



Solar Boats

Lesson 5: How to Measure Output of Solar Modules

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DESCRIPTION: Students will measure output from solar module before a load is attached and relate it to real world output. They will make these measurements using a multimeter and be able to determine the optimal angle at which their module generates a current flow. This process is meant to reveal to students some of the design challenges associated with the usage of photovoltaics, whether it is on top of a house or whether it is on a vehicle such as the solar boat they will be designing. This will facilitate a discussion of the pros and cons of solar modules.

GRADE LEVEL(S): 4, 5, 6

SUBJECT AREA(S): Science, energy, circuit, open circuit, voltage, current, power, short circuit, multimeter, measurement, load

ACTIVITY LENGTH: 1 hour

LEARNING GOAL(S): Students will demonstrate that solar modules create electricity when light strikes the module. Students will determine the optimum angle for the generation of current by a solar cell when given a light source (indoors or outdoors using the sun). Students will be able to effectively use a digital multimeter to measure current and voltage produced by a solar cell.

NEXT GENERATION SCIENCE STANDARDS:

- 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

STUDENT BACKGROUND:

Students are expected to have little-to-no understanding of electricity or solar power.

EDUCATOR BACKGROUND:

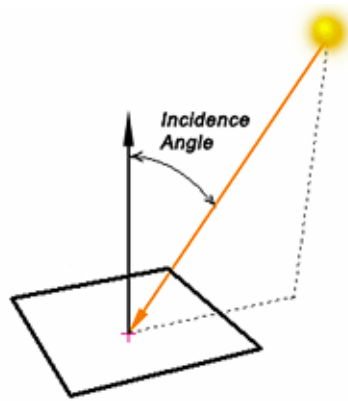
There are two primary forces acting on this science experiment. The first force is gravity. Gravity

- Teachers will need to have a sizeable understanding of the differences between current and voltage and their relationship with each other.
- Every solar panel has a rated output that includes: The peak, "Open-Circuit Voltage" and "Short-Circuit Current" that tell you the voltage and current of the panel when it is not connected to a device or load.

Open Circuit Voltage (V_{oc})	Short Circuit Current (I_{sc})
Peak Voltage (V_{mp})	Peak Current (I_{mp})

Figure 1 Letters/Acronyms you may see on a solar panel that tell its ratings with or without their English counterparts.

- Additionally, there will need to be an understanding of how to use a digital multimeter to take readings of each of these pieces.
- Refer to the **Multimeter Cheat Sheet** in order to gain background information on their usage.
- For taking this activity a step further, review incident angles and methods to calculate them.



Materials List (30-person class)

- Solar panels (one per group is ideal). Consider giving different groups differently-rated solar panels to test.
- Sunlight or another light source (e.g. a few high-powered halogen or incandescent bulbs)
- Multimeters
- Protractors

Vocabulary

- **Voltage (measured in Volts, V):** Voltage is the measure of the difference in electric potential energy between two points.
- **Current (measured in Amps, A):** Current is the measure of the flow of charge through an area over time.

Lesson Details

Solar 4R Schools™ is a program of BEF.

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Activity – Measuring Current and Voltage with no Loads

Have student's measure the output of a solar panel: Students will measure the solar panel output when it is angled directly into the sun (light source) and then use a protractor to test different angles relative to the sun (light source).

A. Measure Open Circuit Voltage –

1. The black lead should be connected to COM
2. The red lead should be connected to V or VDC.
3. If you set the dial to 20, the multimeter can measure up to 20 volts. Always set the dial to amount that is above your expected voltage reading, but as close to it as possible.
4. Touch and hold the black lead to the black wire.
5. Touch and hold the red lead to the red wire.
6. The Volts for the open circuit should be fairly close to the specifications on the solar panel.

B. Measure Short Circuit Current –

1. The black lead should be connected to COM
2. The red lead should be connected to the mA.
3. Set the dial to a current amount (may be indicated as an "A" on the meter dial) that is greater than what you expect the solar panel to produce.
4. Touch and hold the black lead to the black wire.
5. Touch and hold the red lead to the red wire.
6. The Amps for the short circuit should be fairly close to the specifications on the solar panel if the panel is in full sunlight.

A few notes on taking these measurements:

- The amount of current produced will be more impacted by the amount of light striking the solar panel than the amount of voltage will.
- When measuring the open-circuit voltage and short-circuit current, the way that the leads of your meter are connected to the leads of the solar panel will be the same. The difference is in the internal settings of your meter, which you change by moving the dial from taking a voltage reading to taking a current reading. This adjusts the internal resistance of multimeter.
- When reading voltage, the resistance of the meter is very high, preventing current from flowing through the circuit and thereby creating an "open-circuit" configuration.
- When reading current, the resistance of the meter is very low, allowing all available current to flow through the circuit and creating a "short-circuit" configuration.