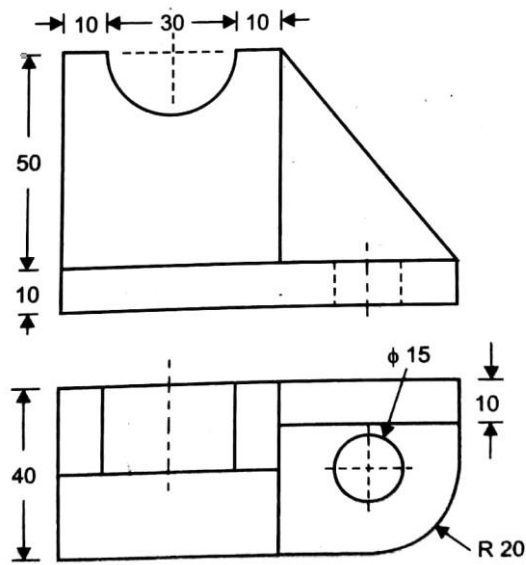


Fig. 4.27

5 DEVELOPMENT OF SURFACES

STRUCTURE

LEARNING OBJECTIVES

- Introduction
- Need for Development Drawing and Methods
- The Development of Surfaces
- Developed Surfaces of Few Solids
- Illustrative Example
- Summary
- Keywords
- Answers to Check Your Progress
- Exercise

LEARNING OBJECTIVES

After reading this unit you will be able to

- state the need of development
- illustrate the concept of developed surface
- explain about the development of surface
- analyse the properties of development of solid surfaces
- define the methods of developing solid surfaces.

5.1 INTRODUCTION

In different kinds of construction full-size *patterns* of some or all the faces of an object are required. For example, in stone cutting, a *template* or pattern giving the shape of an irregular face or in sheet metal work, a pattern to which a sheet may be cut so that when rolled, folded or formed, it will make the object.

In such cases if the complete surface of a three-dimensional object is laid out onto a plane then the resultant shape is called its development.

Thus the development consists of drawing successive surfaces of the object. Surfaces about which a thin sheet of flexible material (such as paper or tin) can be wrapped smoothly are said to be *developable*. These include objects made up of planes and single-curved surfaces only. Warped and double curved surfaces (*e.g.*, a sphere) are non-developable and when patterns are required for their construction, they can be made only by approximate methods.

5.2 NEED FOR DEVELOPMENT DRAWING AND METHODS

The knowledge of development of surfaces is essential particularly in sheet metal work. In construction of boilers, funnels, chimneys, packing boxes, buckets, AC duct, space capsules, cake pans, furnace pipes etc. The pattern is marked and cut according to the development which when folded forms the desired object.

Every line used in making a development must represent the true length of that line on the real surface. The method of finding the true size of plane surface by projecting its normal view is practised earlier. If the true size of all the plane faces of an object are found and joined in order at their common edges so that all faces lie in a common plane, the result will be the developed surface. The methods of development of surfaces are:

- Parallel line or stretch out line method
- Radial line method
- Zone method
- Lune method
- Triangulation method

The methods of drawing development of surfaces of various solids are explained by means of the following typical problems.

In general, development of a surface refers to the development of lateral surface. So, the base and/or end of the solids have been intentionally omitted. However, they can be easily incorporated if required.

5.3 THE DEVELOPMENT OF SURFACES

The basic methods of development of surfaces are broadly classified according to the construction of solids. Prisms and cylinders are developed based on the principle of parallel-line development. Pyramids and cones are developed based on radial-line development principle. The development of sphere is based on entirely different principle and is dealt separately.

The most important thing to be observed in development of surfaces is that when the solid is developed and spread on a plane the sides of the different surfaces have the true lengths. So from the given views after deciding about the principle on which the surfaces are to be developed the true lengths of the edge/generators or lines on the surfaces of the solid must either be identified or found out and only true lengths should be used for development.

In practical applications only cut solids will be developed. The method of joining points on the developed surfaces are tabulated in Table 5.1.

Table 5.1

Solids	Trace of the cutting plane is a straight line	Trace of the cutting plane is a curve
Prisms, pyramids	Join points by means of straight line.	Join points by means of curve.
Cylinders, cones, spheres, and all curved surfaces	Join points by means of curve.	Join points by means of curve.

5.4 DEVELOPED SURFACES OF FEW SOLIDS

(i) Cube (Fig. 5.1)

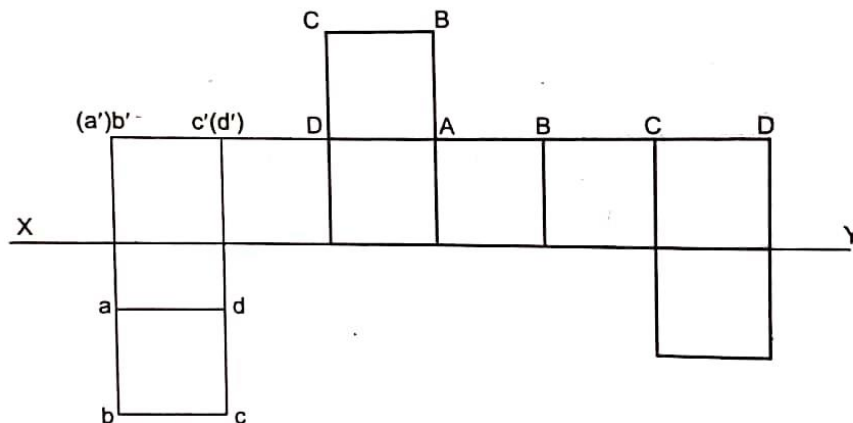


Fig. 5.1

Here, cube is developed adopting parallel line development. After drawing the orthographic projections two parallel lines are drawn having true length of the edge as the distance between them as shown in the Fig. 5.1. This principle is adopted for prisms and cylinders. The cutting points on the edges/generators are transferred to the developed edges maintaining true distances from the end points.

CHECK YOUR PROGRESS

1. What is meant by development of surface of an object?

2. How the section points are joined in solids of curved surfaces?

(ii) Triangular Prism (Fig. 5.2)

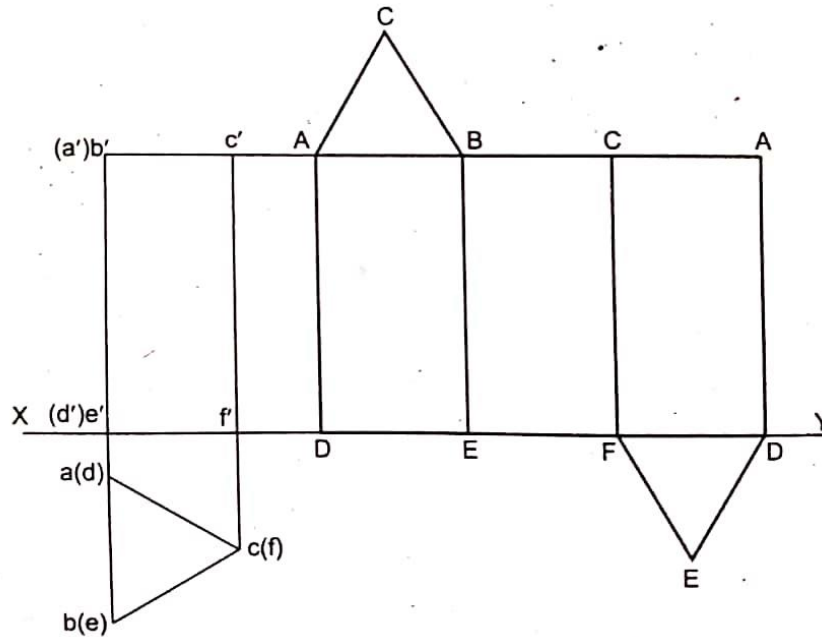


Fig. 5.2

(iii) Rectangular Prism (Fig. 5.3)

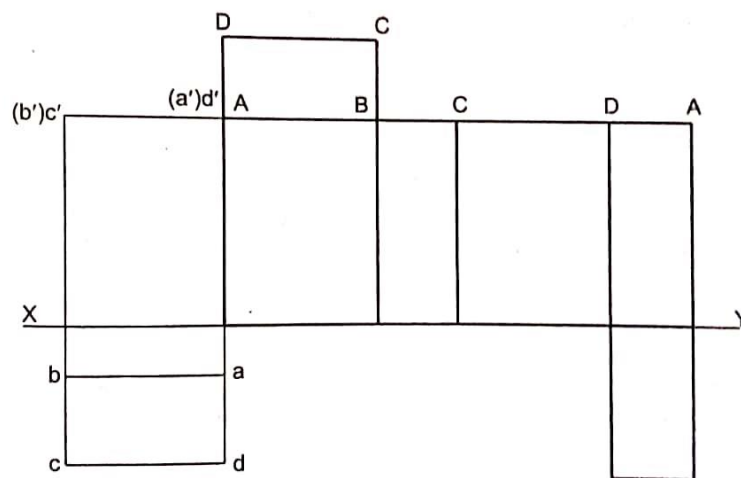


Fig. 5.3

(iv) Cylinder (Fig. 5.4)

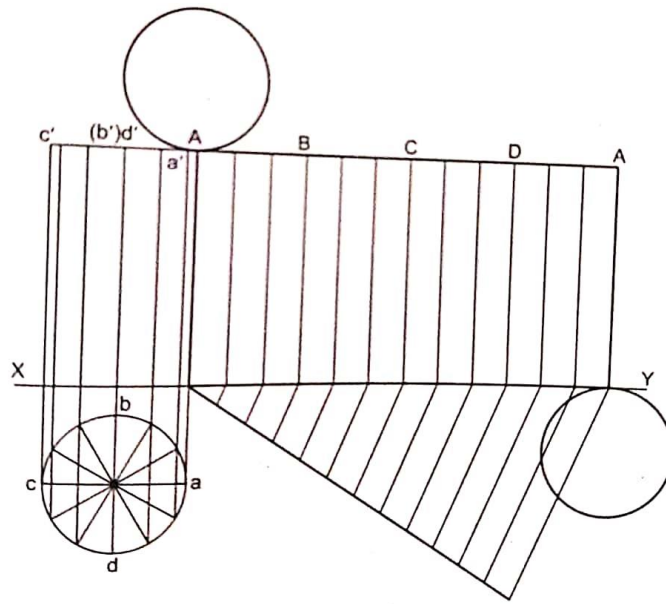


Fig. 5.4

The developed surface of a right, regular cylinder is a rectangle having sides equal to the circumference of the base circle and length of the cylinder.

So the circumference length is calculated and two parallel lines are drawn as shown in Fig. 5.4.

Twelve equally spaced generators on the curved surface are imagined and they are drawn on the developed surface. This is essential to transfer points when a section plane cuts cylinder.

(v) Square Pyramid (Fig. 5.5)

The square pyramid shown in Fig. 5.5 is developed using the principle of radial line development.

In the diagram as oc (top view of slant edge OC) is parallel to XY the true length is available in the front view. So with $o'c'$ as radius and o' as center draw an arc as shown in the figure.

On this arc cut arcs with radius equal to the base side of the pyramid to obtain points D, A, B , and C

The four triangles and the square is the developed surface of the given square pyramid.

This pyramid has been developed about the slant edge OC . It can be observed that only true lengths are marked in the developed surface.

CHECK YOUR PROGRESS

3. What is the developed surface of a cylinder?

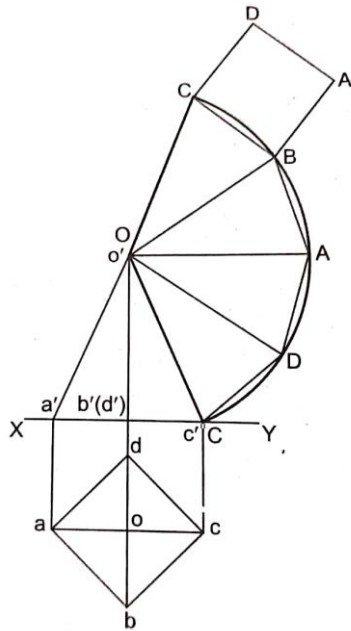


Fig. 5.5

Normally the base figure (here a square) will not be shown in the developed surface as it is not required in practical applications.

(vi) Cone (Fig. 5.6)

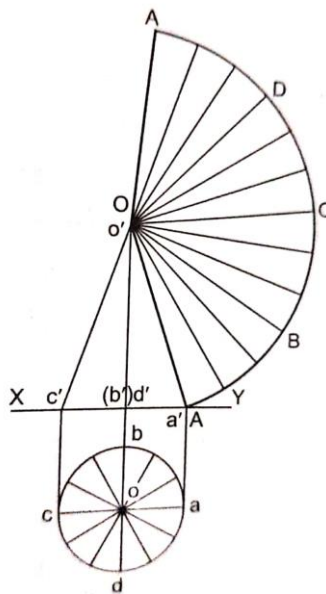


Fig. 5.6

Check your progress

4. What is the development of square pyramid?

For cone, twelve equally spaced generators are imagined on the slant surface and they are shown on the developed surface sequentially. As the points on the base circle are located at equal distances from the apex the developed surface of a cone is a sector of a circle with radius equal to the length of the slant generator of the cone. The angle subtended by the sector at the center is calculated by making use of the formula

$$\theta = \frac{2\pi r}{R}$$

where r = radius of the base circle and R = True length of a generator. With this angle and length of the generator, develop the surface of the cone as shown in Fig. 5.6. The length of the circular arc is equal to the circumference of the base circle.

5.5 ILLUSTRATIVE EXAMPLES

Problem 1: Draw the development of the portion marked as P of a cut triangular prism whose projections are given in Fig. 5.7 (a).

