TVET CERTIFICATE III in CARPENTRY

BASIC DRAWING

CAPBD301

Make basic drawings and cost estimate

Competence

Credits: 120

Learning hours: 120

Sector: Construction

Sub-sector: Carpentry

Module Note Issue date: November, 2020

Purpose statement

This module describes knowledge and skills required to make basic drawings and cost estimate. It describes the skills, knowledge and attitudes required for the trainee to make basic drawings and prepare list materials.

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	1.4 Precise presentation of geometrical drawings	
	1.5Precise presentation of the scales used in drawings (Architect's scale, Metric scale, Engineer's scale)	
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Learning Unit 1 –Make basic drawings

LO 1.1 – Apply basic drawing techniques

- Content/Topic 1 :Drawing techniques:

Is an art of representation an object by using systematic lines on paper.

Technical drawing describes the process of producing a pictorial representation of a designer or engineer's vision into a physical form. Technical drawings serve as a guide or plan to the construction of whatever is represented in the drawing.

Technical drawings use graphics to show details. In other words, they convert ideas into physical form. Also known as drafting, technical drawing is done using a two-dimensional or three-dimensional.

- It is a formal and precise way of communicating information about the shape, size, featuring and precision of physical objects.
- A universal language of engineering used in the design process for solving problems, quickly and accurately visualizing objects, and conducting analysis.
- A graphical representation of objects and structures.
- It can be done by using freehand or computer methods.

Sketching or Drawing

We will treat "sketching" and "drawing" as one

- ✓ "Sketching" generally means freehand drawing.
- ✓ "Drawing" usually means using drawing instruments, from compasses to computers to bring precision to the drawing.

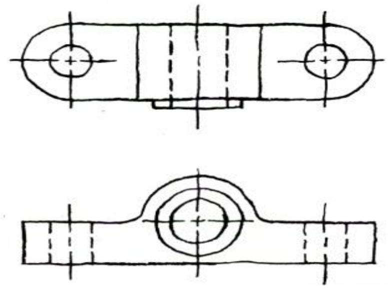
- Content/Topic 2:Free hand drawing

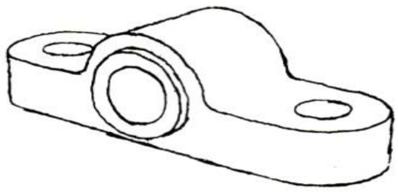
Free hand sketching

Freehand drawing

The lines are sketched without using instruments other than pencils and erasers.

Example

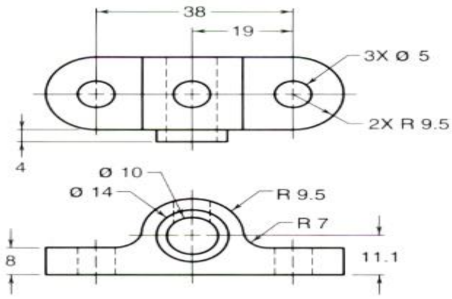




Instrument drawing

Instruments are used to draw straight lines, circles, and curves concisely and accurately. Thus, the drawings are usually made to scale.

Example



Computer drawing

The drawings are usually made by commercial software such as AutoCAD, solid works etc.

Example

- <u>Content /Topic3:Classification of drawing</u>

1. Artistic drawing (free hand or model drawing)

The art of representation of an object such as painting, cinema slide, advertisement boards, etc by the artist by his imagination or by keeping the object before him is known as artistic drawing.

2. Engineering drawing (Instrument drawing)

The art of representation engineering object such as buildings, roads, machines, etc on paper is called Engineering drawing.

Purpose of an Engineering drawing

1. An engineering drawing is not an illustration
2. It is a specification of the size and shape of a part or assembly
3. The important information on a drawing is the dimension and tolerance of all of these features.

❖ The subject of engineering drawing can be divided into the following categories:

1. GEOMETRICAL DRAWING

   i) **Plane geometrical drawing:** The art of representation objects having two dimensions i.e. length and breadth (width) such as square, rectangle, triangle, etc. On paper is called plane geometrical drawing.

   ii) **Solid geometrical drawing:** The art of representation of objects having three dimensions i.e. length, breadth and thickness such as cube, prism, cylinder, sphere, etc. on paper is called solid geometry drawing. It is also called **descriptive** or **practical solid** geometrical drawing

2. MECHANICAL ENGINEERING DRAWING

The art of representation mechanical engineering object such as machines, machine parts, etc. on a paper is called mechanical engineering drawing or **machine** drawing.

3. CIVIL ENGINEERING DRAWING

   The art of representation of civil engineering object such as roads, buildings, bridges, dams, etc. on paper is called civil engineering drawing.

4. ELECTRICAL AND ELECTRONIC ENGINEERING DRAWING

   The art of representation of electrical objects such as motors, generators, transformers, poles towers, wiring diagram, etc. on paper is called electrical engineering drawing or electrical drawing.

- Content/Topic 4: **Use construction drawing instruments, materials and equipment**

1. **Identify construction drawing materials**

➢ **General Introduction to construction drawing**

Normally, construction drawings are prepared with the use of drawing instruments. To prepare a drawing, one can use manual drafting instruments or computer-aided drafting or design (or CAD).

The basic drawing standards and conventions are the same regardless of what design tool you use to make the drawings.

In learning drafting, we will approach it from the perspective of manual drafting. If the drawing is made without either instruments or CAD, it is called a **freehand sketch**.

➢ **Drawing terminology**

✓ **Points**

A point is an exact location in space or on a drawing surface. A point is actually represented on the drawing by a crisscross at its exact location. The exact point in space is where the two lines of the crisscross intersect. When a point is located on an existing line, a light, short dashed line or cross bar is placed on the line at the location of the exact point. Never represent a point on a drawing by a dot; except for sketching locations.

✓ **Lines**

Lines are straight elements that have no width, but are infinite in length (magnitude), and they can be located by two points which are not on the same spot but fall along the line. Lines may be straight lines or curved lines. A straight line is the shortest distance between two points. It can be drawn in any direction. If a line is indefinite, and the ends are not fixed in length is a matter of convenience.
Straight lines and curved lines are considered parallel if the shortest distance between them remains constant. The symbol used for parallel line is **//**. Lines, which are tangent and at 90^0 are considered perpendicular. The symbol for perpendicular line is**⊥.**

✓ **Sections**

A section is a view of a building or object obtained by making an imaginary cut through it. Sometimes called a section plane, it shows the position where the imaginary cut is made. The line itself is a chain dotted line, with the line terminated by arrows which point in the direction of the viewing.

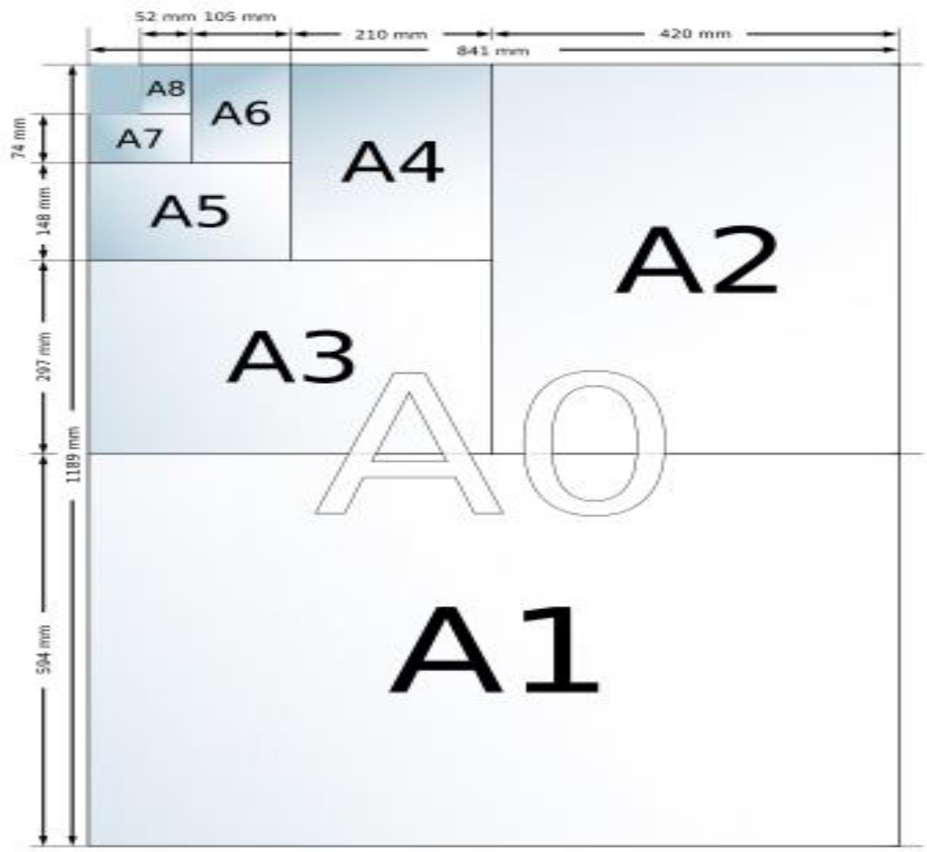
- ✓ Perspectives

A perspective is a view that is normally seen by the eye or camera, and is the most realistic form of pictorial. All parallel lines converge at infinite vanishing points as they receded from the observer.

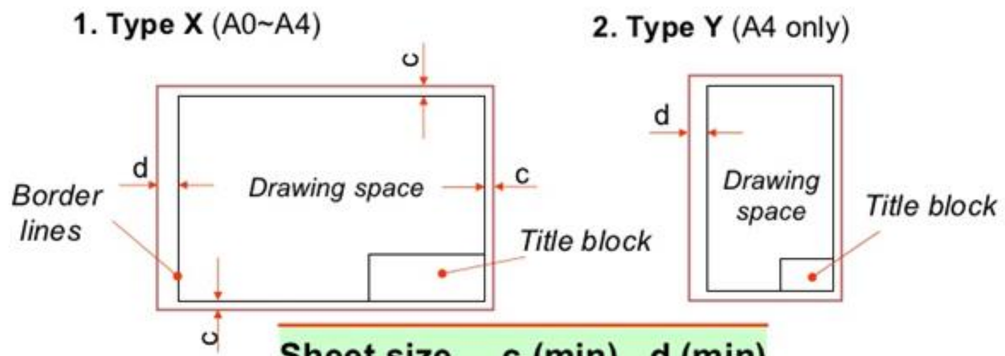
- ➢ Introduction to the paper format

In construction drawing, the sizes of drawing paper used are based on the international standards organization (ISO).

DESIGNATION	SIZES (mm)
A0	841X1189
A1	594X841
A2	420X594
A3	297X420
A4	210X297



Orientation of drawing sheet



Sheet size	c (min)	d (min)
A4	10	25
A3	10	25
A2	10	25
A1	20	25
A0	20	25

- ➢ Types of papers

The following are the types of paper that used in construction drawing.

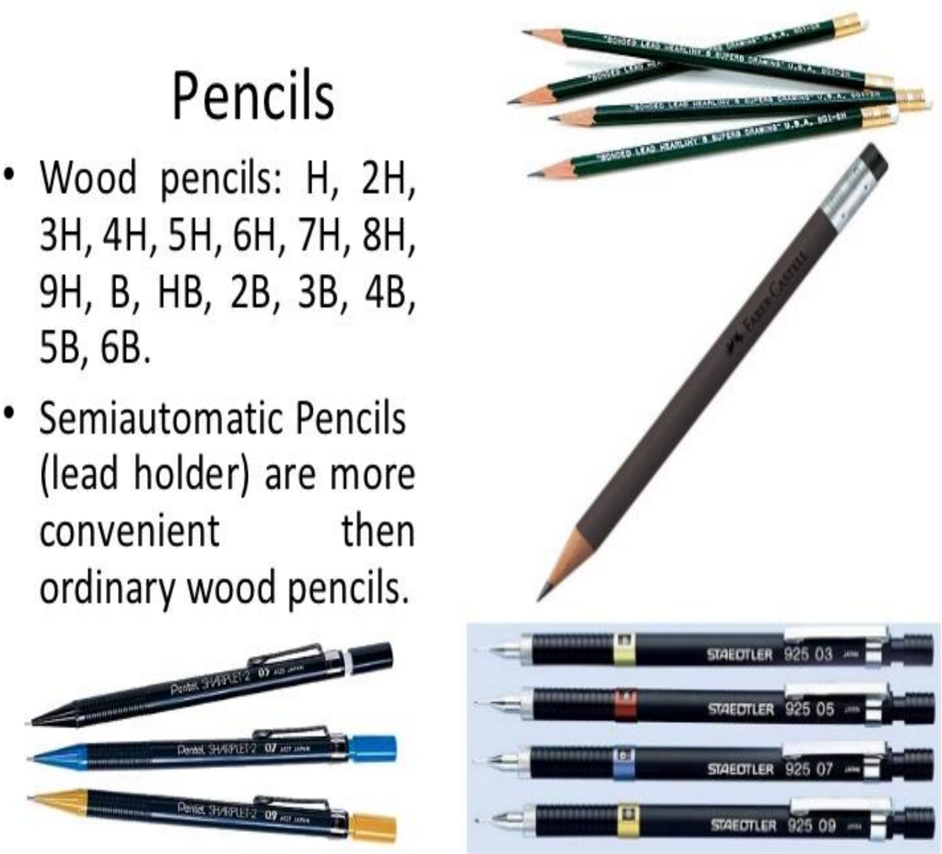
- ✓ Dimensional sheet
- ✓ Tracing paper
- ✓ Bristol

2.Identify construction drawing instruments and equipment

Normally, construction drawings are prepared with the use of drawing instruments. To prepare a drawing, one can use manual drafting instruments or Computer-Aided Drafting or Design, or CAD.

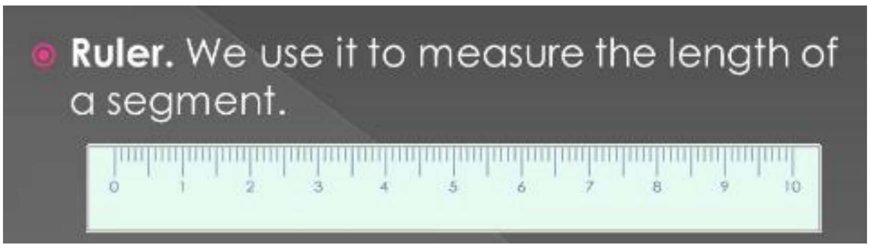
1. Writing instrument

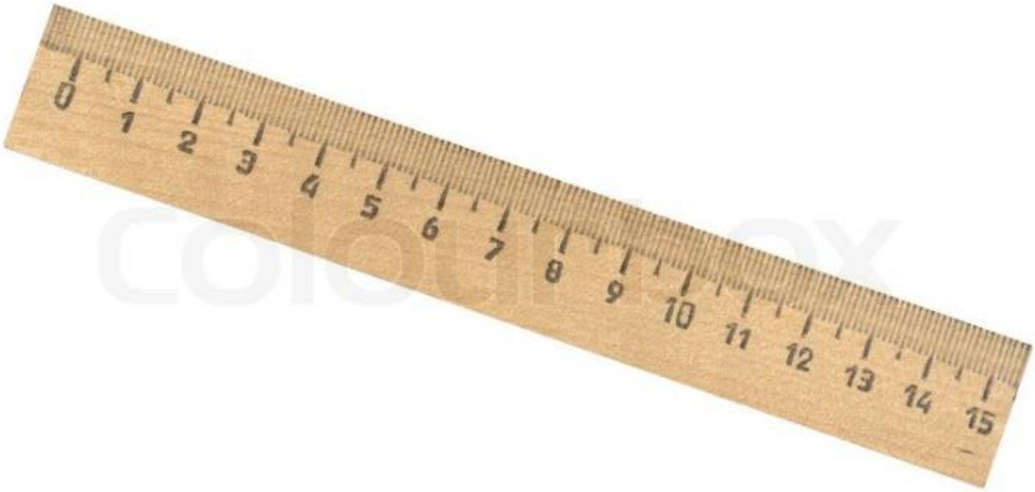
- ✓ Ink-pen
- ✓ Pencils



2. Tracing instrument

- ✓ Rulers

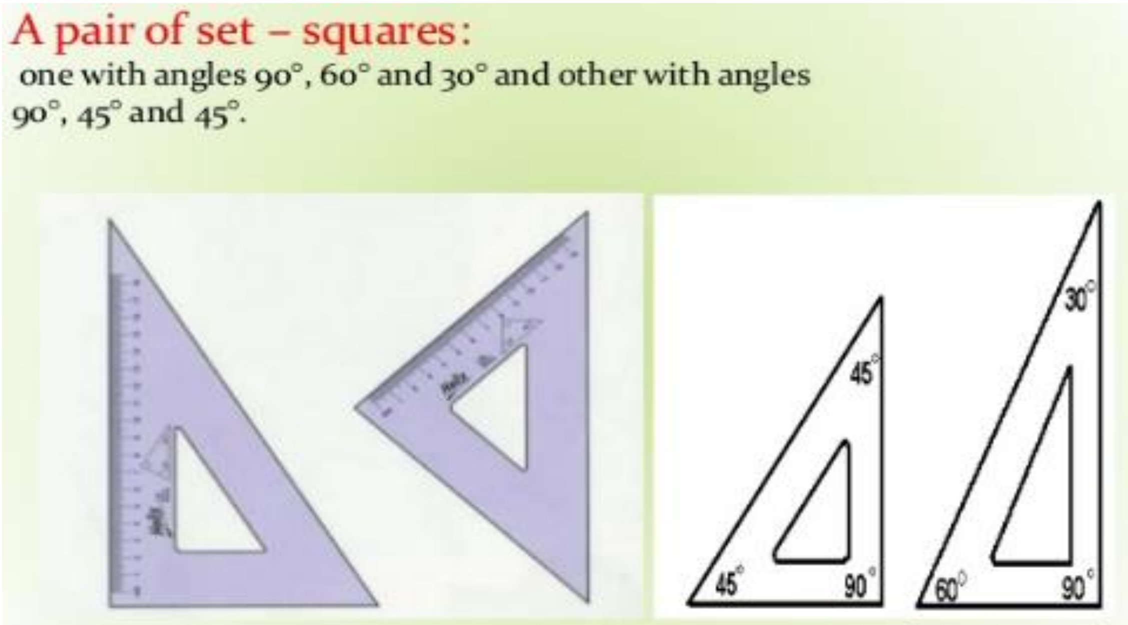




✓ Set squares :

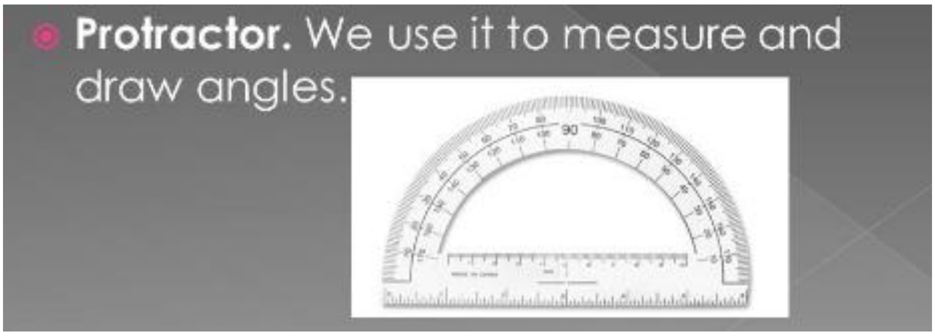
45^0 set square,

30^0-60^0 set square,

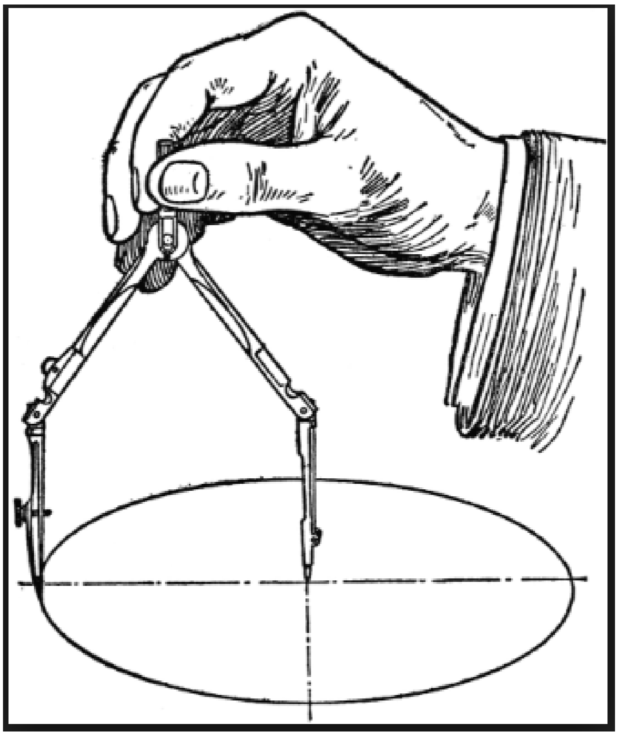


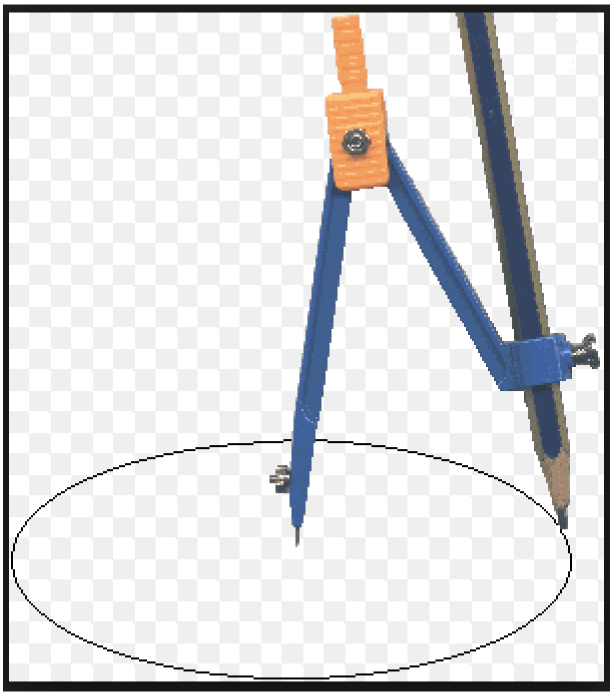
45^0 set square with protractor

✓ Protractor



✓ Compass



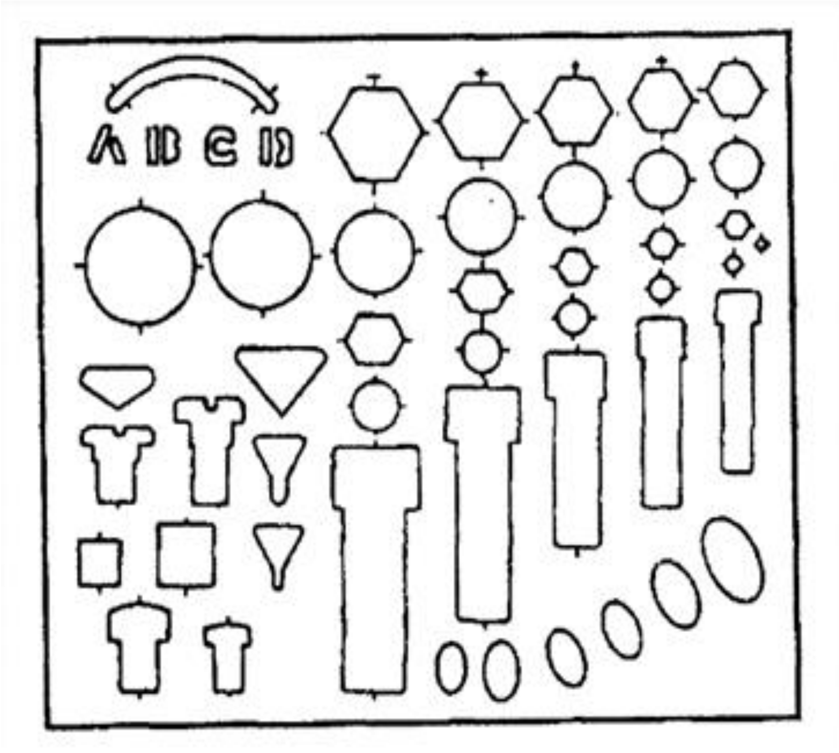


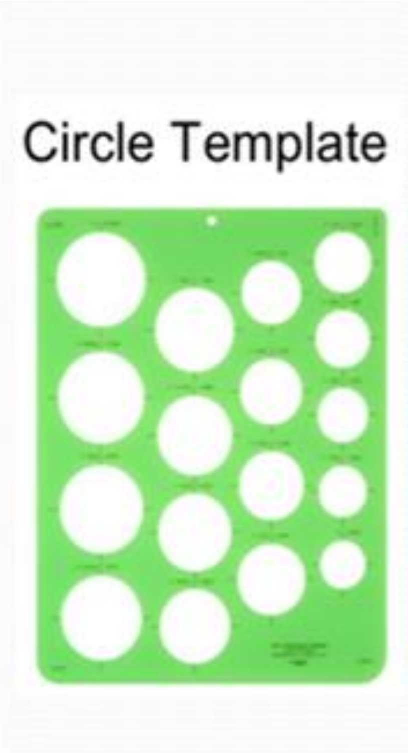
3. Accessories instrument

- ✓ Stencils
- ✓ Flexible curves

French curve

- ✓ Template

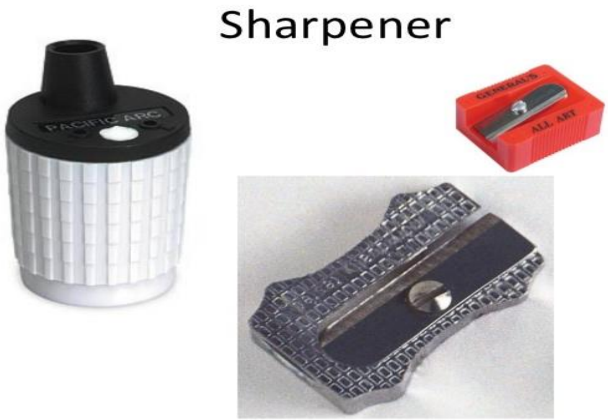




- ✓ Proportion divider

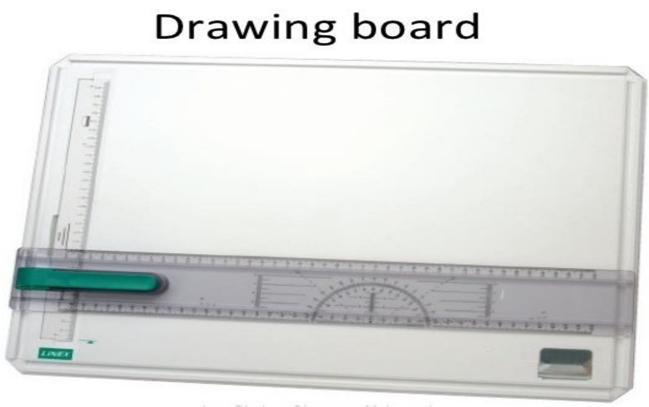
Compass and divider

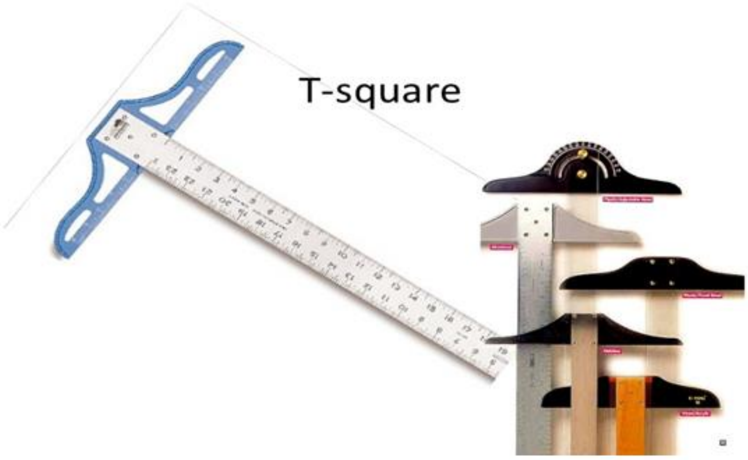
- ✓ Pencil sharpener

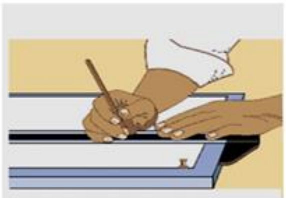


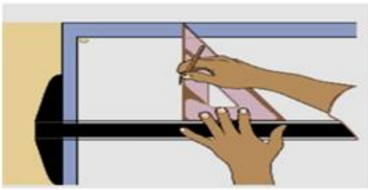
✓ Masking tape

✓ Drawing board









Tissue paper

Clean paper

3. Use drawing materials, instruments and equipment

1. Drawing materials

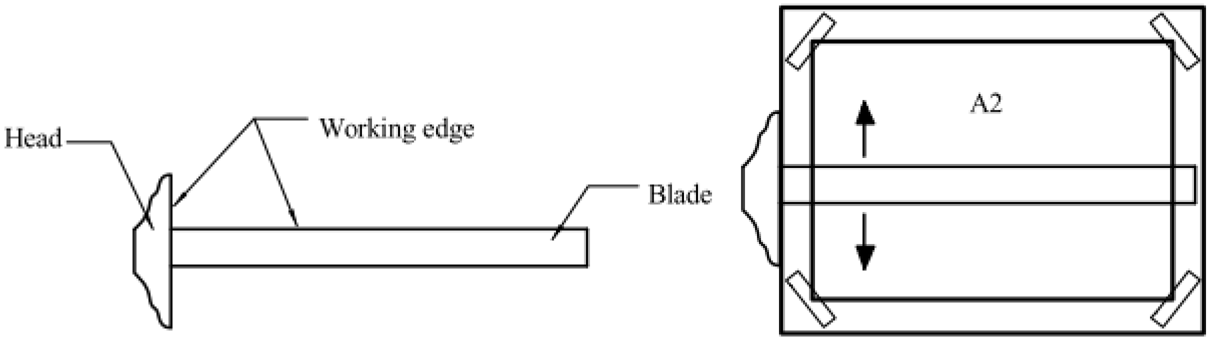
- ✓ Paper
- ✓ Ink

✓ eraser
✓ lead

2. Drawing instruments and equipment

✓ Protractor
✓ Tee-square or T- square

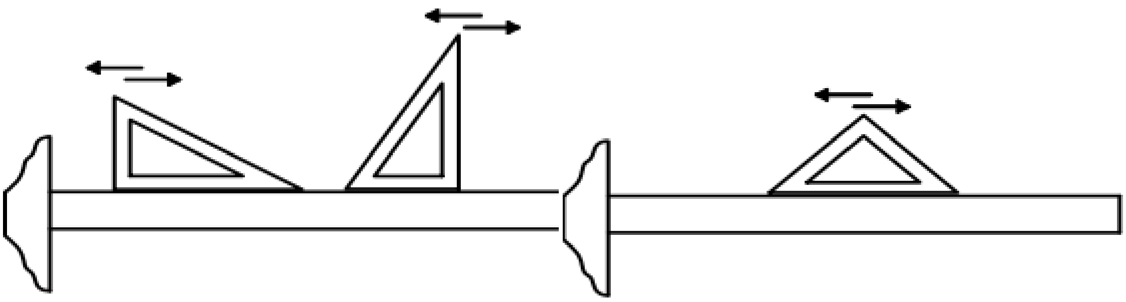
You can use a tee-square to draw horizontal lines; press the stock of the tee- square against the left hand edge of the board and allow it to slide up and down until the blade is in the required position. The pencil should be held against the ruling edge of the tee-square blade.



