

Lab 11:

Light Brightness and Distance: A VERNIER Lab

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UPDATED APRIL 24, 2014

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You have noticed that a light source appears to be brighter when you are close to it and dimmer when you are farther away. The amount of light that enters your eye increases as you move closer to the light source. There are several ways to measure the brightness of light. In this experiment, we will use the Vernier Light Sensor to measure the *illumination* detected by the sensor in *lux*. We will observe how illumination varies with distance, and compare our results to a mathematical model.

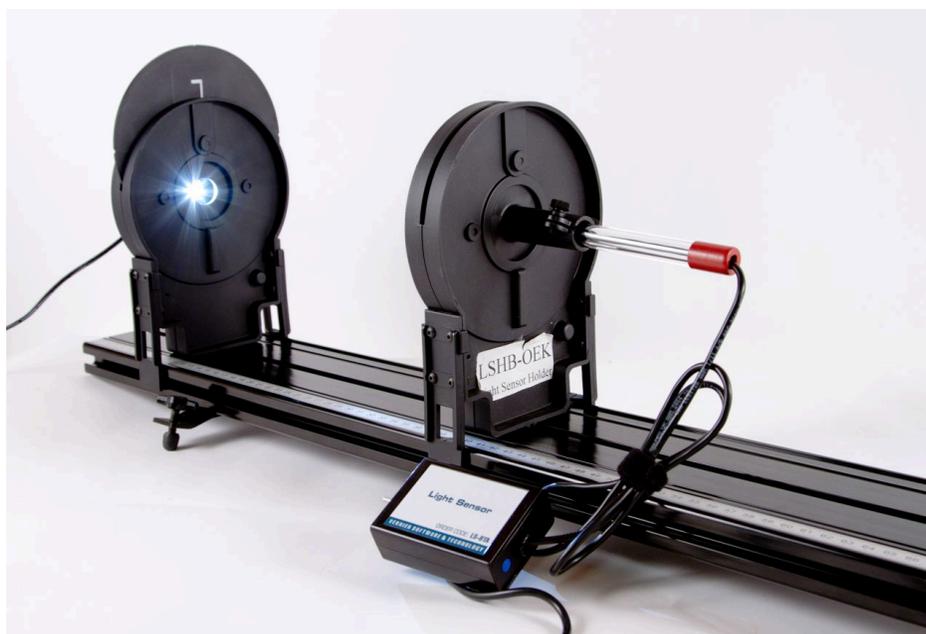


Figure 1

GENERAL OBJECTIVE

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

(ONE SUGGESTED VERSION OF A POSSIBLE) RESEARCH QUESTION

- How does the intensity of light at a certain point in space depend on the distance from the light source to that point? What specific mathematical function most reasonably expresses this dependence?

MATERIALS

Vernier data-collection interface
Logger *Pro* 3 or LabQuest App

Light Sensor

Vernier Dynamics System track
Optics Expansion Kit: light source assembly
and Light Sensor holder

Index card

Large piece of paper or cardboard

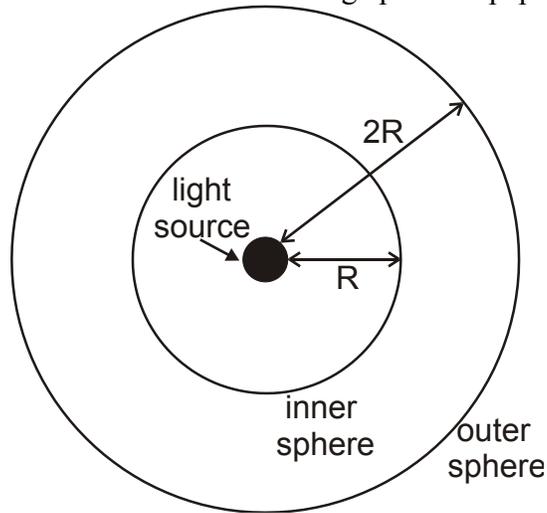


Figure 2

SOME BACKGROUND DEFINITIONS

The following are fundamental definitions of some quantities relevant to this investigation.

These definitions come from the study of classical mechanics.

