# Electricity & Magnetism

Electricity and magnetism are critical concepts in science. The word *electricity* has several different interpretations. You can talk about static electricity, such as arises when you shuffle your feet along the carpet, or comb your hair with a plastic comb on a dry day. The rubbing between the shoe and the carpet transfers electrons from one to the other, leaving you with a net charge. Touching a metal door knob with that charge can be a shocking experience. In this case, electricity refers to a static build up of electric charge.

Electricity also often means electric current or electric voltage. An electric current occurs when charges travel from one place to another. One common example of this is a lightning bolt, where charges flow from one highly-charged part of the atmosphere to another part of the atmosphere, or to a tree or lightning rod. Such electric currents can be very large (even one-million Amperes) and highly destructive. Electrical currents can also be present in wires, such as the wiring in houses. Note that currents only flow in the house wiring if an appliance or a light bulb or some other device is turned on. The electric current flowing in typical household devices might be 0.1 Amperes (a clock), 1 Ampere (a light bulb), or 10 Amperes (a vacuum cleaner). Electric current only flows if a voltage source (such as a battery) is connected to the circuit. Another common source of voltage is the voltage supplied to our houses by electric utility companies.

Magnetism was discovered in ancient times when it was noted that some kinds of rocks (mainly iron oxides) could attract some kinds of materials (mainly iron-based materials). It was soon discovered that magnets in the shape of a thin rod could be made to have a "north" pole at one end and a "south" pole at the other end. If such a bar magnet is suspended horizontally, it will rotate to align the south pole toward the north pole of the earth, and therefore can be used as a compass. North poles of magnets repel each other. Similarly, south poles repel south poles. However, north poles attract south poles and vice versa. We have subsequently learned that materials such as iron and iron oxides are magnetic because of the nature of the atoms making up the material. In fact, each iron atom behaves exactly like a small bar magnet.

The concepts of electricity and magnetism are intimately related. For example, an electric current flowing in a wire can cause a nearby compass needle to deflect. (The electric current creates a magnetic field in its vicinity). Similarly, waving a magnetic bar in the vicinity of a loop of wire can cause an electric current to flow in the wire (the changing magnetic field caused by moving the bar magnet creates an electric voltage, which causes a current to flow in the wire). These interrelationships are very important to the operation of such devices as electric motors, electric generators, and many other technological devices.

# Clingy Comb

**Recommended grade levels:** K-3

**Goal:** Students will observe static electricity and predict how small objects will behave when they come in contact with static electricity.

**Process skills:**

Collecting data
Connections
Making graphs
Observing
Predicting

**Frameworks:** Force and Motion

**Materials:** (per student group)

- one rubber or plastic comb
- wool or nylon cloth
- salt and pepper
- short pieces of thread
- scraps of paper
- one bowl of water

**Teacher background information:**

When a comb is rubbed with wool or nylon, electrons are transferred from the wool to the comb. This causes an excess charge to be present on each item. The comb becomes negatively charged because it now has extra electrons, and the wool becomes positively charged because it now is missing some electrons. When the comb is held near a salt and pepper mixture, there is an electrostatic attraction between the comb and the salt and pepper. The less dense flakes of pepper move onto the comb, while the heavy grains of salt do not.

Devices known as electrostatic precipitators do something similar to polluted air coming from coal-fired power plants. Ash and dust are major pollutants in smoke from these plants. The precipitators work by directing the smoke through a chamber containing electrically-charged plates. The charged plates attract ash and dust, allowing it to be pulled out of the smoke.

**Note:** *Weather conditions will affect the results of this experiment. Dry air is best, as moisture in the air causes charged objects to become uncharged. Do this in the winter if possible.*

**Procedure:**

Students groups will:

1. Rub the comb against the wool or nylon cloth several times.
2. Hold the comb over a small pile of salt and pepper. The salt and pepper will separate as the pepper grains are drawn to the comb.

3. Repeat with the pieces of thread and the scraps of paper. **(See Figure 1.)** Students should rub the comb against the cloth several times before they try each new material and dip the comb in the bowl of water to remove the electrical charge.

## Discussion:

1. What caused the movement of the items?
2. Why did we rub the comb against the cloth?
3. Where is static electricity used?
4. Why do you have to rub the comb against the cloth each time?

## Extensions:

1. Repeat the experiment. Have students try to pick up the aluminum foil with the comb.
2. Have students rub an inflated balloon briskly on their clothing or in their hair. Have them test if it will cling to a wall or other surface.
3. Discuss other aspects of static electricity, such as receiving shocks and hearing the crackling of electricity.
4. Have students create a list of several important items in their home that rely on electricity to operate. Discuss how electricity is created and transferred.
5. Discuss efficiency and conservation. Have students create a list of ways to use electricity without waste.