Check contact of T-square head with drawing board edge.

✓ Drawing pins and clips
✓ Set-squares

You will need to use your set-squares for drawing vertical and sloping lines. Move the straight edge/tee-square to the required position. Place the set-square on the tee-square with its base on the top edge of the blade, and the vertical edge in the required position.



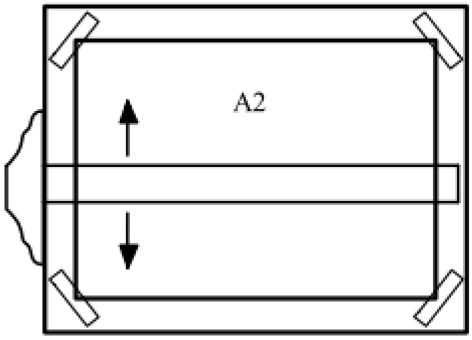
Use Set-squares with T-square

All construction lines should be drawn first, followed by all final lines.

✓ Compass
✓ Drawing pencil
✓ Drawing board

Now that the drawing paper is fixed to the board and you have some general information about drawing lines, the first operation is to draw the border and title panel.

The border should be drawn around ***the four edges of the paper 10mm wide***. Initially just draw the construction lines for the border. Form the title block by drawing a construction line 40mm up from the bottom border line. Add the short vertical and horizontal lines.



- Content/Topic 5: Standardized lettering

❖ **Apply lettering, lines and symbols used in drawing**

1**. Lettering**

The essential features of lettering on technical drawings are legibility, uniformity and suitability for microfilming and other photographic reproductions. In order to meet these requirements, the characters are to be clearly distinguishable from each other in order to avoid any confusion between them, even in the case of slight mutilations.

The two main groups of letters are **"CAPITAL LETTERS or UPPER-CASE LETTERS"** and **"LOWER-CASE LETTERS"**. The use of lower-case letters is generally restricted to notes, but capital letters can be used for both notes and titles. It is easier to produce legible capital letters than lower-case letters, it is suggested that initially you use only capital letters on your drawings. It is important that all letters be formed between guide lines. A lower and upper guide line should be drawn as lightly as possible so that you can just see them. Drawing them takes a little extra effort but is worth the trouble.

The reproductions require the distance between two adjacent lines or the space between letters to be at least equal to twice the line thickness. The line thickness for lower case and capital letters shall be the same in order to facilitate lettering.

1. Text on drawings

Text on construction drawing is used:

❖ To communicate non graphic information
❖ As a substitute for graphic information, in those instance where text can communicate the needed information more clearly and quickly.

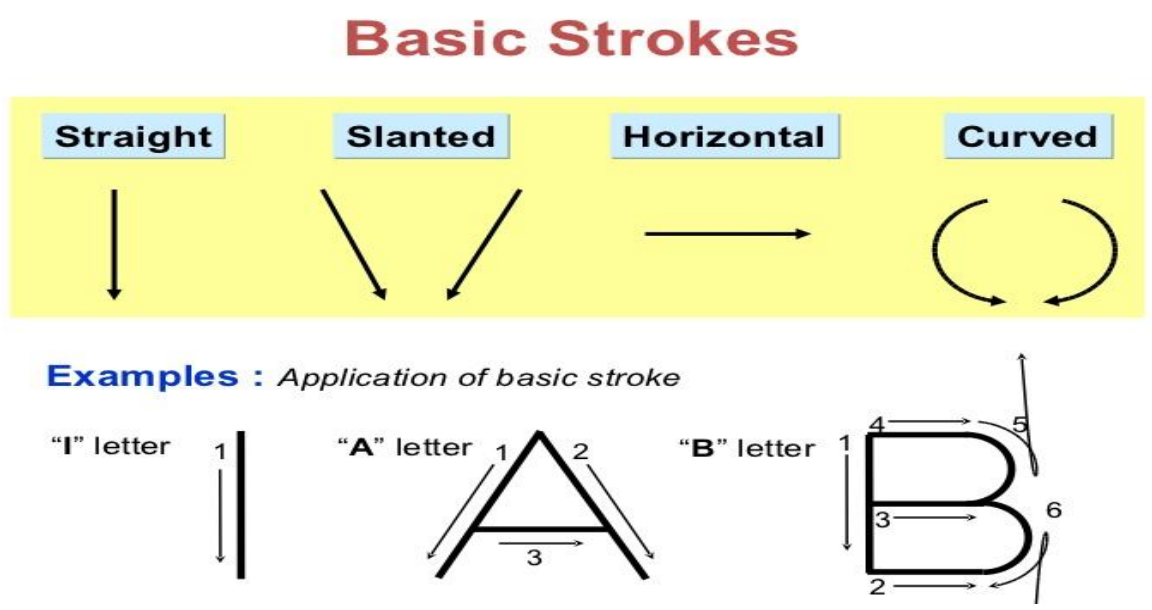
Thus, it must be written with

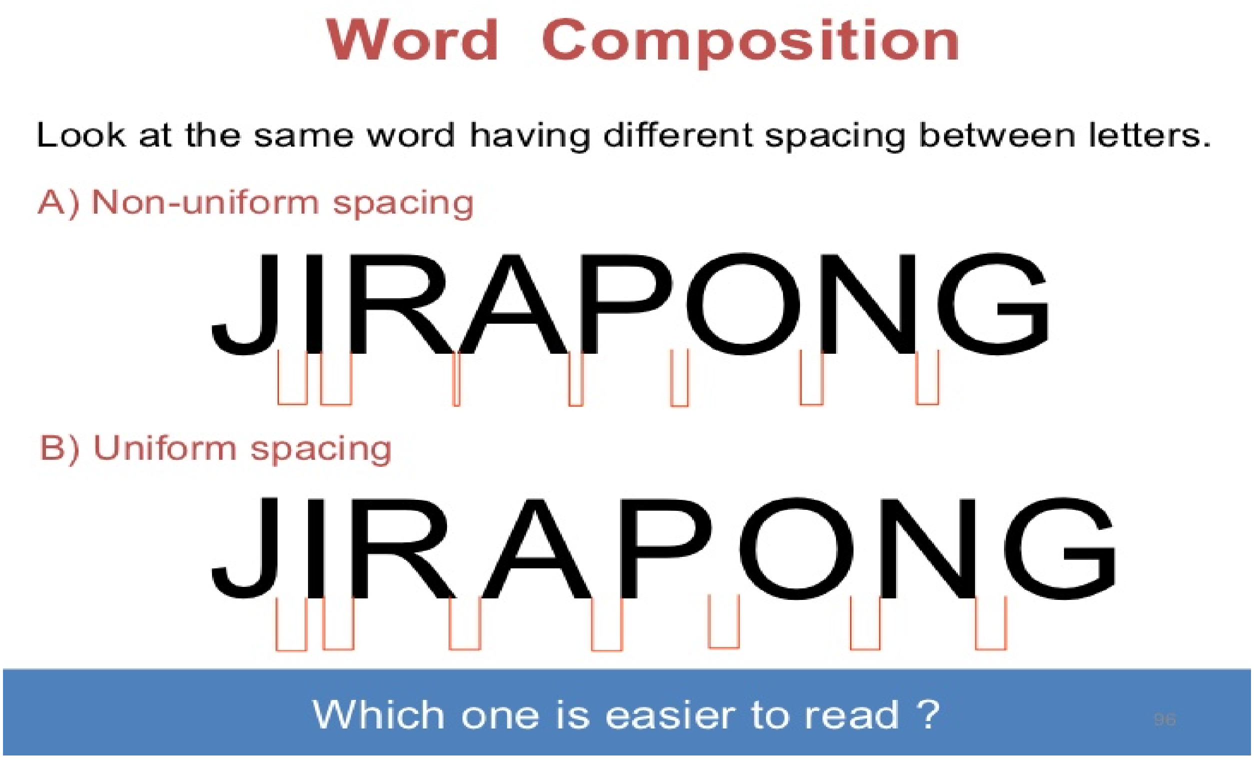
Legibility:

- Shape
- Space between letters and words

Uniformity:

- Size
- Line thickness





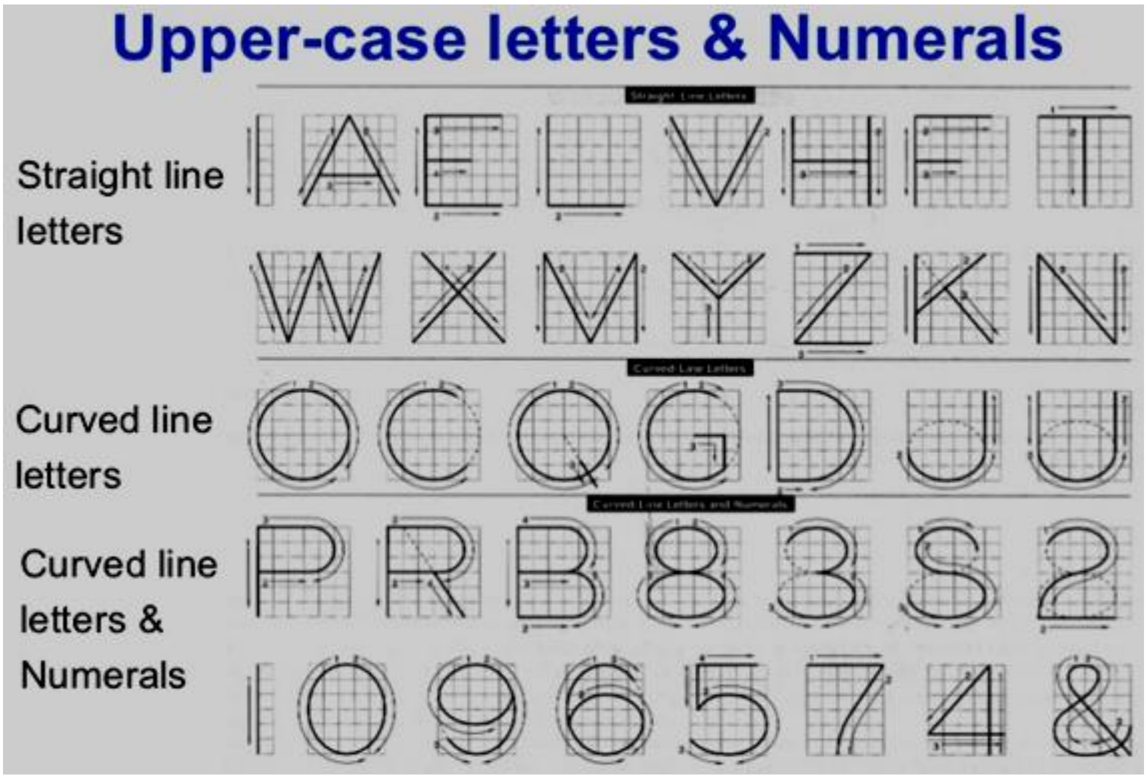
Word Composition

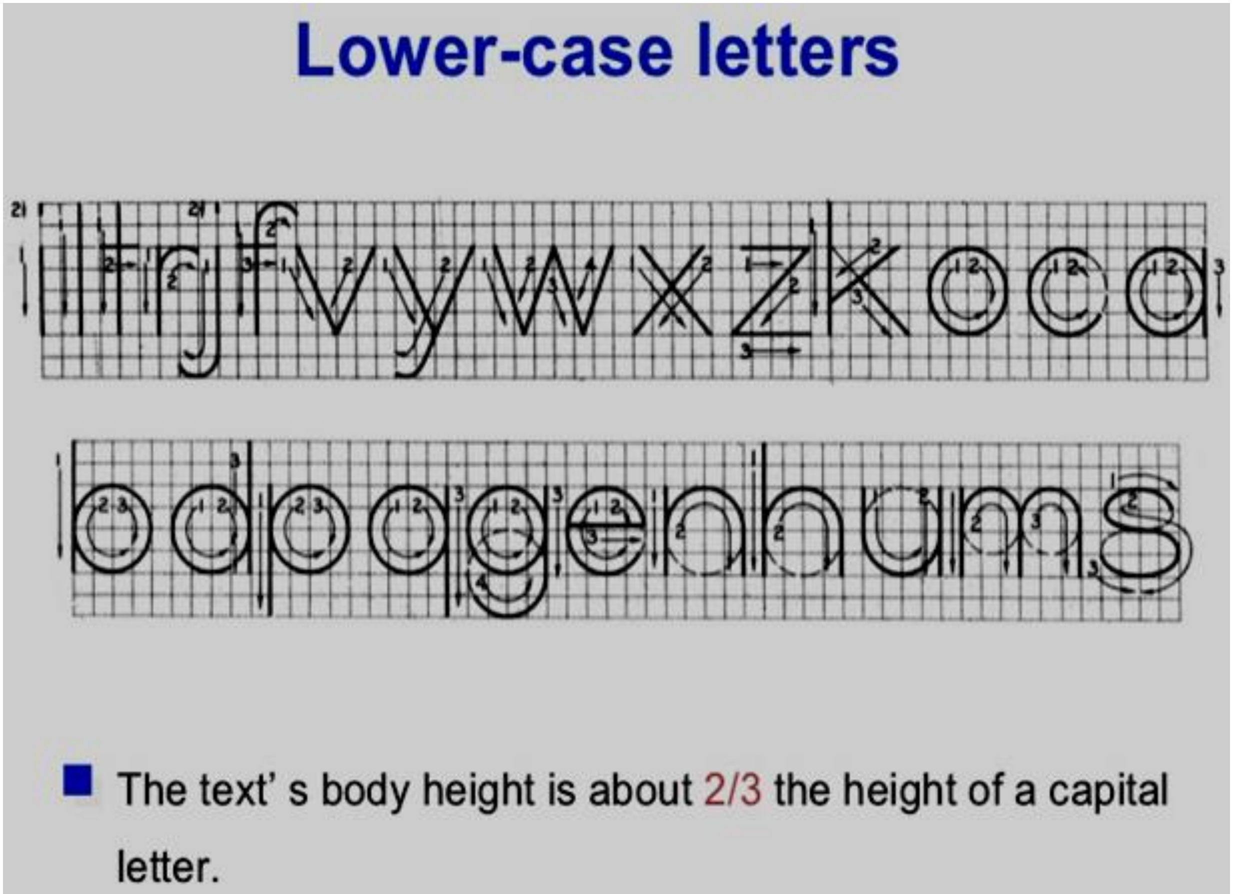
General conclusions are:

- Space between the letters depends on the contour of the letters at an adjacent side.
- Good spacing creates approximately equal ***background area*** between letters.

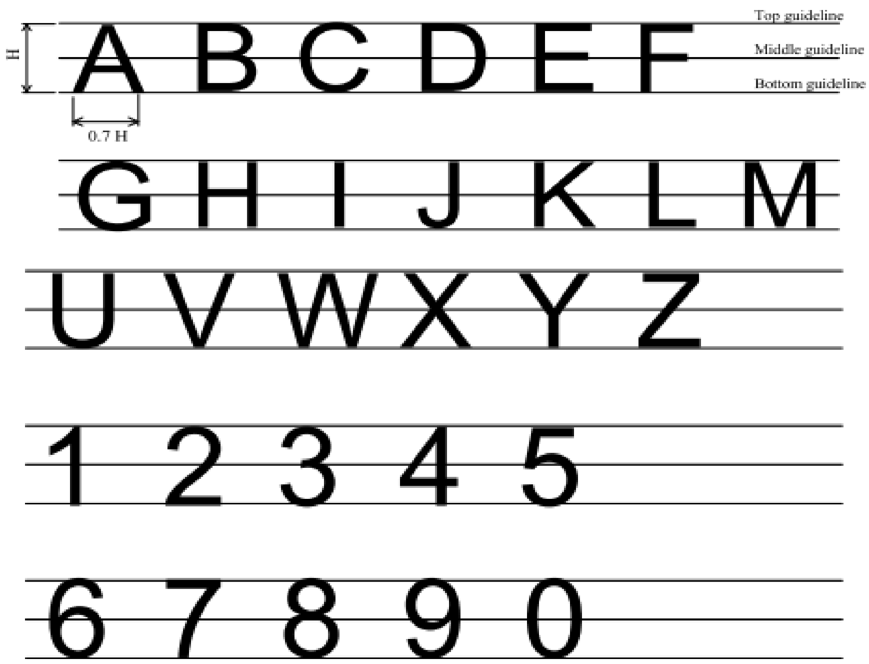
Example : *Good and Poor Lettering*

ESTIMATE	**GOOD**
EsTiMaTE	Not uniform in style.
ESTIMATE ESTIMATE	Not uniform in height.
EST/MATE ESTIMATE	Not uniformly vertical or inclined.
ESTIMATE ESTIMATE	Not uniform in thickness of stroke.
ES T IM AT E	Area between letters not uniform.
ABILITY WILL NEVER CATCH UP WITH THE DEMAND FOR IT	Area between words not uniform.





Example of letters and numbers



2. Apply title block

➢ Definition

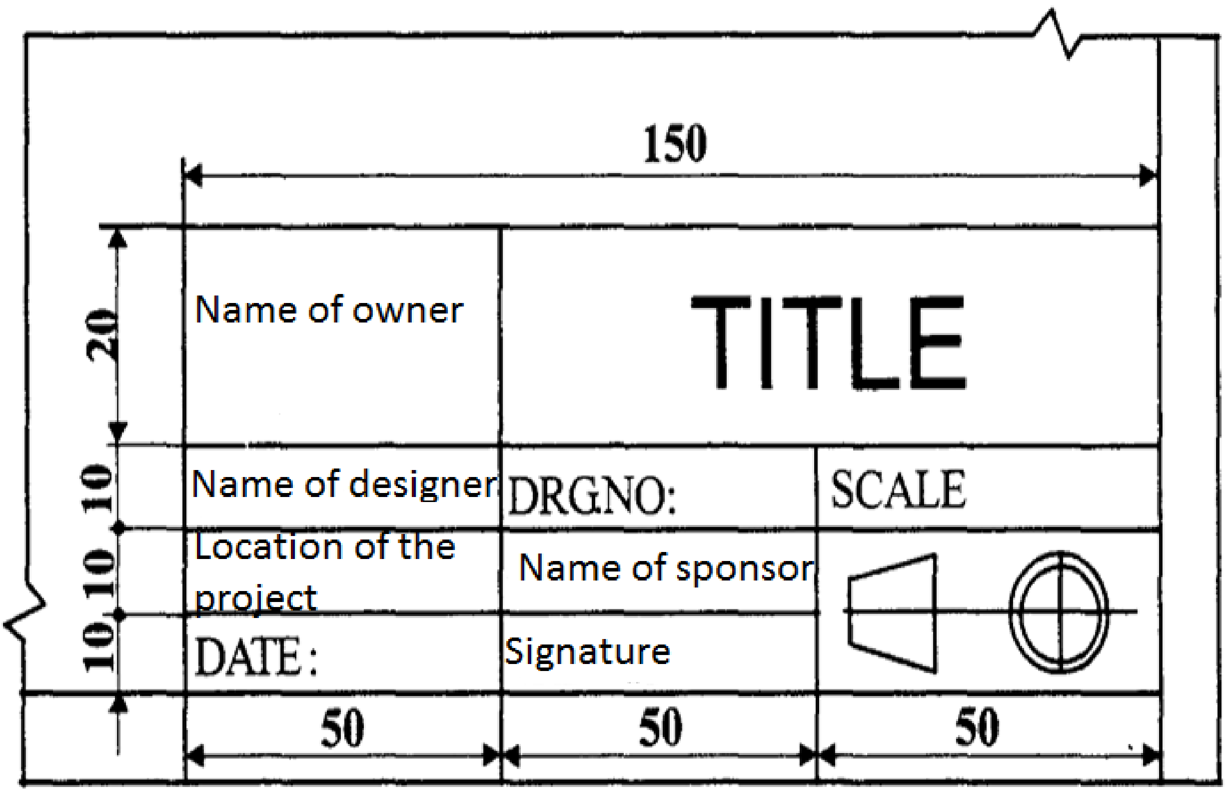
The **title block** (T/B, TB) is an area of the **drawing** that conveys header-type information about the **drawing**, such as: **Drawing** title...

The block of a drawing, usually located on the bottom or lower right hand corner, contains all the information necessary to identify the drawing and to verify its validity. A title block is divided into several areas.

➢ Elements of the title block

- Title of the project
- Name of the owner
- Drawing number (1, 2, 3, ….)
- Signature
- Scales
- Date
- Name of Designer
- Location of the project
- The name of sponsor
- Projection symbol

Example of title block



➤ Lines used in construction drawing

1. Definition of lines used in drawing

Lines of different types and thickness are used for graphical representation of objects. The types of lines and their applications are shown in table below.

Basic Line Types

Types of Lines	Appearance	Name according to application
Continuous thick line		Visible line
Continuous thin line		Dimension line Extension line Leader line
Dash thick line		Hidden line
Chain thin line		Center line

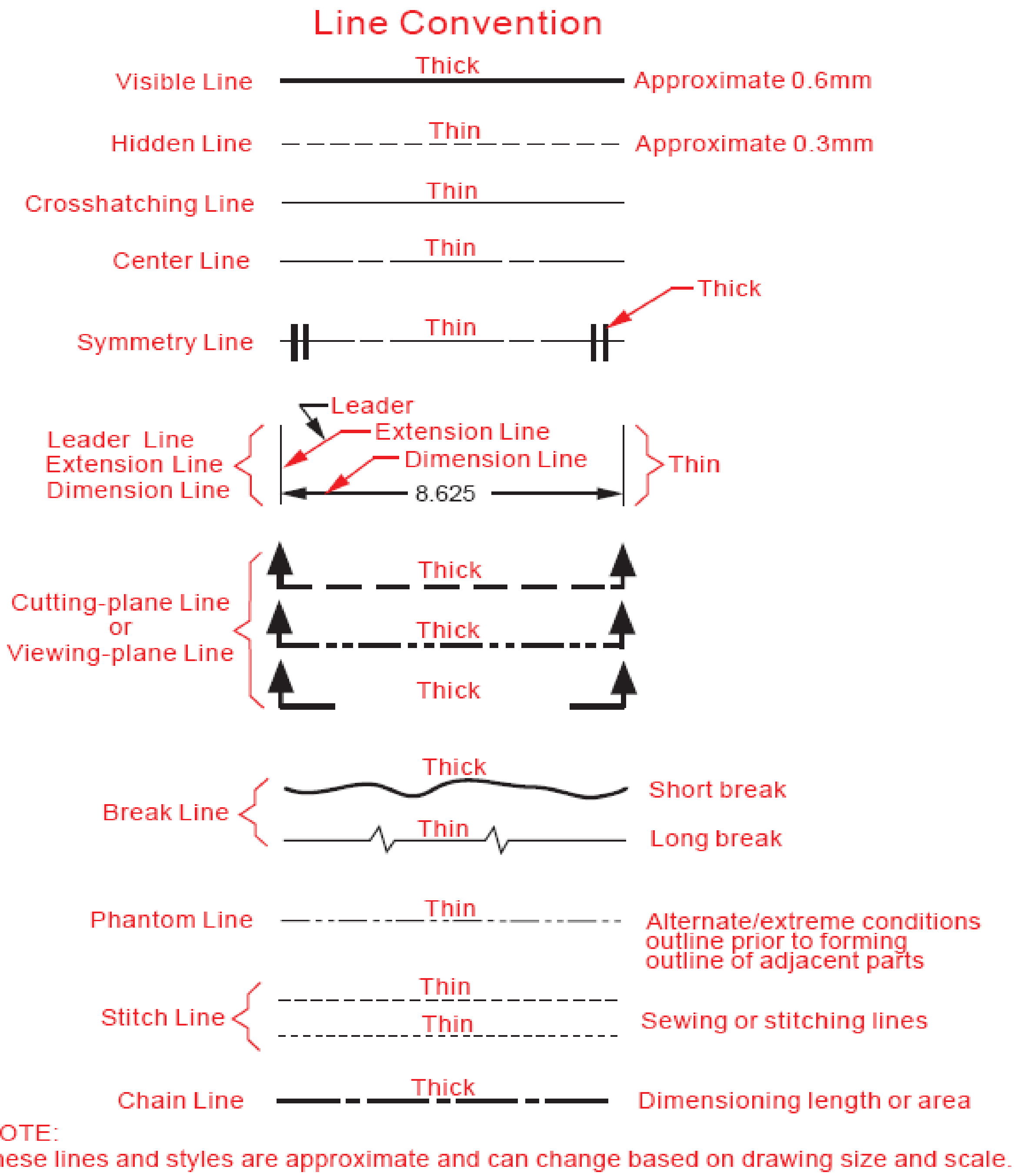
Meaning of Lines

Visible lines represent features that can be seen in the current view

Hidden lines represent features that can not be seen in the current view

Center line represents symmetry, path of motion, centers of circles, axis of axisymmetrical parts

Dimension and Extension lines indicate the sizes and location of features on a drawing

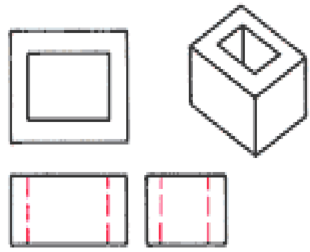
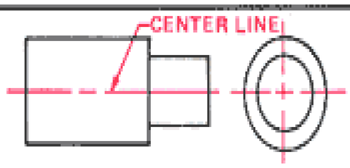
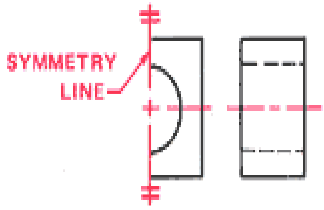
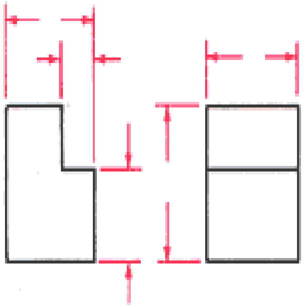
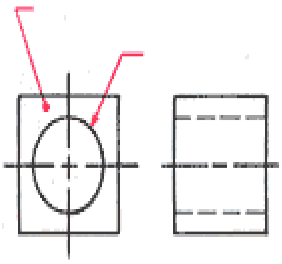


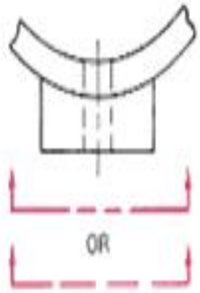
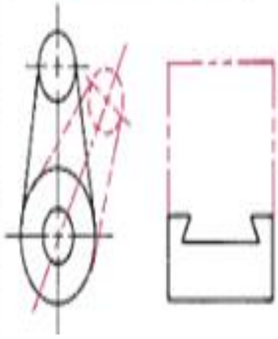
2. Meaning of the lines

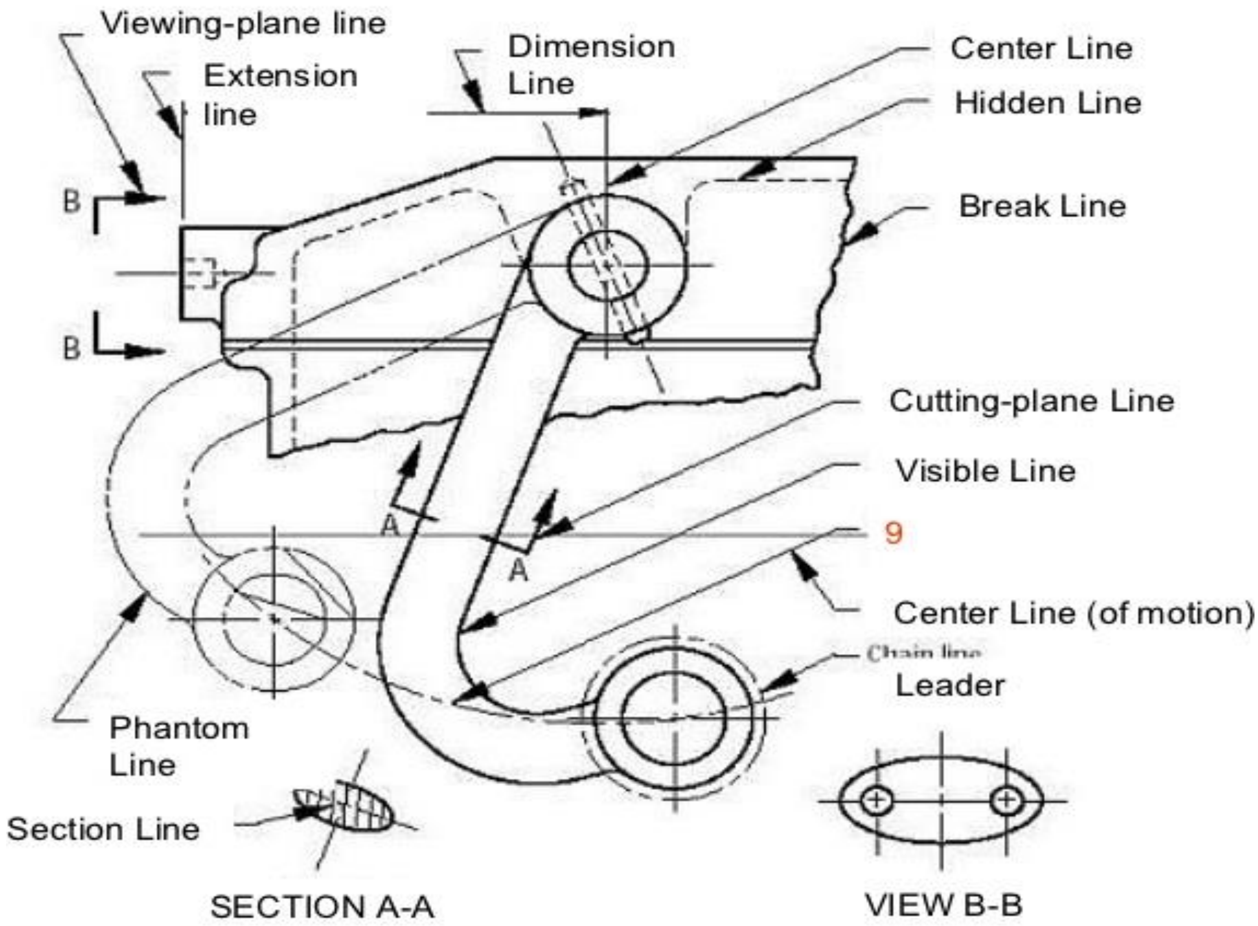
- **Visible lines:** Solid thick lines that represent visible edges or contours
- **Hidden lines:** short evenly spaced dashes that depict hidden features
- **Section lines:** solid thin lines that indicate cut surfaces
- **Center lines:** alternating long and short dashes
- Dimensioning
    - ✓ **Dimension lines:** solid thin lines showing dimension extent/direction
    - ✓ **Extension lines:** solid thin lines showing point or line to which dimension applies
    - ✓ **Leaders:** direct notes, dimensions, symbols, part numbers, etc. to features on drawing
- Cutting-plane and viewing-plane lines-indicate location of cutting planes for sectional views and the viewing position for removed partial views

- **Break lines:** indicate only portion of object is drawn. May be random" squiggled" line or thin dashed joined by zigzags.
- **Phantom lines:** long thin dashes separated by pairs of short dashes indicate alternate positions of moving parts, adjacent position of related parts and repeated detail
- **Chain line:** lines or surfaces with special requirements

3. Application and description of lines used in construction drawing

TYPE OF LINE	APPLICATION	DESCRIPTION
HIDDEN LINE THIN		THE HIDDEN OBJECT LINE IS USED TO SHOW SURFACES, EDGES, OR CORNERS OF AN OBJECT THAT ARE HIDDEN FROM VIEW.
CENTER LINE THIN ALTERNATE LINE AND SHORT DASHES		CENTER LINES ARE USED TO SHOW THE CENTER OF HOLES AND SYMMETRICAL FEATURES.
SYMMETRY LINE CENTER LINE THICK SHORT LINES		SYMMETRY LINES ARE USED WHEN PARTIAL VIEWS OF SYMMETRICAL PARTS ARE DRAWN. IT IS A CENTER LINE WITH TWO THICK SHORT PARALLEL LINES DRAWN AT RIGHT ANGLES TO IT AT BOTH ENDS.
EXTENSION AND DIMENSION LINES THIN DIMENSION LINE EXTENSION LINE		EXTENSION AND DIMENSION LINES ARE USED WHEN DIMENSIONING AN OBJECT.
LEADERS ARROW DOT THIN		LEADERS ARE USED TO INDICATE THE PART OF THE DRAWING TO WHICH A NOTE REFERS. ARROWHEADS TOUCH THE OBJECT LINES WHILE THE DOT RESTS ON A SURFACE.

