Producing More Electricity with Solar Cells and Solar Panels

Summary

A single solar cell or solar panel usually does not make a sufficient amount of electrical power to operate common electrical devices. Fortunately, solar cells and solar panels can be connected together to get greater amounts of electrical power. In this lesson you will learn about two different ways to connect solar cells and solar panels together to get more electrical power.

Engineering Connections

Students will make observations and produce data to serve as the basis for evidence which explains a phenomena or tests a design solution. The scientific ideas will be applied to solve design problems. Students will ask questions that can be investigated within the scope of the classroom, outdoor environment, museums and other public facilities using available resources. When appropriate, students will frame a hypothesis based on observations and scientific principles.

Objectives

- Students will be able to explain how to measure the amount of electricity produced by solar cells or solar panels.
- Students will be able to explain the two different ways that solar cells and solar panels can be connected together to obtain greater amounts of electrical current and voltage.

Standards

6.PS1.4
6.PS3.3
7.ESS3.3

Vocabulary

- Electricity
- Electrical Current
- Multimeter
- Parallel Circuit
- Series Circuit
- Solar Cell
- Solar Panel
- Voltage

Materials List (*To check out a kit go to OREEP.org and fill out a form.)

- Solar Energy Exploration Kit
- Multimeter (Multimeter Tutorial Available on OREEP.org)
- Light Source (the sun or an electrical lamp)

Worksheets and Attachments

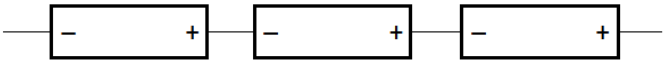
- Lesson Document (pdf)
- Student Activity Worksheets (pdf)
- Student Activity Answer Sheets (pdf)
- Vocabulary Sheet
- Connections Pictures

Teacher Information/Background Information

As with batteries, there are two basic types of electrical connections that can be used to get greater amounts of electrical power from sets of solar cells than is available from a single solar cell. One type of connection is referred to as a **series connection** and is used to obtain higher voltages. Two or more batteries or solar panels are connected in series when the positive terminal of one is connected to the negative terminal of another. When connected in series the total voltage available is the sum of the voltages produced by the individual batteries, solar cells or solar panels. However, the total electrical current available is not simply the sum of the currents available from the individual devices.

Series Connection -

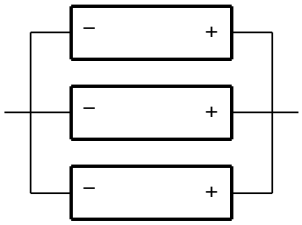
- Batteries End to End
- Positive to Negative
- Red Wires to Black Wires if Battery Holders Used



The second type of connection is known as a **parallel connection** and is used to obtain higher electrical currents. Two or more batteries, solar cells or solar panels are connected in parallel when all of the positive terminals are connected together and all of the negative terminals are connected together. Parallel connections result in the addition of electrical currents from individual batteries, solar cells or solar panels but the voltages are not additive.

Parallel Connections -

- Batteries Side by Side
- All Positives Connect Together
- All Negatives Connect Together
- All Red Wires Connect Together and All Black Wires Connect Together if Battery Holders Used



Summary of Series and Parallel Relationships

Type of Connection	Voltage	Electrical Current
Series Connection	Add Together	Do Not Add
Parallel Connection	Do Not Add	Add Together

Figure 1. One Battery Voltage Measurement.

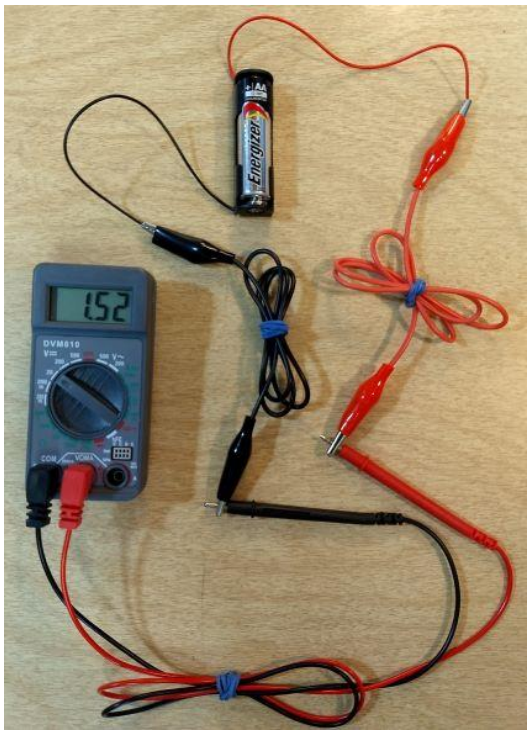


Figure 2. One Battery Current Measurement.

