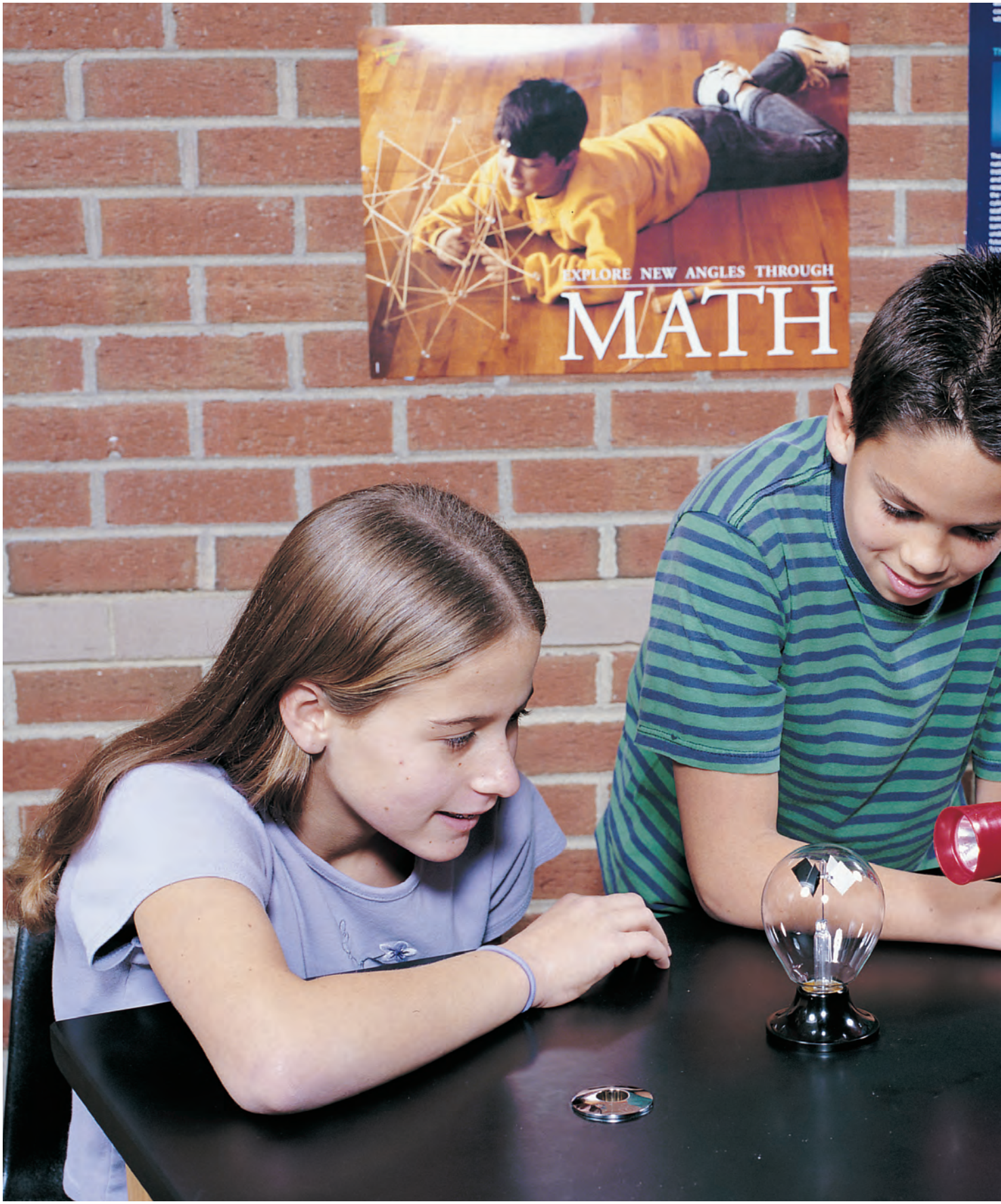


JEFF MCADAMS, PHOTOGRAPHER, COURTESY OF CAROLINA BIOLOGICAL SUPPLY COMPANY

PART 1 The Nature of Light

LESSON 1

Thinking About Light

EXPLORATORIUM: WWW.EXPLORATORIUM.EDU

These students are investigating light at their local science center.

INTRODUCTION

How much do you know about light? When do we encounter light? How do we use it and how does light behave? This first lesson is designed to get you thinking about these questions. You and your lab partner will conduct a series of short inquiries. You will make and record observations and discuss what you think is happening in each inquiry. If you have questions about what is happening, you will write them down. Later in the lesson, you will share your observations, ideas, and questions with your classmates. You will revisit your ideas and questions about light as you proceed through the module.

OBJECTIVES FOR THIS LESSON

Conduct a series of short inquiries about light.

Make and record observations.

Discuss your observations and ideas about what is happening.

Identify and share questions you might have about light.

Getting Started

1. Look at the nail and then stand it in the cup of water. Look at the nail in the water from a variety of different angles. What do you observe?

