

LIGHT, BRIGHTNESS AND DISTANCE

LAB HAND.32

From *Physics with Handhelds*, Vernier Software

INTRODUCTION

You probably have noticed that a light appears to be brighter when you are close to it, and dimmer when you are farther away. If you are reading this page illuminated by a single light bulb, the amount of the light that strikes this page will increase as the page is brought closer to the light source. Using a Light Sensor, you can determine how the brightness of light varies with distance from the source and compare that result to a mathematical model.

There are several ways to measure the brightness of light. Since this experiment can be performed with any of several different light sensors, each of which measure slightly different quantities, we will just use the word *intensity* to describe the relative brightness of the light, although the term may not be strictly appropriate for your sensor. Regardless of the way light is measured, the same relative changes with distance are observed, and that is what you will study today. In this experiment you will measure light intensity at a variety of distances from a small source of light, and see how the intensity varies with distance.

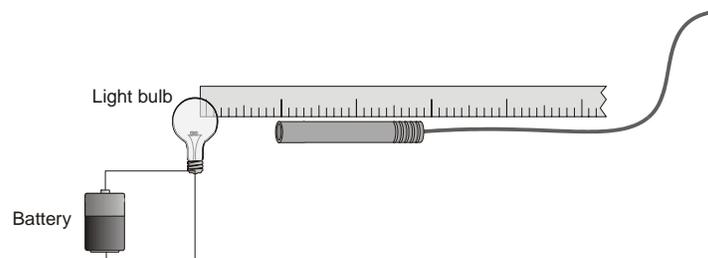


Figure 1

OBJECTIVE

- Determine the mathematical relationship between intensity and distance from a light source.

MATERIALS

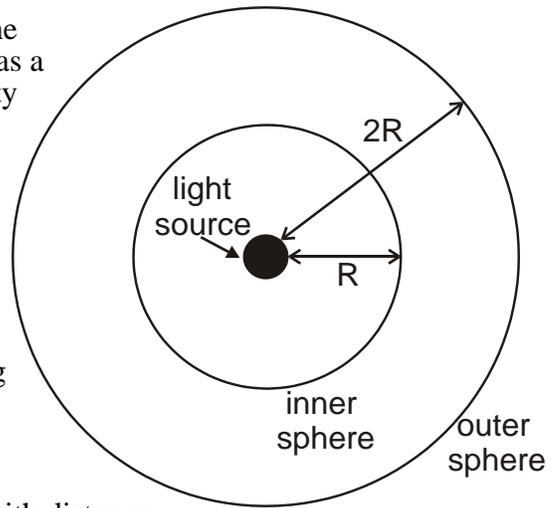
LabPro interface
Palm handheld
Data Pro program
Light Sensor

meter stick
clear glass light bulb (1.5 V penlight type)
battery (1.5 V)

PRELIMINARY QUESTIONS

1. Suppose a very small light source is placed at the center of two transparent spheres. One sphere has a radius, R , and the other a radius, $2R$. An intensity I passes through the surface of the inner sphere. If no light is absorbed, so that all of the light emitted by the source passes through the inner sphere and reaches the outer sphere, what is the intensity at the outer sphere? Solve this problem by considering the following:

- How does the intensity passing through the inner sphere compare to the intensity reaching the outer sphere?
- How do the surface areas of the two spheres compare?
- In general, then, how will the intensity vary with distance from the source?



2. Since most light bulbs that you use are not true point sources of light, how do you think the answer to Question 1 would change if a typical light bulb were used?

INITIAL SETUP

1. Plug the Light Sensor into Channel 1 of the LabPro interface. If your sensor has a range switch, set it to 6000 lux. Connect the handheld to the LabPro using the interface cable. Firmly press in the cable ends.
2. Press the power button on the handheld to turn it on. To start Data Pro, tap the Data Pro icon on the Applications screen. Choose New from the Data Pro menu or tap **New** to reset the program.
3. Set up the handheld and interface for a Light Sensor.
 - a. On the Main screen, tap **Setup**.
 - b. If the handheld displays LIGHT or LIGHT(lux) in CH 1, proceed directly to Step 4. If it does not, continue with this step to set up your sensor manually.
 - c. Tap **CH1:** to select Channel 1.
 - d. Press the Scroll buttons on the handheld to scroll through the list of sensors.
 - e. Choose the correct Light Sensor from the list of sensors.
4. Set up the handheld and the interface for the appropriate data collection mode.
 - a. On the Setup screen, tap **Mode:**, then choose Events with Entry. In this mode you will trigger the interface to record the light intensity for each position you choose.
 - b. Enter the Entry Label (Dist) and Unit (cm). You can enter this information using the onscreen keyboard (tap "abc"), or by using the Graffiti writing area.

