Let's Do

Science

Grade Five

Electricity and Magnetism

5

Electricity and Magnetism

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Electricity and Magnetism

Before You Begin

Students learn about electricity by building and testing circuits. Using batteries, bulbs and wires, students construct simple circuits and test the effects of various modifications. Through such tests, they discover that a circuit requires a closed pathway for electricity and that some materials conduct electricity and others do not. They learn that an electric current can affect a nearby magnet and that this property of electricity is used in making electromagnets and motors. Potential dangers are examined as students learn about the safe use of electricity.

Topic A: Electricity and Magnetism

(Suggested time: 8 weeks)

This unit can be taught at any time of the year. Consider buying hand generators and rechargeable batteries. Make plans to dispose of used batteries in an environmentally appropriate manner. Send a letter home to parents asking for small, old appliances to take apart, and old strings of Christmas lights for bulbs with built in holders.

To deal with the issue of electrical safety you could arrange for an electrical company representative to visit your class and give a safety lesson, or to give you safety information.

Safety Issues

- Wires can become very hot, especially when hooked to a cell without a load (a short circuit).
- Iron filings can enter soft tissue such as fingers or eyes. Caution is recommended.

Background Information

This unit and its companion, Mechanisms Using Electricity, investigate the unique properties of electricity in motion, or *electric current.* These properties include electricity's ability to power devices and its relationship to magnetism. As a precaution against electrical hazards such as electrocution and burns, these principles are demonstrated on a modest scale, with simple circuits that use low-voltage cells rather than the 110-volt current supplied by household electrical outlets.

What is Electricity?

In order to have current, electrons (negatively charged particles) must transfer energy from the negative terminal of a source, through a circuit and back to the positive terminal of a source. This is accomplished by electrons being forced to jump from one atom to the next along conductive material such as copper wire. There is a common misconception that atoms actually flow but that is not the case.

If you think of electrons flowing through a wire in terms of water flowing through a garden hose, the volume of electrons moving forward exerts pressure similar to the water pressure you encounter at the end of the hose. In electrical language, this pressure is a potential difference and is referred to as *electromotive force*, or *voltage*. A low voltage force is used in the classroom (1.5V cells).

Conductors, Insulators and Resistors

Due to electromotive force, electrons transfer energy through a conducting material and continue to do so as long as the potential difference is great enough to overcome resistance encountered along the way. *Conductors,* such as copper, let electrical energy flow easily. This is because electrons are not tightly bound to the nuclei of atoms so when voltage (pressure) is increased, they can break away and jump to the adjacent atom.

Insulators, such as rubber or glass, do not let electrical energy flow easily. This is because their electrons are tightly bound to the nuclei of atoms so even when voltage is increased, the energy will not flow.

Many materials are partial conductors, or *resistors*, letting some electrical current flow through while changing the remainder of the *electrical energy* into heat. Sometimes this heat can be put to good use: incandescent light bulbs glow when the high-resistance tungsten filament inside them heats up. In other cases, the waste heat poses serious problems. For example, a computer can overheat and sustain damage if its internal fan quits, allowing the heat generated by resistance in the circuit boards to build up.

Circuits

Circuits can be as complex as the inner workings of a computer or as simple as a battery, switch and light bulb. A basic electric circuit consists of three components connected by wire (leads): a power source (e.g., *battery* or *generator*), a control device (for example, a switch or a resistor), and a *load* that converts electrical energy into another form of energy (e.g., a light bulb or motor). The parts are connected in a loop, or circuit. Starting at the negative terminal of the cell, the wire goes to the switch, then to the light bulb and finally connects to the positive terminal of the cell (see Fig. 1).

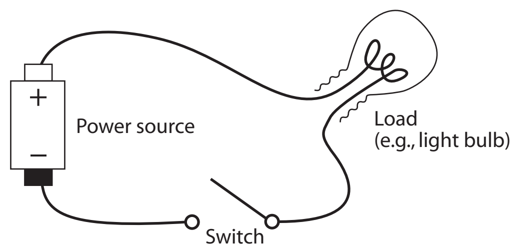

Figure 1.
Simple circuit.

