LESSON 7

Modeling Light

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What happens to some of the movement energy of this boy when he hits the water? What is produced, and what does this have to do with light?

INTRODUCTION

You have spent the last few lessons investigating some of the characteristics of light. You looked at how light is produced and how it spreads out from a light source. You determined that light travels in straight lines and can travel through air and the vacuum of space. You compared the behavior of light when it strikes transparent, opaque, and translucent objects. You used what you have discovered to explain the formation of shadows and images in a pinhole camera using simple ray diagrams. You already know quite a lot about how light behaves!

But what gives light these characteristics? How are the characteristics of light related to one another? What is the exact nature of light? Is there some way you can better understand what light is? Can you use your knowledge of the nature of light to explain why it behaves in particular ways? Can you predict how it will behave in different situations?

One way you can better understand what light is and why it behaves as it does is by using scientific models. After you revisit your ideas about the nature of light, you will discuss the nature of scientific models and then use two scientific models for light. At the end of this lesson, you will be asked to compare how well these models explain what you observed in previous lessons.

OBJECTIVES FOR THIS LESSON

Discuss the nature of light.

Use and compare scientific models for light.

Getting Started

1. In Lesson 1, you were asked the question, What is light? Think about the question again. Discuss any new ideas you have with your group. Have your ideas about the nature of light changed? Have other members of your group reached similar conclusions? In your science notebook, write what you now think light is.

2. If light is a form of energy, how does it move from one place to another? Look at Figure 7.1. What is happening in each photograph? These pictures may give you some ideas about how energy can be moved from one place to another.

3. Discuss your ideas with the class.

4. Read "Scientific Models."

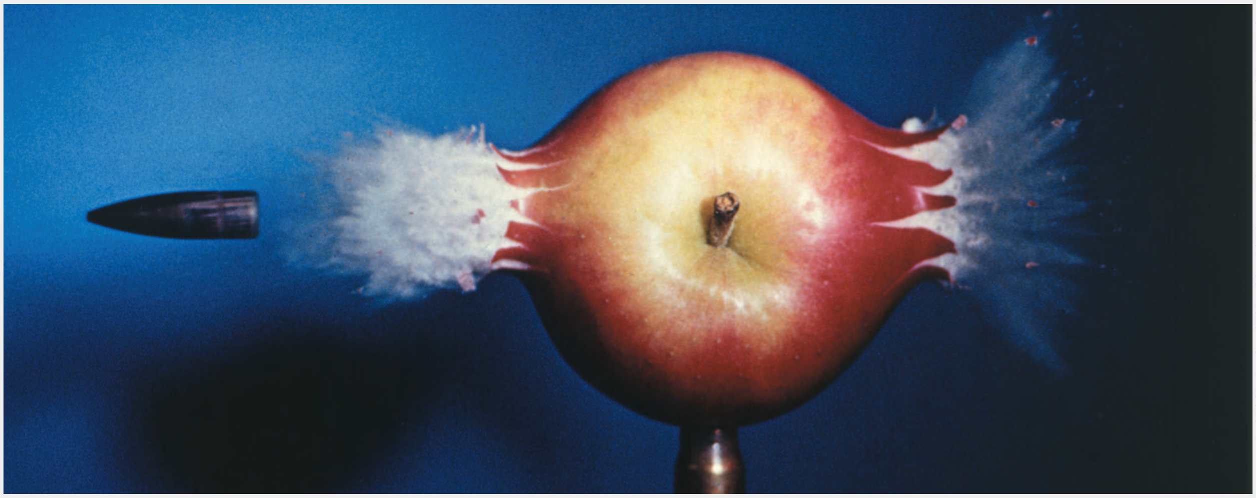
MATERIALS FOR LESSON 7

For you

- 1 copy of Student Sheet 7.1: Using Particles To Model Light
- 1 copy of Student Sheet 7.2: Using Waves To Model Light

For your group

- 15 ball bearings (in a resealable plastic bag)
- 1 straight metal barrier
- 1 transparent tray
- 1 cardboard tube
- 1 transparent cup
- 1 wooden dowel
- 1 folding lamp
- 4 AA batteries
- 2 wooden blocks
- 1 dropping bottle
- 1 metric ruler, 30 cm (12″)
- 1 cork
- 1 sheet of white paper



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How was energy from a gun transferred to this target?

