

TECHNICAL DRAWING

# Chapter II : Geometrical Constructions

Lines – Angles – Polygons – Circles – Conics

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ENP

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- 1 Introduction
- 2 Geometric Nomenclature
  - Line
  - Triangle
  - Polygon
  - Quadrilateral
  - Polyhedron
  - Prism
- 3 Elemental Construction Principles
  - How To Bisect a Line
  - How To Bisect an Angle
  - How To Draw an Arc or Circle through Three Given Points
  - How To Draw a Line Parallel to a Straight Line
  - How To Draw a Perpendicular to a Line at a Point
  - How To Draw a Perpendicular from a Point Not on the Line
- 4 Polygon Construction
  - How To Draw a Square
  - How To Draw a Pentagon (5 Sides)
  - How To Draw a Pentagon Given the Length of Side
  - How To Draw a Hexagon (6 Sides)

Section 1

# Introduction

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- 2 Geometric Nomenclature
- 3 Elemental Construction Principles
- 4 Polygon Construction
- 5 Circular Construction
- 6 Conic Sections
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Machine parts and other manufactured products are constructed of different geometric shapes ranging from squares and cylinders to complex irregular curves.

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- ▶ **Geometric constructions** are methods that can be used to draw various geometric shapes or to perform drafting tasks related to the geometry of product representation and design.
- ▶ The proper use of geometric constructions requires a basic understanding of **plane geometry**.
- ▶ Plane geometry, in its most basic definition, is the geometry of two-dimensional (2-D) objects.

## Section 2

# Geometric Nomenclature

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① Introduction

②  
Line  
Triangle  
Polygon  
Quadrilateral  
Polyhedron  
Prism

③ Elemental Construction Principles

④ Polygon Construction

⑤ Circular Construction

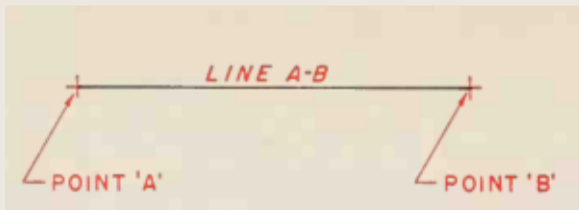
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### Line

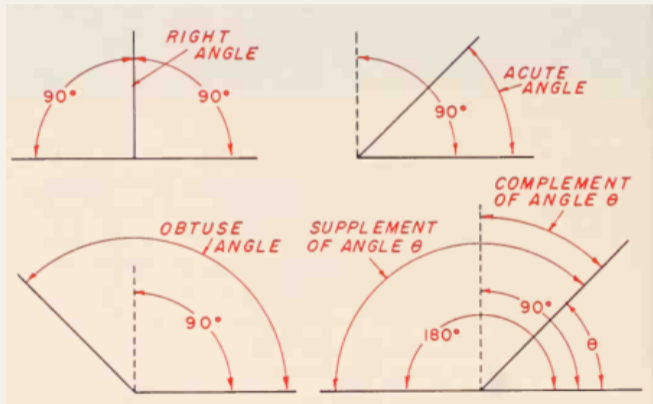
- ▶ A straight line is the shortest distance between two points.



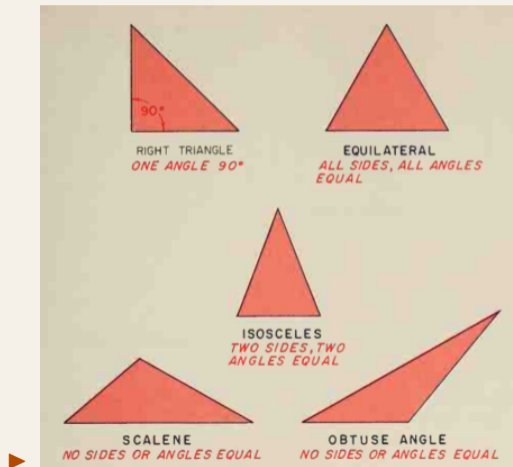
- ▶ It can be drawn in any direction. A line can be straight, an arc, a circle or a free curve, as illustrated in Figure.



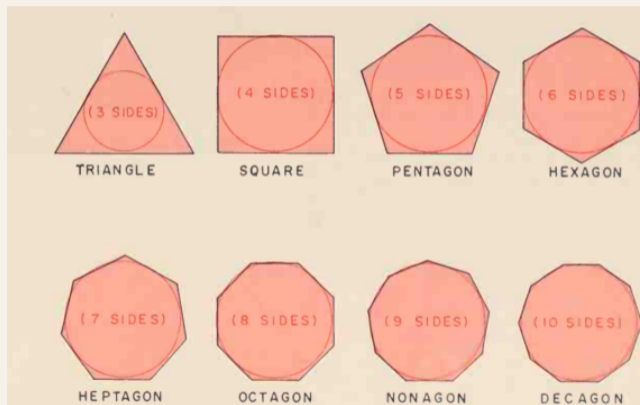
- ▶ An angle is formed by the intersection of two lines. There are three major kinds of angles: **right angles**, **acute angles**, and **obtuse angles**.



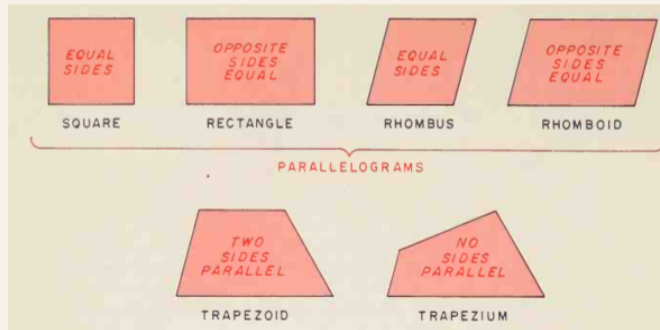
- ▶ A triangle is a closed plane figure with three straight sides and three interior angles. The sum of the three internal angles is always exactly  $180^\circ$ , half of the  $360^\circ$  in a full circle.



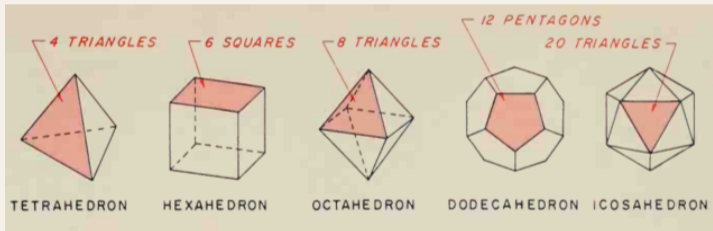
- ▶ A polygon is a closed plane figure with three or more straight sides.



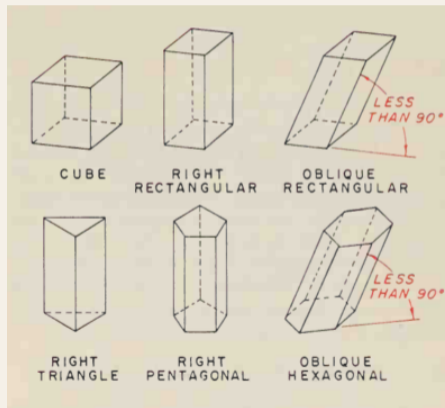
- ▶ A quadrilateral is a plane figure bounded by four straight sides. When opposite sides are parallel, the quadrilateral is also considered to be a parallelogram.



