



### **Acknowledgments:**

A special thank-you to the following individuals for their vision, hard work and dedication in the design, development, and implementation of the Virginia 4-H In-School and School Enrichment Curriculum.

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**Revised 2014**

**Publication 388-800**



**Virginia Cooperative Extension**  
Virginia Tech • Virginia State University

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# ELECTRIC ENERGY



## Introduction

The following lesson plans are designed to satisfy Virginia Science Standard of Learning 4.3. In addition, they support several of the goals in science SOL 4.1. Specifically, Science SOL 4.3 states:

The student will investigate and understand the characteristics of electricity. Key concepts include:

- a) conductors and insulators;
- b) basic circuits (open/closed, parallel/series);
- c) static electricity;
- d) the ability of electrical energy to be transformed into heat, light, and mechanical energy;
- e) simple electromagnets and magnetism; and
- f) historical contributions in understanding electricity.

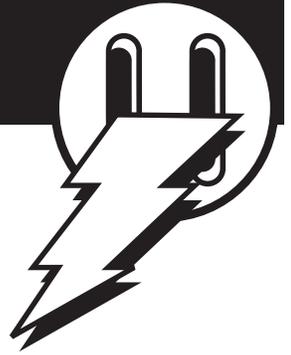
The portions of Science SOL 4.1 that this curriculum supports are the following:

The student will plan and conduct investigations in which:

- distinctions are made among observations, conclusions, inferences, and predictions;
- hypotheses are formulated based on cause-and-effect relationships;
- variables that must be held constant in an experimental situation are defined;
- data are displayed using bar and basic line graphs;
- numerical data that are contradictory or unusual in experimental results are recognized; and
- predictions are made based on data from picture graphs, bar graphs, and basic line graphs.

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# ELECTRIC ENERGY



## Format

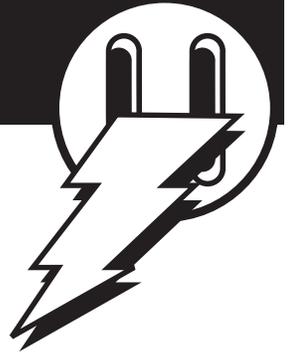
Each Lesson contains both information for the teacher and copy-ready Activity Sheets and Youth Evaluation forms. The teacher section begins by identifying both a life-skill objective and the connection to the SOLs. An estimate of the time required to conduct the lesson and a supply list are provided. A Background Information section prepares the teacher to present the material. The Procedure section describes how to conduct the activity. This is followed by a Answers to the Youth Activity Sheet, which discusses the questions/answers presented to the students by the activity. The Evaluation section contains the questions presented to the students on the Student Evaluation form, along with the answers.

## Resources

Electric Kit. This kit contains most of the supplies required to conduct these lessons. Most 4-H offices in Virginia have a kit that can be borrowed. Please call your local Virginia Cooperative Extension office to arrange to use the kit.

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# Lesson 1—Magnetic Attractions



## Life Skill Objective-Learning through Observation

## Connections to the Standards of Learning

Science SOL 4.3 (e) states that students will investigate and understand simple electromagnets and magnetism.

## Time Required - 50 minutes

## Supply List

- Bar magnets with marked poles, two per group
- Bar magnet with unmarked poles, one per group
- Bowl with water in it
- Several metal paper clips
- Various materials that students can test for magnetic attraction (paper, plastic, wood, metal, etc.)
- Pencils
- Youth Activity Sheet

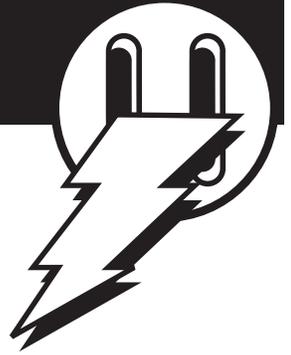
## Background Information (For Group Discussion)

The goal is for youth to “investigate and understand magnets.” There are several concepts and characteristics that should be understood:

- A magnetic field surrounds all magnets;
- A magnetic field surrounds the earth;
- A magnetic field is strongest at the poles and weaker as the distance from the poles increases;
- A magnet field is invisible, but we can see the effect a magnetic field has on metal objects;
- A magnetic field will pass through materials such as glass, plastic, wood, etc.

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# Lesson 1 — Magnetic Attractions



- The poles of a magnet are classified as North and South;
- Like poles repel and opposite poles attract each other.
- Magnets will attract metal objects that contain iron or nickel, but have no effect on other objects. NOTE: A nickel (five cent piece) does not contain the metal nickel and is not attracted by a magnet.

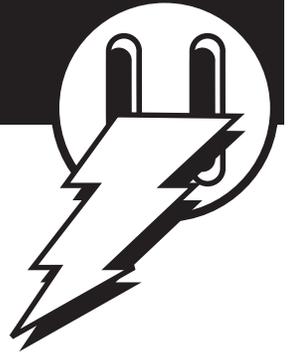
Magnetism is a naturally occurring force that acts on certain metals. Magnets radiate a force field that we call a magnetic field. The earth has a magnetic field around it. Another example of a force field is the force generated by the earth that we call gravity or the gravitational force field.

Hold up a magnet for the class and ask if they can see the magnetic field. Next, ask how we know that a magnetic field exists. Even though a magnetic field is invisible, it is possible to observe the effect of a magnetic field on iron filings. One way to do this is to place the magnet on an overhead projector, lay a blank transparency over the magnet, and lightly sprinkle iron filings over the transparency. The iron filings will align with the magnetic field. Another way to visualize the magnetic field is with the magnetic field demonstrator that is included in the 4-H Electric Energy Kit.

Magnets are said to have a north and a south pole. Scientists named the north pole of a magnet to be the part of the magnet that points toward the magnetic north pole of the earth. The south pole of the magnet is the pole opposite the north pole, or the pole that points towards the magnetic south pole of the earth. THIS IS A LITTLE TRICKY! A north pole of one magnet will attract the south pole of another magnet. Two similar poles will repel or push away from each other. However, the north pole of a magnet will point or be attracted to the north pole of the earth because that is the convention that scientists chose-the north pole of a magnet is the NORTH SEEKING pole, that is, the pole that is attracted to the north pole of the earth.

In this activity youth explore the properties of magnets. In the next activity, they will explore the response of magnets to the magnetic field around the earth.

# Lesson 1 – Magnetic Attractions



## ■ Procedure (Conducting the Activity)

Divide the class into groups and give each group two marked bar magnets and one unmarked bar magnet, a bowl with a small amount of water in it, a few metal paper clips, and a Youth Activity Sheet. They should also have access to other materials to determine which ones are attracted to the magnets. Such things as paper, pencils (wood), pens (plastic), etc are fine.

Have the students complete the activities outlined on the Youth Activity Sheet. Once they have had time to explore and complete the activities discuss the results with the class.

## ■ Answers to Youth Activity Sheet

1. The students should discover that opposite poles attract and like poles repel.
2. Based on the knowledge that opposite poles attract, students can use the marked bar magnet to determine the poles of the unmarked one. For example, the pole of the unmarked magnet that is attracted to the N pole of the marked magnet must be a south pole.
3. One way to check their determination of N and S poles on the unmarked magnet would be to compare with another group. If two groups bring what they determined to be N poles together, and they repel each other, that is an indication that they marked them correctly.
4. Magnets only attract materials with iron or nickel in them. Please note that the nickel (five cent piece) does not contain the metal nickel, and is not attracted by a magnet.
5. A magnetic field is strongest at the poles and weakest at the greatest distance from the poles (in the center of the bar).
6. A magnetic field can pass through materials such as air, water, paper, plastic, etc. The thickness of material that the magnetic field will pass through depends on the field strength. Since a compass works inside of buildings, the earth's magnetic field is passing through the building materials!

