Wind and Solar Energy with KidWind and Vernier

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HANDS-ON ACTIVITIES

Introduction to Wind Turbines
- KidWind Mini Turbine
- Sound and Light Board

Introduction to the Energy Sensor
- KidWind 2V Solar Panels
- Vernier Energy Sensor

Blade Variables and Power Output
- KidWind Mini Turbine
- Vernier Energy Sensor

Making Connections: Circuits
- KidWind 2V Solar Panels
- Vernier Energy Sensor

Introduction to Wind Turbines

For thousands of years, people have been using wind energy to do work—from traveling around the world on sailboats to milling grain using windmills. Today, wind is becoming more common as a renewable energy source through the use of wind turbines.

Wind turbines have three basic parts–a tower, blades, and a generator. These parts work together to convert energy from the wind into electrical energy. When the wind blows, it pushes against the blades, causing them to spin. As the blades spin, they cause the generator to turn. The turning of the generator generates electricity, which can be used to light a light bulb or play music on your stereo.

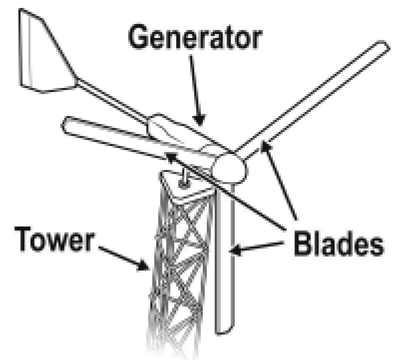


Figure 1

OBJECTIVES

- Explore how wind turbines can be used to generate electricity.
- Use electricity generated by a wind turbine to light an LED.
- Build and understand basic circuits.
- Verify that energy is transferred by electric currents.

MATERIALS

KidWind MINI Wind Turbine
Red Blade Set
KidWind Sound and Light Board
2 wire leads with clips
safety goggles
multi-speed box fan
centimeter ruler

VOCABULARY

Vocabulary term	Explanation
closed circuit	a closed loop that electrons travel through
electricity	moving electrons that can be used to do work, such as light a light bulb or play music on a stereo
wind	moving air
wind turbine	a device that converts energy from the air into electrical energy

PROCEDURE

Part I Exploring wind turbines

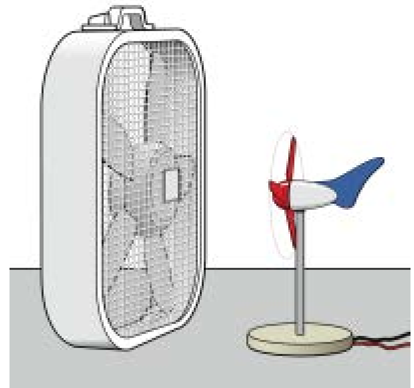


Figure 2

1. Set up the fan and wind turbine.
   a. Assemble the turbine with the Red Blade Set.
   b. Position the fan so the center of the fan is in line with the center of the hub of the turbine (see Figure 2). The fan should be about 15 cm from the turbine.
   c. Clear off your area and make sure that when the fan and the turbine are moving, nothing is in the way.
2. Put on safety goggles and turn on the fan to its LOWEST speed setting. **CAUTION:** Do not stand in the plane of rotation of the wind turbine blades. If the blades do not turn, increase the fan speed setting.

   In which direction does the turbine spin (circle one)?

   clockwise counterclockwise

3. Turn off the fan.
4. Examine the blades.

   Draw one of the blades in the box.

   What makes the blades spin in the direction they do?

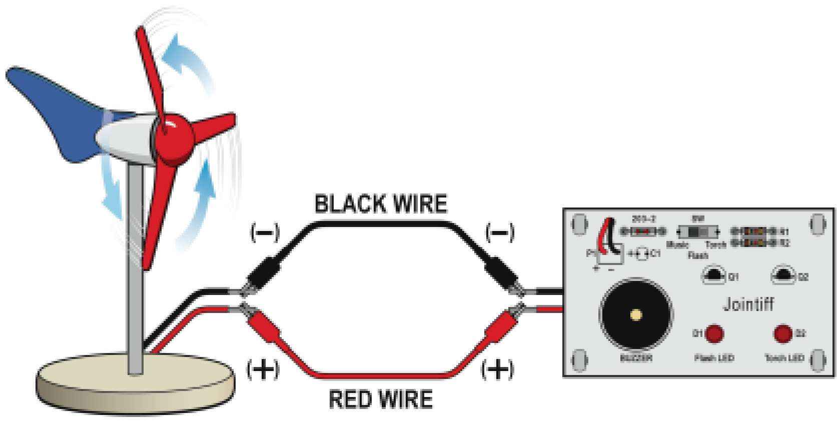
Part II Explore circuits and light an LED

5. Connect the Sound and Light Board to the wind turbine to build a closed circuit.

   a. Use a wire lead to connect the red wire from the Sound and Light Board to the red wire from the wind turbine.

   b. Use the second wire lead to connect the black wire from the Sound and Light Board to the black wire from the wind turbine.

   c. Draw arrows on the wires to show the path that the electricity will travel.



6. Move the switch on the Sound and Light Board to the Torch setting.

7. Put on safety goggles and turn on the fan to the LOWEST speed setting. Wait 30 seconds for the fan to reach a constant speed.

   Does the Torch LED light up? ______________________________

   If the LED does not light up, turn the fan to a higher speed setting until the Torch LED lights up. If it does not light up at any setting, ask your teacher for help.