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How was energy from a distant earthquake transferred to these buildings?

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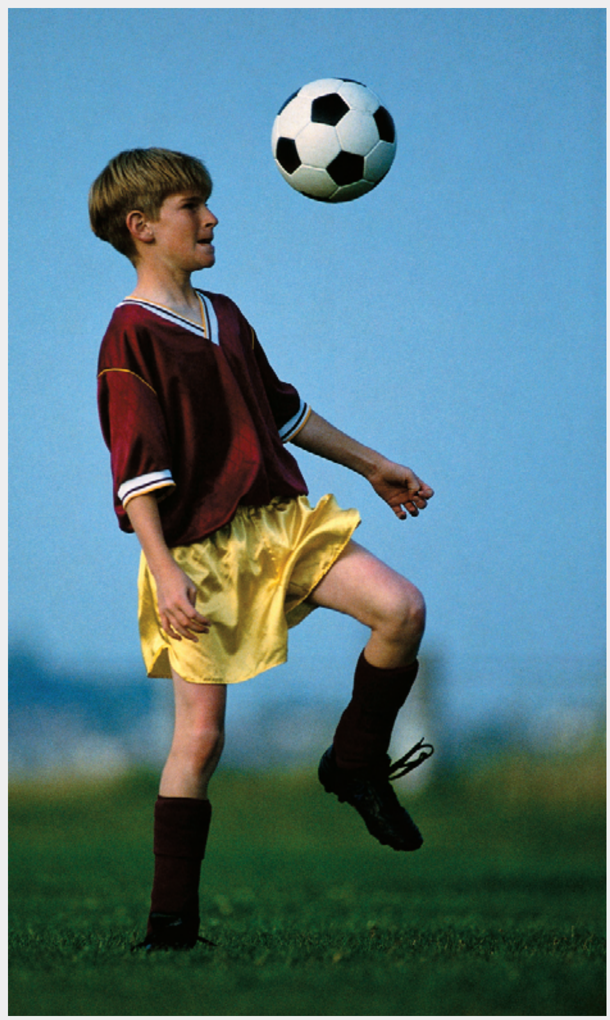
What makes this surfer move? Where did the energy come from? How did it get to the surfer?



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Whoever kicked this ball is about to transfer the energy to the boy's head. How did this energy transfer take place?

Figure 7.1 *How is energy being moved from one place to another?*

SCIENTIFIC MODELS

In this lesson, you will investigate two scientific models for light. A scientific model is a way of thinking about how something works. It is not a copy of an object like a plastic model of an airplane or the human body. Scientific models help scientists understand complex processes or systems that are difficult to understand or observe.

You may already have used scientific models. For example, have you ever used a model of the structure of the atom? You might have also used a model to explain how electrical energy moves around a circuit.

Before scientists construct a scientific model, they closely observe what they are studying. Next, they try to link these observations. Then they design a model that behaves in the same way. The model may be a mathematical one. Today's scientists often simulate models on computers. Or they may make models from materials that *behave like* the thing they are modeling.

Scientists may use scientific models to help predict how the things they are studying will behave. A good model can be used to make accurate predictions. For example, weather forecasters use computer models of Earth's weather (based on lots of data collected from around the world).

Scientists commonly use two scientific models for light: the particle (or photon) model and the wave model. Both can be partly represented using materials that are easy to observe and that sometimes behave in ways similar to light. You will use both models in this lesson.

Accurate models behave just like the things they are modeling. But most scientific models have limitations. They can demonstrate and help explain only some of the observations made by scientists. You will compare the particle and wave models with your own observations and knowledge about light. Is one model better? Think about and evaluate these two models as you work through this module. You will revisit both later in the module.

Inquiry 7.1
Using Particles To Model Light

PROCEDURE

1. One member of your group should collect the plastic box of materials. You will record your observations and explanations for this inquiry on Student Sheet 7.1: Using Particles To Model Light.

