E

Investigating Solar Energy

4th Edition

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ELB-SOLAR

Vernier

Contents

Experiments

Appendices

Equipment Used in Experiments

		Energy Sensor	Surface Temperature Sensor	Resistor Board	Solar Energy Exploration Kit				
					2 V Solar Panel	Sound and Light Board	LED set (red, green, blue)	Pump and Tubing	Motor
1	Introduction to Solar Panels				1	1			
2	Exploring Solar Energy				1	1	1		
3	Intro to the Energy Sensor	X		X	3				
4	Making Connections: Circuits	X		X	3				
5	Solar Panel Output: Effect of Load	X		X	3				
6	Solar Panel Output: Effect of Shade	X		X	3				
7	Solar Panel Output: Effect of Angle	X		X	3				
8	Pumping Water with Solar Energy	X			3			1	
9	Exploring Surface Temperature		X						
10	Project: Solar Homes		X		3				1
11	Project: What's Cookin'?		X						

Name: _____

LabQuest App 2

Exploring Solar Energy

Electricity can be challenging to study because, like wind, you cannot see it. To understand electricity, you need to first learn about atoms.

Atoms are very, very small. Trillions of atoms fit in the period at the end of this sentence. Atoms are the building blocks of everything in the universe—each plant, building, and person.

Atoms are made up of even smaller particles, including particles called *electrons*. Some of the electrons may be knocked loose when they are hit by light energy. The movement of these electrons is what we call electricity.

Solar cells are made of two thin pieces of silicon (an element that forms glass-like crystals) that are connected together. When light energy from the sun strikes the solar cell, energy is transferred to electrons in the silicon. When the solar cell is connected to a closed circuit, the electrons start to flow through the circuit.

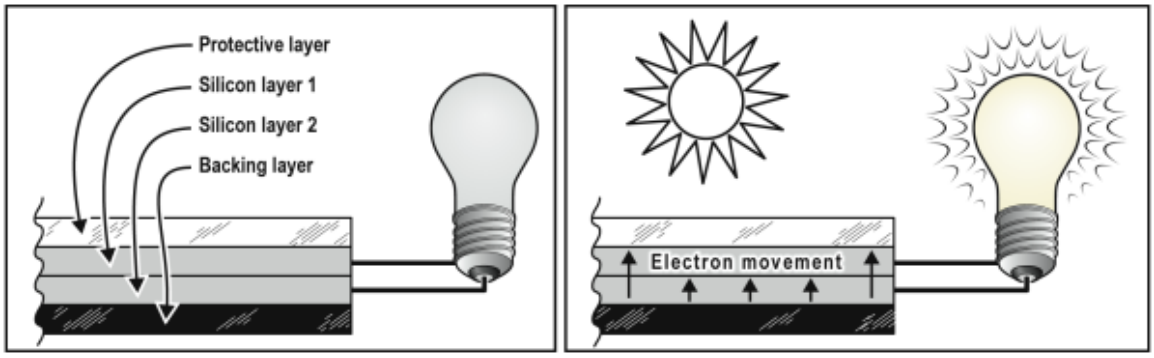


Figure 1

OBJECTIVES

- Use electrical energy produced by a solar panel to play a tune and light up LEDs.
- Investigate the relationship between solar panel angle, orientation, and shade and the ability to play a tune or light up an LED.
- Verify that energy is transferred by electric currents in a closed circuit.

