Appendix E – Science Resources

Scientific Investigation

Modified from:
Science Standards of Learning For Virginia Public Schools

Goals

The purposes of scientific investigation and discovery are to satisfy humankind's quest for knowledge and understanding and to preserve and enhance the quality of the human experience. Therefore, as a result of science instruction, students will be able to achieve the following objectives:

1. Develop and use an experimental design in scientific inquiry.
2. Use the language of science to communicate understanding.
3. Investigate phenomena, using technology.
4. Apply scientific concepts, skills, and processes to everyday experiences.
5. Experience the richness and excitement of scientific discovery of the natural world through the collaborative quest for knowledge and understanding.
6. Make informed decisions regarding contemporary issues, taking into account the following:
   - public policy and legislation;
   - economic costs/benefits;
   - validation from scientific data and the use of scientific reasoning and logic;
   - respect for living things;
   - personal responsibility; and
   - history of scientific discovery.
7. Develop scientific dispositions and habits of mind including:
   - curiosity;
   - demand for verification;
   - respect for logic and rational thinking;
   - consideration of premises and consequences;
   - respect for historical contributions;
   - attention to accuracy and precision; and
   - patience and persistence.
8. Explore science-related careers and interests.

Safety

Teachers must be certain that students know how to follow safety guidelines, demonstrate appropriate laboratory safety techniques, and use equipment safely while working individually and in groups.

Safety must be given the highest priority in implementing any instructional program for science. Correct and safe techniques must be carefully considered with regard to the safety precautions for every instructional activity. Safe science classrooms require thorough planning, careful management, and constant monitoring of student activities. Class enrollment should not exceed the designed capacity of the room.

Investigate and Understand

"Investigate" refers to scientific methodology and implies systematic use of the following inquiry skills:

- observing;
- classifying and sequencing;
- communicating;
- measuring;
- predicting;
- hypothesizing;
- inferring;
- defining, controlling, and manipulating variables in experimentation;
- designing, constructing, and interpreting models; and
- interpreting, analyzing, and evaluating data.

"Understand" refers to various levels of knowledge application. These knowledge levels include the ability to:

- recall or recognize important information, key definitions, terminology, and facts;
- explain the information in one's own words, comprehend how the information is related to other key facts, and suggest additional interpretations of its meaning or importance;
- apply the facts and principles to new problems or situations, recognizing what information is required for a particular situation, using the information to explain new phenomena, and determining when there are exceptions;
- analyze the underlying details of important facts and principles, recognizing the key relations and patterns that are not always readily visible;
- arrange and combine important facts, principles, and other information to produce a new idea, plan, procedure, or product; and
- make judgments about information in terms of its accuracy, precision, consistency, or effectiveness.

Appendix E *(continued)*

Understanding Science Words

Through the centuries, as people learned more and more about all the sciences, including the life sciences, they had to create words to express their new discoveries. Often these "word-makers" put together two or three older words from Greek and Latin to make names for new knowledge, new inventions, new medicines, and new science concepts. Some of the same root words, prefixes, and suffixes have been used over and over again.

If you know the Greek and Latin roots, you will be able to interpret words that you see for the first time. The root words, prefixes, and suffixes listed here are often used in science. Many of them may already be familiar to you.

Root	Meaning	Examples
a-, an-	*not, without*	anaerobic: without oxygen abiotic: not living
aero-	*air*	aerobic: with oxygen aerospace: atmosphere and space beyond
ant-, anti	*against, opposed*	antibody: a molecule that fights against a foreign substance in body
aqua	*water*	aquarium: a tank where water animals and plants live aquatics: sports performed in water
arthr-, arthro	*joint*	arthropod: invertebrate with jointed limbs
audi	*hear*	auditory nerve: nerve conducting messages from ear to brain, allowing a person to hear auditorium: large room where audience hears lectures, plays, concerts
bi	*two*	bivalve: having two valves bisect: cut in two
bio-	*life*	biology: study of life
carbo-	*carbon*	carbohydrate: substance made of carbon and water
carni	*meat, flesh*	carnivore: meat eater
cardi-, cardio	*heart*	cardiology: study of the heart cardiogram: record of heart action
cerebro-	*brain*	cerebrum: largest part of human brain cerebral: involving the brain
-cide	*kill*	insecticide: substance that kills insects
circu-	*circle, ring*	circulate: to go around continuously
corpus	*body*	corpse: body, usually dead
cyto	*cell*	cytoplasm: the "plasm" in a cell but outside the nucleus
den, dent	*tooth*	dentist: doctor who treats teeth denture: artificial teeth
derm	*skin*	dermatologist: doctor who treats skin dermatitis: disease of the skin
-ectomy	*surgical removal of organ*	tonsilectomy: removal of tonsils appendectomy: removal of appendix
epi-	*above, over*	epidermis: top layer of skin, over the dermis epicenter: surface of earth directly above an earthquake
erythro-	*red*	erythrocyte: red blood cell
gastro-	*stomach*	gastric juice: fluids produced in the stomach
-gram	*something written or drawn*	cardiogram: record of action of heart telegram: message sent by wire

