Chapter 9

Motion and Energy

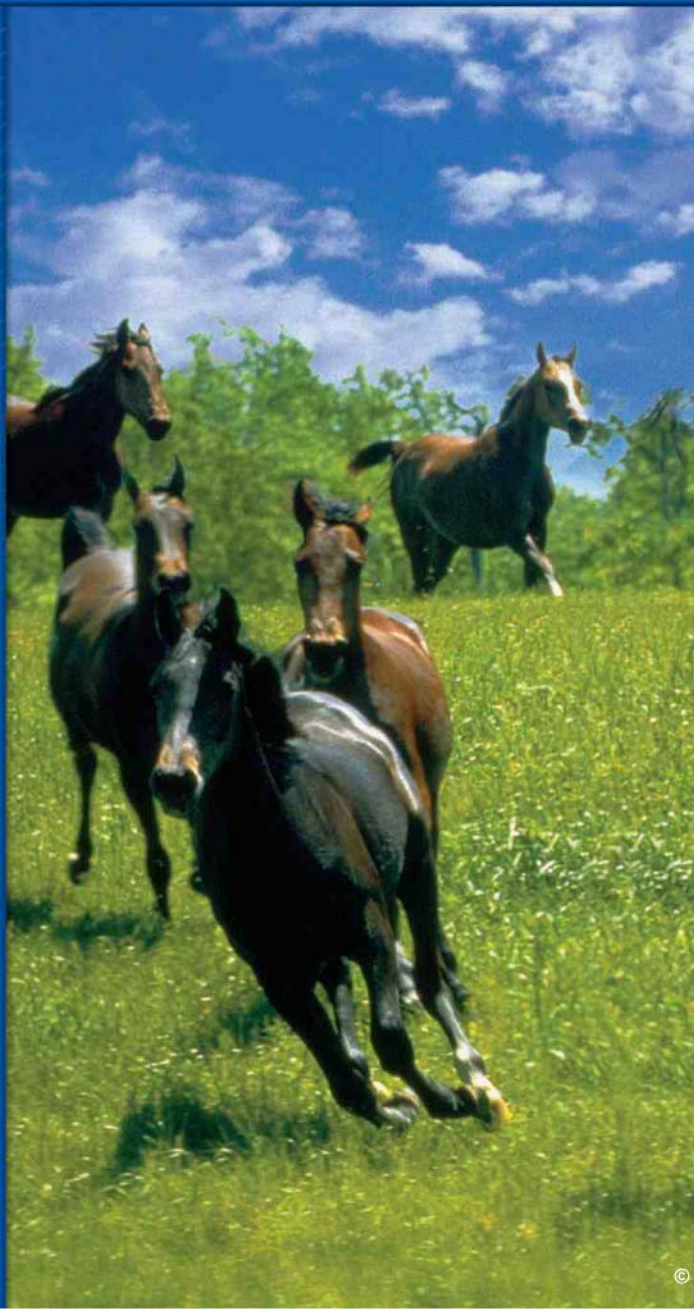
CALIFORNIA Standards Preview

S 8.1 The velocity of an object is the rate of change of its position. As a basis for understanding this concept:

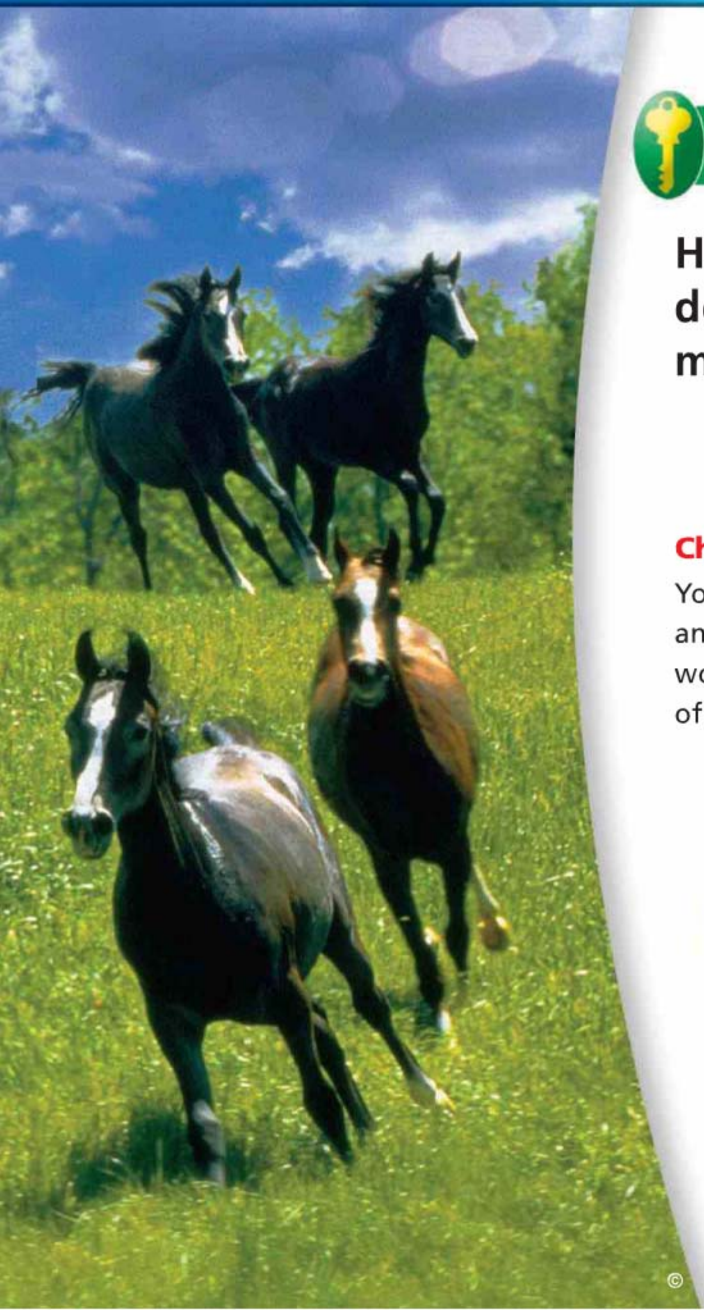
- **a.** Students know position is defined in relation to some choice of a standard reference point and a set of reference directions.
- **b.** Students know that average speed is the total distance traveled divided by the total time elapsed and that the speed of an object along the path traveled can vary.
- **c.** Students know how to solve problems involving distance, time, and average speed.
- **d.** Students know the velocity of an object must be described by specifying both the direction and the speed of the object.
- **e.** Students know changes in velocity may be due to changes in speed, direction, or both.
- **f.** Students know how to interpret graphs of position versus time and graphs of speed versus time for motion in a single direction.

S 8.9 Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- **d.** Recognize the slope of the linear graph as the constant in the relationship $y = kx$ and apply this principle in interpreting graphs constructed from data.
- **g.** Distinguish between linear and nonlinear relationships on a graph of data.



The wild horses running across this meadow are in motion.



Video Preview
Discovery Channel School
Motion

Focus on the
BIG Idea
S 8.1

How can you describe an object's motion?

Check What You Know

You are in a stationary car and another car passes you. How would you describe the motion of the other car?

Build Science Vocabulary

The images shown here represent some of the Key Terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some Key Terms in this chapter.

Vocabulary Skill

High-Use Academic Words

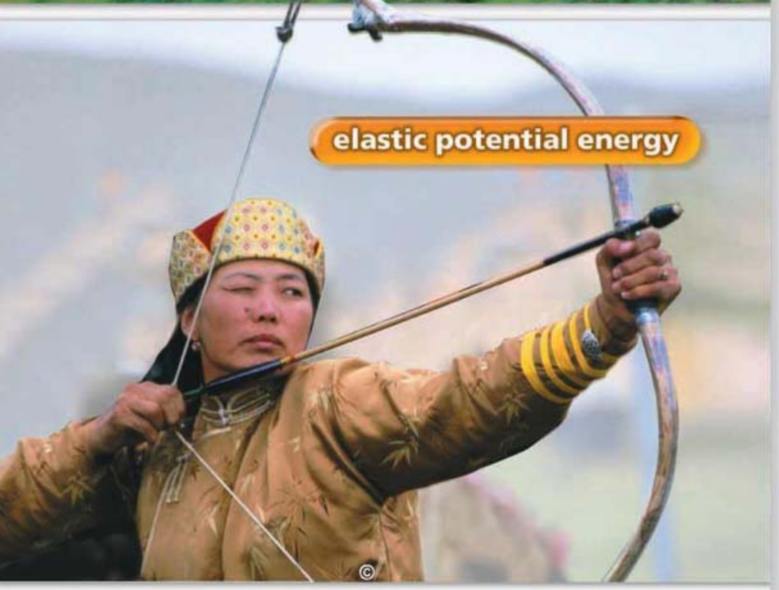
Knowing these academic words will help you become a better reader in all subject areas. Look for these words in context as you read this chapter.

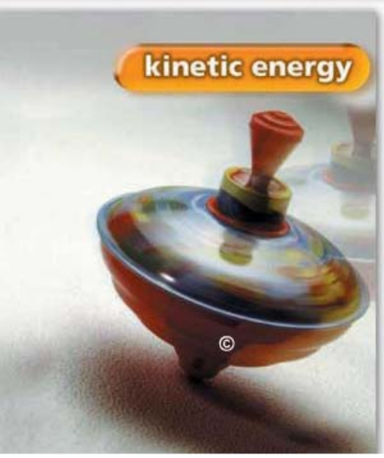
Word	Definition	Example Sentence
conclude (kun **KLOOD**) p. 339	*v.* to decide by reasoning	After investigating the evidence, they concluded that everyone should wear a bicycle helmet.
formula (**FAWR** myoo luh) p. 343	*n.* a series of numbers and symbols that represents a mathematical rule	The formula for the area of a circle is $A = \pi r^2$.
potential (poh **TEN** shul) p. 360	*adj.* the possibility that something will develop in a certain way	The student who is studying chemistry is a potential chemist.