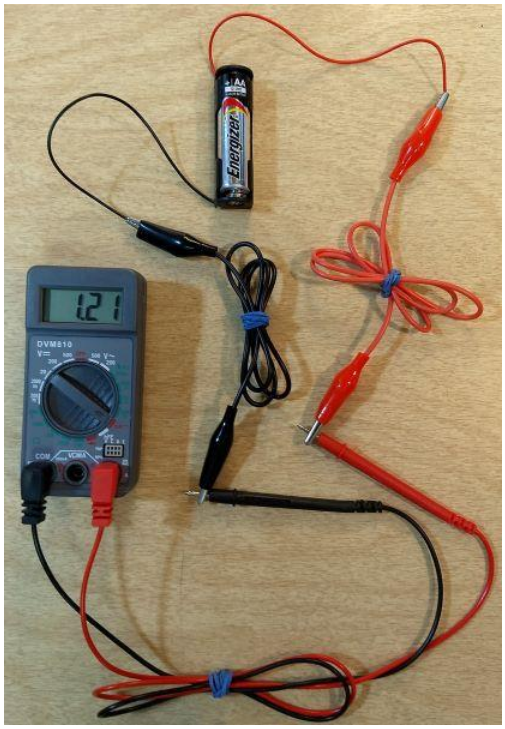


Figure 3. Batteries Connected in Series.

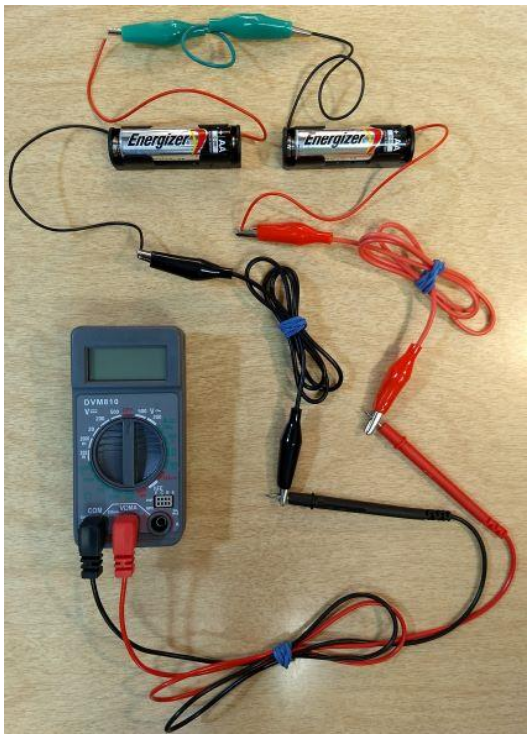
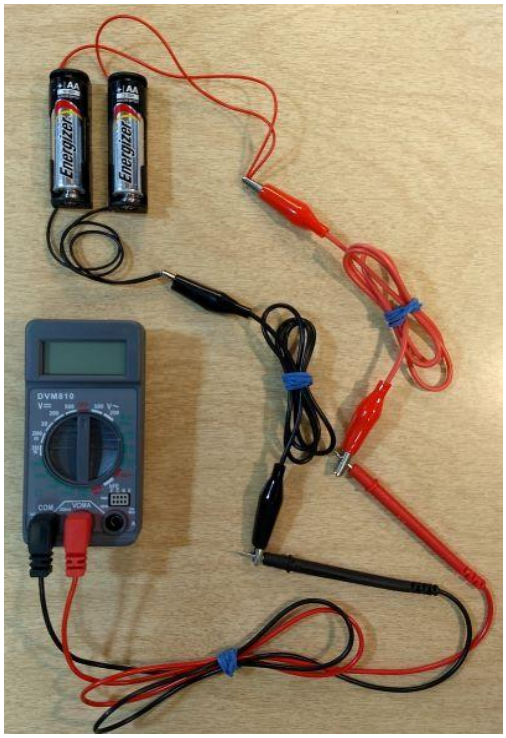


Figure 4. Batteries Connected in Parallel.



Producing More Electricity with Solar Cells and Solar Panels
Student Activity Sheets - Exploration

Engagement

Part 1: You have a flashlight with an LED light bulb that requires 3 volts to light up. The batteries you have each produce 1.5 volts. Can you make the LED light up with the batteries that you have? Perform steps 1 – 9 in the Exploration section to help you answer this question.

