Solar Education for NY
SchoolPower ...Naturally

Solar Kit Lesson #6
Solar-Powered Battery Charger

TEACHER INFORMATION

LEARNING OUTCOME
After designing and testing a solar-powered battery charger, students are able to describe the relationship between the direction of electrons flowing through a battery and a change in the battery's voltage.

LESSON OVERVIEW
In this lesson students design and construct their proposals intended to show the way solar cells must be connected to produce adequate voltage to recharge a battery.

In doing so, students use the simple ammeter they designed and built in the Solar Kit lesson *Build a Simple Ammeter*.

GRADE-LEVEL APPROPRIATENESS
This Level II Physical Setting lesson is intended for use in grades 5–9.

MATERIALS
Per work group
- Digital multimeter
- “Dead” rechargeable D-cell battery
- D-cell battery holder with alligator clip leads
- electromagnet-and-compass ammeter from the Solar Kit lesson *Build a Simple Ammeter*
- masking tape
- two 1 V, 400 mA mini–solar panels* with alligator clip leads
- gooseneck lamp with 150-watt incandescent bulb

* Available in the provided Solar Education Kit; other materials are to be supplied by the teacher

SAFETY
Warn students that the bulb will become hot enough to cause a burn if touched. If a charged battery powers the electromagnet, it should remain connected for only a short period of time. Warn students that if it is connected over a longer period, the battery or wire may get hot enough to cause a burn, and the battery will discharge quickly.

TEACHING THE LESSON
Preferably, this lesson directly follows the Solar Kit lesson *Build a Simple Ammeter*. Students should work in groups of two or more. Set out all materials at the workstations.

The basic concepts of recharging a battery are described in the student handout. If you are unfamiliar with these concepts, read the handout before the classroom discussion. Ask students to describe what they know about batteries and recharging batteries. Tell students that in this lesson they will use these concepts to design and test a solar-powered battery charger.

Show students how to use a digital multimeter to read voltages. If they do not have access to the electromagnet-and-compass ammeters from *Build a Simple Ammeter*, show them how to use the digital multimeter to read current in milliamps. Make sure they understand that if the ammeter reading is positive, the electrons are flowing into the negative terminal of the meter. You may want them to determine this by using the digital ammeter to complete a modified version of step 5 in *Build a Simple Ammeter*.

Pass out the handout and have students follow the directions.

Review Discussion:
Use a drawing or schematic to review with students why placing the solar panels in series was necessary to provide the electromotive force to drive electrons into the negative terminal of the battery.

Have students compare what they learned about placing solar panels in series in this lesson with what they learned about placing solar panels in parallel in *Build a Simple Ammeter*.

Review how to tell if a battery is recharged. (The battery will stop drawing current from the solar panels.)

You may want to set some of the charging circuits in direct sunlight for a day so students can see that the solar panels can fully recharge the batteries.

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION

1. Lamp and solar cell positioned as described in handout.

2. Measurements as follows:

	Voltage
Solar Panel 1	.9 V to 1.0 V
Solar Panel 2	.9 V to 1.0 V
Dead Battery	.3 V to .8 V
Charged Battery	1.5 V

3. Electromagnet-and-compass ammeter working as described.

4. Responses will vary. The final design, however, should show the two mini–solar panels, the dead battery, and the ammeter all wired in series with the negative terminal of the battery connected to the negative terminal of the series solar panels, perhaps through the ammeter. Students can demonstrate how the ammeter indicates that electrons are flowing into the negative terminal of the battery.

5. The solar panels are connected in series so their combined voltage can provide the force needed to push electrons into the negative terminal of the battery, even when it is almost recharged.

   The battery is recharged when the ammeter stops indicating that any electrons are moving. (The battery has stopped drawing current for the solar panels.)

ADDITIONAL SUPPORT FOR TEACHERS

SOURCE FOR THIS ADAPTED ACTIVITY

This activity is adapted from an activity designed and run by Richard Komp, Ph.D., president of the Maine Solar Energy Association and of the Sun Watt Corporation, and Byron Humphries, teacher. In their lesson, students build solar-powered battery chargers out of broken pieces of solar cells.

BACKGROUND INFORMATION

Building a solar-powered battery charger is an inherently safe activity for students because of the way solar cells self-limit the amount of current they produce. Recharging a battery at too fast a rate (too high a current) might cause a buildup of gas inside the battery, potentially causing it to explode. Charging batteries with mini–solar panels eliminates this potential safety hazard.

If a charging battery is left connected with no light source on the solar panels, it will leak current through the panels and slowly discharge. This leakage can be avoided by placing a diode in series in such a way as to block this reverse current. If this is done, another solar panel will be needed to overcome the voltage drop across the diode during charging.

