Solar Kit Lesson #1
Solar Cell Inquiry

TEACHER INFORMATION

LEARNING OUTCOME
After students carry on an open-ended inquiry of how solar panels and an AA battery can be used to power lamps and motors, they infer what forms of energy are used in each instance and predict how long each power source might be able to operate a device.

LESSON OVERVIEW
In this lesson, students use a selection of solar panels, lamps, motors, and an AA battery to get as many motors or lights to operate as they can in an allotted time period. For each successful arrangement, they draw a diagram of their setup, label the energy source and the forms of energy used, and make inferences and predictions.

GRADE-LEVEL APPROPRIATENESS
This lesson is intended for use in grades 2–7. (See Curriculum Standards Section at the bottom of the document)

MATERIALS
Per work group
- One or two (different if possible) small DC motors having an operating range of roughly 1–4 volts*
- One or two (different if possible) light-emitting diodes (LEDs)*
- One or two (different if possible) small incandescent flashlight bulbs
- Two 1V, 400 mA mini–solar panels with alligator clip leads*
- Sunlight, a gooseneck lamp with 100-watt incandescent bulb, or both
- One AA battery in holder with alligator clip leads

* Available on our website to reserve the materials; other materials are to be supplied by the teacher

SAFETY
Warn students
- not to touch lighted incandescent bulbs, since they become hot enough to cause a burn;
- not to let the alligator clips on the two wires connected to the battery touch, since the battery will quickly become "dead" (also, the battery might become hot enough to cause a burn).

TEACHING THE LESSON
Introduce the concept that there are different forms of energy, such as light, mechanical, electrical, chemical, and heat energy.

State that solar cells are objects that convert light energy into electrical energy. Hold up a mini–solar electric panel and show students that it is made up of solar cells.

Form student teams of two or three.

Provide each team with two solar cells, 1 AA battery in a holder, motor(s), a selection of light-emitting diodes (LEDs), a selection of small flashlight bulbs, and if direct sunlight is unavailable, a gooseneck lamp with a 100-watt incandescent bulb.

Challenge students with the task of connecting together items they have been given in ways that will cause a lamp to shine or a motor to spin. Each time they are successful, have them fill in a Record of Inquiry for that test.

Have students determine how long a circuit will remain "on" and compare the results with the proposal they recorded in the Record of Inquiry.

Tell students the cost of a 1V, 400 mA solar cell ($5.00), and the cost of one AA battery. Help them, as needed, as they calculate the cost of running a motor with a battery versus a solar cell for one hour, one week, and one month.

Discussion:
Review with students the different forms of energy that they encountered. Stress the particular form of energy at the source of power (light for photovoltaic-powered circuits and chemical for battery-powered circuits).

Compare the concept of power with the concept of energy. Ask students to identify which test setups produced more power as evidenced by a faster turning motor or a brighter glowing bulb, and which setups had the longer lasting source of energy.

Check to see if any teams noticed that LEDs work only when the red and black wires are connected according to the proper polarity (red to the positive terminal, black to the negative terminal), but that the motors and incandescent lamps work when the red and black wires are connected to either terminal. If so, have those students research the literature to come up with explanations for the phenomena.

Discuss the pros and cons of powering simple circuits using solar cells versus batteries (see the Background Information section).

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION
Answers will vary. Complete answers will include the following.

1) Clearly drawn and labeled diagrams.
2) Correct labeling of each form of energy that exists in the circuit depicted.
3) Correct identification of the source of energy (light from the Sun or a light bulb for photovoltaic-powered circuits and stored chemical energy for battery-powered circuits).

4) An appropriate identification of the power output provided by the circuit.

5) A cogent and feasible explanation of the energy available to power the circuit depicted.

ADDITIONAL SUPPORT FOR TEACHERS

SOURCE FOR THIS ADAPTED ACTIVITY

This lesson plan was developed by School Power Naturally project sponsored by NYSERDA. It was adapted for California by Brent Lee.

BACKGROUND INFORMATION

Photovoltaic Cells: When a solar cell is exposed to typical light sources, negatively charged electrons almost instantly move to the top of the cell, leaving behind a crystal lattice of atoms having more positively charged protons than negatively charged electrons on the bottom of the cell. This movement rapidly reaches an internal state of equilibrium where the solar cell exhibits a voltage difference of about 0.5 volts between the top and the bottom of the cell.

When metal contacts are placed on the top and the bottom of a photovoltaic cell (solar cell) and each cell is connected to an electric circuit, electrons are drawn off the top of the cell, producing a current that can be used externally. Electrons from the top of the cell move through the electric circuit, replacing the missing electrons in the bottom of the cell. This movement continues as long as the cell is exposed to light having photons of sufficient energy to excite the photovoltaic crystal's electrons.

Power Versus Energy: Power is the rate at which work is done. Energy is the capacity of a physical system to do work. In this lesson, power is proportional to how fast a motor spins or how bright a bulb glows.

Energy available to do work depends on the circuit present. Circuits powered by batteries have energy to do work as long as the batteries are "charged" rather than "dead." The length of time that such a circuit will do work depends on the amount of energy stored in the battery. Circuits powered by solar cells have energy to do work as long as light is present.

Light-Emitting Diodes (LEDs): A light-emitting diode produces light when current passes through it. Unlike an incandescent bulb, current can pass through an LED in only one direction. LEDs are now readily available in flashlights and in strings of Christmas tree lights. LEDs typically can be purchased in electric supply stores.

