3•1 Motion and Speed

Science Words

speed
instantaneous speed
constant speed
average speed

Objectives

- Define *speed* as a rate.
- Perform calculations involving speed, time, and distance.
- Interpret distance-time graphs.

Understanding Speed

When something moves, it changes position. It travels from one place to another, even if only for a brief time. Think about an ice skater. If asked to describe the motion of speed skater Bonnie Blair in **Figure 3-1,** you could say something like "leaning forward with repetitive gliding strokes." How would you describe the motion of a person on a swing?

Motion and Position

You don't always have to see something move to know that motion has taken place. For example, suppose you look out a window and see a mail truck parked next to a mailbox. One minute later, you look out again and see the same truck parked down the street from the mailbox. Although you didn't observe the motion, you know the truck moved because its position relative to the mailbox has changed.

Thus, motion can be described as a change in position. To know whether the position of something has changed, you need a reference point. In the case of the mail truck, the mailbox was a reference point. You can also use a reference point to get a rough idea of how far the truck moved. However, you don't know how fast the truck moved to reach its new position.

Motion and Time

Descriptions of motion often include speed—how fast something moves. If you think of motion as a change in position, then speed is an expression of how much time it takes for that change in position to occur. Any change over time is called a rate. **Speed,** then, is the rate of change in position. Speed can also be described as simply a "rate of motion."

There are several useful measures of speed. The speedometer in a car shows instantaneous speed. **Instantaneous speed** is the rate of

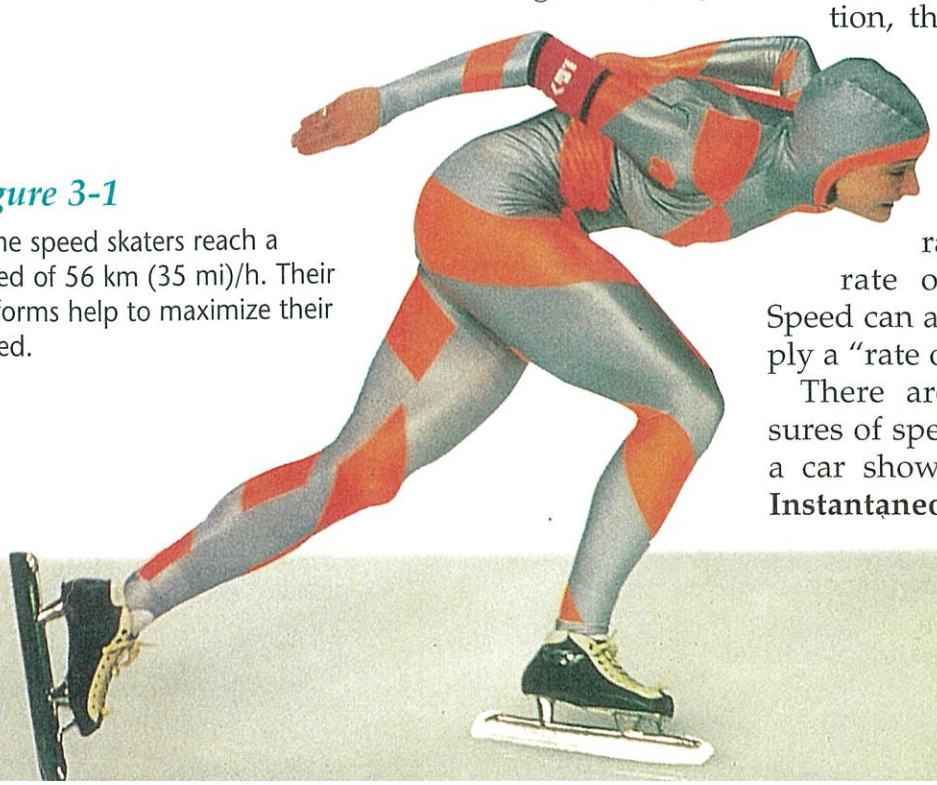

Figure 3-1

Some speed skaters reach a speed of 56 km (35 mi)/h. Their uniforms help to maximize their speed.

