## Speed, Velocity, and Acceleration

### Speed vs. Velocity

*Vocabulary*
**Distance**: How far something travels.
**Displacement**: How far something travels in a given direction.
**Speed**: How fast something is moving.
**Velocity**: How fast something is moving in a given direction.

Notice that distance and displacement are very similar. **Distance** is an example of what we call a *scalar* quantity. In other words, it has magnitude, but no direction. **Displacement** is an example of a *vector* quantity because it has both magnitude and direction.

The SI (Système International) unit for distance and displacement is the **meter (m)**.

Displacements smaller than a meter may be expressed in units of centimeters (cm) or millimeters (mm). Displacements much larger than a meter may be expressed in units of kilometers (km).

**Average speed = distance traveled/elapsed time or $v_{avg} = d/\Delta t$**

**Average velocity = displacement/elapsed time or $v_{avg} = \Delta d/\Delta t = (d_f - d_o)/(t_f - t_o)$**

Where $d_f$ and $t_f$ are the final position and time respectively, and $d_o$ and $t_o$ are initial position and time. The symbol "Δ" (delta) means "change" so Δd is the change is position, or the displacement, while Δt is the change in time.

The SI unit for both speed and velocity is the **meter per second (m/s)**.

When traveling in any moving vehicle, you rarely maintain the same velocity throughout an entire trip. If you did, you would travel at a constant speed in a straight line. Instead, speed and direction usually vary during your time of travel.

If you begin and end at the same location but you travel for a great distance in getting there (for example, when you travel in a circle), you have a measurable average speed. However, since your total displacement for such a trip is zero, your average velocity will be written as $v_{av}$.

## Acceleration

*Vocabulary* **Acceleration:** The rate at which the velocity changes during a given amount of time.

**Acceleration = change in velocity/elapsed time** or $a = \Delta v/\Delta t = (v_f - v_o)/(t_f - t_o)$

Where the terms $v_f$ and $v_o$ mean final velocity and initial velocity, respectively.

The SI unit for acceleration is the **meter per second squared ($m/s^2$).**

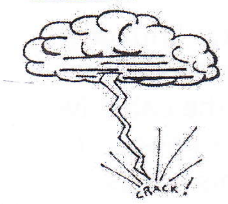
If the final velocity of a moving object is smaller than its initial velocity, the object must be slowing down. A slowing object is sometimes said to have *negative acceleration* because the magnitude of the acceleration is preceded by a negative sign (also known as deceleration).

## Solved Examples: Speed, Velocity & Acceleration

1) Benjamin watches a thunderstorm from his apartment window. He sees the flash of a lightening bold and begins counting the seconds until he hears the clap of thunder 10 s later. Assume that the speed of sound in air is 340 m/s. How far away was the lightning bolt
   a) in m?
   b) in km?

(Note: The speed of light, $3.0 \times 10^8$ m/s, is considerably faster than the speed of sound. That is why you see the lightening flash so much earlier than you hear the clap of thunder. In actuality, the lightening and thunder clap occur almost simultaneously.)

**Sketch:**




**Given:**

$v_{avg} = 340$ m/s

$\Delta t = 10.0$ s

$\Delta d = ?$

**Solve:**

$v_{avg} = \Delta d/\Delta t$

$\Delta d = v_{avg}\Delta t$

$\Delta d = (340 \text{ m/s})(10.0 \text{ s})$

$\Delta d = 3400$ m

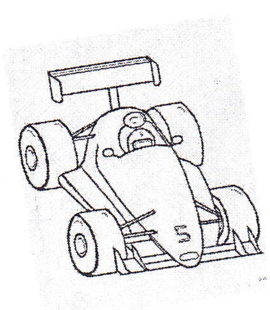
For numbers this large you may wish to express the final answer in km rather than in m. Because "kilo" means 1000, then 1.000 km = 1000. m.

$$3400 \text{ m } (1.000 \text{ km})/1000 \text{ m} = 3.4 \text{ km}$$

The lightening bolt is 3.4 km away, which is just a little over two miles for those of you who think in English units!

