Geometric Drawing

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.

Geometric Nomenclature

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.

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.

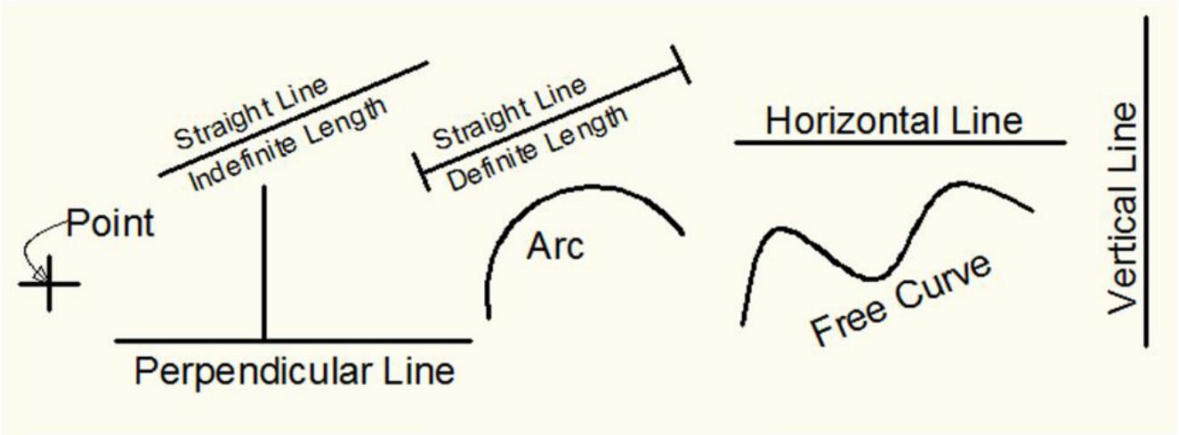


Fig. Points and Lines

Angle

An angle is formed by the intersection of two lines. There are three major kinds of angles: right angels, acute angles and obtuse angles.

Triangles

A triangle is a closed plane figure with three straight sides and their interior angles sum up exactly 180^0. The various kinds of triangles: a right triangle, an equilateral triangle, an isosceles triangle, and an obtuse angled triangle.

Quadrilateral

It is a plane figure bounded by four straight sides. When opposite sides are parallel, the quadrilateral is also considered to be a parallelogram.

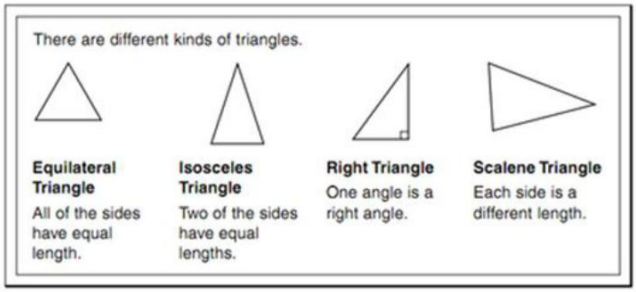


Fig. Triangles

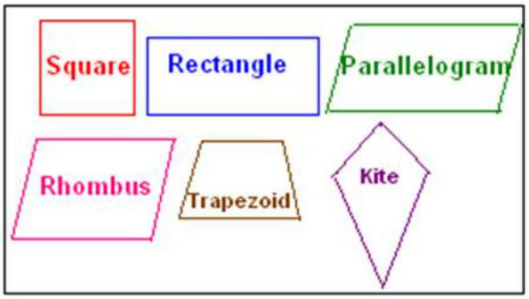


Fig. Quadrilaterals

Polygon

A polygon is a closed plane figure with three or more straight sides. The most important of these polygons as they relate to drafting are probably the triangle with three sides, square with four sides, the hexagon with six sides, and the octagon with eight sides. A polygon is said to be "Regular Polygon" when all of its sides are equal in length and each of the internal angles formed at corners are equal in magnitude. Some helpful relations to be remembered for regular polygons are:

1. $Magnitude\ of\ any\ internal\ angle = \frac{(n-2)\pi}{n};\quad here,\ n = no.\ of\ sides.$
2. $Radius\ of\ outscribing\ circle, R = \frac{s}{2sin\frac{\pi}{n}};\quad here,\ s = length\ of\ each\ side\ and\ n = no.\ of\ sides.$
3. $No.\ of\ diagonals = \frac{n(n-3)}{2}$

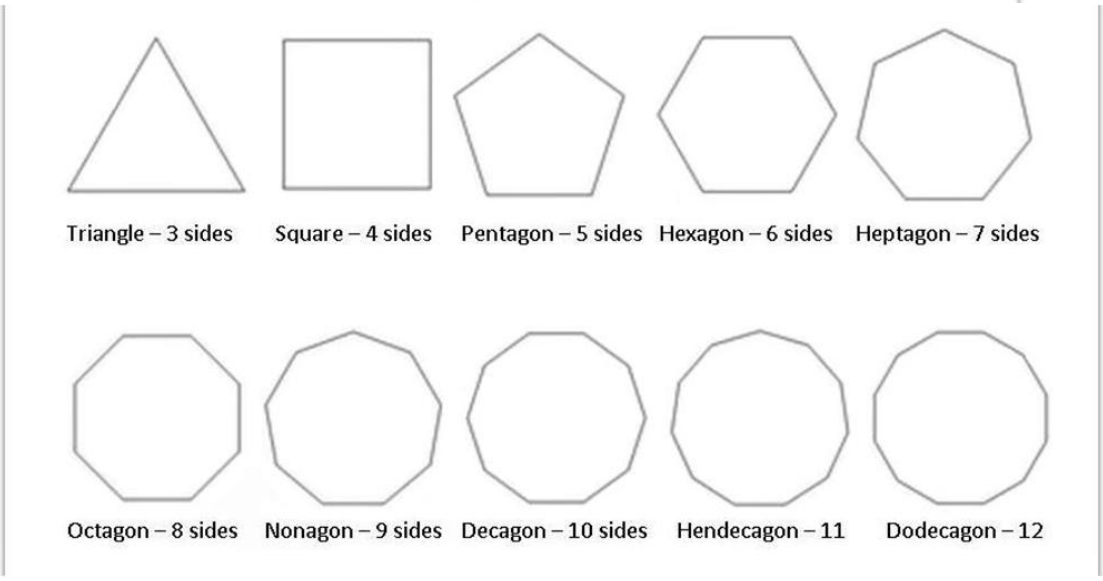


Fig. Polygons

Circle

A circle is a closed curve with all points on the circle at the same distance from the center point. The major components of a circle are the diameter, the radius and circumference.