MATERIALS

KidWind 2 V Solar Panel
KidWind Sound and Light Board
KidWind LEDs (red, green, and blue)
17.5 cm piece of chipboard
marker or colored pencil

VOCABULARY

Vocabulary term	Explanation
atom	Atoms are the building blocks of the universe. Atoms contain protons, neutrons, and electrons.
closed circuit	a closed loop that electrons travel through
electron	the negatively charged particles outside the nucleus of an atom
proton	the positively charged particles that are in the nucleus of an atom
silicon	an element that is a semi-conductor and used in electronics
variable	a factor that can be controlled, changed, or measured in an experiment

PRE-LAB ACTIVITY

1. Label Figure 2 with the following parts:

   a. solar cell
   b. solar panel
   c. red (+) wire
   d. black (–) wire

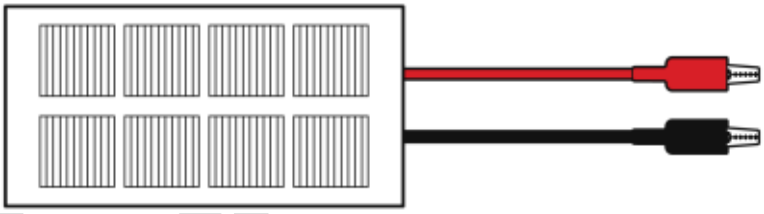


Figure 2

2. Use a marker or colored pencil to trace the path of the flow of electrons in Figure 3.

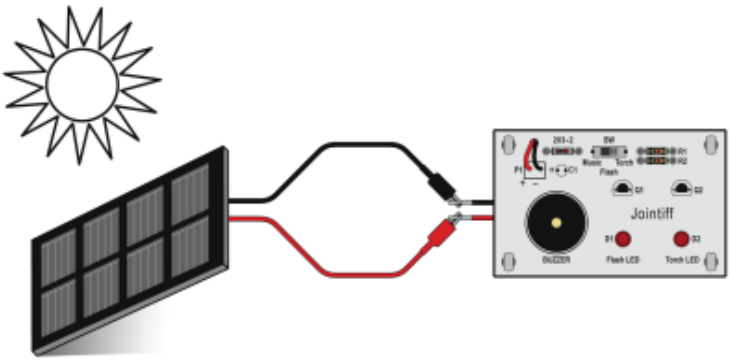


Figure 3

PROCEDURE

Part 1 Set up and check the equipment

1. Go outside and make observations about the place where you will collect data.

Table 1 Observations	
Date	
Time	
Cloud cover	None 25% 50% 75% 100%
Air temperature	
Other	

2. Connect the red LED to the Solar Panel to build a closed circuit (see Figure 4).

   a. Connect the red wire on the red LED to the red wire of the Solar Panel. When you do this, connect the clip from the Solar Panel to the metal part at the end of wire from the LED.

   b. Connect the black wire on the red LED to the black wire of the Solar Panel. When you do this, connect the clip from the Solar Panel to the metal part at the end of wire from the LED.

   c. Clear an area and make sure your Solar Panel is in direct sunlight.

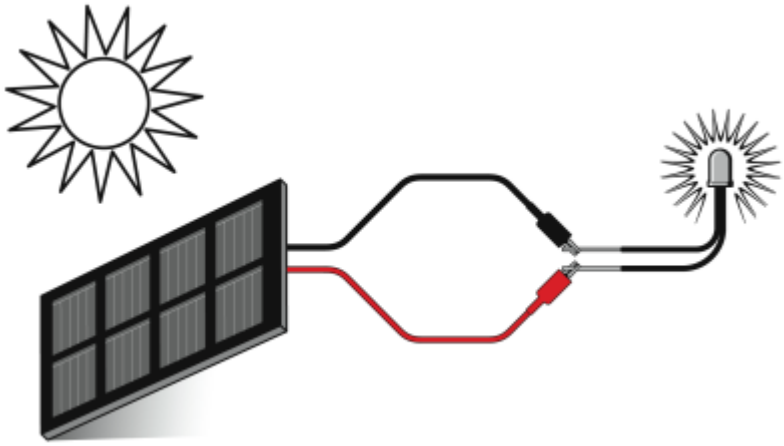


Figure 4

3. Position the Solar Panel and check that everything is working correctly. **CAUTION**: Never look directly at the sun.

Part 2 Exploring Solar Panels, LEDs, and direction

1. Identify where the directions north, east, south, and west are at the location where you are working.

2. Have one person hold the Solar Panel vertically (see Figure 5) while facing north. **CAUTION**: Never look directly at the sun.

