

# Inverse Square Law

ASTRO 1050

February 22, 2014

## Abstract

The purpose of this lab is to investigate how light intensity varies with distance.

## Materials

Incandescent light bulb and dimmer, photocell (and mount), ammeter, meter sticks, black paper, and calculator.

## Introduction

From everyday experience, it is obvious that light sources appear to become brighter as you move closer to them. The apparent brightness of the source is related to its distance. However, moving a light source twice as close to you does not make it twice as bright. In this lab, we will examine this relationship in detail.

Astronomically this correlation between distance and intensity is of great importance, for it allows the determination of distances to distant stars and galaxies. We will determine the relationship experimentally, and then use it to answer some astronomical questions.

For this experiment, we use a light detector (photocell) which enables us to make light intensity measurements that are more precise than those made with the human eye. The photocell converts light intensity to an electrical current, which can be measured with a current meter (ammeter). The current produced by the photocell is directly proportional to the amount of light falling on it. If the light intensity doubles, the meter reading will also double.

## Procedure

It is extremely important to keep stray light out of the detector during this exercise. Moving shadows and reflected light seen by the detector can spoil your results. Avoid unnecessary motion during measurements. In particular, try to keep behind the detector while taking data.

1. Place the light source at a distance,  $d$ , of 40 cm from the detector.  $d$  is measured from the center of the bulb to the surface of the detector. For the “high intensity” source we will set the bulb dimmer at 20 watts.
2. Place a sheet of black paper directly in front of the light source, blocking the light going to the detector from the source.

3. Read the current meter and record your reading in Table 1 in the column marked *Background*. This reading gives the background intensity resulting from stray light in the room.
4. Remove the black paper and record the meter reading in the column marked *Source & Background*.
5. Subtract *Background* from *Source & Background* and enter this value in the column marked *Source*.
6. Repeat steps 2 through 5 for all the other distances indicated in Table 1.

Table 1: High Intensity Source

Distance	Source & Background	Background	Source
40 cm			
60 cm			
80 cm			
100 cm			
120 cm			
140 cm			

Table 2: Error Analysis

Distance	Your Value (Source)	Other Group's	$M_{avg}$	$(M - M_{avg})$	%difference
40 cm					
60 cm					
80 cm					
100 cm					
120 cm					
140 cm					

7. Compare your answers with those of another group and estimate your precision, using Table 2. In the last column calculate % difference =  $[(M - M_{avg}) / (M_{avg})] \times 100\%$  , where M is your measurement and  $M_{avg}$  is the average between your measurement and the other group's. In order to find the approximate precision for the entire experiment, calculate the absolute value of your six % differences and average them.

Approximate Precision \_\_\_\_\_ %

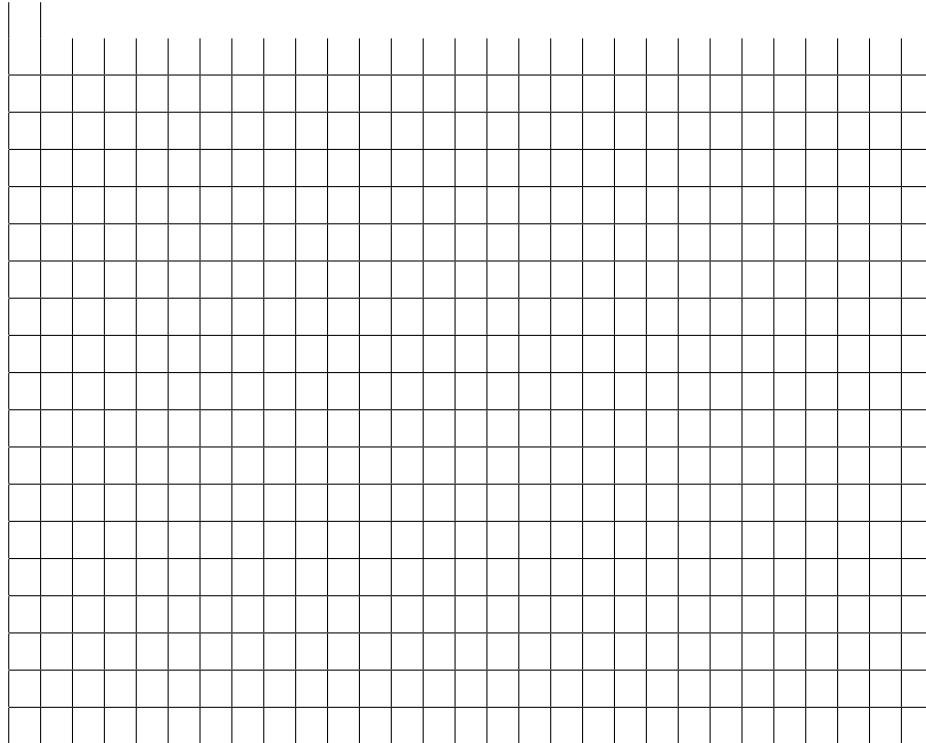
8. Now replace the light bulb with one of a lower wattage (intensity). Follow the same steps as above for the new intensity and record your data in Table 3.

Table 3: Low Intensity Source

Distance	Source & Background	Background	Source
40 cm			
60 cm			
80 cm			
100 cm			
120 cm			
140 cm			

9. Plot your data with distance along the horizontal axis and the light intensity along the vertical axis. Draw two **smooth** curves that best fits your data points, one for each intensity of the light bulb. Do not just connect the dots. Label these curves, one *high intensity*, the other *low intensity*.

