Methods of Motion

Honors Physics

YOU deserve a speeding ticket!

I am the LAW around here and the LAW says that the speed limit is 55 miles per hour!

Here is the scenario!

You wake up late and have 20 minutes to get to school and you especially do not want to be late for physics! You decide to travel at 65 mph in a 55 mph zone. Unfortunately, Officer Bowles pulls you over. You see, the LAW (that's me!) states that you must pay $10 for every mile you are over the speed limit. Therefore, you MUST pay $100 to cover the fine. Being a law abiding citizen you agree, and pay the fine. But as you begin to leave you hear officer Bowles say……..

BUT WAIT!

Our city council just recently passed a law 3 months ago that requires us to fine you for being on the planet Earth as it rotates on it's axis. Since Earth rotates on its axis at 1000 mph you must pay ….

Motion	Speed Over	Fine
On road	10 mph	**$100**
Earth's Rotation	1000 mph	**$10,000**

But as you begin to leave you hear officer Bowles say……..

BUT WAIT!

Our city council just last month passed a law that requires us to fine you for being on the planet Earth as it revolves around our Sun at a speed of 66,621 mph. Thus your fine is…..

Motion	Speed Over	Fine
On road	10 mph	**$100**
Earth's Rotation	1000 mph	**$10,000**
Earth's Revolving	66,621 mph	**$666,210**

But as you begin to leave you hear officer Bowles say……..

BUT WAIT!

Our city council just last week passed a law that requires us to fine you for being on the planet Earth which moves towards Vega in the constellation Lyra at a speed of 44,041 mph. Thus your fine is…..

Motion	Speed Over	Fine
On road	10 mph	**$100**
Earth's Rotation	1000 mph	**$10,000**
Earth's Revolving	66,621 mph	**$666,210**
To Vega	44,041 mph	**$440,410**

But as you begin to leave you hear officer Bowles say……..

BUT WAIT!

Our city council just <u>yesterday</u> passed a law that requires us to fine you for being on the planet Earth in the Milky Way which rotates at a speed of 558,900 mph. Thus your fine is…..

Motion	Speed Over	Fine
On road	10 mph	**$100**
Earth's Rotation	1000 mph	**$10,000**
Earth's Revolving	66,621 mph	**$666,210**
To Vega	44,041 mph	**$440,410**
Milky Way	558,900 mph	**$5,589,000**

Let me total your fine!

You owe……(somehow)

Your total fine is:

$6,705,720

Now be a law abiding citizen and PAY UP!

The bottom line….Motion is RELATIVE

It depends completely on how you want to look at the moving object. You establish a frame of reference!

Example: You are sitting in an airplane which is moving at a speed of 100 km/h and there is a fly sitting on your head.

(a) What is your speed relative to the ground? **100 km/hr**

(b) What is your speed relative to the seat you're sitting it?

0 km/hr

(c) What is the speed of the fly relative to you? **0 km/hr**

Displacement

Displacement (x or y) ***"Change in position"***

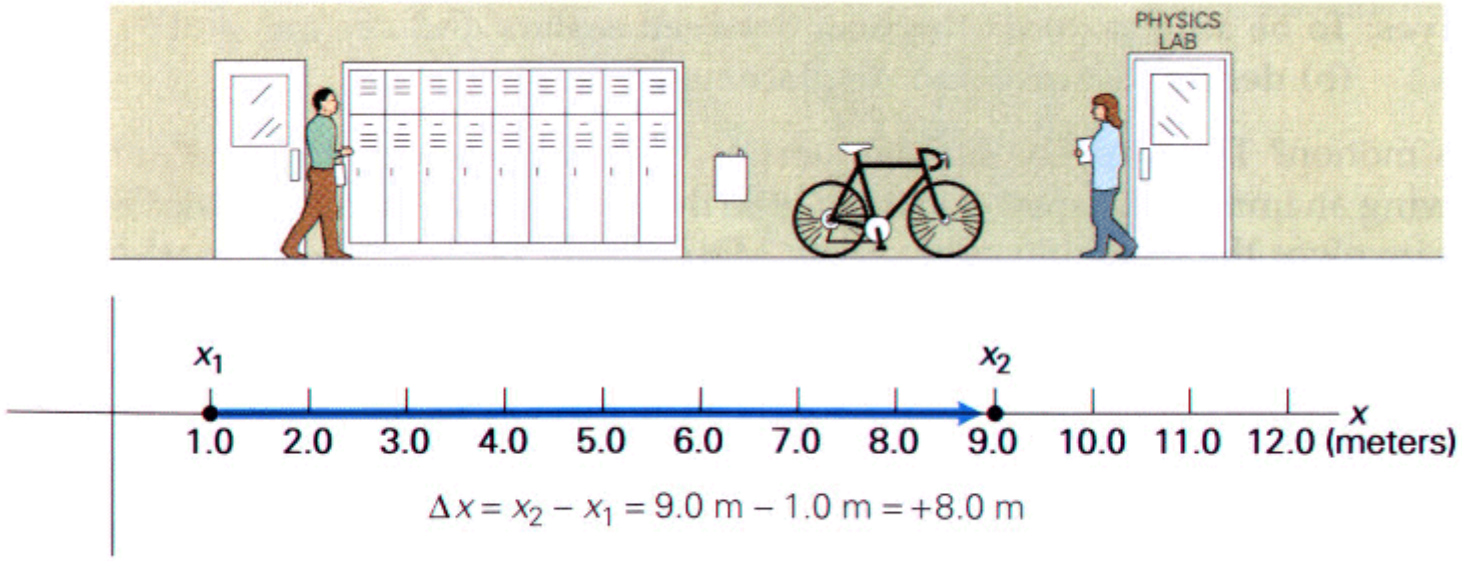
It is not necessarily the total distance traveled. In fact, displacement and distance are entirely different concepts. Displacement is relative to an axis.

