4.5 Investigate

**What Factors Affect the Intensity of Light Energy?**

It may seem odd to you to think about light as energy. However, you did see that when a flashlight was held close to a radiometer, the flags moved more than when the flashlight was held farther away. So, clearly, the light somehow provided energy to the radiometer. You may be wondering how light can provide energy and how light from the Sun can heat Earth. You may also be wondering how light can power devices such as a calculator. Like sound, light energy can travel in waves. In this section, you will investigate light energy and identify factors that affect the amount of light energy emitted by a light source. Your investigations will also help you understand the relationship between light that you see and light energy.

**Demonstration**

Watch as your teacher shines the light from a flashlight on a classroom wall. The beam will make a circle of light on the wall. The teacher will move the flashlight closer to the wall and away from the wall. Work in groups to discuss what is happening during the demonstration.

**Analyze Your Data**

In your group, discuss the following questions:

1. What do you think is happening when the circle of light becomes larger? What about when it becomes smaller?

2. Do you think the light energy emitted by the flashlight changes at any point in the demonstration? If so, how?

3. When a flashlight is close to the wall, the illuminated area is a small circle. How do you think the intensity of the light in the small circle compares with the intensity when the light makes a big circle? In other words, how does the intensity of light striking the wall relate to the distance of the flashlight from the wall?
4. How can you use the area illuminated by a flashlight at different distances to determine how the intensity of light at the wall is related to distance from the source?

5. Suppose you repeat the demonstration, using two flashlights, one of which is brighter and more powerful. Describe the circles of light that will be produced if both flashlights make circles of light that are the same size. How do you think the brightness of the light source will affect light intensity at the wall?

How Does Distance Affect Light Intensity?

The data from the demonstration suggest that as light energy spreads out over a larger area, it decreases in intensity. But you do not know for sure, because you have observed this using the light of just one flashlight. What if the light source was different? Would the same thing happen? You are going to investigate to find the answers.

In this investigation, three lab stations will be set up around the classroom, each using a different light source. Your group will have a chance to run the procedure at least once at one of the lab stations. You will watch as other groups run the procedure at other lab stations. It will be important for you to record observations at all three lab stations. Record your data in an Effect of Distance and Source Brightness on Light Intensity page.
**Procedure**

1. When it is your turn to set up a station using one of the three light sources, start by taping to the wall your group’s laminated poster board with the grid. Make sure you know which light source you are using so you will record your data in the proper place on your Effect of Distance and Source Brightness on Light Intensity page.

2. Position a desk so a light source on it is 100 cm from the wall. One student in the group will hold the poster board with the square hole vertically on the desk. Position it so the hole is right in front of the light source.

3. A second student will turn on the light source and hold it up to the board so the light shines through the hole and strikes the laminated poster board on the wall.

4. A third student will use a marker to outline the illuminated area on the laminated plastic. Estimate the area by counting the grid squares contained inside the outline. Label the area “Produced by source at 100 cm. Area = _____ cm².” Write the area you estimated on the blank line.

5. Notice the intensity of the light striking the laminated poster board. You will not be able to rank the intensity until you have seen other illuminated areas. Until then, look at the center of the illuminated area, where the light intensity is greatest, and notice how intense it is.

6. Repeat Steps 2–5, but this time, move the desk so the light source and the poster board with the hole are 50 cm from the wall. Record your data. Notice if the intensity of light in the illuminated area is greater or smaller than it was when the light was held 100 cm from the poster board.

7. Repeat Steps 2–5, but this time, move the desk so the light source and poster board are 25 cm from the wall. Record your data. Notice if the intensity of light in the illuminated area is greater or smaller than it was when the light was held 50 cm from the poster board.

8. Record the relative intensity of the illuminated areas. Which was most intense? Which was least intense? Which was in the middle?

**Materials**

- one light source: flashlight, table lamp with 25-W bulb, or table lamp with 60-W bulb
- 1 poster board with a 2 cm x 2 cm opening in the center
- 1 poster board, laminated and with 2 cm x 2 cm grid
- 1 washable marker
- masking tape
Watching the Procedure

When your group is watching another group carry out the procedure, you will not get to set up the station. However, you will need to record the data that group is collecting and judge the relative intensity of the illuminated areas.

