SECTION 1

What is motion?

As You Read

What You'll Learn

- **Define** distance, speed, and velocity.
- **Graph** motion.

Vocabulary

speed
average speed
instantaneous speed
velocity

Why It's Important

The different motions of objects you see every day can be described in the same way.

SCIENCE Online

Research Visit the Glencoe Science Web site at **science.glencoe.com** for more information about early attempts to study motion. Make a table to show what you learn.

Matter and Motion

All matter in the universe is constantly in motion, from the revolution of Earth around the Sun to electrons moving around the nucleus of an atom. Plants grow. Lava flows from a volcano. Bees move from flower to flower as they gather pollen. Blood circulates through your body. These are all examples of matter in motion. How can the motion of these different objects be described?

Changing Position

To describe an object in motion, you must recognize first that the object is in motion. Something is in motion if it is changing position. It could be a fast-moving airplane, a leaf swirling in the wind, or water trickling from a hose. Even your school is moving through space attached to Earth. When an object moves from one location to another, it is changing position. The runners shown in **Figure 1** sprint from the start line to the finish line. Their positions change so they are in motion.

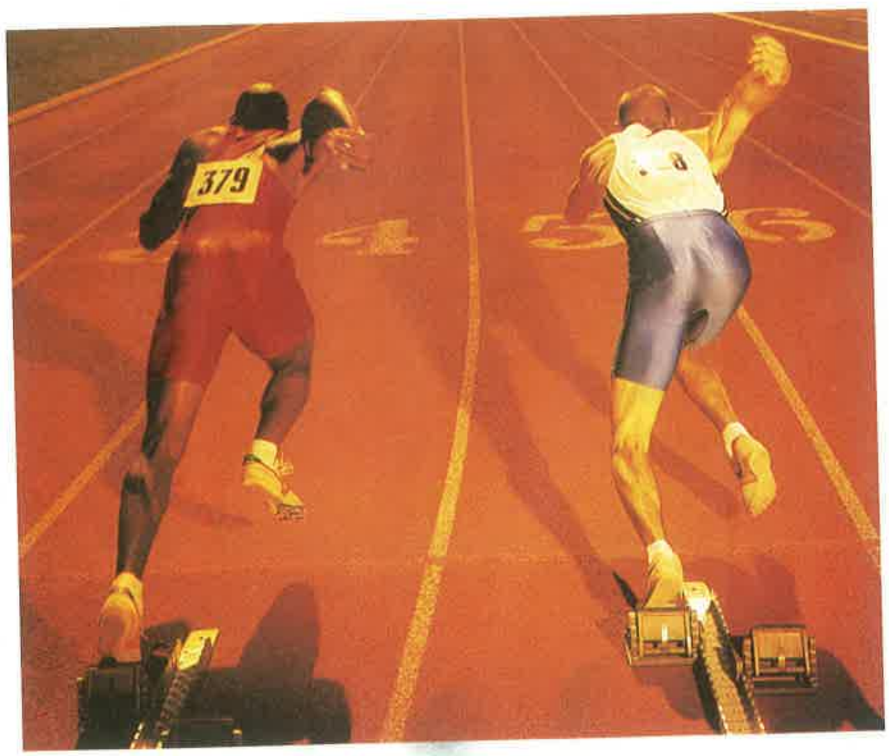


Figure 1
When running a race, you are in motion because your position changes.

Relative Motion Determining whether something changes position requires a point of reference. An object changes position if it moves relative to a reference point. To visualize this, picture yourself competing in a 100-m dash. You begin just behind the start line. When you pass the finish line, you are 100 m from the start line. If the start line is your reference point then your position has changed by 100 m relative to the start line, and motion has occurred. Look at **Figure 2.** How can you determine that the dog has been in motion?

