Section 2

Speed and Velocity

Reading Preview

Key Concepts

- How do you know an object's speed and velocity?
- How can you graph motion?

Key Terms

- speed
- average speed
- instantaneous speed
- velocity
- slope

Target Reading Skill

Previewing Visuals Before you read, preview Figure 5. Then write two questions that you have about the diagram in a graphic organizer like the one below. As you read, answer your questions.

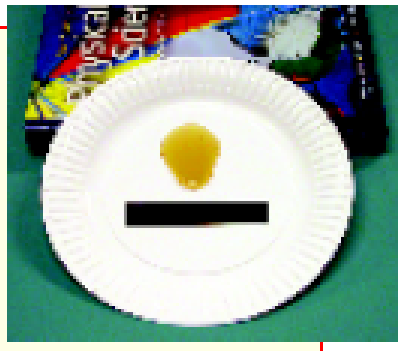
Graphing Motion

Q. How can you determine the slope of a graph?
A.
Q.

Lab zone

Discover Activity

How Slow Can It Flow?



1. Put a spoonful of honey on a plate.
2. Place a piece of tape 4 cm from the bottom edge of the honey.
3. Lift one side of the plate just high enough that the honey starts to flow.
4. Reduce the plate's angle until the honey barely moves. Prop up the plate at this angle.
5. Time how long the honey takes to reach the tape. Calculate the speed of the honey.

Think It Over

Forming Operational Definitions When an object doesn't appear to be moving at first glance, how can you tell if it is?

A measurement of distance can tell you how far an object travels. A cyclist, for example, might travel 30 kilometers. An ant might travel 2 centimeters. **If you know the distance an object travels in a certain amount of time, you can calculate the speed of the object.** Speed is a type of rate. A rate tells you the amount of something that occurs or changes in one unit of time. The **speed** of an object is the distance the object travels per unit of time.

Calculating Speed

To calculate the speed of an object, divide the distance the object travels by the amount of time it takes to travel that distance. This relationship can be written as an equation.

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

The speed equation consists of a unit of distance divided by a unit of time. If you measure distance in meters and time in seconds, you express speed in meters per second, or m/s. (The slash is read as "per.") If you measure distance in kilometers and time in hours, you express speed in kilometers per hour, or km/h. For example, a cyclist who travels 30 kilometers in 1 hour has a speed of 30 km/h. An ant that moves 2 centimeters in 1 second is moving at a speed of 2 centimeters per second, or 2 cm/s.

Average Speed The speed of most moving objects is not constant. The cyclists shown in Figure 4, for example, change their speeds many times during the race. They might ride at a constant speed along flat ground but move more slowly as they climb hills. Then they might move more quickly as they come down hills. Occasionally, they may stop to fix their bikes.

Although a cyclist does not have a constant speed, the cyclist does have an average speed throughout a race. To calculate **average speed**, divide the total distance traveled by the total time. For example, suppose a cyclist travels 32 kilometers during the first 2 hours. Then the cyclist travels 13 kilometers during the next hour. The average speed of the cyclist is the total distance divided by the total time.

$$\text{Total distance} = 32\ \text{km} + 13\ \text{km} = 45\ \text{km}$$

$$\text{Total time} = 2\ \text{h} + 1\ \text{h} = 3\ \text{h}$$

$$\text{Average speed} = \frac{45\ \text{km}}{3\ \text{h}} = 15\ \text{km/h}$$

The cyclist's average speed is 15 kilometers per hour.

Instantaneous Speed Calculating the average speed of a cyclist during a race is important. However, it is also useful to know the cyclist's instantaneous speed. **Instantaneous speed** is the rate at which an object is moving at a given instant in time.

Reading Checkpoint **How do you calculate average speed?**

FIGURE 4
Measuring Speed
Cyclists use an electronic device known as a cyclometer to track the distance and time that they travel. A cyclometer can calculate both average and instantaneous speed.
Comparing and Contrasting
How does average speed compare to instantaneous speed?

Describing Velocity

Knowing the speed at which something travels does not tell you everything about its motion. To describe an object's motion completely, you need to know the direction of its motion. For example, suppose you hear that a thunderstorm is traveling at a speed of 25 km/h. Should you prepare for the storm? That depends on the direction of the storm's motion. Because storms usually travel from west to east in the United States, you need not worry if you live to the west of the storm. But if you live to the east of the storm, take cover.

When you know both the speed and direction of an object's motion, you know the velocity of the object. Speed in a given direction is called **velocity.** You know the velocity of the storm when you know that it is moving 25 km/h eastward.

• Tech & Design in History •

The Speed of Transportation

The speed with which people can travel from one place to another has increased over the years.