- ▶ A polyhedron is a solid object bounded by plane surfaces. Each surface is called a face. If the faces are equal, regular polygons, the solid figure is a regular polyhedron.



- ▶ A prism is a solid having ends that are parallel matched polygons, and sides that are parallelograms. When the polygon on one end of a prism is not parallel to the other end, it is said to be truncated.



## Section 3

# Elemental Principles

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# Construction

① Introduction

② Geometric Nomenclature

③

- How To Bisect a Line
- How To Bisect an Angle
- How To Draw an Arc or Circle through Three Given Points
- How To Draw a Line Parallel to a Straight Line
- How To Draw a Perpendicular to a Line at a Point
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④ Polygon Construction

3

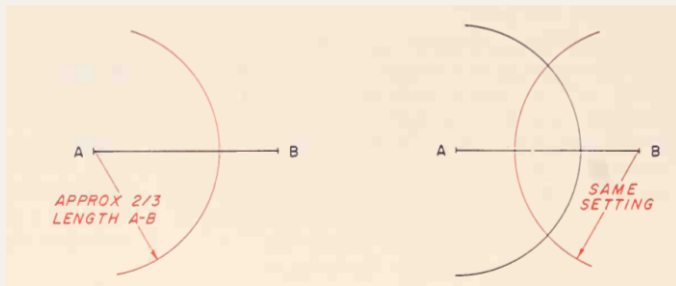
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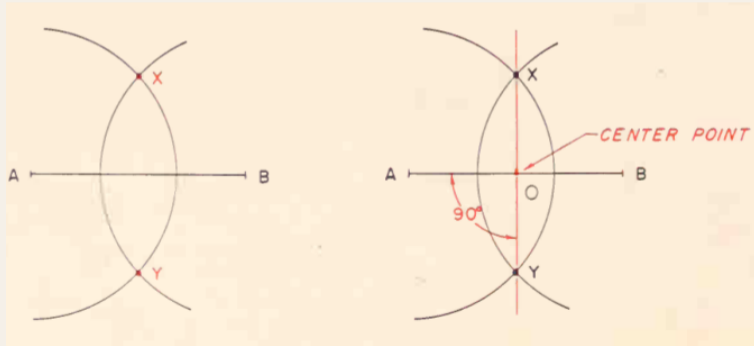
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- ▶ As the beginning drafter uses these geometric construction principles, various shortcuts will become evident, thus reducing the drawing time and increasing accuracy even more.

- ▶ The remaining portion of this chapter is devoted to illustrating step-by-step the many geometric construction principles used by the drafter to develop various geometric forms.
- ▶ It is important that each step be fully understood and followed.
- ▶ As the beginning drafter uses these geometric construction principles, various shortcuts will become evident, thus reducing the drawing time and increasing accuracy even more.
- ▶ At the end of the chapter, each of these techniques is incorporated or used in some way to complete the various given problems.

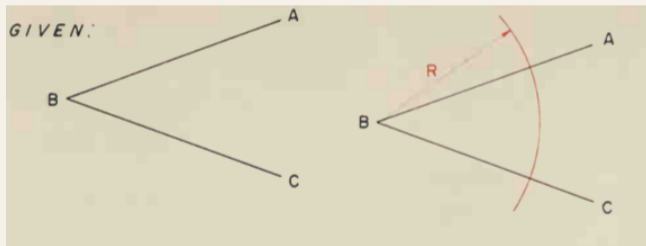
- ▶ To bisect a line means to divide it in half or to find its center point. In the given process, a line will also be constructed at the exact center point at exactly  $90^\circ$ .
- ▶ Set the compass approximately two-thirds of the length of line  $A-B$  and swing an arc from point  $A$ .
- ▶ Using the exact same compass setting, swing an arc from point  $B$ .



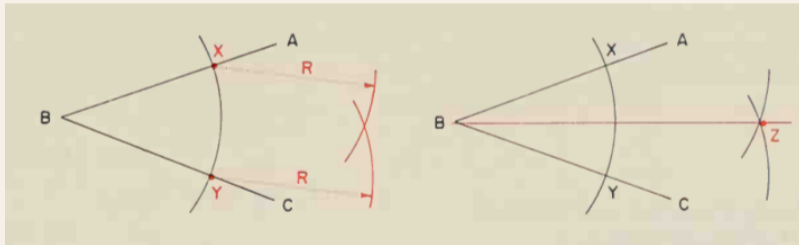
- ▶ At the two intersections of these arcs, locate points  $X$  and  $Y$ .
- ▶ Draw a straight line connecting point  $X$  with point  $Y$ . Where this line intersects line  $A-B$  is the bisect of line  $A-B$ . Line  $X-Y$  is also perpendicular to line  $A-B$  at the exact center point.



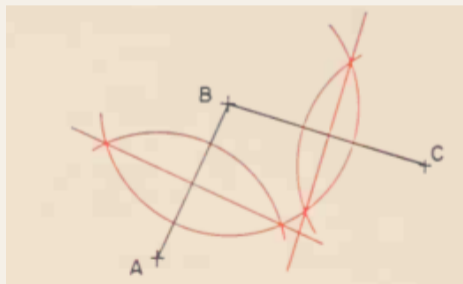
- ▶ To bisect an angle means to divide it in half or to cut it into two equal angles.  
Given: Angle  $ABC$ .
- ▶ Set the compass at any convenient radius and swing an arc from point  $B$ .



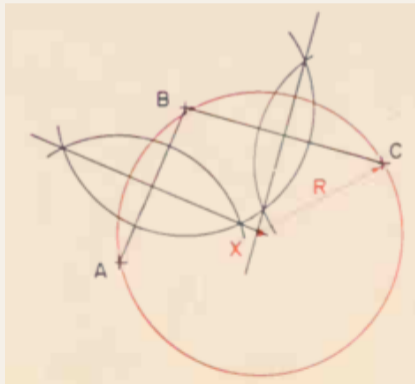
- ▶ Locate points  $X$  and  $Y$  on the legs of the angle, and swing two arcs of the same identical length from points  $X$  and  $Y$  respectively.
- ▶ Where these arcs intersect, locate point  $Z$ . Draw a straight line from  $B$  to  $Z$ . This line will bisect angle  $ABC$  and establish two equal angles:  $ABZ$  and  $ZBC$ .



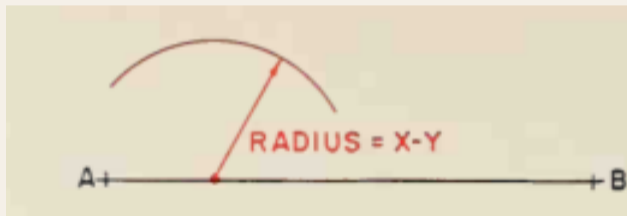
- ▶ Given: Three points in space at random:  $A$ ,  $B$  and  $C$ .
- ▶ With straight lines, lightly connect points  $A$  to  $B$ , and  $B$  to  $C$ .
- ▶ Using the method outlined for bisecting a line, bisect lines  $A-B$  and  $B-C$ .



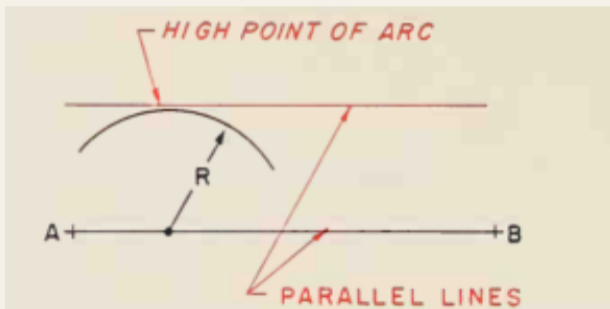
- ▶ Locate point  $X$  where the two extended bisectors meet. Point  $X$  is the exact center of the arc or circle.
- ▶ Place the point of the compass on point  $X$  and adjust the lead to any of the points  $A$ ,  $B$ , or  $C$  (they are the same distance).



