
UNIT 1 INTRODUCTION TO DRAWING

Structure

- 1.1 Introduction
 - Objectives
- 1.2 Drawing Equipment and Instruments
- 1.3 Drawing Sheets and Layout
 - 1.3.1 Sizes of Drawing Sheets
 - 1.3.2 Layout of Drawing Sheets
- 1.4 Types of Letters and Lettering Standard
 - 1.4.1 Dimensions
 - 1.4.2 Style
 - 1.4.3 Recommended Sizes
 - 1.4.4 Free Hand Lettering
- 1.5 Types of Line and Their Applications
 - 1.5.1 Types of Line
 - 1.5.2 Thickness and Proportional Dimensions of Lines
- 1.6 Dimensioning of Drawing
 - 1.6.1 Elements of Dimensioning
 - 1.6.2 Projection Lines, Dimension Lines and Leader Lines
 - 1.6.3 Termination and Origin Indication
 - 1.6.4 Indicating Dimensional Value on Drawings
 - 1.6.5 Arrangement and Indication of Dimension
- 1.7 Drawing Scale
- 1.8 Conventional Representation
- 1.9 Summary
- 1.10 Answers to SAQs

1.1 INTRODUCTION

The development of technical knowledge from the dawn of history has been accompanied and to a larger extent, made possible by a corresponding graphic language. Today the intimate connection between engineering and its universal graphic language is more vital than ever before and the engineer, who is ignorant, or deficient in the principal mode of expression in his technical field, is professionally illiterate. That this is true is shown by the fact that engineering drawing is a required subject in virtually every engineering school in the world. A drawing is a graphic representation of an object, or a part of it. The art of representation of engineering objects such as buildings, roads, machines, parts, etc. on paper is called engineering drawing. Modern engineering produces enormous numbers of articles, each first designed and presented in the form of a technical drawing, and then manufactured on the basis of this drawing. Designing an item involves making sketches, technical drawings and appropriate calculations.

Thus, drawing, known as the language of engineers, is one of the fundamental subjects of engineering education.

Objectives

After studying this unit, you should be able to understand

- importance of drawing for engineers,
- various drawing instruments and equipment used for drawing,
- how to use various drawing instrument and equipment,
- standard layout of the drawing sheet,
- standard practice for writing letters, drawing lines, and dimensioning,
- various types of scales used in engineering drawing and selection according to need, and
- various symbols and conventions on the drawing.

1.2 DRAWING EQUIPMENT AND INSTRUMENTS

Engineering drawing is entirely a graphic language wherein information is recorded with the help of drawing instruments and equipment. A student has to be conversant with all the drawing instruments, to enable him to select and use suitable instruments as per the situations. It is also important to follow certain rules and a code of practice for making a presentable drawing. The following are the drawing instruments and other drawing materials required for preparing drawings.

1.2.1 Drawing Board

Drawing-board is rectangular in shape and is made of strips of well-seasoned soft wood. The wooden strips are cleated at the back by two battens by means of screws. On the left-hand edge of the board, a straight ebony strip is fitted, against

Figure 1.1 : Drawing Board

which the stock of the T-square moves. Drawing board is made in various sizes. Its selection depends upon the size of the drawing paper to be used. The following are the sizes of drawing-boards recommended by the Indian Standards Institution :

Designation	Size (mm)
B0	1000 × 1500
B1	700 × 1000
B2	500 × 700

B3	350 × 500
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For use in schools and colleges, B2 and B3 boards are more convenient. B0 and B1 boards are used in the drawing offices of engineering firms. A drawing-board is placed on the table in front of the student, with its working edge on his left side.

The drawing sheet may be fastened to the board either by pins or clamps. For working it is convenient to keep the board tilted at an inclination of 15° to 20° by a block of wood or a stand as shown in Figure 1.2.

Figure 1.2

1.2.2 T-Square

T-Square has a shape like the English alphabet T. It is made of good quality wood. It consists of two parts, namely stock and blade which are attached to each other at a right angle. It has a straight, hard working edge. Sometimes this edge is made transparent which permits viewing of the line underneath the edge of the blade.

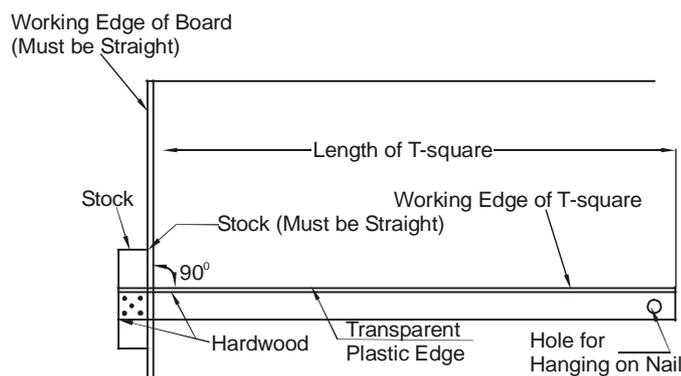


Figure 1.3 : T-Square

The length of the T-square should be such as to suit the length of the board. The T-square can move up and down along the working edge of the drawing-board and is used to draw horizontal lines. The stock of T-square is held firmly against the working edge of the board and then lines can be drawn by a pencil close to the working edge of the blade. Horizontal parallel lines are drawn by sliding the T-square up or down, holding the stock firmly against the working edge of the board.

1.2.3 Set-square

Set-square is of triangular shape and is usually made of clear plastic. There are two types of set-square. They are :

- (a) A $30^\circ - 60^\circ - 90^\circ$ triangle
- (b) A $45^\circ - 45^\circ - 90^\circ$ triangle

All straight lines and perpendicular lines in particular, except horizontal lines, can be drawn with the help of a set-square. In combination with a T-square, lines inclined at 30° , 60° and 45° can be drawn. Using two set-squares along with a T-square, lines inclined at 15° , 75° and 105° can also be drawn. Parallel lines not far apart can be drawn with help of two set-squares.

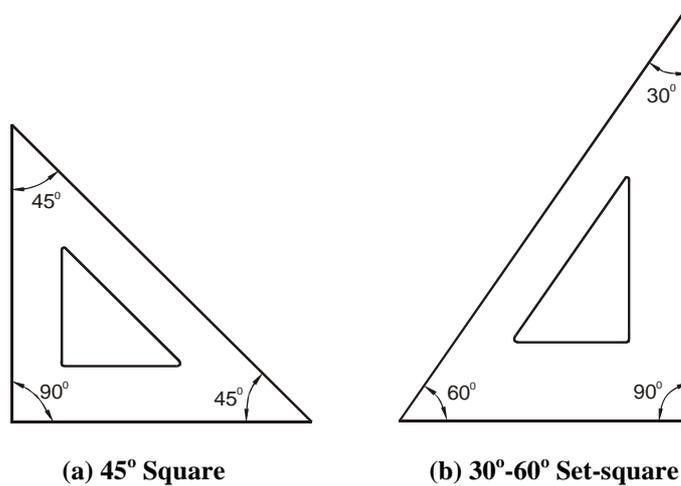


Figure 1.4 : Set-Square

1.2.4 Protractor

Protractor generally made of transparent plastic is circular or semi-circular in shape. The circumference is graduated to 10 divisions and is numbered at every 100 interval. The line joining 00 to 1800 is called the base line. The mid-point of the base line is called the centre of the protractor. It is used for measuring or drawing angles other than those possible with a set-square. It can also be used for dividing any given angle.

Figure 1.5 : Protractor

1.2.5 Scale

Scale is actually a measuring stick, available in a variety of shapes and sizes. It is made of wood, steel, celluloid or plastic. The scale mostly used by students is 30 cm long and is usually flat with bevelled edges. An engineer's scale is such that measurements can be obtained to draw full size (i.e. the length being the same both in the drawing and the object) or half size, one-tenth size, and so on. The main function of the scale is to transfer true or relative dimensions of any part of the object to the drawing. The scale should not be used as a straight edge

for drawing the lines, as it is basically a measuring device. For various other types of scales, refer to Section 1.7.

