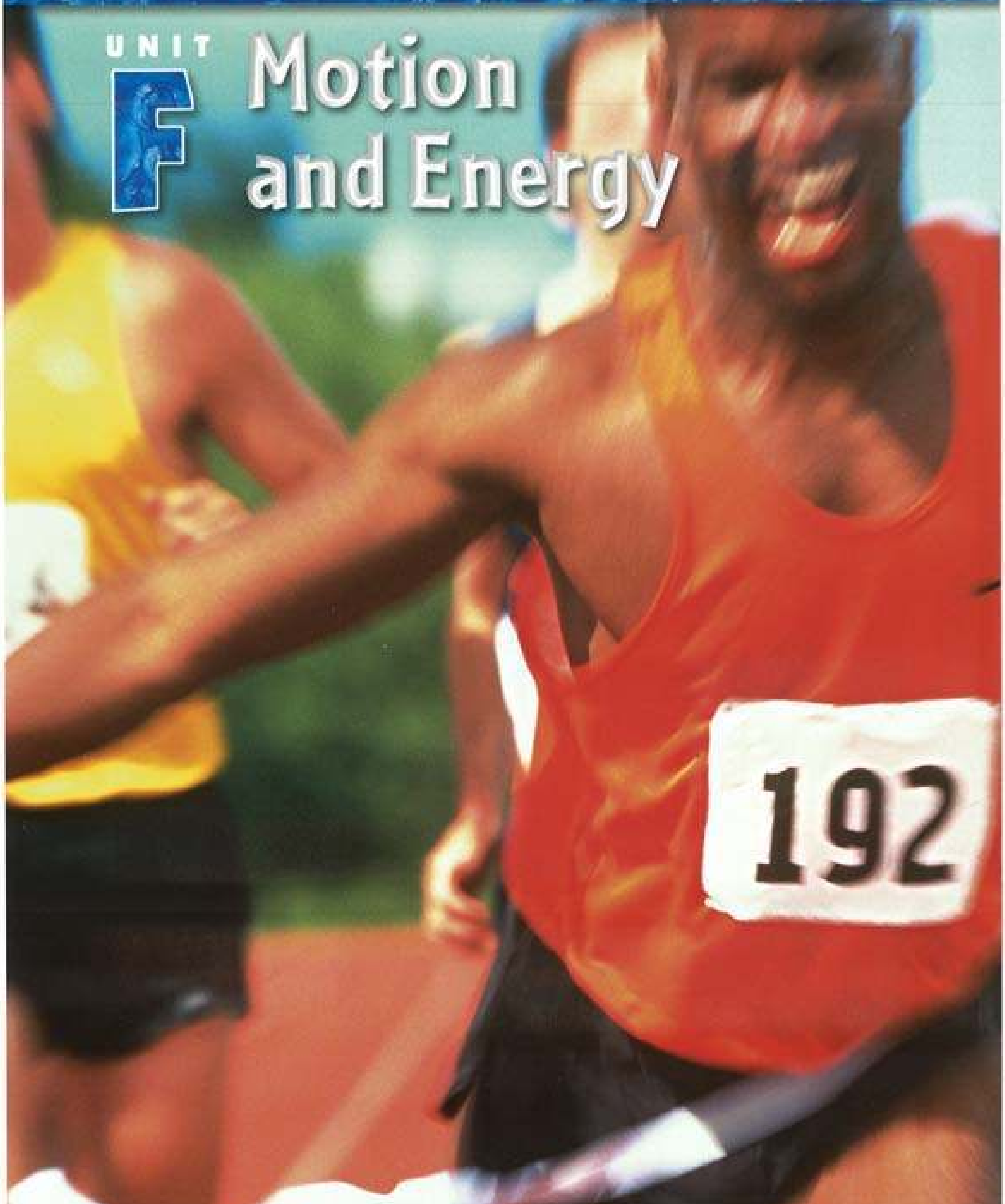
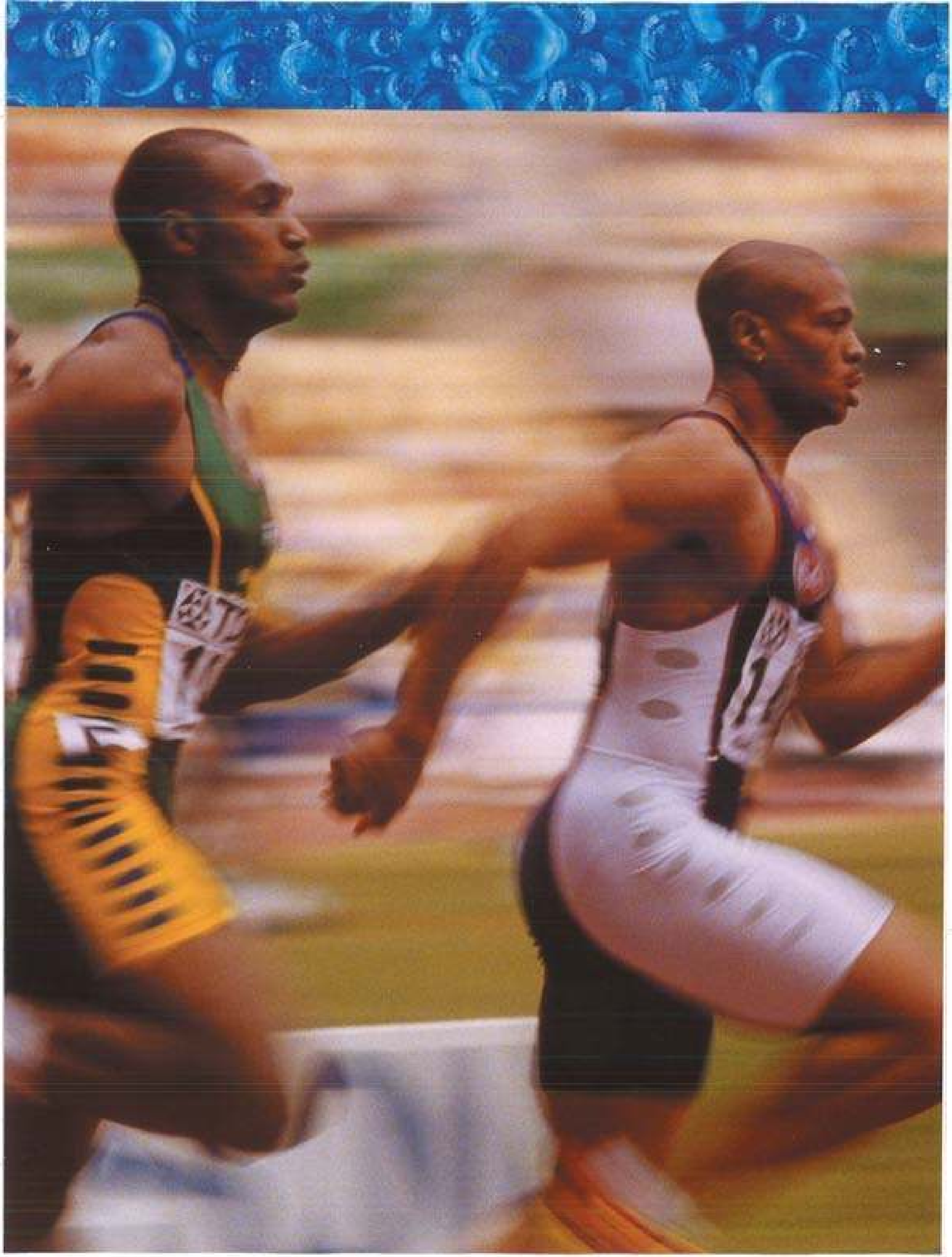
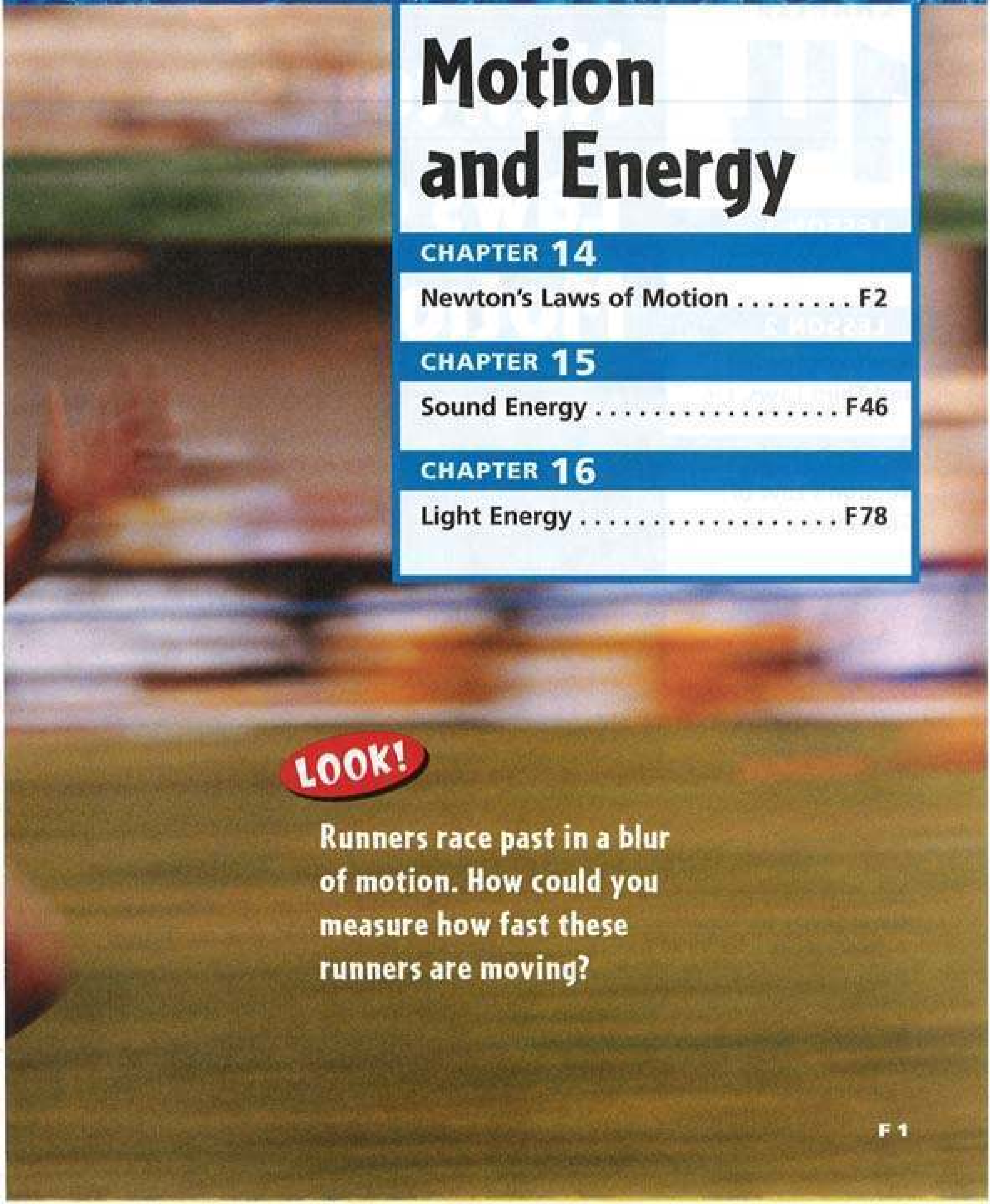
Physical Science

UNIT F Motion and Energy







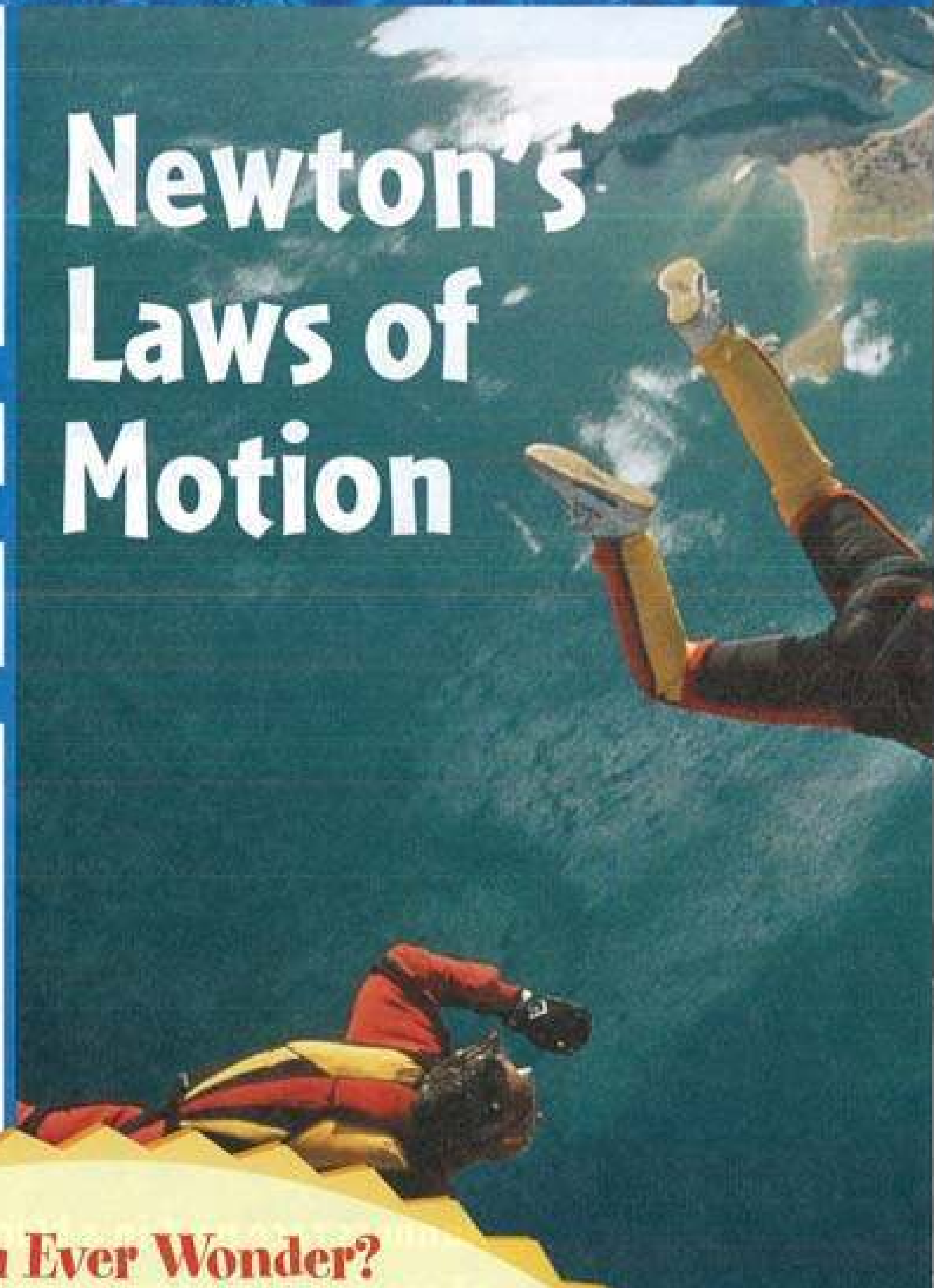
Motion and Energy

LOOK!

Runners race past in a blur of motion. How could you measure how fast these runners are moving?

CHAPTER 14

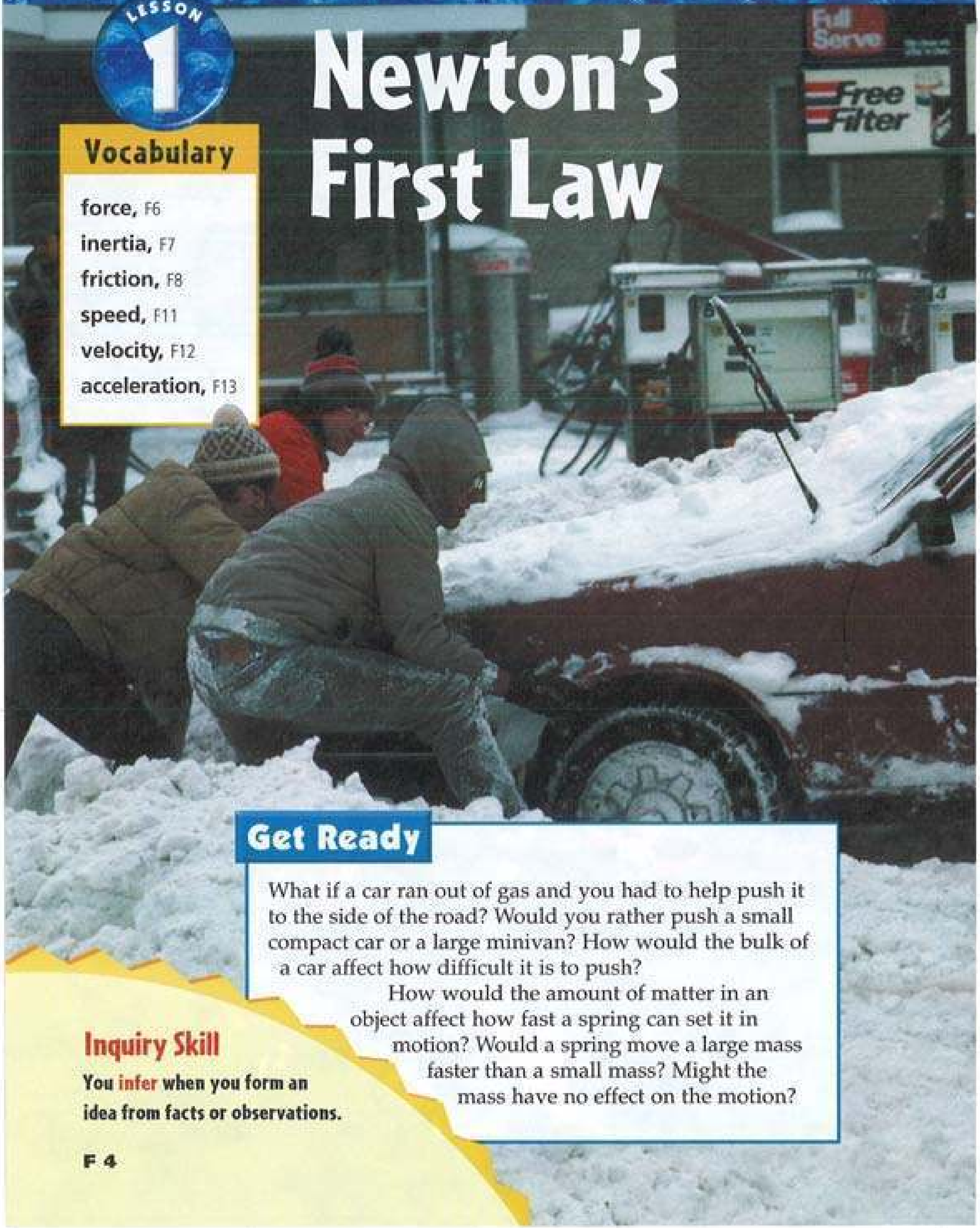
Newton's Laws of Motion



Did You Ever Wonder?

Is it true that what goes up must come down? How can these skydivers appear to float in the air? The skydivers are actually in free fall until their parachutes open. What force pulls them, and all objects, toward Earth? Do all objects fall at the same rate?

INQUIRY SKILL **Predict** Picture each of the skydivers with an open bottle of water. If they tried to drink the water, would the water flow out of the bottles?



LESSON 1

Newton's First Law

Vocabulary

force, F6
inertia, F7
friction, F8
speed, F11
velocity, F12
acceleration, F13

Get Ready

What if a car ran out of gas and you had to help push it to the side of the road? Would you rather push a small compact car or a large minivan? How would the bulk of a car affect how difficult it is to push?

How would the amount of matter in an object affect how fast a spring can set it in motion? Would a spring move a large mass faster than a small mass? Might the mass have no effect on the motion?

Inquiry Skill

You infer when you form an idea from facts or observations.

Explore Activity

How Fast Does a Spring Move Objects?

Procedure

BE CAREFUL! Wear goggles.

1. Attach a mass to the end of a metal ruler with a rubber band. Hold the ruler tightly against the edge of a table as shown so it can act like a spring.
2. **Use Numbers** Pull the mass back 5 cm (2 in.), and release it crisply. Count and record how many swings the mass completes in ten seconds.
3. **Predict** How will adding more mass to the end of the ruler affect how fast it swings back and forth? Record your predictions.
4. Add a second mass, and repeat the procedure. Repeat again with a third mass.

Drawing Conclusions

1. **Infer** Why does the ruler move the attached mass when it is pulled back and released?
2. **Observe** What effect did increasing the mass have on how fast the mass was swung back and forth by the ruler?
3. **Hypothesize** Why do you think the increase in mass had this effect?
4. **Interpret Data** Make a graph of your results. What two variables should you plot?
5. FURTHER INQUIRY **Predict** Use your graph to estimate how many swings would be observed in ten seconds when four masses are attached to the ruler.

Materials

- 3 masses (washers or AAA batteries)
- metal ruler
- rubber bands
- clock with second hand
- graph paper
- goggles

Read to Learn

Main Idea **Objects that contain more matter are harder to set in motion.**

What Does it Take to Make an Object Move?

The students below are investigating how easily objects of different masses are set into motion. First, one student uses a spring scale to pull a toy car from rest through a distance of one meter (39.37 inches). As she pulls, she keeps the reading on the spring scale constant. Her teammate times how long it takes the toy car to travel one meter. Next, the students repeat the experiment using a toy truck that has three times the mass of the toy car.

The results of the experiment show that the toy car traveled the one-meter distance in a shorter time than the toy truck. The amount of pull was kept the same, so why did the car travel faster than the truck? The car traveled faster because objects with more mass are harder to set in motion with a certain push or pull than objects with less mass. The car has less mass, so the pull of the spring scale set it into more rapid motion.

A pull or push that acts on an object is called a **force**. The students' experiment shows you how forces are needed to set objects in motion. As you've seen, objects with more mass move more slowly when acted on by a certain force.

Average Time to Travel 1 Meter with a Steady Pull

An Object's Natural Motion

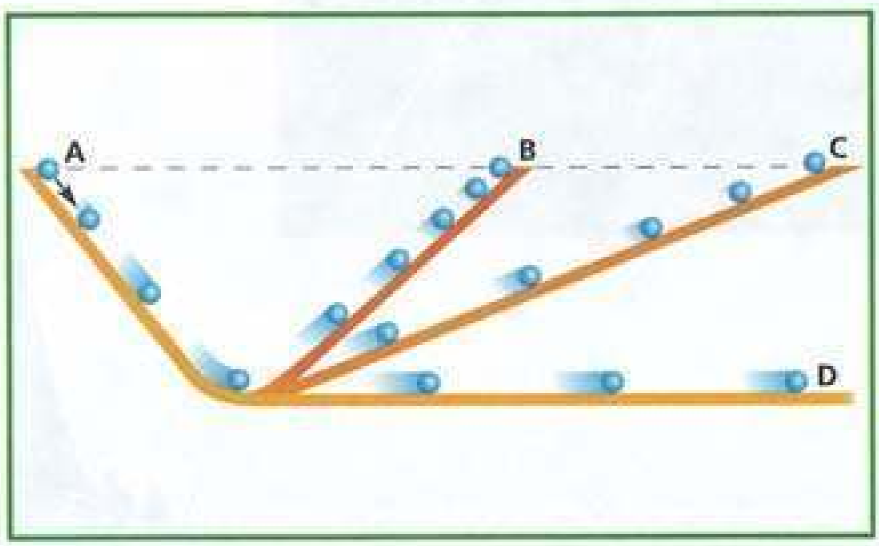
The mass of an object tends to make the object resist being set into motion. That's why objects with more mass are set into less rapid motion by a certain amount of force. The tendency of an object to resist a change in its state of motion is called the object's **inertia**.

Several centuries ago the famous Italian scientist Galileo began to understand how inertia affects the motion of objects. Galileo imagined rolling a ball down a fixed *incline* (ramp) and then back up ramps of varying steepness, as in the diagram. Galileo had observed that pendulums swing back and forth to the same height. He reasoned that the ball would roll to the same height on any ramp. He realized that if the ramp were less steep, the ball would roll a greater distance and slow down more gradually.

Thinking further, Galileo inferred that if the second ramp were flat, the ball would roll forever at a steady rate (assuming no force is acting on the ball). To Galileo this meant that the ball's natural state of motion was coasting. Just as it takes a force to set an object in motion, it also takes a force to slow or stop a coasting object. Without any such force, the object will coast forever in a straight line.

Galileo had observed that pendulums swing back and forth to the same height. He reasoned that a ball rolling down one ramp and up another would roll to the same height on any ramp.

What does it take to change an object's state of motion?



The ball is released from A. It rolls down the incline, then back up one of the facing inclines. If there is no force acting on the ball, it slows and comes to a stop just as it reaches the starting height.

Incline C is not as steep as incline B, so the ball takes longer to slow down. Galileo reasoned that if there were no incline for the ball to climb, it would not slow down at all—as in D.

Is Force Needed to Maintain Motion?

The sailboat in the picture is traveling at a steady rate in a straight line. The wind has filled its sails and is pushing the boat forward. Until just a few centuries ago, most people believed that a force was necessary to keep an object traveling at a steady rate, just like the wind pushing the boat.

Galileo realized that this idea was incorrect. He understood that a force called **friction** acts against moving objects. Friction opposes the motion of one object moving past another. If the friction is taken away, no force is needed to maintain motion at a steady rate. An object's inertia is all that is needed to keep it moving.

Forty-five years after Galileo died, Sir Isaac Newton published a complete description of the concept of inertia. This is *Newton's first law of motion*: Objects at rest remain at rest and objects traveling at a steady rate in a straight line continue that way until a force acts on them.

A spacecraft far from any star or planet can continue traveling in a straight line at a steady speed. There is no air in space, so there is no friction to slow the spacecraft down.

The sailboat needs the force of the wind to keep it moving. That is because the friction between the boat and the water tends to slow the boat down.

The rocket engines must overcome inertia. Their force moves the rocket from rest to high speeds during liftoff. The rocket's momentum is determined by the product of its mass and speed.

How Inertia Works

Newton's first law of motion—the law of inertia—tells us that the state of motion of an object does not change until a force is applied to it. That means, if an object is traveling at a steady rate in a straight line, it will continue to do so until a force is applied to it. Newton's law also means that if the object is sitting at rest, it will continue to be at rest until a force is applied to it. Each of the photographs shows an example of Newton's first law of motion.

Is a force needed to keep a moving spacecraft moving in a straight line?

These race cars could not change their direction of travel without the force of the road surface pushing sideways against the tires.

Both cars and trucks slow down when their drivers use their brakes. The force produced by the brakes slows the vehicles down. A truck has much more mass than a car, so its brakes must provide more force than the car's brakes in order to slow down or stop.

QUICK LAB

Using a Position Grid

FOLDABLES Make a Half-Book using graph paper. (See p. R 41.) Label it as shown.

1. A grid has rows and columns. Each is labeled with letters or numbers. You can locate each box in the grid by its letter and number address. Make your own grid. Number the boxes from 1 to 29 across and from A to G down. Inside your Half-Book, explain why the snail didn't want to move. How is a position grid useful?

2. Find each box, and shade it in with a colored pencil.

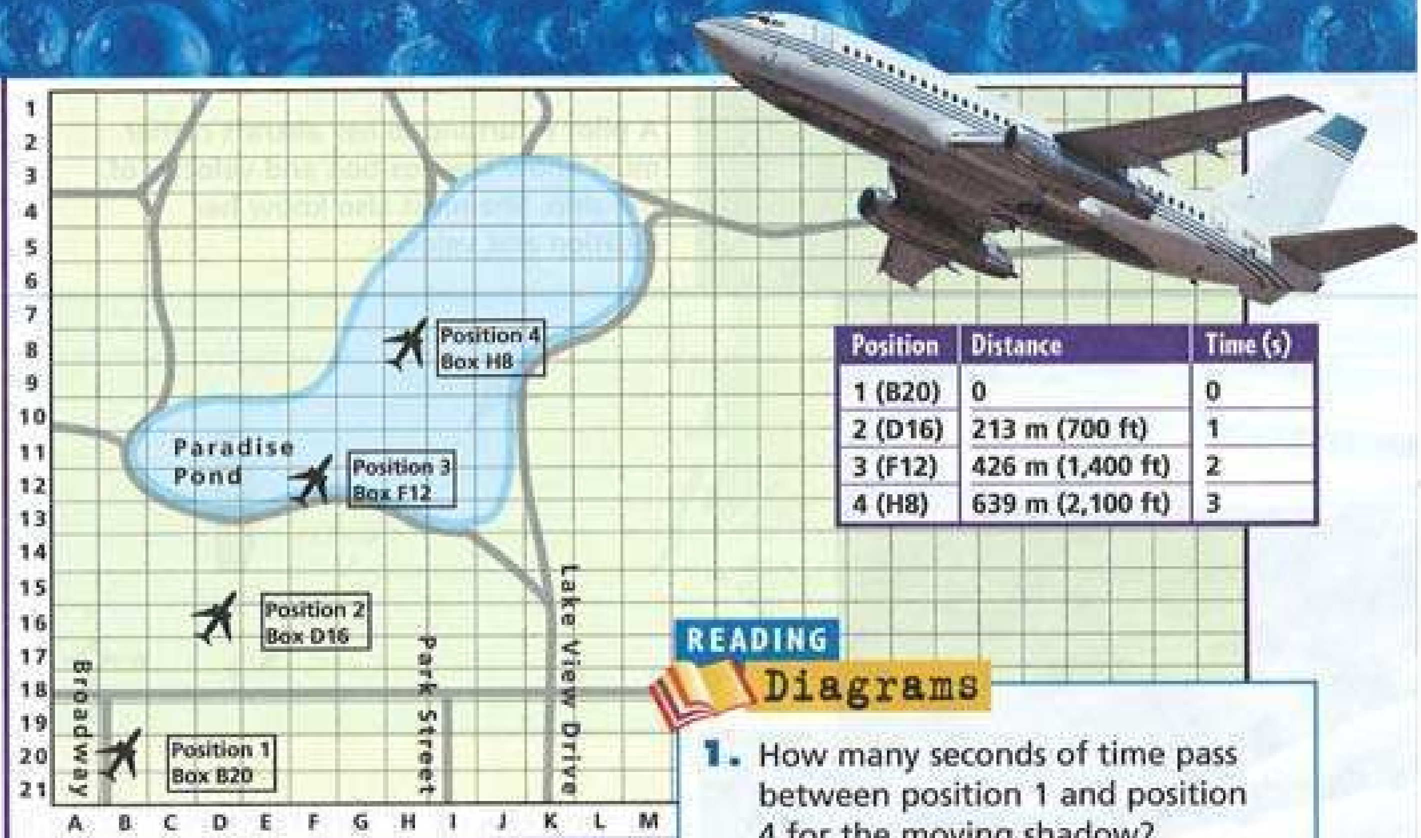
E27, B8, F24, D15, B29, C20, D5, F14, D29, B3, D11, B16, F3, D7, B27, B2, B11, F27, B20, F12, B23, D8, E17, F20, F23, C6, E2, E24, B10, B1, F10, C29, C2, F17, D24, E8, B15, E14, F1, B12, F5, D16, B21, B24, D27, C5, C10, E29, E7, B5, C14, C24, C16, E20, D2, C27, D10, C8, D17, E28, E10, D6, F25, D20, D14, F8, F29, B19, B14, F11, E5, B25, F2, B28

The snail didn't want to move because he had _______.

Where Is It?

How do you know when you are moving? You are moving when you are changing position. Position is the location of an object. Your position might be in front of, behind, to the right or to the left of some object. Cities or landmarks can be located on a map. The position of each object can be found by using a grid. The position of any object on a map is a comparison of the object's location to other things on the map. We can describe positions of things with a grid like the one covering the map. For example, the location of Atlanta can be described as box J16. You can find the number of Atlanta's position along the top or bottom and the letter along either side.

Find the city in each location.
a. K10 b. H11



Position	Distance	Time (s)
1 (B20)	0	0
2 (D16)	213 m (700 ft)	1
3 (F12)	426 m (1,400 ft)	2
4 (H8)	639 m (2,100 ft)	3

The diagram shows the shadow of the airliner moving over a town at a steady speed. The box number at each position gives the location of the center of the plane. One second passes between each position.

READING Diagrams

1. How many seconds of time pass between position 1 and position 4 for the moving shadow?
2. How far does the plane travel between position 2 and position 4?

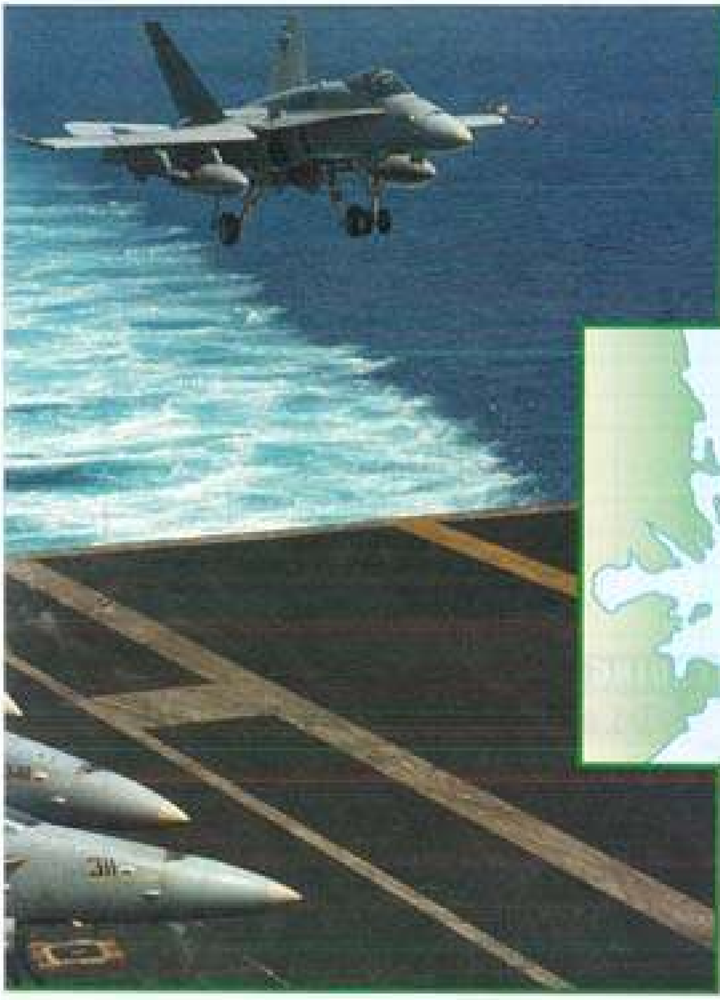
What Speed Is

The airliner in the photo is moving rapidly through the air. How can we tell that it is moving? Think about watching the shadow of the airliner on the ground below, as in the diagram. We can see the shadow sweeping past fixed objects like ponds, homes, or streets. The change in the position of the shadow compared with the surrounding objects reveals its motion, as well as the motion of the airliner.

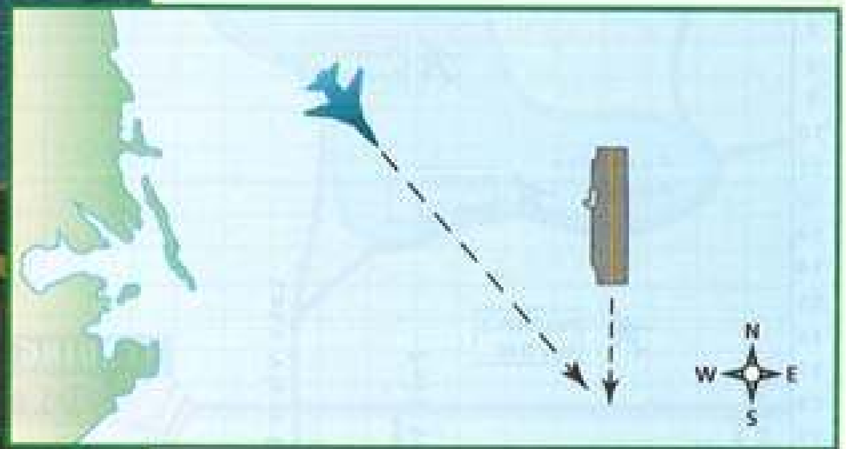
The table describes the motion of the airliner by giving the position of the airliner's shadow at various times. The position can be measured as the box number of the center of the shadow. The position can also be measured as the distance traveled past position 1.

As for any moving object, the **speed** of the airliner is how fast its position is changing with time at any moment. When the distance traveled by an object in a given time is known, the speed is found by dividing the distance by the time. The airliner, for example, travels 213 meters (700 feet) in 1 second. Therefore, the airliner's speed is 213 meters per second (700 feet per second) or 213 meters/second (700 feet/second).

What tells you how fast the plane is moving?



A pilot returning to her aircraft carrier must know the position and velocity of the ship. She must also know her location and velocity.



What Is Velocity?

The pilot of the navy jet is out on a mission. She needs to return to her aircraft carrier before she runs low on fuel. Her position and the position of the aircraft carrier are shown on the map. To get back safely, what information must she obtain from the ship to know in what direction to fly her plane?

First, she must know the position of the ship. She will also need to know the speed and the direction in which the ship is traveling. With this information, plus a knowledge of her own speed, the pilot can decide which direction she must travel in to meet up with the carrier, as shown by the dotted lines.

The speed of a moving object taken together with its direction of travel gives the **velocity** of the object. For example, the velocity of the aircraft carrier might be 40 kilometers/hour (40 km/h) due south, or the velocity of the plane might be 600 km/h to the southeast.

How can you tell the velocity of a car you are riding in? You need to know your speed. The car's speedometer will give you that information. You also need to know the direction you are traveling in. For that, you may need to use a map or road signs.

Two objects can have the same speed but different velocities if they are traveling in different directions. They may also have different velocities if they are traveling in the same direction but with different speeds. The only way two objects can have the same velocity is for the objects to both be traveling in the same direction at the same speed.

How is velocity different from speed?

What Is Acceleration?

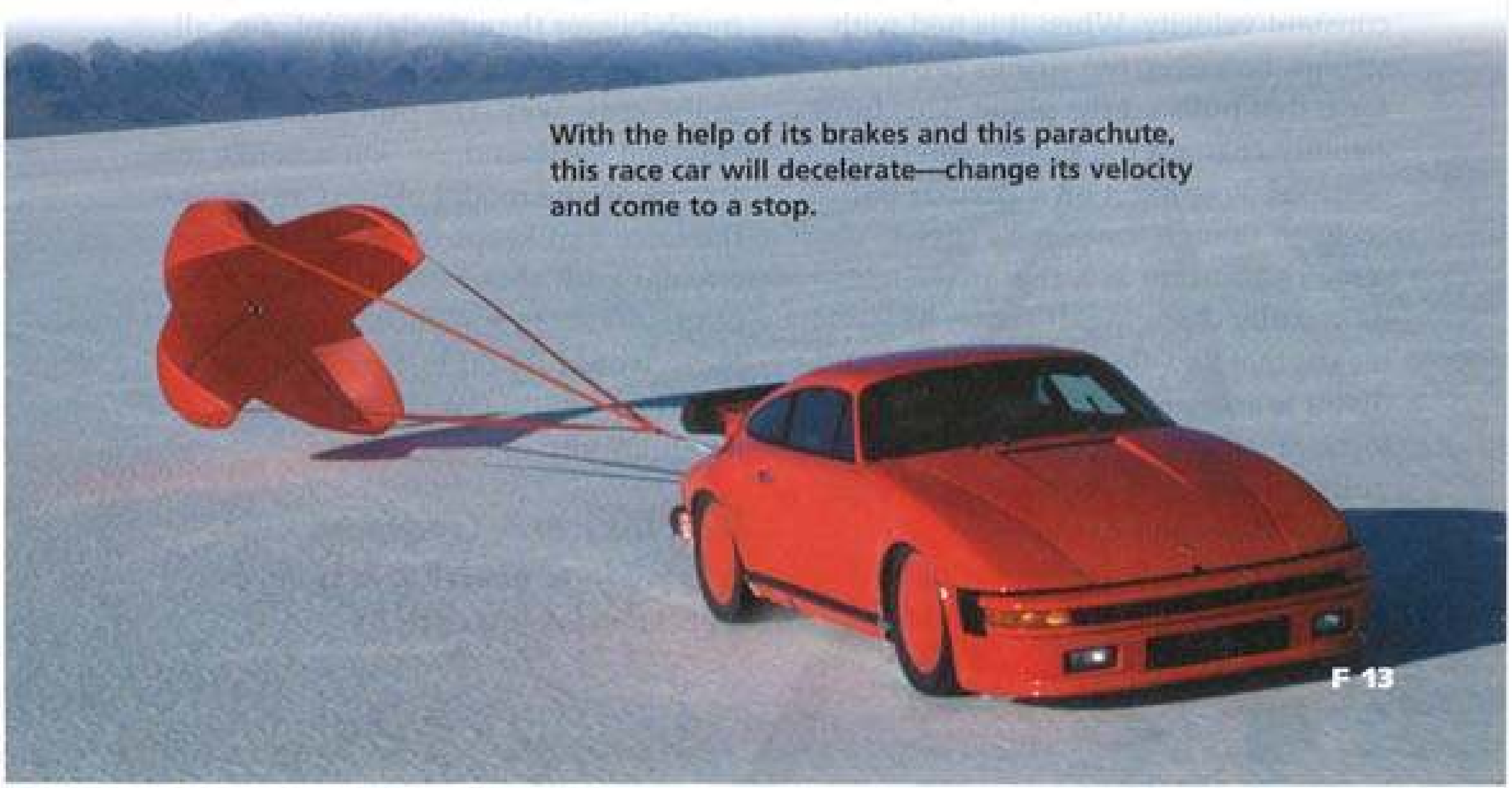
As long as an object travels in a straight line at a steady speed, its velocity is constant. Newton's first law tells us that an object's velocity will remain constant unless a force is applied to it. What if such a force is applied? How could the force affect the velocity of a moving object?

Both of the photographs on this page show how the velocity of an object can change when a force is applied. The force may change the object's speed, its direction of travel, or both. Any of these changes will change the velocity.

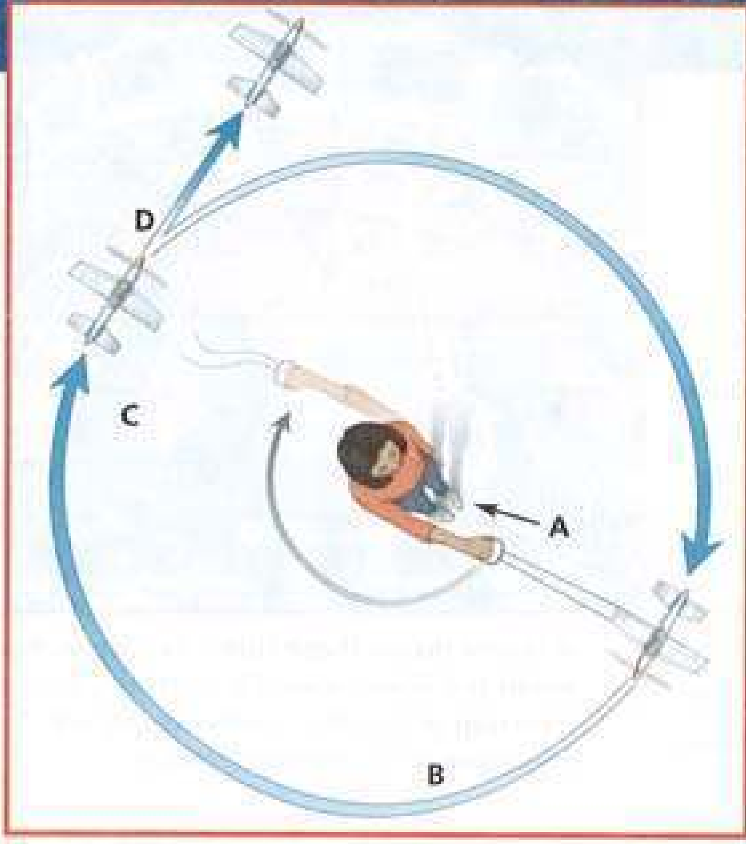
A change in velocity is called **acceleration**. Isaac Newton realized that applying a force to an object would overcome its inertia and change its velocity, causing it to accelerate. A special case of acceleration—*deceleration*—occurs when a force causes the speed of an object to decrease. Look at the photographs. Each photograph shows acceleration due to changing velocity. Which photograph shows a change in direction? Which photograph shows a deceleration?

A motor drives these riders in a circle. Even when the riders' speed is constant, their direction of travel is always changing. Therefore, they are accelerating.

How is acceleration related to velocity?



With the help of its brakes and this parachute, this race car will decelerate—change its velocity and come to a stop.



The inward force of the strings (A) keeps the plane on a circular path (B). If the strings were to break (C), the plane would fly off in a straight line (D) at a constant speed due to inertia.

What Keeps Things Moving in a Circle?

A gas-powered model airplane can be tied to a handle with strings. This allows the plane to be flown in a circle. Without strings, the plane tends to fly in a straight line at constant speed—a constant velocity. When it is tied with strings, however, the strings provide a force that pulls on the plane. This force steadily changes the plane's direction of travel, keeping it on a circular path.

Even though the plane's speed remains constant as it flies in a circle, its steadily changing direction of travel means that its velocity is changing and that it is accelerating. Note how the force causing the acceleration—the pull of the strings—is always directed toward the center of the circle.

If the strings tethering the plane were to break suddenly, it would fly off in a straight line at a constant speed. There would no longer be any force to overcome its inertia, and it would travel with constant velocity.

Although Earth and the Sun are much bigger than model airplanes, all of these objects obey the laws of motion in the same way. The pull of *gravity* between Earth and the Sun acts like the strings on the model plane. Gravity is the force that keeps Earth moving in a circular path about the Sun. If the force of gravity were somehow to disappear, Earth would fly off in a straight line into deep space! (You'll learn more about gravity in Lesson 3.)

READING Draw Conclusions
Why is a force needed to keep an object moving in a circle?

Lesson Review

Why It Matters

In outer space, spacecraft are not slowed by air resistance. When a pilot tries to dock one spacecraft with another, she sets her craft in motion with a burst of gas. To slow her craft, she applies a burst of gas in the opposite direction. With too little force, her craft may strike the other. With too much force, she may start going backward. It takes great skill to guide a spacecraft.

e-Journal Visit our Web site **www.science.mmhschool.com** to do a research project on force and mass.

Think and Write

1. A boat's motor dies when it is traveling at high speed. The boat slows to a stop. Why?
2. On a wet road, a car drives at high speed. At a sharp turn, the car slides straight out into a field. Why?
3. What do you need to know to find a car's velocity?
4. What is happening when a mass on a spring swings back and forth?
5. **Critical Thinking** If you tie a thread to the middle of a water-filled plastic bottle and pull slowly, the bottle moves. If you pull very rapidly, the thread breaks before the bottle can move. Why?

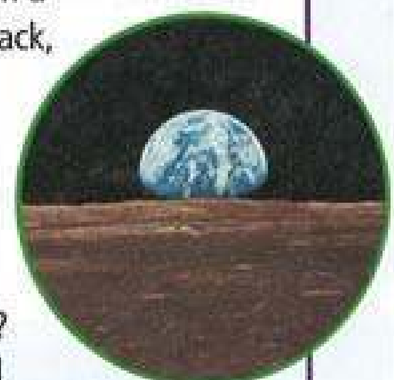
L·I·N·K·S

MATH LINK

Solve a problem. Absolute motion or rest is misleading. You are speeding faster than most airliners as you read this. Why don't you feel it? Where is the evidence that Earth rotates once every 24 hours? Its circumference is about 40,000 km (25,000 mi). Calculate how fast you and Earth are moving.

WRITING LINK

Expository Writing On a trip to the Moon and back, when would the astronauts be accelerating? When would they be traveling at a constant velocity? What forces would they experience? Research this topic and write a report.