**Figure 1.**

## Teacher resource:

Nebraska Public Power District. *Mouse House Surprise*
Gr. K-3. This book is part of the *Discovering Electricity* series. It is a charming story of two mice, Sam and Jody, who learn how electricity is generated and how valuable electricity is to us all.
*For a free copy, call your local Public Power District.*

# Using an Electroscope

**Recommended grade levels:** 4-6

**Goal:** Students will use an electroscope to observe negative and positive charges.

**Process skills:**

Applying concepts
Collecting Data
Connections
Making graphs
Observing
Predicting

**Frameworks:** Force and Motion

**Materials:** (for each student or team of students)

- one large glass jar
- aluminum foil (gum wrapper foil works well)
- stranded wire (#16 electrical primary wire is best)
- one plastic lid (or cardboard)
- white glue
- scissors
- wire cutter
- masking tape
- one comb
- wool or nylon cloth

**Teacher background information:**

All matter is made up of atoms. Atoms are made up of a positively-charged nucleus and negatively-charged electrons. Normally, an atom will have enough electrons to cancel out the positive charge of the nucleus, leaving the atom electrically neutral. In some insulators, however, electrons are more loosely attached to their atoms, making it easy to remove the electrons by friction. In conductors, the electrons are so loosely attached that they are able to move about the material freely. This property makes them good conductors of electricity.

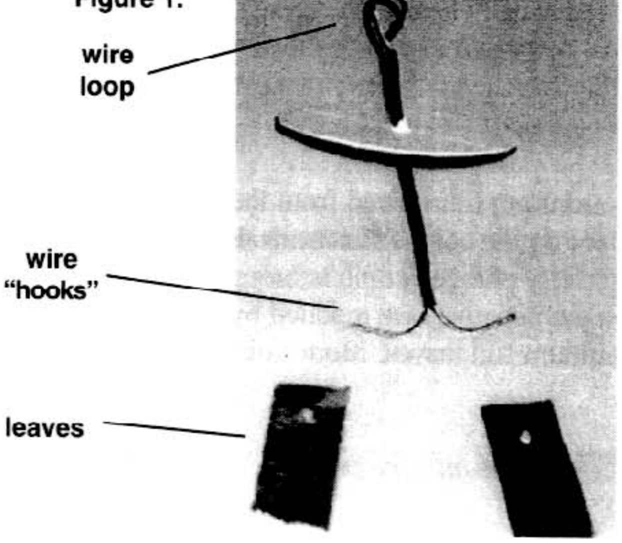
When a comb is rubbed with wool or nylon, electrons are transferred from the wool to the comb. This causes an excess negative charge to be present on the comb. Electrons do not like be near each other ("like charges repel"). When the negatively charged comb is brought near the loop of the electroscope, the electrons in the loop (which are negative) are repelled by the comb and react by moving down the wire and onto the aluminum foil leaves. Both foil leaves become negatively charged and repel each other.

**Note:** *All experiments with charged objects are best done on very dry days. Winter days are ideal.*

## Procedure:

1. Students will cut two 1-1/2" x 1/2" inch strips of aluminum foil. Near one end of each strip, students will carefully punch a small hole. These strips will be the "leaves" of the electroscope. Make sure the leaves are flat and uncrumpled.
2. Students will make a small hole in the plastic lid, just large enough for the wire to fit through. If they are using cardboard, they should cut a circle to fit the jar mouth and then punch the hole in the center.
3. Students will cut a six-inch length of stranded wire. They will strip about two inches of the plastic insulation off one end of the wire and one inch off the other.
4. At the one-inch end, students will divide the bundle of wires into two groups and tightly twist each group into a separate bundle. They will form each twisted bundle into little "hooks." **(See Figure 1.)**
5. Students will tightly twist the wires of the 2" end together to form one bundle and thread the two-inch end through the hole in the lid and pull it until the insulated part of the wire comes through the hole. They should use a dab of glue to hold it if the hole is too big to hold the wire.
6. Students will form a small loop from the straight end of the wire. **(See Figure 1.)**
7. Students will carefully hang the foil leaves on the two wire hooks. They should make sure the holes in the foil are large enough to allow the foil to move easily. The leaves should be able to move in response to even a small tap on the jar. **(See Figure 1.)**
8. Students will put the lid assembly on the jar. If they are using cardboard, they should use the masking tape to tape it in place.
9. To test the electroscope, students will rub a comb briskly with wool or nylon fabric (or comb their hair) and bring the comb near the loop. **(See Figure 2.)** The leaves should swing out away from each other. If they do not, students should check to make sure they are free to move on their hooks. Next, students will charge the comb up again and gently move it against the loop. The leaves should swing up and stay up, showing that they have stored up some of the charge from the comb.

Figure 1.



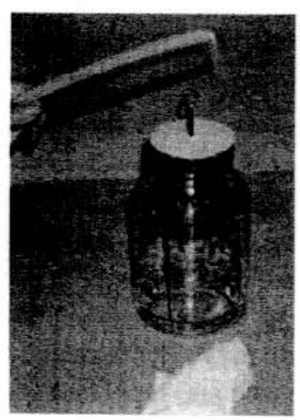



Figure 2.