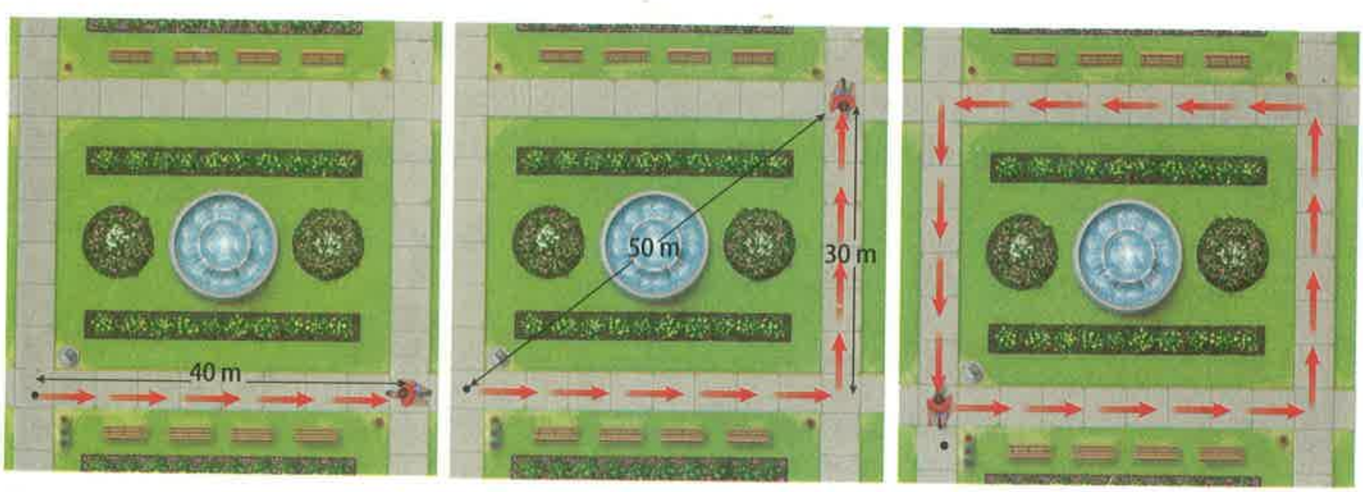
Reading Check *How do you know if an object has changed position?*

Figure 2
Motion occurs when something moves relative to a reference point. ***The dog has moved relative to what object?***

Distance and Displacement Suppose you are to meet your friends at the park in five minutes. Can you get there on time by walking, or should you ride your bike? To help you decide, you need to know the distance you will travel to get to the park. This distance is the length of the route you will travel from your house to the park.

Suppose the distance you traveled from your house to the park was 200 m. When you get to the park, how would you describe your location? You could say that your location was 200 m from your house. To describe your location exactly, you also would have to tell in what direction you traveled. Did you travel 200 m east or 200 m west? Your final position would depend on the distance traveled and the direction. To describe your location, you would specify your displacement. Displacement includes the distance between the starting and stopping points, and the direction in which you travel. **Figure 3** shows the difference between distance and displacement.

Figure 3
Distance is how far you have walked. Displacement is the direction and difference in position between your starting point and your ending point.



Distance: 40 m
Displacement: 40 m east

Distance: 70 m
Displacement: 50 m northeast

Distance: 140 m
Displacement: 0 m

Speed

Knowing how fast something is moving can be important. The faster something is moving, the less time it takes to travel a certain distance. **Speed** is the distance traveled divided by the time taken to travel the distance. This definition can be written as the following equation:

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

For example, the fastest runners can run the 100-m dash in about 10 s. When sprinters run 100 m in 10 s, their speed is as follows:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$
$$= \frac{100 \text{ m}}{10 \text{ s}}$$
$$= 10 \text{ m/s}$$

The units of speed are units of distance divided by units of time. In SI units, the units of speed are meters per second (m/s).

Life Science INTEGRATION

Different animals can move at different top speeds. What are some of the fastest animals? Research the characteristics that help animals run, swim, or fly at high speed.

Math Skills Activity

Calculating Speed

Example Problem

Calculate the speed of a swimmer who swims 100 m in 56 s.

Solution

1. *This is what you know:* distance: 100 m; time: 56 s
2. *This is what you need to know:* speed
3. *This is the equation you need to use:* speed = distance/time
4. *Substitute the known values:* speed = (100 m)/(56 s); speed = 1.8 m/s

Check your answer by multiplying the calculated speed by the time. Did you calculate the distance that was given in the problem?

Practice Problem

A runner completes a 400-m race in 43.9 s. In a 100-m race, he finishes in 10.4 s. In which race was his speed faster?

For more help, refer to the Math Skill Handbook.

Average Speed If a sprinter ran the 100-m dash in 10 s, she probably couldn't have run the entire race with a speed of 10 m/s. Consider that when the race started, the sprinter wasn't moving. Then, as she started running, she moved faster and faster, which increased her speed. During the entire race, the sprinter's speed could have been different from instant to instant. However, the sprinter's motion for the entire race can be described by her average speed, which is 10 m/s. **Average speed** is found by dividing the total distance traveled by the time taken.

