9. Measuring Light Intensity

Bright Lights

Objectives

Students investigate how light intensity changes as they alter the distance between themselves and a light bulb. Students investigate light while:

- Observing interactions of light with matter (air) by transmission and scattering
- Learning that energy is associated with heat, light, electricity, mechanical motion, and the nature of a chemical

Procedural Overview

Students gain experience conducting the following procedures:

- Setting up the equipment and work area to measure the intensity of light
- Using a light sensor to measure the intensity of the light at increasing distances from the light source
- Using math skills to measure distances between a light bulb and sensor and to graph the relationship between light intensity and distance from the light

Time Requirement

■ Introductory discussion and lab activity, Part 1 – Designing a research method and making predictions	50 minutes
■ Lab activity, Part 2 – Measuring the light intensity and Part 3 – Measuring the light intensity at your best study location	30 minutes
■ Analysis	30 minutes

Materials and Equipment

For teacher demonstration:

- ☐ Data collection system
- ☐ Light sensor
- ☐ Sensor extension cable
- ☐ Lamp with incandescent light bulb, without a shade
- ☐ Sheet of white paper
- ☐ Meter stick
- ☐ Clear and frosted incandescent light bulbs (optional)

For each student or group:

- ☐ Data collection system
- ☐ Light sensor
- ☐ Sensor extension cable
- ☐ Meter stick
- ☐ Lamp with incandescent light bulb, without a shade
- ☐ Clear and frosted incandescent light bulbs (optional)

Concepts Students Should Already Know

Students should be familiar with the following concepts:

- "Lux" is the metric unit for light intensity or brightness of a light.
- Light bulbs of all types exist with a wide variety of intensities; students should be familiar with examples of low-intensity light sources such as holiday light bulbs (“mini-lights”), flashlight bulbs, small lamp bulbs, and higher-intensity light sources such as incandescent light bulbs of different wattages.

Related Labs in This Guide

Labs conceptually related to this one include:

- Measuring the Voltage of Elements in Series

Using Your Data Collection System

Students use the following technical procedures in this activity. The instructions for them are in the appendix that corresponds to your PASCO data collection system. Please make copies of these instructions available for your students.

- Starting a new experiment on the data collection system ◆(1.2)
- Connecting a sensor to the data collection system. ◆(2.1)
- Starting a manually sampled new data set. ◆(6.3.1)
- Recording a manually sampled data point. ◆(6.3.2)
- Stopping a manually sampled data set. ◆(6.3.3)
- Displaying data in a graph ◆(7.1.1)
- Adjusting the scale of a graph ◆(7.1.2)
- Displaying data in a digits display ◆(7.3.1)
- Saving your experiment ◆(11.1)

Background

Light from a light bulb is considered a "point source," meaning that it spreads out spherically from its point of origin. Geometrically, the formula for calculating surface area of a sphere is $4\pi r^2$, where r is the radius of the sphere. Because the light is spreading spherically, at twice the distance from the source the light has spread over 2^2, or 4 times, the area. At three times the distance from the source the light has spread out over 3^2, or 9 times, the area. In other words, the farther you are from the source of light, the larger the area a given amount of light spreads over. The result is a decrease in the intensity of the light, as this area increases by the square of the distance. The equation relating the distance from the light source to the light intensity is:

$$I = \frac{S}{4\pi r^2}$$

where I is the intensity of the light. This is called the Inverse Square Law. This inverse square law is observed in other physical phenomena also, including gravitation and sound.

In the case of light, the source is generally denoted by a "source strength" S. The variable S doesn't stand for one particular unit, because there are several different ways to describe a light source, including power in watts, power in the visible range of the electromagnetic spectrum, or even power related to the eye's sensitivity. Regardless of the definition of the source, if you determine the amount of light per unit area reaching 1 unit of distance, then it will be one fourth that amount at 2 units from the source.

Pre-Lab Discussion and Activity

Engage students in the following discussion or activity:

Turn on an incandescent light bulb (without a shade) at the front of the room. (A 60-watt bulb with the light sensor set to the 0 to 260 lux sensitivity works well for this investigation.) Caution the students not to stare directly at the light bulb. Explain that an incandescent light bulb produces visible light by heating a tungsten wire or filament until it glows. Also explain that electrical energy is being converted within the light bulb into both heat and light energy. Ask students to describe the steps or process electricity goes through to cause visible light to be produced.

To demonstrate the change in light intensity with distance from the light source, hold a sheet of white paper about 20 centimeters (cm) from the light bulb when it is turned on. Suggest to students that they determine a way to indicate brightness. Then move the sheet of white paper about 40 cm from the light bulb and ask if the paper appears brighter or dimmer at the greater distance. They should record the distance and their description of the brightness of the paper. Continue to move the sheet of white paper away from the light bulb in 20-cm intervals and again ask the students to describe if the paper is brighter or dimmer. Have students, within their groups, draw a line graph of brightness of the paper versus distance, based on their observations. After a few minutes, ask them to display their graphs to the class. Continue the discussion with the students until they grasp that light spreads out, and therefore is less bright, as it travels away from the light bulb.