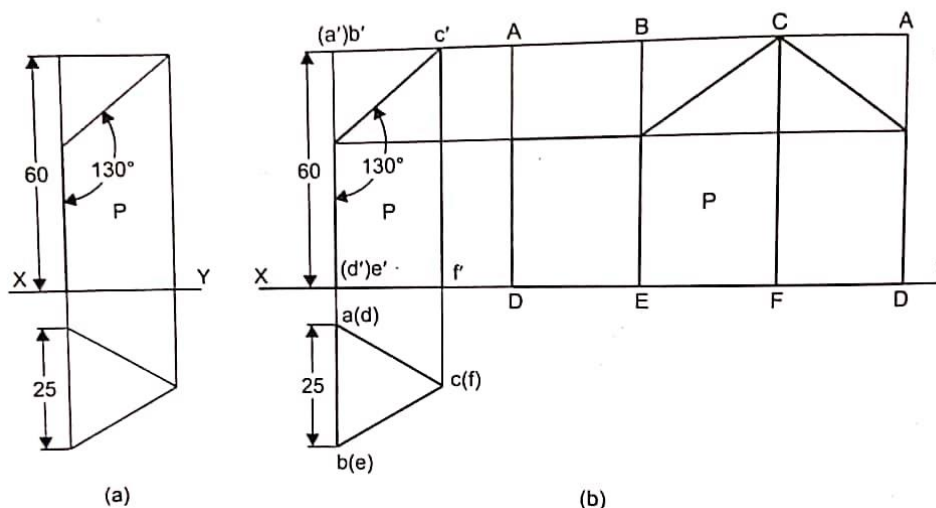


Fig. 5.7

Draw the projections of the prism and develop the full solid. Obtain the cutting points of the section plane on the actual edges on the developed surface and join them in sequence. The developed surface is shown in Fig. 5.7 (b).

Problem 2: A section plane as shown in Fig. 5.8 (a) cuts a pentagonal prism. Draw the development of the surface of the prism.

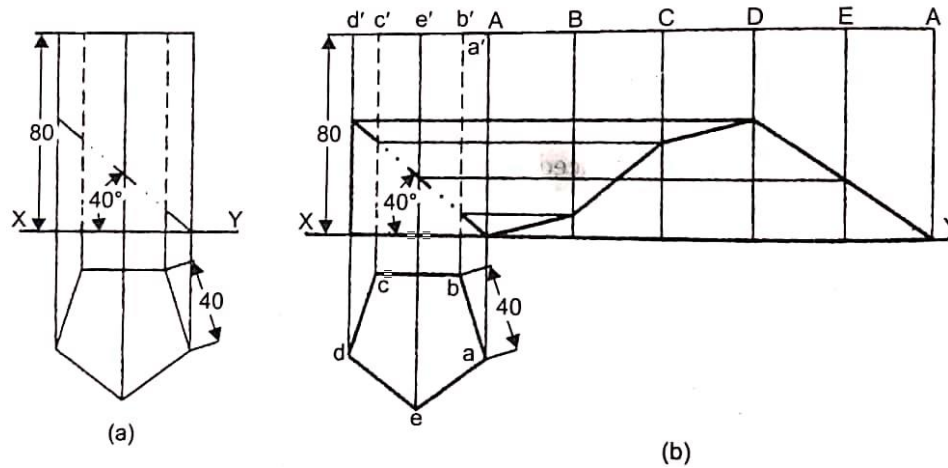


Fig. 5.8

Obtain the true distance of the intersecting points of the cutting plane and vertical edges from the top face from the front view and mark these points on the corresponding edges in the developed surface. Join these points in sequence to obtain the developed surface is shown in Fig. 5.8 (b).

Problem 5 The projection of a regular hexagonal prism, base side 35 mm long and axis 80 mm long with circular hole right through the solid is given in Fig. 5.9 (a). Draw the development.

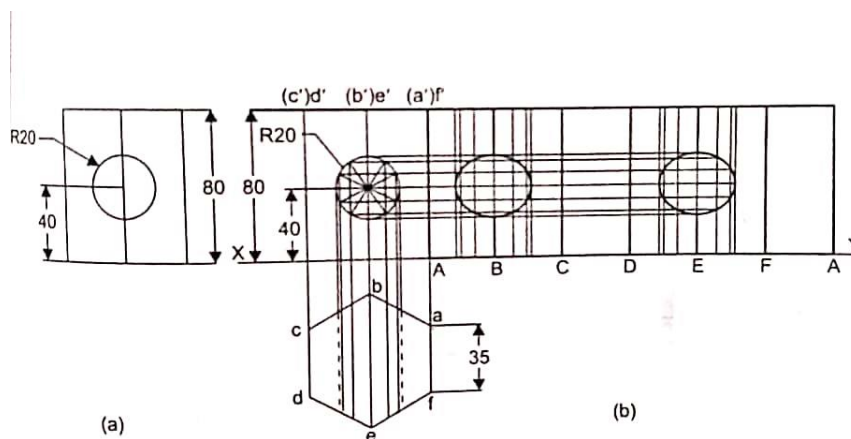


Fig. 5.9

Draw the developed surface of the full solid and name the edges appropriately. To get the hole on the developed surface imagine number of

lines passing through twelve equally spaced points on the circle on the rectangular faces of the solid and obtain their locations on the developed surface after obtaining the distances of these lines from the corner points in the top view. Locate the twelve points on the lines drawn in the developed surface and join them by means of smooth curves as shown in Fig. 5.9(b).

Problem 4: The projections of a cylinder with the VTs' of two parallel section planes are given in Fig. 5.10 (a). Draw the development of the portion Q.

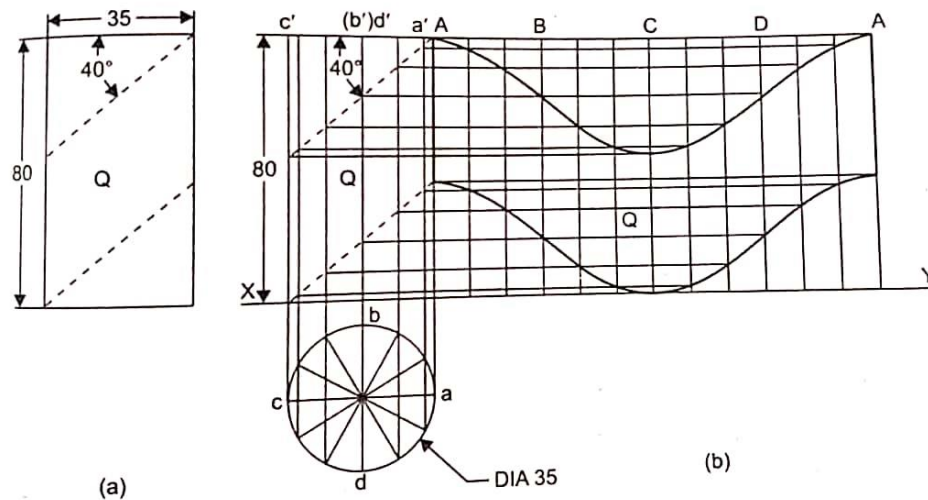


Fig. 5.10

For developing a cylinder, imagine twelve generators to get the locations of the intersecting points on the developed surface and join these points by means of a smooth curve as shown in Fig. 5.10 (b).

Problem 5: A cylinder, base 60 mm diameter and axis 120 mm long, has a square hole, side 50 mm, right through the cylinder with all sides of the square equally inclined to the base of the cylinder. Draw the development of the solid.

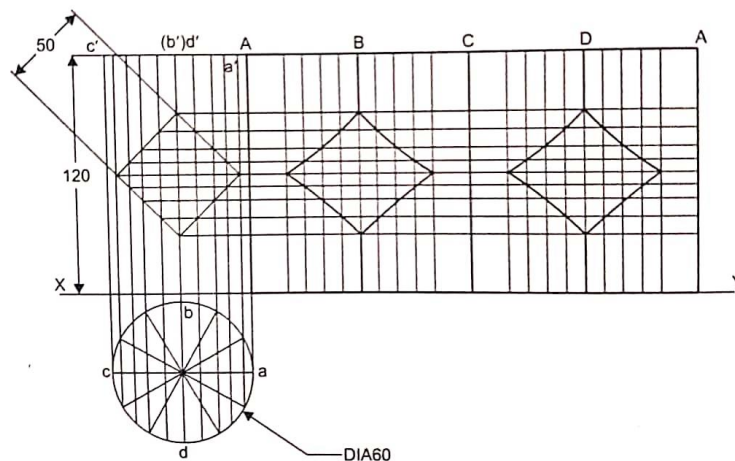


Fig. 5.11

Draw the developed surface of the cylinder and to locate the points on the sides of the square hole in the developed surface, consider the equally spaced points on the square and generators through them. The projections of all generators passing through points on the sides of the square are drawn. These generators are drawn on the developed surface and to obtain the distances of the other generators on the curved surface measure the distances of the respective generators in the top view (chord lengths) and transfer them on the developed surface. Locate the points on the square on the developed surface and join them as shown in Fig. 5.11.

Problem 6: Develop the surface of the Y piece formed by the three cylinder pipes of 60 mm diameter shown in Fig. 5.12 (a).

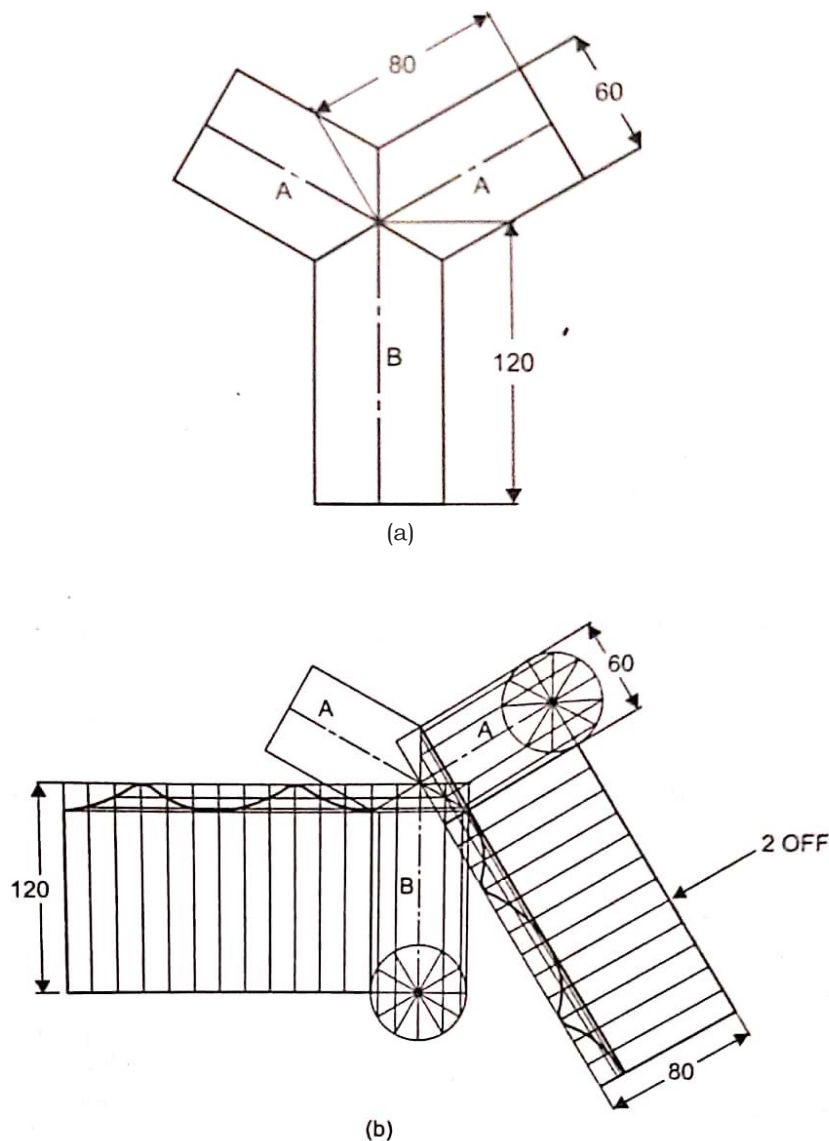


Fig. 5.12

Draw the development of the three cylinders (marked A, A and B) and mark the joining curves on the developed surfaces as shown in Fig. 5.12 (b).

CHECK YOUR PROGRESS

5. How the angle subtended in development of cone is calculated?

5.6 SUMMARY

All the objects can be made by basic manufacturing process, like metal removal or joining processes. But some solids are to be produced only by enclosure to obtain the shape. Such hollow solids or objects are to be formed by sheet metal. Such sheet metals are first to be designed and shaped, so as to obtain the required enclosures. To do such design, first the sheet metal is to be cut of exact shape and dimension. To do such cutting and obtain such solids, the basic concept of development of solid surface is a must.

This chapter clearly gives the idea to prepare such unfolded surfaces of a solid. For practical application in fabrication of industrial equipment's and chambers a concise methodology of development and design for the solid surfaces which is a combination of different equipment's in use.

The various methods of development of surfaces of any object with suitable examples are discussed at length. Through this chapter anyone can understand how the unfolded portions of the solid look like.

5.7 KEYWORDS

1. **Development:** When the surfaces of a solid are unfolded and laid out on a plane, the surface obtained is called its development.
2. **Triangulation Method:** Triangulation method is used for developing transition pieces.
3. **Reducer:** A reducer connects the pipes of same shape and of different size.

5.8 ANSWERS TO CHECK YOUR PROGRESS

1. The development of a surface of an object means the unrolling or unfolding of all the surfaces of the object on a plane.
2. Joined by means of a curve.
3. The developed surface of a right, regular cylinder is a rectangle having sides equal to the circumference of the base circle and length of the cylinder.

4. The four triangles and the square is the developed surface of the given square pyramid.
5. The angle subtended by the sector at the center is calculated by making use of the formula.

$$\theta = \frac{2\pi r}{R}$$

where r = radius of the base circle and R = True length of a generator.

