

Motion, Forces, and Newton's Laws

Describing Motion

..... Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.		
Before	Statement	After
	1. You must use a reference point to describe an object's motion.	
	2. An object that is accelerating must be speeding up.	

..... Read to Learn

Motion

Suppose you have been playing a shuffleboard game in an arcade. You decide you want to try something new, so you walk to a racing game. As you walk to the new game, your position in the room changes. **Motion** is the process of changing position. If the games are 5 m apart, your motion changed your position by a distance of 5 m.

Motion and Reference Points

How would you describe your motion to someone else? You could say you walked 5 m away from the shuffleboard game. Or, you could say that you moved 5 m toward the racing game. *The starting point you use to describe the motion or position of an object is called the reference point.*

You describe motion differently depending on the reference point you choose. You can choose any point as a reference point.

In addition to using a reference point to describe motion, you also need a direction. Identifying whether you move toward or away from a reference point describes a direction. Other descriptions of direction might include east or west, or up or down. When raising your hand, you could use a part of your body as a reference point. ✓

Key Concepts

- What information do you need to describe the motion of an object?
- How are speed, velocity, and acceleration related?
- How can a graph help you understand the motion of an object?

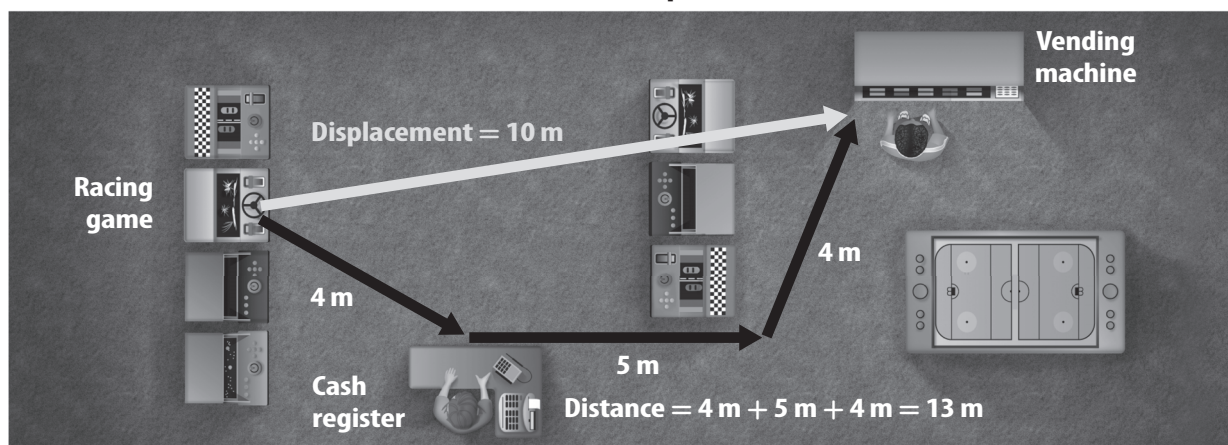
Study Coach

Building Vocabulary Make a vocabulary card for each bold term in this lesson. Write each term on one side of the card. On the other side, write the definition. Use these terms to review the vocabulary for the lesson.

Reading Check

1. Describe your motion as you walk from your desk to the door. Use a reference point and a direction.

Distance and Displacement



Visual Check

2. Contrast Why is the total displacement in the figure different from the total distance?

Key Concept Check

3. Identify What information do you need to describe an object's motion?

Reading Check

4. Generalize What does it mean to say that an object is moving at a "constant speed"?

Distance and Displacement

Suppose you go from the racing game to the cash register to get more tokens. Then you go to the vending machine for a snack. The three dark arrows in the figure above show your path. How far did you travel? **Distance** is the total length of your path. Your total distance is $4\text{ m} + 5\text{ m} + 4\text{ m} = 13\text{ m}$.

Your **displacement** is the distance between your initial, or starting, position and your final position. A straight arrow from the starting point to the ending point represents displacement. The light upper arrow in the figure shows the displacement between the racing game where you started and the vending machine where you stopped. Your displacement is 10 m. A complete description of your motion includes a reference point, your displacement, and your direction.