ART LINK

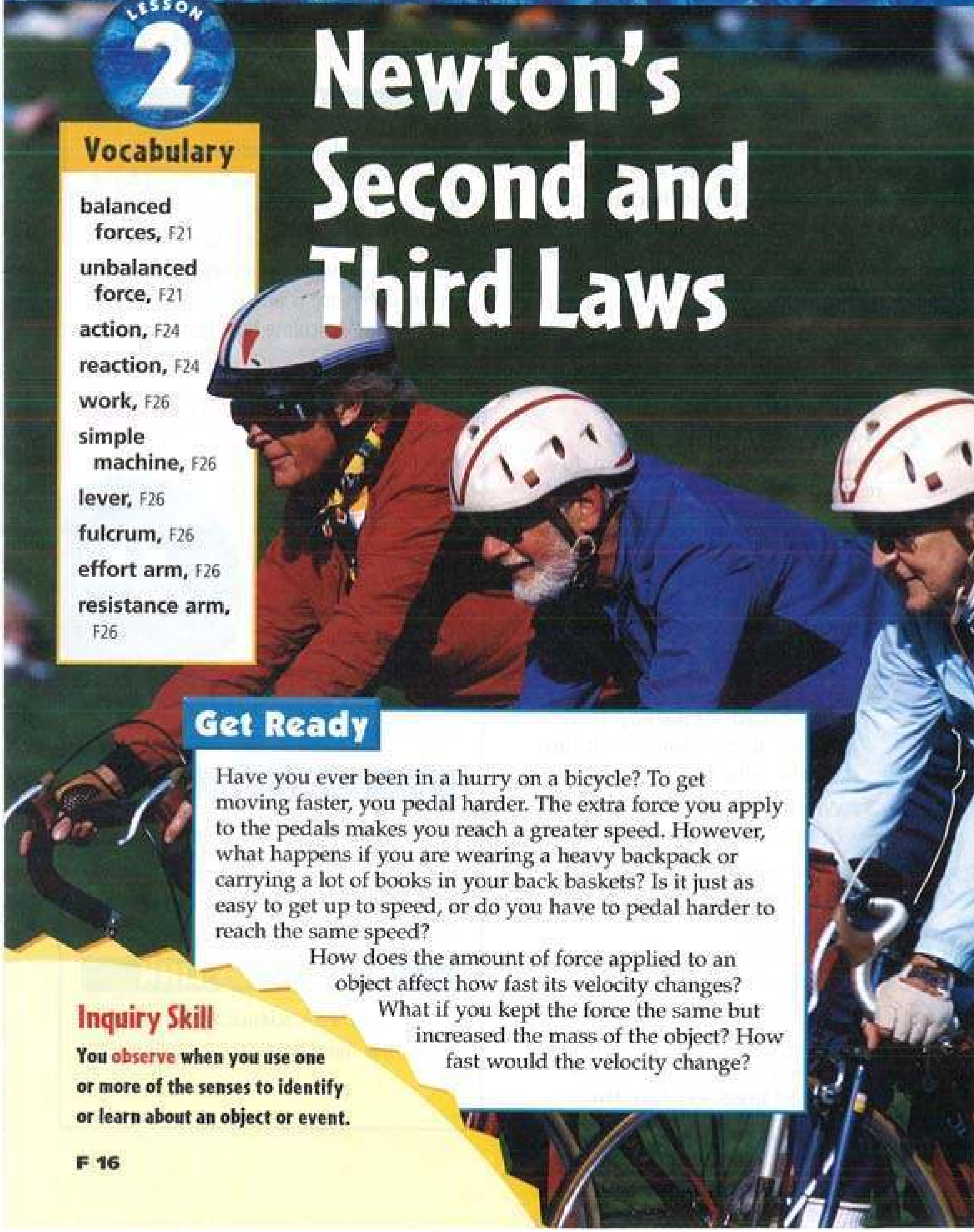
Make a poster. A weather satellite circles Earth at a steady speed. Make a poster that shows its orbit and illustrates why it is accelerating.

TECHNOLOGY LINK

LOG ON Visit **www.science.mmhschool.com** for more links.

LESSON 2

Newton's Second and Third Laws



Vocabulary

balanced forces, F21
unbalanced force, F21
action, F24
reaction, F24
work, F26
simple machine, F26
lever, F26
fulcrum, F26
effort arm, F26
resistance arm, F26

Get Ready

Have you ever been in a hurry on a bicycle? To get moving faster, you pedal harder. The extra force you apply to the pedals makes you reach a greater speed. However, what happens if you are wearing a heavy backpack or carrying a lot of books in your back baskets? Is it just as easy to get up to speed, or do you have to pedal harder to reach the same speed?

How does the amount of force applied to an object affect how fast its velocity changes? What if you kept the force the same but increased the mass of the object? How fast would the velocity change?

Inquiry Skill

You observe when you use one or more of the senses to identify or learn about an object or event.

Explore Activity

How do Different Forces Affect an Object's Motion?

Procedure

BE CAREFUL! Wear goggles

1. Place a 15-cm (6-in.) strip of masking tape on the floor. Hold two boards on either side of the tape with a rubber band stretched between them.
2. **Measure** Pull a toy car back 5-cm (2-in.) against the rubber band to launch it. Use the compass, stopwatch, and meterstick to determine the car's direction, elapsed time, and distance of travel.
3. **Observe** Repeat step 2 twice more. Record your results. Find the average speed.
4. **Predict** What will happen if you use two or three rubber bands to launch the car? Test your prediction.

Materials

- toy car
- 2 boards with hooks for rubber bands
- rubber bands
- meterstick
- masking tape
- goggles
- stopwatch
- compass

Drawing Conclusions

1. **Interpret Data** When did the car move farthest on average—when one, two, or three rubber bands were used?
2. **Infer** How is the distance traveled by the car in any trial related to the speed it was given by the rubber band? Why?
3. **FURTHER INQUIRY** **Predict** If you taped a second toy car on top of the first and launched them with two rubber bands, how far would the cars travel? Test your prediction. Explain your observations.

Read to Learn

Main Idea **As the net force acting on an object increases, the object accelerates more.**

What Affects Acceleration?

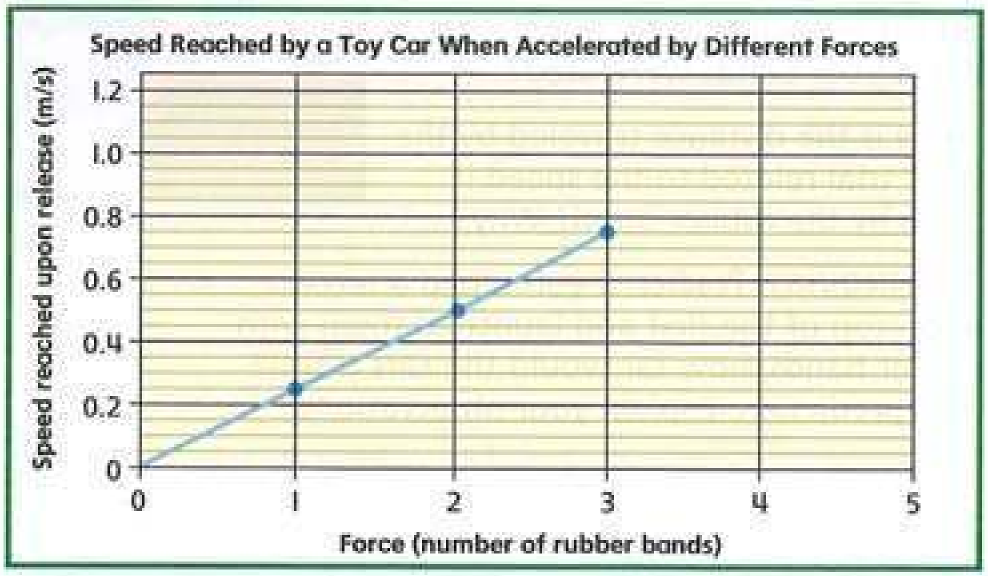
What if you use a rubber band to launch a toy car along the floor? The rubber band will apply a force to the car, and the force will cause the car to speed up. Once the rear of the car passes the starting line, however, the rubber band no longer is applying force. At this point the car will begin coasting until friction brings it to a stop. The farther the car travels before stopping, the faster it must have been going at the start.

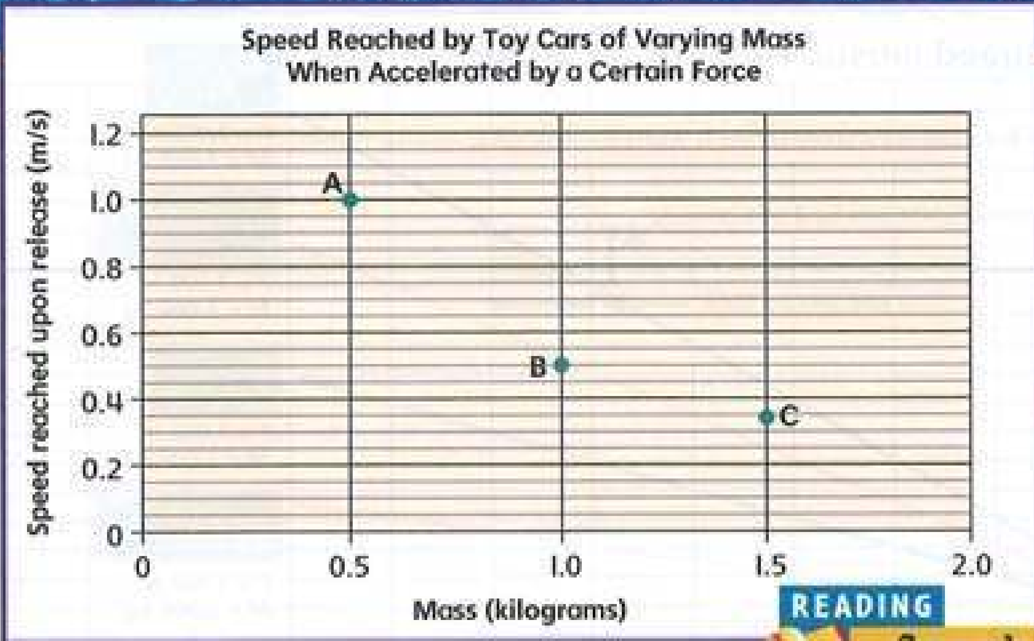
Force and Acceleration

What happens if you add extra rubber bands? Then you are applying more force to the car. As the force increases, the distance the car travels also increases. This, in turn, tells you that the car reaches its greatest starting speed when the force applied to it is greatest.

Sir Isaac Newton realized that forces produce acceleration. In other words, if we apply a force to an object, the object's velocity will change. The object might speed up, slow down, or change direction. It could even change both speed and direction.

Newton reasoned this way: If we multiply the force by a certain amount, we will change the acceleration by the same amount. (This assumes that no other changes are made.) For example, if we triple the force, the acceleration will also be tripled. What if you tried launching your toy car first using one rubber band, then using three rubber bands of the same size? You should see that as the force on the car is increased, the speed it reaches increases by about the same amount. The graph shows an example of how the car's acceleration would be related to the force acting on it, according to Newton's ideas.





Using the same amount of force, it is easier to accelerate a less massive object than a more massive object.

READING Graphs

What would the speed reached be for a mass of 2 kilograms?

Mass and Acceleration

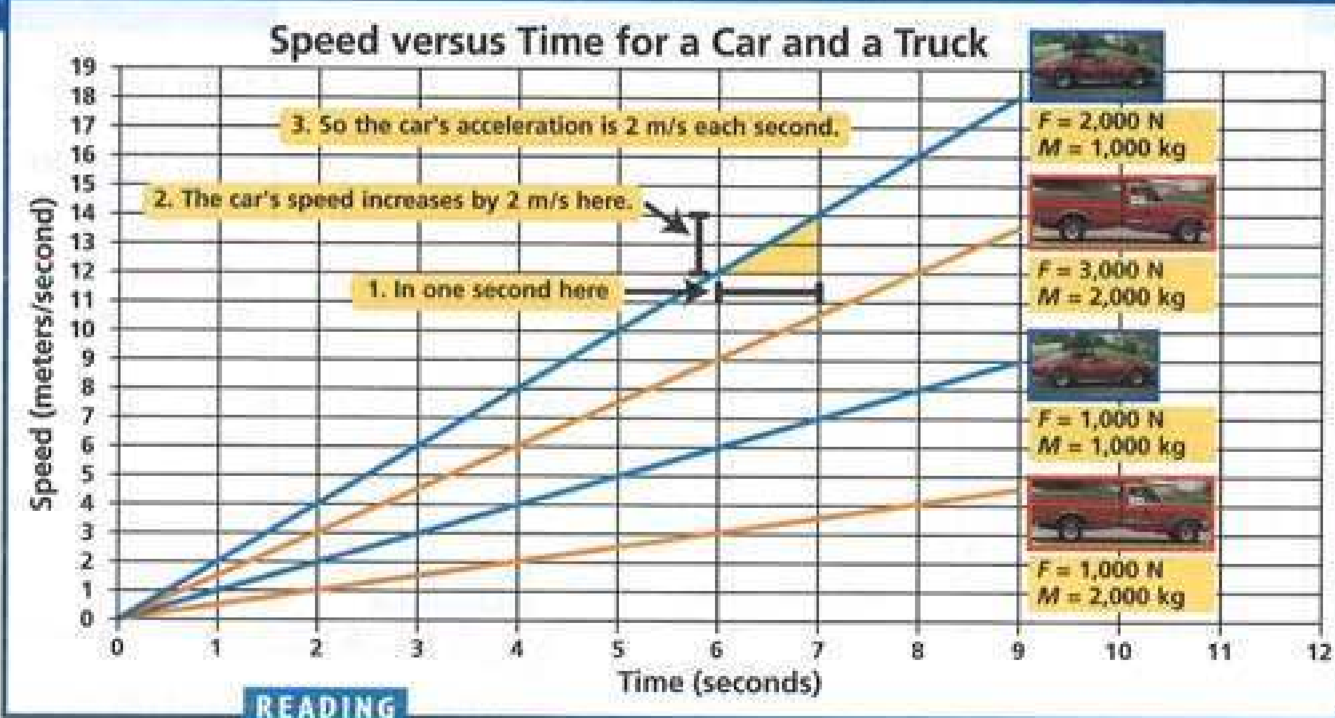
What happens if you tape a second car on top of the first? You double the mass being accelerated by the force from the rubber bands. Now the two cars together will travel only about half as far as one car would alone when launched by the same number of rubber bands. This tells you that doubling the mass resulted in about half the acceleration.

Isaac Newton understood that changing the force isn't the only thing that affects acceleration. He also understood that mass affects acceleration. However, while increasing the force increases the acceleration, increasing the mass decreases the acceleration.

When the mass is multiplied by a certain factor, the new acceleration is obtained by dividing the old acceleration by that factor. (Again, this assumes that nothing else has changed.) For example, what if the mass of an object being accelerated by a certain force is doubled? The new acceleration would then be the previous acceleration divided by 2. Put another way, if the mass is doubled, the acceleration is reduced to one-half of its previous value.

The relationship between acceleration and force is said to be direct—when one is increased, the other increases. The relationship between acceleration and mass, on the other hand, is inverse—when one goes up, the other goes down. The graph shows an example of how the acceleration of a toy car is inversely related to its mass.

What two factors determine how great an object's acceleration is?



READING Graphs

Describe two ways you could use the information on the graph to calculate the acceleration of the truck when a force of 3,000 N acts on it.

How Is Acceleration Calculated?

You learned in Lesson 1 that acceleration is a change in velocity. Recall that velocity describes both the speed and direction of a moving object. To calculate the acceleration of an object moving in a straight line you first must know three things—the object's starting speed, its new speed, and the amount of time it took for the change to occur.

Look at the lowest blue line on the graph above. In one second, the speed of the car has gone from zero to 1 meter per second. For each second that passes, the car's speed increases by another meter per second. The car is accelerating at 1 meter per second each second. Now look at the top blue line for the same 1,000-kg car. In one second the car's speed now increases by 2 meters per second. That means its acceleration is 2 meters per second each second.

What was changed to make the car's acceleration double? The force acting on the car was changed.

We can write an equation to show how acceleration is related to force and mass: $a = F \div m$. This equation says the acceleration is found by dividing the force by the mass. In the examples shown, forces are in units called newtons (N). A force of 1 newton makes the speed of a 1 kg mass change by 1 meter per second each second.

What do you need to know to calculate the acceleration an object will have?

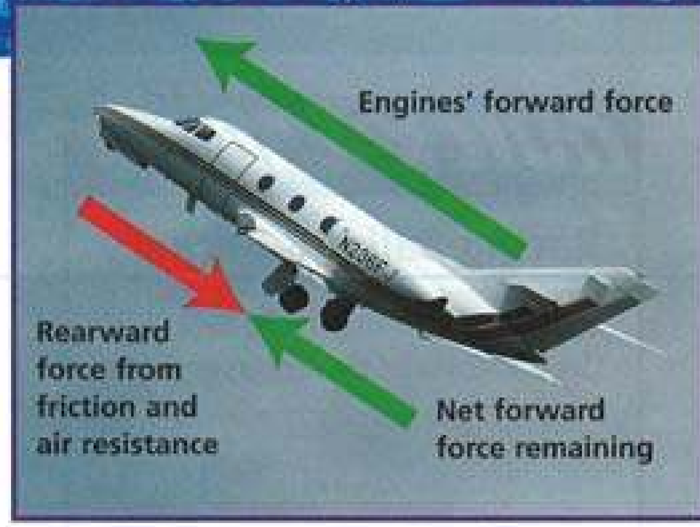
What Are Balanced and Unbalanced Forces?

The plane in the photograph below is flying at a constant speed in a constant direction. Its speed is not changing, nor is its direction of travel, so the plane cannot be accelerating. However, the pilot is using the throttle to make the plane's motor apply a forward force to it. How can the motor apply force to the plane without causing the plane to accelerate?

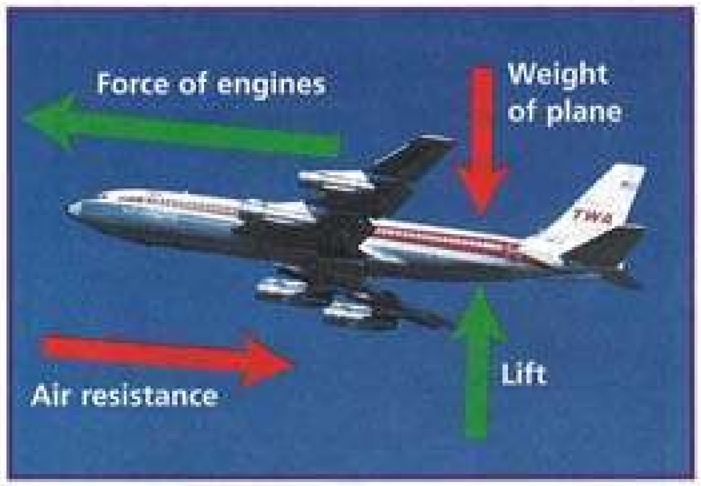
The explanation is that the force of the plane's motor is exactly offset by other forces acting in the opposite direction, as the diagram shows. In fact, there are a number of forces acting on the plane, but for each one there are others that cancel it out. When all of the forces on an object cancel one another out, the forces are said to be **balanced forces**.

In cases where a certain force is either only partially canceled or not canceled at all by other forces, the force is said to be an **unbalanced force**. For example, what if a plane's motor applies more forward force than the amount of friction and air resistance apply against its forward motion? The friction and air resistance will cancel some, but not all, of the forward force. This will leave an unbalanced forward force acting on the plane.

When we use the equation $a = F/m$ to find acceleration, F always stands for the unbalanced force. This equation is actually one possible way of stating *Newton's second law of motion*: When an unbalanced force acts on an object, the object's acceleration equals the force divided by the object's mass.



Are the forces acting on this plane balanced or unbalanced?



Are the forces acting on this plane balanced or unbalanced?

READING **Draw Conclusions**

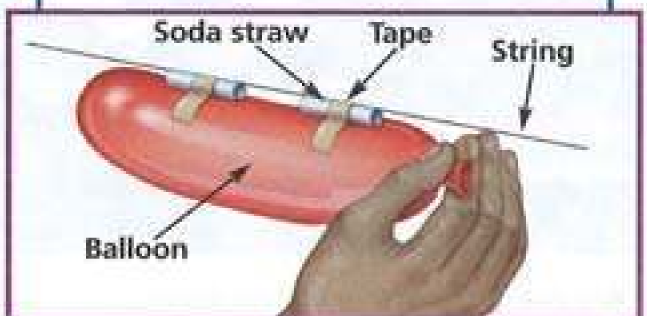
What happens to an object's motion when the forces acting on it are unbalanced?

QUICK LAB

Racing Balloon Rockets

FOLDABLES Make a Shutter Fold. (See p. R 42.) Label the shutters as shown.

1. Pass thread or string through two short lengths of soda straw as shown. Then stretch the string tightly between two chairs.

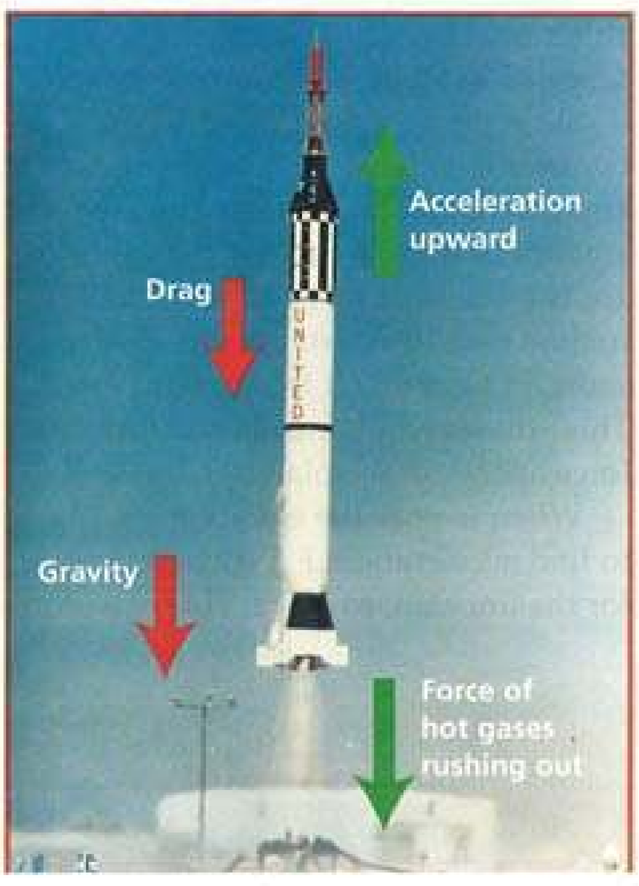


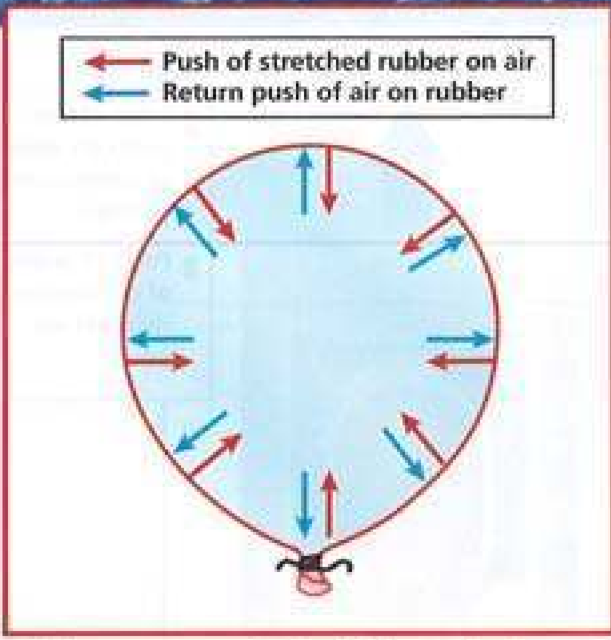
2. Inflate the balloon rocket. Hold the neck closed while your partner tapes it to the straws. Let go and record your observations in the Shutter Fold.
3. **Observe** Compare the direction the balloon moves with the direction of the escaping air.
4. **Infer** Is there an unbalanced force on the balloon? In which direction does it push?

Where Does the Force Come From?

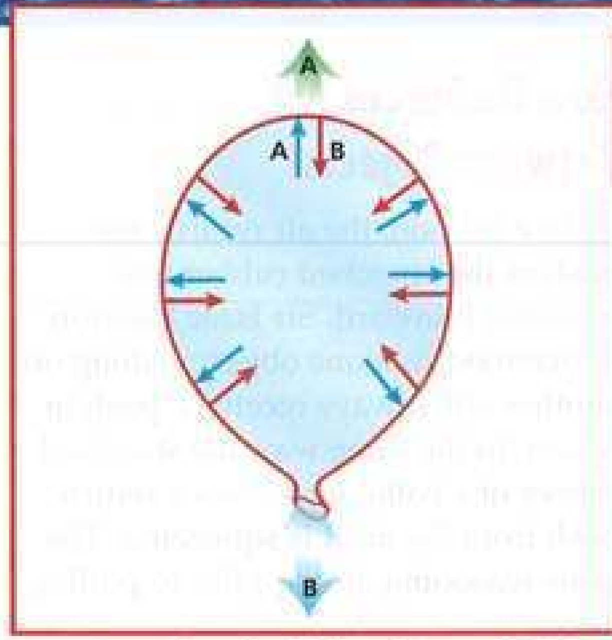
The rocket in the picture is accelerating upward due to the force provided by its engine. Fuel has been burned into hot gases in the engine's combustion chamber. The hot gases rush out of the engine nozzle in a downward direction. How is it that gases rushing down can cause the rocket to accelerate up?

If the rocket is accelerating, it must have an unbalanced force acting on it. Clearly, this force comes from the hot gases in its engines. Knowing the unbalanced force and the rocket's mass, we could calculate the acceleration of the rocket with Newton's second law of motion, $a = F/m$. However, as you will see, it takes another law of motion to explain how gases rushing one way can accelerate the rocket in the opposite direction.





All the way around the balloon, the inward push of the stretched rubber is balanced by the return outward push of the air. The balloon neither expands nor contracts, and it is not moved in any direction.



Force A pushes the balloon forward. When the balloon is opened, there are no longer any forces at the opening to offset forces A and B. Force B makes air rush out of the balloon, as shown by arrow B.

Making a Rocket Go

When you blow up a balloon and then release it without tying it closed, it flies through the air. You can take advantage of this behavior to make a balloon rocket. You know that air rushes out one end of the balloon, while the balloon itself moves in the opposite direction. Where do the forces come from that move the balloon and the air?

The air inside the balloon is "squeezed" by the stretched rubber. At the same time, the air resists being squeezed and pushes back on the rubber. When the balloon is inflated and tied off, these pushes are in balance and the balloon neither changes in size nor moves.

What happens if we leave the neck of the blown-up balloon open, instead? At the point of the opening, there is no stretched rubber squeezing the air. However, there *is* stretched rubber squeezing the air at a point opposite the opening. As a result, there is a net force on the air that pushes it out through the opening.

At the same time, the air pushes forward on the balloon opposite the opening. There is no such push at the opening itself, because there is no rubber surface on which the air can push. Since the push of the air forward on the balloon is not offset by any rearward push, an unbalanced force results that pushes the balloon forward.

What force makes a balloon rocket go forward?

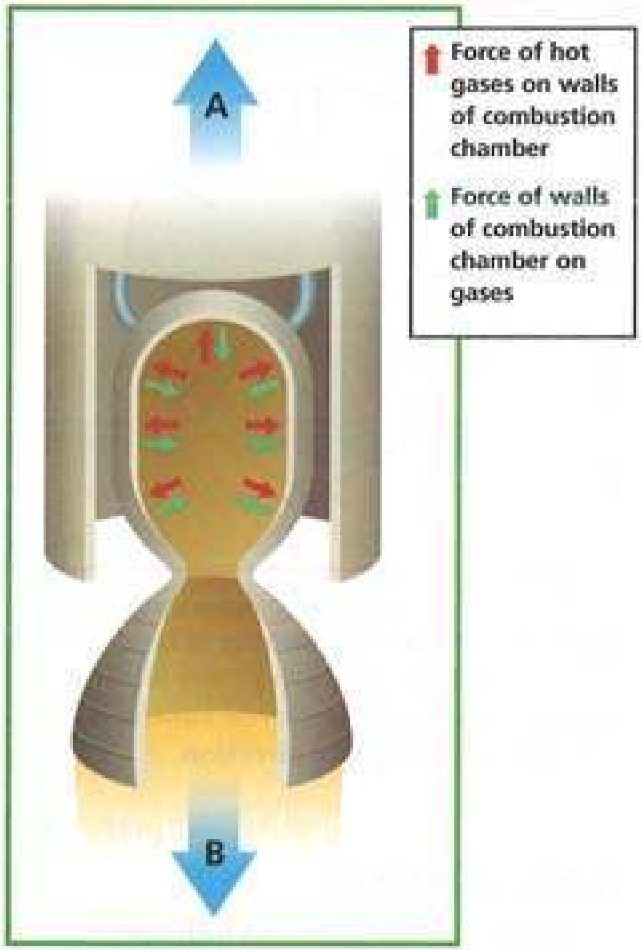
How Do Forces Act Between Objects?

In a balloon, the air returns the push of the stretched rubber that squeezes it inward. Sir Isaac Newton understood that one object pushing on another will always receive a push in return. In the same way, the stretched rubber of a balloon receives a return push from the air it is squeezing. The same reasoning also applies to pulling forces.

When one object applies a force to a second, we call this force the **action**. The force the second object returns to the first is called the **reaction**. Think about what happens when a 50-kg student on ice skates pushes forward on another 50-kg student on ice skates. Both of them wind up moving at the same speed, but in opposite directions. Newton realized that while the action and reaction act in opposite directions, they have the same strength. These ideas are summarized in *Newton's third law of motion*: For every action, there is an equal but opposite reaction.

An accelerating race car demonstrates Newton's third law. The car's tires push to the rear on the road surface. At the same time, the road pushes back on the tires in a forward direction. This reaction force is what propels the car ahead.

Gas rushing out of a rocket engine propels the rocket in the opposite direction. The hot gas tends to expand, so it applies an action force to the walls of the combustion chamber. The walls apply a reaction force to the gas similar to the balloon rocket. The gas pushes the rocket ahead, while the walls of the chamber push the gas to the rear, out through the nozzle.



Action A is an unbalanced force that propels the rocket ahead. Reaction B is an unbalanced force that pushes the hot gases out through the nozzle.

When one object applies a force to another, both objects feel force. The second object feels the action force, while the first object feels the reaction force. If these forces are not balanced by other forces, *both* objects will accelerate.

What happens when one object exerts a force on another?

How Do Forces Affect Us?

Everywhere around us, forces act. Newton's laws of motion give us a useful picture of the way forces work. They also tell us how to predict what will happen when forces are applied to objects. Look at the examples of forces on this page. Think about how Newton's laws explain what is occurring in each case.

The water coming from this hose is under very high pressure. The water applies a large force back on the hose. The firemen have to use great strength to keep the hose from getting loose and flying around dangerously.

The bat applied a force to the ball and sent it flying to the outfield. At the same time, the ball applied a force to the bat, in this case enough to break it!

The hot gases in the jet engines push it forward, while the engines force the hot gases rearward.

How are forces affecting the racing boat?

The crew on this racing craft push on the water with their oars. The water, in turn, pushes back on the oars and moves the boat forward.

What Is a Simple Machine?

People use forces like pushes and pulls to do work. To a scientist, **work** means using force to move an object through a distance. Holding this book in your hand requires force, but no work is done because there is no movement. Opening this book and turning its pages is easy work. When you have to move a heavy object, work is not easy.

Simple machines are devices with few moving parts that make work easier to do. They lower the force needed to move and lift heavy objects and loads. There are six types of simple machines—levers, wheels and axles, pulleys, inclined planes, wedges, and screws.

Levers

Levers help you lift heavy loads or change the direction of a force. A **lever** consists of a rigid bar that rests on a pivot point or **fulcrum**. The lever turns up or down around the fulcrum.

The part of the lever you apply an input effort force to is the **effort arm**. The **resistance arm** of the lever produces an output force to lift the load. If the effort arm is longer than the resistance arm, the lever changes a small input force into a larger output force. In all machines, applying a small input force over a longer distance produces enough work to move a much heavier load a shorter distance. Both arms do the same amount of work. Energy is not being created.

ramp (inclined plane)

pliers (lever)

screw

pulley

old-fashioned bicycle (wheel and axle)

ax (wedge)

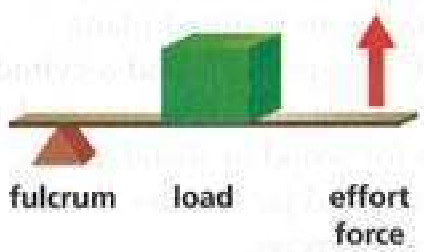
There are three types of levers: first-class, second-class, and third-class. They differ in the positions of the effort arm, resistance arm, and fulcrum.

First-Class Levers

These change the direction of the force and include seesaws and rowboat oars.

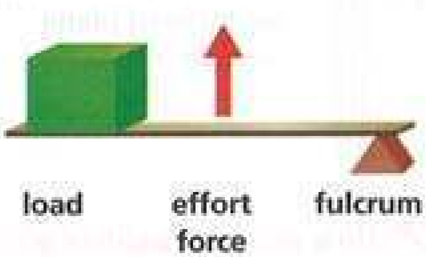
Second-Class Levers

These increase the force used and include wheel barrows and nutcrackers.



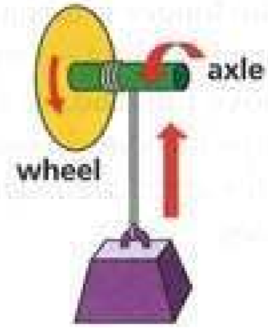
Third-Class Levers

These increase the speed and distance over which a force acts and include fishing rods and baseball bats.



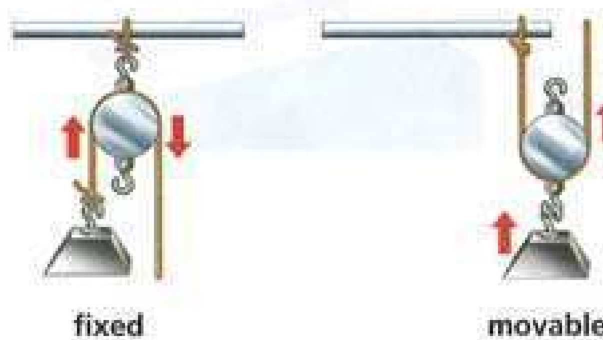
Wheels and Axles

A large-diameter wheel rotates in a circle around a small-diameter axle. A small amount of input force on the wheel becomes a large force on the axle. Doorknobs and screwdrivers use wheels and axles in this way.



Pulleys

A pulley is a wheel with a groove in the rim. A rope fits into the groove. A fixed pulley changes the direction of the effort force. However, the input force must equal the load. A movable pulley decreases the effort force needed to move the load. The rope moves a long distance to move the load a short distance. Pulley systems can combine fixed and movable pulleys.

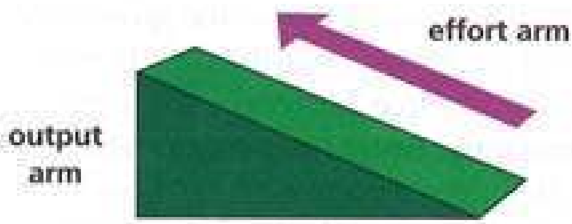


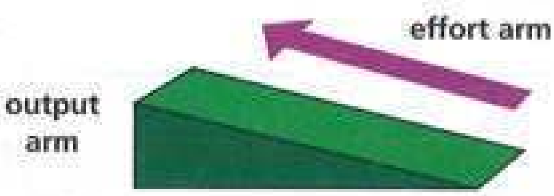
How does a small input force become a big output force?

What Is an Inclined Plane?

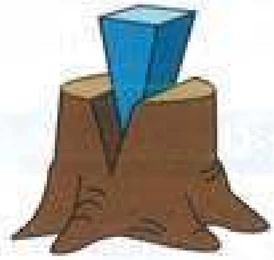
An inclined plane is a flat, slanted surface that makes it easier to move heavy objects to higher levels. The slanted surface is the effort arm. The vertical end of the plane is the output arm. The less steep the slope of the effort arm, the longer it is than the output arm and the less effort is needed to move the load up the ramp. Loading ramps for warehouses and gangplanks for ships are examples of inclined planes.

Inclined plane





Wedge



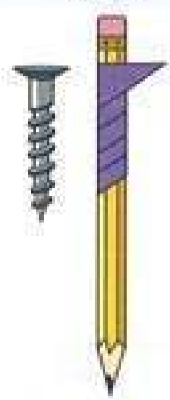
Wedges

A wedge is an inclined plane that is used as a tool for cutting or separating things. Some wedges consist of two inclined planes put together back to back so their slanted sides face outward. The thinner the wedge, the greater is the output force. Needles, ax blades, knife blades, and log splitters are examples of wedges.

Screws

A screw is an inclined plane wrapped in a spiral around a cylinder or cone. Screws and bolts are used as fasteners for wood or metal. Drills, corkscrews, and jar lids are also examples of screws.

Screw



To make a screw, wrap an inclined plane around a cylinder.

How does an inclined plane make loading a truck easier?

Lesson Review

L·I·N·K·S

Why It Matters

In the weightlessness of outer space, it is important to be aware of even small accelerations. While weight seems to disappear in orbit, small accelerations remain, such as gradual slowing due to tiny amounts of air resistance. Measuring these accelerations is important in studying things such as crystal growth and fluid flow in space.

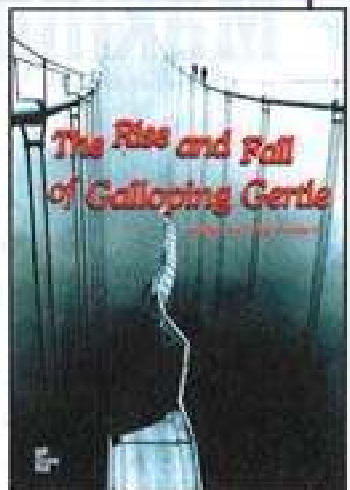
e-Journal Visit our Web site **www.science.mmhschool.com** to do a research project on force and motion.

Think and Write

1. How do you find an object's acceleration from its mass and the force acting on it?
2. How can a boat move at constant velocity if its propeller provides a steady force to it?
3. A 1-kg magnet and a 0.5-kg piece of steel are 25 cm apart. Then they are attracted together. How do they move?
4. How does a lever increase the output force?
5. **Critical Thinking** If you hold a helium-filled balloon in a car with the windows up, the balloon moves forward when the car speeds up and backward when it slows down. Why do you think this happens?

LITERATURE LINK

Read *The Rise and Fall of Galloping Gertie*, to learn about a bridge that was destroyed by wind. When you finish reading, think about how you would design a safer bridge. Try the activities at the end of the book.



WRITING LINK

Personal Narrative What kinds of simple machines do you use every day? Write a letter to a friend telling about the machines you use that make your life easier. Use the correct form for writing a friendly letter.

MATH LINK

Solve this problem. Examine the equation $a = F/m$. Without using numbers, explain what happens to the acceleration if the force increases. Prove it using the equation. What happens to acceleration if mass increases?

TECHNOLOGY LINK

LOG ON Visit **www.science.mmhschool.com** for more links.

Making It Easy with Machines

You use machines every day of your life. Machines help you make dinner, cut the grass, and visit your friends. The can openers, lawn mowers, and bikes we use today evolved from six basic, simple machines that people have used for thousands of years. Most machines are compound machines, which are just combinations of the simple machines.

These inventions make life much easier. But even with the help of a machine, work is not effortless. To do work, every machine needs an energy source. This can be you, the wind, batteries, or fuel. Car engines burn gasoline to power their motion.

A car is basically a combination of two machines: an engine and a transmission. The transmission uses wheels and axles, levers, and gears to turn work from the engine into rotation of the wheels. At 55 miles per hour, the tires spin 750 times a minute. A car has over 15,000 parts and may seem complicated. But at its heart, it's just a collection of simple machines.

The great thing about machines is that we can use them to make other machines. So our machines get bigger and better every year. In the 1800s, it took a dozen people a full day of hard work to cut down five acres of grain. Today, using a machine called a combine harvester, a single farmer can harvest that much grain in an hour, while listening to music!

Let's hear it for machines!

The levers and wheels of a can opener make it easier to fix dinner.

Put the power to the pedal, and the gears and wheels of a bike will get you where you want to go.

The combine harvester not only cuts down the grain, it also sieves it, threshes it, stores it temporarily, and then pours it into the back of a truck. Quite a combination!

Write About It

1. Name three sources of energy used to make a typical car run. (One may not be so obvious.) Explain how each energy source is used to operate the car.
2. Describe how a machine that you see every day helps you to do work.

LOG ON Visit www.science.mmhschool.com to learn more about machines.

LESSON 3

Newton's Law of Gravitation

Vocabulary

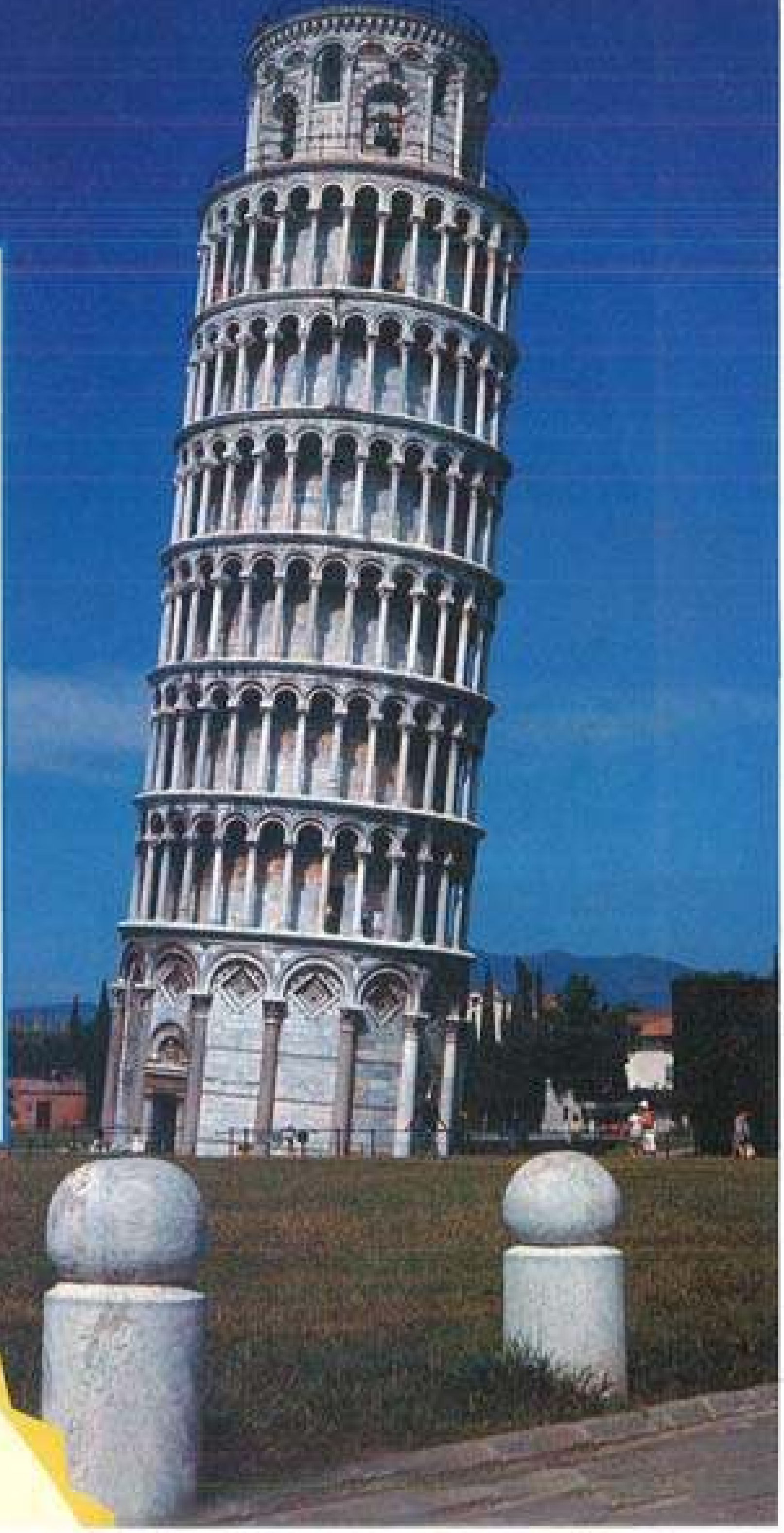
gravity, F35
weight, F36

Get Ready

Think about what happens when you drop two objects with very different weights. Does one fall faster than the other? Thanks to scientists such as Galileo and Newton, we now have a good answer to this question.

About 400 years ago, Galileo described a special experiment. Two objects with different weights were dropped at the same time from a tall tower known as the Leaning Tower of Pisa. What do you think happened to the objects in Galileo's experiment?

You drop a golf ball and a table tennis ball side-by-side from the same height. Which do you think will land first?



Inquiry Skill

You predict when you state possible results of an event or experiment.

Explore Activity

Does Weight Affect How Fast an Object Falls?

Procedure

BE CAREFUL! Wear goggles.

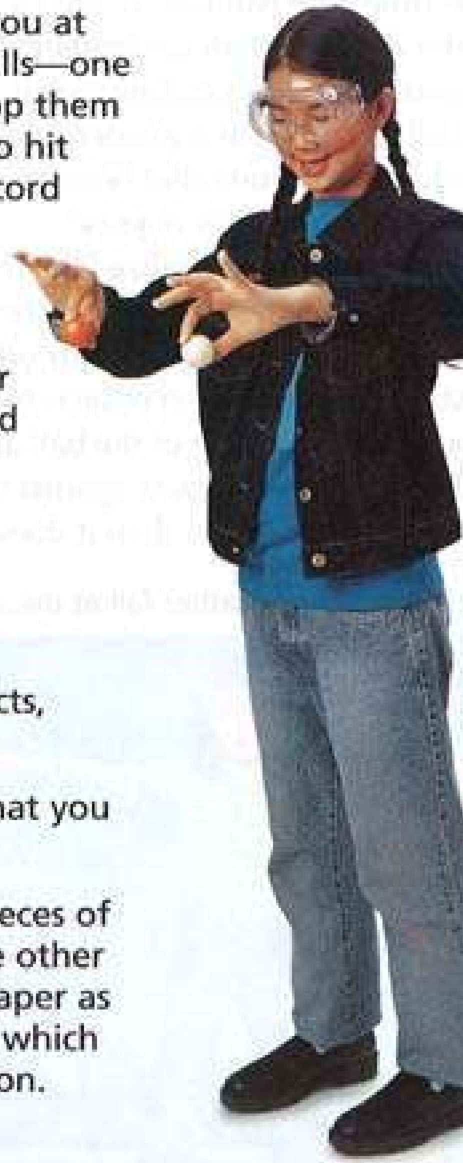
1. **Predict** Do heavy objects fall faster than lighter objects? Record your prediction and your reasons for making it.
2. **Observe** Stretch out your arms in front of you at shoulder height. Hold the two different balls—one in each hand—at the same height, and drop them at exactly the same time. Listen for them to hit the floor. Which one hit the floor first? Record your results.
3. **Experiment** Repeat step 2 several more times to be sure your observations are accurate. Try dropping a pencil or an eraser at the same time as one of the balls. Record your observations.

Drawing Conclusions

1. **Observe** Which ball hit the ground first?
2. **Observe** When you dropped different objects, which hit first, the heavier or the lighter?
3. **Hypothesize** Suggest an explanation for what you observed.
4. FURTHER INQUIRY **Experiment** Take two pieces of paper. Wad one into a tight ball. Leave the other alone. When you drop the two pieces of paper as you did the golf ball and table tennis ball, which will hit the ground first? Test your prediction. Explain your results.

Materials

- table tennis ball
- golf ball
- pencil
- eraser
- goggles



Read to Learn

Main Idea **We are pulled to the ground by the same force that keeps the Moon orbiting Earth, and the planets orbiting the Sun.**

Why Would Air Make a Difference?

The student in the diagram has just dropped a solid rubber ball and a feather from the same height at the same time. The ball has covered a greater distance than the feather in the same amount of time. This means that the ball has fallen at a greater rate. Should we conclude that heavier objects fall faster than lighter objects?

