1 Drawing Instruments and Their Uses

1.1. INTRODUCTION

Engineering drawing is a universal graphic language of engineers. It is used by them to develop and record their ideas and transmit them to others for execution. It is the shortest of all shorthands as it can express the complete information about an object, say a machine part, with the exactness and detail as no written language can describe even in many pages.

Like the rules of any written language drawing has its own rules : it has its grammar in the theory of projection, its idioms in conventionalised practice, and its abbreviations in symbols. As bad language is irksome to a master in language, wrong drawing is annoying to a trained eye. Like music or mathematics, language of drawing must be unambigous and international. This is ensured by various national and international standards in the form of code of practice for engineering drawings. The knowledge of drawing is an important requirement for all technical personnel — engineers, designers, draughtsmen, mechanics, etc.

1.2. DRAWING INSTRUMENTS

A good set of drawing instruments should be possessed by every student before commencing the. study of engineering drawing. The quality and accuracy of drawings depend largely on the quality of instruments. The following is the list of drawing instruments and materials required by students.

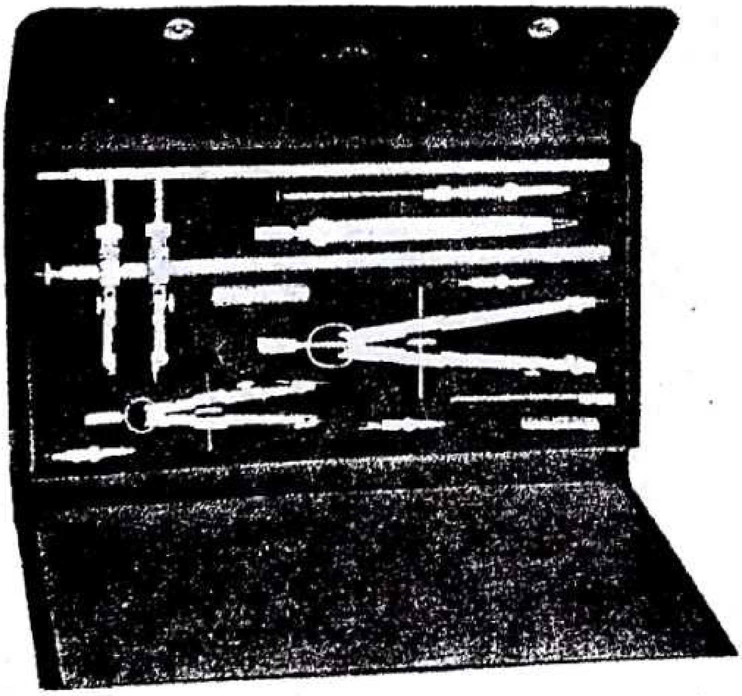


Fig. 1.1 : Drawing instrument box

1. Drawing board, size B, 900 × 650 mm
2. Tee-square 90°
3. Set-squares, 45° (200 mm), and 30°- 60° (250 mm)
4. Drawing instruments box (Fig. 1.1),containing the following :
   (i) Compass with interchangeable pencil and pen legs, size 150 mm
   (ii) Hair spring divider, size 150 mm
   (iii) Bow pencil, size 100 mm
   (iv) Bow pen, size 100 mm
   (v) Bow divider, size 100 mm
   (vi) Lengthening bar, size 125 mm
   (vii) Inking pen, fine and medium, size 150 mm
   (viii) Case of lead
   (ix) Screw driver
   (x) Spare screws and pointers for various joints and instruments.
5. Scale, plastic, boxwood or set of cardboard scales, size 300 mm
6. Protractor, 180° or 360°, size 150 mm
7. Drawing paper
8. Drawing pencils, HB, H, 2H, 3H and 4H, one or more of each grade.
9. Rubber eraser, soft
10. Pocket knife or pencil sharpener
11. Duster or handkerchief
12. Drawing pins or adhesive tape
13. Sand paper, grade 0 to 00, or sand paper block
14. French curves.

Drawing Board. (Fig. 1.2). *Drawing board* is made of best seasoned wood about 25 mm thick. To prevent warping, the board should be made of narrow strips glued edge to edge rather than from one piece. On the underside of the board two battens are fixed by screws in slots to allow contraction or expansion due to atmospheric conditions. On the left side of the board a straight, ebony edge is fitted against which the stock of tee-square moves. This is the working edge of the drawing board. The top face of the board should be perfectly levelled and smooth.

The standard sizes of drawing board according to I.S. 962-1967 are given in Table 1.1.

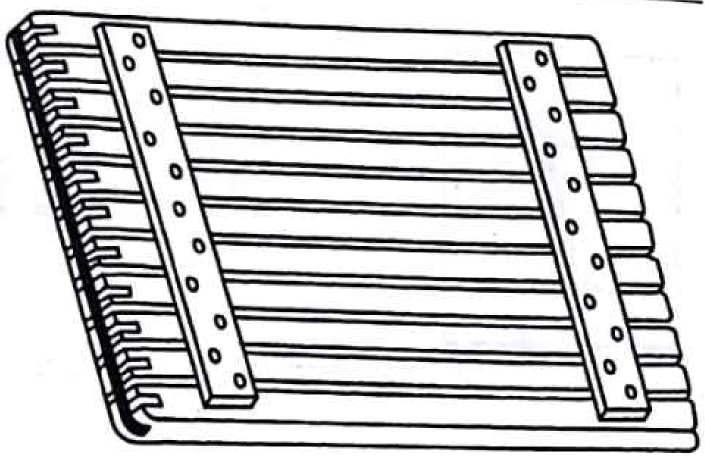


Fig. 1.2 : Back view of a drawing board

Table 1.1 : Standard size of drawing boards

Designation	*Dimensions, mm*
B_0	1500 × 1000
B_1	1000 × 700
B_2	700 × 500
B_3	500 × 350

For working it is convenient to keep the board tilted at an inclination of 15° to 20° by a block of wood or a Trestle as shown in Fig. 1.3. It is tiring to work on a flat board.

Fig. 1.3 : Trestle for drawing board

Tee-square. (Fig. 1.4). The tee-square consists of two parts, the blade and the stock. The blade is rigidly fixed to the stock by brass and ebony pins. The blade has an ebony edge and is generally wider at the stock for rigidity. The stock also has an ebony edge. "The blade has a hole for suspending the tee-square when not in use. The size of the tee-square depends on the size of the board.

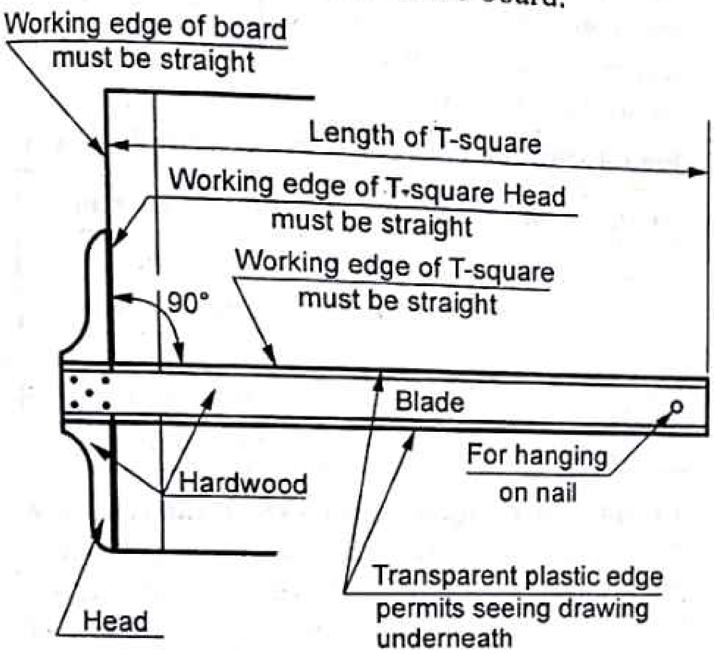


Fig. 1.4 : Tee-square

Before using the tee-square it is necessary to test the straightness of its working edge. It is done as shown in Fig. 1.5. Draw a sharp line with a hard pencil along the entire length of the working edge. Next turn the tee-square over and draw the line again over the same edge. The two lines must coincide if the edge is absolutely straight, otherwise the space between the lines will give twice the error of the blade. The error should be rectified by scraping the edge with a scraper or a sharp file.

The tee-square is a delicate piece of instrument on which the accuracy of drawing depends. It is easily damaged by careless handling and by dropping on the floor. The B.I.S. has recommended the standard sizes of tee-squares as shown in Table 1.2.

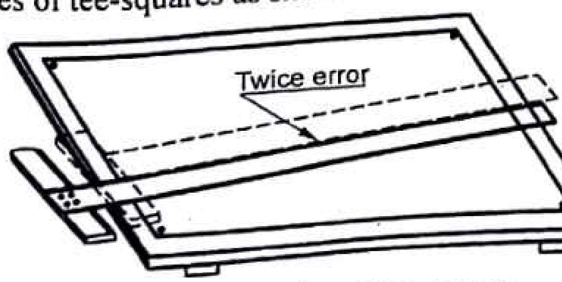


Fig. 1.5 : Testing of tee-square

Table 1.2 : Standard sizes of tee-squares

Designation	*Working edge length in mm*
T_0	1500 ± 10
T_1	1000 ± 10
T_2	700 ± 5
T_3	500 ± 5

Set-square. Transparent, colourless plastic set-squares are most commonly used. They have either straight edge or bevel edge. Thickness varies as a rule between 1.5 mm to 2.5 mm; the latter is more useful for inking work. Two set-squares, 45° and 30°-60°are required. The length of the set-square is given by the longer edge containing the right angle; 45° set-squares are 150, 200, 250, and 320 mm long and 60° set-squares are 200, 320 and 420 mm long.

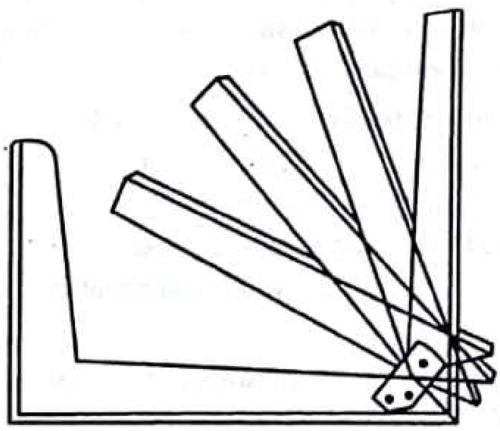


Fig. 1.6 : Clinograph

A **clinograph** is an adjustable set-square (Fig. 1.6).

Scales. In engineering drawing plastic or boxwood scale or a set of cardboard scales is used. The scales are either flat or triangular. Flat scales more than 1.5 mm thick are bevelled at both the edges for ease of measurement. The scale is used to transfer the dimensions of an object to the drawing. It should never be used as a straight edge for drawing lines.

Protractor. Transparent celluloid protractors are generally used. They are semicircular (180°) or circular (360°) in shape. The circumferential edge of a protractor is graduated 1/2° or 1° division, is numbered at every 10° interval and is readable from both the ends as shown in Fig. 1.7. The diameter of the semicircle is called the base of the protractor and its centre is marked by a short line perpendicular to it. The protractor is used to draw or measure such angles as cannot be drawn with the set-square.

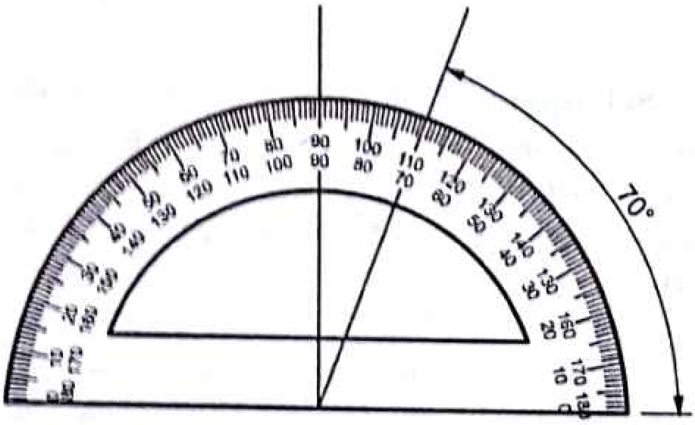


Fig 1.7 : Protractor

Drawing paper. For drawing purposes hand made paper with smooth surface and weighing about 25 or 30 kg per ream is suitable.

The paper should be uniform in thickness and as white as possible. Its fibre should not come out when eraser is used on it. The ink should not spread on paper used for inking. Drawing papers are available in rolls of 75 to 180 cm width and about 20 metres length.

The standard size of drawing sheets, according to IS: 10711 and ISO-A Series (First choice), are given in Table 1.3.

Table 1.3 : Standard size of drawing paper

Sheet Designation	*Trimmed size, mm width × length*	*Untrimmed size, mm width × length*
A_0	841 × 1,189	880 × 1,230
A_1	594 × 841	625 × 880
A_2	420 × 594	450 × 625
A_3	297 × 420	330 × 450
A_4	210 × 397	240 × 330

Notes :

1. Two successive sizes of the series are obtained by halfing or doubling as shown in Fig 1.8.
2. The sides of each size are in the ratio $1:\sqrt{2}$.
3. The surface area of the basic size is one square metre. $x : y = 1 : \sqrt{2}$; $xy = 1$.

   $\therefore \quad x = 0{\cdot}841$ m and $y = 1{\cdot}189$ m
4. **Special elongated size (Second choice).** When sheet of greater length is needed, one of the sizes in Table 1.4 should be used. These sizes are obtained by extending the shorter sides of a format of the ISO-A series to lengths that are multiples of the shorter sides of the chosen basic format.

Table 1.4 : Special elongated sizes (second choice)

Designation	*Dimensions, mm*
$A_3 \times 3$	420 × 891
$A_3 \times 4$	420 × 1189
$A_4 \times 3$	297 × 630
$A_4 \times 3$	297 × 841
$A_4 \times 5$	297 × 1051

5. **Exceptional elongated sizes (Third choice).** When a very large or extra elongated sheet is essential, one of the size in Table 1.5 should be used. These sizes are obtained by extending the shorter sides of a format of the ISO-A series to lengths that are multiples of the shorter sides of the chosen basic format.

Table 1.5 : Exceptional elongated sizes (third choice)

Designation	*Dimensions, mm*
$A_0 \times 2$*	1189 × 1682
$A_1 \times 3$	1189 × 2523+
$A_1 \times 3$	841 × 1783
$A_1 \times 4$	841 × 2378+
$A_2 \times 3$	594 × 1261
$A_2 \times 4$	594 × 1682
$A_2 \times 5$	594 × 2102
$A_3 \times 5$	420 × 1486
$A_3 \times 6$	420 × 1783
$A_3 \times 7$	420 × 2080
$A_4 \times 6$	297 × 1261
$A_4 \times 7$	297 × 1471
$A_4 \times 8$	297 × 1682
$A_4 \times 9$	297 × 1892

* This size is equal to $2A_0$ of the ISO-A series

+ For practical reasons, the use of these sizes is not advisable.

6. The original drawing should be made on the smallest sheet permitting the necessary clarity and resolution.
7. Drawing sheets may be used with their longer sides horizontally or vertically.

Pencil. Drawing pencil leads are made chiefly of graphite mixed with varying quantities of clay to produce 20 degrees of hardness. From soft to hard they are graded as 8B to B, HB, F, H to 10H as given in Table 1.6. The choice of grade of pencil depends on the type of work, texture of paper, atmospheric humidity, make of pencil, etc. In the beginning HB or H grade may be used for freehand sketching and lettering and 2H or 3H grade for outlines. After some practice H grade may be used for freehand sketching and lettering, etc., and 2H or 3H grade for outlines. Lines of uniform thickness and darkness can be more easily drawn with hard grade pencils. The dimension lines and lines which are thin lines shown be drawn with a pencil of a grade or two harder than that for the outline.

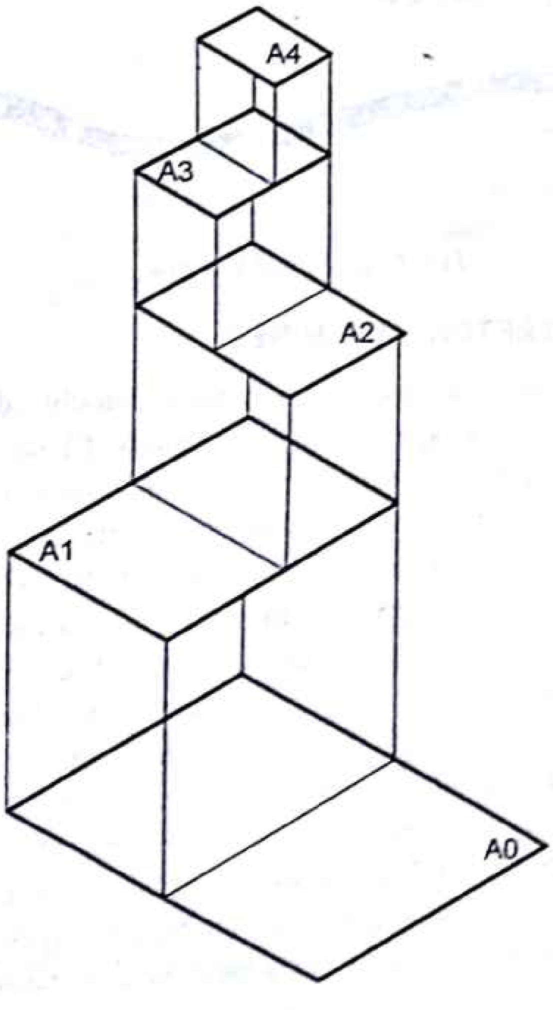


Fig. 1.8 : Successive size of a drawing paper

Table 1.6 : Classification of pencils

Grade of pencil	*Hardness*	*Remark*
10H to 4H	Extremely hard	Not useful for engineering drawing
3H	Very hard	General purpose pencils
2H	Hard	
H	Moderately hard	
F	Firm	
HB	Medium	
B	Moderately soft and black	
2B	Soft and black	Too soft for engineering drawing
3B	Very soft and black	
4B to 8	Very soft and very black	

For hand sketching and lettering a pencil sharpened in the usual conical way should be used but for drawing outlines pencil should be sharpened to a chisel point as shown in Fig. 1.9. With chisel point the width of the line does not sensibly increase as lead wears out.

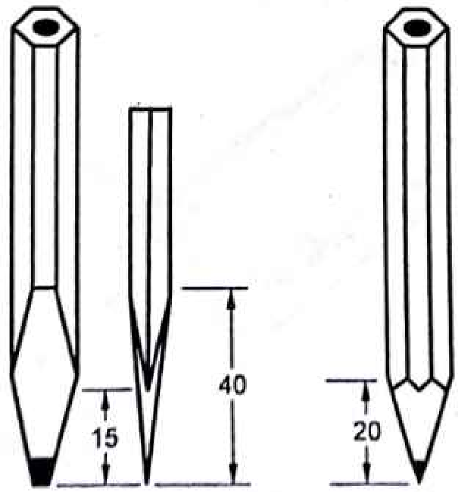


Fig. 1.9 : Chisel and conical points

A conical point will last longer if the pencil is rotated while drawing.

A student should keep two or three pencils of the same grade for drawing outlines so that he has not to sharpen one pencil very often.

Rubber or Eraser. For removing pencil lines from the paper many varieties of Indian rubber of different degrees of hardness are available. Choose a good quality, fairly soft rubber which is effective without damaging the paper. A thin sheet-metal *erasing shield* may be used to prevent erasure of correct lines adjacent to mistakes. *A very soft eraser known as art gum or art cleaner block is very useful for cleaning finished drawings.*

Drawing pins and adhesive tapes. The drawing sheets are fixed on the board by steel pins having curved brass tops. Adhesive tapes are also used for the same purpose and have the advantage that they do not make a hole in the sheet. Clips or metallic fold back clamps may be used in place of pins or adhesive tapes.

The use of drawing pins should be avoided as they ruin expensive boards, especially when used away from their corners.

Sand paper block. (Fig. 1.10). The sand paper block is a wooden block, about 150 × 50 × 12 mm, having a piece of sand paper pasted or nailed over the rectangular portion of the block. The sand paper should be replaced when it is worn out. Sand paper block is used for sharpening the pencils, which is required very frequently.

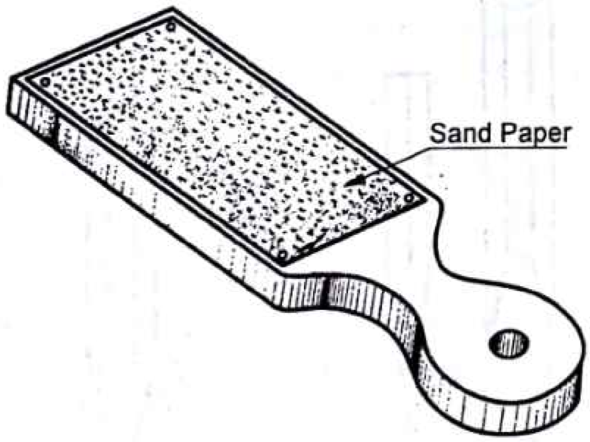


Fig. 1.10 : Sand paper block

French curves. For curves other than circular arcs, a set of French curves made of transparent plastic are used as shown in Fig. 1.11. The method of drawing a curve with French curve is lined up, by trial and error method, so that it passes through at least three points of the required curve. The curve drawn should be smooth without overlapping patches or sudden changes in direction.

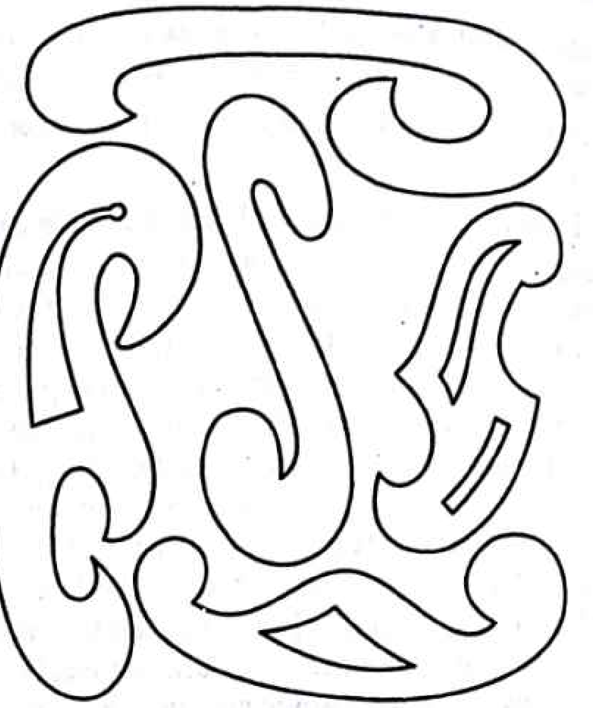


Fig. 1.11 : A set of typical french curves

A flexible curve, Fig. 1.12, if available, is also useful for drawing curves.

Fig. 1.12 : Flexible curve

1.3. DRAFTING MACHINES

Drafting machine is a special form of drafting desk fitted with a linkage to serve the functions of T-square, set-square, parallel ruler, protractor and scales. It is a device to prepare drawings quickly, accurately and neatly, and is used in almost all drawing offices (See Fig. 1.13). The drafting machines board can be adjusted at any angle with the horizontal. The linkage provided in the drafting machine has two blades (straight edges with engraved scales) set at right angles to each other. It remains balanced at any angle. The blades are detachable and can be replaced by a variety of blades. The adjusting head has a protractor with vernier attachment so that the blades may be set at any required angle. Drafting machines are available in various sizes.

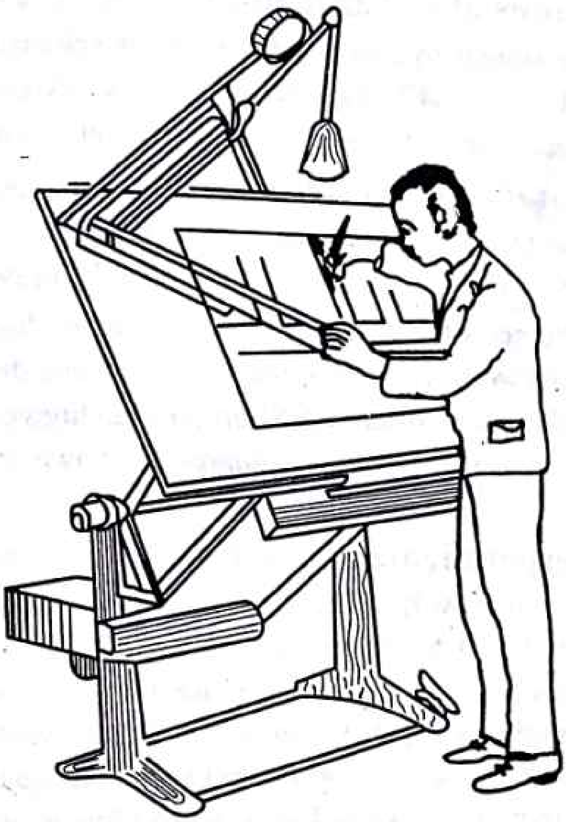


Fig. 1.13 (a) : Drafting machine

Mini-drafter. The engineering students now-a-days use a separate manufactured linkage known as mini-drafter. It has an adjustable head with mutually perpendicular scales attached. It is mounted on a normal drawing board placed on a trestle. Mini-drafter has replaced the tee-square.

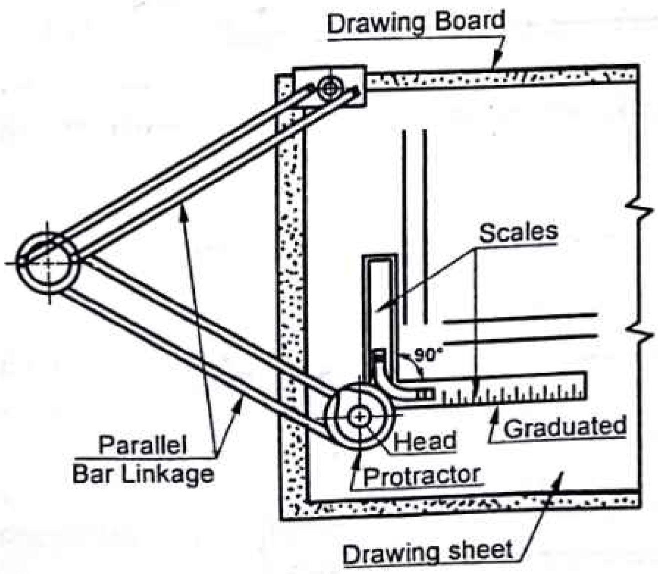


Fig. 1.13 (b) : Mini-drafter

1.4. DRAWING LINES WITH TEE-SQUARE AND SET-SQUARES

The tee-square is used for drawing horizontal lines. Vertical lines are drawn with the tee-square and the set-square. The lines at 45° and 30°- 60° are drawn with set-squares.

Horizontal lines (Fig. 1.14). The horizontal lines are drawn by holding the stock of the tee- square firmly against the drawing board with the left hand while running the pencil along the working edge with the right hand. The pencil should be held in a plane perpendicular to the paper but it should be inclined about 60° to the right, as shown in Fig. 1.14. A line should always be drawn from left to right. If conical point is used, the pencil should be rotated the full length of the line to ensure uniform thickness.

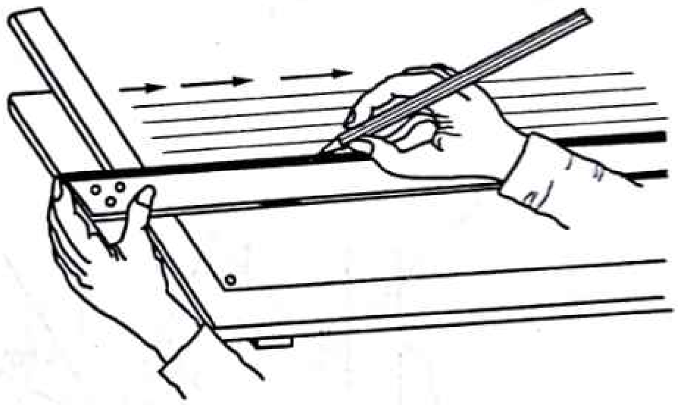


Fig. 1.14 : Drawing horizontal lines

Vertical lines (Fig. 1.15). The vertical lines are drawn by holding the stock of the tee-square firmly against the drawing board with the left hand while placing the 45° and 30° - 60° set-squares along its edge with the right angle of the set-square perpendicular to the tee-square.

Vertical lines are drawn from bottom to top with the pencil tilted about 60° to the right or away from the body.

Lines at 45° and 30° - 60°. A 45° line may be drawn by moving the pencil upward or downward along the hypotenuse of the 45° set-square with either of its legs resting on the tee-square, as shown in Fig. 1.16. A 30° or 60° line may be obtained in a similar manner. A circle can be divided into 8 equal parts with the 45° set square and 12 equal parts with the 30° - 60° set square.

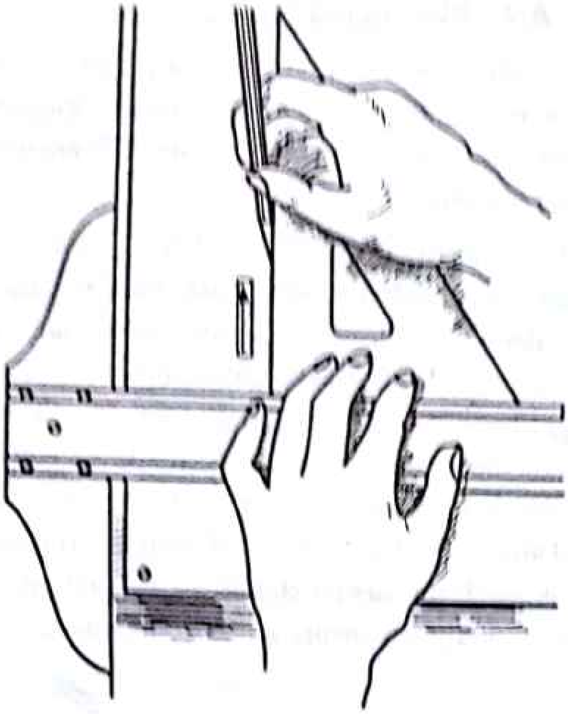


Fig. 1.15 : Drawing vertical lines

Lines at 15° and 30°. Lines at 15° and 30° can be drawn by the combination of set-square as shown in Fig. 1.17. A circle may thus be divided into 24 equal parts with the aid of the two set squares.

Parallel lines. The method to obtain parallel lines consists of lining up the hypotenuse of set-square, as in Fig. 1.18, along the line to be drawn.

The set square is slided backward or forward along the working edge of the tee-square and desired parallel lines are obtained. Short parallel lines can be obtained by using two set-squares as shown in Fig. 1.19.

Perpendicular lines. Perpendicular lines be drawn in many ways. One of the methods is similar to that employed for drawing parallel lines. The set-squares and the tee-squares are lined up in the same way and the set-square is moved to the intersecting point on the given line. At this point the set square is turned over as shown in Fig. 1.20 and line is drawn through this point.

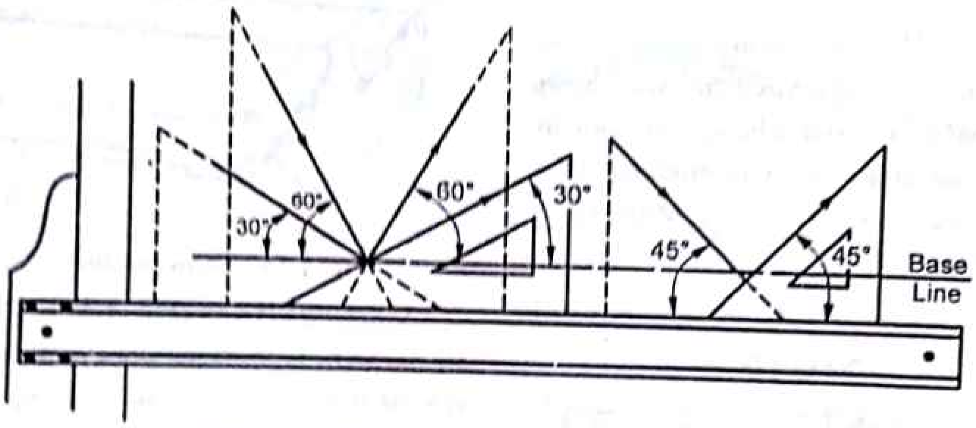


Fig. 1.16 : Drawing lines at 45°, 30° and 60°

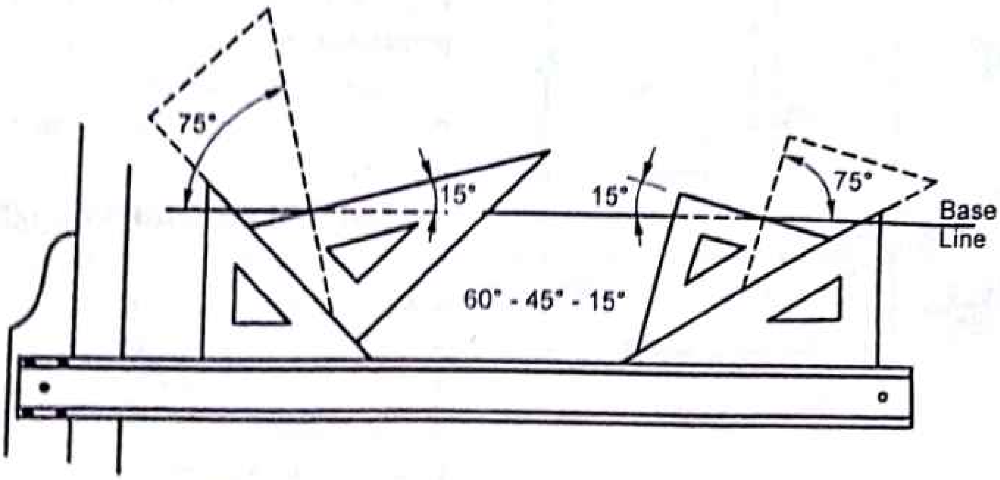


Fig. 1.17 : Drawing lines at 15° and 75°

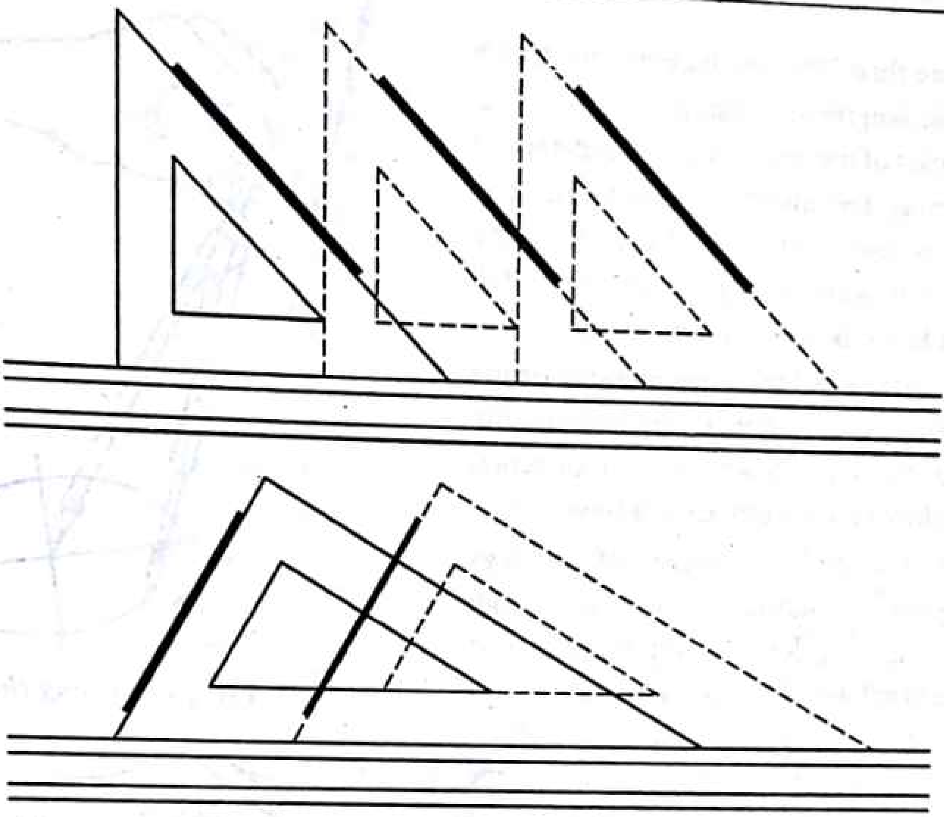


Fig. 1.18 : Drawing parallel lines with tee-square and set-square

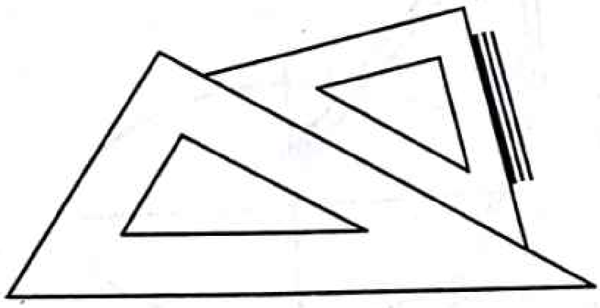


Fig. 1.19 : Drawing parallel lines with two set-square

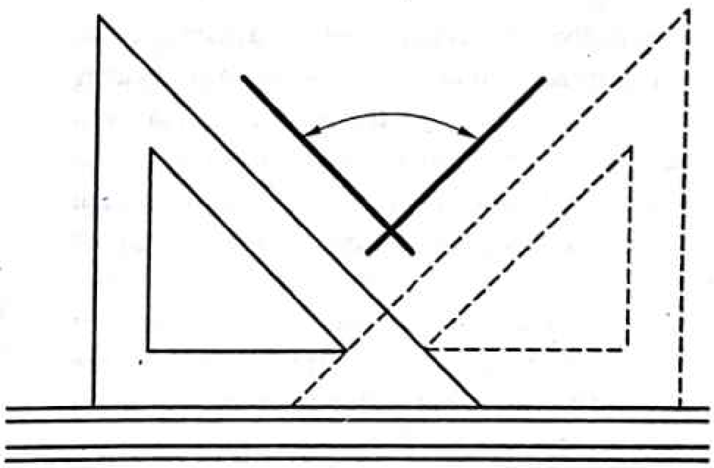


Fig. 1.20 : Drawing perpendicular lines with set-square and tee-square

1.5. USE OF DRAWING INSTRUMENTS

Compass. Circles and arcs of the circles are drawn with the help of the compass. Small circles of up to about 25 mm diameter are drawn with bow compass. Circles up to about 120 mm diameter are drawn with compass having the pencil and inking attachment, with their legs straight as shown in Fig. 1.21.

For drawing larger circles both legs should be bent at the knee joint (breaking the legs) so that they are perpendicular to the surface of the paper as shown in Fig. 1.22.

As the needle is required to be inserted in the paper it is kept about 1 mm longer than the lead point. To draw a circle, first draw its centre lines. Adjust the compass to ths required radius and put the needle point lightly at the intersection of the centre lines. Give a slight inclination to the compass in the forward direction and draw the circle clockwise while rotating the handle between the thumb and the first two fingers of the right hand (Fig. 1.22). While drawing concentric circles smallest circle is drawn first.

Circle of more than 300 mm diameter are drawn with the aid of the lengthening bar, as shown in Fig. 1.23. The lower part of the pencil leg is first detached and the lengthening bar inserted in its place. The detached part is then fitted at the end of the lengthening bar. For drawing large circles it is often necessary to guide the pencil leg with hand.

As it is difficult to exert the same pressure on the lead in the compass as on a pencil, the lead used in compass is about one grade lower than that of pencil to get the same darkness for circles and lines.

Dividers. The divider consists of two legs hinged at the upper end and has steel points at both the lower ends. The divider is manipulated by one hand only. It is used for dividing distances into a prescribed number of equal parts or for transferring dimensions and distances. Small adjustments are made with the hair spring by adjusting the small thumb screw.

The method of dividing a line into a given number of equal parts is as follows (Fig. 1.24). Open the dividers until the distance between the point is estimated to be equal to the length of a division and step off the line lightly by rotating the divider by half revolution alternately in an opposite direction on either side of the line. If the last prick mark misses the end point, increase or decrease the setting by an amount estimated to be equal to the error divided by the numbers of divisions, before lifting the dividers from the paper. Step off the line again and repeat the procedure until the dividers are correctly set and indent the division points.

Small bow divider is adjusted by a nut and should be used for making minute divisions and large number of short equal divisions.

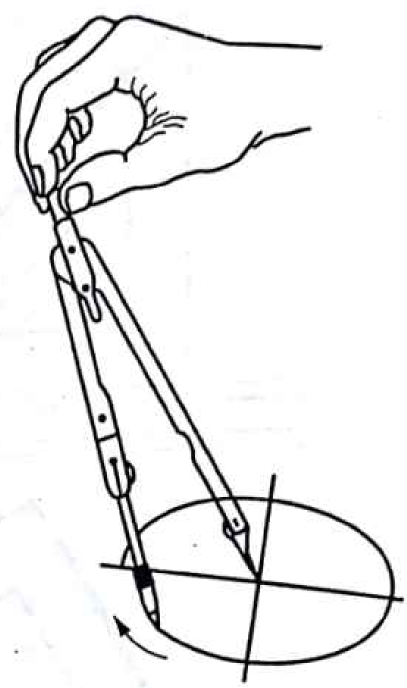


Fig. 1.21 : Using the compass

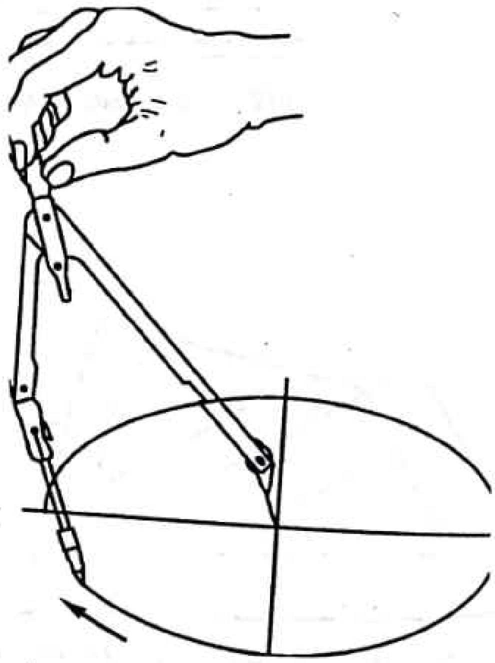


Fig. 1.22 : "Breaking" the legs of the compass

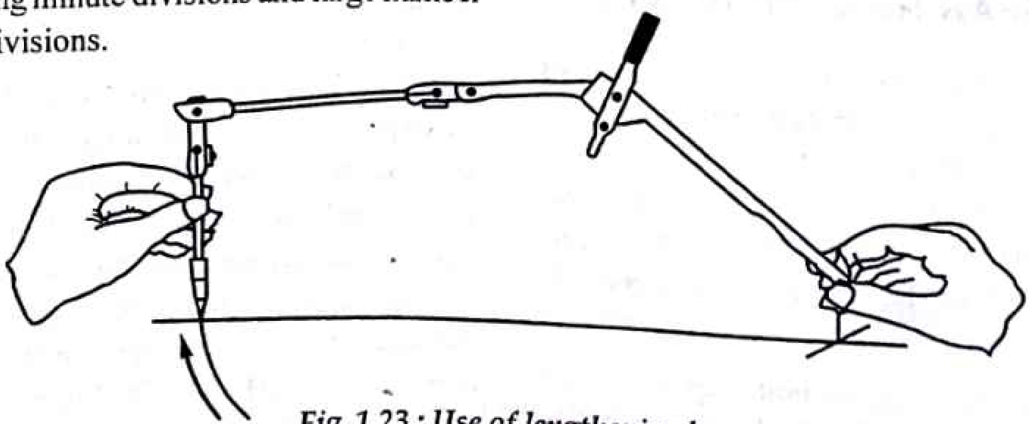


Fig. 1.23 : Use of lengthening bar

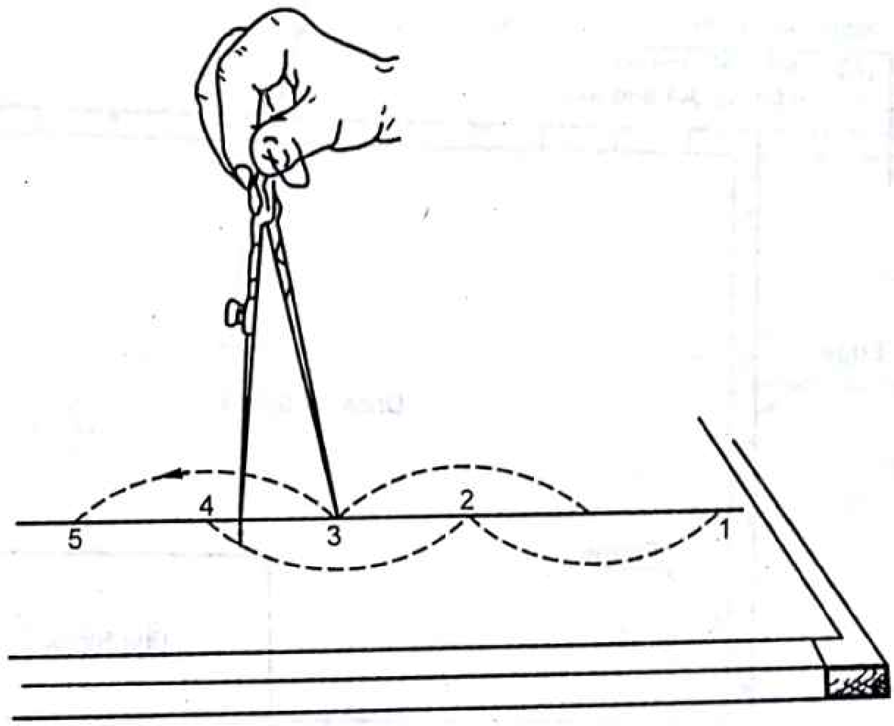


Fig. 1.24 : Dividing a line by dividers

Inking Pen (Fig. 1.25). The inking pen is used for drawing straight lines and irregular curved lines. It consists of a pair of steel nibs fitted to a holder, the nibs being equal and elliptical in shape. Nibs that are too sharp or blunt are unsatisfactory. The worn out nibs can be sharpened by honing.

Black waterproof India ink is used in the inking pen. It is a colloidal solution of fine particles of carbon and gum. The bottle of ink should be carefully covered to prevent evaporation of the solvent. The ink is filled between the nibs of the pen by the quill attached to the stopper of the ink bottle and the thickness of the line is adjusted by the width between the nibs by the adjusting screw. A small amount of ink, about 5 mm high in the pen, should be used at a time. Any ink which may have set outside should be wiped off. Indian ink dries rapidly and deposits of carbon frequently clog the pen. Therefore, the pen should be wiped often with a soft cloth or chamois.

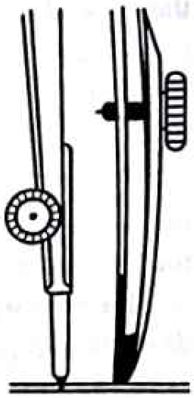


Fig. 1.25 : Inking pen

The technique of drawing lines with inking pen is as follows: Set both nibs of the ruling pen parallel to the guiding edge, as shown in Fig. 1.25 by holding the pen in vertical position inclined about 60° with the paper in the direction of the line. Hold the pen keeping the adjusting screw facing away from the body. Press the pen lightly against the ruling edge to ensure accuracy of linework. At the end of each stroke raise the pen off the paper quickly and move the guiding edge from the wet line.

Ink bow pen and compass with inking attachment are used respectively for small and large circles and area.

1.6. LAYOUT OF DRAWING SHEETS

The layout should facilitate the reading of drawings and make it possible of essential references to be located easily. Sufficient extra margin should be left to facilitate easy filing and binding wherever necessary. The typical layout of drawing sheet A_0 and A_5 are shown in Fig. 1.26.

The following important points may be noted—

1. **Borders and frames.** Borders enclosed by the edges of the trimmed sheet and the frame limiting the drawing space shall be provided with all sizes. It is recommended that these borders have the minimum width of 20 mm for size A_0 and A_1 and a minimum width of 10 mm for size A_2, A_3 and A_4.

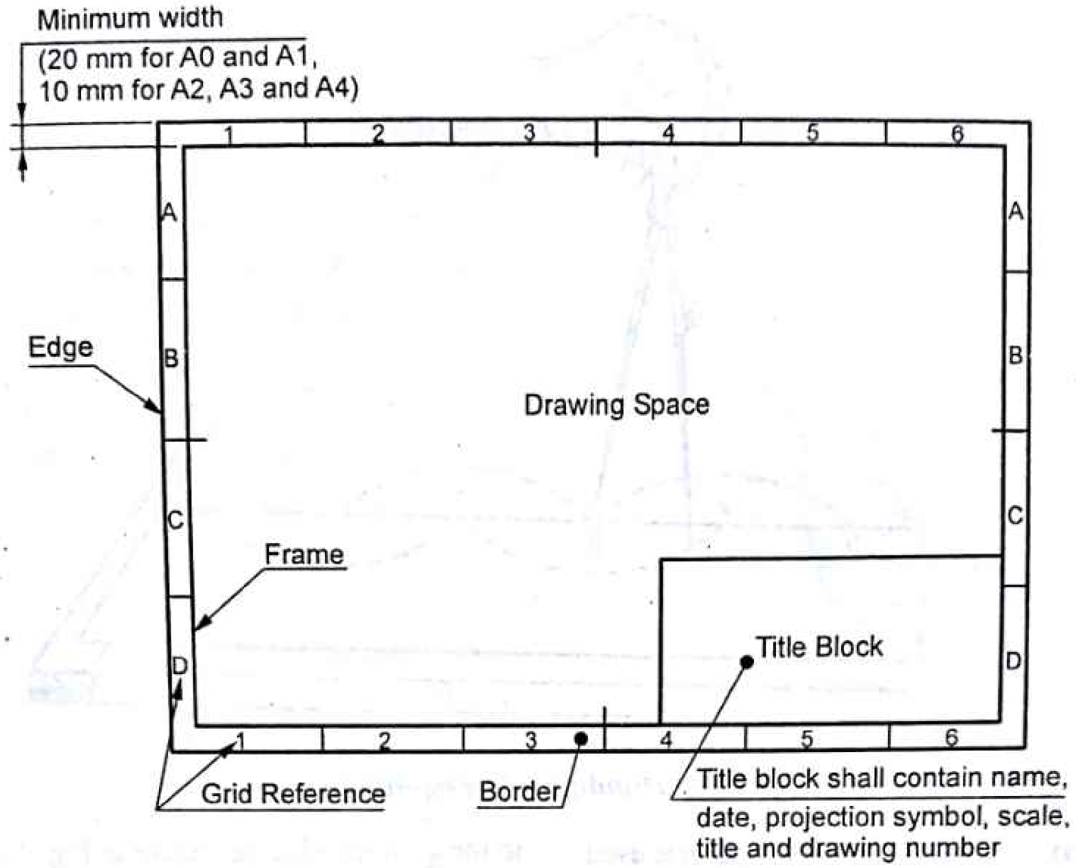


Fig. 1.26 : A typical layout of drawing sheet, sizes A_0 and A_4

2. Centering marks. Four centering marks shall be provided on all drawings in order to facilitate the positioning of the drawing when reproduced or microfilmed.

3. Grid reference. The provision of grid reference system is recommended for all sizes in order to permit easy location on the drawing of details, additions, modifications, etc. The number of divisions should be divisible by two and be chosen in relation to the complexity of the drawing. It is recommended that the length of any side of the rectangles comprising the grid shall not be less than 25 mm and not more than 75 mm.

The rectangles of the grid should be referred by means of capital letters along one edge and numerals along the other edge. The numbering direction may start at the sheet corner opposite to the title block and may be repeated on the opposite sides.

The title block is an important feature in a drawing and should be placed at the bottom right hand corner of the sheet where it is readily seen when the prints are folded in the prescribed manner. The size of the title block recommended is 185 × 65 mm or 170 × 65 for all sizes (See Fig. 1.27). The title block contains the following information: the title of drawing, drawing and sheet number, scale, symbol denoting the method of projection, name of the firm and initials of the technical staff who prepare the drawing. The physical example of parts list on a drawing is shown in Fig. 1.28.

For class work the information in the title block may be modified to suit the requirement. For example the title block may be 30 mm high divided into three sub-block in which name of the institution, title of the drawing and particulars of student may be written.

For class room training, layout as given in Fig. 1.29 may be used.

The spacing of the drawing on the sheet should be central. If more than one figure is to be drawn, the space should be divided in suitable blocks and the figures should be drawn in the centre of these blocks.

The drawing paper should be fixed on the board with equal distance from its top and bottom edges and one of its shorter edges at about 30 mm from the working edge of the board. If the paper is much smaller than the board it may be fixed about 50 mm from its lower edge.

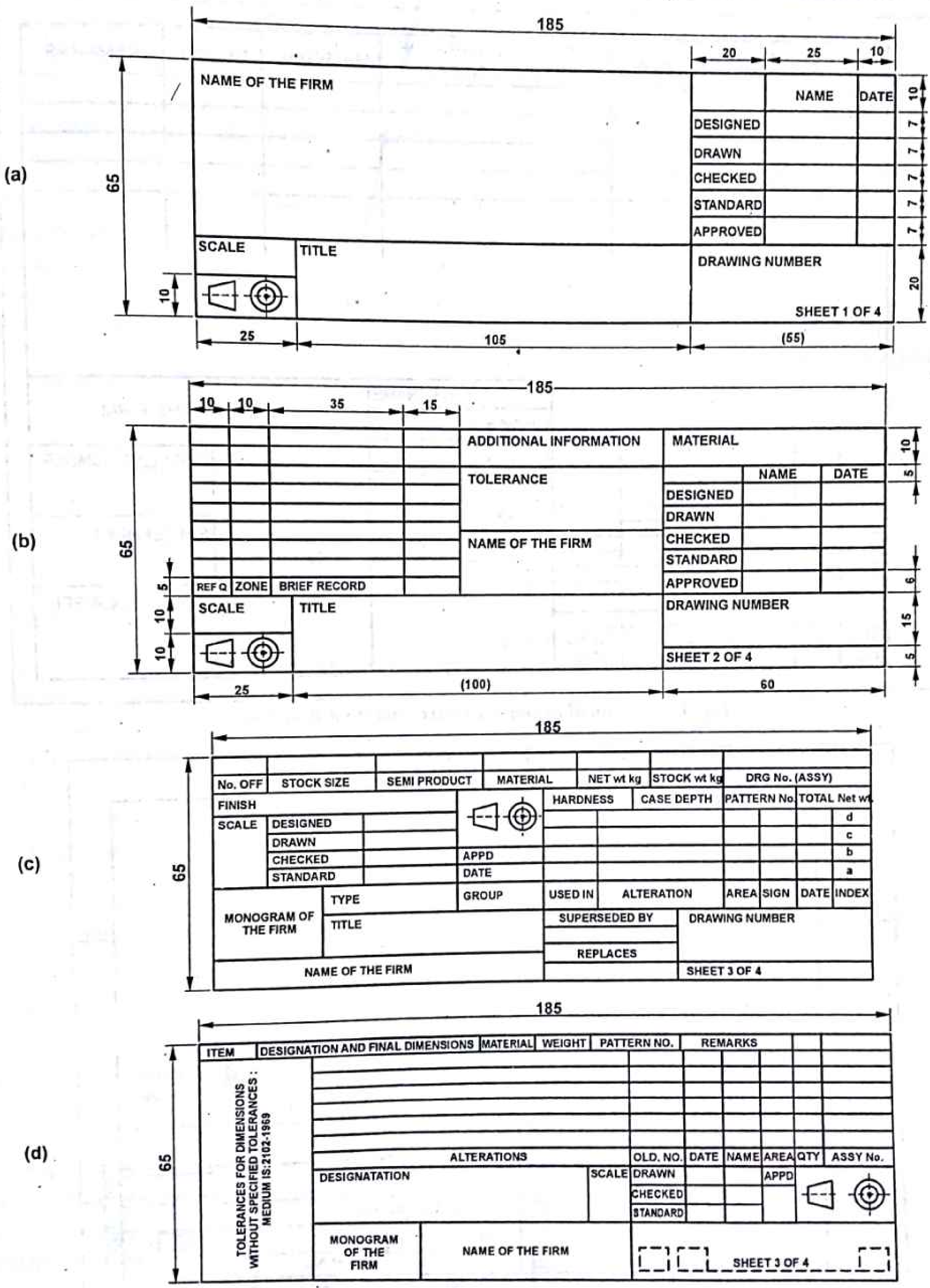


Fig. 1.27. Title blocks

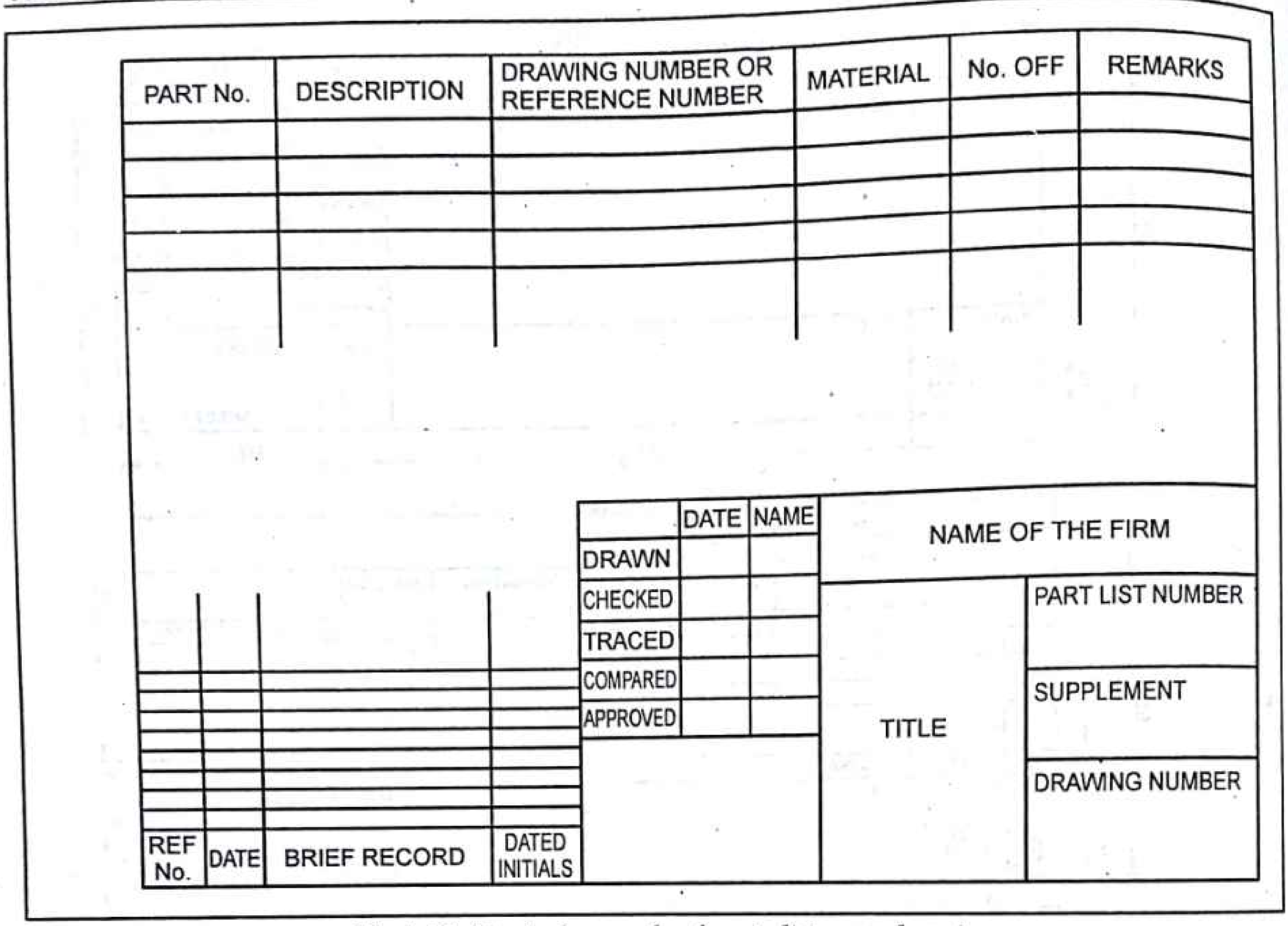


Fig. 1.28 : Typical example of parts list on a drawing

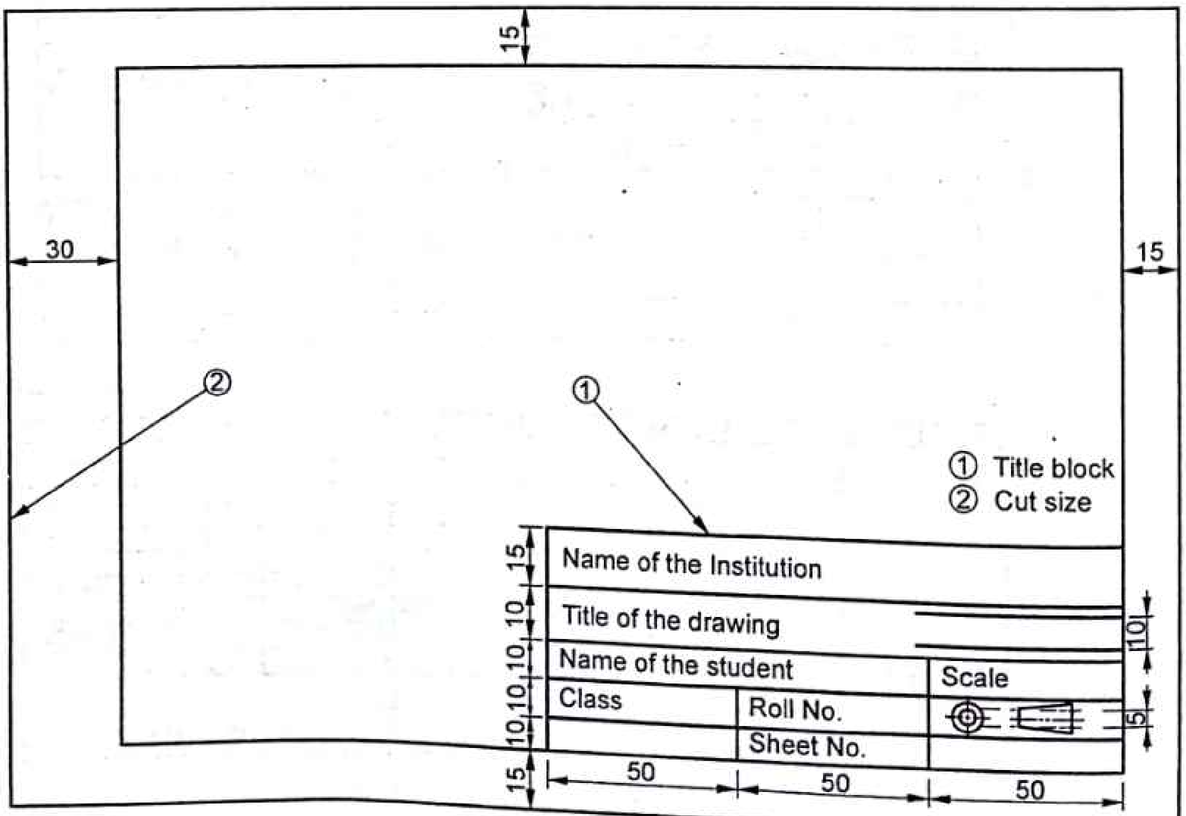


Fig. 1.29 : Sheet layout (suggested for sheets prepared in classrooms)

For clean and good drawing, students are advised to clean the board, the tee-square and the instruments before use.

1.7. NUMBERING MULTIPLE SHEET DRAWINGS

Multiple sheet drawings marked with the same registration or identification number should be indicated by means of a sequential sheet number. In addition, the total number of sheets should be shown on sheet 1, for example:

$$\text{Sheet No.} = \frac{n}{p}$$

where, n = sheet number
and p = total number of sheets

An abbreviated title block containing only the identification zone may be used for all sheets after the first sheet.

1.8. FOLDING OF PRINTS

Two methods of folding of prints, one suitable for prints for filing or binding and the other for keeping in filing cabinet, together with different stages of folding are given in Fig. 1.30 and Fig. 1.31. All large prints of sizes higher than A_4 are folded to A_4 size. The title blocks of all the folded prints appear in topmost position. The bottom right hand corner is the outermost visible section and must have a width not less than 190 mm. Depending on the method of folding adopted, suitable folding marks are to be introduced in the tracing sheets as guide.

1.9. IDEALS OF GOOD DRAWING

The student must make it a habit to produce good drawing. A carelessly done drawing gives a poor impression of habit and knowledge of the student. A good drawing must satisfy the following conditions.

(*a*) *Drawing must be accurate* : An inaccurate drawing loses much of its usefulness. For drawing to be accurate, the instruments must be kept in good condition.

(*b*) *Drawing must be neat* : A neat drawing invites appreciation.

(*c*) *Drawing must follow standard conventions* : Making of drawings is not an end in ilself. The drawing made is "read" by engineers in production department, erection work, etc. Unless the drawing follows the standard conventions, the person who has to read the drawing may get a wrong impression of the object.

Thus, a drawing of maximum usefulness is accurate, neat, legible and conventionally correct.

1.10. IMPORTANT POINTS TO BE OBSERVED AT THE DRAWING BOARD

A fresher invariably finds that his drawings inevitably become dirty and the presentation is not attractive. The following hints are therefore given to help the students in making good drawings.

1. One of the first rule to learn is to keep your pencil sharp so that your lines are always crisp. Never sharpen a pencil so that the dust falls on the drawing board, tee-square. set-squares, etc. Resharpen the pencils as soon as they become blunt. Soft pencils and too superficial lines spread graphite dust. Use hard pencils and complete the heaviest lines last. *Do not draw too faintly and too grey.*

2. Keep your hands clean. Also, keep your instruments clean by wiping with a duster. Remove all loose matter from your drawing with a duster, *not with your hands.*

3. Rubbing out must be reduced to a minimum and should not be over-vigorous. Defer all rubbing on final drawing as long as possible. Eraser dust should be removed by lightly flicking with a clean soft duster. *Never brush across the surface of drawing with the palm of the hand or the shirt/coat sleeve. Brushing by hand or sleeve makes the entire drawing sheet dirty.*

4. Do not collect all of your drawing instruments, sharpener, sand paper, duster, etc., on the drawing board. As far as possible keep them away from the drawing board in a bag or a box.

5. Use a backing paper below the drawing sheet to provide some resilience under the drawing material.

6. Avoid perspiring over the drawing.

7. While not drawing, cover the drawing with a

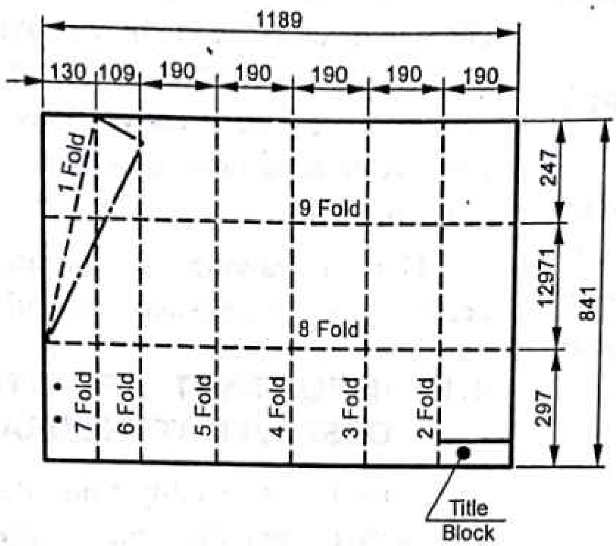
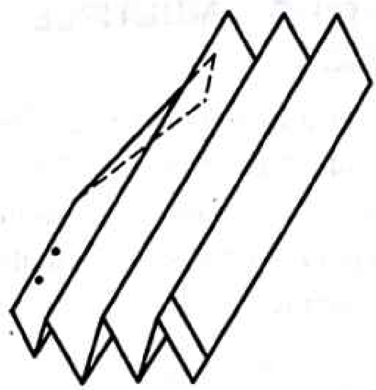
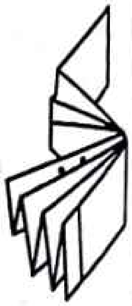
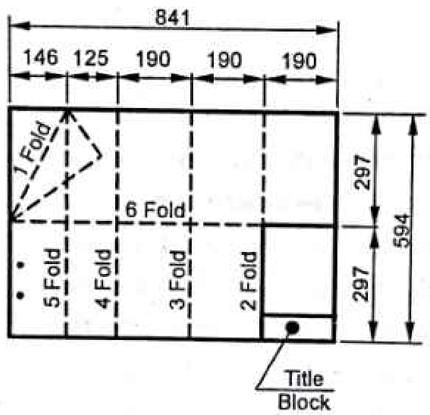
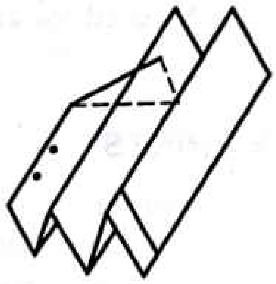
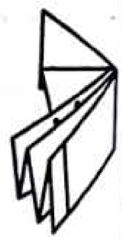
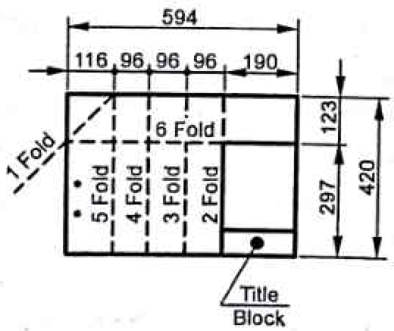
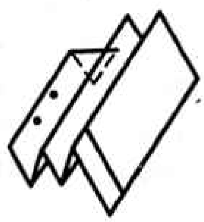
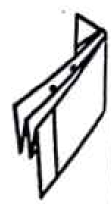
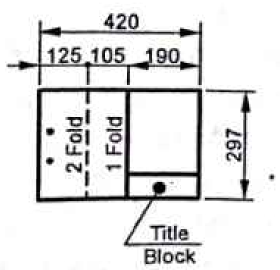
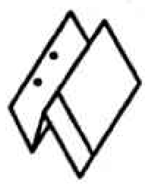
Sheet Designation	Folding Diagram	Lengthwise Folding	Crosswise Folding
A0 841 × 1189			
A1 594 × 841			
A2 420 × 594			
A3 297 × 420			—

Fig. 1.30 : Folding of prints for filing or binding

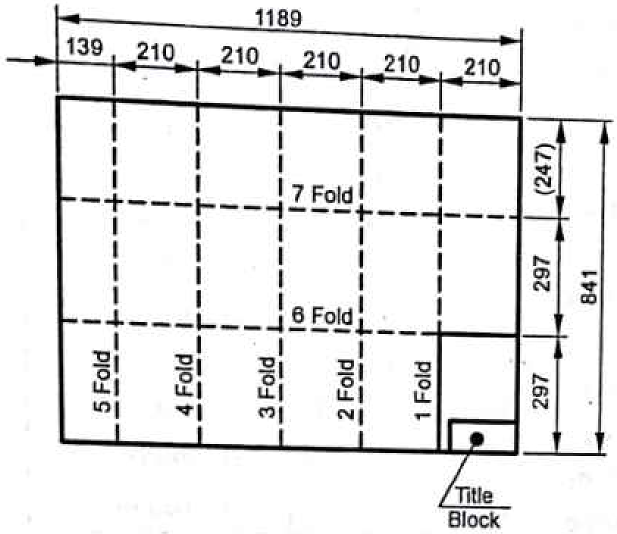
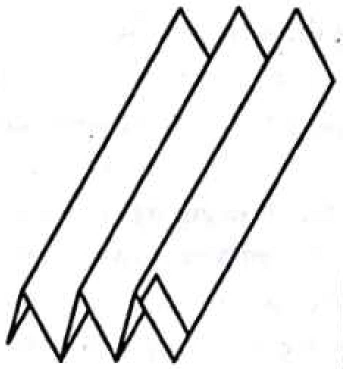
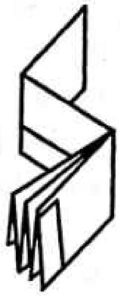
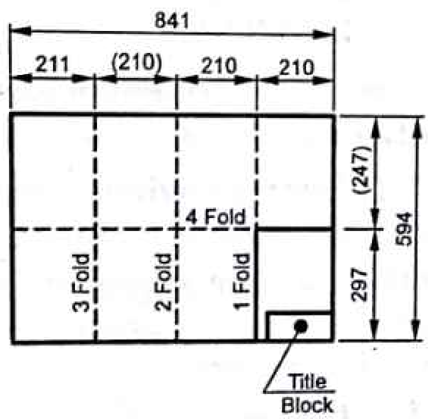
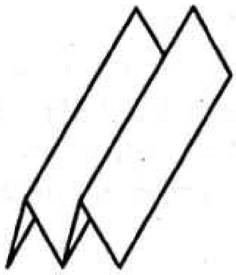
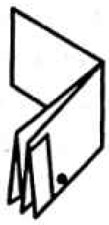
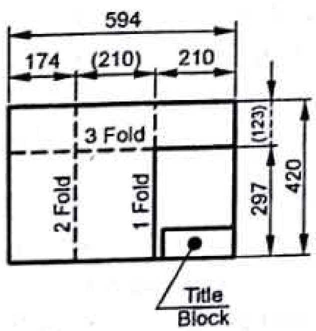
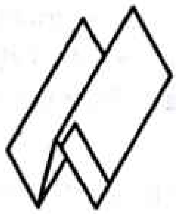
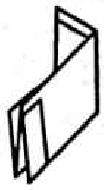
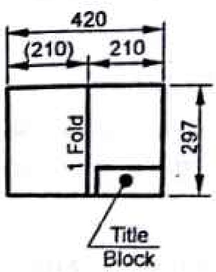
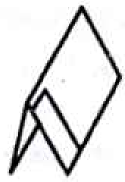
Sheet Designation	Folding Diagram	Lengthwise Folding	Crossing Folding
A0 841 × 1189			
A1 594 × 841			
A2 420 × 594			
A3 297 × 420			—

Fig. 1.31 : Folding of prints for storing in filing cabinet (All dimensions in mm)

sheet of a paper.

8. While lettering, place a paper underhand.

9. Never apply the points of dividers directly to a good scale. The measurement should be taken directly by putting the scale on the line.

10. Always plan the arrangement of the whole drawing on the paper before making any marks whatsoever.

11. Build up the drawing from centre lines and base lines which are common to two views.

12. Do not try to complete one view before proceeding to another. It is better to draw in parts of each view which are aligned along horizontal or vertical lines and work on each of the views in some sort of rotation.

13. Differentiate from the begining between thick and thin lines. Thick lines should be two to three times thicker than thin lines.

14. *If the progress is too slow, usually the procedures are wrong.* Study technique, especially in the use of scale. Much time is lost in attempts to avoid intersecting lines and in rubbing at the faintline stage.

1.11. SCALE DRAWING

Sometimes objects have to be drawn larger or smaller than their actual size. Thus a boiler would be drawn to a reduced scale, whereas parts manufactured on automats would ordinarily be drawn to an enlarged scale. The Indian Standard: SP:46-1988 recommends the scales given in Table 1.7 for use on engineering drawings.

