EXPLORATIONS

Activity 11

WATT's the Deal?

Math Concepts

- Measurement
- Data Analysis
- Algebra

Science Concepts

- Data Collection
- Experimental Design
- Physical Science

Materials

- TI-73 calculator
- CBL™
- Data link cable
- Light probe
- A collection of different size (wattage) light bulbs
- Holder for the light bulbs (lamp)
- Meter stick
- Tape
- TI-GRAPH LINK™ (optional)

In this activity you will:

- Collect data on the brightness of different light bulbs
- Associate these values with the watt ratings for each bulb
- Graph the data
- Compute a rate of change (slope)
- Design an experiment for the collection of data to verify a hypothesis
- Calculate and explore the relationships between power and light intensity
- Measure manually and electronically

Introduction

Light bulbs are rated at different powers levels called watts. Different appliances call for light bulbs that function at different wattages. The power ratings most common for light bulbs are 100W, 75W, 60W, and 40W with the larger number of watts indicating a brighter light. Are these sizes (ratings) placed at these intervals (100, 75, 60, 40) because of their relative brightness,

or is there some pattern that reveals how much brighter a 75W bulb is than a 60W? One might think the ratio is 75:60 or 1.25 times brighter. Is this true?

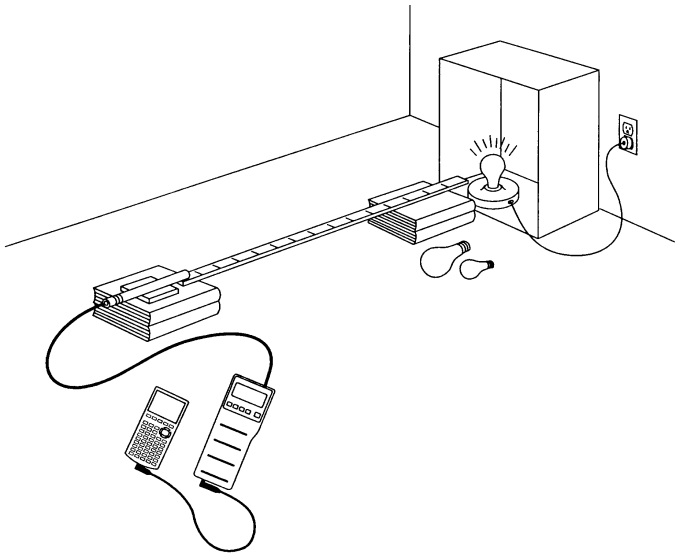
The Problem

Our hypothesis is that there is some relationship between the power of a light bulb (watts) and the amount of light that it gives off. Additionally, the amount of light could be predicted by using that relationship, if given the power rating of a light bulb. To show this, use the CBL™ with the light probe in the **GAUGE** mode to collect a light intensity in milliwatts per square centimeter for light bulbs of different watt ratings set at a fixed distance from the light probe.

Activity

Collecting Data

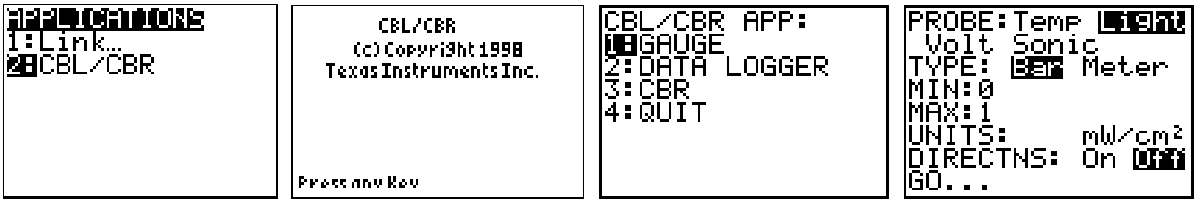
1. Set up the light probe at a height so that it is at the level of the center of the light bulb.
   a. Put the front of the probe at 1.00 meter (or your assigned distance) from the leading edge of the light bulb.
   b. Secure all the parts so they won't accidentally move.
   c. Remove all extraneous light sources and try to focus the light from the bulb on the probe.
   d. Keep your set up consistent for all measures.
   e. Place a box or box lid behind the light source to help "focus" the light on the probe.
2. Connect the TI-73 to the CBL and the light probe to the CBL in **CH1** as shown below.



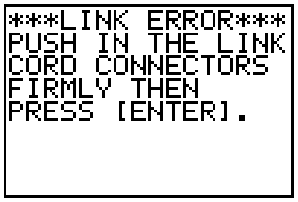
3. Run the **CBL/CBR** program from the **APPS** menu.

a. Press [APPS] and select option **2:CBL/CBR** from the **APPLICATIONS** menu.

