Engineering Drawing for beginners

CHAPTER 1
INTRODUCTION

1.1 Drawing

The graphical representation of any object or idea can be termed as drawing. A drawing can be prepared either using free hand or using engineering instruments or using computer program.

1.2 Types of Drawing

1. Artistic Drawing
2. Engineering Drawing

1.2.1 Artistic Drawing

The drawing representing any object or idea which is sketched in free hand using imagination of artist and in which proper scaling and dimensioning is not maintained is called an artistic drawing. Example: Painting, Posters, arts etc.

1.2.2 Engineering Drawing

Engineering drawing can be defined as a graphical language used by engineers and other technical personnel associated with the engineering profession which fully and clearly defines the requirements for engineered items. It is a two dimensional representation of a three dimensional object. In other words, The art of representing a real or imaginary object precisely using some graphics, symbols, letters and numbers with the help of engineering drawing instruments is called engineering drawing. The art of representing engineering objects such as buildings, roads, machines, circuits etc. on a paper is called engineering drawing. It is used by engineers and technologists. An engineering drawing provides all information about size, shape, surface type, materials etc. of the object. Example: Building drawing for civil engineers, Machine drawing for mechanical engineers, Circuit diagrams for electrical and electronics engineers, computer graphics for one and all etc.

Table 1.1 Difference Between Artistic and Engineering Drawing

Artistic Drawing	Engineering Drawing
Purpose of artistic drawing is to convey emotion or artistic sensitivity in some way.	Purpose of engineering drawing is to convey information about engineering object or idea.
Can be understood by all.	Need some specific knowledge or training to understand.
Scale maintaining is not necessary	Scale maintaining is necessary
No special requirement of engineering instruments.	Engineering drawing instruments is used to make the drawing precise.
An artistic drawing may not be numerically specific and informative.	An engineering drawing must be numerically specific and informative.
Standard drawing code need not to be followed.	Standard drawing code (like ISO, ANSI, JIS, BS etc.) must be maintained.

1.3 Purpose of Engineering drawing

It is very difficult and complex to explain some certain engineering requirements in word. In such cases well dimensioned and properly scaled graphics can make it easy to understand that for technical personnel. Engineering drawing serves this purpose. Any product that is to be manufactured, fabricated, assembled, constructed, built, or subjected to any other types of conversion process must first be designed. To make the outcome from the design understandable to any third party engineering drawing is the best way.

1.4 Applications of Engineering Drawing

Engineering drawing is an essential part of almost all engineering projects. Some important uses of engineering drawing are mentioned below:

1. It is used in ships for navigation.
2. For manufacturing of machines, automobiles etc.
3. For construction of buildings, roads, bridges, dams, electrical and telecommunication structures etc.
4. For manufacturing of electric appliances like TV, phone, computers etc.

1.5 Types of Engineering Drawing

Engineering drawing can be grouped into following 4 major categories:

1. Geometrical Drawing
    a. Plane geometrical drawing
    b. Solid geometrical drawing

2. Mechanical Engineering Drawing
3. Civil Engineering Drawing
4. Electrical & Electronics Engineering drawing etc.

1.5.1 Geometric Drawing

The art of representing geometric objects such as rectangles, squares, cubes, cones, cylinders, spheres etc. on a paper is called geometric drawing. If the object has only 2 dimensions i.e. length and breadth (as rectangles, squares, triangles etc.), it is called Plane geometrical drawing and if it has 3 dimensions i.e. length, breadth and thickness/depth (as cube, prism, sphere, cylinder etc.), it is called Solid geometrical drawing.

1.5.2 Mechanical Engineering Drawing

The art of representing mechanical engineering objects such as machines, machine parts etc. on a paper are called mechanical engineering drawing or machine drawing. It is used by mechanical engineers to express mechanical engineering works and projects for actual execution.

1.5.3 Civil Engineering Drawing

The art of representing civil engineering objects such as buildings, roads, bridges, dams etc. on a paper are called civil engineering drawing. It is used by civil engineers to express civil engineering works and projects for actual execution.

1.5.4 Electrical Engineering Drawing

The art of representing electrical engineering objects such as motors, generators, transformers, wiring diagrams etc. on a paper are called electrical engineering drawing. It is used by electrical engineers to express electrical engineering works and projects for actual execution. The art of representing electronic circuits of TV, Phones, computers etc. on a paper are called electronic engineering drawing or electronic drawing. It is used by electronic engineers to express electronic engineering works and projects for actual execution. etc.

1.8 Elements of Engineering Drawing

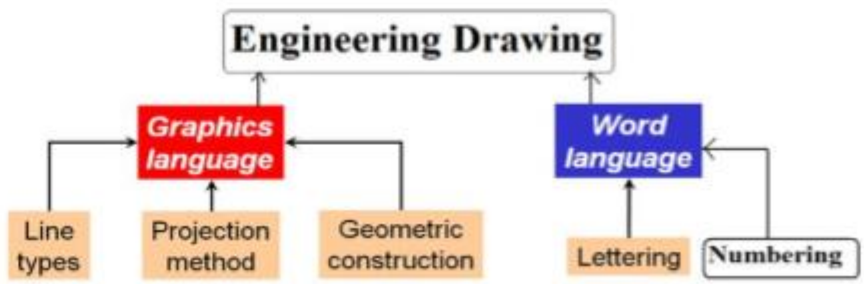


Fig. 1.1 Elements of Engineering Drawing

1.9 Drawing Standards

An engineering drawing should be well specified and universally acceptable. That's why there are some specified rules for engineering drawing. These rules may vary slightly for different regions. There are some drawing standards or drawing codes that accumulates the rules of engineering drawing for a certain region. Well-known drawing codes and their application region is expressed below:

Table 1.2 Drawing Standards

Country/Region	Code/Standard	Full Meaning
Worldwide	**ISO**	International Organization for Standardization
USA JAPAN	ANSI JIS	American National Standards Institute Japanese Industrial Standards
UK	BS	British Standards

1.10 Drawing Instruments

The most common instruments used for engineering drawing are:

1 Drawing Board 4. Rubber/Eraser 7. Instrument box 10. Scales
2. Drawing paper 5. T- square 8. Protractor 11. Pins and clips
3. Pencil 6. Set-square 9. Compass 12. Adhesive tapes
13. French curves etc

Drawing Board

¬ It is a board or platform rectangular in shape.
¬ Size of drawing board need to be larger than that of drawing paper.
¬ It is made of wood.
¬ Top surface should be smooth.

Drawing paper is the paper, on which drawing is to be made. All engineering drawings are made on sheets of paper of strictly defined sizes, which are set forth in the respective standards. The use of standard size saves paper and ensures convenient storage of drawings.

Desirable properties a good drawing paper:

¬ It should be smooth and uniform in thickness.
¬ It should be thick, strong and tough.
¬ Fibers of drawing paper should not be disintegrated when a good eraser is used on it.

Paper Size:

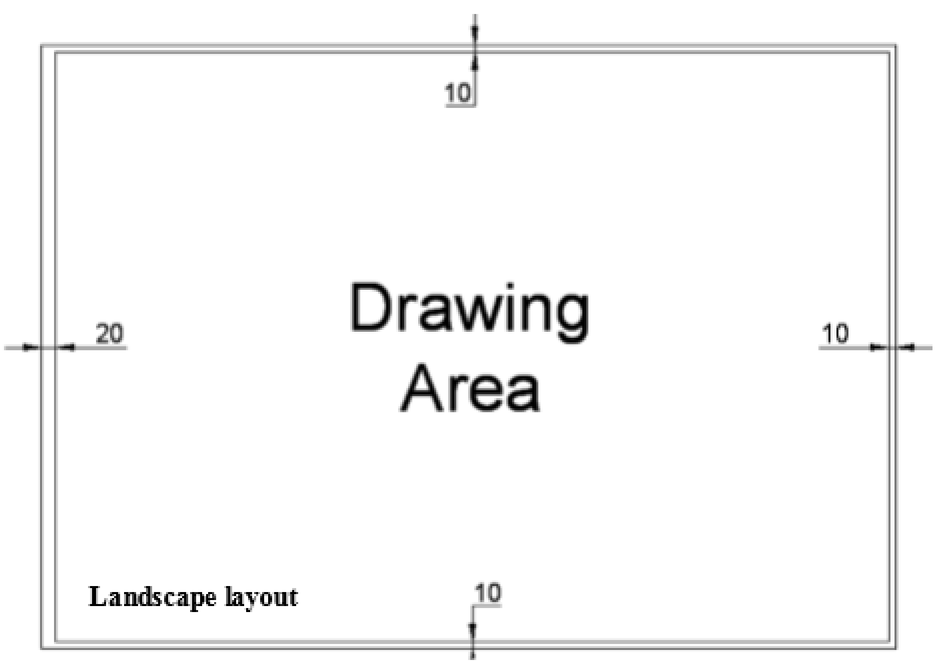
Table 1.3 ISO Paper Sizes (plus rounded inch values)

Format	A series		B series		C series	
Size	**mm × mm**	**in × in**	**mm × mm**	**in × in**	**mm × mm**	**in × in**
0	841 × 1189	33.1 × 46.8	1000 × 1414	39.4 × 55.7	917 × 1297	36.1 × 51.1
1	594 × 841	23.4 × 33.1	707 × 1000	27.8 × 39.4	648 × 917	25.5 × 36.1
2	420 × 594	16.5 × 23.4	500 × 707	19.7 × 27.8	458 × 648	18.0 × 25.5
3	297 × 420	11.7 × 16.5	353 × 500	13.9 × 19.7	324 × 458	12.8 × 18.0
4	210 × 297	8.27 × 11.7	250 × 353	9.84 × 13.9	229 × 324	9.02 × 12.8
5	148 × 210	5.83 × 8.27	176 × 250	6.93 × 9.84	162 × 229	6.38 × 9.02
6	105 × 148	4.13 × 5.83	125 × 176	4.92 × 6.93	114 × 162	4.49 × 6.38
7	74 × 105	2.91 × 4.13	88 × 125	3.46 × 4.92	81 × 114	3.19 × 4.49
8	52 × 74	2.05 × 2.91	62 × 88	2.44 × 3.46	57 × 81	2.24 × 3.19
9	37 × 52	1.46 × 2.05	44 × 62	1.73 × 2.44	40 × 57	1.57 × 2.24
10	26 × 37	1.02 × 1.46	31 × 44	1.22 × 1.73	28 × 40	1.10 × 1.57

The tolerances specified in the standard are

- ±1.5 mm (0.06 in) for dimensions up to 150 mm (5.9 in),
- ±2 mm (0.08 in) for lengths in the range 150 to 600 mm (5.9 to 23.6 in) and
- ±3 mm (0.12 in) for any dimension above 600 mm (23.6 in)

Paper Layout:
The ISO standard (ISO 5457) require a 20mm border to the left hand edge (for filing) and a 10mm border round the other three sides of the drawing sheet. However, the margin of paper can be increased according to requirements and settings of printer/plotter.



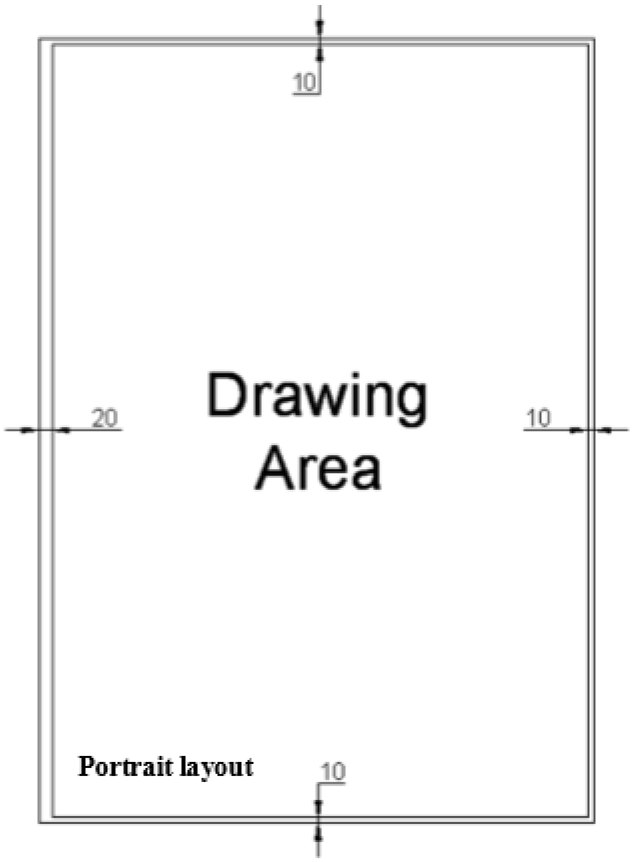
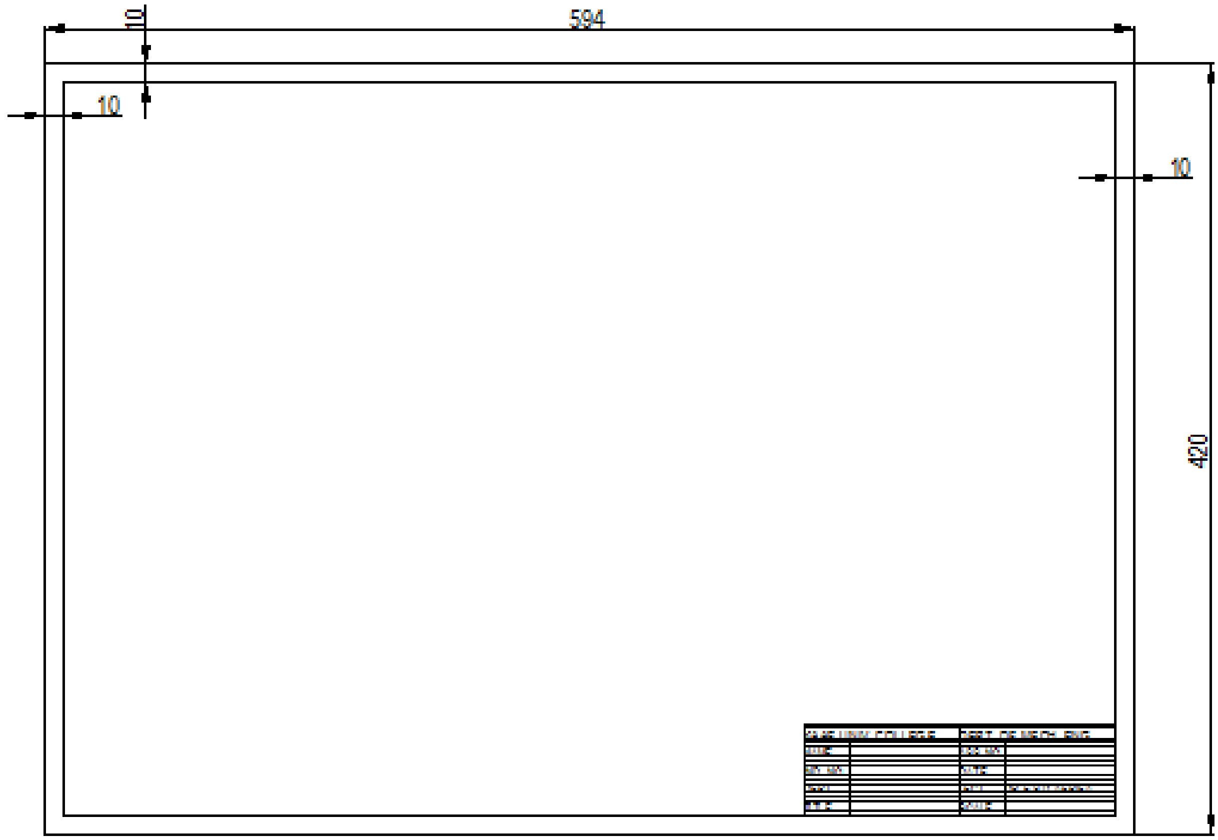


