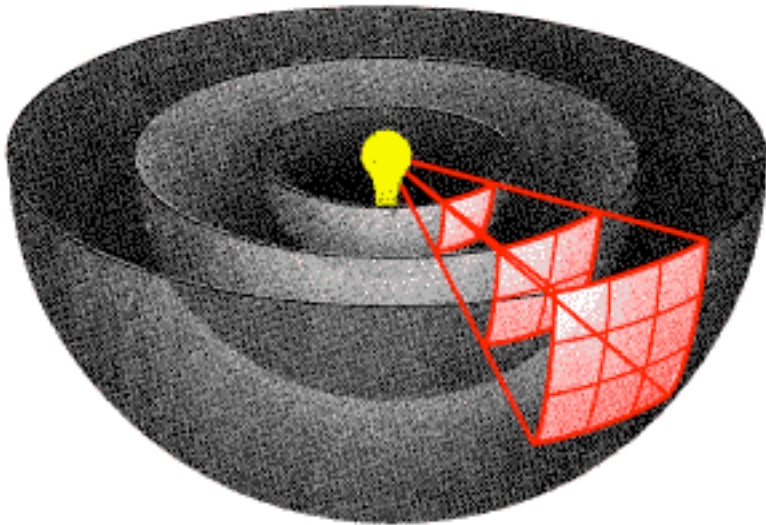


Physics 2310 Lab 7: The Inverse Square Law for Light

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Purpose: The purpose of this lab is to introduce students to the inverse square law. This is the quantitative relationship between the irradiance (surface brightness) of light and the distance from a point source.

Theoretical Basis: We all know that the closer you are to a light source the brighter it appears to your eye. This results from the fact that for a source emitting light in all directions, the fixed size of your eye's iris collects a larger portion of the total light emitted the closer you are to the source. We will use a more quantitative, solid-state device to collect the light from a point source over a range of distances and verify (or not) the inverse square dependence on the irradiance. We will use the SI units of LUX to measure the illuminance. Note that this is not equivalent to irradiance. The difference is that irradiance is measured in watt/meter² without regard to the wavelength of light whereas illuminance is weighted by the response of the human eye. At the peak of the eye's response (555 nm) there are 683 LUX for each watt/meter².



(1) Procedure. Begin by reviewing the equipment on the laboratory optical bench. Draw a quick sketch of the apparatus and label each component. This will be helpful for the description of the apparatus you will put in your lab report. The components include:

Optical Bench: The optical bench includes a track for mounting modular optical components and a scale for reading their positions. Various optical components can be mounted in modular supports that can in turn be positioned and clamped in place on the optical bench. These include lens and mirror holders, filters, light sources, and the light sensor. **Note, never attempt to move a component without unclamping it first and always adjust its position by grasping the bottom of the assembly.**

Light source: The light source consists of a light bulb within a housing containing various apertures. These include a target, a small, pinhole aperture, several slits and colored filters. We will use the pinhole aperture.

LabPro Interface: The spring mounted lens holder can hold small lens of various size. In this lab it is used to imaging the target and/or pinhole onto the detector of the camera. Since the purpose of this lab is to develop experience with the CCD camera we will not be concerned with the properties of the lens. These will be investigated in subsequent labs.

Light Sensor: This device includes a solid-state detector with amplification and produces an analog output that is digitized and calibrated within the LabPro Interface.

Computer: The computer includes the Logger Pro software to control the LabPro Interface used to sample the output from the Light Sensor. We will use Logger Pro to record the data (irradiance and distance) but then export the data table to Microsoft Excel for graphical analysis.

(2) Initial Setup. The components should be mounted at nominal positions on the optical bench. However, note that some calculations will be necessary to convert the positions of the light source and the light sensor into distances. This includes measuring the position of the front face of the sensor relative to the scale on the bench and measuring the position of the light source within the source housing. Record these numbers and note how the correction will need to be applied as you move the sensor mount on the optical bench. **Be sure to orient your computer screen so that it doesn't shine onto the light sensor. Otherwise your measurements could be strongly affected. Move your chair and keyboard if necessary.**

2a) Connect the Light Sensor to Channel 1 of the LabPro Interface.

2b) Make sure that the Light Sensor is horizontal and pointing at the light source pinhole opening.