TYPE OF LINE	APPLICATION	DESCRIPTION
 THIN LINES		SECTION LINING IS USED TO INDICATE THE SURFACE IN THE SECTION VIEW IMAGINED TO HAVE BEEN CUT ALONG THE CUTTING-PLANE LINE.
VIEWING-PLANE LINE  THICK OR	 OR	THE VIEWING-PLANE LINE IS USED TO INDICATE DIRECTION OF SIGHT WHEN A PARTIAL VIEW IS USED.
PHANTOM LINE  THIN		PHANTOM LINES ARE USED TO INDICATE ALTERNATE POSITION OF MOVING PARTS, ADJACENT POSITION OF MOVING PARTS, ADJACENT POSITION OF RELATED PARTS, AND REPETITIVE DETAIL.



- Symbols used in drawing

Construction drawings are a means of communication between the various members of the building team, and it is important that they employ a common graphical language. It helps to achieve this if agreed standards are followed in respect of lines, hatching and symbols, etc.

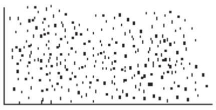
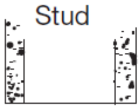
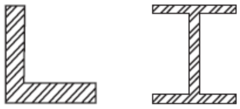
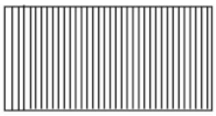
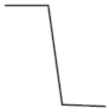
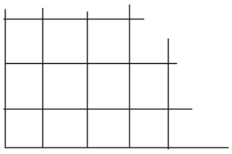
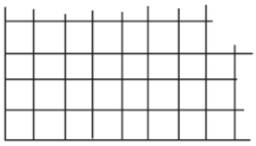
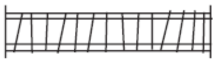
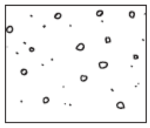
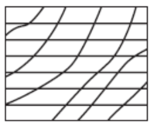
Representation of materials

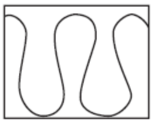
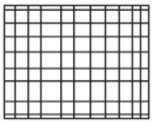
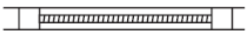
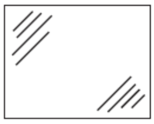
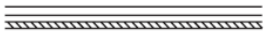
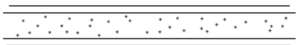
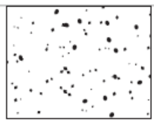
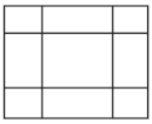
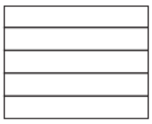
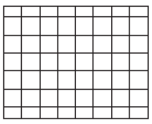
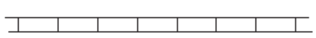
In sectional views of a building, the parts of the structure which are cut by section plane may be hatched to indicate the nature of the materials used.

Common examples of hatching for construction materials:

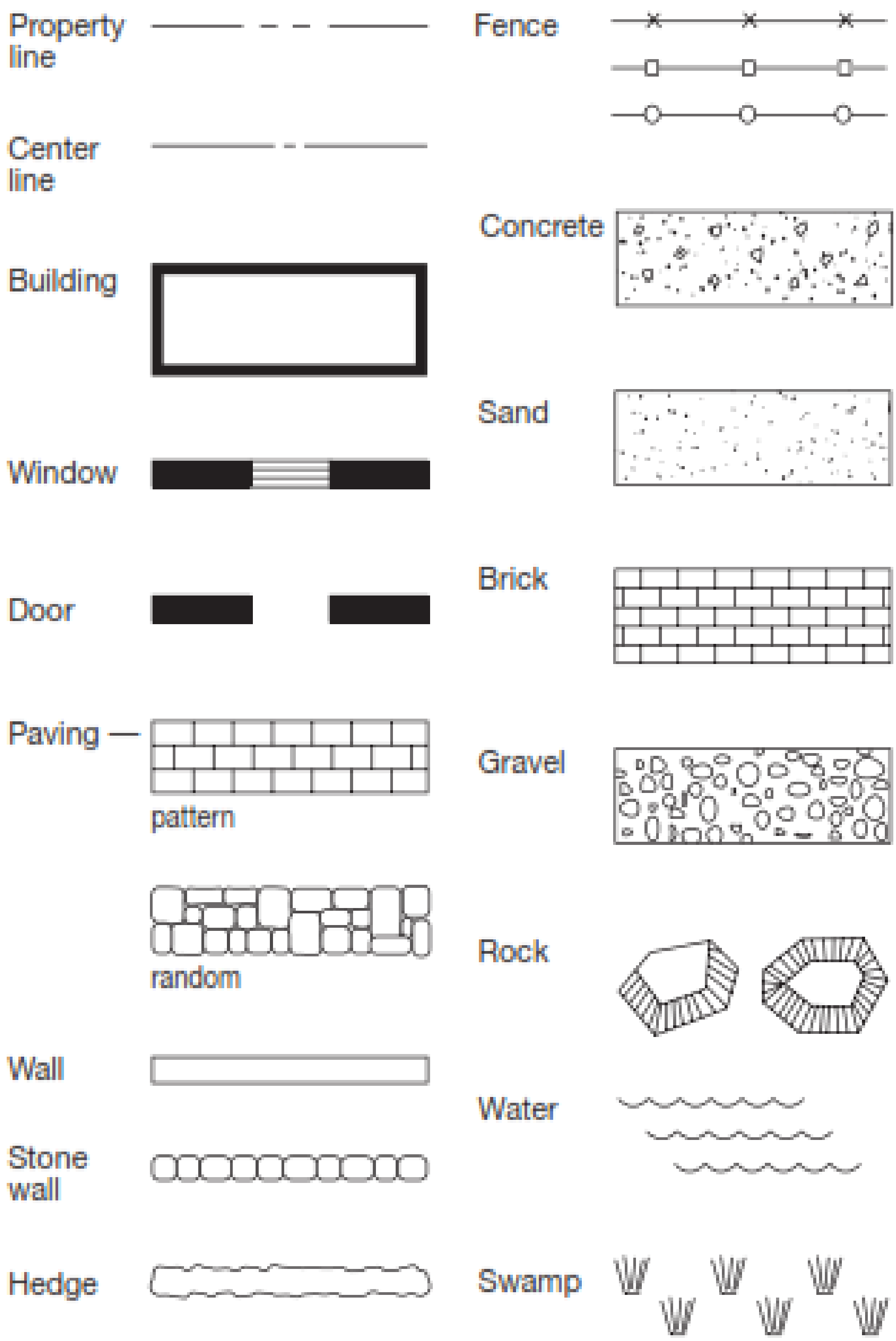
1. Masonry symbols

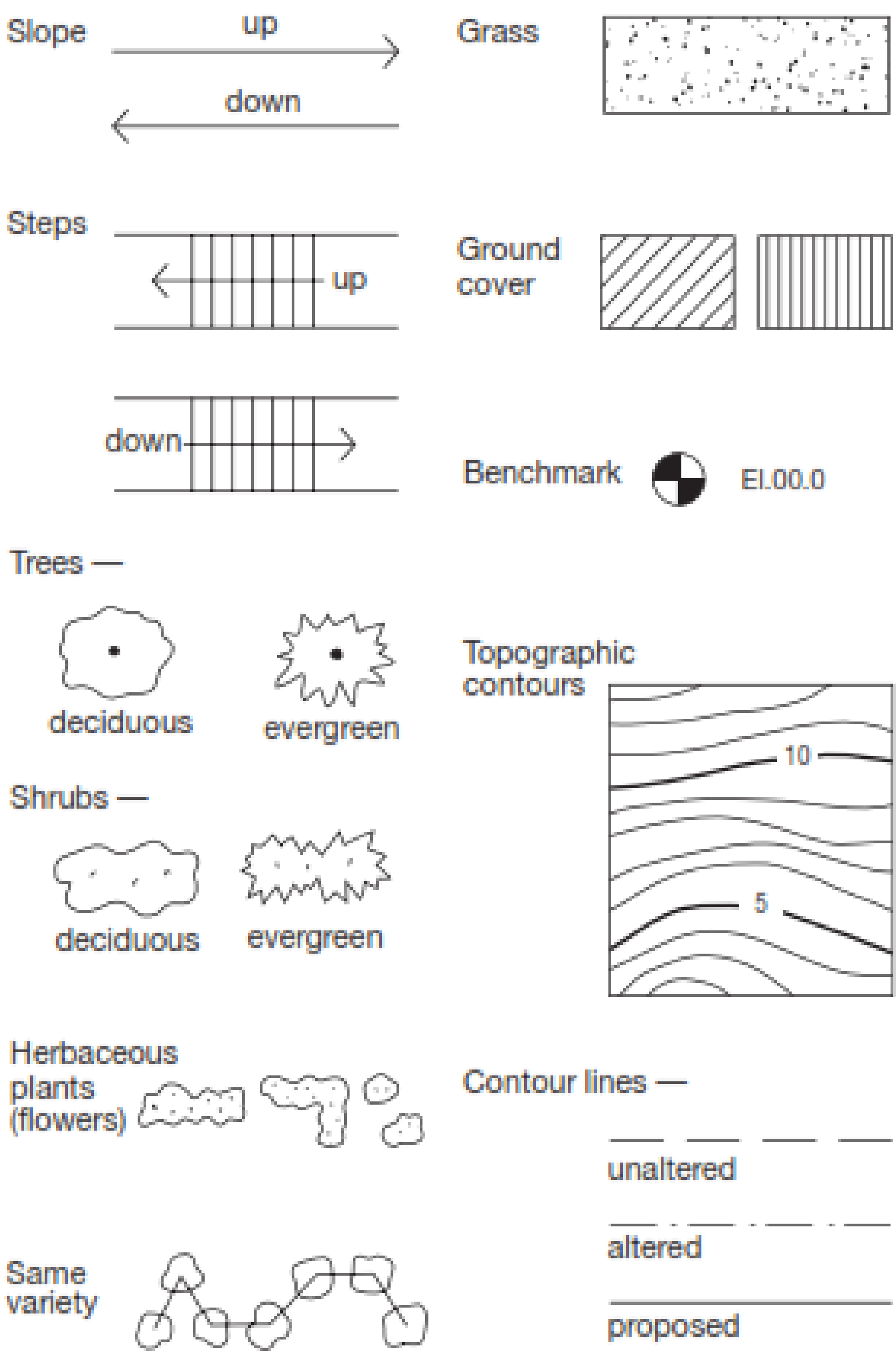
Material	Plan	Elevation	Section
Wood	Floor areas left blank	Siding Panel	Framing Finish
Brick	Face Common	Face or common	Same as plan view
Stone	Cut Rubble	Cut Rubble	Cut Rubble
Concrete			Same as plan view
Concrete block			Same as plan view
Earth	None	None	
Glass			Large scale Small scale
Insulation	Same as section	Insulation	Loose fill or batt Board

Plaster	Same as section	Plaster 	Stud  Lath and plaster
Structural steel		Indicate by note	
Sheet metal flashing	Indicate by note		 Show contour
Tile	 Floor	 Wall	
Porous fill	None	None	
Plywood	Indicated by note	Indicated by note	

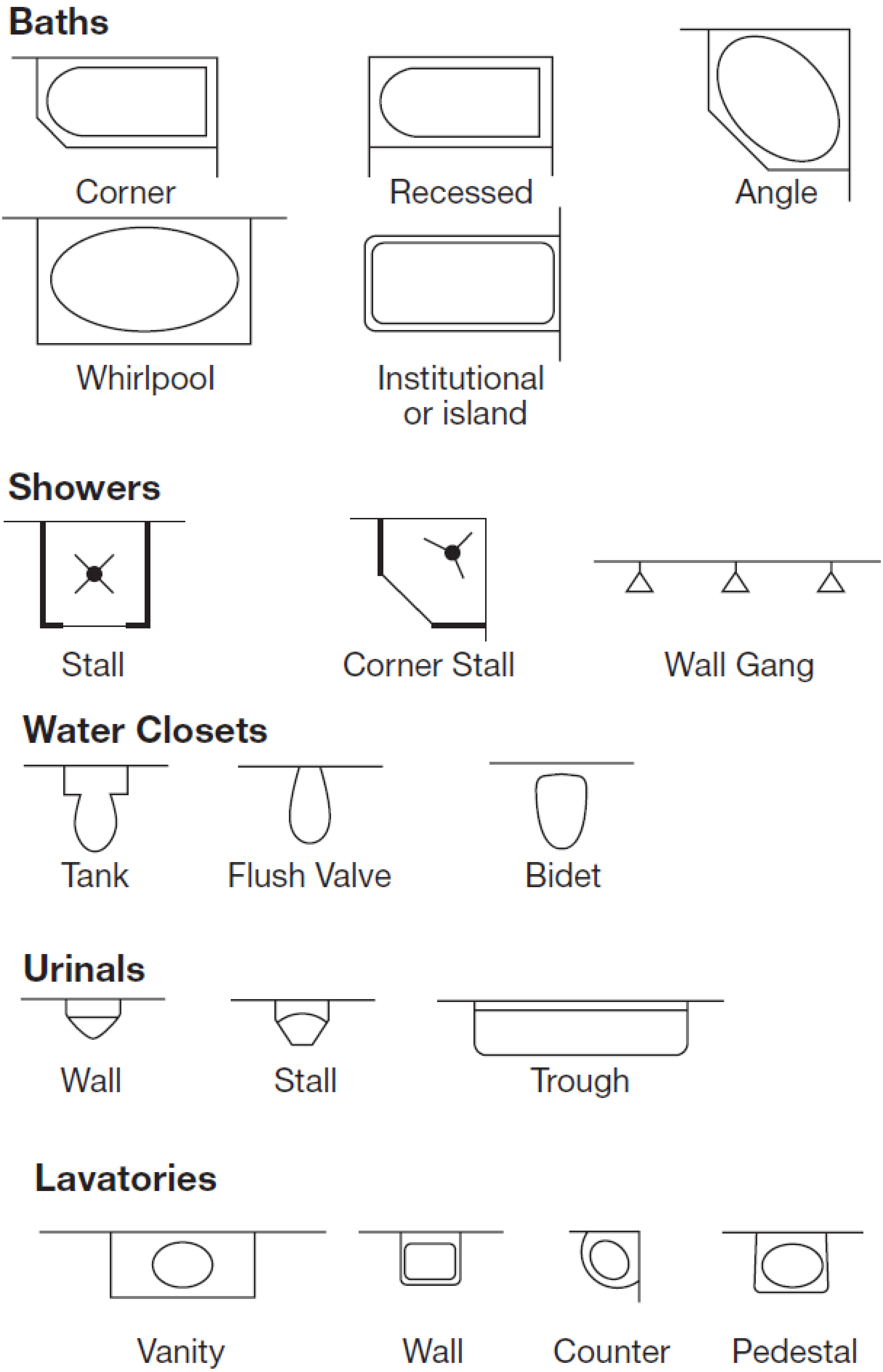
Batt insulation		None	Same as plan
Rigid insulation		None	Same as plan
Glass			Small scale  Large scale
Gypsum wallboard			Same as plan
Acoustical		None	
Ceramic wall tile			Same as plan
Floor tile		None	

2. Landscape systems and graphics

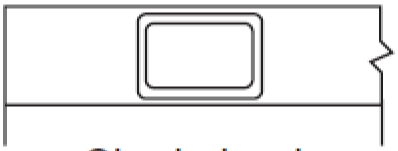

Property line
Center line
Building
Window
Door
Paving
pattern
random
Wall
Stone wall
Hedge
Fence
Concrete
Sand
Brick
Gravel
Rock
Water
Swamp

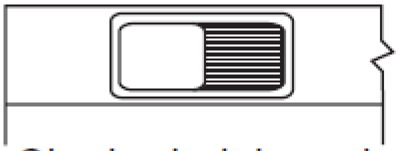

Slope
up
down
Grass
Steps
up
down
Ground cover
Benchmark
El.00.0
Trees —
deciduous
evergreen
Topographic contours
10
5
Shrubs —
deciduous
evergreen
Herbaceous plants (flowers)
Contour lines —
unaltered
altered
proposed
Same variety

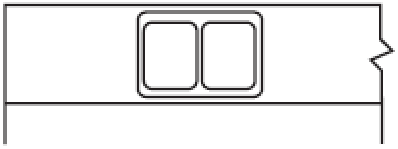
3. Plumbing symbols

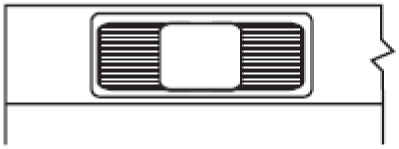


Kitchen Sinks

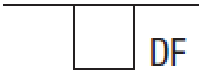

Single basin


Single drainboard

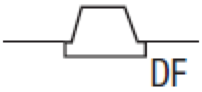

Twin basin


Double drainboard

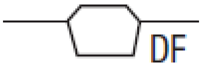
Drinking Fountains or Electric Water Coolers



Floor or wall

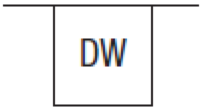


Recessed

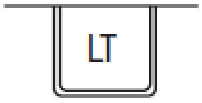


Semirecessed

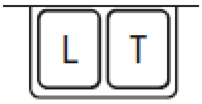
Dishwasher



Laundry Trays



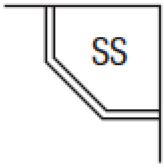
Single



Double

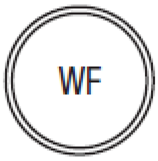
Service Sinks

Wall



Floor

Wash Fountains

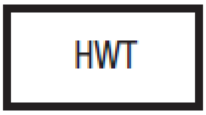


Circular

Semicircular

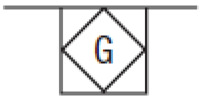
Hot Water

Heater

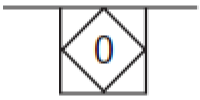


Tank

Separators

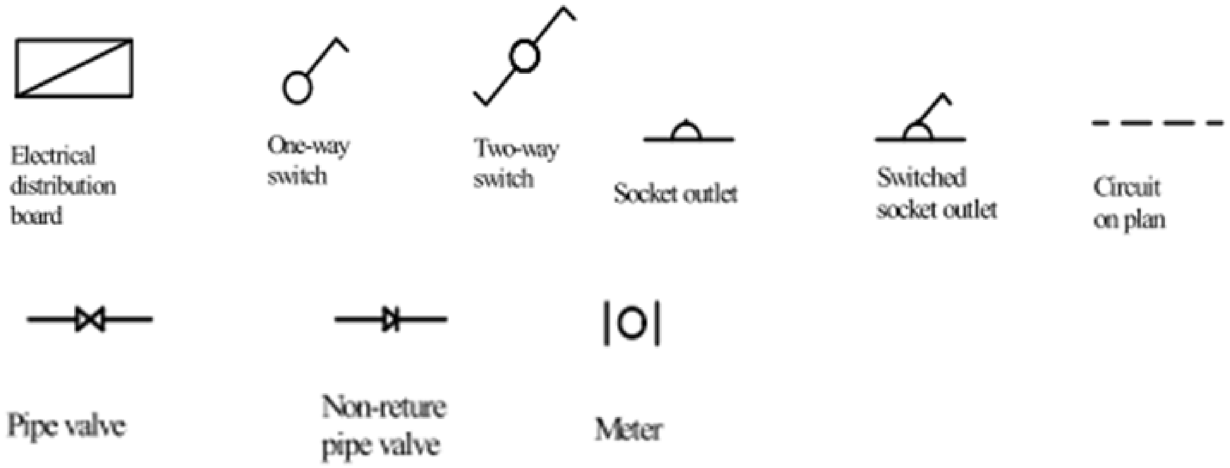


Gas

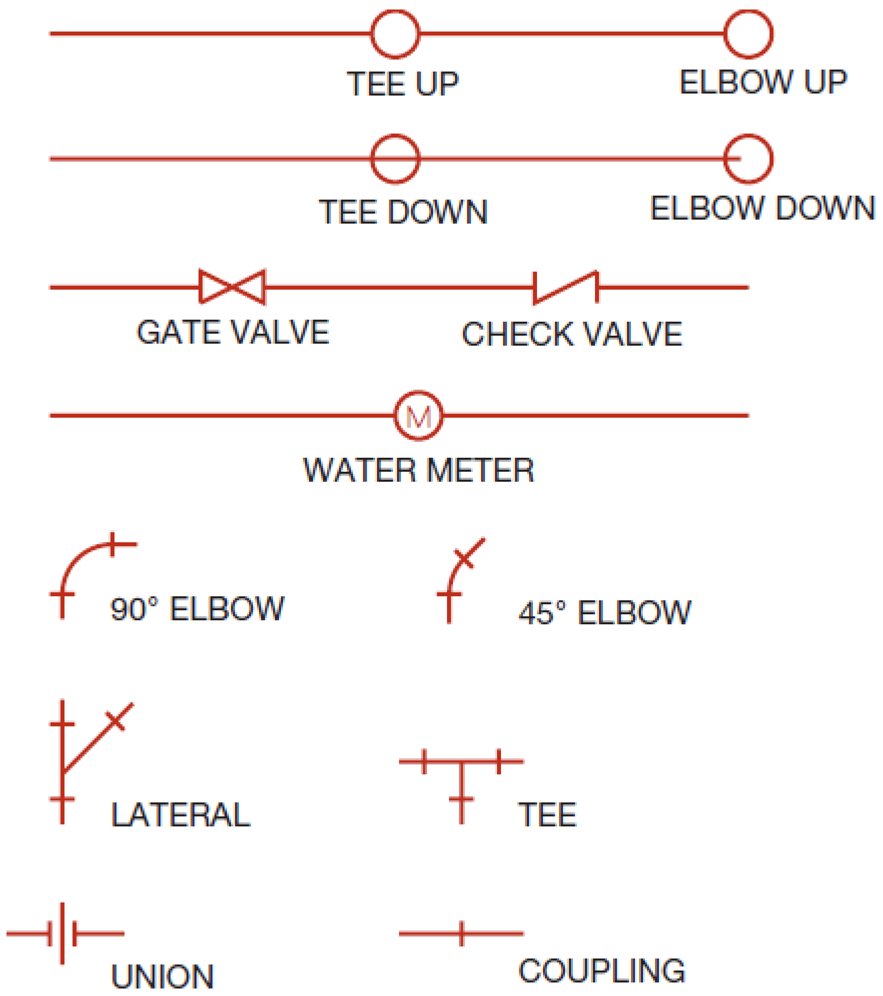


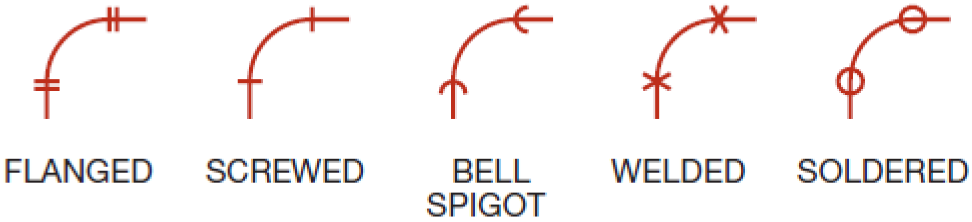
Oil

4. Electrical symbols



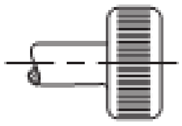
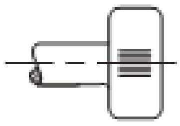
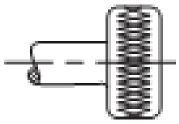
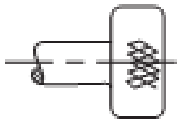
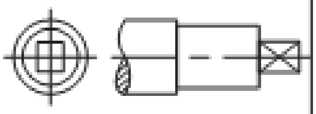
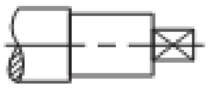
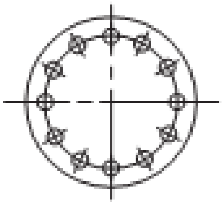
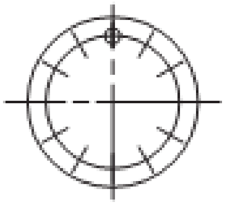
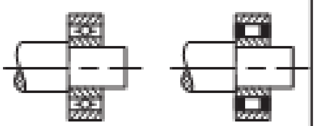
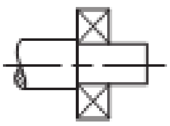
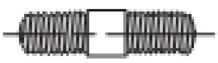
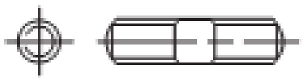
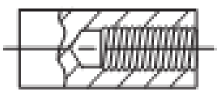
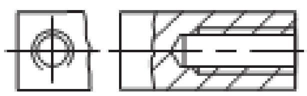
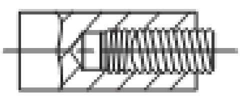
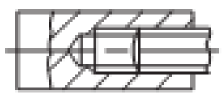
Other symbols

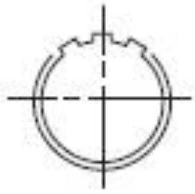
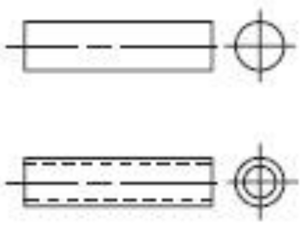
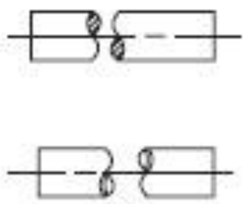
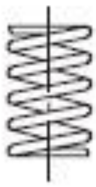




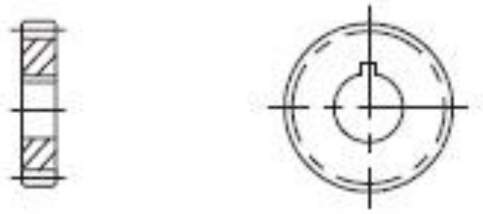
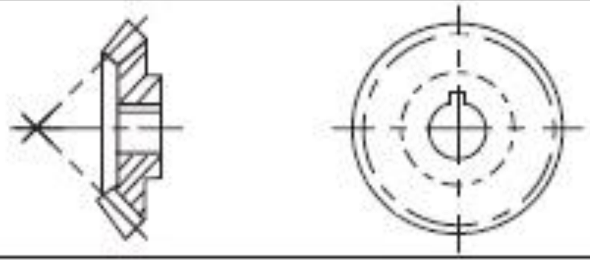
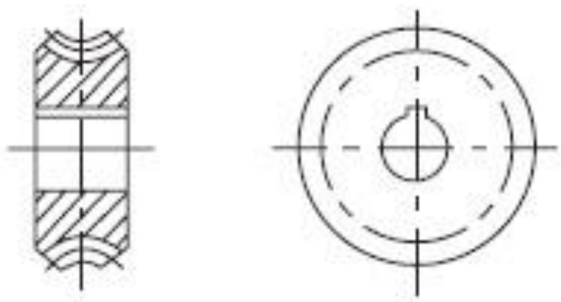
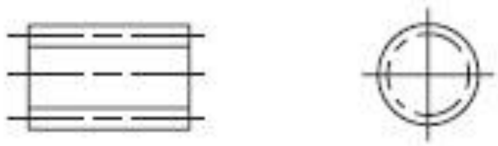
TYPES OF CONNECTIONS

5. Mechanical symbols

Title	Subject	Convention
Straight knurling		
Diamond knurling		
Square on shaft		
Holes on circular pitch		
Bearings		
External screw threads (Detail)		
Internal screw threads (Detail)		
Screw threads (Assembly)		

Title	Subject	Convention	
Splined shafts			
Interrupted views			
Semi-elliptic leaf spring			
Semi-elliptic leaf spring with eyes			
	Subject	Convention	Diagrammatic Representation
Cylindrical compression spring			
Cylindrical tension spring			

(b)

Title	Convention
Spur gear	
Bevel gear	
Worm wheel	
Worm	

- **Dimensioning**

1. Introduction

The purpose of dimensioning is to provide a clear and complete description of an object. A complete set of dimensions will permit only one interpretation needed to construct the part.

Dimensioning should follow these guidelines:

- **Accuracy:** correct values must be given.
- **Clearness:** dimensions must be placed in appropriate positions.
- **Completeness:** nothing must be left out, and nothing duplicated.

- **Readability:** the appropriate line quality must be used for legibility.

2. Dimension guidelines

- Place dimensions away from the profile lines.
- Allow space between individual dimensions.
- A gap must exist between the profile lines and the extension lines.
- The size and style of leader line, text, and arrows should be consistent throughout the drawing.
- Display only the number of decimal places required for manufacturing precision.
- Neatness counts
- Do not cross a dimension lines with another dimension line or with an extension line
- Avoid crossing dimension or extension lines with leader lines
- Dimension should not be duplicated, or the same information given in two different ways.
- ent of the object.
- Designation of a scale consists of the word "SCALE" followed by the indication of its ratio, as follow

  Scale

  Definition: The proportion by which we either reduce or increase the actual size of the object on a drawing is known as drawing to scale or simple scale.

  The scale is actually a measuring stick, graduated with different divisions to represent corresponding actual distances according to some proportion, thus giving rapidity marking off distance on drawing.