Figure 1.6 : Scale

1.2.6 Drafting Machine

The uses and advantages of T-square, set-square, scale and protractor are combined in the drafting machine. The drafting machine is now-a-days commonly used by college students and draughtsman, because it eliminates the use of

T-square, set-square, scale and protractor. Its one end is clamped by means of a screw to the distant longer edge of the drawing-board. At its other end, an adjustable head (H) having protractor marking is fitted. Two blades (B) of transparent celluloid accurately set at right angles to each other are attached to the head. The machine has a device or mechanism (M) which keeps the two blades always parallel to their original position, whenever they are moved on the board. The blades have scales marked on them and are used as straight edges. In some machines, the blades are removable, and hence a variety of scales can be used. The blades may be set at any desired angle with the help of the protractor markings. Thus, by means of this machine, horizontal, vertical or inclined parallel lines of desired lengths can be drawn anywhere on the sheet with considerable ease and saving of time.

Figure 1.7

1.2.7 Drawing Instruments Box

It consists of different drawing instruments for drawing various drawings on a sheet of paper. The box contains the following instruments:

- (a) Large-sized-compass with interchangeable pencil and pen legs
- (b) Large-sized dividers
- (c) Small bow pencil compass
- (d) Small bow pen compass
- (e) Small bow dividers

- (f) Lengthening bar
- (g) Inking pen

Figure 1.8 : Compass

Compass

A large compass is used to draw circles or arcs of circle in pencil or ink. It consists of two legs, one with a detachable needle and the second leg that may have different attachments. The attachments normally used are

- (a) pencil-point, (b) pin-point,
- (c) ink-point, and (d) lengthening bar.

Thus, it can perform triple services, as dividers, a pen compass and a pencil compass. A circle of approximately 12 cm diameter can be drawn with the pencil or ink-point with the legs of the compass kept straight. To draw bigger diameter circles, the lengthening bar can be used as shown in Figure 1.9.

Figure 1.9

For drawing small circles and arcs, a small spring bow pencil compass (Figure 1.10) is used. It is equipped with a centre or side wheel (Figures 1.10(a) and (b)) to get finer adjustments. A bow pen compass as shown in Figure 1.10(c), similar to a bow spring pencil compass, is used to draw circles and arcs in ink.

(a) (b) (c)

Figure 1.10

Dividers

Dividers are used to divide straight lines or curves, to measure the distance from the scale and transfer it to the drawing, or to transfer the distance from one part of the drawing to the other part.

Dividers are available in three basic types :

- (a) Plain dividers (Figure 1.11(a))
- (b) Dividers with hair spring (Figure 1.11(b))
- (c) Bow dividers (Figure 1.11(c))

(a) (b) (c)

Figure 1.11 : Dividers

Plain dividers have two legs hinged at the upper end and are provided with steel points at both the lower ends. By hair spring dividers it is possible to get minor adjustments near to a point with the help of an adjusting screw. Small bow dividers are adjusted by nut and are very convenient for marking minute divisions and a large number of short equal distances.

Inking Pen

It is used for drawings to be drawn in ink. The distance between the two nibs is adjusted by a screw and lines of the required thickness can be drawn and non-circular arcs can be drawn by the inking pen. The ink is to be filled between the two nibs (Figure 1.12).

Figure 1.12 : Inking Pen

French Curves

French curves are used to draw irregular curves. It is desirable to have several French curves of different curvature. French curves are made of wood, plastic or celluloid. The edges of a French curve must be absolutely smooth. Its shape should comprise curves most widely used in drawings and gradually merging into each other. Some set-squares also have these curves all cut in their middle (Figure 1.13).

Figure 1.13 : French Curves

1.2.8 Drawing Pencils

A pencil is used for preparing a drawing on a sheet of paper. The accuracy and appearance of a drawing depends upon the quality of the pencil used. Pencils are of various grades and they are easily recognized by the letters marked on them. The description of different grades of pencils, according to BIS, is given in table below :

Grade of Pencil	Hardness
6H, 5H, 4H	Extremely hard
3H	Very hard
2H	Hard
H	Moderately hard
F	Firm
HB	Medium
B	Moderately soft & black
2B	Soft and black
3B	Very soft and black
4B, 5B, 6B	Very soft and very black

Usually, hard pencils such as H, 2H, etc. are used for making engineering drawings, but for the purpose of lettering and sketching soft pencils such as HB or H, etc. are used. As complicated drawings demand fine lines and minute details, harder pencils such as 4H, 5H, 6H, should be used for this purpose.

Mending a Pencil

The following are two methods of mending a pencil for good and accurate work :

- (a) Chisel edge pencil (Figure 1.14(a))
 (b) Conical or round point pencil (Figure 1.14(b))

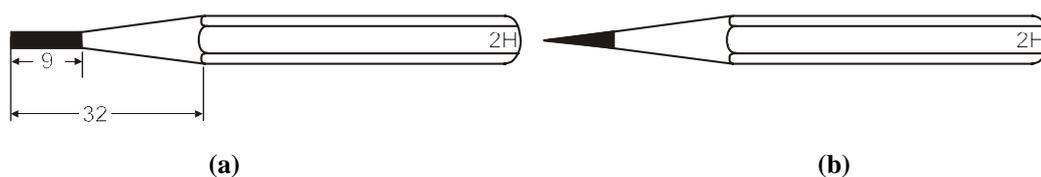


Figure 1.14

A chisel pencil has a chisel edge, flat on each side, which remains fine for a long period and is generally used for drawing straight lines. 2H, 3H, etc. pencils are generally mended to the chisel edge shape, as shown in Figure 1.14a. A medium grade pencil such as HB is sharpened to a conical or round point, as shown in Figure 1.14b and is meant for free hand work. For sharpening a pencil, a small piece of sand-paper of zero grade, pasted upon a piece of wood, will be very useful for keeping the point in good condition. Pull and roll the pencil point on a sand-paper block, as shown in Figure 1.15 to sharpen the pencil point.

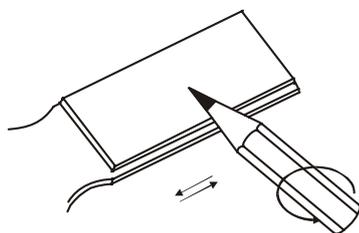


Figure 1.15

1.2.9 Eraser

Soft India-rubber is the most suitable kind of eraser for pencil drawing work. It should be such as not to spoil the surface of the drawing paper. Frequent use of rubber should be avoided by careful planning.

1.2.10 Drawing-pins

Drawing-pins are used to fix the drawing-paper on the drawing-board. The needle part of the pin is so inserted that the head sits on the surface of the paper. The pins may be of plated mild steel or brass. The pins made of brass are quite convenient as they do not rust.

1.3 DRAWING-SHEET AND LAYOUT

Drawing-sheet or drawing-paper should be of uniform thickness with a good finish. Drawing-paper is made in a variety of qualities. The paper used for drawing depends entirely upon the character of the drawing, its purpose, and its use. For ordinary pencil drawings, the drawing paper should be tough and strong, have uniform thickness and be as white as possible. When a rubber eraser is used on it, its fibers should not disintegrate. One side of the drawing-paper is usually rough and the other smooth. The smooth surface is the proper side for drawing. For preparing ferro or ammonia prints, drawings are made in ink on tracing-paper or tracing-cloth. Inking may also be done on ordinary drawing-paper. For the inking purpose, good quality smooth paper, on which ink does not spread, should be used.