**Discussion:**

1. Why do the leaves move?
2. Would this activity work as well in the summer months? Why or why not?
3. How can the electroscope be discharged?

**Extension:**

1. Have students experiment with a variety of objects and fabrics to see if they can generate static electricity. Suggestions: Styrofoam cups, plastic wrap, other kinds of plastic, wood, metal, silk, fur, felt, cotton, balloons.

**Teacher resource:**

Schafer, Larry E. *Taking Charge: An Introduction to Electricity*
Gr. 3-6. The book contains resources and activities that provide a basic understanding of simple electrical phenomena in everyday events. The book has two modules: static electricity and current electricity. Some historical references are included. Materials for activities can be acquired locally.
ISBN: 0-87355-110-9

# Making a Switch

**Recommended grade levels:** 4-6

**Goal:** Students will gain knowledge of electrical circuits by experimenting with a switch.

**Process skills:**
Observing

**Frameworks:** Force and Matter

**Materials:** (for each switch)

- one empty wooden thread spool (or a one-inch section of a wooden broom handle with a hole drilled through the middle)
- two metal washers
- one long screw
- two short flat head nails
- 2" x 2" piece of wood
- aluminum foil
- two paper clips

**Teacher background information:**
This switch is a variation of one invented by Lewis Latimer, an African-American inventor who was one of the early pioneers in electric lighting. Latimer was a highly respected engineer at the Edison Electric Light Company. Researching Latimer's career would be a good way for students to learn about the challenges of bringing electrical lighting to the world.

This activity is offered to provide students with an opportunity to build a simple device. If you choose not to build them in class, these switches are inexpensive and can easily be made in quantity ahead of time for classroom use.

**Procedure:**
Students will:

1. Cut a strip of aluminum foil long enough to go two-thirds the way around the spool and wide enough to cover the main body of the spool. (The spool flanges must remain uncovered.) Spread a thin layer of glue completely over the back of the foil and carefully glue it to the spool.
2. Attach the spool to the piece of wood with the long screw, placing the washers above and below the spool. Leave the spool loose enough to turn easily. **(See Figure 1.)**
3. Pull the two parts of the paper clip apart so that the two bends are about 1 cm apart. **(See Figure 2.)**
4. Using the two small nails, mount the clips to the wood block. The clips must be placed on opposite sides of the spool so that one leg of each clip presses lightly against the spool. **(See Figure 3.)**

## Discussion:

1. Describe how to use this switch. Where would circuit wires connect to the switch?
2. What other ways can you think of to control the flow of electricity?
3. What things in your home are controlled by switches?

## Teacher resource:

Bingham, Jane. *The Usborne Book of Science Experiments*
Gr. 3-6. The book contains many easy-to-follow projects and activities with complete explanations and discussion. Sample activities include: designing a door entry system, batteries and buzzers, and exploring static electricity.
ISBN: 0-7460-0806-6

**Figure 1.**

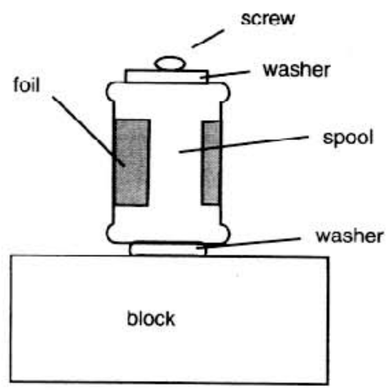



**Figure 2.**

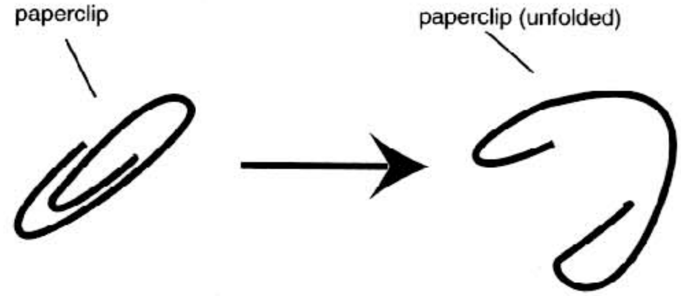
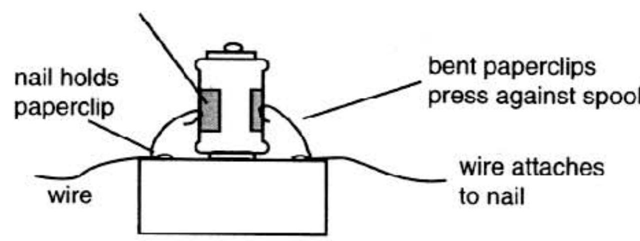



**Figure 3.**

When both clips touch the foil, a circuit is made. When you turn the spool so only one clip touches the foil, the circuit is broken.



