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Engineering Graphics for Diploma

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ENGINEERING GRAPHICS FOR DIPLOMA
K.C. John

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Preface

Engineering Graphics is the language for communication and documentation of engineering design. With the arrival of computers, the usage of this language has advanced into the areas of manufacturing, assembly, inspection and maintenance since all these functions are well executed through computer aided drafting (CAD) and three-dimensional modelling. Based on these developments, it is highly recommended for the students entering the engineering field to study the fundamentals of this language in their first year of the engineering course. Advanced topics in Engineering Graphics are covered in the following years according to their respective branches of study. Three-dimensional objects located in space have to be converted and presented on a two-dimensional drawing sheet or monitor screen using the ISO Standard coding system. To fully understand the techniques used in this process, the student should develop good visualization capacity.

Even though there are a number of textbooks available for engineering drawing, the treatment of the subject is still found to be difficult for an average student. This book is an effort to overcome or reduce this difficulty.

The content of the textbook Engineering Graphics for Diploma is divided into seven modules. A topic is first introduced in each chapter of a module, with brief explanation and necessary pictorial views, and then mastered gradually through a number of worked-out examples. The examples are explained using a step-by-step procedure and illustrating drawings. All the drawings are prepared in First Angle Projection and strictly follow the ISO/BIS format.

Module A—*Preliminaries*, covers the fundamentals of manual drafting, lettering, freehand sketching and dimensioning of views. Module B describes two-dimensional drawings like geometrical constructions, conics, miscellaneous curves and drawing of scales. Three-dimensional drawings are well explained in Module C, starting with projections of points and then straight lines located in all the four quadrants. Projections of plane lamina, geometrical solids and sections of them are also described in detail in the same module. Module D deals with the surfaces of solids, such as intersection of surfaces and their developments.

Drawings of pictorial views of solids and objects are illustrated in Module E. These include isometric projection, oblique projection and perspective projections. The perspective view drawing presented in first angle itself avoids discontinuity in study, as compared to other available textbooks in the market. Fundamentals of machine drawing are covered in Module F in four chapters. The last Module G introduces computer aided drafting (CAD) for producing professional level orthographic drawings. Selected questions from various Diploma Examination question papers and their solutions are also given. This enables students to prepare themselves for Diploma Examinations.

I am highly grateful to the eminent professors, teachers and earnest students of various engineering institutions for their encouragement. Their creative criticism and suggestions helped me to prepare this book in its current form. I extend my heartfelt thanks to PHI Learning for taking interest and the effort to publish this textbook at international standards.

Acknowledgement is also due to the Bureau of Indian Standards, whose work has been consulted for the preparation of this book. I would also like to express my gratitude to various Boards of Technical Education in India, for permitting me to include their examination questions as worked-out examples.

K.C. John

Module A

Preliminaries

CHAPTER 1

Introduction to Engineering Graphics

Engineering graphics is the principal method of communication in the field of engineering and science. The graphics of engineering design and construction is one among the most important courses of all studies for engineering. The indisputable reason why graphics is so important is that, it is the language used by the designer, technician and engineer, to communicate, design and construct details to others.

1.1 THE GRAPHIC LANGUAGE

Engineering drawing is the graphic language used by engineers and technologists globally. The graphic language may be defined as the graphic representation of physical objects and their relationships. Like other spoken and written languages, this graphic language had also been developed through centuries. The language of graphics is written in the form of drawings using straight and curved lines which represent the shape, size and specifications of physical objects. The language is read by interpreting the drawings so that the physical objects can be constructed exactly as conceived by the designer. Like every language, the graphic language also has its own rules of grammar. These rules are governed by certain code of practice. An engineer, should have proper understanding of the theory of projection, dimensioning and conventions related to working drawings, in order to become professionally efficient.

1.2 TRADITIONAL DRAFTING

Engineering drawings are made up of straight and curved lines to represent the surfaces, edges and centres of objects. Symbols, dimensional values and word-notes are added to these lines so that they collectively make the complete description. The traditional drafting is the preparation of these drawings manually, by freehand sketching or with the help of drawing instruments.

Freehand drawing is done by sketching the lines without instruments other than pencil and eraser. They are much used commercially as preliminary designs. Preparation of drawings to scale, using various drawing instruments is the standard conventional drafting method. After the preparation of the scaled drawings, they are traced using instruments and ink pens to the tracing paper or tracing film for taking prints.

1.3 COMPUTER-AIDED DRAFTING (CAD)

In Computer-Aided Drafting (CAD) the drawings are prepared with the help of computer and the prints of the required size are taken, using the output devices. CAD is defined as a process of producing drawings in which a computer software and associated hardware are used. Nowadays, microcomputers are widely employed for automated drafting.

Compared to traditional drafting, CAD is faster as well as efficient and the modifications can be brought out very easily. Depending on the drafting task, the production of drawings can be increased to about 2 to 10 times with a good CAD system. In modern industries the traditional drafting is being replaced by computer aided drafting. This doesn't mean that traditional drafting instruments are totally removed by computer and related output devices. The computer (the hardware and software) is only a strong tool to produce accurate drawings in the shortest time. Trained designers and drafters who know engineering graphics very well are supposed to operate the CAD systems. This training in drafting is given using traditional graphic instruments. After understanding engineering graphics by traditional drafting methods, one can have the expertise in operating CAD system to develop the skill and speed for excellent performance.

1.4 GRAPHIC INSTRUMENTS AND THEIR USE

To prepare a neat and scaled pencil drawing, good drafting instruments are to be used. A list of drawing instruments and materials required for the same is given below:

1. Drawing board
2. Minidrafter or T-square
3. Instrument box containing long compass, spring bow compass, small bow divider etc.
4. Set-squares (45° and 30–60°) and protractor
5. Engineer's scale set and steel rule (30 cm)
6. Drawing pencils (standard and clutch pencils)
7. Eraser
8. Adhesive tape, drawing pins or clips
9. Sandpaper pad
10. Blade, pocket knife or pencil sharpener
11. Handkerchief, duster or dusting brush
12. Letter stencils, french curves, erasing shield and templates

Drawing Board

Drawing board, made up of seasoned soft wood (pine, fir, oak etc.) are used for traditional drafting. Figure 1.1 shows a drawing board with a minidrafter clamped in position. If a T-square is used instead of minidrafter for drafting, a straight working edge of hard wood (ebony) is also required on the left edge of the board. Figure 1.2 shows a drawing board with a T-square in drawing position. The standard sizes of drawing boards as per Bureau of Indian standards are shown in Table 1.1.

Minidrafter

Drafting machines are used for professional drafting of engineering drawings. It mainly consists of two scales at right

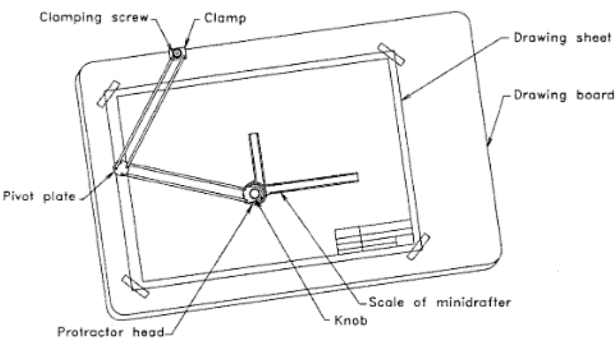


Fig. 1.1 Drawing board with minidrafter clamped in position.

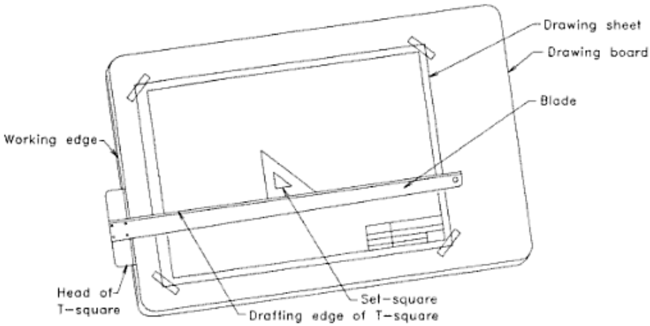


Fig. 1.2 Drafting board with T–square in drawing position.

Table 1.1 Dimensions of drawing boards

Board Designation	Size in mm (width × length)	Sheet size
D_0	1500 × 1000	A_0
D_1	1000 × 700	A_1
D_2	700 × 500	A_2
D_3	500 × 350	A_3

angles which can do the function of T-square and protractor. A simplified version of the drafting machine is called *minidrafter*. Figure 1.1 shows a minidrafter fitted to a drawing board. The unit has a clamping end which is fixed on the board by a hand screw and two mutually perpendicular scales with protractor head on the other end. The body of the minidrafter contains two of parallelograms made of bars pivoted to these ends.

To use the minidrafter, first of all set the protractor head at zero position and tighten the knob. Then clamp the drafter to the top edge of board as shown in Fig. 1.1 using the hand screw so that the horizontal scale is parallel to the horizontal edges of the board.

T-square

T-square is composed of a long strip called *blade* fixed rigidly by screws at right angles to a shorter strip called *head* (stock). Figure 1.2 shows a T-square placed on a drawing board in its drawing position. T-squares are generally made of wood or plastic. For wooden T-squares the top drawing side of the blade and the inner sliding slide of the stock are fitted with straight edges of hardwood.

A T-square is used for drafting on a drawing board fitted with straight working edge in the left hand side (see Fig. 1.2). The stock of the T-square is kept perfectly touching on the working edge and is moved forward and backward by left hand, so that different horizontal positions of the drafting edge are obtained for drawing.

Compared to minidrafter, T-square gives better accuracy in large size drawings, but the speed of drafting is low. For small size drawings as well as for study purpose the use of minidrafter is recommended.

Instrument Box

The drafting instruments like compass, divider, etc. are available in boxes called *engineering drawing instrument box*. A standard three bow-set instrument box contains the following devices:

1. Large size compass
2. Lengthening bar for large size compass
3. Small bow compass
4. Large size divider
5. Small bow divider
6. Small bow ink-pen
7. Inking pens.

The most useful types of compasses and dividers are shown in Fig. 1.3. Inking-pens and bow ink-pen are used for tracing of drawings with ink. The large size compass is used to draw large size circles and arcs. A pointed needle is fitted at

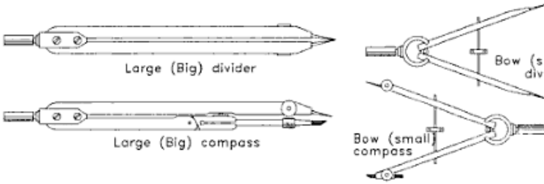


Fig. 1.3 Drawing board with T–square in drawing position.

one leg while a pencil lead is inserted in the other leg. Both the legs are provided with knee joints so that while drawing circles or arcs of radius above 60 mm, they can be bent to keep the lead and the pointed needle almost perpendicular to the surface of drawing sheet. See Fig. 1.4(a). For drawing arcs and circles of radius 180 mm and above, the lengthening bar is to be added to the leg, holding the lead. Circles and arcs of radius less than 15 mm are drawn, using the small bow compass. The lead tip of a compass has to be sharpened and set as shown in Fig. 1.4(b). This shape of point is formed by first sharpening the outside of the lead on the sandpaper pad to a long flat bevel approximately 6 mm long and then finishing it with a slight rocking motion to reduce the width of the point . A soft lead (HB) gives dark thick line which can be used for drawing object boundaries, while a hard lead (H) gives light coloured thin lines used for showing construction lines.

The large size divider is used to divide curved lines or straight lines into desired number of equal parts. They are also used to transfer a length from the scale to the drawing sheet or to transfer a length from drawing sheet to the scale for measurement. Small bow divider is used as the large divider for shorter lengths below 20 mm.

Inking pens and bow pens are also included in the standard instrument box. They are used for tracing of drawings with ink.

Set-squares and Protractor

Set-squares (triangles) and protractor are made of transparent plastic material. See Fig. 1.5. Set-squares (45°

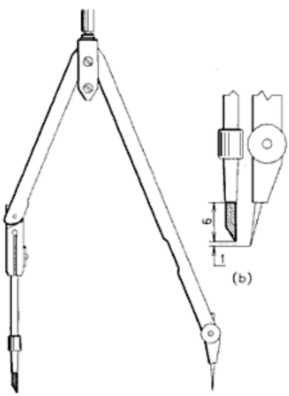


Fig. 1.4 Use of large (big) compass.

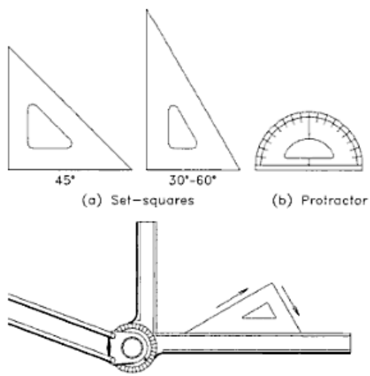


Fig. 1.5 Set-squares and protractor.

and 30°–60°) are used to draw vertical as well as inclined lines. They are also used for setting combination of angles of 15°, while using T-square. Along with minidrafter set-squares are also used to draw inclined lines of 30°, 45° and 60° as shown in Fig. 1.5(c). Protractor of circular or semicircular type is used to set up or measure angles. Since the size of the protractor head of a minidrafter is small, the use of a large size protractor is recommended for accurate angle setup and measurements.

Engineers Scale Set and Steel Rule

A set of 8 scales designated from M1 to M8 are required to take measurements for scaled drawings. They are made of either cardboard or plastic [see Fig. 1.6(a)]. A steel rule of 30 cm length is also recommended to draw inclined lines as well to use as full size scale for measurements.

Drawing Pencils

For the preparation of drawings, two types of pencils are generally used:

(a) Wooden drawing pencils, and

(b) Clutch pencils.

Wooden drawing pencils of hexagonal cross section are the traditional types used for engineering drawings. They are designated as HB, H, 2H etc. Here, H stands for hardness and B for the blackness and softness. They are sharpened as shown in Fig. 1.6(b) to conical point or chisel point. Chisel pointed pencil is used for finishing thick lines. The conical and chisel points are shaped by grinding the cylindrical lead on the sandpaper pad.

Mechanical clutch pencils of lead size 0.5 mm diameter are now available for reasonable prices [see Fig. 1.6(d)]. They are preferred because they can give better uniform line width and no sharpening is required. Lead grades of HB, H and 2H are used in these pencils.

Eraser

Soft natural rubber or nylon rubber is used as eraser to remove unnecessary lines on the drawing sheet [see Fig. 1.6(c)].

Adhesive Tape, Drawing Pins or Clips

To fix the drawing sheet on the drawing board adhesive tape is generally used [see Fig. 1.6(e)]. Use of drawing pins will spoil the surface of the board. Use of clips may not be possible while using a shorter drawing sheet on a large size drawing board.

Sandpaper Pad

This consists of a small wooden block on which fine grained sandpaper is pasted about half of its length (see Fig. 1.6). The sandpaper pad is used to sharpen wooden pencil lead and compass lead tip for correct line thickness.

Blade, Pocket Knife or Pencil Sharpener

These instruments are used for sharpening the wooden pencil and cutting of drawing sheets to the required size.

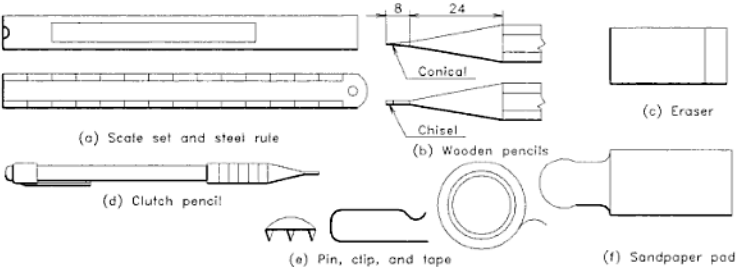
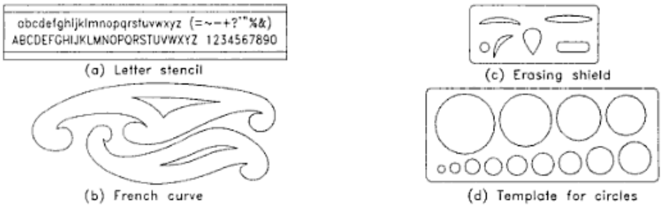


Fig. 1.6 Drawing instruments



(a) Letter stencil (b) French curve (c) Erasing shield (d) Template for circles

Fig.1.7

Handkerchief, Duster or Dusting Brush

Cleaning of board, and drawing sheet can be done using duster or dusting brush. Handkerchief can be used for this as well as for wiping wet hands.

Letter Stencils, French Curves, Erasing Shield and Templates

These items, made from transparent plastic sheets, are used to improve the speed and finish of drawing (see Fig. 1.7). Letter stencils are used to print letters especially in tracing. Curved rulers called *French curves* or *irregular curves* are used for drawing curved lines other than constant radius arcs. They are available in different forms and sizes in boxes. Erasing shield is used to shield the required lines while erasing the nearby unwanted lines. Templates are plastic sheets with the standard shapes like circles, ellipses, symbols etc. cut in them so that the drawing can be made fast and accurate. Templates are widely used for tracing of drawings.

1.5 CODE OF PRACTICE FOR ENGINEERING DRAWING

International Standards Organisation (I.S.O.) Geneva, formulated and issued international standards for engineering drawings in 1982. India, approved the same and accordingly modified the Indian Standards IS: 696-1972 to IS: 10714-1983. The Indian Standards Institution (ISI) which is taking care of standards in India, has been renamed as *Bureau of Indian Standards (B.I.S.).* Engineering Drawing Committee (E.D.C.) of B.I.S. has adopted the I.S.O. standards since 1983. As per letter No: EDC 20:1/T-57 dated 17th April 1984, IS: 696 -1972 has been withdrawn by the B.I.S. The new drawing standards are now available in 19 different booklets. For the use of students, a special publication containing all the relevant information in the field of drawing standards, was brought out in March 1989. This special publication is referred to as SP:46-1988 titled "Engineering Drawing Practice for students of schools and colleges".

All technical institutions should have the complete set of Indian standards accessible to technical drawing classes for the benefit of the students.

1.6 LINES

One of the fundamentals of good draftsmanship is line work. For general engineering drawings, various types of lines are recommended by IS:10714-1983. Each line has a specific meaning and function.

Types of Lines

Different types of lines recommended are shown in Table 1.2. If lines of other types or thickness are to be used for special fields like electrical or pipe work diagrams, or if lines specified in the table are to be used for applications other than those mentioned, the convention adopted should be explained by notes on the drawing itself.

An example of the use of various types of lines is shown in Fig. 1.8. The following are the types of lines used:

1. Type A

These types of lines are continuous thick lines and are used to represent:

A1 Visible out lines and

A2 Visible edges.

Type A Lines are also used for the following applications:

1. Thread ends,
2. Limits of useful thread lengths, and
3. Main representation in diagrams, graphs, charts and flow diagrams.

Table 1.2 Types of lines

	Line	Description
A		Continuous thick
B		Continuous thin
C		Continuous thin freehand
D		Continuous thin with zig-zags
E		Dashed thick
F		Dashed thin
G		Chain thin
H		Chain thin, thick at ends and changes of direction
J		Chain thick
K		Chain thin double dashed

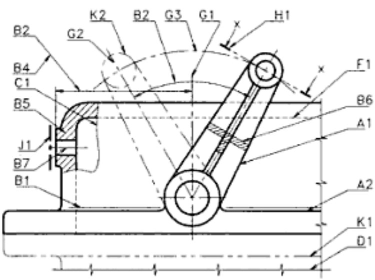


Fig. 1.8 Use of various types of lines.

2. Type B

These types of lines are continuous thin lines and used to represent:

B1 Imaginary lines of intersection
B2 Dimension lines
B3 Projection lines
B4 Leader lines
B5 Hatching (section) lines
B6 Outline of revolved section in place and
B7 Short centre lines.

Type B lines are also used for the following applications:

1. Diagonal cross to represent flat surface
2. Bent lines (as in the sheet metal works)
3. Boxing or encircling of details
4. Representation of repeating details (as root circle of gears)
5. Grain flow direction as in rolling
6. Direction of lay of layers (as transformer stampings) and
7. Grid lines

3. Type C

These types of lines are continuous thin lines drawn freehand and used to represent:

C1 Limits of partial views, interrupted views, and sectional views (if limits are not chain thin lines).

4. Type D

These types of lines are continuous thin (straight or curved) lines with zig-zags and are used to represent:

D1 Limits of partial views, interrupted views, and sectional views (if limits are not chain thin lines).

5. Type E

These types of lines are dashed thick lines and are used to represent:

E1 Hidden outlines and
E2 Hidden edges.

6. Type F

These type of lines are dashed thin lines and are used to represent:

F1 Hidden outlines and
F2 Hidden edges.

7. Type G

These types of lines are chain thin lines and are used to represent:

G1 Centre lines,
G2 Lines of symmetry and
G3 Trajectories.

Type G lines are also used for the following applications :

1. Pitch circle of gears,
2. Pitch circle diameter of holes and
3. Parting-off planes.

8. Type H

These types of lines are chain thin, thick at ends and change of direction. They are used to represent:

H1 Cutting planes.

9. Type J

These types of lines are chain thick lines and are used to represent:

J1 Indication of lines or surfaces to which a special requirement applies.

10. Type K

These types of lines are chain thin double dashed and are used to represent:

K1 Outline of adjacent parts,
K2 Alternative and extreme position of movable parts,
K3 Centroidal lines,
K4 Initial out lines prior to forming and
K5 Parts situated in front of the cutting plane.

These types of lines are also used for the following applications:

1. Outline of selective details,
2. Finish forms of raw parts and
3. Enclosure of special fields/areas.

Thickness (width) of Lines and Their Spacing

The lines used in a drawing can be grouped into two types based on their thicknesses (widths). They are:

1. Thick lines
2. Thin lines.

The ratio of the thick to the thin line should not be less than 2:1. The thickness of lines should be according to the size and shape of the drawing and it can be selected from the following grades:

0.18, 0.25, 0.35, 0.5, 0.7, 1, 1.4, and 2 mm

It may be noted that the grading of these lines, is in $\sqrt{2}$ increments. The distance between parallel lines, including hatching should be greater than twice the thickness of the heaviest line.

Note:

1. The thickness (width) of lines for different views of an object, should be the same, provided the scale used is the same.
2. The line thickness of 0.18 mm may be avoided.
3. The minimum distance between parallel lines including hatching lines should be 0.7 mm.
4. A line width of 0.5 mm for thick lines and 0.25 mm for thin lines are recommended for pencil drawings.

Order of Priority of Coinciding Lines

When two or more lines of different types shown in Fig. 1.8, coincide, the following order of priority should be observed:

(a) *First priority for Type A:* visible outlines and visible edges.
(b) *Second priority for Type E or F:* hidden outlines and hidden edges.
(c) *Third priority for Type H:* cutting planes represented by chain thin lines thickened at ends.
(d) *Forth priority for Type G:* centre lines and lines of symmetry and trajectories.
(e) *Fifth priority for Type K:* centroidal lines.
(f) *Sixth priority for Type B:* projection lines.

Hidden Details

Interior details of an object, which are not visible from outside, are represented by hidden lines. Short dashes having an approximate length of 2 to 3 mm and a distance of 1 to 2 mm between them, maybe used for hidden lines. The dashes of the hidden lines should touch the visible outlines or hidden lines, both at the starting and ending points. Superimposing of hidden details is shown in Fig. 1.9.

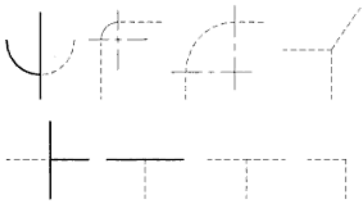


Fig. 1.9 Superimposing of hidden details.

1.7 SCALES

Scales is the ratio of the linear dimensions of one element of an object as represented in original drawing to the real linear dimension of the same element of the object itself. Drawings of small objects can be made of the same size as the object itself. If the actual dimensions of the object are used to prepare its drawing, the scale used is called *full size scale*. For full size scale, the ratio is 1:1. In the case of very large objects, the actual dimensions of the object cannot be used in the preparation of its drawing. Hence, linear dimensions of the object are to be reduced for the purpose of drawing. Now, the scale is called *reduction scale*. For reduction scale, the ratio is smaller than 1:1. In the case of very small objects, the drawings are to be made larger than the object itself. The scale used for this, is called *enlargement scale*. For enlargement scale, the ratio is larger than 1:1.

The complete designation of scales can be indicated as follows:

SCALE 1:1 for full size.
SCALE 1:X for reduced scale.
SCALE X:1 for enlargement scale.

If there is no chance for misunderstanding, the word SCALE may be omitted. Scales recommended by BIS are shown in Table 1.3.

1.8 DRAWING SHEETS AND TITLE BLOCK

Drawing sheets are white papers of good quality used for the preparation of pencil drawings. One of the surfaces of the drawing sheet is usually smooth. This smooth surface is used for drawing.

Table 1.3 Scales for use on technical drawings (IS:46-1988)

Category	Recomended scales
Enlargement scales	50:1, 20:1, 10:1, 5:1, 2:1
Full size	1:1
Reduction scales	1:2, 1:5 1:10, 1:20, 1:50 1:100, 1:200, 1:500, 1:1000 1:2000, 1:5000, 1:10000

Various preferred sizes of drawing sheets are available in the market. I.S:10711-1983 recommends various choices of the drawing sheets based on their sizes. The preferred sizes of the drawing sheets are given in the Table 1.4.

Table 1.4 Preferred sizes of drawing sheets

Designation	Trimmed sizes in mm (width × length)
A_0	841 × 1189
A_1	594 × 841
A_2	420 × 594
A_3	297 × 420
A_4	210 × 297

The ratio between the two adjacent sides of a drawing sheet is $1:\sqrt{2}$ (i.e.1:1.414). The surface area of the sheet designated by A_0 is one square metre. Two successive sizes of drawing sheets are obtained either by halving or doubling the areas. For example, A_1 size drawing sheet is obtained by halving A_0 size sheet.

Selection of the size of the drawing sheet depends on the size of the object to be drawn and the scale used. Drawing sheets may be used with their longer sides placed either horizontally or vertically.

General Features

General features of a drawing sheet is shown in Fig. 1.10. Four centring marks given on the border facilitates the positioning of the drawing when reproduced or microfilmed. Grid reference permits easy location of details, modifications, etc. The rectangular divisions of the grid are marked by capital letters and numerals. Length of the side of the rectangle should not be less than 25 mm and not more than 75 mm. Extra margin may be provided on the left to facilitate easy filing and binding.

Title Block

Title block is to be placed within the drawing space at the bottom right hand corner of the drawing sheet and it should be visible when prints are folded. It should consist of one or

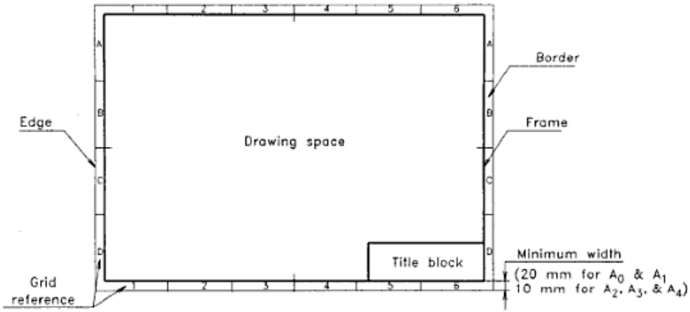


Fig. 1.10 General features of a drawing sheet

more adjoining rectangles. These rectangles may be divided further into boxes for inserting specific information. This information is grouped into zones as follows;

1. Identification zone and
2. One or more zones for additional information.

In the identification zone the following basic information is entered (refer to Fig. 1.11):

(a) The registration or the identification number,
(b) The title of the drawing and
(c) The name of the legal owner of the drawing.

Folding of Drawing Prints

There are two methods of folding of drawing prints. First method of folding is used for filing or binding. The second method of folding is used for keeping the prints individually in filing cabinet and is shown in Fig. 1.12. It should be remembered that all the drawing prints larger than A_4 size should be folded to A_4 size. The title block should be seen outside on the right bottom corner.

1.9 SUGGESTED PROCEDURE FOR DRAFTING

Engineering graphics is a subject to be studied not only by reading the book but also by drafting. A student of graphics should manually draw the figures following the correct procedure. With more practice he can not only get more knowledge in the subject, but also can develop speed, dimensional accuracy and finish of drawing.

Step by Step Procedure for Drafting

1. Set the minidrafter to its zero angle position and fix it on the left top corner of the drawing board such

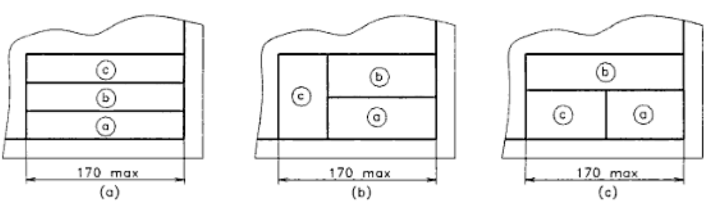


Fig. 1.11 Arrangements of information in the title bolck.

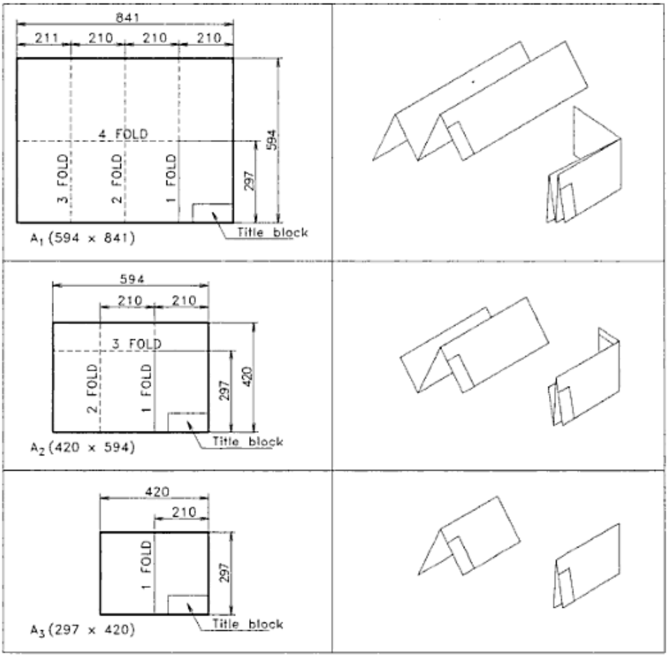


Fig. 1.12 Folding of prints for storing in filling cabinet.

that the long blade (scale) is parallel to the top edge of the board.

2. Fix the drawing sheet using adhesive tape on the drawing board such that the top edge of the sheet is parallel to the edge of the long blade. Now the students are advised to check whether the blades of the minidrafter are reaching the areas where drawings are to be prepared on the sheet.
3. Based on the solutions prepared in the workbook, select the locations for the answers (drawings) on the drawing sheet giving sufficient space between drawings to accommodate details like question number, dimensions, scales, subtitles, etc.
4. Draw the required views in the space intended for the solution of the first question using H pencil. The views should be drawn in thin lines. Erase the unnecessary length of lines, curves, etc.
5. Finish the drawing by converting the thin lines to correct type of lines as recommended in Fig 1.8. Place the dimensions as recommended in section 4.5 of Chapter four and name the views appropriately. Check whether the solution is complete in all respects except the entry of sub-titles.
6. In the similar way, draw the solutions to other questions one by one. After completing the drawing

of all solutions, write the sub-titles using capital letters on each solution as required.

7. Finish the title block and margin lines (Thick 0.5 mm lines) using H pencil. Remove the drawing sheet from the drawing board and fold it in a manner that the title block is visible from outside (see Fig. 1.12).

Layout of Drawing Sheet for Class Work

Although BIS recommends the layout of a standard drawing sheet as given Fig. 1.10, it is difficult to follow exactly the same proportions for the drawing sheet and title block for class work. A modified as well as simplified layout for drawing sheet is given in Fig. 1.13. Figure 1.14 gives the layout suggested for title block.

Directions for Better Drawing Output

Drafting Instruments and materials:

1. Use only standard engineering drawing instruments.
2. If a minidrafter is used, fix it in the proper location on the board tightly without slipping, but without destroying the thread of the screw.
3. If the drawing board surface is not smooth or damaged partially; use a thin plastic film of A_4 size below the drawing sheet. This gives better drawing finish. (A waste X-ray film will do the purpose).
4. Keep the compass ready for drafting, after fixing the HB lead and grinding it on the sandpaper pad to the chisel edge.

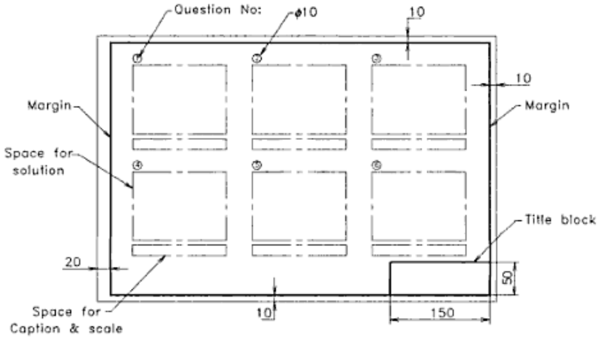


Fig. 1.13 Layout of drawing sheet for class work.

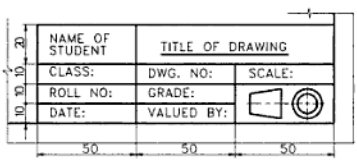


Fig. 1.14 Layout of the title block for class work.

5. Keep the textbook, sketch book and frequently drawing instruments on the right top side of the drawing board.
6. Clutch pencils of 0.5 mm diameter with H and HB lead are recommended for drafting and lettering respectively. Different body colours will help easy identification of H and HB pencils.
7. Adhesive tape is preferred for fixing the drawing sheet on board. After finishing drafting, remove the tape carefully from the drawing board as well as from the sheet before folding to A_4 size.

The drafting practice:

8. The knob of the protractor head of the minidrafter should be lifted slightly by the left hand while moving the drafter scales from one location to another.
9. Keep the two scales of minidrafter in horizontal—vertical position as far as possible. For drawing lines at standard angles (30°, 45°, and 60°) set-squares may be placed over the horizontal scale edge for easy location.
10. To draw a horizontal thin straight line, place the top side of the horizontal scale of minidrafter in position by left hand. Then draw the line from left to right holding the clutch pencil (H) approximately at 60° to the direction of the line and applying slight pressure. Also rotate the pencil slowly in the clockwise direction about it's axis while drawing. To get a thick line, use the same H pencil, change the angle of the pencil from 60° to 80° and draw the line applying moderate pressure. The suggested directions of pencil movements for drawing vertical and inclined lines are shown in Fig. 1.15.
11. To draw an arc or circle, adjust the opening of the leg of the compass to the required radius by measuring the dimension from the steel rule. Then hold the compass with right hand and place the needle point to the paper and draw the arc or circle in the clockwise direction. While drawing, the compass should be slightly inclined towards the direction of its rotation.
12. For getting dimensional accuracy in drafting, set-off the distances on the drawing sheet using divider and steel rule.
13. Use large diameter protractor, graduated up to 0.5°, for better accuracy. Never use the protractor of the minidrafter for angular measurements because it may bring error.
14. To get printing finish, letter stencils maybe used. For printing of all running matters, captions and titles block details, use capital letters of size 4 mm. Use a letter size of 5 to 10 mm (suitable to the space) for the title of the drawing. The printing of dimension numerals maybe done by freehand. But the letters should be of uniform size 3 to 4 mm, similar to the standard letters.

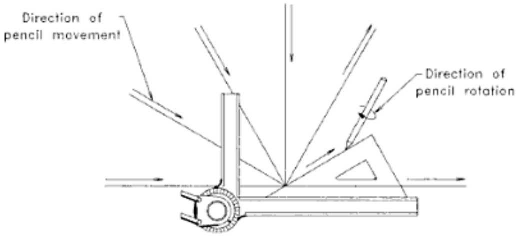


Fig. 1.15 Direction of drawing straight lines.

EXERCISE

1. A beginner in drafting has to draw the following types of figures in order to know the use of various drawing instruments and hence to develop the competance in the line work.

Draw the Figures 1.16 to 1.25 using the standard linetypes as given. The given dimensional values are in mm. Do not dimension the figures.

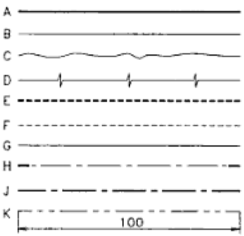


Fig. 1.16

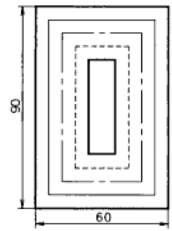


Fig. 1.17

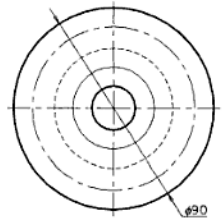


Fig. 1.18

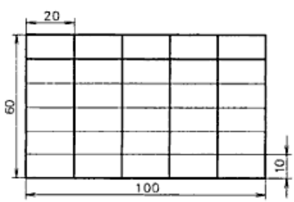


Fig. 1.19

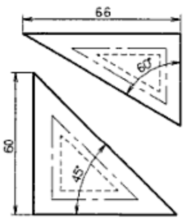


Fig. 1.20

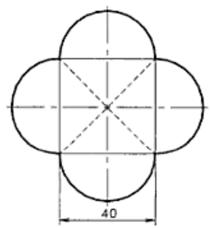


Fig. 1.21

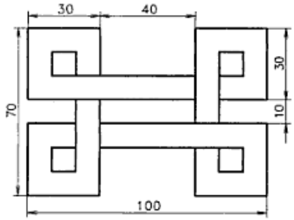


Fig. 1.22

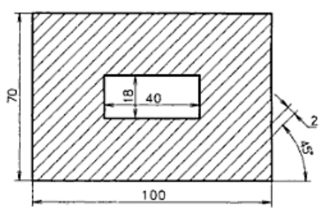


Fig. 1.23

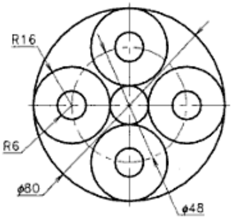


Fig. 1.24

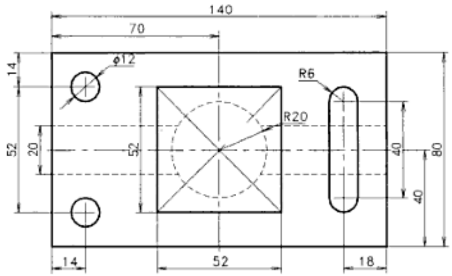


Fig. 1.25

CHAPTER 2

Lettering

The shape of an object which can be clearly described by graphic language is called *drawing*. Size description and instructive specification should also be indicated in the drawing for its completeness. They are in the form of notes and dimensions. All the notes and dimensions in the drawing should be lettered like printing and not as manuscript. Good lettering improves the clarity and appearance of the drawing.

2.1 SINGLE STROKE LETTERS

Bureau of Indian standards (IS: 9609-1990) recommended *single stroke letters* for engineering drawing. The term *single stroke* means that the letters and numerals should be made by uniform thick lines produced by the line width obtained in one stroke of the pencil or pen. This does not mean that the entire letter should be written without lifting the pen or pencil.

2.2 TYPES AND SIZES OF LETTERS

The single stroke letters recommended by BIS can be classified into the following categories:

Classification by inclination:

(i) Vertical (0°)
(ii) Inclined (15° to right)

Classification by height (h) to line thickness (d) ratio:

(i) Lettering A ($d = h/14$)
(ii) Lettering B ($d = h/10$)

The size of letters and numerals are designated by their height. The height of the capital letters is taken as the base of the dimensions. 10 mm letter means the height of the capital letter is 10 mm. The range of standard height (h) recommended for letters and numerals is as given below.

2.5,	3.5,	7,	10,	14	and	20 mm

2.3 VERTICAL AND INCLINED LETTERS

The vertical letters have the stems perpendicular to the base line of lettering. But for inclined letters, the stems are inclined at 15° to the right of the vertical drawn perpendicular to the base line. Figures. 2.1 gives the two types of vertical and inclined letters proportioned as per B.I.S.

2.4 LETTERING A

In lettering A, the height (h) of the letter is divided into 14 equal parts. The thickness of the line is taken as $d = 1/14h$.

The various dimensions of lettering, are taken as per Table 2.1. The location of the dimensional values is shown in Fig. 2.2. It is to be noted that the width of the letters is varying from $1/4h$. (for letter I) to $12/14h$ (for letter W). Figures 2.3 and 2.4 give specimen of 'lettering A, vertical and inclined.

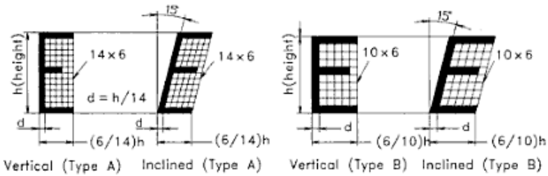


Fig. 2.1 Letter size and type.

Table 2.1 Recommended ratios for different

Characteristic		Ratio	Dimensions in mm			
Lettering height (height of capitals)	*h*	14/14*h*	3.5	5.0	7	14
Height of lowercase letters (without stem or tail)	*c*	10/14*h*	2.5	3.5	5	10
Spacing between characters	*a*	2/14*h*	0.5	0.7	1	2
Minimum spacing of base lines	*b*	20/14*h*	5	7	10	20
Minimum spacing between words	*e*	6/14*h*	1.5	2.1	3	6
Thickness of lines	*d*	1/14*h*	0.25	0.35	0.5	1

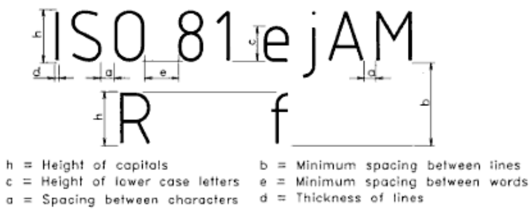


Fig. 2.2 Characteristics of lettering.

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
[(!?:;"-=+x:.%&)] 0123456789 IVX

Fig. 2.3 Specimen of lettering (A vertical).

ABCDEFGHIJKLMNOPQRSTUVWXYZ
abcdefghijklmnopqrstuvwxyz
[(!?:;"-=+x:.%&)] 0123456789 IVX

Fig. 2.4 Specimen of lettering (A inclined).

The system 'lettering A' is recommended for pencil drawings of large size letters.

2.5 LETTERING B

The proportions of 'lettering B' are given in Table 2.2. Here, the height of the letter h is divided into 10 equal parts. The line thickness of the letters is taken as $d = 1/10h$. The lettering B gives comparatively wide letters having more line thickness like bold style. For inking the drawings as well as for small letters using pencil, the proportions of lettering B is preferred more.

2.6 LETTERING PRACTICE

While printing the letter by using pencil, it is not easy to maintain the exact shape, proportions and thickness of lines of H lettering as given in the Tables 2.1 and 2.2. Anyhow, it is essential to maintain an approximate width to height proportion as well as shape for each of the letters and numerals. The thickness of the stem of the letters should be equal to that of produced by pencil point i.e. 0.5 mm. The approximate width to height proportions of the lettering A and lettering B is given in Table 2.3.

For pencil drawings, Type B lettering is recommended up to 10 mm size, because of its larger width. Letter size above 14 mm may be printed in lettering A style.

While printing the letters with pencil, certain order and directions of strokes are followed for better results. The general procedures followed for lettering are given below:

1. First, draw the vertical portions of the letter in the downward direction.
2. Draw the horizontal portions of the letter from the left to right.
3. Draw the inclined line portions in the downward directions, i.e. towards the right and then towards the left.
4. For curved line portions, move the pencil tip from top to bottom in the anticlockwise direction for the left side portion and clockwise direction for the right side portion of the letter.

The above-mentioned procedure are most suited for large size letters. But for small size letters, variations may be accepted.

For inking of drawing letter stencils are recommended. The pen width is selected according to the height of the letters as specified on the stencil. Stencils are also used for pencil drawings in order to improve the finish. The areas like title block, caption, etc. where large size letters are required, may be printed using stencils. However, freehand lettering is preferred in class work to mark dimensional values in order to get fastness. The method of freehand lettering for class work is described by the following examples.

Table 2.2 Recommended ratios for different characteristics for $d = h/10$ (Lettering B)

Characteristic		Ratio	Dimensions in mm			
Lettering height (height of capitals)	h	$10/10h$	3.5	5.0	10	20
Height of lower case letters (without stem or tail)	c	$7/10h$	2.5	3.5	7	14
Spacing between characters	a	$2/10h$	0.7	1.0	2	4
Minimum spacing of base lines	b	$14/10h$	5.0	7.0	14	28
Minimum spacing between words	e	$6/10h$	2.1	3.0	6	12
Thickness of lines	d	$1/10h$	0.35	0.5	1	2

Table 2.3 Appropriate width to height ratio for lettering A and B, h = height of the capital letters

Type \ Letters	W	AMVXY&ϕ	BDGHKNOP QRSTUZ 23456789	CEF LJ −+=	1	I	Minimum space
Lettering A (width / height)	$12/14h$	$9/14h$	$7/14h$	$6/14h$	$3/14h$	$1/14h$	2/14
Lettering B (width / height)	$9/10h$	$7/10h$	$6/10h$	$5/10h$	$3/10h$	$1/10h$	2/10

Example 2.1

Print the matter given below in freehand single stroke, vertical letters having 14 mm height. Follow type-A lettering

" ENGINEERING "

Refer to Fig. 2.5 and Fig. 2.6.

Draw two thin horizontal lines at 14 mm apart and mark off vertical lines for width of the letters and interspaces as given in Table 2.3. Here one unit is meaning 1/14 mm. Then print the letters by drawing the vertical and horizontal line portions using the minidrafter scales. The inclined lines may be finished with the help of a straight edge while the remaining portions by freehand drawing. After completing the lettering, remove the unnecessary thin lines without damaging the letters as given in Fig. 2.6.

Example 2.2

Write the following in freehand, vertical, single stroke letters of 10 mm size:

"Engineering Graphics"

Follow Type B lettering.

Refer to Fig. 2.7.

Draw four thin horizontal lines as shown (Fig. 2.7). Then write the capitals having approximately 10 mm height and lower case letters having 7 mm height. Give an interspacing of 2 mm. Finish the drawing by removing unnecessary lines.

Example 2.3

Write the following sentence in 5 mm or 4 mm capitals. Use Type B vertical lettering.

"DRAWING IS THE LANGUAGE
OF ENGINEERS"

Refer to Fig. 2.8.

Draw two thin base lines horizontally at 7 mm apart and 5 mm letter height lines as shown in the figure. Then print the letters with approximately 3 mm width and word spacing of one letter.

Fig. 2.5 Lettering in progress.

Fig. 2.6 Finished letters (Type A).

Fig. 2.7 Lettering (Type B).

Fig. 2.8 Lettering (Type B).

EXERCISES

1. Print the matter given below in freehand, single stroke, vertical letters having 14 mm height. Follow Type A lettering.

   "LETTERING"

2. Write the capital letters A to Z and numerals 0 to 9 in 21 mm vertical, Type A style.
3. Write capital letters A to Z and 0 to 9 in 5 mm vertical, Type B lettering.
4. Print the following in lettering B vertical:
   (i) "ENGINEERING DRAWING" (h = 10 mm)
   (ii) "FIRST ANGLE PROJECTION" (h = 8 mm)
   (iii) "Lettering should be done in a simple style" (h = 5 mm).
5. Write the following matter using lettering B, inclined:
   (i) A to Z and 0 to 9 (h = 10 mm).
   (ii) "Good lettering gives better appearance" (h = 5 mm).

CHAPTER 3

Freehand Drafting

Freehand drafting is the method of preparing drawings without the use of conventional drawing instruments. The straight or curved lines of a figure are drawn by freehand movement of the pencil or pen. Therefore, this kind of drafting is also called as freehand sketching.

3.1 IMPORTANCE OF FREEHAND DRAFTING

The freehand drafting process is a quick and convenient method of making shape description. Hence, it is very much useful and therefore important to engineers and technicians. A freehand sketch in engineering may be considered as a manuscript in literature prior to the printing . So they should be prepared in a good readable form, obeying all conventions and rules and without much variations in shape proportions. Freehand sketching has applications in the following areas:

1. While designing new products, the designer makes sketches or schematic diagrams to explain his ideas to others.
2. Assembly and working drawings are generally prepared from the initial freehand sketches of the same.
3. Any change in the existing design or shape suggested by the designer is conveyed to the draftsmen by the help of sketches.
4. In maintenance departments, freehand sketches are prepared to give details about the part to be repaired or modified, etc.

The full proficiency in freehand skecthing is obtained only by mastering the graphic language as well as developing the drawing skill with instruments. However, a student in engineering has to start the study of freehand sketching along with the beginning of the graphics study. He has to prepare solutions to various problems in graphics by sketching prior to the final drafting. By developing the capacity of preparing neat and proportional line sketches, an engineering student can not only develop speed and finish in drafting, but he can answer the questions asked in the examination containing figures, in a very beautiful and impressive manner. Even though freehand sketching does not permit the use of instruments, sometimes a straight edge and compass are used in order to draw lengthy lines and long size circles or arcs. In such cases, the drawing is called as *sketching*.

3.2 TYPES OF SKETCHES

While studying engineering graphics, a student has to prepare freehand sketches of almost all the drawings prior to the drafting. The preparation of a scaled drawing should be the transfer of its sketches from the sketchbook to the drawing sheet with the help of instruments. These drawings can be grouped into the following categories:

1. Drawing of two-dimensional figures and objects like conics, miscellaneous curves, templates, etc.
2. Multiview (orthographic) projections of three-dimensional solids and objects.
3. Pictorial views of three-dimensional objects like machine parts, building, steel structures, etc. The views maybe:
   (a) Isometric projection
   (b) Oblique projection, or
   (c) Perspective projection
4. Schematic drawings of various types of welded joints, circuit diagrams, etc.
5. Symbolic drawings like piping layouts, welded joints, circuit diagrams, etc.

The above categories of drawings are discussed in detail in the coming modules. In the present chapter only the fundamentals of freehand drafting are explained.

3.3 MATERIALS FOR SKETCHING

Freehand drafting theoretically permits only pencil, eraser and the drawing paper. The pencil should be with soft lead of H or HB. It can be a wooden pencil or a mechanical clutch pencil. Depending on the type of figure and the purpose of drawing, a variety of drawing papers are used for sketching:

1. Plain paper
2. Paper with rectangular co-ordinates
3. Paper with isometric co-ordinates
4. Tracing paper or film.

Plain paper is the most widely used paper for the preparation of all kinds of freehand sketches. The principal difficulty in using plain paper is that proportions and projections must be estimated by the eyes. This can be solved by the use of paper with thin ruled rectangular co-ordinates as shown in Fig. 3.1. Multiview (Orthographic) projections and oblique projections can be sketched easily with the help of co-ordinate lines. For the preparations of isometric drawings, paper with isometric co-ordinates is used to get the three co-ordinates and proportions. Sketches are made on tracing paper or film, in order to reproduce more copies by any of the transparency methods. The co-ordinate lines on the paper may some times reduce the clarity of the sketch if the ruled lines are too much bright. In such a situation, the rear side of the paper may be used to get light co-ordinate lines.

The use of coordinate paper speeds up the work considerably and gives better proportions. However, only plain paper is suggested for practising freehand drafting at the beginning so that the student can develop a good sense of proportions to the movement of the pencil tip.

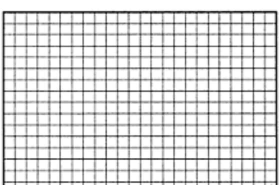


Fig. 3.1 Rectangular coordinate paper.

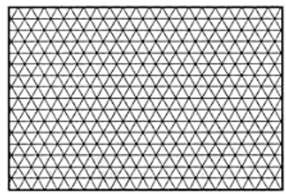


Fig. 3.2 Isometric coordinate paper.

3.4 SKETCHING OF STRAIGHT LINES

Engineering drawings consist mainly of straight and curved lines. The important points to be considered while sketching a straight line are given below.

1. The pencil should rest on the middle finger and should be held smoothly between the thumb and first finger. The tip of the pencil may be about 25 to 35 mm projecting from the finger grip.
2. Sketch horizontal lines from left to right with an easy arm motion.
3. Marking of the end points is advisable for long lines.
4. Just before drawing a line make a few trial motions of the pencil tip between the marked points.
5. First draw a very light line (just visible line) in two three sweeps (see Fig. 3.3).
6. Darken the line by moving the pencil over the light line.
7. It is helpful to turn the drawing paper to bring the line to a convenient position (horizontal or vertical)

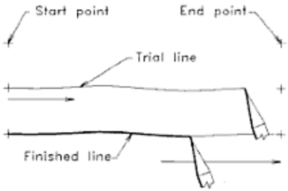


Fig. 3.3 Sketching of horizontal line.

8. Short vertical and inclined lines are drawn in a downward direction as shown in Fig. 3.4.

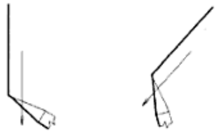


Fig. 3.4 Sketching of vertical and inclined lins.

9. Long vertical and inclined lines may be drawn as horizontal lines after rotating the paper to the required direction.
10. While drawing horizontal and vertical lines, reference should be constantly made to the edge of the paper so that the lines are parallel to them.

Drawings made by sketching should obey the codes of practices; hence, all the standard line types are to be used for sketching also. Figure 3.5 gives the sketches of the line types which are used most frequently.

Fig. 3.5 Important line types for sketching.

3.5 SKETCHING OF CIRCLES

The circumference of a circle is equidistant from its centre. Hence, to get a good circle, mark off as many points as possible at a distance of the radius from the centre. The following points may help to sketch circles with reasonable accuracy:

1. Small circles may be sketched by marking radial distances on perpendicular centre lines [see Fig. 3.6(a)].
2. Large circles may be sketched with the help of intermediate (diagonal) points [see Fig. 3.6(b)].
3. Very large circles may be sketched correctly by marking the points on the circumference with the help of a paper trammel as shown in Fig. 3.6(c).
4. Draw circles by arcs from top to bottom direction keeping the pencil on the concave side of the curve.

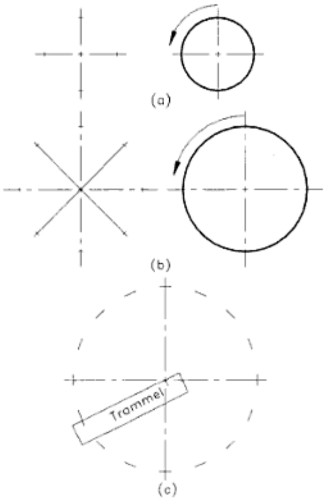


Fig. 3.6 Sketching of circles.

3.6 SKETCHING OF ARCS

Sketching of arcs is almost similar to that of circles. The points of tangency should be carefully approximated as shown in Fig. 3.7. While sketching an arc, the position of the pencil should be on the concave side of it. It should be noted that the centre of the arc will always lie on the intersection point of perpendiculars drawn at the points of tangency. For

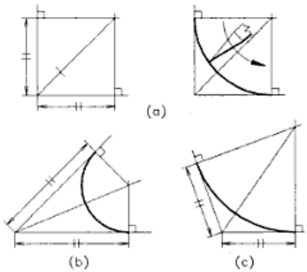


Fig. 3.7 Sketching of arcs.

lengthy arcs, paper trammel method may be adopted to get intermediate points.

3.7 SKETCHING OF ELLIPSES

Ellipse may be considered as a stretched circle, say in the horizontal or vertical direction so that the horizontal diameter differs from that of the vertical. To draw an ellipse, sketch a rectangle having sides equal to the major and minor diameters and then mark off the two diameters as shown in Fig. 3.8(a). Small ellipses can be completed by sketching a smooth curve through the four diameter end points.

To sketch large ellipses intermediate points maybe required. To locate the intermediate points, draw the diagonals as shown in Fig. 3.8(b) and mark off a point P such that $A\ P = 0.4$ times of AB approximately. Similarly, the other intermediate points Q, R and S are located and the ellipse is completed by sketching a smooth curve passing through these points.

3.8 METHOD OF SKETCHING VIEWS

To sketch a view, first of all study the given figure or object in detail and then plan the views to be sketched. Start the sketching of the view or views by following the rules of the graphic language. The suggested procedures for the same are given below.

1 Find the overall dimensions of the view and sketch rectangles of required sizes to enclose the view as shown in Fig. 3.9(a). The relationship between the length and width can be maintained by marking unit lengths on these rectangles.
2. Insert the centre lines for arcs and circles [Fig. 3.9(b)].

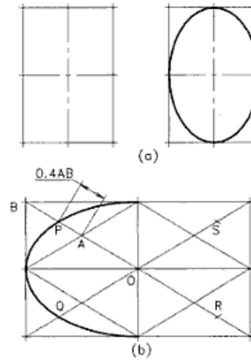


Fig. 3.8 Sketching of ellipse.

3. Sketch the arcs and circles and then the straight lines [Fig. 3.9(c)] considering the unit markings.
4. Remove all unnecessary construction lines and thicken the boundary lines to finish the view [Fig. 3.9(d)].

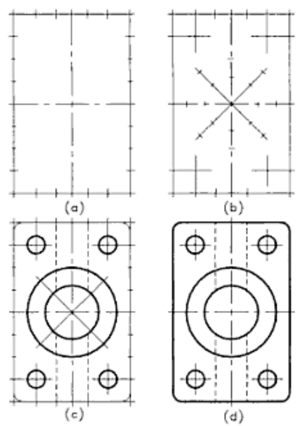


Fig. 3.9 Sketching of a view.

Sketching of various types of pictorial views are done in the same manner as that of orthographic views. Here, the initial rectangles are to be replaced by suitable construction lines following the rules of projection. The dimensional values and notes about the object are to be inserted only at the end.

Example 3.1

Sketch two circles of diameters 20 mm and 40 mm with centres at a distance of 50 mm and mark the common external tangents. Retain the construction lines and do not dimension the figure.

Refer to Fig. 3.10.

1. Sketch a thin horizontal line AB and mark off 5 divisions on it. (units)
2. Draw vertical, horizontal and inclined lines as shown in the figure. Mark off the radii of circles on these lines from the centres A and B.
3. Sketch the two circles and then the two external tangents to these circles using thick lines by freehand.

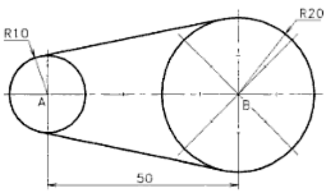


Fig. 3.10 Sketching of external tangents to circles.

Example 3.2

Copy Fig. 3.11(a) by freehand sketching. Retain all the construction lines. Dimensioning of the figure is not required.

Refer to Fig. 3.11.

1. Construct a rectangle to enclose the ellipse and insert the centre lines [see Fig. 3.11(b)].
2. Find the four intermediate points of the ellipse by drawing diagonals and marking the length 0.4 AB as shown in Fig. 3.11.
3. Complete the ellipse, circles and arcs.
4. Sketch the straight lines and finish the drawing.

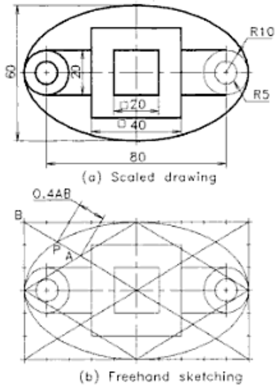


Fig. 3.11 A flange.

EXERCISES

1. Sketch a rectangle of approximately 100 mm by 60 mm and insert a square of side 50 mm at the centre. Fill the square with section lines (hatching) inclined at 45° and spaced by 3 mm. Use thick lines for the rectangle and square while thin lines for the hatching.
2. Sketch the following three concentric circles:
   (a) Circle of diameter 80 mm with thick line.
   (b) Circle of diameter 60 mm with chain line.
   (c) Circle of diameter 40 mm with short dashed line.
3. Sketch an approximate ellipse of major axis 12 cm and minor axis 8 cm.
4. Sketch the geometrical shapes given in Fig. 3.12. Retain all the construction lines and do not dimension the figure.
5. Copy the view given in Fig. 3.13 by freehand drafting and finish the sketches after removing all construction lines. Write the caption and other instructions given. The figure need not be dimensioned.

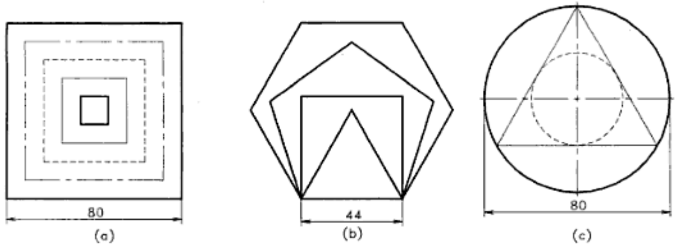


Fig. 3.12 Geometrical shapes.

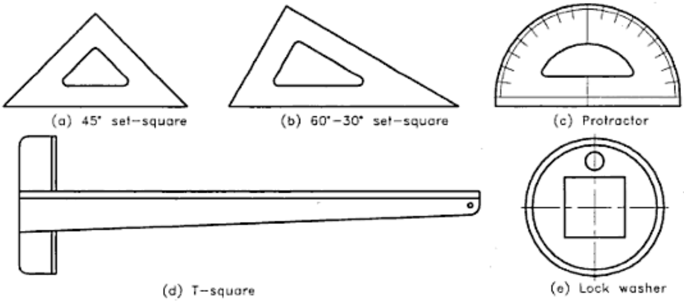


Fig. 3.13 Geometrical shapes.

C H A P T E R 4

Dimensioning

A drawing describes the shape of an object. For complete details of an object, its size description is also required. The information like distance between surfaces and edges with tolerance, location of holes, machining symbols, surface finish, type of material, quantity, etc. is indicated on the drawing by means of lines, symbols, and notes. The process of furnishing this information on a technical drawing as per a code of practice is called *dimensioning*.

4.1 ELEMENTS OF DIMENSIONING

The following are the elements of dimensioning:

1. Projection line
2. Dimension line
3. Leader line
4. Termination of dimension line
5. Dimensional text

These elements of dimensioning are shown in Fig. 4.1.

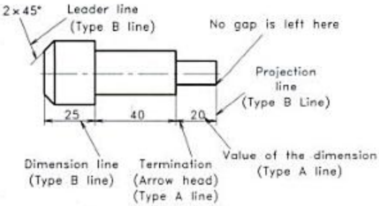


Fig. 4.1 Elements of dimensioning.

Projection Lines

These lines are drawn as continuous thin type B lines. They should be drawn:

1. Extending slightly beyond the respective dimension line
2. Perpendicular to the feature to be dimensioned,
3. Not crossing other lines as far as possible, and
4. May be drawn as extension of centre line or outline of the object as shown in Fig. 4.2.

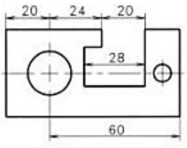


Fig. 4.2 Centre lines and outlines replace projection lines.

Dimension Lines

These lines are drawn as continuous thin type B lines. The following points may be noted while drawing a dimension line.

1. As far as possible, dimension line should not cross other lines.
2. A centre line or outlines of a part should not be used as a dimension line.
3. Dimension lines are preferred to be drawn from visible outlines and not from hidden lines.
4. A broken feature should be marked by an unbroken dimension line as shown in Fig. 4.3.

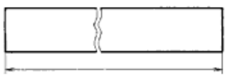


Fig. 4.3 Dimensioning of a broken feature.

Leader Lines

Leader lines are the lines referring to a feature (dimensions, object, outline, etc.) drawn as continuous thin type B lines. The tail end of the leader line should be terminated on a short horizontal bar below the lettering of a note. The head end of the leader line should be terminated in any one of the following forms (see Fig. 4.4)

1. With a dot within the outline of the object (surface).
2. With an arrow head on the outline of an object (edge).
3. Without a dot or an arrow head on a dimension line.

The following points may be noted while describing a leader line:

1. Leader line should not be parallel to adjacent dimension lines or projection lines, where confusion might arise.
2. Leader lines may be drawn at an angle not less than 30° with the horizontal or vertical.
3. The use of common leaders may be avoided.

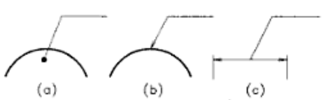


Fig. 4.4 Termination of leader lines.

Termination of Dimension Lines

Dimension lines should carry distinct terminations. Terminations are indicated either by arrowheads or by oblique strokes. The arrowheads are shown in Fig. 4.5(a). The included angle between short lines forming the arrow head may be taken between 15° to 90°. The arrow head may be open, closed or closed and filled in. The oblique strokes are drawn as short lines inclined at 45° to the dimension line as shown in Fig. 4.5(b). While drawing arrow heads or oblique strokes the following points may be noted:

1. The size of the termination of the dimension line should be proportional to the size of the drawing on which they are used.

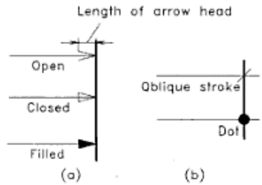


Fig. 4.5 Termination of dimension line.

2. Only one style of arrow head termination should be used on a single drawing. The shape of arrow head used in this book and that suggested for class work is shown in Fig. 4.6.

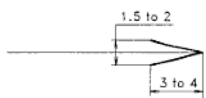


Fig. 4.6 Suggested arrow head shape.

3. Arrow heads may be shown within the limits of the dimension line, if space is available. See the left hand side dimension shown in Fig. 4.7.

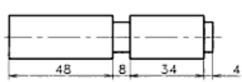


Fig. 4.7 Arrow heads within or outside the limits of dimension line.

4. Arrow head may be shown outside the intended limits of the dimension line if space is not available. See the marking of dimensional value 4 mm.

5. If the space between the projection lines is too small for an arrow head, dots or oblique strokes may be used in the place of arrow heads as shown in Fig. 4.8.
6. Only one arrow head termination is required to indicate the radius of a circle or an arc.

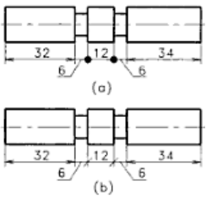


Fig. 4.8 Use of dot or oblique stroke.

Dimensional Text

Dimension is a numerical value expressed in an appropriate unit of measurement. The text size may be 3 mm to 4 mm in height depending on the drawing size. The location of the text value relative to the dimension line is decided by the *Method* of indicating them. While marking dimensional values in millimetres, there is no need of indicating mm after a value. But for the other units like cm, m or km, that should be indicated. If all the dimensions are marked in the same unit other than mm, it may be indicated as a note nearby the title block to avoid writing unit after each value.

4.2 METHODS OF INDICATING DIMENSIONAL VALUES

Two different methods of indicating dimensional values are suggested by *Bureau of Indian Standards* and are called *Method–1* and *Method–2*. Only one method is to be used in a drawing.

Method–1

In this method of dimensioning, the text should be placed aligning to the dimension line, satisfying the following conditions (see Fig. 4.9)

The dimensional values should be:

1. Placed parallel to the dimension line.
2. Placed above the dimension line.
3. Not touching the dimension line.
4. Placed at the middle of the dimension line as far as possible.

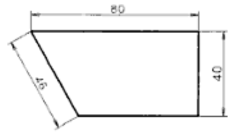


Fig. 4.9 Indicating dimensional value (Method–1).

5. Placed in such a way that it can be read either from the bottom or right hand side of the drawing.
6. Placed as indicated in Fig. 4.10 on inclined features.

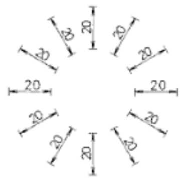


Fig. 4.10 Indicating dimensional values on oblique dimension lines (Method–1).

7. Indicated as shown either in Fig. 4.11(a) or in Fig. 4.11(b) for angular dimensioning. Here, the second one is simple, hence suggested for class work.

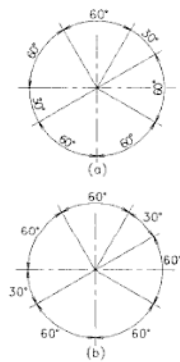


Fig. 4.11 Indicating angular dimensional values (Method–1).

Method–2

In this method of dimensioning, the text should be placed vertical, satisfying the following conditions (see Fig. 4.12).

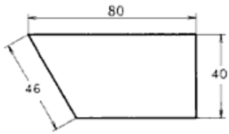


Fig. 4.12 Indicating dimensional values (Method–2).

The dimensional values should be:

1. Placed above the horizontal dimension lines and at the middle as far as possible, without interrupting the dimension line.
2. Placed at the middle by interrupting the dimension line, for non-horizontal (vertical and inclined) dimension lines.
3. Placed in such a way that it can be read from the bottom side.
4. Placed as shown on Fig. 4.13 for angular dimensioning.

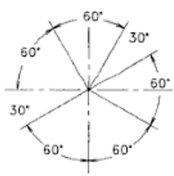


Fig. 4.13 Indicating angular dimensional values (Method–2).

4.3 ARRANGEMENT OF DIMENSION LINES

The dimensions of an object can be placed according to either *Method–1* or *Method–2*, but they are arranged in the following ways. The selection of the type of arrangement depends on the design and construction requirements.

1. *Chain dimensioning:* Here the dimension lines are drawn as a chain as shown in Fig. 4.14. This type of dimensioning is used only where the possible accumulation of tolerances does not endanger the functional requirements of the part.
2. *Parallel dimensioning:* Here the dimension lines are drawn parallel to each other as shown in Fig. 4.15. This type of dimensioning is used only where a number of dimensions of a part have a common datum feature.

Fig. 4.14 Chain dimensioning.

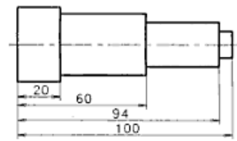


Fig. 4.15 Parallel dimensioning.

3. *Combined dimensioning:* Here a combination chain and parallel dimensioning are applied as given in Fig. 4.16, depending on the requirement.

   The distance of dimension line from the object boundary or nearby dimension line should be at least 5 mm to 6 mm.

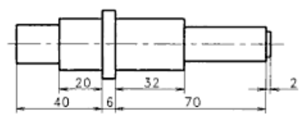


Fig. 4.16 Combined dimensioning.

4. *Superimposed running dimensioning:* This type of dimensioning is a simple parallel dimensioning and may be used where there are space limitations and where no legibility problems will arise. Here, origin is to be indicated appropriately and the opposite end of each dimension line should be terminated only with an arrow head. The dimensional values may be entered as shown in Fig. 4.17(a) or as shown in Fig. 4.17(b). This type of dimensioning can also be used to indicate dimensions in two directions as shown in Fig. 4.18.

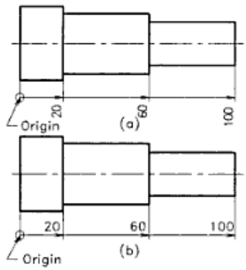


Fig. 4.17 Superimposed running dimensioning in one direction.

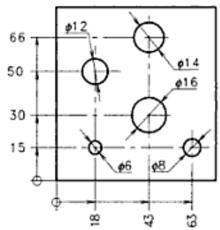
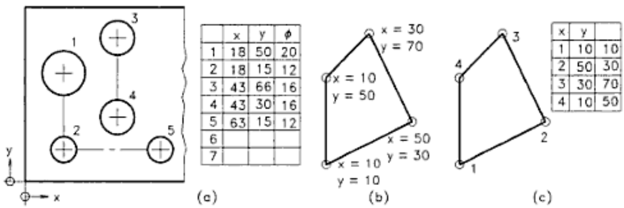


Fig. 4.18 Superimposed running dimensioning in two direction.



	x	y	ϕ
1	18	50	20
2	18	15	12
3	43	66	16
4	43	30	16
5	63	15	12
6			
7			

	x	y
1	10	10
2	50	30
3	30	70
4	10	50

Fig. 4.19 Dimensioning by co-ordinates.

5. *Dimensioning by coordinates:* This type of dimensioning follows the principle of coordinate system of identifying the points. Figure 4.19 shows three ways of representing the dimensional values of each point under reference with respect to the origin. Here, ϕ indicates the diameter of the hole.

4.4 SHAPE INDICATION

While dimensioning an object, the shape of the feature is also indicated along with the dimension value as far as possible. This can improve the drawing interpretation. *Bureau of Indian standards* recommends the following indication (symbols) which should precede the value for dimension.

ϕ	: diameter	S*f*:	spherical diameter
R	: radius	SR :	spherical radius
□	: square.		

Dimensioning of Geometrical Shapes

Circle

A circle shall be dimensioned by any one of the ways shown in Fig. 4.20. Symbol ϕ maybe used to represent the diameter

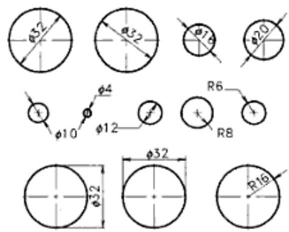


Fig. 4.20 Diameter or radius on circles.

of a circle. This symbol maybe omitted in situations where the circle can be identified without confusion.

Cylindrical diameter

Diameter of a cylindrical feature shall be indicated by any one of the ways shown in Fig. 4.21. Symbol ϕ maybe used to represent the diameter of a cylindrical feature. This symbol maybe omitted in the situation where the cylindrical diameter can be identified without confusion.

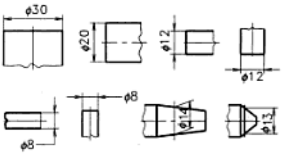


Fig. 4.21 Indicating diameter on cylindrical features.

Radius

Radius of an arc shall be dimensioned by any one of the ways shown in Fig. 4.22. Symbol R shall be used to represent the radius of an arc. Only one arrow head termination is used and it may be located depending upon the size of the feature. Generally, the arrow head is terminated on the feature outline.

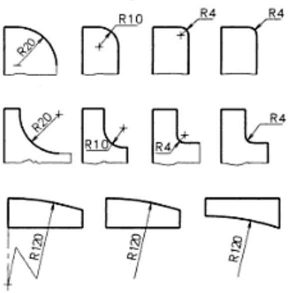


Fig. 4.22 Indicating radius on an arc.

Square

A square shall be dimensioned as shown in Fig. 4.23. Symbol □ may be used to represent a square. This symbol may even be omitted in situations where the square can be identified without confusion. Square ends may be indicated by diagonals drawn as continuous thin lines.

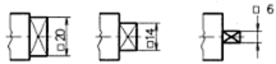


Fig. 4.23 Dimensioning on square features.

Spherical diameter and radius

Diameter and radius of a spherical feature shall be indicated as shown in Fig. 4.24. Symbol S*f* shall be used to represent the spherical diameter. Here, S stands for spherical and ϕ stands for diameter. Symbol SR shall be used to represent the spherical radius. Here, R stands for radius.

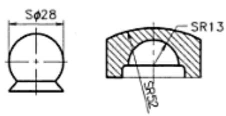


Fig. 4.24 Dimensioning on spherical features.

Chord and arc

Chord and arc shall be dimensioned as shown in Fig. 4.25.

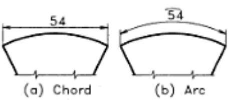


Fig. 4.25 Dimensioning on chord and arc.

Dimensioning of Miscellaneous Features

Chamfers and countersinks

External chamfers shall be dimensioned as shown in Fig. 4.26(a) and (b). Internal chamfers shall be dimensioned as shown in Fig. 4.26(c). If the chamfer angle is 45°, the indication may be simplified as shown in the figure. Countersinks are dimensioned by showing included angle with diameter or depth as given in Fig. 4.27.

4.5 SUGGESTED DIMENSIONING SYSTEM FOR CLASS WORK

Bureau of Indian Standards permits two methods of placing dimensional values *(Method–1 and Method–2)* and various arrangements for indicating dimensions as explained above. Among them the following combination of dimensioning system is used throughout the textbook and the same is suggested for class work.

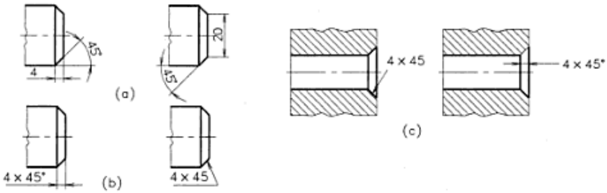


Fig. 4.26 Dimensioning on chamfers.

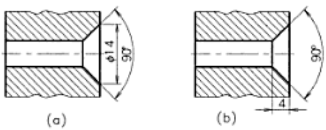


Fig. 4.27 Dimensioning on countersinks.

1. The method of placing dimensional values

The *Method–1*, of placing the dimensional value is followed throughout the textbook. This system of placing dimensional values is almost similar to the old aligned system and gives compact layout for dimensional values having more digits, tolerance, etc.

2. The arrow head

Open type arrow heads having included angle of about 15° is recommended. The length of arrow head may be 3 to 4 mm depending on the size of the pencil drawing. Use thick line (0.5 mm) for arrow head while thin line (0.25 mm) for dimension and projection lines. If the space between projection lines is too small to insert arrow heads, filled dots of about 1.5 mm is used.

3. The printing of dimensional values

The dimensional values are to be printed using letters and numerals of uniform height of about 3 to 4 mm and 0.5 mm line thickness is to be used for the purpose. They should be placed as far as possible at the middle portion, 0.5 to 1 mm above the dimension line. HB pencil is recommended for printing text using stencil.

4. Units for dimensioning

Millimetre is the unit recommended by BIS for all engineering drawings, except for special requirements. Hence, any value written as dimension will be normally considered as in millimetres. Therefore it is not allowed to write "mm" after a dimensional value and also is not necessary to write *All dimensions are in mm* nearby the title block. But, if any unit other than mm is used, then that should be noted either after the dimensional value (as cm, m, etc.) or as a general instruction.

5. Scale of drawing

Generally class work drawings are prepared in 1:1 scale. If a different scale is used, it should be noted below the drawing and in the space provided inside the title block. At the same time, whatever may be the scale of drawing, the actual given dimensions should be written on the dimension lines. For example, 50 m length, drawn to a scale as 100 mm, should be dimensioned as 50 m itself.

6. Answers and captions

Captions like the name of object, views etc., should be written below the drawing using capitals only, of 3 to 5 mm letters. The question number is written at the left top side of the figure and may be enclosed by a circle of 10 mm diameter to identify it.

4.6 RULES OF DIMENSIONING

1. Dimension lines, projection lines, extension lines, and leader lines are drawn as continuous thin lines.

2. Projection lines should extend slightly beyond the dimension line (1 to 2 mm).
3. Extension and dimensioning lines should not cross other lines unless that is unavoidable.
4. Extension lines are drawn in a direction perpendicular to the feature to be dimensioned. They may be drawn obliquely but parallel, to each other on special requirements.
5. Dimensions are to be given from visible outlines rather than from hidden lines.
6. Each end of the dimension line should be defined by an arrow head.
7. Adjacent arrows may be replaced by a clearly marked dot or slash.
8. If dimensioning inside a hatched portion is unavoidable, the hatching lines should not cross the dimensional text.
9. Two systems of dimensioning should not be mixed up in one drawing. Only one system of dimensioning (Method 1 or 2) should be followed throughout a particular drawing.

Example 4.1

Dimensioned view of an L shaped plate is shown in Fig. 4.28(a). Copy the view and place the dimensions as per parallel dimensioning of Method–1, taking the left hand bottom corner as the reference point.

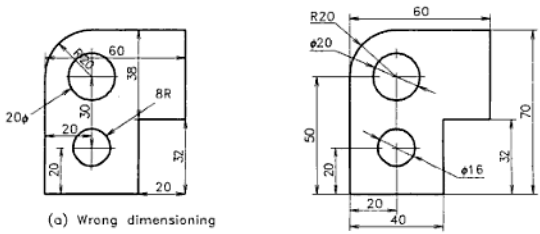
Refer to Fig. 4.28(b).

1. Draw the given L shaped plate.
2. Place the dimensions correctly, following the Method–1 and parallel dimensioning taking the left hand bottom corner as the reference point.

Example 4.2

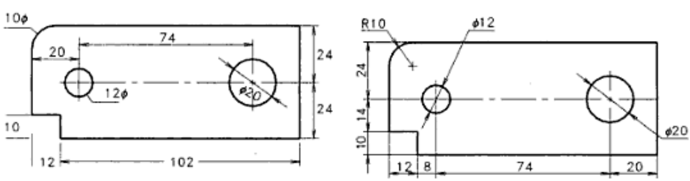
Read the dimensioned drawing of a lock plate shown in Fig. 4.29(a). Redraw the figure to full size and dimension it following Method–1 of chain dimensioning as per Bureau of Indian Standards.

Refer to Fig. 4.29(b).



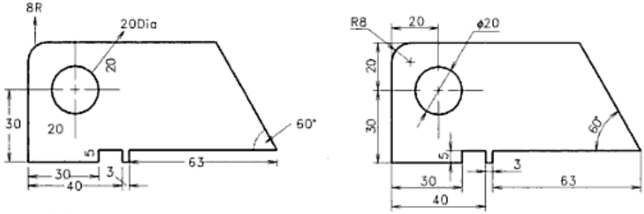
(a) Wrong dimensioning (b) Correct dimensioning

Fig. 4.28 L–plate (parallel dimensioning).



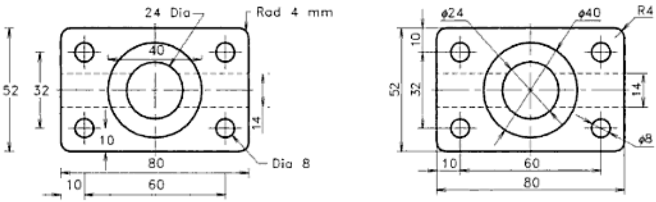
(a) Wrong dimensioning (b) Correct dimensioning

Fig. 4.29 Lock plate (chain dimensioning).



(a) Wrong dimensioning (b) Correct dimensioning

Fig. 4.30 A template (combined dimensioning).



(a) Wrong dimensioning (b) Correct dimensioning

Fig. 4.31 A rod support (combined dimensioning).

Example 4.3
Figure 4.30(a) gives a template dimensioned wrongly. Copy the figure to scale 1:1 and place the dimensional values as per Method–1 and combined dimensioning.
Refer to Fig. 4.30(b).

Example 4.4
Copy the drawing of a rod support given in Fig. 4.31(a) and enter the dimensions following Method–1 of combined system of dimensioning.
Refer to Fig. 4.31(b).

Example 4.5
Figure 4.32(a) shows a wrongly dimensioned gland plate. Redraw the figure and dimension it as per Method –1 of BIS.
Refer to Fig. 4.32(b).

Example 4.6
Draw the given Fig. 4.33(a) to a scale 2:1 after taking measurements from the figure and dimension them following combined dimensioning system of Method–2. The measurements are to be corrected to 1 mm accuracy.
Refer to Fig. 4.33(b).

1. Measure the dimensions of the figure and draw to the double size of each dimension.
2. Mark the dimensional values as per Method–2.

Example 4.7
Copy the cylindrical machine part given in Fig. 4.34(i) using 1:1 scale and place dimensional values changing from Method–1 to Method–2.
Refer to Fig. 4.34(b).

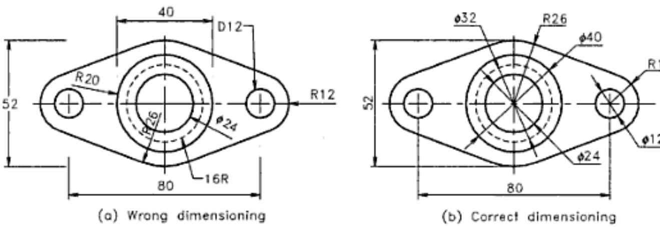


Fig. 4.32 A gland (Method–2 dimensioning).

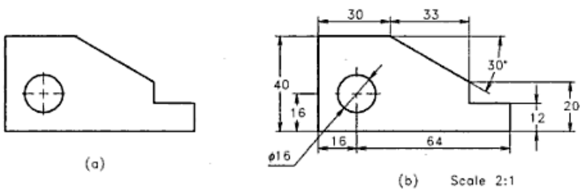


Fig. 4.33 Wedge plate (Method–2 dimensioning).

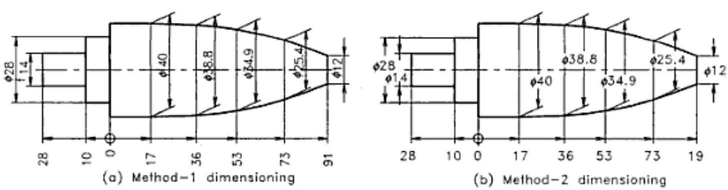


Fig. 4.34 A cylindrical machine part.

EXERCISES

Method–1 dimensioning

1. The following figures give drawings of flat engineering objects with wrong dimensioning. Copy them and insert the dimensional values as per combined dimensioning of Method–1.
   (a) Guiding plate (Fig. 4.35)
   (b) Lock washer (Fig. 4.36)
   (c) U-plate washer (Fig. 4.37)
   (d) Template (Fig. 4.38)
   (e) Lock washer (Fig. 4.39)
   (f) Angle plate (Fig. 4.40)

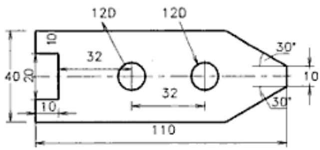


Fig. 4.35 A guiding plate (Wrong dimensioning).

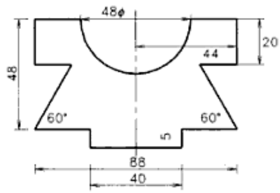


Fig. 4.38 A template (Wrong dimensioning).

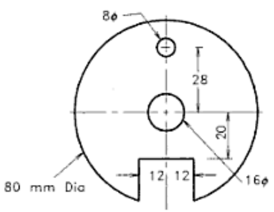


Fig. 4.36 A lock washer (Wrong dimensioning).

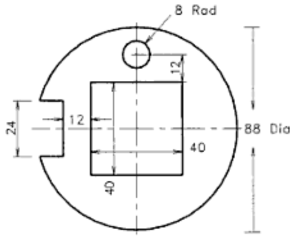


Fig. 4.39 A lock washer (Wrong dimensioning).

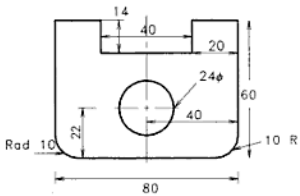


Fig. 4.37 A U-plate washer (Wrong dimensioning).

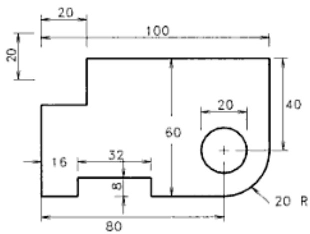


Fig. 4.40 An angle plate (Wrong dimensioning).

Method–2 dimensioning

2. The following figures give drawings of objects with wrong dimensioning. Copy them and insert the dimensional values as per combined dimensioning of Method–2.
   (a) Lock washer (Fig. 4.39)
   (b) Angle plate (Fig. 4.40)
   (c) Go-no-go gauge (Fig. 4.41)
   (d) A machine part (Fig. 4.42)

3. Figure 4.43 shows drawing of an axle with cylindrical shape. Draw the figure to a scale 2:1 after taking measurements from it and dimension them following Method–2 of BIS. The measurements are to be corrected to 1 mm accuracy.

4. Copy the drawing of a machine part given in Fig. 4.44 and enter the dimensions following Method–2 of combined system of dimensioning.

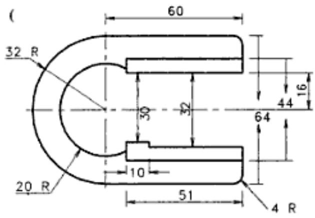


Fig. 4.41 Go-no-go gauge (Wrong dimensioning).

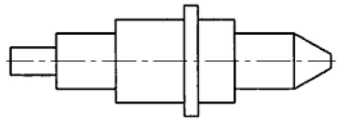


Fig. 4.43 Axle.

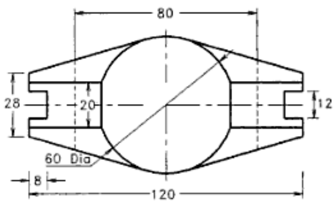


Fig. 4.42 A machine part (Wrong dimensioning).

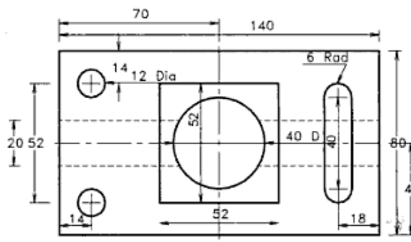


Fig. 4.44 A machine part (Wrong dimensioning).

Module B

Two-Dimensional Drawings

CHAPTER 5

Geometrical Constructions

A student of engineering graphics should be familiar with simplified geometrical constructions explained in the chapter. The constructions have been modified to suit the drafting instruments, so that the time requirement will be less. The knowledge of plane geometry is the only pre-requisite for engineering drawing. Hence, the mathematical proofs are omitted intentionally.

5.1 GEOMETRICAL SHAPES

1. A *straight line* is a line joining between two given points through the shortest path.
2. An *angle* is formed by the two intersecting lines.
3. Any plane figure bounded by more than four straight lines is a *polygon*. A polygon, having equal sides and equal angles, is called a *regular polygon*.
4. A *circle* is generated by a point moving in a plane at a fixed distance from another point called the *centre*. Part of a circle is called an *arc*.

Various plane geometrical shapes formed by straight lines and curved lines are given in Fig. 5.1. They include triangles, quadrilaterals, regular polygons and circles.

5.2 REVISION OF SIMPLE GEOMETRICAL CONSTRUCTIONS

A beginner in engineering graphics has to know the following simple geometrical constructions using only a steel rule and compass:

1. To bisect a straight line AB (see Fig. 5.2).
2. To bisect an arc AB (see Fig. 5.3).
3. To draw a perpendicular to the given inclined line AB from a point P with in it (see Fig. 5.4).
4. To draw a perpendicular from a point P to a given inclined line AB (see Fig. 5.5).
5. To bisect an angle (see Fig. 5.6).
6. To transfer an angle (see Fig. 5.7).
7. To draw a triangle, having given its three sides AB, BC, & CD (see Fig. 5.8).
8. To draw a square, having given one side, AB (see Fig. 5.9).

5.3 DIVIDING A LINE INTO ANY NUMBER OF EQUAL PARTS

A given straight line can be divided into any number of equal parts or into proportional parts. The following example describes the procedure.

Example 5.1
A line AB has a length of 139 mm. Divide it graphically into 9 equal parts.

Refer to Fig. 5.10.

1. Draw a horizontal line AB = 139 mm.

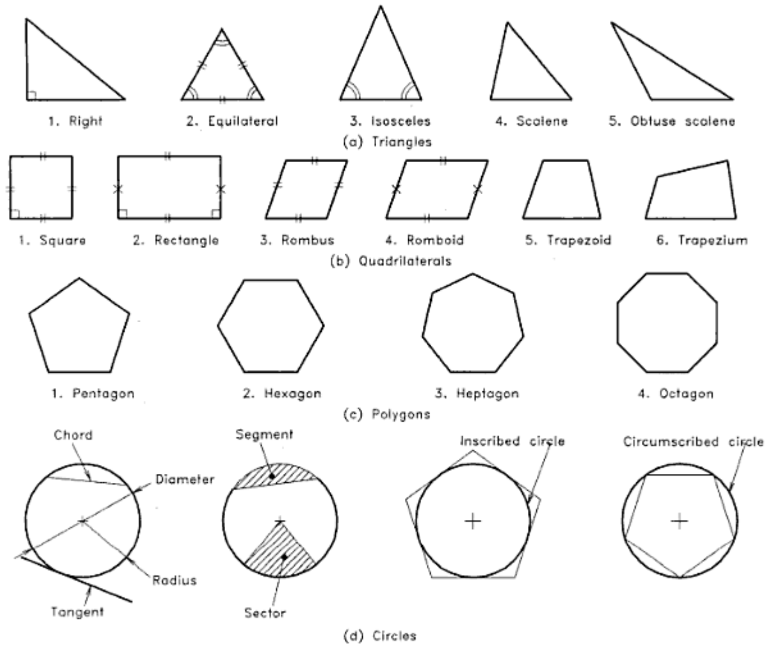


Fig. 5.1 Geometric shapes.

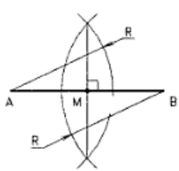


Fig. 5.2 To bisect a line.

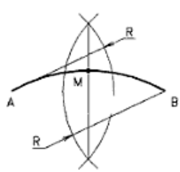


Fig. 5.3 To bisect an arc.

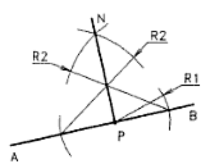


Fig. 5.4 To draw perpendicular from a piont on the line.

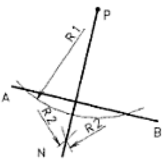


Fig. 5.5 To draw normal to a line from a point.

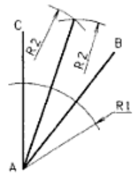


Fig. 5.6 To bisect an angle.

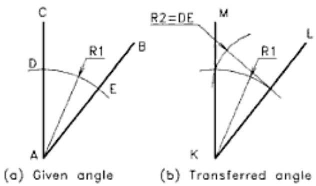


Fig. 5.7 Transferred angle.

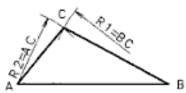


Fig. 5.8 To draw a triangle.

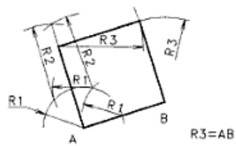


Fig. 5.9 To draw a square.

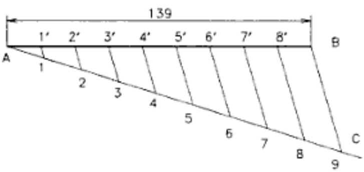


Fig. 5.10 Dividing a line into nine equal parts.

2. Draw another thin line AC at any inclination (about 20° inclined to AB) as shown in figure. Using a divider mark off 9 equal divisions (One division length =1/9 of AB approximately) on AC. Join 9 and B, and draw parallel lines to the line 9-B from points 1, 2, 3, ... etc., to get the points 1′, 2′, 3′, ... etc., on AB. Mini-drafter may be used for drawing the parallel lines.
4. Points 1′, 2′, 3′, ... etc. divide the line AB into 9 equal parts.

5.4 DRAWING OF TANGENT ARCS TO LINES AND CIRCLES

One of the most frequently used geometrical constructions is the drawing of tangent-arcs to circles and drawing of circles or arcs tangent to straight lines or other circles. Some of the most required tangent constructions are described in the following examples.

Example 5.2

A line AB is inclined to another line BC. Draw an arc of radius 25 mm tangential to the lines AB and BC when, angle ABC = 60°.

Refer to Fig. 5.11.

1. Draw lines AB and BC of approximate length of 60 mm making angle ABC = 60°.
2. Draw lines DO and EO parallel to and at a distance of 25 mm from AB and BC respectively. Locate the point of intersection O of the lines DO and EO.

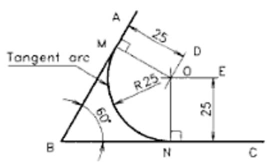


Fig. 5.11 Tangent arc to two straight lines.

3. Draw the lines OM and ON perpendicular to AB and BC respectively.
4. With the centre O and radius equal to 25 mm, draw the required tangent arc MN.

Example 5.3

Draw an arc of radius 20 mm tangential externally to a circle of radius 30 mm and to a horizontal line of 100 mm length drawn at a distance of 50 mm from the centre of the circle. Also mark the points of tangencies.

Refer to Fig. 5.12.

1. Draw the given circle of radius 30 mm and the line PQ 100 mm long at the given distance of 50 mm as shown in figure.

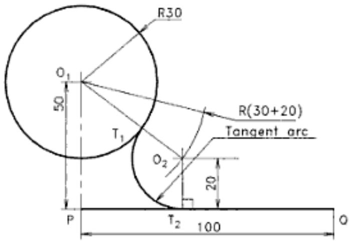


Fig. 5.12 To draw tangent to a line and a circle externally.

2. With centre O_1 and radius (30 + 20) draw an arc.
3. Draw a line parallel to PQ and 20 mm towards the centre of the given circle, to intersect the arc at O_2.
4. With O_2 as centre and radius 20 mm draw the required arc, which will be tangential to both the circle and line.
5. To mark the point of tangencies, join O_1O_2 to get T_1 and drop a perpendicular to the line PQ from O_2 to get T_2.