2. In this inquiry, you will use small ball bearings to model the behavior of light. Take the plastic bag of ball bearings out of the box. Look at and handle them. Discuss with your group how you could use a ball bearing to transfer energy from one place to another.

3. Roll a few ball bearings down the tube and across the flat surface of the transparent tray (see Figure 7.2).

A. Record any energy transformations taking place as the ball bearings move from the top of the tube until after they strike the end of the tray.

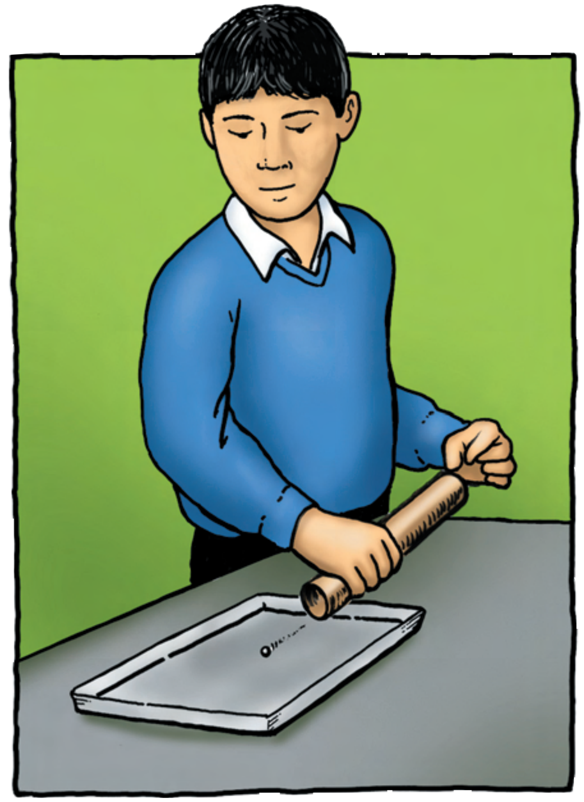


Figure 7.2 *Roll a few ball bearings down the tube and across the transparent tray.*

B. How do the ball bearings behave as they travel across the flat surface? Describe how this aspect of the ball bearing model compares with what you know about light.

4. In Lesson 4, you investigated how light spreads out from a source. Try modeling this using the ball bearings. Hold the tube vertically with one end about 1 cm above the surface of the tray. Use a small piece of scrap paper to help you drop all the ball bearings into the tube at once (as shown in Figure 7.3).

C. How do the ball bearings behave? How does their behavior compare with the way light behaves when it spreads out from a source?

Figure 7.3 *Holding the end of the tube about 1 cm above the tray, drop all the ball bearings into the tube at once.*

5. Think about the shadows you investigated in Lesson 5. If the ball bearings represent light, how can you use the ball bearings, metal barrier, and tray to model shadows? Design and set up a model shadow in the tray.

D. Draw your model design.

E. Describe (using words and a diagram) what happened when you tested your model.

F. Compare what happened in your model to how light behaves.

6. Discuss the following questions with your group:

Is the ball bearing model (usually called a particle model) for light a useful model?

What are its limitations? (How does it fall short in explaining what you already know about light?)

How could the model be improved?

7. Return the ball bearings to the resealable bag. Be sure to seal the top of the bag.

Inquiry 7.2
Using Waves To Model Light

PROCEDURE

1. Record your observations and explanations for this inquiry on Student Sheet 7.2: Using Waves To Model Light. Your teacher will show you how to set up and use a ripple tank.