# Circuits

**Recommended grade levels:** 4-6

**Goal:** Students will comprehend parallel and series circuits and be able to apply knowledge of circuits to build models of parallel and series circuits.

**Process skills:**

Observing
Predicting

**Frameworks:** Force and Motion

**Materials:** (per student or student group)

| **For series circuit:** | **For parallel circuit:** |
|---|---|
| insulated wires | insulated wires |
| 1.5 volt D-cell battery | 1.5 volt D-cell |
| 1.5 volt penlight bulbs (2) | 1.5 volt penlight bulbs (2) |
| switch (1) | switch |

**Teacher background information:**

All simple circuits can be classified as either series or parallel. Complex circuits are a combination of the two. In a series circuit, electricity follows only one path. Electricity may follow two or more paths in a parallel circuit. When a number of electrical devices are wired in parallel, the electricity to one device may be switched off without turning the others off. In a series circuit, switching off one device turns them all off. For example, electrical outlets in houses are wired in parallel. Students should be able to appreciate this fact after experimenting with both types of circuits.

The switches used in this activity can be commercially purchased, made from the directions in the activity, "Making a Switch" on p. 20, or made using two paper brads, a paper clip, two pieces of wire, and a 3"x 5" piece of oaktag or cardboard as shown in **Figure 1**.

**Note:** ***Always keep the switch open when wiring a circuit. The teacher should check each circuit before the switch is closed.***

*Scientists use a type of shorthand notation for drawing electric circuits. They use the following illustrations when diagraming switches.*

switch (closed position)

switch (open position)

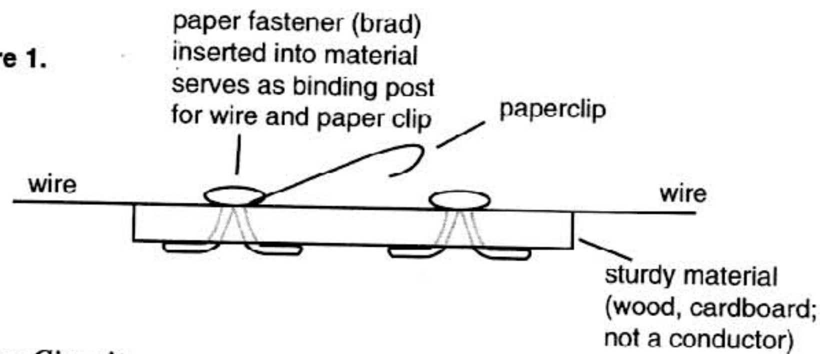
**Procedure:**

*Part I: Switches*

Students will:

1. Push two brads through the oaktag or cardboard about an inch apart.
2. Unfold the paperclip and attach one end to the first brad, as shown in **Figure 1**.
3. Wrap a piece of wire around each brad to help put the switch in the circuit.

**Figure 1.**




*Part II: Series Circuit*

Students will:

1. Connect one light bulb and one battery. The circuit diagram is shown in **Figure 2**. Observe the brightness of the bulb.
2. Add a switch to the circuit as show in **Figure 3**. Open and close the switch. Observe what happens.
3. Connect two bulbs with one circuit. **(See Figure 4.)** Compare the brightness of each bulb here with that of step 1. Test what happens when one bulb is unscrewed.

**Figure 2.**

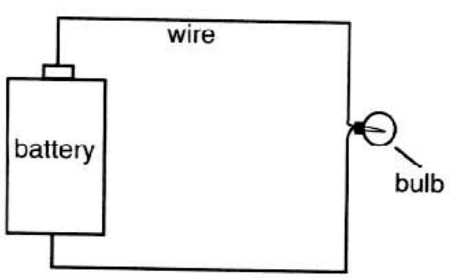



**Figure 3.**

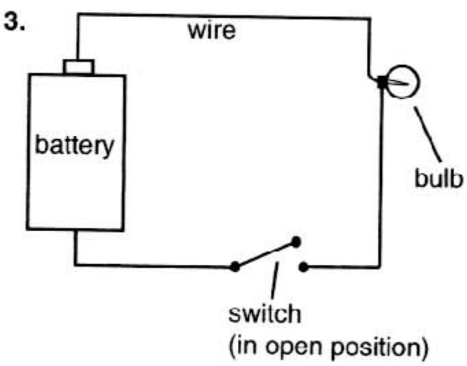
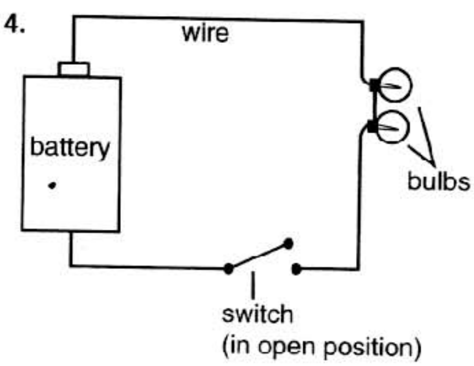


