Calibration Curve for a Radiation Meter

Suggested Level: Grades 7 through 9

LEARNING OUTCOME

After using measurement, students are able to link the concept of "brightness" to a graphical mathematical representation or, for more advanced students, an algebraic mathematical representation. Students ready for algebra are able to determine the slope-intercept equation for this linear relationship.

LESSON OVERVIEW

In this lesson, students determine the relationship between the short circuit output current of a solar panel and the level of radiation striking the panel. They also complete the following:

- Measure a solar panel output current as a function of the level of radiation striking the panel
- Realize that there is a linear relationship present
- Use a solar panel to process energy and information into a more useful form
- Plot solar panel output current versus radiation to obtain a calibration curve for their panel

They may use this curve and the solar panel as a radiation meter in other lessons.

MATERIALS

Per work group

- 60-watt bulb and lamp
- Meter stick
- Vertical stand for solar panel (This could be as simple as a cardboard box or block of wood with 90 degree corners.)
- Graph paper to plot curve
- 1 V, 400 mA mini–solar panel
- Digital multimeter

SAFETY

Warn students that the bulb will become hot enough to cause a burn if touched.

TEACHING THE LESSON

Students should work in groups of two or more. Carry out this lesson on a day of low humidity when students can access periods of unobscured sunlight preferably between 11:30 a.m. and 12:30 p.m. If objects such as clouds, buildings, snow, or haze can reflect diffuse radiation onto the solar panels, the outdoor readings may be high. You can avoid this by mounting the panels in a deep well or box with black interior sides before taking the outdoor reading. Of course, overcast days will produce low readings due to clouds blocking some of the incoming solar radiation.

Set out materials at the workstations.

Tell students that they will be learning how to use a solar panel as a light intensity meter. Demonstrate how to connect the multimeter to the solar panel leads and how to set the scale for reading milliamps. Position the panel near a light source such as an incandescent lamp or overhead projector, and show that the meter reading changes as the panel is held closer or farther from the light. Encourage students to practice by recording the meter reading as they hold the panel at different distances from the light.

Once students are comfortable with recording, relate how they will plot light intensity (radiation) versus short circuit output current of the solar panel. Explain that they will need to record the current at different known levels of light intensity and plot the results on the graph. For this activity, they will use the midday solar intensity (on a clear day), the light intensity at a set distance from a 60-watt incandescent light bulb, and darkness. They should use the values of light intensity given in Table 1.

Have students follow the instructions on their handout. Once all teams have finished, discuss the sources of error in this procedure.

Extension activity for those students ready for algebra:

Have students determine the slope-intercept equation for the calibration curve.

Light intensity (W/m^2) = slope x current (mA) + y-intercept, where slope = change in intensity / change in current

y-intercept = 0 W/m^2

Once this equation is determined, students can calculate the light intensity for any given level of current. Keep the calibration equation with each solar panel for use with other activities.

ACCEPTABLE STUDENT RESPONSES

The following values were measured using a mini–solar panel rated for 1V, 400 mA.

Date: July 31	mA	W/m^2 *
Midday, outdoor reading	317	1029
Reading 10 cm from a 60-watt bulb	66	300
Darkness	0	0