2. Set up your ripple tank, using Figures 7.4–7.6 as a guide.

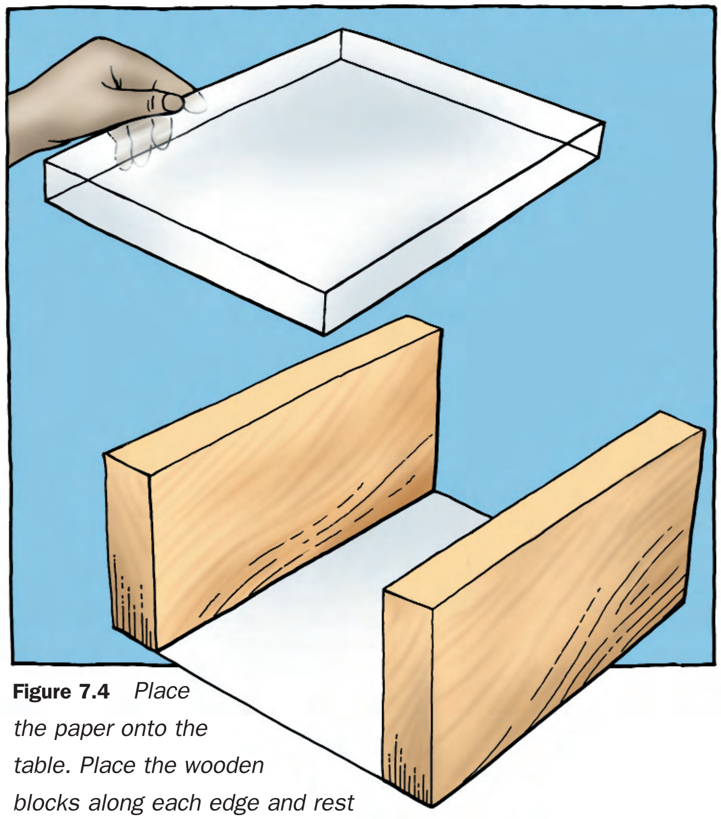


Figure 7.4 *Place the paper onto the table. Place the wooden blocks along each edge and rest the tray across the top of the blocks.*

SAFETY TIP

Make sure the battery box of the lamp is outside of the tray and does not touch the water.

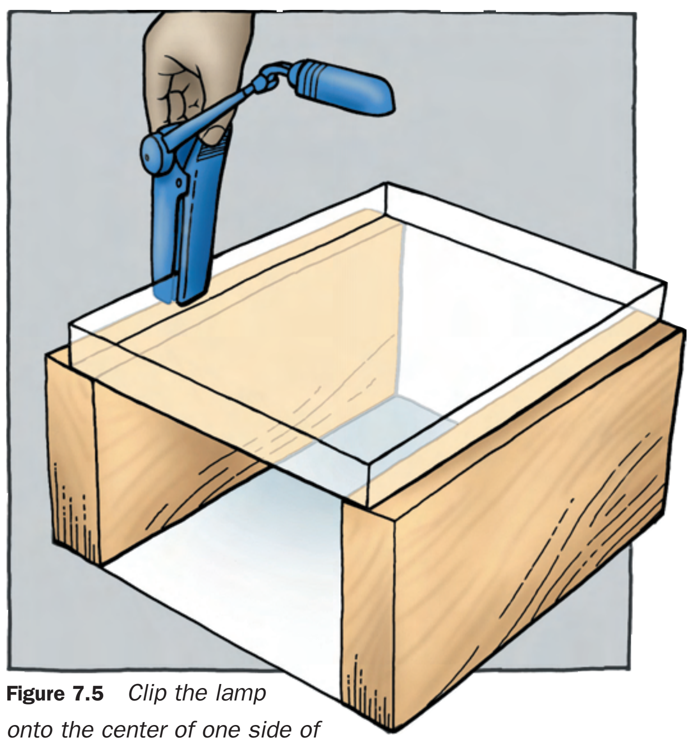


Figure 7.5 *Clip the lamp onto the center of one side of the tray. Make sure that the battery box is on the outside of the tray and the lightbulb is positioned over the center of the tray.*