2. Discuss what you have observed with your group. You will be asked to share your observations with the class.

3. Record the class's observations (write or draw them) in the second column of Table 1 on Student Sheet 1.1: Thinking About Light.

4. Can you explain what is happening? Share your ideas with the class. Record some of the class's ideas in the third column of Table 1.

5. Think of some possible questions that arise from your observations. Share these questions with the class.

6. Write any questions the class has about this exercise in the fourth column of Table 1.

MATERIALS FOR LESSON 1

For you

1 copy of Student Sheet 1.1: Thinking About Light

For your group

1 transparent cup (three-fourths filled with water)
1 aluminum nail
2 index cards
1 marker

Inquiry Procedure

You are now ready to conduct the inquiries in this lesson. Just as in "Getting Started," you will discuss and record your observations, your ideas about what is happening, and your questions in Table 1 on the student sheet. Here are a few general instructions:

1. You will conduct inquiries with another student at eight different stations. The inquiries are numbered from 1.1–1.8 (or 1.1A–1.8A). Each inquiry has instructions you need to follow and questions designed to help you make observations and think about what is happening.

2. Your teacher will tell you and your partner at which station to begin.

3. Record your observations, ideas, and questions for each inquiry in the correct row of Table 1 for that inquiry.

4. When your teacher calls time, make sure you leave each inquiry as you found it before moving on to the inquiry with the next number in the sequence.

5. When you have completed all eight inquiries, return to **your desk.**

Inquiry 1.1
Cutlery Optics

PROCEDURE

1. Look at both sides of the spoon (see Figure 1.1).

2. What do you observe when you look at different sides of the spoon? Carefully record your observations.

3. Discuss what you think is happening with your partner. Record your ideas.

4. Record any questions you have about what you observed.

Figure 1.1 *Hold the spoon by the handle. What do you observe when you look at the inside and the outside of the spoon? Make sure you record your observations.*

Inquiry 1.2
Special Glasses

SAFETY TIP

Do not touch the lightbulb. It gets hot and may burn your fingers!

PROCEDURE

1. Put on the special glasses, and plug in the light stand (see Figure 1.2).
2. Use colored pencils and a sketch to help you describe your observations. What do you think is happening? Where do you think the colors come from?
3. Record any questions you have about what you observed.
4. Unplug the light. Return the glasses to their original position on the desk.

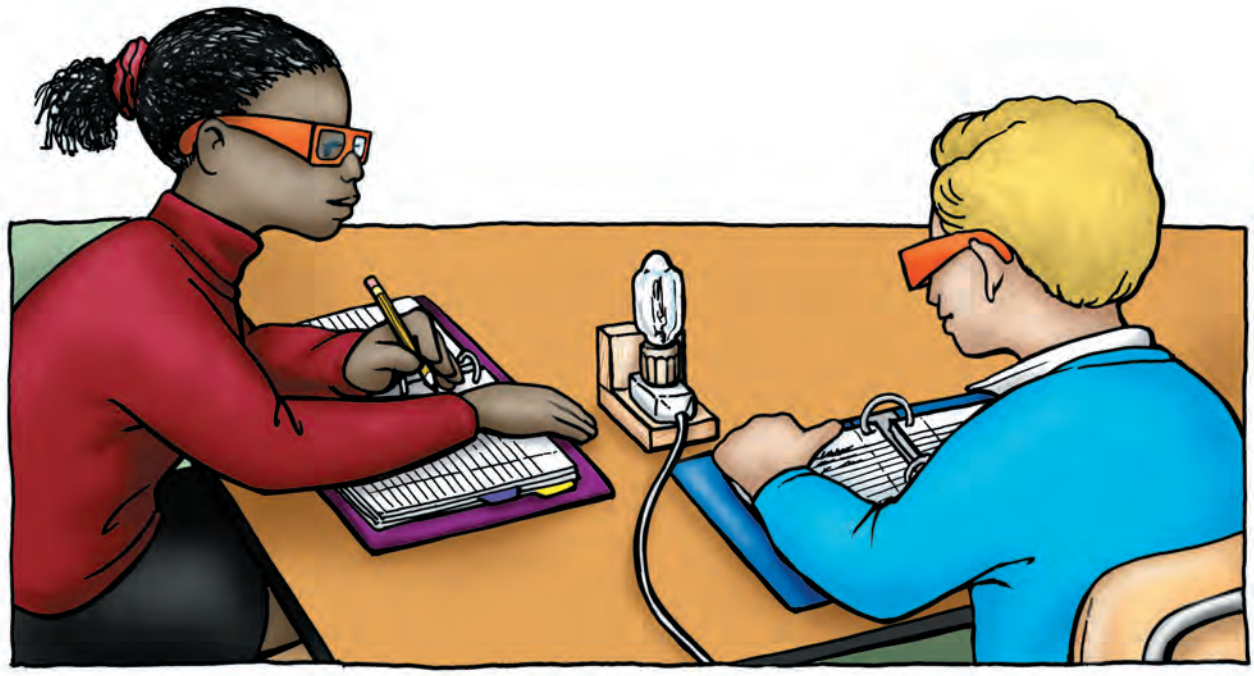


Figure 1.2 *Put on the special glasses and describe what you see. Have you seen something like this before?*

Inquiry 1.3
Lamp Light

SAFETY TIP

Do not touch the lightbulb. It gets hot and may burn your fingers!