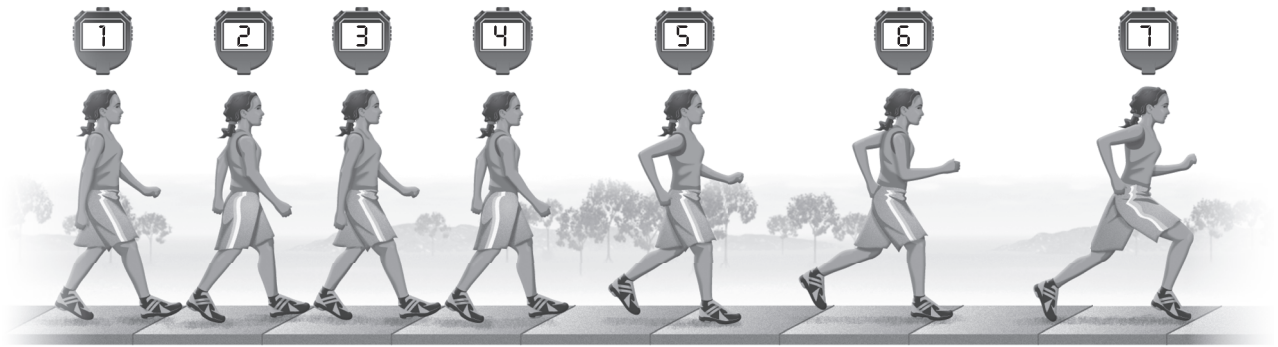
Speed

Suppose you leave the arcade. You walk the first block slowly. Then you realize that you promised to meet a friend at the library in 15 min. You begin to run. You travel the distance of the next block in a much shorter time. What was different between your motion in the first block and your motion in the second block? Your speed was different. **Speed** is the distance an object moves divided by the time it took to move that distance.

Constant and Changing Speed

Speed is either constant or changing. Look at the figure at the top of the next page. The stopwatches show the girl's motion every second for 6 seconds. In the first 4 seconds, she travels the same distance during each second. This means that she was moving with constant, or unchanging, speed. When the girl starts running, the distance she travels each second gets larger and larger. The girl's speed changes.

Constant and Changing Speed



Average Speed

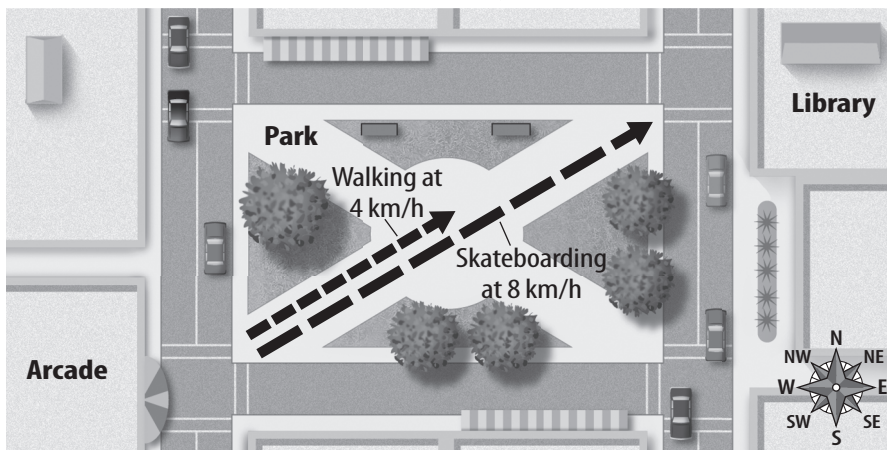
Suppose you want to know how fast you traveled from the arcade to the library. As you moved, your speed changed from second to second. Therefore, in order to describe your speed, you describe the average speed of the entire trip. Average speed is a ratio. It is the distance an object moves divided by the time it takes for the object to move that distance. If you traveled the 1-km distance to the library in 15 min, or 0.25 h, your average speed was 1 km/0.25 h, or 4 km/h.

Velocity

When you describe your motion to a friend, you might say how fast you are traveling. You are describing your speed. You could give your friend a better description of your motion if you also state the direction in which you are moving. **Velocity** is the speed and direction of an object's motion.

