# Practical Geometry for the Woodworker
# Using Compass and Rule

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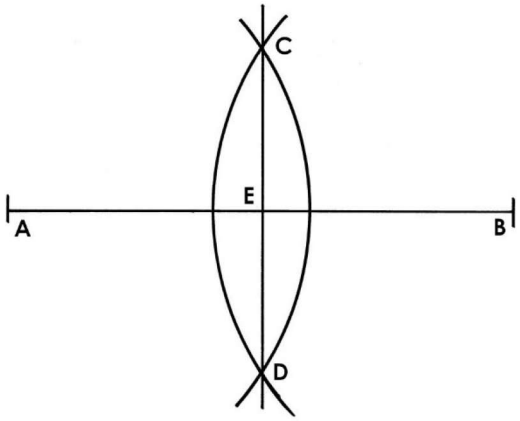
This document aims to highlight practical ways of designing and laying out components of everyday woodworking projects using ancient and overlooked methods. These same techniques were instrumental in crafting remarkable structures throughout the centuries, such as the Vatican, the Pyramids, and the Parthenon, all without the aid of laser levels, digital protractors, or Woodpecker squares. In many instances, the ancients relied on dividers, homemade levels, and straight sticks as their primary layout tools.

So, why delve into these antiquated layout methods when we have Sketchup and CNCs? For one thing, they constitute the foundation of our craft—an integral part of our heritage worth exploring. I believe they still hold value in our digital age. Mastering the basics and foundation of any skill fosters a deeper appreciation for more modern methods. Furthermore, Practical Geometry can provide design elements unavailable when relying solely on technology. As this document will demonstrate, 1/6 and 1/4 circle arcs can yield more aesthetically pleasing curves than those created using Sketchup. Geometry has the additional benefit of introducing a level of efficiency unattainable through technology alone. For example, when calculating 1/6 circle arcs for a set of six cabinet doors with varying widths, the most efficient approach is through Geometry. A layout can be completed before a computer is even booted up and running.

In essence, Practical Geometry is not only fascinating but also immensely satisfying when successfully applied. It is, in some ways, the key through which the ancients comprehended the inherent design of the natural world, quantified it, harnessed it, and applied it to man-made forms. My hope is that you will pull out a ruler and compass and experience first-hand the beauty and simplicity of these techniques.

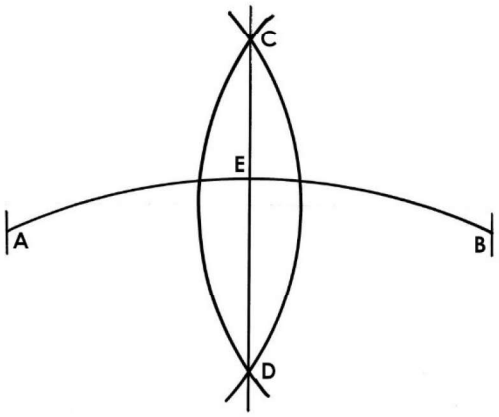
**Handout Code:**
**Line:** a straight line passing through 2 points. "Line AB" indicates a line that passes through points A and B.
**Segment:** section of a line. "Section AB" indicates a section of a line that extends between points A and B.
**Point:** a precise location on a line/segment in space or a place where two lines, segments, arcs or circles intersect. Points are distinguished from one another by attaching letters to them. Point "A" indicates a point on a line where two lines, arcs or circles intersect.
**Circles:** have a defined size and pivot or focal point. Size is indicated by the radius or half the diameter. "Circle AB with focal point C" is a circle with a radius length of "line AB" and focal point of "C".
**Arcs**: any part of the circumference of a circle. "Arc AB with focal point C" is an arc with radius of AB and focal point of C.

**Midpoint/Perpendicular of Line**



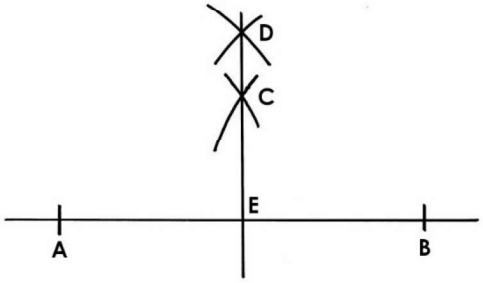

1) Determine segment to bisect as AB. 2) Swing arcs of equal radius and greater than half the distance of AB from focal points A and B to create intersection points C and D. 3) Connect points C and D to create line CD that will be in the center and perpendicular to line AB.

**Midpoint/Perpendicular of Arc**



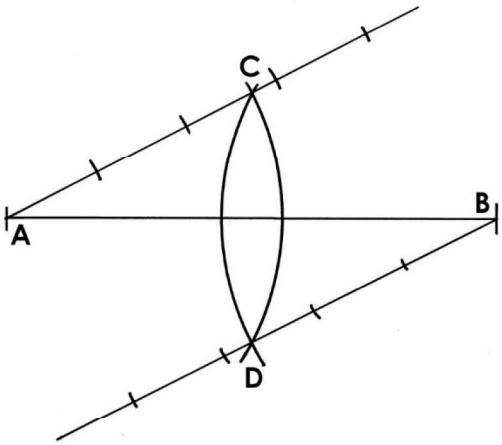

1) Determine given arc to bisect as AB. 2) Swing arcs of equal radius and greater than half the distance of arc AB from focal points A and B to create intersection points C and D. 3) Connect points C and D to create line CD that will be in the center and perpendicular to arc AB.

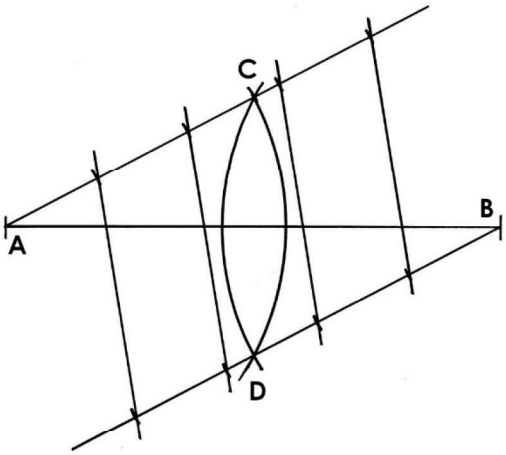
**Midpoint/Perpendicular of Line**




1) Determine given segment to bisect as AB. 2) Draw two sets of arcs from focal points A and B. The first set must have radii greater than half the distance of AB to create point C. The second set must have even larger radii than the first to create point D.
3) Connect points C and D to create line CD that will be in the center and perpendicular to arc AB.

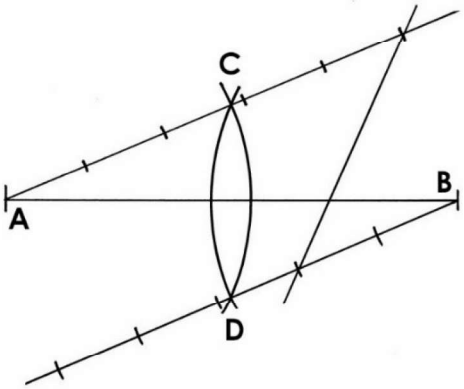
**Dividing Line into Equal Segments**



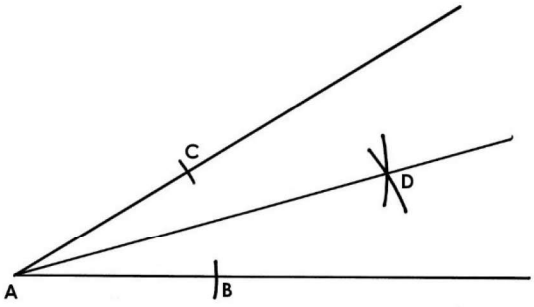

1) Determine segment to be divided and mark end points A and B. In this case the line will be divided into 5 parts so will need 4 partitions. 2) Draw arcs slightly greater than half the distance of AB swinging from points A and B to create points C and D. 3) Draw lines AC and BD to create parallel lines. 4) Starting from Points A and B, mark out equal partitions on lines AC and BD (in this example 4).
5) Connect partition marks to divide line AB in equal segments (in this case 5).