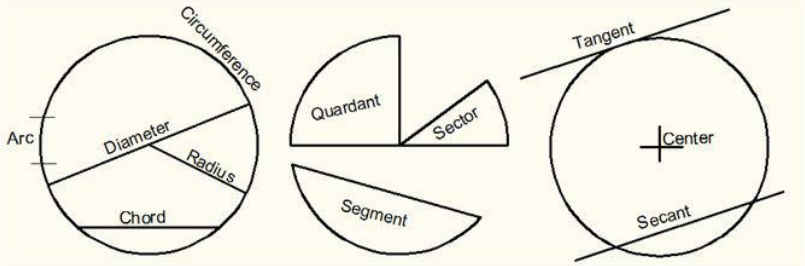


Fig. Circles

Solids

They are geometric figures bounded by plane surfaces. The surfaces are called faces, and if these are equal regular polygons, the solids are regular polyhedral.

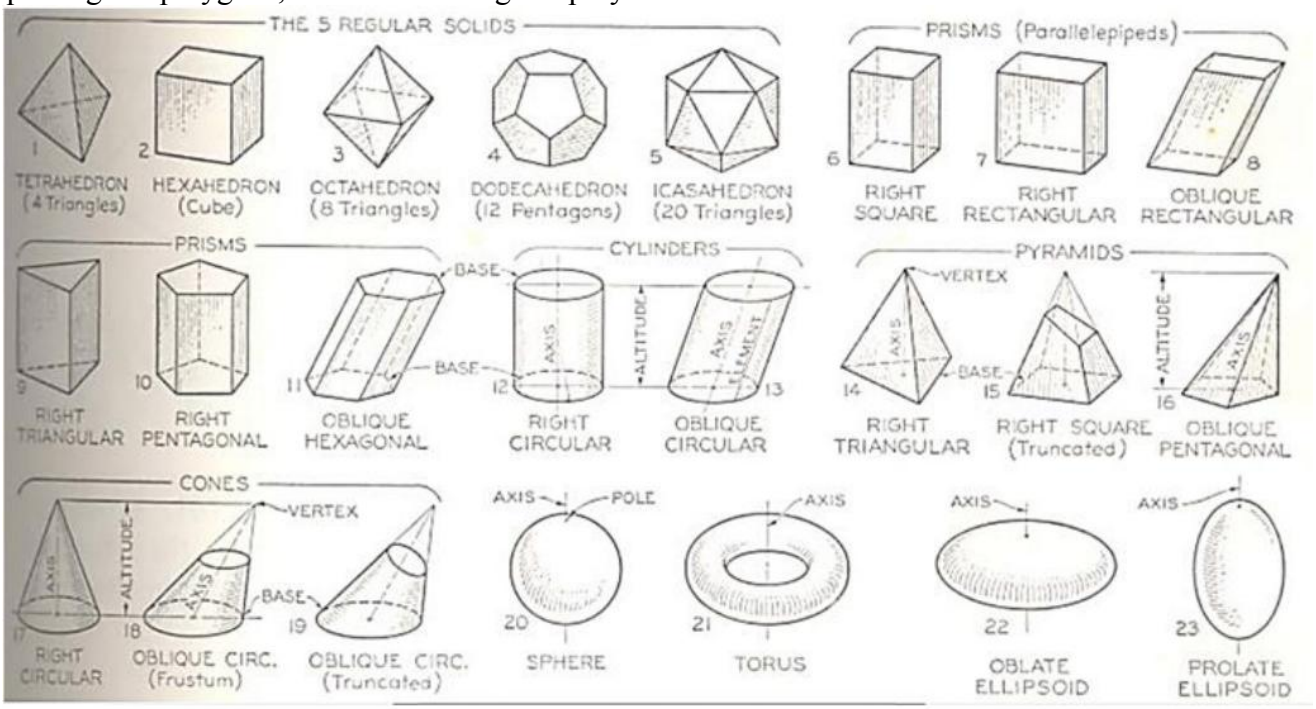


Fig. Solids

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. Fig. 4.7 illustrates it.

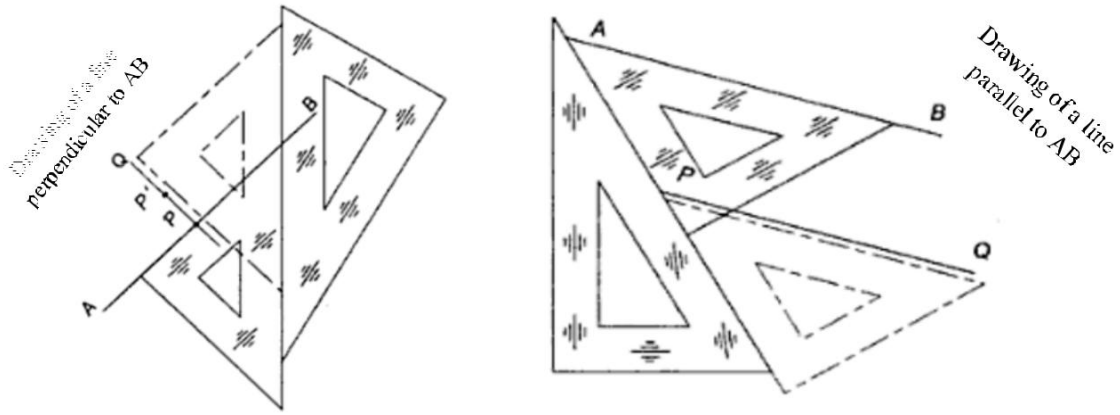


Fig. Use of Set-Square for Making Parallel and Perpendicular Lines

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.

