4

How Light Spreads Out

If you moved far from a fire such as this one, it would soon become too dark to see your surroundings. Do you know why?

INTRODUCTION

What happens to light when it leaves a light source? You got some clues in Lesson 3 when you observed light from a flashlight travel through cloudy water. Think about some other light sources. The Sun, our nearest star, is a huge ball of glowing gas. Where does all the Sun's light go? Does all of it reach Earth? There are millions of other stars in our galaxy— billions in our universe—and many of these stars are much bigger than the Sun. So why isn't the night sky bright with the light these stars produce? Why do these giant stars appear so small and dim when observed from Earth? What about other light sources? For example, what appears to happen to car headlights when they move toward or away from you? Does their brightness appear to change? In this lesson, you will investigate how light behaves after it leaves a light source. By the end of the lesson, you may find it easier to answer some of these questions.

OBJECTIVES FOR THIS LESSON

Investigate whether the appearance of a light source depends on your distance from it.

Investigate the way light behaves as it travels from a light source.

Getting Started

1. One member of your group should collect the plastic box of materials. Remove the flashlight from the box.

2. Working with your partner, shine the flashlight on the wall. What do you see on the wall? Move the flashlight backward and forward. Describe in your science notebook what you observe on the wall.

3. Discuss your observations with your partner. How can you explain your observations? Record your ideas (as sentences or diagrams) in your notebook.

4. Stand at one end of the room. Your partner should be about 2 meters (m) in front of you and should shine the flashlight in your face. Have him or her walk to the other end of the room while pointing the flashlight at you. Observe any changes in the appearance of the flashlight as your partner moves away from you. Record your observations in your notebook. Does the flashlight change in appearance? If so, can you explain why? Record your ideas.

Inquiry 4.1
Measuring Light and Distance

PROCEDURE

1. In this inquiry, you will investigate in more detail the way light behaves when it leaves a light source. You will be recording your observations, results, and explanations on Student Sheet 4.1: Measuring Light and Distance.

2. Divide the remaining materials between the pairs in your group. Put the meterstick on a desk.

3. Attach two binder clips to the short sides of the card with the hole so it stands up (see Figure 4.1). Position the card with the hole exactly 10 centimeters (cm) from the beginning of the meterstick. Place the light stand in a horizontal position, so the end of the lightbulb filament is at the beginning of the meterstick.

10 cm

Figure 4.1   *Use two binder clips to make the card with the hole stand up. Position the card so the hole is 10 cm from the beginning of the meterstick and the tip of the filament of the lightbulb.*

4. Use the other binder clips to attach the paper with 1-cm squares to the screen. Attach the plastic stands to the sides of the screen (see Figure 4.2). (You may need to gently pry the plastic stands open with your fingers.)

5. Stand the screen and the card next to each other so that they are touching. (You will need to bend the card a little so that it touches the screen.) Keep the light source horizontal at the beginning of the meterstick. Make sure the end of the filament is aligned with the hole in the card. The light will shine through the hole in the card (see Figure 4.3).
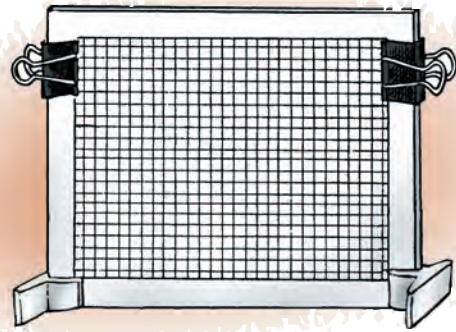

