ACTIVITY 5 A Compass in a Circuit

OBJECTIVES

Students make a circuit and observe that electric current flowing through a wire deflects a compass needle. They observe that electric current flowing through a wire produces an electromagnetic field around that wire.

The students

- construct a circuit
- observe the interaction between electric current flowing in a circuit and a compass
- conclude that the flow of electric current in a circuit creates an electromagnetic field
- conclude that a compass can be used to test a circuit for the presence of current

SCHEDULE

About 45 minutes

VOCABULARY

circuit
electric current
electromagnetic field
electron
energy
polarity

MATERIALS

For each student

1	Activity Sheet 5, Parts A and B

For each team of two

1	battery, D-cell
1	battery holder
1	compass
2	electrical clips
1	magnet, rubberized
1 lgth	thread, 30 cm

For the class

1	ruler, metric*
1 roll	tape, masking
1 roll	tape, transparent*
1 pair	wire cutters
1 roll	wire, plastic-insulated

*provided by the teacher

PREPARATION

1. Make a copy of Activity Sheet 5, Parts A and B, for each student.

2. For each team of two, cut two lengths of plastic-insulated wire: one 15 cm (about 6 in.) long; the other 60 cm (about 2 ft) long. Strip about 1 cm (0.5 in.) of insulation off both ends of each wire by pinching the plastic insulation in the notch of the wire cutters and pulling the cutters toward the end of the wire. It is important that the copper wire inside the plastic insulation not be nicked by the wire cutters.

3. Each pair of students will also need one compass, one D-cell battery, one battery holder, two electrical clips, one rubberized magnet, one or two pieces of tape, and one 30-cm (about 12 in.) piece of thread. You can use the same pieces of thread that were used in Activity 1.

BACKGROUND INFORMATION

The flow of electric charge is called an ***electric current.*** A ***circuit*** is the pathway that the flow of electric current follows. Just as a magnetic field exists around a magnet, the flow of electric current through a wire in a circuit creates a magnetic field around the wire. This field is called an ***electromagnetic field.***

The ***polarity*** (the north-south relationship) of an electromagnetic field is determined by the direction in which the electric current flows. In this activity, the orientation of the battery in the circuit determines the direction of the current. If the direction of the flow of electric current is reversed, the polarity of the electromagnetic field will also be reversed.

▼ Activity Sheet 5, Part A

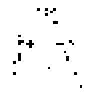
A Compass in a Circuit

1. Tape one end of the thread to a magnet. Tape the other end of the thread to a surface so that the magnet swings free. Build a circuit. Connect the short piece of wire to the electrical clips. Place the circuit so that the wire is vertical and close to the magnet. What happens to the magnet? Turn the circuit 180°. What happens?

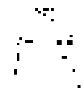
The magnet moved to face the wire.

The opposite side of the magnet faced the wire.

Next, place the circuit so that the wire is horizontal. Then turn the circuit 180°. Record how these positions affect the magnet.



One side of the magnet was attracted to the wire.

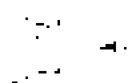


The other side of the magnet was attracted to the wire.

▼ Activity Sheet 5, Part B

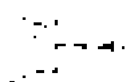
A Compass in a Circuit

2. Hold the circuit near a compass, as shown below. What happens?



The compass needle positions itself at right angles to the wire.

Move the wire back and forth, as shown by the arrows. What happens?



The needle moves back and forth.

3. Disconnect the short piece of wire from the clips. Wrap the long piece of wire once around the compass so that it lines up with the compass needle. Connect one end of the wire to an electrical clip. Touch the other end of the wire to the other clip. Alternately disconnect and connect the wire. What happens to the compass needle?

When the circuit is complete, the compass needle positions itself at right angles to the wire loops. When the circuit is disconnected, the needle returns to its normal position.

4. Now make several wraps (at least four) of wire around the compass. Repeat step 3. Describe your observations.

The needle moved more quickly.

Guiding the Activity

Additional Information

1 Distribute the compasses. Remind students how a compass behaves and that its needle is a magnet whose colored tip always points toward the south pole of a magnet.

2 Distribute **Activity Sheet 5, Parts A and B,** and the remaining materials.

Write *circuit, electric current, electron,* and *energy* on the board. Ask, **How do you make a circuit? What is electric current?** As needed, explain that **electrons** are tiny particles that orbit the nucleus of atoms and that carry negative electrical charge.

*Students may know that a **circuit** consists of an **energy** source (such as a battery) and a path through which an **electric current**—a flow of electrons—can occur.*

Show the students how to place the battery and electrical clips in the battery holder and how to make a circuit by connecting the short piece of wire to the two clips.