A scale of 1 mm to 10 mm (1:10) means that 1 mm on the drawing represents 10 mm on the object. Such a scale *has a representative fraction of* 1/10. Thus Representative Fraction, R.F., is defined as

$$\text{R.F.} = \frac{\text{size on drawing}}{\text{size on object}}$$

"Scales", graduated to facilitate drawing to scale, are time-saving accessories. A *fully divided* scale has the basic units subdivided throughout its length. If only the end unit is subdivided, the scale is said to be *open-divided.*

Table 1.7 Scale for use on technical drawings

Full scale	*Reduced scale*	*Enlarged scale*
1:1	1 : 2	50 : 1
	1 : 5	20 : 1
	1 : 10	10 : 1
	1 : 50	5 : 1
	1 : 100	2 : 1
	1 : 200	
	1 : 500	
	1 : 1000	
	1 : 2000	
	1 : 5000	
	1 : 10000	

1.12. CLASSIFICATION OF MACHINE DRAWINGS

Machine drawings are made for various purposes and are classified as follows :

1. Shop drawings. Shop drawings are a set of drawings for manufacture of each component of a product and their subsequent assembly. The shop drawings therefore consist of part drawings and assembly drawings.

(*a*) ***Part drawings.*** A part drawing is a drawing of all individual parts of the machine with all details necessary for its manufacture. The drawing consists of a sufficient number of views with all the dimensions and limits and surface finish details.

(*b*) ***Assembly drawings.*** An assembly drawing of a product or a machine shows the relative positions of the various parts. In assembly drawing, generally only overall or major dimensions are given and dotted lines are not shown. A table of "parts list" giving the part number, its material and quantity required is generally included.

The shop drawings (part drawings and assembly drawings) form the major bulk of the machine drawings.

2. Drawings for instruction manuals. These are assembly drawings without dimensions but with each component numbered for ease in identifying during disassembly and subsequent reassembly.

3. Drawings for catalogues. The drawings for including in catalogues are merely outlines of assembly drawing with only the major and overall dimensions given to give an idea about the size of the machine and space required for installation.

4. Schematic drawings. Schematic drawings are made for complicated machinery to explain its principle of working. In schematic drawing the parts are replaced by their respective conventional representation.

5. Patent drawings. Patent drawings are drawings filed when a patent is sought for a new design. These drawings contain no dimensions and are not detailed. However, they should be made as self-explanatory as possible by adding pictorial views, if required. The important features may be numbered giving references to specifications.

1.13. REPRODUCTION OF DRAWINGS

The most important method of reproduction of drawings is the *blue printing* process, called ferro-pressiate process.

(*a*) Ferro-pressiate process. It gives prints in white lines on a blue background. In this process the back of the drawing is placed in contact with the sensitized surface of the ferro-pressiate paper and exposed to sunlight or electric arc lamp in a printing frame. The frame is kept facing and normal to the light. The time of exposure is decided by trial. It depends on the intensity of the light, opacity of the tracing and the rapidity of the paper. The printing frame should be opened and closed in the dark room.

The other processes of reproduction are as follows:

(*b*) Ferro-gallic process. This process gives black lines on white background. The ferro-gallic paper has a coating of gallic acid powder. The exposure process is similar to ferro-pressiate process. After exposure, the paper is immersed with face downward in a bath of running water and development is obtained.

(*c*) Ammonia process. This process gives brown or red lines on white background. The ammonia sensitized papers are also exposed in the same way as the ferro-pressiate paper. After the exposure the print is put in the ammonia box containing 10% ammonia solution. The lines are developed by the ammonia vapour. To get rid of ammonia odour the print is kept in the open air for sometime.

(*d*) Sepia or photo process. This process gives white line on a deep brown background. If the negative is made on a thin sepia paper, the prints will be with brown or blue lines on a white background. Sepia papers are sensitized with a solution of silver salts. After exposure the prints are washed with the photo developing process.

(*e*) Photostat. This process is a simplified form of camera and became very common. Enlargement or reduction to any convenient size can also be obtained by photostat process.

(*f*) Drawing storage in digital form. In case of drawing produced on CAD system, they are stored digitally on tape or disks and not as hard copies.

EXERCISES

Section A

1.1. Why drawing is called the universal language of engineers ?

1.2. List the essential drawing materials required to work in a drawing class.

1.3. What are the standard sizes of the drawing board? Drawing paper ? How successive sizes of paper are obtained ?

1.4. How a tee-square can be tested ?

1.5. What is a clinograph ?

2 Types of Lines and Lettering

2·1. TYPES OF LINES

For general engineering the Bureau of Indian Standards (B.I.S.) has recommended the types of lines shown in Figure 2.1 to be used.

1. Outlines (type A). Outlines are continuous thick lines drawn to represent visible edges and surface boundaries of objects. The outline should be outstanding, *i.e.* intensely black in appearance.

Line	*Description*	*General Applications*
A	Continuous thick	A1 Visible outlines A2 Visible edges
B	Continuous thin (straight or curved)	B1 Imaginary lines of intersection B2 Dimension lines B3 Projection lines B4 Leader lines B5 Hatching B6 Outlines of revolved sections in plane B7 Short centre lines
C D[1)]	Continuous thin free hand[1)] Continuous thin (Straight) with zigzags	C1 Limits of partial or interrupted views and sections, if the limit is not a chain thin D1 Line
E F	Dashed thick[2)] Dashed thin	E1 Hidden outlines E2 Hidden edges F1 Hidden outlines F2 Hidden edges
G	Chain thin	G1 Centre lines G2 Lines of symmetry F2 Trajectories
H	Chain thin, thick at ends and changes of direction	H1 Cutting planes
J	Chain thick	J1 Indication of lines of surface to which a special requirement applies
K	Chain thin double-dashed	K1 Outlines of adjacent parts K2 Alternative and extreme position of movable parts K3 Centroidal lines K4 Parts situated in front of the cutting plane

(1) *This type of line is suited for reproduction of drawings by machines.*

(2) *Although two alternatives are available, it is recommended that on any one drawing, only one type of line be used.*

Fig. 2.1 : Types of lines

2. Hidden lines (dotted or dashed lines, type E and F). Hidden lines are thick or thin lines consisting of short dashes, closely and evenly spaced and represent hidden edges or surfaces. Hidden lines should be used only where their use definitely assists in the interpretation of drawing

3. Centre lines (type G). Centre lines are used for symmetrical objects. It consists of a thin line with alternate long and short dashes in proportion ranging from 6:1 to 4 : 1, closely and evenly spaced. The centre lines should project for a short distance beyond the outline to which they refer, but wherever necessary, for dimensioning or to correlate views, they may be extended.

Locus lines are drawn same as centre lines.

4. Dimension lines, extension lines construction lines and hatching lines (type B) Dimensions lines, extension lines, construction lines and hatching lines are drawn as continuous thin lines so as to contrast with the heavier outline on the drawing.

Construction lines are drawn in geometrical drawings only. Section lines are drawn inclined at 45° spaced evenly (about 1.5 mm apart) to make a shaded effect.

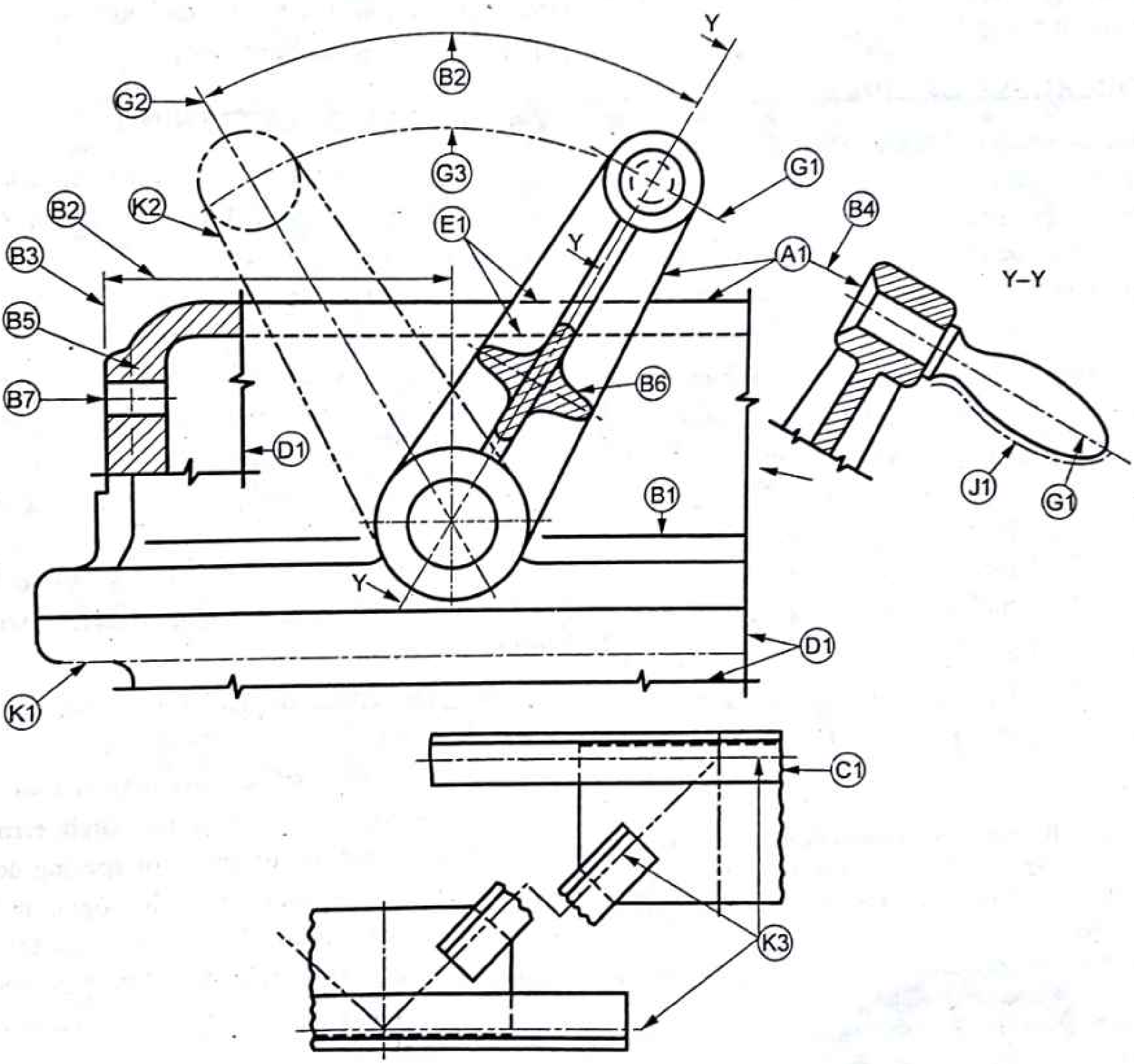


Fig. 2.2 : Typical applications of recommended lines

5. **Cutting plane lines (type H).** The cutting plane on which a section has been taken is indicated by thin, thick at ends and changes of direction.

6. **Break lines (type C and D).** Break lines are used on both detail and assembly drawings. Type C is continuous thin line drawn freehand. This is used for limits of partial or interrupted views and sections. Type D is continuous thin (straight) with zig zags.

7. **Adjacent parts and alternate positions (type K).** A chain thin double-dashed line is used for adjacent parts and for alternate positions. Typical applications of recommended lines are shown in Fig. 2.2

2·2. THICKNESS OF LINES

Two thickness of lines are used. The ratio of the thick to the thin line should not be less than 2:1. Grading of lines is in √2 increments. The thickness of lines should be chosen according to the size and the type of the drawing from the following range: 0·18, 0·25, 0·35, 0·5, 0·7, 1, 1·4 and 2 mm. See Table 2.1.

Table 2·1 : Thickness of lines in mm

Group	*Line Thickness*		*Lettering Dimension figures and Symbols*
	Thick	*Thin*	
0·35	0·35	0·18	0·25
0·50	0·50	0·25	0·35
0·70	0·70	0·35	0·50
1·00	1·00	0·50	0·70
1·40	1·40	0·70	1·00
2·00	2·00	1·00	1·40

Notes :

1. Owing to difficulties in certain methods of reproduction, the line thickness of 0·18 should be avoided.
2. For all views of one piece to the same scale, the thickness of the lines should be the same.
3. The minimum space between parallel lines including hatching should never be less than twice the thickness of the heaviest line. It is recommended that these spaces should never be less than 0·7mm.

2.3. *LETTERING

Lettering is very important in engineering drawing and the student is advised to master it by constant practice and continuous efforts to improve. Bad lettering can spoil the appearance and even usefulness of a drawing. In engineering drawing lettering should not be ornamental and obscure. *The main requirements for lettering on engineering drawings are legibility, uniformity and ease and rapidity in execution.* Simple single-stroke broad letters are best in this respect.

All the letters should be in capital except where lower case letters are accepted in international usage for abbreviations. The lower case letters are, however, used in architectural drawings.

2·4. STYLES OF LETTERING

A few important styles of lettering are given in Fig. 2·3 to 2·7. Fig. 2·3 shows Modern Roman. Fig. 2·4 shows Commercial Gothic which is sometimes used in show drawings and main titles of ink drawings. Fig. 2·5 shows stencil lettering done by stencil plates which are available in sizes from 2 mm to 25 mm. But most of the lettering in engineering drawing is freehand, single-stroke, vertical or sloping as shown in Fig. 2·6 and 2·7. Single stroke means that the thickness of the line of the letter is such as is obtained in one stroke of the pencil. It does not mean that the letter should be made in one stroke without lifting the pencil.

Both the vertical and the sloping types of letters are in general use. For writing numbers, titles and reference numbers vertical style may be used. The sloping style has the advantage that slight errors in inclination, formation of letters or spacing do not show so much as in vertical style. In sloping style an inclination of about 75° to horizontal is recommended. This style should be practised by drawing guide lines and following the sequence of strokes as indicated.

*Lettering is sometimes called "printing" which is a wrong word, as printing refers to only printed words made in press.

3 Orthographic Projections

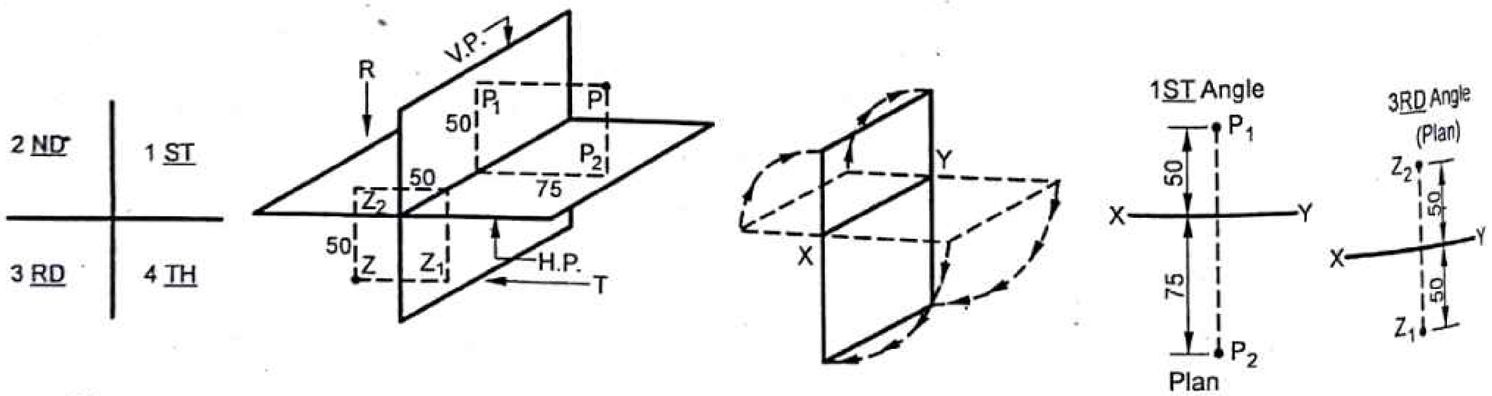
3.1. INTRODUCTION

An object has three dimensions, namely length, breadth and height. The problem is to represent three-dimensional objects on two-dimensional surface of the paper. One method of representation is the *pictorial projection.* (Isometric projection is a kind of pictorial projection). In pictorial projection, we easily get the idea of the actual shape of an object. But this method cannot be universally adopted, mainly because all objects except the simplest cannot be drawn easily and with rapidity in pictorial projection. Other drawbacks of pictorial projection are that all the lines cannot be measured from pictorial views and objects are liable to appear distorted.

3.2. ORTHOGRAPHIC PROJECTION

In machine drawing orthographic projection is universally used. The only disadvantage of this method is that shape cannot be easily interpreted by an untrained eye. It requires a thorough understanding of the principles of projection and a great practice to read orthographic views.

Four dihedral angles or quadrant. A projection is a view obtained on a plane by lines drawn to the plane from every point of an object. These lines are called *projectors*. In orthographic projection, all the projectors are parallel to each other and are perpendicular to the plane of projection. The word orthographic means *to write or to draw at right angles.* Two planes are necessary in this method of projection, the vertical plane (V.P.) and the horizontal plane (H.P.) at right angles to each other. These planes are called the *coordinate planes or principal planes of projection. The* planes may be considered extending infinitely in both directions, as shown in Fig. 3.1 (*a*) forming four dihedral angles. In Fig. 3.1 (*b*), the point *P* is in first quadrant, 50 mm above H.P. and 75 mm in front of V.P. The point *Z* is in third quadrant, 50 mm below H.P. and 50 mm behind V.P. Their views in orthographic projection are shown in Fig. 3.1(*d*) and (*e*) respectively.



(*a*) *Four dihedral angles*

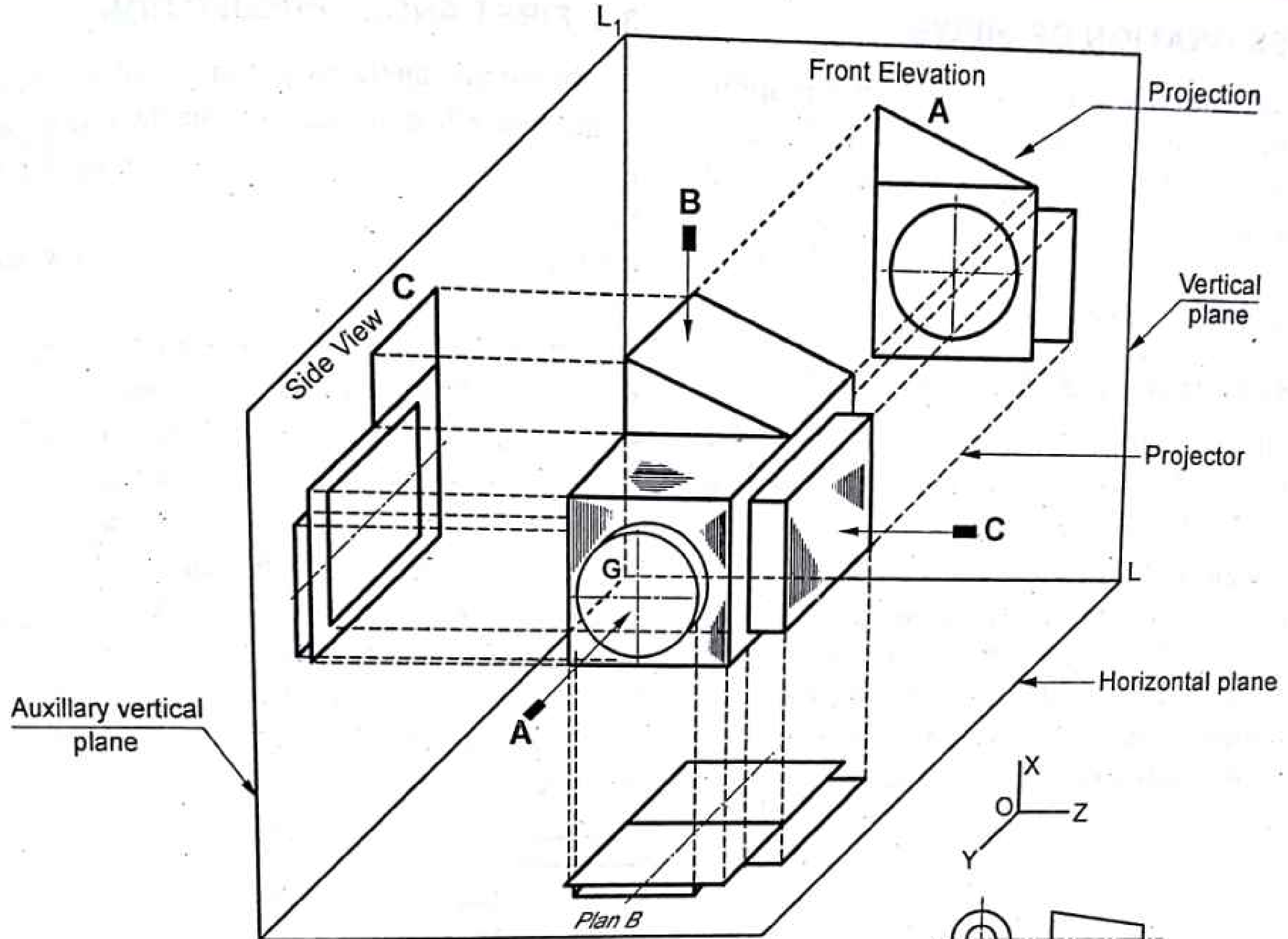
(*b*) *Points in first and third quadrant*

(*c*) *Rotation of H.P. keeping V.P. fixed*

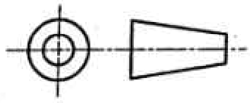
(*d*) *Projection of point*

(*e*) *Projection of point*

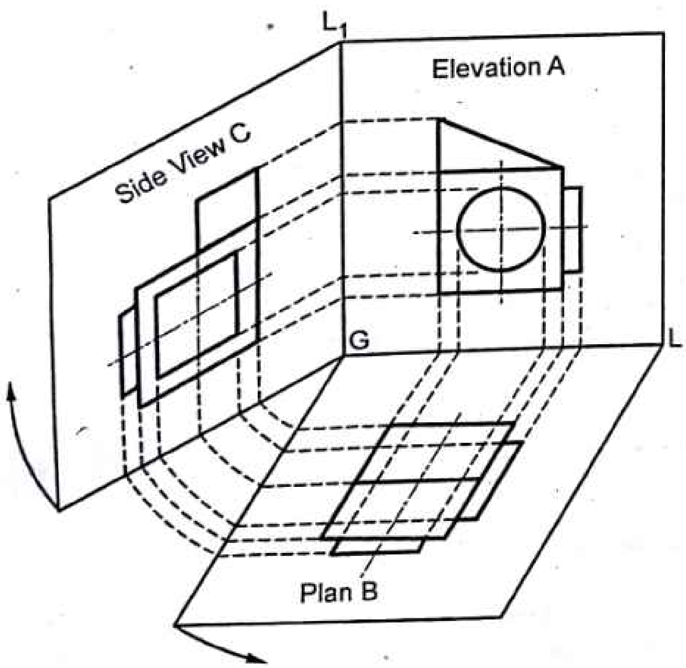
Fig. 3.1 : Projection of points



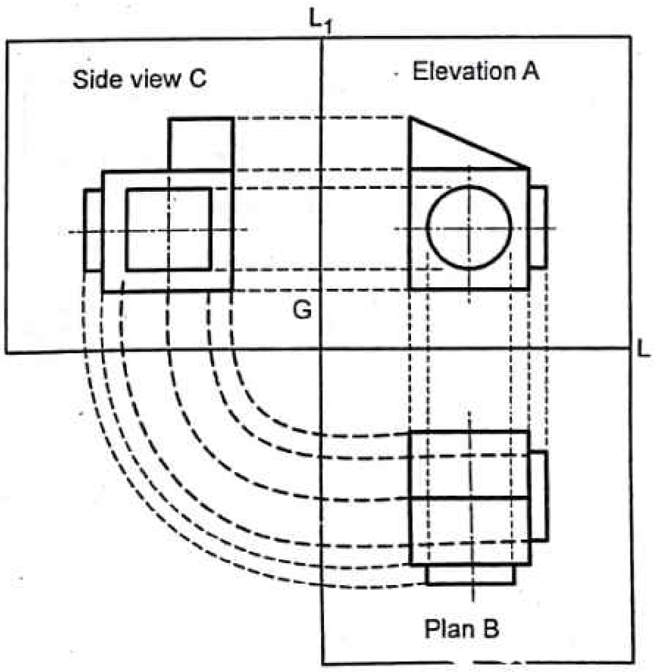
(a)



(b) Conventional representation of first angle projection



(c)



(d)

Fig. 3.2 : First angle method of projection

3.3. DESIGNATION OF VIEWS

There are two methods of orthographic projection: first angle projection and third angle projection. Each of the two methods can be used without prejudice to the principles established. *However, Indian Standards prescribe as a basic requirement use of first angle projection.*

3.4. RELATIVE POSITION OF VIEWS

A three-dimensional object has six views. (See Fig. 3.2 and 3.4). The designation of views is as follows: (Fig. 3.3 and 3.5).

(*i*) View in direction A = View from the front
(*ii*) View in direction B = View from above
(*iii*) View in direction C = View from the right
(*iv*) View in direction D = View from the left
(*v*) View in direction E = View from below
(*vi*) View in direction F = View from the rear

3.5. FIRST ANGLE PROJECTION

In the first angle projection the object is placed in the first dihedral angle or quadrant as shown in Fig. 3.2 and the observer looks from outside from right side of the quadrant (observer is assumed at infinite distance from the object). In other words the object is between the observer and the plane of projection. An object may be viewed in six directions: top, bottom, front, rear, right, side and left side. See Fig. 3.3. Among these views important ones are front view known as *elevation,* top view known as *plan* and side views known as *end views* or *end elevations.* Elevation is projected on V.P., plan on H.P. and side views on auxiliary vertical planes (A.V.P.) which are at right angles to both H.P. and V.P. *It should be noted that every view gives two dimensions: elevation gives length and height, plan gives length and breadth, and side view gives breadth and height.*

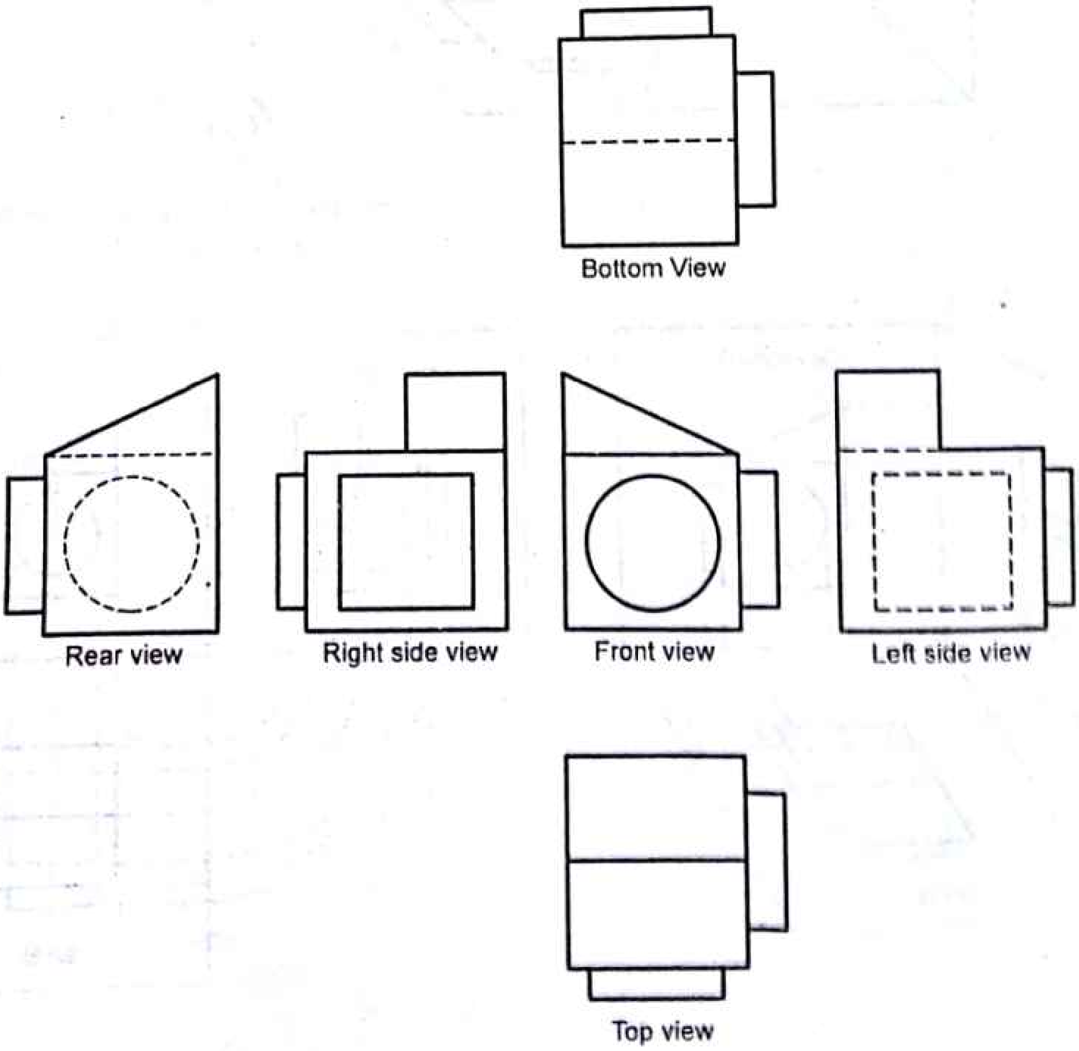
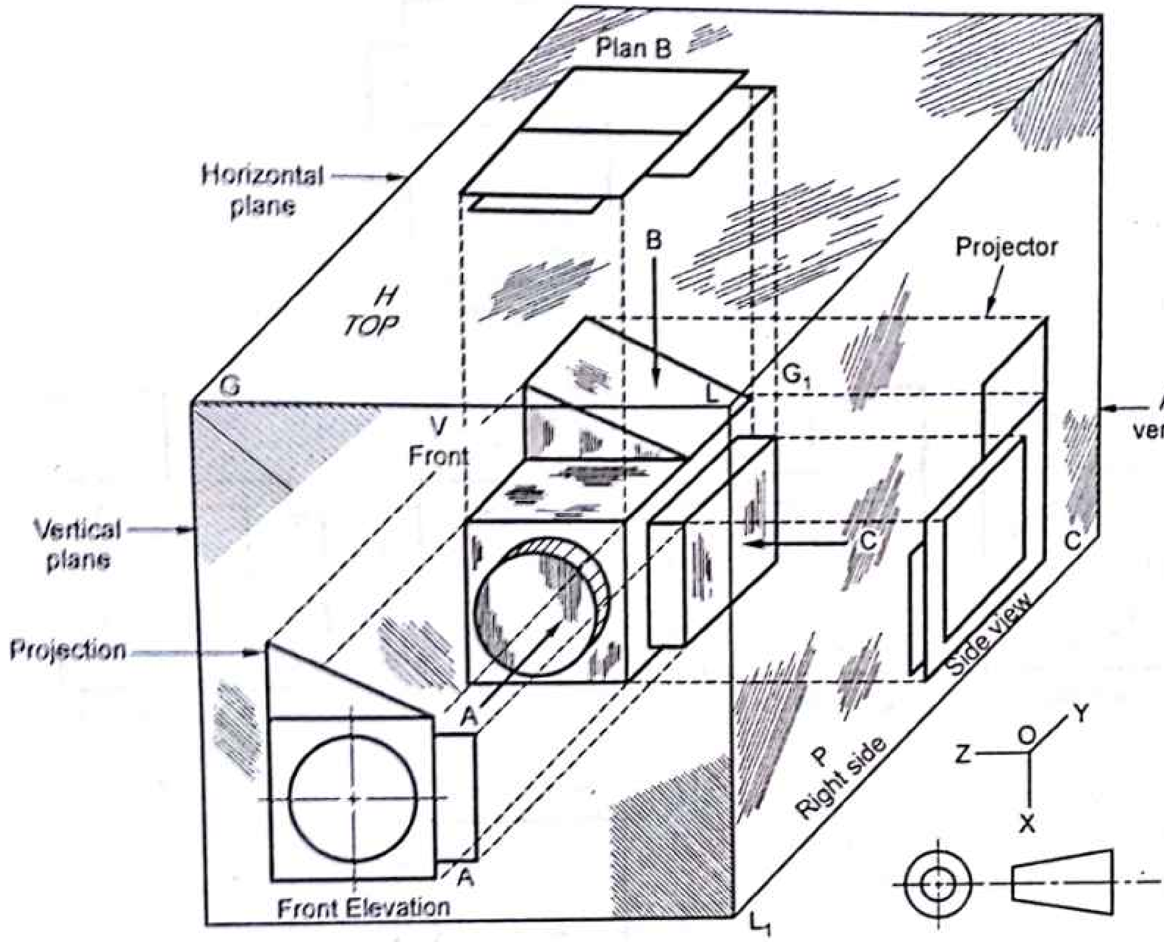
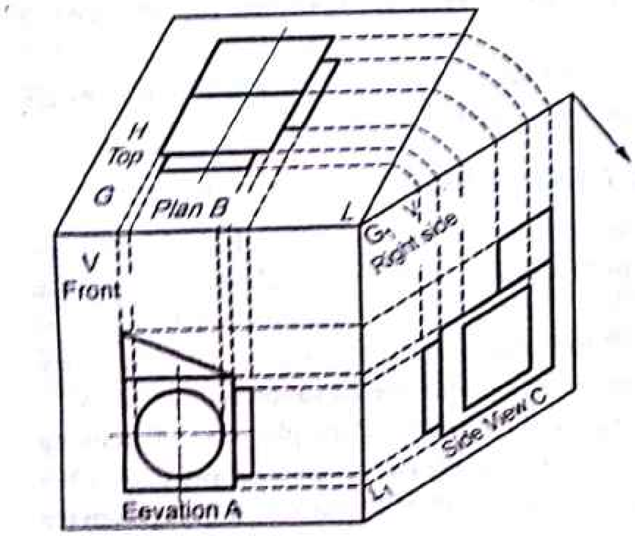


Fig. 3.3 : Six views of on object — First angle projection

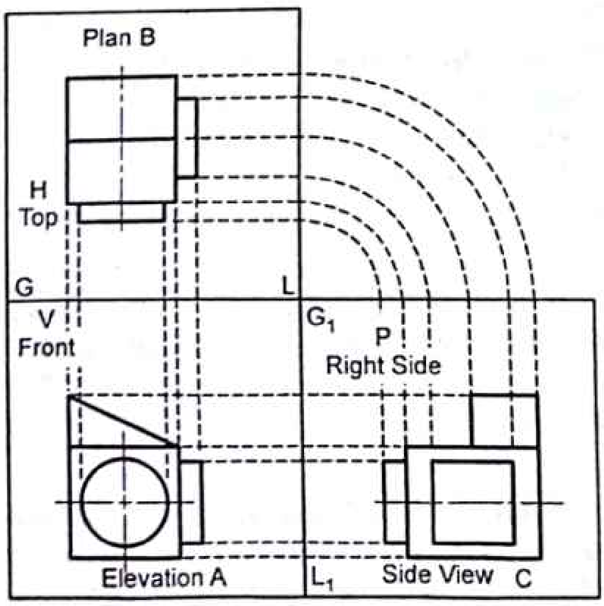


(a)

(b) Conventional Representation of third angle projection



(c)



(d)

Fig. 3.4 : Third angle method of projection

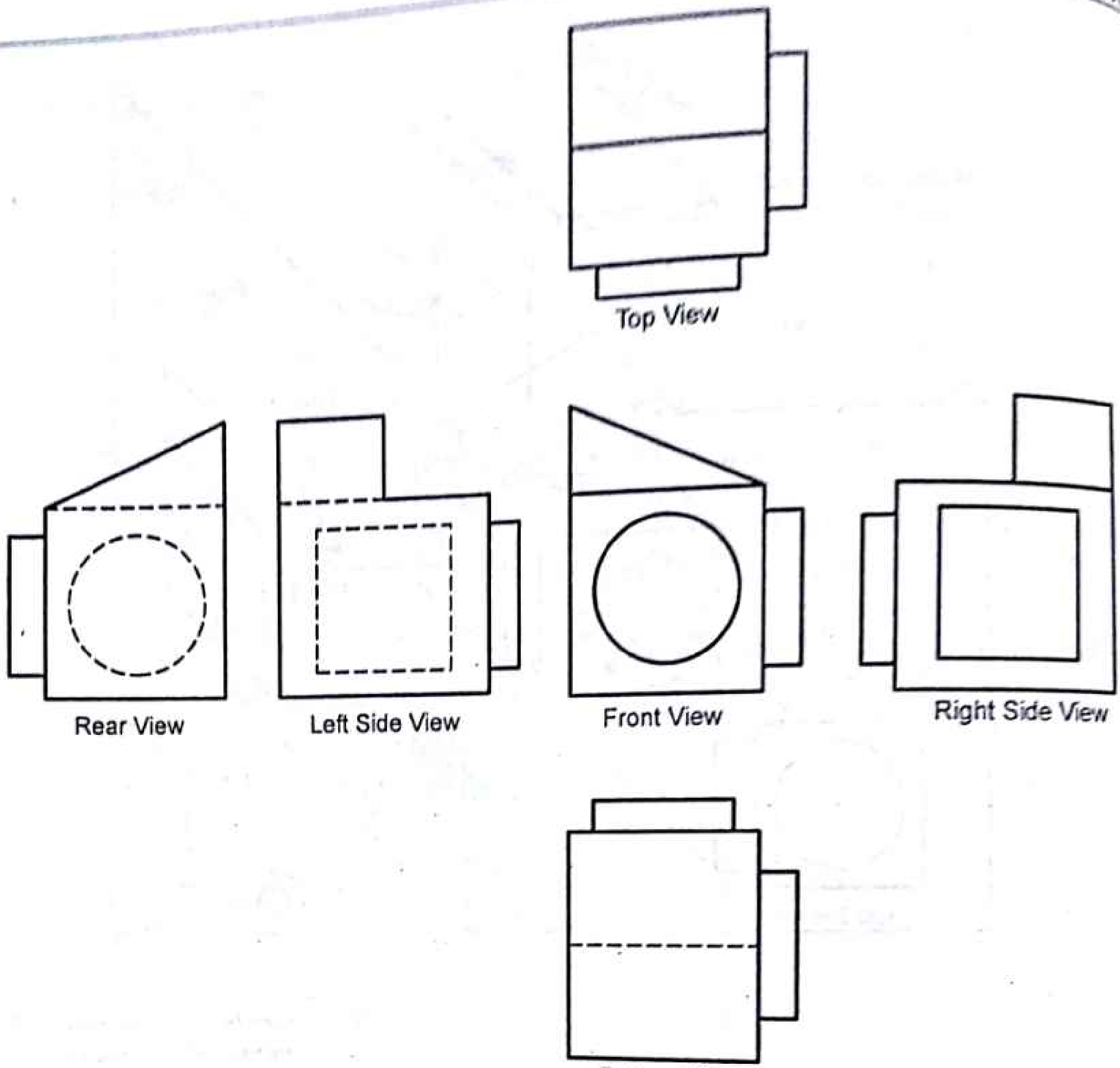


Fig. 3.5 : Six views of an object – Third angle projection

Let L = length, B = breadth, H = height

Elevation gives	L and H
Plan gives	L and B
Side view gives	B and H

Having drawn the three views, we have to rotate H.P. and A.V.P. so that they come in the plane of V.P., because in drawing sheet, all the views are drawn in one plane surface. *The standard method of rotation is to keep V.P. fixed and to revolve H.P. and A.V.P. away from the object as shown in Figs. 3.1 (c) and 3.2 (c).*

By this method of rotation the plan (top view) comes below the elevation and side view viewed from the left comes on the right and the side view viewed from the right comes on the left. The view from the bottom is placed above. The view from the rear may be placed on the left or on the right, as convenient.

The above relative positions of the views is characteristic of the first angle projection. The conventional representation of the first angle projection is shown in Fig. 3.2 (*b*).

3.6. THIRD ANGLE PROJECTION

In third angle projection the object is placed in the third dihedral angle of quadrant as shown in Fig. 3.4. The planes of projection come between the eye of the observer and the object. The planes are assumed transparent. The elevation is drawn on V.P., looking from the front and the plan on H.P., looking from the top. The side views may be drawn on A.V.P.'s perpendicular to both H.P. and V.P., looking from the right or the left as the case may be . As in the case of the first angle projection, H.P. and A.V.P. are assumed to be hinged to V.P. and revolved away from the object in order to bring them in the plane of V.P. It is seen from Fig. 3.4. that the plan comes over the top of the elevation and the side view looking from left comes to the left of the elevation. Similarly, the side view looking from the right comes to the right of the elevation. Fig. 3.5 gives the six views of an object in the third angle projection.

Thus in the third angle projection we get a more natural arrangement of views. *The plan which is looked from the top comes on the top of the elevation. The side views also come on the same side from which they are viewed.* The view from below is placed underneath. The view from the rear may be placed on the left or on the right, as convenient. The reading of the drawing and visualization of the object is easier in the third angle projection, particularly where the shape of the object is complicated and when there are a number of auxiliary views drawn on auxiliary inclined planes.

The third angle method is used in America while the first angle projection is used in some countries of Europe. *The Bureau of Indian Standards has recommended the first angle method projection.* A thorough practice in both the first and the third angle projection should, therefore, be acquired.

It is assumed that H.P. is hinged to V.P., and the H.P. is revolved to bring it in the same plane as V.P. *If the second or the fourth angle projection is adopted the plan and elevation may overlap and hence they are not used.*

3.7. COMBINATION OF TWO SYSTEMS

Sometimes a combination of the first angle and third angle system is made in the same drawing. The plan may be drawn below the elevation as in the first angle projection but the side view may be drawn on the same side from which it is viewed, as in third angle projection. In the combination system, to avoid confusion, arrows should be given indicating the direction from which the object is viewed as in Fig.3.6. or a note should be placed below the view concerned.

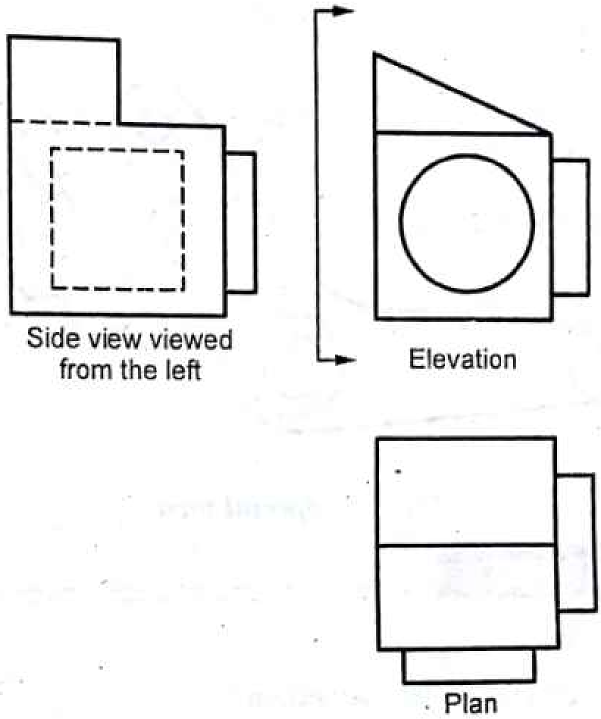


Fig. 3.6 : Combination of first and third angle projection

The combination of first and third angle projection is not recommended.

3.8. CHOICE OF VIEWS

The most informative view of an object should be used as the front or principal view. *Generally, this view shows the part in the functioning position.* Parts which can be used in any position should preferable be drawn in the main position of manufacturing or mounting. The other views, including sections, should be so chosen that the object is made clear with minimum number of views, hidden lines are avoided as far as possible and there is no unnecessary repetition of details.

If the direction of viewing is different than the standard direction, the views may be shown by reference arrows and a capital letter as shown in Fig. 3.7 and 3.8.

Section B

4.1. Sketching orthographic views

Sketch, both in first and third angle projection, plan, elevation and side view from given pictorial views.

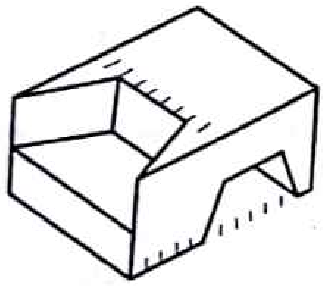


Fig. 4.39

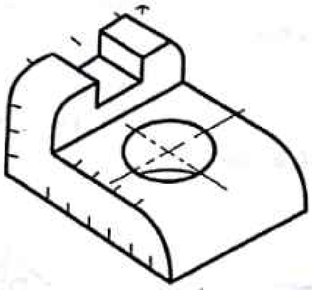


Fig. 4.40

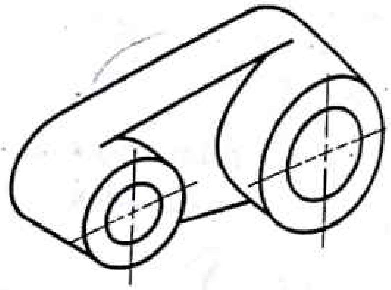


Fig. 4.41

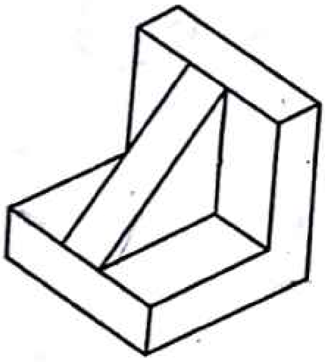


Fig. 4.42

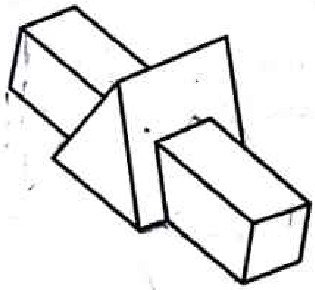


Fig. 4.43

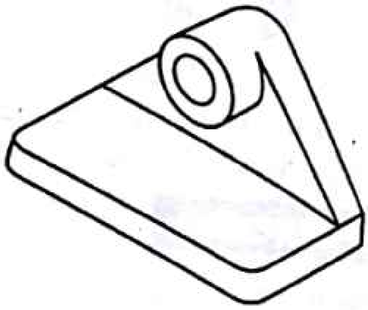


Fig. 4.44

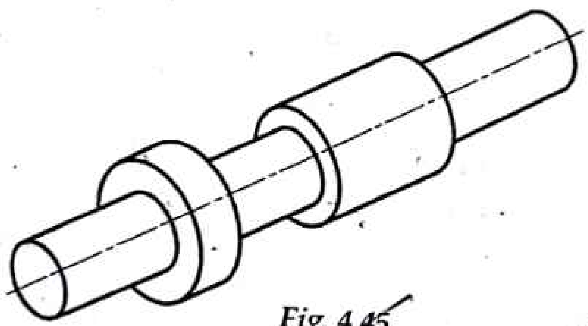


Fig. 4.45

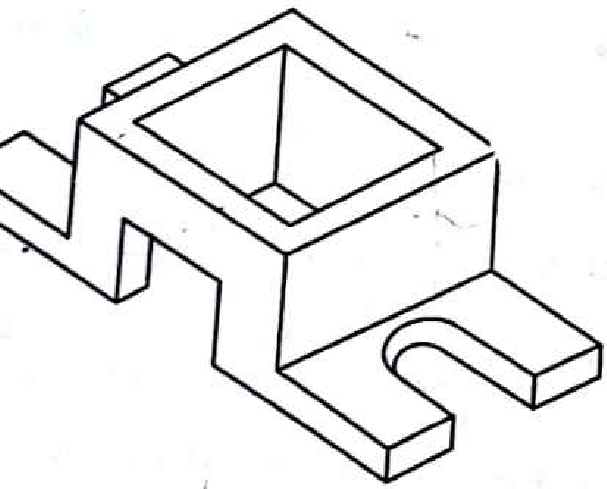


Fig. 4.46

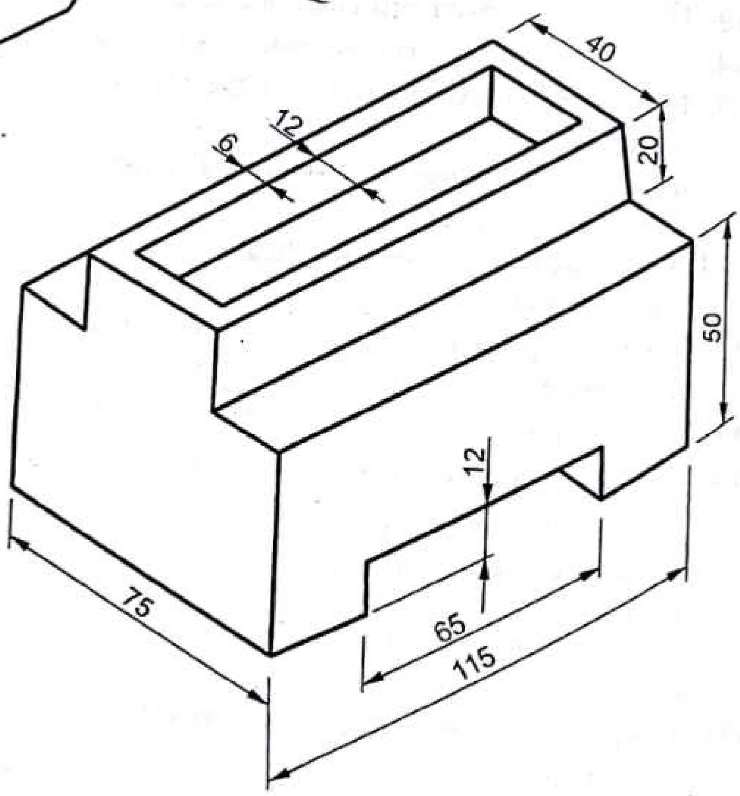


Fig. 4.47

Scanned by CamScanner

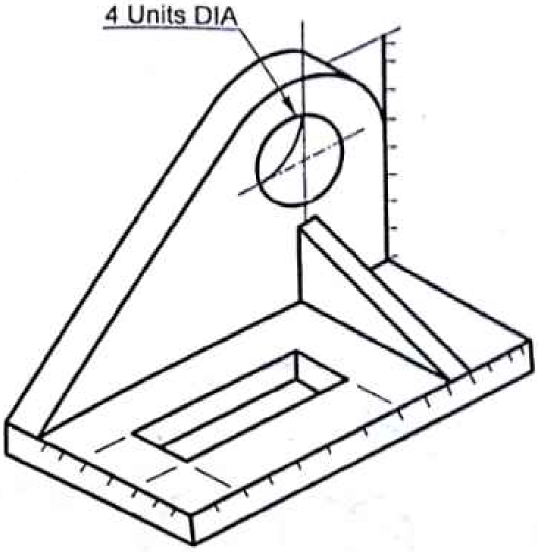


Fig. 4.48

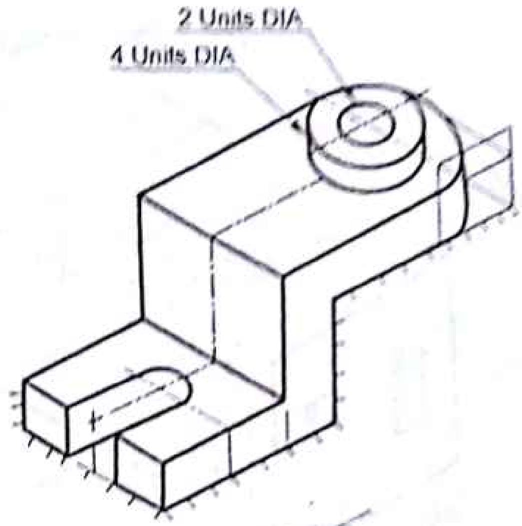


Fig. 4.49

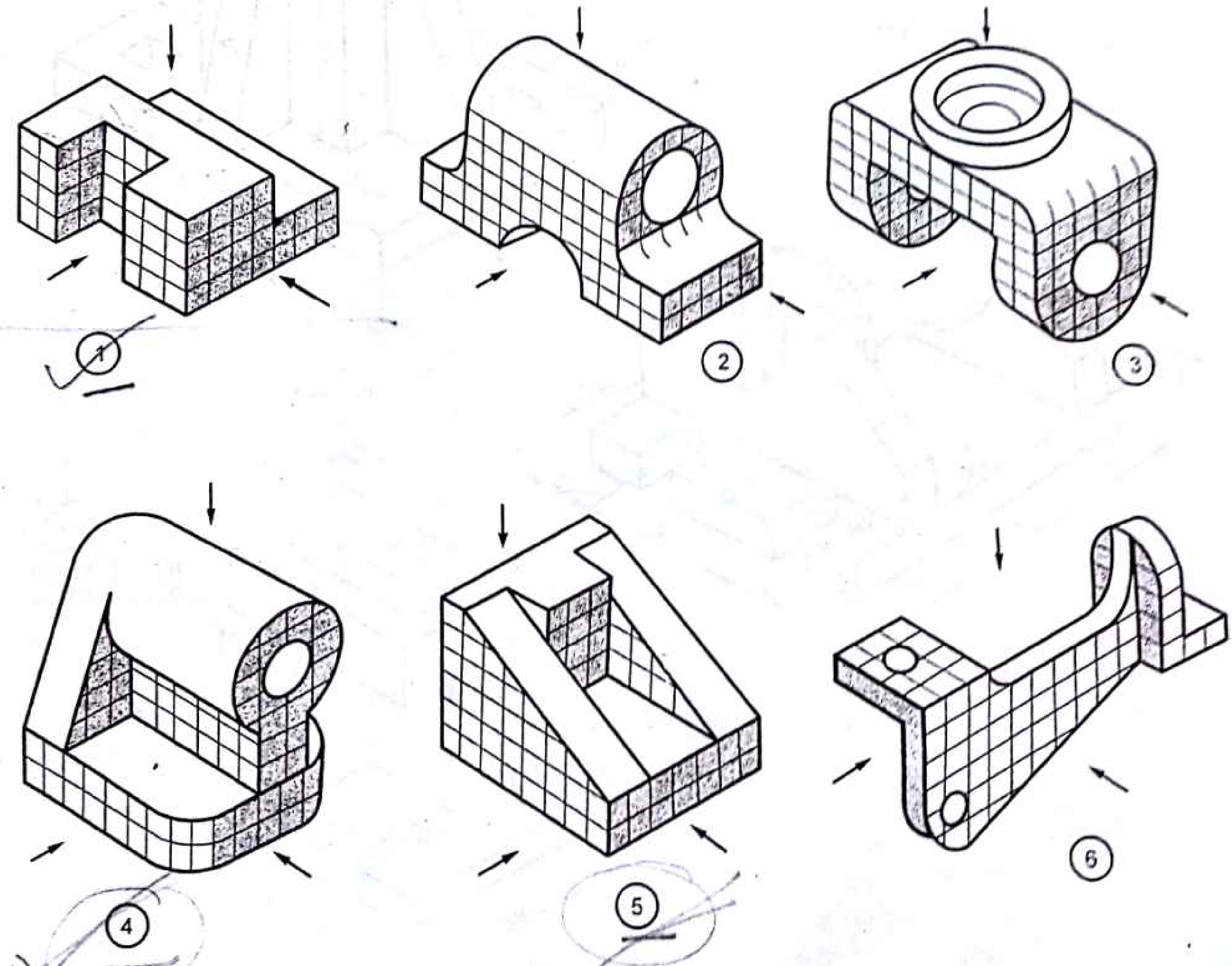


Fig. 4.50

4.2. Drawing of orthographic views.

Draw, both in first and third angle projections, plan, elevation and side view from the given pictorial views.

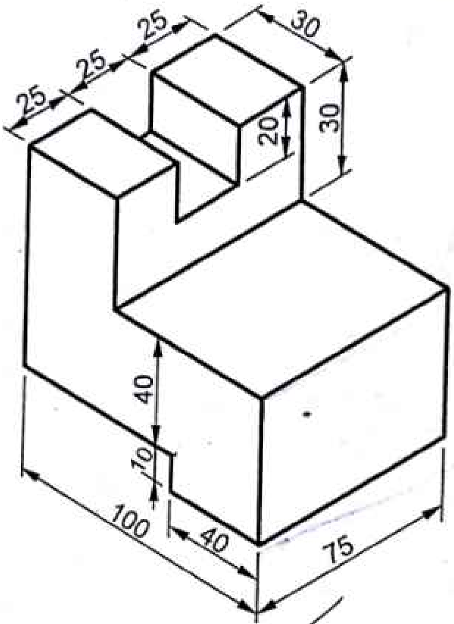


Fig. 4.58

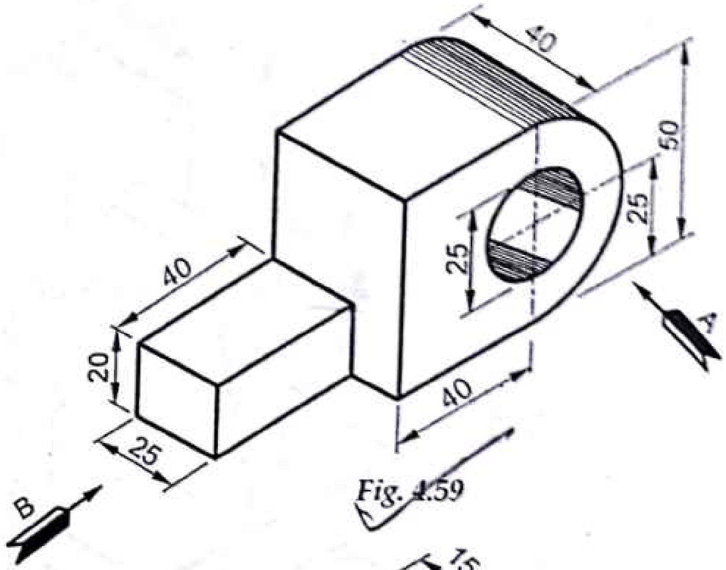


Fig. 4.59

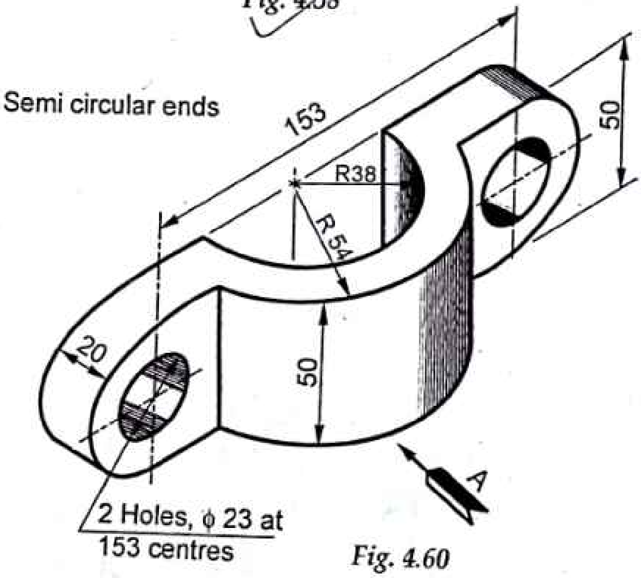


Fig. 4.60

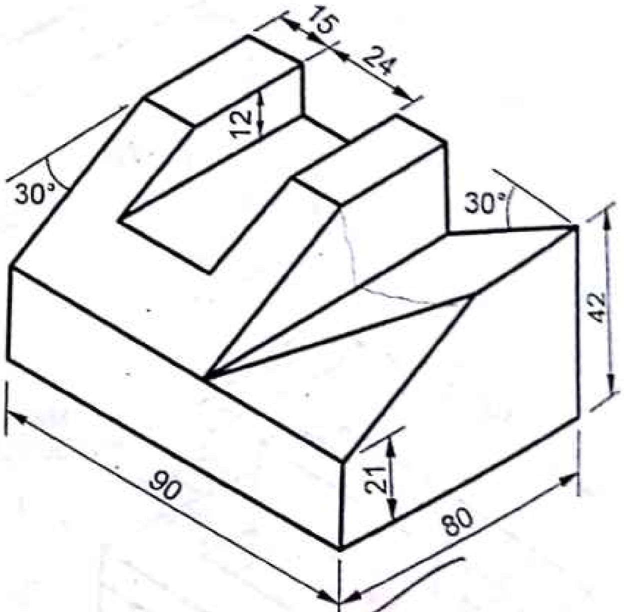


Fig. 4.61

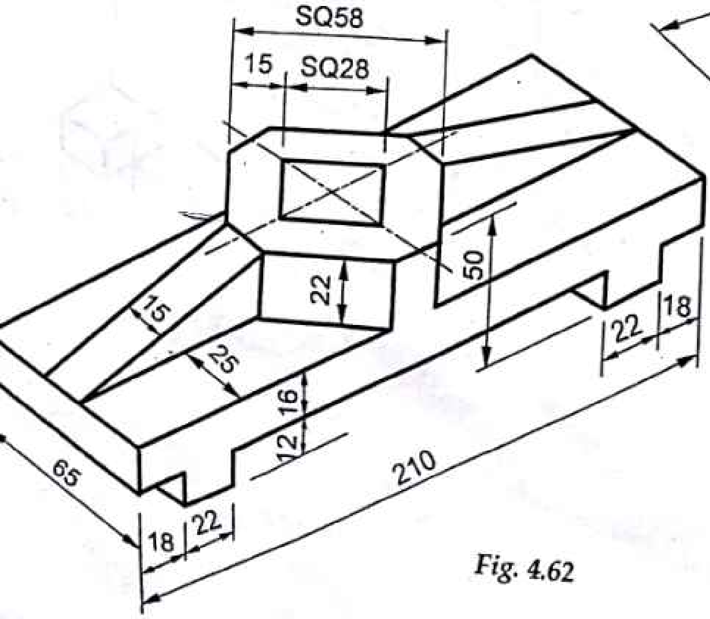


Fig. 4.62

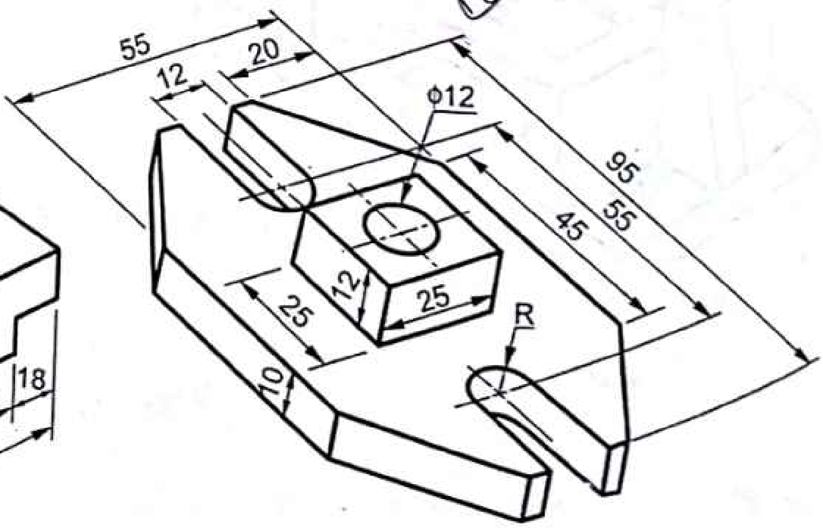


Fig. 4.63

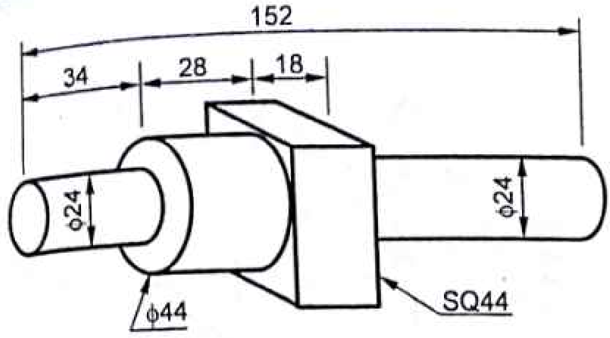


Fig. 4.64

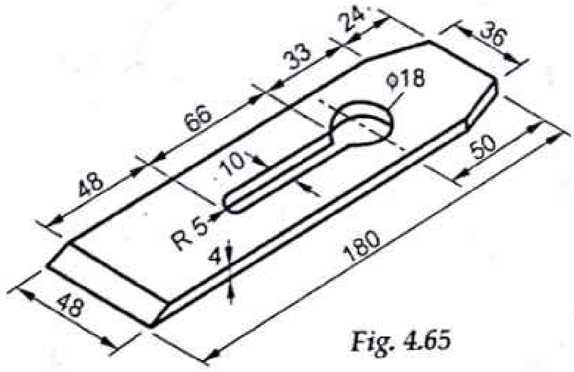


Fig. 4.65

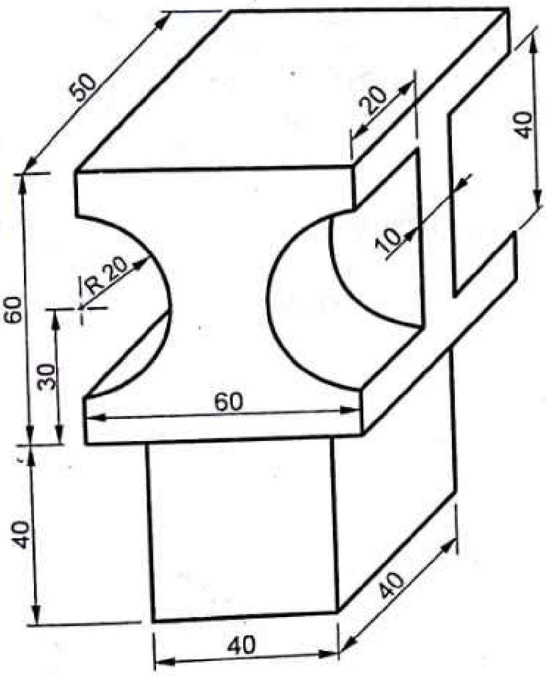


Fig. 4.66

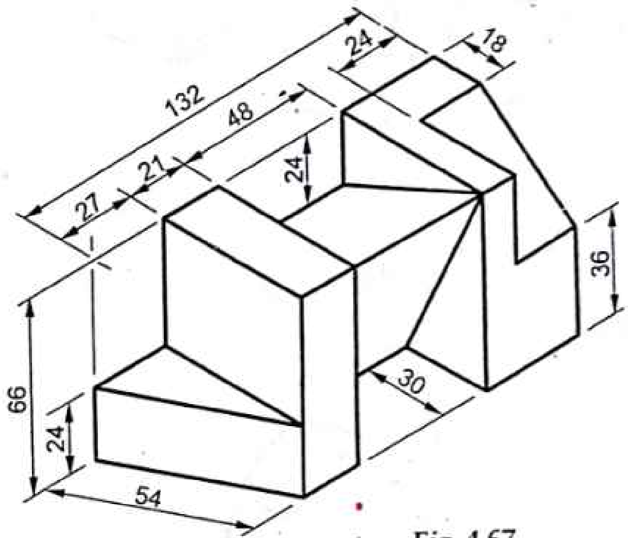


Fig. 4.67

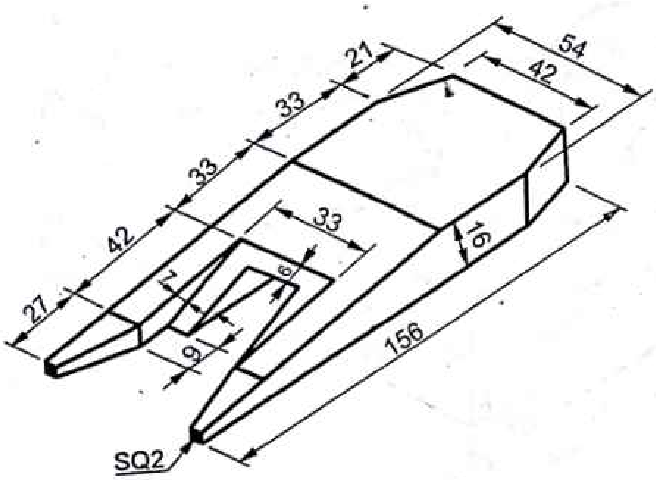


Fig. 4.68

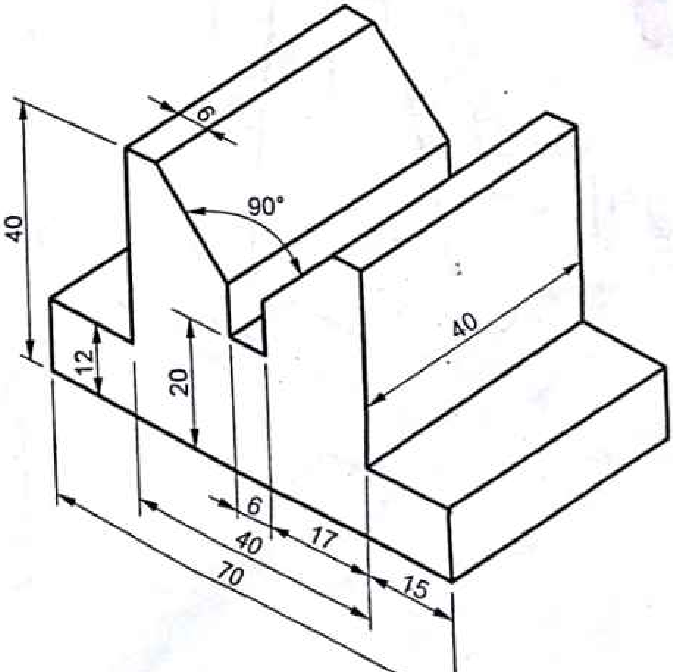


Fig. 4.69

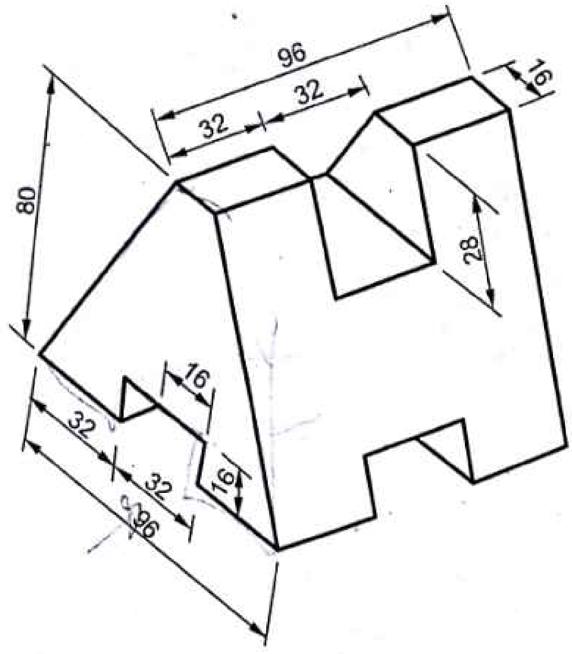


Fig. 4.70

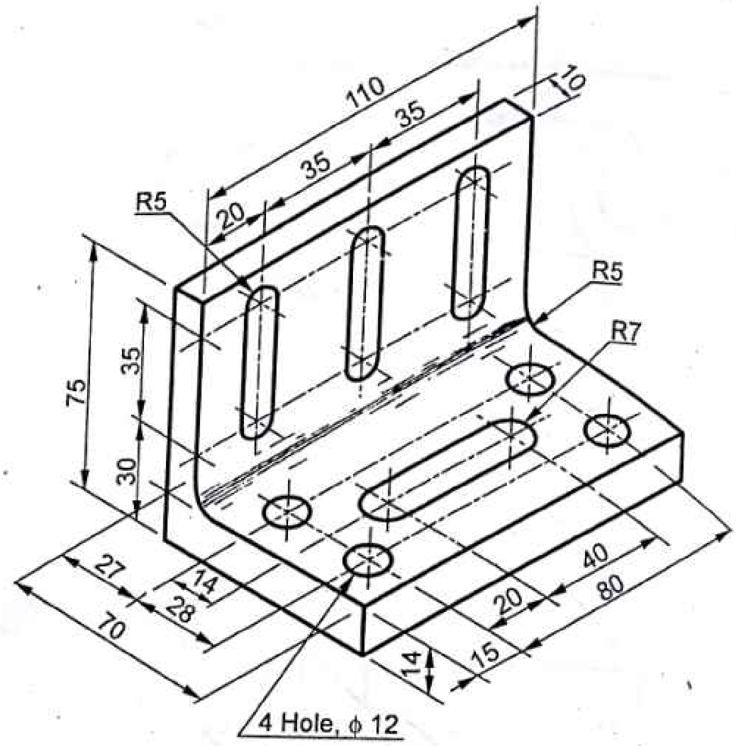
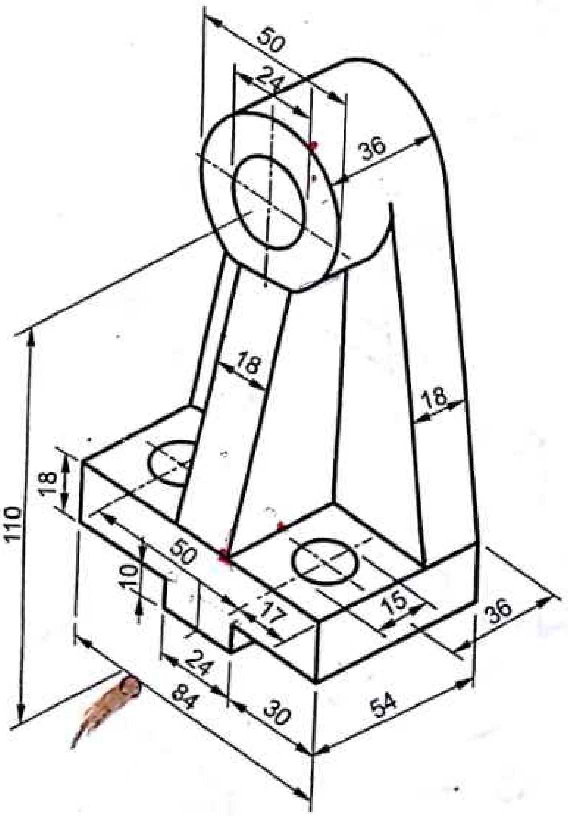


Fig. 4.71



3 Views

Fig. 4.72

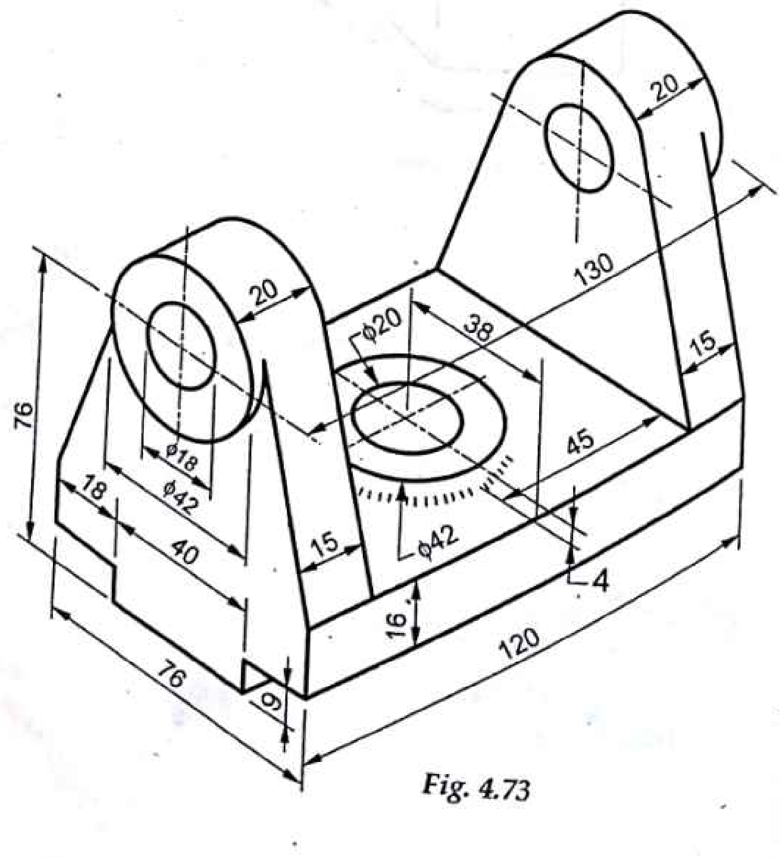
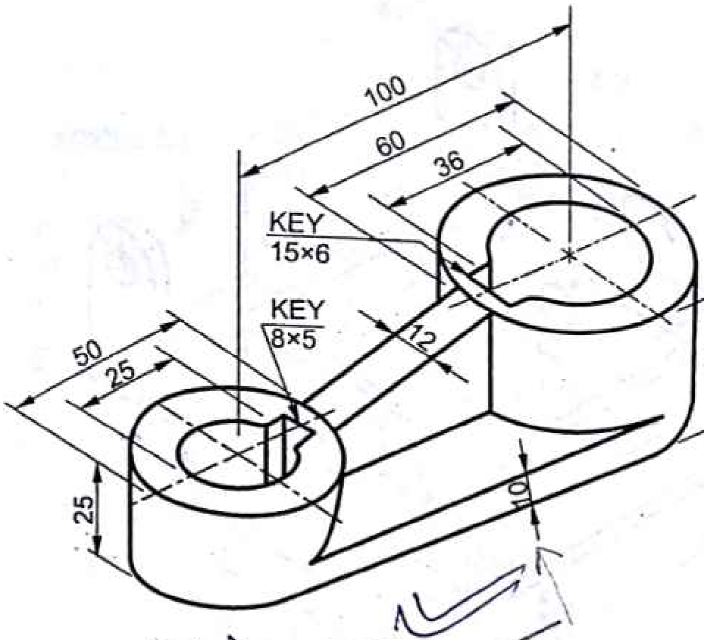


Fig. 4.73



3 Views

Fig. 4.74

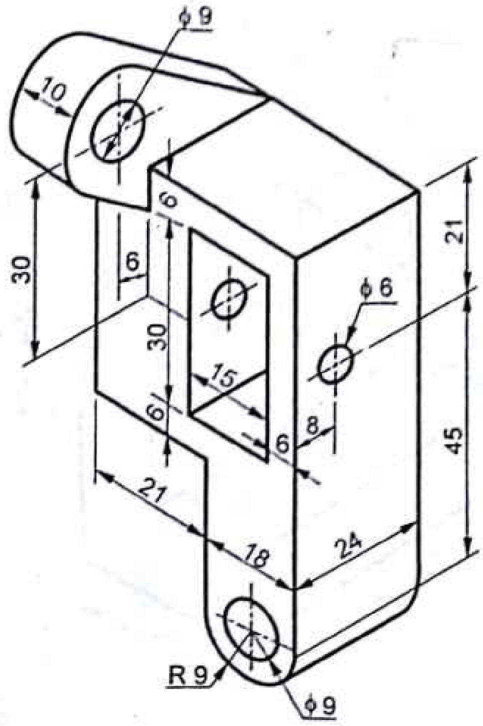


Fig. 4.75

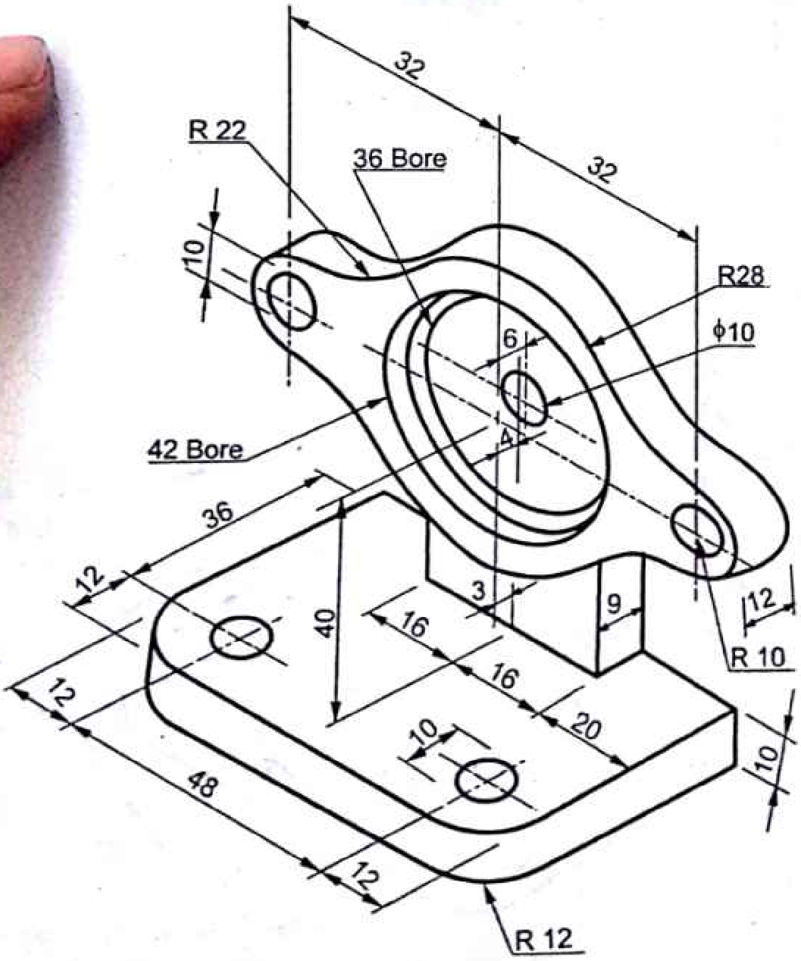


Fig. 4.76

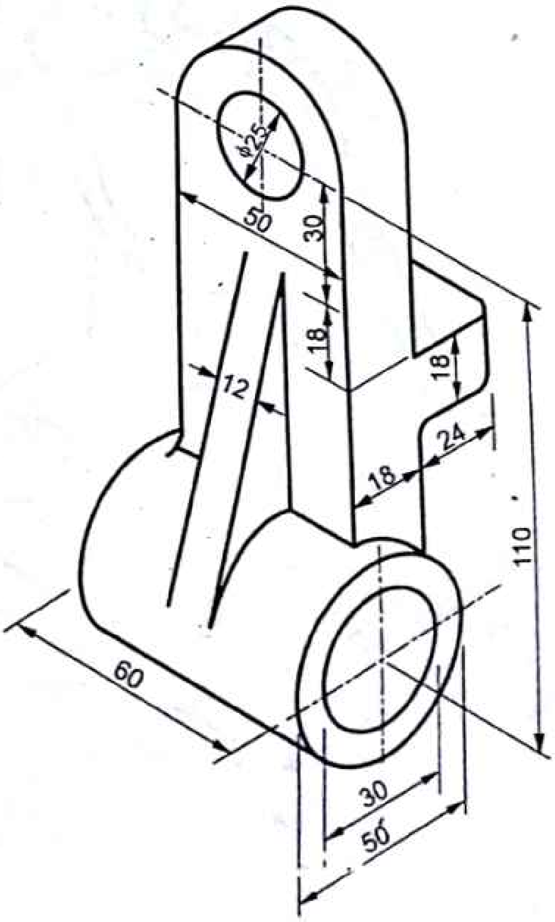


Fig. 4.77

8

Sectional Views

8.1. INTRODUCTION

In an orthographic projection hidden details are shown by dashed lines. When there are too many hidden details the view becomes obscure and cannot be read easily due to a network of dashed lines. In such case it is customary to draw views by assuming the object as being cut through by an imaginary plane. Such views are known as *sectional views* and the imaginary plane is called *a cutting plane or a section plane*. The section plane is taken parallel to the plane on which the view is projected. The sectional view is drawn removing nearer portion view is drawn removing nearer portion of the object. It shows the shape of the section as well as the visible edges and contours of the object behind the section plane.