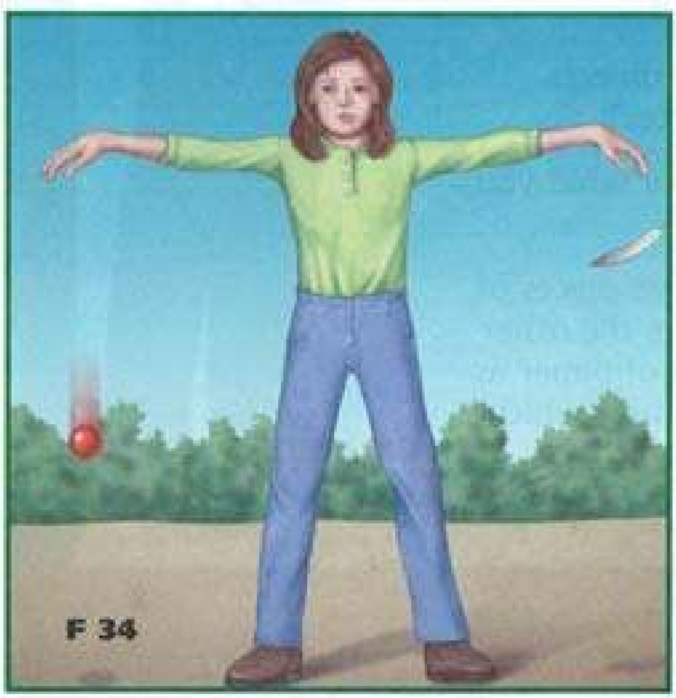
It is important to realize that when the ball and feather are falling, they both must pass through air. Air offers resistance to the motion of objects through it. In the case of the ball and feather, air resistance acts against the feather's motion more than it does against the ball's motion. As a result, the air slows the feather more than it does the ball, and the ball falls farther during the same amount of time.

What would happen, though, if the air were removed so that air resistance disappeared? There is no air on the Moon. If you were to drop a hammer and a feather at the same time on the Moon, would they still fall at different rates? No. Since there is no air resistance, the ball and the feather would fall at the same rate!

Scientists have learned that when the effects of air resistance are removed, objects of different weights do, indeed, fall at the same rate. In addition, air resistance may be too small to matter for objects that are fairly compact. Over short distances such objects fall at the same rate even in air.

How does air affect how a feather falls to the ground?

Do the ball and feather fall at the same rate on Earth as they do on the Moon? Explain.



Before the parachutes open, these skydivers are in *free fall*—falling toward Earth with the acceleration caused by gravity.

What Makes Objects Fall at the Same Rate?

Aristotle was a philosopher who lived in ancient Greece nearly 2,400 years ago. He believed that heavy things fall faster than lighter things. Aristotle's teachings were accepted for nearly 2,000 years after his death.

In the early 1600s, however, Galileo challenged Aristotle's ideas. Galileo reasoned that objects fall at the same rate (ignoring air resistance). To test his ideas about falling objects, Galileo carried out experiments that involved rolling marbles down ramps. He also talked about dropping two objects with different weights off a tall tower to show that they would hit the ground at the same time. Galileo concluded that objects accelerate steadily as they fall and that an object's weight (or mass) does not affect how fast it accelerates when falling.

We know today that Galileo was right. An object is pulled to Earth by gravity, an attraction between the mass of Earth and the mass of the object. Objects with a large mass are pulled on by gravity with more force, but they also have more inertia. (Remember that an object's inertia is its resistance to a change in motion.) This extra resistance to motion exactly offsets the greater pull of gravity on them. Therefore, objects with greater mass fall with the same acceleration as less massive objects!

What force pulls falling objects toward the ground at the same rate?

The 2-kg object is pulled on by twice the force, but its mass is also twice as great, so it has the same acceleration as the 1-kg object.

What Is the Acceleration of Falling Objects?

There is a story that says that a falling apple may have set Isaac Newton to thinking about gravity. In the late 1660s, there was a plague (very bad illness that spread very easily) in Cambridge, England, where Newton had gone to college. To avoid the plague, he went home to the countryside. The legend says Newton was sitting under an apple tree one day when an apple hit him on the head. The legend may or may not be true. However, an idea did hit Newton. That idea was that the force that pulls an apple to the ground is the same force that keeps the Moon in its orbit around Earth.

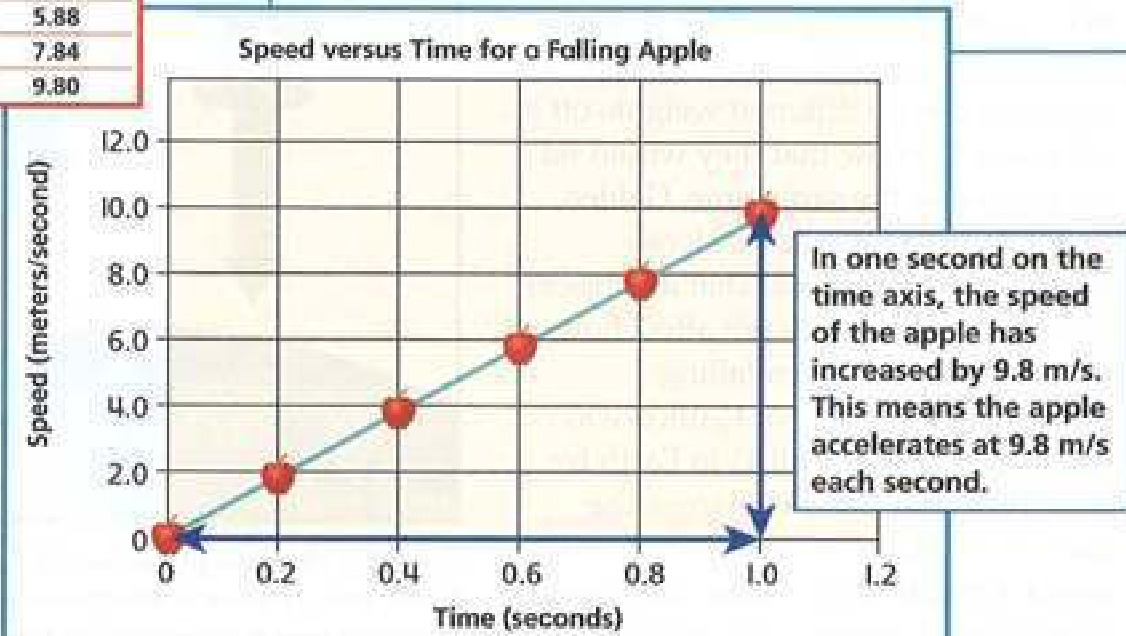
The graph shows how an apple's speed changes as it falls from a tree. Since the apple's speed changes, it must be accelerating. This, in turn, means that it is acted on by an unbalanced force. The force acting on the falling apple is gravity. We give the force of gravity on any object a special name—**weight**. It is the weight of the apple that makes it accelerate to the ground. You can find

Speed Versus Time for a Falling Apple

Time (s)	Speed (m/s)
0.0	0.00
0.2	1.96
0.4	3.92
0.6	5.88
0.8	7.84
1.0	9.80

READING Graphs

What if the apple fell for a full two seconds? Ignoring air resistance, what speed would it reach?



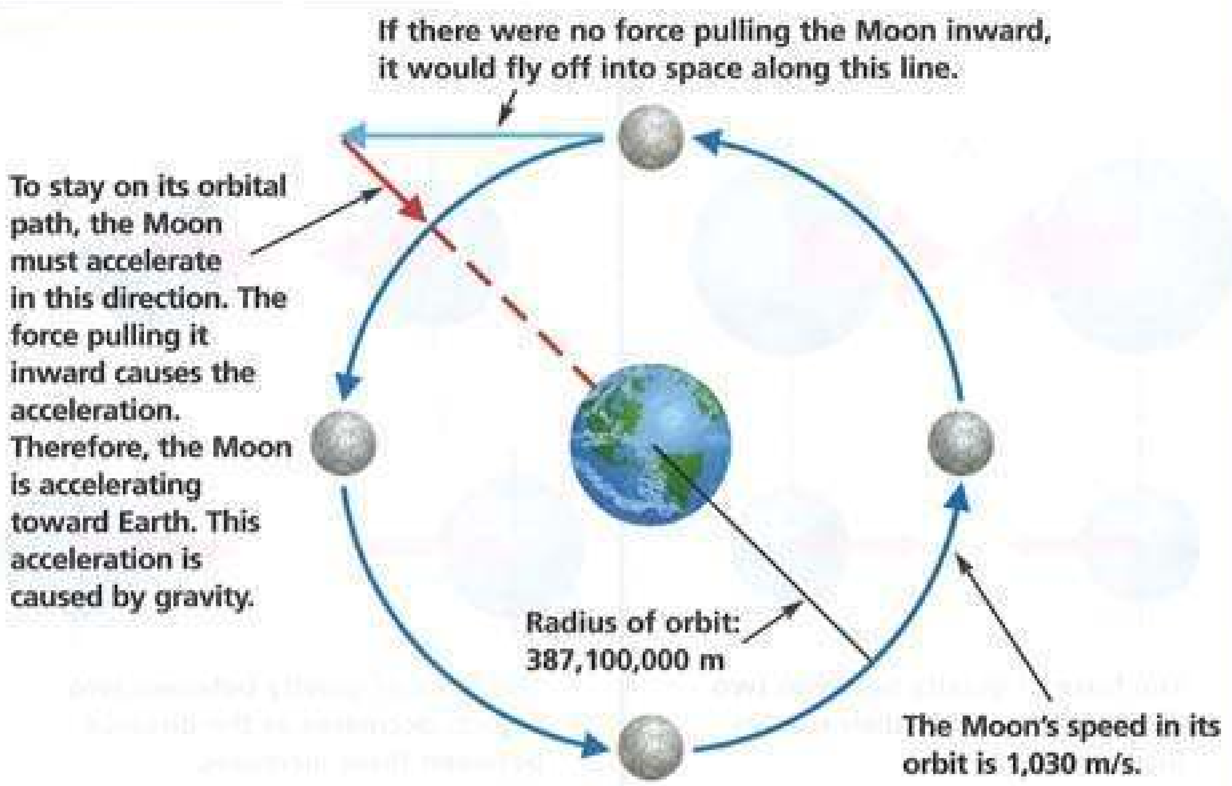
the weight in newtons of any object by multiplying its mass in kilograms by 9.8. If the apple has a mass of 0.4 kg for example, its weight is 0.4 x 9.8 = 3.92 N.

The weight or mass of an object does not affect how fast it accelerates when falling (if we ignore air resistance). This means that all objects accelerate to the ground at 9.8 meters per second each second. Put another way, the speed of any object falling to the ground increases by 9.8 meters per second each second. However, as you will soon learn, this value is only true for objects falling near the surface of Earth.

Isaac Newton once wrote, "I began to think of gravity extending to the orb [orbit] of the Moon." He wondered if the gravity of Earth could be the force that holds the Moon in its orbit. Just as there is a force between an apple and Earth, there is a force between the Moon and Earth. The force is stronger if the objects are more massive, but it is weaker the farther they are apart. The Moon is much more massive than an apple. However, the Moon is also much farther from Earth's surface than an apple hanging on a tree is. Even so, the same force that pulls the apple to the ground keeps the Moon from flying off into outer space. A combination of the Moon's inertia and the force of gravity between Earth and Moon keeps the Moon orbiting Earth.

How fast do falling objects on Earth fall toward the ground?

The Moon's Acceleration



How Can Gravity Be Universal?

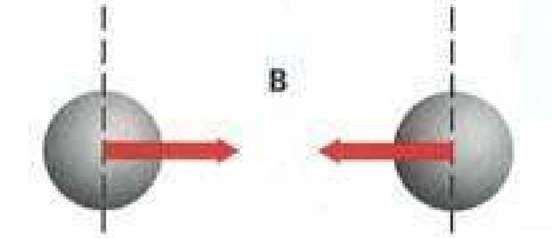
When Isaac Newton discovered that Earth's gravity held the Moon in orbit, he next applied his ideas to the planets in the solar system. Could the Sun's gravity hold the planets in their orbits? First, Newton had to work out how the strength of the force depends on the mass of the Sun and each planet.

Newton decided that as mass increases, the force of gravity also increases. From his third law of motion, he knew that two objects pull on each other due to gravity. Then he reasoned that increasing the mass of either object will increase the force of gravity.

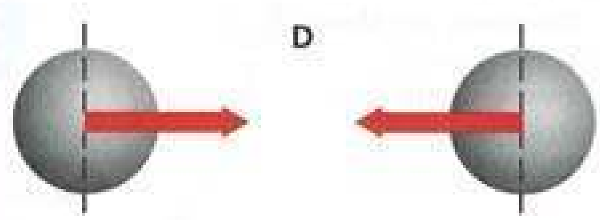
In thinking about the Moon, Newton had already inferred how gravity would change with distance. Putting all of his ideas together, he arrived at another law. This is *Newton's law of universal gravitation:* The force of gravity between two objects increases with the mass of the objects and decreases with the distance between them squared.

Newton's law of gravity is "universal" because it applies to any objects, not just moons, planets, and stars. We could find, for example, the force of gravity between two cars in a parking lot. For light objects the force of gravity is quite weak—it will not pull two parked cars together. For massive objects like moons, planets, and stars, though, the masses are so large that the force of gravity becomes very large also.

What does it mean to say that the law of gravity is universal?



The force of gravity between two objects increases as their masses increase.



The force of gravity between two objects decreases as the distance between them increases.

Inquiry Skill BUILDER

SKILL Use Numbers

What Do I Weigh on Other Worlds?

The Sun, planets, and moons in the solar system have different masses and radii. This causes the force of gravity at their surfaces to vary from world to world (for a gaseous planet, the "surface" is the top of its atmosphere). As the mass of any world increases, surface gravity tends to be stronger. However, as the radius increases, surface gravity tends to weaken. How would your weight change from one world to the next?

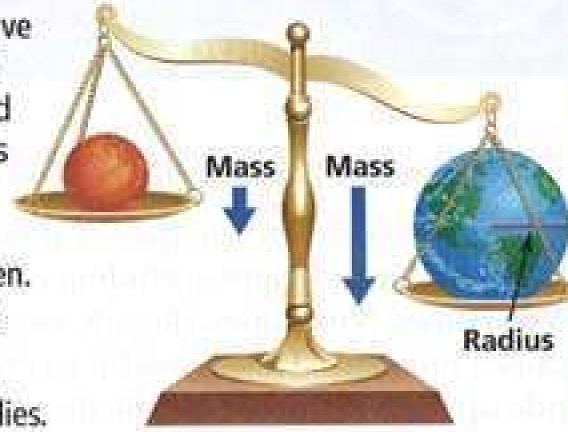


Table 1 lists gravity multipliers for solar system bodies. These values show the combined effect of the objects' different masses and radii on surface gravity compared with Earth. You can use the gravity multipliers to find your weight on other worlds. Just multiply your weight on Earth by the gravity multiplier for the new world. On Neptune, for example, your weight would be your weight on Earth multiplied by 1.1.

Table 1

Object	Gravity (Earth = 1)
Sun	28
Moon	0.16
Mars	0.38
Jupiter	2.6
Saturn	1.07
Neptune	1.1
Venus	0.91
Mercury	0.38
Uranus	0.91

Procedure

1. **Analyze** Study Tables 1 and 2. Look carefully to see how numbers were used in the examples in Table 2.
2. **Use Numbers** Copy and complete Table 2.

Table 2

World	Weight of a 250-Pound Astronaut	Your Weight in Pounds
Sun	7,000 lb	
Moon		
Mars	95 lb	
Jupiter		
Saturn		
Neptune		
Venus		
Mercury		
Uranus	227.5 lb	

Drawing Conclusions

1. **Predict** A student who weighs 95 pounds on Earth has a mass of about 43 kg. What would the student's mass be on each world above?
2. **Infer** Saturn has much more mass than Earth, but your weight on Saturn is about the same as on Earth. How is this possible?

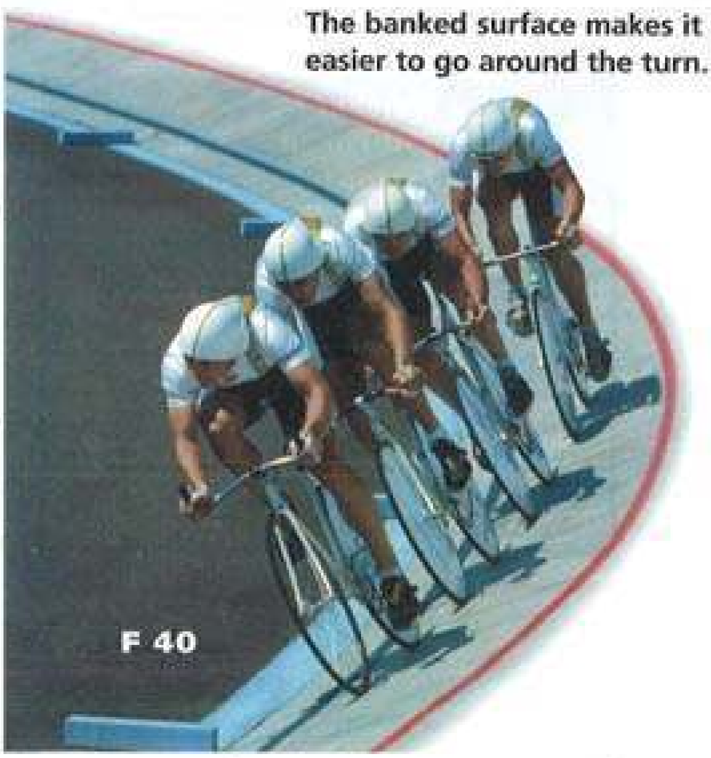
When Is Added Weight Helpful?

We are accustomed to gravity giving things on Earth weight, including our own bodies. Sometimes, though, weight causes problems. How would it feel to ride up a hill on an old bicycle like the one on the left? Compared with the newer one on the right, the older bike is so much more massive that it would take a lot more force to accelerate it. Which would you rather ride?

Older bicycles were made with steel frames. While steel is strong, it is also very heavy. Some modern bicycle frames are made with steel alloys, titanium, aluminum, or carbon fiber. These materials are a great deal lighter than plain steel, and bikes made with them are much easier to pedal. Of course, the lightweight materials are also much more expensive than steel!

In cycling, weight does offer certain advantages. The weight of the rider and bicycle presses the tires against the ground. This downward force creates increased friction between the tires and the road, giving the tires traction. If it were not for the friction, the tires could not push on the road surface to drive the rider forward.

Bicycle racers often travel on a circular path at high speed. There must be a force acting inward on them to change their direction of travel. The banked track they are riding on uses their weight to help provide this force. The weight of each bike and rider presses into the track through the tires. The track, in turn, pushes back through the tires on each bike and rider. Due to the tilt of the track surface, some of this return push is directed inward and can act as the force that changes each bike's direction of travel.


The banked surface makes it easier to go around the turn.

READING **Draw Conclusions**
How is added weight helpful in cycling?

Lesson Review

Why It Matters

On a flat road, the only force available for making cars go around a turn is the friction between the tires and the road surface. In wet or icy weather, the friction may not be strong enough, and the cars can slide off and crash on the turn. If the road is banked like the bicycle race track, though, the inward push of the road surface helps cars to make the turn. The same sort of banking is also done when making auto racetracks.

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Think and Write

1. What causes objects to fall?
2. Ignoring air resistance, why do objects with different masses fall at the same rate?
3. A rubber ball is dropped off a tall tower. After one second, how fast will it be traveling?
4. INQUIRY SKILL **Use Numbers** Two planets in a distant solar system have the same radius but different masses. On which world would you weigh more? Why?
5. **Critical Thinking** How could you carry out a demonstration on Earth of a feather falling at the same rate as a bowling ball?

L·I·N·K·S

MATH LINK

Solve this problem. Look at the tables on page F39. How much would the astronaut weigh on a planet with 1.5 times as much gravity as Neptune?

WRITING LINK

Writing a Story You are a passenger on a space-shuttle flight. You're in orbit. For the first time, you cannot feel your weight. Write a story describing what it feels like to be weightless. Include dialogue with a friend on the ground. Turn your story into a play to perform.

MUSIC LINK

Write a song. Think about what it might be like to live on a world where you weigh half as much as you do now. Write a song describing your experiences.

TECHNOLOGY LINK

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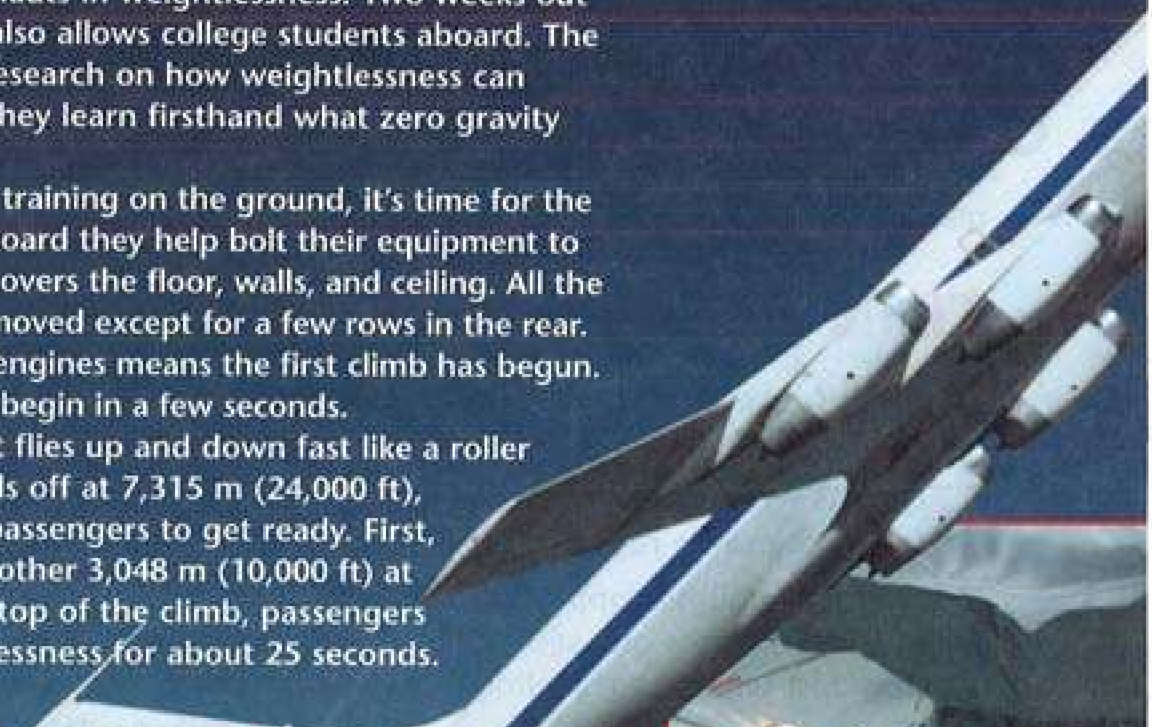
Ride the "Vomit Comet"

It's called the "Vomit Comet," and students can't wait to go on it! It's not an amusement park ride, but it can feel like one. The Vomit Comet is a special NASA aircraft used to train astronauts in weightlessness. Two weeks out of the year, NASA also allows college students aboard. The students conduct research on how weightlessness can affect things, and they learn firsthand what zero gravity feels like.

After testing and training on the ground, it's time for the students to fly. Onboard they help bolt their equipment to the floor. Padding covers the floor, walls, and ceiling. All the seats have been removed except for a few rows in the rear. A deep roar of the engines means the first climb has begun. Weightlessness will begin in a few seconds.

The Vomit Comet flies up and down fast like a roller coaster ride. It levels off at 7,315 m (24,000 ft), and the pilot tells passengers to get ready. First, the plane climbs another 3,048 m (10,000 ft) at high speed. At the top of the climb, passengers experience weightlessness for about 25 seconds. Then, the plane dives 3,048 m (10,000 ft) at high speed. Each climb and dive is called a parabola. Every flight has about 32 parabolas, so passengers have about 13 minutes of weightlessness!



At first, weightlessness is scary. That's because you feel like you're falling. Then, you feel excited because you realize you're floating in space! The hardest part for the students is concentrating on what's happening with their experiments. They have only 25 seconds before the dive!

The dive feels very different. Your body feels much heavier than usual. You can hardly lift your arms. Any movement can make you feel very dizzy. That's because the force you feel pulling down on you is twice the force of gravity.

By the ninth or tenth parabola, some students suffer from motion sickness. They head for the seats in the rear and strap themselves in. It's up to the others to finish the experiments. When it's over, even the sick students say it was the ride of a lifetime. For a short time, they felt just like an astronaut!

Astronauts in training experience several minutes of weightlessness on the Vomit Comet.

What Did I Learn?

1. The Vomit Comet is

A an amusement park ride.
B a NASA aircraft used to train astronauts in weightlessness.
C a special section for student experiments on the space shuttle.
D a strange object from outer space.

2. About how long are the students weightless on a Vomit Comet flight?

F about 13 minutes
G about 25 seconds
H about a day
J about 30 minutes

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Chapter 14 Review

Vocabulary

Fill each blank with the best word or words from the list.

acceleration, F13
balanced forces, F21
force, F6
gravity, F35
inertia, F7
reaction, F24
speed, F11
unbalanced force, F21
velocity, F12
weight, F36

1. How fast the position of an object changes is its _____.

2. An object's speed in a certain direction is its _____.

3. A change in a velocity in a certain amount of time is called _____.

4. How much an object weighs depends on its mass and the force of _____.

5. An object's tendency to resist a change in motion is its _____.

6. An astronaut on the moon has the same mass as she did on Earth, but has less _____.

7. For every action, there is an equal but opposite _____.

8. Pushes or pulls which completely cancel one another out are called _____.

9. A push or pull that acts on an object is called a(n) _____.

10. Pushes or pulls which are not cancelled by other pushes or pulls are called _____.

Test Prep

11. Gravity is a _____.

A velocity
B speed
C force
D weight

12. When object A exerts a force on object B, object B _____.

F doesn't move
G exerts a reaction force on object A
H doesn't affect object A
J exerts an action force on object A

13. A mass accelerates because _____.

A it has inertia
B it is moving
C it isn't moving
D a force is acting on it

14. An object is accelerated when it is acted on by _____.

F an unbalanced force
G a balanced force
H inertia
J velocity

15. A baseball and a sheet of paper are dropped at the same time from the same height. If there is no air resistance ______.

A the baseball will land first

B the paper will float slowly through the air

C the baseball will float slowly through the air

D the baseball and the paper will land at the same time

Concepts and Skills

16. **Reading in Science** How did Newton conclude that the same force that pulls an apple to the ground also keeps the Moon orbiting Earth? Write a paragraph explaining your answer.

17. **Safety** Why do seat belts help protect passengers when a car stops quickly? Write a paragraph explaining your answer.

18. **Scientific Methods** How could you find out how much an object moving in a circle is accelerating? Write up a design for an experiment that would test this.

19. INQUIRY SKILL **Use Numbers** What would a 100-kg astronaut weigh on a planet with five times the gravity of Uranus? Write a paragraph explaining how you would find the answer.

20. **Critical Thinking** You are sitting on a playground merry-go-round holding a cup of water. What happens to the water in the cup as the merry-go-round spins faster and faster? Write your ideas. Describe how you might test them.

Did You Ever Wonder?

INQUIRY SKILL **Make a Model** Draw a girl on a trampoline. Draw her going up, coming down, and at rest. Digital scales in her sneakers provide data to a wireless readout. She weighs 396 N (about 88 lbs). Predict her weight in each position. Discuss your drawings.

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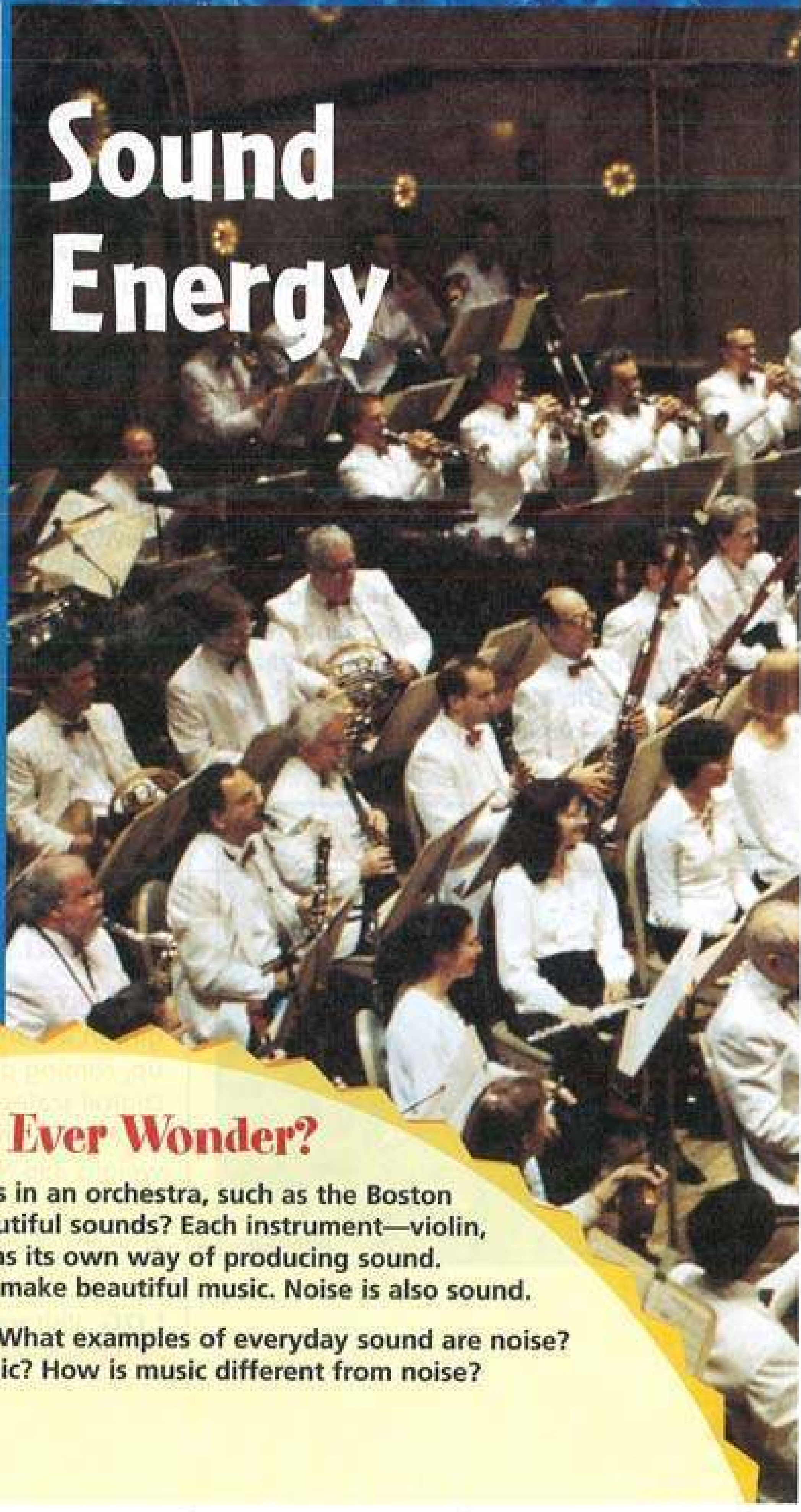
CHAPTER 15

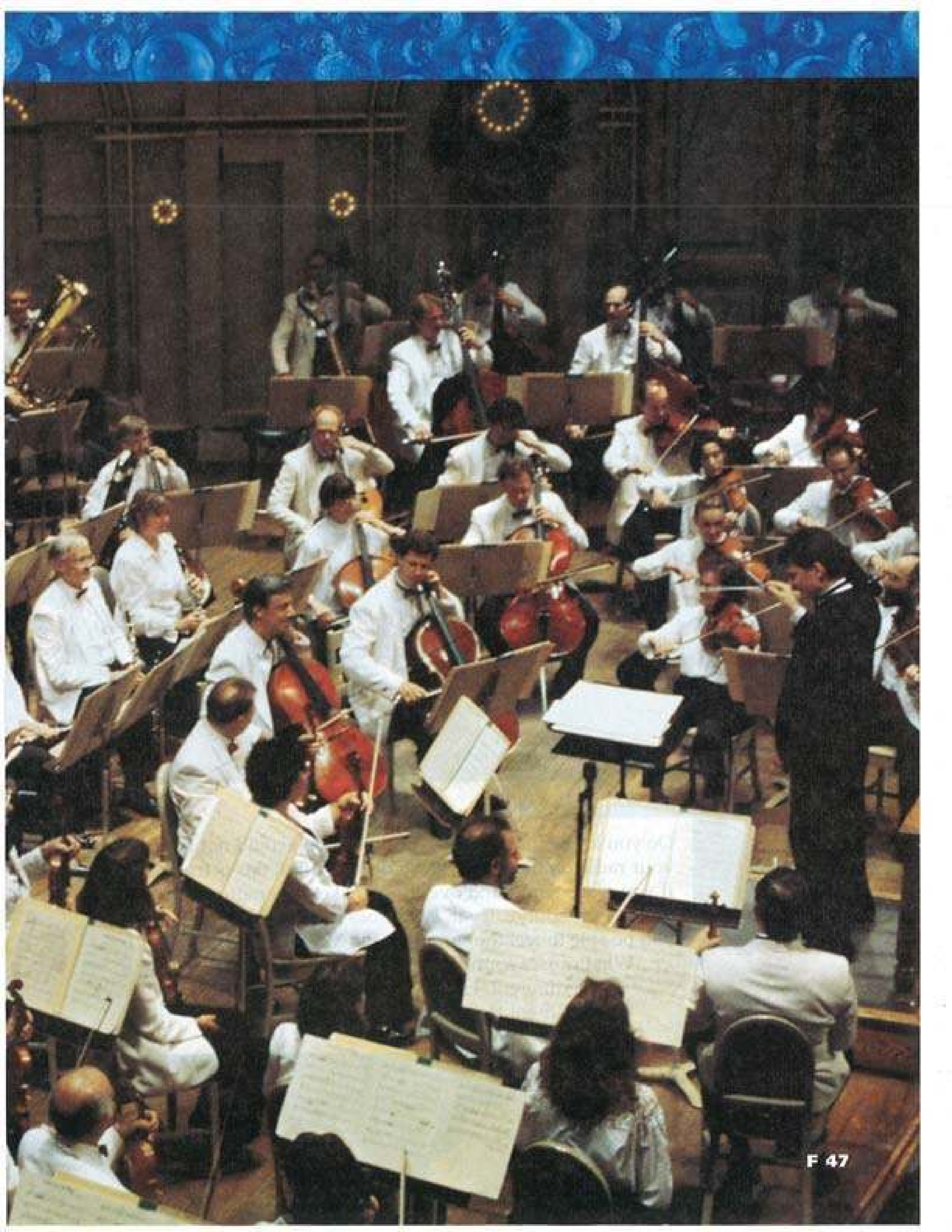


Sound Energy

Did You Ever Wonder?

How do the instruments in an orchestra, such as the Boston Pops, produce such beautiful sounds? Each instrument—violin, tuba, drum, clarinet—has its own way of producing sound. The sounds combine to make beautiful music. Noise is also sound.

INQUIRY SKILL **Classify** **What examples of everyday sound are noise? What examples are music? How is music different from noise?**



LESSON 4

Sound Waves

Vocabulary

vibration, F50
matter, F51
sound wave, F51
compression, F51
rarefaction, F51

Get Ready

Do you know that without earphones you could not hear your radio on the Moon? Why do you think this is true? If you place your hand over the speaker of a radio, you can feel the sound. Try it. Why does it happen? Would you be able to feel the sound on the Moon?

What causes sound? Keep in mind that sounds can be different. How could you build an instrument to test your ideas?

Inquiry Skill

You predict when you state possible results of an event or experiment.

Explore Activity

What Makes Sound?

Procedure

BE CAREFUL! Wear goggles.

1. As you do this activity, observe how sounds are made and changed. Poke a hole in the bottom of the cup. Cut the rubber band. Insert one end into the hole. Make two or three knots in the end to keep it in place.
2. Tape the cup and the stretched rubber band securely to the ruler as shown.
3. **Observe** Hold the cup next to your ear. Pluck the rubber band. Watch a partner do the same thing. Record what you hear and see.
4. **Experiment** Put one finger on the rubber band, hold it against the ruler, and then pluck it again. What happens to the sound?

Drawing Conclusions

1. **Infer** What did you observe that made your instrument work? How can you explain what makes sound?
2. What happened to the sound when you changed the rubber band with your finger? Explain why, based on your observations.
3. **FURTHER INQUIRY** **Predict** What do you think will happen to the sound if you stretch the rubber band tighter? Untape the end of the rubber band and pull it a bit tighter. Retape the end to the ruler. Repeat steps 3 and 4. How do the results compare with your prediction? Give reasons for what happened.

Materials

- wood or plastic ruler
- long rubber band
- plastic or foam cup
- clear tape
- ballpoint pen
- scissors
- goggles

Read to Learn

Main Idea **Sound is provided by the vibrations of objects.**

What Makes Sound?

Sound is provided by making something move back and forth. You can't produce a sound without making something move. If you pluck a rubber band, the rubber band moving back and forth produces twanging sounds. This back-and-forth motion is called a **vibration**. Unless something vibrates, there can be no sound. Many vibrations are too fast for you to see. You may not see the bat vibrating when the ball hits it, but you can still feel it.

Energy Transfer

If you pluck a guitar string, you can see it moving back and forth. You provide the energy necessary for this vibration when you pluck it. This energy is transferred to the rubber band and causes it to vibrate. When you touch the rubber band, you can feel it vibrating.

What can you notice if you place your fingers gently against your throat while you talk or hum? You can feel a vibration. You feel the vibration of your vocal cords. Vocal cords in your throat vibrate when air moves past them, allowing you to speak.

What vibrates when you play a guitar? When the strings of a guitar or violin are bowed or plucked, they begin to vibrate. They produce sounds. However, not all instruments rely on strings. Sounds can also be produced by vibrating surfaces and by vibrating columns of air. The instruments in each section of the orchestra have their own characteristic ways of producing sounds. In each section different materials vibrate.

How Sound Is Produced




Brass	Woodwinds	Percussion	Strings
Vibrating Air	Vibrating Reed	Vibrating Surface	Vibrating Strings
Trumpet Tuba Trombone French Horn	Oboe Clarinet Saxophone Bassoon **Vibrating Air** Flute Piccolo	Drums Piano Tambourine Cymbals Triangle Xylophone	Guitar Violin Viola Cello Harp Bass Banjo

READING Charts

Which two sections of the orchestra are most alike? Explain.

Sound Waves

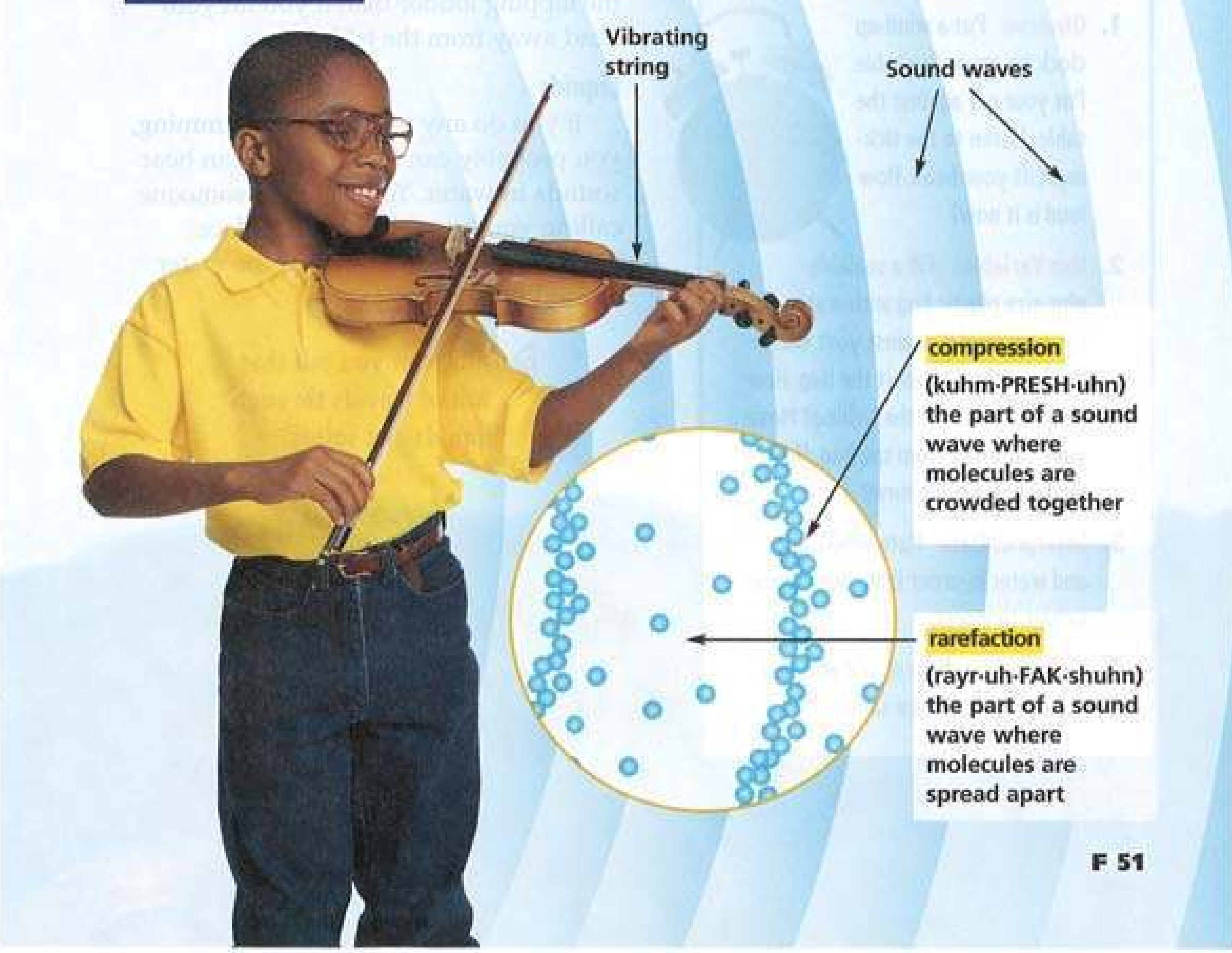
Sound is a vibration that travels through **matter**. Matter is anything that has mass and takes up space. Matter can be a solid, liquid, or gas. Some types of matter are made of pieces too small to be seen, called *molecules*. Molecules are the smallest pieces that matter can be broken into without changing the kind of matter.

How does the sound made by a vibrating string travel? When a string vibrates, it makes molecules of gases in the air next to it vibrate. The molecules squeeze together, then spread apart. The vibrating molecules near the string then make the molecules next to them start to vibrate.

The vibration continues to spread. A vibration that spreads away from a vibrating object is a **sound wave**. It carries the energy from the vibrating object outward in all directions.

READING **Cause and Effect**
What has to happen to make sounds travel?

Sound Waves



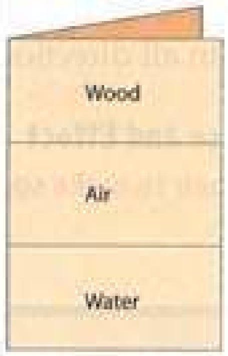
compression (kuhm·PRESH·uhn) the part of a sound wave where molecules are crowded together

rarefaction (rayr·uh·FAK·shuhn) the part of a sound wave where molecules are spread apart

QUICK LAB

Sound Carriers

FOLDABLES Make a Three-Tab Book. (See p. R 43.) Label as shown. Record your observations in the Three-Tab Book.



1. **Observe** Put a wind-up clock on a wooden table. Put your ear against the table. Listen to the ticking. Lift your head. How loud is it now?
2. **Use Variables** Fill a sealable pint-size plastic bag with water. Seal the bag. Hold it against your ear. Hold the clock against the bag. How well can you hear the ticking? Move your ear away from the bag. How loud is the ticking now?
3. **Interpret Data** Rate wood, air, and water in order from best sound carrier to worst.
4. **Experiment** How would you test other materials, like sand?

What Else Can Sound Go Through?

When you hear sounds, what is usually around you? Air! You can hear sounds in the air. When sound waves reach your ear, they make parts inside the ear vibrate. Since air is a mixture of gases, you may conclude that sound can travel through gases. It travels as sound waves.

Solids

Can sound also travel through solids and liquids? You can tell that sound travels through solids just by putting your ear onto a tabletop. If someone taps the table at the other end, you can hear the tapping louder than if you lift your head away from the table.

Liquids

If you do any underwater swimming, you probably can tell that you can hear sounds in water. You can hear someone calling you from above the surface. You can also hear sounds in the water around you.

How can you tell that sound travels through liquids and solids?

Lesson Review

LINKS

Why It Matters

Sound waves can travel through all forms of matter. Without matter, sound waves could not travel. Can you hear sounds in a vacuum? No. A vacuum is a place where there is no matter.

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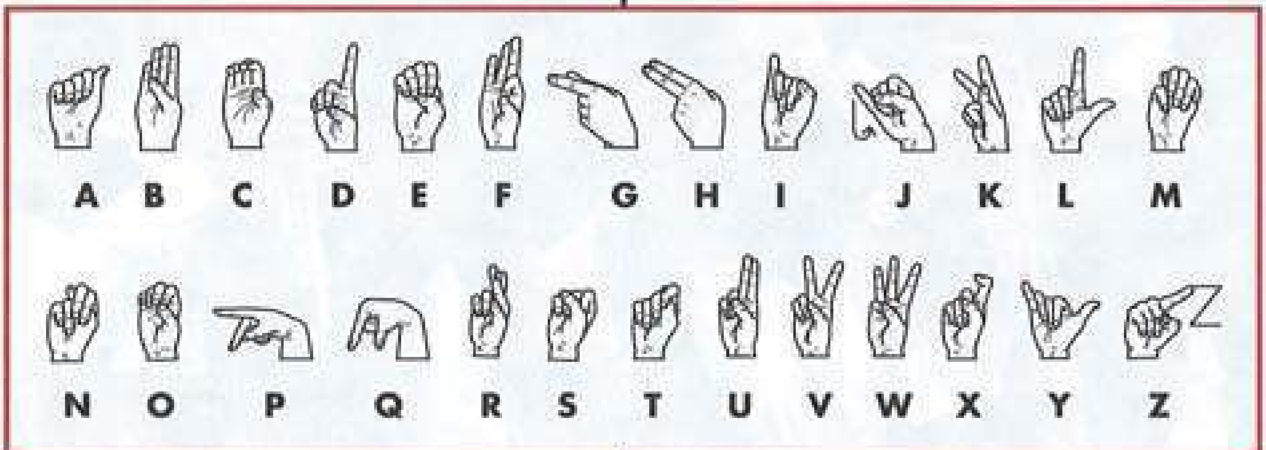
MATH LINK

Solve this problem. A cricket chirps 20 times per minute. How many is that per hour?

WRITING LINK

Explanatory Writing Study the sign-language chart. Write a paragraph to explain how to use sign language.

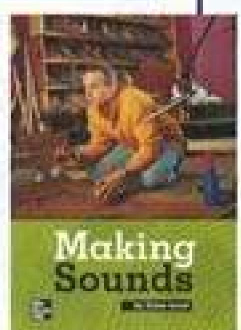


Think and Write

1. What is needed to make sound?
2. What can sounds travel through?
3. How does a vibrating guitar string make sound?
4. How does a drum make sound?
5. **Critical Thinking** What if you put a ticking clock in a box and pump all the air out? The clock is on a thin string so that it is not touching the walls of the box. Would you hear the clock ticking?

LITERATURE LINK

Read *Making Sounds,* to learn how a sound effects studio makes sounds for the movies. When you finish reading, think about how you would make sound effects for a school play. Try the activities at the end of the book.



