LESSON 15

How Is Light Reflected?

NATIONAL ARCHIVES AND RECORDS ADMINISTRATION

What is this naval officer looking through? What is it used for? How does it work?

INTRODUCTION

In Lesson 14, you observed some of the characteristics of images produced by a plane mirror. You discovered that the images appeared to be behind the mirror. Is it possible to use your knowledge of the behavior of light to explain how these images are produced? In this lesson, you will conduct an inquiry on what happens to light when it is reflected from a plane mirror. You then will apply what you have discovered to help you to predict and control the direction of a ray of light. You also will apply what you have discovered to build an optical device called a periscope.

OBJECTIVES FOR THIS LESSON

Observe and measure reflection of light rays off a plane mirror.

Use mirrors to redirect light rays.

Build an optical device that uses mirrors.

Discuss the formation of an image in a plane mirror.

Getting Started

1. Have one member of your group collect the plastic box of materials. You will be recording all your responses for this lesson in your science notebook.

2. Work with your group to set up the ray box so that it produces a single ray of light as shown in Figure 15.1.

3. Experiment with placing the large mirror into the path of the ray of light. Record your observations.

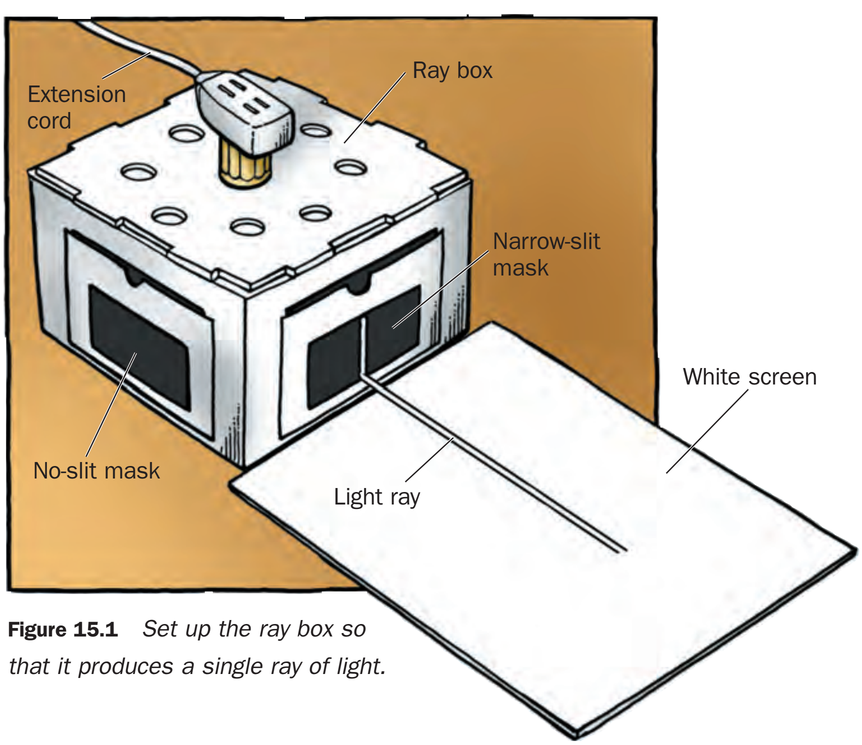


Figure 15.1 *Set up the ray box so that it produces a single ray of light.*

MATERIALS FOR LESSON 15

For your group

1 ray box
1 ray box lid
1 60-W clear halogen lightbulb
1 extension cord
1 bulb holder
1 narrow-slit ray box mask
1 wide-slit ray box mask
2 no-slit ray box masks
1 white screen
1 comb
1 large mirror
1 sheet of white paper
1 box of colored pencils
1 protractor
4 plastic stands
1 copy of Inquiry Master 15.1: Protractor Paper for Inquiry 15.1

For you and your lab partner

1 cardboard tube
2 small mirrors
1 metric ruler, 30 cm (12″)
1 protractor
1 pair of scissors
Masking tape

SAFETY TIP

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

Inquiry 15.1
Measuring Reflection

PROCEDURE

1. Have one member of your group use the scissors to cut along the cutout lines on the protractor paper.

2. Working with your group, set up the apparatus as shown in Figure 15.2. The base of the large mirror should lie along the baseline of the protractor paper. Position the mirror so that its center approximately matches the center of the baseline. Throughout this inquiry, the mirror should stay in this position on the protractor paper. (If you prefer, you may tape your protractor paper to your mirror in the correct position.)

3. Move the mirror and protractor paper so that the ray of light from the narrow slit passes down the 60° line of the protractor paper. The ray should strike the mirror where the 0° line (the line perpendicular to the mirror, which is called the normal) meets at the center of the baseline, as shown in Figure 15.3.