Note: *Tell students not to connect the wire until they are ready to conduct their experiments. A single piece of wire connecting the positive (+) end of the battery to the negative (–) end causes a short circuit. A short circuit is not dangerous, but it will cause the energy stored in the battery to drain quickly.*

Have students complete steps 1 and 2 on Activity Sheet 5, Part A. Encourage them to conduct their experiments quickly, as the amount of energy stored in the batteries is limited.

3 Encourage discussion by asking, **Did you notice any interaction between the circuit and the magnet? between the circuit and the compass? What happened to the compass when you moved the wire back and forth?**

Students should report that the circuit acted somewhat like a magnet in that it seemed to have an invisible magnetic field around it that was interacting with the magnetic fields of the magnet and the compass. The compass needle was deflected as the wire was moved closer to, then farther away from, the compass.

What can you infer about the relationship between the electric current in a circuit and magnetism?

The electric current flowing through the wire creates a magnetic field around the wire.

Write *electromagnetic field* on the board. Explain to students that a magnetic field produced by a current flowing through a wire is called an **electromagnetic field** because it is produced by an electric current.

4 Ask, **What happened to the magnet when you turned the circuit 180 degrees?**

The magnet turned in the opposite direction when the circuit was rotated.

Guiding the Activity

Additional Information

Write *polarity* on the board. Explain that just as a magnet has a north and a south pole, so does the current-carrying wire of the circuit. The **polarity,** or north-south relationship, is determined by the direction of the current in the circuit.

When students held the circuit so that the negative terminal of the battery was up, the wire had a certain polarity. When they then turned the circuit 180 degrees so that the positive terminal was up, the polarity of the wire was reversed.

Ask, **Why do you think the circuit pushed the magnet in one direction while in the first position, and in the opposite direction while in the second position?**

Students should realize that, because the current-carrying wire's polarity was reversed when it was turned 180 degrees, it reacted differently to the magnetic field produced by the (unchanging) pole of the swinging magnet.

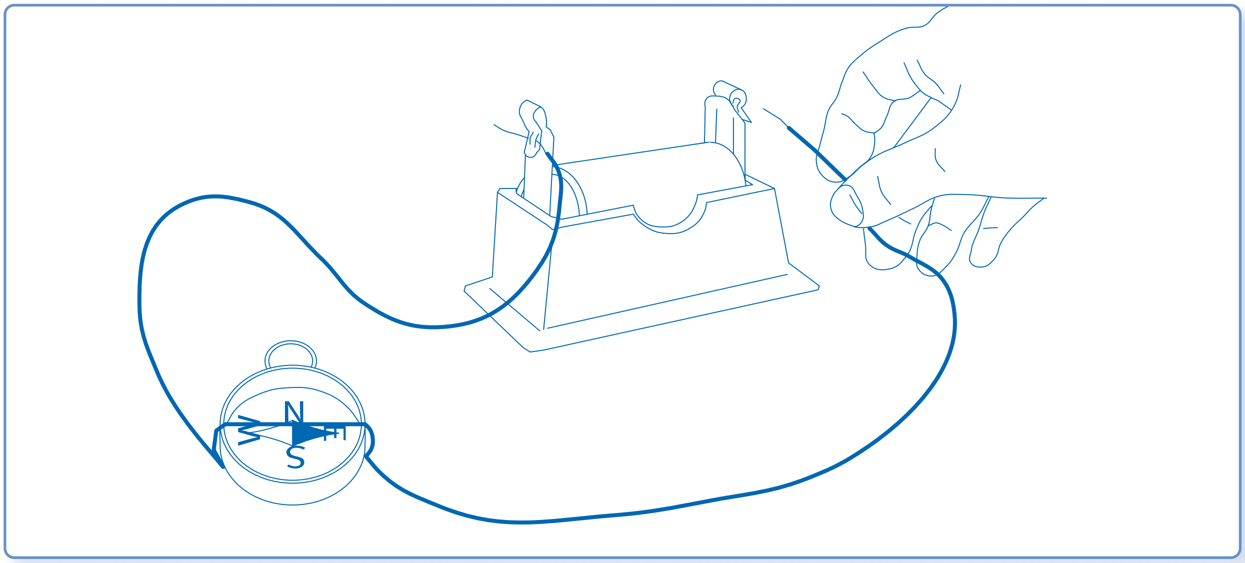
5 Have students complete steps 3 and 4 on Part B of the activity sheet (see Figure 5-1).