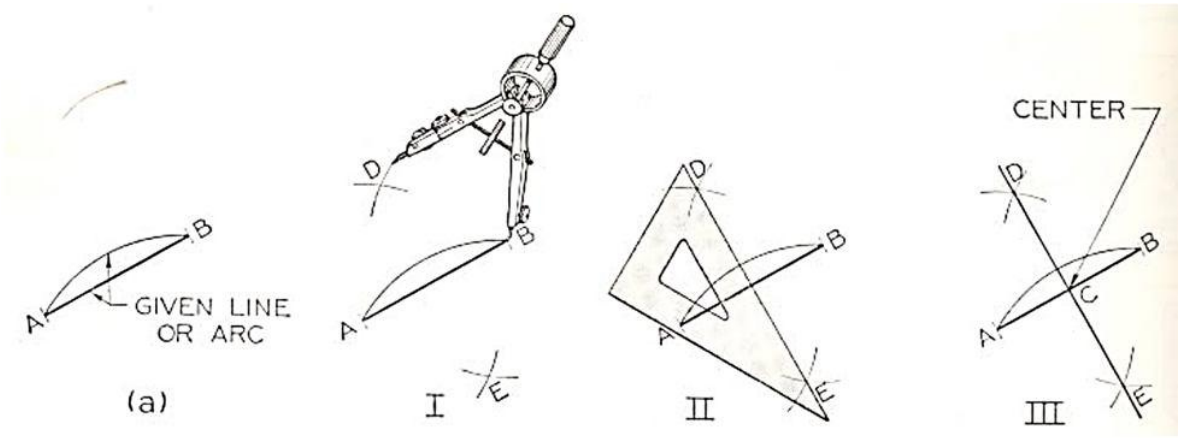


Fig. Bisecting an Arc or a Line

How to 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 30^0 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.

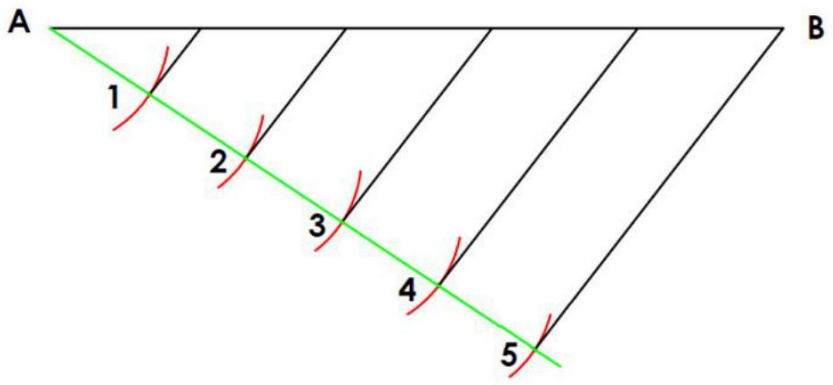


Fig. Dividing a Line into 7 Equal Parts

How to Bisect an Angle

To bisect an angle means to divide it in half or to cut it in to two equal angles.

Given: Angle BAC

 Step 1: Set the compass at any convenient radius and swing an arc from point A
 Step 2: Locate points E and F on the legs of the angle, and swing two arcs of the same identical length from points E and F, respectively.
 Step 3: Where these arcs intersect, locate point D. Draw a straight line from A to D. This line will bisect angle BAC and establish two equal angles: CAD and BAD.

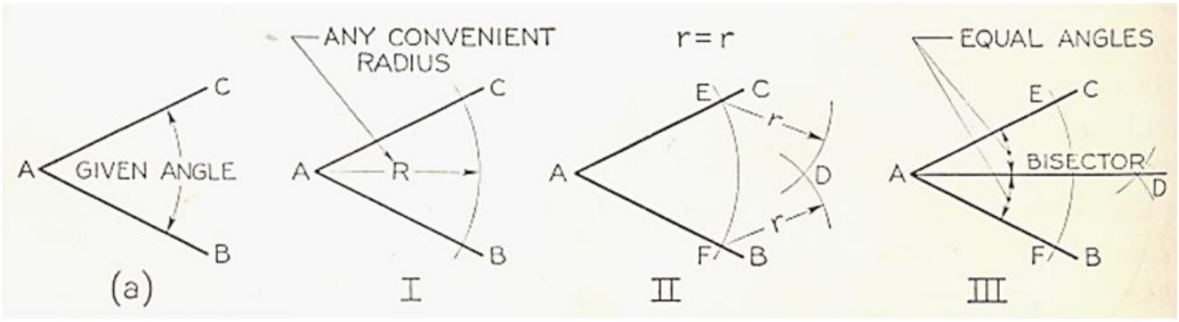


Fig. Bisecting an Angle

How to Draw an Arc or Circle (Radius) through Three Given Points

Given: Three points in space at random: A, B and C.

- **Step 1:** With straight line, lightly connect points A to B, and B to C,
- **Step 2:** Using the method outlined for bisecting a line, bisect lines A-B and B-C
- **Step 3:** Locate point X where the two extended bisectors meet. Point X is the exact center of the arc or circle.
- **Step 4:** Place the point of the compass on point X and adjust the lead to any of the points A, B, or C (they are the same distance), and swing the circle. If all work is done correctly, the arc or circle should pass through each point.