Table 4: Plot of Distance vs. Low and High Intensities



The formal equation for the Inverse Square Law is as follows,

$$\text{Intensity} \propto \frac{1}{\text{distance}^2} \quad \text{or} \quad I \propto \frac{1}{d^2}$$

Note: Always keep in mind that the farther away a light is, the dimmer it becomes and visa versa. The “ $\propto$ ” sign simply means that light intensity is *proportional* to one over the distance squared. So as a light source becomes farther away, the light itself appears dimmer by a square root factor.

## Questions

- From your two measurements of intensity made at  $d = 40$  cm, find the ratio of intensities between the high and low wattage bulbs, dividing the lower intensity by the higher intensity. Repeat this calculation for the other distances and record the results in the space below. Are all of these results nearly the same?

$$40 \text{ cm} = \frac{L_{40}}{H_{40}} = \underline{\hspace{2cm}}$$

$$60 \text{ cm} = \underline{\hspace{2cm}}$$

$$80 \text{ cm} = \underline{\hspace{2cm}}$$

$$100 \text{ cm} = \underline{\hspace{2cm}}$$

$$120 \text{ cm} = \underline{\hspace{2cm}}$$

$$140 \text{ cm} = \underline{\hspace{2cm}}$$

- On the **high intensity** curve at  $d = 60$  cm, find the point that is 1/4 the intensity of the reading. From your graph read off the distance,  $d$ , corresponding to that point. What is the ratio of the distance at 1/4 intensity to the distance of the measurement at 60 cm? What is the ratio for the low intensity curve? Are these two ratios nearly the same?

(a) High intensity measurement at 60 cm = \_\_\_\_\_

(b) 1/4 of the intensity measurement at 60 cm = \_\_\_\_\_

(c) Distance corresponding to the intensity value found in (b) = \_\_\_\_\_ cm

(d) Ratio of distances  $\frac{(c)}{60\text{cm}} = \underline{\hspace{2cm}}$

Repeat for **low intensity**.

(e) Low intensity measurement at 60 cm = \_\_\_\_\_

(f) 1/4 of the intensity measurement at 60 cm = \_\_\_\_\_

(g) Distance corresponding to the intensity value found in (f) = \_\_\_\_\_ cm

- (h) Ratio of distances  $\frac{(g)}{60cm} = \underline{\hspace{2cm}}$
- (i) Are these two ratios nearly the same?
- (j) If the intensity of a source is       as bright, then it is       as far away.

3. On the **high intensity curve** at  $d = 40$  cm, find the point that is  $1/4$  the intensity of the reading. From your graph read off the distance,  $d$ , corresponding to that point. What is the ratio of the difference at  $1/4$  intensity to the distance of the measurement at 40 cm? what is this ratio for the low intensity curve? Are these two ratios nearly the same? Are they approximately the same as the ratios calculated in Problem 2?

- (a) High intensity measurement at 40 cm = \_\_\_\_\_
- (b)  $1/4$  of the intensity measurement at 40 cm = \_\_\_\_\_
- (c) Distance corresponding to the intensity value found in (b) = \_\_\_\_\_ cm
- (d) Ratio of distances  $\frac{(c)}{40\text{cm}} =$  \_\_\_\_\_

Repeat for **low intensity**.

- (e) Low intensity measurement at 40 cm = \_\_\_\_\_
- (f)  $1/4$  of the intensity measurement at 60 cm = \_\_\_\_\_
- (g) Distance corresponding to the intensity value found in (f) = \_\_\_\_\_ cm
- (h) Ratio of distances  $\frac{(g)}{40\text{cm}} =$  \_\_\_\_\_
- (i) Are these two ratios nearly the same?
- (j) If the intensity of a source is \_\_\_\_\_ as bright, then it is \_\_\_\_\_ as far away.

4. On the **high intensity** curve at  $d = 40$  cm, find the point that is  $1/9$  the intensity of the reading. From your graph read off the distance corresponding to that point. What is the ratio of the distance at  $1/9$  intensity to the distance of the measurement at 40 cm? What is this ratio for the low intensity curve? Are these two ratios nearly the same?

- (a) High intensity measurement at 40 cm = \_\_\_\_\_
- (b)  $1/9$  of the intensity measurement at 40 cm = \_\_\_\_\_
- (c) Distance corresponding to the intensity value found in (b) = \_\_\_\_\_ cm
- (d) Ratio of distances  $\frac{(c)}{40\text{cm}} =$  \_\_\_\_\_

Repeat for **low intensity**.

- (e) Low intensity measurement at 40 cm = \_\_\_\_\_
- (f)  $1/9$  of the intensity measurement at 60 cm = \_\_\_\_\_
- (g) Distance corresponding to the intensity value found in (f) = \_\_\_\_\_ cm
- (h) Ratio of distances  $\frac{(g)}{40\text{cm}} =$  \_\_\_\_\_
- (i) Are these two ratios nearly the same?
- (j) If the intensity of a source is \_\_\_\_\_ as bright, then it is \_\_\_\_\_ as far away.

5. Determine the distance  $D$  at which the detector must be placed in order for the intensity to be  $1/4$  as much as the intensity at a distance  $d$  of 100 cm.
6. Determine the distance  $D$  at which a star must be in order for the intensity to be  $1/9$  as much as the intensity at a distance  $d$  of 100 light years.
7. Star A is 100 light years away. Star B is 9 times more luminous than Star A. How far away would Star B need to be to appear the same brightness as Star A?
8. Star C can barely be seen when it is 100 light years away. Star D is 4 times more luminous. How far away must it be to be barely seen? What about Star E, which is 100 times more luminous than Star C?