Short Circuits and Fuses

When experimenting, be wary of creating one particular type of circuit, the *short circuit*. If a wire is connected between the two cell terminals, the electric current opts to take this shortcut rather than continue around the larger loop of the original circuit that contains the load (see Fig. 2).

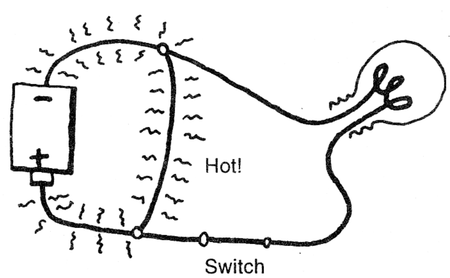

Figure 2.
Short circuit.

Because a load is missing from this path, all of the electrical energy is converted to heat. This drains the cell very quickly, and the wire carrying the electric current becomes VERY HOT. In fact, if a high energy power source like household current is used, a short circuit can burn out the wire and start a fire. In many circuits, like those used in a house or in consumer electronics, fuses or circuit breakers are incorporated that open the circuit, creating a gap, thus protecting the wires and power source in the event of a "short." In this way, a fuse is a special kind of switch.

Notice how electric cables and wires are usually covered with an insulating material. This is done for several reasons. First, the insulating layer protects you from coming in contact with the potentially "live" wire. Second, the coating keeps short circuits from forming and starting fires.

Electromagnetism

Magnetism goes hand in had with electric current: moving electrons generate a magnetic field and a moving electric field generates electricity. This type of magnetism is called *electromagnetism* to distinguish it from the magnetism brought about in materials through the internal alignment of particles with north and south magnetic poles (see the grade 2 unit Magnetism).

Electromagnetism is extremely useful for two reasons. First, the strength of an electromagnetic field can be varied by increasing or decreasing the current producing it. Electromagnets can be constructed that far exceed the strength of the most powerful natural magnets. Second, you can turn it off and on at will. The rapid switching on and off of an electromagnetic field is the driving principle behind electric motors.

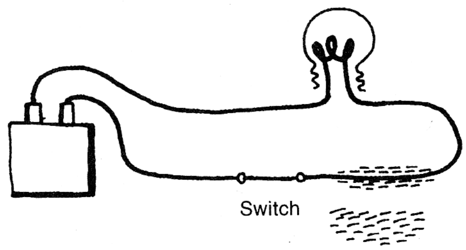

Figure 3. *Effect of a magnetic field on iron filings.*

The relationship between electricity and magnetism can be demonstrated in several ways. To illustrate the magnetic field produced around a current-carrying wire, set up a simple circuit incorporating a 6-volt lantern battery (the current should be relatively strong) and a *load-carrying* (electricity-using) device (see Fig. 3). Complete the circuit and dip the wire into a pile of iron filings. A thick layer of these filings should cling to the wire. This works best if the insulation on the wire is as thin as possible. Now disconnect the circuit and observe that the filings fall away. The magnetic field is gone.

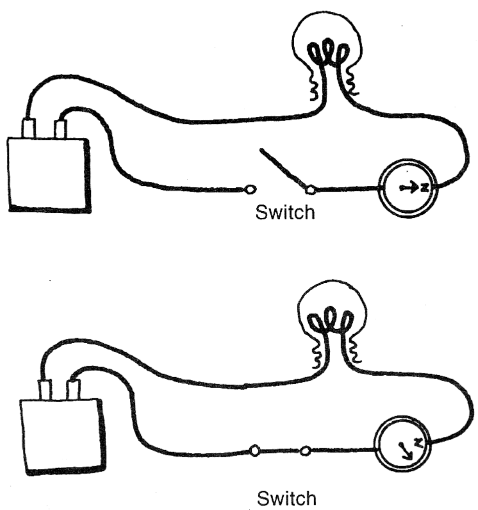

Figure 4. *Effect of a magnetic field on a compass.*

You also can perform this experiment by passing the wire over (but not quite touching) a compass, aligning the wire with the needle (see Fig. 4). Connect the circuit and note that the needle swings to one side under the influence of the magnetic field. This is a simple *galvanometer*, a device used to detect electrical current.

To show that electric current can be generated by a moving magnetic field, make a coil of about 200 turns of fine insulated wire and attach the ends to the poles of a commercial *galvanometer* (a piece of equipment that measures electric current). Now quickly plunge the north pole of a strong bar magnet into the coil. You will see the galvanometer needle register current for a very short period (see Fig. 5).

