

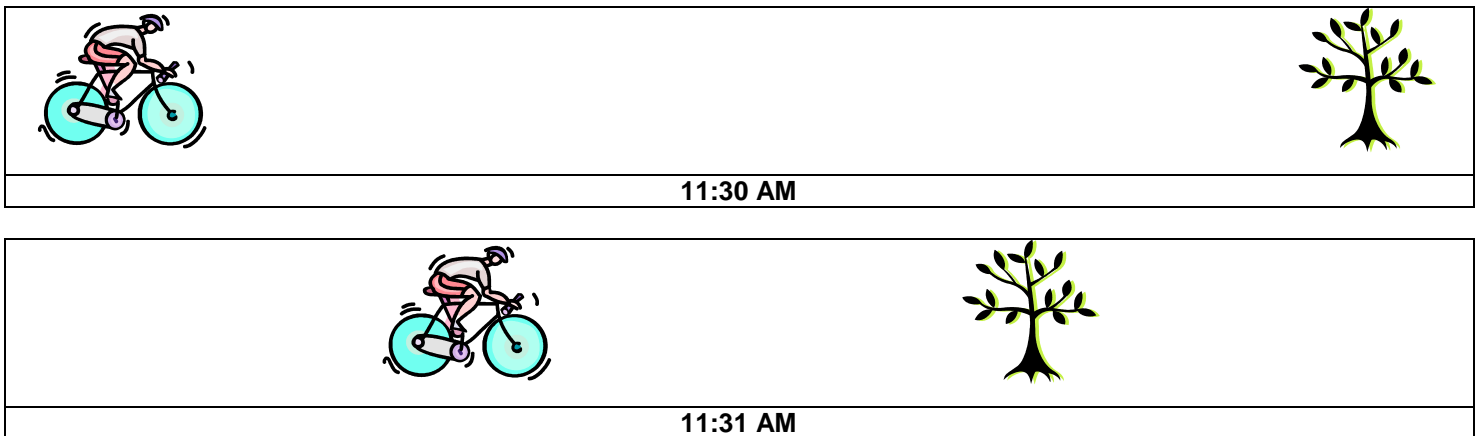
SPEED & VELOCITY

Describing Motion

We use the term motion to describe a change in position of an object relative to some point of reference.

How do you know when something has moved or when something is in motion? In order to observe motion, we need a point of reference. **When an object gets closer to or further away from a point of reference, we can say that the object has moved or is in motion.**

Without a point of reference, it can be very difficult to observe motion or to know that something has actually moved. In the following diagram, it is easy to see that the cyclist has moved. The distance between the cyclist and the tree has changed. The object that we are observing is the cyclist. Our point of reference is the tree. We know that the tree doesn't actually move, so we conclude that the cyclist therefore must be in motion. If trees were capable of moving, we would be unable to say for sure which of these two objects were actually in motion.



Distance – We use the *meter*, which is the SI unit for distance to measure how far something has moved.

Displacement – When we measure the displacement of an object, we are measuring how far an object has moved from its original position. This sounds a lot like our definition for distance. The following diagram will illustrate the difference between the two.

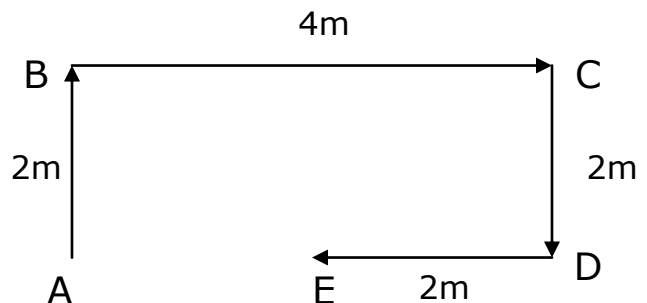
In the following diagram, an object is observed moving from point A to B to C to D and then finally to point E.

The total distance that the object has moved is the sum of all of the distances between each point.