There should be some convention to indicate the portion which has been sectioned. We should also indicate where imaginary cutting plane passes or where the section has been taken.

The section is made evident by drawing hatching lines where the cutting plane cuts the object, as shown in Fig. 8.1. Hatching lines are drawn as thin lines at a well defined angle, preferable 45° to the axis or to the main outline. The hatching lines should be uniformly spaced and should be about 1 to 3 mm apart depending on the size of drawing.

Cutting plane is indicted by a thick long dash and two short dashes alternately and evenly spaced and is designed by capital letters, the direction of viewing being shown by arrows resting on it. The cutting plane line, called the *line of section or trace of the cutting plane*, may be omitted when the location of the cutting plane is quite obvious.

When a portion of the object is removed to make the section in one view it is not assumed to be removed or omitted in making the other views. The other views are drawn as if the entire object exists as a whole. In other words, a section view drawn on one of the projections does not entail changes in any of the other projection.

8.2. FULL SECTION

When an object is assumed to be cut through entirely in to two halves and the front half is removed it is said to be in *full section*. In writing, the world 'full' is generally omitted.

Example 8.1. Fig. 8.1 (*a*) shows the isometric view of a slide block, and Fig 8.1 (*b*) shows its elevation, plan and side view in orthographic projection. For drawing the sectional elevation imagine the object to be cut by a plane *ABCD* and the front portion removed showing the internal features. The sectional view shows the shape of the section along with all visible parts of the object behind it, as shown in Fig. 8.1 (*c*). For drawing the sectional plan imagine the object to be cut by a plane EFGH and the top portion removed as in Fig. 8.1 (*d*). For drawing the sectional side view imagine the object to be cut by a plane *PQRS* and the right half portion removed as in Fig. 8.1(*e*). With the above cutting planes, sectional elevation, sectional plan and sectional side view have been drawn, which should be carefully studied. The traces of the cutting planes shown in other views should be noted.

It is not necessary that in a drawing all the views of an object should be sectional views. Note that different cutting planes are used for different sectional views.

Example 8.2. Fig 8.2 (*a*) shows an object and Fig. 8.2 (*c*) and Fig. 8.2 (*d*) its elevation side view.

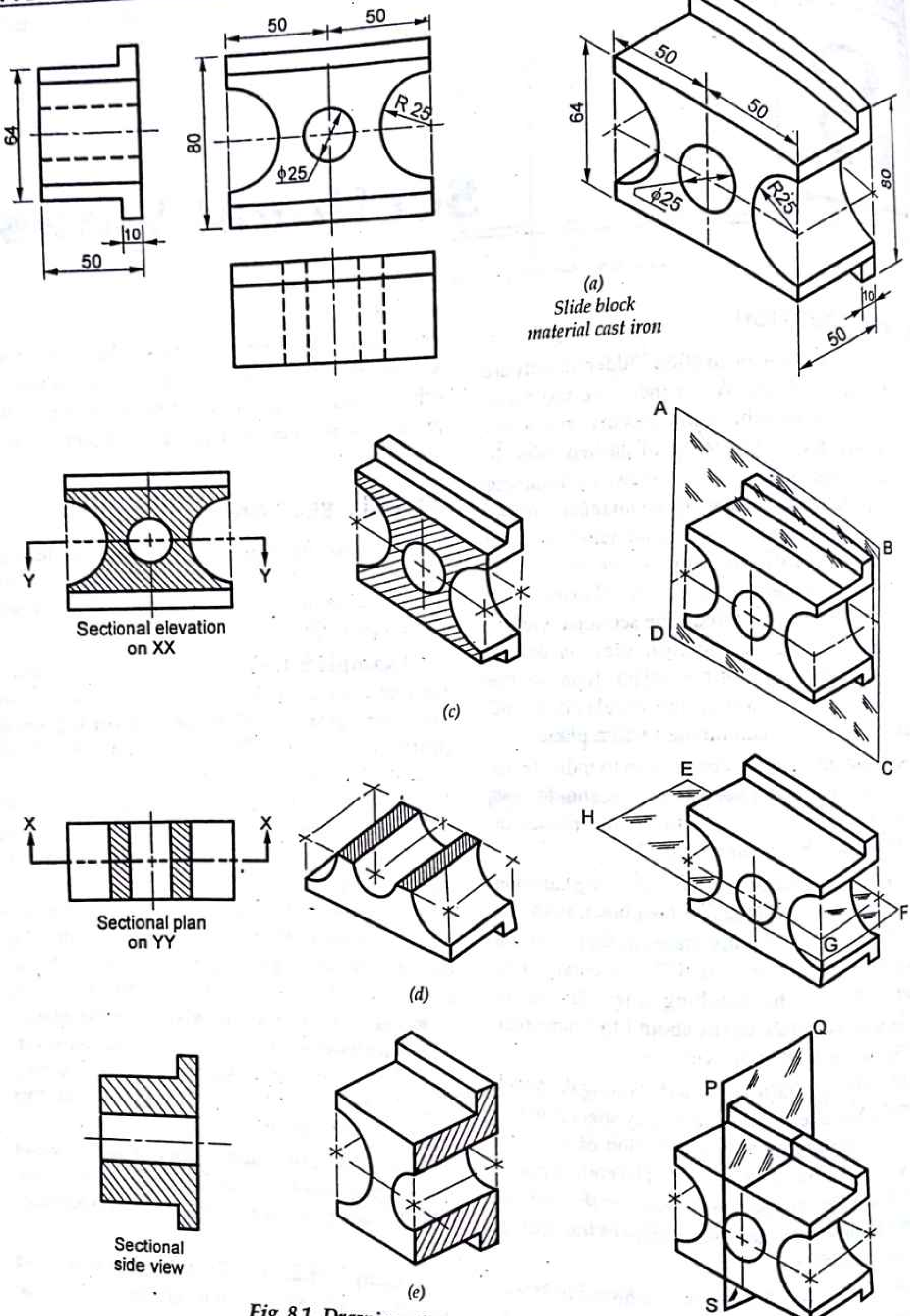
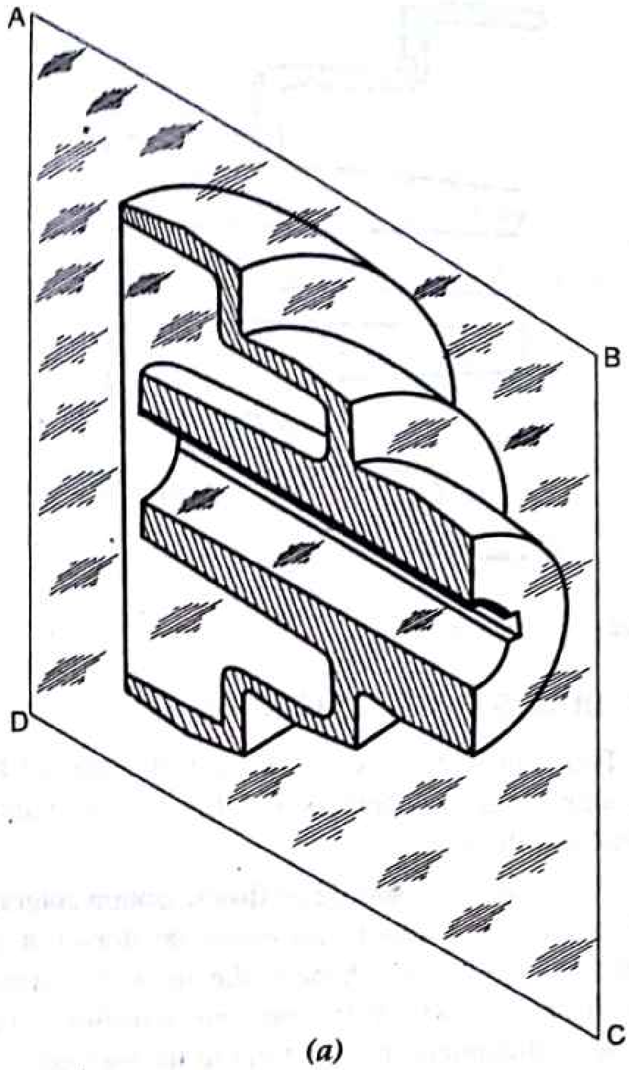
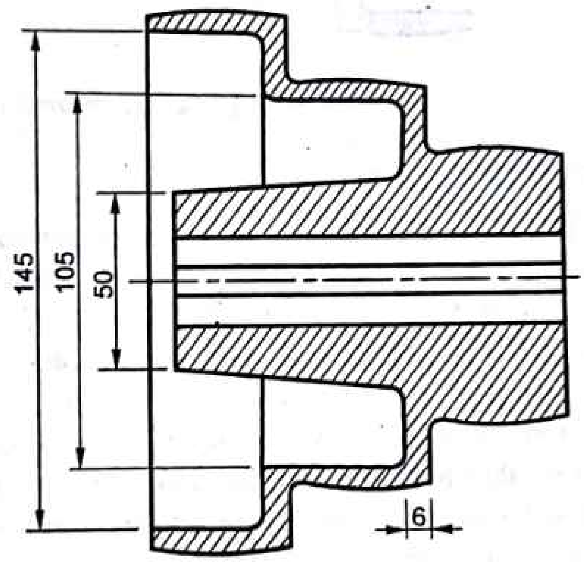


Fig. 8.1. Drawing of sectional views — Slide block

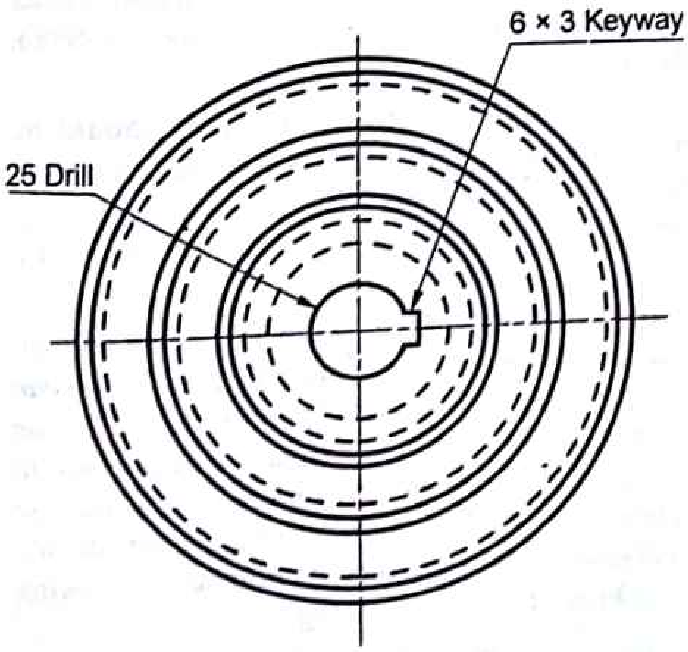


(a)

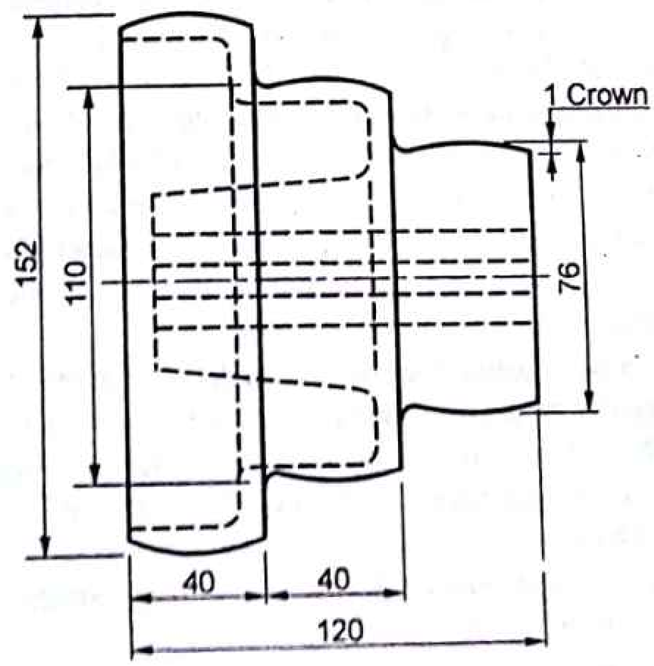
Note that the views are not easily understood due to too many dashed lines. In Fig 8.2 (*a*) the same object has been cut by an imaginary plane *ABCD* and it has been drawn removing the front half of the object in Fig.8.2 (*b*). This view is much easier to understand than the outside view. In Fig. 8.2 (*e*) and Fig. 8.2 (*f*) are shown the mistakes a beginner is likely to make in drawing sectional views. In Fig. 8.2 (*e*) one of the visible edge has been drawn a dotted line, and other dotted lines are unncessary and should be avoided. In Fig. 8.2 (*f*) visible edges have not been drawn.



(b)

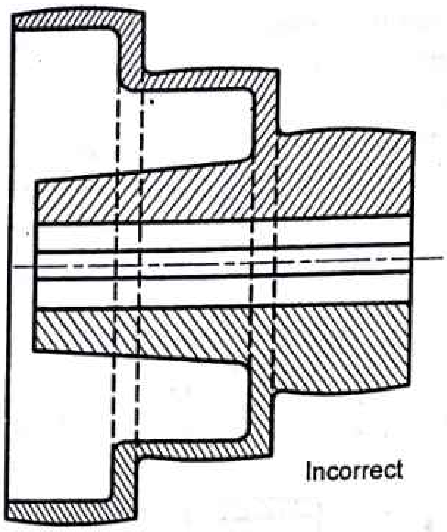


(c)



(d)

Fig. 8.2 (i) Outside and sectional views – Cone pulley



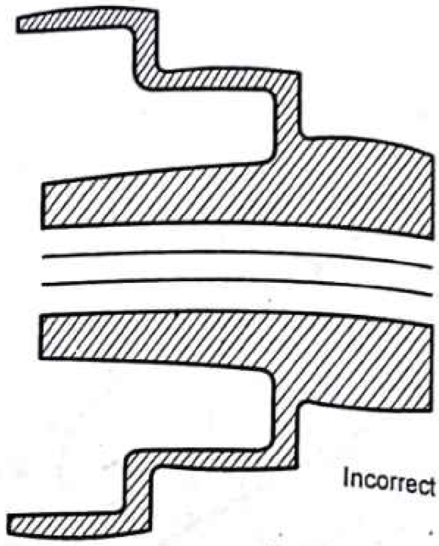


Fig. 8.2. (ii) Incorrect sectional views — Cone pulley

8.3. HALF SECTION

In full section the cutting plane passes fully through the object and the front half of the object is removed. If the cutting plane passes only half way through the object and one quarter of the object in front is removed it is called *half section* as in Fig. 8.3. In half-sectional view, half the object is sectioned and the other half is in outside view. Thus in half-sectional view both inside and outside views are shown in on single view and instead of two views one view is sufficient. The student should compare carefully the outside, full sectional and half-sectional elevations in Fig. 8.3. Half-sectional views are particularly used in assembly drawing. *It would be easily appreciated that half sectional views are mainly applicable to symmetrical objects and when both inside and outside views are essential for understanding the object.* In half sectional views it is preferable to locate the section to the right of the vertical exis or below the horizontal exis.

Note: Dashed lines for hidden details should not generally be drawn in the portion shown in outside view as it complicates the drawing without adding any further information. However this rule may be violated if

(*a*) dashed lines add to the clarity of the drawing, or

(*b*) dashed lines are required for dimensioning of the hidden details.

8.4. RULES OF SECTIONING

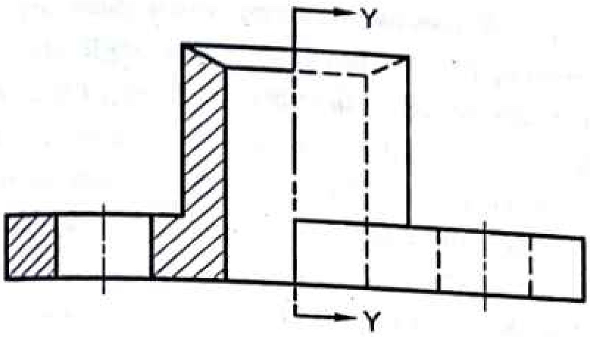
The following rules of sectioning should be thoroughly studied to understand this important topic of machine drawing.

1. Section lines should be thin to obtain contrast with outlines and should normally be drawn at an angle of 45°. When the shape of the object is odd and section lines drawn at 45° become parallel to the outline of the object it is preferable to draw section lines at 45° to the main outline as shown in Fig. 8.4. The pencil used for section lines may be a grade harder (3H for section lines, when 2H for outlines) to obtain thinness.

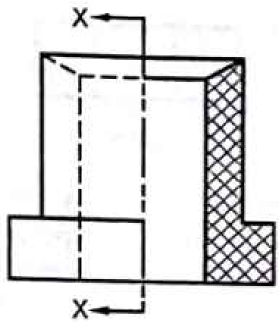
2. The spacing of section lines should be uniform as shown in Fig. 8.5 (*a*). It may vary from 1 mm in small drawings to 3 mm or more in large drawings. For an average drawing a spacing of a about 2 mm is good.

To draw section lines at equal spacing without any aid is difficult for a beginner. *Equal spacing can be obtained easily by marking permanently a line on 45° set-square at a distance from the edge equal to the spacing between the section lines.* This line can be marked by the bow divider. This would obviate the necessity of wasting time on practice of drawing section lines at uniform spacing.

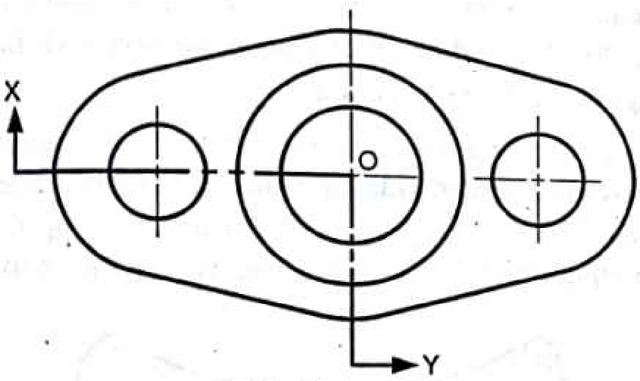
Fig. 8.5 (*b*) and Fig. 8.5 (*c*) show incorrect section lines. In Fig. 8.5 (*b*) the lines are uniformly spaced and are too near. In Fig. 8.5 (*c*) the section lines are too thick.



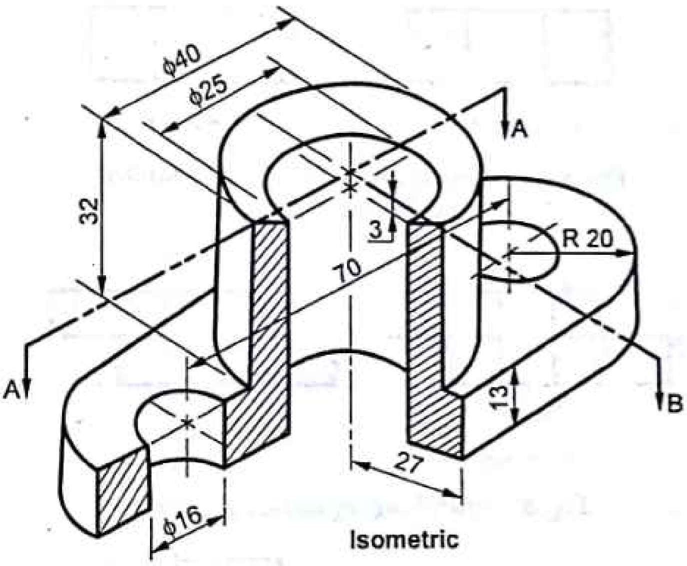
(b) Elevation half in section on XX



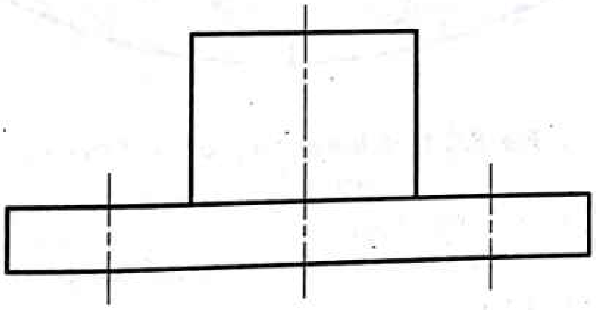
(c) Side view half in section on YY



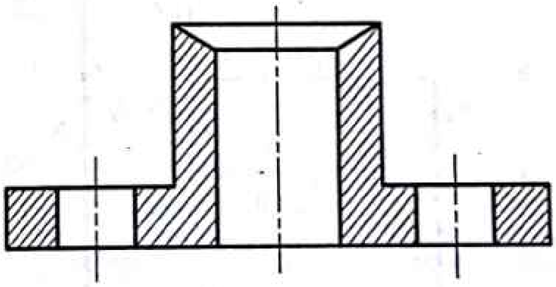
(d) Plan



Isometric



(e)



(e) Elevation full in section

Fig. 8.3. Half-sectional views – Comparison with outside and full sectional views

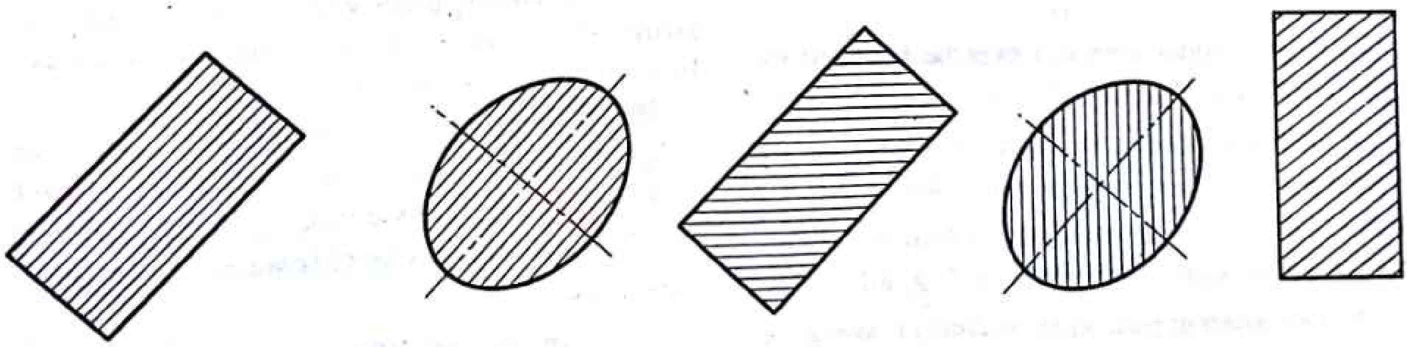


Fig. 8.4. Section lines in odd shapes

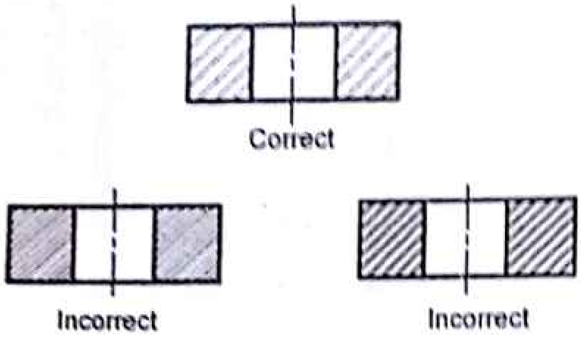


Fig. 8.5. Spacing of section lines

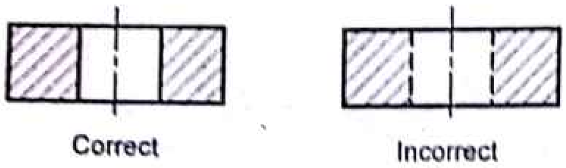


Fig. 8.6. Sectional areas cannot be bounded by dashed lines

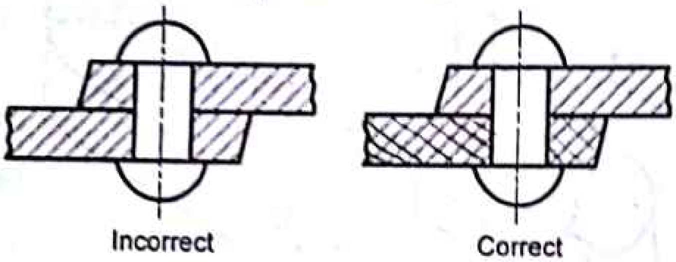


Fig. 8.7. Hatching of adjacent parts

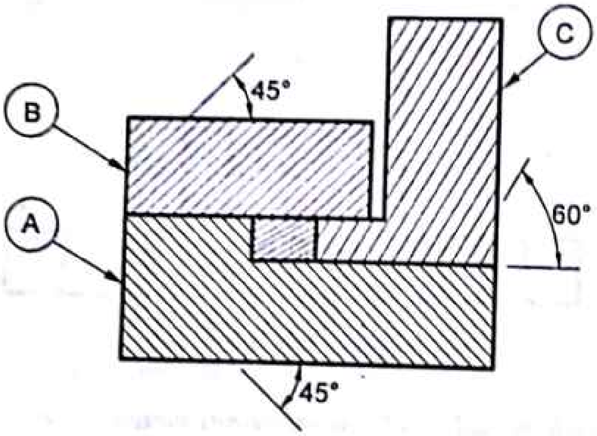


Fig. 8.8. Hatching of many adjacent parts

3. No sectional area can ever be bounded by dashed lines (see Fig. 8.6)

4. All sectioned areas in a view of a single piece must be sectioned in the same direction. Also section lines for the same piece in different views must be in the same direction as in Fig. 8.1 to 8.3.

5. Two adjacent parts in an assembly drawing are hatched in opposite directions as shown in Fig. 8.7.

Fig. 8.8 shows hatching when there are many adjacent parts. The hatching is at an angle of 45° with the main outlines of the view (marked). On a second part, adjacent to the first, the section lines are drawn at an angle of 45° in the opposite direction (marked). On a third part, adjacent to the first two, the lines are drawn at an angle of 30° or 60°, with the main outlines of the view (marked). For additional adjacent parts, any suitable angle may be used to make each part stand out separately and clearly.

6. The visible edges and contours behind the cutting plane must be shown (see Fig. 8.1 and Fig. 8.2) Fig 8.2 (*f*) shows the wrong projection as visible edges have not been shown.

7. Where sections of the same part in parallel planes are shown side by side the hatching lines should be similarly spaced, but offset along the dividing line between the sections (see Fig. 8.9).

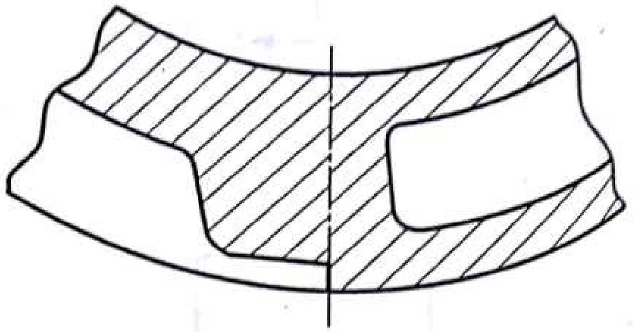


Fig. 8.9. Hatching of a part in different parallel planes

8. Hidden details should bot be shown in sectional views unless necessary for the description and understanding of the object. See Fig. 8.1 and 8.2. Fig. 8.2 (*e*) shows dashed lines in the view which should be avoided.

9. The cutting plane with reference latters and arrows should be indicated in the other view as a line unless it is obvious (See Fig. 8.1).

10. Sometimes more than one view of the object is shown in section. In such cases each section is to be considered separately without reference to what has been removed for the other view (See Fig.8.1).

11. In half sections the line obtained by cutting should not be shown as firm line as it would

be confused with a visible line. See Fig. 8.3 (*b*) and (*c*). It should be remembered that the cut is purely imaginary and no edge is present on the object in that position

12. For large areas full section lines need not be drawn. See Fig 8.10.

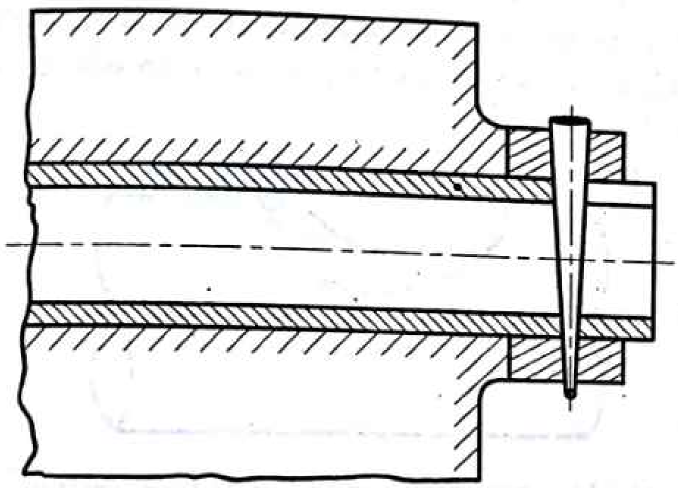
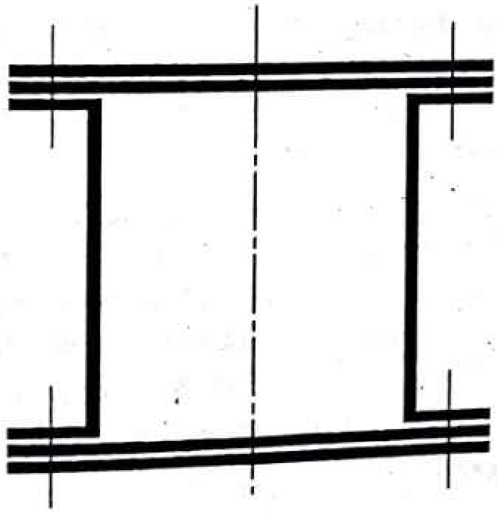
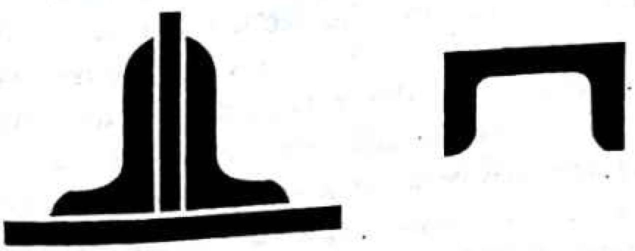


Fig. 8.10. Hatching of large areas

13. Thin sections may be shown entirely black. A space may be left between adjacent sections as shown in Fig. 8.11.



(*a*)



(*b*)

Fig. 8.11. Thin sections

14. Dimensions for a section should be placed outside the section, if possible. If the dimension is inside the sectioned area, an opening in the section line should be left for the dimension as shown in Fig. 8.12. However, no opening should be left for dimension lines or arrowheads.

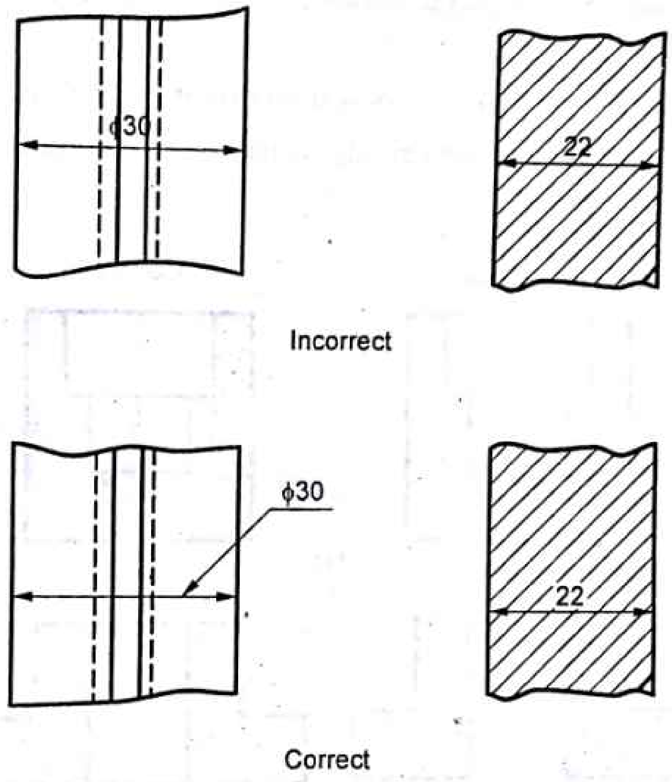


Fig.8.12. Dimensioning in sectional views

15. Number of sectional views should be as small as possible without infringing on the clarity of the drawing as a whole.

8.5. COMMON MISTAKES IN SECTIONING

Fig. 8.13 shows the common mistakes which are committed in sectioning.

1. In Fig. 8.13 (*a*), edges visible behind the actual cut have not been shown. In Fig. 8.13 (*b*) left figure represents two parallel angle iron whereas right hand figure represents a sectioned flanged bush.

2. In Fig. 8.13 (*c*), thick full line must not be cross hatched.

3. In Fig. 8.13 (*d*), dotted line must never border hatching.

4. In Fig. (*e*), chordal sections must be avoided by stepping.

5. In Fig. 8.13 (*f*), all portions of one component must be shown with the same type of hatching.

The common mistakes in drawing section lines are :

(*i*) Lack of uniform spacing

(*ii*) Section lines spaced too close together.

(*iii*) Section lines drawn too heavy due to dull pencil

(*iv*) Section lines not terminated at the outline.

(*v*) Spacing not varying with the size of the area sectioned.

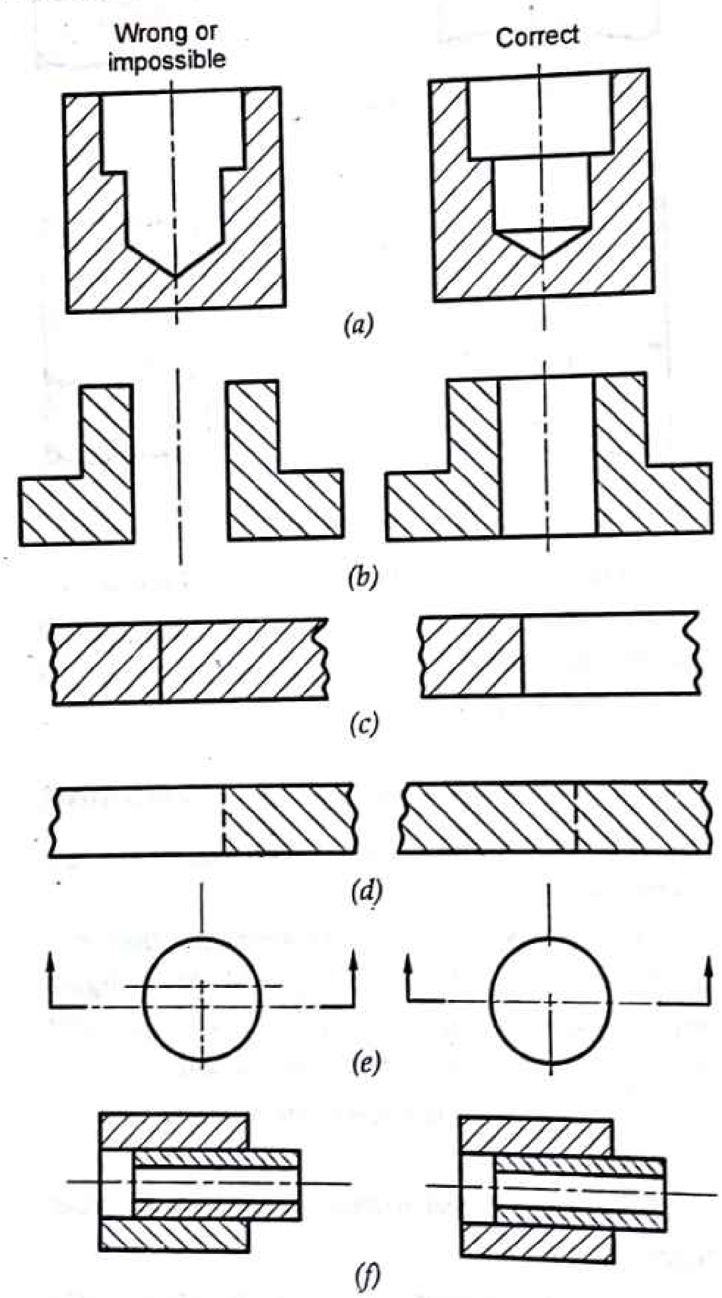


Fig. 8.13. Common mistakes in sectioning

8.6. PARTIAL OR BROKEN OUT OR LOCAL SECTION

Sometimes only a particular hidden detail is required for which either a full sectional or half sectional view is unnecessary or it may cutaway some important outside shape. In such cases a partial section only is taken and the section is limited by a thick, irregular, freehand, break line as shown in Fig. 8.14. Such *a section is called a partial or broken out or local section.*

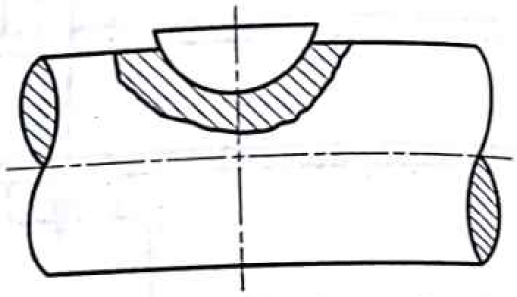


Fig.8.14. Partial or broken out or local section

8.7. REVOLVED SECTION

Revolved section is used to show the cross-section of objects like arms, spokes, structural sections, etc., on the actual view of the part, thus avoiding the drawing of another view. In the revolved section a cutting plane is assumed perpendicular to the centre line or axis, which is then revolved through 90° as shown in Fig. 8.15.

Sometimes, the view may be broken away on each side of a revolved section, as in Fig. 8.16, as in Fig.8.16, to make the section clear. Also, it may be useful if a long drawing is to be reduced, which allows a reasonably big scale as in Fig. 8.17. Fig 8.18 shows the common mistakes in drawing revolved section.

8.8. REMOVED SECTION

A removed section also shows the cross-section of an object, like revolved section, but outside the view, as shown in Fig. 8.19 to 8.21. The removed section is generally drawn around the extension of the cutting plane line as shown in Fig. 8.19 and 8.21. However, it may be drawn in any convenient position on the sheet or even on a separate sheet. In such cases the cutting plane is always shown on the drawing (AA, BB, etc.) and removed section identified by writing the corresponding cutting plane (see Fig. 8.20)

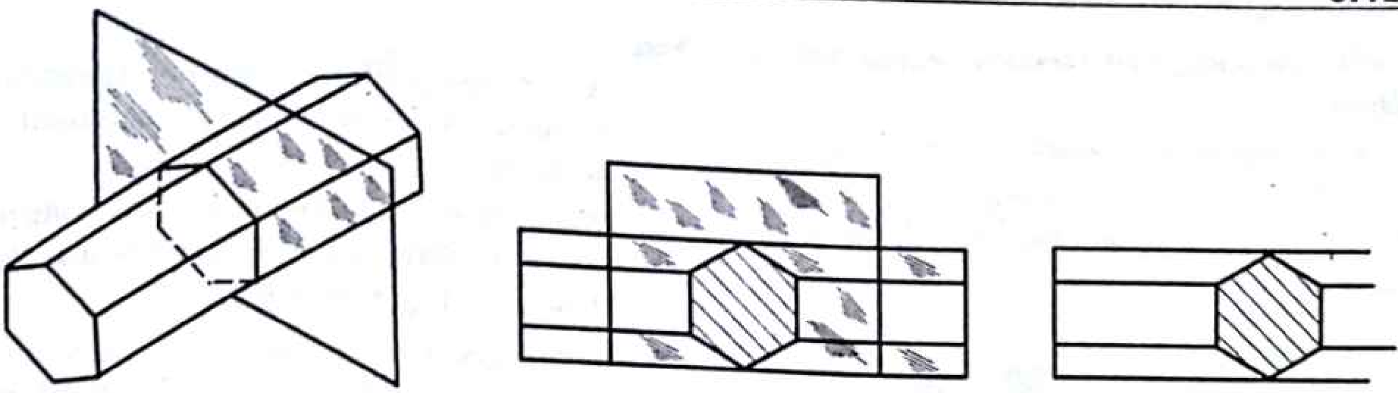


Fig. 8.15. Revolved section

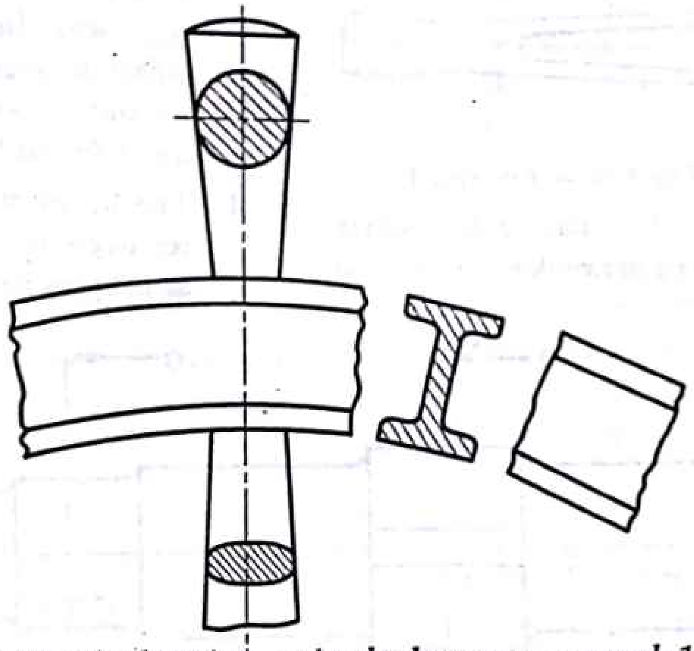


Fig. 8.16. Revolved section – view broken way – example 1

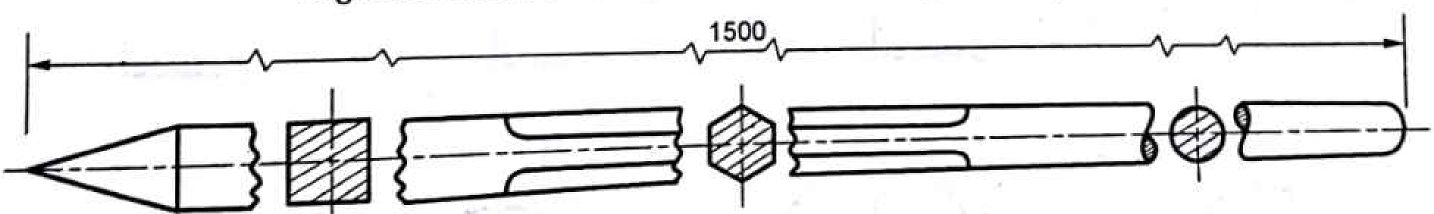


Fig. 8.17. Revolved section – views broken away example 2

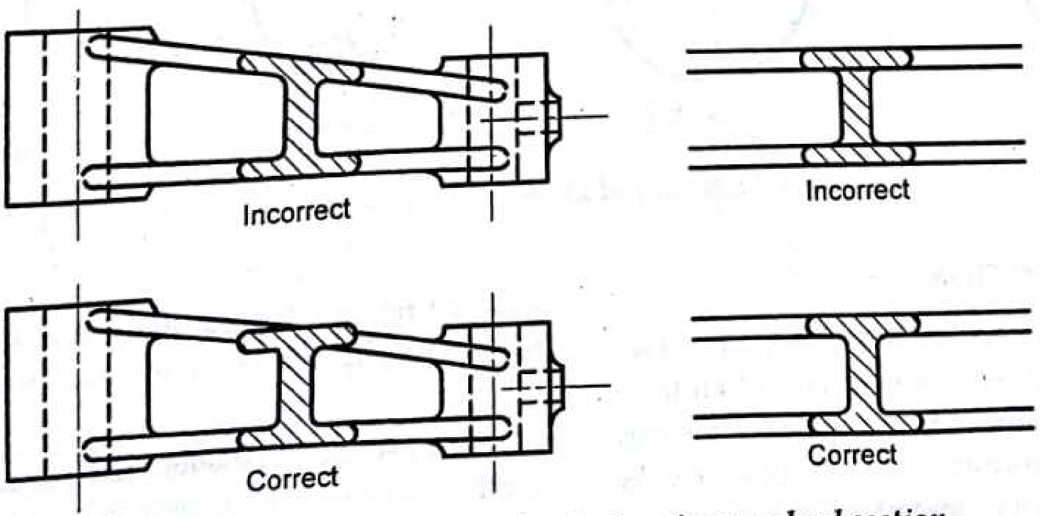


Fig. 8.18. Common mistakes in drawing revolved section

The advantages of removed section are as follows:

1. It keeps the view intact.

2. The removed section may be drawn to a larger scale, if necessary, to show the shape clearly or for clear dimensioning.

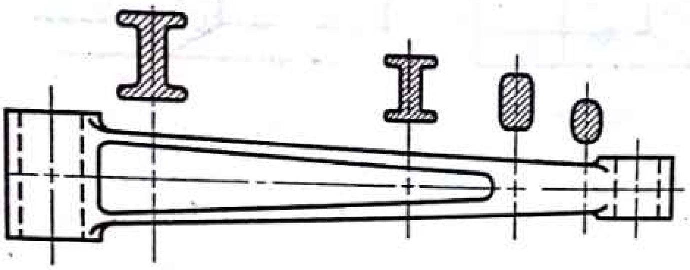


Fig. 8.19. Removed Section – Example 1

3. The removed section may be used where revolved section cannot be drawn due to restriction of space.

Note :

1. A removed section should not be rotated but should be drawn in its natural projected position.
2. When the shape of the object is varying or is not uniform several sections may be shown (see Fig. 8.19 to 8.21).
3. *Difference between sectional view and revolved or removed sections.* The revolved or removed section is a representation of only what lies in the cutting plane itself, while the sectional view is a representation not only of what lies in the cutting plane but also of what lies beyond it.
4. The holes and recesses in revolved and removed section are shown in the same way as in sectional view.

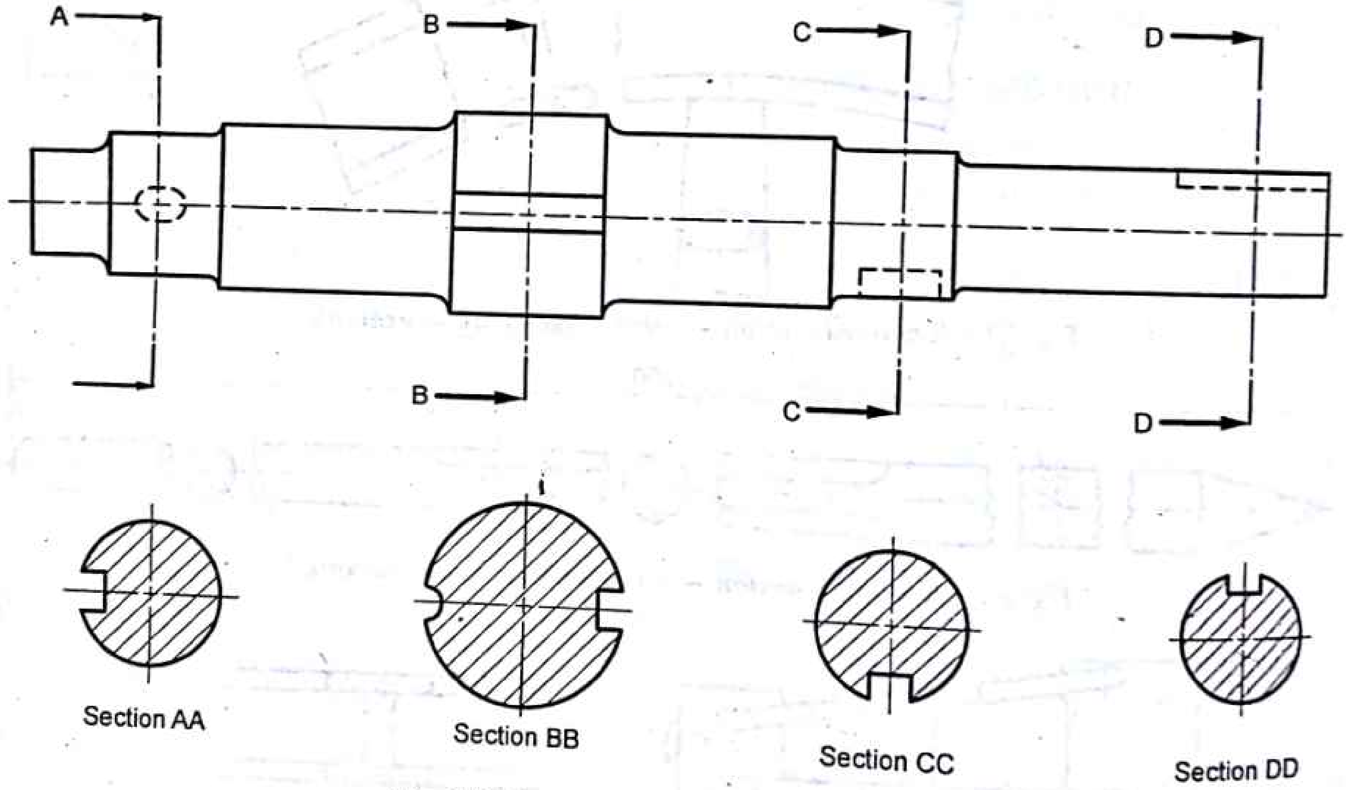


Fig. 8.20. Removed section – Example 2

8.9. OFF-SET SECTION

In an object there may be several features which are not in one continuous straight line. If all these features are to be shown a number of sections may have to be taken. However, all the features may be shown in one section if instead of one straight cutting plane a bent or offset cutting plane is taken which passes through all these features as shown in Fig. 8.22 to 8.24.

Note : As cutting planes are imaginary the bend or offset are not actually there in the object and are, therefore, not shown in the sectional view. The

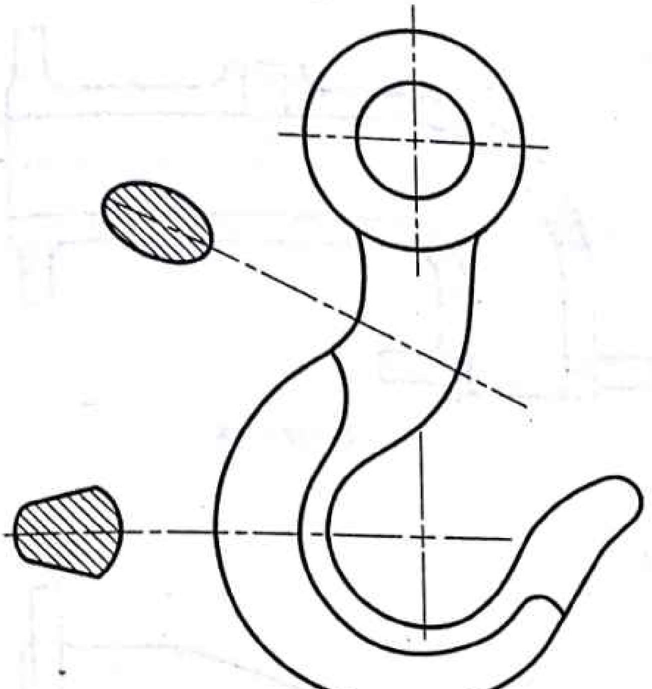


Fig. 8.21. *Removed Section – Example 3*

position of the offset plane is always shown by a cutting plane line in the view in which it is seen edgewise.

Where the location of a single cutting plane is obvious, no indication of its position or identification is required (see Fig. 8.25).

8.10 CONVENTIONAL VIOLATIONS OR EXCEPTIONAL CASES.

1. Exceptions to the general rule for indicating sectioning is made where sectioning plane passes through rivets, bolts, nuts, rods, keys, pins, cotters, shafts, pulley, arms, etc., as shown in Fig. 8.26. These should be normal outside views. The reason for not sectioning these parts is that they have no internal construction and are more easily recognized by their exterior views. If these parts are sectioned, drawing may become more confusing and difficult to read.

2. Ribs or Webs in section. A rib or web is a thin flat part of an object used for bracings or adding strength (see Fig. 8.27). When a cutting plane passes longitudinally through the centre of rib or web, the rib should not be sectioned as it would give a

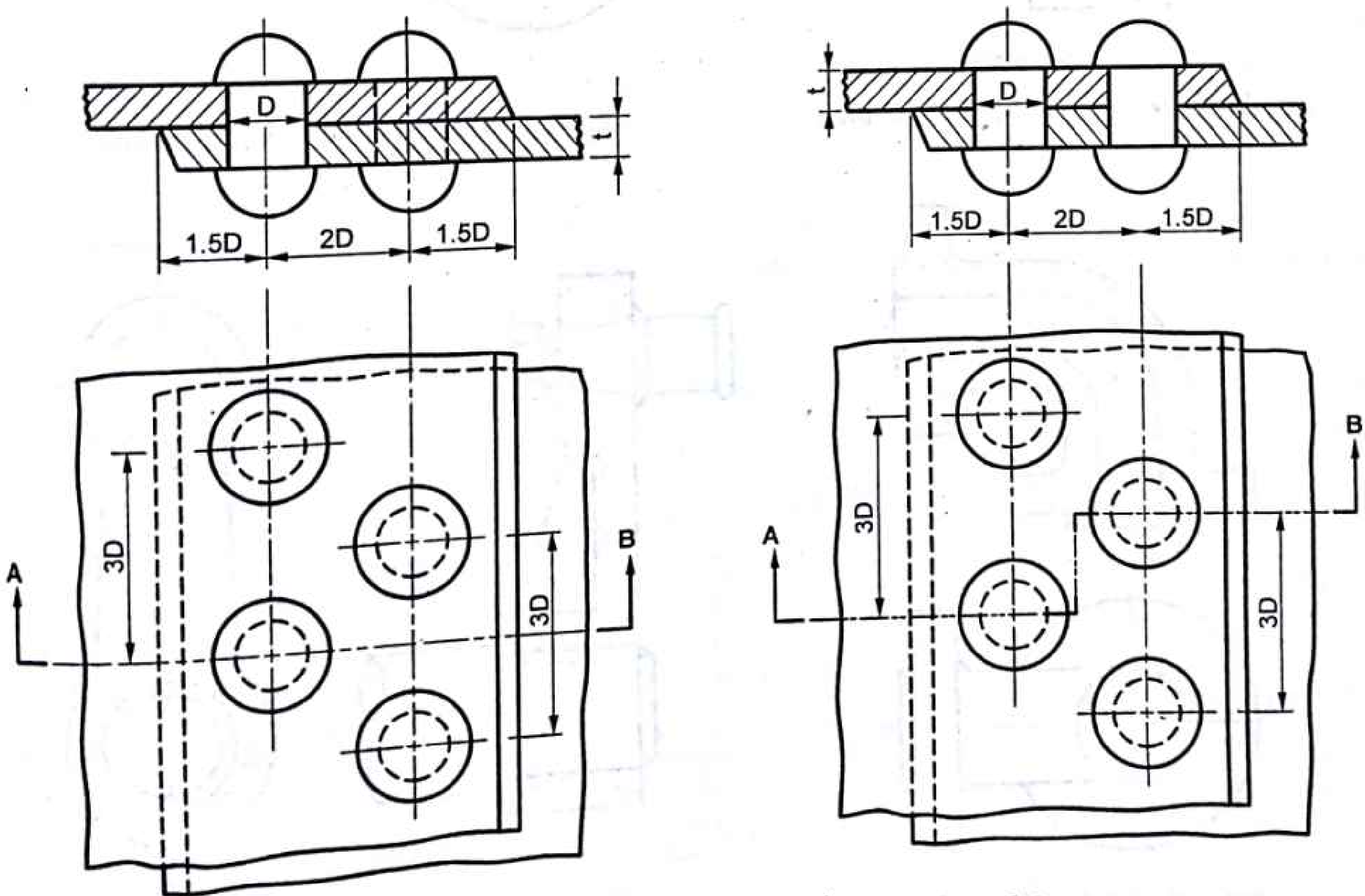


Fig. 8.22. Off-set section in two parallel – Example1

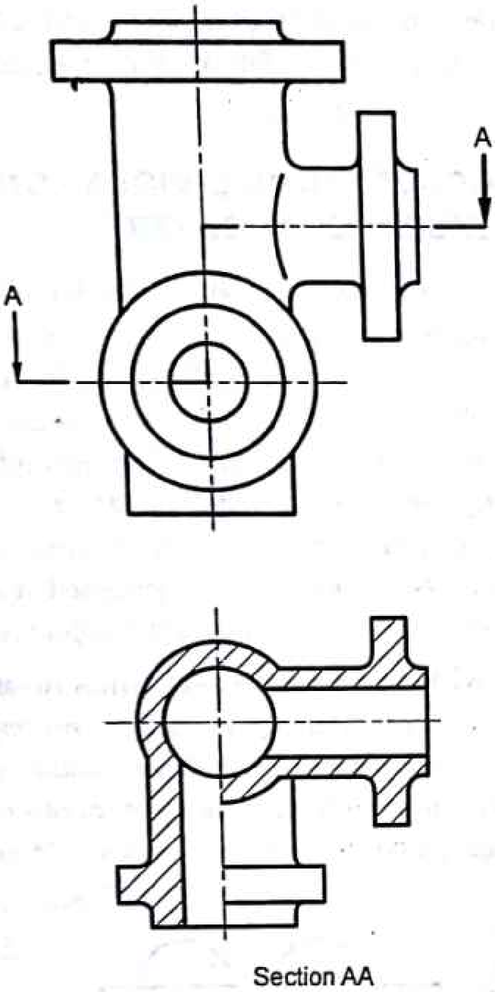


Fig. 8.23. *Off-set section in two parallel planes — Example 2*

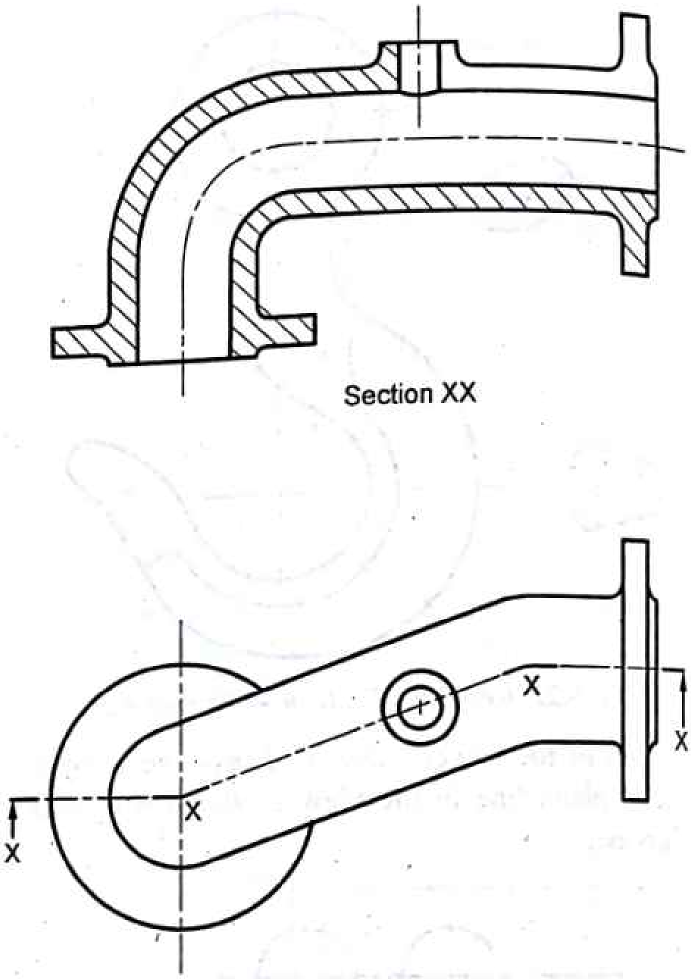


Fig. 8.24. *Off-set section in three planes*

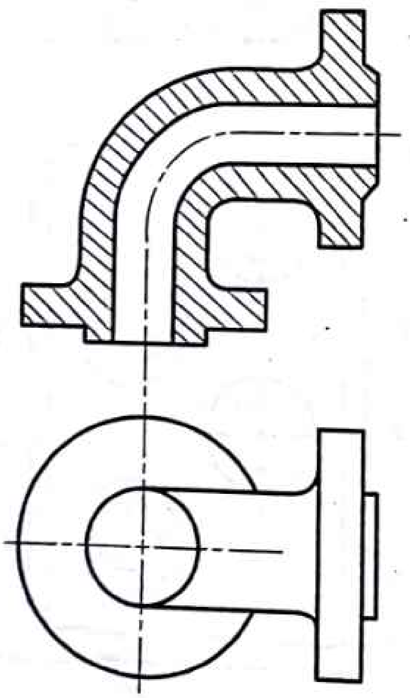


Fig. 8.25. *Single cutting plane*

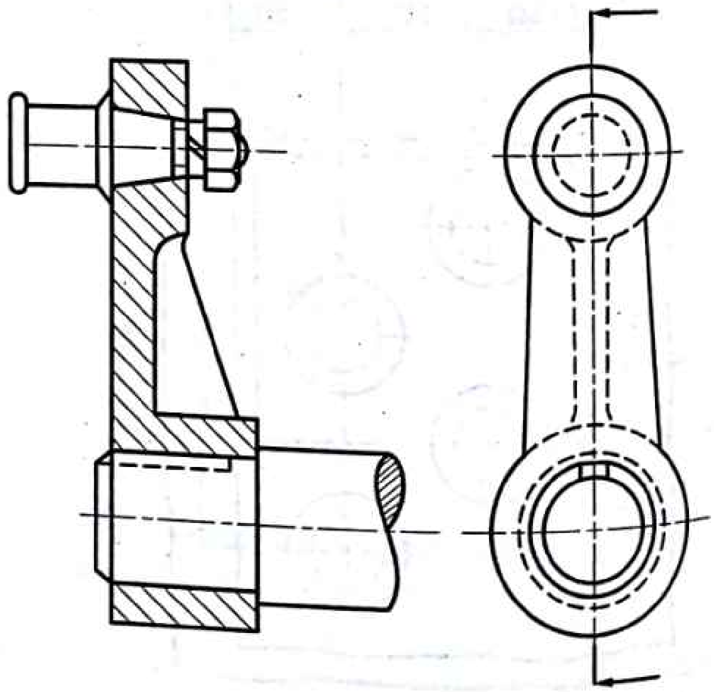


Fig. 8.26. *Rib, shaft and crank pin are not shown in section*

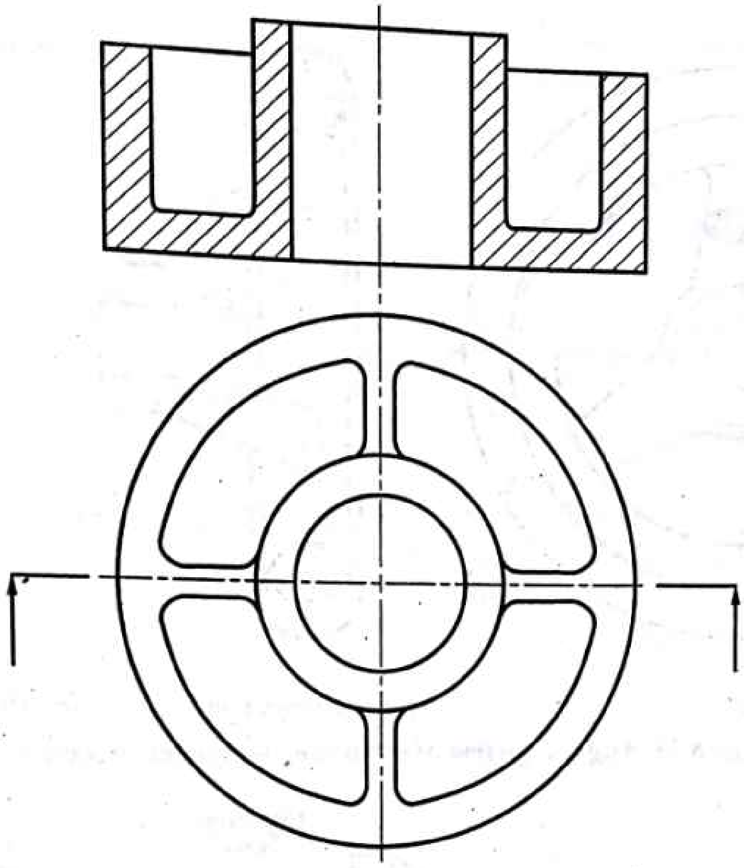


Fig. 8.27. Ribs or webs in section. No section lines when cutting plane passes longitudinally

false impression of thickness or solidity. However, if the cutting plane passes crosswise through the rib or web, it would be sectioned [see Fig. 8.28 (*a*)]

3. Spokes in section. The spokes of a wheel are not sectioned because otherwise they would not show the open effect of spokes and would give the appearance of solid web [see Fig. 8.28 (*b*)]

4. Aligned section-Revolution of features. Any part having odd number (1, 3, 5, 9, etc.) of spokes, ribs or holes will give an unsymmetrical and misleading section if the principles of true projection are strictly adhered to, as illustrated by the drawing of a hand wheel in Fig. 8.29 (*b*). In such cases, when the true projection of a piece could result in confusion, foreshortening, or in unnecessary expenditure of time by draughtsman, the inclined elements should be rotated in the plane of paper (See Fig. 8.29 (*c*) and Fig. 8.30.