PROCEDURE

1. Slowly slide the dimmer switch up and down (see Figure 1.3). Record your observations.

2. What do you think is happening? Discuss your ideas with your partner before you write them down.

3. Record any questions you have about what you observed.

4. Switch off the lamp.

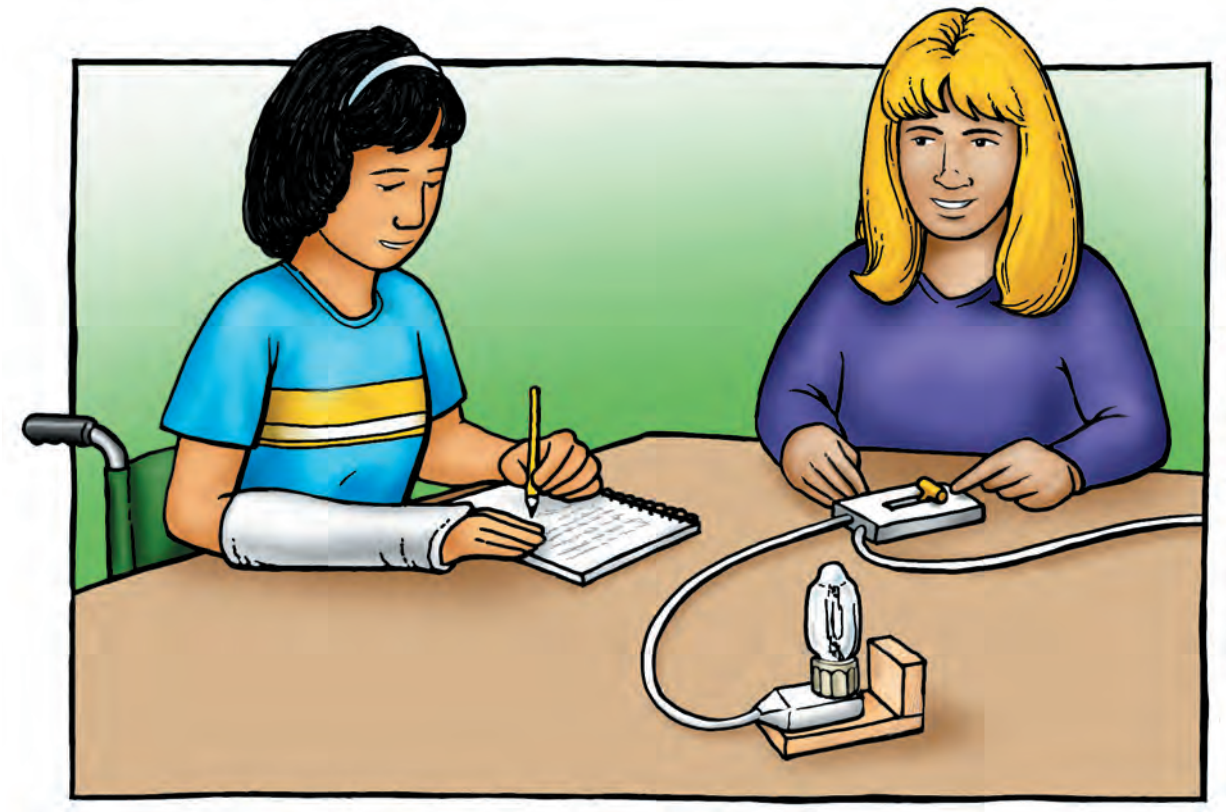


Figure 1.3 *Can you describe what happens inside the lightbulb when you slide the dimmer switch up and down? (Note: The dimmer switch you are using may differ slightly from the one shown.)*

Inquiry 1.4
The Radiometer

PROCEDURE

1. Switch on the flashlight. Point the beam at the radiometer. (See Figure 1.4.)

2. Record what you observe. What effect does moving the flashlight nearer to and farther from the radiometer have on the radiometer?

3. Record what you think is happening.

4. Record any questions you have about what you observed.

Figure 1.4 *What effect does moving the flashlight nearer to and farther from the radiometer have on the radiometer?*

SAFETY TIP

The lightbulbs are very hot. Do not touch the lightbulbs with your hand or the paper.

Inquiry 1.5
Colored Lightbulbs

PROCEDURE

1. Switch on the power strip with the three colored lightbulbs.
2. Hold the piece of paper above the lightbulbs, and look at the paper (see Figure 1.5).
3. Being careful not to touch the lightbulbs, place one hand between the paper and the lightbulbs.
4. Describe what you see on the paper.
5. Try to explain to your partner what you observe. Record your ideas, explanations, and any questions you have about this inquiry.
6. Switch off the strip of lightbulbs.