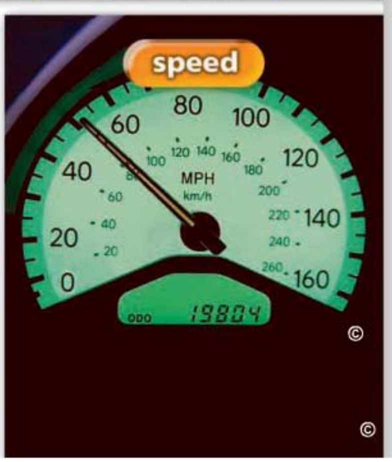
Apply It!

Choose the word from the table that best completes the sentence.

1. The _____ for finding the area of a rectangle is $A = \ell \times w$.
2. After waiting for 20 minutes, he _____ that his friend was not coming.
3. The heavy rains and rising river are a _____ problem for people who live beside the river.







Chapter 9 Vocabulary

Section 1 (page 338)
motion
reference point
distance
displacement
vector

Section 2 (page 342)
speed
average speed
instantaneous speed
velocity
slope

Section 3 (page 350)
acceleration

Section 4 (page 358)
work
energy
kinetic energy
potential energy
gravitational potential energy
elastic potential energy
mechanical energy
law of conservation of energy

Interactive Textbook
Build Science Vocabulary
Online
Visit: PHSchool.com
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How to Read Science

Reading Skill

Identify Main Ideas

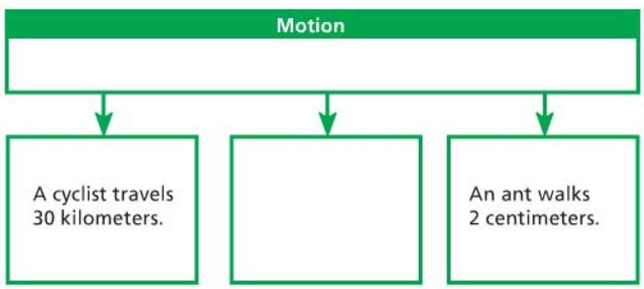
The main idea is the most important point in a passage of text. Sometimes the main idea is stated directly at the beginning or end of a passage. The main idea is supported by details and examples.

Here are some tips to help you identify the main idea.

- Note the details in the passage.
- Look for the connections among the supporting details.
- Then look for a sentence that pulls all the details together.

Read the paragraph below and identify the main idea and supporting details.

A measurement of distance can tell you how far an object travels. A cyclist, for example, might travel 30 kilometers. A sprinter runs 100 meters. An ant might walk 2 centimeters.



Apply It!

Draw a graphic organizer like the one shown. Fill in the main idea and details. Then answer the following questions.

1. What is the main idea in the paragraph?
2. What is a good title for this graphic organizer?

Complete a graphic organizer like the one above for the headings Calculating Speed in Section 2, Changing Velocity in Section 3, and Potential Energy in Section 4.

Lab zone

Standards Investigation

S 8.1.b, 8.1.c

Show Some Motion

You are constantly surrounded by objects in motion. Cars, trains, buses, and airplanes carry people from one place to another. Baseballs, animals, and even the planets in the sky also move. How can you measure the motion you see?

Your Goal

In this investigation, you will identify the motion of several common objects and calculate how fast each one moves.

To complete this investigation, you must

- measure distance and time accurately
- calculate the average speed of each object using your data
- prepare display cards of your data, diagrams, and calculations
- follow the safety guidelines in Appendix A

Plan It!

With your classmates, brainstorm several examples of objects in motion, such as a feather falling, your friend riding a bicycle, or the minute hand moving on a clock. Choose your examples and have your teacher approve them. Create a data table for each example and record your measurements. For accuracy, repeat your measurements. Then calculate the average speed of each object. Make display cards for each example that show data, diagrams, and calculations.

Section 1

Describing Motion

CALIFORNIA Standards Focus

S 8.1.a Students know position is defined in relation to some choice of a standard reference point and a set of reference directions.

- When is an object in motion?
- What is the difference between distance and displacement?

Key Terms

- motion
- reference point
- distance
- displacement
- vector

Lab zone **Standards Warm-Up**

How Fast and How Far?

1. Using a stopwatch, find out how long it takes you to walk 5 meters at a normal pace. Record your time.
2. Now choose a starting point and find out how far you can walk in 5 seconds at a normal pace. Record your distance.
3. Repeat Steps 1 and 2, walking slower than your normal pace. Then repeat Steps 1 and 2 walking faster than your normal pace.

Think It Over

Inferring What is the relationship between the distance you walk, the time it takes you to walk, and your walking speed?

How do you know if you are moving? If you've ever traveled on a train, you know you cannot always tell if you are in motion. Looking at a building outside the window helps you decide. Although the building seems to move past the train, it's you and the train that are moving.

However, sometimes you may see another train that appears to be moving. Is the other train really moving, or is your train moving? How do you tell?

Motion

How do you decide if an object is moving? You are probably sitting in a chair as you read this book. Are you moving? Your eyes blink and your chest moves up and down. But you would probably say that you are not moving. An object is in **motion** if its distance from another object is changing. Because your distance from your chair is not changing, you conclude you are not in motion.

Reference Points To decide if you are moving, you use your chair as a reference point. A **reference point** is a place or object used for comparison to determine if something is in motion. **An object is in motion if it changes position relative to a reference point.**

Objects that we call stationary—such as a tree, a flagpole, or a building—make good reference points. From the point of view of the train passenger in Figure 1, such objects are not in motion. If the passenger is moving relative to a tree, he can conclude that the train is in motion.

Once you have selected your reference point, you can indicate a change in position by using a plus (+) or minus (−) sign. The signs stand for any pair of opposing directions from the reference point, such as to the right and left, up and down, away from and toward, or in front of and behind. If you make the passenger on the train your reference point, then three seats in front of him could be shown as +3. A distance of −5 would mean 5 seats behind him.

Reading Checkpoint What is a reference point?

FIGURE 1
Reference Points
The passenger can use a tree as a reference point to decide if the train is moving. A tree makes a good reference point because it is stationary from the passenger's point of view.
Applying Concepts *Why is it important to choose a stationary object as a reference point?*

FIGURE 2
Relative Motion Whether or not an object is in motion depends on the reference point.
Comparing and Contrasting *Are the skydivers moving relative to the airplane from which they jumped? Are they moving relative to the ground?*

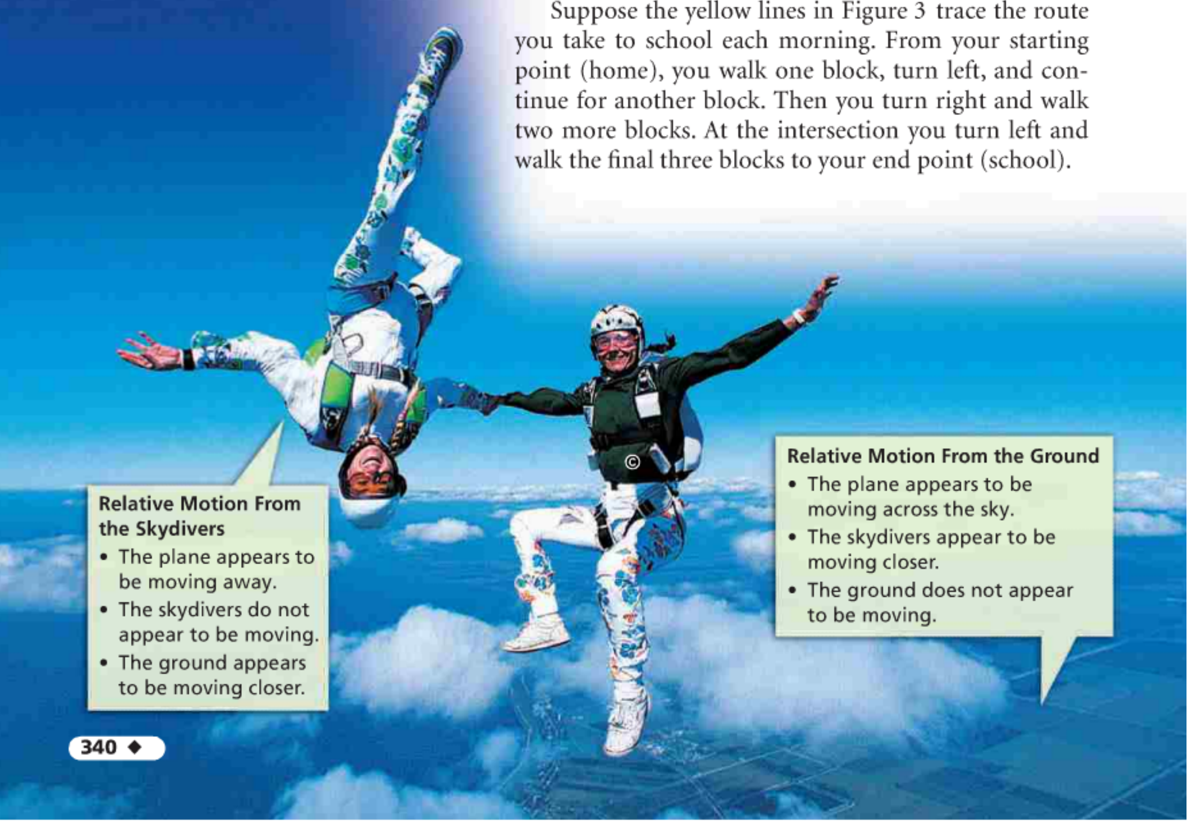
Relative Motion Are you moving as you read this book? The answer depends on your reference point. When your chair is your reference point, you are not moving. But if you choose another reference point, you may be moving.