Example 5.4

Draw an arc of radius 30 mm, tangential internally to an arc of a circle of radius 60 mm and to a horizontal line PQ 80 mm length drawn at a distance of 40 mm from the centre of the R60 circle. Also mark the points of tangency.

Refer to Fig. 5.13.

1. Draw the given circle and the line at a distance 40 mm from the centre of R60 circle.
2. With centre O_1 and radius (60–30) mm draw an arc.

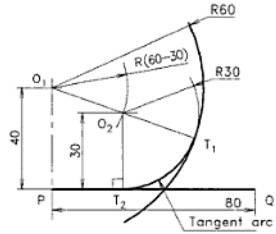


Fig. 5.13 To draw an arc tangential to a line and a circle internally.

3. Draw a line parallel to PQ at a distance of 30 mm to intersect the arc at O_2.
4. With centre O_2 and radius 30 mm draw the required tangent arc.
5. Join O_1O_2 and extent it to meet the circle at T_1 which gives a point of tangency. Drop a normal from O_2 to the line PQ to get the second point of tangency at T_2.

Example 5.5

Draw an arc of radius 40 mm tangential externally to two circles having their centres 80 mm apart and radii 30 mm and 20 mm respectively. Also mark the points of tangency.

Refer to Fig. 5.14.

1. Draw the given circles R30 and R20 with a distance of 80 mm between their centres.

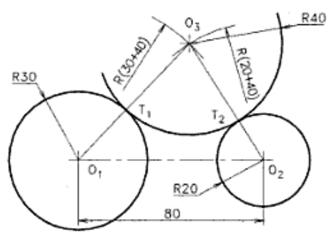


Fig. 5.14 To draw an arc tangential to two circles externally.

2. With centre O_1 and radius (30 + 40) mm draw an arc. With centre O_2 and radius (20 + 40) mm draw the second arc to intersect the first arc at O_3.

3. With O_3 as centre and radius 40 mm, draw the required external tangent arc.
4. Join O_1 and O_3 to get the point T_1, and O_2 and O_3 to get the point T_2. The points of tangency are T_1 and T_2.

5.5 DRAWING OF TANGENTS TO CIRCLES

Similar to tangent arcs, drawing of straight line tangents to circles or arcs are also frequently required in engineering graphics. The following examples describe the method of drawing tangents to one or two circles.

Example 5.6

Draw two tangents to a circle of diameter 60 mm from a point P, 90 mm away from the centre of circle. The line joining the centre of circle and the point P is inclined at 15° to the horizontal.

Refer to Fig. 5.15.

1. With centre O_1 draw the circle R30.
2. Draw a line of length 90 mm so that O_1P is 15° inclined to the horizontal.
3. Bisect the line O_1P at O_2.
4. With centre O_2 and O_1P as diameter draw an arc to cut the circle at two points T_1 and T_2.
5. Join PT_1 and PT_2 and extend them to get the required tangents.

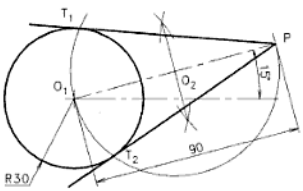


Fig. 5.15 To draw tangent to a circle.

Example 5.7

Draw common external tangents to circles of diameters 60 mm and 32 mm whose centres are located 80 mm apart.

Refer to Fig. 5.16.

1. Draw circles of radii 30 mm and 16 mm with centres O_1 and O_2 respectively which are 80 mm apart.

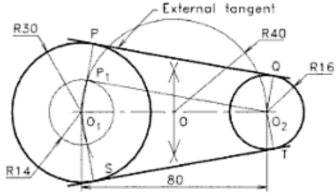


Fig. 5.16 External tangents to circles.

2. With centre O_1 and radius equal to 14 mm (30 – 16) draw another circle.
3. With O_1O_2 as diameter draw a semicircle to cut the circle of R14 mm at P_1 and join O_2P_1.
4. Join O_1P_1 and produce it to cut at P.
5. Draw line PQ parallel to O_2P_1. Similarly, draw the line ST. These lines are the required external tangents.

Example 5.8

Draw common internal tangents to circles of diameter 40 mm and 20 mm, whose centres are located 70 mm apart.

Refer to Fig. 5.17.

1. Draw circles of radii 20 mm and 10 mm with centres O_1 and O_2 respectively, which are 70 mm apart.

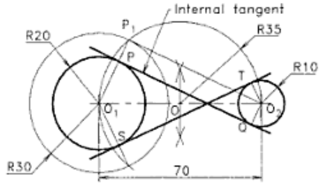


Fig. 5.17 Internal tangents to circles.

2. With centre O_1 and radius equal to 30 mm (20 + 10) draw another circle.
3. With O_1 and O_2 as diameter draw a semi circle to cut the circle of radius 30 mm at P_1 and join O_2P_1.
4. Join O_1P_1 to cut the circle R20 at P.
5. Draw PQ parallel to P_1O_2. Similarly, draw the other tangent ST. They are the required internal tangents.

5.6 CONSTRUCTION OF REGULAR POLYGONS

Regular polygons like pentagon, hexagon, heptagon and octagon are used frequently in geometrical drawing. Various methods of constructing them using drawing instruments are explained in the following examples.

Example 5.9

Construct a regular pentagon having side length equal to 40 mm.

Method–I (using angle 54° and a circle)

Refer to Fig. 5.18.

1. Draw the horizontal side AB = 40 mm.
2. Draw lines at 54° to get the isosceles triangle ABO.
3. With centre O and radius OA, draw a circle to pass through AB.
4. With radius equal to AB, cut the circle successively at C, D and E. Join these points by straight lines to get the required pentagon ABCDE.

The above procedure may be followed to construct hexagon, heptagon and octagon using the angles 60°, 64° and 67.5° respectively.

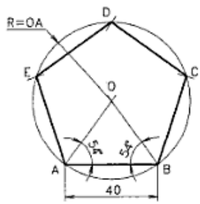


Fig. 5.18 Pentagon (Using angle 54° and a circle).

Method–II (using two circles and an arc)

Refer to Fig. 5.19.

1. Draw the side AB = 40 mm
2. With AB as radius, draw two circles at the centres A and B, as well as one arc at the intersetting point C of these circles.
3. Draw a line joining the intersecting points D to C as the perpendicular bisector of AB, which cuts the arc at E.
4. Draw a line from F to E and extent it to meet the second circle at K. Similarly, join GE and extend to L on the first circle.
5. With K and L as centres and AB as radius draw arcs to get the point M.

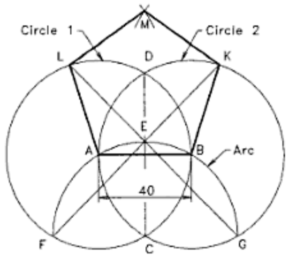


Fig. 5.19 Pentagon (Using two circles and one arc).

6. Join BK, KM, ML, and LA to get the required pentagon.

Method–III (using three arcs)

Refer to Fig. 5.20.

1. Draw the side AB = 40 mm.
2. With B as centre and radius equal to AB draw the first arc and erect a perpendicular at B to cut the arc at P.
3. Bisect AB at O and draw the second arc with O as centre and OP as radius to cut the line AB produced at Q.
3. With A as centre and AQ as radius draw the third arc to cut the first arc at C.
5. To get the point E, draw arcs with centres A and B and radii equal to AB and AQ respectively.
6. To get the point D, draw arcs with centres C and E and radius equal to AB.
7. Join ABCDE with straight lines to get the required pentagon.

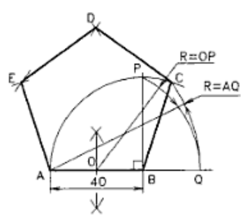


Fig. 5.20 Pentagon (Using three arcs).

Example 5.10

Construct a regular hexagon having length of a side equal to 30 mm.

Method–I (using 60° inclined lines)

Refer to Fig. 5.21.

1. Draw a horizontal line AB = 30 mm.
2. Draw four 60° inclined lines from A and B as shown in the figure.
3. Draw a line through O, parallel to AB, to meet the remaining two 60° inclined lines at F and C.
4. Draw again 60° inclined lines at F and C to get the points E and D.
5. Join ABCDEF with straight lines to get the required hexagon.

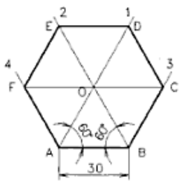


Fig. 5.21 Hexagon (Using 60–30 set square).

Method–II (using a compass)

Refer to Fig. 5.22.

1. Draw a circle with any point O as centre and radius equal to 30 mm.

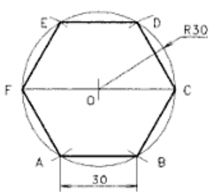


Fig. 5.22 Hexagon (Using a compass).

2. Draw the diameter line FOC horizontally.
3. With radius equal to 30 mm cut the circle at A and E as well as B and D, taking centres at F and C respectively.
4. Join ABCDEF to get the required hexagon.

It is to be noted that, to get a hexagon having one side AB inclined at an angle, the diameter FC has to be constructed at that angle.

Example 5.11

Construct a polygon having n sides and length of side equal to *s*.

Method–I (using n divisions of a semicircle)

Refer to Fig. 5. 23 (Say $n = 7$ and $s = 25$ mm).

1. Draw AB equal to *s* (25 mm) and extend to P so that BP = AB.
2. With B as centre and AB as radius draw a semicircle on AP.

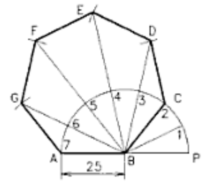


Fig. 5.23 Heptagon (Using *n* divisions of a semicircle).

3. Divide the semicircle into *n* (7) equal divisions by trial and error method. For this take a length approximately equal to 1/7 of the semicircle perimeter on a divider and successively mark it along the circumference from P to A. If any excess or less length to the last division occur, adjust the divider to 1/7 of that difference and try again. By repeating the same for 2 or 3 times, the equal division points are obtained and mark the divisions as 1, 2, 3, etc.
4. Draw a line from B to the second division 2 to get the second side of the polygon. Then draw lines from B to 3, 4, 5 and 6 and extent them as shown in the figure.
5. Cut these lines by arcs having radius equal to AB successively, taking centres at C, D, A and G to get the sides of the required polygon ABCDEFG.

Method–II (using perpendicular bisector, two arcs and a circle)

Refer to Fig. 5.24. (say $n = 8$ and $s = 25$ mm)

1. Draw line AB equal to 25 mm.
2. Construct a perpendicular bisector to AB at O.
3. With centre O and radius OA draw the arc A to the point 4.

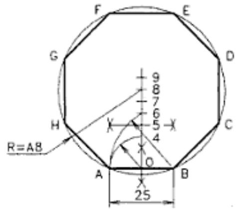


Fig. 5.24 Octagon (Using perpendicular bisector, two arcs and a circle).

4. With centre B and radius AB draw a second arc A to a point 6.
5. Find the midpoint of the distance 4 to 6 at 5.
6. Take the distance 4 to 5 in a divider and mark it on the perpendicular bisector to get the centre points 7, 8, 9, etc. at equal intervals.
7. With point 8 as centre and radius equal to 8 A draw a circle.
8. Mark off the eight sides of the octagon on the circle by cutting arcs with radius equal to AB.
9. Join the sides to get the required octagon ABCDEFGH.

Here, the points 4, 5, 6, 7, 8, etc. represent the centres of the circles which pass through the corners of polygons having side length equal to AB and number of sides equal to 4, 5, 6, 7, 8, etc.

5.7 SCRIBING A CIRCLE IN OR ON ANY TRIANGLE

A circle drawn inside a triangle touching the three sides is called the *inscribed circle*. Whereas, if the circle is drawn passing through the three corners of a triangle, then it is called the *superscribed*, *circumscribed* or *described* circle about the triangle. The following examples explain the methods of inscribing or superscribing of circles.

Example 5.12

Construct a triangle ABC such that AB = 100 mm, BC = 80 mm and CA = 70 mm. Inscribe a circle in this triangle.

Refer to Fig. 5.25.

1. Construct the triangle ABC taking AB = 100 mm, BC = 80 mm and CA = 70 mm.
2. Draw angular bisectors at angles A and B to intersect at O.
3. Erect a normal from O to the side AB as ON.

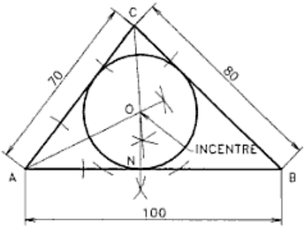


Fig. 5.25 Inscribed circle.

4. With centre O and radius equal to ON draw the required circle touching the other two sides.

Example 5.13

Construct a triangle ABC such that AB = 70 mm, BC = 60 mm and CA = 50 mm. Superscribe a circle about this triangle.

Refer to Fig. 5.26.

1. Construct the given triangle ABC.
2. Draw perpendicular bisectors to AB and AC to intersect at O.
3. With centre O and radius equal to AO draw the superscribing circle.

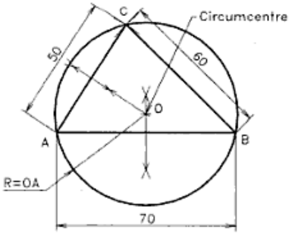


Fig. 5.26 Superscribed circle.

5.8 SCRIBING OF A REGULAR POLYGON IN OR ON A CIRCLE

Scribing a regular polygon about a circle is actually the construction of the polygon keeping the sides tangential to the given circle. It is called as *superscribing*, *describing* or *circumscribing* of the polygon on a circle. Whereas, inscribing a regular polygon in a circle is the construction of the largest polygon inside that circle so that the corners are on the circumference. The following examples explain the procedure of superscribing or inscribing of regular polygons.

Example 5.14
Superscribe an octagon about a circle of diameter equal to 70 mm.

Refer to Fig. 5.27

1. Draw a circle with centre O and diameter equal to 70 mm.
2. Draw 4 diametrical lines at 45° as shown in figure.
3. Draw eight tangents at the ends of the diameters to complete the required octagon 1, 2, 3, ..., 8.

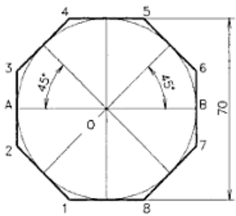


Fig. 5.27 Superscribed octagon.

Example 5.15
Inscribe a regular pentagon inside the given circle of diameter 80 mm.

Refer to Fig. 5.28.

1 Draw a circle with centre O and diameter equal to 80 mm.

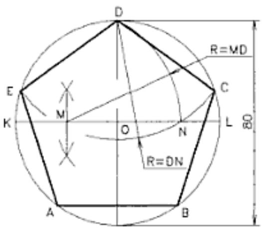


Fig. 5.28 Inscribed pentagon.

2. Draw two mutually perpendicular diameters as shown in figure.
3. Bisect KO to get the point M. With centre M and radius equal to MD, draw an arc to cut the diameter KL at N.
4. With centre D and radius equal to DN draw an arc to cut the circle at C and E.
5. With centres C and E and radius = DN draw arcs to get points A and B.
6. Join the points A, B, C, D, and E with straight lines to complete the required pentagon.

Example 5.16
Inscribe a regular polygon of *n* sides in a given circle of diameter *d* mm.

Refer to Fig. 5.29. (say $n = 7$ and $d = 80$ mm)

1 Draw a circle with centre O and diameter equal to *d* (80 mm)
2. Draw a diameter AE and divide it into *n* (7) equal number of divisions.

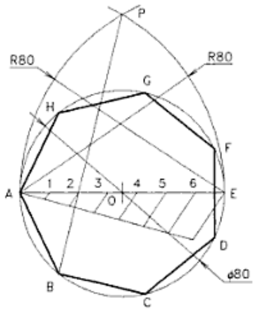


Fig. 5.29 Inscribed heptagon.

3. With centres A and E and radius AE, draw arcs to intersect each other at P.
4. Join P to the point 2 and extend it to cut the circle at B, so that AB is one side of the polygon.
5. Taking AB as side length, mark off the sides of the required polygon on the circle.
6. Join the points with straight lines to complete the required polygon (heptagon).

It is to be noted that the diameter AE has to be divided into n equal divisions and the line PB has to be drawn through the second point of the division to get the side length AB of the regular polygon having *n* sides.

5.9 CONSTRUCTION OF OGEE (REVERSE) CURVES

Ogee or reverse curves are used to connect two straight lines by two tangential curves smoothly. The lines may be parallel or inclined. The curves are drawn tangentially such that one arc curve will be in the reverse direction to the other. Ogee curves are used to layout centre lines for rail, road tracks, pipe lines, etc. The following examples explain the two types of ogee curves.

Example 5.17

AB and CD are two horizontal lines, existing at a vertical distance of 60 mm such that the point C is 70 mm away from point B in the horizontal direction. Draw the lines and construct an ogee curve to join the points B and C. Assume that the curves reverse at the midpoint of the line BC.

Refer to Fig. 5.30.

1. Draw the given two lines, AB and CD.
2. Join BC and locate the midpoint M of the line BC.
3. Draw perpendicular bisector of MC to intersect the perpendicular drawn to CD at C and name the point as O.
4. Join OM and extent to intersect the perpendicular to AB, drawn at B and name the point as P.
5. With centres O and P and radius equal to OM, draw two curves to complete the required ogee curve.

It is to be noted that the tangent point M may be at any location on the line BC so that the radii of the curves are changed accordingly.

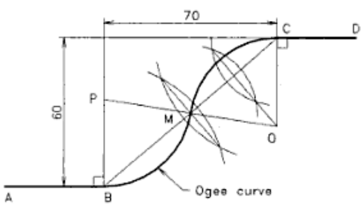


Fig. 5.30 Ogee curve connecting two parallel lines.

Example 5.18

AB is a 60° inclined line of length 60 mm, to a horizontal line BC of length 130 mm. D is a point on BC such that BD is equal to 86 mm. Construct an ogee curve to join the ends B and D such that the radius of the curve touching the point B is 30 mm.

Refer to Fig. 5.31.

1. Draw the lines AB and BC at 60° angle and mark the point D, 86 mm away from B as shown in the figure.
2. Draw a perpendicular to AB at B and locate the point O on it at a distance of 30 mm from B.
3. With centre O and radius equal to 30 mm, draw the first tangent curve.
4. Erect a perpendicular to the line BD such that it passed through point O and intersects the first curve at E as shown in figure.
5. Join ED to cut the curve at M.
6. Draw a perpendicular DP to the line DC. Join OM and produce it to meet the perpendicular DP drawn at P.
7. With centre P and radius = DP draw the second tangent curve to join the points M and D. The curves BM and MD forms the required ogee curve.

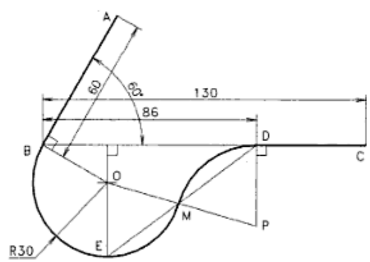


Fig. 5.31 Ogee curve to connect two nonparallel lines.

EXERCISES

SECTION A

1. A line AB has a length of 128 mm. Divide it graphically into 7 equal parts.
2. A line AB is inclined to another line BC. Draw an arc of radius 30 mm tangential to the lines AB and BC when the angle ABC is equal to 70°.
3. Draw an arc of radius 25 mm tangential externally to a circle of radius 35 mm and to a horizontal line of 80mm length, drawn at a distance of 55 mm from the centre of the circle. Also mark the points of tangencies.
4. Draw an arc of radius 25 mm tangential internally to an arc of circle of radius 50 mm and to a horizontal line PQ 70 mm long, drawn 35 mm away from the centre of the circle. Also mark the points of tangency.
5. Draw an arc of radius 60 mm tangential externally to two circles having their centres 90 mm apart and radii 35 mm and 30 mm respectively. Also mark the points of tangency.
6. Draw two tangents to a circle of diameter 100 mm from a point P, 100 mm away from the centre of circle. The line joining the centre of circle and the point P 30° is inclined to horizontal.
7. Draw common external tangents to circles of diameter 80 mm and 50 mm whose centres are located of 120 mm apart.
8. Draw common internal tangents to circles of diameter 50 mm and 30 mm, whose centres are located of 90 mm apart.
9. Construct pentagons having side length equal to 45 mm by the following methods:
   (a) Using angle 54° and a circle
   (b) Using two circles and an arc
   (c) Using three arcs.
10. Construct regular hexagons having length of side equal to 35 mm by the following methods.
    (a) Using 60° inclined lines.
    (b) Using a circle and a diameter.
11. Construct a regular heptagon having length of sides equal to 30 mm. Use division of semicircle method.
12. Construct a regular octagon having length of side equal to 30 mm. Use perpendicular bisector, two arcs and a circle method.
13. Construct a triangle ABC such that AB = 110 mm, BC = 90 mm and CA = 80 mm. Inscribe a circle in this triangle.
14. Construct a triangle ABC such that AB = 80 mm, BC = 70 mm and CA = 60 mm. Superscribe a circle about this triangle.
15. Superscribe an octagon about a circle of diameter equal to 80 mm.
16. Inscribe a regular pentagon inside the given circle of diameter 90 mm.
17. Inscribe a regular heptagon in a given circle of diameter 90 mm.
18. AB and CD are two horizontal lines existing at a vertical distance of 70 mm, such that point C is 90 mm away from point B in the horizontal direction. Draw the lines and construct an ogee curve to join the points B and C. Assume that the curves reverse at the midpoint of the line BC.

SECTION B

19. A line has a length of 152 mm. Divide that into the ratio 4:6:5 and construct a triangle using the three lengths. Also inscribe a circle in the triangle.
20. Centres of two circles of diameter 40 mm and 20 mm are located on a vertical line at a distance of 50 mm part. Draw a third circle of radius 60 mm tangential to these circles so that the smaller circle is outside while the bigger circle is inside.
21. Two pulleys of diameter 70 mm and 40 mm are connected by a flat belt in the crossed way. Draw the line diagram of the system assuming zero thickness for the belt. The centres of the pulleys are located on a line inclined 30° to the horizontal and the centre to centre distance is 110 cm. Use a suitable scale.
22. Construct a pentagon and a hexagon on a common side of length 35 mm.
23. Construct a heptagon of side length equal to 40 mm and inscribe a circle.
24. Draw a hexagon of side 20 mm and construct seven circles of equal diameter, such that each circle is touching other three circles.
25. Draw three circles A, B and C with radii 35 mm, 25 mm and 20 mm respectively, such that they are touching each other and the line joining the centres of A and C is vertical.
26. Construct five circles of equal diameter, such that each circle is touching the other two and draw a circumscribing circle of 110 mm diameter.

27. Two railway tracks which are parallel have their centre lines at a distance 3.5 m apart. It is required to connect these tracks by an ogee curve such that the straight line distance from the curve starting point to the ending point is 12 m and the direction changing point is 7 m from the starting point. Fit the curve and draw the track rails. The distance between rails is 80 cm.

28. AB is the centre line of a pipe line inclined 70° to another horizontal pipe line BC. A point D is located on the centre line BC such that BD is equal to 200 cm. Construct an ogee curve to join the points B and D of the pipe lines such that the radius of the curve touching the end B is 40 cm.

CHAPTER 6

Conic Sections

A cone is a surface generated by totating a straight line keeping one of its ends in contact with a fixed point and the other in contact with a closed curve. The rotating straight line is called *generator*, the fixed point is called *apex* or *vetex*. The closed curve is called *base*. The base of a circular solid cone is a circle. The line joining the centre of the circle and the apex is called the *axis* of the cone. If the axis of a circular cone is perpendicular to its base, the cone is called right *right circular cone*.

If a solid is cut by a lane, a section is obtained. The sections obtained by cutting a right circular cone at different angles, are called *conic sections*. Conic surface is supposed to extend the infinity in both directions from the apex, giving rise to a double cone. Each half of the double cone is called *nappe*. A right circular double cone is shown in Fig. 6.1.

6.1 TYPES OF CONIC SECTIONS

The following are the types of conic sections obtained by cutting a right circular cone by section plane AA, BB, CC, DD, EE, and FF as shown in Fig. 6.1.

1. ***Circle:*** When a right circular cone is cut by a section plane AAAA, perpendicular to the axis of the cone, the section obtained is called *circle*.
2. ***Ellipse:*** When a right circular cone is cut by a section plane BBBB, inclined to the axis of the cone and if the plane cuts all the generators, the section obtained is called *ellipse*.
3. ***Parabola:*** When a right circular cone is cut by a section plane CCCC, inclined to the axis of the cone and parallel to one of the generators, the section obtained is called *parabola*.
4. ***Hyperbola:*** When a right circular cone is cut by a section plane DDDD, inclined to the axis by an angle smaller than that the generators make with the axis, the conic section obtained is called *hyperbola*.
5. ***Rectangular hyperbola:*** When a section plane EEEE, cuts both parts of the double cone on the same side of the axis and parallel to it, the section obtained is called *rectangular hyperbola*.
6. ***Isosceles triangle:*** When a right circular cone is cut by a section plane through the apex of the cone, the section obtained is called *isosceles triangle*.

For the pictorial view of the above sections see Figs. 6.2 (a) to (f).

6.2 NOMENCLATURE

The concept of important terms used in conic can be better understood by cutting a right circular cone by a tangent plane and a section plane. The section plane may be taken in five

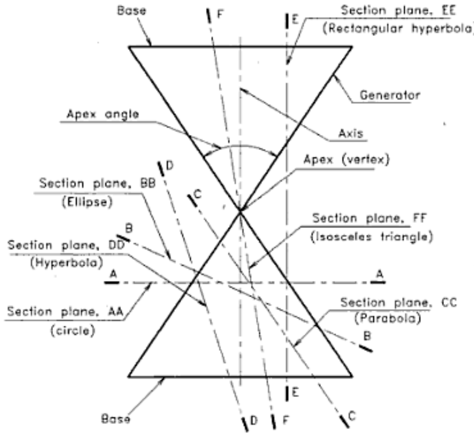


Fig. 6.1 A right circular double cone cut by section planes.

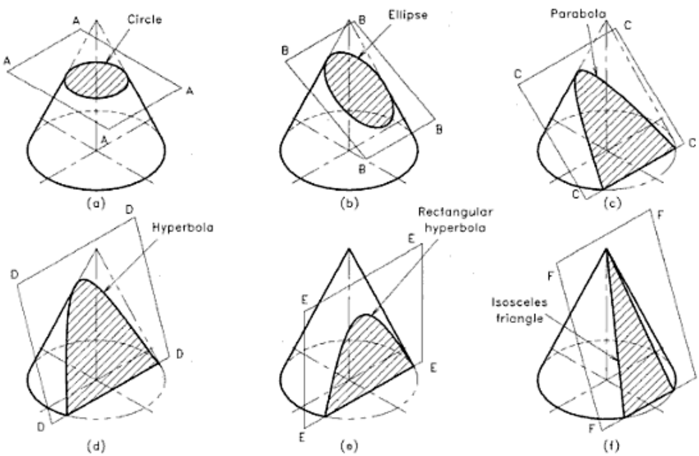


Fig. 6.2 Types of conic sections.

different ways as discussed in the above section. The important terms used in conics are defined below:

1. ***Tangent plane:*** If a sphere is inscribed in a cone, the sphere touches the cone in a circle. The plane containing the circle is called *tangent plane*. Tangent plane is perpendicular to the axis of the cone.
2. ***Focal sphere:*** The sphere inscribed in a cone touching the section plane is called *focal sphere*.
3. ***Focus of the conic:*** If a sphere is inscribed in a cone to touch the section plane, the point of contact between the sphere and the section plane is called *focus of the conic*.
4. ***Directrix of the conic:*** Tangent plane and section plane meet along a line which is called *directrix of the conic*.
5. ***Axis of the conic:*** The line passing through the focus and perpendicular to the directrix is called *axis of the conic*. Note that the axis of the cone is different from the axis of the conic.
6. ***Vertex of the conic:*** The point at which the conic cuts its axis is called *vertex of the conic*.
7. ***Chord of a conic:*** A straight line joining two points on a conic is called *chord of a conic*.
8. ***Focal chord:*** A chord which passes through the focus is called *focal chord*.
9. ***Ordinate:*** The perpendicular from any point on a conic to its axis is called *ordinate*.
10. ***Double ordinate:*** A length twice that of the ordinate is called *double ordinate*.
11. ***Latus rectum:*** A double ordinate that passes through the focus is called *latus rectum*.
12. ***Abscissa:*** The distance along the axis between the vertex of the conic and the point where the ordinate cuts the axis is called *abscissa*.

6.3 CONIC DEFINED AS LOCI

Apart from the definitions given in the above section, a conic can be defined as the path of a point moving in a plane satisfying certain conditions as described below.

A conic may be defined as the locus of a point which moves in a plane such that the ratio of its distance from a fixed point and a fixed straight line in the plane, is a constant. The fixed points are called *focus* and the fixed straight line is called *directrix*. (see Fig. 6.3).

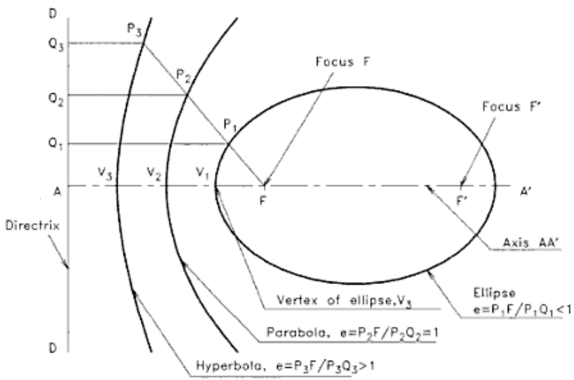


Fig. 6.3 Conic curves defined as loci.

Eccentricity of a conic is the ratio of the distance of the point from the focus to it's perpendicular distance from the directrix. It is constant for a conic and is usually denoted by *e*.

Let P be any point on a curve moving in such a way that the ratio of its distance from a fixed point F and a fixed straight line, DD is constant. PF is the distance of the moving point P from the focus F and PQ is the distance of the moving point P from the directrix.

1. If the ratio $P_1F/P_1Q_1 < 1$, the curve obtained is called *ellipse*.
2. If the ratio $P_2F/P_2Q_2 = 1$, the curve obtained is called *parabola*.
3. If the ratio $P_3F/P_3Q_3 > 1$, the curve obtained is called *hyperbola*.

6.4 ELLIPSE

An ellipse may be defined as a curve traced out by a point moving in a plane such that its distance from a fixed point called *focus* is always less than its distance from a fixed line called *directrix*. An ellipse can also be defined as a curve traced out by a point moving in a plane such that the sum of its distances from two fixed points is a constant. An ellipse has two foci and two directrices (see Fig. 6.4). Since the ellipse cuts the axis of the conic at two points, it is called a *central conic*.

The important terms associated with an ellipse are defined below:

1. ***Major axis:*** It is the line which passes through the foci and terminated by the ellipse.
2. ***Minor axis:*** It is the line which passes through the geometrical centre of the ellipse and perpendicular to the major axis and terminated by the ellipse.
3. ***Auxiliary circles:*** The circles described about the major and minor axes as diameters are called *auxiliary circles*.
4. ***Major diameter:*** The diameter of the circle described on the major axis of the ellipse is called *major diameter*.
5. ***Minor diameter:*** The diameter of the circle described as the minor axis of the ellipse is called *minor diameter*.
6. ***Tangent to an ellipse:*** It is a line which passes through a point on the ellipse and bisects the exterior angle formed by the focal lines at that point. Tangents at the extremities of any diameter are parallel.
7. ***Normal to an ellipse:*** Normal to an ellipse at any point is the perpendicular to the tangent at that point.
8. ***Conjugate diameters:*** These are two lines

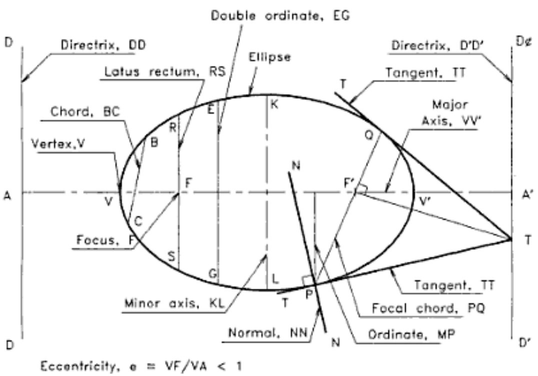


Fig. 6.4 Terminology of ellipse.

intersecting each other at the centre of the ellipse such that each is parallel to the tangents drawn at the extremities of the other.

6.5 METHODS OF CONSTRUCTION OF ELLIPSE

Ellipse is the most commonly used mathematical curve. The elliptical shapes are used for the arches of buildings, in architecture, flanges of machine parts, elliptical gears, drawing pipe end when joining to a plane, etc. There are various methods of constructing an ellipse. A list of the commonly used methods are given below.

1. Eccentricity method
2. Concentric auxiliary circle method
3. Rectangular oblong method
4. Parallelogram method
5. Intersecting arc method
6. Pin and thread method
7. Circle method.
8. Approximate ellipse by four centres.

The data required to construct an ellipse varies with the method of construction. The following examples explain the first six methods of the above list. Procedure of drawing tangent and normal to the curve is also described with them.

Example 6.1

Construct a conic when the distance of its focus from its directrix is equal to 50 mm and its eccentricity is 2/3. Name the curve, mark its major axis and minor axis. Draw a tangent at any point P on the curve

Refer to Fig. 6.5.

1. As the eccentricity is less than 1, i.e. $e = 2/3 < 1$, the curve is ellipse. Draw one directrix DD and the axis AA perpendicular to DD and mark the focus F such that FA = 50 mm.
2. As the eccentricity is 2/3, divide FA into 2 + 3 = 5 equal parts. By definition VF/VA = 2/3 and hence locate the vertex V.
3. Draw VE perpendicular to the axis such that VE = VF. Join AE and extend it as shown in Fig. 6.5. This is the eccentricity scale, which gives the distance directly in the required ratio. In triangle AVE, VE/VA = VF/VA = 2/3.
4. Mark any point 1 on the axis and draw a perpendicular through it to intersect AE produced at 1. With centre F and radius equal to 1-1 draw arcs to intersect the perpendicular through 1 at P_1, both above and below the axis of the conics.

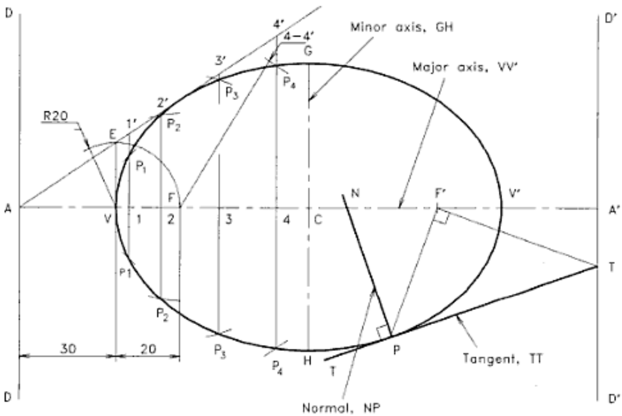


Fig. 6.5 Construction of an ellipse (eccentricity method).

5. Similarly, mark points 2, 3, 4, etc. on the axis and obtain points P_2, P_3, P_4, etc. as described above. Draw a smooth curve passing through the points V, P_1, P_2, P_3, P_4 etc. which is the required ellipse.
6. Mark the centre C of the ellipse and draw a perpendicular GH to the axis. Also mark the other focus F such that CF = CF.
7. Tangent at any point P on the ellipse can be drawn by joining PF′ and by drawing F′T perpendicular to PF′. Join TP and extend. Draw NP perpendicular to TP. Now, TPT and NPN are the required tangent and normal at P respectively.

Example 6.2

Draw an ellipse by concentric circles or auxiliary circle method. Given the major and minor axes as 120 mm and 80 mm respectively. Draw a tangent at any point on the ellipse using auxiliary circles.

Refer to Fig. 6.6.

1. With diameters AB = 120 mm and CD = 80 mm, draw two concentric circles with O as centre. Divide the circle into any number of equal parts (say 12) as shown in Fig. 6.6.
2. Through 2 and 2′, draw parallels to CD and AB respectively to intersect them at P_2.
3. Similarly, obtain other points P_3, P_5, P_6, etc. Point P_1 will be at A itself.
4. Draw a smooth curve passing through all these points to get the required ellipse.
5. Tangent at any point P on the ellipse can be drawn by first locating points E and F. For this, draw horizontal and vertical lines through P to meet the circles at E and F. Draw a radial line OEF. Draw a tangent ET, at E to meet the minor diameter at T_1.
6. Similarly, draw another tangent FT_2 at F to meet the major diameter at T_2.
7. Join T_1PT_2 and it is the required tangent. Draw NPN perpendicular to T_1PT_2 to get the required normal.

Example 6.3

Draw an ellipse by rectangular method, given the major and minor axes as 150 mm and 90 mm respectively. Draw normal and tangent at any point on the ellipse at a distance of 55 mm from the geometrical centre of the ellipse.

Refer to Fig. 6.7.

1. Draw two axes AB = 150 mm and CD = 90 mm bisecting each other at O and construct a circumscribing rectangle EGKL as shown in Fig. 6.7.
2. Divide AO and AE into the same number of equal parts (say 4) and name the dividing points. Join C with the points on the side AE.
3. Draw lines from D through points on side AO and extend these lines to intersect the previously drawn lines at P_1 and P_2. Note that 1C intersects with 1′D produced at P, and so on.
4. Similarly, obtain points on the other side of the axis. Draw a smooth curve passing through all these points and the curve obtained is the required ellipse.
5. Mark any point P on the ellipse at a distance of 55 mm from the geometrical centre of the ellipse.

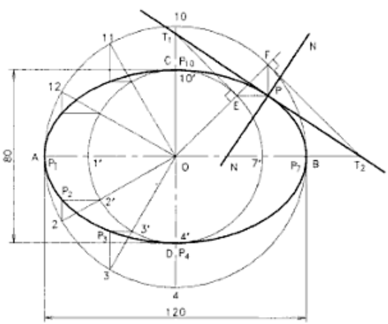


Fig. 6.6 Construction of an ellipse (concentric or auxiliary circle method).

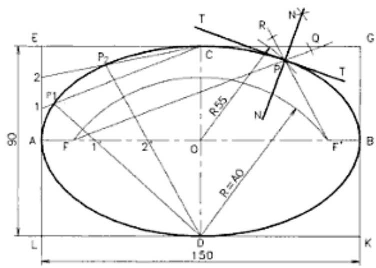


Fig. 6.7 Construction of an ellipse (rectangular or oblong method).

Locate the foci F and F'. Join FP and F'P and produce these lines to Q and R respectively.

6. Draw a line TPT bisecting the angle F'PQ. Now, TPT is the required tangent. Draw another line NPN bisecting the angle RPQ. Here, NPN is the required normal.

Example 6.4

Draw an ellipse by the parallelogram method if the conjugate diameters are 150 mm and 108 mm with an included angle of 70°. Also mark the minor axis of the curve.

Refer to Fig. 6.8.

1. Draw the given conjugate diameters AB = 150 mm and CD = 108 mm with an included angle of 70°. The conjugate diameters bisect at O as shown in Fig. 6.8. Draw the circumscribing parallelogram EFGH.
2. Construct the ellipse by rectangular method as shown.
3. Draw a semicircle with O as centre and OD as radius to intersect the ellipse at K. Join CK. The line LM passing through the centre O and parallel to CK is the minor axis.
4. Draw a line NS perpendicular to LM. Here, NS is the major axis.

Example 6.5

The foci of an ellipse are 100 mm apart and the minor axis is 80 mm long. Measure the length of the major axis. Draw the ellipse by using intersecting-arc method. Also draw a tangent to the ellipse from any point outside the ellipse.

Refer to Fig. 6.9.

1. Draw a horizontal line and mark the foci F and F' on this line such that FF' = 100 mm. Draw a perpendicular bisector and mark points C and D such that CO = DO = 40 mm.
2. Mark A on the horizontal line such that AO = CF. Similarly, obtain the point B. Now AB is the major axis.
3. Mark some points on AO equal to the number of points desired to be plotted in each quadrant of the ellipse.
4. With centres F and F' and radii equal to 1A and 1B respectively draw arcs to intersect at P_1 on either side of the major axis. Similarly with centres F and F' and radii equal to 1B and 1A respectively draw arcs to intersect at points P_1 on the right hand side of the minor axis.
5. Repeat the procedure explained above and get the corresponding points P_2, P_3, etc.
6. Draw a smooth curve passing through all these points using french curves and the curve obtained is the required ellipse.
7. Mark any point P outside the ellipse. With F as centre and AB as radius draw an arc GH. With P as centre and PF' as radius draw another arc to intersect the arc GH at points G and H.

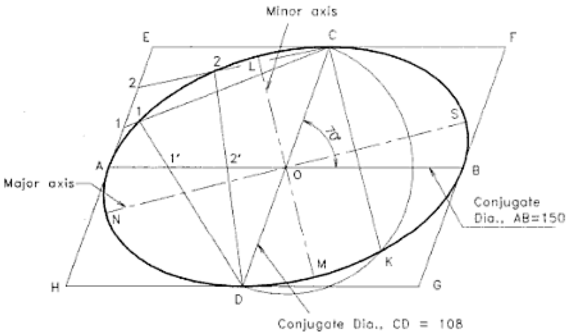


Fig. 6.8 Construction of an ellipse (parallelogram method–conjugate diameters geven).

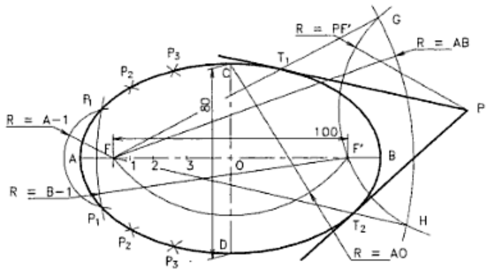


Fig. 6.9 Construction of an ellipse (intersecting-arc method).

8. Join FG and FH, intersecting the ellipse at T_1 and T_2 respectively. Join PT_1 and PT_2. These are the required tangents.

Example 6.6

The distance between two coplanar fixed points is 100 mm. Trace the complete path of a point P moving in the same plane in such a way that the sum of the distances from the fixed points is always 152 mm. Draw the curve.

Refer to Fig. 6.10.

1. Draw a horizontal line and mark the fixed points F and F′ in such a way FF′ = 100 mm.
2. Draw perpendicular bisector COD. Mark the point C such that FC = F′C = 152/2 = 76 mm. Also mark the points A and B such that AO = OB = FC = 76 mm.
3. Mark a number of points on FO equal to the number of points required to be plotted in that portion of the ellipse. With F as centre and radius equal to A1 draw an arc to cut the arc drawn with F′ as centre and radius equal to B1. The point of intersection is marked as P_1.
4. Similarly obtain other points of intersection P_2, P_3, etc. It may be noted that $P_1F + P_1F' = P_2F + P_2F' = \ldots = 152$ mm.
5. Draw a smooth curve passing through all these points to get the required ellipse.

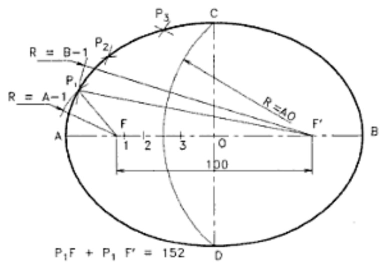


Fig. 6.10 Construction of an ellipse (given fixed points and the sum of distances or pin and thread method).

6.6 PARABOLA

A parabola may be defined as a curve traced out by a point moving in a plane such that its distance from a fixed point called *focus* is always equal to its distance from a fixed line called *directrix*. A parabola has only one focus and one directrix. The terminology of parabola is shown in Fig. 6.11 and they are self explanatory.

Some of the important properties mentioned below will be useful in the construction of a parabola.

1. Area of the parabola is two-third the area of the circumscribing parallelogram.
2. Tangents PT and QT drawn from the extremities of any focal chord PQ intersect at T on the directrix at right angles.
3. Tangents drawn from the extremities of any chord intersect on the diameter which bisects that chord.

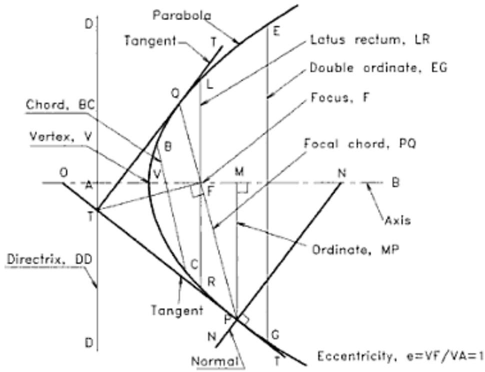


Fig. 6.11 Terminology of parabola.

4. Sub-tangent OM is bisected by the vertex of the parabola, V.
5. Sub-normal MN has a constant length and it is equal to twice the distance between the vertex and the focus.

Parabolic shapes are widely used in engineering practice. Some examples are head lamp reflector of automobiles, reflectors to concentrate solar power, bridge arches, cantilever bodies, shapes of machine tools, etc. The trajectory of missiles, the path of a jet of water, etc. are parabolic in shape.

6.7 METHODS OF CONSTRUCTION OF PARABOLA

A parabola can be constructed by various methods. A list of commonly used methods are given below.

1. Eccentricity method
2. Tangent method
3. Rectangular method
4. Parallelogram method
5. Offset method.

The following examples explain the five methods of construction of parabola and the drawing of tangent and normal to the curve.

Example 6.7

Construct a conic, when the distance between its focus and directrix is equal to 50 mm and its eccentricity is one. Name the curve. Draw a tangent at any point on the curve.

Refer to Fig. 6.12.

1. As the eccentricity of the conic (e) = 1, the curve is a parabola . Draw the directrix DD and the axis AB

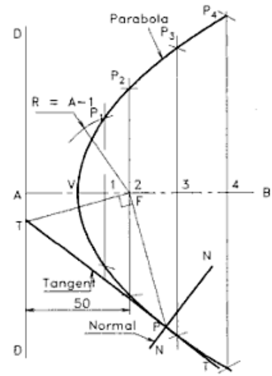


Fig. 6.12 Construction of an parabola (eccentricity method).

perpendicular to DD. Mark the focus F such that AF = 50 mm

2. By definition VF/VA = 1 and hence mark the point V, the vertex at the midpoint of AF as shown in Fig. 6.12.
3. Mark any number of points (say 4) on VB and draw perpendiculars through these points. With F as centre and and A-1 as radius draw an arc to cut the perpendicular through point 1 at P_1.
4. Similarly, obtain points P_2, P_3, P_4, etc. Draw a smooth curve passing through these points to obtain the required parabola.
5. Tangent at any point P on the parabola can be drawn by joining FP and by drawing FT perpendicular to FP and extend. Draw NP perpendicular to TP. Now, TPT and NPN are the required tangent and normal at P.

Example 6.8

Draw a parabola by tangent method. Given its double ordinate = 120 mm and abscissa = 90 mm. Also locate the focus and directrix of the parabola.

Refer to Fig. 6.13.

1. Draw the double ordinate AB =120 mm and its abscissa CV = 90 mm.
2. Extend the axis CV to E such that CV = VE = 90 mm. Join AE and BE and they are tangents to the parabola at A and B respectively.
3. Divide AE and BE into the same number of equal parts (say 8). Join 1-1′, 2-2′, etc.
4. Draw the curve tangential to all these line. This curve is the required parabola.
5. Draw a line BJ parallel to EC. Locate the line BF such that angle JBE = angle EBF. Now, F is the focus of the parabola.
6. With centre V and radius =VF draw a semicircle to cut EC at G.
7. Draw a line DD perpendicular to EC through the point G. Now DD represents the directrix.

Example 6.9

Draw a parabolic arc with a span of 1000 mm and a rise of 800 mm. Use rectangle method. Draw a tangent and normal at any point P on the curve.

Refer to Fig. 6.14.

1. Draw an enclosing rectangle ABCD with base AB = 1000 mm and height BC = 800 mm using a suitable scale.
2. Mark the axis VH of the parabola, where V is the vertex and midpoint of line CD.
3. Divide DV and AD into the same number of equal parts (say 4).
4. Draw a vertical line through the point 1′ lying on the line DV. Join V with 1 lying on the line AD. These lines intersect at point P_1 as shown in Fig. 6.14. Similarly obtain other points P_2, P_3, etc.
5. Draw a smooth curve passing through these points to obtain the required parabola.

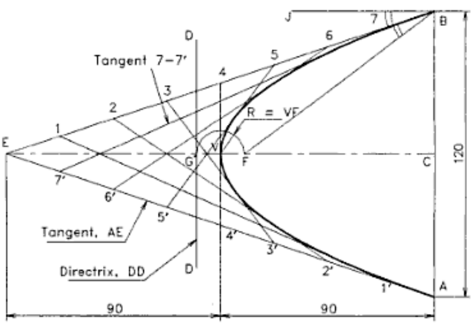


Fig. 6.13 Construction of a parabola (tangent method).

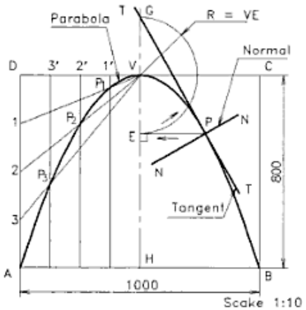


Fig. 6.14 Construction of a parabola (rectangle method).

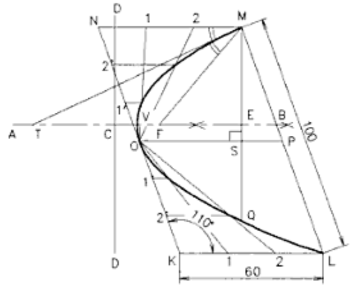


Fig. 6.15 Construction of a parabola (parallelogram method).

6. From point P draw the ordinate PE. With V as centre and VE as radius draw a semicircle to cut the axis produced at G.
7. Join GP and extend it to T. Draw NP perpendicular to TP. Now, TPT and NPN are the required tangent and normal at P.

Example 6.10

Construct a parabola in a parallelogram of side 100 mm (chord) by 60 mm and with an included angle of 110°. Find the axis, focus and directrix.

Refer to Fig. 6.15.

1. Draw the parallelogram KLMN as shown in Fig. 6.15.
2. Join the midpoint O and P of the sides KN and ML.
3. Divide the side KL and KO into equal number of divisions and join them as did in the Example 6.9 to get the points on the parabola.
4. Repeat the same on the other half and draw a smooth curve through the points to complete the parabola.
5. Draw MQ normal to OP and draw the perpendicular bisector AB to the line MQ. AB is the axis of the curve and V is the vertex.
6. Mark a point T such that VT = VE and join TM.
7. Draw the line MF such that ∠TMN = ∠TMF. Point F gives the focus of the curve.
8. Mark the point C on AB such that CV = VF. Draw DD perpendicular to AB through point C. DD is the direction of the parabola.

Example 6.11

Draw a parabola by offset method, given its base and axis as 160 mm and 96 mm respectively. Also draw tangents from any point Q outside the curve.

Refer to Fig. 6.16.

1. Draw a rectangle KLMN such that KL = 160 mm and LM = 96 mm as shown in Fig. 6.16.
2. Draw the perpendicular bisector AV of the line KL.
3. Divide the side NV into any number of equal parts (say 4) and the side KN into the square of that ($4^2 = 16$).
4. Draw horizontal lines from the divisions on the side KN at points 1′ = 1, 2′ = 4 and 3′ = 9. Also drop verticals from the divisions 1, 2, and 3 of the side NV to offset the point on the horizontals drawn such that $(1^2,1)$ gives point P_1, $(2^2,2)$ gives P_2 and $(3^2,3)$ gives P_3 on the required parabola.
5. Repeat the same on the right half and complete the curve.
6. Draw the line EG such that BV = VG. Then find the focus F by drawing the line EF keeping ∠GE3 = ∠GEF. Also locate the directrix DD by taking the length FV = VC.
7. Let Q be the point outside the curve. To draw the tangents from Q, join Q to F and construct an arc at Q with radius QF to cut the directrix at points H and J.
8. Draw perpendiculars to DD at H and J, to cut the parabola at T_1 and T_2. Draw QT_1 and QT_2 to get the required tangents.

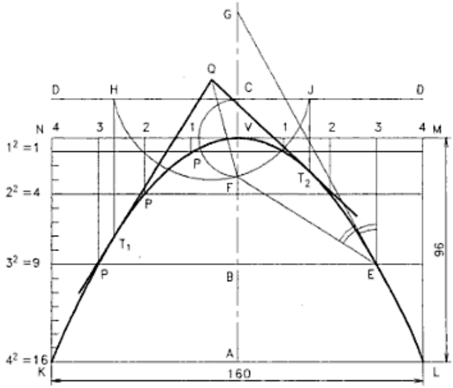


Fig. 6.16 Construction of a parabola (offset method).

6.8 HYPERBOLA

A hyperbola may be defined as a curve traced out by a point moving in a plane such that the difference between its distances from two fixed points called the *foci*, is a constant.

A hyperbola has two branches, *two foci* and *two directrices*. Each branch of the curve has the same eccentricity and hence hyperbola is also known as *central conic*. The terminology of hyperbola is shown in Fig. 6.17.

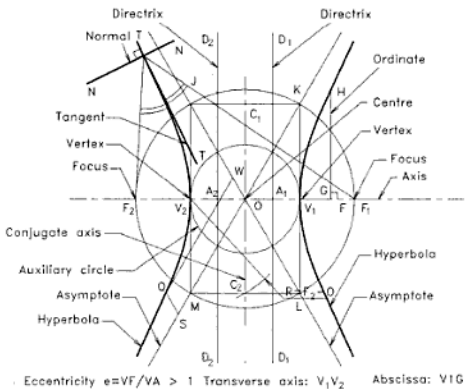


Fig. 6.17 Terminology of hyperbola.

The important terms associated with a hyperbola are defined below.

1. ***Transverse axis:*** It is the portion of the axis which lies between the two vertices V_1 and V_2 of the hyperbola.
2. ***Centre:*** It is the midpoint O of the transverse axis V_1V_2.
3. ***Conjugate axis:*** It is the line C_1C_2 perpendicular to the transverse axis and passing through the midpoint O. The point C_2 can be located by cutting an arc with centre V_2 and radius equal to F_2O, on the perpendicular bisector of V_1V_2.
4. ***Auxiliary circle:*** It is the circle drawn with midpoint O as centre and transverse axis V_1V_2 as diameter.
5. ***Asymptote:*** It is a tangent drawn at infinity to the curve. Actually, asymptote is a straight line which approaches the hyperbola without touching them, but it will touch the curves at infinity.

Asymptotes intersect the auxiliary circle on the directrix. Here, D_2D_2 and D_1D_1 are the directrices. The product of the distances of a point on a hyperbola from asymptote, one measured parallel to one asymptotes and the other measured parallel to the other asymptote is a constant; i.e. QS × QW = constant.

It may be noted that tangent at any point P on the curve bisects the angle F_2PF_1 i.e. angle F_2PT is equal to angle F_1PT. Here, MN is the normal.

A rectangular or equilateral hyperbola may be defined as the locus of a point moving in such a way that the product of its distances from two fixed lines at right angle to each other is constant. These fixed lines are the asymptotes to the rectangular hyperbola.

6.9 METHODS OF CONSTRUCTION OF HYPERBOLA

Similar to parabola, hyperbola also can be constructed by various methods. A list of commonly used methods are given below.

1. Eccentricity (focus and directrix) method.
2. Foci and the difference of the distances method.
3. Ordinate, abscissa and transverse axis method.
4. Asymptotes and a point on the curve method.

The following examples explain the four methods of construction of hyperbola and the drawing of tangent and normal to the curve.

Example 6.12

Construct a conic, when the distance of any point P between the focus and the directrix is constant and is equal to 3/2. Name the curve. Draw a tangent and normal at any point on the curve. The focus is located 50 mm away from the directrix.

Refer to Fig. 6.18.

1. As the eccentricity is greater than 1, i.e. e = 3/2 >1, the curve is a hyperbola. Draw one directrix DD and the axis AB perpendicular to DD and mark the focus F such that FA = 50 mm. As the eccentricity is 3/2, divide FA into 3 + 2 = 5 equal parts. By definition VF/VA = 3/2 and hence locate the vertex V.

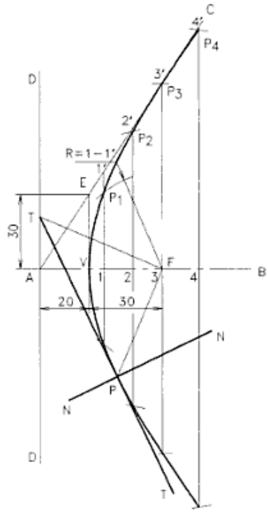


Fig. 6.18 Construction of a hyperbola (given focus and directrix).

3. Draw perpendicular to the axis such that VE = VF. Join AE and extend it as shown in Fig. 6.18. This is the eccentricity scale, which gives the distances in the required ratio. In triangle AVE, EF/VA = VF/VA = 3/2.
4. Mark any point 1on the axis and proceed further as explained in Example 6.7 to get the points P_1, P_2, P_3, etc. which is the required hyperbola.
5. Tangent and normal at any point P on the hyperbola can be drawn as shown in the Fig. 6.18.

Example 6.13

Two points F_1 and F_2 are located on a plane sheet 100 mm apart. A point P on the curve moves such that the difference of its distances from F_1 and F_2 always remains 50 m. Find the locus of the point and name the curve. Mark asymptotes and directrices.

Refer to Fig. 6.19.

1. A curve traced out by a point moving in the same plane in such a way that the difference of the distance from two fixed points is constant, is called a *hyperbola*. Draw a horizontal line and mak the fixed points F_2 and F_1 in such a way that F_2F_1 = 100 mm.
2. Draw a perpendicular bisector C_1OC_2 to F_2F_1 as shown in Fig. 6.19. Mark the points V_2 and V_1 on the horizontal line such that V_2V_1 = 50 mm and $V_2O = V_1O$.

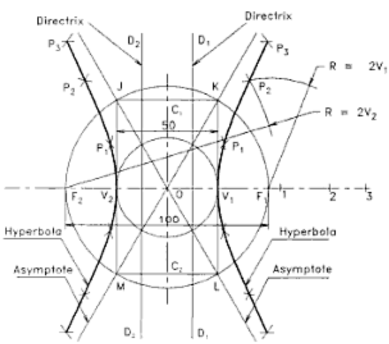


Fig. 6.19 Construction of a hyperbola (given fixed points and the difference of the distances).

3. With centre O and radius equal to F_2O draw a circle.
4. Draw tangents at V_2 and V_1 to intersect the above circle at J, M, K and L as shown.
5. Draw a line joining JOL and produce it and this line is one asymptote. The othe asymptote is the line passing through KOM.
6. Mark any number of points 2, 3, 4, etc. on the axis of the hyperbola. With F_2 as centre and radius equal to $2V_2$ draw an arc to cut the arc drawn with F_1 as centre and radius equal to $2V_1$. The point of intersection is marked as P_2. Similarly, obtain other points of intersection P_3, P_4. etc.
7. It may be noted that the differences $P_2F_2 - P_2F_1 = P_3F_2 - P_3F_1 = \cdots = 50$ mm. Draw a smooth curve passing through the points V, P_1, P_2, P_3, etc. which is the required hyperbola. Also draw another hyperbola on the other side of teh axis, symmetrical about C_1 and C_2 as shown in the Fig. 6.19.

Example 6.14

Draw a hyperbola, given the transverse axis = 80 mm, single ordinate = 60 mm and abscissa = 48 mm.

Refer to Fig. 6.20.

1. Draw a horizontal line V_2V_1 of length 80 mm to represent the transverse axis and extent it to E such that V_1E is equal to 48 mm. V_1E represents the abscissa.
2. Draw a double ordinate, BEC of length two times that of the ordinate (i.e. 2 × 60 mm) perpendicular to the axis. Complete the rectangle ABCD. Divide the sides DC and CE into the same number of equal parts (say 4) as shown in Fig. 6.20.

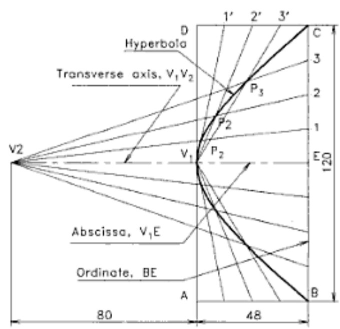


Fig. 6.20 Construction of a hyperbola (given ordinate, abscissa and transverse axis).

3. Join V_1 with 1′, 2′ and 3′. Also join V_2 with 1, 2 and 3 to get the intersecting points P_1, P_2 and P_3 respectively.
4. Similarly, get the intersecting points on the other side of the axis. Draw a smooth curve passing through all these points which gives the required hyperbola.

Example 6.15

The asymptotes of a hyperbola make 80° with each other. A point P on the curve is at a distance of 30 mm from the horizontal asymptote and 45 mm from the inclined asymptote when measured horizontally. Plot the hyperbola. Draw tangent and normal at any point M on the curve.

Refer to Fig. 6.21.

1. Draw the asymptotes OX and OY making an angle of 80° with each other as shown in Fig. 6.21. Mark the given point P. Through point P draw line AB and CD parallel to OX and OY respectively. Mark any point 1 on the line PC and join O1 which intersects the line AP at 1′.
2. Through points 1 and 1′ draw lines $1P_1$ and $1'P_1$ parallel to OX and OY respectively to intersect at P_1. Similarly, obtain points P_2, P_3, P_4, etc. after marking points 2, 3, 4, etc. on both lines PC and PB.
3. Draw a smooth curve passing through all these points to give the required hyperbola.
4. To draw a tangent at any point M on the curve mark point M and complete the parallelogram OLMK.
5. Mark the point T_1 on OY such that $OT_1 = 2 \times OL$ and mark T_2 on OX such that $OT_2 = 2 \times OK$.
6. Join T_1 and T_2 through the points M. Now, NMN is the required normal at M.

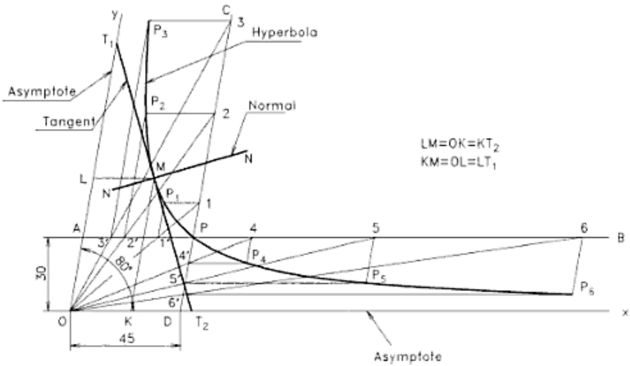


Fig. 6.21 Construction of a hyperbola (given asymptotes and a point on the curve).

EXERCISES

Ellipse

1. The focus of an ellipse is 50 mm away from its directrix. If the eccentricity is 2/3, draw the curve and measure its major and minor axes. A point P is located 45 mm from the second vertex. Draw tangent and normal to the curve at that point.
2. The major and minor axes of an ellipse are 100 mm and 70 mm respectively. Construct the curve using the method of auxiliary circles. Draw a tangent and normal at a point P on the curve located at 35 mm from the top end of the minor axis, towards left.
3. Draw the largest possible ellipse in a rectangle of 120 × 80 mm and mark its focus and axes using the oblong method. A point P on the lower half of the curve is at a distance of 20 mm from the left end of the major axis. Mark the point and draw tangent to the curve at that point.
4. The conjugate diameters of the ellipse are 130 mm and 90 mm with an included angle 65°. Draw the ellipse by parallelogram method and determine its axes.
5. The foci of an ellipse are 100 mm apart and the minor

axis is 70 mm long. Draw an ellipse by intersecting arc method. A point P is located outside the curve at a distance of 80 mm from the bottom end of the minor axis and 20 mm from the right end of the major axis. Draw tangents to the curve from the point P.

6. The distance between two coplanar fixed points is 110 mm. Trace the complete path of a point P moving in the same plane in such a way that the sum of the distances from the fixed point is always 150 mm. Draw the curve and a tangent at any point on the curve located at the right top quarter.

Parabola

7. Construct a conic when the distance between its focus and directrix is equal to 40 mm and its eccentricity is one. Draw a tangent at a point on the upper half of the curve located 60 mm from the focus.
8. The double ordinate of a parabola is 110 mm and abscissa is 80 mm. Draw the parabola and locate its focus and directrix.
9. The span and rise of a parabola are 1200 mm and 880 mm respectively. Using rectangle method, construct the parabola and draw tangent and normal to the curve at a point on it, located 30 mm from the vertex on the right side.
10. Construct a parabola in a parallelogram of side 100 mm (chord) × 60 mm and with an inclined angle of 120°. Find the axis, focus and directrix of the curve.
11. By offset method, construct a parabola having base equal to 120 mm and axis 112 mm. Draw the tangents to the curve from a point P outside the curve such that the point P is located 20 mm towards the left of the axis and 5 mm below the directrix.

Hyperbola

12. Construct a conic when the eccentricity is 5/4 and the distance between directrix and the focus is 54 mm. Draw tangent and normal to the curve at a point on the lower half of the curve measuring 45 mm from the focus.
13. The foci of the two branches of a hyperbola are located at a distance of 80 mm. A point P on the curve moves such that the difference of its distances from the foci always remain 40 mm. Find the focus of the two branches of the curve, mark the asymptotes and measure the angle between them.
14. Draw a hyperbola when the transverse axis is equal to 90 mm, double ordinate = 144 mm and abscissa is equal to 48 mm.
15. The asymptotes of a hyperbola are at an angle of 75°. A point P on the curve is 25 mm away from the horizontal asymptote and 40 mm away from the inclined asymptote, when measured horizontally. Construct the curve and draw tangent and normal at a point M on the curve, 50 mm above the horizontal asymptote.

CHAPTER 7

Miscellaneous Curves

In the preparation of certain engineering drawings, non-circular curves may have to be drawn for representing certain machine parts, arches, etc. These non-circular curves may be of closed or open type and cannot be constructed by using a compass alone. These curves are generally drawn after locating various intermediate points and then joining these points by using French curves.

The following types of curves come under this group:

1. Roulettes
2. Spiral curves
3. Helix.

7.1 ROULETTES

Roulettes are the curves generated by a fixed point on the circumferences of a rolling curve which rolls without slipping along a fixed straight line or a curve. The rolling curve may be a rolling circle. The fixed straight line (fixed circle) is called the *directing line (directing circle or base circle)*. Figure 7.1 gives the general layout of different types of roulettes.

Roulettes are classified into the following types:

1. Cycloid
2. Trochoids
   (a) Superior trochoid
   (b) Inferior trochoid
3. Epicycloid
4. Epitrochoids
   (a) Superior epitrochoid
   (b) Inferior epitrochoid
5. Hypocycloid
6. Hypotrochoids
   (a) Superior hypotrochoid
   (b) Inferior Hypotrochoid
7. Involute

7.2 CYCLOID

Cycloid is a curve generated by a point on the circumference of a circle which rolls without slipping along a fixed straight line. A cycloidal curve is shown in Fig. 7.1. Cycloidal curves are drawn to represent the profiles of gear teeth.

In the case of cycloidal curves, a normal at any point on the cycloidal curve will pass through the point of contact between the directing line and rolling circle at that position. A tangent at any point on the curve will always be perpendicular to the normal at that point.

Example 7.1

Construct a cycloid having a generating circle of 50 mm diameter and draw tangent and normal at any point M on the curve.

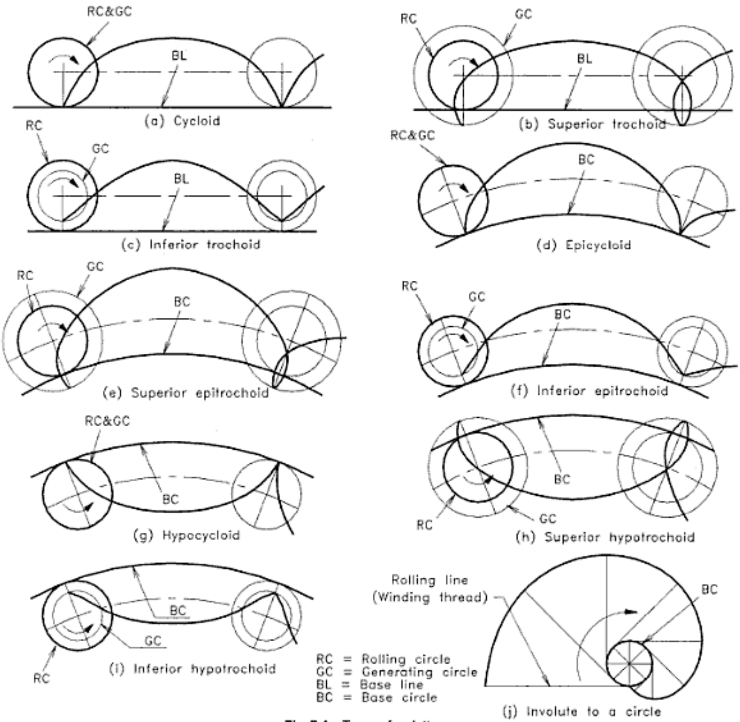


Fig. 7.1 Types of roulettes.

Refer to Fig. 7.2.

1. Draw a horizontal line C_aC_b of length equal to the circumference of the rolling circle.

   $C_aC_b = 2\pi \times$ radius of the rolling circle

   $= 2\pi \times 25$

   $= 50\ \pi$mm.

2. With centre C_a and radius equal to 25 mm, draw the initial position of the rolling circle. Divide the circle into any number of equal parts (say 12). Also divide the line C_aC_b, which is the locus of the centre of the rolling circle, into the same number of equal parts and mark the points as C_1, C_2, C_3, etc. as shown in figure.
3. Draw a tangent AB of length equal to C_aC_b to represent the fixed line or base line.
4. The required cycloid is the path of a point P on the periphery of the rolling circle when it rolls over AB. Let P_0 be the initial position of the point P. When the

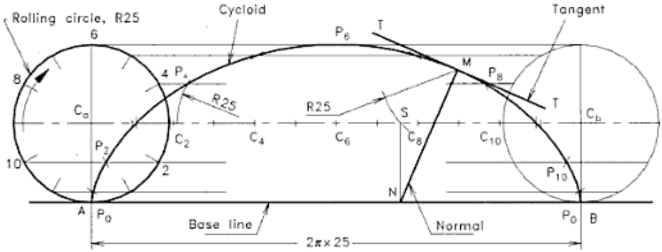


Fig. 7.2 Cycloid.

rolling circle rolls once on AB, the final position of the point P coincides with the point B and hence mark it as P_0.

5. To locate intermediate positions of the point P, such as P_1, P_2, P_3, etc., draw horizontals through points 1, 2, 3, 4, etc. To get one of the intermediate positions of the point P (say P_4), with centre C_4 draw an arc of radius equal to 25 mm, to cut the horizontal through the point 4 at P_4. Similarly, obtain other intermediate points like P_1, P_2, P_3, etc. Draw a smooth curve passing through all these points to get the required cycloid.
6. To draw a tangent at any point M on the curve, with centre M draw an arc of radius equal to 35 mm to cut the line C_aC_b at S. From point S, draw a perpendicular to AB to meet it at N. Join NM, which is the required normal to the curve. Draw a line TMT perpendicular to NM. Now, TMT is the required tangent at M.

7.3 TROCHOIDS

Trochoid is a curve generated by a point fixed to a generating circle in such a way that, the point is lying inside or outside the circumference of the rolling circle. When the rolling circle rolls along a straight line without slipping, the point outside the circle generates a *superior trochoid*. Meanwhile, the point inside the rolling circle generates an *inferior trochoid* [see Fig. 7.1(c)].

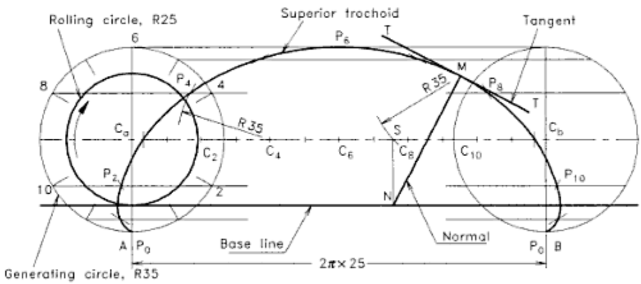


Fig. 7.3 Superior trochoid.

Example 7.2

Construct a superior trochoid for a point situated 10 mm outside a rolling circle 50 mm diameter. Also draw a tangent at any point M on the curve.

Refer to Fig. 7.3.

1. Draw a horizontal line C_aC_b of length equal to the circumference of the rolling circle. With centre C_a and radius equal to 25 mm, draw the initial position of the rolling circle. Also draw the generating circle with centre C_a and radius equal to (25 + 10 = 35 mm). Divide this circle into any number of equal parts (say 12).
2. Also divide the line C_aC_b, which is the locus of the centre of the rolling circle, into same number of equal parts and mark the points as C_1, C_2, C_3, etc. as shown in Fig. 7.3.
3. The required curve (superior trochoid) is the path of a point P on the periphery of the generating circle of radius equal to 35 mm. Let P_0 be the initial position of the point P. When the rolling circle rolls once, the point P will be on the vertical line through C_b and mark it as P'_0.
4. To locate the intermediate positions of the point P i.e. P_1, P_2, P_3, etc. draw horizontal lines through points 1, 2, 3, etc.
5. To get one of the intermediate positions of the point P (say P_4), with centre C_4 draw an arc of radius 35 mm to cut the horizontal line through the point 4 at P_4. Similarly obtain other intermediate points P_1, P_2, P_3, etc. Draw a smooth curve passing through all these points to get the required superior trochoid.
6. To draw a tangent at any point M on the curve, with centre M draw an arc of radius 35 mm to cut the line C_aC_b at S. From point S draw a perpendicular to AB to meet it at N. Join NM which is the required normal to the curve. Draw a line TMT perpendicular to NM. Now, TMT is the required tangent at M.

Example 7.3

Construct an inferior trochoid for a point situated 7 mm inside a rolling circle of 50 mm diameter. Draw tangent and normal at any point M on the curve.

Refer to Fig. 7.4.

1. Draw a horizontal line C_aC_b of length 50π mm and draw a circle with centre C_a and radius equal to 25 mm.
2. Divide C_aC_b into 12 equal parts as explained in example 7.2.
3. Draw the generating circle with centre C_a and radius equal to 18 mm (i.e. 25 – 7) and divide this circle into 12 equal parts. Let P_0 be the initial position of the point P on the periphery of this circle.
4. The positions of point P such as P_1, P_2, etc. can be located as shown in Fig. 7.4. The curve passing through all these points is the required inferior trochoid.
5. The construction of the normal NM and the tangent TMT is also shown in the figure.

7.4 EPICYCLOID

Epicyloid is the curve generated by a point on the circumference of a circle which rolls without slipping, around the outside of a fixed circle. An epicycloid is shown in Fig. 7.4.

Example 7.4

Draw an epicycloid having a generating circle of diameter 50 mm and a directing curve of radius 100 mm. Also draw normal and tangent at any point M on the curve.

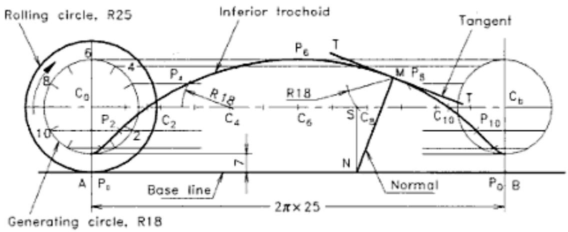


Fig. 7.4 Inferior trochid.

Refer to Fig. 7.5

1. Let AB be the circumference of the generating circle of radius $r = 25$ mm. Let θ be the angle subtended at the centre of the directing (base) circle of radius = 100 mm by the arc AB.
   Then,
   $$\frac{\angle AOB}{360} = \frac{\text{(Arc AB)}}{\text{Circumference of directing circle}}$$
   i.e.
   $$\frac{\theta}{360} = \frac{2\pi r}{2\pi R} = \frac{25}{100}$$
   $$\therefore \quad \theta = \frac{25 \times 360^\circ}{100} = 90^\circ$$
2. Draw the arc AB with centre O and radius = 100 mm in such a way that $\angle AOB = 90^\circ$.
3. Join OA and extend it to C_a such that AC_a is equal to the radius of the rolling circle. With centre C_2 and radius = 25 mm draw the rolling circle.
4. Draw an arc C_aC_b with centre O and radius = OC_a, to intersect the line OB produced at C_b. Here, C_aC_b represents the locus of the centre of the rolling circle.
5. Divide the rolling circle into any number of equal parts (say 12). Also divide the arc C_aC_b into the same number of equal parts and mark the points
6. The required curve (epicycloid) is the path of the point P on the circumference of the rolling circle which rolls over the basic circ. Let P_0 be the initial position of the point P and it coincides with the point A. When the rolling circle rolls once on arc AB, the point P will coincide with B and mark it as P_0.
7. To locate the intermediate positions of the point P such as P_1, P_2, P_3, P_4, etc. draw a arcs through points 1, 2, 3, etc. To get one of the intermediate positions of the point P (say P_4), with centre C_4 draw an arc of radius equal to 25 mm, to cut the arc through the point 4 at P_4. Similarly, obtain other intermediate points P_1, P_2, P_3, etc. Draw a smooth curve passing through all these points to get the required epicycloid.
8. To draw a tangent at any point M on the curve, with centre M draw an arc of radius equal to 25 mm, to cut the arc C_aC_b at S. From points S, draw a normal to AB to meet it at N. Join NM, which is the required normal to the curve. Draw a line TMT perpendicular to NM. Now, TMT is the required tangent at M.

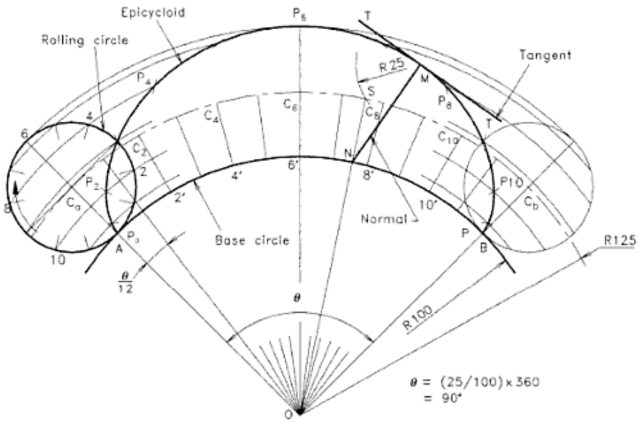


Fig.7.5 Epicycloid.

7.5 EPITROCHOIDS

Epitrochoid is a curve generated by a point fixed to a generating circle in such a way that the point is lying inside or outside the circumference of the rolling circle. When the rolling circle rolls without slipping along the outside surface of directing (base) circle, the point outside the circle generates a *superior epitrochoid*. Meanwhile, the point inside the rolling circle generates an *inferior epitrochoid*.

The method employed for drawing trochoids can be used for drawing epitrochoids by treating AB as an arc instead as a straight line [see Fig. 7.1(e) and (f)].

7.6 HYPOCYCLOID

Hypocycloid is a curve generated by a point on the circumference of a circle which rolls without slipping along the inside surface of a fixed (base) circle. This is shown in Fig. 7.1(g).

It is to be noted that if the radius of the rolling circle is equal to half the radius of the directing circle, then the hypocycloid become a straight line.

Example 7.5

Draw a hypocycloid having a rolling circle of diameter 50 mm and directing circle of radius 100 mm. Also draw normal and tangent at any point M on the curve.

Refer to Fig. 7.6.

The construction of a hypocycloid is almost the same as that of an epicycloid. Here, the centre of the generating circle C is inside the directing circle. The tangent and normal drawn at the point M on the hypocycloid are shown in the figure.

7.7 HYPOTROCHOIDS

Hypotrochoid is a curve generated by a point fixed to a generating circle in such a way that the point is lying inside or outside the circumference of the rolling circle. When the rolling circle rolls without slipping along the inside surface of directing (base) circle, the point outside the circle generates a *superior hypotrochoid*. Meanwhile, the point inside the rolling circle generates an *inferior hypotrochoid*.

The method employed for drawing trochoids can be used for drawing hypotrochoids treating AB as an arc instead as a straight line. See Fig. 7.1(h) and (i).

7.8 INVOLUTES

Involute is a curve traced out by a point on a taut inextensible string which is being wound around a circle or polygon . It is also a curve traced out by a point on a straight line which rolls around a circle or a polygon, without slipping.

Gear teeth profiles are based on the involute of a circle. Involute of a circle is shown in Fig. 7.1(j).

Example 7.6

Draw an involute of a circle of diameter 40 mm. Also draw normal and tangent at any point M on the curve.

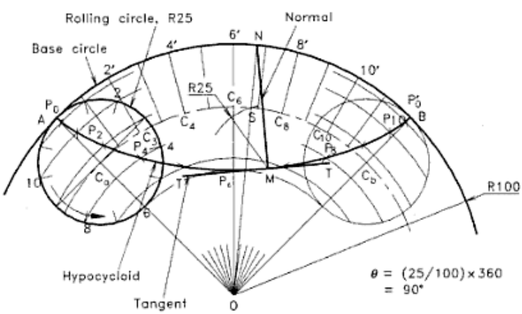


Fig. 7.6 Hypocycloid.

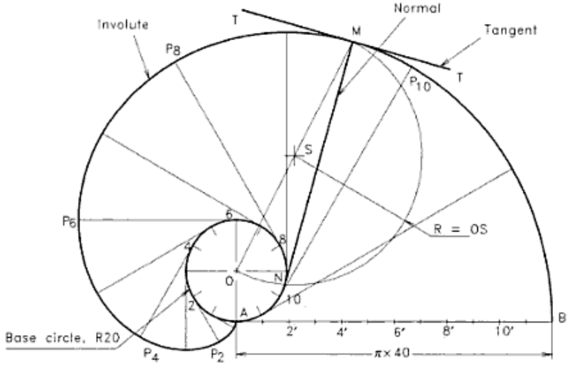


Fig. 7.7 Involutes of a circles.

Refer to Fig. 7.7.

1. Draw a base circle with centre O and diameter equal to 40 mm. Draw a tangent AB of length = p × 40 mm at a point A on the circumference.
2. Divide the circle and the line AB into the same number of equal parts (say 12) as shown in figure.
3. The required curve is the path of a point P lying on a string wound round on the base circle. Let A be the initial position of the point P on the string. When the string is unwound from A by one turn, the point P will coincide with B. To locate the intermediate positions of the point P such as P_1, P_2, P_3, P_4, etc., draw tangents at points 1, 2, 3, etc.
4. To get one of the intermediate positions of the point P (say P_4), with centre 4, draw an arc of radius equal to A4′ to cut the tangent through the point 4 at P_4. Similarly, obtain other intermediate points P_1, P_2, P_3, etc.
5. Draw a smooth curve passing through all these points to get the required involute of a circle.
6. To draw a normal at any point M on the curve, join MO and draw a semicircle on this line to cut the base circle at N in the direction of the involute as shown. Join NM which is the required normal to the curve. Draw a line TMT perpendicular to NM. Now, TMT is the required tangent at M.

Example 7.7

Draw involutes of (i) an equilateral triangle of side 20 mm and (ii) a square of side 15 mm.

Also draw tangent and normal at any point on the curve. Refer to Fig. 7.8(a) and (b).

The required involutes can be drawn by following the procedure explained in Example 7.6. It is to be noted that each segment of the involutes is drawn by arcs as shown in figure.

7.9 SPIRAL CURVES

If a point moves continuously along a line from one end to the other and at the same time if the line rotates in a plane about one of its ends, then the locus of the moving point is called a *spiral*. The point about which the line rotates is called the *pole* or *axis* of the spiral and the part of the line between the moving point and the pole is called the *radius vector*. The two important types of spirals discussed here are:

1. Archimedian spiral and
2. Logarithmic spiral.

The general layout of these spirals are shown in Fig. 7.9.

Archimedian Spiral

Archimedian spiral is the curve traced out by a point moving along a line while the it rotates with uniform angular velocity

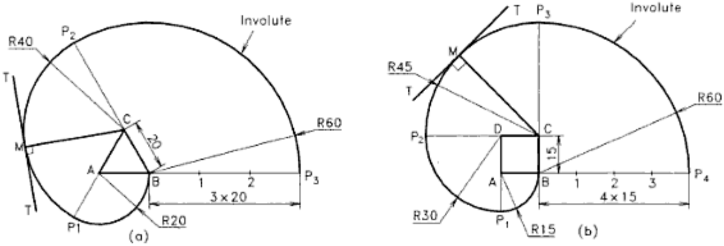


Fig. 7.8 Involutes of polygons.

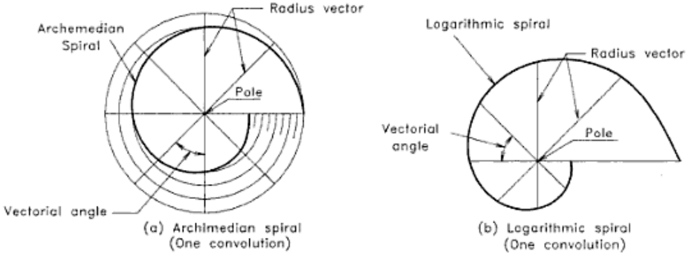


Fig. 7.9 Involutes of polygons.

about the pole in such a way that its linear displacement towards or away from the pole is constant for each equal angular displacement of the line. Note that the point traces one convolution when the line rotates once.

It is widely used in mechanical engineering fields such as cam design, scroll of self centring chuck, volute casing of centrifugal pumps, etc.

Example 7.8

Construct an archimedian spiral for one convolution. The greatest and the least radii are 80 mm and 20 mm respectively. Also draw normal and tangent at any point M on the spiral.

Refer to Fig. 7.10.

1. Draw a horizontal line OB of length 80 mm to represent the greatest radius. Mark a point A on OB such that OA = 20 mm to represent the least radius.
2. With centre O and radius equal to 80 mm, draw a circle. Divide the circle into any number of equal parts (say 12) and also divide AB into the same number of equal parts.
3. The required curve is the path of point P moving from A to B along a radius vector while AB rotates one time about the pole O. To get one of the intermediate positions of the points P (say P_4), with centre O and radius equal to O4′ draw an arc to cut the radial line O4 at P_4.
4. Similarly, obtain other intermediate points P_1, P_2, P_3, etc. Draw a smooth curve passing through all these points to get one convolution of the spiral.
5. To draw a normal at any point M on the curve, locate the point M and calculate the constant of the curve.

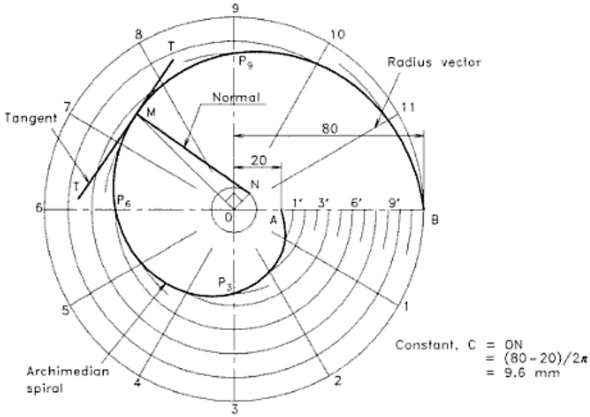


Fig. 7.10 Archimedian spiral (one convolution).

Constant of the curve,

$$C = \frac{\text{Radial distance moved by the point P}}{\text{Corresponding angular measure for the movement}}$$

$$= \frac{OB - OA}{2\pi}$$

$$= \frac{80 - 20}{2\pi}$$

$$= 9.6 \text{ mm}$$

6. Join MO and draw ON perpendicular to OM such that ON = the constant C of the curve. It may be noted that ON is marked in the direction in which the length of the radial vector is increasing. Join NM which is the required normal to the curve. Draw a line TMT perpendicular to NM. Now, TMT is the required tangent at M.

Example 7.9

A lever 100 mm long, swings about a point from its vertical position to its right side through an angle of 30°. Then it swings to the opposite direction through an angle of 60° and returns to its initial position. During this period a particle travels from top to the bottom along the lever at uniform speed. Trace the locus of the particle assuming uniform angular velocity of the lever.

Refer to Fig. 7.11.

1. Draw a vertical line OA of 100 mm length. Also draw OB and OC at 30° angle to this line. Then insert the angular bisector of AOB and AOC.
2. The lever end A swings from A to B, B to C and then back to A. Mark this path by 8 points as 1, 2, 3,...,8.

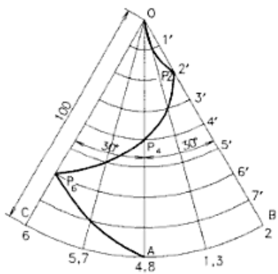


Fig. 7.11 Loci of a point.

3. Divide OB also into the same number of 8 parts as 1′, 2′, ... , etc. and draw 8 arcs through these points with centre O.
4. The intersection of radial vector 1 and arc 1′ gives the first point P_1. Similarly locate points P_2, P_3, ..., etc. and join them by a smooth curve to get the locus of the particle P.

Logarithmic Spiral

Logarithmic spiral is the curve traced out by a point moving along a line such that for equal angular displacements of the line the ratio of the lengths of consecutive radial vectors is constant. In logarithmic spiral, vectorial angles increase by equal amounts and they are in arithmetic progression and the corresponding radial vectors are in geometric progression. Note that the point P traces one convolution when the line rotates once. A tangent at any point M on the curve makes a constant angle with the radius vector passing through the point M. Hence, the curve is also called *equiangular spiral.*

Example 7.10

Draw a logarithmic spiral for one convolution such that the angle between two consecutive radii is 30°. The ratio of succeeding radii is 6:5 and the greatest radii being 108 mm. Draw tangent and normal at any point on the curve .

Refer to Fig. 7.12.

1. Draw a horizontal line OP of length equal to 108 mm, the greatest radial vector.
2. Draw 12 radial vectors with 30° angle through the pole O.
3. Construct a supplementary figure to get the various radial lengths [Fig. 7.12(b)]. For, this draw AB = AC = 108 mm, the greatest radial vectors at 30° angles. Mark AD = 5/6 of AB. Join CD.
4. With A as centre and AD as radius, draw an arc to cut AC at E .Through E, draw a line parallel to CD to cut AB at 11 . Repeat the process to get the point, 10, 9... and 1.
5. Transfer the distance A1 on OP to get the point P_1. Similarly, set off points P_2, P_3, etc. on the respective radial lines such that OP_2 = A2, OP_3 = A3 etc. Draw a smooth curve to get the logarithmic spiral.
6. The tangent at any point on a logarithmic spiral always makes a constant angle a with the radius drawn at that point. The value of a depends on the ratio of the two succeeding radii and the angle between them. This can be calculated by the given equation:

$$\tan \alpha = \theta \left(\frac{\log e}{\log r} \right)$$

where, $\theta = 30°$

$$= \frac{\pi}{6 \text{ radians}}$$

$$e = 2.718$$

$$r = \frac{6}{5}$$

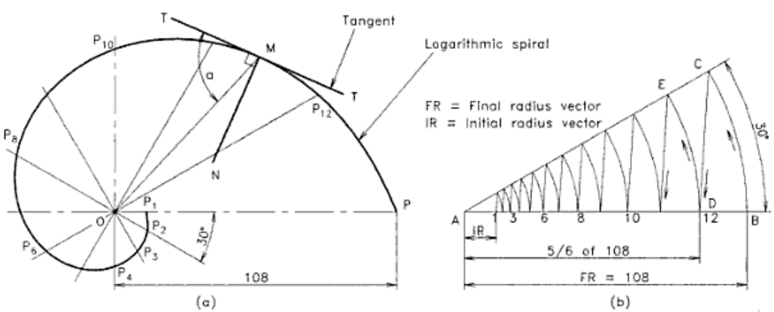


Fig. 7.12 Logarithmic spiral (one convolution).

$$\tan \alpha = \frac{\pi}{6} \times \frac{\log 2.718}{6 \log r}$$
$$= 2.871$$
$$\alpha = \tan^{-1} 2.871$$
$$= 70.8°$$

7.10 HELIX

Helix is defined as a space curve generated by a point which moves on the surface of a cylinder or cone in a circumferential direction at a constant angular speed and with a simultaneous axial advancement at a uniform rate.

Helix can also be defined as a space curve generated by a point which moves uniformly about another line called axis. If this straight line revolves parallel to the axis, it will generate a cylinder and the corresponding curve generated by the point is called *cylindrical helix*. If this straight line revolves intersecting the axis at one point, it will generate a cone and the corresponding curve generated by the point is called *conic helix* or *conical helix*. If the straight line revolves intersecting the axis at right angles at one point, the curve generated by the point will be an *archimedian spiral*.

Cylindrical Helix

Cylindrical helix may be defined as a space curve generated by a point which moves on the surface of a cylinder in a circumferential direction at a constant angular speed and with a simultaneous axial advancement at a uniform rate. The term helix is commonly used to represent a cylindrical helix. A helix may be either right handed or left handed as shown in Fig. 7.13(a) and (b) respectively.

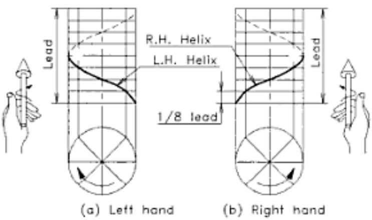


Fig. 7.13 Cylindrical helix.

The axial movement of the point during one complete revolution of the cylinder is called *lead*. For a single start helix, the axial movement is called pitch. For multistart helices,

$$\text{Pitch} = \frac{\text{Lead}}{\text{Number of starts}}$$

Conical Helix

Conical helix is defined as a space curve generated by a point which moves on the surface of a cone in a circumferential direction at a constant angular speed and with a simultaneous axial advancement at a uniform rate (see Fig. 7.14).

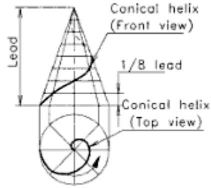


Fig. 7.14 Conical helix (right hand).

The axial movement of a point during one revolution of the cone is called pitch. It is measured parallel to the axis of the cone. The surface of the cone is seen completely in the top view and hence the helix on the cone will also be seen in the top view.

Example 7.11

Draw a right hand single start helix of one convolution. Take pitch = 56 mm and the cylinder diameter = 40 mm.

Refer to Fig. 7.15.

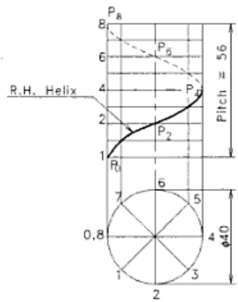


Fig. 7.15 Construction of helix.

1. For one convolution, the height of the cylinder is equal to pitch = 56 mm. Draw the top view and front view of the cylinder.
2. Divide top view into any number of equal parts (say 8). Also divide the height of the cylinder into the same number of equal parts and name the points as shown.

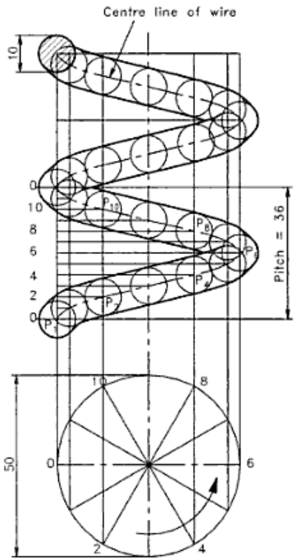


Fig. 7.16 Open coil helical spring.

3. Let P_0 be the initial position of the point P on the helix. As it moves around the circumference of the cylinder in the anticlockwise wise direction through an angle as indicated by 0 to 1 in the top view (i.e. 1/8th of one rotation), it gets an axial advancement from 0 to 1 in the front view (i.e. 1/8 of the pitch of the helix) simultaneously. This position of the point P is represented by the point P_1. This is the point of intersection of the vertical line through 1 in the top view and the horizontal line through the point 1 in the front view.
4. Similarly obtain other points P_2, P_3, etc. The portion of the curve from P_4 to P_8 is on the rear side of the cylinder and hence it is shown by short dashes. The curve passing through P_0, P_1, P_2, etc. is the required helix of one convolution.

Example 7.12

Draw two complete turns of an open coil helical spring of wire diameter 10 mm . The mean diameter of the spring is 50 mm and the pitch is 36 mm .

Refer to Fig. 7.16.