* from Table 1

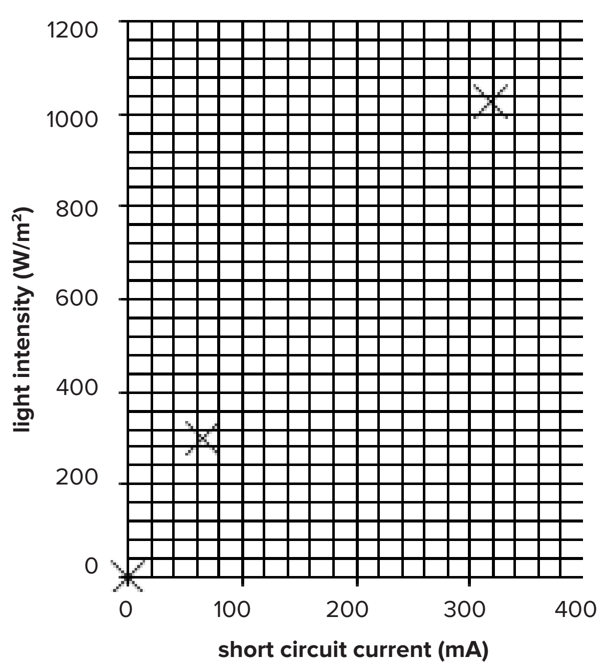

Figure 1: Calibration Curve

BACKGROUND INFORMATION

A solar cell's short circuit current is proportional to the number of photons absorbed by the cell. The sun delivers an average of 1,353 W/m^2 to the edge of earth's atmosphere. This is known as the *solar constant*. Because the atmosphere reflects and absorbs some of this energy, the solar intensity at sea level is less—about 1,000 W/m^2 in the summer. The solar intensity at earth's surface varies with the seasons. This variation is caused by the changing tilt of locations on earth with respect to the sun. Solar intensity at earth's surface also varies with atmospheric conditions such as cloud cover and humidity.

(STUDENT HANDOUT FOLLOWS)

Name ______________________ Date __________

Calibration Curve for a Radiation Meter

What does someone mean when they say “it is a bright day outside” or “that is a bright light”? How bright is “bright”? In this activity you devise a way to use a solar panel to measure how bright something is. To do so, you develop a calibration curve that will enable you to use a solar panel as a light intensity meter.

To do this, you plot on graph paper light intensity (W/m^2) versus a solar panel’s short circuit output current (mA) for three levels of known light intensity. This works because a solar cell’s short circuit current is proportional to the amount of light (number of photons) absorbed by the cell. Complete the following steps, using the values of light intensity given in Table 1.

Table 1

	watts/meter^2
midday winter sun (Nov. 1 to Feb. 1)	868
midday fall or spring sun	952
midday summer sun (May 15 to Aug. 15)	1029
10 cm away from a 60 W incandescent bulb	300
darkness	0

Follow your teacher’s instructions on how to measure the short circuit output current of the solar panel.

1) Step outside and aim your solar panel at the sun. Adjust the angle of the panel until the short circuit current reading is at its maximum. Record this value in your Calibration Data Table.

2) In the classroom, mount your solar panel on the vertical mount provided so it is centered at the height of the light bulb filament.

3) Turn on the light bulb and place a meter stick so its 0 mark is at the light bulb’s filament.

4) Place the solar panel at the 10 cm mark and turn the panel to face the light bulb directly. Measure the short circuit output current and record this value in your Calibration Data Table. Turn off the light.

5) Cover your solar panel so no light can get to the cells. Measure the short circuit output current and record this value in your calibration table.

6) Plot these three points on the graph paper provided.

Name ____________________ Date __________

7) Use a straightedge to connect, as closely as possible, all three points. The point *0 mA, 0 W/m*^{2} should lie on the line; the other two points should lie as close as possible. Extend the line to the edge of the graph.

8) Consider some of the inherent sources of error in using this method to measure light intensity. Write down your ideas on a separate sheet of paper. Consider:

a) How might a nearby object such a snow-covered tree or a light-colored building affect your outdoor reading?

b) How might atmospheric conditions such as a hazy sky or scattered clouds affect your outdoor reading? How about an overcast sky?

c) Do all bright, clear summer, winter, spring, or fall days have the same level of light intensity as is shown in Table 1?

d) Do all 60-watt light bulbs give off the exact same amount of light?

e) How would a slight change in the angle of the solar panel affect your results?

Calibration Data Table

Date: __________	mA	W/m^2 *
Midday, outdoor reading		
Reading 10 cm from a 60-watt bulb		
Darkness		

* Fill in appropriate values from Table 1.

To use the solar panel and calibration curve to find the intensity of a light source:

1) Measure the short circuit current.
2) Find that value on the horizontal axis.
3) Trace upward parallel to the vertical axis until you intersect the line.
4) Go left parallel to the horizontal axis until you reach the vertical axis.

The value at that point is the intensity of the light source.