2) On May 28, 2000, Juan Montoya became the first Colombian citizen to win the Indianapolis 500. Montoya completed the race in a time of 2.98 h. What was Montoya's average speed during the 500 mi race? (Note: Generally the unit "miles" is not used in physics exercises. However, the Indianapolis 500 is a race that is measured in miles, so the mile is appropriate there. Don't forget, the SI unit for distance is the meter.)

**Sketch:**




**Given:**

$d = 500$ mi

$\Delta t = 2.98$ h

$v_{avg} = ?$

**Solve:**

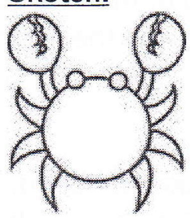
$\Delta t = \Delta d/v$

$\Delta t = 500 \text{ mi}/2.98 \text{ h}$

$\Delta t = 168$ mi/h

3) The slowest animal ever discovered was a crab found in the Red Sea. It traveled with an average speed of 5.70 km/y. How long would it take this crab to travel 100. km?

**Sketch:**



**Given:**

$\Delta d$ = 100 km

$v_{avg}$ = 5.70 km/y

$\Delta t$ = ?

**Solve:**

$\Delta t = \Delta d / v_{avg}$

$\Delta t$ = 100 km/5.70 km/y

$\Delta t$ = 17.5 y

A very long time!

4) Kim, who is opening a new Broadway show, has some limo trouble in the city. With only 8.0 minutes until curtain time, she hails a cab and they speed off to the theater down a 1000 m long one-way street at a speed of 25 m/s. At the end of the street the cab driver waits at a traffic light for 1.5 min and then turns north unto a 1700 m long traffic-filled avenue on which he is able to travel at a speed of only 10.0 m/s. Finally, this brings them to the theater.

**a)** Draw a distance vs. time graph of the situation.

**b)** Does Kim arrive before the theater lights dim?

**Solution:** First, break this exercise down into segments and solve each segment independently.

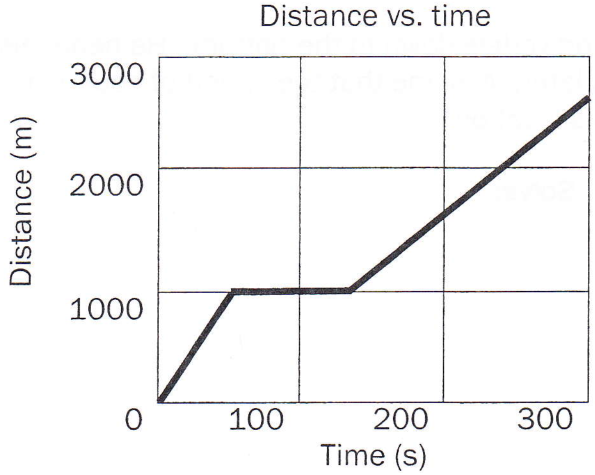
In Segment 1, the distance of 1000. m was covered in a fairly short amount of time, which means that the cab was traveling quickly. This high speed can be seen as a steep slope on the graph.

In Segment 2, the cab was at rest. Notice that even though the cab did not move, time continued on, resulting in a horizontal line of the graph.

In Segment 3, the distance of 1700 m was covered in a much longer amount of time so the cab was traveling slowly. This low speed is indicated by a slope that is not as steep as that in segment 1.

Remember, all graphs should have titles and the axes should be labeled with the correct units.

**Sketch:**




**Given:**

Seg. 1

$\Delta d = 1000$ m
$v_{avg} = 25$ m/s
$\Delta t = ?$

**Solve:**

$v_{avg} = \Delta d/\Delta t$
$\Delta t = \Delta d/v_{avg}$
$\Delta t = 1000$ m/25 m/s
$\Delta t = 40$ s

Seg. 2

$\Delta t = 1.5$ min

(1.5 min)(60 s/1.0 min) = 90 s

Seg. 3

$\Delta d = 1700$ m
$v_{avg} = 10.0$ m/s
$\Delta t = ?$

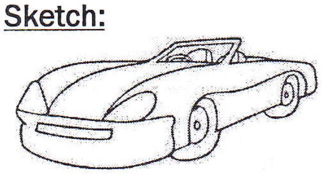
$v_{avg} = \Delta d/\Delta t$
$\Delta t = \Delta d/v_{avg}$
$\Delta t = 1700$ m/10 m/s
$\Delta t = 170$ s

total time = 40 s + 90 s + 170 s
= 300 s
(300 s)(1.0 min/60 s) = 5.0 min

Yes, she not only makes it to the show in time, but she even has 3.0 minutes to spare to put on her costume and make-up.