5. Half views. In limited space half views may be drawn of a symmetrical object. If the front view is a half or full section, it is customary to draw

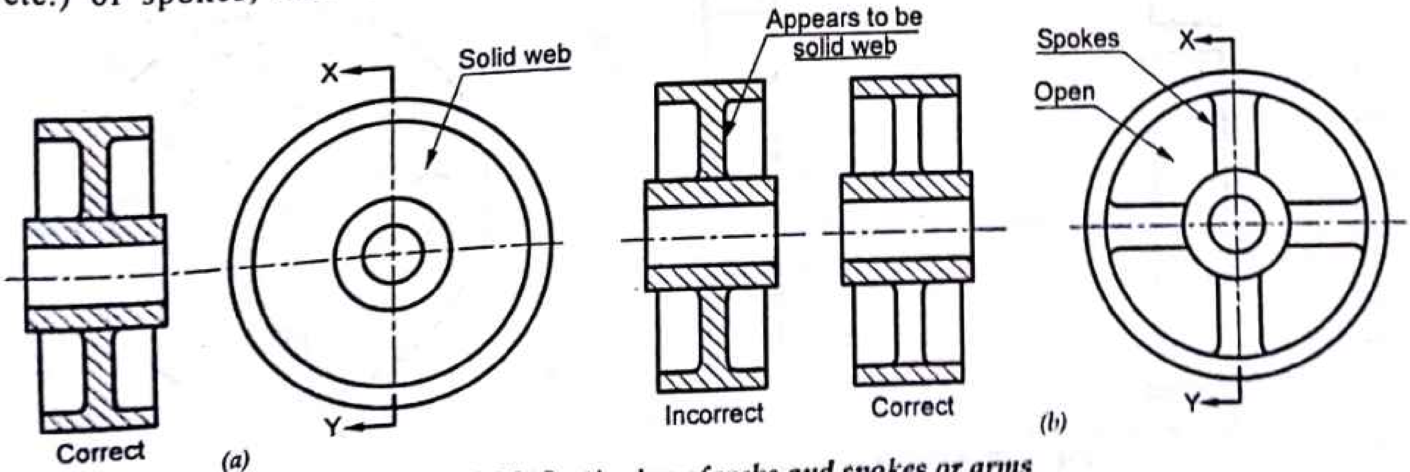
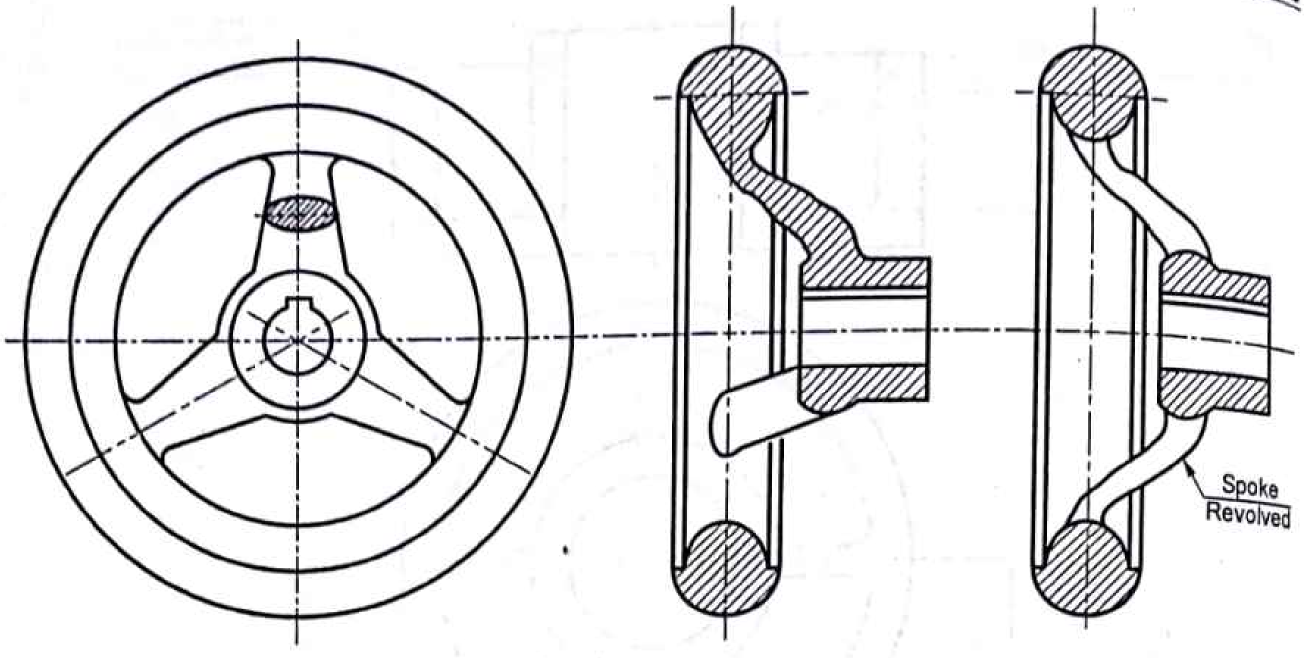


Fig. 8.28. Sectioning of webs and spokes or arms



(a) (b) true projection (c) Aligned projection

Fig. 8.29. Aligned system of sectioning — spokes in section

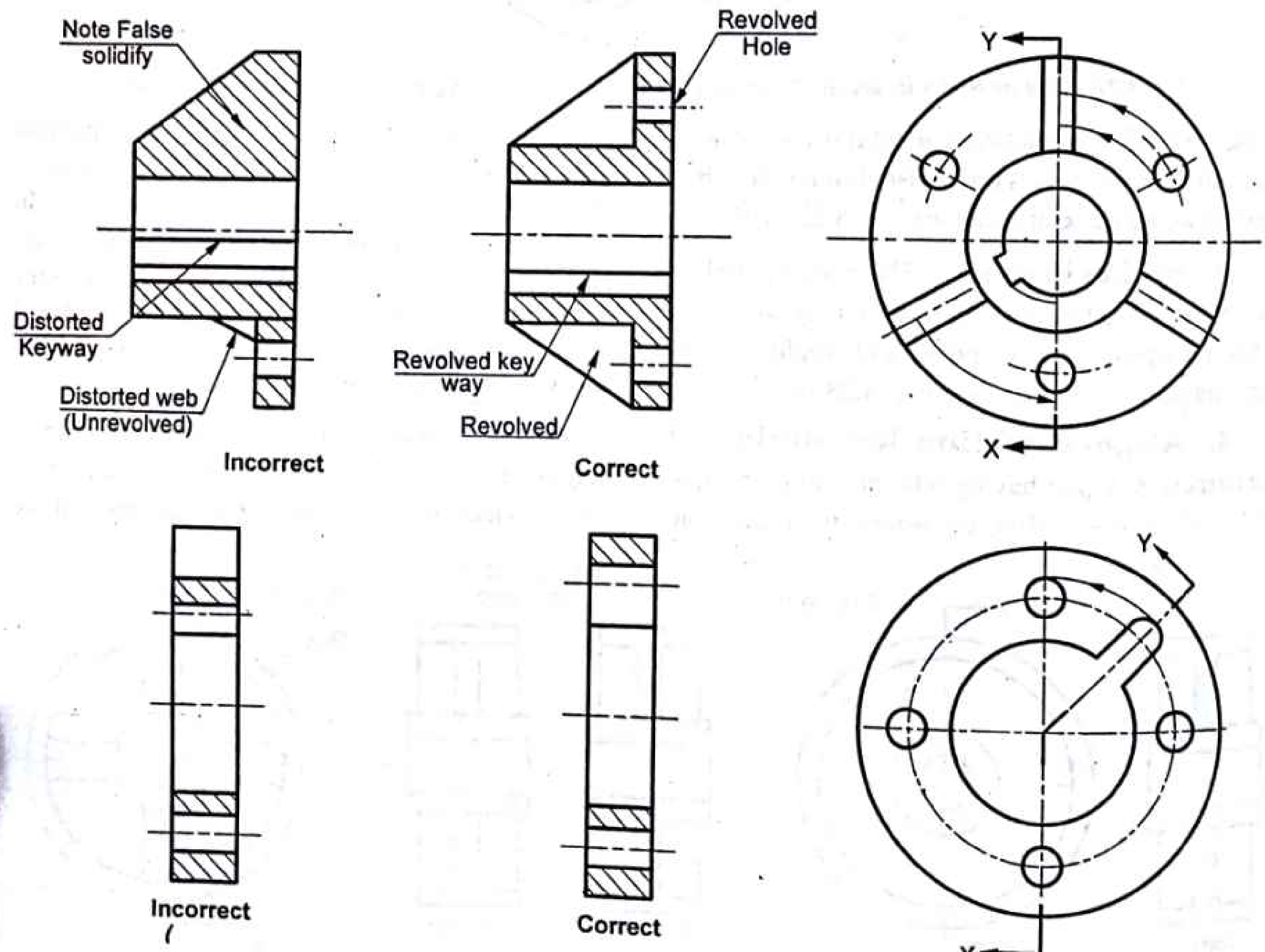
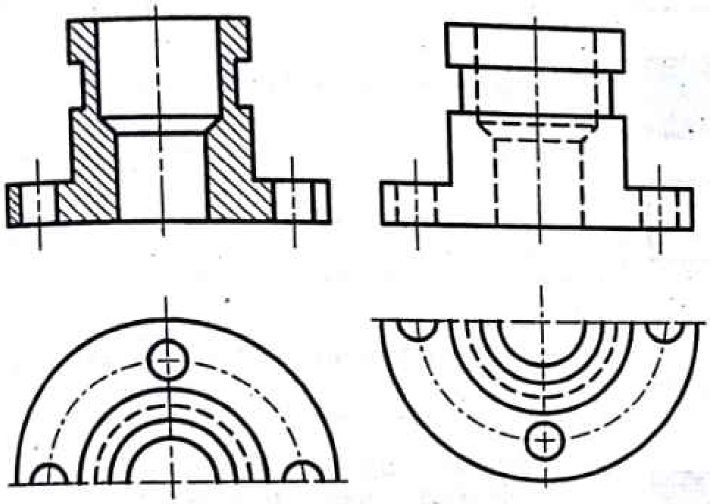


Fig. 8.30. Aligned system of sectionin — webs in section

the back half of the top view [see Fig. 8.31 (*a*)]. If the front view is not sectioned and a half top view is shown, it should be of the front half of the object [See Fig. 8.31 (*b*)].



(a) (b)

Fig. 8.31. Drawing of half view

8.11. SPECIAL CASES

(*a*) Intersection in section. When a section is drawn through an intersection in which the exact figure or curve of intersection is small or of no consequence, the figure of curve of intersection may be simplified as in Fig. 8.32.

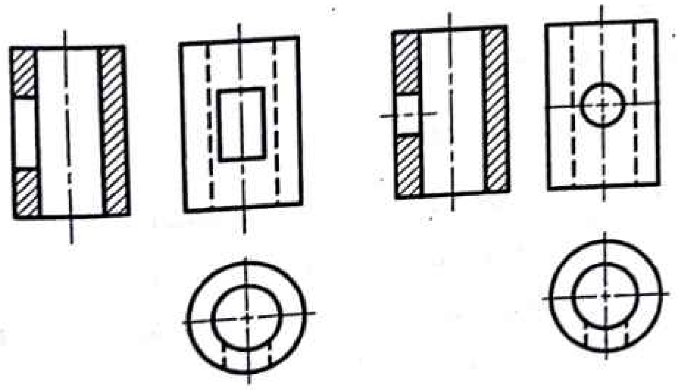


Fig. 8.32. Cylindrical intersection simplification

(*b*) Adjacent parts. Where their representation is necessary, parts adjacent to an object are drawn with continues thin lines. The adjacent part must never hide the principal part but may be hidden by the latter. These parts should be hatched only to avoid confusion and hatching should then be only along the outlines (see Fig. 8.33).

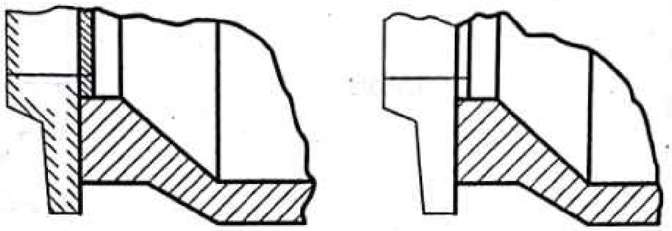


Fig. 8.33. Hatching of adjacent parts

(*c*) Parts located in front of a cutting plane. When it is necessary to represent parts located in front of the cutting planes, these parts are represented by thin long chain lines see Fig. 8.34).

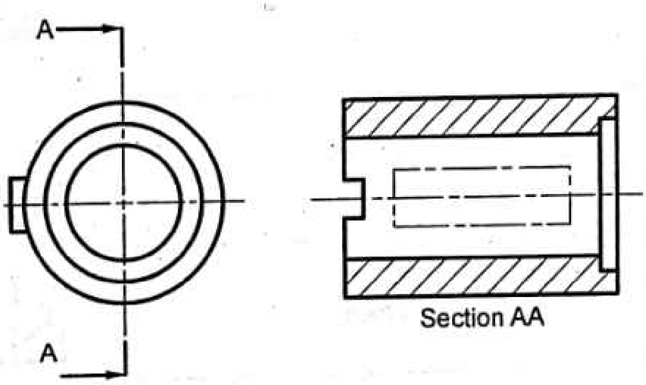


Fig. 8.34. Part located in front of a cutting plane

8.12. CONVENTIONAL REPRESENTATION OF MATERIALS

In view of the variety of materials used, B.I.S. has recommended that different conventions of section lining to differentiate between various materials be made use of. Recommended conventions to indicate different materials in section are illustrated in Fig. 8.35.

Note: B.I.S., recommends that in every case different materials should be indicated by notes on drawings or tracings. Any special means (for example hatching or coloring) used to indicate different material should be shown by color or colored lines. The following colours are recommended by B.I.S.

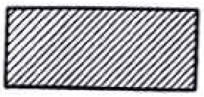
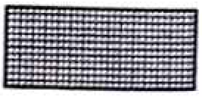
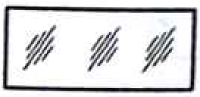
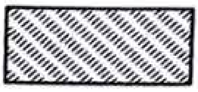
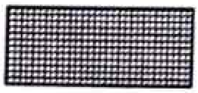
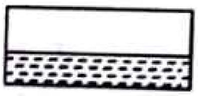
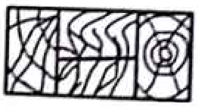
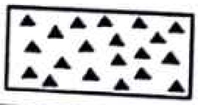
Type	Convention	Material
Metals		Steel, cast iron, copper and alloys, aluminium and its alloys, etc.
		Lead, Zinc, tin, white-metal, etc.
Glass		Glass
Packing and insulating materials		Porcelain, stoneware, marble, slate, etc.
		Asbestos, fibre, felt, synthetic resin products, paper, cork, linoleum, rubber, leather, wax insulating and filling materials
Liquids		Water, oil, petrol, kerosene, etc.
Wood		Wood, plywood, etc.
Concrete		

Fig. 8.35. Conventional representation of materials

Table 8.1 : B.I.S. recommendations for colours for various materials

S.No.	*Material*	*Colour*	*S.No.*	*Material*	*Colour*
1.	Cast iron	Payne's grey	7.	Brickwork	Vermilion
2.	Steel	Purple	8.	Concrete	Light green
3.	Wrought iron	Prussian blue	9.	Earth, Rock	Sepia
4.	Brass, Phosphor-bronze and Gun metal	Light Yellow	10.	Timber	Brunt sienna
5.	Copper	Crimson lake	11.	Glass	Pale blue wash
6.	Aluminium, White metals, Tins and Light alloys	Light green	12.	Insulation (electrical)	Black

8.13 CONVENTIONAL BREAKS

The method of indicating the ends of shafts, rods, tubes, etc., which have a portion of the length broken out is shown in Fig. 8.36. The long lengths of shafts, pipes, etc., are generally shown broken in the middle as above to accomodate their views in a drawing sheet without reducing the scale.

The exact construction of drawing "S" break for solid shaft is shown in Fig. 8.37. In practice it is drawn freehand. The student should try to get nearly the same shape by freehand as shown here.

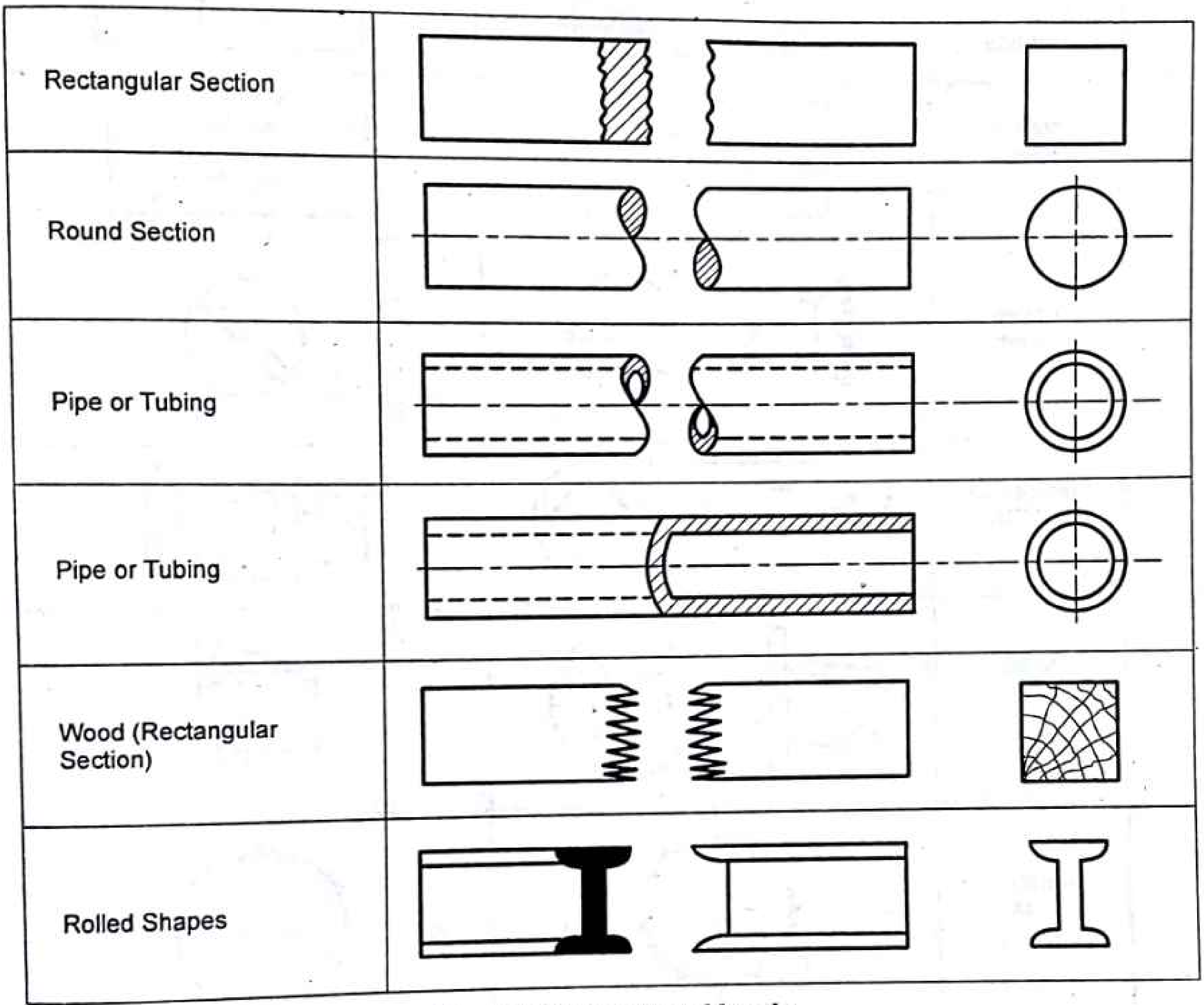


Fig. 8.36. Conventional breaks

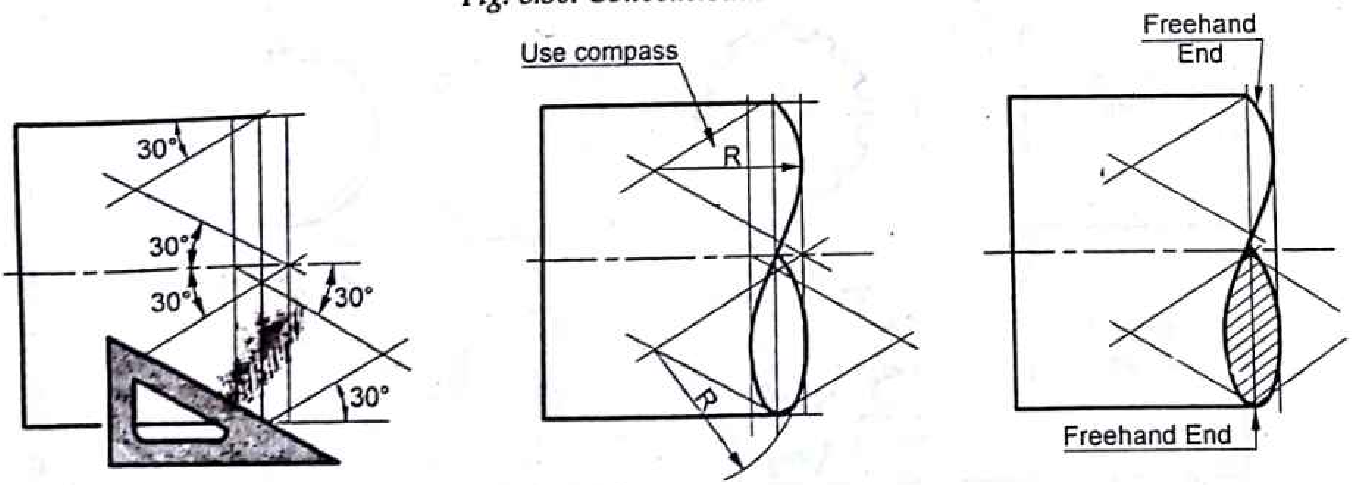


Fig. 8.37. Drawing of "S" break

8.14. CONVENTIONAL REPRESENTATION OF COMMON FEATURES

Conventional representation is adopted where complete delineation of the part would involve necessary drawing time or space [see Fig. 8.38 (*a*), (*b*) and (*c*)].

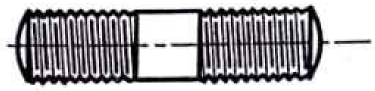
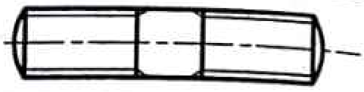
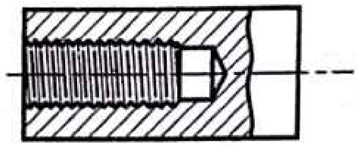
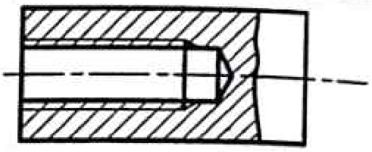
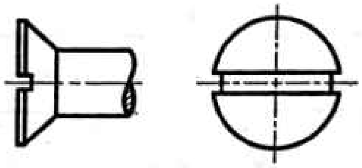
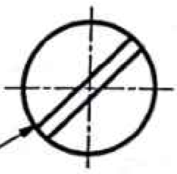
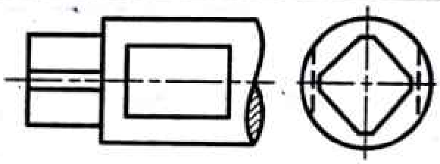
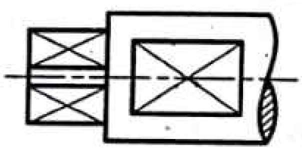
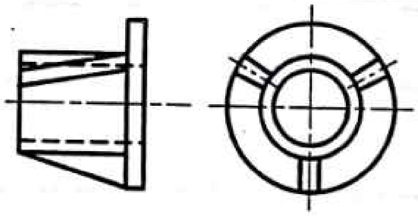
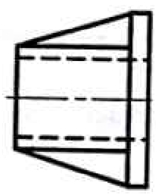
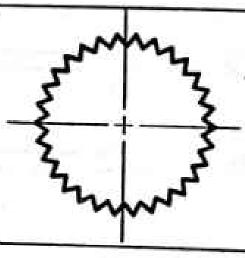
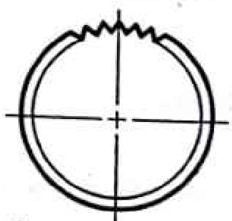
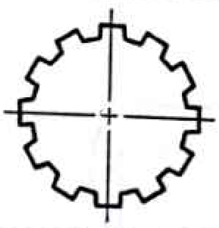
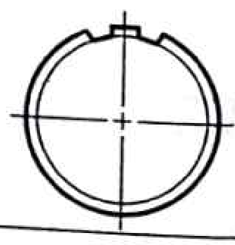
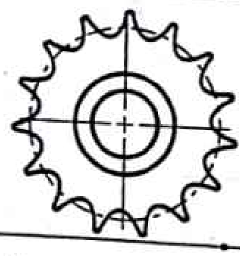
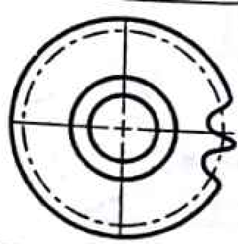
Title	Actual Projection/Section	Convention
External Threads		
Internal Threads		
Slotted Head		 To be drawin at 45°
Square end and Flat		
Radial Ribs		
Serrated Shaft		
Splined Shaft		
Chain Wheel		

Fig. 8.38 (a) Conventional representation of common features

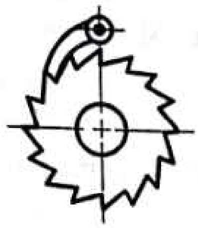
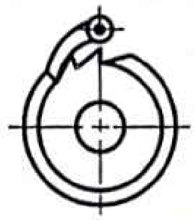
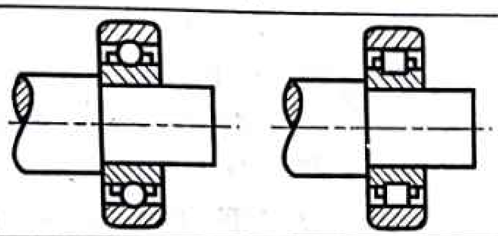
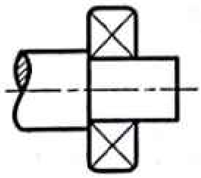
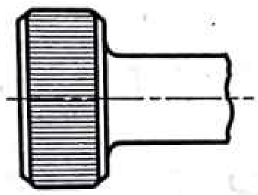
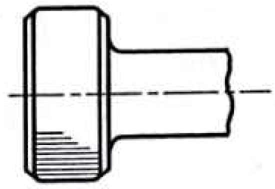
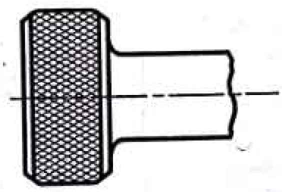
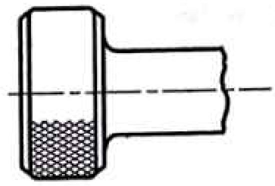
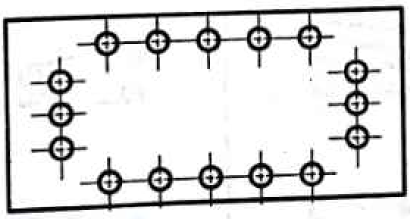
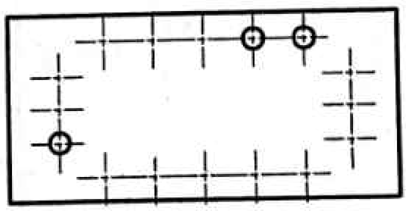
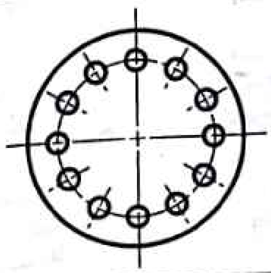
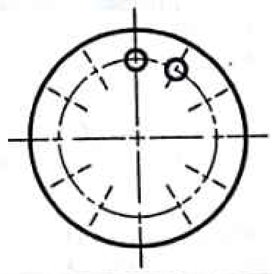
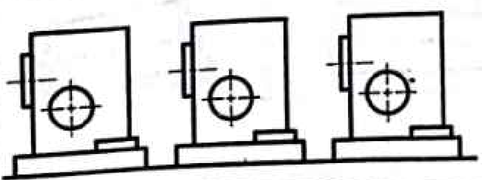
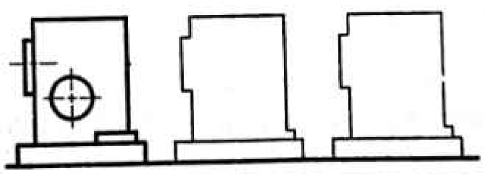
Title	Actual projection/section	Convention
Ratchet and pinion		
Bearing		
Straight knurling		
Diamond knurling		
Holes on a linear pitch		
Holes on circular pitch		
Repeated parts		

Fig. 8.38 (b) Conventional representation of common features

8.15. SPRINGS

The springs are classified as follows :-

(*i*) Compression springs
(*ii*) Tension springs
(*iii*) Torsion springs
(*iv*) Leaf springs
(*v*) Cup springs
(*vi*) Spiral springs

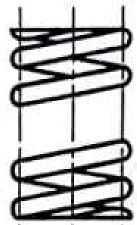
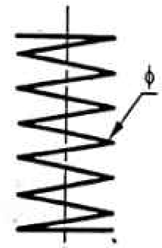
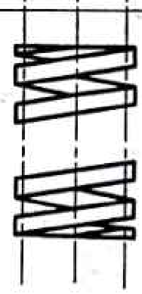
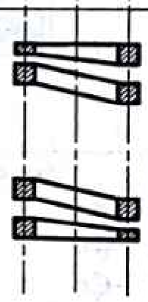
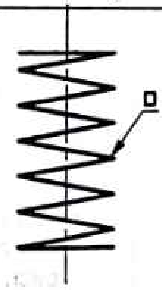
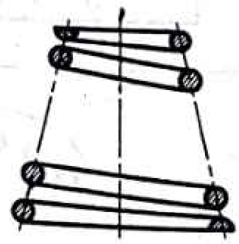
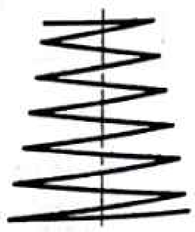
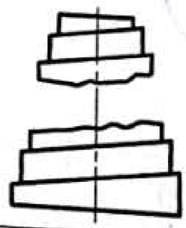
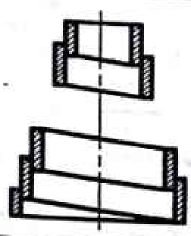
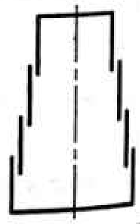
A torsion spring offers resistance to a torque load. The extended ends form the torque arms which are rotated about the axis of the spring.

A flat spring is made of strip material. The conventional representation of six types of springs are shown in Fig. 8.39 (*a*) to (*f*).

A spring can be formed by winding oil tempered spring wire around a cylindrical bar. The wire follows a helical path of the screw. Therefore, a spring can be drawn similarly to the screw thread. Pitch distance are marked off and the coils are given a slope of one-half of the pitch.

The detail working drawing of a spring is drawn to show its free lenght.

The springs are generally not made individually but purchased from a spring manufacturer.

Title	Representation		
	View	Section	Simplified
10.3.1.1 Cylindrical helical compression spring of wire of circular cross-section			
10.3.1.2 Cylindrical helical compression spring of wire of rectangular cross-section			
10.3.1.3 Conical helical compression spring of wire of circular cross-section			
10.3.1.4 Conical helical compression spring of wire of rectangular cross-section (volute spring)			

(1) If necessary, indicate wound left (or right) hand.
If necessary the cross-section of spring material may be indicated in word or by symbol.

Fig. 8.39 (a) Convetional representation of springs — Compression springs

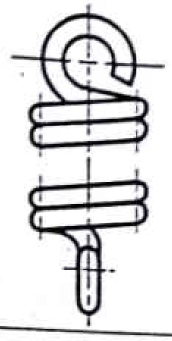
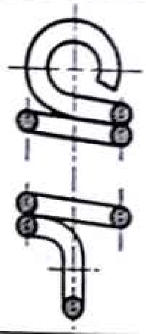
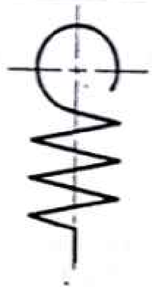
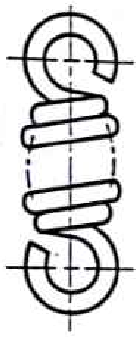
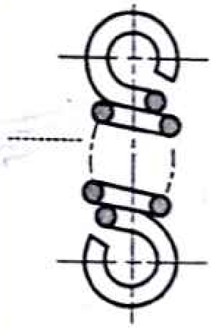
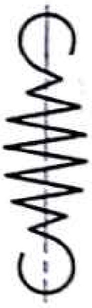
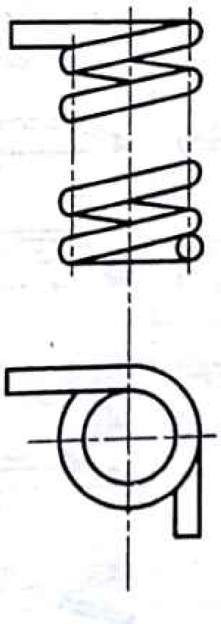
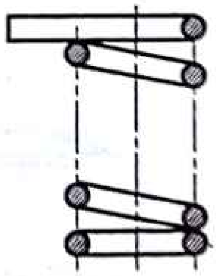
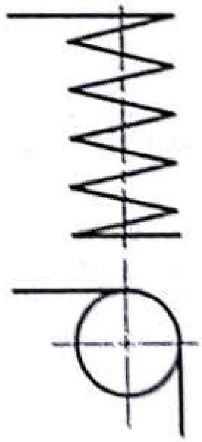
Tiele	Representation		
	view	section	simplified
10.3.2.1 Cylindrical helical tension spring of wire of circular cross-section.			
10.3.2.2 Double conical helical tension spring of circular cross-section			

Fig. 8.39 (b) Convetional representation of springs — Tension springs

Title	Representation		
	view	section	simplified
10.3.3.1 Cylindcrical helical torsion spring of wire of circular cross-section (wound right hand)			

(1) If necessary, indicate wound left (or right) hand.

(2) If necessary the cross-section of spring material may be indicated in words or by symbol (see 10.3.1.2)

Fig. 8.39 (c). Conventional representation of springs — Tension springs

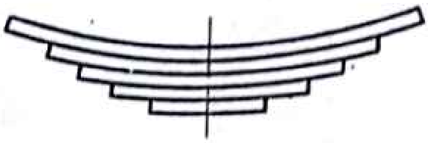
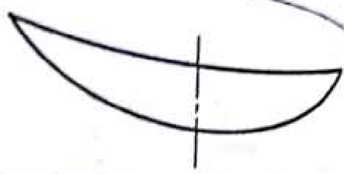
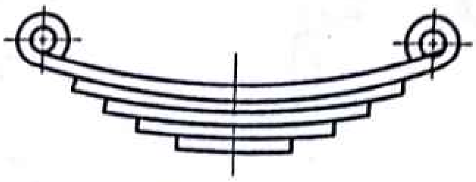
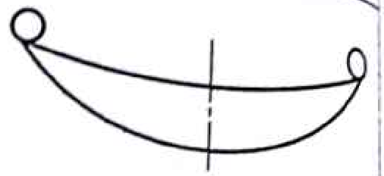
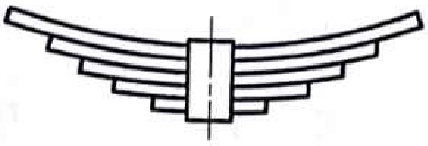
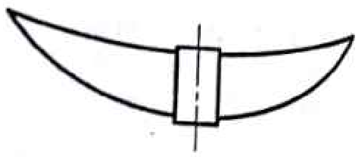
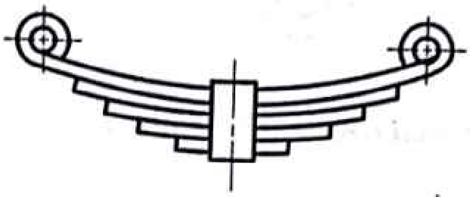
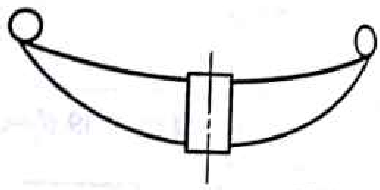
Title	Representation	
	view	simplifed
10.3.4.1. Semi-eliptic leaf spring (multi-elliptical spring shown)		
10.3.4.2. Semi-elliptic leaf spring with eyelets		
10.3.4.3. Semi-elliptic leaf spring with centre band		
10.3.4.4. Sei-elliptic leaf spring with eyelets centre band		

Fig. 8.39 (d). Conventional representation of springs -- Leaf springs

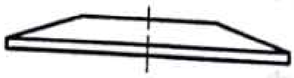
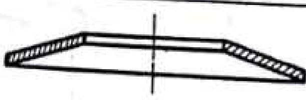
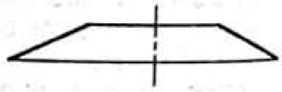
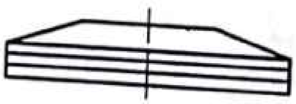
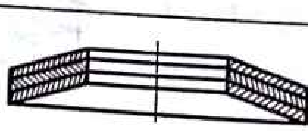
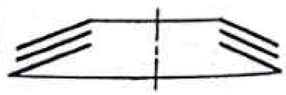
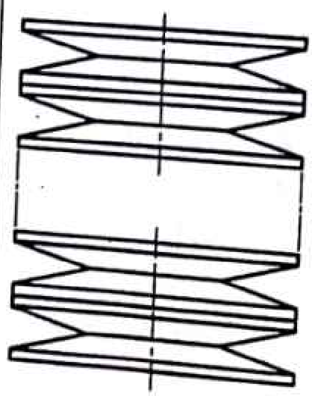
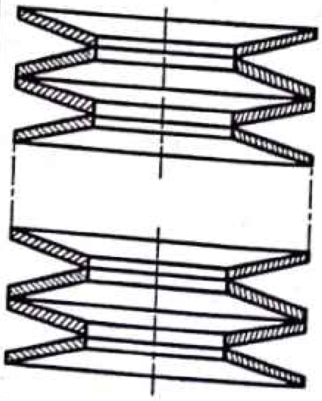
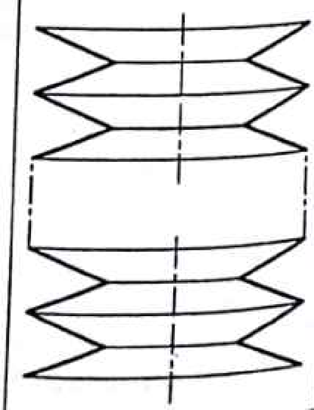
Title	Representation		
	view	section	simplified
10.3.5.1. Cup spring			
10.3.5.1. Multi-cup spring (cups placed in the same direction)			
10.3.5.1. Multi-cup spring (successive cups alternating in direction)			

Fig. 8.39 (e). Conventional representation of springs-Cup springs

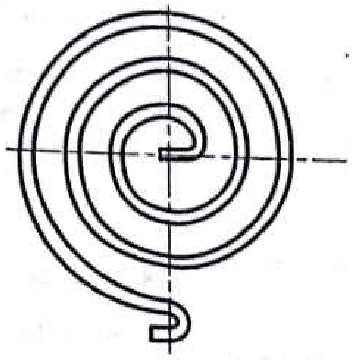
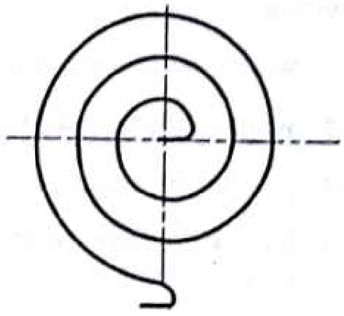
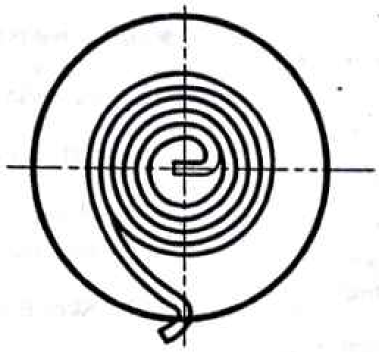
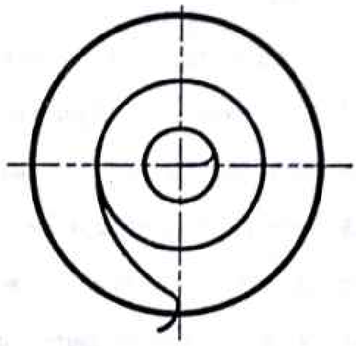
Title	Representation	
	view	simplified
10.3.6.1. Spiral spring		
10.3.6.2. Spiral spring (the spring is wound by rotating the box)		

Fig. 8.39 (f). Conventional representation of springs-Spiral springs

8.16. STRUCTURAL SECTIONS

The mild steel "sections" or rolled bars of many shapes are used in structural and other works. The four common sections are angle, channel, tee and I or H or joist (see Fig. 8.40). in drawing, tapers in the sections are not shown.

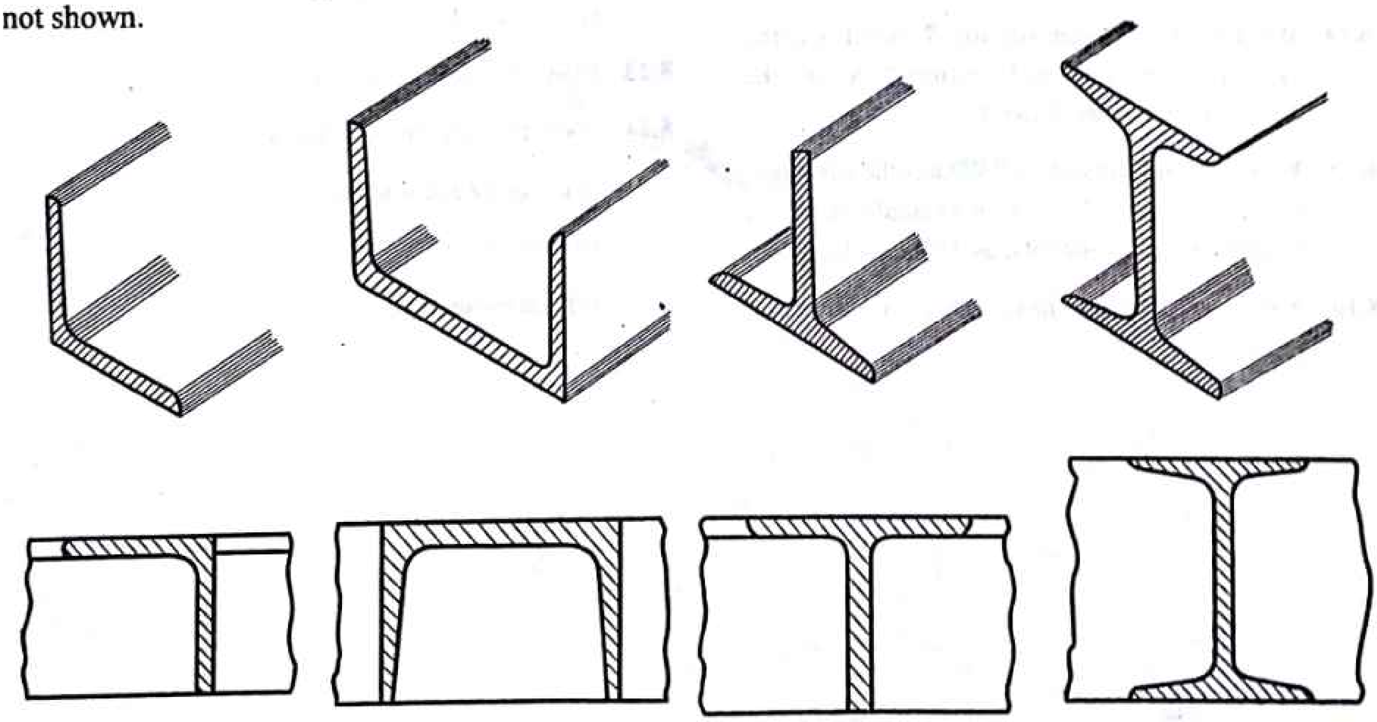


Fig. 8.40. Structural sections

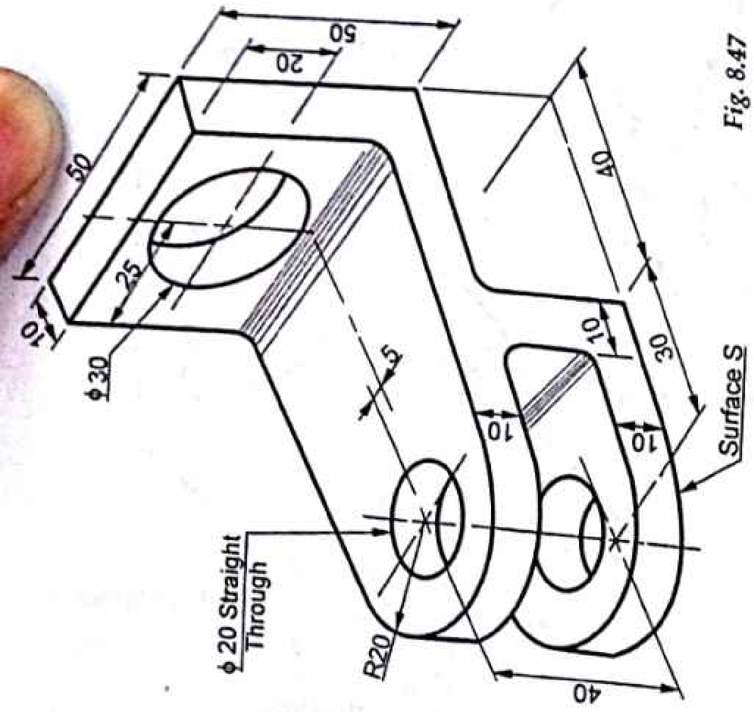


Fig. 8.47

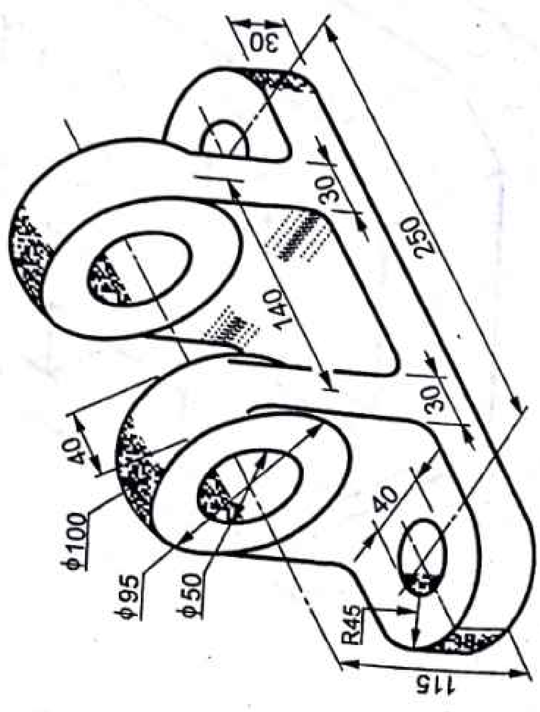


Fig. 8.48

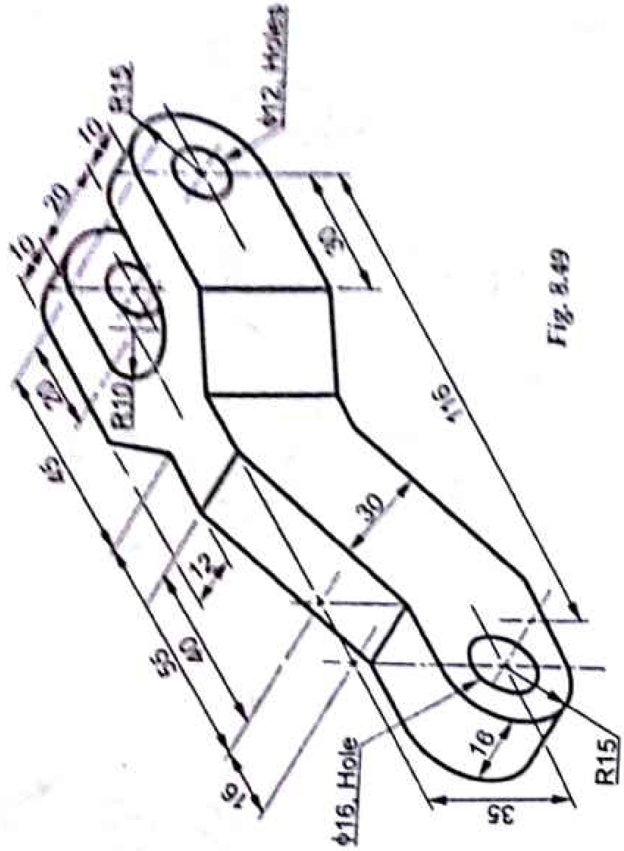


Fig. 8.49

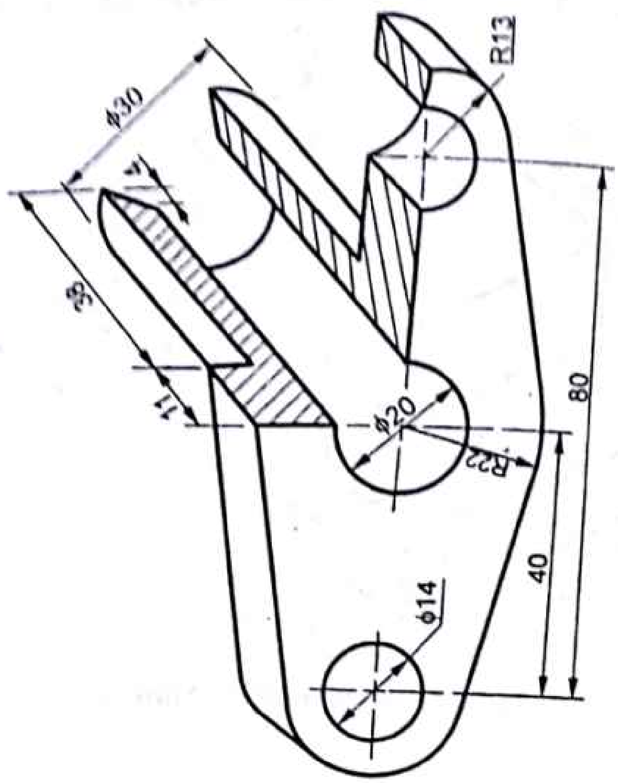


Fig. 8.50

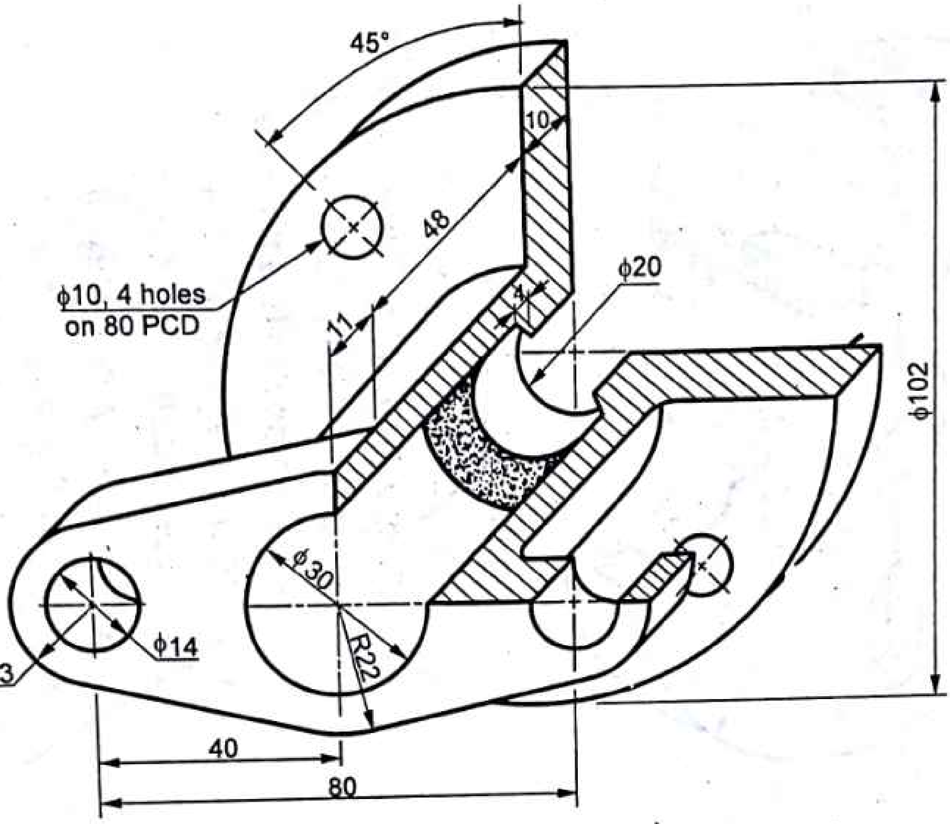


Fig. 8.51

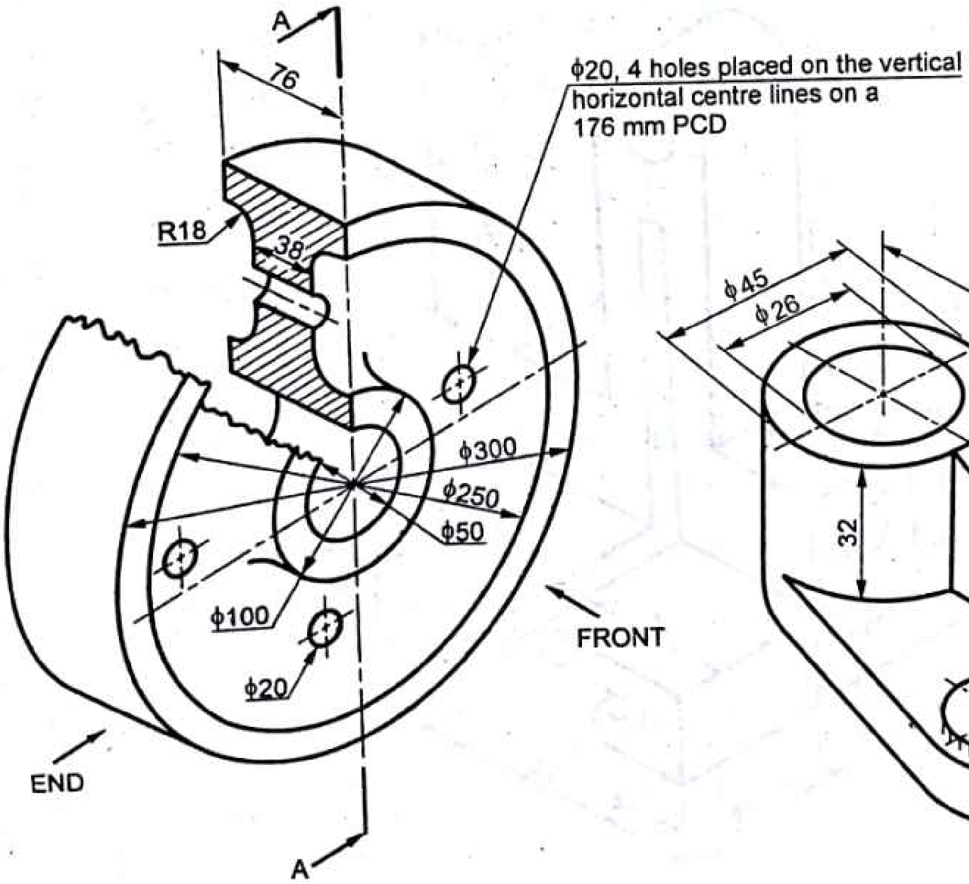


Fig. 8.52

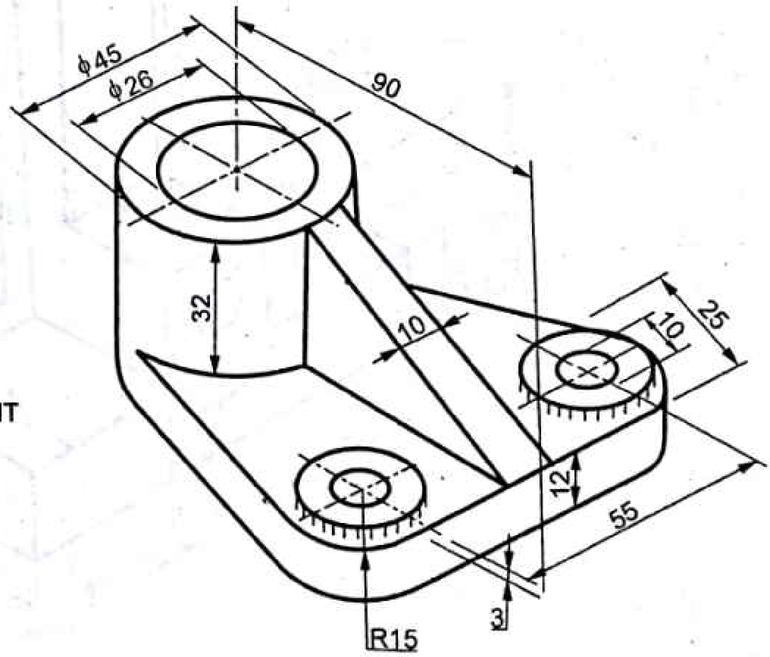


Fig. 8.53

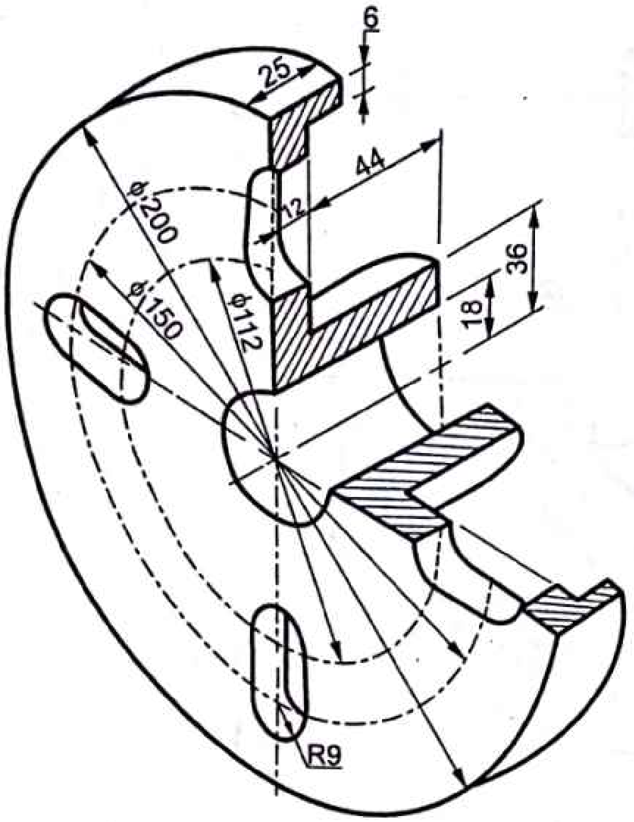


Fig. 8.54. Face plate

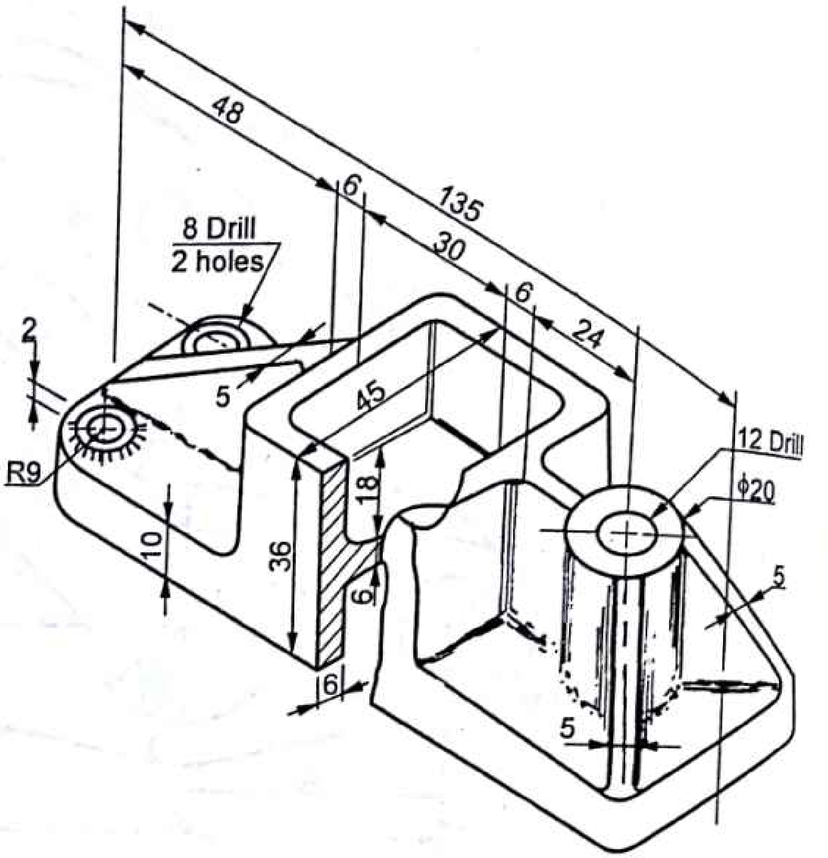


Fig. 8.55

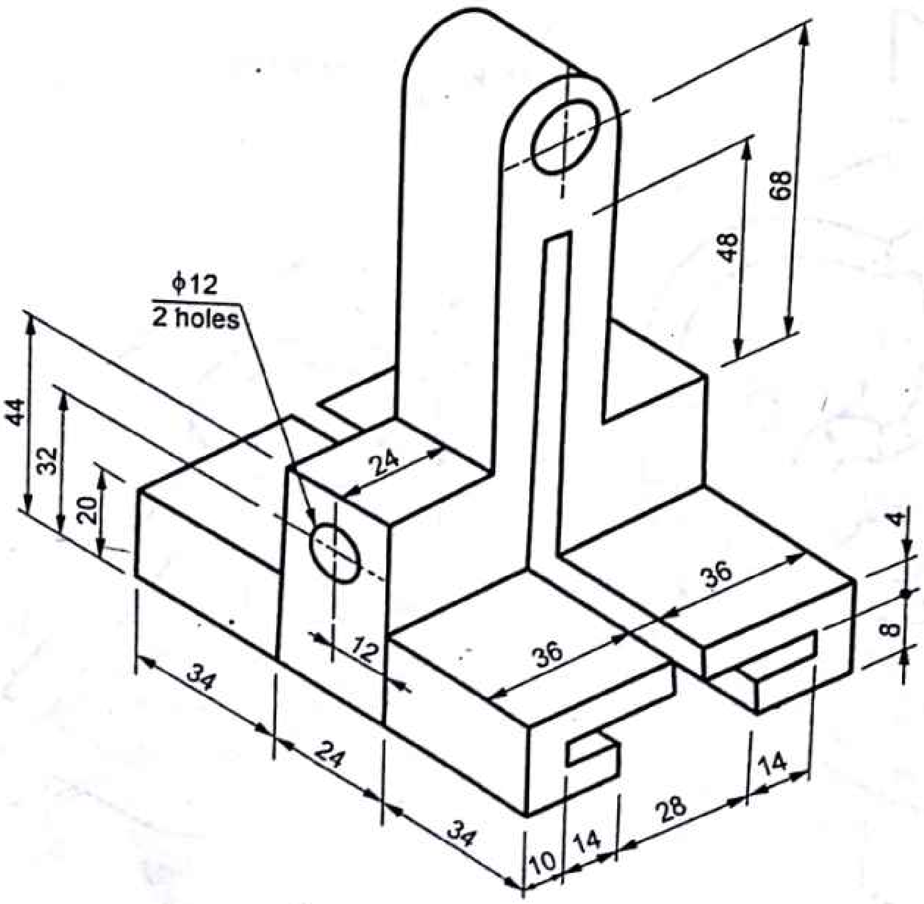


Fig. 8.56

8.13. Errors in sectioning occur in each of the drawings below. Trace or redraw a correct sectional view in each case. State the methods of projection used where applicable (Fig. 8.71)

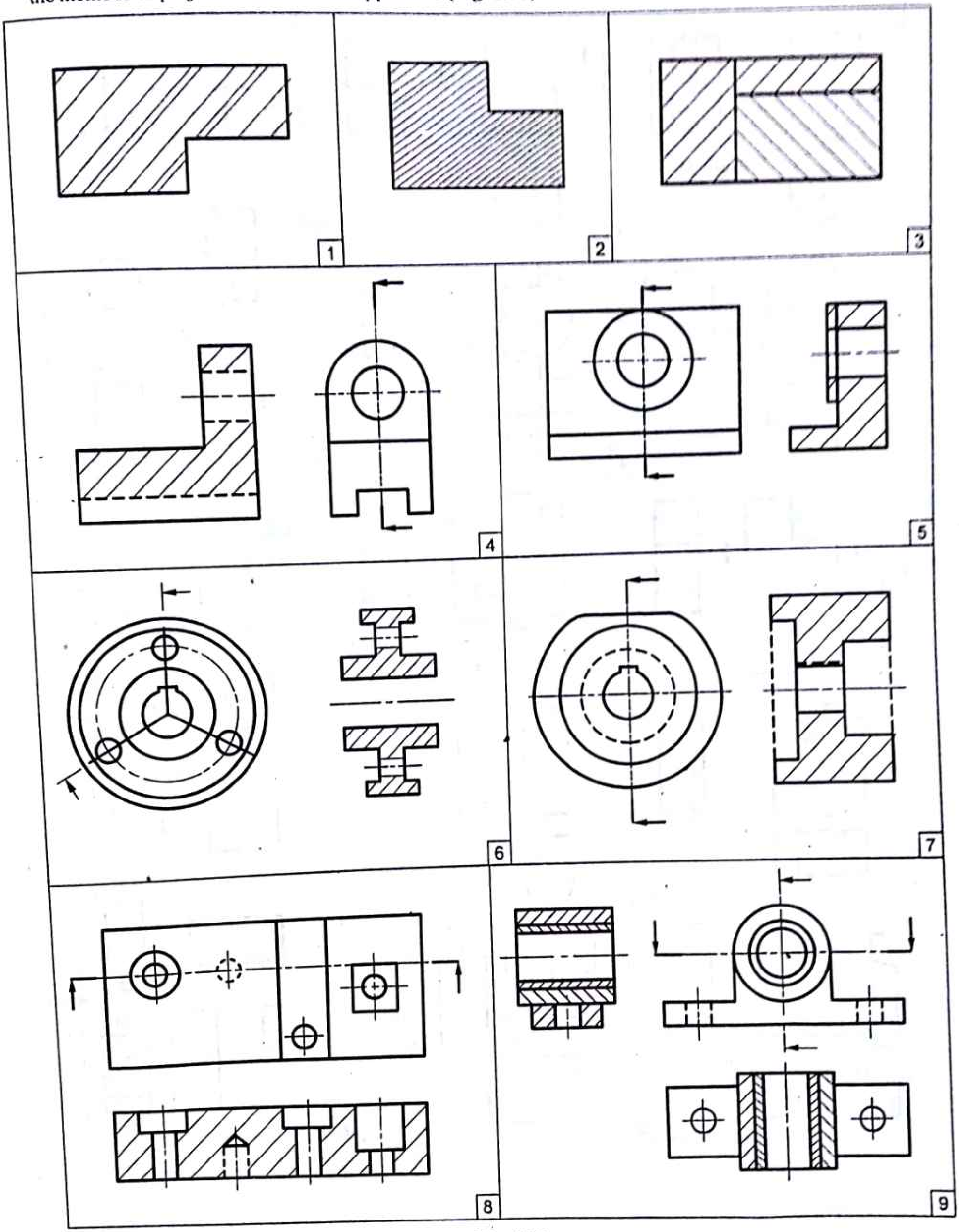


Fig .8.71

8.14. From the lettered drawings choose the correct sectional views for each number drawing drawn in first angle. Sketch the views in the space provide. (Fig. 8.72)

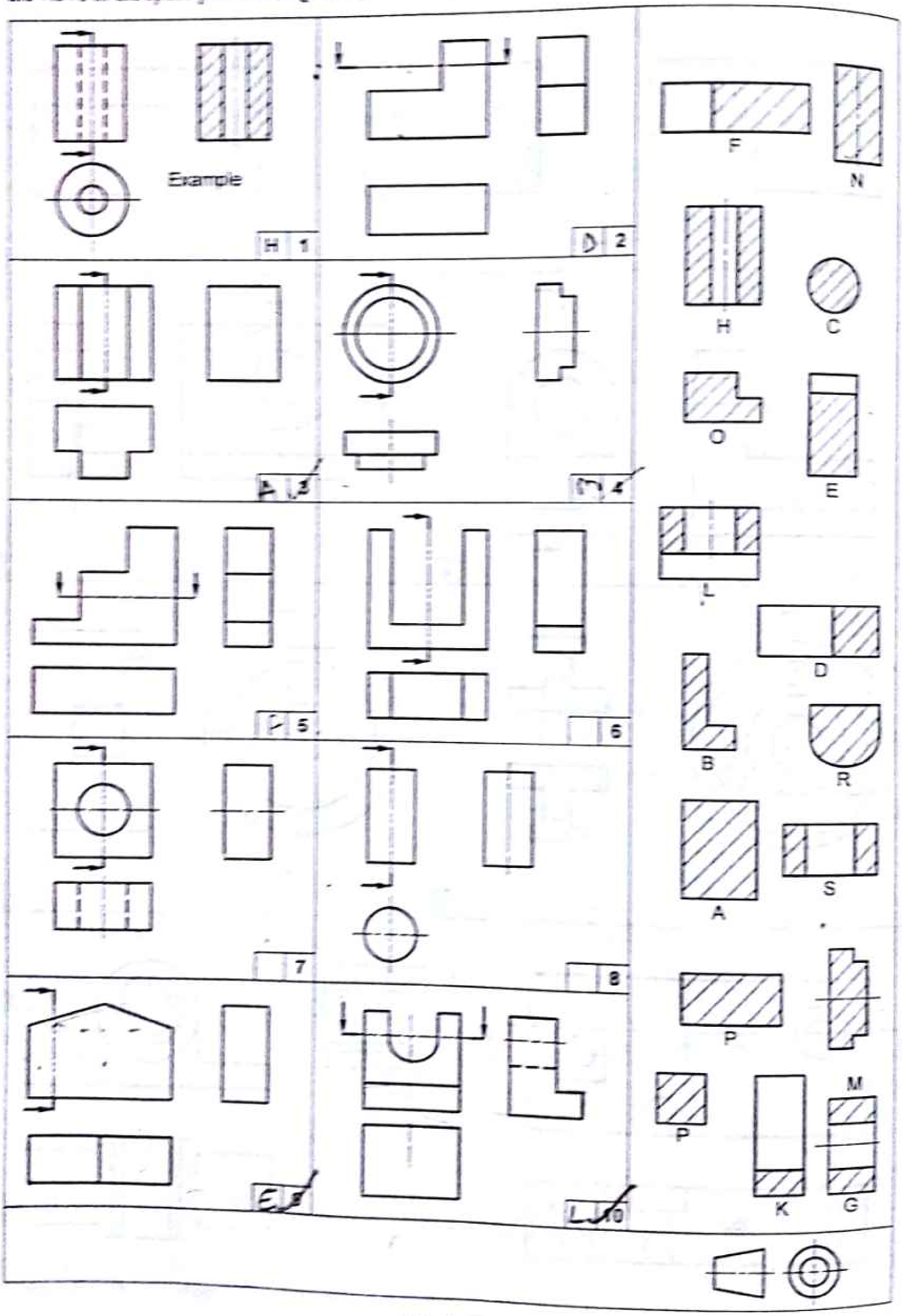


Fig. 8.72

SECT
8.15
(a
(b

9 Dimensioning

9.1. INTRODUCTION

Dimensioning has an important place in the study of machine drawing. A drawing gives the shape and size of the object. The shape of the object is defined by the views drawn according to the principles of projection. The size of the object is known by the dimensions given in the drawing.

Dimension can be defined as a numerical value expressed in appropriate units of measurement and indicated graphically on technical drawings with lines, symbols and notes.

An object is manufactured in workshop according to the drawing supplied. The dimensions should be such that they are easily located and there is no ambiguity in their understanding by the workman. Also, the workman should not have the necessity of calculating, scaling or assuming dimensions for manufacturing the object. Rules are laid to ensure correct and efficient dimensioning, but perfection in it can only be achieved by persistent practice. *The student should make it a habit to study dimensioning of any orthographic view which he comes across and thus get habituated to the art of dimensioning.*

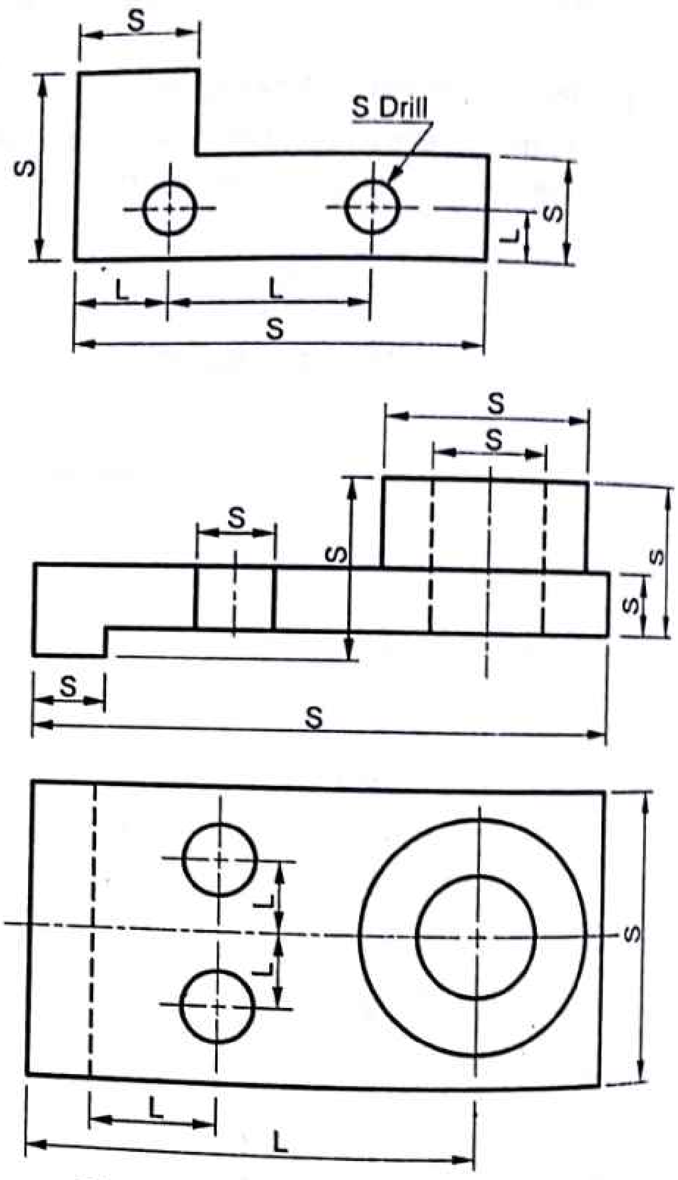


Fig. 9.1. Size and location dimensions

9.2. SIZE AND LOCATION DIMENSIONS

Object of any shape may be considered to be made as of a number of geometrical shape such as pyramids, cones, etc., or parts of such shapes. When the size of each simple shape is defined and the relative positions are given, the size description is complete. Thus we have two types of dimensions. *size dimensions and location dimensions*. Size dimensions (S) are those which give the size of the geometric shapes. Location dimension (L) are those which locate the geometric shapes. Study carefully the size and location dimensions in the views shown in Fig. 9.1. Note that length, breadth, height, and diameter of holes are given as size dimensions, and distance between the centre lines of the hole from the edge are given as location dimensions.

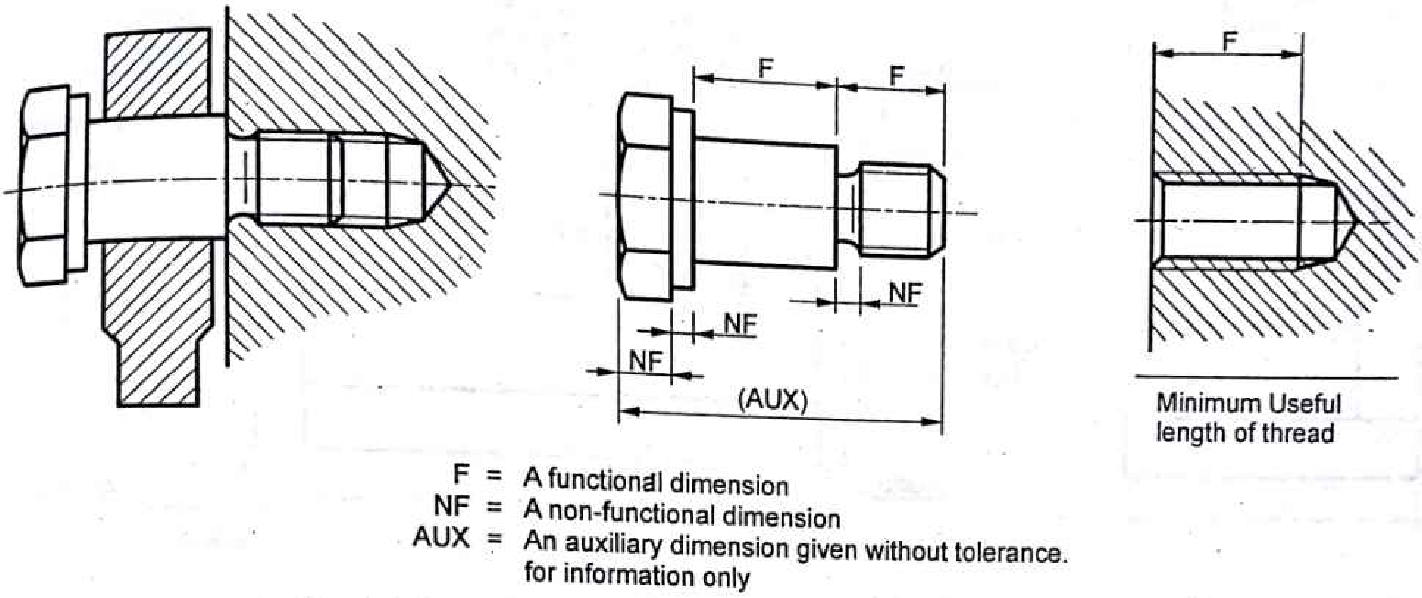


Fig. 9.2. Functional, non-functional and auxiliary dimensions

9.3. FUNCTIONAL AND DATUM DIMENSIONS

A *functional dimension* is a dimension which is essential to the function of piece or space (see F in Fig. 9.2). A *non-functional* dimension is a dimension which is not essential to the function of the piece or space (See NF in Fig. 9.2). An *auxiliary dimension* is one which is given for information purpose only. It does not govern production or inspection operations and is derived from other values shown on the drawing or in related documents. An auxiliary dimension is given in parenthesis and no tolerance applies to it (see AUX. in Fig. 9.2). A *datum dimension* is a dimension which locates a point, line or plane exactly. It is enclosed in a frame, thus $\boxed{30}$. It may also be used to specify the position of an ordinate or a point which establishes a true profile.

9.4. ELEMENTS OF DIMENSIONING

The elements of dimensioning consist of dimension lines, extension lines, leaders, arrowheads, figures, notes and symbols. Their definitions are given which should be read with reference to Fig. 9.3.

