Investigating What Happens When You Use More Than One Solar Cell

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DESCRIPTION: Students first explore with 0.5 Volt solar cells to see whether adding cells to a circuit increases the amount of water pumped by a small pump. They are introduced to parallel and series wiring. They then design and carry out a formal experiment to test their ideas. This lesson may be used with minor modifications to fulfill Oregon's Science Inquiry Work Sample.

GRADE LEVEL(S): 3, 4, 5

SUBJECT AREA(S): Science

ACTIVITY LENGTH: 3-4 hours of class time over several sessions

LEARNING GOAL(S):

- Students will apply scientific ideas to design and test a solar powered water pump that moves water at the fastest rate.
- Students will experiment and build understanding of parallel and series wiring and how energy moves in these circuits.
- Students will record data accurately into a table.

STANDARDS MET:

Common Core:

- CCSS 3.MD.2 Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters.

Next Generation Science Standards:

- 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
- 4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

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Student Background:

Students should have some prior knowledge on measuring volume and understanding units for measuring volume (e.g., fractions of a cup, mL, L). Students should be familiar with forms of energy such as light, heat, electrical and motion. Students should be familiar with the idea that energy changes form and be able to describe some examples of those transformations. It is helpful if students are familiar with the idea of a circuit and the basic concept of electricity as flow of electrical charges.

This lesson is intended to be the fifth in a solar energy unit, and so my students will already have completed the follow lessons:

- Introducing Solar Energy: Hypothesizing on Why Solar Beads Change Color
- What is Renewable Energy and Why is It Important?
- Energy Changes Form
- Laboratory Introduction to Solar Cells: Exploring Solar Powered Water Pumps

Educator Background:

Electricity and circuits: Electricity is a form of energy that occurs when electrons flow from one atom to another. Electricity flows more easily through some materials (conductors) than others (insulators). The path that electricity flows along is called a circuit. There may be loads on the circuit that change electricity into another form of energy, such has heat, light or motion.

Measuring electricity: volts and amps. One can draw a parallel between electricity in wires and water in a pipe. The water may flow through the pipe with more or less force (or pressure). **Amps** measure the rate of flow of electric charge through the wire, which is also called the **electric current**. The **resistance**, which is metaphorically like the size of the pipe, also affects how much current flows through a wire. A small wire will not carry as much current as a larger wire. **Volts** measure the electromotive force or **voltage** with which electricity is being “pushed” through a wire in a circuit.

Types of circuits. **Series circuits** are simple circuits where there is only one path for electricity to take from the source (battery or solar cell) through the conductors (such as wires) and load(s). However, in our homes, series circuits would not be practical because all of our appliances would have to be on at the same time. **Parallel circuits** have more than one path for electricity to flow, and allow for more than one switch. When you put several solar cells in a series, you can add together the volts of the cells to find the total volts expected to be produced by the series. Four 0.5 V solar cells wired in series should produce 2 V. Wiring in parallel increases the current, but not the voltage.

Timing the lesson. When the sun is higher in the sky, the angle of the sun provides the most light per unit area of ground (later in spring or summer). That affects how much light is available to power the solar cells. This lesson will be most successful if it can be conducted on a sunny day, preferably between 11:00 am and 3:00 pm. At those times, the solar cells will be able to make enough electricity to power the pump. In our experience in Oregon, during these hours,

the pump ran slowly to not at all with less than four (4) 0.5 V cells. The pumps ran well with 6 cells as long as all of the cells were angled toward the sun. Again, it will depend on your geographic location.

Science Kit Materials List:

- For each group of 3 students:
    - (6) 0.5 volt Solar Schoolhouse solar cells
    - (1) DC water pump with PVC tubing

Other Materials List:

- Solar Cell Lab 2, 3 and 4 handouts printed for each student
- Electrical Circuits and Currents by Barbara Somervill
- For each group of 3 students:
    - (1) Low flat plastic container of water
    - (1) Larger plastic container to pump water into
    - Timer
    - (1) Cup measuring cup marked in fractions of a cup and mL
    - Small roll of electrical tape
    - Scissors

Vocabulary:

- Circuit – the path along which electricity flows
- Load – the power drained (used) by any machine or electric circuit
- Parallel circuit – circuit that connects a power source, a load and conductors in multiple loops
- Series circuit – circuit that connects a power source, a load and conductors in a single loop

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Lesson Details:

Part I: Exploring the Materials and Reflecting

Time: 1 hour

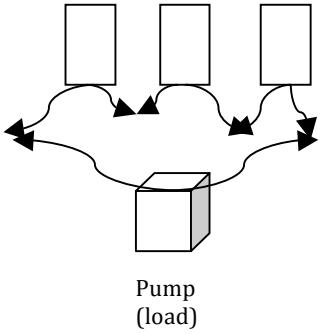
Activity plan

- Go over today's guiding questions/challenge:
    - What happens when you use more than one cell in a circuit?
    - Can you attach them in a way that moves more water?
    - How do you know that it is moving more water? Can you provide evidence? How much more water can it move?