  Numerically scales indicate the relation between the dimensions on the drawing and actual dimensions of the object.

  The scales are either flat or triangular and the material used in their construction may be wood, celluloid, metal, etc. In drawing, scale should not be selected arbitrarily, but standard recommended scales should be adopted as far as possible.

  Types of scale

  SCALE 1:1 for full size

  SCALE X:1 for ***enlargement*** scales (X > 1)

  SCALE 1:X for ***reduction*** scales (X > 1)

- Dimension numbers shown in the drawing are correspond to "true size" of the object and they are independent of the scale used in creating that drawing.

Examples:

- Reduction scales: 1:2, 1:5, 1:10, 1:20, 1:50, 1:100, …..
- Enlarging scales: 2:1, 5:1, 10:1, 100:1, …..

Notice: If all drawings are made to the same scale, the scale should be indicated in or near the title block. When it is necessary to use more than one scale on a drawing, the main scale only should be shown in the title block and all the other scales, adjacent to the item reference number of the part concerned or near the drawings.

To make scale independent of the units it is preferable to use representative fraction which may be defined as the ratio of one unit on paper to the number of units it represent on the ground.

Thus, 1 mm = 1 m is equivalent to RF = 1/1ooo

Scale can be represented by the following methods:

1. One cm on the plan represents some whole number of meters on the ground, such as a 1 cm = 10 m.

This type of scale is called ***engineers scale.***

2. One unit of length on the plan represents some number of some units of length of the ground, such as 1/1000.

This ratio of plane distance to the corresponding ground distance is independent of units of measurement and is called ***representative fraction (R.F).***

$$\mathrm{RF}=\frac{\textit{Drawing size of an object}}{\textit{Actual size of an object}}\ \textbf{(In same units)}$$

- Content/Topic 7:Geometrical construction

1. Angles

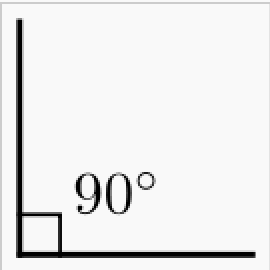
When two straight lines meet (AB and AC below), they form an angle. Angles are measured in degree $(^0)$. There are 360^0 in a circle. Angles can be drawn and measured using a protractor.

➢ Types of angles

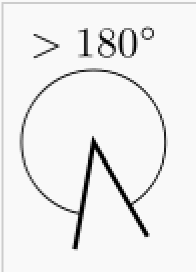
- ✓ Acute angle is less than 90°
- ✓ Right angle is 90°exactly
- ✓ Obtuse angle is greater than 90° but less than 180°
- ✓ Straight angle is 180° exactly

- ✓ Reflex angle is greater than 180°
- ✓ Full rotation angle is 360° exactly

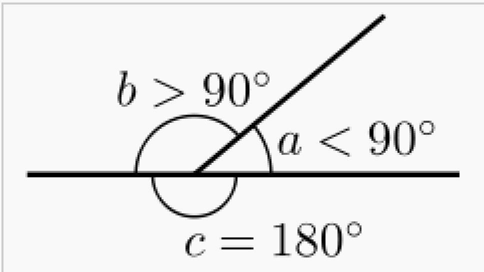
	Degrees	Radians
Zero	$\alpha = 0$	$\alpha = 0$
Acute	$0 < \alpha < 90^o$	$0 < \alpha < \pi/2$
Right	$\alpha = 90^o$	$\alpha = \pi/2$
Obtuse	$90^o < \alpha < 180^o$	$\pi/2 < \alpha < \pi$
Straight	$\alpha = 180^o$	$\alpha = \pi$
Reflex	$180^o < \alpha < 360^o$	$\pi < \alpha < 2\pi$
Full	$\alpha = 360^o$	$\alpha = 2\pi$



Right angle.



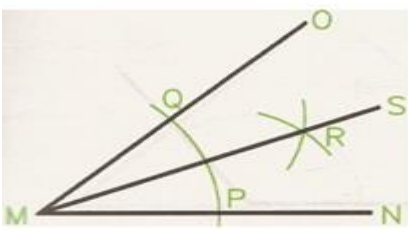
Reflex angle.



Acute (*a*), obtuse (*b*), and straight (*c*) angles.

➢ To bisect a given angle

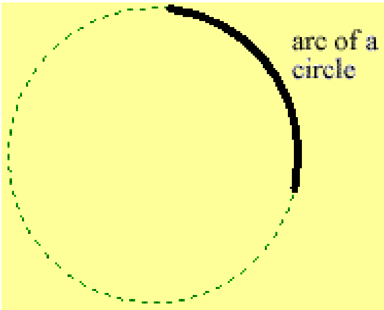
1. Draw any angle.
   Draw any arc PQ. Set compasses to a sensible size and with the compass centred first at P, then at Q draw crossing arcs at R.
2. Draw MS passing through R. The angles NMS and SMO are equal.



2. Arcs

➢ . Definition:

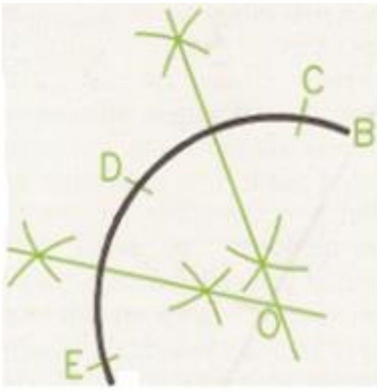
A portion of the circumference of a circle is known as an arc.



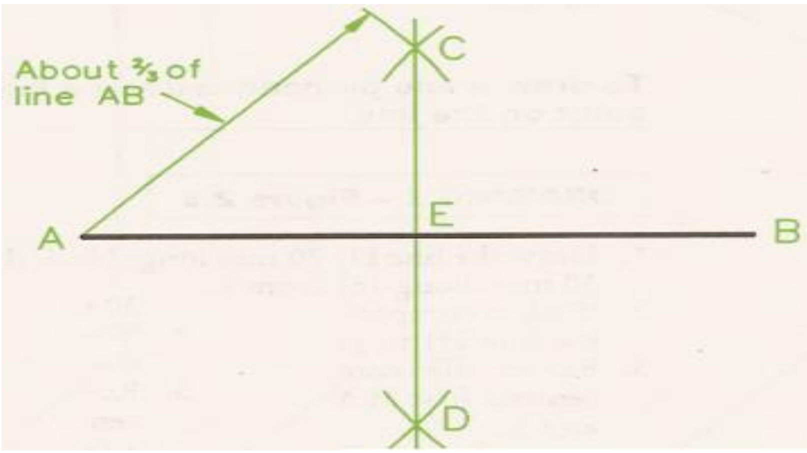
➢ Finding the centre of an arc

1. Draw any arc
2. Mark off any three points C, D and E on the arc.
3. Bisect the two arcs CD nd DE. The bisection lines cross at O, which is the centre of the arc.
4. Check that you have found the correct centre by centring a compass at O and attempting to complete the circle of which the arc is a part.

The bisector of any arc passes through its centre. It follows that if any two arcs of an arc or a circle are bisected, they must intersect at the centre of the arc or circle.

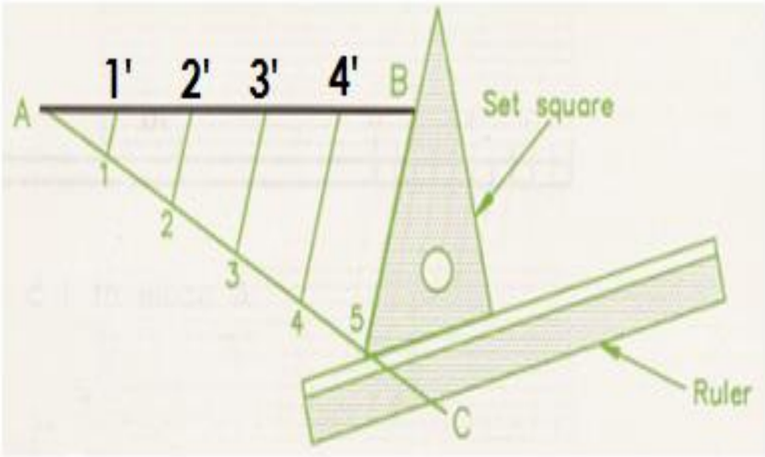


➢ To bisect a straight line



- AB is the given line to be divided into two equal parts
- With A and B as centers, strike the intersecting arcs as shown using radius greater than one half of AB. A straight line through point C and D bisects AB.

i) To divider a straight line into a given number of equal parts



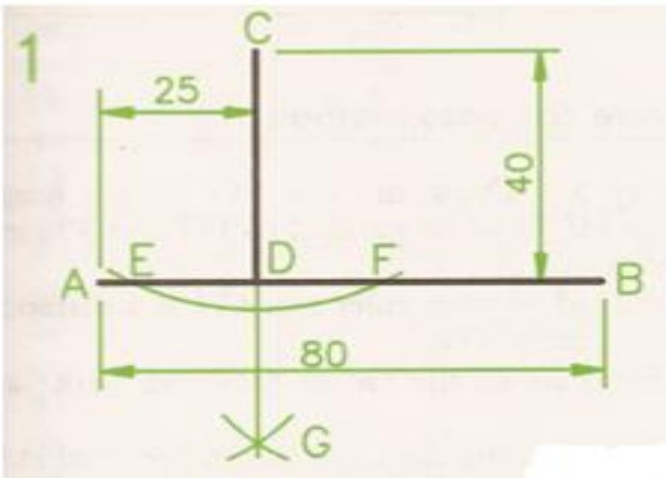
The following procedure illustrates how to divide a line into 5 equal parts

- AB is the given line to be divided into 5 equal parts
- Draw a construction line AC at any convenient angle.
- On AC mark successively five equal divisions of any convenient angle
- Name the division points as 1, 2, 3, 4 and 5 on AC.
- Connect last division point, fifth to point B and then from point 4, 3, 2 and 1. Draw line parallel to the B5 to intersect the line AB at point 4’, 3’, 2’ and 1’ as shown in previous figure. Thus the line AB is divided into five equal parts.

ii) Perpendicular lines

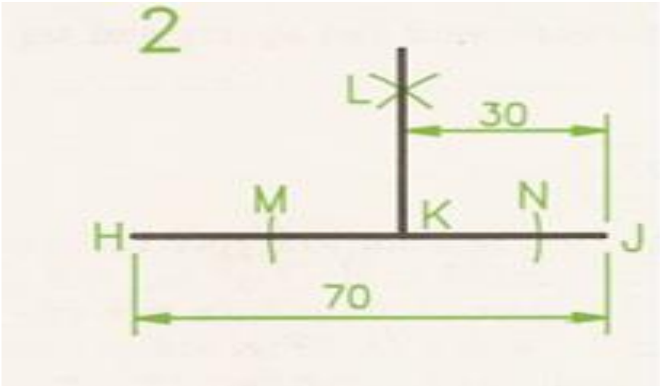
(1) To draw a line perpendicular to a line from a point to the line

1. Draw the line AB 80 mm long. Mark the point C 40 mm above the line and 25 mm from the left hand end.
2. Set a compass, centred at C, to a suitable size so as to draw an arc which cuts the line AB at E and F.
3. Re-set the compass and, with the compass centred at E, then at F draw the crossing arcs G.
4. Draw a line CG. The line CD is perpendicular to AB.



(2) To draw a line perpendicular to a line from a point on the line

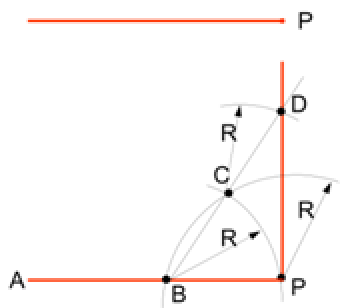
1. Draw the HJ 70 mm long. Mark the point K 30 mm along HJ from J.
2. With a compass centred at K draw arcs across the line HJ to give the points M and N.
3. Re-set the compass and, with the compass centred first at M, then at N draw the crossing arcs L.
4. Draw the line KL. The line is perpendicular to line HJ.



iii) Drawing a vertical line at the end of a line

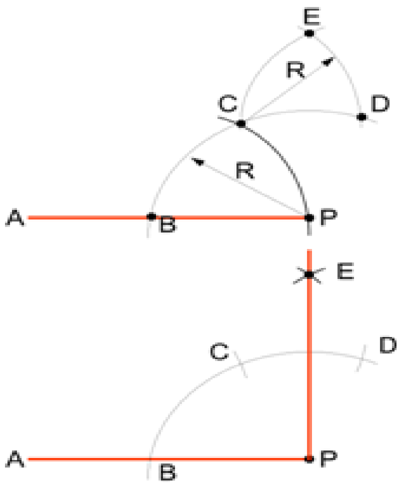
Way I:

1. Accept point P as centre. Draw arc R and mark point B.
2. Don't move compass angle, accept point b as center, and draw an arc crossing point P and previous arc. Obtain point C.
3. Connect point B and C and prolong this new line.
4. Accept point C as center; draw an arc intercepting BC line. Mark point D at the intersection point.
5. Connect point P and D.



Way II:

1. Accept point P as center. Open the compass as R amount and Mark point B.
2. Don't move the compass; accepting B, C and D as center, respectively; draw the arcs intersecting each other. Obtain point E.
3. Connect point P and E.



➢ To draw a Circular arc tangents to two lines

Drawing 1 Drawing a radius of 20 mm where two lines meet at 90 degrees.

1. Draw the two lines to give the angle BAC.
2. Set a compass to 20 mm and from each line in turn construct parallel lines D and E.
3. Centre the compass at the point O, where the two lines D and E meet, and draw the required radius.

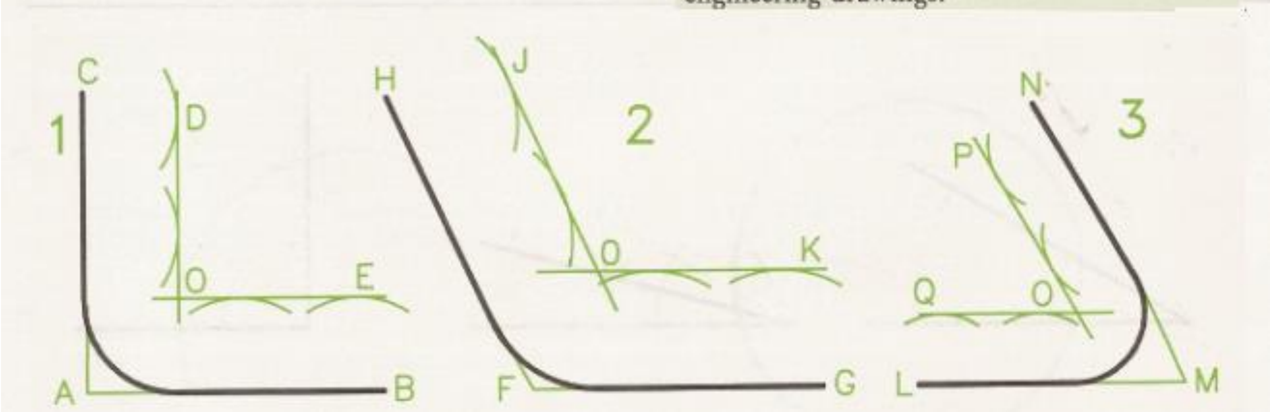
Drawing 2 Drawing a radius of 25 mm where two lines meet at 120 degrees.

1. Draw the two lines to give the angle GFH.
2. Follow the same procedure as for the first radiused corner, except that the compass is set to 25 mm.

Drawing 3 Drawing a fillet of 15 mm to two lines meeting at 60 degrees.

1. Draw the two lines to give the angle LMN.
2. Follow the same procedure as for the first radiused corner, except that the compass is set to 15 mm.

The drawing of a radius at a corner where lines meet to form an angle is known as drawing a **fillet**, particularly when working with engineering drawings.



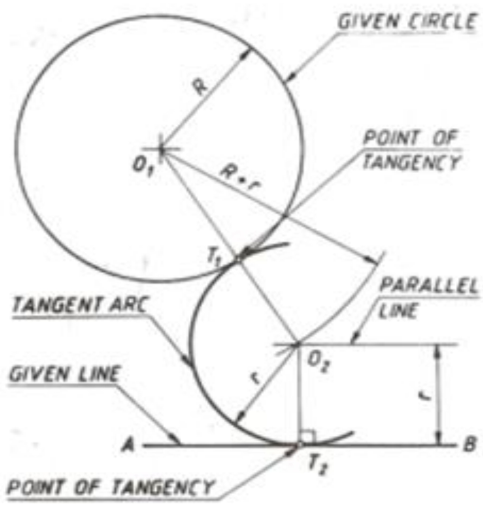
➢ To draw a circular arc tangents to a circle and a line

a) External tangent

AB is the line and the circle is of radius R. It is required to draw an arc of a circle of radius r tangential externally to the circle and the line AB.

With O_1 as centre and radius (R + r) draw an arc. Draw a line parallel to AB at a distance r to intersect the previously draw arc at O_2. With O_2 as centre and radius r, draw the required arc, which will be tangential to both the circle and the line.

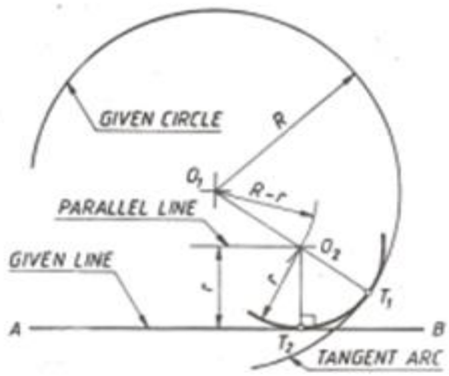
To obtain the points of tangencies, connect O_1O_2, which intersects the arc and the circle at T_1; from O_2 draw a line perpendicular to the line AB to intersect it at T_2. T_1 and T_2 are the required points of tangencies.



External tangent arc to a circle and a line

b) Internal tangent

AB is the line and the circle is of radius R. It is required to draw an arc of a circle of radius r tangential internally to the circle and to the line AB. With O_1 as centre and radius (R - r), draw an arc. Draw a line parallel to AB at a distance r to intersect the previously drawn arc at O_2. With O_2 as centre and radius r, draw the required arc, which will be tangential internally to the circle and to the line AB.
To obtain the points of tangencies, connect the two centres O_1 and O_2 and produce which intersects.

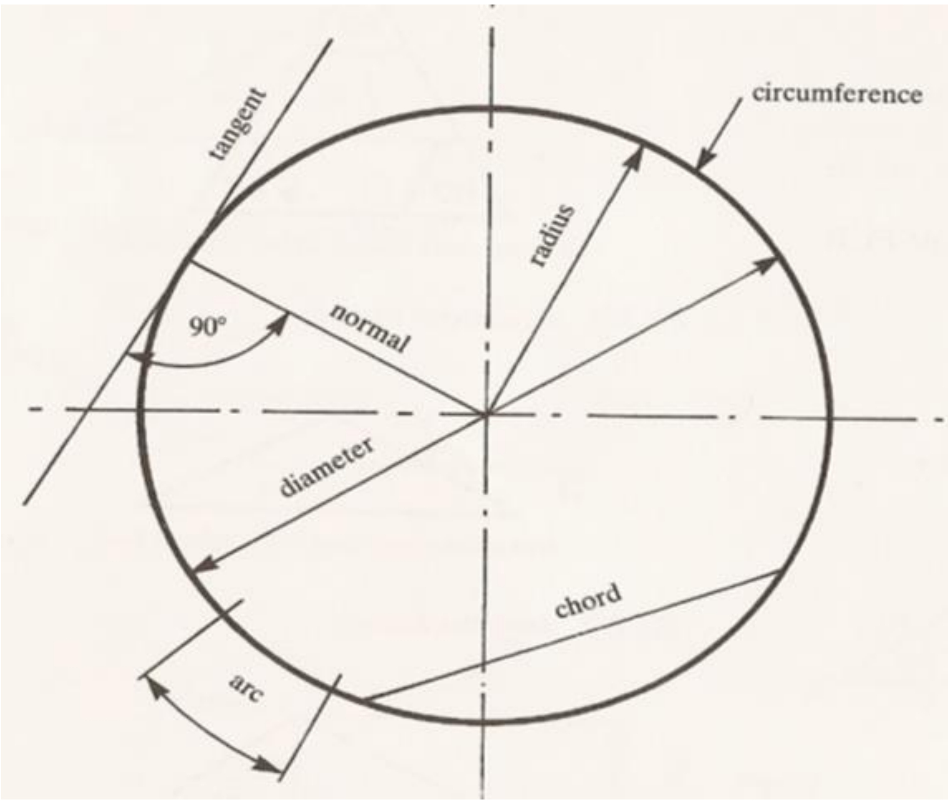


Internal tangent arc to a circle and a line

3. Circles

Terminology

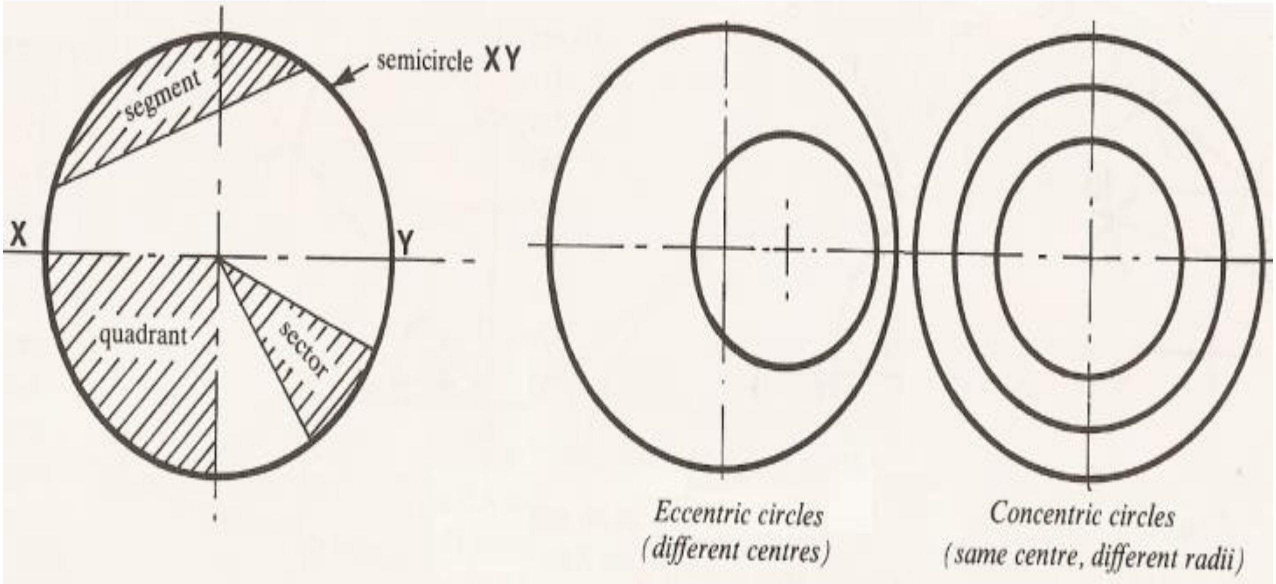
A circle is a plane figure bounded by a line called the circumference which is always equidistant from the centre of the circle. The distance from the centre to the circumference is called radius; the distance from one edge of the circumference to the other through the centre of the circle is called the diameter.
An arc is any part of the circumference.
A chord is any straight line drawn across the circle meeting the circumference at both ends. Any such line passing through the centre of the circle is called the **diameter**.
A tangent is a straight line that touches the circumference. It is always at right angles to the radius at the point of contact.
The line drawn from the point of contact to the centre of the circle is called the **Normal**.



The region between a chord of a circle and its associated arc is known as **a segment**.

A quarter of a circle made of two radii at right angles, one being horizontal and the other being vertical is known as **a quadrant**.

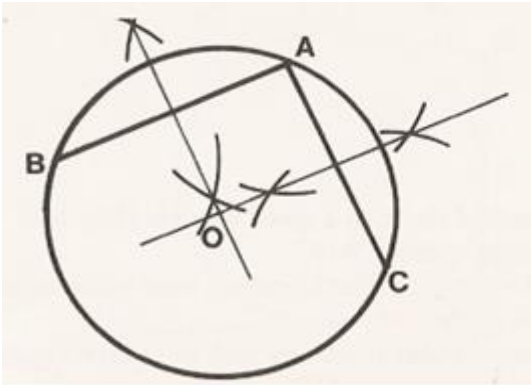
The area enclosed by two radii of a circle and their intercepted arc is known as **a sector**.



➢ Operations on Circles

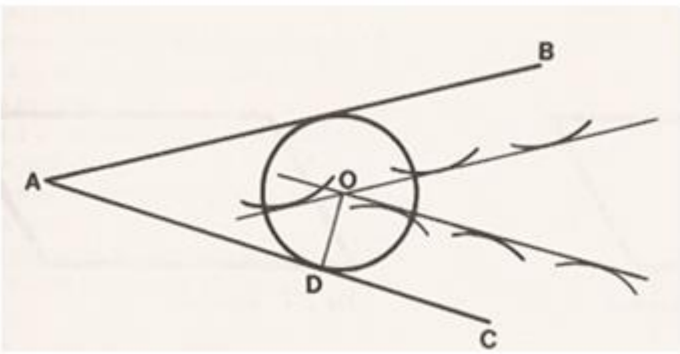
(1) To find the centre of a circle

1. Draw any two chords AB and AC
2. Bisect AB and AC. The bisecting lines intersect at O, which is the centre of the circle.



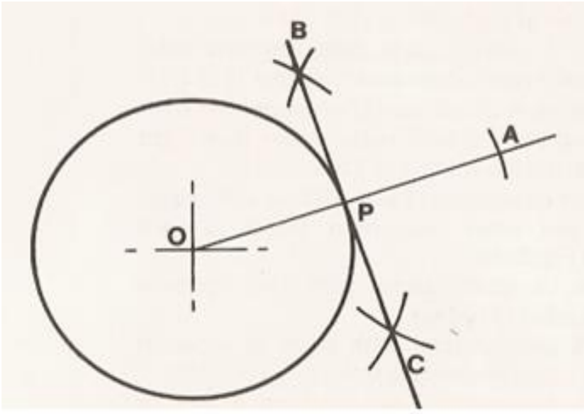
(2) To draw a circle or arc of given radius to touch two given converging lines

1. Draw given lines AB and AC
2. Draw lines parallel to AB and AC at a distance equal to radius of required circle, to intersect at O.
3. Draw a line perpendicular to AC from O (line OD).
4. With centre O and radius OD draw required arc or circle.



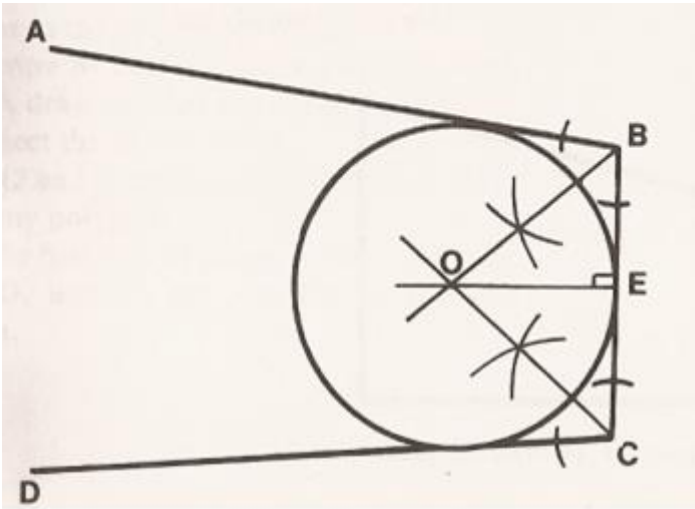
(3) To construct a tangent to a circle at a given point on the circumference

1. Draw circle with centre O. Indicate given point P
2. Draw line OP and extend beyond circle
3. With centre P and radius OP draw an arc to cut extended line at A
4. Bisect OA. Bisector BC is required tangent.



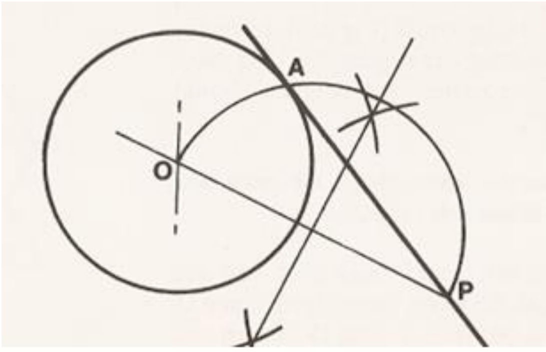
(4) To draw a circle to touch three given lines

1. Draw three given lines AB, BC, CD
2. Bisect the two angles ABC and BCD. Bisecting lines intersect at O, the centre of required circle
3. Draw a line OE perpendicular to any side from O
4. With centre O and radius OE draw required circle



(5) To construct a tangent to a circle from a given point outside

1. Draw circle with centre O. Indicate given point P
2. Draw line OP
3. Construct a semi-circle on OP to cut circle at A
4. Extend line from P through A. This is the required tangent.