Fig. 1.3 Landscape and Portrait Layout of Drawing Paper

For Class Work: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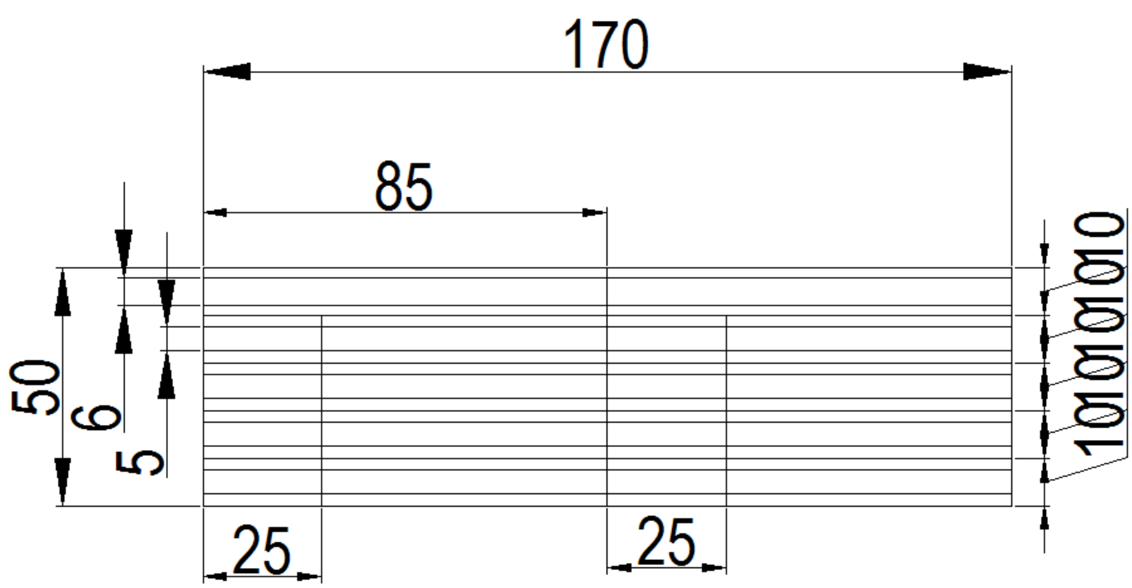
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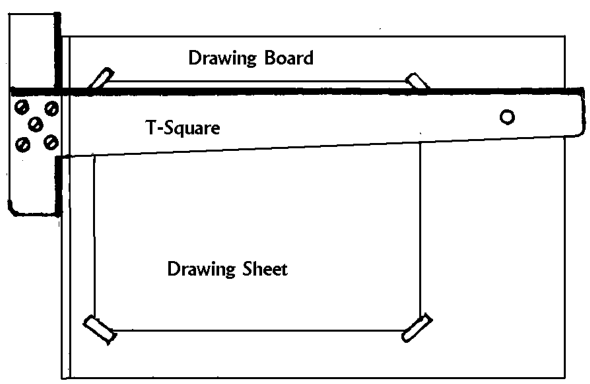
KAAF UNIV. COLLEGE		DEPT. OF MECH. ENG.	
NAME		ASS. NO.	
IND. NO		DATE	
DEPT.		LECT.	DR E.S.D. AFRIFA
TITLE		SCALE	

1-1.2 Technique of Laying Out a Drawing Paper

i. The drawing paper is to be positioned by aligning the long top edge of the paper with the straight edge of the T-square that has its herd aligned with the drawing board. The paper is then cello taped or clipped to the board.



Border Lines

If the paper is not pre-bordered, draw the borderlines by measuring 20mm from the left edge or as specified above and 10mm from right, bottom and top edges of the drawing paper. Draw vertical lines as the left and right hand border lines, and horizontal lines as the lower and upper border-lines.

Title Block

The title block is an important feature in drawing because it gives all the information of the prepared drawing. It is located at the right hand bottom corner of the drawing paper. See the figure above.

There are several standard title blocks (e.g. ISO, DIN etc. title blocks) as well as company-specific title blocks. All title blocks must contain at least the following information:

- ✓ Title of drawing,
- ✓ Name of firm/institution
- ✓ Names and dates of the drafters, checker, designer,
- ✓ Scale.

The details of the title block for drawings within ME 159 are shown below:

Pencil:
Pencils are used to draw different lines, shapes, symbols and to write texts in engineering drawing. Based on the hardness of lead pencils are classified in three major grades as hard, medium and soft. They are further subdivided and numbered as mentioned in table below:

Table 1.4 Pencils of Different Grades

Grade	**Items arranged ordering harder to softer**
Hard	9H> 8H> 7H>6H>5H>4H
Medium	3H>**2H**>H>F>**HB**>B
Soft	2B>3B>4B>5B>6B>7B

Selection of proper grade pencil or lead is important for quality drawing. One has to be careful in selecting a lead because very hard lead might penetrate the drawing, on the other hand, soft lead may smear. Quality and type of drawing paper is an important factor in selecting lead. One other importance consideration is the importance of line to be drawn. Inferior lines (like border lines, guide lines, construction lines and any other auxiliary lines needed to be erased later) are drawn using harder pencil. Comparatively softer grade pencil is used for drawing superior items (like object line, texts, symbols etc.).
Common uses of different grade pencil are tabulated below:

Table 1.5 Pencil Usage Guideline for Different Line Types

Task	**Lead**	**Task**	**Lead**	**Task**	**Lead**
Border Lines	3H, 2H	Centerlines	2H,H	Leaders	2H, H
Construction Lines	3H, 2H	Phantom Lines	2H,H	Hidden Lines	2H, H
Guide Lines	3H, 2H	Long Break Lines	2H, H	Cross Hatching Lines	2H,H
Lettering	H, F, HB	Visible Lines	H, F, HB	Extension Lines	2H, H
Dimension Lines	2H, H	Cutting Plane Lines	H, F, HB	Short Break lines	H, F, HB

For convenience we will use 2H or H and HB pencils for our assignments and class drawings.

T-square:
1. Used to draw horizontal straight line.
2. Used to guide the triangles when drawing vertical and inclined lines.

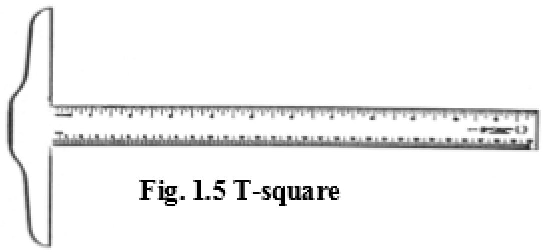
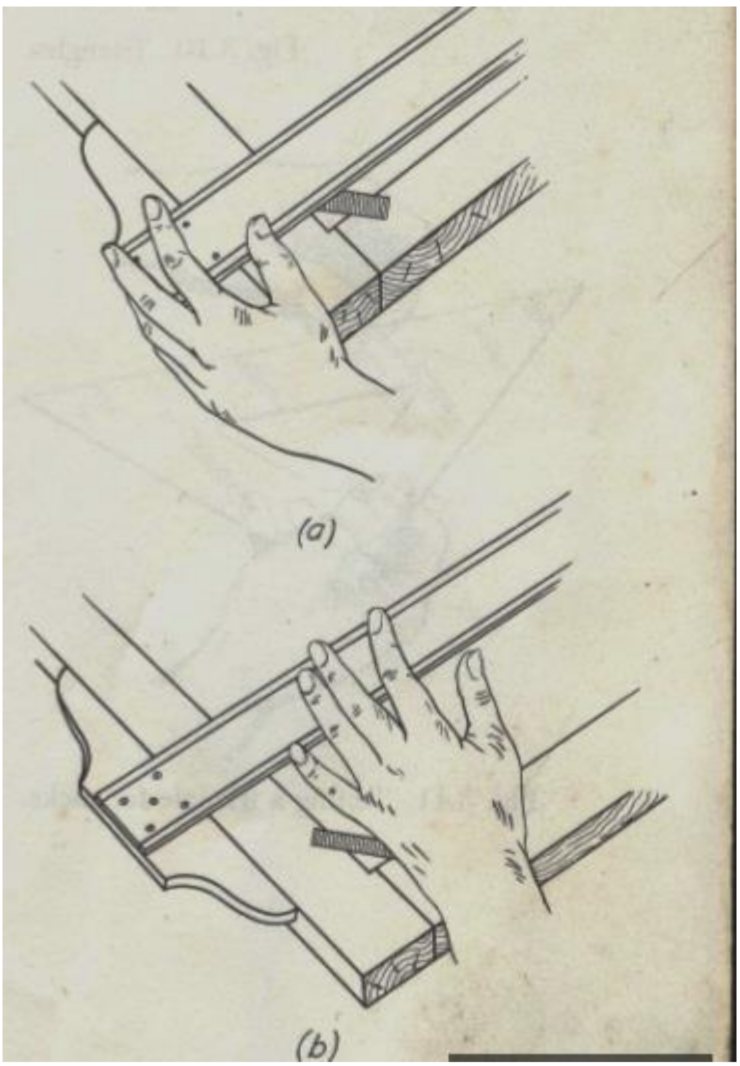
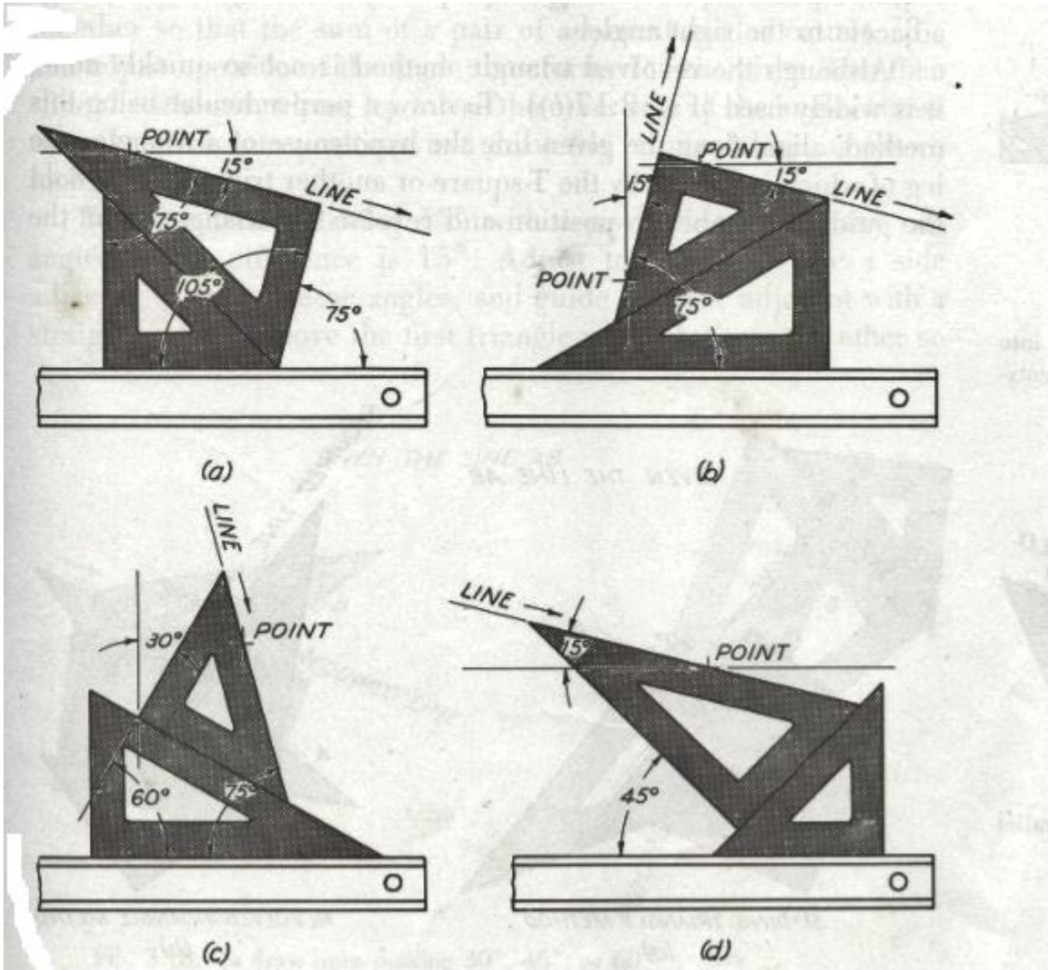


Fig. 1.5 T-square



Set-square:
1. Used to construct the most common angles (i.e. 30^0 , 45^0 and 60^0) in technical drawings.
2. Used to draw parallel and perpendicular lines quickly and conveniently.



Drawing inclined lines with triangles.