1.3.1 Sizes of Drawing-sheets

Drawing-sheets are sized according to the ISO-A series, where for normal practical purposes the area of the largest sheet is one square meter and the sides are in the ratio $1 : \sqrt{2}$ (Figure 1.16). Table 1.1 shows the BIS recommended sizes of drawing sheets.

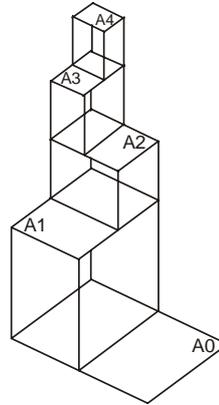


Figure 1.16

Table 1.1

Sl. No.	Designation	Trimmed Size in mm Width × Length
1	A0	841 × 1189
2	A1	594 × 841
3	A2	420 × 594
4	A3	297 × 420
5	A4	210 × 297
6	A5	148 × 210

1.3.2 Layout of Drawing Sheets

The original drawing should be made on the smallest sheet, permitting the necessary clarity and resolution. The general features of a drawing-sheet are as shown in Figure 1.17 as per SP : 46-1998. Drawing-sheets may be used with their longer sides positioned either horizontally (Figure 1.18) or vertically (Figure 1.19).

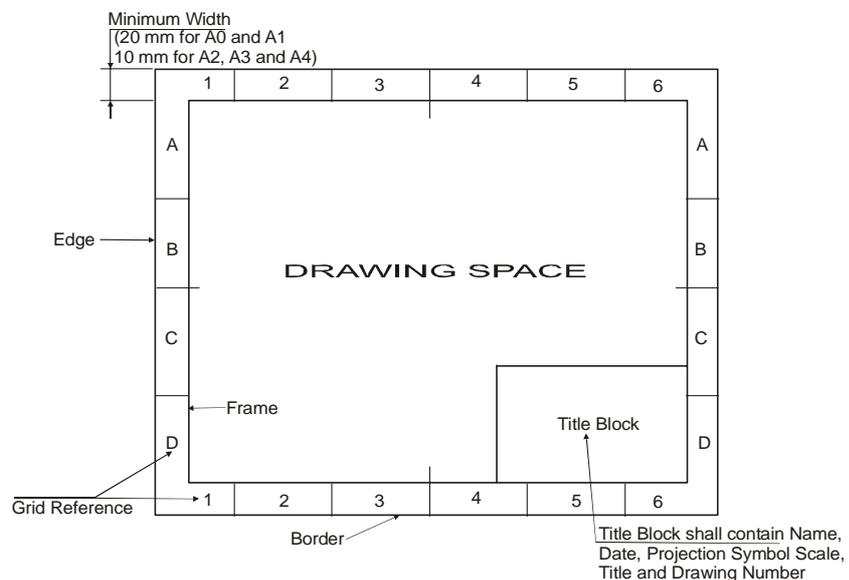
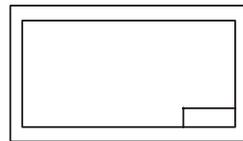
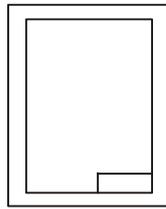


Figure 1.17



Type x

Figure 1.18



Type y

Figure 1.19

Title Block

The position of the title block should be within the drawing space (Figure 1.17) such that the portion of the title block containing the identification of the drawing is situated in the bottom right-hand corner of the drawing space both for sheets positioned horizontally (Type x, see Figure 1.18) or vertically (Type y, see Figure 1.19). The title block should preferably consist of one or more adjoining rectangles. These may be sub-divided into boxes for the insertion of specific information (Figures 1.20, 1.21 and 1.22).

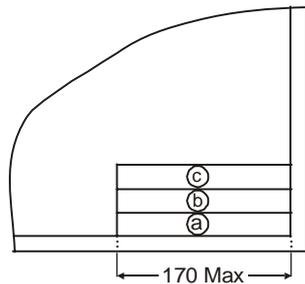


Figure 1.20

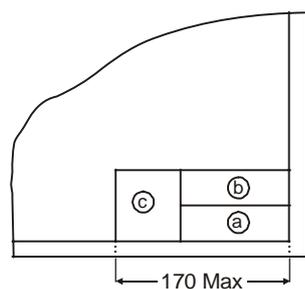


Figure 1.21

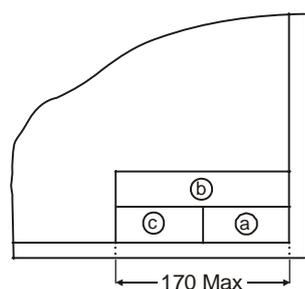


Figure 1.22

Border and Frame

Borders enclosed by the edges of a trimmed sheet and the frame limiting the drawing space shall be provided with all sizes. It is recommended that these borders have a minimum width of 20 mm for size A0 and A1 and a minimum width of 10 mm for size A2, A3 and A4 (Figure 1.17).

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 to 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 be repeated on the opposite sides (Figure 1.17).

1.4 TYPES OF LETTERS AND LETTERING STANDARD

Here we specify the characteristics of lettering used on technical drawings, and associated documents. It concerns primarily the letters written with the aid of stencils but is equally applicable for free hand-lettering.

1.4.1 Dimensions

The height h of the capital letter is taken as the base of dimensioning (Table 1.2 and Table 1.3 and Figure 1.23). The two standard ratios for d/h equal to $1/14$ and $1/10$ are most economical as they result in a minimum number of line thicknesses, as is illustrated in Table 1.2 and 1.3. The recommended ratios for the height of lower case letters (without stem or tail), for the space between characters, for the minimum space of the base lines and the minimum space of words are given in Table 1.2 and Table 1.3 (Refer Figure 1.23).

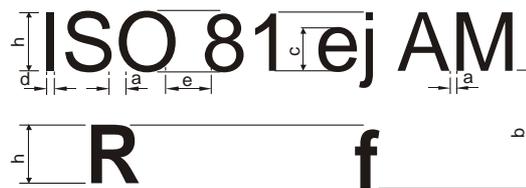


Figure 1.23 : Dimensions

Table 1.2

Lettering A ($d = h/14$)
Millimeters

Values in

Characteristics	Ratio	Dimensions						
		2.5	3.5	5	7	10	14	20
Lettering height h	(14/14) h	2.5	3.5	5	7	10	14	20
Height of capitals								
Height of lower-case letters c (Without stem or tail)	(10/14) h	–	2.5	3.5	5	7	10	14
Spacing between characters a	(2/14) h	0.35	0.5	0.7	1	1.4	2	2.8
Minimum spacing of base line b	(20/14) h	3.5	5.0	7	10	14	20	28
Minimum spacing between words e	(6/14) h	1.05	1.5	2.1	3	4.2	6	8.4
Thickness of line d	(1/14) h	0.18	0.25	0.35	0.5	0.7	1	1.4

[Note : The spacing *a* between two characters may be reduced by half if this gives a better visual effect, as for example LA, TV; it than equals the line thickness *d*.]

Table 1.3

Lettering A ($d = h/10$)

Values in Millimeters

Characteristics	Ratio	Dimensions						
		2.5	3.5	5	7	10	14	20
Lettering height h	(10/10) h	2.5	3.5	5	7	10	14	20
Height of capitals								
Height of lower-case letters c (Without stem of tail)	(7/10) h	–	2.5	3.5	5	7	10	14
Spacing between characters a	(2/10) h	0.5	0.7	1	1.4	2	2.8	4
Minimum spacing of base line b	(14/10) h	3.5	5	7	10	14	28	28
Minimum spacing between words e	(6/10) h	1.5	2.1	3	4.2	6	8.4	12
Thickness of line d	(1/10) h	0.25	0.35	0.5	0.7	1	1.4	2

[Note : The spacing *a* between two characters may be reduced by half if this gives a better visual effect, as for example LA, TV; it than equals the line thickness *d*.]