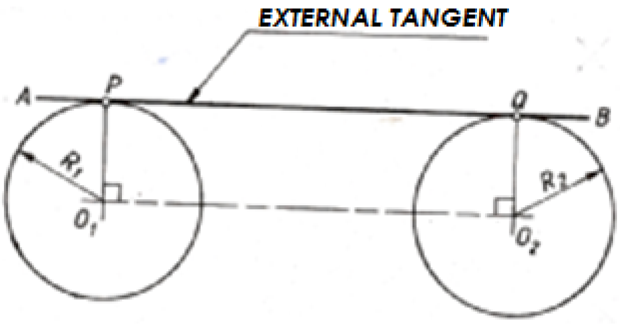
(6) To draw a line tangent to two given circles

a) External tangent

a) 1. Two circles of equal radii

Procedure:

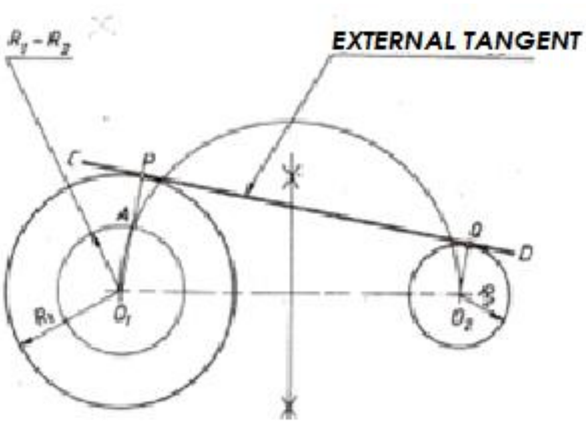
- Draw the two given circles of equal radii at the given centre distance
- O_1 and O_2 are centers of the two circles of equal radii
- Connect O_1 and O_2 and draw perpendiculars from O_1 and O_2
- These perpendiculars intersect the circles at point P and Q respectively
- Connect P and Q and extend it on either sides
- AB is the required common tangent



a) 2. Two circles of different radius

Procedure:

- O_1 and O_2 are the centers of two circle of unequal radii R_1 and R_2
- With O_1 as centre and radius (R_1-R_2), draw a circle
- With O_1O_2 as diameter, draw a semicircle to cut the circle of radius (R_1-R_2) at A
- Connect O_1A and Extend it to meet the given circle at P.
- Through O_2, draw a parallel line to O_1P to cut at Q in the given circle
- Connect PQ and extend it on either sides
- CD is the required common external tangent

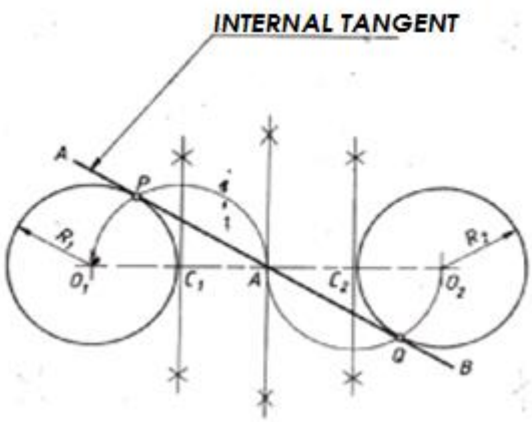


b) Internal tangent

b) 1. Two given circles of equal radii

Procedure:

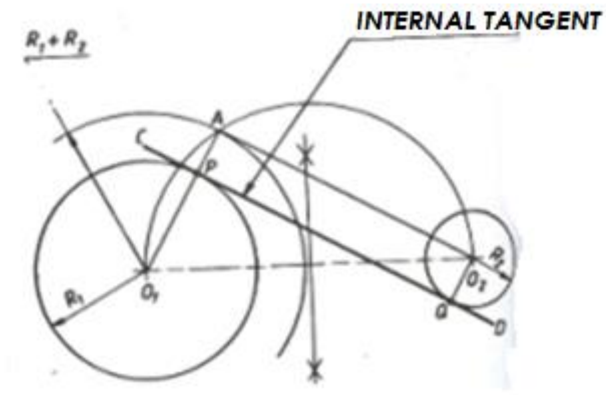
- O_1 and O_2 are the centre of the two circle of equal radii
- Connect O_1 and O_2 and bisect it at A_1
- Similarly bisect O_1A at C_1 and O_2A at C_2
- With C_1 and C_2 as centers, O_1A and O_2A as diameters, Draw two semi circles at P and Q. Connect PQ and produce (extended) it on either sides
- AB is the required common internal tangent.



b) 2. Two given circles of unequal radii

Procedure:

- O_1 and O_2 are the centre of the two circles of unequal radii R_1 and R_2
- With O_1 as centre, draw an arc of circle with radius (R_1+R_2)
- With O_1O_2 as diameter, draw a semicircle to cut the arc of circle of radius (R_1+R_2) at A.
- Connect O_1A and draw O_2Q parallel to it
- O_1A cuts the given circle of radius R_1 at P
- Connect PQ and extend it on either side
- CD is the required common internal tangent



4. Triangles

1. Terminology

A triangle is a closed geometric figure having three sides and three angles.

1. Triangle vertices are often lettered, using capitals, when the triangle may be, for example triangle ABC.

2. If sides are lettered, lower case is used, e.g. **a**, **b** and **c**.

3. The angles of triangle **ABC** are **BAC**, **ABC** and **ACB** – the middle letter being the angle where the letter is positioned.

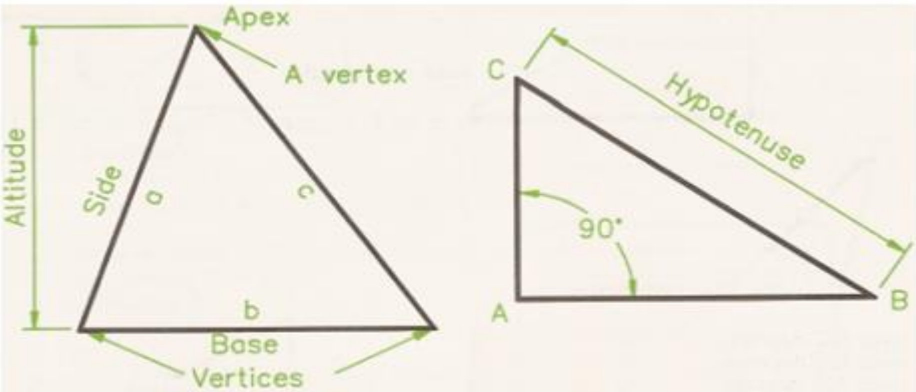
4. **The base** of a triangle is the side on which it is standing.

5. **The altitude** is the vertical height above the base.

6. The term **hypotenuse** is only used with reference to right - angle triangles.

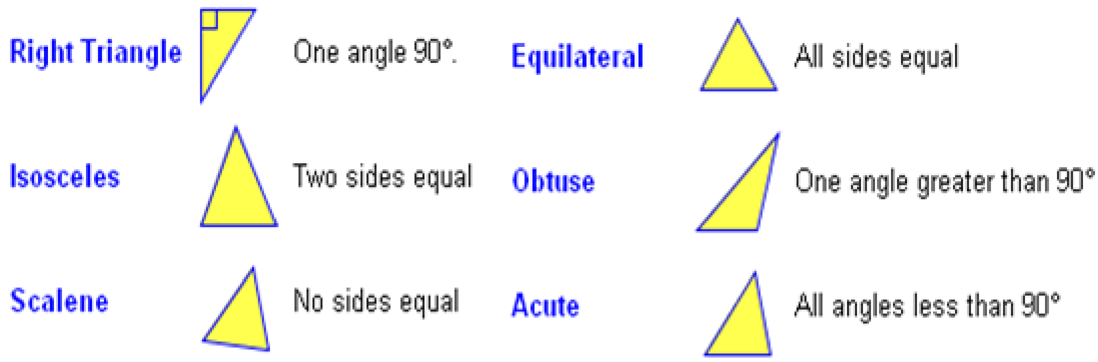
7. The **vertical angle** is the angle opposite the base.

8. Note the term vertex. Its plural is vertices.



2. Types of triangle

Triangles are classified into the following groups, depending on various properties. Note that a given triangle can be in more that one group. For example, it could be both a right triangle and a scalene triangle at the same time.



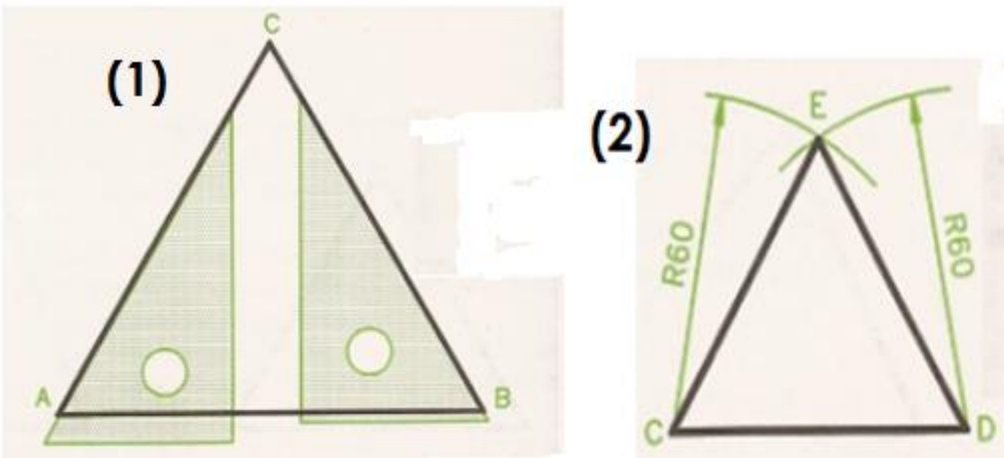
3. Construction of triangles

(i) Constructing an equilateral triangle

There are two methods to construct an equilateral triangle

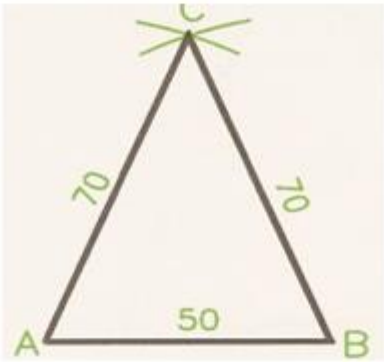
(1) With the aid of a 30, 60 set square, using the 60 degree angle. Start by drawing the base, AB, then draw lines, meeting at C, at 60 degrees from each end of the base with the aid of the set square.

(2) Strike off compass arcs with the compass set to the length of the side. The side length of the equilateral triangle is 60 mm. Start by drawing the base a line 60 mm long; then set a compass to 60 mm and strike arcs from each end of the base; draw lines from the ends of the base to the intersection of the two arcs.



(ii) To construct triangle ABC

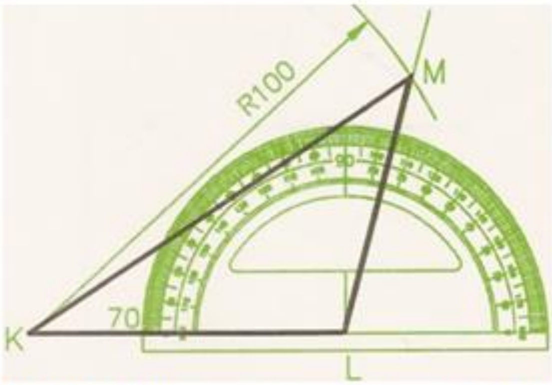
1. Draw the base AB, 50 mm long. Set a compass to 70 mm.
2. With the compass centred first at A, then at B strike intersecting arcs to give C.
3. Join AC and BC to complete the triangle.



Note: Triangle ABC is isoscele.

(iii) To construct triangle KLM

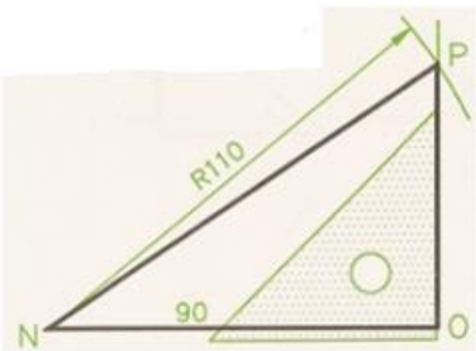
1. Draw KL 70 mm long.
2. With the aid of a protractor construct a 105 degree angle at L, and draw a line from L at that angle.
3. Set a compass to 100 mm. With the compass centred at K strike an arc across the arm of the line at 105 degrees from L, to give M.
4. Join LM to complete the triangle.



Note: KLM is a scalene triangle, which is obtuse.

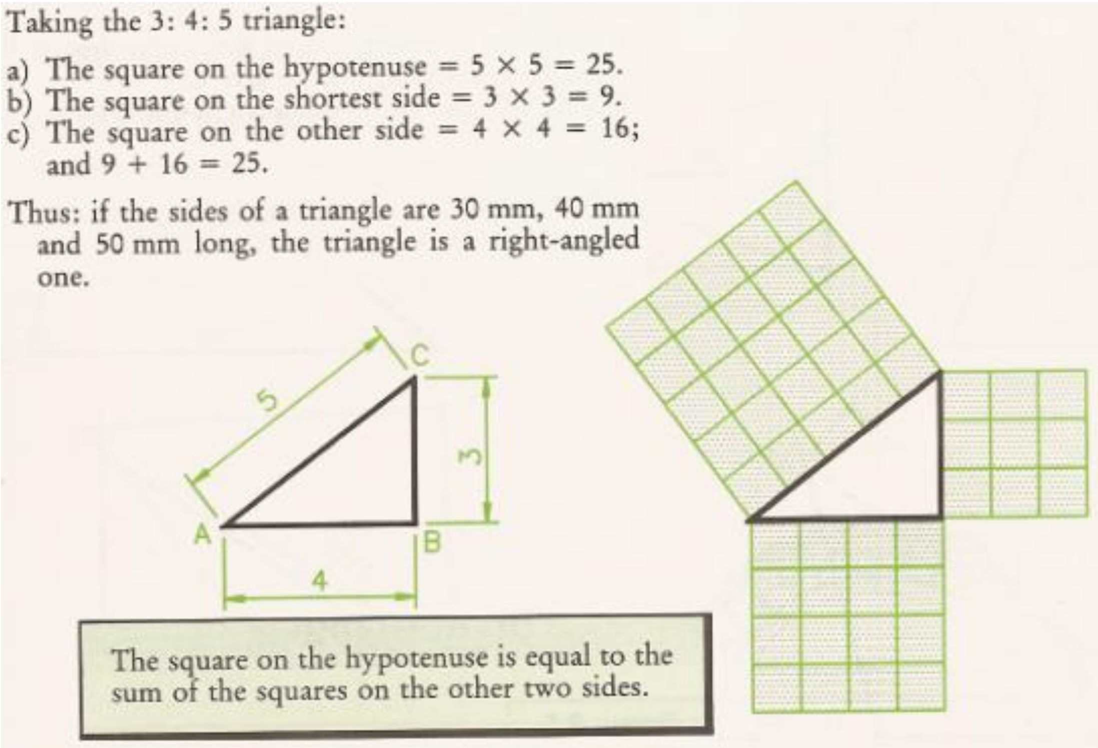
(iv) To construct triangle NOP

1. Draw NO 90 mm long.
2. Draw the angle NOP with a set square.
3. Set a compass to 110 mm. With the compass centred at N strike an arc across the 90 degree line from O to give P.
4. Join NP to complete the triangle.



Note: Triangle NOP is a right - angle triangle

(v) Note on right angle triangle


Taking the 3: 4: 5 triangle:

a) The square on the hypotenuse = 5 × 5 = 25.
b) The square on the shortest side = 3 × 3 = 9.
c) The square on the other side = 4 × 4 = 16; and 9 + 16 = 25.

Thus: if the sides of a triangle are 30 mm, 40 mm and 50 mm long, the triangle is a right-angled one.

The square on the hypotenuse is equal to the sum of the squares on the other two sides.

.5. Polygons

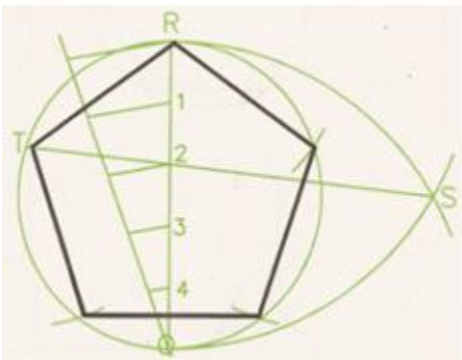
1. Definition

A polygon is a figure with more than four sides. According to the number of sides, a polygon has, it may be termed a pentagon (5 sides), hexagon (6), heptagon (7), Octagon (8), nonagon (9) or Decagon (10).

Regular polygons have sides of equal lengths with all included angle equal.

2. To construct a regular polygon within a circle

1. Draw a circle of 80 mm diameter
2. Draw the vertical diameter QR and divide it into 5 equal parts
3. Draw arcs radius RQ from R and Q to meet at S
4. Draw ST through point 2 on RQ
5. RT is the side of the required regular pentagon



3. To draw a regular polygon given the length of one side

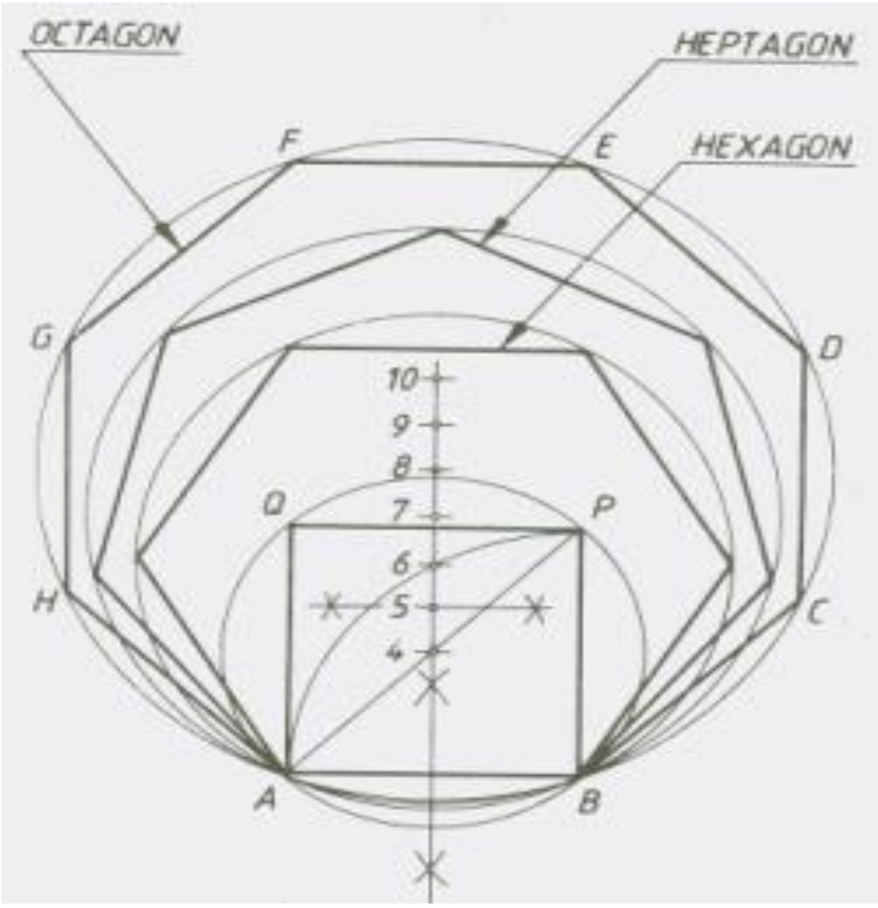
Method 1:

- Draw line AB equal in length to one of the side of polygon
- Bisect AB
- From B draw an angle of 45^0 to intersect the bisector at point 4
- From B, draw an angle of 60^0 to intersect bisector at 6.
- Bisect between 4 and 6 to give point 5
- Use a compass width equal to 5, 6 to find Point 7, 8, 9 and 10.

Note: Point 4 is the centre of the circle, radius 4A, containing a square

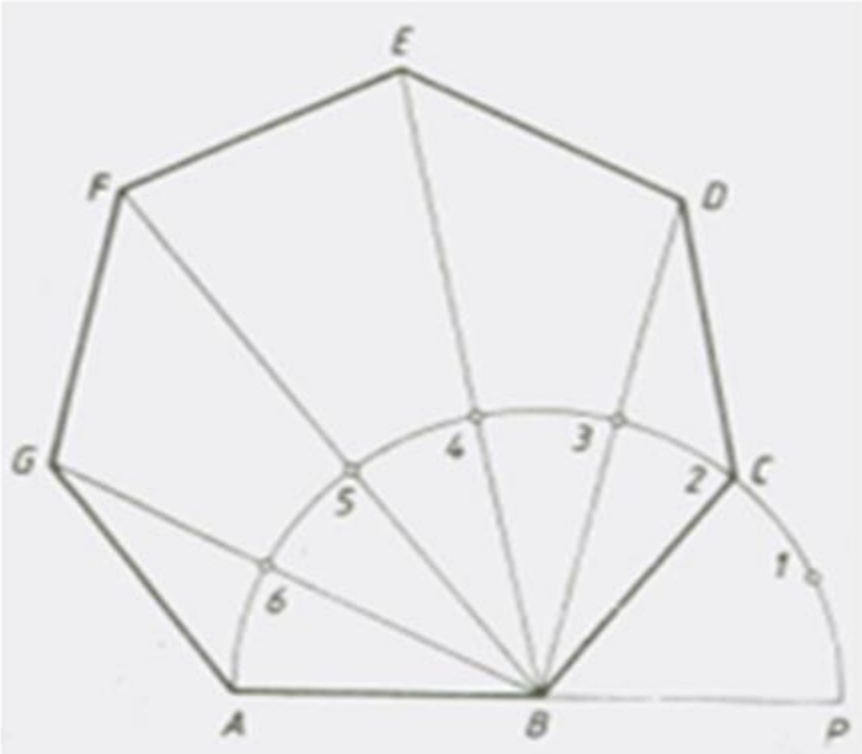
a. Point 5 is the centre of circle, radius 5A, containing a pentagon
b. Point 6 is the centre of circle, radius 6A, containing a hexagon

- To draw a hexagon, mark off point 6 as described below.
- With centre at point 6, draw a circle radius 6A
- Draw the remaining sides of the polygon by putting the length=AB on the circumference of circle.



Method 2:

AB is the given side. It is required to draw a regular polygon, for example, say a **heptagon**. Produce AB to P such that AB=BP. With B as centre and radius AB draw a semicircle. Divide the semicircle by trial and error into number of equal arcs, equal to the number of sides of the polygon, in this case, divide into seven equal parts and number the division points as 1, 2, 3, ect. Connect B to the division points 2, 3, 4, 5 and 6 and produce. Always the line connecting the second division point and B represents the second side of the polygon, i.e BC. With C as centre and radius equal to AB, cut B3 produced at D. Now with D as centre and with the same radius cut B4 produced at E. Similarly find the other points and by connecting them complete the required polygon.



6. Conic sections

1. Definition

A cone is a surface generated by the rotation of a straight line whose one end is in contact with a fixed point while the other end is in contact with a closed curve, not lying in the plane of the curve. **A right circular cone** is a cone having its axis perpendicular to its base.

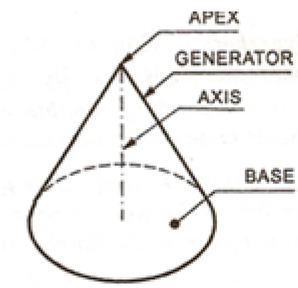
Apex or **vertex** is the top point of the cone.

Axis is imaginary line joining apex & centre of base.

Generator is the straight line which is generating the surface of the cone.

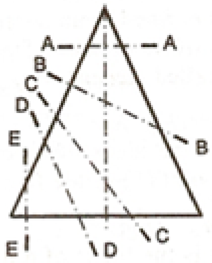
Base of the cone is the closed curve.

See the following figure:



A right circular cone can be cut by section (cutting) planes in different positions relative to the axis of the cone to obtain cut sections of different shapes, namely, circle, ellipse, parabola, hyperbola and rectangular hyperbola. These cut sections seen on the cone are called **conic sections or simply conics.**

In the following figure the cutting plane is shown in different positions, viz., AA, BB, CC, DD and EE.



2. Several shapes form conic section

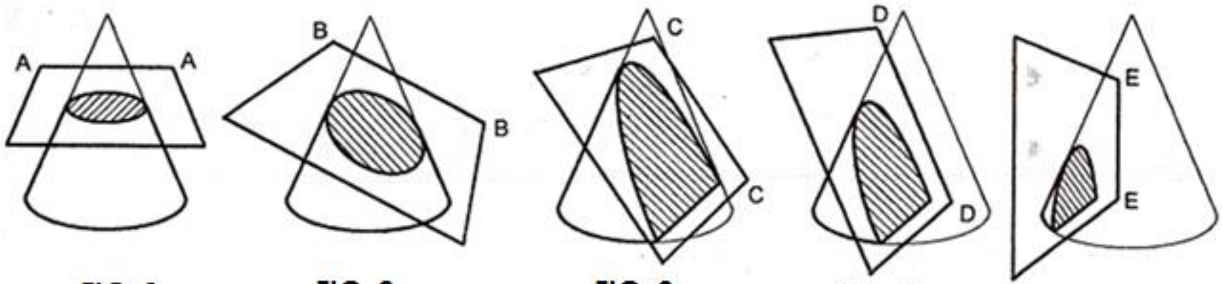


FIG. 1 CIRCLE

FIG. 2 ELLIPSE

FIG. 3 PARABOLA

FIG. 4 HYPERBOLA

FIG. 5 RECTANGULAR HYPEBOLA

Circle: Fig. 1) When the cutting plane AA is perpendicular to the axis and cuts all the generators, the section obtain is a circle.

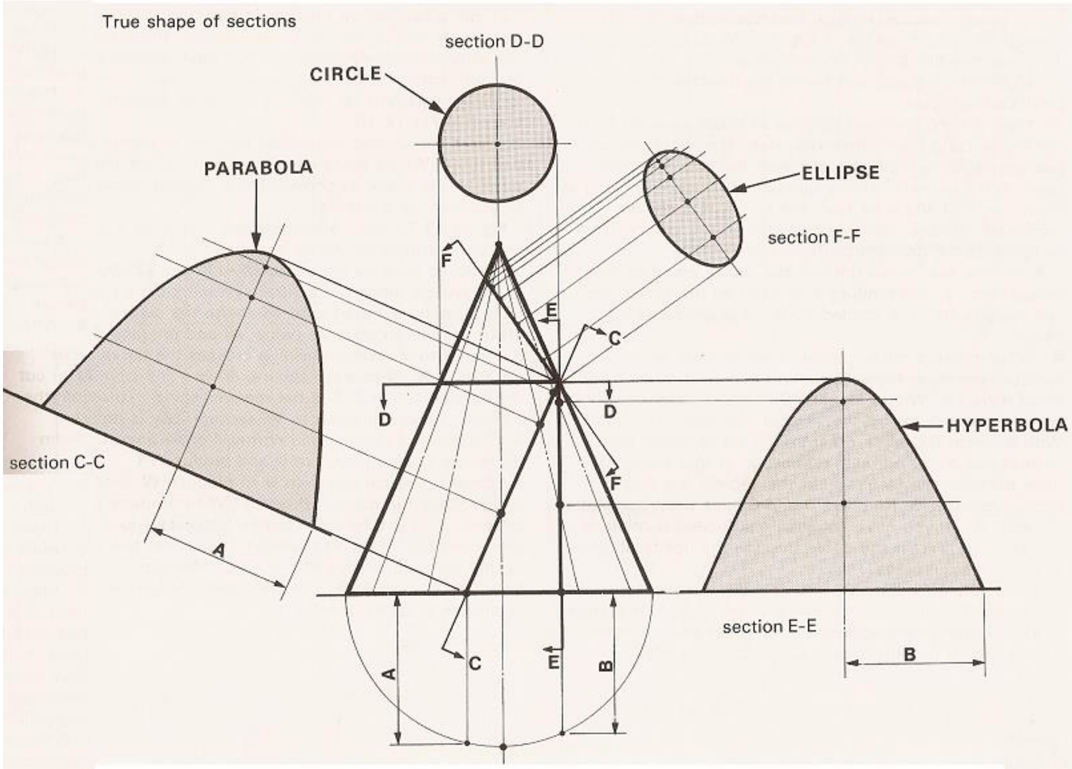
Ellipse: (Fig. 2) When the cutting plane BB is inclined to the axis of the cone and cuts all the generators on one side of the apex, the section obtained is an ellipse. Only when the cutting plane cuts all the generators of the cone, the elliptical section formed is a closed one.

Parabola: (Fig.3) When the cutting plane CC is inclined to the axis of the cone and parallel to one of the generator, the section obtained is a parabola.

Hyperbola: (Fig.4) When the cutting plane DD makes a smaller angle with the axis than that of the angle made by the generator of the cone, the section obtained is a hyperbola.

Rectangular hyperbola *or* ***equilateral hyperbola:*** (Fig. 5) When the cutting plane EE is parallel to the axis of cone, but does not pass through the apex, one of the generator, the section obtained is a Rectangular or Equilateral hyperbola.

Refer to this figure for more understanding



2. Procedure for drawing an ellipse

1. Focal method:

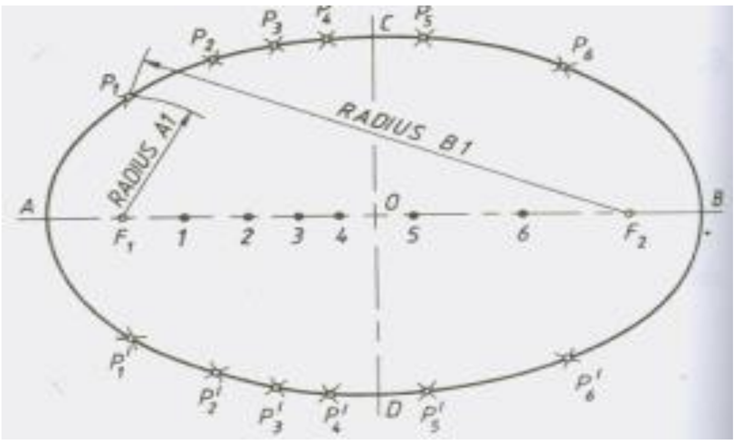
- ✓ Set out the major axis AB and minor axis CD
- ✓ To find the focal point, draw an arc equal to the semi major axis at F_1 and F_2. These are the focal axis point (As $CF_1+CF_2=AB$, thus satisfying the definition of an ellipse).
- ✓ Other point on the ellipse, such as P_1, may be found by drawing arcs from F_1 and F_2, such that the sum of the radii of the arcs is equal to AB (for example radius A_1+ radius B_1= AB). The intersection of the arcs is a point on the ellipse.

Required equation

$x^2/a^2+ y^2/b^2=1$, $a^2=c^2+b^2$, $b^2=a^2-c^2$, $c^2=a^2-b^2$

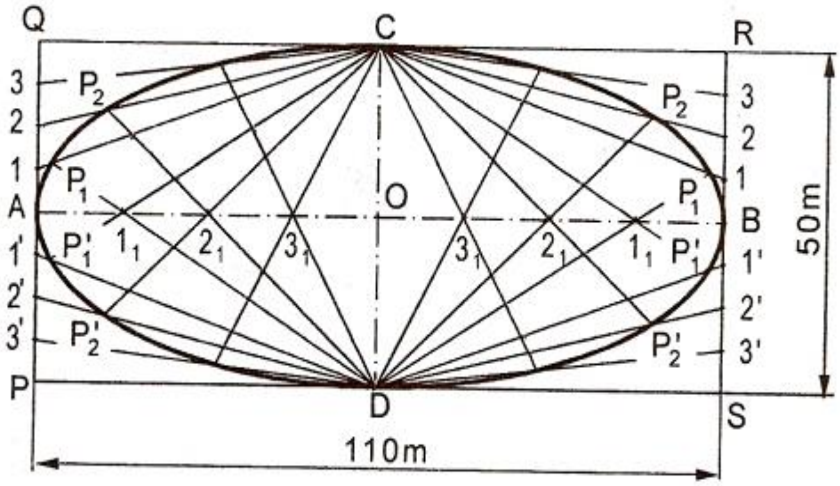
With: AB= major axis (2a distance), CD= minor axis (2b distance),

F_1F_2= focal point (2c distance).



2. Rectangular method:

A plot of ground is in the shape of a rectangle 110 m x 50 m. Inscribe an elliptical lawn in it. Take a suitable scale.