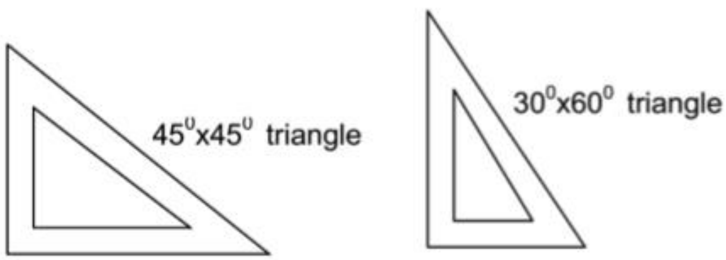


Fig. 1.6 Set-square

Protractor:

It is used for laying out and measuring angle.

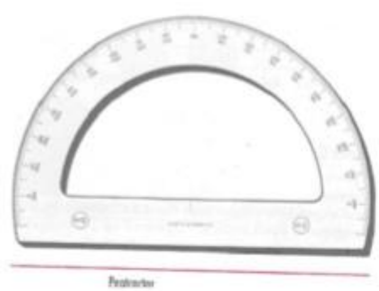


Fig. 1.7 Protractor

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Scale (ruler):
A number of kinds of scales are available for varied types of engineering design. Scales with beveled edges graduated in mm are usually used.

Compass
It is used to draw circles and arcs both in pencil and ink. It consists of two legs pivoted at the top. One leg is equipped with a steel needle attached with a screw, and other shorter leg is, provided with a socket for detachable inserts.

Dividers:
Used chiefly for transferring distances and occasionally for dividing spaces into equal parts. i.e. for dividing curved and straight lines into any number of equal parts, and for transferring measurements.

French curve:
It is used to draw irregular curves that are not circle arcs. The shape varies according to the shape of irregular curve.

Fig. 1.9 Compass and Divider

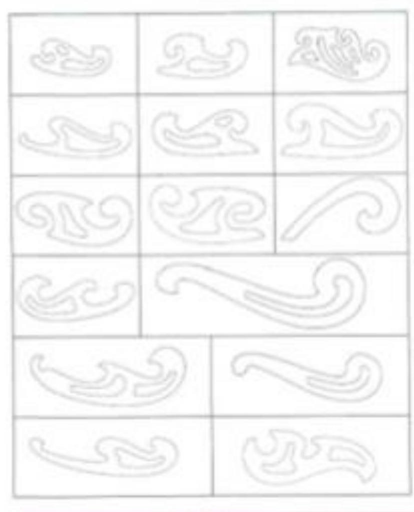
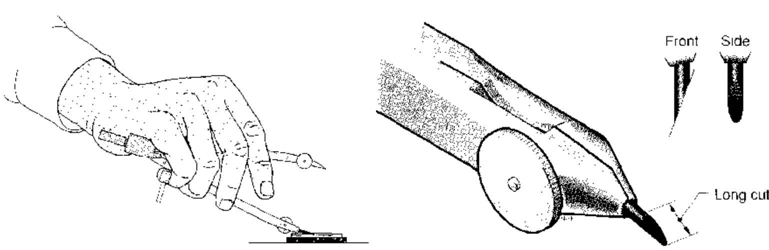


Fig. 1.10 French Curves



Sharpening of the pencil end of the compass

Review Questions
1. Define drawing and classify it.
2. What are the differences between engineering drawing and artistic drawing?
3. Why Engineering drawing is called the language of engineers?
4. What are specific applications of engineering drawing for your discipline?
5. Classify engineering drawing and give example of each branch.
6. Classify civil engineering drawing.
7. What is difference between plan, elevation and section?
8. Name some codes/standards of engineering drawing. Which one is used in Bangladesh/USA/UK?
9. Name some common drawing instruments and their uses.
10. What is the standard size of a drawing board?
11. What is the standard proportion of drawing paper's length and width?
12. What is the measurement of an A0/A1/A2/A3/A4 paper?
13. What is the difference between white drawing paper and tracing paper?
14. How pencils are classified?
15. On what considerations you will choose pencil for a drawing?
16. Which pencil should be used for drawing object boundary/guideline/dimension line/border line/texts.
17. How paper quality affects choice of pencil?
18. Which angles can be drawn directly with set-squares?

CHAPTER 2 LINES AND LETTERING

Objectives (Lines)
Objective of studying this chapter are:
¬ To learn to explain the different line types
¬ To learn to mention the application of each line type in technical drawings
¬ To learn to mention the application of different symbols.

2.1 Conventional Lines
Each line on a technical drawing has a definite meaning and is drawn in certain ways. There are certain conventional lines recommended by drawing codes. Usually two types of widths are used for the lines; they are thick and thin. Thick lines are in between 0.5 mm to 0.8 mm wide while the thin lines are between 0.3 mm to 0.5 mm wide. However, the exact thickness may vary according to the size and type of drawing. If the size of drawing is larger, the width of the line becomes higher. There should also be a distinct contrast in the thickness of different kinds of lines, particularly between the thick lines and thin lines. Visible, cutting plane and short break lines are thick lines, on the other hand hidden, center, extension, dimension, leader, section, phantom and long break lines are thin.

Table 2.1 Conventional Lines and Their Usage

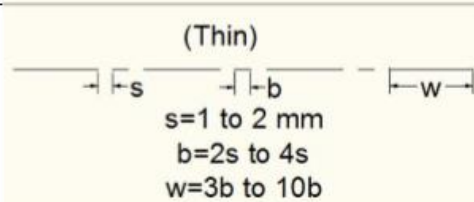
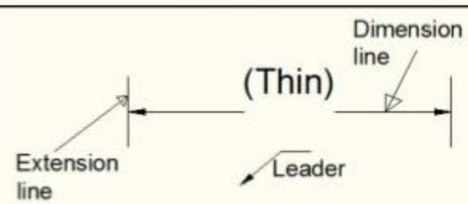
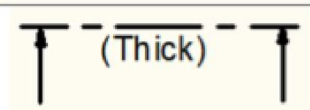
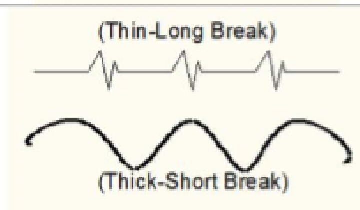
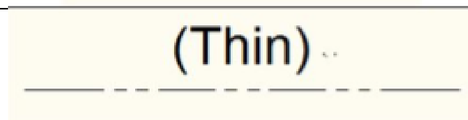
SL No.	Name of line type	Line appearance	Usage
01	Visible line/ Object line		To indicate all visible outlines/boundary of an object. It shows the shape of an object
02	Hidden line/ Dashed line		To represent hidden edge of an object. They should end on both sides by touching the visible lines and should touch themselves at intersection (if any).
03	Center line		To show a line passing through center of hole, pitch line etc.
04	Extension line, Dimension line and leaders		To show dimension of an object

Table 2.1 Conventional Lines and Their Usage (Contd.)

SL No.	Name of line type	Line appearance	Usage
05	Section line		To indicate cut portion of an object
06	Cutting plane line		To show imaginary cutting of an object.
07	ISO cutting planeline		
08	Break lines		To show break of an object in order to shorten the view of a long part.
09	Phantom line/ Repeat line		To show alternate position of an object or the position of an adjacent part.

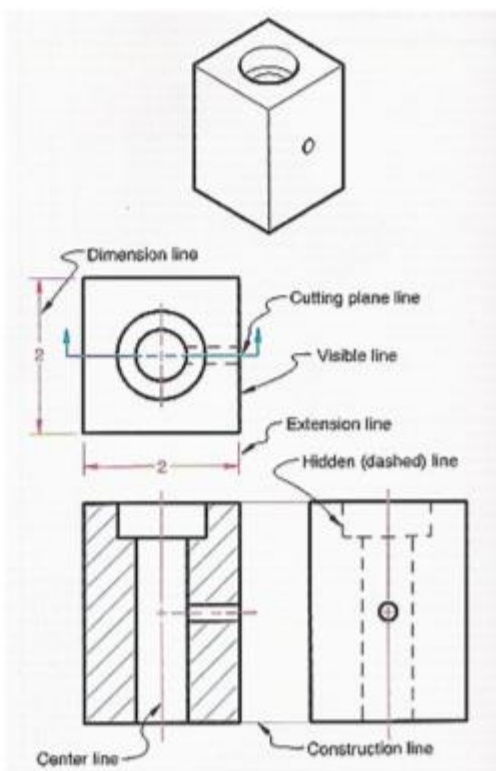
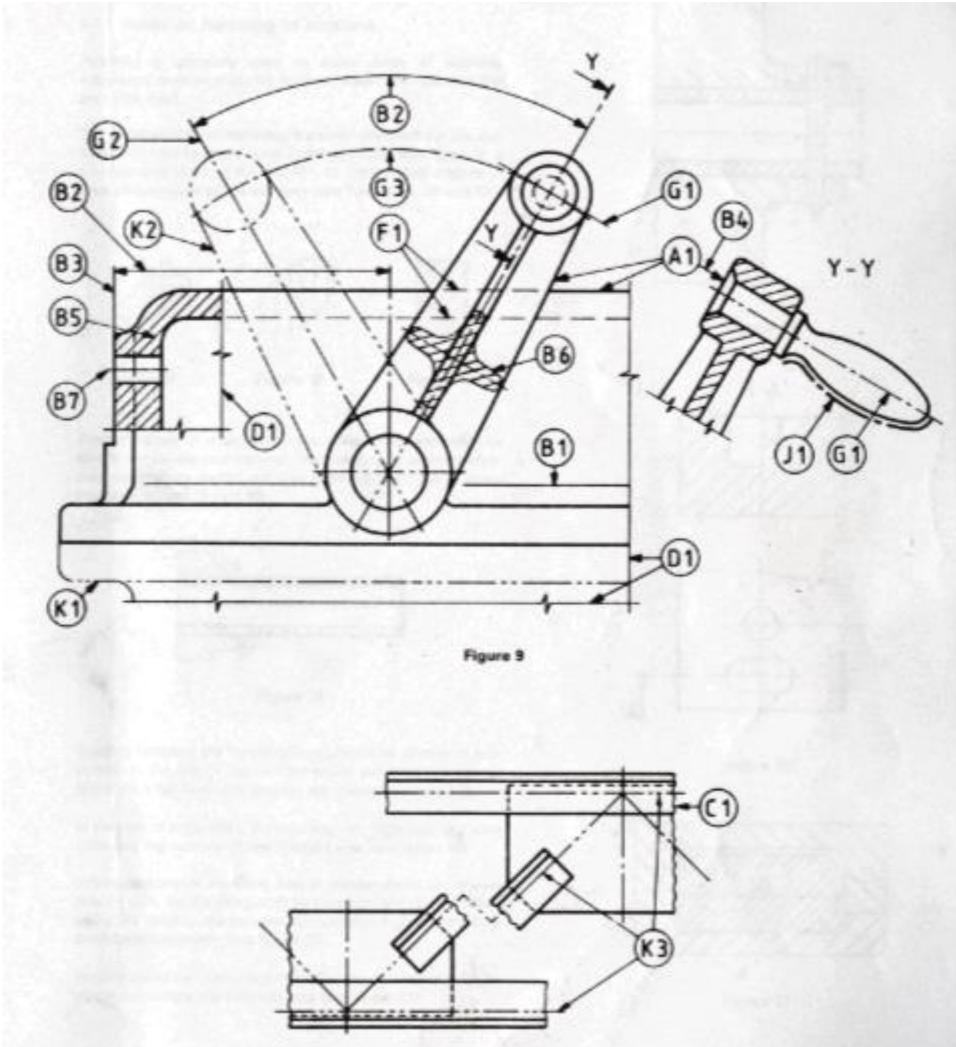


Fig. 2.1 Use of Different Types of Lines

Line	Description	General applications See figures 9, 10 and other relevant figures
A	Continuous thick	A1 Visible outlines A2 Visible edges
B	Continuous thin (straight or curved)	B1 Imaginary lines of intersection B2 Dimension lines B3 Projection lines B4 Leader lines B5 Hatching B6 Outlines of revolved sections in place B7 Short centre lines
C	Continuous thin freehand 2)	C1 Limits of partial or interrupted views and sections, if the limit is not a chain thin
D 1)	Continuous thin (straight) with zigzags	D1 line (see figures 53 and 54)
E	Dashed thick 2)	E1 Hidden outlines E2 Hidden edges
F	Dashed thin	F1 Hidden outlines F2 Hidden edges
G	Chain thin	G1 Centre lines G2 Lines of symmetry G3 Trajectories
H	Chain thin, thick at ends and changes of direction	H1 Cutting planes
J	Chain thick	J1 Indication of lines or surfaces to which a special requirement applies
K	Chain thin double-dashed	K1 Outlines of adjacent parts K2 Alternative and extreme positions of movable parts K3 Centroidal lines K4 Initial outlines prior to forming (see figure 58) K5 Parts situated in front of the cutting plane (see figure 48)

1) This type of line is suited for production of drawings by machines.

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



1. Why have you studied lines
2. Draw a standard hidden/ center/ cutting plane/ section/ break line and show an example of its use.
3. What is the standard proportion of solid segments and gaps in a hidden/center line.
4. Why there is no specified proportion for dimension and extension line?
5. What is difference between applicability of a section line and a break line?
6. Which conventional lined are to be drawn with 2H pencils?
7. Which conventional lined are to be drawn with HB pencils?
8. What is the standard symbol to show diameter/ radius/ slope/ datum?
9. What is the standard symbol for single /double opening in/out doors?
10. What is the standard symbol for showing sectioning through earth/ concrete/ brick/ metal/ wood.
11. What is the standard symbol to show inductor/ resistor/ gates?
12. Draw some electrical symbol for household weiring.

LETTERING AND NUMBERING

Objectives

Objectives of studying this chapter are:

¬ To know different style of lettering.

¬ To learn to write letters and numbers according to the standard

LETTERING

GENERAL. The lettering must be sharp and dense to assure good reproduction. The single stroke inclined or vertical letters and numerals which are illustrated should be used for all general purposes. One style of lettering should be used throughout a drawing. Original lettering should be matched when making additions or revisions.

On mechanical drawings it is recommended that capitals be used for all lettering. On the body of structural drawings it is customary to use lower case letters with the first letters of principal words capitalized. Identifying titles, however, are in capital letters.