Figure 5

3. Have another person place cupped hands around the red LED.

4. Move the Solar Panel slowly in a circle clockwise to face east, south, west, and then back to north. **CAUTION**: Never look directly at the sun.

5. Describe what you observed with the brightness of the red LED when the Solar Panel faced different directions.

_____

_____

_____

6. Disconnect the red LED, and connect the green LED.

7. Have one person hold the Solar Panel vertically while facing north, and have another person place cupped hands around the green LED.

8. Move the Solar Panel slowly in a circle clockwise to face east, south, west, and then back to north. **CAUTION**: Never look directly at the sun.

9. Describe what you observed with the brightness of the green LED when the Solar Panel faced different directions.

_____

_____

_____

10. Disconnect the green LED, and connect the blue LED.

11. Have one person hold the Solar Panel vertically while facing north, and have another person place cupped hands around the blue LED.

12. Move the Solar Panel slowly in a circle clockwise to face east, south, west, and then back to north. **CAUTION**: Never look directly at the sun.

13. Describe what you observed with the brightness of the blue LED when it faced in different directions.

_____

_____

_____

14. Which LED was the brightest? Explain why you think this happened.

_____

_____

_____

Part 3 Exploring Solar Panels, the Sound and Light Board, and direction

1. Connect the Sound and Light Board to the Solar Panel to build a closed circuit (see Figure 6).

   a. Connect the red wire on the Sound and Light Board to the red wire of the Solar Panel. When you do this, connect the clip from the Solar Panel to the metal part at the end of the wire from the Sound and Light Board.

   b. Connect the black wire on the Sound and Light Board to the black wire of the Solar Panel. When you do this, connect the clip from the Solar Panel to the metal part at the end of wire from the Sound and Light Board.

   c. Clear an area and make sure your Solar Panel is in direct sunlight.

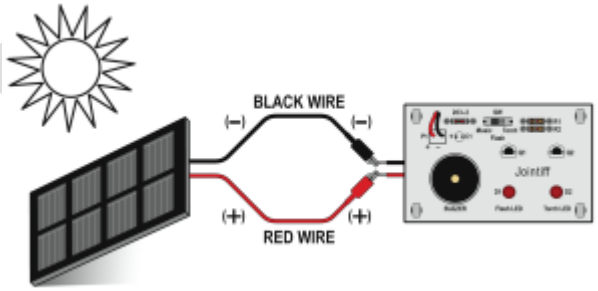


Figure 6

2. Move the switch marked SW on the Sound and Light Board to the Music setting.

3. Position the Solar Panel and check that everything is working correctly. **CAUTION**: Never look directly at the sun.

4. Have one person hold the Solar Panel vertically while facing north. **CAUTION**: Never look directly at the sun.

5. Move the Solar Panel slowly in a circle clockwise to face east, south, west, and then back to north. **CAUTION**: Never look directly at the sun.

6. Describe what you observed with the speed and pitch in which the tune was playing when it was facing different directions. Explain why you think this happened.

_____

_____

_____

Part 4 Exploring Solar Panels, LEDs, and angle

1. In Part 1, which LED was brightest? (Circle one.)

red **green** **blue**

2. Connect the brightest LED from Part 1 to the Solar Panel to build a closed circuit.

   a. Connect the red wire on the LED to the red wire of the Solar Panel (see Figure 4). When you do this, connect the clip from the Solar Panel to the metal part at the end of wire from the Sound and Light Board.

   b. Connect the black wire on the LED to the black wire of the Solar Panel. When you do this, connect the clip from the Solar Panel to the metal part at the end of wire from the Sound and Light Board.

   c. Clear an area and make sure your Solar Panel is in direct sunlight.

   d. Check that everything is working correctly.