**Divide Line into Ratio**



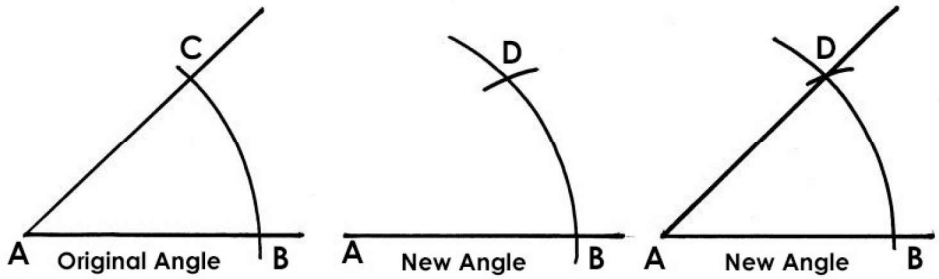

1) Determine segment to be divided and mark end points A and B. In this example we are dividing segment in a ratio of 5:2. 2) Draw arcs slightly greater than half the distance AB from points A and B to create points C and D. 3) Draw lines AC and BD to create parallel lines. 4) Starting from points A and B, mark out equal partitions on lines AC and BD (in this example 5). Connect partitions 5 and 2 to obtain desired 5:2 ratio.

**Bisect Angle**



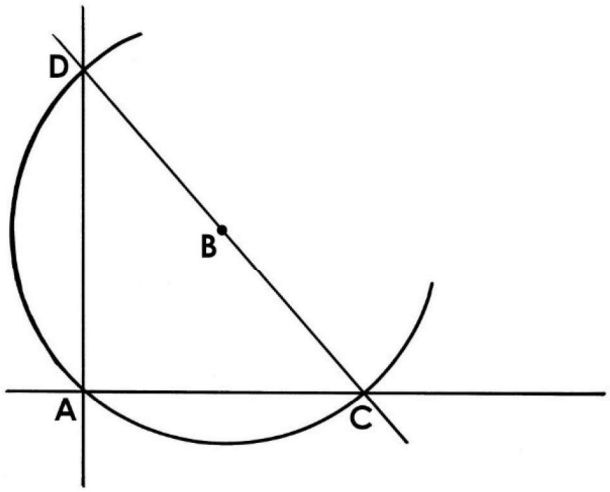

1) Draw angle to bisect and designate origin point as A
2) Swing two arcs of equal length from point A that cross each leg to create points B and C. 3) Swing two arcs of equal length from B and C to create point D. 4) Draw line AD to bisect angle.

**Copy Angle**



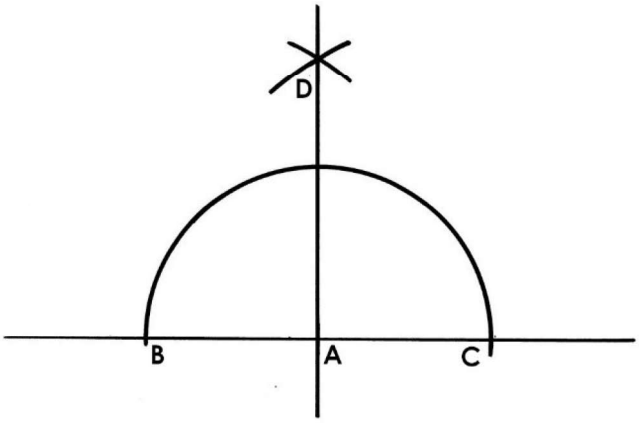

1) Draw original angle to be copied and designate origin point as A 2) Swing arc from point A that crosses both legs to create points B and C. 2) Copy arc with radius AB to new line from new origin point A 3) Set compass on original angle to arc BC And swing this arc on new angle from focal point B to create point D. 4) Draw line AD to reproduce angle.

**Find Perpendicular Line from Point**



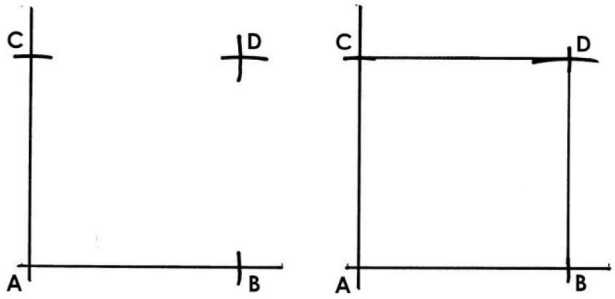

1) Mark point where you want perpendicular line and label A. 2) Set compass to draw an arc. The exact distance is not important. Using compass setting, mark focal point B referencing from point A. 3) Draw Arc with radius AB from focal point B that extends above point A and intersects with the line to create point C. (If you prefer, draw a complete circle) Draw line CB extending until it connects with the arc to create point D. Draw line AD to create line perpendicular to line AC.

**Find Perpendicular Line from Point**



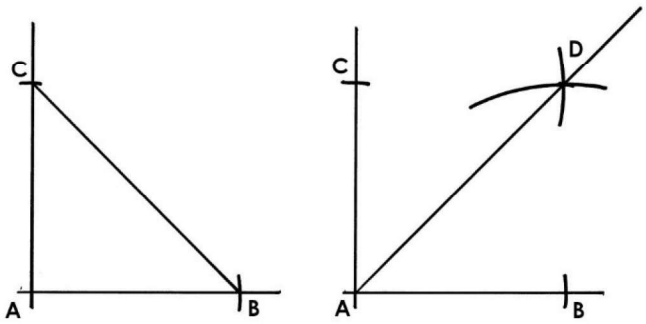

1) Mark point on a line where you want perpendicular line and label A. 2) Set compass to draw an arc. The exact distance is not important. 3) Draw Arc until it crosses your line at each end to create points B and C. 4) Draw 2 larger arcs from points B and C to create point D. 5) Draw line AD, which will be perpendicular to point A.

**Construct Square**



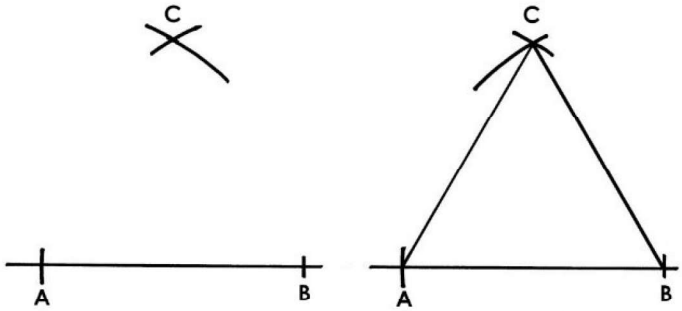

1) Draw horizontal and perpendicular lines and label intersection point A. 2) Set compass to desired side length and swing points B and C. 3) Using same compass setting define point D swinging arcs from focal points B and C. 4) Draw segments CD and BD for a perfect square.

