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# Quick Study ACADEMIC TRIGONOMETRY

triangles, circles, trigonometric functions, lines

**Trigonometry (Trig)** means measurement of triangles. It is usually studied as measurements of sides and angles of triangles and as points on a unit circle. This study guide is basically separated into three main sections: trig with triangles and trig with a unit circle. In trigonometry, the measures of angles are usually represented by letters from the Greek alphabet. The Greek letters  $\theta$ ,  $\alpha$ ,  $\nu$ , and  $\beta$  will be used throughout this study guide to represent angle measures.

## TRIG WITH TRIANGLES

**A. Right Triangle**

- A right triangle is a triangle with exactly one  $90^\circ$  (right) angle.
- The **hypotenuse** is the longest side of a right triangle, and is always located opposite the right ( $90^\circ$ ) angle.
- The two shorter sides of a right triangle are both called **legs**.
- The **Pythagorean Theorem** ( $\text{leg}^2 + \text{leg}^2 = \text{hypotenuse}^2$  or  $a^2 + b^2 = c^2$  where  $a$  and  $b$  are leg lengths and  $c$  is the hypotenuse length) may be used to find the length of any third side of a right triangle when any two side lengths are known.
  - When the two leg lengths are known, square the length of each leg, add these two squares together and square root the resulting sum. For example:
 
$$a^2 + b^2 = c^2$$

$$9^2 + 16^2 = c^2$$

$$81 + 256 = c^2$$

$$337 = c^2$$

$$\sqrt{337} = c$$

$$18.36 = c = \text{hypotenuse}$$
  - When the length of the hypotenuse and either leg are known, square the length of the hypotenuse, square the length of the leg, subtract these two squares, and square root the resulting difference. For example:
 
$$a^2 + b^2 = c^2$$

$$8^2 + b^2 = 10^2$$

$$64 + b^2 = 100$$

$$b^2 = 100 - 64$$

$$b^2 = 36$$

$$b = \sqrt{36}$$

$$\text{leg} = b = 6$$

**5. Special right triangles** exist that are used so often that the relationships of the side lengths should be memorized.

- $30^\circ$ - $60^\circ$ - $90^\circ$  triangles have side lengths with ratios of  $1 : \sqrt{3} : 2$ . That is, the longest leg is always  $\sqrt{3}$  times the length of the shortest leg, and the hypotenuse is always 2 times the shortest leg. This relationship can be used to find all side lengths when given only one side length. For example:
 
$$c = \text{hypotenuse} = 2x$$

$$b = \text{longest leg} = x\sqrt{3}$$

$$a = \text{shortest leg} = x$$
 If  $a = 5$  then  $c = 2 \cdot 5 = 10$  and  $b = 5 \cdot \sqrt{3} = 8.7$   
 If  $b = 8$  then  $a = 8 \cdot \frac{1}{\sqrt{3}} = 4.6$  and  $c = 2 \cdot 8 = 16$
- $45^\circ$ - $45^\circ$ - $90^\circ$  triangles have side lengths with ratios of  $1 : 1 : \sqrt{2}$ . That is, the two legs have the same length (if two angles of a right triangle are equal, then the two legs are equal), and the hypotenuse is  $\sqrt{2}$  times the length of either leg. For example:
 
$$a = \text{leg} = x$$

$$b = \text{leg} = x$$

$$c = \text{hypotenuse} = x\sqrt{2}$$
 If  $a = 7$  then  $b = 7$  and  $c = 7 \cdot \sqrt{2} = 9.9$   
 If  $c = 12$  then  $a = 12 \cdot \frac{1}{\sqrt{2}} = 8.5$  and  $b = 8.5$

**B. Right Triangle Trigonometry**

- The trigonometric (trig) functions of an angle are related to the ratios of the sides of a right triangle.
- The trig functions are defined in the following manner where  $\theta$  stands for either of the acute (less than  $90^\circ$ ) angles in the right triangle. These definitions should be memorized:
 
$$\sin \theta = \frac{\text{opposite leg}}{\text{hypotenuse}}$$

$$\csc \theta = \frac{\text{hypotenuse}}{\text{opposite leg}}$$

$$\cos \theta = \frac{\text{adjacent leg}}{\text{hypotenuse}}$$

$$\sec \theta = \frac{\text{hypotenuse}}{\text{adjacent leg}}$$

$$\tan \theta = \frac{\text{opposite leg}}{\text{adjacent leg}}$$

$$\cot \theta = \frac{\text{adjacent leg}}{\text{opposite leg}}$$

**NOTE:** The leg of the right triangle, which is considered either the opposite leg or the adjacent leg, changes depending on which of the acute angles is being evaluated in the trig function.