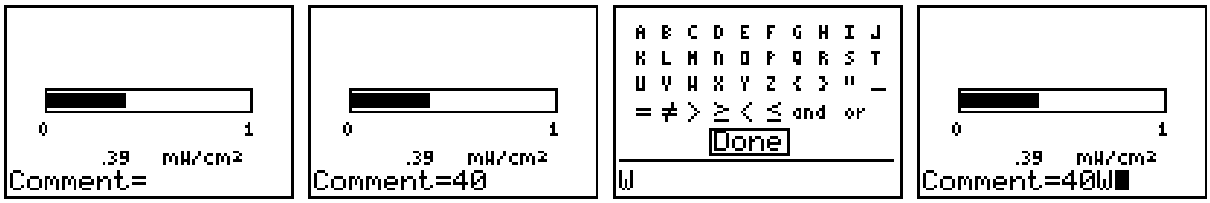
b. Press any key and select option **1:GAUGE** from the **CBL/CBR APP** menu and set up as shown below.



If the connection is not good (or the CBL™ is not on) you will get the following message. If so, check the connections until you get the **GAUGE**. Note the **- - -** on the CBL that indicates the "all clear" message, and then the changing values, relating to the light levels. If you have difficulty, set the option **DIRECTNS** to **On**.



4. As the **GAUGE** fluctuates, watch for the value that appears to be a recurring maximum. Press [ENTER] when this appears, and then use the keyboard and Text editor to enter a name for this data. If you miss the point, just put in a comment and continue, trying again.



a. Once you have the value for the light bulb, turn off the light and when it is cool enough, remove it, replacing it with another kind of bulb.

b. Repeat the process until all data is collected. Make sure you keep the equipment plugged in, and don't accidentally press keys on the CBL or TI-73.

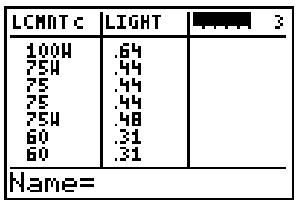
c. If the process is interrupted, sometimes the lists are erased as you start over. The time between light bulb collection needs to be small, but 2 or 3 minutes would be OK.

5. Once all the data is collected, press [CLEAR] [2nd] [QUIT] and select option **4:QUIT** from the **CBL/CBR APP** menu.

a. Set the two lists (**LCMNT** and **LIGHT**) to view in the list editor.

b. From the Home screen, press [LIST] and move to a free place, placing the list names in by pressing [2nd] [STAT] and selecting the list desired from the **Ls** menu (if these lists are not already present).

c. Check and see if you have all the data. If not, repeat the process. Sample data collected for different light bulbs is shown below.



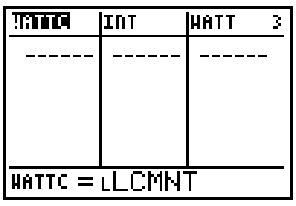
6. You may have incorrect data in the list due to miscues during data collection, and since the program creates these two lists when executed, you will need to copy the list to another location.

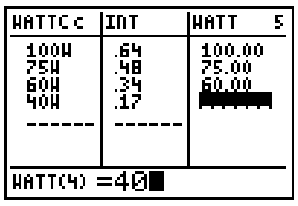
a. In the List Editor, move to the next free space and enter the name of the light bulb in a categorical list (**WATTC**), the intensity of the light (**INT**), and the numbers that relate to the wattage (**WATT**).

b. Copy lists **LCMNT** and **LIGHT** into the first two new lists and delete any extra values if there were any miscues. Make sure you keep track of what is deleted, since when you press [DEL] in a list, all the values move up one. Remember that these are ordered pairs (triples).

c. Repeat the process and then fill the **WATT** list with the appropriate whole number values.

✎ Answer questions 1 and 2 on the student data sheet.

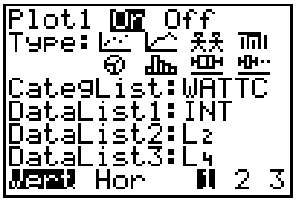


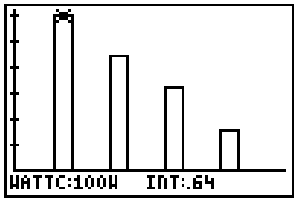


7. Now, set up a plot to show the pattern in the data.

a. Press [2nd] [PLOT] to set up a plot. Make sure that all other plots are off and set up **Plot1** as shown below, selecting only one DataList (**INT**). See the TI-73 manual on how to place list names in the Plot menu.