   The lowest fan speed setting that makes the LED light is (circle one)

   Low Medium High

8. Disconnect something in the circuit to create an open circuit.

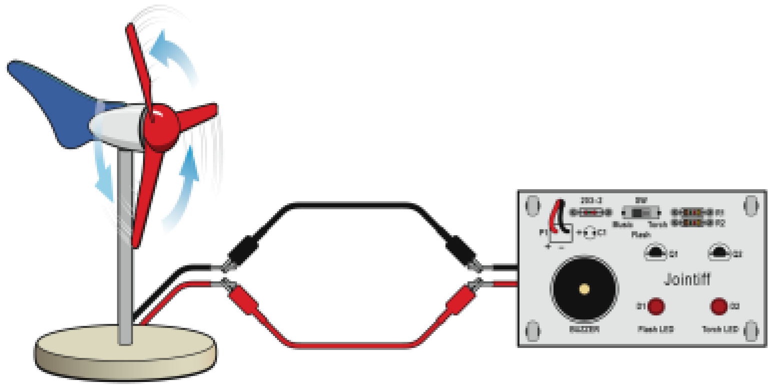
   Describe what you did to create an open circuit.

   ____

   ____

   ____

Mark an **X** on the wire to show where you opened the circuit:



9. Turn on the fan to test the open circuit. Set it to the same fan speed that you used to light the Torch LED.

   Did the LED light? ______________________________

   Why did this happen?

   ____

   ____

10. Was energy transferred through the closed circuit? ______________________________

    How do you know?

    ____

    ____

    ____

11. Was energy transferred through the open circuit? ______________________________

    How do you know?

    ____

    ____

    ____

Introduction to the Vernier Energy Sensor

When sunlight hits a solar panel, the energy of the sun is transferred to the electrons that make up the solar panel. This causes the electrons to start moving through the wires connected to the panel. In this experiment, you will use a Vernier 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 an AA battery in a flashlight, it has an output 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 play music on a stereo or defrost a window on a cold day.

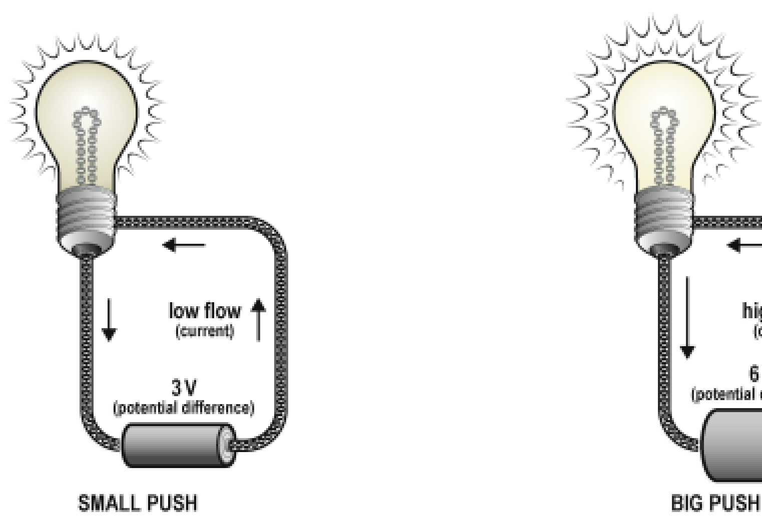


Figure 1

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

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

Introduction to the Vernier Energy Sensor

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

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 a Vernier 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 wire leads with clips (2 black and 2 red)

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 missing spaces in the table:

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

VOCABULARY

Vocabulary term	Explanation
closed circuit	a complete path or loop
current	the flow of electrons in a circuit
electron	a particle with a negative charge
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.
volt	A volt is the unit used to measure potential difference. The symbol used to represent a volt is V.

PROCEDURE

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

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

Introduction to the Vernier Energy Sensor

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.

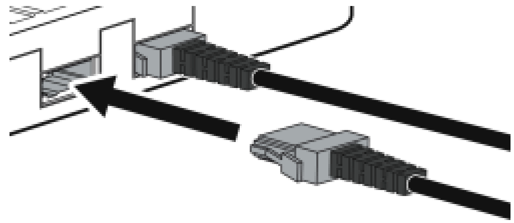


Figure 2

3. Zero the Energy Sensor.

   a. Connect the Energy Sensor Source terminals to each other with a wire lead, as shown in Figure 3. **Note**: The color of the wire lead is not important; any color will work.

   b. Choose Zero►All Sensors from the Sensors menu.

   c. Disconnect the wire lead that connects the Source terminals to each other.

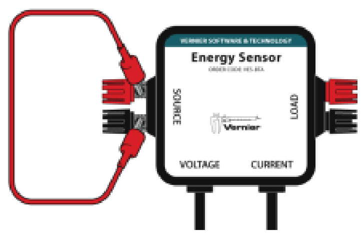


Figure 3

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

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

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

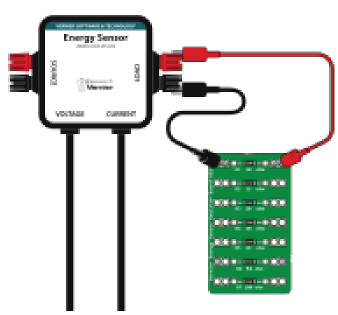


Figure 4

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 wire leads to connect the Solar Panel to the Source terminals of the Energy Sensor.

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

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

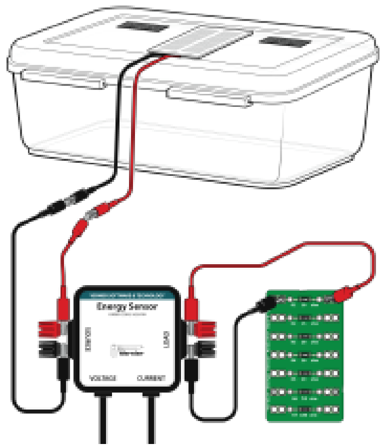


Figure 5

7. Check the connections in the circuit.

    a. Look at the current, potential difference, and power values on the screen, 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.