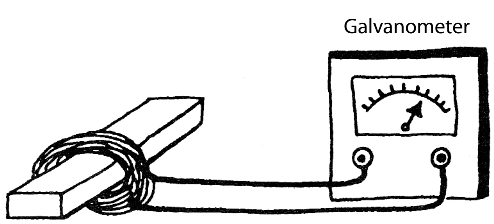

Figure 5. *Effect of a moving magnetic field*

As long as you hold the magnet still in the centre of the coil, it will not induce current in the wire, The magnet must be in motion to generate a current because it is the energy you expend to move the magnet that is transformed into electrical energy. An electric current produced in a coil in this way, by *magnetic induction*, is called an *induced current,* and this is how electrical generators produce electricity.

There are many more demonstrations and experiments you can carry out with electricity and magnetism, but one of the most elegantly simple and entertaining activities is construction of a small electromagnet. Wrap several turns of insulated wire around an iron nail or a small iron bolt and connect the wire ends to the poles of a cell. The iron core becomes an electromagnet capable of picking up small bits of iron and steel. See how much weight your electromagnet can lift and note that the amount increases as you increase the number of turns of wire wrapped around the core. (**Note**: ensure you incorporate a load-carrying device somewhere in your circuit—a light bulb, for example—to avoid creating a short circuit.)

Using Electricity

It is important to prevent excessive use of electricity around the house in order to keep utility bills within reason. The *power* supplied by electromotive force, for example, the ability of electric current to do *work*, is measured in *watts*. Your electric bill is based on the amount of power consumed by your electric appliances, measured in *kilowatt-hours*, the equivalent of drawing 1,000 watts continuously over the period of one hour. Many appliances have EnerGuide labels to show how much power they typically use over a period of one month or one year.

Elementary Science Program of Studies

General and Specific Learner Expectations

The following general and specific learner expectations have been taken directly from the 1996 Elementary Science Program of Studies. The specific learner expectations (SLEs) are referred to by number in the second column of the activities table.

General Learner Expectation

Students will be able to:

Demonstrate safe methods for the study of magnetism and electricity, identify methods for measurement and control, and apply techniques for evaluating magnetic and electrical properties of materials.

Specific Learner Expectations

Students will be able to:

1. Recognize and appreciate the potential dangers involved in using sources of electrical currents:
   - understand that household electrical currents are potentially dangerous and not a suitable source for experimentation;
   - understand that small batteries are a relatively safe source of electricity for experimentation and study, but that care should be taken to avoid short circuits; and
   - understand that short circuits may cause wires to heat up, as well as waste the limited amount of energy in batteries.
2. Describe and demonstrate example activities that show that electricity and magnetism are related:
   - demonstrate that electricity can be used to create magnetism; and
   - demonstrate that a moving magnet can be used to generate electricity.
3. Demonstrate and interpret evidence of magnetic fields by use of iron filings, or by use of one or more compasses.
4. Demonstrate that a continuous loop of conducting material is needed for an uninterrupted flow of current in a circuit.
5. Distinguish electrical conductors—materials that allow electricity to flow through them—from insulators, materials that do not allow the flow of electricity through them.
6. Recognize and demonstrate that some materials, including resistors, are partial conductors of electricity.
7. Predict the effect of placing an electrical resistance in a simple circuit; for example in a cirucuit with a light bulb or electric motor.
8. Recognize that the amount of electricity we use in our homes is measured in kilowatt hours.

9. Interpret and explain:
   - the reading on a household electrical meter; and
   - efficiency labels on electrical appliances.
10. Draw and interpret, with guidance, circuit diagrams that include symbols for switches, power sources, resistors, lights and motors.

Cross-curricular Connections

Mathematics

- Graphing
- Calculate kilowatt hours or energy from EnerGuide labels.

Social Studies

- Discuss how electricity meets the needs of Canadian society.

Language Arts

- *Explorations in Science, Explore!* student book, level 5.
- *Innovations in Science, Process and Inquiry* student book, level 5.

Fine Arts

- Perform a skit of energy moving through a circuit.
- Create a water analogy of electrical energy using media of choice.

