Engineering with Renewable Energy: Solar Water Pumping

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DESCRIPTION: Students will learn that energy from a renewable resource can be converted to electrical energy to do work by engineering a water pump system powered by the sun. They will compare the volume of water pumped by different designs and graph data collected and use the data to evaluate their designs. The lessons integrate Common Core State Standards for reading informational text and for math (graphing). The final design project could serve as an Oregon Engineering Design work sample.

GRADE LEVEL(S): 4, 5

SUBJECT AREA(S): Engineering, science

ACTIVITY LENGTH: 2 hours

LEARNING GOAL(S):

- The students will be able to learn what a solar cell looks like and how light energy triggers the cell to release negative charges to move toward the positive side, creating power as it moves from one side to the other. Students will be able to arrange four panels into the correct order to create power for an object and interact with a 3D model of a module to understand how the electricity to power the fan is created.
- The students will be able to experiment with solar panels (angle, direction) to power a small fan/LED light/circuit board. Students will be able to identify the best position/angle for maximum power.
- 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.

STANDARDS MET:
Common Core:

- CCSS ELA 4.RI.1. Refer to details and examples in a text when explaining what the text says explicitly and when drawing inferences from the text.
- CCSS ELA 4.RI.9. Integrate information from two texts on the same topic in order to write or speak about it knowledgeably.

- CCSS ELA 4.RI.7. Interpret information presented visually, orally, or quantitatively (e.g., in charts, graphs, diagrams, time lines, animations, or interactive elements on Web pages) and explain how the information contributes to an understanding of the text in which it appears.
- CCSS Math 3.MD.2. Measure and estimate liquid volumes and masses of objects using standard units of grams (g), kilograms (kg), and liters.
- CCSS Math 3.MD.3. Draw a scaled picture graph and a scaled bar graph to represent a data set with several categories.
- CCSS 5.G.2. Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values.

Next Generation Science Standards:

- NGSS 4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.
- NGSS 4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.
- NGSS 4-ESS3-1. Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.

Student Background:

- Prior knowledge of measuring volume and creating a graph.

Educator Background:

- Electrical energy is the flow of electrical charges, often harnessed to do work. Sunlight causes the charges in solar panels to gain energy, allowing electrons to flow in a single direction, which generates electricity.
- A solar cell is an invention that converts light to electric current by the photovoltaic effect.
- Solar energy is considered renewable energy because it comes from sources that can easily be replaced, unlike oil, gas, and coal.

Science Kit Materials List:

Lesson 1:

- Individual Solar Module, 2 Volt, 500 mA

Lesson 2:

- (24) Individual Solar Module, 1.5 Volt, 500 mA

Other Materials List:

- “3D Model of a Solar Cell” handout
- “3D Solar Panel Model” student handout

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Lesson 1:
- Laminated activity sheets for Solar Cells
- 3-D model (see 3-D module sheet)
- Styrofoam board, 1/5” thick
- Reflective pattern poster board (Tip: I cut mine from a gift bag.)
- Clear glass stones
- Colorful beads
- Cardboard
- Duct tape
- Wires to connect to the appliance (i.e. load) that you are powering

Lesson 2:
- (8) Solar powered fans
- (8) LED lights
- (8) Circuit boards - light, music
- (16) 3 Volt solar modules
- (2) Work lamps (if sun is not available). (Note: fluorescent lights will not work for this.)

Lab 1 and 2:
- (64) 0.5 volt solar cells
- (8) Small DC Water Pumps
- Roll of electrical tape
- (16) Plastic tubs (such as recycled 1 pint containers)
- (16) Timers
- (8) Plastic graduated cylinders
- (6) Packages of adhesive Velcro (to attach the 0.5 volt cells to a binder)

Vocabulary:
- Energy
- Photovoltaic

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Lesson Details:

Part 1: Building Background Knowledge for Students

Lesson 1: How solar cells work

Time needed: 20 minutes

Goal: The students will learn what a solar cell looks like and how light energy triggers the cell to release negative charges to move toward the positive side, creating power as it moves through a circuit from one side to the other. Students will be able to arrange four panels into the correct

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order to create power for an object and interact with a 3D model of a module to understand how the electricity to power the fan is created.

Materials:

- Laminated activity sheets for Solar Cells
- Individual Solar Module, 2 Volt, 500 mA
- 3D model (Styrofoam, cardboard, paper, beads, clear glass rocks, small fan)

Activity Plan and Lesson Notes:

1. Ask the students to write down a definition of solar power in their notebook or one or two facts they know about the sun or solar energy.

2. Have each student write down one or more questions that they have about solar power.

3. Introduce the key word photovoltaic - sometimes called PV – which is the process of converting sunlight into electricity. Ask the student to repeat the word with you.
    - Photo = light, and voltaic = electricity

4. The module consists of two layers.
    - One with available electrons (n, or negative layer).
    - One that needs more electrons (p, or positive layer).
    - They are separated by a junction that is like a one-way door - electrons can move from the lower p-layer to the upper n-layer, but not back the other way.

5. Think of the electrons as food.
    - The n-layer has a lot of food that it wants to deliver to the p-layer, but it doesn't have permission to leave its layer
    - When energy from the sunlight hits the solar module, it give the n-layer permission to leave its layer to deliver the food to the p-layer
    - Because the door between the layers is one-way, the food can't be delivered downward through the junction. Therefore, the food must travel through another path – in reality, through the wire connecting the top and bottom layers. This creates the circuit.
    - On the way, the current caused by the "food delivery" creates electricity which can be used to power a light bulb
    - Eventually the food/extra electrons move back to the n-layer through the one-way door of the junction and the system is ready to go again.