1.4.2 Style

The lettering may be inclined 15° to the right or may be vertical.

1.4.3 Recommended Sizes

- (a) Lettering A ($d = h/14$), Table 1.2, Figure 1.24 lettering A vertical.
- (b) Lettering B ($d = h/10$), Table 1.3, Figure 1.25 lettering B vertical.

ABCDEFGHIJKLMNPO

QRSTUVWXYZ

abcdefghijklmnopq

rstuvwxyz

[(?;,'-+=x.v%&)]ø

01234567789 IVX

Figure 1.24

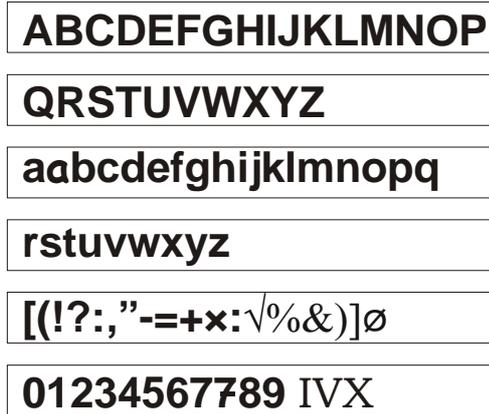


Figure 1.25

1.4.4 Free Hand Lettering

The style of writing free hand single stroke vertical and inclined lettering is illustrated in Figures 1.26 and 1.27.

Figure 1.26

Figure 1.27

1.5 TYPES OF LINE AND THEIR APPLICATIONS

Here we specify the types of lines, their thickness and application for use in technical drawings.

1.5.1 Types of Line

The types of line and their applications are as given in Table 1.4. It is recommended that only line types as given in Table 1.4 shall be used. Typical applications of different types of line are shown in Figures 1.28, 1.29, 1.30, 1.31, 1.32 and 1.33.

Table 1.4 : Types of Line

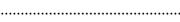
Line	Description	General Application (See Figures 1.23, 1.24 and other Relevant Figures)
A 	Continuous thick	A1 Visible Outlines A2 Visible Edges
B 	Continuous thin (straight or curved)	B1 Imaginary lines of intersection B2 Dimension lines B3 Project lines B4 Leader lines B5 Hatching B6 Outlines of revolved sections in place B7 Short centre lines
C  D 	Continuous thick freehand ² Continuous thin (straight) with zigzags	C1 Limits of partial or interrupted views and sections, if the limit is not a chain C2 Thin line (see Figures 1.25 and 1.26)
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 G3 Trajectories
H 	Chain thick	H1 Cutting planes
J 	Chain thin, thick at ends and changes of direction	J1 Indication of lines or surfaces to which a special requirement applies
K 	Chain thick double dashed	K1 Outlines of adjacent parts K2 Alternative and extreme positions of movable parts K3 Centroidal lines K4 Initial outlines prior to forming (see Figures 1.27 and 1.28)

Figure 1.28

Figure 1.29

Figure 1.30

Figure 1.31

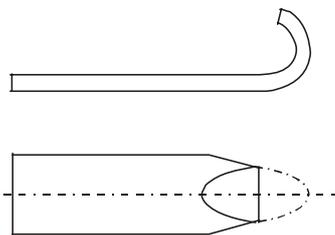
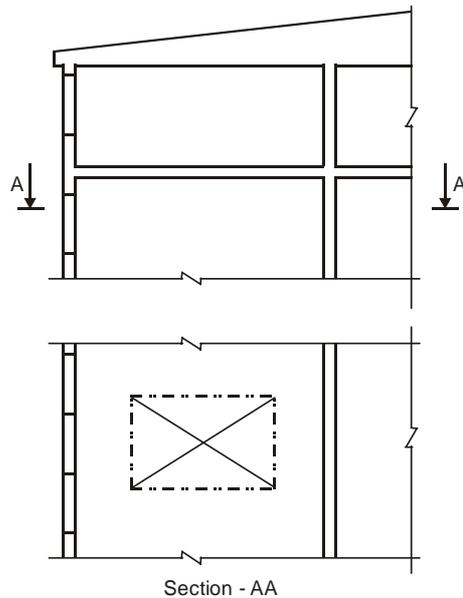


Figure 1.32



Section - AA
Figure 1.33

1.5.2 Thickness and Proportional Dimensions of Lines

Two thicknesses of lines are used. The ratio of the thick to the thin line shall not be less than 2 : 1. Grading of lines is in two 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, 2 mm. For all views of one piece to the same scale, the thickness of the lines should be the same.

1.6 DIMENSIONING OF DRAWING

Dimension is a numerical value expressed in appropriate units of measurement and indicated graphically on technical drawings with lines, symbols and notes. All dimensional information necessary to define a part or a component clearly and completely shall be shown directly on a drawing. Each feature shall be dimensioned once only on a drawing. Dimension shall be placed on the view or section that most clearly shows the corresponding features.

1.6.1 Elements of Dimensioning

The elements of dimensioning include projection line, dimension line, leader line, dimension line termination, origin indication and dimension itself. The various elements of dimensioning are illustrated in Figures 1.34 and 1.35.

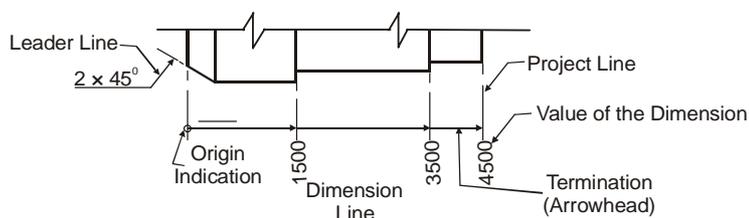


Figure 1.34

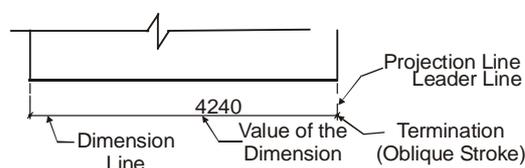


Figure 1.35

1.6.2 Projection Lines, Dimension Lines and Leader Lines

Projection lines, dimension lines and leader lines are drawn as thin continuous lines, as shown in Section 1.5.1, Table 1.4 and Figures 1.34 and 1.35.

- (a) Projection lines shall extend slightly beyond the respective dimension line (see Figures 1.34 and 1.35).
- (b) Projection lines shall be drawn perpendicular to the feature being dimensioned. Where necessary, however, they may be drawn obliquely but parallel to each other (Figure 1.36).

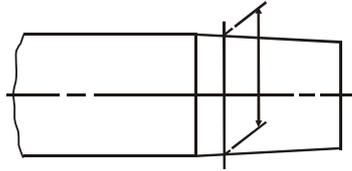


Figure 1.36

- (c) Intersecting construction and projection lines shall extend slightly beyond their point of intersection (Figure 1.37).

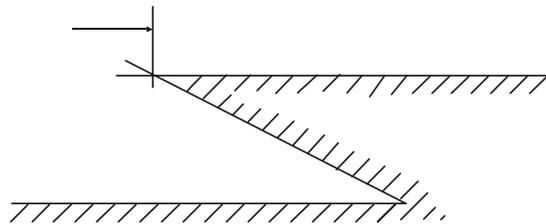


Figure 1.37

- (d) In general, projection lines and dimension lines should not cross other lines unless this is unavoidable (Figure 1.38).

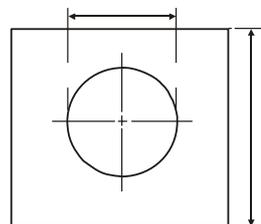


Figure 1.38

- (e) A dimension line shall be shown unbroken where the feature to which it refers is shown broken (Figure 1.39).