1. Draw a circle of diameter 50 mm to represent the top view of the mean diameter of the spring. Divide the circle into 12 radial divisions and mark them as 0, 1, 2, 3, ... etc.
2. Draw vertical lines through these points and mark off the pitch 36 mm, two times as shown in figure.
3. Divide one pitch into 12 parts and draw horizontals through 1, 2, 3, ... etc.
4. Locate the intersection points P_0, P_1, P_2, etc. as explained in example 7.11 and draw a helix by joining the points using a smooth curve to get the centre line of the spring.
5. With P_0, P_1, P_2, etc. as centres and diameter equal to 100 mm draw circles. Draw two curves running tangential at the top and bottom sides of the circles as shown in figure to show the wire.

EXERCISES

Cycloidal curves

1. A circular wheel of diameter 56 mm rolls without slipping along a straight line. Draw the curve traced by a point P on its rim for one revolution of the wheel. Draw tangent and normal to the curve at a point located 40 mm away from the line.
2. A carriage wheel having a diameter of 48 cm is rolled on a rail. The wheel has a flange of 60 cm diameter. Draw the path of a point on the flange for one complete rotation of the wheel. Also draw tangent and normal at a point located 46 cm high above the rail top. Use suitable scale.
3. A circular disc of 52 mm diameter rolls without slipping along a line. Draw the locus of a point which lies at a distance of 16 mm from the centre of the disc, for one revolution. Also draw tangent and normal at any point on the first half of the curve.
4. A circle of diameter 46 mm rolls over the circumference of another circle of diameter 180 mm. Assuming no slip, trace the locus of a point on the circumference of the rolling circle for one complete revolution. Show tangent and normal at any point on the second quarter of the curve.
5. A circle of 44 mm diameter rolls along the inside of another circle of 200 mm diameter. Draw the path described by a point on the circumference of the rolling circle for one complete revolution. Draw tangent and normal at a point on the third quarter of the curve.

Involutes

6. Draw the involute of a circle having diameter 40 mm. Draw tangent and normal at a point on the curve located at a radial distance of 100 mm.
7. Draw involutes to the following shapes and mark the tangent and normal at the midpoint of the third segment of each curve.
   1. Equilateral triangle of side 30 mm.
   2. Square of side 25 mm.

Spiral curves

8. Draw an archimedian spiral for one convolution. The initial and final radial vectors are 30 mm and 90 mm long respectively. Draw tangent and normal to the spiral at a point 45 mm away from the pole.
9. A rod OP of length 120 mm oscillates through 80° about the centre O with a uniform angular velocity. During one oscillation a point K moves from the point O to the end P with a uniform velocity. Trace the path of the point K.
10. Draw a logarithmic spiral for one convolution, the ratio of successive radii is 7:6, the final radial vector is 112 mm long and the angle between successive radii is 30°. Draw normal and tangent at a point on the curve, 60 mm away from the pole.

Helix

11. Plot two complete turns of a cylindrical right hand helix of 50 mm diameter and 48 mm pitch.
12. Draw two complete coils of a helical spring with a circular section of diameter 12 mm. The outside diameter of the spring is 62 mm and pitch is 48 mm.

CHAPTER 8

Scales

All the engineering drawings are prepared to scale. The type of scale used for a drawing should be mentioned. For the clarity of a drawing, the scale adopted should be the largest possible. If a drawing is made of the same size as the object, the view obtained will have the same size as the object. The drawing thus obtained is called a *full size drawing* and the scale used is called *full size scale*.

If an object is larger in size, like a building or a motor car, its drawing is made smaller than the object. The scale used for this drawing is called a *reduced scale*. If an object is small in size, like watch parts or electronic components, its drawing is made larger than the object. The scale used here is called an *enlarged scale*. Thus a scale is used to prepare a reduced or an enlarged size drawing. It can also be used either to measure distances or to set off dimensions.

Standard scales used in engineering practice are readily available in sets of 8 scales or 12 scales. These standard sets of scales are called *drafter's scales*. Whenever a scale other than the standard one is to be used for the preparation of a drawing, such a scale should be constructed along with the drawing.

8.1 CLASSIFICATION OF SCALES

Types of scales used in engineering practice are classified as below:

1. Plain scale
2. Diagonal scale
3. Vernier scale
4. Comparative scale
5. Isometric scale
6. Scale of chords

The comparative scales are basically plain scales or diagonal scales drawn in pairs, having the same representative fraction for the purpose of comparison. One of the scales of the comparative scale is graduated to read different units from the other scale so that the same drawing can be read in both units simultaneously.

Isometric scale is used in the preparation of isometric projection of objects. The method of constructing an isometric scale is explained in Chapter 16. Scale of chords is used either to measure or to mark off angles if a protractor of convenient size is not available. This scale is constructed by using the length of chords of different angles, measured on the same arc. Among the above six types of scales, only plain, diagonal and vernier scales are explained in the following sections.

8.2 REPRESENTATIVE FRACTION

Representative fraction is the ratio of the distance between any two points on the object (length of the object) in the drawing to the actual distance between the same points on the object (i.e. the actual length of the object). The representative fraction is usually abbreviated as R.F.

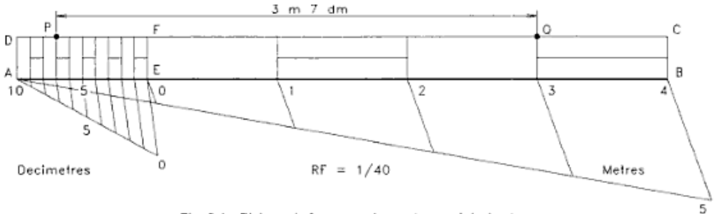


Fig. 8.1 Plain scale for measuring metres and decimetres.

For example, if an actual length of 4 m of an object is represented as an object 20 mm length in the drawing, then

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

$$= \frac{20 \text{ mm}}{4 \text{ m}}$$

$$= \frac{20 \text{ mm}}{(4 \times 1000) \text{ mm}}$$

$$= \frac{1}{200}$$

i.e. R.F. = 1:200

This represents a reduced scale.

8.3 PLAIN SCALE

A plain scale is the simplest scale in which a line is used to represent dimensions. Thus the line is divided into a suitable number of equal parts or units and the first division is subdivided into equal number of smaller parts or sub units. Thus a plain scale represents either two units or a single unit and its subdivisions are as shown in Fig. 8.1.

For the construction of a plain scale the following data are required;

1. Representative fraction (R.F.) of the scale,
2. Units and subdivisions to be represented, and
3. The largest dimension to be measured.

The method of construction and the practice of labelling various informations can be better understood with the help of the following example.

Example 8.1

Construct a plain scale of R.F. = 1 : 40 to show metres and decimetres and long enough to measure up to 5 metres. Mark a dimension on the scale representing 3.7 metres.

Refer to Fig. 8.1

1. Representative fraction,

$$\text{R.F.} = \frac{1}{40}$$

$$\text{Length of scale} = \left(\frac{1}{40}\right)(5 \times 1000)$$

$$= 125 \text{ mm.}$$

2. Draw a line AB = 125 mm long, and divide the line into 5 equal parts as shown in the figure. Each part represents one metre. Subdivide the first part AE into 10 equal subdivisions. Each subdivision represents one decimetre.
3. The scale is shown in the form of a rectangle ABCD of convenient width (say 10 mm). To distinguish the divisions, draw thick horizontal lines in the alternate divisions representing both metres and decimetres. Write down the units and R.F. as shown in the figure.
4. The required dimension of PQ = 3.7 m, i.e. 3 m 7 dm, is also marked in the figure.

8.4 DIAGONAL SCALE

Diagonal scale represents three different units such as metres, decimetres and centimetres simultaneously. In a diagonal scale, a line is divided into suitable number of equal parts or units and the first division is subdivided into smaller parts or units diagonally. Thus a diagonal scale represents either three units or a unit and its subdivisions to the second place of decimal point as shown in Fig. 8.2.

Example 8.2

Construct a diagonal scale of R.F. 3:90 to show metres, decimetres and centimetre and to measure up to 4 m. Show a distance of 2 m, 3 dm and 5 cm on the scale.

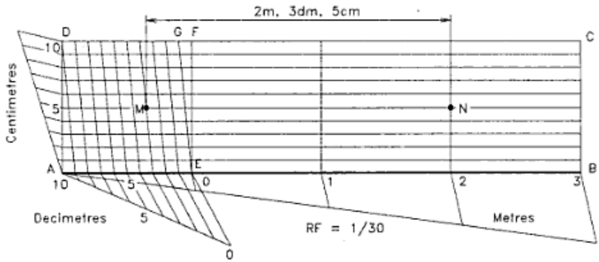


Fig. 8.2 Diagonal scale for measuring m, dm, and cm.

Refer to Fig. 8.2.

1. Representative fraction

$$R.F. = \frac{3}{90}$$
$$= \frac{1}{30}$$
$$\text{Length of scale} = \left(\frac{1}{30}\right) \times (4 \times 1000)$$
$$= 133 \text{ mm (Approx.)}$$

2. Draw a line AB = 133 mm long and divide the line into 4 equal parts as shown in figure. Each part represents one metre. Subdivide the first part into 10 equal number of small parts. Each subdivision represents one decimetre.
3. Draw perpendiculars AD and BC of convenient length (say 40 mm) at the points A and B respectively and complete the rectangle ABCD as shown.
4. Divide the line AD into 10 equal divisions and name the points from 0 to 10. Draw horizontal lines through these points. Also transfer the subdivisions from line AE to the line DF. Join the ninth subdivision on AE with D.
5. Draw lines parallel to 9D through points 8, 7, etc. on AE as shown in the figure. These parallel but inclined lines are called *diagonal lines*.
6. In the figure, length GF represents 1 decimetre. The diagonal line GE of the right angled triangle GEF progressively increases from 0 to E to 1 dm at GE. The required dimension of 2 m, 2 dm and 5 cm is marked as the distance between the points M and N.

8.5 VERNIER SCALES

Vernier scales are modified forms of diagonal scales and are used to measure very small units with great accuracy. A vernier scale consists of a primary long scale similar to a plain scale called *main scale* and a secondary short scale called *vernier scale*. Vernier scale slides on the main scale and they are combinedly used to measure small divisions up to three different units as in diagonal scale.

To represent the third unit in a vernier scale, a line is divided into suitable number of equal parts or units. As it is difficult to further subdivide these small parts, so a vernier scale is used.

Vernier scales are of two types:

1. Backward or Retrograde vernier.
2. Forward or Direct vernier.

Backward Vernier

In a backward (retrograde) vernier, the length of $(n + 1)$ divisions on the main scale is divided into n numbers, so that each division on vernier scale is $(n + 1)/n$ i.e. $1/n$ times larger than one division on the main scale (see Fig. 8.3). Also the vernier divisions are numbered in the opposite direction as those on the main scale. The increase of $1/n$ times of each division provides the facility to measure one more subdivision of the unit of main scale division and that subdivision is called the *least count* of the vernier.

Forward Vernier

In a forward (direct) vernier, the length of $(n - 1)$ divisions on the main scale is divided into n divisions. So that each

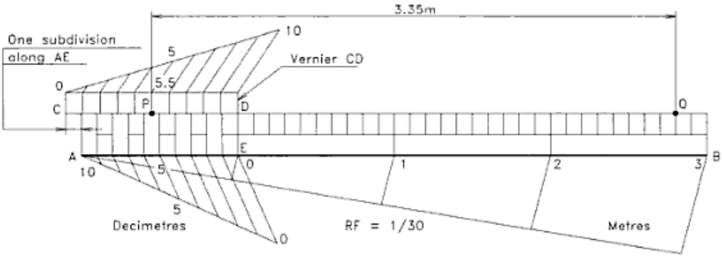


Fig. 8.3 Backward or retrograde vernier scale.

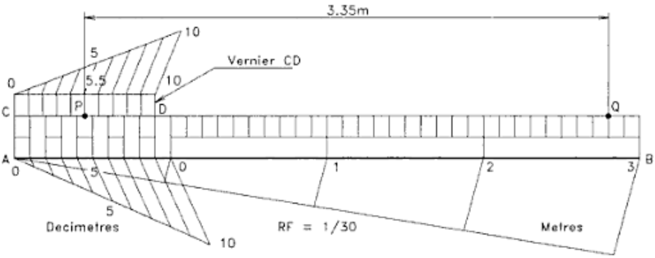


Fig. 8.4 Forward or direct vernier scale.

division on vernier scale is $(n - 1)/n$ i.e. $1/n$ times smaller than one division on the main scale (see Fig. 8.4). Here the vernier divisions are numbered in the same direction as that of the main scale. The decrease of $1/n$ times of each division enables to measure one more subdivision of the unit of main scale division and that subdivision is called the *least count* of the vernier.

The following examples give the method of construction of backward as well as forward verniers in detail.

Example 8.3

Construct a backward vernier scale of R.F. 1/30 to show metres, decimetres and centimetres. The scale is to be used for reading 4 m length. Mark a distance of 3 m, 3 dm and 5 cm on the scale.

Refer to Fig. 8.3.

1. Representative fraction,

   R.F. = 1/30

   Length of scale = (1/30) × (4 × 1000)

   = 133 mm (Approx.)

2. Draw a line AB 133 mm long and divide it into 4 equal parts. Then each part represents one metre. Subdivide each metre into 10 subdivisions. Each of these subdivisions represents one decimetre as shown in the figure.
3. Draw a line CD having the length of 11 subdivisions and divide it into 10 equal parts as shown. Each of the subdivisions on the vernier scale represents

   11/10 = 1.1 dm

   = 11 cm.

4. To mark the required length PQ = 3.35 m, take 2 main divisions representing 2 m, 8 subdivisions on the main scale representing 8 dm and 5 divisions on the vernier representing 55 cm.

$$\text{Length of PQ} = 2\text{ m} + 8\text{ dm} + 11 \times 5\text{ cm}$$
$$= 2\text{ m} + 0.8\text{ m} + 0.55\text{ m}$$
$$= 3.35\text{ m.}$$

Example 8.4

Construct a forward vernier of R.F. 1/30 to show metres, decimetres, and centimetres. The scale is to be used for reading 4 m. Mark a distance of 3 m, 3 dm and 5 cm on the scale.

Refer to Fig. 8.4.

1. Representative fraction,

$$\text{R.F.} = 1/30$$
$$\text{Length of scale} = (1/30) \times (4 \times 1000)$$
$$= 133\text{ mm (Approx.)}$$

2. Draw a line AB 133 mm long and divide it into 4 equal parts. Then each part represents one metre. Subdivide each metre into 10 subdivisions. Each of these subdivisions represents one decimetre as shown in the figure.
3. Draw line CD having the length of 9 divisions and divide it to 10 equal parts as shown. Each of the subdivisions on the vernier scale represents

$$9/10 = 0.9\text{ dm}$$
$$= 9\text{ cm}$$

4. To mark the required length PQ = 3.35 m, take 2 main divisions representing 2 m, 9 subdivisions on the main scale representing 9 dm and 5 divisions on the vernier scale representing 4 cm.

$$\therefore \quad \text{Length of PQ} = 2\text{ m} + 9\text{ dm} + 9 \times 5\text{ cm}$$
$$= 2\text{ m} + 0.9\text{ m} + 0.45\text{ m}$$
$$= 3.35\text{ m}$$

8.6 SCALE OF CHORDS

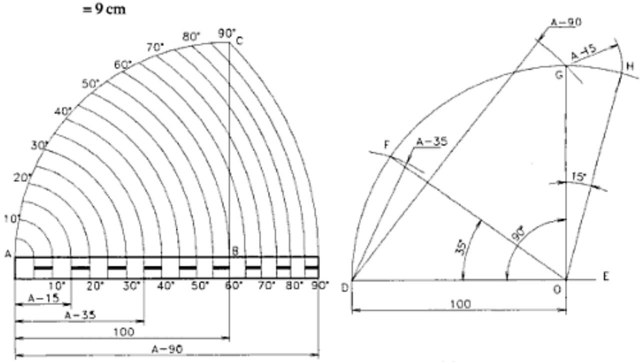
The scale of chords is a linear scale constructed to measure angles. It is based on the length of chords of different angles measured on the same arc. The method of its construction of the scale of chords and its use to set-out angles are explained in the following examples.

Example 8.5

Construct a scale of chords having 5° divisions and with its aid, set off angles 35° and 105°.

Refer to Figs. 8.5(a) and (b).

1. Draw line AB of any length (say 100 mm) and erect the perpendicular BC.
2. With centre B and radius AB, draw the arc AC. The chord of arc AC subtends 90° angle at the centre B.
3. Divide the arc AC into 18 equal parts so that, each part subtends an angle of 5° at B.
4. Turn down the division points to the line AB and complete the scale as shown in figure.



(a) Construction (b) Marking of angle

Fig. 8.5 Scale of chords.

5. To mark the required angles, draw any line DE and construct an arc of radius equal of the scale of chords (AB = 100 mm) taking centre at any point O on DE.
6. To set-out 35°, cut an arc with centre A and radius equal to the length A-35°, taken from the scale of chords. This gives point F on the arc. Join O and F and angle DOF is the required angle 35°.
7. To set-out 105°, first mark 90° and then 15° as explained earlier. Angle DOH gives angle 105°.

EXERCISES

Plain scale

1. Draw a plain scale to show decimetres and centimetres. Show a length of 8.2 dm if the R.F. of the scale is 1:7. The maximum length of the scale should be 12 dm.
2. The distance between two cities is 250 km and is represented by a line of length 50 mm on a map. What is its R.F? Draw a plain scale showing upto 10 km and indicate a distance of 530 km on it.

Diagonal scale

3. Construct a diagonal scale of R.F. 1/40 to show metres and long enough to measure upto 6 metres. Mark the following distances on the scale:
   (i) 3.37 m
   (ii) 4.79 m
4. An area of 50 sq.km of a field is represented by an area of 150 sq.cm on a map. Determine the R.F. of the scale used in the map. Also construct a diagonal scale to show kilometres, hectometres and decametres. The maximum length to be indicated on the scale is 10 km. Show a distance of 6.48 km on the scale.

Vernier scale

5. Draw a backward vernier scale with R.F. = 1/40, to read metres and capable of reading in steps of 5 cm. Mark a distance of 3.85 m on the vernier scale.
6. Draw a forward vernier scale to read upto the second decimal place of a dimension in metres and mark a distance of 2.75 m on it, if R.F. = 1/25.

Module C

Three-Dimensional Drawings

C H A P T E R

9

Projections of Points

Engineers, design and develop machines or structures and direct their construction. For this purpose, each and every information about the shape and size of the whole machine or structure, has to be noted in detail. Graphics is the fundamental method used to document as well as communicate them to the manufacturing group. The task of recording shapes and sizes of three-dimensional objects on two-dimension drawing sheets is done using the method of projection.

Projection is the representation of the image of an object on a plane surface, as it is observed by a viewer. The word, projection is of Latin origin and means to throw forward. Thus, a projection is an image of an object thrown upon a picture plane by means of straight lines or visual rays.

9.1 SYSTEMS OF PROJECTION

The shape of a three-dimensional object is described on the picture plane, that is drawing sheet, by means of projection. The methods of projection vary according to the direction in which the rays of sight are taken to the picture plane. If the rays are converging to a particular station point as in a camera, the result is a *perspective projection*. When the rays are parallel but at an angle to the picture plane, the projection is called *oblique projection*. If the rays are parallel as well as perpendicular to the picture plane, the method is called *orthographic projection*. The different systems of projections can be classified as given below:

Pictorial views are obtained in all the above types of projections, expect in the *multiview*. In multiview (orthographic) projection, the object shape is represented by two or more views taken at right angles to each other.

Perspective projection is described in Chapter 18 and oblique projection in Chapter 18. Isometric projection is comes under the principle of orthographic projection and is explained in Chapter 16.

9.2 MULTIVIEW PROJECTION

Multiview projection is an orthographic projection in which the exact shape of an object is represented by two or more separate views projected on planes that are perpendicular to each other. Each view shows the shape of the object for a particular view direction and these views altogether describe the object completely. Because of these reasons, this method of projection is the most widely used for preparing engineering drawings. The term *orthographic projection* is also used to represent multiview projection.

Planes of Projection

The plane surfaces, which are used to project the views of an

SYSTEMS OF PROJECTION

- **Perspective** *(Converging projectors)*
  - Parallel perspective *(1 point)*
  - Angular perspective *(2 point)*
  - Oblique perspective *(3 point)*
- **Oblique** *(Parallel projectors inclined to picture plane)*
  - Cavalier
  - Cabinet
  - General
- **Orthographic** *(Parallel projectors perpendicular to picture plane)*
  - Axonometric
    - Isometric
    - Dimetric
    - Trimetric
  - Multiview
    - First angle projection
    - Third angle projection

object in multiview projection are called *principal planes* or *reference planes*. Out of these mutually perpendicular planes, one plane is horizontal and it is called *horizontal plane* (HP). The other plane is vertical and it is called *vertical plane* (VP). A third vertical plane which is perpendicular to both HP and VP is also added in order to get the side or end view of the object projected. This plane is called *Profile Plane* (PP). These three mutually perpendicular coordinate planes produce eight compartments in the space called *octants* (see Fig. 9.1). Here, the intersection point of the three planes is considered as the origin O and the quadrants are counted in the anticlockwise direction, when viewed from the left side.

For this anticlockwise system, the front, top and left sides are as shown.

For easy understanding of the projection method, the right part of the octants containing four compartments (right side) may be eliminated. Then the left part forms the four quadrants as shown in Fig. 9.2. These imaginary reference planes are assumed as transparent and these planes form the basis to obtain views for describing objects in engineering problems.

The multiview projection method is classified into two types, such as *First angle projection* and *Third angle projection*.

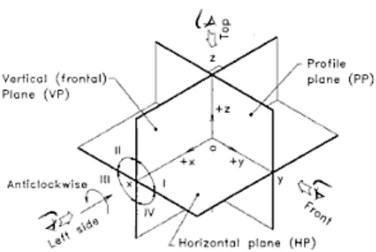


Fig. 9.1 Three planes of projection forming eight spaces-octants (anticlockwise system).

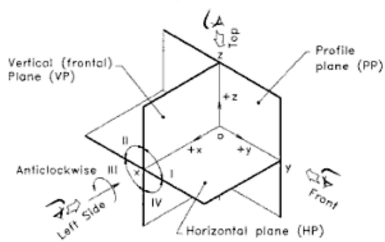


Fig. 9.2 The four quadrants for orthographic projection left side view (anticlockwise system).

First Angle Projection

In first angle projection the object (say, a vertical cylinder) is assumed to be placed in the first angle (quadrant) as shown in Fig. 9.3. Then the object is viewed from the front side as well as top side in a direction perpendicular (orthogonal) to VP and HP respectively. The views are projected on VP and HP

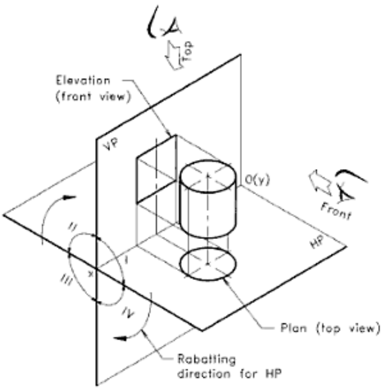


Fig. 9.3 Principal planes with an object in the first quadrant (first angle projection).

in order to get the front view (elevation) and top view (plan) respectively. After projecting the views, the horizontal plane, HP is rotated (rabatted) about the reference line *ox* as indicated by the arrows, so that the horizontal plane coincides with the vertical plane VP. Now the two views are seen in a single vertical plane, i.e., in the plane of the drawing sheet, as shown in Fig. 9.4.

Third Angle Projection

In the third angle projection, the object (cylinder) is assumed to be placed in the third quadrant and is viewed from the same front, top sides orthogonally (see Fig. 9.5). Note that, the front and top views are seen through the transparent planes. The two views are projected on VP and HP. After rotating (rabatting) the planes as done in the previous case, the front

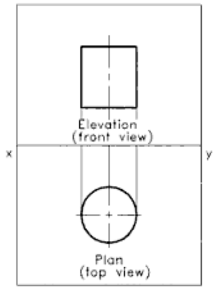


Fig. 9.4 First angle projections of a vertical cylinder.

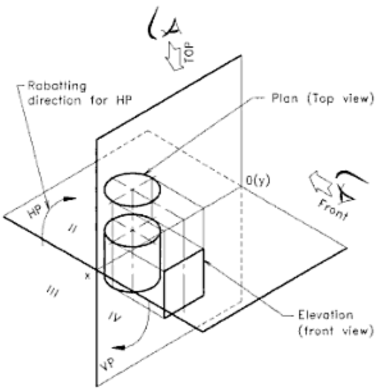


Fig. 9.5 Principal planes with an object in the third quadrant (third angle projection).

and top views of the cylinder are obtained as shown in Fig. 9.6. It is to be noted that the views are the same as that of first angle projection but the location of views are interchanged in the third angle projection.

ISO Symbol to Indicate the Angle of Projection

While drawing orthographic views on a drawing sheet, the

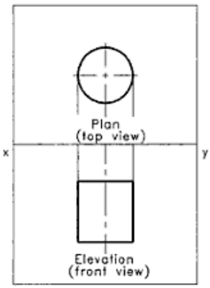


Fig. 9.6 Third angle projections of a vertical cylinder.

method of projection (First angle or third angle) should be indicated using symbols inside the title block. The symbol recommended by ISO as well as Bureau of Indian Standards for the first angle projection is shown in Fig. 9.7. The symbol shows two views of a frustum of a cone lying in the first quadrant keeping its axis horizontal.

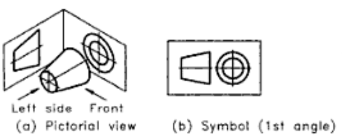


Fig. 9.7 Symbol for first angle projection.

In third angle projection the same frustum of cone is placed horizontal in the third quadrant and the views are obtained as shown in Fig. 9.8. Here, the end view as circles are obtained on the left side of the front view.

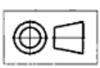


Fig. 9.8 Symbol for third-angle projection.

Bureau of Indian Standards has recommended first angle projection method for the preparation of engineering drawings of objects. USSR and other East European countries coming under ISO, follow first angle projection method, while USA follows third angle projection. In UK, both the methods of projection are used.

It may be noted that both the second angle and fourth angle methods of projection are not in use for objects, because the top and front views get superimposed, when the horizontal plane is rotated in the clockwise direction. However, projections of points and lines are drawn after placing them in all the four quadrants. Hence, an engineering student must study and practice the projections of points and lines placed in all the four quadrants.

9.3 THE PRINCIPLE OF ORTHOGRAPHIC PROJECTIONS OF A POINT ON HP AND VP

Conversion of a Solid to a Point

A solid (say a vertical cylinder) is formed by three-dimensions measured in the three mutually perpendicular directions. If one of the dimensions (say height) is made zero, the object is converted into a two-dimensional plane (circular lamina). Out of the two remaining dimensions, if one more dimension is reduced to zero, the plane is changed into a line. Lastly, if the remaining dimension is also reduced to zero, the line is shortened into zero length, and forms a point. Hence, a point in three-dimensional geometry may be considered as the smallest, dimension-less form of a solid, which can be situated any where in the space. In orthographic projection, this dimensionless object is specified by its location only with respect to the three principal planes VP, HP and PP. The point may be situated in any of the four quadrants (angles) or may lie in the principal planes.

Drawing of a Point

A point-object is represented by a dot in a drawing. Assume that a point-object P is placed in the first quadrant (above HP and in front of VP) as shown in Fig. 9.9. For simplicity, the

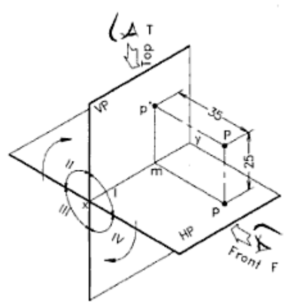


Fig. 9.9 Principal planes with point P in the 1st quadrant.

profile plane PP is not considered here. View the point P from the front and top sides orthogonally. Project the views to the VP and HP respectively by dropping projectors perpendicular to the reference planes. The point of intersection of the projector with the surface of plane is the projection of the point on that plane. Here, the front view on VP is named as p', and the top view on HP is named as p.

After marking the views and the projectors mp' and mp on the planes, the HP is rabatted (rotated) clockwise about the reference line xy to bring it in the same plane of VP. Now the projection planes will be seen as in Fig. 9.10. The line xy represents the intersection of HP and VP. The rectangles representing the planes are not shown in the final projection form. Figure 9.11 shows the final form of projections of point P situated in the first quadrant.

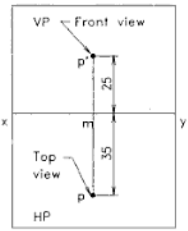


Fig. 9.10 Principal planes with the projected images of point P.

9.4 CONVENTIONAL REPRESENTATION OF VIEWS

In order to distinguish between the projected points, lines, objects, projection lines, etc. of views, certain conventional representations are followed in orthographic projections of solids, similar to that of a language. These conventional representations are obeyed internationally and a variation will be treated as a spelling or grammar mistake in the graphics' language. The conventional representations, relevant to the projections of points, are given below:

1. The actual point is represented by the capital letters as seen in the pictorial view (Fig. 9.9).
2. The top view points are represented by small (lower case) letters such as a, b, c, etc. The front view points are represented by small letters with single primes (dashes) as a', b', c', etc. while the side view points are represented by small letters with double primes (dashes) as a'', b'', c'', etc.
3. The planes of projection are assumed to be transparent as well as endless; so that their boundaries are not shown in projections. But the intersection line of HP and VP is shown in geometrical drawings as the reference line xy. Thin line and lower case letters are used for this.
4. The projectors are usually shown in orthographic projections of solids. Thin continuous (Type B) lines are used to draw them. Projection lines are drawn always perpendicular to the reference line xy, because it is orthographic projection.
5. The object is drawn using thick (Type A) lines while all the remaining lines are drawn as thin. For the representation of a point-object, a thick dot (say, 1 mm) may be used (see Fig. 9.11).

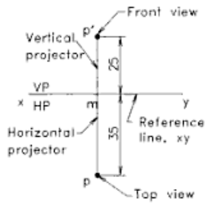


Fig. 9.11 Projections of point P in the 1st quadrant.

9.5 VISUALIZATION OF THE REFERENCE PLANES

To locate the projections of points and lines in the front and top views with respect to the reference line xy, a student may visualize the VP and HP in the following manner.

Refer Fig. 9.12(a). To mark the front view, assume that you are looking at the reference planes from the front side *F*. Now HP coincides with xy line so that, any thing above the xy line means *above HP* and that below the xy line means *below HP*. To get a physical concept, HP (xy line) may be interpreted as a floor with a tree growing above (up wards) and the root growing below (downwards) [see Fig. 9.12(b)]. Similarly, if you are looking from the top side T, the VP coincides with xy line, so that anything *in front of VP* is in front of xy line and that *behind VP* means behind xy line. Here, the VP (xy line) may be interpreted as a wall with a jet plane getting ready to takeoff [see Fig. 9.12(c)]. The Jet moves forward from the VP (wall) while the exhaust gas moves backward. If the two views are combined, Fig. 9.12(d) is obtained.

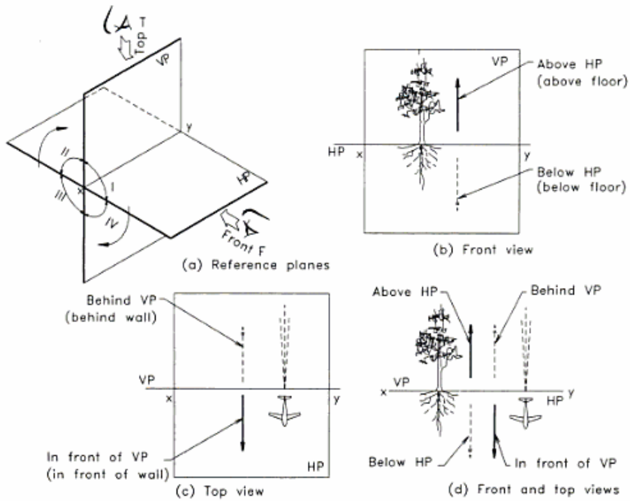


Fig. 9.12 Visualization of principal planes.

It is to be noted that the same *xy* line is representing the HP (floor) in the front view and VP (wall) in the top view. This makes a little confusion to a beginner. To overcome this, think about a tree standing on the floor (HP) while considering front view and mark the above as well as below distances from HP (*xy* line), the floor. Similarly think about the jet staying in front of the wall (VP) while considering the top view and mark the front well as behind distances from VP (*xy* line), the wall.

> **Meaning of *xy* line in projection**
> *For all front views, xy line represents the elevation of HP (floor) so that, above xy line means above HP and below xy line means below HP. For all top views, xy line represents the plan of VP (wall) so that, in front of xy line means infront of VP and behind xy line means behind VP.*

9.6 PROJECTIONS OF A POINT IN THE FIRST QUADRANT

When a point is situated in the first quadrant, its front view will be above the *xy* line and the top view will be below the *xy* line. Refer to Figs. 9.9 and 9.11. The following example explains the method of solution.

Example 9.1

A point 'A' is 36 mm above HP and 30 mm in front of VP. Draw its projections.

Refer to Fig. 9.13.

1. Draw a horizontal thin line to represent the reference planes and mark *xy* at the ends.
2. To locate the front view of A, assume that *xy* line represents the elevation of HP (floor). Then draw the vertical projector *ma′* using a thin continuous line and mark off 36 mm above *xy*, as above HP. Here, *a′* is the front view of the point A.
3. To get the top view, assume that *xy* line represents the plan of VP (wall). Extend the vertical projector from *m* to a using thin line, so that *ma* is 30 mm in front of *xy* line, i.e., in front of VP. Here, *a* is the top view of point A.

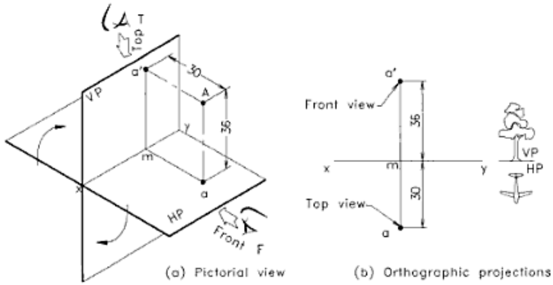


Fig. 9.13 Projections of a point in the 1st quadrant.

4. Place thick dots at a' and a. Write the given dimensions as shown in figure to complete the drawing.

9.7 PROJECTIONS OF A POINT IN THE THIRD QUADRANT

In engineering graphics, points and lines have the freedom to occupy any quadrant irrespective of the angle of projection. The location of a point B in the third quadrant is shown in Fig. 9.14(a). The orthographic projections are given in Fig. 9.14(b). Here, the point B is situated below HP, so the front view b' is located below the xy line. Similarly, the point is behind VP, therefore the plan view b is behind the xy line.

Example 9.2

A point B is located 32 mm behind VP and 22 mm below HP. Draw its orthographic projections.

Refer to Fig. 9.14.

1. Draw a horizontal thin line to represent the reference planes and name it xy.
2. To locate the front view of B, assume that the xy line represents the elevation of HP (floor). Draw the vertical projector mb', 22 mm below xy i.e., below HP. Locate the front view of point B as b' using a thick dot.
3. To locate the top view of B, assume that the xy line represents the plan of VP (wall). Extent the projector from m to b so that, mb is 32 mm behind xy

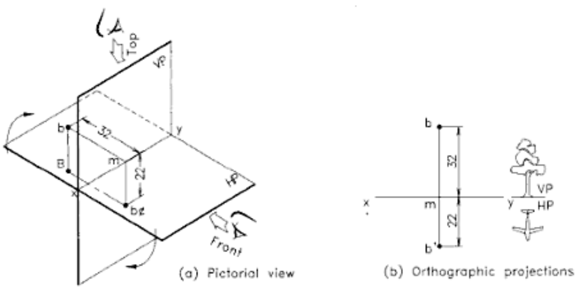
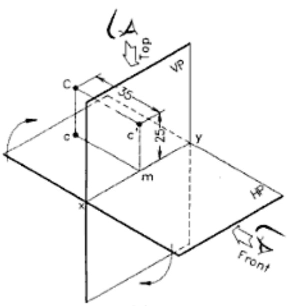


Fig. 9.14 A point in the third quadrant.

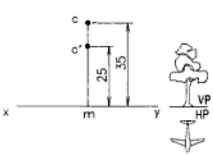
line i.e., behind VP. The line *mb* represents the horizontal projector. Locate the top view of point B as *b* by a thick dot. Write the given dimensions as shown in the figure in order to complete drawing.

9.8 PROJECTIONS OF POINTS IN ALL THE FOUR QUADRANTS

If an object is placed in the second or fourth quadrant, the orthographic projections of them will be overlapping. This happens due to the rabation of the HP about *xy* line in the clockwise direction to align with the VP. Hence, the second and fourth angle (quadrant) projection is not applicable to objects. However, for points and lines, this limitation is not considered. Fig. 9.15(a) shows the pictorial view of a point C, placed in the second quadrant. When the HP is rabatted, the two projections will come to the same side of *xy* line. The final view will be as shown in Fig. 9.15(b). Similarly, for a point D located in the forth quadrant, the projections will be as seen in the Fig. 9.16(a) and will be falling below the *xy* line as shown in Fig. 9.16(b). The following examples give the projections of points, situated in the four quadrants.

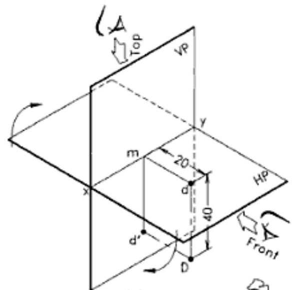


(a) Pictorial view

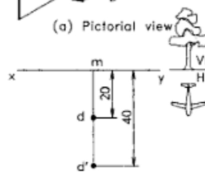


(b) Orthographic projection

Fig. 9.15 A point in the second quadrant.



(a) Pictorial view



(b) Orthographic projection

Fig. 9.16 A point in the fourth quadrant.

Example 9.3

A point C is situated 35 mm behind VP and 25 mm above HP. Draw its projections.

Refer to Fig. 9.15.

1. Draw the *xy* line.
2. To locate the front view of C, assume that the *xy* line represents the elevation of HP (floor). Draw the vertical projector *mc'* equal to 25 mm above *xy* line i.e. above HP.
3. To locate the top view of C, assume that the *xy* line represents the plan of VP (wall). Draw the projectors *mc*, equal to 35 mm behind *xy* i.e. behind the VP as shown in figure.
4. Mark *c* and *c'* with thick dots and place the given dimensions. It is seen that points *c* and *c'* lie on the same side of the *xy* line, because the point C is in the second quadrant.

Example 9.4

A point D is situated 40 mm below HP and 20 mm in front of VP. Draw its projections.

Refer to Fig. 9.16.

1. Draw the *xy* line.
2. Draw the projector *md'* equal to 40 mm below *xy* line i.e., below HP (floor).
3. Locate the plan view as *d* on the projector, so that *md* is 20 mm in front of *xy* line i.e., in front of VP (wall).
4. Mark *d* and *d'* with thick dots and place the dimensions. Here, the views d and *d'* lie on the same side of the *xy* line, because the point is situated in the fourth quadrant.

Example 9.5

The following four points PQRS are situated in the four quadrants. Draw the orthographic projections of them about a single reference line, assuming that their projectors are spaced 30 mm apart horizontally.

(a) P is 30 mm above HP and 40 mm in front of VP.
(b) Q is 25 mm above HP and 35 mm behind VP.
(c) R is 32 mm below HP and 38 mm behind VP.
(d) S is 36 mm below HP and 15 mm in front of VP.

Refer to Fig. 9.12.

1. Draw the *xy* line.
2. Draw projectors 30 mm apart, perpendicular to the reference line, on the *xy* line as shown in the figure. Locate the front view and top view of the points PQRS located in quadrants I, II, III and IV.
3. Mark the location of the points with thick dots and dimension them to complete the drawing.

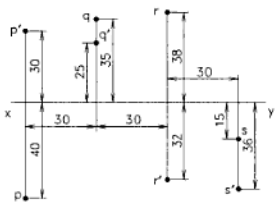


Fig. 9.17 Projections of points in the four quadrants.

9.9 INTERPRETATION OF PROJECTIONS OF POINTS

A student in engineering graphics should develop the capacity to interpret (read) the views and understand the information contained in them. This is a reverse process of what was explained in the previous examples.

Example 9.6

Figure 9.18 gives the projections of points M, N, O and P. Interpret them and determine the positions of the points with respect to the principal planes.

Print the answer using capital letters as given below:

1. Point *m* is 30 mm above HP and 20 mm in front of VP.
2. Point *n* is 35 mm below HP and 15 mm in front of VP.
3. Point *o* is in the HP and 26 mm behind VP.
4. Point *p* is in both HP and VP.

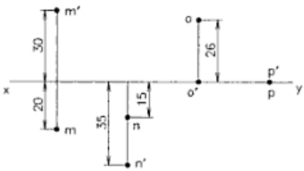


Fig. 9.18 Projections of points in the four quadrants.

9.10 PROJECTIONS OF POINTS ON HP, VP AND PP

A point is fully located in the space, when the distance from the profile plane is also marked in addition to that from HP and VP. Figure 9.19 shows pictorial view of point P located in the first quadrant. Here, *o* is the intersection point of the three planes called the ***origin***. The intersection line of VP and HP is marked as *ox*, that of PP and HP is marked as *oy* and the inter section line of PP and VP is marked as *oz*. To get the projection of P on profile plane, the point is viewed from the left side and projected perpendicular to PP. The view on PP is named as *p''*. To bring the three planes aligned to VP, the HP is rabatted about *xo* line and PP is rabatted about *zo* line resulting the opening of the first quadrant to a single plane. The pictorial view is shown in Fig. 9.20 and the front view in Fig. 9.21. Here, note that the three planes overlap each other. The final view of the projections is shown in Fig. 9.22. Since the distance from the PP is not given, the front and top views may be placed at any convenient distance from *oz* line.

Note that the horizontal line *xo* is extended to y and the vertical line *zo* is extended to y_1 to represent the intersection of the three planes. Here, lines *oy* and oy_1 are the split form of

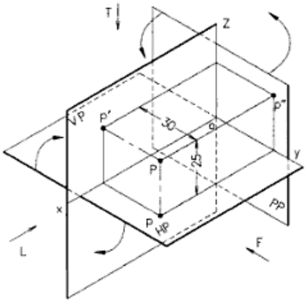


Fig. 9.19 Three principal planes with point P in the 1st quadrant (pictorial view).

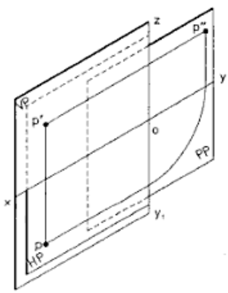


Fig. 9.20 Three principal lanes with projected views of point P (pictorial view–after rabation).

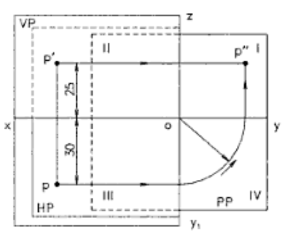


Fig. 9.21 Three principal planes with projected views of point P (orthographic view).

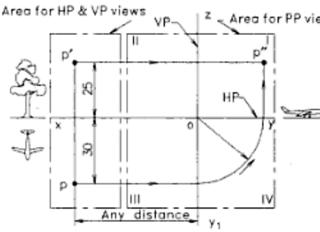


Fig. 9.22 Three orthographic views of point P in the 1st quadrant.

the intersection line oy marked on the pictorial view of planes in Fig. 9.22. It is to be noted that if a profile view is not required, xoy line is reduced as xy line and the zoy_1 line is eliminated for simplicity of presentation.

Example 9.7

Draw three views of a point P located in the first quadrant and dimension them as per BIS. The point P is 25 mm above HP and 30 mm in front of VP.

Refer to Fig. 9.22.

1. Draw the xoy line horizontal and the zoy_1 line vertical through the origin o as shown.
2. Mark front and top views p' and p of point P, after drawing the projectors at a convenient distance from zoy_1 line.
3. Draw horizontal projector through p to meet line oy_1 and rotate it anticlockwise about o to oy. Then project the line upwards to meet the horizontal projector drawn from p', to get the point p'' in the first quadrant.
4. Dimension the views as per BIS.

Example 9.8

Point A is located in the third quadrant. The distance from HP is 30 mm and that from VP is 20 mm. Draw projections of the point on HP, VP and PP.

Refer to Fig. 9.23.

1. Draw the xoy line horizontal and the zoy_1 line vertical through the origin o as shown.
2. Mark front and top views a' and a, after drawing the projectors at a convenient distance from the zoy_1 line.
3. Draw horizontal projector through a to meet the line oz and rotate it anticlockwise about o to ox.

Then project the line downwards to meet the horizontal projector drawn from a', to get the point a'' in the third quadrant.

4. Dimension the views and complete the drawing.

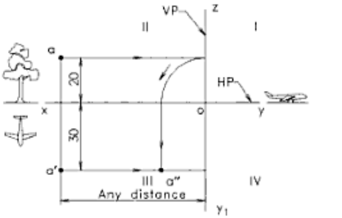


Fig. 9.23 Three orthographic views of point A in the 3rd quadrant.

Example 9.9

Point B is located in the second quadrant. The distances from HP and VP are 28 mm and 18 mm respectively. Similarly point C is located in the fourth quadrant. The distances from HP and VP are 30 mm and 15 mm respectively. Draw projections of the points on HP, VP and PP. The distance between points along xy line may be taken as 20 mm.

Refer to Fig. 9.24.

1. Draw the xoy line horizontal and the zoy_1 line vertical through the origin o as shown.
2. Mark front and top views b' and b, after drawing the projectors at a convenient distance from the zoy_1 line.
3. Draw horizontal projector through b to meet the line oz and rotate it anticlockwise about o to ox. Then project the line upwards to meet the

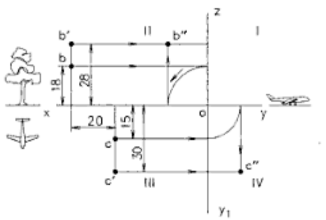


Fig. 9.24 Three orthographic views of point A in the 3rd quadrant.

horizontal projector drawn from b', to get the point b'' in the second quadrant.

4. Similarly, mark the front and top views c' and c, after drawing the projectors at a distance of 20 mm from projection line bb' as shown in the figure.
5. Draw horizontal projector through c to meet the line oy_1 and rotate it anticlockwise about o to oy. Then project the line downwards to meet the horizontal projector drawn from c', to get the point c'' in the fourth quadrant.
6. Dimension the views and complete the drawing.

Example 9.10

A point D is located in the first quadrant. The shortest radial distance line drawn from the point D to the intersection of HP and VP has 40 mm length and is inclined at 60° to HP. Draw front and top views of the point D.

Refer to Fig. 9.25.

1. Draw the xoy line horizontal and the zoy_1 line vertical through the origin o as shown.
2. Mark the left side view d'' on PP, after drawing a 60° inclined radial line of length 40 mm from origin o, in the first quadrant as shown in the figure.
3. Draw a vertical projector ($d'd$) at a convenient distance from the zoy_1 line. Then draw a horizontal projector through d'' to meet the vertical projector at d'.
4. Draw vertical projector through d'' to meet the line oy and rotate it clockwise about o to oy_1. Then project from the point horizontally to meet the vertical projector drawn from d', to get the point d.
5. Dimension the views and complete the drawing.

Example 9.11

The shortest distance of a point E to the intersection line of HP and VP is 36 mm and the point is 20 mm above HP. Draw the front and top views, if the point is in the second quadrant.

Refer to Fig. 9.26.

1. Draw the xoy line horizontal and the zoy_1 line vertical through the origin o as shown.
2. Mark the left side view e'' on PP, after drawing a horizontal line at a distance of 20 mm above HP and cutting an arc of radius 36 mm from origin o, in the second quadrant as shown in the figure.
3. Draw a vertical projector at a convenient distance from the zoy_1 line. Then draw a horizontal projector through e'' to meet the vertical projector at e'.
4. Draw vertical projector through e'' to meet the line ox and rotate it clockwise about o to meet oz. Then project from the point horizontally to meet the vertical projector drawn from e', to get the point e.
5. Dimension the views and complete the drawing.

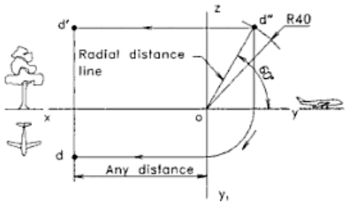


Fig. 9.25 Three orthographic views of point D in the 1st quadrant.

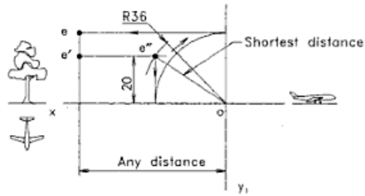


Fig. 9.26 Three orthographic views of point E in the 2nd quadrant.

EXERCISES

Projections on HP and VP

1. A point K is 35 mm above HP and 25 mm in front of VP. Draw the orthographic projections.
2. A point L is located 30 mm below HP and 36 mm behind VP. Draw the projections of point L.
3. Point M is situated 32 mm behind VP and 22 mm above HP. Draw its projections and dimension them.
4. A point N is situated 20 mm below HP and 40 mm in front of VP. Draw the projections.
5. Draw the projections of the following points. Take the distance between the projectors as 25 mm:
   (i) Point A is 20 mm above HP and 42 mm in front of VP.
   (ii) Point B is 35 mm below HP and 20 mm in front of VP.
   (iii) Point C is 20 mm above HP and 36 mm behind VP.
   (iv) Point D is 42 mm below HP and 25 mm behind VP.

   Dimension the figures as per BIS.
6. Figure 9.27 gives the orthographic projections of certain points. Interpret them and write the positions of the points with respect to VP and HP using 4 mm capitals.

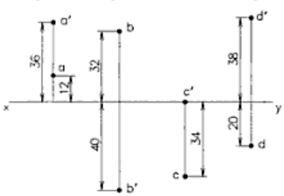


Fig. 9.27

7. Draw projections of the following points and show the dimensions as per BIS. The distance between the projectors is 30 mm.
   (a) Point P is in the VP and 34 mm below HP.
   (b) Point Q is in the HP and 32 mm behind VP.
   (c) Point R is in both the HP and VP.
   (d) Point S is in the third quadrant and 35 mm away from both HP and VP.
8. The orthographic projections of certain points are shown in Fig. 19.28. Determine their positions with respect to the reference planes and print them using 4 mm letters.

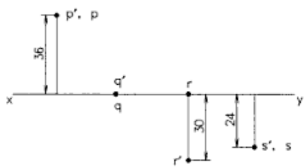


Fig. 9.28

Projections on HP, VP and PP

9. Draw three views of a point Q located in the first quadrant and dimension them as per BIS. The point Q is 35 mm above HP and 20 mm in front of VP.
10. Point E is located in the third quadrant. The distance from HP is 32 mm and that from VP is 26 mm. Draw projections of the point on HP, VP and PP.

11. Point F is located in the second quadrant. The distances from HP and VP are 38 mm and 28 mm respectively. Similarly, point G is located in the fourth quadrant. The distances from HP and VP are 40 mm and 25 mm respectively. Draw projections of the points on HP, VP and PP. The distance between points along *xy* line may be taken as 30 mm.
12. A point H is located in the first quadrant. The shortest radial distance line drawn from the point H to the intersection of HP and VP has 50 mm length and is inclined at 30° to HP. Draw front and top views of the point H.
13. The shortest distance of a point J to the intersection line of HP and VP is 46 mm and the point is 25 mm above HP. Draw the front and top views, if the point is in the second quadrant.
14. A point M is lying in the first quadrant. The shortest distance of the point from *xy* line is 55 mm. If the point is 30 mm above HP, draw its projections.

C H A P T E R

10

Projections of Straight Lines

A straight line may be defined as the *locus* of a point which moves along the shortest path joining two given points. It may also be defined as the locus of a point which moves linearly. A line in this chapter is considered to be a straight line unless the shape is specified.

The shape of an object is formed by different surfaces. A geometrical surface is formed by rotating or moving a straight line in different forms. Various machine parts, concrete structures, etc., are formed by such geometrical shapes. Hence, clear grasping of projections of lines is a necessary requirement for engineers to understand the three-dimensional shapes, positions, etc. and solve the related problems.

10.1 CLASSIFICATION OF LINE POSITIONS

A line may be placed in infinite number of positions with reference to the vertical and horizontal and profile planes. These positions may be classified according to the inclination of the line to the reference planes and the quadrants in which it is placed. The classification based on inclination is given in Fig. 10.1. They are:

(a) Line parallel to both the reference planes
(b) Line perpendicular to one of the reference planes
(c) Line inclined to HP but parallel to VP
(d) Line inclined to VP but parallel to HP
(e) Line inclined to both HP and VP (oblique line)
(f) Oblique line parallel to PP

The classification of lines, based on the quadrants in which they are placed is:

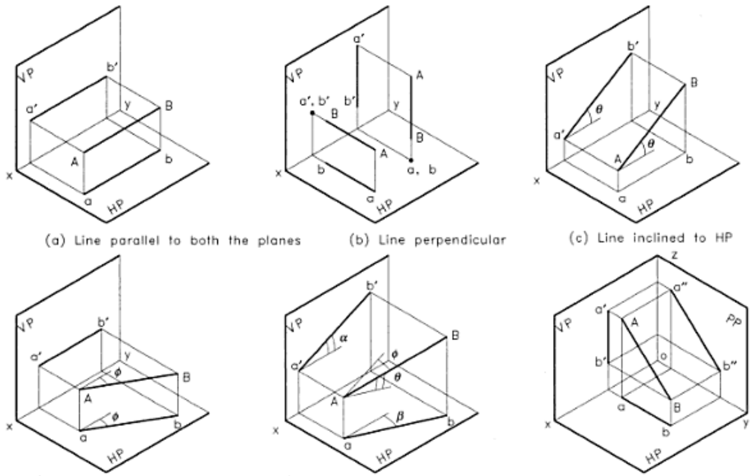
(a) Line placed in one of the four quadrants
(b) Line contained in one of the planes
(c) Line placed in two quadrants
(d) Line placed in three quadrants

Figure 10.2 gives the pictorial view of the above classes of lines and their orthographic projections.

As per ISO as well as Bureau of Indian Standards, first angle projection has to be followed for all engineering drawings. But as mentioned earlier, points and lines are free from this rule. A student of Engineering Graphics has to study the projections of lines, placed anywhere in the four quadrants.

10.2 LINE PARALLEL TO BOTH THE REFERENCE PLANES

Figure 10.3(a) gives the pictorial view of a line AB placed parallel to both the reference planes. If the points A and B are projected to the vertical and horizontal planes, the front view (elevation) *a′b′* and top view (plan) *ab* are obtained on the



(a) Line parallel to both the planes (b) Line perpendicular (c) Line inclined to HP

(d) Line inclined to VP (e) Line inclined to both the planes (f) Line contained in PP

Fig. 10.1 Line positions by inclination.

respective planes. After rotating the HP, the view will occupy a position shown in Fig. 10.3(b). Here *xy* line represents the intersection of HP and VP. The two projections of the line can be visualised as did for the projection of the points. Figure 10.3(c) shows the projected views of the line to be presented by a student in his drawing. The following important points may be noted from the views.

1. The line AB is parallel to both the planes, hence the projections *a′b′* and *ab* will be having the true length of AB.
2. Since the line is parallel to both the planes, the projections will be parallel to *xy* line.
3. The lines *a′b′* and *ab* represents the projections of the given object, hence they are drawn by using Type A thick (0.5 mm) continuous lines. All the remaining lines are drawn using Type B thin (0.25 mm) continuous lines.
4. The projectors connecting front and top views will be always perpendicular to *xy* line and are represented by Type B thin (0.25 mm) lines.

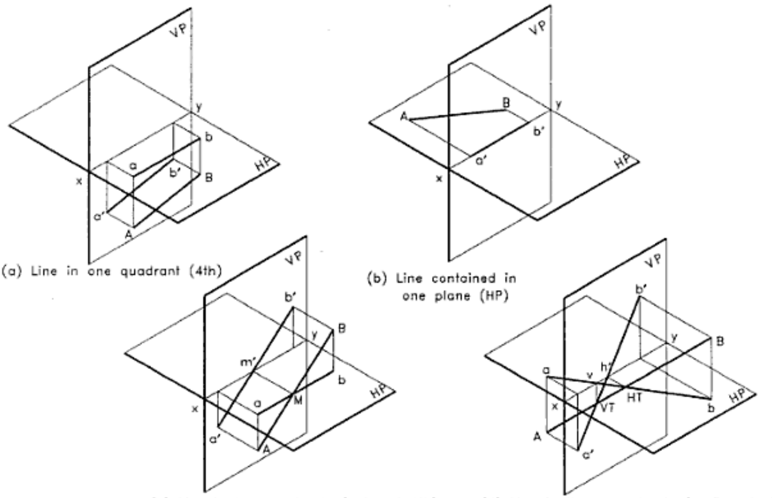
> **Meaning of *xy* line in projection**
> *For all front views, xy line represents the elevation of HP (floor) so that, above xy line means above HP and below xy line means below HP. For all top views, xy line represents the plan of VP (wall) so that, in front of xy line means infront of VP and behind xy line means behind VP.*

Example 10.1

A line AB 50 mm long is parallel to both HP and VP. The point A is 20 mm above HP and the point B is 40 mm in front of VP. Draw its projections.

Refer to Fig. 10.3(c).

1. Draw the *xy* line.
2. The line AB is in the first quadrant. Since the line is parallel to HP and VP, the projections of the line will be parallel to *xy*. Draw the line *a′b′* as front view, 20 mm above *xy* line (HP) and line *ab* as top view, 40 mm in front of *xy* line (VP).
3. The line AB is parallel to both the planes, hence the two projections will have the true length 50 mm. Draw the end projectors perpendicular to *xy* line.



(a) Line in one quadrant (4th)

(b) Line contained in one plane (HP)

(c) Line in two quadrants (1st and 4th)

(d) Line in three quadrants (1, 3 and 4)

Fig. 10.2 Line positions by quadrant.

4. Finish the views by converting them into thick lines. Name the points and print the given dimensions as shown in Figure 10.3(c).

10.3 LINE PERPENDICULAR TO ONE OF THE REFERENCE PLANES

When a line is perpendicular to one of the reference planes, it will be automatically parallel to the other plane. Figure 10.4(a) shows the pictorial view of a line AB perpendicular to VP. Since the line is perpendicular to VP, its projection of end points *a′* and *b′* coincide to form a single point. The line is parallel to HP, so, its projection on HP has the true length. After rabatting the planes, the view will occupy a position as shown in Fig. 10.4(b).

Example 10.2

A 40 mm long line AB is positioned in such a way that it is perpendicular to VP and the end B is 10 mm in front of VP and 30 mm above HP. Draw its projections, keeping the line in the first quadrant.

Refer to Fig. 10.4.

1. Draw the *xy* line.
2. The line is perpendicular to VP, hence it is parallel to HP. In the VP, ends *a′* and *b′* coincide to form a point. Therefore, draw a line perpendicular to *xy* line. Locate the front view as a thick point (*a′b′*) at a height of 30 mm above HP (above *xy* line).
3. Unless and otherwise stated, a line is assumed to be in the first quadrant. So, mark *ab* = 40 mm (true length) on the perpendicular drawn to *xy* line, such that point *b* is 10 mm in front of VP (in front of *xy* line)
4. Convert *ab* to thick line to represent the plan of AB and note the given dimensions as shown in figure to complete the views.

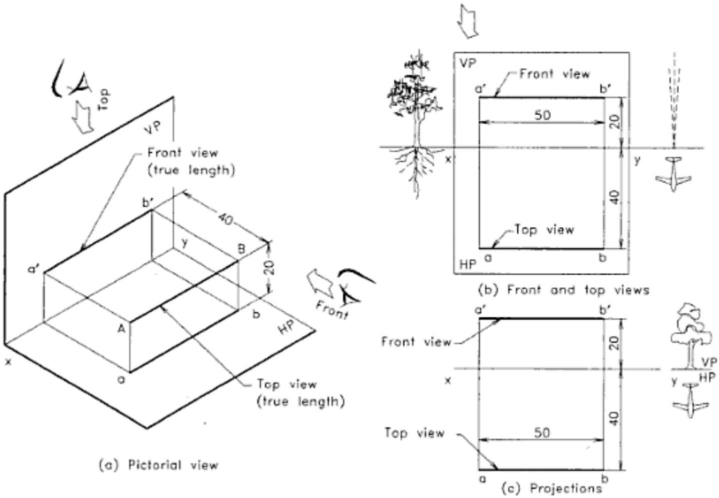


Fig. 10.3 Line parallel to both the planes.

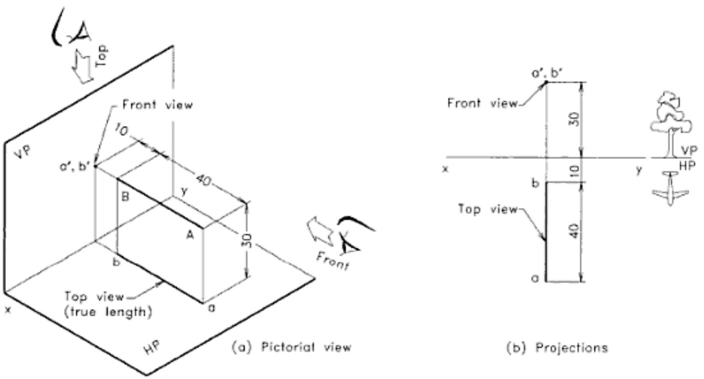


Fig. 10.4 Line perpendicular to VP.

Example 10.3

Line CD, 36 mm long is in the first quadrant. End D is 12 mm above HP and 24 mm in front of VP. If the line is perpendicular to HP draw its projections.

Refer to Fig. 10.5.

1. Draw the *xy* line.
2. As the line CD is vertical, the top view of the points C and D will coincide. Hence, mark a point *c*, *d* as top view, 24 mm in front of *xy* line (VP).
3. The line is vertical means it is parallel to VP and the projection on VP will show the true length. Therefore, draw a projector from *c d*, perpendicular to *xy* line and mark the point *d′*, 12 mm above *xy* line (HP) and line *c′d′* = 36 mm.
4. Give appropriate thickness to the lines and place the given dimensions to complete the projections as shown in the figure.

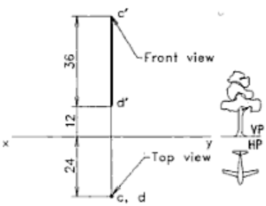


Fig. 10.5 Line perpendicular to VP.

10.4 INCLINED LINE PLACED IN FIRST QUADRANT

When a line is parallel to one of the reference planes and inclined to the other, may be called as *inclined line*. Its projection on the plane to which it is parallel will have the true length (TL) and true inclination (θ or ϕ). Figure 10.6(a) shows the pictorial view of a line inclined at $\theta°$ to HP. The projection *a′b′* on VP has the true length of AB and the true inclination $\theta°$. But the top view *ab* is parallel to *xy* and has an apparent length (plan length = PL) less than the true length. Similarly, when a line is $\phi°$ inclined to VP but parallel to HP, the projection on HP has the true length (TL) and true inclination $\phi°$ as shown in Fig. 10.7(a). Here the line is contained in the HP. The front view is on *xy* line and has an apparent length (elevation length = EL) less the true length. From the above two figures the following properties of projections of an inclined line may be noted.

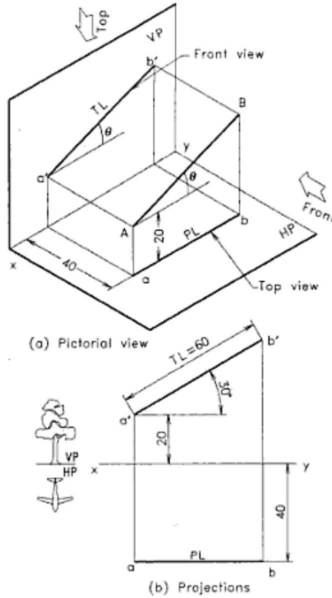


Fig. 10.6 Line inclined to HP (line in 1st quadrant).

1. The projection on the plane to which the line is parallel will have the true length TL and true inclination θ or ϕ.
2. The projection on the plane to which the line is inclined will have a reduced apparent length PL or EL .
3. If a line is contained in a plane, its projection on the other plane will be on the *xy* line itself.

Example 10.4

A line AB, 60 mm long is parallel to VP and inclined at 30° to HP. The end A is 20 mm above HP and 40 mm in front of VP. Draw the projections.

Refer to Fig. 10.6.

1. Draw the *xy* line.
2. Mark points *a'* and *a*, 20 mm above HP (*xy* line) and 40 mm in front of VP (*xy* line).
3. Draw the 30° inclined line *a'b'* having a true length 60 mm and place the end projector *b'b* perpendicular to the *xy* line.
4. Draw *ab* parallel to *xy* to represent the top view.
5. Finish the drawing by giving proper line thickness and print the given dimensions.

Example 10.5
Line CD is inclined at 45° to VP and is contained in HP. The end C is 16 mm in front of VP. Draw the projections of the line, if the true length of line CD is 50 mm.

Refer to Fig. 10.7.

1. Draw the *xy* line.
2. Locate point *c'* on *xy* line (HP) and point *c*, 16 mm in front of *xy* line (VP).
3. Draw CD = 50 mm, the true length, at 45° to VP (*xy* line) and insert end projector *dd'* perpendicular to *xy*.
4. Draw thick line to represent elevation *c'd'*, on *xy*.
5. Finish the drawing by giving proper line thickness and print the given dimensions.

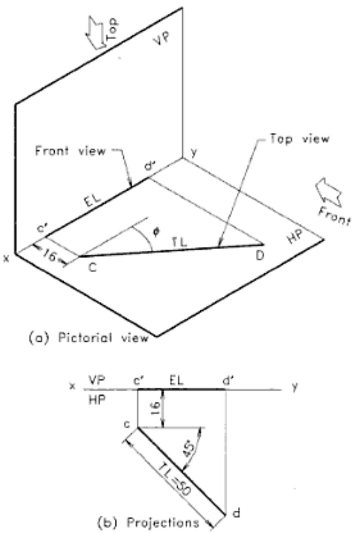


Fig. 10.7 Line inclined to VP (line in 1st quadrant).

10.6 INCLINED LINE PLACED IN ANY ONE OF THE FOUR QUADRANTS

Line inclined to one of the reference planes may be placed in any one of the four quadrants. Such a line can be drawn by marking the end points as is done in the previous problems. The following examples explain the procedure.

Example 10.6
A line MN, has end M 20 mm below and 30° inclined to HP. If the line is 30 mm behind and parallel to VP, draw projections and find its true length. The distance between the end projectors is 60 mm and the line is in the third quadrant.

Refer to Fig. 10.8.

1. Draw the *xy* line.
2. Locate point *m'*, 20 mm below HP and *m*, 30 mm behind VP.
3. Draw *m'n'* at 30° to HP (*xy* line) to intersect the vertical projector drawn at 60 mm distance from the projector *mm'*.
4. Draw line *mn* (PL) parallel to *xy* to mark the plan.
5. Measure the true length (TL) of line *m'n'* and print the answer below the drawing.
6. Finish the drawing by giving proper line thickness and print the given dimensions.

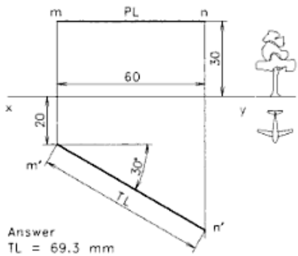


Fig. 10.8 Line inclined to HP (line in 3rd quadrant).

Example 10.7

A line PQ, has end P 26 mm behind VP and on HP. If the line has 80 mm length and parallel to VP, draw projections and find its true inclination and plan length. The end Q is 60 mm above HP and the line is in the second quadrant.

Refer to Fig. 10.9

1. Draw the *xy* line.
2. Locate point *p*, 26 mm behind VP and *p′* on HP.
3. Draw a line *h′h′*, 60 mm above *xy* (HP) and cut an arc of radius 80 mm from *p′* to locate *q′* on line *h′h′*. Now *p′q′* is the elevation of the line.
4. Draw line *pq* (PL) parallel to *xy* to get the plan.
5. Finish the drawing by giving proper line thickness and print the given dimensions.
6. Measure the plan length PL of line *pq* and the inclination *θ* of line *p′q′* to *xy*. Print the values as answer, below the drawing.

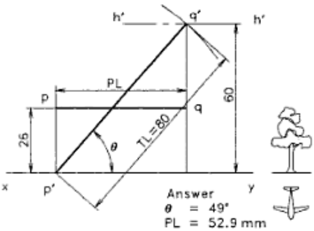


Fig. 10.9 Line inclined to HP (line in 2nd quadrant).

Example 10.8

Line RS of length 84 mm is placed in the fourth quadrant so that it is parallel to HP and the ends are 60 mm below. If the end R is 40 mm and end S is 15 mm in front of VP, draw the projections and find the elevation length and inclination of the line with VP.

Refer to Fig. 10.10

1. Draw the *xy*-line. Locate the top view of the end *r* at a distance of 40 mm and *s* at a distance of 15 mm in front of VP (*xy* line). The point *s* is obtained after drawing the *vv* line at 15 mm distance and cutting an arc of radius 84 mm from *r* on it.
2. Draw vertical projectors through points *r* and *s*.
3. Draw a horizontal line *r′s′*, 60 mm below the *xy* line (HP) to represent the elevation.
4. Finish the drawing and print the given dimensions as shown in the figure.

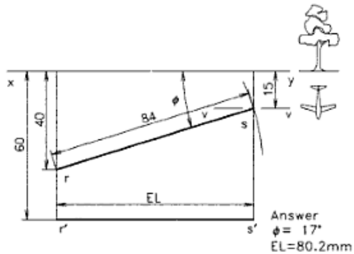


Fig. 10.10 Line inclined to VP (line in 4th quadrant).

5. Measure the elevation length EL and the inclination *ϕ* with VP (the *xy* line) and print the values.

10.6 TRACE OF AN INCLINED LINE PLACED IN ONE QUADRANT

The point at which a line or the produced line meets the reference plane is called the *trace* of the line on that plane. If a line is perpendicular or inclined to a plane, the line will penetrate that plane to form a trace when it is produced. But if the line is parallel to a plane, it will not meet that plane and hence there will be no trace on that plane. Figure 10.11(a) shows the pictorial view of a line inclined to HP but parallel to VP. Here, the produced line meets the HP to form a trace called *Horizontal Trace (HT)*. The front view of the point HT will be on the *xy* line and is marked as *h′*. Similarly Fig. 10.12(a) shows the pictorial view of a line inclined to VP but parallel to HP. Here, the meeting point of the produced line on VP is called the *Vertical Trace (VT)*. The top view of the trace VT will be also on the *xy* line and is marked as *v*. The orthographic projections of these lines are shown in Figs. 10.11(b) and 10.12(b).

Example 10.9

A line AB of length 60 mm is parallel to VP and 30 mm in front of it. If the point A is 16 mm above and the point B is 50 mm above HP. Draw its projections and find the horizontal trace.

Refer to Fig. 10.11.

1. Draw the front view as *a′b′* and top view as *ab* of the given line AB as shown in the Fig. 10.11.
2. Extend *b′a′* to meet the *xy* line at *h′*.
3. Draw a projector through *h′* to intersect the line *ba*, extended at the point HT.
4. Finish the drawing with proper line thickness and print the given dimensions.

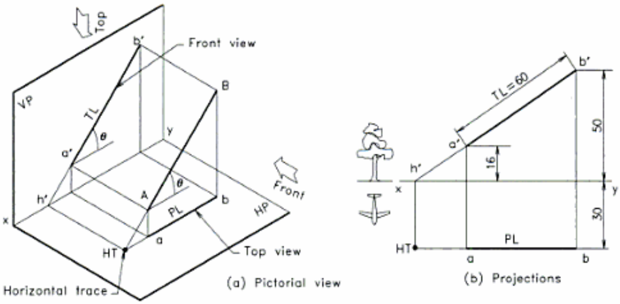


Fig. 10.11 Horizontal trace of an inclined line (line in 1st quadrant).

> **Properties of traces**
> 1. Trace of a line on a plane exists, if the line is inclined or perpendicular to that plane.
> 2. The HT of a line will be on the top view, or the top view produced. Similarly VT of a line will be on the front view or front view produced.
> 3. The point *h'* will be on the *xy* line as well as on the front view or front view produced. Similarly, the point *v* will be on the *xy* line as well as on the top view or top view produced.
> 4. The line joining HT and *h'* is a projector, hence it will be perpendicular to *xy* line. Similarly the line joining VT and *v* is a projector, perpendicular to the *xy* line.

Example 10.10

The end C of a line CD is 20 mm in front of VP while the end D is 32 mm above HP. The line is parallel to HP and 45° inclined to VP. Draw its projections and mark its vertical trace, if the length of the line is 50 mm.

Refer to Fig. 10.12.

1. Draw the top view *cd* and then the front view *c'd'* of the line CD as shown in figure.
2. Extend *dc* to meet the *xy* line at *v*.
3. Draw a projector through *v* to intersect the line *d'c'* extended at the point VT.
4. Finish the drawing with proper line thickness and print the given dimensions.

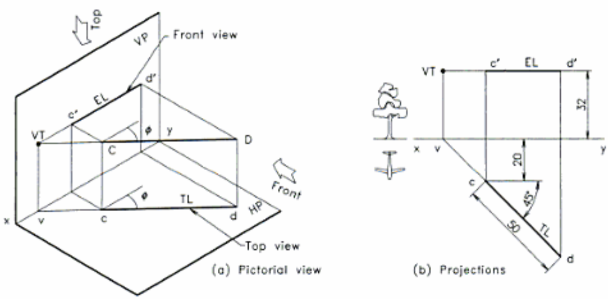


Fig. 10.12 Vertical trace of an inclined line (line in 1st quadrant).

10.7 TRACE OF AN INCLINED LINE PLACED IN TWO QUADRANTS

When an inclined line is placed in two quadrants it will be penetrating one of the reference planes. The point of penetration will be its trace. Since the line is parallel to one of the planes, it will be having only one trace and that is the penetration point. Figure 10.13 shows the vertical trace of an inclined line placed in 1st and 2nd quadrants. Similarly, Fig. 10.14 shows the horizontal trace of an inclined line placed in 2nd and 3rd quadrants.

Example 10.11

A line PQ, 70 mm long is parallel to HP. Its one end P is 20 mm in front of VP and Q is 30 mm behind VP. If the line is 40 mm above HP, draw the projections, locate the traces and find its inclination to VP.

Refer to Fig. 10.13.

1. Draw the *xy*-line. Locate the top view of the point *p* at a distance of 20 mm in front of the VP (*xy* line).
2. Draw a line *vv* of any length to represent the path of the top view of the point Q, parallel to and at a distance of 30 mm behind the *xy* line. Now, the top view of the point Q lies on *vv* and the length of the top view i.e. *pq* = 70 mm. With centre P and radius = 70 mm, draw an arc to cut the line *vv* at *q*.
3. Draw projectors through points *p* and *q*. Also draw a horizontal line *p′q′* at a height of 40 mm above the VP (*xy* line), to get the elevation.
4. The inclination of the top view with the *xy* line is the inclination of the line PQ with VP.
5. Locate *v* at the intersecting point of plan *pq* on *xy* and draw a projector at *v* to meet the elevation *p′q′* at VT.
6. Finish the drawing, measure angle ϕ and print the given dimensions as well as the answer.

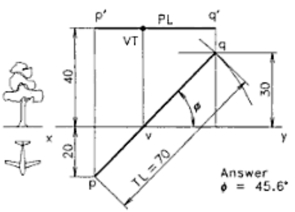


Fig. 10.13 Trace of a line inclined to VP (line in two quadrants).

Example 10.12

The front view of a line RS is 80 mm long and it makes an angle of 45° to *xy* line. The midpoint *m′* of the line *r′s′* is 8 mm below the *xy* line and the end R is in the second quadrant. If the line is 16 mm behind and parallel to VP, draw its projections and mark the traces.

Refer to Fig. 10.14.

1. Draw the *xy* line.
2. In the given position, the end R is in the 2nd quadrant and the end S is in the 3rd quadrant. Locate the mid point as *m′* and *m*, 8 mm below and 16 mm behind the *xy* line.
3. Draw the front view *r′s′* 80 mm long, inclined at 45° to *xy* line, through the midpoint *m′* so that *m′s′* is 40 mm and the end R is situated above HP (*xy* line).
4. Draw the end projectors through *r′* and *s′* and construct the line *rs*, 16 mm behind and parallel to VP (*xy* line) to get the top view of RS.
5. Draw projector *m′m*, measure the top view length PL and print the value as the answer.
6. To locate the HT, mark *h′* at the crossing point of *r′s′* on the *xy* line and draw projector through *h′* to intersect the top view at HT.
7. Finish the drawing with proper line thickness and print the given dimensions.

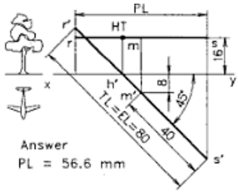


Fig. 10.14 Trace of a line inclined to HP (line in two quadrants).

10.8 THREE VIEWS AND TRACES OF AN INCLINED LINE

The left side view on the profile plane PP is considered as the third principal view added to the usual front and top views. The method of getting profile plane view of a point is already explained in Chapter 9 (Refer Figs. 9.21 and 9.22.) The same procedure is followed for straight lines also. Figure 10.15 shows three views of an inclined line parallel to VP, placed in the first quadrant.

For easy understanding of the projections of planes, the left side portion of the projection may be considered on the space for usual front and top views and the right side portion for the end view of HP and VP, forming the four quadrants. These two portions may have any distance, since the distance of the line from PP is not usually specified. Here, the points on profile view are identified by adding double prime to lowercase letters as shown. The view of HT on profile plane is h'' and is obtained on end view of HP (xoy), where the profile view $a''b''$ or its extension intersects.

A line inclined to VP and parallel to HP is shown in Fig. 10.16. The line is in the third quadrant. Here the side view is a horizontal line $d''c''$. The view of VT on profile plane is v'' and is obtained on end view of VP (zoy_1), where the profile view $c''d''$ or its extension intersects.

Example 10.13

Line AB is parallel to VP and has a plan length 48 mm in the top view. If the end A is 40 mm above HP, and 24 mm in front of VP while the end B is 10 mm above HP, draw the front, top and side views of the line. Also mark its traces on the three views. What is the true length and inclination of the line?

Refer to Fig. 10.15.

1. Draw the xoy line horizontal and the zoy_1 line vertical through the origin o as shown.
2. Mark front and top views a' and a of the end A, after drawing vertical projector at any convenient distance from zoy_1 line.
3. Draw ab, the top view of length 48 mm parallel to xy and locate b' 10 mm above HP, after drawing a vertical projector through b. Join $a'b'$ to get the front view.

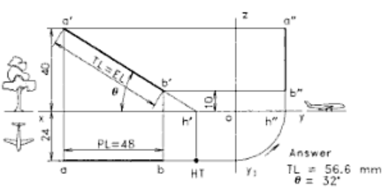


Fig. 10.15 Three orthographic views of a line in the 1st quadrant.

4. Draw horizontal projector through points a and b to meet oy_1 line, rotate it anticlockwise about the origin o to meet xoy (direction opposite to rabation) and then project upwards. Insert horizontal projectors through a' and b' to intersect this line at points a'' and b'', which gives the side view.
5. Extend $a'b'$ to intersect xy line at h' and mark HT by drawing vertical projector. The side view of HT is marked as h'' and is obtained on the end view of HP (xoy line), where the profile view $a''b''$ or its extension intersects.
6. Measure $a'b'$ as true length and its inclination to HP as θ. Print the given dimensions and the answer.

Example 10.14

A line CD is parallel to HP and has a length 60 mm. If the end C is 20 mm below HP, and 10 mm behind VP while the end D is 36 mm behind VP, draw the front, top and side views of the line. Mark its traces in the three views. Also find the elevation length and inclination of the line to VP by graphical methods.

Refer to Fig. 10.16.

1. Draw the xoy line horizontal and the zoy_1 line vertical through the origin o as shown.
2. Mark front and top views of the line CD as $c'd'$ and cd as shown in the figure. Note that the line is in the 3rd quadrant.
3. Draw horizontal projectors from c and d to meet line oz (side view of VP) and rotate them anticlockwise about the origin o (direction opposite to rabation) to the line oxy (side view of HP). Project downwards from there to meet the horizontal projector drawn from $c'd'$, to get the required side view $c''d''$.
4. Extend cd to intersect the xy line at v and project downwards to meet the line $c'd'$ produced at VT.
5. The side view v'' of VT is on the line oy_1 (side view of VP) and is obtained by extending $d''c''$.
6. Measure $c'd'$ as elevation length and the inclination to VP as ϕ. Print the given dimensions and the answer.

10.9 LINE INCLINED TO BOTH THE HP AND VP (OBLIQUE LINE)

View of a Line in Oblique Position

Figure 10.17 gives the pictorial view of an inclined line moving to oblique position (inclined to both the HP and VP). Here, line AB_1 is parallel to VP and inclined $\theta°$ to HP. The top

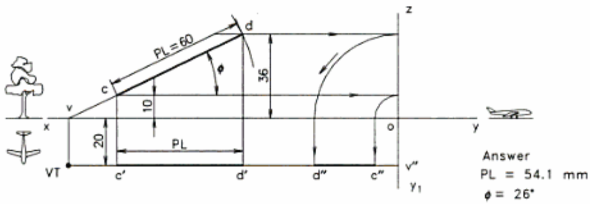


Fig. 10.16 Trace of a line inclined to VP (line in two quadrants).

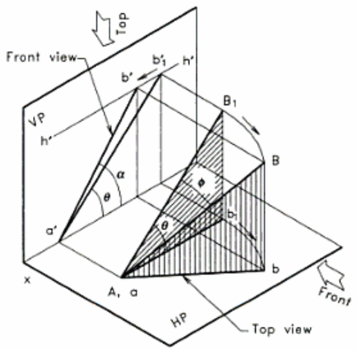


Fig. 10.17 Line inclined to both the planes.

view ab_1, the projector B_1b_1 and the line AB_1 forms a right-angled triangle like a set-square. As the set-square containing the line AB_1 moves from its parallel position (parallel to VP) to the inclined position AB, the line becomes $\phi°$ inclined to VP also. This is the oblique position of the line (inclined to HP and VP). As the line moves to oblique position, the projector moves from b_1' to b'. Note that this will increase the true angle $\theta°$ to the apparent angle $\alpha°$ in the front view.

When the line AB_1 moves to the AB position, the top view ab_1 also moves to ab position, making an angle of β with xy line. Here, β is the inclination of top view to the xy line, which is the apparent angle corresponding to the true angle ϕ. Angle b will be larger than the true angle ϕ. Note that the true angle (θ or ϕ) of an oblique line is measured along a plane, which is containing the line and kept perpendicular to the reference plane.

The following points may be remembered while solving a problems of oblique lines.

Properties of oblique line

1. If a line is inclined to both the planes (oblique line), its projections will have shorter lengths (EL and PL) than the true length (TL).
2. The projections of oblique line will make apparent angles α and β to the xy line and these angles will be larger than their true angles θ and ϕ.

The Conical Movement of Line from Parallel to Oblique Position

The method of solving problems of oblique lines can be illustrated by the pictorial views given in Figs. 10.18 and 10.19. A line position, which is inclined to both the planes, may be represented by a generator (straight line on the conical surface) of a semi-cone with vertical axis. Refer to Fig. 10.18(a). The generator AB of the semi-cone is parallel to VP and inclined at $\theta°$ (true angle) to HP in the initial position. As the end B_1 is moving along the base of the cone, keeping the angle θ constant and end A fixed, the top view of B_1 moves along arc b_1b and the front view moves along the horizontal line (locus line $h'h'$) from b_1' to b'. Let B be any intermediate point along the path. In this position, the front view $a'b'$ makes an angle $\alpha°$ with xy line, which is larger than $\theta°$. The length of the front view (EL) is less than the true length $a'b_1'$ (TL). The required oblique position of the line will be anywhere between the starting point B_1 and the mid position B_3. In the top view, the point b_1 moves along the arc b_1b with centre a and radius PL. Orthographic view of this line position is given in Fig. 10.18(b).

Consider a second semi-cone having a horizontal axis as given in Fig. 10.19(a), so that the oblique line is a generator of that cone also. Assume that the straight line is initially parallel to HP and is $\phi°$ inclined to VP (line AB_2). Now its top

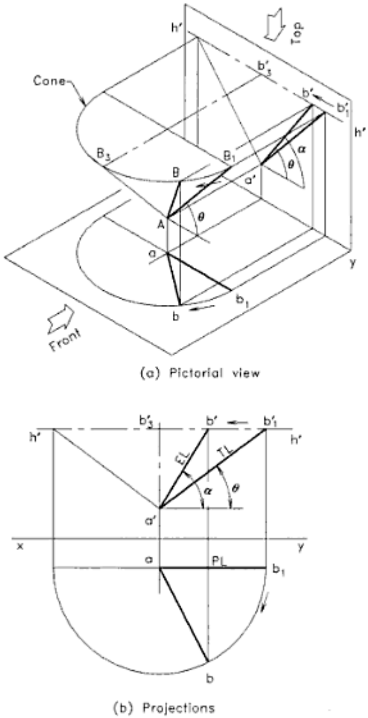


Fig. 10.18 Line moving from position parallel to VP to the inclined position.

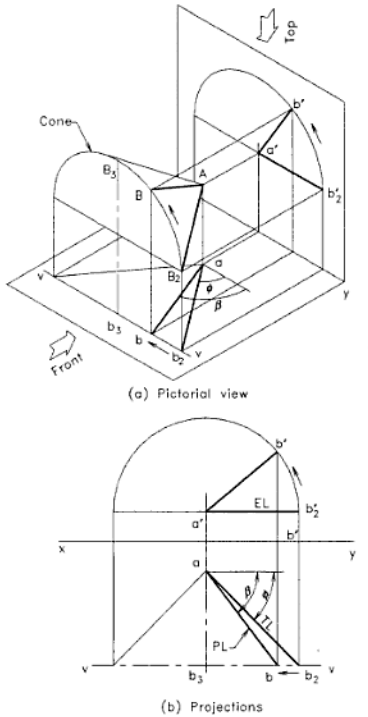
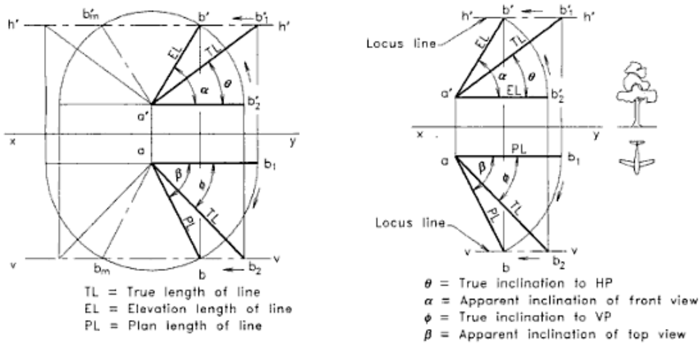


Fig. 10.19 Line moving from position parallel to HP to the inclined position.

view ab_2 will show the true length and inclination. But, if the line is revolving about the fixed point A, keeping the inclination $\phi°$ to VP a constant, it will form the horizontal cone as shown in the figure. As the end B_2 moves along the base of the semi-cone, the top view of it moves along the locus line *vv* from b_2 to b, which is parallel to *xy* line. The point b_2' of the front view moves along an arc with centre a' and radius EL. In this position, the top view *ab* makes an apparent angle $\beta°$, which is larger than $\phi°$ and the length of *ab* (PL) is less than the true length AB. Orthographic views of this line position is given in Fig. 10.19(b).

Principle of Getting the Projections

Now, if the required true inclinations of the line to HP and VP are $\theta°$ and $\phi°$, that position can be obtained by combining the



(a) The combined form of views

(b) The final form of views

Fig. 10.20 A Line inclined to both the reference planes.

Figs. 10.18(b) and 10.19(b) as given in 10.20(a). It may be concluded that the required position of the point satisfying the two inclinations is the intersection of the circular path of b'_2 and linear path of b'_1 at b' in the front view. The line joining a' and b' is the required front view of the line AB. Similarly, in the top view, the intersection of the circular path of b_1 and linear path of b_2 at b gives the position of the end point, satisfying the two inclinations. The line joining a and b is the required top view of the line AB. The apparent angles α and β, are larger than θ and ϕ respectively. The projector joining b and b' will be perpendicular to xy line. This property can be used as a check for the accuracy of the drawing.

In the Fig. 10.20(a), there is the possibility of obtaining a second position of point B as a mirror image (b_m and b_m'), satisfying the given conditions. If the mirror image is eliminated the final form is as given in Fig. 10.20(b). Here, $h'h'$ is the locus of B in the front view and vv is the locus of B in the top view.

Properties of Projections of an Oblique Line

1. The elevation length EL and the plan length PL of an oblique line are always less than the true length TL.
2. The apparent angle a of the front view with xy line is always larger than θ, the true inclination with HP. Similarly, the apparent angle β of the top view with xy line is always larger than ϕ, the true inclination with VP.
3. The locus line $h'h'$ is the path of end of an oblique line in front view, while it moves from parallel to oblique position. Similarly, the locus line vv is the path of end of the oblique line in top view, while it moves from parallel to oblique position.
4. The locus lines $h'h'$ and vv are always parallel to the xy line and they may be positioned on both sides or on one side of the xy line, depending on the position of the oblique line.
5. Since a visible object is to be presented using thick line in projections as per BIS, all the views of the given line are to be converted into thick (Type A) line while finishing the drawing.

Example 10.15

A line AB, 60 mm long has its end A in the HP and 20 mm in front of VP. If the line is 45° inclined to HP and 30° inclined to VP, draw its projections.

Refer to Fig. 10.21.

1. Draw the xy line.
2. Locate point a' on xy line and point a 20 mm in front of xy line.
3. Draw line $a'b'_1$ = 60 mm (TL) long, at the angle 45° to xy line and project to get the plan view ab_1 (PL).
4. Draw a line ab_2 = 60 mm (TL) long, at the angle 30° to xy line and project to get the front view $a'b'_2$ (EL).

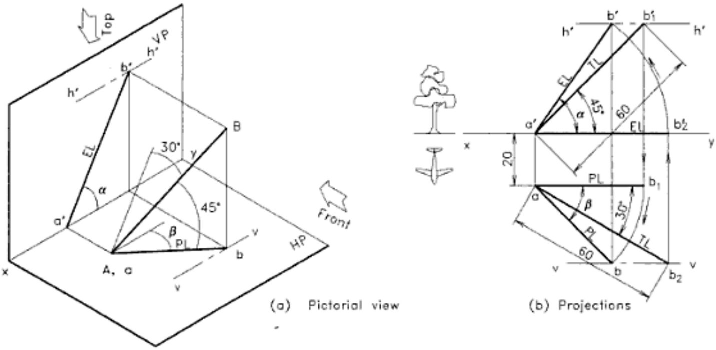


Fig. 10.21 Oblique line in first quadrant.

5. Draw line $h'h'$, the locus of b'_1 and a line vv, the locus of b_2, parallel to xy line.
6. Draw the locus of b'_2 by drawing an arc with centre a' and radius $= a'b_2'$ (EL) to intersect the line $h'h'$ at b'. Join $a'b'$ to get the required front view.
7. Draw the locus of b_1 by drawing the arc with centre a and radius $= ab_1$ (PL), to intersect the line vv at b. Join ab to get the required top view.
8. Drop a perpendicular from point b' to xy line and extend it so that the projector will pass through point b.
9. Give proper line thickness and print the given dimensions as shown in Fig. 10.21(b) to complete the drawing.

Example 10.16

A line PQ, 64 mm long has one of its extremities 20 mm in front of VP and the other 50 mm above HP. The line is inclined at 40° to HP and 25° to VP. Draw its top and front views.

Refer to Fig. 10.22.

1. Draw the xy line and locate the end P at 20 mm in front of VP and assume it on HP as p and p'_1. Draw the locus line $h'h'$ of end Q, 50 mm above HP.
2. Draw the line $pq_1 = 64$ mm (TL) at an angle 25° to VP and project to get the elevation length $p'_1q'_1$ (EL).
3. Draw another line $p'_1 q'_2 = 64$ mm at an angle 40° to VP and project to get the plan length pq_2 (PL).
4. With centre p and radius pq_2 (PL), draw arc to intersect the locus line vv at q. Join pq to get the top view.
5. Draw a projector through q to intersect the locus line $h'_1h'_1$ at q'_3. Join q'_3 to p'_1 to get the front view.
6. Since p'_1 is an assumed position of the point and q'_3 is to be at 50 mm above HP, lift the front view ($q'_3 p'_1$) to the position q', without changing the angle α. This gives the required front view $p'q'$.
7. The same can be directly obtained by drawing an arc with centre q' and radius = the elevation length EL to cut the projector drawn through p at p'. Join p' q' to get the required front view.
8. Give proper line thickness and print the given dimensions to complete the drawing as given in Fig. 10.22(b).

Example 10.17

One end M of the line MN, 80 mm long is 10 mm below HP and 15 mm behind VP. The line is inclined at 40° to HP and the top view makes 50° with VP. Draw projections, if the line is in the third quadrant.

Refer to Fig. 10.23.

1. Draw the xy line and locate the end M at 15mm behind VP and 10 mm below HP.
2. Keep the line parallel to VP and inclined 40° to HP and then draw the locus line $h'h'$ of the end n'_1.
3. Project from the parallel line end and find the plan length (PL) mn_1. Draw the plan view mn of length equal to PL and inclined 50° to xy line.

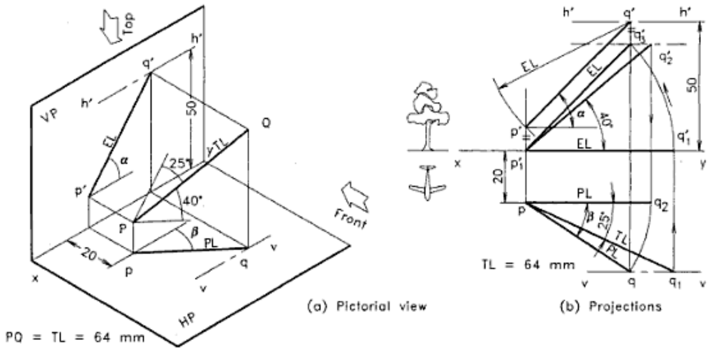


Fig. 10.22 Oblique line in first quadrant.

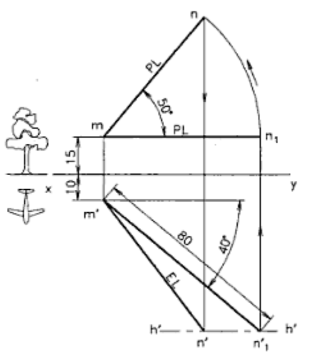


Fig. 10.23 Oblique line in the third quadrant.

4. Project vertically from n to intersect $h'h'$ line at n' so that, by drawing line $m'n'$ the front view is obtained.
5. Give proper line thickness and print the given dimensions to complete the drawing.

Example 10.18

Line CD is in the second quadrant and has 25° inclination with HP, while the front view has 30° inclination with xy line and 60 mm length. If the end C is 12 mm above HP and the end D is 60 mm behind VP, draw its projections.

Refer to Fig. 10.24.

1. Draw the xy line and locate the end C, 12 mm above HP and draw the front view $c'd'$ of length 60 mm and inclination 30° to xy line.
2. Mark the locus line $h'h'$ through d' and draw the true length line $c'd'_1$ at 25° with HP. Project vertically from d'_1 to get the plan c_1d_1 on xy line.
3. Draw the vv line at 60 mm behind VP and drop a projector through d' to locate d. Cut an arc of radius equal to PL from d to get point c on the projector through c', so that cd is the required top view.
4. Give proper line thickness and print the given dimensions to complete the drawing.

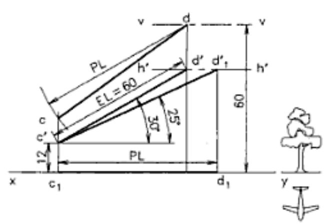


Fig. 10.24 Oblique line in the second quadrant.

Example 10.19

A 100 mm long line EF has 70 mm length in the top view and 84 mm length in the front view. If the line end E is in HP and F is in VP, draw its projections, keeping the line in the fourth quadrant.

Refer to Figs. 10.25.