Reading Check *How is average speed calculated?*

An object in motion can change speeds many times as it speeds up or slows down. The speed of an object at one instant of time is the object's **instantaneous speed.** To understand the difference between average and instantaneous speeds, think about walking to the library. If it takes you 0.5 h to walk 2 km to the library, your average speed would be as follows:

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

$$= \frac{2\ \text{km}}{0.5\ \text{h}} = 4\ \text{km/h}$$

However, you might not have been moving at the same speed throughout the trip. At a crosswalk, your instantaneous speed might have been 0 km/h. If you raced across the street, your speed might have been 7 km/h. If you were able to walk at a steady rate of 4 km/h during the entire trip, you would have moved at a constant speed. Average speed, instantaneous speed, and constant speed are illustrated in **Figure 4.**

TRY AT HOME Mini LAB

Measuring Average Speed

Procedure

1. Measure the distance between two marks, such as two doorways.
2. Time yourself walking from one mark to the other.
3. Time yourself walking slowly, walking safely and quickly, and walking with a varying speed; for example, slow/fast/slow.

Analysis

1. Calculate your average speed in each case.
2. Predict how long it would take you to walk 100 m slowly, at your normal speed, and quickly.

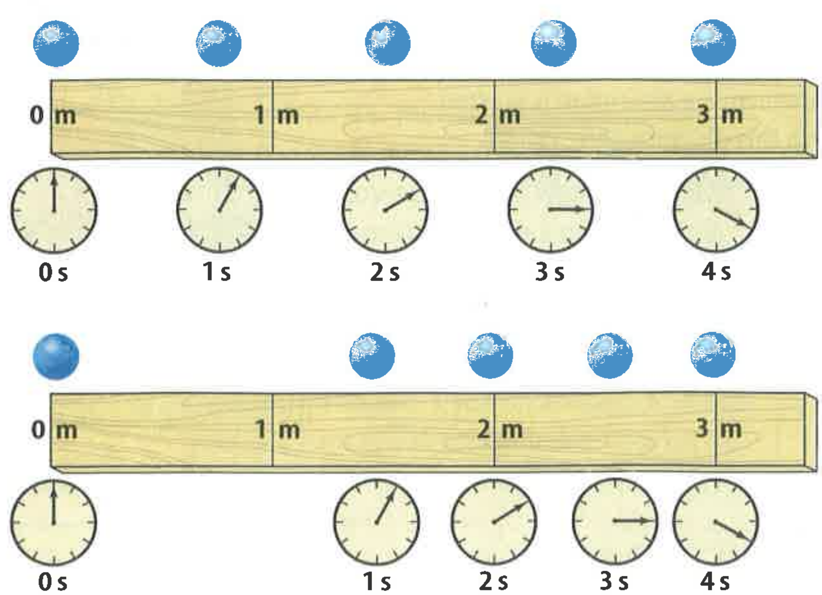


Figure 4
The average speed of each ball is the same from 0 s to 4 s.

A This ball is moving at a constant speed. In each second, the ball moves the same distance.

B This ball has a varying speed. Its instantaneous speed is fast between 0 s and 1 s and slow between 2 s and 3 s.

Graphing Motion

You can represent the motion of an object with a distance-time graph. For this type of graph, time is plotted on the horizontal axis and distance is plotted on the vertical axis. **Figure 5** shows the motion of two students who walked across a classroom, plotted on a distance-time graph.

SCIENCE Online

Research Visit the Glencoe Science Web site at **science.glencoe.com** for information about how the land speed record has changed over the past century. Make a chart showing what you learn.

Distance-Time Graphs and Speed The distance-time graph can be used to compare the speeds of objects. Look at the graph shown in **Figure 5.** According to the graph, after 1 s student A traveled 1 m. Her average speed during the first second is as follows:

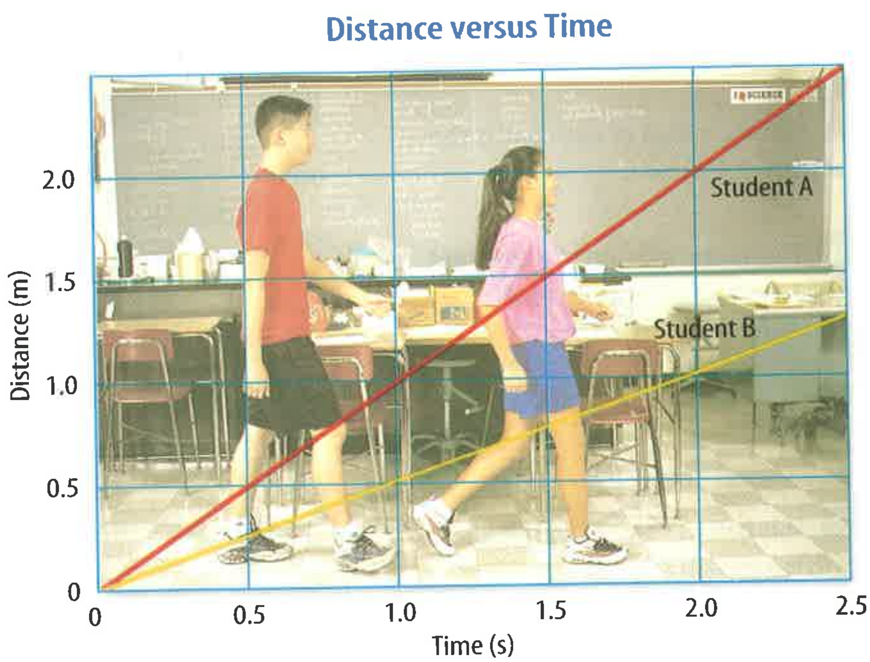
$$\text{speed} = \frac{\text{distance}}{\text{time}} = \frac{1\text{ m}}{1\text{ s}} = 1\text{ m/s}$$