# Lesson 1 — Magnetic Attractions



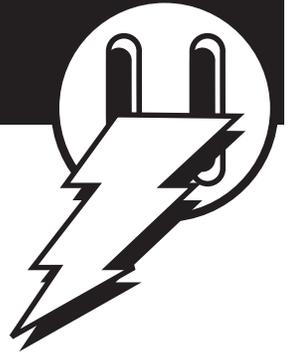
## Evaluation (Answer Sheet)

Ask the students to write a short story with the ending “it just goes to show that likes repel” or “it just goes to show that opposites attract!”

For each of the following questions, mark the correct answer.

1. A magnetic field can be thought of as
  - something unnatural
  - a force field
  - something seen
2. Magnets have
  - east and west poles
  - north, south, east, and west poles.
  - left and right poles
  - north and south poles
3. “Like” poles of a magnet
  - attract each other
  - repel each other
  - both attract and repel each other
4. The north pole of a magnet is attracted to a certain part of the earth. That part is
  - London, England
  - the south pole
  - the north pole
  - Washington, D.C.
5. Magnets are attracted to
  - water
  - certain types of metal
  - wood
  - sunlight

## Lesson 2 - The Magnetic Field Around the Earth



### Life Skill Objective—Learning through Observation

### Connection to Standards of Learning

Science SOL 4.3 (e) states that students will investigate and understand simple electromagnets and magnetism.

### Time Required—30 minutes

### Supply List

One set of the following for each group. Groups no bigger than three are recommended:

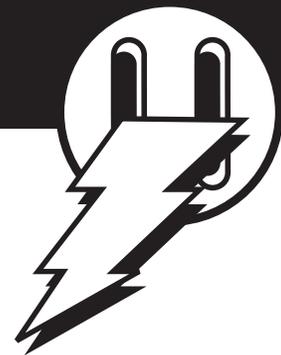
- bowl with small amount of water in it
- large needle
- a bar magnet with the poles marked (use magnets from previous exercise)
- styrofoam disk, about 1 inch in diameter, cut from a disposable plate, fast food clam shell, etc.
- Youth Activity Sheet

### Background Information (For Group Discussion)

A magnetic field surrounds the earth. This magnetic field has two poles—a north and a south. Just as opposite poles of a magnet will be attracted to each other, a magnet that is allowed to turn freely will be attracted to the magnetic poles of the earth. This is the principle that a compass uses to point north. The needle of a compass is a magnet, and the needle is allowed to turn freely. It will align itself with the magnetic poles of the earth. The magnetic poles of the earth are close to the geographical poles, but not in exactly the same location. This means that a compass points to the magnetic pole, but not true north/south. To navigate with a compass, it is necessary to correct the compass reading to true north/south. The exact correction depends on where you are relative to the poles. In Virginia, the correction is very small—approximately 2 degrees.

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## Lesson 2 - The Magnetic Field Around the Earth



Today you will build a compass and observe how it responds to the earth's magnetic field.

### ■ Procedure (Conducting the Activity):

Divide the class into working groups and give each group one set of materials. You may want to give each group one activity sheet, or you may choose to give one sheet to each child. Instruct the groups to follow the directions provided to build a compass. You may wish to use class discussion to answer the questions on the Youth Activity Sheets.

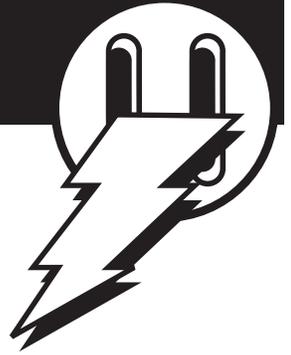
Note to the Instructor: Once the needle is magnetized and put in the bowl to float, it should point to magnetic north/south. However, if there is a permanent magnet somewhere close to the bowl, the magnet field from the magnet may be stronger than the earth's magnetic field, and it will attract the needle. Caution students not to leave the permanent magnet near their bowl when they are trying to use it as a compass.

### ■ Answers to Youth Activity Sheet:

1. The needle points north/south because it has been magnetized and a magnet will respond (be attracted/repelled) to the magnetic field of the earth.
2. You really can't tell which direction is north and which is south from looking at the needle. You need some other way of knowing, such as knowing where the sun rises and sets, or by using a magnet with known poles. The end of the needle that points north will be attracted to the south pole of a magnet and repelled from the north pole. Once you know which way is north, you can mark that end of the needle for future reference. If you look at a real compass, you will see that one end is colored or shaped like an arrow. The colored end (or the arrow end) is the north seeking pole of the magnetic needle and it points north.
3. If all the needles in the bowls are pointing the same way, it makes sense to think that "something" is causing it—it isn't just a random occurrence. With only one needle in a bowl, there is no way to be sure it didn't point north by chance alone.
4. Scientists conduct an experiment more than once (use repeated trials) to make sure something is repeatable—that it will occur the same way every time. This provides evidence that something is happening for a reason, not just by chance.

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## Lesson 2 - The Magnetic Field Around the Earth



### Evaluation (Answer Sheet)

Ask your students to write a paragraph that explains how a compass works. A compass works because there is a magnetic field around the earth and the needle of a compass is a magnet. The compass needle is attracted to the magnetic poles of the earth, so it points north/south.

For each of the following questions, mark the correct answer.

1. When you rub a magnet against a needle, what happens?

- the needle changes color
- the needle is magnetized
- the needle is energized
- nothing happens to the needle

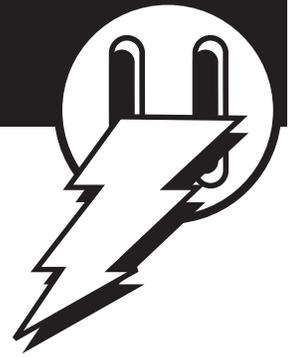
2. The needle in a compass points:

- north/south
- east/west
- it depends on where you are when you use it
- toward the nearest electric outlet

3. The needle in a compass lines up with:

- the electric field around the earth
- the magnetic field around the earth
- the gravitational force around the earth
- all of the above

# Lesson 3 — Static Electricity



## Life Skill Objective—Learning through Observation

## Connection to Standards of Learning

Science SOL 4.3 (c) states that students will investigate and understand the characteristics of electricity including static electricity.