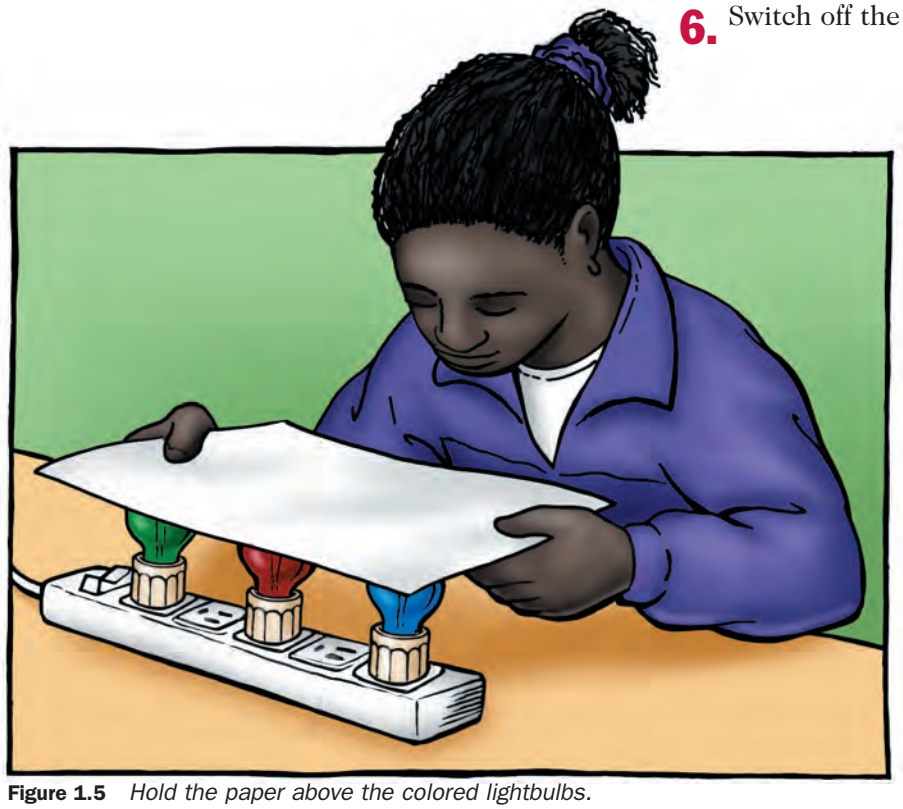


Figure 1.5 *Hold the paper above the colored lightbulbs.*

Inquiry 1.6
Looking Behind

PROCEDURE

1. Hold the mirror in front of you, while your partner stands behind you. Move the mirror so that you can see your partner. Record your observations.

2. Try drawing a sketch in the third column of Table 1 that explains how you can see your partner.

3. Record any questions you have about what you observed.

Inquiry 1.7
Missing Flesh

PROCEDURE

1. You and your partner can do this experiment at the same time. Pick up a tube and hold it to your right eye. Look down the tube.

2. Position your left hand halfway down the side of the tube with the palm facing you (see Figure 1.6).

3. Keeping both eyes open, describe what you see to your partner. Record your observations.

4. Is there any missing flesh? Discuss with your partner what is really happening. Record your ideas and questions.

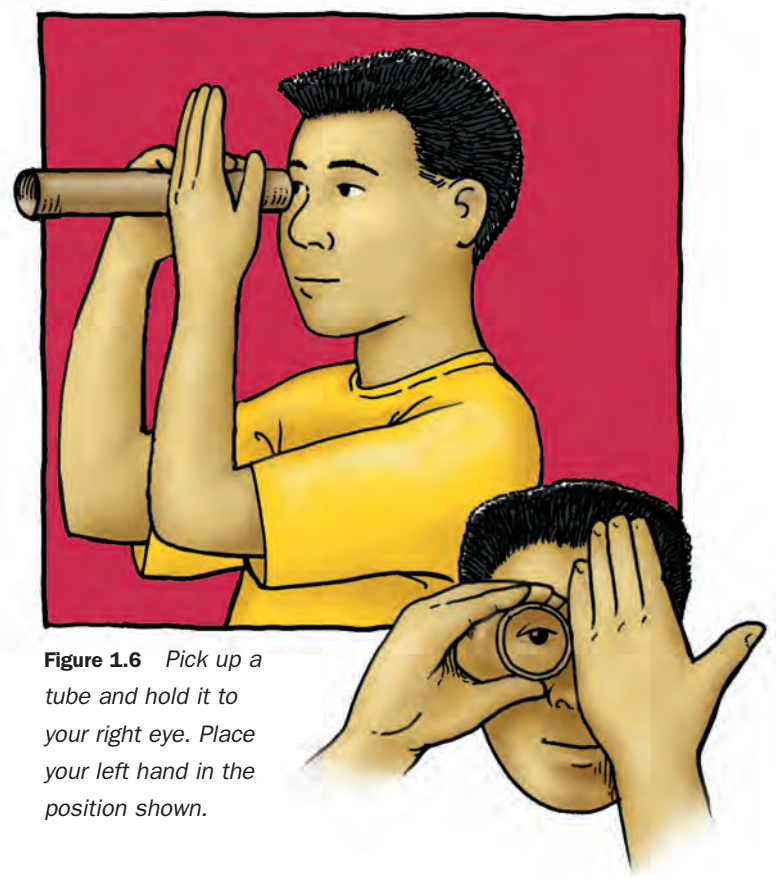


Figure 1.6 *Pick up a tube and hold it to your right eye. Place your left hand in the position shown.*

