Testing PV Cells

RENEWABLE ENERGY
THE INFINITE POWER OF TEXAS

FOR USE WITH FACT SHEET NO. 11: INTRODUCTION TO PHOTOVOLTAIC SYSTEMS

TEXAS ESSENTIAL KNOWLEDGE AND SKILLS

TEKS utilized: **SCI.** (c) 1(B) make wise choices in the use and conservation of resources; 2(A) plan and implement investigation procedures; 2(B) collect data and make measurements with precision; 6(C) analyze the efficiency of energy conversions that are responsible for the production of electricity such as...radiant; 6(D) investigate and compare economic and environmental impacts of using…energy sources...such as...PV cells; **ALG.** 2(B) collect data and make measurements with precision; (b) 1(B) gather and record data; 2(D) collect and organize data; **WORLD GEO.** (c) 19(A) evaluate…major technological innovations; 20(A) describe the impact of new technologies…and revised perceptions of resources; 20(B) analyze the role of technology in agriculture and other primary economic activities and identify the environmental consequences of the changes that have taken place; **L.A.** 1(A) write to report and describe; 20 (A) describe the impact of...new technologies.

OVERVIEW

Students will construct a simple photovoltaic (PV) system, using a PV cell and a DC ammeter, to learn how the amount and wavelength of light affects the generation of electricity. Students will learn how PV systems are connected for AC and DC power. Temperature changes affecting the efficiency of a PV cell is an additional test students will perform.

TIME FRAME

One 1-hour period

TEACHER GUIDE

Background Information

In less than 40 minutes, the United States receives more solar energy than from all of the fossil fuels (oil, gas, etc.) used across the nation in one year. Texas has thousands of square miles useful for solar power plants.

Solar energy can be part of a mixture of renewable energies used to meet the need for electricity. Using photovoltaic cells (also called solar cells), solar energy can become either direct current electricity or alternating current electricity or both. This electricity can be used at night by employing a storage mechanism, such as a battery. Batteries used for this purpose have a large storage capacity.

Photovoltaic cells were developed in the 1950s as part of the space program. They are made from silicon, a semiconductor. When light hits the PV cell, electrons move and travel along wires inside the PV cell, just as electrons travel through the wiring in our homes. A PV cell changes sunlight into electricity by causing electrons to move toward the treated front surface of the cell. This creates an electron imbalance. When a connector, like a wire, joins the electron-poor back and electron-rich front, a current of electricity flows between the negative front and positive backsides. Photovoltaic systems are set up to maximize the sun's light, and the system angles can be changed for winter and summer, always facing the PV system south.

Students are familiar with the PV cells used in most calculators. In fact some students may wish to try some of the activities on a calculator PV cell for comparison. More possible future photovoltaic applications can be discussed with students.

Teaching Instructions

Teachers should read the student activity first. Students will test PV cell response to shade, to temperature, and to different wavelengths of light. Emphasize to the class safety

precautions when taking current and voltage readings using volt- and ammeters. Use either meter leads that have alligator clips on the ends, or attach insulated alligator clips to the wire ends that come into contact with the meter leads. Students should never touch any bare or exposed metal in a circuit that is generating electricity (i.e. meter leads, bare wire, etc.). Give students clear instructions on how to safely measure voltage and current using meters. The PV cell (or PV cells wired in series) needs at least 0.5v output. The colored transparency sheets can be cut into pieces large enough to completely shade the PV cell. Students should read Fact Sheet #11, *Introduction to Photovoltaic Systems,* before they set up their apparatus, as key vocabulary words in the Fact Sheet will assist them. Appropriate safety guidelines should be reviewed.

Students can read the instructions and create their data table forms before performing the activity. The students can compile results of their findings. These results can be averaged so that the class can draw conclusions.

Students can research the uses of PV systems in countries of the Caribbean, in Mexico, and South America and compare with the United States. The advantages for PV are self-evident where no power grid exists. With increasing costs for electricity and potential black-outs, a solar self-sufficient alternative in U.S. homes for providing part of the power needed may be a viable answer to the energy problem.