3. Place the Solar Panel horizontally on a flat surface at an angle of 0° (see Figure 7).

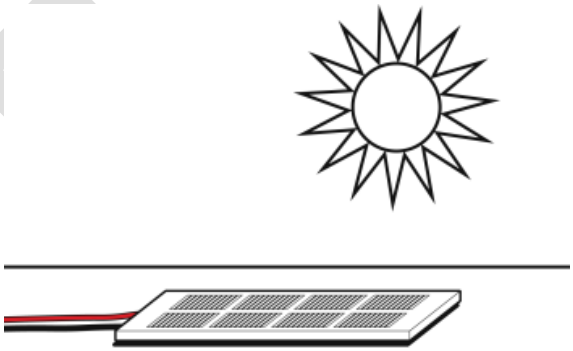


Figure 7

4. Observe the brightness of the LED.

5. Hold the Solar Panel at a 45° angle facing the sun (see Figure 8) and make observations about the brightness of the LED. **CAUTION**: Never look directly at the sun.

6. Hold the Solar Panel vertically at a 90° angle facing the sun (see Figure 9) and make observations about the brightness of the LED. **CAUTION**: Never look directly at the sun.

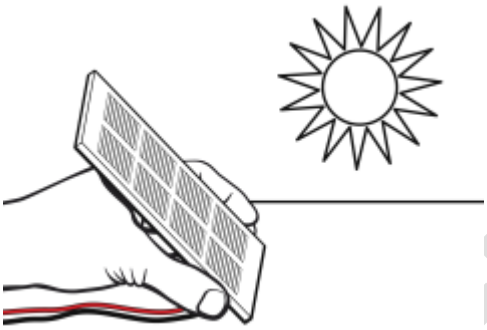


Figure 8 Solar Panel at 45º

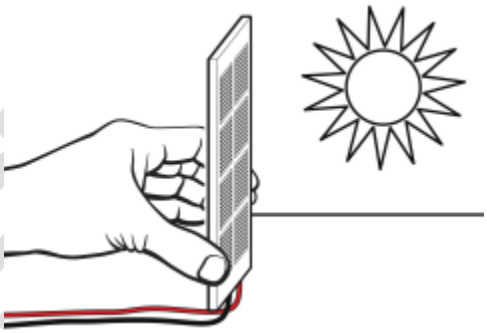


Figure 9 Solar Panel at 90º

7. Describe what you observed with the brightness of the LED when it was held at different angles. Explain why you think this happened.

_____

_____

_____

Part 5 Exploring Solar Panels, the Sound and Light Board, and angle

1. Connect the Sound and Light Board to the Solar Panel to build a closed circuit (see Figure 6).
   a. Connect the red wire on the Sound and Light Board to the red wire of the Solar Panel. When you do this, connect the clip from the Solar Panel to the metal part at the end of wire from the Sound and Light Board.
   b. Connect the black wire on the Sound and Light Board to the black wire of the Solar Panel. When you do this, connect the clip from the Solar Panel to the metal part at the end of wire from the Sound and Light Board.
   c. Clear an area and make sure your Solar Panel is in direct sunlight.
2. Move the switch marked SW on the Sound and Light Board to the Music setting.

3. Position the Solar Panel. **CAUTION**: Never look directly at the sun.

4. Check that everything is working correctly.

5. Place the Solar Panel horizontally on a flat surface at a 0° angle (see Figure 7) and make observations about the speed at which the tune plays.

6. Hold the Solar Panel at a 45° angle facing the sun (see Figure 8) and make observations about the speed at which the tune plays. **CAUTION**: Never look directly at the sun.

7. Hold the Solar Panel vertically at a 90° angle facing the sun (see Figure 9) and make observations about the speed at which the tune plays. **CAUTION**: Never look directly at the sun.

8. Describe what you observed with the speed and pitch at which the tune was playing when it was held at different angles. Explain why you think this happened.