Suppose you choose the sun as a reference point instead of your chair. If you compare yourself to the sun, you are moving quite rapidly. This is because you and your chair are on Earth, which moves around the sun. Earth moves about 30 kilometers every second. So you, your chair, this book, and everything else on Earth move that quickly as well. Going that fast, you could travel from New York City to Los Angeles in about 2 minutes! Relative to the sun, both you and your chair are in motion. But because you are moving with Earth, you do not seem to be moving.

Distance and Displacement

When you move, the distance between you and a reference point changes. **Distance** is the length of a path between two points.

Suppose the yellow lines in Figure 3 trace the route you take to school each morning. From your starting point (home), you walk one block, turn left, and continue for another block. Then you turn right and walk two more blocks. At the intersection you turn left and walk the final three blocks to your end point (school).



How many blocks did you walk in all? The lengths of the segments of your walk are 1 block, 1 block, 2 blocks, and 3 blocks. Therefore, your walk from home to school is a total distance of 7 blocks.

Now look at the red arrow in Figure 3. It shows the displacement from the starting point. **Displacement** is the length and direction that an object has moved from its starting point.

Distance is the total length of the actual path between two points. Displacement is the length and direction of a straight line between starting and ending points. According to Figure 3, you walked a *distance* (yellow lines) of 7 blocks, but your *displacement* (red arrow) was 5 blocks northeast.

As you learn about motion, you will find other measurements that also have a magnitude, or size, and a direction. A quantity that consists of both a magnitude and a direction is called a **vector.** Displacement is a vector, but distance is not. Other examples of vectors include velocity, acceleration, and force. You will learn about these vectors later in this book.

Vectors are shown graphically by using an arrow. The length of the arrow represents the vector's magnitude. The direction of the arrow indicates the direction of the vector.

FIGURE 3
Distance and Displacement
The yellow lines show the distance between home and school along a particular path. The red arrow shows the displacement between the same two points.

Reading Checkpoint What is displacement?

Section 1 Assessment

S 8.1.a, E-LA: Reading 8.1.0

Vocabulary Skill High-Use Academic Words
Describe a situation in which you have used a reference point to determine your relative motion. Use the word *conclude* in your explanation.

Reviewing Key Concepts

HINT **1. a. Reviewing** How do you know if an object is moving?

HINT **b. Explaining** Why is it important to know if your reference point is moving?

HINT **c. Applying Concepts** Suppose you are riding in a car. Describe your motion relative to the car, the road, and the sun.

HINT **2. a. Defining** What is displacement?

HINT **b. Comparing and Contrasting** How are distance and displacement similar? How are they different?

c. Applying Concepts An object moves 3 cm to the right, then 6 cm to the left, then 8 cm to the right. What is the object's final displacement from its origin? HINT

Lab zone At-Home Activity

Walkabout Place a penny or other marker on the floor or ground to show your starting point. Then walk a few steps in one direction and a few more in another. Use a ruler to estimate the distance that you walked and your displacement from the starting point. How do these values compare?

Section 2

Speed and Velocity

CALIFORNIA Standards Focus

S 8.1.b Students know that average speed is the total distance traveled divided by the total time elapsed and that the speed of an object along the path traveled can vary.

S 8.1.c Students know how to solve problems involving distance, time, and average speed.

S 8.1.d Students know the velocity of an object must be described by specifying both the direction and the speed of the object.

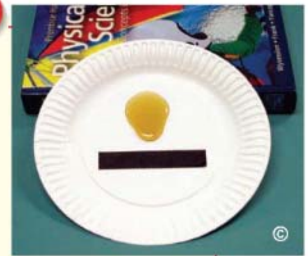
- How do you calculate speed?
- How can you describe changes in velocity?
- How can you interpret graphs of distance versus time?

Key Terms

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

Lab zone Standards Warm-Up

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. Predict how far the honey would move in twice the time.

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** (v), divide the total distance traveled (d) by the total time (t).

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.

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

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

$$\text{Average speed } (v) = \frac{d}{t} = \frac{45\text{ km}}{3\text{h}} = 15\text{ km/h}$$

The cyclist's average speed is 15 kilometers per hour. You can write the formula for speed $v = d/t$ as $d = vt$ or $t = d/v$. So, if you know any two of these quantities, you can calculate the third.

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 their speed over the course of their travel. A cyclometer can calculate both average and instantaneous speed.
Comparing and Contrasting *Explain why the instantaneous speed and the average speed shown below are different.*

Video Field Trip
Discovery Channel School
Motion

Velocity

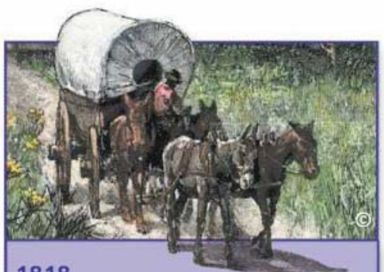
Suppose you hear that a thunderstorm is traveling at a speed of 25 km/h. Should you prepare for the storm? That depends on the direction of the storm's motion.

Velocity (v) is speed in a given direction. Like displacement, velocity is a vector. It has both a magnitude (speed) and a direction. For example, the velocity of a storm can be described as moving 25 km/h to the east. As with all vectors, the magnitude and direction of velocity are shown by the length and the direction of an arrow. Like speed, velocity may change over time. **Changes in velocity may be due to changes in speed, changes in direction, or both.** Thus, if the storm continued to move at the same speed but changed direction, this would be a change in its velocity.

• 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.



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.

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.

1800 1850 1900

In some situations, 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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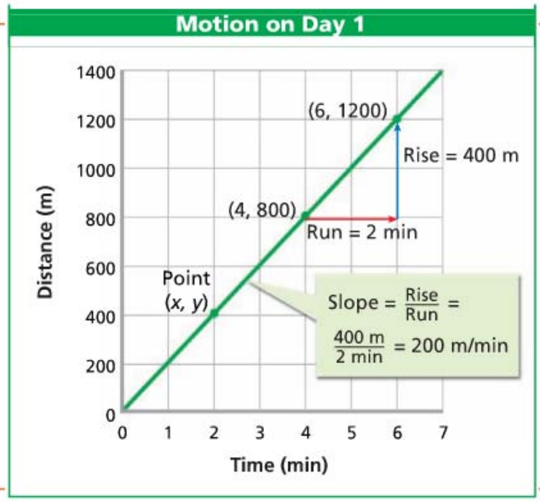
FIGURE 5
Graphing Motion
You can use distance-versus-time graphs to interpret motion. On the jogger's first day of training, her speed is the same at every point. On the second day of training, her speed varies. **Reading Graphs** *On the first day, how far does the jogger run in 5 minutes?*



Graphing Speed

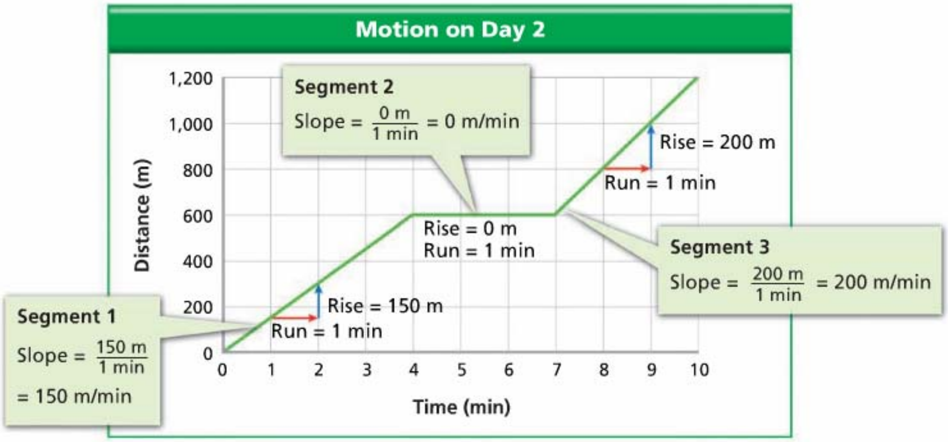
You can show the motion of an object on a line graph in which you plot distance versus time. The graphs you see in Figure 5 are distance-versus-time graphs. Time is shown on the horizontal axis, or x-axis. Distance, or position, is shown on the vertical axis, or y-axis. A point on the line represents the distance an object has traveled from the origin or a reference point 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. **The slope of a distance-versus-time graph represents speed, that is, the rate that distance changes in relation to time.** 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.

Section 2 Assessment

S 8.1.b, 8.1.c, 8.1.d, E-LA: Reading 8.2.4, Writing 8.2.0

Target Reading Skill **Identify Main Ideas** Reread the first two paragraphs under *Calculating Speed* on page 342. Draw a graphic organizer showing the main idea and supporting details. The boldfaced sentence is the main idea.

Reviewing Key Concepts

1. a. Defining What is speed? HINT
b. Calculating What is the average speed of a car that travels 160 km in 2 hours? HINT
c. Calculating If you walked at an average speed of 1.2 m/s, how long would it take to cross a road that is 16-m wide? HINT

2. a. Defining What is velocity? HINT
b. Describing Describe the two ways in which velocity can change. HINT
c. Applying Concepts Your car's speedometer reads a constant 35 mi/hr. Can you say your velocity is constant? Explain. HINT

3. a. Identifying What does the slope of a distance-versus-time graph show you about the motion of an object? HINT
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? HINT

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.