Introduction to the Vernier Energy Sensor

10. Check the connections in the circuit.

    a. Look at the current, potential difference, and power values on the screen 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.

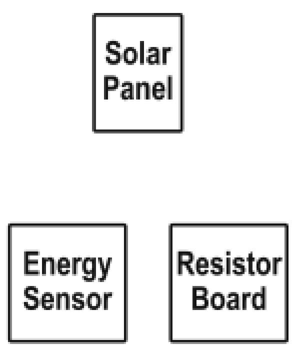
11. Make sure that the panel is not shaded and look at the current, potential difference, and power values on the screen.

    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 path of the electrons 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

6. 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.

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

8. 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:

Mean potential difference	V

9. 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:

Mean current	mA

0. 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:

Mean power	mW

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.

1. 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.
2. 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.
3. Determine the mean potential difference value.
   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.
4. 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 the data table.
5. 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 the data table.

DATA TABLE

Mean potential difference (V)	Mean current (mA)	Mean power (mW)

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.

Wind Turbine Output: The Effect of Load

A *load* is a device that uses electricity to do work or perform a job when connected to a circuit. A light bulb is an example of a load. If a light bulb is connected to the wind turbine, the electricity generated by the generator can do the work of lighting the light bulb.

Sometimes it is useful to control the flow of electrons in a circuit. An example of a time when it is important to control the flow of electrons is when you are using a generator like the one in your wind turbine. Generators are designed to produce the most power when a very specific amount of load is connected to the circuit.

One way to create the optimal load for the generator in your wind turbine is to connect multiple light bulbs to the circuit. While this would work, it is not very practical to always carry a bunch of light bulbs around with you!

Instead, you will use a device called a resistor to add load to the circuit. *Resistors* are used to control the flow of electrons in a circuit. Resistors are rated based on how much resistance they add to the circuit. Resistance is measured in units of ohms.

In this experiment, you will experiment to find the optimal resistance for the generator in your wind turbine.

OBJECTIVES

- Measure current, potential difference (voltage), and power output of a wind turbine with a Vernier Energy Sensor.
- Explore how current, potential difference (voltage), and power output vary depending on the resistance (load) in the circuit.
- Investigate the relationship between optimal resistance and maximum power output.

MATERIALS

LabQuest
LabQuest App
Vernier Energy Sensor
Vernier Resistor Board
KidWind MINI Wind Turbine
Red Blade Set
2 wire leads with clips
safety goggles
multi-speed box fan
centimeter ruler

VOCABULARY

Vocabulary term	Explanation
axis	the vertical or horizontal lines that cross at right angles to form a graph
load	a device connected to a circuit that uses current to do work
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.
watt	A watt is the unit used to measure power. The symbol used to represent a watt is W. In this experiment, we measure current in milliwatts (mW). 1000 mW = 1 W
ohm	An ohm is the unit used to measure resistance. The symbol used to represent the ohm is Ω.
optimal	best
resistor	a device used to control the flow of electrons

PROCEDURE

1. Set up the fan and wind turbine.
   a. Assemble the turbine with the Red Blade Set (see Figure 1).
   b. Position the fan so the center of the fan is in line with the center of the hub of the turbine. The fan should be 15 cm from the turbine. The distance needs to be the same each time you collect data.
   c. Clear off your area and make sure that when the fan and the turbine are moving, nothing is in the way.
2. Connect the Vernier Energy Sensor Current and Voltage connectors to LabQuest. Choose New from the File menu.

3. Zero the Energy Sensor.
   a. Connect the Energy Sensor Source terminals to each other with a wire lead, as shown in Figure 2.
   b. Choose Zero ►All Sensors from the Sensors menu. **Note:** The resistance value is not meaningful when the current and voltage values are near zero.

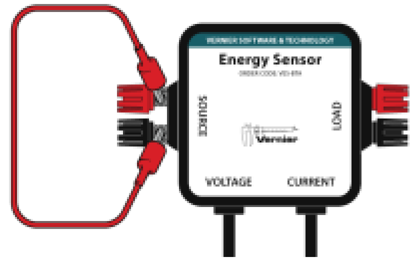


Figure 2

4. Connect the wind turbine to the Energy Sensor Source terminals.
   a. Disconnect the wire lead that is connecting the Source terminals.
   b. Connect the red wire from the turbine to the red Source terminal.
   c. Connect the black wire from the turbine to the black Source terminal.
5. Use two wire leads to connect the Resistor Board to the Energy Sensor Load terminals.
   a. Clip one lead to the black Load terminal and then to the hole on the left side of the 10 ohm resistor (see Figure 3).
   b. Use the other lead to connect the red Load terminal to the hole on the right side of the 10 ohm resistor. **Note:** The color of the leads does not matter when connecting the Resistor Board.

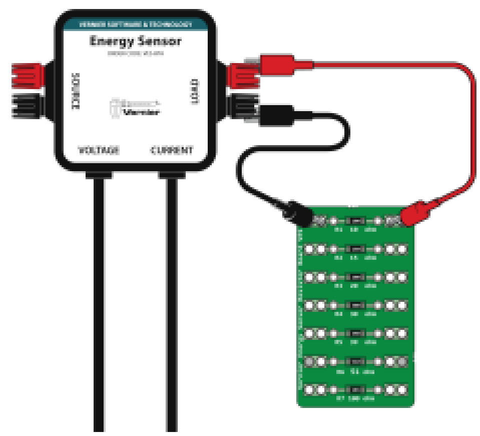


Figure 3

6. Get ready for data collection.
   a. Check that the fan and turbine are lined up correctly. Measure to make sure they are 15 cm apart.
   b. Put on safety goggles.
   c. Turn on the fan to the highest speed setting. **CAUTION:** Do not stand in the plane of rotation of the wind turbine blades.
7. Collect data.
   a. After the fan has been on for at least 30 seconds, you are ready to collect data. This ensures that the wind turbine is spinning at a constant speed. Start data collection. Data collection will stop after 30 seconds.
   b. When data collection finishes, turn off the fan.
8. Determine the mean power value.
   a. Choose Show Graph ►Graph 1 from the Graph menu. A single graph is shown.
   b. Tap the y-axis label and select Power. You will see a graph of power *vs.* time.
   c. Choose Statistics ►Power from the Analyze menu.
   d. Record the mean power value in Table 1.