ELLIPSE - RECTANGLE or OBLONG METHOD

1. Select scale 1 : 1000.
2. Draw major axis AB = 110 mm and minor axis CD = 50 mm. Both bisect at O.
3. Through A and B draw lines parallel to CD.
4. Through C and D draw lines parallel to AB and construct the rectangle PQRS. Now PS = AB and SR = CD.
5. Divide AQ and AP into any number of equal parts (*say 4*) and name the points as 1, 2, 3 and 1′, 2′, 3′ respectively starting from A on AQ and AP.
6. Divide AO into same (4) number of equal parts, and name the points as 1_1, 2_1, 3_1 starting from A on AO.
7. Join 1, 2, 3 with C.
8. Join $D1_1$ and extend it to intersect C1 at P_1.
9. Similarly extend $D2_1$ and $D3_1$ to intersect C2 and C3 at P_2 and P_3 respectively.
10. Join 1′, 2′, 3′ with D.
11. Join $C1_1$ and extend it to intersect D1′ at P_1'.
12. Similarly extend $C2_1$ & $C3_1$ to intersect D2′ & D3′ at P_2' & P_3' respectively.
13. Draw a smooth curve through C, P_3, P_2, P_1, A, P_1', P_2', P_3', D and obtain *one half* (*left-half*) of the ellipse.
14. Repeat the above and *draw the right-half of ellipse, symmetrical to the left-half.*

3. Concentric Circles Method:

1. Draw the major and minor axes AB and CD and locate the centre O.

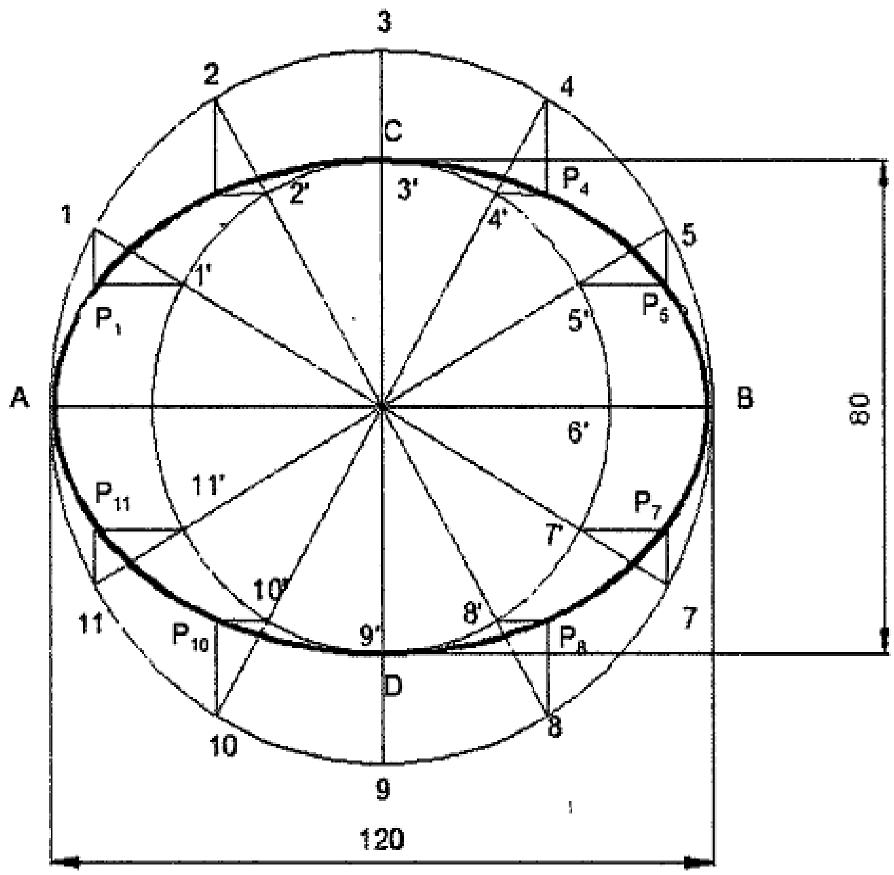
2. With centre O and major axis and minor axes as diameters, draw two concentric circles.

3. Divide both the circles into equal number of parts, say 12 and draw the radial lines.

4. Considering the radial line 0-1' -1, draw a horizontal line from 1' to meet the vertical line from 1 at P_1.

5. Repeat the steps 4 and obtain other points P_2, P_3, etc.

6. Join the points by a smooth curve forming the required ellipse.



7. Involutes and cycloid

1. Involutes

Involutes

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

Application

Involute is employed in the design of geartooth of gear wheels used for general purpose applications as it is easy to manufacture and offers smooth working. The surfaces of the gear teeth are machined to involute shape as shown in *Fig. 6.35*. The casings of centrifugal pumps are designed to involute shape to reduce the loss of impact and to increase the pressure of the discharging fluid.

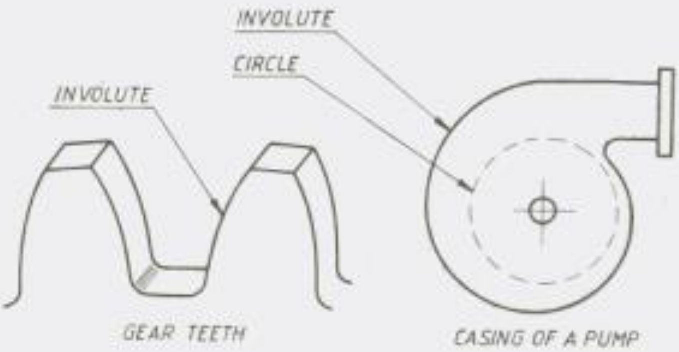


Fig. 6.35 Application of Involute

1. Involute of a Line

Problem

Draw the involute of a line of 15mm for 5 turns.

Solution: *Fig. 6.36*

AB is the given line. With centre *B* and radius $AB = R_1$, draw a semicircle. Now with centre *A* and radius $AC = R_2$ draw the semicircle *CD*. With centre *B* and radius $BD = R_3$ draw the semicircle *DE*. With centre *A* and radius $AE = R_4$

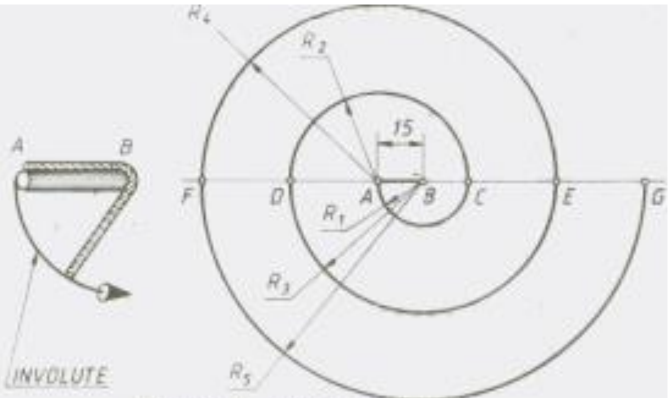


Fig. 6.36 Involute of a Line

draw a semicircle *EF*. Similarly continue with centres *A* and *B* alternately till the required number of turns are obtaned.

2. Involute of a Triangle

Problem

Draw the involute of an equilateral triangle of 15 mm side.

Solution: *Fig. 6.37*

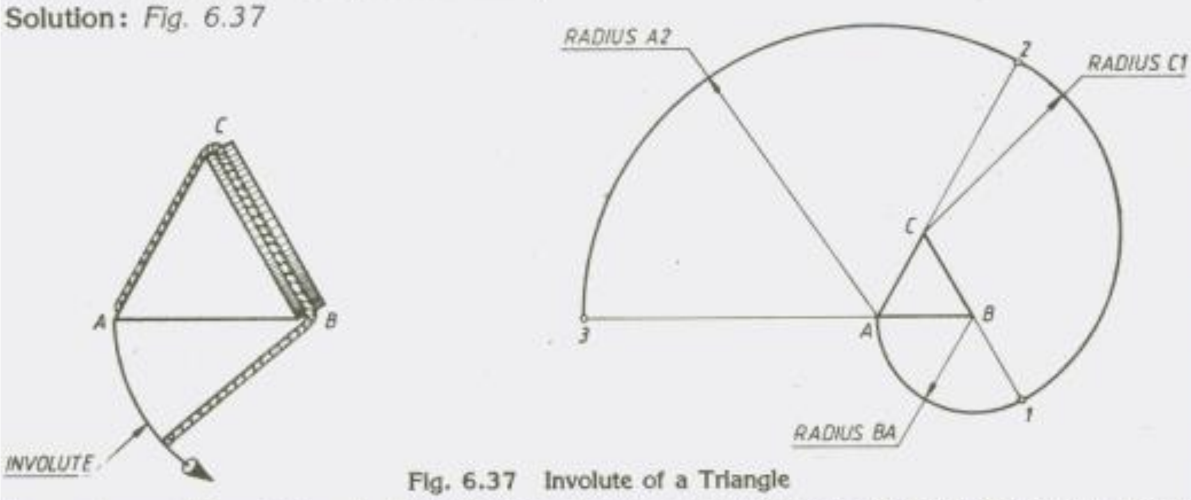


Fig. 6.37 Involute of a Triangle

Draw the equilateral triangle *ABC*. Produce the lines *BA*, *CB* and *AC*. With the centre *B* and radius *BA* draw an arc to intersect *CB* produced at *1*. Now with the centre *C* and radius *C1* draw an arc to intersect *AC* produced at *2*. Lastly with the centre *A* and radius *A2*, draw an arc to intersect *BA* produced at *3* and complete the curve.

3. Involute of a Polygon

Problem

Draw the involute of a pentagon of 20 mm side.

Solution: *Fig. 6.38*

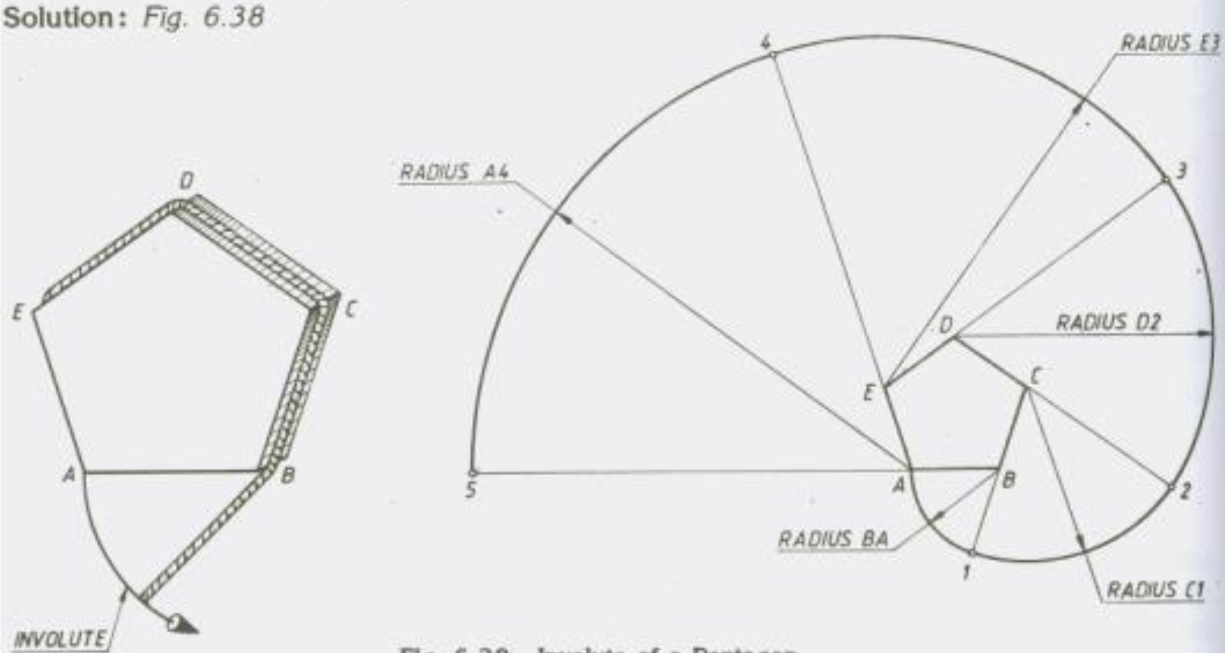


Fig. 6.38 Involute of a Pentagon

Draw the given polygon, say a *pentagon*. Produce the sides *BA*, *CB*, *DC*, *ED* and *AE*. With the centre at *B* and radius *BA* draw an arc to intersect *CB* produced at *1*.

Now with the centre at *C* and radius *C1*, draw an arc to intersect *DC* produced at *2*. Similarly, with the centres *D*, *E* and *A*, and radii *D2*, *E3*, *A4* draw arcs and complete the curve. This procedure is to be followed to draw the involute of any other required polygon.

4. *Involute of a Circle*

Problem

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

Solution: *Fig. 6.39*

Draw the given circle. Divide the circle into twelve equal divisions. Draw tangents at all the division points. Measure *PQ* equal to the circumference of the circle and divide it into twelve equal parts. On the tangent drawn at point *1*, step off $1P_1 = P1_1$. Similarly obtain the points P_2, P_3,.*P4*. etc., and draw a smooth curve passing through these points.

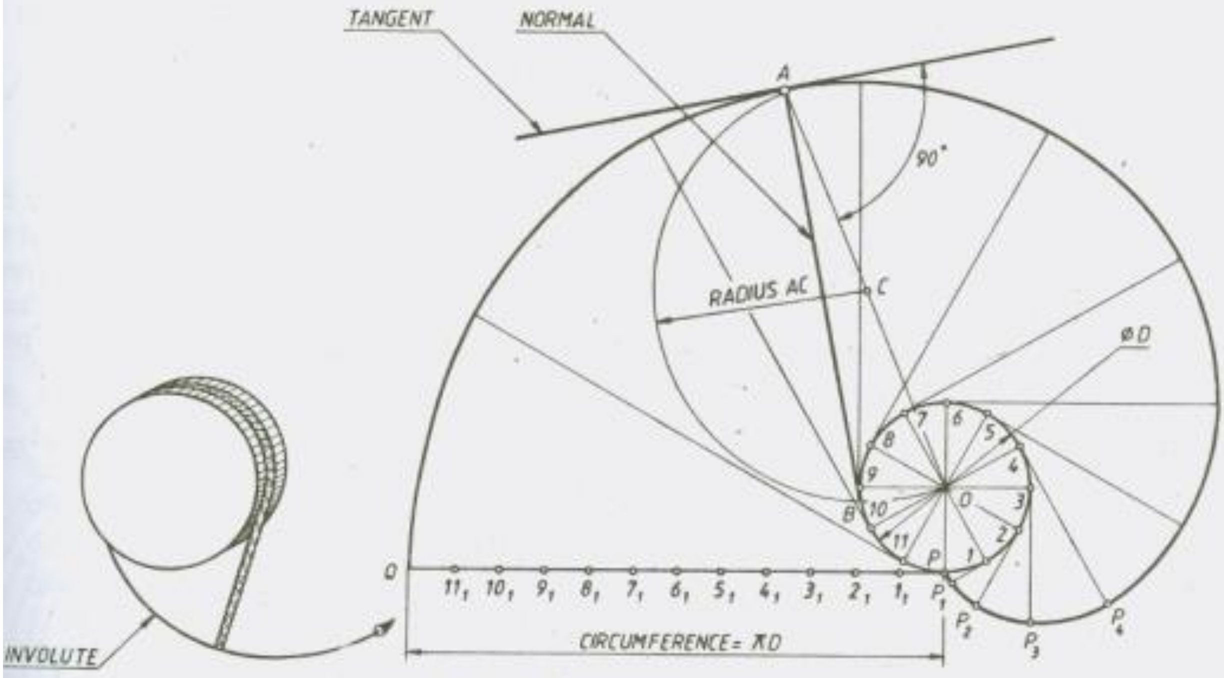


Fig. 6.39 Involute of a circle

Tangent and Normal to the Involute

Mark the point *A* at which the tangent is to be drawn. Connect *AO* and mark the point *C* as the mid point of *AO*. With centre *C* and radius *AC*, describe a semicircle which cuts the circle with centre *O* at *B*. Connect *AB*, the normal and draw the tangent perpendicular to it and passing through the point *A*.

2. Cycloidal curves

Cycloidal Curves

Cycloidal curves are formed by a point on the circumference of a circle, rolling upon a line or an another circle. The rolling circle is called the generating circle. The line on which the generating circle rolls is called *base line*. The circle on which the generating circle rolls is called *directing or base circle.*

A cycloid is a curve traced by a point on the circumference of a circle which rolls without slipping along a line.

Application

Cycloidal curves were used for gear teeth profiles. These are superseded by the involute gears which are easier to cut. However cyclodial teeth gears are used for small gears. The cycloidal curve is used for both the faces and flanks of the cycloidal rack teeth as shown in *Fig. 6.45*.

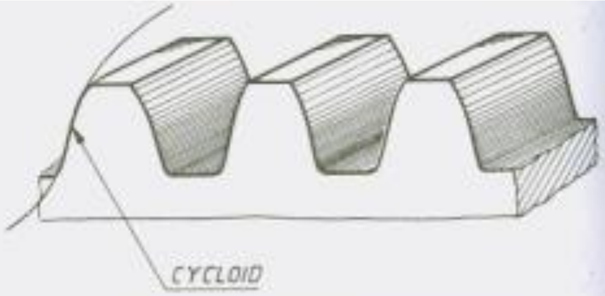


Fig. 6.45 Application of Cycloid

Problem

A circle of 50 mm diameter rolls along a line. A point on the circumference of the circle is in contact with the line in the beginning and after one complete revolution. Draw the cycloidal path of the point. Draw a tangent and normal at any point on the curve.

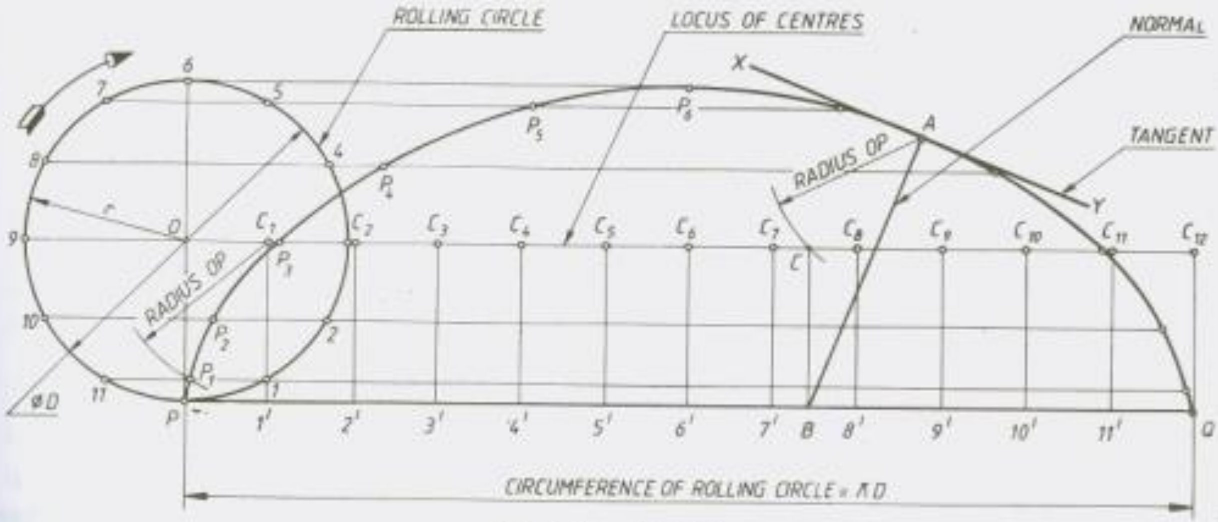


Fig. 6.46 Cycloid

Divide *PQ* also into the *same* number of equal parts at the division points *1′, 2′, 3′*, etc. At *1′, 2′, 3′*, etc., draw lines perpendicular to *PQ* to intersect the horizontal line drawn through *O*, called the *locus of centres* respectively at C_1, C_2, C_3, etc.

When the rolling circle rolls forward in the *clockwise* direction by 1/12th of a revolution, the division point *1* on the rolling circle will come in cotanct with *1′* and the centre of the rolling circle moves forward to the new position C_1 which is vertically above *1′*. Since the point *1* is in contact with the line at *1′*, the generating point *P* will have moved in the *clockwise* direction to the level of the point *1*, in the original position before rotation, and also it will be at a distance $r = OP$ from the new centre C_1. Therefore with the centre C_1, and radius $r = OP$, the radius of the rolling circle, cut the horizontal line drawn through the point *1* at P_1. Similarly, obtain P_2, P_3, etc. Passing through the points *P*, P_1, P_2, P_3, P_4, etc., draw a smooth curve.

To draw a Tangent and Normal

Let *A* be the point on the curve at which the tangent and normal are to be drawn. With centre *A* and radius $r = OP$, cut the line of the locus of centres at *C*. From *C*, draw a perpendicular to *PQ* to get the point *B*. Connect *AB*, which will be the normal. At *A*, draw a line *XY* perpendicular to *AB* to get the required tangent.

8. Solids

1. Definition

A solid is normally a sample of matter that retains its shape when not confined. In engineering drawing a solid is an object having three dimensions which are the length, breadth and height or thickness. It is bounded by planes faces or curved surfaces or a combination of both.

2. Types of solids

When the axis of a solid is perpendicular to its base, it is a "*right solid*". If all edges of the base of a right solid are of equal length is known as a "*right regular solid*", otherwise "*irregular solid*". Solids are classified into two main groups: Polyhedron and Solids of Revolution. When these two are cut in a certain way, they give what is known as Frustums and Truncated Solids.

- Polyhedron

A polyhedron is solid which is bounded by plane surfaces.

Faces: The regular plane surfaces which form the surfaces of a polyhedron are called faces.

Edges: The lines along which two plane faces or surfaces meet are called Edges of the solid.

1. TETRAHEDRON

See Fig. 1(i).

A tetrahedron has *four* equal equilateral triangular ***Faces***: ABC, OAB, OBC and OCA.

Six ***Edges:*** AB, BC, CA, OA, OB and OC.

O – ***Apex***

2. CUBE

See Fig. 1(ii).

A cube has *six* equal regular squares.

3. OCTAHEDRON

See Fig. 1(iii).

An octahedron has eight equal equilateral triangular ***Faces***, *viz.*, AO_1B, BO_1C, CO_1D, DO_1A, AO_2B, BO_2C, CO_2D and DO_2A.

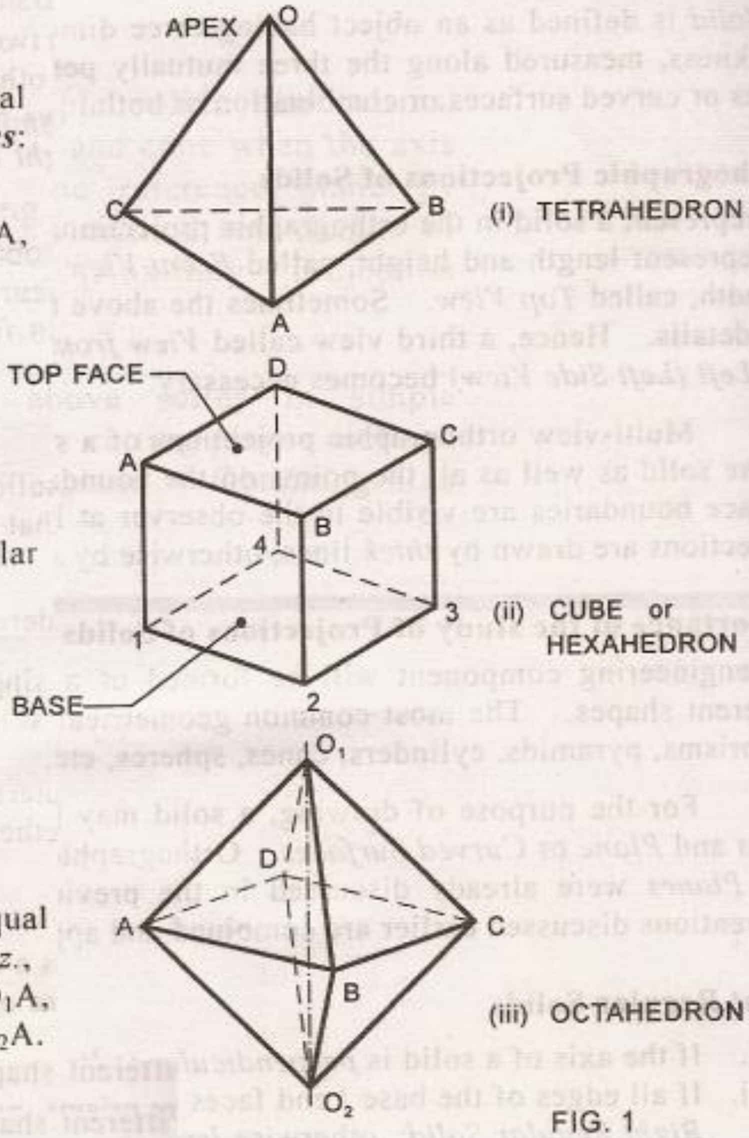


FIG. 1

4. PRISMS

A *Prism* is a polyhedron having two equal and similar faces (called top face and bottom base), parallel to each other and joined by other faces which may be *Rectangles* or *Parallelograms*.

Axis: The imaginary line joining the centers of the faces is called the *Axis*.

NOTE : ***A prism is said to be a right regular prism when its axis is perpendicular to its base and all its faces (i.e., lateral surfaces) are equal rectangles.***

Types of Regular Prisms

See Fig. 2.

Prism is named according to the shape of its base as :

Triangular,
Square, Rectangular,
Pentagonal,
Hexagonal, etc.

Nomenclatures of a prism

Axis,
Top face,
Bottom face (Base),
Rectangular faces and
Longer edges.

These are clearly indicated in *Fig. 2.*

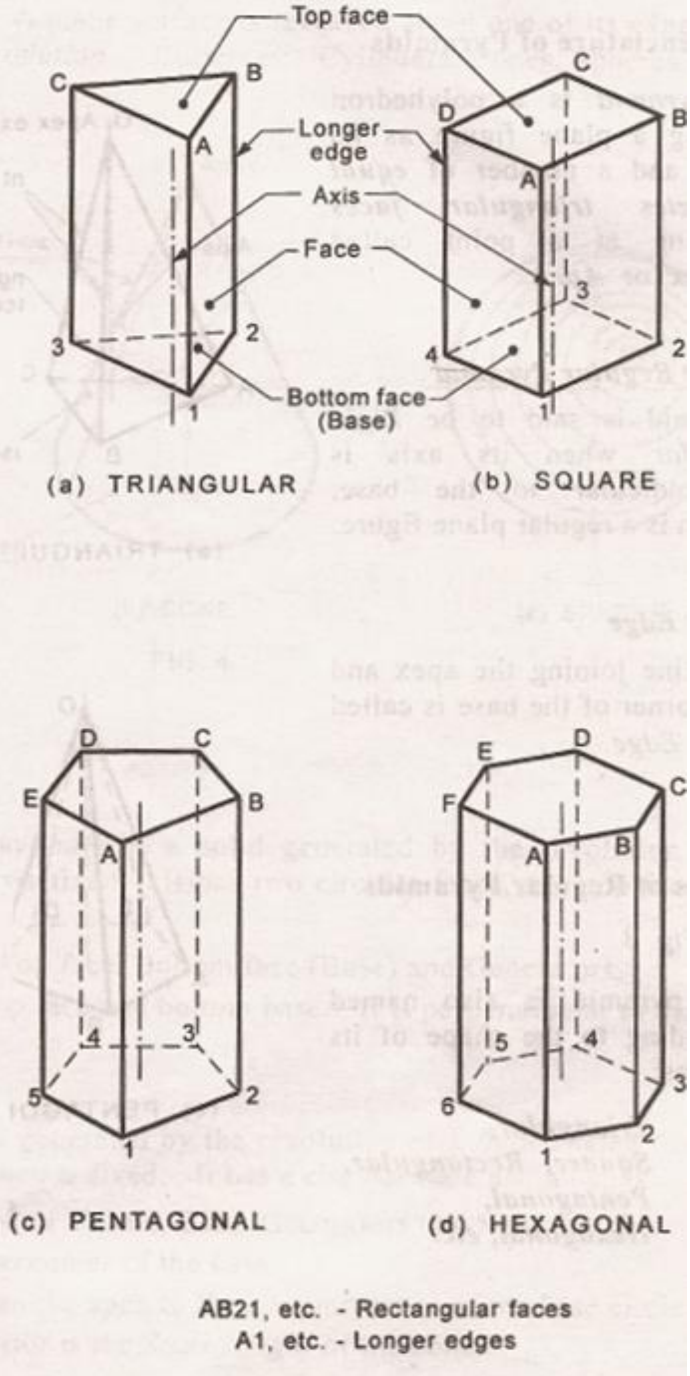


FIG. 2 PRISMS

5. PYRAMIDS

Nomenclature of Pyramids

A *Pyramid* is a polyhedron having a plane figure as its ***base*** and a number of ***equal isosceles triangular faces*** meeting at a point called ***Vertex*** or ***Apex***.

Right Regular Pyramid

Pyramid is said to be *Right Regular* when its axis is perpendicular to the base, which is a regular plane figure.

Slant Edge

The line joining the apex and the corner of the base is called *Slant Edge*.

Types of Regular Pyramids

See Fig. 3.

The pyramid is also named according to the shape of its base as:

Triangular,
Square, Rectangular,
Pentagonal,
Hexagonal, etc.

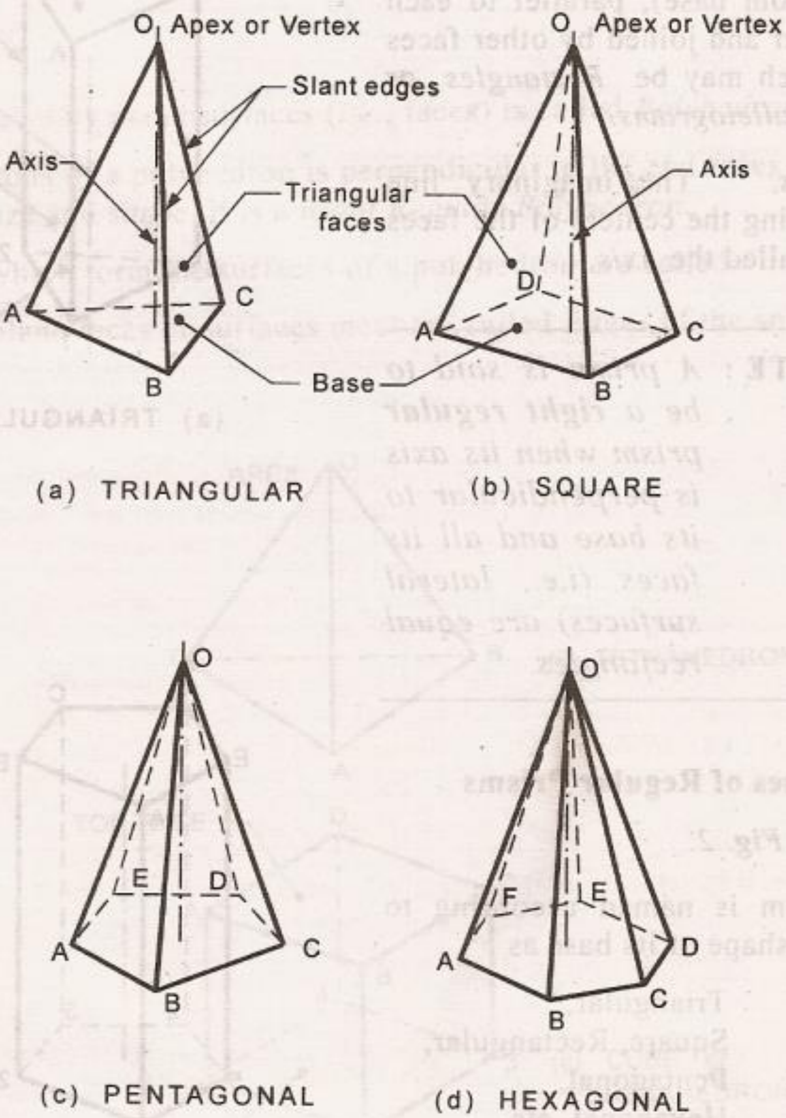


FIG. 3 PYRAMIDS

- Solids of Revolution

These are obtained by revolving a plane surface about one of its edges.