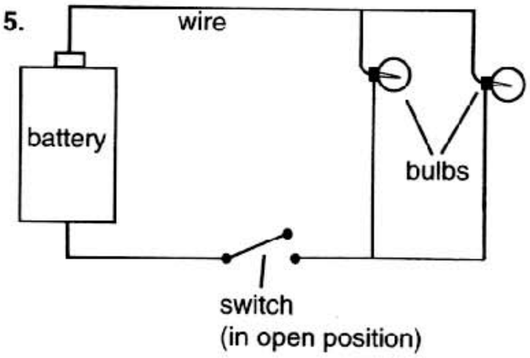

**Figure 4.**



***Part III: Parallel Circuit***

1. Have the students wire the circuit shown in **Figure 5.**
2. Have the teacher check the circuit before closing the switch.
3. What happens if you unscrew one of the bulbs?

**Figure 5.**




## Discussion:

1. Which circuit gives the most control over the number of lights you have?
2. Which circuit do you think is used in wiring the outlets of your house?
3. A series circuit could be used in what type of applications?
4. How does the number of bulbs in a circuit affect their brightness?

## Teacher resource:

Gibson, Gary. *Understanding Electricity*

Gr. 3-5. *Understanding Electricity* uses a 6-volt lightbulb along with other simple household products to explain resistance and electroplating as well as the parts of an electric circuit itself. There are also projects showing the effects of static electricity and how batteries work.

ISBN: 1-55858-163-4

# Conductors and Insulators

**Recommended grade levels:** 4-6

**Goal:** Students will comprehend the role of conductors and insulators by observation and experimentation.

**Process skills:**

Classifying
Collecting data
Controlling variables
Hypothesizing
Observing
Predicting

**Frameworks:** Force and Motion

**Materials:** (per student or student group)

**Tester:**
1 D-cell battery
flashlight bulb (1.5 volt)
wire (or aluminum foil clipped to test object with clothes pin)
masking tape

**Things to Test:**
insulated wire
steel wire
rubber band
string
paper clip
coin
waxed paper
pen
pencil
plastic bag

**Teacher background information:**

This activity is intended to follow "Circuits," p. 22. You may do this activity without having done the other, but the students will need some instruction on how to set up a circuit so the light bulb will light.

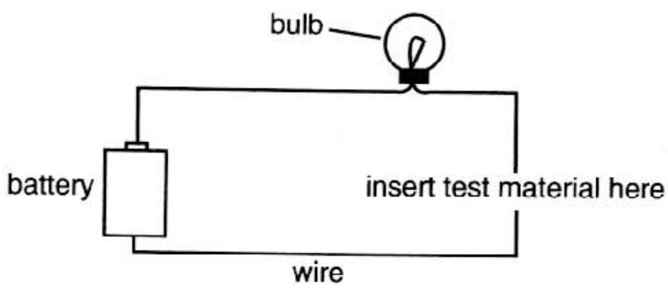
Electricity can easily move through some types of material. Materials through which an electric current moves easily are called conductors. Most metals are good conductors. Some metals are better conductors than others. Gold, silver, and copper are all good conductors. Copper is used most often to make wires because it is low-priced and easy to obtain. Many things, including our bodies, air, and water also conduct electricity in varying degrees.

Materials that are not good conductors are called insulators. An insulator may be used to cover wires to prevent electric shock. Current can not move easily through wood, rubber, glass, and some plastic.

**Procedure:**

1. Refer to "Circuits," p. 22. Students should explore which of the listed materials are conductors and which are insulators. The circuit shown in **Figure 1** can be used to test the materials.

**Figure 1.**




2. Have students work in groups and record their experiment in lab books using the scientific method:
   - State problem or problems.
   - Form hypothesis. (Which materials are likely to be good conductors? Why?)
   - List materials.
   - Data sheet (attached).
   - Collect data (see next procedure).
   - Interpret data.
   - Write conclusion.
3. Have students test each item and other items they may select and record the results on their data sheet.

## Discussion:

1. What types of materials were conductors?
2. What types of materials were insulators?
3. What importance do insulators have?

## Extension:

1. List other types of materials and have students predict if they are conductors or insulators.

## Teacher resources:

Simon, Seymour. *Lightning*

Gr. 2-3. Readers will be fascinated by the spectacular full-color photographs and clear, concise text that explores one of nature's most dramatic phenomena. Several of the photos have a Midwestern look to the landscape. Students enjoy this book and it promotes good science discussion. Safety tips are included.