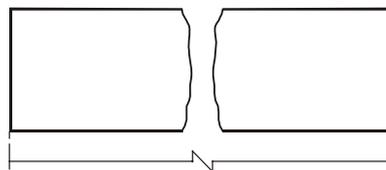


Figure 1.39

- (f) Intersecting projection and dimension lines should be avoided. Where unavoidable, however, either line shall be shown with a break (Figure 1.40).
- (g) A centre line or the outline of a part shall not be used as a dimension line but may be used in place of a projection line (Figure 1.40).

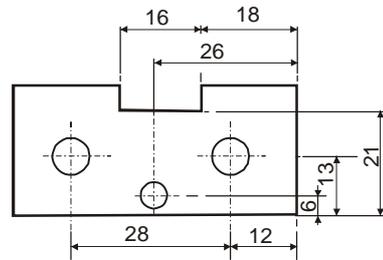


Figure 1.40

1.6.3 Termination and Origin Indication

Dimension lines show distinct terminations (that is either arrowheads or oblique strokes) or, where applicable, an origin indication.

- (a) Two dimension line terminations (Figure 1.41) and an origin indication (Figure 1.42) are specified as below :
 - (i) The arrowhead is drawn as short lines forming barbs at any convenient angle between 15° and 90° . The arrowhead may be open, closed or closed and fitted in (Figure 1.41(a)).
 - (ii) The oblique stroke shown as a short line inclined at 45° (Figure 1.41(b)).

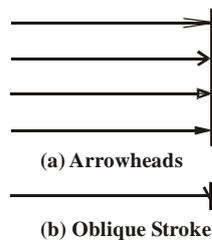


Figure 1.41

- (iii) The origin indication drawn as a small open circle of approximately 3 mm in diameter (Figure 1.42).



Figure 1.42

- (b) The size of the terminations shall be proportional to the size of the drawing on which they are used.
- (c) One style of arrowhead termination only shall be used on a single drawing. However, where space is too small for an arrowhead, the oblique stroke or a dot may be substituted (Figure 1.45).
- (d) Arrowhead termination shall be shown within the limits of the dimension line where space is available (Figure 1.43). Where space is limited, the arrowhead termination may be shown outside the intended limits of the dimension line that is extended for that purpose (Figure 1.44).

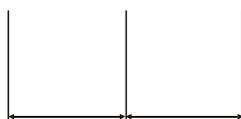


Figure 1.43



Figure 1.44

- (e) Only one arrowhead termination with its point on the arc end of the dimension line shall be used, where a radius is dimensioned as shown in Figure 1.45.

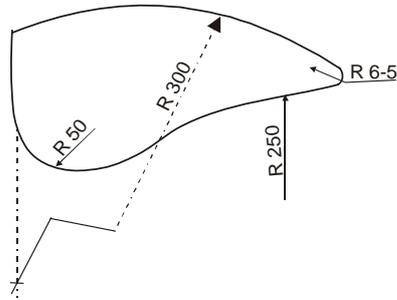


Figure 1.45

1.6.4 Indicating Dimensional Value on Drawings

Dimensional value shall be shown on the drawings in characters of sufficient size to ensure complete legibility. They shall be placed in such a way that they are not crossed or separated by any other line on the drawing. Values shall be indicated on the drawing according to one of the following two methods. Only one method should be used on any one drawing.

Method I – Aligned System

- (a) Dimensional value shall be placed parallel to their dimension lines and preferably near the middle above and clear of the dimension line (Figure 1.46).

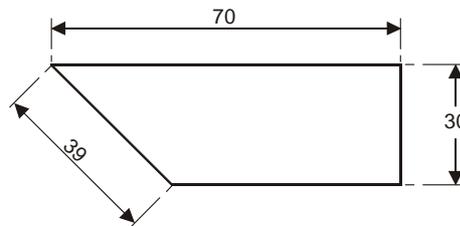


Figure 1.46

- (b) Values shall be indicated so that they may be read from the bottom or from the right hand side of the drawing values on oblique dimensions line shall be oriented as shown in Figure 1.47.

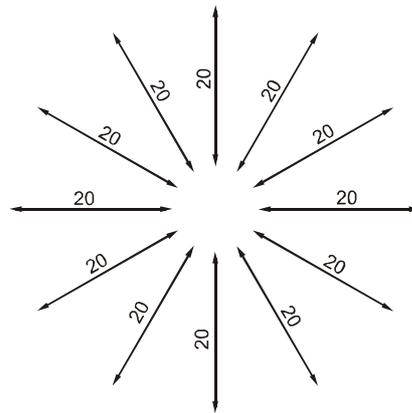


Figure 1.47

- (c) Angular dimensional values may be oriented either as in Figure 1.48 or Figure 1.49.

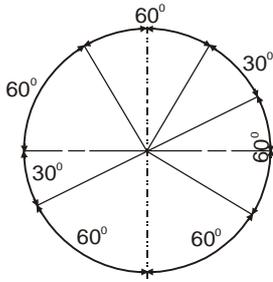


Figure 1.48

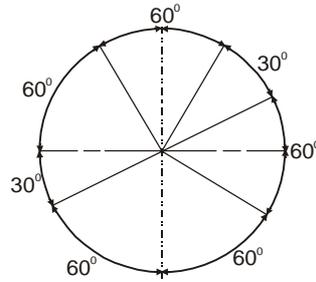


Figure 1.49

Method II – Unidirectional System

- (a) Dimensional values shall be indicated so that they may be read from the bottom of the drawing-sheet. Non-horizontal dimension lines are interrupted, preferably near the middle, so that the value may be inserted (Figures 1.50 and 1.51).

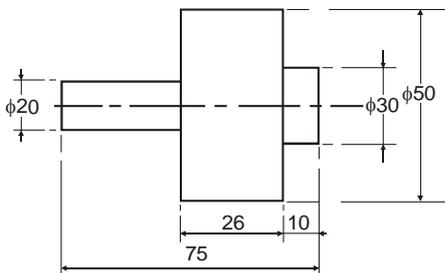


Figure 1.50

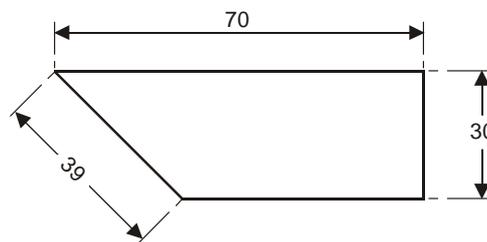


Figure 1.51

- (b) Angular dimensional values may be oriented either as in Figure 1.49 or Figure 1.52.

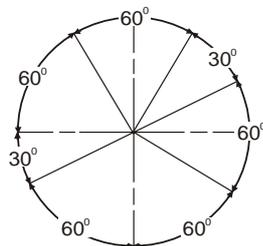


Figure 1.52

- (c) The positioning of dimensional values frequently needs adapting to different situations. Therefore, for example, values may be

- (i) Close to a termination to avoid having to follow a long dimension line where only part of the dimension line needs to be shown (Figure 1.53).

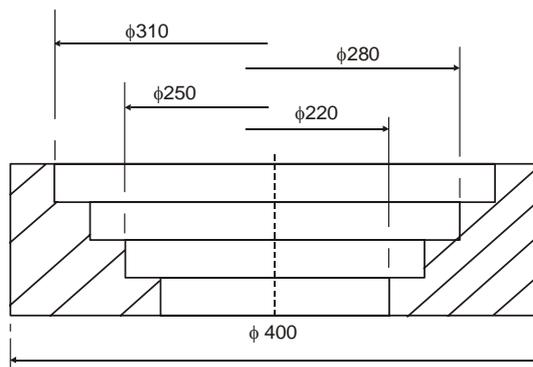


Figure 1.53

- (ii) Above the extension of the dimension line beyond one of the terminations, if space is limited (Figure 1.54).