1908
Ford Model T Mass-Produced
Between 1908 and 1927, over 15 million of these automobiles were sold. The Model T had a top speed of 65 km/h.

1818
National Road Constructed
The speed of transportation has been limited largely by the quality of roadways. The U.S. government paid for the construction of a highway named the Cumberland Road. It ran from Cumberland, Maryland, to Wheeling, in present-day West Virginia. Travel by horse and carriage on the roadway was at a speed of about 11 km/h.

1885
Benz Tricycle Car Introduced
This odd-looking vehicle was the first internal combustion (gasoline-powered) automobile sold to the public. Although it is an ancestor of the modern automobile, its top speed was only about 15 km/h—not much faster than a horse-drawn carriage.

1800 1850 1900

At times, describing the velocity of moving objects can be very important. For example, air traffic controllers must keep close track of the velocities of the aircraft under their control. These velocities continually change as airplanes move overhead and on the runways. An error in determining a velocity, either in speed or in direction, could lead to a collision.

Velocity is also important to airplane pilots. For example, stunt pilots make spectacular use of their control over the velocity of their aircrafts. To avoid colliding with other aircraft, these skilled pilots must have precise control of both their speed and direction. Stunt pilots use this control to stay in close formation while flying graceful maneuvers at high speed.

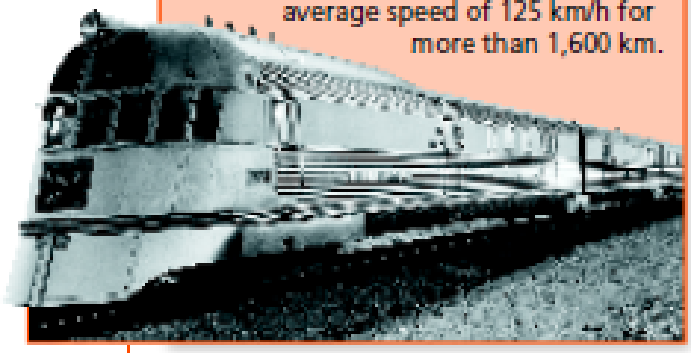
Reading Checkpoint **What is velocity?**

Writing in Science

Research and Write What styles of automobile were most popular during the 1950s, 1960s, and 1970s? Were sedans, convertibles, station wagons, or sports cars the bestsellers? Choose an era and research automobiles of that time. Then write an advertisement for one particular style of car. Be sure to include information from your research.

1934 Zephyr Introduced

The first diesel passenger train in the United States was the *Zephyr*. The *Zephyr* set a long-distance record, traveling from Denver to Chicago at an average speed of 125 km/h for more than 1,600 km.



1956 Interstate Highway System Established

The passage of the Federal-Aid Highway Act established the Highway Trust Fund. This act allowed the construction of the Interstate and Defense Highways. Nonstop transcontinental auto travel became possible. Speed limits in many parts of the system were more than 100 km/h.

2003 Maglev in Motion

The first commercial application of high-speed maglev (magnetic levitation) was unveiled in Shanghai, China. During the 30-km trip from Pudong International Airport to Shanghai's financial district, the train operates at a top speed of 430 km/h, reducing commuting time from 45 minutes to just 8 minutes.

1950 2000 2050

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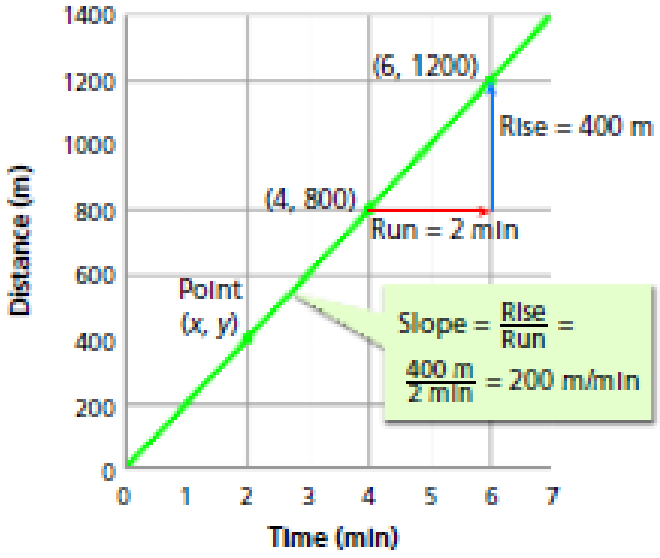
Figure 5
Graphing Motion
Distance-versus-time graphs can be used to analyze motion. On the jogger's first day of training, her speed is the same at every point. On the second day of training, her speed varies. Reading Graphs *On the first day, how far does the jogger run in 5 minutes?*