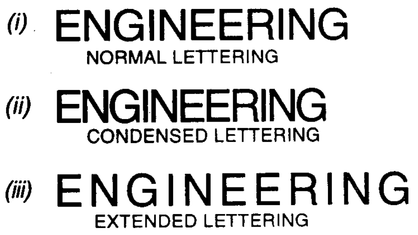
Classification of Letters

Extended and Condensed Letters

To meet design or space requirements, letters may be narrower and spaced closer together, in which case they are called “Compressed” or “Condensed” letters. If the letters are wider than normal, they are referred to as “Extended” letters.

Requirement of Good Lettering:

- ✓ The proportion of lettering refers to the relationship between the height, width and spacing of each letter. There is no fixed standards for the proportions of each letter, but the following proportions of lettering are known:



Technique of Lettering

"Any normal person can learn to letter if he is persistent and intelligent in his efforts." While it is true that "Practice makes perfect," it must be understood that practice alone is not enough; it must be accompanied by continuous effort to improve.

There are three necessary steps in learning to letter:

¬ Knowledge of the proportions and forms of the letters and the order of the strokes.

¬ Knowledge of composition- the spacing of the letters and words.

¬ Persistent practice, with continuous effort to improve.

Guide Lines

Extremely light horizontal guidelines are necessary to regulate the height of letters. In addition, light vertical or inclined guidelines are needed to keep the letters uniformly vertical or inclined. Guidelines are absolutely essential for good lettering and should be regarded as a welcome aid, not as an unnecessary requirement. Make guidelines light, so that they can be erased after the lettering has been completed. Use a relatively hard pencil such as a 4H to 6H, with a long, sharp, conical point.

Guidelines for Capital Letters

On working drawings, capital letters are commonly made 3mm high, with the space between lines of lettering from 2 mm to the full height of the letters. The vertical guidelines are not used to space the letters (as this should always be done by eye while lettering), but only to keep the letters uniformly vertical, and they should accordingly be drawn at random. A guideline for inclined capital letters is somewhat different. The spacing of horizontal guidelines is the same as for vertical capital lettering. The American Standard recommends slope of approximately 68.2^0 with the horizontal and may be established by drawing a "sloped triangle", and drawing the guidelines at random with T-square and triangles.

Guidelines for Lower-Case Letters

Lower-case letters have four horizontal guidelines, called the cap line, waistline, and base line and drop line. Strokes of letters that extend up to the cap line are called ascenders, and those that extend down to the drop line, descenders. Since there are only five letters (p, q.g, j, y) that have descenders, the drop lines are little needed and are usually omitted. In spacing guidelines, space "a" may vary from 3/5to 2/3 of space "b". 27The term single stoke or one stoke does not mean that the entire letter is made without lifting the pencil. But the width of the stroke is the width of the stem of the letter.

Summary of ISO rules for Lettering

1. Most of the lettering is done in single stroke either in vertical or in inclined manner.
2. Only one style of lettering should be used throughout the drawing.
3. Lettering can be done either in free hand or using templates.
4. Proportion of Height & width a. For A,M,O,Q,T,V,X and Y, Height = Width. b. For W, height<Width.. c. For Other latters, Height>Width. d. For all numbers Height>Width
5. Line thickness of lower & upper case letters are made same as well as uniform.
6. Distance between adjacent lines or space between letters or numbers $\geq 2\times h$
7. If thickness of 2 adjacent line is different, spacing $=2\times h$ x Thickness of heavier line
8. Standard height of letters and numbers are 2.5,3.5,5.0,7.0,10.0,14.0 and 20.0 mm
9. Height of letter or number≥2.5
10. When both capital and lower-case letters are to be combined, if c=2.5mm then h will be 3.5mm.

ASSIGNMENT 1

TITLE; LINES AND LETTERING

1 Copy the following in 3 mm, 6mm, and 10 mm guide lines

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

a b c d e f g h I j k l m n o p q r s t u v w x y z

1 2 3 4 5 6 7 8 9 0

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

a b c d e f g h I j k l m n o p q r s t u v w x y z

1 2 3 4 5 6 7 8 9 0

2 Copy the following in 10 mm guide lines

4 HOLES Φ5.5 SPACED AS SHOWN

3 BOSSES Φ16 EQUISPACED ON 108 PCD

DRILL AND REAM IN POSITION FOR Φ4.7 TAPER PIN

24 SERRATIONS 30 LG ONE LEFT UNCUT WHERE SHOWN

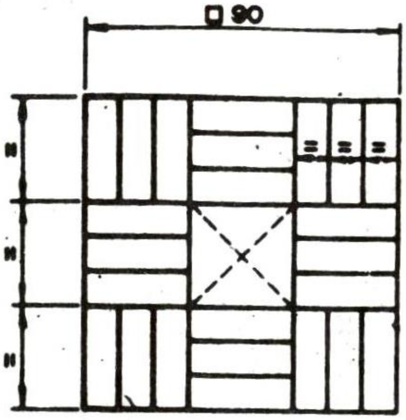
C’BORE BRONZE BUSH Φ24 X 9.5 DEEP ON ASSEMBLY

CADIUM PLATE 0.05 THICK ALL OVER EXCEPT WHERE MARKED

3 Copy the following figures

LINE PROBLEMS

1



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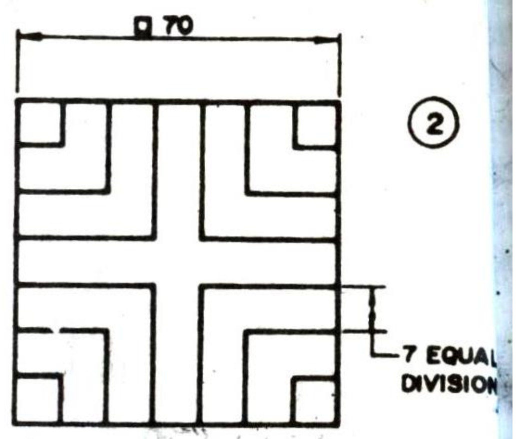

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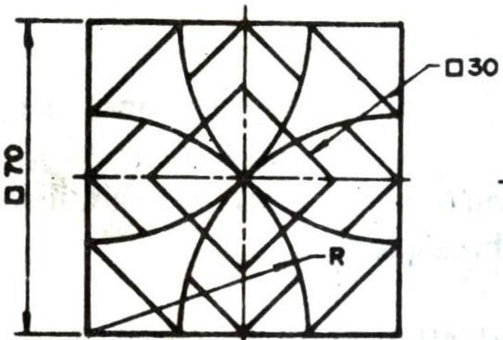

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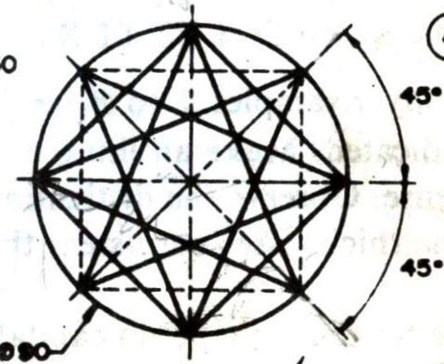

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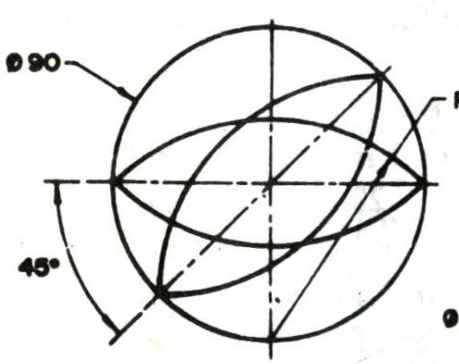

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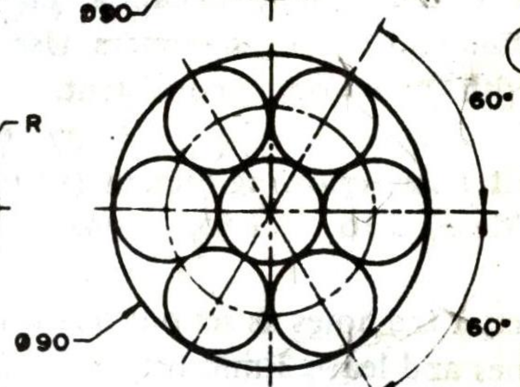

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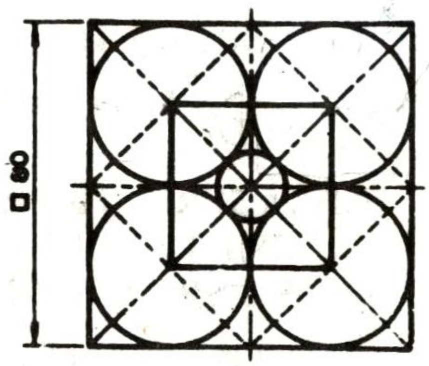

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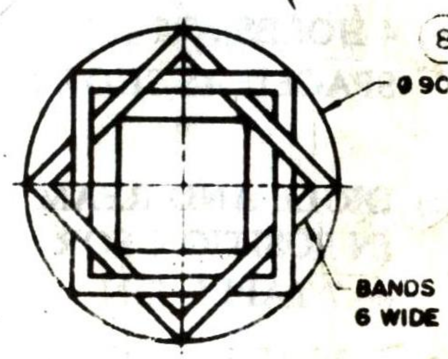


Review Questions:
1. Why have you studied lettering?
2. What is the difference between Gothic and Roman letters?
3. Write the letter “A”/ “a”/“T” in Gothic, Roman, Italic and Text style.
4. Which style of lettering is most commonly used in engineering drawing and why?
5. What do you mean by guidelines? Why is it used?
6. How guidelines are drawn for uppercase/lowercase letters?
7. What are the ISO rules for lettering?
8. How do you maintain the spaces between letters, words and lines?
9. Which letters have equal height and width?
10. Which letters have height>width and which one have width>height?
11. What are the standard heights of letters in engineering drawing?
12. Write a word/your name/Course code in single stroke gothic letters.

CHAPTER 3 GEOMETRIC CONSTRUCTION

Objectives

Objectives of studying geometric figures are:
- To learn to define geometric nomenclatures like angles, lines etc.
- To improve expertise in using drawing instruments.
- To learn the steps to construct different geometric figures like lines, arcs, polygon, ellipse etc. in convenient way.

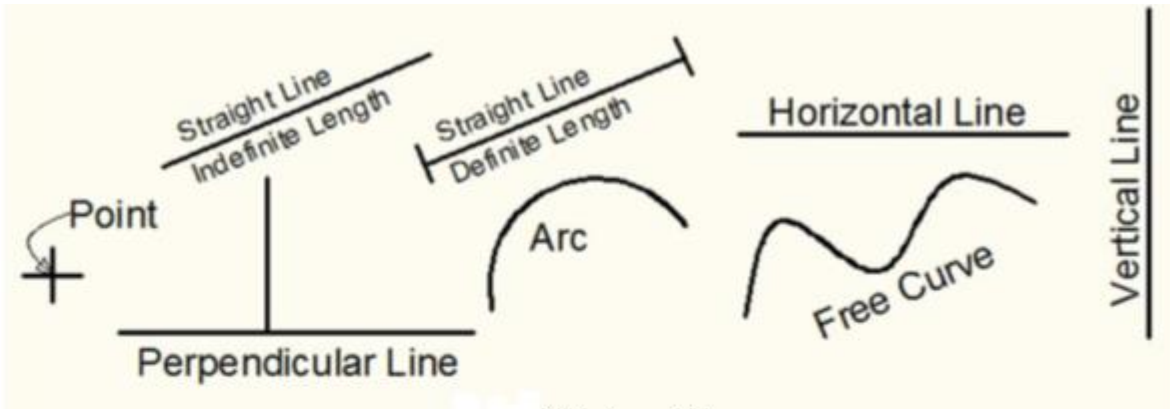
3.1 Introduction

To be truly proficient in the layout of both simple and complex drawings, the drafter must know and fully understand the many geometric construction methods used. These methods are illustrated in this chapter, and are basically simple principles of pure geometry. These simple principles are used to actually develop a drawing with complete accuracy, and in the fastest time possible, without wasted motion or any guesswork. Applying these geometric construction principles give drawings a finished, professional appearance. Strict interpretation of geometric construction allows use of only the compass and an instrument for drawing straight lines but in technical drawing, the principles of geometry are employed constantly, but instruments are not limited to the basic two as T-squares, triangles, scales, curves etc. are used to make constructions with speed and accuracy. Since there is continual application of geometric principles, the methods given in this chapter should be mastered thoroughly. It is assumed that students using this book understand the elements of plane geometry and will be able to apply their knowledge.

3.2 Geometric Nomenclature

3.2.1 Points in Space

A point is an exact location in space or on a drawing surface. It is actually represented on the drawing by a crisscross at its exact location.



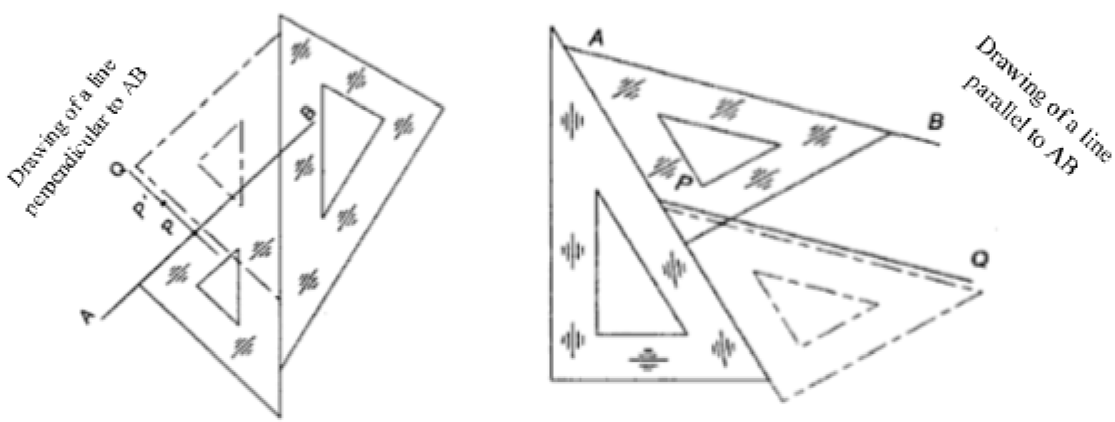
Points and Lines

3.2.2 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.