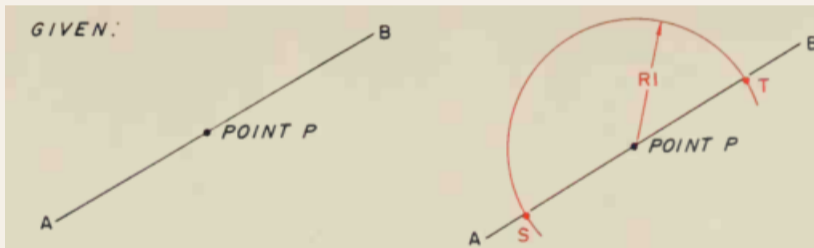
- ▶ Given: Line  $A-B$ , and a required distance to the parallel line.
- ▶ Set the compass at the required distance. Place the point of the compass at any location on the given line, and swing a light arc whose radius is the required distance.



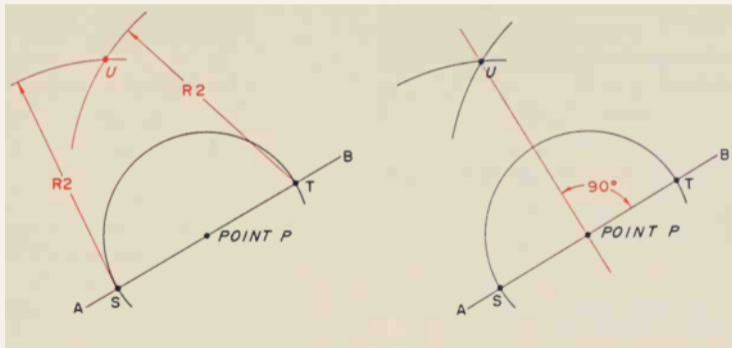
- ▶ Adjust the straightedge of either a drafting machine or an adjustable triangle so that it lines up with line  $A-B$ , slide the straightedge up or down to the extreme high point of the arc, then draw the parallel line.



- ▶ Using  $P$  as the center, make two arcs of equal radius or one continuous arc ( $R_1$ ) to intercept line  $A-B$  on either side of point  $P$ , at points  $S$  and  $T$ .



- ▶ Swing larger but equal arcs ( $R_2$ ) from each of points  $S$  and  $T$  to cross each other at point  $U$ .
- ▶ A line from  $U$  to  $P$  is perpendicular to line  $A-B$  at point  $P$ .

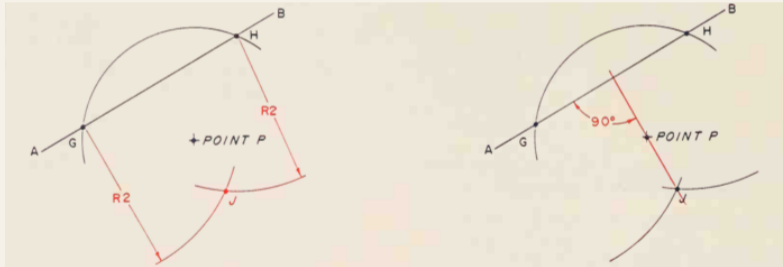


Given: Line  $A-B$  and point  $P$ .

- ▶ Using  $P$  as a center, swing an arc ( $R_1$ ) to intercept line  $A-B$  at points  $G$  and  $H$ .



- ▶ Swing larger, but equal length arcs ( $R_2$ ) from each of the points  $G$  and  $H$  to intercept each other at point  $J$ .
- ▶ Line  $P-J$  is perpendicular to line  $A-B$ .



## Section 4

# Polygon Construction

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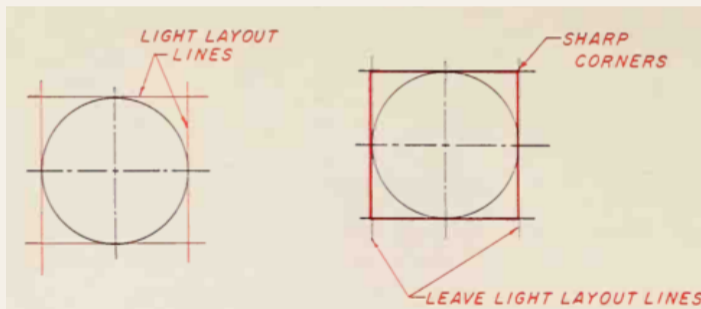
- 1 Introduction
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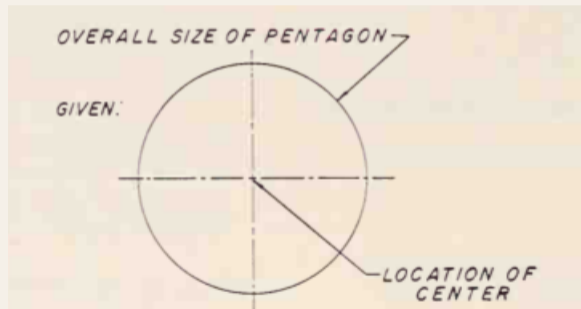
- ▶ Given: The location of the center and the required distance across the “flats” of a square.
- ▶ Lightly draw a circle with a diameter equal to the distance across the “flats” of the square. Set the compass at half the required diameter.



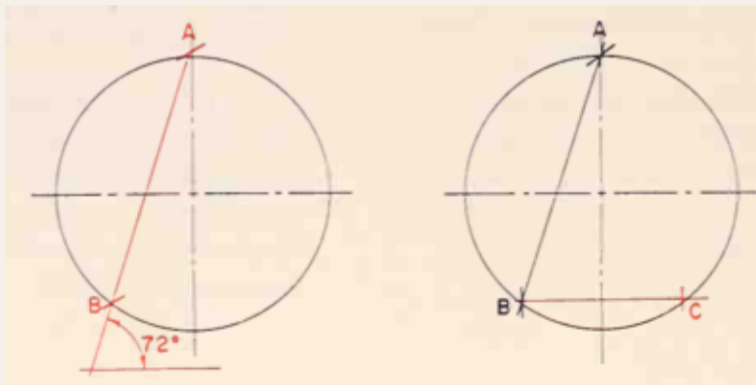
- ▶ Using a triangle, lightly complete the square by constructing tangent lines to the circle. Allow the light construction lines to project from the square, as shown, without erasing them.



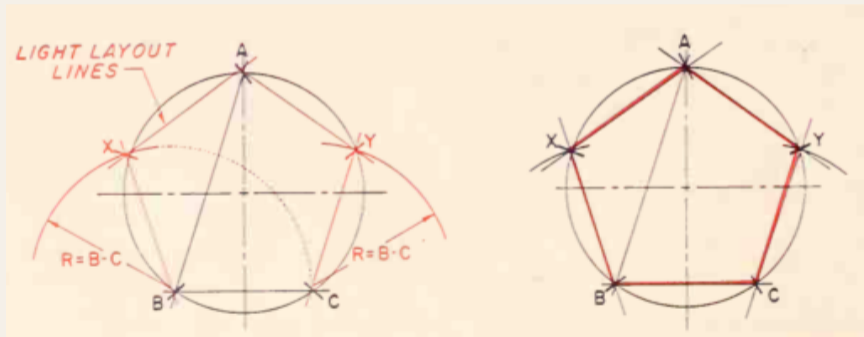
- ▶ Given: The location of the pentagon center, and the diameter that will circumscribe the pentagon.