- "x" displacement means you are moving horizontally either right or left.
- "y" displacement means you are moving vertically either up or down.
- The word ***change*** is expressed using the Greek letter **DELTA (Δ)**.
- To find the ***change*** you ALWAYS subtract your **FINAL - INITIAL** position
- It is therefore expressed as either $\Delta x = x_f - x_i$ or $\Delta y = y_f - y_i$

Distance - How far you travel regardless of direction.

Example

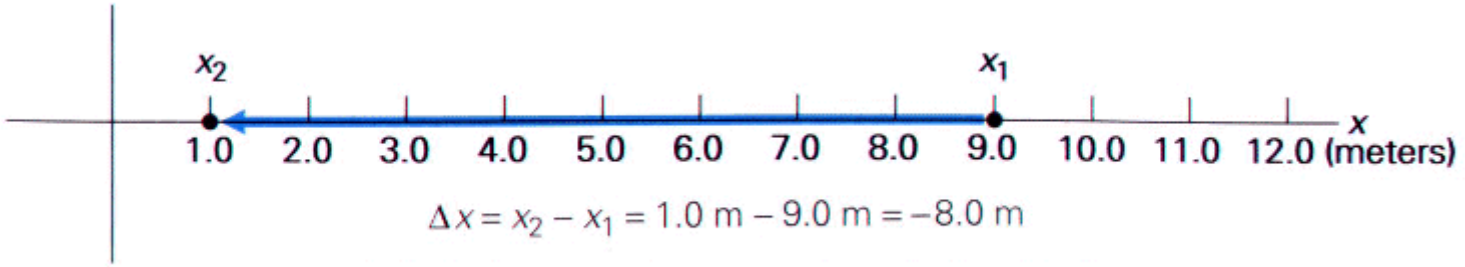
Suppose a person moves in a straight line from the lockers(at a position x = 1.0 m) toward the physics lab(at a position x = 9.0 m) , as shown below



The answer is positive so the person must have been traveling horizontally <u>to the right.</u>

Example

Suppose the person turns around!



The answer is negative so the person must have been traveling horizontally <u>to the left</u>

What is the *DISPLACEMENT* for the entire trip?

$$\Delta x = x_{final} - x_{initial} = 1.0 - 1.0 = 0m$$

What is the total *DISTANCE* for the entire trip?

$$8 + 8 = 16m$$

Average Velocity

Velocity is defined as: "The ***RATE*** at which ***DISPLACEMENT*** changes".

Rate = ANY quantity divided by ***TIME***.

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{x_{final} - x_{inital}}{t_{final} - t_{initial}}$$

Average ***SPEED*** is simply the "RATE at which DISTANCE changes".

$$\bar{s} = \frac{\Delta d}{\Delta t}$$

Example

A quarterback throws a pass to a defender on the other team who intercepts the football. Assume the defender had to run 50 m away from the quarterback to catch the ball, then 15 m towards the quarterback before he is tackled. The entire play took 8 seconds.

Let's look at the defender's average velocity:

$$\bar{v} = \frac{\Delta x}{\Delta t} = \frac{35m - 0m}{8s - 0s} = 4.38\, m/s$$

Let's look at the defender's speed:

$$\bar{s} = \frac{d}{t} = \frac{65m}{8s} = 8.125\, m/s$$

"**m/s**" is the derived unit for both speed and velocity.