3.3 Techniques of Geometric constructions

To construct the above mentioned geometric figures, we have to know some principles and procedures of geometric construction. Thus, the remaining of this chapter is devoted to illustrate step-by-step geometric construction procedures used by drafters and technicians to develop various geometric forms. First of all we have to be well-expertise in using set squares particularly for drawing parallel and perpendicular lines.



Use of Set-Square for Making Parallel and Perpendicular Lines

How to Bisect a Line or an Arc

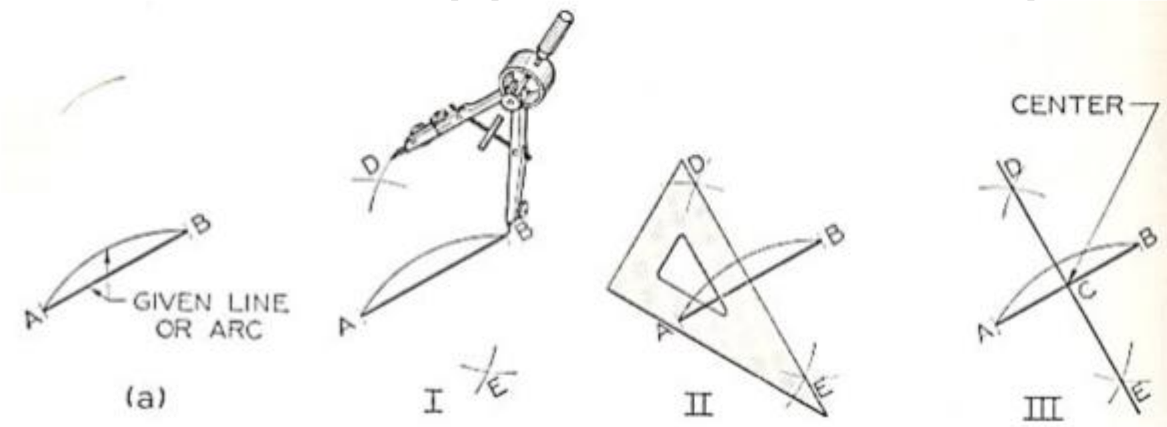
To bisect a line means to divide it in half or to find its center point. In the given process, a line will also be constructed at the exact center point at exactly 90^0
.

Given: Line A-B

Step 1: Set the compass approximately two-thirds of the length of line A-B and swing an arc from point A.

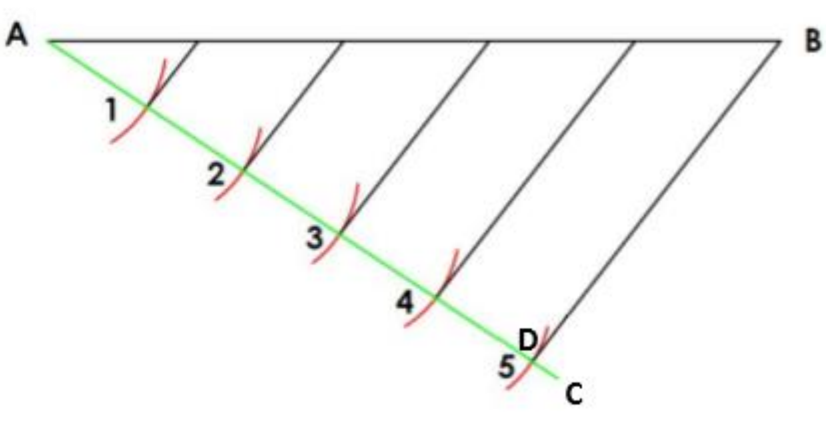
Step 2: Using the exact same compass setting, swing an arc from point B.

Step 3: At the two intersections of these arcs, locate points D and E
Step 4: Draw a straight-line connecting point D with point E. Where this line intersects line A-B, it bisects line A-B. Line D-E is also perpendicular to line A-B at the exact center point.



Bisecting an Arc or a Line

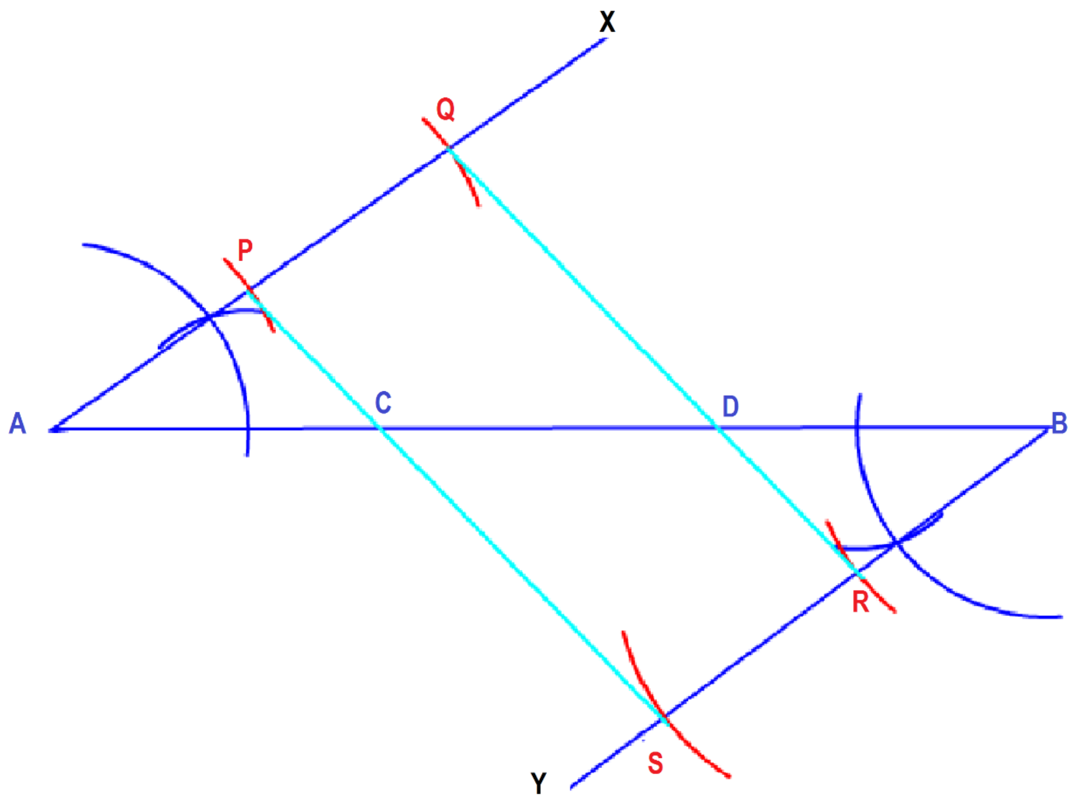
Divide a Line into a Number of Equal Parts
Given: Line A-B
Step 1: Draw a construction line AC that starts at end A of given line AB. This new line is longer than the given line and makes an angle preferably of not more than 300 with it.
Step 2: Find a scale that will approximately divide the line AB in to the number of parts needed (5 in the example below), and mark these divisions on the line AC. There are now 'n' equal divisions from A to D that lie on the line AC (5 in this example).
Step 3: Set the adjustable triangle to draw a construction line from point D to point B. Then draw construction lines through each of the remaining 'n-1' divisions parallel to the first line BD by sliding the triangle along the straight edge. The original line AB will now be accurately divided.



Dividing a Line into 5 Equal Parts

To Trisect a line
1. Start with the given line segment AB.

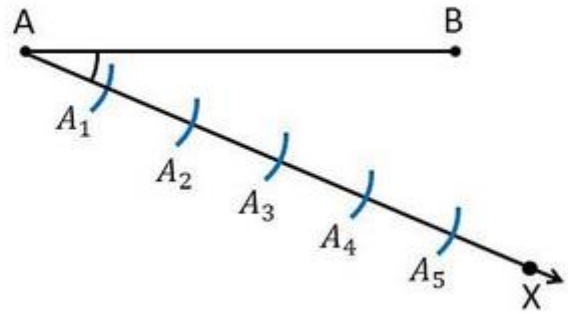
2. At A, draw a new line AX through A not coinciding with AB.
3. Using any convenient length, mark off points P and Q on that line such that AP = PQ.
4. Through B, draw a line BY parallel to AX.
5. On this line, using the same length as before, mark off points R and S such that BR = RS = AP = PQ, and R and S are on opposite sides of line AB from points P and Q.
6. Connect PS and QR. Those two lines will cut AB into equal thirds. AC = CD = DB

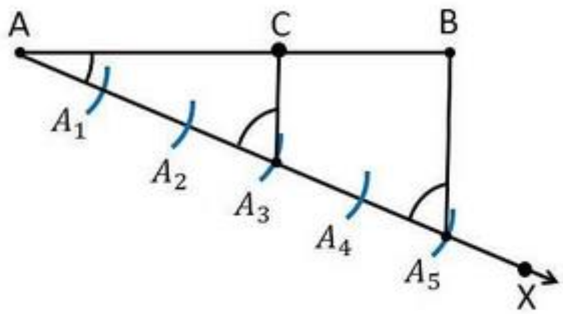


To trisect a given line AB

To divide a given line AB in a given ratio say. Ratio 3:2

1. Draw the given AB
2. Draw any ray AX
3. Mark 5 points (3+2) A_1, A_2, A_3 A_4, A_5 on AX such that $AA_1 = A_1A_2 = A_2A_3 = A_3A_4 = A_4A_5$ by drawing equal arcs

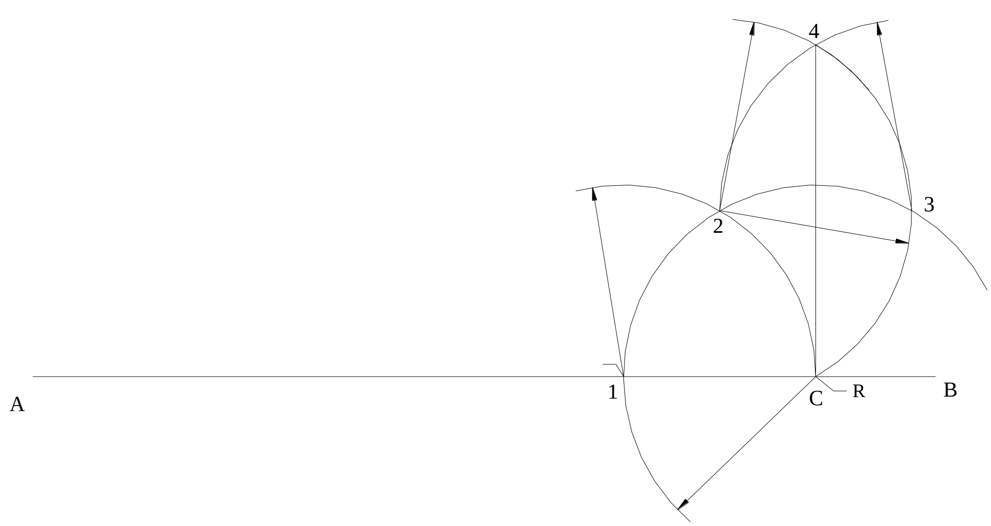




To divide a line in a given ratio say 3:2

4. Join BA_5
5. Since we want ratio 3:2. Through point A_3 draw a line parrarrel to A_5B by making $<AA_3C = < AA_5$. Thus AC:B = 3:2

To construct a line perpendicular to a given line AB through a point C on the line



i. With any arbitrary radius R, and C as centre describe an arc to intersect the line AB to give point 1.

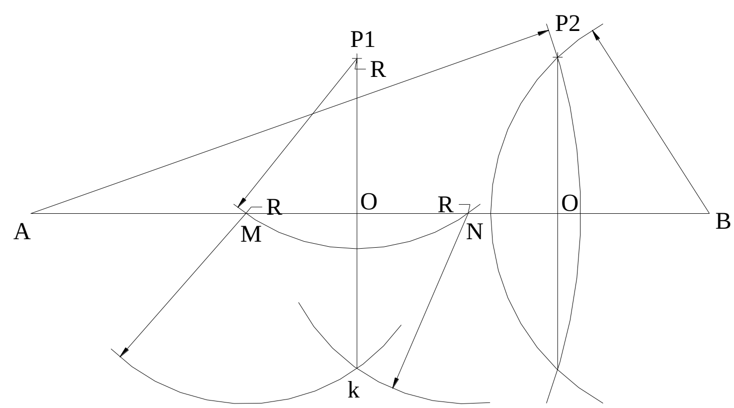
ii. With the same radius R and with 1 as centre, describe arc to intersect the arc obtained in step 1 to give point 2.

iii. With point 2 as centre and same radius R describe arc to obtain point 3.

iv. With points 2 and 3 as centres describe arcs to intersect one another to obtain point 4.

v. The line 4C is perpendicular to AB.

To construct a line perpendicular to a given line AB through a point P outside the line



a. The given point is nearly over the middle of the given line

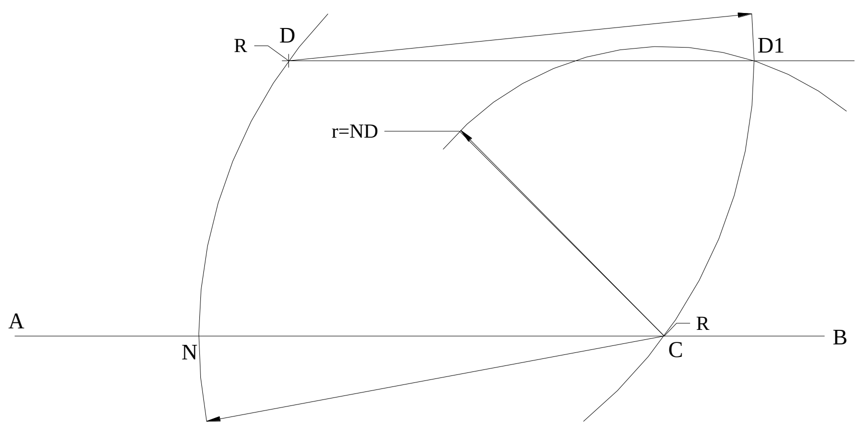
1. With any arbitrary radius R and P_1 as centre describe an arc to intersect the line AB to give points M and N.
2. With the same radius R and with M and N as centre, describe arcs to intersect each other to give point k.
3. Join P_1 and k thereby cutting the line at O. The line OP is the perpendicular line.

b. The given point is nearly over the extremity of the given line

1. With A and B as centres describe an arcs that pass through P_2 and intersect each other.
2. Draw a line through the intersects of these arcs that cut the line at O.