_____

_____

_____

Part 6 Exploring Solar Panels, the Sound and Light Board, and shade

1. Disconnect one of the wire leads from the Solar Panel to create an open circuit.

2. Observe the Solar Panel.

   a. How many solar cells are on the Solar Panel? _____

   b. If two of the solar cells are covered on the Solar Panel, what fraction of the Solar Panel would be shaded? _____/_____ What is another name for this fraction? _____/_____

   c. If three of the solar cells are covered on the Solar Panel, what fraction of the Solar Panel would be shaded? _____/_____

3. For this part, decide whether you want to use the music setting on the Sound and Light Board or one of the colored LEDs. (Circle one. Write the name of the color if you use an LED.)

Music **_____ LED**

4. Connect the LED or Sound and Light Board to make a closed circuit.

5. Find the piece of chipboard. You will use it to cover parts of the Solar Panel.

6. Choose an angle to hold the Solar Panel facing the sun for this experiment. (Circle one.)

0° **45°** **90°**

7. Hold the Solar Panel at the angle you chose in Step 6 facing the sun. **CAUTION**: Never look directly at the sun.

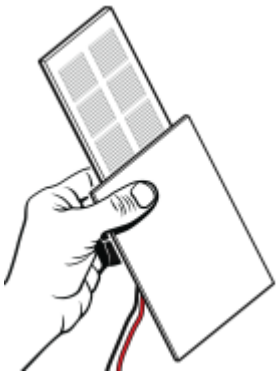


Figure 10

8. Shade the Solar Panel with the piece of cardboard (see Figure 10) in the fractional amounts listed in Table 2. Record your observations about the music or LED.

Table 2	
Shaded part of Solar Panel	**Observations**
Example	*The music plays fast and at a high pitch.*
1/4	
2/4 (1/2)	
4/4	

9. Summarize what you learned about shading the Solar Panel and the ability to play music or illuminate the LEDs.

_____

_____

10. Explain why the state of Arizona generates more yearly solar power than the state of Wisconsin. You may need to research the locations and the climates to help answer this question.

_____

_____

_____

11. Summarize what you have learned about solar energy transfer. Where does it come from? What type of energies did solar energy transform into during your experiments with the Solar Panel and the Sound and Light Board?

_____

_____

_____

CHALLENGE

In Part 6, you used cardboard to shade the solar cells on the Solar Panel and recorded observations about how the shade affected LEDs or music. Take this investigation a step further by devising a systematic way to cover the Solar Panel so you can make observations of the quality of an LED or music tune in greater detail. You might describe the shading in more detailed fractions.

Examples

- 5 out of 8 cells shaded = 5/8 shaded
- 2 complete cells and 5 out of 10 parts of the next cell shaded = 5/16 shaded (half of one cell = 1/16 of all cells on the Solar Panel)

1. Using a ruler and pencil, add more rows to the table, as needed.

2. Place a star next to the row where the music quality or LED brightness noticeably changed.

Table 3	
Shaded part of Solar Panel	**Observations** **music or _____ LED** **(Circle one. Write the name of the color if you use an LED.)**

Name: _____

LabQuest App 3

Introduction to the Energy Sensor

When sunlight hits a solar panel, energy from the sun is transferred to some electrons in the solar panel. This causes the electrons to start moving through the wires connected to the panel. In this experiment, you will use an Energy Sensor to measure the electrons as they move. Three values are used to measure the movement of electrons: current, potential difference, and power.

Current is the measure of the flow of electrons through the wires. When the current is high, the electrons flow quickly through the wire. When the current is low, the electrons flow more slowly. Current is measured in units of milliamperes, often called milliamps for short. The symbol used to represent milliamps is mA.

To make the electrons move through the wire, they need to be "pushed." The amount of push is called the *potential difference*. Potential difference is measured in units of volts. The letter V is used to represent a volt. If you use a AA battery in a flashlight, it has a potential difference of 1.5 V. The AA battery pushes enough electrons to light up the light bulb. Car batteries are usually 12 V. They push more electrons—enough to run the windshield wipers or defrost a window on a cold day.

