

# Photovoltaic Cells/ Angle of Light\*

**Author:** Bruce Howard

**Subject:** Science

**Grade Level:** 5-9

## VITAL INFORMATION

**Site:** CLC of Wheeling, WV

**Mission Scenario:** Moon, Mars, Shuttle, Space Station, Engineering Design

**Application to**

**Mission Preparation:** Teaches science content related to the Life Support Station

**Whole Group/Small**

**Group/Individual:** Pairs

**Team (if applicable):** Life Support. Also appropriate for the whole class.

**Summary:** Short experiment using Photovoltaic (PV) cells, flashlight, a nail, clay, and power meter to show how light intensity changes with angle of the light. Similar to Life Support PV/Ammeter activity with more depth.

## LESSON AT A GLANCE

**Objective:** Students will use repeated measurements to derive the concept that as the angle of light changes, its effect on a photovoltaic cell changes.

**Standards:**

### **USA- National Science Education Standards**

- **Chapter Chapter 6:** Science Content Standards
- **Grade Level :** 5-8
- **Content Standard B:** Physical Science: As a result of their activities in grades 5-8, all students should develop an understanding of
  - **Ability/ Concept :** Transfer of energy
  - **Detail :** Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of

a chemical. Energy is transferred in many ways.

■ **Detail :** Light interacts with matter by transmission (including refraction), absorption, or scattering (including reflection). To see an object, light from that object--emitted by or scattered from it--must enter the eye.

■ **Detail :** Electrical circuits provide a means of transferring electrical energy when heat, light, sound, and chemical changes are produced.

■ **Detail :** The sun is a major source of energy for changes on the earth's surface. The sun loses energy by emitting light. A tiny fraction of that light reaches the earth, transferring energy from the sun to the earth. The sun's energy arrives as light with a range of wavelengths, consisting of visible light, infrared, and ultraviolet radiation

**Time Required:** 1 class period. 20 Min. per class.

**Essential Question:** Light carries energy. Energy may be transferred from light to matter. This energy may be harnessed and reused.

**Lesson Overview:** Using a light source (flashlight), a photovoltaic cell connected to a ammeter, a string, a nail, and a piece of clay pairs of students will change the angle of the light while holding distance constant and record the effect on power (amperes) being generated.

## **TEACHER PREPARATION**

**Subject Matter Overview:** The physical process by which a photovoltaic (PV) cell changes light energy into electrical energy is called the Photovoltaic Effect. The light rays from the sun are made up of packets of solar energy called “photons”. The photons contain different amounts of electrical energy. When a PV cell is exposed to photons the energy can either be reflected by the material or absorbed by the material. The amount of energy absorbed depends on the intensity and orientation of the light energy source with the PV arrays. PV cells operate at their highest efficiency when the light rays are directly hitting the solar cells perpendicular with the surface of the panels. If the position of the solar panel changes causing the angle of the light rays to be less than 90 degrees, the output voltage of the PV cells will be reduced.

This is sort of like the automobile crash tests we have seen on TV. If the car hits a wall directly all of the energy is transferred into the wall. If a car hits a wall at an angle only a portion of the energy is transferred into the wall.

PV arrays are fundamental to engineering design for the ISS and lunar or Martian bases. In the present and recent past, the space shuttle has carried several sets of PV arrays to the international space station. When fully extended, the solar arrays on the space station are as large as a football field. Computer-controlled motors constantly adjust the position of the solar arrays so that they remain perpendicular to the sun's light rays. If the angle of orientation is not constantly adjusted, power generation decreases dramatically. When the station is in the Earth's shadow, the ISS uses electricity generated by rechargeable Nickel-Hydrogen batteries.

**Materials:**

- Small piece of clay or quick-dry glue
- 2" Nail
- Photovoltaic cell
- Digital power meter able to read amps to three decimals
- Light source (recommended to use a plug-in lamp or very bright flashlight with plenty of battery reserve)
- Included sheet marked with printed circles

**Preparation:**

Gather the materials. Double check the ammeter is properly connected and works.

**Differentiated Instruction:**

This lesson works across learning styles and multiple abilities. Short timeframe and active nature makes it ideal for students with ADHD.

## **TEACHING THE LESSON**

**Lesson Management:** This is a simple inquiry-based experiment. Depending on the age of your students you may be able to discuss the topic of variables and how to hold all but one constant.

In the Challenger Center mission, the life support team may encounter a similar activity involving light, a PV cell and an ammeter. In that activity, however, the students are examining a different set of variables.

**Teaching Tips:**

It is unlikely that you will be able to obtain enough materials for the entire class to do this simultaneously. Therefore, it is recommended that this experiment be part of a set of

experiments that students would rotate through. Alternatively, only the Life Support students would conduct this activity.

### **Student Instructions: Part One - Setting Up the Experiment**

#### **PROCEDURE FOR PART ONE**

- 1 Place the sheet with printed circles on the table in front of you.
- 2 Stick a small piece of clay in the center of the smallest circle. The head of the nail or clay may be larger than the printed circles. This is okay.
- 3 Press the head of the nail into the clay, so that the nail is standing as straight as possible.
- 4 Locate the X on the right side of the paper. Center the photovoltaic cell upon this X.
- 5 Using electrical tape, connect the ends of both wires from the photovoltaic cell to the ends of both wires from the ammeter. Place the ammeter on the table where both people may read it.
- 6 With the light source off, note the reading on the ammeter. This is a measure of the background light. Make sure the ammeter is adjusted to take readings to three decimals with milliamps.
- 7 Make sure to use a light source with as focused a light as possible. Turn on your light source and move it about 18" above the photovoltaic cell and make general observations about the change in the readings. Move it back and forth and observe the changes.
- 8 Cut a string 12" to 20" long and hold one end at the edge of the PV cell and the other end at the edge of the light source. If possible, tape this string in place. This string will be used to assure that as the light source is moved around, the distance to the PV cell is held constant.

### **Part Two-Performing the Experiment**

#### **PROCEDURE FOR PART TWO**

- 1 Begin by shining your light source at the photovoltaic cell from directly behind the nail (on the left). Move the light source until the tip of the nail's shadow touches the rim of the outside circle.
- 2 Note the angle reading located next to the outer circle. Record this number in the left column.
- 3 Record the ammeter reading in the right column next to the correct angle.

- 4 Move your light source until the tip of the nail's shadow touches the rim of the next largest circle. Record the angle and the volt meter reading in the columns.
- 5 Repeat Step 4 until you reach the innermost circle. Continue to record all angles and corresponding ammeter readings.

### DATA ANALYSIS

Design a graph to plot your data. Plot the angles in degrees on the x-axis and the readings from the volt meter in milliamps on the y-axis.

### Closure Questions

1. Using the graph, at what angle did you record the most milliamps?
2. Use this information to determine how the space station can use the solar array panels to provide enough energy for vital station functions

Going Beyond: Thinking about the scientific method, look back at step 8 in Part One. Why did we hold distance constant in this experiment? What other variables did we hold constant?

**Student Worksheets:** [Student Worksheet with Circles](#) This is the sheet students lay on the table and attach the nail to.

## ASSESSMENT AND EXTENSIONS

**Rubrics:** [Science Experiment\\*](#)