Solar Energy Discovery Lab

Objective

Set up circuits with solar cells in series and parallel and analyze the resulting characteristics.

Introduction

A photovoltaic solar cell converts radiant (solar) energy into electrical energy, using diode technology. Two layers of a semiconductor, such as silicon are each *doped* by adding small amounts impurities. The two layers are then joined together. Each layer is doped differently, resulting in an electric field at the junction of the two layers. Sunlight ionizes some of the atoms in the top, exposed layer of the solar cell and they migrate toward the inner layer, effectively turning the outer layer into a cathode (positive terminal) and the other into an anode (negative terminal). If the circuit is completed, conventional current will flow from the cathode to the anode.

Equipment

Solar panel containing three 1.5-volt solar cells (2 per group), alligator clip leads, solar irradiance meter (only one for the class), small table (outside only) flood lamp, blue ammeter, orange voltmeters, meter stick, support stand, frosted light bulb, music toy, tumble buggy, transistor radio, LED circuit, 20-ohm resistor

←Solar panel with 3 cells

Irradience meter →

Preliminary Activity

Get acquainted with your solar panel. Note that each 1.5-volt cell consists of 3 separate strips, made of doped silicon crystals. Each strip is actually a "mini-cell". The 3 strips make up one of the 3 cells in the panel. They are permanently connected in series by a thin metallic band, which connects to a positive and negative terminal. There are 3 of these cells, each physically separated from the other two. Turn the panel over to see the connections. Each panel has 4 yellow wires with circular connectors at the end. This allows you to connect the 3 cells in series or parallel. The panel is on a base that allows it to be tilted at an optimum angle (90°!) relative to the rays of the light source.

Part 1 – Ideal current and voltage

The open-circuit voltage (V_{oc}) of a solar cell along with the short-circuit current (I_{sc}) are ideal values for a solar cell. V_{OC} is the maximum voltage available from a solar cell, and this occurs at zero current. I_{sc} is the current through the solar cell when the voltage across the solar cell is zero (i.e., when the solar cell is short circuited). They are both measured without any load. In this activity you will measure V_{oc} and I_{sc} for the following combinations: 1 cell, 2 cells in series, 3 cells in series, 2 cells in parallel, 3 cells in parallel. The schematics on pages 3 and 4 explain how to wire the different combinations. You can use the orange multimeter as both a voltmeter (red lead in the volt/ohm hole, 20 V) and an ammeter (red lead in the mA hole, 200 mA), without changing its position. The short-circuit current and the open-circuit voltage are the maximum current and voltage respectively from a solar cell. At both of these operating points, the power (P= IV) from the solar cell is zero. Keeping this in mind, we will calculate the product of V_{oc} and I_{sc} to see how this value varies with the different combinations. Note: If doing the experiment indoors, the flood lamp should be 20 cm from the solar cell.

Data for Part 1

Wiring (series/parallel)	V_{oc} (volts)	I_{sc} (mA)	V_{oc} x I_{sc} (mW)
Single cell			
2 cells in series			
3 cells in series			
2 cells in parallel			
3 cells in parallel			

Parallel Connections

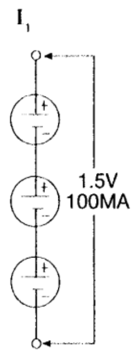

Figure 13

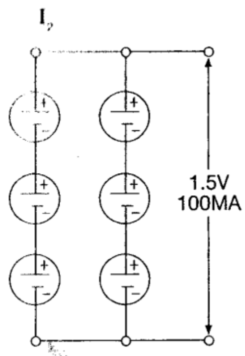

Figure 14

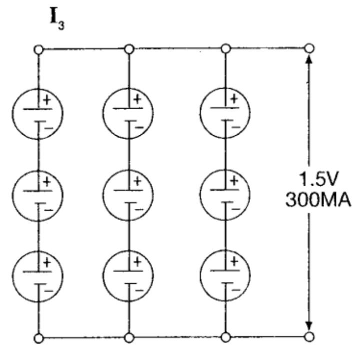

Figure 15

I_1
1.5V 100mA connecting system (see Figure 13).

I_2
1.5V 200mA connecting in parallel system (see Figure 14).