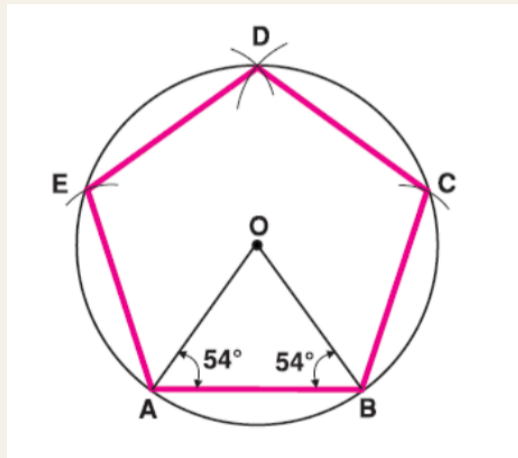
- ▶ Locate point *A* at the top-center of the circle and, using a drafting machine, position an angle of  $72^\circ$  ( $360/5$ ) from the horizontal (or  $18^\circ$  from the vertical) through point *A* to locate point *B* where the angle crosses the circumference of the circle.



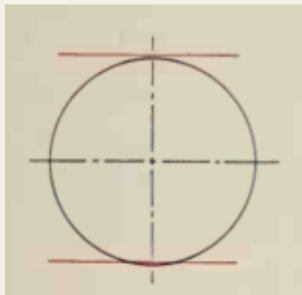
- Set the compass at the distance from point  $B$  to point  $C$ , and swing this distance from the points as illustrated in Figure to locate points  $X$  and  $Y$ .



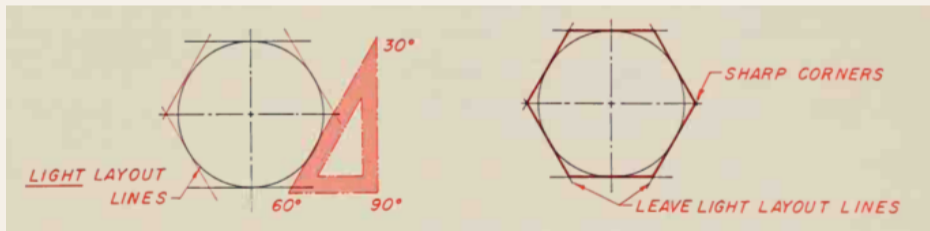
- ▶ Draw a line  $AB$  equal to the given length of the side.
- ▶ Draw an angle of  $54^\circ$  at each point  $A$  and  $B$ , meeting at point  $O$ .
- ▶ With centre  $O$  and radius  $OA$  or  $OB$ , draw a circle.
- ▶ With centre  $B$  and radius  $AB$ , draw an arc intersecting the circle at point  $C$ .
- ▶ Similarly with centre  $A$  and radius  $AB$ , draw an arc intersecting the circle at point  $E$ .
- ▶ With  $C$  and  $E$  as centres and radius  $AB$ , draw arcs intersecting each other at point  $D$  on the circle.
- ▶ Draw lines  $AB$ ,  $BC$ ,  $CD$ ,  $DE$  and  $EA$ , thus completing the regular pentagon.



- ▶ Given: The location of the required center and the required distance across the “flats” of a hexagon.
- ▶ Lightly draw a circle with a diameter equal to the distance across the “flats” of the hexagon.
- ▶ Draw two horizontal lines tangent to the curve, or two vertical lines if the hexagon is to be oriented at  $90^\circ$  to the illustrated position.



- ▶ Using a  $30^{\circ}$ - $60^{\circ}$  triangle, lightly complete the hexagon by constructing tangent lines to the circle.
- ▶ Lightly draw a circle with a diameter equal to the distance across the “flats” of the hexagon.
- ▶ Allow the light construction lines to extend as shown; do not erase them.



## Section 5

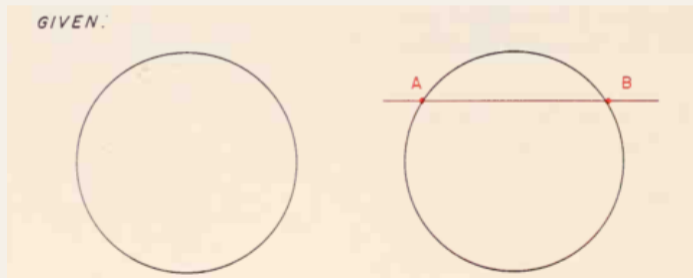
# Circular Construction

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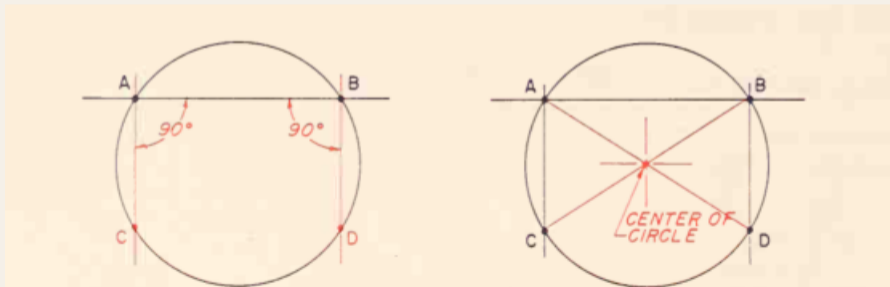
- 1 Introduction
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  - How To Locate the Center of a Given Circle
  - Tangent Points
  - How To Locate Tangent Points
  - How To Construct an Arc Tangent to a Right Angle
  - How To Construct an Arc Tangent to an Acute Angle
  - How To Construct an Arc Tangent to an Obtuse Angle

5

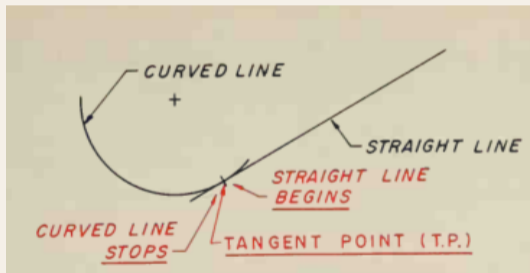
- ▶ Given: A circle without a center point.
- ▶ Using the drafting machine or T-square, draw a horizontal line across the circle approximately halfway between the estimated center of the given circle and the uppermost point on the circumference. Label the end points of the chord thus formed as *A* and *B*.



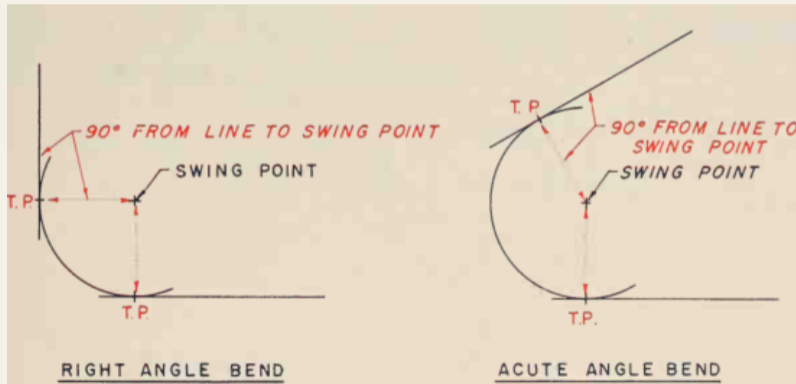
- ▶ Draw perpendicular lines ( $90^\circ$ ) downward from points  $A$  and  $B$ . Locate points  $C$  and  $D$  where these two lines pass through the circle.
- ▶ Carefully draw a straight line from point  $A$  to point  $D$  and from point  $C$  to point  $B$ . Where these lines cross is the exact center 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.