Slope – A basic graph model

A basic model for understanding graphs in physics is *SLOPE*.

$$Slope = \frac{Rise}{Run} \; or \; \frac{\Delta y}{\Delta x}$$

$$y = mx + b$$

Using the model - **Look at the formula for velocity.** $$slope = \frac{Rise}{Run} \Leftrightarrow \bar{v} = \frac{\Delta x}{\Delta t}$$

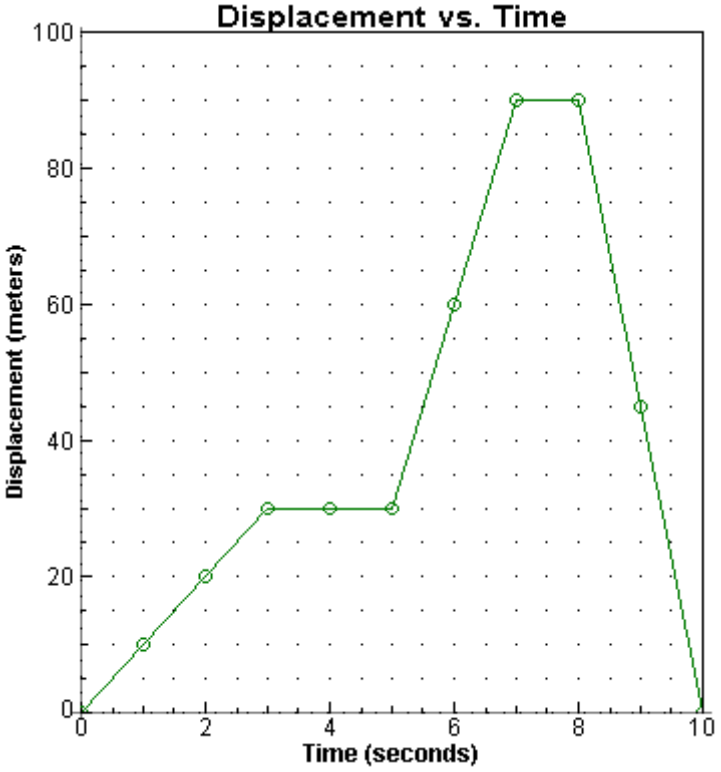
Who gets to play the role of the slope? **Velocity**

Who gets to play the role of the y-axis or the rise? **Displacement**

Who get to play the role of the x-axis or the run? **Time**

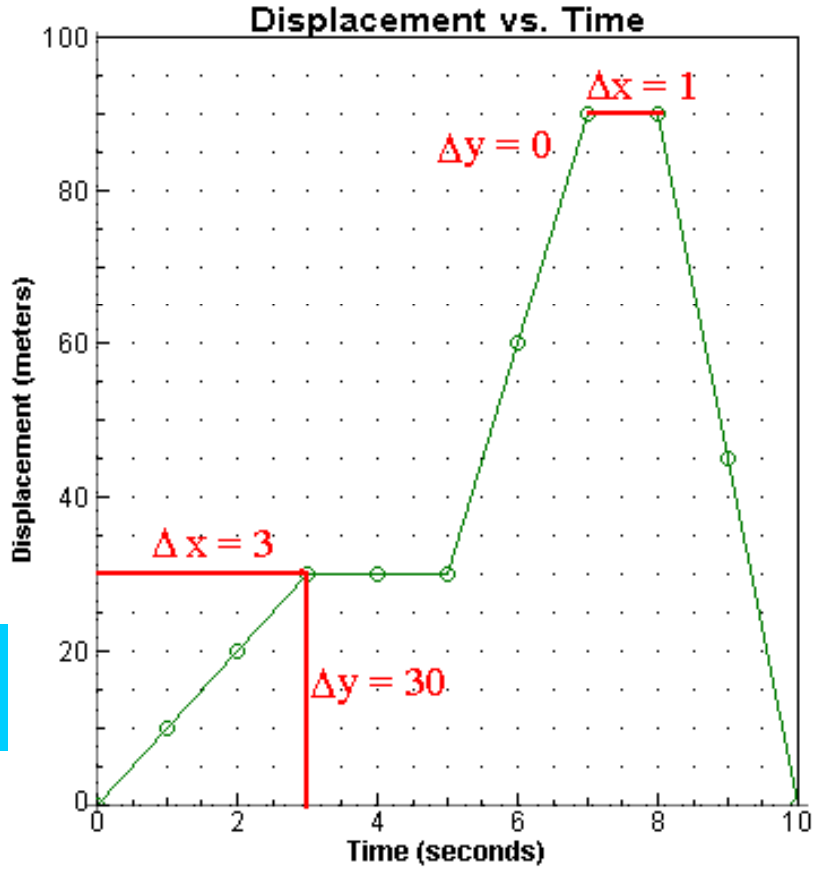
What does all the mean? It means that if your are given a *Displacement vs. Time* graph, to find the velocity of an object during specific time intervals simply find the slope.