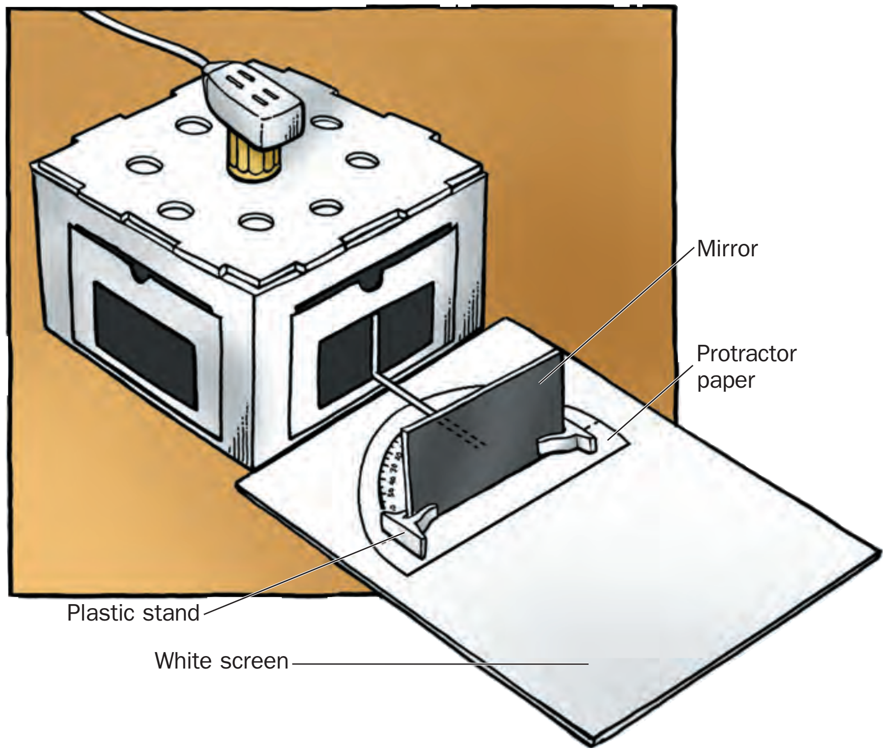


Figure 15.2 *Position the large mirror, white screen, and protractor paper as shown.*

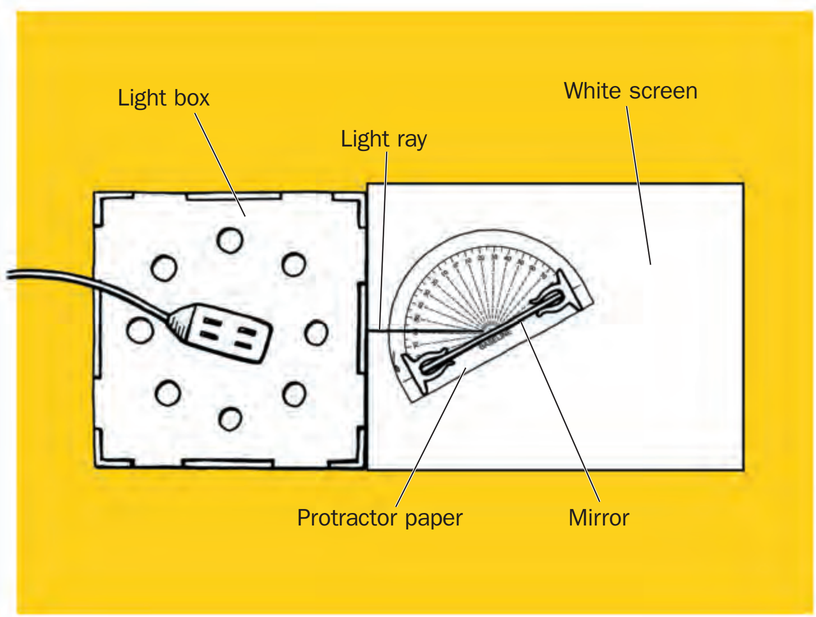


Figure 15.3 *Move the mirror and protractor paper so that the ray of light from the narrow slit passes down the 60° line of the protractor paper. The ray should strike the mirror where the 0° line (the line perpendicular to the mirror, which is called the normal) meets at the center of the baseline.*

4. On the protractor paper, use a colored pencil and a ruler to accurately draw a line that follows the ray of light from the center of the ray box to the large mirror. This ray is called the *incident ray*. Next draw a line that follows the center of the ray of light reflected from the mirror. This ray is called the *reflected ray*.

5. Move the mirror and protractor paper to change the angle of the incident ray. Aim the ray at the same point on the mirror. Draw a line on the protractor paper (in a different color) that follows the incident ray and another line that follows the reflected ray. Do not confuse this set of rays with the rays you recorded in Step 4.

6. Repeat Step 5 a few more times.

7. For each set of incident and reflected rays, use the protractor paper to determine the angle between each ray and the line perpendicular to the mirror (the line labeled "Normal" in Figure 15.4).

8. Design and then draw a table for your data in your notebook. Record your data.

9. Compare your results with those from another group. What can you conclude from your results? Record your ideas.

10. Move the white screen and the mirror to the side of the ray box with the wide-slit mask. Use the comb against the wide-slit mask to produce multiple rays as shown in Figure 15.5. Direct the rays at the mirror. Draw what you observe. Be prepared to share your observations with the class.