Graphing Motion

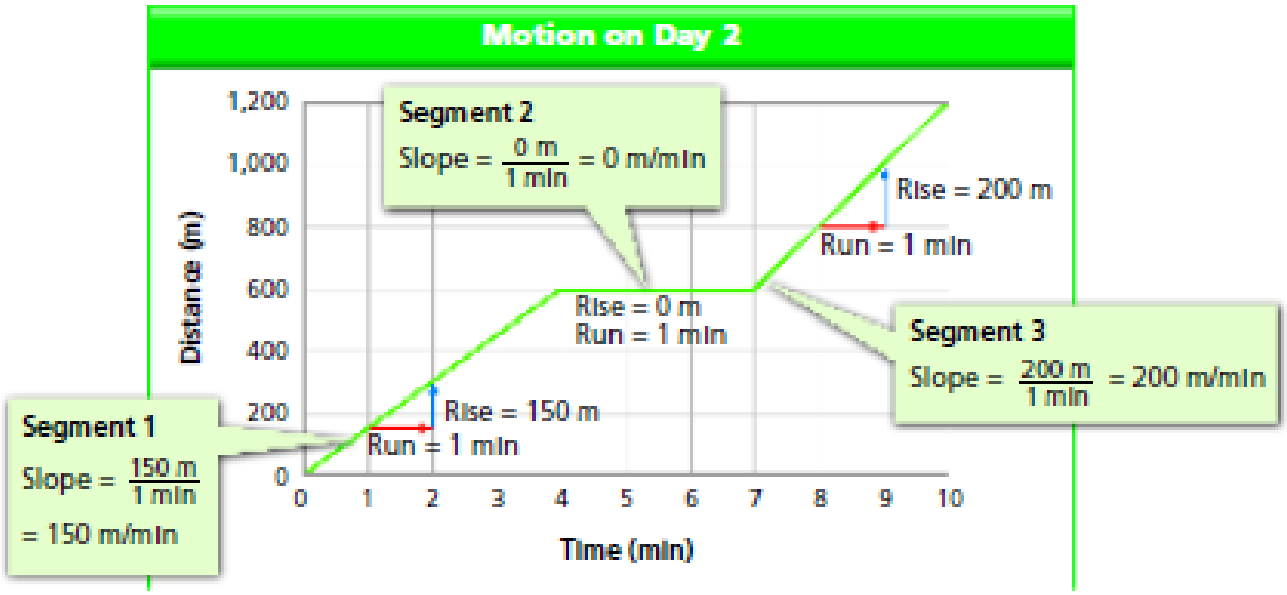
You can show the motion of an object on a line graph in which you plot distance versus time. The graphs you see in Figure 5 are distance-versus-time motion graphs. Time is shown on the horizontal axis, or x-axis. Distance is shown on the vertical axis, or y-axis. A point on the line represents the distance an object has traveled at a particular time. The x value of the point is time, and the y value is distance.

The steepness of a line on a graph is called **slope.** The slope tells you how fast one variable changes in relation to the other variable in the graph. In other words, slope tells you the rate of change. Since speed is the rate that distance changes in relation to time, the slope of a distance-versus-time graph represents speed. The steeper the slope is, the greater the speed. A constant slope represents motion at constant speed.

Calculating Slope You can calculate the slope of a line by dividing the rise by the run. The rise is the vertical difference between any two points on the line. The run is the horizontal difference between the same two points.

$$\text{Slope} = \frac{\text{Rise}}{\text{Run}}$$

In Figure 5, using the points shown, the rise is 400 meters and the run is 2 minutes. To find the slope, you divide 400 meters by 2 minutes. The slope is 200 meters per minute.



Different Slopes Most moving objects do not travel at a constant speed. The graph above shows a jogger's motion on her second day. The line is divided into three segments. The slope of each segment is different. From the steepness of the slopes you can tell that the jogger ran the fastest during the third segment. The horizontal line in the second segment shows that the jogger's distance did not change at all.

Reading Checkpoint **What is the slope of a graph?**

Section 2 Assessment

Target Reading Skill Previewing Visuals Refer to your questions and answers about Figure 5 to help you answer Question 2 below.

Reviewing Key Concepts

1. a. Defining What is speed?
   b. Describing What do you know about the motion of an object that has an average speed of 1 m/s?
   c. Comparing and Contrasting What is the difference between speed and velocity?
2. a. Identifying What does the slope of a distance-versus-time graph show you about the motion of an object?
   b. Calculating The rise of a line on a distance-versus-time graph is 600 m and the run is 3 minutes. What is the slope of the line?

Writing in Science

Explanation Think about a recent trip that you have taken. What was the approximate total distance that you traveled and the total time it took? Calculate your average speed from this information. Then explain how your instantaneous speed varied over the course of the trip.