5) Jody is driving her sports car at 30 m/s when a ball rolls out into the street in front of her. Jody slams on the brakes and comes to a stop in 3.0 s. What was the acceleration of Jody's car?

**Sketch:**



**Given:**

$v_o = 30$ m/s
$v_f = 0$ m/s
$\Delta t = 3.0$ s
$a = ?$

**Solve:**

$a = (v_f - v_o)/\Delta t$
$a = (0 \text{ m/s} - 30 \text{ m/s})/3.0 \text{ s}$
$a = -10 \text{ m/s}^2$

A negative sign means the car was slowing down.

Name:____________________________

Date:____________________________

## Practice Exercises: Speed, Velocity & Acceleration

1) Paul stands at the rim of the Grand Canyon and yodels down to the bottom. He hears his yodel echo back from the canyon floor 5.20 s later. Assume that the speed of sound in air is 340 m/s. How deep is the canyon at this location?

**Sketch:** **Given:** **Solve:**

**Answer:** ____________

2) The world speed record on water was set on October 8, 1978 by Ken Warby of Blowering Dam, Australia. If Ken drove his motorboat a distance of 1000. m in 7.045 s, how fast was his boat moving
   **a)** in m/s?
   **b)** in mi/h?

**Sketch:** **Given:** **Solve:**

**Answer: a.** __________

**Answer: b.** __________

Name:________________________

Date:________________________

**3)** According to the World Flying Disk Federation, on April 8, 2000, Jennifer Griffin of Fredericksburg, Virginia threw a Frisbee for a distance of 138.56 m to capture the women's record. If the Frisbee was thrown horizontally with a speed of 13.0 m/s, how long did the Frisbee remain aloft?

**Sketch:** **Given:** **Solve:**

**Answer:** ___________

**4)** Is it now 10:29 a.m., but when the bell rings at 10:30 a.m., Jaime will be late for French class for the third time this week. She must get from one side of the school to the other by hurrying down three different hallways. She runs down the first hallway, a distance of 35 m, at a speed of 3.50 m/s. The second hallway is filled with students, and she covers its 48 m length at an average speed of 1.20 m/s. The final hallway is empty, and she sprints its 60 m length at a speed of 5.00 m/s. Does Jaime make it to class on time or does she get detention for being late again?

**Sketch:** **Given:** **Solve:**

**Answer:** ___________

Name:______________________________

Date:______________________________

**5)** A jumbo jet taxiing down the runway receives word that it must return to the gate to pick up an important passenger who was late to his connecting flight. The jet is traveling at 45.0 m/s when the pilot receives the message. What is the acceleration (deceleration) of the plane if it takes the pilot 5.00 s to bring the plane to a halt?

**Sketch:** **Given:** **Solve:**

**Answer:** ____________

**6)** While driving his sports car at 20.0 m/s down a four-lane highway, Todd comes up behind a slow-moving dump truck and decides to pass it in the left-hand lane. If Todd can accelerate at 5.00 $m/s^2$, how long will it take for him to reach a speed of 30.0 m/s?

**Sketch:** **Given:** **Solve:**

**Answer:** ____________

Name:________________________

Date:_________________________

7) Courtney is walking to the hairdresser's at 1.3 m/s when she glances at her watch and realizes that she is going to be late for her appointment. Courtney gradually quickens her pace at a rate of 0.090 $m/s^2$.
   a) What is Courtney's speed after 10.0 s?
   b) At this speed, is Courtney walking, jogging, or running very fast?

**Sketch:** **Given:** **Solve:**

**Answer: a.** _________

**Answer: b.** _________

8) A torpedo fired from a submerged submarine is propelled through the water with a speed of 20.00 m/s and explodes upon impact with a target 2000 m away. If the sound of the impact is heard 101.4 s after the torpedo was fired, what is the speed of sound in water? (Because the torpedo is held at a constant speed by it propeller, the effect of water resistance can be neglected.)

**Sketch:** **Given:** **Solve:**

**Answer:** ___________