TECHNOLOGY LINK

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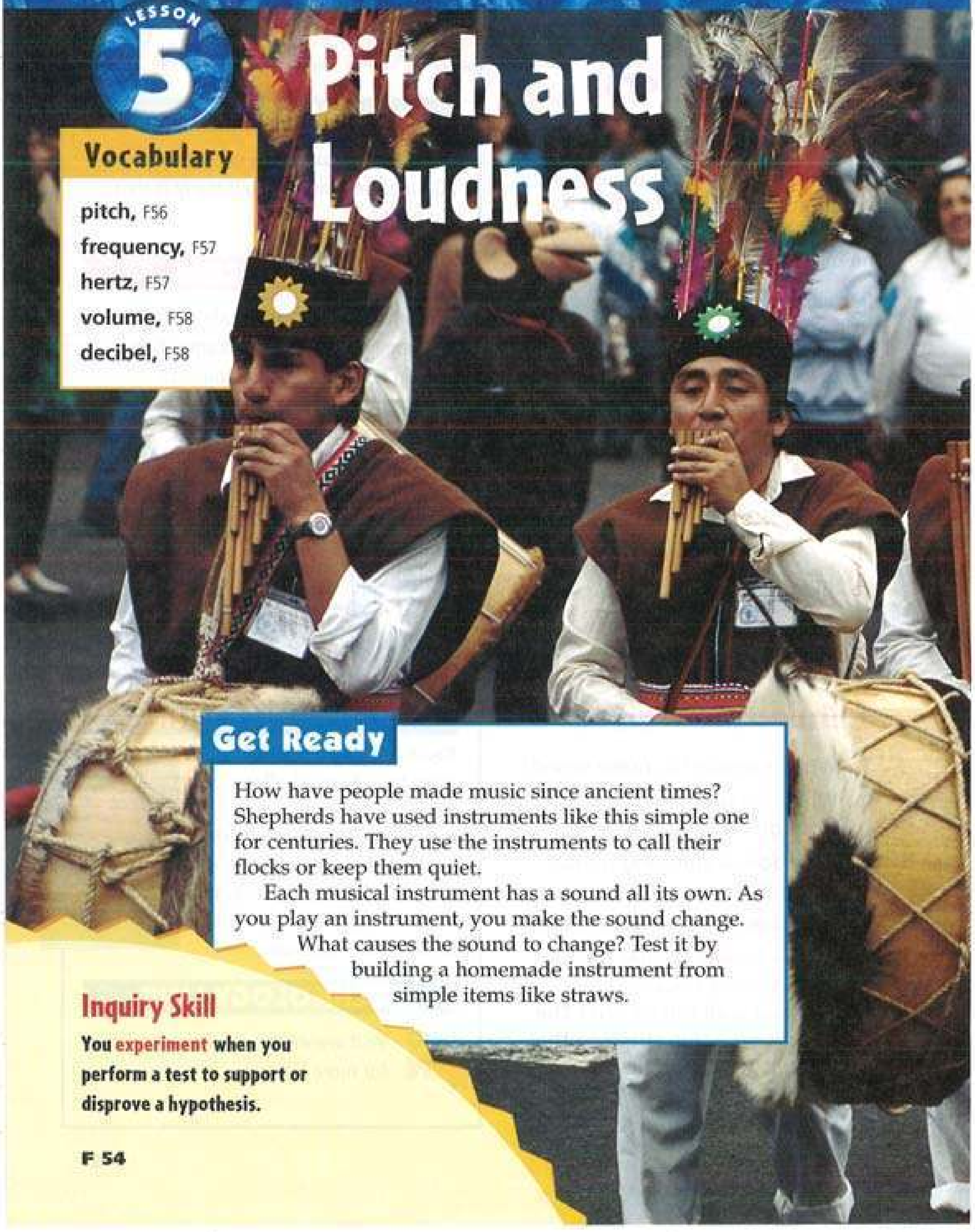
LESSON 5

Pitch and Loudness



Vocabulary

pitch, F56
frequency, F57
hertz, F57
volume, F58
decibel, F58

Get Ready

How have people made music since ancient times? Shepherds have used instruments like this simple one for centuries. They use the instruments to call their flocks or keep them quiet.

Each musical instrument has a sound all its own. As you play an instrument, you make the sound change. What causes the sound to change? Test it by building a homemade instrument from simple items like straws.

Inquiry Skill

You experiment when you perform a test to support or disprove a hypothesis.

Explore Activity

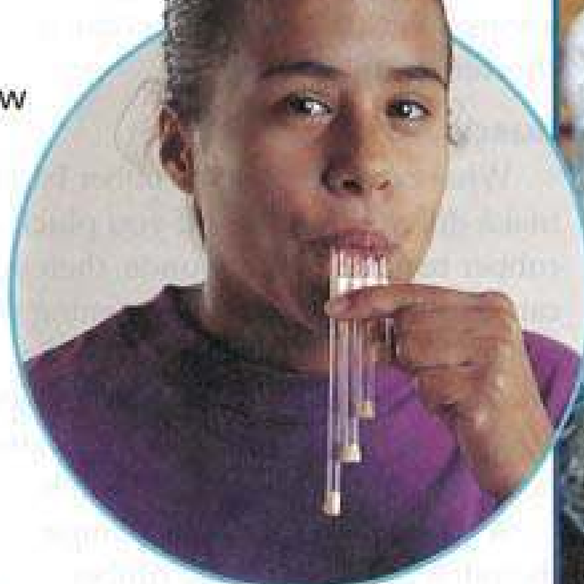
How Can You Change a Sound?

Materials

- 12 plastic drinking straws
- scissors
- metric ruler
- masking tape

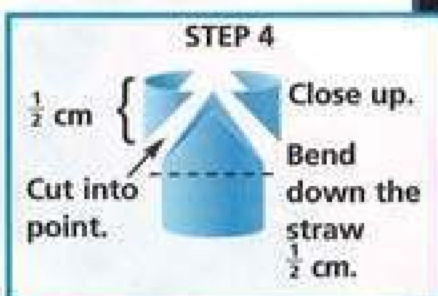
Procedure: Design Your Own

1. **Predict** Work in pairs to make a homemade instrument. Start with straws. Blow over one end of a straw. Will there be a difference if you seal the other end with tape? Record your prediction.
2. **Observe** Tape one end, and blow over the open end. Describe what you hear. Does it work better with or without one end taped?
3. **Classify** Repeat with different lengths cut from a straw. Try at least four lengths. How are the sounds different? Arrange the straws in order to hear the difference.
4. **Experiment** Flatten one end of a straw. Cut the end to a point. Wet it. With your lips stretched across your teeth, blow into that end of the straw. Try to make different sounds with the straw. How might you modify the instrument the girl is using?



Drawing Conclusions

1. **Infer** Why do you think the sounds changed when you cut different lengths of straw? Hint: What is inside a straw—even if it looks empty?
2. **Communicate** Write a description of your instruments for a partner to build them exactly as you did. Include measurements taken with a ruler.
3. FURTHER INQUIRY **Experiment** Try other materials to make other instruments. Try such things as bottles with water, craft sticks, and so forth. Tell what causes the sound to change in each case.



Read to Learn

Main Idea **Pitch and loudness are two characteristics of sound.**

What Is Pitch?

Some sounds are "higher" than others; some sounds are "lower." *High* and *low* are words that describe the **pitch** of a sound. In the sixth century B.C., the Greek mathematician Pythagoras (pi·THAG·uhr·uhs) observed that a longer string produces a sound with a lower pitch than a shorter string.

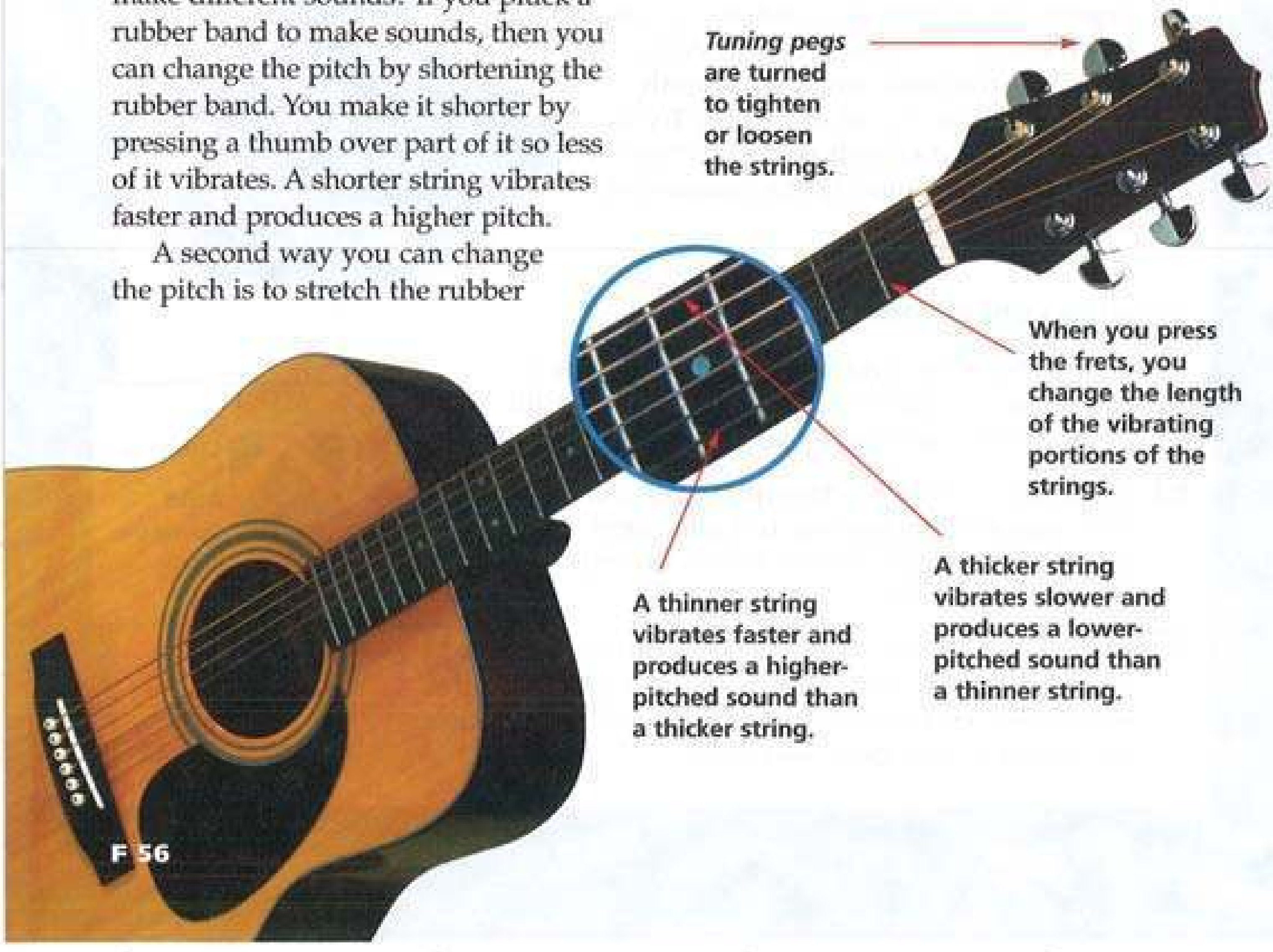
Changes in Pitch

What can you do to a rubber band to make different sounds? If you pluck a rubber band to make sounds, then you can change the pitch by shortening the rubber band. You make it shorter by pressing a thumb over part of it so less of it vibrates. A shorter string vibrates faster and produces a higher pitch.

A second way you can change the pitch is to stretch the rubber band tighter. This causes the rubber band to vibrate faster and, therefore, to produce a higher-pitched sound. The pitch of a vibrating string is also related to its thickness. Compare the strings of this guitar.

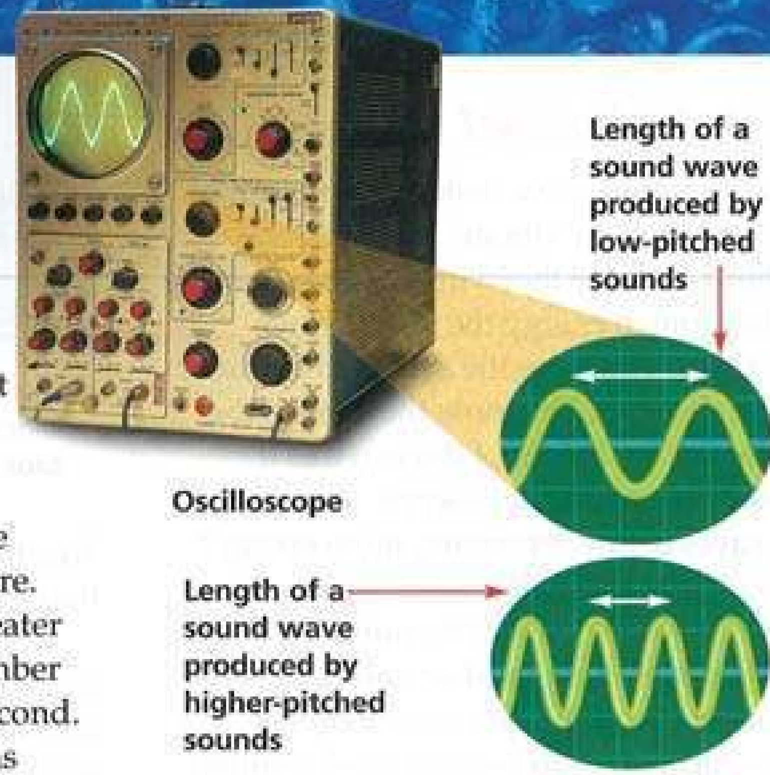
Did you know that the length and thickness of your vocal cords, and how you tighten or relax them, affects the pitch of your voice?

Singers can sing a range from high to lower notes by tightening and relaxing their vocal cords. Men usually have longer and thicker vocal cords than women, so men's voices tend to be lower pitched than women's voices.



Sound Waves

You can't see sound waves, but scientists study them with an oscilloscope. This device makes a "picture" of sound waves. An oscilloscope allows you to compare the waves of sounds that have different pitches.



Oscilloscope

Frequency

The higher the pitch, the more "squeezed together" the waves are. Higher-pitched waves have a greater **frequency**. Frequency is the number of times an object vibrates per second.

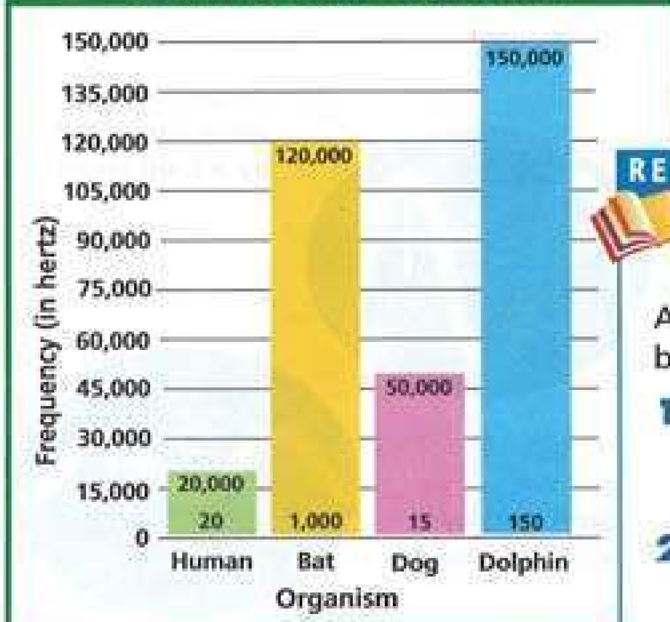
Frequency describes vibrations and sound waves. Pitch describes how your brain interprets a sound. A flute has a high pitch. A bass guitar has a low pitch. Frequency and pitch are related: the higher the frequency, the higher the pitch; the lower the frequency, the lower the pitch.

Frequency is measured in units called **hertz**. A frequency of one vibration per second is one hertz (Hz). *Hertz* comes from the name of Heinrich Hertz (1857–1894), a German physicist who studied sound and radio waves.

Humans hear from about 20 Hz to about 20,000 Hz. Sounds with a frequency higher than 20,000 Hz are *ultrasonic*—too high to be heard by humans, but not by some animals.

How are frequency and pitch related?

Frequencies of Sounds Heard by Some Organisms



READING Graphs

A range graph shows differences between highest and lowest.

1. Arrange organisms in order of range of hearing, from greatest to least.
2. Put organisms in order of the highest frequencies they hear.

Another way to communicate is by using Morse code—a series of long and short taps sent out by telegraph.

What Is Volume?

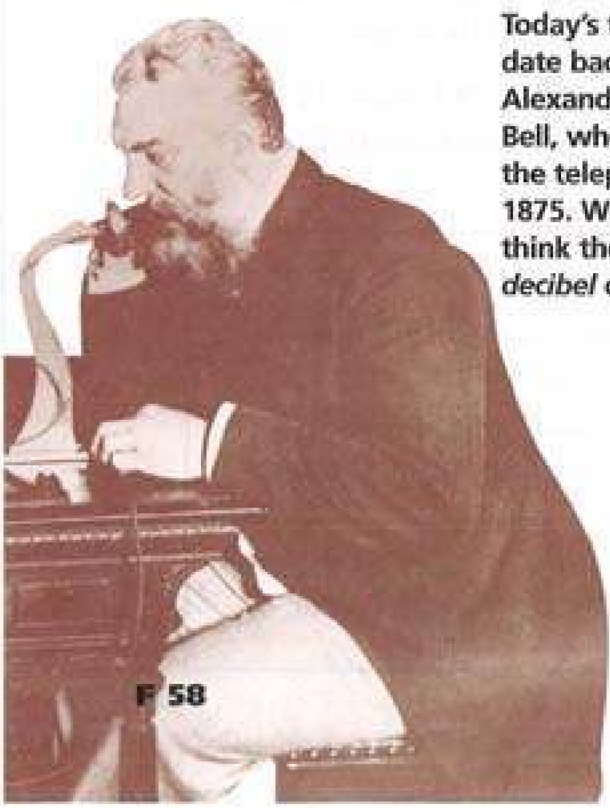
A sound wave makes the molecules of gases in air vibrate. The back-and-forth distance they vibrate is based on how much energy the sound wave carries. The more the energy, the greater the distance. The more the energy, the greater the height of the wave as it appears on an oscilloscope. Which of the waves below is carrying more energy?

What is the difference between a yell and a whisper? A sound's **volume**—how loud or soft it is—depends on the amount of energy in a sound wave. To make a louder sound with a rubber band, pluck it harder. A loud sound has more energy than a soft sound and produces a taller wave on an oscilloscope.

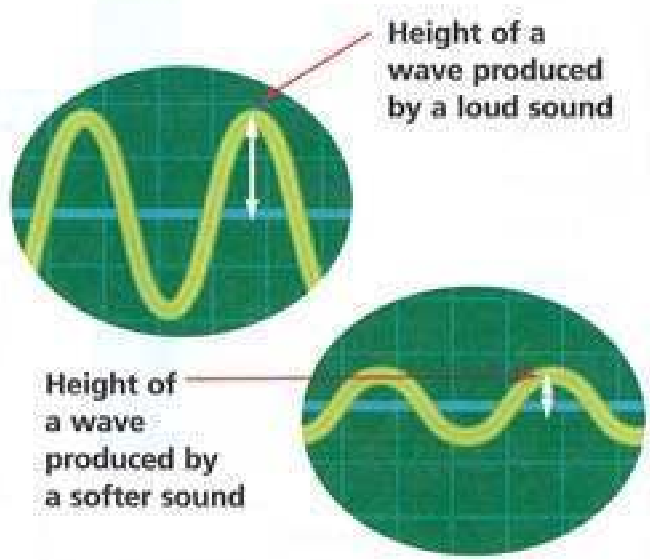
You can also make a sound louder by increasing the amount of surface that vibrates. For example, when a cup is attached to a rubber band, the cup and rubber band vibrate together. Together they make a louder sound than just a rubber band alone.

Volume is measured in units called **decibels** (dB) with an instrument called a decibel meter. On the decibel scale, a sound that measures 50 dB is 10 times louder than one that measures 40 dB. The same 50-dB sound is 100 times louder than a 30-dB sound—that is, 10 x 10 times louder. The 50-dB sound is 1,000 times louder than a 20-dB sound—10 x 10 x 10 times louder.

READING **Cause and Effect**
Why do sounds differ in volume?



Today's telephones date back to Alexander Graham Bell, who invented the telephone in 1875. Where do you think the word *decibel* came from?



Inquiry Skill BUILDER

SKILL Communicate

Making Tables and Graphs

In this activity you will interpret data, classify sounds, and create your own table. Tables are helpful tools that organize information. The table shown gives the loudness of some common sounds in decibels (dB). Sounds below 30 dB can barely be heard. Quiet sounds are between 30 dB and 50 dB. Moderate sounds begin at 50 dB. At 70 dB, sounds are considered noisy. At 110 dB and above, sounds are unbearable.

Procedure

1. **Classify** Determine which sounds are barely audible (can barely be heard), quiet, moderate, noisy, or unbearable.
2. **Communicate** Make your own table to show how you classified the sounds.
3. **Communicate** Make a data table to record how many quiet, moderate, noisy, or unbearable sounds you hear in one hour. Make a graph to show your results. "Number" is the vertical axis. "Kind of Sound" is the horizontal axis.

Loudness of Some Sounds

Sound	Loudness (in decibels)
Hearing limit	0
Rustling leaves	10
Whisper	20
Nighttime noises in house	30
Soft radio	40
Classroom/office	50
Normal conversation	60
Inside car on highway	70
Busy city street	80
Subway	90
Siren (30 meters away)	100
Thunder	110
Pain threshold	120
Loud indoor rock concert	120
Jet plane (30 meters away)	140

Drawing Conclusions

1. **Interpret Data** How much louder is a soft radio than your house at night? A classroom than a house at night?
2. **Interpret Data** How much softer is normal conversation than thunder?
3. **Communicate** Make a chart listing loud sounds in the environment. What can you do to protect your ears from harm done by each loud noise?

How Is Sound Recorded?


Microphone

What if there were no favorite recordings of music? Fortunately, Thomas Alva Edison first recorded sound back in 1877. Today sound is recorded like this.

A microphone includes a diaphragm, a coil of fine wire, and a magnet. When you sing, speak, or play music into the microphone, sound waves make the diaphragm vibrate. The pitch of the sound determines how fast the diaphragm vibrates. The loudness of the sound determines how far the diaphragm moves with each vibration.

The vibration of the diaphragm makes the coil of wire vibrate near the magnet. Each vibration produces a tiny current of electricity. The coil sends this electric pattern to an amplifier.

The tiny pulses of electricity coming from the coil are very weak. The amplifier makes them up to 50,000 times stronger.

Blank tapes are coated with scrambled magnetic particles. During recording, the electric current from the amplifier arranges the particles on the tape into a pattern—a "code" for the sounds.

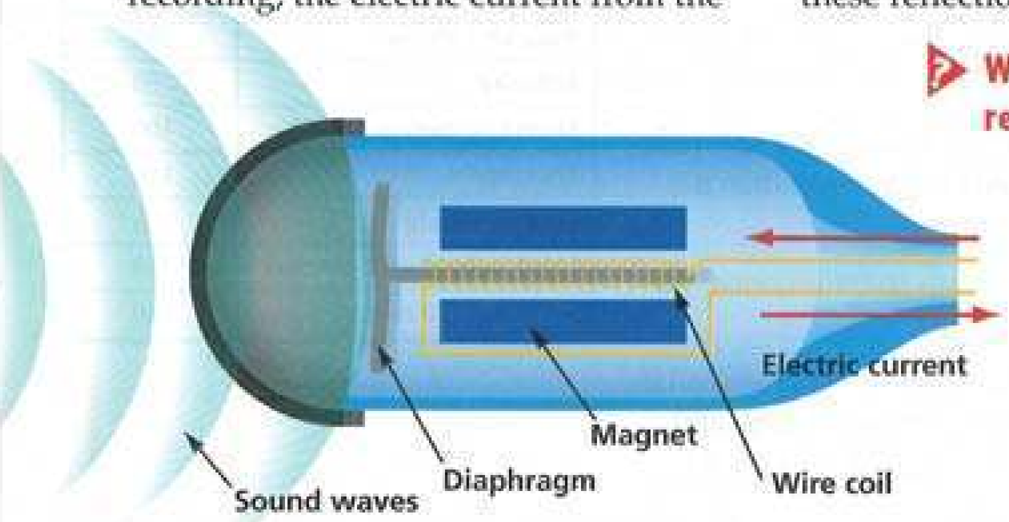
When you push "play," the process reverses. The magnetic particles on the tape create a current in the coil. This current vibrates a stiff paper cone in the speaker. This creates the sound waves you hear.

Compact discs do not store sound in magnetic patterns. Instead, a computer in CD-recording equipment translates the sound waves into a code. The code is a combination of 1s and 0s.

Then a laser beam uses the code to cut millions of tiny pits into a blank compact disc. About 85,000 pits cover only one inch of the disc.

When you play a CD, a laser beam shines on it. The flat parts of the CD reflect light back to a small computer. The computer changes the pattern of these reflections back into sound.

What steps are involved in recording and playing a CD?



How does a microphone work? Sound waves make the diaphragm in the microphone vibrate. That makes the coil of wire vibrate, sending an electric pattern to an amplifier.

Lesson Review

Why It Matters

Next time you strum a guitar, pound a drum, or sing a tune, keep in mind what you learned in this lesson. The different musical sounds you make on an instrument or when you sing are different pitches. You can play an instrument at different volumes—to make the sounds louder or softer. You sing louder when you take a deeper breath and breathe out harder. You use loudness and pitch to express different emotions, too.

e-Journal Visit our Web site **www.science.mmhschool.com** to do a research project on the effect of pitch and volume on hearing loss.

Think and Write

1. On a stringed instrument, why are some sounds higher than others?
2. How is pitch related to frequency?
3. How can sounds be changed into an electric current?
4. INQUIRY SKILL **Communicate** How is loudness measured? How would you set up a table showing the loudness of different sounds?
5. **Critical Thinking** Why do the notes of a musical instrument have different sounds?

L·I·N·K·S

WRITING LINK

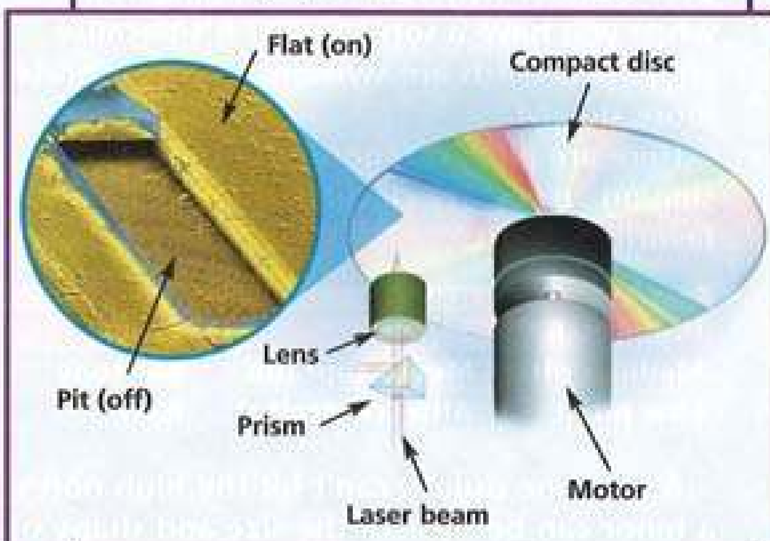
Expository Writing How can a dog hear a dog whistle, but a person can't? Research the answer, and write an essay. Draw a conclusion based on the information you find.

MATH LINK

Solve this problem. How many times louder is a loud indoor rock concert than a busy city street? See pp. F58-59.

ART LINK

Make a poster. Illustrate how CDs are made and played.



TECHNOLOGY LINK

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Hit That Note!

Ever think of yourself as a musician? Well you are one. When you sing you play an instrument—your voice!

Musical instruments vary in the pitches, or tones, they can produce. It all depends on the frequencies of vibrating parts. Singers produce different tones, too.

You've probably noticed differences in the sounds of some of your favorite singers. The tones they use depend on the vibrations of their vocal cords. Thicker, longer cords vibrate more slowly and have lower tones. Ever wonder why your voice sounds lower when you have a sore throat? It's because your vocal cords are swollen, so they vibrate more slowly!

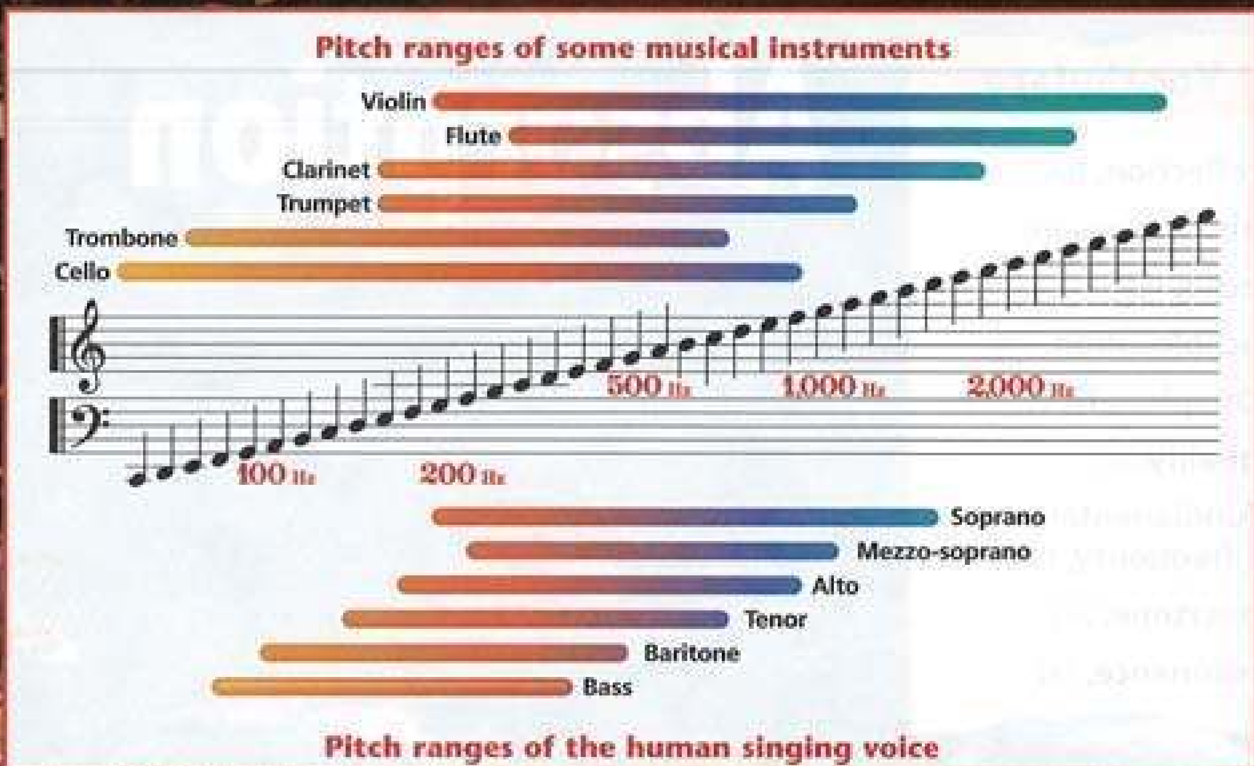
Here are pitch categories for most human singing voices. Try classifying some of your favorite singers.

	FEMALE	MALE
High pitch	**Soprano**	**Tenor**
Medium pitch	**Mezzo-soprano**	**Baritone**
Low pitch	**Alto (contralto)**	**Bass**

A baritone usually can't hit the high notes a tenor can because of the size and shape of his vocal cords. Likewise a tenor usually can't hit the low notes a baritone can.

When composers write music, they think about the notes that each instrument and voice can produce.

LOG ON Visit **www.science.mmhschool.com** to learn more about music.



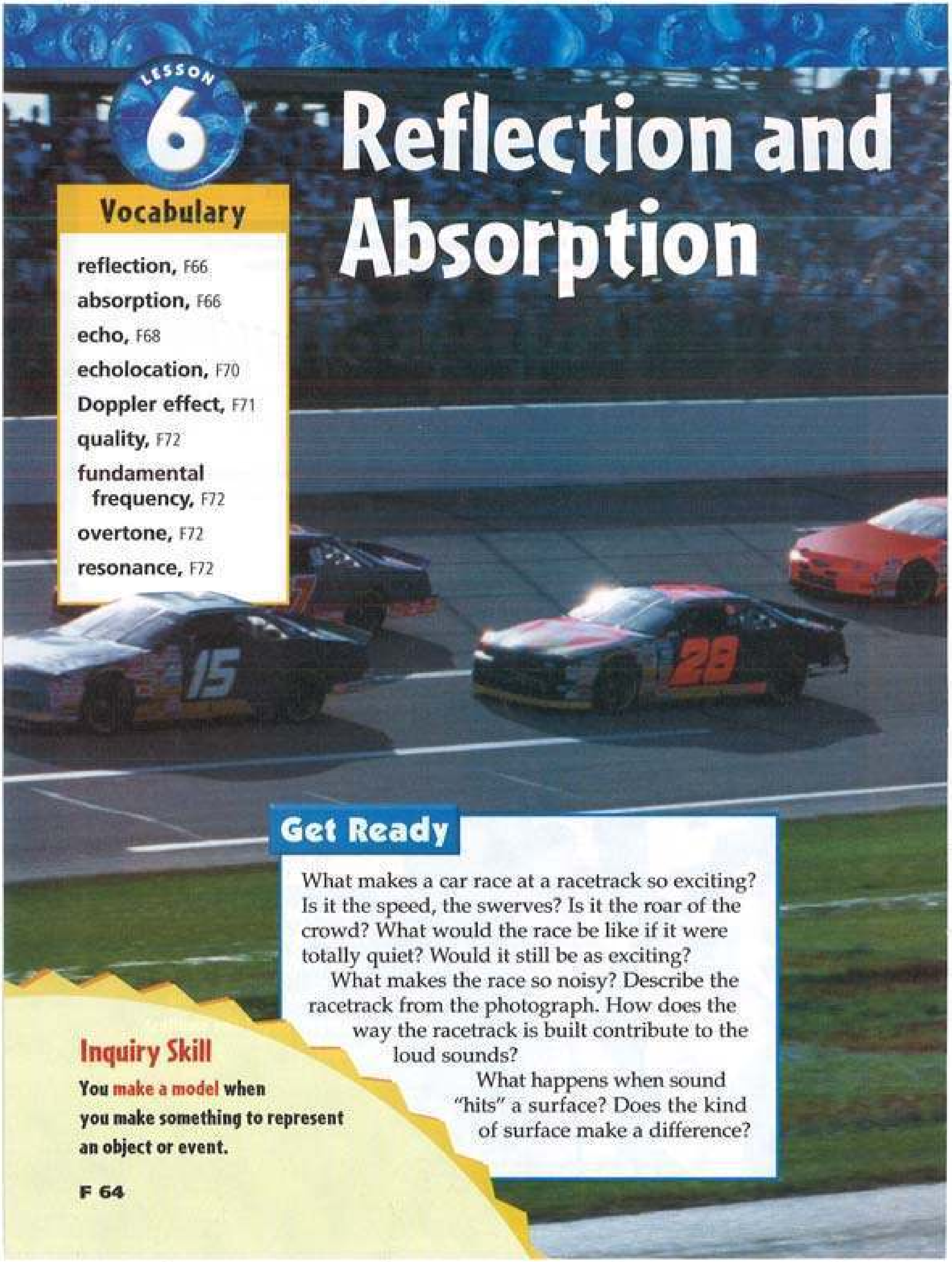
This diagram shows the lowest to the highest notes for each instrument and singing voice. The difference between the highest and lowest is called a range.

Write ABOUT IT

1. Which instrument shown can reach the highest pitch? About what frequency is that?
2. Which instrument has the greatest range? The smallest range?

LESSON 6

Reflection and Absorption



Vocabulary

reflection, F66
absorption, F66
echo, F68
echolocation, F70
Doppler effect, F71
quality, F72
fundamental frequency, F72
overtone, F72
resonance, F72

Get Ready

What makes a car race at a racetrack so exciting? Is it the speed, the swerves? Is it the roar of the crowd? What would the race be like if it were totally quiet? Would it still be as exciting?

What makes the race so noisy? Describe the racetrack from the photograph. How does the way the racetrack is built contribute to the loud sounds?

What happens when sound "hits" a surface? Does the kind of surface make a difference?

Inquiry Skill

You make a model when you make something to represent an object or event.

Explore Activity

Do Sounds Bounce?

Materials

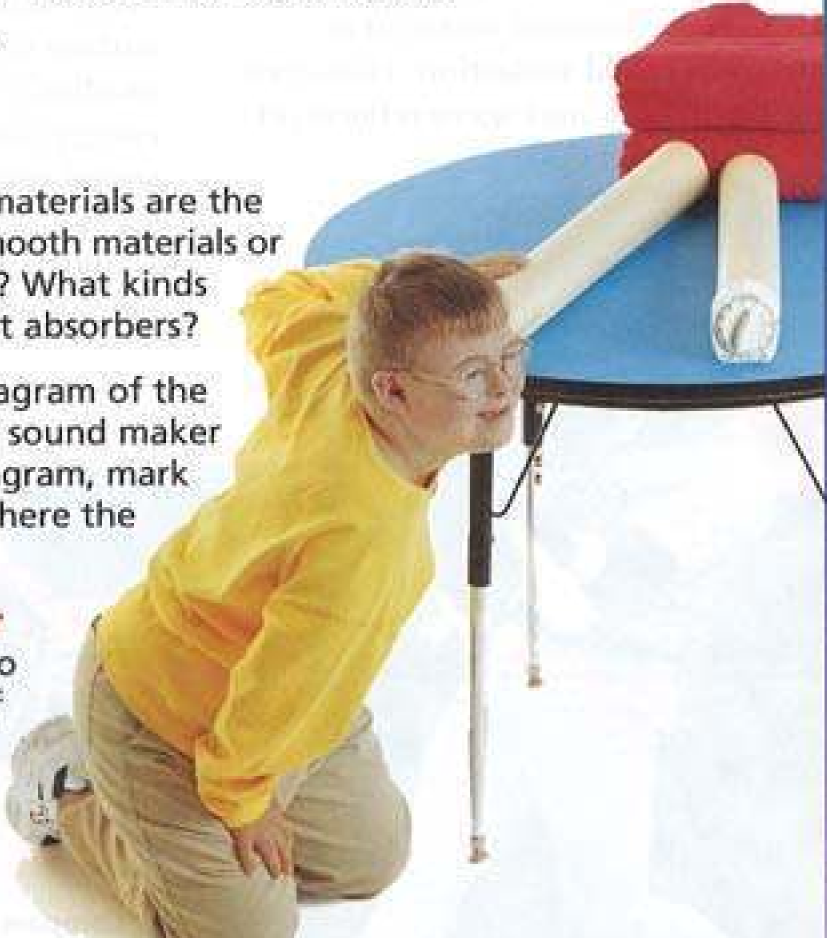
- 2 long cardboard tubes (can be taped, rolled-up newspapers)
- sound maker, such as a clicker or timer
- hard and soft test materials, such as a book, wood block, cloth, metal sheet, sponge, towel

Procedure

1. Collect a variety of hard, smooth materials and soft, textured materials. Place one of the objects on a table. Set up your tubes in a V-shaped pattern on a table, as shown. The V should meet at the object you are testing. Record the name of the object.
2. **Observe** Place a sound maker (clicker or timer) at one end of the V. Listen for ticking at the other end of the V. Rank the loudness of the ticking on a scale of 1 (lowest) to 5 (highest). Record the number.
3. **Experiment** Repeat steps 1 and 2 with the different materials you collected.

Drawing Conclusions

1. **Classify** What kinds of materials are the best reflectors—hard, smooth materials or soft, textured materials? What kinds of materials are the best absorbers?
2. **Make a Model** Draw a diagram of the path of sound from the sound maker to your ear. On your diagram, mark the point in the path where the sound wave bounced.
3. **FURTHER INQUIRY** **Infer** Design an experiment to test the effectiveness of draperies or rugs in absorbing sound in a room.



Read to Learn

Main Idea **Sounds vary because objects reflect, absorb, or transmit sound differently.**

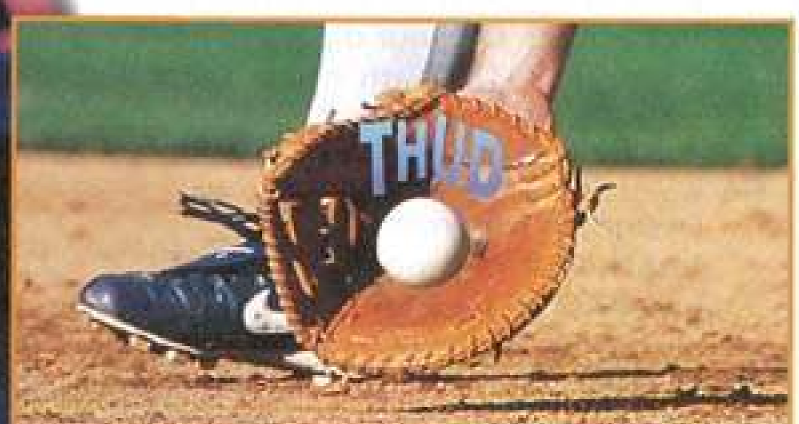
Do Sounds Bounce?

A sound hitting a towel will sound different from the same sound hitting a metal sheet. Why? A sound wave does not act the same way when it hits a hard, smooth surface as it does when it hits a soft, textured surface.

The pictures below show what happens when sound waves come into contact with a surface. When a sound wave hits a surface, some of its energy bounces off the surface. The bouncing of a sound wave off a surface is called **reflection**. However, not all of the sound wave reflects off the surface. Some of the wave's energy enters the surface, and part of the sound disappears. The disappearance of a sound wave into a surface is called **absorption**.

When a sound wave is absorbed, its energy is changed into heat energy. Sometimes not all of the energy that enters a surface is absorbed. Part of the energy of the sound wave may also travel through a surface and come out the other side—like when you hear a sound through a wall.

How much of the sound wave's energy is reflected or absorbed depends on the kind of material of the surface. When sound waves hit a hard, smooth surface such as the wall around the racetrack, much of the sound wave's energy is reflected. However, when sound waves hit a soft, textured surface such as a towel, less of the sound wave's energy is reflected and more is absorbed.



Compare the crack of the bat when the ball and bat meet with the sound when the ball hits the glove.

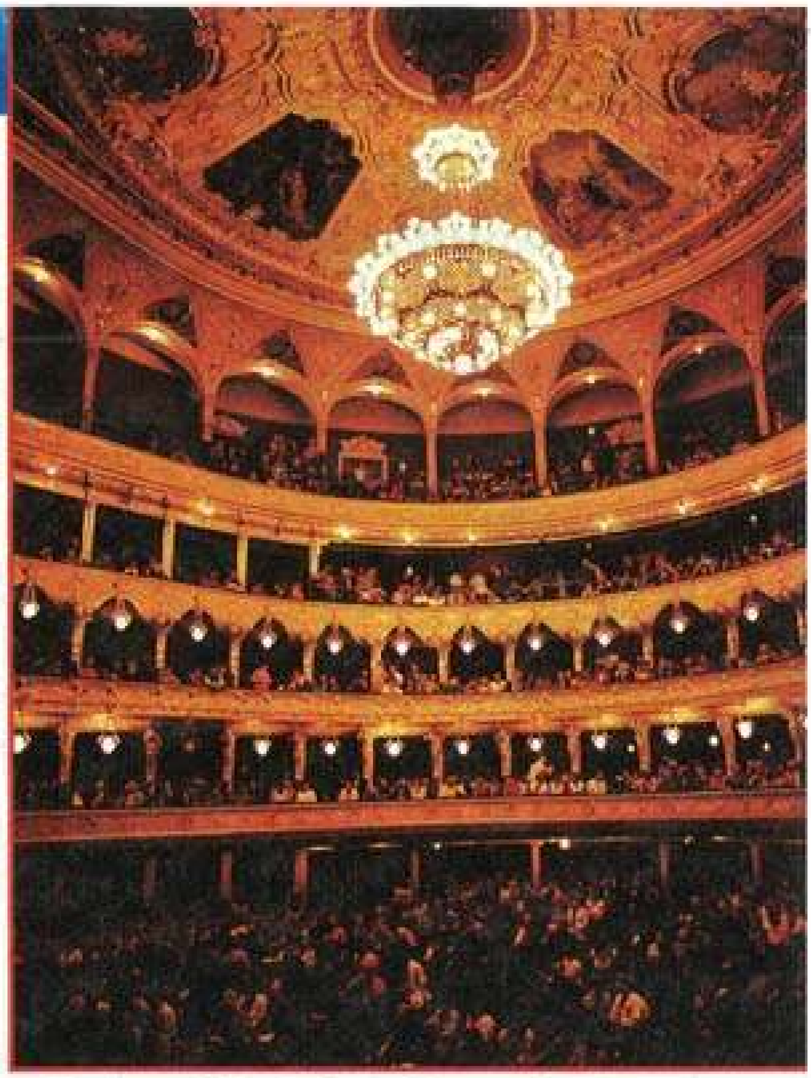
How Reflection and Absorption Affect Concert Halls

Designing concert halls has always been a tricky business. To get the "right" sound, engineers try to get a good balance of reflection and absorption. Too much reflection results in an empty, hollow sound. Too much absorption deadens the music.

When the London Music Hall was built in 1871, the hall was considered to be one of the great places in the world to hear music. By the 1930s listeners complained that the music did not sound good anymore. Sound engineers were baffled. Nothing in the concert hall had changed since it was built, over 60 years earlier.

Finally, an explanation was found. The concert hall may have stayed the same, but its audience had changed. Most importantly, women were no longer wearing the billowing, layered, sound-absorbing gowns that had been popular earlier. The new styles were shorter and simpler, and didn't absorb sound as well. Overall they changed the balance of reflection and absorption of sound in the room.

Do more sound waves bounce from hard, smooth surfaces or soft, textured surfaces?

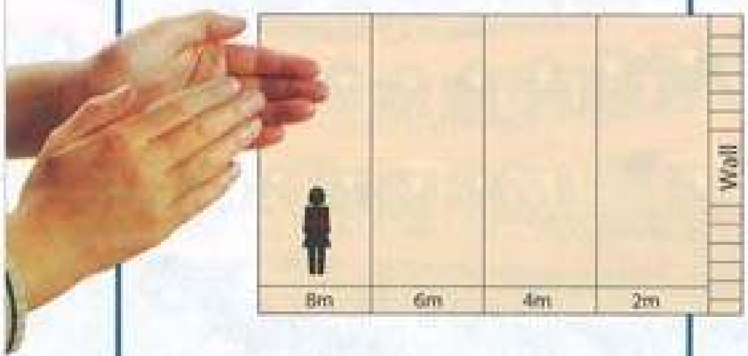


The group below is dressed in a style common in the mid- to late 1800s. The billowy gowns and long coats had an effect on sound in a concert hall.

QUICK LAB

Clap! Clap!

FOLDABLES **Make a Four-Column Folded Chart. (See p. R 44.) Label as shown. Record your echo data in the meter columns.**



1. **Observe** Stand about 8 m away from a large wall, such as the side of your school building. Make sure there is plenty of open space between you and the wall. Clap your hands, and listen for an echo. Notice how much time there is between your clap and the echo.
2. **Observe** Move closer to the wall, and clap again. Listen for an echo. Try this several times.
3. **Observe** As you got closer to the wall, how did the time between the clap and the echo change? Did you always hear an echo? Explain.
4. **Experiment** Repeat at different distances. What happens?

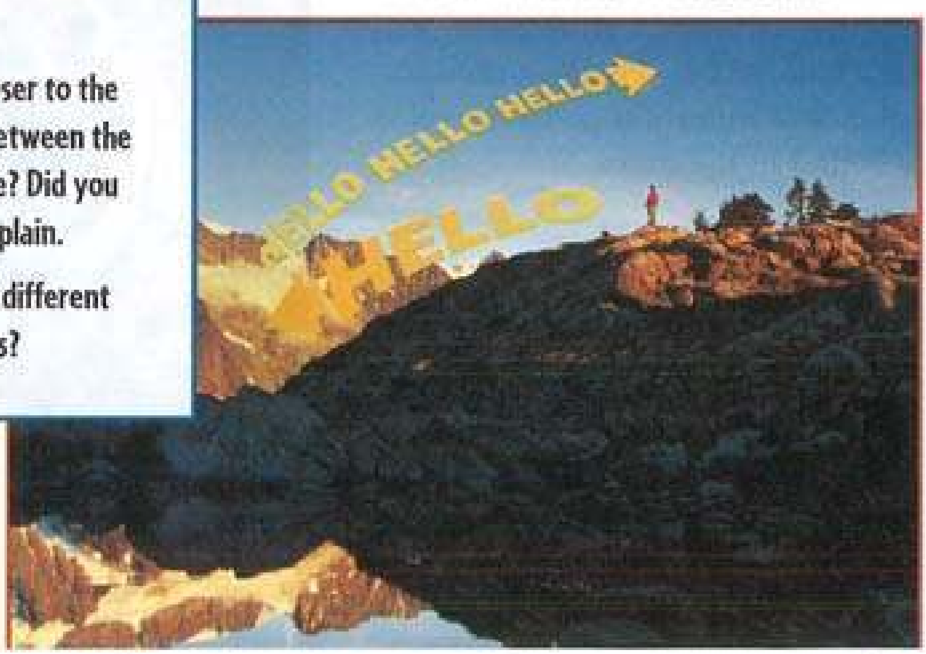
What Is an Echo?