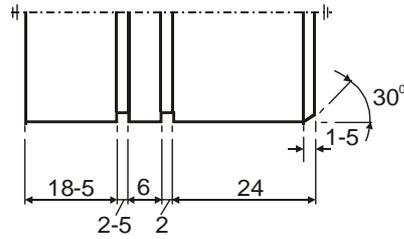


Figure 1.54

- (iii) At the end of a dimension line that is too short for dimensional value to be indicated in the usual way (Figure 1.54).
- (iv) Above a horizontal extension of a leader line which terminates on a dimension line where space does not allow a placement at the interruption of a non-horizontal dimension line Figure 1.55.

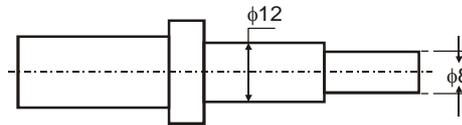


Figure 1.55

- (v) The following indications are used with dimensions to show applicable shape identification and to improve drawing interpretation. The applicable indication (symbol) shall precede the value for dimension (Figures 1.56 to 1.60).

- f : Diameter
 Sf : Spherical diameter
 SR : Spherical Radius
 R : Radius
 n : Square

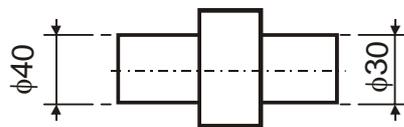


Figure 1.56

Figure 1.57

Figure 1.58

1.6.5 Arrangement and Indication of Dimension

The arrangement of dimensioning on a drawing shall indicate clearly the design purpose. Generally, the arrangement of dimensions is the result of a combination of various design requirements.

Chain Dimensioning

Chains of single dimensions (Figure 1.61) should be used only where the possible accumulation of letters does not impinge on the functional requirements of the part.

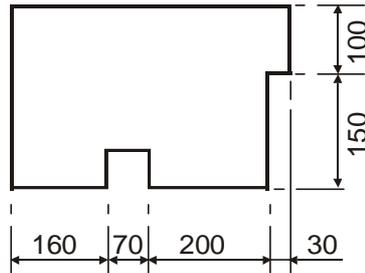


Figure 1.61

Dimensioning from a Common Features

This method of dimensioning is used where a number of dimensions of the same direction relate to a common origin. Dimensioning from a common feature may be executed as parallel dimensioning or as superimposed running dimensioning.

Parallel dimensioning is the placement of a number of single dimension lines parallel to one another and spaced out so that the dimensional value can easily be added in (Figures 1.62 and 1.63). Superimposed running dimensioning is simplified parallel dimensioning and may be used where there are space limitations and where no legibility problems would occur (Figures 1.64 and 1.65).

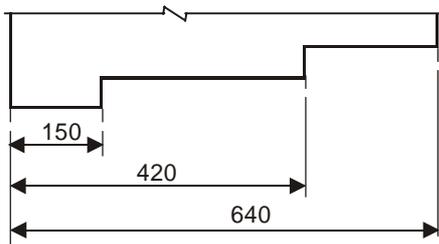


Figure 1.62

Figure 1.63

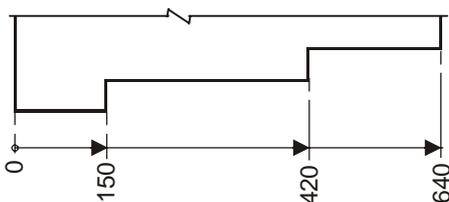


Figure 1.64

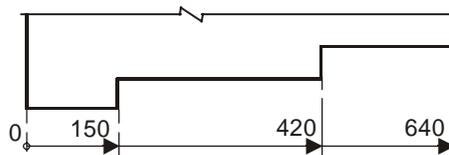


Figure 1.65

1.7 DRAWING SCALE

Engineering drawing is the graphical language of engineers and through this medium, they convey their conceptual ideas, constructive thoughts and designs. A drawing of an object, if prepared to actual sizes, gives a clear idea of the object without leaving anything for the imagination. Such a drawing is called full-sized drawing. Sometimes, it becomes inconvenient or rather impracticable to prepare full-sized drawing. For instance, if a drawing of a big building is to be prepared, we cannot take drawing-paper as big as the building. Or if the map of Madhya Pradesh is to be drawn, it is beyond our imagination to prepare full-sized drawing. Thus, it becomes important to select an appropriate scale for proper representation.

1.7.1 Reduction and Enlargement Scales

When the drawings are prepared to a size smaller than the actual size of the objects, they are called to have been drawn to a *Reduction Scale*. Objects such as buildings, bridges, town plans, maps of countries, large machine parts and their assemblies etc. are generally drawn to reduction scales. When a drawing made is of a larger size than the object, such a drawing is called an enlarged drawing or a drawing made on an *Enlargement Scale*. For instance, if a profile of the tooth of a wrist-watch pinion is to be drawn, it will be very difficult, if not impossible, to draw it to the full size because even the point of a pencil will be thicker than the tooth itself. Similarly, the integrated circuit of an electronic component cannot be prepared to its full size. Hundreds of transistors, diodes, and other components are placed and connected in as small a chip as 1 sq cm. Therefore, in such cases, drawings are prepared much larger than the actual size of the objects. Such drawings are known as enlargement drawings or drawings made on enlarged scales.

1.7.2 Representative Fraction

It is a linear ratio, i.e. the ratio of the length of a drawing to the actual length of an object. The numerator and the denominator should be in the same units, hence the Representative Fraction (*RF*) is a number only.

$$RF = \frac{\text{Length of drawing}}{\text{Actual length of object}}$$

Example 1.1

If a length of 5 m on the ground is represented by 5 cm line on a drawing, the RF of the scale

$$= \frac{5 \text{ cm}}{5 \times 100 \text{ cm}} = \frac{1}{100}$$

It is always customary to represent RF as a fraction 1 upon something.

Example 1.2

A length of 3 km on the ground is represented by 6 cm length on a map. Find the RF on the scale on which it has been drawn.

$$\begin{aligned} \text{RF} &= \frac{\text{Length of drawing}}{\text{Length of object}} = \frac{6 \text{ cm}}{3 \times 1000 \times 100 \text{ cm}} \\ &= \frac{1}{5 \times 10^4} \end{aligned}$$

Example 1.3

An area of 36 sq km on the ground is represented by an area of 144 sq cm on a map. Determine the RF of the scale for this map.

Here, instead of lengths, area has been given and we will be committing a mistake if we take the ratio of areas (RF is a ratio between lengths and not areas). By a simple unitary method we know that 144 sq cm on the map represents 36 sq km on the ground. Taking square root on both the sides we get 1 cm will represent $\frac{1}{4}$ sq km or $\frac{1}{2}$ km the

$$\text{RF} = 1 \text{ cm} / 0.5 \times 1000 \times 100 \text{ cm} = 1 / 0.5 \times 10^5.$$

1.7.3 Construction Scales

For the construction of an engineering scale, it is necessary to have the following information :

- (a) Representative fraction (RF).
- (b) Units in which the scale has to measure, e.g. meters, kms, yards, inches, miles, feet, etc.
- (c) The largest length which is required to be measured (in one placing) by this scale.
- (d) Actual length of the scale to be constructed.