ISBN: 0-688-14638-4

Gibson, Gary. *Understanding Electricity*
Gr. 3-5. *Understanding Electricity* uses a 6-volt lightbulb along with other simple household products to explain resistance and electroplating as well as the parts of an electric circuit itself. There are also projects showing the effects of static electricity and how batteries work.
ISBN: 1-55858-163-4

Peacock, Graham. *Electricity*
Gr. 3-5. This book contains a section on supplying energy from a power plant to a home. It has clear illustrations and large print for younger readers, as well as a glossary.
ISBN: 1-56847-048-7

# A Simple Burglar Alarm

**Recommended grade levels:** 4-6

**Goal:** Students will apply knowledge of circuits by building a model of a simple burglar alarm.

**Process skills:**
Observing

**Frameworks:** Force and Motion

**Materials:** (per student or student group)

one battery
wire
one doorbell buzzer
thin cardboard (3" x 3")
string
one trigger
(trigger materials: 2" x 2" piece of wood, 2 small nails, 2 strips of 2" x 1/2" metal)

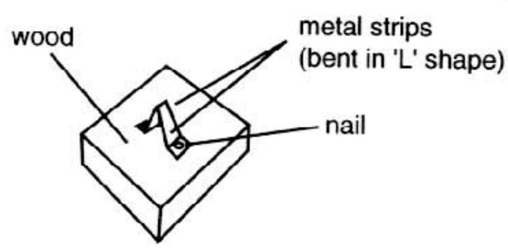
**Teacher background information:**
In this activity, the students construct a series circuit that works as an alarm. (For more information on circuits, see "Circuits," p. 22.) The circuit is normally open, due to the cardstock in the trigger. When the windowor door is opened, the cardstock is pulled out and the circuit closes, turning on the alarm.

**Note:** *Not all buzzers work well for this activity. Some experimentation may be necessary to find a type that will buzz with the amount of electricity the batteries can provide.*

**Procedure:**
Students will:

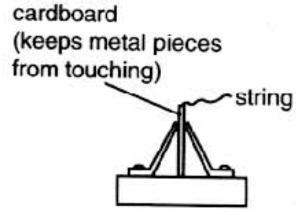
1. Construct the trigger. This is done by bending the two metal strips into an "L" shape and attaching them to the wood piece with the nails. The strips should be positioned so that their vertical parts are touching. **(See Figure 1.)**

**Figure 1.**



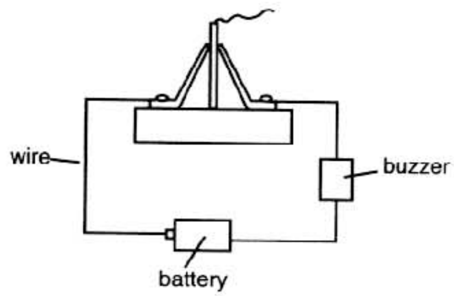
2. Punch a small hole in the cardboard near one corner and tie the string to it. Gently slide the cardboard in between the two metal pieces of the trigger, so that the metal pieces do not touch. **(See Figure 2.)**

**Figure 2.**




3. Construct the circuit shown in **Figure 3**. When the cardboard is removed, the buzzer should sound.

**Figure 3.**




4. To test the alarm, attach the free end of the string to a window or door. The alarm circuit should be arranged so when the window or door is opened, the string pulls the cardboard out from between the trigger strips. It may be necessary to attach the trigger to a heavy book or a brick, so that it does not fly up with the card.

## Discussion:

1. Why does the light in a refrigerator turn on when you open the door and turn off when you close it?
2. What are some other things in your house that work this way?

## Extension:

1. Have students find out how a home fire alarm works.

## Teacher resources:

Barr, George. *Science Projects for Young People*
Gr. 3-6. This book has clear illustrations and projects that are of high interest to students. Of particular note is the experiment entitled, "How to Burglar Proof Your Book Bag." This book also contains many carefully explained projects using simple, easy to find materials.
ISBN: 0-486-25235-3

Cleary, Beverly. *Dear Mr. Henshaw*
Gr. 4-6. A student builds an alarm to catch the thief who is stealing from his lunchbox. The alarms works, but does not catch the thief. The boy makes a new friend who asks him to rig up a special burglar alarm for his room.
ISBN: 0-440-71794-9

# Building a Flashlight

**Recommended grade levels:** 4-6

**Goal:** Students will apply knowledge of circuits and produce a working model of a flashlight.

**Process skills:**

Applying concepts
Classifying
Estimating
Measuring
Observing
Predicting

**Frameworks:** Force and Motion

**Materials:** (for each student or pair)

- one Styrofoam cup (6-8 oz.)
- toilet paper and/or paper towel tubes or sheets of oaktag
- insulated wire (or aluminum foil)
- paper clips
- thumbtacks
- electric tape
- masking tape
- two D cell batteries
- one small flashlight bulb (3 volt)
- aluminum foil

**Teacher background information:**

This activity may be used as an assessment. Students will use their knowledge about circuits, light reflectors, and switches. The diagram that is included is for teacher reference and not for student observation. **(See Figure 1.)**