1. Draw the *xy* line and locate the end E on HP as well as on VP by e' and e_1.

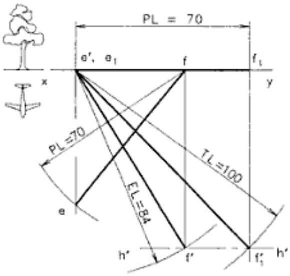


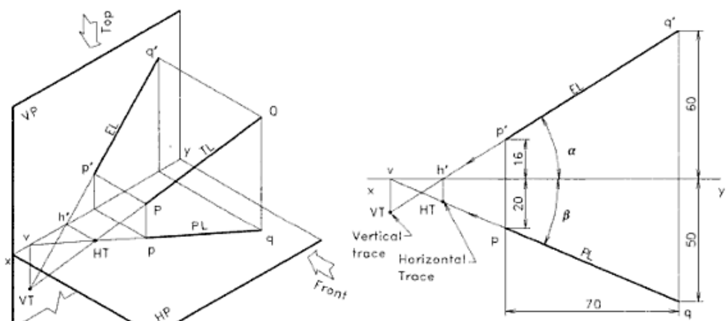
Fig. 10.25 Oblique line in the fourth quadrant.

2. Mark e_1f_1 as the plan length 70 mm on *xy* line and drop a vertical projector through f_1. Cut an arc with centre e' and radius equal to the true length 100 mm to cut the projector drawn at f_1'.
3. Draw the locus line $h'h'$ through f'_1 and cut the elevation length 84 mm on that line to get f'. Join $e'f'$ as the front view.
4. Since end F is on VP, the top view *f* will be on *xy* line and is located on the vertical projector drawn from f'.
5. To get the top view of the line cut an arc with centre *f* and radius equal to plan length 70 mm on the projector drawn through e'. The line *ef* gives the required top view.
6. Give proper line thickness and print the given dimensions to complete the drawing.

10.10 TRACES OF AN OBLIQUE LINE

If a line is inclined to both HP and VP (oblique), the line or the line produced will penetrate the two planes forming both the horizontal trace (HT) and the vertical trace (VT) [see Fig. 10.26(a)]. The properties of the traces are the same as that explained for inclined lines, but are combined together or superimposed. From the projections [Fig.10. 26(b)], the following features may be noted:

1. The points p', q', h' and VT lie on a straight line inclined $\alpha°$ and h' is located on the *xy* line.
2. The points *p*, *q*, *v* and HT lie on a straight line inclined $\beta°$ and *v* is located on the *xy* line.
3. The horizontal trace HT and its front view h' lie on a vertical projector.
4. The vertical trace VT and its top view *v* lie on another vertical projector.



(a) Pictorial view (b) Projections

Fig. 10.26 Traces of an oblique line placed in 1st quadrant.

In order to locate the HT of a line, extend the front view to cross xy line at h' and drop a vertical line through the point to intersect on the top view or top view produced. This intersection point gives HT. Similarly, to locate VT of a line, extend the top view to cross xy line at v and drop a vertical line through the point to intersect on the front view or front view produced. This intersection point gives VT. Note that h' and v are located always on the xy line.

Example 10.20

An end P of a line PQ is 16 mm above HP and 20 mm in front of VP while the end Q is 60 mm above HP and 50 mm in front of VP. If the end projectors are at a distance of 70 mm, draw the top and front views of the line and mark its traces.

Refer to Fig. 10.26.

1. Draw the xy line and locate the points p, p', q and q' at the given dimensions and draw the top view and front view of the line PQ as shown in figure.
2. Extend $q'p'$ to cross xy line at h'. Similarly, extend qp to cross xy line at v.
3. Drop vertical lines through h' and v to intersect the lines qp and $q'p'$ produced to intersect at HT and VT respectively.
4. Give proper line thickness and print the dimensions to complete the drawing.

Example 10.21

The projections of a line AB has 35° inclination in top view and 40° inclination in the front view with an elevation length of 60 mm. If the end A is 10 mm below HP and B is 12 mm behind VP, draw the projections and locate the traces keeping the line in the third quadrant.

Refer to Fig. 10.27.

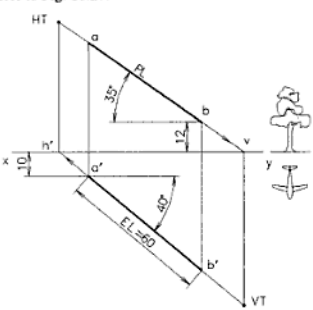


Fig. 10.27 Traces of an oblique line placed in 3rd quadrant.

1. Draw the xy line and locate the points a' 10 mm below HP.
2. Draw the elevation $a'b'$ of 60 mm length and of inclination 40° to xy line.
3. Locate the end b, 12 mm behind VP on the projector through b' and draw the plan ab at 35° inclination.
4. Extend the elevation $a'b'$ to get h' on xy line and draw projector through h' to intersect the plan extended at HT.
5. Extend the plan ab to get v on xy line and draw projector through v to intersect the elevation extended at VT.
6. Give proper line thickness and print the dimensions to complete the drawing.

10.11 TRUE LENGTH AND TRUE INCLINATIONS OF AN OBLIQUE LINE

The true length and true inclination of a line is seen in a projection when the line is parallel to that plane of projection. This principle is followed to determine the true length and inclination of a line inclined to both the reference planes. Two methods are suggested here for finding them.

Parallel Line Method

In this method, each view of the line is made parallel to the xy line (i.e. elevation EL and plan PL are rotated so that they are parallel to the reference planes) and is projected to get the parallel view from it. This is a reversal of the process explained for drawing the projections of an oblique line. When the line is parallel to a plane, it will show its true length TL and true inclination $\theta°$ or $\phi°$ on that plane. This method of finding the true length and inclinations is explained in Example 10.22(a).

Plane Rotation Method

In this method, the triangular plane containing the projected view of the line, the trace on it, and the original line is rotated about the projected view to coincide with the plane of projection. This can be made clear by the pictorial view, as shown in Figure 10.28. Here, the triangular plane containing plan ab, the trace HT, and the original line AB is rotated about the plan ab to fall on HP. This triangle gives the true angle $\theta°$ at HT and the true length AB. Similarly, the triangular plane containing $a'b'$, VT and AB can be rotated about $a'b'$ to fall on the VP to get the true angle $\phi°$ and the true length AB. This method of finding the true length and inclinations is explained in Example 10.22(b).

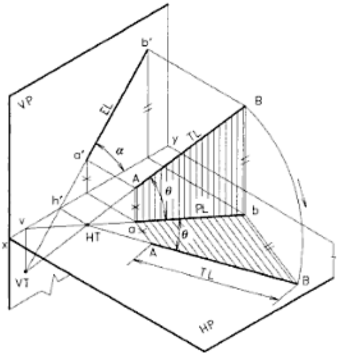


Fig. 10.28 True length and inclinations (Plane rotation method).

Example 10.22

An end A of a line AB is 16 mm above HP and 20 mm in front of VP, while the end B is 60 mm above HP and 50 mm in front of VP. If the end *projectors* are at a distance of 70 mm, find the true length and true inclination of the line to the reference planes by the following methods:

(a) Parallel line method.
(b) Plane rotation method.

(a) Parallel line method

Refer to Fig. 10.29(a).

1. Draw the xy line and mark the end points a', b', a and b as per given dimensions and complete the front and top views.
2. Draw the locus lines $h'h'$ and vv through b' and b respectively.
3. Rotate ab about a to bring it parallel to xy and project vertically to meet $h'h'$ at b_1'. Join a' and b_1' to get the true length (TL) and true inclination $\theta°$ with HP (xy line).
4. Similarly rotate $a'b'$ about a' to bring it parallel to xy line and project vertically to meet vv at b_2. Join ab_2

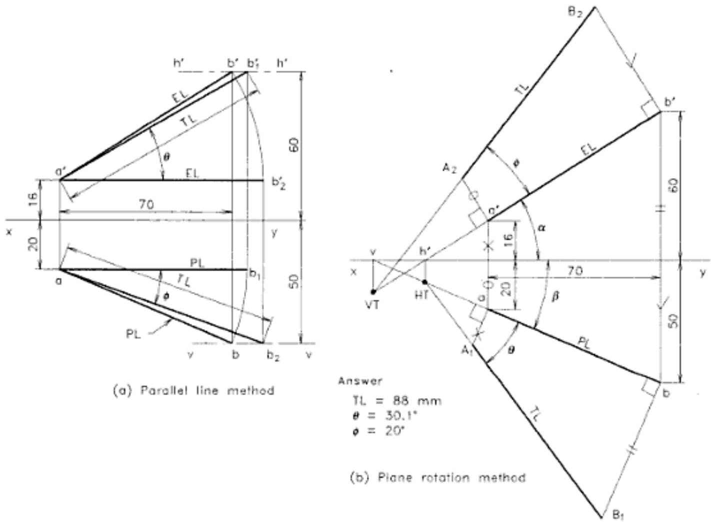


Fig. 10.29 True length and inclinations (oblique line in the first quadrant).

to get the true length (TL) of same value and the true inclination $\phi°$ with VP (*xy* line).

5. Measure the values and print them below the views as answer.
6. Give proper line thickness and print the dimensions to complete the drawing.

(b) Plane rotation method

Refer to Fig. 10.29(b).

1. Draw *xy* line and complete the projections of the line as per the given dimensions.
2. Extend the lines *a′b′* and *ab*, and mark HT and VT as shown in figure.
3. Draw perpendiculars at *b* and *b′* and mark elevation distance of *b′* from *xy* line (60 mm) at *b* and the plan distance of *b* from *xy* line (50 mm) at *b′*, to get points B_1 and B_2 respectively. Join HT to B_1 and VT to B_2.
4. Also drop perpendiculars at *a* and *a′* to get points A_1 and A_2 as shown in the figure. Now $A_1B_1 = A_2B_2 =$ the true length TL of line AB.
5. The angle between plan (PL) and true length line (TL) is $= \theta =$ the true inclination to HP. Similarly, the angle between elevation (EL) and true length line (TL) is $= \phi =$ the true inclination to VP.
6. Measure the values and print them below the view as the answer.
7. Give proper line thickness and print the dimensions to complete the drawing.

Example 10.23

The top view of a line CD has points *c* and *d*, 10 mm and 50 mm below the *xy* line and the front view has points *c′* and *d′*, 40 mm and 16 mm above the *xy* line respectively. Determine:

(i) the true length and inclinations of the line with HP and VP, and

(ii) HT and VT of the line.

Take the distance between the end projectors as 66 mm.

Refer to Fig. 10.30 (Plane rotation method)

1. Draw *xy* line and complete the projections of the line as per the given dimensions.
2. Extend the lines *c′d′* and *cd*, and mark HT and VT as shown in figure.
3. Draw perpendiculars at *c* and *d′* and mark elevation distance of *c′* from *xy* line (40 mm) at *c* and the plan distance of *d* from *xy* line (50 mm) at *d′*, to get points C_1 and D_2 respectively. Join HT to C_1 and VT to D_2.
4. Also drop perpendiculars at *d* and *c′* to get points D_1 and C_2 as shown in the figure. Now $C_1D_1 = C_2D_2 =$ the true length TL of line CD.
5. Angle between plan PL and true length line TL $= \theta =$ the true inclination to HP. Similarly, angle between elevation EL and true length line TL $= \phi =$ the true inclination to VP.
6. Measure the values and print them below the view as answer.
7. Give proper line thickness and print the dimensions to complete the drawing.

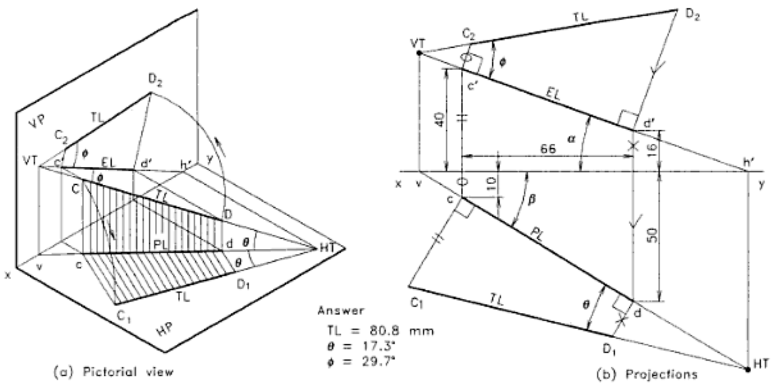


Fig. 10.30 True length and inclinations (plane rotation method).

EXERCISES

(# Problems similar to the worked out examples)

Line parallel to both or perpedicular to the reference planes

1. A line PQ 70 mm long is parallel to both HP and VP. The point P is 30 mm above HP and the point Q is 50 mm in front of VP. Draw its projections. (#)
2. A 50 mm long line CD is positioned in such a way that it is perpendicular to VP and the end D is 15 mm in front of VP and 40 mm above HP. Draw its projections, keeping the line in the first quadrant. (#)
3. Line EF, 36 mm long is in the first quadrant. The end F is 12 mm above HP and 24 mm in front of VP. If the line is perpendicular to HP draw its projections. (#)
4. Draw projections of a line PQ 70 mm long, when it is placed in the third quadrant and parallel to both HP and VP. The end P is 60 mm below HP, and 50 mm behind VP.
5. Draw projections of a line MN, 60 mm long, placed perpendicular to HP in the third quadrant. The line is 40 mm behind VP and the upper end of the line is 20 mm below HP.

Line Inclined to one of the reference planes

6. A line PQ, 80 mm long is parallel to VP and inclined at 45° to HP. The end P is 10 mm above HP and 35 mm in front of VP. Draw the projections. (#)
7. Line GH is inclined at 30° to VP and is contained in HP. The end G is 20 mm in front of VP. Draw the projections of the line, if the true length of line GH is 70 mm. (#)
8. A line EF , has end E 15 mm below and 45° inclined to HP. If the line is 40 mm behind and parallel to VP, draw projections and find its true length. The distance between the end projectors is 65 mm and the line is in the third quadrant. (#)
9. A line KL , has end K 16 mm behind VP and on HP. If the line has 90 mm length and parallel to VP, draw projections and find its true inclination and plan length. The end L is 56 mm above HP and the line is in the second quadrant. (#)
10. Line AB of length 90 mm is placed in the fourth quadrant so that it is parallel to HP and the ends are 70 mm below. If the end A is 10 mm and end B is 50 mm in front of VP, draw the projections and find the elevation length and inclination of the line with VP. (#)
11. The top view of a line AB measures 60 mm. The line is parallel to VP and inclined at 30° to HP. Its end A is 12 mm below HP and 24 mm behind VP. Draw the projections of the line and determine its true length, assuming that the line is in the third quadrant.
12. A line RS, 80 mm long is parallel to HP. Its end R is 30 mm in front of VP and the end S is 20 mm behind VP. If the line is 36 mm above HP, draw the projections of the line and find the inclination of the line with VP.

Trace of an inclined line

13. A line PQ of length 80 mm is parallel to VP and 35 mm in front of it. If the point P is 60 mm above and the point Q is 15 mm above HP. Draw its projections and find the traces. (#)
14. The end B of a line AB is 10 mm in front of VP while the end A is 40 mm above HP. The line is parallel to HP and 30° inclined to VP. Draw its projections and mark its traces, if the length of the line is 60 mm. (#)
15. A line ST, 80 mm long is parallel to HP. Its one end S is 25 mm in front of VP and T is 40 mm behind VP. If the line is 50 mm above HP, draw the projections, locate the traces and find its inclination to VP. (#)
16. The front view of a line EF is 90 mm long and it makes an angle of 45° to *xy* line. The midpoint *m′* of the line *e′f′* is 10 mm below the *xy* line and the end F is in the second quadrant. If the line is 15 mm behind and parallel to VP, draw its projections and mark the traces. (#)
17. A 75 mm long line BC has end B in the first quadrant and the other end C is in the second quadrant. If B is 35 mm in front of VP and C is 15 mm behind VP, draw its projections and mark its VT. The line BC is parallel to and 25 mm above HP. Also determine the elevation length of the line.
18. An inclined pipe line is running along a vertical wall of a building, so that one end is touching the floor of the ground floor, while the other end is touching the roof of the first floor. If the distance between the pipe ends measured horizontally is 7 m, while that measured vertically is 8 m. If the roof height of the first floor is 3 m, find graphically the length of the pipe, it's inclination to the ground and the point at which the pipe

penetrates the first floor. Draw the views to a suitable scale, neglecting the thickness of the slabs.

Three views and trace of an inclined line

19. Line PQ is parallel to VP and has a plan length 50 mm in the top view. If the end P is 12 mm above HP, and 30 mm in front of VP while the end Q is 60 mm above HP, draw the front, top and side views of the line. Also mark its traces on the three views. What is the true length and inclination of the line?(#)
20. A line EF is parallel to HP and has a length 70 mm. If the end E is 25 mm below HP, and 40 mm behind VP while the end F is 12 mm behind VP, draw the front, top and side views of the line. Mark its traces in the three views. Also find the elevation length and inclination of the line to VP by graphical methods. (#)
21. Line CD is parallel to HP and has an elevation length 40 mm. If the end C is 35 mm above HP, and 50 mm in front of VP while the end D is 10 mm in front of VP, draw the front, top and side views of the line. Also mark its trace on the three views. What is the true length and inclination of the line?

Projections of oblique line

22. A line PQ, 80 mm long has its end P in the HP and 30 mm in front of VP. If the line is 30° inclined to HP and 45° inclined to VP, draw its projections. (#)
23. A line AB, 70 mm long has one of its extremities 30 mm in front of VP and the other 70 mm above HP. The line is inclined at 45° to HP and 30° to VP. Draw its top and front views. (#)
24. One end J of the line JK, 90 mm long is 10 mm below HP and 20 mm behind VP. The line is inclined at 35° to HP and the top view makes 45° with VP. Draw projections, if the line is in the third quadrant. (#)
25. Line RS is in the second quadrant and has 30° inclination with HP, while the front view has 40° inclination with *xy* line and 70 mm length. If the end R is 15 mm above HP and the end S is 80 mm behind VP, draw its projections. (#)
26. A 110 mm long line CD has 75 mm length in the top view and 85 mm length in the front view. If the line end C is in HP and D is in VP, draw its projections, keeping the line in the fourth quadrant. (#)

Traces of oblique line

27. An end A of a line AB is 50 mm above HP and 60 mm in front of VP while the end B is 20 mm above HP and 15 mm in front of VP. If the end projectors are at a distance of 65 mm, draw the top and front views of the line and mark its traces. (#)
28. The projections of a line CD has 45° inclination in top view and 40° inclination in the front view with an elevation length of 70 mm. If the end C is 15 mm below HP and D is 20 mm behind VP, draw the projections and locate the traces keeping the line in the third quadrant. (#)

True length and inclinations of oblique line

29. An end P of a line PQ is 15 mm above HP and 25 mm in front of VP, while the end Q is 60 mm above HP and 50 mm in front of VP. If the end projectors are at a distance of 65 mm, find the true length and true inclination of the line to the reference planes by the following methods:
    (a) Parallel line method.
    (b) Plane rotation method. (#)
30. The top view of a line EF has points *e* and f, 12 mm and 60 mm below the *xy* line and the front view has points *e′* and *f′*, 50 mm and 15 mm above the *xy* line respectively. Determine: (i) the true length and inclinations of the line with HP and VP, and (ii) HT and VT of the line. Take the distance between the end projectors as 70 mm. (#)
31. Line CD has 80 mm length in the front view and 70 mm length in the top view. The end C is 50 mm below HP and 40 mm behind VP, while the end D is 10 mm below HP. Draw the projections of the line, locate the traces and determine the true length and inclinations of the line with the reference planes. (#)
32. A line MN has end the M on HP and 50 mm in front of VP while the end N is on VP and 40 mm above HP. If the inclination of the top view is 35° to the *xy* line, draw the projections, locate the traces and find the true length as well as the true inclinations of the line with the reference planes.

CHAPTER 11

Projections of Plane Figures

Plane figures or surfaces (laminae) are two-dimensional entities enclosed by straight lines or curves or both. A plane figure has only two dimensions i.e. length and breadth and it has no thickness. A plane surface is obtained from a three-dimensional object by eliminating one of the three-dimensions.

11.1 TYPES OF PLANE FIGURES

A plane figure or lamina may be bounded by straight lines, curves or both. If the sides of a plane figure are equal, it is called a ***regular plane figure***. If the sides are not equal, it is called as an ***irregular plane figure***. The plane figures used here for projection are triangle, square, rectangle, rhombus, pentagon, hexagon, circle, ellipse, etc. as shown in Fig. 11.1.

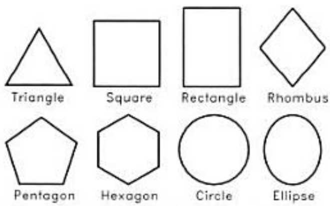
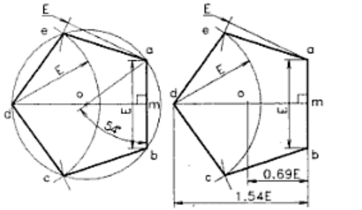


Fig. 11.1 Geometrical plane figures.

Construction of Pentagon and Hexagon

Construction of pentagon and hexagon is frequently required in projections of planes and solids. Two easy methods for the same are explained below:

1. *Pentagon*
   (a) Using protractor: [Refer to Fig. 11.2(a)]
   Draw the side *ab* of edge length E and insert a perpendicular at the middle *m*. At the end *a* draw 54° inclined line to *ab* using protractor in order to get the centre *o*. With centre *o* and radius *oa*, draw a circle to pass through *a*, *b* and *d* as shown in the figure. Cut the edge length E on the circle from these points to get the remaining corners *c* and *e* to complete the pentagon *abcde*.
   (b) Using calculated lengths: [Refer to Fig. 11.2(b)]
   Draw the side *ab* of edge length E and insert a perpendicular at the middle *m* for length = 1.54E. Locate *o* on that line so that *mo* = 0.69E. Draw arcs of radius equal to the edge length E at points a, *b* and *d* to get the remaining corners *c* and *e* of the pentagon *abcde*.
2. *Hexagon*
   (a) Using 60-30 set squares: [Refer to Fig. 11.3(a)]
   Draw the side *ab* of edge length E and insert 60° inclined lines at the ends *a* and *b* using set square in order to get the centre '*o*' of the hexagon. Extend



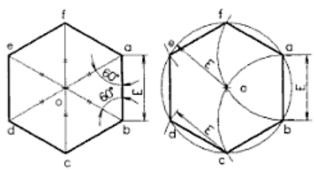
(a) Using Protractor (b) Using calculated lengths

Fig. 11.2 Construction of pentagon.

these lines so that *od* = *oe* = E. Draw a parallel to *ab* through o such that *oc* = *of* = E as shown in figure. The lines joining *abcdef* give the hexagon.

(b) Using compass: [Refer to Fig. 11.3(b)]
Draw the side *ab* of edge length E and scribe arcs of radius = E at the ends *a* and *b* to get the centre *o* of the hexagon. With centre *o* and radius *oa*, draw a circle to pass through the ends *a* and *b*, cutting the arcs at *c* and *f* as shown. Cut the edge length E on the circle from points *c* and *f* to get the remaining corners *d* and *e* in order to complete the hexagon *abcdef*.

Any of the above methods convenient to a student may be used to construct a pentagon or hexagon. The construction lines need not be removed.



(a) Using 60–30 set square (b) Using compass

Fig. 11.3 Construction of hexagon.

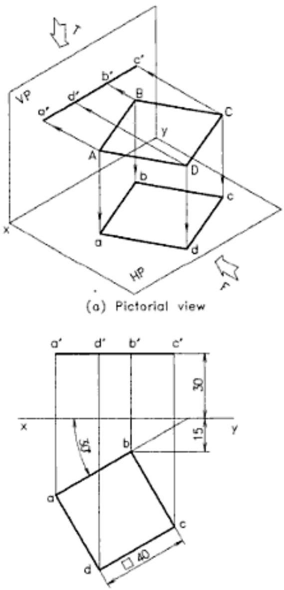
11.2 POSITIONS OF PLANE FIGURES

With respect to the reference planes (HP and VP), the position of plane figures can be classified as follows:

1. Plane figures perpendicular to both the reference planes.
2. Plane figures perpendicular to one of the reference planes and parallel to the other.
3. Plane figures inclined to one of the reference planes and perpendicular to the other.
4. Plane figures inclined to both the reference planes, but perpendicular to the profile plane.
5. Plane figures inclined to both the reference planes as well as to the profile plane.

11.3 PLANE FIGURES PARALLEL TO ONE OF THE REFERENCE PLANES

When a plane figure or lamina is kept parallel to a reference plane, its projection on that plane will show its true shape and size. The projection on the other plane to which the lamina is perpendicular, will be a straight line. See Fig. 11.4.



(b) Orthographic views

Fig. 11.4 Square lamina parallel to HP.

Example 11.1

A square lamina ABCD of 40 mm edge length is kept parallel to HP so that the edge AB is 30° inclined to VP and the nearest corner B is 15 mm in front of it. If the lamina is 30 mm above HP draw its projections.

Refer to Fig. 11.4.

1. The lamina is parallel to HP, hence the top view will show its true shape and inclination. Draw *xy* line and scribe a 30° inclined line to *xy*. Mark point *b* on that line at a distance 15 mm from *xy* line (VP).
2. Using the mini drafter construct the square *abcd* of 40 mm side on point *b* so that the edge *ab* is 30° inclined to *xy* line.
3. Project upwards from *abcd* and draw a horizontal line at a height of 30 mm to represent the front view *a′b′c′d′* of the lamina.
4. Convert the edges of the object into thick line and mark off the given dimensions to complete the drawing.

Example 11.2

A pentagonal lamina of 40 mm edge length is kept parallel to VP so that one edge is perpendicular to HP and the lamina is 20 mm in front of VP. If the centre of the lamina is 45 mm above HP, draw its projections.

Refer to Fig. 11.5.

1. The lamina is parallel to VP, hence the front view will show its true shape and size. Draw *xy* line and scribe a horizontal thin line 45 mm above HP.
2. Construct the pentagon *abcde* of 40 mm side on point *m* so that the edge *ab* is perpendicular to *xy* line and *m* is the mid point of edge *ab*.
3. Project downwards from *abcde* and draw a horizontal line at a distance of 20 mm from *xy* line to represent the top view *a′b′c′d′e′* of the lamina.

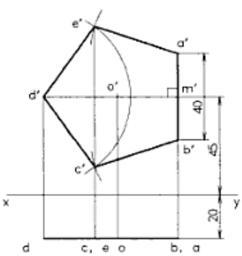


Fig. 11.5 Pentagonal lamina parallel to VP.

4. Convert the edges of the object into thick line and mark off the given dimensions to complete the drawing.

Example 11.3

A hexagonal plate of 30 mm edge length is kept parallel to HP so that one edge is parallel to and 20 mm in front of VP. If the plate is 24 mm above HP, draw its projections.

Refer to Fig. 11.6.

1. The lamina is parallel to HP, hence the top view will show its true shape. Draw *xy* line and construct the hexagon 20 mm in front of VP such that the edge *ab* is parallel to the reference line.
2. Project upwards from *abcdef* and draw a horizontal line at a distance of 24 mm from *xy* line to represent the front view *a′b′c′d′e′f′* of the lamina.
3. Convert the edges of the object into thick line and mark off the given dimensions to complete the drawing.

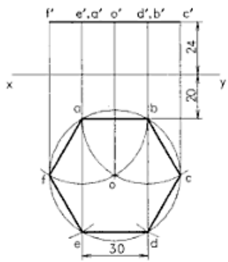


Fig. 11.6 Hexagonal laming parallel to HP.

Example 11.4

A square lamina of 40 mm edge length has a square hole of 24 mm side, cut at the centre and parallel with its outer edges. It is kept parallel to VP so that the edges are equally inclined to and the centre is 40 mm above HP. If the surface of the lamina is 28 mm in front of VP, draw its projections.

Refer to Fig. 11.7.

1. The lamina is parallel to VP, hence the front view will show its true shape. Draw *xy* line and locate the centre of the lamina *o′* at a height of 40 mm.
2. Since the edges are equally inclined to HP, the inclination of edges will be 45° to *xy* line. To get the front view, draw a 45° inclined line through *o′* and

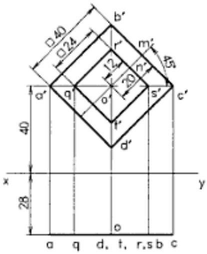


Fig. 11.7 Squarfe lamina parallel to VP.

mark off n' and m' at 12 mm and 20 mm lengths respectively on that line from o'. Construct the lamina through these points using the mini-drafter.

3. Project downwards from the front view and draw a horizontal line at a distance of 28 mm from *xy* line to represent the top view.
4. Convert the edges of the object into thick line and mark off the given dimensions to complete the drawing.

11.4 PLANE FIGURES INCLINED TO ONE OF THE REFERENCE PLANES

Figure 11.8 shows a square plane figure inclined to HP and perpendicular to VP. Since the square lamina is inclined to HP, its projection on HP will not give the true shape. The two edges, parallel to HP, will have the true lengths, but the other edges will be foreshortened. The projection on VP will be a line, because the lamina is perpendicular to that plane.

To get the projections of the lamina in the required position, first the lamina is kept parallel to HP and the two views (Set-1) are drawn. Then the front view is tilted about an edge (line for tilting LT), parallel to the line of sight for front view, so that the required inclination to HP is obtained. Copy the tilted front view on the same *xy* line. Draw projectors vertically from the new front view and horizontally from the previous top view to get the points of intersection for the required top view. This method of projection may be called as *change of position method* and is shown in Fig. 11.8(b). Set-2 gives the required projections.

A similar condition exists when the lamina is inclined to VP but perpendicular to HP. Figure 11.9 shows the method of projecting a hexagonal lamina inclined to VP but perpendicular to HP. The same change of position method is followed for the solution. The lamina is initially kept parallel to VP and the views are drawn as Set-1. Then the top view is tilted about an edge parallel to the line of sight for top view (LT), so that the required inclination to VP is obtained. Draw projectors vertically upwards from the top view and horizontally from the previous front view to get the points of intersection for the required front view of Set-2.

Traces

If a plane is extended, it will intersect the two reference planes (HP and VP) along two different lines, unless the plane is parallel to either of the *reference planes*. These lines of intersection are called *traces of the plane*. The line of intersection of the plane with HP is called the *horizontal*

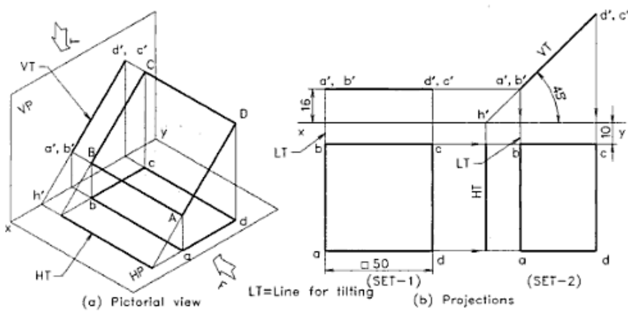


Fig. 11.8 Square lamina inclined to HP.

trace. Horizontal trace is abbreviated as HT. The line of intersection of the plane with VP is called the *vertical trace*, and is abbreviated as VT. See Fig. 11.8.

Example 11.5

A square lamina ABCD of 50 mm side has its plane perpendicular to VP and inclined by 45° to HP. The edge AB is 16 mm above HP and the corner B is 10 mm in front of VP. Draw the projections of the square lamina and show its traces.

Refer to Fig. 11.8.

1. Draw the top view *abcd* and the front view *a′b′c′d′* of the square lamina ABCD keeping it parallel to HP and perpendicular to VP, so that the edge *ab* (line for tilting-LT) is perpendicular to *xy*. This gives the Set-1 of the views.
2. Copy the front view of Set-1 after tilting the view about the edge *a′b′* (LT), so that the lamina is 45° inclined to HP and mark *a′b′c′d′*.
3. Draw vertical projectors from all the points *a′b′c′d′* of the new front view. Also draw horizontal lines from all the points *abcd* of the top view of Set-1, so that they intersect to get the final top view of Set-2. Also mark the HT and VT of the lamina as shown in figure.
4. Finish the views by giving proper line thickness and enter the given dimensions to complete the drawing.

Example 11.6

A plane figure ABCDEF of the shape of a hexagon of 30 mm side has its one edge parallel to VP and is 16 mm in front of it. If the plane is 40° inclined to VP, draw its projections and mark its traces, keeping the lowest corner 12 mm above HP.

Refer to Fig. 11.9.

1. Draw the front view *a′b′c′d′e′f′* and the top view *abcdef* of the lamina, keeping it parallel to VP and an edge *a′f′* (line for tilting, LT) perpendicular to HP. This gives the Set-1 of the views.
2. Copy the top view after tilting it about the edge af (LT), so that the lamina is 40° inclined to VP.
3. Draw projectors vertically from all the points of the new top view. Also draw horizontal lines from all the points of the front view of Set-1, so that they intersect to get the final front view of Set-2 in the required position. Also mark the traces of the lamina.
4. Finish the views by giving proper line thickness and print the given dimensions to complete the drawing.

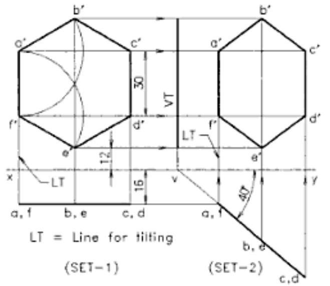


Fig. 11.9 Hexagonal lamina inclined to VP.

Example 11.7

A circular lamina of 60 mm diameter is kept 30° inclined to HP and perpendicular to VP, so that the centre of the lamina is 40 mm in front of VP and the lowest of the circular edge is 14 mm above HP. Draw projections of the lamina.

Refer to Fig. 11.10.

1. Draw the top view and front view of the lamina keeping it parallel to HP so that the centre *o* is 40 mm in front of VP and the surface is 14 mm above HP.
2. Divide the circle radially into 12 equal parts and name them clockwise as shown in figure. Note that the horizontal and vertical centre lines should be

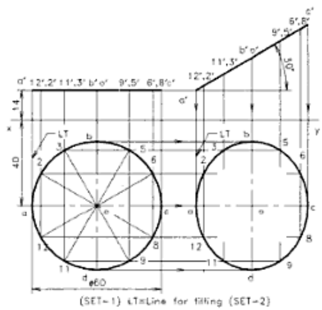


Fig. 11.10 Circular lamina inclined to HP.

drawn using chain (Type G) lines and may be named as *abcd*. Project upwards from all points and mark the divisions on the front view.

3. Copy the front view and the points on them after tilting the view 30° to HP about the line for tilting (LT). Note that LT is kept perpendicular to *xy* in the true shape drawing.
4. Project vertically downwards from the 2nd front view and horizontally from the 1st top view to get the 12 points of intersection and name them. Draw a smooth cure through these points resulting an ellipse. Freehand drawing is enough but use of a suitable french curve gives better finish.
5. Finish the views by giving proper line thickness and print the given dimensions.

11.5 PLANE FIGURES INCLINED TO THE TWO REFERENCE PLANES

If a plane figure is inclined to HP and VP, the projections on these planes will not show its true size and shape, at the same time will be a squeezed or distorted. The final views are usually obtained by drawing three sets of views (see Fig. 11.1), the projections of a rectangular lamina. Here, the lamina is kept initially parallel to HP, such that the line for tilting (LT) is positioned perpendicular to the *xy* line as well as the true shape is seen. Draw the projections to get the Set-1 views (Parallel position). Now, the front view is tilted about LT so that the required true inclination ($\theta°$) to HP is obtained. Here, *ab* is the edge for tilting. Copy the front view after tilting and project vertically downwards from all the corner points. Similarly project horizontally from the top view of (Set-1) to get the points of intersection as the second top view (Inclined position). Now, copy this second top view of Set-2, after turning the edge *ab* about *b* (the point for turning PT) so that the angle seen in the top view (β) is inclined 60° to *xy* line ($\beta = \phi° = 60°$, because the edge is on HP). This gives the third top view. Project vertically upwards from the third top view and horizontally from the second front view to get the points of intersection of the third front view. Set-3 gives the required projections.

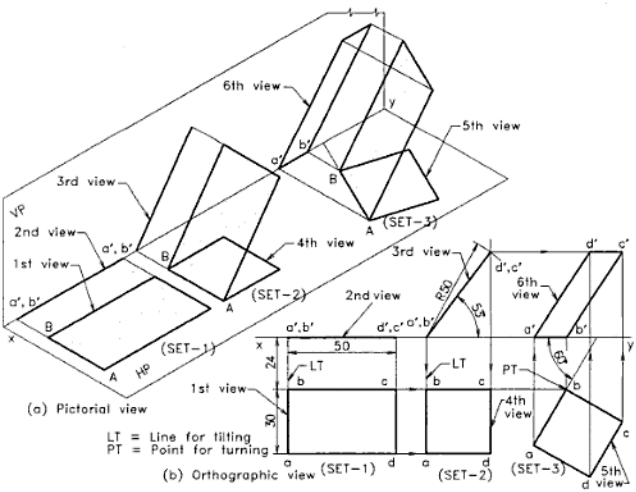


Fig. 11.11 Rectangular lamina inclined to HP and VP.

Planning the Three Sets of Views and the Order of Drafting

1. Visualize the oblique position of the lamina (Set-3) in the given problem by considering the two inclinations.
2. Select the point for turning PT in a view of Set-3 such that, if the inclination seen in the view (apparent angle α or β) is turned back, the lamina changes from oblique position to the inclined position (Set-2). Here, the related view is seen as a straight line. Also the line for tilting LT becomes perpendicular to the *xy* line.
3. Tilt back the straight line view about LT to the other given angle (θ or ϕ) to get the parallel position of lamina so that the true shape is visible in the related view.
4. After planning the three sets of views, start drawing the true shape of the lamina (1st view), keeping LT perpendicular to *xy* line and complete the two views of Set-1.
5. Copy the line view (2nd view) after tilting it about LT to the first inclination (θ or ϕ), so that the 3rd view is formed. Project from the 3rd and 1st views to get the 4th view, completing the Set-2.
6. Copy the 4th view after turning it about PT to the apparent angle (α or β) so that the 5th view is formed. Project from the 5th and 4th views to get the 6th view and thus to complete the Set-3.

The six views can be reduced to four views if the *auxiliary-plane method* of projection is used. This method is discussed at the end of the chapter.

Example 11.8

A rectangular lamina ABCD of 30 × 50 mm size stands on one of its shorter edges AB on HP such that the surface is 53° inclined to HP and the nearest corner to VP is at a distance of 24 mm. If the edge on which it rests is inclined at 60° to VP, draw the projections.

Refer to Fig. 11.11.

1. Place the lamina on HP in horizontal position and the edge AB perpendicular to and 24 mm in front of VP. Draw the top view and then the front view to complete the Set-1. Here, the line *ab* is the line for tilting (LT).
2. Copy the front view as the 3rd view, after tilting it about LT in order to make the surface inclined 53° to HP.
3. Draw projectors vertically downwards from the 3rd view and draw horizontal projectors from the first top view. Join the intersecting points by straight lines to get the second top view (4th view).
4. Copy the second top view (4th view) after rotating it about the point of turning PT, so that the edge *ab* is seen inclined at 60° to VP in the top view (Here, $\beta = \phi° = 60°$, because the edge is on HP).
5. Draw vertical projectors upwards from the third top view (5th view) and horizontal projectors from the second front view (3rd view), so that the intersecting points give the third front view (6th view). Join the points using straight lines and thus complete the Set-3.
6. Finish the drawing by giving proper line thickness and print the given dimensions.

Example 11.9

A hexagonal lamina of 30 mm side stands with one of its edges parallel to and 16 mm in front of VP, such that the surface is 40° inclined to VP. If the edge parallel to VP is inclined at 50° to HP, draw the projections of the lamina.

Refer to Fig. 11.12.

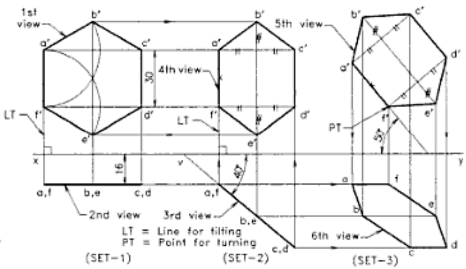


Fig. 11.12 Hexagonal lamina inclined to HP and VP.

1. Place the lamina parallel to VP and 16 mm in front of it, such that one edge $a'f'$ (LT) is perpendicular to HP. Draw the front view and then the top view to complete the Set-1.
2. Copy the top view as the 3rd view, after tilting it about LT in order to make it 40° to VP.
3. Draw projectors vertically upwards from the 3rd view and draw horizontal lines from the first front view. Join the intersecting points by straight lines to get the second front view (4th view).
4. Copy the second front view (4th view) after rotating it about the point of turning PT, so that the edge $a'f'$ is seen inclined at 50° to HP in the front view (Here, $\alpha = \theta = 50°$, because the edge is parallel to VP).
5. Draw vertical projectors downwards from the third front view (5th view) and horizontal lines from the second top view (3rd view), so that the intersecting points give the third top view (6th view). Join the points using straight lines and thus complete the Set-3.

Example 11.10

A pentagonal lamina ABCDE of 40 mm side is resting upon its edge AE on HP, so that the surface is inclined at 45° to HP. Its diameter joining the vertex to the midpoint F of the edge AE is inclined at 30° to VP. Draw the projections of the lamina keeping the vertex C nearer to VP.

Refer to Fig. 11.13.

1. Draw the projections of the lamina keeping on HP and the edge *ae* of the top view (LT) perpendicular to VP. Join the midpoint *f* of *ae* to *c* as the diameter. Thus complete the Set-1.
2. Tilt the front view by 45° (about LT) and copy it as the second front view. Draw vertical projectors from the second front view and horizontal projectors from the first top view to get the points of intersection for the second top view. Join the points and complete the Set-2.
3. Since the diameter FC is inclined 45° to HP and 30° to VP, the angle seen in top view will be β, which is greater than 30°. The angle β can be determined by a construction. Draw the diameter FC of the first top view as the true length fc_1 (TL) at an angle 30° to horizontal. Mark the *vv* line through c_1 and cut the plan length (PL) on *vv*. The line *fc* gives apparent inclination *b*.
4. Copy the second top view after turning to an angle β about PT to complete the third top view.
5. Project vertically upwards from the third top view and horizontally from the second front view to get the intersection points. By joining the points as shown in Fig. 11.13, the third front view is also completed.

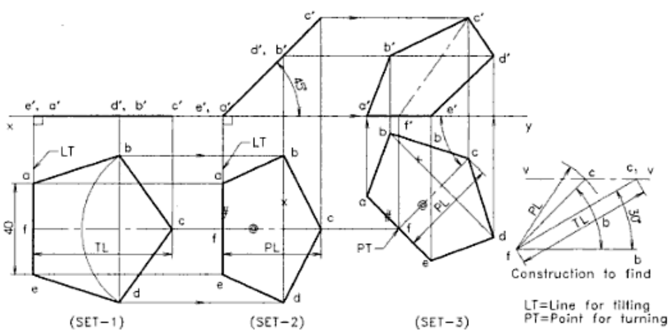


Fig. 11.13 Pentagonal lamina inclined to HP and VP.

Example 11.11
A circular lamina of 80 mm diameter rests above HP on a point A on its circumference. If its plane is inclined at 45° to HP and the top view of the diameter AC makes an angle of 40° with the *xy* line, draw the projections of the lamina.

Refer to Fig. 11.14.

1. Draw the top view and front view of the circular lamina keeping it parallel to HP. Divide the circle radially into 12 equal parts. Mark the points 1, 2, 3, ... 12 , on the circumference of top and friend views as shown. Locate the diameter ac parallel to VP and *bd* perpendicular to it using chain line. This completes Set-1.
2. Tilt the front view of the lamina about LT by an angle 45° and copy it as the second front view.

   Project from the second front view and from the first top view to get the points of intersection. Join the 12 points using a smooth curve to get the second top view. This is an ellipse with minor diameter equal to the plan length (PL) of *a′c′*.
3. Since the top view of diameter AC makes 40° (*β*) with *xy* line, copy the second top view after turning it by 40° about PT. For this draw *ac* at 40° as the minor axis and *bd* perpendicular to it as the major axis. Copy the horizontal lines through points 1 to 12 on this major axis using a bow divider in order to get the points on ellipse and complete the figure. This gives the third top view in position.
4. Project from the third top view and from the second front view to get the intersection points. Join these points to form the final front view which is another ellipse. The Set-3 gives the required solution for the problem.
5. Finish the drawing by giving proper line thickness and print the given dimensions.

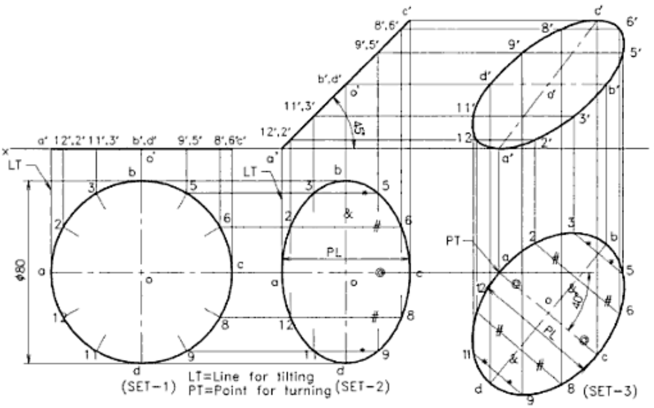


Fig. 11.14 Circular lamina inclined to HP and VP.

EXERCISES

(# Problems similar to the worked-out examples)

1. A square lamina PQRS of 50 mm edge length is kept parallel to HP so that the edge PQ is 20° inclined to VP and the nearest corner Q is 20 mm in front of it. If the lamina is 35 mm above HP draw its projections. (#)
2. A pentagonal lamina of 40 mm edge length is kept parallel to VP so that one edge is parallel to HP and the lamina is 30 mm in front of VP. If the centre of the lamina is 60 mm above HP, draw its projections. (#)
3. A hexagonal plate of 30 mm edge length is kept parallel to HP so that one edge is perpendicular to VP. If the plate is 24 mm above HP and 20 mm in front of VP, draw its projections. (#)
4. A square lamina of 60 mm edge length has a square hole of 30 mm side, cut at the centre and parallel with its outer edges. It is kept parallel to VP so that the edges are equally inclined to and the centre is 60 mm above HP. If the surface of the lamina is 30 mm in front of VP, draw its projections. (#)
5. A square lamina KLMN of 60 mm side has its plane perpendicular to VP and inclined by 60° to HP. The edge KL is 20 mm above HP and the corner L is 15 mm in front of VP. Draw the projections of the square lamina and show its traces. (#)
6. A plane figure with the shape of a hexagon of 35 mm side has its one edge parallel to VP and is 20 mm in front of it. If the plane is 45° inclined to VP, draw its projections and mark its traces, keeping the lowest corner 15 mm above HP. (#)
7. A circular lamina of 80 mm diameter is kept 45° inclined to HP and perpendicular to VP, so that the centre of the lamina is 60 mm in front of VP and the lowest point of the circular edge is 20 mm above HP. Draw projections of the lamina. (#)
8. A rectangular lamina PQRS of 40 × 70 mm size stands on one of its shorter edges PQ on HP such that the surface is 60° inclined to HP and the nearest corner to VP is at a distance of 25 mm. If the edge on which it rests is inclined at 55° to VP, draw the projections. (#)
9. A hexagonal lamina of 35 mm side stands with one of its edges parallel to and 20 mm in front of VP, such that the surface is 45° inclined to VP. If the edge parallel to VP is inclined at 60° to HP, draw the projections of the lamina. (#)
10. A pentagonal lamina JKLMN of 40 mm side is resting upon its edge JN on HP, so that the surface is inclined at 50° to HP. Its diameter joining the vertex L to the midpoint P of the edge JN is inclined at 25° to VP. Draw the projections of the lamina keeping the vertex L nearer to VP. (#)
11. A circular lamina of 80 mm diameter rests above HP on a point A on its circumference. If its plane is inclined at 40° to HP and the top view of the diameter AC makes an angle of 45° with the *xy* line, draw the projections of the lamina. (#)

CHAPTER 12

Projections of Solids

A solid may be defined as an object having three dimensions such as length, breadth and thickness, measured along the three mutually perpendicular axes. This chapter discusses the method of drawing of orthographic views of geometrical solids.

For the purpose of drawing, a solid may be considered as a combination of points, lines and planes, flat or curved. The method of projection of points, lines and planes was already discussed in the previous chapters. Here, the procedure and conventions which were discussed in the previous chapters have to be combined and applied together.

12.1 CLASSIFICATION OF SOLIDS

The solids generally used for the study of Engineering Graphics may be classified as:

1. Polyhedra
2. Solids of revolution.

Solids may also be classified as:

1. Right solids, and
2. Oblique solids.

If the axis of a solid is perpendicular to its base or end faces, that solid is called a *right solid*. Further, if all the edges of the base or of the end faces of a right solid are of equal lengths and they form a plane figure, that right solid is called a *right regular solid*. See Fig. 12.1.

If the axis of a solid is inclined to its base or end faces, that solid is called an *oblique solid*. Further, if all the edges of the base or of the end faces of an oblique solid are of equal lengths and they form a plane figure, that oblique solid is called an *oblique regular solid*. Figure 12.2 gives the pictorial views of oblique solids.

A *polyhedron* is defined as a solid bounded by planes called *faces*. Platonic solids, prisms and pyramids are some of the solids coming under this group.

A *solid of revolution* is defined as a solid generated by the revolution of a plane figure about a line called *axis*. Cylinders, cones and spheres are some of the solids coming under this group.

Regular Polyhedra

A regular polyhedron is defined as a solid bounded by regular planes called *faces*, whose edges are equal in length and the angles between the adjacent faces are equal. The following are the five regular polyhedra called *platonic solids*.

1. **Tetrahedron:** It consists of four equal equilateral triangular faces.
2. **Hexahedron (cube):** It consists of six equal square faces.
3. **Octahedron:** It consists of eight equal equilateral triangular faces.

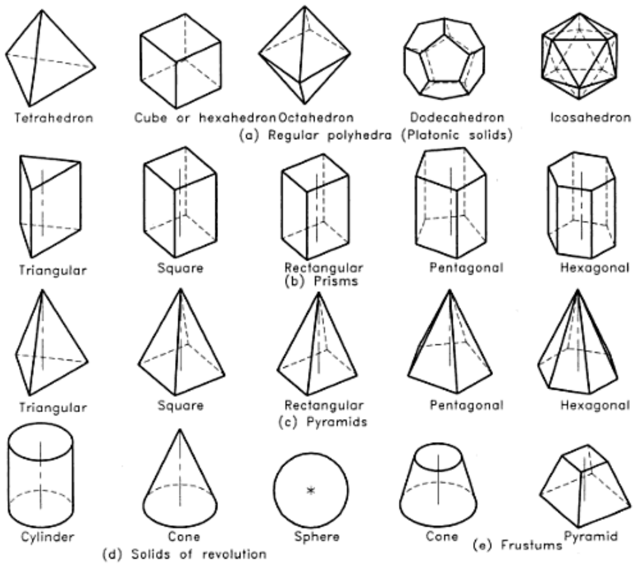


Fig. 12.1 Ritht regular solids.

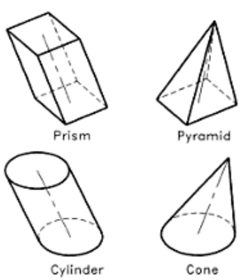


Fig. 12.2 Oblique solids.

4. **Dodecahedron:** It consists of twelve equal pentagonal faces.
5. **Icosahedron:** It consists of twenty equal equilateral triangular faces.

Prisms

A prism is a polyhedron having two equal and similar end faces, parallel to each other and joined by side faces which are either rectangular or parallelograms. Prisms are named according to the shape of the end faces such as triangular, square, rectangular, pentagonal, hexagonal, etc. A parallelopiped is a prism having parallelograms as end faces.

In a right prism, its axis is perpendicular to its base; but in an oblique prism, its axis is inclined to its base. Axis of a prism is an imaginary line joining the centres of the end faces. Nomenclature of a square prism is shown in Fig. 12.3 and it is self explanatory.

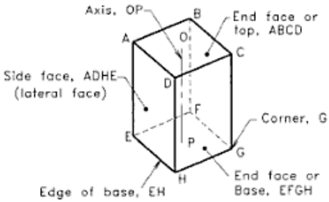


Fig. 12.3 Prism.

Pyramids

A pyramid is a polyhedron having a polygon as base and isosceles triangular faces equal to the number of sides of the polygon, as the lateral faces. They all meet at a point called *apex* or *vertex*. Pyramids are named according to the shape of its base, such as triangular, square, pentagonal, hexagonal, etc.

Nomenclature of a square pyramid is shown in Fig. 12.4 and it is self explanatory. Axis of a pyramid is an imaginary line, joining the vertex to the centre of its base. The perpendicular distance between the vertex and the base of the pyramid is called the *altitude* or *height of the prism*. In the figure, the distance OP is the height. In a right pyramid, its axis is perpendicular to its base; but in an oblique pyramid, its axis is inclined to its base.

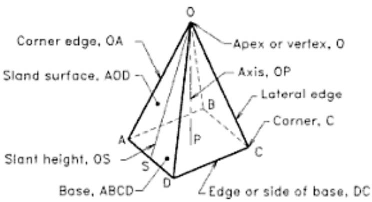


Fig. 12.4 Pyramid.

Solids of Revolution

A solid of revolution is defined as a solid generated by the revolution of a plane figure about a line called *axis*. Cylinders, cones and spheres are some of the solids coming under this group.

Cylinder

A solid generated by the revolution of a rectangle about one of its sides fixed, is called a *right circular cylinder*. A right circular cylinder is shown in Fig. 12.5. It is generated by the revolution of the rectangle ABOP about OP.

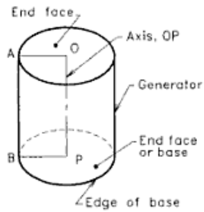


Fig. 12.5 Cylinder.

Cone

A solid generated by the revolution of a right angled triangle about one of its sides, that which remains fixed and contains the right angle, is called right circular cone. A right circular cone is shown in Fig. 12.6. It is generated by the revolution of the right angled triangle OPA about OP.

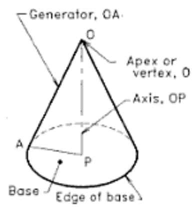


Fig. 12.6 Cone.

Sphere

A solid generated by the revolution of a semicircle about its diameter which remains fixed, is called a *sphere*.

Frustums

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

12.2 POSITION OF A SOLID WITH RESPECT TO THE REFERENCE PLANES

The solids under discussion are generally placed in any one of the following ways, based on the inclination of its axes with the reference planes.

1. Simple *position*
   - (a) Axis perpendicular to HP.
   - (b) Axis perpendicular to VP.
   - (c) Axis parallel to HP and VP (i.e. perpendicular to PP).
2. Axis *inclined to one of the reference planes.*
   - (a) Axis parallel to HP but inclined to VP.
   - (b) Axis parallel to VP but inclined to HP.
2. Axis *inclined to both the reference planes.*

The position of solids with reference to the reference planes can also be grouped as:

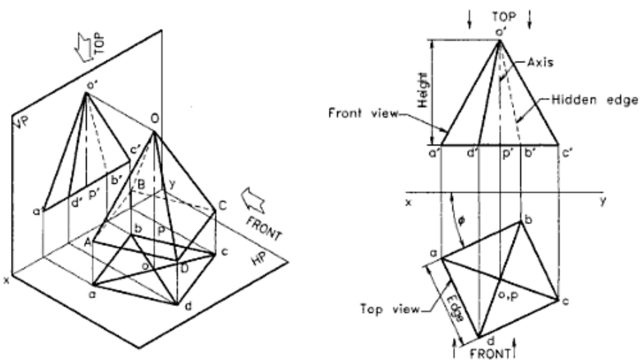
1. Solid resting on its base.
2. Solid resting on any one of its faces, edges of faces, edges of base, generators, slant edges, etc.
3. Solid suspended freely from one of its corners, edges, etc.

12.3 METHOD OF DRAWING ORTHOGRAPHIC PROJECTIONS OF SOLIDS

The method of drawing orthographic views is similar to that of plane figures. Here, the third dimension i.e. thickness or height of that object is also considered for drawing. The object is assumed to be placed, unless otherwise specified, in the first quadrant, because first angle projection method is followed. Generally, the projections on the two principal planes are sufficient to describe the object. To fulfil some special requirements, the projection on the profile plane (side view) is also added. Figure 12.7 gives the pictorial view of a square pyramid and its projections on the principal planes. By referring the projections, the following points may be noted:

Rules and Conventions

1. All the rules of projections for points, lines and plane figures are applicable for solids also.
2. Unless otherwise specified, the object is assumed to be contained in the first quadrant, since first angle projection method is followed.
3. If the distance from HP and VP are not given, any convenient distances may be assumed. Similarly, if the direction of the inclination of axis, like towards left or right, towards or away from the observer etc., is not given, any convenient simple position may be selected for drawing.
4. Unless otherwise specified, the views may be drawn by following either *change of position of view method* or *auxiliary projection method.*



(a) Pictorial view (b) Orthographic view

Fig. 12.7 A square pyramid in parallel position.

Types of Lines Used and the Order of Priority

1. *Type A line (continuous-Thick)* is used to represent the outline and visible edges of solids.
2. *Type E or F lines (Dashed- thick or thin)* are used to represent hidden outlines or edges.
3. *Type G lines (chain-thin)* are used to represent the axis, lines of symmetry and trajectories.
4. *Type B line (continuous-thin)* is used for all the remaining portions of the drawing like *xy* line, projectors, dimension lines, leader lines, construction lines, etc. Type B line has the least importance compared to the other types of lines. Hence it maybe broken or removed partially, for the clarity of the drawing.
5. As mentioned in the Chapter 1, when two or more lines of different types coincide, the order of priority should be:

First	Type A (continuous- thick)
Second	Type E or F (short dashes)
Third	Type G (chain-thin)
Fourth	Type K (chain-thin double dashed)
Fifth	Type B (continuous-thin)

Figure 12.8 shows orthographic views of solids in simple position.

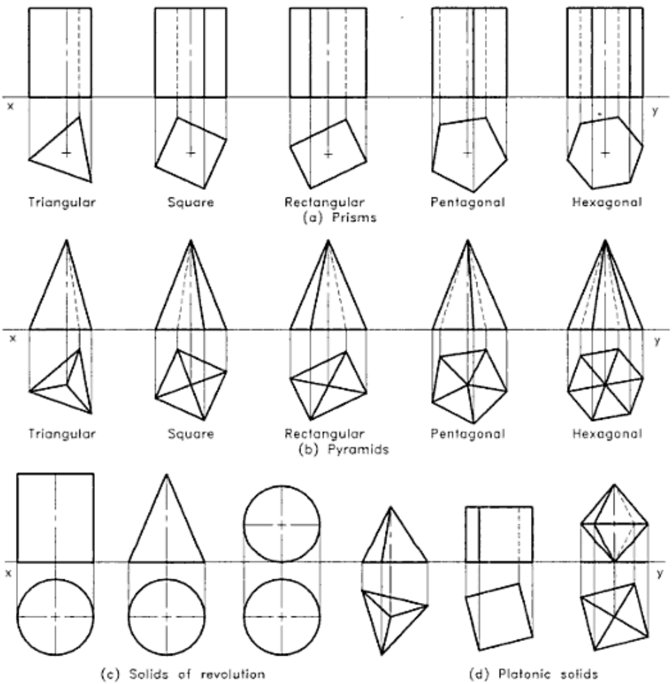


Fig. 12.8 Orthographic views of solids in simple position.

Naming of Corners and Dimensioning

The name of corners and axis of the solid are not usually given in questions. But for drawing purpose, it is a good practice to name them systematically. In this text book, the first set of names for corners is given as ABCD, etc. and the second set is given as QRST, etc. These names are given clockwise only for uniformity. The axis is named OP giving O for apex or top end.

The given dimensions should be marked in the views. For this, the view showing the true shape has to be selected. Usually the dimensions of the solid are marked in first set (views in simple position) and the inclinations are shown at the point of its application.

Identification of Hidden Edges

While drawing the views of solids, generally some of the edges are not visible in a view of a solid. These hidden edges will be behind the visible portion and are represented by short dashes.

1. In a view, the outermost lines will be always visible and they form a closed figure of lines or curves i.e. short dashes will not come as outlines but they will be inside only.
2. If a solid has two parallel faces and if one of them is visible, the other parallel face will be hidden.
3. For cones and pyramids, if the apex is pointing to the observer, the base will be hidden.
4. In a projected view, if two lines representing the edges of a solid cross each other, one of the lines will be hidden either completely or partly.

While viewing a solid, the edges or faces nearby the observer are always visible but the edges or faces behind the solid are hidden. To identify these edges, the orthographic views may be reviewed from top and front sides as shown in Fig. 12.7(b).

12.4 SOLIDS IN SIMPLE POSITION

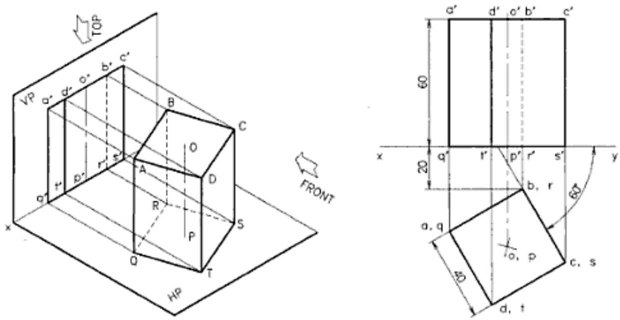
If a solid is placed in the first quadrant with its axis perpendicular to HP, VP or PP, the position of the solid is considered as in simple position, since the true shape of base and true length of axis are seen in the views. Normally, one set of views will be sufficient to get the answer. The views showing the true shape of the base is drawn first and then projected to the other planes to get the related views. If the axis of the solid is parallel to HP and VP, the true shape of the base is obtained in the end view on PP.

Example 12.1

A square prism of 40 mm side and 60 mm height is resting on HP with one of its rectangular faces inclined at 60° to VP. If the nearest vertical edge is 20 mm in front of VP, draw its projections.

Refer to Fig. 12.9.

1. Draw the *xy* line. Construct a square of 40 mm side with one side 60° inclined to and the nearest edge 20 mm away from the *xy* line, as the top view of the prism.
2. Mark the axis position by drawing a cross mark in the direction of the diagonals of the square. Then name the top face corners as *abcd*, the base corners as *qrst* and axis as *op*.



(a) Pictorial view (b) Orthographic views

Fig. 12.9 Projections of a square prism (axis perpendicular to HP).

3. Draw vertical projectors up to 60 mm height above the *xy* line to represent the front view. Name the corners corresponding to the names given in the top view. Finish the outline of the elevation using thick lines. The edge *dt* is visible in the front view, hence convert *d′t′* to continuous thick line, while the edge br is hidden, and so convert *b′r′* to short dashes. Draw the axis *o′p′* using chain line.
4. Finish the view and print the given dimensions to complete the projections.

Example 12.2

A pentagonal pyramid of 30 mm side and axis 60 mm long is resting upon its base on HP such that one of the base edges is perpendicular to VP. If the axis of the pyramid is parallel to and 40 mm away from VP, draw its projections.

Refer to Fig. 12.10.

1. Draw a vertical line *ab* of 30 mm length and construct a pentagon on it by any method (54° and a circle method is preferred). Mark the corners as *abcde* and join them to the centre *op*, to complete the top view.
2. Draw the *xy* line at 50 mm distance from *op* and project from all the points of the top view to get the points *a′*, *b′*, *c′*, *d′*, *e′*, and *p′* on the *xy* line.
3. Extend the *pp′* line to *o′* so that *o′p′* = 60 mm, to represent the axis of the pyramid. Join the points *a′*, *d′* and *e′* to *o′*, to complete the front view. It is to be noted that hidden edges *b′o′* and *c′o′* are coinciding with the visible edges.
4. Finish the view, name the corners and print the given dimensions to complete the drawing.

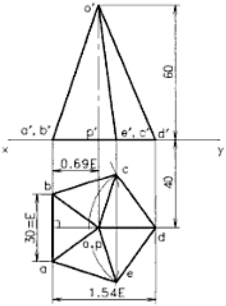


Fig. 12.10 Projections of a pyramid (axis perpendicular to HP).

Example 12.3

A hexagonal pyramid of base side 26 mm and height 64 mm is placed on VP, such that the axis is perpendicular to and the vertex is touching the VP at a height of 40 mm from HP. Draw its projections, if one edge of the base is making 15° to HP.

Refer to Fig. 12.11.

1. Draw *xy* line and locate the front view of the axis *o′p′* at 40 mm height from it.
2. Draw a circle of 26 mm radius at *o′p′* mark the diameter *b′e′* through that point at an angle of 15° to horizontal. Construct a regular hexagon of side 26 mm on that diameter.
3. Name the corners and drop projectors downwards. Complete the top view keeping the vertex *o* on *xy* line.
4. Draw the hidden edges using short dashes and the axis using chain line as shown in figure.
5. Finish the view, name all the corner points and print the given dimensions.

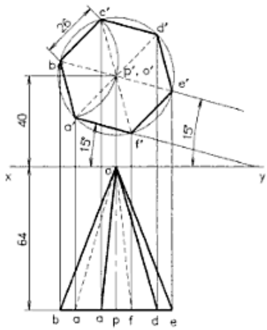


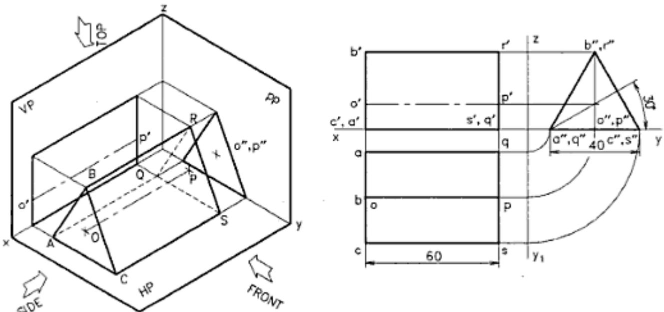
Fig. 12.11 Projections of a pyramid (axis perpendicular to VP).

Example 12.4

An equilateral triangular prism of side 40 mm and length 60 mm has its axis parallel to both HP and VP. Draw its front view, top view and side view on profile plane.

Refer to Fig. 12.12.

1. Draw the *xy* line horizontally and y_1z vertically as shown in the figure.
2. Since the prism is parallel to HP and VP, the true shape of the prism is obtained in the profile plane *pp*. Hence, draw an equilateral triangle of 40 mm side as the end view and mark its centre *o″p″* for the axis position.



(a) Pictorial view (b) Orthographic views

Fig. 12.12 Projections of a triangular prism (axis perpendicular to PP).

3. Project from the end view to get the elevation and plan of the prism as given in figure.
4. Mark the axis in the two views and name the corners.
5. Finish the drawing and enter the given dimensions.

Example 12.5

A frustum of a cone of base diameter 50 mm, top diameter 30 mm and height 44 mm, is placed in the first quadrant such that its axis is parallel to both HP and VP. If the axis is 35 mm above HP, and the base is on the right hand side of the observer, draw its projections.

Refer to Fig. 12.13.

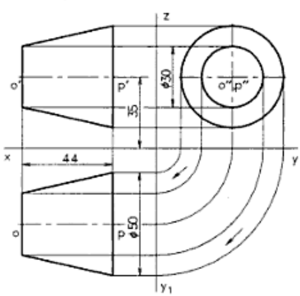


Fig. 12.13 Frustum of a cone.

1. Draw the xy and y_1z lines. Construct two concentric circles of diameters 50 mm and 30 mm at a height of 35 mm to represent the end view of the frustum of the cone as shown in Fig. 12.13.
2. Project from the end view and draw the top and front views.
3. Mark the axis using chain lines, finish the drawing and print the given dimensions.

12.5 AXIS INCLINED TO ONE OF THE REFERENCE PLANES

The drawing of orthographic views of solids with the axis inclined to one of the reference planes and parallel to the other, is similar to that explained for plane figures in Chapter 11. Here, the height of the solid (the third dimension) is also considered. Figure 12.14 gives the views of a square pyramid resting on one of its base edges with the axis inclined to HP.

As explained in the projection of plane figures, the solid is initially kept in simple position, suitable to get the required tilted position, and the first set of views is drawn. In the given example, the solid has to be tilted about a base edge, hence that edge is placed perpendicular to the xy line (may be called as the line for *tilting* LT). Then the front view is tilted and drawn. Project vertically from the new front view and horizontally from the previous top view to get the points of intersection for the required top view. This method of projection may be termed as *change of position method*. The second set of views gives the required projections.

Example 12.6

A square pyramid of 50 mm base and 70 mm height is resting on one of its base edges on HP. If the axis is parallel to VP and inclined 45° to HP, draw its projections.

Refer to Fig. 12.14.

1. Draw the *xy* line and construct a square of 50 mm at a convenient distance from it to get the top view. Here the base edge *cd* is kept perpendicular to *xy* line and it is used as the line for tilting LT.
2. Project upwards from the top view and complete the front view as the 2nd.
3. Copy the front view keeping the edge *c′d′* on *xy* line and the base making 45° so that, the axis is inclined 45° to HP. This is the 3rd view.
4. Project vertically downwards from the 3rd view and horizontally from the 1st view to get the intersection points of the 4th view.
5. Convert the outermost lines and the edges representing the top triangular surface into visible edges. But the crossing line *c′d′*, which is below, is converted as hidden edge.
6. Finish the views, name all the corners and print the given dimensions to complete the drawing.

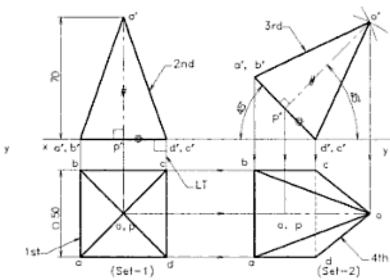


Fig. 12.14 Square pyramid (axis inclined to HP).

Example 12.7

A hexagonal prism of base side 26 mm and height 60 mm rests with one of its rectangular faces on HP. If the axis is inclined at 30° to VP, draw its projections.

Refer to Fig. 12.15.

1. Draw the *xy* line. Place the prism in the simple horizontal position keeping one rectangular face on HP. The final required inclined position is obtained by tilting the solid about the line for tilt LT. Draw the front view and then the top view as the 2nd.

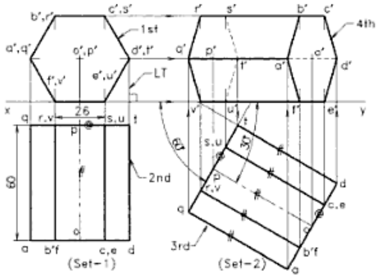


Fig. 12.15 Drawing board with minidrafter clamped

2. Copy the top view after rotating, so that the axis makes 30° with VP. This is the 3rd view.
3. Project upwards from the 3rd view and project horizontally from the 1st view, so that their intersection points give the final 4th view.
4. Convert the outermost edges of 4th view to thick lines. Look to the top view (3rd) from the front side and identify the visible face *abcde*. Convert this face as visible one in the elevation (4th), while the parallel face as hidden. Also note that in the view, the line *t′d′* is representing a hidden edge. Since the visible edge *q′a′* is coinciding with the hidden edge from *t′* to *a′*, only the line *a′d′* is to be drawn in short dashes.
5. Finish the views, name all the corners and print the given dimensions to complete the drawing.

Example 12.8

A regular pentagonal pyramid has an altitude of 60 mm and base side 30 mm. The pyramid rests with one of its sides of the base on HP such that the triangular face containing that side is perpendicular to both HP and VP. Draw its projections.

Refer to Fig. 12.16.

1. Since one of the triangular slant surfaces of the pyramid is to be perpendicular to HP, the pyramid has to be kept initially in simple vertical position, and one of the base edges *cd* perpendicular to VP. Draw the top and front views.
2. Redraw the front view, keeping the face *o′d′c′* perpendicular to *xy* line. For this, first draw the line

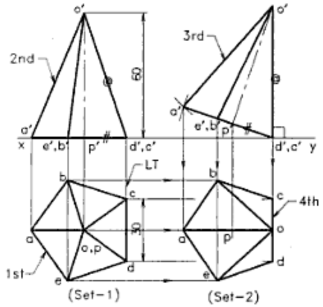


Fig. 12.16 Pentagonal pyramid (slant furface perpendicular to HP).

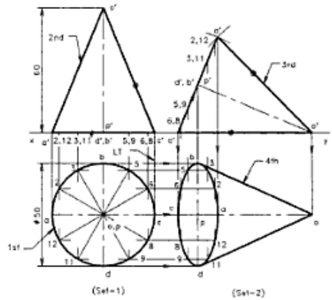


Fig. 12.17 Cone (A generator on HP).

o'd', perpendicular to *xy* and construct the triangle *a'd'o'* on that line. Then complete the 3rd view.

3. Project horizontally from the first view and vertically from 3rd view so that the intersections of the lines locate the corners of the 4th view. It is to be noted that, the triangular face odc is perpendicular to both HP and VP.
4. Finish the view, name the corners and print the given dimensions.

Example 12.9

A cone of base 50 mm diameter and axis 60 mm long has one of its generators on HP. If the axis is parallel to VP, draw its projections.

Refer to Fig. 12.17

1. Draw the projections of the cone, keeping the base on HP.
2. Divide the top view, which is a circle, radially into 12 equal parts and mark its diameter as *ac* and *bd* in top view and in front view.
3. Copy the front view, so that the generator *o'c'* is on the *xy* line. For this, mark the distance *o'c'* on *xy* line and construct the triangle *a'o'c'* on it. Draw the axis *o'p'* and mark the generators on the 3rd view.
4. Project horizontally from the first view and vertically from the 3rd view, to get the various points of the 4th view. Here, the circular base is seen as an ellipse. Draw the ellipse by joining the points using french curves or by freehand drawing. Then draw two tangents from the apex *o* to the ellipse to represent the outermost generators. It is to be noted that, in this position all the edges are visible in all the views.
5. Finish the drawing and print the given dimensions.

Example 12.10

A cylindrical disc of 60 mm diameter and 40 mm length is resting upon one of its generators on HP. If the axis of the cylinder makes 60° to VP, draw its projections.

Refer to Fig. 12.18.

1. Draw front and top views of the cylinder, keeping one of the generators on HP and the axis perpendicular to VP.
2. Divide the front view, which is a circle, radially into 12 equal parts and name them clockwise. Also name the horizontal and vertical diameters as *a'c'*, *g'd'*, *q's'*, etc. in front view and the same in top view.
3. Copy the top view and generators after rotating it, so that the axis makes 60° with the xy line.
4. Project horizontally from the first front view and vertically from the 3rd view, so that the points of intersection of lines form the 4th view.
5. In the 4th view the front face *abcd* of the disc is visible ellipse, while the rear face *qrst* is hidden. The edge *t'q'r'* is visible because it is the outermost edge, but the edge *r's't'* is hidden, hence it should be represented by short dashes. Join the points by drawing smooth curves either using suitable french curves or freehand.
6. Finish the view, name the corners and print the dimensions.

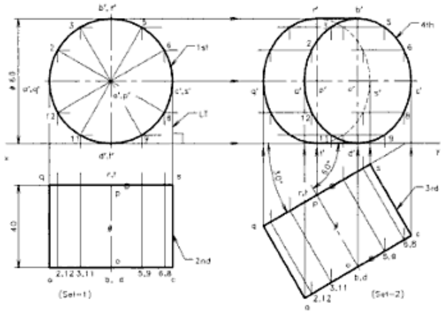


Fig. 12.18 Cylindrical disc (axis inclined to VP).

Example 12.11

A triangular pyramid of base side 40 mm and axis 56 mm long is freely suspended from one of the corners of its base. Draw its projections, if the axis is parallel to VP.

Refer to Fig. 12.19.

1. Draw the top and front views of the pyramid, keeping the base on HP and one of the base edges (say *bc*) perpendicular to the *xy* line. This position brings the line joining the point of suspension and the centre of gravity *ag* parallel to VP.

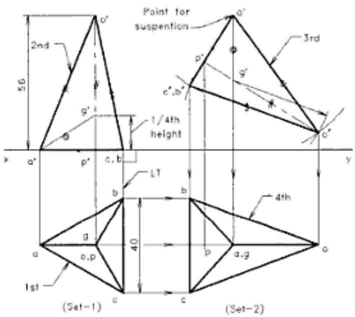


Fig. 12.19 Suspended triangular pyramid (axis inclined to HP).

2. For all pyramids and cones the centre of gravity is located at 1/4 th the height from the base. Therefore mark the centre of gravity of the solid in the front view as g'.
3. Join the corner a' to g'. If the pyramid is suspended from the corner a', the line $a'g'$ will be perpendicular to the *xy* line in the front view. Hence, copy the first front view, keeping the line $a'g'$ vertical. For this, draw a line perpendicular to *xy* and mark the distance $a'g'$ on it. Construct the triangle $a'o'g'$ on that line and then the triangle $a'o'b'$, to complete the 3rd view.
4. Project horizontally from the first top view and vertically from the 3rd view, to get the points of the 4th view. Here, all the edges are visible.
5. Finish the view, name the corners and print the dimensions.

Example 12.12

A frustum of a square pyramid of base side 32 mm, top side 16 mm and height 40 mm is resting on one of its base corners, such that the base is 45° inclined to HP. Draw the projections.

Refer to Fig. 12.20.

1. Since the base edges are to be at equal inclinations to HP, the solid has to be kept initially in the simple position, so that the sides are at equal inclinations to the projector cc' (LT). Draw the top view and then the front view.
2. Copy the front view after tilting the view about the corner c' so that the base makes 45° inclination with

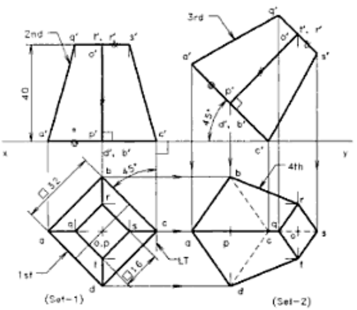


Fig. 12.20 Frustum of a pyramid (axis inclined to HP).

the xy line. This can be done by drawing $c'o'$ at 45° and copying the front view on it.

3. Project horizontally from the first top view and vertically from the 3rd view to get the points of intersection which represents the corners of the 4th view.
4. Identify the hidden lines and join the edges with proper lines.
5. Finish the view, name the corners and print the given dimensions.

12.6 AXIS INCLINED TO BOTH THE REFERENCE PLANES

When the axis of a solid is inclined to both the reference planes, its projected views are usually obtained in three stages of projection, following the *change of position method*. This is an extension of the procedure followed in the previous sections. The three sets of views to be completed are:

Set-1 The axis of the object is kept in simple position (i.e. perpendicular to one of the reference planes), suitable to reach the final required position, and the first set of views (1st and 2nd) are drawn.

Set-2 The object is tilted to bring the axis inclined one of the reference planes and parallel to the other. Then the second set of views (3rd and 4th) are drawn.

Set-3 The object is further tilted to bring the axis inclined to both the reference planes. The third set of views (5th and 6th) are drawn now to get the answer.

The change of position method is similar to the one explained in projections of plane figures. Here, a total of six views are generally drawn to satisfy the required conditions. Figure 12.21 gives the projections of a square pyramid with axis inclined to both the reference planes. If the direction of inclination is not specified in the question, the tilting of the solid can be in the opposite direction also. Similarly, the apex of the pyramid may be directing towards or away from the VP. This will result in three more different solutions. Figure 12.22 shows these three possible (Set-3) solutions. It is to be noted that, as the direction of tilting is different for the

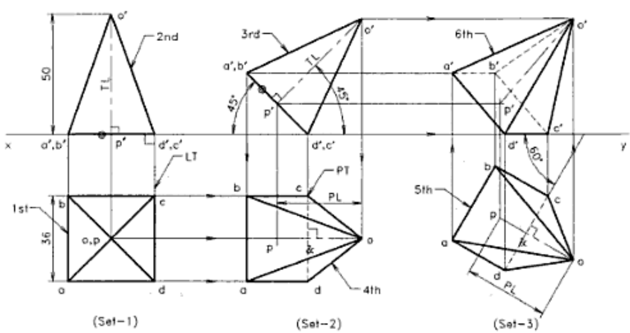
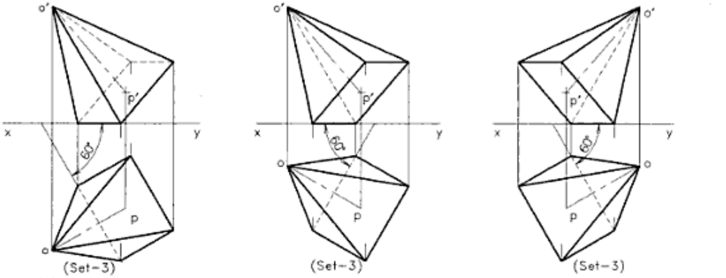


Fig. 12.21 A square pyramid (axis in oblique position–apex pointing towards right and away from VP).



(a) Apex pointing towards left and away from VP (b) Apex pointing towards left and nearer to VP (c) Apex pointing towards right and nearer to VP

Fig. 12.22 A square pyramid—the three different solutions.

same angle of inclination, the visible and hidden edges are interchanged. The following examples explain the procedure of drawing various solids in oblique positions.

Example 12.13

A square pyramid has its axis inclined at 45° to HP and one edge of its base is inclined at 60° to VP. If the length of the edge of its base is 36 mm and the height is 50 mm, draw the projections of the object, keeping one of the edges of its base on HP.

Refer to Fig. 12.21.

1. Draw the projections of the pyramid, keeping the base on HP and one of the base edges (LT) perpendicular to VP.
2. Copy the front view after tilting the axis by 45° to the *xy* line. Project horizontally from the top (1st) view and vertically from the second front (3rd) view to get the second top (4th) view.
3. Produce the second top view, keeping the edge *cd* inclined at 60° to the *xy* line (turn the top view about point c, the point of turning PT) to get the third top (5th) view. Project horizontally from the second front view (4th) and vertically from all the points on the third top view (5th) to locate the corners of the third front (6th) view.
4. Join the points of intersection using continuous thick lines for visible edges and short dashes for hidden edges. The method for identification of visible and hidden edges are the same as that explained in article 12.3 of this chapter.
5. Finish the three sets of views, name the corners and print the given dimensions.

Figure 12.22 gives three more solutions (final set of views) to the same question. Note that the hidden edges are changed as the direction of inclination changes. It can be identified by looking from the front side of the top view. As the apex points the observer the base cannot be seen.

Example 12.14

A square prism of base side 30 mm and height 50 mm has its axis inclined at 35° to VP and has a base edge on VP, inclined at 45° to HP. Draw its projections.

Refer to Fig. 12.23.

1. Draw the projections of the square prism, keeping the axis perpendicular to VP and one edge of base on VP, perpendicular to *xy* line (LT).
2. Copy the top view (2nd), after tilting the axis to make 35° to the *xy* line. The edge st of the base is placed on VP. Project horizontally from the front (1st) view and vertically from the second top (3rd) view to get the second front (4th) view.
3. Reproduce the second front (4th) view, keeping the edge *s't'* inclined at 45° to the *xy* line, to get the third front (5th) view. Project horizontally from the second top (3rd) view and vertically from the third front (5th) view, to get the third top (6th) view.
4. Join the points of intersection using continuous thick lines for visible edges and short dashes for hidden edges as explained in Section 12.3.
5. Finish the three sets of views, name the corners and print the given dimensions.

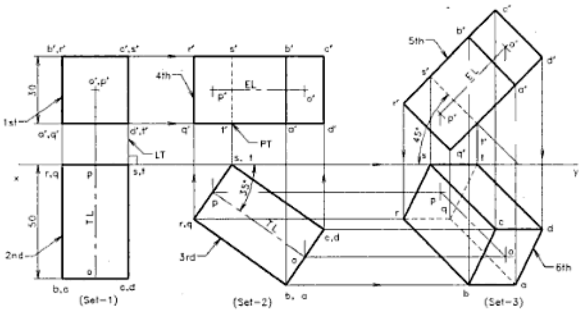


Fig. 12.23 A square prism (axis in oblique position).

Example 12.15

A cone, of base diameter 50 mm and 60 mm height, has one of its generators on HP. If the axis of the cone is seen as 45° inclined to *xy* line in the top view and the apex is nearer to VP, draw the projections of the cone.

Refer to Fig. 12.24.

1. Keeping the base on HP, draw the projections of the cone in simple position. Divide the base circle radially into 12 equal parts and name these generators as given in figure.
2. Copy the front (2nd) view, keeping the generator *o′c′* on the *xy* line. Project horizontally from the top view and vertically from the second front view to get the second top (4th) view as explained in Example 12.9.
3. Reproduce the second top (4th) view, so that the axis of the view is 45° inclined to the *xy* line and the apex is nearer to it. Here, the ellipse has to be copied by measuring and marking the major and minor axes as well as the intermediate line lengths

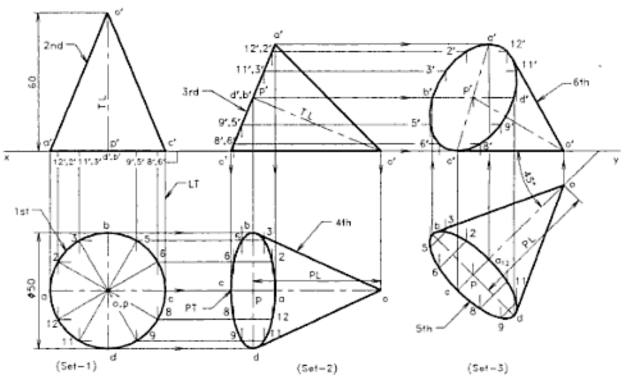


Fig. 12.24 A cone (axis in oblique position).

connecting the 12 points perpendicular to the major axis. This gives the third top (5th) view.

4. Project horizontally from the second top (3rd) view and vertically from the third top (5th) view to form the third front (6th) view. It is to be noted that for cones, the outer most generator has to be drawn in all these views. To obtain the outermost generators, draw tangents from the apex to the ellipse, which represents the base of the cone.
5. Finish the three sets of views, name the points and print the given dimensions.

Example 12.16

Draw projections of a pentagonal pyramid 30 mm side and axis 60 mm long, when it is resting on one of its base edges with

(a) the axis making an angle of 30° with HP and the top view of the axis making 45° with VP, and

(b) the axis making an angle of 30° with HP and 45° with VP.

Refer to Fig. 12.25.

1. Here, the first two sets of views are the same for the two given (a and b) conditions. Therefore, draw the first set of projections of the pyramid, keeping the base on HP and one of the base edges (LT) perpendicular to VP.
2. Copy the front view keeping the axis inclined at 30° to the *xy* line. Project horizontally from the top view and vertically from the second front view to get the second top view.

Solution to (a) part

3. As per the given conditions in part (a), the axis of the top view makes 45° to the *xy* line. This means the angle given is the apparent angle β and equal to 45°. Hence, reproduce the second top view keeping the axis of the view 45° inclined to the *xy* line, to get the third top view. Project horizontally from the second front view and vertically from the third top view to get the third front view.

Solution to (b) part

4. In this part the angle of inclination of the axis is 45° with VP. This means the given angle is the true inclination ϕ and not the apparent angle. Hence to proceed, the apparent angle β (the angle seen in the projection, which is always larger than the true angle), has to be determined graphically. To find the apparent angle β, do the geometrical construction near by the view. Draw a line po_1 = the true length TL of the axis, at the true angle 45° to VP and mark the locus line *vv* parallel to *xy* line, passing through o_1. With centre *p*, cut an arc of

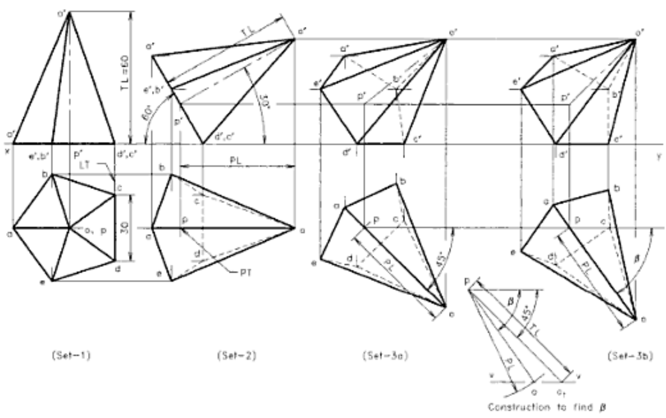


Fig. 12.25 A pentagonal pyramid (axis inclined to both the reference planes).

radius equal to the plan length PL of the axis (*op* of the second top view) on the locus line *vv*. The inclination of line *po* gives the angle β to the horizontal.

5. Reproduce the second top view at this angle β to the *xy* line in order to get the fourth top view.
6. Project horizontally from the second front view and vertically from the fourth top view, to get the fourth front view. This set of views is marked as Set-3b. It is to be noted that the third and fourth front views are almost similar but not exactly the same.
7. Finish the four sets of views with proper lines and print the given dimensions.

While solving a problem of solid in oblique position, the student has to identify from the question, whether the given second angle of inclination is the true angle or the apparent angle. If it is the true angle the apparent angle has to be determined.

Example 12.17

A square pyramid of base side 32 mm, axis 56 mm long, is suspended freely from one of the corners of its base. If a vertical plane containing the axis is seen 60° inclined to the *xy* line in the top view, draw the projections of the suspended pyramid.

Refer to Fig. 12.26.

1. Draw the projections of the square pyramid keeping the base on HP. Let the point of suspension is the corner *a* of the base on left side. The centre of gravity *g* of the pyramid is on the axis at 1/4th height from the base. The line joining *a* and *g* in the first top view should be kept parallel to the *xy* line initially. Hence, place the base edges of square pyramid equally inclined (45°) to the line for tilting LT.
2. Draw the first front view and mark the centre of gravity *g′* of the pyramid at 1/4th height from the base. Join *a′* to *g′*. If the solid is suspended from corner *a′*, the line *a′g′* will be seen perpendicular to the *xy* line in the second front view. Hence, copy the first front view, keeping the line *a′g′* vertical. The copy can be made on *a′g*; by considering the view as a combination of triangles as explained in Example 12.11.
3. Project horizontally from the top view and vertically from the second front view to get the second top view.

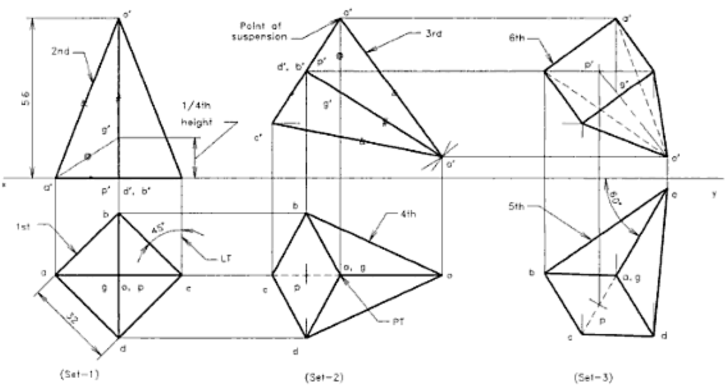


Fig. 12.26 A suspended square pyramid.

4. Since the axis is lying in a vertical plane, inclined at 60° to VP, the apparent angle of the axis to the *xy* line also 60°. So, redraw the second top view, keeping the axis inclined at 60° to the *xy* line, to get the third top view.
5. Project horizontally from the second front view and vertically from the third top view, to get the third front view.
6. Finish the views, name the corners and print the given dimensions.

Example 12.18

Draw front, top and side views of a square pyramid of base side 34 mm and axis 40 mm long such that the axis is inclined 40° to VP and 50° to HP. One base edge is on HP and the apex of the pyramid is kept near by VP than the base.

Refer to Fig. 12.27.

1. The total of the true inclinations of the axis (40 + 50) is 90. That means the axis is parallel to PP and hence the true angles and TL will be seen in the side view. If the usual procedure is followed, first draw the plan and elevation of the pyramid in simple position keeping one base edge perpendicular VP.
2. Tilt solid to 50° in the elevation and get the second top view by projecting downwards.
3. Copy this second plan (4th) after turning 90° anticlockwise about PT. Project upwards from the third plan (5th) and draw horizontal lines from the second elevation to get the third (6th) front view.
4. Now the pyramid is in the required position. Draw zy_1 line perpendicular to xy line and get the side view on the profile plane as shown in the figure.
5. Finish the views and print the given dimensions.

If the student can visualise the position of the pyramid in the side view without confusion, that view (7th) can be drawn directly on PP using the given true angles and lengths. Then the required elevation and plan can be obtained by projecting backwards to VP and HP. Thus the solution is completed in three views instead of seven.

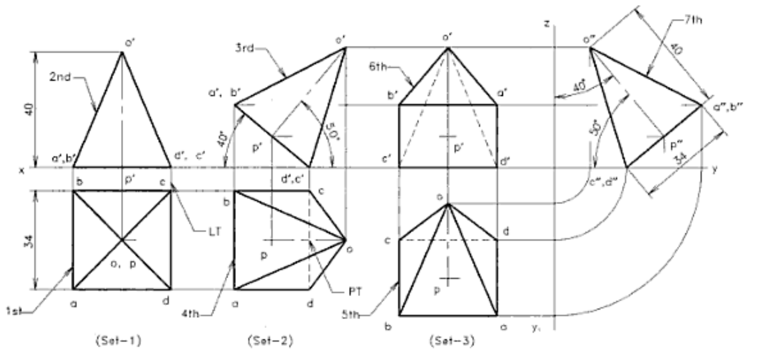


Fig. 12.27 Three views of a square pyramid in oblique position.

EXERCISES

(# Problems similar to the worked-out examples)

Solids in simple position

1. A square prism of 50 mm side and 70 mm height is resting on HP with one of its rectangular faces inclined at 65° to VP. If the nearest vertical edge is 25 mm in front of VP, draw its projections. (#)
2. A pentagonal pyramid of 40 mm side and axis 75 mm long is resting upon its base on HP such that one of the

base edges is perpendicular to VP. If the axis of the pyramid is parallel to and 60 mm away from VP, draw its projections. (#)

3. A hexagonal pyramid of base side 30 mm and height 70 mm is placed on VP, such that the axis is perpendicular to and the vertex is touching the VP at a height of 50 mm from HP. Draw its projections, if one edge of the base is making 10° to HP. (#)
4. An equilateral triangular prism of side 45 mm and length 70 mm has its axis parallel to both HP and VP. Draw its front view, top view and side view on profile plane. (#)
5. A frustum of a cone of base diameter 46 mm, top diameter 26 mm and height 40 mm, is placed in the first quadrant such that its axis is parallel to both HP and VP. If the axis is 36 mm above HP, and the base is on the right hand side of the observer, draw its projections. (#)
6. A frustum of a square pyramid of base side 40 mm, 25 mm top side and height 50 mm is placed in the first quadrant such that its axis is parallel to both the reference planes. If the axis is 36 mm above HP, and the base is on the right hand side of the observer, keeping the base edges at equal inclination to VP, draw the projections.

Axis inclined to one of the reference planes

7. A square pyramid of 40 mm base and 60 mm height is resting on one of its base edges on HP. If the axis is parallel to VP and inclined 30° to HP, draw its projections. (#)
8. A pentagonal prism of base side 30 mm and height 70 mm rests with one of its rectangular faces on HP. If the axis is inclined at 30° to VP, draw its projections. (#)
9. A regular hexagonal pyramid has an altitude of 60 mm and base side 26 mm. The pyramid rests with one of its sides of the base on HP such that the triangular face containing that side is perpendicular to both HP and VP. Draw its projections. (#)
10. A cone of base 60 mm diameter and axis 70 mm long has one of its generators on HP. If the axis is parallel to VP, draw its projections. (#)
11. A cylindrical disc of 64 mm diameter and 40 mm length is resting upon one of its generators on HP. If the axis of the cylinder makes 45° to VP, draw its projections. (#)
12. A triangular pyramid of base side 50 mm and axis 60 mm long is freely suspended from one of the corners of its base. Draw its projections, if the axis is parallel to VP. (#)
13. A frustum of a square pyramid of base side 40 mm, top side 20 mm and height 50 mm is resting on one of its base corners, such that the base is 30° inclined to HP. Draw the projections. (#)
14. A cone of base 50 mm diameter and axis 60 mm long has one of its generators on VP. If the axis is parallel to HP, and pointing left side, draw its projections.
15. A pentagonal prism of base side 30 mm and axis 60 mm long is freely suspended from one of the corners of its base. Draw its projections, if the axis is parallel to VP.

