

# Trigonometry *Without* Right Angles

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This article describes how trigonometric functions can be defined for non-right-angled triangles. In particular, the ratios *csin*, *ccos*, and *ctan*, corresponding to the sine, cosine, and tangent ratios, are defined for triangles containing a  $\pi/3$  angle. Some of the implications are discussed, including the graphs of these functions and the small-angle approximations.

How important are right angles for trigonometry? The standard trigonometric functions are defined as the ratios of sides within right-angled triangles, but is this essential? On a square lattice it makes sense to draw right-angled triangles and label the sides 'opposite', 'adjacent', and 'hypotenuse', but what about on an *icosometric* grid?

We will label the sides of a triangle containing a  $\frac{\pi}{3}$  angle as 'adjacent' and 'opposite' to a given angle ( $\theta$  in figure 1) and call the side opposite the  $\frac{\pi}{3}$  angle the 'hypotenuse'. Then we can define 'equilateral' trigonometric functions *csin*, *ccos*, and *ctan* by analogy with the *sin*, *cos*, and *tan* functions.

We can express the *e*-trigonometric functions in terms of the ordinary trigonometric functions by using the sine rule and the cosine rule on the  $\frac{\pi}{3}$  triangle. Using *o* for opposite, *a* for adjacent, and *h* for 'hypotenuse' in the  $\frac{\pi}{3}$  triangle we have, from the sine rule, that

$$\frac{o}{\sin \theta} = \frac{h}{\sin(\frac{\pi}{3})} = \frac{a}{\sin(\pi - \frac{\pi}{3} - \theta)} \quad (1)$$

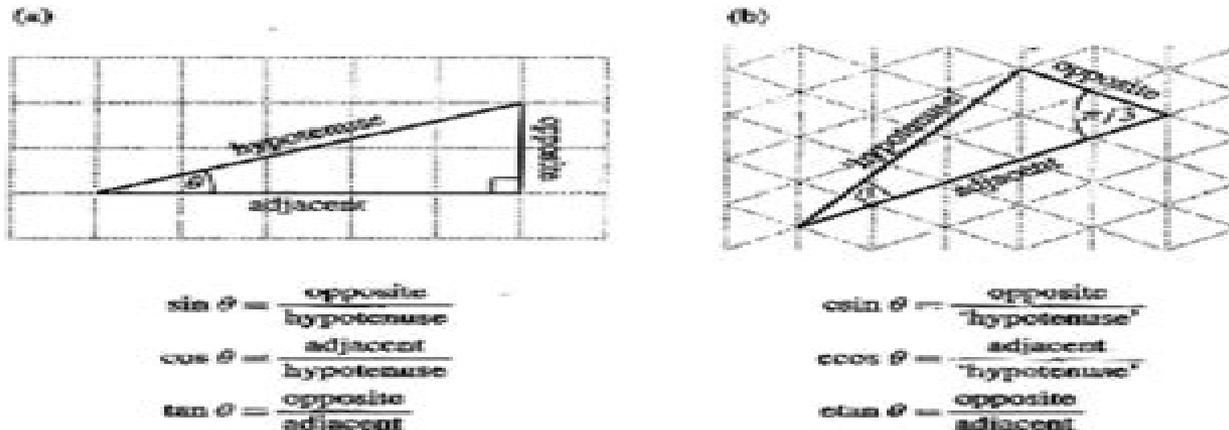


Figure 1 (a) Trigonometry in a right-angled triangle; (b) *e*-trigonometry in a  $\frac{\pi}{3}$  triangle.

# Without Right Angles

**G Thomas**



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