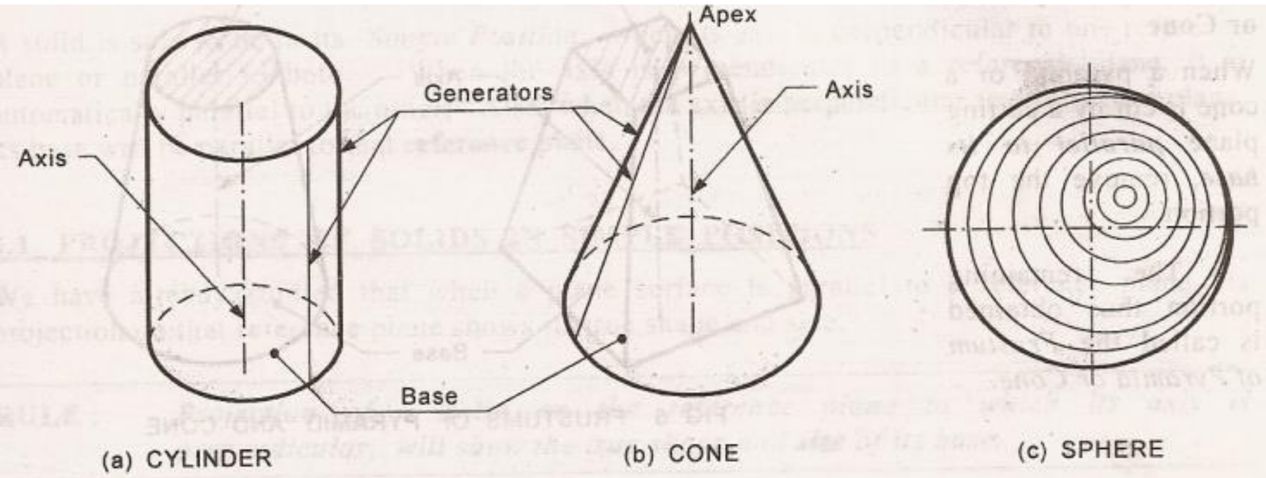


FIG. 4

1. CYLINDER

See Fig. 4(a). A *Right Circular Cylinder* is a solid generated by the revolution of a rectangle about one of its sides which is fixed. It has two circular faces, *i.e.*, top face and bottom base.

Nomenclatures of a Cylinder: Axis, Top face, Bottom face (Base) and Generators.

Axis is the line joining the centers of top face and bottom base. It is perpendicular to base.

2. CONE

See Fig. 4(b). A *Right Cone* is a solid generated by the revolution of a right-angled triangle about one of its perpendicular sides which is fixed. It has a circular base and an apex.

Nomenclatures of a cone: Axis, Apex or Vertex, Base, Generators and Slant Height.

Axis is the line joining the apex with the center of the base.

Generators are straight lines drawn from the apex to the circumference of the base circle.

Slant Height: The length of the generator is the *Slant Height* of the cone.

3. SPHERE

See Fig. 4(c). A *Sphere* is a solid generated by the revolution of a semi-circle about its diameter as its axis. The mid-point of the diameter is the center of the sphere. All points on the surface of the sphere are at equal distance from its center.

- Frustums and Truncated Solids

1. FRUSTUMS

See Fig. 5.

Frustums of Pyramid or Cone

When a pyramid or a cone is cut by a cutting plane ***parallel to its base***, remove the top portion.

The remaining portion thus obtained is called the *Frustum of Pyramid or Cone*.

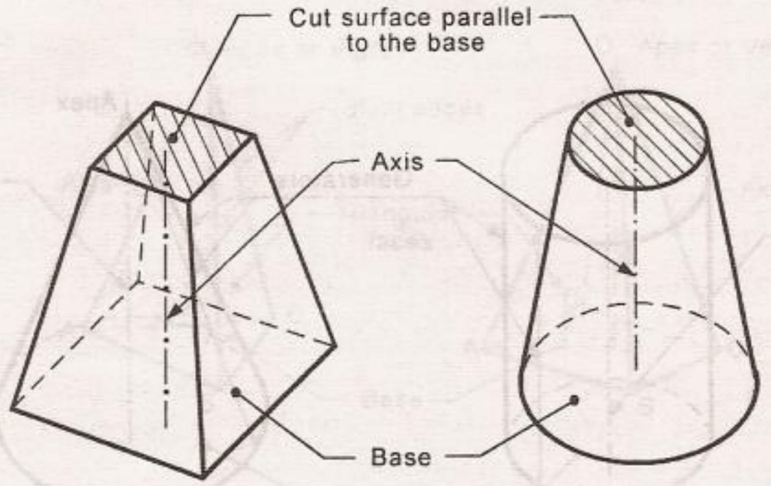


FIG. 5 FRUSTUMS OF PYRAMID AND CONE

2. TRUNCATED SOLIDS

See Fig. 6.

When a solid (prism / cylinder / pyramid / cone) is cut by a cutting plane ***inclined to its base*** (not parallel), remove the top portion.

The remaining portion thus obtained is called the *Truncated Solid*.

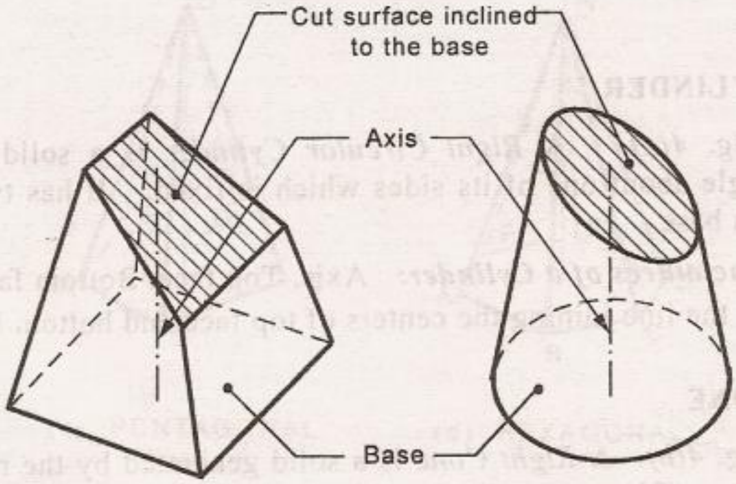


FIG. 6 TRUNCATED PYRAMID AND CONE

❖ Apply projections

.1. Introduction

Engineering drawing is the universal graphic language by means of which the shape and size of an object can be specified on plane of paper.

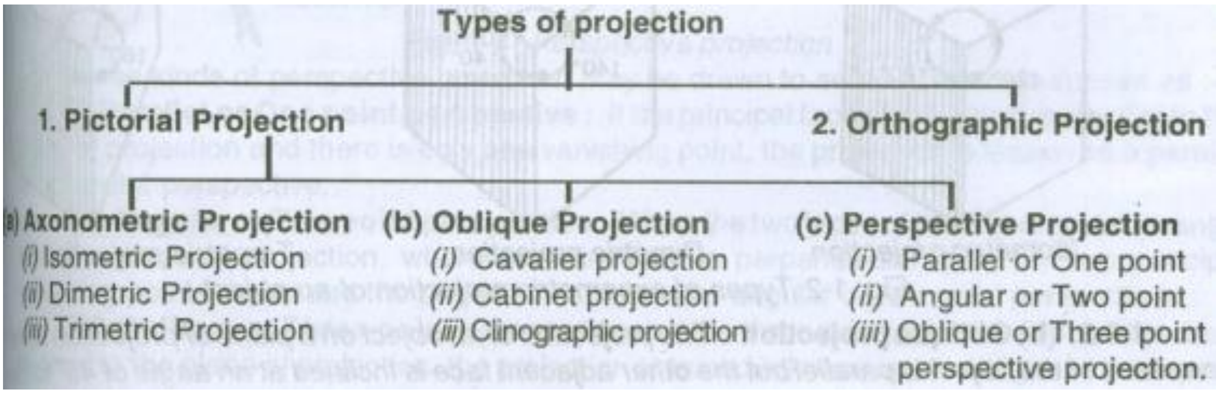
In order to represent the true shape and size of the object, different straight lines are drawn from the various points on the contour of the object on the plane of paper

2. Definition of projection

Any kind of representation of an object on a paper, screen or similar surface by drawing or by photography is called the projection of that object.

.3. Types of projection

In engineering practice, the followings are the common types of projections:



1. Pictorial projection

The projection in which the length, breadth and height of an object are shown in one view is known as pictorial projection. This type of projection has the advantage of conveying an immediate impression of the general shape of the object, but does not necessarily show the exact dimensions.

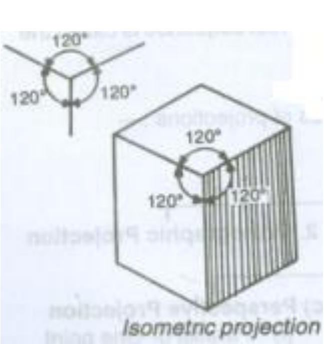
The pictorial projection is: axonometric projection, oblique projection and perspective projections.

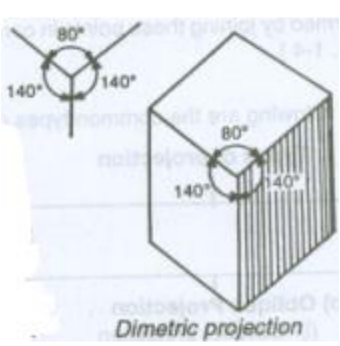
a) Axonometric projection

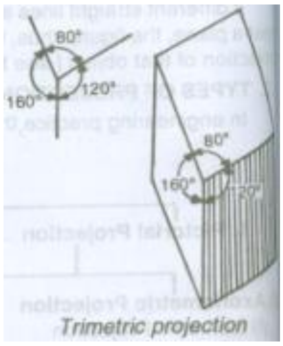
If the object is turned and then tilted so as that three faces are inclined to the plane of projection, the resulting projection is a special type of orthographic projection known as axonometric projection. Note that the projectors from the plane to the object are perpendicular to the plane. This axonometric or pictorial view shows three of the object's sides in one projection and therefore is called a one plane projection.

There are three subdivisions of axonometric projection:

1. **Isometric:** Three sides of the object are shown on one projection plane and are equally inclined.
2. **Dimetric:** Three sides of the object are shown on one projection plane and two of the three sides are equally inclined
3. **Trimetric:** Three sides of the object are shown on one projection plane and are inclined differently.







b) Oblique projection

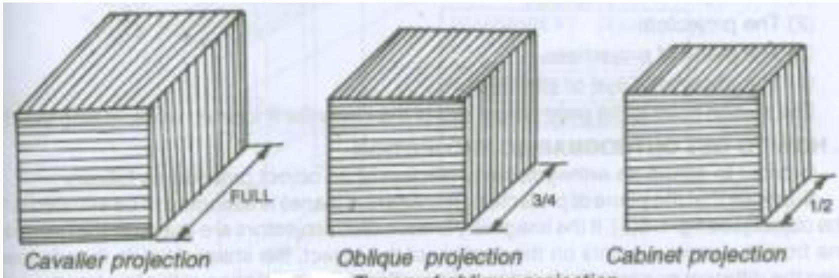
Another form of one plane projection is the oblique projection. This is not an orthographic projection because, although one face is imagined to be parallel to the plane of projection, the projectors are not perpendicular to it. Oblique projection provides an easy way of turning an existing orthographic view into a pictorial view.

The oblique projection is further discussed as under:

i) **Cavalier projection:** when the projection lines make angle of 45^0 with the plane of projection, the projection is called a cavalier projection.

ii) **Cabinet projection:** When the angle that the projecting lines make with the plane of projection is such that the scale on the reading axis in the drawing is about one half as long as the two axes, the result is called a cabinet projection.

iii) **Clinographic projection:** In cavalier and cabinet projections the principal face of the object is made parallel to the plane of projection. For some cases it may be desirable to turn the object at an angle with respect to the plane of projection and is known as clinographic projection.



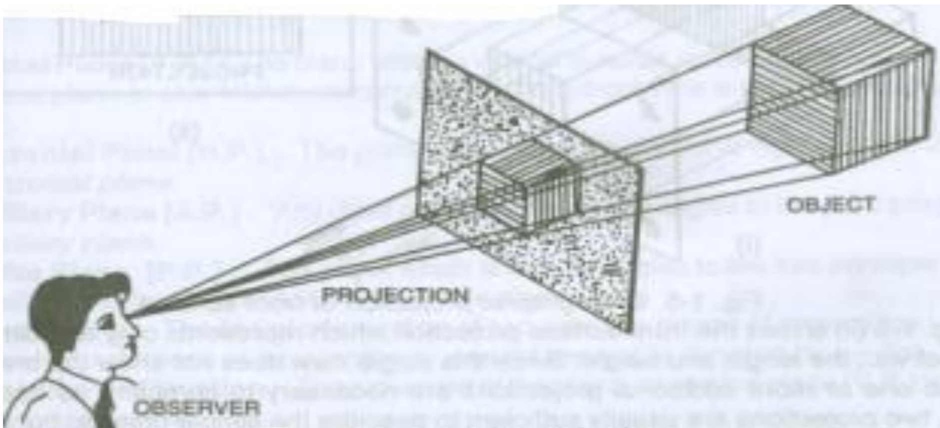
Types of oblique projection

c) **Perspective projection:** The projection obtained on a plane when the projectors converge to a point is known as perspective projection. There are three kinds of perspective projections.

i) **Parallel or one-point perspective projection**: if the principal face of the object is parallel to the plane of projection and there is only one vanish point; the projection is known as parallel or one-point perspective projection.

ii) **Angular or two-point perspective projection**: When the two faces of the object are at an angle with plane of projection, where the third face is perpendicular to it, the two principal vanish points occur and the projection is known as angular or two-point perspective projection.

iii) **Oblique or three-point perspective projection:** If the three principal faces of the object are inclined to the plane of projection, the projection obtained is known as an oblique or three-point perspective projection.



Perspective projection

2. **Orthographic projection**

The projection or view obtained on a plane of projection when the projectors are parallel to each other, but perpendicular to the plane of projection, is known as orthographic projection.

While drawing the orthographic projections, the following items should invariably exist:

1. The object to be projected
2. The projector
3. The plane of projections
4. The observer's eye or station point.

4.Plane of projection

The plane which is used for the purpose of projection is called **plane of projection**.

4.1. Type of projection plane

1. **Reference plane:** In general, two planes are employed for projection and are known as reference planes or principal planes of projection.
   These planes intersect at right angle to each other.

2. **Vertical plane (V.P):** The plane which is vertical is called vertical plane and is denoted by **V.P.** Vertical plane is also known as **frontal plane** since front view is projected on this plane.
3. **Horizontal plane (H.P):** The plane which is horizontal but at right angle to the V.P.
4. **Auxiliary plane (A.P):** Any other plane placed at any angles to the principle planes.
5. **Profile plane (P.P):** The plane which is at right angles to the two principle plane is called **auxiliary vertical plane** (A.V.P).

LO 1.2 –Draw objects

- Content/Topic 1:Different views of Objects

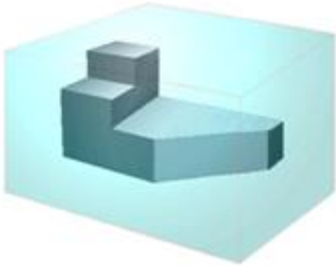
➢ Type of views

1. Front view or elevation
2. Rear view
3. Top view or plan
4. Bottom view
5. Right view
6. left view or Side view or Side elevation or profile view
7. Auxiliary view: The object is projected on an auxiliary plane

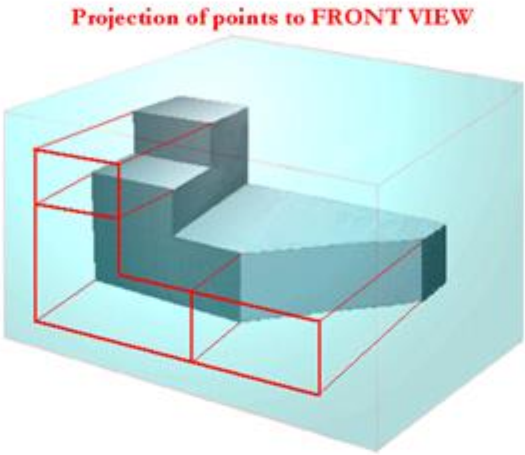
➢ Method of obtaining views

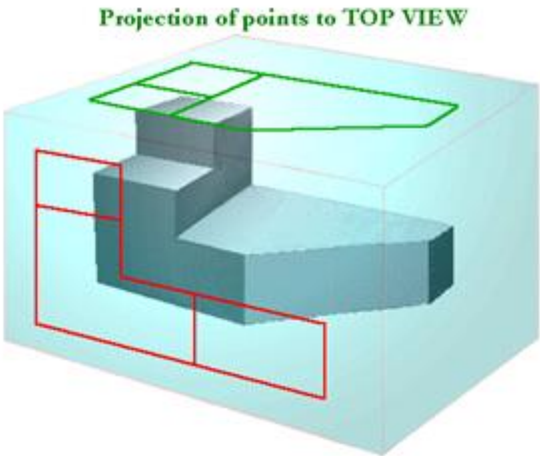
1. Glass box method

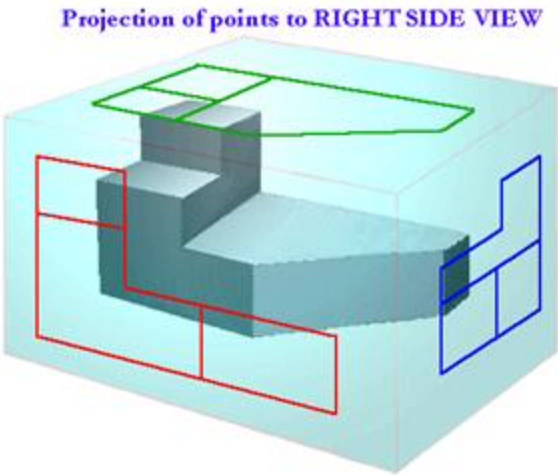
This method is in accordance with the theory of orthographic projection. The theory of orthographic projection states that the projection may be formed by extending perpendicular projectors from the object to the plane. It may be considered that planes of projection placed parallel to the six faces of an object form an enclosing glass box. The observer views the enclosed object from the outside. The views are obtained by running projectors from points of the object to the planes.



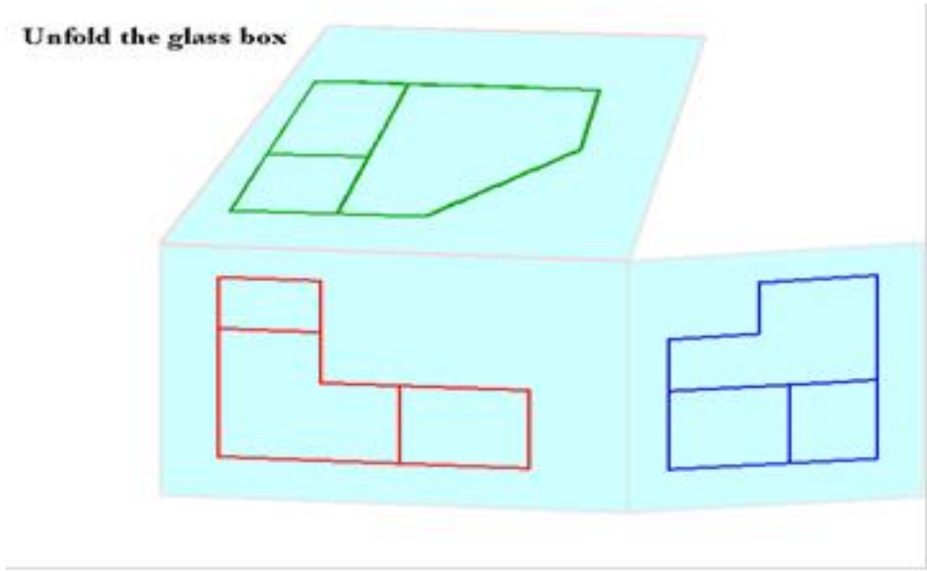
Now assume that the faces of the object are projected to the surfaces of the glass box that they are facing.

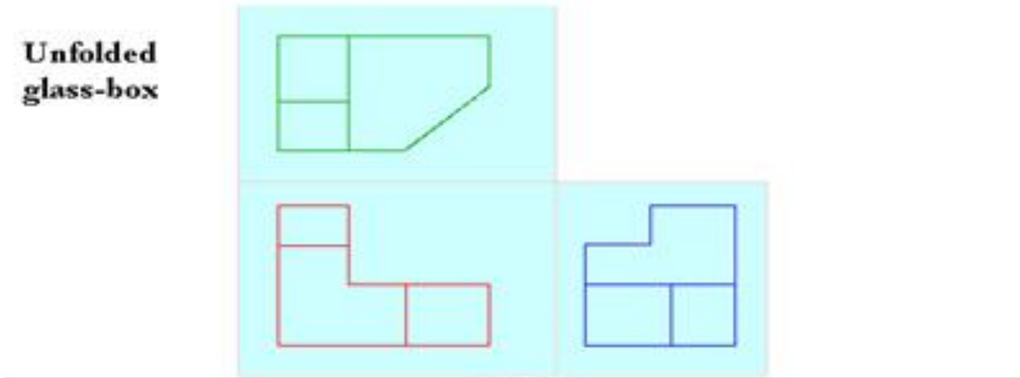


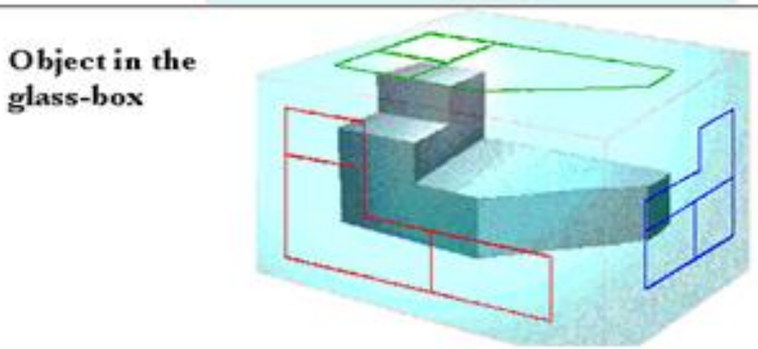




Now imagine that the glass box faces are unfolded



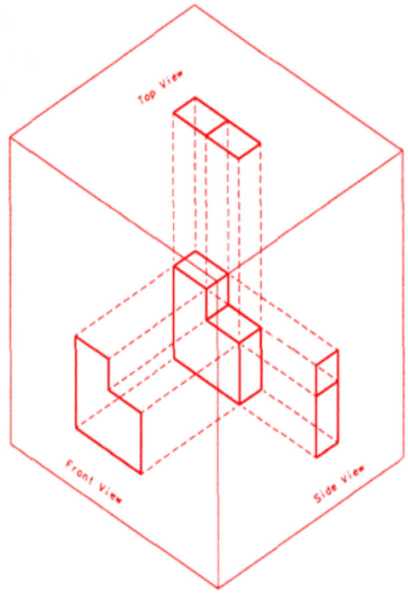




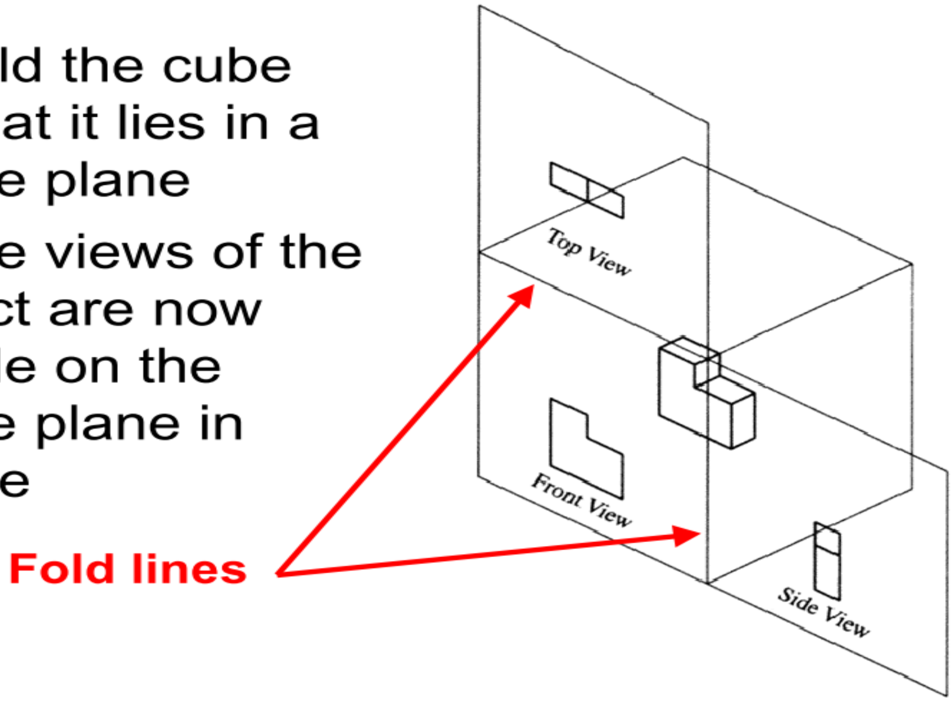
Then the following picture shows the Top, the Front and the Right view of the object.

Example:

- Imagine the object is surrounded by a glass cube.
- Object surfaces are projected onto the faces.

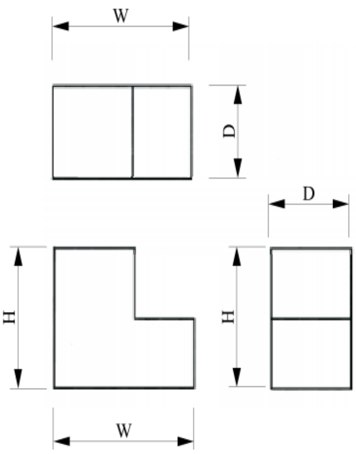


- Unfold the cube so that it lies in a single plane
- Three views of the object are now visible on the same plane in space



When the glass cube is unfolded:

- <u>Front view</u>: Height and Width
- <u>Top view</u>: Width and Depth
- <u>Right view</u>: Depth and Height

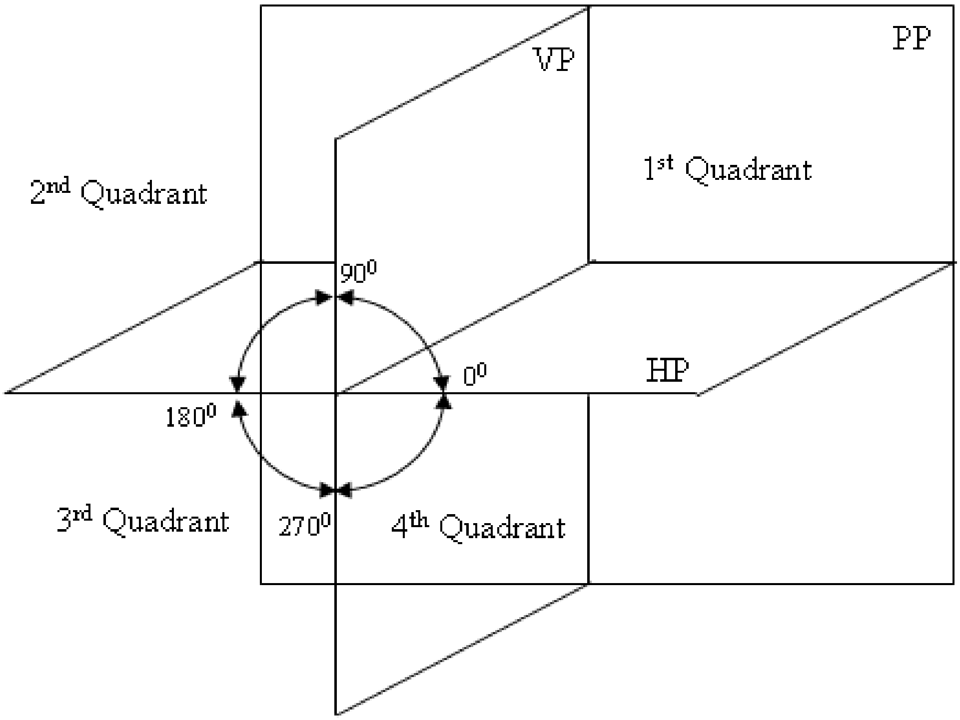


2. Quadrants Method Approach

FOUR QUADRANTS

Orthographic projection is also done on the **Vertical Plane (VP)**, the **Horizontal Plane (HP)** and the **Profile Plane (PP)** all referred to as **principle planes**, which are defined with reference to the four quadrants shown in Figure below:

To start with let us draw two perpendicular planes a vertical one (VP) and a horizontal one (HP) that will make four quadrants:



The position of the object placed in any one of the quadrant is described above

1. In the first quadrant – above H.P and in front of V.P
2. In the second quadrant – above H.P and behind of V.P
3. In the third quadrant – below H.P and behind V.P
4. In the fourth quadrant – below H.P and in front of V.P

- Types of orthographic projection
  - First angle projection
  - Third angle projection

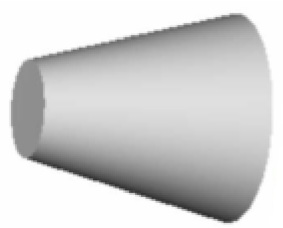
Theoretically, the object could be placed in any of the four quadrants. Engineering custom in the **United States** dictates the use of ***the third angle***. This quadrant is used because the views, when revolved 90^0 into the plane of the front view, are in their natural positions. In some countries the ***first angle projection*** is used for engineering drawing.

The difference between 1st angle and 3rd angle projection is that when 1st angle projection is used and planes are revolved, the top view will be below the front view, and that the left side view will be to the right of the front view.

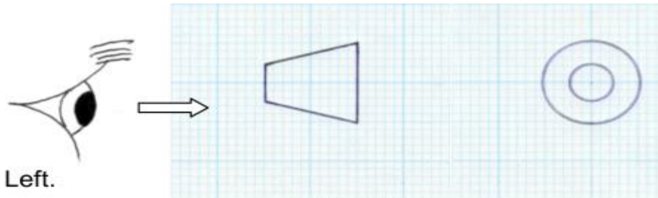
5.6. Identifying the angle of projection

On each orthographic drawing produced the symbol the method used has to be indicated on the drawing sheet. This is conventionally done by means of symbols.