## Time Required—35 minutes

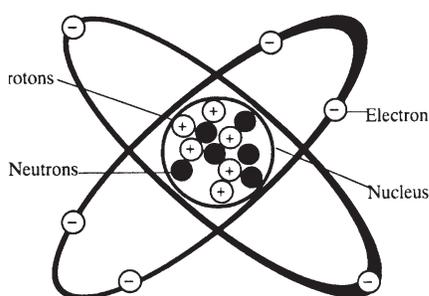
## Supply List

- balloons (two per cooperative learning group)
- about 2 feet of string or thread per group
- 1/4 sheet of notebook paper per group
- a small piece of cloth, preferably wool
- a copy of the Youth Activity Sheet for each student or each group

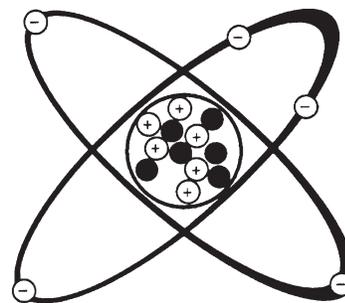
## Background Information (For Group Discussion)

All matter is composed of atoms. Even though we can't see the atom, scientists have discovered many interesting things related to the atom and electricity.

An atom has both positive and negative charges, which are in balance. The center of an atom, called the nucleus, contains neutrons and protons. Neutrons have no electrical charge—they are neutral. Protons have a positive charge.



A Carbon Atom



Positive Ion

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## Lesson 3 — Static Electricity



Moving in an orbit around the nucleus are electrons. Electrons have a negative charge and are free to move about the nucleus. The movement of electrons makes it possible for atoms to share electrons and is what binds matter together.

The electrons farthest from the nucleus are easiest to move. When it is cold and dry and you rub your feet across a carpet, you can rub electrons off the carpet and collect them on your body. This collection of electrons creates a negative charge relative to the things around you—it is called static electricity. After you collect electrons, you can cause an electrical discharge by touching another object. This is what happens when you get a small shock after running across carpet on a cold day.

You saw that with magnets opposite poles attracted each other and like poles repelled each other. This concept applies to electrical charges too. A negative charge is attracted to a positive charge but two negative charges will repel or push away from each other. Now you will have a chance to “collect electrons” and build some negative charges.

### ■ Procedure (Conducting the Activity)

After discussing the concept of an atom orbited by electrons and introducing the idea that electrons can be “collected,” thus resulting in a negative charge, break the class into working groups. Groups of three are probably best. Give each group two balloons, two pieces of string, and a piece of paper. Note: These activities work best in the winter, when the air is dry. Very humid conditions make the collection of a static charge difficult.

Distribute copies of the Youth Activity Sheets to each student (or each group). Ask them to read the instructions, conduct the experiments, and record their results. You may want each child to record results for themselves, or you may ask each group to select a group recorder. After everyone has conducted the experiments, discuss the results with the class.

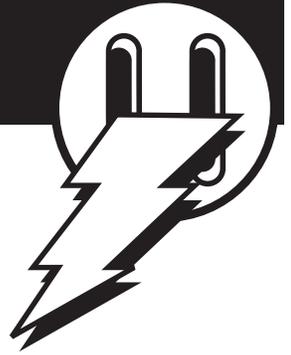
### ■ Additional Activity (Optional)

Here is an additional activity that you may want your students to conduct at home.

Find a plastic comb and something made out of wool. Charge the comb with static electricity by rubbing it several times on the wool cloth. Turn on the faucet in a bathroom or kitchen to make a SMALL stream of

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## Lesson 3 — Static Electricity



water. Hold the comb very near the stream of water BUT DO NOT GET IT IN THE WATER. What happens?

Next, put the comb in the stream of water for a few seconds. After getting the comb wet, put it back close to the stream, but not in it. Does the comb still attract the water? Why or why not?

### Answers to Youth Activity Sheet:

1. The team member's hair "stands up" or is attracted to the balloon because the balloon has a charge because it has exchanged electrons with the cloth. The balloon and cloth will have opposite charges. It's not really obvious which has a positive charge and which has a negative charge.
2. The pieces of paper are attracted to the balloon because it carries a static charge.
3. When the two balloons are brought close together, they will repel each other because they both have the same charge and "likes" repel.

The take home exercise: Rubbing the comb with wool put a static charge on it, which attracted the stream of water. Putting the comb in the water allowed the water to carry away the charge, leaving the comb uncharged. After the comb lost its charge, it did not attract the stream of water.

### Evaluation (Answer Sheet)

Static electricity is a collection of electrons.

Two balloons with a static charge will attract or repel each other? repel

For each of the following questions, mark the correct answer.

1. All matter is composed of:
  - fiber
  - cells
  - atoms
  - minerals

## Lesson 3 — Static Electricity



2. Two types of charges of an atom are:

- positive and negative.
- up and down.
- left and right.
- neutral and positive.

3. Moving in an orbit around an atom's nucleus are:

- electrons
- protons
- neutrons

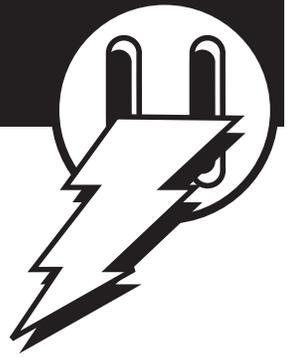
4. When it is cold and dry and you rub your feet across a carpet, you can rub \_\_\_\_\_ off the carpet and collect them on your body.

- electrons
- protons
- atoms
- neutrons

5. What charge do electrons have?

- positive
- negative
- neutral

## Lesson 4 — Current Electricity & Circuit Building



### ■ Life Skill Objective—Learning through Observation

### ■ Connection to Standards of Learning

Science SOL 4.3 (a and b) states that students will investigate and understand basic circuits (open/closed, parallel/series) and conductors and insulators.

### ■ Time Required—One hour

### ■ Supply List

For each group:

- two D-cell battery holders
- two D-cell batteries
- two flashlight bulbs (1.5 or 3 volt)
- two light bulb holders
- six pieces of insulated wire (22 to 26 gauge, solid core) with the ends stripped about 1/2 inch.
- Youth Activity Sheet

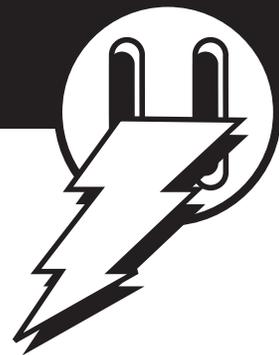
### ■ Background Information (For Group Discussion)

Static electricity is one form of electricity, but it is not very useful—we cannot control it to do useful work for us. Another form of electricity is current electricity. Whenever we talk about electricity, we are referring to current electricity.

Electricity is the flow of electrons. What does it take to make electrons flow? It takes two things—something to push the electrons and a path for the electrons to travel. The force that pushes electrons is called voltage and is measured in volts. The flow of electrons is called current and is measured in amperes or just amps for short.

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## Lesson 4 — Current Electricity & Circuit Building



A good analogy to understand electricity is to compare it to the flow of water. Voltage, the force that pushes electrons, is analogous to water pressure, the force that pushes water in pipes. Amperage, which is a measure of the rate of flow of electrons, is analogous to the rate of flow of water. We measure water pressure in pounds per square inch (psi); we measure electrical pressure in Volts. We measure the flow of water in gallons per minute (gpm); we measure the flow of electrons (electricity) in Amperage or Amps for short.

Another component of a water system is resistance. A good example of a variable resistance in a water “circuit” is a faucet. The more open the faucet, the less the resistance to the flow of water, and the more water that will flow. When the faucet is closed, the resistance to the flow of water is so high that no water can flow. In an electrical circuit, the components (light bulbs, toasters, hair dryers, etc.) each have an internal resistance. Switches have a very low resistance when they are closed (ON) and a very high resistance when they are open (OFF). For a given electrical pressure (voltage), the higher the resistance (measured in Ohms) in a circuit, the less electricity will flow.