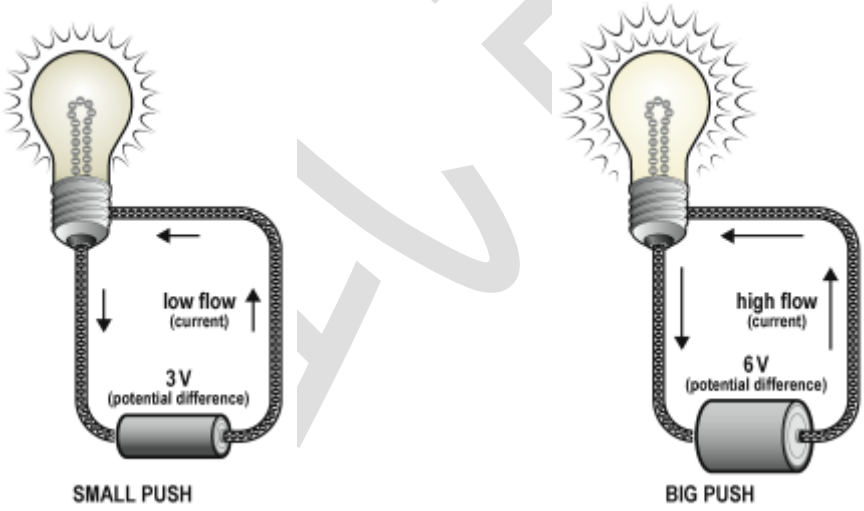


Figure 1

Power is the measure of how quickly energy is generated or used. In this experiment, power is measured in units of milliwatts. The symbol used for milliwatts is mW.

Power is a value that is calculated by multiplying the current and the potential difference

$$\text{power} = \text{current} \times \text{potential difference}$$

The data-collection software that you use in this experiment will do the calculation for you.

Introduction to the Energy Sensor

The following table summarizes the measurements and units you will use in this experiment.

Measurement	Unit	Symbol
current	milliampere	mA
potential difference	volt	V
power	milliwatt	mW

OBJECTIVES

- Set up the data-collection equipment.
- Measure current, potential difference (voltage), and power output of a Solar Panel with the Energy Sensor.
- Use data-collection software to calculate mean (average) values.

MATERIALS

LabQuest
Vernier Energy Sensor
Vernier Resistor Board
KidWind 2 V Solar Panel
box from the Solar Energy Exploration Kit
4 wires with clips (2 black and 2 red)

VOCABULARY

Vocabulary term	Explanation
closed circuit	a closed loop that electrons travel through
current	the flow of electrons in a circuit
electron	the negatively charged particles outside the nucleus of an atom
mean	The mean is the sum of a group of numbers divided by the total number of numbers in the group; sometimes the mean is also called an average.
milliampere	A milliampere is a unit used to measure current. The symbol used to represent a milliampere is mA.
milliwatt	A milliwatt is a unit used to measure power. The symbol used to represent a milliwatt is mW.
ohm	An ohm is the unit used to measure resistance. The symbol used to represent an ohm is Ω.
volt	A volt is the unit used to measure potential difference. The symbol used to represent a volt is V.

PRE-LAB ACTIVITY

In this experiment, there is a lot to learn! Cover up the Vocabulary section and the Introduction so you cannot see them. Then, do your best to fill in the blank spaces in the table:

Measurement	Describe in your own words	Unit	Symbol
current		milliamp	mA
potential difference		volt	
power			mW

PROCEDURE

1. Go outside and make observations about the place where you will collect data. Record your observations in Table 1.

Table 1 Observations					
Date					
Time					
Cloud cover	None	25%	50%	75%	100%
Air temperature					
Other					

Part 1 Set up the equipment

2. Set up the data-collection equipment.
   a. Connect the Vernier Energy Sensor Current and Voltage connectors to LabQuest.
   b. In LabQuest App, choose New from the File menu.