5.9 EXERCISES

1. What is the shape of the figure you will obtain when you develop a hexagonal prism?
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 30° to VP. It is cut by a section plane inclined at 60° to HP and perpendicular to VP so as to pass through a point on the axis 30 mm above the base. Develop the truncated portion of the prism so as to produce a one piece development.
3. 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 by a section plane perpendicular to VP and inclined at 45° to HP and bisecting the axis. Draw the development of the bottom part of the cut pyramid.
4. A hexagonal pyramid, edge of base 25 mm and axis 75 mm long is lying on one of its triangular faces on HP and with its axis parallel to VP. It is cut by a sectional plane perpendicular to VP and inclined at 45° to HP and bisecting the axis. Draw the development of the front portion of the pyramid.
5. A right circular cone 55 mm diameter and 75 mm high stands on its base on HP. A plane cuts the cone at an angle of 45° to VP and is at a distance of 10 mm from the axis of the cone. Obtain the development of the lateral surface of the truncated cone.
6. A cube of side 30 mm rests on its base on the HP with vertical face inclined at 30° to VP. A plane perpendicular to VP and inclined at 50° to HP. The plane bisects the axis of the cube. Draw the development of the surfaces of the right portion of the cube.
7. A hexagonal prism of base 30 mm and height 50 mm rests vertically on the HP with one of the sides of the base inclined at 30° to VP. A string is wound round the surfaces of the prism starting from left extreme point on the base and ending at the same point. Find graphically the shortest length of the string required.
8. A hexagonal prism of side of base 30 mm and axis 65 mm stands on one of its ends in HP with two of its rectangular faces parallel to VP. A circular hole of diameter 40 mm is drilled completely through the prism such that

the axis of the hole is perpendicular to VP and bisects the axis of the prism. Draw the development of the lateral surface of the prism showing the shape of the holes formed on it.

9. A hexagonal pyramid of side of base and axis 70 mm rests on its base with two edges of base parallel to VP. A circular hole of diameter 30 mm is completely drilled through the pyramid such that the axis of the hole is perpendicular to VP and intersects the axis of the pyramid 20 mm above the base. Draw the development of lateral surface of the pyramid showing the true shape of the hole formed on it.
10. A square pyramid of base side 30 mm and altitude 60 mm rests on the HP on its base with the base edges equally inclined to the VP. It is cut by a plane perpendicular to the VP and inclined at 30° to the HP meeting the axis at 20 mm above the HP. Draw the development of the lateral surfaces of the square pyramid.
11. A hexagonal pyramid of base side 30 mm and height 50 mm rests vertically on HP with one of the base sides making 30° to VP. A string is wound round the surfaces of the prism from the left extreme point on the base and ending at the same point. Find graphically the shortest length of the string required. Also trace the path of the string in the front and top views.
12. Draw the development of the lower portion of a cylinder of diameter 60 mm and axis 70 mm when sectioned by a plane inclined at 40° to HP perpendicular to VP and bisecting the axis.
13. A cone of base 50 mm diameter and height 70 mm with its base on HP. A section plane perpendicular to VP and inclined at 30° to HP bisects the axis of the cone. Draw the development of the lateral surface of the truncated cone.

6

AUTOCAD

STRUCTURE

LEARNING OBJECTIVES

- Introduction to AutoCAD Commands
- Draw Commands
- Dimensions Commands
- Edit Commands
- Illustrative Examples
- Summary
- Keywords
- Answers to Check Your Progress
- Exercise

LEARNING OBJECTIVES

After reading this unit you will be able to

- start AutoCAD and start a drawing.
- draw lines using line commands
- draw the arc and circle
- draw the ellipses, arc and polygon
- create the dimensions and tolerance
- use of erase command to clear the drawing area
- apply the selection method
- copy object with the base point using topic command
- use the mirror offset
- move the object using move command
- how to use the rotate command

6.1 INTRODUCTION TO AUTOCAD COMMANDS

In today's world computers are used to perform many tasks which were done by man earlier. Computers use different software to perform these

tasks. With the help of special software, computers can be advantageously used to do the working of drafting.

The process of constructing the drawing on computer screen with the help of special software and hardware is called Computer Aided Drafting (CAD).


The AutoCAD is very effective CAD software. It is used globally to CAD professionals. It support 2D drafting and 3D Modeling. This Chapter explains with the help of practice sections, examples and assignments, important commands needed to draw 2D drawings.

The process of drafting and drawing the objects on the computer screen with special software and hardware are the latest techniques called CAD.

The AutoCAD is very effective CAD software. It is used globally by CAD professionals. It supports 2D drafting and 3D modeling. AutoCAD is user friendly and easy to learn.

6.2 DRAW COMMANDS

6.2.1 LINE

Draw Toolbar : 
Command Line : LINE
Specify first point : Specify a point or press ENTER to continue from the last drawn line or arc.


Specify next point or [Close/Undo]

To draw lines

1. From the Draw menu, choose Line.
2. Specify the start point. You can use the pointing device or enter a coordinate on the command line.
3. Complete the first line segment by specifying the endpoint.
To undo the previous line segment during the LINE command, enter u or choose Undo on the toolbar.
4. Specify the endpoints of any additional line segments.
5. Press ENTER to end or c to close a series of line segments.

To start a new line at the endpoint of the last line drawn, start the LINE command again the press ENTER at the Specify Start Point prompt.

6.2.2 ARC

Draw Toolbar : 
Command Line : ARC
Specify start point of arc of [CEnter] : Specify a poin, enter ce, or press ENTER to star tangent to last line, arc or poly line.

To draw an arc by specifying three points

1. From the Draw menu, choose Arc - 3 Points.
2. Specify the start point.
3. Specify a point on the arc.
4. Specify the endpoint.

CHECK YOUR PROGRESS

1. What is the use of 'line' command?

To draw an arc using a start point, a center point, and an endpoint

1. From the Draw menu, choose Arc-Start, Center, End.
2. Specify a start point.
3. Specify the center point.
4. Specify the endpoint.

To continue an arc with a tangential line

1. Complete the arc.
2. From the Draw menu, choose Line.
3. Press ENTER at the first prompt.
4. Enter the length of the line and press ENTER

To continue an arc with a tangential arc

1. Complete the arc.
2. From the Draw menu, choose Arc-Continue.
3. Specify the second endpoint of the tangent arc.

6.2.3 CIRCLE

Draw Toolbar



Command Line

: Circle

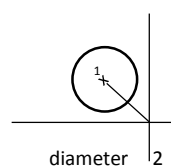
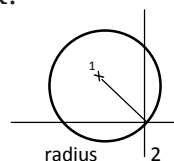
Specify center point for circle or
[3P (Three Points)/2P (Two Points)/

Ttr (tan tan radius)

: Specify a point or enter an option

Center point

Specify radius of circle or (Diameter): Specify a point, enter a value, enter d , or press ENTER.



Radius

Defines the radius of the circle. Enter a value, or specify a point (2). The distance between this point and the center point determines the radius of the circle.

Radius

Draws a circle using the center point and a specified distance for the diameter.

Specify diameter of circle current Specify a point (2), enter a value, or press ENTER.

3P (Three points)

Draws a circle based on three points on the circumference.

Specify first point on circle: Specify a point (1)

Specify second point on circle: Specify a point (2)

Specify third point on circle: Specify a point (3)



2P (Two points)

Draws a circle based on two endpoints of the diameter.

Specify first endpoint of circle's diameter: Specify a point (1)

Specify second endpoint of circle's diameter: Specify a point (2)

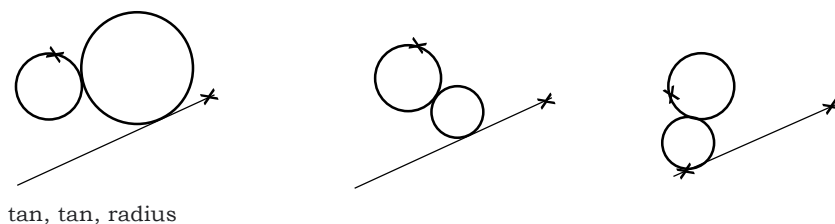
ITR (Tan Tan Rad)

Draws a circle with a specified radius tangent to two objects.

Specify point on object for first tangent of circle: Select a circle, arc, or line.

Specify point on object for second tangent of circle: Select a circle, arc, or line.

Specify radius of circle <current>:



Sometimes more than one circle matches the specified criteria. AutoCAD draws the circle of the specified radius whose tangent points are closest to the selected points.

6.2.4 ELLIPSE

Draw Toolbar



Command Line

Specify axis endpoint of ellipse or (Arc/Center) : Specify a point or enter an option

Defines the first axis by its two endpoints. The angle of the first axis determines the angle of the ellipse. The first axis can define either the major or the minor axis of the ellipse.

Specify other end point of axis

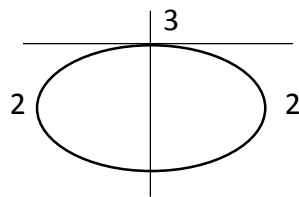
: Specify a point (2)

Specify distance to other axis or (Rotation)

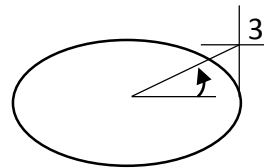
: Specify a distance by entering a value or locating a point (3), or enter r .

Distance to Other Axis

Defines the second axis using the distance from the midpoint of the first axis to the endpoint of the second axis (3).



Ellipse by axis endpoint



Ellipse by rotation

Rotation

Creates the ellipse by appearing to rotate a circle about the first axis.

Specify rotation around major axis: Specify a point (3), or enter an angle value between 0 and 89.4.

Move the crosshairs around the center of the ellipse and click. If you enter a value, the higher the value, the greater the eccentricity of the ellipse. Entering 0 defines a circular ellipse.

Arc

Creates an elliptical arc. The angle of the first axis determines the angle of the elliptical arc. The first axis can define either the major or the minor axis of the elliptical arc.

Specify axis endpoint of elliptical arc or (Center): Specify a point or enter c Axis Endpoint.

Defines the start point of the first axis.

Specify other endpoint of axis:

Specify distance to other axis or (Rotation): Specify a distance or enter r

The descriptions of the Distance to Other Axis and Rotation options match those of the corresponding options under Center.

Center

Creates the elliptical arc using a center point you specify.

Specify center of elliptical arc:

Specify endpoint of axis:

Specify distance to other axis or (Rotation): Specify a distance or enter *r*

Distance to Other Axis

Defines the second axis as the distance from the center of the elliptical arc, or midpoint of the first axis, to the point you specify.

Specify start angle or Parameter: Specify a point (1), enter a value, or enter *p*

Defines the major to minor axis ratio of the ellipse by rotating a circle about the first axis. The higher the value (from 0 through 89.4 degrees), the greater the ratio of minor to major axis. Entering 0 defines a circle.

Specify rotation around major axis: Specify a rotation angle

Specify start angle or Parameter: Specify an angle or enter *p*

Start angle

Defines the first endpoint of the elliptical arc. The Start Angle option toggles from Parameter mode to Angle mode. The mode you are in determine how AutoCAD calculates the ellipse.

Specify end angle or (Parameter/Included angle): Specify a point (2), enter a value, or enter an option.

Specify rotation around major axis: Specify a rotation angle

Specify start angle or (Parameter): Specify an angle or enter *p*.

CHECK YOUR PROGRESS

2. What is the use of ZOOM command?

6.2.5 POLYGON

Draw Toolbar



Command Line

: POLYGON

Enter number of sides <current

: Enter a value between 3 and 1024 or press ENTER

Specify center of polygon or (Edge)

: Specify a point (1) or enter *e*

To draw a circumscribed polygon

1. From the Draw menu, choose Polygon.
2. On the command line, enter the number of sides.
3. Specify the center of the polygon (1).
4. Enter *c* to specify a polygon circumscribed about a circle.
5. Enter the radius length (2).

To draw an inscribed polygon

1. From the Draw menu, choose Polygon.
2. On the command line, enter the number of sides.
3. Specify the center of the polygon.
4. Enter *i* to specify a polygon inscribed within a circle of specified points.
5. Enter the radius length.

To draw a polygon by specifying one edge

1. From the Draw menu, choose Polygon.
2. On the command line, enter the number of sides.
3. Enter e (Edge).
4. Specify the start point for one polygon segment.
5. Specify the endpoint of the polygon segment.

6.2.6 RECTANGLE

Draw Toolbar



Command Line

: Rectang or rectangle

Specify first corner point or

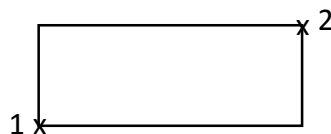
(Chamfer/Elevation/Fillet/Thickness/Width)

: Enter an option or specify a point

First corner

1. Specifies a corner point of the rectangle.
2. Specify other corner point or (Dimensions): Specify a point (2) or enter d.

Other corner



Creates a rectangle using the specified points as diagonally opposite corners. The sides of the rectangle are parallel to the X and Y axis of the current UCS.

Dimensions

1. Creates a rectangle using length and width values. A second specified point locates the rectangle in one of four locations relative to the first corner point.
2. Specify length for rectangles <0.0000> Enter the length of the rectangle.
3. Specify width for rectangles <0.0000> Enter the width of the rectangle.
4. Specify other corner point or Dimensions Specify a point; move the cursor to display one of four possible locations for the rectangle and click the one that you want.

Chamfer

1. Sets the chamfer distances for the rectangle.
2. Specify first chamfer distance for rectangles <current>: Specify a distance or press ENTER.
3. Specify second chamfer distance for rectangles <current>: Specify a distance or press ENTER.

Elevation

1. Specifies the elevation of the rectangle.
2. Specify the elevation for rectangles <current>: Specify a distance or press ENTER.

Fillet

1. Specifies the fillet radius of the rectangle.
2. Specify fillet radius for rectangles <current>: Specify a distance or press ENTER.

