Solar Kit Lesson #5
Build a Simple Ammeter

TEACHER INFORMATION

LEARNING OUTCOME

After building and working with a simple ammeter, students are able to describe the relationship between the direction of a current and the magnetic field it produces.

LESSON OVERVIEW

In this lesson, students:

- propose and test theories on why solar cells connected in parallel produce more current than in series; and
- apply conventional standards of (a) clockwise analog meter movement and (b) electrons flowing from a negative terminal.

Students build a simple ammeter to indicate the presence, direction, and strength of an electric current flowing through a wire. This device may be used later on to help students design and build a solar-powered battery charger in the Solar Kit lesson *Solar-Powered Battery Charger*.

GRADE-LEVEL APPROPRIATENESS

This Level II Physical Setting lesson is intended for use in physical science and technology education classes in grades 5–9.

MATERIALS

Per work group

- 150 cm enamel-coated magnet wire
- 2.5 cm length of drinking straw
- compass
- 2 large ("jumbo") metal paper clips straightened and cut into six 5 cm long pieces of "wire"
- 15 x 40 cm piece of cardboard or card stock
- masking tape
- scissors
- 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 battery is used to power the electromagnet, it should be connected for only short periods 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. Connecting an electromagnet to a mini–solar panel, however, poses no safety hazards.

TEACHING THE LESSON

Preparation: Prepare the workgroup materials. Use a pair of diagonal cutters to cut the jumbo paper clips into 5 cm long pieces and scissors to cut drinking straws into 2.5 cm long pieces.

Students should work in groups of two or more. Set out all materials but hold back one of the mini–solar panels at each of the workstations.

The basic concepts for an electromagnet are described in the student handout. If you need to familiarize yourself with these concepts, read the handout before holding the classroom discussion. Ask students to describe what they already know about electromagnets. Tell students that they will use such information in this activity to design and build a device to indicate the presence, direction, and strength of a current flowing from one or two solar panels. Pass out the handout and have students follow the directions.

Between steps 1 and 2, you may want to allow time for students to test their electromagnet by using a battery (for a current source) to pick up metal paper clips. Remember to warn students to connect the battery for only a short period of time.

Step 6 asks students to make a prediction expressed through a drawing. Tell them that after they complete their prediction, you will check their work and provide them with the second mini–solar panel.

Review Discussion:

Review with the students that the electromagnet exerts a force on the compass needle.

Discuss with students how a pointer swinging in a clockwise direction, by convention, describes a positive increase in value. Think of a speedometer on a car. Have students connect a solar panel so that the compass needle swings clockwise (toward the east). Then have them mark the terminal connected to the black wire with a minus (-) sign and the terminal connected to the red wire with a plus (+) sign.

Ask students to share their explanations of why parallel solar cells produce the most current. Help them understand that a solar cell limits the amount of current that flows through it.

ACCEPTABLE RESPONSES FOR DEVELOP YOUR UNDERSTANDING SECTION

1) The finished electromagnet will have two 5 cm wire leads with the insulation removed.
2) Lamp and solar cell will be positioned as described in the handout.
3) Students can show that turning the light on and off will cause the compass needle to shift by 15 to 20 degrees.
4) The compass needle deflects in the opposite direction.

5) Arrows are drawn on the ammeter pointing along the two terminals. One terminal is marked with an *E*, the other with a *W*. Given a solar panel connected with either polarity, students can predict which way the compass needle will deflect.

6–7) Responses will vary in this part of the activity, but the diagram will typically show the two solar panels connected in parallel with the ammeter. Students will likely offer the following reason for connecting the panels in parallel: When solar panels are connected side by side (in parallel), the electrons from the second panel don't have to go through the higher resistance of a first solar panel, as they would if the panels were connected front to back (in series).

ADDITIONAL SUPPORT FOR TEACHERS

SOURCE FOR THIS ADAPTED ACTIVITY

The idea of using an electromagnet and a compass to form a simple ammeter came from *"Thames & Kosmos Power House Experiments in Future Technics Experiment Manual,"* produced by Thames & Kosmos, LLC, Newport, RI, 2001.

BACKGROUND INFORMATION

Ammeters are designed with the use of a sensitive current detector. In this case, the current detector is a compass needle (a small magnet), held in the variable magnetic field of an electromagnet. As current in the electromagnet varies, so does the force on the compass needle.

Electricity flowing through a wire creates a magnetic field around that wire. Wrapping that wire in a coil creates an electromagnet. Wrapping the wire around a material that can be magnetized —iron objects, for example—turns such material into a magnet and effectively amplifies the magnetic field formed by the wire coil.

In this lesson, students use the magnetic field around a wire to create an electromagnet that is used to deflect a compass's magnetic needle, forming a simple ammeter. During the lesson they may notice that some of the paper clip wire has become semipermanently magnetized. Their design will need to compensate for this by adjusting the position of the ammeter on the table.

Commercial analog ammeters use a galvanometer as a sensitive current detector. A galvanometer contains a small coil attached to a spring placed in a fixed magnetic field. When current flows through the coil, magnetic attraction turns the coil against the pull of the spring. The coil is attached to the pointer of the analog meter.