3. The line OP is the perpendicular.

Construct a line through the point D and parallel to a given line (AB)



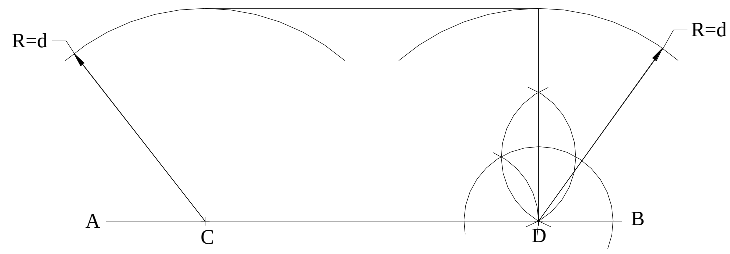
i. With the point D as the centre describe an arbitrary arc with radius R to cut the line AB at C.

ii. At point C on the line AB describe an arc with the same radius R through D to intersect the line AB at N.

iii. With the point C as centre describe an arc with the radius $r = \mathrm{ND}$ to cut the arc in step 1 to obtain the point D1.

iv. Draw the parallel line through points D and D1.

Construct a parallel line at a given distance d to a given line AB

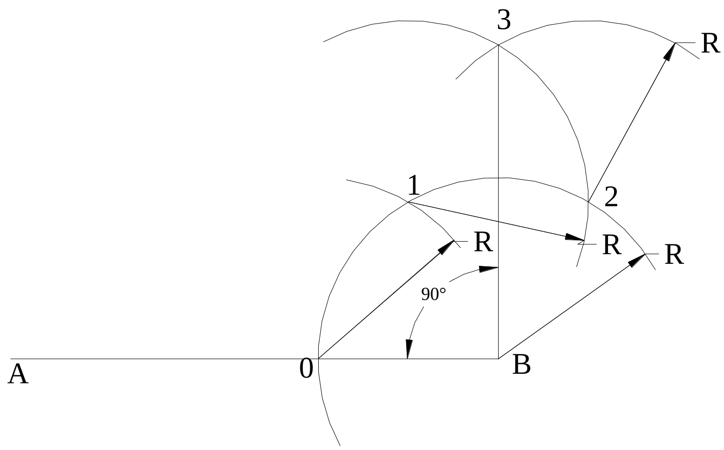


i. Select two points C and D on line AB at convenient distance apart.
ii. With points C and D as centres describe arcs with radius R=d on one side of AB.
iii. Erect a perpendicular at D.
iv. Draw a line just to touch the two arcs.

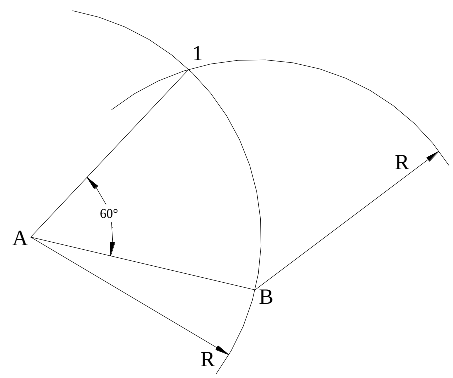
Angles

An angle is the inclination between two intersecting lines.

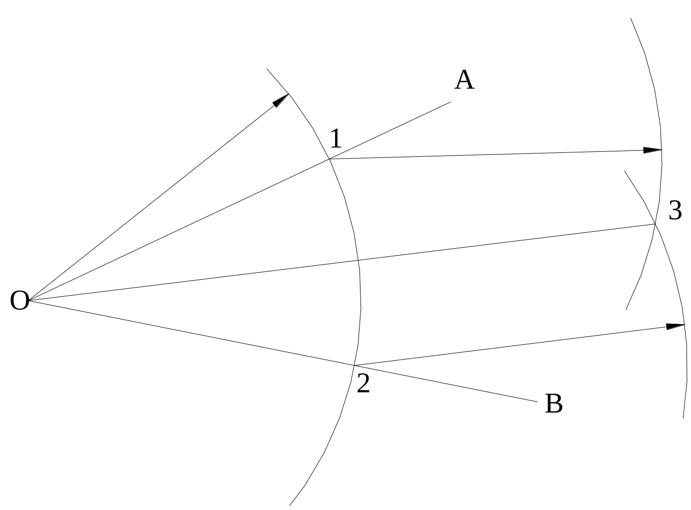
<u>Construction of a 90° angle</u>



. <u>Construction of a 60° angle</u>



. Bisection of an Angle (30°, 15°, 45°)



i. Draw the angle $A\hat{O}B$ (using a protractor or a setsquare).

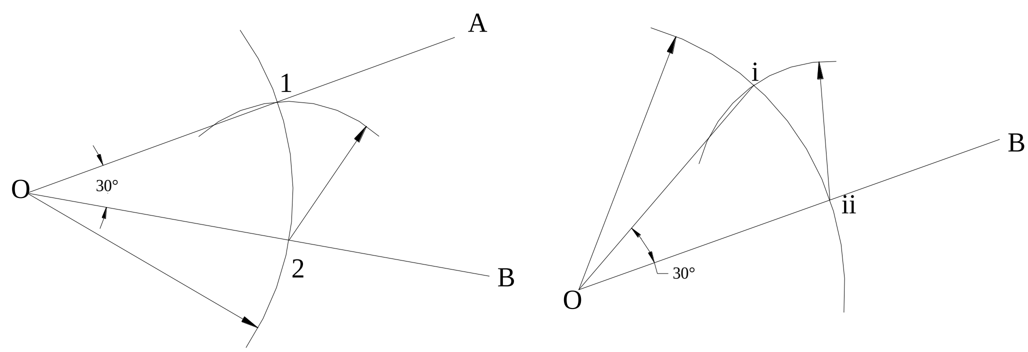
ii. With an arbitrary radius R and centre O describe an arc to cut OB and OA at 1 and 2 respectively.

iii. With 1 and 2 as centres describe arcs with radius R to intersect each other at 3.

iv. Draw a line from O to 3.

v. The angle $A\hat{O}3 = 3\hat{O}B$

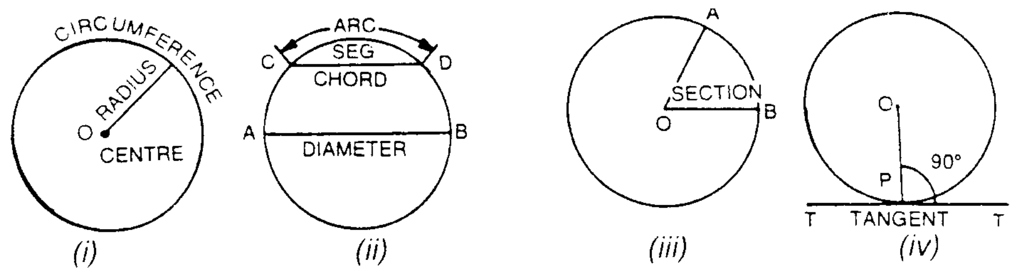
5. <u>Transfer of an Angle AOB to a new position & orientation</u>



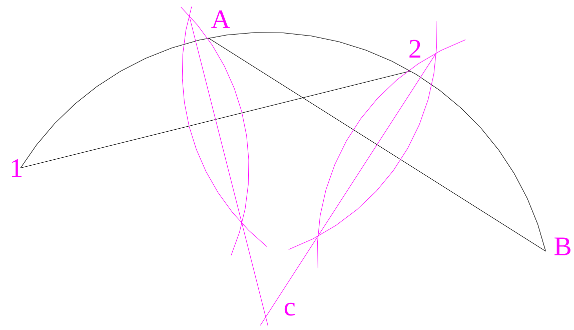
1. Draw line $O^{/}B^{/}$ properly oriented at the new location.
2. On the original angle with O as datum and with any arbitrary radius R_1 describe an arc to cut OA and OB at 1and 2 respectively.
3. At the new position and with the same radius R_1, describe an arc with centre $O^{/}$ to cut $O^{/}B^{/}$ at ii.
4. On the original angle with 2 as centre pick the radius R_2= 12 of the arc that passes through 1.
5. At new position with centre ii and radius R_2, describe an arc to cut the arc drawn in step 3 at i.
6. Draw a straight line through O and i.
7. Angle <i$\hat{O}$ ii= <A$\hat{O}$ B.

Circles and Arcs

A circle is a plane figure bounded by the circumference that is always equidistance from a fix point known as the centre.



1 To find the centre point of a circle

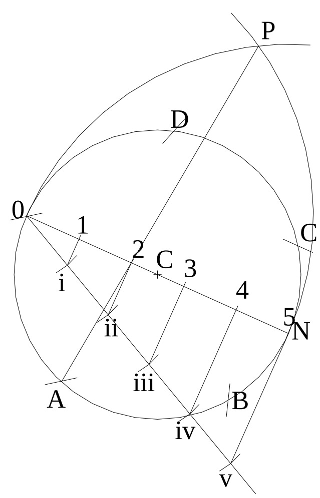


i. Construct two chords that are not parallel to another on the circle.

ii. Construct perpendicular bisectors to the two chords.

iii. The interception of the perpendicular bisectors is the centre point.

2 <u>Divide the circumference of a Circle into a number of equal parts. Inscribe a regular polygon given the diameter of a circle</u>



i. Draw a line 0N that cuts the circle and goes through the centre of the circle.

ii. Divide the line 0N equally into the number of parts required eg. 5.

iii. With 0 and N as centres describe arcs of radius R= diameter to intersect each other to give the point P.

iv. Draw a line from P through point 2 to cut the other side of the circle (point A).

v. With A as centre describe an arc of radius $r = 0\mathrm{A}$ to intersect the circle at point B.

vi. Repeat step 5 for points C, D, etc.

3 Determine the Length of an arc

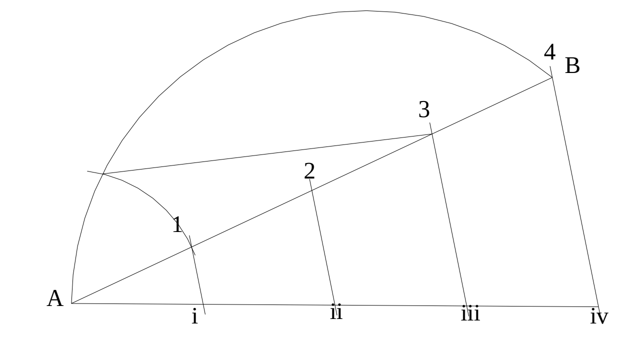
There are two methods available:

Method A

i. The chord is equally divided into four parts and labelled 1 to 4,

ii. With A as centre and radius A1 an arc is prescribed to give point C on the arc,

iii. Draw a line from C to 3, the distance C3 is equal to half the length of the arc AB



Method B

i. Draw the chord AB, and bisect the chord to intersect the arc to give the point C. This perpendicular bisector will also go through the centre of the arc O.

ii. Draw a line from O to B, and construct a perpendicular to OB through B.

iii. With B as the centre and radius equal to BC prescribe an arc.

iv. Extend the line AB to intersect the arc obtained in the above step to yield the point D.

v. With D as the centre and radius AD prescribe an arc to intersect the line BM to give the point E.

vi. The length of the line EB is equal the length of the arc.

4 Determine the Circumference of circle (given the diameter)

i. Draw a circle with the required diameter.

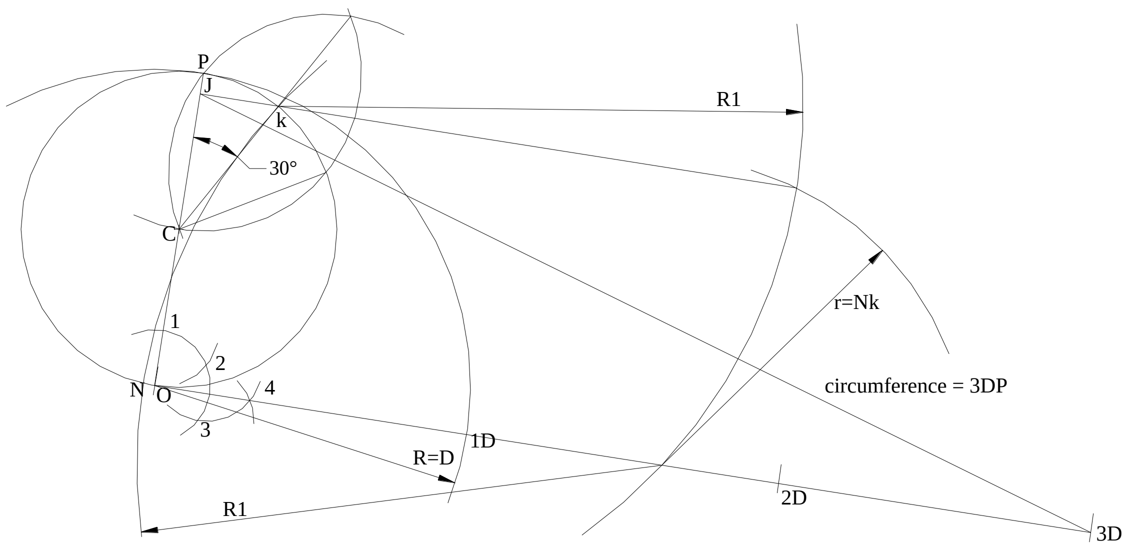
ii. Select a point P the circle and draw a line from P through the centre to intersect the other side of the circle to give the point O.

iii. Construct a perpendicular to OP through O and locate points 1D, 2D and 3D at interval of the diameter.