Student B, however, only traveled 0.5 m in the first second. His average speed is

$$\text{speed} = \frac{\text{distance}}{\text{time}} = \frac{0.5\text{ m}}{1\text{ s}} = 0.5\text{ m/s}$$

So student A traveled faster than student B. Now compare the steepness of the lines on the graph in **Figure 5.** The line representing the motion of student A is steeper than the line of student B. A steeper line on the distance-time graph represents a greater speed. A horizontal line on the distance-time graph means that no change in position occurs. Then the speed, represented by the line on the graph, is zero.

Figure 5
The motion of two students walking across a classroom is plotted on this distance-time graph.
Which student moved faster?



Velocity

If you are hiking in the woods, it is important to know in which direction you should walk in order to get back to camp. You want to know not only your speed, but also the direction in which you are moving. The **velocity** of an object is the speed of the object and direction of its motion. This is why a compass and a map, like the one shown in **Figure 6,** are useful to hikers. To get back to camp before nightfall, they need to know how far, how fast, and in what direction they need to travel. The map and the compass help the hikers to determine what their velocity must be. Velocity has the same units as speed, but it also includes the direction of motion.

The velocity of an object can change if the object's speed changes, its direction of motion changes, or they both change. For example, suppose a car is traveling at a speed of 60 km/h north and then turns left at an intersection and continues on with a speed of 60 km/h. The speed of the car is constant at 60 km/h, but the velocity changes from 60 km/h north to 60 km/h west. Why can you say the velocity of a car changes as it comes to a stop at an intersection?

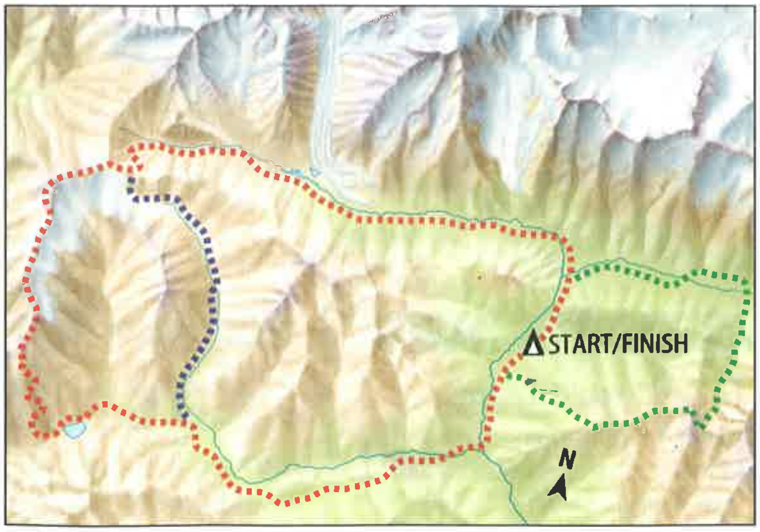


Figure 6
A map helps determine the direction in which you need to travel.

Section 1 Assessment

1. A dancer moves 5 m toward the left of the stage over the course of 15 s. What is her average velocity for this time?
2. If you know an object's velocity, do you know its speed? Explain.
3. An airplane flies a distance of 650 km at an average speed of 300 km/h. How much time did the flight take?
4. **Think Critically** A bee flies 25 m north of the hive, then 10 m east, 5 m west, and 10 m south. How far north and east of the hive is it now? Explain how you calculated your answer.

Skill Builder Activities

5. **Making and Using Graphs** You walk forward at 1.5 m/s for 8 s. Your friend decides to walk faster and starts out at 2.0 m/s for the first 4 s. But then she slows down and walks forward at 1.0 m/s for the next 4 s. Make a distance-time graph of your motion and your friend's motion. Who walked farther? **For more help, refer to the** Science Skill Handbook.
6. **Using a Database** Use a database to research the top speeds of different animals. Convert all data to units of m/s. **For more help, refer to the** Technology Skill Handbook.