So... $2\text{m} + 4\text{m} + 2\text{m} + 2\text{m} = 10$ meters

14 meters is the **distance** that the object has moved.

However, when at location E, the object has only been **displaced** by a distance of 2 meters from A.



Speed & Motion

We can learn more about the motion of an object by determining how fast or how slow the object is moving. **Speed** tells us how far an object moves in a certain amount of time.

Determining Speed:

To calculate speed, we need to know two things: HOW FAR (distance) the object has moved and HOW LONG (time) it took the object to get there.

$$\text{speed} = \text{distance} / \text{time}$$

Consider the following data collected for a car moving in a straight line.

Determine the speed of a car that moves 10 meters in 2 seconds.

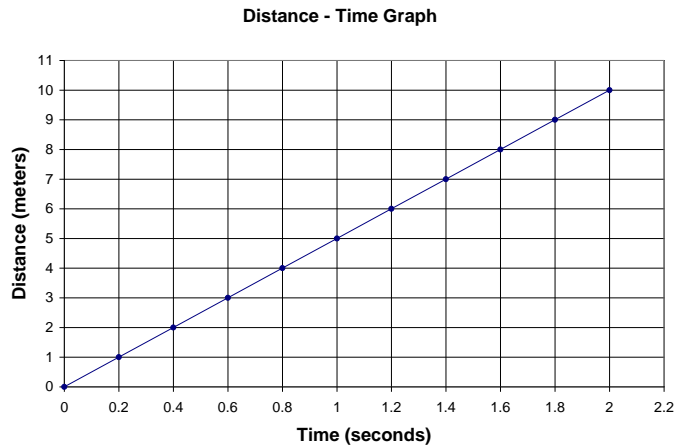
$$\text{speed} = 10 \text{ meters} / 2 \text{ seconds}$$

$$\text{speed} = 5 \text{ meters per second}$$

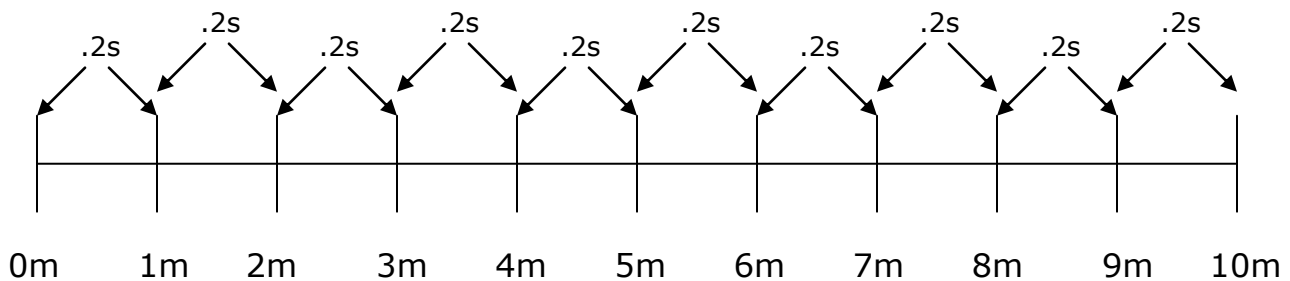
As you can see, it is fairly easy to calculate the speed of a moving object if you know the distance that the object has moved and the time it takes to move that distance. In the example above, if the car were to travel at the same speed for another 2 seconds, it would have traveled another 10 meters or a total distance of 20 meters. This car is said to be traveling at a **constant speed**.

Consider the following data collected for the same car. If you were to make a graph of the distance versus time it would look something like this...