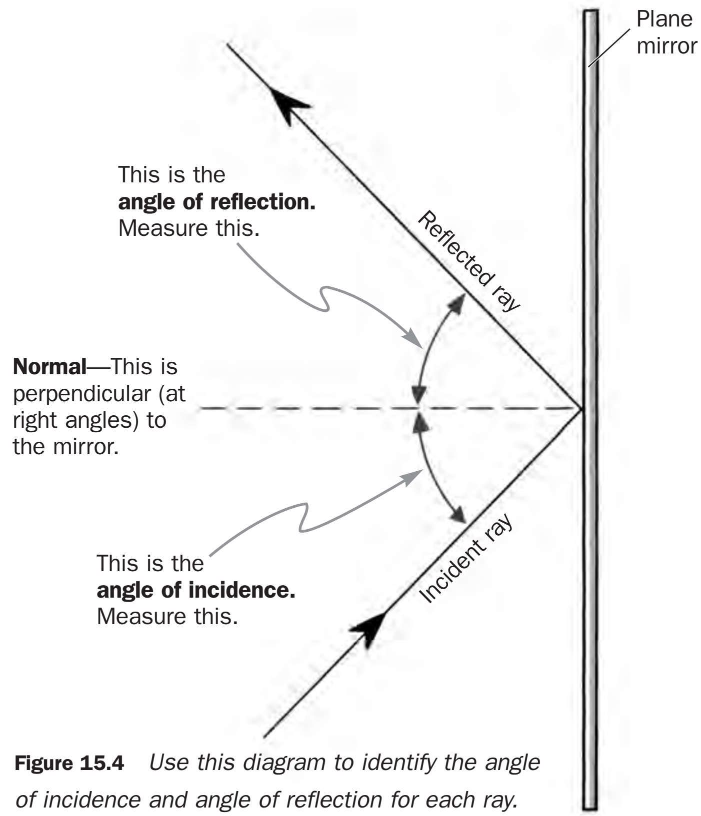


Figure 15.4 *Use this diagram to identify the angle of incidence and angle of reflection for each ray. Use the protractor paper to measure these angles.*

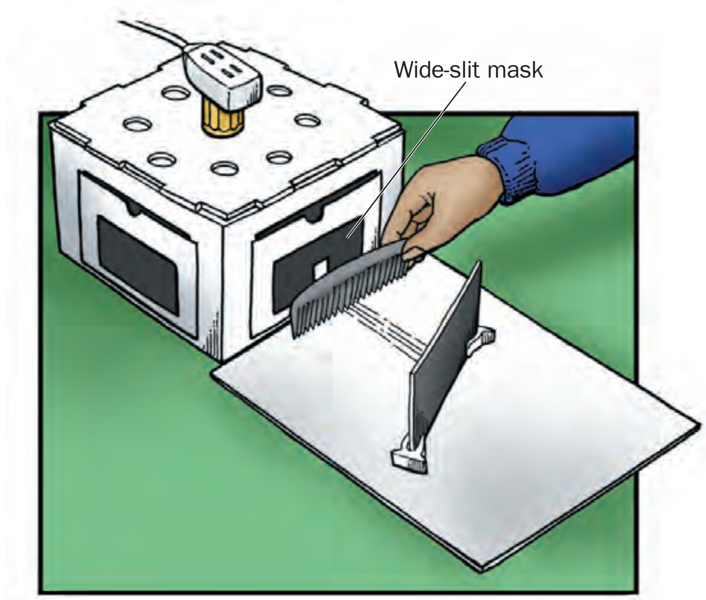


Figure 15.5 *Direct multiple rays at the mirror. What do you observe?*

Inquiry 15.2
Changing the Path of a Light Ray

PROCEDURE

1. Look at the ray box setup from Inquiry 15.1. Predict the angle at which the mirror will have to be held so that the ray of light turns through a right angle (90°). Record your prediction and write a sentence explaining how you reached it.

2. Test your prediction. Use the protractor to measure the angles.

3. Keep your apparatus in place, and use a second mirror to redirect the light ray so that it continues on each of the following paths:
   - a path that is parallel to the existing ray leaving the box and in the same direction
   - a path that is parallel to the existing ray leaving the box, but in the opposite direction
   - a path that returns the ray to the slit in the ray box

4. Which group in the class can construct the most complicated ray path using multiple mirrors? Use all the mirrors and plastic stands at your disposal. Spend a few minutes constructing your ray path. *What problem do you encounter? Can you reflect light from the same ray off the same mirror more than once? Compare your ray path with those constructed by other groups.*

