Solar Powered System

Student Objective
The student
- understands that light energy from the sun can be turned into electricity with a photovoltaic (solar) cell
- knows how variables such as clouds, shading and direction of panel tilt, that can affect the electrical output of the photovoltaic cell
- will be able to explain how reflectors and temperature affect the electrical output of the photovoltaic panel
- will be able to determine the angle of incidence of the sun.

Key Words:
ampere (amp)
angle of incidence
coulomb
current
load
multimeter
orientation
photovoltaic (PV)
system
volt
watt

Materials
- 3V photovoltaic panel (1 per group)
- wires with alligator clips (2 per group)
- multimeter (1 per group)
- protractor (1 per group)
- ice
- aluminum (foil or disposable baking pans) or other reflective material
- Laboratory Manual pages

Time:
1 class period

Background Information

PV cells use light to produce electricity. Photovoltaic systems are quiet, clean, and non-polluting. Photovoltaic cells (called PV or solar cells) are made of silicon (sand). The silicon is heated to extreme temperatures. It is doped (coated/mixed) with chemicals, usually boron and phosphorous. This sets up an unstable environment within the photovoltaic cell. When light strikes the cell, electrons are dislodged and travel along wires placed within the cell. The electron's energy flows through the wire and power whatever load is attached, in this case a motor. This flow of electron energy is called electricity.

Procedure

1. **Engage:** Discuss what a photovoltaic (PV or 'solar') cell is made of and how it works.
2. Distribute materials.
3. **Explore:** Have the students complete the activity as outlined in the Laboratory Manual stopping before the Writing Assignment.
4. **Explain and Elaborate:** After completing the activity, have the students share their results with the class, and discuss the variables that affect the output of the photovoltaic cell such as:
   - time of day
   - weather conditions including temperature and available radiation
   - time of year
   - location (latitude) on earth
   - thickness of atmosphere that sunlight must penetrate
   - angle the panel's installation

   Have the students reach a consensus of which variables/conditions increase the power output of a photovoltaic cell, and which variables/conditions decrease the power output. Which of these can be controlled?
5. Questions for further discussion:
   - What can we do to produce even more electricity? *(Use more panels)*
   - How do you use photovoltaics to power things at night? Hint: You need a device to store the electricity. *(A battery)*
   - What could we do to produce more electricity on a cloudy day? *(Use more cells/panels in the system)*
6. Explain to the students that they will be using the results of their investigation to write a magazine (or scientific journal) article titled "How to produce the most electric power from photovoltaics in _____ , Florida (insert your city)." These articles will then be shared. This article can be assigned for homework, or done during class time at the instructor's discretion.

Procedure (presentation day)

1. Each group selects the best written article from their group to present to the class.
2. After the presentations, the class decides which article from the presentations to share within the school and/or community.

Evaluation and Student Assessment

You may wish to review the students' lab results, but the main focus should be the student's ability to generate an explanation, report evidence and reasoning, communicate the results of a scientific investigation, and to evaluate the merits of explanations produced by others.

Use a holistic FCAT Writes scoring guide to rate these criteria points:

Criteria	Mastered the skill	Some mastery is evident	Needs improvement
Procedure - explained logically and flows smoothly			
Terms and units - used appropriately			
Scientific principle - at least one is included			
Data - is provided and justified by referencing multiple trials			
Summary - reported data supports the claims and guidelines			
Reasoning is logical			
Overall scientific writing ability			

Related Research

1. How are photovoltaics used in the space program? In telecommunications? Use the internet to collect data and pictures of these applications. Are the photovoltaic cells different or the same as those used in terrestrial applications?
2. How are photovoltaic cells made? Research the difference between single crystal, poly crystal and thin film cells. Which type is the cheapest to produce? Which has the highest efficiency?
3. How can silicon be obtained from sand? Demonstrate the chemical reaction in this activity: **http://www.popsci.com/diy/article/2005-10/making-silicon-sand** Use all chemical safety practices or team this activity with your chemistry teacher.
4. At the present time there are more photovoltaics in use on the continent of Africa than the North American continent. Why is this so? (Hint: It has nothing to do with climate, weather or latitude)
5. What are the leading countries (and/or states in the U.S.) using photovoltaic cells and solar energy to produce electricity?
6. Where in your school and/or community can photovoltaics be easily used to create more solar electricity generation? Think outside the box!
7. Develop a marketing survey to determine the public's view of using solar energy to produce electricity. Survey fellow students, family, and friends to obtain survey results and use this information to produce a 60 second infomercial about photovoltaics.