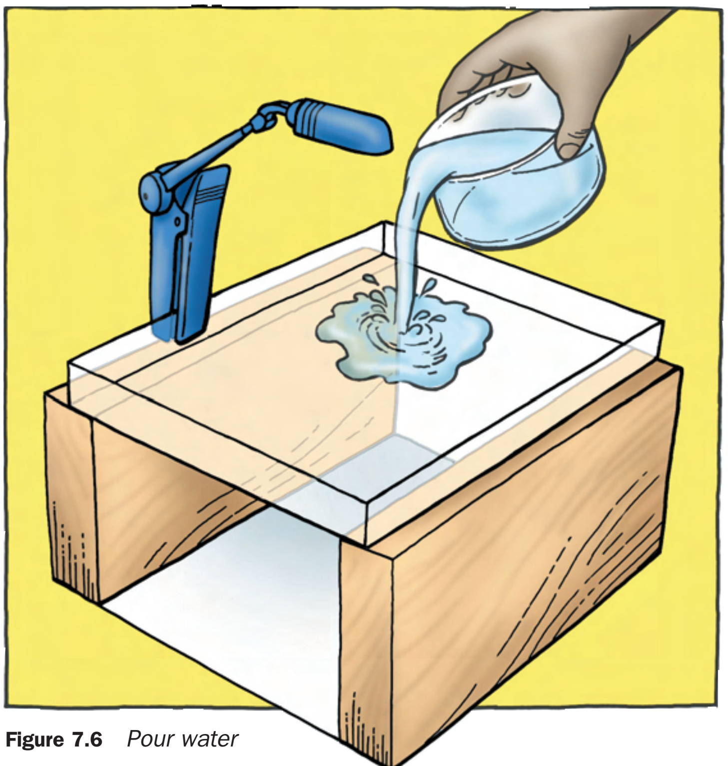


Figure 7.6 *Pour water into the tray to a depth of 1 cm.*

3. Float the cork in the water at one end of the tray. How can you transfer energy from your finger at one corner of the tray to the cork at the other end of the tray without touching the cork? Try out your ideas.

   A. Describe what you did and what you observed.

   B. Identify any energy transformations that took place.

4. Remove the cork from the tray. Switch on the lamp.

5. Use the dropping bottle to drop one drop of water into the center of the tray. Look carefully at the paper.

   C. Draw and describe what you observe.

   D. How does the behavior of the water around the drop compare with the behavior of light as it spreads out from a light source?

6. Your teacher will demonstrate how to generate waves using the wooden dowel. Practice generating waves (see Figure 7.7) by making—

- a single wave that travels the length of the tray.
- the waves as straight as possible.
- five or six closely spaced waves travel the length of the tray at one time.

7. Observe the waves on the sheet of paper below the tray.

E. What do you notice about the speed of the waves?

F. What happens to the distance between the waves when you increase the rate at which you generate them?

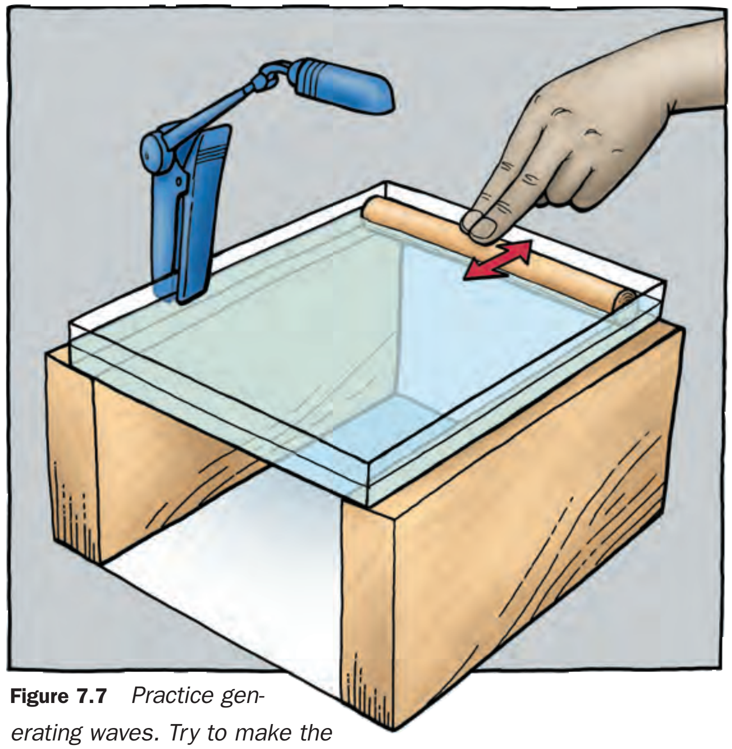


Figure 7.7 *Practice generating waves. Try to make the waves as straight as possible. Single waves can be generated by slowly rolling the dowel backward and forward a few millimeters (mm) in the water. Make closely spaced waves by rapidly rolling the dowel a few mm backward and forward. The waves can be best observed by looking below the tray where they are projected onto the paper. Do it gently. Don't splash water out of the tray.*