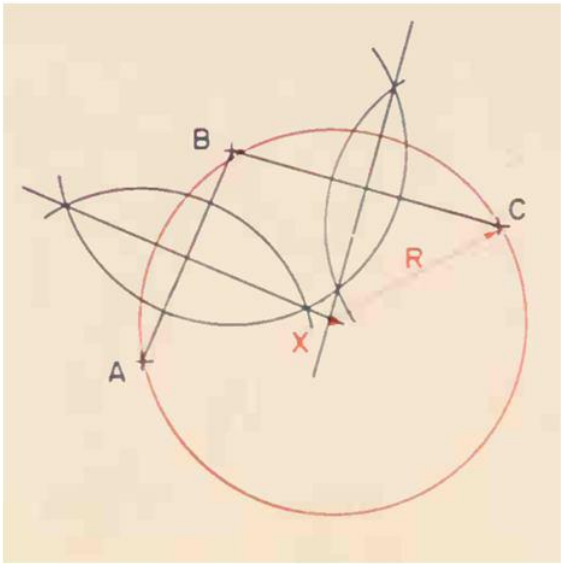


Fig. Drawing of Arc Through 3 Points

How to Transfer an Odd Shape (Triangular)

Given: Triangle ABC.

- **Step 1:** Letter or number the various corners and point locations of the odd shape in counterclockwise order around its perimeter. In this example, place the compass point at point A of the original shape and extend the lead to point B. Swing a light arc at the new desired location. Letter the center point as A' and add letter B' at any convenient location on the arc. It is a good habit to lightly letter each point as you proceed.
- **Step 2.** Place the compass point at letter B of the original shape and extend the compass lead to letter C of the original shape.
- **Step 3.** Transfer this distance, B-C, to the layout.
- **Steps 4 and 5.** Going back to the original object, place the compass point at letter A and extend the compass lead to letter C. Transfer the distance A-C as illustrated in Figure. Locate and letter each point.
- **Step 6.** Connect points A', B', and C' with light, straight lines. This completes the transfer of the object. Recheck all work and, if correct, darken lines to the correct line weight.

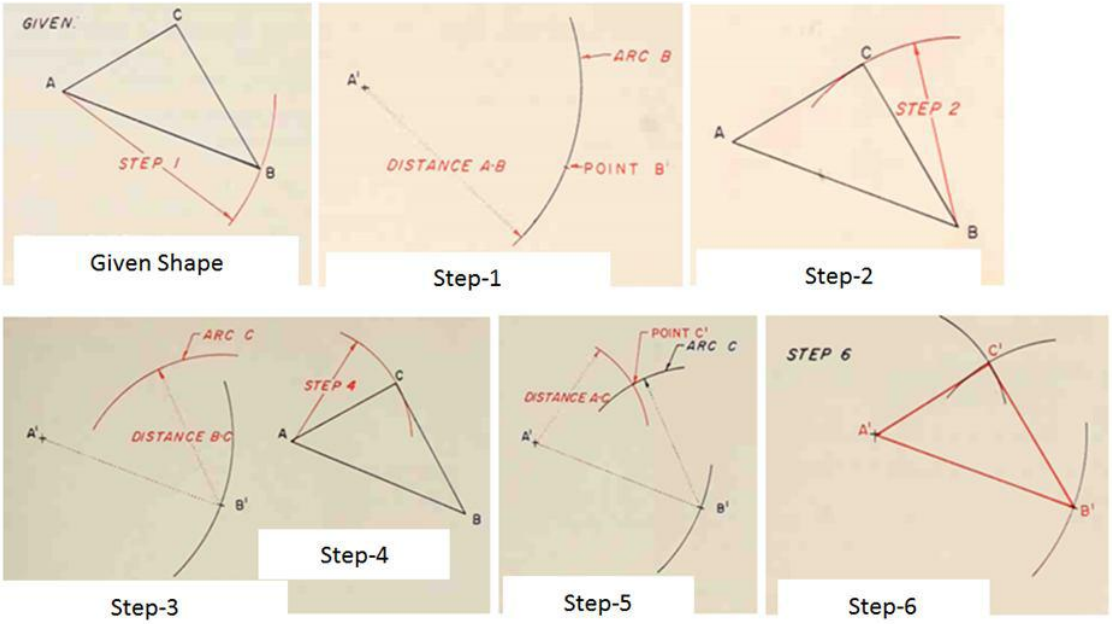


Fig. Transferring a Triangle to Another Location

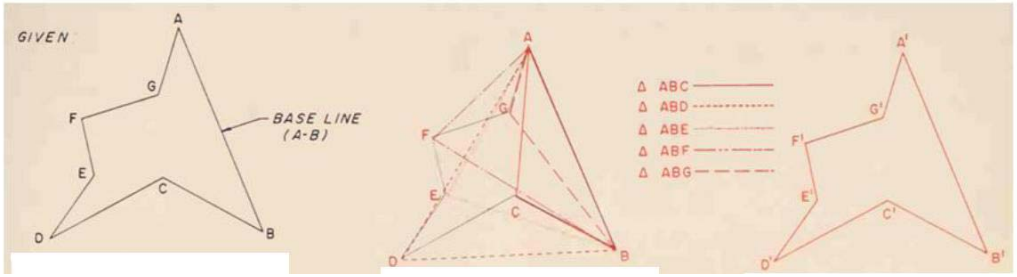
How to Transfer Complex Shapes

A complex shape can be transferred in exactly the same way by reducing the shape into simple triangles and transferring each triangle using the foregoing method.

Given: An odd shape, A, B, C, D, E, F, G.

 Step 1: Letter or number the various corners and point locations of the odd shape in clockwise order around the perimeter. Use the longest line or any convenient line as a starting point. Line A-B is chosen here as the example. Lightly divide the shape into triangle divisions, using the baseline if possible. Transfer each triangle in the manner described in previous procedure. Suggested triangles to be used in example are ABC, ABD, ABE, ABF and ABG.

 Step 2: This completes the transfer. Check all work and, if correct, darken in lines to correct line thickness.



Given Shape

Step 1 Step 2

Fig. Transferring a Complex Shape to Another Location

How to Draw A Pentagon (5 Sides)

Given: The locations of the pentagon center and the diameter of circle that will circumscribe the pentagon.