Thickness

1. Specifies the thickness of the rectangle.
2. Specify thickness for rectangles <current>: Specify a distance or press ENTER.

Width


1. Specify line width for rectangles currents: Specify a distance or press ENTER.
2. The values become the current chamfer distances for subsequent RECTANG.

CHECK YOUR PROGRESS

3. Name the commands used to create a rectangle?

6.3 DIMENSION COMMANDS

Quick Dimension

Dimension Toolbar	: 
Dimension Menu	: Quick Dimension
Command Line	: qdim

Use QDIM to quickly create or edit a series of dimensions. The command is particularly useful for creating a series of baseline or continued dimensions, or for dimensioning a series of circles and arcs.

Select geometry to dimension: Select the objects you want to dimension or the dimensions you want to edit and press ENTER.

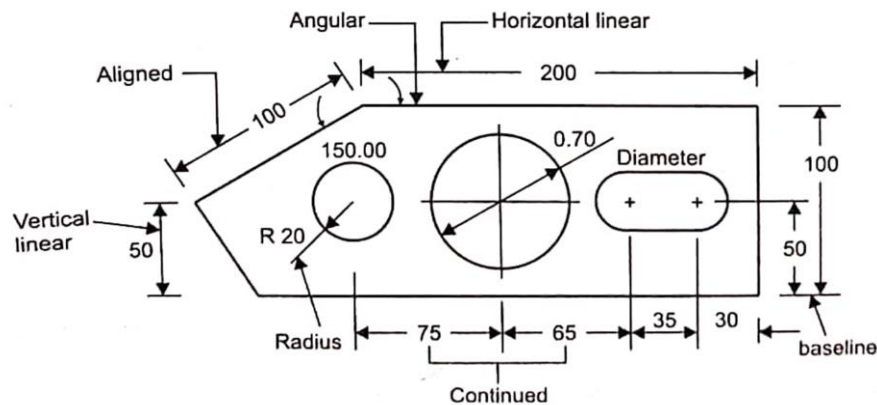
Specify dimension line position, or (Continuous/Staggered/Baseline/Ordinate/Radii/Diameter/datum Point/Edit/seTtings] <current>: Enter an option or press ENTER.

Dimensioning is the process of adding measurement annotation to a drawing.


You can create dimensions for a variety of object types in many orientations. The basic types of dimensioning are

- Linear
- Radial (radius and diameter)
- Angular
- Ordinate
- Arc Length

Linear dimensions can be horizontal, vertical, aligned, rotated, baseline, or continued (chained). Some examples are shown in the illustration.



6.3.1 LINEAR

Dimension Toolbar : 
Dimension Menu : Linear
Command Line : Dimlinear

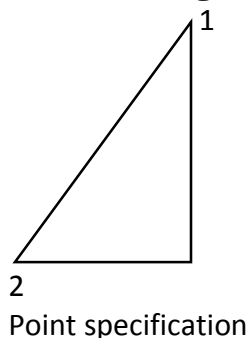
Specify first extension line origin or <select object>: Specify a point or press ENTER to select an object to dimension.

After you specify the extension Line origin points or the object to dimension, the following prompt is displayed:

First Extension Line Origin

Prompts for the origin point of the second extension line after you specify the origin point of the first.

Specify second extension line origin: Specify a point (2)



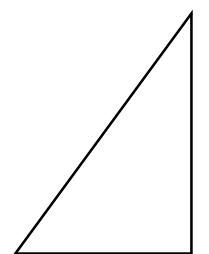
Object Selection

Automatically determines the origin points of the first and second extension lines after you select an object.

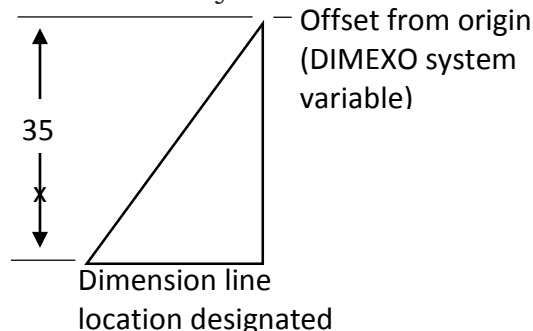
Select object to dimension

For polylines and other explodable objects, only the individual line and arc segments are dimensioned. You cannot select objects in a non-uniformly scaled block reference.

If you select a line or an arc, the line or arc endpoints are used as the origins of the extension lines. The extension lines are offset from the endpoints by the distance you specify in Offset from Origin in the Lines and Arrows tab of the New, Modify, and Override Dimension Style dialog boxes. See DIMSTYLE. This value is stored in the DIMEXO system variable.



Object selected

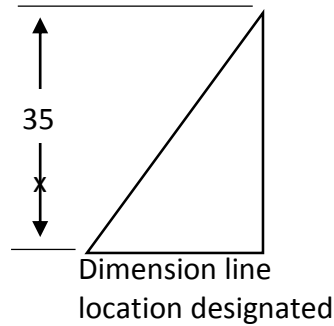


If you select a circle, the diameter endpoints are used as the origins of the extension line. When the point used to select the circle is close to the north or south quadrant point, a horizontal dimension is drawn. When the point used to select the circle is close to the east or west quadrant point, a vertical dimension is drawn.

Specify dimension line location or [Mtext/Text/Angle/Horizontal/Vertical/Rotated]: Specify a point or enter an option.

Dimension Line Location

Uses the point you specify to locate the dimension line and determines the direction to draw the extension lines. After you specify the location, the dimension is drawn.



Mtext

Displays the In-Place Text Editor, which you can use to edit dimension text. To add a prefix or a suffix, enter the prefix or suffix text before or after the generated measurement. Use control codes and Unicode character strings to enter special characters or symbols. See Control Codes and Special Characters.

To edit or replace the generated measurement, delete the text, enter the new text, and then click OK. If alternate units are not turned on in the dimension style, you can display them by entering square brackets ([]). For more information about formatting dimension text, see "Change Existing Objects", in the User's Guide.

The current dimension style determines the appearance of the generated measurements.

Text

Customizes the dimension text on the command line. The generated dimension measurement is displayed within angle brackets.

Enter dimension text <current>:

Enter the dimension text, or press ENTER to accept the generated measurement. To include the generated measurement, use angle brackets (< >) to represent the generated measurement. If alternate units are not turned on in the dimension style, you can display alternate units by entering square brackets ([]).

Dimension text properties are set on the Text tab of the New, Modify, and Override Dimension Style dialog boxes.

Angle

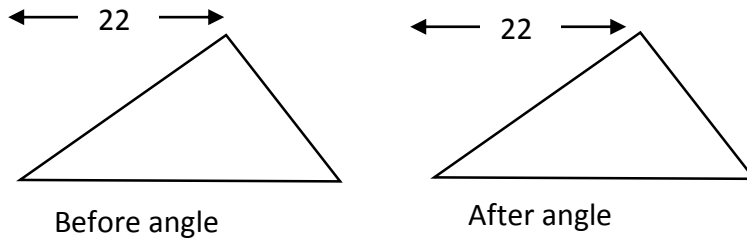
Changes the angle of the dimension text.

Specify angle of dimension text:

Enter an angle. For example, to rotate the text 90 degrees, enter 90.

CHECK YOUR PROGRESS

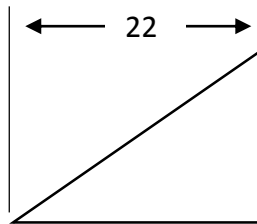
4. What is the use of Quick Dimension Command?



Horizontal

Creates horizontal linear dimensions

Specify dimension line location or [Mtext/Text/Angle): Specify a point or enter an option.



Dimension Line Location

Uses the point you specify to locate the dimension line. After you specify the location, the dimension is drawn.

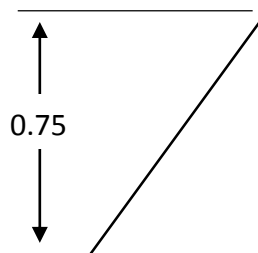
Mtext, Text, Angle

These text editing and formatting options are identical in all dimension commands. See the option descriptions provided earlier in this command.

Vertical

Creates vertical linear dimensions

Specify dimension line location or (Mtext/Text/Angle): Specify a point or enter an option.



Dimension Line Location

Uses the point you specify to locate the dimension line. After you specify the location, the dimension is drawn.

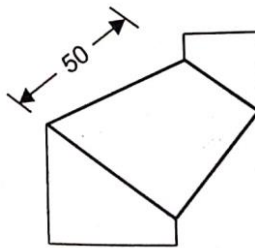
Mtext, Text, Angle

These text editing and formatting options are identical in all dimension commands. See the option descriptions provided earlier in this command.

Rotated

Creates rotated linear dimensions.

Specify angle of dimension line <current>: Specify an angle or press ENTER.

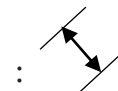


6.3.2 Aligned

Dimension Toolbar

Dimension Menu

Command Line



: Aligned

: Dimaligned

Specify first extension line origin or <select object>

: Specify a point for manual extension lines, or press ENTER for automatic extension lines

After you specify either manual or automatic extension lines, the following prompt is displayed:

Specify dimension line location or (Mtext/Text/Angle): Specify a point or enter an option.

Extension Line Origin

Specifies the first extension line origin (1). You are prompted to specify the second one.

Specify second extension line origin: Specify a point (2)

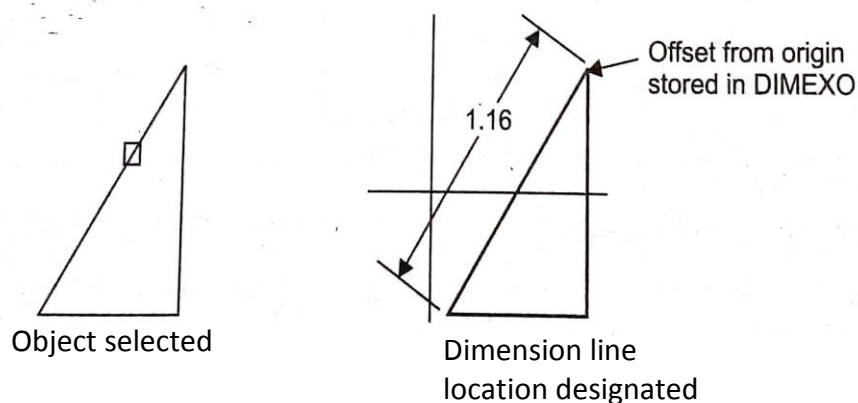
Object Selection

Automatically determines the origin points of the first and second extension lines after you select an object.

Select object to dimension

For polylines and other explodable objects, only the individual line and arc segments are dimensioned. You cannot select objects in a nonuniformly scaled block reference.

If you select a line or an arc, its endpoints are used as the origins of the extension lines. The extension lines are offset from the endpoints by the distance specified in Offset from Origin on the Lines and Arrows tab of the New, Modify, and Override Dimension Style dialog boxes (see DIMSTYLE). This value is stored in the DIMEXO system variable.



If you select a circle, the endpoints of its diameter are used as the origins of the extension line. The point used to select the circle defines the origin of the first extension line.

Dimension Line Location

Specifies the placement of the dimension line and determines the direction to draw the extension lines. After you specify the location, the DIMALIGNED command ends.

Mtext

Displays the In-Place Text Editor, which you can use to edit the dimension text. The generated measurement is represented with angle brackets (< >). To add a prefix or a Suffix to the generated measurement, enter the prefix or suffix before or after the angle brackets. Use control codes and Unicode character strings to enter special characters or symbols. See Control Codes and Special Characters.

To edit or replace the generated measurement, delete the angle brackets, enter the new dimension text, and then click OK. If alternate units are not turned on in the dimension style, you can display them by entering square brackets ([]). For more information about formatting dimension text, see "Change Existing Objects" in the User's Guide.

The current dimension style determines the appearance of the generated measurements.

Text

Customizes the dimension text at the command line. The generated dimension measurement is displayed within angle brackets.

Enter dimension text <current>:

Enter the dimension text, or press ENTER to accept the generated measurement. To include the generated measurement, use angle brackets (< >) to represent the generated measurement. If alternate units are not turned on in the dimension style, you can display alternate units by entering square brackets ([]).

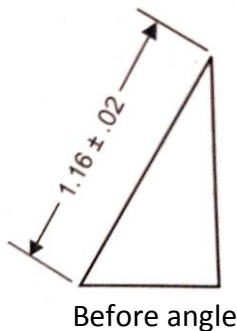
Dimension text properties are set on the Text tab of the New, Modify, and Override Dimension Style dialog boxes.

Angle

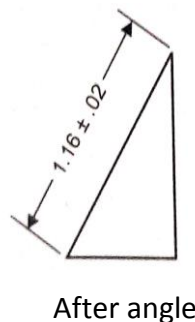
Changes the angle of the dimension text.

Specify angle of dimension text:


Enter an angle. For example, to rotate the text 45 degrees, enter 45.



After you specify the angle, the Dimension Line Location prompt is redisplayed.



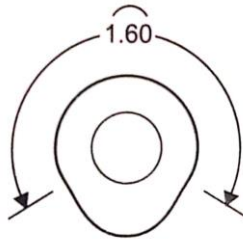
6.3.3 ARC

Dimension Toolbar	: 
Dimension Menu	: Arc Length
Command Line	: Dimarc
Select arc or polyline arc segment	: Use an object selection method

Specify arc length dimension location or Mtext/Text/Angle/ Partial/ Leader): Specify a point or enter an option.

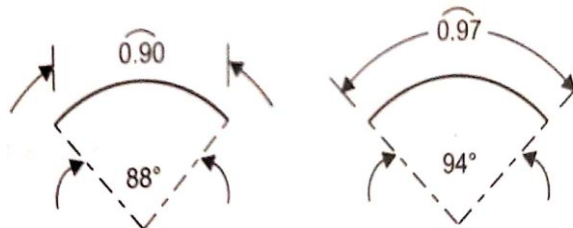
Arc length dimensions measure the distance along an arc or polyline segment.

