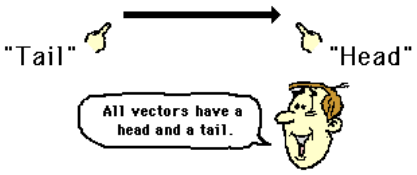


PHYSICS INTRO: SCALARS AND VECTORS

The motion of objects can be described by words. Even a person without a background in physics has a collection of words that can be used to describe moving objects. Words and phrases such as *going fast*, *stopped*, *slowing down*, *speeding up*, and *turning* provide a sufficient vocabulary for describing the motion of objects. We will be expanding upon this vocabulary list with words such as *distance*, *displacement*, *speed*, *velocity*, and *acceleration*. The mathematical quantities that are used to describe the motion of objects can be divided into two categories. The quantity is either a vector or a scalar.

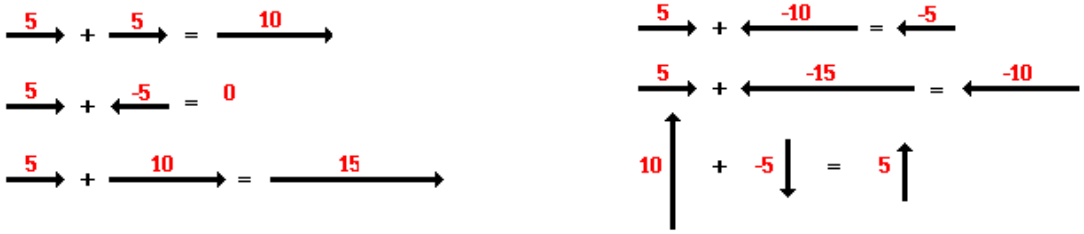
- **Scalars** are quantities that are fully described by a magnitude (or numerical value) alone.
  - Examples – length, area, volume, speed, mass, density, pressure, temperature, energy, work, and power
- **Vectors** are quantities that are fully described by both a magnitude and a direction.
  - Examples – displacement, velocity, acceleration, momentum, force, lift, drag, thrust, and weight.

1. To test your understanding of this distinction, consider the following quantities listed below. Categorize each quantity as being either a vector or a scalar.

Quantity	Category		Quantity	Category
5 meters			5 miles, North	
30 m/sec, East			20 degrees Celsius	

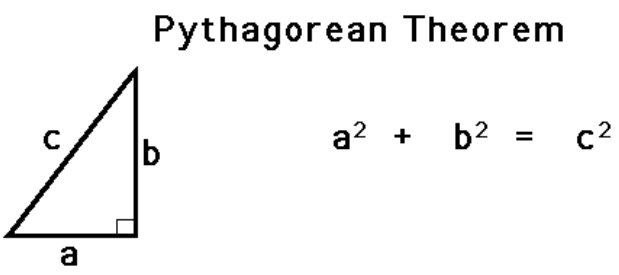
Vector Addition

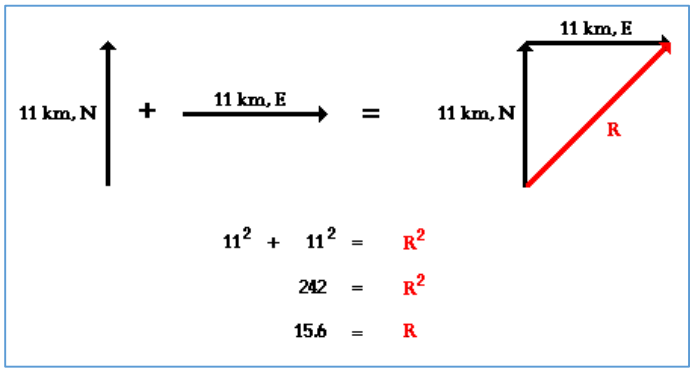
A variety of mathematical operations can be performed with and upon vectors. One such operation is the addition of vectors. Two vectors can be added together to determine the result (or **resultant**).



The Pythagorean Theorem

The Pythagorean theorem is a useful method for determining the result of adding two (and only two) vectors that make a right angle to each other. The method is not applicable for adding more than two vectors or for adding vectors that are not at 90-degrees to each other. The Pythagorean theorem is a mathematical equation that relates the length of the sides of a right triangle to the length of the hypotenuse of a right triangle.

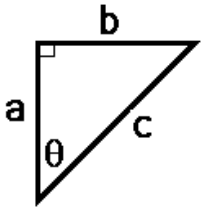




Eric leaves the base camp and hikes 11 km, north and then hikes 11 km east. Determine Eric's resulting displacement. The result of adding 11 km, north plus 11 km, east is a vector with a magnitude of 15.6 km.