Expected Observations

Students should see the effects of more and less light and different wavelengths of light on the PV cell, and of the cell's temperature. Voltage readings will be larger when more light is absorbed. Readings should be smaller when the PV cell is cold, though this temperature effect may be too minor to observe on a small scale. The PV cell should remain dry. The decreasing angles from the sun (light source) result in lower readings.

Assessment Answers

Short Answer Questions

1. Colors with wavelengths like yellow interfere less with absorption which allows more electricity to be generated. Colors closer to black absorb more light and block out the light's passage. Shade prevents the PV cell from absorbing light.
2. Using solar power can reduce the cost of electricity, diminish our dependence on imported energy, provide cleaner air to breathe and provide a convenient source of power independent of the power grid in remote areas.
3. For industrial countries with a well-developed electricity grid system, photovoltaic electrical generation can provide energy and reduce the occurrence of black-outs. Industrial countries produce significant amounts of pollution, and PV electricity can help clean the air by using less oil and coal. Less developed countries can have more options than just grid power and have independent electricity generation anywhere it is desired. The costs of running power lines across hundreds of miles will not be needed.
4. If the PV cell changes angles during the day for optimum light, the output will increase.
5. South

Multiple Choice Questions

1 c 2 d 3 d 4 d 5 c
6 c 7 d 8 d (best answer)
9 b 10 c

GLOSSARY

alternating current (AC) – an electrical current that reverses its polarity at regular intervals (changes direction)

ammeter – instrument for measuring electrical current, in amperes

array – modules wired into series and parallel arrangements

direct current (DC) – electric current that flows in one direction only

electricity – a flow of energy; electrons and some other sub atomic particles

module – dozens of PV cells interconnected and sealed to be weatherproof

parallel – a connection of 2 or more power sources (i.e. battery, solar cell, solar module) where the positive terminal of one power source is connected to the positive terminal of another power source, and similarly, negative to negative

photovoltaics – comes from "photo" meaning light and "voltaic" referring to producing electricity; refers to PV cells

series – a connection of 2 or more power sources (i.e. battery, solar cell, solar module) where the positive terminal of one power source is connected to the negative terminal of another power source

PV cell – (also called photovoltaic cell or photo cell) converts sunlight into electricity; made from at least 2 layers of semiconductor material (silicon)

voltmeter – instrument for measuring electric potential in volts (volts = ohms x amperes)

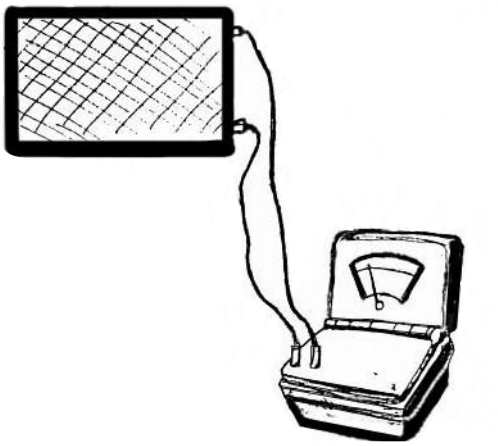
STUDENT ACTIVITY #11: TESTING PV CELLS

Key Vocabulary
define the following terms:
alternating current (AC), ammeter, array, direct current (DC), electricity, module, parallel, photovoltaics (PV), series, PV cell, volt meter

Materials
- small PV cell, at least 0.5v output, or several PV cells in series (found at most science supply companies and electronic stores).
- several sheets of colored transparency film in various colors, including yellow and blue (office supply stores). Small pieces will be used.
- 30 cm of thin electrical wire (use with alligator clips unless the meter leads have alligator clips on their ends)
- DC ammeter (reads amps)
- DC volt meter
- direct sunlight (desk lamp or flashlight could be substituted)
- magnifying glass
- aluminum foil
- protractor
- ice in sealed plastic bag
- goggles

I. Constructing the Photovoltaic Energy System for Light Source Changes (wear goggles)

1. If your PV cell does not have wires already attached to it, you should attach 15 cm of wire to each node of the PV cell. The cell should have either clips or hooks around which you can manually twist the wire.
2. Follow your teacher's safety instructions and attach the red wire from the PV cell to the red lead of the ammeter (either clip or wrap the wires together).
3. Similarly, attach the black wires from the PV cell to the black lead of the ammeter.
4. Use the sun, or shine a light source on the PV cell, to see if you are getting a current reading. If the ammeter shows no current, check the wire connections.