Students will find it helpful to use transparent tape to hold the wire on the compass.

Then ask, **What happened to the compass needle when you wrapped wire around the compass and connected the wire to the battery? What happened when you disconnected the wire from the battery?**

The compass needle moved when the wire was connected to the battery. The important point here is that the needle is affected by the wire only when both ends of the wire are connected to the battery because only at this time is current flowing through the circuit.

Point out to students that because the compass needle is deflected in the presence of an electromagnetic field, it is a useful tool for detecting the presence of current in a wire.



▲ ***Figure 5-1.*** *A compass in a circuit.*

Guiding the Activity

6 Ask, **What effect does the number of turns of wire have on the strength of the electromagnetic field?**

Additional Information

When more turns of wire are used, the compass needle is deflected faster and farther, indicating an increase in the strength of the electromagnetic field.

Reinforcement

If students are having trouble understanding that electric current produces a magnetic field around the wires in a closed circuit, give them more opportunities to experience the phenomenon. Set up an electric circuit and a compass next to a magnet and a compass and ask the students to describe the similarities they observe in the behavior of the compass when they (a) close the electric circuit, and (b) when they move a magnet near the compass.

Science Journals

Have students place their completed activity sheets in their science journals.

Cleanup

Remove the thread from the magnets and return them to the kit. Return the pieces of wire and the other equipment to the kit so that they may be used again.

Science at Home

Encourage students to use a compass to identify places in the home where electromagnetic fields exist. Tell them to record their findings. (Hint: Most electric household appliances, such as a fan and a can opener, generate an electromagnetic field when they are turned on.)

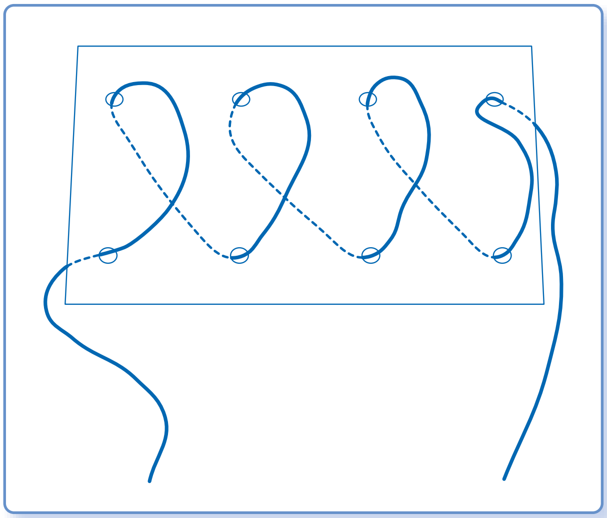
Connections

Science Challenge

Challenge students to use what they have observed in their experiments to explain why a compass should not be used near iron-containing objects. The magnetized compass needle would be attracted to the iron and thus would be deflected from its alignment with Earth's magnetic field.

Science Extension

- Ask students how the strength of the magnetic field might be affected by adding another D-cell battery to the circuit they made for the activity sheet. Let students test their predictions. Students will discover that adding another D-cell battery increases the strength of the field. Ask students to suggest a reason for this. (Adding another battery increases the strength of the current flowing through the wire.)
- Instead of a compass, students can use iron filings to show the electromagnetic field produced by an electric current in a wire. Tell students to construct a circuit as before, but this time they should omit the compass, pass the wire through one or more holes in a sheet of stiff paper (see below), and then sprinkle the paper with iron filings.



Science and Math

Help students graph their findings in their experiments with different numbers of turns of wire around the compass. Tell them to label the horizontal axis *Number of Turns* and the vertical axis *Distance Moved.* Students will discover that increasing the number of turns increases the distance that the compass needle moves.

Science and Health

Ask students whether they have seen high-tension power lines that are used to transmit electricity over long distances. Explain that the powerful electric current running through the wires produces strong electric and magnetic fields. These fields give off a type of energy called *electromagnetic radiation* (EMR). Some people, including some scientists, believe that prolonged exposure to EMR can be harmful to people. For example, some studies suggest a link between prolonged exposure to EMR and increased risk of developing cancer. Encourage interested students to research this issue further and report to the class.

Science and Language Arts

Hide a small object somewhere in the classroom and direct a student to its location using compass directions (for example, "five paces at 85 degrees, then ten paces at 325 degrees"). Ask the student to repeat the directions before he or she completes each stage. You can also use north, northeast, north-northeast, and so on. Although less precise, giving directions in this way provides more of a challenge.