Velocity often is shown by using an arrow, as illustrated in the figure below. The length of the arrow represents the speed of an object. The direction in which the arrow points represents the direction in which the object is moving.

Velocity

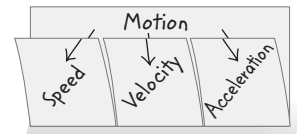


Visual Check

5. Interpret When does the girl's speed begin to change?

FOLDABLES®

Make a three-tab concept map book to organize your notes on motion.



Visual Check

6. Interpret Which velocity shown in the figure is greater? (Circle the correct answer.)

- a. skateboarding
- b. walking
- c. equal

✓ Reading Check

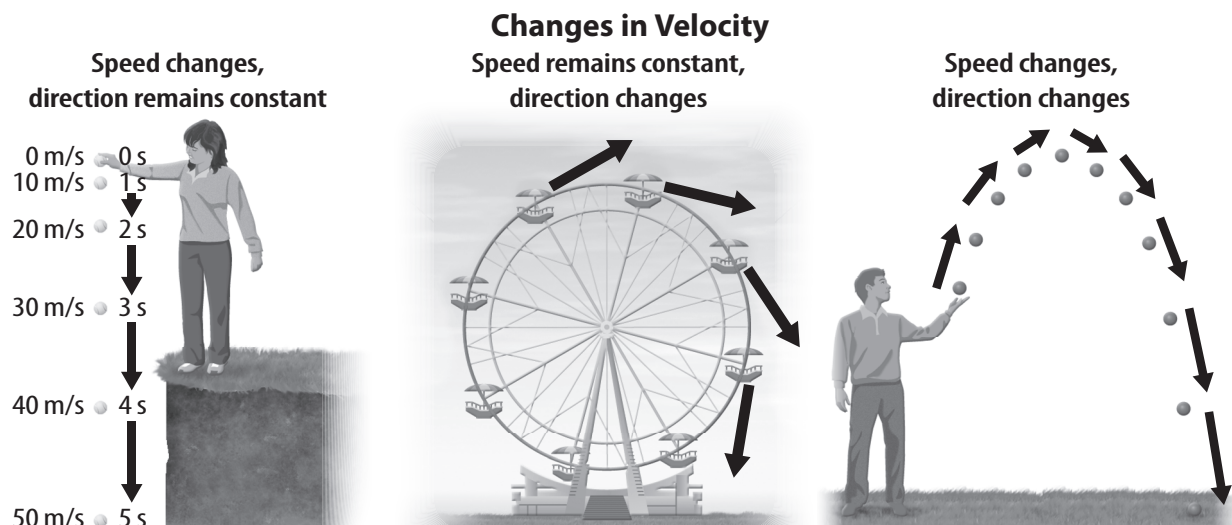
7. Point Out What two factors must be constant in order for velocity to be constant?

🔑 Key Concept Check

8. Explain Can an object traveling at a constant speed have a changing velocity? Why or why not?

✓ Visual Check

9. Identify In the caption of each panel, highlight the factor that changes, resulting in a changing velocity.



Constant Velocity

Velocity is constant, or does not change, when an object's speed and direction of movement do not change. If you use an arrow to describe velocity, you can divide the arrow into segments to show whether velocity is constant. ✓

Look at the skateboarding arrow in the figure at the bottom of the previous page. Each segment of the arrow shows the distance and the direction the skateboarder moves in a given unit of time. Notice that each segment is the same length. This means the skateboarder is moving the same distance and in the same direction during each unit of time. Both speed and direction of movement are constant, so the skateboarder is moving at a constant velocity.

Look at the walking arrow in the figure at the bottom of the previous page. The skateboarder's velocity is greater than the walker's velocity. Both velocities are constant because the arrows show a constant speed and direction.

Changing Velocity

Velocity can change even if the speed of an object remains constant. Recall that velocity includes an object's speed and the direction it is traveling. The velocity changes when speed changes, direction changes, or both change. The figure below shows examples of changing velocity. ✓

Change in Speed In the first panel, the ball drops toward the ground in a straight line, or constant direction. The increasing length of each arrow shows that the speed of the ball increases as it falls. As speed changes, velocity changes, even when direction remains constant.