1. Make sure you know which light source the group is using, and make sure you always know how far away from the laminated board they are positioning the light source.

2. Each time the group running the procedure creates an illuminated area, notice how large it is, and make sure they tell you how many square centimeters they measured. If you cannot hear the size, ask them to repeat it. Record the size of each illuminated area.

3. Notice the intensity of the light in each illuminated area. Observe how the intensity changes as the distance from the light to the laminated board changes. Notice, too, the differences in intensity between the illuminated areas created by the different light sources. Make notes so you will remember these differences.

4. You will need to rank the intensity of the illuminated areas produced by each of the light sources at each distance from the laminated board. So, if you need to, go back and observe a procedure a second time so you can be more exact about the intensity of light at different distances and using different light sources.
Analyze Your Data

1. Begin by doing your best to rank the intensity of the light in the illuminated areas you observed, and graph the results. Which light source and distance produced the most intense illumination? Which produced the least intense illumination? Which ones were very similar to each other? Assign a number between 1 and 10 to the intensity of the light in each illuminated area.

2. What relationship do you see between the size of the illuminated area and the distance of the light source from the wall?

3. What relationship do you see between the size of the illuminated area and the intensity of the illuminated area when the light source is the same?

4. What relationship do you see between the brightness of the light source and the size of the illuminated area?

5. What relationship do you see between the brightness of the light source and the intensity of the illuminated area when the light sources are the same distance from the illuminated area?

Communicate

Share Your Results

Although all of the groups did the same investigation, different groups may have analyzed the results differently.

When it is your group’s turn to present, show the class your data table. As you show your data table and graph, tell the class how you ranked the intensity of the illuminated areas, and point out the trends you see.

As you listen to the other groups, notice ways in which each group’s data are similar to yours and ways in which their data are different. Notice the relationships groups are proposing between distance and area, area and light intensity, or distance and light intensity. For each presentation, decide if you agree. As always, if you do not understand what is being presented, ask questions. If you think the data are not trustworthy, also ask questions about that. Remember to be respectful, even if you disagree with a group.
Reflect

Discuss the following questions as a group. Be prepared to share your answers with the class.

1. How do the graphs of different groups compare? What are the similarities and differences?

2. Based on the graphs, develop a statement about the relationship between the distance from the light source and the intensity of light at the poster board.

3. Based on the graphs, develop a statement about the relationship between the brightness of the light source and the intensity of light at the poster board.

4. Develop a statement about the relationship between the amount of illuminated area and the intensity of light at the poster board.

5. Develop a statement about the relationship between the amount of illuminated area and the distance from the poster board.

6. Now think back to the radiometer. As the flashlight was brought closer to the radiometer, the flags moved faster. Based on what you observed in this experiment and on your observations of the radiometer, what do you think is the relationship between light intensity and light energy?

7. What are two factors that determine the available amount of light energy?

8. Do you think light energy is a type of kinetic energy or a type of potential energy? Why?
Why Does Light Intensity Decrease With Distance From the Source?

You observed that light travels in a straight line. Even though the wave model of light can be used to explain how light travels, some characteristics of light are easier to understand using another model. One model scientists use to describe the behavior of light is a particle model. You can think about a beam of light as a stream of tiny particles, or packets of energy, called **photons**. Photons do not lose energy as they travel.

Like sound, light spreads out as it moves away from the source. The explosion of fireworks sends out material in all directions. In much the same way, as photons travel away from a light source, the photons disperse, or spread apart from one another. This dispersion of light is the reason that as you move a light source away from a wall, the illuminated area increases. At the same time, intensity decreases because as the photons spread apart, each square centimeter on the wall has fewer photons striking it every second.

If you think about light as packets of energy, then you can better understand how light intensity affects the speed of the flags in a radiometer. When a flashlight is close to the radiometer, the photons emitted by the flashlight are concentrated close together, so a large number of photons hit each flag every second. The more photons that hit each flag every second, the greater the kinetic energy that results when light energy of the photons is transformed into kinetic energy of the flags.

**Reflect**

Think about what you have learned about photons and intensity of light. Answer these questions and be prepared to discuss the answers with your class.