(i) Dimension lines. Dimension lines are light full lines used to indicate the measurement, the amount of which is denoted by figures in a space left in the dimension line, in unidirectional system, or above the dimension line (in aligned system): The dimension is terminated by arrowheads. *Dimension lines, in general, should be placed 6 to 8 mm away from the outlines and should be spaced uniformly 6 to 8 mm from each other.*

(ii) Extension or projection lines. Extension or projection lines are light full lines extending slightly beyond outline and used when dimension is placed outside the object. Projection line may be drawn from the outline of the object or leaving a gap of about 2 mm from the outline. On the other end the extension line should extend about 3 mm beyond the dimension line. Extension lines are drawn in a direction perpendicular to the feature to be dimensioned. Therefore the dimension line, terminated with the arrowhead, meets the extension line at right angles.

(iii) Leaders or pointer lines. Leaders are lines drawn from notes and figures to show where these apply, *i.e.* they 'lead' from a note or a dimension. These are thin straight lines terminated by arrowheads on lines or dots within the outline of the object. (see Fig. 9.40 and 9.40). Leader are drawn at any convenient angle not less than 30°, usually 30°, 45° and 60°. Note that leaders are never drawn vertical or horizontal or curved. When pointing to a circle or arc it is drawn radially. The use of long leaders should be avoided (see Fig. 9.43 and 9.44).

(iv) Arrowheads. Arrowheads are used to terminate dimension lines. The length of the arrowhead should be about 3 mm for smaller drawings and 4 to 5

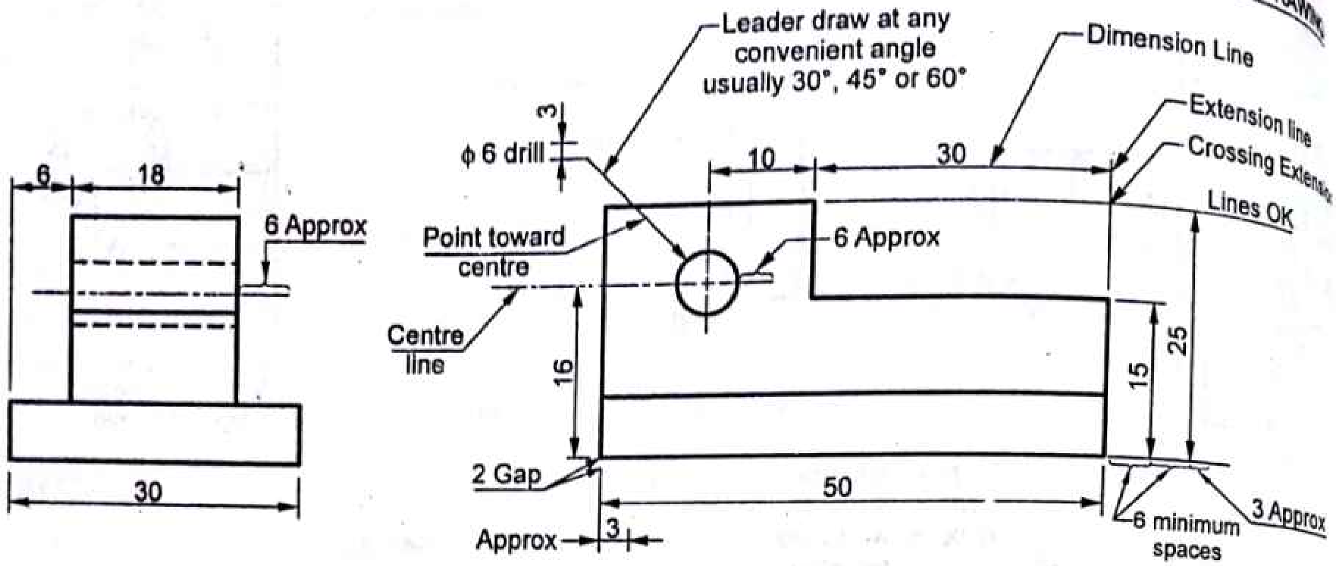


Fig. 9.3. Notation of dimensioning

mm for larger drawings and the base or the depth of the arrowheads should be about one-third of the length as shown in Fig. 9.4. The arrowhead may be drawn open or solid. The open arrowhead may be drawn either in one stroke towards the point and then away from it, or in two strokes towards the point as shown in enlarged form in Fig. 9.4.

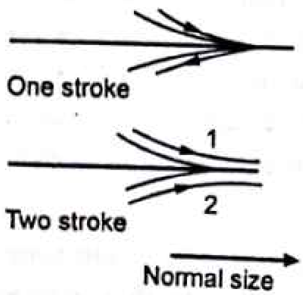


Fig. 9.4. Open arrowhead

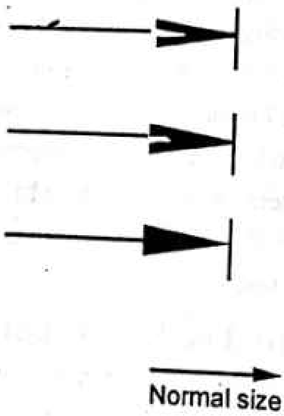


Fig. 9.5 Solid arrowhead

The solid arrowhead is usually made narrower and slightly longer than the open arrowhead and has practically no curvature to the sides as shown in Fig. 9.5. It is made in one stroke and then filled without lifting the pen or pencil.

B.I.S. recommends the use of solid arrowheads.

Beginners often draw the arrowheads incorrectly as shown in Fig. 9.6. Proficiency in drawing arrowheads can be achieved only by painstaking practice.

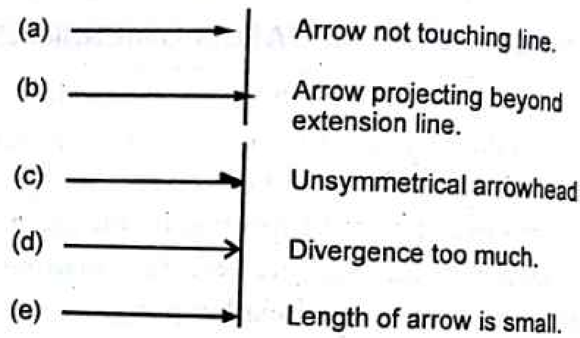


Fig. 9.6. Incorrect arrowheads

(*v*) **Dots.** Clearly marked dotes may be used in place of adjacent arrowheads where space is limited.

(*vi*) The oblique stroke, drawn as a short line inclined at 45° may also be used (see Fig. 9.7.)

Fig. 9.7. Oblique stroke

(*vii*) The indication of origin is given by drawing a small open circle of approximately 3 mm in diameter (see Fig. 9.8).

Fig. 9.8. Origin

9.5. PLACING OF DIMENSIONS

Dimensions should be placed on the view which shows the relevant features most clearly. The I.S.I. recommends the following two systems of placing the dimensions :

(*a*) Aligned system.

(*b*) Unidirectional system.

(a) Aligned system. In this system, all dimensions are so placed that they may be read from the bottom or from the right side of the drawing as shown in Fig. 9.9. and all dimensions should be placed above the dimension line.

As far as possible dimension lines should be drawn in accordance with Fig. 9.9 and 9.19.

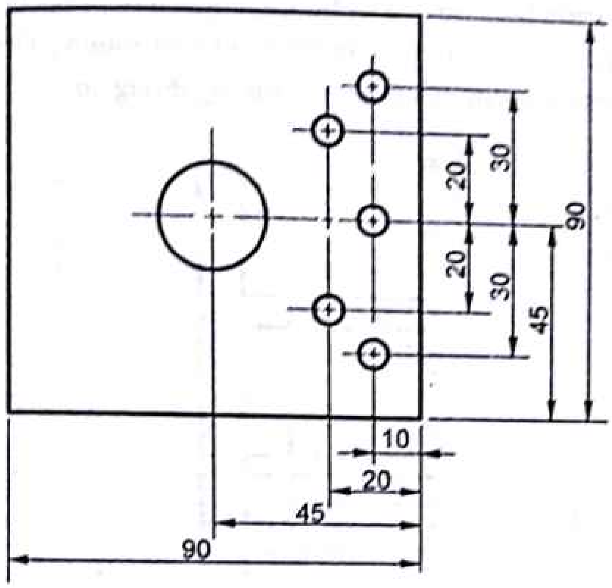


Fig 9.9. Aligned system of dimensioning

(b) Unidirectional system. In this system, all dimensions are so placed that they may be read from the bottom edge of the drawing sheet as shown in Fig. 9.10. In this system dimension lines are broken to insert dimensions.

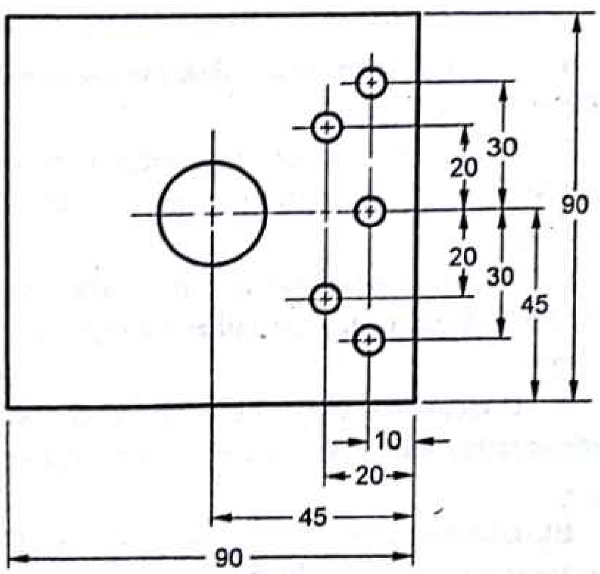


Fig. 9.10. Unidirectional system of dimensioning

In unidirectional system there is no restriction controlling the direction of dimension lines.

The unidirectional system is advantageous on large drawings, where it is inconvenient to read dimensions from the right-hand side or any other directions.

Note:

1. Notes must be lettered horizontally and are read from the bottom of the drawing in either system.
2. Fig. 9.9 and 9.10. shows *progressive* dimensioning which avoids cumulative errors. *Note* : other type of dimensioning, *continuous* dimensioning. Figure 9.20.

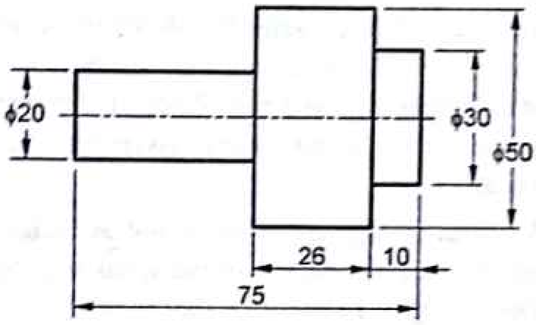


Fig. 9.11. Non-horizontal dimension lines are interrupted

3. Non-horizontal dimensions lines are interrupted, preferably near the middle so that the value may be inserted (see. Fig. 9.11 and 9.12).

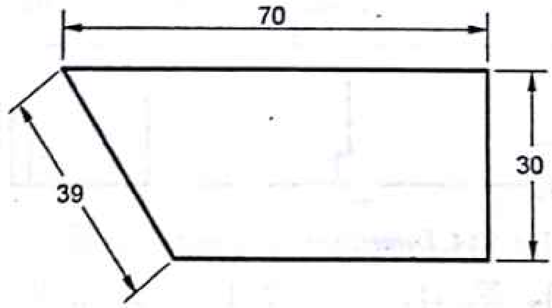


Fig. 9.12. Non-horizontal dimension lines are interrupted

9.6. GENERAL RULES OF DIMENSIONING

The art of dimensioning is a difficult one and hence certain rules have been evolved to achieve the basic aims of clarity, readability and utility. The student should study these rules carefully and apply them in practice. Any violation to these rules can be accepted when it contributes to greater clarity and usefulness.

A few rules have already been given under the heading Notation of Dimensioning. The following rules are in addition to them.

1. Standard size of letters and figures are shown in Fig. 9.13.

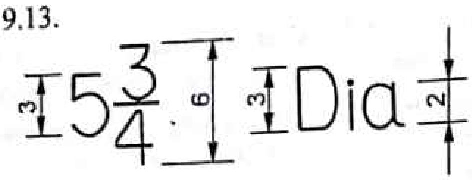


Fig. 9.13. Standard size of letters

2. As far as possible dimensions should be expressed in one unit only. In inch-foot system dimension upto 2 ft. are generally shown in inches. In S.I. units generally the dimensions are in mm. The height of figures may be 3 mm. When all dimensions are in one unit, a general note is given omitting the abbreviation.

3. When sufficient space is not available for placing the dimensions, any of the suitable methods as shown in Fig. 9.14 and 9.15 may be used.

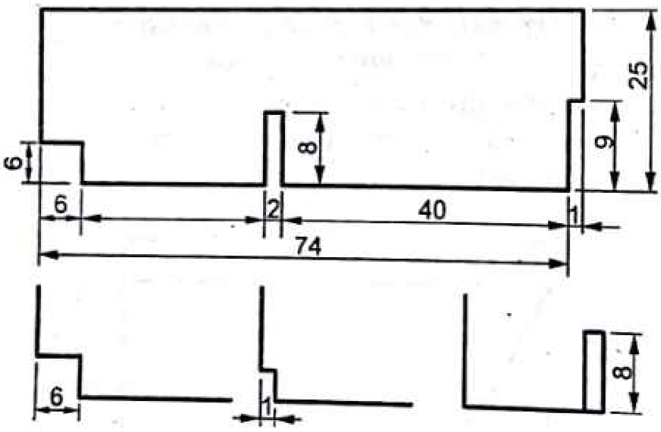


Fig. 9.14. Dimensioning in restricted space

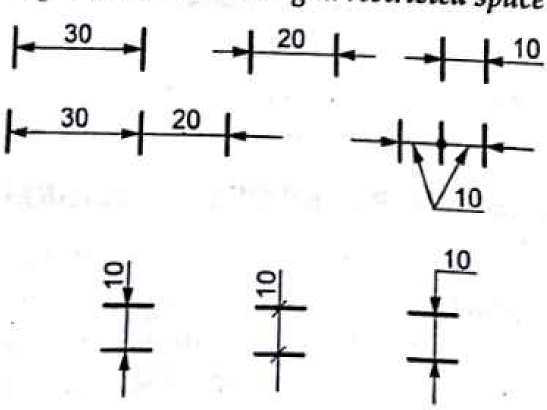


Fig. 9.15. Methods of dimensioning a length

When space is restricted, adjacent arrowheads may be replaced by a clearly marked dot (see Fig. 9.16).

As far as possible dimensions should be placed (*a*) outside the views, and (*b*) between the views as shown in Figs. 9.17 and 9.18. Dimensions between the views serve to tie the views together and help to interpret the drawing as they act in lieu of projection lines. Dimensions should not be placed within a view unless drawing becomes clearer by doing so.

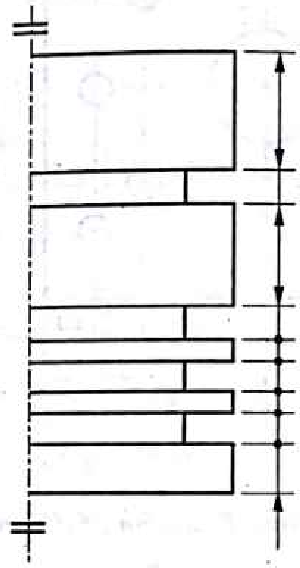


Fig. 9.16. Arrowheads replaced by dots

4. Dimensions should not be placed too close to each other or to the parts being dimensioned.

5. In aligned system of dimensioning, except where unavoidable, dimension lines should not be placed in the 30° zone shown hatched in Fig. 9.19.

6. Angular dimensional values may be oriented as Fig. 9.20 or 9.21.

7. Dimensions should be placed on the view which shows the relevant features most clearly (see Fig. 9.22).

8. Dimensions relative to a particular feature should be placed in one view rather than spread over several views.

9. Dimensions are to be taken from visible outlines rather than from hidden lines as shown in Fig. 9.23.

10. Dimensions are to be given from a base line, a centre line of a hole or cylindrical part and important hole or a finished surface which may be readily

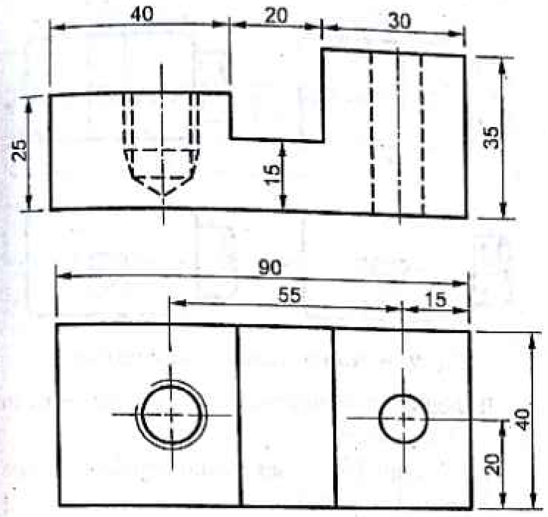


Fig. 9.17. Dimensioning outside the view and between the views

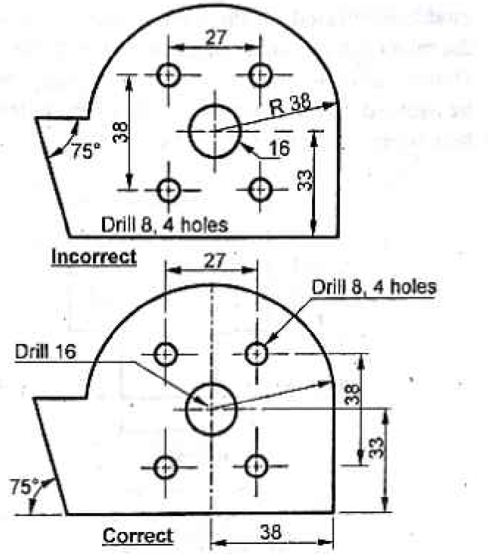


Fig. 9.18. Correct and Incorrect dimensioning

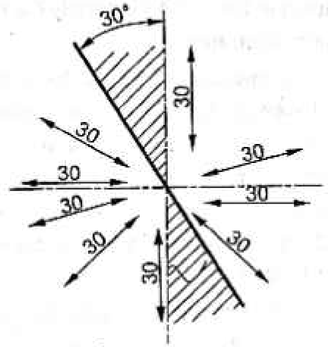


Fig. 9.19. Avoid hatched area for dimensioning in aligned system of dimensioning

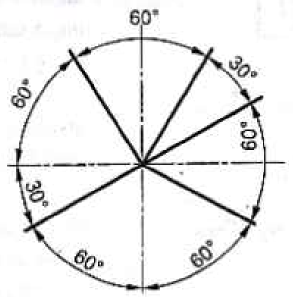


Fig. 9.20. Orientation of angular dimensional values

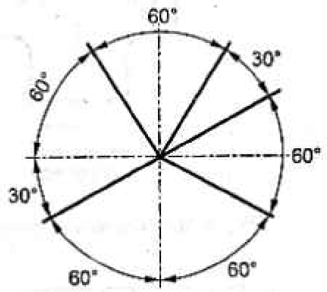


Fig. 9.21. Orientation of angular dimensional values.

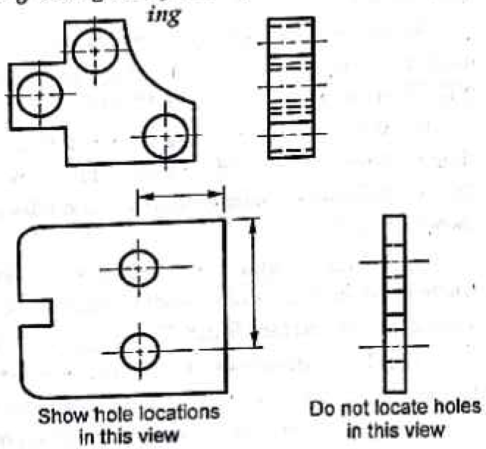


Fig. 9.22. Correct views for dimensioning - location of the position of holes

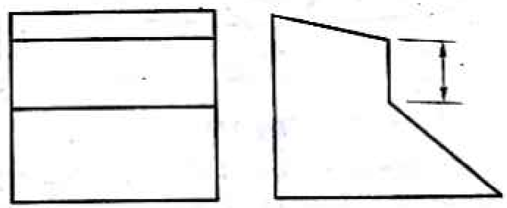


Fig. 9.23. No dimension from hidden line

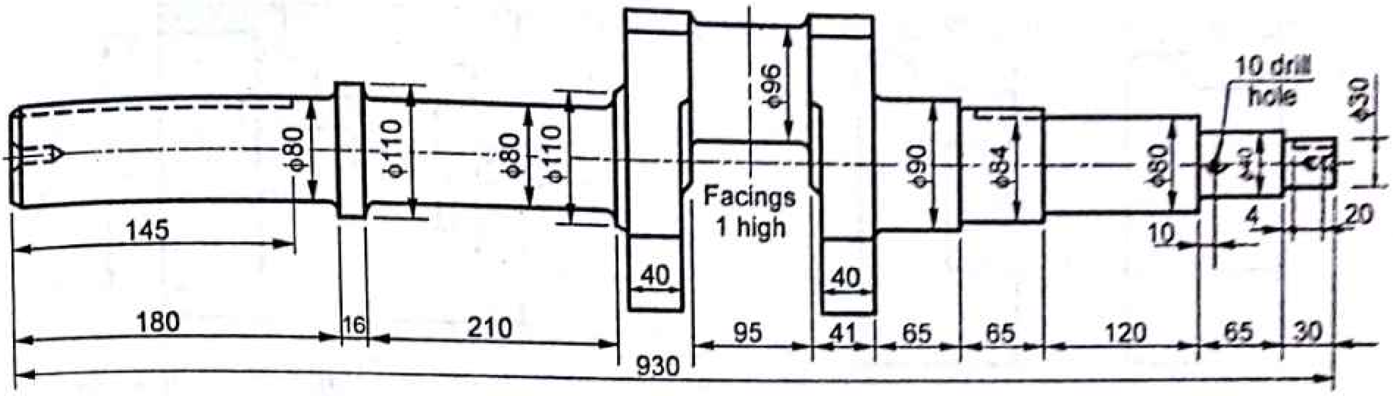


Fig. 9.27. Overall dimensions

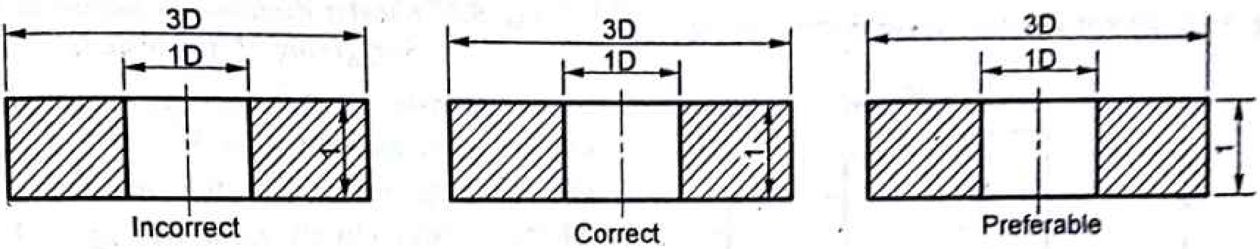


Fig. 9.28. Dimensioning in sectional views

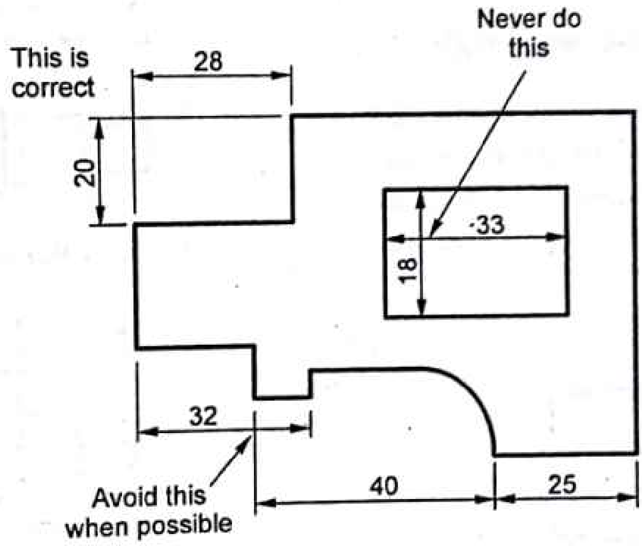


Fig. 9.29. Crossing of dimension and extension lines should be avoided

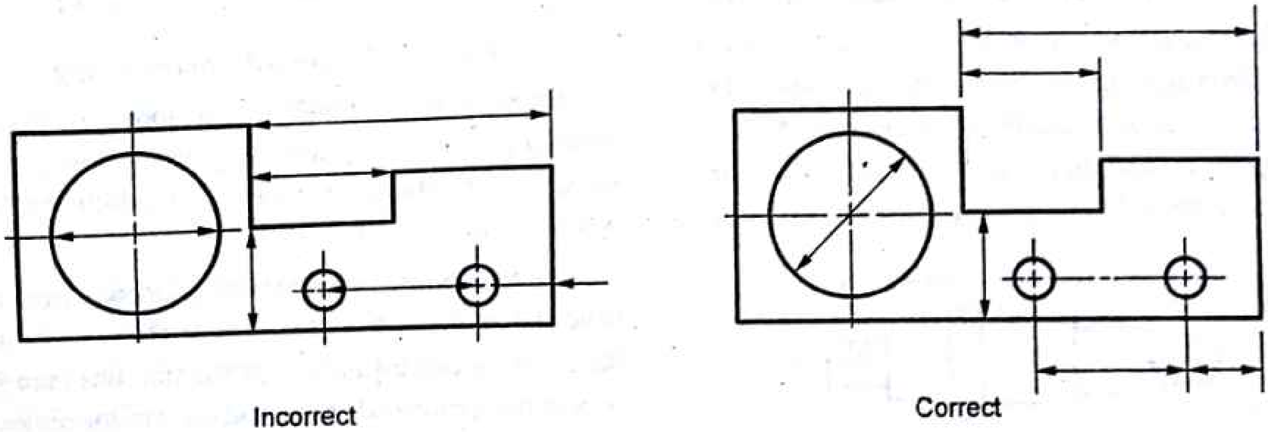


Fig. 9.30. Do not use axis or a contour line as dimension line

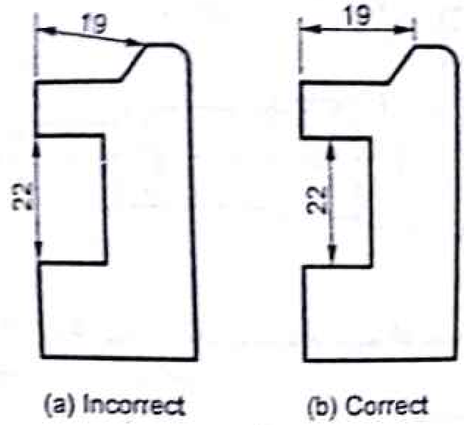


Fig. 9.31. Do not use outline for dimensioning

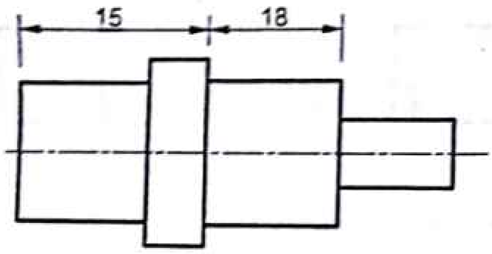


Fig. 9.33. Value of dimensions out of angle

19. Projection lines are to be drawn perpendicular to the outline of the feature to be dimensioned. However, they can be drawn obliquely, but parallel to each other in special cases such as on tapered features as shown in Fig. 9.34.

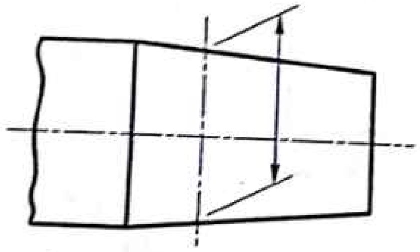


Fig. 9.34. Projection lines on a tapered feature

20. *Arrangement of Dimensions.* Fig. 9.35 shows *chain dimensioning.* It should be used only where the possible accumulation of tolerances does not endanger the functional requirements of the part. Where a number of dimensions of the same direction

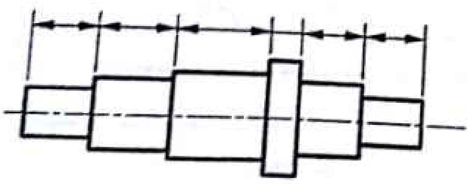


Fig.9.35. Chain dimensioning

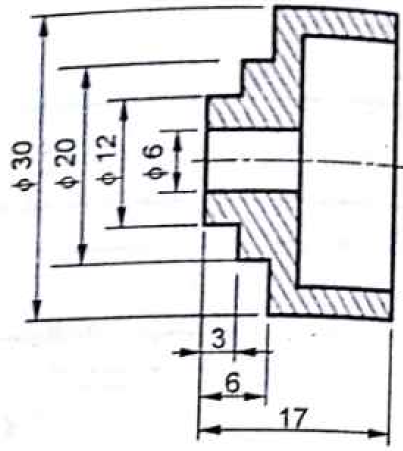


Fig. 9.32 Shorter dimensions nearer the view Staggering of dimensions.

have a common datum feature, parallel dimensioning can be used as shown in Fig. 9.36. *Combined dimensioning* results from the simultaneous use of the above two methods, as shown Fig. 9.37.

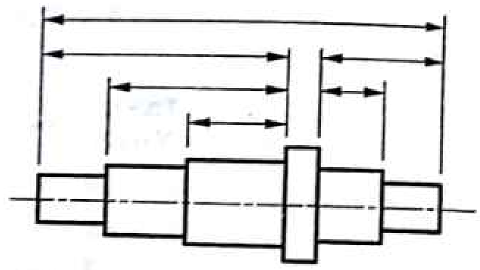


Fig.9.36. Parallel Dimensioning.

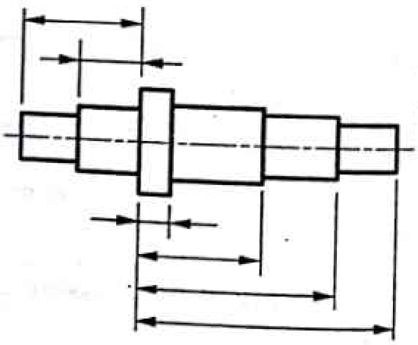


Fig.9.37. Combined dimensioning

Superimposed running dimensioning is simplified parallel dimensioning and may be used where there are space limitations and where no legibility problems would occur.

Dimensional values may be placed, where there is no risk of confusion, either near the arrowhead, in line with the corresponding projection line (see 9.38) or near the arrowhead above and clear of the dimension line. (see Fig. 9.39).

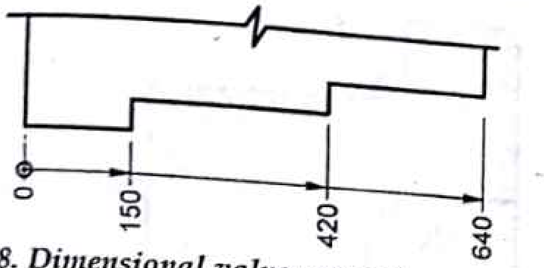


Fig.9.38. *Dimensional values near the arrowhead.*

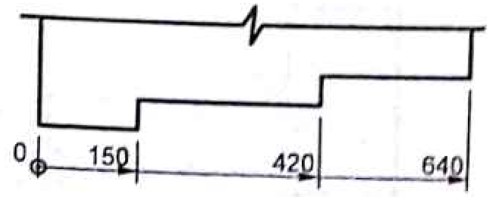


Fig.9.39. Dimensional values near the arrowheads.

21. *Leaders.* (*i*) Leaders should not be drawn curved or made freehand. The leaders may terminate in a short horizontal bar at the mid-height of lettering of the first or last line of the note as shown in Fig. 9.40.

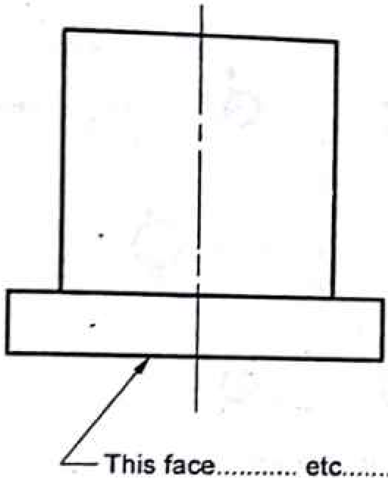


Fig. 9.40. Leader terminating in a short horizontal bar at the mid-height of the lettering

(*ii*) The arrowhead of the leader should always terminate on a line. If the arrowhead terminates within the outline of the object it should end with a dot instead of arrowhead as shown in Fig. 9.41.

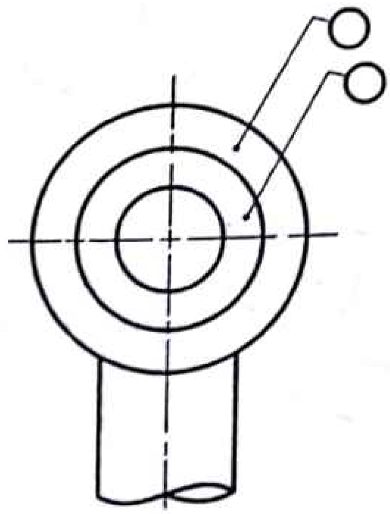


Fig. 9.41. Arrowhead within the outline of the object

(*iii*) Leaders which touch lines should normally do so at an angle not less than 30°; they should not be parallel to adjacent dimension or projection lines, otherwise it might cause confusion (see Fig. 9.42).

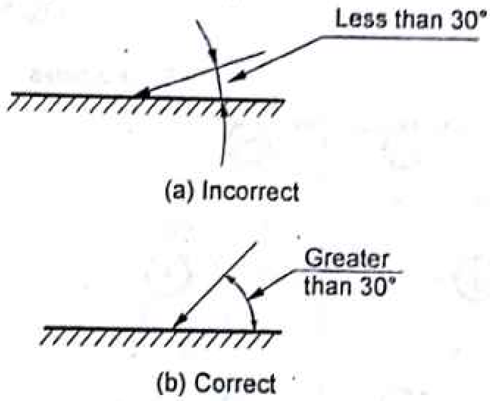


Fig. 9.42. Inclination of leaders

(*iv*) The use of long leaders should be avoided even if it means repeating dimensions or notes (see Fig. 9.43.) or using letter symbols (see Fig. 9.44).

22. *Equidistant features.* When equidistant features or uniformly arranged elements are part of the drawing specification, dimensioning may be simplified as follows.

(*i*) Linear spacing may be dimensioned as shown in Fig. 9.45. If there is any possibility of confusion between the length of the space and the number of spacing, one space shall be dimensioned as in Fig. 9.46.

(*ii*) Angular spacing of holes and other features may be dimensioned as in Fig. 9.47.

(*iii*) The angles of the spacing may be omitted if their number is evident without confusion (see Fig. 9.48).

(*iv*) Circular spacings may be dimensioned indirectly by giving the number of elements as shown in Fig. 9.49.

(*v*) In repeated features, repeating the dimensions may be avoided as shown in Fig. 9.50 and 9.51.

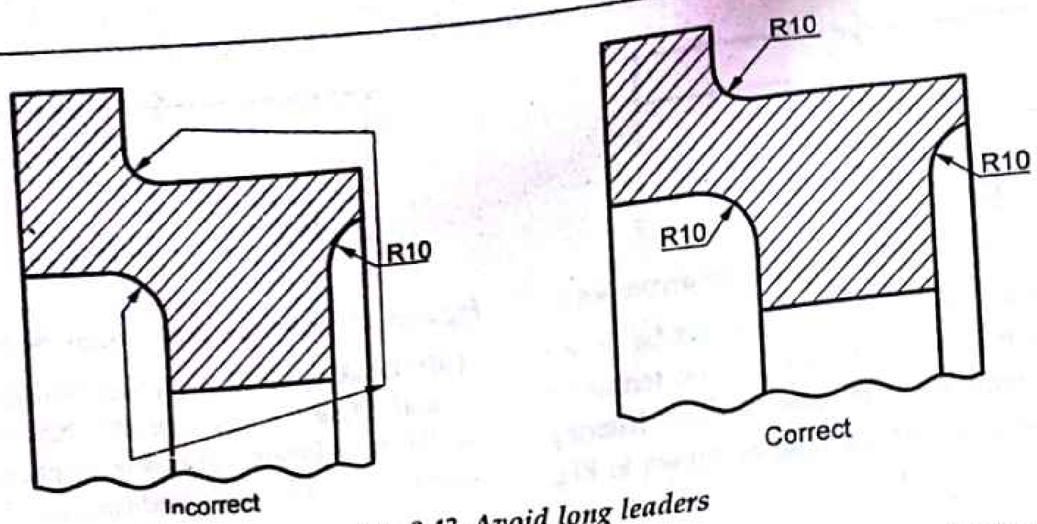


Fig. 9.43. Avoid long leaders

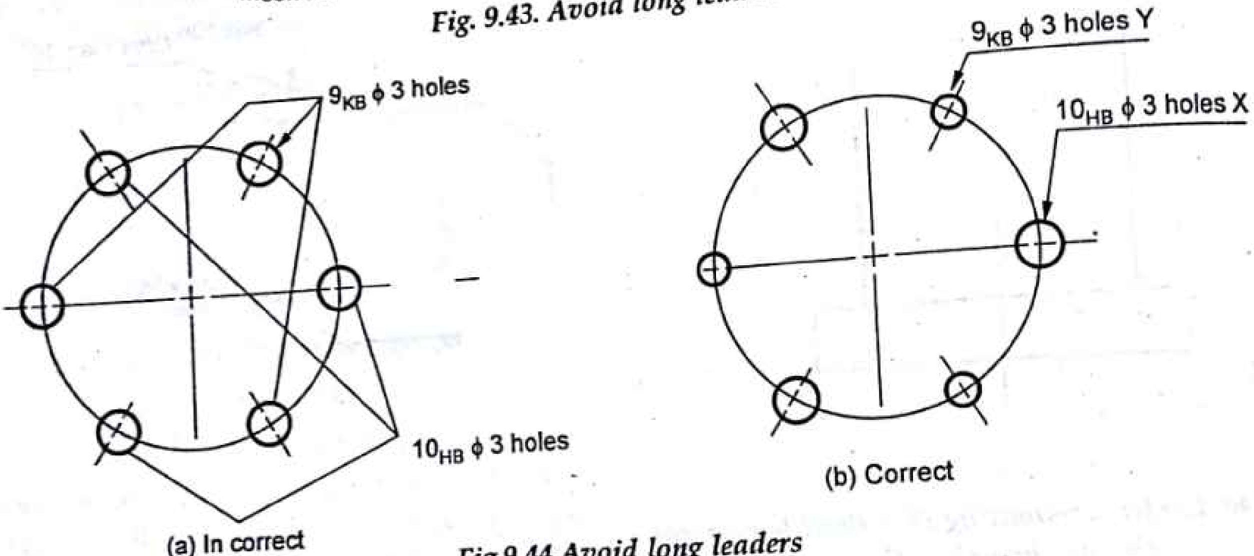


Fig.9.44 Avoid long leaders

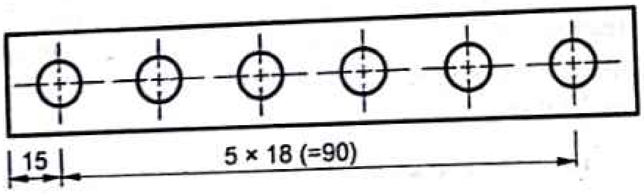


Fig. 9.45

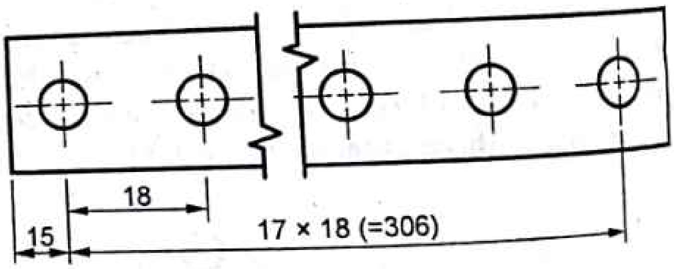


Fig. 9.46 : Dimensioning of linear spacing

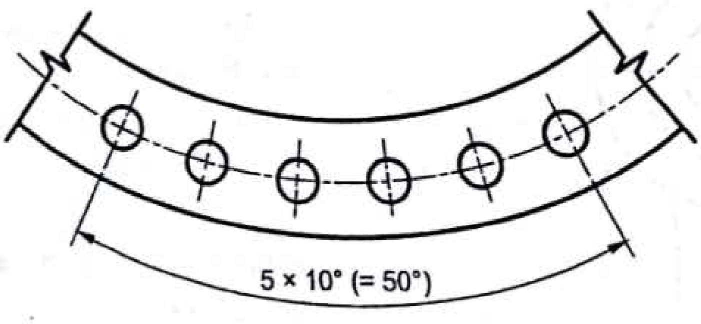


Fig. 9.47. Dimensioning of angular spacing.

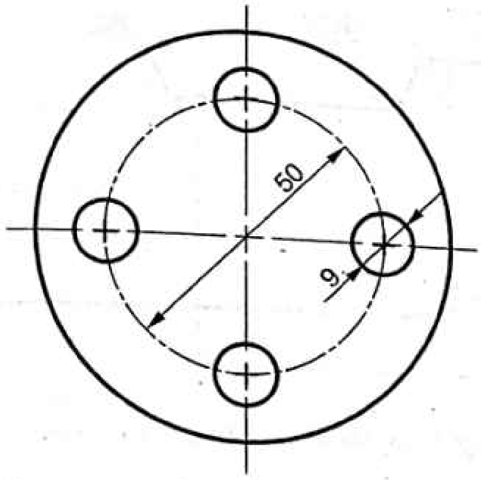


Fig. 9.48. Omission of angle of spacing if no confusion.

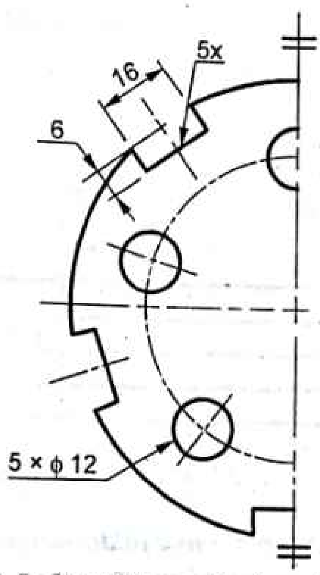


Fig. 9.49. Indirect dimensioning of circular spacing.

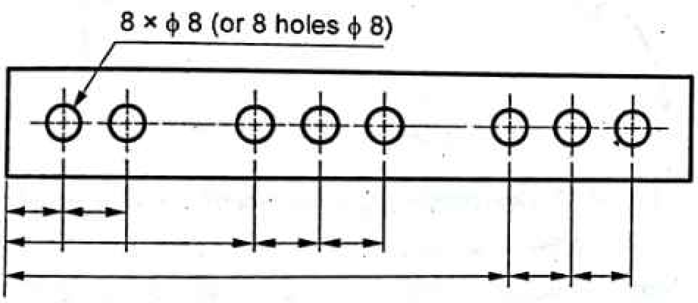


Fig. 9.50. Avoid repeating the dimensions.

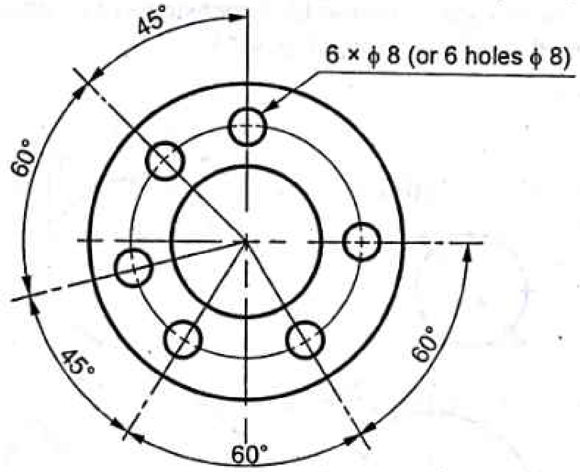


Fig. 9.51. Avoid repeating of dimensions.

9.7. METHODS OF DIMENSIONING COMMON FEATURES

1. Diameters. (*i*) The diameters of a cylinder should generally be given in rectangular view in preference to the view in which it occurs as circles and should be preceded by symbol ϕ in order to distinguish the diameter from a length. Never give radius of a cylinder (see Fig. 9.52.)

(*ii*) Where half views of symmetrical parts, such as cylindrical parts, are drawn the portions of the dimension lines shown should be extended slightly beyond the centre line and the second arrow omitted. (see Fig. 9.53).

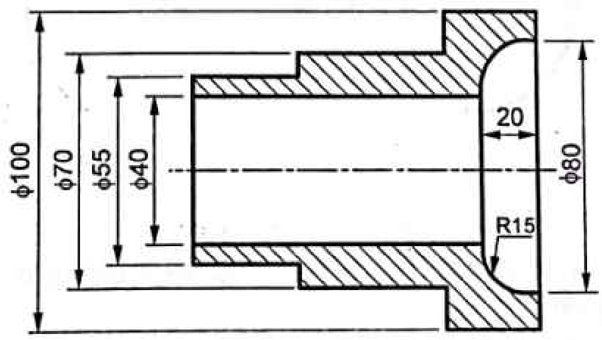


Fig. 9.52. Dimensioning diameter of cylinder

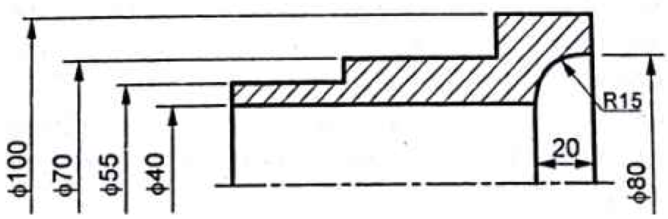


Fig. 9.53. Dimensioning half views of symmetrical parts

(*iii*) Where space is restricted, one of the methods shown in Fig. 9.54 should be used.

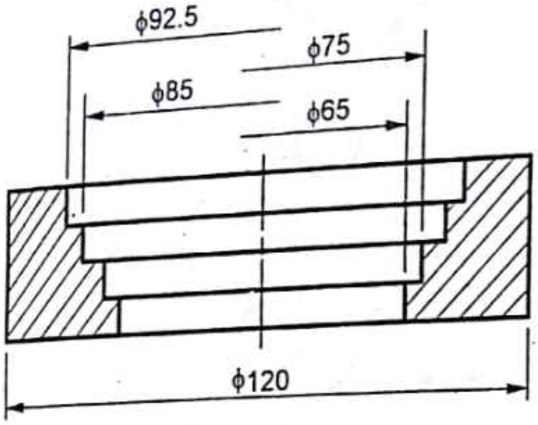


Fig. 9.54. Dimensioning of diameter in restricted space

(*iv*) Circles should be dimensioned by one of the methods illustrated in Fig. 9.55.

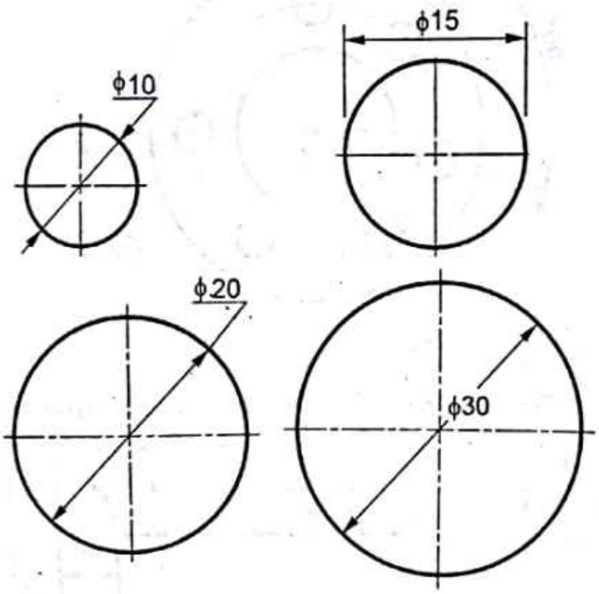


Fig. 9.55. Dimensioning of circles

(*v*) The diameter of spherical surface should be dimensioned as shown in Fig. 9.60.

2. Radii. (*i*) As far as possible the dimension line of a radius should pass through the centre of the arc., Where the centre is located by dimensions, the centre shall be marked by a clear dot. While dimensioning small radii, the arrow may be reversed (see Fig. 9.56). The dimension of a radius is always preceded by 'R'

(*ii*) Radii of acres arcs need not have their centres located should be dimensioned as in Fig. 9.57.

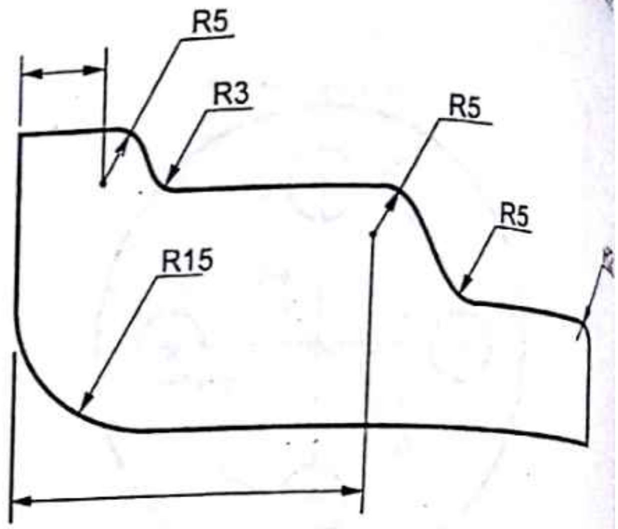


Fig. 9.56. Dimensioning radii-centre located

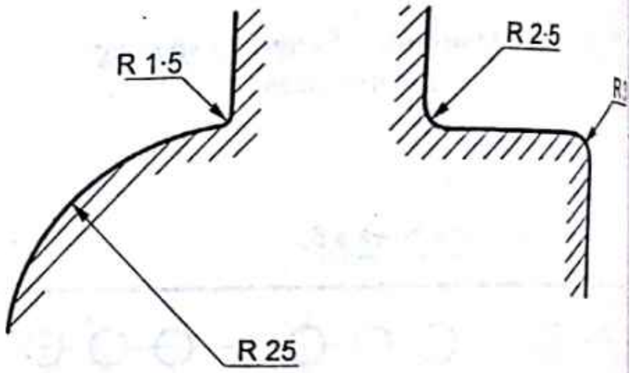


Fig. 9.57. Dimensioning radii -centre not located

(*iii*) When the centre of an arc falls outside the limits of the space available, the dimension line of the radius should be broken or interrupted according to whether or not it is necessary to locate the centre (see Fig. 9.58).

(*iv*) Where the size of the radius can be derived from other dimension it shall be indicated with a radius arrow and the symbol R without an indication (see Fig. 9.59).

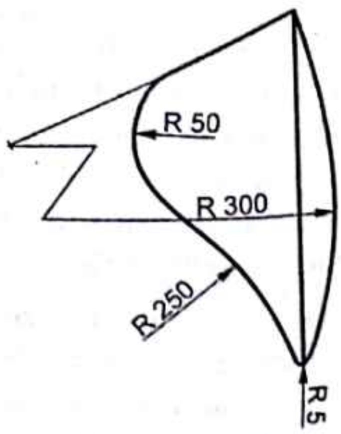


Fig. 9.58. Dimensioning radii-centre of arc outside the space available

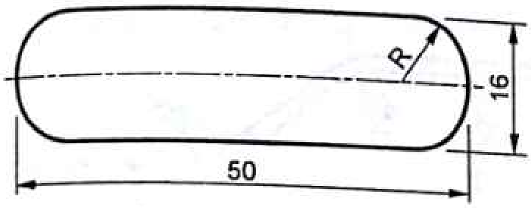


Fig. 9.59. Radius symbol without dimensions

(*v*) The radius of a spherical surface should be dimensioned as shown in Fig. 9.60. The dimension should be preceded by

Sϕ : Spherical diameter

SR : Spherical radius.

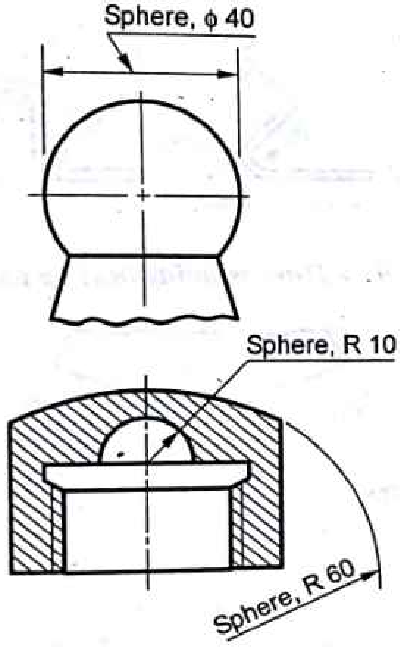


Fig. 9.60 Dimensioning radius of a spherical surface

3. Square. The symbol for square. See Fig. 9.61. The diameter and square symbols may be omitted where the shape is clearly indicated.

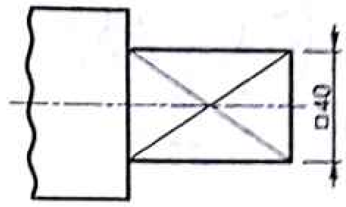


Fig. 9.61. Square symbol.

4. Holes. Location of holes would be dimensioned where possible in the plan view of holes, See Fig. 9.62.

The method of dimensioning holes on pitch circles is shown in Fig 9.63.

5. Bent-up parts. The method of dimensioning bent-up parts is shown in Fig. 9.64.

6. Chords, arcs and angles. Chords and arcs should be dimensioned as shown in Fig. 9.65 and angles should be dimensioned as Fig. 9.66, and the dimensions be so placed as to read from the bottom of the sheet.

7. Countersunk and counterbore. Fig. 9.67 and 9.68. show respectively dimensioning of a countersunk and counterbore hole. It is dimensioned by giving maximum diameter and the included single.

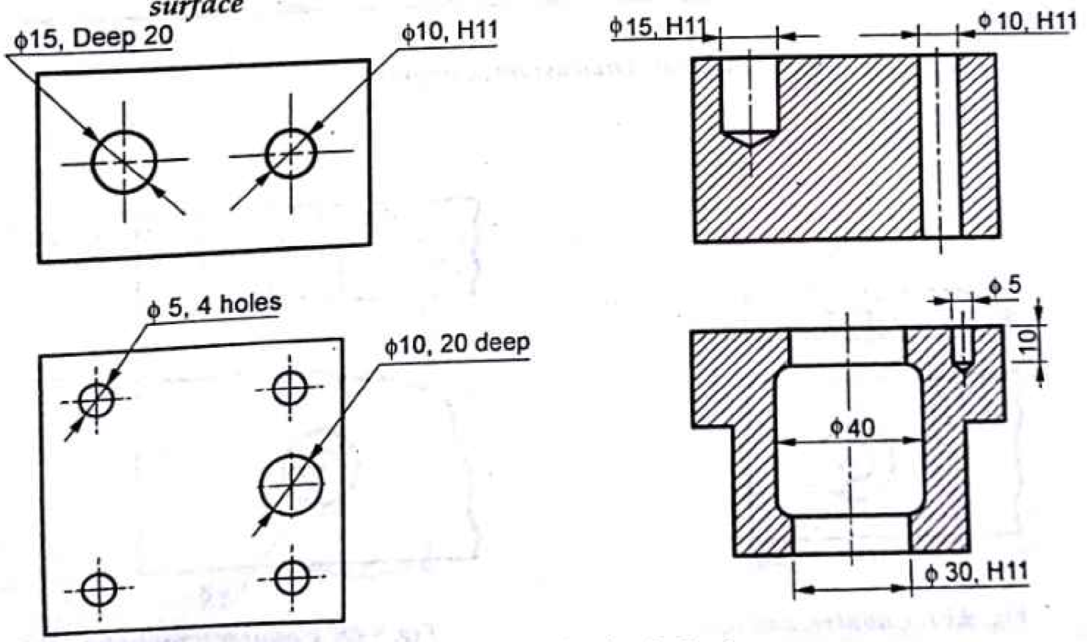


Fig. 9.62. Dimensioning hole sizes

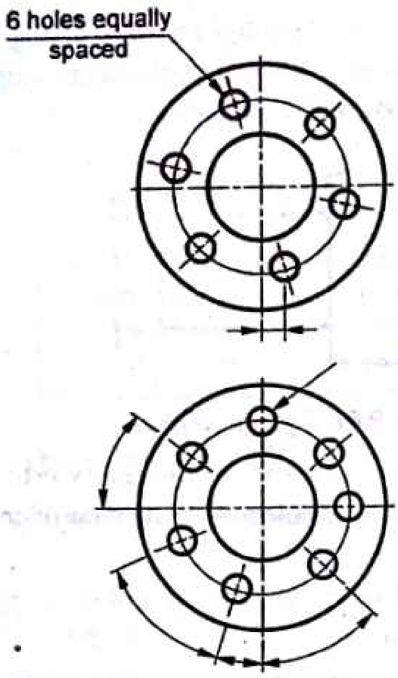


Fig. 9.63. Dimensioning holes on pitch circle

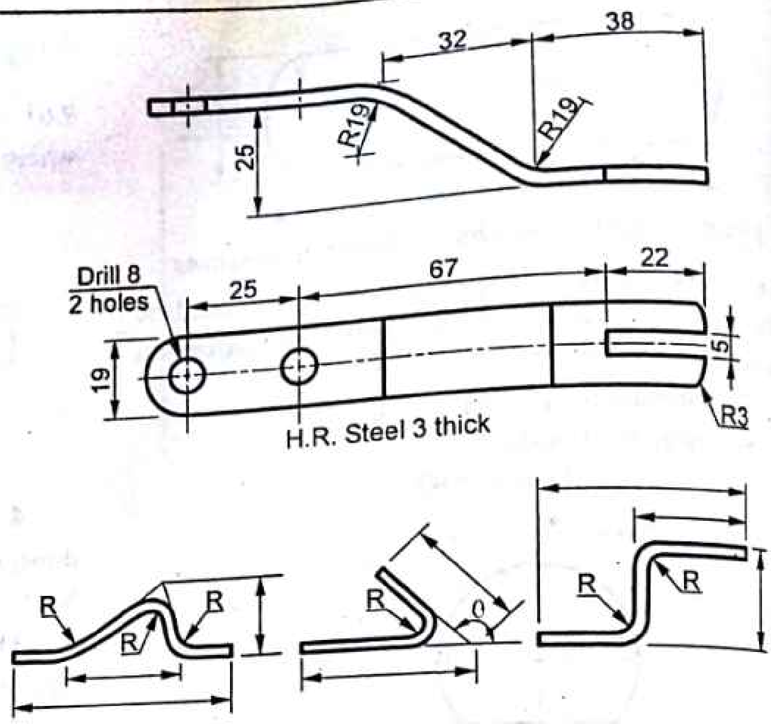


Fig. 9.64. Dimensioning bent up parts

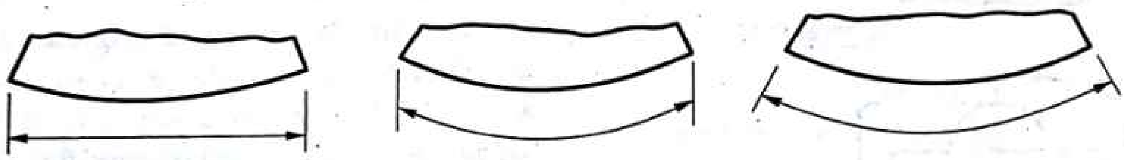


Fig. 9.65. Dimensioning chords and arcs

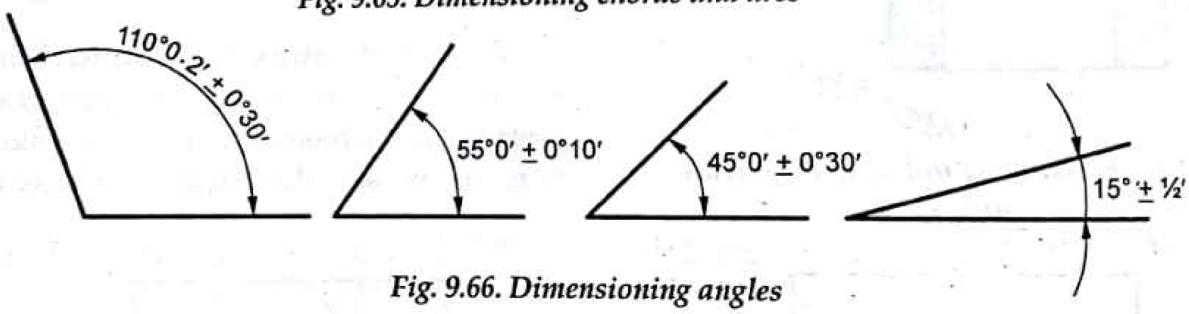


Fig. 9.66. Dimensioning angles

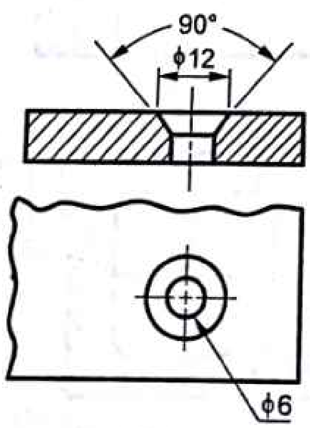


Fig. 9.67. Countersunk hole

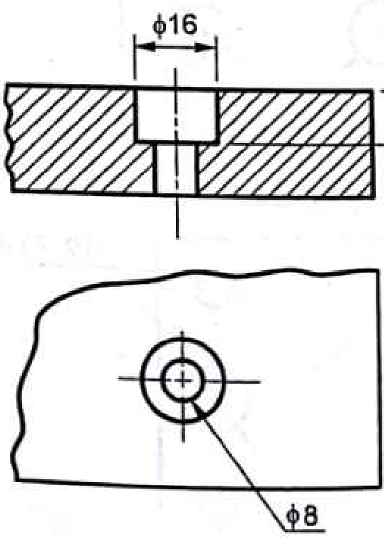


Fig. 9.68. Counter bore hole

8. Spot face. Fig. 9.69 shows dimensioning of a spot-faced hole.

9. Chamfer. Chamfer should be specified as shown in Fig. 9.70, 9.71 &72 by the length and angle on chamfer and not by a note and a leader.

10. Screw thread. A screw thread should be accompanied by a note stating its size and type. A metric screw thread is designated by the letter M followed by the diameter.

11. Taper. A taper is defined as unit alteration (in thickness or diameter) in a specific length measured along the axis in case of shafts and a base line or a centre line in case of flat pieces (see Fig. 9.73). Dimensioning of external taper is shown Fig. 9.74. Dimensioning of internal taper is illustrated in Fig. 9.75.

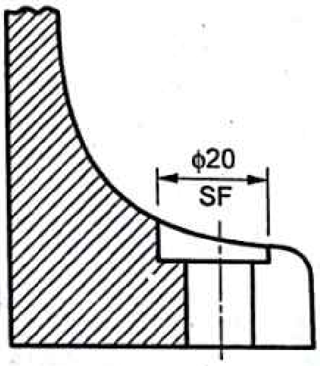
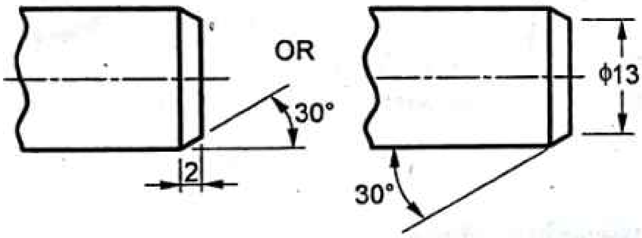


Fig. 9.69. Spot-face



9.70. Chamfers dimensioned

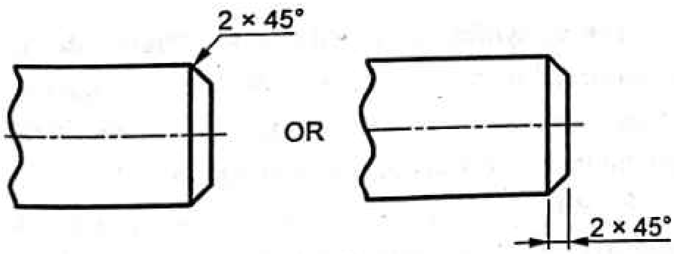


Fig. 9.71. Chamfers simplified

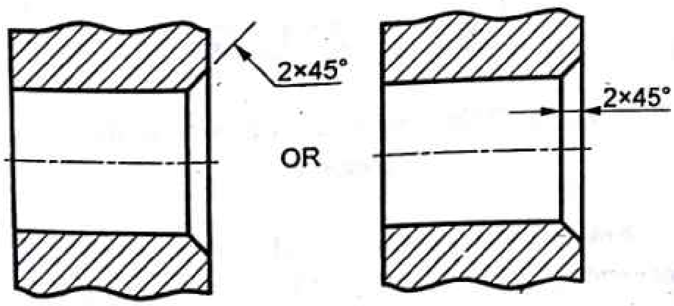


Fig. 9.72. Internal chamfers

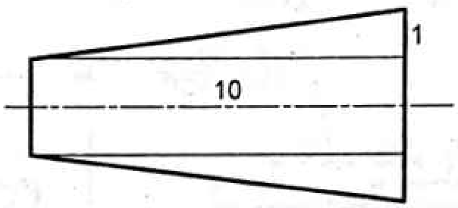


Fig. 9.73. Taper

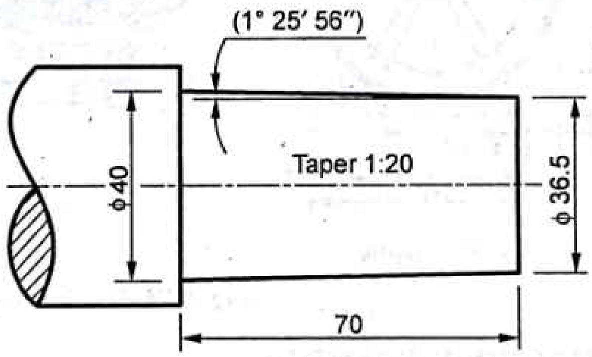


Fig. 9.74. Dimensioning of external taper

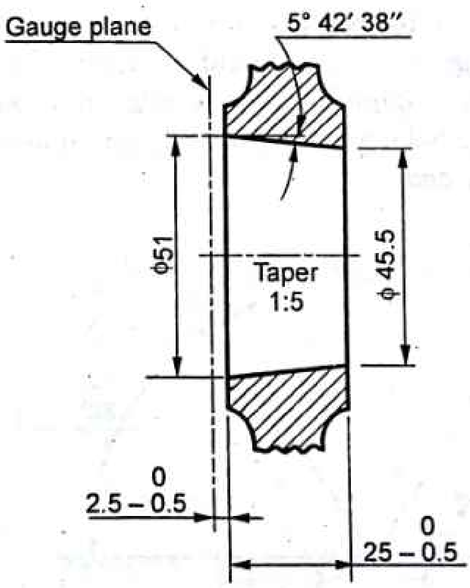


Fig. 9.75. Dimensioning of the internal taper.

9.8. DIMENSIONING OF ASSEMBLY DRAWINGS

Assembly drawings are made for the following purposes:

(*i*) One kind of assembly drawing is used for putting the machine or mechanism together. In this drawing part list of each detail is indicated by leaders from the number to the details to which they refer. A bill of materials with sizes of standard parts like bolts, nuts, rivets., is also given.

(*ii*) Another kind of assembly drawing is one which is used for planning of foundation and placing the anchor bolts. It may show the size and location of pulleys, shafting, piping, wiring, etc., for use in setting up the machine. Such drawings do not show the details of internal construction of the machine.

(*iii*) Yet another kind of the assembly drawing is used to show the space that the machine will occupy when set up. One example of assembly drawing is given in Fig. 9.76.

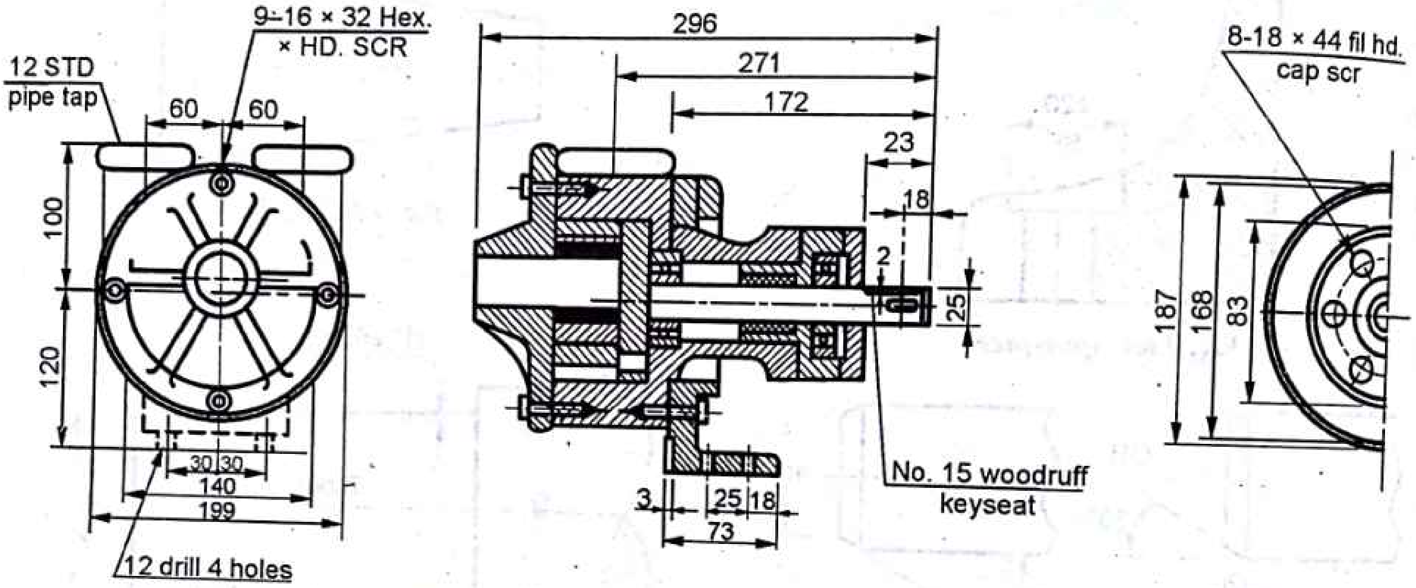


Fig. 9.76. Dimensioning of assembly drawing

9.9. MACHINING SYMBOL

(*i*) Wherever it is necessary to indicate that the surface is machined without either defining the grade of roughness or the process to be used, a symbol as shown in Fig. 9.77. (*a*) should be applied which represents in a simplified way the edge of a cutting tool. This symbol implies that a machining allowance shall be provided.

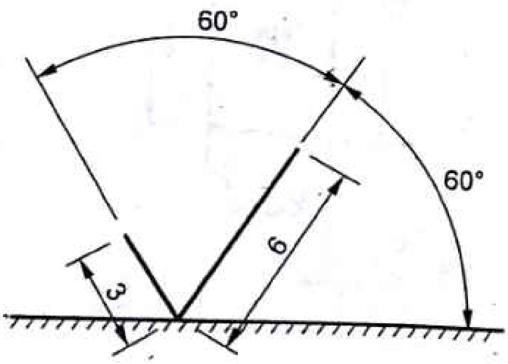


Fig. 9.77. (a) General machining symbol

The ✓ symbol is placed to read "right side up' when possible it is placed outside of the boundaries of the view rather than within. The use of the machining symbol should be avoided on dashed lines

(*ii*) Where all the surfaces are to be machined and stipulation on the surface finished is required, the symbol in Fig. 9.77 (*b*) may be used.

√ALL OVER

Fig. 9.77 (b) symbol for all surfaces to be machined

Note: Machining symbols, like dimensions, shoul not normally be duplicated and it is desirable that they ma be placed on the size or location of the surface concerne

13 Rivets and Riveted Joints

13.1. FASTENINGS

In engineering practice fastenings are used to join together parts in machines or structures. The fastenings may be of the temporary nature which can be unfastened easily without breaking anything or of permanent nature where the fastening has to be broken to separate the two joining parts. Both types of fastenings find extensive use in engineering.

(*a*) **Temporary fastenings.** Examples of temporary fastenings are bolts and nuts, studs and nuts, keys, cotters, pins, etc. They are used in shaft couplings, machine parts and temporary structures. Screwed fastening like bolts and nuts, and keys, cotters or pins can be easily removed by light hammering

(*b*) **Permanent fastenings.** Examples of permanent fastenings are soldering, brazing, welding and riveting. Soldering and brazing are used where less strength is required and welding or riveting where more strength is required. Rivets are used in structural works like roof trusses, bridges, ship building, aircraft work and in pressure vessels like boilers, air receivers and hydraulic tanks. A riveted joint cannot usually be dismantled without destroying the rivet. Riveting is however, being replaced in many of these fields by welding as the latter is more economical and stronger.

13.2. RIVETS AND METHOD OF RIVETING

A rivet is made of round wrought iron or steel bar with cup or other shaped head on one side formed by dies in special machines. Fig. 13.1 shows a snap head, a cylindrical body or shank and a slightly tapered tail. Fig. 13.2 show forming another rivet head out of the tail. A rivet is specified by the diameter of the shank and length and type of head.

In the past wroght iron was used for rivets. Now a days mild steel rivets are universally used. The B.I.S. recommends that rivets shall be manufactured from steel conforming either to IS 1148-1957, Specifications for Rivet Bars for Structure Purpose, or to I.S. 1149-1957 'Specifications for High Tensile Rivet Bars for Structural Purposes'. The rivets of copper and aluminium are also used for special applications. The basic requirement of rivet material is that it should be ductile.

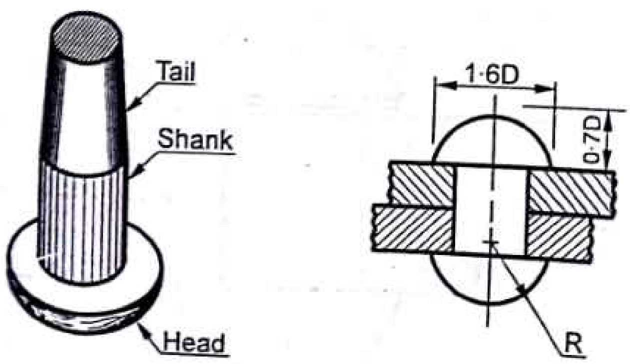


Fig. 13.1 Snap head rivet in critical form

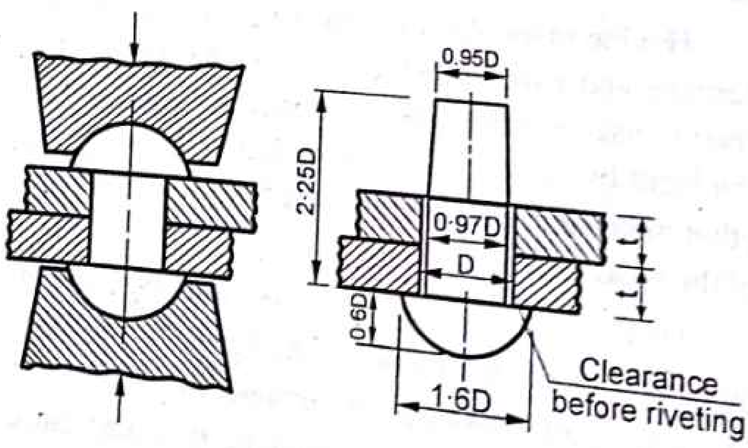


Fig. 13.2. Making the rivet head

A rivet may be made either by cold heading or by hot forging. In boiler work riveting is always done hot whereas in aircraft work riveting is usually done cold. If rivets are made by the cold-heading process, they shall subsequently be adequately heat-treated so that the stresses set up in the cold heading process are eliminated. If they are made by hot-forging process, care shall be taken to see that the finished rivets cool gradually. The rivets shall be clearly finished with heads concentric with the shanks they shall be free from imperfections and heavy scales. The ends of rivets shall by square, cleanly sheared and free from rag or burr.