**Draw 45 Degree Angles-Two methods**



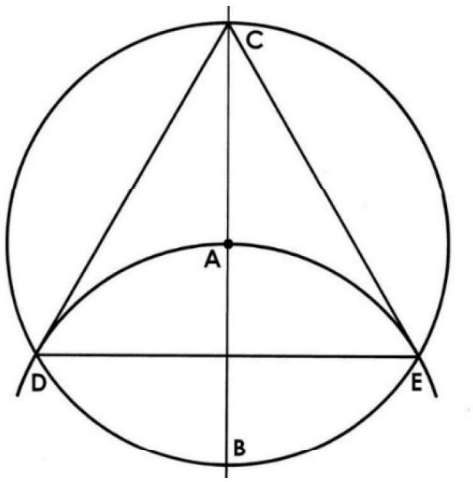

***Method 1:*** 1) Draw horizontal and perpendicular lines and label intersection point A. 2) Set compass to desired altitude and swing points B and C. 3) Draw segment BC for 45-degree side.
***Method 2:*** 1) Draw horizontal and perpendicular lines and label intersection point A. 2) Set compass to desired altitude and swing points B and C. 3) Using same compass setting define point D swinging arcs from focal points B and C. 4) Draw diagonal line AD for 45-degrees angle.

**Equilateral Triangle**



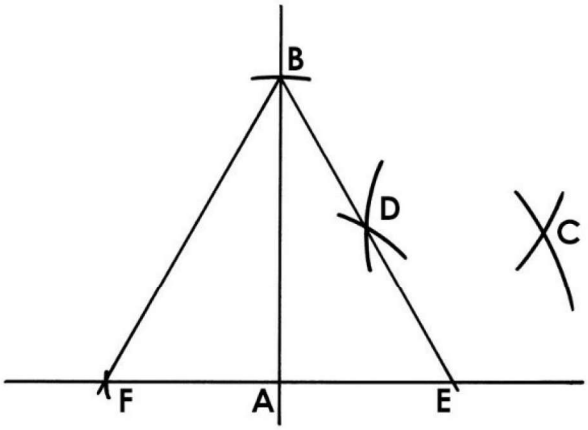

1) Determine side length and set compass to this distance. 2) Swing arc from point A on line to create point B. 3) Swing arcs from focal points A and B to create point C. 4) Draw segments AC and BC to create equilateral triangle.

## Draw Equilateral Triangle in Circle



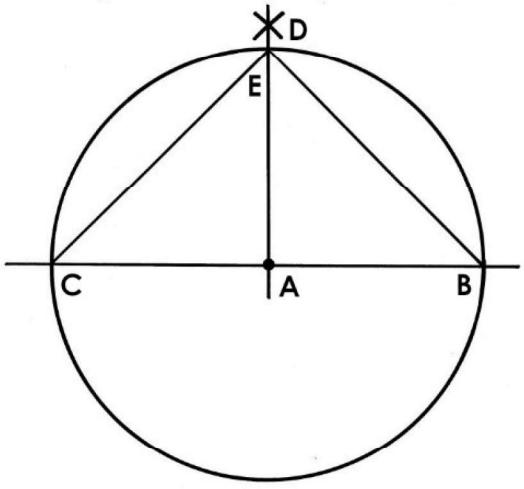

1) Draw circle to desired size. 2) Bisect circle vertically to create points B and C. 3) Swing Arc with radius of AB from focal point B until it intersects with circumference of circle to create points D and E. 4) Draw lines DE, DC and CE to complete triangle.

## Equilateral Triangle with Known Altitude



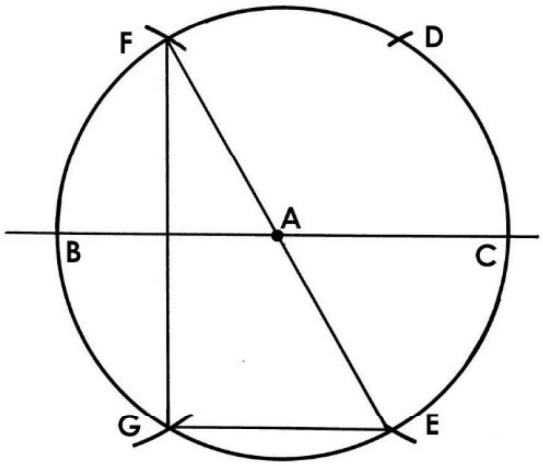

1) Draw horizontal and perpendicular line to create point A. 2) Determine altitude, set compass and swing arc to create Point B. 3) Swing arc with radius of AB from focal points A and B to create intersection point C. 3) Bisect distance of arc AC to create intersection point D. 4) Draw line BD and extend to horizontal line to create point E. 5) Set compass for distance BE and swing arc from focal point E to create Point F. 6) Draw Line FB to complete triangle.

## Right Triangle



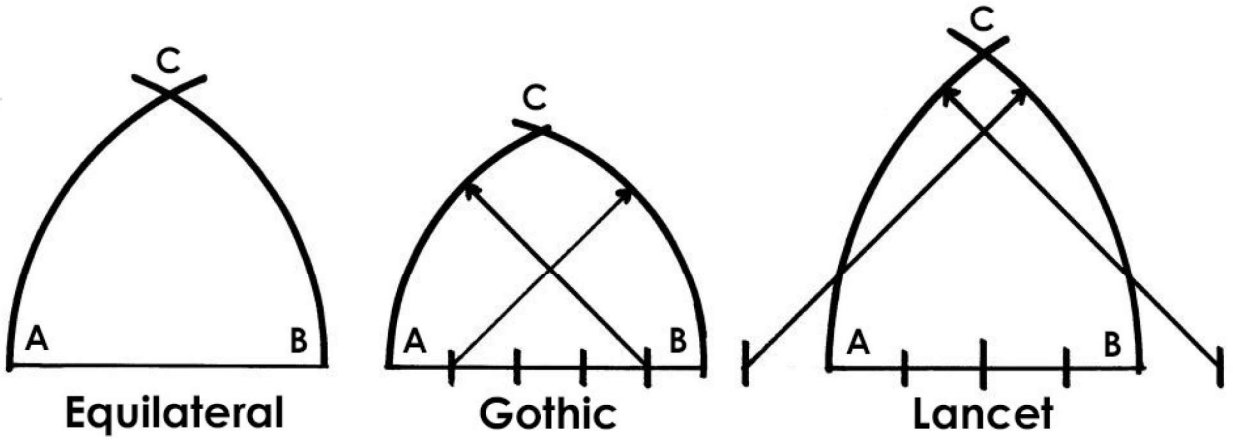

1) Draw circle from focal point A and bisect to create points B and C. 2) Bisect BC by swinging arcs from points B and C to create center point D. 3) Draw line DA to create point E that intersects with circumference of circle. 4) Draw segments CE and BE to complete the right triangle.