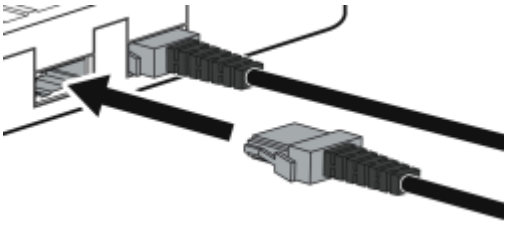


Figure 2

3. Zero the Energy Sensor.
   a. Connect the Energy Sensor Source terminals to each other with a wire, as shown in Figure 3. **Note**: The color of the wire is not important; any color will work.
   b. Choose Zero►All Sensors from the Sensors menu.
   c. Disconnect the wire that connects the Source terminals to each other.

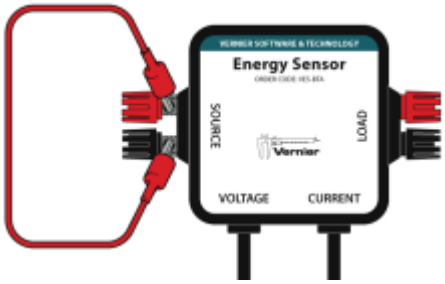


Figure 3

4. Use wires to connect the Resistor Board to the Load terminals of the Energy Sensor.

   a. Clip one end of a wire to the black Load terminal and the other end of the wire to the hole on the left side of the 10 Ω resistor (see Figure 4). **Note**: If you have a black wire, use it. If not, you can use any other color.

   b. Use another wire to connect the red Load terminal to the hole on the right side of the 10 Ω resistor. **Note**: If you have a red wire, use it. If not, use any other color.

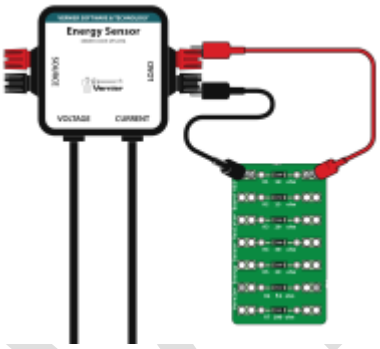


Figure 4

5. Set up the Solar Panel and the Solar Energy Exploration Kit box (see Figure 5).

   a. Attach the Solar Panel to the lid using the hook-and-pile pieces.

   b. Close the lid of the Solar Energy Kit box so the panel lays flat.

Part 2 Explore how to connect the Solar Panel

6. Use wires to connect the Solar Panel to the Source terminals of the Energy Sensor.

   a. Use a **black** wire to connect the black wire from the Solar Panel to the **black** Source terminal (see Figure 5).

   b. Use a **red** wire to connect the red wire from the Solar Panel to the **red** Source terminal.

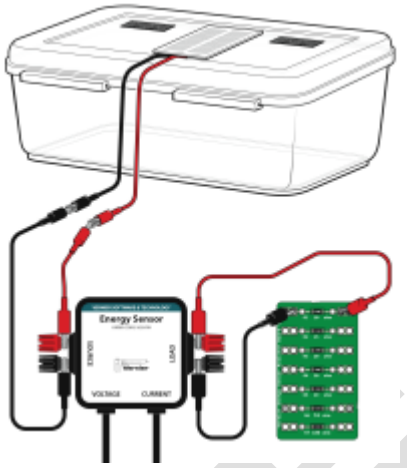


Figure 5

7. Check the connections in the circuit.

   a. Look at the current, potential difference, and power values, and then cover the panel with your hands.

   b. Do the values change when you cover the panel? If they do, everything is set up correctly. If the values do not change, ask your teacher for help.