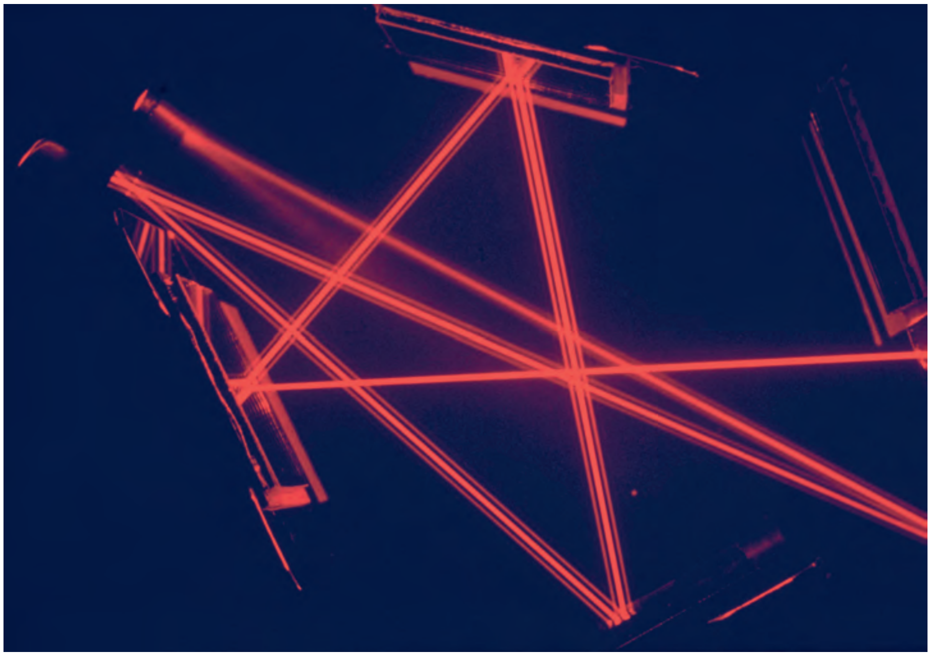
5. Read "Redirecting Light, Images, and the Law of Reflection."

SAFETY TIP

Turn off the ray box immediately after you finish using it. Allow the ray box to cool.

REDIRECTING LIGHT, IMAGES, AND THE LAW OF REFLECTION

You have determined that the angle of reflection from a plane mirror equals the angle of incidence. This rule is called the law of reflection. By altering the angle of a mirror with respect to the incident ray, you can alter the direction in which the ray travels. By reflecting light from one mirror to another, light can be made to change direction many times and can be directed around opaque objects.



E.R. DEGGINGER/COLOR-PIC, INC.

Light can be reflected from one mirrored surface to another.

Inquiry 15.3
Constructing a Device To See Over Objects

PROCEDURE

1. Look at the picture in Figure 15.6. How could you and your partner use the small mirrors, tube, scissors, and tape in the box of materials to construct a device to observe the bird on the feeder? Discuss your ideas with your partner.

2. Your teacher will tell you how to proceed with this inquiry. Be prepared to explain and demonstrate the device you make.