motion at any given instant. At the moment the picture in **Figure 3-2** was taken, the car was traveling at a speed of 80 km/h. On a highway, a car may travel at the same speed for a fairly long period of time. A speed that does not vary is called a **constant speed.**

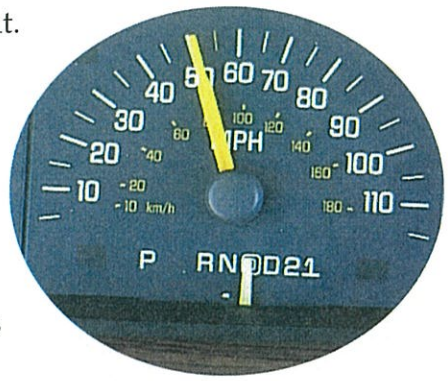

Figure 3-2

The speedometer of a car shows how fast the car is moving at any given instant. *Would the car's instantaneous speed remain the same or change if you measure it frequently during a rush-hour drive?*

Changing Speed

Much of the time, the speeds you deal with are not constant. Think about riding your bicycle for a distance of 5 km. As you start out, your speed increases from 0 km/h to, say, 20 km/h. You slow down to 12 km/h as you pedal up a steep hill and speed up to 35 km/h going down the other side of the hill. You stop for a red light, speed up again, and move at a constant speed for a while. As you near the end of the trip, you slow down and then stop. Checking your watch, you find that the trip took 15 minutes, or one-quarter of an hour. How would you express your speed on such a trip? Would you use your fastest speed, your slowest speed, or some speed in between the two?

In cases where rate of motion varies a great deal, the best way to describe speed is to use average speed. **Average speed** is the total distance traveled divided by total time of travel. On the trip just described, your average speed was 5 km divided by ¼ hour, or 20 km/h.

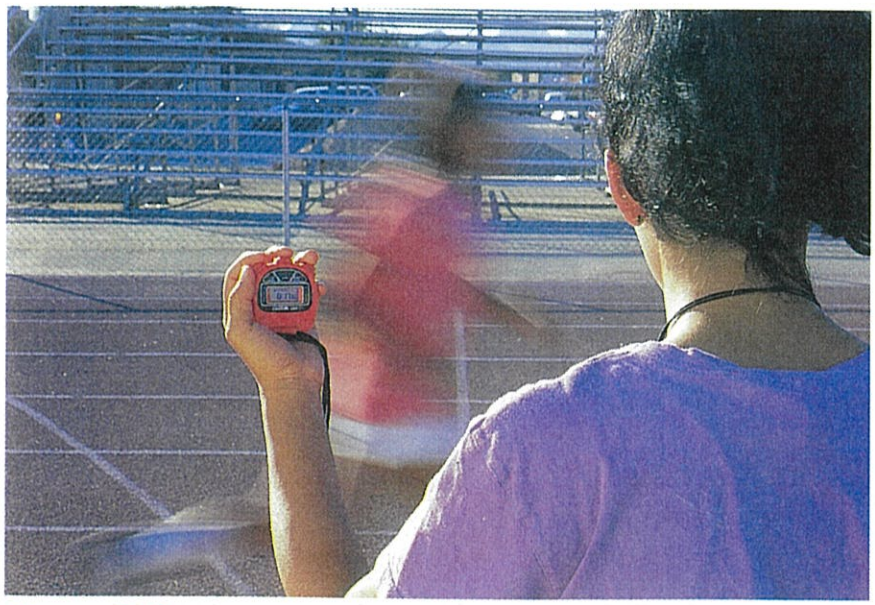

Figure 3-3

A runner's speed can change from moment to moment during a race.

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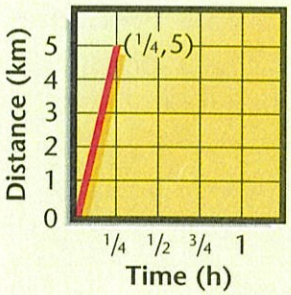
A line graph provides a "picture" of the bicyclist traveling 5 km in ¼ hour.