Everyday Applications

- Importance of turning off electrical appliances when not in use.
- Understanding bicycle generators.

Children's Alternative Frameworks

Children think electricity actually flows, but there is no movement of atoms, only energy. They may believe any electrical source, including a 1.5V cell, is going to hurt them

Activities

Classroom teachers have identified the following activities that may be done to address the Specific Learner Expectations (SLEs) in the Program of Studies. The list is not prescriptive and teachers may select activities that are most appropriate for their students.

Activities have been listed under two headings: Key Activities and Extension Activities. Key activities are supported by authorized resources and identify "powerful and practical" means for achieving learner expectations. Extension activities represent alternative ways of achieving or supporting learner expectations.

Key Activities

Key Activity	SLE	Print Resources	Essential Materials	Comments
Exploring electricity	1, 3	*Explorations in Science, Level 5, Zap! It's Electric (Free Exploration)*, p. 7	small bar magnets and U-shaped magnets, assorted metal and non-metal objects, flashlights of various sizes, cells, a piece of flat rigid plastic, bits of tissue paper, bits of plastic film	After this initial exploration and recording of their findings, the teacher will have insight into the children's knowledge of electricity and magnetism. Fear often makes students uncomfortable with electricity. Assure them the voltage in a 1.5V cell is harmless.
Exploring magnetism and magnetic fields	2, 3	*Explorations in Science, Level 5, Zap! It's Electric (Poles Apart)*, p. 10 *Science and Technology for Children, Magnets and Motors, Teacher's Guide, Lesson 2 (What Can Magnets Do?)*, p. 11 *Science and Technology for Children, Magnets and Motors, Teacher's Guide, Lesson 3 (How Can You Find Out What Magnets Can Do?)*, p. 15	small bar magnets, U-shaped magnets, assorted metal and non-metal objects (screws, aluminum and steel nails, coins, paper clips, buttons, chalk, toothpicks, iron filings, etc.), 2 blank overhead transparencies and an overhead projector	When working with iron filings, safety goggles are a good idea.

Key Activity	SLE	Print Resources	Essential Materials	Comments
Exploring the relationship between electricity and magnetism	2	*Explorations in Science, Level 5, Zap! It's Electric (Electromagnets)*, p. 26	steel nails, insulated wires about 40 cm long, cells and holders, straight pins, staples, small paper clips	NEVER use electrical outlets as your source of electricity.
		Explorations in Science, Level 5, Zap! It's Electric (More About Electromagnets), p. 27 *Electrical Connections (The Electromagnetic Connection)*, p. 61 *Science and Technology for Children, Magnets and Motors, Teacher's Guide, Lesson 7 (Creating Magnetism Through Electricity)*, p. 43 *Science and Technology for Children, Magnets and Motors, Teacher's Guide, Lesson 8 (Making Magnets with Electricity)*, p. 49	large straws (one per pair of students), compasses, magnets, insulated wires 40 cm long, cells, holders, straight pins	**Note**: any student who has an electric train will know about transformers. They can be useful power sources. Also, students may wish to try some of these activities at home. They must be careful not to leave the transformer on for too long.
Making and testing electromagnets	2, 3	*Electrical Energy: Teacher's Planning Guide* (Atwater et al.) *(Turning the Field On and Off)*, p. 56	closed staples, 1 m insulated wire, 2 D-cell batteries and holders, steel nail, small piece of sandpaper	Remind students to disconnect the circuit after using, especially if they have not included a load such as a light bulb. The wire will become hot very quickly.
		Electrical Energy: Teacher's Planning Guide (Atwater et al.) *(What Makes Electric Current?)*, p. 66 *Science and Technology for Children, Magnets and Motors, Teacher's Guide, Lesson 8 (Making Magnets with Electricity)*, p. 49 *Science and Technology for Children, Magnets and Motors, Teacher's Guide, Lesson 9 (Planning an Experiment to Test the Strength of an Electromagnet)*, p. 57 *Science and Technology for Children, Magnets and Motors, Teacher's Guide, Lesson 10 (Testing an Electromagnet)*, p. 67	compass, bar magnet, cardboard tube, 3 m and 1 m of insulated wire with ends stripped, transparent tape, D-cell, D-cell holder	