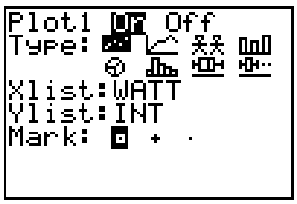
b. Press [GRAPH] and [TRACE] to explore the data.

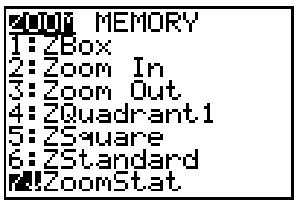


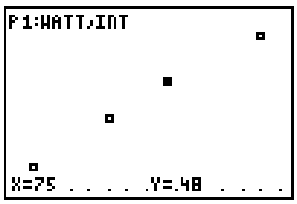


✎ Answer question 3 on the student data sheet.

8. Now change **Plot1** to a scatterplot as shown below. Press ZOOM and select **7: ZoomStat** to set the window and then press TRACE and explore the data.

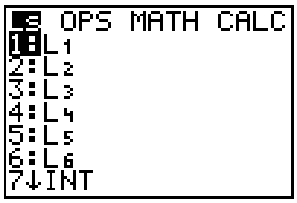


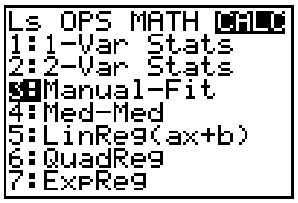


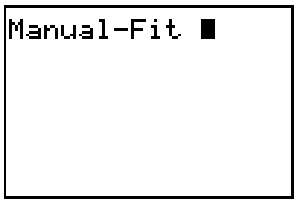


9. Since the data seems to form a straight line, you can get a representation of the relationship between the watts and the light intensity by doing a **Manual-Fit** calculation.

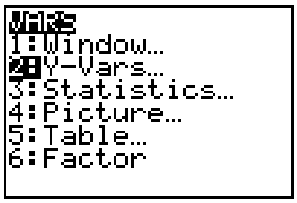
a. From the Home screen, press CLEAR 2nd [STAT] ◄ **CALC** and select **3:Manual-Fit** from the **CALC** menu.

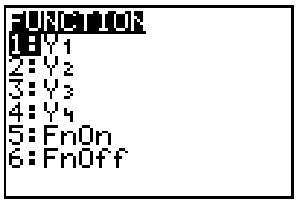


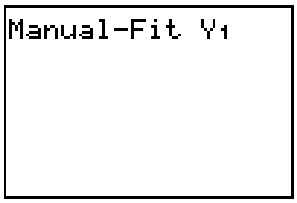




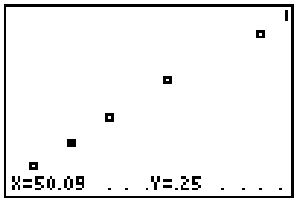
b. Press 2nd [VARS], select **2:Y-Vars** from the **VARS** menu, and then select option **1:Y1** from the **FUNCTION** menu.



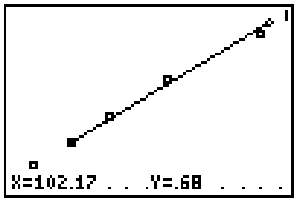




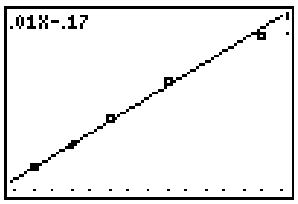
c. Press ENTER from the Home screen to go to the graph screen and move the cursor around to identify the start of your proposed line.



d. Press ENTER when you feel you are at the correct starting point on the left side of the screen and then move to the other end (right side) of the fit line.



e. Press [ENTER] again to finish the line. If this is not what you wanted, move the line around using the cursor keys until you are satisfied. Press [ENTER] to store the line.



✎ Answer questions 4 - 5 on the student data sheet.

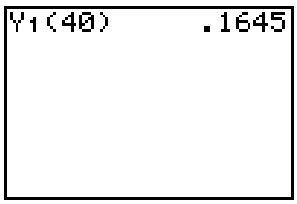
10. Use this function to test the values for the light bulbs used.

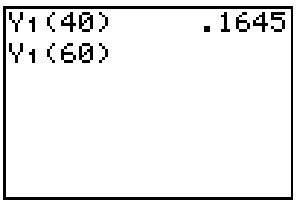
a. From the Home screen, press [CLEAR] [2nd] [VARS] select **2:Y-Vars** from the **VARS** menu and then select option **1: Y1** from the **FUNCTION** menu.