The *slope*, or steepness, of the line represents the average speed. Suppose another bicyclist traveled 5 km in ½ hour. Compared to the first graph, is this more steep or less steep? Is the average speed greater or less than the first speed?

Calculating Speed

How could you find out who the fastest runner in your school is? One way would be to get all the students together to run in a giant race. However, this isn't very practical. A better way would be to have each student run a certain distance and to time each runner, as shown in **Figure 3-3** on page 65. The runner with the shortest time is the fastest student.

The relationship between distance, speed, and time is shown in the equation $d = v \times t$, where d = distance, v = speed, and t = time. If you know the distance and time, you can rewrite the equation as

$$v = \frac{d}{t}$$

to calculate the average speed.

The problems below will give you practice in calculating the average speed.

Graphing Speed

A distance-time graph makes it possible to "see" the motion of an object over a period of time. For example, the graph in **Figure 3-4** shows how two swimmers performed during a 30-minute workout. The smooth red line represents the

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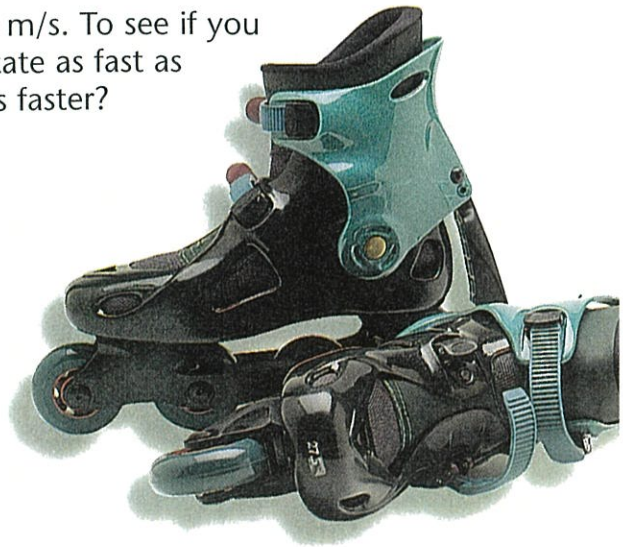
Calculating Speed

Example Problem:

Your neighbor says she can skate at a speed of 4 m/s. To see if you can skate faster, you have her time you as you skate as fast as you can for 100 m. Your time is 20 s. Who skates faster?



Problem-Solving Steps:

1. What is known?
   distance, d = 100 m; time, t = 20 s
2. What is unknown? average speed, v
3. Use the equation $v = \frac{d}{t}$
4. **Solution:** $v = \frac{d}{t}$

$$v = \frac{100 \text{ m}}{20 \text{ s}} = 5 \text{ m/s}$$

Your neighbor's speed is 4 m/s; you skate faster.

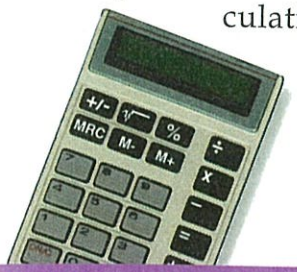
Practice Problem

Florence Griffith Joyner set a world record by running 200 m in 21.34 s. What was her average speed?

Strategy Hint: In what units will your answer be given?

motion of a swimmer who swam 800 m during each 10-minute period. Her speed was constant at 80 m/min.

The blue line represents the motion of a second swimmer, who did not swim at a constant speed. She covered 400 m during the first 10 minutes of her workout. Then she rested for the next 10 minutes. During this time, her speed was 0 m/min. The slope of the graph over the next 10 minutes shows that she swam faster than before and covered 800 m. What total distance did she cover? What was her average speed for the 30-minute period? The problems below will give you practice in calculating the time during which a motion occurs.