8. Make sure that the panel is not shaded and look at the current, potential difference, and power values on the screen.

   Are the values positive or negative? (Circle your answers.)

current	positive	negative (–)
potential difference	positive	negative (–)
power	positive	negative (–)

9. Switch the way the Solar Panel is connected to the Source terminals on the Energy Sensor.

   a. Attach the **red** lead to the **black** Source terminal.

   b. Attach the **black** lead to the **red** Source terminal.

10. Check the connections in the circuit.

    a. Look at the current, potential difference, and power values, and then cover the panel with your hands.

    b. Do the values change when you cover the panel? If they do, everything is set up correctly. If the values do not change, ask your teacher for help.

11. Make sure that the panel is not shaded and look at the current, potential difference, and power values on the screen.

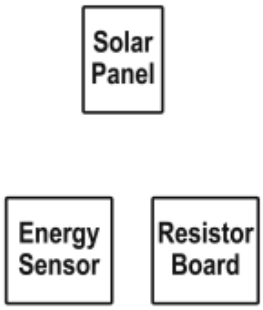
Introduction to the Energy Sensor

Are the values positive or negative? (Circle your answers.)

current	positive	negative (–)
potential difference	positive	negative (–)
power	positive	negative (–)

12. When everything is connected correctly, the current, potential difference, and power values will all be positive. Connect the Solar Panel, the Resistor Board, and the Energy Sensor so the current, potential difference, and power values are all positive.

13. Draw lines on the diagram to connect the boxes to show the connections in the circuit you created for this experiment.



14. Did you draw a closed or open circuit? (Circle one.) **open** **closed**

15. Was energy transferred through the circuit? How do you know?

_____

_____

_____

Part 3 Collect data

16. Make sure that the panel is not shaded and everything is still connected correctly. The box should be closed so the Solar Panel is horizontal.

17. Start data collection. Data collection will stop after 30 seconds.

18. Determine the mean potential difference value.

    a. Choose Show Graph ►Graph 1 from the Graph menu. A single graph is shown.

    b. Tap the y-axis label and select Potential. You will see a graph of potential difference (voltage) *vs*. time.

    c. Choose Statistics ►Potential from the Analyze menu.

    d. Record the mean potential difference (voltage) value in Table 2 in the Data Table section.

19. Determine the mean current value.

    a. Tap the y-axis label and select Current. You will see a graph of current *vs*. time.
    b. Choose Statistics ►Current from the Analyze menu.
    c. Record the mean current value in Table 2.

20. Determine the mean power value.

    a. Tap the y-axis label and select Power. You will see a graph of power *vs*. time.
    b. Choose Statistics ►Power from the Analyze menu.
    c. Record the mean power value in Table 2.

Part 4 How much power can you get?

In this part of the experiment, you will change the angle of the lid to try to get the most power from your Solar Panel.

21. Collect data with the Solar Panel at an angle.

    a. Open the lid and experiment to find the greatest power values that you can find.
    b. As you experiment, check the setup.
        - Is there any shade on the Solar Panel?
        - What happens if you turn the box so the Solar Panel is pointed directly at the sun? **CAUTION**: Never look directly at the sun.

22. When you have found the best angle for your Solar Panel, start data collection. Hold the lid in the same place until data collection ends. Data collection will stop after 30 s.

23. Determine the mean potential difference, current, and power values.

    a. Tap the y-axis label and select Potential. You will see a graph of potential difference (voltage) *vs*. time.
    b. Choose Statistics ►Potential from the Analyze menu.
    c. Record the mean potential difference (voltage) value in the data table.
    d. As you did in Part 3, change the y-axis to determine the mean current and power values. Record the values in Table 2.

DATA TABLE

Table 2: Data Table

Position of the Solar Panel	Mean potential difference (V)	Mean current (mA)	Mean power (mW)
Horizontal (Part 3)			
Angle (Part 4)			

DATA ANALYSIS

1. Compare the mean power when the Solar Panel was horizontal to the mean power when the Solar Panel was at an angle. In what situation was the power greater? Why do you think there is a difference?

2. Describe what you learned about the effect of angle on the output from the Solar Panel.