II. Performing the Activity for Light (wear goggles)

1. Keeping the sunlight constant (or the light source at constant distance), cover the PV cell(s) with a piece of colored transparency film. Repeat with the other colors of transparency film, and then use just direct sunlight alone (or light substitute). Record the amps generated for all colors tested and for direct light in a data chart.
2. Shade 1/4 of the PV cell(s) with a piece of cardboard or paper and take a reading. Shade 1/2, 3/4 and then all of the photovoltaic cell(s). Record the readings in a data chart.
3. Place the PV cell(s) directly pointed at the sun (or light source). Using a protractor to determine the angle, slant the PV cell(s) at 15-degree intervals away from the direct perpendicular position. Record the amps generated at every 15-degree change in a data table.
4. Take a magnifying glass and concentrate the sunlight (or light source) on the PV cell. Measure the new current and record.
5. Take a piece of aluminum foil and design a light reflector for your PV cell to concentrate the light shining on it. Measure the new current with the reflector attached.

III. Constructing the Photovoltaic Energy System for Temperature Changes (wear goggles)

Take your PV cell(s) with its attached wires and attach the red wire from the PV cell to the red lead of the voltmeter. Attach the black wire from the PV cell to the black lead of the voltmeter. Check that you are getting a reading. If you do not get a reading check the wire connections.

IV. Performing the Activity for Temperature (wear goggles)

1. Take your PV cell(s) that is connected to the voltmeter and, shading the PV cell, read the voltmeter at regular room or outside temperature and record your readings in a data chart. Place the PV cell directly in the sun (or under a lamp) so that the cell becomes warm. Record this new reading. Place both readings in a chart.
2. Place some crushed ice in a Ziploc bag then set the PV cell(s) on top, so the cell(s) becomes cold. Take 3 readings over a 5-minute interval. Place the readings in a chart.

ASSESSMENT

Short Answer Questions

1. Which colors allowed the most electricity to be generated? What happens when the PV cell is shaded?

2. What benefits come from the use of solar power?

3. Does the future for both industrial and less developed countries hold a place for the use of photovoltaic systems? Discuss.

4. How could you increase the output of a PV cell during the day, when the angle of the sun's rays is constantly changing?

5. In what direction would you face a photovoltaic system being installed on your home?

Mulitiple Choice Questions

1. The word photovoltaic comes from words meaning:
   a) wind energy
   b) brightness
   c) light producing electricity
   d) picture which moves

2. A PV module is:
   a) dozens of photovoltaic cells connected together
   b) wired in series
   c) wired in parallel
   d) all answers a, b, c

3. Solar PV systems can be:
   a) connected to the power grid
   b) used to sell power to the grid
   c) a stand alone source of electricity
   d) all answers a, b, c

4. In the shade:
   a) PV cells absorb much less light
   b) less current is generated in PV cells
   c) the PV cell is cooler
   d) all answers a, b, c

5. Improving the efficiency of a PV cell can be done by:
   a) adjusting the light facing angle all day
   b) placing colored acetates on the cell
   c) cooling the cell
   d) changing its direction to north

6. Solar photovoltaic cells were originally developed for:
   a) desert cooling
   b) winter use
   c) the space program
   d) brick houses

7. Developing solar energy is important because it:
   a) does not produce pollution
   b) keeps energy costs down
   c) reduces our dependency on imported energy
   d) all of the above

8. When planning your future home you will:
   a) never consider photovoltaic systems
   b) research the cost of a PV system as a supplement to the grid
   c) work with local builders to find out if PV will be possible
   d) b and c

9. The ammeter reads:
   a) volts
   b) amps
   c) ohms
   d) none of the answers

10. In a series connection:
    a) the positive terminal is connected to the positive terminal
    b) the negative terminal is connected to the negative terminal
    c) the positive terminal is connected to the negative terminal
    d) all of the above

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