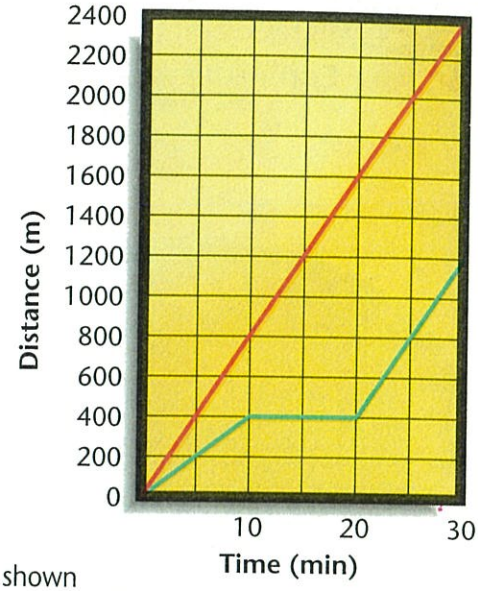


Figure 3-4

The distance-time graph shown here makes it possible to visualize the motion of the swimmers. *Which person swam the farthest during the 30-minute workout?*

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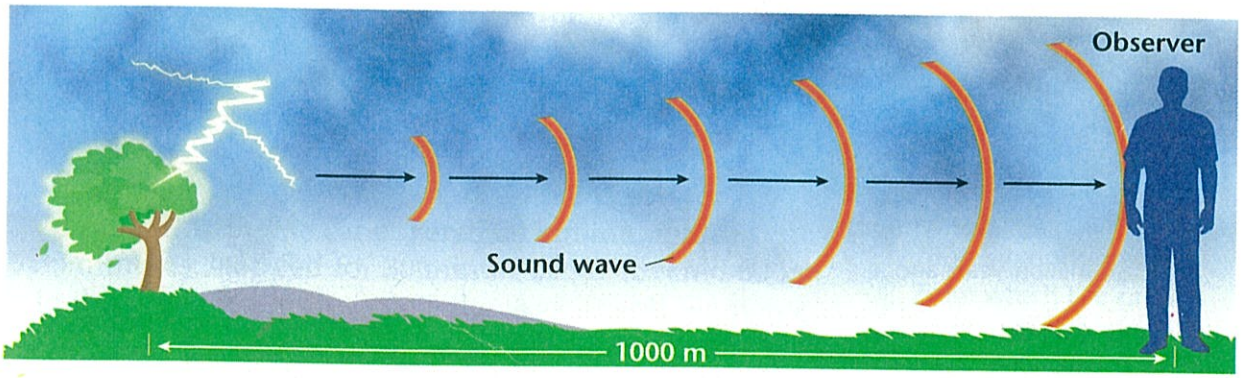
Calculating Time from Speed

Example Problem:

Sound travels at a speed of 330 m/s. If a lightning bolt strikes the ground 1 km away from you, how long will it take for the sound to reach you?

1. What is known? distance, $d = 1$ km; speed, $v = 330$ m/s
2. Use the equation $d = v \times t$. Since you know d and v, rewrite the equation as $t = \frac{d}{v}$ to find the time t.



3. Solution: $t = \frac{d}{v}$ $t = \frac{1\text{ km}}{330\text{ m/s}} = \frac{1000\text{ m}}{330\text{ m/s}} = 3.03\text{ s}$

Practice Problem

The world's fastest passenger elevator operates at an average speed of about 10 m/s. If the 60th floor is 219 m above the first floor, how long does it take the elevator to go from the first floor to the 60th floor?

Strategy Hint: Rearrange the equation.

INTEGRATION
Earth Science

Earth's Crust—Moving Right Along

Can you think of something that is moving so slowly you cannot watch its motion directly, yet you can see evidence of its motion over long periods of time? As you look around the surface of Earth from year to year, the basic structure of our planet seems the same. Yet, if you examined geological evidence of what Earth's surface looked like over hundreds of millions of years, you would see an ever-changing place, as shown in **Figure 3-5.**

250 million years ago

180 million years ago

Figure 3-5

About 250 million years ago, the arrangement of the continents formed the supercontinent called Pangaea. *Are modern-day Europe, Asia and North America found in the northern or southern portion of Pangaea?*

A About 180 million years ago, Pangaea began to separate into smaller pieces.