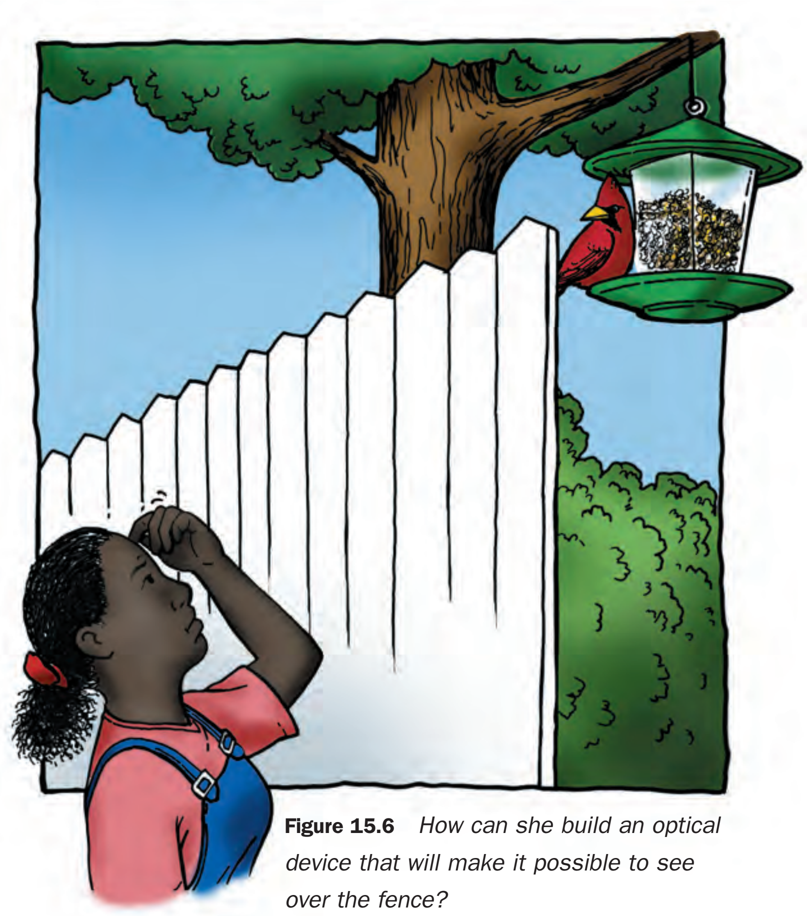
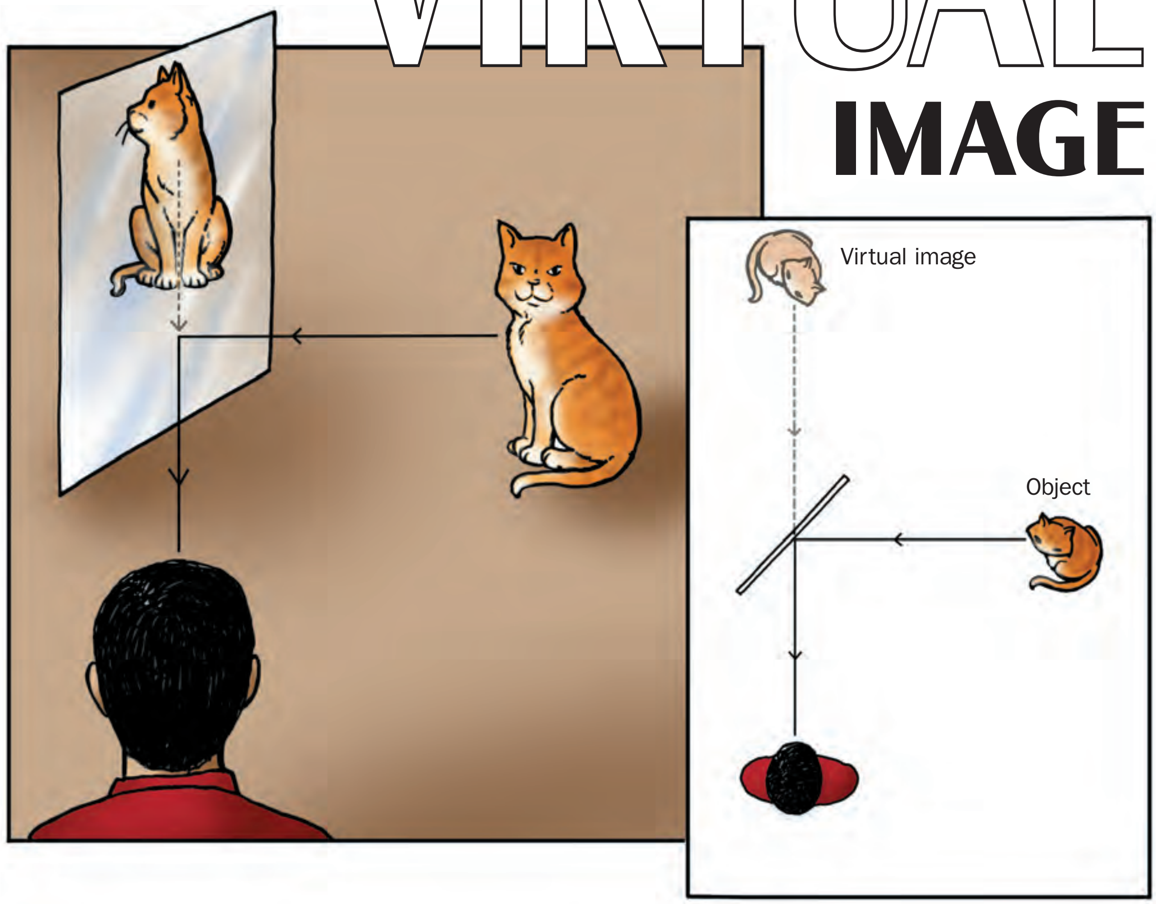


Figure 15.6 *How can she build an optical device that will make it possible to see over the fence?*

REFLECTING ON WHAT YOU'VE DONE

Refer back to your response for Inquiry 1.6 on Student Sheet 1.1. Can you explain now how you were able to use a mirror to look behind you? Redraw your diagram from that inquiry in your notebook. This time add arrows to the rays (to indicate the direction you think the light is traveling) and label the various rays and angles. Write a few sentences using the correct terminology to describe what is happening in your diagram.

EXPLAINING THE VIRTUAL IMAGE



The law of reflection can be used to explain the position of an image seen in a mirror. Imagine looking at an image of an object in a mirror—for example, a cat. You see an image of the cat because some of the light from a source (for example, a lightbulb or the Sun) hits the cat. Because the cat is a rough surface and not a smooth mirror, this light reflects off the cat in many directions. Some of these reflected light rays travel toward the mirror. When these incident rays strike the mirror, they are reflected. Some of these rays are reflected to your eyes. When your eyes detect these rays, you see the image of the cat.

The cat appears to be behind the mirror. This is because your brain assumes that light has traveled in a straight line coming from the image. But your brain does not take into account that the rays of light have been reflected off the mirror. Instead, your brain assumes that the cat lies in a straight line—backward along the direction of the light ray entering your eye. Therefore, you see the cat as being behind the mirror.