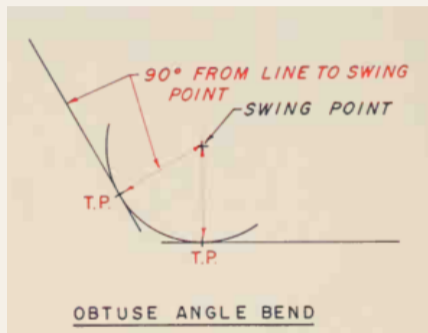
- ▶ A tangent point is the exact location or point where one line stops and another line begins. Tangent also means to “touch.” As an example, a tangent point is the exact point where a curved line stops and a straight line begins.



- ▶ The tangent points for a right angle bend are illustrated, and the tangent points for an acute angle bend are illustrated in Figure.



- ▶ The tangent points for an obtuse angle bend are illustrated in Figure.



- ▶ In each preceding example, a light line is constructed  $90^\circ$  from the straight line to the exact swing point of the radius.

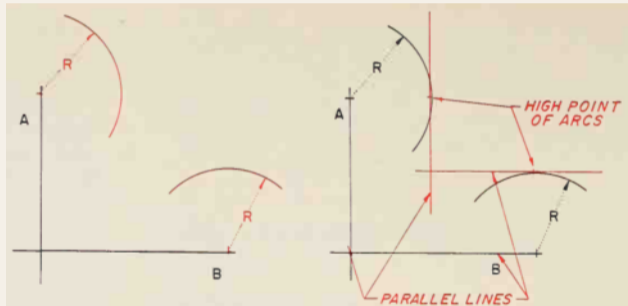
- ▶ The tangent point between two arcs or circles is the exact point where one arc or circle ends and the next arc or circle begins.



- ▶ The tangent point is found by drawing a straight line from the swing point of the first arc or circle to the swing point of the second arc or circle.

Given: A right angle ( $90^\circ$ ), lines  $A$  and  $B$  and a required radius.

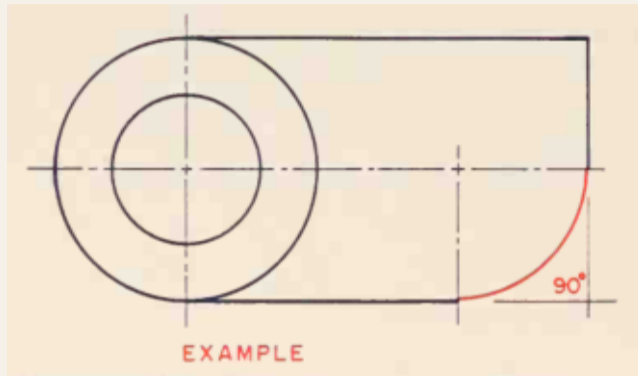
- ▶ Set the compass at the required radius and, out of the way, swing a radius from line  $A$  and one from line  $B$ .



- ▶ From the extreme high points of each radius, construct a light line parallel to line  $A$  and another line parallel to line  $B$ .
- ▶ Where these lines intersect is the exact location of the required swing point.

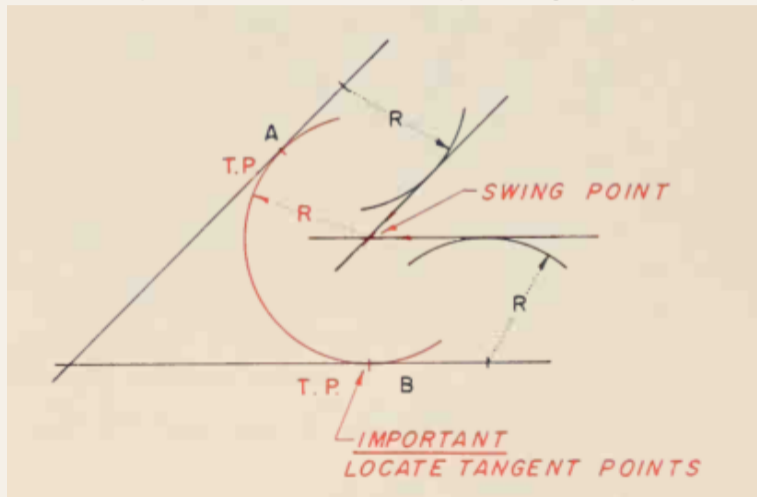


- ▶ An example of an arc tangent to two lines at a right angle (90°) is illustrated.

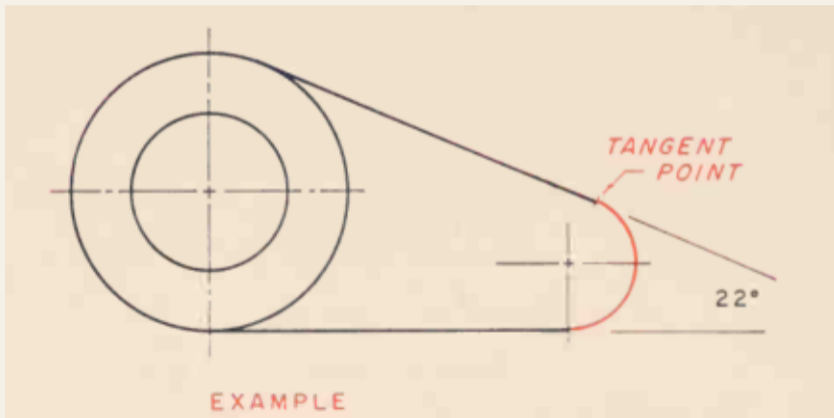


Given: An acute angle, lines A and B, and a required radius.

- ▶ Follow the exact same procedure as outlined in the preceding example.

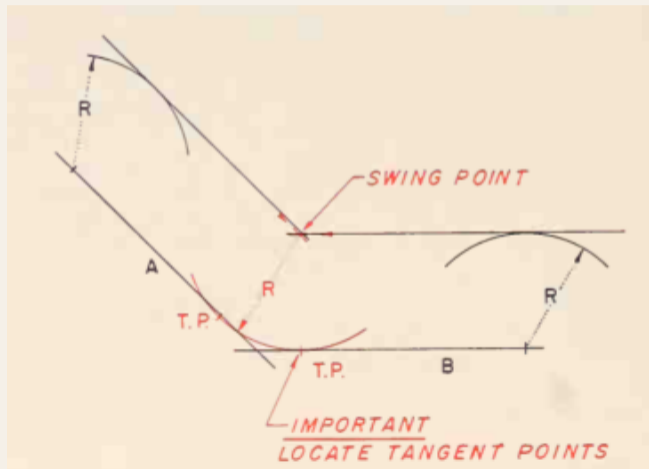


- ▶ An example of an arc tangent to two lines at an acute angle ( $22^\circ$ ) is illustrated in Figure.