- **Step 1**: Draw the circle with given diameter taking given location as center (C). Letter a diameter as HB.
- **Step 2**: Draw a perpendicular CD that meets the circumference at D.
- **Step 3:** Bisect radius CB at A.
- **Step 4:** With A as center, and CD as radius, strike arc DE that meets the radius CH at E.
- **Step 5:** With D as center, and DE as radius, strike arc EF that meets the nearest circumference at F.
- **Step 6:** Draw line DF, this is the length of one side. Now set off distances DE around the circumference of the circle, and draw the sides through these points.

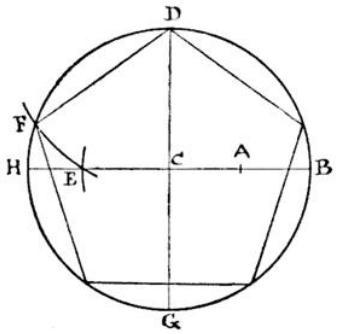


Fig. Drawing of a Pentagon

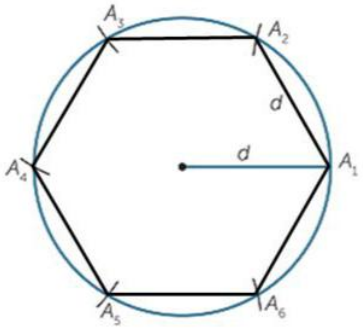


Fig. Drawing of a Hexagon

How to Draw a Hexagon (6 Sides)

Given: The locations of the hexagon center and the diameter of circle that will circumscribe the hexagon.

- **Step 1**: Draw the circle with given diameter taking given location as center.
- **Step 2**: Extend the compass upto a length equal to the radius of the ciecle.
- **Step 3:** Starting from any point, say A_1, on the circumference, cut 6 equal segments and mark the points as A_1, A_2, A_3, A_4, A_5 and A_6.
- **Step 4:** Join each 2 consecutive points to obtain the hexagon A_1 A_2 A_3 A_4 A_5A_6.

How to Draw an Octagon (8 Sides)

Given: The locations of the octagon center and the diameter of circle that will be inscribed by the octagon.

- **Step 1**: Draw the circle with given diameter taking given location as center.
- **Step 2**: Draw any two mutually perpendicular diameters.
- **Step 3**: Draw tangents to the circle at the ends of diameters to obtain a square.
- **Step 4**: Draw diagonals of the square. Diagonals will intersect the circle at 4 points.
- **Step 5**: Draw tangent to the circle at the 4 intersection points obtained in step 4. These tangents will meet the sides of square drawn in step 3. Now darken the obtained octagon.

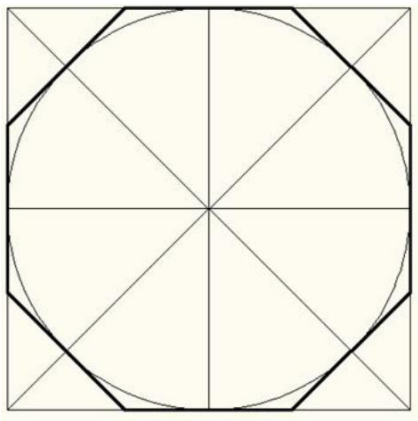


Fig. Drawing of an Octagon

How to Draw any Sided Regular Polygon

i. Given: Number of sides and the diameter of circle that will circumscribe the polygon.

- **Step 1**: Draw the circle with given diameter taking given location as center. Mark a diameter. As example let us draw a 7 sided polygon. Mark the diameter as 0-7.
- **Step 2**: Divide the diameter in "n" equal segments using parallel line method. Here n=7 for our case.
- **Step 3**: Construct an equilateral triangle (0-7-8) with the diameter (0-7) as one of its sides.
- **Step 4**: Draw a line from the apex (point 8) through the second point on the line (point 2) and extend line 8-2 until it intersects the circle at point 9.
- **Step 5**: Now 0-9 is the length of each side of the polygon. Taking 0-9 as radius of compass, cut the circumference in 7 equal segments to obtain the corners of the seven sided polygon and connect the points.

ii. Given: Length of one side and number of sides (i.e. 5 for pentagon, 6 for hexagon, 8 for octagon etc.)

Step 1: Calculate one internal angle of the polygon using formula $\frac{(n-2)\pi}{n}$;

- **Step 2:** Draw a line of length equal to the given side.
- **Step 3:** Draw the obtained internal angle at one end of the line and set off distances equal to the given side.
- **Step 4:** Continue **r**epeating the step 3 until you reach another end of 1st line. Thus the polygon will be drawn.

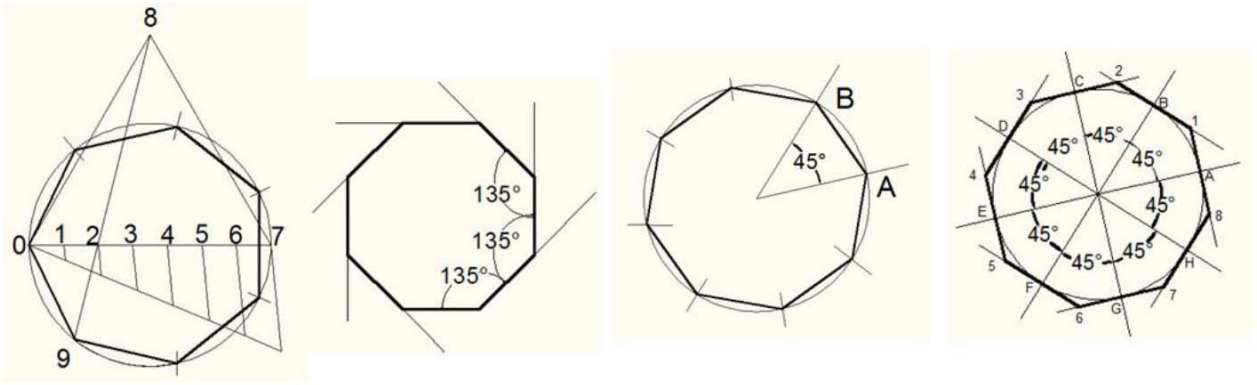
iii. Given: Number of sides and diameter of out scribing circle.