I_3
1.5V 300mA connecting in parallel system (see Figure 15).

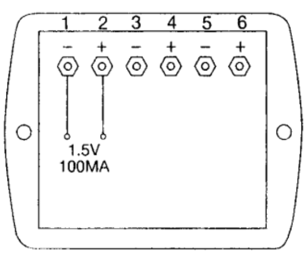

Figure 16

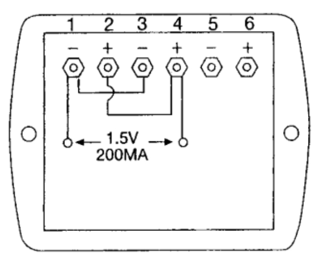

Figure 17

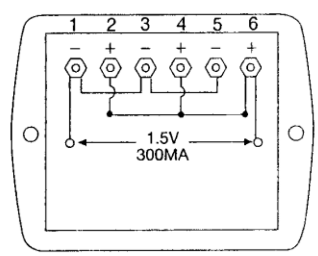

Figure 18

Screw point No.1 and No.2 are the output (see Figure 11 & 30).

Positve screw point (No.2) connect to positive (No.4), negative (No.1) connect to negative (No.3), then No.1 and No.4 are the output at 1.5V 200mA (see Figure 17, 20 & 21).

Positve screw point (No.2) connect to positive (No.4), negative (No.1) connect to negative (No.3), positve (No.4) connect to positive (No.6), negative (No.3) connect to negative (No.5), then No.1 and No.6 are the output at 1.5V 300mA or No.1 and No.2 are the same output at 1.5V 300mA (see Figure 18, 20, 21, 22, 23 & 24).

Series Connections

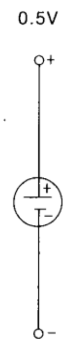

Figure 6

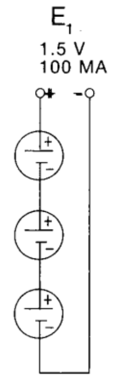

Figure 7

E_1
1.5V 100mA connecting system (see Figure 7).

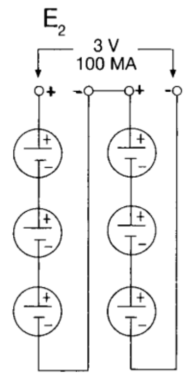

Figure 8

E_2
3V 100mA connecting in series system, negative connect to positive (see Figure 8).

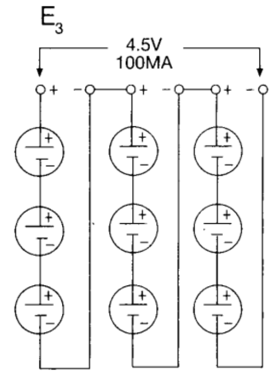

Figure 9

E_3
4.5V 100mA connecting in series system, negative connect to positive (see Figure 9).

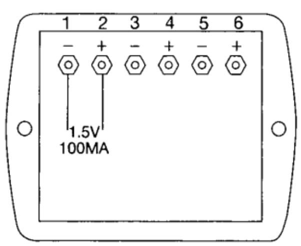

Figure 10

Screw point No.1 and No.2 are the output (see Figure 10 & 30).

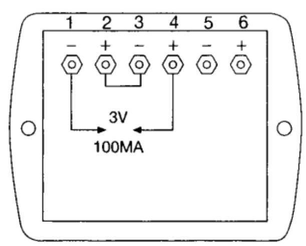

Figure 11

Screw point No.2 connect to No.3, then No.1 screw point and No.4 are the output (see Figure 11 & 31).

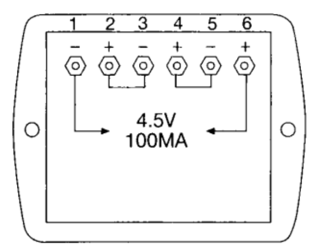

Figure 12

Screw point No.2 connect to No.3, screw point No.4 connect to No.5, then screw point No. 1 and No.6 are the output (see Figure 12 & 32).