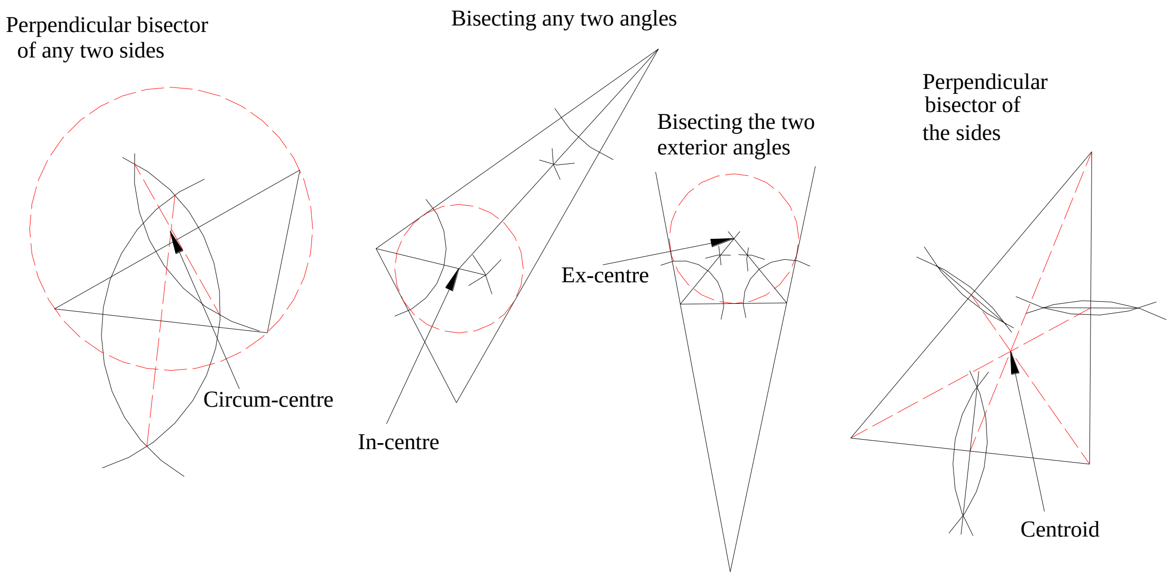
iv. Construct a line inclined 30° upwards to OP and passing through C to cut the circle at k.

v. Construct a line parallel to 3DO passing through k to intersect line OP at J.

vi. Join J to 3D, the length 3DJ is the circumference.



Circum-centre, in-centre, ex-centre and centre of a given triangle



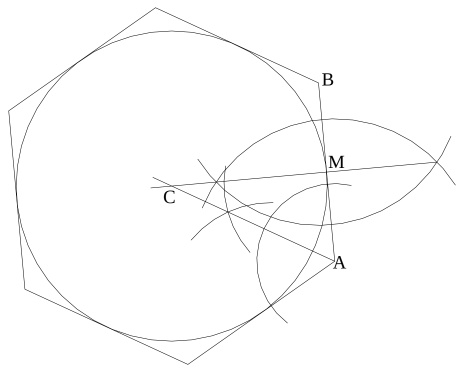
Polygons

A polygon is a plane figure bounded by more than 4 straight sides. (pentagon, hexagon, heptagon, octagon, nonagon, decagon etc.). A regular polygon has all its sides equal (exterior and interior angles are constant).

It is possible to construct a circle within (inscribed) a <u>regular</u> polygon so that all its sides are tangential to that circle. The diameter of that circle is called the diameter of the polygon.

It is also possible to circumscribe a circle to a regular polygon.

To construct the inscribed circle of a regular polygon



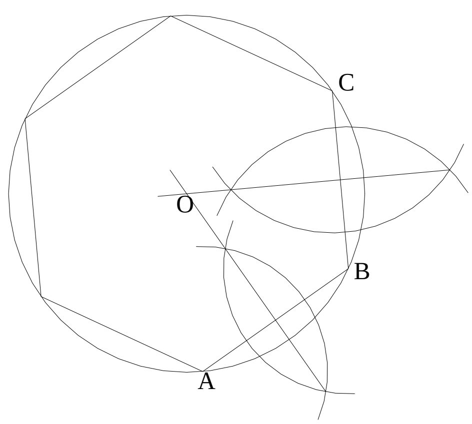
i. Perpendicularly bisect any side AB to give M,

ii. Bisecting of adjacent angle to AB to intersect the above perpendicular bisector to give the centre C

iii. Centre C prescribe a circle or radius CM.

iv. C is the centre of the inscribed circle (The centre is called the incentre).

2 <u>Circumscribed circle of a regular polygon</u>



i. Perpendicularly bisect any two sides to give O,

ii. Centre O prescribe a circle or radius OA

iii. O is the centre of the circumscribed circle (The centre is called the ex-centre).

To draw a regular pentagon given a side AB

1. Draw the given line AB
2. Centre A radios AB draw circle 1
3. Centre B radius AB draw circle 2

4. Centre C radius AB draw circle 3

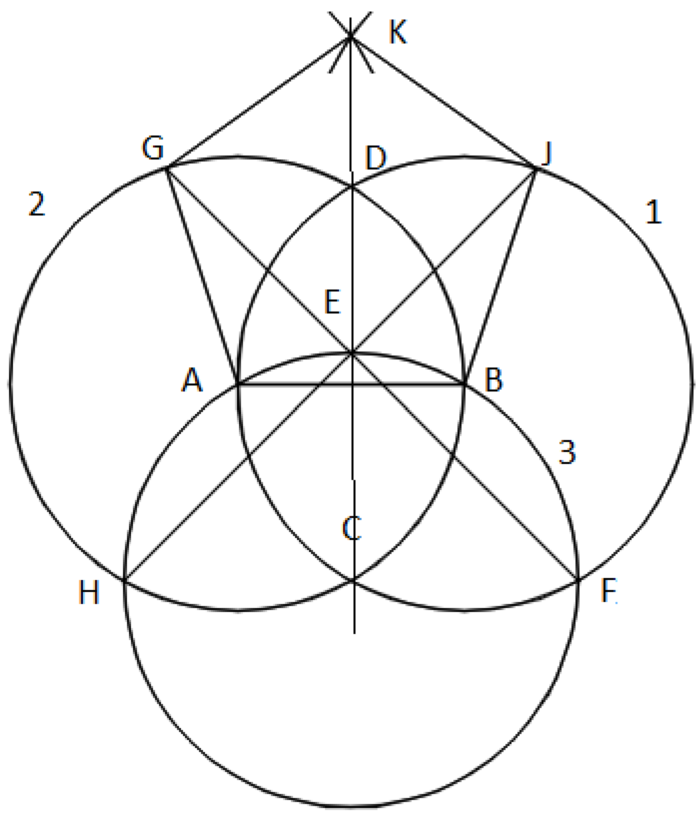
5. Join D to C

6. Join F to E and extend to G

7. Join H to E and extend to J

8. With centres G and J radius Ab mark point K

ABJKG is the required pentagon



Construct a regular pentagon given side AB

To CONSTRUCT ANY REGULAR POLYGON WITH A GIVEN LENGTH OF SIDE

To draw a nine-sided regular polygon with length of side equal to AB,

1. Extend AB to C, making CA equal to AB.

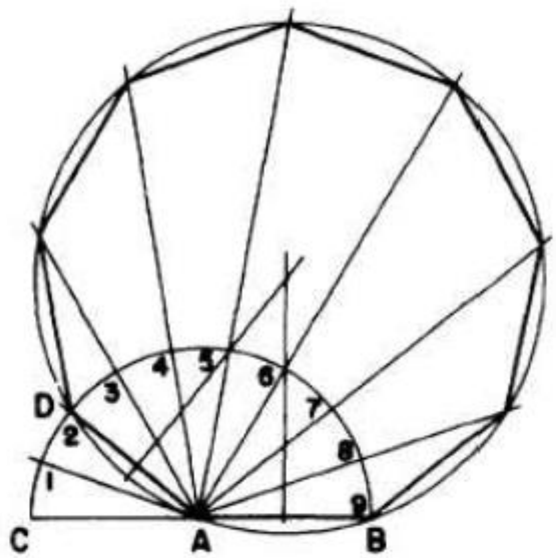
2 With A as a center and AB (or CA) as a radius, draw a semicircle as shown.

3. Divide the semicircle into nine equal segments from C to B with a protractor), and draw radii from A to the points of intersection. The radius A2 is always the second side of the polygon.

4.Draw a circle through points A, B, and D.

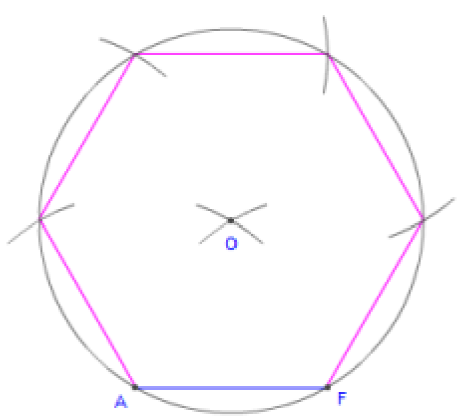
5.To do this, first erect perpendicular bisectors from DA and AB. The point of intersection of the bisectors is the center of the circle. The circle is the circumscribed circle of the polygon.

6. To draw the remaining sides, extend the radii from the semicircle as shown, and connect the points where they intersect the circumscribed circle.



.-Any regular polygon with a given length of side.

To Draw a regular hexagon given one side AF



1. Set the compasses' point on A, and set its width to F. ***the compasses must remain at this width for the remainder of the construction***.

2. From points A and F, draw two arcs so that they intersect. Mark this as point O.
This is the center of the hexagon's circumcircle.

3. Move the compasses to O and draw a circle.
This is the hexagon's circumcircle - the circle that passes through all six vertices.

4. Move the compasses on to A and draw an arc across the circle. This is the next vertex of the hexagon.

5. Move the compasses to this arc and draw an arc across the circle to create the next vertex.

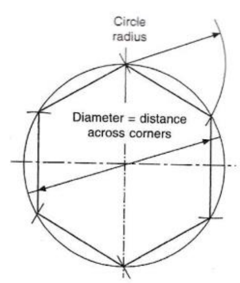
6. Continue in this way until you have all six vertices. (Four new ones plus the points A and F you started with.)

7. Draw a line between each successive pairs of vertices. These lines form a regular hexagon where each side is equal in length to AF.

To Draw a Hexagon, Given the Distance across the Corners

Method A

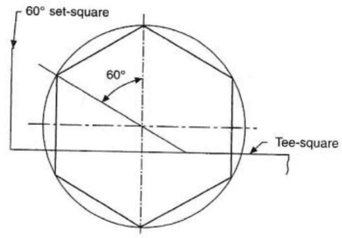
1. Draw vertical and horizontal centre lines and a circle with a diameter equal to the given distance.
2. Step off the radius around the circle to give six equally spaced points, and join the points to give the required hexagon.



Hexagon giving the distance across corners

Method B

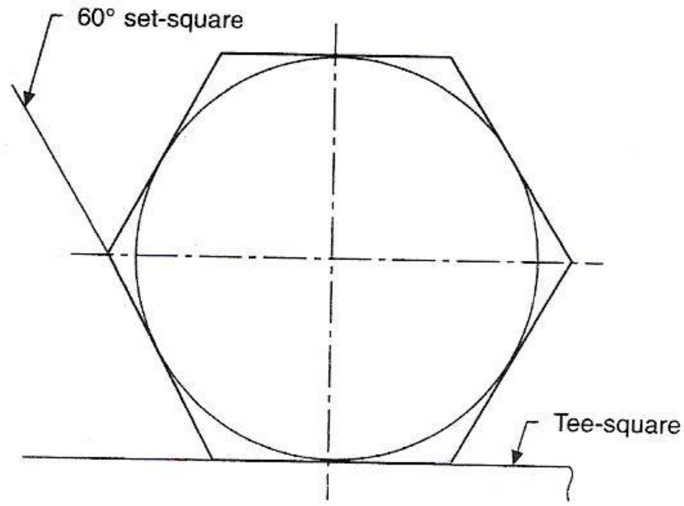
1. Draw vertical and horizontal centre lines and a circle with a diameter equal to the given distance.
2. With a 60° set-square, draw points on the circumference 60° apart.
3. Connect these six points by straight lines to give the required hexagon.



Hexagon giving the distance across corners

To Draw a Hexagon, Given the Distance across the Flats

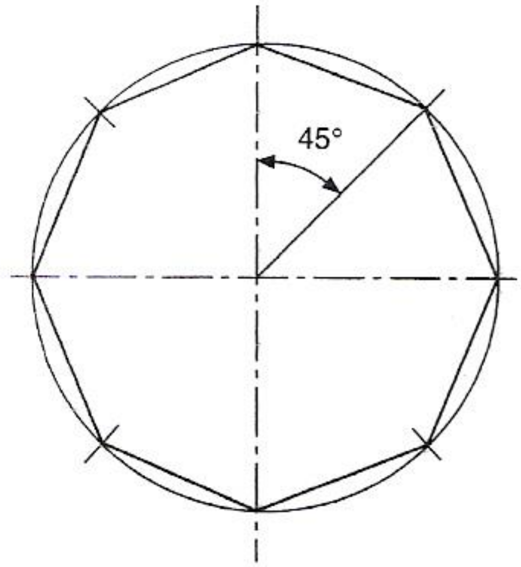
1. Draw vertical and horizontal centre lines and a circle with a diameter equal to the given distance.
2. Use a 60° set-square and tee-square as shown, to give the six sides.



Hexagon giving the distance across flats

To Draw a Regular Octagon, Given the Distance across Corners

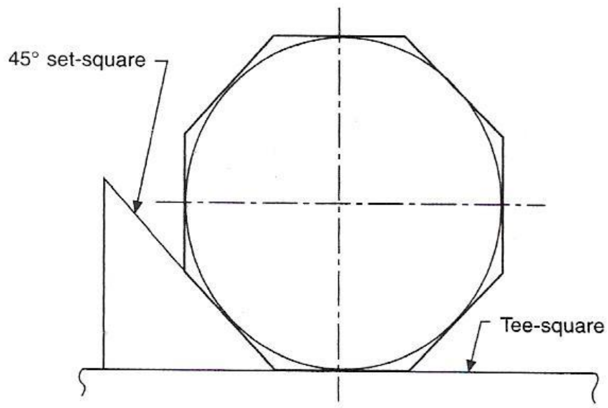
Repeat the instructions in hexagon giving the distance across corners but use a 45° set-square, then connect the eight points to give the required octagon.



Octagon given distance across corners

To Draw a Regular Octagon, Given the Distance across the Flats

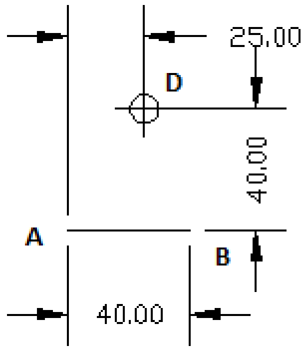
Repeat the instructions in Hexagon giving the distance across flats but use a 45° set-square to give the required octagon.