Change in Direction See the second panel of the figure on the previous page. Each arrow is the same length. This tells you that the Ferris-wheel cars travel around the circle at a constant speed. However, the arrows show that the cars are changing direction. As direction changes, velocity changes, even when speed remains constant.


Change in Speed and Direction The third panel of the figure on the previous page shows the path of a ball thrown into the air. The arrows show that the ball's speed and its direction change, so its velocity changes.

Acceleration When an object's speed or its velocity changes, the object is accelerating. **Acceleration** is a measure of how quickly the velocity of an object changes.

Calculating Acceleration

As shown in the first panel of the figure on the previous page, a ball speeds up as it falls toward the ground. The velocity of the ball is changing. Objects accelerate any time their velocity changes. You can calculate average acceleration using the following equation:

$$\bar{a} = \frac{v_f - v_i}{t}$$

Notice that this equation refers only to a change in speed, not direction. The symbol for average acceleration is \bar{a} . The symbol v_f means the final velocity. The symbol v_i means the initial, or starting, velocity. The symbol t stands for the period of time it takes to make that change in velocity. 

Positive Acceleration

When an object speeds up, as when a ball rolls down a hill, its final velocity (v_f) is greater than its initial velocity (v_i). If you calculate the ball's average acceleration, the numerator (final velocity minus initial velocity) is positive. When you divide the positive numerator by time (t) to find the average acceleration, the result will also be positive. Therefore, when an object speeds up, it has positive acceleration.

Negative Acceleration

When the ball from the above example starts to roll up the next hill, it slows down. The initial velocity of the ball is greater than its final velocity. The numerator in the equation is negative. Thus, the average acceleration is negative. As an object slows down, it has negative acceleration. Some people refer to negative acceleration as deceleration.

Key Concept Check

10. Contrast How does acceleration differ from velocity?

Math Skills

A skateboarder moves at 2 m/s as he or she starts moving down a ramp. As the skateboarder heads down the ramp, he or she accelerates to a speed of 6 m/s in 4 seconds. What is the skateboarder's acceleration?

- This is what you know:
final velocity: $v_f = 6 \text{ m/s}$
initial velocity: $v_i = 2 \text{ m/s}$
time: $t = 4 \text{ s}$
- You need to find out:
average acceleration: \bar{a}
- Use this formula:
$$\bar{a} = \frac{v_f - v_i}{t}$$
- Substitute: the values for v_f , v_i , and t : $\frac{6 \text{ m/s} - 2 \text{ m/s}}{4 \text{ s}}$
subtract and divide:
$$\frac{4 \text{ m/s}}{4 \text{ s}} = 1 \text{ m/s}^2$$

Answer: The average acceleration is 1 m/s^2 .

11. Solve for Average Acceleration As the skateboarder starts moving up the other side of the ramp, his or her velocity drops from 6 m/s to 0 m/s in 3 seconds. What was his or her acceleration?

ACADEMIC VOCABULARY

satellite

(noun) an object in orbit around another object



Visual Check

12. Interpreting Graphs

What was the average speed of the bear between hours 7 and 11?