Related Reading

- ***From Space to Earth: The Story of Solar Electricity*** by John Perlin (Aatec Publications, 1999)

  John Perlin surveys the fascinating evolution of photovoltaics from its problematic and controversial nineteenth century beginnings to its indispensable and versatile role as a power source for contemporary daily life. More than the story of a technology, From Space To Earth is also a chronicle of the individuals who persevered, took chances, bucked authority, innovated, invented, and crusaded to provide humanity with renewable energy.

Internet Sites

http://www.fsec.ucf.edu/en/consumer/solar_electricity/basics/index.htm

Florida Solar Energy Center's photovoltaic fundamentals page explains the basics of photovoltaic cells including their manufacture, the components of systems, as well as the pros and cons of photovoltaic power.

http://www.mathconnect.com/ENGINEERING-Formula.htm

Common electrical formulas and conversions

http://www.jc-solarhomes.com/photovolt.htm

Basics on the physics behind photovoltaics. Includes a Discovery Channel video on how photovoltaic cells are made.

http://www.nmsea.org/Curriculum/Primer/from_oil_wells_to_solar_cells.htm

New Mexico Solar Energy Association's *From Oil Wells to Solar Cells: A Renewable Energy Primer*. Contains an overview of renewable energy including benefits, costs and obstacles to implementation. Also includes a good introduction to solar energy technology.

http://qrg.northwestern.edu/projects/vss/docs/Power/zoom-solar-panels.html

Northwestern University, Qualitative Reasoning Group's website containing modules explaining the use of radiant energy in space systems including the use of photovoltaics.

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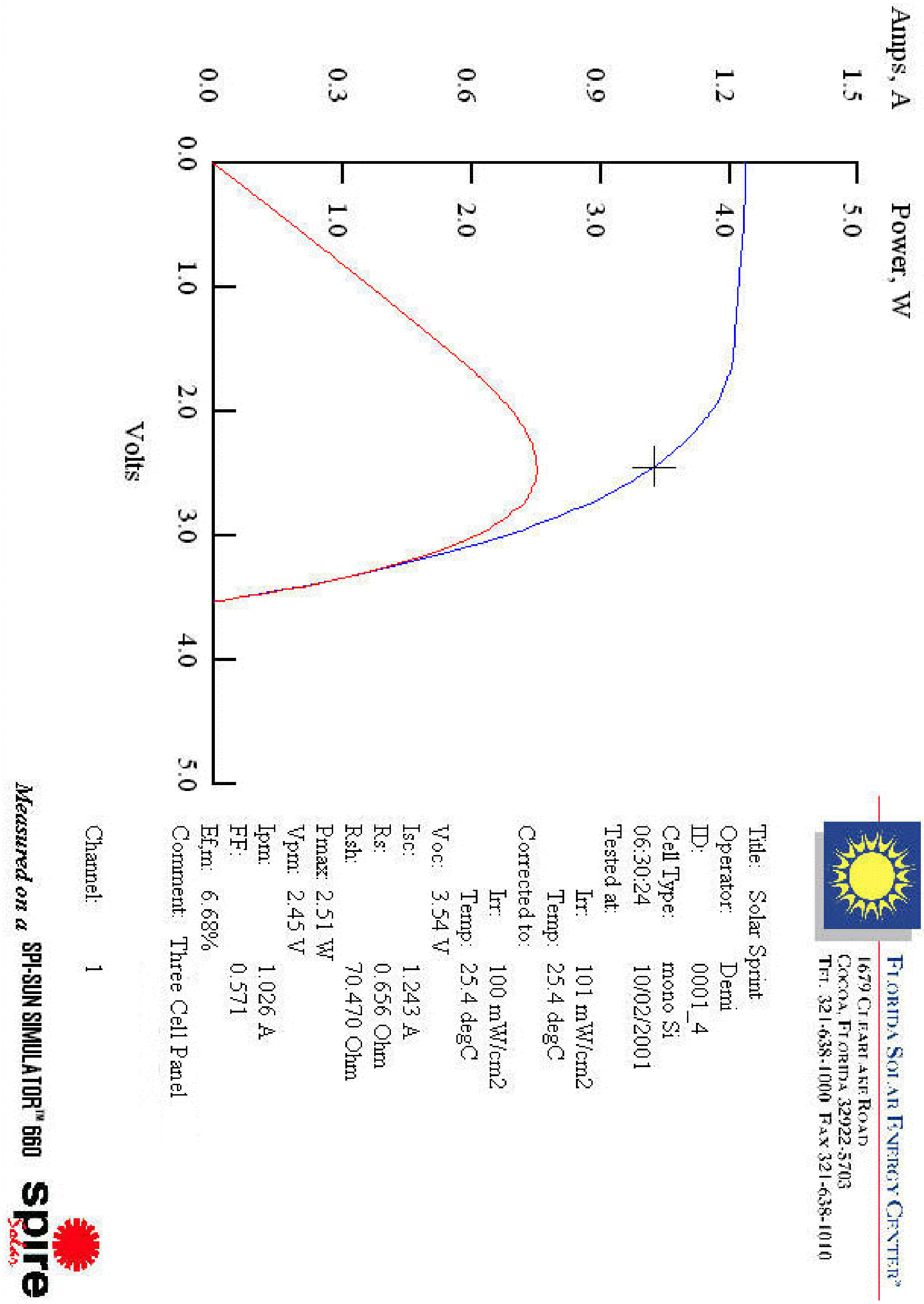