1. In *Learning Set 1*, you messed about with a device powered by photovoltaic cells. What do you think would happen if you were to shine a brighter light on the device? What if you used a dimmer light? Why?

2. Light does not pass through some materials. What do you think happens to the energy of photons when photons strike a surface and are absorbed? What indicators would tell you that the energy of the photons has been transformed?
3. How do you know that light travels faster than sound? (Hint: Give an example of something that produces sound and light at the same time.)

4. Why do you think light is sometimes called “visible light?” What other kinds of light have you heard about or read about?

**Explain**

It is time to update your Energy Types page or use a new Energy Types page to record what you know about light energy.

You are also ready now to try to explain how each factor you identified affects light energy. Use a different Create Your Explanation page to record each of your claims.

Start by making a claim about how a factor you identified affects light energy. Try to state your claim this way:

When [your factor] [increases/decreases], light energy [increases/decreases/stays the same].

Describe the evidence from the explorations that supports your claim. Record science knowledge from what you have read. Then develop a statement that uses your evidence and science knowledge and tell why the factor you chose affects light energy. This will be your explanation.

As you are working on your explanation, remember to use all your science knowledge, as well as evidence from your investigations, explorations, and readings, to support your explanation. Science knowledge is knowledge about how things work. This knowledge can come through readings, discussion, talking to an expert, or other experiences. You may include what you read in this Learning Set or knowledge you have gained in other classes. Do not worry if you cannot create a perfect explanation. Just work with what you know for now. You will have opportunities later to revise your claims and explanations.
Conference

Share Your Explanations

Share your explanations with the class. As a class, come to agreement on explanations about why each factor you have identified affects the amount of light energy.

Solar Energy

Solar energy is energy from the Sun. It travels from the Sun to Earth in the form of **electromagnetic radiation**. Electromagnetic radiation is energy that moves as waves through a **vacuum** and through matter. Vacuum is any space that contains no matter. The space between the Sun and Earth’s atmosphere is a vacuum. Because energy from the Sun is a form of electromagnetic radiation, it is able to travel through the vacuum to reach Earth’s atmosphere. Then it travels through the layer of gases that make up Earth’s atmosphere.

Solar radiation accounts for most of the renewable energy on Earth. Finding ways to harness it better would lead to less dependence on the nonrenewable sources of fossil fuels. Electrical energy and heat for homes would cost less, and there would be less pollution.

There are several ways in which solar energy can be made usable. Buildings can be designed so that in cold weather, solar energy can readily enter and heat the buildings. Windows and awnings can be placed in such a way that permits solar radiation to enter in the cold, winter weather and not enter during hot, summer weather. In some parts of the world, solar energy is used to heat water in tanks on the roofs of houses. Using solar energy to heat water reduces the amount of nonrenewable resources needed to heat water for showers, baths, and cleaning.

Light energy from the Sun can also be transformed into other types of energy. For example, light striking solar cells on the roof of a house can be transformed into electrical energy and then stored as chemical energy in batteries until it is required.

Solar energy can also be used in an indirect way. Wind, waves, and hydroelectricity result from energy that came from the Sun. All of these are sources of renewable energy.
Reflect

Answer the following questions in your group. Be prepared to share your answers with the class.

1. Why do you think a house that uses solar energy needs to store chemical energy in batteries?

2. What is the source of almost all energy on Earth? Justify your answer.

Update the Project Board

Think about the results of the demonstration and the investigation, as well as what you have read. Record what you learned about light energy in the What are we learning? column of the Project Board. Do not forget to add supporting evidence to the What is our evidence? column.

Again, it is important to recognize any questions you may have. Well-developed questions can guide your learning. Any questions you have about light energy should be recorded in the What do we need to investigate? column.

What’s the Point?

Light intensity depends mainly on two factors: the strength (brightness) of the light source and distance from the source. Close to the source, the intensity is greatest. As you move farther away from the light source, intensity decreases. This can be explained with a particle model of light in which photons emitted by the light source travel outward in all directions. As the photons move farther from the source, they spread apart, and fewer photons pass through each unit area. A brighter light source emits more photons. This is what makes it brighter.