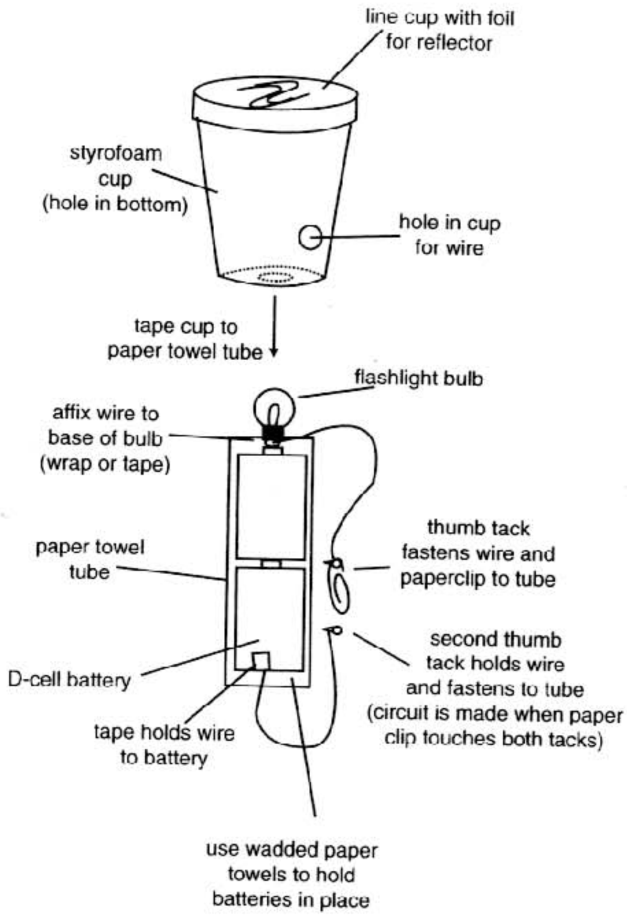
**Procedure:**

1. Explain to students that they are to build a working flashlight with the materials that are provided. The flashlight must have an on/off switch, a reflector, and produce light. They may work alone or in pairs for this activity.
2. If they need anything else, they may ask for it, or they may borrow it if it is available.

**Discussion:**

1. What prior knowledge did you use to build your flashlight?
2. What was the most difficult part when building your flashlight?
3. What kind of circuit did you build?

**Figure 1.**




## Extensions:

***Language***

1. Have students write an advertisement to sell a flashlight and present it to the class. This advertisement may include a poster.

***Math***

2. Assign a cost to the materials used, and ask students to figure the cost of their flashlight. How much is their time worth? How much would they have to sell the flashlight for to make a 10% profit?

***Social Studies***

3. • Research and report on inventors such as Benjamin Franklin, Thomas Edison, Samuel Morse, Alessandro Volta, Robert Fulton, Luigi Galvani, Harold Edgerton, Joseph Henry, Michael Faraday, Lewis Howard Latimer, Alexander Graham Bell, Edwin Drake.
   • Make a time line of discoveries in electricity.
   • Research and construct a class project.

## Teacher resource:

Parker, Steve. *Thomas Edison & Electricity*
Gr. 4-6. This book includes a history of Thomas Edison's life and works as well as information on electrical engineering.
ISBN: 0-06-446144-0

# Building an Electromagnet and Measuring Its Strength

**Recommended grade levels:** 4-6

**Goal:** Students will further explore electricity by building an electromagnet.

**Process skills:**

Applying concepts
Classifying
Collecting data
Communicating
Controlling variables
Estimating
Hypothesizing
Making graphs
Measuring
Observing
Predicting

**Frameworks:** Force and Motion

**Materials:** (per student or student group)

nails or screws (3-4 cm. long)
iron filings
one oak tag sheet
two feet of insulated wire-narrow gauge winding wire
one D-cell battery with battery holder
wire stripper
one 5-6 in. long permanent bar magnet
steel washers
paper clips

**Teacher background information:**

In 1831, a scientist named Michael Faraday found that a magnet could be used to produce electricity. Faraday moved a strong magnet back and forth through a coil of wire. The magnetic field produced by the magnet caused the electrons inside the wire to move resulting in an electric current. Faraday's discovery is the basis for a machine that is still in use today–the generator. A generator changes the energy of motion into electrical energy. When coils of wire cut through a magnetic field, electrons move through the wire. To keep the electrons moving, the wire or the magnet must be kept moving. In an electromagnet, the process is reversed: electrical current produces a magnetic field. In this case, the magnetic field only exists while the electric current is flowing.

**Procedure:**

1. Discuss and investigate permanent magnets and electromagnets with students. Introduce the concept of permanent magnets and electromagnets.

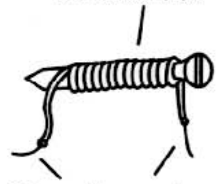
Students will:

2. Investigate permanent magnets and test them for strength. Test how many paper clips the magnet will pick up at a time. Record data.