Distance (meters)	Time (sec)
0	0
1	0.2
2	0.4
3	0.6
4	0.8
5	1
6	1.2
7	1.4
8	1.6
9	1.8
10	2

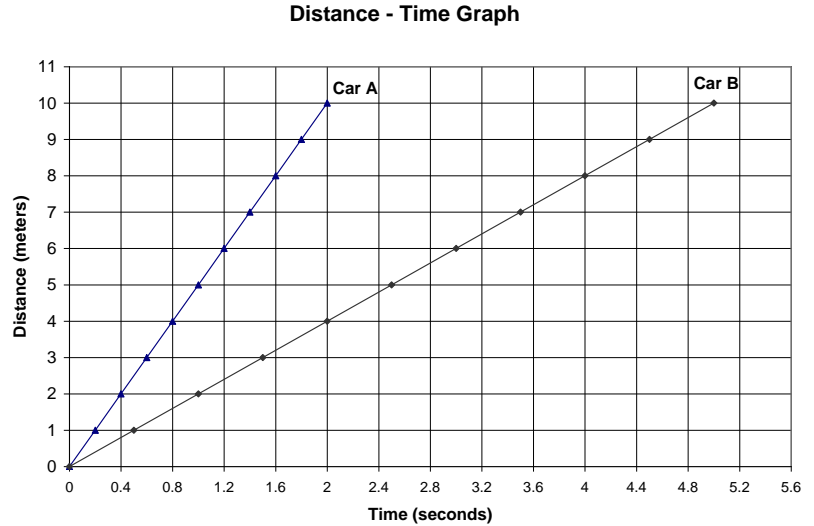


The graph above is consistent with an object that is moving at a **constant speed**, sometimes called **uniform motion**. It takes two tenths of a second (.2 seconds) to travel one meter. In fact, it takes .2 seconds to travel the first meter and .2 seconds to travel the second meter and .2 seconds to travel the third meter and so on...



Look at this next example of two different objects. Each traveling at different, but constant speed.

Distance (meters)	Time (sec) Car A	Time (sec) Car B
0	0	0
1	0.2	0.5
2	0.4	1
3	0.6	1.5
4	0.8	2
5	1	2.5
6	1.2	3
7	1.4	3.5
8	1.6	4
9	1.8	4.5
10	2	5



From the data and graph, the following can be concluded:

Car A is traveling faster than Car B.

Car A and Car B are both traveling at a constant speed.

Let's calculate the speed for each car. Actually, let's calculate the speed of each car over each meter. The following data table lists the distance, time and calculated speed.

Notice how the speed is the same or **constant** or **uniform** for both cars.

Also,

Notice that Car A is traveling faster than Car B.

Car A

Distance (m)	0	1	2	3	4	5	6	7	8	9	10
Time (sec)	0	0.2	0.4	0.6	0.8	1	1.2	1.4	1.6	1.8	2
Speed (m/s)	0	5	5	5	5	5	5	5	5	5	5

Car B

Distance (m)	0	1	2	3	4	5	6	7	8	9	10
Time (sec)	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
Speed (m/s)	0	2	2	2	2	2	2	2	2	2	2

It is important to note the difference between what is called an **AVERAGE SPEED** and what is referred to as an **INSTANTANEOUS SPEED**.

Average Speed – speed of motion when speed is changing.

$$\text{speed} = \text{total distance} / \text{total travel time}$$

Therefore, when we calculated the speed of Car A over the entire 10 meters, we were actually calculating the average speed. Recall the problem from before:

Car A travels a total distance of 10 meters in 2 seconds.

$$\text{average speed} = 10 \text{ meters} / 2 \text{ seconds}$$

$$\text{average speed} = 5 \text{ meters per second}$$

The example I like to use here is my morning and afternoon commute to and from school here in Barrington to my home in Little Compton. The total driving distance is about 30 miles. It takes me about 45 minutes to get to and from school. With this distance and time information, you can calculate the average speed that I travel.

$$\text{average speed} = 30 \text{ miles} / .75 \text{ hours}$$

$$\text{average speed} = 40 \text{ miles per hour}$$

Now, I have to stop at several stop signs and traffic signals and my speed is pretty much always changing throughout the trip. The average speed calculation is useful, but it doesn't really tell you much about what happens along my trip to and from school.

Instantaneous speed will give me the speed at any given point in time along my trip.

I like to think of the speedometer in my car. It continually calculates my speed using distance and time information. I can look down at my speedometer and it will tell me exactly what my speed is at that moment.