Axis inclined to both the reference planes

16. A square pyramid has its axis inclined at 30° to HP and one edge of its base is inclined at 45° to VP. If the length of the edge of its base is 40 mm and the height is 60 mm, draw the projections of the object, keeping one edge of its base on HP. (#)
17. A triangular prism of base side 40 mm and height 50 mm has its axis inclined at 40° to VP and has a base edge on VP, inclined at 50° to HP. Draw its projections. (#)
18. A cone, of base diameter 52 mm and 64 mm height, has one of its generators on HP. If the axis of the cone is seen as 30° inclined to *xy* line in the top view and the base is nearer to VP, draw the projections of the cone. (#)
19. Draw projections of a hexagonal pyramid 26 mm side and axis 60 mm long, when it is resting on one of its base edges with,
    (a) the axis making an angle of 35° with HP and the top view of the axis making 40° with VP, and
    (b) the axis making an angle of 35° with HP and 40° with VP. (#)
20. A square pyramid of base side 36 mm, axis 60 mm long, is suspended freely from one of the corners of its base. If a vertical plane containing the axis is seen 50° inclined to the *xy* line in the top view, draw the projections of the suspended pyramid keeping the apex away from VP than its base. (#)
21. Draw front, top and side views of a pentagonal pyramid of base side 30 mm and axis 50 mm long such that the axis is inclined 35° to VP and 55° to HP. One base edge is on HP and the apex of the pyramid is kept nearby VP than the base. (#)

CHAPTER 13

Sections of Solids

The internal details of an object can be made visible by cutting the object using an imaginary plane and removing that portion of the object which is between the imaginary plane and the observer. This imaginary plane is called *cutting plane or section plane*. The surface seen on the object, while cutting it by the section plane, is called the *section*. The projection of the sectioned surface, along with the remaining portion of the object, on to the reference plane is called *sectional view*. Very often, the term section is used to mention a sectional view.

13.1 REPRESENTATION OF THE SECTION PLANE AND THE SURFACE FORMED BY CUTTING

Section plane or cutting plane is an imaginary plane used to cut the solid, so that by removing a portion of the solid the shape of the cut surface as well as the hidden details are exposed. Figure 13.1(a) shows the pictorial view of a pyramid, cut by a section plane parallel to HP. The portion between the cutting plane and the observer is assumed to be removed for the sectional view. This shows the cut surface, which is represented by section lines. Orthographic views of the pyramid are shown in Fig.13.1(b). Here the top view is the sectional view of the pyramid. It is to be noted that the front view is not affected by the section. Only the trace of the section plane is to be marked over it.

A section plane is represented by its trace, drawn in thin chain lines thickened at ends (type H lines). The direction of viewing is shown by arrows and designated by capital letters. Figure 13.2 shows the representation of the traces of section planes. When several cutting planes are joined together to bring out the section details at different angles or different offset layers, then the plane is represented by thin chain line, thickened at the ends and at the changes of direction.

The sectioned surface is indicated by a closed boundary using thick line (Type A line) and is filled with section lines. The section lines are drawn using thin line (Type B line) of equal spacing from boundary to boundary. The spacing can be 1 to 3 mm, depending on the size of the drawing. The preferred angle is 45° (towards left or right) to the reference line (see Fig. 13.3). If the major portion of the boundary of sectioned surface become almost parallel or perpendicular to the section lines, the inclination maybe changed to an angle of 45° to the longitudinal axis of the sectioned surface. The section lines should be interrupted at the places of text. The process of drawing section lines is called *hatching*.

13.2 TRUE AND APPARENT SHAPES OF SECTION

If a solid is sectioned by a plane and it is projected to a plane parallel to it, the shape of the section obtained will be exactly

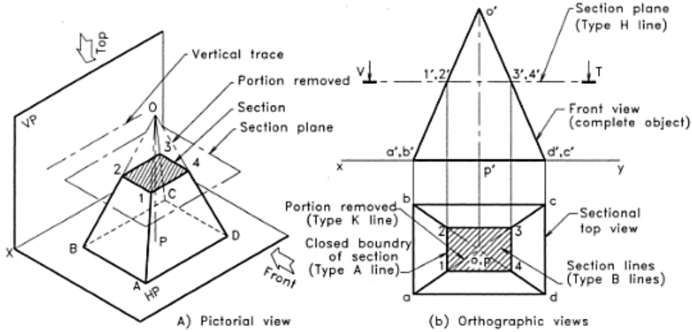


Fig. 13.1 Sectional top view of a pyramid.

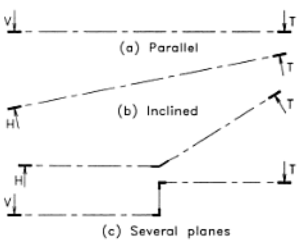


Fig. 13.2 Traces of section planes.

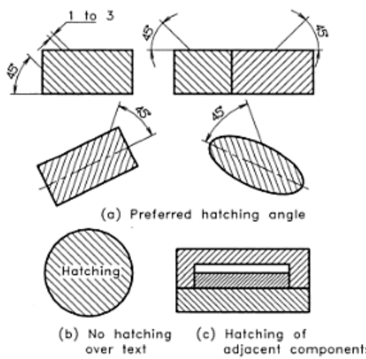


Fig. 13.3 Hatching.

the section exposed by the cutting plane. This shape is called the *true shape of section*. If the cutting plane is inclined to the plane of projection, the shape obtained will not be the true shape. Such a shape is called the *apparent shape of section*. Figure 13.4 gives an example to the true shape of section and apparent shape of section obtained while cutting a cylinder by an inclined cutting plane.

13.3 SUGGESTED PROCEDURE FOR DRAWING A SECTIONAL VIEW

Drawing of sectional views is an extension of projections of solids. Hence, the procedure explained in previous chapters is to be followed here also.

1. Draw the projections of the complete solid in the required position using thin lines.
2. Mark the given section plane (i.e. the trace of the section plane using Type H line) in the appropriate view, so that the other related view can be converted into the required sectional view.
3. Then project from all the points of intersection of the section plane and the view boundaries, to the

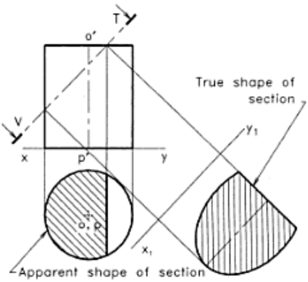


Fig. 13.4 True and apparent shape of section.

other side of the reference line. This gives the points for the boundary of the sectioned surface.

4. Assuming that the portion between the section plane and the observer is removed, complete the drawing of the remaining portion in the sectioned view. Draw the boundary of the sectioned surface and the view of the remaining portion by thick lines.
6. Finish the other view in which the trace of the section plane is marked using proper line types.
7. Print the given dimensions and details.
8. Hatch the sectioned surface using Type B lines at equal spacing of 1 to 3 mm.
9. In a sectional view, if the portion of the solid removed by the section plane is to be shown, it can be represented by Type K line (chain-thin double-dashed).

Notes

The following points have to be considered while drawing the sectional views.

1. The section plane has to be shown using Type H line. The direction of viewing should be marked by two short arrows and the name of trace should be marked as HT or VT.
2. The removal of the portion between the section plane and the observer is applicable only to the sectional view. The other view on which the section plane is marked is not affected by the sectioning.
3. The boundary of the sectioned area should always be thick line and a closed one. There should be no thick continuous line inside the boundary of the sectioned area.
4. A flat surface cut by a plane, gives a straight boundary while a curved surface cut by a plane gives a curved boundary in the sectional view.
5. The sectioned surface is represented by hatching lines of approximately equal spacing (1 to 3 mm). Thin lines are to be drawn from boundary to boundary, preferably at large spacing and inclined at 45° to the reference line.
6. As far as possible, the text inside a sectioned surface should be avoided. In unavoidable situations, the hatching lines are to be drawn without crossing the text.
7. The hatching lines are to be drawn at the end of a drawing, i.e. only after finishing the drawing and printing the text.

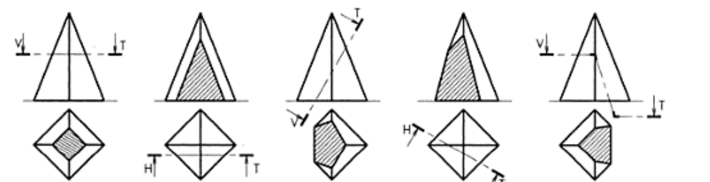


Fig. 13.5 Types of section planes and sectional views.

If a section plane cuts a solid having flat surfaces, the number of straight edges formed by cutting is = the number of points of intersection = the the number of surfaces cut. Also the figure will be a closed one.

13.4 CLASSIFICATION OF SECTION PLANES

A section plane is considered as an imaginary plane perpendicular to one of the reference planes. Hence, the projection of the section plane to which it is perpendicular will be a line representing its trace. Figure 13.5 gives the example for five different types of section planes and the sectional views obtained by cutting a square pyramid.

The classification of the section planes are:

1. Section plane parallel to HP.
2. Section plane parallel to VP.
3. Section plane inclined to HP.
4. Section plane inclined to VP.
5. Combination of several section planes.

13.5 SECTION PLANE PARALLEL TO HP

A section plane parallel to HP and perpendicular to VP gives a sectional top view. As the section plane is parallel to HP, the projection of the section on the HP is of true shape and size. Figure 13.6 gives an example for sectioning a prism lying on HP by a cutting plane parallel to HP.

Example 13.1

A right regular pentagonal prism, side of base 32 mm and height 60 mm, is lying on one of its rectangular faces upon HP, keeping the axis perpendicular to VP. A section plane parallel to HP cuts the solid at a height of 40 mm above the resting surface. Draw the front and sectional top views of the prism.

Refer to Fig. 13.6.

1. Draw the front and top views of the pentagonal prism using thin lines and name the corners.
2. Name the trace VT of the cutting plane at the given height above the *xy*-line in the front view.
3. Name the points of intersection of the cutting plane with the surfaces one by one in the clockwise direction, as 1′, 2′, 3′, and 4′, since the plane cuts four surfaces.
4. Draw projectors from these points to get the corresponding points in the top view. Join 1,2,3, and 4 by thick lines to get the cut surface.
5. Convert the thin lines to the proper line types and print the given dimensions. Hatch the cut surface formed by points 1, 2, 3 and 4 using thin lines (Type B line), drawn at 45° to the *xy* line.

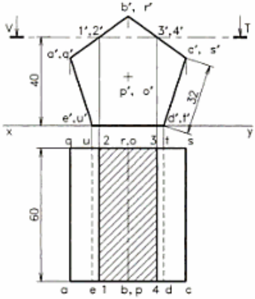


Fig. 13.6 Sectional tap view of a prism (section plane parallel to HP).

13.6 SECTION PLANE PARALLEL TO VP

The method of taking sectional view of a solid by a cutting plane parallel to VP is similar to that when it is parallel to HP. Since the section plane is parallel to VP, the sectional view obtained on VP will be of the true shape and size.

Example 13.2

A right regular triangular pyramid, edge of base 60 mm and height 70 mm, is resting on HP on its base with one edge of its base parallel to and closer to VP. A cutting plane, parallel to and passing through a point 16 mm in front of the top view of the axis, cuts the solid. Draw the sectional front view of the pyramid.

Refer to Fig. 13.7.

1. Draw the top and front views of the pyramid in the given position using thin lines and name the corners.
2. Mark the HT of the section plane on the top view and locate the intersection points 1, 2, and 3 on the three surfaces of the pyramid.
3. Project from 1 and 3 to the front view and mark the points 1′ and 3′ on the base edges. The point 2′ lies on a vertical line in the front view, so the projector from point 2 will not intersect but coinside the edges $o'c'$. In a similar situation, construct the true length line $o'c_1'$ by rotating the top view of the edge oc to oc_1 position and projecting upwards as shown in figure. Then the distance from o to 2 is

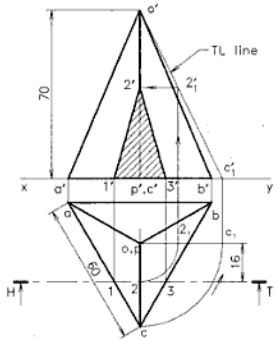


Fig. 13.7 Sectional front view.

transferred to the true length line by drawing an arc and a projector to get the point 2′ on it. A horizontal line drawn through that point intersects the edge $o'c'$ giving the point 2′. Join 1′, 2′, and 3′ by thick lines to get the boundary of the section.

4. Finish the top and front views, print the given dimensions and hatch the sectioned surface to complete the drawing.

13.7 SECTION PLANE INCLINED TO HP

If the cutting plane is inclined to HP and perpendicular to VP, the top view gives the section of the solid.

Example 13.7

A square pyramid of side 50 mm and height 70 mm is kept on HP so that the sides are equally inclined to VP. A cutting plane perpendicular to VP, but inclined 60° to HP cuts and removes the apex portion so that the plane passes through the mid-point of the axis in the front view. Draw front view, sectional top view and the true shape of section.

Refer to Fig. 13.8.

1. Draw the top and front views of the pyramid keeping the square base 45° inclined to VP.
2. Mark the section plane VT in the front view so that it makes 60° to the xy line and passing through the mid point of the axis.
3. Name the points of intersection of cutting plane with edges as 1′, 2′, ... 5′ in order to get a sectional top view marked clockwise. Here, five surfaces are cut hence, five points of intersection are obtained.
4. Project from points 1′, 2′, ... 5′ to the top view and mark the same at the intersection points on the corresponding edges. Join these points by straight lines to get the apparent shape of section.
5. The apparent shape of the section is symmetrical about the line jk drawn through $o'p'$, parallel to xy line. To get the true shape of section, draw a line of symmetry j_1k_1 at any position parallel to the section plane VT and draw projectors from points 1′, 2′, 3′, ... etc., perpendicular to the line j_1k_1 as shown in figure. Measure the distances of points 1, 2, ... 5 from jk line, in the top view and mark them symmetrically along corresponding projectors on both sides about the line j_1k_1. Join the points by straight lines, to get the true shape of section.
6. Finish the views, enter the given dimensions and hatch the apparent as well as the true shape of section by drawing section lines at 45° inclination to the line of symmetry.

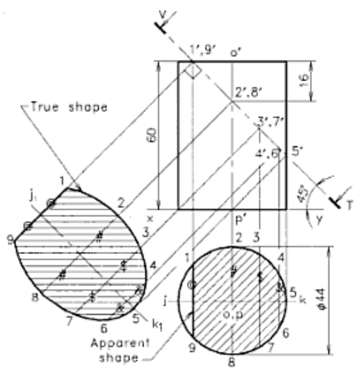


Fig. 13.8 Sectional top view (section plane inclined to HP).

EXERCISES

(# Problem similar to the worked-out examples)

1. A right regular pentagonal prism, side of base 30 mm and height 66 mm, is lying on one of its rectangular faces upon HP, keeping the axis perpendicular to VP. A section plane parallel to HP cuts the solid at a height of 34 mm above the resting surface. Draw the front and sectional top views of the prism. #
2. A pentagonal pyramid, side of base 32 mm and height 65 mm, is resting on HP keeping the axis vertical and an edge of base perpendicular to VP. A horizontal cutting plane cuts the solid at a height of 25 mm from the base. Draw front and sectional top view of the pyramid. #
3. A right regular square pyramid, side of base 55 mm and height 66 mm, lies on one of its triangular faces upon ground such that its axis is parallel to VP. A section plane parallel to HP cuts the axis at its midpoint. Draw its front view and sectional top view. #
4. A pentagonal pyramid, side of base 35 mm and height 66 mm, lies on one of its triangular faces upon ground such that its axis is parallel to VP. A section plane parallel to HP cuts the axis at its midpoint. Draw its front view and sectional top view. #
5. A square pyramid, edge of base 50 mm and height 70 mm, is resting upon HP on its base, keeping the base edges equally inclined to VP. A cutting plane, parallel to VP and passing through a point located 10 mm in front of the top view of the axis, cuts the solid. Draw the sectional front view of the pyramid. #
6. A hexagonal pyramid of 32 mm side and height 66 mm rests on HP keeping one of its base edges parallel to VP. A cutting plane parallel to VP cuts the solid 12 mm in front of the vertical axis. Draw sectional front view and top view of the pyramid. #
7. A pentagonal pyramid of side 36 mm and height 80 mm is kept on HP so that one side is perpendicular to VP. A cutting plane perpendicular to VP, but inclined 65° to HP cuts and removes the apex portion so that the plane passes through the mid point of the axis in the front view. Draw front view, sectional top view and the true shape of section. #
8. A cylinder is resting on its base upon HP. It is cut by a plane inclined at 60° to HP, cutting the axis at a point 20 mm from the top. If the diameter of the cylinder is 50 mm and length is 70 mm, draw the projections of the sectioned cylinder and the true shape of section. #
9. A hexagonal pyramid, base 32 mm side and axis 70 mm long, is lying on one of its triangular faces on the ground with the axis parallel to VP. A vertical section plane, whose HT passes through the mid point of the axis of pyramid in the given position, makes an angle of 25° with the reference line and cuts the pyramid removing a portion of the base. Draw the top view, sectional front view and the true shape of section.

Module D

Drawing of Surfaces

CHAPTER 14

Intersection of Surfaces

The term 'intersection of surfaces' refers to the lines that occur when geometrical surfaces such as planes, cylinders, cones, etc. intersect one another. The line of intersection will be common to the surfaces of the intersecting solids. The line of intersection may be straight or curved, based on the shape of the intersecting surfaces and can be drawn by determining a number of points in order. When a solid penetrates another solid, the line of intersection of the surfaces may be called *lines or curves of intersection.*

14.1 CLASSIFICATION OF INTERSECTING SURFACES

Intersecting surfaces can be classified into three categories:

1. Intersection of two plane surfaces

The intersection of two plane surfaces is a straight line. Prism and prism, prism and pyramid or pyramid and pyramid intersect each other forming straight lines as curves of intersection.

2. Intersection of two curved surfaces

The intersection of two curved surfaces is a curve. Cylinder and cylinder, cone and cone or cylinder and cone intersect each other along in a curve.

3. Intersection of one plane surface and a curved surface

The intersection of a plane surface and a curved surface is a curve. Prism and cylinder, pyramid and cylinder, prism and cone or pyramid and cone intersect each other in a curve.

14.2 METHODS USED TO DRAW THE LINE OF INTERSECTION

The following are the methods used to draw the line of intersection.

1. Line method or piercing point method

In this method a number of straight lines are drawn on one of the solid surfaces and the lines of intersection are drawn.

2. Cutting plane method

In this method, the two solids are assumed to be cut by planes parallel, perpendicular or inclined and the lines of intersection are drawn.

14.3 LINE OF INTERSECTION OF PRISMS

Prisms have only plane surfaces. Therefore, when one prism penetrates another prism, the intersection of surfaces results in straight lines only. Each intersection line starts and ends at points where edges of one prism meet a plane surface or edges of another prism. Also the intersection lines form a closed polygon.

Example 14.1

A square prism, base 50 mm side and 80 mm long, is resting vertically on HP. It is penetrated by a triangular prism of 44 mm side and 100 mm length, so that their axes intersect each other at right angles. If the faces of the square prism are equally inclined to VP and one of the rectangular faces of the triangular prism is paralleled to HP, draw the projections of the solids showing the lines of intersection.

Refer to Fig. 14.1.

1. Draw the top, front and side views of the vertical square prism, with sides 45° to VP. Name the corners p, q, r and s as sown in figure. Also draw the side, front and top views of the triangular prism keeping its axis horizontal and intersecting the axis of the square prism at the centre. For this, locate the centre h'' at the middle of axis of the side view, construct 60° lines and draw the horizontal base of equilateral triangle. Complete the side view and then the other two views overlapping the vertical prism.
2. Here the two solids have plane surfaces to intersect and their axes are meeting at the centre. Hence, the lines of intersection are straight lines and they form two closed straight line figures symmetrical about the vertical axis in the front and top views. The left side points of intersection may be called a_1, a_2, etc. and the right side b_1, b_2, etc. In the side view, they are coinciding, so only $a_1, a_2, \ldots$, are marked. The number of intersecting plane surfaces of the prisms in the given position are four, so there are four points of intersection and hence, four straight lines. The points may be named clockwise as a_1'', a_2'', a_3'' and a_4''.
3. In the top view the three edges of the triangular prism intersect on the left faces of square prism at four points a_1, a_2, a_3, and a_4. Similarly, on the right

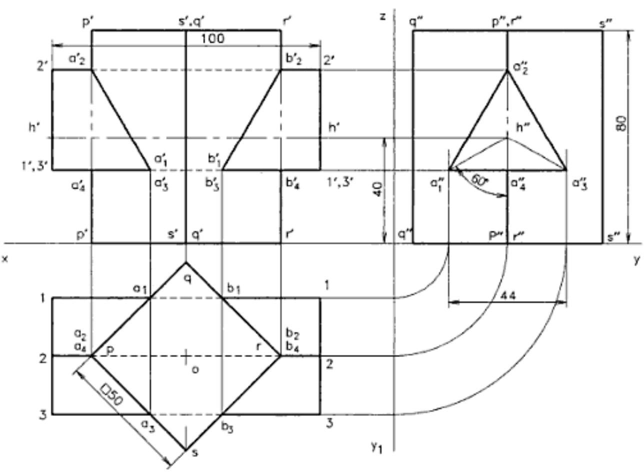


Fig. 14.1 Intersection of prism in prism.

faces, the four points of intersection are b_1, b_2, b_3 and b_4. Convert the edges of the triangular prism coming inside the square prism as hidden lines.

4. Draw the projectors through the points of intersection from both side view as well as top view and obtain the corresponding points in the front view. For example point a'_2 will be the point of intersection of vertical projector from a_2 and horizontal projector a''_2. Similarly, obtain the remaining points. Join $a'_1a'_2a'_3a'_4$ in order by using thick straight lines to complete the line of intersection on the left side.
5. Following the same method get $b'_1b'_2b'_3b'_4$ which are the points of intersection on right side. They form a mirror image of left side shape. It may be noted that in the front view, the lines of intersection on front and back of the prisms overlap and thus forms the closed figure. The portions of triangular prism hidden in front view are shown using short dashes and the edges of square prism penetrated are shown using Type K line.
6. Finish the views and print the given dimensions to complete the drawing.

Example 14.2

A vertical hexagonal prism, side of base 40 mm and 80 mm long, is completely penetrated by a horizontal square prism of 36 mm side and 120 mm length. The axis of the horizontal prism is parallel to VP and 6 mm in front of the axis of the hexagonal prism. If one rectangular face of the hexagonal prism is parallel to VP and all the faces of the square prism are equally inclined to HP, draw the projections of the prisms showing the lines of intersection.

Refer to Fig. 14.2.

1. Draw the three views of the two prisms in the given position as well as overlapping each other and name the corners.
2. Here the two solids have plane surfaces and their axes are at a distance of 6 mm. The lines of intersection are straight lines. The number of intersecting plane surfaces of the prisms in the given position are six, so there are six points of

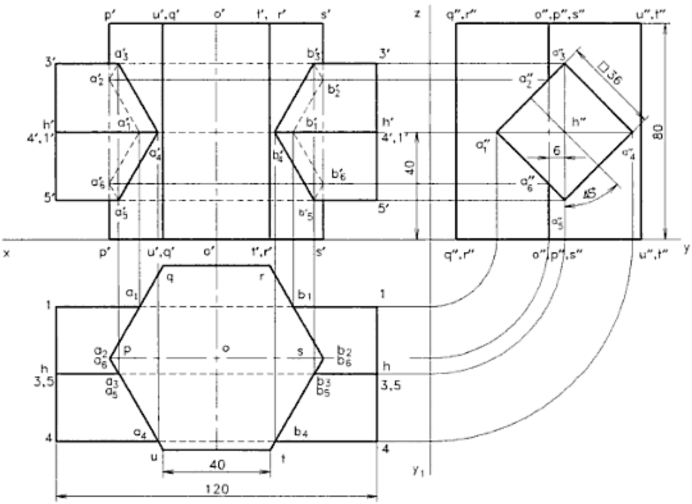


Fig. 14.2 Intersection of prism in prism.

intersection and hence, six straight lines. The points may be named clockwise as $a''_1, a''_2, ..., a''_6$ as in the side view.

3. In the top view the four edges of the square prism intersect on the left faces of hexagonal prism at six points, namely $a_1, a_2, ..., a_6$. Similarly, on the right faces the six points of intersection are $b_1, b_2, ..., b_6$.
4. Draw the projectors through the points of intersection from both side view as well as top view and obtain the corresponding points in the front view as done in Example 14.1. Join $a'_1, a'_2, ..., a'_6$ in order by using visible or hidden lines to complete the line of intersection on the left side.
5. Following the same method get $b'_1, b'_2, ..., b'_6$ which are the points of intersection on right side. They form a mirror image of left side shape. It may be noted that, in the front view, the lines of intersection on front and back of the prisms are not overlapping and they form closed figures, partly visible and partly hidden. The portions of square prism hidden, are shown using short dashes and the edges of hexagonal prism penetrated by the other are represented by Type K line.
6. Finish the views using proper line types and print the given dimensions.

14.4 LINES OF INTERSECTION OF CYLINDERS

Cylinders have curved lateral surfaces. Therefore, when they intersect, the line of intersection will be a closed curve. Since cylinders have no edges like prisms, to draw the intersection curve, cutting plane method is used. Figure 14.3 shows the pictorial view of intersection of cylinders cut by an imaginary cutting plane C1-2. Here, the section of vertical cylinder is a circle while that of a horizontal cylinder is a rectangle. The intersection points of the circle with rectangle gives the required points of intersection. Similarly, by assuming different cutting planes, the required number of points on the intersection curve can be determined.

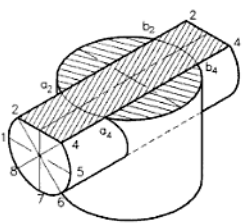


Fig. 14.3 Cylinder in cylinder (cutting plane method).

Example 14.3

A vertical cylinder of 72 mm diameter and 80 mm length is penetrated by another horizontal cylinder, 56 mm diameter and 100 mm long. The axis of the horizontal cylinder is parallel to VP and 6 mm in front of the axis of the vertical cylinder. Draw the projections showing the curves of intersection.

Refer to Fig. 14.4.

1. Draw the three views of the two cylinders in the given position as well as overlapping each other.
2. Divide the circle representing the horizontal cylinder in the side view, radially into 8 equal parts. Name them as 1″, 2″, ..., 8″ and mark the cutting planes $c_{2\text{-}4}$, $c_{1\text{-}5}$, and $c_{6\text{-}8}$ as shown. Note that these cutting planes passes through the 8 points marked. Draw lines to represent the edges formed by these imaginary cutting planes in the top and front views and name them. The crossing points of these imaginary edges on the circle representing the vertical cylinder in top view gives the points of intersection on the left and right sides as $a_1, a_2, ..., a_8$ and $b_1, b_2, ..., b_8$ respectively.
3. Draw projectors through the points of intersection from both side view as well as top view and obtain the corresponding meeting points in the front view as did in Example 14.1. Join $a'_1, a'_2, ..., a'_8$, in order by using visible or hidden curved lines to complete the line of intersection on the left side of front view. Repeat the same to get points $b'_1, b'_2, ..., b'_8$ which are the points of intersection on right side. They form a mirror image of left side shape.
4. Finish the views using proper line types and print the given dimensions.

Example 14.4

A vertical cylinder of 72 mm diameter and 100 mm length is penetrated by another cylinder, 48 mm diameter and 120 mm long. The axis of the penetrating cylinder is inclined at 25° to HP and parallel to VP. Draw the projections showing the line of intersection, if the two axes of the cylinders intersect at their mid points.

Refer to Fig. 14.5.

1. Draw the top and front views of the given cylinders with their axes intersecting at an angle of 25°. Here the end view of the inclined cylinder can be

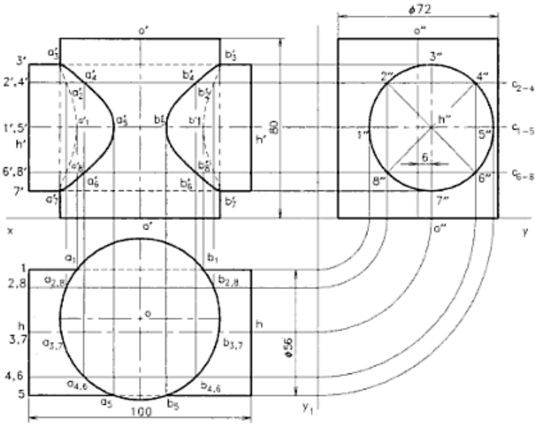


Fig. 14.4 Cylinder in cylinder (cutting plane method).

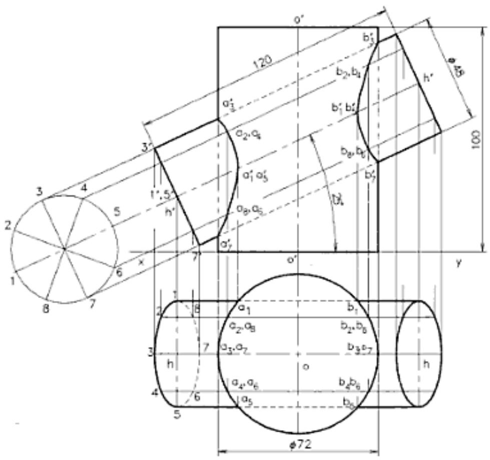


Fig. 14.5 Cylinder in cylinder (line method).

replaced by a circle of its diameter drawn on its axis in the front view as shown.

2. Divide the circle into 8 equal parts radially and name them. Follow the cutting plane method Explained in Example 14.3 and get the curved lines of intersection in the front view. Note that the hidden intersection lines are coinciding with the visible ones, since the axes are intersecting each other.
3. Finish the views using proper line types and print the given dimensions.

14.5 LINES OF INTERSECTION OF CYLINDER AND CONE

When a cylinder penetrates a cone, the lines of intersection will be a closed curve because they have curved lateral surfaces. Cutting plane method is used to determine the curves of intersection. If the axis of cylinder is right angled to that of the cone, cutting planes perpendicular to the axis of the cone are used. Figure 14.6 gives an example for a similar solution.

Example 14.5

A vertical cone, 84 mm of base diameter and axis of 100 mm high is completely penetrated by a horizontal cylinder, of 50 mm diameter and 102 mm length. If the axis of the cylinder intersects the axis of the cone at height of 30 mm from the base and is parallel to VP. Draw the projections of the solid, showing the curves of intersection.

Refer to Fig. 14.6.

1. Draw the three views of the cone and cylinder with their axes intersecting at right angles as well as overlapping each other.
2. Divide the circle representing the horizontal cylinder in the side view, radially into 12 equal parts. Name them as 1″, 2″, ... 12″ and mark the cutting planes $c_{3.5}, c_{2.8}, \ldots, c_{11.9}$ as shown. Note that these cutting planes passes through the 12 points marked. Draw lines to represent the edges formed

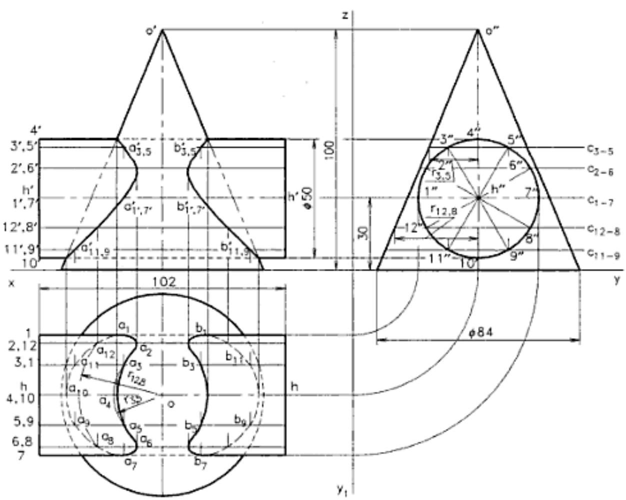


Fig. 14.6 Cylinder in cone (cutting plane method).

by these imaginary cutting planes in the top and front views and name them.

3. To mark the intersection points a_3 and a_5 in the top view, measure the radius of the cone along the cutting plane $c_{3\text{-}5}$ as $r_{3,5}$ and draw an arc of that radius with centre o in the top view. The arc cuts the lines 3-3 and 5-5 marking a_3 and a_5. Similarly, mark the remaining points using the cone radii along different cutting planes. Join them using smooth curves of visible and hidden lines on left and right sides as shown in top view.
4. Draw projectors through the points of intersection from both side view as well as top view and obtain the corresponding meeting points in the front view as did in Example 14.1. Note that the hidden intersection lines are coinciding with the visible ones, since the axes are intersecting each other.
5. Finish the views using proper line types and print the given dimensions.

Example 14.6

A cone, 84 mm diameter and 100 mm length, is resting on its base upon HP and it is penetrated by a horizontal cylinder, 50 mm diameter and 102 mm long. The axis of the horizontal cylinder is 30 mm above the base of the cone and parallel to VP. If the axis of the cone is 10 mm behind the axis of the cylinder, draw the projections of the solids showing the curves of intersections.

Refer to Fig. 14.7.

1. Draw the three views of the cone and cylinder with their axes at a distance of 10 mm as well as overlapping each other.
2. Divide the circle representing the horizontal cylinder in the side view, radially into 8 equal parts. Name them as 1″, 2″, ..., 8″ and mark the cutting planes $c_{2\text{-}4}$, $c_{1\text{-}5}$, and $c_{8\text{-}6}$ as shown. Draw lines to represent the edges formed by these imaginary cutting planes in the top and front views and name them. Also mark the points n'' and m'' representing

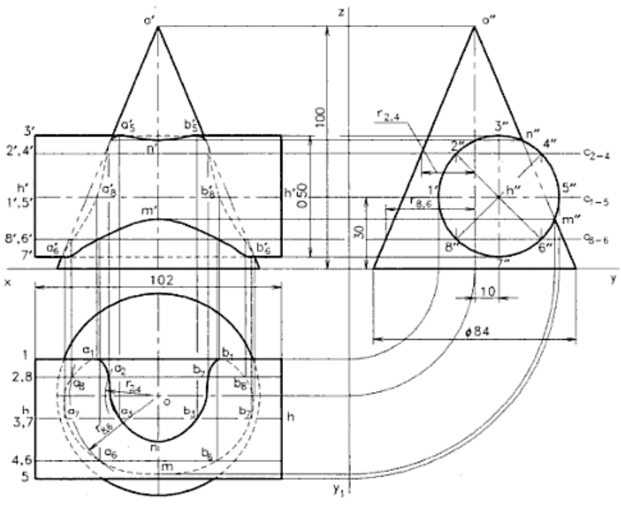


Fig. 14.7 Cylinder in cone (cutting plane method).

the cylinder protruding points from the outermost generator of the cone.

3. Mark the intersection points in the top view and then in the front view as done in Example 14.5. Here, note that the left and right curves join to form a single one at points *n* and *m* in the top view and at *n'* and *m'* in the front view. This is because the cylinder surface is partially outside the outermost generator of the cone.
4. Finish the views using proper line types and print the given dimensions.

EXERCISES

(# Problems similar to the worked-out examples)

1. A square prism, base 54 mm side and 90 mm length, is resting vertically on HP. It is penetrated by a triangular prism of 50 mm side and 110 mm length, so that their axes intersect each other at right angles. If the faces of the square prism are equally inclined to VP and one of the rectangular faces of the triangular prism is paralleled to HP, draw the projections of the solids showing the lines of intersection. (#)
2. A vertical hexagonal prism, side of base 42 mm and 80 mm length, is completely penetrated by a horizontal square prism of 36 mm side and 120 mm length. The axis of the horizontal prism is parallel to VP and 8 mm in front of the axis of the hexagonal prism. If one rectangular face of the hexagonal prism is parallel to VP and all the faces of the square prism are equally inclined to HP, draw the projections of the prisms showing the lines of intersection. (#)
3. A vertical cylinder of 76 mm diameter and 90 mm length is penetrated by another horizontal cylinder, 54 mm diameter and 110 mm length. The axis of the horizontal cylinder is parallel to VP and 9 mm in front of the axis of the vertical cylinder. Draw the projections showing the curves of intersection. (#)
4. A vertical cylinder of 76 mm diameter and 120 mm length is penetrated by another cylinder, 60 mm diameter and 120 mm length. The axis of the penetrating cylinder is inclined at 20° to HP and parallel to VP. Draw the projections showing the line of intersection, if the two axes of the cylinders intersect at their mid points. (#)
5. A vertical cone of base 90 mm diameter and axis 110 mm high is completely penetrated by a horizontal cylinder of 50 mm diameter and 110 mm length. If the axis of the cylinder intersects the axis of the cone at height of 32 mm from the base and is parallel to VP. Draw the projections of the solid, showing the curves of intersection. (#)
6. A cone, 90 mm diameter and 100 mm height, is resting on its base upon HP and it is penetrated by a horizontal cylinder, 50 mm diameter and 110 mm length. The axis of the horizontal cylinder is 32 mm above the base of the cone and parallel to VP. If the axis of the cone is 12 mm behind the axis of the cylinder, draw the projections of the solids showing the curves of intersections. (#)

CHAPTER 15

Development of Surfaces

The process of opening out all the surfaces of a three-dimensional body onto a flat plane is called *development of surfaces* and the resulting shape is called the *pattern*. The surface so laid out is termed as its *development*. The process of development consists of drawing successive surfaces of the object and every line on the development should have the true length.

15.1 THE PRINCIPLE OF DEVELOPMENT OF SURFACES

The surfaces of most solids which are used in engineering design work can however be opened out into a flat plane by the process of development. The setting out of a pattern forms the basis for the manufacture of fabricated sheet metal or plate components. After the development has been cut out, it is bent or rolled into the required shape. The objects produced by development and fabrication include pipes, ducts, pans, bins , buckets, tanks, etc.

The development of surfaces of the most common solids is shown in the Fig. 15.1. The patterns of prism and pyramid are nearly the side and end faces unfolded into a plane surface, while the patterns for cylinder and cone are simply the curved surfaces and ends rolled or unfolded into a plane surface. It may be noted that the development of a surface is usually drawn showing the inside pattern and the true length dimensions are marked on it accordingly.

The solids bound by plane surfaces are polyhedra. Their development can be obtained by turning the object so as to unroll the imaginary enclosing surface upon a plane. Since

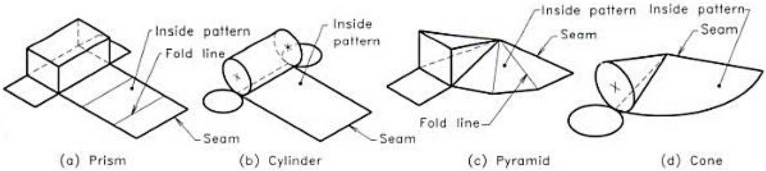


Fig. 15.1 Development of surfaces of solids.

cones and cylinders are solids bound by curved surfaces, their developments can be obtained easily by unrolling the imaginary enclosing surface upon a plane. Solids bound by double curved surfaces or wrapped surfaces are spheres, paraboloid, etc. Their development cannot be obtained by just unrolling them. A double curved surface is a surface generated by revolving a curved edge about a straight line.

To make objects using sheet metal, paper cardboard, etc. allowances for the lap and seams are to be added to the inside pattern, obtained by the development. Here, for avoiding confusion in the beginning, that part is not included in the worked-out examples. Any how, students are advised to make models of the solids after drawing the patterns with sufficient overlaps for cut and paste. This will help to understand the shapes of various solids, and their developments clearly.

15.2 METHODS FOR DRAWING THE DEVELOPMENT OF SURFACES

The following are the principal methods used for development of surfaces.

1. **Parallel line development:** This method is used when the surfaces of the solid are generated by a line which moves parallel to the axis of the solid. Development of prisms and cylinders can be drawn by this method i.e. by drawing *stretch out line* or *girth line*. Stretch out line gives the perimeter of the object.
2. **Radial line development:** This method is used when the surfaces of the solid are generated by a line, one end of which remains stationary while the other end traces out any path. Pyramids and cones can be drawn by this method.
3. **Triangulation development:** This method is used when the surfaces of the solid can be imagined to consist of a number of triangles. Transition pieces are developed using this method.
4. **Approximate development:** This method is used in the development of surfaces of solids bound by double curved surfaces. Development of a sphere is obtained by using this method.

Figure 15.2 shows general form of the four methods of developing surfaces. The development of surfaces may also be grouped according to the shape of the solid as polyhedra, cylinder, cone, truncated solids, intersecting solids, transition pieces, objects, spheres, etc.

Notes:

1. Development of a surface is drawn using the true lengths only.
2. The inside pattern is drawn as a development, so that by folding or rolling it the shape of the surface is obtained.
3. Usually the development is prepared by referring the front view.
4. The outline of the developed surface is represented by thick lines and the folding by thin lines.
5. Usually capital letters are used to name the corners of the development.

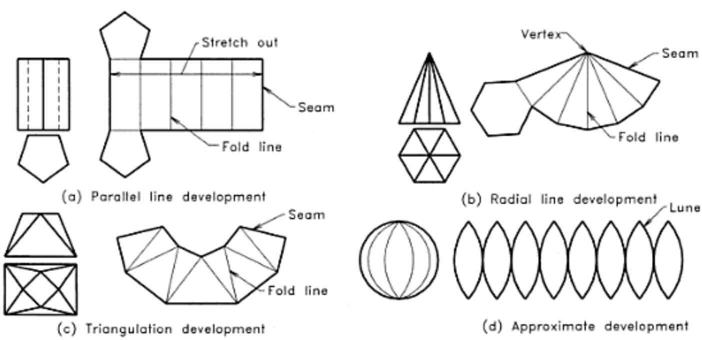


Fig. 15.2 Methods of development of surfaces.

6. Parallel line method is used to develop solids having uniform cross-section about its axis.
7. Radial line method is used to develop solids having uniformly varying cross-section along the axis.
8. Triangulation method is applied for transition pieces which are having a single curved surface.
9. For double curved surfaces like spheres, only approximate development can be obtained.

15.3 DEVELOPMENT OF POLYHEDRA

Development of prisms, pyramids and platonic solids can be done using either parallel line development or radial line development method. Figure 15.3(a) shows the complete development of various prisms using parallel line development method. Radial line development method is used for developing pyramids. The varieties are shown in Figure 15.3(b). For platonic solids, the cube may be treated as a prism. Tetrahedron and octahedron may be developed by drawing the triangular faces with one touching to the other. Figure 15.3(c) shows the development of platonic solids. The following examples explain the step by step procedure to develop polyhedra.

Example 15.1

Draw the development of the surface of a rectangular prism, base 24 mm × 30 mm sides and axis 40 mm long, having a longer edge of the base parallel to VP.

Refer to Fig. 15.4.

1. Draw the top and front views of the prism. Locate the left corner of the top view as the seam (joint) and name the corners clockwise from this corner.
2. Draw the stretch out lines 5 to 5 and 1 to 1 as shown in figure. Mark the lines 5-6 and 7-8 of length 24 mm, and 6-7 and 8-5 of length 30 mm to represent the true lengths of sides at the base. Mark the verticals 5-1, 6-2, etc. of length 40 mm to represent the true height of the edges and the fold lines. Also draw the two rectangles 5,6,7,8 and 1,2,3,4 to represent the true size of the base and top of the rectangular prism.
3. Convert the outline of the development to thick line and keep the foldings as thin line. Print the given dimensions on both the projections as well as on the development.

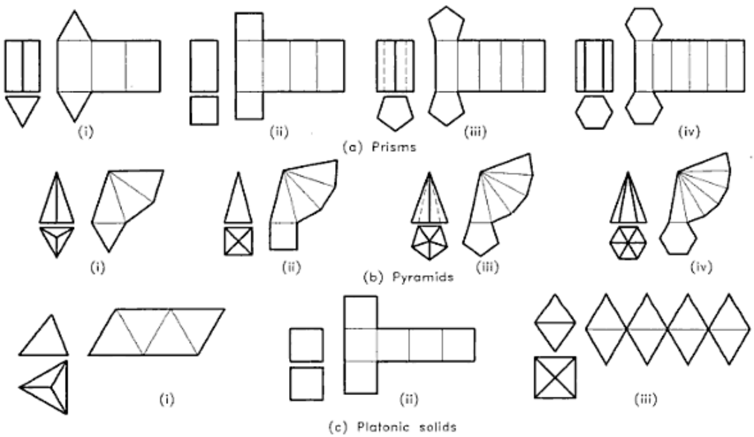


Fig. 15.3 Development of polyhedra.

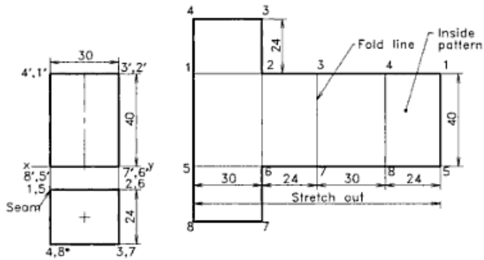


Fig. 15.4 Development of a rectangular prism.

Example 15.2

Develop the full size pattern of a right regular pentagonal pyramid, base 24 mm and height 50 mm.

Refer to Fig. 15.5.

1. Draw the top and front views of the pentagonal pyramid keeping one sloping edge parallel to VP in order to get the true length (TL) directly from the front view. Locate *oa* as the seam (joint) of the development on left side and name the corners clockwise starting from this corner.
2. Measure the true length (TL) of the sloping edge from the elevation and use it to draw the lateral surface of the pyramid as shown in figure. An arc with radius equal to TL may be drawn first. Then mark the true length of the base edge of the pyramid on the arc.

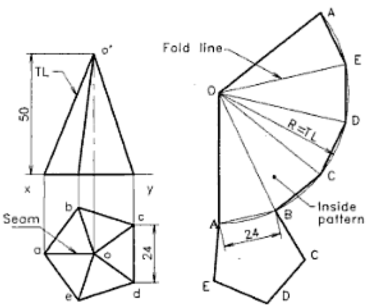


Fig. 15.5 Development of a pyramid.

3. Add a pentagon of true size to one of the base lines, preferably to the first edge.
4. Finish the drawing, thicken the outline and print the given dimensions to complete.

Example 15.3

Draw the development of the lateral surface of a right regular hexagonal prism of 24 mm base edge and 56 mm height. An ant moves on its surface from a corner on the base to the diametrically opposite corner on the top face, by the shortest route along the front side. Sketch the path in the elevation.

Refer to Fig. 15.6.

1. Draw the top and front views of the hexagonal prism. Locate corner a as the seam (joint) of the development on left side and name the corners clockwise starting from this corner.
2. Draw the stretch out line AA of length 6 × 24 mm and complete the development of the prism as shown in figure.
3. Assume that the ant moves from *a'* to *d'* in the elevation along the front side. Join AD in the developed surface, which is the shortest distance between A and D. This line cuts the fold lines E and F at N and M respectively. Draw horizontals to cut the respective edges at *n'* and *m'* in the elevation. Join *a'*, *n'*, *m'* and *d'* to represent the shortest path along front side in the elevation.
4. The ant can also have the shortest path along the rear side of the prism. This has to be shown in short dashes.
5. Finish the views using proper line types and print the given dimensions to complete the drawing.

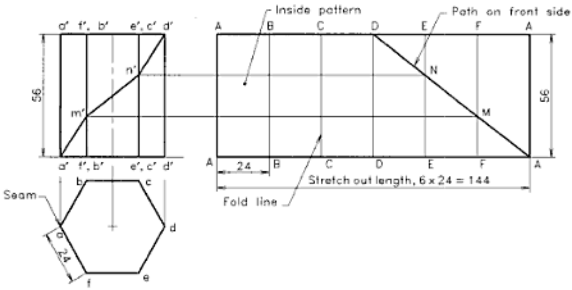


Fig. 15.6 Lateral surface of a prism.

15.4 DEVELOPMENT OF CYLINDER AND CONE

Development of the lateral surface of a cylinder is a rectangle having width equal to length of the cylinder and the stretchout length = $p \times$ diameter of the base. For showing details on the lateral surface, the cylinder may be assumed as a prism having 12 sides (generators).

Development of the lateral surface of a cone is a sector of a circle having radius equal to the length of the generator (slant height of the cone). The angle at the centre of the sector depends on the circumference of the base of the cone and the length of generator.

The sector angle $\theta = 360 \times r/R$

where

r = radius of base circle and

R = slant height (generator) of cone (TL)

For showing details on the lateral surface, the cone may be assumed as a pyramid having 12 number of sides. Parallel line development is applicable to the development of cylinders while radial line development is used for the development of cones.

Example 15.4

A right circular vertical cylinder of 44 mm diameter and height 60 mm rotates uniformly. A plotter pen-tip moves vertically at uniform speed on the surface of the cylinder from the bottom to the top, so it moves 60 mm while the cylinder completes one rotation. Draw the line marked on the cylinder in the front view and measure the true length of it.

Refer to Fig. 15.7.

1. Draw the top and front views of the cylinder.
2. Draw the development of the cylinder after marking the stretch out length = $\pi \times 44$.

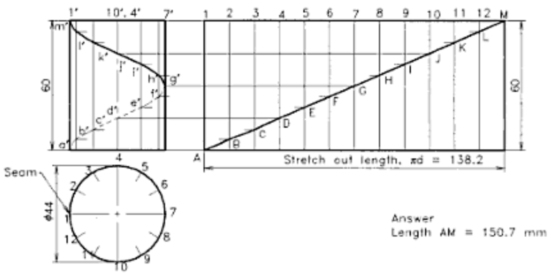


Fig. 15.7 Lateral surface of a cylinder.

3. As the plotter pen moves axially, the cylinder rotates once, marking a helix on the surface of the cylinder in the front view. To draw the helix, divide the base circle of the top view into 12 parts radially and the stretch out length into the same number of divisions. Locate the seam (joint) of the development on left side and name the 12 generators clockwise starting from this point.
4. The helix seen in the front view is the diagonal to the rectangular pattern. Hence, draw the diagonal AM and mark the intermediate points. Mark the 12 generators on the front view and draw horizontal lines from A, B, C, D, ... M to get a', b', c', ..., m' on these generators, which forms the helix.
5. Join the points a', b', c', ..., m' by a smooth curve of thick line for the visible portion and short dashes for the hidden portion of the helix. Also measure the length AM and print it against the answer.

Example 15.5

A right circular cone has 50 mm diameter and 50 mm height. Draw the complete development of the cone showing the twelve generators.

Refer to Fig. 15.8.

1. Draw the top and front views of the cone and mark the 12 generators on them. Locate the seam (joint) on the left side of top view and name the generators clockwise starting from this point. Also measure the generator length, TL.
2. To draw the development of the cone, calculate the sector angle $\theta = 360 * R/TL = 161°$, where R is the radius of the cone. Draw an arc with radius = TL to get the sector of angle θ, which forms the development of the lateral surface of cone.
3. To mark the 12 generators on the sector, divide the angle θ into half by drawing the angular bisector O-7 using a compass. Similarly, redivide them by drawing lines O-4 and O-10 as shown using compass. Further divide the 1/4th sector into three equal parts by trial and error method using a bow divider. For this take 1/12th of the circumference of the base circle on the bow divider and mark it along the circular portion of the sector successively. If the third leg is not coinciding with the end point of the arc, adjust 1/3rd of this difference on the divider and repeat the same from the beginning. By one or two trials the required divisions are obtained with reasonable accuracy.
4. Draw radial lines from O to the divisions to represent the 12 generators and name them. Add a circle of base diameter of cone to any one (say to the 7th) of the generators and divide that also into 12 parts radially.
5. Finish the views using proper line types and print the given dimensions to complete the drawing.

Example 15.6

Draw the development of a right circular cone of base diameter 60 mm and height 64 mm resting upon HP on its base. An insect moves from a point on the base edge to the

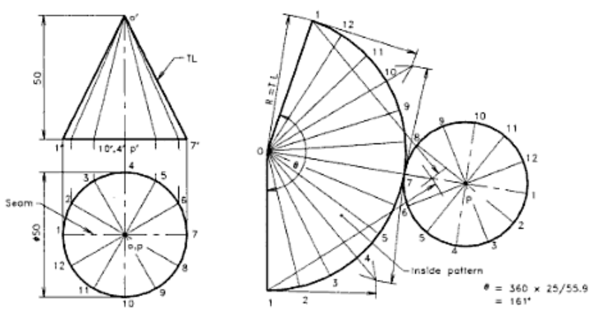


Fig. 15.8 Complete development of a cone showing the twelve generators.

diametrically opposite point on the same edge through a shortest path along the curved surface on front side. Mark the shortest path in the front and top views of the cone.

Refer to Fig. 15.9.

1. Draw the top and front views of the cone and mark the 12 generators on them. Locate the seam (joint) on the left side of top view and name the generators clockwise starting from this point. Also measure the generator length, TL.
2. To draw the development of the cone, calculate the sector angle $\theta = 360 * R/TL = 152.5°$

   Draw an arc with radius = TL to get the sector of angle θ and complete the development of the cone.
3. To find the path of the insect, divide the sector radially into 12 as explained in example 15.5 and name them.
4. Let the shortest path of the insect be from 7 to 1, along the curved surface on front side. In the pattern, draw a straight line AG from point 7 to 1, crossing the generators at B,C, D, etc. to represent the shortest path. Measure the radial distance OB, OC, OD, etc. and mark as $o'b''$, $o'd''$, etc. on the true length line TL in the front view. Here, TL is the outermost generator of the cone. Draw horizontal lines from b'', c'' and d'' to intersect their respective generators. Join the points a', b', c', etc., by a smooth curve to obtain the shortest path in the front view.
5. Project vertically downwards from the points a', b', c' etc. to get the corresponding points on the generators drawn in the top view as a, b, c, etc. Join the points by a smooth curve to get the top view of the shortest path.
6. Finish the views using proper line types and print the given dimensions to complete the drawing.

15.5 DEVELOPMENT OF TRUNCATED SOLIDS

If a solid is cut by a plane inclined to its base, the portion obtained after removing the top is a truncated solid. If solids with uniform cross-section are truncated, their development can be obtained by parallel line development method. If the solids are of uniformly varying cross-section, the development of sectioned solids of that group are drawn using radial line development method. In both cases, the projections of the complete solids are drawn first and the section plane is marked. The true lengths of the intermediate points formed by cutting are measured from the two views and marked them on the foldings or generators to get the final shape of the development.

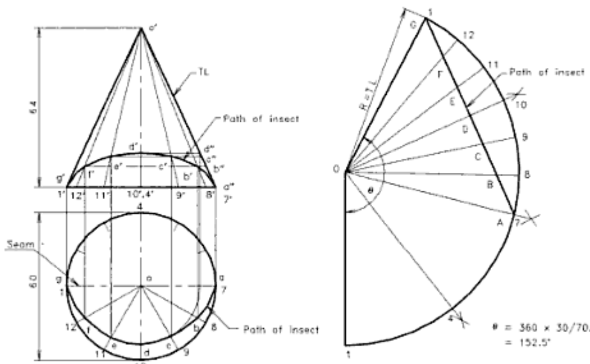


Fig. 15.9 Lateral surface of a cone.

Example 15.7

A right regular hexagonal prism of base edge 20 mm and height 50 mm rests on its base with one of its base edges perpendicular to VP. A section plane inclined 45° to HP cuts its axis at its middle. Draw the complete development of the truncated prism including the sectioned surface.

Refer to Fig. 15.10.

1. Draw the top front views of the prism in the position given. Mark the section plane at an angle of 45° to HP, cutting the axis at the middle. Also locate the seam at the left corner of the top view and name the corners clockwise.
2. Draw the stretch-out line 1-1 of length 6 × 20 mm and mark the fold lines 1, 2, 3, etc. on it. The section plane cuts the six edges of prism, so mark these six points as *p′q′r′s′t′u′* on the front view. Then get the true shape of sectioned surface.
3. Draw a horizontal lines from points *p′*, *q′*, *r′*, *s′*, *t′* and *u′* to intersect the fold lines at P, Q, R, S, T, and U, respectively. Join the points by straight lines to obtain the development of the lateral surface. Add a hexagon of true size of base to the first fold in order to complete the full development.
4. Finish the views using proper line types and print the given dimensions to complete the drawing.

Example 15.8

A right regular pentagonal pyramid, side of base, 36 mm and height 64 mm, rests on its base upon the ground with one of its base sides parallel to VP. A section plane perpendicular to VP and inclined at 30° to HP cuts the pyramid, bisecting its axis. Draw the development of the truncated pyramid.

Refer to Fig. 15.11.

1. Draw the top and front views of the pyramid and mark the section plane at 30° on the front view. Also locate the seam at the left corner of the top view and name the corners clockwise.
2. To draw the development of the pyramid, get the true length line of the sloping edge as *o′u′* in the front view by rotating the line O_3, as shown in the figure. With radius equal to the true length of sloping edge (TL) draw an arc, mark the five sides on it and complete the development of lateral surface of the pyramid.
3. To mark the points P, Q, R, S, T on the development, the true distances of these points from the apex O have to be determined. For this, draw horizontal lines from *p′*, *q′*, *r′*, *s′* and *t′* to the true length line *o′u′* and get the points *p″*, *q″*, *r″*, *s″* and *t″*. Then the distances *o′p″*, *o′q″*, etc. are marked as OP, OQ, etc. on the corresponding sloping edges, to get the points PQRS and T on the development. Join them by straight lines to get the final form of the lateral surface of the truncated pyramid.
4. Finish the views using proper line types and print the given dimensions to complete the drawing.

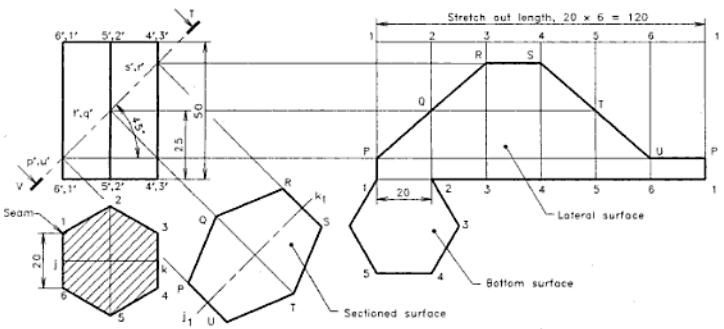


Fig. 15.10 Complete development of a truncated prism.

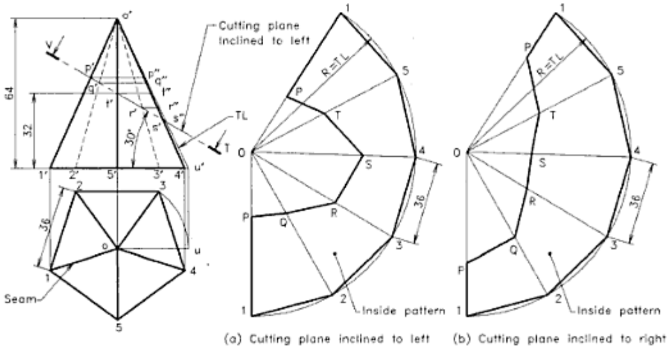


Fig. 15.11 Lateral surface of a truncated pyramid.

Example 15.9

Draw the development of the lateral surface of the truncated right circular cylinder of diameter 44 mm and height 70 mm. The tube is placed on HP. A section plane, passing through the geometrical centre of the top face of the tube, perpendicular to VP and inclined at 45° to HP, cuts off the top portion of the tube. A similar sectional plane making an angle of 30° to HP in the opposite direction, cuts the axis at a height of 14 mm from the base.

Refer to Fig. 15.12.

1. Draw the top and front views of the cylinder and mark the section planes.
2. Divide the base circle into 12 equal parts. Draw vertical projectors through the 12 points and obtain the corresponding points in the front view. Also locate the seam at the left side of the top view and name the generators clockwise.
3. Draw the stretch out line and mark the 12 generators on it. Point A on the development is the point of

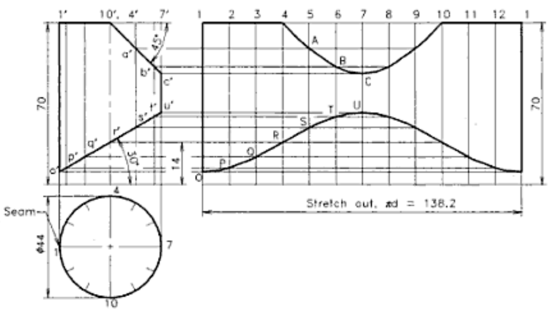


Fig. 15.12 Lateral surcace of a truncated cylinder.

intersection of the horizontal line through a' and the vertical line through point 5. Similarly, obtain the other points B, C, D and E and points P, Q, R, S, T, etc. as shown in the figure. Complete the development by drawing smooth curves through these points.

4. Finish the views using proper line types and print the given dimensions to complete the drawing.

Example 15.10

A right circular cone, 70 mm base and 70 mm height, rests on its base on the ground plane. A section plane perpendicular to VP and inclined at 30° to HP cuts the cone, bisecting its axis. Draw the development of the lateral surface of the cone.

Refer to Fig. 15.13.

1. Draw the top and front views of the cone and mark the section plane at an angle of 30° to HP.
2. Measure the true length TL of the outermost generator and calculate the sector angle,

$$\theta = 360 * R/TL = 161°$$

   Using TL and $\theta°$, draw the sector to get the development of the cone.
3. Divide the top view into 12 equal divisions and draw the corresponding generators in the front view as well as in the pattern as explained in Example 15.5. Also locate the seam at the left side of the top view and name the generators clockwise.
4. Let the sectional plane cut the generators in the front view at points a', b', c', etc. Draw horizontal lines from these points to get their true lengths. Mark OA = $o'a''$, OB = $o'b''$ and so on in the pattern to get the points A, B, C, etc. on generators 1, 2, 3, etc. Join the points A, B, C, etc. to get the first half of the curve. Since the section is symmetrical about the generator O_7, copy the first half of the curve to the remaining portion as a mirror image by drawing arcs. This completes the drawing of the lateral surface of the truncated cone as shown in Fig. 15.13(b).
5. If the direction of inclination of cutting plane is changed, the development of the cone is seen as in Fig. 15.13(c). Note that both developments are the same and only the seam is different relative to the direction of inclination.
6. Finish the views using proper line types and print the given dimensions to complete the drawing.

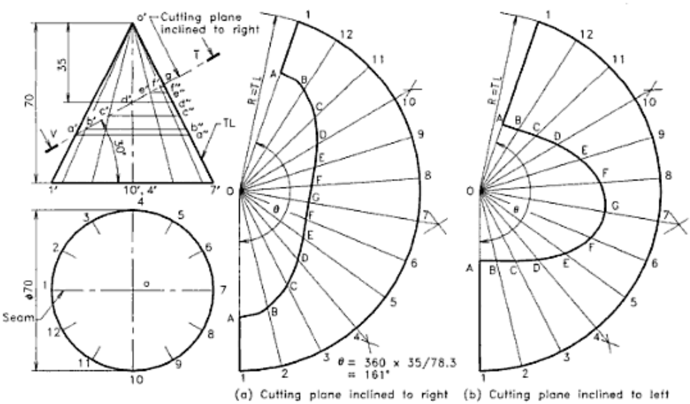


Fig. 15.13 Lateral surface of a truncated cone.

15.6 DEVELOPMENT OF SOLIDS HAVING HOLE OR CUT

The development of the lateral surface of solids having holes or cut, can be drawn by following the methods explained for truncated solids. The orthographic views and development of the lateral surface of the full solid are drawn first. The hole or cutting is marked in the front view showing the true shape, and sufficient number of generators are drawn over it in order to get points of intersection. Then these points of intersection are transferred to the pattern, after finding the true lengths either by following the parallel development method or radial line development method, which ever is applicable.

Example 15.11

A square prism of 40 mm side length and 60 mm height rests on its base upon HP, such that the vertical faces are equally inclined to VP. A horizontal hole, 40 mm diameter is drilled through the geometrical centre of the prism with the axis perpendicular to VP. Develop the lateral surface of the prism.

Refer to Fig. 15.14.

1. Draw the top and front views of the prism in the given position and draw a circle of diameter 40 mm at the centre of the axis to represent the hole.
2. Draw the development of the lateral surface of the prism. Also locate the seam at the left side of the top view.
3. Divide the circular hole in the front view radially into 12 divisions and transfer the points of intersection 1′, 2′, and 3′, to the top view as shown.

   The true distance of point 1′ from the edge *b*′ is the distance of point 1′ from edge *b* in the top view. Let this true distance = L_1. Similarly, the true distances of points 2 and 3 can be marked as L_2, L_3 in the top view.
4. To draw the development of the hole, insert horizontal lines through points 1′, 2′, 3′ and 4′ towards the pattern. Mark L_1, L_2, and L_3, the true distances along these lines from fold line B to get the points 1, 2, and 3 on the left side of the line B. Take a mirror image of these points on right side of the line B and join them by a smooth curve to get the ellipse as shown.
5. Repeat the same about the fold line D also to get the second ellipse on the development.
6. Finish the views using proper line types and print the given dimensions to complete the drawing.

Example 15.12

A vertical cylinder of diameter 60 mm has a central horizontal square through hole of side 40 mm. The centre of the hole is coinciding with the centre of the axis of cylinder and the sides are equally inclined to HP. Draw development of the lateral surface of the cylinder with hole.

Refer to Fig. 15.15.

1. Draw the top and front views of the cylinder in the given position and construct the square hole. For this draw a line *l*′*m*′*n*′ of length 40 mm at an angle of 45°, keeping the mid point *m*′ at the middle of the

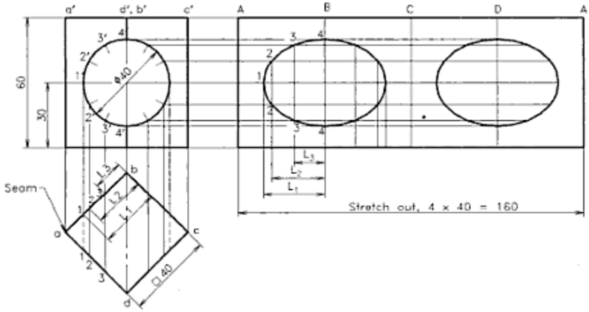


Fig. 15.14 Lateral surface of a prism with a hole.

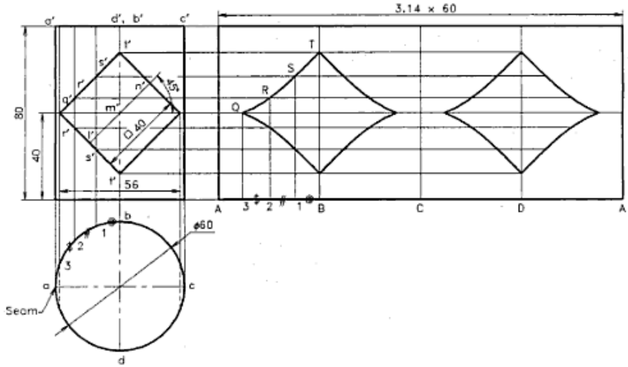


Fig. 15.15 Lateral surface of a cylinder with a hole.

axis. Construct the required square by drawing lines parallel and perpendicular to this line.

2. Draw the development of the lateral surface of the cylinder and locate the seam at the left side of the top view. Also mark the lines B, C, and D to represent the quadrants of the cylinder on the pattern.
3. Mark q' and t' at the corners of the hole and two intermediate points r' and s' between them so that, the generators through these points locate 1, 2, and 3 in the top view at almost equal distances along the perimeter.
4. Using a bow divider measure the distance from b to 1 in the top view and mark it to locate the generator 1 on left side of line B in the development. Similarly, measure distances from 1 to 2 as well as 2 to 3 and locate the 2nd and 3rd generators on left side of B as shown. Draw horizontal lines through q', r', s' and t' to intersect the generators drawn at 3, 2, 1 and B on the pattern, giving points Q, R, S and T respectively. Join them by curves to get one side of the hole. Take a mirror image of the curves to get the full hole.
5. Repeat the same about the fold line D also to get the second hole on the development.
6. Finish the views using proper line types and print the given dimensions to complete the drawing.

Example 15.13

A cone of base diameter 80 mm and height 80 mm is resting upon HP on its base. A horizontal square through hole of 40 mm side is cut in the cone in such a way that the axis of the hole intersects the axis of the cone at a height of 16 mm from the base. If he four sides of the hole are equally inclined to HP, draw the development of the lateral surface of the cone.

Refer to Fig. 15.16.

1. Draw the top and front views of the cone and mark the square hole in the given position. For this draw a line $l'm'n'$ of length 40 mm at an angle of 45°, keeping the mid point m' as the centre of hole on the axis. Construct the required square by drawing lines parallel and perpendicular to this line. Also locate the seam at the left side of the top view.
2. After measuring the true length of the generator TL and calculating the angle $\theta = 360 * R/TL = 161°$, draw the development of the uncut cone. Mark the four quadrant generators $abcd$ in the top view, $a'b'c'd'$ in the front view and the corresponding ABCD in the development as shown in figure.
3. The square hole is symmetrical about the line $o'b'$. To draw the left half of the development of the hole, mark the generators 1′, 2′ and 3′ as shown in the front view and project to the top view to get the same points as 1, 2 and 3. To mark these generators in the pattern, measure the chordal distances b to 1,

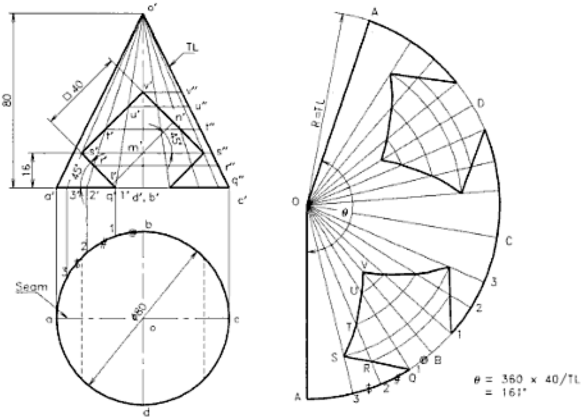


Fig. 15.16 Lateral surface of a cone with a square cut.

1 to 2 and 2 to 3, using a bow divider and mark the same on the left side of the line OB. (This kind of marking on small distances may result a shortening of a small % in length. This error is negligible.)

4. In the front view, name the intersecting points of generators 1, 2 and 3 with the left side edges of the hole as q', r, s', etc, and draw horizontal lines through the points in order to get q'', r'', s'', etc. on the true length line TL.
5. To locate a point, say S, measure the true distance $o's''$ from the front view and mark it as OS along the generator O_3 in the pattern. Similarly, mark the remaining points and join them by a smooth curve as shown in the figure. Repeat the same on the right side of OB to complete one hole. Copy the same hole about the generator OD to complete the development of the cone.
6. Finish the views using proper line types and print the given dimensions to complete the drawing.

Example 15.14

Development of a cone is a semicircle with radius 60 mm. A circle of maximum diameter is inscribed on the development and then it is rolled back to the cone. Draw front and top views of that cone showing the circle.

Refer to Fig. 15.17.

1. Draw a semicircle of radius 60 mm as the development of the cone and inscribe the largest circle (diameter 60 mm) at the middle of it as shown.
2. Divide the development radially into 12 equal parts and name the intersection points on the circle as PQRSTU.
3. Calculate the diameter of the cone corresponding to the semicircular development (cone diameter = 60 mm) and draw the top and front views of the cone. Mark the 12 generators on the views.
4. Locate the points p'', q'', r'', etc. on the true length line TL corresponding to the distances OP, OQ, OR, etc. marked from the apex o'. Draw horizontal lines from these points to get p', q', r', etc. on the respective generators. Join them by a smooth curve to obtain the front view of the inscribed circle.
5. Project from these points downwards to intersect on the respective generators on the top view, locating points p, q, r, etc. Join them by a smooth curve to complete the top view.
6. Mark the seam and finish the views using proper line types.

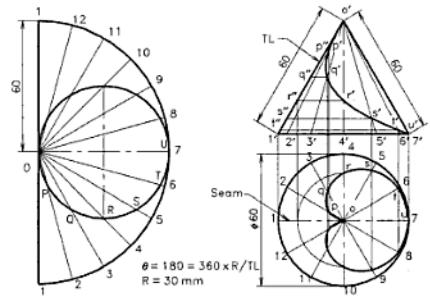


Fig. 15.17 A cone made of a semicircular lamina with a circular hole.

15.7 DEVELOPMENT OF TRANSITION PIECES

Transition piece is a part of a component whose surface transforms from one shape to another. A transformer is called a rectilinear transformer, if its surface is bound by straight lines. A *rectilinear transformer* is shown in Fig. 15.18(c).

The exact development of the rectilinear transformer is possible by the method of triangulation. This is the process of dividing the surface of an object into a number of triangles. However, the surface of the object is curved, triangulation will introduce some error.

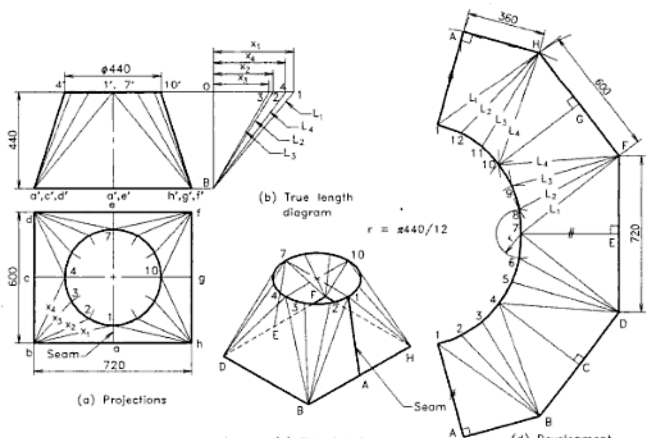


Fig. 15.18 Transition piece (rectangle reducing to circle) (Triangulation method).

Example 15.15

Draw the development of a transition piece connecting a 44 cm diameter pipe and a 72 cm × 60 cm rectangular pipe. Height of transition piece is 44 cm. The centre lines of both the circular pipe and the rectangular pipe are vertical and are in alignment.

Refer to Fig. 15.18.

1. Draw the top and front views of the transition piece, keeping the rectangular base on HP.
2. Transition pieces are developed by triangulation method. Hence, the top and front views are converted into triangles by dividing the circle into any number of equal parts (say 12) as shown in figure. It is to be noted that by dividing the surface as shown in figure, the object is converted into four symmetrical quadrants containing triangles.
3. To determine the true length of the sides of the triangles, a true length diagram is drawn. Let x_1, x_2, x_3 and x_4 be the plan lengths of the edges of triangles. Construct right angled triangles having vertical side = the height of the transition piece and horizontal side = the plan length x_1, so that the hypotenuse gives the true lengths as L_1. Similarly find L_2, L_3 and L_4.
4. To save space and to get the development symmetrical about a horizontal line, assume that the piece is opened along A-1 which forms the seam.
5. To start the development, draw a horizontal line 7E as the midline of the pattern and a perpendicular to it (FD) of length 720 mm, such that E is the mid point of FD. Locate point 7 by cutting arcs of length L_1 from F and D. With centre 7 and radius r = length of arc 1-2 in the top view ($r = \pi * 440/12$), draw an arc to intersect another arc drawn with centre F and radius = L_2 at point 8. Similarly, obtain the points 9 and 10 as given in the figure.
6. Locate the point H so that FH is 600 mm and 10-H is length L_4 by drawing arcs. Proceed as before and locate the remaining points 11, 12, and 1. Find point A such that HA = 360 mm and 1-A = 7-E. Similarly, draw the lower half developed as a mirror image of the upper half. Join points 1, 2, 3, etc. by a smooth curve to obtain the required development.
7. Finish the pattern using proper line types and print the given dimensions to complete the drawing of transition piece.

Example 15.16

A transition piece connects a 36 cm square pipe at the top and a 70 cm circular pipe at the bottom. If the centre line of the circular pipe coincides with the geometrical centre of the square pipe in the top view and the height of the transition piece is 38 cm, draw its development.

Refer to Fig. 15.19.

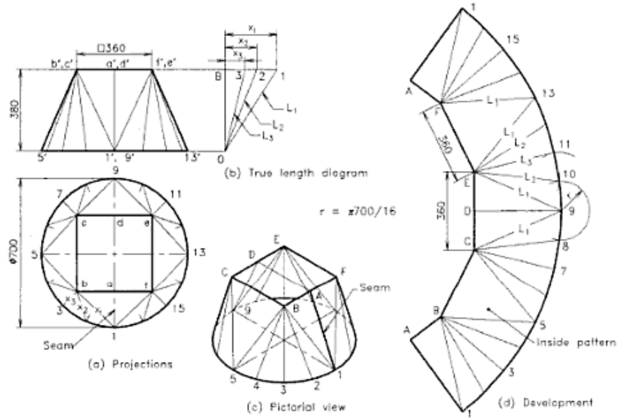


Fig. 15.19 Transition piece (circle reducing to square) (triangulation method).

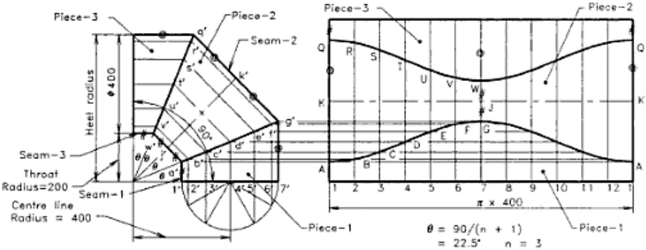


Fig. 15.21 Development of a three piece pipe and (layout of the three pieces for zero waste).

Example 15.18
Develop lateral surface of a three piece pipe bend of 90°. The pipe has a diameter of 400 mm. The heel radius is 600 mm and the throat radius is 200 mm resulting a centre line radius of 400 mm. Layout the developed pieces in order to cut them from a minimum size of sheet without waste.

Refer to Fig. 15.21.

1. Draw the front view of the 90° bend as given in the figure. Here angle θ is equal to 90/(3+1) and the centre line radius is 400 mm. The piece 1 and 3 are identical in size and the piece 2 is of double size than the others. Also note the seam positions marked on the pieces.
2. Construct a semicircle on the vertical pipe end to represent half of plan view of pipe piece 1. Divide this semicircle radially into 6 equal divisions in order to get the 12 generator positions on the vertical pipe. These generators may be extended to the other pieces by drawing them parallel to their centre lines.
3. The vertical piece may be developed by following the method explained in Example 15.9. The angle of cutting on the cylinder is $\theta°$.
4. After developing piece 1, the piece 2 and 3 can be drawn by transferring the points A, B, C, ... G, correspondingly as Q, R, S, ... W, marking symmetrically about the centre line KJK as shown in the figure. Here note that the length $q'k' = k'g' =$ QK = KA. Similarly, $w'j' = j'a' =$ WJ = JG. The piece 3 is a mirror image of piece 1 about the centre line KJK. By arranging the three pieces as shown, there will be zero wasting of sheet, while cutting them from a rectangle.
5. Finish the pattern using proper line types and print the given dimensions to complete the drawing.

Example 15.19
Draw the development of the sheet metal tray shown in Fig. 15.22(a) and show the given dimensions on the pattern.

Refer to Fig. 15.19.

1. Draw the front and top views of the tray.
2. Assume that the joints at the four slant edges of the tray are removed and the four sides are brought to the HP by rotating about the four base edges. The outline of the tray in this position gives the required development.
3. In order to mark the corner B, rotate $a'b'$ in the front view about a' to the horizontal position and project downwards to meet the line db extended at B. To get point B_1, draw an arc with centre A and radius = AB, to intersect the projector $b'b$ at B_1, so that AB = AB_1. Similarly, find CD, CD_1 and the remaining two corners.
4. Finish the pattern using proper line types and print the given dimensions to complete the drawing.

15.9 DEVELOPMENT OF SPHERES

Spheres have double curved surfaces. Hence, while bringing the surface to a plane by development, only an approximate pattern is obtained. A spherical surface can be developed by the following two methods.

Lune Method

In this method the sphere is assumed to be cut by vertical planes passing through the vertical axis, so that the whole

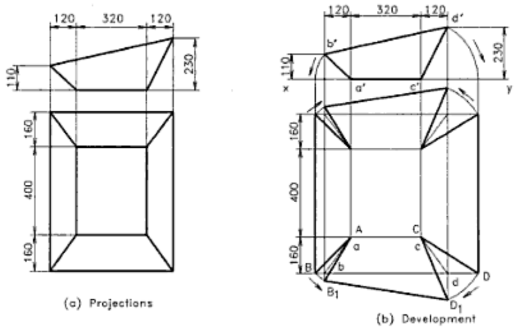


Fig. 15.22 A rectangular tray.

sphere is converted into 12 or 16 *lunes* of equal size as shown in Fig. 15.23. The cutting planes resemble the meridian planes passing through the poles of earth. Each piece is then assumed as a part of a horizontal cylinder having the same diameter of the sphere and is developed accordingly. Because of this kind of approximation, *lune* method is also known as *polycylindric* method or *gore* method.

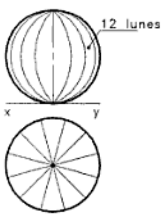


Fig. 15.23 Lunes of a sphere.

Zone Method

In this method, the sphere is assumed to be cut by horizontal planes to form a series *zones* of equal width as shown in Fig. 15.24. Here, each zone is then assumed as a frustum of a right circular cone and it is developed accordingly. Because of this kind of approximation, *zone method* is also known as *polyconic method.*

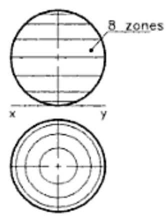


Fig. 15.24 Zones of sphere.

In the lune or zone method the development obtained is an approximate one. If the lunes or zones are inscribed within the sphere, the resulting spherical surface will be slightly less than the actual. At the same time, if it is superscribed the sphere, it will result in a slightly larger one. For a reasonably accurate one, an intermediate position has to be selected. Also, if the number of divisions are increased to 16 or more, better accuracy and smoothness of surface is obtained.

Example 15.20

Draw twelve piece development of the surface of a sphere of diameter 92 mm. Use Lune method.

Refer to Fig. 15.25.

1. Draw the top and front views of the given sphere.
2. The circle in the top view is divided into 12 lunes. The included angle between the cutting planes is

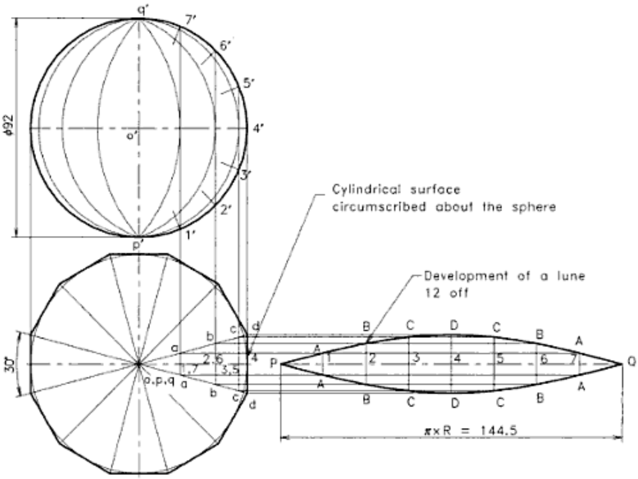


Fig. 15.25 Development (12 piece) of a sphere (Lune method).

360°/12 = 30° and these planes are kept at 15° symmetrical about the horizontal centre line.

3. To get intermediate points on the lune, divide the right semicircle portion of the front view into any number of equal parts (say 8). Name them as 1′, 2′, 3′, etc. and project downwards to obtain the corresponding points on the top view as 1, 2, 3, etc. Note that this lune is half of a cylinder circumscribed about the sphere.

4. To get the development of the lune, mark *aa*, *bb*, *cc* and *dd* on the plan of the lune such that, they are the intersection points of projectors drawn through 1, 2, 3 etc. on the two edges of the lune. Draw the horizontal stretch-line PQ of length $\pi * 92/2$, as an extension of centre line passing through *o*, *p*, *q*. Divide PQ into 8 equal parts and insert vertical sort lines. Draw horizontal lines through points *a*, *b*, *c* and *d* to intersect these vertical lines at A, B, C and D respectively. Draw two smooth curves passing through these points to get the developments of one lune as shown.

5. To complete the sphere, 12 such lunes are required. Hence, that may be written on the drawing as "12 off". It may be noted that the development obtained by this method is circumscribed about the sphere.

Example 15.21

Draw eight piece development of surface of a sphere of diameter 60 mm. Use Zone method.

Refer to Fig. 15.26.

1. Draw the front view of the sphere.
2. Divide the top half of the sphere into 4 zones of equal width. The zones A, B, C, and D have a width equal to $p'q' = q'r' = s'o_1$. Assume that each zone is a frustum of a cone inscribed within the sphere, except the zone D which is a full cone of small altitude.
3. The development of the zones can be drawn after locating the apex of the cones as o_1, o_2, o_3 and o_4, and calculating the sector angles θ_1, θ_2, θ_3 and θ_4. For example, to develop the zone B, draw the arc QQ with centre O_3 and radius = $o_3\theta'$, considering

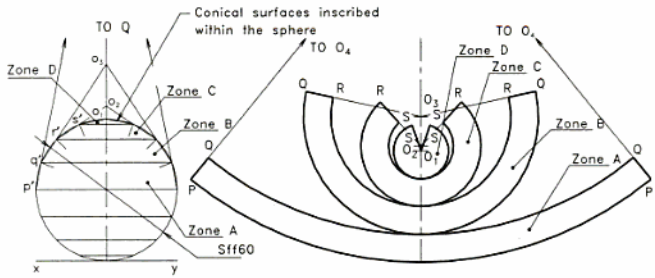


Fig. 15.26 Development (4 × 2 = 8 pieces) of a sphere (Zone method).

the subtended angle θ_3. The same way draw another arc RR of radius o_3r' with the same centre as shown in the figure. Now, QQRR represents the development of the zone B. Similarly, obtain the development of the zones A and C. Development of zone D is similar to the development of a right circular cone with sector angle θ_4.

4. The four zones together represent the development of one hemisphere. Hence, each piece should be marked 2 off to get the full sphere. It may be noted that the development obtained by this method is inscribed with in the sphere.

Example 15.22

A dish antenna made up of sheet metal has a diameter of 144 cm and the spherical radius is 90 cm. If the number of lunes forming the dish is 12, draw the development of one lune so as to get SR90 cm inside the dish.

Refer to Fig. 15.27.

1. Draw the front view and the top view of the dish antenna as shown in figure.
2. The circle in the top view is divided into 12 lunes. The included angle between the cutting planes is 360°/12 = 30° and these planes are kept at 15° symmetrical about the horizontal centre line.
3. To get intermediate points on the lune, divide the $p'q'$ in the front view into 4 equal parts. Name them as 1′, 2′, 3′ and project downwards to obtain the corresponding points on the top view as 1, 2, 3.
4. To get the development of the lune, mark *aa*, *bb*, *cc* and *dd* on the plan of the lune such that, they are the intersection points of projectors drawn through 1, 2, 3, on the two edges of the lune. Draw the horizontal stretch-line PQ of length of arc $p'q'$, as an extension of centre line passing through *o*, *p*, *q*. This can be marked as 4 times the distance $p'1'$ with a bow divider. Draw horizontal lines through points *a*, *b*, *c* and *d* to intersect these vertical lines at A, B, C and D respectively. Draw two smooth curves passing through these points to get the developments of one lune as shown.
5. To complete the dish, 12 such lunes are required. Hence, that may written on the drawing as "12 off".

Tools to solve development problems

1. Development is drawn using only the true lengths on the surface of object.
2. The inside pattern is drawn as a development, so that by folding the shape is obtained.
3. The seam is usually marked on the left side of plan view and the intermediate points in the clockwise direction.
4. For cones and pyramids, the distances should be transferred through the true length line only, to a development or backwards from it.
5. The shortest path is obtained by drawing a straight line between the points marked on the development.

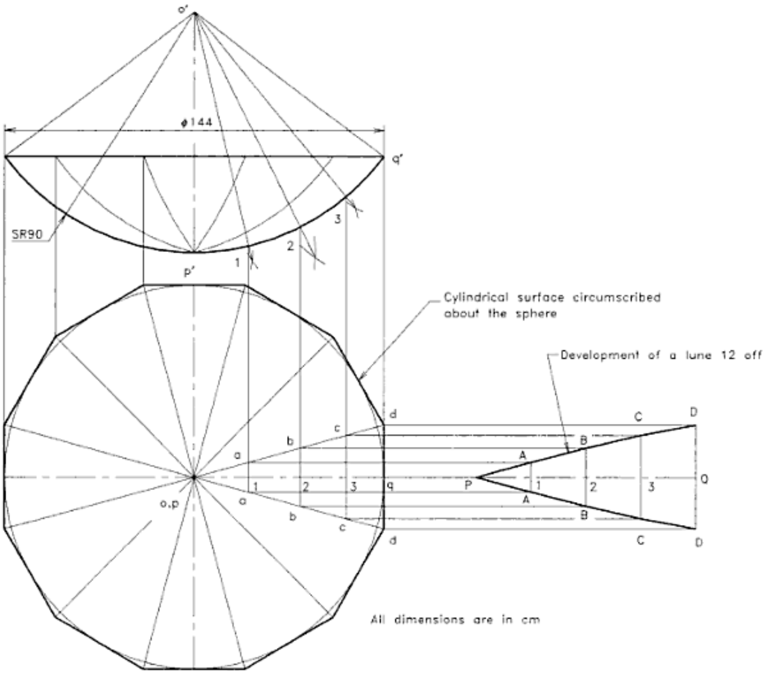


Fig. 15.27 Dish antenna (12 pieces) by lune method.

EXERCISES

SECTION A

(# Problems similar to workedout examples)

1. Draw the development of the surface of a rectangular prism, base 26 mm × 32 mm sides and axis 50 mm long, having a shorter edge of the base parallel to VP. (#)
2. Develop the full size pattern of a right regular hexagonal pyramid, base 24 mm and height 50 mm. (#)
3. Draw the development of the lateral surface of a right regular hexagonal prism of 26 mm base edge and 60 mm height. An ant moves on its surface from a corner on the base to the diametrically opposite corner on the

top face, by the shortest route along the front side. Sketch the path in the elevation. (#)

4. A right circular vertical cylinder of 46 mm diameter and height 50 mm rotates uniformly. A plotter pen-tip moves vertically at uniform speed on the surface of the cylinder from the bottom to the top, so it moves 50 mm while the cylinder completes one rotation. Draw the line marked on the cylinder in the front view and measure the true length of it. (#)
5. A right circular cone has 60 mm diameter and 70 mm height. Draw the complete development of the cone showing the twelve generators. (#)
6. Draw the development of a right circular cone of base diameter 70 mm and height 72 mm resting upon HP on its base. An insect moves from a point on the base edge to the diametrically opposite point on the same edge through a shortest path along the curved surface on front side. Mark the shortest path in the front and top views of the cone. (#)
7. A right regular hexagonal prism of base edge 22 mm and height 60 mm rests on its base with one of its base edges perpendicular to VP. A section plane inclined 40° to HP cuts its axis at its middle. Draw the complete development of the truncated prism including the sectioned surface. (#)
8. A right regular pentagonal pyramid, side of base, 36 mm and height 64 mm, rests on its base upon the ground with one of its base sides parallel to VP. A section plane perpendicular to VP and inclined at 35° to HP cuts the pyramid, bisecting its axis. Draw the development of the truncated pyramid. (#)
9. Draw the development of the lateral surface of the truncated right circular cylinder of diameter 50 mm and height 80 mm. The tube is placed on HP. A section plane, passing through the geometrical centre of the top face of the tube, perpendicular to VP and inclined at 40° to HP, cuts off the top portion of the tube. A similar sectional plane making an angle of 35° to HP in the opposite direction, cuts the axis at a height of 16 mm from the base. (#)
10. A right circular cone, 80 mm base and 80 mm height, rests on its base on the ground plane. A section plane perpendicular to VP and inclined at 45° to HP cuts the cone, bisecting its axis. Draw the development of the lateral surface of the cone. (#)
11. A square prism of 50 mm side length and 70 mm height rests on its base upon HP, such that the vertical faces are equally inclined to VP. A horizontal hole, 50 mm diameter is drilled through the geometrical centre of the prism with the axis perpendicular to VP. Develop the lateral surface of the prism. (#)
12. A vertical cylinder of diameter 70 mm has a central horizontal square through hole of side 48 mm. The centre of the hole is coinciding with the centre of the axis of cylinder and the sides are equally inclined to HP. Draw development of the lateral surface of the cylinder with hole. (#)
13. A cone of base diameter 76 mm and height 76 mm is resting upon HP on its base. A horizontal square through hole of 36 mm side is cut in the cone in such a way that the axis of the hole intersects the axis of the cone at a height of 14 mm from the base. If the four sides of the hole are equally inclined to HP, draw the development of the lateral surface of the cone. (#)
14. Development of a cone is a semicircle with radius 70 mm. A hole of maximum diameter is cut on the development and then it is rolled back to the cone. Draw front and top views of that cone showing the cutting of the hole. (#)
15. Draw the development of a transition piece connecting a 50 cm diameter pipe and a 80 cm × 64 cm rectangular pipe. Height of transition piece is 48 cm. The centre lines of both the circular pipe and the rectangular pipe are vertical and are in alignment. (#)
16. A transition piece connects a 40 cm square pipe at the top and a 80 cm circular pipe at the bottom. If the centre line of the circular pipe coincides with the geometrical centre of the square pipe in the top view and the height of the transition piece is 40 cm, draw its development. (#)
17. Develop the lateral surface of a 90° pipe elbow. Each pipe has a diameter of 500 mm. The maximum length of one leg of the elbow is 700 mm. (#)
18. Develop lateral surface of a three piece pipe bend of 90°. The pipe has a diameter of 500 mm. The heel radius is 750 mm and the throat radius is 250 mm resulting a centre line radius of 500 mm. (#)
19. Draw the development of the sheet metal tray shown in Fig. 15.28 and show the given dimensions on the pattern. Layout the developed pieces in order to cut them from a minimum size of sheet. (#)
20. Draw twelve piece development of the surface of a sphere of diameter 100 mm. Use Lune method. (#)
21. Draw eight piece development of surface of a sphere of diameter 70 mm. Use Zone method. (#)

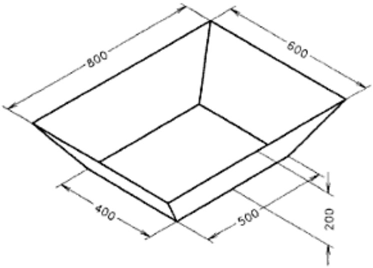


Fig. 15.28 A tray.

22. A dish antina made up of sheet metal has a diameter of 150 cm and the spherical radius is 100 cm. If the number of lunes forming the dish is 12, draw the development of one lune so as to get SR100 cm inside the dish. (#)
23. Figure 15.29 gives the pictorial view of a waste basket. Draw the development of the complete surfaces of the basket.

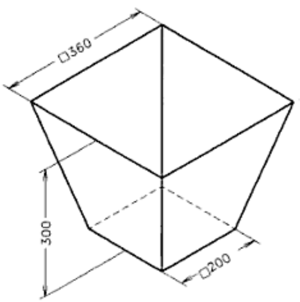


Fig. 15.29 A waste basket.

24. A cone of base diameter 80 mm and height 80 mm is resting upon HP on its base. A triangular horizontal through hole of 50 mm side is cut in the cone in such a way that the axis of the hole intersects the axis of the cone at a height of 25 mm from the base and the bottom side of the hole is parallel to HP. Draw the development of the lateral surface of the cone.

SECTION B

25. A frustum of a hexagonal pyramid has its base 30 mm side, top 16 mm side and height 40 mm and is resting on HP with a base edge parallel to VP. Find the length of a line drawn on the lateral surface from one top corner to the diametrically opposite bottom corner of the pyramid through the shortest path. Also mark the line in the top and front views.
26. Draw the development of an oblique pentagonal prism, the base and top sides are parallel and are regular pentagons of 24 mm side. The top pentagonal face is 60 mm above the bottom one and the axis is inclined at 60° to the base.
27. A pentagonal pyramid of base edge 25 mm and height 50 mm rests on a pentagonal prism of side 25 mm and height 20 mm symmetrically with the corners of the pyramid and prism coinciding. The combined object is cut by an inclined plane making 45° to the horizontal and passing through the centre of the hexagonal faces of contact of the objects. Draw the development of the surface on one side of the section plane, where the apex is existing.
28. A hexagonal pyramid of 30 mm side and 80 mm height rests with its base on HP and one edge of base 20° inclined to VP. A point P, initially situated at the extreme right end of the base, moves around the surface of the pyramid and finally comes back to the starting point. Find the length of the shortest path of the point and show the path in the top and front views.
29. A pentagonal pyramid with base side 25 mm and height 50 mm is sitting on one of the base corners such that the axis is inclined at 30° to HP. In this position, the pyramid is cut by an inclined plane making an angle of 40° with the axis and bisecting it. Draw the projections of the truncated pyramid and the development of the bottom half of the truncated pyramid.
30. A right regular square pyramid, 40 mm base and 70 mm height, rests on its base upon the ground, such that the vertical faces are equally inclined to VP. A horizontal hole of radius 15 mm is drilled through one of the vertical faces. The axis of the hole is perpendicular to VP and 20 mm above HP. Develop the lateral surface of the pyramid.