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		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Nature of Science																					
Standard 1	**SC.912.N.1.**	**X**																			
Physical Science																					
Standard 10	**SC.912.P.10.**	**X**														**X**					
Life Science																					
Standard 17	**SC.912.L.17.**																	**X**			
Language Arts Standards		**LA910.4.2.1, LA910.4.2.2, LA910.4.2.3, LA.1112.4.2.1, LA1112.4.2.2, LA1112.4.2.3**																			

Science Standards

Standard 1: The Practice of Science

- SC.912.N.1.1- Define a problem based on a specific body of knowledge, for example: biology, chemistry, physics, and earth/space science, and do the following:
  1. pose questions about the natural world
  2. conduct systematic observations
  3. examine books and other sources of information to see what is already known
  4. review what is known in light of empirical evidence
  5. plan investigations
  6. use tools to gather, analyze, and interpret data (this includes the use of measurement in metric and other systems, and also the generation and interpretation of graphical representations of data, including data tables and graphs)
  7. pose answers, explanations, or descriptions of events
  8. generate explanations that explicate or describe natural phenomena (inferences)
  9. use appropriate evidence and reasoning to justify these explanations to others
  10. communicate results of scientific investigations, and
  11. evaluate the merits of the explanations produced by others.

Standard 10: Energy

- SC.912.P.10.1 - Differentiate among the various forms of energy and recognize that they can be transformed from one form to others.
- SC912.P.10.15 - Investigate and explain the relationships among current, voltage, resistance and power.

Standard 17: Interdependence

- SC.912.L.17.17 - Assess the effectiveness of innovative methods of protecting the environment.

Language Arts Standards

Writing Applications - Standard 2: Informative

- LA.910.4.2.1 - The student will write in a variety of informational/expository forms, including a variety of technical documents
- LA.910.4.2.2 - The student will record information and ideas from primary and/or secondary sources accurately and coherently, noting the validity and reliability of these sources and attributing sources of information.
- LA.910.4.2.3 - The student will write informational/expository essays that speculate on the causes and effects of a situation, establish the connection between the postulated causes or effects, offer evidence supporting the validity of the proposed causes or effects, and include introductory, body, and concluding paragraphs.
- LA.1112.4.2.1 - The student will write in a variety of informational/expository forms, including documents using precise technical and scientific vocabulary.
- LA.1112.4.2.2 - The student will record information and ideas from primary and/or secondary sources accurately and coherently, noting the validity and reliability of these sources and attributing sources of information.
- LA.1112.4.2.3 - The student will write informational/expository essays that speculate on the causes and effects of a situation, establish the connection between the postulated causes or effects, offer evidence supporting the validity of the proposed causes or effects, and include introductory, body, and concluding paragraphs.