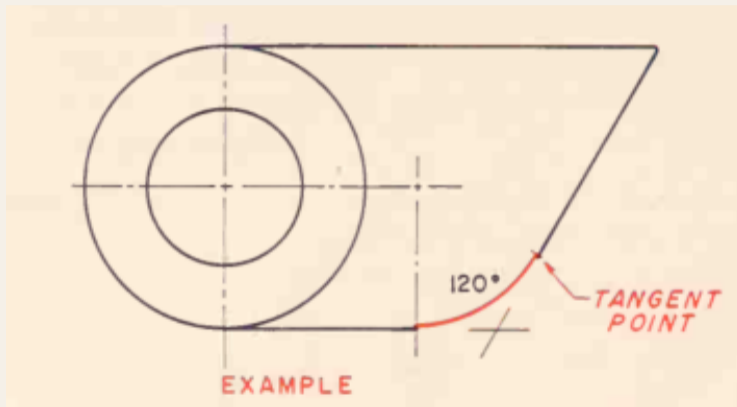


Given: An obtuse angle, lines *A* and *B*, and a required radius.

- ▶ Follow the exact same procedure as outlined in the two preceding examples.

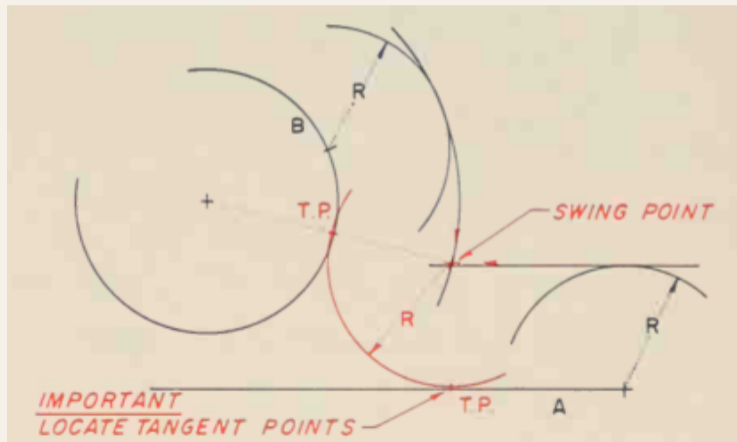


- ▶ An example of an arc tangent to two lines at an obtuse angle ( $120^\circ$ ) is illustrated in Figure.

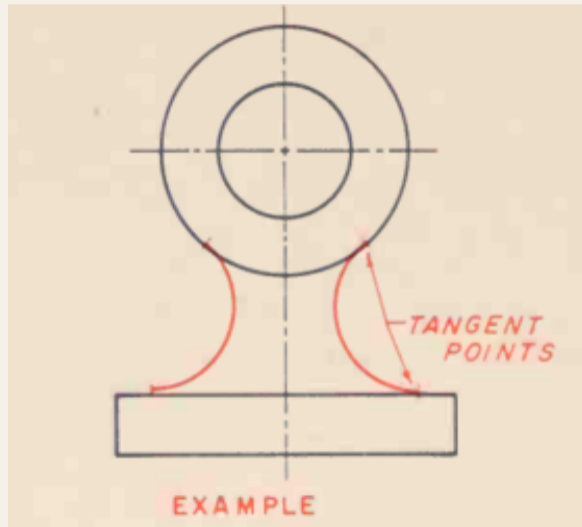


Given: Straight line  $A$ , an arc  $B$  with a center point, and a required radius.

- The same procedure as outlined.

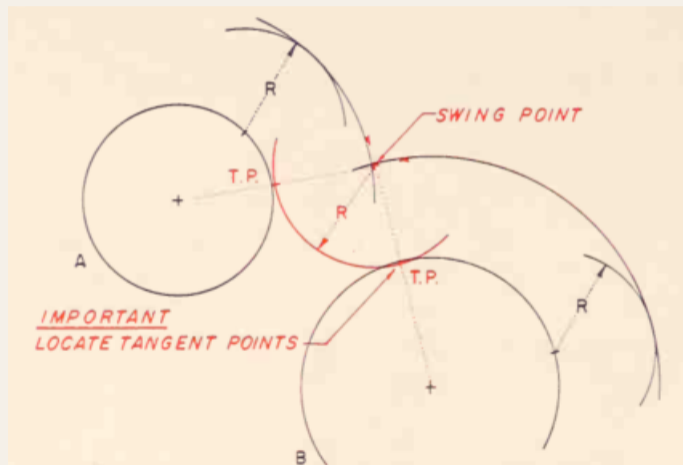


- ▶ An example of an arc tangent to a straight line and a curve is illustrated in Figure.

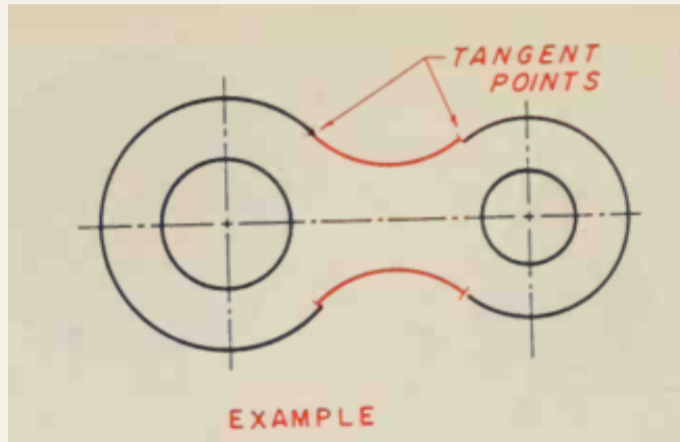


Given: Diameter  $A$  and arc  $B$  with center points located, and the required radius.

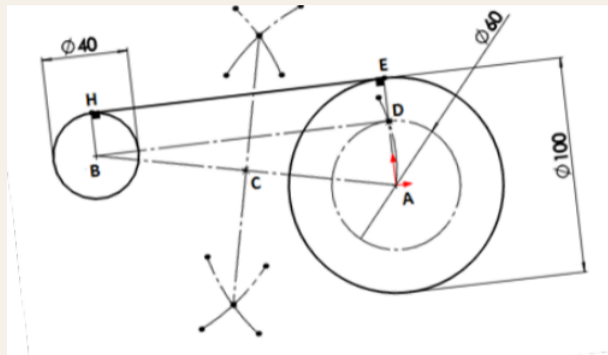
- ▶ The same procedure as outlined.



- ▶ An example of an arc tangent to two radii is illustrated in Figure.

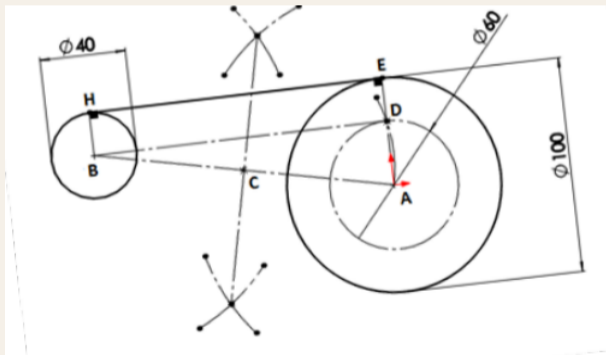


- ▶ Join the centres of the circles by line  $AB$ , bisect  $AB$ .