9. 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 1.
10. Determine the mean potential difference (voltage) value.
    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 Table 1.
11. In the next step, you will change the resistor in the circuit from the 10 ohm resistor to a 15 ohm resistor. Before collecting new data, make a prediction about the effect of changing the resistance on the potential difference, current, and power output.
    a. PREDICTION: When the resistor is changed from 10 ohms to 15 ohms, do you think the mean potential difference will increase, decrease, or stay the same? Record your prediction in Table 2.
    b. PREDICTION: When the resistor is changed from 10 ohms to 15 ohms, do you think the mean current will increase, decrease, or stay the same? Record your prediction in Table 2.
    c. PREDICTION: When the resistor is changed from 10 ohms to 15 ohms, do you think the mean power will increase, decrease, or stay the same? Record your prediction in Table 2.
12. Move the alligator clips to the holes on the left and right side of the 15 ohm resistor to change the resistance (load) in the circuit to 15 ohms.
13. Collect data.
    a. Check that the fan and turbine are lined up. Measure to make sure they are 15 cm apart.
    b. Turn the fan to the highest speed setting.
    c. After the fan has been on for at least 30 seconds, start data collection.
    d. You are asked to store, append, or discard the latest run. Tap Discard.
    e. Data collection will stop after 30 seconds. When data collection finishes, turn off the fan.
14. Determine the mean power, current, and potential difference (voltage) values.
    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 1.
    d. Tap the y-axis label and select Current. You will see a graph of current *vs.* time.
    e. Choose Statistics ►Current from the Analyze menu and record the mean current value in your Table 1.

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

g. Choose Statistics ►Potential from the Analyze menu and record the mean potential difference (voltage) value in Table 1.

15. In the next step, you will change the resistor in the circuit from the 15 ohm resistor to a 20 ohm resistor. Before collecting new data, make a prediction about the effect of changing the resistance in the circuit on the potential difference, current, and power.

    a. PREDICTION: When the resistor is changed from 15 ohms to 20 ohms, do you think the mean potential difference will increase, decrease, or stay the same? Record your prediction in Table 2.

    b. PREDICTION: When the resistor is changed from 15 ohms to 20 ohms, do you think the mean current will increase, decrease, or stay the same? Record your prediction in Table 2.

    c. PREDICTION: When the resistor is changed from 15 ohms to 20 ohms, do you think the mean power will increase, decrease, or stay the same? Record your prediction in Table 2.

16. To change the resistance (load) in the circuit to 20 ohms, move the alligator clips to the holes on the left and right side of the 20 ohm resistor.

17. Repeat Steps 13–14 for the 20 ohm resistor.

18. Make predictions for the 30 ohm resistor and write them in Table 2.

19. Repeat Steps 12–14 for the 30 ohm resistor.

20. Make predictions for the 39 ohm resistor and write them in Table 2. Then, repeat Steps 12–14 for the 39 ohm resistor.

21. Make predictions for the 51 ohm resistor and write them in Table 2. Then, repeat Steps 12–14 for the 51 ohm resistor.

22. Make predictions for the 100 ohm resistor and write them in Table 2. Then, repeat Steps 12–14 for the 100 ohm resistor.

DATA

Table 1: Red Blade Set			
Resistance (ohms)	Mean potential (V)	Mean current (mA)	Mean power (mW)
10			
15			
20			
30			
39			
51			
100			

Table 2: Predictions			
Resistance change (ohms)	Mean potential prediction	Mean current prediction	Mean power prediction
Example	*same*	*increase*	*decrease*
10 to 15			
15 to 20			
20 to 30			
30 to 39			
39 to 51			
51 to 100			