If you build two circuits—one with one battery and one light bulb and a second with one battery and two light bulbs in series, you will see that the bulb in the circuit with only one bulb burns much brighter than the bulbs in the circuit with two bulbs. This is because the two-bulb circuit has twice the resistance to the flow of electricity—the amperage flowing in the two-bulb circuit is only half of the amount flowing in the one-bulb circuit. A two-bulb circuit (compared to a one-bulb circuit) is like a half open faucet compared to a completely open faucet—two bulbs have twice the resistance of one and a half-closed faucet has more resistance than a completely open faucet.

If you build one circuit with one battery and one bulb and a second circuit with two batteries and one bulb, you will see that the bulb in the circuit with two batteries is brighter than the one with only one battery. This is because the voltage (electrical pressure) is greater with two batteries. This would be analogous to observing the flow of water from your faucet at some faucet setting, and then increasing the water pressure in your house and observing the flow from the faucet without changing the setting on the faucet.

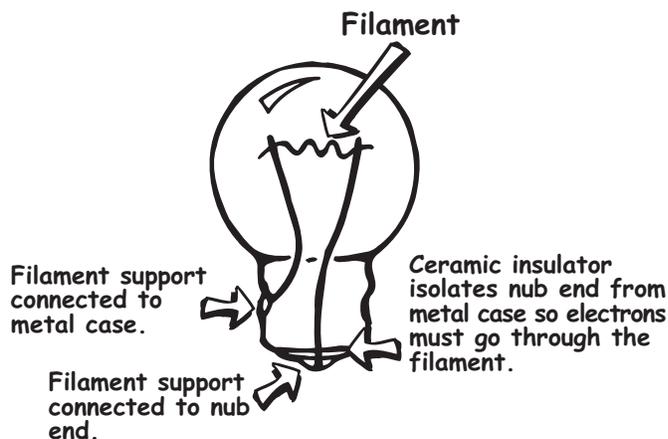
Note: The path that electrons follow through a light bulb is not obvious, because you cannot see the connections from the filament to the filament supports. If you could cut open a light bulb (Figure 1), you would find that one end of the filament support connects to the metal case that screws in to the light bulb receptacle, and the other end of the filament

## Lesson 4 — Current Electricity & Circuit Building



support connects to the nub end of the bulb. Note that there is a ceramic ring (this is an insulator) that separates the metal case from the metal nub end. So, electrons flow from the nub end, through the filament support, to the filament, to the other filament support, to the metal case. One of the electrical leads on a bulb holder connects to the metal case and the other to the nub end.

Figure 1. Schematic showing the path electrons follow through a light bulb.



### Procedure (Conducting the Activity)

Explain briefly to the class the concept of static versus current electricity. Tell them that they are going to explore current electricity. It is important to discuss electrical safety with your students. You might say something like the following:

I'm sure you have been told that electricity is dangerous—that it can kill you. This is true. However, the 1.5 volt batteries that we will be working with in class cannot hurt you. They do not have enough “push” or voltage to make current flow through your body. So do not worry that any of the exercises that you do in class are dangerous—they are not. However, the 120 volts at an electrical outlet does have enough push to kill you. You should never experiment with the wiring in your home without the help and supervision of an adult who knows what they are doing.

Explain the concept of an electrical circuit by saying that it contains something to push electrons (in this case—a battery), a path for the electrons to flow along (in this case—wire) and something for the electrons to do (in this case—light a bulb). If the path for electrons to follow is complete (makes a circle), then it is called a closed circuit, electrons will flow, and the light will be on. If the path is not complete, then it is called an open circuit, electricity will not flow, and the light will not be on.

Explain to the class the analogy between water pressure and electrical pressure, water flow and electron flow, and resistance in a faucet and resistance in an electrical circuit.

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## Lesson 4 — Current Electricity & Circuit Building



Divide the class into working groups and give each group a battery, a light bulb and a piece of wire (about 6 inches long). Note: Depending on the students, you may want to strip about one-half inch of insulation off each end of the wire or you may want to give them wire with the insulation left on and make them figure out that it needs to be stripped. They may have no basis for knowing about insulation on wire—this concept is introduced in the next lesson. Ask them to work together to make the bulb light. There are four ways to accomplish this (Figure 2). Note that all four ways involve connecting the screw-in bulb case to one side of the battery and the nub end to the other side of the battery.

Figure 2

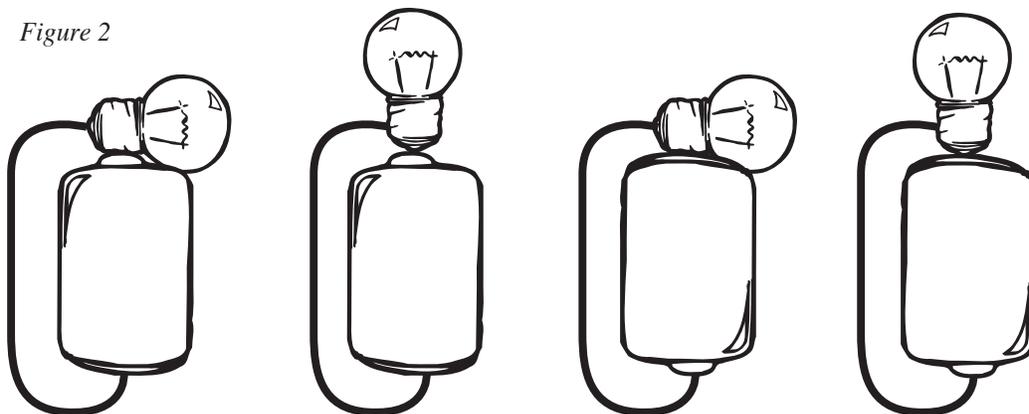


Figure 2. Possible ways to light a light bulb with a battery, bulb and single piece of wire. Note: the third and fourth approach are identical to the first and second, except the battery is turned over (bulb sitting on opposite battery terminal). In every case, one terminal of the battery is touching the screw-in case of the bulb (either directly or connected by a wire) and the other terminal of the battery is touching the nub end of the bulb.

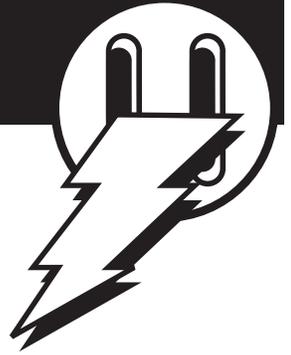
After the students have accomplished this task, distribute holders for batteries and bulbs, an additional battery, bulbs, and wires to each group. Give each group (or each student) a Youth Activity Sheet and ask them to follow the instructions given on the activity sheets. You may have to demonstrate to students how to put the batteries in the battery holders and how to connect wires to the clips on the battery and bulb holders.