Typical uses of arc length dimensions include measuring the travel distance around a cam or indicating the length of a cable. To differentiate them from linear or angular dimensions, arc length dimensions display an arc symbol by default.



The arc symbol, also called a hat or cap, is displayed either above the dimension line or preceding the dimension text. You can specify the placement style using the Dimension Style Manager. The placement style can be changed on the Symbols and Arrows tab of either the New Dimension Style dialog box or the Modify Dimension Style dialog box.

The extension lines of an arc length dimension can be orthogonal or radial.



Note Orthogonal extension lines are displayed only when the included angle of the arc is less than 90 degrees.

Arc Length Dimension Location

Specifies the placement of the dimension line and determines the direction of the extension lines.

Mtext

Displays the In-Place Text Editor, which you can use to edit the dimension text. To add a prefix or a suffix, enter the prefix or suffix text before or after the generated measurement. Use control codes and Unicode character strings to enter special characters or symbols. See Control Codes and Special Characters.

To edit or replace the generated measurement, delete the text, enter the new text, and then click OK. If alternate units are not turned on in the dimension style, you can display them by entering square brackets ([]). For

more information about formatting dimension text, see "Change Existing Objects" in the User's Guide.

The current dimension style determines the appearance of the generated measurements.

CHECK YOUR PROGRESS

5. What is the use of Arc command?

Text

Customizes the dimension text at the command line. The generated dimension measurement is displayed within the angle brackets.

Enter dimension text <current>:

Enter the dimension text, or press ENTER to accept the generated measurement. To include the generated measurement, use angle brackets (< >) to represent the generated measurement. If alternate units are not turned on in the dimension style, you can display alternate units by entering square brackets ([]).

Dimension text properties are set on the Text tab of the New, Modify, and Override Dimension Style dialog boxes.

Angle

Changes the angle of the dimension text.

Specify angle of dimension text:

Enter an angle. For example, to rotate the text 45 degrees, enter 45.

Partial

Reduces the length of the arc length dimension.

Specify first point for arc length dimension:

Specify a point on the arc where the arc length dimension should begin.

Specify second point for arc length dimension:

Specify a point on the arc where the arc length dimension should end.

Leader


Adds a leader object. This option is displayed only if the arc (or arc segment) is greater than 90 degrees. The leader is drawn radially, pointing towards the center of the arc being dimensioned.

Specify arc length dimension location or (Mtext/Text/Angle/Partial/No leader):

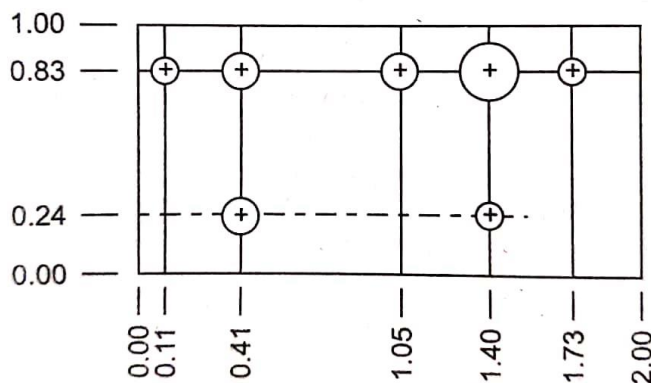
Specify a point or enter an option. The leader is created automatically. The No Leader option cancels the Leader option before the leader is created.

To remove a leader, delete the arc length dimension and recreate it without the leader option.

6.3.4 ORDINATE

Dimension Toolbar : 
Dimension Menu : Ordinate
Command Line : Dimordinate
Specify feature location : Specify a point or snap to an object

Specify leader endpoint or (Xdatum/Ydatum/Mtext/Text/Angle): Specify a point or enter an option.

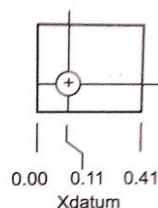


Leader Endpoint Specification

Uses the difference between the feature location and the leader endpoint to determine whether it is an X or a Y ordinate dimension. If the difference in the Y ordinate is greater, the dimension measures the X ordinate. Otherwise, it measures the ordinate.

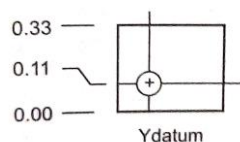
Xdatum

Measures the X ordinate and determines the orientation of the leader line and dimension text. The Leader Endpoint prompt is displayed, where you can specify the endpoint.



Ydatum

Measures the Y ordinate and determines the orientation of the leader line and dimension text. The Leader Endpoint prompts are displayed, where you can specify the endpoint.



Mtext

Displays the In-Place Text Editor, which you can use to edit the dimension text. To add a prefix or a suffix, enter the prefix or suffix text before or after the generated measurement. Use control codes and Unicode character strings to enter special characters or symbols. See Control Codes and Special Characters.

To edit or replace the generated measurement, delete the text, enter the new text, and then click OK. If alternate units are not turned on in the dimension style, you can display them by entering square brackets ([]). For more information about formatting dimension text, see "Change Existing Objects," in the User's Guide.

The current dimension style determines the appearance of the generated measurements. After you choose OK, the Leader Endpoint prompt is redisplayed.

Text

Customizes the dimension text on the command line. The generated dimension measurement is displayed within angle brackets.

Enter dimension text <current> : Enter the dimension text, or press ENTER to accept the generated measurement.

To include the generated measurement, use angle brackets (< >) to represent the generated measurement. If alternate units are not turned on in the dimension style, you can display alternate units by entering square brackets ([]).

Dimension text properties are set on the Text tab of the New, Modify and Override Dimension Style dialog boxes. After you press ENTER, the Leader Endpoint prompt is redisplayed.

Angle


Change the angle of the dimension text.

Swift angle of dimension text:

Enter an angle. For example, to rotate the text 45 degrees, enter 45.

After you specify the angle, the leader Endpoint prompt is redisplayed.

6.3.5 RADIUS

Dimension Toolbar	:	
Dimension Menu	:	Radius
Command Line	:	Dimradius

Select are or circle:

DIMRADIUS measures the radius of the selected are or circle and displays the dimension text with a radius symbol in front of it.

Specify dimension line location or Mtext/Text/Angle: Specify a point or enter an option.

DINRADIUS measures the radius of an arc or circle, and displays the dimension text with the letter R in front of it.



Dimension Line Location

Determines the angle of the dimension line and the location of the dimension text.

Mtext

Displays the In-Place Text Editor, which you can use to edit the dimension text. To add a prefix or a suffix, enter the prefix or suffix text before or after the generated measurement. Use control codes and Unicode character strings to enter special characters or symbols. See Control Codes and Special Characters.

To edit or replace the generated measurement, delete text, enter the new text, and then click OK. If alternate units are not turned on in the dimension style, you can display them by entering square brackets ([]). For more information about formatting dimension text, see "Change Existing Objects" in the User's Guide. The current dimension style determines the appearance of the generated measurements.

Text

Customizes the dimension text on the command line. The generated dimension measurement is displayed within angle brackets.

Enter dimension text <current> : Enter the dimension text, or press ENTER to accept the generated measurement.

To include the generated measurement, use angle brackets (< >) to represent the generated measurement. If alternate units are not turned on in the dimension style, you can display alternate units by entering square brackets ([])

Dimension text properties are set on the Text tab of the New, Modify, and Override Dimension Style dialog boxes.


Angle

Changes the angle of the dimension text.

Specify angle of dimension text: Enter an angle

For example, to rotate the text 45 degrees, enter 45.

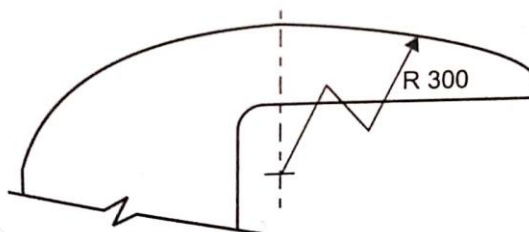
6.3.6 JOGGED

Dimension Toolbar	: 
Dimension Menu	: Jogged
Command Line	: dimjogged
Select arc or circle	: Select an arc, circle, or polyline arc segment

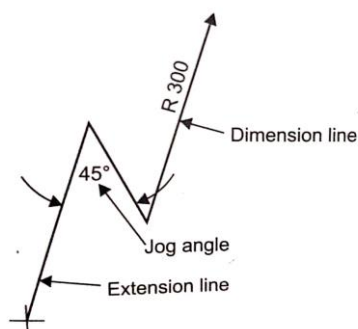
DIMJOGGED measures the radius of the selected object and displays the dimension text with a radius symbol in front of it. The origin point of the dimension line can be specified at any convenient location.

Create Jogged Radius Dimensions

With DIMJOGGED, you can create jogged radius dimensions, also called "foreshortened radius dimensions," when the center of an arc or circle is located off the layout and cannot be displayed in its true location. The origin point of the dimension can be specified at a more convenient location called the center location override.



You can control the default angle of the jog in the Modify Dimension Style dialog box, Symbols and Arrows tab, under Radius Dimension Jog.




Once a jogged radius dimension is created, you can modify the jog and the center location override by

Using grips to move the features

Changing the locations of the features with the Properties palette

Using STRETCH

6.3.7 DIAMETER

Dimension Toolbar	: 
Dimension Menu	: Diameter
Command Line	: Dimdiameter

CHECK YOUR PROGRESS

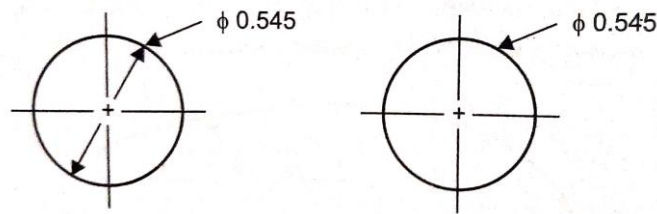
6. What is the use of Diameter Command?

Select are or circle

DIMDIAMETER measures the diameter of the selected circle or arc and displays the dimension text with a diameter symbol in front of it.


Specify dimension line location or (Mtext/Text/Angle): Specify a point or enter an option.

DIMDIAMETER measures the diameter of an arc or circle, and displays the dimension text with the diameter symbol in front of it.



For horizontal dimension text, if the angle of the radial dimension line is greater than 15 degrees from horizontal, a hook line, also called a dogleg or landing, one arrowhead long, is created next to the dimension text.

6.3.8 ANGULAR

Dimension Toolbar : 

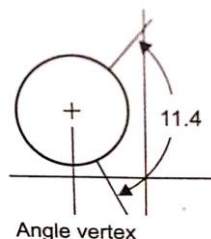
Dimension Menu : Angular

Command Line : Dimangular


Select arc, circle, line, or <specify vertex> : Select an arc, circle, or line, or press ENTER to create the angular dimension by specifying three points.

After you define the angle to dimension, the following prompt is displayed:

Specify dimension arc line location or [Mtext/Text/Angle]:



13.9 BASELINE

Dimension Toolbar : 
Dimension Menu : Baseline
Command Line : Dimbaseline

If no dimension was created in the current session, you are prompted to select a linear, ordinate, or angular dimension to use as the base for the baseline dimension.

Select base dimension: Select a linear, ordinate, or angular dimension.

Otherwise, the program skips this prompt and uses the dimension object that was last created in the current session. If the base dimension is linear or angular, the following prompt is displayed:

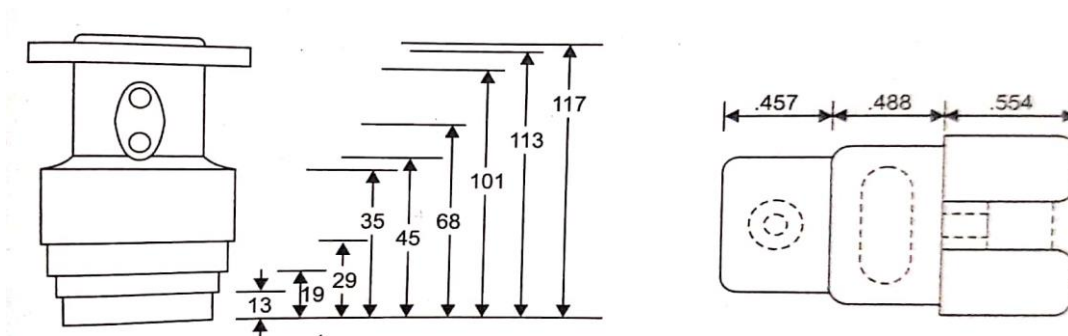
Specify a second extension line origin or (Undo/Select) <Select>:
Specify a point, enter an option, or press ENTER to select a base dimension.

If the base dimension is ordinate, the following prompt is displayed:

Specify feature location or Undo/Select) <Select>:

To end the command, press ENTER twice, or press ESC. The current dimension style determines the appearance of the text.


Baseline dimensions are multiple dimensions measured from the same baseline. Continued dimensions are multiple dimensions placed end to end. You must create a linear, aligned, or angular dimension before you create baseline or continued dimensions. You create



Baseline dimensions incrementally from the most recently created dimension in the current session.

Both baseline and continued dimensions are measured from the previous extension line unless you specify another point as the point of origin.

6.3.10 CONTINUE

Dimension Toolbar : 
Dimension Menu : Continue
Command Line : Discontinue

If no dimension was created in the current session, you are prompted to select a linear, ordinate, or angular dimension to use as the base for the continued dimension.

Select continued dimension: Select a linear, ordinate, or angular dimension.

Otherwise, the program skips this prompt and uses the dimensions object that was last created in the current session. If the base dimension is linear or angular, the following prompt is displayed:


Specify a second extension line origin or (Undo/Select) <Select>:
Specify a point enter an option, or press ENTER to select a base dimension.

