The Colour Sensitivity of a Photovoltaic Cell

Brief description

In this activity, students will use coloured light projected from the lens of an LCD projector to test the colour sensitivity of one or more kinds of photovoltaic (PV) cells. Using digital voltmeters, students will measure the voltages developed by the PV cells, and then graph the results.

Learning objectives

Students will

- identify manipulated and responding variables in a simple optics experiment
- demonstrate skill in the measurement of small voltages using digital measuring equipment
- describe how PV cells generate electricity
- graph the quantitative observations of this experiment
- draw conclusions about the efficiency of PV cells based on their observations

Length of Time

Two class periods
Period 1: background reading (optional)
Period 2: investigation

Background

Not all photovoltaic cells are equal. There are several different kinds, and many manufacturers. The substrate materials, protective coverings, and photosensitive layers of which they are composed each affect their efficiency at producing electricity. Currently, the efficiency of solar cells ranges from between about 10 and 20per cent, depending on the type of cell. Predictably, the most efficient cells are also the most expensive and difficult to make. The most efficient cells available today are those cut from single giant crystals of silicon. These are called “monocrystalline” PV cells. Cheaper, but slightly less efficient, are the “polycrystalline” PV cells, cut from masses of smaller, compact silicon crystals. The least efficient, but also the least expensive are “amorphous” PV cells, made by layering vaporized silicon onto a glass or plastic substrate.

Not only do PV cells vary with respect to their efficiency – they also vary widely in terms of their response to different wavelengths of light. The broader the spectrum of light to which the PV cell is sensitive, the more electricity it can produce from white light or sunlight. The aim of much current research is to make PV cells that respond well to the widest possible range of incoming light frequencies. This research is helping to make PV cells ever more efficient.

Materials

- digital voltmeter
- PV cell (with attached leads)
- access to an LCD projector and computer

- student worksheet: Measuring The Colour Sensitivity of Photovoltaic Cells
- student backgrounder: Solar Electricity from the re-energy.ca Web site (http://www.re-energy.ca/pdf/bg3.pdf)

Procedure

Period 1: *Background reading on solar electricity.*

Distribute copies of the Solar Electricity backgrounder, and have students read through it (this may best be assigned as homework). Be prepared to take up questions when students have finished reading the backgrounder.

From the backgrounder:

- List all the appliances in your home, school, or neighbourhood that have a PV cell or array on them. *Answers will vary. Students may be able to identify calculators, roadside emergency phones, PV-powered road construction signs, and other applications. Many other appliances have very small "photocells"—small, button-sized photosensitive elements used in cameras, automatic outdoor security lights, digital alarm clocks, and other systems.*

- What are the advantages of generating electricity using PV cells over that made from fossil fuels, nuclear fuels, or hydroelectricity? *The main advantages are as follows: a) no fuels of any kind are consumed during the production of the electricity, and no flooding or other forms of environmental disturbance is required once the panels are put into service; b)PV cells do not produce pollution or noise during operation; c) without any moving parts, PV cells require very little maintenance.*

- What are the problems or disadvantages of generating electricity using PV cells? *a) PV panels are expensive to make and install; b) they only work during the day, and most efficiently when skies are cloud-free; c) they produce relatively little electricity per day, and therefore place severe restrictions on what can be powered by them.*

Period 2*: Measuring the Colour Sensitivity of Solar Cells*

Complete instructions for conducting this activity appear in the Student Activity component, below. To prepare, you will need to create a PowerPoint? slide series featuring blank slides of different colours. Your students will expose their solar cells to these slides, and record the voltages produced. Begin by creating five blank slides in PowerPoint?. Next, right mouse click on each slide to set its background fill color. From the "more colors" drop-down menu, select red, orange, yellow, green, medium blue, and medium purple. Save your slides as a desktop file and connect the computer to the LCD projector. You will need to set this up in a dark corner of your classroom.

Comprehension

Answers to the student questions will vary depending on the kind of PV cells they are using.

Tips and extension activities

If you do not have access to an LCD projector, you may be able to substitute 35mm colour slides. Simply shoot pictures of clean, brightly coloured paper using 35mm slide film, and then have the film developed. You can load your colour slides into a carousel and direct an unfocused beam onto a wall or screen for your students to use.

Student Activity

Introduction and Background

Not all photovoltaic (PV) cells are equal. There are several different kinds, and many manufacturers. Their substrate materials, protective coverings, and photosensitive layers of which they are composed each affect their efficiency at producing electricity. Currently, the efficiency of solar cells ranges from between about 10 and 20 per cent, depending on the type of cell.

Not only do PV cells vary with respect to their efficiency – they also vary widely in terms of their response to different wavelengths of light. The broader the spectrum of light to which the PV cell is sensitive, the more electricity it can produce from white light or sunlight. The aim of much current research is to find ways to manufacturer PV cells that respond well to the widest possible range of incoming light frequencies. This research is helping to make PV cells increasingly more efficient.

Your task in this investigation is to discover to which colours or wavelengths of light a solar cell is most sensitive. You will be measuring this by recording the voltage produced by a solar cell when it is exposed to different colours of light.

What you will learn

When you have completed this investigation, you should be able to

- identify manipulated and responding variables in simple optics experiment
- demonstrate skill in the measurement of small voltages using digital measuring equipment
- graph the quantitative observations of this experiment and
- draw conclusions about the efficiency of PV cells based on observations

Materials

You will need

- digital voltmeter
- PV cell
- Student Observation Sheet (attached)

Procedure

Your teacher has created a series of coloured slides. You will be working with a partner to complete this investigation. You or your partner will expose your PV cell to the coloured light from the slides and the other person will measure the voltages the cell produces.

1. Set your voltmeter so that it measures direct current (DC) voltages. If your voltmeter does not automatically detect voltage ranges, set the meter to its lowest range (most have a 2-volt range).
2. Connect your voltmeter to the PV cell. If necessary, use alligator clip test leads to secure the connections.
3. Test your voltmeter to be sure it is working. Do this by covering your PV cell with your hand or a piece of paper. The voltage should drop noticeably.
4. Go to the location where the slides are set up, and test your PV cell with each of the colours. Be sure the room lights are turned off during this step. Hold the PV cell against the screen or wall so that the projector's beam falls directly onto it. Have your partner record your measurements on the attached observation sheet.
5. Answer the questions outlined on the observation sheet.

Observation Sheet

Colour	Approximate wavelength (nanometers)	DC Voltage
Purple	390-455	
Blue	455-492	
Green	492-577	
Yellow	577-597	
Orange	597-622	
Red	622-780	

Graph your Results

You can use this chart to illustrate your results, or you may use a computer and graphing software such as Microsoft Excel to prepare a bar chart.

0Volts (DC) 0 .1 .2 .3 .4 .5 .6 .7 .8 .9						
	Red	Orange	Yellow	Green	Blue	Purple

Questions

1. Which colour produced the greatest voltage?

2. Which colour produced the smallest voltage?

3. What is the consequence of a PV being more sensitive to some colours than to others?

4. At what time of the day would you expect the PV cell to produce the most electricity? Why?