

# Build a Simple Ammeter

Suggested Level: Grades 5 through 9

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## 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 will complete the following:

- 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 lesson *Solar-Powered Battery Charger*.

## 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
- 15 x 40 cm piece of cardboard or card stock
- Masking tape
- Scissors
- Two 1 V, 400 mA mini–solar panels or similar cells
- Gooseneck lamp with 100-watt incandescent bulb
- Alligator clip wires

## 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

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.

### **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 STUDENT RESPONSES**

- 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).

### **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 semi-permanently 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.

### **(STUDENT HANDOUT FOLLOWS)**

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## Build a Simple Ammeter

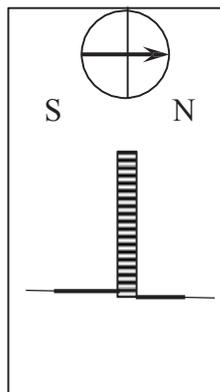
In an upcoming lesson, you will design a solar-powered battery charger. But first, you need a way to test whether that battery charger is delivering electrons to the proper terminal of a dead battery. To do this, you now will build a simple ammeter that indicates the presence, direction, and strength 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 100-watt lamp 20 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 20 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?