

Essentials of Trigonometry

Math 0861

Learning Centre



Essentials of Trigonometry 2: Beyond Right Triangles

THE UNIT CIRCLE

Trigonometry with right triangles can only tell us about acute angles, but we can extend the concept of trig ratios to obtuse angles, **reflex angles** (angles measuring between 180° and 360°), and even angles measuring greater than 360° or less than 0° . To do this we create right triangles within a **unit circle**, a circle drawn with its centre at $(0, 0)$ and a radius of 1.

In using the unit circle, the angle θ starts at the positive x-axis, and opens counterclockwise. The arm of the angle that isn't on the x-axis intersects the unit circle at a point (x, y) . We create a triangle by drawing a vertical line between (x, y) and the x-axis. If θ is an acute angle, then the six trigonometric ratios can be calculated using these coordinates and the radius of the circle, r .



$$\begin{aligned} \sin \theta &= \frac{\text{opposite}}{\text{hypotenuse}} = \frac{y}{r} & \cos \theta &= \frac{\text{adjacent}}{\text{hypotenuse}} = \frac{x}{r} & \tan \theta &= \frac{\text{opposite}}{\text{adjacent}} = \frac{y}{x} \\ \csc \theta &= \frac{\text{hypotenuse}}{\text{opposite}} = \frac{r}{y} & \sec \theta &= \frac{\text{hypotenuse}}{\text{adjacent}} = \frac{r}{x} & \cot \theta &= \frac{\text{adjacent}}{\text{opposite}} = \frac{x}{y} \end{aligned}$$

Because of the specific way the triangle is constructed, hypotenuse always goes with r , adjacent goes with x , and opposite goes with y .

For acute angles, x and y are always positive. We can form a trigonometric ratio for angles that are 90° or more by going past the positive y -axis on the way around the circle. In these cases, the x - or y -coordinate (or both) might be negative; r is never negative because it is considered to be a distance, and distances cannot be negative.

We divide the unit circle into **quadrants**. They're numbered as shown in the diagram. The values of each ratio are consistently positive or negative within a quadrant, but change from quadrant to quadrant. Remember that if a particular ratio is positive (or negative), then its reciprocal will have the same sign. In this diagram, then, only the three main ratios are shown. In quadrant I everything is positive. In quadrant II, \sin is positive; \cos and \tan are negative. In quadrant III, \tan is positive; \sin and \cos are negative. In quadrant IV, \cos is positive; \sin and \tan are negative. Memorize this by remembering CAST: positive goes, g l, g in, j an starting from quadrant IV and moving counterclockwise.



We form trig ratios for angles higher than 360° by going around the unit circle more than once. For negative angles, go clockwise from the positive x -axis rather than counterclockwise. A unit circle diagram for any angle outside the range 0° to 360° looks just like the diagram for some angle between 0° and 360° — they cross the unit circle in the same place. (The diagrams for 370° and -350° , for example, both look the same as

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