- The **opposite leg** of a right triangle is the leg which does not touch the vertex of the angle that is named in the trig function.
- The **adjacent leg** of a right triangle is the leg which does touch the vertex of the angle that is named in the trig function. For example: When evaluating the trig functions for angle  $A$  in this right triangle, leg  $p$  is the opposite leg for angle  $A$  because it does not touch point  $A$ ; however, leg  $x$  is the adjacent leg for angle  $A$  because it does touch point  $A$ . The hypotenuse is side  $c$ . In the same right triangle, leg  $x$  is the opposite leg for angle  $B$  because it does not touch point  $B$ ; however, leg  $p$  is the adjacent leg for angle  $B$  because it does touch point  $B$ .

**NOTICE:** The leg that is the opposite leg for angle  $A$  is the same leg that is the adjacent leg for angle  $B$ , and the leg that is the adjacent leg for angle  $A$  is the same leg that is the opposite leg for angle  $B$ . The hypotenuse is never considered as the opposite side nor as the adjacent side because it is not a leg.

5. Since trig functions are ratios, and ratios can be written as decimal numbers, trig functions are either converted to decimal numbers or left as radical expressions in longer terms (for example,  $\frac{1}{2}$  or  $2\sqrt{6}$ ). For example, in the right triangles above, if  $x = 9$ ,  $p = 7$ , and  $a = \sqrt{32} = 4\sqrt{2}$  then

$$\sin A = \frac{p}{c} = \frac{7}{9} = .7778$$

$$\cos A = \frac{x}{c} = \frac{9}{9} = 1.0000$$

$$\tan A = \frac{p}{x} = \frac{7}{9} = .7778$$

$$\csc A = \frac{c}{p} = \frac{9}{7} = 1.2857$$

$$\sec A = \frac{c}{x} = \frac{9}{9} = 1.0000$$

$$\cot A = \frac{x}{p} = \frac{9}{7} = 1.2857$$

6. Using the trig function decimal number values to find or use angle measures requires either a trig function chart or a calculator with trig function options. For example, if you have found that  $\sin \theta = .7778$  then, by using either a trig chart or calculator, the measure of angle  $\theta$  is about  $51^\circ$ .

$\theta$ degrees	sine	cosine	tangent
0	0	1	0
10	.1736	.9848	.1763
20	.3420	.9397	.3640
30	.5000	.8660	.5774
40	.6428	.7660	.9176
50	.7660	.6428	1.1918
60	.8660	.5000	1.7321
70	.9397	.3420	2.7475
80	.9848	.1736	5.9631
90	1	0	undefined

If using a calculator, follow the calculator directions.

### C. Triangle Trig Applications

There are two basic ways in which trig functions are used with triangles: to find angle measures and to find side lengths.

**1. Right Triangles**

- Finding Acute Angle Measures**  
To find the two acute angle measures when given two sides of a right triangle, it is easiest to find the length of the third side first. For example, in the following right triangle, if you know the length of any two sides, then you may use the Pythagorean Theorem ( $\text{leg}^2 + \text{leg}^2 = \text{hypotenuse}^2$ ) to find the length of the third side. Once the three side lengths are found (it is not necessary to find the three side lengths in order to find the angle measures, but it is easiest), then use the trig functions to find the degree measure of one acute angle. Using the same right triangle above, the measure of  $\cos \theta$  can be found using any of the trig functions, so just pick one of them. For example: The measure of the second acute angle may be found by simply subtracting the measure of  $\sin \theta = \frac{8}{20} = .4000$  so  $\theta = 23^\circ 30'$  the acute angle just found from  $90^\circ$  because the sum of the three angles of any triangle is  $180^\circ$ .  $\beta = 90^\circ - 23^\circ 30' = 66^\circ 30'$

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