If the base dimension is ordinate, the following prompt is displayed:

Specify feature location or (Undo/Select) <Select>:

To end the command press ENTER twice, or press ESC. The current dimension style determines the appearance of the text.

6.3.11 LEADER

Dimension Toolbar : 
Dimension Menu : Leader
Command Line : Qleader

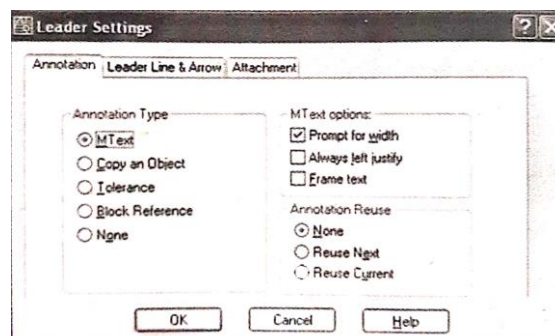


Use QLEADER to quickly create leaders and leader annotation. You can use the Leader Settings dialog box to customize the command so that it prompts you for the number of leader points and the annotation type suited to your drawing needs. You can use QLEADER to.

CHECK YOUR PROGRESS

7. How QLeader is working?


- Specify leader annotation and annotation format
- Set the location where leaders attach to multiline text annotation
- Limit the number of leader points
- Constrain the angle of the first and second leader segments.



If associative dimensioning is turned on with DIMASSOC, the leader start point can be associated with a location on an object. If the object is relocated, the arrowhead remains attached to the object and the leader line stretches, but the text or feature control frame remains in place.

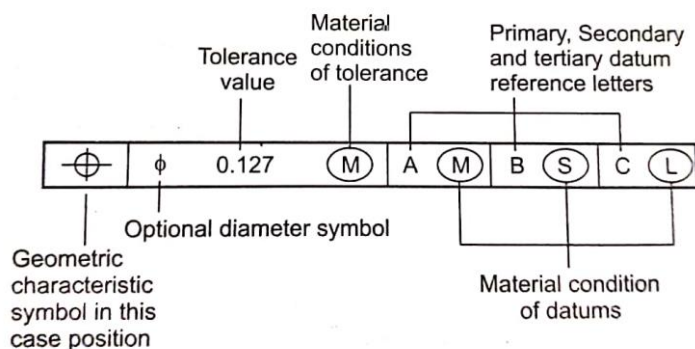
Specify first leader point, or [Settings] <Settings>: Specify the first leader point or press ENTER to specify leader settings].

6.3.12 TOLERANCE

Dimension Toolbar : 
Dimension Menu : Tolerance
Command Line : Tolerance

The Geometric Tolerance dialog box is displayed.


Geometric tolerances show acceptable deviations of form, profile, orientation, location, and run out of a feature. You add geometric tolerances in feature control frames. These frames contain all the tolerance information for a single dimension. Geometric tolerances can be created with or without leader lines, depending on whether you create them with TOLERANCE and LEADER.



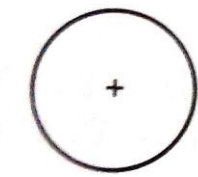
A feature control frame consists of two or more components. The first feature control frame contains a symbol that represents the geometric characteristic to which a tolerance is being applied, for example, location, profile, form, orientation, or runout. Form tolerances control straightness, flatness, circularity and cylindricity; profiles control line and surface. In the illustration, the characteristic is position.

You can use most editing commands to change feature control frames, and you can snap to them using the object snap modes. You can also edit them with grips.

6.3.13 CENTER MARK

Dimension Toolbar : 
Dimension Menu : Center Mark
Command Line : Dimcenter
Select arc or circle : Use an object selection method

You can choose between center marks and centerlines and specify their size when you set up the dimension style. See DIMSTYLE. You can also change center mark setting using the DIMCEN system variable.



Center mark



Centerlines

DIMEDIT

To make extension lines oblique

Click Dimension menu → Oblique.

Select the dimension.

Enter a value for the angle of obliqueness, or specify two points.

Dimension toolbar :

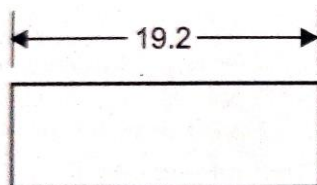
Command line : DIMEDIT

Enter type of dimension editing [Home/New /Rotate/Oblique)
<Home>: Enter an option or press ENTER

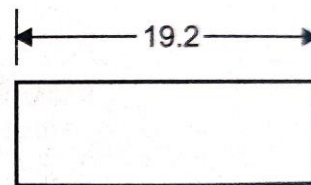
Home

Moves rotated dimension text back to its default position.

Select objects: Use an object selection method to select dimension objects.



Before home

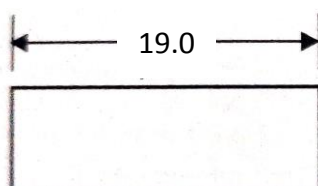


After home

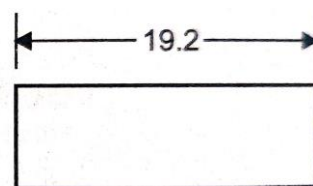
The selected dimension text is returned to its default position and rotation as specified in its dimension style.

New

Changes dimension text using the In-Place Text Editor.



Before home



After home

The generated measurement is represented with angle brackets (< >). To add a prefix or suffix to the generated measurement, enter the prefix or suffix before or after the angle brackets. Use control codes and Unicode character strings to enter special characters or symbols. See Control Codes and Special Characters.

To edit or replace the generated measurement, delete the angle brackets, enter the new dimension text, and then choose OK. If alternate units are not turned on in the dimension style, you can display them by entering square brackets ([]). For more information about formatting dimension text, see "Change Existing Objects," in the User's Guide.

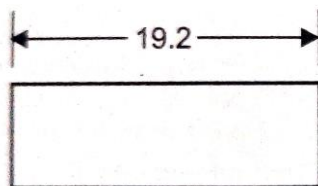
Rotate

Rotates dimension text. This option is similar to the Angle option of DIMTEDIT.

Enter text angle:

Entering 0 places the text in its default orientation, which is determined by the vertical and horizontal text settings on the Text tab of the New, Modify, and Override Dimension Style dialog boxes. See DIMSTYLE. The DIMTIH and DIMTOH system variables control this orientation.

Select objects: Use an object selection method to select dimension objects.



Rotate text


Oblique

Adjusts the oblique angle of the extension lines for linear dimensions. Linear dimensions are created with extension lines perpendicular to the direction of the dimension line. The Oblique option is useful when extension lines conflict with other features of the drawing.

Select objects: Use an object selection method to select dimension objects.

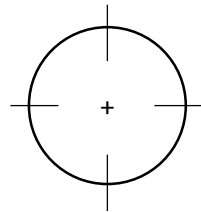
Enter oblique angle (press ENTER for none): Enter an angle or press ENTER.

6.3.14 ERASE

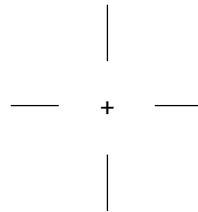
Modify Toolbar : 
Modify Menu : Erase
Shortcut Menu : Select the objects to erase, right-click in the drawing area, and click Erase.

Command Line : Erase
Select objects : Use an object selection method and press ENTER when you finish selecting objects.

The objects are removed from the drawing.



Object selected

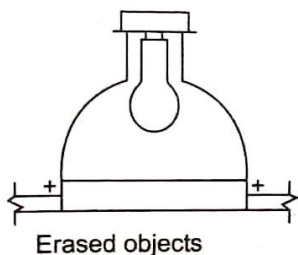


Object erased

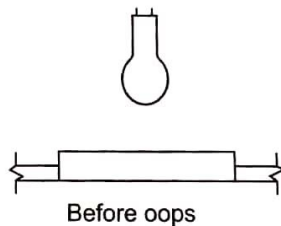
6.3.15 OOPS

Command Line : Oops

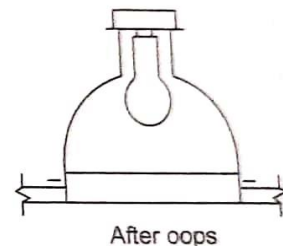
OOPS restores objects erased by the last ERASE command.



Erased objects



Before oops




After oops

You can also use OOPS after BLOCK or WBLOCK because these commands can erase the selected objects after creating a block. However, you cannot use OOPS to restore parameters, actions, or grips in the Block Editor.

You cannot use OOPS to restore objects on a layer that has been removed with the PURGE command.

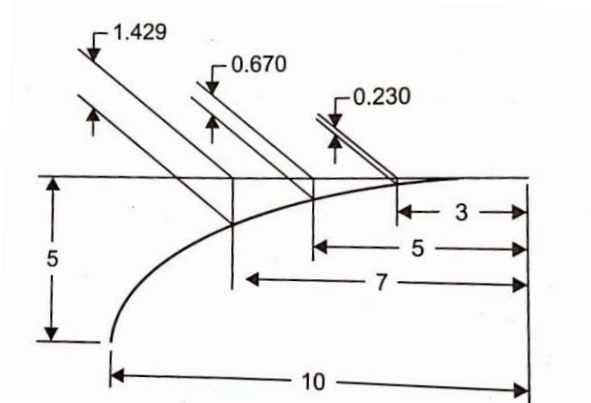
6.3.16 COPY

Modify Toolbar : 
Modify Menu : Copy
Shortcut menu : Select the objects to copy, and right-click in the drawing area
Command Line : Copy
Select objects : Use an object selection method and press ENTER when you finish

Specify base point or (Displacement)<Displacement>: Specify a base point or enter d

The two points you specify define a vector that indicates how far the copied objects are to be moved and in what direction. If you press ENTER at the Specify Second Point prompt, the first point is interpreted as a relative

X,Y,Z displacement. For example, if you specify 2,3 for the base point and press ENTER at the next prompt, the objects are copied 2 units in the X direction and 3 units in the y direction from their current position.



The COPY command repeats for convenience. To exit the command press ENTER.


Displacement

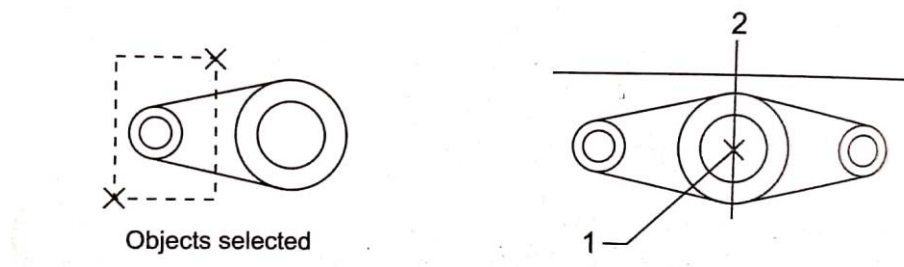
Specify displacement <last values>: Enter coordinates to represent a vector

The coordinate values that you enter specify a relative distance and direction.

6.4 EDIT COMMANDS

6.4.1 MIRROR

- Modify Toolbar : 
- Modify Menu : Mirror
- Command Line : Mirror
- Select objects : Use an object selection method and press ENTER to finish
- Specify first point of mirror line : Specify a point
- Specify second point of mirror line : Specify a point

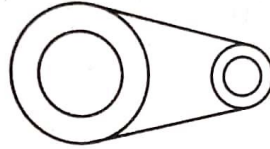


The two specified points become the endpoints of a line about which the selected objects are mirrored. For mirroring in 3D this line defines a mirroring plane perpendicular to the XY plane of the user coordinate system (UCS) containing the mirror line.

Erase source objects? [Yes/No] <N>: Enter y or n, or press ENTER

Yes

Places the mirrored image into the drawing and erases the original objects.

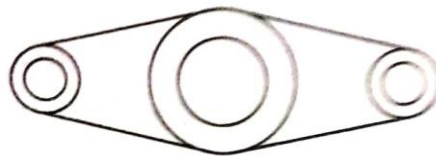


Object selected deleted

CHECK YOUR PROGRESS

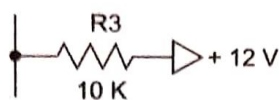
8. How Mirror command is working?

Places the mirrored image into the drawing and retains the original objects.

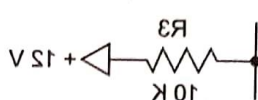


Original objects retained

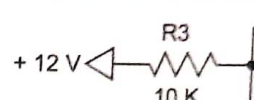
To manage the mirror properties of text objects, use the MIRRTEXT system variable. The default setting of MIRRTEXT is 1 (on), which causes a text object to be mirrored just like any other object. When MIRRTEXT is off (0), text is not reversed.



Before mirroring




After mirroring
Mirrtext - 1

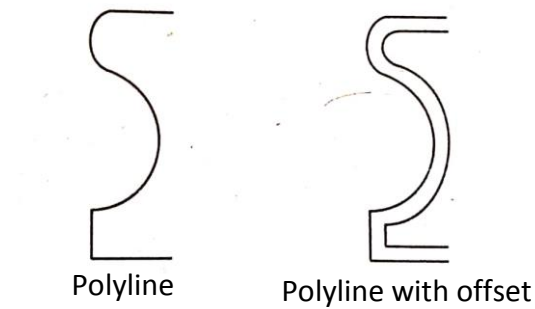


After mirroring
Mirrtext - 0

6.4.2 OFFSET

Modify Toolbar : 
Modify Menu : Offset
Command Line : Offset
Current settings : Erase source = current Layer = current OFFSETGAPTYPE = current.

Specify offset distance or (Through/Erase/Layer) <current>:Specify a distance, enter an option, or press ENTER



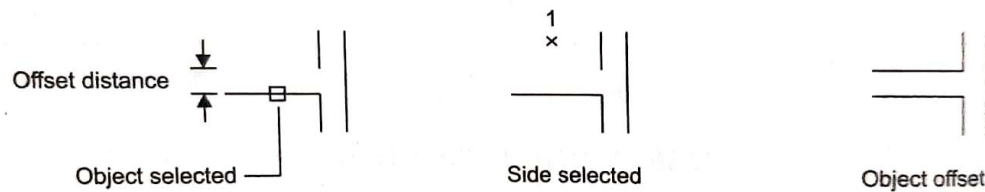
The OFFSET command repeats for convenience. To exit the command press ENTER.