Questions for Part 1

1. Which solar cell configuration resulted in the largest V_{oc}? ________________________

2. Which solar cell configuration resulted in the largest I_{sc}? ___________________________

3. How did V_{oc} change when you added cells in series? In parallel?

4. How did I_{sc} change when you added cells in series? In parallel?

5. What observations did you make regarding the product V_{oc} x I_{sc} ? How did it vary among the different configurations?

6. Based on your results, how would you wire solar cells when the load draws a high current, but does not need a large voltage? Would you change the wiring if the load required a relatively high voltage and less current? If so, how?

Part 2: Playing with Toys

For each of the 5 items available, determine if it operates better with 3 cells wired in series or in parallel. Choose the best configuration and then try it with 2 cells wired together in the same configuration (i.e. series or parallel). If it still works, try it with a single cell. Write down your observations in the table provided below (did it get weaker, slower, etc.):

Data for Part 2

Toy	3 Series	2 Series	3 Parallel	2 Parallel	Single
music					
radio					
bulb					
LEDs					
buggy					

Questions for Part 2

1. According to your observations, which device (or devices if was close) do you think require the most voltage to operate? Explain your reasoning:

2. According to your observations, which device do you think require the most current to operate? Explain your reasoning:

3. Why do you think noise came out of the music player even when there was no light directly on the solar panel? Do you think this device uses a lot of either voltage or current? Explain:

Part 3: Efficiency of a solar cell

Efficiency is defined as the ratio of energy output from the solar cell to input energy from the sun or other light source. Since the total energy output is dependent on both the amount of time, and the area of the solar cell, we use the ratio of intensities, where intensity is energy per unit second per unit area. Input intensity is given by the irradiance meter (see photo). This value (in Watts/m^2) is called the solar intensity (just light intensity if it's not the sun). We assume the irradiance meter reads 100% of the light intensity (not entirely true, but its tiny solar panel is of very high quality). The irradiance meter tells us the input intensity, and we measure the output intensity of the solar cell as follows.

Procedure

1. Set up a circuit using a single solar cell in series with a 20-ohm resistance. This resistance was chosen experimentally because it produces maximum power for our solar cell. While the sun or light is shining on the solar cell, determine the voltage across the resistor. Repeat this for the other two single cells, for a total of 3 voltage measurements. Record your values in the table.

2. Measure the area of a single solar cell. This is everything that is blue between the two connected terminals. Assume all of the cells on your panel have the same area. These are very small measurements, so be accurate. Report your answer in SI units: ________________

3. Calculate the output intensity by first determining the solar cell's output power (P = IV and I = V/R) in watts and dividing that by the area of the one cell in square meters. Record your answers in the table below.

4. Use the irradiance meter, either outside or indoors at a distance of 20 cm from the flood lamp, to find the input light intensity. Be sure that the tiny wafer on the front of the meter is at right angles to the incoming light. Record your answer here. Include units!

____

5. Calculate Efficiency: Eff% = Output Intensity/ Input Intensity x 100%. Record your results in the table below.

Data for Part 3

Circuit Voltage (V)	Power (W)	Ouput Intensity (W/m^2)	Efficiency (Eff%)
1.			
2.			
3.			
Av:			

Questions for Part 3

1. Were you surprised to find out what the efficiency of the solar cell is ? Do some research to find out what the typical efficiencies of a solar cell are in the "real world" . How does your efficiency compare? Hint: solar handout #2 gives both optimistic and typical values for solar cell efficiency

2. According to handout #2 (or any other source you may find) what are some reasons that the efficiency is not higher?

Part 4: Solar power vs. wind power

When available, investigate the small wind power demo set up on one of the lab tables.

Questions:

1. Describe the behavior of the current, voltage and bulb brightness as you make the "wind" stronger:

2. How does this compare with the behavior of the solar cell as you increase either voltage or current?

Conclusions

1. What are some of the disadvantages of using solar energy (by the way, did you go outside today?)? What are some of its advantages? Is San Diego a promising location for solar power? Why or why not?

2. If you decided to install solar panels on your roof to “get off the grid”, what are some of the factors you might want to consider beforehand, based on the results of this lab?

3. What might be some of the disadvantages associated with using wind energy? What are some of its advantages? Is San Diego a promising location for wind power? Why or why not?