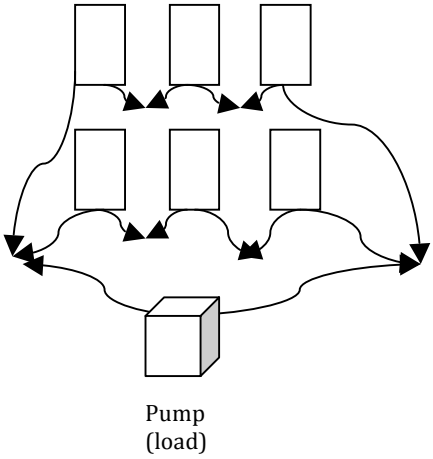
- What happens if you cover one of the cells as you work? What conclusions can you make about why that happens?

- Review expectations about how to safely and carefully work with the materials. Discuss which materials they might use if they wanted to test if the pump was moving more water.
- Allow exploration time with the materials.
- As students work, discuss their ideas and have them try to support their theories with evidence. When some students have come up with a working series or parallel circuit, have them demonstrate it for the rest of the students.
- Introduce parallel circuit and series circuit on the board and draw diagrams comparing the two.

Circuit 1: Series circuit



Circuit 2: Parallel and Series circuit



In Circuit 1 above, three solar modules are shown in a single series string. In Circuit two, two of these series strings of three solar modules are connected together in parallel.

- Have students return to work. Allow students to combine materials with other groups if desired.
- When they are finished exploring or in a second session, have them work in pairs or alone to write answers to the Guiding Questions on Solar Cell Lab 2 Handout. Also, have them copy the diagrams of series and parallel wiring on the back of the handout.
- Closure: Read pp. 22-23 in Electrical Circuits and Currents to reinforce the concepts of parallel and series circuits.

Part II: Planning an Investigation

Time: 45 minutes

Activity plan

- Introduce idea of how engineers work in a scientific manner by quantitatively measuring how well something works and how making changes to a system will impact how well it operates. They record data and then share it on a graph. Discuss why careful measurements are important in science and engineering.

- Discuss student ideas of how we might fairly test how much more water is pumped if more solar cells are added to a circuit.

- Hand out the investigation planning sheet (#3). Let the students know that they get to plan their own investigation to test this idea. Solicit ideas of how the question might be phrased to be testable. For example, "How much more water is pumped in one minute when more solar cells are added to a circuit?" Students are instructed to use any question that can be answered fairly with data.

- Review the other parts of the planning sheet with the students before they take time to fill it out. After making a prediction or hypothesis, they should write a little about the background information that they are basing their hypothesis on, list the materials they will need for the experiment, and make a plan of how to carry out their experiments. For example, students might:
    - Add 1 solar cell at a time to their circuits.
    - Measure each time the volume of water that is pumped in the set amount of time in cups.
    - Round the answer to the nearest ¼ cup.

Part III: Conducting an Investigation: Scientists Measure and Record Data –> How Much Water is Pumped?

Time: 45 minutes

<u>Activity plan:</u>

- When the investigation day arrives, students will need to take a little time to make a chart to record their data. Remind them that they should think about how many tries they are going to make for each number of solar cells and what units they are measuring in as they design their charts.

One possible data table:

	Amount of Water Pumped in mL		
Number of Panels	Try 1	Try 2	Try 3
2			
4			
6			

- Students gather their materials, carry out their investigations according to their plans outside and write their data in their charts.
- Students clean up their materials. It helps to empty the water out of the hoses on the pumps and unhook the solar cells. The solar cells can be stored with a rubber band around the 6 cells. Any electrical tape should be taken off and thrown away.

Part IV: Reflecting on our Data and Drawing Conclusions

Time: 45 minutes

Activity plan:

- Review the final questions on the Investigation Sheet (#4). Go over the difference between the results and the conclusions. Results are statements about the numbers they measured. Conclusions are explanations of why they got the results and any errors they may have made.

Extension:
If time allows, invite parents or another class for a presentation. Allow the students to demonstrate their experiments and read their results and conclusions to their peers or parents.

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