1.7.4 Method of Construction

- (a) Determine the representative fraction (RF) as explained earlier in this unit.
- (b) Units are usually given in the problem itself.
- (c) The largest length is also indicated in problem.
- (d) The actual length of the scale can be calculated by the following formula :

$$\text{Actual length of the scale} = \text{RF} \times \text{Maximum length to be measured.}$$

1.7.5 Types of Scale

The following types of scales are commonly used in preparing engineering drawings :

- (a) Plain Scale
- (b) Diagonal Scale
- (c) Vernier Scale

Plain Scale

Plain scale is made to measure lengths in two units only, i.e. units and sub-units such as yards and feet or meters and decimeters or centimeters and millimeters. In other words, we can use a plain scale for reading only up to the first decimal place, for example, meter and decimeter, centimeter and

millimeter. The following are the important steps for the construction of a plain scale :

- (a) Calculate RF, if not given.
- (b) Calculate the length of the scale (L), using the formula :

$$L = RF \times \text{Maximum length to be measured}$$
- (c) If the maximum length to be measured not given in the problem, adopt $L = 15$ cm (minimum) or 30 cm (maximum). This is as per BIS.
- (d) Draw a straight line of length L and divide it geometrically into a number of equal parts as required. These are the main units.
- (e) Draw another line parallel to, and just above, this line at a distance of 3 to 5 mm and of the same length. Drawing vertical lines at the ends complete the rectangle. Draw vertical lines from each division to join both horizontal lines.
- (f) From the left end write zero ("0") at the first division, and write 1, 2, 3 etc. main divisions on subsequent divisions on the right side. Write units at the end.
- (g) Divide the first division into equal parts (geometrically) such that the numbers are equal to sub-divisions. For example, if the main divisions are meter, then the first division must be divided into ten equal parts so that each sub-division represents $1/10^{\text{th}}$ of a meter of a decimeter.
- (h) Write RF of the scale just above and at the middle length of the scale.

Example 1.4

The distance between Bhopal and Indore is 180 km. It is represented on the map by 9 cm. Construct a plain scale for this map, showing minimum 1 km distance and long enough to measure 360 km.

Solution

$$\text{RF of the scale as} = \frac{9 \text{ cm}}{180 \times 1000 \times 100 \text{ cm}} = \frac{1}{2 \times 10^6}$$

Length of the scale = RF \times Maximum length to be measured

$$\frac{1}{2 \times 10^6} \times 360 \times 10^5 \text{ cm} = 18 \text{ cm}$$

Now, the minimum distance which this scale should be able to read is given as 1 km and as this is a plain scale, the main divisions will be of 10 km each and sub-divisions of 1 km each.

- (a) Draw a line 18 cm long and divide it into 36 equal divisions. Each division will represent 10 km.
- (b) Draw another line parallel to, and 5 mm above, this line of the same length.

$$RF = \frac{1}{2 \times 10^6}$$

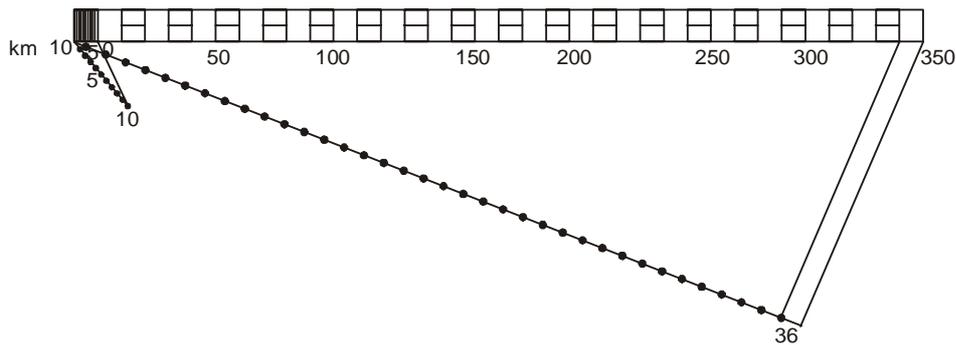


Figure 1.66

- (c) Complete the rectangle and draw vertical lines from each division to join both horizontal lines.
- (d) Sub-divide the first division into ten equal parts.
- (e) Write zero (“0”) at the first division and 10, 20, 30 ... 350 at the subsequent division on the right-hand side.
- (f) Mark 1 2 3 ... 10 on sub-divisions but starting from zero and proceeding on the left-hand side.
- (g) Write RF just above the scale.

Diagonal Scale

If a fractional portion of a secondary division is required, which is too small to be sub-divided, a diagonal scale may be used with ease. This scale can read meter, decimeter and centimeter or km, hectometer and decameter, etc. Thus, with the help of a diagonal scale, one can measure up to the second place of decimal.

Principle of Diagonal Scale

- (a) Draw a rectangle $ABCD$.
- (b) Divide it into ten equal parts by horizontal lines.
- (c) Draw the diagonal BD , intersecting the above lines.
- (d) Draw perpendiculars from the above points to form a series of steps.

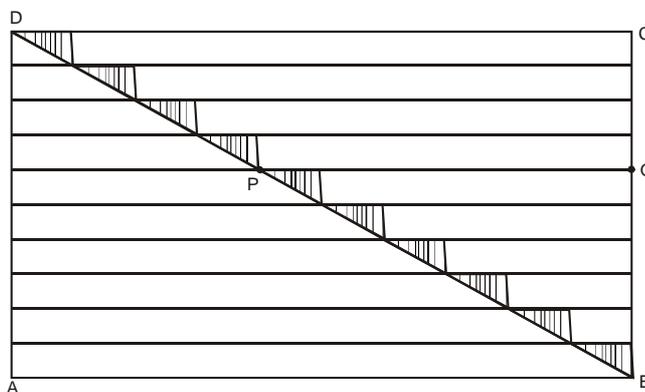


Figure 1.67

As one moves along the diagonal BD , when a fresh line is crossed, the movement is $1/10 AB$ to the left.

PQ is $3/5 AB$.

In constructing a diagonal scale, it must be remembered that the same number of equidistant parallel lines must be drawn above AB , as there is a third dimension in one secondary division.

Example 1.5

Construct a diagonal scale of $RF = 1/48$, showing yards, feet and inches to represent a maximum length of 7 yards. Mark a distance of 3 yards and 7 inches on this scale.

Solution

- (a) Obtain the length, $L = \frac{1 \times 7 \times 36 \text{ inches}}{48}$
 $= 5.25 \text{ inches}$
- (b) Draw a line AB , 5.25 inches long, and divide it into seven equal parts to show yards.
- (c) Divide the first part into three equal divisions.
- (d) Draw 12 equidistant (about 3 mm apart) parallel lines above AB and complete the rectangle $ABCD$. Join $D-2$ and draw parallel through 0, 1 and 2.

Distance PQ represents the length 3 yards and 7 inches.

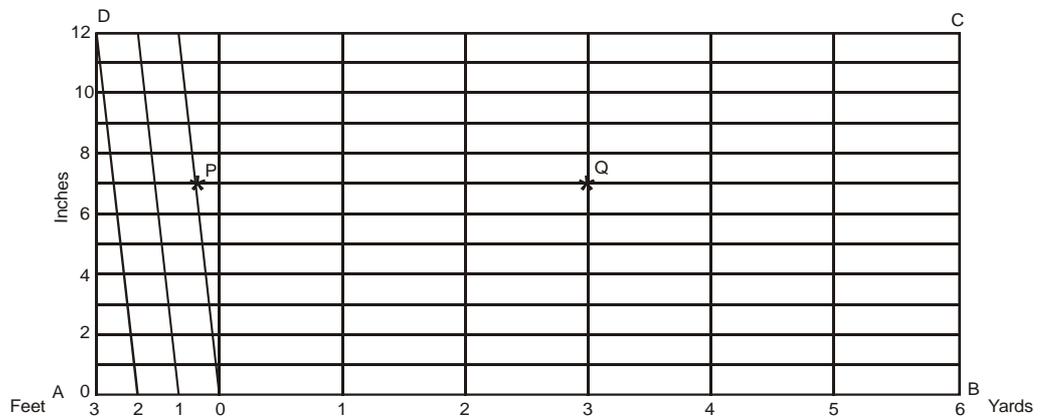


Figure 1.68

Example 1.6

Construct a diagonal scale of $RF = 1/4000$ to show meters and long enough to measure 600 meters. Mark a distance of 387 meters on this scale.