Inquiry 1.8
Looking Through an Object

PROCEDURE

1. Examine the object you have been given. Draw the object in the second column of Table 1. Write a short description of the object under your drawing. Describe what you observe when you look through the object at the print on this page (as shown in Figure 1.7). Now look at more distant things, such as the other side of the room or the scene outside the window.

2. Discuss with your partner how the object produces these effects. Record your ideas and explanations.

3. Record any questions you have about what you observed.

Figure 1.7 *Look through the object to view the print and pictures on this page.*

REFLECTING ON WHAT YOU'VE DONE

1. Share your observations, ideas, and explanations with the other pair of students in your group. Compare the questions you have generated.

2. From these questions, select the two questions that your group members agree they would most like to be able to answer.

3. Work with your group to improve the wording of these two questions.

A. Write the questions on your student sheet. Be sure to indicate which inquiry each question came from.

4. Your teacher will give you two index cards. Use the marker to write one question on each card. Write clearly and include the number of the inquiry your question relates to at the top left corner of the card (see Figure 1.8).

5. Your teacher will lead a review of the class's observations, ideas, and questions. Here are some things you might like to think about during this review.

Have some groups asked similar questions? Are some versions of these questions better than others?

Can the questions be placed into groups or topics? Can you suggest names for these topics?

Figure 1.8 *Discuss with your group your questions for the inquiries. Identify your group's two questions and write one question on each of the index cards as shown.*

Using and Studying Light

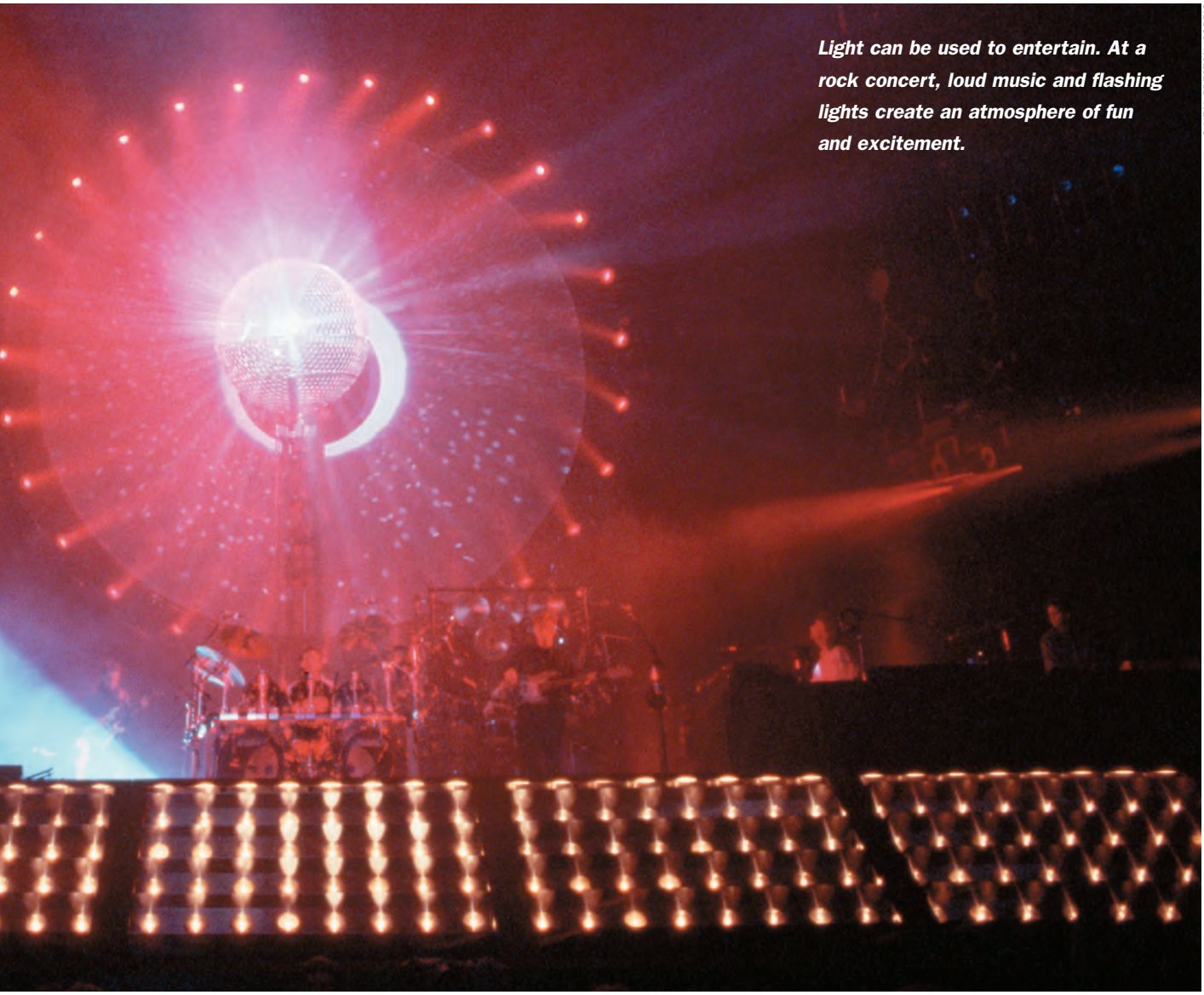
Light is an important part of our lives. Even so, most of the time we take it for granted. Few people consider where light comes from, how it is detected, or how it behaves. But light is present almost all of the time. Even at night, we can see shadows indicating that there is light—perhaps from the stars or the Moon. Only in the darkest room or in a deep cave can there be a complete lack of light. However, humans have found ways to bring light into dark places, for example, by using fire, flashlights, and other light sources.