**30/60/90 Triangle**



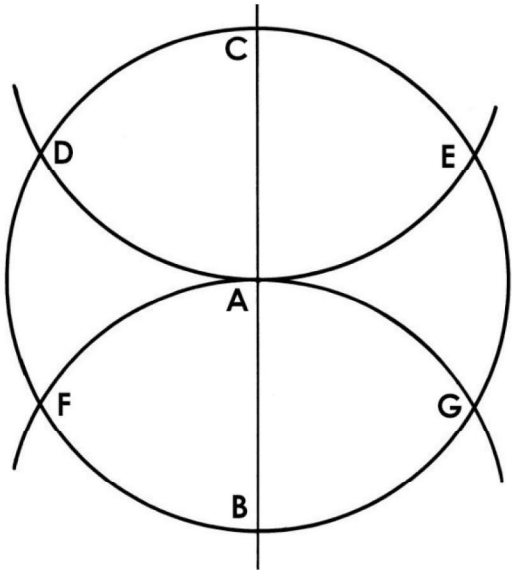

1) Draw circle with radius AC
2) Draw horizontal bisector BC.
3) Swing arcs with radius AC from points B and C intersecting with circumference of circle to create points D, E, F and G. 3) Draw segments FG, GE and FE to complete 30/60/90 triangle.

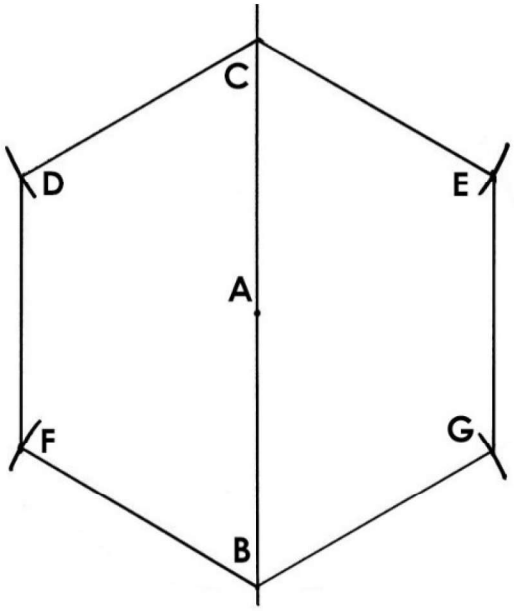
**Arches**




**Equilateral Arch:** 1) draw horizontal baseline 2) determine desired width and set compass to that distance 3) Mark boundaries as points A and B 4) swing arcs from both focal points A and B to create point C and complete arch.
**Gothic Arch (short and squat):** 1) draw horizontal baseline 2) determine desired width and set compass to that distance 3) Mark boundaries as points A and B 4) divide segment AB into 5 equal divisions 5) strike arcs starting from points A and B from focal points 1 and 4 to create point C and complete Gothic arc.
**Lancet Arc (tall and thin):** 1) draw horizontal baseline 2) determine desired width and set compass to that distance 3) Mark boundaries as points A and B 4) divide segment AB into 4 equal divisions and add one division to outside of base 5) Swing arcs starting from points A and B from both outside focal points to create point C and complete Lancet arch.

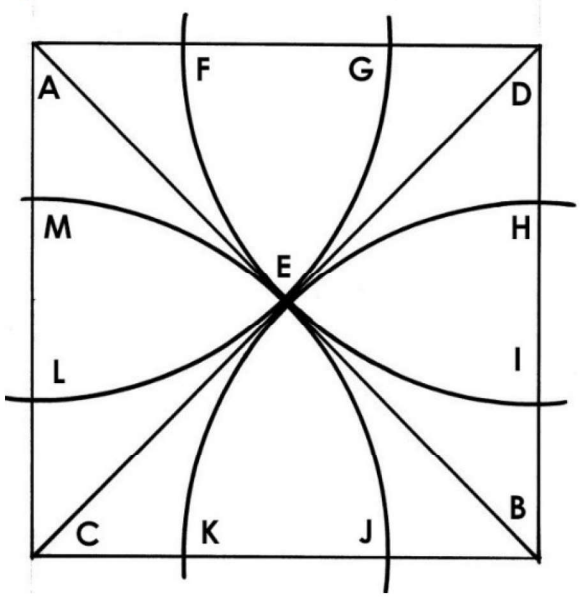
**Hexagon**

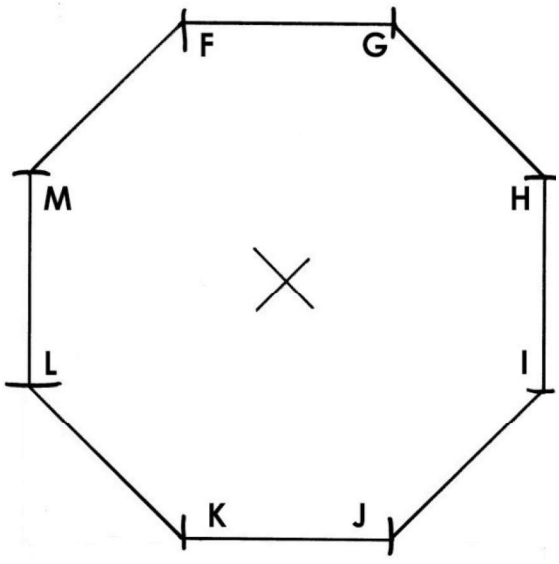



1) Draw circle with radius AC 2) Draw horizontal bisector BC. 3) Swing arcs with radius AC from points B and C that intersect with circumference of circle to create points D, E, F and G. 3) Draw segments DC, CE, EG, GB, BF and FD to complete the hexagon.

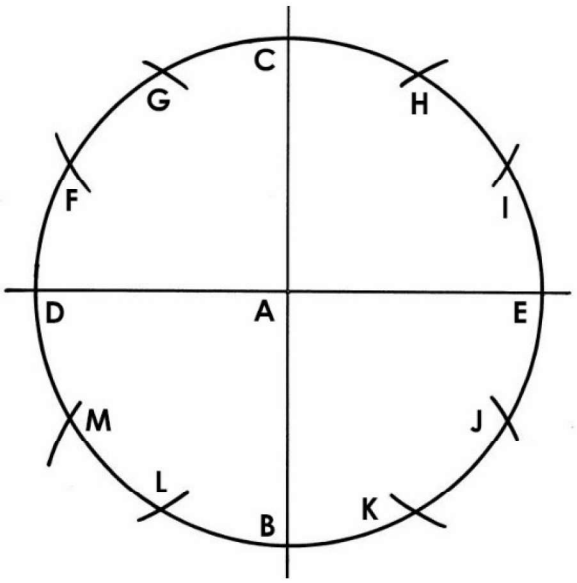
**Octagon**



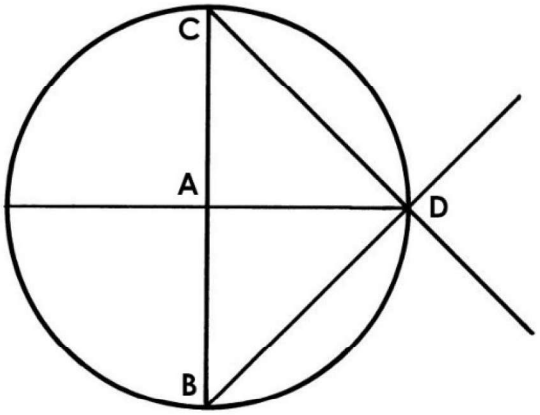

1) Draw square. 2) Bisect diagonally to create Points A, B, C, D and E. 3) Swing arcs with radius ED from points A, B, C and D to create points F, G, H, I, J, K L and M. 4) Draw segments MF, GH, IJ and KL to complete octagon.