- **Step 1:** Draw the circle. Using protractor, Draw an angle equal to $360^0/n$ at the center of circle where n = number of sides.
- **Step 2:** The lines drawn for the angle cuts the circle at A and B. Then AB is the length of one side. Now set off distances AB around the circumference of the circle, and draw the sides through these points.

iv . Given: Number of sides and diameter of inscribing circle.

 Step 1: Draw the circle. Using protractor, Divide the central 360^0 angle into "n" number of equal part by drawing "n" number of angles each equal to $360^0/n$ at the center of circle where n = number of sides.

 Step 2: The lines drawn for the angles cuts the circle at A, B, C, D…. etc. At each point of intersection draw a tangent to the circle. The tangents will meet each other at 1, 2, 3, 4…… etc. Then 1-2-3-4-….. is the required polygon.



(i) **(ii)** **(iii)** **(iv)**

Fig. Drawing of Any Sided Polygon

How to Locate the Center of a Given Circle

Given: A circle without a center point.

 Step 1: Using the T-square, draw a horizontal line across the circle approximately halfway between the estimated center of the given circle and the uppermost point on the circumference. Label the end points of the chord thus formed as A and B.

 Step 2: Draw perpendicular lines (90°) downward from points A and B. Locate points C and D where these two lines pass through the circle.

 Step 3: Carefully draw a straight line from point A to point D and from point C to point B. Where these lines cross is the exact center of the given circle. Place a compass point on the center point; adjust the lead to the edge of the circle and swing an arc to check that the center is accurate.

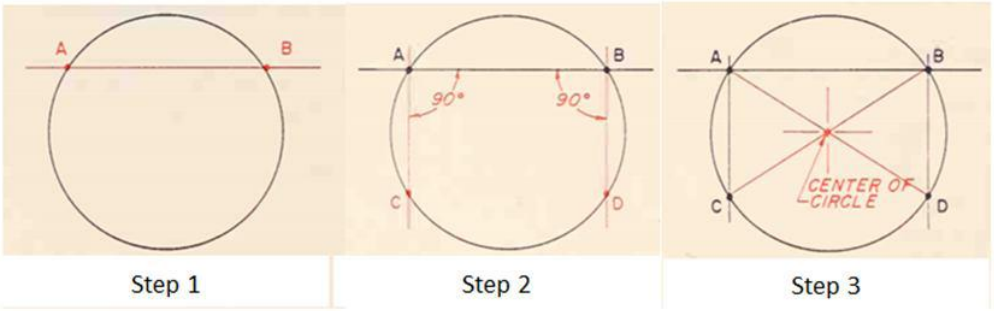


Fig. Locating the Center of Given Circle

How to Draw Arc Tangent to a Straight Line and a Curve

Given: Straight line AB, an arc with a center point O or radius r, and a required radius (R) of arc tangent.

- **Step 1:** Take a radius equal to r+R, place the needle of compass at the center of given curve and draw an arc EF.
- **Step 2:** Draw a line CD parallel to AB at a distance R so that the line CD and arc EF intersects at point G.
- **Step 3:** Taking G as center and R as radius draw an arc. This arc will touch the line AB and the given arc.

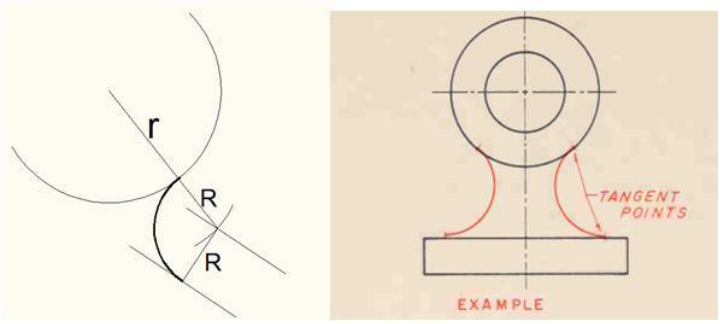
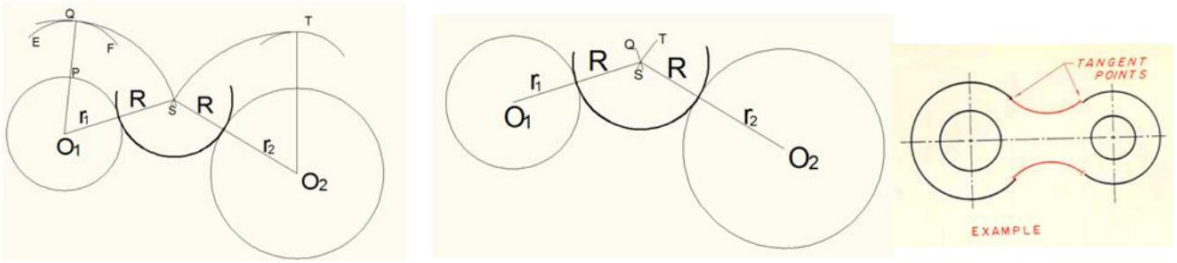


Fig. Drawing of Arc Tangent to a Straight Line and Curve

How to Draw Arc Tangent to Two Arcs of Different Radius

Given: Two arcs AB, CD with their center point O_1 and O_2 or radius r_1 and r_2, and a required radius (R) of arc tangent.

- **Step 1:** If radius of arcs are not given but their center location is known, say O_1 and O_2 ; Take any point P on the 1st arc and taking it as center draw an arc EF with radius R. Join O_1P and extend it until it meets the curve EF at Q. Take O_1 as center and O_1Q as radius draw another arc QS. If the radius of arcs are given then simply take O_1 as center and draw the arc QS by taking radius equal to r_1+R.
- **Step 2:** Following similar method as in step 1, draw another arc TS taking O_2 (Center of 2nd arc) as center such that TS intersects QS at S.
- **Step 3:** Take S as center and R as radius, draw an arc that will touch the given 2 arcs.