Offset Distance

Creates an object at a specified distance from an existing object.

Select object to offset or Exit/Undo) <exit: Select one object, enter an option, or press ENTER to end the command.

Specify point on side to offset or [Exit/Multiple/Undo] <exit or next object>: Specify a point (1) on the side of the object you want to offset or enter an option.

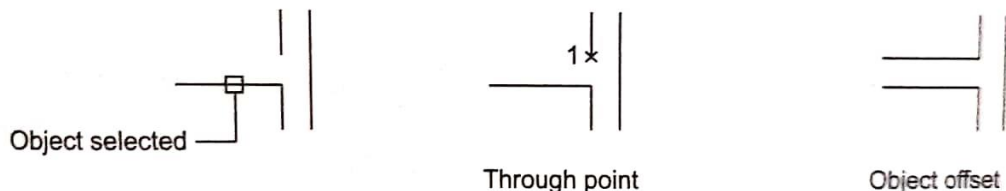


Through

Creates an object passing through a specified point.

Select object to offset or <exit>: Select one object or press ENTER to end the command.

Specify through point or (Exit/Multiple/Undo)<exit or next object>: Specify a point (1) through which you want the offset object to pass or enter a distance.



Erase

Erases the source object after it is offset.

Erase source object after offsetting? [Yes/No]<current>: Enter y or n

Layer

Determine whether offset objects are created on the current layer or on the layer of the source object.

Enter layer option for offset objects (Current Source]<current>: Enter an option.

Exit

Exits the OFFSET command.

Multiple

Enters the Multiple offset mode, which repeats the offset operation using the current offset distance.

Undo

Reverses the previous offset.

6.4.3 MOVE

Modify Toolbar : 

Modify Menu : Move

Shortcut menu : Select the objects to move, and right-click in the drawing area. Click Move

Command Line : Move

Select objects : Use an object selection method and press ENTER when you finish.

Specify base point or (Displacement <Displacement>: Specify a base point or enter d.

Specify second point or <use first point as displacement>: Specify a point or press ENTER.

The two points you specify define a vector that indicates how far the selected objects are to be moved and in what direction.

If you press ENTER at the Specify Second Point prompt, the first point is interpreted as a relative X,Y,Z displacement. For example, if you specify 2,3 for the base point and press ENTER at the next prompt, the objects move 2 units in the X direction and 3 units in the Y direction from their current position.

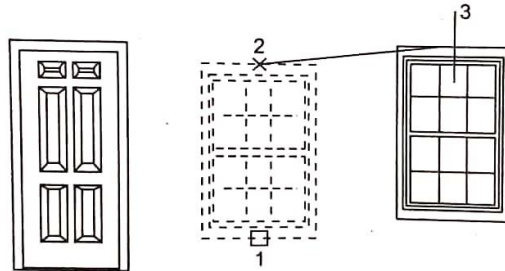
Displacement

Specify displacement <last values>: Enter coordinates to represent a vector

The coordinate values that you enter specify a relative distance and direction.

Specify Distance with Two Points

Move an object using the distance and direction specified by a base point followed by a Second point. In this example, you move the block representing a window. After clicking Move on the Edit menu, select the object to be moved (1). Specify the base point for the move (2) followed by a second point (3). The object is moved the distance and direction of point 2 to point 3.



Specify Distance with Relative Coordinates

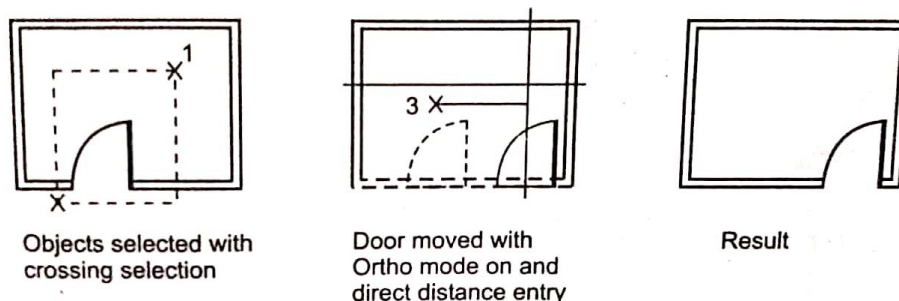
You can move an object using a relative distance by entering coordinate values for the list point and pressing ENTER for the second point. The coordinate values are used as a relative displacement rather than the location of a base point.

Note: Do not include an @ sign as you normally would for relative coordinates, because relative coordinates are expected.

To copy objects a specified distance, you can also use direct distance entry with Ortho mode and polar tracking. For more information, see Enter Direct Distances.

Use a Stretch-Move

You can also STRETCH to move objects if all their endpoints lie entirely within the selection window. Turn on Ortho mode or polar tracking to move the objects at a specific angle.




A practical example is moving a door in a wall. The door in the illustration is entirely within a crossing selection, while the wall lines are only partly within the crossing selection area.

The result is that only the endpoints that lie within the crossing selection move.

CHECK YOUR PROGRESS

9. How move command is working?

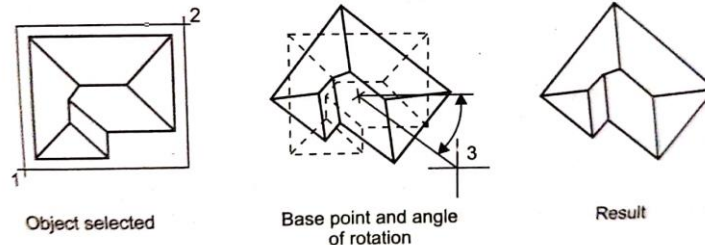
6.4.4 ROTATE

Modify Toolbar	: 
Modify Menu	: Rotate
Shortcut menu	: Select the objects to rotate, and right-click in the drawing area. Click Rotate.
Command line	: rotate
Current positive angle in UCS	: ANGDIR=current ANGBASE-current
Select objects	: Use an object selection method and press ENTER when you finish
Specify base point	: Specify a point
Specify rotation angle or [Copy/Reference]	: Enter an angle, specify a point, enter c, or Enter r

Rotate an Object by Dragging

Drag the object around the base point and specify a second point. Use Ortho mode, polar tracking, or object snaps for greater precision.

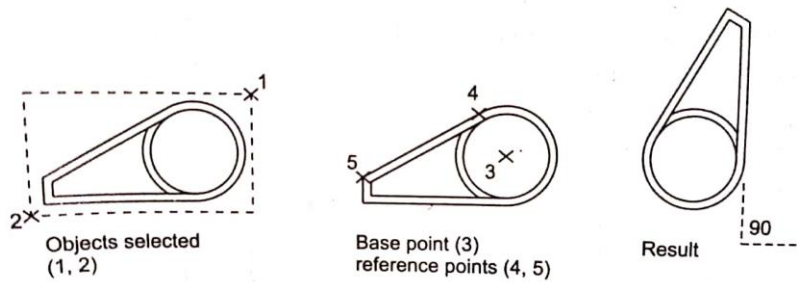
For example, you can rotate the plan view of a house by selecting the objects (1), specifying a base point (2), and specifying an angle of rotation by dragging to another point (3).



Rotate an Object to an Absolute Angle

With the Reference option, you can rotate an object to align it to an absolute angle.

For example, to rotate the part in the illustration so the diagonal edge rotates to 90 degrees, you select the objects to be rotated (1, 2), specify the base point (3), and enter the Reference option. For the reference angle, specify the two endpoints of the diagonal line (4,5). For the new angle, enter 90.

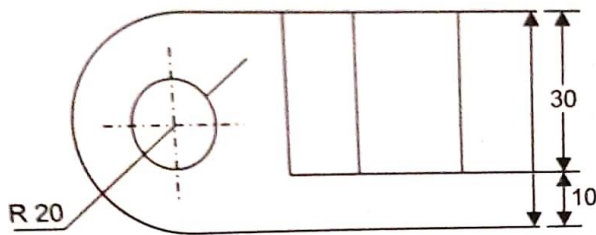


CHECK YOUR PROGRESS

10. How Rotate command is working?

6.5 ILLUSTRATIVE EXAMPLES

1. Command: LINE



Specify first point: 0,0

Specify next point or (Undo): 60,0

Specify next point or (Undo): 60,10

Specify next point or (Close/Undo): 20,10

Specify next point or (Close/Undo): 20,40

Specify next point or (Close/Undo): 0,40

Command: ARC

Specify start point of arc or (Center):

Specify second point of arc or (Center/End): _e

Specify end point of arc:

Specify center point of arc or (Angle/Direction/Radius: _r Specify radius of arc: 20

Command: CIRCLE

Specify center point for circle or [3P/2P/Ttr (tan tan radius)]:

Specify radius of circle or (Diameter)

Command: LINE

Specify first point: 20,40

Specify next point or (Undo): 60,40

Specify next point or (Undo): 60,10

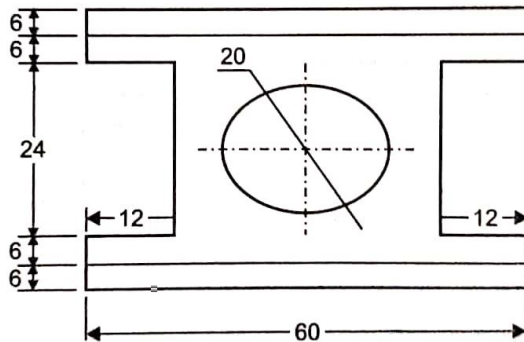
Specify next point or (Close/Undo):

Command: LINE

Specify first point: 0,34

Specify next point or (Undo): 60,34

3. Command: LINE



Specify first point: 0,0

Specify next point or (Undo): 60,0

Specify next point or (Undo): 60,6

Specify next point or (Close/Undo): 0,6

Specify next point or (Close/Undo): 0,0

Specify next point or (Close/Undo):

Command: LINE

Specify first point: 0,6

Specify next point or (Undo): 0,12

Specify next point or (Undo): 12,12

Specify next point or (Close/Undo): 12,36

Specify next point or (Close/Undo): 0,36

Specify next point or (Close/Undo): 0,42

Specify next point or (Close/Undo): 60,42

Specify next point or (Close/Undo): 60,36

Specify next point or (Close/Undo): 48,36

Specify next point or (Close/Undo): 48,12

Specify next point or (Close/Undo): 60,12

Specify next point or (Close/Undo): 60,6

Specify next point or (Close/Undo):

Command: LINE

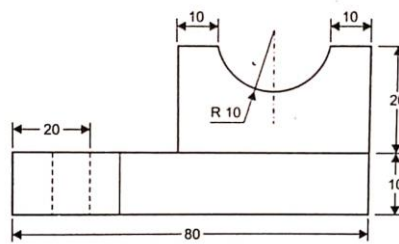
Specify first point: 0,42

Specify next point or (Undo): 0,48

Specify next point or (Undo): 60,48

Specify next point or (Close/Undo): 60,42

4. Command: LINE



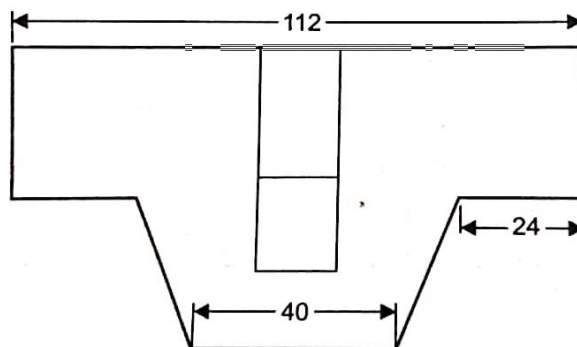
Specify first point: 0,0
Specify next point or (Undo): 80,0
Specify next point or (Undo): 80,10
Specify next point or (Close/Undo): 0,10
Specify next point or (Close/Undo): 0,0
Specify next point or (Close/Undo):

Command: LINE
Specify first point: 80,10
Specify next point or (Undo): 80,30
Specify next point or (Undo): 70,30
Specify next point or (Close/Undo):

Command: LINE
Specify first point: 40,10
Specify next point or (Undo): 40,30
Specify next point or (Undo): 50,30
Specify next point or (Close/Undo):

Command: ARC
Specify start point of arc or (Center):
Specify second point of arc or (Center/End): _e
Specify end point of arc:
Specify center point of arc or (Angle/Direction/Radius): _r
Specify radius of arc: 10

5. Command: LINE



Specify first point: 0,0
Specify next point or (Undo): 24,0
Specify next point or (Undo): 36,-20

Specify next point or (Close/Undo): 76,-20
Specify next point or (Close/Undo): 88,0
Specify next point or (Close/Undo): 112,0
Specify next point or (Close/Undo): 112,20
Specify next point or (Close/Undo): 0,20
Specify next point or (Close/Undo): c

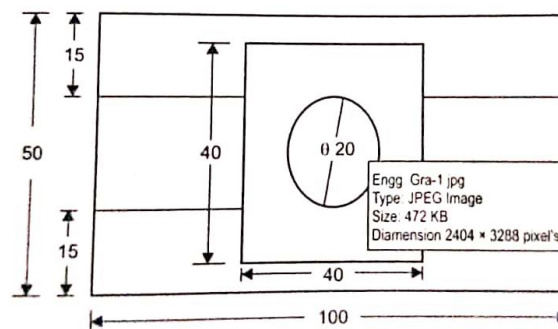
Command: LINE

Specify first point: 51,20
Specify next point or (Undo): 51,-10
Specify next point or (Undo): 61,-10
Specify next point or (Close/Undo): 61,20
Specify next point or (Close/Undo):