Have you ever made an echo? When you yell "hello!" your vocal cords make sound waves that travel away from you in all directions. If the sound wave hits a surface, some of the sound wave's energy will reflect off the surface and travel back to you. A reflected sound wave is called an **echo**. If the echo is strong enough, you will hear yourself yelling "hello!" after you said it! If there is more than one reflecting surface near you, you may hear "hello!" several more times.

If you sing in the shower, you may notice how rich your voice sounds. The hard, smooth walls of the bathroom are often great for making echoes. The echoes reflect back and forth off the walls many times. They make your voice sound rich and mellow, as if background singers were repeating each note you sing.

READING **Cause and Effect**
How are echoes made?

You hear sound as soon as you make it. After it reaches a reflecting surface, you hear the echo when the waves return.



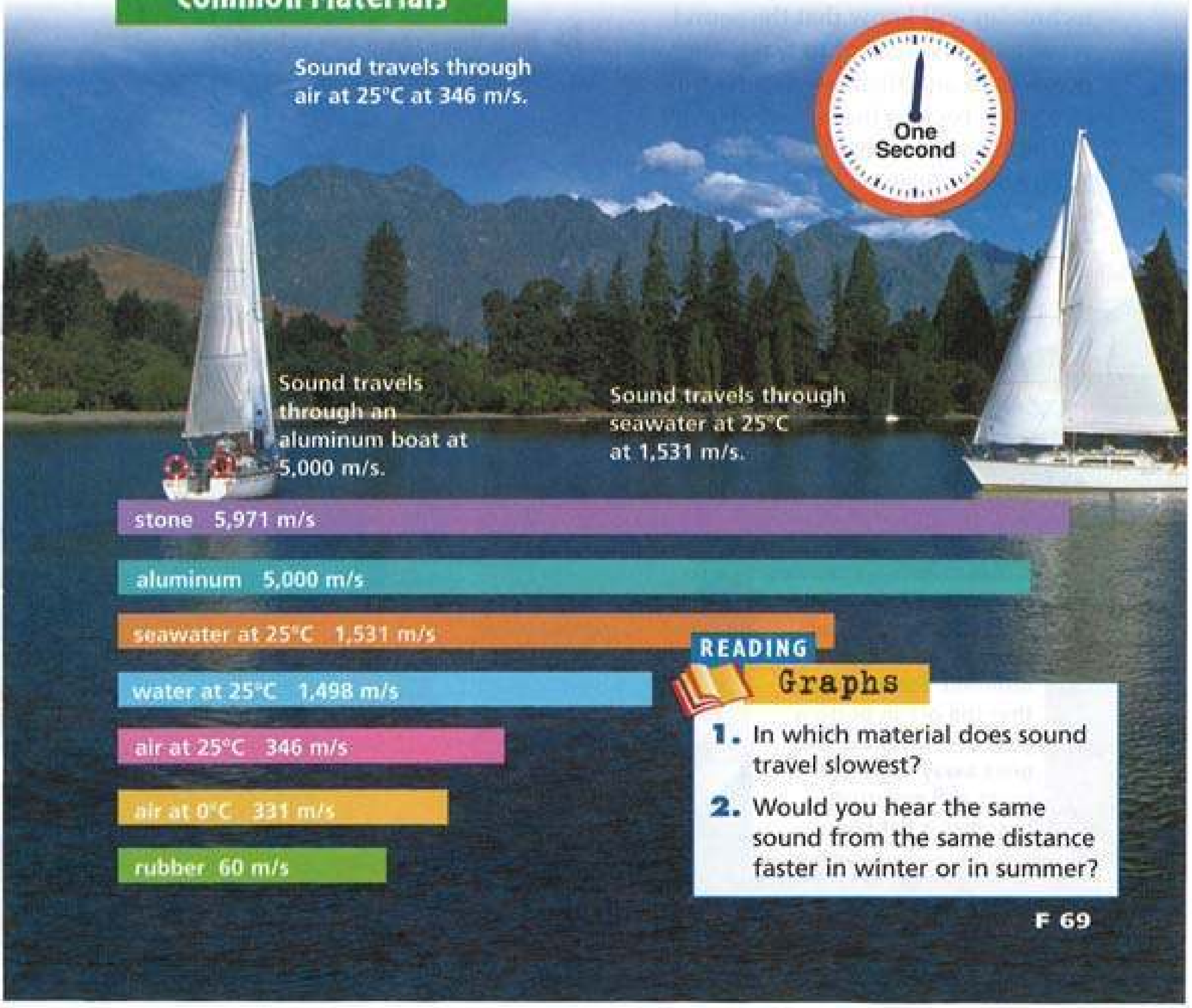
How Fast Is Sound?

It takes almost no time for an echo to bounce back to you after you yell "hello!" Sound waves travel fast. In air at room temperature (20°C), sound waves travel 343 meters per second, faster than most jet planes. In general, sound waves have a greater speed in a solid than in a liquid, and a greater speed in a liquid than in a gas.

The speed of sound waves depends largely on the molecules of the material—on how tightly packed molecules are and how easily they spread apart and move together. Temperature affects the speed of sound. In general, temperature affects the speed of sound more in gases than in liquids and solids.

Will sound travel faster through air or steel?

Speed of Sound Through Common Materials



READING Graphs

1. In which material does sound travel slowest?
2. Would you hear the same sound from the same distance faster in winter or in summer?

What Can Echoes Do?

Sonar, or *so*und *na*vigation and *r*anging, uses sound waves to detect objects far away. A sonar technician sends out sound waves and then times how long those sound waves take to bounce off distant objects and return.

What if a sonar technician on a ship sends out a sound wave toward the ocean bottom? Sound waves travel about 1,500 meters per second in water.

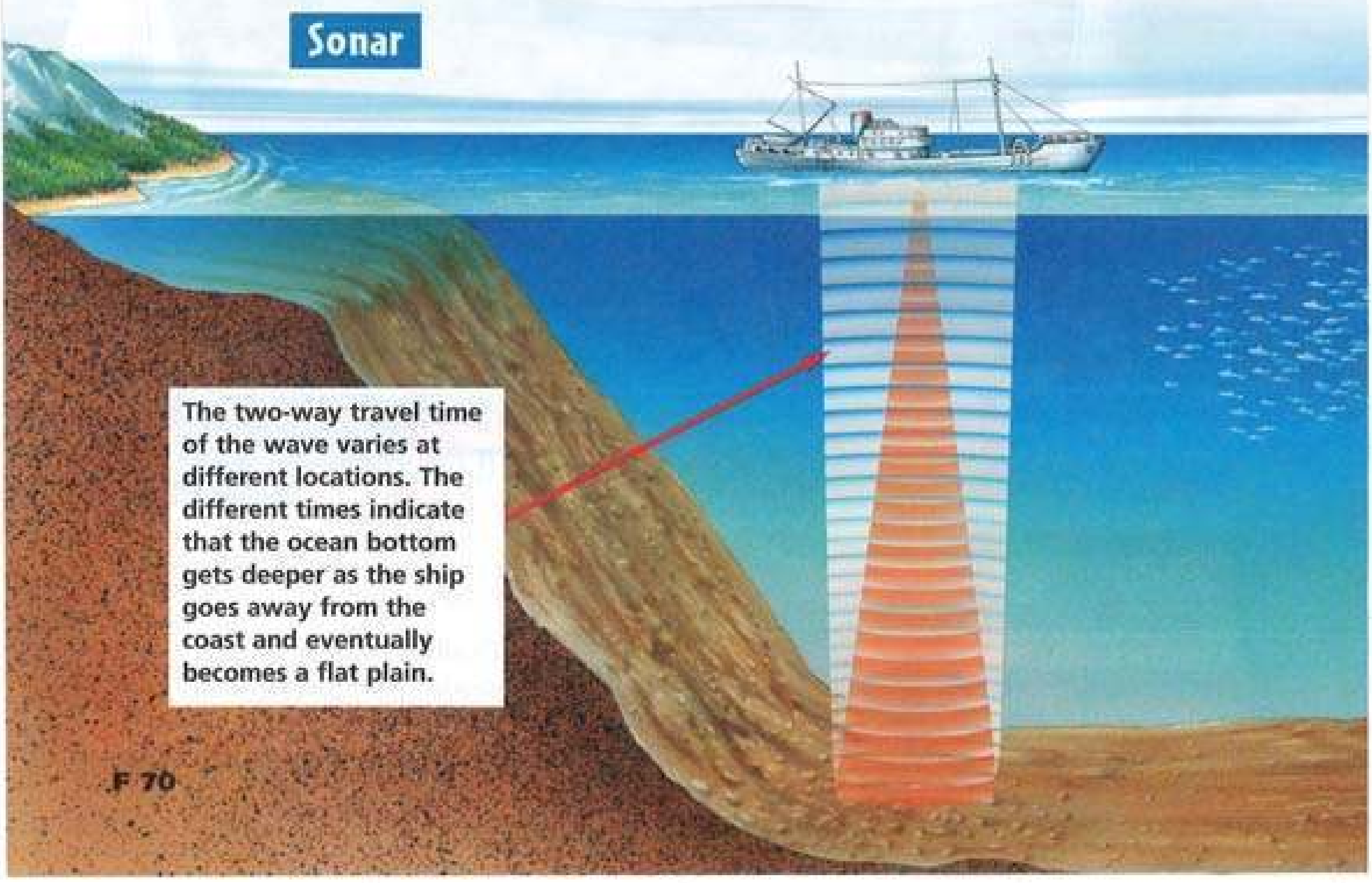
What if the sound wave takes two seconds to return to the ship? The technician will know that the sound wave took one second to reach the ocean floor and then one second more to bounce back to the surface. He or she will conclude that the ocean is 1,500 meters deep.

Many animals find things around them with a form of sonar called **echolocation**. Whales and dolphins bounce sound waves off objects to find out how far away they are.

Bats are able to live in dark caves because they use a form of echolocation rather than sight to navigate. Bats send out high-pitched squeals and clicks into the air at their prey. Their large, forward-pointing ears pick up the echoes. Using this information, bats can close in on their prey.

How does sonar use echoes to locate objects?

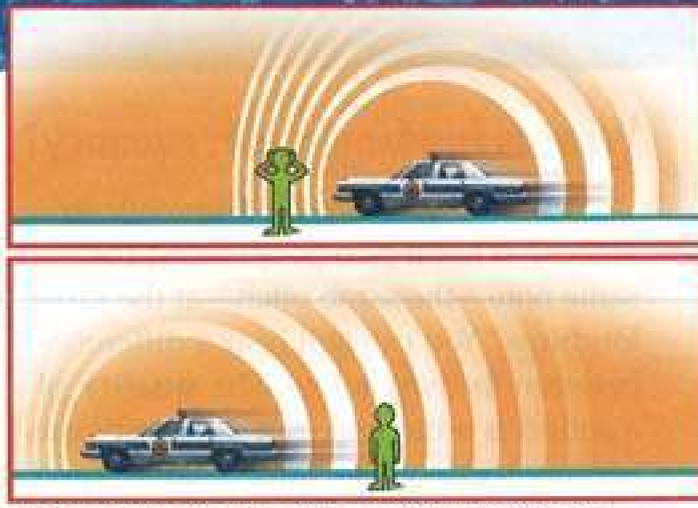
Sonar



The two-way travel time of the wave varies at different locations. The different times indicate that the ocean bottom gets deeper as the ship goes away from the coast and eventually becomes a flat plain.

How Do Moving Sounds Change?

An echo is a copy of the original sound. Both the original sound and the echo have the same pitch. However, have you ever heard a siren blaring as a police car sped past you? If you listened carefully, you may have noticed that the pitch of the siren changed as the police car sped by. As the car came toward you, the siren was higher in pitch. As it sped away from you, the pitch was lower.



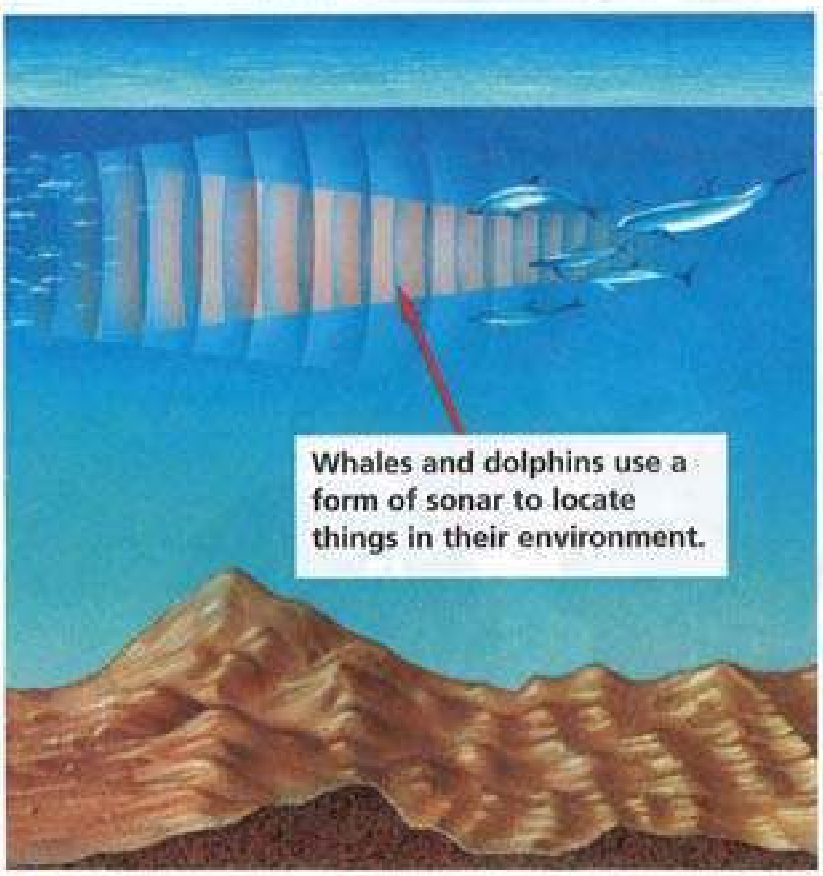
Sound waves from the moving police car bunch together (1) as the car approaches the listener. They spread apart (2) as the police car moves away from the listener.

Approaching Sound

As the blaring siren approaches, its sound waves crowd together. There are more sound waves reaching your ear each second than there would be if the police car were standing still. The frequency of the sound increases. The pitch is higher.

Departing Sound

As the siren moves away from you, its sound waves spread apart. There are fewer sound waves reaching your ear each second than there would be if the police car were standing still. The frequency of the sound decreases. The pitch of the siren moving away from you is lower.



Whales and dolphins use a form of sonar to locate things in their environment.

Change of Frequency

This change in frequency (and pitch) as a source of sound moves toward or away from you is known as the **Doppler effect**. It is named for the 19th century Austrian scientist Christian Johann Doppler, who first described it.

Many radar (*ra*dio *d*etection *a*nd *r*anging) devices use the effect to find the speed of objects. Patrol cars detect changes in frequency as a way of detecting speeding vehicles.

How does a sound that is moving away from you change in pitch?

What Is Fundamental Frequency?

How can you tell the difference in voices? What if two people sing the same note—the same pitch—at the same loudness? You can still hear a difference between the two voices. The **quality** of a sound is what makes it different from another sound of the same loudness and pitch. Quality makes a sound unique.

The quality of a sound depends on the vibrations that produce the sound. When a string vibrates, for example, it vibrates at more than one frequency at a time. The whole string vibrates at the **fundamental frequency**, the lowest frequency at which it vibrates.

At the same time, sections of the string are vibrating at higher frequencies, called **overtones**. Each overtone is a different pitch. It is the blend of the fundamental frequencies and the overtones produced that gives each sound its own quality.

Each sound—whether it's a voice or musical instrument, whether produced by a vibrating string or column of air—is different from all other sounds. Each sound has its own blend of fundamental frequency and overtones that allows you to identify it.

What do buildings and bridges have in common with musical instruments? Each has its own natural frequency of vibration. If a vibrating force shakes them at their natural frequency, the vibration builds up. This buildup results in a condition called **resonance**. Resonance can make a violin or trumpet sound louder. However, resonance can also cause great damage to buildings and bridges, making them rattle and sway. Bridges have collapsed as a result of resonance.

Why is fundamental frequency important in designing buildings?

If the saxophone and the trumpet play the same note at the same loudness, the sound waves differ because the blend of overtones differs.

Wynton Marsalis

Lesson Review

Why It Matters

Knowing how different materials reflect and absorb sound waves can be helpful at school or home. Your school library probably has stacks of books and other sound-absorbing materials. They help keep the library quiet so you can read and study. Whether you are a student deciding what furniture to put in a room to make it quiet or an architect deciding how to design a building, you must know how different materials affect sound waves.

e-Journal Visit our Web site **www.science.mmhschool.com** to do a research project on soundproofing.

Think and Write

1. What is an echo? What is necessary in order to hear an echo?
2. How can sound be used to find the depth of the ocean?
3. Why does the same note played on two different instruments at about the same loudness sound different?
4. What kinds of materials reflect sound best? What kinds of materials absorb sound best?
5. **Critical Thinking** Does sound travel with the same speed through all materials? Write a paragraph explaining your answer.

L·I·N·K·S

WRITING LINK

Persuasive Writing Research the importance of "tuning" a car's suspension. Why is it especially important for the suspension of a Monster Car? Write an editorial to persuade drivers to "tune" their car's suspension before the next Monster Car rally.

MATH LINK

Solve this problem. Sound waves travel about 1,500 meters per second in water. A ship sends a sound wave to the ocean floor. The echo takes four seconds to return. How deep is the ocean there?

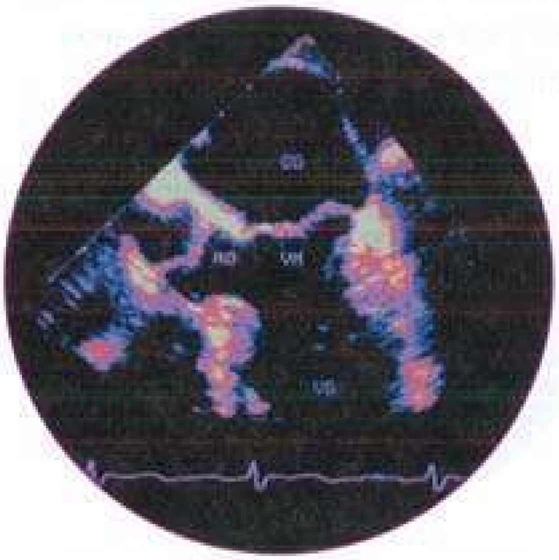
TECHNOLOGY LINK

Science Newsroom CD-ROM Choose *Sounds Good to Me* to learn how sound waves move through matter.

LOG ON Visit **www.science.mmhschool.com** for more links.

Sonograms

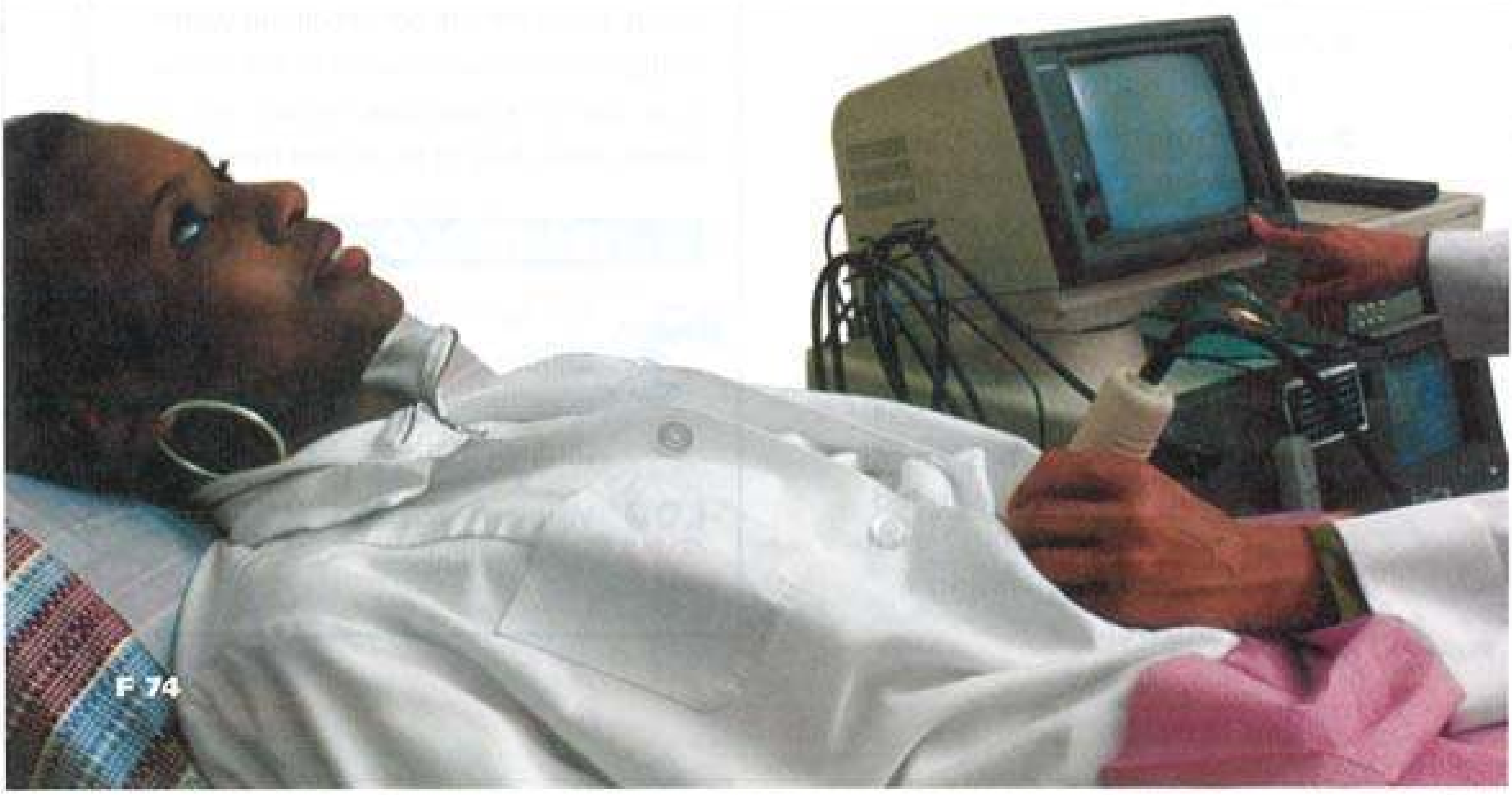
Seeing with Sound



With sonograms doctors can look at organs in hard-to-reach places, such as the heart shown in this sonogram.

What's a sonogram? Does it hurt? Relax! It's a painless medical test that uses sound waves to make a high-tech picture of your internal organs and tissues. Sonograms can be used to look at an unborn baby in its mother's womb (see below) or a beating heart.

Here's how it works. Sound waves are sent through your body using a gadget called a transducer, or probe. The probe is placed on the skin. It sends high-pitched sound waves into your body. The sounds are pitched too high for the human ear to hear.



The sound waves travel through your body until they hit a boundary. Here some of the sound waves are absorbed, and some are reflected back to the probe as "echoes." The secret to the sonogram is that sound waves travel through different materials at different speeds. So the time it takes the echoes to get back to the probe depends on whether they traveled through blood vessels, muscles, or organs.

When the echoes return to the probe, they are sent to a computer. The computer keeps track of the time that the different echoes arrive back at the probe. From this the computer can figure out what the sound waves traveled through. It shows what the sound waves "see" during their journey through your body. The computer uses the echoes to calculate the sizes and shapes of your body parts. Then it produces a picture—a sonogram!

Write About It

1. Sonograms can help doctors look at a patient's internal organs without having to perform surgery. Why is this good for patients? and for doctors?
2. Sonograms are often used to take pictures of developing fetuses. Why would this be helpful to doctors?

LOG ON Visit **www.science.mmhschool.com** to learn more about sonograms.

Chapter 15 Review

Vocabulary

Fill each blank with the best word or words from the list.

absorption, F66
compression, F51
decibel, F58
echo, F68
hertz, F57
quality, F72
rarefaction, F51
reflection, F66
sound wave, F51
vibration, F50

1. The unit for measuring frequency is a(n) ______.

2. An echo is caused by a(n) ______.

3. A sound starts with a(n) ______.

4. Loudness is measured in a unit called a(n) ______.

5. Overtones affect the ______ of a sound.

6. A sound travels as a(n) ______.

7. A reflected sound is called a(n) ______.

8. Sound tends not to bounce off carpets because of ______.

9. When molecules bunch together, that's the ______ stage of a sound wave.

10. When molecules spread apart, that's the ______ stage of a sound wave.

Test Prep

11. If the frequency of a musical note is increased, ______.

A the note gets louder
B the note gets softer
C the note gets higher
D the note gets lower

12. Echoes are the result of ______.

F the Doppler effect
G reflection
H absorption
J quality

13. The two parts of a sound wave are ______.

A compression and rarefaction
B pitch and quality
C overtone and resonance
D absorption and reflection

14. The changing pitch of a moving siren is caused by ______.

F the Doppler effect
G reflection
H absorption
J quality

15. Two differences we hear in sounds are ______.

A compression and rarefaction
B absorption and rarefaction
C pitch and quality
D absorption and reflection

Concepts and Skills

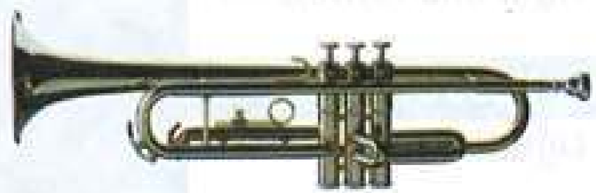
16. **Reading in Science** Write a paragraph explaining how a sound reaches your ear.

17. **Decision Making** You are organizing a band. Some of the band members want to play their music as loud as possible all the time. Some of them say it is safer for everyone's hearing to play much more softly. How loud would you tell everyone to play? Write a paragraph explaining your answer.

18. **Scientific Methods** Do people learn better if they listen to Mozart's music than if they listen to rock music? Write up a design for an experiment that would test this.

19. **Critical Thinking** Do you think louder sounds travel faster than softer ones? Write and explain a hypothesis. Describe how you might test your idea

20. INQUIRY SKILL **Communicate** Write a paragraph explaining how the instruments below were built to make different sounds.



Did You Ever Wonder?

INQUIRY SKILL **Communicate**
In 1947, Chuck Yeager became the first person to fly faster than the speed of sound. Imagine you were flying with him when he broke the sound barrier. What would you have heard at this historic moment?

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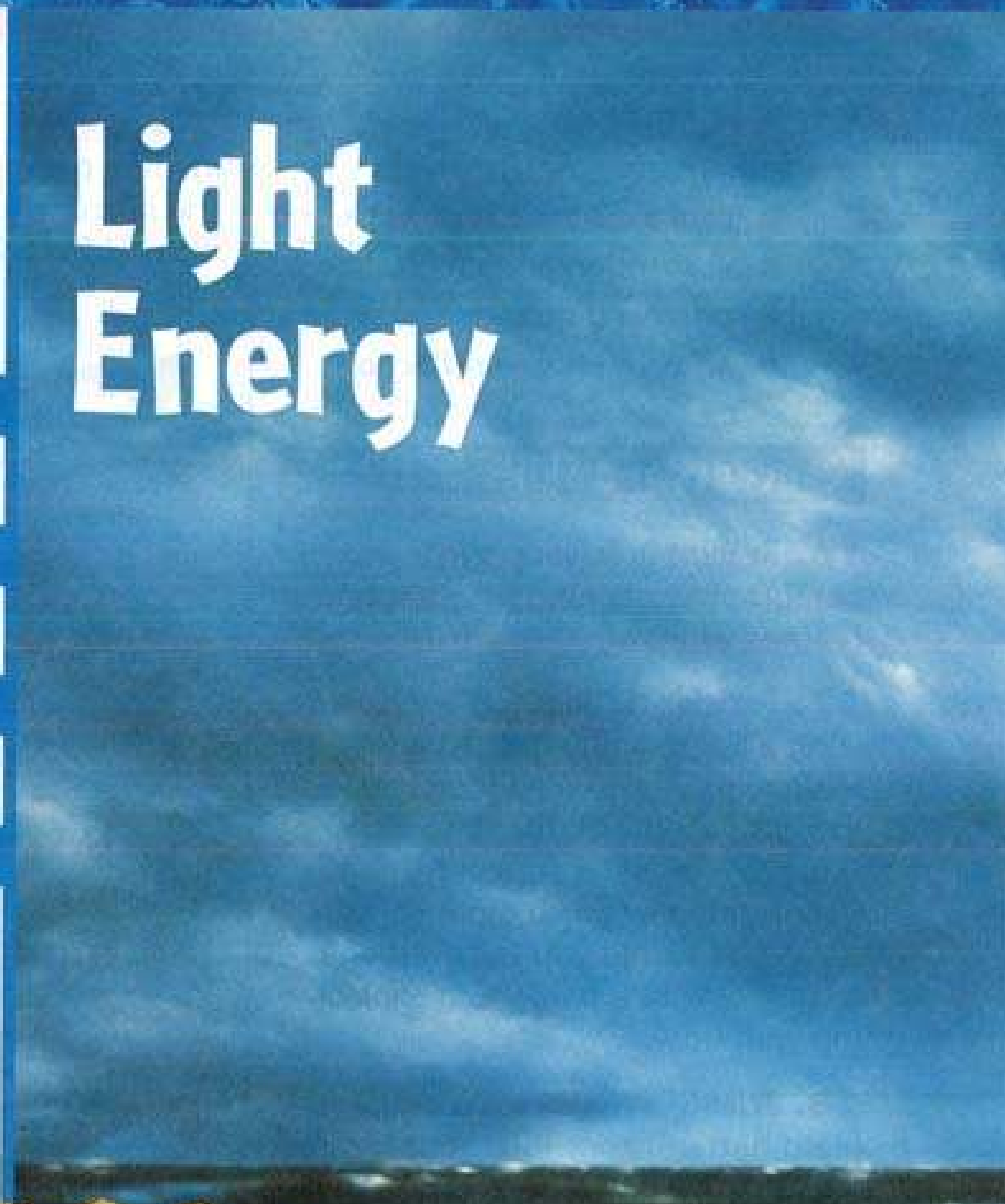
CHAPTER

16

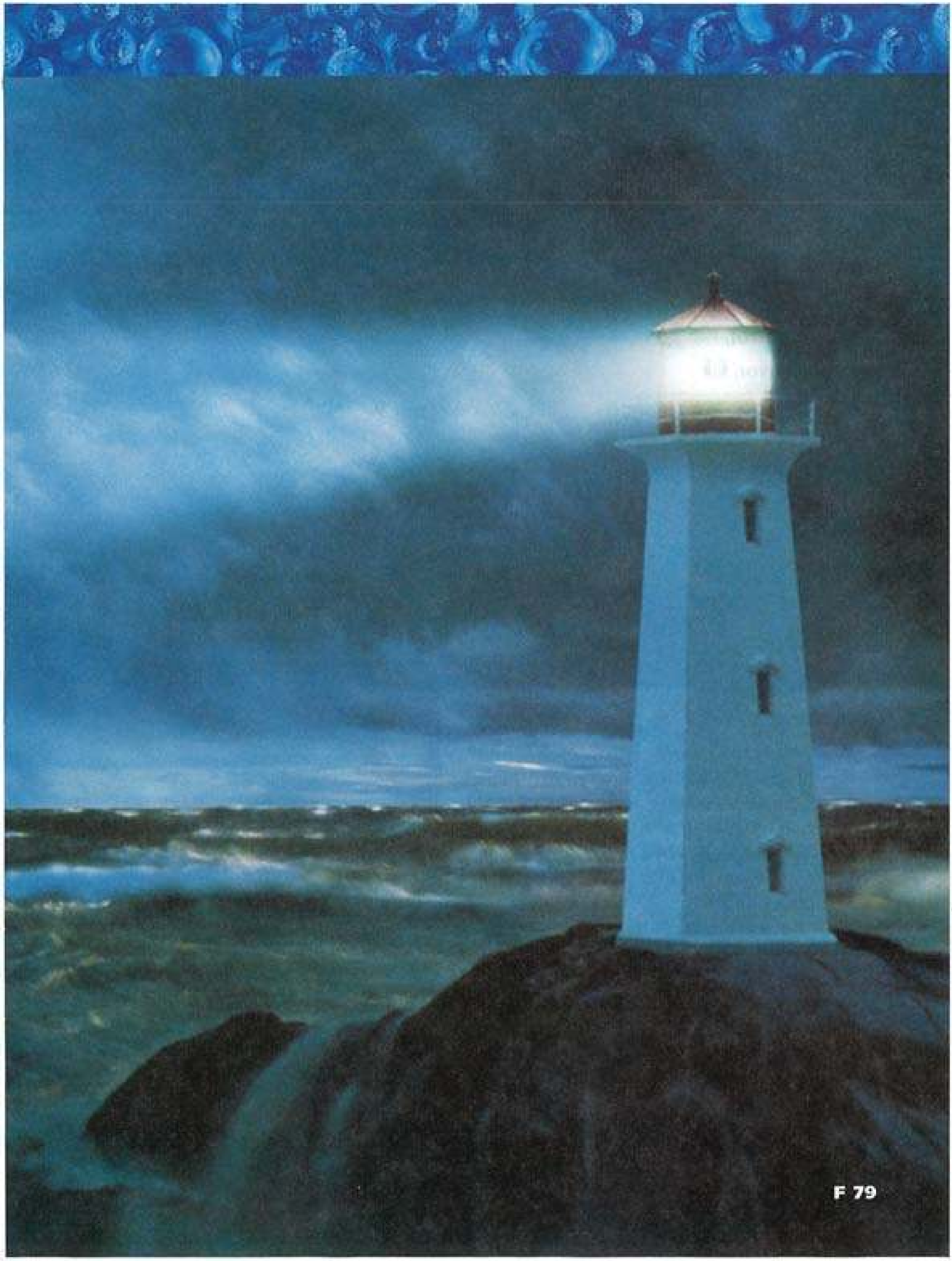
Light Energy

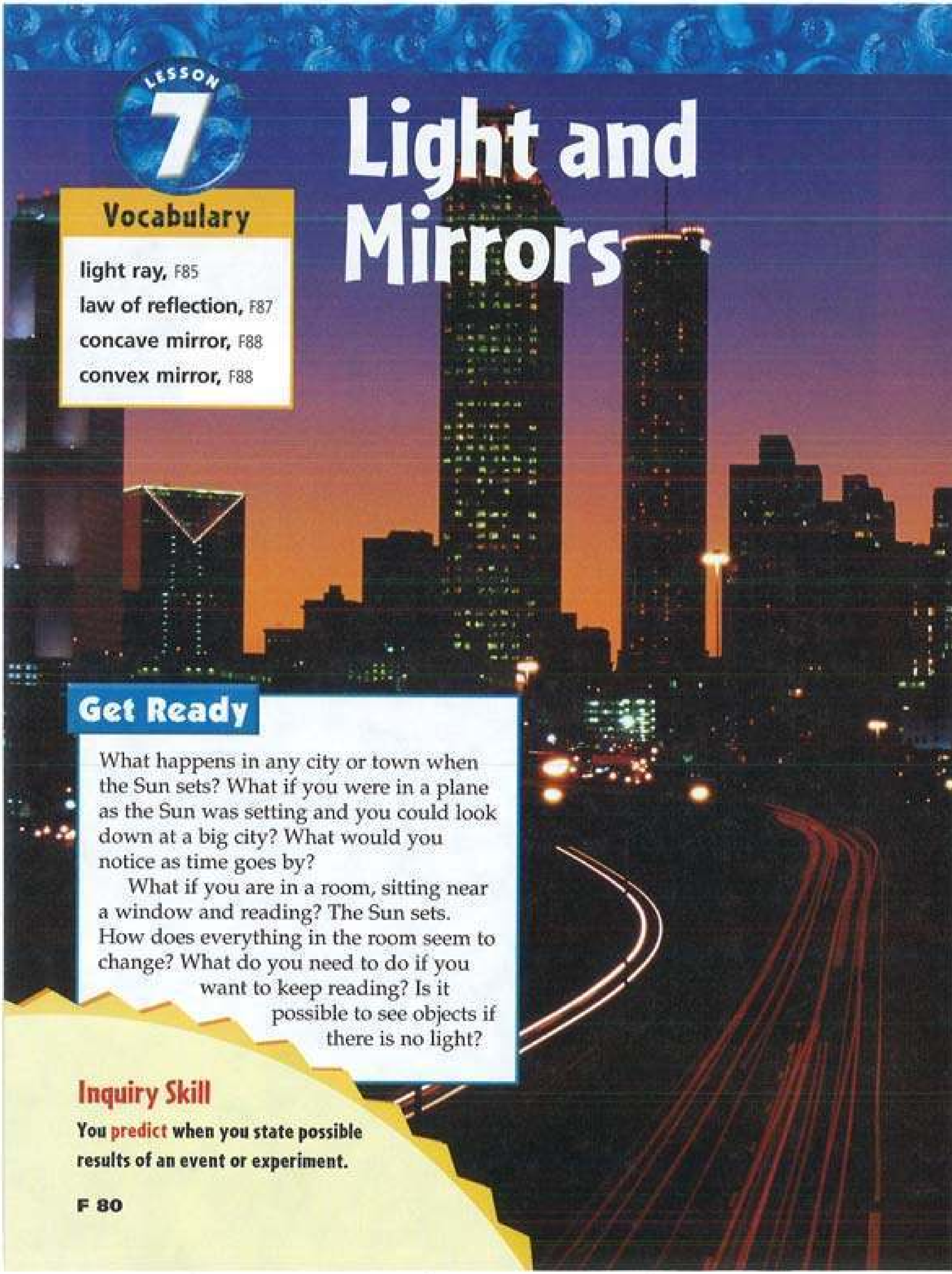


Did You Ever Wonder?

How does a lighthouse work? This lighthouse on the coast uses powerful lenses to focus a beam of light so it can be seen far out at sea. How are lenses able to focus light? Are the lenses in a lighthouse the same as the lenses in a pair of eyeglasses?

INQUIRY SKILL **Make a Model** A lighthouse is 61 m (about 200 feet) high. Its light can be seen at a distance of 30 km (18.6 miles). Why does the distance the light can be seen depend on the height of the lighthouse? Make a drawing to answer the question.





LESSON 7

Light and Mirrors

Vocabulary

light ray, F85
law of reflection, F87
concave mirror, F88
convex mirror, F88

Get Ready

What happens in any city or town when the Sun sets? What if you were in a plane as the Sun was setting and you could look down at a big city? What would you notice as time goes by?

What if you are in a room, sitting near a window and reading? The Sun sets. How does everything in the room seem to change? What do you need to do if you want to keep reading? Is it possible to see objects if there is no light?

Inquiry Skill

You predict when you state possible results of an event or experiment.

Explore Activity

Can You See Without Light?

Materials

- small cardboard box with lid
- small object to put inside box, such as an eraser, crayon, or coin
- scissors
- flashlight

Procedure

BE CAREFUL! Handle scissors carefully. Do not put any sharp objects in the box.

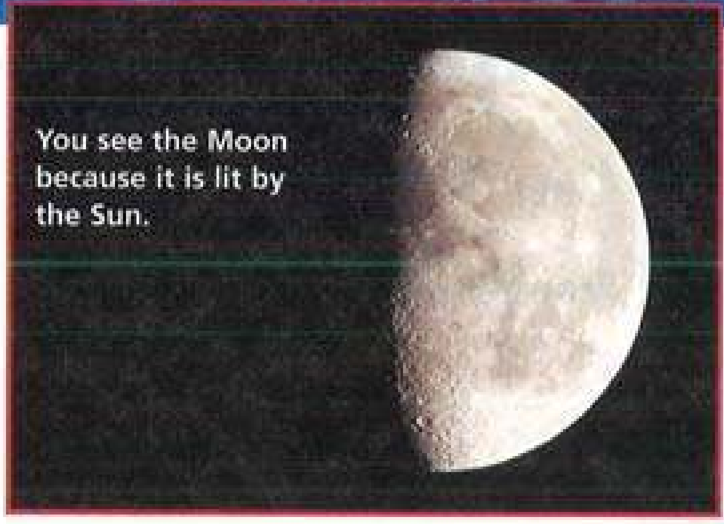
1. Can you design a test to find out how well you see without light? Cut a dime-sized hole in the box as shown. Put an object inside the box. Close the lid.
2. **Observe** Look in the box through the hole. What do you see? Write a description of it.
3. Now cut a small hole in the top of the box.
4. **Experiment** Shine the flashlight through the top hole while you look into the box again. Can you see the object this time?

Drawing Conclusions

1. **Communicate** Could you see the object inside the box in step 2? In step 4? Explain any difference in your answers.
2. **Infer** Is it possible to see an object in the dark? Explain.
3. **Predict** Do any characteristics of the object in the box affect the results? Try different kinds of objects. Predict any differences in your results. Test your ideas.
4. **FURTHER INQUIRY** **Predict** How much extra lighting would you need on a dark, cloudy day in order to safely walk around your classroom or your room at home? Would a night-light work? How would you test your ideas safely?

Read to Learn

Main Idea Light is a form of energy that is reflected from some objects.



You see the Moon because it is lit by the Sun.

Can You See Without Light?

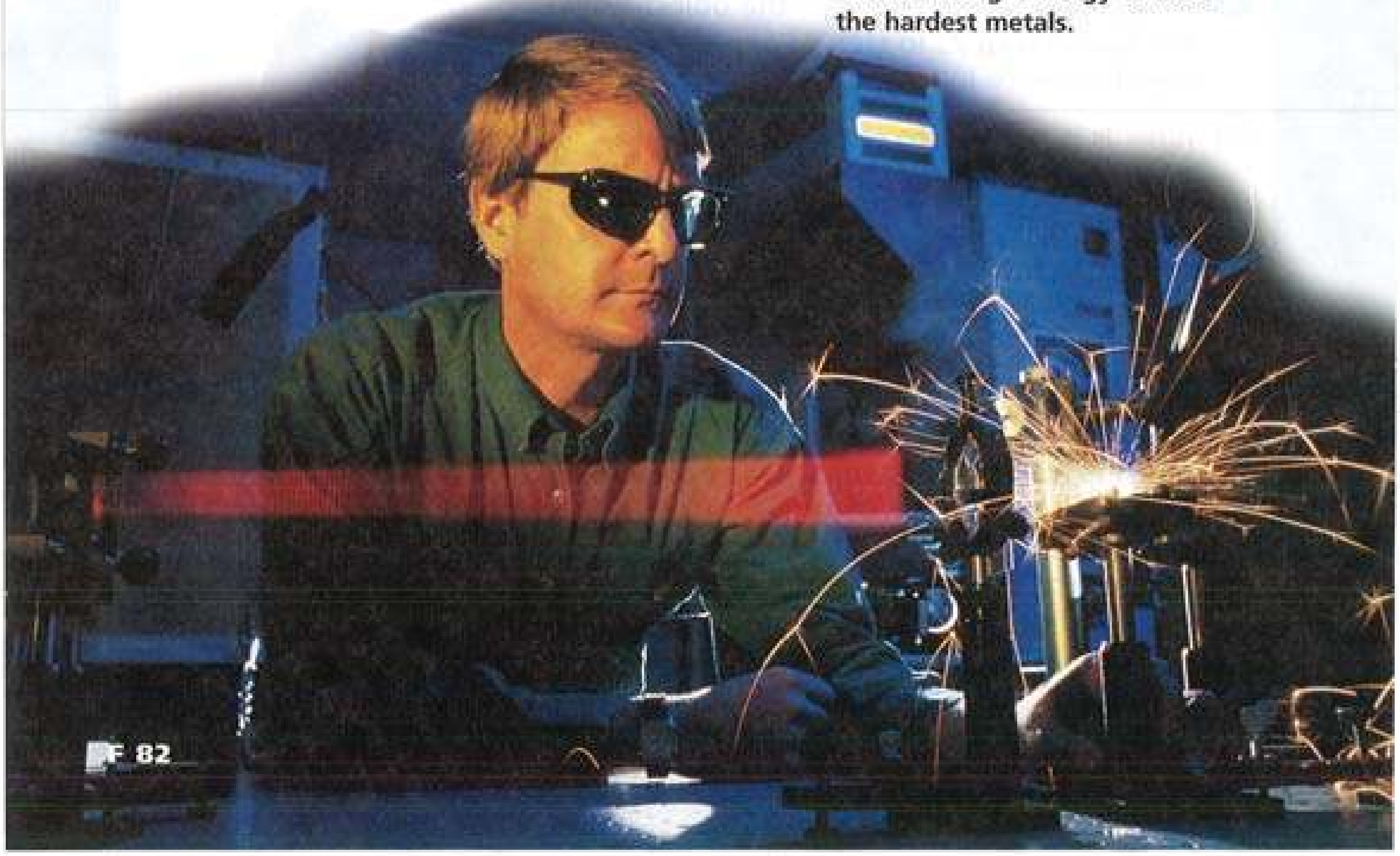
The Moon looks very bright in the evening sky. However, the Moon does not give off any light of its own.

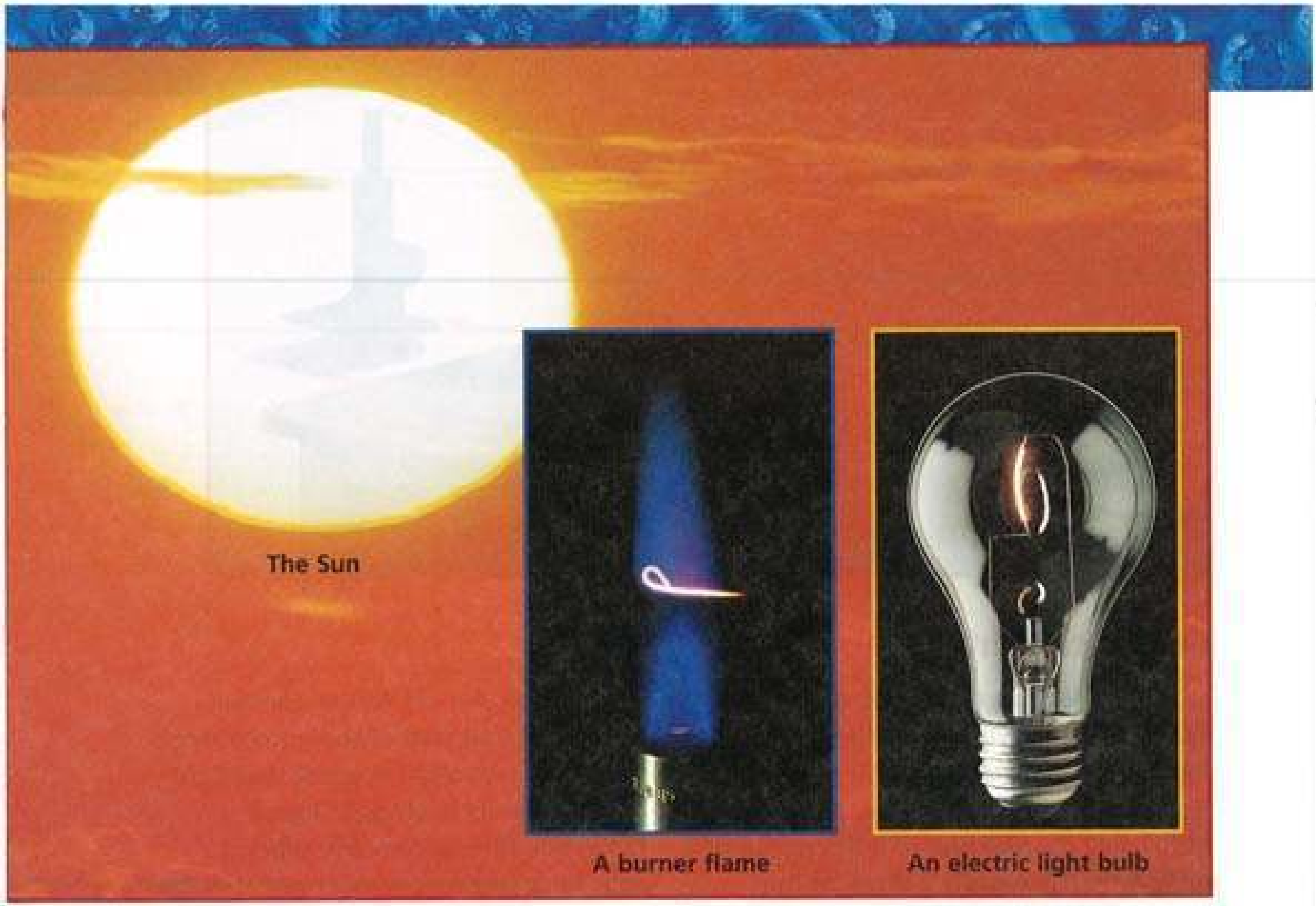
We are able to see the Moon only because sunlight bounces off the Moon's surface and into our eyes. The dark half of the Moon in the photo is actually a part of the side of the Moon that is not being lit by the Sun. Since sunlight does not reach the Moon there, we cannot see this part of the Moon's surface.