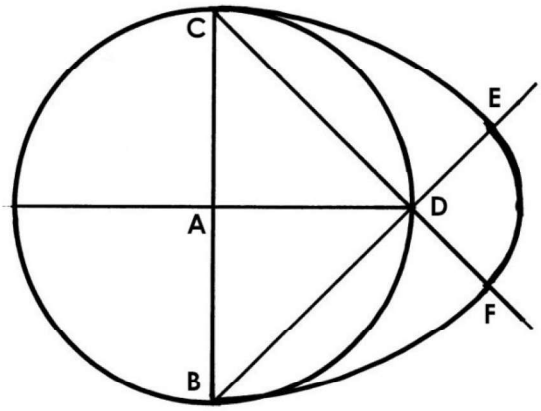
**Clock Face**




1) Draw circle with radius AC
2) Draw horizontal and vertical bisectors 3) Swing arcs with radius AC from Points B, C, D, E that intersect with circumference of circle to create points F, G, H, I, J, K, L, and M.

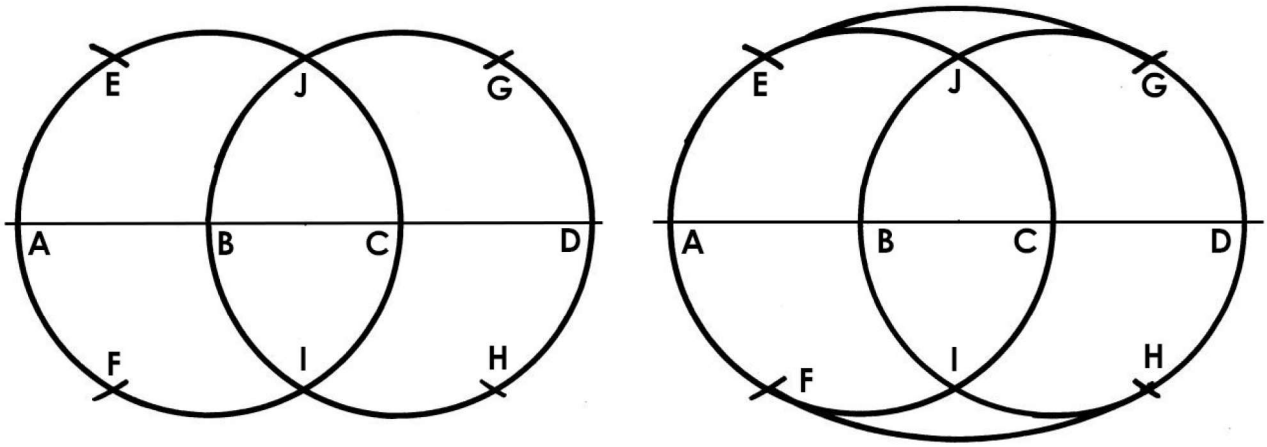
**Oval (oblong)**



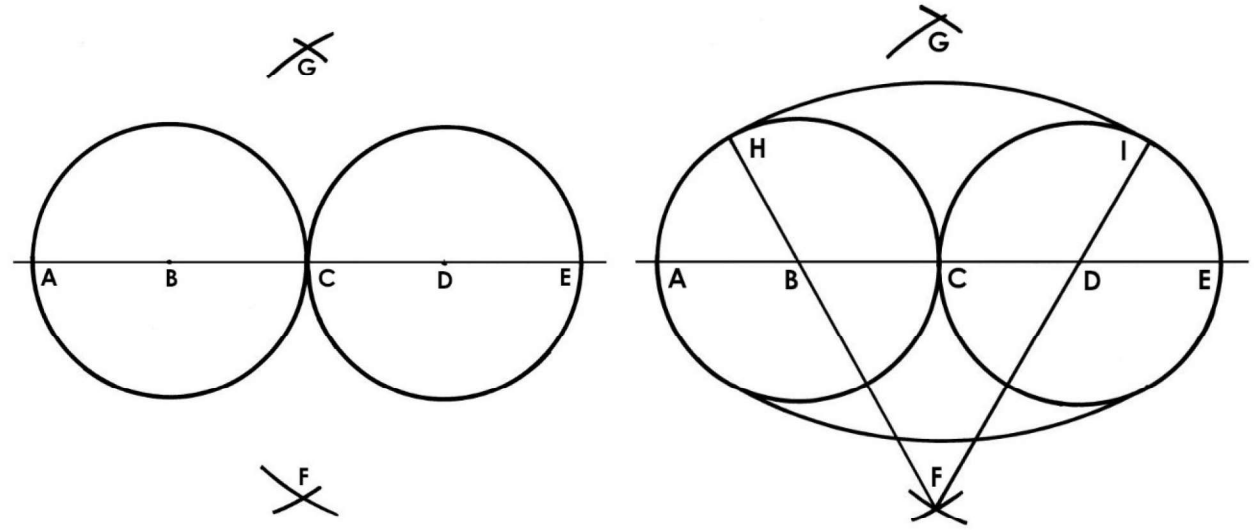

1) Draw circle with horizontal and vertical bisectors to create center point A.
2) Draw diagonal lines BD and CD that extend past circle circumference. 2) Draw arc with radius BC and focal point C until touches line CD. Draw arc with radius BC with focal point B until reaches Line BD. 3) Draw arc from focal point D with radius DE from points E to F to complete oval.

**Oval with Known Width (Squat)**



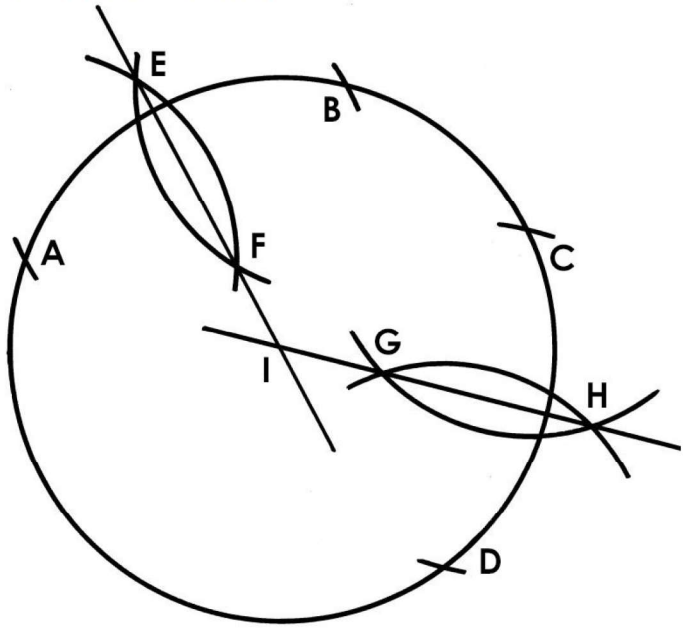

1) Determine desired width of oval and label as AD. 2) divide AD into 3 equal parts. 3) Draw 2 overlapping circles with Radius CD from focal points B and C. 4) Draw arcs with radius CD from focal points A and D that intersect with circle circumference to create Points E, F, G and H. 5) Draw arcs with radius IE from focal points I and J between points E and G and F and H to blend circles and create oval.