Lab zone **Skills Lab**

Inclined to Roll

S 8.1.b, S 8.9.e

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Problem

How does the steepness of a ramp affect how fast an object rolling off it moves across the floor?

Skills Focus

measuring, calculating, graphing

Materials

- skateboard
- meter stick
- protractor
- masking tape
- flat board, about 1.5 m long
- small piece of sturdy cardboard
- supports to prop up the board (books, boxes)
- two stopwatches

Procedure

1. In your notebook, make a data table like the one below. Include space for five angles.
2. Lay the board flat on the floor. Using masking tape, mark a starting line in the middle of the board. Mark a finish line on the floor 1.5 m beyond one end of the board. Place a barrier after the finish line.
3. Prop up the other end of the board to make a slight incline. Use a protractor to measure the angle that the board makes with the ground. Record the angle in your data table.
4. Working in groups of three, have one person hold the skateboard so that its front wheels are even with the starting line. As the holder releases the skateboard, the other two students should start their stopwatches.
5. One timer should stop his or her stopwatch when the front wheels of the skateboard reach the end of the incline.
6. The second timer should stop his or her stopwatch when the front wheels reach the finish line. Record the times in your data table in the columns labeled Time 1 and Time 2.
7. Repeat Steps 4–6 two more times. If your results for the three times aren't within 0.2 second of one another, carry out more trials.

Data Table

Angle (degrees)	Trial Number	Time 1 (to bottom) (s)	Time 2 (to finish) (s)	Avg Time 1 (s)	Avg Time 2 (s)	Avg Time 2 – Avg Time 1 (s)	Avg Speed (m/s)
	1						
	2						
	3						
	1						
	2						
	3						
	1						
	2						

8. Repeat Steps 3–7 four more times, making the ramp gradually steeper each time.
9. For each angle of the incline, complete the following calculations and record them in your data table.
   a. Find the average time the skateboard takes to get to the bottom of the ramp (Time 1).
   b. Find the average time the skateboard takes to get to the finish line (Time 2).
   c. Subtract the average of Time 1 from the average of Time 2.

Analyze and Conclude

1. **Calculating** How can you find the average speed of the skateboard across the floor for each angle of the incline? Determine the average speed for each angle and record it in your data table.
2. **Classifying** Which is your manipulated variable and which is your responding variable in this experiment? Explain. (For a discussion of manipulated and responding variables, see the Skills Handbook.)
3. **Graphing** On a graph, plot the average speed of the skateboard (on the *y*-axis) against the angle of the ramp (on the *x*-axis).
4. **Drawing Conclusions** What does your graph show about the relationship between the skateboard's speed and the angle of the ramp?
5. **Measuring** If your measurements for distance, time, or angle were inaccurate, how would your results have been affected?
6. **Communicating** Do you think your method of timing was accurate? Did the timers start and stop their stopwatches exactly at the appropriate points? How could the accuracy of the timing be improved? Write a brief procedure for your method.

Design an Experiment

A truck driver transporting new cars needs to roll the cars off the truck. You offer to design a ramp to help with the task. What measurements would you make that might be useful? Design an experiment to test your ideas. Obtain your teacher's permission before carrying out your investigation.

Section 3

Integrating Mathematics

Acceleration

CALIFORNIA Standards Focus

S 8.1.e Students know changes in velocity may be due to changes in speed, direction, or both.

S 8.1.f Students know how to interpret graphs of position versus time and graphs of speed versus time for motion in a single direction.

- What kind of motion does acceleration refer to?
- How do you calculate acceleration?
- What graphs can be used to analyze the motion of an accelerating object?

Key Term

- acceleration

Lab zone **Standards Warm-Up**

Will You Hurry Up?

1. Measure 10 meters in an open area. Mark the distance with masking tape.
2. Walk the 10 meters in such a way that you keep moving faster throughout the entire distance. Have a partner time you.
3. Repeat Step 2, walking the 10 meters in less time than you did before. Then try it again, this time walking the distance in twice the time as the first. Remember to keep speeding up throughout the entire 10 meters.

Think It Over

Inferring How is the change in your speed related to the time in which you walk the 10-meter course?

The pitcher throws. The ball speeds toward the batter. Off the bat it goes. It's going, going, gone! A home run!

Before landing, the ball went through several changes in motion. It sped up in the pitcher's hand, and lost speed as it traveled toward the batter. The ball stopped when it hit the bat, changed direction, sped up again, and eventually slowed down. Most examples of motion involve similar changes.

Changing Velocity

Suppose you are a passenger in a car stopped at a red light. When the light changes to green, the driver steps on the accelerator. As a result, the car speeds up, or accelerates. In everyday language, *acceleration* means "the process of speeding up."

Acceleration has a more specific definition in science. Scientists define **acceleration** as the rate at which velocity changes with time. Recall that velocity describes both the speed and direction of an object. A change in velocity can involve a change in either speed or direction—or both. **In science, acceleration refers to increasing speed, decreasing speed, or changing direction.** Like displacement and velocity, acceleration is a vector with a magnitude and a direction.

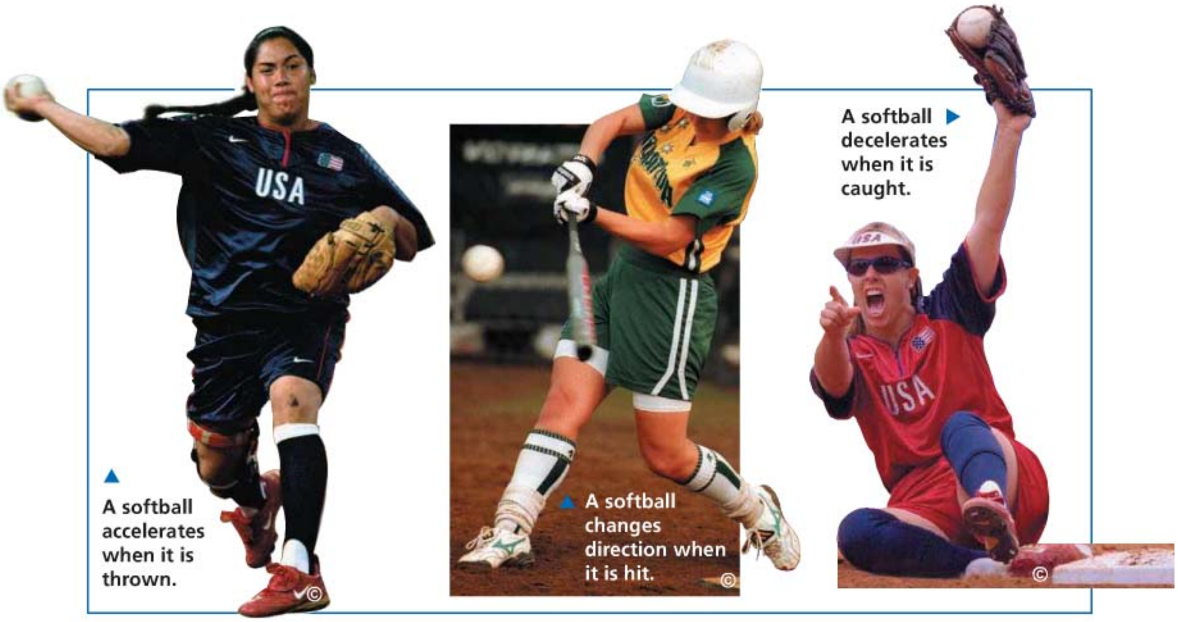

FIGURE 6
Acceleration
A softball accelerates when it is thrown, caught, or hit.
Classifying *What change in motion occurs in each example?*

Increasing Speed Whenever an object's speed increases, the object accelerates. A softball accelerates when the pitcher throws it, and again when a bat hits it. A car that begins to move from a stopped position or speeds up to pass another car is accelerating. People can accelerate too. For example, you accelerate when you coast down a hill on your bike.

Decreasing Speed Just as objects can speed up, they can also slow down. This change in speed is sometimes called deceleration, or negative acceleration. For example, a softball decelerates when it lands in a fielder's mitt. A car decelerates when it stops at a red light.

Changing Direction Even an object that is traveling at a constant speed can be accelerating. Recall that acceleration can be a change in direction. Therefore, a car accelerates as it follows a curve in the road, even if its speed remains constant. Runners accelerate as they round the curve in a track. A softball accelerates when it changes direction as it is hit. Thus acceleration may be due to changes in speed, direction, or both.

Many objects continuously change direction without changing speed. The simplest example of this type of motion is circular motion, or motion along a circular path. For example, the seats on a Ferris wheel accelerate because they move in a circle.

Reading Checkpoint **How can a car be accelerating if its speed is constant at 65 km/h?**

FIGURE 7
Analyzing Acceleration
The velocity of the airplane above increases by the same amount each second. **Interpreting Diagrams** *How does the distance traveled change in each second?*

Calculating Acceleration

Acceleration describes the rate at which velocity changes. Like velocity, acceleration is a vector. It has both a magnitude and a direction. If an object is not changing direction, you can describe its acceleration as the rate at which its speed changes.

To determine the acceleration of an object, you must calculate its change in velocity per unit of time. This is summarized by the following formula.

$$\text{Acceleration} = \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time}}$$

If velocity is measured in meters per second (m/s) and time is measured in seconds, the SI unit of acceleration is meters per second per second, or m/s^2. Suppose velocity is measured in kilometers per hour and time is measured in hours. Then the unit for acceleration is kilometers per hour per hour, or km/h^2.