Figure 4.2 *Use the other binder clips to attach the squared paper to the screen. Attach the plastic stands to the sides of the screen.*
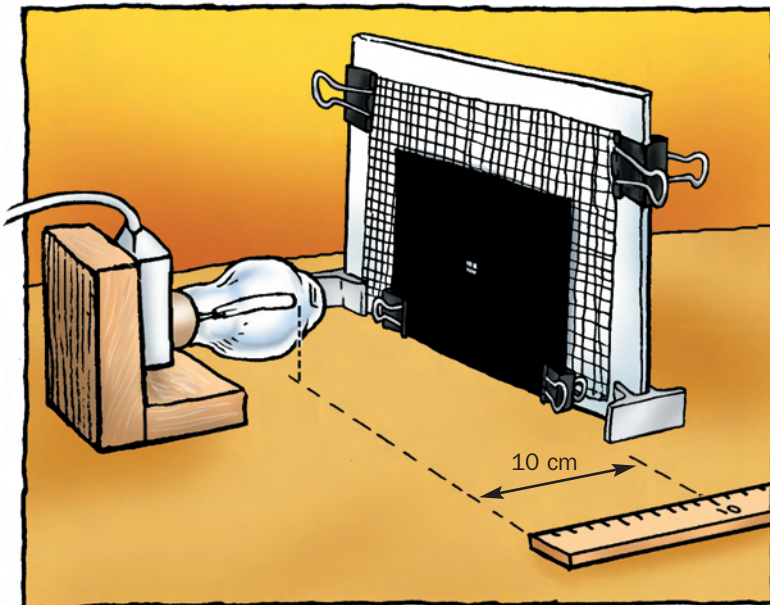

10 cm

Figure 4.3 *Make sure the end of the filament is aligned with the hole in the card. Position the screen and the card next to each other so that they touch.*

6. What area of the squared paper does the light illuminate? Use a colored pencil to record the approximate area illuminated by tracing its outline on the squared paper on the screen. This is the area illuminated through the hole when the screen is 10 cm from the light source. Use the same colored pencil to record the distance of the screen from the light source (the beginning of the meterstick) inside the area you outlined on the squared paper.
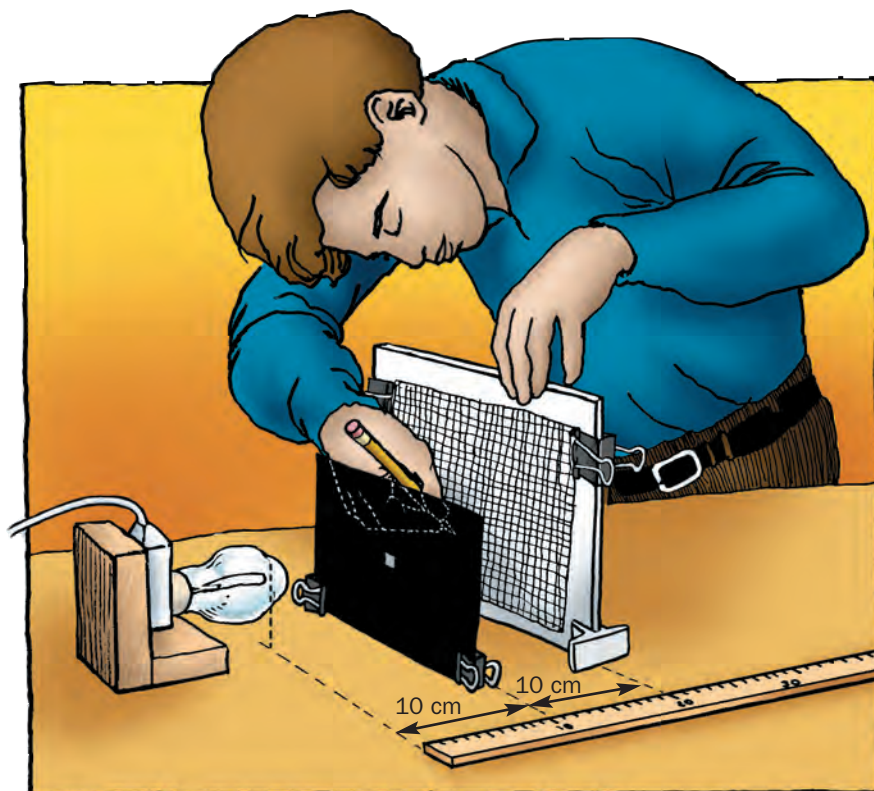
7. Do not move the lightbulb or the card with the hole. Move the screen 10 cm away from the card with the hole. Use a colored pencil of a different color to trace the area illuminated on the squared paper in the same way (see Figure 4.4). How far is the screen from the light source? Record this distance inside the area you outlined on the squared paper.

8. Repeat the procedure with the screen 30 cm, 40 cm, and 50 cm from the light source. For each distance, determine the approximate area of the squared paper illuminated through the hole.