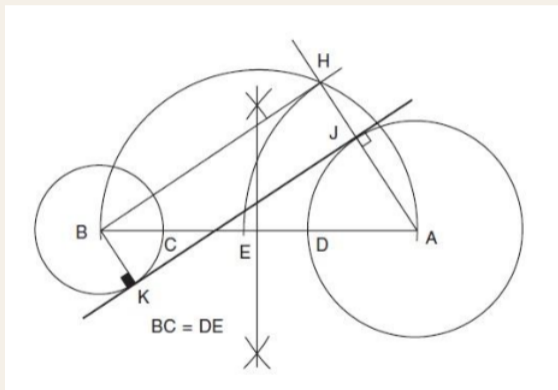


- ▶ Draw a circle from point  $A$  with radius equal to the difference between the 2 radii.
- ▶ From point  $C$ , draw an arc with radius equal to  $CA$  and intersect with the new circle at point  $D$ .

- ▶ Draw a line from  $A$  that goes through  $D$  and intersects with the large circle at point  $E$ .
- ▶ From point  $B$  draw a line normal to  $BD$  and intersects with the small circle at  $H$ .
- ▶ Line  $EH$  is the required tangent line.

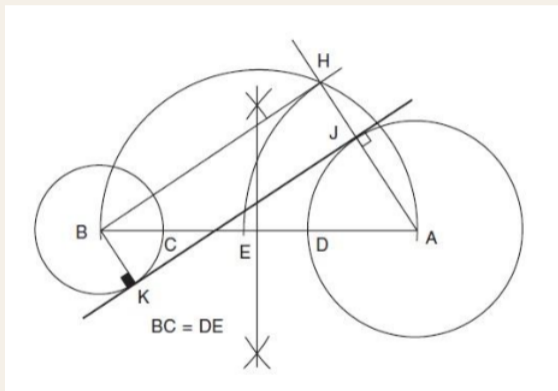


- ▶ Join the centres of the circles by line  $AB$ , bisect  $AB$  and draw a semi-circle from the midpoint of  $AB$  with  $R$  equal to half  $AB$ .



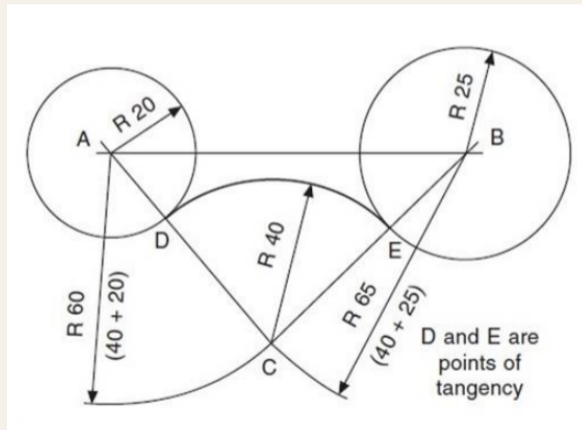
- ▶ From point  $A$ , with  $R$  equal to the sum of the 2 radii, draw an arc to cut the semi-circle in  $H$ .

- ▶ Join  $AH$ ; this line crosses the larger circle circumference at  $J$ .

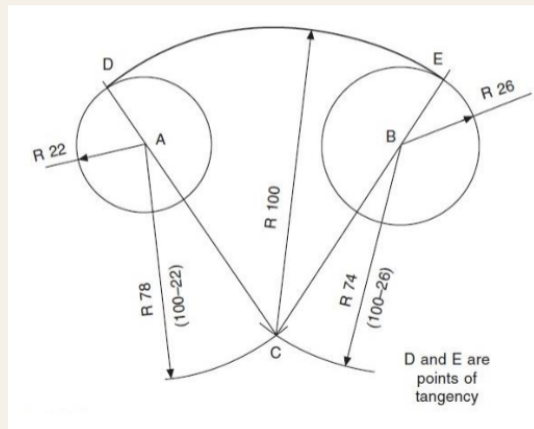


- ▶ Draw line  $BH$  and from  $J$  draw a line parallel to  $BH$  to touch the smaller circle at  $K$ . Line  $JK$  is the required tangent.

- ▶ With centre  $A$ , describe an arc equal to  $20 + 40 = 60$  mm.
- ▶ With centre  $B$ , describe an arc equal to  $25 + 40 = 65$  mm. The above arcs intersect at point  $C$ .



- ▶ With centre  $A$ , describe an arc equal to  $100 - 22 = 78$  mm.
- ▶ With centre  $B$ , describe an arc equal to  $100 - 26 = 74$  mm. The above arcs intersect at point  $C$ .



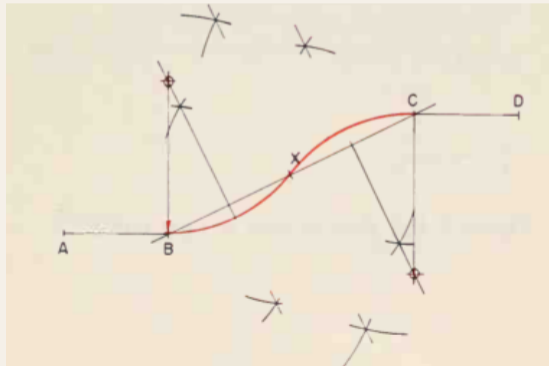
- ▶ An ogee curve is used to join two parallel lines. It forms a gentle curve that reverses itself in a neat symmetrical geometric form.

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

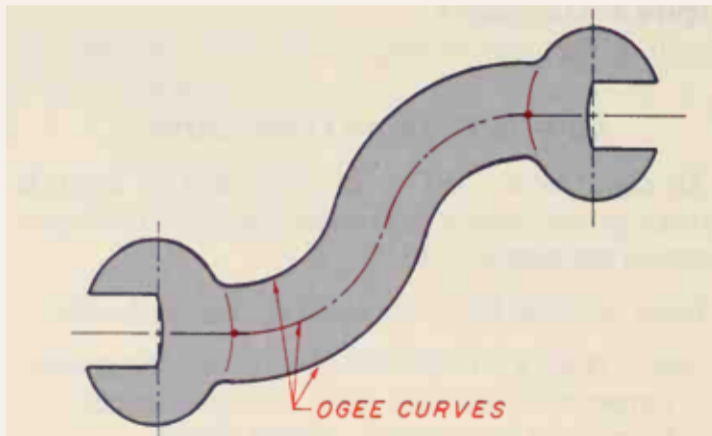


- ▶ Draw a straight line connecting the space between the parallel lines, from point  $B$  to point  $C$ .
- ▶ Make a perpendicular bisector to line  $B-C$  to establish point  $X$ .

- ▶ Make perpendicular bisectors to the lines  $B-X$  and  $X-C$ .
- ▶ 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.