40. Figure 15.34 shows the elevation of a funnel. Draw the complete development of the funnel.

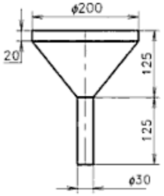


Fig. 15.34

41. Draw the development of the square hood given in Fig. 15. 35.

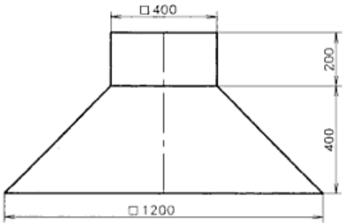


Fig. 15.35

42. Figure 15.36 shows the front view of a square pipe to connect two square pipe lines offset for 200 mm from centre to centre. Draw the development of the connecting pipe.

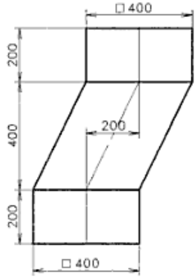


Fig. 15.36

43. A cylindrical water tank of 2 m diameter has a hemispherical bottom. If the height of the cylindrical portion is 1 m, draw the development of the tank. Use lune method to develop the spherical bottom side.

44. A dish antenna made up of sheet metal has a diameter of 24 m. The spherical surface has a radius of 16 m. If the dish has 16 lunes, draw the development of one of the lunes.

45. A cylindrical tank has a hemispherical top of diameter 4 m. If the top is made up of four zones, draw the development of the hemisphere.

CHAPTER

16

Isometric Projection

Isometric projection is a pictorial projection of an object in which a three-dimensional view of an object is shown on a two-dimensional drawing sheet. This projection shows view of three faces of the object equally and hence, it is helpful even to a layman for the proper understanding of the shape of object. It is used by construction engineers for the preparation of pictorial views at the work site as well as by design engineers in the design and development of new or complicated parts, when the shape is difficult to understand from the multiview projection. Three-dimensional piping network can be easily represented by isometric projection. Isometric projection is found more suitable for getting pictorial views of comparatively small objects, because the perspective effect is not considered here.

16.1 PRINCIPLE OF ISOMETRIC PROJECTION

Isometric projection is one of the axonometric projections as explained in Section 9.1 of Chapter 9. It is a pictorial orthographic projection of an object in which a transparent cube containing the object is tilted until one of the solid diagonals of the cube becomes perpendicular to the vertical (picture) plane and the three axes of the cube are equally inclined (35°16′) to this vertical plane.

Isometric projection of a cube can be theoretically obtained by employing the change of position method and is shown in Fig. 16.1. Here, the third elevation $a'b'c'd'e'f'g'h'$ is the isometric projection of the cube. The front view of the cube is resting on one of its corners (g') on the ground with a solid diagonal $e'c'$ perpendicular to VP. This view (front view) shows the right, top and left square faces of the cube as rhombus with equal measure "*Isometric*". It is to be noted that the three faces together form a regular hexagon with inclined edges at 30° to horizontal. The isometric projection of the cube is alone reproduced in Fig. 16.2. In order to distinguish the isometric projection from the usual front view, capital letters are used in this book.

When the three axes (the three mutually perpendicular edges $c'a'$, $c'f'$, and $c'h'$ of the cube in the front view of Fig. 16.1) are equally inclined 35°16′ to the vertical (picture) plane, the edges $g'f'$ and $g'h'$ are seen 30° inclined to the reference line, while the $g'e'$ is seen vertical. Since the edges are equally inclined to VP, they are equally foreshortened to a value of cosine of 35°16′ (approx. 82%). The pictorial view formed by isometric projection can be drawn directly from the projections of the solid in simple position. Figures 16.3 and 16.4 show the method applied to a cube and a rectangular prism. Here, the x and y direction measurements are marked at 30° to the horizontal towards right and left respectively, while the z direction vertical upwards as shown. The edge lengths are marked along these axes after foreshortening to 82%.

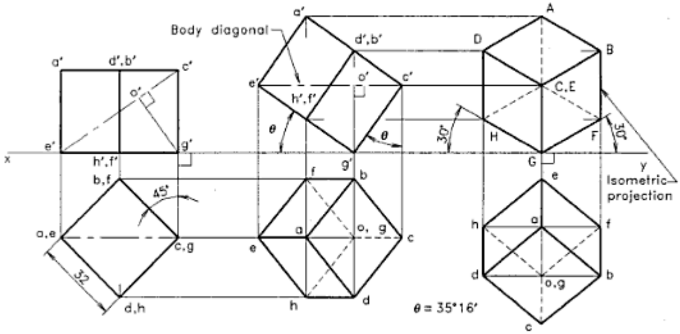


Fig. 16.1 Isometric projection from conventional orthographic projections.

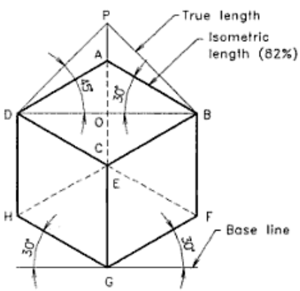


Fig. 16.2 Isometric projection from conventional orthographic projections.

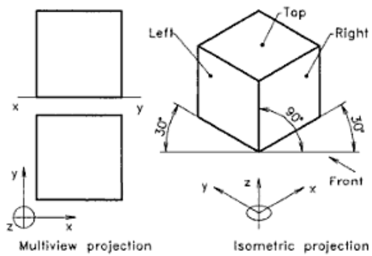


Fig. 16.3 A cube.

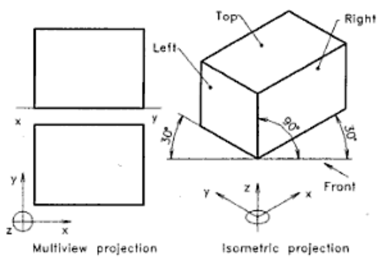


Fig. 16.4 A rectangular prism.

16.2 ISOMETRIC SCALE

In the isometric projection of a cube shown in Fig. 16.2, the top face ABCD is sloping away from the observer and hence the edges of the top face will appear foreshortened. The true shape of the triangle DAB is represented by the triangle DPB.

The extent of reduction of an isometric line can be easily found by constructing a diagram called *isometric scale*. For this, reproduce the triangle DPA as shown in Fig. 16.5. Mark the division of true length on DP. Through these divisions draw vertical lines to get the corresponding points on D'A'.

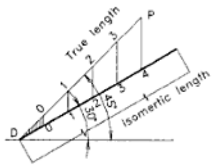


Fig. 16.5 Construction of isometric scale.

The divisions of the line DA give the dimensions to isometric scale.

From the triangles ADO and PDO, the ratio of the isometric length to the true length.

i.e. $DA/DP = \cos 45°/\cos 30°$

$= 0.816$ (cosine of $35°16'$)

The isometric axes are reduced in the ratio

1: 0.816, i.e. 82% approximately.

The isometric scale can be drawn in a simple form as shown in Fig. 16.6. The true length is marked as AB. A line AC is drawn at 15° to AB to intersect another line inclined at 45° to

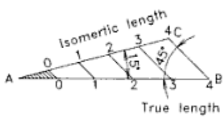


Fig. 16.6 Simplified isometric scale.

horizontal and drawn from B. Then 45° inclined lines are drawn from the divisions on the true length scale AB, so that the corresponding isometric lengths are obtained on the line AC. Even though it is easy to calculate the isometric lengths (82%) with the help of a calculator, it is a custom to show isometric scale nearby the isometric projection (on top or right side) for identification.

16.3 PROCEDURE FOR DRAWING ISOMETRIC PROJECTION

Even though the isometric projection of an object can be drawn by ordinary change of position of view method or auxiliary projection method, they are time consuming and tedious. With the help of the top and front views in simple position, the isometric projection of an object can be directly drawn by using any one or a combination of the two following methods:

1. Box method
2. Coordinate or offset method.

Box Method

In this method, the object is assumed to be enclosed in a transparent rectangular box of size just to fit the object, at the same time the sides of the box are parallel to the three reference planes. This transparent box is drawn first, over the top and front views using thin lines.

The zero position of the *x*, *y* and *z* axes of measurements and their +ve directions are marked in the top view as given in Fig. 17.7(a). Let the zero position be at the corner a (the

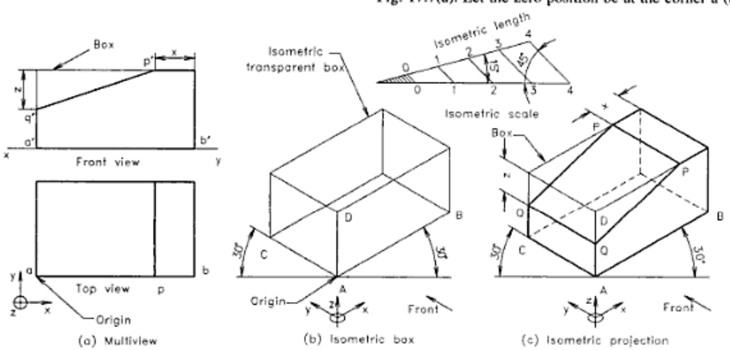


Fig. 16.7 Isometric projection (box method).

'origin'). The circle with '+' mark may be assumed the upward direction from the plane of paper.

After drawing an isometric scale, the isometric drawing can be started. From the orthographic views, take the dimensions in the *x*, *y*, *z* directions from the 'origin' *a*, convert them into isometric lengths (either by using isometric scale or by using calculator) and draw the transparent box [Fig. 16.7(b)]. For this, draw a horizontal reference line of short length and mark point A (origin) at the middle of it. Draw two 30° inclined lines and a vertical line through the point A to locate the three isometric axes AB, AC, and AD respectively to represent the mutually perpendicular edges of the box in isometric projection.

After completing the box, the object is constructed inside, relative to the edges of the box (see Fig. 16.8(c)). On the isometric box the line PP can be marked by locating distance '*x*' multiplied by 0.82 from the end face of box. Similarly, the line QQ can be marked from top face at '*z*' distance in isometric length. By marking various points in the respective *xyz* directions using isometric lengths and converting the thin lines representing the object to the visible and hidden edges, the isometric drawing is completed.

Coordinate or Offset Method

In this method, one of the three isometric planes (top, left or right) is taken as the reference plane and the end points of the edges of the object are marked along an axis perpendicular to this reference plane. Figure 16.8 shows the construction of the isometric drawing by coordinate method. After drawing the top and front views and the isometric scale, the construction of the isometric projection is started by drawing the base of the object. As is done in the box method, the horizontal reference line of short length is drawn and the zero position of the axes (point A) is marked at the middle of it. Now, the 30° lines are drawn to locate the isometric *x* and *y* axes. The base of the object is now completed in the *x* and *y* directions giving the isometric rectangle. The vertical height points are then marked by measuring the *z* values from the front view and converting them to the isometric lengths. For example, to get point *p*, the height *z* is marked at *x* distance along the *x* axis. After marking all the required points and converting the thin lines representing the object to the visible and hidden edges, the isometric drawing is completed.

Coordinate or offset method is best suited for objects containing a large number of non-isometric lines and planes. For certain shapes, a combination of the two methods may have to be applied to get the drawing in a shorter time. It is to be noted that, in isometric projection all the measurements are taken in the *x*, *y*, *z* directions only and they are marked along the respective isometric axes after multiplying by the isometric scale factor 0.82.

Hidden Lines

The hidden edges of the isometric projections are represented by short dashes (Type E or F) and the rules for drawing them are the same as followed for multiview projection. Hidden

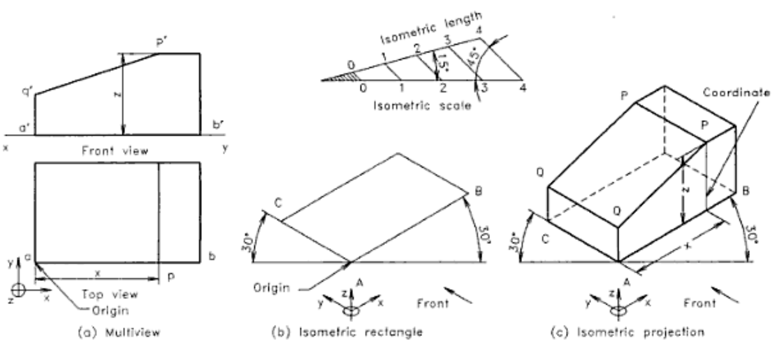


Fig. 16.8 Isometric projection (coordinate method).

lines are generally omitted in isometric projection of objects having a number of hidden edges, because drawing of these lines will reduce the clarity. But simple objects as well as objects requiring the drawing of hidden details, are provided with the invisible informations of the shape.

Selection of Isometric Axes

The isometric axes may be placed in any desired position with respect to the objects. Generally, the axes are determined by the position from which the object is usually viewed or by the position which describes the shape of object more clearly. Figure 16.9 shows the result of varying the origin of the axes and their directions. Here, the second isometric view, showing the top side and keeping the origin at B, gives a better clarity to the shape. To show the bottom side of the object, the third or fourth position may be selected.

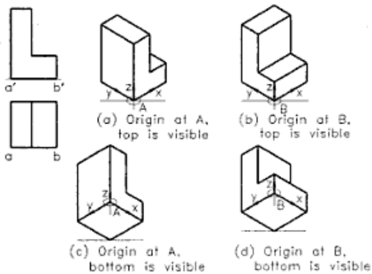


Fig. 16.9 Isometric projection of various axis positions and directions.

Dimensioning

The general rules for the dimensioning of multiview projection is applicable for isometric projection also, except the following.

1. All the extension lines and dimension lines should be parallel to the isometric axes and they should lie on any of the isometric planes.
2. The text should be placed at the middle of the dimension line, after breaking it for a short length.
3. The dimensional values in x direction should be readable from the right side, while those in y direction should be readable from the left side. The dimensional values in z direction should be readable horizontally from the right side.
4. The numerals placed along the three axes should be aligned with the direction of the axes.

Figure 16.10 shows the recommended dimensioning layout for isometric drawing by B.I.S.

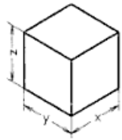


Fig. 16.10 Dimensioning of isometric drawings.

16.4 ISOMETRIC PROJECTION AND ISOMETRIC VIEW

As discussed earlier, isometric projection of an object is the front view of the object placed in the isometric position. Isometric projection is the actual projection of the object on VP. Here, as the edges of the transparent cube are inclined 35°16′ to VP, their projection on VP will have a length of about 82% of the true length, when measured in the isometric position.

To avoid the difficulty in determining the foreshortened lengths, the foreshortening of the axes may be ignored. Hence, isometric projection can be drawn directly, using the true length of the edges of the cube along the isometric axes. As a result, the projection obtained is larger in size than the actual. This projection is called *isometric view* or *isometric drawing*. Thus in short, as the length of the edge of the cube, which are inclined to VP, are taken as equal to the true length of the object itself, the view obtained will be larger than the isometric projection. This enlargement will be to the tune of 1 / 0.816 (i.e. 22.5% larger).

An isometric projection and an isometric view of a cube are shown in Fig. 16.11.

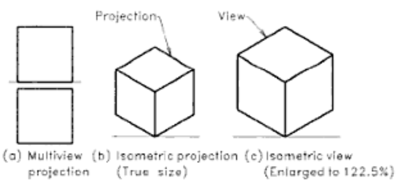


Fig. 16.11 Comparison between isometric projectiona and isometric view.

Notes:

1. An isometric projection of the *x*, *y*, *z* axes are equally inclined to the vertical plane, hence the edges of the object which are parallel to them are foreshortened (to about 82%).
2. The three isometric axes form the three isometric planes namely left, right and top.
3. All the dimensions are measured and marked along the isometric axes only.
4. Isometric projection is the actual size of the pictorial view after foreshortening the true length to about 82%. The isometric scale is drawn nearby the figure to identify the isometric projection.
5. A line or plane which is not parallel to the three axes or the three planes, is called a non-isometric line or plane.
6. The location of the origin of axes may be suitably selected to show maximum details clearly. Generally the front side may be taken towards left or towards right, suitable to the object.
7. Drawing of the isometric projection or view may be done using box method, coordinate (offset) method or a combination of the two.
8. The hidden edges are shown usually for simple objects only or for indicating certain important hidden details.
9. The edge of isometric projection or view are named using capital letters.
10. Isometric drawings are dimensioned along the three axes only.
11. The dimensional value is entered at the middle of the dimension line, after breaking it for a short length. The text should be entered along the directions of *x* and *y*. For *z* direction it should be readable from right side.

16.5 PLANE FIGURES

Isometric projection or view of plane figures are generally drawn on any one of the isometric planes such as top, right or left.

Pentagonal Lamina

Figure 16.12 shows isometric projection of a pentagonal lamina. Here the lamina is kept parallel to HP so that the top isometric plane is seen. To get the projection, the top view of lamina is enclosed in a rectangle 1234 and the origin is marked. Draw a reference line and mark point 1 at the middle of it. Construct the isometric rectangle 1234, parallel to the isometric axes *x* and *y*, after converting the side length as per

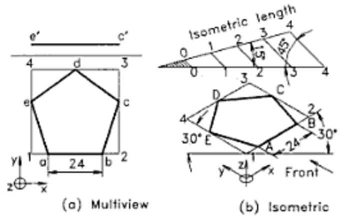


Fig. 16.12 A pentagonal lamina.

the isometric scale. To mark point A, measure the distance in the top view from 1 to a, convert that to isometric length and mark it along the isometric *x*-axis. Similarly, locate the remaining points BCDE on the isometric rectangle. Join the points by thick line to complete the isometric projection on the top plane.

Circular Lamina

Figure 16.14 shows isometric views of a circular lamina of 50 mm diameter, seen on left, top and right planes as ellipses. To get the views, enclose the given circle in a square 1234.

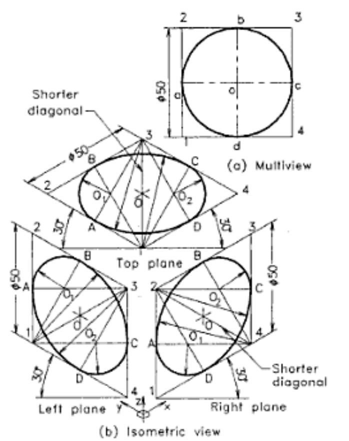


Fig. 16.13 A circular lamina (four-centre construction).

Construct three isometric squares (rhombus) of 50 mm side for the left, top, and right faces as shown in figure. Since the isometric view (not the projection) is required, there is no need of drawing the isometric scale and foreshorten the lengths. In an isometric view, a circle is seen as an isometric circle, i.e. ellipse.

The isometric circle (ellipse) may be constructed approximately by arcs using the four centre method. To locate the four centres and the ends of arcs, join the mid points A, D to the corner 3 and B, C to the corner 1 of the shorter diagonal in the top isometric plane. The intersection points O_1 and O_2 are the centres for short arcs, while the corners 1 and 3 are the centres for long arcs. Draw the short arcs AB and DC with centres O_1 and O_2 respectively. Similarly, draw long arcs BC and DA with centres 1 and 3 respectively to complete the approximate ellipse. The same is repeated on the other two faces to get the isocircles.

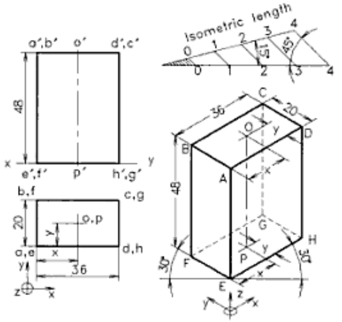


Fig. 16.14 Isometric projection.

16.6 SOLIDS

Isometric projection or view of a solid can be drawn by following the box method or coordinate method explained earlier. The isometric circles may be easily drawn by using the four centre method. The following examples explain the procedure of drawing.

Example 16.1

Draw the isometric projection of a rectangular prism of side of base 36 mm × 20 mm and height 48 mm, resting upon its base on HP and the 36 mm long edges are parallel to VP.

Refer to Fig. 16.14.

1. Draw multi-view projection of the prism in the given position and name the corners. Locate the origin of axes on the left side of top view in order to get the front view on the right isometric plane.
2. Construct the isometric scale as explained earlier (Fig. 16.6) on the top or right side of the area provided for the isometric projection.
3. Draw a short horizontal thin line and mark the mid point of it as the origin (corner E) of the isometric axes *xyz*. From the origin draw 30° inclined line EH towards right to represent *x* direction and another 30° line EF towards left to represent *y* direction. The vertical line EA upwards represents the *z* axis. A symbol for isometric axes may also be marked below this origin as shown in figure for identifying the directions without mistakes.
4. From the top view take the distance *eh* along *x* direction, multiply it by 0.82 and mark it along the *x* isometric axis as EH. Again from the top view take the distance ef along *y* direction, multiply it by 0.82 and mark it along the *y* isometric axis as EF. Similarly, from the front view take the distance *e'a'* along *z* direction, multiply it by 0.82 and mark it along the *z* isometric axis as EA. Repeat the same for all edges along *xyz* directions to get the isometric projection, drawn in thin lines.
5. To locate the vertical axis OP, measure the *x* and *y* distances of *o*, *p* from the top view, multiply it by 0.82 and mark it along the *x* and *y* isometric axes from the corner E at the bottom, as well as from A at the top corner of the isometric box. Join OP by chain line along the *z* axis to indicate the axis.
6. Convert the thin lines to visible and hidden edges as done for projections of solids. Name the corners and axis using capitals, and print the given dimensions as permitted for pictorial views (Refer Fig. 16.10) to complete the drawing.

Example 16.2

Draw isometric view of a hexagonal prism of 50 mm height and side 20 mm long, lying on HP with the axis perpendicular to VP. Select the origin of the isometric axes suitable to get the front view on the left isometric plane.

Refer to Fig. 16.15.

1. Draw the multiview projection of the prism in the given position.
2. Enclose the front view in a box 1'2'3'4' and locate the origin of the isometric axes on the right corner of the top view in order to get the front view on the left (*yz*) isometric plane as shown.

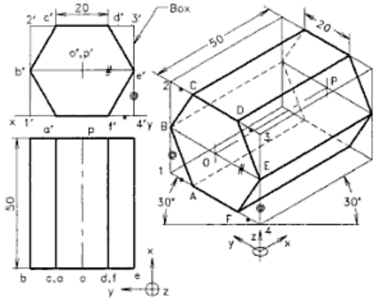


Fig. 16.15 Isometric view (box method).

3. Draw a short horizontal thin line and mark the mid point of it as the origin (4) of the isometric axes *xyz*. From the origin (4) draw 30° inclined thin lines towards right and left directions to represent *x* and *y* isometric axes respectively and a vertical thin line for *z* axis. The symbol for isometric axes may also be marked below this origin.
4. Draw the isometric view of the box 1234 using the lengths measured along *xyz* directions from the front and top views as explained in Example 16.1. Here, the lengths are not foreshortened, because requirement is not an isometric projection but a view.
5. Construct the isometric hexagon ABCDEF on the left isometric plane (1234) of the box. To mark the corner F, take the distance $4'f'$ using a bow divider and mark it along the same (*y*) direction from 4 to F on the isometric box. Similarly to mark the corner E, take the distance $4'e'$ using a bow divider and mark it along the same (*z*) direction from 4 to E on the isometric box. Following the same method mark the remaining corners of the hexagon at the relative positions to the box corners 1234 along the *x*, *y* and *z* directions. Repeat the same for the back hexagonal face of the prism. Complete the view by joining the front and back corners with thin lines along the *x* direction.
6. To locate the horizontal axis OP, join BE, and mark O the mid point as one end of axis. Similarly, on the back face locate P and join OP by chain line to indicate the axis.
7. Convert the thin lines to visible and hidden edges as done for projections of solids. Name the corners and axis using capitals, and print the given dimensions as permitted for pictorial views (Refer Fig. 16.10) to complete the drawing.

Example 16.3

Draw isometric view of a cylinder of 50 mm height and diameter 40 mm, lying on one of its generators on HP with the axis perpendicular to VP. Select the origin of the isometric axes suitable to get the front view on the left isometric plane.

Refer to Fig. 16.16.

1. Draw the multiview projection of the cylinder in the given position.
2. Enclose the front view in a square box $1'2'3'4'$ and locate the origin of the isometric axes on the right corner of the top view in order to get the front view on the left (*yz*) isometric plane as shown.
3. Draw a short horizontal thin line and mark the mid point of it as the origin (4) of the isometric axes *xyz*. From the origin (4) draw 30° inclined thin lines towards right and left directions to represent *x* and *y* isometric axes respectively and a vertical thin line for *z* axis. The symbol for isometric axes may also be marked below this origin.
4. Draw the isometric view of the box 1234 using the lengths measured along *xyz* directions from the front and top views. Here, the lengths are not foreshortened, because requirement is not an isometric projection but a view.

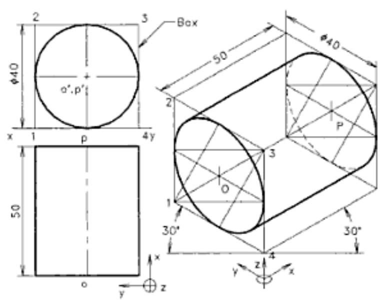


Fig. 16.16 Isometric view (box method).

5. Construct the isometric circle (four-centered ellipse) on the left isometric plane (1234) of the box as explained in Fig 16.13. Repeat the same for the back end face of the box. Complete the view by drawing tangents to the front and back ellipses with thick lines along the *x* direction.
6. To locate the horizontal axis OP, join AC, and mark O, the mid-point as one end of axis. Similarly, on the back face locate P and join OP by chain line to indicate the axis.
7. Convert the hidden edge of the cylinder (half of the back side) to short dashes. Name the axis using capitals, and print the given dimensions as permitted for pictorial views (Refer to Fig. 16.10) to complete the drawing.

Example 16.4

Draw the isometric projection of a pentagonal prism of side of base 30 mm and height 60 mm, resting upon its base on HP and a rectangular face is parallel to VP.

Refer to Fig. 16.17.

1. Draw the multiview projections of the pentagonal prism in the given position.
2. Enclose the object into a rectangular box and name the corners.
3. Construct the isometric scale and draw the isometric projection of the box using isometric lengths. Also add the symbol for isometric axes.
4. Construct the isometric pentagon in the bottom isometric plane, using the top view lengths converted into the isometric lengths.
6. Draw the parallel isometric pentagon on the top isometric plane following the same procedure and join the corners by vertical lines. Also indicate the axis OP as done in Example 16.1.
7. Convert the hidden edges to short dashes, finish the view and enter the dimensions as per BIS to complete the drawing.

Example 16.5

A hexagonal pyramid of height 50 mm and side 24 mm is resting on HP, keeping its axis vertical and one edge of the base parallel to VP. Draw isometric view of the solid.

Refer to Fig. 16.18.

1. Draw the top and front views of the hexagonal pyramid in the given position and enclose the top view of in a rectangle.
2. Construct the isometric view of the rectangle and draw the isometric base of the hexagonal pyramid in side. Also add the symbol for isometric axes.
3. Locate the centre of the isometric hexagon and draw the vertical axis OP of given length. Then join the apex O to the six base corners to complete the pyramid.
4. Finish the view using proper line types, indicate the hidden portion pyramid and dimension the figure as per BIS to complete the drawing.

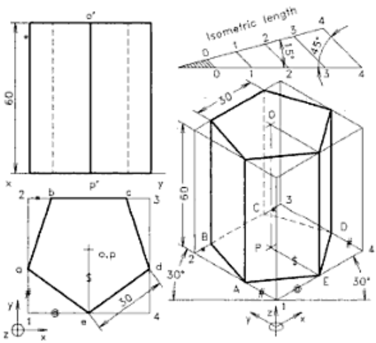


Fig. 16.17 Isometric projection (box method).

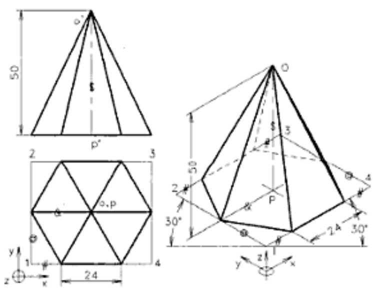


Fig. 16.18 Isometric view (coordinate method).

Example 16.6

A cone of height 50 mm and diameter 48 mm is resting on HP, keeping its axis vertical. Draw isometric view of the solid.

Refer to Fig. 16.19.

1. Draw the top and front views of the cone and enclose the top view of in a square.
2. Construct the isometric view of the square and draw the isometric circle (ellipse) of the cone in side (Refer to Fig. 16.13). Also add the symbol for isometric axes.
3. Locate the centre of the isometric square and draw the vertical axis OP of given length. Then draw the outermost generators of cone by drawing tangents from O to the base (ellipse).
4. Finish the view using proper line types, indicate the hidden portion of the ellipse and dimension the figure as per BIS to complete the drawing.

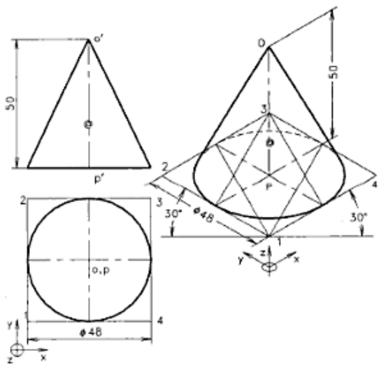


Fig. 16.19 Isometric view of solids (coordinate method).

Example 16.7

A frustum of a cone of base diameter 50 mm, top diameter 30 mm, and height 45 mm is resting upon its base on HP. Draw the isometric projection of the frustum.

Refer to Fig. 16.20.

1. Draw the top and front views of the frustum of cone and enclose the circles of top view inside squares.

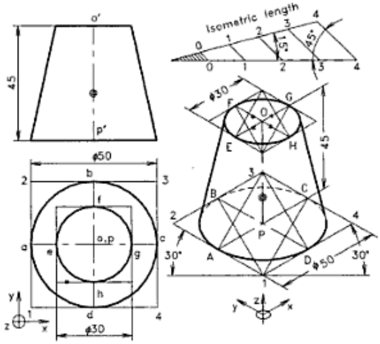


Fig. 16.20 Isometric projection of a frustum (coordinate method).

2. Construct the isometric scale and draw the isometric square 1234 for the base of the cone. Also add the symbol for isometric axes.
3. Construct the isometric circle (ellipse) ABCD inside the isometric square 1234 (refer to Fig. 16.13) and draw the vertical axis OP at the centre of it. Mark the height of the axis after converting it to the isometric length.
4. To construct the top isometric circle about the centre O, draw 30° inclined lines EG and FH through O and mark the length equal to the isometric radius of the top face of cone on them, i.e. OE = OG = OF = OH. Draw the isometric square 5678 (rhombus) parallel to these lines as given in figure and construct the isocircle (ellipse) EFGH inside.
5. Draw the outermost generators of the cone as tangents to the two ellipses. Note that all the true lengths should be multiplied by the isometric scale (82%) before marking, since an isometric projection is the requirement.
6. Finish the view using proper line types, indicate the hidden portion of the ellipse and dimension the figure as per BIS to complete the drawing.

Example 16.8

A square pyramid, edge of base 40 mm and axis 60 mm long, is lying on one of its triangular faces upon HP and its axis

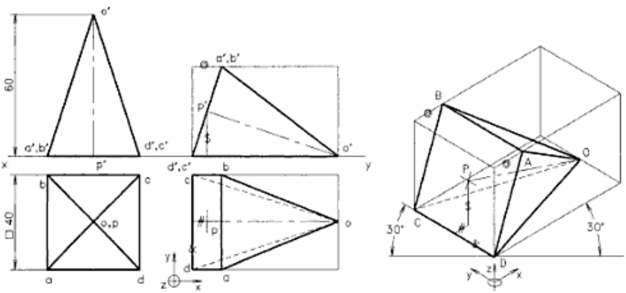


Fig. 16.21 Isometric view of a square pyramid (box-method).

parallel to VP. Draw the isometric view of the given pyramid showing the base.

Refer to Fig. 16.21.

1. Draw the front and top views of the pyramid in the given position and enclose it in a rectangular box.
2. Draw the isometric view of the box using the lengths measured along *xyz* directions. Also add the symbol for isometric axes.
3. Mark the base points ABCD on the box corners and edges and locate the apex O at the middle of bottom edge of the back face. Join these points using thin lines to get the view.
4. To draw the inclined axis OP, locate the end P by marking the *xyz* distances obtained from the top and front views as shown in the figure. Join OP by chain line to indicate the axis. A short cross mark may be shown at P for which the lines are drawn parallel to the base edges.
5. Finish the view using proper line types to complete the drawing.

16.7 SECTIONED SOLIDS

Isometric view of a solid, sectioned by a cutting plane, can be drawn by box method or coordinate method. In box method, after drawing the isometric view of the box, the cutting plane is marked in it and the cut surface is drawn on that plane. But in coordinate method, the sectioned surface is obtained by marking the coordinates of the boundary points from an isometric plane as reference. Figure 16.22 shows isometric projection of a sectioned vertical pentagonal prism using coordinate method. Similarly, Fig. 16.23 shows isometric view of a sectioned horizontal hexagonal prism. Generally coordinate method is found more easy to get the isometric projection or view of a sectioned solid.

Example 16.9

A pentagonal prism of side of base 30 mm and height 60 mm is resting on its base upon HP, keeping one base edge parallel and nearer to VP. The prism is cut by a section plane, 30° inclined to HP and passing through a point on the axis, 40 mm above the base. Draw isometric projection of the prism showing the sectioned surface.

Refer to Fig. 16.22.

1. Draw the top and front views of the sectioned prism in the given position and name the section as 12345. Enclose the plan in a rectangle.
2. Construct the isometric scale and draw the isometric projection of the rectangle to enclose the base of the prism. Also add the symbol for isometric axes.
3. Mark the base points ABCDE on the isometric rectangle and locate the axis end P at the middle of base by measuring the distances along *xy* directions and multiplying by 0.82. Join these points using thin lines to get the isometric pentagon.
4. To draw the sectioned prism, measure the distance $a'1'$, multiply by 0.82 and mark it from the corner A in the *z* direction to obtain the vertical edge A1. Similarly, mark the remaining four vertical edges and the axis as shown in figure. Join the corners to get the projection.
5. Finish the view using proper line types and hatch the cut surface to complete the drawing.

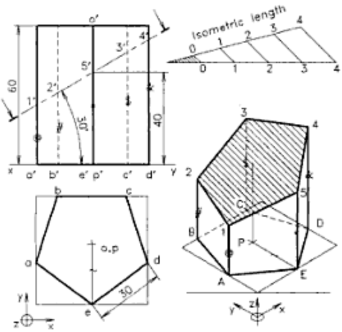


Fig. 16.22 Isometric projection (coordinate method).

Example 16.10

A hexagonal prism of side of base 20 mm and length 50 mm is resting on one of its rectangular faces upon HP, keeping the base parallel to VP. The prism is cut by a vertical section plane 30° inclined to VP and passing through the mid point on the axis. Draw isometric view of the prism showing the sectioned surface.

Refer to Fig. 16.23.

1. Draw the front and top views of the sectioned prism in the given position and name the section as 123456. Enclose the elevation in a rectangle.

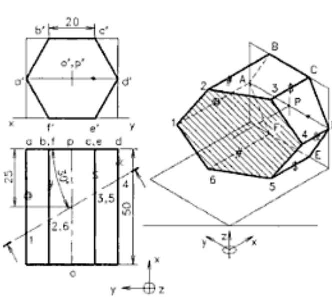


Fig. 16.23 Isometric view (coordinate method).

2. Draw the isometric view of the rectangle enclosing the plan and then construct the isometric view of the rectangle enclosing the elevation on it as shown in figure. Also add the symbol for isometric axes.
3. Mark the base points ABCDEF on the vertical isometric rectangle and locate the axis end P at the middle of base by measuring the distances along y and z directions. Join these points using thin lines to get the isometric hexagon.
4. To draw the sectioned prism, measure the distance a to 1, and mark it from the corner A in the x direction to obtain the horizontal edge A1. Similarly, mark the remaining five horizontal edges and the axis as shown in the figure. Join the corners to get the view.
5. Finish the view using proper line types and draw section lines on the cut surface to complete the drawing.

Example 16.11

A square pyramid of side of base 40 mm and height 60 mm is resting on its base upon HP, keeping the base edges equally inclined to VP. The pyramid is cut by a section plane, 30° inclined to HP and passing through the midpoint of the axis. Draw isometric view of pyramid showing the section.

Refer to Fig. 16.24.

1. Draw the top and front views of the sectioned pyramid in the given position and name the sectioned surface as 1234.

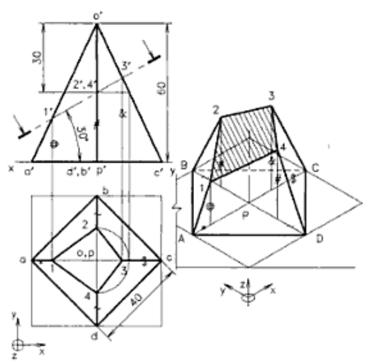


Fig. 16.24 Isometric view (coordinate method).

2. Enclose the base *abcd* in a square as shown in the figure. Draw the isometric view of this square and mark the base points ABCD on it.
3. To locate the corners 1, 2, 3, and 4 of the cut-surface, use the coordinate method. To obtain point 1, measure the coordinate values of the point in the *x*, *y* and *z* directions from the top and front views respectively and mark the same along the isometric axes. Similarly locate 2, 3 and 4, and join them by straight lines to get the cut-surface.
4. Join the points 1234 to the respective base corners A,B,C and D to get the base portion of the pyramid. Locate the axis position P and draw the vertical axis through the point.
5. Finish the view using proper line types, and hatch the cut surface to complete the drawing.

Example 16.12

A cylinder of diameter 48 mm base and 60 mm height, is resting upon its base on HP. A section plane of 45° inclination to HP bisects the axis of the cylinder. Draw the isometric view of the cylinder showing the sectioned surface.

Refer to Fig. 16.25.

1. Draw the top and front views of the cylinder and mark the section plane at 45°. Enclose the base of the cylinder in a square.
2. Construct the isometric view of the square and draw an isometric circle (ellipse) inside to represent the base of the cylinder.
3. In the top view, draw diagonals to the square and mark the points 1, 2, 3, ..., 8 at the eight intersection points of the diagonals on the circle. Mark these two diagonals in the isometric view of the square and locate the points 1, 2, 3, ..., 8 at the intersection of isocircle in the same order.
4. To construct the isometric view of the sectioned cylinder, join the points 8 and 2 in the top view, and then produce to the front view to get point 2′8′ on the section line. This vertical line through 2′8′ is a generator of the cylinder in the front view. Similarly, mark generators through 3′7′ and 4′8′ on the section line. Points 1′ and 5′ represent the extreme points on the section line.
5. Measure the heights (*z* values) of these generators from the base of cylinder to the points 1, 2, 3, ..., 8, in the front view and mark them in the same order on the isometric view as 1-1, 2-2, 3-3, ..., 8-8 in the *z* direction as shown in the figure. Join all the top points by a smooth curve to get the elliptical sectioned surface 1, 2, 3, ..., 8. Also draw vertical lines tangential to the two ellipses to represent the outermost generators of the cylinder.
6. Finish the view using proper line types, and hatch the cut surface to complete the drawing.

16.8 COMBINATION OF SOLIDS

Drawing procedure for the isometric projection of a combination of two or more solids is similar to that of individual solids. The point to be specially considered is the relative position of them in the isometric view. Figure 16.26 shows the isometric view of a cone placed over a square slab.

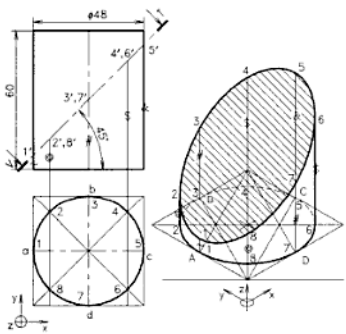


Fig. 16.25 Isometric view (coordinate method).

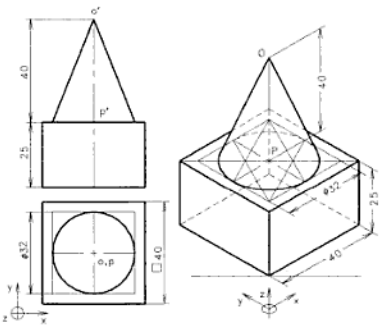


Fig. 16.26 Isometric view (combination of solids).

Here, the base of the cone is placed over the top face of the slab, so that the axes are coinciding.

When a sphere is to be drawn in combination with the another solid, care should be taken to avoid mistakes in marking the centre of the sphere. The method of drawing the isometric projection and view of a hemisphere resting on a square slab, is given Fig. 16.27.

Example 16.13

A cone of diameter 32 mm base and 40 mm height is surmounted over a square slab of 40 mm side and 25 mm thickness on HP so that one edge of the square is parallel to VP. Draw isometric view of the combination.

Refer to Fig. 16.26.

1. Draw the top and front views of the combination of solids keeping the cone centrally over the square slab. Enclose the base circle of the cone in a square.
2. Construct the isometric view of the square slab and mark point P at the middle of the diagonal of top face of the slab, as the axis end of cone. Draw an isometric square (rhombus) of 32 mm side keeping the centre at P. Construct isometric circle (ellipse) inside the rhombus to represent the base of the cone.
3. Mark the axis height OP for the cone and complete the cone by drawing tangents to the ellipse.
4. Finish the view using proper line types, indicate the hidden portions and dimension the figure as per BIS to complete the drawing.

Isometric Projection of a Hemisphere Resting on a Slab

If a hemisphere with centre O and radius R is placed on a square slab as shown in Fig. 16.24(a), the line joining the centre of the sphere o' to the point of contact of the spherical surface with the top of slab p' will be vertical in the front view. If the sphere is tilted and brought to the isometric position, the vertical distance $o'p'$ will be inclined 35°16′ and hence it will get foreshortened to 82% approximately as explained earlier. Thus, in the isometric projection of a hemisphere, the centre will be at a height of 82% of R from the point of contact. Here, OP is the isometric distance of $o'p'$ and is equal to R_i =82% of R [Fig. 16.27(b)]. However, the radius of the outer surface of the hemisphere is same as SR (because there is no difference in size if a sphere is tilted) and is equal to half the major axis of the ellipse representing the top circular plane.

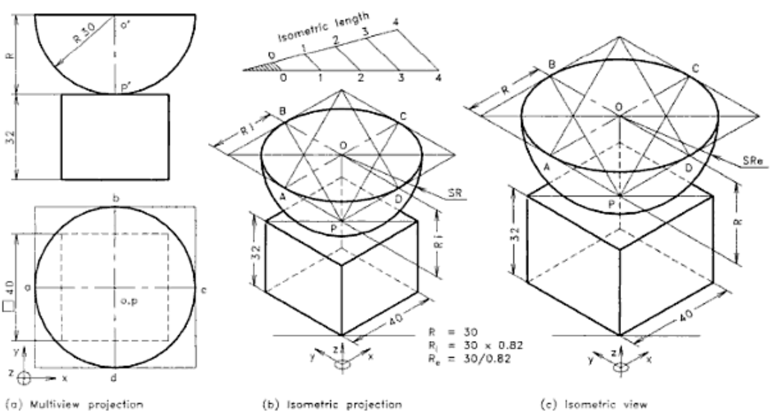


Fig. 16.27 A hemisphere on a square slab.

Isometric View of a Hemisphere Resting on a Slab

In the preparation of isometric view of an object, the foreshortening of the isometric axes is ignored and the true length of the edges of the object are used directly for drawing. As a result, the isometric view obtained will be 22.5% larger in size. Similarly, if the isometric view of the hemisphere is drawn, the view obtained should be 22.5% larger than the given sphere itself [Fig. 16.27(c)]. So, the radius of the hemisphere in the isometric view should be enlarged to 22%, ie, SR_e is equal to $1.225 \times R$, which is half the major axis of the ellipse representing the top circular plane. As the dimensions along the isometric axes are not foreshortened, the line joining the centre of the hemisphere to the point of contact of the spherical surface with the top of the slab $o'p'$ is also not foreshortened. Hence, $o'p' = OP = R$.

Hence, by the above explanations it is clear that:

1. For an isometric projection, all dimensions along *xyz* directions are foreshortened to 82% but the radius for the spherical surface should not be reduced.
2. For an isometric view, all dimensions along *xyz* directions are directly used but the radius for the spherical surface should be enlarged to 122.5%.

Example 16.14

A hemisphere of radius 30 mm is placed centrally on a square slab of side 40 mm and thickness 32 mm so that the flat circular surface is on the top. Draw the isometric projection and view of the solids in the given position.

Refer to Fig. 16.27.

1. Draw the multiview projection of the slab and hemisphere in the given position and enclose the circle in a square.
2. Construct the isometric scale and draw the isometric projection of the slab using isometric (82%) lengths.
3. Also draw the isometric view of the slab using the given dimensions directly.
4. To draw the isometric projection of the hemisphere, (b) locate the centre P of the top face of the isometric projection of the slab and draw a vertical line $OP = R_i$, ie, the isometric length of $o'p'$ (30×0.82 mm). With centre O, draw the isometric square (rhombus) and construct the isocircle (ellipse) of radius R_i inside as shown in the figure. Construct a semicircle of radius equal to half the major axis of the ellipse (SR) at centre O to represent the spherical surface of the hemisphere. Note that the circle is not passing through the point P.
5. To draw the isometric view of the hemisphere, (c) locate the centre P of the top face of the isometric view of the slab and draw a vertical line OP = R, ie, the length of $o'p'$ (30 mm). With centre O, draw the isometric square (rhombus) and construct the isocircle (ellipse) of radius R inside as shown in figure. Construct a semicircle of radius equal to half the major axis of the ellipse (SRe = 30/0.82) at centre O to represent the spherical surface of the hemisphere. Note that here also the circle is not passing through the point P.
6. Finish the view and print the given dimensions to complete the drawing.

Example 16.15

A sphere of 18 mm radius is placed centrally over a hexagonal slab of side length 24 mm and thickness 25 mm. Draw isometric view of the combination.

Refer to Fig. 16.28.

1. Draw the multiview projection of the hexagonal slab and sphere in the given position. Enclose the hexagon in a square.
2. Construct the isometric view of the hexagonal slab using the given dimensions directly as shown.
3. To draw the isometric view of the sphere, locate the centre P of the top face of the isometric view of the slab (centre of line1-4) and draw a vertical line OP = R, i.e, the length of $o'p'$ (18 mm). Construct a circle of radius SRe = 18/0.82 mm at centre O to represent the surface of the sphere.
4. Finish the view and print the given dimensions to complete the drawing.

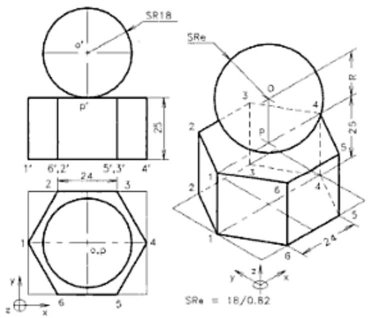


Fig. 16.28 Isometric view .

16.9 OBJECTS

Simple engineering objects can be very clearly described by isometric projection or view. Since the preparation of isometric view is simpler, generally that is preferred for engineering objects. The hidden lines are shown only if they are necessary. The following examples describe the procedure of drawing and they are self-explanatory. The construction lines are retained in order to understand the method of drawing. Since the problems are given as multiview projection, the student has to develop the capacity to read and visualize the shape of object, before starting the drawing. The location of the origin of the isometric axes has to be fixed in such a way that it brings out maximum information of the object.

Example 16.16

Draw the isometric view of the block shown in Fig. 16.29(a).

Refer to Fig. 16.29(b).

1. Locate the origin of the isometric axes on the left bottom corner of the top view and draw the isometric view of the box containing the block.
2. Mark the corners of the block relative to the edges of the box as shown in the figure.
3. Finish the view and print the given dimensions to complete the drawing.

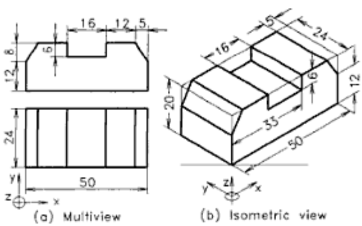


Fig. 16.29 A block.

Example 16.17

Draw the isometric view of the bracket shown in Fig. 16.30(a).

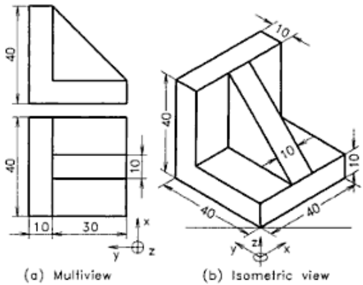


Fig. 16.30 A bracket.

Refer to Fig. 16.30(b).

1. Locate the origin of the isometric axes on the right bottom corner of the top view in order to get clear view of the web on the right isometric plane.
2. Draw isometric view of the bracket considering it as three slabs such as a square horizontal slab, a rectangular vertical slab and a vertical triangular slab joined together.
3. Finish the view and print the given dimensions to complete the drawing.

Example 16.18

Draw the isometric view of the machine part shown in Fig. 16.31(a).

Refer to Fig. 16.31(b).

Draw isometric view of the machine part considering it as three slabs such as a rectangular horizontal slab with a slot, a rectangular vertical slab and a semicircular vertical slab joined together.

Example 16.19

Draw the isometric view of the block shown in Fig. 16.32(a) and need not dimension.

Refer to Fig. 16.32(b).

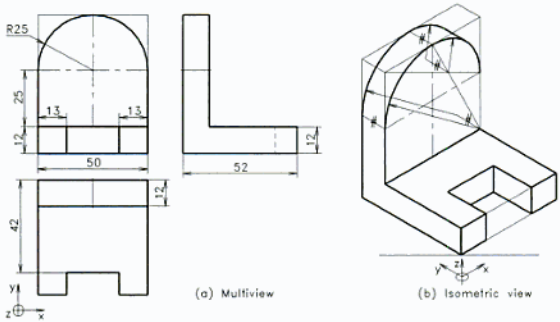


Fig. 16.31 A machine part.

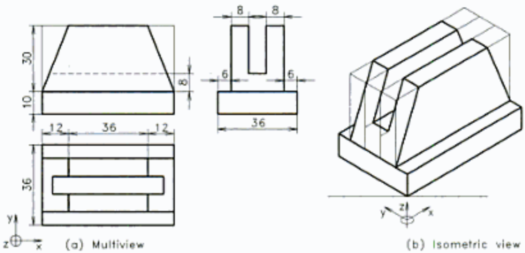


Fig. 16.32 A block.

Tools to solve isometric projection problems

1. The isometric axes in x and y directions are drawn at 30° inclination to horizontal and z axis in vertical direction.
2. In isometric projection, the dimensions measured from multiview along xyz directions should be foreshortened and marked in the corresponding isometric axes.
3. In isometric view, the dimensions measured from multiview along xyz directions are marked directly in the corresponding isometric axes.
4. The radius of arc representing a spherical surface should not be foreshortened in isometric projection, whereas in isometric view it has to be enlarged to 122.5%.
5. Box method or coordinate method can be used interchangeably in isometric drawings. For pyramids, cones and sectioned solids coordinate method is found more fast to reach solution whereas the box method is better for solids in inclined position or objects have intricate shapes.
6. A circle is seen as ellipse and it can be drawn by four centre method.
7. If the origin of axes is kept at the left bottom corner of the top view; the front, top and left side views are seen on right, top and left isometric planes respectively. Similarly, If the origin of axes is kept at the right bottom corner of the top view; the front, top and right side views are seen on left, top and right isometric planes respectively.

EXERCISES

SECTION A

(# Problems similar to workedout examples)

Solids

1. Draw the isometric projection of a rectangular prism of side of base 40 mm × 24 mm and height 50 mm, resting upon its base on HP and the 40 mm long edges are parallel to VP. (#)
2. Draw isometric view of a pentagonal prism of 52 mm height and side 26 mm long, lying on HP with the axis perpendicular to VP. Select the origin of the isometric axes suitable to get the front view on the left isometric plane. (#)
3. Draw isometric view of a cylinder of 60 mm height and diameter 44 mm, lying on one of its generators on HP with the axis perpendicular to VP. Select the origin of the isometric axes suitable to get the front view on the right isometric plane. (#)
4. Draw the isometric projection of a hexagonal prism of side of base 26 mm and height 64 mm, resting upon its base on HP and a rectangular face is parallel to VP. (#)
5. A pentagonal pyramid of height 60 mm and side 28 mm is resting on HP, keeping its axis vertical and one edge of the base parallel to VP. Draw isometric view of the solid. (#)
6. A cone of height 70 mm and diameter 52 mm is resting on HP, keeping its axis vertical. Draw isometric view of the solid. (#)
7. A frustum of a cone of base diameter 56 mm, top diameter 32 mm, and height 52 mm is resting upon its base on HP. Draw the isometric projection of the frustum. (#)
8. A square pyramid, edge of base 52 mm and axis 64 mm long, is lying on one of its triangular faces upon HP and its axis parallel to VP. Draw the isometric view of the given pyramid showing the base. (#)
9. A pentagonal pyramid, edge of base 30 mm and axis 60 mm long, is lying on one of its triangular faces upon HP and its axis parallel to VP. Draw the isometric view of the given pyramid without showing the base surface.

Sectioned solids

10. A hexagonal prism of side of base 26 mm and height 64 mm is resting on its base upon HP, keeping one base edge parallel and nearer to VP. The prism is cut by a section plane, 30° inclined to HP and passing through a point on the axis, 40 mm above the base. Draw isometric projection of the prism showing the sectioned surface. (#)
11. A pentagonal prism of side of base 24 mm and length 64 mm is resting on one of its rectangular faces upon HP, keeping the base parallel to VP. The prism is cut by a vertical section plane 30° inclined to VP and passing through the mid-point on the axis. Draw isometric view of the prism showing the sectioned surface. (#)
12. A hexagonal pyramid of side of base 26 mm and height 64 mm is resting on its base upon HP, keeping two base edges parallel to VP. The pyramid is cut by a section plane, 30° inclined to HP and passing through the midpoint of the axis. Draw isometric view of pyramid showing the section. (#)
13. A cylinder of diameter 56 mm base and 80 mm height is resting upon its base on HP. A section plane of 45° inclination to HP bisects the axis of the cylinder. Draw the isometric view of the cylinder showing the sectioned surface. (#)
14. A cylinder of diameter 50 mm base and 70 mm height is resting upon its base on HP. A section plane of 60° inclination to HP cuts the axis of the cylinder at a height of 55 mm from the base. Draw the isometric view of the cylinder showing the sectioned surface.

Combination of solids

15. A hexagonal pyramid of base edge 20 mm and height 50 mm is surmounted over a square slab of 50 mm side and 30 mm thickness on HP so that one side of the square and one base edge of the pyramid are parallel to VP. Draw isometric view of the combination. (#)
16. A hemisphere of radius 32 mm is placed centrally on a square slab of side 36 mm and thickness 30 mm so that the flat circular surface is on the top. Draw the isometric projection and view of the solids in the given position. (#)
17. A sphere of 20 mm radius is placed centrally over a pentagonal slab of side length 30 mm and thickness 36 mm. Draw isometric view of the combination. (#)

Objects

18. Draw isometric view of the block shown in Fig. 16.33. (#)
19. Orthographic views of a block are shown in Fig. 16.34. Draw the isometric view. (#)

47. Orthographic view of a V-block is shown in Fig. 16.45. Draw the isometric view.

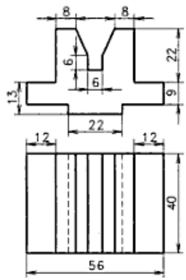


Fig. 16.45

48. A cast iron block is shown in front and side views. Draw its isometric view. Refer Fig. 16.46.

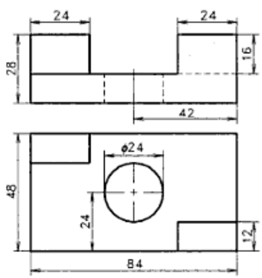


Fig. 16.46

49. A rod support is shown in Fig. 16.47. Draw its isometric view.

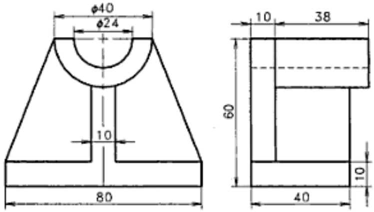


Fig. 16.47

50. Multiview projection of a crank is shown in Fig. 16.48. Draw the isometric view of the crank.

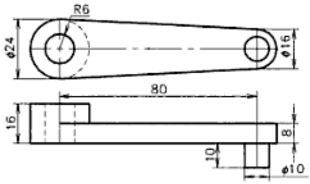


Fig. 16.48

CHAPTER

17

Oblique Projection

Oblique projection is a pictorial projection in which the view of the object is obtained by using parallel projection lines inclined to (not orthographic) the plane of projection. This type of projection is considered as the simplest type of pictorial projection in which the front face is seen as the true shape i.e. just like the front view. Since it is very simple to construct an oblique drawing from its front view, this system of projection is commonly used to sketch the pictorial views of machine components, assemblies etc.

17.1 PRINCIPLE OF OBLIQUE PROJECTION

In oblique projection, parallel projectors are taken from points on the contour of the object to meet the plane of projection (vertical plane) obliquely i.e. at an angle. The angle between the parallel projectors and the picture plane (vertical plane) is generally taken as 45°, while that with HP is taken to be any angle θ. The principle of oblique projection is explained by Fig. 17.1.

In Fig. 17.1(a), a horizontal prism is projected from its top view orthographically as well as at 45° to the VP. Here, the parallel rays of projection are parallel to HP i.e. $\theta = 0°$. This results a kind of pictorial view of the prism, which shows the front view and right side only. Note that the front side has exactly the same size of the elevation.

In Fig. 17.1(b) also the prism is projected from its top view orthographically as well as at an oblique angle 45° to VP and $\theta°$ to HP. Here, the parallel rays are seen with apparent inclinations of α and β to the *xy* line in the top and front views. This results an oblique projection showing the front, right and top sides. Note that, here also the front side of the oblique view is exactly the same as that of the elevation. The apparent angle β is generally taken as 30° or 45°. Although oblique projection is a true parallel projection similar to the orthographic projection, the view can be drawn very easily by constructing the front view and extending the receding edges at β angle to one side. The following sections explain the direct method of drawing oblique views without using the standard projection methods.

17.2 RECEDING LINES AND THEIR ANGLES

In oblique projection, the front face is kept parallel to the plane of projection and the receding axis (which is actually perpendicular to the plane of projection) is drawn at an inclination β. The inclination of the receding axis may be taken as 30° or 45° to the horizontal. The receding lines may be drawn in the following ways.

1. Sloping upwards and to the left,
2. Sloping upwards and to the right,

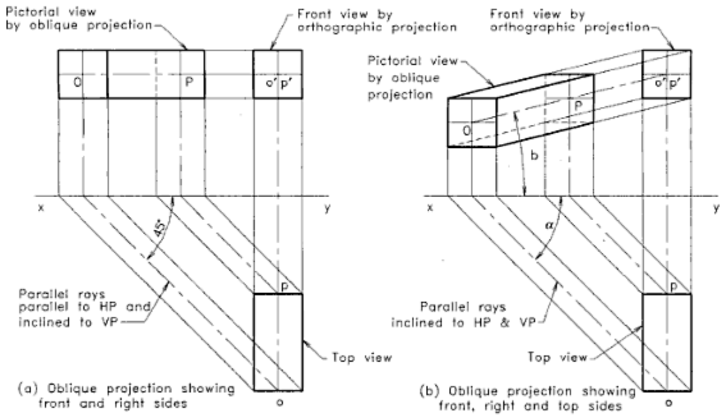


Fig. 17.1 Principle of oblique porjection.

3. Sloping downwards and to the left,
4. Sloping downwards and to the right.

Oblique views of a prism with the above arrangements are shown in Fig. 17.2. Here, the front side is seen as a square in all the four views. Along with the front view, one of the left or right sides and one of the top or bottom sides are also seen. The receding lines are parallel, hence any detail parallel to the vertical plane will be seen with its true size and shape. In the first oblique view the x and z axes are perpendicular to each other, while the y axis is inclined at $\beta°$ to the horizontal. In the second view, y and z axes form the front view and receding lines are along x axis. This change of axes depends on the location of the axis origin in the top view, as did for isometric projection.

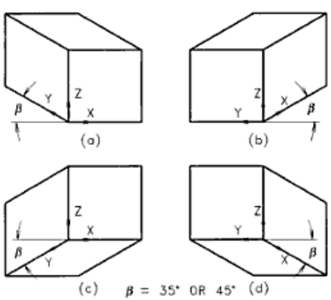


Fig. 17.2 Receding lines and their angles.

17.3 TYPES OF OBLIQUE PROJECTION

Oblique projection can be broadly classified into three types, depending on the shortening of the receding axis.

1. Cavalier projection
2. Cabinet projection
3. General oblique projection

Cavalier Projection

In this type of projection, the angle between the lines of projection and the plane of projection is 45° (i.e. $\theta = 45°$). Hence, the receding lines are drawn to their true lengths. The most common receding angles are 30° and 45°. Cavalier drawing of a cube is shown in Fig. 17.3(a). Here, the width, the height and the depth axes are drawn to the full scale and are marked as 1:1:1. The slope of the lines may be drawn upwards and either to the left or to the right.

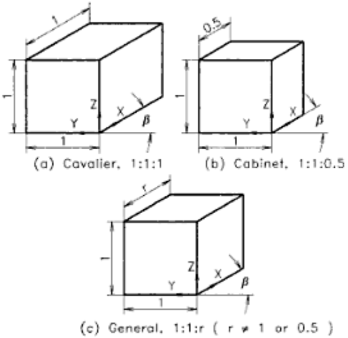


Fig. 17.3 Types of oblique projections.

Cabinet Projection

In this type of projection, the angle between the lines of projection and the plane of projection is 63° 26′ (i.e. θ = 63°). Hence, the receding lines are drawn to half the full size. The most common receding angles are 30° and 45°. Cabinet drawing of a cube is shown in Fig. 17.3(b). Here, the width and height axes are drawn to full scale and the depth axis is drawn to half full size and are marked as 1:1:0.5. The slope of the lines may be drawn upwards or downwards, and either to the left or to the right.

General Oblique

In this type of projection, the lines of projection makes an angle other than 45° and 63° 26′ with the plane of projection (i.e. θ should not be equal to either 45° or 63°). Here, suitable reduction in dimension may be taken along the depth axis, depending upon the angle θ. The most common receding angle are 30° and 45°. The general oblique drawing of a cube is shown in Fig. 17.3(c). Here, the width and the height axes are drawn to full scale and the depth axis is drawn to a scale other than full scale or half full scale and are marked as 1:1:r. Here, r is not equal to 1 or 0.5. The slope of the lines may be drawn upwards or downwards, and either to the left or to the right.

17.4 METHOD OF DRAWING OBLIQUE PROJECTION

Similar to isometric drawing, oblique drawings are also prepared from orthographic views. The front and top views are generally used for this. The various points on the oblique view may be located by the box method or coordinate method, as used in isometric projection. In the two methods, the top view is enclosed in a rectangle as shown in Fig. 17.4(a). The origin of axes is then fixed at the left or right bottom corner of the rectangle in order to see the left or right side of the object in the pictorial view. Here, in Fig. 17.4(a), the right bottom corner is selected so that the details on the right side shall become visible. The angle β of the receding axis (x-axis) is then selected (say 30°). If the box method of marking points is followed, the box which contains the object is drawn from the origin, in the direction of the axes. Figure 17.4(b) shows these details. The lengths of receding lines are governed by the type of view required i.e. cavalier, cabinet or general oblique. Note that, here the y and z axes are at right angles and they form the front plane which gives the front view. After marking the various points by box method, the view can be finished. For coordinate method also the same steps are to be followed. After removing the construction lines, the final view is obtained as shown in Fig. 17.4(c). Note that the details in the front plane has no

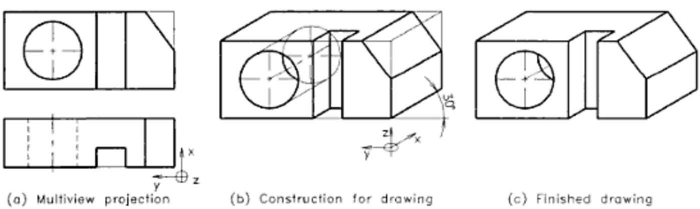


Fig. 17.4 Method of drawing on oblique view.

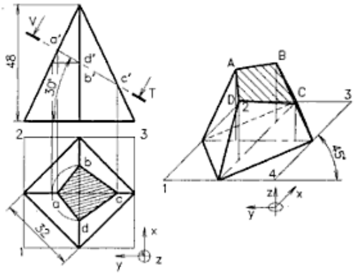


Fig. 17.8 Oblique projection of a pyramid (cavalier, 1:1:1).

17.6 OBLIQUE PROJECTION OF OBJECTS

The method of drawing oblique projection of objects is similar to that of solids. The face containing more number of circles and similar curved shapes is taken as the front plane and hence they can be drawn without distortion. While drawing oblique views, the object may be considered as a box having parallel surfaces. The details on these parallel surfaces are drawn and then they are joined by tangents or corner lines. The principle of box method is generally preferred here. The following examples explain the drawing of oblique views.

Example 17.5

A front and side views of a V-block are shown in Fig. 17.9(a). Draw the cavalier oblique drawing. Take the receding axis at 45° to the horizontal, sloping upwards and to the right.

Refer to Fig. 17.9(b).

1. Construct a rectangular block of width 80 mm, height 60 mm and depth 50 mm taking the receding axis at 45° to the horizontal.
2. Draw the front view within the front face of the rectangular block.
3. Draw receding lines at 45° to the horizontal and with centre o_2 draw an arc on the rear face. Note that $O_1O_2 = 50$ mm.
4. Finish the drawing and print the dimensions.

Example 17.6

Orthographic views of a bracket are shown in Fig. 17.10 (i). Draw its cabinet oblique drawing, keeping the receding axis sloping upwards and to the left, at an angle of 30°.

Refer to Fig. 17.10.

1. As the view required is a cabinet one, the depth of the bracket is to be halved. Construct the base of the bracket taking the width 76 mm, the height 12 mm and the depth half of 60 mm i.e. 30 mm. Complete the front view of the front face. With O_1 as centre, draw to circles.
2. Receding lines may be drawn at an angle of 30° as shown. Also mark the receding axis. Mark O_2 on the receding axis such that $O_1O_2 = 60/2 = 30$ mm. Also mark O_2 on the receding axis such a way that, $O_3O_2 = 12/2 = 6$ mm. With centres O_2 and O_3, draw arcs as shown to obtain the required view.
3. Finish the view and print the given dimensions.

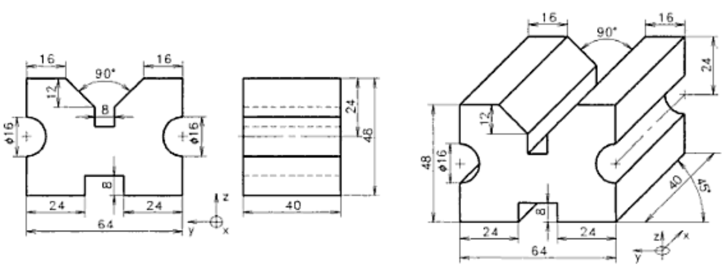


Fig. 17.9 A vee-block (cavalier, 1:1:1).

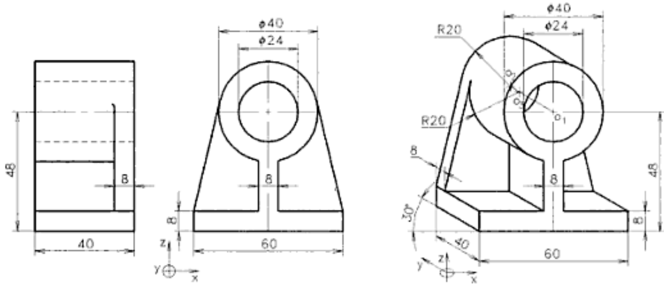


Fig. 17.10 A bracket (cabinet, 1:1:0.4).

EXERCISES

Solids

1. A hexagonal prism of side of base 24 mm and axis 60 mm long rests on one of its rectangular faces upon HP and the axis perpendicular to VP. Draw the oblique projection of the prism by cavalier method, with receding axis inclined at 45°.
2. A cylinder of 60 mm diameter and 80 mm long is lying on one of its generators upon HP and the axis perpendicular to VP. If the cylinder has an axial square hole of 20 mm side equally inclined to HP, draw the oblique projection of the cylinder by cabinet method. The receding axis is sloping 30° upwards and to the left.
3. A pentagonal prism of side of base 30 mm and axis 70 mm long rests with its base on HP and two of the rectangular faces are equally inclined to VP and nearer to it. Draw the oblique projection of the prism by cabinet method, with the receding axis inclined at 45°.
4. Draw the general oblique projection of a hollow cylinder of outside diameter 60 mm, inside diameter 40 mm and height 70 mm, keeping the axis of the cylinder vertical. The receding axis is inclined at 45° in the view, and it is fore-shortened to 0.75 of the full length.
5. A pentagonal pyramid, side base of 32 mm and height 80 mm, rests on its base upon HP such that one base edge is perpendicular to VP. A section plane, inclined at 30° to HP, bisects the axis of the pyramid. Draw the oblique projection of the truncated pyramid by cavalier method, when the receding axis is inclined at 45°.

Objects

6. A tea-poy is made of a rectangular wooden plank of size 900 mm × 600 mm × 25 mm and four vertical legs of section 30 mm × 600 mm. The total height of the table is 400 mm. Draw its oblique projection following cavalier method, with the receding axis inclined at 30° to the horizontal.
7. Elevation and plan of a U-clamp are shown in Fig. 17.11. Draw the cabinet oblique drawing, taking receding axis inclined at 45°, sloping downwards and to the right.

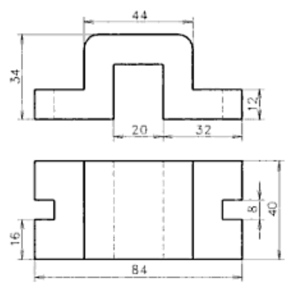


Fig. 17.11 U-Clamp.

12. Front and top views of a shaft support is shown in Fig. 17.16. Draw the oblique projection by cabinet method. The receding axis is inclined at 30°.

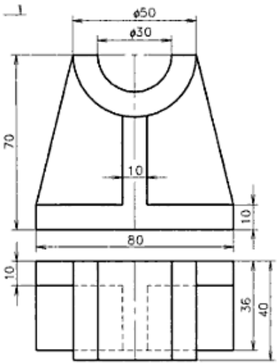


Fig. 17.16 Shaft-support.

CHAPTER 18

Perspective Projection

Perspective projection is a method of graphic representation of an object on a single plane called *picture plane* as seen by an observer stationed at a particular position relative to the object. As the object is placed behind the picture plane and the observer is stationed in front of the picture plane, visual rays from the eye of the observer to the object are cut by the picture plane. The visual rays locate the position of the object on the picture plane. This type of projection is called *perspective projection*. This is also known as *scenographic projection* or *convergent projection*.

18.1 PRINCIPLE OF PERSPECTIVE PROJECTION

In perspective projection, the projectors or visual rays intersect at a common point known as *station point*. A perspective projection of a street with posts holding lights, as viewed by an observer from a station point, is shown in Fig. 18.1(a). The observer sees the object through a transparent vertical plane called *picture plane*. The view obtained on the picture plane is shown in Fig. 18.1(b). In this view, the true shape and size of the street will not be seen as such, since the object is viewed from a station point to which the visual rays converge. On the picture plane the same size objects become smaller as it is going away from the observer. Finally, they become small as a point on the horizon and vanish.

Perspective projection is theoretically very similar to the optical system in photography. It is extensively employed by architects to show the appearance of a building or by an artist-draftsman in the preparation of illustrations of huge machinery.

18.2 NOMENCLATURE OF PERSPECTIVE PROJECTION

The elements of perspective projection are shown in Fig. 18.2. The important terms used in perspective projection are defined below:

1. *Ground Plane (GP)* : This is the plane on which the object is assumed to be placed.
2. *Auxiliary Ground Plane* : This is any plane parallel to the ground plane (not shown).
3. *Station Point (SP)*: This is the position of the observer's eye, from where the object is viewed.
4. *Picture Plane (PP)* : This is the transparent vertical plane positioned in between the station point and the object to be viewed. Perspective view is formed on this vertical plane.
5. *Ground Line (GL)* : This is the line of intersection of the picture plane with the ground plane.

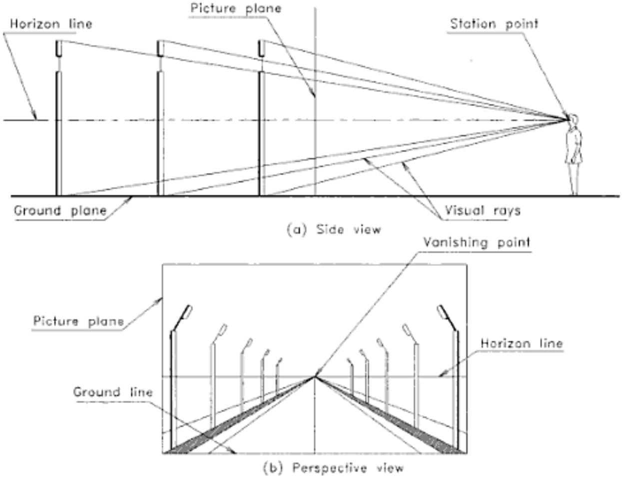


Fig. 18.1 View of a street.

6. *Auxiliary Ground Line:* This is the line of intersection of the picture plane with the auxiliary ground plane (not shown).
7. *Horizon Plane*: This is an imaginary horizontal plane perpendicular to the picture plane and passing through the station point. This plane lies at the level of the observer.
8. *Horizon Line (HL)*: This is the line of intersection of the horizon plane with the picture plane. This plane is parallel to the ground line.
9. *Axis of Vision (AV)*: This is the line drawn perpendicular to the picture plane and passing through the station point. The axis of vision is also called the *line of sight* or *perpendicular axis*.
10. *Centre of Vision (CV)*: This is the point through which the axis of vision pierces the picture plane. This is also the point of intersection of the horizon line with the axis of vision.
11. *Central Plane (CP)*: This is an imaginary plane perpendicular to both the ground plane and the picture plane. It passes through the centre of vision and the station point, while containing the axis of vision.
12. *Visual Rays (VR)*: These are imaginary lines or projectors, joining the station point to the various points on the object. These rays converge to a point.

18.3 CLASSIFICATION OF PERSPECTIVE VIEWS

Perspective views are classified into three categories.

1. Parallel perspective or single point perspective.
2. Angular perspective or two point perspective.
3. Oblique perspective or three point perspective.

The perspective views are based on the relative positions of the object with respect to the picture plane. All the three types of perspectives are shown in Fig. 18.3.

Parallel Perspective (Single Point)

If the principal face of the object viewed is parallel to the picture plane, the perspective view formed is called *parallel*

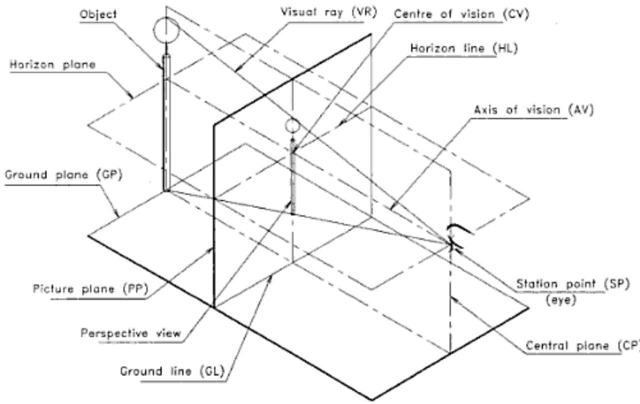


Fig. 18.2 Nomenclature of perspective projection.

perspective. Such a perspective view is shown in Fig. 18.3(a). In parallel perspective views, the horizontal lines receding the object converge to a single point called *vanishing point (VP).* But the vertical and horizontal lines on the principal face and the faces parallel to it on the object do not converge, if these lines are parallel to the picture plane. Because the lines on the faces parallel to the picture plane, do not converge to a point and the horizontal lines receding the object coverage to a single vanishing point, the perspective projection obtained is called ***parallel*** or ***single point perspective.*** Single point perspective projection is generally used to show the interior details of rooms, interior features of various components, etc.

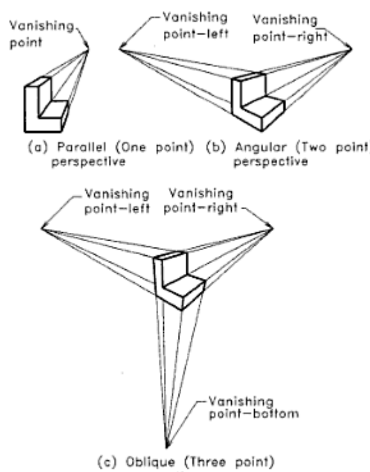


Fig. 18.3 Perspective projections.

Angular Perspective (Two Point)

If the two principal faces of the object viewed are inclined to the picture plane, that perspective view formed is called *angular perspective.* Such a perspective view is shown in Fig. 18.3 (b). In angular perspective views, all the horizontal lines converge to two different points called *vanishing point left* (VPL) and *vanishing point right (VPR).* But the vertical lines remain vertical. Because the two principal faces are inclined to the picture plane and all the horizontal lines on the object converge to two different vanishing points, the perspective view obtained is called *angular or two point perspective.* Two point perspective projection is the most generally used one to present the pictorial views of long and wide objects like buildings, structures, machines, etc.

Oblique Perspective (Three point)

If all the three mutually perpendicular principal faces of the object viewed are inclined to the picture plane, the perspective view formed is called *oblique perspective*. Such a perspective view is shown in Fig. 18.3(c). In oblique perspective views, all the horizontal lines coverage to two different points called *vanishing point left* (VPL) and *vanishing point right* (VPR) and all the vertical lines converge to a third vanishing point located either above or below the horizon line. Because all the three principal faces are inclined to the picture plane and all the horizontal and vertical lines on the object converge to three different vanishing points, the perspective view obtained is called *oblique* or *three point perspective*.

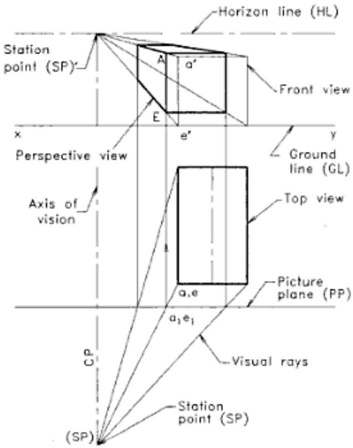


Fig. 18.4 Elements of perspective projection (visual ray method–using front view).

Three point perspective projection may be used to draw pictorial views of huge and tall objects like tall buildings, towers, structures, etc. If the station point is nearby the ground plane, the vertical lines will vanish at a point above the horizon line. If the station point is located above the object, all the vertical lines will vanish to a point below the horizon line.

18.4 METHODS OF DRAWING PERSPECTIVE VIEWS

Perspective view of an object can be drawn by following any one of the methods:

1. Visual ray method.
   (a) Using top and front views.
   (b) Using top and side views.
2. Vanishing point method.

To obtain a perspective view (parallel, angular or oblique), by the visual ray or vanishing point method, there are different approaches in practice. Here, one among the simplest, which is obeying the first angle projection, is explained.

To start the drawing of a perspective view, the following data are the basic requirements.

1. The top and front or side views of the object.
2. The location of the station point SP (the point of sight or camera position) in relation to the object, in three dimensions.
3. The location of the picture plane PP in relation to the object, in three dimensions.

In visual ray method, the points forming the perspective view are obtained by drawing visual rays from the station points (the point of sight) SP and SP′ or SP″ to the top and front or side views respectively of the object.

In vanishing point method, the vanishing point or points are to be located initially. Vanishing points are the imaginary points located at infinite distance from the observer and they exist on the horizon line. The parallel edges, which are perpendicular or inclined to the picture plane, will converge to a point, if they are extended to infinity. Following the principle, the parallel edges going away from the picture plane are drawn converging to the vanishing point or points, to get the perspective view.

18.5 VISUAL RAY METHOD, USING TOP AND FRONT VIEWS

After obtaining or fixing the required data, the top and front views of the object are drawn following the first angle projection theory as shown in Fig.18.4. Here, the top view, the picture plane PP, the plan of station point SP and the visual rays are drawn initially below the ground (*xy*) line GL. The front view, horizon line HL, elevation of the station point SP′ and the visual rays are drawn next. This completes the drawing of elements of perspective projection. In Fig. 18.4, a square prism is lying on ground with the square face parallel to PP. To get the perspective view seen from SP, draw vertical projectors through the crossing points of visual rays on picture plane PP. The points of intersection of these vertical projectors on the visual rays drawn in the front view give the perspective view. For example, corners A and E on the perspective view are obtained by drawing vertical projectors through a_1 and e_1 on PP, and extending them to intersect on visual rays drawn to a' and e' respectively.

It is to be noted that the top and perspective views are finished using thick lines, while all the remaining lines are left as thin. The corners of the perspective view may be marked with capital letters, as did for other pictorial views. Dimensions are not usually marked on perspective views but the elements used for perspective view drawing should be dimensioned fully by a student without failure.

Parallel Perspective by Visual Ray Method

In parallel perspective, the principal face of the object is kept parallel to the picture plane (PP). If a face is kept touching the PP, that face will be seen in its true size and shape. As the face goes behind the PP, the view of it will be reduced in size, but will keep the true shape i.e. a circle or square will retain its shape, if the plane containing it is parallel to PP. Figure 18.5 shows the parallel perspective of a square prism. Here, the front face is slightly behind the PP, hence that face is seen to be slightly reduced in size, but keeps the square shape. Similarly, Fig. 18.6 shows the parallel perspective of a horizontal pentagonal prism. Here the prism is touching the PP hence, that face is seen as the true size and shape. The back side face is also a regular pentagon but of smaller size because it is parallel to and behind the PP.

If there are curved or non-parallel edges on the object and are not parallel to picture plane, the perspective of such shapes can be drawn by enclosing them in rectangles or boxes as did for other pictorial views. Fig. 18.7 shows the parallel perspective of a circle contained in HP. The intermediate points are located in relation to the edges of the rectangle or box.

Example 18.1

A square prism of 30 cm side and 50 cm length is lying on the ground plane on one of its rectangular faces, in such a way that one of its square faces is parallel to and 10 cm behind the picture plane. The station point is located 60 cm in front of the picture plane and 40 cm above the ground plane. The central plane is 50 cm away from the axis of the prism towards the left. Draw the perspective view of the prism.

Refer to Fig. 18.5.

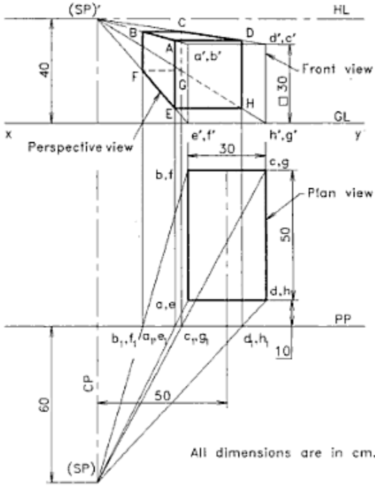


Fig. 18.5 Parallel perspective (visual ray method—using front view).

1. Draw the xy (GL) line and construct the top and front views of the prism in the given position following the orthographic projection rules as shown in figure.
2. Mark the top view of the picture plane (PP) and the front view of the horizon plane HL at a distance of 40 cm above the xy line (GL). Locate the central plane (CP) 50 cm away from the axis of the prism, towards the left side. Locate the top view of the station point (SP) at a distance of 60 cm in front of the PP and on the CP. Also mark the front view of the station point (SP)′ on the HL.
3. Draw visual rays from (SP) to the various corners of the top view of the prism, piercing the PP at a_1, b_1, c_1, etc. Also draw the visual rays from (SP)′ to all corners of the front view.
4. Draw vertical lines upwards from the points a_1, b_1, c_1, etc. to intersect the corresponding visual rays

drawn from a', b', c', etc. Join the points to get the required perspective ABCDEFGH.

5. Convert the top and perspective views to proper line types and print the given dimensions.

Angular Perspective by Visual Ray Method

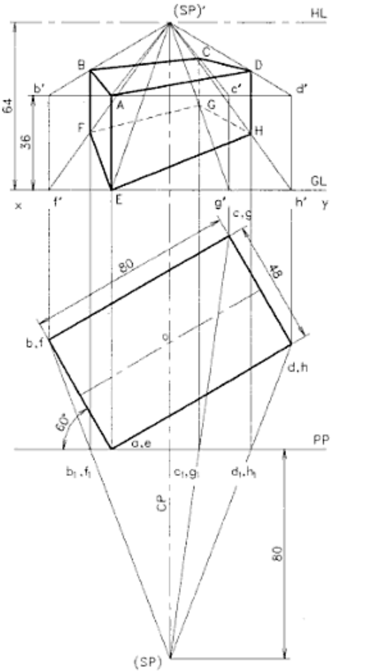
In angular perspective projection, two principal faces (front face and one side face) of the object are kept at an angle, usually 30° or 60°, to the PP. As is done in the parallel perspective, the top view, front view and the perspective elements are also drawn for the angular perspective. The visual rays are drawn from (SP) to the top view corners and from (SP)′ to the front view corners. The points on the perspective view are obtained by inserting verticals from the points of intersection of visual rays with PP, to meet the visual rays drawn to the front view.

Example 18.2

Draw the perspective view of a rectangular prism of 80 cm × 48 cm × 36 cm size, lying on its 80 cm × 48 cm rectangular face on the ground plane, with a vertical edge touching the picture plane and the end faces inclined at 60° with the picture plane. The station point is 80 cm in front of the picture plane, 64 cm above the ground plane and it lies in a central plane, which passes through the centre of the prism.

Refer to Fig. 18.6.

1. Draw the top view, front view and the perspective elements of the prism as per the given data.
2. Draw visual rays from (SP) to the corners of the top view and from (SP)′ to the front view.
3. Insert verticals through the visual ray piercing points on PP, to meet the visual rays drawn to the front view. For example, to get the point B on the perspective view, join (SP) to b in the top view to cross PP and at b_1. Insert a vertical line from b_1 to meet the visual ray to b'(SP)′ at B. Similarly obtain A, C, etc.
4. Convert the top, side and perspective views to proper line types and print the given dimensions.



All dimensions are in cm.

Fig. 18.6 Angular perspective (visual ray method-using front view).

18.9 ANGULAR PERSPECTIVE BY VANISHING POINT METHOD

In vanishing point method, the vanishing point or points are to be located on picture plane. Vanishing points are the imaginary points located at infinite distance from the observer. In perspective drawings, if a visual ray is drawn from a station point to an infinite distant object, the point of piercing of that ray through the picture plane (PP) is referred to as the vanishing point on the PP.

Three top views of a horizontal line PQ, inclined at θ degrees to the picture plane, located in three different positions with respect to the station point, are shown in Fig. 18.7. When the top view pq is in position (i), the length of the line obtained on PP is p_1q_1. As the top view moves towards the left side, without changing the inclination θ, the length of the line obtained on PP reduces to p_2q_2 and is shown

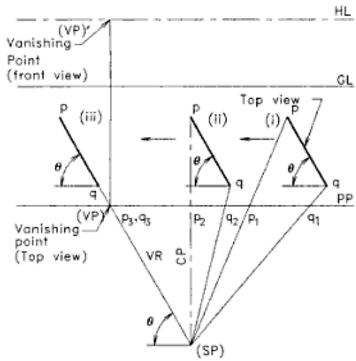


Fig. 18.7 Vanishing point of a line inclined to the picture plane.

in position (ii). When it moves further towards the left, the length of the line on PP gradually reduces and finally, it becomes zero. Hence P_3 coincides with q_3. This point is called the *top view of the vanishing point* (VP) of the line PQ on PP, for the given conditions. It may be noted that the inclination of the visual rays, drawn to the vanishing point, has the same inclination as that of the line *pq*. The front view of the vanishing point (VP)″ lies on the horizon line (HL). Hence, the point of intersection of the vertical line through VP and the horizon line HL is (VP)′.

To draw the angular perspective of an object, the top view and the elements of perspective are drawn first. Then the vanishing points (VPL) and (VPR) are determined by the above principle. By considering the height of the object, rays are drawn to the two vanishing points. Vertical lines are drawn from the visual ray-crossing points on the PP, to intersect these rays for the points on the perspective view.

Example 18.3

A rectangular prism of dimensions 80 cm × 48 cm × 32 cm is lying on the ground in such a way that one of the largest faces is on the ground. A vertical edge is 10 cm behind PP and longer face containing that edge makes 30° inclination with PP. The station point is 80 cm in front of the PP, 60 cm above the ground and lies in a central plane which passes through the centre of the prism. Draw the perspective view by vanishing point method.

Refer to Fig. 18.8.

1. Draw the top view of picture plane PP, the top view of the prism at the given position and mark the station point (SP), as shown in the figure. Also draw the ground line GL at any convenient distance from PP and mark the horizon line HL.
2. Through (SP), draw lines parallel to the edges *ad* and *ab* of the top view of the prism, to intersect PP at (VPR) and (VPL) respectively. Draw vertical lines from (VPR) and (VPL) to intersect HL at (VPR)′ and (VPL)′ respectively, which are the front views of the vanishing points.
3. Since the edge ae is 10 cm behind the picture plane, produce the face adeh to meet the PP at the point *s*,*t*. Draw a vertical line from the point *s*, *t* to intersect the ground line GL at T. Since the edge *st* is touching on PP, it will have the true length in the perspective view. Hence, mark ST = 32 cm, (the thickness of the prism) from the line GL as shown in the figure.
4. Join points S and T to (VPR)′ and drop a vertical line from point (a_1, e_1) to intersect these rays at A and E. Draw rays from points A and E to (VPL)′ and drop a vertical line from (b_1, f_1) to intersect these rays at B and F. Now ABFE is a face on the perspective view. Similarly find out points C, D, G and H and join these points to get the perspective view.
5. Draw the visible edges with thick lines and convert the hidden edges to short dashes, to complete the required view.
6. Finish the view and print the given dimensions as shown in the figure.

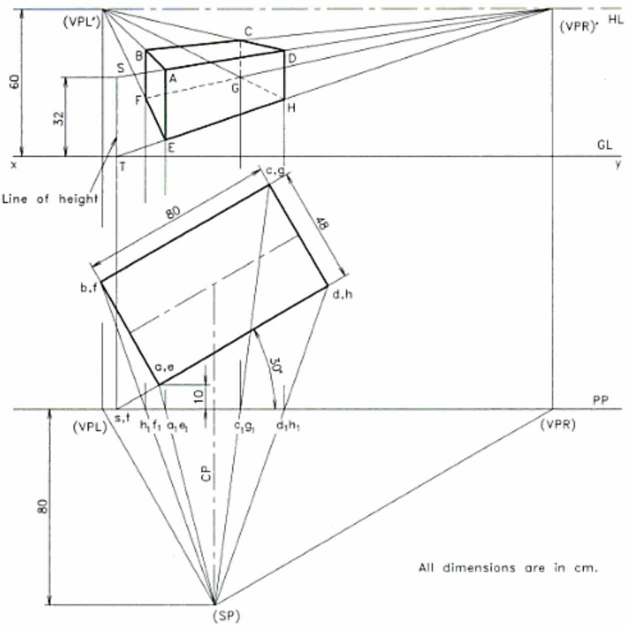


Fig. 18.8 Angular perspective (vanishing point method).

EXERCISES

(# Problems similar to the workedout examples)

Visual ray method

1. A square prism of 32 cm side and 54 cm length is lying on the ground plane on one of its rectangular faces, in such a way that one of its square faces is parallel to and 12 cm behind the picture plane. The station point is located 60 cm in front of the picture plane and 48 cm above the ground plane. The central plane is 50 cm away from the axis of the prism towards the left. Draw the perspective view of the prism. (#)
2. Draw the perspective view of a hexagonal prism, 20 cm side and 40 cm long, lying on one of its rectangular faces on the ground plane. One of its pentagonal faces touches the picture plane and the station point is 60 cm in front of the picture plane, 28 cm above the ground plane and lies in the central plane, which is 70 cm to the left of the centre of the prism. (#)
3. Draw the perspective view of a rectangular prism of 70 cm × 44 cm × 32 cm size, lying on its 70 cm × 44 cm rectangular face on the ground plane, with a vertical edge touching the picture plane and the end faces inclined at 60° with the picture plane. The station point is 80 cm in front of the picture plane, 70 cm above the ground plane and it lies in a central plane, which passes through the centre of the prism. (#)

Vanishing point method

4. A rectangular prism of dimensions 75 cm × 50 cm × 30 cm is lying on the ground in such a way that one of the largest faces is on the ground. A vertical edge is 12 cm behind PP and longer face containing that edge makes 30° inclination with PP. The station point is 90 cm in front of the PP, 64 cm above the ground and lies in a central plane which passes through the centre of the prism. Draw the perspective view by vanishing point method. (#)
5. A circular lamina of 60 cm diameter is kept vertical on the ground plane and is inclined 45° to the picture plane. The station point is positioned 80 cm in front of the picture plane and 82 cm above the ground plane. The central plane containing the station point passes 40 cm away to the right of the centre of the circular lamina. Draw the perspective view of the lamina, if its periphery is in contact with the picture plane. Employ vanishing point method. (#)
6. A vertical rectangular prism of dimensions 60 cm × 50 cm × 30 cm is standing on the ground on one of the end faces such that the picture plane passes through the prism. A vertical edge of 60 cm length is 12 cm infront of PP and the 60 cm × 30 cm face containing that edge makes 30° inclination with PP. The station point is 140 cm in front of the PP, 90 cm above the ground and lies in a central plane which passes through the corner infront of PP. Draw the perspective view by vanishing point method. (#)

Module F

Introduction to Machine Drawing

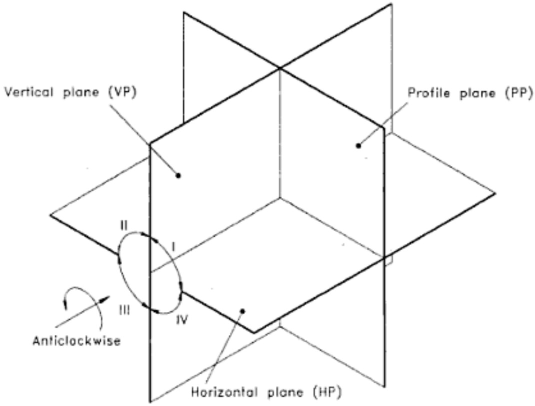


Figure 19.1 Planes of projection showing octants (anticlockwise system).

19.2 FIRST ANGLE PROJECTION AND THE LOCATIONS OF THE THREE VIEWS

In first angle projection, the object is assumed to be positioned in the first quadrant as shown in Figure 19.2. Here, the object is placed in such a way that its main faces are parallel to the principal planes and hence the projections of these faces on the principal planes will have the true shape and size.

The three views formed on the principal planes are described below:

1. Front view: The view of the object formed on the vertical plane (VP) or frontal plane, when looked orthogonally at the object in the direction marked FRONT, is called *front view*. Here, the VP is behind the object. Thus, the object is in between the plane of projection and the eye. This is indicated by

EYE > OBJECT > PLANE

2. Top view: The view of the object formed on the horizontal plane (HP) when looked orthogonally at the object from the top in the direction marked TOP, is called *top view*. Here, the horizontal plane is below the object. Thus, the object is in between the plane of projection and the eye. This is indicated by

EYE > OBJECT > PLANE

3. Left side view: The view of the object formed on the profile plane (PP), when looked orthogonally at the object in the direction marked LEFT-HAND SIDE, is called *left side view*. Here, the profile plane is behind the object. Thus, the object is in between the eye and the plane of projection. This is also indicated by

EYE > OBJECT > PLANE

To bring the three views into a single plane, revolve the coordinate planes through 90°, as indicated by the arrows. The complete layout of the three views of the object, after rabation, will be as shown in Figure 19.3.