2c) Verify that the Light Source and Light Sensor are at the same vertical height.

2d) Locate the Logger Pro software on the computer's desktop and open it. Find the experiment file for the Light Sensor (*File/Open: Physics with Vernier/29 Light Brightness with Dist.*). A graph will appear near the center of the screen with a table should appear to the left. If the light sensor is not detected have the software look for it by clicking on *Connect*.

2e) Once everyone is ready, plug in the light source and darken the room lights.

Note: be careful moving around in the darkened lab.

2f) Verify that the irradiance in LUX is displayed on the computer and that a data point has appeared on the graph. Now carefully cover the light source with your hand so that no light reaches the sensor and select the option to calibrate the sensor (*Experiment/Zero*). This ensures that the sensor is calibrated at an intensity of 0 LUX.

(3) Taking data.

3a) Start with the Light Sensor about 10 cm from the Light Source. Set the gain value using both the switch on the Light Sensor cable and the computer (*Experiment/Setup Sensors/Show all interfaces and then click light*). Note that the current gain value is shown on the button. If you need to change it just click and click on *change sensor range*.

3b) Select *Experiment/Data Collection* and make sure that the *Use 10s Average* button is deselected.

3b) Click *Collect* (green button) to begin data collection. Click on *Keep* to recorded the irradiance in the data table. A dialog box should open for entering the distance between the Light Source and Light Sensor. *Be sure to make any corrections there for positions. Don't just record the values from the scale on the optical bench. For each distance take 5 measurements.* Right click on the graph and select *Autoscale* to your data plotted.

3d) Next, move the Light Sensor about 5 cm further away from the light source and repeat the above steps. Be sure that you enter the corrected distance in the table.

3e) Continue making LUX measurements at intervals of 5 cm until you reach the end of the optical bench.

3g) Examine the graph and verify that you have a nice, smooth set of data. If not, go back and retake the data for any discrepant point(s). You will have to edit the data in Excel later to remove the discrepant point. When you have finished click *Stop*.

3h) Now use the *Export* option to export your data table to MS Excel.

(4) Data Analysis.

4a) Open your Excel data and verify that it is correctly exported.

4b) Edit your Excel table so that each of your 5 measurements at a single distance is in a separate column. That is, we want all 5 measurements for one distance in a single row. This means lots of cutting and pasting but what can you do?

4c) Now add two columns for the average and standard deviation of your irradiance measurement. Label them and set up Excel to compute the average and standard deviation for each distance in the appropriate column. *HINT: Highlight the cell and use the function key or ask for help.* When finished be sure to save your spreadsheet.

4d) Now make a graph (chart) using the scatter-plot option to make a graph of your average LUX measure vs. distance. You should see a nice curve. If you're not sure how to do this ask for some help.

4e) Now we want to be more quantitative. Our theoretical expectation is that the irradiance should fall off as $1/R^2$ but we want to test this. If we adopt a form for our mathematical model like:

$$I = P/R^2 \quad \text{or equivalently, } I = PR^{-2}$$

We can easily test this by taking the log of both sides of the equation.

4f) Assuming that P is the output optical power of the lamp, an unknown but a constant, write down the new logarithmic form for this equation, i.e., our model:

What is the mathematical form for the new equation?

4g) Add two more columns for the log of the average LUX and the log of the distance. Have Excel compute these values.

4h) Now make a new graph in which you plot the logs of your measured quantities. Select a data point to highlight the data series. Then under *Chart Tools* select the *Layout* tab and select *Trendline/More Trendline* options. Within the dialog box within *Trend/Regression Type* box select Linear and then check box for *Display Equation on Chart*. What do you see and is it consistent with what you expect from the equation you wrote in (4f)?

4g) Now use the line fitting capabilities of Excel to determine the best fit line to your logarithmic data. Comment on how well your data fits the theoretical expectation (model).

Before you leave the lab make sure that you have your lab partner's email so that the data can be shared within your lab group.

Summary: In this lab we've learned to operate the Logger Pro software to record data and to export it to Excel for analysis. You then analyzed your data to see how well it fit the inverse square law, our theoretical model. These skills should prove useful in later labs for quantitative measurements of optical phenomena.