Solution

- (a) Length of the scale $= \frac{1}{4000} \times 600 \times 100 \text{ cm}$
 $= 15 \text{ cm}$
- (b) Draw a line AB 15 cm long and divide it into six equal parts to represent hectometers.

(c) Divide the first part into ten equal parts to represent decameters.

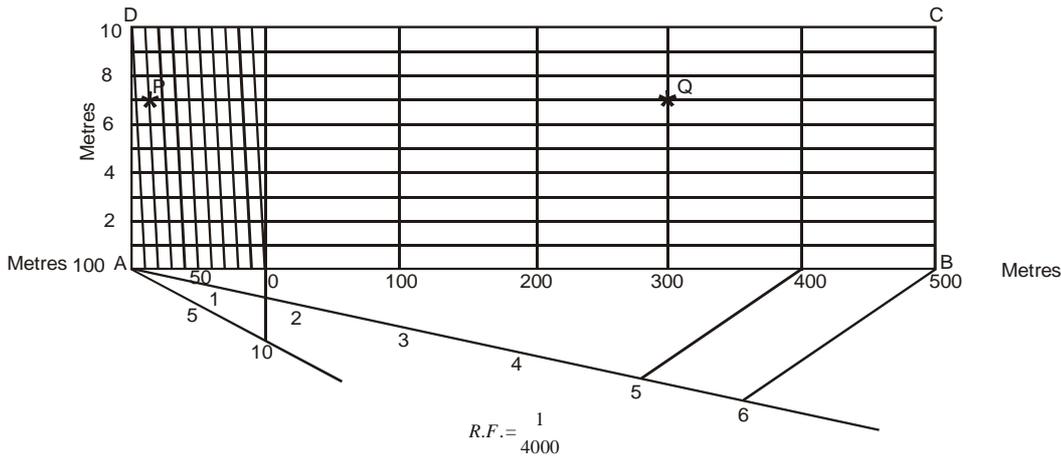


Figure 1.69

(d) Draw ten equidistant (3 mm apart) parallel lines above AB and complete the rectangle $ABCD$. Join the first sub-division towards the left from the zero at the line AB , to the second division at the top (10th) line, thus completing the diagonals. On these diagonals, the least count is $10/10 = 1$ meter.

PQ represents the distance of 387 meters.

Vernier Scale

Vernier scale consists of a primary scale, fully divided into minor divisions, and a vernier having graduations derived from the primary scale graduations. It is called either retrograde vernier or direct vernier. In the first case ($n + 1$) vernier; whereas, ($n - 1$) division on primary scale are divided into n equal divisions in the direct vernier scale. In either case, the difference between one main scale division and one vernier scale division is equal to $1/n$ and is known as the least count of the vernier. The difference between two main scale divisions and two vernier scale divisions is $2/n$, and so on.

Example 1.7

Construct a retrograde vernier to a scale of $1/5$, to show inches and 10th, and 30 inches and long enough to read to mark distance of 11.3 inches on it.

Solution

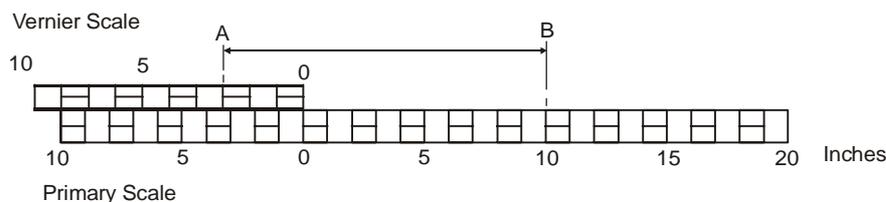


Figure 1.70

- Length of primary scale = $1/5 \times 30 = 6$ inches.
- Draw a line 6 inches long and divide it into 30 equal parts representing inches, thus forming a primary scale.

- (c) Set off 11 equal parts to the left and above the primary scale and divide it into ten equal parts, thus forming a vernier.
- (d) Each division of the vernier represents 1.1 inch. AB represents the required distance.

1.7.6 Scales for Technical Drawings

As per the Indian standard, the complete designation of a scale shall consist of the word 'SCALE' followed by the indication of its ratio as follows :

- SCALE 1 : 1 for full size
- SCALE X : 1 for enlargement
- SCALE 1 : X for reduction

Category	Recommended Scales		
Enlargement Scales	50 : 1	20: 1	10 : 1
Full Size	1 : 1		
Reduction	1 : 2	1 : 5	1 : 10
Scales	1 : 20	1 : 50	1 : 100
	1 : 200	1 : 500	1 : 1000
	1 : 2000	1 : 5000	1 : 10000

[**Note** : A scale to be chosen for a drawing will depend upon the complexity of an object to be depicted and the purpose of representation. In all cases, the selected scale shall be large enough to permit easy and clear interpretation of the information depicted.]

1.8 CONVENTIONAL REPRESENTATION

Representation of Engineering Materials

In engineering practice, there are different types of materials used for manufacturing the various parts of a machine. It is, therefore, desirable that different conventions should be adopted to differentiate various materials for convenience on the drawing. The conventions of materials, thus, save time and labour of drawing-work. The Indian Standard Institution has recommended the conventions for various types of materials, as shown in Figure 1.71, when these are sectioned.

Sl. No.	Materials	Convention
1.	Steel, Cast Iron, Copper, Aluminium and its alloys, etc.	
2.	Lead, Zinc, Tin, White, Metal etc.	
3.	Brass, Bronze, Gun Metal, etc.	
4.	Glass	
5.	Porcelain, Stone Ware, Marble and Slate, etc.	
6.	Asbestos Felt, Paper, Mica, Cork Rubber, Leather, Wax and Insulating Materials	

7.	Wood, Plywood etc.	
8.	Earth	
9.	Brick Work, Masonry Fire Bricks etc.	
10.	Concrete	
11.	Water, Oil, Petrol, Kerosene etc.	

Figure 1.71

SAQ 1

- (a) Draw a line perpendicular to a given line with the help of two set-square.
- (b) Draw parallel lines at an angle of 20° to the edge of the drawing board using a T-square.
- (c) How is a slant of 75° obtained by means of two set-square.
- (d) What determines the line thickness of letters and figures.
- (e) Draw in 100 mm height, giving correct spacing “DRAWING IS THE LANGUAGE OF ENGINEERS.”
- (f) Draw in 5 mm height the alphabets, free hand single stroke vertical and inclined style.
- (g) Draw the various lines as per Section 1.5.1 shown in Table 1.4.
- (h) Explain the following with a neat sketch
 - (i) Aligned system of dimensioning
 - (ii) Unidirectional system of dimensioning
 - (iii) Chain dimensioning
 - (iv) Dimensioning from a common feature
- (i) Draw a 10 mm dia circle, 100 mm side square, 100 mm side hexagon and give dimensions on all side.
- (j) Construct a plain scale of 2 cm to 1 meter to read meters and decimeters. Indicate on this scale a length of 6 m and 3 decimeters.
- (k) A map $500 \text{ cm} \times 50 \text{ cm}$ wide represent an area of 6250 square kilometers. Construct a diagonal scale to measure on this a length of 5 km, 5 hectometer and 5 decameters. What is the RF of this scale.

1.9 SUMMARY

An engineer may frequently have to prepare drawing and to direct the making of the working drawings. In this unit, various drawing equipment and instruments commonly used are explained along with their proper handling, care and method of using them. As per the BIS recommendation, various sizes of drawing sheets and their use along with standard practice of layout of drawing sheets is described. Method of writing letters, various types of lines and dimensioning as per standard practice is explained.

For making drawing on drawing sheet, selection and use of various scale is explained and you are introduced with the conventional representation of various features on drawing.

1.10 ANSWERS TO SAQs

Refer the relevant preceding text in the unit or other useful books on the topic listed in the 'Further Reading' given at the end to get the answers of SAQs.