Using Graphs to Represent Motion

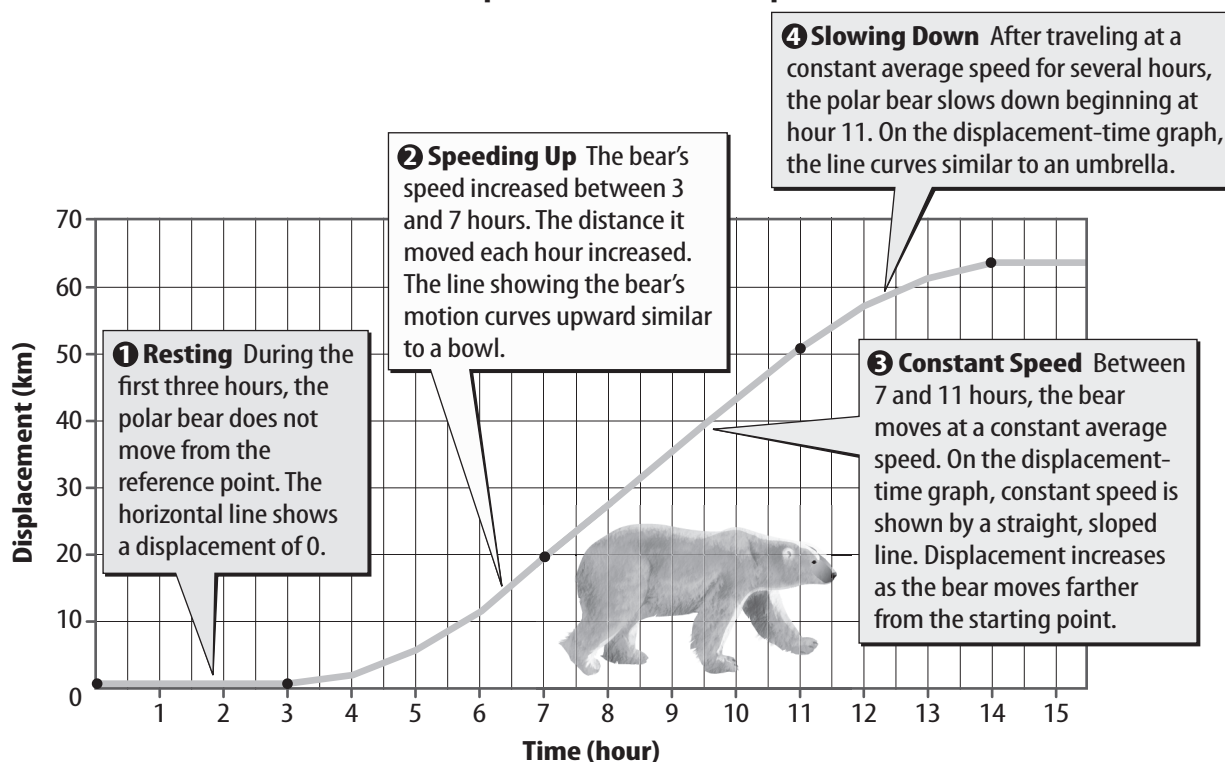
How can you track the motion of an animal that can move hundreds of miles without being seen by humans? To understand the movements of animals, such as the polar bear shown in the figure below, biologists put tracking devices on them. These devices constantly send information about the position of the animal to satellites. Biologists download the data from the satellites. They use the data to create graphs of motion, such as those shown below and on the next page.

Displacement-Time Graphs

The graph below is a displacement-time graph of a polar bear's motion. The x -axis shows the time. The y -axis shows the displacement of the polar bear from a reference point. The displacement-time graph shows the bear's speed and displacement from the reference point at any point in time.

The line on the displacement-time graph represents the average speed of the bear at that moment in time. The line does not show the actual path of motion. As the average speed of the bear changes, the slope of the line on the graph changes. Because of this, you can use a displacement-time graph to describe the motion of an object.

Displacement-Time Graph




Copyright © Glencoe/McGraw-Hill, a division of The McGraw-Hill Companies, Inc.

Speed-Time Graphs

The graph below is a speed-time graph of the polar bear's motion. The x -axis shows the time, and the y -axis shows the speed of the bear. In this case, the line shows how the speed changes as the bear moves. It does not show how displacement changes. The speed-time graph shows the speed of the bear at any point during its journey.

A horizontal line on a speed-time graph shows an object in constant motion—either at rest or moving at a constant speed. On the graph below, the horizontal line at $y = 0$ means the bear is at rest, because its speed is 0 km/h. Notice that a horizontal line at $y = 0$ on a displacement-time graph or a speed-time graph represents an object at rest.