66 million years ago

B Continental movement continued. *In which direction is India moving in this diagram?*

Present

C *Will the present arrangement of the continents change in the future? Explain.*

How can continents move?

You may have studied about the theory of plate tectonics, which suggests that Earth's crust and solid upper mantle, shown in **Figure 3-6** as the lithosphere, form huge sections called plates. If you compare Earth to an egg, these plates are about as thick as the eggshell. The plates slide around slowly

on a putty-like layer of partly molten mantle called the asthenosphere. A variety of geological changes, such as the formation of mountain ranges, earthquakes, and volcanic eruptions, can occur when these moving plates interact in different ways.

Measuring Speeds of Tectonic Movements

In most of the examples in this chapter, we were measuring speed based on traveling an easily measurable distance in a few seconds or minutes. The speeds of tectonic movements are best described in distance per year. In California, the movement along the San Andreas fault has an average drift speed of about 2 cm per year. The Australian plate's movement is one of the fastest, pushing Australia north at an average speed of about 17 cm per year. **Figure 3-5** illustrates the slow, long-term movement of the continents.

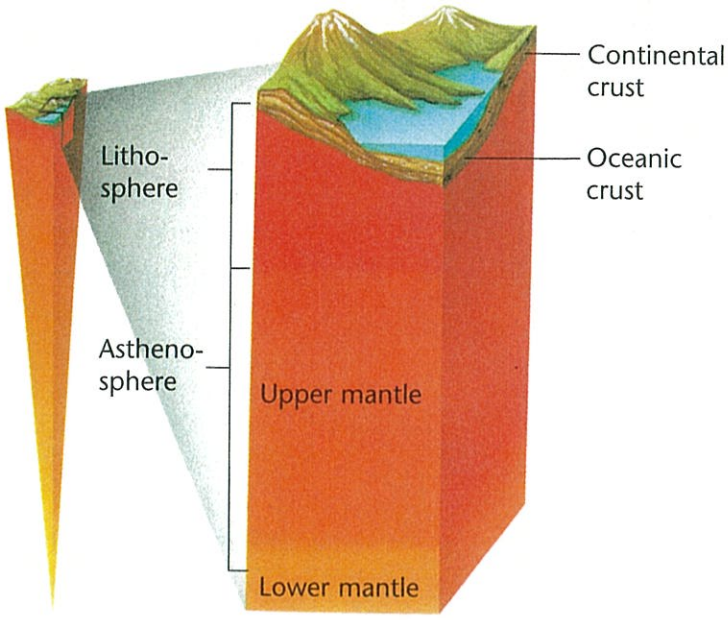


Figure 3-6
The diagram shows the different layers of Earth's crust and mantle.

Section Wrap-up

Review

1. What units would you use to describe the speed of a car? Would you use different units for the speeds of runners in a neighborhood race? Explain.
2. In a skateboarding marathon, the winner covered 435 km in 36.75 h. What was the winner's average speed?
3. **Think Critically:** Make a distance-time graph for a 2-hour car trip. The car covered 50 km in the first 30 minutes, stopped for 30 minutes, and covered 60 km in the final 60 minutes. Note the three graph segments. Which graph segment slopes the most? Which one does not slope? What was the car's average speed?

Skill Builder
Comparing and Contrasting

Compare and contrast the motions of a person on a swing and a person riding a merry-go-round. If you need help, refer to Comparing and Contrasting in the **Skill Handbook.**

Using Computers

Spreadsheet Given the information in the graph in **Figure 3-4,** use a computer to construct a data table listing the distance and time measurements from which the graph was made. Use a spreadsheet program to make your data table and use it, if possible, to re-create the graphs.