Displacement vs. Time graph



What is the *velocity* of the object from 0 seconds to 3 seconds?

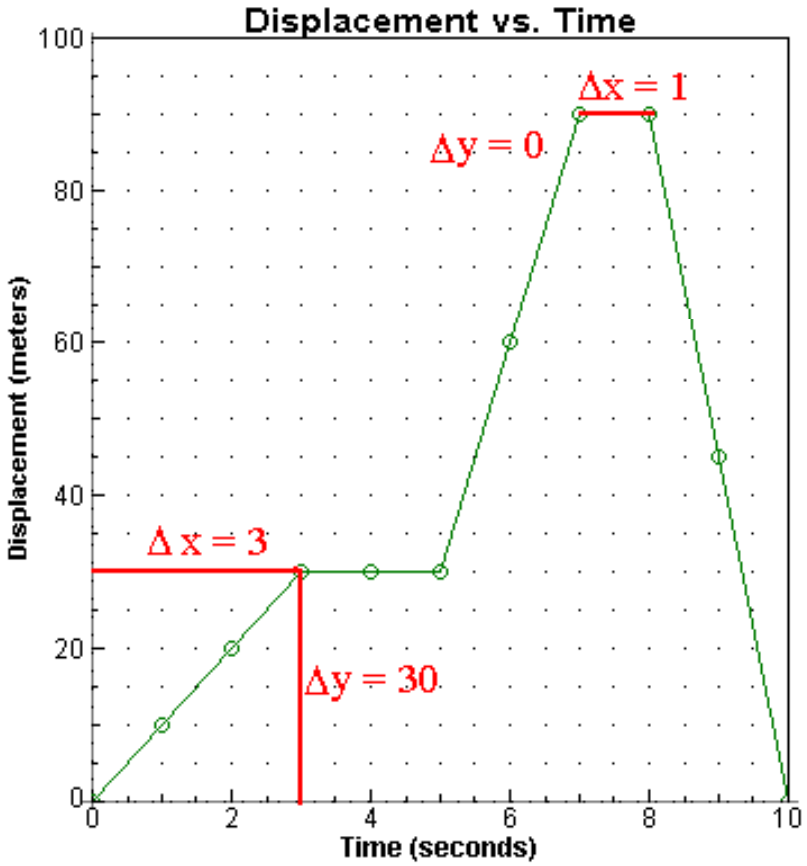
The velocity is the slope!



$$\frac{\Delta y}{\Delta x} = slope = velocity = \frac{30-0}{3-0} = 10 m/s$$

Displacement vs. Time graph

What is the *velocity* of the object from 7 seconds to 8 seconds? Once again...find the slope!