19.3 THIRD ANGLE PROJECTION AND THE LOCATIONS OF THE THREE VIEWS

In third angle projection, the object is assumed to be positioned in the third quadrant. Here, the object is placed in such a way that its main faces are parallel to the principal planes and hence the projections of these faces on the principal planes will have the true shape and size.

The complete layout of the three views of an object in third angle projection is as shown in Figure 19.4.

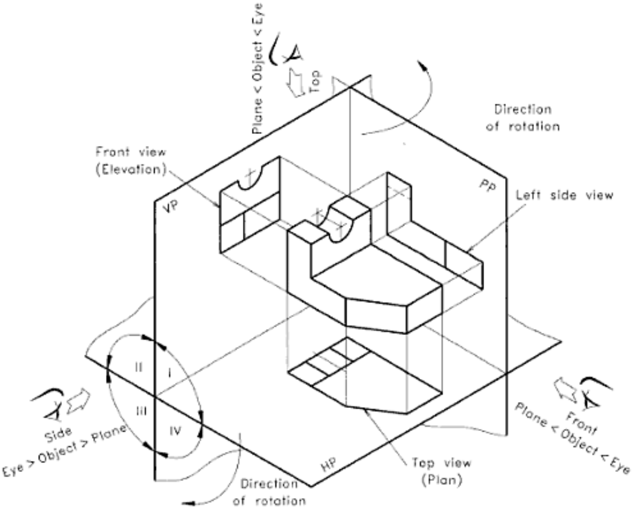


Figure 19.2 First angle projection following anticlockwise system.

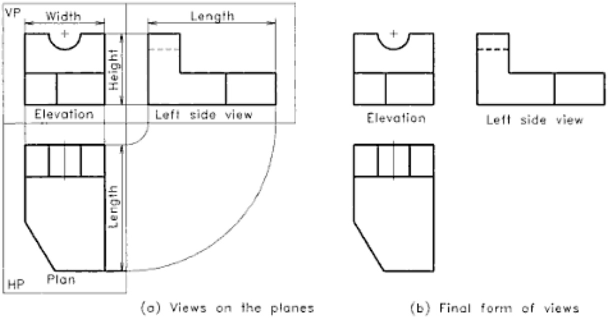
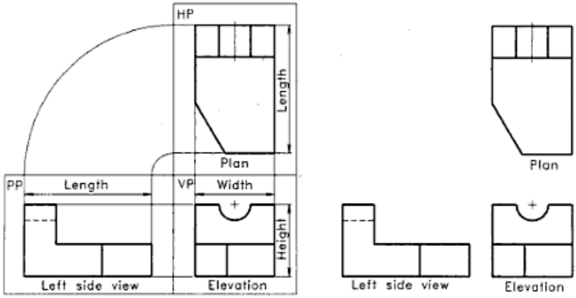


Figure 19.3 Layout of the principal views (first angle projection).



(a) Views on the planes (b) Final form of views

Figure 19.4 Layout of the principal views (third angle projection).

19.4 TRANSPARENT BOX AND THE SIX ORTHOGRAPHIC VIEWS

To describe the shape and size of a complicated object completely on a sheet of paper, sometimes, more than three views are required. In such cases, transparent box method can be used to get six different views of the object. Here, the object is assumed to be placed inside a transparent box, keeping its important face parallel to the front side of the box (see Figure 19.5). The six sides of the box are assumed to be six planes of projection. The observer views the enclosed object from outside. Six views are obtained on the six planes by drawing projectors from various points on the object to these planes. These views are called *front, top , right side, left side, bottom* and *rear views*. To transfer these six views, the box is opened to one plane, the plane of the drawing sheet. The six views can be developed by applying the principle of first and third angle projection methods.

In first angle projection method, the object is placed between the eye and the plane of projection. Hence, we follow the *EYE* > *OBJECT* > *PLANE* principle.

Consider a transparent box ABCDEFGH containing an object inside it, as shown in Figure 19.5. The following are the views obtained on the six sides of the transparent box.

1. *Front view:* The view of the object formed on the rear side ABCD of the box, when looked in the direction of the arrow marked by FRONT, is called *front view*.

2. *Top view:* The view of the object formed on the bottom side DCGH of the box, when looked in the direction of the arrow marked by TOP, is called *top view*.

3. *Left side view:* The view of the object formed on the right side BFGC of the box when looked in the direction of the arrow marked by LEFT SIDE, is called *left side view*.

4. *Right side view:* The view of the object formed on the left side AEHD of the box, when looked in the direction of the arrow marked by RIGHT SIDE, is called *right side view*.

5. *Bottom view:* The view of the object formed on the top side ABFE of the box, when looked in the direction of the arrow marked by BOTTOM, is called *bottom view*.

6. *Rear view:* The view of the object formed on the front side EFGH of the box, when looked in the direction of the arrow marked by REAR, is called *rear view*.

Assume that the transparent box is formed by hinging the sides of the box onto the edges of these sides. It may be noted that all the sides of the transparent box except the front side EFGH, are hinged to the four edges AB, BC, CD and DA of the rear side ABCD. The front side EFGH is hinged to the edge FC. There are two hinges on each side. Now to open the box, rotate the sides of the box outwards about the respective hinges as shown in Figure 19.6. All the sides of the box are opened out in such a way that the front view occupies the central position. Continue the process of the rotation until all sides of the box lie in a single plane, the plane of the drawing sheet.

The layout of the six views in first angle projection method is shown in Figure 19.7. The rear view may also be placed to the left-hand side of the right side view.

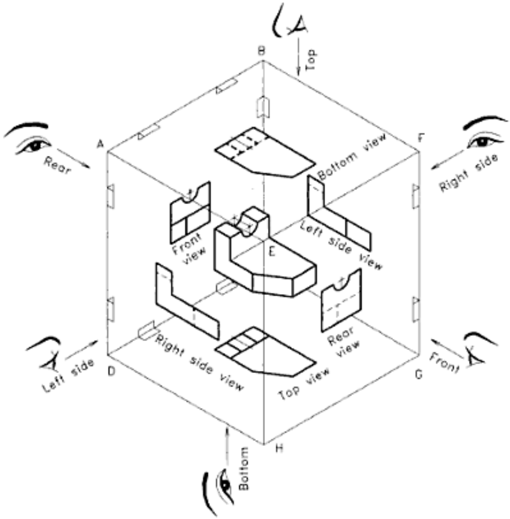


Figure 19.5 Transparent box containing an object (first angle projection).

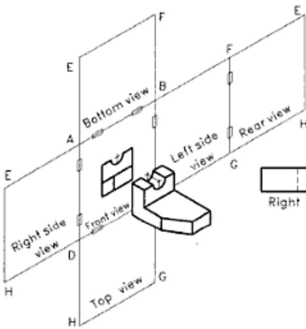


Figure 19.6 Opening of the transparent box (first angle projection).

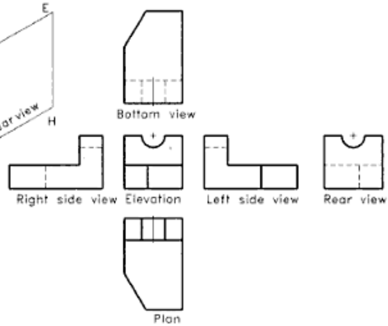


Figure 19.7 Layout of the six views (first angle projection).

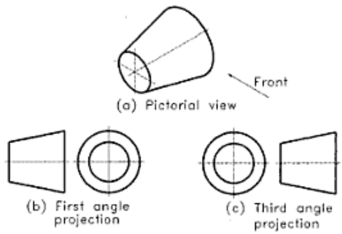


Figure 19.8 Symbol for first angle poojection.

19.5 INDICATION OF FIRST ANGLE PROJECTION

The method of projection used, must be indicated inside the space provided in the title block of the drawing sheet. A distinguishing symbol is recommended by the Bureau of Indian Standards for this purpose. The front and left side views of a frustum of a cone lying with its axis horizontal, is used for this. The symbol for first angle projection is shown in Figure 19.8.

19.6 SELECTION OF MINIMUM NUMBER OF VIEWS

For describing the shape of an object completely by its orthographic views, it is necessary to select the number of views required, and combine.

The number of views required for describing an object clearly and completely depends upon the extent of complexity involved in it. Based upon the number of views required, the drawings can be classified into the following categories:

1. One-view drawing
2. Two-view drawing
3. Three-view drawing

It may be noted that only minimum number of views, that will describe the object clearly and completely, should be drawn.

One-view Drawing

An object having cylindrical, square or hexagonal features can be completely described by a single orthographic view. Such a drawing is called *one-view drawing*. Here, the features are expressed by a note or an abbreviation.

In Figure 19.9, the cylindrical part is indicated by the notation ϕ and the square part is indicated by the notation □. The square part is identified by drawing thin crossed diagonal lines on the feature. Plate of any size can be described by a single orthographic view. The thickness of the plate may be expressed by a note.

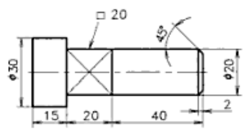


Figure 19.9 A pin (one view drawing).

Two-view Drawing

Objects which are symmetrical about two axes can be represented clearly and completely by two views. Such a drawing is called *two-view drawing*.

The largest face, showing most of the details and having minimum number of hidden lines, is selected as the front view. The second view may be the top or the side view.

It may be noted that any two views will not be sufficient to describe an object completely. Proper combination of the views should be selected. Isometric views of three prisms and the plan of these prisms are shown in Figure 19.10(a). The front and top views of these prisms shown in Figure 19.10(b) are not sufficient to describe them completely. But, the front and side views of these prisms describe the objects clearly and completely. Side views of the prisms are shown in Figure 19.10(c).

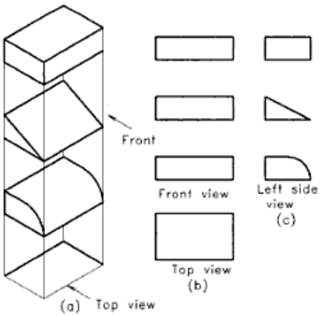


Figure 19.10 Two-view drawing of prisms.

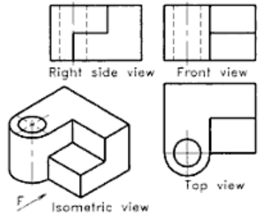


Figure 19.11 Three view drawing of a cast iron block.

Three-view Drawing

Most of the objects can be represented clearly and completely by three views. Such a drawing is called *three-view drawing*. The largest face showing most of the details is selected as the front view. Here, the object is placed in its functional position as far as possible and with the principal faces parallel to the planes of projection. A three view drawing of a cast iron block is shown in Figure 19.11.

19.7 USE OF LINE TYPES AND DIMENSIONING OF VIEWS

Orthographic views are drawn with proper line types as allowed by BIS. Figure 19.12 shows three orthographic views of an object drawn in first angle projection with proper line types and dimensioning. The pictorial view is also given for reference. The important points to be considered are given below.

Line Types for Orthographic View

1. The visible edges and all the outermost edges and surfaces are represented by continuous thick lines, i.e. Type A lines.

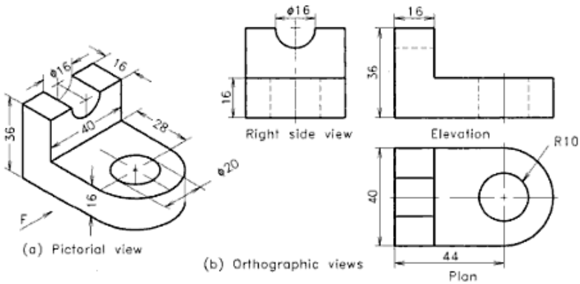


Figure 19.12 A machine part.

2. The hidden details are shown only if they are required. They are represented by short dashes using Type E or F lines. The method of drawing hidden lines and the rules for superimposing them are explained in Chapter 1.
3. Thin chain line (Type G) is used to represent centre lines and lines of symmetry.
4. Orthographic projections of machine parts generally have holes, circles, lines of symmetry, etc. Hence, the fixing of the view location and the further construction of shapes are progressed only after drawing all the important centre lines of the related views.
5. As a rule, a circular hole or projection should be drawn with the centre lines in horizontal and vertical directions. On a pitch circle, the hole centre is represented by the pitch circle drawn with chain line, and an intersecting radial chain line is drawn from the centre of the pitch circle.
6. Thin continuous line (Type B) is used for sketching views, section lines, construction lines and dimension lines.
7. Projection lines and reference lines are assumed to be invisible in the orthographic views of objects, even though they are compulsory for orthographic views of solids. It has to be noted that projection lines are not drawn, but the views and their details should lie in the exact alignment obeying the rules of projection.

Dimensioning of Orthographic Views

1. Dimensioning of orthographic views of objects is done by following Method-1, as described in Chapter 4. Method-2 is also permitted by BIS. Since Method-1 has certain advantages, it is generally followed for machine drawing.
2. The dimension lines are drawn using thin continuous (Type B) lines and the text is printed using thick single stroke letters as explained in Chapter 2.
3. The complete dimensional values have to be shown on the related orthographic views. They may be distributed in all the related views almost evenly.
4. Writing dimensional values on hidden details and over the view should be avoided.
5. There is no need of repeating a dimension, directly or indirectly. For example, the closing dimension has to be avoided if the total length is given.
6. For more details about dimensioning, refer to Chapter 4.

19.8 SUGGESTED DRAFTING PROCEDURE

To develop speed and accuracy in drawing, it is better to follow a certain order of drafting. All the instruments required for drawing should be placed at their proper locations in order to save time. The steps to be followed in making orthographic views are suggested below:

1. Decide the directions of the principal view (front view) and the combination of views such that it will best describe the object. Prepare freehand sketches of the required views and mark the overall dimensions on these views.
2. Considering the number of views to be drawn, with their overall dimensions and the size of the drawing sheet being given, select a suitable scale. But in industrial practice, the size of the drawing sheet is to be selected according to the number of views, overall dimensions and the scale of the drawing. The scale should be selected without spoiling the clarity of the drawing.
3. Draw the border line and outline of the title block. Leave sufficient space in between the views and the border line of the sheet. Care must be taken to provide necessary space for printing dimensions, notes, etc. [see Figure 19.13(b)]. As far as possible, provide equal space between the views for a better appearance.
4. Mark centre lines at appropriate places [see Figure 19.13(c)].
5. As far as possible, draw the details simultaneously in all the views. The following order of priority may be preferred as:
    1. Circles and arcs
    2. Straight lines which form the major shape of the object
    3. Straight lines, curves for the minor details like fillets, rounds, etc.
6. Draw all the details, except the hidden lines in all the views.
7. Erase all the unnecessary lines, construction lines, etc. Finish the drawing by thickening the appropriate lines.
8. Draw the hidden lines [see Figure 19.13(f)].
9. Enter all the dimensional values, distributing them appropriately in all the views.
10. Draw section lines, if any.
11. Name the views if necessary. Also enter other data necessary for the completion of the drawing. Check the drawing carefully and see whether there is any missing dimension, details, etc.
12. Print the title block details.

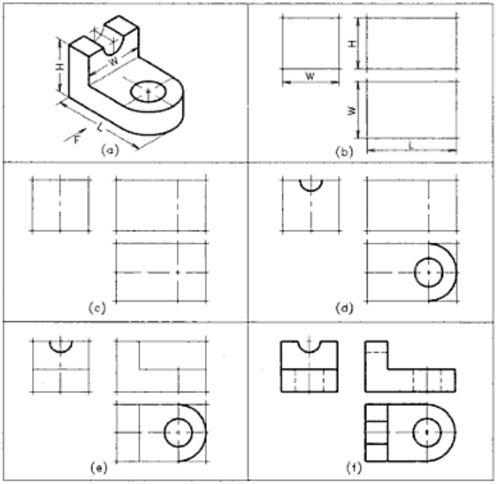


Figure 19.13 Drawing procedure for orthographic views.

Notes

1. Unless and otherwise specified, follow first angle projection method.
2. Symbol of the projection should be shown in the title block of the drawing sheet.
3. If third angle projection method is used along with first angle projection as a special requirement, it should be shown below the drawing by symbol or in writing.
4. Students are advised to name the orthographic views below them, until they develop the capacity to identify the views.
5. Projection lines and construction lines are not shown in orthographic views of objects.
6. Every circle should has two centre lines intersecting at the centre.
7. Axis of symmetry as well as axis of cylindrical holes, etc. should be drawn with the centre lines.
8. Choose a larger scale always for better clarity of views.
9. The hidden lines in a drawing should be minimised by orienting the object properly. Unimportant hidden details may be avoided, especially when the drawing is a complicated one.
10. While orienting an object for orthographic projection, the most important vertical face should be selected for the front view.
11. Front view is assumed to be the primary view for orthographic projection and all the remaining views are oriented in relation to the front view.
12. All the views should be drawn in the correct location with respect to front view as if there are projection lines. Shifted position of a view is assumed to be a spelling or grammar mistake, which will lead to wrong meanings in the graphic language.

19.9 FIRST ANGLE PROJECT OF OBJECTS HAVING PLANE SURFACES

Objects having plane surfaces alone may have the surface parallel to, inclined to or oblique to the reference planes. Figure 19.14 shows simple examples to these type of surfaces.

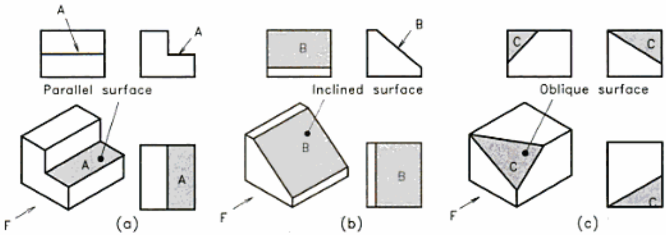


Figure 19.14 Objects having plane surfaces.

Parallel Surface

If a surface of an object is parallel to one of the reference planes of projection, the projection of the surface on that plane to which it is parallel will have its true size and shape. The projection of a surface which is normal to the plane of projection, is represented by a straight line.

Inclined Surface

If a surface of an object is perpendicular to one of the principal planes and inclined to the other two principal planes, the projections of the surface to which it is perpendicular will be a straight line, inclined to the other two reference lines. The projections of the surface on the reference planes to which it is inclined will appear foreshortened.

Oblique Surface

If a surface of an object is inclined to the three reference planes, the surface can be called as an *oblique surface*. If a surface is an oblique one, its projection will show areas on the three reference planes can be represented only by areas which will not give its true size and shape.

The following examples illustrate how orthographic views are drawn from pictorial views of objects having the above three types of plane surfaces.

Example 19.1

An isometric view of a parallel key is shown in Figure 19.15(a). Draw its front, top and left side views. The direction of the arrow, *F* shows the front side of the key.

Refer Figure 19.15(b). Follow the procedure explained in Section 1.8 to get the views.

Example 19.2

Draw the front, top and right side views of the angle-bracket shown in Figure 19.16(a).

Refer Figure 19.16(b). Follow the procedure explained in Section 19.8.

Example 19.3

Figure 19.17(a) shows an isometric view of a rectangular block having an oblique surface. Draw the front view looking in the direction of *F*. Add the top and the right side views.

Refer Figure 19.17(b). Follow the procedure explained in Section 19.8.

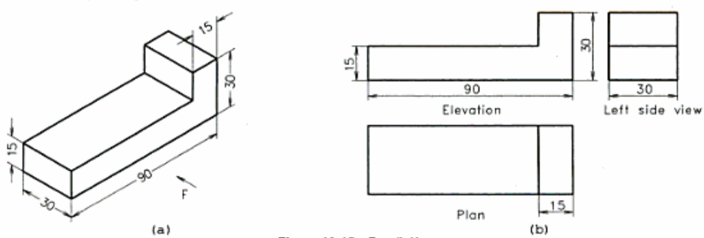


Figure 19.15 Parallel key.

weak. The radius of a fillet depends upon the thickness of the metal and other design requirements.

A rounded external corner on a casting is called *round*. External corners or angles are rounded for the appearance and comfort of persons who handle the casting.

Fillets and rounds actually prevent intersecting surfaces as they eliminate abrupt change in direction. This leads to certain problems in orthographic projections and the view becomes confusing (see Figure 19.19). To avoid this, lines are projected from approximate intersections.

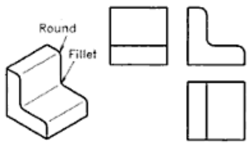


Figure 19.19 Fillets and rounds.

The radius of a fillet or round may sometimes be given on the view itself or as a general instruction. If the radius is not specified but the shape is shown in the given view, the radius may be assumed as 3 to 6 mm depending on the size of the object.

Example 19.4

Draw the three principal views of a cylindrical block shown in Figure 19.20(a).

Refer Figure 19.20(b).

Follow the procedure explained in Section 19.8.

Example 19.5

Isometric view of a shaft support is shown in Figure 19.21(a). Draw the front view, looking in the direction of the arrow *F*. Also draw top and the side views. Use a suitable scale.

Refer Figure 19.21(b).

Follow the procedure explained in Section 19.8.

Example 19.6

Isometric view of an object is shown in Figure 19.22(a). Draw the front view, looking in the direction of the arrow *F*. Also draw top and the side views. Use a suitable scale.

Refer Figure 19.22(b).

Follow the procedure explained in Section 19.8.

19.11 THIRD ANGLE PROJECTION OF OBJECTS

In the third angle system of projection, the object is assumed to be placed in the third quadrant and the views are obtained in the same side of viewing as explained in the Section 19.3. Except the change of position of views, there is no practical difference between first angle projection and third angle projection. In third angle projection, the top view is obtained on the top side of front view, the right side view is obtained on the right side of front view, and so on. This difference may be noted in the following example.

Example 19.7

Draw the front, top and right side views of an adjustable rod support shown in Figure 19.23(a). Use third angle projection method.

Refer Figure 19.23(b).

Draw the views as shown in figure, following the procedure explained above. Add an extra note "THIRD ANGLE PROJECTION" below the views.

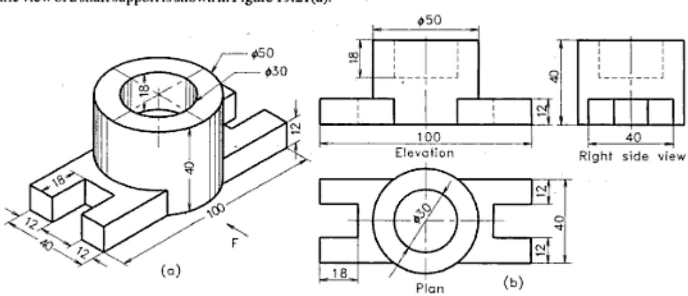


Figure 19.20 Cylindrical block.

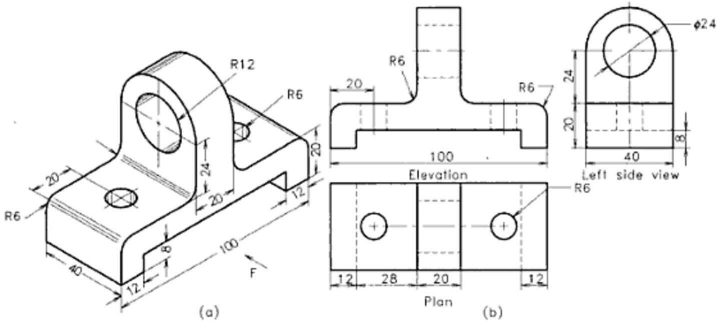


Figure 19.21 Shaft support.

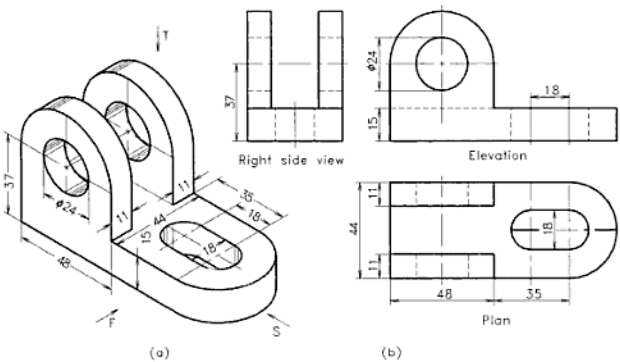


Figure 19.22 Bearing block.

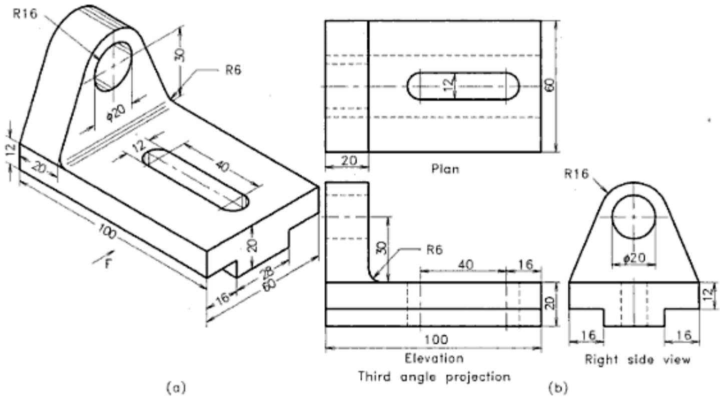


Figure 3.23 Adjustable rod support.

EXERCISES

Draw the orthographic views of the engineering objects as per the instructions given along with the Figures 19.24 to 19.40. View the objects in the direction of arrow marked with F. Name the view and dimension them as per BIS.

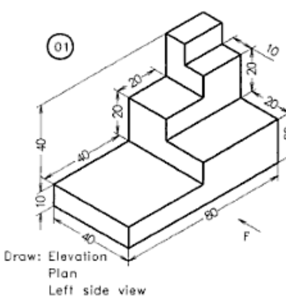


Figure 19.24 Ablock.

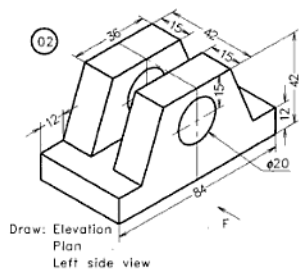
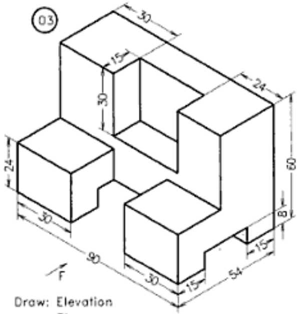
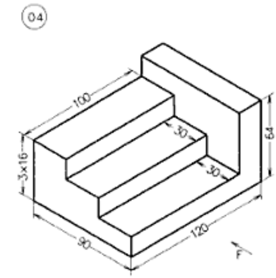


Figure 19.25 Ablock.



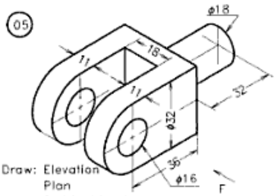
Draw: Elevation
Plan
Left side view

Figure 19.26 A block.



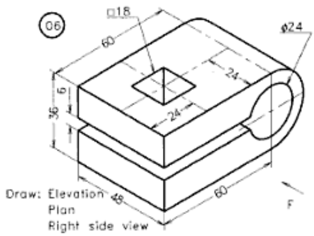
Draw: Elevation
Plan
Left side view

Figure 19.27 A stepped block.



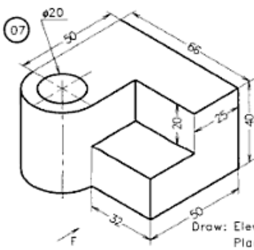
Draw: Elevation
Plan
Right side view

Figure 19.28 Fork end.



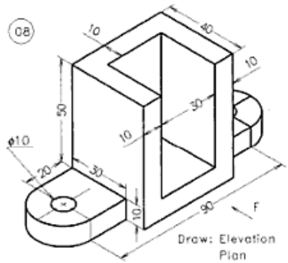
Draw: Elevation
Plan
Right side view

Figure 19.29 Fork end.



Draw: Elevation
Plan
Right side view

Figure 19.30 A cast iron block.



Draw: Elevation
Plan
Right side view

Figure 19.31 A stopper.

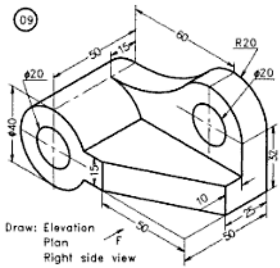


Figure 19.32 A shaft support.

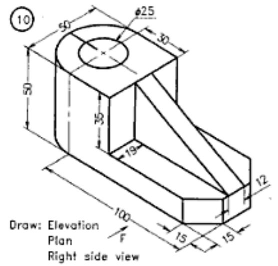


Figure 19.33 A block.

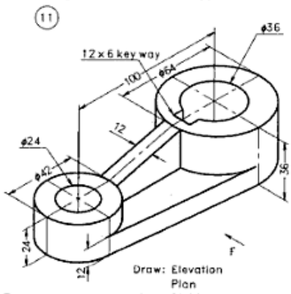


Figure 19.34 A lever.

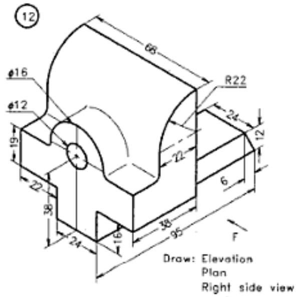


Figure 19.35 Jaw of a vice.

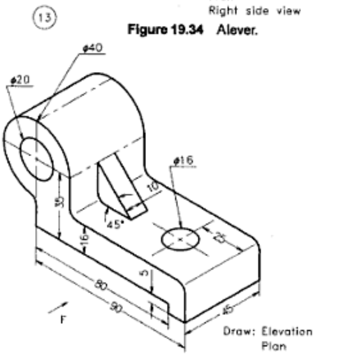


Figure 19.36 A bearing.

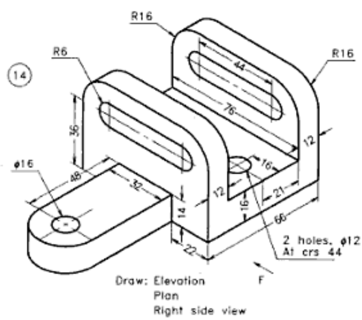


Figure 19.37 A bracket.

CHAPTER 20

Auxiliary View of Objects

If the surface of an object is inclined to any of the planes of projection, the view of the surface on that plane will not show its true shape and size. In certain cases, it will be difficult to read and draw such a view. To overcome this difficulty, a view of the inclined surface is projected on an imaginary plane, parallel to this inclined surface. This imaginary plane is called *auxiliary plane* and the view obtained on it is called *auxiliary view*.

20.1 PRINCIPLES OF AUXILIARY VIEWS

Auxiliary view is a projection obtained on the auxiliary plane when viewed in a direction perpendicular to the inclined surface. *Normal view* is another term used for this kind of projection. The method of projecting the view of the inclined surface of an object onto an auxiliary plane is similar to orthographic projection.

An auxiliary view is generally a partial view of an object showing only the inclined surfaces. A complete auxiliary view, showing the entire object, is not shown usually as it may result in a confused appearance of the view. The method of laying out an auxiliary view using reference arrows is shown in Fig. 20.1.

20.2 LOCATION OF AUXILIARY VIEWS

If a view cannot be placed in its correct position, as per the angle of projection followed, Bureau of Indian Standards permits the following ways to layout the views.

Special (full) Auxiliary Views: If the direction of viewing is different from those for the *six views*, or if the view cannot be placed in its correct position, reference arrows as shown in Fig. 20.1 shall be used to indicate the view direction and the views shall be placed on the same side. Such views are grouped under the name special (full) auxiliary views.

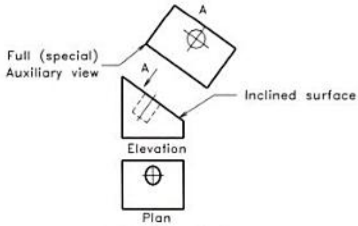


Fig. 20.1 Auxiliary view.

Partial Auxiliary Views: These views may be used where a complete view would not improve the information to be given. Partial view shall be cut off by continuous thin freehand line or straight lines with zig-zag.

Local Auxiliary Views: For symmetrical items, it is permitted to give a *local auxiliary view* instead of a complete or partial view. Local auxiliary view should be drawn in third angle projection, regardless of the arrangement used for the general execution of the drawing.

A local view shall be drawn with continuous thick line and shall be connected to the principal view by a centre line.

Auxiliary views, thus fall under any one of the following types of views, namely special, full, partial or local auxiliary views. As directed by BIS, the auxiliary views are placed nearby the inclined face itself as given in Fig 20.1. This follows the layout of auxiliary view in third angle projection. An arrow mark and a name to indicate the direction of viewing is also given.

20.3 THE NEED FOR DRAWING AUXILIARY VIEWS

The basic need of an auxiliary view in a drawing is to show the true shape and size of an inclined surface and the details on it. The standard orthographic views of an inclined surface show only foreshortened lengths and hence the resulting shape will be a distorted one. For example, a circular hole on an inclined surface will be an ellipse in a standard auxiliary view. But at the same time, if the auxiliary view is drawn for the complete object, the portion other than the inclined surface will be seen distorted, since their edges and surfaces are inclined to the auxiliary plane. To avoid this, in commercial drawings auxiliary views are prepared for the inclined surfaces, as in partial views. Fig. 20.2 shows the partial and full auxiliary views of a clamp. Note that the full auxiliary view is confusing and also difficult to read and draw.

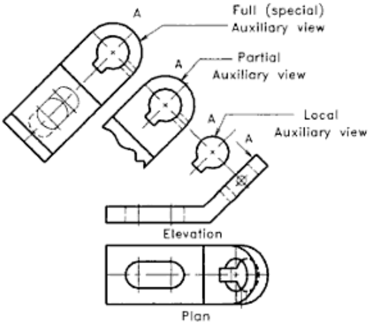


Fig. 20.2 Local, partial, and full auxiliary views.

Another need for auxiliary view is to prepare the standard view of objects, containing inclined portions. The auxiliary view is initially drawn with true dimensions and it is projected onto the required inclined plane, to get the foreshortened shapes. For example, in Fig. 20.2 the right half of the plan view can be easily prepared by projecting from the partial auxiliary view.

Certain machine parts may contain surfaces inclined to all the principal planes. Such oblique surfaces may also contain certain details like holes, slots, projections, etc. An auxiliary view, parallel to such an oblique surface, has to be prepared to know the real shape and size of the details on the faces.

20.4 CLASSIFICATION OF AUXILIARY VIEWS

Auxiliary views may be of infinite number of position in relation to the three principal planes of projection. They can be broadly grouped into two classes.

1. *Primary auxiliary views:* These are auxiliary views of surfaces inclined to two of the principal planes but perpendicular to the third one.

2. *Secondary auxiliary views:* Certain machine parts maybe having surfaces inclined to all the three principal planes. Such plane surfaces are called oblique or skew surfaces and the auxiliary views of them are called secondary auxiliary views.

Primary Auxiliary Views

Primary auxiliary views are further classified into three categories as given below:

1. *Front auxiliary view:* Here, the auxiliary view is projected from the front view. The auxiliary plane is kept perpendicular to the vertical plane and inclined to the horizontal plane and there fore to the profile plane [see Fig. 20.3(a)].

2. *Top auxiliary view*: Here, the auxiliary view is projected from the top view. The plane of projection is kept perpendicular to the horizontal plane and inclined to both vertical plane and profile plane [see Fig. 20.3(b)].

3. *Side auxiliary view*: Here, the auxiliary view is projected from the side view. The projection plane is kept perpendicular to the profile plane and inclined to both vertical and horizontal planes [see Fig. 20.3(c)].

Auxiliary views can also be classified as symmetrical and unsymmetrical auxiliary views.

1. *Symmetrical auxiliary views*: A symmetrical auxiliary

To draw the front auxiliary view, a centre line *cl* is marked in the plan view. The auxiliary view of *cl* is then marked as CL, parallel to the inclined surface and at a convenient distance from it. Then projectors are drawn perpendicular to CL from various points of the inclined surface in the front view. To mark a point P in the auxiliary view, measure the distance *k* of the point *p* from *cl* and mark it from CL along the projector drawn from *p*′. Similarly all the points on one side and their mirror images on the other side are marked to get the shape of the view. These points are then joined by thick lines as in the front view to complete the auxiliary view.

Reference Line Method

If the auxiliary view is not of symmetrical nature, then reference line method is more suitable. Figure 20.5 explains this method. To draw the front auxiliary view, a reference line *rl* is drawn in the top view. The auxiliary view of this reference line RL is marked parallel to the inclined surface of the front view at a convenient distance. The point P is marked by measuring the distance *k* from the top view as explained in centre line method. After marking all the points on one side of the reference line RL, they are joined by thick continuous lines as in the front view to complete the auxiliary view.

Same methods are applicable for top and side auxiliary views also.

20.6 SYMMETRICAL AUXILIARY VIEWS

As explained in the classification of auxiliary views, an auxiliary view may be symmetrical about a centre line drawn parallel to the trace of the auxiliary plane. For such objects, the view can be prepared by centre line method. The following examples explain the procedure in detail.

Example 20.1

Pictorial view of a machine block is given in Fig. 20.6(a). Draw the front view, looking in the direction F and also the front auxiliary view of the sloping surface. Need not dimension the figure.

Refer Fig. 20.6(b).

1. Draw the front view of the clamp.
2. Since the sloping side is symmetrical about the centre line, draw the centre line CL parallel to the inclined edge of front view.
3. Draw the front auxiliary view of the sloping surface after marking dimensions from the centre line.
4. Finish the views using proper line types.

Example 20.2

Pictorial view of a jig angle is given in figure 20.7(a). Draw the front view, in the direction F, side view and side auxiliary view of the inclined surface. Need not dimension the figure.

Refer Fig. 20.7(b).

1. Draw the left side view and front view of the jig angle without the holes.
2. From the side view, draw the side auxiliary view by centre line method.
3. Complete the side view of the holes and locate the position of the holes in the front view by drawing horizontal projectors.
4. Remove the projection lines, construction lines etc. and finish the views.

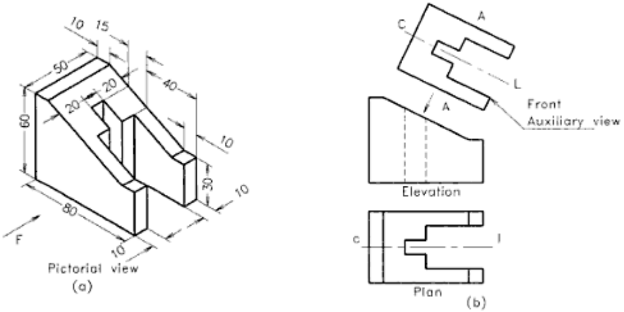


Fig. 20.6 A machine block (front auxiliary view).

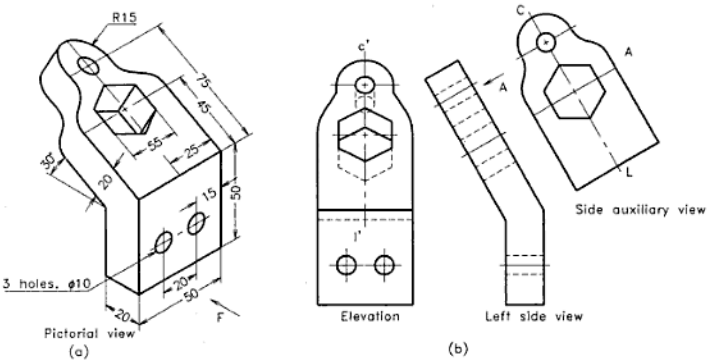


Fig. 20.7 A jig angle (side auxiliary view).

20.7 UNSYMMETRICAL AUXILIARY VIEWS

When an auxiliary view is unsymmetrical, reference line method may be used to prepare the auxiliary view. The following examples explain the procedure in detail.

Example 20.3

Figure 20.8(a) shows the pictorial view of a machine part with an arrow showing the front side. Draw the front and top views of the machine part and add a top-auxiliary view, showing the true shape and size of the sloping surface. Need not dimension the figure.

Refer Fig. 20.8(b).

1. Draw the front view and then the top view, without details on the sloping surface.
2. Construct the front-auxiliary view after marking the reference line RL.
3. Mark the reference line *rl* as shown in the top view and transfer the dimensions from the auxiliary view to the top view, and then to the front view by the help of projectors.
4. Remove the construction lines and finish the views.

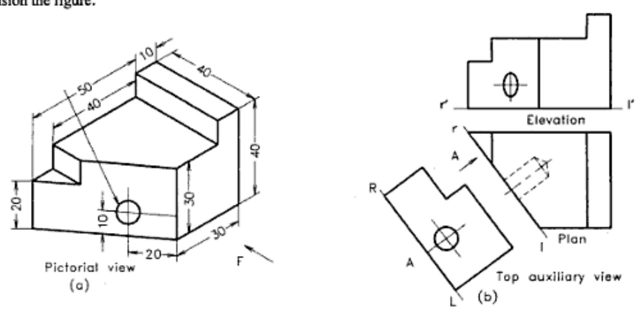


Fig. 20.8 A machine part.

EXERCISES

1. Isometric view of a wedge block is given in Fig. 20.9. Draw the side auxiliary view of the sloping surface, after drawing the front and side views. Take the arrow direction as the front side.

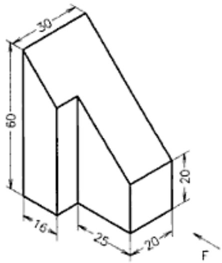


Fig. 20.9 Wedge block.

2. Draw the front view, top view and a front auxiliary view of the C-block given in Fig. 20.10. The arrow mark with letter F shows the front side.

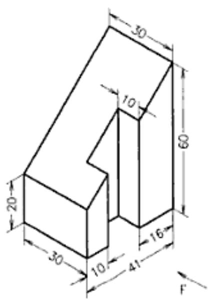


Fig. 20.10 C–block.

3. Figure 20.11 gives the pictorial view of an inverted T-block with a sloping surface. Draw the front view in the arrow direction. Add a partial auxiliary view of the sloping surface and a top view.

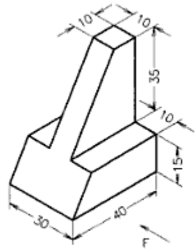


Fig. 20.11 Tee–block.

4. A pictorial view of a slotted block is shown in Fig. 20.12. Draw the front view and an auxiliary view of the inclined surface. The arrow mark with letter F indicates the front side.

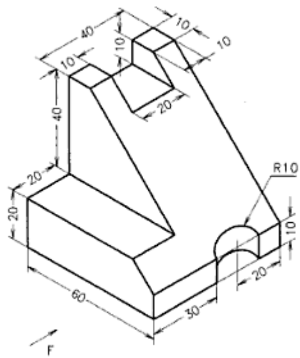


Fig. 20.12 Slotted block.

5. The isometric view of a rod guide is given in Fig. 20.13. Prepare the following views;
   (a) plan,
   (b) front view in the direction of arrow,
   (c) side view and
   (d) partial side auxiliary view.

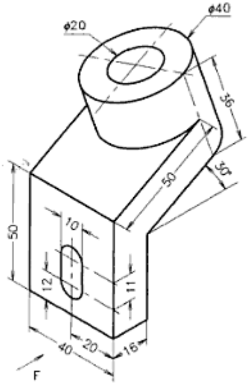


Fig. 20.13 Rod guide.

6. Figure 20.14 shows a bracket with a sloping surface. Draw an auxiliary view of the inclined surface, after preparing any two orthographic views. An arrow mark with letter F shows the front side.

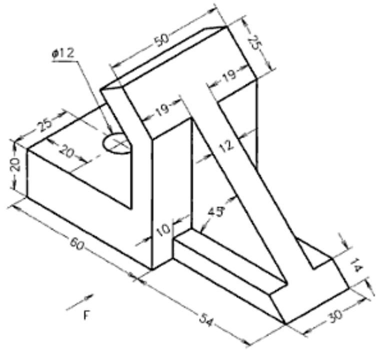


Fig. 20.14 A bracket.

CHAPTER 21

Visualization of Objects

The ability to *read and write* orthographic language is a basic requirement for all engineers. Reading of orthographic language is a mental process in which the shape and details about objects are visualized for further processing. The capacity for visualization develops with experience and exercise.

21.1 PRINCIPLE OF VISUALIZATION OF OBJECTS

Visualization is the medium through which the details given in a drawing is translated to the reader, resulting clear understanding of the shape of the object. This ability of visualization is mainly governed by a person's knowledge of the principles of orthographic projection.

Reading a drawing can be defined as "*the process of recognizing and applying the principles of orthographic projections to interpret the shape of an object from the orthographic views*".

The simplest method of visualizing shapes is illustrated in Fig. 21.1. To understand the shape of the object, break an object down into simple geometrical forms like prisms, cylinders, cones, etc. These shapes may be additions in the form of projections or subtractions in the form of cavities. By assembling them mentally, the final shape is obtained. Here, the rod support is formed by addition of three prisms and subtraction of three cylinders.

While analysing an orthographic view, it may not be some times possible for a beginner to understand whether a part is an addition (projection) or a subtraction (cavity) at a glance. He has to read patiently and systematically all the related views back and forth several times. At the same time, the reader must imagine a three-dimensional object and not a two-dimensional flat projection. Thus by a mental exercise, the three-dimensional shape of the object becomes clear to the reader.

21.2 THE NEED FOR VISUALIZATION

Since reading and writing of orthographic language is a common and important affair in engineering profession the visualization process, which is the understanding part of the reading of drawings, becomes the primary requisite for technical literacy. An engineer has to develop the capacity of visualizing objects for the following purposes.

1. For design calculation, estimation and related affairs.
2. For material requisition, tooling, fabrication and similar processes of production.
3. For assembling, maintenance, inspection etc.

The above functions are executed by reading different types of views and if needed converting them into the required form of views. During the design and drafting stage of an

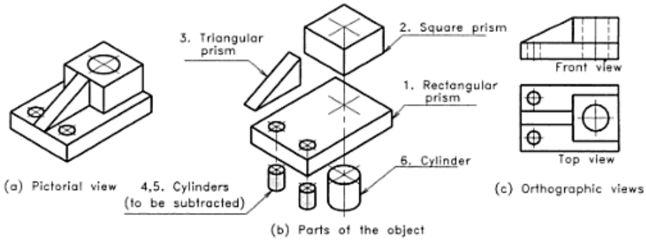


Fig. 21.1 A rod support (breaking down method).

object, visualization is fully utilized in the following ways:

1. Reading of the drawing available in pictorial forms like isometric, oblique or perspective views to prepare its orthographic views.
2. Reading of orthographic views to prepare its pictorial views.
3. Reading of orthographic views to add extra views for more details.
4. Reading of pictorial or orthographic views to prepare their sectional views.
5. Reading of orthographic views to prepare assembly drawings.
6. Reading of assembly drawings to prepare their part drawings or exploded views.

21.3 THE METHOD OF VISUALIZATION OF THREE-DIMENSIONAL OBJECTS

A drawing is read by visualizing the shape details one at a time. Similarly, each portion of the drawing is read and they are combined to interpret the whole object finally. The process of reading drawings can be grouped into two sections, such as reading of pictorial views and reading of orthographic views.

Pictorial Views

Reading a pictorial view is rather easy and fast compared to orthographic drawings. But pictorial views cannot give full dimensional details, true shapes and other parameters related to geometry, especially when the object is complex. Hence in engineering profession, pictorial views are used only to show the overall shape of the assembly or that of an individual part. Full details are marked generally on orthographic views. However, for simple objects, the details can be drawn on pictorial views also. The pictorial view may be isometric, oblique or perspective projections, depending on the requirement. The three surfaces (usually top, right and left) and the details on them are read one by one to visualize the object. Section 21.5 explains the procedure with examples.

Orthographic Views

Reading of orthographic views is primarily a reversal of the process of making drawings. For a beginner, the reading of orthographic views can be assumed as the formation of a pictorial view from orthographic views. Figure 21.2 shows an example to this kind of reading. From the orthographic views, the pictorial view is shaped and sometimes sketched. Simple objects can be visualized in pictorial form, but for complex objects this is difficult.

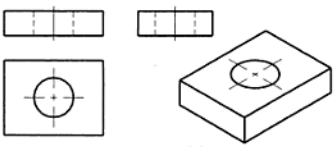


Fig. 21.2 Visualization of a plate by pictorial view.

Another method of reading is by recognising the geometry of the solids forming the object. Figure 21.3 gives one set of front view, side views and 4 different shapes of top views. By reading the front and side views, the shape of the object may be recognised as a rectangular plate having a cut

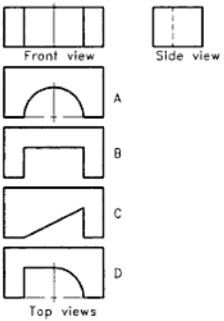


Fig. 21.3 Different top views to suit a set of front and side views.

from the front side. The shape of the cut is fully understood by reading the top view. The possible different forms of cuts are shown as A, B, C and D, which are matching the front and side views. Now the shape is finalized mentally by the three-view combination. An experienced person reads the drawing within shortest time by going through the three or more views and analysing the geometry of each part subconsciously. The reader shifts his eyes rapidly back and forth from the front view to the top view or side views and finalizes the shape in his mind.

To visualize an object from orthographic views, the reader must have reasonable knowledge about the principles of orthographic projection. He must acquire a complete understanding of the meaning of various types of lines, areas, etc. Then he has to exercise the metal process of interpreting them. By reading different sets of orthographic views of simple to complex objects, one can become an expert in visualization.

The general procedure of reading orthographic views contains the following steps.

1. Obtain a general idea about the overall shape of the object and study the dominant features by referring all the related views.
2. Start reading the simpler individual features as well as the dominating ones. Preference may be given to familiar shapes and read them completely by noting the extend of hole, thickness of rib, etc.
3. After reading all familiar and simple features, start reading unfamiliar and complex features.
4. Note the relationship between individual parts and their way of joining. This is more relevant for assembly drawings.
5. Finally, read the details, specifications and similar minute informations. The areas which are found completed in first sight are read once again to make it clear and the reading process is completed.

21.4 MEANING OF LINES AND AREAS IN ORTHOGRAPHIC DRAWINGS

Engineering drawings of three-dimensional objects are prepared completely on two-dimensional drawing sheets by drawing lines and areas. Hence, the meaning of lines and areas should be clearly known to understand the graphic language.

Representation of a Line

A line on a drawing may represent the following directional changes on an object:

1. An edge view of a surface,
2. An intersection of two surfaces,
3. A surface limit.

An *edge view of a surface* is a line showing the edge of a surface which is perpendicular to the plane of projection. An *intersection of two surfaces* is a line. The intersecting surfaces may be of plane, curved or spherical shape. A *surface limit* is a line showing the reversal of direction of a curved surface.

Representation of an Area

An area in a drawing represents the projected surface area of an object. If a surface of an object is perpendicular to the plane of projection, that surface area is represented by a line in the view on that plane of projection. The meaning of an area in a drawing can be understood only after analysing the corresponding part in the other view or views.

The representation of an area in orthographic views can be divided in the following ways:

1. *Area parallel or perpendicular to the planes of projection:* This area is visible in its true form and size on a view which is taken parallel to that surface. In the other two views, the area is seen as a straight line.
2. *Area inclined to two planes of projection and perpendicular to the other:* An inclined area will be seen foreshortened in two views. But in the third view it will be a straight line.

3. *Area inclined to all the three planes of projection:* An oblique area is inclined to all the three planes and is seen in all the three views in foreshortened form.
4. *A curved area, perpendicular to one of the plane of projection:* A curved area is seen as a curved line in one view and is visible as foreshortened in the other two views.
5. *A hidden area:* The representations of hidden areas are similar to that of visible ones, but they are shown by short dashes. These areas may be sometimes confusing to read because the areas may overlap or even coincide with each other.

21.5 VISUALIZATION OF OBJECTS FROM PICTORIAL VIEWS

A pictorial view shows three mutually perpendicular planes (faces), generally the top, left and right sides. An object can be fully understood by breaking down it into primary geometrical shapes as mentioned in Section 21.1. Then the three faces and their combinations for each part are identified for recognising the visible and hidden surfaces. The following examples explain the process clearly.

Example 21.1

Figure 21.4 shows the pictorial view of an object in which various surfaces are marked by alphabets. Three orthographic views are also given in which the surfaces are marked by numerals. Identify all the surfaces marked by alphabets with their corresponding numerals in the orthographic views and present them in a tabular form.

Refer to Fig. 21.4.

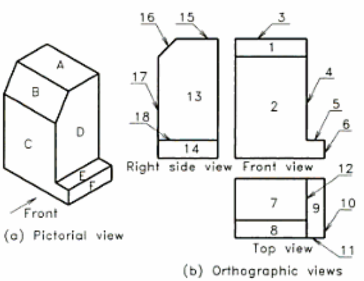


Fig. 21.4 Visualization of a pictorial view.

As the top surface A is horizontal, in the front view the surface is represented by a horizontal line 3. In the top view, this surface is represented by a rectangle marked 7 and in the side view the same is represented by a horizontal line 15. As the surface B is inclined to both the vertical and horizontal planes, it will be seen as foreshortened rectangles 1 and 8 in the front and top views respectively. But in the side view, this surface is represented by a line marked 16. Similarly, all the other surfaces can be identified and tabulated as shown in Table 21.1.

Table 21.1 Solution to Example 21.1

Surface name on pictorial view	No. on front view	No. on top view	No. on side view
A	3	7	15
B	1	8	16
C	2	11	17
D	4	12	13
E	5	9	18
F	6	10	14

Example 21.2

Figure 21.5 shows the pictorial view of an angle block in which various surfaces are marked by alphabets. Orthographic views are given. Sketch the given orthographic views and mark all the given alphabets on the surfaces of each view after identifying them.

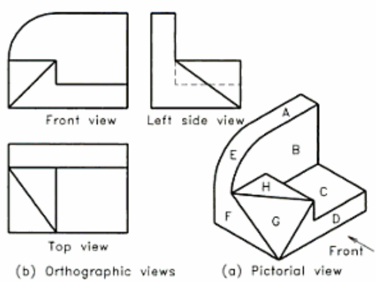


Fig. 21.5 Visualization of an object from its pictorial view.

Refer to Fig. 21.6.

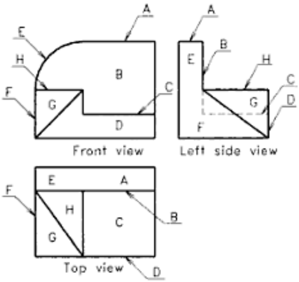


Fig. 21.6 Orthographic views of an object (with alphabets on the surfaces).

Sketch the given orthographic views. All the surfaces, expect E and C in the isometric view, can be identified as explained in Example 21.1. As the surface E is a curved one, it is represented by two foreshortened rectangles in the top and side views respectively. The triangular surface G is seen as foreshortened triangles in the front, top and left side views respectively, because the surface G is oblique. All the surfaces are thus identified and marked as shown in Fig. 21.6.

21.6 VISUALIZATION OF OBJECTS FROM ORTHOGRAPHIC VIEWS

The method of visualization of objects from orthographic views has been already explained in Section 21.3. The reading process can be practised by doing the following types of exercises.

1. Read the given orthographic views and interpret the surfaces by locating them correctly on the given pictorial view using identification letters.
2. Read the given orthographic views, visualize the shape fully, sketch a pictorial view of the object and mark the identification letters.
3. Read the given orthographic views, visualize the shape fully and fill the missing lines in the given orthographic views.
4. Read the given orthographic views, visualize the shape fully and add orthographic views which are not given.
5. Read the given orthographic views, visualize the shape fully and draw sectional views.
6. Read the orthographic views, visualize the shape fully and make a model of the object using soft materials like thermocol, wood, clay etc.

Examples to the first four types of exercises are given below for practice.

Example 21.3

Orthographic views of a block and its pictorial view are given in Fig. 21.7. Copy the given pictorial view. Read the orthographic views and indicate the given identification letters on the pictorial view after recognising the surfaces.

Refer to Fig. 21.8.

Copy the given pictorial view. Read the three views and identify the surface on the front, top and left sides. Mark the identification letters systematically on the pictorial view. Since the object has one inclined surface, this surface is seen in the top and front views resulting two letters for identification. So mark them as C and F on the pictorial view.

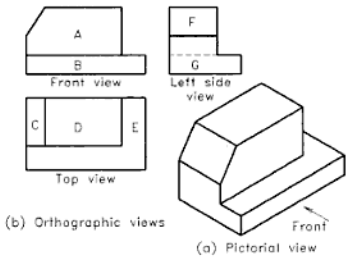


Fig. 21.7 Visualization of an object from its orthographic views.

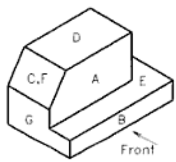


Fig. 21.8 Pictorial view of an object (with alphabets marked on the surface).

Example 21.4

Three orthographic views and an isometric view of a block are given in Fig. 21.9. Sketch the pictorial view and mark the corresponding surfaces from the given orthographic views.

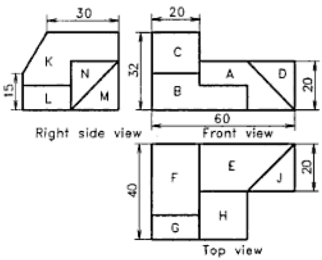


Fig. 21.9 Visualization of an object from its orthographic view.

Refer to Fig. 21.10.

Sketch the given pictorial view and mark the surfaces as given on the orthographic views. There is one inclined surface and one oblique surface on the block. The remaining surfaces are parallel or perpendicular to the plane of projection.

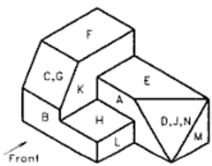


Fig. 21.10 Pictorial view of an object (with alphabets marked on the surface).

Example 21.5

Figure 21.11 shows 3 views of a block. Visualize the object and sketch an isometric view of the block. Identify the surfaces by marking alphabets on the respective surfaces on the pictorial view.

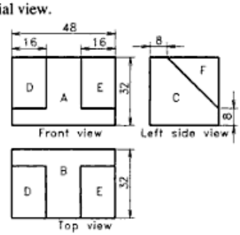


Fig. 21.11 Visualization of an object from its orthographic views.

Refer to Fig. 21.12.

Sketch the isometric view. Surfaces of the object are identified by marking alphabets on the respective surfaces.

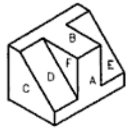


Fig. 21.12 Pictorial view of an object (with alphabets marked on the surfaces).

Example 21.6

Figure 21.13 shows three orthographic views of a bracket with either a line or lines missing in a view. Read the drawing and copy the views after adding the missing line or lines.

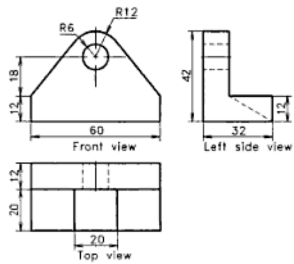


Fig. 21.13 Orthographic views of a bracket (some lines are missing).

Refer to Fig. 21.14.

Copy the views of the bracket after adding the missing lines as shown in the figure.

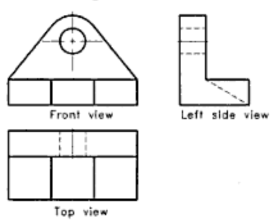


Fig. 21.14 Orthographic views of a bracket (no line is missing).

Example 21.7

Two orthographic views of a block are shown in Fig. 21.15. Visualize the object, copy the given views and add a view on the right side looking the object from left side.

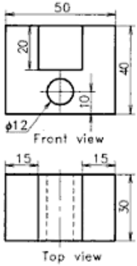


Fig. 21.15 Two views of a block.

Refer to Fig. 21.16.

Copy the given top and front views, visualize the object and understand the meaning of each area and line. By referring plan view, draw the side view as shown in the figure. Finish the views after removing projection and construction lines.

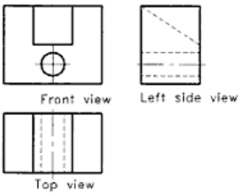


Fig. 21.16 Three views of a block.

Example 21.8

Two orthographic views of a simple bearing is shown in Fig. 21.17. Copy the front view, visualize the object and draw a side view looking from right side. Dimension the views.

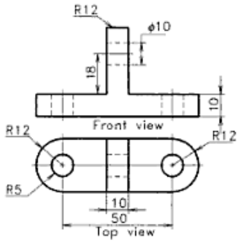


Fig. 21.17 A bearing (front and top views).

Refer to Fig. 21.18.

Copy the front view, visualize the object and understand the meaning of lines and areas. Project horizontally and mark the widths by measuring from the top view. Complete the view and print dimensions.

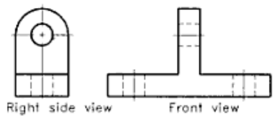


Fig. 21.18 A bearing (front and side views).

EXERCISES

1. Isometric view of an angle stop is shown in Fig. 21.19 in which various surfaces are marked by alphabets. Three orthographic views are also given in which the same surfaces are marked by numerals. Identify the surfaces marked by the alphabets with their corresponding numerals in the orthographic views and present them in a table.
2. Figure 21.20 shows three views of a holder. Visualize the object and sketch an isometric view of the object. Identify the surfaces of the pictorial view drawn.
3. Orthographic views of a block are shown in Fig. 21.21. Visualise the object and prepare an isometric drawing. Mark the given alphabets on the corresponding surfaces.

4. Three views of a fork are shown in Fig. 21.22. Visualize the object and sketch the isometric view of the object. Identify the surfaces by marking the given alphabets on respective surfaces of the pictorial view.

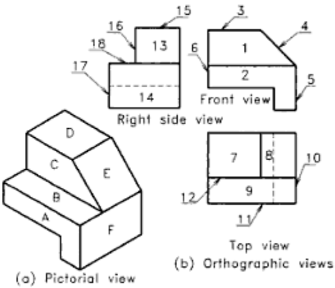


Fig. 21.19 Angle stop.

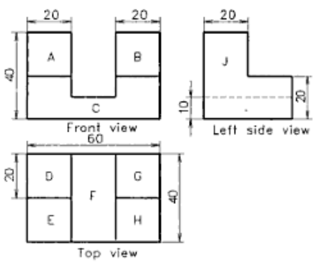


Fig. 21.20 Holder.

5. Two orthographic views of a connector are given in Fig. 21.23. Visualize the object and draw its front and top views.

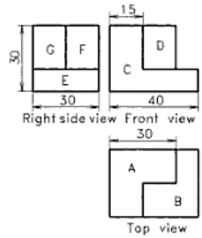


Fig. 21.21 A block.

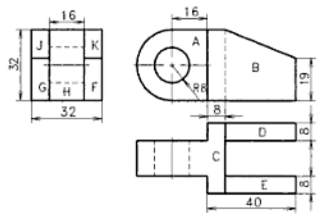


Fig. 21.22 Fork.

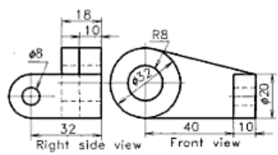


Fig. 21.23 Connector.

C H A P T E R

22

Sectional Views of Objects

Interior details of an object are not always clearly shown or easy to read on principal exterior views, especially when there are too many hidden lines. In such cases, an imaginary cutting (sectioning) plane may be used to cut through the object so that the portion in front of the plane can be imagined to be removed so as to expose inner details. Drawings of complex machine parts, assemblies, etc. are prepared along with sectional views.

22.1 PRINCIPLE OF SECTIONAL VIEWS OF OBJECTS

In orthographic projection, hidden lines are used to represent the details of an object which are not seen from the outside. In order to avoid too many hidden lines and to make the drawing more understandable, the object is cut by an imaginary cutting plane in such a way as to expose the required inner details of the object. The cutting plane is also called *section plane*. An object with a section plane is shown in Fig. 22.1(a). After cutting the object by an imaginary plane A, the piece N which is between the observer and the cutting plane is removed. The remaining portion M is shown in Fig. 22.1(b). The portion of the object cut by the cutting plane is made clear by drawing hatching lines. Now the hidden details are very clear from the cut face. Orthographic projection of the remaining piece M of the object is called *sectional view* or

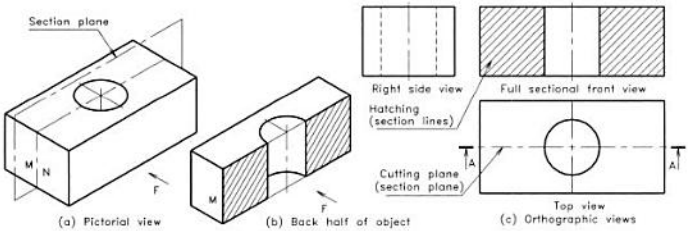


Fig. 22.1 Principle of sectional view.

sectional projection. Although the cutting planes are shown in isometric view, only the cutting line is shown in practice to locate the position of the plane. The cutting plane is also called *section plane*, *line of section* or *trace of the cutting plane*. The cutting plane is represented by chain thin lines-thickened at the ends i.e. type H lines. The direction of viewing is shown by arrows and designated by capital letters. Figure 22.2 shows examples to the conventional representation of cutting planes.

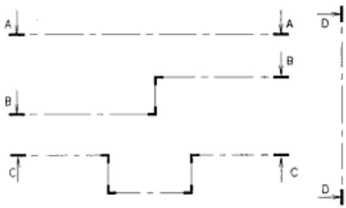


Fig. 22.2 Conventional representation of cutting planes.

While drawing sectional orthographic views, following conventions may be noted by referring Fig. 22.1(c).

1. The front view is a fully sectioned one while top and side views are drawn completely, because the object has not been actually cut.
2. The cut surface is indicated by *section lines*, with parallel and equally spaced inclined lines (also called *hatching lines*).
3. The cutting plane is shown by type H line.
4. Arrows show the direction in which the section is viewed.
5. The cutting plane is identified by letters like AA, BB etc.
6. The sectioned surface is enclosed in thick line boundaries.
7. Visible lines beyond the cutting plane are shown as in orthographic views.
8. Hidden lines beyond the cutting plane are not generally shown.

22.2 CLASSIFICATION OF SECTIONAL VIEWS

Sectional views may be taken by cutting the object at any angle and location. But in engineering practice, to serve the purpose of drawing, a section is taken generally along the centre line of the object. For exposing details at some odd parts of the object, special sectional views are also prepared. The types of sectional views frequently used in engineering may be displayed as follows.

1. *Full sectional views:* Here the entire object is sectioned by the imaginary cutting plane. An example is Fig. 22.3(a).
2. *Half sectional views:* Here, only one half of the view is under section while the other half of the view is without section [see Fig. 22.3(b)].

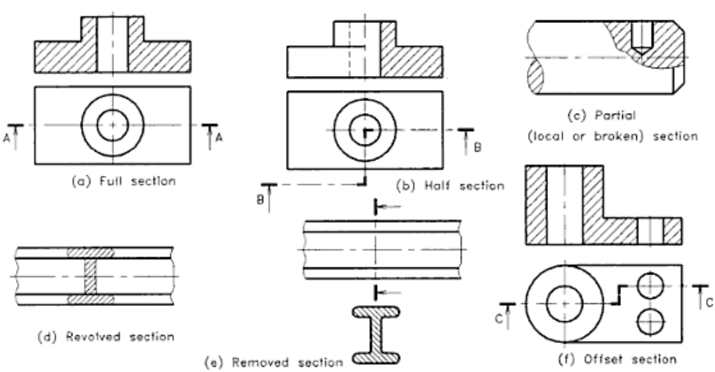


Fig. 22.3 Types of sectional veiws.

3. *Partial (local)* or *broken section:* In this type of section, only a small portion of the component is shown for the purpose of revealing details [see Fig. 22.3(c)].
4. *Revolved section:* Here, the cutting plane, which is perpendicular to the axis of the object, is revolved to bring it into the plane of the axis. Outlines of the revolved section are shown in continuous thin lines [see Fig. 22.3(d)].
5. *Removed section:* When the above revolved section is removed outside the object, then it is called *removed section*. The outline is shown with thick continuous line [see Fig. 22.3(e)].
6. *Offset section:* To expose more details by a single cutting, the section plane is offset through the details as shown in Fig. 22.3(f). In the related view, details of the offsetting should be shown by type H cutting line.

Among the above six types of sectional views, full sectional and half sectional views are explained with examples in this chapter.

22.3 FULL SECTIONAL VIEWS

For getting full sectional view, the entire object is sectioned by an imaginary cutting plane and the portion between the cutting plane and observer is removed. Orthographic view of the remaining object is the *full sectional view*.

Full sectional views may be classified as follows:

1. Full sectional front view (elevation)
2. Full sectional top view (plan)
3. Full sectional right side view (end view), and
4. Full sectional left side view (end view).

Full sectional bottom and rear views are not generally drawn. Thus, there are at least six different ways of drawing full sectional views.

For obtaining all the above full sectional views, the entire object is to be sectioned by three imaginary cutting planes which are parallel to the three co-ordinate planes.

For obtaining full sectional front view of an object, it is cut by a section plane A, parallel to the vertical plane. This plane divides the object into two pieces M and N. Piece M is behind the section plane A and piece N is infront of the section plane A. The front piece N is imagined to be removed. This assumption is applicable only to this view; but other views are not affected by this. It may be noted that piece N is the portion of the object lying between the cutting plane and observer. Front view of the remaining piece M of the object, projected on the vertical plane, is called *full sectional front view*. The trace of section plane A is indicated by the section line A-A in the top view. Here, the direction of viewing is indicated by two arrow heads as shown in Fig. 22.4(c).

For obtaining full sectional left side view of an object, it is first cut by a section plane B, parallel to the profile plane, and then the object is viewed from the left side. This plane divides the object into two pieces L and R. Piece L is on the left and piece R is on the right side of the section plane B. The piece L is imagined to be removed. It may be noted that piece L is the portion of the object lying between the cutting plane and the observer. The side view of the remaining piece R of the object, projected on the profile plane, is called *full sectional left side view. The* direction of viewing is shown in the top view. Here, the trace of the section plane is indicated by section line B-B in the top view. Full sectional left side view is shown in Fig. 22.4 (c). Full sectional right side view can be obtained by removing the piece of the object lying to the right side of section plane B and viewing the portion L from the right.

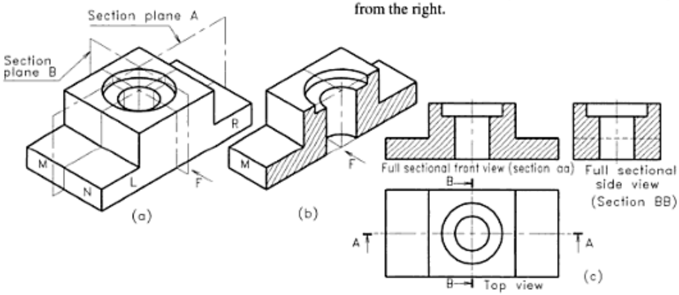


Fig. 22.4 Full sectional views.

Similarly, for obtaining the full sectional top view of an object, it is first cut by a section plane parallel to the horizontal plane. This plane divides the object into two pieces, one above and the other below the section plane. The piece above the section plane is imagined to be removed. Top view of the remaining piece, lying below the section plane and projected on the horizontal plane, is called *full sectional top view*. Trace of this section plane can be indicated by a section line in the front view and two arrow heads are drawn in the downward direction to indicate the direction of viewing.

22.4 HALF SECTIONAL VIEWS

When an object is symmetrical about its centre line, one half of a full section is needed to be drawn. Such a view is called *half sectional view*.

For getting a half sectional view, the object is cut by two imaginary cutting planes which are perpendicular to each other. Now, one quarter of the object is imagined to be removed and it is shown in Fig. 22.5(a). Orthographic view of the remaining three fourth portion of the object is called *half sectional view*. The sectional views obtained in this case are called *"front view, left half in section"* and *"left side view, right half in section"*. They are shown in Fig. 22.5(b). It may be noted that the top view is not affected by sectioning.

Half sectional views may be classified as follows:

1. Top half sectional views:
   (a) Front view, top half in section
   (b) Top view, top half in section
   (c) Right side view, top half in section
   (d) Left side view, top half in section.
2. Bottom half sectional views:
   (a) Front view, bottom half in section
   (b) Top view, bottom half in section
   (c) Right side view, bottom half in section
   (d) Left side view, bottom half in section.
3. Right half sectional views:
   (a) Front view, right half in section
   (b) Top view, right half in section
   (c) Right side view, right half in section
   (d) Left side view, right half in section.
4. Left half sectional views:
   (a) Front view, left half in section
   (b) Top view, left half in section
   (c) Right side view, left half in section
   (d) Left side view, left half in section.

Half sectional bottom and rear views are not generally drawn. Thus, there are at least 24 different ways of drawing half sectional views, including both half sectional bottom and rear views.

Figure 22.6 shows different outside views and sectional views of a simple guide block. Students are advised to identify and draw the remaining sectional views of this block which are not shown.

22.5 CONVENTION FOR SECTIONING

Hatching is used to show the areas of section clearly. Hatching is done by drawing continuous thin lines (Type B lines) at a convenient angle. The preferred hatching angle is 45° for principal outlines or lines of symmetry of the sections (see Fig. 22.7). Hatching of adjacent components is done in different directions or spacings (see Fig. 22.8). Hatching may be interrupted for dimensioning, if it is not possible to place the dimensions outside the hatching.

In the case of large areas, hatching may be limited to a zone as shown in Fig. 22.9. If sections of the same component in parallel planes are to be shown side by side, the hatching should be identical; but the hatching may be offset along the dividing line between the sections.

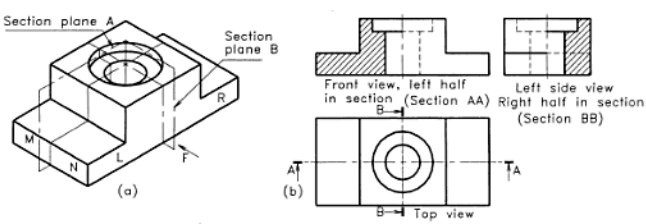


Fig. 22.5 Half sectional views.

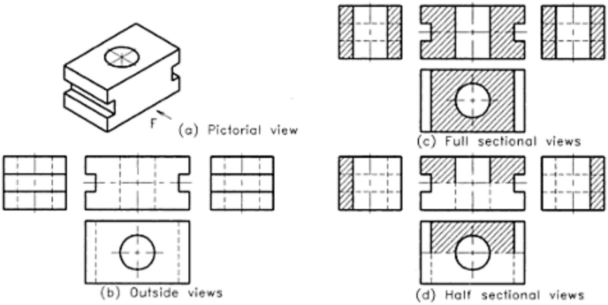


Fig. 22.6 Different views of a guide block.

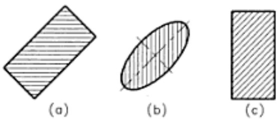


Fig. 22.7 Pereferred hatching angles.

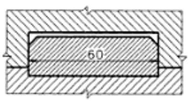


Fig. 22.8 Hatching of adjacent parts and dimensioning.

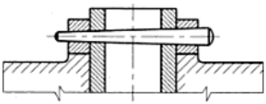


Fig. 22.9 Sectioning of large areas.

When a cutting plane passes longitudinally through the centre of a rib or a web, the rib should not be sectioned (see Fig. 22.10). But the rib is shown in section when the cutting plane passes crosswise through the rib. Spokes or arms of wheels or pulleys, shafts and fasteners like bolts, nuts rods, rivets, keys, pins, cotters, etc. are not sectioned longitudinally. Hence, they should not be hatched. They are shown in section, if the cutting plane is at right angles to their axis.

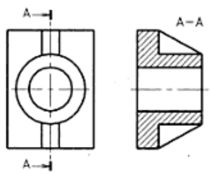


Fig. 22.10 Sectioning of an object with web.

22.6 CONVENTIONAL REPRESENTATION OF MATERIALS

Different materials are shown symbolically in different hatching patterns. BIS gives the conventional representations of materials. The different hatching patterns to be adopted are shown in Table 22.1. It may be noted that different materials should be indicated by notes on the drawings.

Example 22.1

Isometric view of a lever is shown in Fig. 22.11. Draw its full sectional elevation and plan.

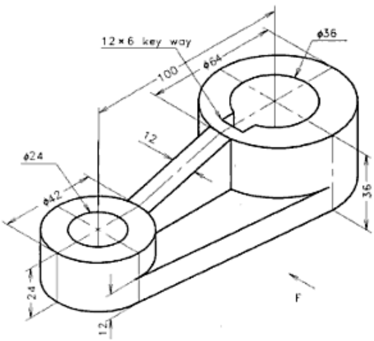


Fig. 22.11 A lever.

Refer to Fig. 22.12.

As per question, the section plane is to be taken parallel to VP. Draw the top view first and then the sectional front view. Section lines should be avoided at the holes and key way.

As the cutting plane passes longitudinally through the centre of the web, it need not be sectioned.

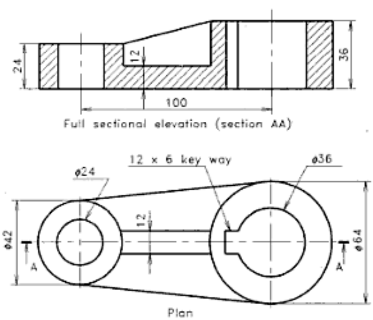


Fig. 22.12 A lever (sectional view).

Example 22.2

Orthographic views of a forked end of a machine part are shown in Fig. 22.13. Draw the following views:

(a) Front view, top half in section,

(b) Top view bottom half in section.

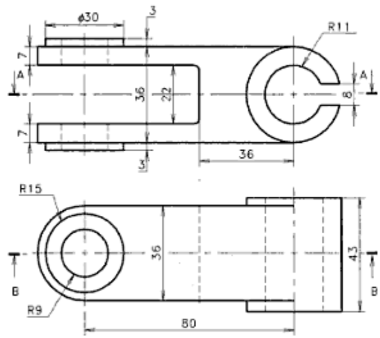


Fig. 22.13 Forked end of a machine part (orthographic views).

Refer to Fig. 22.14.

Draw the elevation top half in section and plan bottom half in section. Avoid hidden lines in the sectioned areas.

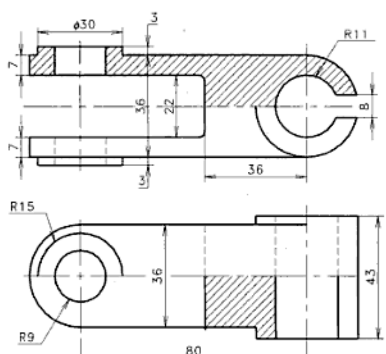


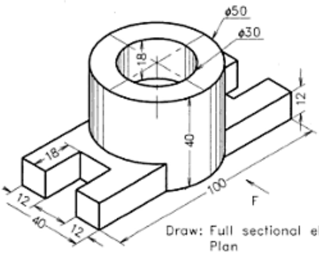
Fig. 22.14 Forked end of a machine part (half sectional views).

Table 22.1 Hatching patterns

Steel, cast iron, copper, aluminium and its alloys		Marble, porcelain, etc.	
Lead, zinc, tin, etc.		Rubber, leather, etc.	

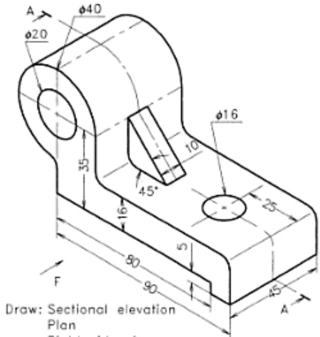
EXERCISES

Draw sectional views of the machine parts given in Figs. 22.15 to 22.19, taking section along their centre lines. The views are specified along with the drawings. Take the arrow mark with F as the direction for the front view.



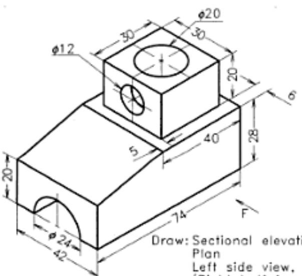
Draw: Full sectional elevation
Plan
Left side view

Fig. 22.15 Cylindrical block.



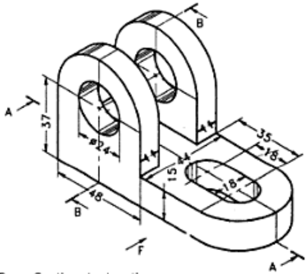
Draw: Sectional elevation
Plan
Right side view

Fig. 22.17 A bearing.



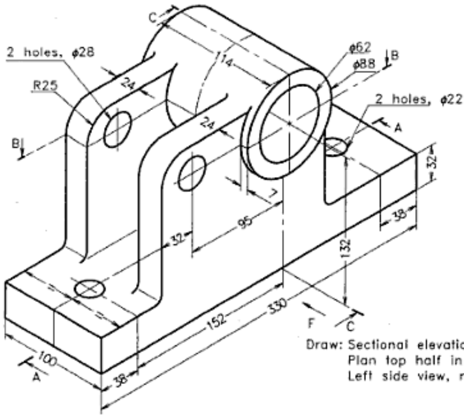
Draw: Sectional elevation
Plan
Left side view,
(Right half in section)

Fig. 22.16 A machine part.



Draw: Sectional elevation
Right side view (right half in section)

Fig. 22.18 Bearing block.



Draw: Sectional elevation
Plan top half in section
Left side view, right half in section

Fig. 22.19 A bearing block

Module G

Computer Aided Drafting

CHAPTER 23

Introduction to CAD

Computer Aided Drafting (CAD) is defined as a process of producing drawings in which, computer software and related hardware are used. The software stored in the disk provides the programme and the drafter gives the commands and data to the computer to perform the drawing task. The hardware is the physical equipment or device associated with the computer.

The term CAD is sometimes referred to as computer aided design also. A computer aided design system can perform automated drafting, design and analysis. For this, more powerful softwares are required.

The beginning of computer graphics is assumed to have happened in 1950. The 'Whirlwind computer' at Massachusetts Institute of Technology (MIT) was installed and drawing of simple figures was started in that year. When the International Business Machine Corp. (IBM) started making computers suitable for graphics in 1964, CAD became commercially available. A tremendous advance in hardware as well as software was made in the eighties. After a slow start, the computer graphics grew dramatically and became a popular system for drafting by the beginning of the nineties.

23.1 HARDWARE FOR CAD

Hardware of a computer system includes all the physical equipment or devices associated with it. A system for CAD may contain different combinations of equipment or devices (hardware) regardless of the system application. A specific combination selected depends largely on the needs of the user. Generally, each piece of equipment is coming under any one of the following groups.

1. Central processing unit (CPU)
2. Peripherals
   (a) Input devices
   (b) Secondary storage devices
   (c) Display devices
   (d) Output devices

Central Processing Unit (CPU)

The central processing unit (CPU) is the most important part of a personal computer (PC) hardware, since it is the 'brain' and all the processing are done in this unit. This is an integrated circuit (IC) and sometimes referred to as a microprocessor. The CPU of a PC consists of the following sections.

1. Primary storage section
2. Arithmetic logic unit (ALU)
3. Computer section

RAM and ROM

The primary storage component used in CPU is often referred to as Random Access Memory (RAM) chip. In a

RAM, programmes can be stored, altered or retrieved. But once the power supply is switched off, the data and programmes are lost. But the control instructions that cause the machine to operate should be available at any time as a permanent storage. This permanent storage element is called Read Only Memory (ROM), which is also a microprocessor (chip). ROM chips retain data when the power goes off. But it is a read only memory so that it cannot accept any input data or instructions from the computer user.

Bit and Byte

The microprocessor of a digital computer works only with the binary numbers (ones and zeros). The information is converted into this form and processed inside the CPU. The binary value, one or zero (1 or 0) constitutes a bit. The CPU handle the bits in the form of groups of 8, 16 or 32 and hence this determines the classifications of the microprocessor. Most of the CAD system have 16 or 32 bit microprocessors. The group of 8 bits is called a byte and the memory of a device is measured and represented in bytes. RAM capacities of PC may range from Mega bytes to 40 Giga bites or more.

Clock Speed

The speed with which an instruction is executed in CPU is directly related to the computer built-in clock speed, which is the number of pulses produced in each second. This clock speed is measured in Mega Hertz (MHz ie., 10^6 times per second). The present personal computers are having clock speeds ranging to 2 Giga Hz.

Input Devises

Input device is a mechanism used to present data to the processing unit in a readable form to the computer. Although key board is a common input device, there are other devices also in use. A list of the input devices generally used in the CAD systems is given below:

1. Keyboard
2. Mouse
3. Graphic tablet
4. Automatic scanners
5. Miscellaneous input scanners

In addition to the above, drives are also used as input devices to read the information stored in the Floppy disks, Hard disks, Compact disks and Magnetic tapes. The input devices other than the above explained are:

1. Light pen
2. Joy stick
3. Finger wheels
4. Track ball

Secondary Storage Devices

In a computer there are two types of storage (memory).

1. Primary storage (inside CPU)
2. Secondary storage (inside peripherals)

The secondary storage components supplement the primary storage in most computers. In personal computers the secondary storage devices are generally fitted inside the system cabinet itself as drivers. The classification of the secondary storage devices is given below.

Floppy Disks

The new member of the floppy disk family is the compact 3.5 inch size disk called *microdisk*. They are packed in a non-bendable shirt pocket sized plastic case. The storage capacity is 1.44 MB.

Hard Disk

Hard disks are rigid aluminium platens with a magnetic coating similar to floppy disks. They spin inside an air tight enclosure. The rotation may be as fast as 3600 rpm, so that storage and retrieval are faster. In a hard disk pack, several metallic disks are put together on a single shaft. There may be 10 recording surfaces on a six disk pack. The storage capacity is in the order of Giga (10^9) bytes.

Hard disks are kept inside the system cabinet of a personal computer. For a CAD station, hard disk of higher storage capacity is preferred in order to keep large number and size of drawing files as well as the softwares.

Compact Disk (CD)

The optical disks (called CD) used for storing data, are made of transparent glass or plastic and has a reflective metal film coating. An information is stored in the digital form by focusing a laser beam at the desired location and thereby creating a small hole (of one micron) or a pit in the film. The absence of hole is another binary state (zero). These holes or pits are read by a less powerful laser beam. A hole or pit in the reflective film changes the amount of light reflected from that spot, which is sensed by the reading head.

Optical compact disks are generally available as 'read only memory' in computers and hence they are called as CD-ROM. The storage density of CD-ROM is about 800 MB and the diameter is 4.7 inches only. There are now optical disks

EXERCISES

1. Explain the following terms in connection with a computer used for drafting:
   (a) Central processing unit (CPU).
   (b) RAM and ROM
   (c) Input devices
   (d) Secondary storage devices
   (e) Display devices
   (f) Output devices
2. What are the general features of a drawing generation process, using computer? Describe the following:
   (a) Draw commands
   (b) Edit commands
   (c) Display commands
   (d) Print commands
3. What is meant by menu in CAD software? Describe the difference between master menu and auxiliary menu.
4. What are the methods of getting drawing commands and editing commands in AutoCAD software?
5. Distinguish between the world coordinate system and the user coordinate system.
6. Explain the terms Grid, Snap and Object Snap.
7. What is a layer in CAD? How is the layer system used in drafting? Explain the advantages of using layers in drafting.
8. How are different line types and colours incorporated in layer system?
9. What is meant by edit function in drafting? List down commonly used 10 edit functions in computer aided drafting.

CHAPTER 24

Starting to Use CAD Software

The software explained in this book for the study of Computer Aided Drafting is based on AutoCAD 2002. The workstation configuration minimum required for the use of the software and the methods of setting an electronic drawing sheet suitable to the drafting are explained in the chapter.

24.1 SETTING OF WORKSTATION

A workstation, having AutoCAD2002 installed, is required a clear understanding of the topic explained. For loading AutoCAD2002, an IBM compatible pentium computer having at least 32MB RAM capacity, 150MB hard disk space in windows 95 or above version is required. After installing and configuring the software with the help of an expert, the user can open the program.

Choose the programme AutoCAD2002 >
Enter.

The same can be opened by double clicking on the AutoCAD2002 icon using the mouse. This opens the graphic screen after displaying the start up dialogue box.

24.2 START UP DIALOGUE BOX

Start up dialogue box placed overlapping the graphic screen, contains three compartments (see Fig. 24.1) Here, "My Drawing Compartment" has three pages. Page one is for "Open Drawings", page two is for "Creating New Drawings" and page three is for "Symbol Libraries".

The remaining two compartments named "Bulletin Board" and "autodesk Point A" are related web facilities through the software. A beginner has to click, "Create drawings" for setting up a new drawing sheet for drafting. To open an existing drawing file, "Open drawing" has to be clicked. The start up window is closed by clicking on the button with *x* mark placed at the right hand top corner.

24.3 THE GRAPHIC SCREEN

Pull Down Menu Bar

Like many other Windows programmes, AutoCAD2002 has the pull down menu bar having 12 titles shown on the top side of the screen (see Fig. 24.2). When the pointer is brought to each title, a list of menu can be opened for selection. The titles cover the important menus for commands and functions of AutoCAD.

The title "File" gives pull down menu for the management of files like Opening, Saving, Exporting, Printing, etc. To exit from AutoCAD, click on Exit. The pull down menu file also shows previously opened four files for fast selection. The menu under "Edit" covers the file editing operations like Undo, Redo, Cut, Copy, Paste, etc. The title

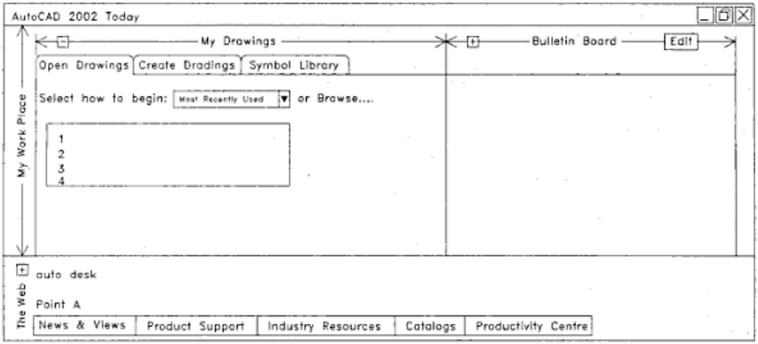


Fig. 24.1 Opening Menu.

"View" covers all about the views on the drawing screen like Zoom, Redrawing, 3D views, Shading, Rendering, Display of various items like World Coordinates, Tool bars, etc. The title "Insert" covers mainly blocking and inserting of drawings while the title "Format" is used for settling various features like Layers Colours Dimension Styles, Line types, etc. Different tools used in AutoCAD like Drawing settings, User coordinates (UCS) Object Snap settings, etc. can be selected or set by the pull down menu under "Tools". The title "Draw" gives all drawing commands for 2D and 3D drawings while the title "Dimension" covers the different Dim Commands. The pull down menu "Modify" opens the drawing modification commands like Erase, Break, Copy, Scale, Fillet, etc. "Image" shows the overlay files and window to make the screen for different tiled views. The details about AutoCAD 2002 software and the help topics are explained under the title "Help".

Press the Esc (Escape) key in order to close a pull down menu without selection. It has to be noted that Esc is the common key to cancel any action, command or selection made in its midway. The student has to click on each pull down menu bar and verify the details.

The Command Window and Status Bar

The rectangular horizontal window at lower side of the screen is the command area (refer Fig. 24.2). Here, AutoCAD displays the command selected, the input, the messages, etc. The instructions given to the computer through keyboard is shown here. The user has to read and follow the instructions shown at the command window and has to give data accordingly. For a beginner, command area instructions are very much helpful to proceed fast.

The status bar is given below the command window. This gives information about the drawing at a glance, like coordinates of the cursor (cross hair) position, Snap, Grid, Ortho, Polar, Osnap, etc.

Tool Bars

In addition to the pull down menus, AutoCAD 2002 provides sets of buttons marked with icons for selecting the commands directly. By clicking on a button, the command corresponding to the icon is opened immediately at the command window. This helps to improve the speed of drawing. A group of such buttons is called a *Tool bar.*

There are 26 tool bars readily available and the most frequently required 4 numbers are shown in the opening drawing screen. They are:

1. Standard tool bar
2. Object properties tool bar
3. Draw tool bar and
4. Modify tool bar

These tool bars are checked (placed safely) to the margin side of the drawing area. All the tool bars can be made visible (opened) or closed individually as per the user's requirement.

simple 2D drawings, five layers are suggested namely THK (thick line), THI (Thin line), CEN (Centre line) HID (Hidden line) and HAT (Hatching line). The method of setting layers and assigning colours, line type and line weight are given the following set up.

Set up 4 (Layers and line type)

Format > Layer > New >

Type THK over "Layer-1", click on colour "White" to get the colour box "Select Color" and type 130 over "White". Then click on the square box on the right side of it to get the colour selected and click OK. To select line weight, click on "Default", select 0.4 mm from the box for "Line weight" and click OK. Following the same method create the required five layers as given below.

Layer Name	Colour No.	Line weight
THK	130	0.40 mm
THI	40	0.20 mm
CEN	200	0.20 mm
HID	150	0.20 mm
HAT	160	0.15 mm

To assign the line type for centre line, click on "Continuous" of the CEN layer to open the box named "Select line type". Here, the required types of lines, (Centre line and Hidden line) are to be loaded first.

Load... > CENTER x 2 > OK
Load... > HIDDEN x 2 > OK

After loading the above line types, select the appropriate line type for the layers. By clicking OK of Layer Properties Manager, the layer setting process is completed. Now the layers can be seen on the object properties tool bar. Note that, each layer can be made current, turned on or off, freeze or thaw, lock or unlock, as required for the drafting.

After setting the layers, the same can be tested on the electronic drawing sheet by drawing lines in different layers.

Text Style

Any type of text can be selected from the font library and used on the drawing sheet. 2 mm size of "Romand.shx" text is suggested for captions and dimensioning, since its shape is almost the one suggested by BIS. The method of setting text style is given below:

Set up 5 (Text Style)

Format > Text Style... > New >
Style Name "Romand2" OK >
Font Name: Romand. shx > height 2mm >
Apply > Close.

This makes text 'Romand 2' of 2mm height. Similarly 5 mm text also can be set for title block of the sheet. It is to be noted that, the letter size at required places can be modified by using "Change Properties" icon of standard tool bar or "Text Edit" icon.

Dimension Style

Dimensioning of a feature is done automatically in AutCAD by clicking on the entity. Before this, the system of dimensioning has to be set as required in Method 1 of BIS. The following set up is suggested for orthographic views.

Set up 6 (Dimension Style)

Format > Dimension style...> New >
New style Name: BIS > Continue.

This opens the dialogue box "New Dimension Style Copy of Standard". Here, there are 6 pages and the settings are required in the first four pages .

Set up 6A (Page-Lines and Arrows)

6A1 (Subsection - Dimension lines)
Color - By layer > Line weight bylayer >
Base line spacing - 5 mm.

6A2 (Subsection - Extension lines)
Color - By layer >
Line weight - By layer >
Extension beyond line - 1 mm >
Offset from origin - 0mm.

6A3 (Subsection - Arrow heads)
1st: Closed filled > 2nd: Closed filled >
Leader: Closed filled > Arrow size 2 mm.

6A4 (Subsection - Centre marks for circles)
Type: Mark > Size : 2 mm.

Set up 6B (Page-Text)

6B1 (Subsection Text appearance)
Text style: Romand2 >
Text color: By layer > Text height - 2 mm.
(Note that the Romand2 text is ready by Set up 5)

6B2 (Subsection - Text placement)
Vertical: Above > Horizontal: Centred >
Offset from Dim line : 1 mm.

6B3 (Subsection - Text Alignment)
Select: ISO standard.

Set up 6C (Page-Fit)

6C1 (Subsection - Fit Options)
Select: Either the text or the arrows.

6C2 (Subsection Text placement)
Select: Beside the dimension line.

6C3 (Subsection - Scale for Dimension Features)
Select: Use overall Scale of 1.
6C4 (Subsection - Fine tuning)
Select: Always draw Dim line between ext lines.

Set up 6D (Primary Units)

6D1 (Subsection - Linear Dimensions)
Unit Format: Decimal > precision : 0.
6D2 (Subsection - Measurement Scale)
Scale Factor: 2.
6D3 (Subsection - Angular Dimensions)
Unit for mat: Decimal Degrees >
Precision: O.

Clicking of OK of the dialogue box brings back the "Dimension style Manager". This shows the final dimension set up on the drawing shown in the page noting the changes made as description. Modifications can be further made by clicking on the button named "Modify". After checking the dim style made, click on the button "Close" to complete the Set up 6.