Center locations given Radius given

Fig. Drawing of Arc Tangent to 2 Arcs

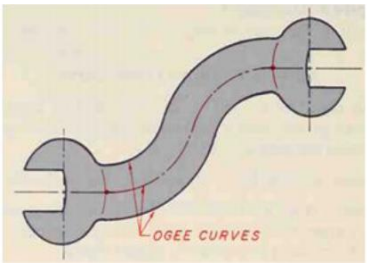
How to Draw an Ogee Curve

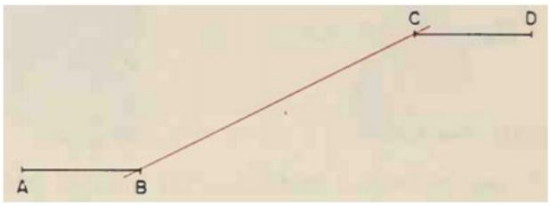
An ogee curve is used to join two parallel lines. It forms a gentle curve that reverses itself in a neat symmetrical geometric form.

Given: Parallel lines A-B and C-D.

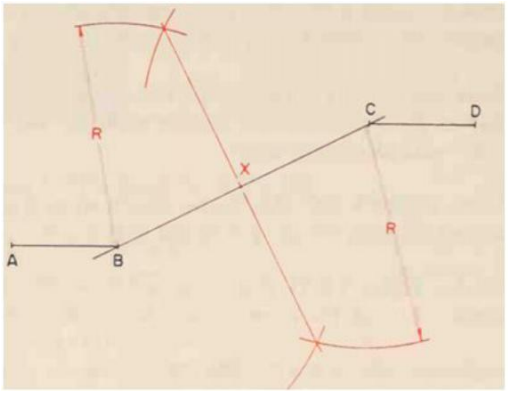
- **Step 1**: Draw a straight line connecting the space between the parallel lines. In this example, from point B to point C.
- **Step 2:** Make a perpendicular bisector to line B-C to establish point X.
- **Step 3**: Make perpendicular bisectors to the lines B-X and X-C.
- **Step 4**: Draw a perpendicular from line A-B at point B to intersect the perpendicular bisector of B-X, which locates the first required swing center. Draw a perpendicular from line C-D at point C to intersect the perpendicular bisector of C-X which locates the second required swing center.
- **Step 5**: Place the compass point on the first swing point and adjust the compass lead to point B, and swing an arc from B to X. Place the compass point on the second swing point and swing an arc from X to C.

This completes the ogee curve.
Note: point X is the tangent point between arcs. Check and. if correct, darken in all work.

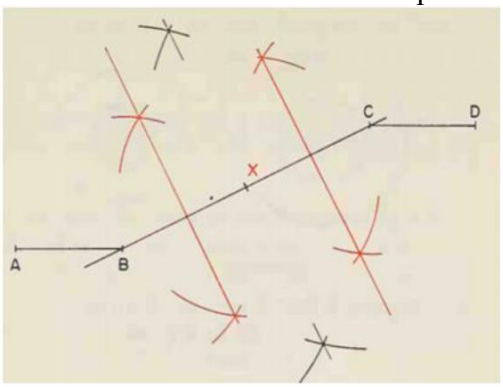




Step-1



Step-2



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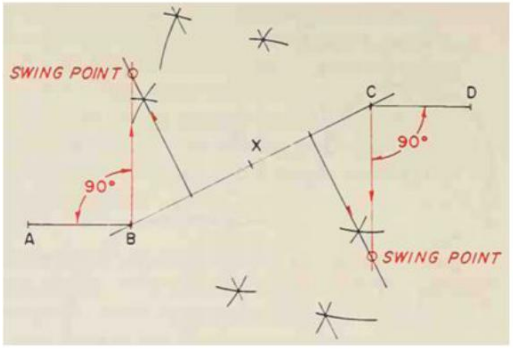
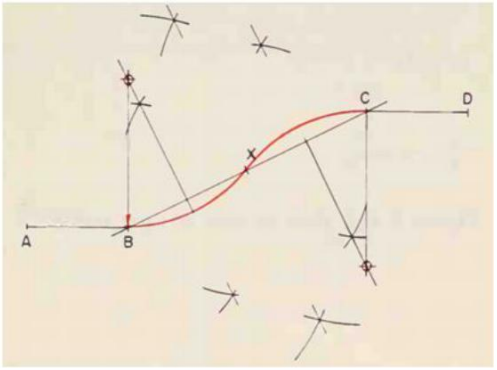


Step-4



Step-5

Fig. Drawing of an Ogee Curve

How to Draw Straight Tangent to Two Arcs of Different Radius

Given: Two arcs of different radius and their center location A and B or radius r_1 , r_2 and center distance AB.

- **Step 1**: Consider the two given circles with centers A and B respectively. If r_1 , r_2 and AB are given draw them accordingly.
- **Step 2:** Draw any radius of the curve having larger diameter, BC, in example. Cut BD=radius of curve with smaller diameter. Taking center as B and radius as CD draw an arc EF. If value of r_1 , r_2 are given simply draw the arc EF taking radius as r_2- r_1 and center as B.
- **Step 3:** Using set square draw a tangent AF to the arc EF from point A.
- **Step 4:** Join BF and extend it until it meets the given curve at P.
- **Step 5:** Complete the rectangle AFPQ. Then PQ will be the required tangent.

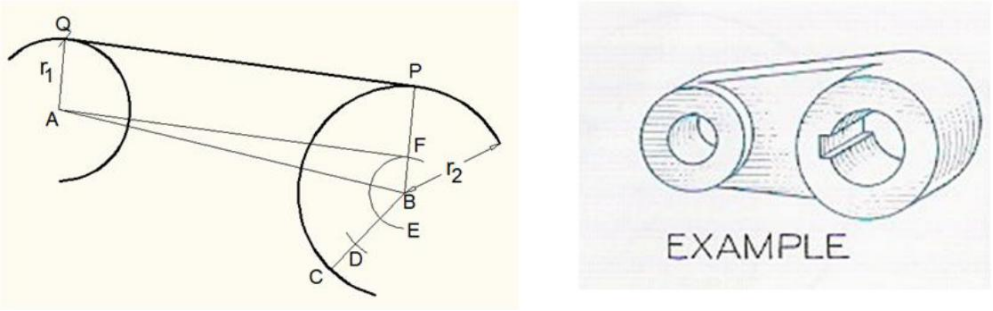


Fig. Drawing of a Common Tangent to 2 Curves

How to Draw an Ellipse (Four-centered Approximate Method)

Given: Major and Minor axis length (say, a and b respectively).