LINKS TO MST LEARNING STANDARDS AND CORE CURRICULA

Standard 1—Analysis, Inquiry, and Design: Students will use mathematical analysis, scientific inquiry, and engineering design, as appropriate, to pose questions, seek answers, and develop solutions.

Mathematical Analysis Key Idea 1: Abstraction and symbolic representation are used to communicate mathematically. (elementary)

Key Idea 2: Deductive and inductive reasoning are used to reach mathematical conclusions. (elementary)

Key Idea 3: Critical thinking skills are used in the solution of mathematical problems. (elementary and intermediate)

Scientific Inquiry Key Idea 1: The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process. (elementary and intermediate)

Key Idea 2: Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity. (elementary and intermediate)

Key Idea 3: The observations made while testing proposed explanations, when analyzed using conventional and invented methods, provide new insights into phenomena. (elementary)

Engineering Design Key Idea 1: Engineering design is an iterative process involving modeling and optimization (finding the best solution within given constraints); this process is used to develop technological solutions to problems within given constraints. (elementary)

Standard 3—Mathematics: Students will understand mathematics and become mathematically confident by communicating and reasoning mathematically, by applying mathematics in real-world settings, and by solving problems through the integrated study of number systems, geometry, algebra, data analysis, probability, and trigonometry.

Key Idea 5: Students use measurement in both metric and English measure to provide a major link between the abstractions of mathematics and the real world in order to describe and compare objects and data. (elementary and intermediate)

Key Idea 6: Students use ideas of uncertainty to illustrate that mathematics involves more than exactness when dealing with everyday situations. (elementary)

Standard 4—The Physical Setting: Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science.

Key Idea 4: Energy exists in many forms, and when these forms change energy is conserved. (elementary and intermediate)

Key Idea 5: Energy and motion interact through forces that result in changes in motion. (elementary and intermediate)

Standard 5—Technology: Students will apply technological knowledge and skills to design, construct, use, and evaluate products and systems to satisfy human and environmental needs.

Key Idea 1: Engineering design is an iterative process involving modeling and optimization used to develop technological solutions to problems within given constraints. (elementary and intermediate)

Standard 6—Interconnectedness: Common Themes: Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.

Key Idea 5: Identifying patterns of change is necessary for making predictions about future behavior and conditions. (elementary and intermediate)

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www.nyserda.org

Should you have questions about this activity or suggestions for improvement, please contact Chris Mason at cmason@nesea.org.

(STUDENT HANDOUT SECTION FOLLOWS)

Name ___________________________________

Date ____________________________________

Solar-Powered Battery Charger

In this activity you will design and test a solar-powered battery charger.

Introduction
The voltage of a power source indicates its ability to force electrons through an electrical circuit. When a battery is connected to a circuit (such as when you turn on the switch of a flashlight to connect its battery to its light bulb), it forces electrons out of its negative terminal (marked with a minus [-] sign), through the circuit, and into its positive terminal (marked with a plus [+] sign). This action slowly changes the chemical makeup of the battery. With use, this change reduces the voltage of the battery and at some point the battery can no longer force the electrons through the circuit. At this point we say the battery is "dead."

For some dead batteries, another power source can be used to force the electrons to flow in the opposite direction and cause the chemical makeup of the battery to return to its original state. The battery is then "recharged." In order to do this, the voltage of the other power source must be greater than the charged voltage of the battery.

In this lab you will use two mini–solar panels as a power source to recharge your battery.

1) **Power Source:** Tape two mini–solar panels to the table and position the 150-watt lamp 120 cm above the panels. Do not place the lamp any closer, as it may melt a panel's plastic cover. Position the lamp so it is the same distance from both panels. Turn the lamp on only when taking a measurement or testing your design.

2) **Measure voltages:** Follow your teacher's instructions on how to measure the open circuit output voltage of each solar panel and the dead battery. Record these measurements in table 1.

Table 1

	Voltage
Solar Panel 1	
Solar Panel 2	
Dead Battery	
Charged Battery	1.5 V

3) **Set up an ammeter:** Set up the electromagnet-and-compass ammeter your team built. Using one solar panel, test the ammeter to ensure it is still operational. The needle should deflect 15 to 20 degrees when the lamp is turned on.

4) **Design and test the battery charger:** On paper, draw a diagram showing how to connect the two solar panels, the dead battery, and the ammeter so that when the light is turned on, electrons will flow from the solar panels into the negative terminal (-) of the battery. Remember, your ammeter has been calibrated to tell you the direction in which electrons are flowing.

   Once you have drawn a circuit you believe will work, build and test it. If your ammeter does not show you that electrons are flowing into the negative terminal of the battery, check all of your connections. If this is not the problem, redesign your circuit. Then rebuild and retest it.

   When you have a working circuit, ask your teacher to confirm it.

5) **Complete the following:**
   Explain WHY you connected the two solar panels in the way you did in hopes of producing a working battery charger.

   Without touching the circuit, how would you know when your battery is recharged?