What is light? Scientists know that light, like sound, is not matter. We could never observe a "piece" of light at rest, taking up space and having mass. Light and sound are both means of transferring energy between points.

The photograph below clearly shows that light carries energy. In fact, light is a form of energy.

A beam of light from a laser carries enough energy to melt the hardest metals.





The Sun

A burner flame

An electric light bulb

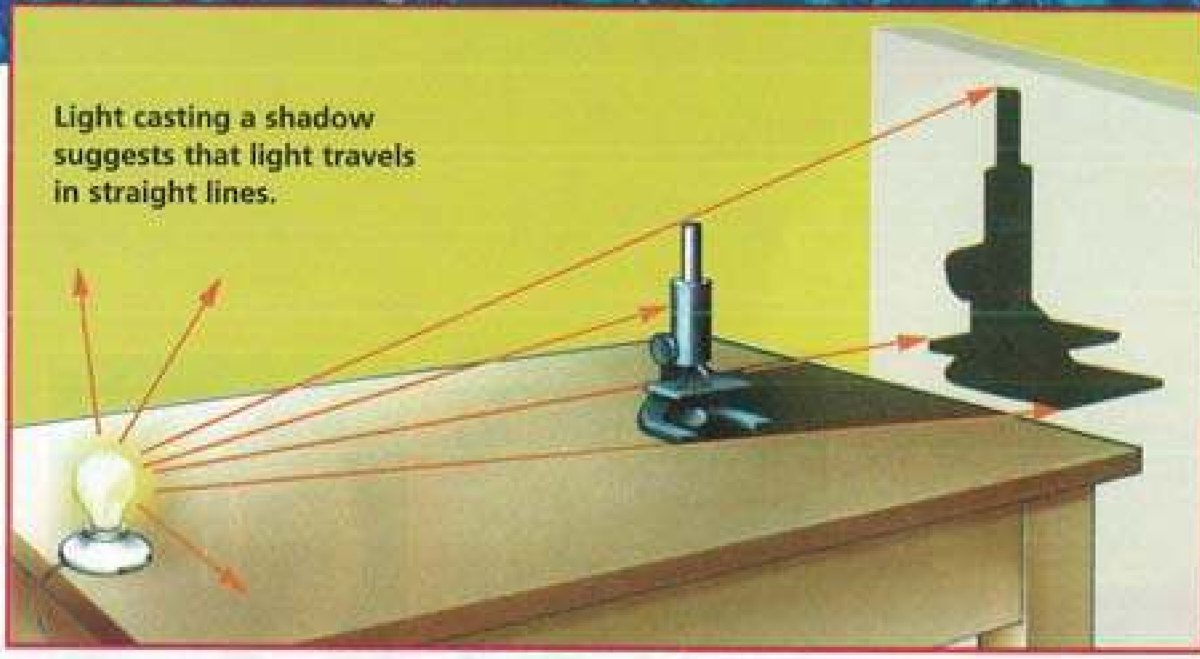
How Light Is Produced

All the objects we can see either give off their own light or, more often, reflect the light from a source such as a light bulb or the Sun. The photos show objects that produce light. As you can see, heat is involved in all three cases. Nuclear reactions heat the Sun. Chemical reactions heat the burner flame. Electricity heats the glowing wire of the light bulb.

In a very hot material, the molecules move swiftly. At times when these molecules collide, some energy from the collision may be given off as light. At other times the molecules themselves vibrate and give off light waves.

Any light source converts energy of one kind into light energy. For example, the Sun makes light from nuclear energy, a burner makes light from chemical energy, and an electric light bulb makes light from electrical energy. The light waves given off by these sources carry the energy away at great speed.

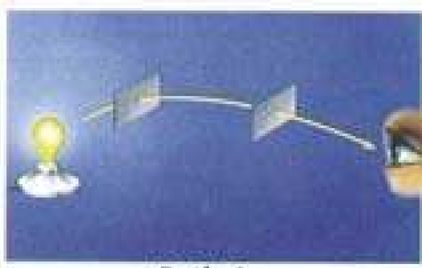
What can you see in a room that is totally dark?



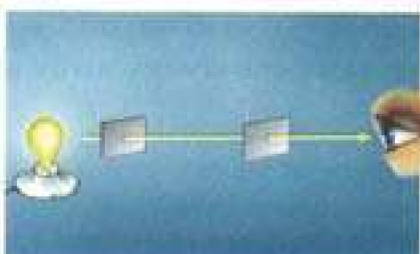
How Does Light Travel?

Take a look at the drawings below. Which path do you think shows how light travels to your eyes?

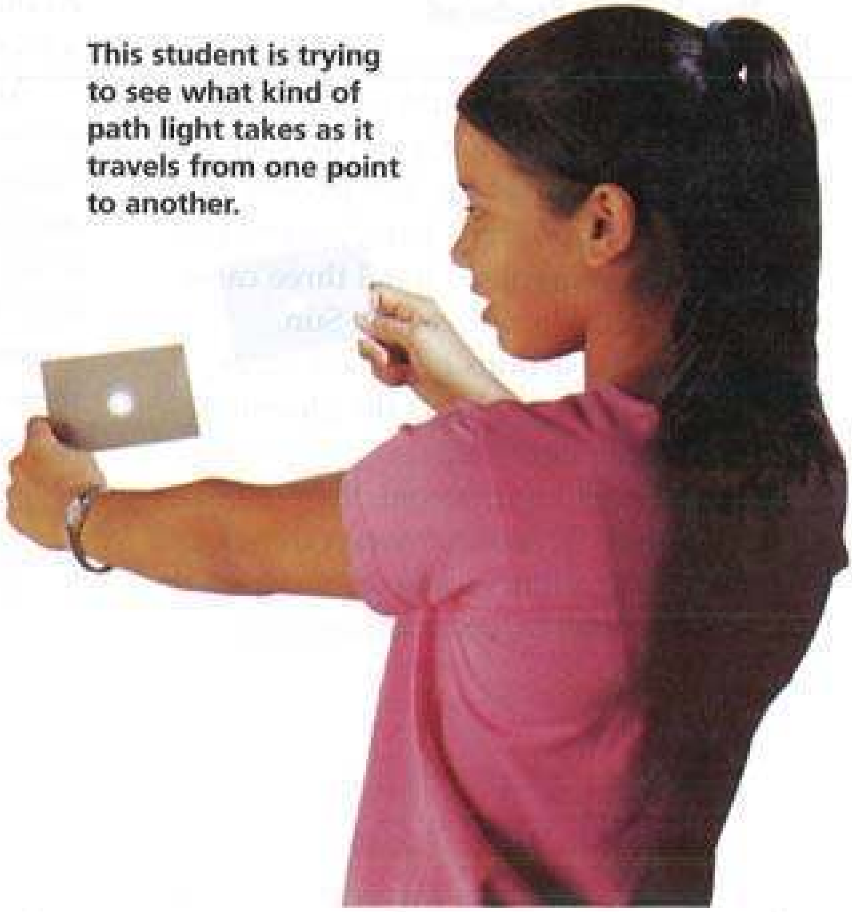
In the illustration above, a light bulb casts the shadow of a microscope on a wall. If we draw a straight line from the light bulb to any part of the microscope, we can follow the line directly to that part of the microscope's shadow. This might suggest that light always travels in straight lines. However, this is true only when a substance like air or water remains the same along the whole pathway of light.



Path A



Path B

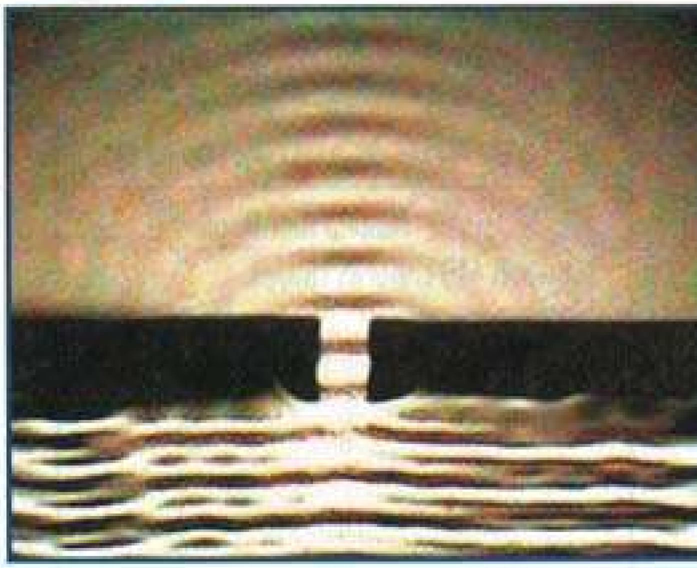


This student is trying to see what kind of path light takes as it travels from one point to another.

In fact, light usually changes direction when it passes from one substance into another. Otherwise, as long as light travels through air or water, it follows a straight line.

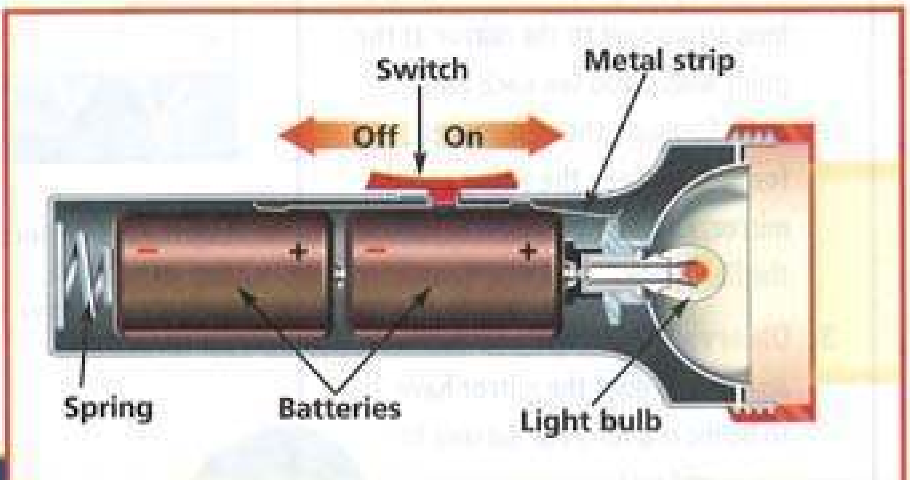
Actually, light travels as a series of waves. These waves can be disturbed or bent when they travel past the edge of a thin object or flow through a very narrow opening.

When free of snags, however, light waves move as shown below. If we could follow a point on a light wave as it ripples outward from its source, we would trace a straight line. This beam of light is called a **light ray**.

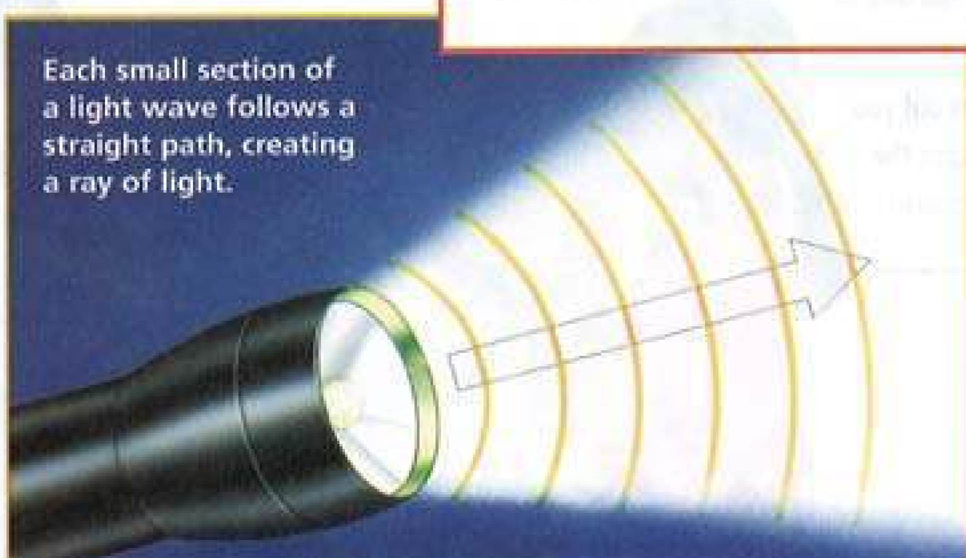


This model uses water waves to show how light waves bend as they travel past very thin objects or pass through very tiny holes.

How does light travel when it passes from one substance into another?



When the flashlight is on, electric current from the batteries flows through the metal strip and lights the bulb.



QUICK LAB

Follow the Bouncing Light

FOLDABLES Make a Half-Book. (See p. R 41.) Label as shown.

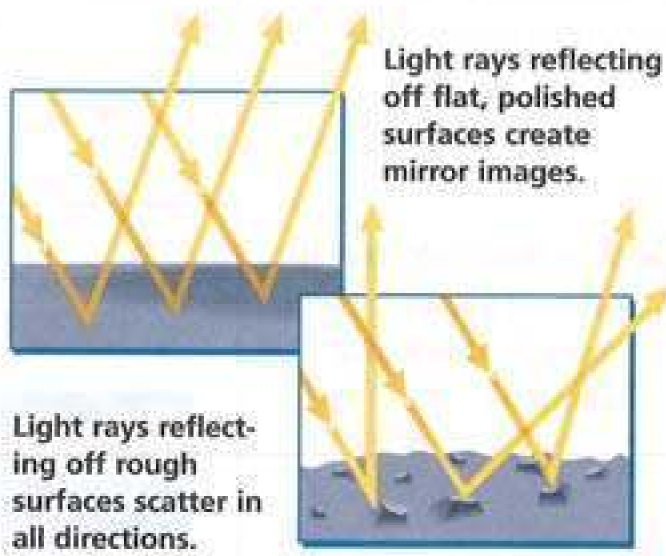
Observation 1 Angles	Observation 2 Angles

1. Hold a small pocket mirror as shown. Adjust it so your partner can see your face in the middle of the mirror.
2. You and your partner should hold a long string taut to the mirror at the point where you see each other's nose. Compare the two angles formed between the string and the mirror. Record your observations in the Half-Book.
3. **Observe** Move a little farther apart. How does the mirror have to be moved for your partner to see your face?
4. **Interpret Data** What did you observe about the angles the string made with the mirror?

How Does Light Bounce Off Objects?

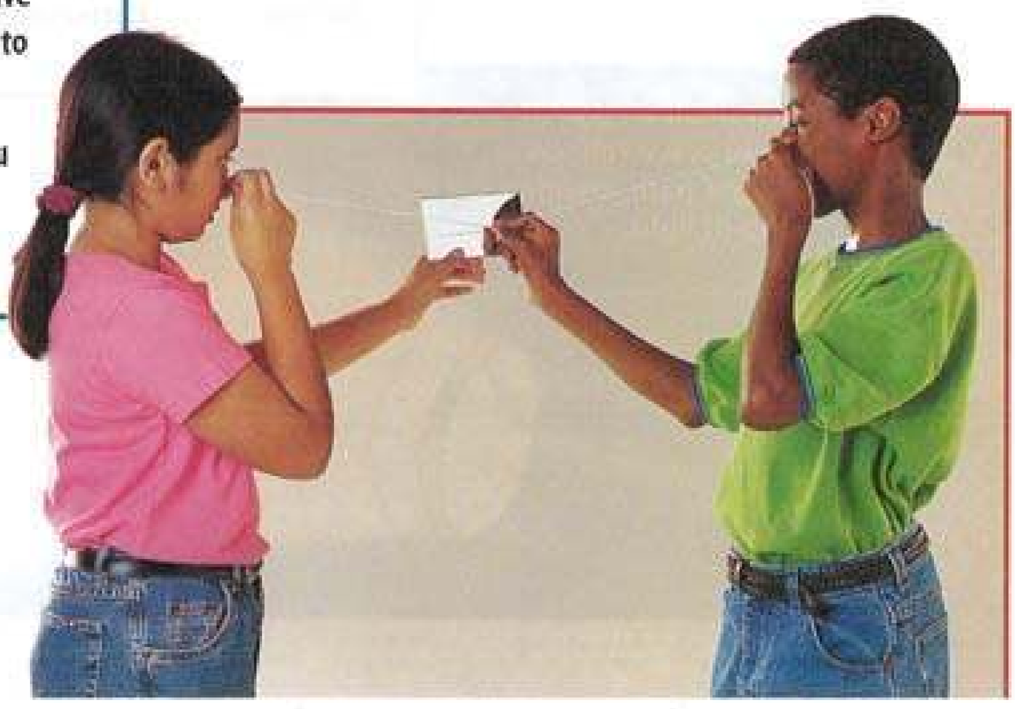
Review how any visible object must either give off its own light or reflect light from another light source. We can picture how light reflects (bounces) off objects using light rays as in the diagram.

How is light reflected by a mirror? When a ray of light reaches your eye from a mirror, where did the light come from before it struck the mirror?



Light rays reflecting off flat, polished surfaces create mirror images.

Light rays reflecting off rough surfaces scatter in all directions.

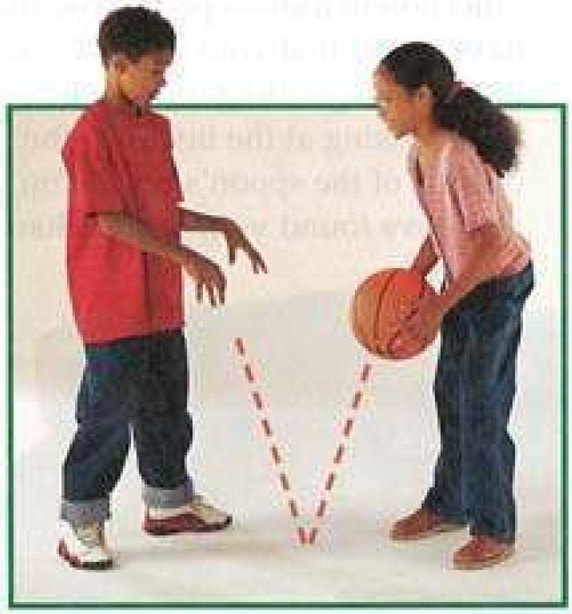


The Law of Reflection

The angle between an incoming light ray and a surface equals the angle between the reflected light ray and the surface. This is called the **law of reflection**. The illustration below helps to demonstrate this idea.

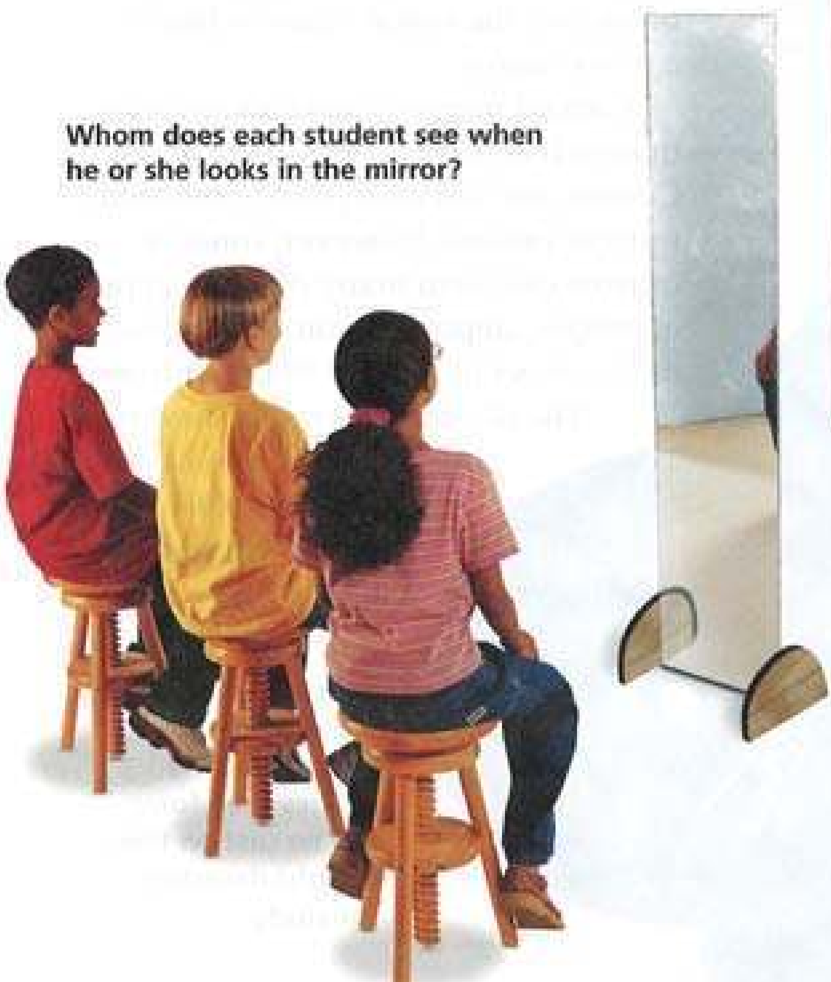
Light rays that bounce off polished, shiny surfaces can reflect a "picture" of the light source, called an *image*. The things you see when you look in a flat mirror, for example, look very real, almost as if they existed on the other side of a window. However, your experience tells you they are not real—they are just images of the real things in your world. The picture shows how flat mirrors form images.

Ambulance signs are often done in "mirror writing" so that they read correctly when seen in a rearview mirror.



The path taken by the basketball shows what a light ray does when it reflects off a surface. The angles between the path of the ball and the floor are equal on either side of the bounce.

Whom does each student see when he or she looks in the mirror?



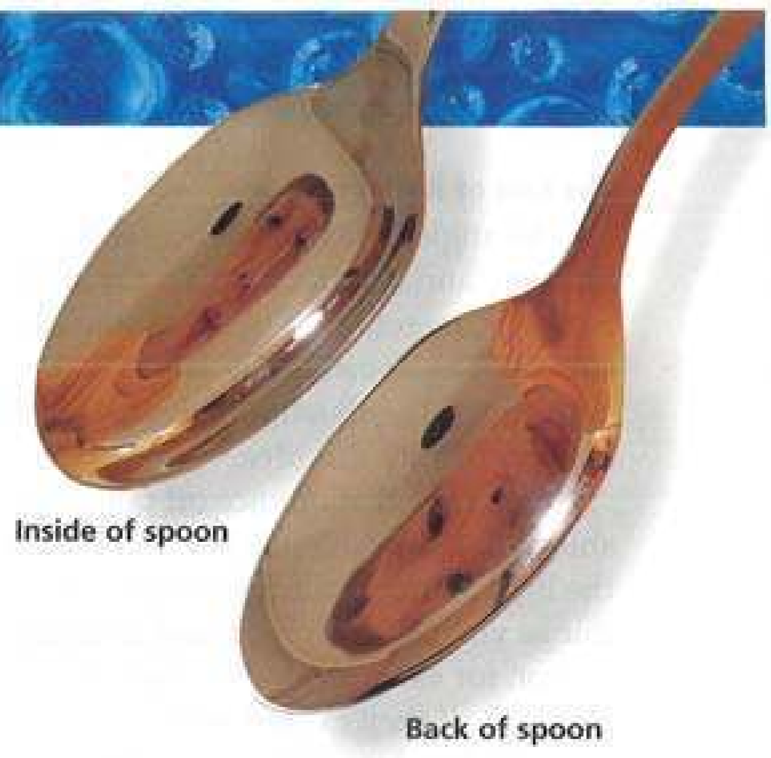
How does light bounce off a mirror?

How Do Curved Mirrors Form Images?

Mirrors that curve in on the shiny side are **concave mirrors**, while mirrors that curve out on the shiny side are **convex mirrors**. Curved mirrors form images that are different from those formed by flat mirrors.

How do you think the images formed by concave and convex mirrors will differ from one another? From the image formed by a flat mirror?

Have you ever looked at your reflection in a soupspoon? You may have found that your image looked different depending on whether you were looking at the inside or the outside of the spoon's bowl. You may also have found your image changed, depending on how far away you held the spoon.

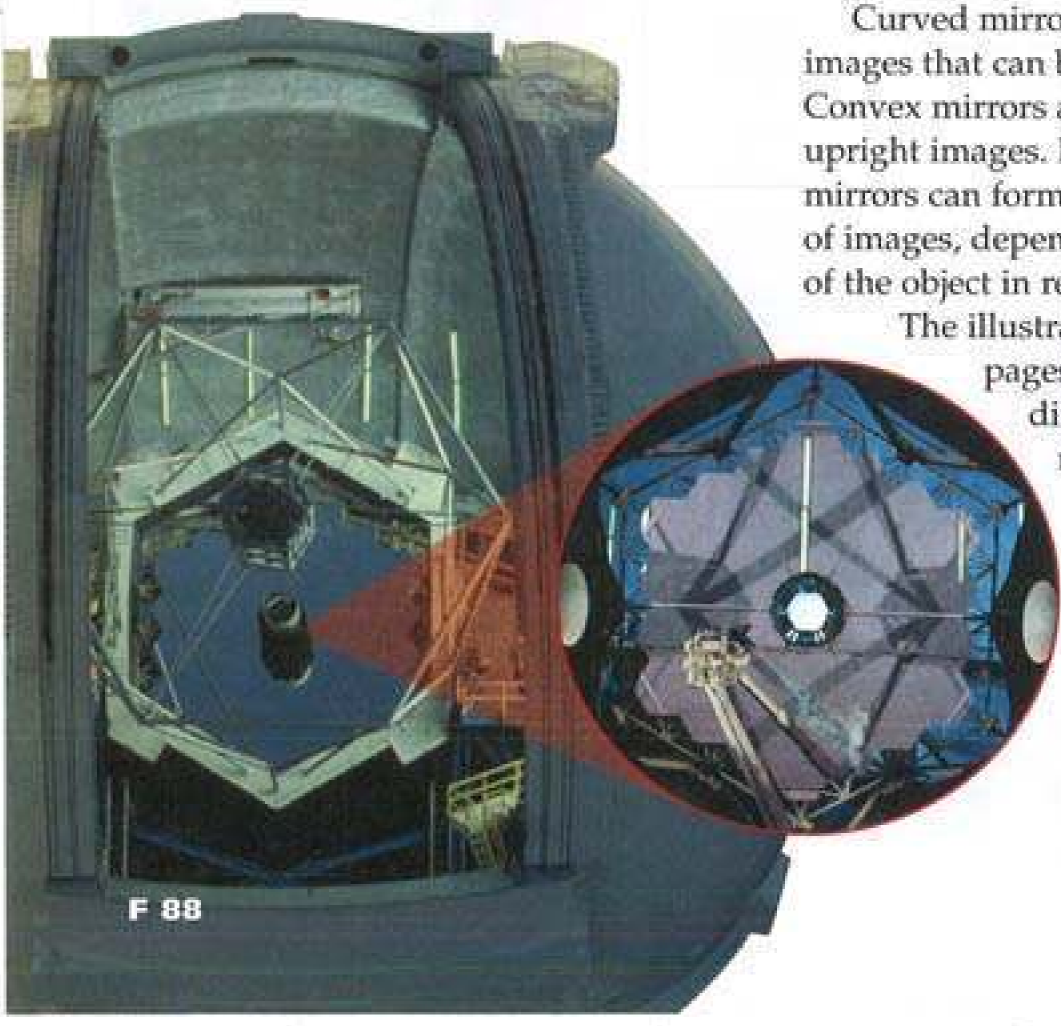


Inside of spoon

Back of spoon

The inside of the soupspoon behaves like a concave mirror. The outside of the spoon behaves like a convex mirror.

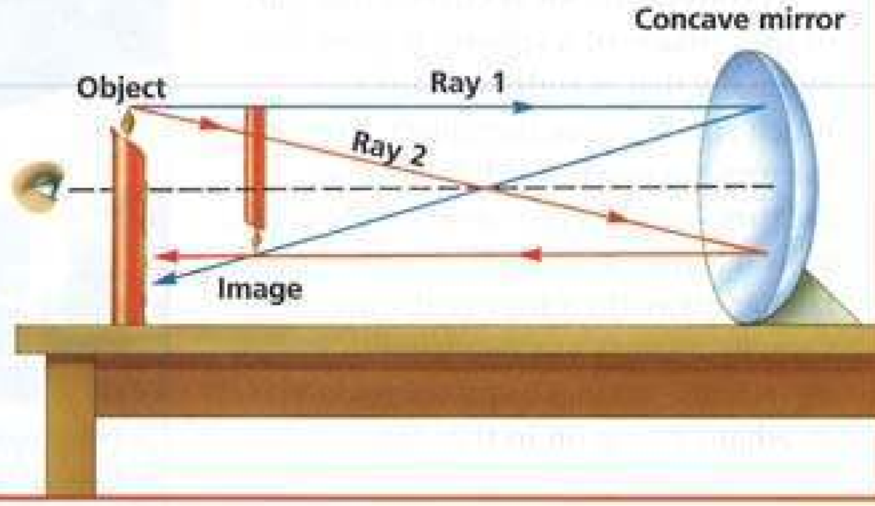
Curved mirrors create a variety of images that can be of practical use. Convex mirrors always form reduced, upright images. However, concave mirrors can form many different types of images, depending on the position of the object in relation to the mirror. The illustrations on the next two pages demonstrate how different kinds of mirrors form images.



Concave mirrors are often used in telescopes. The images they form can be cast on film or light detectors for study.

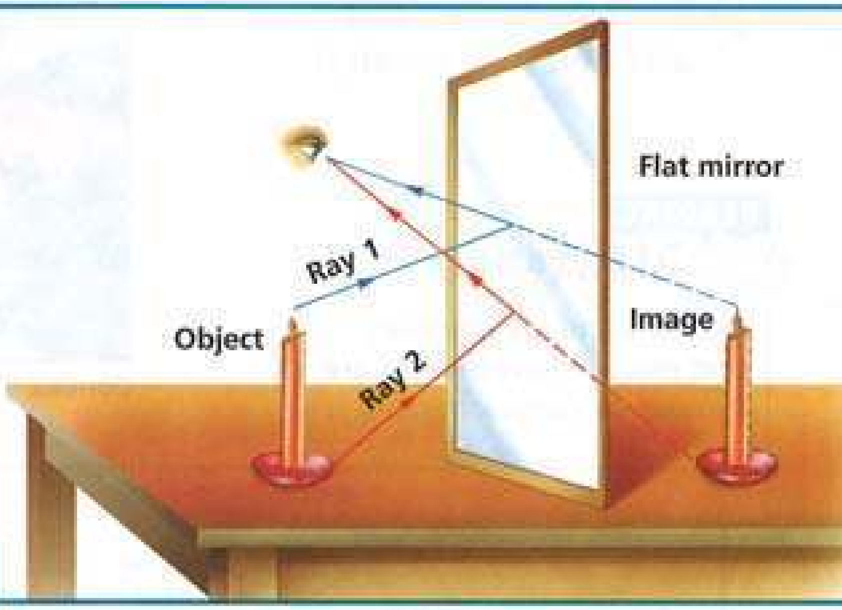
Concave Mirrors

Images formed by a concave mirror depend on how far the object is from the mirror. Objects very close to the mirror produce enlarged, right-side-up images. Objects a bit farther back produce enlarged, upside-down images. As the object moves back even farther from the mirror, the image remains upside-down but gets smaller and smaller.



Flat Mirrors

Light rays coming from the candle bounce off the flat mirror and create an image on the other side of the mirror. The image in a flat mirror is always upright, life sized, and left-to-right reversed.



READING Diagrams

1. What happens to the light rays reflected by the concave mirror?
2. Look at the image produced by the concave mirror. How do the image and object compare?

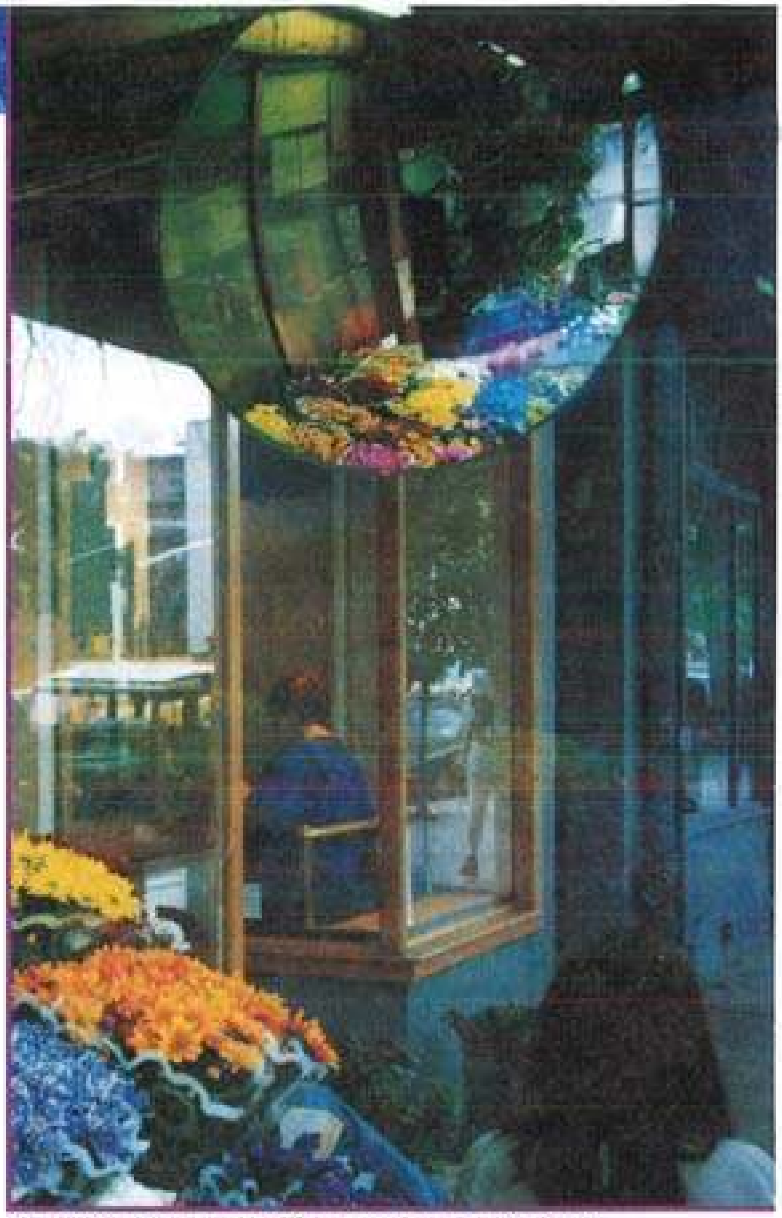
READING Compare and Contrast

How are images formed by curved mirrors different from those of flat mirrors?

How Do Convex Mirrors Work?

A convex mirror is curved like part of the outside of a sphere. It produces an image that is right-side up and much smaller than the object. Convex mirrors are used as side rearview mirrors in cars. They give a wide-angle view. However, the cars seem to be farther away than they really are. Convex mirrors are also used in stores as security mirrors to give a wide view of what's going on in the store.

Why is a convex mirror useful for store security?

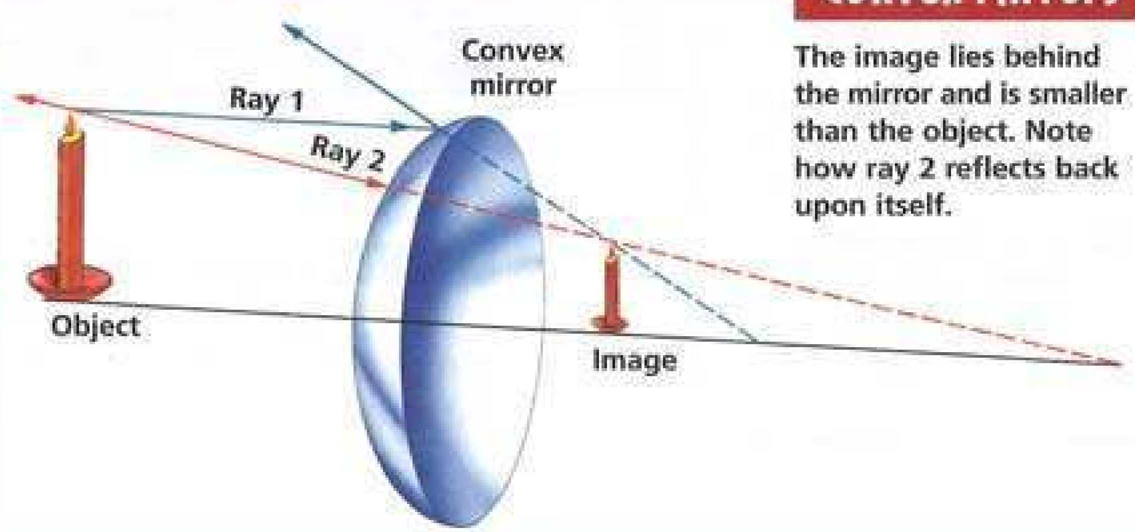


Convex mirrors provide a wide-angle view.

READING Diagrams

Examine the ray diagram, and explain how images are formed by convex mirrors.

Convex Mirrors



The image lies behind the mirror and is smaller than the object. Note how ray 2 reflects back upon itself.

Lesson Review

Why It Matters

Have you ever gone to a parade and missed almost everything because the people in front of you were taller than you? A simple periscope might have helped. Simple periscopes are tall tubes with mirrors inside that help you see over things that would otherwise block your view. Periscopes are also used in submarines to allow the subs to stay underwater while getting a look at what's going on above the water's surface.

e-Journal Visit our Web site **www.science.mmhschool.com** to do a research project on how mirrors reflect light.

Think and Write

1. Is it possible to see in the dark? Explain.
2. What evidence can you give that light travels in straight lines?
3. How are the images formed by concave mirrors different from those formed by convex mirrors?
4. The rearview mirror on the right side of a car is usually convex. Why is a convex mirror best for this purpose?
5. **Critical Thinking** Describe a demonstration that would show how light carries energy.

L•I•N•K•S

WRITING LINK

Writing a Poem You visit a "fun house" of mirrors and are amazed at what you see. Write a humorous poem describing how you look in these different kinds of mirrors and why.

MATH LINK

Solve this problem. How many 2 x 4 ft mirrors are needed to cover the walls and ceiling of a rectangular room that is 10 x 8 x 8 ft? The room has no doors or windows.

ART LINK

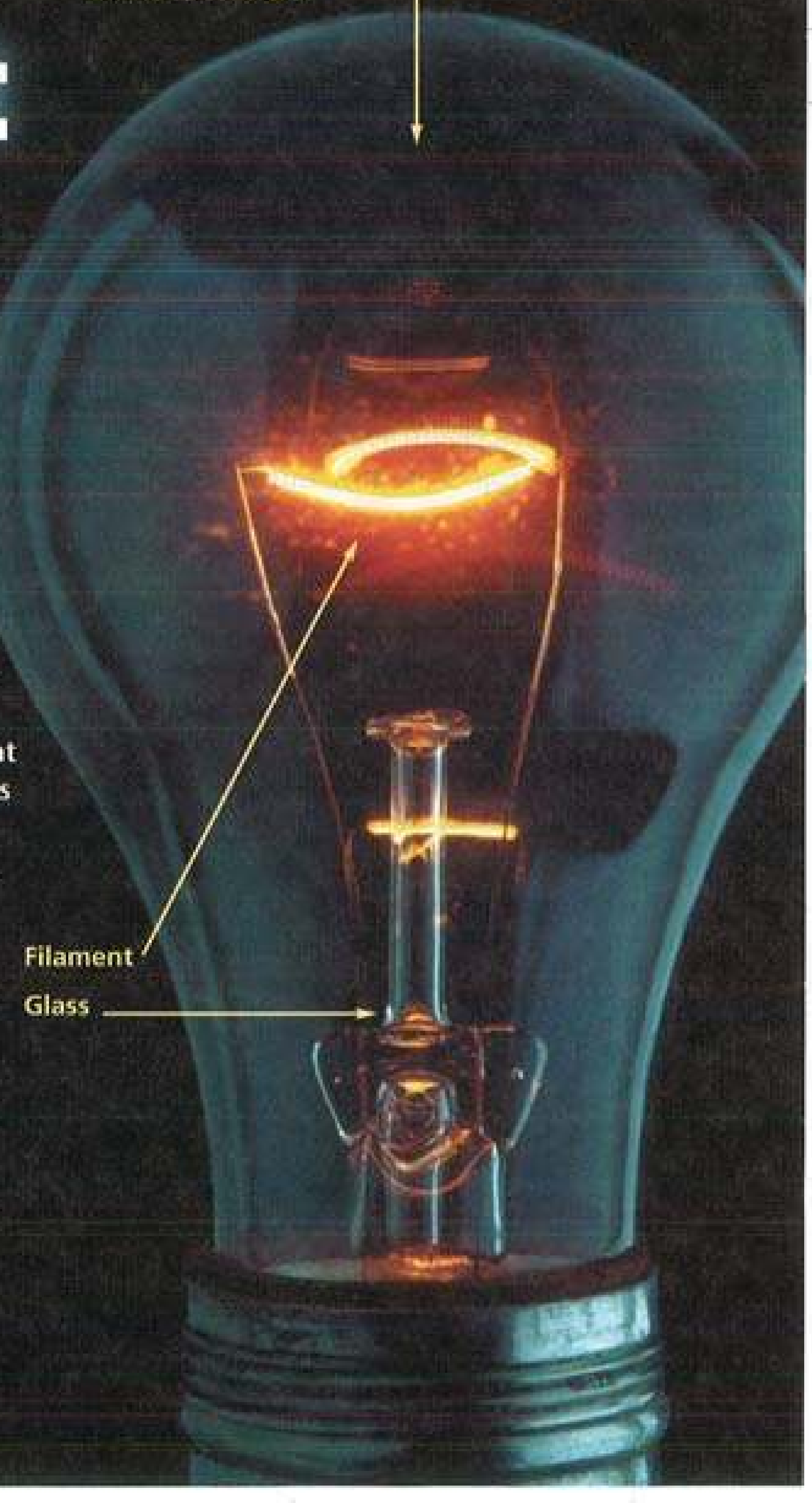
Make a kaleidoscope. Use simple materials. Consult books from the library or the Internet. Draw up a plan to build one. Get permission from your teacher to build it. When it's finished, hold it up to the light. Turn it to see the patterns that form. Describe what you see.

TECHNOLOGY LINK

LOG ON Visit **www.science.mmhschool.com** for more links.

BULBS: The Bright Idea!

This has been the typical light bulb for more than 60 years. It has a tightly coiled tungsten filament in a bulb that's filled with a special gas.



Whose bright idea was the light bulb? No one person can take all the credit because you need electricity to light the bulb!

It began in 1800, when Alessandro Volta produced the first steady electric current. In 1820 an inventor put a current through a metal wire, saw a glow, and put it in a closed glass container, creating the first light bulb.

In 1841 someone built the first light with glowing carbon. Other inventors used other kinds of filaments—thin materials that glow when electrified.

Alessandro Volta

Thomas Edison

The first popular light bulb in the United States was a carbon-filament bulb invented by Thomas Edison in 1879. Two years later Lewis Howard Latimer patented an improved bulb with a carbon filament he invented. Latimer was later hired by Edison.

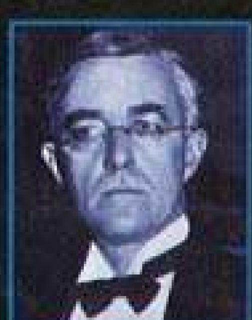
In the 1980s small fluorescent bulbs that screw into ordinary sockets were introduced. These use much less electricity than ordinary light bulbs.

By 1902 metal-filament light bulbs were for sale, but they were very expensive. The General Electric Corporation set up a laboratory to create new bulbs. By 1910 lab workers discovered how to make inexpensive, bright bulbs with tungsten filaments. Sadly, black material coated the inside of the bulbs, dimming the light.

Lab scientist Irving Langmuir found that by filling the bulbs with a special gas, they didn't turn black. By 1934 he'd learned that coiling the filament made the light brighter. Our modern light bulb had arrived!

Fluorescent light bulbs were also produced in the 1930s. They use light from a glowing gas to make a coating inside the bulbs glow. Fluorescent lights use less electricity and are cooler than ordinary bulbs.

Lewis Howard Latimer

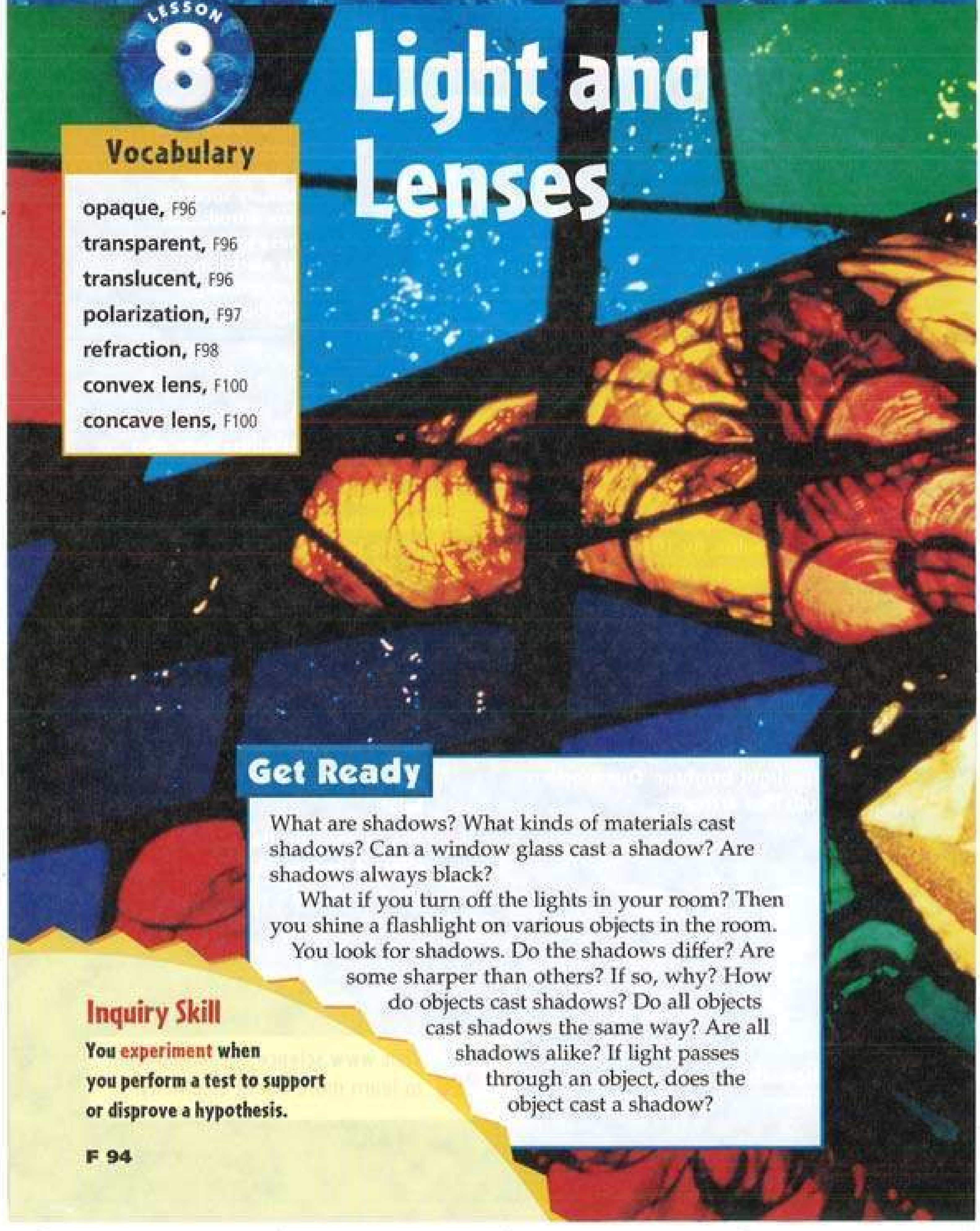


Irving Langmuir

Write ABOUT IT

1. **What's the difference between an ordinary light bulb and a fluorescent light bulb?**
2. **How has the invention of the light bulb affected the space shuttle? The camera? The automobile?**

LOG ON Visit **www.science.mmhschool.com** to learn more about electricity.