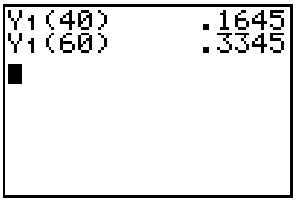
b. Press [(] **40** [)] [ENTER] to get the value of your equation in **Y1** when x (watt) is 40.

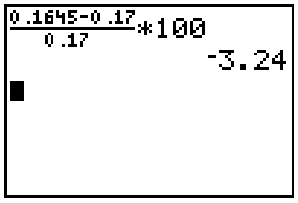
c. Press the [▲] until you see the command **Y1**(40) again and press [ENTER].

d. Edit the 40 for the next value for the next light bulb and continue. In this case, one model predicts an intensity of 0.1645 mW/cm^2 for the 40 Watt bulb — but you measured a value of 0.17 mW/cm^2 for that bulb. This model then predicts a value 3.24% below what you measured.









✎ Answer questions 6 - 8 on the student data sheet.

Going Further

1. Since a watt is a measure of power, what is the meaning of the units of light intensity (milliwatts per square centimeters)?
2. Given the following data, determine the rate of change (slope) of the light intensity as one changes the watts. Complete the table using this factor.

Light Bulb (watts)	Light Intensity (mW/cm^2)
15	0.10
40	0.27
60	0.40
75	0.50
100	0.67
150	1.00
77	
	1.7

3. What do you think would happen to the numbers for the intensity if you cut your distance in half for the experiment? Why?
4. Express the rate in terms of a 10-watt change in the light bulb. ($mWatts/cm^2$ per 10 watts).

Student Data Collection and Analysis Sheet

Name(s) _____

Date _____

Activity 11

WATT's the Deal?

1. Report the data in the table below and save the list to the computer with the TI-GRAPH LINK™ or write a program to store the list (see *Appendix A: Saving Lists*).

Light Bulb (watts)	Light Intensity (mW/cm^2)

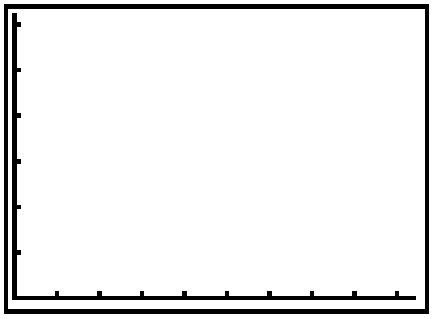
2. What pattern do you see in the data from the list of numbers? That is, what is the relationship between the number of watts for a light bulb and the brightness of that bulb? Use numbers in your answer if possible.

_____

_____

_____

3. Sketch the bar graph from your data in the area provided below. Label each part.



4. What was the name of the line (the rule or equation/function) that you got from the Manual-Fit?

_____

5. The number in front of the x value is the rate of change of light intensity per change in wattage (light intensity per watt). Use this value from the expression in question 4 and compare it with your guess about the pattern in question 2.

_____

_____

_____

6. Complete the table below for your experiment:

Light Bulb (watts)	Light Intensity Measured (mW/cm^2)	Y1 Value for Light Intensity (mW/cm^2)	Percent Difference (Y1 - M) * 100/M

7. What does your model predict for the light intensity of a 300 watt light bulb?

_____

8. What does your model suggest would be needed to create a light intensity of 1.00 mW/cm^2?

_____

Teacher Notes

Math Strand: Measurement, and Data Analysis and Algebra

Students will collect data on the brightness of different light bulbs and pair these values with the watt ratings for each bulb. This data will be graphed and a rate of change (slope) will be determined.

Science Strand: Data Collection, Experimental Design, and Physical Science

The students will be involved in experimental design and the collection of data to verify a hypothesis. Relationships between power and light intensity will be calculated and explored. Measurements, both manually and electronically, will be made.

Classroom Management and Safety

Each group should collect the data using the assigned distance and collection of light bulbs. One person should be in charge of the CBL™ while another should work with the TI-73. Care should be taken in handling the light bulb. Use a potholder or mitt to remove "hot" bulbs, placing them in a holder so they don't roll onto the floor and break as they cool. Watch the power cord for the lamp or light source and avoid other light sources, as these will increase the amount of light received by the light probe. The distance between the light bulb and the light probe should be kept constant, and the probe should be secured in some way to keep it pointing at the center of the light at the assigned distance. Avoid long periods of staring into the light source. It might be good to set up 4 or 5 stations, with a different light bulb at each location, and then have the students move through each station. If you do this, be careful to control all other variables.