Method of riveting. First of all the holes required in the plate for inserting the rivets are punched or drilled. In punching, the spacing and alignment of holes are very imperfect and holes are generally forced in agreement by hammering a conical drift into them. This may reduce their cross sectional area. Besides the metal round the hole is injured by the lateral flow of the metal under the pressure of the punch. Therefore, the practice of making holes by punching has almost been superseded by drilling.

For drilling holes the two plates to be joined are first "tacked", *i.e.* clamped together by a few bolts on seam (edge) and then the holes are drilled in both the plates simultaneously. This removes the danger of misalignment. After drilling "burrs" left may be removed by slight countersinking. The size of the hole is 1 mm greater than the size of the rivet for rivet diameters upto 24 mm, 1.5 mm greater than the size of rivet for rivet diameters 27 mm to 36 mm, and 2 mm greater for rivet diameters 39 mm and bigger than 39 mm. This is to allow for expansion when rivet is heated.

Having made the holes the rivets are heated in a furnace and carried to the plates to be joined. The rivet is inserted in the hole. One man holds and presses the head by means of a tool, called dolly, while the other man hammers the end of the body into the shape of the head (see Fig. 13.2).

This hammering may be done either by hand or by pneumatic or hydraulic machine. In machine riveting steady pressure is maintained which fills the holes in the plate more completely. It is also more rapid and economical. Therefore in large works machine riveting is always preferred. The length of body required to form a cup or a conical head is about 1.25 d and to form a countersunk head about 0.9 D, where D is the diameter of the rivet. The length also depends upon whether the head is formed by hand or machine; the machine riveting requires about 0.13D more length than hand riveting as the machine compresses and swells the rivet till it completely fills the hole, thus making a perfect job. This avoids bending of rivet under load. When they cool, rivets tends to pull the plates more closely together.

A riveted joint is a permanent fastening and can only be separated by chipping off the head of the rivets.

Note: Rivets are generally used in shear whereas bolts are generally used in tension.

13.3. CAULKING AND FULLERING

In pressure vessels like boilers we require a steam tight joint. This cannot be achieved however carefully the riveting is made unless an additional operation, *caulking or fullering* is resorted to. Caulking is an operation of burring down the edges of the plates and heads of the rivets to form a metal to metal joint as shown in Fig. 13.3. It is done by a tool of the shape of a flat-ended cold chiesel about 5 mm thick at the end and of 40 mm breadth, the edge ground to an angle of 80^0 to horizontal to facilitate this operation. Both internal and external caulking is done in many cases. Care should be taken not to damage the plate below the tool or spring the joint open.

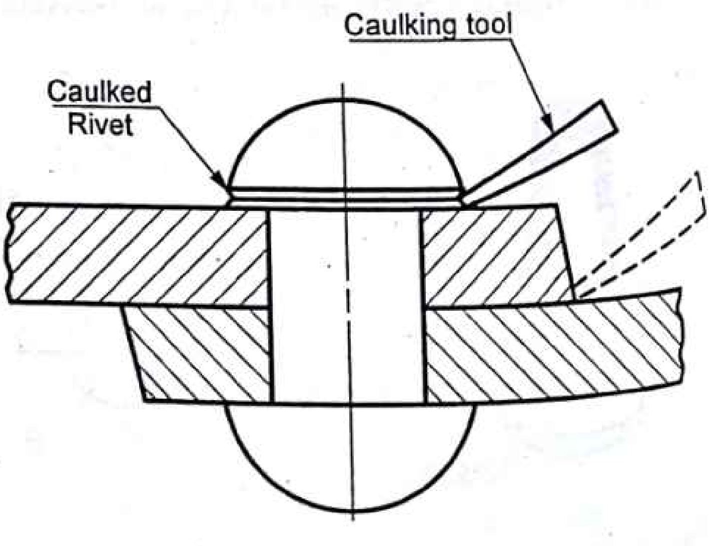


Fig. 13.3. Caulking

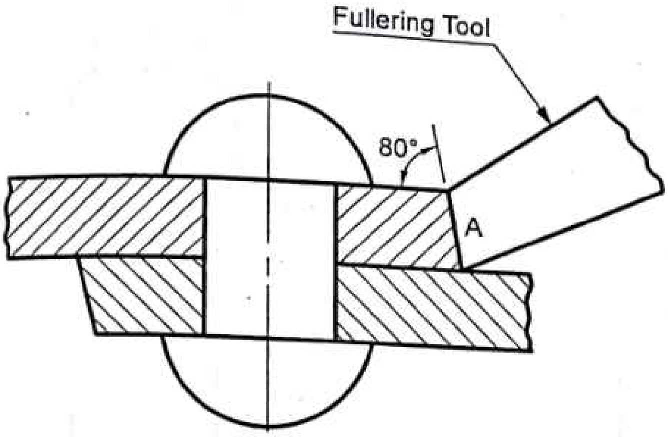


Fig. 13.4 Fullering

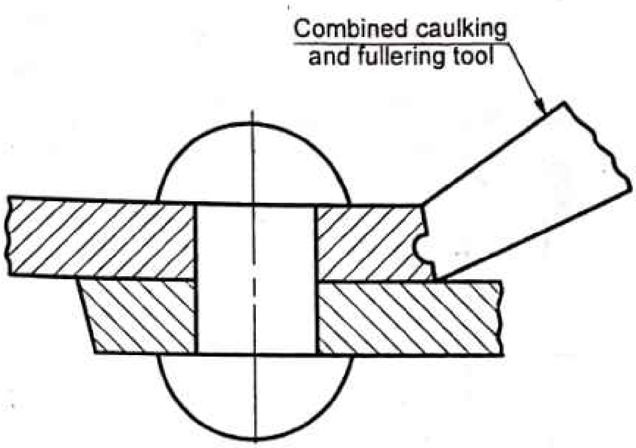


Fig. 13.5. Combined caulking and fullering

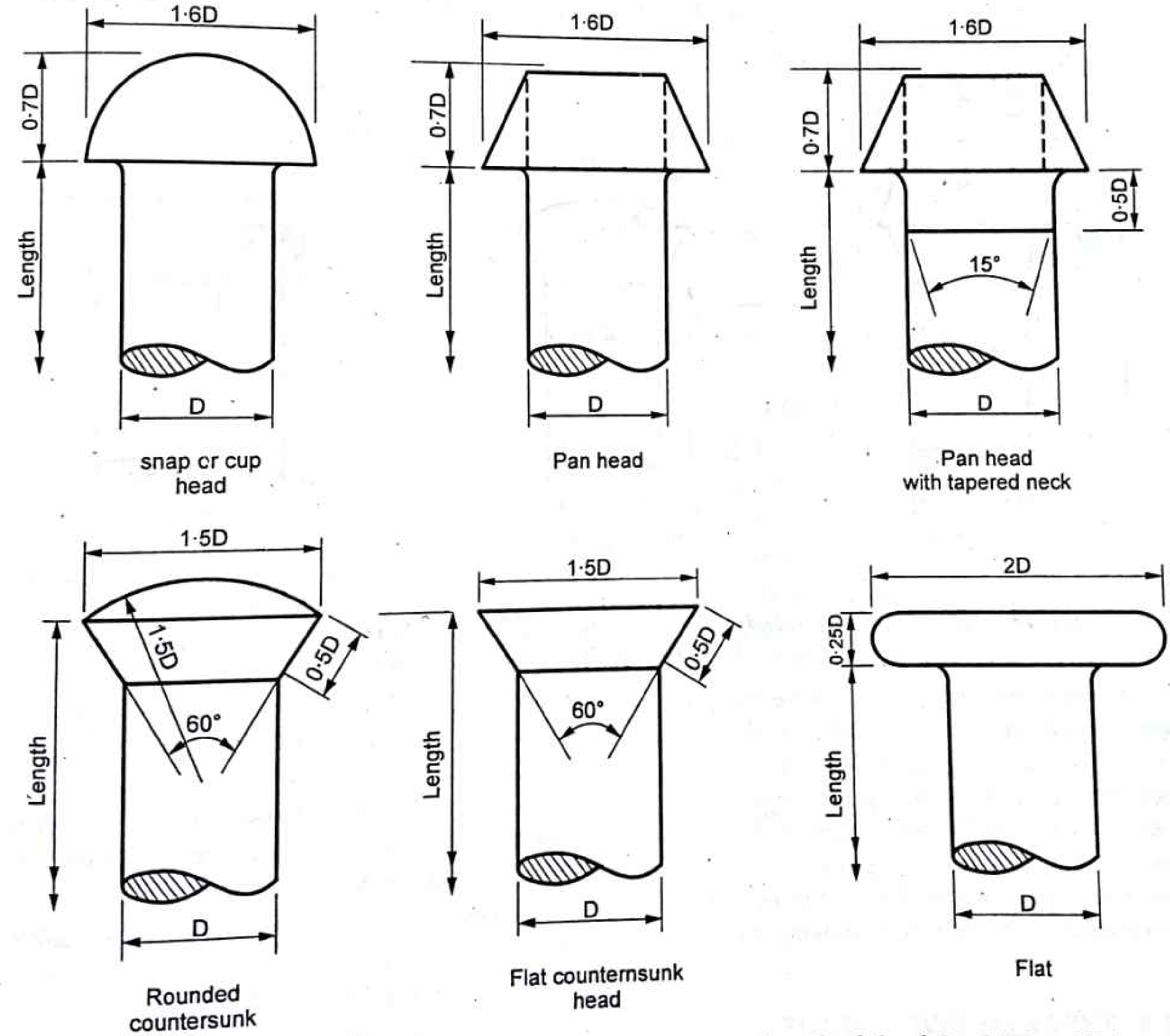


Fig. 13.6(a) Indian Standard rivet heads for general purposes (length of shank L = 2.5D to 10D) (see I.S. : 1929 and I.S. : 2155 for preferred length combination)

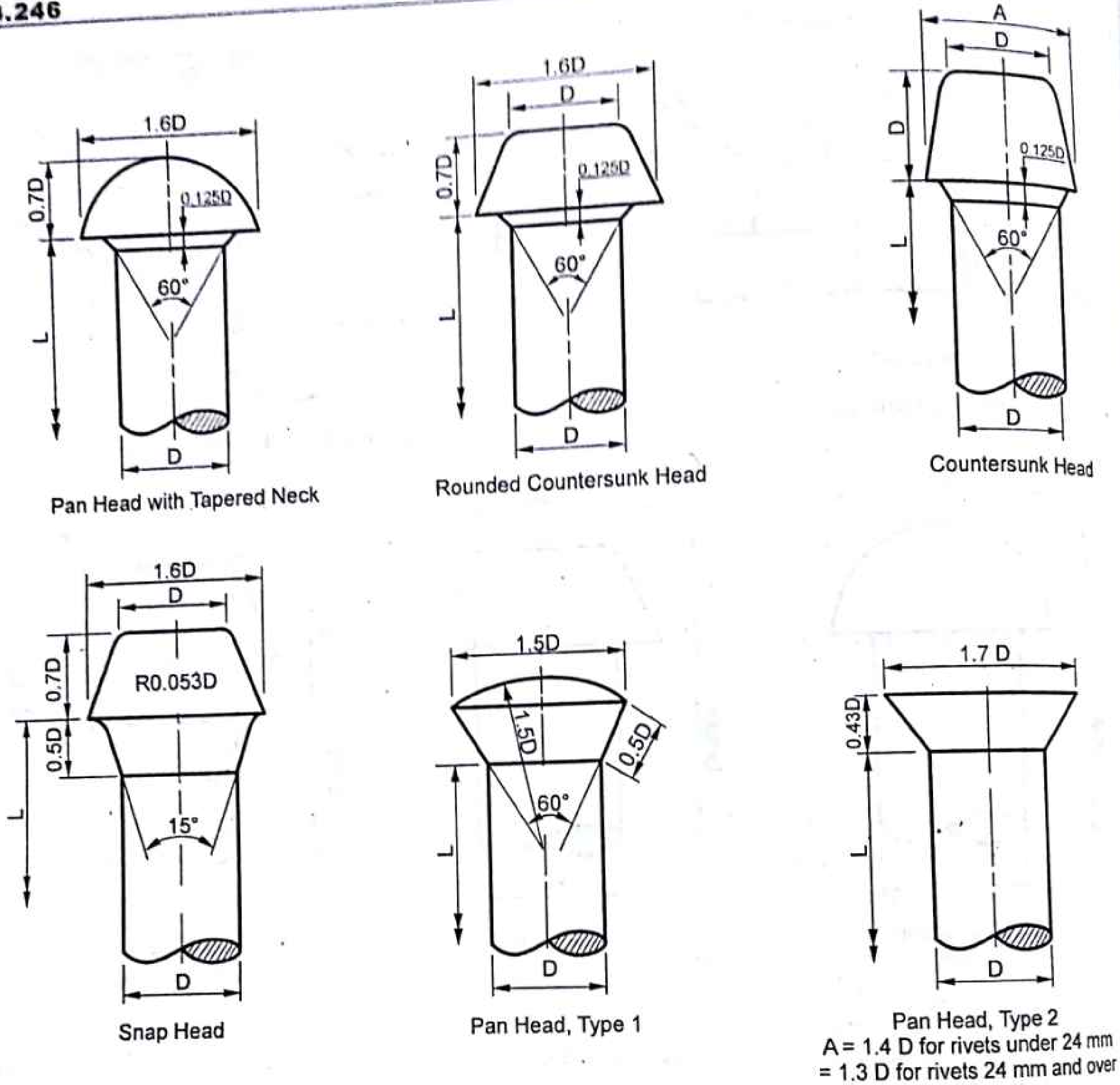


Fig. 13.6 (b) Proportions of Indian Standard boiler rivets L = 2.5D to 7D (see I.S. : 1928 for preferred length and diameter combination)

A better fluid tight joint can be made by the operation known as fullering which is shown in Fig 13.4. It has largely replaced caulking. The fullering tool, having thickness at the end equal to that of plate, is used in such a way that the greatest pressure due to blow occurs at A giving a clean finish with less risk of damaging the plate. Fig. 13.5 show a tool which combines the features of both caulking and fullering.

13.4. TYPES OF RIVET HEADS

The forms of rivets heads specified by B.I.S. are shown in Fig. 13.6. Fig. 13.7 (*a*) shows the method of drawing a snap head. Fig. 13.7 (*b*) shows the rough method of drawing snap head quickly. Note that a snap head is not shown as a semicircle.

A rivet head is designated as follows : A pan head rivet of 6 mm diameter and length 30 mm :

Pan head rivet 6 × 30 I.S. : 2155.

Riveted joints in common use can be classified as :

(*i*) structure joints (see IS : 1929)

(*ii*) boiler joints (see IS : 1928)

The following are the important shape of rivet heads :

1. Snap or Button head. It is the most common shape with machine riveting and used in structural work. It is easily shaped.

2. Pan head. It has maximum strength but is difficult to shape. Pan head rivet on opposite generally has a snap head Fig. 13.7 (*a*).

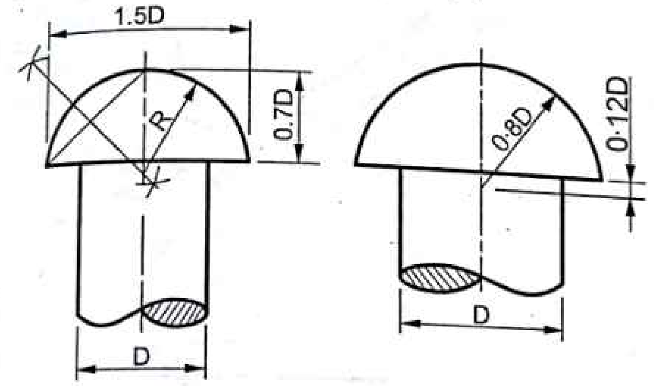


Fig.13.7 (a) Locating centre for arc of a snap head

Fig. 13.7 (b) Drawing of a snap head approximately.

3. Conical head. In confined positions where it is not possible to snap the heads they are finished by harmmering to the conical form. It is not as strong as the snap head. A hammer weighing 4 to 5 kg may be used for shaping the conical head whereas a 8 kg hammer is required for shaping the snap head.

4. Countersunk head. It is used where flush surfaces are necessary as in ship building and the seating of girders. It is the weakest and the least reliable of all shapes. Countersunk head rivet may have a snap head or countersunk head on the opposite end.

5. Flat head. Flat head is used where the projecting head of the rivet is objectionable. It is also a weak rivet.

6. Tubular rivet. See Fig. 13.8. 'Blind tubular rivets are used when access is restricted to one side only of metal sheets to be joined. The tubular rivet is a hollow rivet. It is preassembled on to a mandrel. For riveting operation it is inserted into a drilled hole.

Then the mandrel is pulled by a special tool deforming the rivet. At predetermined point the mandrel breaks when the joint is tight.

Structural rivets are used for structures and are standardized from 12 to 48 mm diameter. Boiler rivet, used for boiler work, are generally provided with

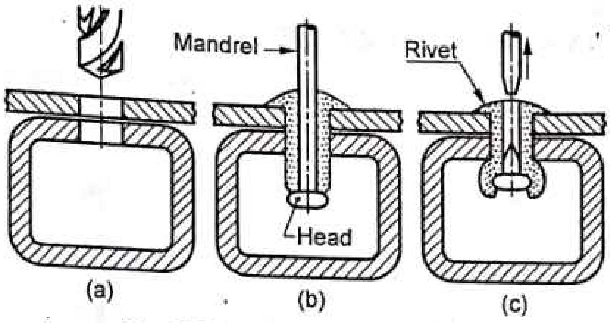


Fig. 13.8. Tubular (hollow) rivet

chamfer of 60° for steam tightness. They are standardized from 12 to 48 mm diameter. Small rivet are used for general purposes and are standardized from 1.6 to 10 mm diameter and may be made of steel, copper, brass or aluminium. See Table 13.1.

Table 13.1. Standard diameter of rivets

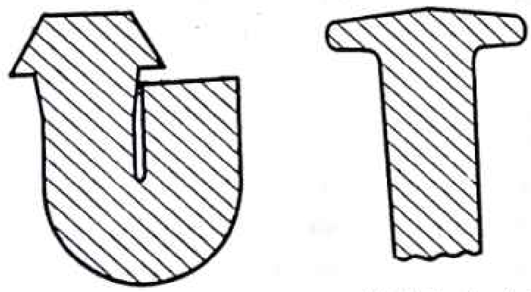
Type of rivets	*Standard diameter*
1. General purpose rivets below 12 mm diameter	1.6, 2, 2.5, 3, 4, 5, 6, 8 and 10 mm
2. General purpose and boiler rivets 12-48 mm diameter	12, 14, 16, 18, 20, 22, 24, 27, 30, 33, 36, 39, 42, and 48 mm

Note: Corresponding rivet hole diameters:
13, 15, 17, 19, 21, 23, 25, 28.5, 31.5, 34.5, 37.5, 41, 44, 50

13.5. TESTING MANUFACTURED RIVETS

1. Bend Test. The rivet shank is bent cold and hammered until the two parts of the shank touch in the manner shown in Fig. 13.9 (*a*). There should be no fracture on the outside of the bend.

2. Flattening Test. The rivet head is flattened, while hot, in the manner shown in Fig. 13.9 (*b*). The head is flattened until its diameter is 2.5 times the diameter of the shank. There should be no cracking at the edges.



(a) Bend test *(b) Flattening test*

Fig. 13.9. Testing manufactured rivets

13.6. RIVET SYMBOLS

The B.I.S. recommends the rivet symbols as shown in Fig. 13.10.

Shop snap-headed rivets
Shop Csk (near side rivets)
Shop Csk (far side) rivets
Shop Csk (both side) rivets
Site snap-headed rivets
Site Csk (near side) rivets
Site Csk (far side) rivets
Site Csk (both side) rivets
Open hole

Fig. 13.10. Rivet symbols

13.7. TYPES OF JOINTS

Riveted joints may be classified in two types :-

(*a*) Lap joint. In lap joints one plate overlaps the other and in drawing are shown in different planes. All the rivets pass through both plates. The joint is known as *single riveted* if there is one row of rivets, as shown in Fig. 13.11, *double riveted* if there are two rows of rivets as shown in Fig. 13.12 (*a*) and (*b*), and so on.

Important note : Rivets are not sectioned as they have standard shape and no extra details are shown by sectioning.

(*b*) Butt joint. In butt joints the ends of the main plates butt up against each other and may be considered as lying in the same plane. One or two strap or cover plates are placed over the joint and riveted to each plate. If there is one cover plate it is known as single strap butt joint as shown in Fig. 13.13. If there are two cover plates it is known as double strap butt joint, as shown in Fig. 13.14. Butt joints are stronger than lap joints and are generally used for joining thick plates.

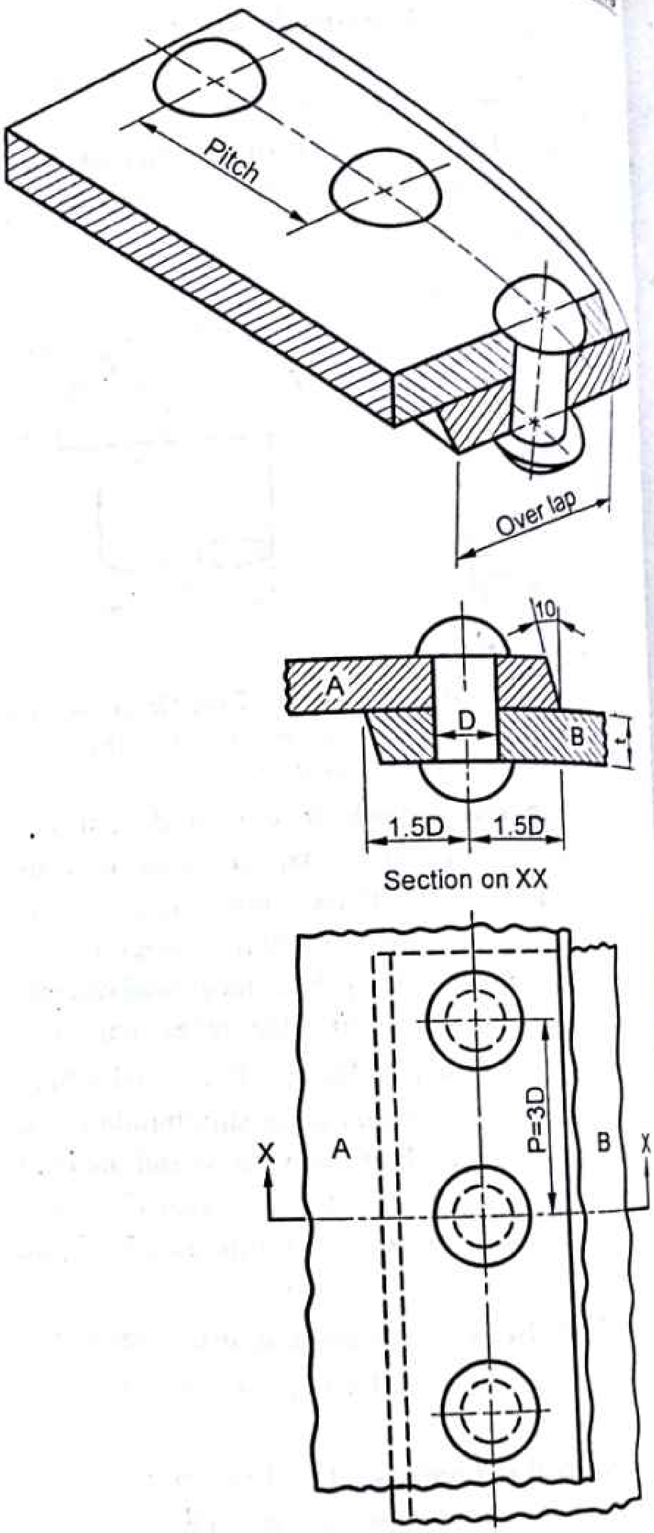


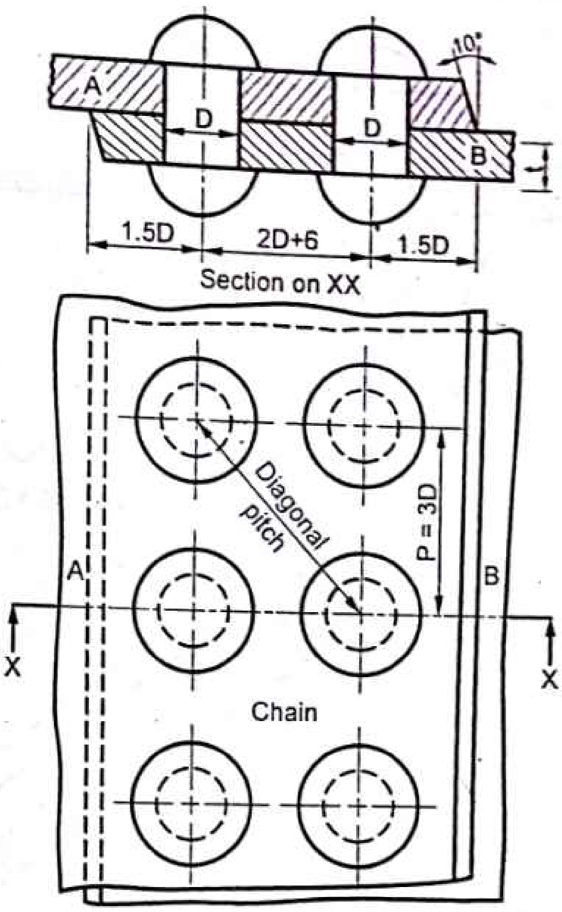
Fig. 13.11. Single riveted lap joint

In practice generally two cover plates are used one on either side of the main plates.

A butt joint may be single riveted as in Fig. 13.15, double riveted as in Fig. 13.16, and so on, depending on the number of rows of rivets in each of the main plates.

Important note : In Fig. 13.16 the elevation has been drawn with section at XX and only outer rows of rivets are cut and hence in elevation the inner two rows of rivets are shown by dashed. Lines'

Fig. 13.17. shows a combined lap and butt joint, which is occasionally used in locomotive boiler work.



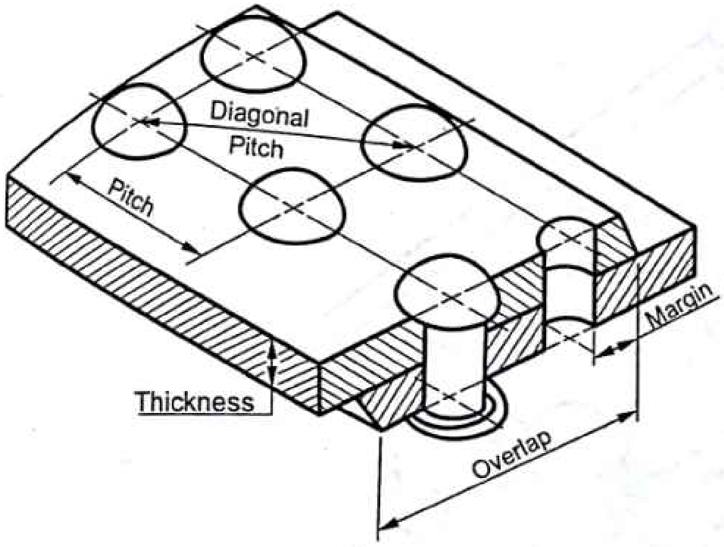
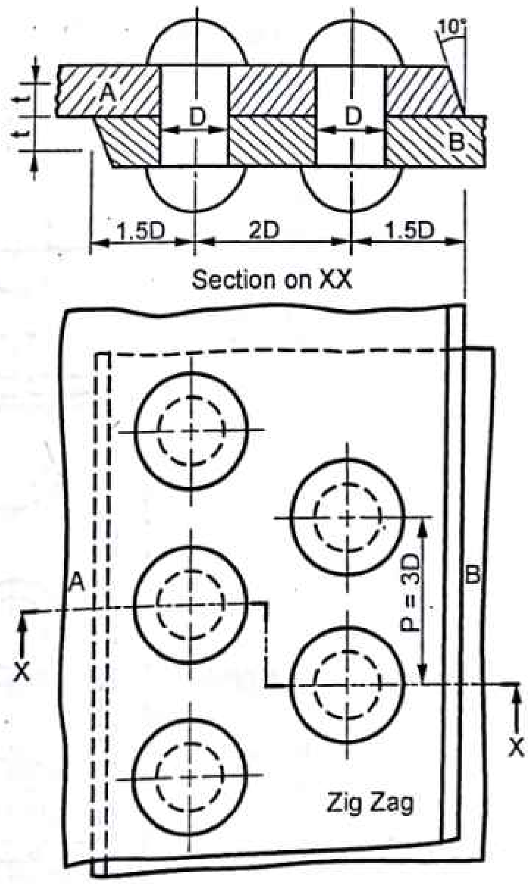


Fig. 13.12 (a) Double riveted lap point, chain riveting

13.8. DEFINITIONS

The terms associated with riveted joints are defined below.

1. Pitch. Pitch., p, is the distance from the centre of one rivet to the centre of the next rivet in the same row measured parallel with the seam (see Fig. 13.11 and Fig. 13.12).



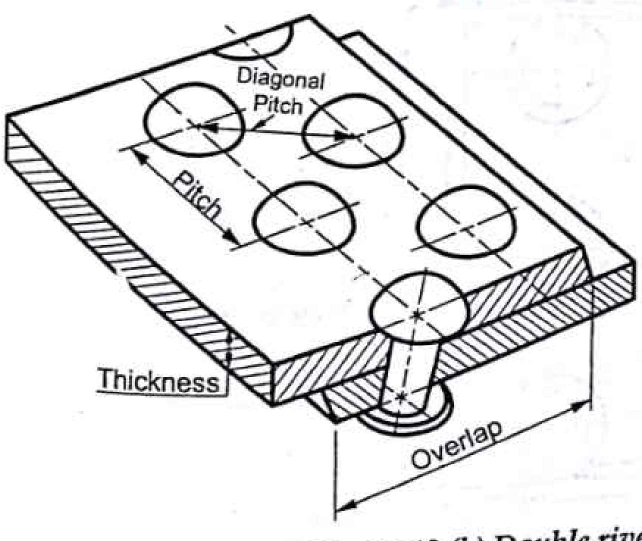


Fig. 13.12 (b) Double riveted lap point zigzag riveting

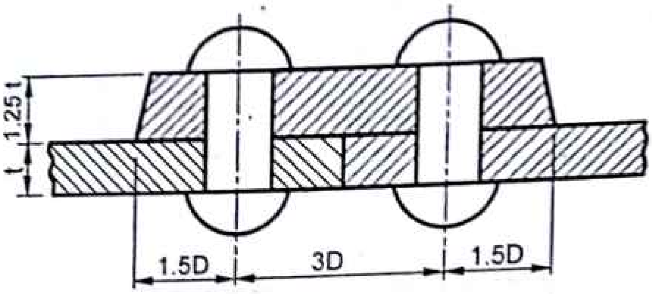


Fig. 13.13 Single strap butt joint

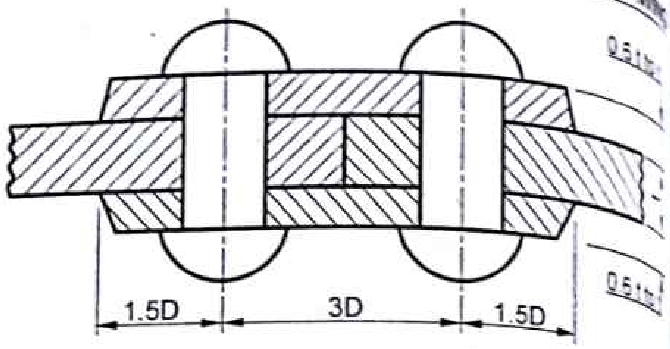


Fig. 13.14. Double strap butt joint

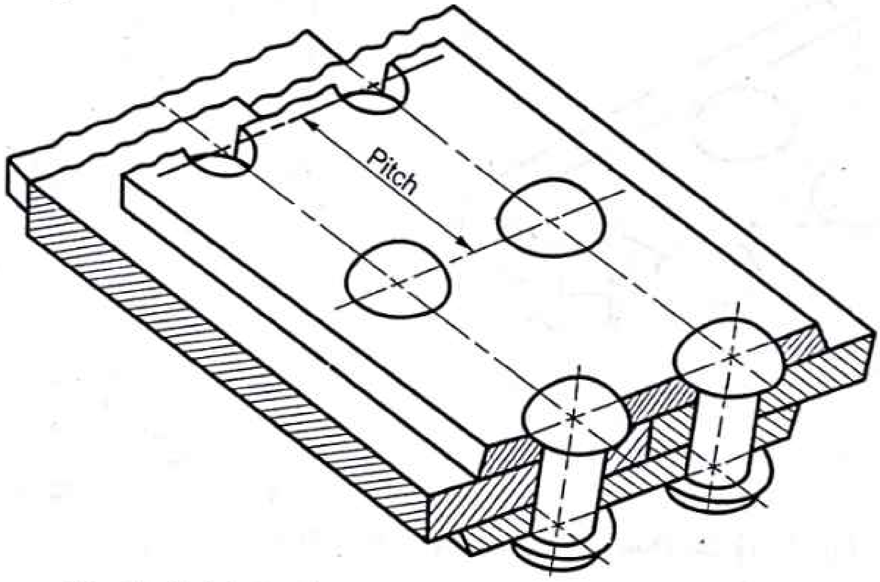


Fig. 13.15 (a) Single riveted butt joint, double cover plate

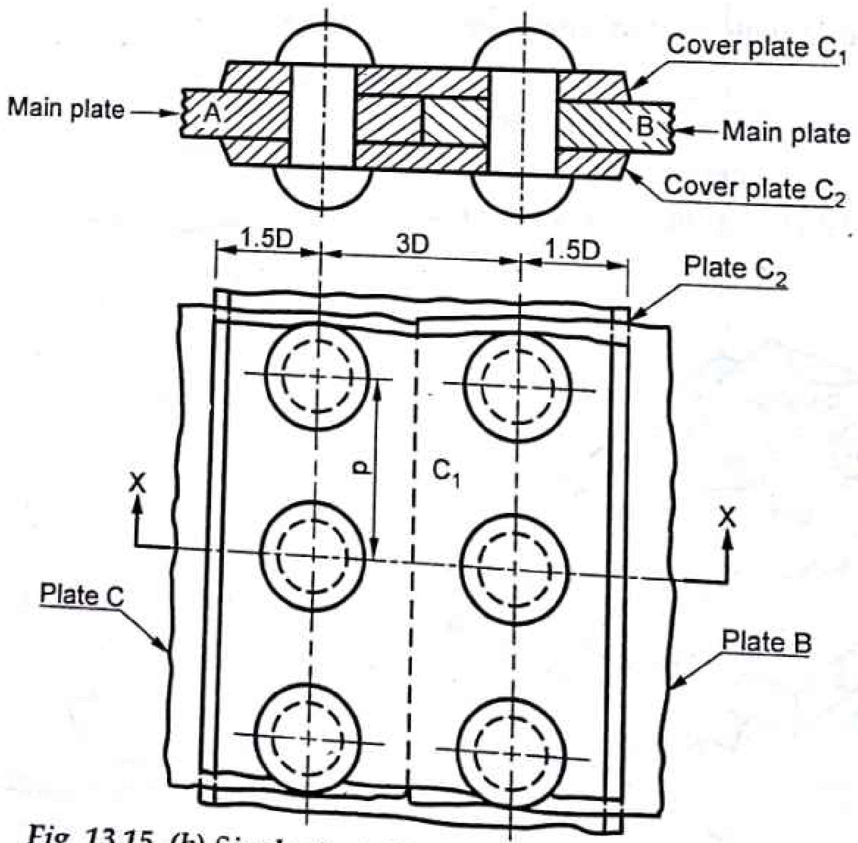


Fig. 13.15. (b) Single riveted butt joint, double cover plate

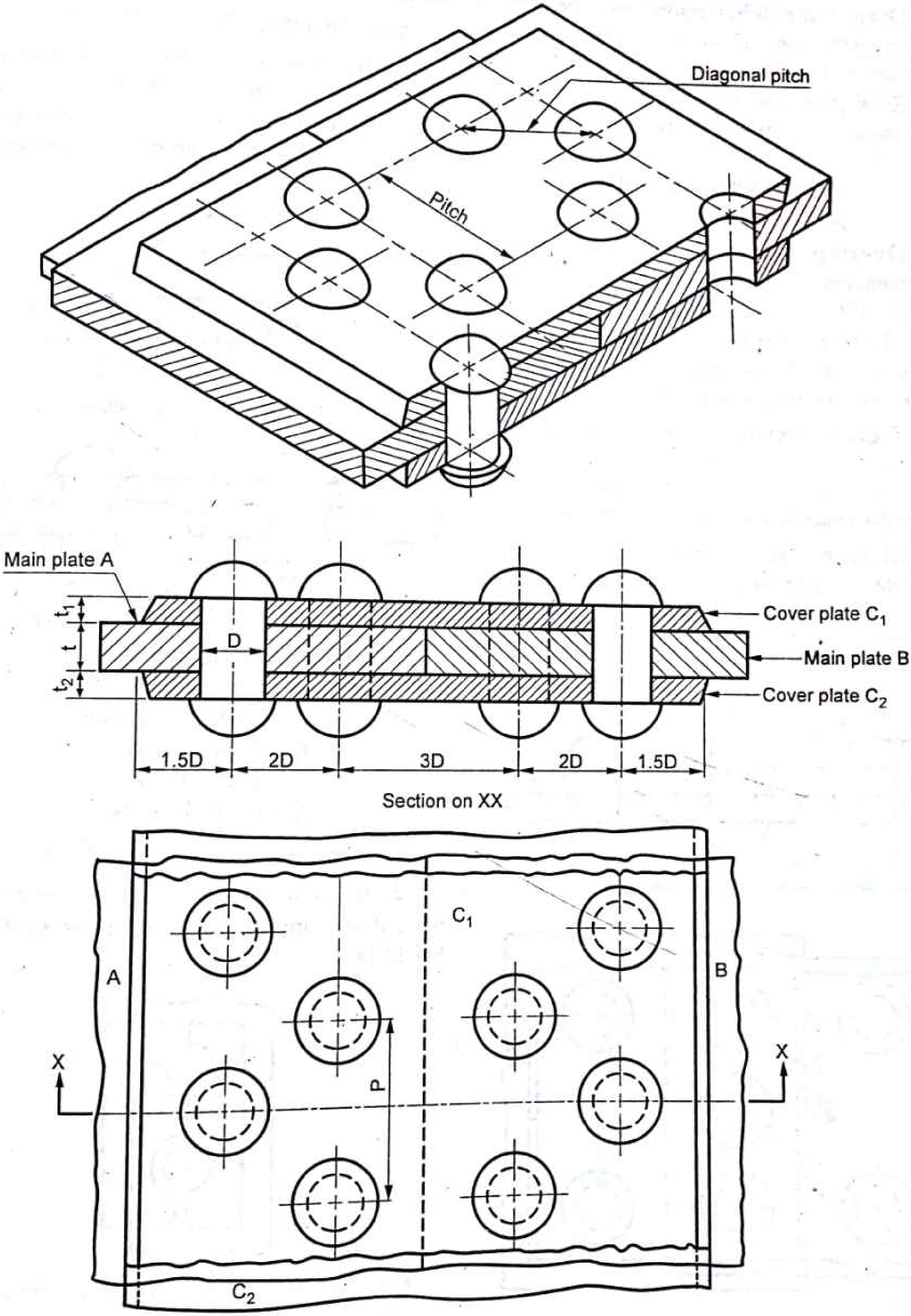


Fig. 13.16. Double riveted butt joint, double cover plate, zigzag riveting

2. Diagonal pitch. Diagonal pitch, pd, is the distance from the centre of one rivet to the centre of the next rivet in the adjoining row (see Fig. 13.12).

3. Row pitch. Row pitch, pr, is the distance between the adjacent rows of rivets in a multi-riveted joint.

pr = 0.6p, for zigzag riveting

pr = 0.8 p for chain riveting

4. Overlap. In lap joints the overlap of two plates (minimum 1.5 D + 1.5 D) is known as overlap (See Fi.g 13.12).

5. Chain riveting. If the rivets on the same plate are arranged directly opposite each other it is known as chain riveting as in Fig. 13.12 (*a*).

6. Zigzag riveting. If the rivets on one plate are arranged zigzag, *i.e.*, rivets in one row are placed facing between the two rivets of other row it, is called zigzag or diagonal riveting as in Fig. 13.13. and 13.17.

7. Margin. The distance between the edge of the plate and rivert hole is called margin "*m*" see Fig. 13.12 (*a*). As $m = d$ the distance of the centre line of the nearest row of rivets from the edge of the plate is equal to 1.5 *d*.

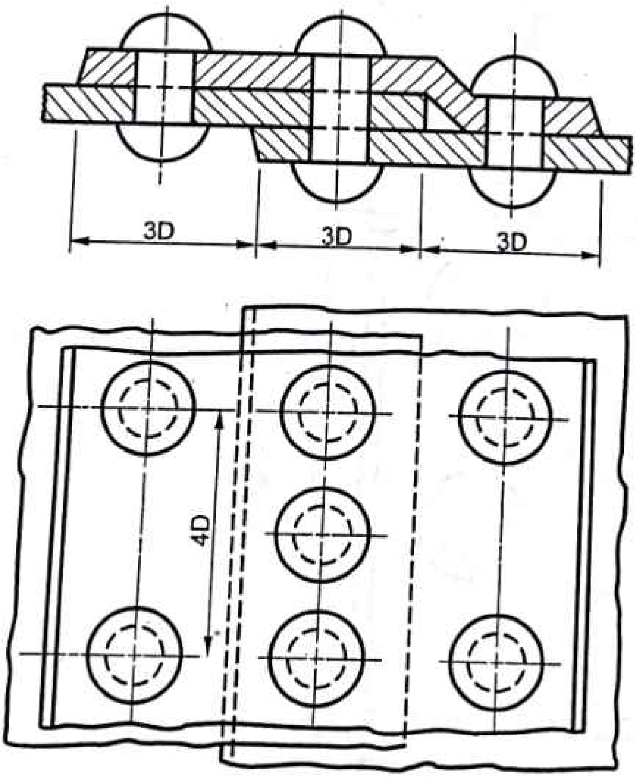
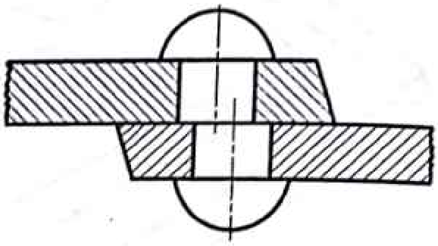


Fig. 13.17. Combined lap and butt joint

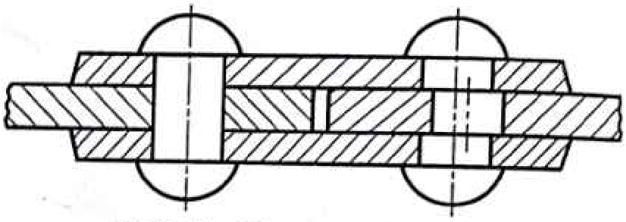
13.9. FAILURE OF RIVETED JOINTS

A riveted joints may fail in four ways.

1. By *shearing of rivets*, if the diameter of the rivets is smaller than necessary. A rivet is in single shear in a lap joint and single strap butt joint, and is in double shear in double strap butt joint, as shown in Fig. 13.18.



(a) Rivet in single shear



13.18 (b) : Rivets in double shear

d = diameter of rivet

p = pitch of rivets

t = thickness of plate

f_1 = tensile stress

f_s = shear stress

f_c = crushing stress

Rivet resistance to shear = $\frac{\pi}{4} d^2 \times f_s$

2. *By the tearing of plates between the rivets holes* if they are very near each other, as shown in Fig. 13.19.

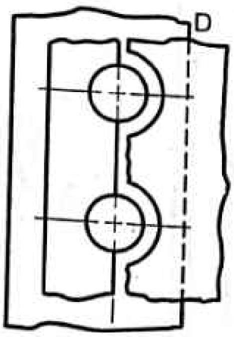


Fig. 13.19. Tearing of the plate between rivets

Plate resistance to tension

$= (p - d)\, t \times f_t$, ...(13.2)

3. *By the crushing of the rivets or the plate* by compression making the joint loose, as shown in Fig. 13.20.

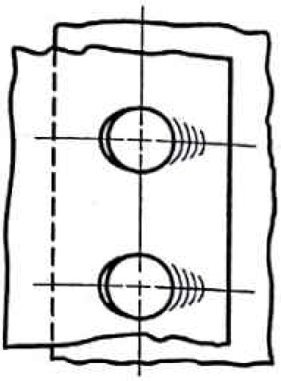


Fig. 13.20. Crushing of the rivets and plates

Resistance to crushing

$$= d \times t \times f_c \qquad ...(13.3)$$

4. By the tearing of the plate between its edge and the rivet holes, as shown in Fig. 13.21.

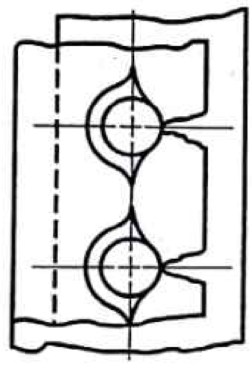


Fig. 13.21. Tearing of plate between its edge and rivet holes

In addition to the above failures rivets may bend if too long or the plates may be deformed without fracture as discussed later.

13.10. EMPIRICAL PROPORTIONS

To avoid the failure of riveted joints by the above causes the following empirical proportions based on experience are taken which ensure a safe joint.

1. Rivet diameter and plate thickness

$$d = 6\sqrt{t}$$

where t is the thickness of the main plate in mm. This avoids shearing and crushing of rivets.

The other empirical relation is

$$d = 3\sqrt{t} + 10 \text{ mm}$$

2. Pitch. Pitch is determined by consideration of strength. The minimum value of pitch is that which would permit the formation of heads. Too small pitch may cause tearing of the plate between the rivets. Too large pitch will make the joint loose. Pitch is generally taken as $3d$. In structural joints maximum pitch is kept $16t$. However, in boiler joints maximum pitch is kept $8t$ for steam tightness.

3. Diagonal pitch. The diagonal pitch is given by

$$pd = \frac{2p + d}{3}$$

4. Minimum perpendicular distance between rows of rivets or row pitch (pr). For drawing work it may be taken as follows :

Type of riveting	In terms of d	In terms of p
In chain riveting	$2d + 6$ mm	$0.8\,p$
In Zigzag riveting	$2d$	$0.6\,p$

These minimum values allow formation of heads. In zigzag riveting pr can be taken less which explains its advantage over chain riveting. In chain riveting overlap is reduced.

5. The distance from the centre of the rivet hole to the nearest edge of the plate (I). It is kept minimum 1.5 d (margin d), so that the plate may not split.

6. Thickness of cover plates or straps. For equal strength the thickness of single cover plates in a butt joint may be taken equal to the main plate, but it is taken slightly more, $1.125t$, so that the joint may not fail due to cover plate. When two cover plates are used the thickness is divided between the two and each plate thickness, t_2, is taken 0.7 t to $0.8t$.

For convenience, the empirical proportion for riveting are tabulated in Table 13.2. All dimensions are in mm.

Table 13.2. Empirical proportions for riveting

$$d = 6\sqrt{t} \ \text{ or } \ 3\sqrt{t} + 10 \text{ mm}$$

$$p = 3d, \qquad m = d$$

$$l = 1.5d, \qquad pd = \frac{2p + d}{3}$$

pr = perpendicular distance between rows of rivets.
pr in chain riveting = $2d \pm 6$ mm or $0.8\,p$
pr in zig-zig riveting = $2d$ or $0.6\,p$
$t_1 = 1.125\,t$, if single strap
$t_2 = 0.7$ to $0.8\,t$, if double strip

Table 13.3 gives the diameter of rivets for different thickness of plates.

14 Welded Joints

14.1. INTRODUCTION

Welding is, like riveting, a method of making permanent joint. It is a process of uniting two pieces of metal by fusing them together. This may be done with or without additional (filler) metal and with or without the application of pressure. Welding is being used for ever increasing variety of mechanical and structural purposes such as building up and fastening parts together. Welding has displaced riveting in many industries because of savings in labour as well as material and reduction in weight by the use of lighter plates and the elimination of all overlaps and rivets. Sheet metal work such as tanks and other containers can be simplified by welding instead of riveting the joints. Fabrication by welding is now commonplace. Standard steel shapes, plates and bars may be welded together to make machine frames, bases, jigs and fixtures, and so forth. For joining of very high pressure steam pipe, welding is the only acceptable process.

Cast iron, steel and iron alloys, brass, copper and aluminium are metals that can be welded.

The aircraft, automotive and ship building industries have developed welding as a major fabrication method for aluminium and magnesium as well as for steel.

14.2. WELDING PROCESSES

The two basic welding processes are *fusion welding and pressure welding.*

Fusion welding. It makes use of welding material in the form of a wire or rod which is added to the weld. The composition of the welding rod is almost the same as that of the parts to be welded. These filler rods combine with the metal being welded.

Gas or *electric arc* is used to create the heat so that the metals flow together (become plastic).

Gas welding. In this fusion process heat is provided by burning a gas (acetylene, propane or hydrogen) mixed with oxygen. A welding torch is used for this purpose. Gas welding owing to its relatively low temperature, is more suitable for light work. Preparation of plates for oxy-acetylene welding is shown in Fig. 14.1.

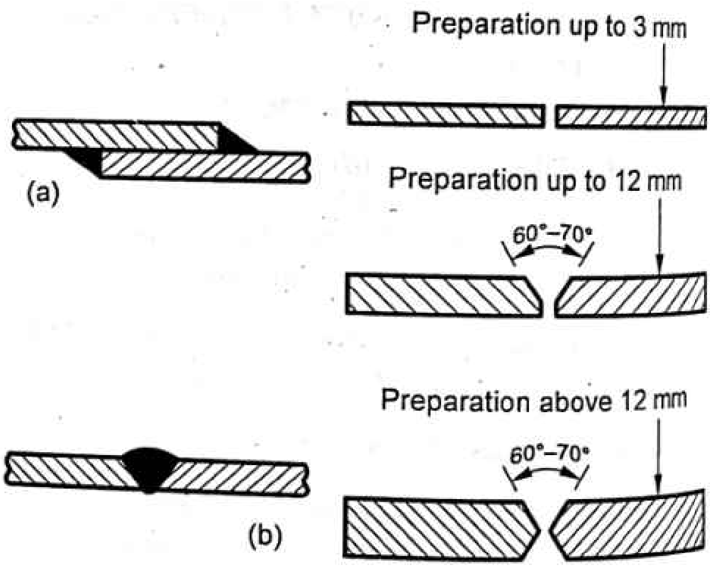
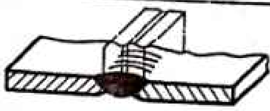
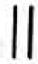
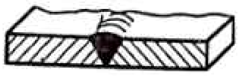
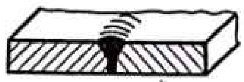
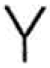
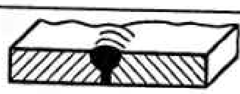
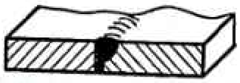
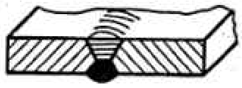
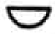
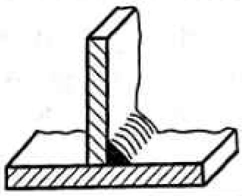
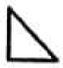
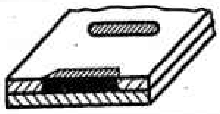
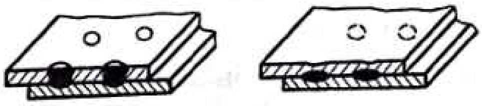
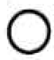
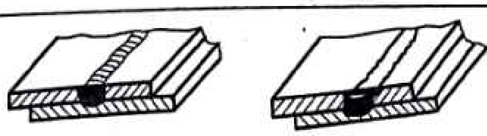
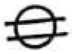


Fig. 14.1 Preparation of plates for oxy-acetylene welding

Electric arc welding. In this fusion process a local area of intense heat is created by passing an electric current through a filler rod, which acts as an electrode, held at a short distance from the joint so that the electric current is completed by arching. Electric arc welding is more suitable for heavy work.

No.	Designation	Illustration	Symbol
1.	Butt weld between plates with raised edges; edge flanged weld.		
2.	Square butt weld		
3.	Single-V butt weld		
4.	Single-bevel butt weld		
5.	Single-V butt weld broad root face		
6.	Single-bevel butt weld with broad root face		
7.	Single-U butt weld (parallel or sloping sides)		
8.	Single-J butt weld		
9.	Backing run ; back or backing weld		
10.	Fillet weld		
11.	Plug weld, plug or slot weld/USA		
12.	Spot weld		
13.	Seam weld		

1. Butt welds between plates with raised edges (symbol 1) not completely penetrated are symbolized as square butt welds (symbol 2) with the weld thickness shown.

Fig. 14.2. Basic welding symbols

Pressure welding. In this process the areas to be joined are heated until they become plastic and are then welded together by applying pressure or sometimes hammering.

Forge welding is a pressure welding process in which pieces to be joined are heated and then hammered together. It is the old welding process. Wrought iron and low carbon steel can be forge welding.

Resistance welding is pressure welding process in which work is heated by a strong electrical current and then pressure is applied to create the weld. The forms of resistance welding are : projection welding, seam welding, spot welding and flash welding. In *spot welding*, the parts are overlapped and welds are made at successive single spots. In *flash welding*, the pieces are so placed that they are butted, then the weld is made by heating electrically and squeezing the parts together. A *seam weld* is similar to a spot weld except that a continuous weld is produced. In projection welding one part is embossed and welds are made at the successive projections.

14.3. TYPES & REPRESENTATION OF WELDS

Fig. 14.2 shows basic symbols for various forms of welded joints as recommended by Bureau of Indian Standards. The symbol, in general, is similar to the shape of the welds to be made. When required, combination of elementary symbols can be used. Typical examples are given in Fig. 14.3.

A welded joint is represented on drawing by

(*a*) A basic symbol used to specify the type of weld (Fig. 14.2).

(*b*) An arrow and a reference line to indicate the location of the weld in a joint.

(*c*) Supplementary symbols to indicate special instructions, such as finish, weld-all-round, etc (Fig. 14.4 (*a*) and (*b*).

The absence of a supplementary symbol means that the shape of the weld surface does not need to be indicated precisely. Examples of combinations of elementary and supplementary symbols are given in Fig 14.5.

(*d*) Dimension of the weld in cross-section and in length, where required.

The elements for the representation of welds shall have specific locations with respect to each other as shown in Fig. 14.6.

Table 14.1. Shape of weld

Shape of weld surface	*Symbol*
(*a*) Flat (usually finished flush)	—
(*b*) convex	⌒
(*c*) Concave	◡

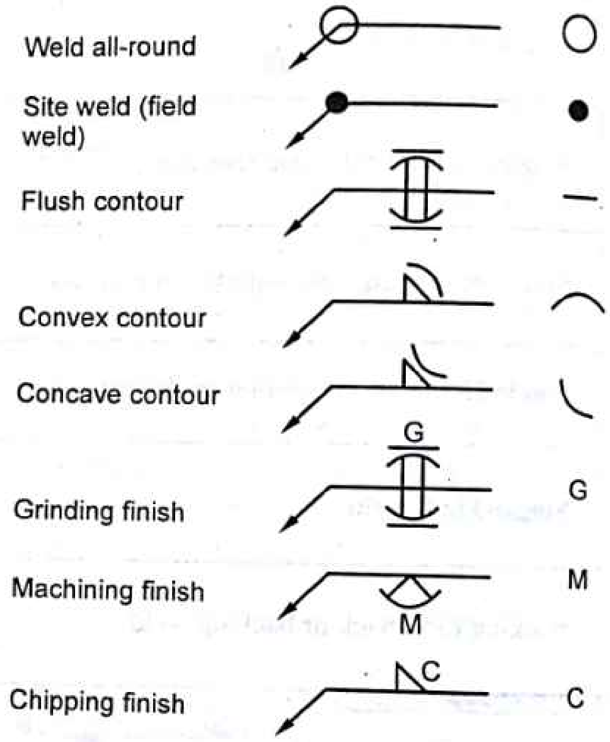


Fig. 14.3

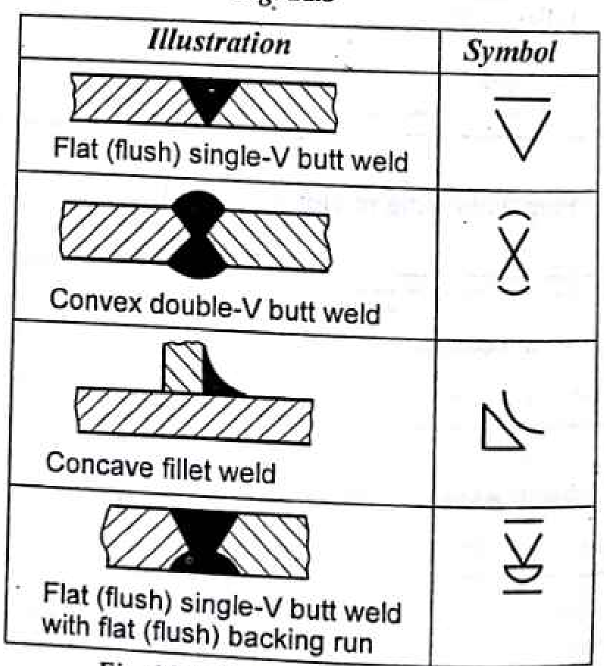


Fig. 14.4. Example of Application of supplementary symbols

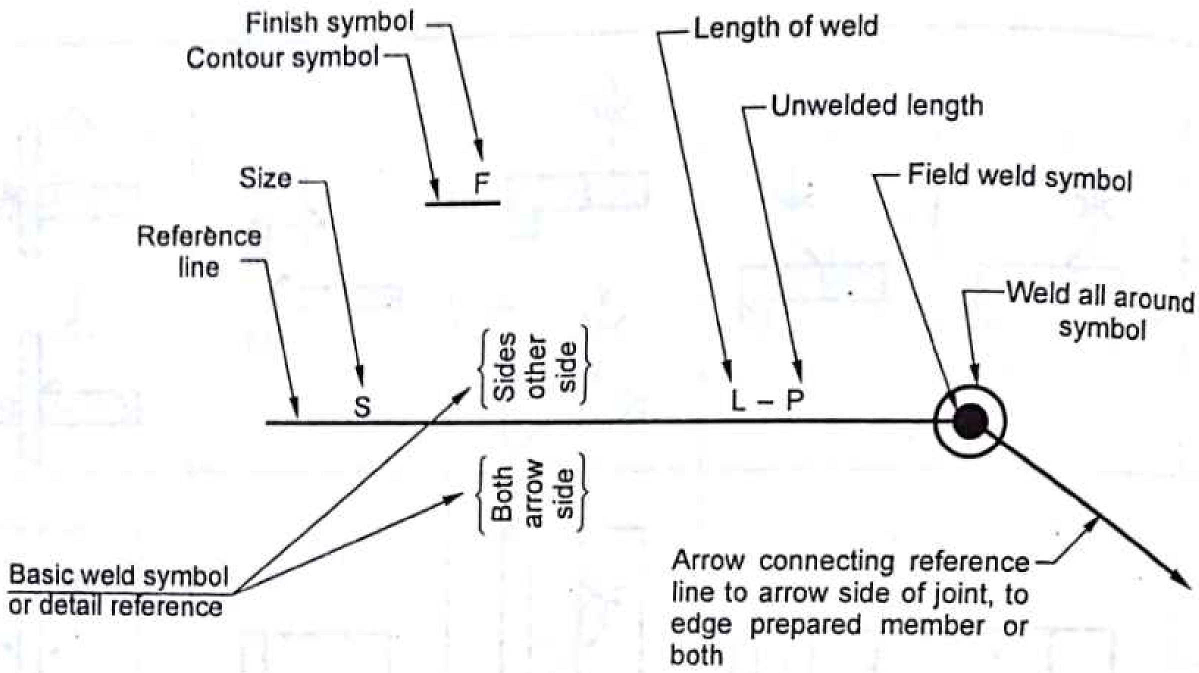


Fig. 14.6. Standard location of elements of a welding symbol

14.4. TYPICAL EXAMPLES OF REPRESENTATION OF WELDS

Fig. 14.7, 14.8 and 14.9 give typical examples of representation of welds.

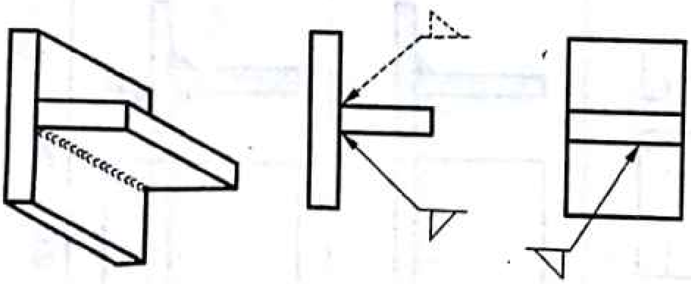


Fig. 14.7. Fillet weld, one side of Tee

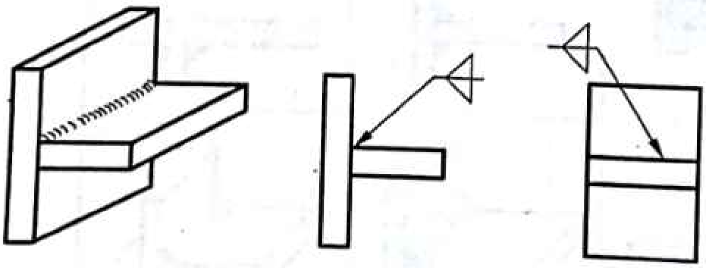


Fig. 14.8. Fillet weld, each side of Tee

Note that when the weld is to be made on the arrow side of a joint, the appropriate symbol should be inverted and placed below the reference line. For weld to be made on the other side of a joint, the appropriate symbol should be placed *over* and *below* the reference line. In all cases the vertical portion of the symbol should be shown on the left hand side of the symbol irrespective of the orientation of the weld metal.

In cases of joints, where only one plate is prepared, the arrow should point at the plate, the direction of the edge of preparation being indicated by the disposition of the symbol relative to the reference line as shown in Fig. 14.10. The meaning of arrow side and other side is shown in Fig. 4.11 and Fig. 4.12.

Size. The size of the weld is indicated by inserting a dimension on the left hand side of the symbol as shown in Fig 14.13, and 14.14.

Weld contours. The nominal contours for fusion, butt and fillet weld should be indicated as in Fig. 14.15 and 14.16.

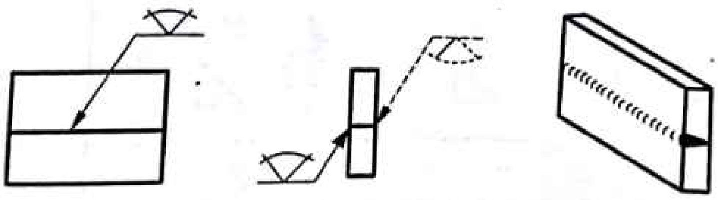


Fig. 14.9. Single-V butt weld

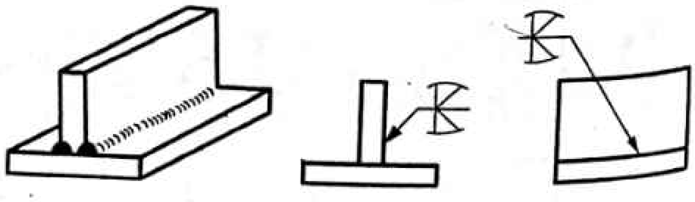
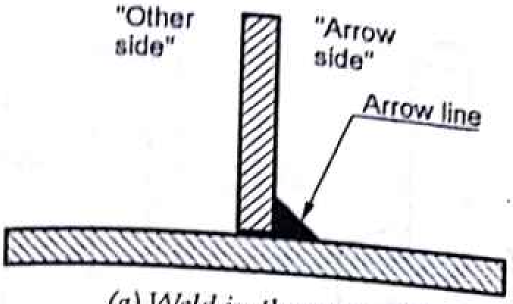
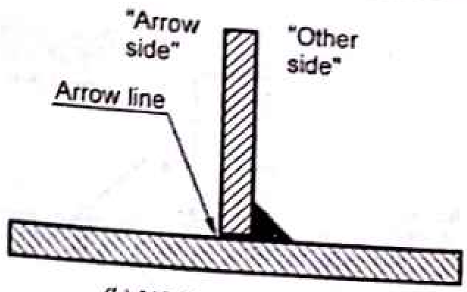


Fig. 14.10. Double bevel butt-arrowhead indicating plate to be prepared



(a) Weld in the arrow side



(b) Weld on the other side

Fig 14.11. T-joint with one fillet weld

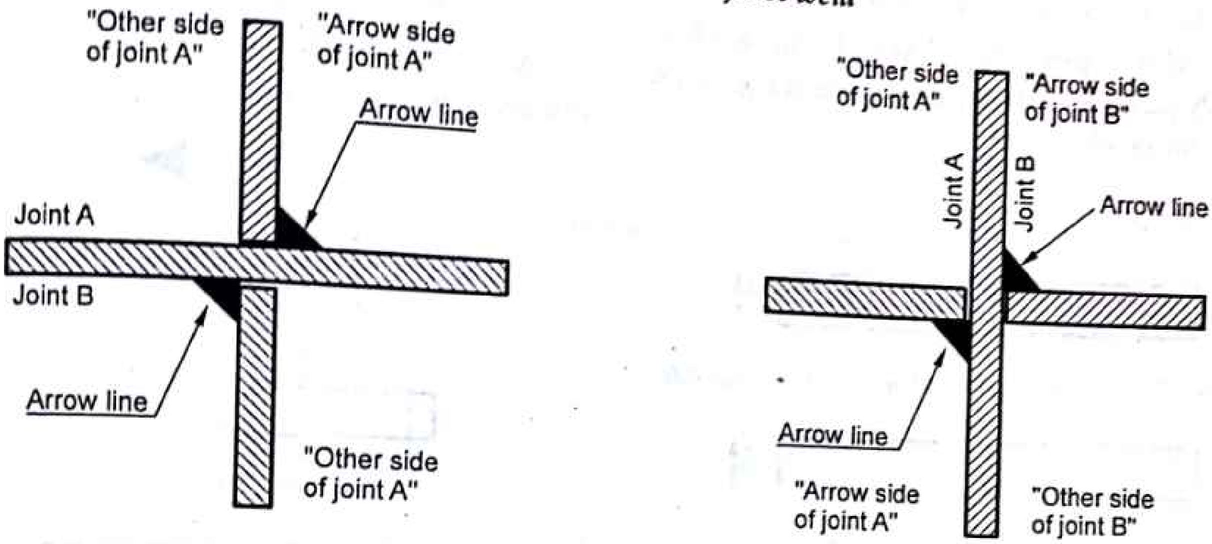


Fig. 14.12. Cruciform joint with two fillet welds

Note: The position of the arrow in these sketches is chosen for purposes of clarity. Normally, it would be placed immediately adjacent to the joint.

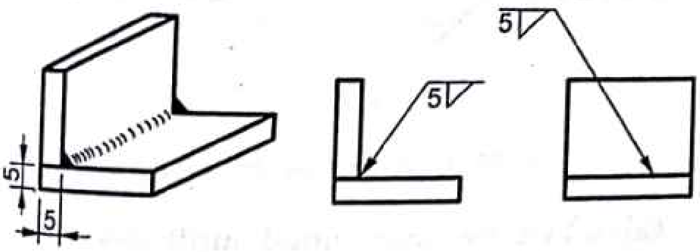


Fig.14.13. Size of fillet weld

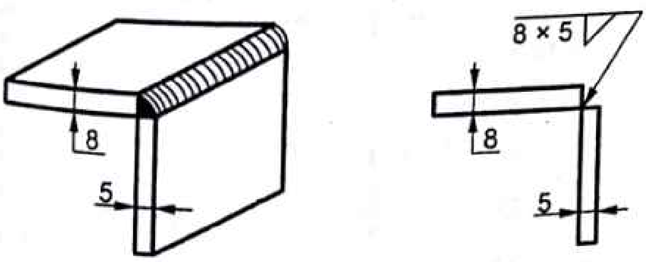


Fig.14.14. Size of unequal weld

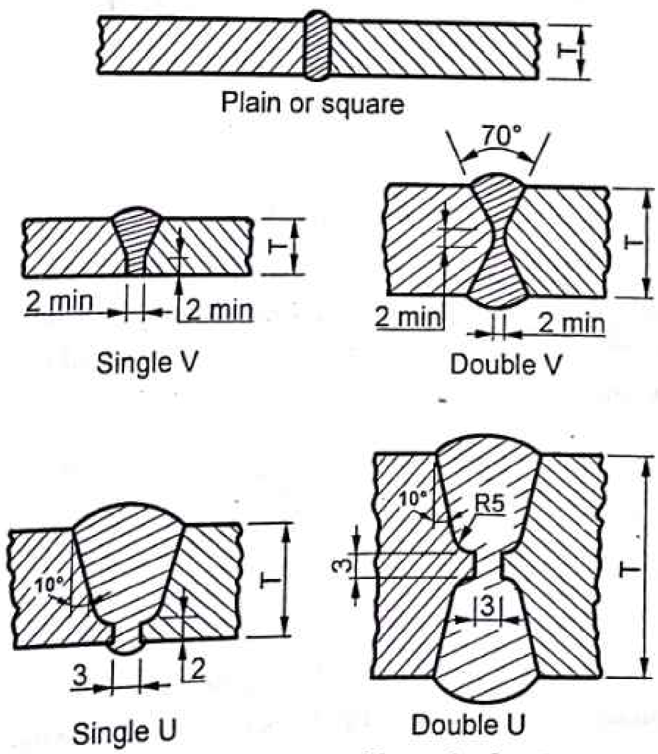


Fig. 14.15. Fusion butt weld nominal contours

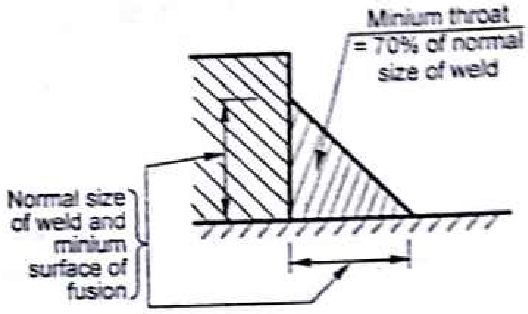


Fig. 14.16. Fillet weld, nominal contours

Partially penetrated weld. The depth of partially penetrated butt welds is given in Fig.14.17, 14.18 and 14.19.

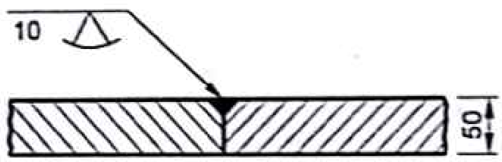


Fig. 14.17. Partially penetrated butt-weld on one side

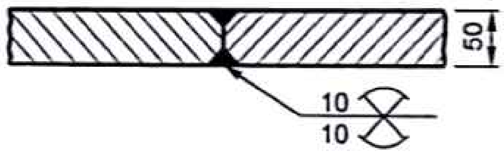


Fig. 14.18 Partially penetrated butt-weld on both sides

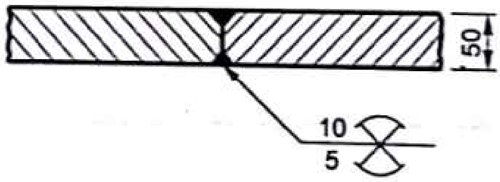


Fig. 14.19. Partially penetrated butt weld assymetrical in from

Flush Finish. Where a weld is required to have an approximately flush finish without recourse to any method of finishing, a straight line should be added as shown in Fig. 14.20.

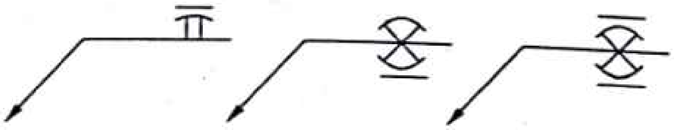


Fig. 14.20 Fusion weld with flush finishes

Weld-All-Round. A weld all round a joint is shown by a circle placed at the below, connecting the arrow to the reference line as shown in Fig. 14.21.

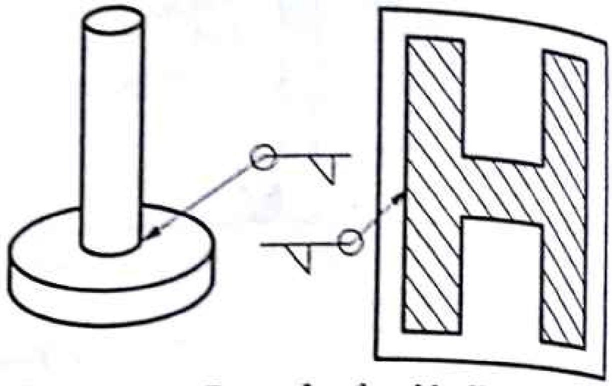


Fig 14.21. Example of weld-all-round

A weld to be made on site is indicated by a filled in triangle as shown in Fig. 14.22.

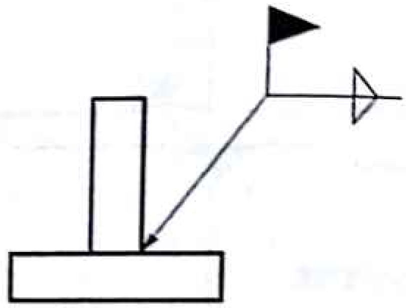


Fig 14.22

14.5. DIMENSIONING OF WELDS

The dimensioning is given as follows (see Fig. 14.23).

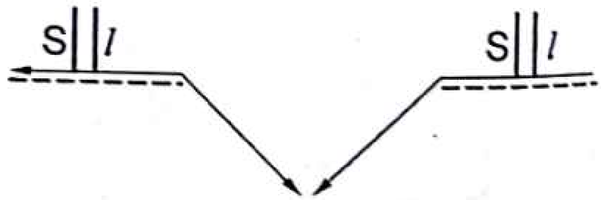


Fig. 14.23. Examples of the principle

Table 14.2. Recommended minimum size of fillet welds

Plate thickness, mm	*Minimum size of weld, mm*
3 to 5	3
6 to 8	5
10 to 16	6
17 to 20	10
21 to 35	15
over 36	20

15 Screw Threads and Screwed Fastenings

15.1. SCREW THREADS

Bolts and nuts, etc., are widely used for temporary fastening in engineering. These involve what are known as *screw threads*. A screw thread is formed by cutting or rolling a continuous helical groove on a cylindrical surface as shown in 15.1. The thread portion or screw engages with a corresponding threaded hole in a nut or other machine part. The screw and nut together are called a *screw pair.*

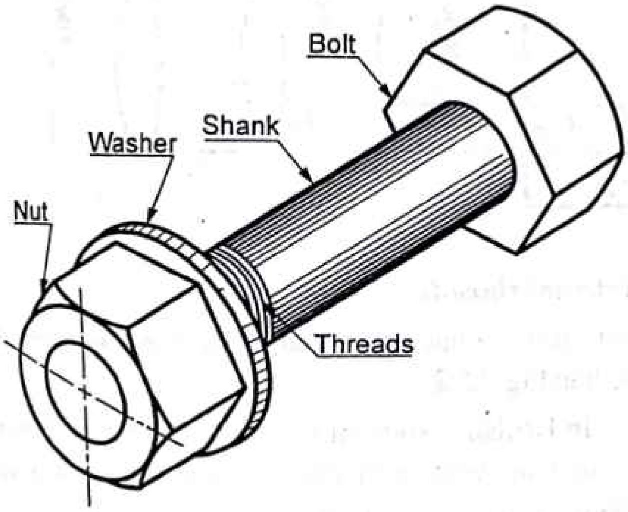


Fig. 15.1. Bolt and Nut

The screw threads are of many forms as described later. The two main forms are Square and Vee. The thread may be *right handed or left handed and single-start* or *multi-start* as defined in the next article.