The above exercise provides you an opportunity to review line graphs. If students displayed a straight line, ask them what this implies, and how it corresponds to the x-axis and y-axis definitions. Using the graph, help them relate an increase in brightness to a decrease in distance or a decrease in brightness to an increase in distance.

If they drew a curve, use their graph to see if it showed a larger decrease in brightness with each increase in distance from the light. That is to say, does light intensity decrease by the same

amount each time you move 10 cm away (a linear decrease)? Or, does it decrease by a greater amount each time you move 10 cm away (a nonlinear decrease)?

At this point, students should realize that they need a better method of measuring the brightness of the light bulb. Show the students a light sensor. Explain to them that the sensor offers a more exact way to measure the brightness of the light (also referred to as "intensity"). Introduce the light intensity unit called lux (symbol: "lx"). If available, show the students several incandescent light bulbs, some frosted and some not.

Direct students to the "Thinking about the Question" section of this lab. Allow them to work within their groups for a few minutes to determine how to find their ideal distance from a light bulb for studying at night. Ask them to present their designs to the class. Did they consider all of the variables, such as direction from the light bulb, reflective surfaces close to the light bulb, and so on?

This activity prepares the students for their investigations because they will design their own method for determining the amount of light they need for studying and measuring the light intensity at varying distances from an incandescent light bulb. Approve student designs before directing them to the "Investigating the Question" section of the lab.

Preparation and Tips

These are the materials and equipment to set up prior to the lab:

- The light sensor should be set to the 0 to 260 lux sensitivity for light bulbs of 60 watts or less. For higher wattages, it may be necessary to set the sensitivity to the 0 – 26,000 Lux setting on the sensor.

- Students design the procedure for this activity, so you may want to provide them with a variety of materials for measuring distance and angles from the light source.

Safety

Add this important safety precaution to your normal laboratory procedures:

- Do not touch or stare directly at the light bulb while it is lit—extreme burns and damage to the eyes might result! Any metal or plastic directly touching the light bulb might get very hot.

Driving Question

How does the brightness of an incandescent light bulb vary with distance?

Thinking about the Question

When you are studying at night, does it matter how close you sit to the light? What is the light intensity at the position you find best? When the light bulb is turned on, light spreads out as it travels away from the bulb. The farther you are from the source of light, the larger the area a given amount of light covers.

Keeping this in mind, work with your group to design a way to determine the ideal distance you should be from the light bulb while studying at night.

Student answers will vary. Students may say that they can measure the intensity of the light at different distances from the lamp. They may suggest comparing the brightness, or intensity of light, to the distance from the light bulb.

Sequencing Challenge

Note: This is an optional ancillary activity

The steps below are part of the Procedure for this lab activity. They are not in the right order. Determine the proper order and write numbers in the circles that put the steps in the correct sequence.

5	2	1	4	3
Analyze the way the light intensity changes with increasing distance from the light bulb. Find the light intensity at the study point.	Design a way to obtain light intensity using the light sensor at different distances from the light bulb.	Make sure that each lab group member is aware of safety rules for this lab.	Determine the best distance from the light bulb for studying.	Connect the light sensor to the data collection system. Record the light intensity at the different distances.

Investigating the Question

Note: When students see the symbol "**[1]**" with a superscripted number following a step, they should refer to the numbered Tech Tips listed in the Tech Tips appendix that corresponds to your PASCO data collection system. There they will find detailed technical instructions for performing that step. Please make copies of these instructions available for your students.

Part 1 – Designing a research method and making predictions

1. ☐ Design a method of measuring light at varying distances (between 20 to 80 cm) from a light source at intervals of 10 cm. Record your investigative procedure by writing a description of your plans or steps in the space below.

   The methods students design will vary. Students might choose to use any clamps, lab apparatus, and support stands available; they might decide to use a plumb bob, to mount a meter stick, attach a wire cage around the light bulb, and so on. Methods suggested by the students will depend on materials they will have available or are allowed to provide themselves, including tape, extra wire, etc.

2. ☐ Predict how the intensity of the light changes as you increase the distance from the light bulb.

   Student answers will vary. Many students will state that light intensity will decrease by the same amount each time they move 10 cm away, but the light intensity actually decreases a greater amount each time they move 10 cm away from the light.

Part 2 – Measuring the light intensity

3. ☐ Start a new experiment on the data collection system. (1.2)

4. ☐ Connect the light sensor to the data collection system. (2.1)

5. ☐ Display light intensity in a digits display. (7.3.1)

6. ☐ Put the data collection system into manual sampling mode with manually entered data. (5.2.1)

   Note: Enter "Light Intensity" with the units of "lx" and "Distance" with the units of "cm", with two digits past the decimal point displayed.

7. ☐ Start a new, manually sampled data set. (6.3.1)

8. ☐ Using the method of positioning the light sensor your group developed to obtain the light intensity at the different positions from the light bulb, record each data point as follows:

   a. Record the light intensity and enter the distance from the light bulb. (6.3.2)

   b. Record the light intensity for each distance in Table 1.

