Rowan Introduction to Astronomy

Lab 8 / The Inverse-Square Law for Light

Name: ______________________________________ **Score:** ____________________

◢Objectives

- Measure the brightness of a light bulb with a photoelectric detector.
- Measure the intensity change as the light bulb and detector are moved farther apart.
- Tabulate the intensity change data for two different wattage light bulbs.
- Graph the data tabulated.
- Predict the brightness of the light bulb at unmeasured locations.

Note: This lab has been modified so that the intensity data for both 60-watt and 100-watt bulbs have already been provided.

◢Materials

- ▶ Scientific Calculator (borrow one if necessary)
- ▶ Graph Paper (online see **www.mathematicshelpcentral.com/graph_paper.htm**)
- ▶ Optical bench
- ▶ Spherically radiating light source: two light bulbs of different wattages
- ▶ Photoelectric detector with meter (meter is done digitally through the computer workstation)

◢Student Requirements

- Students may work in pairs or groups during data collection.
- Graphing and answering questions are to be done individually, using the student's own words.

◢Background and Theory

Almost everyone is aware that as a light source gets closer it appears to become brighter. Conversely, as it moves farther away, the source appears less bright. It may be tempting to believe that when a light source appears to double in brightness, its distance has decreased by one half. In Figure 1, one can see that light radiating from a spherically radiating source spreads out over an area four times larger when the distance from the source is doubled. Thus, the brightness decreases to one fourth of the original intensity. Mathematically, this relation can be expressed as ratios

$$\frac{I_2}{I_1} = \left(\frac{d_1}{d_2}\right)^2 \qquad (1)$$

where $\boldsymbol{I_1}$ and $\boldsymbol{I_2}$ are the intensities at distances $\boldsymbol{d_1}$ and $\boldsymbol{d_2}$, respectively. If $\boldsymbol{d_1}$ is one distance unit and the initial value of $\boldsymbol{I_1}$ at $\boldsymbol{d_1}$ equals one intensity unit, then equation 1 becomes

$$\frac{I_2}{I} = \left(\frac{1}{d_2}\right)^2 \qquad (2)$$

More generally, equation 2 can be written as

$$I \propto \left(\frac{1}{d_2}\right) \qquad (3)$$

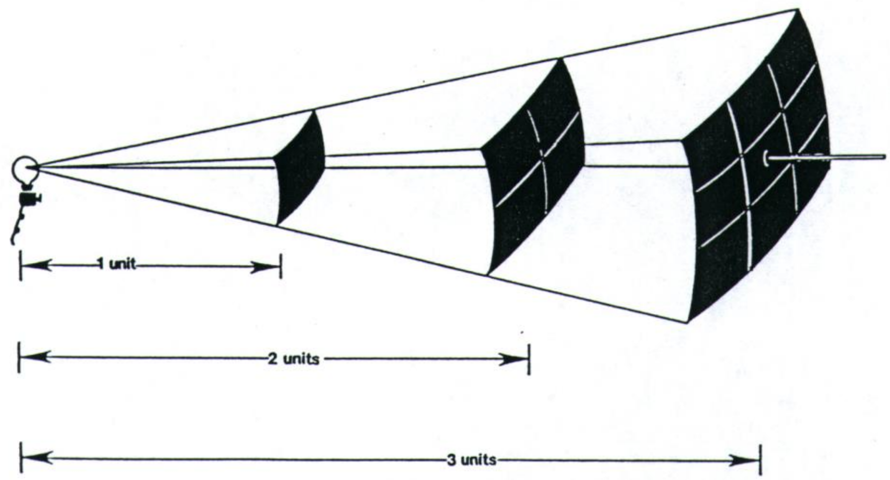

Figure 1. Pictorial form of the inverse-square law for light.

◢Procedure

It is important to keep stray light to a minimum. Reflections and shadows can and do affect your experimental results.

1. Set up an optical bench with a 100-watt bulb and a photoelectric detector with meter (a digital meter is available via the computer workstation), as shown in Figure 2.

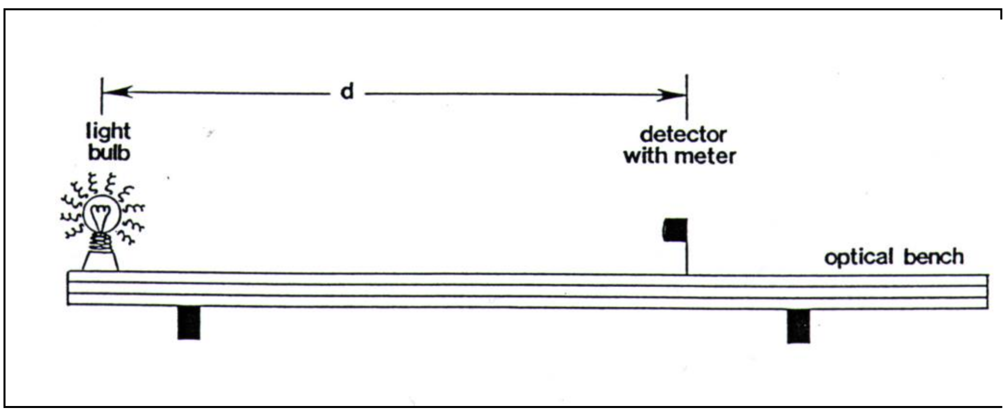

Figure 2. Laboratory setup for measuring intensities in inverse-square law experiment.