- c. Tap twice to return to the Main screen.
5. Make sure that the filament axis of the light bulb is horizontal and pointing directly at the Light Sensor. This makes the light bulb look more like a point source of light as seen by the Light Sensor.
6. The filament and Light Sensor should be at the same vertical height (Figure 1). Place the end of the filament (not the glass) at the 0.0 cm mark of the meter stick.
7. Turn down the lights to darken the room. A very dark room is critical to obtaining good results. There should be no reflective surfaces behind, beside, or below the bulb.

PROCEDURE

1. Place the Light Sensor 2 cm from the light bulb filament. Move the sensor away from the bulb and watch the displayed illuminance values on the handheld screen. What is your prediction for the relationship between illuminance and the distance to a light source?
2. Again place the Light Sensor 2 cm from the light bulb filament. **Important:** The distance must be measured carefully. Be sure you measure from the filament of the lamp to the sensor tip on the Light Sensor.
3. Tap to prepare for data collection.
4. Wait for the value displayed on the handheld to stabilize, then tap . Enter the distance between the Light Sensor and the light source and tap to store the data.
5. Move the Light Sensor 1 cm farther away from the light source and repeat Step 4.
6. Continue moving the sensor in 1 cm increments until the Light Sensor is 10 cm from the light source, collecting data as before. After the last point, tap , then tap to view a graph of light intensity vs. distance.

DATA TABLE

Left-most point X value, X_L	
Left-most point Y value, Y_L	
Model parameter A	

ANALYSIS

1. Examine the graph of light intensity vs. distance. Does it appear to be consistent with the model you predicted in the Preliminary Questions? How can you tell?

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2. To examine the displayed graph, tap or any data point. As you move the examine line, the light intensity and distance values of each data point are displayed to the right of the graph. Move the examine line to the left most point of the graph. Record the coordinates of the point in your data table. You will use this value later in comparing your data to the model.
3. To compare your data to your model, you can plot the equation $y = A/X^2$ along with your data. By adjusting A you will change the overall scale of the model. Only if the model and data are consistent should it be possible to adjust the single parameter A so that the model comes very close to all the data points.
4. Before plotting the equation, you will need to calculate the value for A. Because the exact value of the parameter A is unknown, first you will use the coordinates of the left-most point you recorded in your data table (X_L, Y_L) to force the model equation to pass through this point. In this case, $A = Y_L * X_L^2$. You can perform this calculation using the calculator in your handheld. For example, if $Y_L = 4000$ and $X_L = 3$, navigate to the handheld
 - a. calculator and enter “4000 x 3 x 3 =” Write down this value and navigate back to the Data Pro program. When you restart Data Pro, you will be returned to the Graph screen.
 - b. On the Graph screen, tap Analyze and then tap Model.
 - c. Tap Choose Equation and choose the equation, A / X^B.
 - d. Leave the X = value as “Dist(cm)”.
 - e. For the A = value, enter the value you obtained from you calculation of $Y_L * X_L^2$ using the onscreen keyboard (tap “123”), or by using the Graffiti writing area.
 - f. For the B = value, enter “2”.
4. To plot your data and the inverse-square model on the graph at the same time
 - a. Tap OK to view a graph with the fitted model.
 - b. The graph you see shows the experimental data points and the equation with your first value for A. If the curve is systematically below the data points, you need to increase A. If the curve is systematically above the data points, you need to decrease A.
 - c. Tap Model to view the Model screen. Adjust the A = value as described above and tap OK to view a graph with the new fitted model.
 - d. Continue to navigate between the Analyze and Model screens, adjusting your A = value, until you have a good fit of the curve to the data points.
 - e. Record the numeric value of A in your data table.
5. How well does the inverse-square model $y = A/X^2$ fit your experimental data?
6. Does the model agree with your model of light intensity using the concentric spheres?
7. List some reasons why your experimental setup might not exactly match the relationship you predicted in the Preliminary Questions between intensity and distance.

EXTENSIONS

1. Confirm the relationship between intensity and distance by finding the linear plot of $I = k \cdot 1/d^2$. You can use your handheld, *Logger Pro*, or Graphical Analysis to verify the inverse square relationship between intensity and distance. Enter the data, and then create a new list or modified column of data containing the $1/\text{distance}^2$ data. Graph the measured irradiance vs. $1/\text{distance}^2$. A straight line that passes through the origin would verify the inverse square relationship.
2. Using the Light Sensor, measure the intensity of the sun over the period of a school day.
3. Use the Light Sensor to examine sunglasses. By what percentage is the sun's intensity at your location reduced when sunlight passes through the lens of sunglasses?
4. Use the sensor to compare other light sources to the light source that you used in the lab. For instance, how does intensity vary as you move away from a long fluorescent bulb or a circular fluorescent bulb?