REFERENCES FOR BACKGROUND INFORMATION

The Columbia Encyclopedia, Sixth Edition. 2001.
The American Heritage® Dictionary of the English Language: Fourth Edition. 2000.

APPLICABILITY TO THE CALIFORNIA STANDARD CURRICULUM

Grade Two

Physical Sciences

1. Energy and matter have multiple forms and can be changed from one form to another.
    a. Students know energy comes from the Sun to Earth in the form of light.
    b. Students know sources of stored energy take many forms, such as food, fuel, and batteries.
    c. Students know machines and living things convert stored energy to motion and heat.
    d. Students know energy can be carried from one place to another by waves, such as water waves and sound waves, by electric current, and by moving objects.
2. Light has a source and travels in a direction.
    a. Students know sunlight can be blocked to create shadows.

Investigation and Experimentation

3. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations.
    a. Repeat observations to improve accuracy and know that the results of similar scientific investigations seldom turn out exactly the same because of differences in the things being investigated, methods being used, or uncertainty in the observation.
    b. Differentiate evidence from opinion and know that scientists do not rely on claims or conclusions unless they are backed by observations that can be confirmed.
    c. Use numerical data in describing and comparing objects, events, and measurements.
    e. Predict the outcome of a simple investigation and compare the result with the prediction.
    f. Collect data in an investigation and analyze those data to develop a logical conclusion.

Grade Four

Physical Sciences

1. Electricity and magnetism are related effects that have many useful applications in everyday life.
    a. Students know how to design and build simple series and parallel circuits by using components such as wires, batteries, and bulbs.
    b. Students know electrical energy can be converted to heat, light, and motion.

Investigation and Experimentation

2. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations.
    a. Differentiate observation from inference (interpretation) and know scientists' explanations come partly from what they observe and partly from how they interpret their observations.
    b. Formulate and justify predictions based on cause-and-effect relationships.
    c. Conduct multiple trials to test a prediction and draw conclusions about the relationships between predictions and results.
    d. Construct and interpret graphs from measurements.

e. Follow a set of written instructions for a scientific investigation.

Grade Five

Investigation and Experimentation

1. Scientific Process is made by asking meaningful questions and conducting careful investigations. As a basic for understanding this concept and addressing the content in the other three strands, student should develop their own questions and perform investigations

a. Develop a testable question
b. Plan and conduct a simple investigation based on a student-developed question and write instructions others can follow to carry out the procedure.
c. Select appropriate tools (e.g. thermometers, meter sticks…) and make quantitative results
d. Record data by using appropriate graphic representations and make inferences based on those data
e. Draw conclusions from scientific evidence and indicate whether further information is needed to support a specific conclusion
f. Write a report of an investigation that includes conducting tests, collecting data or examining evidence, and drawing conclusions

Grade six

Earth Sciences (main focus)

Resources

1. Sources of energy and materials differ in amounts, distribution, usefulness, and the time required for their formation

a. Students know the utility of energy sources is determined by factors that are involved in converting these sources to useful forms and the consequences of the conversion process.
b. Students know different natural energy and material resources and know how to classify them as renewable or nonrenewable

Investigation and Experimentation

2. Scientific Process is made by asking meaningful questions and conducting careful investigations. As a basic for understanding this concept and addressing the content in the other three strands, student should develop their own questions and perform investigations

a. Develop a hypothesis
b. Select and use appropriate tools and technology to perform tests, collect data, and display data
c. Construct appropriate graphs from data and develop qualitative statements about the relationship between variables
d. Communicate the steps and results from an investigation in written reports and oral presentations
e. Recognize whether evidence is consistent with a proposed explanation

Grade Seven

Focus on Life Sciences

Investigation and Experimentation

1. Scientific Process is made by asking meaningful questions and conducting careful investigations. As a basic for understanding this concept and addressing the content in the other three strands, student should develop their own questions and perform investigations

a. Select and use appropriate tools and technology to perform tests, collect data (Vernier), and display data

b. Communicate the logical connection among hypotheses, science concepts, tests conducted, data collected, and conclusions drawn from scientific evidence
c. Construct scale models, maps, and appropriately labeled diagrams to communicate scientific knowledge

Produced by the Northeast Sustainable Energy Association in coordination with the Research Foundation of the State University of New York with funding from the New York State Energy Research and Development Authority (NYSERDA)

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Should you have questions about this activity or suggestions for improvement, please contact Professor Jan Kleissl at jkleissl@ucsd.edu.

(STUDENT HANDOUT SECTION FOLLOWS)

Name _____

Date _____

Solar Cell Inquiry

Complete a **Record of Inquiry** each time a new arrangement succeeds—that is, each time a lamp goes on or a motor works.

Record of Inquiry

Test Number: _____

1) Draw a diagram that shows how the items you used are connected. On your diagram, label each item and the color of the wires.

2) On your diagram, identify where each of the following forms of energy is present.

   Light Mechanical Electrical Chemical Heat

3) Where does the energy that powers the small lamp or motor come from?

4) How fast is the motor spinning, or how bright is the lamp operating? On a scale of one to five, circle the appropriate number.

LAMP					MOTOR				
1	2	3	4	5	1	2	3	4	5
Dim				Bright	Slow				Fast

5) How long do you predict the motor or lamp will remain on, if left as you have it connected? Back up your claim by explaining your prediction.