Key Activity	SLE	Print Resources	Essential Materials	Comments
Making and testing electromagnets (cont'd)		*Innovations in Science, Level 5, Switched On,* Activity Card 67*: An Attractive Idea*	67: 1 m insulated wire, iron nail, 1.5V cells, switch	Use no more than four 1.5V cells or the electromagnet becomes too hot to hold. Also, leaving the circuit closed for a long period of time quickly drains your cells.
		Innovations in Science, Level 5, Switched On, Activity Card 68: *Magnet Search*	68: electrical appliances that move or make sounds, a broken electrical device that contains an electromagnet	Electromagnets can be identified by the many coils of wire (e.g., a doorbell has an electromagnet). Remove the power cord so that no one attempts to plug it in.
Exploring currents with bulbs and batteries	1, 4, 10	*Explorations in Science, Level 5, Zap! It's Electric (Simple Circuits)*, p. 14 *Science and Technology for Children, Electric Circuits, Teacher's Guide, Lesson 2 (What Electricity Can Do)*, p. 1	one 30 cm piece of wire with bare ends, one D-Cell, one low-voltage flashlight bulb for each student	Sandpaper can be used to remove plastic coating on the ends of the insulated wire or wire strippers may be used. Have students draw their circuit using electrical symbols.
Exploring simple circuits with additional materials	4, 5, 6, 10	*Explorations in Science, Level 5, Zap! It's Electric (No Hands Needed)*, p. 16 *Science and Technology for Children, Electric Circuits, Teacher's Guide, Lesson 5 (Building a Circuit)*, p. 29	same as for simple circuits, plus bulb holders, battery holders, alligator clips	
		Innovations in Science, Level 5, Switched On (Light Up Your Life), p. 8	small box (shoe box), thin insulated wire, 6-8 alligator clips, 4 dry cells (D-type), three 6V flashlight bulbs, 3 elastics (16 cm long), 3 cardboard tubes from paper towels or wrapping paper, 3 bulb holders, 3 switches (knife), 3 or 4 pieces of aluminum foil (about 8 cm square), roll of electrical tape, roll of transparent tape	These materials could be shared by 2 or 3 students and stored in a box (Watts box). A homemade switch can be made with a large paper clip, 2 thumbtacks and a strip of soft wood or thick cardboard. Bulbs and bulb holders can be replaced with cut up Christmas tree lights for an economical alternative. Have students draw their circuits using electrical symbols.
		Electrical Energy: Teacher's Planning Guide (Atwater et al.) *(Pathmaking)*, p. 24	aluminum foil, scissors, D-cell, flashlight bulb, masking tape (20 cm)	

Key Activity	SLE	Print Resources	Essential Materials	Comments
Exploring simple circuits with additional materials (cont'd)		*Electrical Energy: Teacher's Planning Guide* (Atwater et al.) *(Water Wire)*, p. 27 *Science and Technology for Children, Electric Circuits , Teacher's Guide, Lesson 3 (A Closer Look at Circuits)*, p. 19	1 m piece of clear plastic tubing, food colouring, plastic box, funnel, water	Avoid spilling water on the floor for safety reasons.
Exploring conductors and insulators	1, 5	*Innovations in Science, Level 5, Switched On (Let the Flow Go)*, p. 17	Watts boxes, at least 12 different objects to test (such as paper, plastic, coins, nails, aluminum foil, wood, stones, paper clips, scissors, mineral oil, vinegar, salt water, tap water, rubber, cloth, pieces of wire, etc.), plastic or glass containers for the liquids	
		Explorations in Science, Level 5, Zap! It's Electric (No Hands Needed), p. 16	three 30 cm insulated wires with bare ends, 3 wires with alligator clips, low-voltage flashlight bulb, D-cell holder, bulb holder, an assortment of metal and non-metal objects (as above)	
		Electrical Energy: Teacher's Planning Guide (Atwater et al.) *(What Turns It On?)*, p. 28 *Electrical Connections (Conductor or Insulator)*, p. 40 *Science and Technology for Children, Electric Circuits, Teacher's Guide, Lesson 7 (Conductors and Insulators)*, p. 43	D-cell, flashlight bulb, aluminum foil, masking tape, scissors, piece of cardboard about 6 cm x 6 cm, 2 paper boards (butterfly clips or thin nails), a variety of items—both metallic and non-metallic	
Examining partial conductors (resistors)	6, 7	*Explorations in Science, Level 5, Zap! It's Electric (Resistance)*, p. 19 *Electrical Connections (Make a Dimmer Switch)*, p. 44	insulated wires with bare ends (about 30 cm long), wires with alligator clips, low-voltage flashlight bulbs, D-cell, bulb holders, cell holders, HB pencils, sharp knife or X-Acto blade	For safety, prepare the pencils ahead of time. Use a sharp knife and cut away the wood on one side, about 10 cm away from the tip, so the lead is exposed.