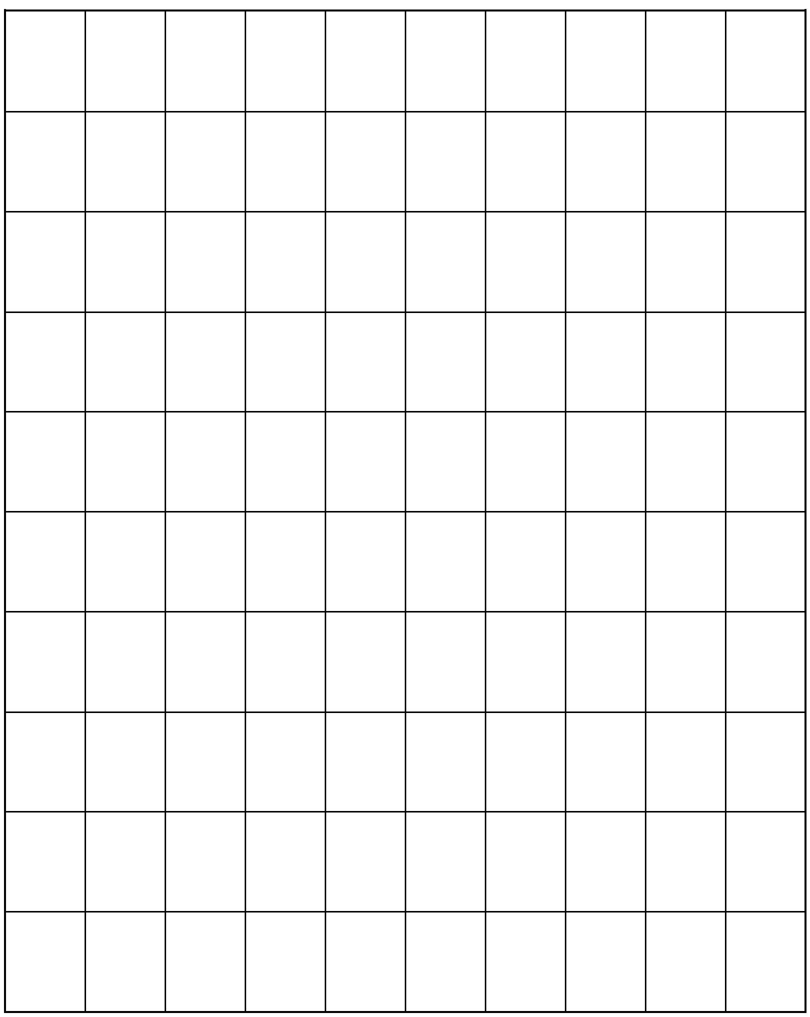
DATA ANALYSIS

1. Examine the data in Table 1. As the resistance increased, what happened to the mean potential difference values?

2. Examine the data in Table 1. As the resistance increased, what happened to the mean current?

3. Use the data in Table 1 to create a bar graph.
   - Graph the resistance values on the x-axis (horizontal).
   - Graph the mean power data on the y-axis (vertical).
   - Label the x-axis and the y-axis of your graph.

Graph of power *vs*. resistance



4. Subtract to find the difference between the greatest and smallest power values. Show your work.

5. Examine your data table and bar graph. What happened to the wind turbine power as the resistor values increased?

   When I look at the resistance and power in my graph I notice

   ____

   ____

   ____

6. What is the optimal resistance for the greatest power output for your turbine? __________

Making Connections: Circuits

The solar panels you use in this experiment produce a relatively small amount of power—only enough to light up a single LED or quietly play a song. What if you want more power? Do you think you could connect multiple solar panels together? How would you do this? In this experiment you will explore different ways of connecting solar panels.

OBJECTIVES

- Measure the power output of one, two, and three solar panels with an Energy Sensor.
- Build series and parallel circuits.
- Use data-collection software to calculate mean (average) values.

MATERIALS

LabQuest
Vernier Energy Sensor
Vernier Resistor Board
3 KidWind 2 V Solar Panels
box from the Solar Energy Exploration Kit
4 wire leads with clips (2 black and 2 red)
17.5 cm piece of chipboard
Parallel Circuit Connection Tool
red and black color pencils or markers

VOCABULARY

Vocabulary term	Explanation
axis	the vertical or horizontal lines that cross at right angles to form a graph
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.
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.
parallel circuit	a closed circuit where the parts of the circuit are connected so that there are multiple paths through which the electrical energy can travel
series circuit	a closed circuit where the parts of the circuit are connected so that there is a single path through which the electrical energy can travel

PRE-LAB ACTIVITY

Use red and black colored pencils or markers to draw connections to create a closed circuit that will produce positive readings.

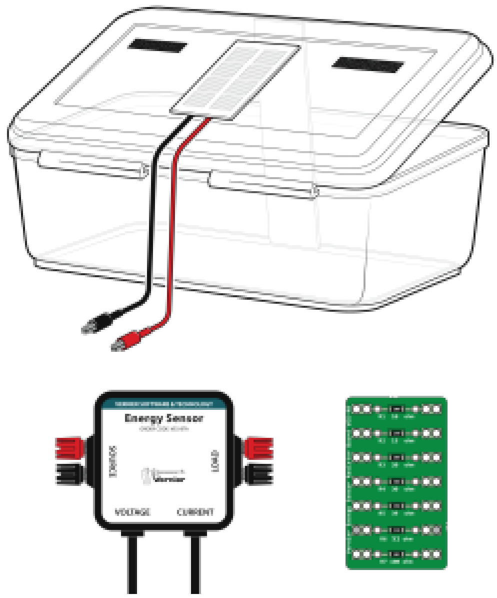


Figure 1

PROCEDURE

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

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

2. Connect the Vernier Energy Sensor Current and Voltage connectors to LabQuest. Choose New from the File menu.

3. Zero the Energy Sensor.

   a. Connect the Energy Sensor Source terminals to each other with a wire lead, as shown in Figure 3.

   b. Choose Zero►All Sensors from the Sensors menu.

   c. Disconnect the wire lead that connects the Source terminals to each other.

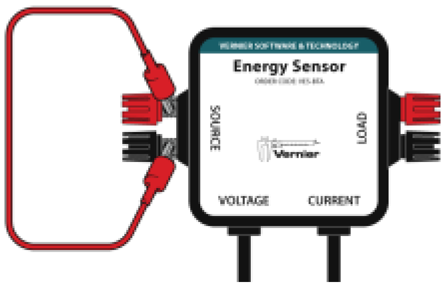


Figure 2

Part 1 Series Circuits

In this part you will connect the Solar Panels so they create a closed circuit where the electrons flow from one Solar Panel to the next in a big loop. All the electrons flow in the same path, like when you run around a track. Scientists call this connecting the Solar Panels in series or building a series circuit.