To understand acceleration, imagine a small airplane moving down a runway in a straight line. Figure 7 shows the airplane's motion after each of the first five seconds of its acceleration. To calculate the acceleration of the airplane, you must first subtract the initial velocity of 0 m/s from the final velocity of 40 m/s. Then divide the change in velocity by the time, 5 seconds.

$$\text{Acceleration} = \frac{40 \text{ m/s} - 0 \text{ m/s}}{5 \text{ s}}$$

$$\text{Acceleration} = 8 \text{ m/s}^2$$

The airplane accelerates to the right at a rate of 8 m/s^2. This means that the airplane's velocity increases by 8 m/s every second. Notice in Figure 7 that, after each second of travel, the airplane's velocity is 8 m/s greater than it was the previous second.

Reading Checkpoint **What must you know about an object to calculate its acceleration?**

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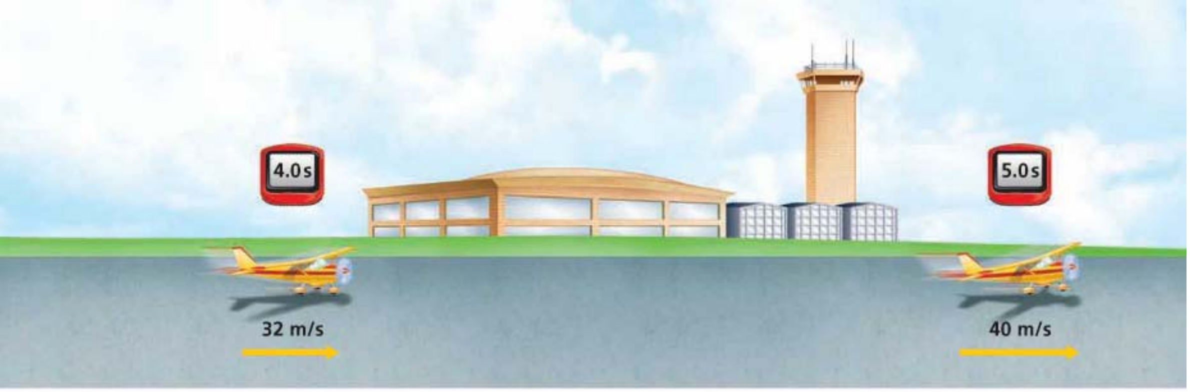

Math: Algebra I, 15.0

Math Sample Problem

Calculating Acceleration

As a roller coaster car starts down a slope, its velocity is 4 m/s. But 3 seconds later, its velocity is 22 m/s in the same direction. What is its acceleration?

1 Read and Understand

What information are you given?

Initial velocity = 4 m/s

Final velocity = 22 m/s

Time = 3 s

2 Plan and Solve

What quantity are you trying to calculate?

The acceleration of the roller coaster car = ■

What formula contains the given quantities and the unknown quantity?

$$\text{Acceleration} = \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time}}$$

Perform the calculation.

$$\text{Acceleration} = \frac{22\ \text{m/s} - 4\ \text{m/s}}{3\ \text{s}}$$

$$\text{Acceleration} = \frac{18\ \text{m/s}}{3\ \text{s}}$$

$$\text{Acceleration} = 6\ \text{m/s}^2$$

The acceleration is 6 m/s^2 down the slope.

3 Look Back and Check

Does your answer make sense?

The answer is reasonable. If the car's velocity increases by 6 m/s each second, its velocity will be 10 m/s after 1 second, 16 m/s after 2 seconds, and 22 m/s after 3 seconds.

Math Practice

1. **Calculating Acceleration** A falling raindrop accelerates from 10 m/s to 30 m/s in 2 seconds. What is the raindrop's acceleration?
2. **Calculating Acceleration** A certain car can accelerate from rest to 27 m/s in 9 seconds. Find the car's acceleration.

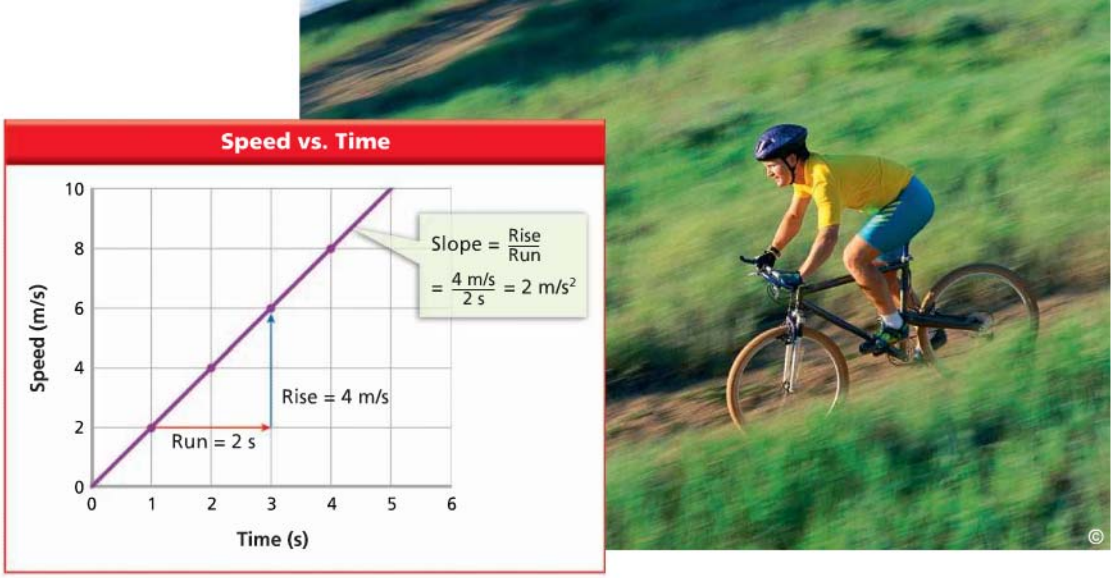

FIGURE 8
Speed-Versus-Time Graph
The slanted, straight line on this speed-versus-time graph tells you that the cyclist is accelerating at a constant rate. The slope of a speed-versus-time graph tells you the object's acceleration.
Predicting *How would the slope of the graph change if the cyclist were accelerating at a greater rate? At a lesser rate?*

Graphing Acceleration

Suppose you ride your bicycle down a long, steep hill. At the top of the hill your speed is 0 m/s. As you start down the hill, your speed increases. Each second, you move at a greater speed and travel a greater distance than the second before. During the five seconds it takes you to reach the bottom of the hill, you are an accelerating object. **You can use both a speed-versus-time graph and a distance-versus-time graph to analyze the motion of an accelerating object.**

Speed-Versus-Time Graph Figure 8 shows a speed-versus-time graph for your bicycle ride down the hill. What can you learn by analyzing this graph? Since the line slants upward, the graph shows that your speed was increasing. Next, since the line is straight, you can tell that your acceleration was constant. A slanted, straight line on a speed-versus-time graph means that the object is accelerating at a constant rate. This is an example of a linear graph. In a linear graph, the displayed data form a straight line. A horizontal line on a speed-versus-time graph means that the object is moving at a constant speed. The slope of a line on a speed-versus-time graph represents acceleration. To calculate the slope, choose any two points on the line. Then, divide the rise by the run.

$$\text{Slope} = \frac{\text{Rise}}{\text{Run}} = \frac{8\text{ m/s} - 4\text{ m/s}}{4\text{ s} - 2\text{ s}} = \frac{4\text{ m/s}}{2\text{ s}} = 2\text{ m/s}^2$$

You accelerated down the hill at a constant rate of 2 m/s^2.

Distance-Versus-Time Graph You can also show the motion of an accelerating object with a distance-versus-time graph. Figure 9 shows a distance-versus-time graph for your bike ride. On this type of graph, a curved line means that the object is accelerating. The graph shown in Figure 9 is nonlinear. In a nonlinear graph, the data form a curved line when plotted.

The curved line in Figure 9 tells you that during each second, you traveled a greater distance than the second before. For example, you traveled a greater distance during the third second than you did during the first second.

The curved line in Figure 9 also tells you that during each second your speed is greater than the second before. Recall that the slope of a distance-versus-time graph is the speed of an object. From second to second, the slope of the line in Figure 9 gets steeper and steeper. Since the slope is increasing, you can conclude that the speed is also increasing. You are accelerating.

Reading Checkpoint **What does a curved line on a distance-versus-time graph tell you?**

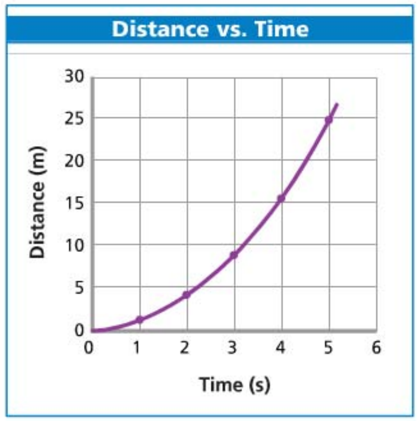

FIGURE 9
Distance-Versus-Time Graph
The curved line on this distance-versus-time graph tells you that the cyclist is accelerating.

Section 3 Assessment

S 8.1.e, 8.1.f, E-LA: Reading 8.2.4, Math: Algebra I, 8.15.0

Target Reading Skill **Identify Main Ideas** Reread the text under *Changing Velocity* on pages 350–351. Draw a graphic organizer for this topic. Use the boldfaced sentence as the main idea.

Reviewing Key Concepts

HINT **1. a. Describing** What are the three ways that an object can accelerate?

HINT **b. Summarizing** Describe how a baseball player accelerates as he runs around the bases after hitting a home run.

HINT **c. Applying Concepts** An ice skater glides around a rink at a constant speed of 2 m/s. Is the skater accelerating? Explain your answer.

HINT **2. a. Identifying** What formula do you use to calculate the acceleration of an object moving in a straight line?