**Approximate Elipse**



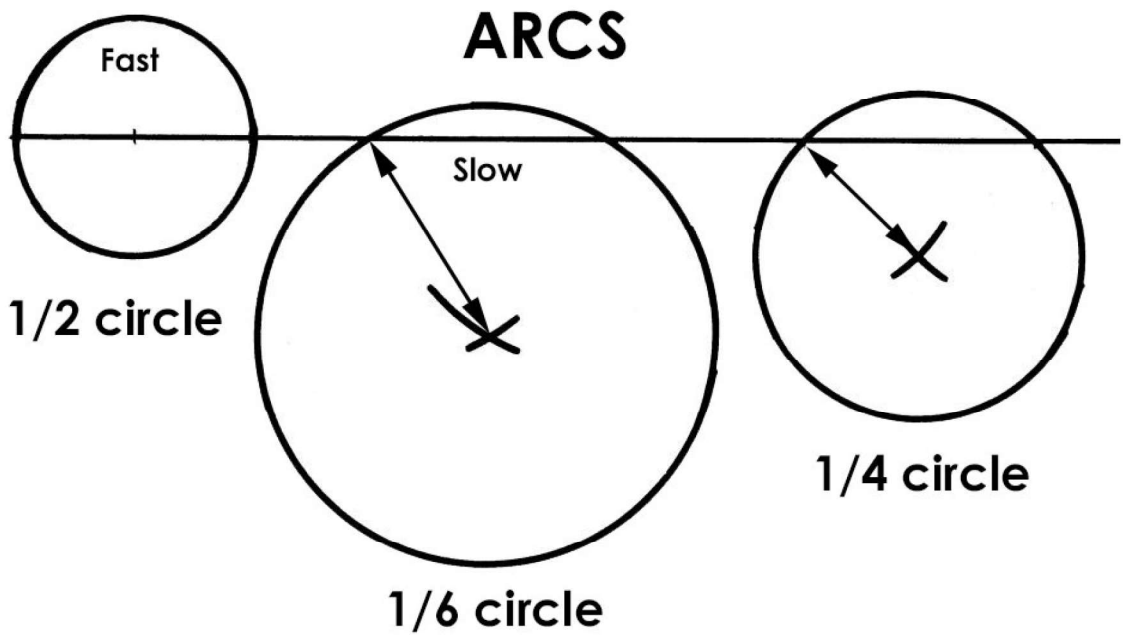

1) Determine desired width of ellipse and label AE. 2) Divide AE into 4 equal parts making Points A, B, C, D and E. 3) Scribe two touching circles with radius AB from focal points B and D. 4) With radius AC scribe arcs from focal points B and D to create intersection points F and G. 5) Draw lines FB and FD that extend to circle circumference that create points H and I. 6) Scribe arc with radius of FH from focal point F between points H and I to bend circles. Repeat arc FH from focal point G to complete Ellipse.

**Find Center of Circle**

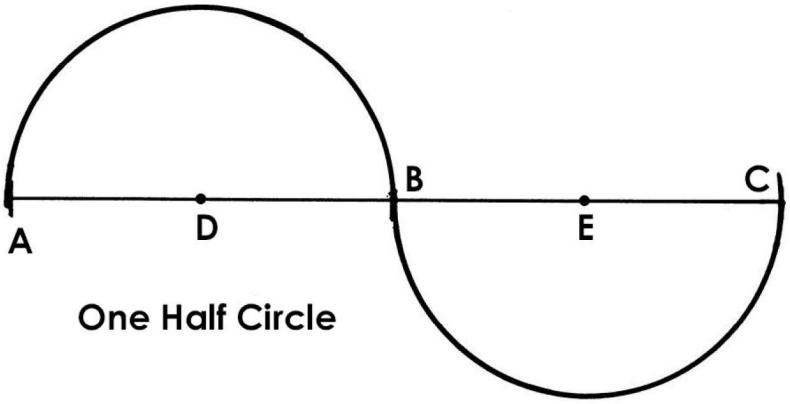



1) Draw circle. 2) Mark off 2 sections and label section endpoints A, B, C and D. The length of these sections is not important, just make sure both sections are somewhat perpendicular to one another.
3) Find midpoints of these sections and label intersectins points E, F, G and H. Draw lines EF and GH and extend past the center of the circle to create intersection point I, the exact center.

**Arcs: visible portion of a circle**

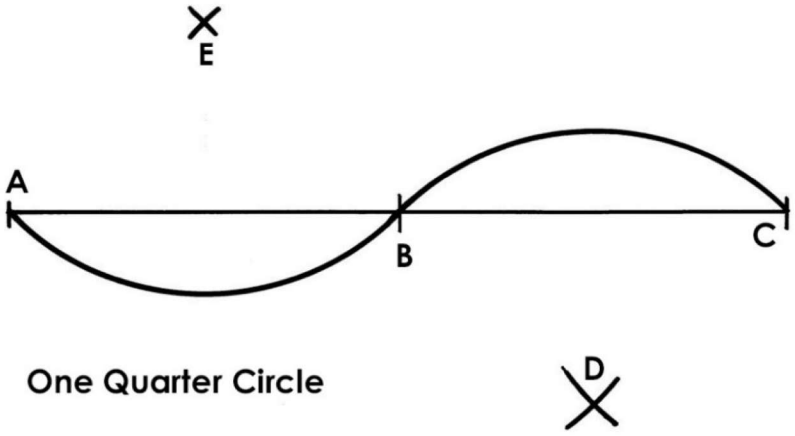


**One Half Circle**



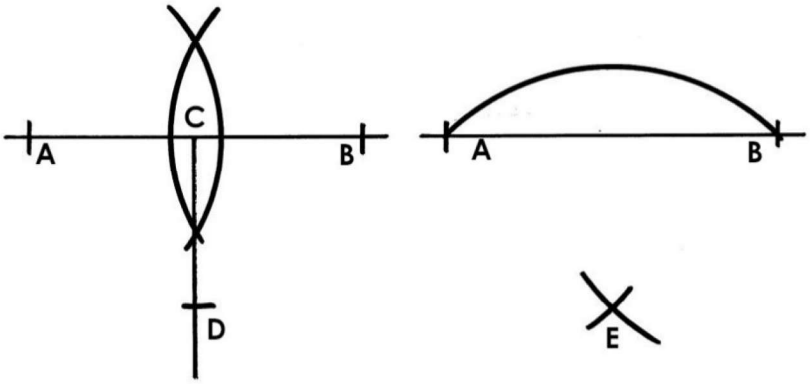

Focal point at D and E with radius AD

**One Quarter Circle**



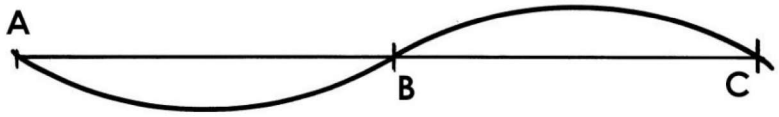

Focal point D and E with radius determined below.

**Finding Focal Point for One Quarter Circles**




1) Determine width of arc with points A and B. 2) Bisect line and mark point C
3) Extend line below line AB. 3) Swing arc BC on vertical line CD to create point D.
4) Set compass for distance DB and swing arcs from focal points A and B to create focal point E. 5) Swing arc between points A and B to create one quarter circle arc.