24.6 SAVING THE BLANK SHEET

After creating the A4 size Electronic Blank Sheet as per the BIS system of dimensioning, save the file as Blank Sheet-1 in your folder under User area. Now the blank sheet is ready to use in your folder. Whenever you are beginning a new drawing, call a copy of the blank sheet-1, save it immediately as the name of drawing and start drafting. This will keep the Blank Sheet-1 as such and the new drawing with all the settings made. Different drawing sheets such as Portrait and Landscape orientation of size A1, A2, A3, etc., having margin and title block of the user type can be made and stored ready for drafting purpose.

EXERCISES

1. Explain how the software, AutoCAD is started, to begin drafting. Give the step by step procedure required for a particular version of the software.
2. Explain the general layout of the graphic screen of AutoCAD software. Also briefly show the following terms related with the graphic screen:
   (a) Command window and status bar
   (b) Tool bars
   (c) Cross hair and world coordinates
   (d) Standard screen menu
3. What is meant by a function key? Give a list of function keys used in drafting and their action.
4. How a blank drawing sheet is prepared, which is suitable to orthographic projection of objects? Describe the steps.
5. Explain how the layers, line types and their colours are set for a blank drawing sheet used for orthographic drawings.
6. What are the important points to be considered when a dimension style is adopted for a drawing. Briefly explain the how the setup is made to get Method-1 dimensioning system as per ISO.
7. Describe how a blank drawing sheet is saved in a computer after making it for a specific drafting purpose using AutoCAD.

CHAPTER 25

Drafting of 2D Figures

After preparing the electronic drawing sheet called *Blank Sheet* with all required settings as per BIS, the drawing of 2D figures can be started. Here, in AutoCAD, 2D figures mean the figures drawn on the *xy* plane of the screen. The method of using important Draw and Modify Commands are explained in this chapter. The examples and exercise give introduction to drafting of multiview projection and isometric projection of simple objects. Printing of them is also explained at the end of the chapter.

25.1 DRAW COMMANDS

Frequently used draw commands are:

1. Line
2. Circle
3. Arc
4. Polygon
5. Ellipse
6. Hatch
7. Text

These commands create the shapes and each one will be an entity. After clicking on an icon specified for each command, the data are fed one by one as asked in the command window to complete the entity.

1. Line

A straight line is specified by its two end points. To draw a line, click on the icon named "Line". This shows instructions in the command window in the following order:

Command: Line specify first point: *(Click a point on the drawing screen using cursor)*

Specify next point or [Undo]: *(Click the end point of line using cursor).*

Specify next point or [Close/Undo]: *(Show a third point to draw the second line).*

Specify next point or [Close/Undo]. *(Press enter key (↵) of key board or right button of mouse to open window for enter key and press on it using left button of mouse).*

The above process creates two straight lines touching at the ends as shown in Fig. 25.1.

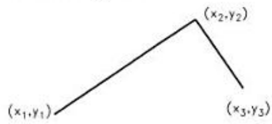


Fig. 25.1 Drawing of two lines.

Notes:

1. The end points of a line can be specified either by typing the *x*, *y* coordinate values in the command widow or by clicking on the screen using the cross hair.

2. The cross hair position can be noted from the coordinate values shown on the left hand bottom corner of the screen.
3. After starting a line from a point, it stretches, like a rubber band.
4. Press on the "Snap" button of status bar to make it on (if it is in off position) so that, coordinate values will be snapping without decimal values.
5. Press on the "Grid" button of Status bar to switch on the grid. This can help to locate coordinate point easily.
6. While drawing horizontal or vertical lines, "Ortho" of Status bar can be switched on for easy drafting of orthogonal lines. To draw inclined lines, "Ortho" should be switched off.

To draw a line of specific length say, 40.3 mm and inclination say 40° to horizontal, from point (x_1, y_1), type the following at the command window, after starting the line command.

Specify next point or [Undo]:
@ 40.3 < 40 ↵ ↵

This creates the inclined line as shown in Fig. 25.2.

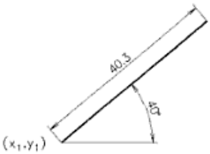


Fig. 25.2 Drawing of inclined line.

Using the line command number of straight lines from point to point can be drawn continuously from point to point. Finally, to draw a line to the starting point, the Close option can be selected. Similarly to Undo a step, the Undo option can be used. The Esc key of the keyboard can be used to come out at the middle of any command.

2. Circle

To draw a circle, click on the icon 'circle'. Then feed in the command area as given below.

Command: circle specify centre point for circle or [3p/2p/Ttr (tan tan radius)]:
(Locate the centre point using cross hair)
Specify radius of the circle or [Diameter]:
(Using cross hair Locate a second point to specify radius or type the value, ↵)

This completes the drawing of circle using centre point and radius [see Fig. 25.3(a)].

Circles can be drawn using 3 points (3p), two points (2p) or tangent to two lines or circles and radius (Ttr). These commands are to be typed in the command window for getting the options. Figure 25.3 shows the four methods of drawing a circle. They can be selected according to the use.

3. Arc

A three point arc, can be drawn using the icon Arc of the Draw Tool bar.

Command: arc, specify start point of arc or [center]: *(Click start point)*
Specify second point of arc or [Centre /End]: (Click *second point)*
Specify end point of arc: (Click *end point).*

This completes the 3 point arc as given in Fig. 25.4. Instead of clicking the first point, if "C" is typed in the command window, the arc can be drawn specifying the centre of arc, then start point and lastly end point or angle/chord length. Thus, using the combinations of geometrical data

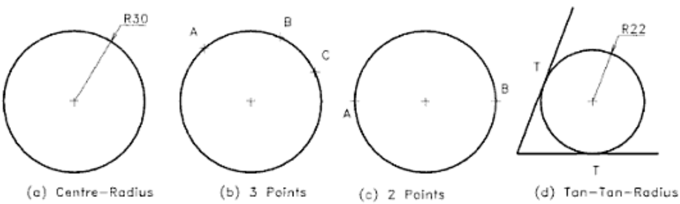


Fig. 25.3 Drawing of circles.

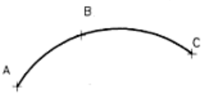


Fig. 25.4 3 point arc.

(Start point, Second point, End point, Centre of arc, Angle, Chord length, Direction and Radius) the arc can be draw in 11 different ways. Note that the direction of generating arc is in the anti-clockwise direction, similar to the measurement of angle.

4. Polygon

A polygon of sides ranging from 3 to any number can be drawn by clicking on the icon "Polygon". Number of sides, centre of polygon & radius of inscribing or circumscribing circle have to be given in the command area. Instead of this, feeding of the number of sides and the edge points can also draw the polygon. Figure 25.5 shows a pentagon drawn by the command. Note that this pentagon has five lines, but it is treated as a single entity for Modify (Edit) commands.

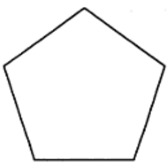


Fig. 25.5 Polygon.

5. Ellipse

An ellipse is drawn by clicking on the icon "Ellipse" and locating the two end points of one axis and one half length of the second axis. Figure 25.6 shows the ellipse drawn using the command.

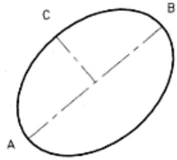


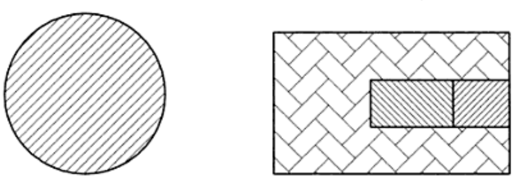
Fig. 25.6 Ellipse.

6. Hatch

Hatching of an enclosed area can be done very easily using Hatch command. After drawing a figure, say a circle, click on the icon "Hatch". This opens the dialogue box named "Boundary Hatch". Here click on the button Pick Points and then click inside the actual area to be hatched. Finally, click Enter key to recall the dialogue box and by pressing OK button complete the hatching process [see Fig. 25.7(a)]. Note that, to get the required pattern of hatching, its direction and scale, the same should be set initially as given below.

In the page "Quick" of the Boundary hatch, the following points may be noted.

1. Hatching patterns of different types can be selected by clicking on the button against patterns.
2. Angle of the pattern and the scale factor can be selected from scroll bar of Angle: and Scale: respectively.
3. "Pick points" button provides selection of the area with closed boundary, for hatching.
4. "Select objects" button provides selection of hatching area by clicking on the entities forming the boundary.
5. "Inherit Properties" button provides copying the same type of hatching on another areas.
6. "Preview" button provides preview of the hatching so that, changes of pattern, angle, scale, etc., can be modified if required, before clicking OK.



(a) Single (b) Different patterns and directions

Fig. 25.7 Hatching.

7. Text

Text can be written by clicking on the icon called "Multiline text". The area in which the text is to be written should be located first on the screen using the cross hair. Completion of this action shows the "Multi line text editor", in which the required text can be typed like a word processor. Here, the font, size of letter, etc. can be modified as required. For marking the degree, and diameter, the following symbols can be used.

For diameter (f50), %% c50

for Degrees (50°), %% d50

For more types of text edit icons, switch on "Text" of "Tool bars...." under pull down menu "View".

25.2 MODIFY COMMANDS

Frequently used Modify (Edit) commands are:

1. Erase
2. Move
3. Rotate
4. Copy object
5. Mirror
6. Break
7. Break at point
8. Trim
9. Extend
10. Scale
11. Stretch
12. Array
13. Fillet
14. Explode

The above-mentioned powerful Modify commands make the drafting fast and easy. To use most of the Modify commands, the object has to be selected first. There are three methods used to select objects. After clicking on an icon for Modify command, the cross hair is converted to a small pick box. Now an entity or a group of them can be selected by any combination of the following:

1. **Pick box:** Bring the pick box on the entity and press the left button of mouse. This selects the entity and is converted to dotted line for identification of selection.

2. **Window:** A group of entities can be selected by bringing them fully inside a rubber band like window. To create the window, click the left button of mouse, keeping the pick box at one point and move diagonally to the opposite corner to form the window, keeping the x direction positive. This creates the window made of continuous line and by pressing the left "button" again, the entities enclosed fully inside the window are selected (see Fig. 25.8).

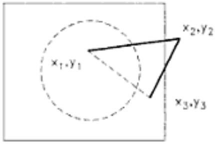


Fig. 25.8 Window for selection.

3. **Crossing (Window):** This option is similar to the Window, but the direction of movement of mouse should be in the negative direction of x. Here, a window of dotted line is formed and all the entities inside and crossing the window are selected (see Fig. 25.9).

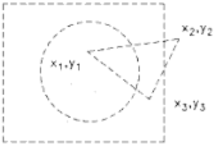


Fig. 25.9 Cross window for selection.

1. Erase

Erase command is used to remove one or a group of entities simultaneously. For this modification, press on the icon "Erase", select the objects, and press the right button of mouse or Enter key of key board. The selected objects are identified by the conversion to dotted lines, before erasing. The "Undo" button of standard tool bar can be used to cancel a completed activity to go one step back, if required.

2. Move

To move one or a group of objects from one location to another, press on the icon "Move", select the objects and click on the right button of mouse to end selection of objects. Locate the base point from where the objects are displaced and finally locate the destination point of displacement. This moves the object to the required location. Here, the base point and the final destination should be correctly located.

3. Rotate

Similar to move, "Rotation" command is also applied, but the rotation is about the base point selected and the angle can be typed at command prompt in degrees, measured from 3'O' clock position. The rotated position can also be located by the movement of cross hair. The value of radial distance and angular rotations from the base point to the cross hair position can be noted from the coordinate values as 'Distance< angle'

4. Copy object

This command is applied similar to 'Move' and gives a copy of the object selected at the destination point. "Multiple Copy" option, is obtained by typing 'M' at command prompt, before specifying the base point. This gives multiple copy at each clicking of destination point . Pressing of right button of mouse, Enter key or Esc key stops the action of the Multiple copy.

5. Mirror

This command is applied to get a mirror image of the object. Click on the icon "Mirror", select objects, click on right button of mouse and specify end points of the mirror line. Now the command prompt asks, whether to delete the original object or not. The default is < N > means not deleted (see Fig. 25.10).

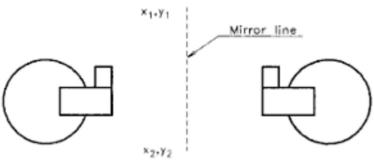


Fig. 25.10 Mirror image of an object.

6. Break

To break an entity for a length, click on the icon named "Break". Click on the entity using pick box and click the second point of brake, using the cross hair. This removes the line from the first point to the second point. For a full circle, this breaking length will be measured in the anti-clockwise direction about the centre of circle.

7. Break at point

This command selects an entity first and then breaks it into two entities at the point clicked, without any gap. For a full circle, this command will not work.

8. Trim

To remove the excess length of an entity from another entity, the "Trim" can be used. Click on the icon "Trim", select the cutting edge or edges by pick box and press the right button or Enter key. Now click on the extra length of the objects to be trimmed one by one. Pressing of Enter key stops the command (see Fig. 25.11).

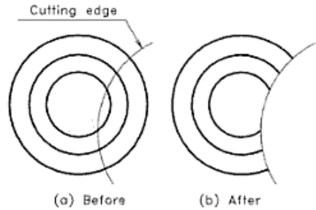


Fig. 25.11 Trimming.

9. Extend

Extend command works similar to Trim, but adds length of an entity in the same direction up to the boundaries specified. Click on the "Extend", select the boundary line using pick box, and press right button of mouse or Enter key. Now, click on the lines to be extended one by one. Pressing of Enter key stops the command (see Fig. 25.12).

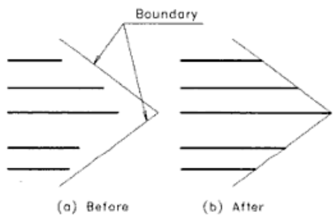


Fig. 25.12 Extension.

10. Scale

The command scale is used to enlarge or reduce the size of a drawing to the required ratio. Click on the icon "Scale", select the objects using pick box or window, click on right button to end selection, specify base point of scaling using cross hair, type the scale factor at command prompt and press the Enter key to get the scaled view with reference to the base point.

11. Stretch

Stretch command is used to stretch to enlarge or reduce a portion of a figure containing one or more entities simultaneously. Click on the icon "Stretch", select the objects to be stretched by cross window only, click on the right

Example 25.2
Draw a circle of diameter 80 mm and inscribe the largest isosceles triangle on the horizontal diameter AB of the circle. Also inscribe the largest circle in the remaining half.

Refer to Fig. 25.20.

Commands required:

Circle, Line, Text, and Dim commands.

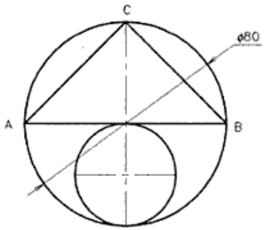


Fig. 25.20 Geometrical construction.

Example 25.3
Figure 25.21 shows a view of an object. Copy the same and dimension as per BIS.

Refer to Fig. 25.21

Commands required:

Line, Ellipse, Circle, Polygon, Fillet, Trim, and Dim commands.

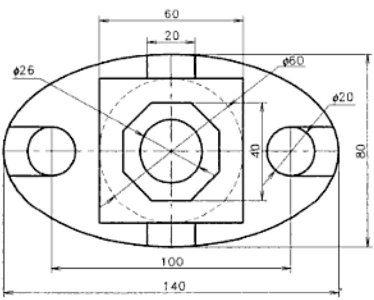


Fig. 25.21 Flange.

Example 25.4
Draw sectional elevation and end view of the bush given in Fig. 25.22.

Refer to Fig. 25.22.

Commands required:

Line, Circle, Trim, Mirror, Polar array, Fillet and Hatch.

To get sectional elevation draw one half up to centre line, take mirror image and then hatch. For side view, draw one hole with the grove and take Polar array.

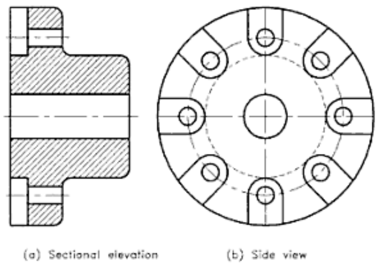


Fig. 25.22 Bush

Example 25.5
Draw isometric view of the block given in Fig. 25.23.

Refer to Fig. 25.23.

Commands required:

Line, Isocircle of ellipse.

Convert the drafting settings to isometric snap and draw the left, right and top faces of the block by changing the places using Ctrl-E or F5.

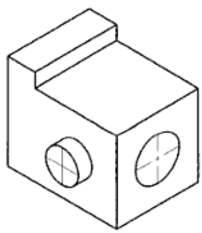


Fig. 25.23 Block (isometric view).

EXERCISES

1. Draw the following views using CAD:

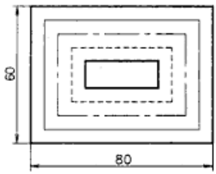


Fig. 25.24

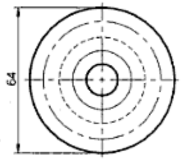


Fig. 25.25

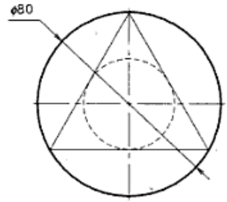


Fig. 25.26

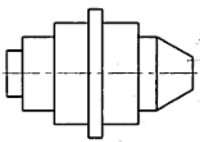


Fig. 25.27 Axle.

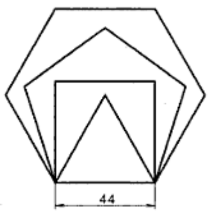


Fig. 25.28 Geometrical shapes.

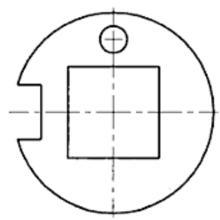


Fig. 25.29 A block washer.

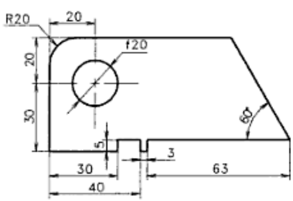


Fig. 25.30 A template.

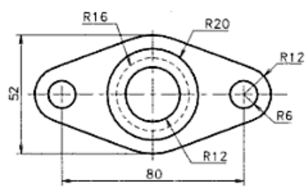


Fig. 25.31 Gland.

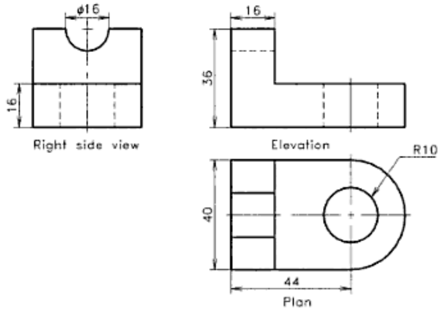


Fig. 25.32 A machine part.

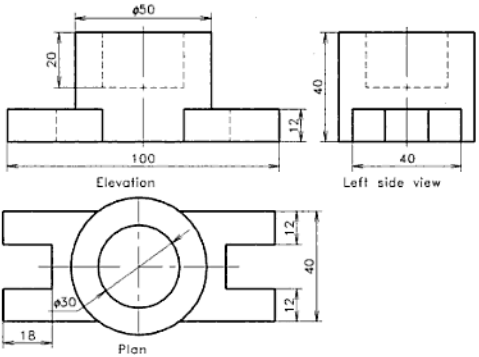


Fig. 25.33 A cylindrical block.

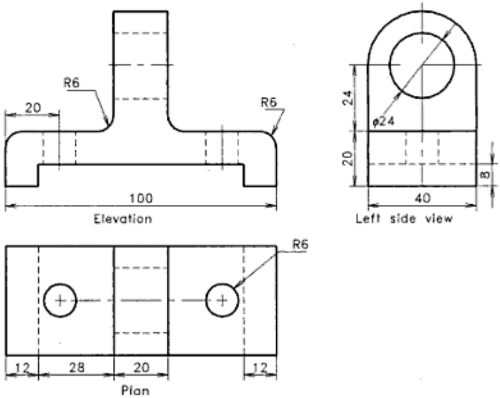


Fig. 25.34 Shaft support.

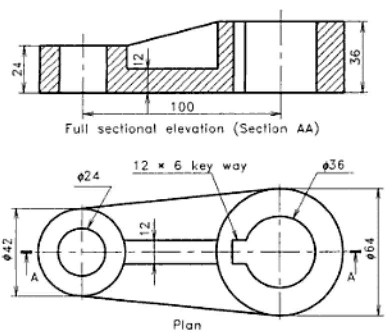


Fig. 25.35 A lever (sectional view).

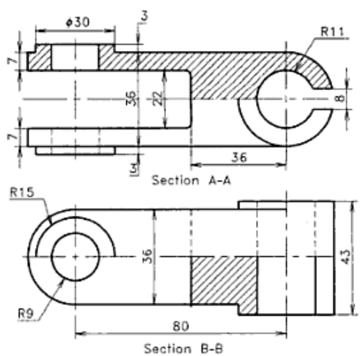


Fig. 25.36 Forked end of a machine part (half sectional views).

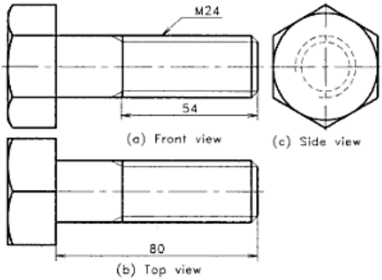


Fig. 25.37 Hexagonal headed bolt.

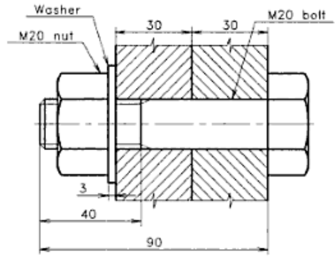


Fig. 25.38 Assembly of hexagonal bolt, nut and a washer.

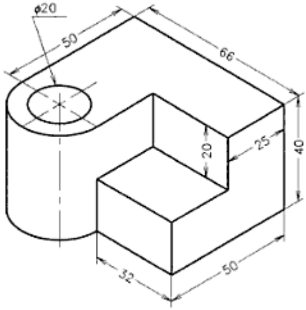


Fig. 25.39 C.I. block

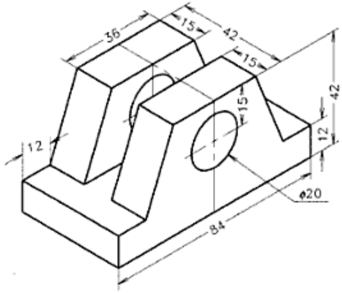


Fig. 25.40 A block.

Problems and Solutions

CHAPTER 5: GEOMETRICAL CONSTRUCTIONS

Problem 1

A line AB has a length of 127 mm. Divide the line graphically in the ratio 1:3:4.

Solution: See Fig. P5.1.

Help: Divide the line into 1 + 3 + 4 = 8 equal divisions and get 1, 3 and 4 units.

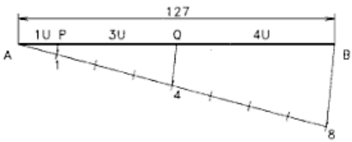


Fig. P5.1

Problem 2

Divide a line of length 131 mm into the ratio 3:5:4 and construct a triangle using these line segments.

Solution: See Fig. P5.2.

Help: Divide the line into 3 + 5 + 4 = 12 equal divisions, mark off 3, 5, and 4 units and construct the triangle.

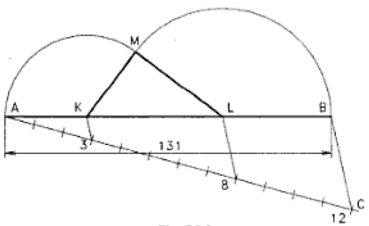


Fig. P5.2

Problem 3

Two lines AB and BC of any length have an included angle of 110°. Draw an arc of radius 25 mm tangential to these lines.

Solution: See Fig. P5.3.

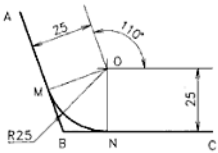


Fig. P5.3

Problem 4

Draw an arc of radius 80 mm such that two circles of radii 30 mm and 20 mm are touching this arc internally. The centres of circles are at a distance of 70 mm. Also mark the points of tangency.

Solution: See Fig. P5.4.

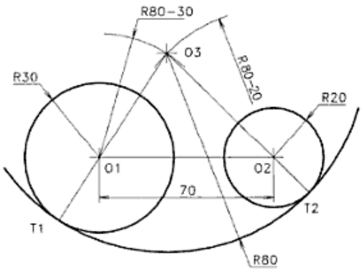


Fig. P5.4

Problem 5

Draw an arc of radius 70 mm tangential externally to a circle of radius 20 mm and internally to another circle of radius 30 mm. The centres of the two circles are 60 mm apart. Also mark the points of tangency.

Solution: See Fig. P5.5.

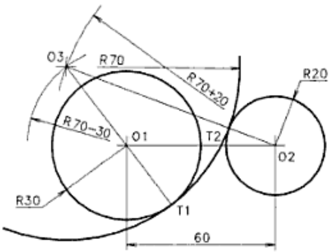


Fig. P5.5

Problem 6

Two circles of equal radii 20 mm are located 96 mm apart. Draw external and internal tangents to these circles.

Solution: See Fig. P5.6.

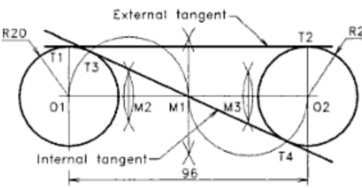


Fig. P5.6

Problem 7

Two pulleys of diameter 20 cm and 40 cm are connected by a flat belt in open system. Draw a line diagram of the system. The distance between the centres is equal to 160 cm and the line joining the centres is vertical.

Solution: See Fig. P5.7.

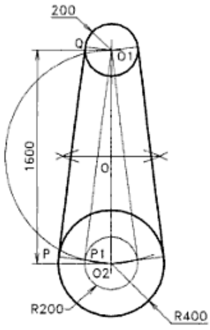


Fig. P5.7

Problem 8

Construct the following regular polygons on an edge AB equal to 40 mm.

(i) Square,
(ii) Pentagon,
(iii) Hexagon,
(iv) Heptagon, and
(v) Octagon.

Solution: See Fig. P5.8.

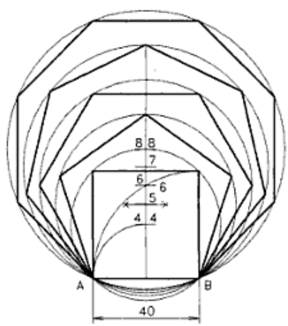


Fig. P5.8

Problem 9

Draw three circles K, L and M with radii 30 mm, 20 mm and 15 mm respectively, such that they are touching each other and the line joining the centres of K and L is horizontal.

Solution: See Fig. P5.9.

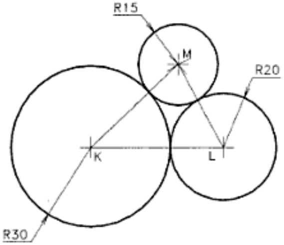


Fig. P5.9

Problem 10

Draw a circle of 100 mm diameter and construct four equal circles in it, each touching the given circle and two other circles.

Solution: See Fig. P5.10.

Help: Divide the circle radially into four and complete the triangle OAC, such that angle AOC equal to 360°/8 = 45°. Draw the triangular bisector AP to get the point P, the centre of the small circle and PC, the radius of the circle.

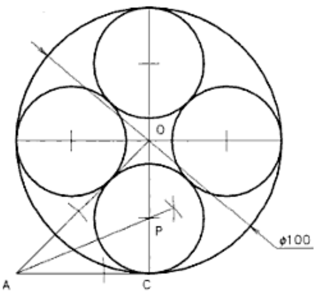


Fig. P5.10

Problem 11

Construct a pentagon of 20 mm side and draw five circles of equal diameter, each to touch one side of the polygon and two of the other circles externally.

Solution: See Fig. P5.11.

Help: Construct the polygon and extent OA to P outside. Draw the angular bisector of angle PAB to intersect the perpendicular OM produced at Q. Point Q is the centre and QM is the radius of one of the five circles.

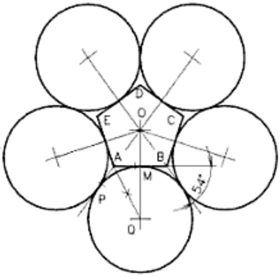


Fig. P5.11

Problem 12

Centre lines of two metre-gauge railway tracks are at a distance of 5 m. It is required to connect them by an ogee curve starting from a point A on the first track to the point B on the second track such that the straight line distance AB is equal to 14 m. The point of tangency of the two curves is located 6 m from A. Draw the centre line and the railway tracks of the curve to a scale of 1:100. Retain all the construction lines.

Solution: See Fig. P5.12.

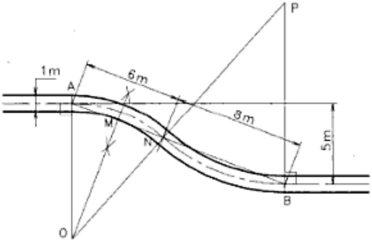


Fig. P5.12

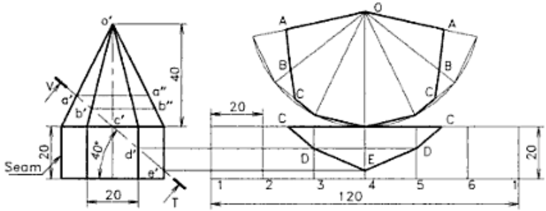


Fig. P15.3

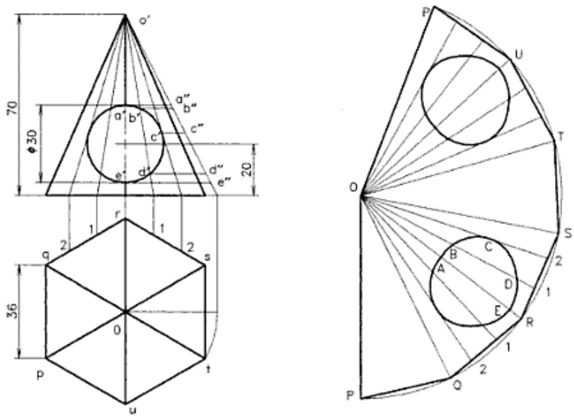


Fig. P15.4

Problem 5

Draw the development of the lateral surfaces of a square prism whose front view is shown in the Fig. P15.5(a). The length of the base side is 30 mm and all the faces are equally inclined to VP.

Solution: See Fig. P15.5(b)

Problem 6

Construct the pattern for a square to rectangle transformer, side of top square is 200 mm and size of the rectangle is 440 mm × 700 mm. The length is 400 mm. The transformer is vertical and the centre line passing through the geometrical centres of the square and the rectangle is also vertical. In the top view, the diagonals of the square top are perpendicular to the sides of the rectangle.

Solution: See Fig. P15.6.

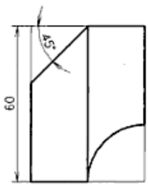


Fig. P15.5(a)

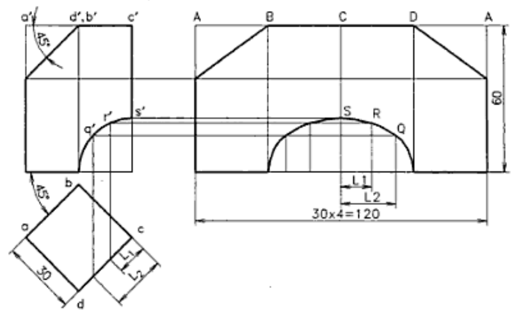


Fig. P15.5(b)

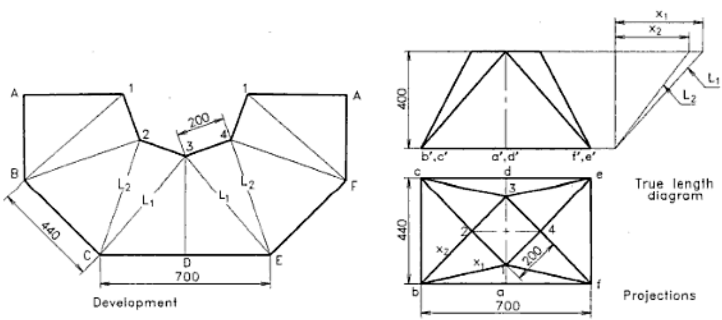


Fig. P15.6

Problem 7

Draw the development of the lateral surface of the cylinder cut as shown in Fig. P15.7(a).

Solution: See Fig. P15.7(b).

Problem 8

Draw the development of a cylinder with a portion of a square hole on its surface shown in Fig. P15.8(a).

Solution: See Fig. P15.8(b).

Problem 9

Draw the development of one half of the transition piece about the line of symmetry, shown in Fig. P15.9(a).

Solution: See Fig. P15.9(b).

Problem 10

Draw the development of the transition piece, shown in Fig. P15.10(a).

Solution: See Fig. P15.10(b).

Help: The complete pattern is formed by 12 triangles.

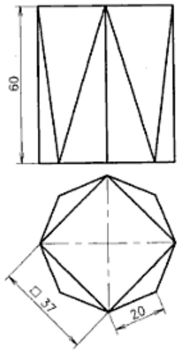


Fig. P15.10(a)

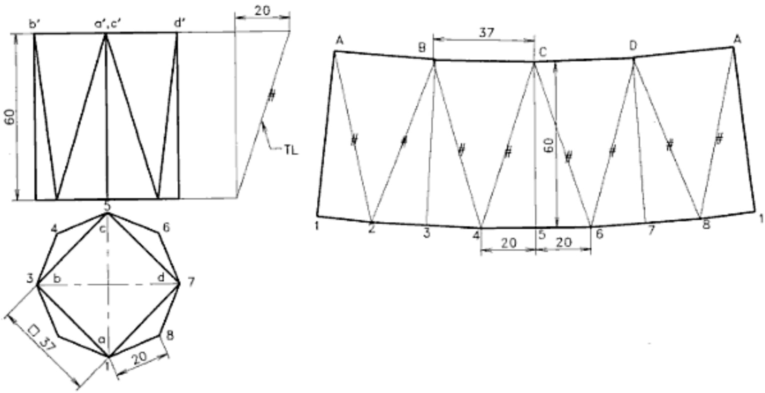


Fig. P15.10(b)

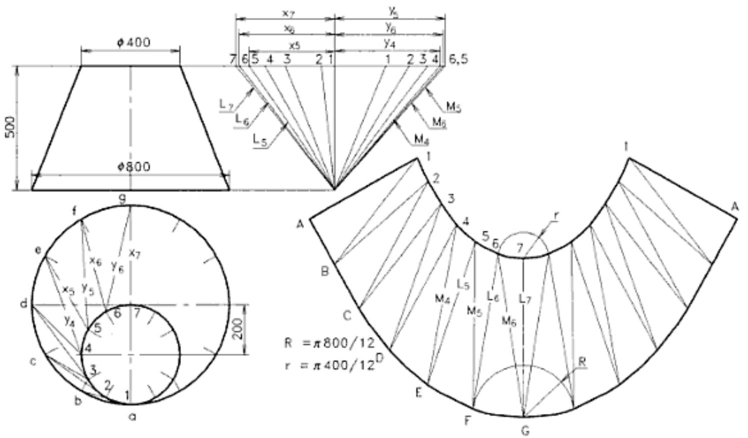


Fig. P15.12

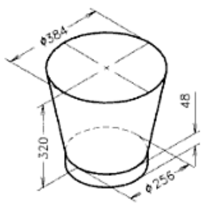


Fig. P15.13(a)

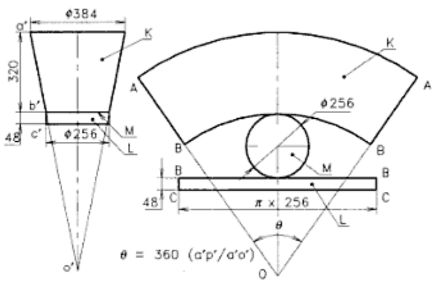


Fig. P15.13(b)

Problem 14

Figure P15.14(a) gives the pictorial view of a funnel. Draw the complete development of it.

Solution: See Fig. P15.14(b).

Problem 15

Develop the inside pattern of a 4 piece bent whose front is given in Fig. P15.15(a). Layout the pieces in order to cut them to a minimum size of sheet.

Solution: See Fig. P15.15(b).

Problem 2

A cylindrical slab, 60 mm in diameter and 16 mm thick, is surmounted by a cube of 30 mm side. On the top of the cube rests a square pyramid of altitude 30 mm and side of base 24 mm. The axes of the solids are in the same straight line. Draw the isometric view of the combination of the solids.

Solution: See Fig. P16.2.

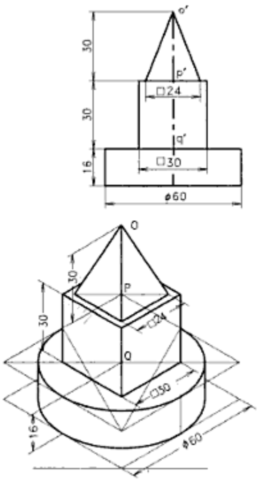


Fig. P16.2

Problem 3

A hemisphere of diameter 60 mm is resting on the ground with its flat surface facing upwards. A square pyramid, having side of base 30 mm and axis 40 mm, is resting on its base centrally on the top of the hemisphere. Draw the isometric projection of the solids.

Solution: See Fig. P16.3.

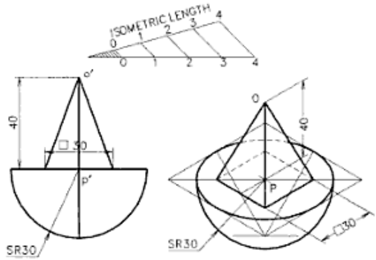


Fig. P16.3

Problem 4

A hollow square prism, standing upright, has outside faces measuring 50 mm × 40 mm high, four inside faces measuring 40 mm × 40 mm high. A hemisphere of radius 26 mm is resting with its curved surface on the prism and flat face horizontal. Draw the isometric projection of the combination.

Solution: See Fig. P16.4.

Help: Draw the front view of the combination and find the height L. Draw the isometric projection using isometric lengths and construct the circle for sphere using the true radius = 26 mm.

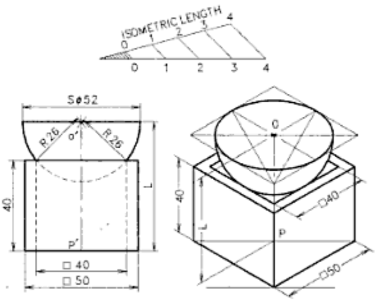


Fig. P16.4

Problem 5

A hollow cylinder of inside diameter 20 mm, outside diameter 40 mm and 65 mm long is resting centrally with its axis horizontal on a block, 65 mm square and 16 mm thick. Draw an isometric projection of this setup. Use isometric scale.

Solution: See Fig. P16.5.

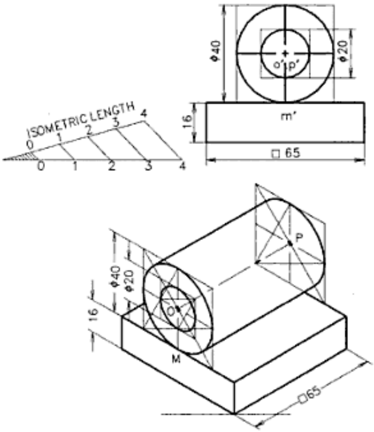


Fig. P16.5

Problem 6

A waste paper basket is in the form of a frustum of a hexagonal pyramid with base 90 mm side and top 150 mm side. Draw the isometric view of the basket, if the height is 200 mm.

Solution: See Fig. P16.6.

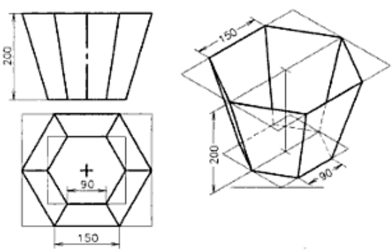


Fig. P16.6

Problem 7

Figure Fig. P16.7(a) gives the multiview projection of a tray. Draw the isometric view of the tray.

Solution: See Fig. P16.7(b).

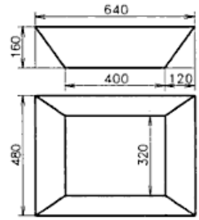


Fig. P16.7(a)

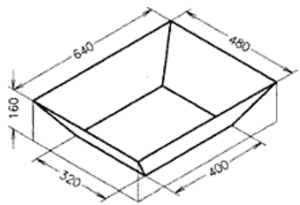


Fig. P16.7(b)

Problem 8

Draw the isometric view of the steps given in Fig. P16.8(a). Need not dimension the figure.

Solution: See Fig. P16.8(b).

Problem 9

Draw the isometric view of the pin support shown in Fig. P16.9(a).

Solution: See Fig. P16.9(b).

Problem 10

Orthographic view of a clamp is given Fig. P16.10(a). Draw its isometric view. Need not dimension the figure.

Solution: See Fig. P16.10(b).

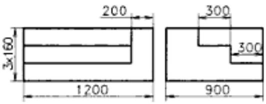


Fig. P16.8(a)

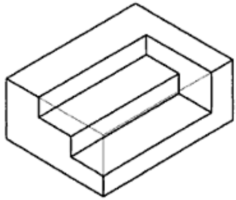


Fig. P16.8(b)

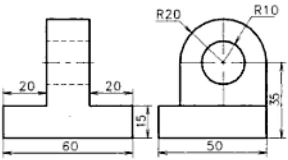


Fig. P16.9(a)

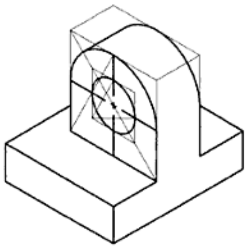


Fig. P16.9(b)

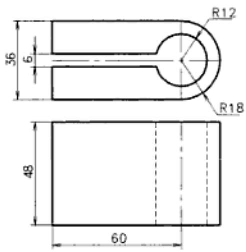


Fig. P16.10(a)

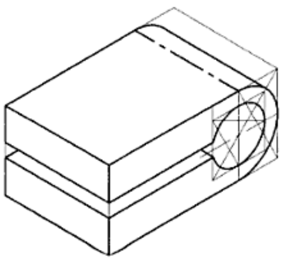


Fig. P16.10(b)

Problem 11

A cone of base diameter 60 mm and height 70 mm is cut by a plane inclined at 30° to HP and bisecting the axis. Draw the isometric view of the cone, showing the cut-surface.

Solution: See Fig. P16.11.

Help : Draw the top and front views of the sectioned cone and construct the isometric view by box method.

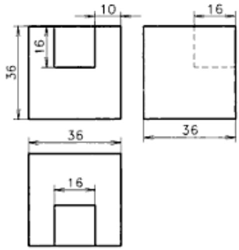


Fig. P16.13(a)

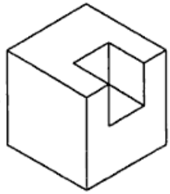


Fig. P16.13(b)

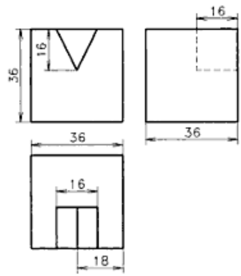


Fig. P16.14(a)

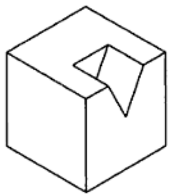


Fig. P16.14(b)

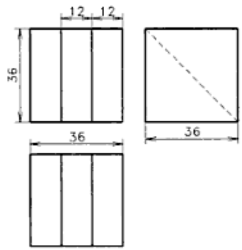


Fig. P16.15(a)

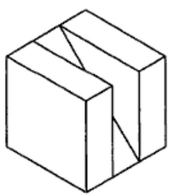


Fig. P16.15(b)

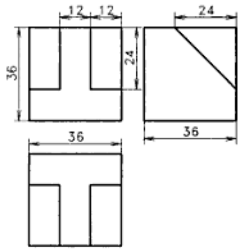


Fig. P16.16(a)

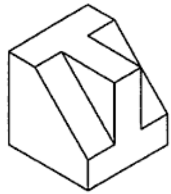


Fig. P16.16(b)

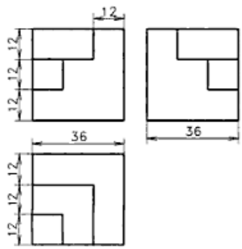


Fig. P16.17(a)

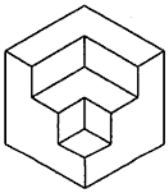


Fig. P16.17(b)

CHAPTER 19: MULTIVIEW PROJECTION OF OBJECTS

Draw the orhtographic views of the engineering objects as per the instructions given along with the Figs. P19.1 to P19.8. View the objects in the direction of arrow marked with F. Name the views and dimension them as per BIS.

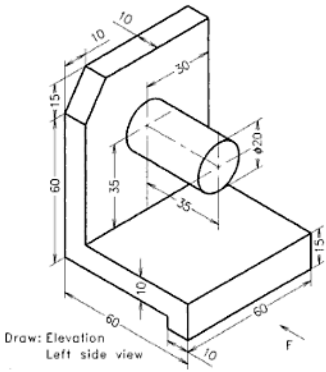


Fig. P19.1(a) A machine part.

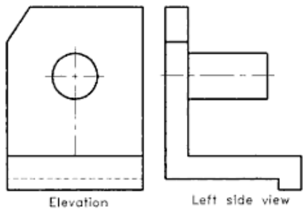


Fig. P19.1(b) A machine part.

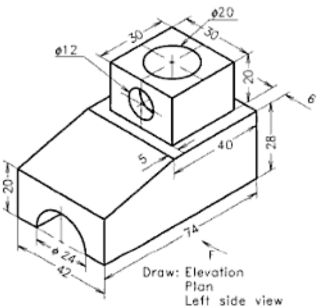


Fig. P19.2(a) A machine part.

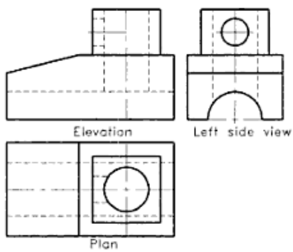


Fig. P19.2(b) A machine part.

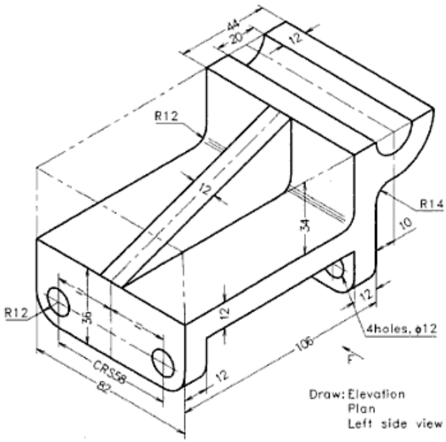


Fig. P19.5(a) A rod support.

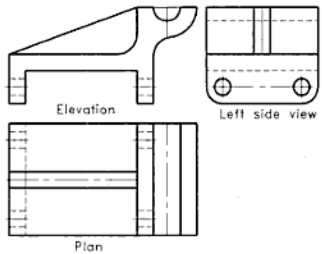


Fig. P19.5(b) A rod support.

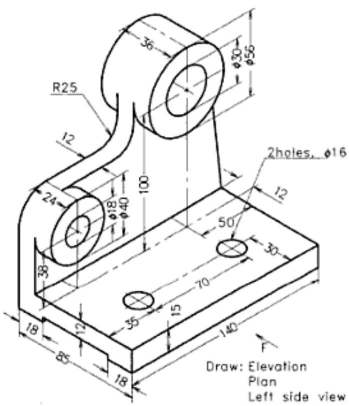


Fig. P19.6(a) End bracket.

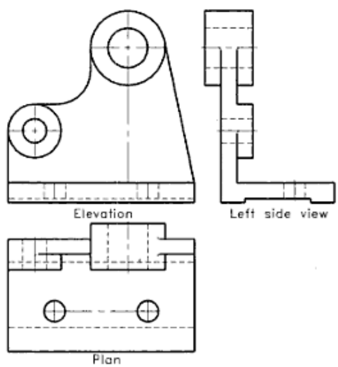


Fig. P19.6(b) End bracket.

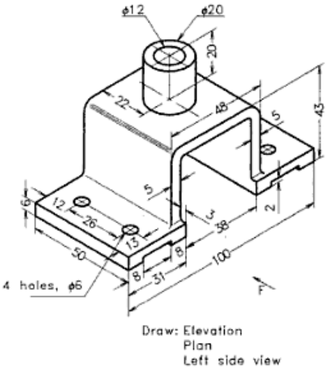


Fig. P19.7(a) Rod support.

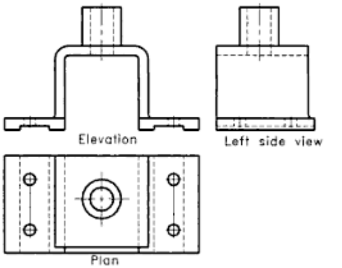


Fig. P19.7(b) Rod support.

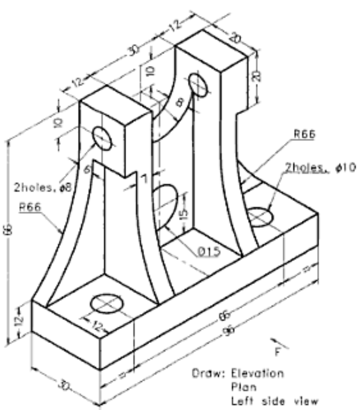


Fig. P19.8(a) Bracket.

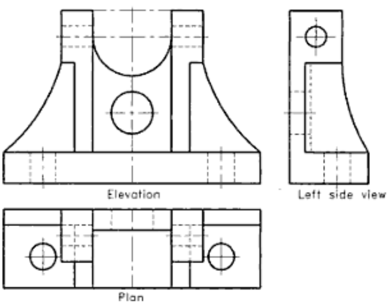


Fig. P19.8(b) Bracket.

Selected Polytechnic Examination Questions and Answers

Dimensioning

Question 1

Read the dimensioned drawing as shown in Fig. 1(a). Redraw the figure and dimension as per BIS. (1995)

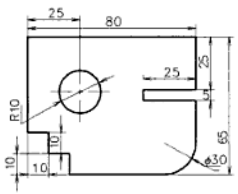


Fig. 1(a)

Answer: See Fig. 1(b).

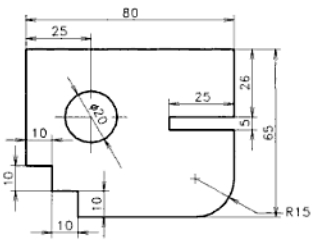


Fig. 1(b)

Question 2

Read the dimensional drawing as shown in Fig. 2(a). Redraw the figure and dimension as per Indian standards. (1995)

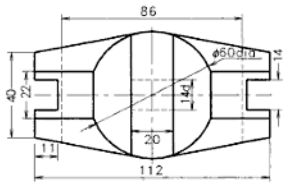


Fig. 2(a)

Answer: See Fig. 2(b).

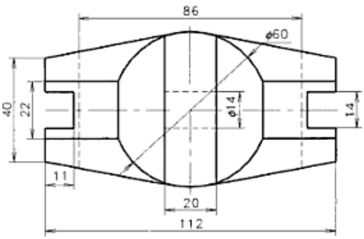


Fig. 2(b)

Question 3

Read the dimensioned drawing shown in the Fig. 3(a). Redraw the figure to full size and dimension it as per Indian Standards. (1995)

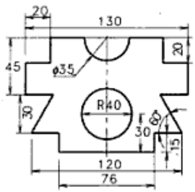


Fig. 3(a)

Answer: See Fig. 3(b).

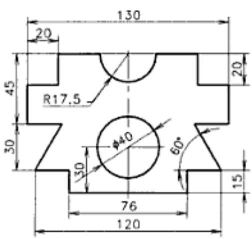


Fig. 3(b)

Question 4

Read the dimensioned drawing shown in the Fig. 4(a). Redraw the figure to full size and dimension it as per Indian Standards. (1995)

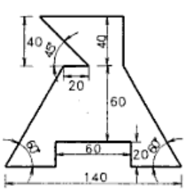


Fig. 4(a)

Answer: See Fig. 4(b).

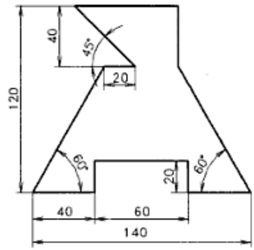


Fig. 4(b)

Question 5

Read dimensioned drawing shown in Fig. 5(a) and redraw the same to full size and dimension it as per Indian Standards. (1996)

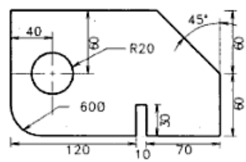


Fig. 5(a)

Answer: See Fig. 5(b).

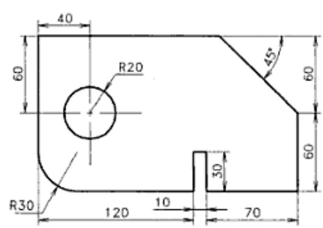


Fig. 5(b)

Question 6

Read the dimensional drawing shown in Fig. 6(a) and redraw the same to full size and dimension it as per Indian Standards. (1997)

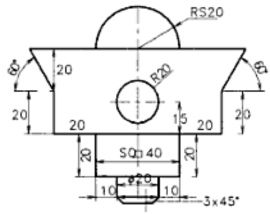


Fig. 6(a)

Answer: See Fig. 6(b).

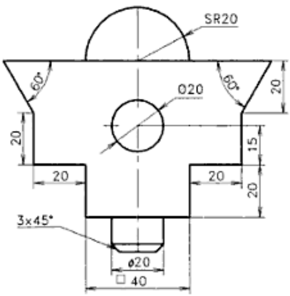


Fig. 6(b)

Geometrical Constructions

Question 7

Draw the layout of a octagonal garden yard on an available open space of 6 m × 6 m.

Answer: See Fig .7. (1997)

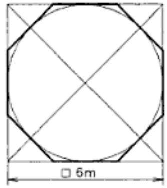


Fig. 7

Question 8

Draw an arc of radius 30 mm tangential to a circle of radius 45 mm and passing through a point at a distance of 80 mm from the centre of the circle.

Answer: See Fig. 8. (1998)

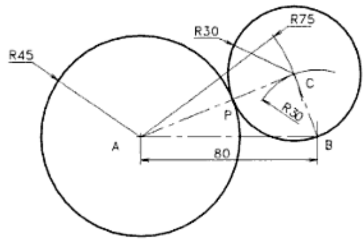


Fig. 8

Question 9

Find the approximate length of the circumfrence of a circle of radius 45 mm by geometrical method.

Answer: See Fig. 9. (2004)

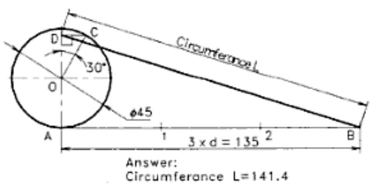


Fig. 9

Miscellaneous Curves

Question 10

Draw an involute of a pentagon of side 20 mm.

Answer: See Fig. 10. (1998)

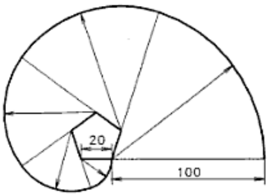


Fig. 10

Question 11

Draw the involute of a heptagon of 15 mm side and draw a tangent and a normal at any point P on the involute.

Answer: See Fig. 11. (2003)

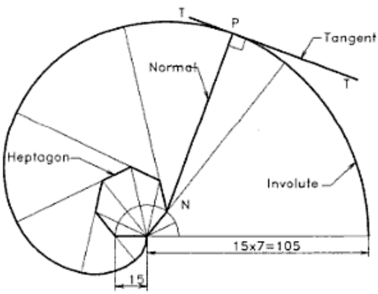


Fig. 11

Projections of Points

Question 12

Draw the projections of the following points:

1. Point A is 2 cm in front of VP and 4cm below HP.
2. Point B is 3 cm behind VP and 5cm below HP.
3. Point C is in the VP and 3 cm above HP.
4. Point D is in both HP and VP.

Answer: See Fig. 12. (1998)

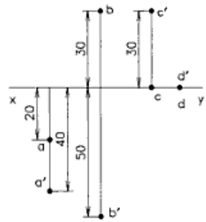


Fig. 12

Projections of Straight Lines

Question 13

A line AB is 60 mm long, A is 30 mm above the HP and 10 mm in front of the VP. The line is inclined at 40° to the HP. The plan is inclined at 25° to XY. Draw the plan and elevation of the line and find its traces and inclination to the VP.

(1995)

Answer: See Fig. 13.

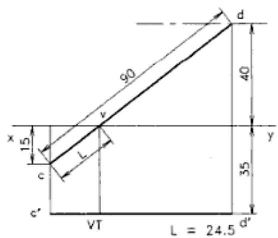


Fig. 13

Question 14

The end C of the line CD (90 mm long) is 15 mm in front of VP and 35 mm below HP. The end D is also 35 mm below HP but 40 mm behind VP.

1. Draw the projections of the line CD.
2. Mark the traces.
3. At what distance from the end C, the line CD penetrates VP. (1995)

Answer: See Fig. 14.

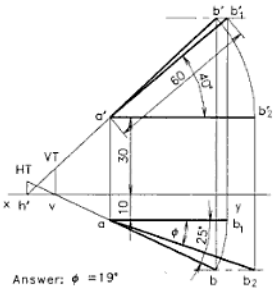


Fig. 14

Question 15

A line AB 70 mm long, has its end A in HP and end B in VP. The line is inclined at 45° to the HP and 40° to the VP. Draw its projections when the line lies in first quadrant. (1997)

Answer: See Fig. 15.

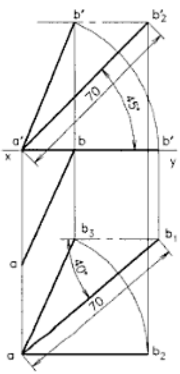


Fig. 15

Question 16

A straight line AB is inclined to both the reference planes, point A is 15 mm behind VP and 20 mm below HP point B is 30 mm behind VP and 20 mm above HP. The projections of A and B are 40 mm apart. Draw the top view and front views of the line.

Answer: See Fig. 16. (1999)

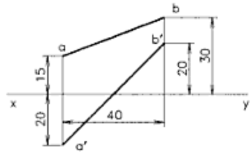


Fig. 16

Question 17

A line AB is 80 mm long. End A is in the HP and is 20 mm in front of VP. The line is inclined at 45° to HP and 30° to VP. Draw the projection and measure their inclinations with *xy* line.

Answer: Similar to Fig. 17. (1999)

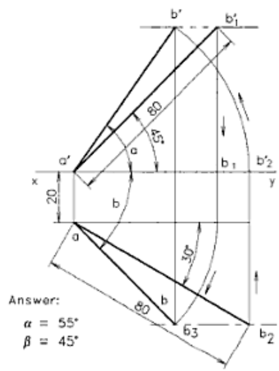
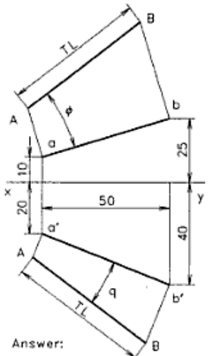


Fig. 17

Question 18

A line AB is inclined to both reference planes. Point A is 10 mm behind VP and 20 mm below HP. Point B is 25 mm behind VP and 40 mm below HP. The distance between A and B along *xy* is 50 mm. Determine the true length and true inclinations of the line with reference planes.

Answer: See Fig. 18. (2000)



Answer:

θ = 16°

ϕ = 21°

TL= 56

Fig. 18

Projections of Plane Figures

Question 19

Draw the projections of a regular hexagonal lamina of 25 mm side. The lamina is resting on the vertical plane on one of its sides and the lamina is parallel and at a distance of 25 mm above HP.

Answer: See Fig. 19. (2000)

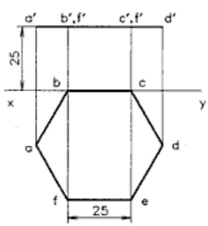


Fig. 19

Question 20

Draw the plan and elevation of an octagonal lamina of side 20 mm. The lamina is resting on HP with one of its corners at a distance of 30 mm. from the VP and parallel to it.

Answer: See Fig. 20. (2000)

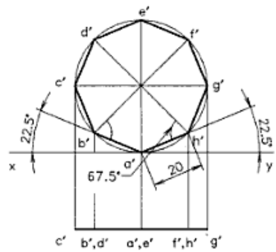


Fig. 20

Question 21

A regular pentagonal lamina of side 30 mm is resting on the vertical plane, 30 mm above HP, on one of its side and is parallel to HP. Draw its projections.

Answer: See Fig. 21. (2003)

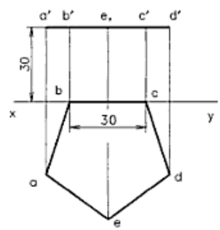


Fig. 21

Projections of Solids

Question 22

A square pyramid having base 45 mm sides and axis 75 mm long is lying on the ground at an inclination of 20° to the VP on one of its faces. Draw its projections on the HP and VP. (1995)

Answer: See Fig. 22.

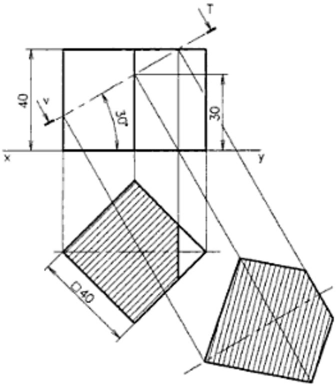


Fig. 25

Question 26

A hexagonal prism of side 35 mm and height 75 mm axis length, lies with one of its rectangular faces on the HP with its axis inclined at 30° to the VP. A vertical section plane, parallel to VP cuts the axis at a distance of 10 mm from the end away from VP. Draw its plan and true shape of section. (1997)

Answer: See Fig. 26.

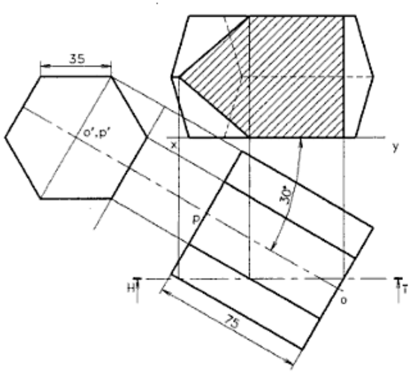


Fig. 26

Question 27

A pentagonal pyramid, side of base 30 mm and height 65 mm rests on its base on the HP with one of its base edge perpendicular to VP. An auxiliary inclined plane (AIP) inclined to HP at angle of 45° cuts the pyramid bisecting its axis. Draw the elevation, sectional plan and true shape of the section.

Answer: See Fig. 27. (1998)

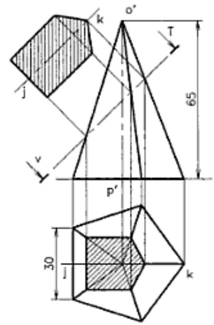


Fig. 27

Question 28

Orthographic views of an object are given in Fig. 28(a). Draw the following sectional views:

1. Sectional elevation, when the section plane passes through "XX" (HT).

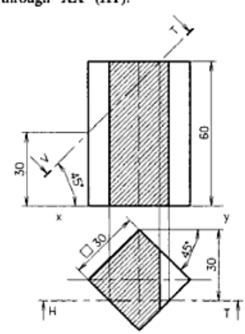


Fig. 28(a)

2. Sectional plan, when the section plane passes through "YY" (VT).

Answer: See Fig. 28(b). (2003)

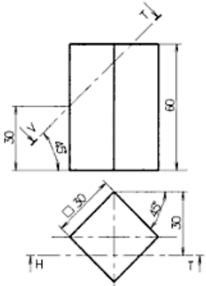


Fig. 28(b)

Development of Surfaces

Question 29

A cone of base diameter 60 mm and height 70 mm is resting on its base on the ground. It is cut by a horizontal plane at a distance of 15 mm from the vertex. It is also cut by a plane inclined at 40° to the base and meeting the axis at a point 15 mm above the base. Draw the development of the lateral surface of the cut cone. (1996)

Answer: See Fig. 29.

Question 30

Develop the inside pattern of measuring can as shown in Fig. 30(a). (1997)

Answer: See Fig. 30(b).

Question 31

A square pyramid of base side 40 mm and axis 75 mm rests on the ground with two of its edges perpendicular to VP. It is cut by a cutting plane perpendicular to VP and inclined at 60° to the HP. The cutting plane passes through a point 30 mm below the vertex on the axis. Draw the development of the lateral surface of the pyramid below the cutting plane.

Answer: See Fig. 31. (1999)

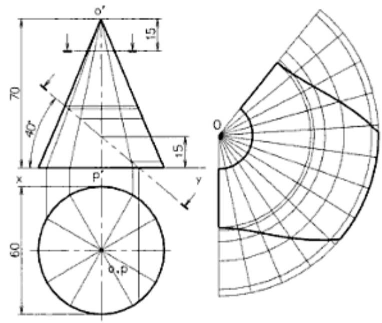


Fig. 29

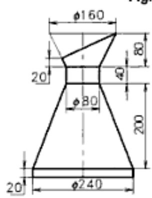


Fig. 30(a)

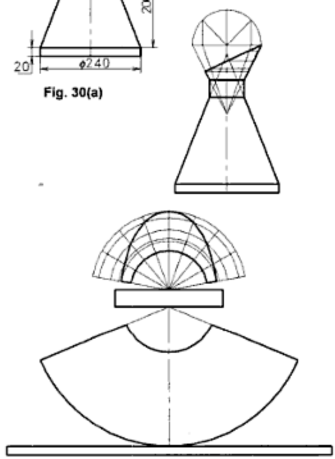


Fig. 30(b)

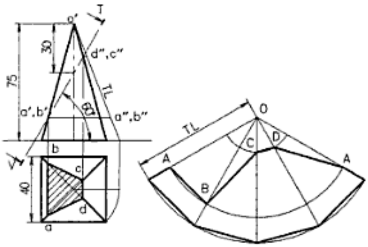


Fig. 31

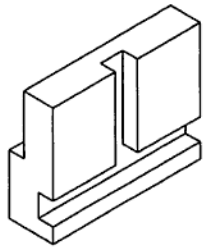


Fig. 33(a)

Isometric Projection

Question 32

A square slab of 60 mm side and 15 mm height is surmounted by another square slab of 45 mm side and 24 mm height. On its top a right circular cone of diameter 40 mm and height 60mm is placed. The axis of the solids are in a same vertical line. Draw the isometric view of the solids in position.

Answer: See Fig. 32. (1995)

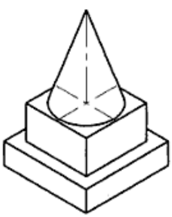


Fig. 32

Question 33

Figure 33(a) shows the orthographic projections of an object. Draw the isometric view to full scale.

(1995)

Answer: See Fig. 33(b).

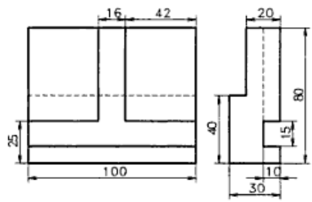


Fig. 33(b)

Question 34

Figure 34(a) shows the orthographic projections of an object. Draw the isometric view to full scale.

(1996)

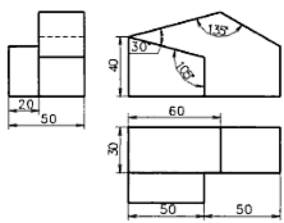


Fig. 34(a)

Answer: See Fig. 34(b).

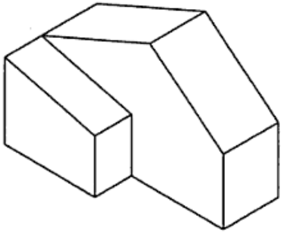


Fig. 34(b)

Question 35

Figure 35(a) shows the orthographic projection of an object. Draw the isometric view to full size. (1998)

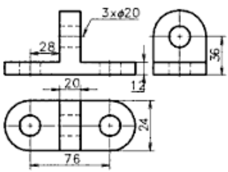


Fig. 35(a)

Answer: See Fig. 35(b).

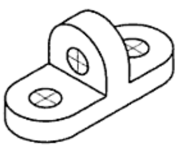


Fig. 35(b)

Question 36

Orthographic views of a block are in Fig. 36(a). Draw its isometric view. Dimensioning is not necessary.

Answer: See Fig. 36(b). (1999)

Question 37

Figure 37(a) shows the orthographic projections of an object. Draw its isometric view, to full scale.

(1999)

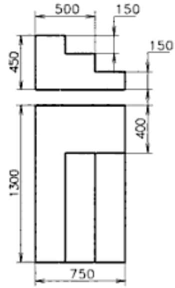


Fig. 36(a)

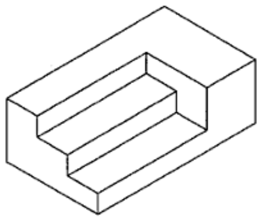


Fig. 36(b)

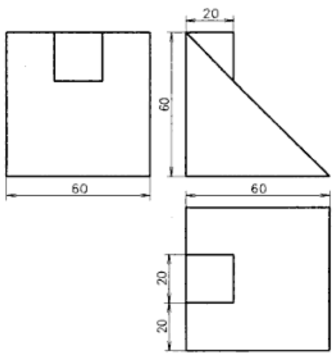


Fig. 37(a)

Answer: See Fig. 37(b).

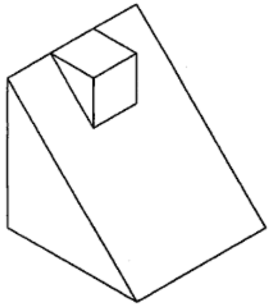


Fig. 37(b)

Question 38

Orthographic view of an object is shown in Fig. 38(a). Draw the isometric view. (2001)

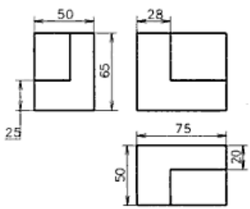


Fig. 38(a)

Answer: See Fig. 38(b).

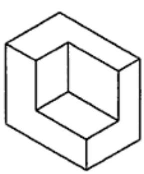


Fig. 38(b)

Question 39

Figure 39(a) shows the orthographic views. Draw the isometric view. (2001)

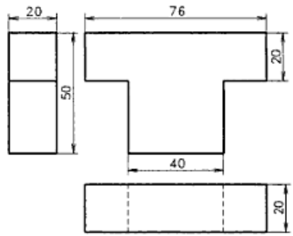


Fig. 39(a)

Answer: See Fig. 39(b).

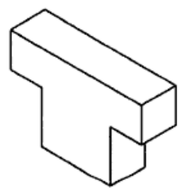


Fig. 39(b)

Oblique Projection

Question 40

Orthographic views of an object are shown in Fig. 40(a). Draw the cavalier oblique drawing. Take receding axis at 45° to the horizontal, sloping upwards to the right.

(1995)

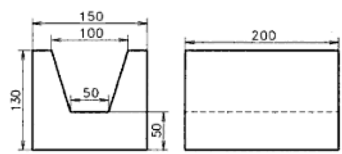


Fig. 40(a)

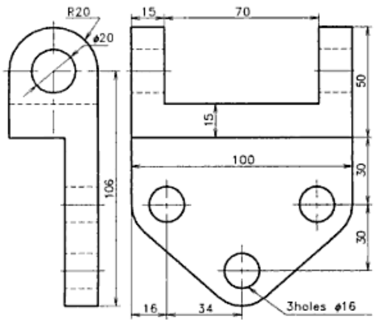


Fig. 43(a)

Answer: See Fig. 43(b).

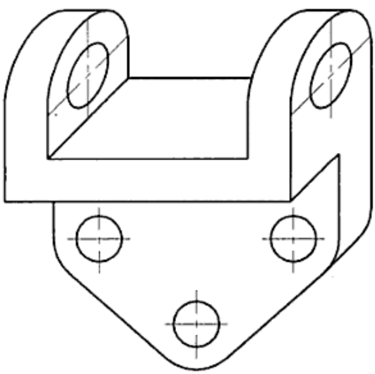


Fig. 43(b)

Question 44

Draw the cavalier oblique view of the hinge shown in Fig. 44(a). (1998)

Answer: See Fig. 44(b).

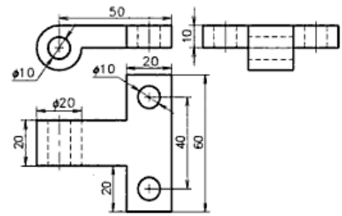


Fig. 44(a)

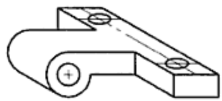


Fig. 44(b)

Question 45

Orthographic views of a block are shown in Fig. 45(a). Draw the cavalier oblique view taking the receding axis inclined at 30° to the horizontal sloping upwards to the right. Dimensioning is not necessary. (1999)

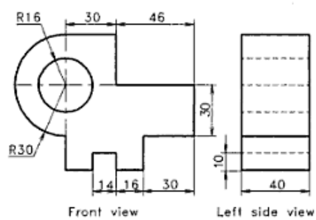


Fig. 45(a)

Answer: See Fig. 45(b).

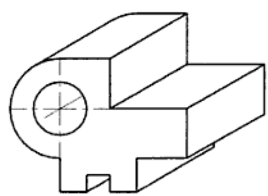


Fig. 45(b)

Multiview Projection of Objects

Question 46

Figure 46(a) shows a pictorial view of a cast iron machine block. Draw its front and right side views.

(1996)

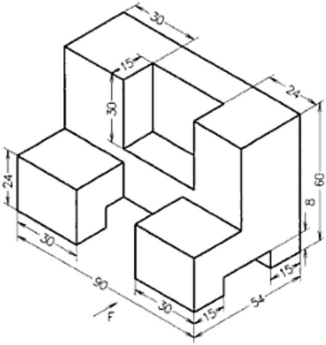


Fig. 46(a)

Answer: See Fig. 46(b).

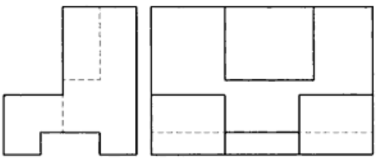


Fig. 46(b)

Question 47

The isometric view of a block is shown in Fig. 47(a). Draw the following:

(a) Elevation looking in the direction of arrow X,

(b) Plan, and

(c) Side view looking from right side.

Answer: See Fig. 47(b). (1998)

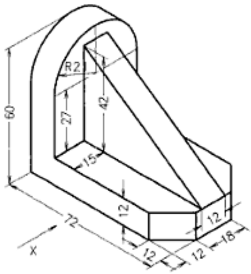


Fig. 47(a)

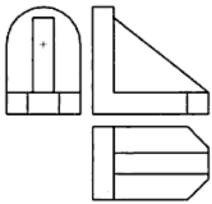


Fig. 47(b)

Question 48

Pictorial view of a wall bracket is shown in Fig. 48(a). Draw the following views:

(a) Front view in the direction of F,

(b) Right side end view, and

(c) Top view.

Show the principal dimensions. (1998)

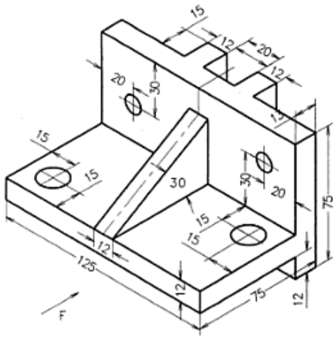


Fig. 48(a)

Answer: See Fig. 48(b).

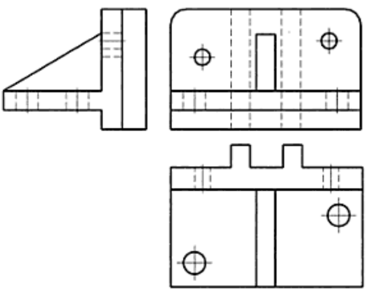


Fig. 48(b)

Question 49

Pictorial view of an object is shown in Fig. 49(a). Draw the following views:

(a) Front view in the direction of F,

(b) Left side end view, and

(c) Top view.

Show the principle dimensions.

Answer: See Fig. 49(b). (1998)

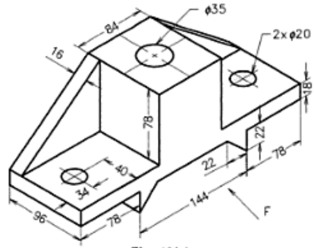


Fig. 49(a)

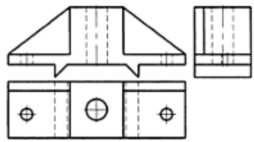


Fig. 49(b)

Question 50

Isometric drawing of a block is shown in Fig. 50(a). Draw:

(i) Front view in the direction F,

(ii) Top view and

(iii) Right side view. (1999)

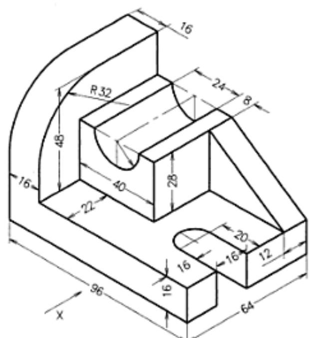


Fig. 50(a)

Answer: See Fig. 50(b).

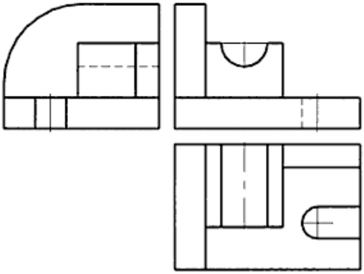


Fig. 50(b)

Answer: See Fig. 51(b).

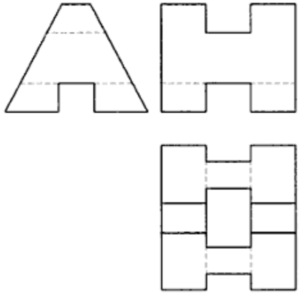


Fig. 51(b)

Question 51

Figure 51(a) shows the pictorial view of an engineering component. Draw the following views to full size.

(a) Elevation from the arrow side.
(b) Plan.
(c) Right side view. (1999)

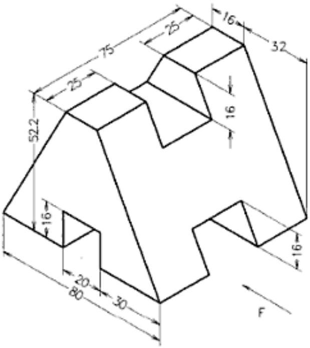


Fig. 51(a)

Auxiliary View of Objects

Question 52

The isometric view of a block is shown in Fig. 52(a). Draw the following:

(a) Elevation looking in the direction of arrow X.
(b) Plan, and
(c) Auxiliary view parallel to the inclined surface. (1998)

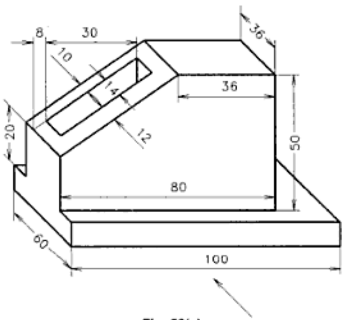


Fig. 52(a)

Answer: See Fig. 52(b).

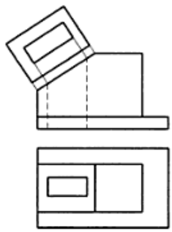


Fig. 52(b)

Sectional Views of Objects

Question 53

Figure 53(a) shows a pictorial view of an object. Draw the following views:

1. Sectional elevation (section through AA).
2. Plan.
3. Sectional end view (section through BB).

(1996)

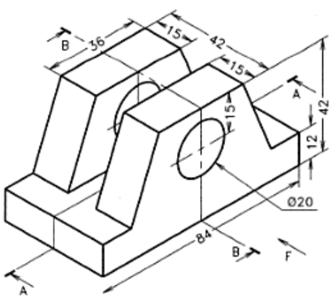


Fig. 53(a)

Answer: See Fig. 53(b).

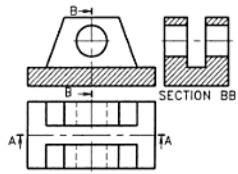


Fig. 53(b)

Question 54

Figure 54(a) shows a set of orthographic views of an object. Draw to full size:

1. Sectional front view, and
2. Side view from the left. (1997)

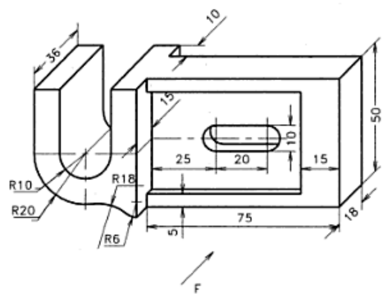


Fig. 54(a)

Answer: See Fig. 54(b).

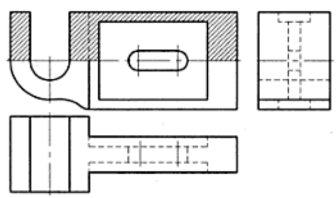


Fig. 54(b)

Question 55

Figure 55(a) shows a set of orthographic views of an object. Draw to full size:

1. Sectional front view, and
2. Side view from the left. (1998)

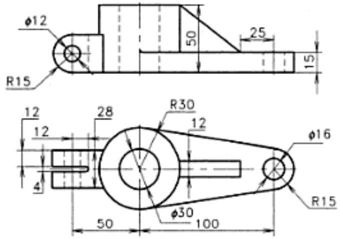


Fig. 55(a)

Answer: See Fig. 55(b).

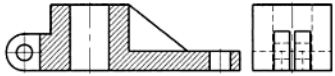


Fig. 55(b)

Model Polytechnic Examination Questions

Dimensioning

Question 1

Read the dimensioned slider plate drawing shown in Fig. 1. Redraw the figure and dimension as per I.S.

(2007)

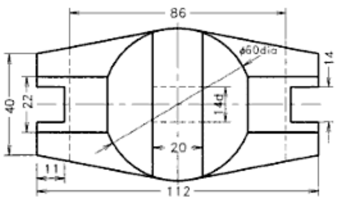


Fig. 1

Question 2

Read the given dimensioned drawing (Fig. 2) and redraw it to full size. Dimension the figure as per BIS.

(2008)

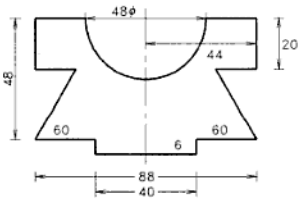


Fig. 2

Geometrical Constructions

Question 3

Construct a heptagon of side length 45 mm and inscribe in a circle. (2005)

Question 4

Draw a common internal tangent to two circles of diameter 70 mm and 30 mm whose centres are 90 mm apart.

(2006)

Question 5

Inscribe a regular heptagon in a circle of 100 mm diameter.

(2006)

Question 6

Draw the lay out of a drawing sheet for class work and the title block as per standard dimensions. (2007)

Question 7

Inscribe a regular pentagon in a circle where the length of one side is equal to 25 mm. (2007)

Question 8

A circle of diameter 50 mm is drawn and inscribe a regular pentagon with in the circle. (2007)

Question 9

Draw a regular heptagon of side 25 mm by general method.

(2008)

Conic Sections

Question 10

A rhombus of side 80 mm is formed with major and minor axes as diagonals. The eccentricity is 0.6. Construct the ellipse by intersecting arcs method.

(2005)

Question 11

The transverse axis and distance between foci is 50 mm and 90 mm respectively. Draw one branch of hyperbola and mark the directrix and asymptotes.

(2005)

Question 12

Construct an ellipse having major and minor axis in the ratio of 3:2, when major axis is 135 mm, by concentric circles method. (2006)

Question 13

A curve of eccentricity 2/3 has its focus at distance of 60 mm from the directrix. Draw the curve and name it. Also draw a tangent and normal to the curve through any point on the curve. (2008)

Miscellaneous Curves

Question 14

Draw the involute of a circle having diameter 50 mm. Draw tangent and normal to it 100 mm away from the centre of the circle. (2005)

Question 15

Draw a helix for one revolution on a cylinder of diameter 60 mm, height 72 mm and pitch 72 mm.

(2006)

Question 16

Draw an involute of a square of side 25 mm.

(2008)

Projections of Points

Question 17

Draw the projections of the following points:

1. Point 'A' is 20 mm below HP, 20 mm in front of VP
2. Point 'B' is 30 mm behind VP, 30 mm above HP
3. Point 'C' is on VP, 20 mm below HP
4. Point 'D' is on reference line
5. Point 'E' is on HP, 20 mm behind VP.

(2005)

Question 18

Draw the projections of the following points:

(i) Point A is 30 mm above the HP and 20 mm in front of the VP

(ii) Point B is 30 mm below the HP and 30 mm behind the VP

(iii) Point C is 30 mm above the HP and 15 mm behind the VP

(iv) Point D is 15 mm below the HP and 35 mm in front of the VP. (2006)

Question 19

Draw the projections of the following points:

(i) Point A is 25 mm in front of VP and 20 mm above HP

(ii) Point B is 30 mm below HP and 40 mm behind VP

(iii) Point C is 10 mm above HP and 30 mm behind VP

(iv) Point D is 15 mm below HP and 20 mm in front of VP

(v) Point E is in the HP and 25 mm in front of VP.

(2007)

Question 20

Orthographic projections of points PQRST are shown in Fig. 3. Read the views and state their positions with respect to HP and VP.

(2007)

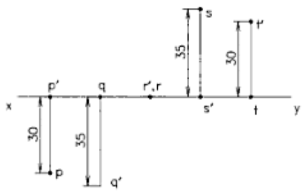


Fig. 3

Question 21

Draw projections of the following points on a common xy line. Take the distances between the projectors as 25 mm.

(i) Point A 20 mm above HP and 40 mm in front of VP

(ii) Point B 35 mm below HP and 45 mm in front of VP

(iii) Point C 15 mm behind VP and 40 mm below HP

(iv) Point D 50 mm above HP and 20 mm behind V.

(v) Point E 55 mm below HP on VP.

(2008)

Projections of Straight Lines

Question 22

The front view of a line MN has points m' and n' are 20 mm and 60 mm above the xy line, the plan has points m and n, 50 mm & 20 mm below the xy line. The distance between the projectors is 70 mm. Find the true length and true inclinations of the line to reference planes. (2005)

Question 23

An 80 mm long line AB is 20 mm above HP and parallel to HP. The end A is in II quadrant and 25 mm behind VP. The other end 'B' is in I quadrant and 35mm in front of VP. Find the vertical trace and draw the projections. (2005)

Question 24

A line RS is 35 degrees inclined to HP and 45 degrees to VP end R is in HP and 30 mm behind VP. If this 75 mm long line is in III quadrant, draw the projections. (2005)

Question 25

The length of elevation of a line PQ which is parallel to the HP and inclined at 30 degrees to the VP is 60 mm. The end P of the line is 20 mm in front of the VP and 25 mm above the HP. Draw the projections of the line and find its true length. (2006)

Question 26

The length of the top view of the line AB is parallel to the VP and inclined at 45 degrees to the HP is 50 mm. One end of the line is 12 mm above the HP and 25 mm in front of the VP. Draw the projections of the line and determine its true length. Also locate its traces. (2006)

Question 27

A line CD is inclined at 45 degrees to VP and is contained in HP. The end C is 16mm in front of VP. If the true length of CD is 50 mm, draw the projections of the line. (2007)

Question 28

A line AB measuring 70 mm has its end A 15 mm in front of VP and 20 mm above HP. End B is 60 mm in front of VP and 50 mm above HP. Draw the projections of the line and find the inclinations of the line with reference to both planes of projections. (2007)

Question 29

The front view of a line PQ measures 55 mm. The line is parallel to HP and inclined at 30° to VP. The end P is 25 mm in front of VP and 10mm below HP. Draw the projections of the line and find its true length. (2008)

Question 30

The end M of a line MN is 20 mm above HP and 30 mm in front of VP, while the other end N is 60 mm in front of VP. The line is parallel to HP. Draw the projections of the line MN and determine its true length and true inclination with VP. The distance between projectors is 60 mm. (2008)

Projections of Plane Figures

Question 31

A regular pentagonal lamina of 40 mm side has its plain vertical and inclined at 30 degrees to the VP. Draw its projections when one of its sides is perpendicular to the HP. (2006)

Question 32

A regular hexagonal lamina of side 30 mm is perpendicular to HP and inclined at 30° to VP. The lower side of the lamina is 20 mm above HP and the nearest corner is 25 mm in front of VP. Draw the projections of the lamina. (2008)

Development of Surfaces

Question 33

Develop the complete surface of the frustum of the cone with base diameter 65 mm top diameter 30mm with height of 30 mm. (2005)

Question 34

Draw the development of 90 degrees two piece elbow with pipe diameter 60 mm and edge height 70 mm. (2005)

Question 35

Draw the complete development of a bucket shown in Fig. 4. (2006)

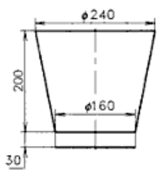


Fig. 4

Question 36

Draw the development of an elbow shown in Fig. 5. (2006)

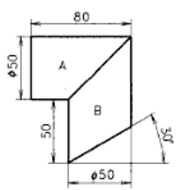


Fig. 5

Question 37

Draw the complete development of an elbow shown in Fig. 6. (2007)

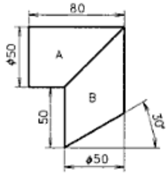


Fig. 6

Question 38

Draw the development of the elbow shown in Fig. 7 (2008)

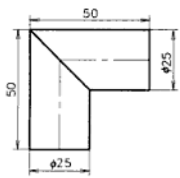


Fig. 7

Question 39

Draw development of a funnel shown in Fig. 8. (2008)

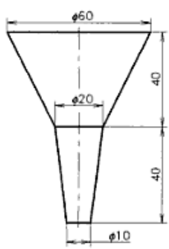


Fig. 8

Isometric Projection

Question 40

A waste basket in the form of a frustum of hexagonal pyramid with base 100 mm side and top 150 mm side. If the height is 200 mm, draw the isometric projection of the basket. (2005)

Question 41

Orthographic views of an object is shown in Fig. 9. Draw the isometric view and mark all dimensions. (2006)

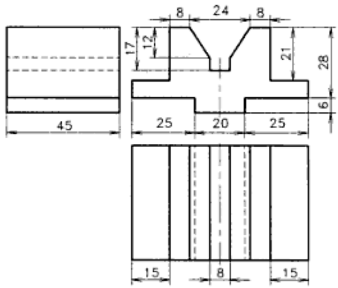


Fig. 9

Question 42

Draw to isometric view of the orthographic projection shown in Fig. 10. (2007)

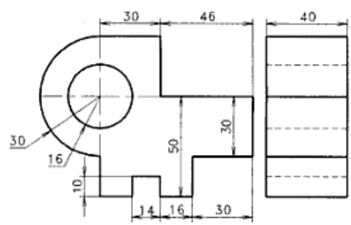


Fig. 10

Question 43

Draw isometric view of a cylinder of diameter 75 mm and height 100 mm. (2008)

Question 44

Draw isometric view of the object shown in Fig. 11. (2008)

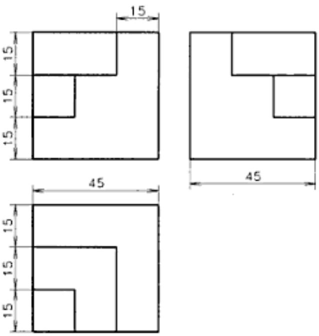


Fig. 11

Oblique Projection

Question 45

Draw the cavalier oblique projection of the object with the given orthographic view as shown in Fig 12. Receding axis inclination is 45 degrees. (2005)

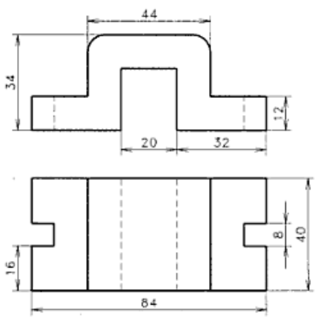


Fig. 12

Question 46

Draw the oblique projection of the object shown in Fig. 13 by cavalier method with the receding axis inclined at 30 degrees. (2006)

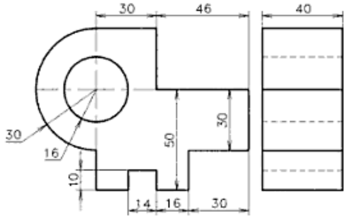


Fig. 13

Question 47

Draw the oblique cavalier view from the orthographic views in Fig. 14. (2007)

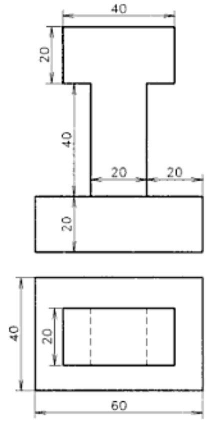


Fig. 14

Multiview Projection of Objects

Question 48

Figure 15 shows the isometric view of an object. Draw the following orthographic views and mark the dimensions:

1. Front looking from direction F
2. Top view
3. Left side view. (2005)

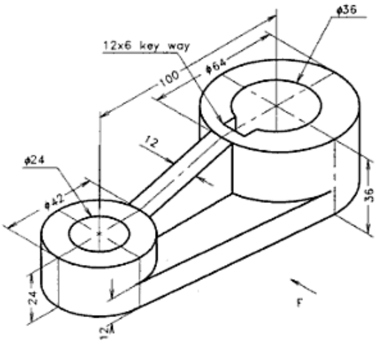


Fig. 15

Question 49

Figure 16 shows the isometric view of an object. Draw the following views and mark all the dimensions:

1. Elevation from direction F
2. Left side view
3. Plan. (2005)

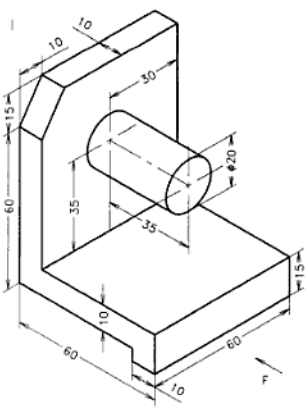


Fig. 16

Question 50

Figure 17 shows the isometric view of an object. Draw the following views and mark all the dimensions:

1. Sectional elevation from direction F
2. Left side view
3. Plan. (2005)

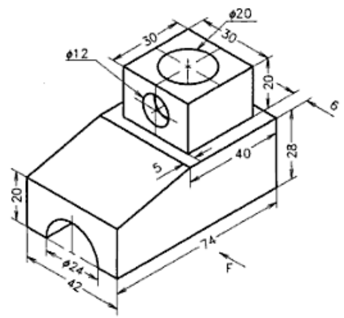


Fig. 17

Question 51

Figure 18 shows the pictorial view of an object. Draw the following orthographic views and mark all dimensions:

(i) Font view looking from the direction F
(ii) Top view and
(iii) Right side view. (2006)

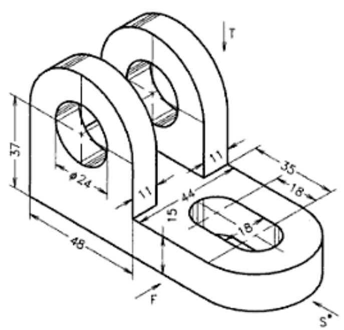


Fig. 18

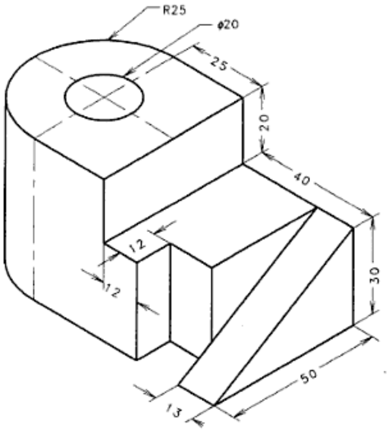

R25
φ20
25
20
40
30
12
12
50
13

Fig. 28

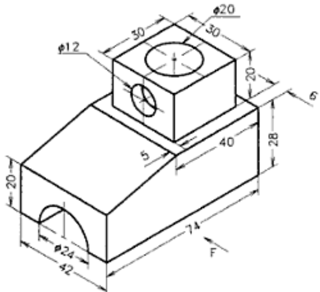

φ20
30
30
φ12
20
6
28
40
5
20
φ24
42
74
F

Fig. 29

Index

Engineering Graphics *for* Diploma

K.C. John

This book provides a detailed study of geometrical drawing through simple and well-explained worked-out examples and exercises. This book is designed for students of first year Engineering Diploma course, irrespective of their branches of study.

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- Follows the International Standard Organization (ISO) code of practice for drawing.
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