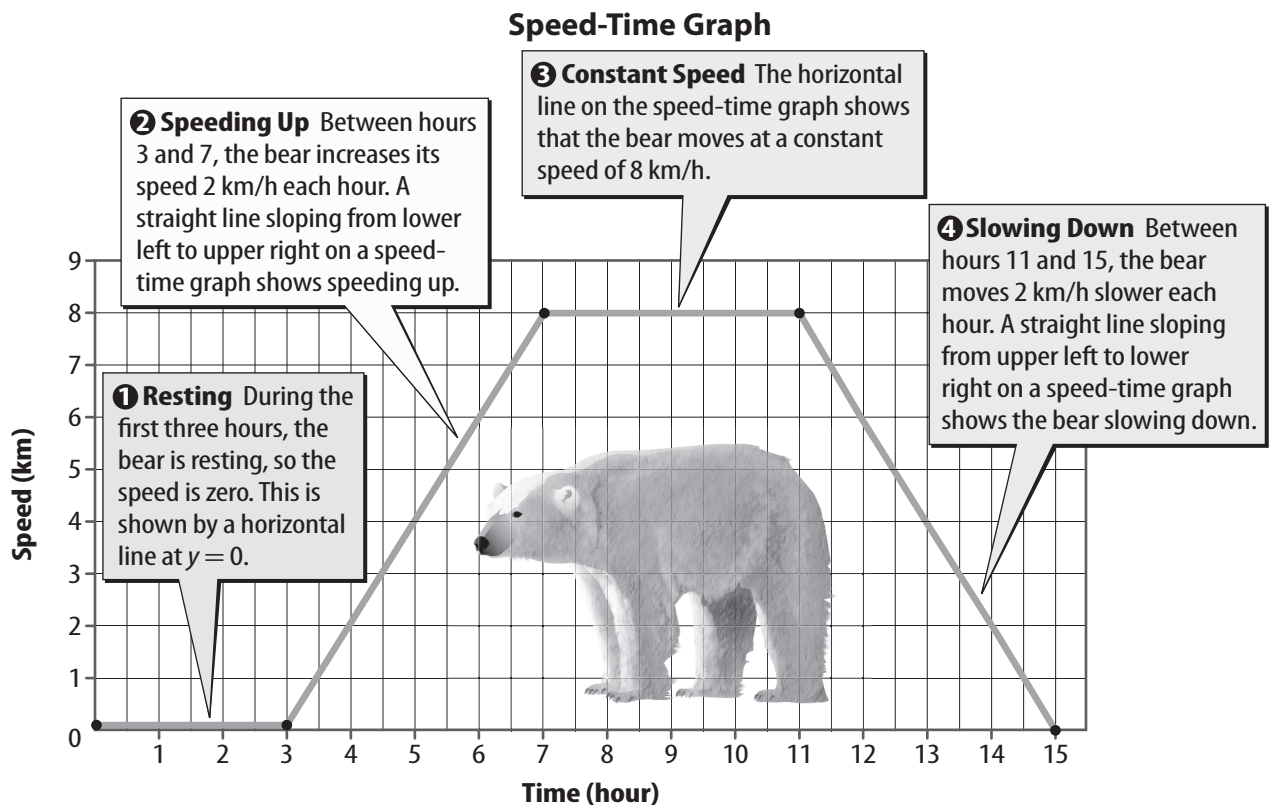
Keep in mind that “constant speed” describes average speed. The bear might have sped up or slowed down slightly each second. But, during hours 7–11, you could describe that the bear's average remained constant since it covered the same distance each hour. 

Key Concept Check

13. Analyze How can a graph help you understand an object's motion?

Visual Check

14. Interpreting Graphs What happened to the bear's speed between hours 5 and 6?



Mini Glossary

acceleration: a measure of how quickly the velocity of an object changes

displacement: the distance between an initial, or starting, position and the final position

distance: the total length of a path

motion: the process of changing position





reference point: the starting point you use to describe the motion or the position of an object

speed: the distance an object moves divided by the time it took to move that distance

velocity: the speed and direction of an object's motion

1. Review the terms and their definitions in the Mini Glossary. Write a sentence that describes a motion, including a reference point, displacement, and direction.

2. The arrows in the table below describe motion. Put a check in the columns to identify the factors that changed in each motion. The arrows may show a change in one factor, in more than one factor, or in no factors.

Motion	What changed?		
	Speed	Direction	Velocity
a. 			
b. 			
c. 			
d. 			

Copyright © Glencoe/McGraw-Hill, a division of The McGraw-Hill Companies, Inc.

What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?



Log on to ConnectED.mcgraw-hill.com and access your textbook to find this lesson's resources.

END OF LESSON