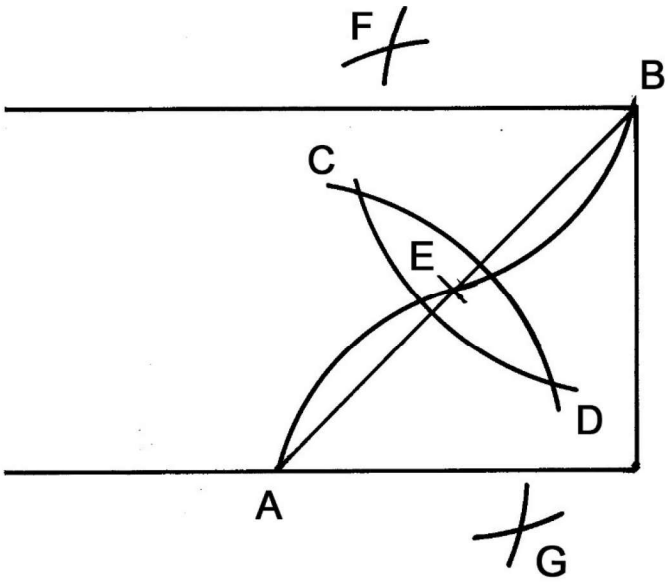
**One-Sixth Circle**


One sixth circle

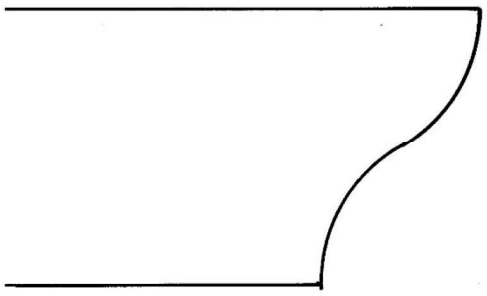

Focal point E and D with arc radius AB

**Draw Cyma Curve on Molding or Bracket**

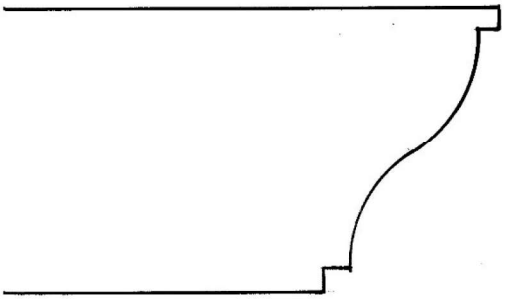



1) Draw line AB for Cyma curve to follow, in this case, at 45 degrees 2) From points A and B, swing arcs C and D to make intersection points C and D. 3) Connect points C and D to find Midpoint E of line AB. 4) Set compass for distance AE ($1/6^{th}$ circle) and swing arc from pints A and E to create point G and from points E and B to create point F. Swings arc AE from point G and arc BE from point F to create symmetrical $1/6^{th}$ circle Cyma Curve.

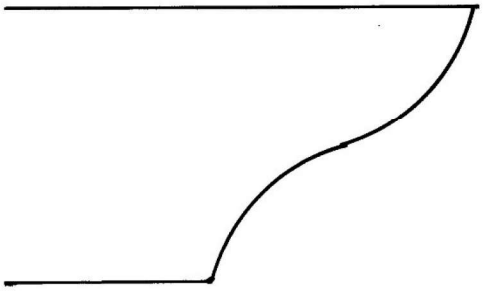
**Examples of Cyma Curves in Molding or Brackets**



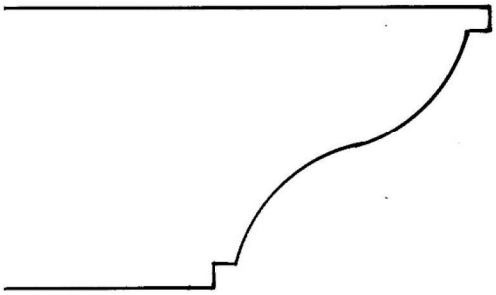
30 Degree Cyma Curve 1/6th Arc



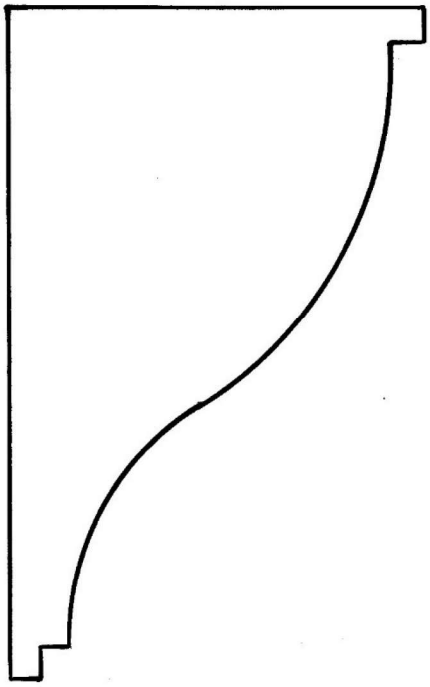
30 Degree Cyma Curve with Upper & Lower Fillet