Octagon Distance across flats

ASSIGNMENT 2 GEOMETRIC CONSTRUCTION

1 Draw a line AB 89mm. Bisect the line
2 Draw a line AB, 100 mm long. Trisect the line
3 Draw a line AB 90mm. Divide the line into seven (7) equal parts.
4 Draw a line AB 90mm. Divide the line internally in the ratio: AC:CB =4:3
5 Draw a line AB 50mm. Divide the line externally in the ratio: AB:BC =4:3
6 Given a line AB = 50mm, draw a perpendicular line to AB at either A or B
7 Draw a line through D perpendicular to AB.



8 Draw a line through D parallel to AB.

9 Draw two lines making an angle 35.0^{o} with each other. Bisect the angle and transfer one half of it to a new position.

10 Draw an arc radius 40mm subtending an angle 75^{o}. Using construction, locate the centre of the arc.

11 Using the angles of the 45^{o} & 60^{o} set squares as a basis, construct the following angles: (a) 22.5^{o}, (b)15^{o}, (c) 52.5^{o}, (d) 112.5^{o}, (e) 37.5^{o}, (f) 146.25^{o}. Each angle should be shown separately and the angle indicated,

12 A triangle ABC stands on side AB as base and has the following dimensions:

AB 89mm, AC 76mm, angle CAB 67.5^{o}. Construct the triangle and draw the inscribed circle.

13 Construct a triangle ABC on AB as base with AB 70mm, AC 57mm, BC 76mm and draw the circumscribed circle.

14 Find graphically the circumference of a circle of diameter 70 mm and check the result by calculation,

15 Construct a regular hexagon to the following dimensions: (a) 90mm across flats (b) 95mm across corners.

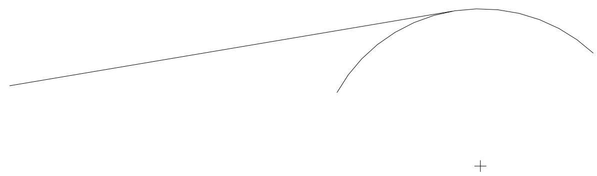
16 Draw a pentagon given one side AB 42mm.

17 Draw a circle diameter 84mm. Inscribe the circle with a regular heptagon.

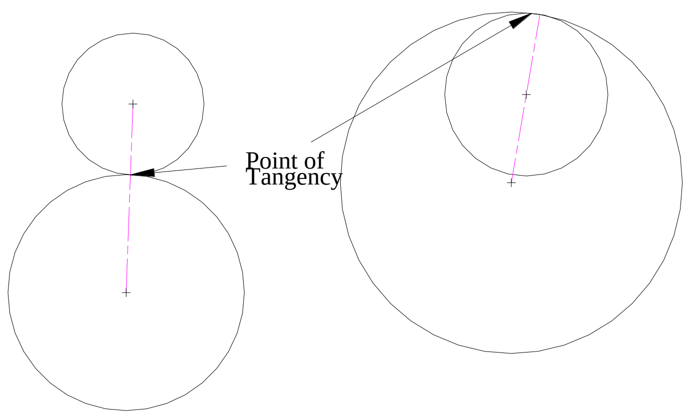
18 Draw two regular octagons, one 76mm across flats and the other 82mm across corners

Tangency

A line is said to be tangential to another line if it touches the line but does not cross it. We normally speak of a straight line and a circle or tangency relationship:



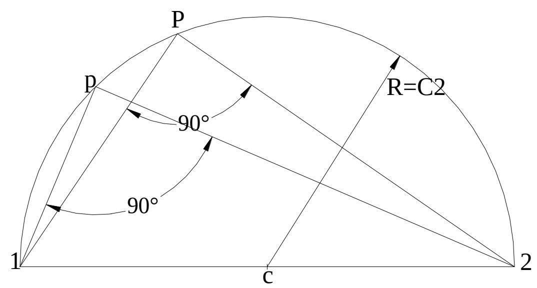
However, tangential relationship does exist between two arcs or/and circles:



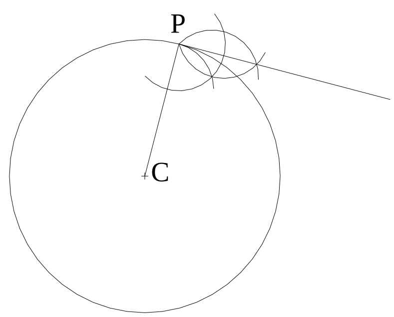
Straight line-Arc Tangency Relationship

Theory

The semi-circle theory: A line drawn from one end point of a diameter to a point on a semi-circle and than to the other end of the diameter will be at 90° to each other.



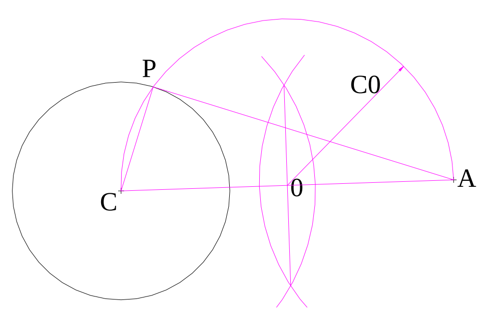
1 <u>To construct a tangent to a circle at a point P on the circle</u>



i. Draw a line from P to the centre of the circle C.

ii. Construct a perpendicular the line PC through the point P.

2 <u>To construct a line tangent to a circle through a point A outside the circle</u>

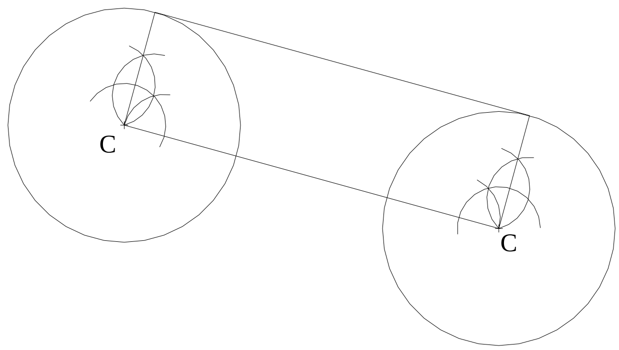


i. The point A is connected to the centre, C, of the circle.

ii. Erect a perpendicular bisector to CA which cuts CA at point O

iii. With O as centre draw a semi-circle to cut the circle at A.

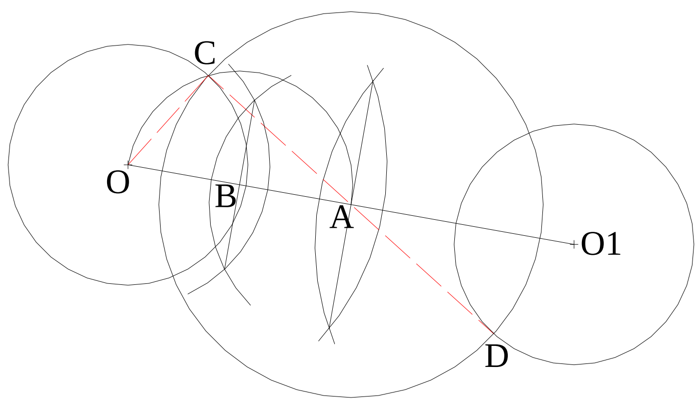
3 <u>To construct a common tangent to two equal circles (common exterior tangent)</u>



i. Join the centres of the two circles.

ii. From each centre, construct lines at 90° to the centre line. The intersection of these perpendiculars with the circles gives the points of tangency.

4 <u>To construct the common interior (Transverse or cross) tangent to two equal circles</u>



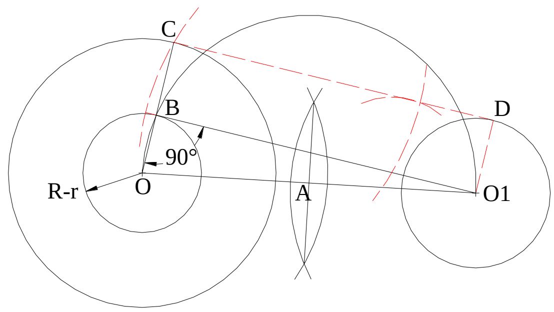
i. Join the centres of the two circles OO_1.

ii. Bisect OO_1 in A

iii. Bisect OA in B and draw a semi-circle with radius BA to cut the semi-circle at C.

iv. With centre A and radius AC draw an arc to cut the second circle in D. CD is the required tangent.

5 To construct the common exterior tangent between two unequal circles.



i. Join the two centres OO_1.

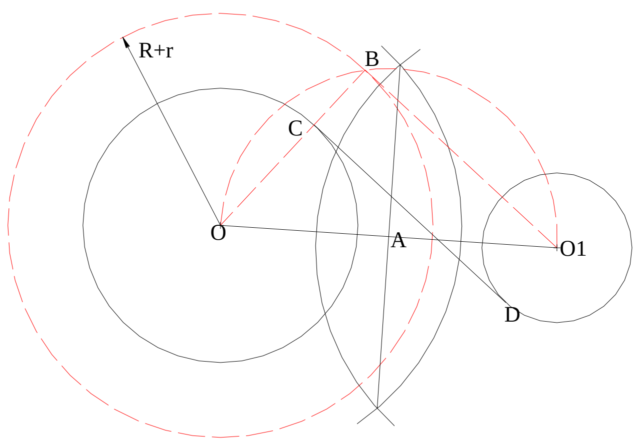
ii. Bisect OO_1 in A and draw a semi-circle of radius AO

iii. With centre O draw a circle of radius R-r to cut the semi-circle at B.

iv. Join OB and extend to cut the larger circle at C.

v. Draw CD parallel to BO_1.

6 To construct the common interior tangent between two unequal circles



i. Join the centres OO_1

ii. Bisect OO_1 in A and draw a semi-circle of radius OA

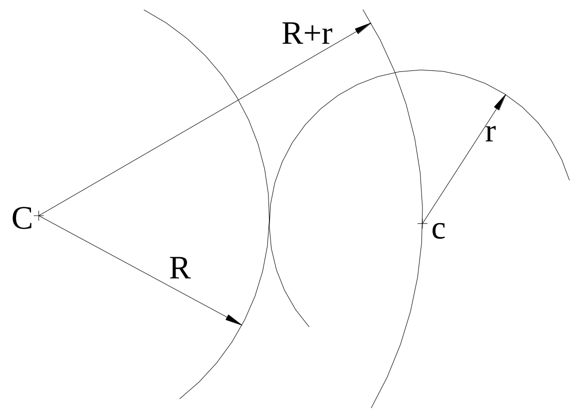
iii. With centre O draw a circle of radius R+r to cut the semi-circle at B

iv. Join OB. This cuts the small circle at C.

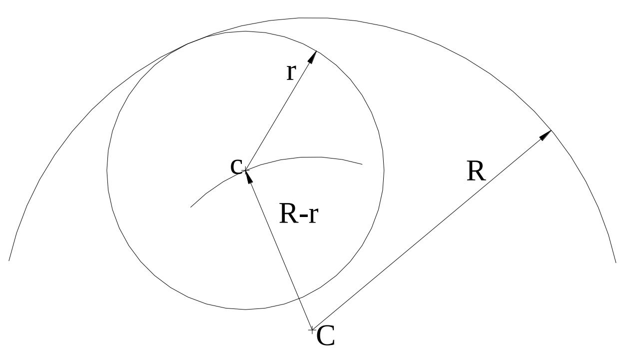
v. Draw CD_1D parallel to BO_1.

Arc-Arc Tangential Relationship

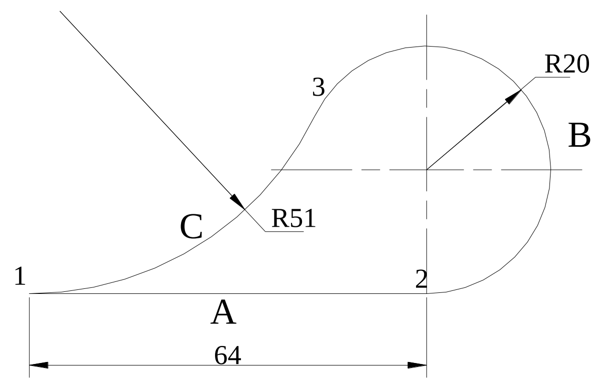
1. <u>External tangential relationship between two arcs</u>



2. <u>Internal tangential relationship between two arcs</u>



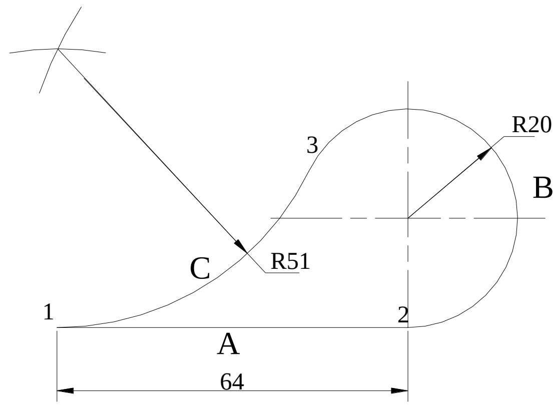
A technical drawing must entail all the necessary information required to reproduce it. It must not be left to guess work. A technical drawing consists of lines that represent the projection of the edges. This may consist of several lines that may assumed to be elements. These lines (elements) have their properties (curvature, length, position, etc.). These lines are also connected to one another under well-defined conditions: a line may either intersect another line at a particular angle or tangent another line. If therefore the property of a line or its relationship to another line is not well defined, then that drawing could be miss-read. Take a look at the figure below:



This figure consists of three elements A, B and C which are connected at points 1, 2, and 3. The element A will be the first element to be drawn. The centre of element B is explicitly given: it is located by the intersection of the centre lines. The vertical centre line goes right through the connecting point 2 and that establishes the tangential relationship between elements A and B. On the other hand, the centre of element C is not explicitly given. It is therefore determined by determining its relationships at points 1 and 3.

The location of point 1 is clear given, and therefore the centre of the arc C that goes through 1 must be on an arc of radius 51 from 1. That means it could be an intersect or a tangent point.

The location of the point 3 is not explicitly given. The simplest assumption required to locate point 3 is to assume the point 3 is an external tangential relationship.



c