Name_____ **Section**_____

Partner(s)_____ **Date**_____

EXPLORING THE RELATIONSHIP BETWEEN LIGHT INTENSITY AND DISTANCE

We commonly refer to light intensity as *brightness.* More precisely, intensity is defined as the rate at which energy is transferred per unit area, measured in watts per square meter. How do you think the intensity of light varies as you move farther away from the light source? Why?

In astronomy, the light sources will be stars. Let's explore to see what the relationship is.

Equipment Required

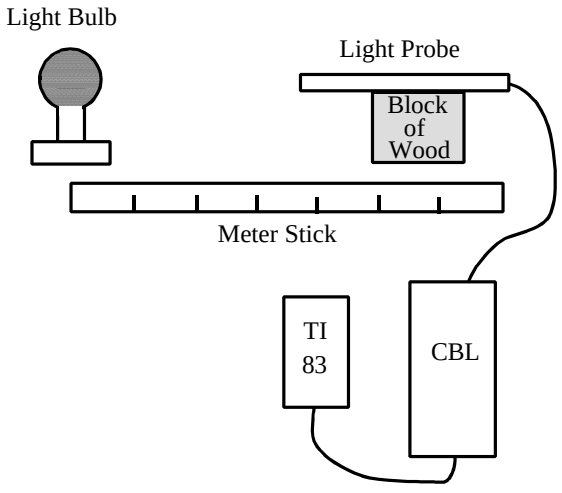
- CBL unit with TI light probe
- TI-83 graphing calculator with a unit-to-unit link cable
- CHEMBIO program from Vernier
- Standard light bulbs, clear not frosted (15 Watt)
- Tape
- Wooden block
- Meter stick

Procedure

This experiment requires that you access the CHEMBIO program which has been downloaded into your TI-83 calculator.

1. Connect the CBL unit to the TI-83 calculator with the unit-to-unit link cable using the I/O ports located on the bottom edge of each unit. Be sure the cable ends are in firmly!

2. Set up the equipment as shown in the figure. The light probe, taped to the wooden block should be aligned with the light source. The zero on the meter stick should be **aligned** with the center of the light bulb.



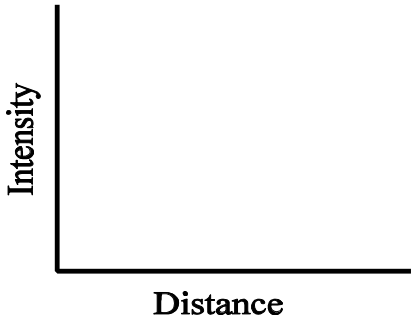
3. Turn on the CBL unit and the calculator. On the TI-83 press **[PRGM]** and select CHEMBIO from the menu. Press **[ENTER]** to start the program. Select "Set-up the Probe" and follow the instructions for the light probe.

4. After the light probe is ready, select "Collect Data" from the menu. Use the trigger/prompt mode for data collection. When ready, press the trigger button on CBL to record the light intensity, then the calculator will prompt (ask) you to enter the distance in centimeters. The first measurement should be at 15 cm from the bulb.

5. Continue measurements at 20, 25, 30, 40, 50, 70, and 90 cm. The data will automatically be stored in the calculator. When you have recorded the last datum point, select "Graph Data" to obtain a plot of intensity vs. distance. After getting the plot press **[ENTER]** and **[7]** to quit the CHEMBIO program. The data is stored in lists in the calculator- L_1 contains the distance while L_2 contains the intensity data. Press **[STAT]** EDIT to view the data in the lists and to record in the table.

Distance	Intensity
L_1	L_2
15	
20	
25	
30	
40	
50	
70	
90	

Sketch the data points below:



Predict the value of the intensity at 120 cm**.**

@120 cm I = _____

Explain your choice.

Analysis

From the graph can you determine the relationship between light intensity and distance? We want to mathematically model the data. Using **[WINDOW]** set Xmax to 120 before going on.

Is the data linear? Explain.

Now let's try curve fitting two types of regressions and judge the best-fit by the coefficient of determination, r^2, and how well the curve predicts at larger distances. The coefficient of determination, r^2, gives the fraction of variation in the y variable explained by the x variable. An r^2 of one is a perfect fit, while a value of zero is none of the variation is explained.