LESSON 8

Light and Lenses

Vocabulary

opaque, F96
transparent, F96
translucent, F96
polarization, F97
refraction, F98
convex lens, F100
concave lens, F100

Get Ready

What are shadows? What kinds of materials cast shadows? Can a window glass cast a shadow? Are shadows always black?

What if you turn off the lights in your room? Then you shine a flashlight on various objects in the room. You look for shadows. Do the shadows differ? Are some sharper than others? If so, why? How do objects cast shadows? Do all objects cast shadows the same way? Are all shadows alike? If light passes through an object, does the object cast a shadow?

Inquiry Skill

You experiment when you perform a test to support or disprove a hypothesis.

Explore Activity

What Can Light Pass Through?

Procedure

1. **Classify** Sort the test materials into those that you think light can pass through and those that light cannot pass through.
2. **Experiment** Use the flashlight to test if light can pass through each of the solid materials. Record your observations. Test if light will pass through water. What about water colored with food dye?
3. **Infer** How can you test if light passes through gases? Explain. What materials would you need?

Materials

- plastic sandwich bag
- paper
- waxed paper
- aluminum foil
- other assorted materials to test
- flashlight
- clear plastic cup
- water (other liquids, optional)
- food dye

Drawing Conclusions

1. **Interpret Data** Can light pass through all the materials equally well?
2. **Interpret Data** Can light pass through solids, liquids, and gases?
3. **Predict** What else might you add to water to see if light gets through—sand, ink, instant coffee? Predict if each lets light through. How would you test your ideas?
4. **FURTHER INQUIRY** **Experiment** Design a room from window coverings to lighting, where shadows of objects are always soft and fuzzy, never sharp. What sorts of materials would you use?

Read to Learn

Main Idea Light is blocked by some objects and passes through others.

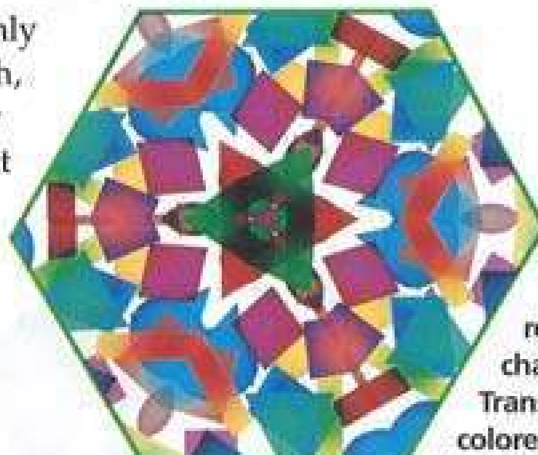
Light from celestial objects, such as this galaxy, passes through empty space to reach us.

What Can Light Pass Through?

Sometimes when light strikes matter, almost all the light gets through. Sometimes only some light gets through. Sometimes none of it gets through.

- **Opaque** materials completely block light from passing through.
- **Transparent** materials allow light to pass through with almost no disturbance. Transparent materials may or may not color the light, but you can see objects clearly through them.
- **Translucent** materials allow only part of the light to pass through, while also bouncing it in many new directions. Since translucent materials give only a blurry view, they are often used in shower doors. They let some light in, but provide privacy.

You might think empty space is opaque to light. After all, light and sound are both waves, and sound waves do need some kind of matter to travel through. However, as the starry night sky shows, light can travel through empty space. We'll learn why in Lesson 10.



Kaleidoscopes use mirrors to turn reflected light into changing patterns. Translucent pieces of colored glass or plastic are often used to create various designs inside.

Which objects in this scene are transparent? Translucent? Opaque?

Controlling Light

In our daily lives, we use many products to control light. You may be familiar with some of the products shown here.

One of the most interesting ways of controlling light depends on **polarization** (poh·luhr·uh·ZAY·shuhn). Light travels in waves. Normally these waves vibrate in all directions. However, light can be *polarized* by some materials. That is, only one direction of light vibrations can pass through them.

Polarized sunglasses use one kind of polarizing material to help us see better on a bright day. On bright days much of the glare we see comes from light reflecting off water and other surfaces.

This reflected light is often naturally polarized to vibrate sideways. Polarizing materials in sunglasses, however, let through only the light that is vibrating up and down. This blocks glare and all other kinds of light that vibrates sideways.

Scientists have also developed sunglasses that change color by themselves! They turn dark in the sunlight but lighten indoors. The lenses of self-tinting glasses contain very small amounts of a transparent, silver-containing chemical. When struck by bright light, this chemical turns into tiny silver particles. These particles block light and darken the glass.

When taken indoors, the silver particles become transparent again, so the lenses automatically lighten.

Thin plastic films can be applied to car windows to give them a darker tint. This cuts down on the brightness of the light coming through.

READING **Compare and Contrast**
Compare how light passes through opaque, transparent, and translucent materials.

Self-tinting glasses indoors

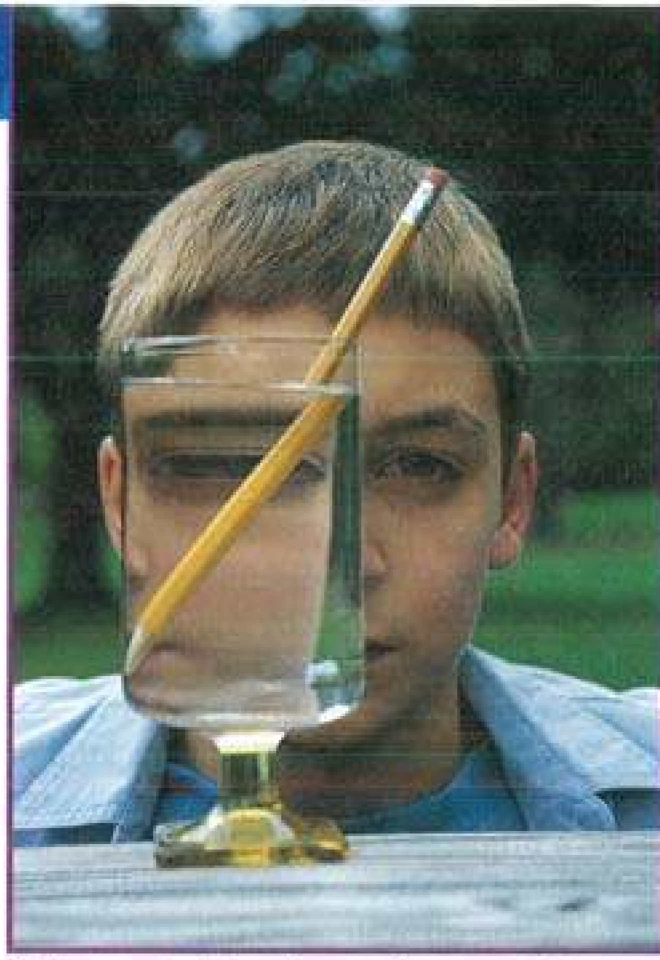
Outside in bright light

How Can Light Rays Be Bent?

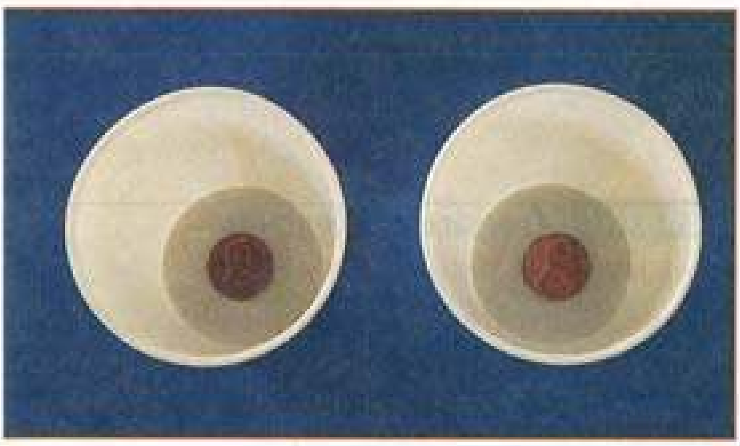
The pencil in the photograph certainly appears to be bent. However, the bend is actually just a "trick" that light rays play on our eyes. The illusion is caused when light rays from the lower part of the pencil change direction as they go from water into air. The bending of light rays as they pass from one substance into another is called **refraction** (ri·FRAK·shuhn). The photographs on page F99 illustrate the refraction of a light beam.

How does light affect what you see when it passes through water?

You've seen that light rays may bend as they move from one substance into another. Can light rays move from one substance into another without bending?



Light rays bend as they go from water into air, making the pencil appear to be bent.



How Refraction Works

Imagine skating onto grass from a sidewalk. If you skate straight onto the grass at a 90° angle, you will slow down, but your direction will remain the same. If you skate onto the grass at any other angle, though, one skate will slow before the other. This will cause you to turn in a new direction. The shallower the angle between your original path and the grass, the more your direction will change.

Put a penny in each cup. Add a little water to one cup. Stand away from the table. Can you see both pennies? What would you have to do so that you could see both coins at the same time?

Like a skater, light traveling from one substance into a denser substance slows down. (The denser substance is made of material that is packed together more tightly than the material that makes up the less-dense substance.)

If light strikes the new material head-on, its direction is unchanged. However, if it strikes at any other angle, it gets refracted into a new direction. The amount of refraction increases as the incoming angle gets shallower.

Look at the photos of the skaters. The first skater skates onto the grass at a 90° angle. Both skates hit the grass at the same time. The second skater's skates don't hit the grass at the same time. Why not? How will the path the second skater takes differ from the path the first skater takes? How do the paths the skaters take compare with the paths the light beams take?

When do light rays bend?

READING Charts

1. What happens as the light beams enter the glass? Compare the paths of the two light beams. Why are they different?
2. How do the paths the light beams take compare with the paths the skaters take? Why do you think this is so?

QUICK LAB

Seeing Through a Lens

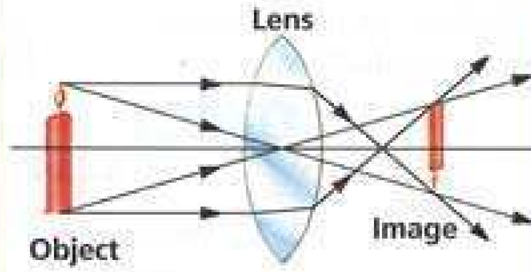
FOLDABLES Make a Six-Row Folded Chart. (See p. R 44.) Label as shown.

Step	Observation
1 (Room)	
1 (Book)	
2	
3	
4	

1. **Observe** Hold a convex lens about a foot from your eye. View the image of the room around you. Record what you see. Repeat with the lens quite close to the page of a book.
2. **Experiment** Aim the lens at a light bulb or window. Move an index card back and forth on the other side of the lens until you see an image of the light source cast sharply on the card. Record what you see.
3. **Observe** Is an upright image enlarged or reduced?
4. **Observe** Is an image cast on the card upright or inverted?
5. **Classify** Summarize your observations in a table.

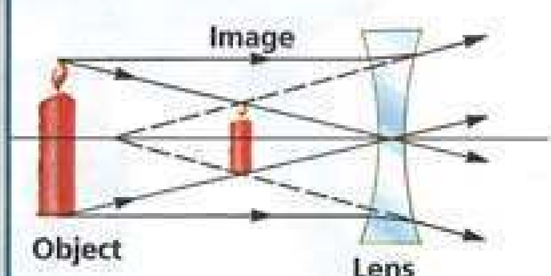
How Do Lenses Work?

Lenses are pieces of transparent materials with curved surfaces that use the refraction of light to make images. **Convex lenses** curve outward, while **concave lenses** curve inward. The diagrams show how these lenses form images.



Convex lenses form images by refracting light rays together. The size and position of the image depend on how far the object is from the lens.

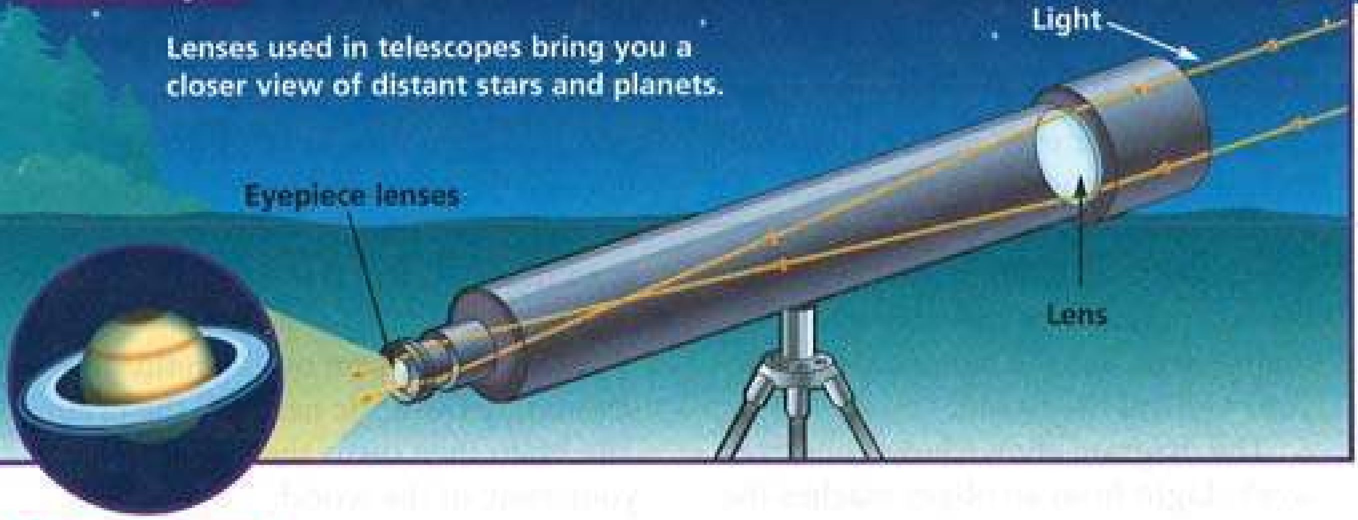
Concave lenses form images by refracting light rays apart. These images are always right-side-up and smaller than the object.



How do convex and concave lenses work?

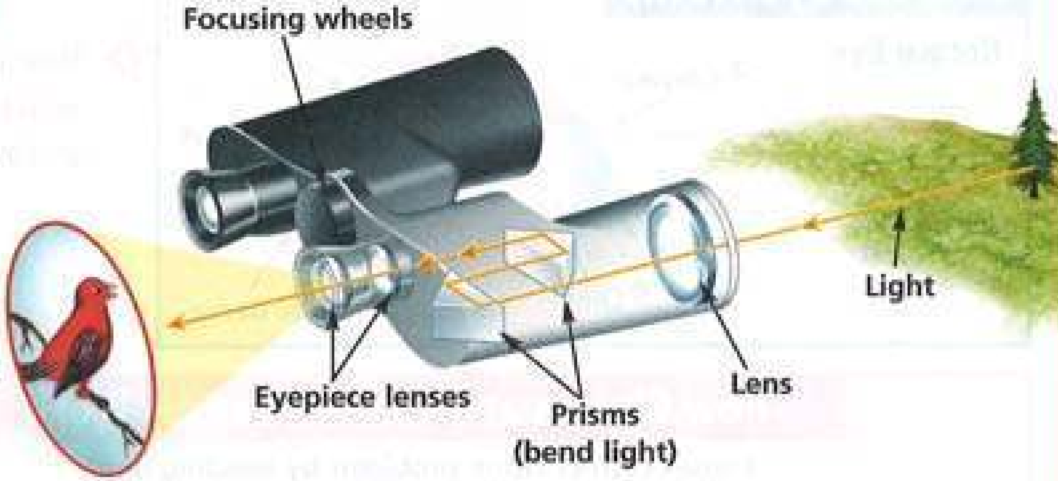
Telescope

Lenses used in telescopes bring you a closer view of distant stars and planets.



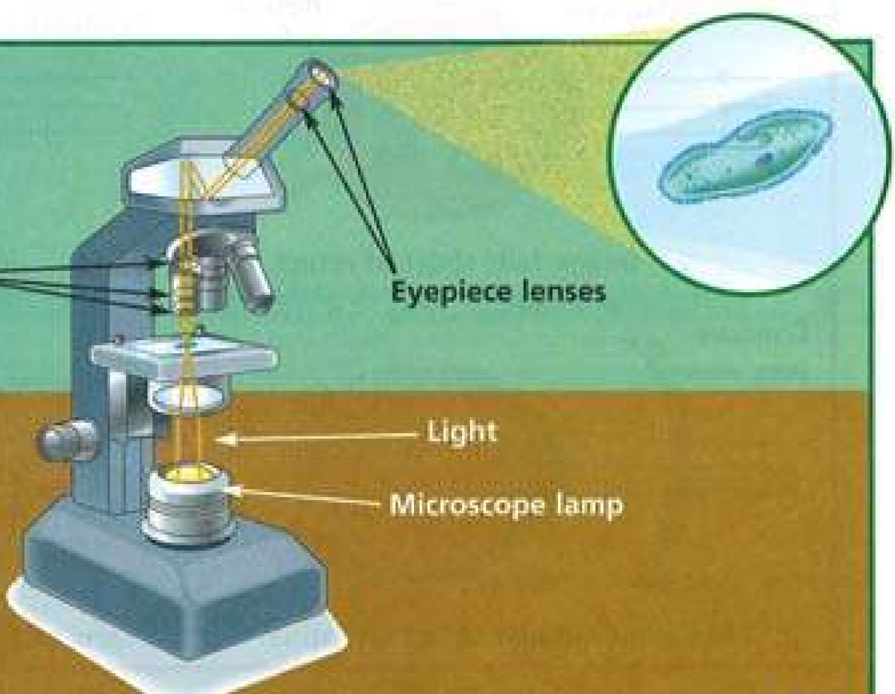
Binoculars

Binoculars work like a pair of small telescopes—one for each eye. They are used for viewing distant objects. Unlike most telescopes, binoculars give an enlarged, right-side-up view.



Microscope

Lenses used in microscopes help you see a tiny world that is invisible to your unaided eye.



READING Diagrams

Why does the telescope pictured give an upside-down view of the planets?

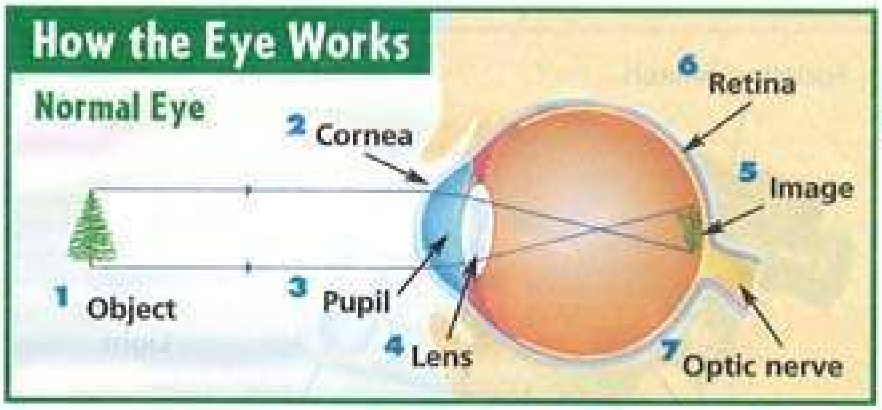
How Does the Eye Work?

Each of your eyes has a convex lens that casts an image onto the back of the eye. Here a sheet of tissue called the retina converts the light into signals that nerves carry to the brain. Your brain then turns the nerve signals into your view of the world.

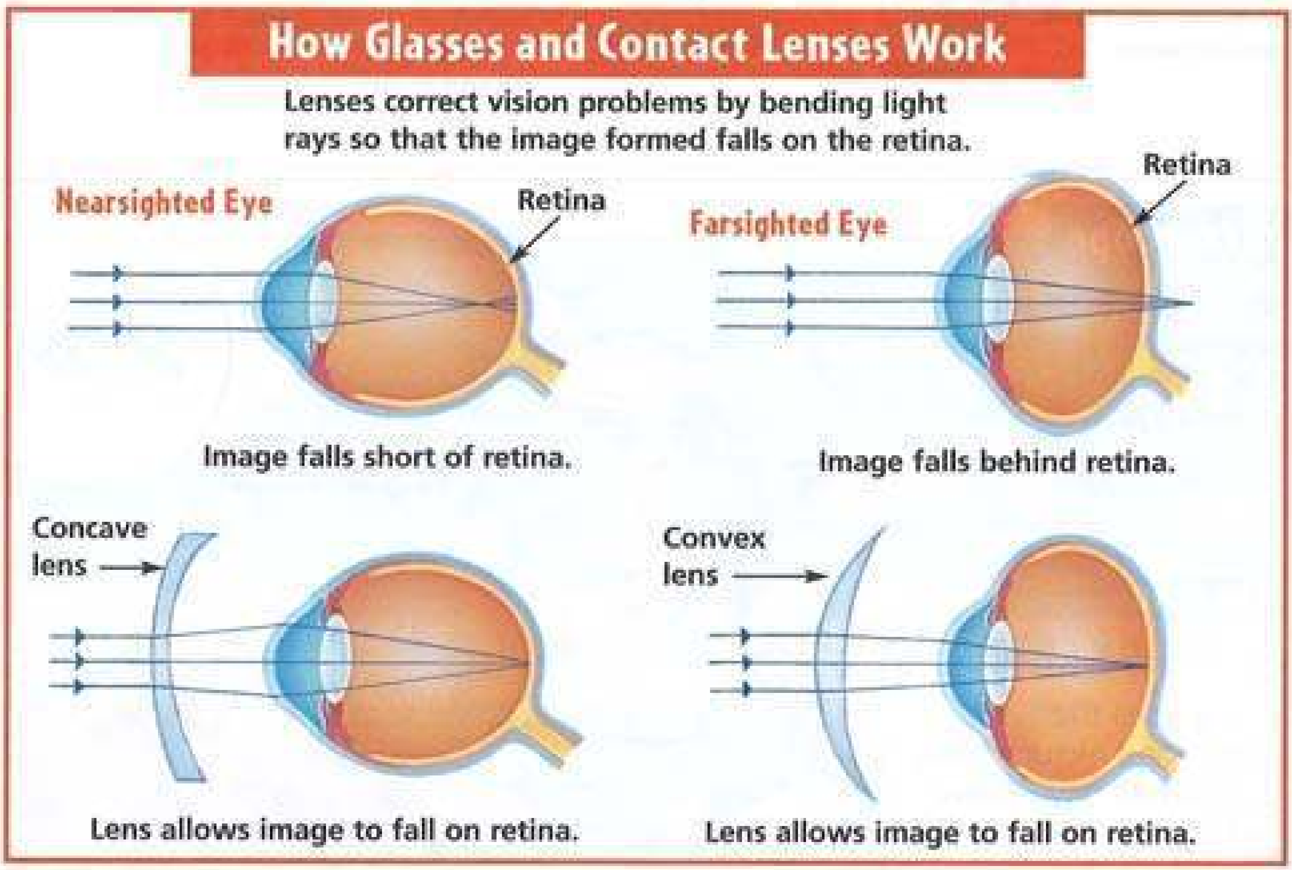
The diagram shows how your eyes work. Light from an object reaches the eye and is refracted by the cornea. The refracted light then enters the eye through the pupil and travels to the lens.

The lens of the eye bends the light even more, so that it forms an image on the retina.

Images that form on the retina are sent on by the optic nerve to the brain. The brain then turns these images into your view of the world.



How can lenses help nearsighted eyes work better?



Lesson Review

L·I·N·K·S

Why It Matters

Light bends as it travels from one kind of substance to another. You can use lenses to focus light and form various kinds of images. The cornea and lens of your eye act as lenses to focus light rays on the retina of your eye. Without this focusing ability, you would not be able to see things clearly.

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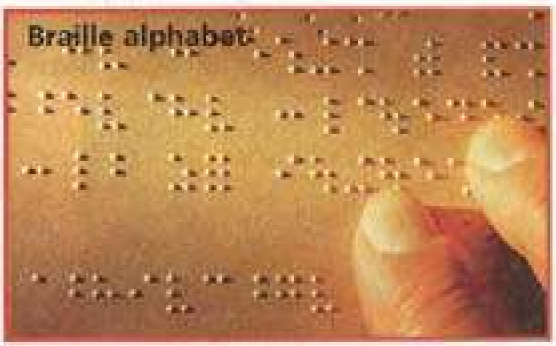


Think and Write

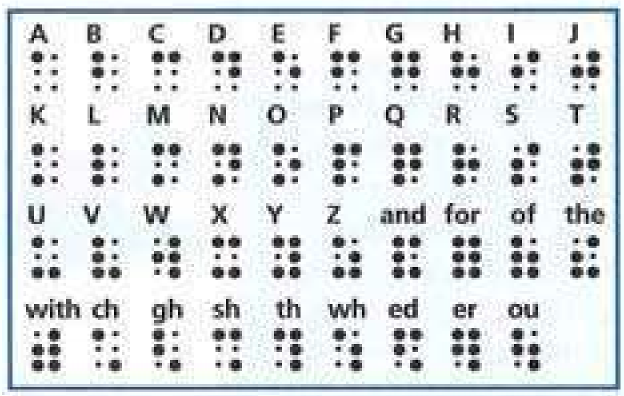
1. Give two examples each of opaque, transparent, and translucent materials.
2. What entry angle allows light rays to avoid being refracted?
3. Why are lenses curved?
4. If it weren't for your brain, you might see the world upside down. Why?
5. **Critical Thinking** How can the Sun be visible before it rises above the horizon?

WRITING LINK

Writing That Compares Lenses affect the way you see things. Write a paragraph that compares and contrasts convex and concave lenses. How are these lenses alike and different?

ART LINK

Make a poster. Research the types of aids available to visually impaired people, and make a poster describing them.



MATH LINK

Solve this problem. A microscope enlarges an object 200 times. How big does the object appear if its actual width is 0.0015 cm?

TECHNOLOGY LINK

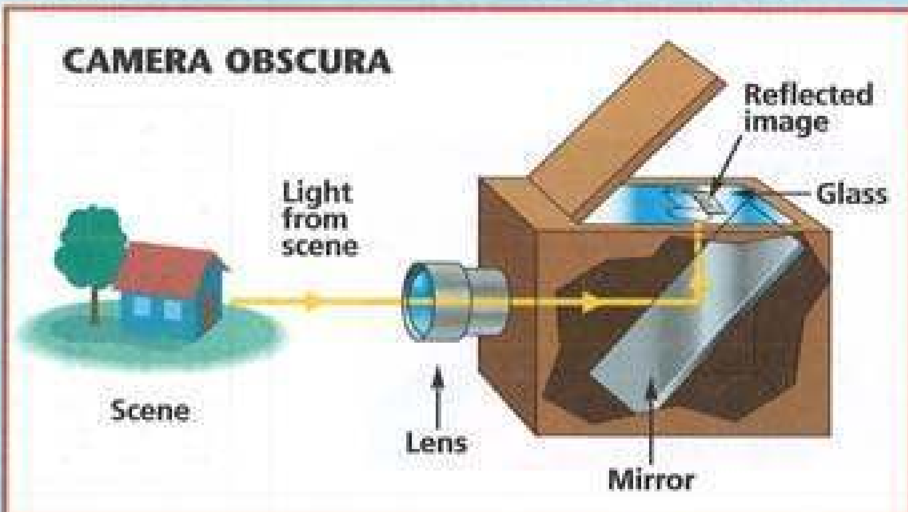
LOG ON Visit **www.science.mmhschool.com** for more links.

History of Science

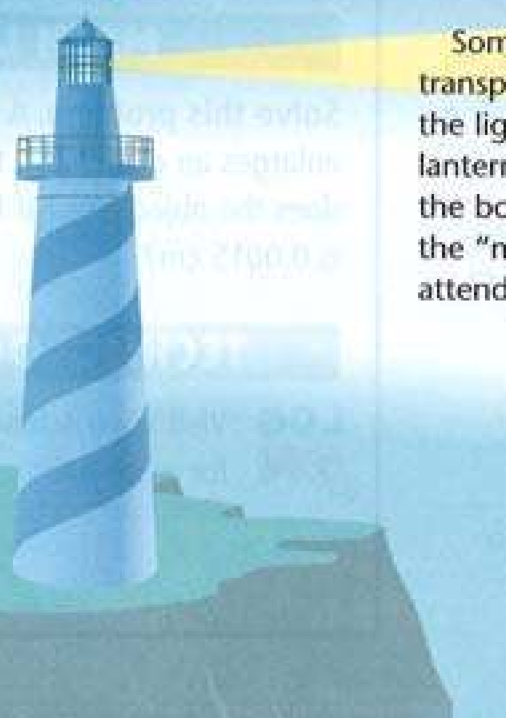
Cameras—Say "Cheese"!

Even in ancient times, people knew how to make glass. Later they found that curved-glass lenses made an object appear larger or smaller.

One of the earliest devices with a lens was the *camera obscura.* (That's Latin for "dark room.") It was a closed box with a lens on the front, a tilted mirror inside, and glass on the top. The lens allowed light from an object into the box. The light hit the mirror and reflected an image of the object onto the glass.



A "bull's-eye" lantern was also an enclosed box with a lens. When a light was placed inside the box, a narrow, bright beam shone through the lens. The lantern was used in lighthouses.



Like the bull's-eye lantern, lenses have also been used in lighthouses. They create beams of light that can even cut through fog.

Someone placed an image on a transparent sheet and placed it between the light and the lens of a bull's-eye lantern. The image was projected outside the box! The device became known as the "magic lantern," and many people attended magic-lantern shows!

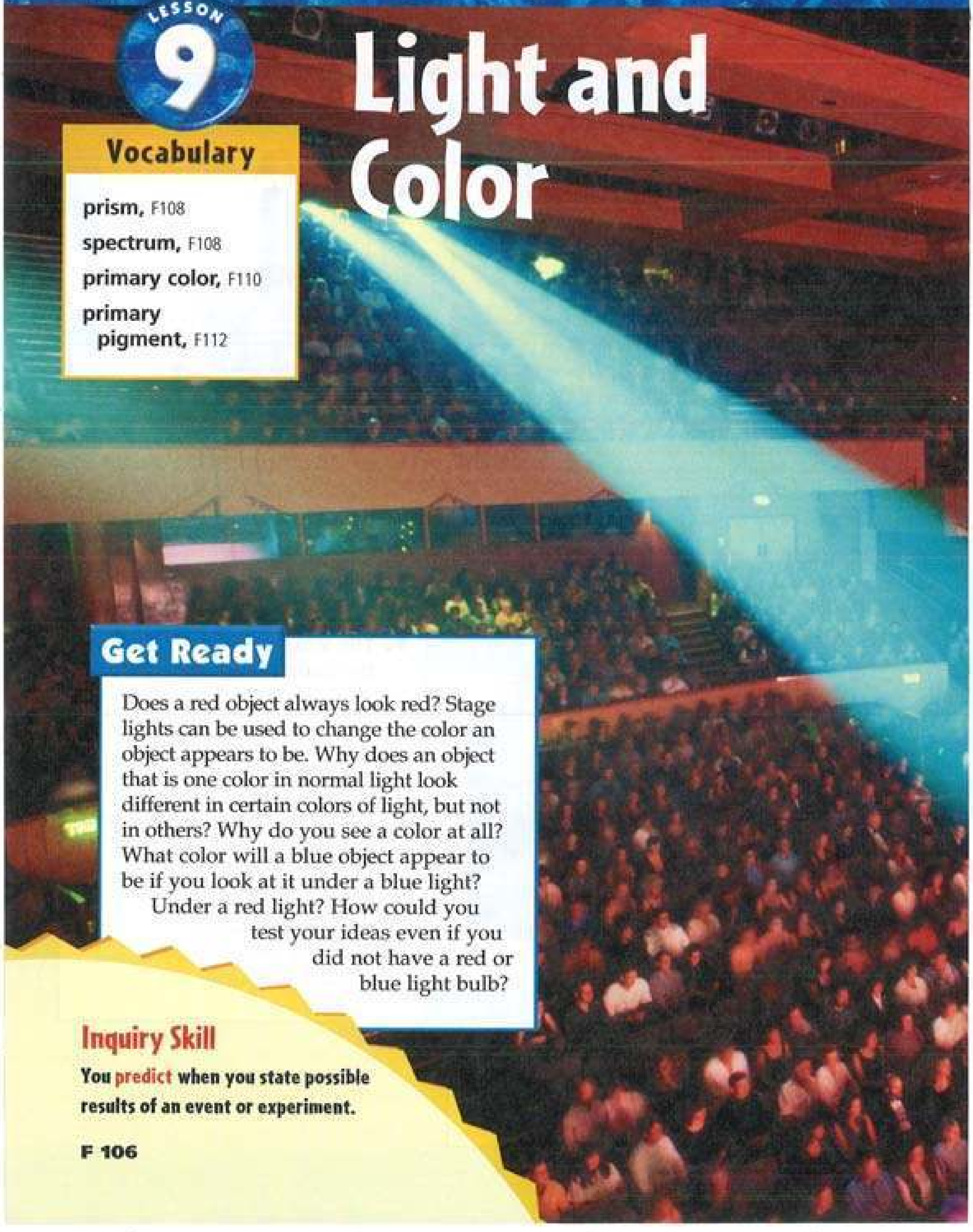
The lens and chamber of the eye are like a small camera obscura. Sometimes an image is formed either too far in front or too far in back of the eye. This can be corrected by adding other lenses in front of the eyes—glasses or contacts!

Some chemicals change color when light shines on them. Inventors put a surface coated with such chemicals at the back of a camera obscura. After many improvements this became the most common way of taking pictures. No one called it a camera obscura anymore. They just called it a "camera"!

What Did I Learn?

1. The word *camera* comes from the Latin phrase for
   - A dark room.
   - B image taker.
   - C picture.
   - D image maker.
2. Which one of these was used to produce a lighthouse's beam of light?
   - F bull's-eye lantern
   - G camera obscura
   - H magic lantern
   - J camera shutter

LOG ON Visit www.science.mmhschool.com to learn more about lenses.



LESSON 9

Light and Color

Vocabulary

prism, F108

spectrum, F108

primary color, F110

primary pigment, F112

Get Ready

Does a red object always look red? Stage lights can be used to change the color an object appears to be. Why does an object that is one color in normal light look different in certain colors of light, but not in others? Why do you see a color at all? What color will a blue object appear to be if you look at it under a blue light? Under a red light? How could you test your ideas even if you did not have a red or blue light bulb?

Inquiry Skill

You predict when you state possible results of an event or experiment.

Explore Activity

What Is Color?

Procedure

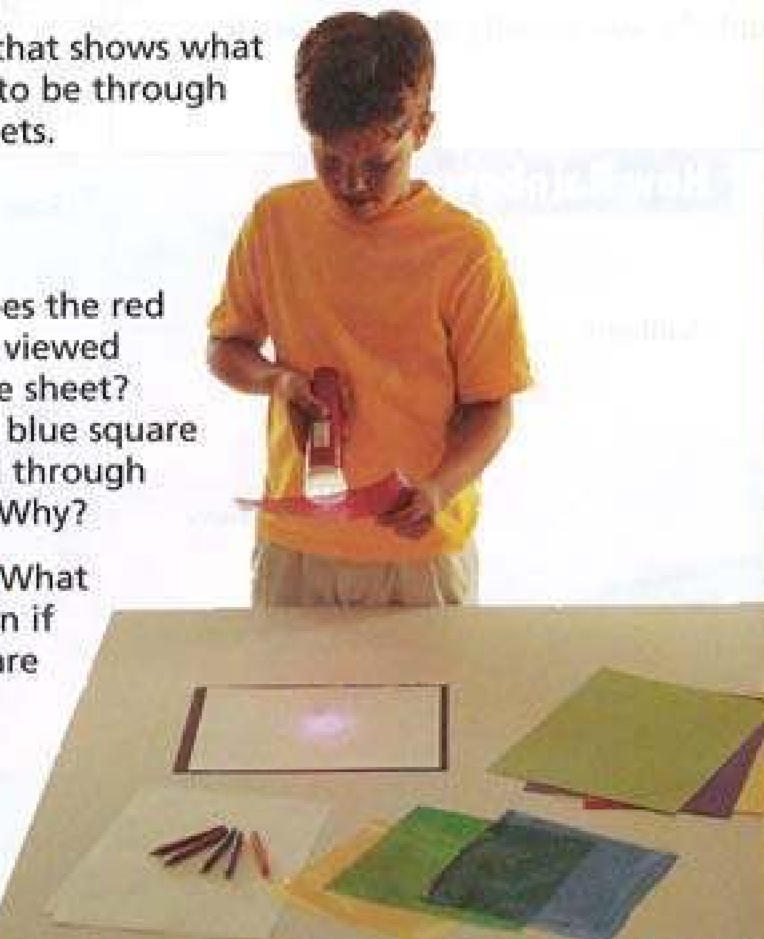
1. **Observe** Instead of using colored light bulbs, shine a flashlight at a sheet of white paper through each of the cellophane sheets. Record what you see.
2. **Predict** Is there a difference if you observe the paper by looking through colored cellophane instead? What color will each of the colored squares appear to be through each of the cellophane sheets? Check your predictions.
3. **Make a Model** Use the crayons to make additional colored squares to view through the cellophane sheets.
4. **Communicate** Make a table that shows what color each square appears to be through each of the cellophane sheets.

Drawing Conclusions

1. **Communicate** What color does the red square appear to be when viewed through the red cellophane sheet? Why? What color does the blue square appear to be when viewed through the red cellophane sheet? Why?
2. FURTHER INQUIRY **Predict** What do you think would happen if you looked at the red square through both the red and blue cellophane sheets at the same time? Try it to test your prediction.

Materials

- red, yellow, blue, and green cellophane sheets
- white paper
- crayons
- red, yellow, blue, green, and black squares of construction paper
- flashlight



Read to Learn

Main Idea White light is a combination of all colors.

How Do You Get Color from White Light?

When Sir Isaac Newton passed a beam of white sunlight through a **prism**—a triangular piece of cut and polished glass—in a dark room, he was startled to see a band of rainbow colors. He called the color band a **spectrum** after a word meaning "ghostly vision."

Newton wanted to know more about the colors cast by the prism. Where did they come from? He believed that white sunlight was actually a mixture of all the colors. The prism simply spread the colors out by refracting each one at a different angle. Red is refracted the least, violet the most.

Later, Newton predicted that if the spectral colors cast by one prism were passed through a second prism, the colors would recombine into white light.

The result proved his prediction was right. White light is really made up of many colors, including red, orange, yellow, green, blue, and violet.

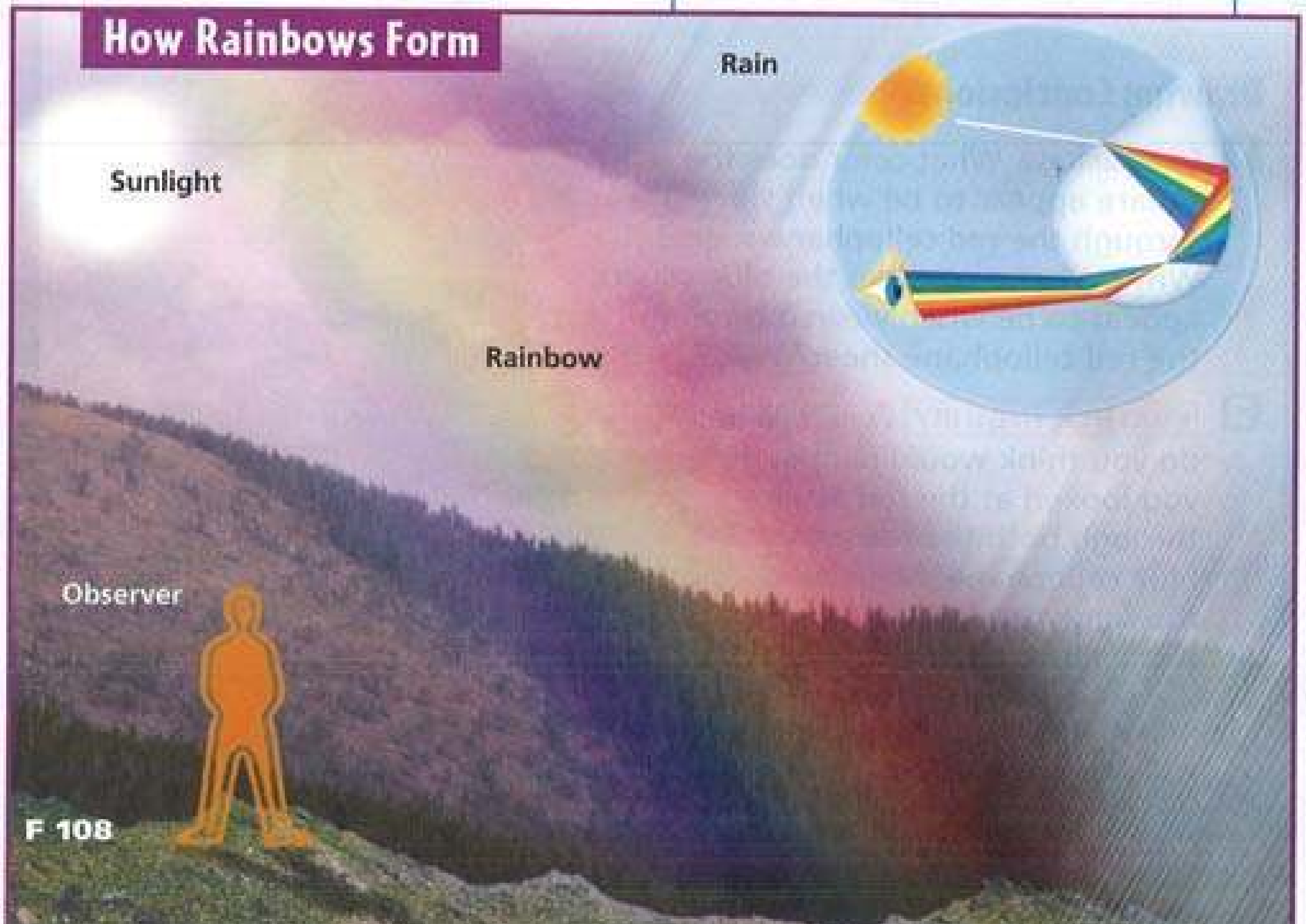
Rainbows

The rainbow colors you see after a storm result from water drops that act

READING Diagrams

How do raindrops break up the Sun's light into different colors?

How Rainbows Form



both as prisms and mirrors. The drops bend rays of sunlight at different angles, causing the colors to spread out. Then the various colors reflect off the back of the drops into your eye. As the drawing shows, that is how rainbows form in the sky.

Can you make a rainbow with a garden hose? If you've stood with your back to the Sun and looked at the fine mist from a hose, fountain, or waterfall, you've probably seen a rainbow form.

You can also make a rainbow indoors, as this student (top right) is doing. Fill a clear-plastic cup about halfway with water. Carefully place it on the edge of a table. A third of it should extend over the edge. Hold a piece of white paper directly behind the cup. Shine a flashlight vertically through the bottom of the cup. You should see a rainbow on the paper.

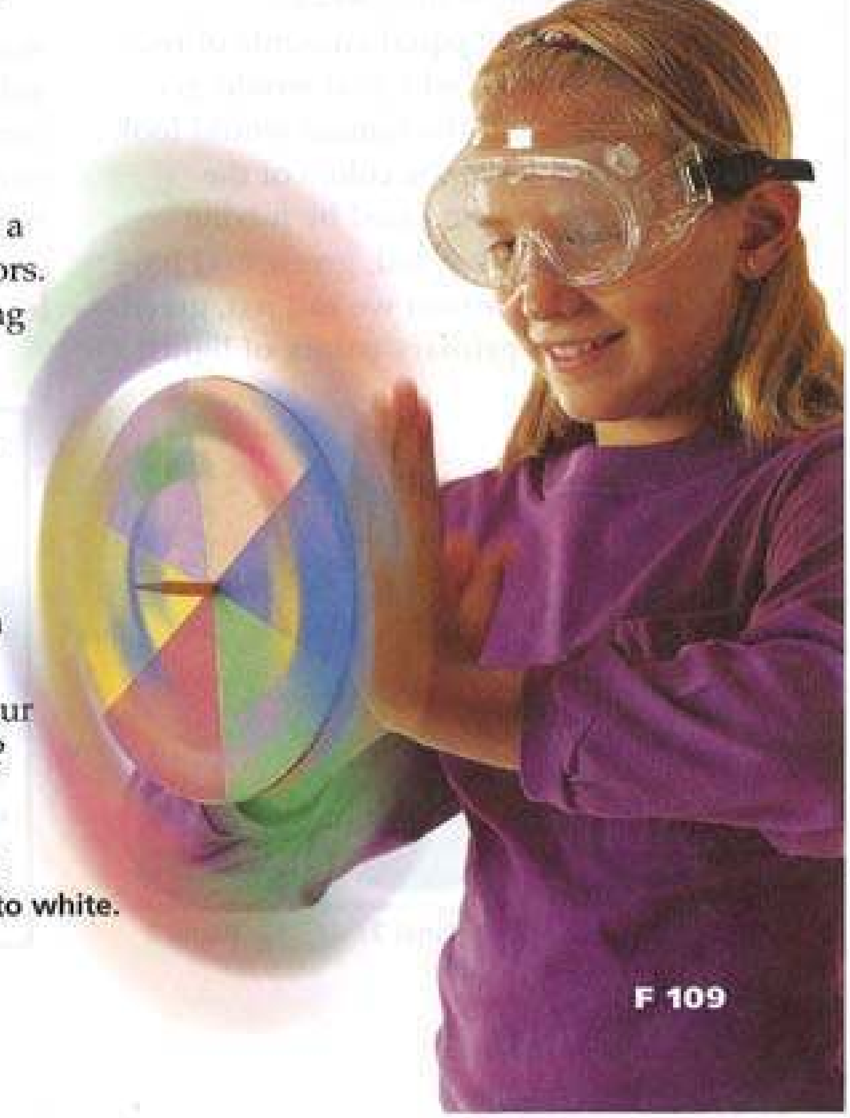
Can you make a rainbow indoors?

READING **Compare and Contrast**
How do raindrops and prisms produce rainbow colors from white light?

A Recipe for White Light

You've learned that white light is a mixture of an entire spectrum of colors. In the picture at right, the girl is using a color spinner she made from cardboard. She pushed a pencil through the center so that when she twirls it between her palms, others can see the colors mix. She is trying to make the right mix of colors so that others will see white light when she spins the spinner.

What colors would you put on your spinner to try to produce white light?



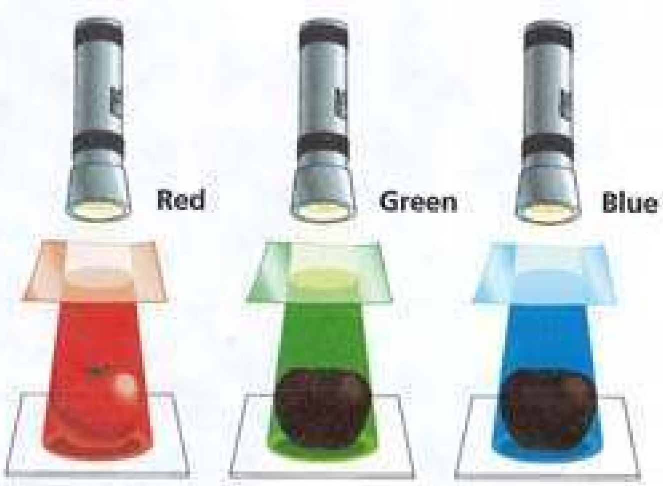
When the spinner is twirled at the right speed, you can see all the colors turn into white.

