Photovoltaic Cells

Lesson 2 of 2

Grade Level: 9-12
Subject(s): Physics, Mathematics, Technology
Prep Time: 10- 30 minutes
Activity Duration: 50 minutes
Materials Category: Special requirements

National Education Standards				
Science	Mathematics	Technology		Geography
		ISTE	ITEA	
3b, 3f, 6a, 7c, 7d	4b, 5a, 6c		3b, 3d, 5a, 16b, 16d, 16e	

Objective:

To test and calculate the effectiveness of a solar panel.

Materials:

- Small direct current (DC) electric motor
- Solar panel
- String
- Mass set
- Stopwatch
- Meter stick
- Ring stand and clamps
- Multimeter
- A strong light source

Related Link(s):

Solar Energy Conversion
http://spacescience.nasa.gov/osstech/solar.htm

Solar Physics
http://wwwssl.msfc.nasa.gov/ssl/pad/solar/

Pre-lesson Instructions

- Obtain materials.
- Put together one experimental setup to use as a display and to show students how to set up their equipment.
- Show students how to connect the multimeter to the solar panel.

Background

Most photovoltaic cells are made of silicon. Silicon makes up 28 percent of the Earth's crust. The silicon is heated to extreme temperatures. It is doped with chemicals, usually boron and phosphorous. This sets up an unstable environment within the cell. When light strikes the cell, electrons are dislodged and travel along wires placed within the cell. The electrons follow the wire and power to whatever is attached.

Guidelines

1. Read the 9-12 NASAexplores article, "Beaming Down Energy." Discuss the advantages and disadvantages of using solar energy.
2. Check each experimental set up after students have attached the motor to the ring stand. Do not let students proceed with the procedure until their experimental set up has been approved.

Discussion / Wrap-up

- Discuss results with students.
- Go over the answers to the questions with the class.
- Conclude by asking students "*Would you recommend the use of photovoltaic cells (PV) cells in a home? Why or Why not?*"

Extension(s)

- ❑ Complete Lesson 1 under the article 9-12 NASAexplores entitled, "Beaming Down Energy."
- ❑ Read the 9-12 NASAexplores article, "Helios, Taking Power From The Sun," then complete Lesson 3 "Build A Solar Vehicle" under this article.

Photovoltaic Cells

Student Sheet(s)

Background

Photovoltaic (PV) cells are devices that convert sunlight to electricity. PV stands for photo (light) and voltaic (electricity), whereby sunlight photons free electrons from common silicon. In 1839, a French scientist named Edmund Becquerel observed that light, falling on certain materials, produced electricity. The amount of electricity varied with the amount and intensity of light. Scientists made solar cells of selenium in the 1880s. Modern PV technologies were developed at Bell Labs and RCA Labs in the mid 1950s. During the Carter administration, the US Department of Energy spent $ 500 million developing this technology.

PV is a semiconductor-based technology used to convert light energy into direct current (DC) electricity, using no moving parts, consuming no conventional fuels, and creating no pollution. Simple PV systems power everyday items like calculators and watches. More complicated systems run appliances, houses, the Hubble telescope, and spacecraft such as the International Space Station. The largest market for PV today is in developing countries, in village power and remote communications systems (estimates indicate that more than 2 billion people world wide have no access to conventional electric power).

In a PV cell, a semiconductor composed of a thin layer of silicon crystal absorbs photons, or particles, of solar energy. The energy of the photons transfers to electrons in the semiconductor. The energized electrons then break free from the silicon atoms and flow in an electric current.

Typical solar cells include a glass cover to keep the weather out, an antireflective coating to prevent sunlight from bouncing off, and electrical contacts, or metallic grids, that collect photons from the semiconductor and transfer them to an electric circuit.

The use of silicon crystals in the photovoltaic cells makes it expensive. First of all, silicon crystals are currently assembled manually. Secondly, silicon purification is difficult, and a lot of silicon is wasted. In addition, the operation of silicon cells require a cooling system because performance degrades at high temperatures. However, it has convinced analysts that solar cells will become a significant source of energy by the end of the century. Today, the chemical giant Exxon is the second largest producer of solar cells.

Using a PV system can be more expensive than buying power from the local utility. However, it is dramatically less expensive than running a power line to a site currently without service (off-grid homes, more than 0.25 mile [or 0.4 kilometer] away from power, or a mountain-top communications system). The total system cost could be as low as U.S. $7/watt or as much as U.S. $20/watt or more, depending on the complexity.

How much PV you need depends on your power loads. If you wanted to completely replace your current electrical purchases from the utility with a PV system, you could look at your kilowatts per hour (kWh) usage on your electric bills for a year, calculate a daily average, and divide that by the number of average daily Sun hours for your location. (3600 kWh/yr divided by 365 days/yr equals approximately 10 kWh/day, divided by 5 Sun-hours per day (for locations in middle America), equals 2 kW. This would indicate that a 2-kW system would, over the course of an average year, produce enough energy to replace the power you are currently using. The majority of home systems range from 1 kW to 2 kW.

Materials

- Small DC electric motor
- Solar panel
- String
- Mass set
- Stopwatch
- Meter stick
- Ring stand and clamps
- Multimeter
- A strong light source

Procedure

1. Clamp the electric motor to the ring stand and position the motor so the shaft extends out over the edge of the table.

2. Attach the string to the shaft of the electric motor so that when the motor runs the string will wind up around the shaft.

3. Put the solar panel on the table, wire it to the motor, and check its polarity.

4. Shine a bright light on the solar panel and watch for the motor shaft to begin turning. If it fails to turn, use the multimeter to check for output from the solar panel and input to the motor. Change connections as needed. (Note—in most cases you will connect the red clamp on the PV cell to the red clamp on the meter. Connect the black clamp on the PV cell to the black clamp on the meter).

5. Attach a known mass to the loose end of the string so that as the shaft of the motor turns, the mass is lifted from the floor.

6. Choose a light source and place it at a set distance from the cell so that most of the light hits the solar panel. Connect the panel to start the motor turning.

7. As the mass is raised, use the stopwatch to measure how long it takes it to reach the top of the ring stand. Record data.

8. Repeat step 7, this time using the multimeter to measure current flowing to the motor and the motor's resistance. Record data.

9. Calculate the efficiency of the solar cell by comparing output power to input power using the following equation:

   power input (watts) =
   Current (amps measured by the multimeter) squared resistance (ohms) x time needed to raise the weight (sec)

10. Determine the output power using this equation:

   power output (watts) =
Mass of the weight (kg) x gravity (9.8 m/s^2) x height (distance mass was raised), divided by time needed to raise the mass (sec) power output (watts).

11. Determine the efficiency by dividing the output power by the input power and multiplying the result by 100%.

Questions

1. What is a photovoltaic cell?

2. How does a photovoltaic cell work?

3. What are the advantages of using photovoltaic cells versus other energy sources?

4. Why are photovoltaic cells expensive?

5. What variables are in or could be introduced to this experiment?

6. Summarize your findings of this experiment.