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

   a. Clip one end of a wire lead to the black Load terminal and the other end of the wire lead to the hole on the left side of the 30 ohm resistor (see Figure 3). **Note**: If you have a black wire lead, use it. If not, you can use any other color.

   b. Use another wire lead to connect the red Load terminal to the hole on the right side of the 30 ohm resistor. **Note**: If you have a red wire lead, use it. If not, use any other color.

5. Set up the Solar Panels and the Solar Energy Exploration Kit box (see Figure 3).

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

   b. Use a piece of chipboard to prop the lid of the box at an angle.

6. Use wire leads to connect Solar Panel 1 to the Source terminals of the Energy Sensor.

   a. Use a wire lead to connect the black wire from Solar Panel 1 to the black Source terminal (see Figure 3). **Note**: If you have a black wire lead, use it. If not, you can use any other color.

   b. Use a wire lead to connect the red wire from Solar Panel 1 to the red Source terminal. **Note**: If you have a red wire lead, use it. If not, use any other color.

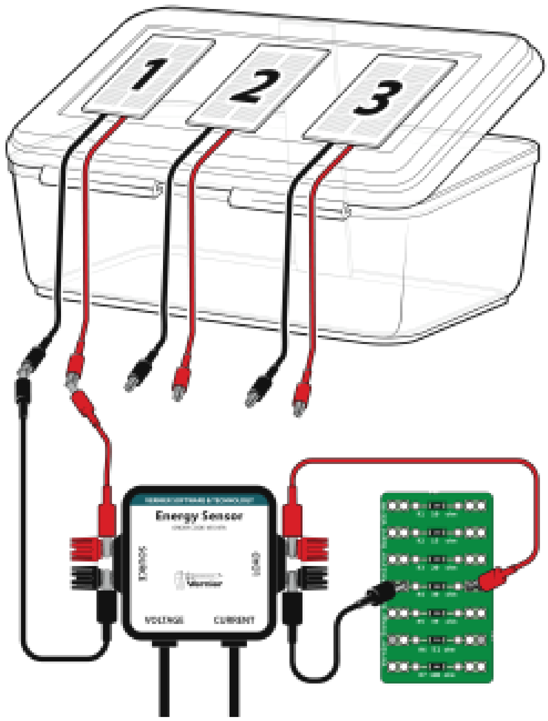


Figure 3

4. Position the box and check that everything is set up correctly.

   a. Rotate the box so the panels are pointed toward the sun. **CAUTION**: Never look directly at the sun.

   b. Look at the power values on the screen, and then cover the panel with your hands.

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

5. Make sure that the panels are not shaded and start data collection. Data collection will stop after 30 seconds.

6. Determine the mean power value.

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

   b. Tap the y-axis label and select Power. You will see a graph of power *vs*. time.

   c. Choose Statistics ►Power from the Analyze menu.

   d. Record the mean power value in Table 1.

7. Set up a circuit with two Solar Panels connected in series.

   a. Disconnect the red Solar Panel clip from the wire lead connected to the red Source terminal (see Figure 4).

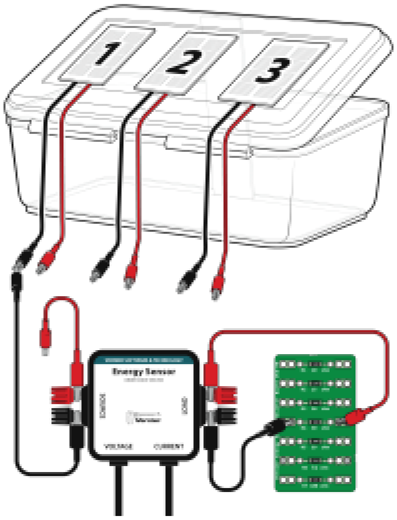


Figure 4

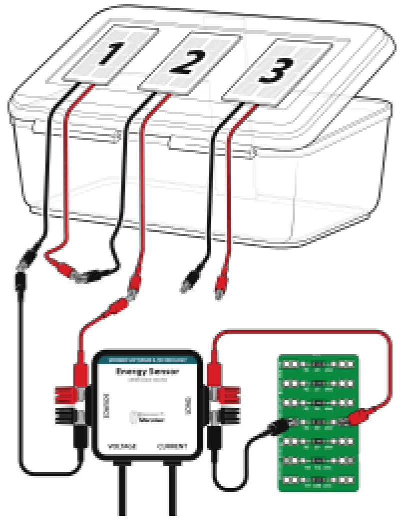


Figure 5

   b. Connect the red clip from Solar Panel 1 to the black clip from Solar Panel 2 (see Figure 5).

   c. Connect the red clip from Solar Panel 2 to the wire lead connected to the red Source terminal. Now you have two Solar Panels connected in series!

8. Collect data for two Solar Panels connected in series.

   a. Check the setup. Are the wires still connected? Is the box facing the right direction? Is there any shade on the panels?

   b. Start data collection. Data collection will stop after 30 s.

   c. Choose Statistics ►Power from the Analyze menu.

   d. Record the mean power value in the correct row in Table 1.

9. Set up a circuit with three Solar Panels connected in series (see Figure 6).

   a. Disconnect the red clip from Solar Panel 2 and the wire lead connected to the red Source terminal.

   b. Connect the red clip from Solar Panel 2 to the black clip from Solar Panel 3.

   c. Connect the red clip from Solar Panel 3 to the wire lead connected to the red Source terminal. Now you have three Solar Panels connected in series!