2. Depending on the apparatus supplied, either the light source is fixed and the detector is moved or the detector is fixed and the light source is moved.

3. Place the detector at a distance of 30 cm from the light bulb.

4. Place a large black card in front of the light bulb .

5. With the card blocking the light from the light bulb, use the meter to measure the stray background light level reaching the detector. Do ***not*** turn the light bulb off to do this because the bulb itself contributes to the background. Record the background level s for the range 30 cm to 110 cm (changing position every 10 cm) in Table 1.

6. Measure the light bulb's brightness by removing the black card and recording the result in Table 1 under "source + background."

7. Calculate the bulb's brightness by subtracting the background from the "source + background" columns. Record the result in the source column of Table 1.

8. Repeat this procedure for distances of 40, 50, 60, 70, 80, 90, 100, and 110 centimeters.

9. Replace the 100-watt bulb with a 60-watt light bulb. Repeat the above procedure with the 60-watt bulb and record the data in Table 2.

Remember, you are not actually performing the experiment but are using the data from such an experiment.

◢Graphing [Each correctly plotted curve is worth 28 pts for a total of 56 pts.]

1. Plot the data for both bulbs on the graph paper attached (Fig. 3). Use dots (●) for the 100-watt bulb and x's (✕) for the 60-watt bulb. Plot intensity (*I*) on the ***y*-axis** and distance (*d*) on the ***x*-axis**. Spread out your scale for each axis so as to use as many blocks as possible. (Don't squish the data!) The scale for each axis has to be uniform: **the incremental value between each tic mark must remain constant.** Be sure to indicate the range of values for each axis, correctly label each axis, and label each curve (i.e., 60-w and 100-w). [Note: Each of these things counts in determining total points.]

2. Draw a smooth curve through the data points for each bulb. Typically, if you were to do the experiment, your curves would, go through some data points and above or below other data points. In this instance, your curves will nicely go through all the data points listed in the table. [Hint: To get a sense of what your graph should look like, go to the following web page: http://csep10.phys.utk.edu/astr162/lect/light/intensity.html.]

◢Data

Table 1. Data for 100-Watt Light Bulb

Position (cm)	Distance *d* (cm)	Source Intensity
0	20	15.75
0	30	7.00
0	40	3.94
0	50	2.52
0	60	1.75
0	70	1.29
0	80	0.98
0	90	0.78
0	100	0.63
0	110	0.52

Position (cm)	Distance *d* (cm)	Source Intensity
0	20	6.98
0	30	3.10
0	40	1.74
0	50	1.12
0	60	0.78
0	70	0.57
0	80	0.44
0	90	0.34
0	100	0.28
0	110	0.23

Table 2. Data for 60-Watt Light Bulb

◢Questions [This part is worth a total of 44 pts.]

1. Use the smooth curve you drew for the 100-watt bulb (or consult the table) and determine the intensity at each of the distances, ***d*,** listed below. [Question 1 is worth 12 pts.]

d_1 = 30 cm I_1 = _______________ Is $I_2 = \frac{1}{4} I_1$? _______________ [when rounded to 2 decimals]

d_2 = 60 cm I_2 = _______________ Is $I_3 = 1/9\ I_1$? _______________ [when rounded to 2 decimals]

d_3 = 90 cm I_3 = _______________

Do the data for the 100-watt bulb confirm the Inverse-Square Law? ____

2. Repeat question 1 for the 60-watt bulb. [Question 2 is worth 12 pts.]

d_1 = 30 cm I_1 = _______________ Is $I_2 = \frac{1}{4} I_1$? _______________ [when rounded to 2 decimals]

d_2 = 60 cm I_2 = _______________ Is $I_3 = 1/9\ I_1$? _______________ [when rounded to 2 decimals]

d_3 = 90 cm I_3 = _______________

Do the data for the 60-watt bulb confirm the Inverse-Square Law? ____

3. Use the intensity at 30 cm for the 100-watt bulb and equation (1) to predict the intensity at 15 cm and 120 cm. (Hint: I_1 = intensity at 30 cm and d_1 = 30 cm.). *To receive full credit be sure to show all mathematical steps.*
[Question 3 is worth 10 pts for each part for a total of 20 pts.]

I_{15} = _______________

$$\frac{I_2}{I_1} = \left(\frac{d_1}{d_2}\right)^2$$

I_{120} = _______________

Read this equation carefully!

<u>Note</u>: Spread out your scale on each axis. Plot <u>both</u> curves here (one will plot next to the other.)