Throughout the study of electricity, magnetism and optics, the definitions continue to be helpful for fundamental understanding.

For practical and specific application to light, other units (such as the *lux*) end up being more common – because they account for the human eye’s non-uniform sensitivity. That is, units such as the lux actually incorporate a variation (dependence) from color to color into the measurement of intensity (or, in this specific context, *luminosity*).

The following background should nonetheless help strengthen our understanding of the type of physical quantity we seek to investigate and measure.

$$\text{Intensity} \equiv \frac{\text{Power Transferred (or Delivered)}}{\text{Surface Area (to which the Power is Transferred)}}$$

$$\text{Power} \equiv \frac{\text{Energy Transferred (i.e.: Work Done)}}{\text{Time (during which the Energy is Transferred)}}$$

That is:

$$I \equiv \frac{\Delta E}{tA}$$

Regarding Units:

$$1 \text{ Watt/m}^2 \text{ of Intensity} \equiv \frac{1 \text{ Joule (of Energy delivered)}}{1 \text{ sec-meter}^2}$$

*** PRELIMINARY QUESTIONS

- *** Suppose a small light source is placed at the center of two transparent spheres. One sphere has a radius R , and the other a radius $2R$. Energy in the form of light leaves the source at a rate P . That same power P passes through the surface of the inner sphere and reaches the outer sphere. Intensity is the power per unit area. What is the intensity at each sphere? Solve this problem by considering the following:
 - *** How does the power passing through the inner sphere compare to the power 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?
- *** 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. Connect the Light Sensor to Channel 1 of the interface. If your sensor has a range switch, set it to the 0-6000 lux range.
2. Position the light source assembly so that the LED is exposed and is facing along the length of the track. Align the marker at the base of the light source assembly with the 10 cm mark on the track.
3. Turn on the light source. The brightness of the LED light source varies when it is first turned on. Make a note of the current time so that you can ensure 15 minutes have passed before you begin making the measurements in Step 4 of the Procedure.
4. Attach a light sensor to the light sensor holder. Insert the Vernier Light Sensor until it reaches the stop. The location of the sensor can be read using the notched arrow on the base of the holder. Position the light sensor at the 20 cm mark.
5. Set up data collection:

Using Logger Pro

- a. Open the file “29 Light Brightness Dist” in the Physics with Vernier folder. You may get a warning that the sensor range setting is not correct for the experiment. Choose Use Sensor Setting in the Change Sensor Setting alert window.
- b. The meter window will display light intensity.

Using LabQuest as a standalone device

- a. Choose Data Collection from the Sensors menu.
 - b. Choose Events with Entry from the Mode menu.
 - c. Set the Number of Columns to 1, then set the Name to “distance” and Units to “cm.”
 - d. Select OK.
6. Turn down the lights to darken the room. A dark room is critical to obtaining good results. There must be no reflective surfaces behind or beside the Light Source.

PROCEDURE

1. In this experiment, you will vary the distance between the light source and the Light Sensor and measure the light intensity.
2. *** What is your prediction for the relationship between intensity and the distance from a light source? Sketch a graph of how you think intensity will vary with distance.
3. To explore the relationship between intensity and distance, stand the screen vertically at the end of the track opposite the Light Source. Hold up an index card between the screen and Light Source so that a shadow is produced on the screen.
4. *** Where does the card produce the largest shadow?
*** Where does it produce the smallest shadow?

5. *** If you were to think of the card as “catching” light, where does the card catch the greatest quantity of light? The least?
6. *** Where would a measurement of the light intensity striking the card be greatest? Do your observations change how you would sketch the graph of intensity vs. distance?
7. After the Light Source has been on continuously for at least fifteen minutes, begin data collection. Place the Light Sensor 10 cm from the light source and select Collect.
8. Select Keep to take the first data point, then enter the distance between the Light Sensor and the light source. Select OK to record the value. A point will be plotted on the graph.
9. Move the Light Sensor 1 cm farther away from the light source and repeat Step 3.
10. Repeat Step 5, moving the sensor in 1 cm increments until the Light Sensor is 20 cm from the light source.
11. Repeat Step 5, this time moving the sensor in 10 cm increments until the Light Sensor is 110 cm from the light source.
12. Stop data collection when you have finished.