Threads are generally cut by an accurate thread cutting tool in a machine, called *lathe*. Thread on small sizes screws are cut by a tool known as *die*. The small size holes are threaded by a tool called *tap* and the holes so threaded are called *tapped holes*. A thread cut on the surface of a screw is called an *external thread* while that cut in a hole is called an *internal thread*. For example, bolt has external threads while nut has internal threads.

15.2. DEFINITIONS

The various parts of a screw thread are shown in Fig. 15.2. and are defined below.

1. Crest. The crest is the top surface joining the two sides of a thread. Note the crests in external and internal threads in Fig. 15.2.

2. Root. The root is the bottom surface joining the sides of two adjacent threads. Note the root both in external and internal threads in Fig. 15.2

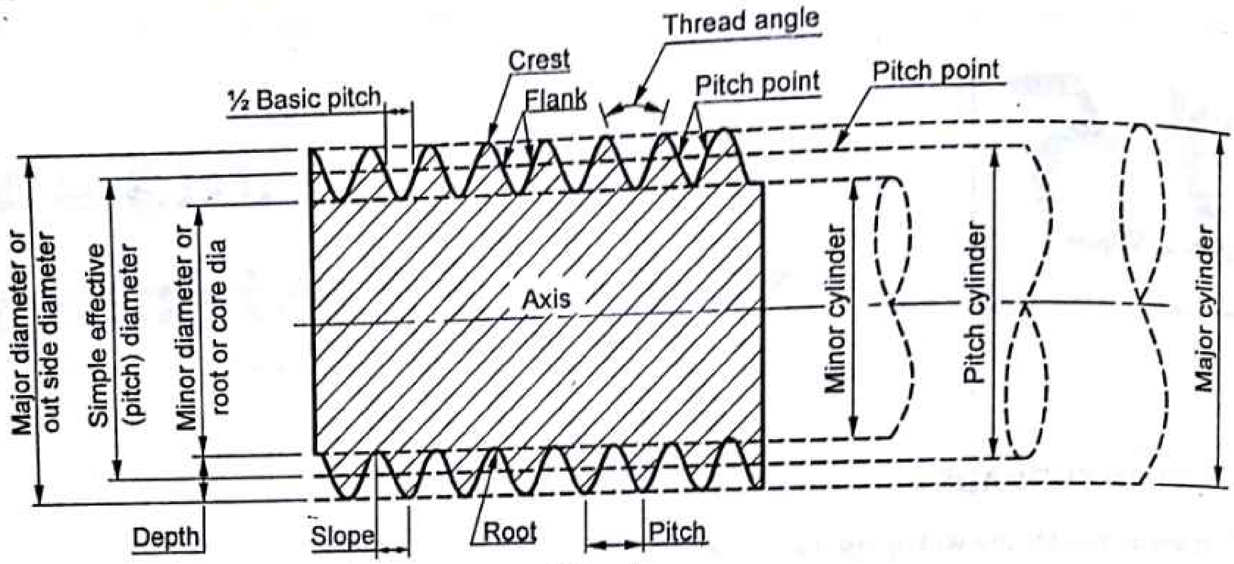
3. Flank. The flank of the thread is the surface between the crest and the root.

4. Thread angle. The angle of the thread is the angle between the flank as measured on an axial plane.

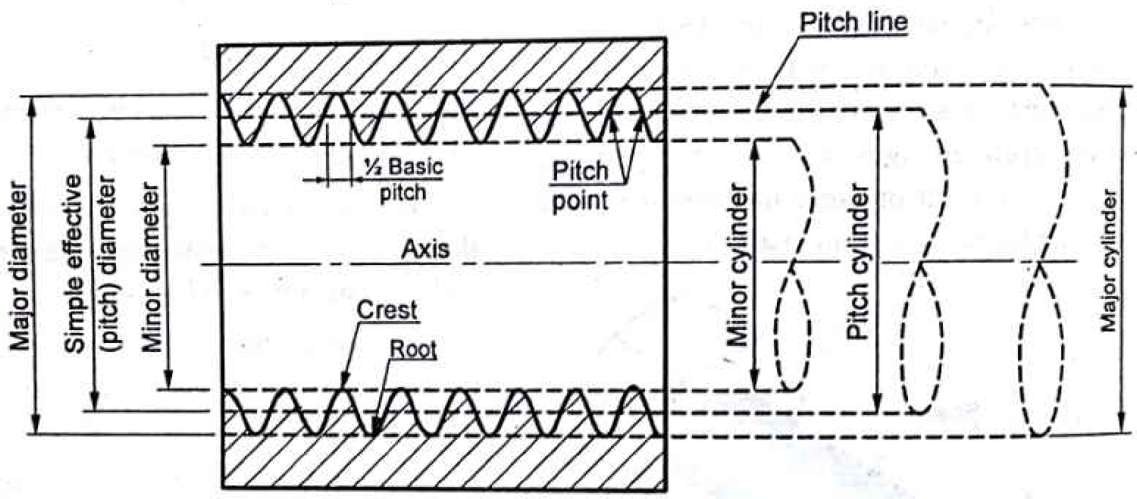
5. Depth of thread. The depth of thread is the distance between the crest and the root of thread measured perpendicular to axis.

6. Nominal diameter. The nominal diameter is the diameter of the cylindrical piece on which the threads are cut. The screw is specified by this diameter.

7. Major diameter. The major diameter is the diameter of the imaginary cylinder coaxial with the thread which just touches the *crests* of an external thread or *roots* of an internal thread. It is also known as outside, crest or full diameter. It is the greatest diameter of a thread.



(a) External Threads



(b) Internal Threads

Fig. 15.2. External and internal threads

8. Minor diameter. Minor diameter is the diameter of the imaginary cylinder, coaxial with the thread which just touches the roots of an external thread or the crests of an internal thread. It is often referred to as the *root diameter* or *core diameter* on external threads. It is the smallest diameter of a thread.

9. Effective diameter or pitch diameter. The effective diameter or pitch diameter is the diameter of the imaginary cylinder whose surface would pass through the threads at such point as to make the width of the thread and of the spaces between the threads equal form is pitch. Note the pitch line.

10. Pitch. The pitch is the distance from a point on a screw thread to a corresponding point on the next thread measured parallel to the axis. For example the distance from crest to crest or root to root taking adjacent thread form is pitch. Note the pitch in Fig. 15.2.

In British system of units the number of threads per inch are written in abbreviation as t.p.i. It is seen that pitch is reciprocal of t.p.i.

$$\text{pitch} = \frac{1}{\text{t.p.i.}}$$

11. Lead. The lead is the distance a screw thread advances axially in one turn. In single-start threads lead is equal to pitch. For two-start thread the lead is equal to twice the pitch. For a three-start thread the lead is three times the pitch (see Fig. 15.25 and 1526). and so on.

12. Slope. The slope equals half the lead. On single -start threads this is the same as saying "slope equal half the pitch".

13. Right-hand and left-hand threads. Screw threads may be right hand or left hand depending on the direction of helix (See. Fig. 15.3). When a clockwise rotation screws it on a bolt it is said be right-handed. When a clockwise rotation screws *off* a bolt, the thread is said to be left-handed. In left-handed thread an anticlockwise rotation of the nut screws it *on* the bolt.

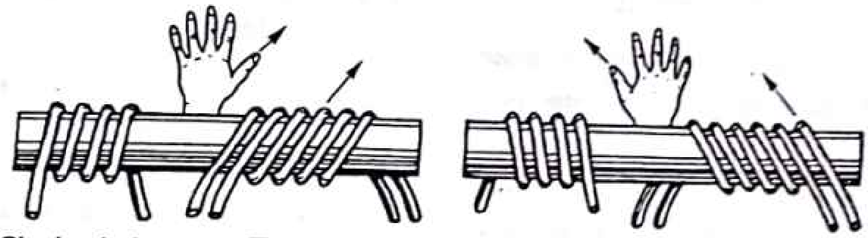
If a thread is left-handed it should be written as L.H. If is is right handed not necessary to write it.

Note: In right-handed threads, with the axis of the screw horizontal, the lines slope down from left to right. However, a section through a tapped hole exposes the threads and a right-hand thread will appear left-handed in the section of a tapped hole, and vice-versa, as shown in Fig. 15.4.

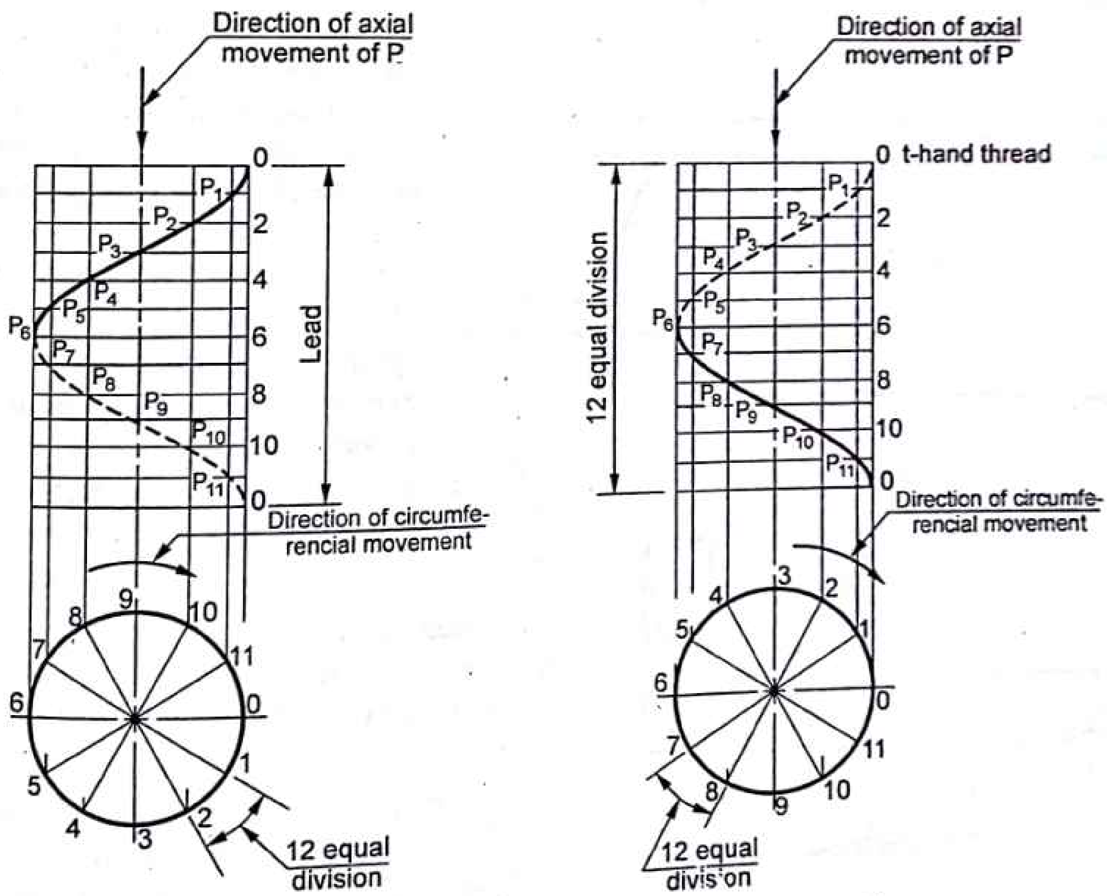
14. Multi-start thread. In multiple threads more than one thread is wrapped round the cylinder on parallel helix. (see Fig. 15.3 and Fig. 15.4). The lead in multi-start thread is equal to (number of threads wrapped × pitch). Multi-start threads are used when quick advance is desired.

Multi-start threads are discussed in detail later.

Example. Suppose we have a two-start thread of 8 mm lead. If the screw is held firmly the nut will have an axial advance of 8 mm for one rotation. The pitch, however, will be 4 mm.

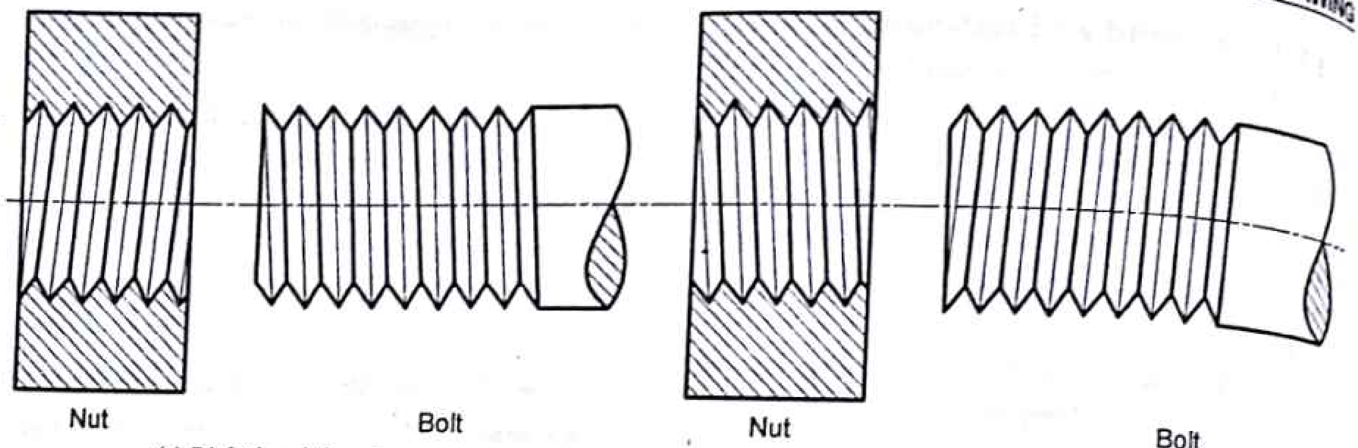


(a) Left-hand thread *(b) Right-hand thread*



(a) Right hand helix *(b) Left hand helix*

Fig. 15.3. Directions of helix



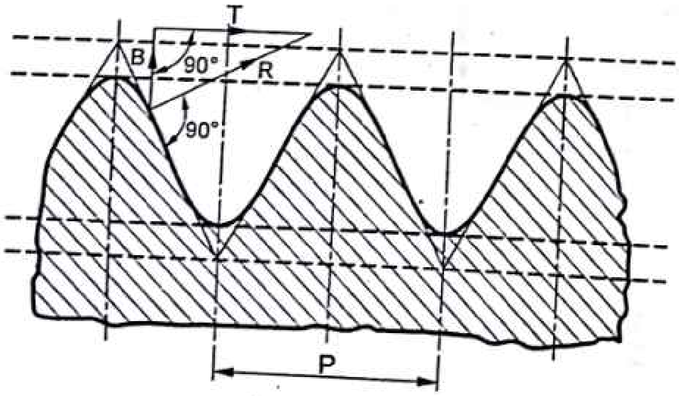
(a) Right hand threads (b) Left hand threads

Fig. 15.4. Right hand and left-hand threads

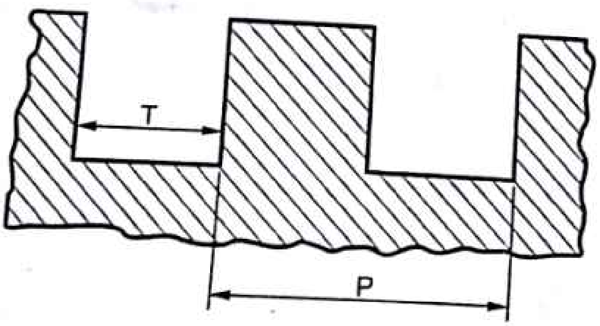
15.3. FORMS OF SCREW THREAD

The standardization of the form of screw thread was an important advancement in engineering as it enabled interchangeability of screwed fastenings.

There are two main types of screw thread forms : (*a*) vee type, used mainly for fastening and adjusting purpose, and (*b*) square type, used for transmitting power. (see Fig. 15.5)



(a) Vee thread



(b) Square thread

Fig. 15.5. Vee and Square threads

15.3.1. Comparison of Vee and Square Threads

1. Vee threads are stronger than the square threads as for the same depth a vee thread screw has twice the amount of material resisting the shearing action at the root of the thread than a screw with square thread as shown in Fig. 15.5.

2. Vee threads offers greater frictional resistance to motion than square threads. In Vee threads a tensile force T in the direction of axis has a component perpendicular to axis which has bursting action on the nut and causes friction. *It is obvious that friction will increase with the increase in the angle of thread.* In the square thread there is no component of T-force perpendicular to the axis and is, therefore,, the ideal thread for power transmission.

3. Square threads are costly to produce as they cannot be cut by dies.

High frictional resistance of vee threads is an advantage in preventing a nut from slackening back. *Therefore, vee threads are used to tighten pieces together as in bolts and nuts, studs and nuts, tap bolts, screws, etc.*

Square threads on the other hand are suitable for power transmission, on both axial directions, on feed mechanism of machine tools, valve spindles, vice screws, screw jacks, tec., where less friction means saving of power. Square threads are also used for *obtaining larger axial movement of the nut or the screw per revolution.* Square thread to some extent has been replaced by Acme thread which is a modification of the former.

15.3.2. Forms of Vee Threads

(i) British Standard Whitworth (B.S.W.) thread. (Fig. 15.6 and 15.7 (*a*).

The British Standard Whitworth thread is the old standard thread of Britain. It was commonly used but has been superseded by I.S.O metric thread. In B.S.W. thread the angle between the slopes of the vees measured in an axial plane is 55° and one-sixth of the depth of the full vee is rounded of at top and bottom.

Method of drawing Whitworth thread section Fig. 15.6.

$$\text{Pitch} = \frac{1}{\text{t.p.i}}$$

(dimension H is also known as the height of the fundamental triangle).

1. Draw vertical lines "pitch apart".
2. Draw horizontals to indicate the theoretical depth, H.
3. Cut off one sixth of the theoretical depth at top and bottom.
4. Draw the slanting line representing the sides of the thread.
5. Fillet the valleys and radius the crests as shown in detail in Fig. 15.6 (*b*).
6. Hatch and dimension as shown.

(ii) British Standard Fine (B.S.F.) Thread. The pitches of Whitworth series are not fine enough for many purposes and therefore a system of fine pitches of the Whitworth form, known as British Standard Fine Thread, has been adopted from 1/4 inch to 4 inch, both inclusive. B.S.F. thread has larger effective and core diameter than the B.S.W. thread and enables small axial adjustments. B.S.F. threads are generally used in automobiles and aircraft work.

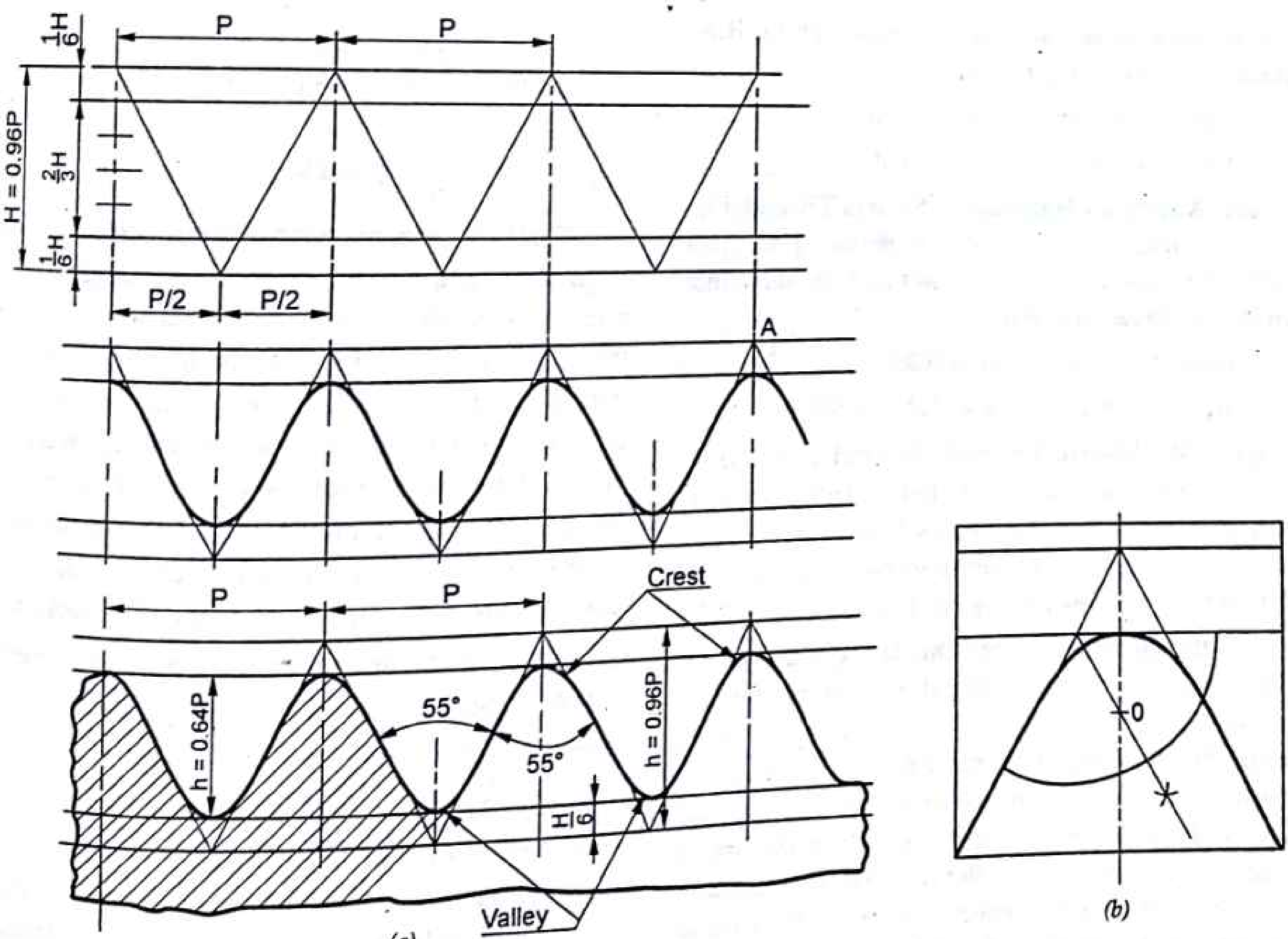


Fig. 15.6. Whitworth thread

(iii) **British Standard Pipe (B.S.P.)** British standard pipe thread is a modification of the Whitworth thread. Its section has idential proportions, but finer pitches are provided so that internal and external threads may be cut on thin tubing and piping. It is used for iron and steel piping and for tubes for gas, steam and water. When used for specific high-pressure applications, the BSP threads are cut in a tapered rather than a cylindrical surface.

With external pipe threading, the diameter usually quoted is the bore (against the usual practice) and not the outside diameter of the thread. Thus,the outside diameter of a threaded pipe having a bore of 1 inch nominal diameter is 1.309 inch. Pipes of 1 inch to 6 inch diameters have the same number of threads per inch, viz. 11.

(iv) **British Association (B.A.) Thread.** Fig. 15.7 (*b*). B.A. thread is used in small instruments below ¼inch diameter. B.S.W. thread in the smaller sizes, say upto 1/8 inch are considerably coarser in pitch than B.A. thread; consequently the latter hold with greater tenacity and stronger in cross-section. B.A. thread of a thread angle of 41½°.

Theoretical depth, $H = 1.136P$

Actual depth $h = 0.6P$

(v) **American National or Sellers Thread.** Fig. 15.7 (*c*). It is the old standard vee thread of America with a thread angle of 60°. Its uses correspond to that of B.S.W. thread in Britain.

Theoretical depth, $H = 0.866P$

Actual depth, $h = \frac{3}{4}H = 0.649P$

(vi) **ISO Metric Thread.** The Indian Standard Institution has adopted ISO (International Organization for Standardization) metric thread. The basic profile of the ISO metric screw thread is a vee-form thread as shown in Fig. 15.7 (*d*-1).

In the ISO metric screw thread the angle is 60°. The design profiles of external and internal threads are shown in [Fig. 15.7 (*d*-2)]. It may be noted that the root which is sharp in the basic profile is rounded at the minor diameter in the design profile of an external thread. In the case of an internal thread, the root is rounded at the major diameter to avoid sharp corners. The following are the relations between the various parameters designated in Fig. 15.7. (*d*-2).

Internal thread	*External thread*
D = Major diameter	d = Major diameter
D_2 = Pitch diameter	d_2 = Pitch diameter
D_1 = Minor diameter	d_3 = Minor diameter

$$P = \text{pitch}$$

$$H = 0.866025\,p$$

$$D = d = \text{major diameter}$$

$$D_2 = d_2 = d - \frac{3}{4}H$$

$$= d - 0.64952\,p$$

$$D_1 = d_2 - 2\left(\frac{H}{2} - \frac{H}{4}\right) = d - 24,$$

$$= d - 1.08253\,p$$

$$d_3 = d_2 - 2\left(\frac{H}{2} - \frac{H}{6}\right) = d - 1.22687\,p$$

$$H_1 = \frac{D - D_1}{2} = \frac{5}{8}H = 0.54127\,p$$

$$h_3 = \frac{d - d_3}{2} = \frac{17}{24}H = 0.61343\,p$$

$$R = \frac{H}{6} = 0.14434\,p$$

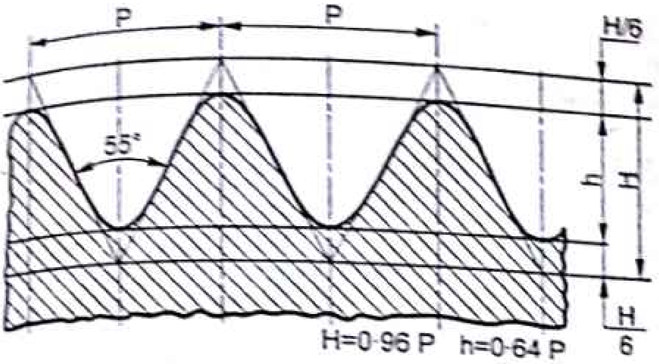
The B.I.S. recommends two thread series—*coarse pitch series* and *fine pitch series*. The largest of the pitches associated with a thread diameter is called the *coarse pitch*. The rest of the pitches associated with that diameter are called fine pitch. The diameters are given as first choice as second choice, and third choice. The coarse series is suitable for fasteners and for general purpose application. The fine series is used for special applications such as for thin walled components, fine adjustment on machine tools, etc.

The diameter pitch combination for I.S.O. metric screw threads is given in Table.

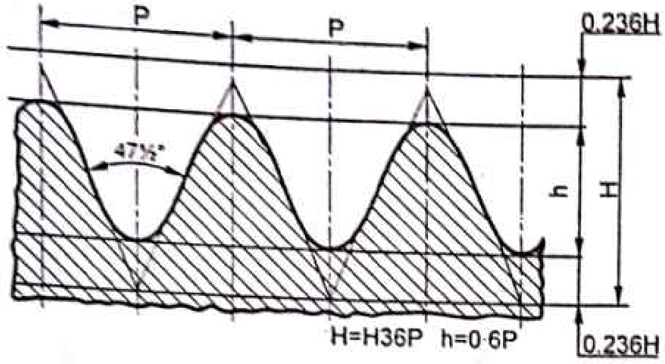
To drawing ISO metric thread

(*a*) *To draw an external (bolt thread) M 24 × 3 to a scale of 20:1 (see Fig. 15.8)*

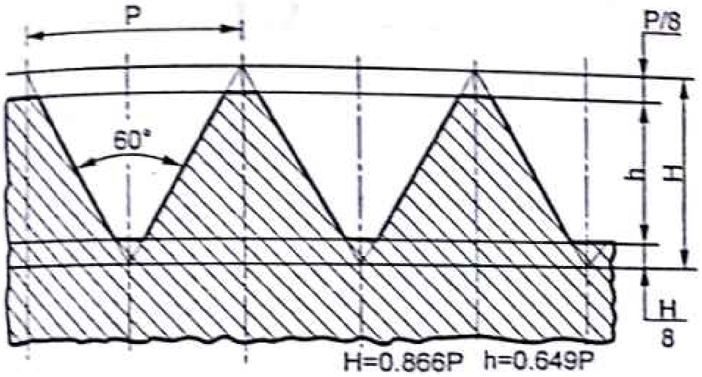
1. Draw a horizontal line *AB* and from it draw vertical lines (say seven) half a pitch (30 mm) apart.



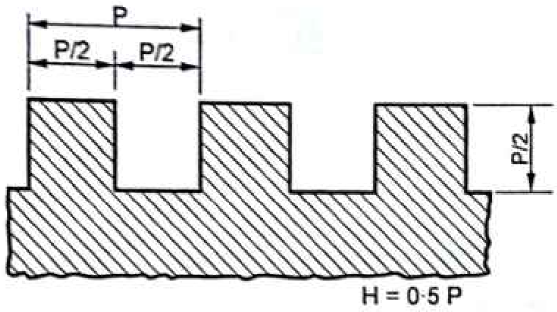
(a) B.S.W. Thread



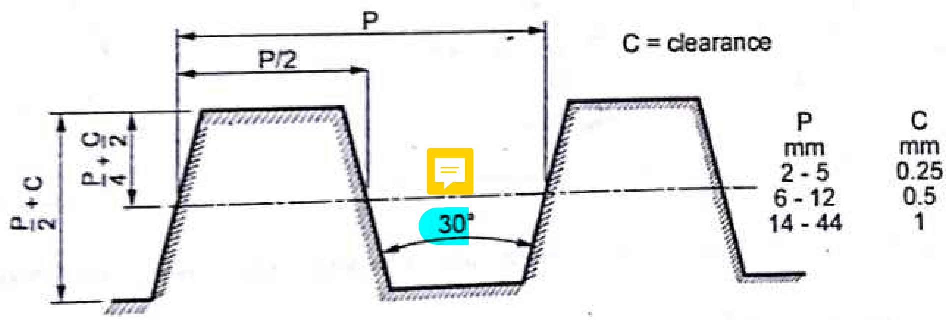
(b) B.A.Thread



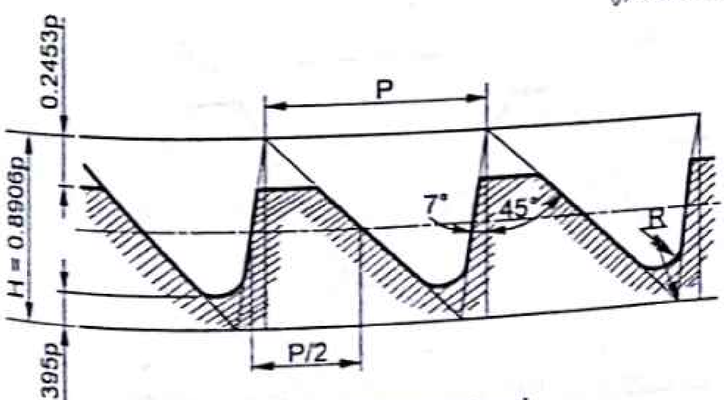
(c) American National Thread



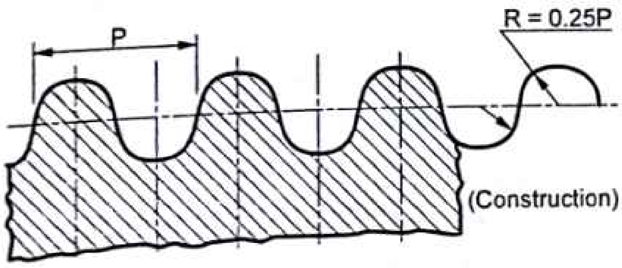
(e) Square Thread



(f) Acme Thread



(g) Buttress Thread



(h) Knuckle Thread

Fig. 15.7. Forms of screw thread

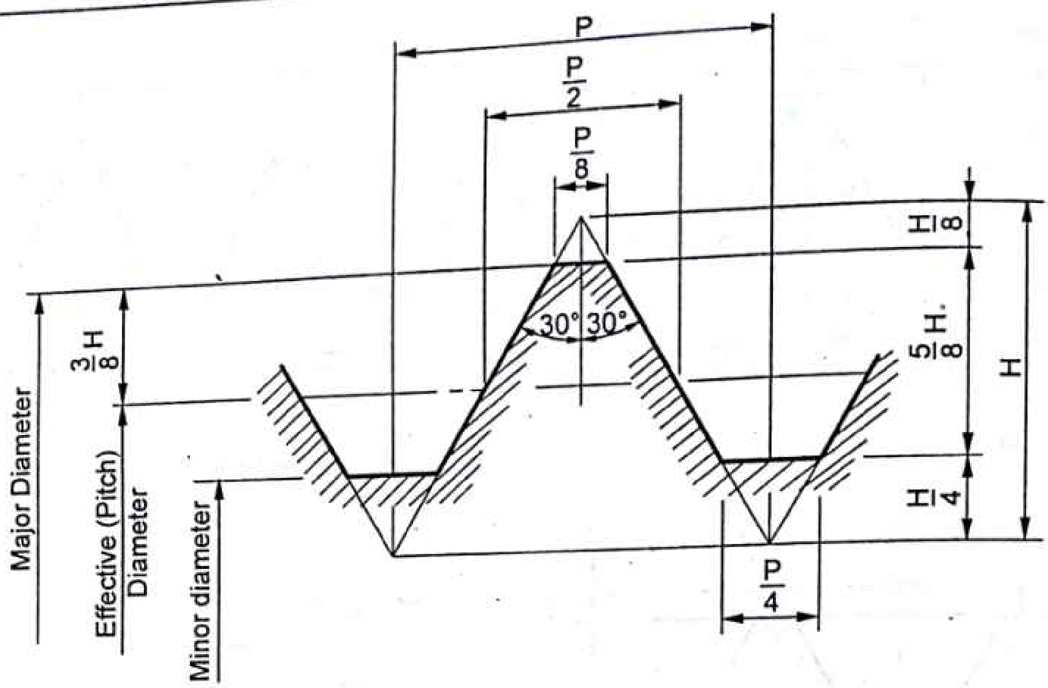


Fig. 15.7 (d-1) Basic profile of the ISO metric screw thread

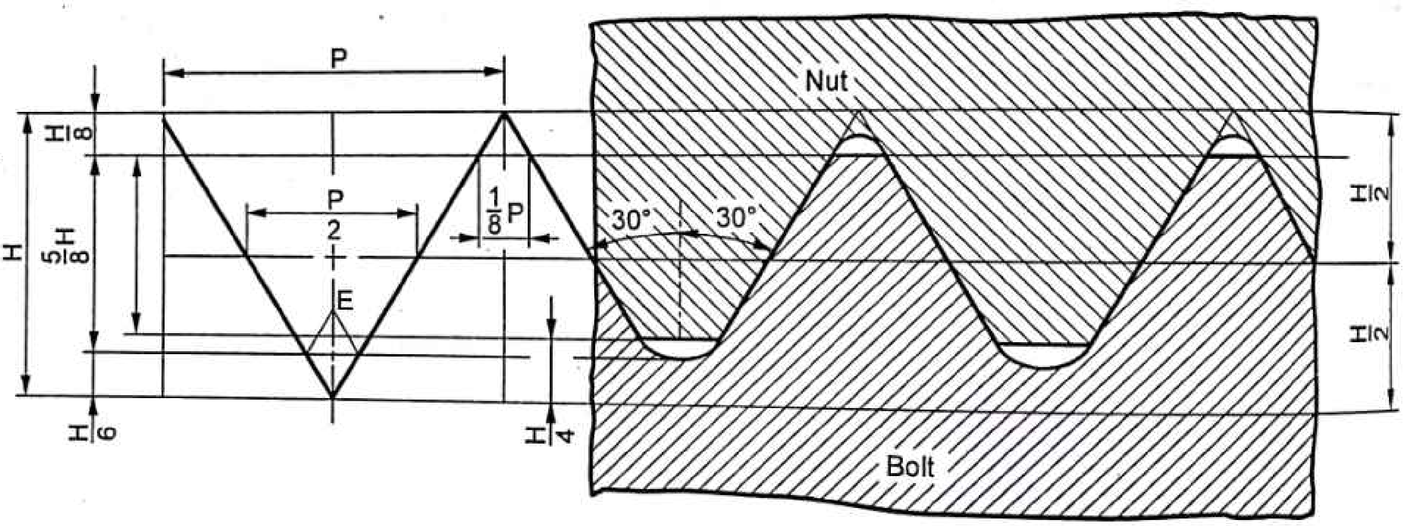


Fig. 15.7 (d-2) ISO metric screw thread design profiles of external screw threads

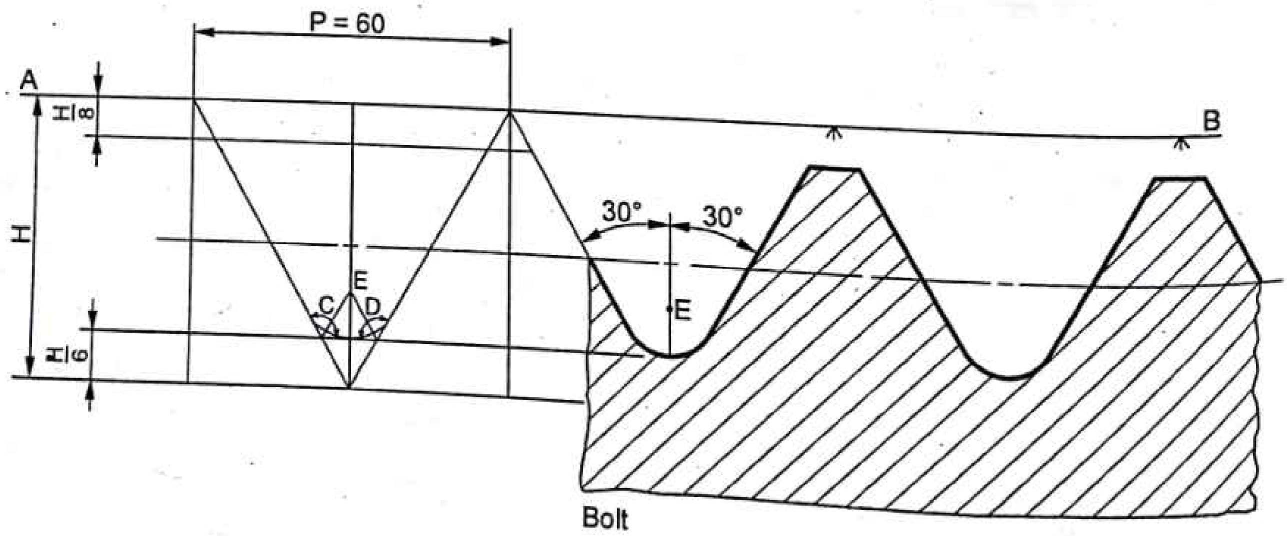


Fig. 15.8. ISO metric external thread

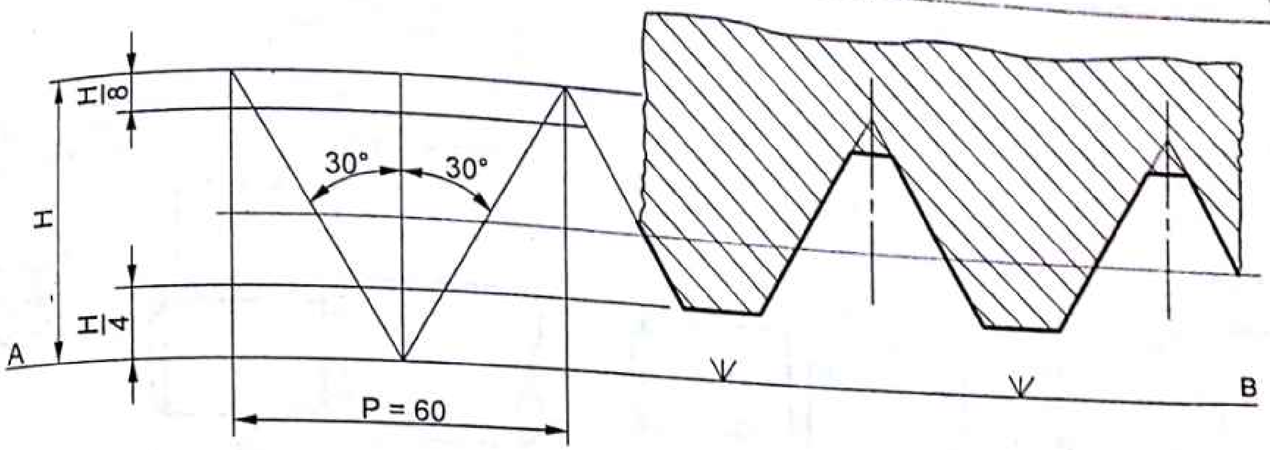


Fig. 15.9. ISO metric internal thread

2. Draw the flanks inclined at 30°
3. Join the apex points to obtain the height H.
4. At H/8 from the top and H/6 from the bottom, draw horizontal lines.
5. At H/6 bisect the angles marked *C* and *D* to obtain the intersection point *E* which must lie on the vertical construction line.
6. With centre *E* draw tangential root arcs and complete the required thread profile by drawing the thick outlines.

(*b*) *To draw an internal (nut) thread M 24 × 3 to a scale of 20:1. (see Fig. 15.9).*

1. Process as in the case of external bolt thread and draw horizontal lines at H/8 from the top and H/4 from the bottom.
2. Complete the required thread profile by drawing the thick outlines.

Designation of ISO metric screw thread. The pitch-diameter combination of an ISO metric screw thread is designated by the letter 'M' followed by the values of the nominal diameter and the pitch, with the two values being separated by the sign (×). For example a pitch-diameter combination of thread size 10 mm and pitch 1.25 mm is designated as M 10 × 1.25.

If there is no indication of pitch in the designation, it means the standard coarse pitch. For example M 10 designates a pitch diameter combination thread size 10 mm and pitch. 1.5 mm.

There are three classes of fit between external (bolt) threads and internal (nut) threads :

(*i*) The *close fit* for high quality precision work; it is a fine tolerance fit and requires very thorough inspection.

(*ii*) The *Medium fit* for general application.

(*iii*) The *free fit* for quick and easy assembly with threads occasionally becoming dirty and slightly damaged

The complete designation of thread may be given M 10 × 1.25 – 6H for internal thread and M 10 × 1.25 – 6g for external thread or M 10 × 1.25 – 6H/6g for the pair; 6H/6g is tolerance class symbol. See Fig. 15.10. The class of fit is given in table 15.1.

Table 15.1. Class of fit for threads

Class of fit	*Tolerance class*	
	Internal	*External*
Close	6H	4h
Medium	6H	6g
Free	7H	8g

For external threads

Tolerance position "e" (large allowance)

Tolerance position "g" (small allowance)

Tolerance position "h" (no allowance)

For internal threads

Tolerance position "G" (small allowance)

Tolerance position "H" (no allowance)

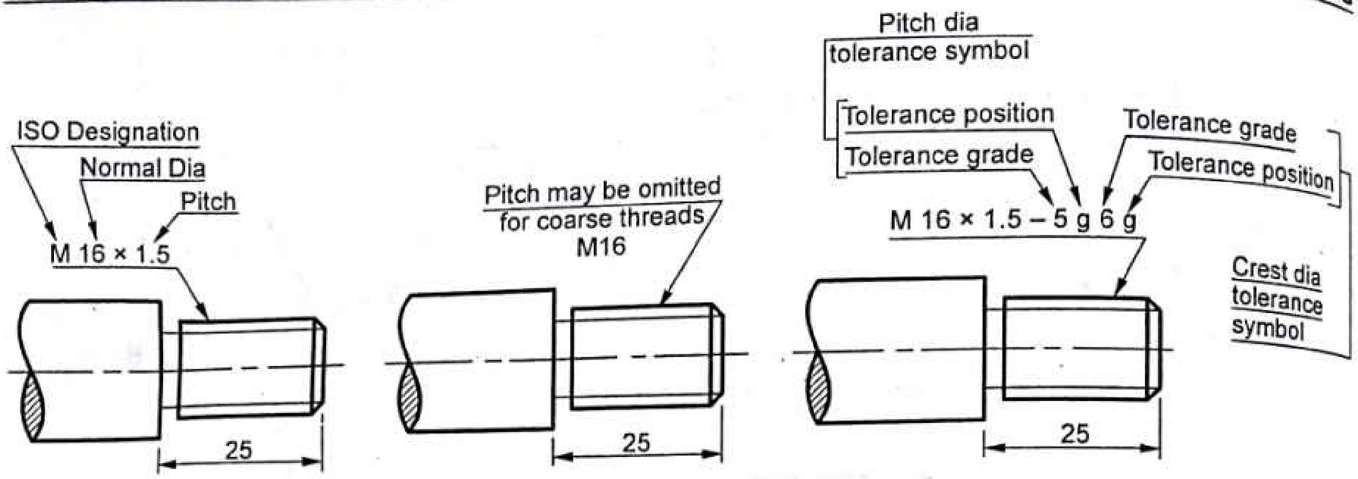


Fig. 15.10. Thread designation

15.3.3. Square Thread. Fig. 15.7 (*e*). In square thread the depth is half the pitch. To draw the square thread section, first draw two horizontal 1/2 P apart and then a number of perpendiculars 1/2 P apart so as to have a row of squares and complete as shown in Fig. 15.7 (*e*).

15.3.4. Modification of square vee form. Fig. 15.7 (*f*) (*g*) and (*h*).

(*i*) **Acme Thread** Fig.15.7 (*f*). Acme literally means point of perfection. Acme thread is a modification of square thread. It is easier to cut (due to its taper) as they can be cut in thread milling machines. Also it is stronger at the root because of the wider base. Other advantage of Acme thread over square thread is that it can be easily disengaged from a split nut, (made in two halves), as on the lead screw is required. Acme thread has applications in valve spindles, lathe lead screws and heavy power transmission, but its inclined flanks give rise to some frictional resistance.

(*ii*) **Buttress Thread.** Fig.15.7 (*g*). Buttress literally means a projecting support built on to the outside of a wall. This form of thread is known as Buttress thread due to its shape. Buttress thread is a combination of the vee and the square threads. It combines the low frictional resistance of the square thread with the strength of vee thread when the force acts in one direction only, *i.e.* at right angles to the vertical face. It has applications where little work is to be done during reverse motion as in certain types of screw presses, quick-acting wood vices, slides breech-locks of large guns, jacks in aeroplane propellers, etc.

Buttress thread is easily produced in thread milling and thread grinding machines.

Theoretical depth, $H = P$

Actual depth, $H = 3/4\,H = 0.75\,P$

Fig. 15.7 (g) shows the profile of modern buttress thread.

(*iii*) **Knuckle Thread.** Fig. 15.7 (*h*). Though knuckle thread is a crude thread, it is the only thread which can be rolled as well as cast. It is a special purpose thread having applications where there is rough usage and heavy wear. Knuckle thread is used in instances where the corners of screw are liable to be damaged as in heavy outdoor applications. It is used in modified forms in electric bulbs and sockets, bottle tops, fountain pen caps, hydrants, etc.

In knuckle thread there is an increased amount of screw friction, so that rather more clearance between screw and nut is necessary.

The depth of knuckle thread is ½ P. To draw a knuckle section, on either side of a thin centre line describe a row of tangential semicircles of radius ¼P.

15.4. TRUE PROJECTION OF SCREW THREAD

The true shape of a screw thread is a helical curve.

The true projections of a vee thread and square thread are shown in Fig. 15.11 and 15.12 respectively.

As the time and labour involved in drawing true projections is considerable they are generally not used in practice; instead quick conventional methods are used, as given below.

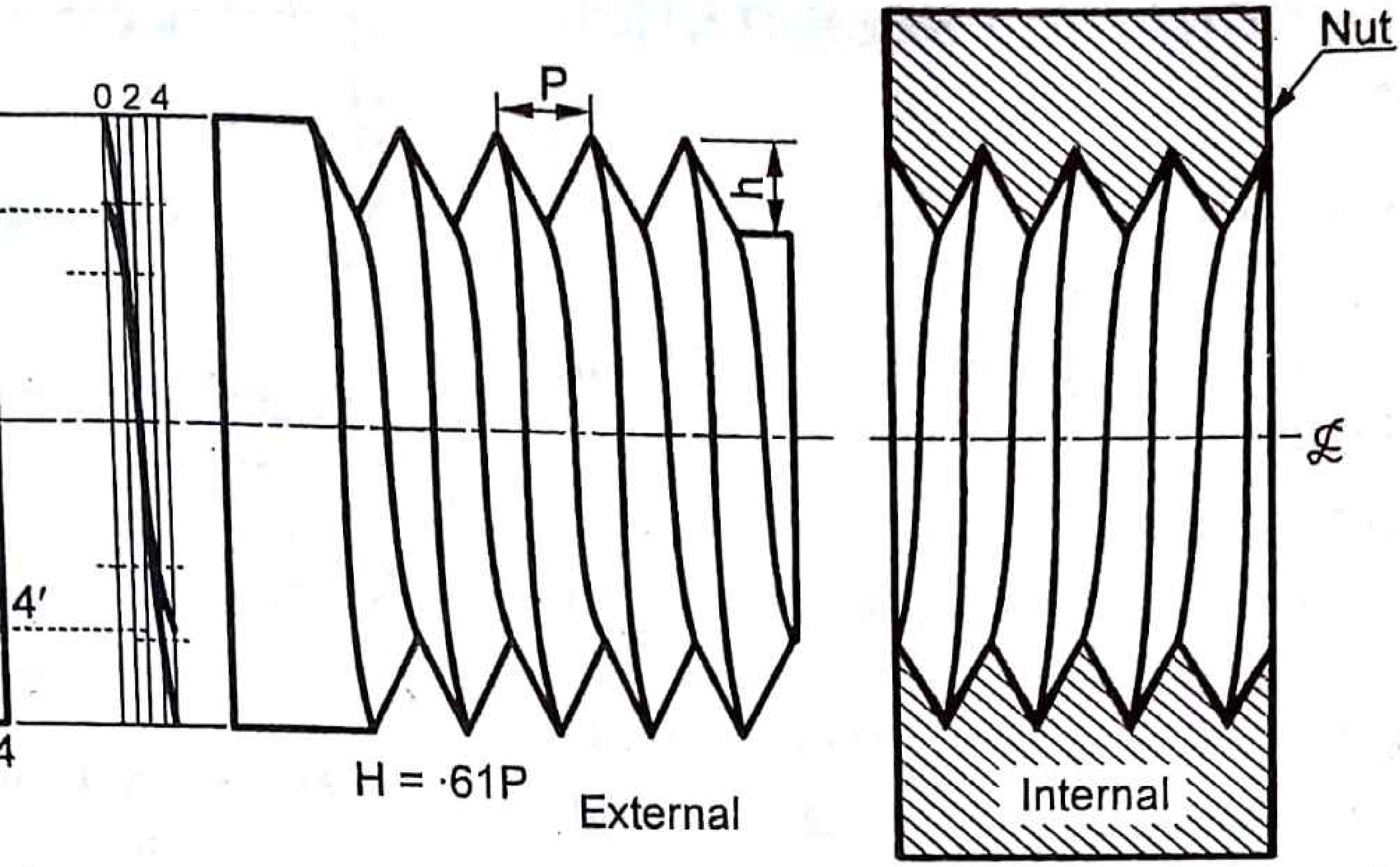


Fig. 15.11. True projection of vee threads

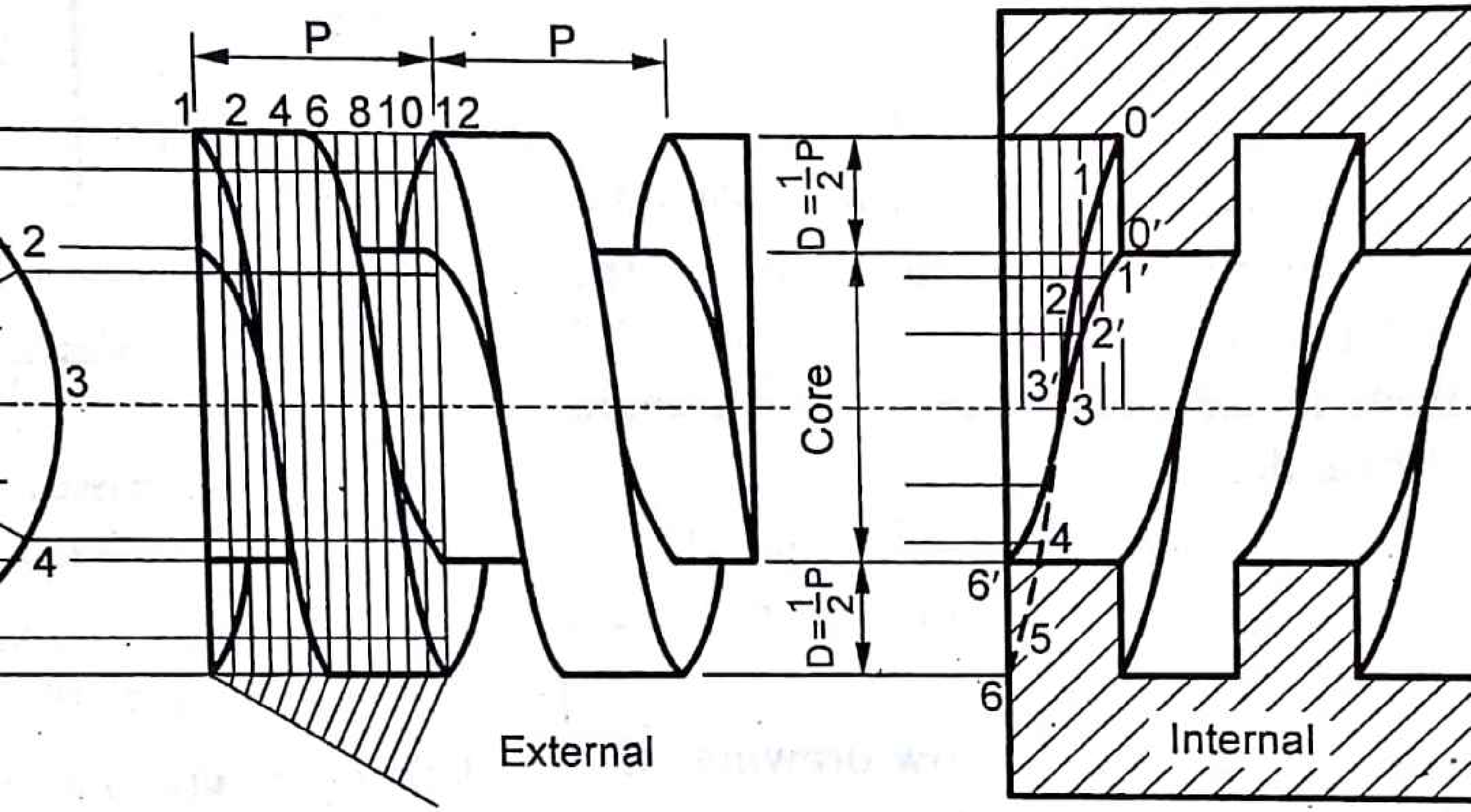


Fig. 15.12. True projection of square threads

15.5. CONVENTIONAL REPRESENTATION OF SCREW THREADS

15.5.1 Vee Thread (See Fig. 15.13)

To draw by a conventional method a righthanded ISO metric threaded piece, 36 mm diameter, 75 mm long and pitch 4 mm.

1. Draw two rectangle of 36 mm × 75 mm.
2. For right hand thread, mark off 4 mm (equal to pitch) spaces along the bottom of the rectangle. Mark off 2 mm (equal to 1/2 P) for the first division at the top left-hand end of the rectangle, and make all the other spaces 4 mm (equal to pitch) along the top. Join the points as shown.

Slope of each line = 2 mm = 1/2 P.

The depth of the thread = 0.61 P = 0.61 × 4 = 2.44 mm (exact 2.45 mm according to the table). Therefore, draw very light lines 2.5 mm from the top and bottom of the rectangle to indicate depth.

4. Draw the dark lines (representing the valleys) midway between the light sloping lines indicating crests.

For larger drawings or show drawings the lines representing the crests and the valleys are joined which gives the slope of vee as shown in Fig. 15.14. Also see Fig. 15.4 and note the slope of internal threads in section which is opposite to that of the external threads because in section the other side of is hole visible.

Simple Thread Convention or Symbol

The simplest thread convention or rather symbol is drawing two lines to indicate the depth of the thread as represented in Fig. 15.15 to 15.18.

Fig. 15.15 and 15.16 show the external and internal thread respectively.

For visible screw threads, the crests of threads are defined by a continuous thick line and roots of threads by a continous thin line. For hidden screw threads the crest and the roots of threads are shown by medium thick short dashes. In threaded parts shown in section, hatching is extended to the line defining the crests of the threads. For an end view of screw threads, the thread roots are represented by a part of a circle, about three quarters the circumference in length.

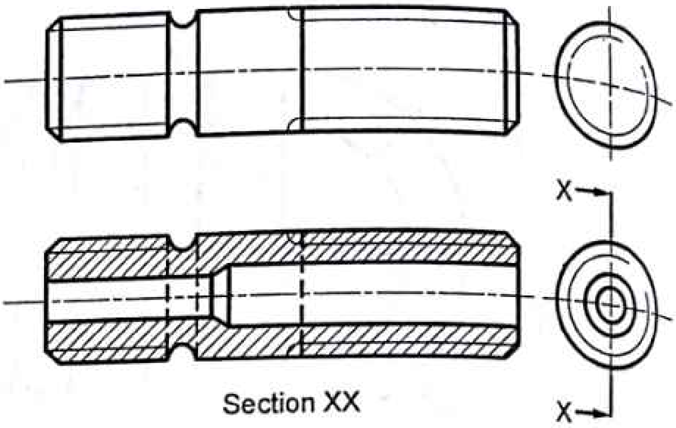


Fig. 15.15. Conventional representation (symbol) of extenal threads

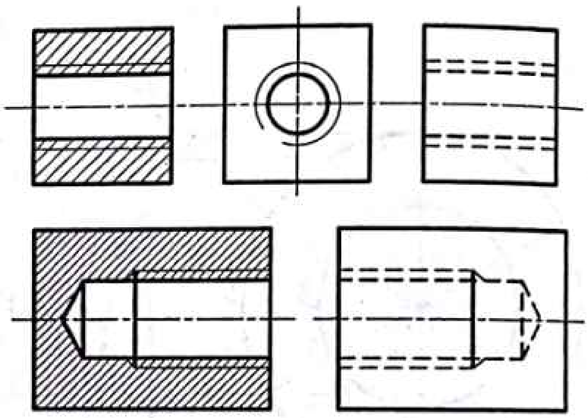
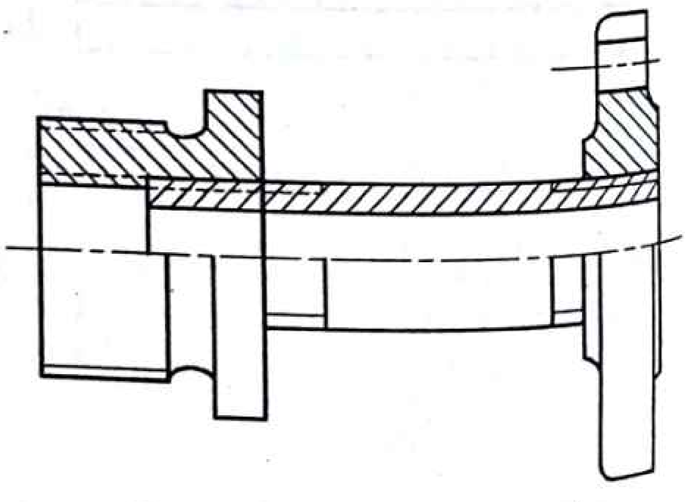


Fig. 15.16. Conventional representation (symbol) of intenal threads

Note. In assemblies of threaded parts externally threaded parts are always shown covering internally threaded parts and are not hidden by them as shown in Fig. 15.17.



15.17. Assembly of threaded parts

15.5.2. Pipe Threads

Fig. 15.18 shows conventions of representing external pipe threads in section.

Fig. 15.19 shows conventions of internal pipe thread in section.

15.5.3. Square Threads [Fig. 15.20 (*a*)]

To draw by a conventional method a right-handed and a left-handed square threaded piece 100 mm diameter, 150 mm long and pitch 24 mm.

(*i*) *Normal method*

1. Draw two rectangles 100 mm × 150 mm.
2. Mark space 12 mm (1/2 P) along the top and bottom of the rectangle.
3. The depth being 1/2 P, draw horizontal lines 12 mm from the top and bottom of the rectangle.
4. Finish off the threads as shown in Fig. 15.20 (*a*).

Fig. 15.20 (*b*) shows the conventional representation of internal threads. Note in section the thread has square shape.

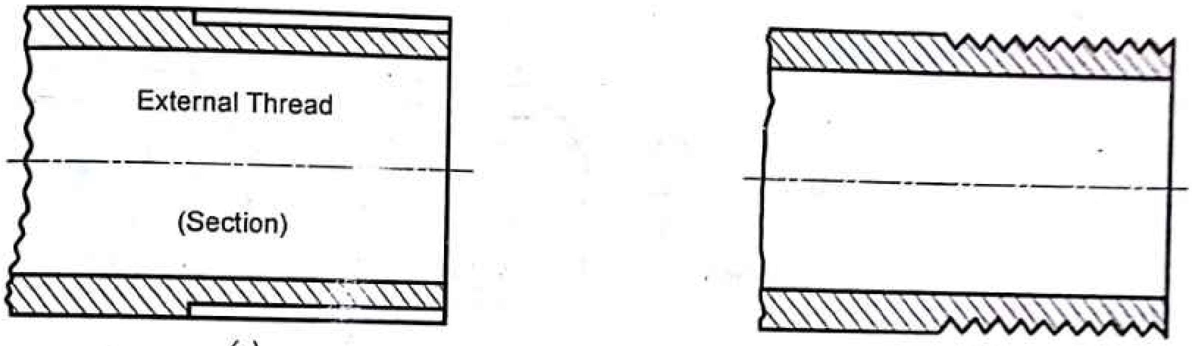


Fig. 15.18. External pipe threads in section

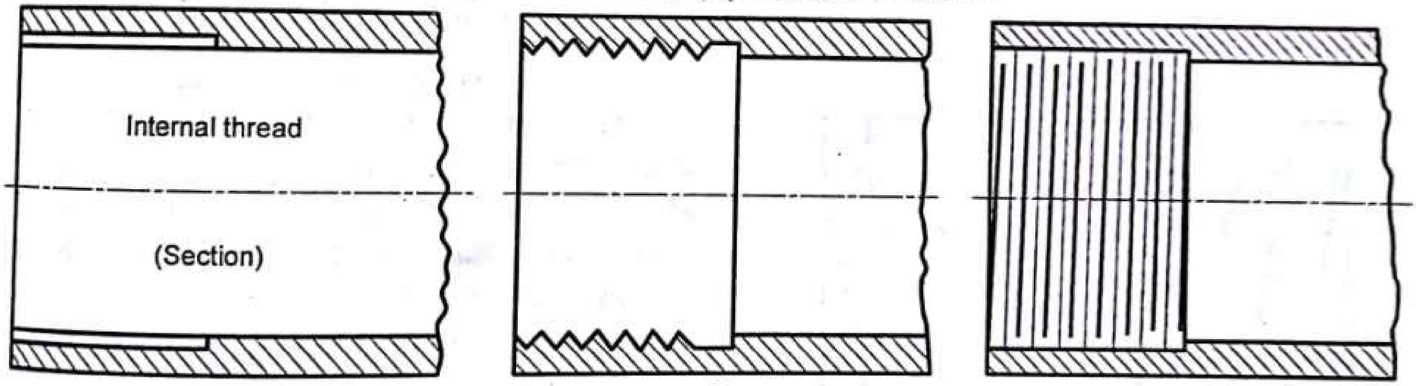


Fig. 15.19. Internal pipe threads in section

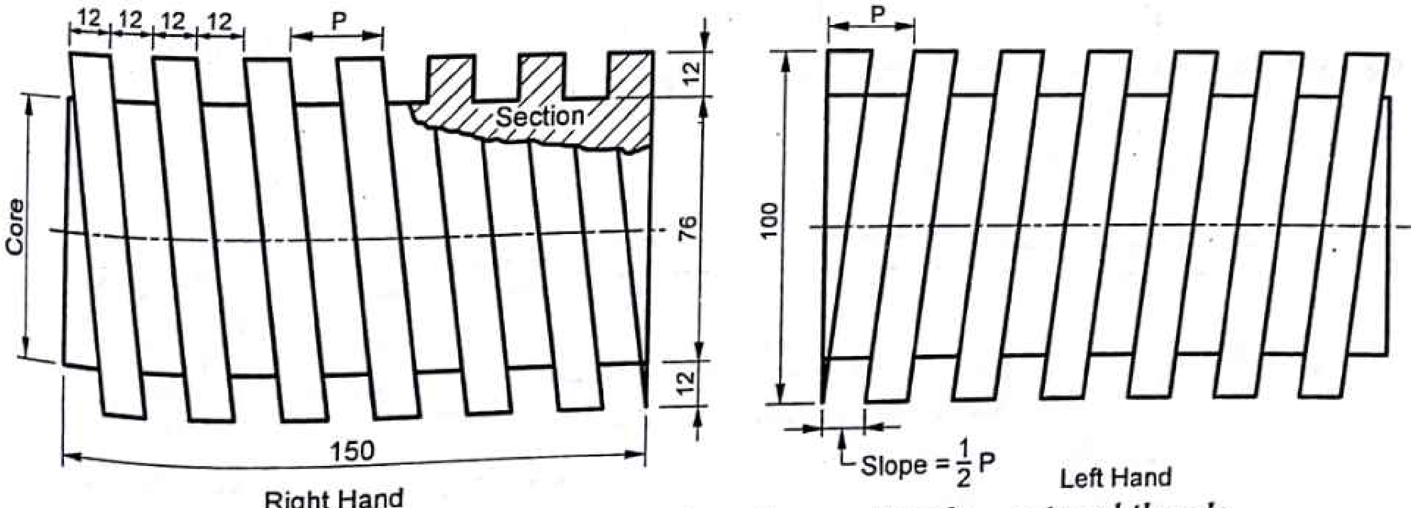


Fig. 15.20 (a) Conventional representation of square threads — external threads

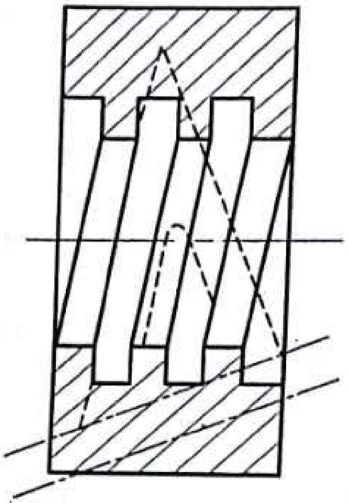


Fig. 15.20 (b) Conventional representation of square threads – internal threads

(*ii*) *Elaborate method* : For a large or show drawing the thread may be drawn as shown in Fig. 15.21, which gives the idea of the sides of the threads. Study the figure minutely for clearly understanding the construction.

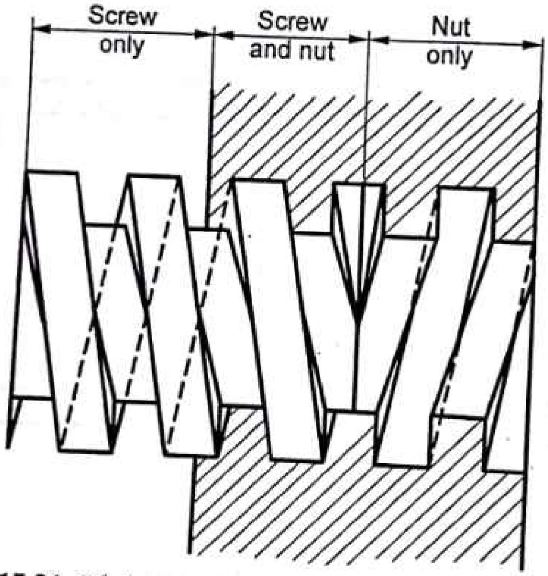


Fig. 15.21. Elaborate conventional representation of square threads

15.6. EXAMPLE OF THREADED PIECES

1. Lifting Eye-bolt

Fig 15.22 shows an eye bolt used for lifting machines. It is screwed above the centre of gravity of the job.

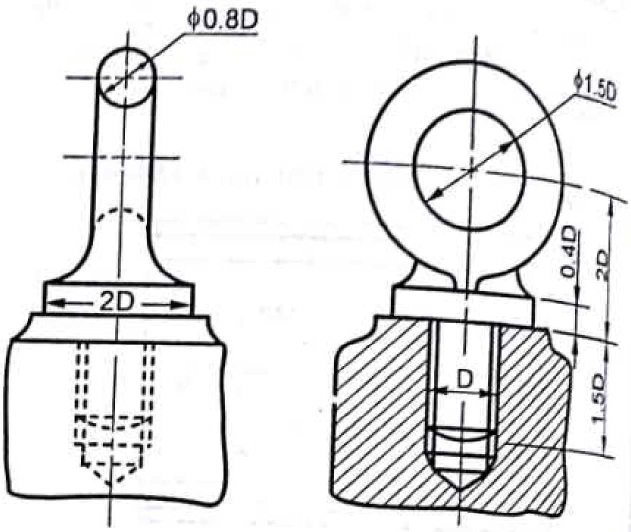


Fig. 15.22. Lifting eye bolt

2. Adjustable joint for round rods

The joint shown in Fig. 15.23 is used for connection of tension members of steel structures, cranes, tension rope of telegraph and electric poles, etc. The joint allows length of a tie bar to be adjusted. Looking from the right, if the nut is turned in the clockwise direction the ends of the rods will move closer to each other but if it is turned in the anticlockwise direction they will move further apart.

3. Coupler

Fig. 15.24 shows a coupler which is used for railway carriage.

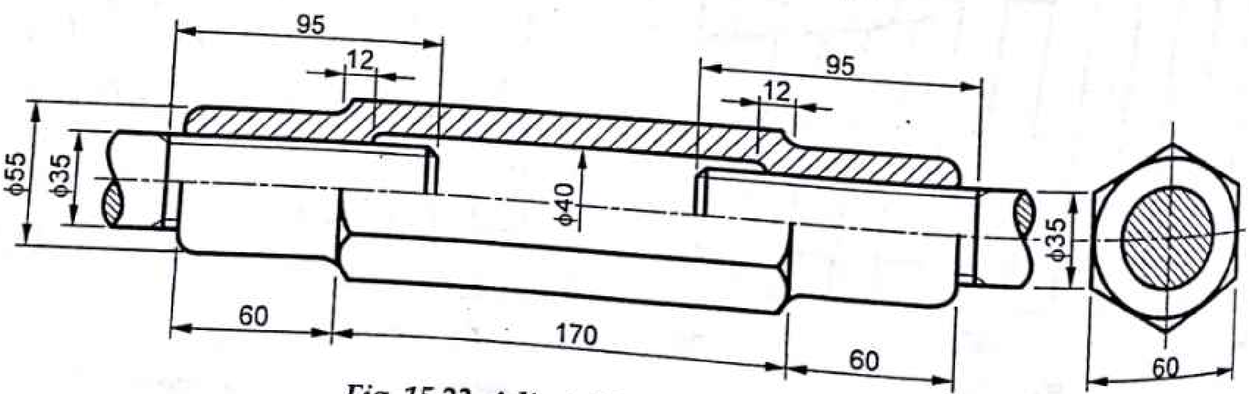


Fig. 15.23. Adjustable joint for round rods

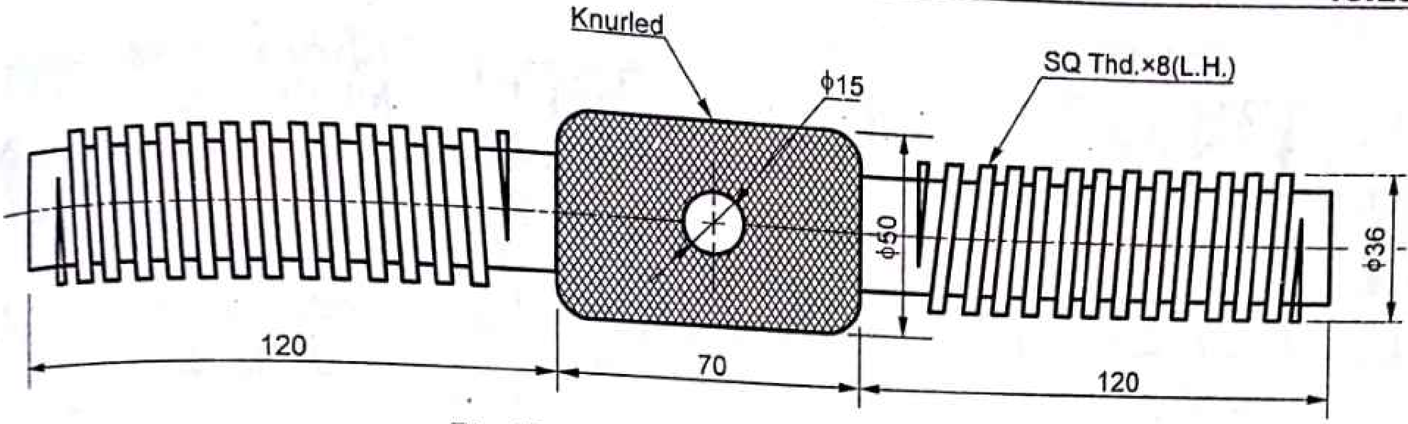


Fig. 15.24. Coupler for railway carriage

15.7. MULTI-START THREADS

Fig. 15.25. and 15.26. A single-start thread is composed of a single ridge around a shaft with each turn next to the pervious turn. It is similar to a single cord wound round a rod each turn packed tightly against the previous one. Multiple threads are composed of two or more ridges side by side which is similar to two or more cords wound round a rod as shown Fig.15.25.

In single-start threads if the axial advance of nut per revolution is increased by increasing the pitch, the depth is correspondingly increased, as there is a definite relation between pitch and the depth. It reduces the minimum cross-section of the bolt and thus the bolt becomes weak.

In multiple start threads

Lead = pitch × number of start.