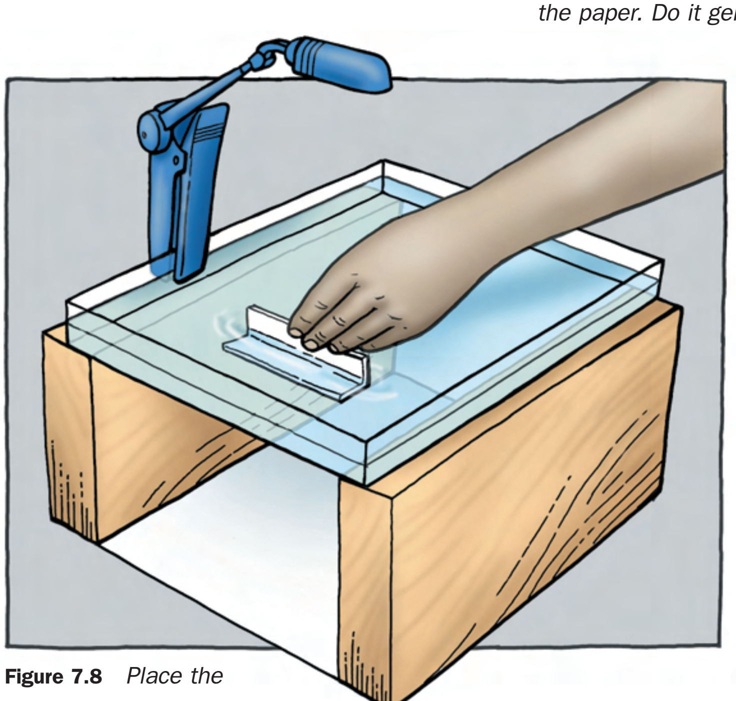


Figure 7.8 *Place the metal barrier in the ripple tank. Direct waves at the barrier.*

8. Place the metal barrier in the ripple tank as shown in Figure 7.8. Direct waves at the barrier.

G. Use a diagram and words to record any evidence of shadow formation.

9. Review your procedures, observations, and conclusions as you did in Inquiry 7.1 by using the discussion questions under Step 6 in that inquiry.

10. Dismantle your ripple tank. Pour the water out of the tray. Dry the tray with a paper towel. Return all the materials to the box.