The Set Up

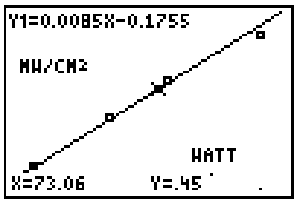
Set up the lamp or light socket so that the light probe picks up no large amount of extraneous light. Placing the lamp in a box (or box lid) turned on edge will help focus the light. Make all parts steady, so that distances and angles don't change during the experiment. A switch to turn off the lamp and allow the light bulb to cool before unscrewing would be ideal. Make sure the amount of extra light is constant throughout the period of data collection.

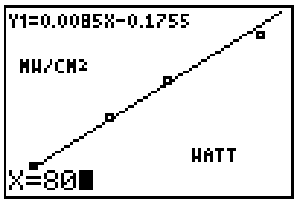
Activity

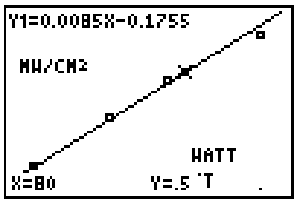
- Instructions on creating a categorical list are in the TI-73 manual.
- When doing the manual-fit and collecting data the mode setting will need to be set to **Float** or some larger number of digits than 2.
- Groups could collect unique data if you wish by assigning each group a different distance. 100 cm, 75 cm, 50 cm, 25 cm, and so on. If this is done, the **GAUGE** might peg (max out) for closer distances, so have the students explore the best settings for maximum (1 mW/cm^2 is used in this example

for the distance of 1 meter). Since I α Watts/distance^2 (the inverse square law) if the distance is reduced by ½ the Intensity will be increased by 4 times.

- Using fluorescent lights or lamps with three-way bulbs could be an alternative. Or using a MagLite (or adjustable flashlight) with turns of the lamp of ¼, ½, ¾, and 1 turns could be used for varying light bulbs.
- Watts (Power) = volts * amps; Intensity = Watts/4π*distance^2.
- Use the Linear regression for another type of fit and the Median-Median if you have a lot of data. Even a fit by hand would be informative.
- Collect the values from the model (function) by tracing on the line and keying in any wattage in the displayed range of x values.



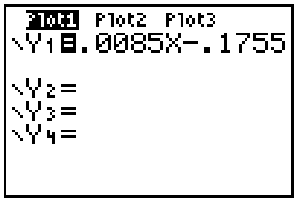




Note**: Sample data is in a program named **WATT.73p

Student Data Collection and Analysis Sheet – Key

1. The data from the lists in the table, and the location and names of the lists in the computer, or the name of the program with the lists.
2. 1/150th with an explanation of guess.
3. Looking for a histogram with the values and light bulb names on the sketch.
4. Y = □ X + Δ.



5. Compare the 1/150 * I to the 0.0085 * I from the fit.
6. In this case:

Light Bulb (watts)	Light Intensity Measured (mW/cm^2)	Y1 Value for Light Intensity (mW/cm^2)	Percent Difference (Y1 - M) * 100 M
100	0.64	0.67	5.36%
75	0.48	0.46	-2.86%
60	0.34	0.33	-1.57%
40	0.17	0.16	-2.36%

7. I = □ 300 + Δ.

8. 1.00 = □X + Δ.

Going Further – Key

1. This is like a pressure, or flow. The number of watts (milliwatts) falling on an area (square centimeters).

2. Y = (1/150)X

Light Bulb (watts)	Light Intensity (mW/cm^2)
15	0.10
40	0.27
60	0.40
75	0.50
100	0.67
150	1.00
77	**0.51**
255	1.7

3. Since intensity varies as 1/distance squared, you would have 4 times brighter intensity. The students would probably have an response less mathematical, but more than just twice as bright would be a good response, based on the data from groups that had other distances.

4. 0.085 mW/cm^2/W becomes 0.85 mW/cm^2/10W by multiplying by 10.

Extensions

- Use light bulbs of different colors, but the same wattage.
- Vary the distance and repeat the experiment (less than a meter), to see if you get the same results.
- Set up the experiment on a light fixture with a dimmer and see if there is a relation ship between the degree of turn and the light level (1/4 turn, 15 degrees, and so forth).
- Have the students produce a graph with their model shown on the screen in some way with the units of measure and the collected data. Save this as a **Pic**.