Part 2: What if you do not have any batteries but do have some solar cells. Could you use the solar cells to make the LED light up? Perform steps 10 – 18 in the Exploration section to help you answer this question.

Exploration

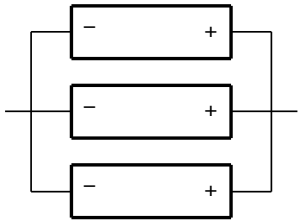
Part 1: Explore what happens when batteries are connected in different ways.

Series Connection: According to electrical theory when batteries are connected in series the total voltage available from the batteries is approximately equal to the sum of the voltages of the individual batteries. However, when batteries are connected in series the electrical currents available from the individual batteries do not simply add up so the total current available is not the sum of the currents from the individual batteries.

Parallel Connection: Electrical theory also states that when batteries are connected in parallel the total electrical current available from the batteries is approximately equal to the sum of currents from the individual batteries. However, when connected in parallel the voltages available from the individual batteries do not simply add up so the total voltage available is not the sum of the voltages from individual batteries.

Series Connection -
- Batteries End to End
- Positive to Negative

Parallel Connection -
- Batteries Side by Side
- All Positives Connected Together
- All Negatives Connected Together



Part 1. Explore series and parallel relationships with batteries.

1. Use the multimeter to measure the voltage produced by one AA battery. Write the results of your measurement including the units for the measurement?
(20 volt DC multimeter scale) *Approximately 1.5 volts*

2. Use the multimeter to measure the electrical current produced by one AA battery. Write the results of your measurement including the units for the measurement?
(10 amp multimeter scale) *Variable but approximately 1.0 - 2.0 amps, it is more difficult to make accurate measurements of electrical current than it is for voltage.*

3. Use the multimeter to measure the voltage in a simple circuit consisting of two AA batteries connected in series. Write the results of your measurement including the units for the measurement?
(20 volt DC multimeter scale) *Approximately 3.0 volts*

4. Use the multimeter to measure the current in a simple circuit consisting of two AA batteries connected in series. Write the results of your measurement including the units for the measurement?
(10 amp multimeter scale) *Variable but approximately 1.0 - 2.0 amps*

5. Use the multimeter to measure the voltage in a simple circuit consisting of two AA batteries connected in parallel. Write the results of your measurement including the units for the measurement?
(20 volt DC multimeter scale) *Approximately 1.5 volts*

6. Use the multimeter to measure the electrical current in a simple circuit consisting of two AA batteries connected in parallel. Write the results of your measurement including the units for the measurement?
(10 amp multimeter scale) *Variable but approximately 1.0 - 2.0 amps*

7. Was the voltage measured from two AA batteries connected in series (Step 3) twice the voltage from one AA battery (same as adding two separate AA batteries together)?
Should be approximately 3.0 volts which twice the voltage of one AA battery.

8. If you have a 3 volt LED, try to make it light up using one or more batteries. If you were able to make the LED light up use words or draw a diagram to describe how you connected the LED and the batteries together?
LED should not light up when connected to one AA battery but should light up when connected to two AA batteries in series. (LED + to batteries +, LED - to batteries -)

9. If you have a small motor, try to make it operate using one battery and then try two batteries. Did you observe any differences? Draw a diagram of your connections.

Part 2: Explore series and parallel relationships with solar cells.

10. Use the multimeter to measure the voltage produced by one solar cell. Write the results of your measurement including the units for the measurement?
(20 volt DC multimeter scale) *Dependent upon which solar cell used and how much light but approximately 0.5 - 2.0 volts.*
11. Use the multimeter to measure the electrical current produced by one solar cell. Write the results of your measurement including the units for the measurement?
(200 milliamp multimeter scale) *Dependent upon which solar cell used and how much light but approximately 1.0 - 40.0 milliamps.*
12. Use the multimeter to measure the voltage in a simple circuit consisting of two solar cells connected in series. Write the results of your measurement including the units for the measurement?
(20 volt DC scale) *Dependent upon which solar cell used and how much light but approximately twice the volts measured in Step 10.*
13. Use the multimeter to measure the electrical current in a simple circuit consisting of two solar cells connected in series. Write the results of your measurement including the units for the measurement?
(200 milliamp multimeter scale) *Dependent upon which solar cell used and how much light but approximately the same as in Step 11 and may be slightly greater.*
14. Use the multimeter to measure the voltage in a simple circuit consisting of two solar cells connected in parallel. Write the results of your measurement including the units for the measurement?
(20 volt DC scale) *Dependent upon which solar cell used and how much light but approximately the same as in Step 10 so 0.5 - 2.0 volts.*
15. Use the multimeter to measure the electrical current in a simple circuit consisting of two solar cells connected in parallel. Write the results of your measurement including the units for the measurement?
(200 milliamp multimeter scale) *Dependent upon which solar cell used and how much light but more than in Step 11 up to approximately twice as much as in Step 11.*
16. Was the voltage measured from two solar cells connected in series (Step. 12) twice the voltage from one solar cell (same as adding two separate solar cells together)?
Should be approximately twice the volts of one solar cell.
17. If you have a 3 volt LED, try to make it light up using one or more solar cells. If you were able to make the LED light up use words or draw a diagram to describe how you connected the LED and the solar cells together?
LED should not light up when connected to one solar cell but should light up when connected to two solar cells in series. (LED + to solar cells + , LED - to solar cells -)
18. If you have a small motor, try to make it operate using one solar cell and then try using two. Did you observe any differences? Draw a diagram of your connections.

