

Luminosity

•Materials

Solar cell with leads
 Voltmeter
 Ammeter
 1-Ohm resistor
 Calculator

•Introduction

In this lab, you will make an order of magnitude estimate of the sun's luminosity. **Luminosity** is the amount of light energy a star emits each second. We will measure the luminosity in watts, one watt = 1 joule per second.

To find the luminosity, we first need to think a little about geometry. Picture a series of concentric hollow spheres with the sun at the center. The farther away the sphere is from the sun, the larger its surface area. The surface area of a sphere is $4\pi r^2$, where r is the radius. On Earth, we do not receive the total amount of light emitted from the sun every second. We receive only our surface area divided by the surface area of the sphere at 1 AU. The surface area of this sphere is $A_E = 4\pi d^2$, where the radius of the sphere reaching from the Sun to Earth is $d = 1 \text{ AU} = 1.5 \times 10^{11} \text{ m}$. In this lab, we will be collecting sunlight on a small solar cell, and will need to account for its surface area size in comparison with the surface area of solar irradiance at Earth's distance, A_E .

The quantity we'll actually be measuring is brightness, the amount of energy that passes each second through a square meter of A_E .

$$b_o = L_o/4\pi d^2 \quad (1)$$

To recover L_o from our measurement, we'll multiply b_o by $4\pi d^2$. Find the numerical value for A_E , and complete the equation below.

$$L_o = \text{_____} b_o \quad (2)$$

The next detail we must consider is the size of our solar cell. Above, we accounted for measuring light energy in one square meter of the whole surface area A_E . In reality, we are not measuring even one square meter, unless we had a large solar cell that was 1 m by 1 m.

So we need to know how much of a square meter our solar cell is, and account for it in our luminosity calculation. For example, if our solar cell is 5 cm by 5 cm, its total area is $0.05\text{m} \times 0.05\text{m} = 0.0025 \text{ m}^2$. To get the brightness, watts per m^2 , we need to multiply our measured value for power by $1/0.0025 = 400$. If M denotes our measured value, and A is the area of our solar cell in *meters*,

$$b_o = (1/A) \times M \quad (3)$$

The next factor to consider is the efficiency of the solar cell, how much power is put out over the power input. It is beyond the scope of this lab to measure the exact efficiency of the cell, so assume the solar cell has a 10% efficiency. To account for this, you need to multiply b_o by a factor of 10; the real power per square meter is ten times what you get as the output power.

$$b_o = 10 \times (1/A) \times M \quad (4)$$

Okay, we now have the basic geometry of the problem down. Now, there is one more important factor to account for. If we could go into space and do this measurement, we would have all of the factors we needed. However, we are not in space, and there is a dense atmosphere between us and the pure solar light energy. There is a whole field of science that measures the amount of light we receive on the ground for various weather and atmospheric conditions. Here, if it is a sunny day, simply assume that you receive just 10% of the total amount of sunlight that is radiated upon the Earth *above* the atmosphere. So we must multiply b_o by another factor of 10,

$$b_o = 10 \times 10 \times (1/A) \times M. \quad (5)$$

Finally you have all of the tools you need to make an order of magnitude calculation of the luminosity of the sun.

•Procedure

This experiment should be conducted outdoors on a sunny day.

- 1) Obtain a solar cell, two digital multimeters (each with a black and a red connection wire), and one 1 Ohm resistor from your lab instructor.
- 2) Hook up your solar cell according to the instructions on the next page.

3) Take your cell outside, and point it in the direction of the sun.

4) After waiting a few moments for the readings to become stable, make several measurements of the output in Amps and Volts.

5) Back inside, calculate the power output of your solar cell:

$$\text{Power} = \text{Amps} \times \text{Volts} \quad (6)$$

(Power = current x voltage)

6) This power of the solar cell is the M in equation (5). Plug in your value and write the answer here:

$$b_o = 10 \times 10 \times (1/A) \times \underline{\hspace{2cm}}$$

$$b_o = \underline{\hspace{2cm}}$$

7) Now you're ready to find your luminosity estimate. Use equation (2) and your value of b_o above to calculate L_o .

$$L_o = 4\pi d^2 b_o = \underline{\hspace{2cm}}$$

8) Compare your answer to the actual value of about 4×10^{26} W. What is your percentage error?

$$\% \text{ error} = (|\text{actual-measured}|/\text{actual}) \times 100.$$

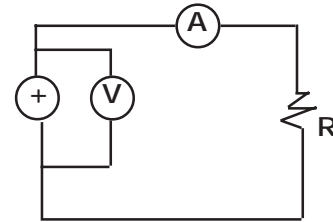
$$\% \text{ error} = \underline{\hspace{2cm}}$$

9) Where do you think your error came in? How could you measure the luminosity more correctly?

For credit, turn in your calculations, measured values and answers to all questions posed.

•Directions for hooking up your solar cell

As a guide, look at the circuit diagram below. If you have trouble connecting your circuit, ask your lab instructor for assistance.



a) The symbol with the + sign refers to the solar cell. It is your power source. Attach the red lead from the solar cell to the mA (milliamp) setting on your ammeter. An **ammeter** measures current. The symbol A in the diagram above refers to the ammeter.

b) The symbol R is the 1-Ohm resistor. Attach the black (ground) ammeter connector to one end of the resistor.

c) Attach the other end of the resistor to the black lead from the solar cell.

d) V in the diagram refers to the voltmeter. A **voltmeter** measures volts. Attach the two connectors from the voltmeter, with the red connector in the millivolt setting, one to each solar cell lead.

e) Your circuit is now set up. Both meter's black connectors should be plugged into ground (COM). If you have trouble getting a reading, try checking the order of your circuit - you might be registering negative values.

f) Remember when making your measurements to convert from milliamps and millivolts back to amps and volts.