Command: LINE

Specify first point: 51,4
Specify next point or (Undo): 61,4

6. Command: LINE



Specify first point: 0,0
Specify next point or (Undo): 100,0
Specify next point or (Undo): 100,50
Specify next point or (Close/Undo): 0,50
Specify next point or (Close/Undo): 0,0

Command: LINE

Specify first point: 30,5
Specify next point or (Undo): 70,5
Specify next point or (Undo): 70,45
Specify next point or (Close/Undo): 30,45
Specify next point or (Close/Undo): 30,5

Command: CIRCLE

Specify center point for circle or (3p/2P/Ttr (tan tan radius): 50,25
Specify radius of circle or Diameter: 10

Command: LINE

Specify first point: 0,15

Specify next point or (Undo): 30,15

Specify next point or (Undo):

Command: LINE

Specify first point: 0,35

Specify next point or (Undo): 30,35

Specify next point or (Undo):

Command: LINE

Specify first point: 70,15

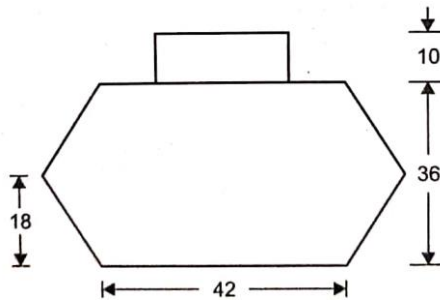
Specify next point or (Undo): 100,15

Command: LINE

Specify first point: 70,35

Specify next point or (Undo): 100,35

7. Command: LINE



Specify first point: 10,0

Specify next point or (Undo): 52,0

Specify next point or (Undo): 62,18

Specify next point or (Close/Undo): 52,36

Specify next point or (Close/Undo): 10,36

Specify next point or (Close/Undo): 0,18

Specify next point or (Close/Undo): c

Command: LINE

Specify first point: 21,36

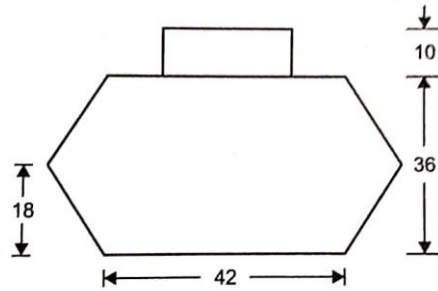
Specify next point or (Undo): 21,46

Specify next point or (Undo): 41,46

Specify next point or (Close/Undo): 41,36

Specify next point or (Close/Undo):

8. Command: LINE



Specify first point: 0,0
Specify next point or (Undo): 60,0
Specify next point or (Undo): 60,48
Specify next point or (Close/Undo): 0,48
Specify next point or (Close/Undo): 0,27
Specify next point or (Close/Undo): 55, 27
Specify next point or (Close/Undo): 55,21
Specify next point or (Close/Undo): 0,21
Specify next point or (Close/Undo): c

Command: CIRCLE

Specify center point for circle or (3P/2P/Ttr (tan tan radius): 60,24
Specify radius of circle or (Diameter): 24

Command: CIRCLE

Specify center point for circle or (3P/2P/Ttr (tan tan radius): 60,24
Specify radius of circle or (Diameter) <24.0000>: 10

Command. TRIM

Current settings: Projection=UCS, Edge=Extend Select cutting edges...

Select objects or <select all>: select all

Select object to trim or shift-select to extend or
(Fence/Crossing/Project/Edge/eRase/Undo):

Select object to trim or shift-select to extend or
(Fence/Crossing/Project/Edge/eRase/Undo):

Select object to trim or shift-select to extend or
(Fence/Crossing/Project/Edge/eRase/Undo):

Select object to trim or shift-select to extend or
(Fence/Crossing/Project/Edge/eRase/Undo):

Select object to trim or shift-select to extend or
(Fence/Crossing/Project/Edge/eRase/Undo):

Select object to trim or shift-select to extend or
(Fence/Crossing/Project/Edge/eRase/Undo):

Select object to trim or shift-select to extend or
(Fence/Crossing/Project/Edge/eRase/Undo):

Select object to trim or shift-select to extend or
(Fence/Crossing/Project/Edge/cRase/Undo):

Select object to trim or shift-select to extend or
(Fence/Crossing/Project/Edge/eRase/Undo): "Cancel"

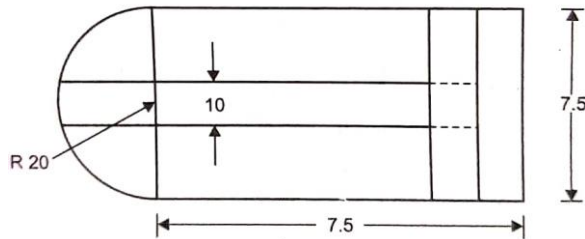
Command: ERASE

Select objects: Specify opposite corner: 0 found

Select objects: 1 found

Select objects: 1 found, 2 total

9. Command: LINE



Specify first point: 0,0

Specify next point or (Undo): 75,0

Specify next point or (Undo): 75,40

Specify next point or (Close/Undo): 0,40

Specify next point or (Clone/Undo): c

Command: CIRCLE

Specify center point for circle or (3P/2P/Ttr (tan tan radius): 0,20

Specify radius of circle or (Diameter): 20

Command: LINE

Specify first point: 65,0

Specify next point or (Undo): 65,40

Specify next point or (Undo):

Command: LINE

Specify first point: 55,0

Specify next point or (Undo): 55,40

Specify next point or (Undo):

Command: LINE

Specify first point: 55,15

Specify next point or (Undo): 0,15

Specify next point or (Undo):

Command: LINE

Specify first point: 55,25

Specify next point or (Undo): 0,25

Specify next point or (Undo):

Command: trim

Current settings: Projection=UCS, Edge=Extend

Select cutting edges...

Select objects or <select all>:

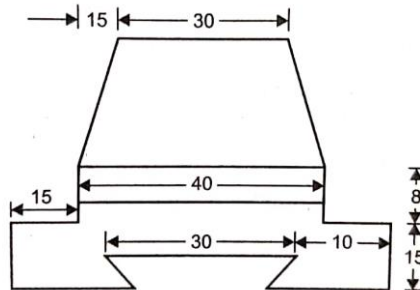
Select object to trim or shift-select to extend or
(Fence/Crossing/Project/Edge/eRase/Undo):

Select object to trim or shift-select to extend or
(Fence/Crossing/Project/Edge/eRase/Undo):

Select object to trim or shift-select to extend or
(Fence/Crossing/Project/Edge/eRase/Undo):

Select object to trim or shift-select to extend or
(Fence/Crossing Project/Edge/eRase/Undo): "Cancel"

10. Command: LINE



Specify first point: 0,0

Specify next point or (Undo): 25,0

Specify next point or (Undo): 20,5

Specify next point or (Close/Undo): 50,5

Specify next point or (Close/Undo): 45,0

Specify next point or (Close/Undo): 70,0

Specify next point or (Close/Undo): 70,15

Specify next point or (Close/Undo): 55,15

Specify next point or (Close/Undo): 55,8

Specify next point or (Close/Undo): 50,50

Specify next point or (Close/Undo): 20,50

Specify next point or (Close/Undo): 15,23

Specify next point or (Close/Undo): 15,15

Specify next point or (Close/Undo): 0,15

Specify next point or (Close/Undo):

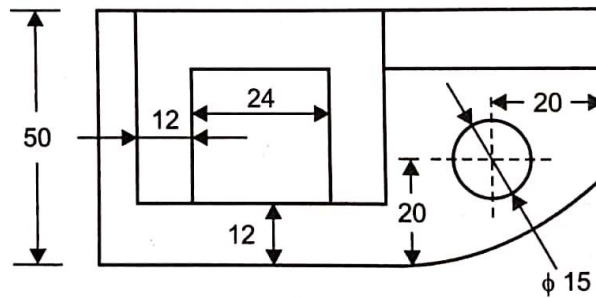
Command: LINE

Specify first point: 15,23

Specify next point or (Undo): 55,23

Specify next point or (Undo):

11. Command: LINE



Specify first point: 0,0
Specify next point or (Undo): 100,0
Specify next point or (Undo): 100,50
Specify next point or (Close/Undo): 0,50
Specify next point or (Close/Undo): c

Command: LINE
Specify first point: 6,50
Specify next point or (Undo): 6,12
Specify next point or (Undo): 54,12
Specify next point or (Close/Undo): 54,50
Specify next point or (Close/Undo):

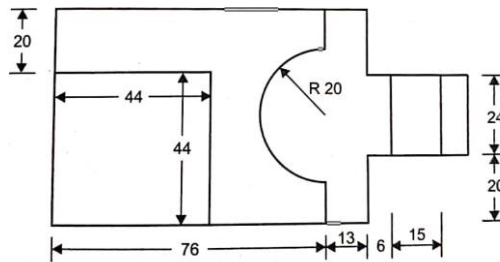
Command: LINE
Specify first point: 18,12
Specify next point or (Undo): 18,38
Specify next point or (Undo): 42,38
Specify next point or (Close/Undo): 42,12
Specify next point or (Close/Undo):

Command: LINE
Specify first point: 54,38
Specify next point or (Undo): 100,38
Specify next point or (Undo):

Command: CIRCLE
Specify center point for circle or (3P/2P/Ttr (tan tan radius)): 80,20
Specify radius of circle or (Diameter): d Specify diameter of circle: 15

Command: FILLET
Current settings: Mode = TRIM, Radius = 0.0000
Select first object or (Undo/Polyline/Radius/Trim/Multiple): r Specify
fillet radius
<0.0000>: 25

12 Command: LINE



Specify first point: 0,0
Specify next point or (Undo): 89,0
Specify next point or (Undo): 89,20
Specify next point or (Close/Undo): 95,20
Specify next point or (Close/Undo): 95,44
Specify next point or (Close/Undo): 89,44
Specify next point or (Close/Undo): 89,64
Specify next point or (Close/Undo): 0,64
Specify next point or (Close/Undo): c

Command: LINE
Specify first point: 0,44
Specify next point or (Undo): 44,44
Specify next point or (Undo): 44,0
Specify next point or (Close/Undo):

Command: PLINE
Specify start point: 76,64
Current line-width is 0.0000
Specify next point or (Arc/Halfwidth/Length/Undo/Width): 76,52
Specify next point or (Arc/Close/Halfwidth/Length/Undo/Width): arc
Specify endpoint of arc or
(Angle/Center/CLOSE/Direction/Halfwidth/Line/Radius/Second pt/Undo/Width): r
Specify radius of arc: 20
Specify endpoint of arc or (Angle): 76,12
Specify endpoint of arc or
Angle/CENTER/CLOSE/Direction/Halfwidth/Line/Radius/Second pt/Undo/Width): r line
Specify next point or (Arc/Close/Half width/Length/Undo/Width): 76,0
Specify next point or (Arc/Clone/Half width/Length/Undo/Width):

6.6 SUMMARY

In the present world computers are used to perform many tasks which were done by man earlier. Computers used different softwares to perform their tasks. By means of some special kinds of software, computer can effectively be used to do the work of even drafting.

The process of drafting and drawing the objects on the computer screen with special software and hardware are the latest techniques called CAD.

The CAD technique is based on interactive computer graphics (ICG). This helps to convert the data given /entered by the operator/system programmer into the form of graphics. The programmer enters the data in the form of commands by using hardware through input devices which is converted into graphics by the software.

AutoCAD is very effective CAD software. It is used globally by CAD professionals. It supports 2D drafting and 3D modeling, AutoCAD is user friendly and easy to learn.

The chapter explains, with the help of practice sessions, examples and assignments, the important commands needed to draw 2D drawings. This book is not enough to explore AutoCAD in 3D environment. Interested readers may go through the advance books on AutoCAD for this purpose.

In this unit we have studied basically how to give command draw line, arc, circle, polygon, ellipse and rectangle. Of course this unit has given a systematic idea of editing and dimensioning software command. The different types of examples and exercises given, have briefly and concisely explained the AutoCAD fundamentals.

6.7 KEYWORDS

1. **Construction Plane:** The two dimensional XY plane is ACAD
2. **Undo:** The most recently used action
3. **View Ports:** Viewport is a bounded area that display some portion of the model space of a drawing.
4. **UCS:** UCS is used to change the location of the 0,0,0 origin point and the orientation of the XY plane and the Z-axis.
5. **Offset:** It is used to copies of lines at a specified distance
6. **Dimangular:** It is used to create an aligned linear dimension

6.8 ANSWERS TO CHECK YOUR PROGRESS

1. LINE Command is used to create single lines, multiple line segments with and without arcs, multiple parallel lines and free hand sketch lines.
2. ZOOM command is used to increase or decrease the size of the image displayed in the graphics area.
3. RECTANG and PLINE are the commands used to create a rectangle.
4. DIAMETER measure the diameter of the selected circle or arc and displays the dimension text with a diameter symbol in front of it.
5. Use an object selection method and press ENTER to finish.
6. Arc length dimensions measure the distance along an arc or polyline arc segment.
7. QLEADER to quickly create leaders and leader annotation.
8. The two specified points become the endpoints of a line about which the selected objects are mirrored.

9. Select the objects to move, and right-click in the drawing area. Click Move.
10. Select the objects to rotate, and right-click in the drawing area. Click Rotate.

6.9 EXERCISE

1. What is mean by Line Command? Explain How to draw line using Line Command?
2. Using ARC command how to draw Arc using different coordination point? Explain.
3. Explain Center Point, Radius, Diameter in ARC Command.
4. Explain RECTANGLE command with its properties.
5. What Quick Dimension? Explain with its types Draw appropriate diagram.
6. Explain the MIRROR Command with its example.
7. Explain the MOVE command with its example.
8. Explain the ROTATE Command with its example.
9. Write the AutoCAD commands for the exercises given below.