### Answers to Youth Activity Sheet

1. Closed, on
2. Open, off
3. Closed, on
4. Open, off
5. Open, off.

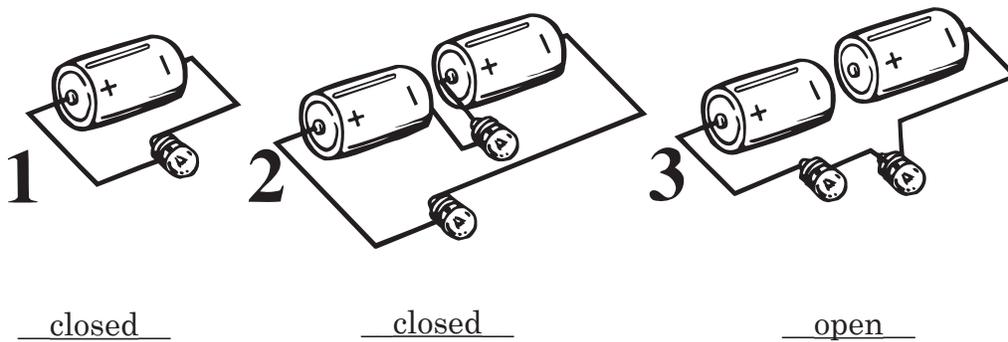
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# Lesson 4 — Current Electricity & Circuit Building



## Evaluation (Answer Sheet)

1. An open circuit will allow electrons to flow (true or false).
2. If a light is on, the circuit is closed (open or closed).
3. Mark the following, as open or closed.

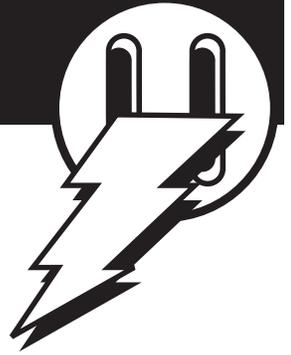


For each of the following questions, circle the correct answer.

4. When we talk about “electricity” we are usually referring to
  - static electricity
  - current electricity
  - neutron electricity
  - proton electricity
5. Electricity can be defined as the flow of
  - neutrons
  - protons
  - electrons
  - water
6. For electricity to flow, two things are necessary-something to push electrons and a path for them to follow
  - True
  - False

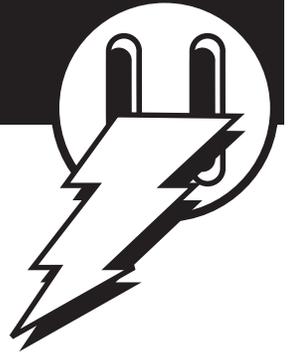
Science SOL  
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## Lesson 4 — Current Electricity & Circuit Building



7. The force that pushes electrons is called:
- voltage
  - current
  - magnetism
  - gravity
8. The flow of electrons is called:
- voltage
  - magnetism
  - current
  - gravity
9. The flow of electrons is measured in units called:
- amperes
  - volts
  - ohms
  - millimeters
10. The resistance to the flow of electrons is measured in:
- volts
  - amps
  - ohms
  - gallons

# Lesson 5 — Conductors and Insulators



## ■ Life Skill Objective—Learning through Observation

## ■ Connection to Standards of Learning

Science SOL 4.3 (a) states that the student will investigate and understand conductors and insulators.

## ■ Time Required—45 minutes

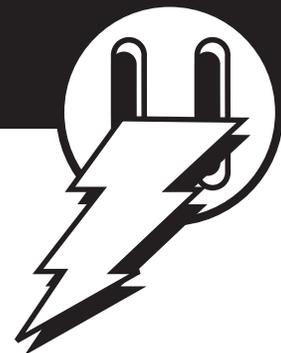
## ■ Supply List:

For each group:

- 1 index card
- 1 pair of scissors
- 1 metal paper clip
- 2 metal paper fasteners/brads (at least 1/4 inch; 1/2 inch are OK too)
- 2 D-cell batteries
- 2 D-cell battery holders
- 1 flashlight bulb (1.5 or 3 volt)
- 1 light bulb holder
- 6 pieces of insulated wire (22 to 26 gauge, solid core) with the ends stripped about 1/2 inch
- Materials for testing to determine if they are insulators or conductors. Possible materials include: wood (a pencil); plastic (a pen); paper, rubber (rubber bands), metal (aluminum foil, etc.)
- Youth Activity Sheets

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# Lesson 5 — Conductors and Insulators



## Background (For Group Discussion)

An electrical circuit requires three things: a path for electricity, something to push the electrons—a voltage source, and some kind of appliance or device for the electricity to power. Generally, a circuit also contains a switch, which allows the circuit to be opened and closed easily, turning the flow of electricity (and therefore the appliance) on or off.

Some materials allow electrons to flow and are called conductors. They have a low resistance to the flow of electrons. Other materials have a very high resistance to the flow of electrons and are called insulators. Metals have low resistance to electricity flow and make good conductors. That is why electrical wiring, which is designed to provide a path for electricity to flow, is made out of copper or aluminum. Plastic, glass and rubber are good electric insulators. Electricians and others who work around electricity wear rubber protective clothing to avoid being shocked.

## Procedure (Conducting the Activity)

Tell the students that they are going to make a switch that they will be using for other activities. Distribute to each group an index card, two metal paper fasteners (brads), a metal paper clip and two pieces of solid core wire (about 6 inches long, with 1/2 inch of insulation stripped from each end of the wires), and the Youth Activity Sheet.

After the switches are made (this should take no more than 10 minutes), explain to the students the concept of insulators (that do not allow electrons to flow) and conductors (that do allow electrons to flow).

Tell the students that they are going to use their switch to make a conductivity tester and use it to decide if a material is an insulator or conductor. Distribute materials to be tested.

Have students list the materials they have in the first column of their data table. Next, have them guess or predict if the material is a conductor or insulator. Finally, have them test their prediction by opening their switch and placing the material to be tested across the metal paper fasteners on the switch. In other words, have them use the material to be tested in place of the paper clip. Make sure the material is really touching both metal paper fasteners. If the light comes on, then the material is allowing electricity to flow. That means the material is a conductor. If the light does not come on (and they are making a good connection between the material they are testing and the metal paper

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# Lesson 5 — Conductors and Insulators



fasteners), then the material will not allow electricity to flow, and it is an insulator. Have the youth record the results of each test in the data table provided.

## Answers to Youth Activity Sheet

1. By using the conductivity tester they built, students should discover that metal objects conduct electricity (allow electrons to flow), while other objects (paper, plastic, glass, air) are insulators and do not allow electricity to flow.
2. Air is an insulator. Students should know this because in the previous exercise, when the circuit was “open”, i.e., part of the path from one terminal of the battery back to the other terminal consisted of air, the light bulb was not on.
3. Electricians wear clothing that insulates them from electricity because they do not want to be part of an electrical circuit. People who work with high-voltage electricity wear rubber gloves and rubber soled shoes. Rubber is a good insulator.
4. Extension cords are covered with rubber or plastic because both are good insulators. Since the cord is insulated, it doesn't matter what it touches, because anything it touches will not be “exposed” to electricity. If an extension cord were made covered with a conductor, i.e., metal, and it touched any other conducting material, then the material it touched would provide a path for electricity to flow. The electricity would then be taking an unintended path. This is called a SHORT circuit or just a “Short”.

## Evaluation (Answer Sheet)

For each of the following questions, mark the correct answer.