HINT **b. Calculating** The velocity of a cyclist moving in a straight line changes from 0 m/s to 15 m/s in 10 seconds. What is the cyclist's acceleration?

3. a. Naming What types of graphs can you use to analyze the acceleration of an object? HINT

b. Describing Describe the motion of an object if its speed-versus-time graph is a horizontal line. HINT

c. Predicting What would a distance-versus-time graph look like for the moving object in part (b)? HINT

Math Practice

4. Calculating Acceleration A downhill skier reaches the steepest part of a trail. Her velocity increases from 9 m/s to 18 m/s in 3 seconds. What is her acceleration?

5. Calculating Acceleration What is a race car's acceleration if its velocity changes from 0 m/s to 40 m/s in 4 seconds?

Lab zone **Skills Lab**

Stopping on a Dime

S 8.1.c, S 8.9.f

Problem

The school will put in a new basketball court in a small area between two buildings. Safety is an important consideration in the design of the court. What is the distance needed between an out-of-bounds line and a wall so that a player can stop before hitting the wall?

Skills Focus

calculating, interpreting data

Materials

- wooden meter stick
- tape measure
- 2 stopwatches or watches with second hands

Procedure

PART 1 Reaction Time

1. Have your partner suspend a wooden meter stick, zero end down, between your thumb and index finger, as shown. Your thumb and index finger should be about 3 cm apart.

Reaction Time

Distance (cm)	Time (s)	Distance (cm)	Time (s)
15	0.175	25	0.226
16	0.181	26	0.230
17	0.186	27	0.235
18	0.192	28	0.239
19	0.197	29	0.243
20	0.202	30	0.247
21	0.207	31	0.252
22	0.212	32	0.256
23	0.217	33	0.260
24	0.221	34	0.263

2. Your partner will drop the meter stick without giving you any warning. Try to grab it with your thumb and index finger.
3. Note the level at which you grabbed the meter stick and use the chart shown to determine your reaction time. Record the time in the class data table.
4. Reverse roles with your partner and repeat Steps 1–3.

PART 2 Stopping Distance

5. On the school field or in the gymnasium, mark off a distance of 25 m. **CAUTION:** *Be sure to remove any obstacles from the course.*
6. Have your partner time how long it takes you to run the course at full speed. After you pass the 25-m mark, come to a stop as quickly as possible and remain standing. You must not slow down before the mark.
7. Have your partner measure the distance from the 25-m mark to your final position. This is the distance you need to come to a complete stop. Enter your time and distance into the class data table.
8. Reverse roles with your partner. Enter your partner's time and distance into the class data table.

Class Data Table			
Student Name	Reaction Time (s)	Running Time (s)	Stopping Distance (m)

Analyze and Conclude

1. **Calculating** Calculate the average speed of the student who ran the 25-m course the fastest.
2. **Interpreting Data** Multiply the speed of the fastest student (calculated in Question 1) by the slowest reaction time listed in the class data table. Why would you be interested in this product?
3. **Interpreting Data** Add the distance calculated in Question 2 to the longest stopping distance in the class data table. What does this total distance represent?
4. **Drawing Conclusions** Explain why it is important to use the fastest speed, the slowest reaction time, and the longest stopping distance in your calculations.
5. **Controlling Variables** What other factors should you take into account to get results that apply to a real basketball court?
6. **Communicating** Suppose you calculate that the distance from the out-of-bounds line to the wall of the basketball court is too short for safety. Write a proposal to the school that describes the problem. In your proposal, suggest a strategy for making the court safer.

More to Explore

Visit a local playground and examine it from the viewpoint of safety. Use what you learned about stopping distance as one of your guidelines, but also try to identify other potentially unsafe conditions. Write a letter to the Department of Parks or to the officials of your town informing them of your findings.

Section 4

Energy

CALIFORNIA Standards Focus

S 8 Framework Students should begin to grasp four concepts that help to unify physical sciences: force and energy; the laws of conservation; . . .

- What factors affect an object's kinetic energy and potential energy?
- How can kinetic energy and potential energy be transformed?
- What is the law of conservation of energy?

Key Terms

- work
- energy
- kinetic energy
- potential energy
- gravitational potential energy
- elastic potential energy
- mechanical energy
- law of conservation of energy

Lab zone Standards Warm-Up

How High Does a Ball Bounce?

1. Hold a meter stick vertically, with the zero end on the ground.
2. Drop a tennis ball from 50 cm. Record the height to which it bounces.
3. Drop the tennis ball from the 100-cm mark and record the height to which it bounces.
4. Predict how high the ball will bounce if dropped from the 75-cm mark. Test your prediction.

Think It Over

Observing How does the height from which you drop the ball relate to the height to which the ball bounces?

When a breeze blows a leaf through the air, it causes a change. In this case, the change is in the position of the leaf. A scientist would describe the wind as doing work on the leaf. **Work** is done when an object is caused to move a certain distance. The ability to do work or cause change is called **energy.** So, the wind has energy.

When an object or living thing does work on another object, some of its energy is transferred to that second object. You can think of work, then, as the transfer of energy. When energy is transferred, the object upon which work is done gains energy. The SI unit for both work and energy is the joule.

When a breeze does work lifting leaves, it transfers energy to them. ▶

Kinetic Energy

A moving object, such as the wind, can do work when it strikes another object and moves it some distance. Because the moving object does work, it has energy. The energy an object has due to its motion is called **kinetic energy**. The word *kinetic* comes from the Greek word *kinetos*, which means "moving."

The kinetic energy of an object depends on both its mass and its speed. Kinetic energy increases as mass increases. For example, the left lane in Figure 10 shows a bowling ball and a golf ball rolling down a bowling lane at the same speed. The bowling ball has more mass, so you must use more energy to roll it. The bowling ball is more likely to knock down the pins because it has more kinetic energy than the golf ball.

Kinetic energy also increases when speed increases. For example, suppose you have two identical bowling balls and you roll one ball so it moves at a greater speed than the other. You must throw the ball harder to give it the greater speed. In other words, you transfer more energy to it. Therefore, the faster ball has more kinetic energy. There is a mathematical relationship between kinetic energy, mass, and speed.

$$\text{Kinetic energy} = \frac{1}{2} \times \text{Mass} \times \text{Speed}^2$$

Note that changing the speed of an object will have a greater effect on its kinetic energy than changing its mass by the same factor. This is because speed is squared in the kinetic energy equation. For instance, doubling the mass of an object will double its kinetic energy. But doubling its speed will quadruple its kinetic energy.

Reading Checkpoint What is kinetic energy?

Math Skills

Exponents

An exponent tells how many times a number is used as a factor. For example, 3×3 can be written as 3^2. You read this number as "three squared." In the formula for kinetic energy, speed is squared. For example, you can calculate the kinetic energy of a 70-kg person moving at a speed of 2 m/s using the formula below.

$$\begin{aligned} KE &= \frac{1}{2} \times \text{Mass} \times \text{Speed}^2 \\ &= \frac{1}{2} \times 70 \text{ kg} \times (2 \text{ m/s})^2 \\ &= 140 \text{ kg} \cdot \text{m}^2/\text{s}^2 \\ &\text{or } 140 \text{ joules} \end{aligned}$$

Note: $1 \text{ kg} \cdot \text{m}^2/\text{s}^2 = 1$ joule

Practice Problem What is the kinetic energy of a 30-kg rock moving at a speed of 10 m/s?

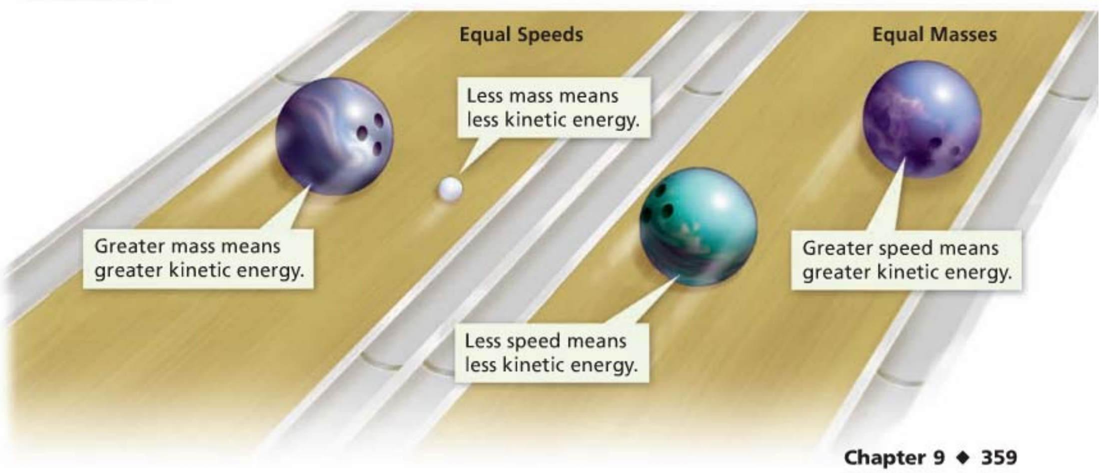

FIGURE 10
Kinetic Energy
Kinetic energy increases as mass and speed increase.
Predicting *In each example, which object will transfer more energy to the pins? Why?*