3. Make a washer into a magnet by rubbing it on the permanent magnet in one direction. Test its strength by counting how many paper clips will it pick up. Record this data.
4. Investigate magnetic fields. Sprinkle iron filings on a piece of oak tag and place a permanent magnet under the oaktag. Observe and record what happens. Test the washer magnet in the same way and observe and record observations.
5. Pass out materials for groups (nail, winding wire, shared wire stripper).
6. Using the materials, build an electromagnet:

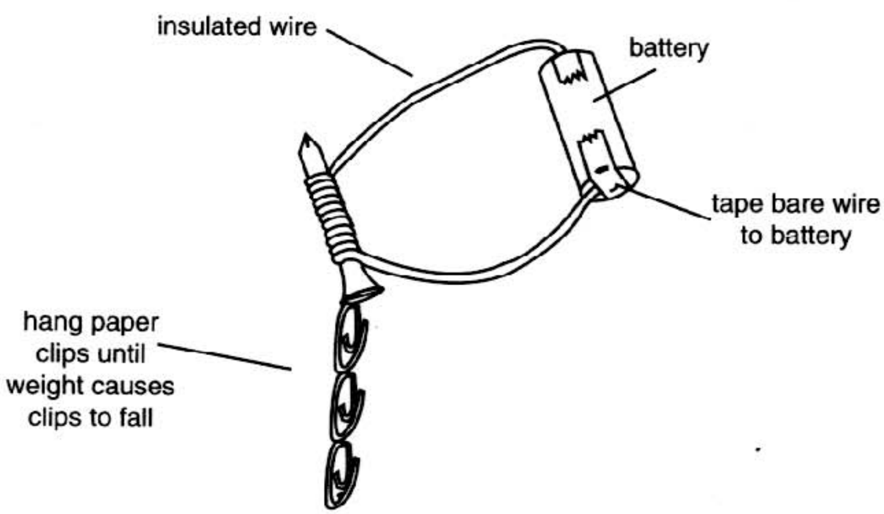
   • Wind the wire (about 2 feet) carefully around the nail. Leave three inches free on each end and remove the insulation from the free ends.
   **(See Figure 1.)**

**Figure 1.**




   • Attach one of the free wire ends to one end of the battery holder and the other end of the wire to the other end of the battery holder. **(See Figure 2.)** Students can do this activity without a battery holder by using their fingertips to hold the wires to the battery–*but students must hold the wire only where it is insulated.* Predict how strong the electromagnet will be (How many paper clips will it hold?). Test predictions and record the number of paper clips it holds.

**Figure 2.**




7. Using their results, hypothesize how they can increase or decrease the strength of an electromagnet.
8. Experiment and record their findings.
9. Compare their results with other groups.

**Discussion:**

1. Was the electromagnet as strong as the permanent magnet? Why or why not?
2. How was the nail able to pick up the paper clips?
3. Were you able to make the electromagnet stronger? How?

**Extension:**

1. Have students make another electromagnet with twice as much wire. How does the strength of this electromagnet compare with the first?

**Teacher resources:**

Ardley, Neil. *The Science Book of Magnets*
Gr. 2-6. This book contains simple experiments to illustrate the principles of magnetism. Other energy-related titles in this series include: *Water, Light, Sound, Motion, Energy, Machines, Electricity*, and *Weather*.
ISBN: 0-15-365405-8

Gardner, Robert. *Electricity and Magnetism*
Gr. 6 & Up. This book features 17 activities dealing with static electricity, magnetism, electromagnetism, and basic electrical properties such as simple circuits. Gardner fits his demonstrations into a historical narrative that is sprinkled with contemporary "gee-whiz" tidbits–for example, the role of static electricity in photocopiers, and magnetism as a possible cause of whales beaching themselves.
ISBN: 0-80-502850-1

Pfeffer, Wendy. *Marta's Magnets*
Gr. 2-4. Marta's sister, Rosa, calls her magnet collection "junk" but Marta's magnets help her make friends in her new home and help her retrieve a lost key for Rosa's new friend. This is an excellent muticultural science-literature connection.
ISBN: 0-382-24930-5

Robson, Pam. *Science Workshop: Magnetism*
Gr. 2-6. Robson explores the properties of magnets and ways to work with the forces of attraction and repulsion. Easy-to-make science experiments with clear explanations as to how and why they work are included.
ISBN: 0-15-365405-8

Vecchione, Glen. *Magnet Science*
Gr. 5-9. From the discovery of the lodestone (an ancient Greek legend) to the use of magnetic technology in the space program, this book introduces the science of magnets. Activities vary from simple (magnetizing a screwdriver) to practical (building a motor) to playful (making a magnetic hockey game) to out-of-this-world (collecting and identifying micrometeorites).
ISBN: 0-8069-0888-2