1. For each material, mark I for insulator or C for conductor.

	I	C		I	C
Wood	●	○	Rubber	●	○
Copper	○	●	Glass	●	○
Metal	○	●	Air	●	○
Plastic	●	○			

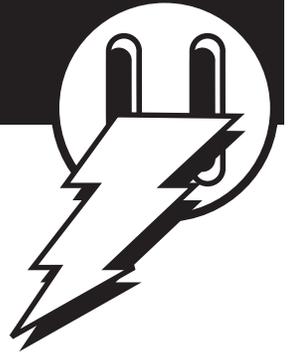
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## Lesson 5 — Conductors and Insulators



2. The purpose of an electric switch is
- to measure amounts of electricity
  - to redirect the flow of electricity
  - to turn the flow of electricity off and on
  - Don't know
3. All materials allow electrons (electricity) to flow.
- True
  - False
4. Materials called conductors have \_\_\_\_\_ resistance to the flow of electrons (electricity).
- Low
  - High
  - Medium
5. Materials called insulators have \_\_\_\_\_ resistance to the flow of electrons (electricity).
- Low
  - High
  - Medium
6. Which of the following would not be a good conductor of electricity?
- copper
  - aluminum
  - wood
  - metal
7. Which of the following would not be a good insulator of electricity?
- rubber
  - metal pipe
  - plastic
  - glass

# Lesson 6 -Circuit Building-Series and Parallel Circuits



## Life Skill Objective-Learning through Observation

## Connections to Standards of Learning

Science SOL 4.3 (b) states that students will investigate and understand characteristics of basic circuits (open/closed, parallel/series).

## Time Required-One hour

## Supply List

For each group:

- One D-cell battery holder
- One D-cell battery
- Two flashlight bulbs (1.5 or 3 v)
- Two light bulb holders
- Four pieces of insulated wire (22 to 26 gauge, solid core) with ends stripped about 1/2 inch.
- Youth Activity Sheet

## Background (For group discussion)

There are two basic types of circuits—one is called a series circuit and the other is called a parallel circuit. In a series circuit, there is only one path for electrons to follow from one terminal of the battery back to the other terminal. In a parallel circuit, there is more than one path that the electrons can follow in their journey from the negative terminal back to the positive one. To decide how many paths a circuit has, you can do the following:

1. Start at the negative terminal of a battery in the circuit.
2. With your index finger, trace the path that the electrons will follow (along a wire, or through a component such as a light bulb or buzzer etc) by moving your finger along the path. Remember, any conductor can be a path for electrons, but an insulator (such as air, glass, rub-

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## Lesson 6 -Circuit Building-Series and Parallel Circuits



ber, or plastic) will not provide a path for electrons. Also, remember that a battery is a path for electrons. If there is not a complete path, the circuit is open, electrons will not flow, and the appliance will not be on.

3. As you trace the path, check and see if there is more than one way the electrons can flow in the circuit-there is more than one way that electrons can flow if there is more than one wire connected together at a single point.

Series circuits behave differently from parallel circuits. If two light bulbs are wired in series, then the electrons must flow through one bulb to get to the next one (see Figure 1). This means if the first bulb burns out (and becomes an open circuit!) then the second bulb will not glow, because the electrons cannot reach it. Also, when two light bulbs are in series, their resistances add, so the total resistance in the circuit is increased and the amount of electricity flowing is reduced (just like closing down on a faucet increases resistance and decreases the flow of water). With less electricity flowing, the bulbs will be less bright.

In a parallel circuit, each bulb will have a path to the battery that can carry electrons, so if one bulb is removed from the circuit (or burns out), the other bulb will continue to burn because it still has a path for electrons (see Figure 2) to travel back to the battery. Also, each bulb will burn as brightly as if the other was not there. This is because the resistance to the flow of electrons is just one bulb's worth in each path, not the combined resistance of two bulbs.

A good analogy for thinking of series and parallel circuits is a bucket of water, with two faucets attached to it. Imagine that this is a magic bucket that always remains full, no matter how much water is running out of it. If the water has more than one way to leave the bucket (two faucets open) then it is analogous to a parallel circuit. If there is only one way for water to leave the bucket (one faucet open), then it is analogous to a Series circuit. With the two-faucet/parallel circuit analogy, you can see that closing one faucet will have no effect on the other. Also, the rate of flow from each faucet when both are wide open would be the same as the rate of flow from one faucet wide open. This is why two bulbs in a parallel circuit each burn as brightly as one bulb in a series circuit.

So how can this analogy be used to describe two light bulbs in series? It is a bit of a stretch, but first remember that since we are talking about a series circuit, there must be only one way for water to leave the bucket, so think of one faucet. With one bulb, the faucet is open at some setting; when the second bulb is added, it is like forcing the water through a

## Lesson 6 -Circuit Building-Series and Parallel Circuits



second restriction (more resistance), as if the faucet were partially shut down. The effect will be to reduce the flow of water out of the bucket. Likewise in a series circuit, adding a second bulb in the same path (remember, a series circuit only has one path for electrons to follow) will increase the resistance and therefore reduce the flow of electrons. The effect of reducing the flow of electrons on the light bulbs is to reduce the amount of light produced by the bulbs.

The bucket analogy can also be used to see the effect of increasing the voltage (adding more batteries) to the circuit. Remember, voltage is electrical pressure, so increasing the batteries (voltage) is like increasing the water pressure. This could be accomplished by increasing the height of the water column in the bucket. As the height of the water above the faucets increases, the water pressure on the faucets increases, and the flow of water from a given faucet opening (fixed resistance) will increase. Likewise as the number of batteries in a circuit increases, the electrical pressure (voltage) increases, and the flow of electrons (amperage) also increases for a given number of light bulbs (fixed resistance); thus the bulb(s) burn brighter.

Build the circuits shown in Figures 1 and 2 and make sure you can follow the path of the electrons before introducing this lesson to your students.

### Looking at Figure 1:

We think of electrons being repelled from the negative pole of the battery and being attracted to the positive pole. The path for electrons is through wire 1 to bulb 1, through the bulb to wire 2, through wire 2 to bulb 2, through bulb 2 to wire 3, and through wire 3 back to the battery. Note that removing either bulb from the circuit will eliminate the path for electrons, since air is an insulator and the electrons can't travel through the air (where the bulb was) to continue their journey back to the battery.

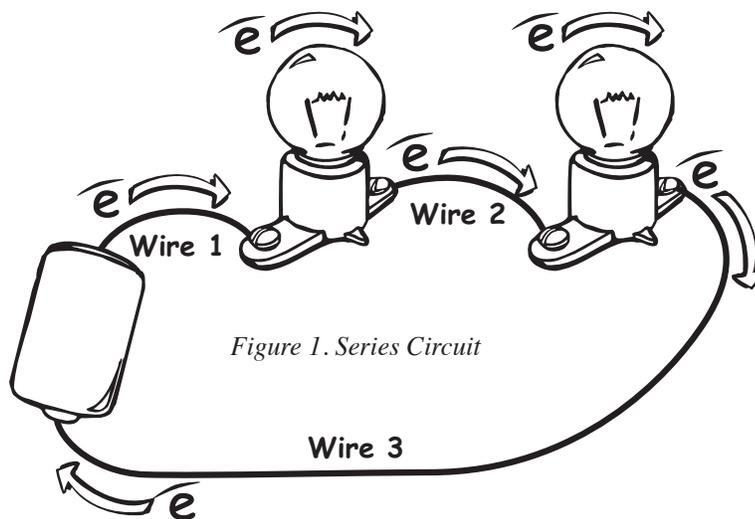
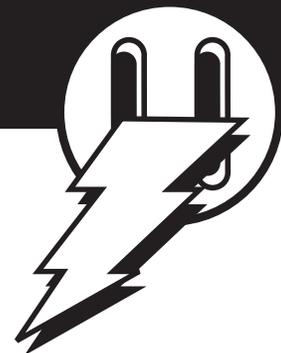