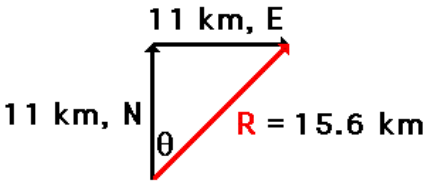
Using Trigonometry to Determine a Vector's Direction

The direction of a *resultant* vector can often be determined by use of trigonometric functions. Most students recall the meaning of the useful mnemonic SOH CAH TOA from their course in trigonometry. These three functions relate an acute angle in a right triangle to the ratio of the lengths of two of the sides of the right triangle. The **sine function** relates the measure of an acute angle to the ratio of the length of the side opposite the angle to the length of the hypotenuse. The **cosine function** relates the measure of an acute angle to the ratio of the length of the side adjacent the angle to the length of the hypotenuse. The **tangent function** relates the measure of an angle to the ratio of the length of the side opposite the angle to the length of the side adjacent to the angle. The three equations below summarize these three functions in equation form.



a=side adjacent to angle Θ
b=side opposite to angle Θ
c=hypotenuse of triangle

$$\sin\Theta = \frac{b}{c} \qquad \cos\Theta = \frac{a}{c} \qquad \tan\Theta = \frac{b}{a}$$

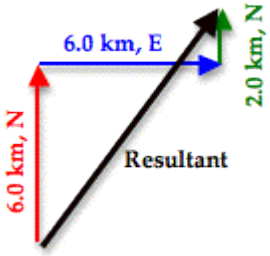


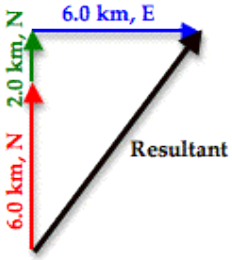
$$\sin\Theta = \frac{11\ \text{km}}{15.6\ \text{km}} = 0.7051$$

$$\Theta = \sin^{-1}(0.7051) = 45°$$

A student drives his car 6.0 km, North before making a right hand turn and driving 6.0 km to the East. Finally, the student makes a left hand turn and travels another 2.0 km to the north. What is the magnitude of the overall displacement of the student? But if the three vectors are added in the order 6.0 km, N + 2.0 km, N + 6.0 km, E, then the diagram will look like this:

$R^2 = (8.0\ \text{km})^2 + (6.0\ \text{km})^2$
$R^2 = 64.0\ \text{km}^2 + 36.0\ \text{km}^2$
$R^2 = 100.0\ \text{km}^2$
R = SQRT (100.0 km2)
R = 10.0 km

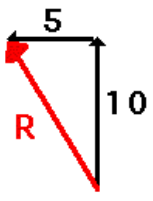




Practice

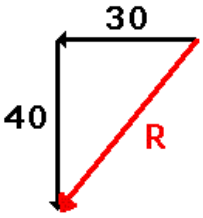
1

10 km, North
+
5 km, West



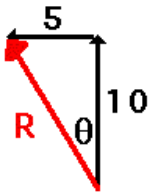
2

30 km, West
+
40 km, South



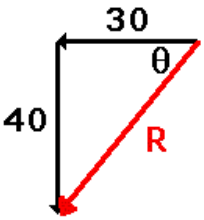
3

10 km, North
+
5 km, West



4

30 km, West
+
40 km, South



5) In the Vector Addition Lab, Anna starts at the classroom door and walks:

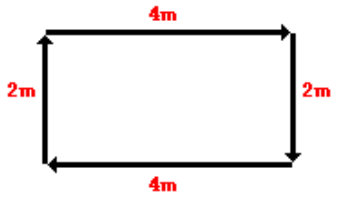
- **2.0 meters, West**
- **12.0 meters, North,**
- **31.0 meters, West,**
- **8.0 meters, South**
- **3.0 meters, East**

Using a diagram, determine the magnitude and direction of Anna's resulting displacement.

Distance and displacement are two quantities that may seem to mean the same thing yet have distinctly different definitions and meanings.

- **Distance** is a scalar quantity that refers to "how much ground an object has covered" during its motion.
- **Displacement** is a vector quantity that refers to "how far out of place an object is"; it is the object's overall change in position.

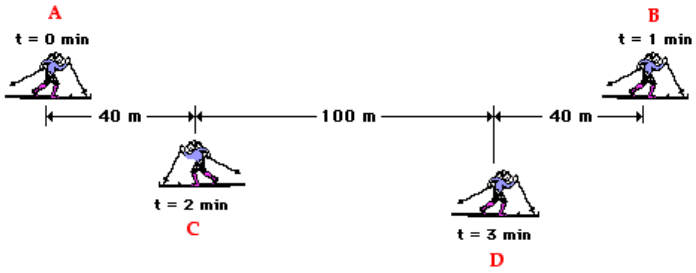
To test your understanding of this distinction, consider the motion depicted in the diagram below. A physics teacher walks 4 meters East, 2 meters South, 4 meters West, and finally 2 meters North.



2. What is the total distance of the physics teacher? _____

3. What is the displacement of the physics teacher? _____

Use the diagram to determine the resulting displacement and the distance traveled by the skier during these three minutes. At each of the indicated times, the skier turns around and reverses the direction of travel. In other words, the skier moves from A to B to C to D.



4. What is the total distance of the skier? _____

5. What is the displacement of the skier? _____

6. What is the distance and the displacement of the race car drivers in the Indy 500? _____

Distance/Displacement Worksheet

1. **True or False: An object moving for 10s can still have zero displacement?**

2. **If the above statement is true, then describe an example of such motion. If the above statement is false, then explain why it is false.**