Sensing Light

Light is so important to living things that almost all organisms can detect light in some way. For instance, plants grow in such a way as to bend toward light. Microbes sometimes move either toward or away from light.

Most animals have special light detectors. Humans have two light detectors: their eyes. Without light we couldn't use one of our five senses—sight. We would have no way to see the world around us. No one could enjoy the work of great painters who express themselves using shape and color.

Without light we couldn't use some types of technology to learn, entertain, and communicate. Photographers used light to make images on light-sensitive film to produce the pictures you see in this book. Movies, television shows, and computer games use light to entertain us. People even listen to music by using laser light in CD players. Make a phone call or send an e-mail or instant message to your friends, and chances are you are communicating through tiny glass fiber-optic cables that carry your message as pulses of light.



Light can be used to entertain. At a rock concert, loud music and flashing lights create an atmosphere of fun and excitement.

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These flowers open during the daytime and close at night. To do this, the plant must have some way to detect light. How does the plant detect light? How do we detect light?

NATURAL HISTORY PHOTOGRAPHIC AGENCY/©ANTHONY BANNISTER

Humans have used fire for hundreds of thousands of years to provide light and heat. This San nomad from southern Africa coaxes a cooking fire by blowing on burning grass and twigs. How does a fire like this produce light?

COURTESY OF GARY BERDEAUX

Without a light source, these cavers would see nothing of this immense cavern.

Light and Science

As scientists work to understand the natural world, they use light to make observations. They may use special instruments that use light to assist them in this work. For example, astronomers use telescopes to observe the night sky. They use other instruments to analyze light from distant stars and galaxies to determine the substances from which they are composed. Biologists use microscopes to uncover the hidden workings of cells. But before scientists could construct these modern scientific tools, they had to learn about the nature and behavior of light. This study of light is called optics.

Humans' interest in optics can be traced back thousands of years—even before recorded history. The first book about optics was written more than two thousand years ago. Early questions about light may have included the following: Why can reflections be seen on the surface of water? Why does sunlight produce fire when it passes through specially shaped polished crystals? Perhaps the most difficult question may have been, What is light? This question continues to preoccupy even modern scientists. □

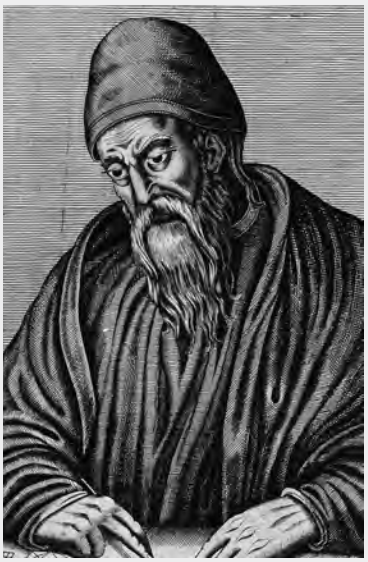
MARK HANNA/NATIONAL OPTICAL ASTRONOMY OBSERVATORY/ASSOCIATION OF UNIVERSITIES FOR RESEARCH IN ASTRONOMY/NATIONAL SCIENCE FOUNDATION

AGRICULTURAL RESEARCH SERVICE/ UNITED STATES DEPARTMENT OF AGRICULTURE

Our knowledge of optics has enabled us to build giant telescopes that allow us to see deep into the universe. This telescope sits atop Kitt Peak in Arizona. A knowledge of optics also allows us to look at the world of the very small—the microscopic.