Figure 1. Series Circuit

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## Lesson 6 -Circuit Building-Series and Parallel Circuits



### Looking at Figure 2:

Electrons travel through wire 1 to bulb 1. At this point, there are two possible paths back to the battery—either through bulb 1 and then wire 4 OR through wire 2, bulb 2, wire 3 and wire 4 back to the battery. Note that with either path, the electrons must go through a light bulb to get back to the

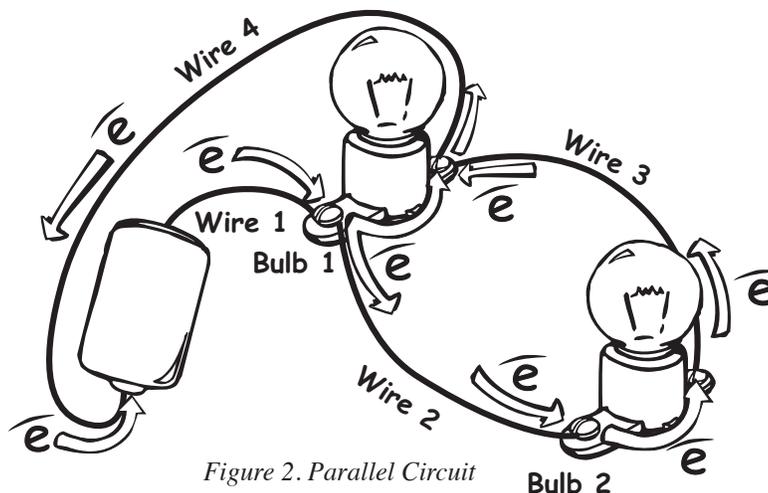


Figure 2. Parallel Circuit

battery. Why is this important? The amount of electrons that follow each path is inversely proportional to the resistance along the path—put more simply, a lot of electrons will take a path with little resistance, and very few electrons will take a path with a great deal of resistance. In this instance, the resistance in either path is the same (the added resistance due to longer wires is negligible!), so the same number of electrons will take each path. This means the two bulbs will be at the same brightness.

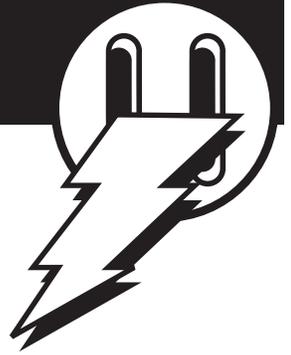
Try this experiment: Take the ends of wires 2 and 3 and disconnect them from bulb 2. (Note what happens to bulb 1.) Now, connect the ends of wires 2 and 3 together. What happens to bulb 1? In this case, there are two paths for electrons to follow back to the battery—the path through bulb 1 OR the path through wire 1 to wire 2 to wire 3 to wire 4 back to the battery. In one path, the light bulb represents high resistance compared to the resistance in the other path, which is just wire. The vast majority of electrons take the path with little resistance, so there are not enough electrons flowing through the light bulb to make it light.

### Procedure (Conducting the Activity)

Organize your students into working groups. Explain to the students that they will be building series and parallel circuits and learning how each one behaves. Distribute the materials to each group and ask them to follow the directions on the Student Activity Sheet.

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## Lesson 6 -Circuit Building-Series and Parallel Circuits



### Answers to Youth Activity Sheet

On the Youth Activity Sheet, the students are asked to describe the path the electrons take in words. For the series circuit (the first activity), a suitable answer is: The electrons travel along the first wire to the bulb, through the first bulb to the second wire, through the second wire to the second bulb, through the second bulb to the third wire and through the third wire to the positive terminal of the battery.

When one bulb is unscrewed in the series circuit, the other bulb goes out because the missing bulb causes an open circuit and the electrons do not have a complete path to follow.

When they traced the path for electrons to follow, there was only ONE path for electrons to follow.

This type of circuit is called a SERIES circuit.

For the second circuit, a suitable description is:

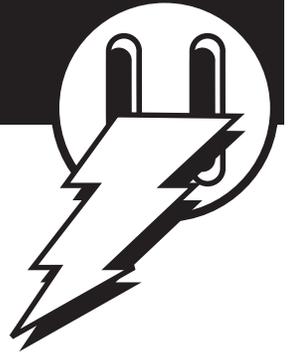
The electrons travel along the first wire to the first bulb. When they get to the first bulb, some of the electrons go through the bulb, but some of the electrons go through the second wire to the second bulb. After the electrons go through the first bulb, they travel through the fourth wire back to the battery. The electrons that go through the second bulb travel through the third wire back to the first bulb, but instead of going through the first bulb, they follow the fourth wire back to the battery.

Was there ever a point when the electrons could go to more than one place (a branch in the circuit)? Yes. At bulb one, some of the electrons went through the bulb back to the battery, but some went on to the second bulb without going through the first bulb.

This is a PARALLEL circuit.

When one bulb is unscrewed, the other remains on, because it still has a complete path for electrons.

## Lesson 6 – Circuit Building-Series and Parallel Circuits



### Evaluation (Answer Sheet)

- In a series circuit with two light bulbs, if one of the bulbs burns out, the other bulb will:
  - go out also
  - burn more brightly
  - not change at all
  - burn less brightly
- In a parallel circuit with two light bulbs, if one of the bulbs burns out, the other bulb will:
  - go out also
  - burn more brightly
  - not change at all
  - burn less brightly
- In a series circuit the electrons:
  - have only one path to follow
  - have more than one path to follow
  - only flow if it is an open circuit
  - a and c are both correct answers
- In a parallel circuit the electrons:
  - have only one path to follow
  - have more than one path to follow
  - only flow if it is an open circuit
  - a and c are both correct answers
- The circuits in my house are wired in parallel because:
  - if they were in series, and I turned off one appliance, all the other appliances on the same circuit would go out too.
  - it takes less wire to make a parallel circuit
  - a parallel circuit is safer
  - they are wired in series, not parallel.

## Lesson 7 — Electromagnets



### Life Skill Objective—Learning through Observation

### Connection to Standards of Learning

Science SOL 4.3 (e) states that students will investigate and understand characteristics of electromagnets and magnetism.

### Time Required—One hour

### Supply List

- One set of the following for each working group:
- two D-Cell batteries
- two battery holders
- about 3 feet of insulated wire (20, 22, or 24 gauge is fine) with about 1/2 inch of insulation removed from each end
- one large nail (3 or 4 inches)
- several metal paper clips
- the switch from the previous lesson
- pencils
- Youth Activity Sheets

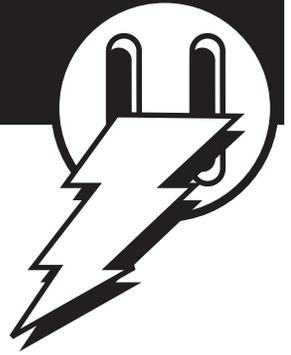
### Background Information (For Group Discussion)

Whenever electricity flows, a magnetic field is present—this is a phenomenon that scientists have observed. No one knows why, any more than we know why there is gravity or why there are magnetic fields. You can demonstrate the fact that a magnetic field is present when electricity flows by building an electromagnet.