Key Activity	SLE	Print Resources	Essential Materials	Comments
Looking at home energy consumption	8, 9	*Innovations in Science, Level 5, Switched On (Watt's Up?)*, p. 33	poster, paper, pencils, crayons, felt pens, paints, brushes	
		Explorations in Science, Level 5, Energy for the Future (Draft Detectors), p. 23	goose down (small quantity), tissue paper or plastic wrap, toothpicks, white glue, other materials as requested by the students	
		Science Turns Minds On: Electricity and Magnetism, Teacher's Planning Guide (Atwater et al.) *(Where Does Electric Power Come From?)*, p. 72	200 cm of 18-gauge insulated wire, 2 D-cells with holders, sandpaper, 2 giant paper clips, two 25 cm lengths of insulated wire, switch, bar magnet	
		Utility bill	electrical utility bill	
Interpreting and explaining efficiency labels on household electrical appliances	9	*Innovations in Science, Level 5, Switched On,* Activity Card 70: *Hot Issue*	students' appliance research, appliances such as refrigerators, stoves, dishwashers, hair dryers, toasters, etc.	This information can be obtained directly from many new appliances. Also, contact the utility companies for this information.

Extension Activities

Extension Activity	SLE	Print Resources	Essential Materials	Comments
Exploring static electricity		*Explorations in Science, Level 5, Zap! It's Electric (Static Cling)*, p. 12	round balloons, combs, plastic "blister packs" for packaging (12), sand, large paper clips, tissue, sheets of recycled paper, string, thread, pins	
Examining household electrical currents, short circuits and safety	1	*Innovations in Science, Level 5, Switched On,* Activity Card 64: *Obstacle Course*	1.5V dry cell, flashlight bulb, bulb holder, cell holder, three 20 cm lengths of insulated wires with ends stripped of covering	
Discovering the effects of magnets on a recording tape		*Electrical Energy: Teacher's Planning Guide* (Atwater et al.) *(Writing on Tape)*, p. 61	cassette player, blank cassette tape, pencil, electromagnet	
Making and testing an electric filament	1, 7	*Explorations in Science, Level 5, Zap! It's Electric (Heat and Light)*, p. 20	cells, bulbs, wires with alligator clips, bulb holders, cell holders, fine steel wool (one package), 6 clear flashlight bulbs, cookie sheet, magnifying lenses	Adequate supervision is necessary for this investigation because of the heat generated. (It is recommended that this investigation be done on a cookie sheet.)
Making and testing fuses	1, 7	*Explorations in Science, Level 5, Zap! It's Electric (Using Fuses)*, p. 21	same as above, bare copper wire, collection of car fuses (some used)	
Using conductors and insulators to design and build an electric quiz game		*Innovations in Science, Level 5, Switched On (Electric Trivia)*, p. 25	Watts boxes, Bristol board, thumb tacks, unpainted brass butterfly clips (12 per student), aluminum foil	
Finding ways to conserve energy	8	*Explorations in Science, Level 5, Energy for the Future (What Can We Do?)*, p. 34	a variety of resources with information about energy conservation, art materials, video camera (optional)	

Assessment

For a broader discussion of science classroom assessment techniques see *Assessing Student Learning* in the introduction of this publication on p. 15. Good places to begin looking for the unit-related ideas are *Explorations in Science* assessment handbooks, *Innovations in Science* teaching notes, Unit tests and Portfolio ideas, Alberta Education sample tests at **www.education.gov.ab.ca** and Alberta Assessment Consortium at **www.aac.ab.ca**

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