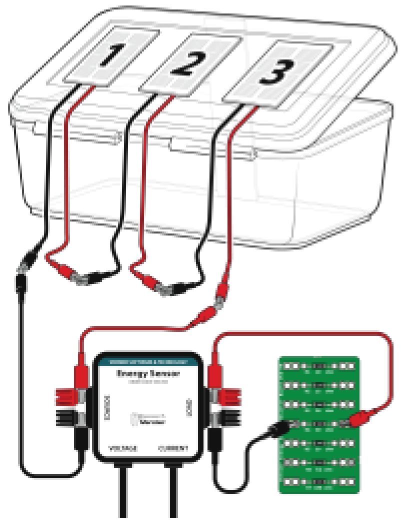


Figure 6

10. Collect data for three Solar Panels connected in series.

    a. Check the setup. Are the wires still connected? Is the box facing the right direction? Is there any shade on the panels?

    b. Start data collection. Data collection will stop after 30 s.

    c. Choose Statistics ►Power from the Analyze menu.

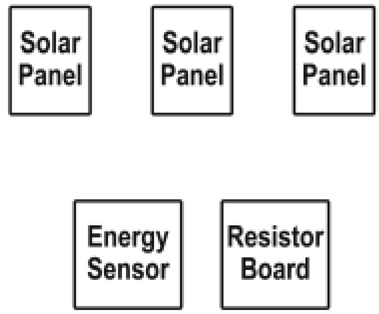
    d. Record the mean power value in the correct row in Table 1.

Part 1 Data Table

Table 1 Series Circuit	
Panels	Mean power (mW)
1	
2	
3	

Part 1 Data Analysis

1. Draw lines to show the path of the electrons in the circuit you created for this part when all three panels were connected in series.



2. Which setup, one, two, or three panels, generated the most power?

Part 2 Parallel Circuits

In Part 1, you connected the Solar Panels to each other to build a series circuit. In this part, you will build a parallel circuit by connecting each Solar Panel directly to the Energy Sensor rather than to each other. In a parallel circuit, the electrons can take many different paths instead of just one.

14. Set up the equipment.
    - If the equipment is set up for Part 1, disconnect the Solar Panels, the Energy Sensor, and the Resistor Board and continue with Step 15.
    - If the Energy Sensor is not connected to the interface, do Steps 2–3 from Part 1.
15. Use wire leads to connect the Resistor Board to the Load terminals of the Energy Sensor.
    a. Clip one end of a wire lead to the black Load terminal and the other end of the wire lead to the hole on the left side of the 10 ohm resistor (see Figure 7). **Note**: If you have a black wire lead, use it. If not, you can use any other color.
    b. Use another wire lead to connect the red Load terminal to the hole on the right side of the 10 ohm resistor. **Note**: If you have a red wire lead, use it. If not, use any other color.

Making Connections: Circuits

16. Connect the Energy Sensor to the paper clips (see Figure 7).

    a. Use a wire lead to connect the black Source terminal to the paper clip labeled Black. **Note**: If you have a black wire lead, use it. If not, you can use any other color.

    b. Use a wire lead to connect the red Source terminal to the paper clip labeled Red. **Note**: If you have a red wire lead, use it. If not, use any other color.

17. Connect Solar Panel 1 to the paper clips (see Figure 7).

    a. Connect the black clip of Solar Panel 1 to the paper clip labeled Black.

    b. Connect the red clip of Solar Panel 1 to the paper clip labeled Red.

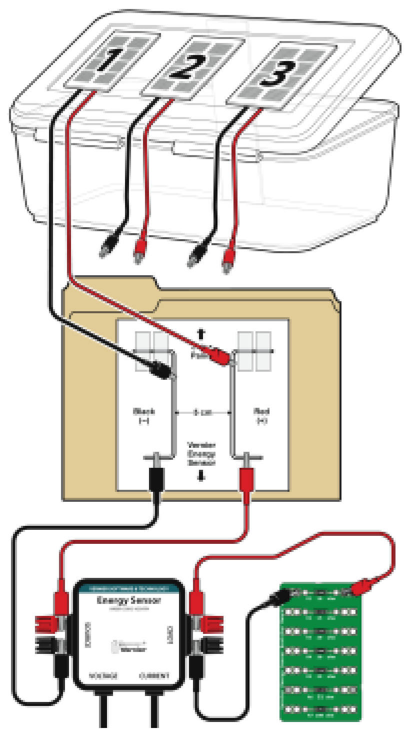


Figure 7

14. Check that everything is set up correctly.

    a. Are the clips connected to the 10 ohm resistor on the Resistor Board? If they are not, move the clips.

    b. Turn the box so the panels point at the sun. **CAUTION**: Never look directly at the sun.

    c. Look at the power values on the screen and then cover the panels with your hands.

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

15. Make sure that the panels are not shaded and start data collection. Data collection will stop after 30 seconds.

16. Determine the mean power value.

    a. Choose Show Graph ►Graph 1 from the Graph menu. A single graph is shown.
    b. Tap the y-axis label and select Power. You will see a graph of power *vs*. time.
    c. Choose Statistics ►Power from the Analyze menu.
    d. Record the mean power value in Table 1.

17. Set up a circuit with two Solar Panels connected in parallel (see Figure 8).

    a. Connect the black clip from Solar Panel 2 to the paper clip labeled Black.
    b. Connect the red clip from Solar Panel 2 to the paper clip labeled Red. Now you have two Solar Panels connected in parallel!