Consider yourself looking at the following cone

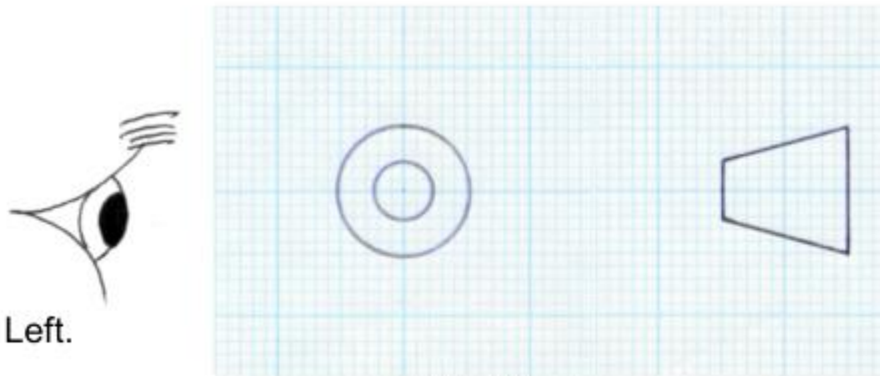


If you draw its front and left view and present it as in the figure below then your method of drawing will be **First Angle Projection**.



First Angle.

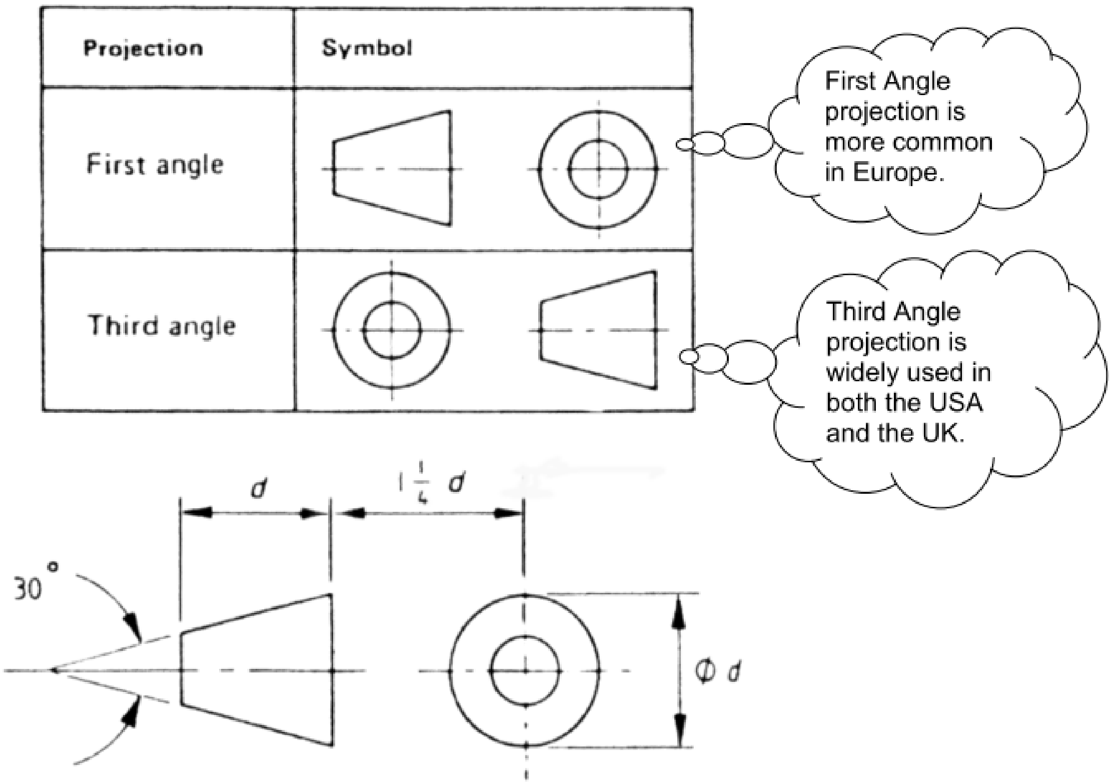
Once again if you draw its front and left view and present it as in the figure below then your method of drawing will be **Third Angle Projection**.



Third Angle.

There you are! You have got the international representation of objects in First and Third Angle Projection.

Both systems of projection, First and Third angle, are approved internationally and have equal status. The system used must be clearly indicated on every drawing, using the appropriate symbol shown in Figure below.



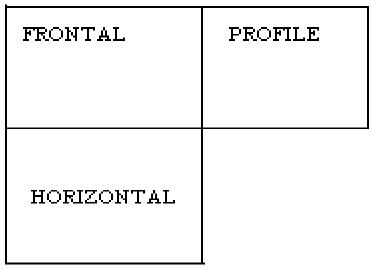
Projection system symbols and recommended proportions.

The difference between 1st angle and 3rd angle projection is that when 1st angle projection is used and planes are revolved, the **top view** will be ***below the front view***, and that the **left side view** will be to ***the right of the front view***.

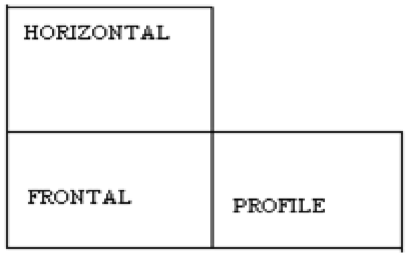
	First angle projection	Third angle projection
1	Object is kept in the first quadrant	Object is assumed to be kept in the third quadrant
2	Object lies between observer and the plane of projection	Plane of projection lies between the observer and the object
3	The plane of projection is assumed to be non-transparent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

5.7. Rotation of planes

When the projection of an object has been made on the various planes, they are brought together on a single sheet of paper by rotating the planes. The standard practice of rotation of planes is to keep the V.P fixed and to rotate H.P and P.P away from the object so that they may come in line with V.P. The following figures show frontal, profile and horizontal plane revolved in the plane of the paper.

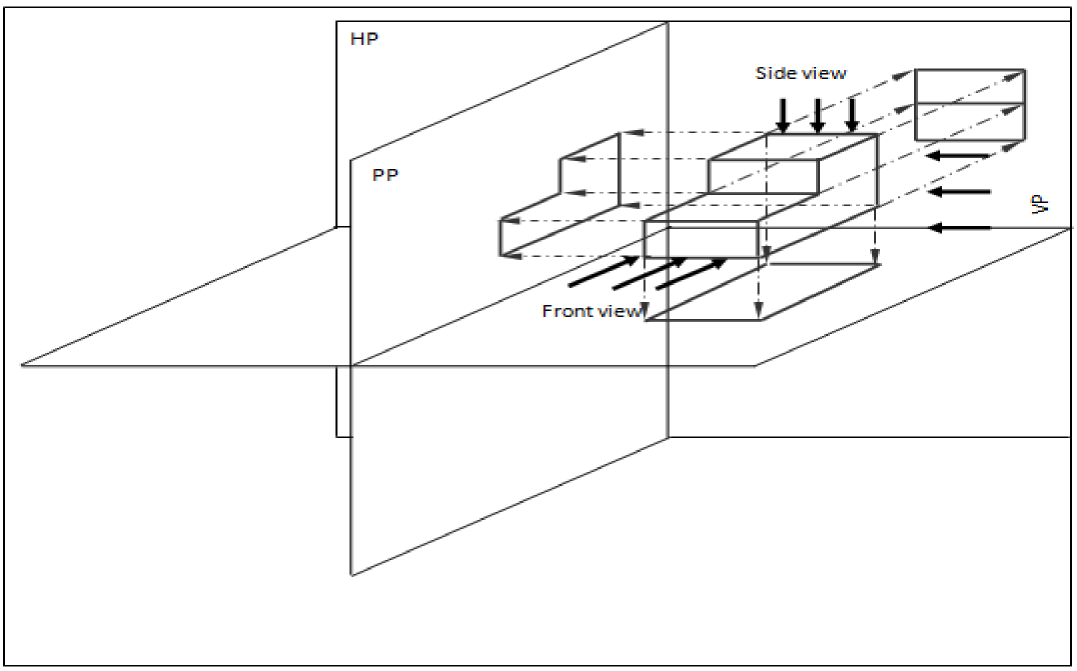


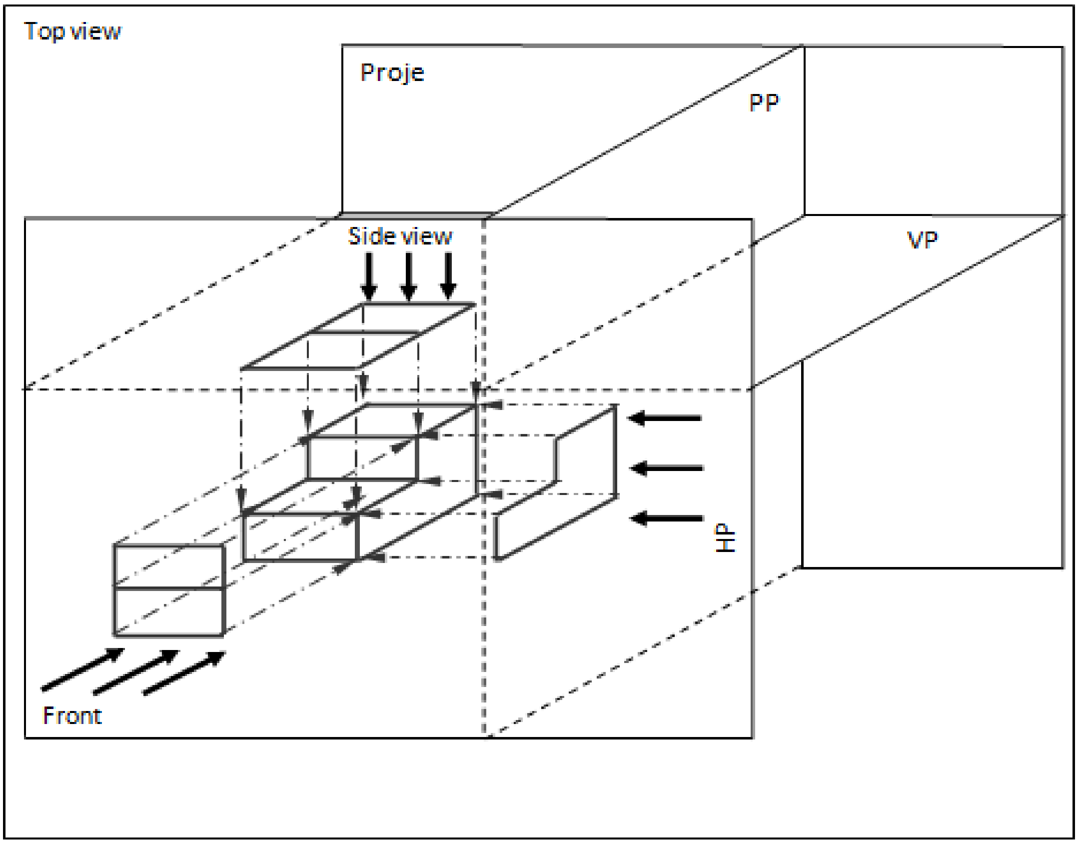
1st angle projection



3rd angle projection

In engineering drawing objects to be represented are placed in the first or the third quadrant.





Line Styles and Symbols:

Lines on an engineering drawing signify more than just the geometry of the object and it is important that the appropriate line type is used.

A thick continuous line is used for visible edges and outlines.

Thin chain lines are a common feature on engineering drawings used to indicate centre lines. Centre lines are used to identify the centre of a circle, cylindrical features, or a line of symmetry.

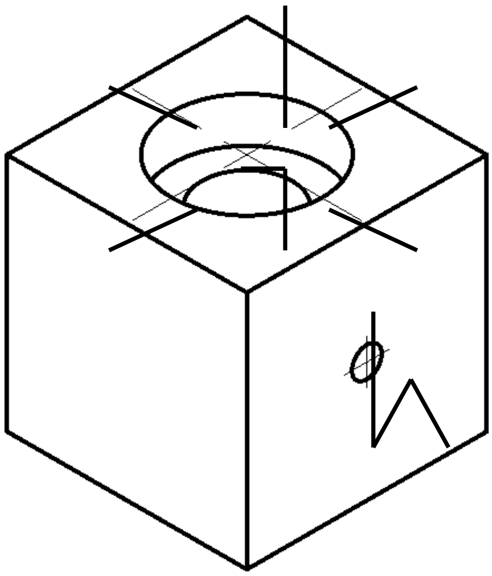
Dashed lines are used to show important hidden detail for example wall thickness and holes...

Precedence of Lines

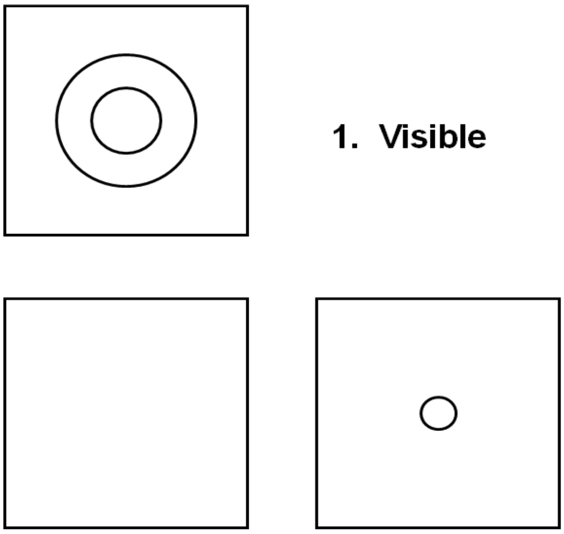
- **Visible lines** takes precedence over all other lines
- **Hidden lines** and **cutting plane lines** take precedence over center lines
- **Center lines** have lowest precedence.

Example:

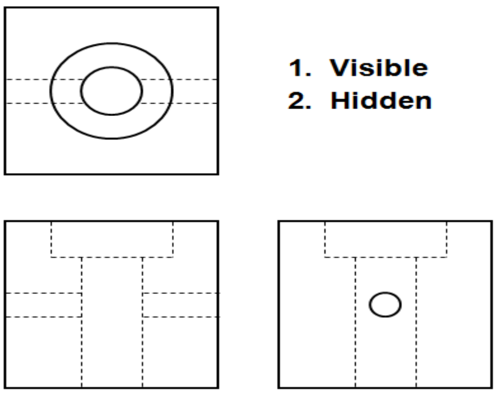
Let us present the following object in orthographic projection.



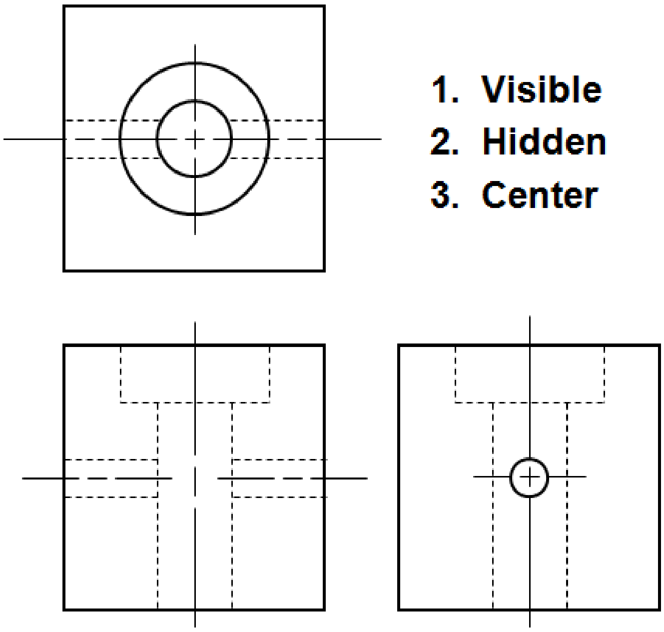
1^0)First of all visible lines are drawn.



2^0) Secondary hidden details are shown:



3^0)And finally center lines are included:

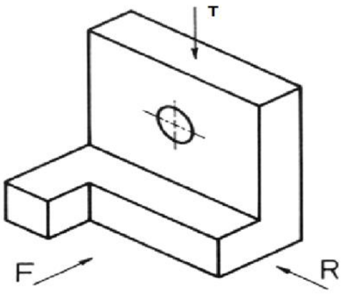


5.8. Creating orthographic projections

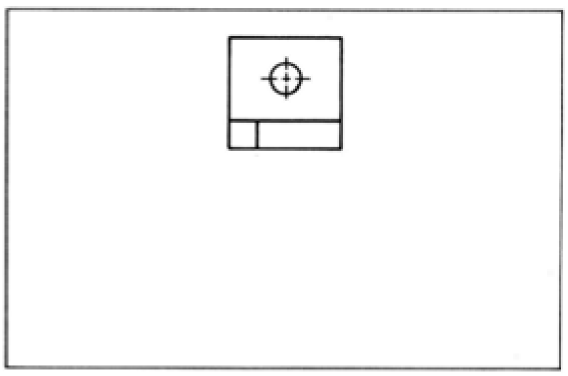
In creating the orthographic projections, normally you will be starting by drawing the Front View. In class exercises, the Front View is indicated by an arrow however when it is not given or during design it is a good practice to choose the view that will reveal most of the details about the object. This view will be the one showing the object in its natural position and be the one having less hidden parts. Draw the remaining views ensuring dimensional consistency.

Let us do it through an example:

You will create the First Angle Projection of the following object showing its Front, Right and Top View.

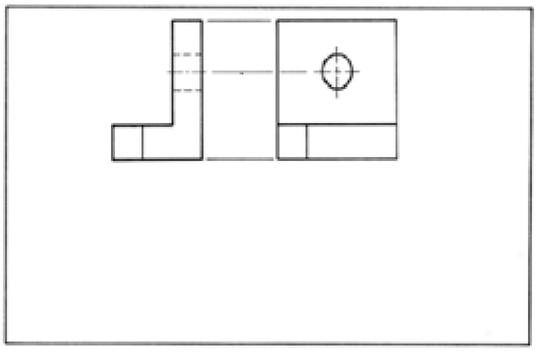


1^0) Start by **drawing the Front view** leaving enough space for other views.



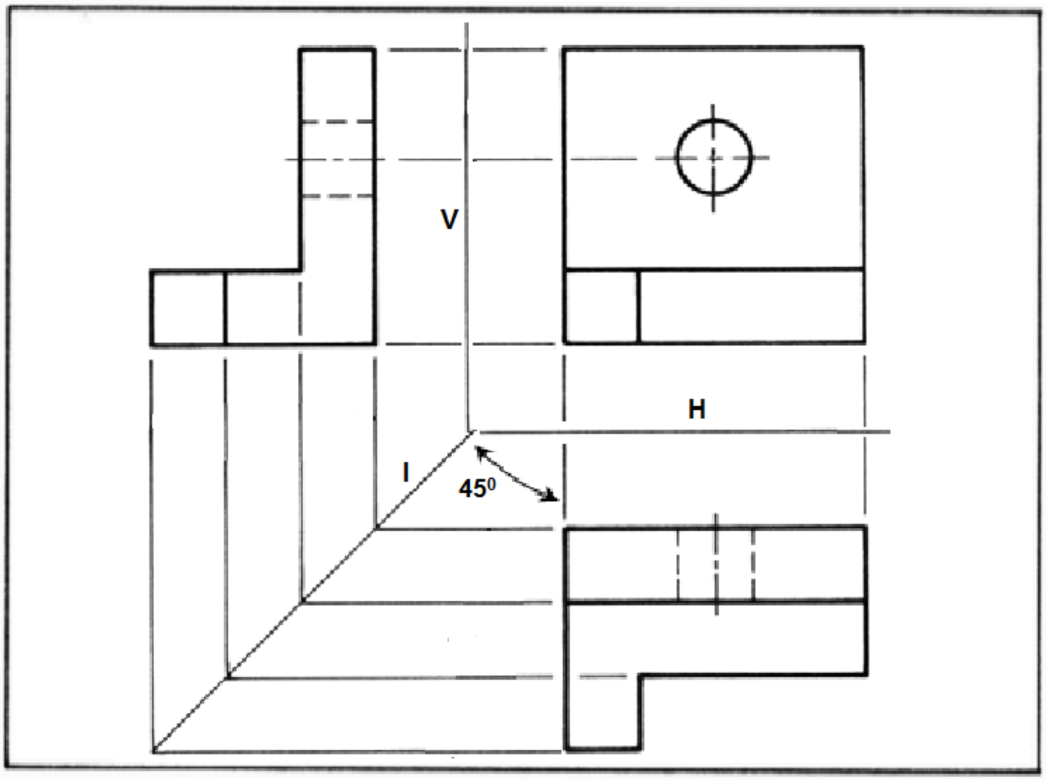
2^0) **Draw the Right Side View.** By projecting the construction lines draw the second view (the Right side view in our example).

Construction lines ensure quick dimensional consistency as well as alignment of views.



3^0) Draw the Top View.

- Draw a vertical line (V in the example) between the Front side view and the Right side view.
- Draw a horizontal line (H in our example) below the Front side view.
- Draw an inclined line at 45^0(I in the example) where the vertical line and the horizontal line meet.
- Project vertical construction lines from the Right Side View edges to meet the inclined line.
- Where those vertical lines meet the inclined line, draw horizontal lines.
- Project vertical construction lines from the Front Side View edges to meet the horizontal lines stated above.
- Where horizontal lines from the Right Side View meet the vertical lines from the Front view, construct the top view.



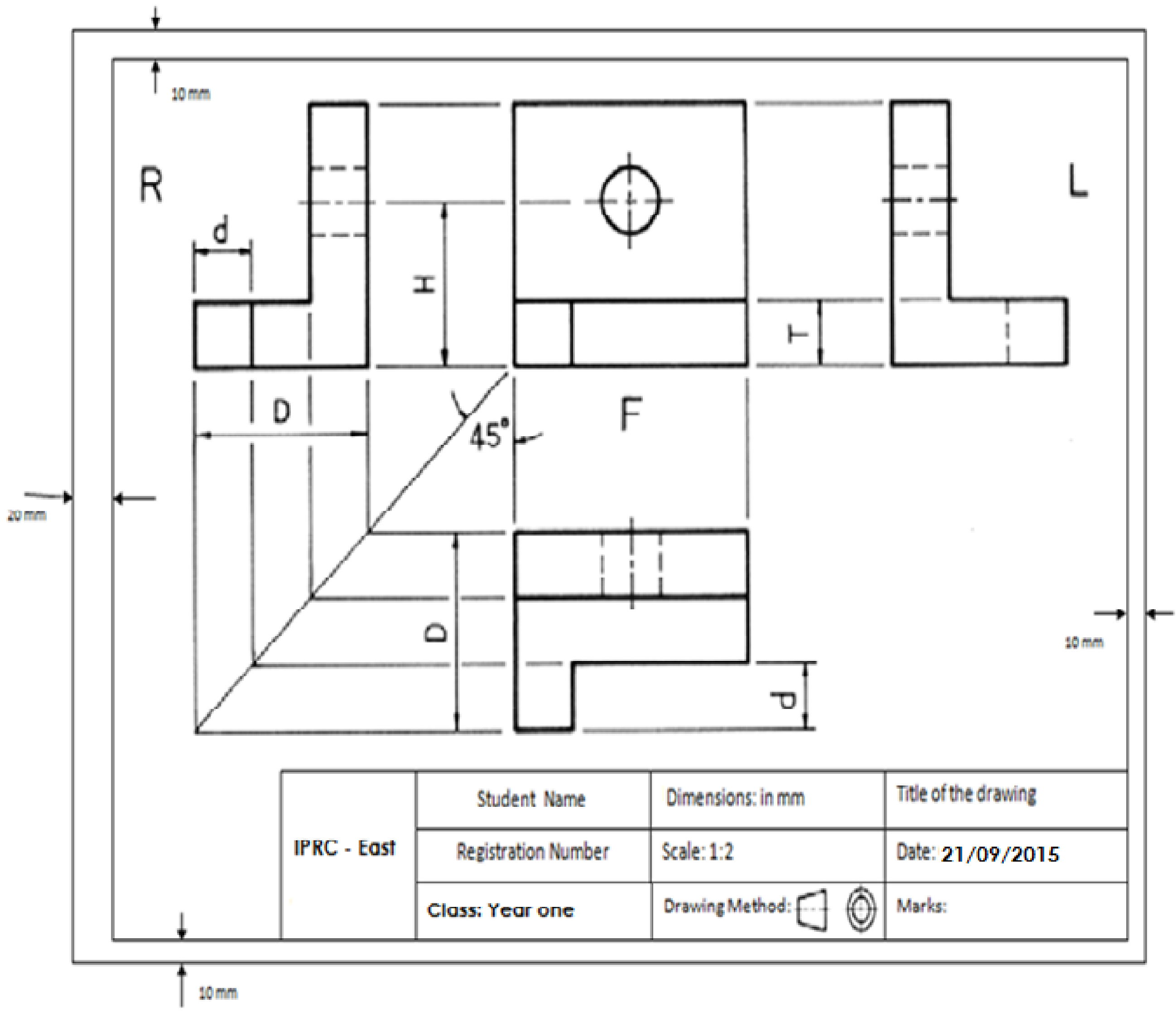
The procedure described above is also applicable to Third angle projection. In First Angle Projection the Top view is below the Front view while in Third Angle Projection it is above the Front view.

Layout of an engineering drawing

Although the general sheet layout was given at the beginning, orthographic projection being a kind of drawing that gives multiple it is important to show how those views should be presented.

- ✓ Margins should be drawn first. Note that though the recommended margin is 10 mm for an A4 size paper, it is good to leave 20 mm on the left side so that in case the paper needs to be punched and filed the drawing remains untouched.
- ✓ The student should make sure that he/she will be having enough space for the Side and Top or Bottom Views before placing the Front View.
- ✓ The student should try his/her best to place his/her drawings at the center of the paper.
- ✓ The student should fill in all the necessary information in the title block.

The drawing layout should be looking like below with slight changes due to a typical case.



Learning Unit 2 –Prepare list materials

LO 2.1 –Prepare list of materials

- <u>Content/Topic 1:Criteria of choosing materials:</u>

- ➢ Nature (types): are considered to belong into this category. Natural materials are used as building materials and clothing
- ➢ Sizes: is a measurement or amount of a materials
- ➢ Availability The quality or state of being available trying to improve the availability of affordable

housing.

LO 2.2 –Determine cost of materials

- Content/Topic 1:Determination of quantity

CALCULATING MATERIALS

From the Plans and Specifications, you should have gathered a list of all material requirements for a specified project; you now need to calculate the amounts of materials required. To estimate materials accurately it is necessary to be able to measure and calculate material requirements. A summary of the formulae for calculating materials is listed below. For more advanced calculations used to calculate material requirements refer to the Carry out Measurements and Calculations Learner Guide.

- **Linear**: Calculating Linear Measurements
  Calculating linear measurements is straightforward, using the appropriate tool, measure the perimeter of an object and that would equal the linear measurement required.
  Is the measure of a quantity of any characteristic value per unit of length?
- **Surface**: Calculating Area Measurements
  As area measurements are two dimensional to calculate the surface area you multiply the length by the width.
  Area = Length x Width
- Volume: Calculating Volume Measurements
  Volume measurements are three dimensional therefore to calculate the cubic content of a space you multiply the length by the width by the depth/ height.
  Volume = Length x Width x Depth

LO 2.3 – Calculate overall cost

- Content/Topic 1 Basic components of an estimate:

- Materials, labour cost, Overhead,
- Profit.
- Calculate costs:

Now that you have estimated the materials, miscellaneous items and labor requirements for a project the next step is to calculate the actual cost.
It is important that this step is carried out accurately as a mistake at this stage can make the difference between a projects being profitable or not.

- **Material costs**: The first step in calculating material costs is to contact suppliers to determine actual costs of supplies. Supply costs do vary so it may be necessary to contact several suppliers to achieve the best price. Make sure you also enquire about the availability of materials and their delivery costs as these also vary.

To calculate the cost of the required material for a specified project or task you must take into account the amount needed, including wastage, plus any delivery and storage charges.

For example, if you are cornicing a 4m x 4m room. You need to purchase 4 lengths of 4.8m to allow for wastage. Each length costs $20 therefore the 4 lengths that you require will total $80.

- **Miscellaneous costs**

Miscellaneous costs are likely to be unique to each job and therefore can be listed as a direct cost. E.g. If you need to purchase bales of hay for a silt trap and they cost $50 you add this $50 to your estimate.

- **Labour costs**

If you are a sole trader your labor costs are straight forward. That is you will have a set hourly rate. However, if you have employees, in addition to the hourly rate of labor, you have to factor into the labor costs additional amounts to cover – these are often referred to as on-costs and include:

- Supervisor rates
- Apprentice rates
- Penalty rates
- Site allowances
- Travel allowances
- Holiday and sick pay
- Inclement weather
- Work cover payments
- Payroll tax if applicable
- Crib time
- Redundancy contributions
- Incentive and bonus schemes.

- **Overheads**

Overheads are the costs incurred in running a business. The cost of overheads will vary depending on the size of your business. They include items such as:

- computing and phone equipment
- professional development advertising costs
- insurance e.g. professional indemnity, public liability
- bank charges
- travel and vehicle expenses
- office maintenance
- stationery cost of new tools, equipment and plant
- maintenance of tools, equipment and plant
- motor vehicle.

All of these items need to be factored into the estimate.
There are a number of ways that overheads can be calculated ranging from very sophisticated accounting tools used by large corporations to simple methods favored by sole traders and sub-contractors.
A simple method to calculate the overheads of a small business are as follows.
Collect all of the bills that relate to the above list of overheads for one year. Add the amounts together to get a total annual overhead expense. Divide this amount by the number of days in the year that you worked (e.g. 240 days) to give you a daily overhead rate. If you cost your projects by the hour, divide your daily rate by the average number of hours in your working day (e.g. 8 hours).

Overhead calculation example.
Total of overhead bills for 1 year $28,800
Divided by 240 days $120
Divided by 8 hours $15

- Contingency allowance

A good estimator always allows for contingencies in their calculations - especially if the project will be undertaken over a considerable length of time. Contingencies are those unexpected events that can impact on a job. They include sick leave, project slippage, job re-work etc.
Contingency allowances protect the project estimate against inflation and also cover:

- minor changes
- omissions
- uncertainties
- risks.

Contingencies can be calculated in a number of ways. Some estimators choose to add a percentage to the total job cost e.g. 10%, other estimators increase the amount of hours allocated to the job or increase the hourly rate.

- Mark-up percentages

A mark-up percentage is added to an estimate to ensure the project results in a net profit. The mark-up percentage can vary depending on factors such as the size of the project or the competitiveness of the market.
An example of calculating mark-up is given below.
The total cost of labour and materials for a given project is $75,000 a mark-up percentage of 10%

- Total job calculation

Once you have estimated and costed all the components of a job you are ready to calculate the total job cost. The total job cost is made up of:
Materials costs
+
Labor costs
+
Miscellaneous costs
+
Overhead costs
+
Contingencies
+
Mark up percentage

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APA format

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