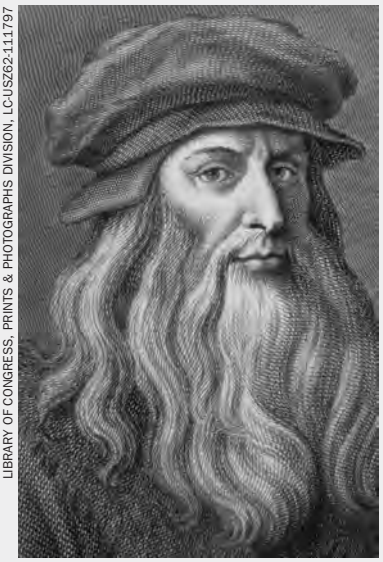
Light Pioneers

For thousands of years scientists and artists have studied light.



COURTESY OF THE ROYAL ASTRONOMICAL SOCIETY, LONDON

Euclid (330 B.C.–260 B.C.), a Greek mathematician and physicist, probably wrote the first book about optics two thousand years ago.



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Leonardo da Vinci (1452–1519) had one of the most curious minds in history. This Italian artist, scientist, and engineer observed light and asked himself many questions about it. He then applied the results of his inquiries into the nature of light, reflections, and shadows to his great works of art.

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The scientist Albert Einstein (1879–1955) is perhaps the most famous of the many scientists who have contributed over the past hundred years to a better understanding of the nature of light.

The Sun:

A SOURCE OF LIGHT, MYTH, AND TRADITION

Each dawn, not far from the shores of the Bay of Bengal, India, the first rays of the rising Sun strike the 13th–century sun temple of Konark. The temple was built in the form of a giant 24–wheeled chariot drawn by seven horses to honor the sun god Surya. According to legend, only such a magnificent chariot was fit to carry Surya across the sky in his dawn-to-dusk journey.

ASIAN ART ARCHIVES, UNIVERSITY OF MICHIGAN, ANN ARBOR

The Konark temple in India was built in the form of a chariot. In legend, this horse-drawn chariot carries the sun god Surya across the sky.

COURTESY INDIA TOURIST OFFICE, NEW YORK

A wheel from a temple chariot fit for a sun god

Six hours later, the Sun's early morning rays touch the stones of Stonehenge in England. Ancient Britons built this giant astronomical calendar and center for sun worship four thousand years ago. Throughout history, people from all over the world have worshipped the Sun, our closest star. They have recognized it as the source of the light and heat so essential for life. No wonder many cultures gave the Sun the status of a god.

The early Egyptians built elaborate temples to their sun gods, Re and Aton. The ancient Greeks also had sun gods—first Helios and then Apollo. The Greeks also explained the Sun's apparent movement across the sky in terms of a golden chariot light for both humans and gods.

In addition to worshipping sun gods, some peoples—like the Japanese—believed that their rulers were descended from sun gods.

ENGLISH HERITAGE

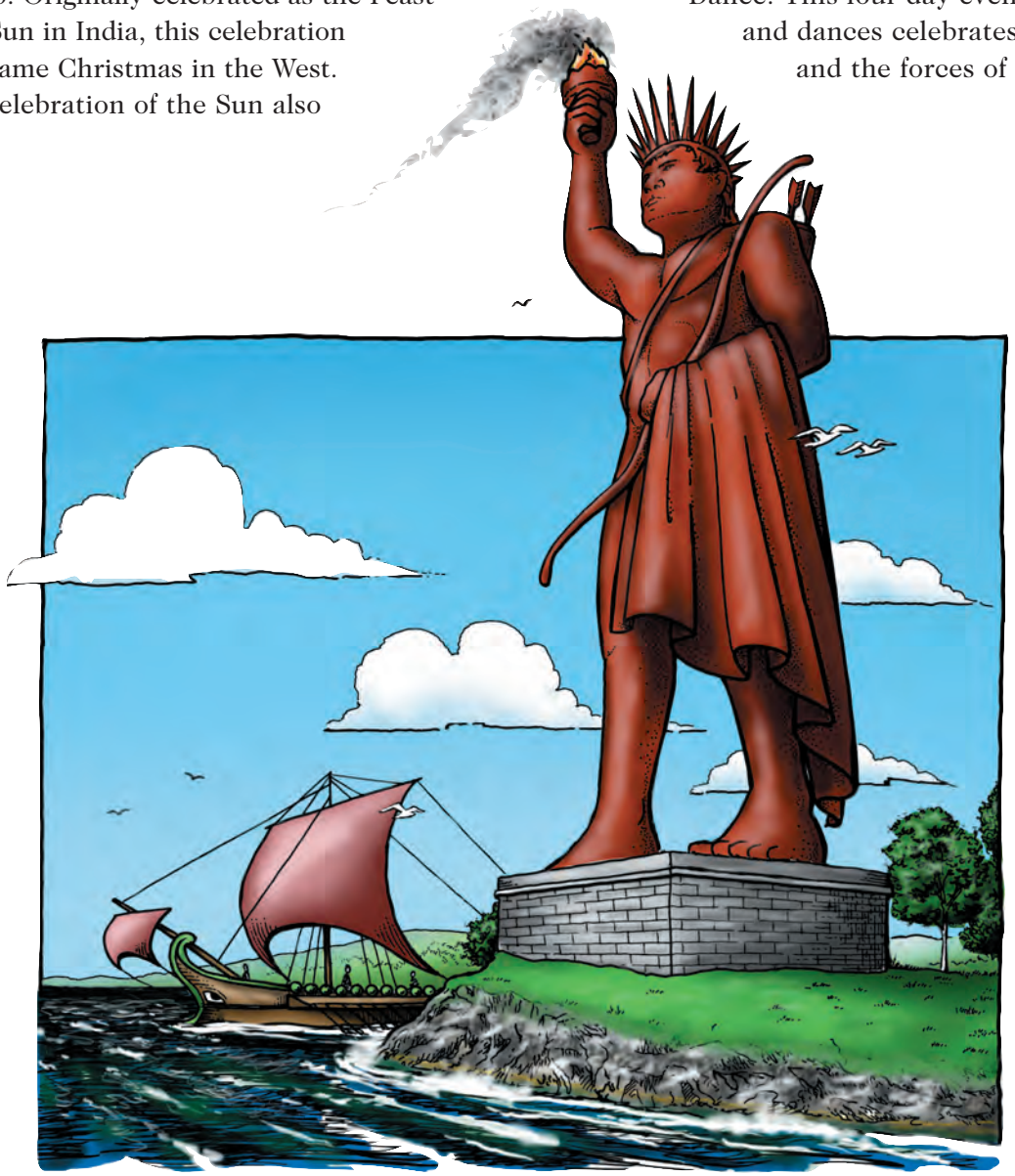
Ancient Britons built Stonehenge as an astronomical calendar and a place of sun worship. Some of its giant stones were dragged over 160 kilometers (100 miles) to the site. The stones are arranged so that on a midsummer's day the rays of the rising Sun shine into the center of the monument.