Explanation

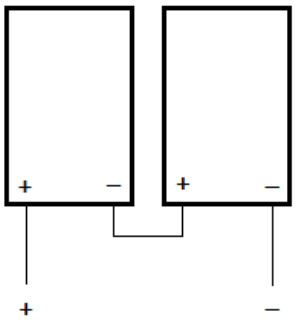
1. Was there an independent variable in these experiments? If so, what was it?
Yes. There were actually two independent variables. One was the number of batteries or solar cells. The second was the type of circuit either series or parallel.

2. Was there a dependent variable in these experiments? If so, what was it?
Yes. The dependent variable was the amount of electricity produced measured as either the number of volts or amps.

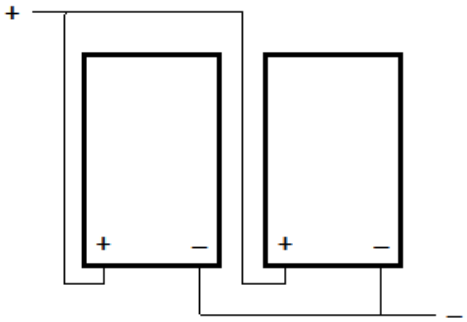
Extension

The electrical devices in your house require a voltage of 120 volts. You have four solar panels that each produce 30 volts. Can these solar panels be used to obtain a voltage of 120 volts? If so, use words or draw a diagram to describe how you would connect them together to obtain 120 volts.

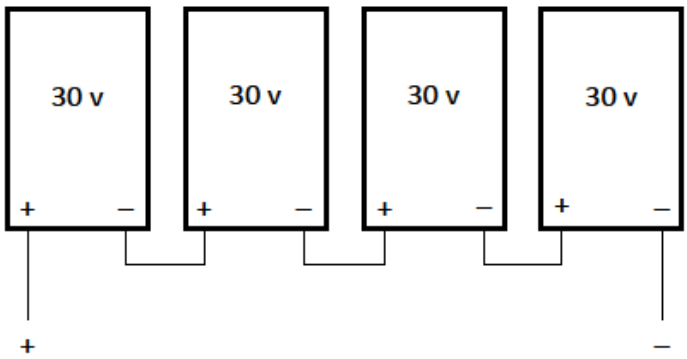
Example of two solar panels in series.



Example of two solar panels in parallel.



Yes. Connect all four solar panels in series since the voltages are additive in series circuits.