- **Step 1**: Draw a line PQ=a and find out its mid-point O. At O draw a perpendiculars OR=OS=b/2.
- **Step 2**: Taking center O and radius OP, draw an arc PA that intersects the extended minor axis (RS) at A.
- **Step 3**: Join PR. Taking R as center and RA as radius draw an arc that intersects PR at B.
- **Step 4**: Bisect PB at C and draw a perpendicular at C that intersects the extended minor axis (RS) at D. The line CD also intersects PO at E.
- **Step 5**: Draw OE' equal to OE and OD' equal to OD. Join DE', D'E and D'E' and extend them.
- **Step 6**: Taking D and D' as centers and DR or D'S as radius draw 2 arcs MRN and KSL respectively.
- **Step 7:** Taking E and E' as centers and PE or QE' as radius draw another 2 arcs KPM and NQL respectively. Thus the ellipse will be completed.

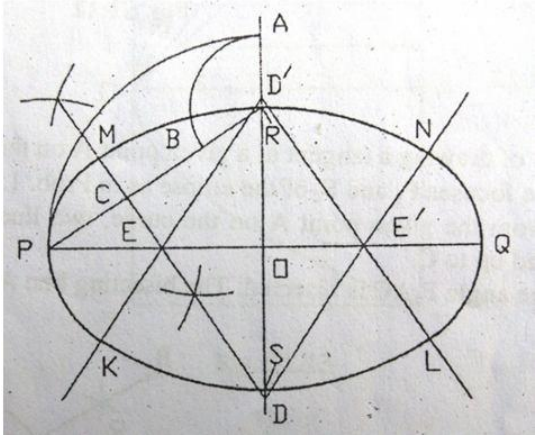


Fig. Drawing of an Ellipse

Conventional Symbols

A variety of symbols are used in engineering drawing to represent different elements, properties, material types etc. Some geometric symbols are commonly used in almost every types of drawing while there are some special symbols used in specific types (civil, mechanical, electrical etc.) of drawing.

Common Geometric Symbols used in Engineering Drawing

Table. Conventional Geometric Symbols

SYMBOL FOR :	ANSI Y14.5
STRAIGHTNESS	—
FLATNESS	▱
CIRCULARITY †	○
CYLINDRICITY †	⌭
PROFILE OF A LINE	⌒
PROFILE OF A SURFACE	⌓
ALL AROUND-PROFILE	⌀
ANGULARITY	∠
PERPENDICULARITY	⊥
PARALLELISM	//
POSITION	⌖
CONCENTRICITY/COAXIALITY †	◎
SYMMETRY ‡	NONE
CIRCULAR RUNOUT	↗
TOTAL RUNOUT	⌰
AT MAXIMUM MATERIAL CONDITION	Ⓜ
AT LEAST MATERIAL CONDITION	Ⓛ
REGARDLESS OF FEATURE SIZE	Ⓢ
PROJECTED TOLERANCE ZONE	Ⓟ

SYMBOL FOR :	ANSI Y14.5
DIAMETER	Ø
BASIC DIMENSION	50
REFERENCE DIMENSION	(50)
DATUM FEATURE	-A-
DATUM TARGET	Ø6 A1
TARGET POINT	×
DIMENSION ORIGIN	⌖
CONICAL TAPER	▷
SLOPE	⏥
COUNTERBORE/SPOTFACE	⌴
COUNTERSINK	⌵
DEPTH/DEEP	↧
SQUARE (SHAPE)	□
DIMENSION NOT TO SCALE	15
NUMBER OF TIMES/PLACES	8X
ARC LENGTH	⌒105
RADIUS	R
SPHERICAL RADIUS	SR
SPHERICAL DIAMETER	SØ

* MAY BE FILLED IN

† Not recommended, use runout
‡ Not used

Exercise and Assignments

1. Divide a line of length 40mm into 7 equal parts.
2. Draw a circle touching three points A, B and C with coordinates A(0,0), B(0,20) and C(15,0).
3. Draw a regular pentagon inscribing a circle of diameter 80mm. Avoid use of protractor.
4. Draw a regular pentagon out scribing a circle of diameter 100mm.
5. Draw a regular pentagon having length of side as 45mm.
6. Draw a regular hexagon inscribing a circle of diameter 80mm. Avoid use of protractor.
7. Draw a regular hexagon out scribing a circle of diameter 100mm.
8. Draw a regular hexagon having length of side as 45mm.
9. Draw a regular octagon inscribing a circle of diameter 80mm. Avoid use of protractor.
10. Draw a regular octagon out scribing a circle of diameter 100mm. Avoid use of protractor.
11. Draw a regular octagon having length of side as 45mm.
12. Draw a 9 sided regular polygon inscribing a circle of radius 50mm.
13. A 80mm long horizontal straight line is located outside a circle of radius 30mm, such that a 50mm line drawn from center of the circle meets the mid-point of the straight line at right angle. Draw two arc tangents, each having a radius of 40mm touching the circle and one of the ends of the straight line.
14. Draw a common arc tangent of radius 70mm to the two circles having their centers 80mm apart and having diameters of 50mm and 30mm respectively.
15. Draw an ogee curve to connect two parallel lines each of length 20mm and their mid-points spaced 30mm vertically and 70mm horizontally.
16. Two wheels with diameters 3.5m and 2m are required to be provided with a belt. Draw the line diagram of the arrangement. Use a reduced scale.
17. Draw an ellipse having major and minor axis length as 90mm and 60mm.