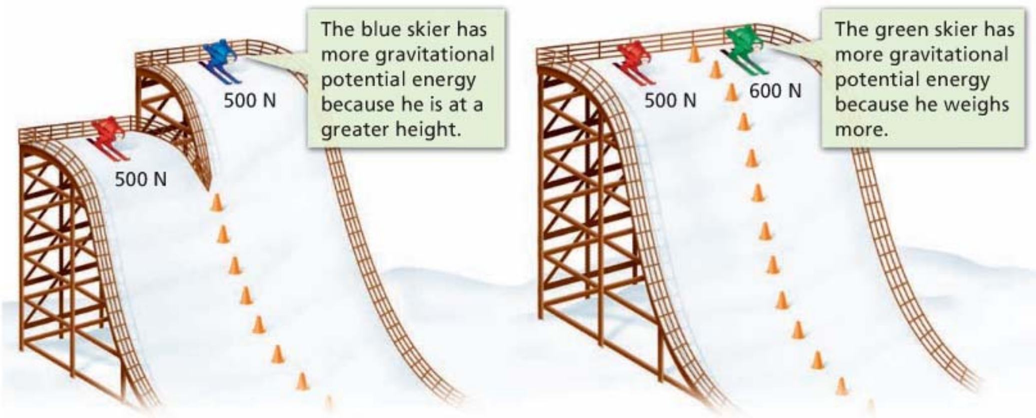

FIGURE 11
Gravitational Potential Energy
Gravitational potential energy increases as weight and height increase. **Interpreting Diagrams** *Does the red skier have more gravitational potential energy on the higher ski jump or the lower one? Why?*

Potential Energy

Some objects have stored energy as a result of their positions or shapes. When you lift a book up from the floor or compress a spring, you transfer energy to it. The energy is stored. It might be used later when the book falls to the floor or the spring is released. Stored energy that results from the position or shape of an object is called **potential energy**. This type of energy has the potential to do work.

Gravitational Potential Energy Potential energy related to an object's height is called **gravitational potential energy**. **An object's gravitational potential energy depends on its weight and on its height relative to a reference point.**

Gravitational potential energy = Weight × Height

For example, the red skier on the left in Figure 11 weighs 500 newtons. If the ski jump is 40 meters high, the skier has 500 newtons × 40 meters, or 20,000 J, of gravitational potential energy. A 500-newton skier has more gravitational potential energy on a high ski jump than on a low one. The more an object weighs, or the greater its height, the greater its gravitational potential energy. At the same height, a 600-newton skier has more gravitational potential energy than a 500-newton skier.

Elastic Potential Energy An object gains a different type of potential energy when it is stretched or squeezed. The potential energy of objects that can be stretched or compressed is called **elastic potential energy**. For example, an archer pulling back on an arrow changes the shape of the bow. The bow now has potential energy that can be used to send the arrow flying to its target.

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Energy Transformation and Conservation

Look at Figure 12. The quarterback transfers energy to the football as he throws it to the receiver. As the ball sails through the air, it has kinetic energy because it is moving. The ball also has potential energy because of its position above the ground. An object's combined kinetic energy and potential energy is called **mechanical energy**.

You can find an object's mechanical energy by adding the object's kinetic energy and potential energy.

Mechanical energy = Kinetic energy + Potential energy

You can use this formula to find the mechanical energy of the football in Figure 12. Suppose a football has a weight of 4 newtons and a mass of 0.4 kg. If the football is moving at a speed of 14 m/s, it has a kinetic energy of $1/2 \times 0.4 \text{ kg} \times (14 \text{ m/s})^2 = 39 \text{ J}$. If the football is 3 meters above the ground, it has a gravitational potential energy of $4 \text{ N} \times 3 \text{ m} = 12 \text{ J}$ due to its position. The total mechanical energy of the football at that point is 39 joules + 12 joules, or 51 joules.

Reading Checkpoint **What two forms of energy combine to make mechanical energy?**

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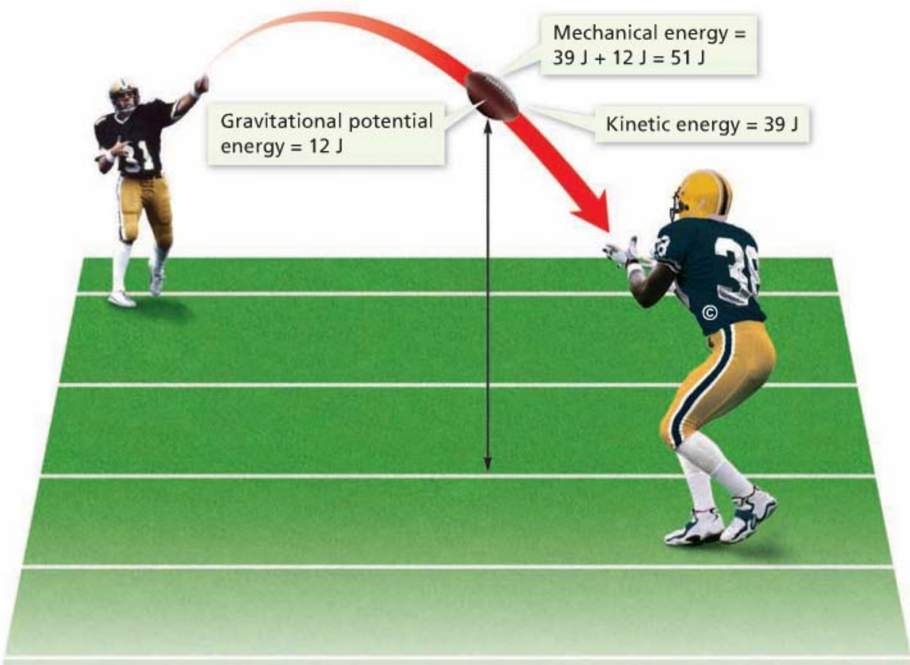

FIGURE 12
Mechanical Energy
To find the football's mechanical energy, add its kinetic energy to its potential energy. **Observing** *Why does the football have potential energy?*

FIGURE 13
Juggling
The kinetic energy of an orange thrown into the air becomes gravitational potential energy. Its potential energy becomes kinetic energy as it falls.

Transformations Between Potential and Kinetic Energy One of the most common energy transformations is the transformation between potential energy and kinetic energy. In waterfalls such as Yosemite Falls, potential energy is transformed to kinetic energy. The water at the top of the falls has gravitational potential energy. As the water plunges, its speed increases. Its potential energy becomes kinetic energy.

Any object that rises or falls experiences a change in its kinetic and gravitational potential energy. Look at the orange in Figure 13. When it moves, the orange has kinetic energy. As it rises, it slows down. Its potential energy increases as its kinetic energy decreases. At the highest point in its path, the orange stops moving for an instant. Since there is no motion, the orange no longer has kinetic energy. But it has potential energy. As the orange falls, kinetic energy increases while potential energy decreases.

In a pendulum, a continuous transformation between kinetic and potential energy takes place. At the highest point in its swing, the pendulum in Figure 14 comes to a stop, so it has only gravitational potential energy. As the pendulum swings downward, it speeds up. Its potential energy is transformed to kinetic energy. The pendulum is at its greatest speed at the bottom of its swing. There, all its energy is kinetic energy.

As the pendulum swings to the other side, its height increases. The pendulum regains gravitational potential energy and loses kinetic energy. At the top of its swing, it comes to a stop again. The pattern of energy transformation continues.

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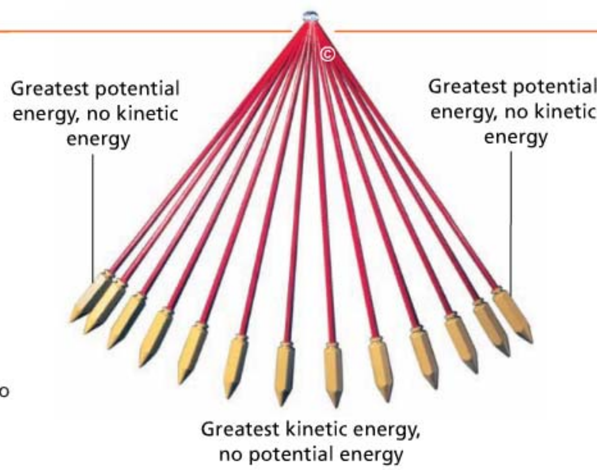

FIGURE 14
Pendulum
A pendulum continuously transforms energy from kinetic to potential energy and back.
Interpreting Diagrams *At what two points is the pendulum's potential energy greatest?*

Conservation of Energy If you set a spinning top in motion, will the top remain in motion forever? No, it will not. Then what happens to its energy? Is the energy destroyed? Again, the answer is no. The **law of conservation of energy** states that when one form of energy is transformed to another, no energy is destroyed in the process. **According to the law of conservation of energy, energy cannot be created or destroyed.** So the total amount of energy is the same before and after any transformation. If you add up all the new forms of energy after a transformation, all of the original energy will be accounted for.

So what happens to the energy of the top in Figure 15? As the top spins, it rubs against the floor and encounters air resistance. As a result, some of its kinetic energy is transformed into thermal energy. So, the mechanical energy of the spinning top is transformed to thermal energy. The top slows and eventually falls on its side, but its energy is not destroyed—it is transformed.

Reading Checkpoint **What causes a top to stop spinning?**

FIGURE 15
Conservation of Energy
A spinning top's kinetic energy is not lost. It is transformed into thermal energy through friction. **Applying Concepts** *How much of the top's kinetic energy becomes thermal energy?*

Section 4 Assessment

S 8 Framework, E-LA: Reading 8.1.0 Reviewing Math: NS 7.2.3

Vocabulary Skill High-Use Academic Words
What is the meaning of the word *potential* in the term *potential energy?*

Reviewing Key Concepts

HINT **1. a. Identifying** What is kinetic energy? In what unit is it measured?
HINT **b. Explaining** What factors affect an object's kinetic energy?
HINT **c. Calculating** A 1,500-kg car is moving at a speed of 10 m/s. What is the car's kinetic energy?