REFLECTING ON WHAT YOU'VE DONE

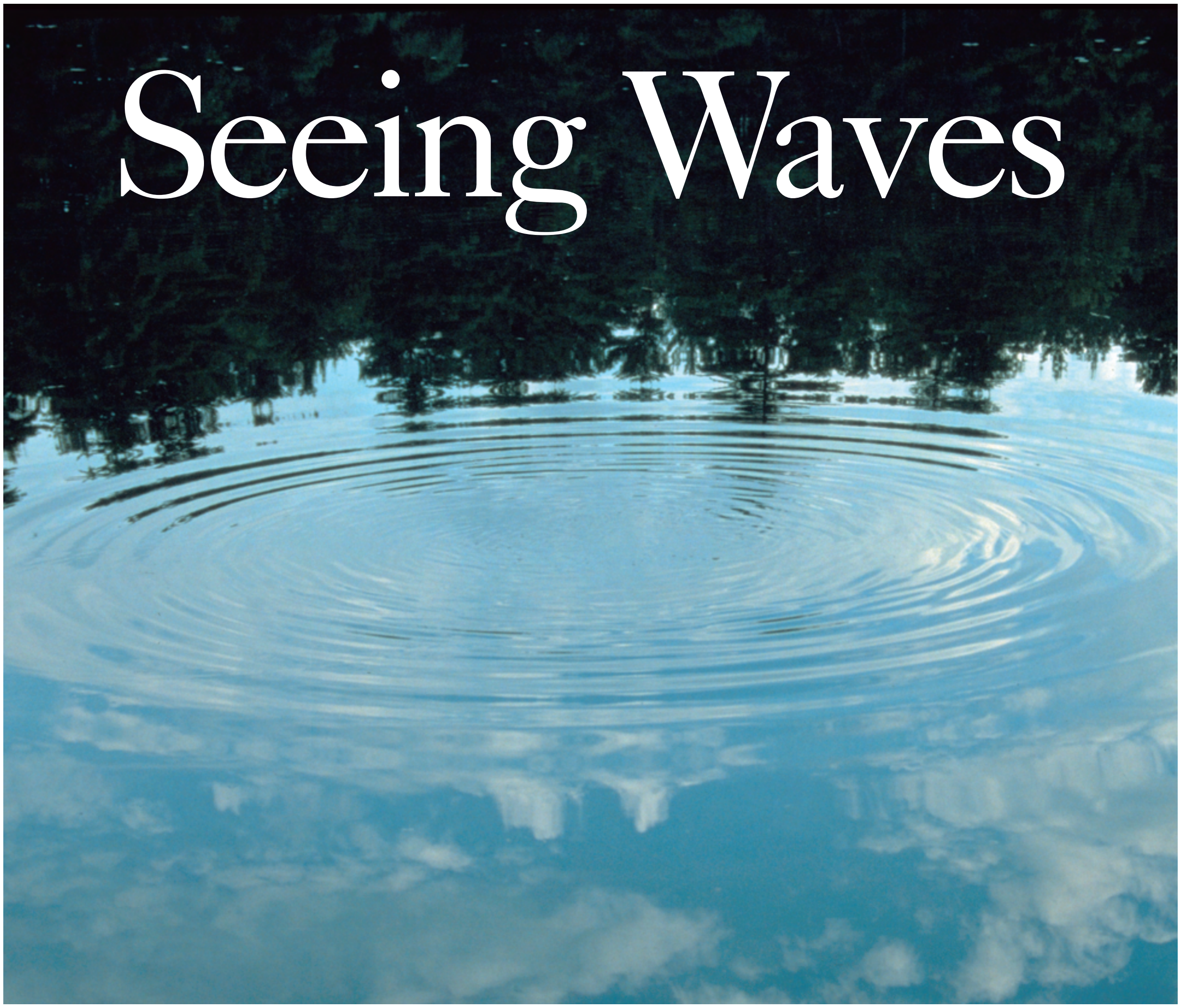
With your group, discuss how the behavior of ball bearings and water waves compares with the behavior of light.

A. Summarize your ideas in Table 1 on Student Sheet 7.2.

B. From your observations, do you think light behaves like waves, like particles, or sometimes like both waves and particles? Record your own ideas about this. Be prepared to share your ideas with the class.

WAVE OR PARTICLE MODELS

Many of the characteristics of light can be modeled as waves and as particles. Scientists find both models useful in understanding the behavior of light. These models allow scientists to discuss and think about light as electromagnetic wave energy or as particles (more accurately, as packets of energy called photons). Often scientists use both of these ideas in thinking about the nature of light. You will learn more about each of these ideas as you work through this module.



Energy from a stone dropped into the water is transmitted through this pool of water as waves.

When most people think of waves, they think of waves in water. For example, you have probably seen waves breaking on a beach or waves made by someone jumping into a swimming pool.

Think about the waves produced when you throw a stone into a pool of still water. When the stone hits the water, you see a splash. Then a wave, or waves, radiates out from the point of impact. Where did the energy come from to make that wave?

All waves carry energy. A surfer riding a giant roller off the coast of California is using energy that may have been carried thousands of kilometers across the ocean—energy gained from the wind of a storm on the shores of another continent. As a wave moves through the ocean, it does not carry water with it. Instead, the water moves up and down in a circular motion as the wave passes through it. When the wave meets a distant shore, it breaks, transferring its energy to the shore. Sometimes this causes disastrous results. The large waves of hurricanes and other storms often destroy waterfront property.

Waves Are All Around Us

You may not recognize them, but you see

waves all the time. Think about flags flying on a windy day. If you look closely at the way they flap in the wind, you can usually see waves passing along the fabric. The energy carried by the wave comes from the wind and travels along the cloth.