- ▶ Sample construction:



Section 6

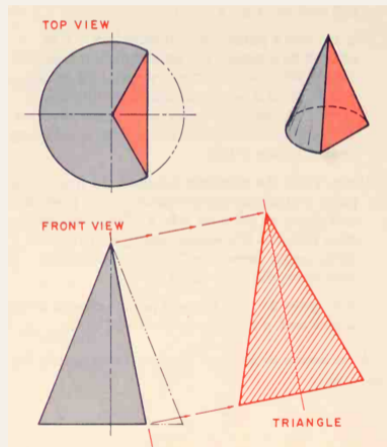
# Conic Sections

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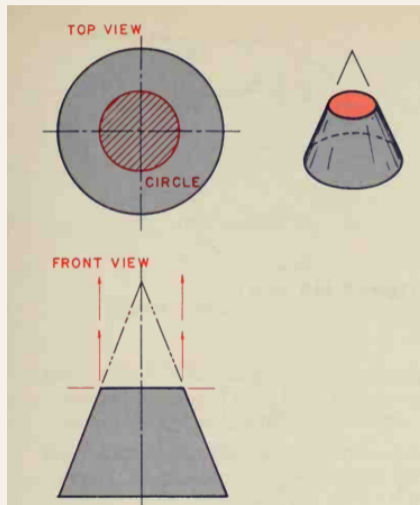
- 1 Introduction
- 2 Geometric Nomenclature
- 3 Elemental Construction Principles
- 4 Polygon Construction
- 5 Circular Construction
- 6 Conic Sections**
- 7 Ellipse Construction

6

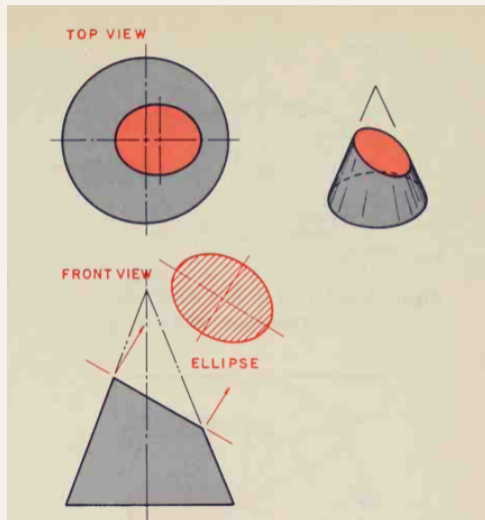
- ▶ A conic section is a section cut by a plane passing through a cone. Depending upon where the section is cut, the various shapes can be a triangle, a circle, an ellipse, a parabola or a hyperbola.



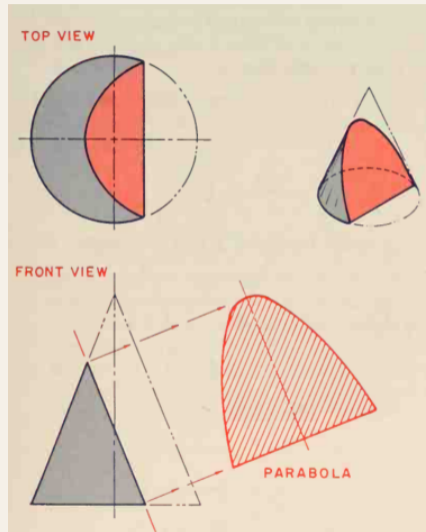
- ▶ A circle shape:



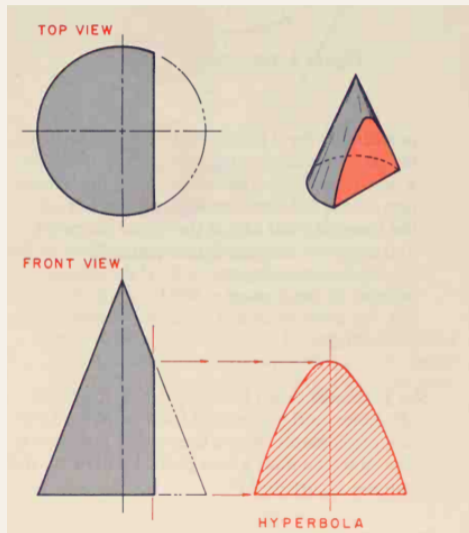
- ▶ An ellipse shape:



- ▶ A parabola shape:



- ▶ A hyperbola shape:



## Section 7

# Ellipse Construction

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- 1 Introduction
- 2 Geometric Nomenclature
- 3 Elemental Construction Principles
- 4 Polygon Construction
- 5 Circular Construction
- 6 Conic Sections

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Oblong / Rectangle Method

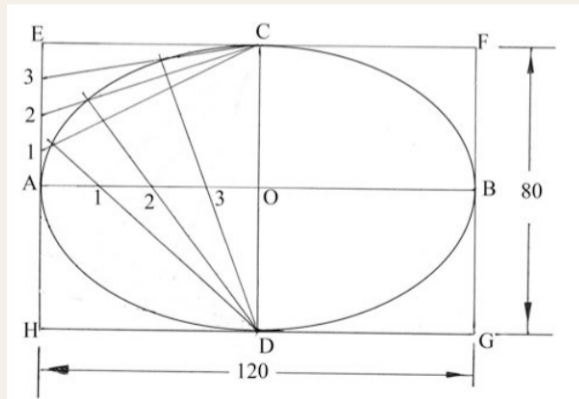
Archie's Circle Method

7

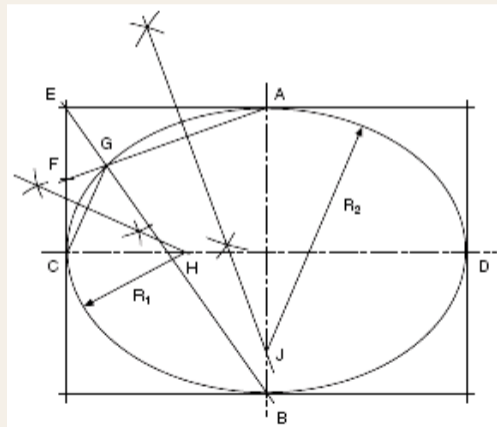
Draw an ellipse whose major axis is 120 mm and minor axis is 80 mm.

- ▶ Construct a rectangle  $EFGH$  using the given major axis and minor axis as its sides.
- ▶ Join the mid-points on the opposite sides of the rectangle to show the major axis  $AB$  and the minor axis  $CD$ . The centre of the ellipse is designated as  $O$ .
- ▶ Divide  $AO$  and  $AE$  into the same number of equal parts (four in this case) and number the division points from  $A$ .

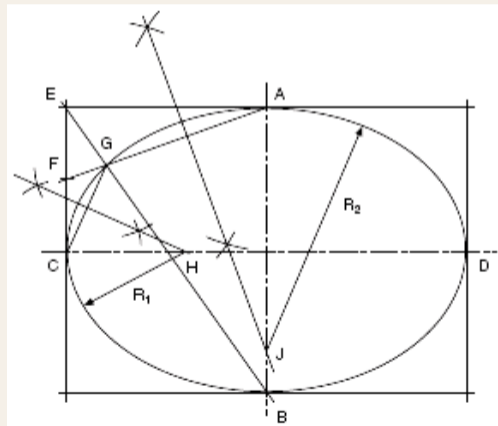
- ▶ Draw a line from  $C$  through point 1 on the line  $AE$  and draw another line from  $D$  through point 1 on the line  $AO$ . The point of intersection of these lines is a point on the ellipse.
- ▶ Similarly, the intersections of lines from  $C$  and  $D$  through points 2 and 3 will also be on the ellipse.



- ▶ Draw the rectangle  $ABCD$  circumscribed by the ellipse.
- ▶ Let  $F$  be the middle of  $EC$ , join  $AF$  and  $BE$ , to obtain the intersection point  $G$ .



- ▶ Draw the bisector of  $AG$  intersecting  $AB$  at  $J$ , and the bisector of  $CG$  intersecting  $CD$  at  $H$ .
- ▶ Trace the arcs ( $H, R_1 = HC$ ) and ( $J, R_2 = JA$ ).



**Thank you for your attention.**

Mr. ZENNADI Karim – ENP