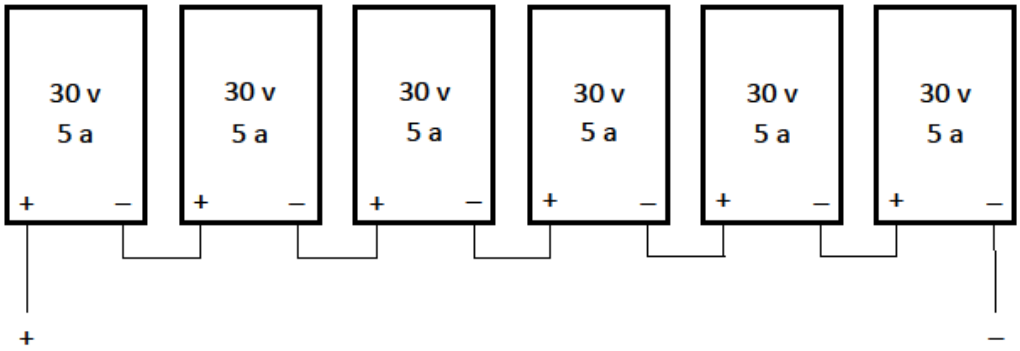


30 volts + 30 volts + 30 volts + 30 volts = 120 volts

Evaluation

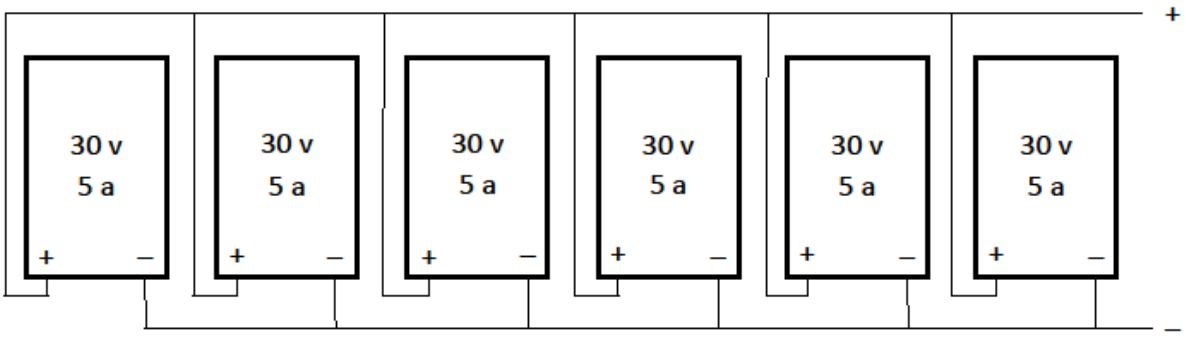
You have six solar panels each of which produces 30 volts and 5 amperes.

1. Draw a diagram that shows the set of six solar panels all connected in series. What voltage would you measure from all six when they are connected together? What electrical current would you measure from all six connected together?



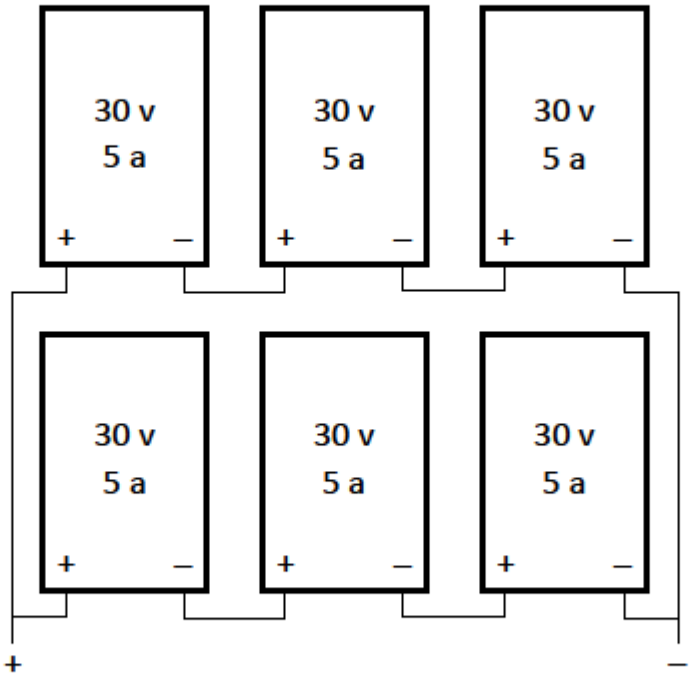
Voltage from all eight would be 6 x 30 volts = 180 volts since voltages are additive in series circuits. The electrical current would only be 5 amps since the current is not additive in series circuits.

2. Draw a diagram that shows a set of six solar panels all connected in parallel. What voltage would you measure from all six connected together? What electrical current would you measure from all six connected together?



Voltage from all six would be 30 volts because voltages are not additive in parallel circuits. The electrical current would be 6 x 5 amps = 30 amps since currents are additive in parallel circuits.

3. Draw a diagram that shows two sets of three solar panels with the three panels in a set all connected in series and then connect the two sets in parallel. What voltage would you measure from all six? What electrical current would you measure from all six?



The voltage from each set of three would be 3 x 30 volts = 90 volts but the two sets are connected in parallel so the voltage from all six would still be 90 volts. The electrical current in each set of three is 5 amps since the current does not add in series circuits but the current from all six would be 2 x 5 = 10 amps since the two sets are connected in parallel.

References

Exploring Photovoltaics Teachers Guide, National Energy Education Development Project (The NEED Project), Manassas, VA, 2017

Exploring Photovoltaics Students Guide, National Energy Education Development Project (The NEED Project), Manassas, VA, 2017

Schools Going Solar, National Energy Education Development Project (The NEED Project), Manassas, VA, 2017