REFERENCES FOR BACKGROUND INFORMATION

Georgia State University. C. R. Nave. HyperPhysics website:
http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html

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.

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)

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 and intermediate)

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.

Measurement 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)

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 3: Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity. (elementary)

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

Key Idea 5: Energy and matter 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)

Key Idea 2: Technological tools, materials, and other resources should be selected on the basis of safety, cost, availability, appropriateness, and environmental impact; technological processes change energy, information, and material resources into more useful forms. (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 3: The grouping of magnitudes of size, time, frequency, and pressures or other units of measurement into a series of relative order provides a useful way to deal with the immense range and the changes in scale that affect the behavior and design of systems. (elementary and intermediate)

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

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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 ____________________________________

Build a Simple Ammeter

In an upcoming lesson, you will design a solar-powered battery charger. But first, you need a way to test whether that battery charger is delivering electrons to the proper terminal of a dead battery. To do this, you now will build a simple ammeter that indicates the presence, direction, and strength of an electric current flowing through a wire.

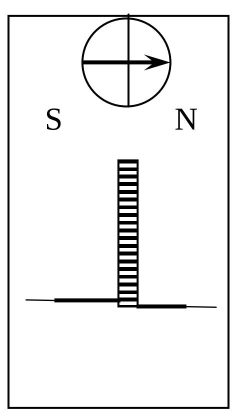
Here is information useful for completing this task:

1. Electricity flowing through a wire creates a magnetic field around that wire.
2. Wrapping that wire in a coil concentrates this field in a small space, making what is known as an electromagnet.
3. Wrapping the wire around a material that can be magnetized—iron objects, for example—turns such material into a magnet and effectively amplifies the magnetic field formed by the wire coil.
4. A magnetic field can move a magnet such as a compass needle.

1) Build a small electromagnet. Tape off one end of the straw. Tightly wrap the provided wire around 2.5 cm of drinking straw, leaving about 5 cm of each end of the wire unwrapped. If you run out of room on the straw, start another layer on top of the one just completed. When all the wire is wrapped, tape the wire in place. With scissors, scrape the insulation from the last 1 cm of both ends of the wire. The strength of this electromagnet can be adjusted by inserting various types and amounts of materials that can be magnetized (such as the wire used to make paper clips) into the coil.

2) Current source: Tape one mini–solar panel to the table and position the 150-watt lamp 120 cm above the panel. Do not place the lamp any closer as it may melt the panel's plastic cover. Turn the lamp on only while taking a measurement.

Figure 1



3) **Build the ammeter.** See figure 1. You are to construct a device that will deflect a compass needle 15 to 20 degrees when powered by the current source described above. Connect the solar cell leads to the two electromagnet leads.

Tape the compass to one end of the piece of cardboard so that the east-west axis is parallel to the long axis of the cardboard. Make sure that the north half of the compass face is visible. Position the electromagnet next to the compass. Adjust its position and the number of inserted paper clip wires to produce a device that will deflect the compass needle 15 to 20 degrees when the light is turned on.

When you have a working device, tape the electromagnet to the cardboard and the cardboard to the table.

4) **Test for the direction of a current.** Switch the solar panel's red and black wires. What do you see? Why?

5) **Calibrate your ammeter for direction of current.** On your ammeter, indicate the direction in which electrons flow to deflect the compass needle
   1) toward the west compass mark and
   2) toward the east compass mark.

Previously you learned that electrons flow from the top of a solar cell, making the top the negative terminal of a cell. By convention (artificial agreement), the black wire is connected to the negative terminal of the solar panel and the electrons flow out of the black wire.

Next to the terminal that is connected to the solar panel's black wire, draw an arrow indicating the direction in which the electrons are flowing. Next to the arrow, write a *W* if the compass needle is deflected toward the west compass mark and an *E* if it is deflected toward the east mark. Swap red and black wires and repeat.

6) **Make a prediction.** Draw a diagram that predicts how to connect two mini–solar panels to the ammeter so that the current is the greatest. Explain why you would connect the panels in this way. [Hint: Think of the electrons that are being energized by the light as workers traveling to their place of work, each in his or her own car.]

7) **Test for strength of current.** Tape the two solar panels to the table side by side. Position the lamp so it is the same distance from both panels. Again, do not place the lamp any closer to the panels than 120 cm or it may melt a panel's plastic cover.

Connect the two solar panels to the electromagnet in many different ways. For each way, draw a diagram to predict how the panels are connected. Make sure to indicate red (positive) and black (negative) wires. For each, write down in which direction and how far the compass's needle is deflected. Circle the diagram that produces the most current (deflects the compass needle the most when the light is turned on). Does it match your prediction? If it does not, give a revised reason to explain why this configuration produces the most current.

Extension Activity. Modify the design of your ammeter so that it can be used to test the strength of an AA battery.

Caution: Connect a battery to your ammeter for only a short time. If you leave it connected for too long, the battery and the wire might overheat and cause a burn, plus the battery will discharge rapidly.

Solar panels self-limit the amount of current they produce. Household batteries can produce a much larger current when shorted. For this reason a battery would "peg" the ammeter you just built, making it useless as an indicator of strength. How might you modify the design of your ammeter so that it would work with a higher current device such as an AA battery?