In this next example, the total distance from point A to B is 10 miles. Assume it takes the car 15 minutes or .25 hours to get there. What is the average speed?



Velocity – Speed is very useful in describing the motion of an object. However, it doesn't tell us much about the direction of a moving object. Velocity not only tells us about the speed at which an object is moving but also the direction that it is moving as well.

Velocity can change when speed changes. It can also change when direction changes. For example, car is traveling 50 km per hour east. It then makes a turn to the north while maintaining the same speed of 50 km/hr. The speed of the car the whole time was 50 km/hr. However, the velocity has changed from 50 km/hr east to 50 km/hr north.

Changing Speed

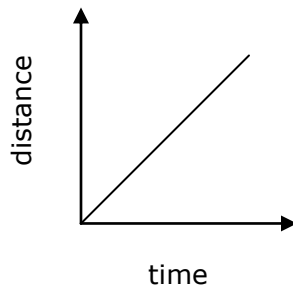
Life would be pretty boring if things always traveled at the same speed. So what happens when speed changes? Let's look at some graphs of some things that are moving to see if we can better understand the relationship between distance and time.

GRAPHING MOTION

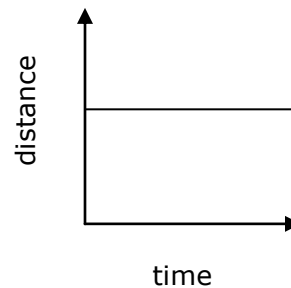
Distance-Time Graphs

Distance-time graphs display motion of objects over time. So far, we have looked at objects that travel at uniform speed. We also have look at objects that travel at different speeds. Take a look at the next few graphs and see if you can tell what the graph tells us about the motion of the object.

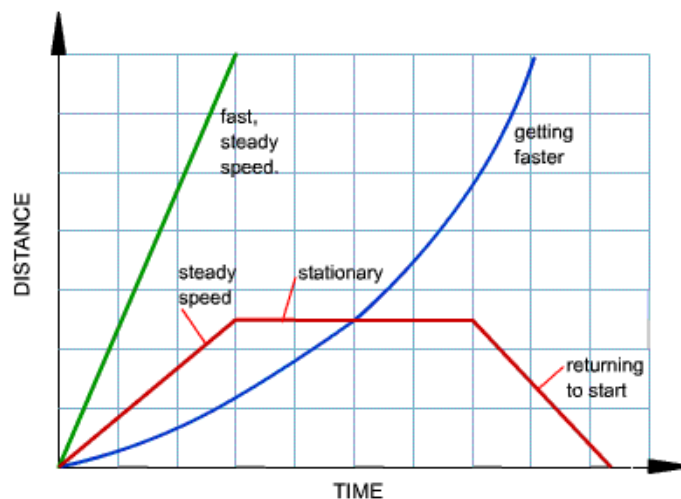
Constant Velocity



Zero Velocity



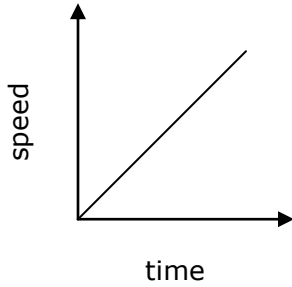
Look at this next graph to see how a distance time graph can tell us about the motion of an object.



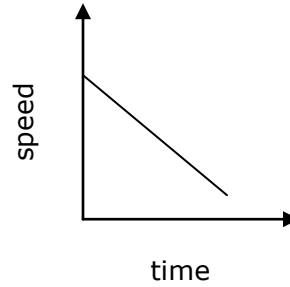
Speed-Time Graphs

Speed-time graphs also tell us something about the motion of objects. They look similar to the distance-time graphs above, but they can tell a much different story. Notice how the straight line graph(s) indicate a change in speed or velocity over time. The graph on the bottom shows an object moving at constant or uniform motion.

Increasing Velocity



Decreasing Velocity



Constant Velocity