The image of the cat also appears to be the same distance behind the mirror as the actual distance the cat sits in front of the mirror. You measured the same phenomenon with the half-silvered glass and wooden blocks in Inquiry 14.2.

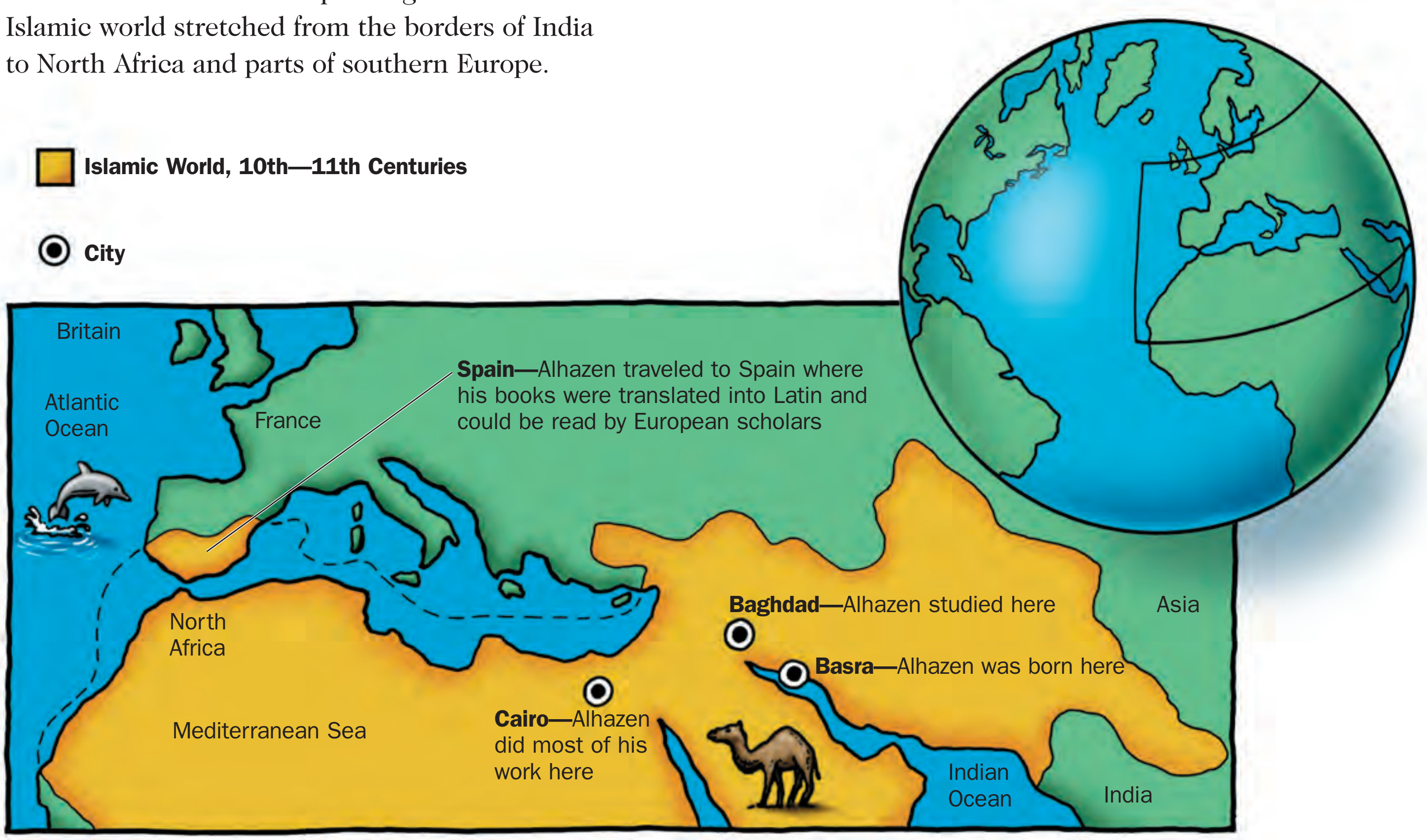
The image of the cat formed by a plane mirror is an example of what is called a virtual image. It is called a virtual image—as opposed to a real image—because where it appears to be (behind the mirror) there are no light rays that could be reflected from the object. ☐