Figure 4.4 *Use a colored pencil to trace the outline of the illuminated area on the squared paper.*

A. Design a table for your results. Complete the table.

B. Plot a graph of your results. You will need to decide on the axes you are going to use and the type of graph you should plot.

C. Is there any mathematical relationship between the distance of the screen from the light source and the area of illumination on the screen? If there is, describe it.

D. Use your data and graph to predict the area that would be illuminated if the screen was placed 60 cm and 80 cm from the light source. Record your predictions.

REFLECTING ON WHAT YOU'VE DONE

1. How do you think light spreads out from a lightbulb? Record your responses on the student sheet. Be prepared to share your responses with the class.

A. Draw a diagram that shows how light spreads out from the lightbulb onto the screen.

B. Write a paragraph explaining why a light source appears less bright as you move away from it. Think about the following questions before you write your explanation:

Does the brightness of the light source really change?

What happens to light when it leaves the source?

Does the light always shine on the same size area?

2. Some stars (apart from our Sun) look very small—sometimes just pinpoints of light—and dim.

C. Why is this so? Write a sentence giving your ideas.

3. Review the question bank cards generated in Lesson 1. Can you answer any more of them now? Identify those you feel comfortable answering.

LIGHT and DISTANCE

Why do lights look dimmer when they are farther away? In Inquiry 4.1, you determined that light spreads out from its source. Think about what happens when you quickly turn a lightbulb on and off again? A flash or pulse of light is produced. This pulse of light can be thought of as moving away from the lightbulb in all directions, like a shell or hollow sphere of light. The farther the pulse of light is from the lightbulb, the bigger the hollow sphere of light becomes.
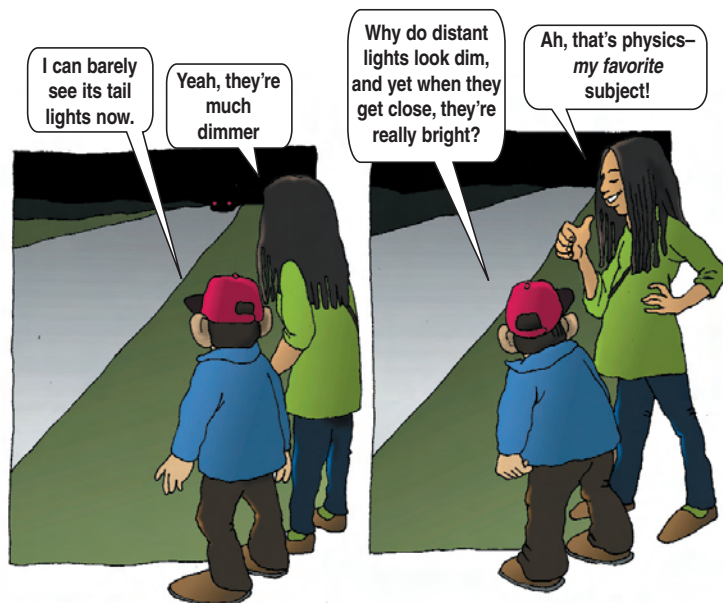
As the sphere of light gets bigger, the light spreads out. The area illuminated by the pulse of light increases very quickly. The *amount* of light reaching each square centimeter gets smaller. This explains why the farther you get from a light source, the less bright it appears.

