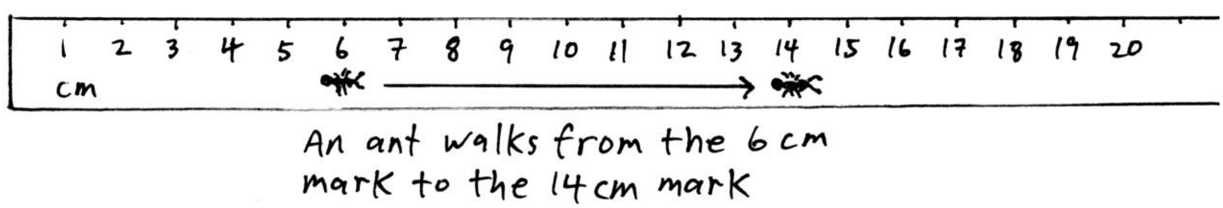
Physics Lecture #1: Displacement and Average Velocity

Displacement is the change in position of a moving object. You find displacement by drawing a straight line from the object's starting point to its new location after it has moved.

Suppose an ant is walking in a straight line across the edge of a ruler. He starts at the 6 cm mark and ends up at the 14 cm mark. What is the ant's displacement?



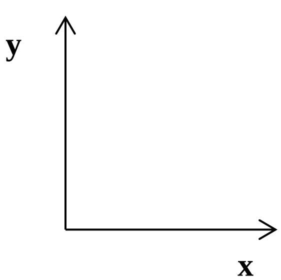
Displacement = final position – initial position

$\Delta x = x_f - x_i$

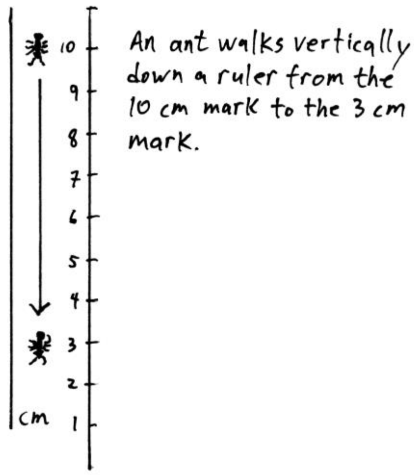
$\Delta x = 14 \text{ cm} - 6 \text{ cm}$

$\Delta x = 8 \text{ cm}$

The ant's displacement is 8 cm. The triangle, Δ, means "change." So, Δx means "change in the horizontal position." Since the ant moves horizontally, we use x. If the ant was moving up or down, we'd use Δy, which means "change in vertical position." This matches the x and y axis of a graph.



Suppose the ruler is oriented vertically, and the ant walks down the ruler from the 10 cm mark to the 3 cm mark.



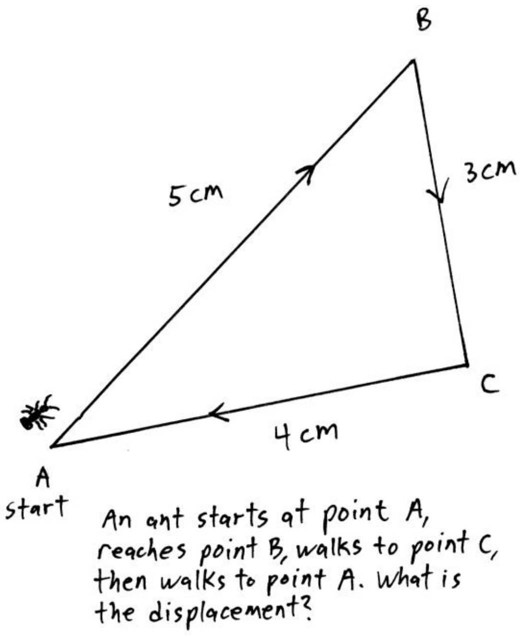
The displacement of the ant can be calculated using

$\Delta y = y_f - y_i$
$\Delta y = 3\text{ cm} - 10\text{ cm}$
$\Delta y = -7\text{ cm}$

The negative sign in front of the 7 cm indicates that the displacement is in a downward direction. If you write $\Delta y = +7$ cm, the positive sign says that the object is moving up or north.

Likewise, if you write $\Delta x = -7$ cm, you are indicating that the object is moving horizontally to the left. If $\Delta x = +7$ cm, you are indicating that the object is moving horizontally to the right or to the east.

Displacement and distance are not necessarily the same thing. Displacement is the distance between where you started and where you ended up. For example, suppose the ant started walking at point A, reached point B, walked to point C, then returned to point A.



What is the displacement of the ant? The answer: zero. Since the ant started and ended at point A, the distance between where it started and where it ended is zero. While the displacement is zero, we can say that the total distance it walked is 5 + 3 + 4 = 12 cm.

Speed is the displacement of the object divided by the time it takes the object to move.

$$\text{Speed} = \frac{\text{displacement}}{\text{time}}$$

For example, if a car covers a displacement of 12 m in 4.0 seconds, its speed is

$$\text{Speed} = \frac{\text{displacement}}{\text{time}} = \frac{12\ \text{m}}{4.0\ \text{s}} = \frac{3.0\ \text{m}}{\text{s}}$$

Most of the time, we use meters as our unit of length and seconds as our unit of time. Thus, the common unit for speed is m/s.

Velocity is the speed *and direction* of the moving object. If the car in the above example is moving north, then its velocity is 3.0 m/s north.

The words "velocity" and "speed" are often used interchangeably, but velocity requires both speed and direction.

Velocity is calculated the same way that speed is calculated: displacement divided by time. Unfortunately, different physics texts use different letters to represent displacement. Some books use the letter "s" to represent displacement. Others use the letter "d", which is problematic since "d" can also represent density.

I'll be using "x" to represent displacements that move horizontally, and "y" for displacements that move vertically.

When displacement is divided by time, and a direction is given, we have average velocity (v_{avg}). Sometimes average velocity is shown as a letter "v" with a line above it, and subscripts x or y to indicate a vertical or horizontal motion.

$$\bar{v}_x$$

And sometimes I'll get lazy and just write the letter "v".

$$v_{avg} = \frac{\Delta x}{t} = \frac{x_f - x_i}{t} \qquad v_{avg} = \frac{\Delta y}{t} = \frac{y_f - y_i}{t}$$

Most of the time Δx or Δy is given to you, and you don't have to calculate it.

Problem: A rocket travels 370 m to the west in 5.0 seconds. Find its velocity.

Answer

$$v_{avg} = \frac{\Delta x}{t} = \frac{-370\ m}{5.0\ s} = \frac{-74\ m}{s}$$

The velocity is 74 m/s to the west (or $\bar{v}_x$ = -74 m/s).