HINT **2. a. Identifying** What is potential energy?
HINT **b. Explaining** What factors affect an object's gravitational potential energy?
HINT **c. Calculating** What is the potential energy of a 500-N pole-vaulter when she is 4 m above the ground?

3. a. Summarizing State the law of conservation of energy in your own words. HINT
b. Describing Describe the energy transformations that occur when you bounce a ball. HINT
c. Applying Concepts Suppose a ball had a potential energy of 5 J when you dropped it. What would be its kinetic energy just as it hit the ground? (Ignore the effect of air resistance.) HINT

Math Practice

4. Exponents What is the kinetic energy of a 1.0-kg ball moving at 3.0 m/s?

5. Exponents How would the kinetic energy of the ball in Question 4 change if its mass were doubled? If its speed were doubled?

Chapter 9 Study Guide

The BIG Idea You can describe the motion of an object by its position, speed, direction, and acceleration.

1 Describing Motion

Key Concepts S 8.1.a

- An object is in motion if it changes position relative to a reference point.
- Distance is the total length of the actual path between two points. Displacement is the length and direction of a straight line between starting and ending points.

Key Terms

motion
reference point
distance
displacement
vector

2 Speed and Velocity

Key Concepts S 8.1.b, 8.1.c, 8.1.d

- To calculate the speed of the object, divide the distance the object travels by the time it takes to travel that distance.
- $\text{Speed} = \frac{\text{Distance}}{\text{Time}}$
- Changes in velocity may be due to changes in speed, changes in direction, or both.
- The slope of a distance-versus-time graph represents speed, that is, the rate that distance changes in relation to time.
- $\text{Slope} = \frac{\text{Rise}}{\text{Run}}$

Key Terms

speed
average speed
instantaneous speed
velocity
slope

3 Acceleration

Key Concepts S 8.1.e, 8.1.f

- In science, acceleration refers to increasing speed, decreasing speed, or changing direction.
- To determine the acceleration of an object, you must calculate its change in velocity per unit of time.
- $\text{Acceleration} = \frac{\text{Final velocity} - \text{Initial velocity}}{\text{Time}}$
- You can use both a speed-versus-time graph and a distance-versus-time graph to analyze the motion of an accelerating object.

Key Term

acceleration

4 Energy

Key Concepts S 8 Framework

- The kinetic energy of an object depends on both its mass and its speed.
- $\text{Kinetic Energy} = \frac{1}{2} \times \text{Mass} \times \text{Speed}^2$
- An object's gravitational potential energy depends on its weight and on its height relative to a reference point.
- $\text{Gravitational potential energy} = \text{Weight} \times \text{Height}$
- $\text{Mechanical energy} = \text{Potential energy} + \text{Kinetic energy}$
- Any object that rises or falls experiences a change in its kinetic and gravitational potential energy.
- According to the law of conservation of energy, energy cannot be created or destroyed.

Key Terms

work
energy
kinetic energy
potential energy
gravitational potential energy
elastic potential energy
mechanical energy
law of conservation of energy

Review and Assessment

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Target Reading Skill

Identifying Main Ideas Reread the first paragraph under *Potential Energy*. Then complete the following graphic organizer.

Potential Energy

Some objects have stored energy.

Reviewing Key Terms

Choose the letter of the best answer.

HINT **1.** A change in position with respect to a reference point is called
- **a.** acceleration.
- **b.** velocity.
- **c.** direction.
- **d.** motion.

HINT **2.** If you know a car travels 30 km in 20 minutes, you can find its
- **a.** acceleration.
- **b.** average speed.
- **c.** direction.
- **d.** instantaneous speed.

HINT **3.** You do not know an object's velocity until you know its
- **a.** speed and distance.
- **b.** displacement.
- **c.** speed and direction.
- **d.** acceleration.

HINT **4.** The rate at which velocity changes is called
- **a.** acceleration.
- **b.** constant speed.
- **c.** average speed.
- **d.** displacement.

HINT **5.** The energy that an object has due to its motion is called
- **a.** gravitational potential energy.
- **b.** elastic potential energy.
- **c.** kinetic energy.
- **d.** thermal energy.

Complete the following sentences so that your answers clearly explain the key terms.

6. **Displacement** is different from distance because ________ . HINT

7. Both velocity and acceleration are **vectors** because ________ . HINT

8. You can calculate the **average speed** of an object by ________ . HINT

9. An object moving in a circle at a constant speed is undergoing **acceleration** because ________ . HINT

10. The **law of conservation of energy** states that ________ . HINT

Writing in Science

News Report Two trucks have competed in a race. Write an article describing the race and who won. Explain the role the average speed of the trucks played. Tell how average speed can be calculated.

Video Assessment
Discovery Channel School
Motion

Review and Assessment

Checking Concepts

11. A passenger walks toward the rear of a moving train. Describe her motion as seen from a reference point on the train. Then describe it from a reference point on the ground.

12. Which has a greater speed, a heron that travels 600 m in 60 seconds or a duck that travels 60 m in 5 seconds? Explain.

13. An insect lands on a compact disc that is put into a player. If the insect spins with the disc, is the insect accelerating? Why or why not?

14. An eagle flies from its perch in a tree to the ground. Describe its energy transformations.

Thinking Critically

15. Inferring How can you tell if an object is moving when its motion is too slow to see?

16. Interpreting Graphs The graph below shows the motion of a remote-control car. Calculate the car's average speed over the time intervals 0-4 s, 4-8 s, 8-12 s, and over the entire time shown. During which interval is the car moving the fastest? The slowest?

17. Applying Concepts A family takes a car trip. They travel for an hour at 80 km/h and then for 2 hours at 40 km/h. Find their average speed during the trip.

18. Problem Solving A 380-N girl walks down a flight of stairs so that she is 2.5 m below her starting level. What is the change in the girl's gravitational potential energy?

Math Practice

19. Calculating Acceleration During a slap shot, a hockey puck takes 0.5 second to accelerate from 0 m/s to 35 m/s. What is the puck's acceleration?

20. Exponents What is the value of 12^2?

21. Exponents What is the kinetic energy of a 1,350 kg car travelling at 12 m/s?

Applying Skills

Use the illustration of the motion of a ladybug to answer Questions 22–24.

22. Measuring Measure the distance from the starting line to line B, and from line B to the finish line. Measure to the nearest tenth of a centimeter.

23. Calculating Starting at rest, the ladybug accelerated to line B and then moved at a constant speed until it reached the finish line. If the ladybug took 2.5 seconds to move from line B to the finish line, calculate its constant speed during that time.

24. Interpreting Data The speed you calculated in Question 23 is also the speed the ladybug had at the end of its acceleration at line B. If it took 2 seconds for the ladybug to accelerate from the start line to line B, what is its acceleration during that time?

Lab zone Standards Investigation

Performance Assessment Organize your display cards so that they are easy to follow. Remember to put a title on each card stating the speed that you measured. Place the cards in order from the slowest speed to the fastest. Then display them. Compare your results with those of other students.

CALIFORNIA Standards Practice

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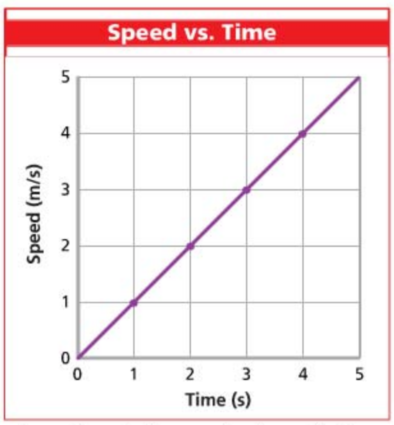
Choose the letter of the best answer.

1. Suppose you moved 8 meters forward and then 3 meters backward. What is your displacement from your original position?
A 5 m forward **B** 8 m forward
C 11 m backward **D** 24 m backward
S 8.1.a

2. Your father is driving to the beach. He drives at one speed for two hours. He drives at a different speed for another two hours and a third speed for the final hour. How would you find his average speed for all five hours?
A Divide total time by total distance.
B Multiply total time by total distance.
C Divide total distance by total time.
D Subtract total time from total distance.
S 8.1.b

3. A car travels at a constant speed of 60 km/h for 3 hours. What is the total distance that the car traveled?
A 20 km **B** 57 km
C 63 km **D** 180 km **S 8.1.c**

Use the graph below to answer Question 4.

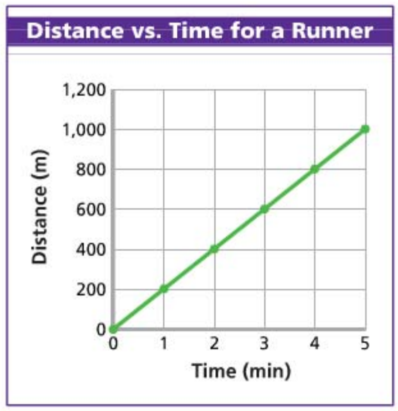


4. According to the graph of a cyclist's motion above, the cyclist is
A moving at a constant speed.
B accelerating at a constant rate.
C slowing down at a constant rate.
D moving a constant distance per second.
S 8.1.f

5. Which of the following is NOT a vector?
A displacement
B speed
C velocity
D acceleration **S 8.1.d**

6. Two objects traveling at the same speed have different velocities if they
A start at different times.
B travel different distances.
C have different masses.
D move in different directions. **S 8.1.e**

Use the graph below to answer Question 7.



7. The graph shows distance versus time for a runner moving at a constant speed. What is the runner's speed?
A 100 m/min
B 200 m/min
C 400 m/min
D 1,000 m/min **S 8.1.f**

Apply the BIG Idea

8. Write a paragraph that describes the similarities and differences among speed, velocity, and acceleration. **S 8.1.e**