Explain to the class that they are going to work in groups to build an electromagnet and to conduct an experiment to see if the number of times they wrap the wire around the nail in the electromagnet will affect

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## Lesson 7 — Build an Electromagnet



how strong the magnet is. Each group will collect one set of data and then share their data with the class. Each group will serve as one trial, and all the groups together will make a set of repeated trials.

Explain to the class that if they test 5 wraps and then 10 and then 15 and then 25, the batteries will be getting a little weaker with each test and they won't be sure if any differences they see are due to a difference in the number of wraps or a difference in battery strength. You might ask the class for ideas of how to solve this problem. Possible solutions include using fresh batteries for every test or using a 6-volt power supply instead of batteries (the power supply uses electricity and won't get weaker over time.) Another solution is to randomize the order in which the number of wraps are tested. That way, some groups will test high wrap numbers with fresh batteries, and some will test low wrap numbers with fresh batteries; the effect of battery freshness will be averaged out. Tell the groups that they will randomize the order in which they conduct their tests.

### ■ Procedure (Conducting the Activity)

Divide the class into groups and give each group a set of materials to build an electromagnet. You may want each group to complete one Youth Activity Sheet, or you may want each student to complete his or her own sheet.

Tell the students to follow the directions on the Youth Activity Sheet and complete the data table.

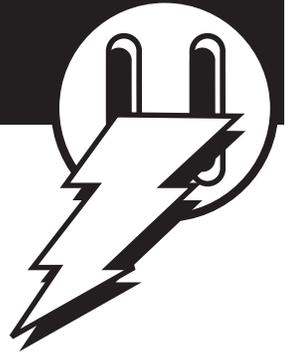
Make sure that each group connects its batteries correctly—the positive terminal from one battery must be connected to the negative terminal of the next.

After the groups have had a chance to collect their data, have each group report their data to the class and record the observations on the board. In this way, each group serves as a repeated trial in the experiment. The number of paper clips picked up for each number of wraps of wire will vary from group to group.

Once the data is collected and displayed on the board, have the groups find the average number of paper clips picked up for each number of wraps of wire (average the observations of all the groups.)

Ask the groups to plot the data that they generated as a class. You might have some groups make bar graphs and some make line graphs.

# Lesson 7 — Build an Electromagnet



Ask the class to draw a conclusion from their data. Does the number of wraps of wire around the nail affect the strength of the electromagnet?

In general, the greater the number of wraps of wire the stronger the electromagnet, and the more paper clips picked up.

## ■ Evaluation (Answer Sheet)

1. Why did you draw numbers to determine the order in which you tested the number of wraps of wire?

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2. Why did the class combine their data?

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For each of the following questions, mark the correct answer:

3. When electricity flows, a magnetic field is present.

- True                                       False

4. An electromagnet demonstrates that

- electricity produces a magnetic field.  
 gravity is a natural force.  
 static electricity can be used.  
 Don't know.

5. When conducting an experiment, why is data collected?

- To take up class time  
 To practice writing  
 To provide information about the experiment

## Lesson 8 — Electrical Safety



**Life Skill Objective** - decision-making for personal safety

### Connection to Standards of Learning

SOL 4.3 (a) states that the student will investigate and understand the characteristics of electricity.

**Time Required** - 1 hour

### Supply List

- Pencils
- Youth Activity Sheet

### Background Information

Electricity is always looking for the easiest path to ground. In this sense, ground is any avenue through which electricity travels to reach the earth. Electricity will travel through anything that is a “conductor” or something that is used to get to something else. Just as electricity travels from a battery through a wire to light a bulb or power an electromagnet, electricity could travel from energized equipment through a person to get to the earth, making people great conductors.

When electricity passes through the body, it’s called electrical shock and can be very damaging. The current may cause 1st, 2nd, or 3rd degree burns. It can be crippling, and a victim may lose one or more limbs where the electricity has destroyed tissue. An electrical shock can cause a person’s heart to stop, and sometimes, electrical shock victims die.

The typical voltage in a common household outlet is about 100 times greater than what is in a (D-cell) flashlight battery. But even the amount of voltage in an electrical outlet can push enough current through the human body to injure or kill a person, should he or she become a path to ground! Outside electrical equipment operates at thousands of times more voltage than what is found at a household outlet. Examples of outdoor electrical equipment include the following: substations, transmission towers, underground cables, pad-mount transformers, distribution lines and meter bases (see illustrations in youth activity sheet).

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## Lesson 8 — Electrical Safety



It's important to respect the power of electricity. For their own safety, youth must understand that they should stay away from outdoor electrical equipment. This means they should never climb transmission towers, service poles, substation fences, etc. No one should go near exposed or downed wires. Students should be instructed to immediately report such a problem to an adult; in turn, the adult should call the power company to get the problem corrected.

### ■ Procedure

Make sure that the students understand the following:

- Everyone should stay away from outdoor electrical equipment - it poses a potential hazard to anyone who tries to interact with it.
- Youth should use their knowledge about electrical safety to negotiate out of peer pressure situations.
- Youth should immediately report electrical hazards to an adult, who, in turn, should call the power company to get the problem corrected.

Show the various illustrations of outdoor electrical equipment to the class and discuss them to familiarize the students with the terminology. You might ask if they have seen any of this equipment, and if so, where is it located (near the school, their homes, etc.)?

Divide the class into groups and assign a different skit to each group. Tell the students to follow the directions on the Youth Activity Sheet. Each group will:

- assign actors
- read through one of the skits
- role play the scenario that is outlined, practicing a couple of times
- be prepared to perform its skit to the class

After the groups have had a chance to practice, ask each group to present its skit to the class.

Ask the students to complete the evaluation provided in the Youth Activity Sheet.

## Lesson 8 — Electrical Safety



### ■ Answers to Youth Activity Sheet (none)

### ■ Evaluation

#### Evaluation Scenario #1

After explaining to Bobby that he could be seriously injured if he touches anything inside the transformer, Jenny should keep some distance from the transformer and seek adult intervention if possible. In the event that Bobby did get inside the transformer, Jenny should not approach it or Bobby, even if he is hurt. She should seek adult help.

QUESTION: What should Jenny do in this situation?

ANSWER: Jenny should step back from the hazard and continue to warn Bobby to stop. If he persists, she should get an adult or the bus driver to intervene. The adult should also call the power company to report damage to the equipment. These transformers are safe when locked, but they are equipment-not toys. Children shouldn't play on or around them, and if something looks damaged, the child should report it to an adult so the power company can be called.

#### Evaluation Scenario #2

Dennis should not retrieve the kite because in doing so, they might become a path for electricity and be seriously injured. Dennis and Kara should inform an adult about the kite and either they or the adult should inform the power company.

QUESTION: What should Dennis do? Should Dennis retrieve the kite? Why/why not?

ANSWER: No, Dennis should not retrieve the kite because electricity is always looking for a path to ground, and the current can travel through the string - and through Dennis - to reach the earth. Dennis should use his knowledge about electrical safety and refuse to retrieve the kite. The children should then go get an adult to call the power company.