The apparent brightness of light, or how it looks to your eyes, decreases much more quickly than you might think. This is because
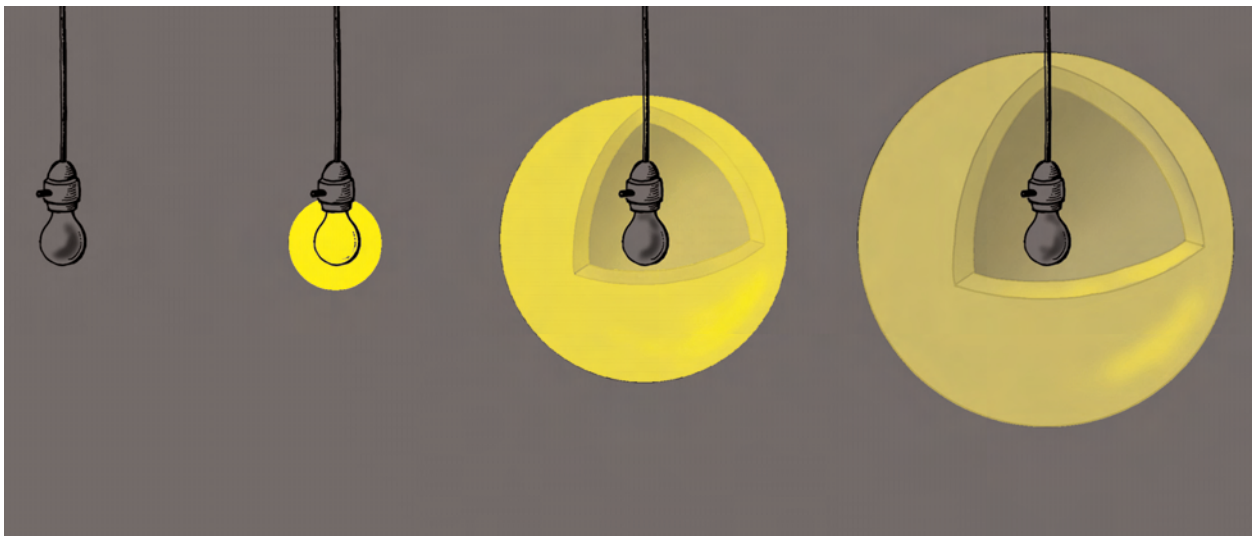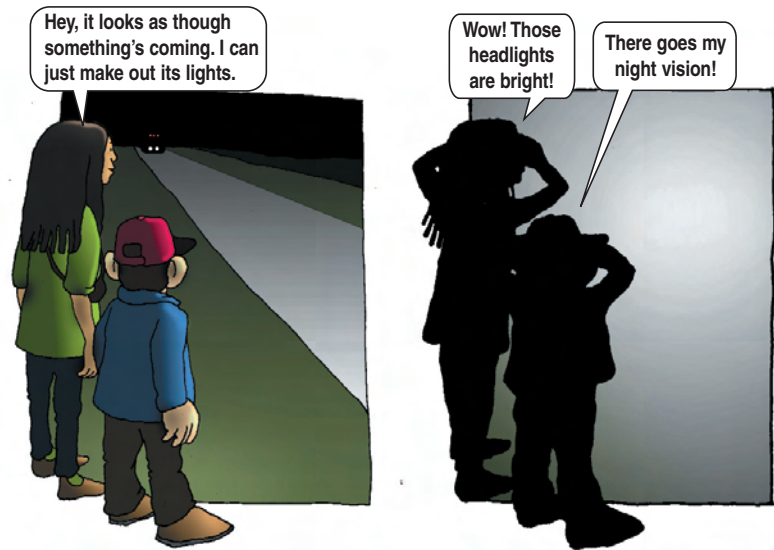
When this lightbulb flashes, light spreads out from it in all directions like a shell or hollow sphere of light.

the area over which the light spreads—the surface area of the hollow sphere of light—grows faster than the distance the light travels. In your inquiry, when you doubled the distance from the lightbulb (from 10 to 20 cm) the light spread out over an area four times as large.

Observed from this distance, the lightbulb appears one-fourth as bright. Double the distance again, this time to 40 cm, and the same lightbulb appears only one-sixteenth as bright!

This rapid change in the apparent brightness of light as you move away from its source is sometimes called the inverse square law, which is shown in the following equation:

Apparent brightness = Brightness at source/distance^2

This law explains why bright street lamps can be seen for only a few miles and why it gets dark quickly when you walk away from a nighttime campfire. □

Doing the Math on Spreading Light

The following equations give some mathematical proof for inverse square law:
The area illuminated by a sphere of light is—

$4 \times \pi \times$ radius of the sphere^2

If the approximate value of π is taken as 3.14, then:
The area illuminated by a sphere of light with a radius of 10 cm is

$4 \times 3.14 \times 10 \times 10 = 1256$ cm^2

The area illuminated by a sphere of light with a radius of 20 cm is

$4 \times 3.14 \times 20 \times 20 = 5024$ cm^2

What will be the area illuminated by a sphere of light if the sphere of light has a radius of 30 cm?