As you perform various regressions, note how the curves behave at the extremes of the data. Do the curves make sense when predicting at larger distances?

Press **[STAT]**, **[<]** to display the STAT CALC menu. Select QuadReg, press **[ENTER]**, then **[ENTER]** again. You should get a quadratic equation (Fits data to $y=ax^2+bx+c$.) and r^2 on the homescreen. Record in the table below. Press the following keys to paste the regression equation into the function editor for graphing: **[Y=]**, **[VARS]**, **[5]**, **[<]**, **[<]**, **[ENTER]**. Now press **[GRAPH]**.

Type of Regression	Equation and coefficients, a,b, and c	Coefficient of determination, r^2	Predictability at large distances?
quadratic			
power			

Repeat the above procedure this time selecting PwrReg. You should get the power law (Fits data to $y=ax^b$.) and r^2 on the homescreen. Record, paste, and then press **[GRAPH]**.

Which curve is the best-fit model to the data? Support your answer with an explanation.

Discussion

As light propagates away from its source, the energy associated with it tends to spread out. Consequently, the intensity of the light, *I*, decreases as the distance from the source, *d*, increases. This relationship is known as the inverse square law, which holds exactly for point sources of light, and can be mathematically stated as the power law:

$$I = kd^{-2} = \frac{k}{d^2}$$ where *k* is a constant that depends on the light source.

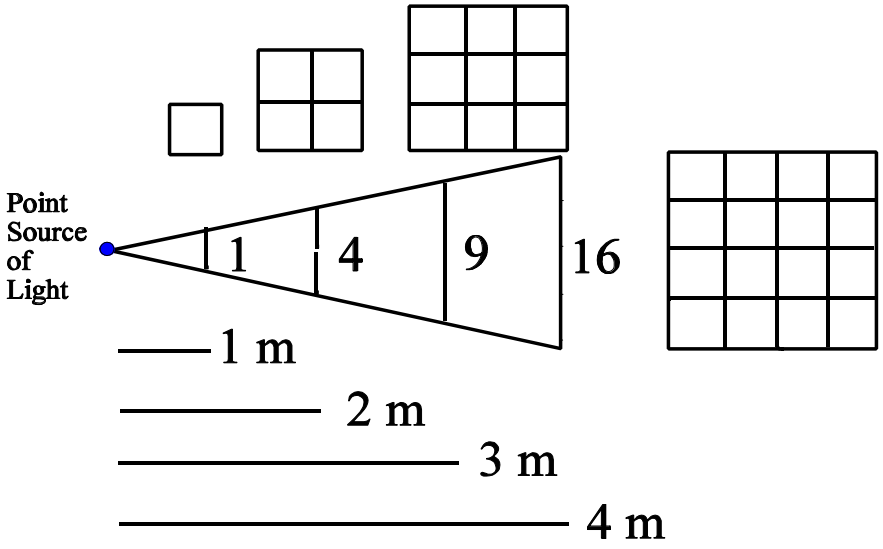
Your best fit for the data should occur with a power regression, $Y = aX^b$, giving an exponent (b) value close to -2.

How close did your experimental value of the exponent or power come to -2?

When distance is doubled, what happens to intensity? Explain.

Suggest some possible sources of error for this activity.

As distance increases from a point source, the electromagnetic radiation spreads out over a larger area, hence the intensity at any single point (or small area) decreases.



As you will see in a later activity, most stars fall in spectral classes of the main sequence. Stars in the same spectral class have the same brightness; hence a distance scale or measuring technique can be accomplished using the relationship between light intensity and distance. We can judge how far a known light source is!

The inverse square law is the basis of measuring distance by the standard-candle method. To find a star's distance compared to another star (the standard candle) of the same luminosity (energy radiated per second), find the apparent brightness ratio and take its square root. Solve for the distance, d, to the distant star after determining its brightness, B.

$$\frac{B_{standard}}{B_{distant}} \quad , \quad \frac{(d_{distant})^2}{(d_{standard})^2}$$

If a star at a distance of 25 pc and has a brightness of 3.0 L_{sun}, what is the distance to a similar type star, same spectra class, if its brightness is 2.0 L_{sun}?