Other solid objects also show wave motion. Look at a field of grass on a windy day. Energy from the wind creates waves that are transmitted from plant to plant as they sway. The top of the grass creates

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All waves transmit energy. The transfer of energy from ocean waves to the shore can be very destructive.


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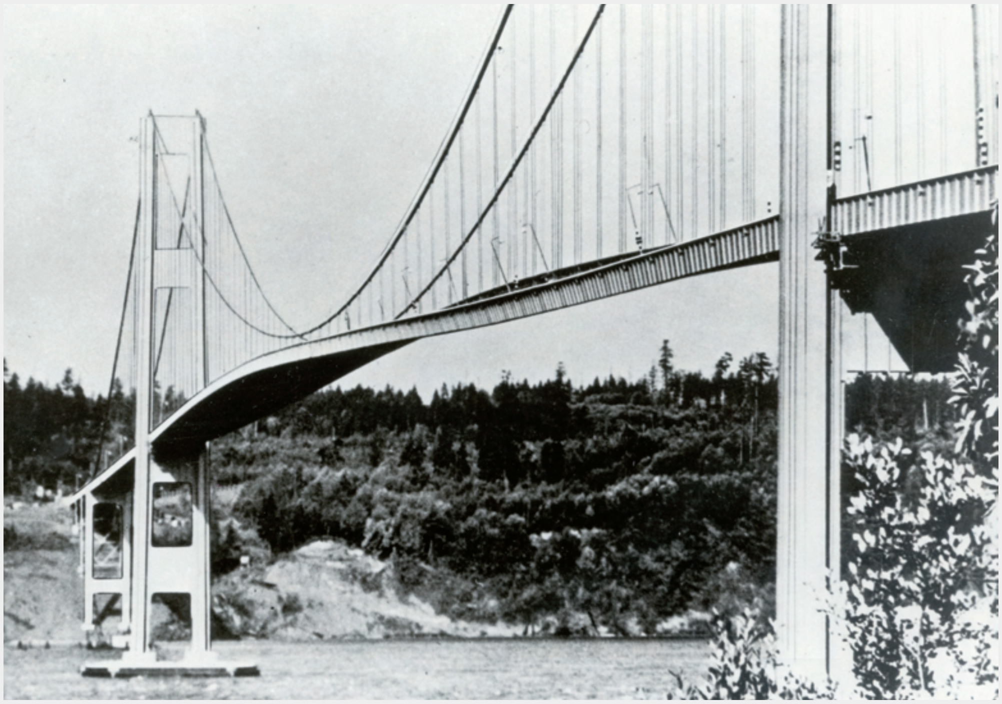
Waves are traveling along these flags.

Galloping Gertie Waves Goodbye



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Would you like to drive across a bridge such as this? The Tacoma Narrows Bridge in Washington State was nicknamed "Galloping Gertie" because of wave action caused by even slight winds.

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Eventually, on November 7, 1940, the Tacoma Narrows Bridge collapsed during moderate wind conditions. What do you think caused the bridge to fail?

the illusion of a "sea of grass." Tall buildings and bridges also sway in the wind as waves are transmitted through their structures. Earthquakes are transmitted by waves that travel through the ground. They can make buildings sway so much that they collapse.

Some waves are invisible. For example, sound is transmitted by waves that travel through the air or other matter. We hear sounds when the waves strike our eardrums and cause waves, or vibrations, in the eardrums.

The types of waves that have already been discussed are called mechanical waves. Mechanical waves can travel only through matter (that is, solids, liquids, and gases). Light also can travel through some matter—through glass or air, for example. Light is considered to be a type of wave, but not a mechanical wave. Light is an electromagnetic wave.

Unlike mechanical waves, electromagnetic waves can travel through a vacuum—the absence of matter. This means they can travel through the emptiness of space. All waves—both mechanical and electromagnetic—transmit energy and have certain other features in common. You will learn more about the nature of electromagnetic waves in Lesson 9. You also will have an opportunity to observe and measure some of the features of waves in that lesson. □

THE NATIONAL SYMPHONY ORCHESTRA, LEONARD SLATKIN, MUSIC DIRECTOR. PHOTOGRAPHER MARGOT I. SHULMAN

Music from this orchestra is transmitted as sound waves through the air to the ears of the audience.