27C Efficiency of a Solar Cell

How can we use energy from the sun to generate electricity?

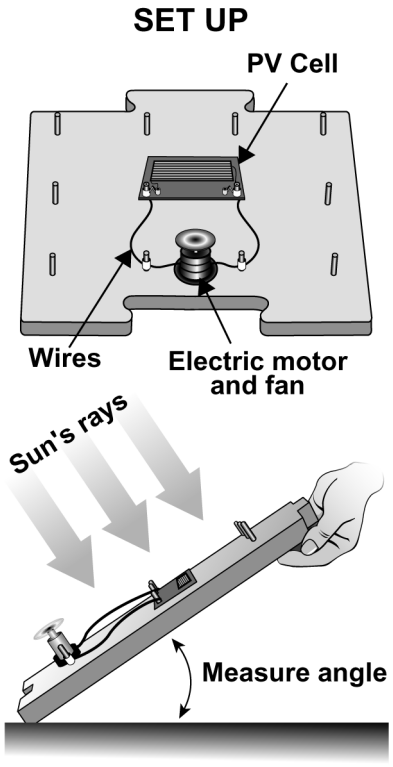
The sun produces 3.9×10^{26} watts of energy every second. Of that amount, 1,386 watts fall on a square meter of Earth's atmosphere and even less reaches Earth's surface. This energy can be used to generate electricity without producing pollution or dangerous wastes. Photovoltaic (PV) cells convert sunlight *directly* into electricity and are used to run small appliances such as calculators and outdoor light fixtures. Many PV cells can be wired together to form *panels* that can be used to run larger devices such as irrigation pumps, radar stations, and even refrigerators. How much power does a PV cell produce? How efficient is a PV cell at converting the sun's energy into power?

Materials

- Solar cell with electric motor
- Small box
- Light fixture or lamp
- 100 W Light bulb
- Multimeter
- Electric Circuits kit

1 Setting up

1. Gather the following materials: PV cell, electric motor with fan, wires, circuit grid, digital multimeter, protractor.
2. Measure the length and width of your PV cell (do not include the base) and calculate its area in square centimeters. Record this value.
3. Build a circuit with the PV cell and the electric motor with fan on the circuit grid. Use the wires to make connections.
4. Bring this setup outside into direct sunlight.
5. Set the circuit grid on level ground and hold it so that the sun casts no shadow over it.
6. Vary the angle of the electric circuit board by tipping one end of it up or down. Record your observations of what happens to the speed of the fan at different angles.
7. Record the angle at which you get the fastest fan speed.

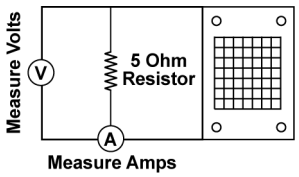


a. How does changing the angle of the PV cell affect the speed of the fan?

b. At which angle is the fan's speed the fastest?

c. Why do you think the angle of the PV cell affects the speed of the fan?

2 Measuring electrical quantities in the circuit



1. Readjust the angle of the electric circuit board until the fan's speed is its fastest. Record the angle.
2. Replace the fan with a 5-ohm resistor.
3. Use the digital multimeter to measure **voltage** across the resistor.
   Record the voltage.
4. Disconnect the circuit at point A and measure **current** in the circuit.
   Record the current.

3 How efficient is your photovoltaic cell?

In this part of the Investigation, you will determine how much of the energy that is reaching your PV cell is being converted into **power**. To do this, you will use your data from Parts 1 and 2.

a. Use the formula below to calculate the **power output** of your PV cell in watts/cm^2.

$$\frac{\text{voltage} \times \text{current}}{\text{area}} = \text{watts}/\text{cm}^2$$

Record your result.

b. Multiply your result by 10,000 to convert the value to watts/m^2. Record your result.

The amount of the sun's energy that reaches the edge of Earth's atmosphere is known as the **solar constant**. While the solar constant varies slightly, the average value is 1,368 watts per square meter (W/m^2). To visualize this amount of energy, imagine the energy of thirteen 100-watt light bulbs spread over a single square-meter surface.

How much of this energy actually reaches Earth's surface on a sunny day? This amount varies according to the time of year. The following values are estimates for how much energy reaches Earth's surface on a sunny day, according to the time of year:

- 1000 watts/m^2 on a sunny summer day.
- 900 watts/m^2 on a sunny autumn or spring day.
- 700 watts/m^2 on a sunny winter day.

Depending on the time of year, one of the values above is the *power input from the sun* that is converted into electrical energy by your PV cell

c. Calculate the efficiency of your photovoltaic cell using the formula below.

$$\%\ \text{efficiency} = \left(\frac{\text{power output of your PV cell}}{\text{power input from the sun}} \right) \times 100$$

Record your result.

d. Most PV cells have efficiencies between 5 and 20 percent. How does yours compare?

4 Applying your knowledge

a. Besides angle, what other factors do you think will affect the energy output of your PV cell?

b. PV cells are found on satellites, space probes, and the space shuttle. Do you think the power output of your PV cell would be greater or less just beyond Earth's atmosphere? Explain your answer.

c. With your group, design and conduct an experiment that addresses one of the questions below. Prepare a lab report that explains your hypothesis, procedure, data analysis, and conclusions.

- How does the *distance from a light source* affect the power output of a PV cell?
- How does the *color of light* affect the power output of a PV cell?
- How does *temperature* affect the power output and efficiency of a PV cell?