6. Before the lesson, I built a 3D model to show my students. At this point, you could let your class look at the model as you explain how the system works with the accompanying worksheet.
    - In the 3D model, the sun (their hand) will contact the top layer, releasing energy to the n-layer.
    - The n-layer has extra electrons (colored beads) that now have the energy to move (create a current) to the fan. This is the electricity that powers the fan.

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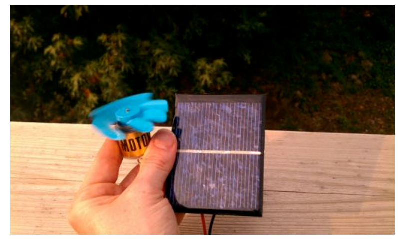
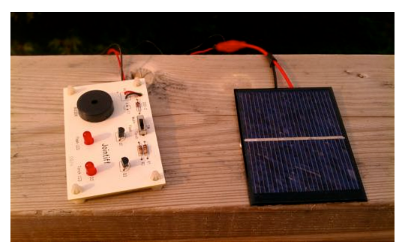
- The extra electrons would then move to the p-layer and then back up (through the p-n-junction layer – i.e. cardboard) to the n-layer. The process can start again.

7. After you have explained the process, ask students to place the four phases in the correct order (1, 2, 3, 4 = solar energy, n-layer, electricity, p-layer).

8. Ask the students to write down three things that they have learned about solar energy and one more question.

Lesson 2: How to connect a solar powered circuit





Time needed: 30 minutes

Goal: The students will be able to experiment with solar panels (angle, direction) to power a small fan/LED light/circuit board. They will be able to identify the best position/angle for maximum power.

Materials:
- (8) Solar powered fans
- (8) LED Lights
- (8) Power Output Boards
- (24) Individual Solar Module—1.5-Volt, 500 mA
- (16) 3 Volt Solar Modules
- (2) Work lamps (if sun is not available)

Guiding questions:
1. How do the wires need to be attached to work the fan/lights/board?
2. What observations can you make about whether energy is moving from place to place? What is your evidence?
3. What is the minimum voltage needed to operate each fan/light/board?

Activity Plan:
1. Go over today's guiding questions/challenge.

2. Encourage the students to try the smaller modules first and then move to the larger modules. They can also connect two 1.5V modules to increase the energy to power the fan/light. To connect two modules, connect one red to the black of the second module and then complete the circuit by connecting red-to-red wires and black-to-black wires with the fan/light.

3. Closure: Share observations and conclusions. Model thinking about whether something was an observation or a conclusion. Depending on time, it also might be useful to draw a diagram (as a group) of the students' conclusions about how energy is moving and changing form.

4. Have the students write answers to the guiding questions in their notebooks.

Notes:

- If it is cloudy, you can use a work lamp to power the solar cells. The lamp can be rather hot so please do not let the students touch the unit. Note that fluorescent lamps will not work for this activity.

Part 2: Labs

Lab 1: Exploring solar pumping

Learning goals:

- 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.

Materials

For each team of students:

- 1.5 Volt Solar Schoolhouse solar cell
- KidWind pump with PVC tubing
- Low flat plastic container of water
- Larger plastic container to pump water into (e.g., plastic shoebox)
- Roll of electrical tape
- Scissors

Time needed: 30 minutes

Guiding questions:

1. How do the wires need to be attached to work the pump?
2. Can you find a way to make the pump work more quickly or more slowly?
3. What observations can you make about whether energy is moving from place to place? What is your evidence?
4. What observations can you make about whether energy is changing form? What is your evidence?

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Activity plan:

1. Introduce materials. Solicit ideas about how they might work. Go over expectations about how to safely and carefully work with the materials.
2. Review guiding questions and have them copy them into their science notebook.
3. Allow exploration time with the materials.
4. Take a break and pair-share about the guiding questions and share partner's response with the group. Define evidence and conclusions.
5. Allow students to finish exploring or move on to written work if they are ready.
6. Closure: Share observations and conclusions.

Lab 2: Exploring what happens when you use more than one cell

Prior knowledge expected:

- Math lessons on measuring volume
- Math lesson on creating a graph

Time needed: 30 minutes

Guiding questions:

1. What happens when you have more than one cell?
2. Can you attach them in a way that moves more water?
3. How do you know that it is moving more water? Can you provide evidence? How much more water can it move?
4. What happens if you cover one of the cells as you work? What conclusions can you make about why that happens?

Materials:

For each group of 4 students:

- (8) 0.5 Volt Solar Modules
- Small DC Water Pump
- Low flat plastic container of water
- Larger plastic container to pump water into (e.g., plastic shoebox)
- Roll of electrical tape
- Scissors
- Timer
- Plastic graduated cylinder
- (6) Packages of adhesive Velcro (to attach the 0.5 Volt cells to a binder)

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Activity plan

1. Go over today's guiding questions/challenge
2. Review expectations about how to safely and carefully work with the materials.
3. Allow exploration time with the materials.
4. As students work, discuss their ideas and have them try to support their theories with evidence.
5. When some students have come up with a working series or parallel circuit, have them demonstrate it for the rest of the children. Introduce the two terms on the board and draw diagrams comparing the two. Allow students to combine materials with other groups if desired.
6. Have students return to work. When they are finished exploring, have them work in pairs or alone to write answers to the Guiding Questions in their science notebooks. Also, have them copy the diagrams of series and parallel wiring into their notebooks.
7. Ask the teams to graph their data in their notebooks.
8. Closure – Share observations and conclusions. Have the teams compare their graphs to look for trends in the class data.

Lesson Wrap-Up:

1. Have the students write a definition of solar power. Compare it to the definition they wrote in the beginning of the unit.
2. Ask the students to review the questions that they had on the first day. Were they answered? Write the unanswered questions on the board. Have the students write down one question that interests them and have them research it at home and bring in the answer the following week.