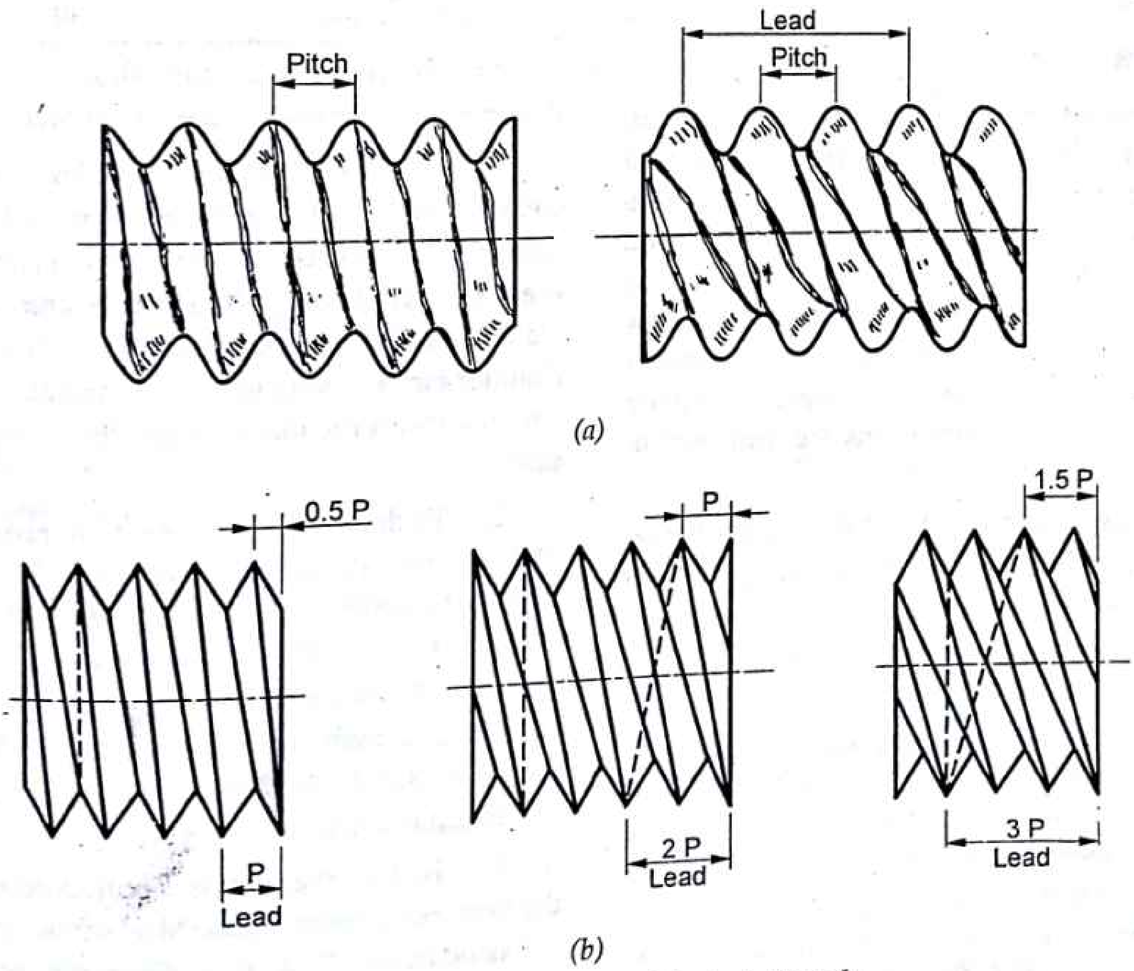


Fig. 15.25. Single and multi-start threads

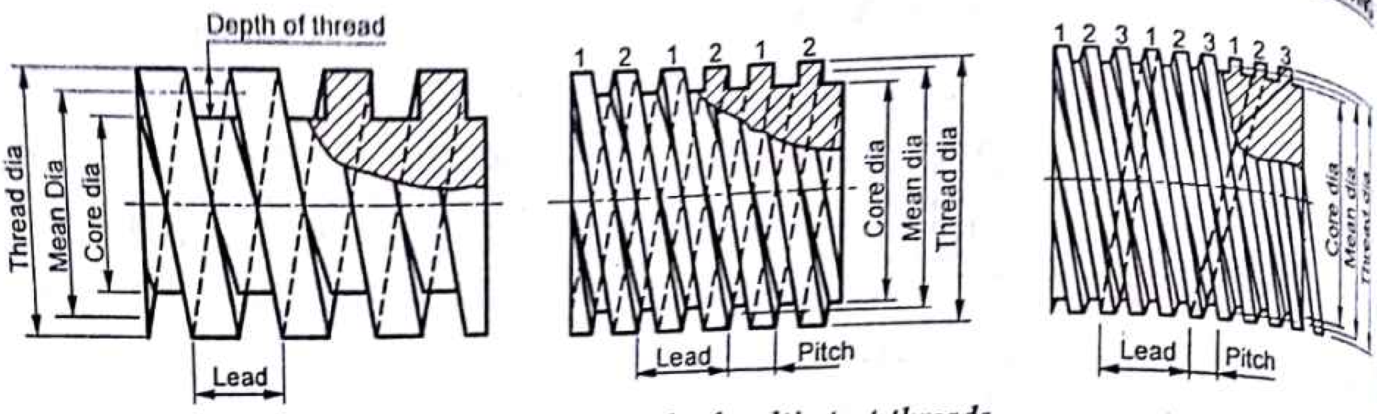


Fig. 15.26. Depth of multi-start threads

Thus for the lead the pitch and consequently the depth decrease as the number of start increases as shown in Fig. 15.25. Therefore the application of multi-start thread is where large lead is required without reducing the cross-section of the nut. Multiple-start threads are also used where easy screwing is required as in the cap of fountain pens, valve stems, etc.

Note : In even number of threads, as two-start and four-start, the crests on both sides are directly opposite each other. In odd number of threads, as in single-start and three-start crest on one side of the screw is opposite the root of the other.

15.8. NUTS

A nut has internal threads. The most common form of nuts is hexagonal. It roughly comprises a hexagonal prism. For screwing it is turned by a spanner (of the open-ended, ring or socket type) and a new hold is obtained by turning through 60°. In square nuts the spanner has a better hold but a new hold is obtained by turning through 90° and hence it is not so convenient. Besides hexagonal and square shape, cylindrical and other forms are also used to suit particular requirements.

Hexagonal Nut. Fig. 15.27 shows a hexagonal nut. The upper corners of the hexagonal prism are bevelled off or chamfered at 30° to the base of the nut. It is done to remove the sharp corners which may hurt the workman. The chamfering is generally conical.

The dimensions of the hexagonal nut cannot be expressed in terms of the nominal diameter of the bolt. The Indian Standards proportions for nuts and bolts are given in table at the end of the book. The three important dimensions of a hexagonal nut are size across corner, size across flats and height. For elementary work the following approximate dimensions expressed in terms of D, the diameter of the screwed hole in the nut, may be used.

Table 15.3. Approximate dimensions of hexagonal nut

Let D = Diameter of the screwed hole in hexagonal nut and outside or nominal diameter of bolt.

Size across flats	= 1·25 D + 6 mm
Size across corners	= (Flats) × 1·555
Height of nut	= 0·8 D to D
Radius of front chamfer	= D to 1·2 S
Chamfer at top	= 30° to base of nut

The following procedure should be adopted in drawing three views of a hexagonal nut.

1. Commence with the plan. Draw a circle (open-ended) equal to D to represent nominal or outside diameter. To represent minor (or root or core) diameter draw a full circle of 3/4 D. Describe third circle with diameter equal to size across flats. This represents chamfer circle. Using tee square and 60° set-square circumscribe a regular hexagon, thus completing the plan.

2. To draw the front elevation, project outline from the plan and describe arc ABC of radius 1.2 D cutting the verticals in A and C. Mark off the points D, A, C. E in one line. Draw the vertical through K bisecting the distance between D and A. Join D, K and bisect at right angles, thus locating the centre of arc DKA. Similarly, draw the arc CLE. By using the 30° set-square chamfer the corners.

3. To draw the side view, project its outline from the front elevation and plan. Mark off points F, G, H in the same line as D, A, C, E. Draw the arc FMG and GNH in the same way as in the front elevation.

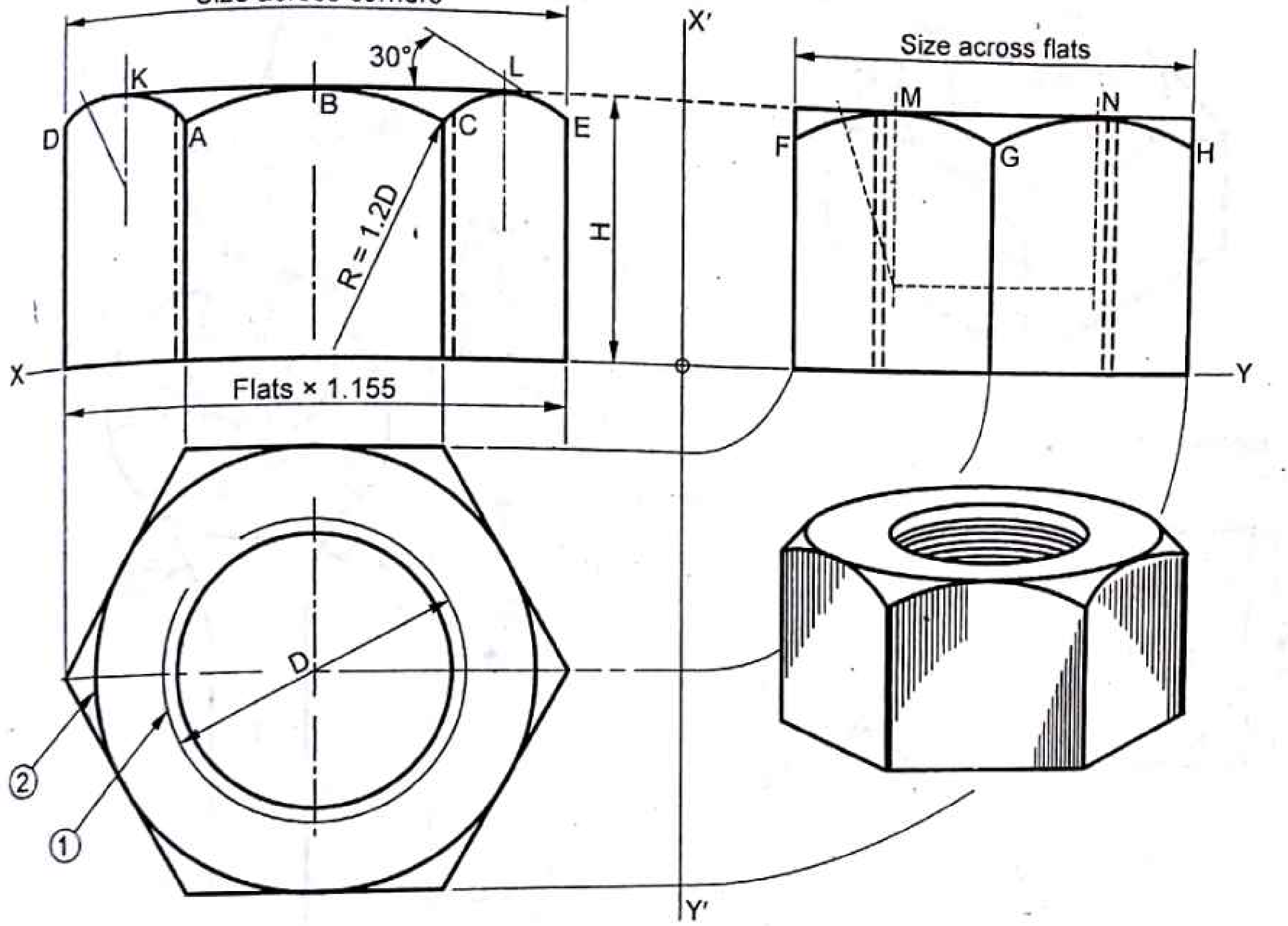


Fig. 15.27. Hexagonl nut

Important Note:

1. When two or more views of a hexagonal nut are required commence with the view showing the circles, thus using the "Size across flats".
2. When only one view of the nut is to be drawn it should be the view having "Size across corners".
3. On elevation showing three faces of the hexagonal nuts, show the upper corners chamfered.
4. On elevation showing two faces of the hexagonal nut, show upper corner square. *Remember always that in this view a rectangular outline is obtained.*

Sketching a hexagonal nut. For quick sketching proportions take "size across corner" = 2D.

Fig. 15.28 shows the steps in sketching a nut.

Square nut. Fig. 15.29 shows the three views of a square nut. In this nut the distance a cross flats is the same as in the hexagonal nut. The Indian Standards proportions for square bolts and nuts are given in table at end of the book. The following are the approximate proportions.

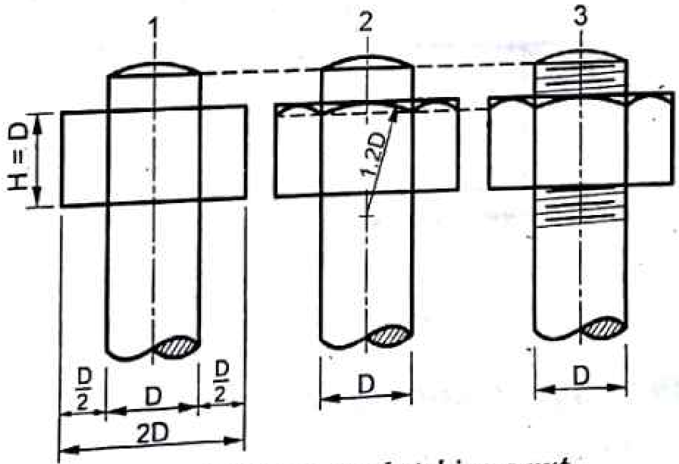
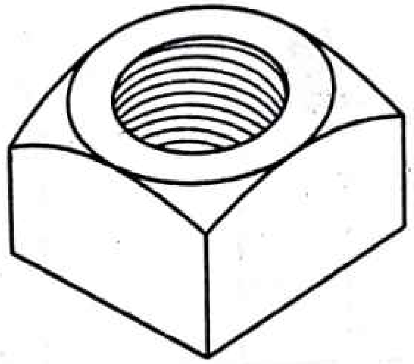


Fig. 15.28. Steps in sketching a nut

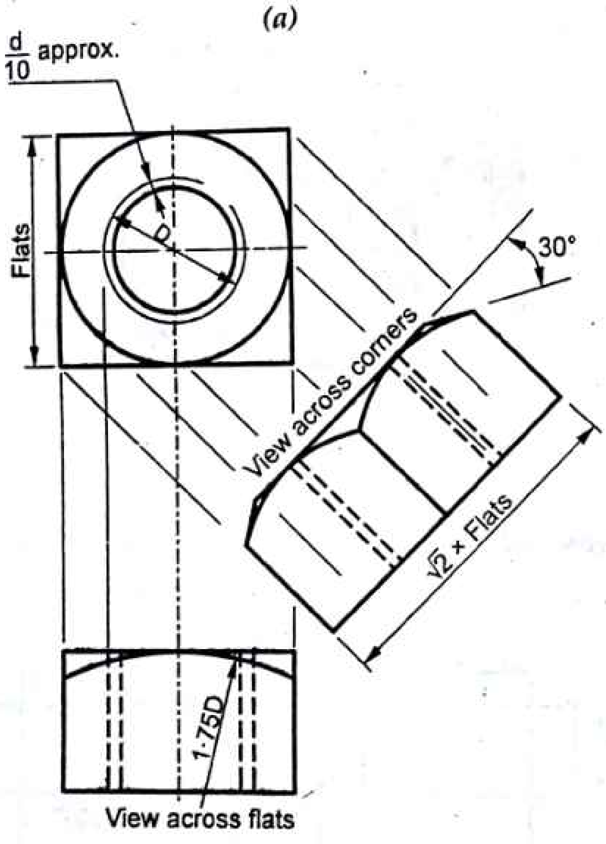
Table 15.4 Approximate proportion of square nut

Size across flats	= 1.25 D + 6 mm
Size across corners	= (flats) × $\sqrt{2}$
	= (flats) × 1.414
Radius of the view across flat	= 1.75 D

Fig. 15.30 shows a spanner which holds the "size across flats" of a nut of any shape.



(a)



(b)

Fig. 15.29. Square nut

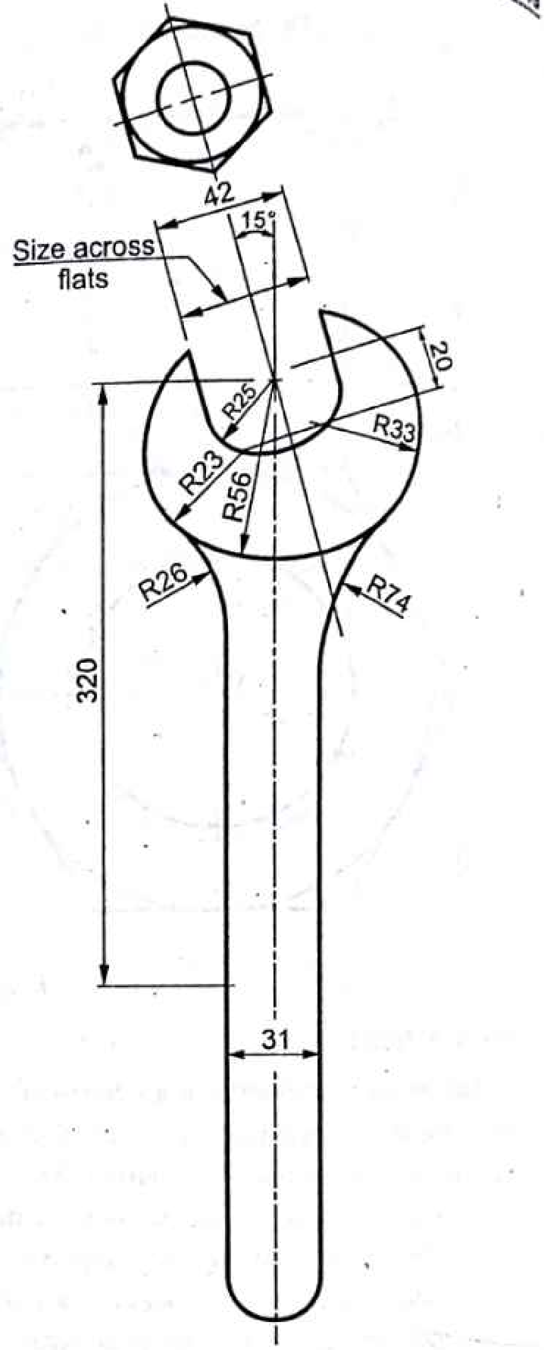


Fig. 15.30. Spanner

15.9. BOLTS AND NUTS

Example. To draw three views of a 24 mm diameter, 95 mm long, hexagonal-headed bolt and nut, Fig. 15.31.

1. Draw the centre line of the front view and about it draw the rectangle 24 mm × 95 mm.

2. Describe a circle in the end view of diameter 1.25D + 6 mm (size across flat), and about it circumscribe a regular hexagon using the tee-square and the 60° set-square.

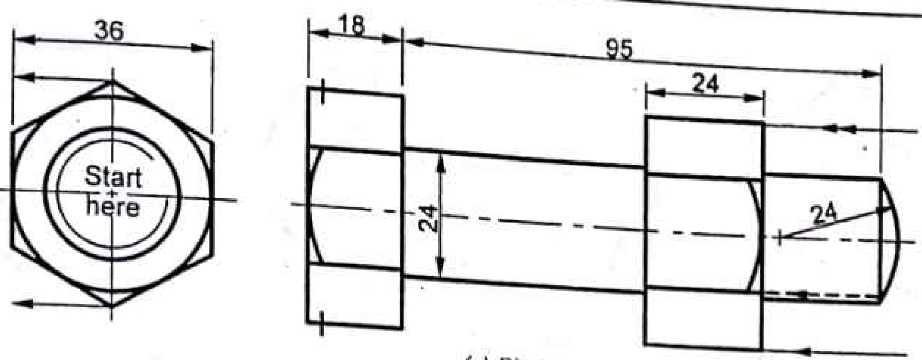
3. Anywhere on the threaded portion of the bolt draw the front view of the nut outline, projected from the end view. Similarly add the outline bolt head. Bolt heads are usually thinner than nuts, about 2/3D.

4. Take the pitch of the screw threads as 3 mm from table and complete the views as shown.

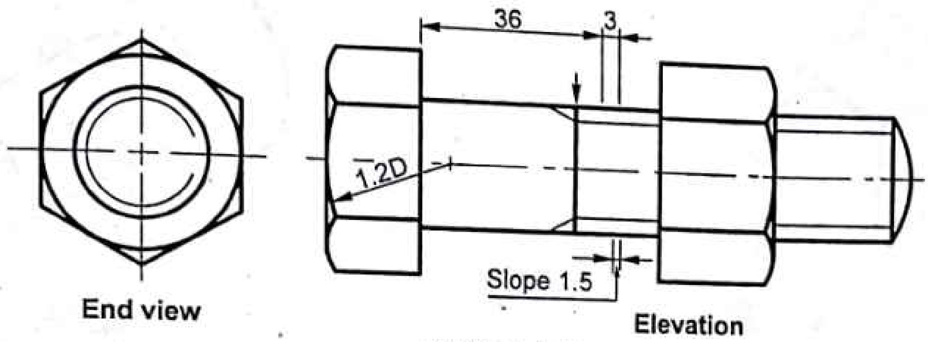
Fig. 15.32 shows square-headed bolt and nut.

Table 15.5. I.S.I specification for thread length (I.S.1363-1060)

Bolt length	*Thread length*
(*i*) For lengths up to and including 80 mm	2 D + 5 mm
(*ii*) For lengths above 80 mm and including 200 mm	2d + 10 mm
(*iii*) For length above 200 mm	2d + 20 mm



(a) First steps



(b) Finished view

Fig. 15.31. Steps in drawing three views of hexagonal-headed bolt and nut

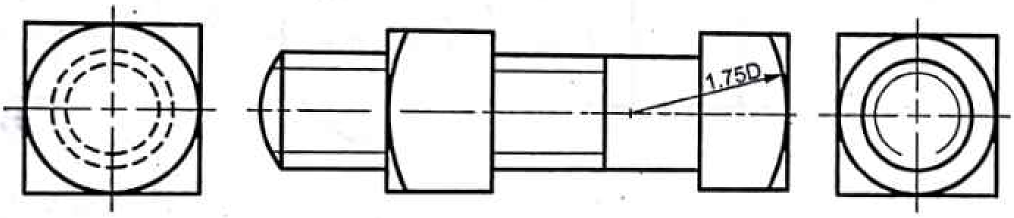


Fig. 15.32. Square-headed bolt and nut

Designation. A black hexagonal bolt of nominal diameter 12 mm and length 70 mm provided with a hexagonal nut is designated as Hexagonal bolt M12 × 70 N [IS : 1363]. Leading dimensions of bolts and nuts are given in table at the end of the book.

15.9.1. Other Forms of Boltheads and Nuts

Tee and Cheese heads. Fig. 15.33 (*a*) and (*b*) show respectively a tee head and cheese or cylindrical head. The tee-headed bolts are used as fasteners where bolts can slide in tee slots as in lathes and other machine tools. Cheese head is easy to manufacture by turning in lathes.

Note : A square on the shaft is represented conventionally by two thin cross line.

Castle Nut. Fig. 15.34 (*a*) shows two views of a castle nut. The castle nut consists of a simple hexagonal nut with a superimposed cylindrical portion of the shape of a castle. Six slot are cut in the circular portion for inserting a split pin for locking. Locking can be done at every 60° or 1/6th revolution of the nut. This nut is largely used in automobile work and in machine parts subjected to sudden shocks and much vibration. The dimensions of castle nut should be taken from the table given at the end of the book.

For castle nut of about 25 mm diameter the following approximate proportion can be used.

$$s = d_2 = D, W = 1.1D, M\,0.1D, n = 0.25D$$

Note: The views of castle nut should be drawn commencing with plan, as it contains circles. Note the projection of slots. The slot in elevation shows true shape as it is parallel to the plane of projection (V.P.) The side slots are inclined. to V.P. and therefore they are narrower in elevation.

Washers. Fig. 15.36. Washer is a metal piece placed below the nut or below head in case of tap bolt or screw to serve the following purposes :

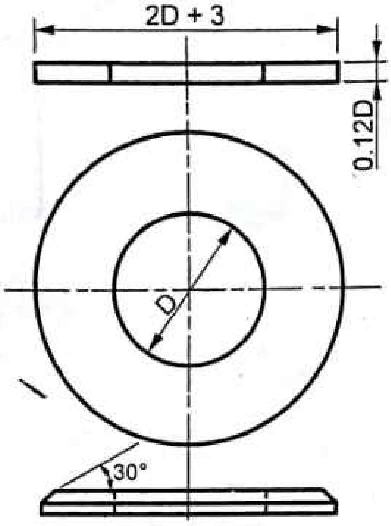


Fig. 15.36. Washer

1. To provide a smooth seating for the nut to turn on.
2. To distribute the force over a large area.
3. To prevent the nut from cutting into the metal.

Table 15.6. Dimensions of washer of for drawing purpose :

Diameter of washer	= 2D to 2D + 3D
Thickness of whasher	= .012 D to 0.2D
Diameter of hole	= D + 0.5 mm to D + 1mm
Chamfer, if provided	= 30°

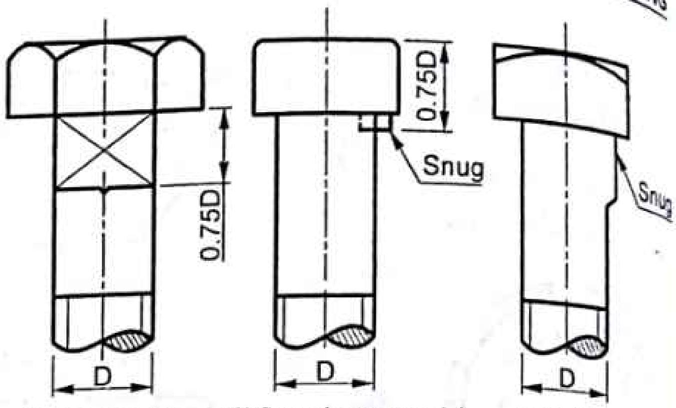
15.10. PREVENTION OF BOLT HEAD ROTATION

Fig. 15.37. If threads of nut are even slightly tight on threads of bolt when nut is screwed, the whole bolt rotates and nut cannot be tightened. The only way to tighten the nut is to hold the bolt head by hand or spanner or better to provide something to prevent bolt head rotation.

The two methods of preventing bolt head rotation are :

1. to provide square neck in bolt which fits in a square hole [see Fig. 15.37(*a*)].

2. to provide a *snug*, a pin fixed near the bolt head or an integral projection below the bolt head, whiich fits in a corresponding hole in the object. [See Fig. 15.37 (*b*) and (*c*)].



(*a*) Square neck (*b*) Snug (separate pin) (*c*) Integral snug

Fig. 15.37. Preveation of bolt head rotation

15.11. LOCKING DEVICES

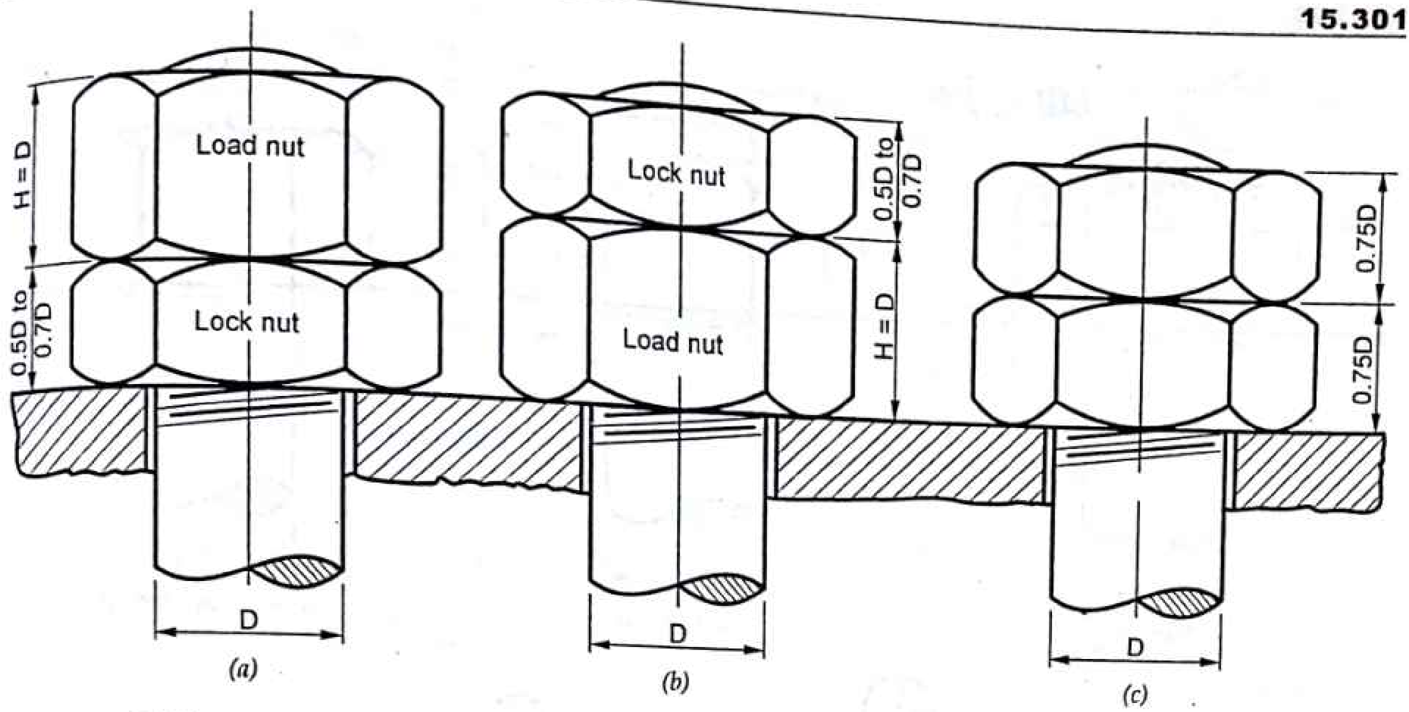
When a bolted machine part is subjected to vibration the nut tends to get loose or slacken back, as in crossheads and connecting rods. Many locking devices for nuts are used in practice.

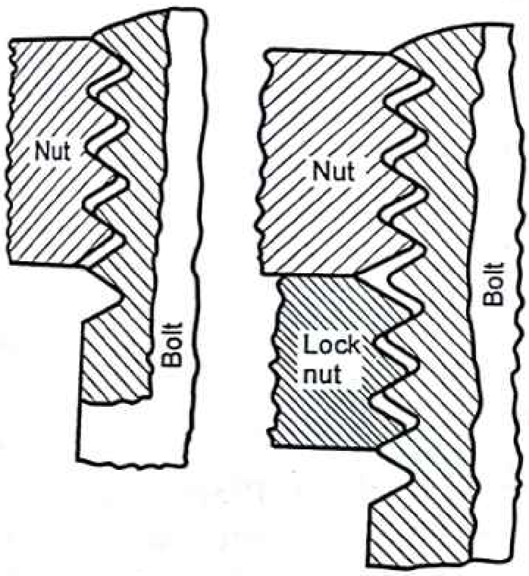
Some are friction locks and some are positive locks. The important of these devices are described below.

1. Lock Nut. Fig. 15.38. This is the most common locking device. In this device a nut is tightened in the ordinary way and then another nut is tightened over it almost to its limit. The upper nut is then held by a spanner while the lower nut is turned back as far as possible by another spanner. The threads of the two nuts will now be in contact as shown in Fig. 15.38 (*d*) with opposite clearances which provide a wedging action. The upper nut carries the total axial load and is made of normal thickness while the lower nut is reduced in thickness to one-half or two-third of this for the sake of economy [see Fig. 15.38 (*a*)]

However, in majority of the cases the smaller nut is put at the top as placing it in the bottom necessitates the use of a thin spanner which is not generally available [see Fig. 15.38 (b)]. Sometimes as a compromise both nuts are made in thickness equal to three-fourth of the normal [see Fig. 15.38 (c)]

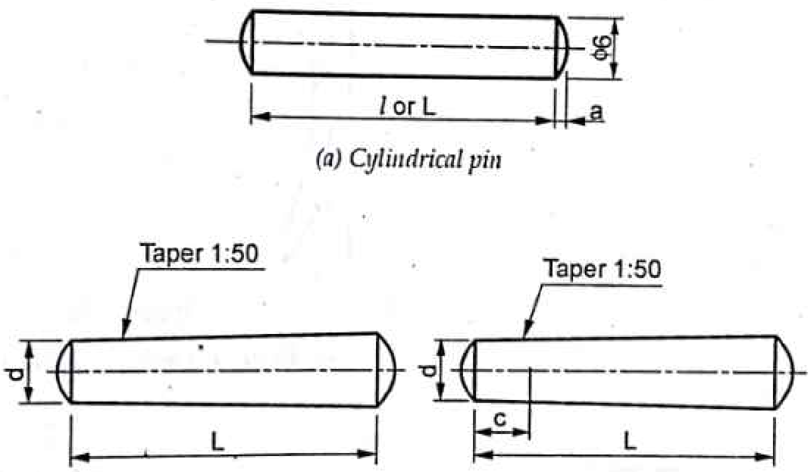
2. Pins. Fig. 15.39 and 15.40 (*d,e*). There are three types of pins—cylindrical, tapered and split. Tapered pins may be used passing through the bolt and the middle of the nut. Tapered pins generally have a taper of 1 in 50. Split pins are driven through





(d)

Fig. 15.38. Lock nut



(a) Cylindrical pin

(b) Solid tapered pin *(c) Split tapered pin*

Fig. 15.39. Cylindrical and tapered pins

the bolt above the nut [see Fig. 15.39 (*d*)]. When pins are used, threads on the bolt are turned down to core diameter to avoid the burring of the threads caused by drilling. Pins are often used as extra locking arrangements.

3. Castle Nut. See Fig. 15.34 (*a*)

4. Slotted Nut. See Fig. 15.34 (*b*) and 15.40 (*a*).

5. Sawn nut or Wiles lock nut. Fig. 15.40 (*b*). A sawn nut is a regular hexagonal nut having a saw cut and is screwed in the normal way and then locked by tightening the set-screw. The hole of the set screw in the upper portion of the nut is a clearance hole whereas in the lower portion it is tapped. In small nuts instead of using a set-screw, locking is done by hammering the two halves of the nut together.

6. Ring, Penn and Grooved Nut. Fig. 15.41. A grooved nut is a regular nut with a cylindrical extension on the lower part, which sits in a counterboard hole. Locking is done by a set-screw passing from the edge which bears in a recess in the cylindrical portion. This method of locking is only possible if the bolt is reasonably near the edge as in the marine type connecting rod ends. If the edge is not near, a separate collar may be used as in Fig. 15.41.

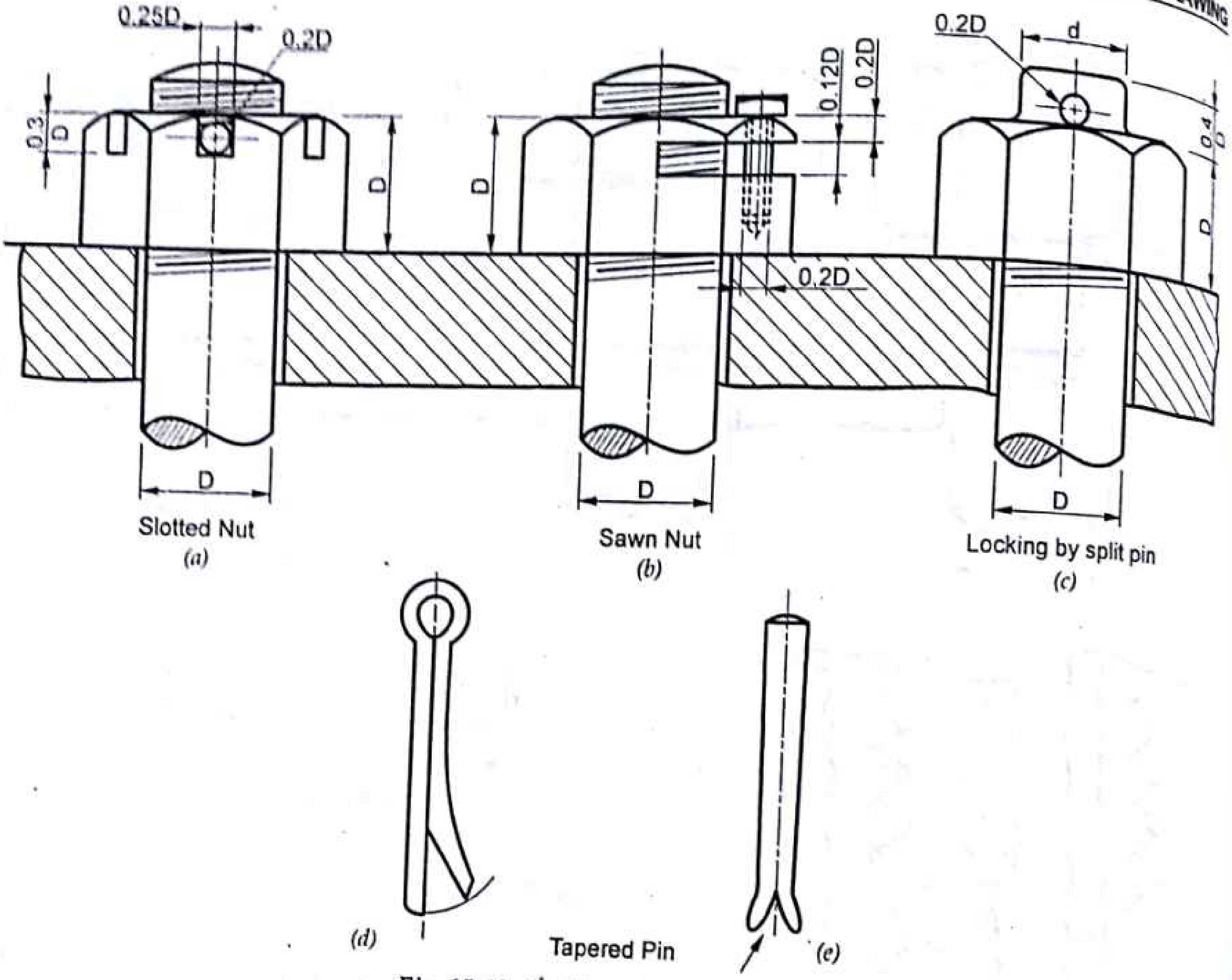


Fig. 15.40. Locking devices for nut

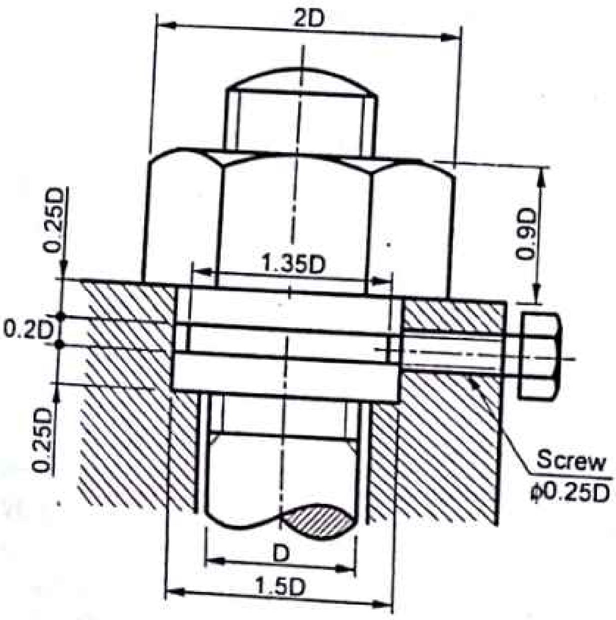


Fig. 15.41. Ring Penn or Grooved nut with separate collar

7. Stop or Locking Plate. Fig. 15.42 shows a locking plate. Adjustment of the nut is possible by angular interval of 60°. In small nuts a copper or brass strip with a hole for the bolt is used.

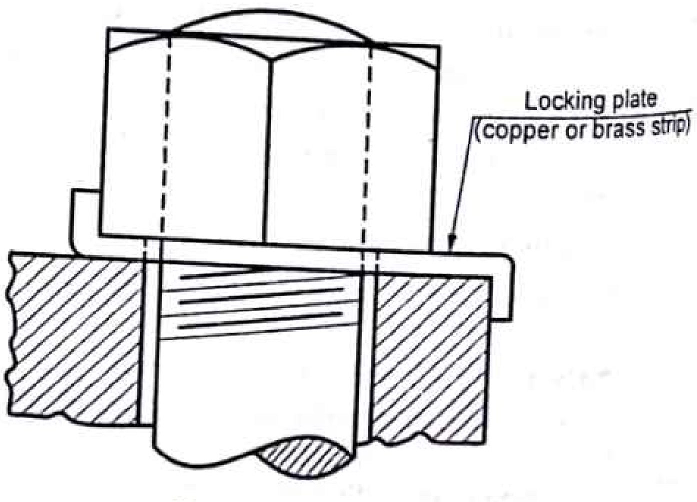


Fig. 15.42. Stop or locking plate

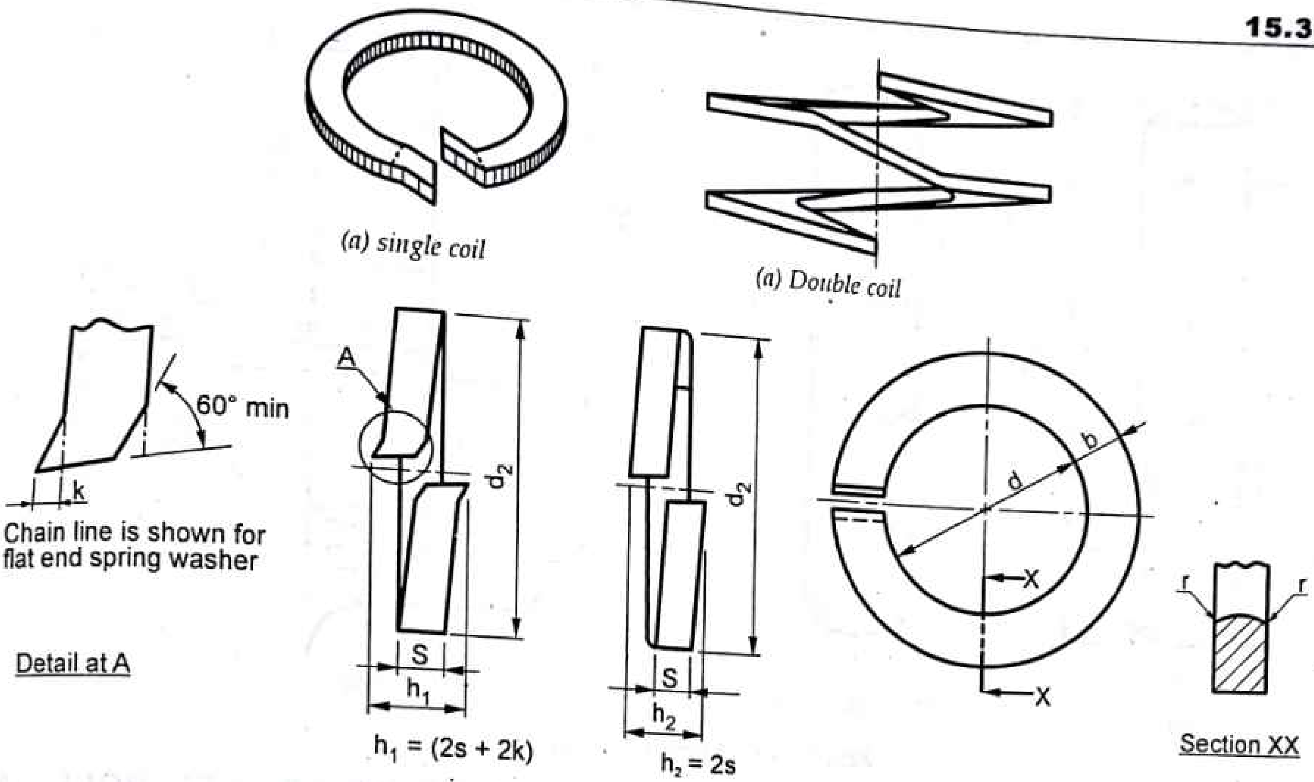
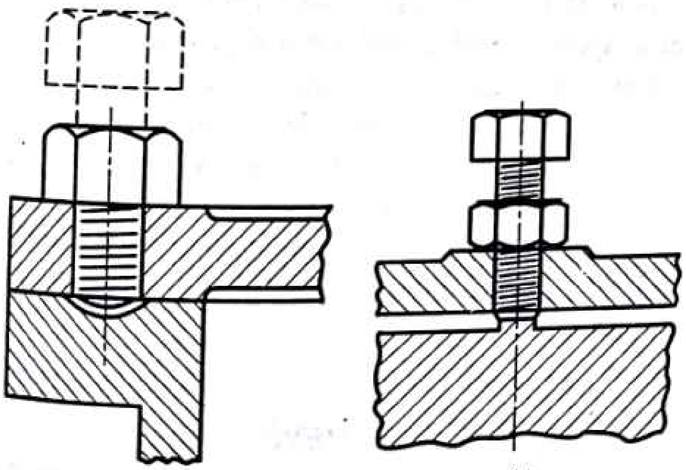


Fig. 15.43. Spring washer

After tightening the nut the two edges of the strip are turned up and down respectively.

8. Spring Washers. Fig. 15.43. Spring washers are often used under the nut for locking . By putting a spring washer under the nut thread of the bolt is pressed against the thread of the nut. Spring washers may be single coil or double coil. The ends of the washers may be bent or flat.



(a) (b)

Fig. 15.44. Tap bolt

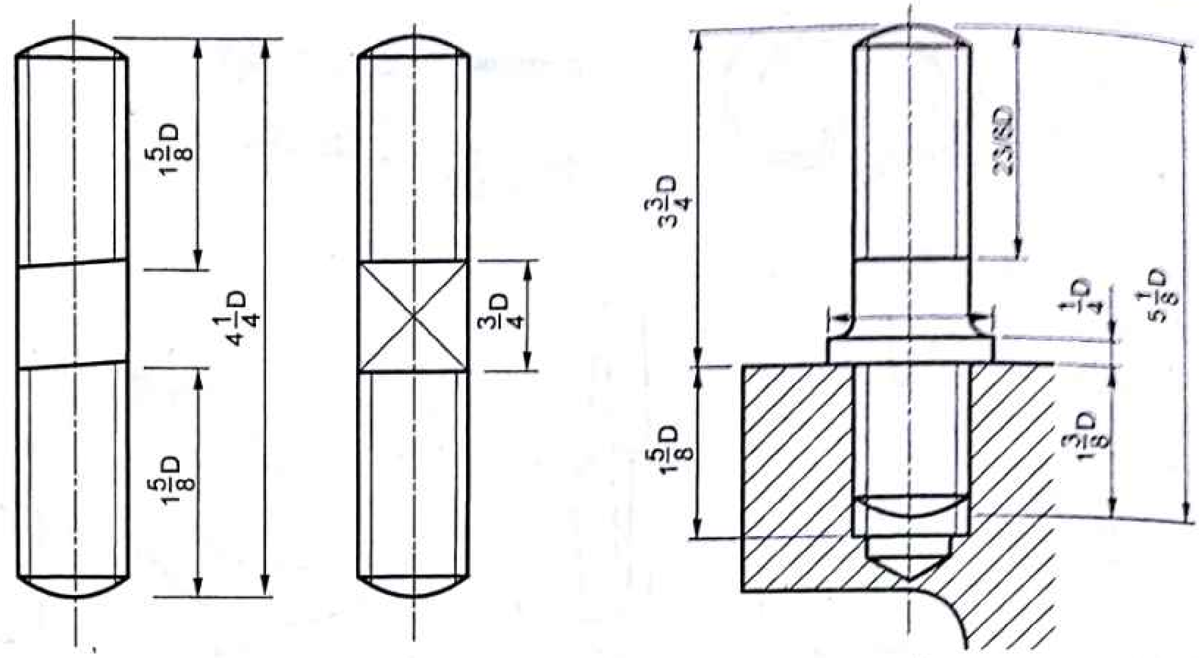
15.12. TAP BOLTS AND STUDS

Fig. 15.44 and Fig. 15.46 (*c*).

Bolt and nuts can be used only when there is sufficient space for bolt head on one side and nut on the other. When there is not sufficient space on one side either a tap bolt or a stud is used.

A tap bolt is an ordinary bolt [see Fig. 15.44. and Fig. 15.46 (*c*)] but threaded almost throughout its length. It passes through a clearance hole in one machine part and screwed in a tapped hole in other. Tap bolts should not be used when screwing and unscrewing is required often, otherwise the threads are damaged particularly if the material is cast iron. (A tap bolt or set-screw may be used as an adjusting screw and to close a hole meant for a lifting screw. The eye bolt shown in Fig. 15.22 is a form of tap bolt).

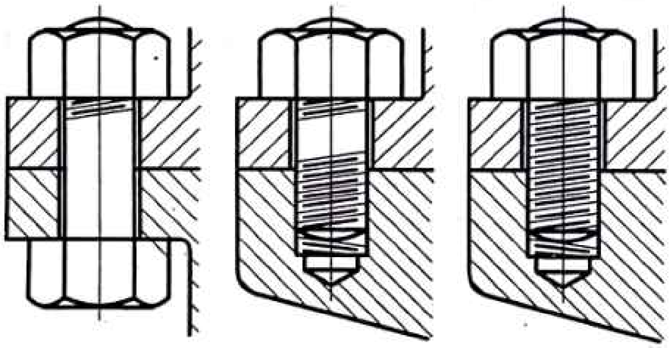
The above disadvantage of tap bolt is eliminated in the use of a studs [Fig. 15.45 (*a*)], which are used for components that are removed frequently, like cylinder heads, cover lids, etc. A stud is a cylindrical piece threaded at both ends and plain in the middle. One end of stud is screwed tightly in a tapped hole of one machine part. The plain portion passes through the second part and the nut is tightened over it. At (*b*) the stud has a squre neck. At (*c*) is a stud with a collar. The two removing parts can be separated by simply removing the nut without uncrewing the stud.



(a) (b) (c)

Fig. 15.45. Different types of studs

Thus the threads in the tapped hole are not damaged. Fig. 15.46 shows the use of bolt, stud, and tap bolt.



(a) Bolt (b) Stud (c) Tap bolt

Fig. 15.46 Use of bolt, stud, and tap bolt

To ensure that the nut is fully engaged when assembled the bolt or stud thread must be long enough to extend on both sides of the nut in its tightened position, as shown in Fig. 15.46 (*a*) and (*b*).

Methods of tightening a stud. A stud with plain cylindrical middle cannot be tightened in the tapped hole by a spanner or an ordinary nut. It may be tightened by two nuts locked mutually upon the upper cylindrical portion. For unscrewing the stud the same methods as for fixing is used.

15.13. ENDS OF DRILLED HOLES AND SCREWED PIECES

A drill has a conical end with an angle of 118°. The drilled end of a hole in drawing is made with an angle of 120° for convenience (see Fig. 15.47). The diameter of the drilled hole is the core diameter of the tapped hole. In order to facilitate tapping of a blind hole, the depth of the drilled hole should always be greater than the length of the threaded portion as shown in Fig. 15.45 (*c*). Note that the threads in the hole appear left-handed for a right-handed stud or screw. The stud or screw should never bear against the bottom of the tapped hole. A gap of two or three times the thread pitch is left to allow for partially cut thread at the bottom of the hole.

Note the left-handed appearance of threads of tapped hole under the stud (having right-handed threads). The screwed depth for cast iron may be taken $1\frac{1}{2}$ D and the depth of the tapped hole $1\frac{5}{8}$ D.

15.14. MACHINE SCREWS

Machine screws are used in machines for fastening two parts together. One of the parts has a tapped hole and the other part has clearance hole. The screw is used by passing it through the clearance hole in one part to screw into the threaded hole in the other. Screws are not secured by a nut. Various forms of machine screws are shown in Fig. 15.48.

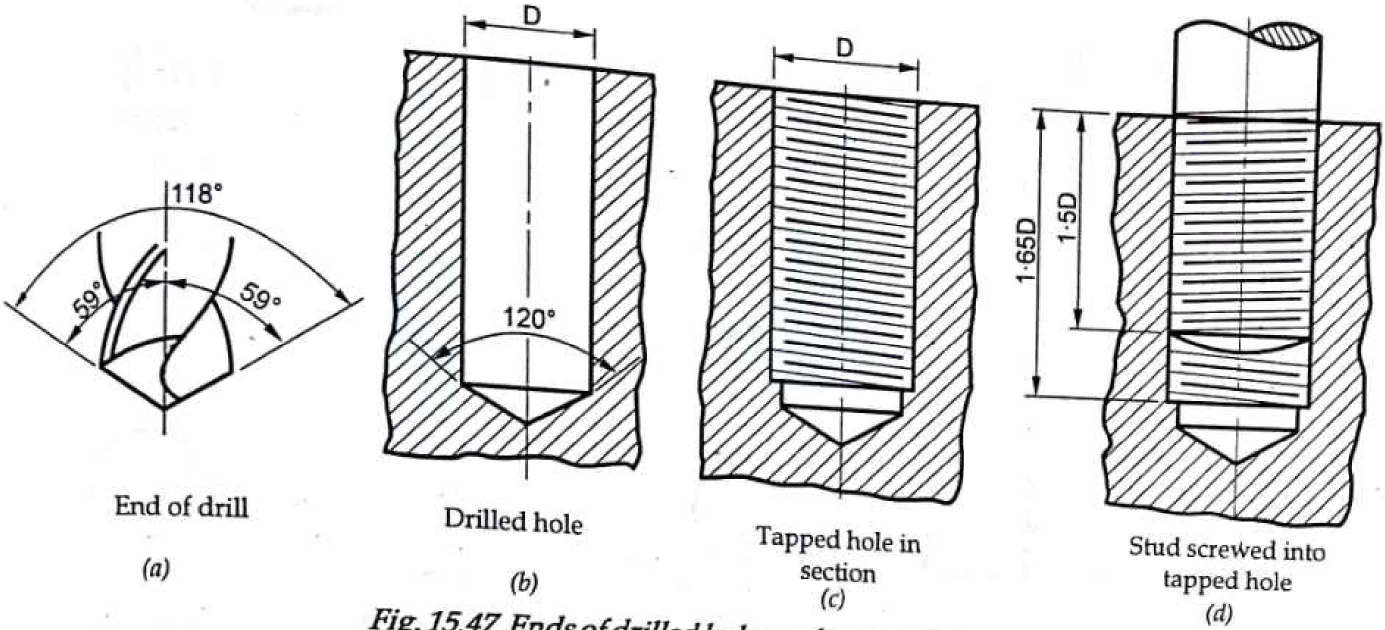


Fig. 15.47. Ends of drilled holes and screwed pieces

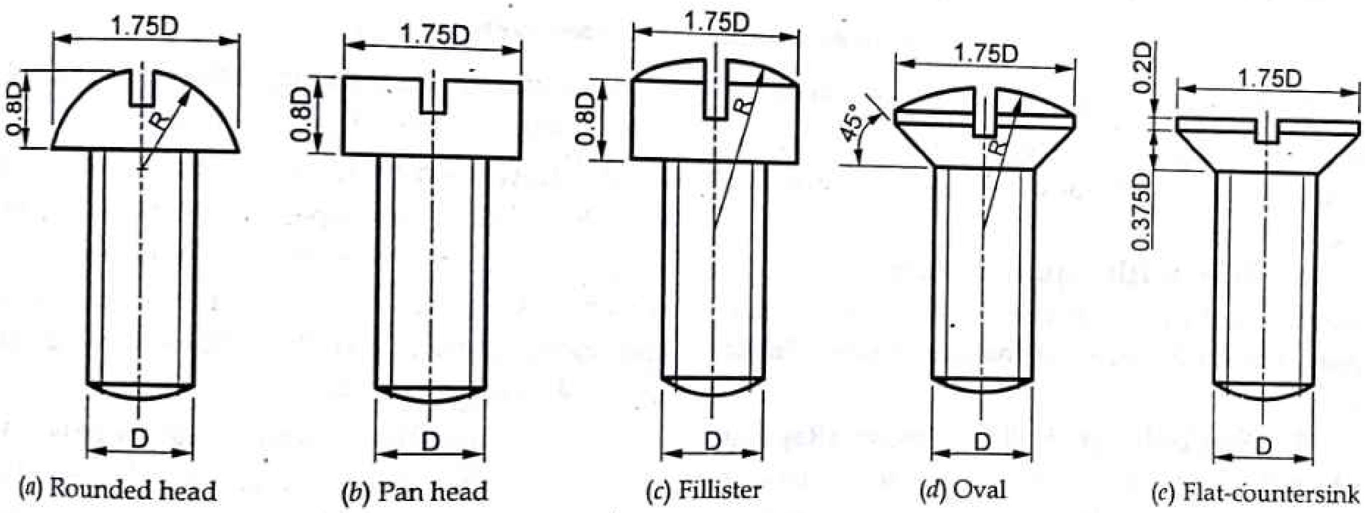


Fig. 15.48. Various types of machine screws

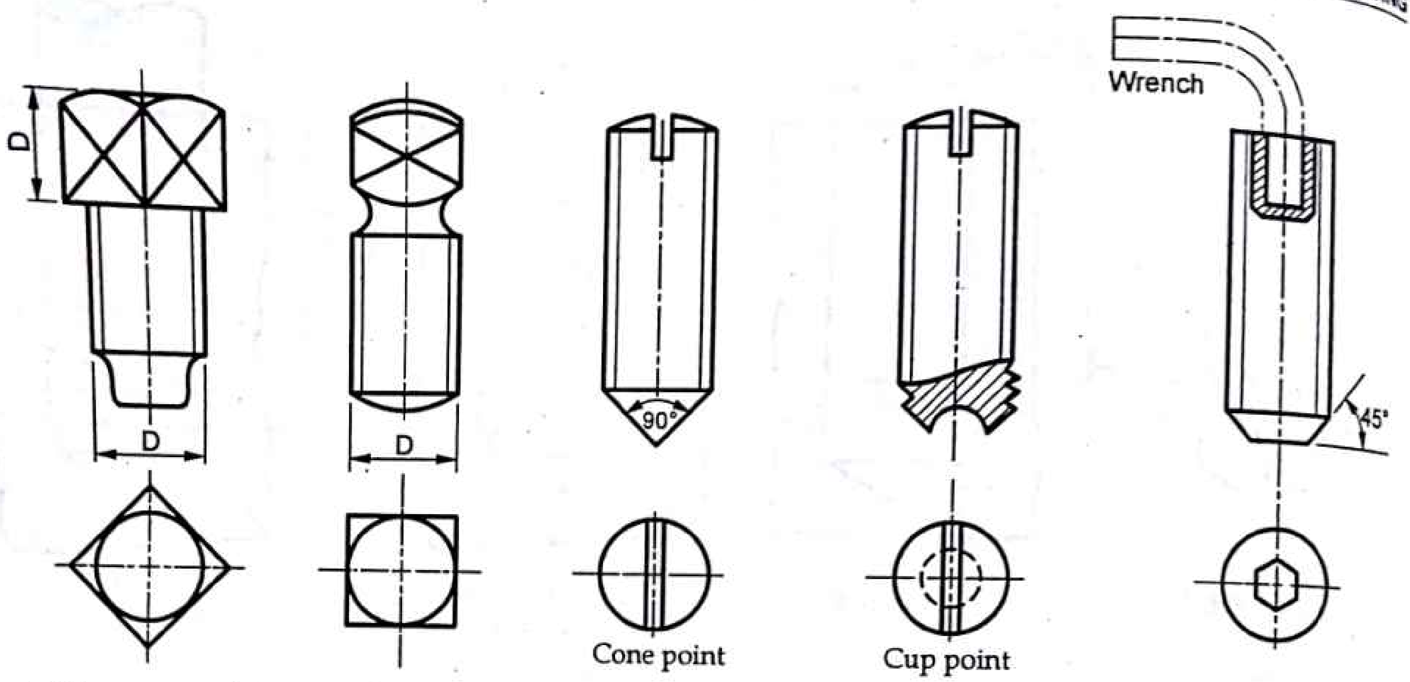
They are provided with a slot in the head for a screw driver. The thread for the countersunk-head screw is taken up to the head while for the others a distance equal to 2 × pitch or less is left plain.

Set-screws. Set-screws are mainly used for preventing relative movement between two machine parts such as between eccentric sheave and crankshaft of a steam engine. The various types of set-screws and their heads are shown in Fig. 15.49. The headless type of set screw are known as *grub screws.* These are used where a projecting head would be dangerous. They may be provided with a slot for screw driver or a hexagonal hole for a wrench. Grub screws are used for locating collars.

15.15. FOUNDATION BOLTS

Foundation bolts are used for fixing machines to their foundations. They are of various shapes. The common method of fixing a foundation bolt is to suspend it in a hole and after levelling the machine fill the same with a fine thin grout consisting of equal parts of sand and cement. When grout is set, which takes about a week, the nut is finally adjusted.

Instead of cement grout molten lead and sulphur may be employed. The advantage of lead and sulphur is that they set in a few minutes. Lead requires caulking after it has set. The various types of foundation bolts are given below :



(a) Square cog point (b) Oval (c) Screw driver head Flat point

Fig. 15.49. Various types of set-screws

1. Loop bolt. A simple form of foundation bolt is forged from a mild steel bar by forming an eye at the bottom. A cross piece is fixed in the eye [see Fig. 15.50 (*a*)]

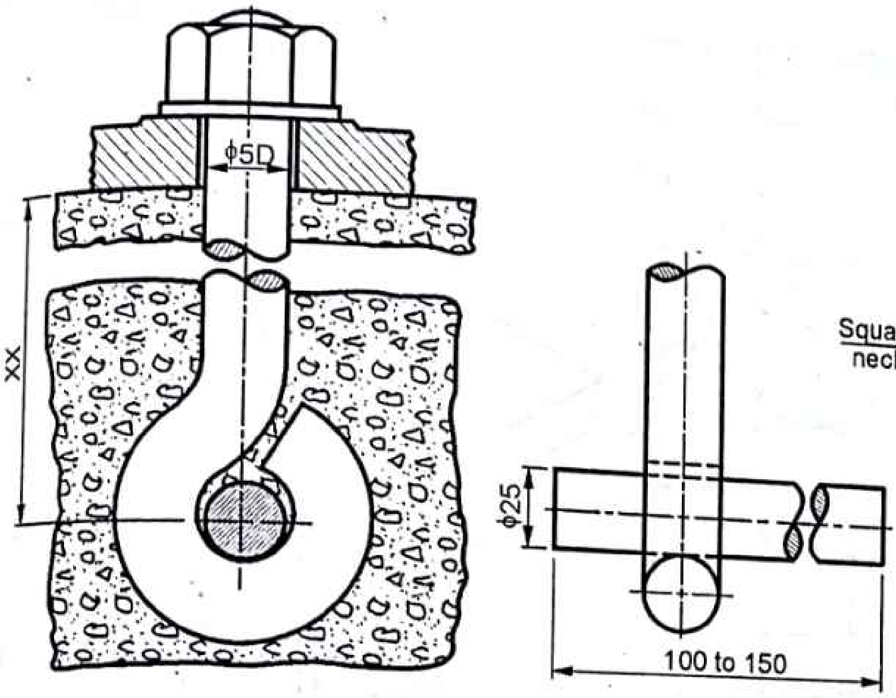
2. Bolt with square plate. At (*b*) is shown a bolt with a square neck carrying a square plate. The square plate distributes load over a larger area.

3. Rag bolt. At 15.50 (*c*) is shown a Rag bolt which is used for fixing heavy machines to stone or concrete foundations. It is a tapered bolt of rectangular section. Its edges or sides are indented or gashed with a black smit's sett.

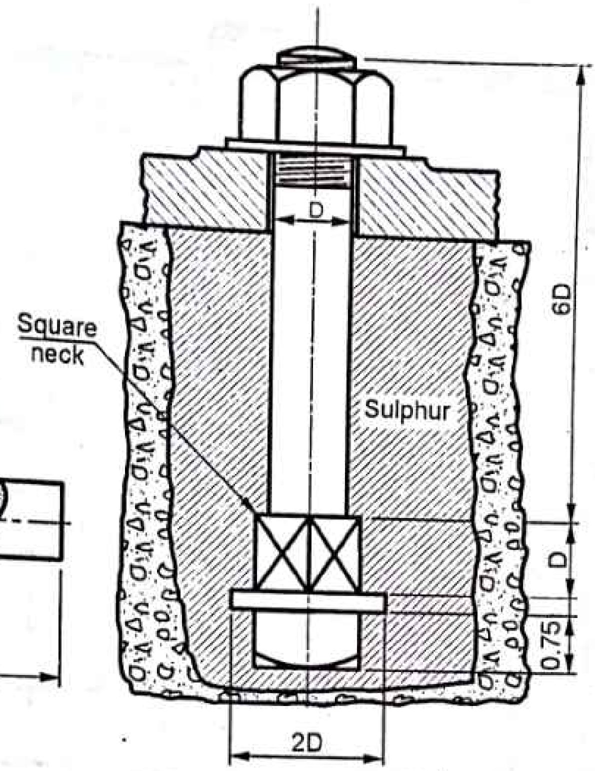
4. Cottered bolt. At 15.50 (*d*) is shown a cottered bolt which is used in various forms. It consists of a cotter bearing against a washer and is screwed below the floor or foundation level. It should be noted that the cotter slot must be longer than the full depth of the horns or extended ends of the cotter.

5. Lewis Bolt. At 15.50 (*e*) is shown a Lewis bolt which is used for temporary foundation and for slinging blocks of stone. It has one tapering side which lies against a side of the hole having corresponding taper. This bolt can be easily withdrawn by simply removing the key.

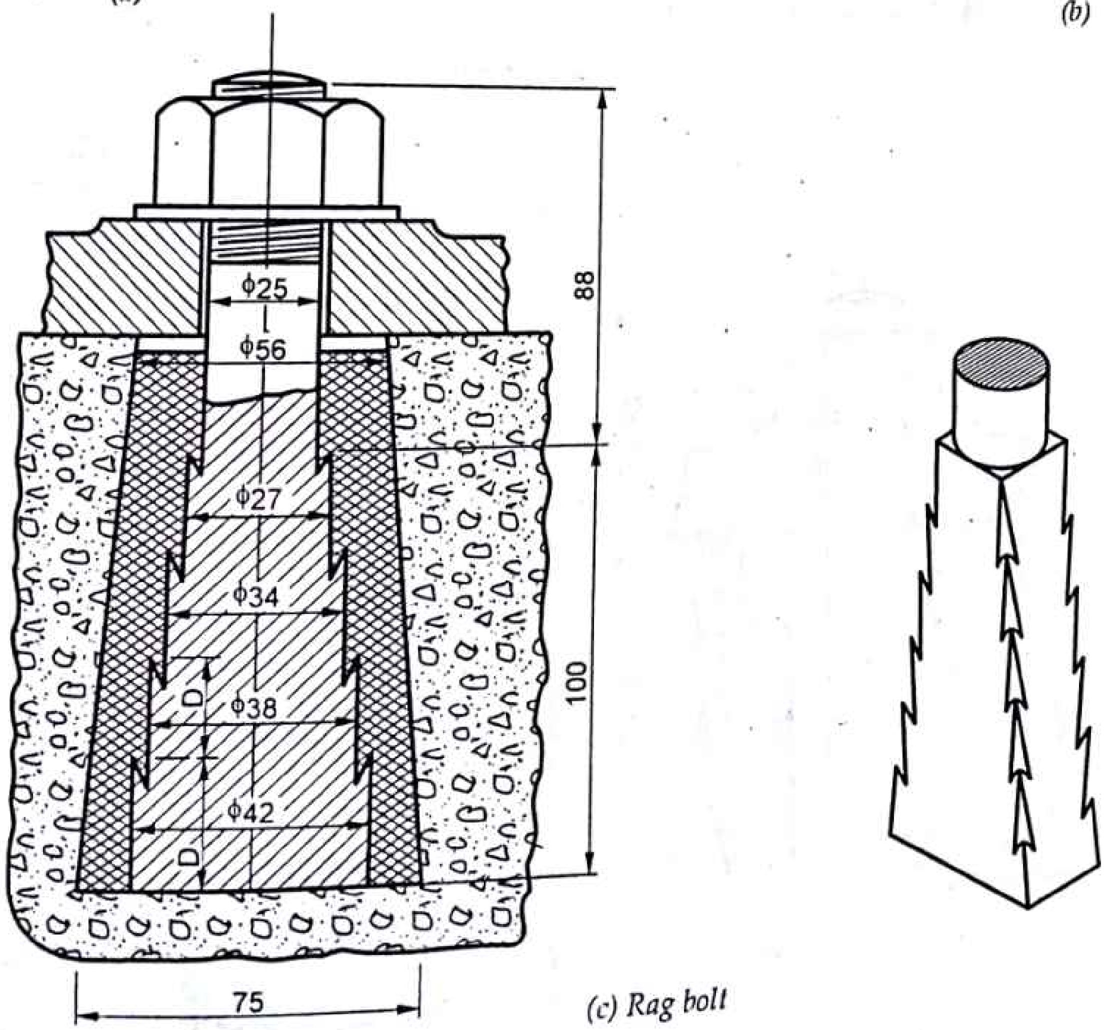
6. Foundation Nut and Screw. At 15.50 (*f*) is shown a foundation nut and screw. The nut is grouted in the floor without any projection and therefore machine can be slide over without lifting. After putting the machine in position and levelling it, the screw is tightened by an Allen key. The machine can be easily removed by simply withdrawing the screw.


ϕ5D
XX
ϕ25
100 to 150

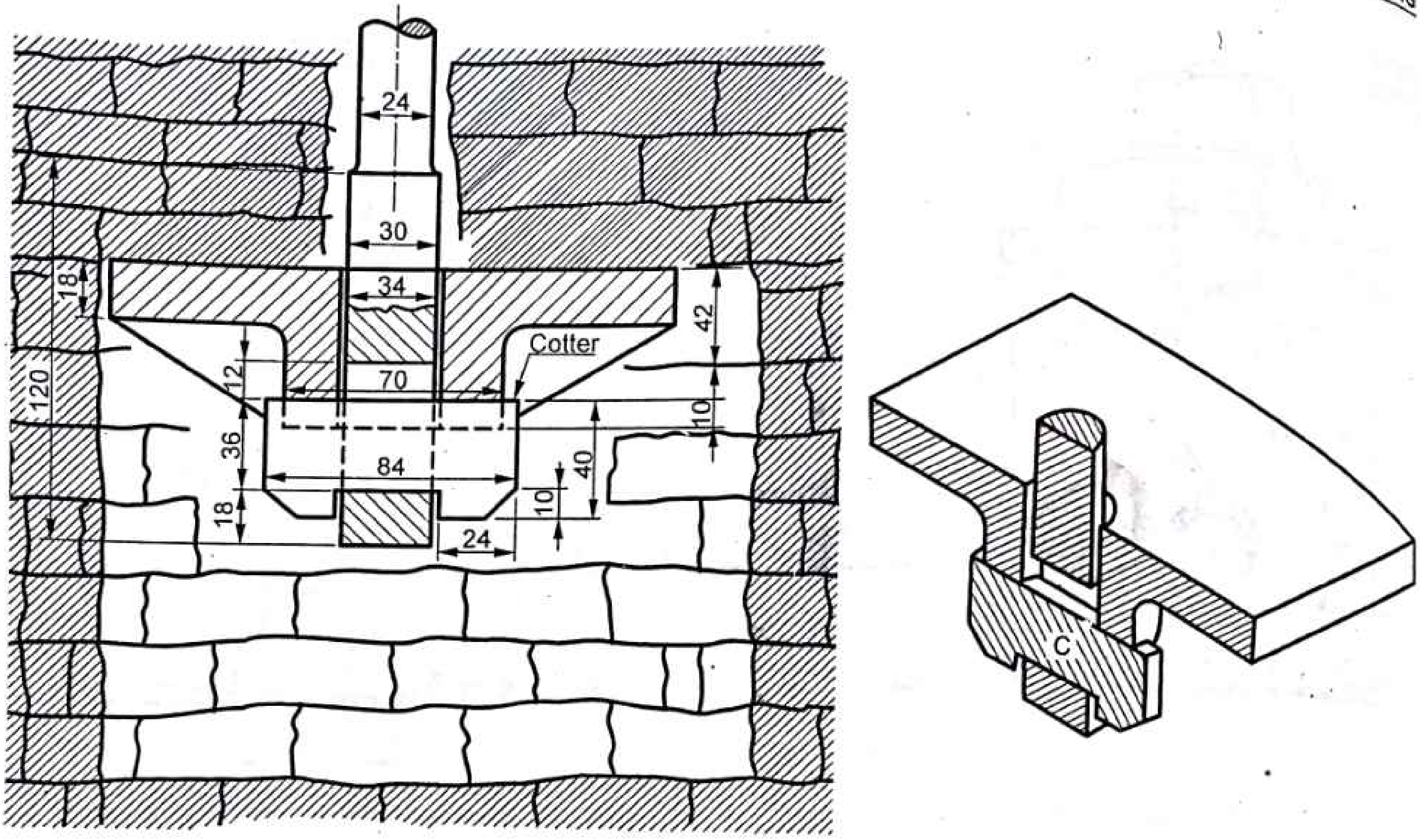
(a)


Square neck
D
Sulphur
6D
D
0.75
2D

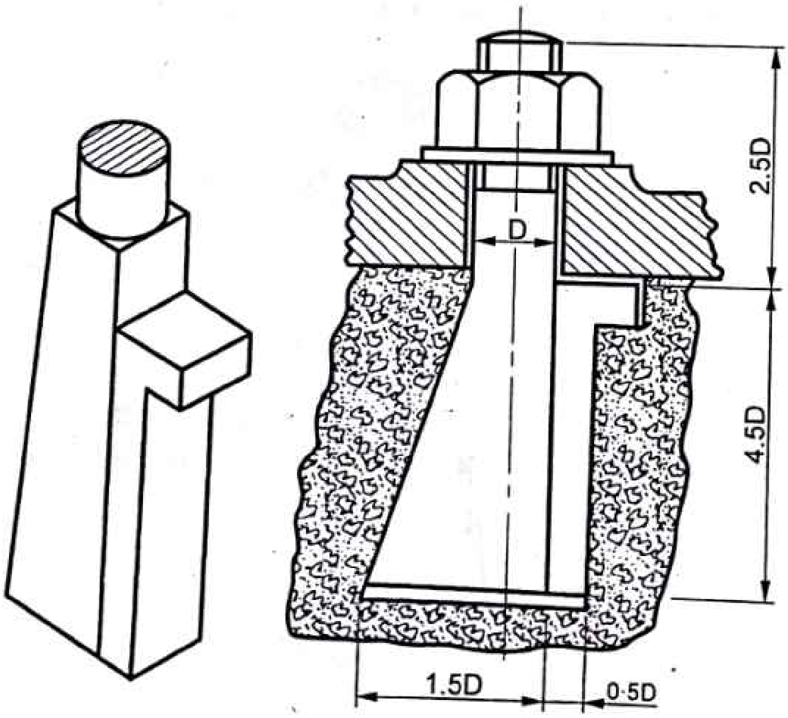
(b)


ϕ25
ϕ56
88
ϕ27
ϕ34
ϕ38
D
ϕ42
D
100
75

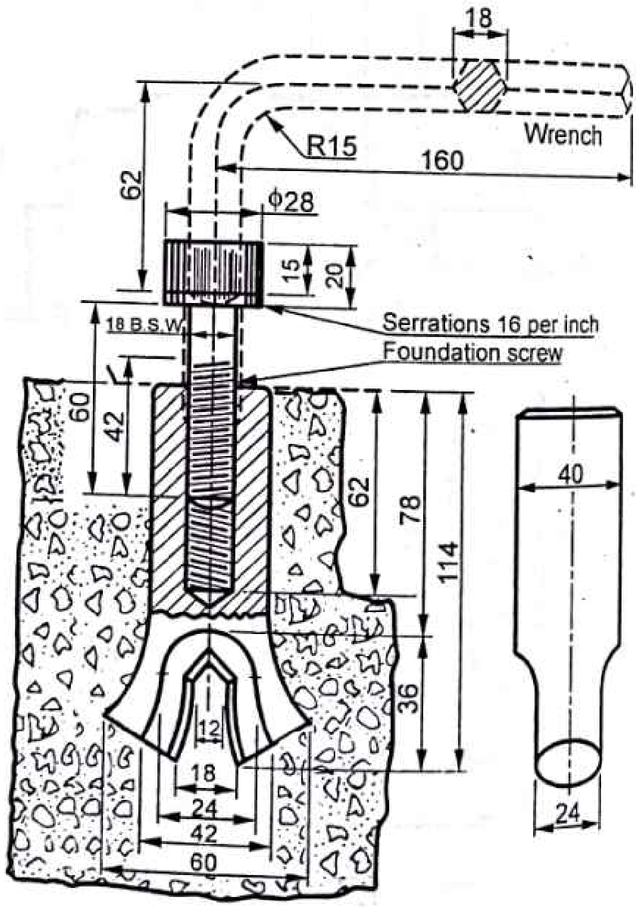
(c) Rag bolt



(d) Cottered bolt



(e) Lewis bolt



(f) Foundation nut and screw

Fig. 15.50. Foundation bolts