45 Degree Cyma Curve with 1/6th Arc

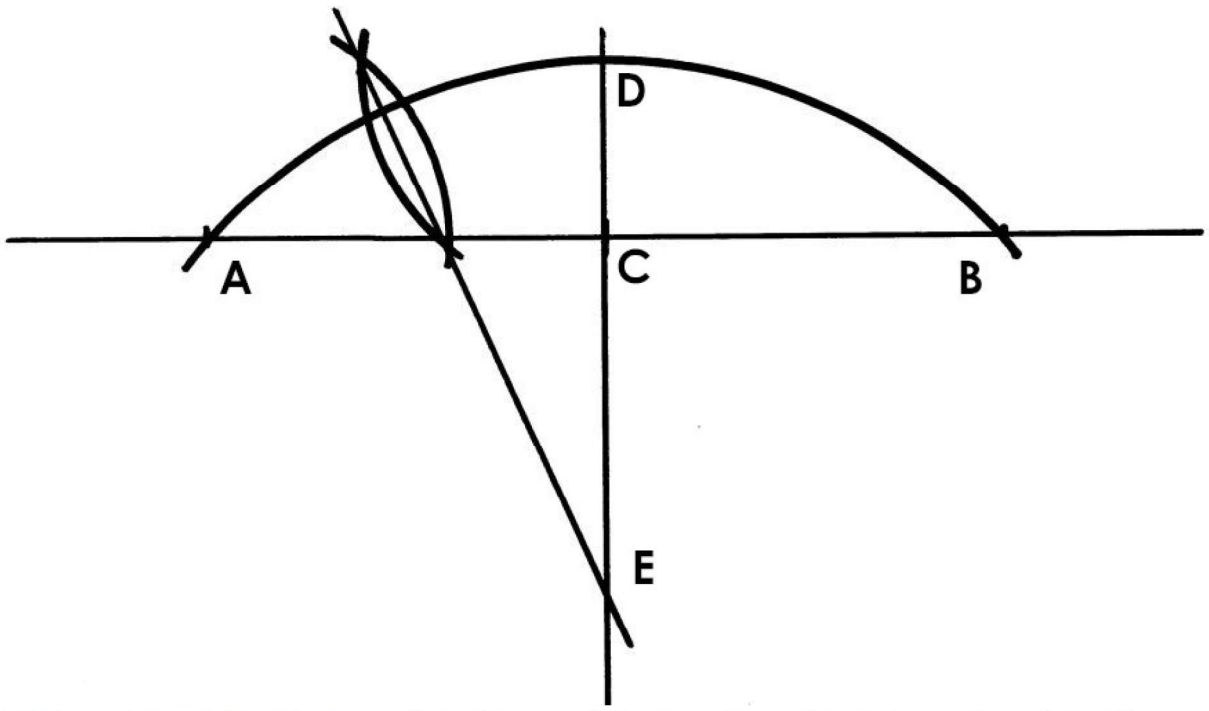


45 Degree Cyma Curve with Upper & Lower Fillet



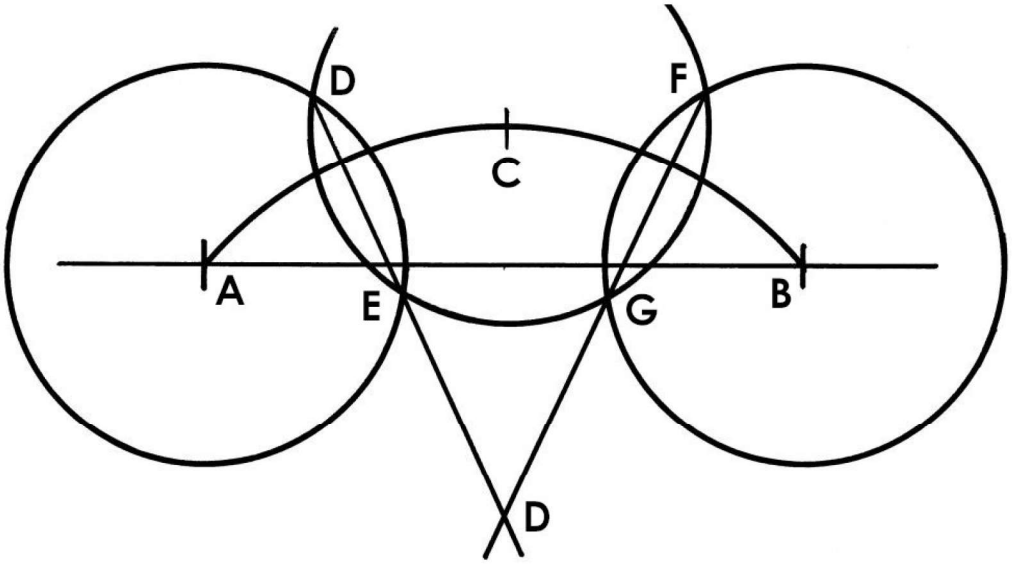
Bracket with overall size at golden ration (1:1.618) width to height with 30 degree Cyma curve divided in 5 parts with 3/5ths convex and 2/5$^{th}$ concave.

**Finding Focal Point of Arc with Known Width and Height**



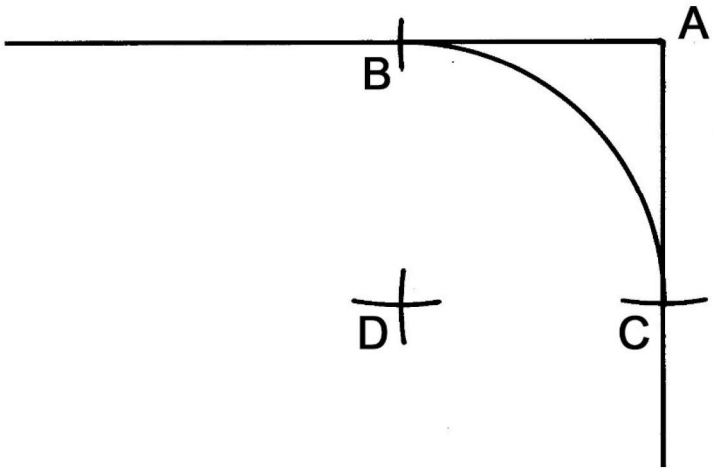

1) Determine width of arc on baseline and designate end points as A and B. 2) Bisect line AB and extend perpendicular line above and below line AB. 3) Determine height of arc and label point D. 4) Bisect distance AD and extend line until crosses line CD to create focal point E. 5) Swing arc DE from focal point E between points A, D and B to complete arc.

**Finding Focal Point for Arc with Known Width and Height**



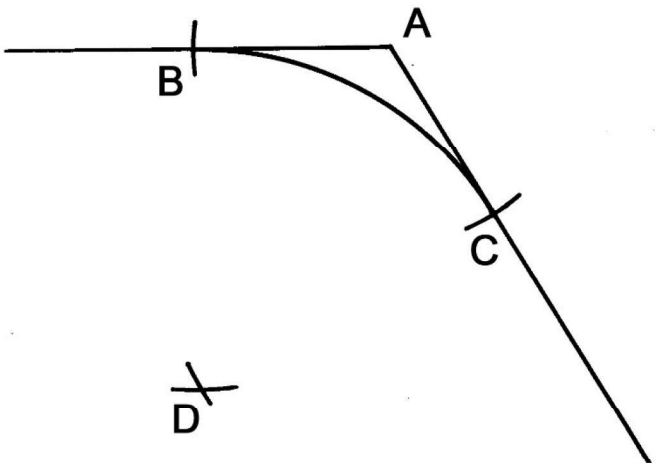

1) Determine width of arc on baseline and designate endpoints A and B. 2) Bisect line AB and mark appropriate arc height as point C. 4) Swing circles from focal points A, B and C making sure the circles overlap to create intersection points D, E, F and G. Connect and extend lines DE and FG to create intersection point D. 5) Swing arc DA from focal point D between points A, B and C to complete arc.

**Drawing Quarter Circle Arc on 90 Degree Corner**



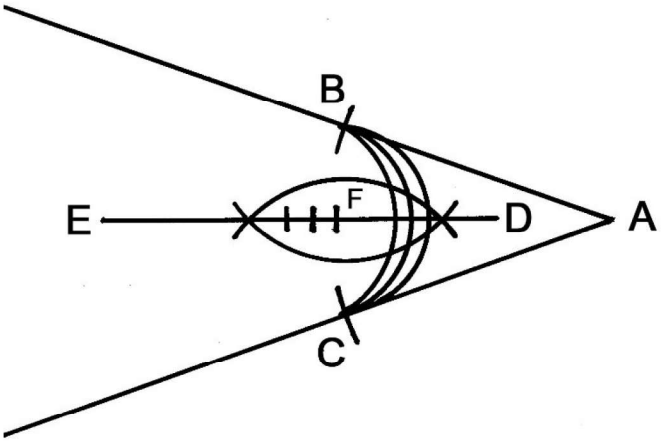

1) Determine size of arc and set compass for that distance, in this case AB or AC. 2) Swing arcs from corner point A to create starting and end points B and C. 3) Swing arcs from points B and C to create intersection point D. 4) Create arc BC from focal point D to create quarter circle.

**Drawing Arc on Obtuse Corner**




1) Determine size of arc and set compass at that distance, in this case AB or AC. 2) Swing arcs from corner point A to create starting and end points B and C. 3) Set compass for distance BC. 4) Swing arcs from points B and C to create intersection point D. 4) Create arc BC from focal point D to create one-sixth circle.

**Drawing Arc on Acute Corner**




1) Determine size of arc and set compass at that distance, in this case AB or AC. 2) Swing arcs from corner point A to create starting and end points B and C. 3) Bisect distance BC and draw line AB. 4) Set compass from various focal points (F) on line DE to points B and C and swing arcs of varying sizes until you find one that looks best and stays fully within the apex.