Abu Ali Hasan Ibn al-Haytham

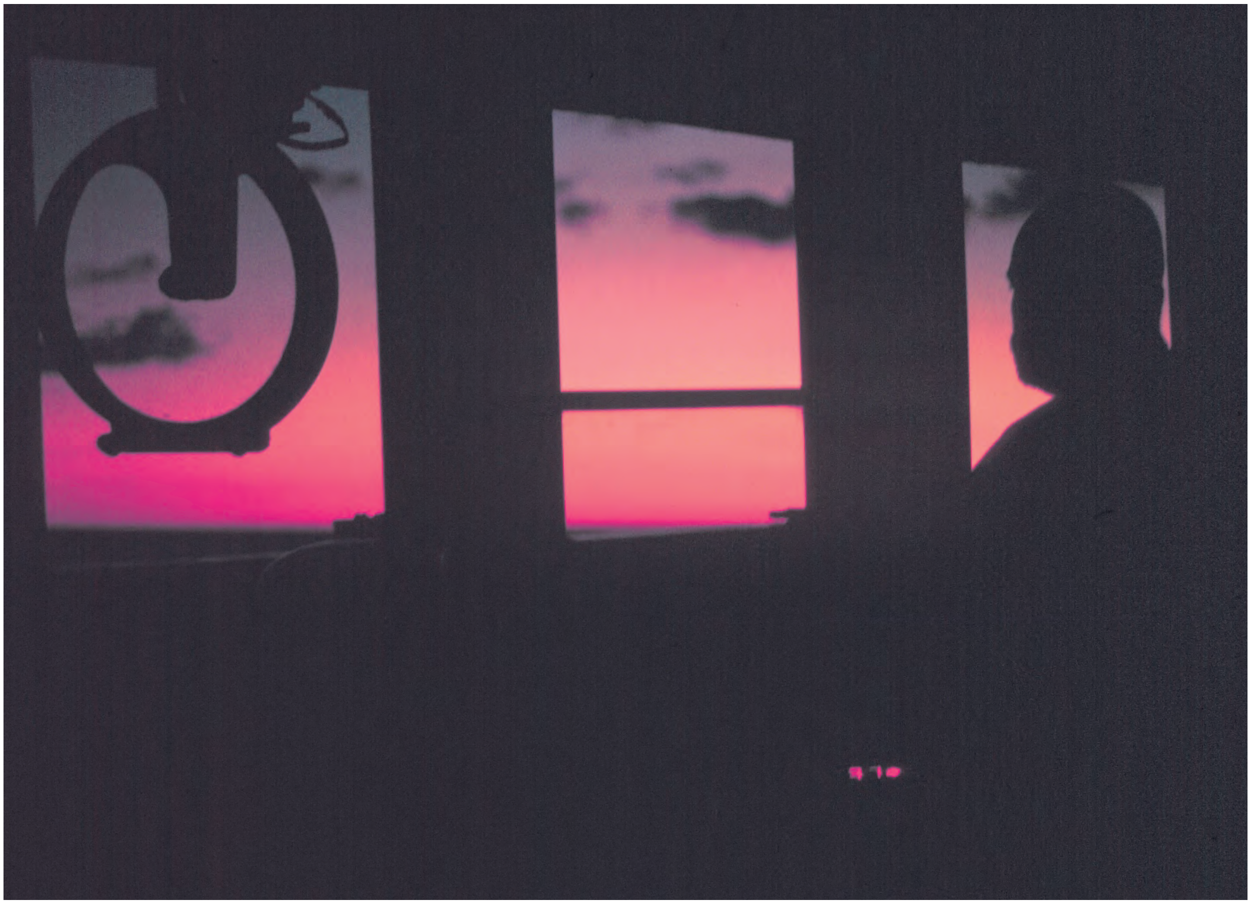
Many cultures have contributed to current scientific knowledge. Alhazen, or more correctly Abu Ali Hasan Ibn al-Haytham, an Arab from the ancient city of Basra, is one of the founders of the science of optics. He also was one of the earliest developers of the scientific method.

Just like art, literature, and music, science has its roots in many cultures. At the turn of the first millennium—1000 A.D.—the culture and learning of the Greeks, although still important, were ancient history. The Roman Empire's rule over Europe had long before fallen apart and much of Europe was just emerging from the so-called Dark Ages. But other cultures were blossoming.

Islamic influence was expanding and the Islamic world stretched from the borders of India to North Africa and parts of southern Europe.



During Alhazen's lifetime (965–1040), Islamic rule and scholarship stretched from the Indian Ocean to the North Atlantic.



NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION (NOAA) PHOTO LIBRARY/NOAA CENTRAL LIBRARY

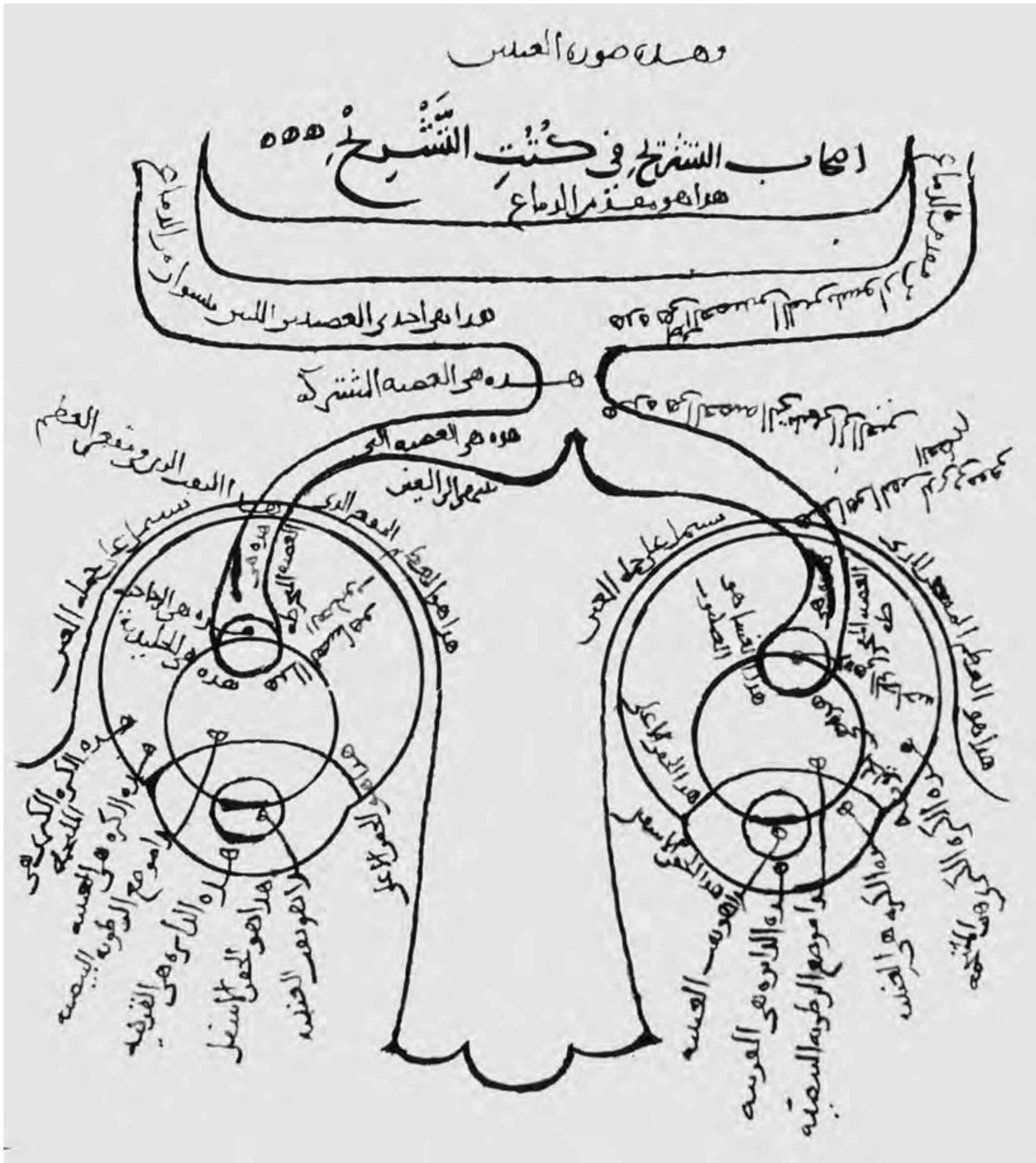
Why can you see sunlight when the Sun is below the horizon and not visible in the sky? Alhazen suggested that light from the Sun below the horizon traveled around Earth by somehow being reflected from high in the atmosphere. We now know this process involves light being scattered from molecules high in the atmosphere. This scattering also bends light around Earth during a lunar eclipse and explains why the Moon often reflects a dim red light during a total eclipse.

Islamic scholars were considered the most learned in the world. They worked in all aspects of art, mathematics, and science and had access to the world's best universities and libraries. They were well educated and widely traveled.

One such scholar was an Arab born in Basra, an important city located in what is now Iraq. His name was Abu Ali Hasan Ibn al-Haytham. He is better known in the Western world by a shortened version of his name, Alhazen. Alhazen was interested in many subjects, but he specialized in mathematics, astronomy, and physics. One of his favorite subjects was optics.

Alhazen liked to design inquiries to test his theories as well as those of others. He studied light from sources such as lamps, fire, the Moon, and the Sun. He suggested that light was a single phenomenon, regardless of its source or color. He conducted experiments to determine that light travels in straight lines. He also studied what happens to light when it enters a transparent material. He used a prism to make a colored spectrum. He even correctly suggested the cause of twilight.

Alhazen investigated how the eyes worked. He was probably the first person to record the



PRIVATE DONOR

Alhazen investigated how the eyes worked. Here is one of his diagrams of the human visual system.

idea that light travels from an object to the eye, and not in the opposite direction.

Although Alhazen studied human vision, he is best known for his research on reflection. Alhazen's studies of reflection confirmed earlier Greek theories about reflection from plane mirrors—including the law of reflection, which states that the angle of incidence equals the angle of reflection. He then applied these laws to curved mirrors.

Alhazen wrote about 200 books. He developed a scientific methodology, an experimental approach to explaining the natural world. This approach was adopted 500 years later by European scientists in the forefront of a new revolution in the arts and the sciences known as the Renaissance. ☐