9. ☐ When you have recorded all of your data, stop the data set. (6.3.3)

10. ☐ Display Light Intensity on the y-axis of a graph with Distance on the x-axis. (7.1.1)

Note: Adjust the scale of the graph as needed. (7.1.2)

Table 1: Change in light intensity as distance changes

Distance from Light (cm)	Light Intensity (lx)
20	259.10
30	120.15
40	73.40
50	37.10
60	24.41
70	17.83
80	9.26

Part 3 – Measuring the light intensity at your best study location

11. ☐ Determine the distance from the light bulb at the position you find best for studying. Record that distance.

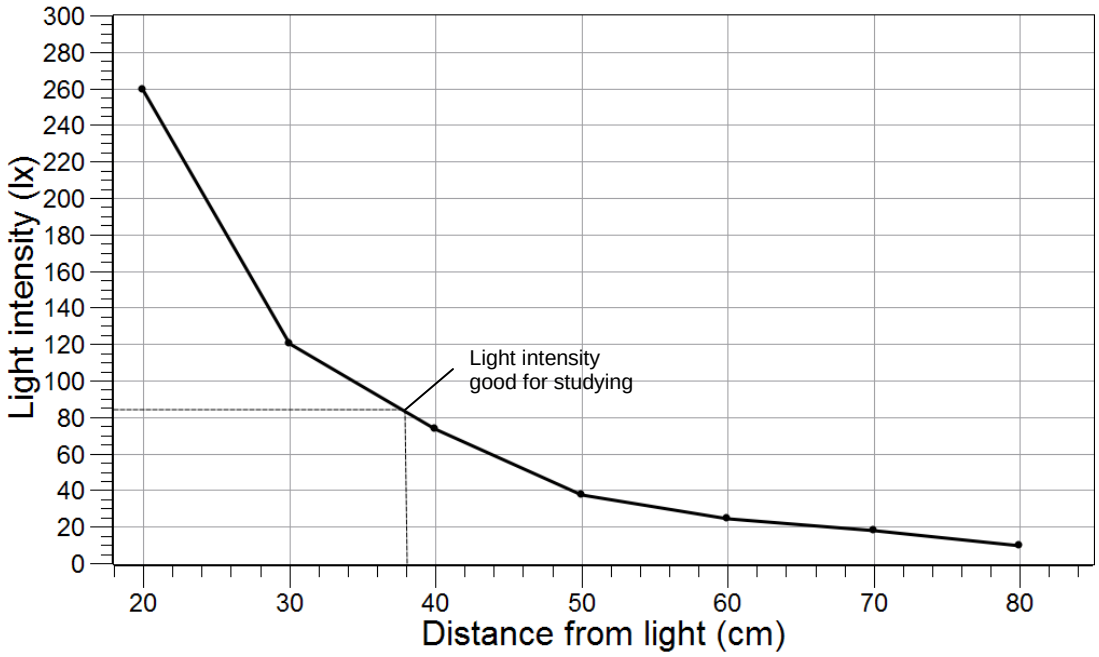
    Distance from the light bulb 38 cm

12. ☐ Save your experiment (11.1) and clean up according to your teacher's instructions.

Answering the Question

Analysis

1. Display data in a graph to show Light Intensity versus Distance. (7.1.1) Sketch the Light Intensity versus Distance on the graph below.



2. Explain the relationship between distance from the source and the light intensity with the diffuser.

Light intensity decreased with an increase in distance but not at the same rate.

3. Using the graph, determine the light intensity at the distance you determined in Part 3. Note this distance on the graph.

Answers will vary. For this example, the light intensity that corresponds to 38 cm is 83 lx.

Multiple Choice

Circle the best answer or completion to each of the questions or incomplete statements below.

1. In the SI System of measurement, what is the unit for light intensity?

   A. Watts
   B. Lux
   C. Decibels

2. When you are father away from a light source, the intensity of the light is:

   A. Less than when you are closer
   B. Greater than when you are closer
   C. Exactly the same regardless of your distance away

3. A possible set of data recorded by someone backing away from a light source could be:

   A. 5.8 lux, 33.8 lux, 1142.4 lux
   B. 37.5 lux, 7.2 lux, 2.6 lux
   C. 10 lux, 20 lux, 30 lux

4. Light intensity generally varies with:

   A. A person's eyesight
   B. The diameter of the light bulb
   C. The distance from the light source

True or False

Enter a "T" if the statement is true or an "F" if it is false.

T 1. A graph of light intensity versus distance from the light source will show a curve that decreases as distance increases.

F 2. The light intensity that is best for studying is the same for everyone.

T 3. If a light bulb is "incandescent," it glows as the result of being heated by a current flowing through it.

Further Investigations

Predict the changes in light intensity at different angles around the light bulb. Design and conduct an investigation to measure light intensity at different angles and at the same and increasing distances from the light bulb.

Have students use several light bulbs with different wattage to find the position that provides the amount of light needed for studying. Compare the intensity of the light at each position for each bulb. Was the light intensity about the same for each light bulb? Was the light intensity the only factor in determining that position?

Is there a difference in illumination between a frosted and non-frosted light bulb? Test your prediction.

Rubric

For scoring students' accomplishments and performance in the different sections of this laboratory activity, refer to the Activity Rubric in the Introduction.