Celebrating the Sun

Have you ever thought about where the word "Sunday" came from? In A.D. 313, the Roman emperor Constantine became a Christian. He then changed the day for worshipping the Roman sun god, Sol Victis, into a day for worship for Christians—*Sun*day. Even celebrations on December 25 began as a day of sun worship. Originally celebrated as the Feast of Sun in India, this celebration became Christmas in the West.

Celebration of the Sun also was common among the early inhabitants of the Americas. The Aztecs, Incas, and Mayans recognized the Sun as a deity. They staged elaborate rituals and sacrifices in temples created specially for these gods.

Some of the native peoples of the North American plains still hold a renewal ceremony in spring or early summer, called the Sun Dance. This four-day event of rituals and dances celebrates the Sun and the forces of nature.



Just as the Statue of Liberty stands at the gateway to New York, so a statue of the sun god Helios guarded the ancient harbor of Rhodes, a Greek island. The statue, known as the Colossus of Rhodes, is considered one of the Seven Wonders of the Ancient World. It stood more than 30 meters tall and was made from bronze melted down from the weapons of a defeated enemy.

The Sun has long been important to the culture and traditions of the world's peoples. Modern scientists explain the Sun, not as a god, but as a giant ball of gas—about 1,400,000 kilometers in diameter—that releases light and heat from the nuclear reactions that occur inside it. □

EXERCISE

Use books, CD-ROMs, or the Internet to research examples of sun worship other than the ones mentioned in the reader. Write a paragraph about an example you find.

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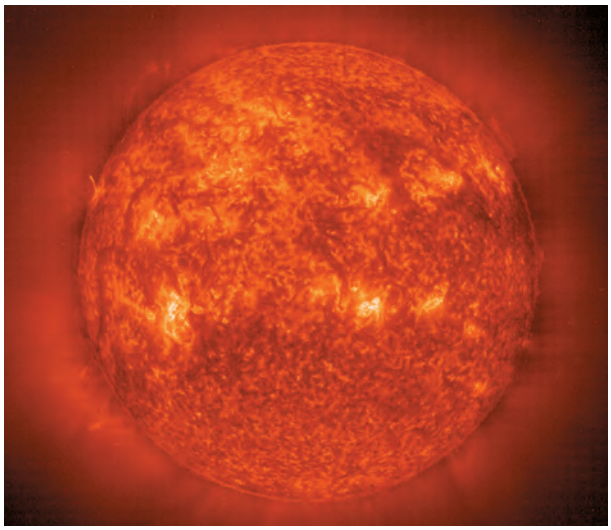
Until 1945, the Japanese royal family traced its descent from the sun goddess Amaterasu Omikami (here being released from a cave), a goddess of one of Japan's oldest religions, Shinto.

MUSEO NACIONAL DE ANTROPOLOGIA, MEXICO CITY

This Aztec calendar stone, or sun stone, weighs almost 25 tons. In 1497, the stone was dedicated to the Aztec's main deity—the Sun. The stone's many carvings bear witness to the great cultural significance of the Sun to the Aztec culture.

SOLAR AND HELIOSPHERIC OBSERVATORY/EXTREME ULTRAVIOLET IMAGING TELESCOPE CONSORTIUM



The surface of the Sun is very hot and releases a lot of light. Are light and heat related?