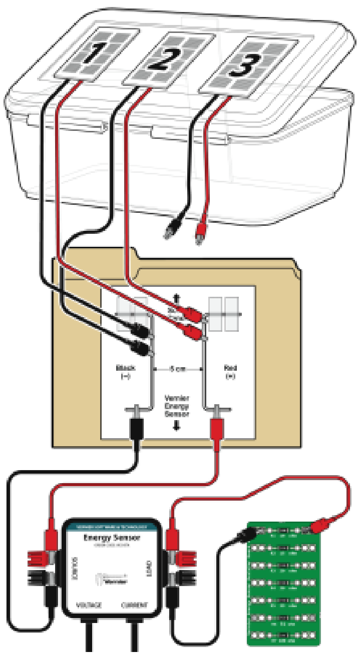


Figure 8

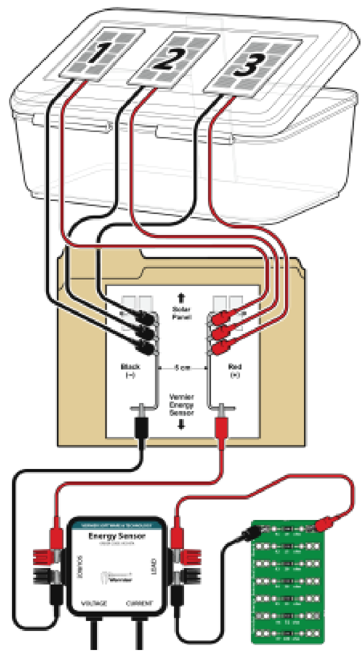


Figure 9

18. Collect data for two Solar Panels connected in parallel.

    a. Check the setup. Are the wires still connected? Are the panels facing toward the sun? Is there any shade on the panels?
    b. Start data collection. Data collection will stop after 30 s.
    c. Choose Statistics ►Power from the Analyze menu.
    d. Record the mean power value in the correct row in Table 2.

19. Set up a circuit with three Solar Panels connected in parallel (see Figure 9).

    a. Connect the black clip from Solar Panel 3 to the paper clip labeled Black.
    b. Connect the red clip from Solar Panel 3 to the paper clip labeled Red. Now you have three Solar Panels connected in parallel!

20. Collect data for three Solar Panels connected in parallel.

    a. Check the setup. Are the wires still connected? Are the panels facing toward the sun? Is there any shade on the panels?

    b. Start data collection. Data collection will stop after 30 s.

    c. Choose Statistics ►Power from the Analyze menu.

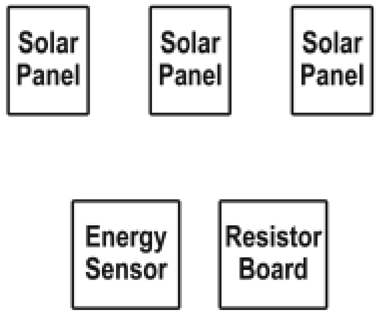
    d. Record the mean power value in the correct row in Table 2.

Part 2 Data Table

Table 2 Parallel Circuit	
Panels	Mean power (mW)
1	
2	
3	

Part 2 Data Analysis

1. Draw lines on the diagram to connect the boxes to show the path of the electrons in the circuit you created for this part when all three panels were connected in parallel.



2. Which setup, one, two, or three panels, generated the most power?

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DATA ANALYSIS (BOTH PARTS)

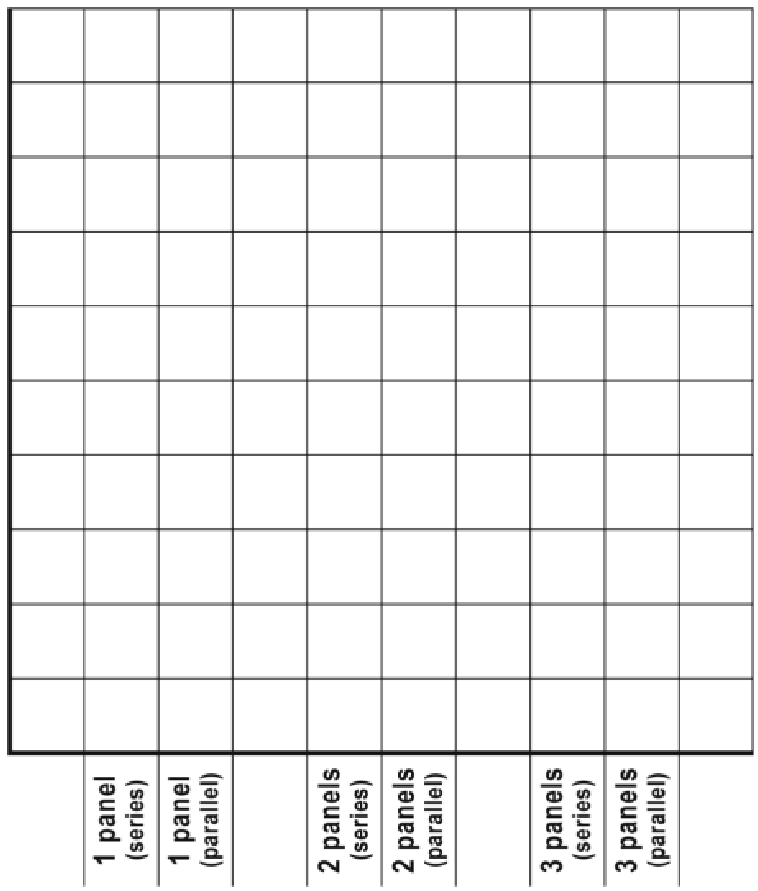
1. Transfer all of your data into Table 3 so you can create a single graph with all your data.

Table 3 Compare Series and Parallel Circuits		
Panels	Series circuit Mean power (mW)	Parallel circuit Mean power (mW)
1		
2		
3		

2. Use the data in Table 3 to create a bar graph.

   - The x-axis (horizontal) has been filled in for you.
   - Graph the mean power data on the y-axis (vertical).
   - Label the y-axis of your graph.

Graph of power *vs*. number of panels



3. Compare the values from the panels when they were connected in series to the values when the panels were connected in parallel. Do you get more power when the panels are connected in series or when they are connected in parallel?

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4. Summarize what you learned about the relationship between number of panels and power output.

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