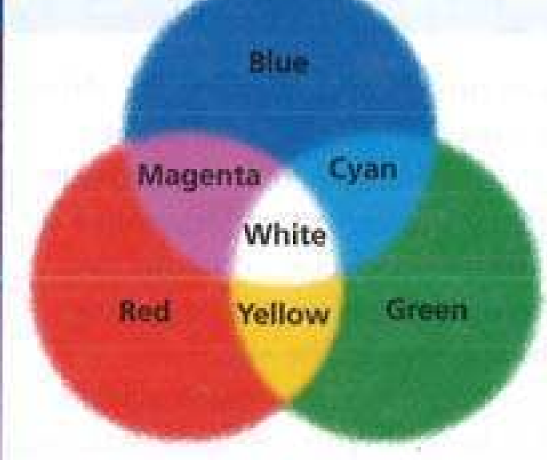
How Do Colors Look in Colored Light?

A color filter is a material that absorbs certain colors of light and allows others to pass through. The color of an object depends on the color of the light hitting it. What if you looked through colored cellophane sheets as color filters? For example, the red cellophane allows red light to pass through it but blocks other colors.

Try shining a flashlight on a red tomato. Use a sheet of red cellophane as your filter. The tomato still looks red. Now try a green sheet as your filter. Since the tomato can only reflect red light, it now looks black. Try other filters to see how they work.

If you mixed equal amounts of red, green, and blue light, you would get white light, and the tomato would look red. In fact, all of the colors of the spectrum can be created by mixing proper amounts of red, green, and blue light. For this reason we call red, green, and blue the **primary colors** of light.





Mixing red, green, and blue light. Note that white is formed in the middle.

Our eyes have cells in the retina that react to colors of light. Some cells react only to red, others only to green, and still others only to blue. If the retina is struck with equal amounts of red, green, and blue light, we see white.

However, if the retina is struck with only red and green light, we see yellow. The drawing above shows some of the different colors that various mixtures of red, green, and blue light can cause us to see.

How does a red object look in green light?

Stare steadily at the blue square above. This tires the cells in your eye that react to blue light. After a full minute, quickly look at a piece of white paper. What color do you see? Why?

Inquiry Skill BUILDER

SKILL Predict

Mixing Colors

You will use pigments—colored substances—in this activity to see the way pigments blend to make other colors.

In this activity you will make a prediction before you do the activity. That is, you will make a reasonable guess about what you expect the results to be. Predict what colors will result when you mix certain colors of food dye together.

Materials

- red, yellow, blue, and green food dyes
- water
- plastic cups
- goggles

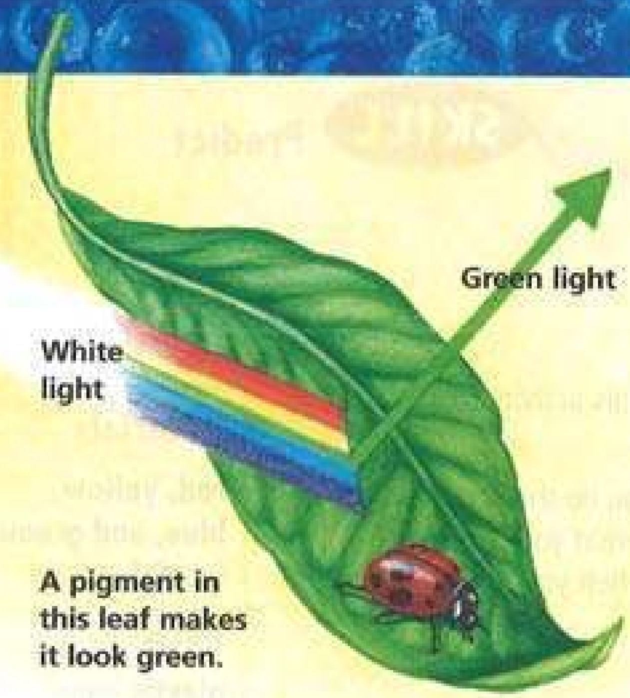
Procedure

BE CAREFUL! Wear goggles.

1. Place four cups on a piece of paper. Add enough water to each cup to cover the bottom.
2. **Predict** What color will be made by mixing one drop of red food dye and one drop of yellow food dye in the water? Mix well. Record the result.
3. **Experiment** Do step 2 with red and blue dyes. Be sure to make a prediction before you mix the colors.
4. **Experiment** Do step 2 again with yellow and blue, and then with all four colors. Again, be sure to make your predictions before you mix the colors.

Drawing Conclusions

1. **Communicate** What color resulted when you mixed red and yellow?
2. **Communicate** What color resulted when you mixed red and blue? Blue and yellow? When you mixed all four colors?
3. **Infer** What would happen if you used different amounts of each dye? Experiment to find out. Make predictions about the final color before you mix the dyes.



What Happens When Color Is Reflected?

When light strikes an object, pigments—colored substances—in the object reflect some colors but absorb other colors. The absorbed colors are missing in the reflected light. The reflected colors mix to produce the color of the object, as shown above.

The leaf in the drawing looks green because it has a pigment that absorbs red and blue light but reflects green light. Some materials reflect all colors and so appear white. Other materials absorb all colors and so appear black.

Colors Made by Blending Paints

Remember that the colors that result when you blend paints are different from the colors that result when you blend colored lights. As you mix colored lights, you keep adding light until you get white.

As you mix pigments, such as food dyes or markers or paints, you keep subtracting colors until you get black. That is how black is formed at the center of the color wheel below.

Magenta, cyan, and yellow are called the **primary pigments**. Each absorbs one primary color of light and reflects the other two. When properly mixed, these pigments can create any desired color by reflecting a blend of primary colors of light.

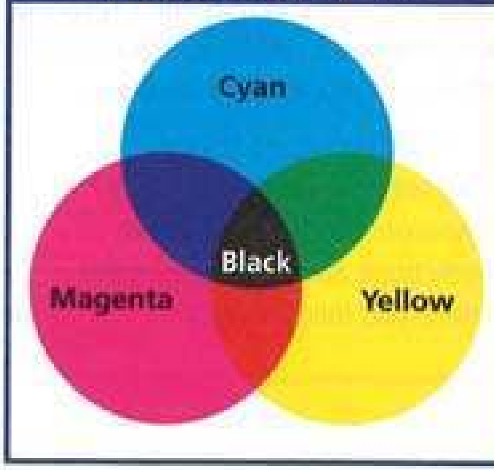
Under white light, for example, equal amounts of magenta and cyan would produce the color blue. The cyan would absorb the red out of the white light and the magenta would absorb the green out of the light. Only blue would be reflected.

What happens when an object absorbs red and green light and reflects blue light?

READING Diagrams

What colors would you see if you mixed equal amounts of magenta and yellow? Cyan and yellow?

The Color Wheel



Lesson Review

L·I·N·K·S

Why It Matters

The four-color printing process uses yellow, magenta, cyan, and black plates to make four-color photos. Red is a combination of yellow and magenta. Blue is a mixture of cyan and magenta. Green is a mixture of cyan and yellow. Other colors are formed by mixing various amounts of three or all four color plates.

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Think and Write

1. Why do objects appear to be different colors when seen under different-colored lights? When seen through different-colored filters?
2. What happens when white light passes through a prism?
3. What are the primary colors of light? The primary colors of pigments? Why are they different?
4. INQUIRY SKILL **Predict** What color would be created by mixing red and green light? What color would be created by mixing cyan and yellow pigments?
5. **Critical Thinking** Where in nature can you see a spectrum? Explain.

WRITING LINK

Writing a Story What are some of the ways color is important to your life? Write a science fiction story about a world without color. What would life in your story be like?

MATH LINK

Solve this problem. A four-way traffic light requires many lenses. It uses red, yellow, and green colored lenses to control traffic in each direction. How many lenses would you need to build 10 four-way traffic lights?

TECHNOLOGY LINK

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LESSON 10

Invisible Light

Vocabulary

electromagnetism, F118

electromagnetic spectrum, F119

laser, F122

Get Ready

How long does it take to see light when you turn on a lamp in a darkened room? How long does it take for light from a lamp at the end of a long hallway to reach the other end?

It takes about eight minutes for light from the Sun to reach Earth. It can take hundreds, thousands, millions or billions of years for the light from distant stars to reach us.

How does light travel? Sound travels in waves. If light travels in waves, could they be different from sound waves? Explain.

Inquiry Skill

You experiment when you perform a test to support or disprove a hypothesis.

Explore Activity

How Do Waves Move?

Materials

spring toy
meterstick
stopwatch or digital watch

Procedure

1. One way to experiment with waves is to use a spring toy as a model. Work in groups of three. Two students should stretch the spring toy out 2 meters. One student should jiggle the spring toy slowly up and down to form waves that move along its length.
2. **Observe** The third student should time how long the wave takes to travel from end to end. Repeat several times. Record the results.
3. **Experiment** See what factors affect the size and speed of the wave produced. Compare results when the spring toy is loosely stretched and tightly stretched.

Drawing Conclusions

1. **Observe** In what direction does the wave move? In what direction do the spirals move?
2. **Interpret Data** How does holding it tighter or looser change how the wave moves?
3. FURTHER INQUIRY
   Experiment Try moving one end of the spring toy with a faster speed of the up and down movement. Again, vary the length of the spring toy. What happens?

Read to Learn

Main Idea Waves that produce visible light are part of the electromagnetic spectrum.

How Do Waves Move?

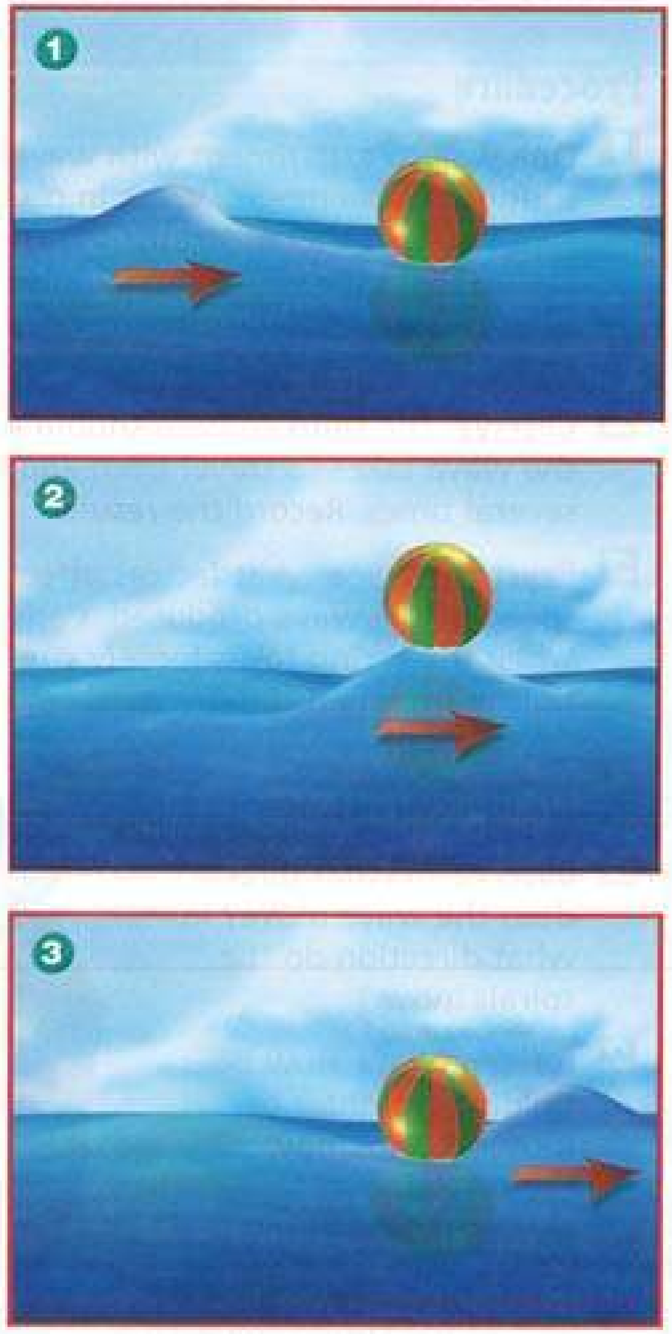
All waves carry energy from place to place. The way a wave carries energy depends on the kind of wave motion.

Remember that sound waves are produced by vibrations. As a string or some other object vibrates, it causes molecules of gas in the air to move back and forth. The energy of the vibration is carried through the air to your ear. In a similar way, sound waves travel through solids, liquids, and gases.

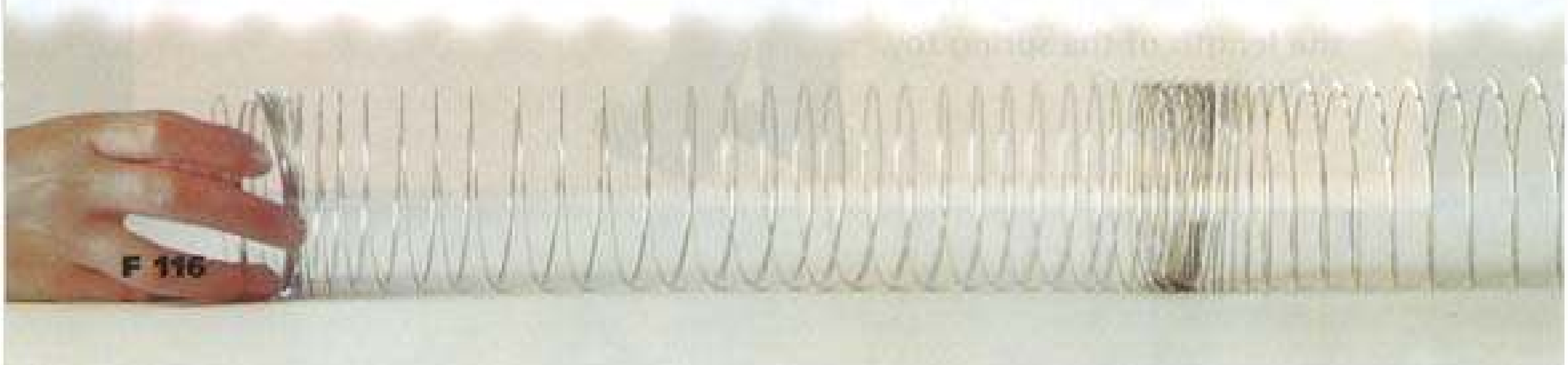
The wave in the spring below moves from left to right. Notice that the particles of matter also vibrate back and forth along the *same* direction—from left to right.

Without particles vibrating back and forth in the direction the sound is traveling, the energy of the sound vibration could not travel. Sound waves cannot travel in a *vacuum*, a space where there is no matter.

As the wave moves from left to right, how do the water and the ball move?



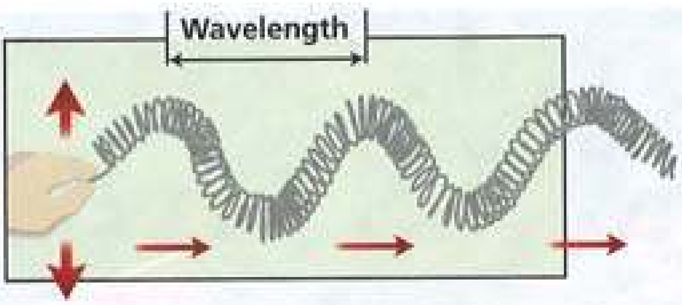
By vibrating one end of a spring toy in and out, you can see waves that travel much as sound waves do.



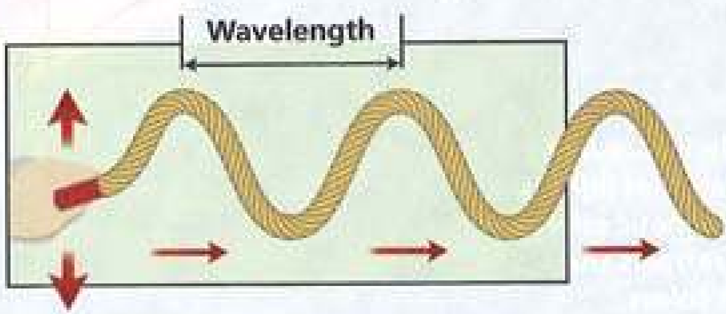
If you toss a pebble into a quiet pond, you can see waves travel across the surface. How does a particle of matter move in the water as the wave moves past it from left to right? Each particle moves in a circle. So does the ball floating on the water.

The waves shown below also move from left to right. How does a particle in the rope or the spring move when a wave passes through it? It does not move back and forth as in a sound wave. It does not move in a circle as in a water wave. It moves up and down.

Do all waves move the same way?



By vibrating one end of a spring toy up and down, you can see waves travel much as waves do on a watery surface.

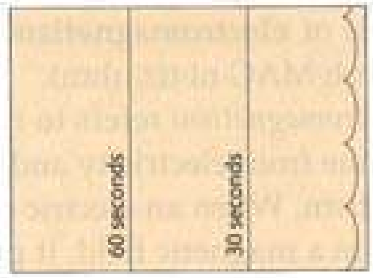


How do the waves made by a jump rope behave?

QUICK LAB

Water Waves

FOLDABLES Make a Trifold Book. (See p. R 42.) Label as shown.



1. Fill a shallow pan or tray (20 cm by 28 cm) half full of water. Fold small squares of foil (1 cm by 1 cm) into tiny "boats." Place several boats on the water.

2. At one end of the tray, make waves on the water's surface.
3. **Predict** What do you think will happen to the boats after 30 seconds? After one minute?
4. **Observe** What happened to the boats? How did they move? How far did they move? Were your predictions correct? Use the Trifold Book to record your predictions and results.
5. **Experiment** What happens if you change how fast you make the waves? What happens if you change the number of boats you use?

How Do Light Waves Travel?

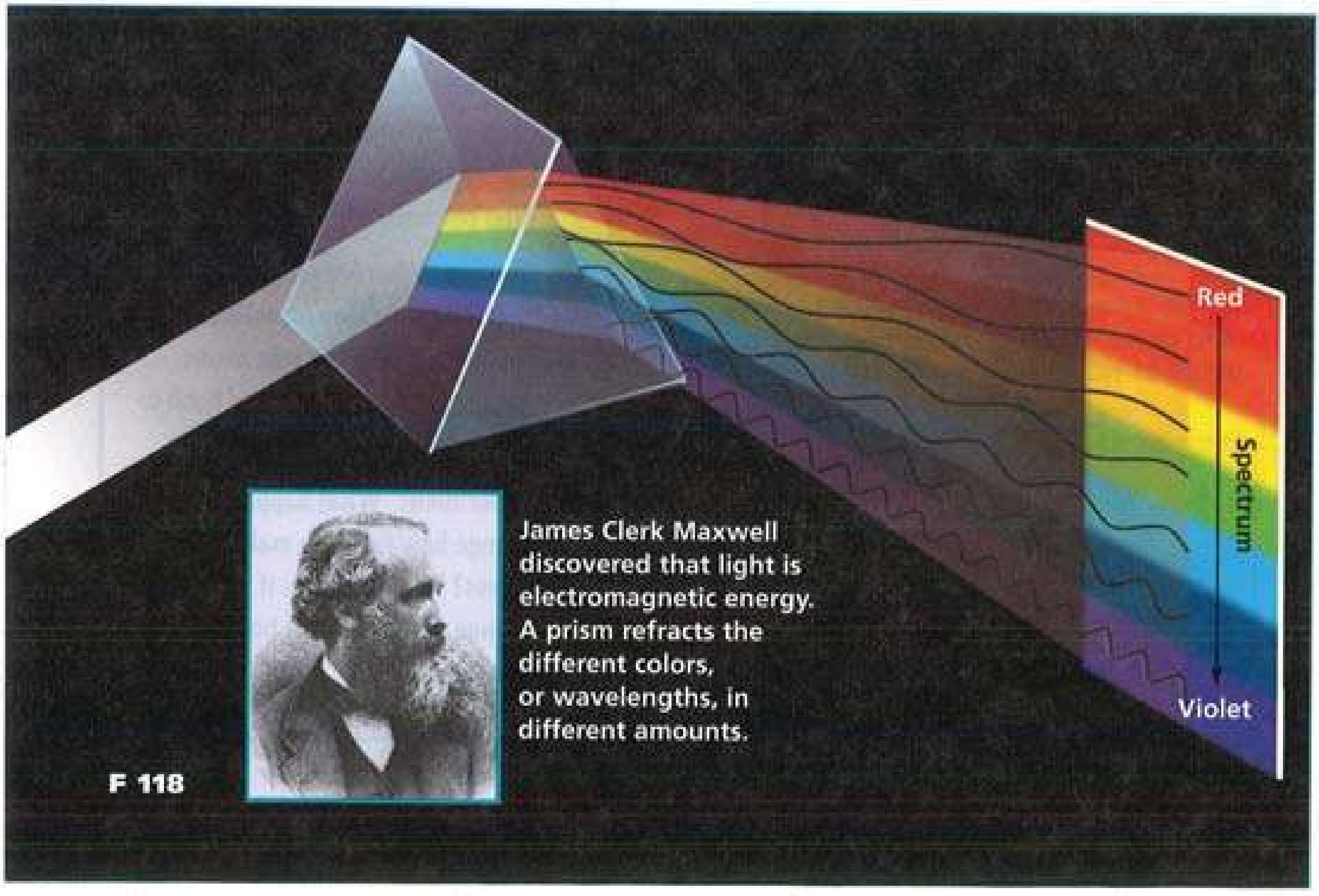
Connect both ends of a wire to a battery, then put a compass near the wire. The compass needle moves. The electric charges flowing through the wire create a magnetic field that affects the compass. This is an example of **electromagnetism** (i·lek·troh·MAG·ni·tiz·uhm).

Electromagnetism refers to forces that come from electricity and magnetism. When an electric charge moves in a magnetic field, it produces electromagnetic energy.

In the 1850s, James Clerk Maxwell concluded from his work that light is electromagnetic energy. The electrical and magnetic parts of the energy can carry themselves as a wave moving through space. Electromagnetic waves can travel without matter or through matter.

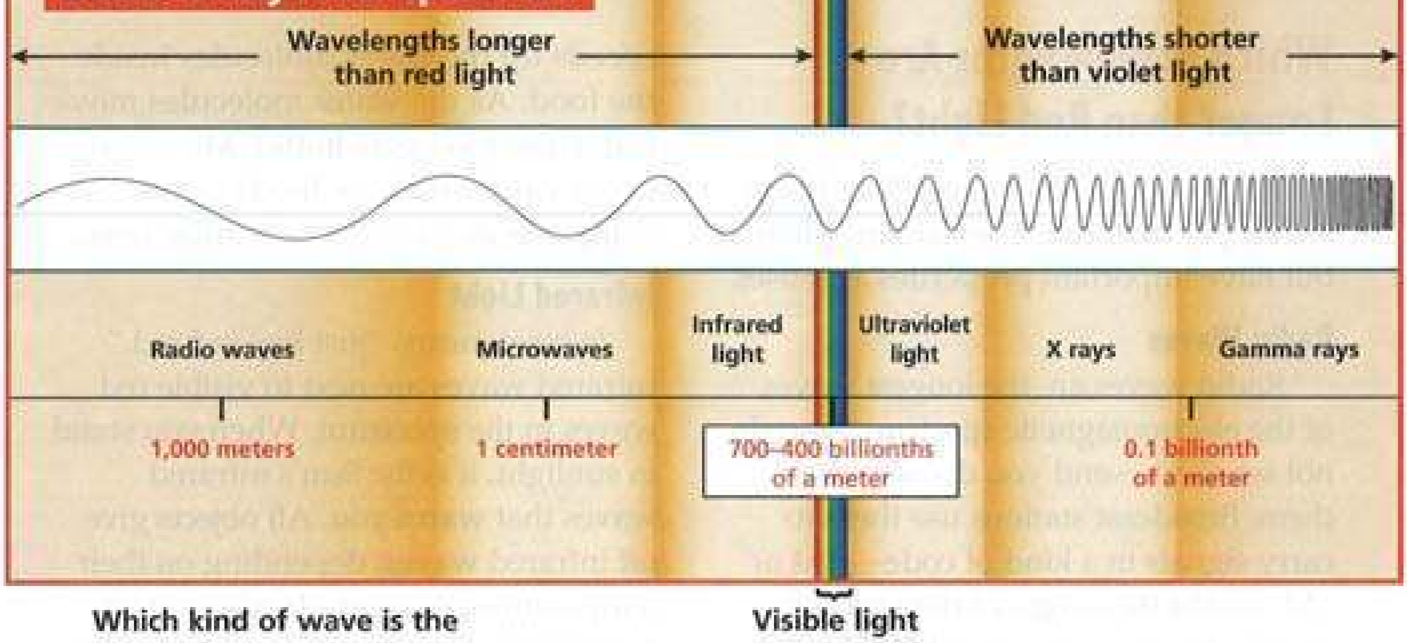
Electromagnetic waves vibrate back and forth across *(perpendicular to)* the direction in which light travels. Water waves are usually used as models for light waves. The wavelength is the distance from crest to crest. However, light is not just one wavelength. It is many wavelengths. The colors of light are different wavelengths. A prism refracts the different wavelengths in different amounts.

However, all the wavelengths of light travel through empty space at the same speed—over 300 million meters per second. Light slows down when it travels through matter. However, it always travels much, much faster than sound. That's why you see a lightning flash before you hear the thunder.



James Clerk Maxwell discovered that light is electromagnetic energy. A prism refracts the different colors, or wavelengths, in different amounts.

Electromagnetic Spectrum



Which kind of wave is the shortest? The longest?

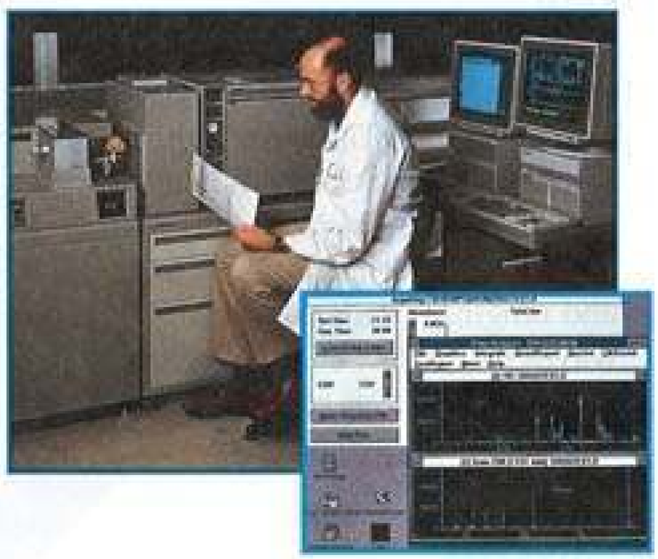
Since Maxwell's work, scientists have formed another idea of how light travels. Rather than as a smooth vibrating wave, perhaps light travels as tiny bundles of energy. Scientists call the bundles *photons*.

Waves or photons? Scientists use both models to explain light. For example, your eye picks up only so many photons of light at any instant. We can see the wavelengths of light that make up the colors of light.

However, there are wavelengths longer than red light and shorter than violet. We cannot see these wavelengths. Together all these wavelengths of light, the ones we see and the ones we cannot see, are called the **electromagnetic spectrum**.

Although we cannot see wavelengths longer than red or shorter than violet, we can detect them, and we can use them in many ways. One way to detect some of this "invisible light" is by using a spectroscope.

READING Compare and Contrast
What is one difference between the ways light waves travel and sound waves travel?



Instruments such as this spectroscope (above) allow us to detect forms of light we can't see. This image (right), taken by the spectroscope, analyzes the light coming from an object.

Which Wavelengths Are Longer than Red Light?

The wavelengths of light listed here are longer than red. They are invisible but have important properties and uses.

Radio Waves

Radio waves are the longest waves of the electromagnetic spectrum. You do not see them—and you do not hear them. Broadcast stations use them to carry signals in a kind of code—AM or FM. In AM the height of the waves is changed to carry the signal. In FM the frequency changes. The number of your favorite radio station represents the frequency at which the station sends out radio waves. When these signals are picked up by a radio or television, they produce the sounds and sights that you hear and see.

Radar

Some animals, such as bats and whales, send out sound waves with a high frequency. The echo of the waves helps the animals locate things. Radar works in a similar way. *Radar* stands for "**ra**dio **d**etecting **a**nd **r**anging." Radar uses radio waves that reflect off many objects. The waves can help weather forecasters detect rain and thick fog.

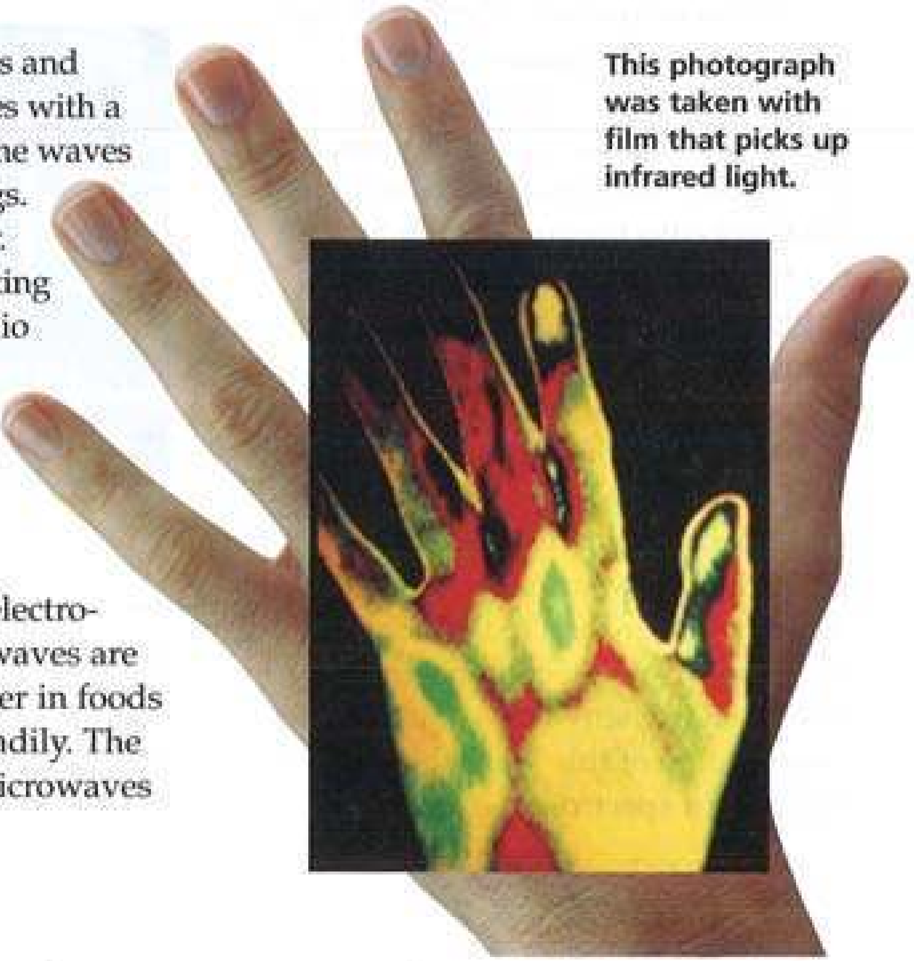
Microwaves

A microwave oven uses electromagnetic waves, too. Microwaves are shortwave radio waves. Water in foods absorbs microwaves very readily. The energy from the absorbed microwaves speeds up the water molecules inside the food. As the water molecules move faster, the food gets hotter. Microwave ovens can heat many foods faster, using less energy than a regular oven.

Infrared Light

Infrared means "just beyond red." Infrared waves are next to visible red waves in the spectrum. When you stand in sunlight, it is the Sun's infrared waves that warm you. All objects give off infrared waves, depending on their temperature. Warmer objects give off more infrared waves than cooler objects do. Special photographic film and electronic sensors can detect infrared light.

What kinds of electromagnetic energy have longer wavelengths than visible light?



This photograph was taken with film that picks up infrared light.

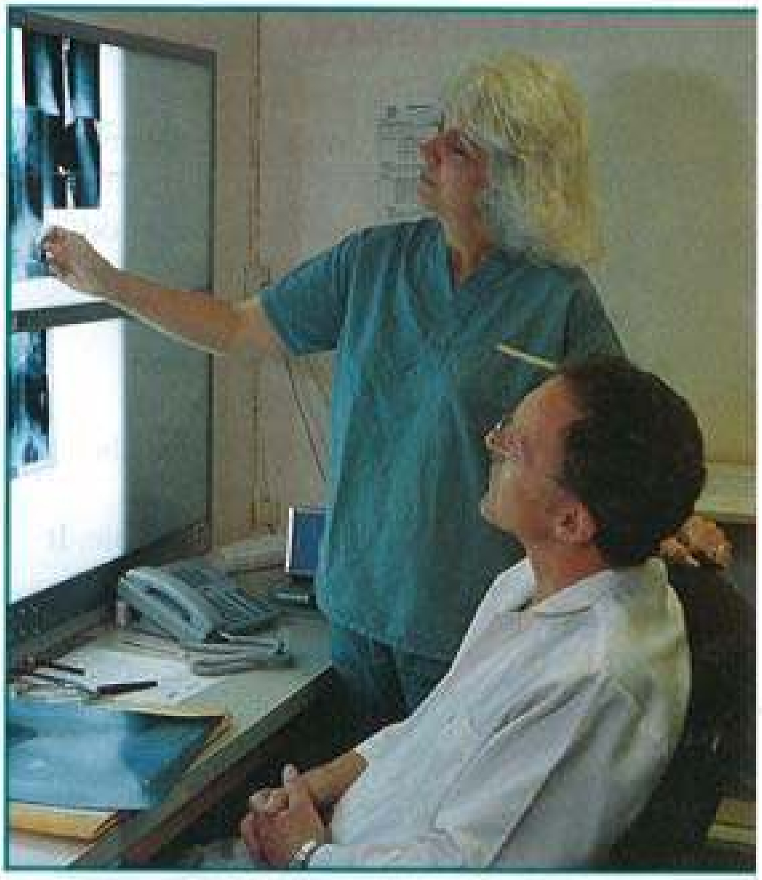
Which Wavelengths Are Shorter than Violet Light?

The wavelengths of light listed here are shorter than violet light. They are invisible but have important properties and uses.

Ultraviolet Light

Ultraviolet (UV) light is made up of waves just shorter than visible violet light on the spectrum. UV light causes chemical changes. It can produce vitamin D in your body. You need vitamin D for healthy bones and teeth. Ultraviolet light produces vitamin D in milk. Hospitals use ultraviolet light to kill harmful bacteria in equipment used in operating rooms. However, UV light can cause harm. UV light from the Sun can cause a sunburn. Scientists have found that UV light can also cause some forms of cancer on the skin. Cancer is a disease in which cells multiply rapidly with harmful effects.

Earth is protected from much of the Sun's UV light by the ozone layer. The ozone layer is a part of the upper atmosphere that screens out UV light. However, some chemicals produced by factories are eating away at the ozone layer. Thus more of the Sun's UV light will pass through to Earth's surface. Care is being taken to prohibit the chemicals from being manufactured.



Doctors use light boxes to examine X rays.

X Rays and Gamma Rays

The shortest wavelengths of the spectrum—X rays and gamma rays—have great penetrating power. X rays can pass right through most objects. Thicker or denser objects tend to absorb X rays. This means that X rays can produce a picture when they pass through an arm or leg, or your jaw. The denser objects, such as bones and teeth, can show up very clearly on the finished picture.

What kinds of electromagnetic energy have shorter wavelengths than visible light?

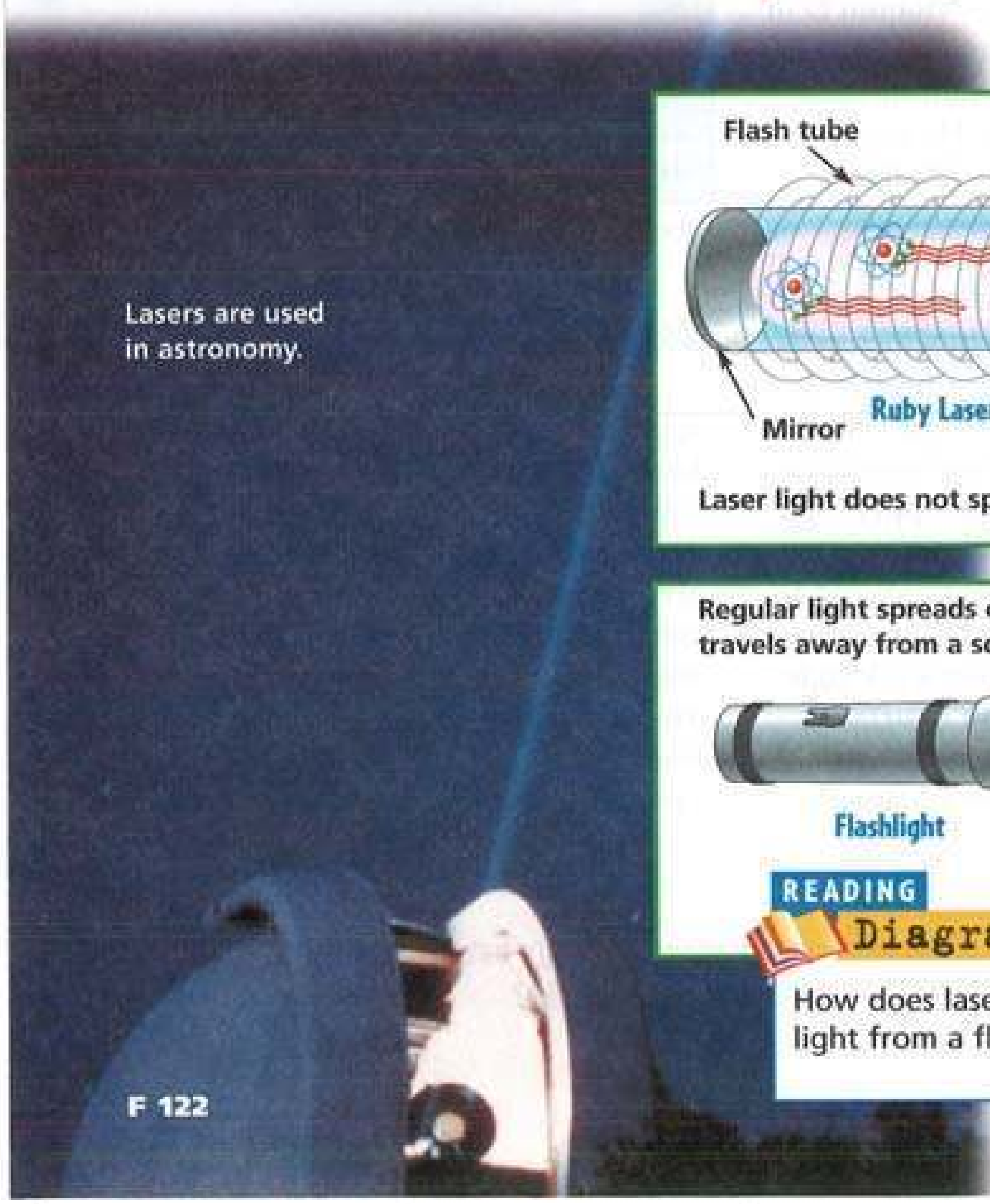
What Are Lasers?

You've seen **lasers** in many places—such as at music events and even the checkout counter at the supermarket. Lasers are devices that produce thin streams of light. What makes light from a laser special?

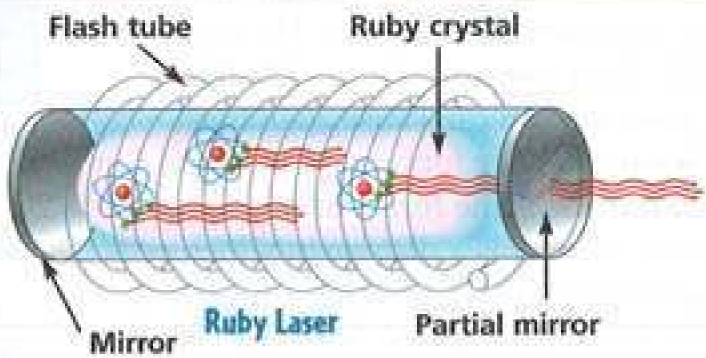
Regular light from a bulb or a candle has many wavelengths all mixed together. As the light travels away from the bulb or candle, it spreads out and gets less noticeable. It gets weaker and weaker the farther it travels.

Lasers produce light that does not spread out or become weaker. Lasers, such as this device using a red ruby, produce light by absorbing flashes of light from a coiled tube. Inside the ruby the absorbed light bounces back and forth between mirrors at the ends of the ruby. As a result, the ruby gives off a light of just a few close wavelengths. The wavelengths are all one color and line up "in step." The beam that comes out of the ruby is narrow and direct.

What is special about laser light?



Lasers are used in astronomy.



Laser light does not spread out.

Regular light spreads out as it travels away from a source.

READING Diagrams

How does laser light compare to light from a flashlight?

Lesson Review

Why It Matters

Light has many wavelengths. Only some are visible.

Radar waves help forecasters predict the weather. X rays help dentists and doctors check for cavities and broken bones. Every time you turn on a radio or TV, you are picking up invisible waves of "light."

Some laser beams can be used to melt metals and "crack open" granite. Doctors can use other kinds of lasers to perform delicate surgery. There are even weak laser beams in CD players.

e-Journal Visit our Web site **www.science.mmhschool.com** to do a research project on light.

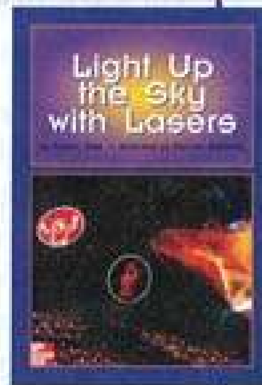
Think and Write

1. How does light travel? Does it travel the same way as sound?
2. What is radar? How is it used in weather forecasting?
3. How is ultraviolet light harmful? How is it helpful?
4. If a spacecraft were 900 million meters from Earth, how long would it take to send a radio signal from Earth to the spacecraft?
5. **Critical Thinking** What's the difference between a beam of light from a flashlight and a beam of light from a laser?

L·I·N·K·S

LITERATURE LINK

Read *Light Up the Sky with Lasers*, to learn how scientists and artists create laser light shows for planetariums and special events. When you finish reading, think about what you would like to see in a laser light show. Try the activities at the end of the book.



MATH LINK

Make a graph. Use encyclopedias or other reference books to find the wavelengths of the different colors of light. Also research the wavelengths for invisible light in the electromagnetic spectrum. Prepare a color-coded bar graph comparing the wavelengths.

WRITING LINK

Expository Writing Research the history of lasers. Write a report for the class.

TECHNOLOGY LINK

Science Newsroom CD-ROM Choose *Out of Sight* to learn how infrared and ultraviolet light differ from visible light.

LOG ON Visit **www.science.mmhschool.com** for more links.

Chapter 16 Review

Vocabulary

Fill each blank with the best word or words from the list.

concave mirror, F88
convex lens, F100
convex mirror, F88
electromagnetic spectrum, F119
light ray, F85
opaque, F96
primary color, F110
prism, F108
translucent, F96
transparent, F96

1. A straight-line narrow beam of light traveling out from its source is a(n) ______.

2. A mirror that curves in on its shiny side is a(n) ______.

3. A lens that curves outward is a(n) ______.

4. White light is broken up into a rainbow of colors by a(n) ______.

5. A kind of material that allows some light to pass through but may give a blurry view is called ______.

6. Red, blue, or green—each is a ______ of light.

7. A material that light cannot pass through is called ______.

8. A material that light can easily pass through is called ______.

9. Microwaves and X rays are part of the ______.

10. A security mirror used in a store is a(n) ______.

Test Prep

11. Light is a form of ______.

A heat
B electricity
C energy
D sound

12. Which of the following is translucent?

F a car windshield
G a convex mirror
H a frosted light bulb
J a concrete block

13. Which is NOT found in the electromagnetic spectrum?

A X rays
B infrared light
C FM radio waves
D sound waves

14. Sunglasses that reduce glare are ______.

F transparent
G translucent
H cloudy
J polarized

15. Objects that light can easily pass through are called ______.
A translucent
B transparent
C opaque
D cloudy

Concepts and Skills

16. **Scientific Methods** Copy and complete the diagram to show what happens to a light ray as it passes through the lens. Write a paragraph explaining your diagram.

17. **Product Ads** How does TV advertising use light and color to capture your attention? Write a paragraph giving three examples.

18. **Reading in Science** What is the difference between the primary colors of light and the primary colors of pigments? Why won't combining colors of paints give you the same results as combining colors of light? Write a paragraph explaining your answer.

19. INQUIRY SKILL **Predict** How many different colors do you think you could make using two flashlights, a piece of white paper, one piece of red and one piece of green cellophane? What if you placed the two pieces of cellophane on top of each other and looked through them. Do you think you would get the same result? Write a paragraph explaining your answer.

20. **Critical Thinking** Cameras let you take pictures by using lenses to focus light onto film. What if you wanted to make a simple camera but didn't have any lenses. Would you be able to use a mirror instead? What kind of mirror might you try? State and explain a hypothesis. Write a paragraph describing how you would test your idea.

Did You Ever Wonder?

INQUIRY SKILL **Communicate** Imagine tonight we experienced a blackout and you had to live one week without electricity and therefore without lights. How would life be different?

LOG ON Visit www.science.mmhschool.com to boost your test scores.

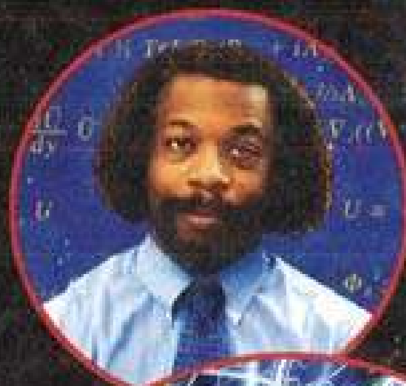
Dr. S. J. Gates

PHYSICIST

Is everything in the universe made up of tiny little strings? Dr. S.J. Gates, a theoretical physicist, thinks so! Physicists study energy and matter, and how the two interact. Gates is trying to discover the basic building blocks of the universe.

Scientists used to think that the tiniest building blocks were "points." To imagine a point, think of a very, very small ball. But Dr. Gates and other string theorists think that the smallest particles may actually look like short strings.

String theory could help scientists unlock some of the greatest mysteries of the universe. "My type of science is about uncovering the 'code' that runs our universe," Dr. Gates says. "So just as DNA is the code of life, superstrings could be the code of existence."



Tiny superstrings may explain how *everything* works.

TIME FOR KIDS

TOP 5 Jobs for a Physicist

Dr. Gates is a physicist on the go. Ideas hit him anywhere. Where would you work if you were a physicist? We've put together a list of 5 possible places:

1. NASA as a researcher
2. College as a professor
3. Manufacturer as a developer of new products
4. Home as a writer/thinker
5. Museum as a creator of exhibitions

Science and scientists don't have all the answers to a question. New discoveries change old ideas. So we don't know everything about the code that runs the universe. "We try to figure out the new part of the code simply by 'making it up.' Then we check whether what we made up is really the way the universe works," Dr. Gates says. "The imagination is the only thing we have that allows us to make up new ideas."

Write About It

1. What is S.J. Gates trying to discover?
2. Why is imagination so important to science and scientists?

LOG ON Visit **www.science.mmhschool.com** to learn more about the work of physicists.

It's the LAW!

Your goal is to show how Newton's laws of motion work.

What to Do

1. Place a ball in a shoe box open at one end. Facing the open end, slowly push the box forward. Suddenly stop it. What happens?
2. Push against a wall. What do you feel? Record your observations.

Analyze Your Results

Relate your observations to Newton's laws.

Good VIBRATIONS

Your goal is to make and use an instrument to detect sound vibrations.

What to Do

1. Stretch plastic wrap over one end of a tube. Secure it with a rubber band. Tape a straw to the plastic wrap.
2. Hold the detector still. Talk into the open end while you gently touch the straw. Use a low voice then a high voice. Record your observations.

Analyze Your Results

Draw a diagram of your detector showing how energy is transmitted from you to the straw.

COLOR VISION

Your goal is to explain what happens when you look at colored objects through different color filters.

What to Do

1. Predict which color cellophane you need to look through to make an object look the same color or appear black.
2. Test your predictions. Record your observations.

Analyze Your Results

Which color cellophane made both a red and a green object appear black? Explain.