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ampere (amp) - the electrical unit for current, measuring flow of electron energy through a conducting material, per second

angle of incidence - the angle formed from the incoming ray (incident ray) and the perpendicular angle formed from the reflecting. The angle of incidence varies according to location (latitude) and time of day.

coulomb - the unit of measure of electric charge, that is defined as the charge transported by a steady current of one ampere in one second

current - the rate of flow of the charged particles amps flowing through the circuit at a particular time

load - a device to which power is delivered, such as a motor, a light, or a household appliance

multimeter - an instrument used to measure electrical output in either amps and volts and resistance in ohms.

orientation - position in relation to the reference points of the compass and elevation angle

photovoltaic - the effect of producing electric current using photons of light energy

system - a defined group or combination of the components of a unified whole

volt - the unit measuring the electric force or potential difference in a circuit.

watt - the standard unit of power; equivalent to one joule per second.

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Effect of Shadows

1. Attach the leads of the solar panel to a multimeter and set the multimeter to read direct current voltage. Investigate the effect of shadows on part of the panel: What happens to the voltage of the panel if you cover one of the three cells?

2. What happens if you shade ½ of one of these cells?

Angle of the Panel

3. Determine the angle of incidence of the sun. To do this, take a long slender object (such as a pencil) and with one end touching the ground, point the other end towards the sun. (When you are pointing directly at the sun, the pointer will not cast any shadow.) Then with your protractor, measure this angle from the normal (the angle that is perpendicular to the ground) and record it below and in the chart in #4. Complete the data below.

   Time of day: _____ Daylight savings time? ____ Yes ____ No

   Angle of incidence _____

   Complimentary angle to the angle of incidence (hint: sum of both equal 90°) _____

4. Determine if the angle of the panel has an effect on its power output. Using your protractor to measure the angle between the ground and the panel, set your panel at the angles listed in the chart below. Then record the voltage measurement using the same circuit arrangement as in question 1.
   Note: To get an accurate reading, make sure that the tilted side of your panel is in an orientation that is facing toward the sun! An angle of 0° would be flat on the ground. A 90° degree angle would be perpendicular to the ground

Angle of Panel	Voltage measurement
0°	
20°	
40°	
60°	
Angle of incidence _____	

5. What angle produced the highest voltage reading?

6. How did this compare to your angle of incidence? What conclusion can you make about which direction to point your panel to get the highest voltage output?

Reflectors

7. Will reflecting more light into the panel significantly increase the output of the panel? To find out, use aluminum foil or other shiny surface to reflect more light onto the panel. Take an voltage reading without the reflector first, then add your reflective material. Try varying the angle of the reflector to get the highest reading possible. Record your findings below.

   Voltage without reflector _____

   Highest voltage obtained using a reflector _____

8. Describe what you did to get your highest voltage reading?

9. How does changing the angle of reflection (independent variable) effect the voltage output (the dependable variable)?

Temperature

Solar car race teams that race full size solar cars (such as the Dell-Winston Solar Car Challenge) will often spray water on the car's solar panel to keep them cool. Investigate how temperature affects your panel.

10. Your panel is probably fairly warm from being in the sun during the previous exercises; however, if you have just brought your panel out into the sun, give it a few minutes to warm up a bit before you take your reading. Then take your 'warm' voltage reading and record it below. Then take a piece of ice or a cloth dampened with ice water and chill the bottom surface of the panel. Take a second reading and record below.

    'Warm' voltage _____ 'Chilled' voltage _____

11. Did cooling off the panel seem to make a difference? If so, how?

12. How would this affect panels in cooler climates?

13. Identify the independent and dependent variable during this investigation.

Writing Assignment

14. Based on the results from this lab activity and the class discussion, write a newspaper or magazine article reporting "How to produce the most electric power from photovoltaics in _____ , Florida (insert your city)" Your article is to include:
    - title
    - procedure used during your investigative study
    - results of your data
    - guidelines and precautions for others to consider when installing photovoltaics.
    - validating results. Note: Scientists often perform multiple trials to validate the evidence and claims of their investigative results. Use your classmates' results in your article to support the evidence and claims you make in your summary. Remember, you must give credit to others' (your classmates) results!