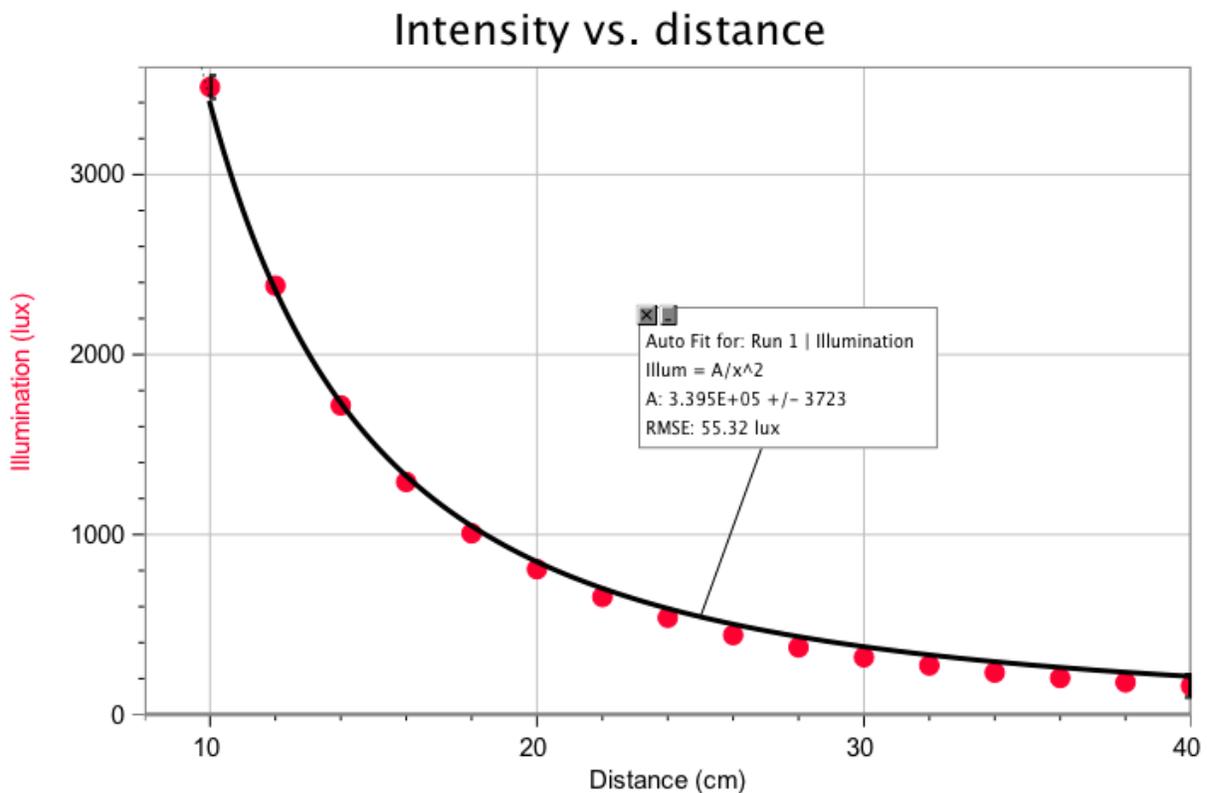
13. *** In your data table, record the intensity and distance data pairs displayed in the table.

Using LabQuest as a standalone device

To model an inverse square on LabQuest, we will first find the inverse square of the distance, then compare it to the illumination.

- a. In the Table tab, choose New Calculated Column from the Table menu.
 - b. Enter the Name “1/d2” and select “A/X^B” for the Equation Type.
 - c. Enter 1 for the value of A and 2 for the value of B.
 - d. In the graph tab, tap on the X axis label and change it to “1/d2”
 - e. Select Curve Fit from the Analyze menu. Choose Illumination.
 - f. Select Proportional from the Fit Equation list.
 - e. Select OK.
3. *** How well does the model fit your experimental data? Do your data approximately follow an inverse square function? Does the equation agree with your model of light intensity using the concentric spheres?

Sample Data



Intensity vs. inverse square of distance