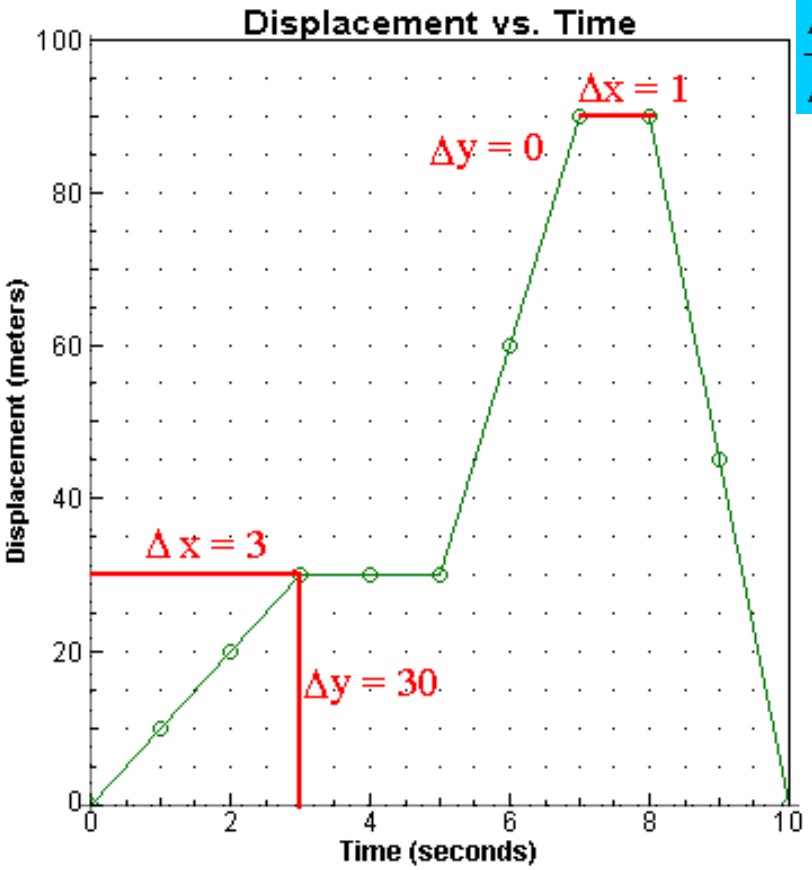


$$\frac{\Delta y}{\Delta x} = slope = velocity = \frac{90-90}{8-7} = 0 m/s$$

A velocity of 0 m/s. What does this mean? It is simple....the object has simply stopped moving for 1 second.

Displacement vs. Time graph

What is the *velocity* from 8-10 seconds? You must remember! To find the *change* it is final - initial.



$$\frac{\Delta y}{\Delta x} = slope = velocity = \frac{0-90}{10-8} = \frac{-90}{2} = -45 m/s$$

The answer is negative! It is no surprise, because the slope is considered to be negative.

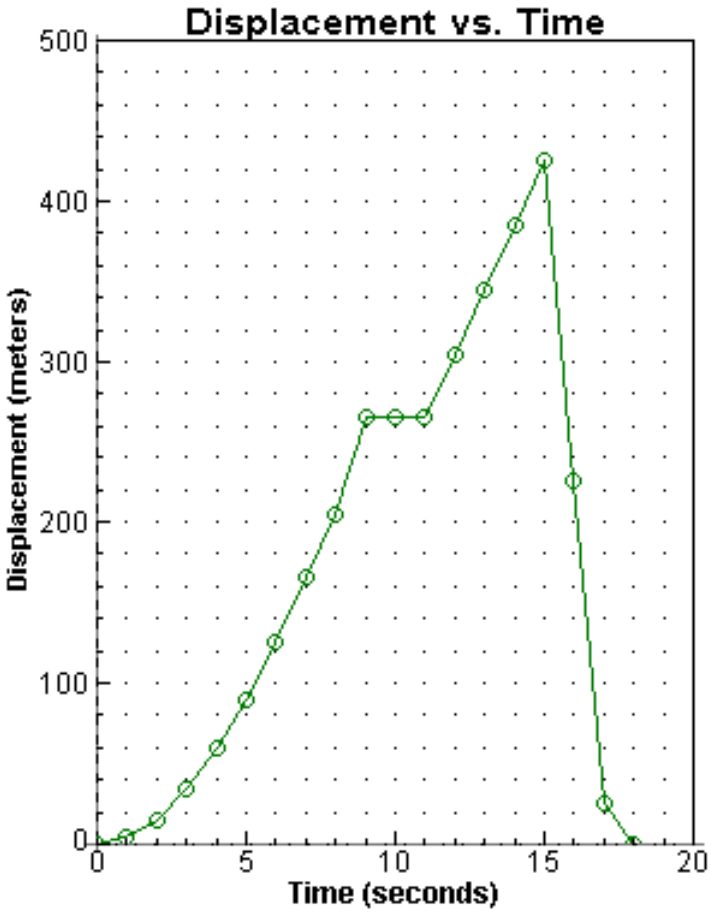
This value could mean several things: The object could be traveling WEST or SOUTH. The object is going backwards - this being the more likely choice!

You should also understand that the slope does NOT change from 0-3s , 5 to 7s and 8-10s.

This means that the object has a CONSTANT VELOCITY or IT IS NOT ACCELERATING.

Example

It is very important that you are able to look at a graph and explain it's motion in great detail. These graphs can be very conceptual.



Look at the time interval t = 0 to t = 9 seconds. What does the slope do?

It increases, the velocity is increasing

Look at the time interval t = 9 to t = 11 seconds. What does the slope do?

No slope. The velocity is ZERO.

Look at the time interval t = 11 to t = 15 seconds. What does the slope do?

The slope is constant and positive. The object is moving forwards at a constant velocity.

Look at the time interval t = 15 to t = 17 seconds. What does the slope do?

The slope is constant and negative. The object is moving backwards at a constant velocity.