Root	**Meaning**	**Examples**
hemo-	*blood*	hemoglobin: substance in red blood cells hemorrhage: heavy bleeding
herb-	*leafy plant*	herbivore: organism that eats plants
hydro-	*water*	hydrogen: combines with oxygen to produce water hydroelectrity: electric energy converted from running water
hyper-	*excessive*	hypertension: high blood pressure hyperactive: excessively active
-itis	*inflammation*	arthritis: inflammation of joints appendicitis: disease of appendix
-logy	*study of*	cardiology: study of the heart biology: study of living things
macro-	*very large*	macrocosm: a large system, universe
-meter	*a measure, tool for measuring*	millimeter: one-thousandth of a meter thermometer: tool for measuring heat
micro-	*very small*	microcosm: very small system
mort-	*death*	mortality: death, death rate mortal: subject to death
neuro-	*nerve*	neuron: nerve cell nervous: high strung, jittery
omni	*all*	omnivore: animal that eats all foods, from both plants and animals
ova	*egg*	ovary: female gland that produces eggs oval: egg shaped
ped	*foot*	pedestrian: person who is walking pedometer: device for measuring distance walked
pesti	*pest*	pesticide: chemical used to kill pests
photo	*light*	photosynthesis: process in which green plants use the energy from light to make carbohydrates from carbon dioxide and water
pneum-	*breath, air*	pneumonia: inflammation of lungs that affects breathing
post-	*after*	postnatal: occurring after birth postmortem: occurring after death
pre-	*before*	prenatal: occurring before birth predict: to state what may happen before it happens
pulmo	*lung*	pulmonary artery: artery from heart to lung pulmonary vein: vein from lung to heart
-scope	*device for viewing*	telescope: device for viewing distant objects
-sect	*cut, divide*	dissect: cut apart section: a part of a larger whole
syn	*together*	synthesis: coming together of parts to form a whole photosynthesis: process in which green plants use the energy from light to make carbohydrates from carbon dioxide and water
terra	*land*	terrarium: small enclosure with soil where plants are grown and small land animals may live terrestrial: living on land
therm	*heat*	thermometer: device for measuring heat thermos bottle: container to keep liquids warm
-vore	*devour*	herbivore: animal that eats plants voracious: exceedingly hungry
zoo	*animal*	zoology: study of animals zoo: public park where animals are shown

(From Thurgood Marshall Middle School, see website in Appendix A)

Appendix E *(continued)*

Electricity and Magnetism

A Science Museum of Virginia Activity
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Introducing Electricity and Magnetism

A Mysterious Force

The ancient Greeks discovered that certain stones found near the city of Magnesia in Asia Minor attracted bits of iron. These lodestones (naturally occurring magnets) fascinated early natural philosophers. Although they were unable to explain how a magnet worked, several properties were well known. They knew, for example, that a magnet has polarity (a north-seeking end and a south-seeking end). They knew that lodestones would attract iron filings, and that magnetic poles that are alike repel each other while unlike poles attract each other.

Magnetism

Magnetic effects occur in metals as a result of the arrangement of the electrons associated with the atoms. Atoms contain from one to more than a hundred electrons. Each electron is constantly moving as it orbits the atomic nucleus and as it spins on its axis. These motions of electric charge are, in effect, small currents. Each produces a magnetic field. In most materials, the electron spins and orbits are oriented so that the magnetic fields associated with them cancel each other, and each atom is left with no net magnetic field. However, a few materials, such as iron, nickel and cobalt, have atoms that end up with a small net magnetic field. In these materials, groups of atoms align themselves in each other's fields, forming magnetic domains. Once these domains are aligned, they produce the magnetic effects observed in magnets.

A magnet can actually be produced from a piece of iron simply by attaching the iron to a permanent magnet or even by rubbing it with a magnet. The magnetic field of the permanent magnet aligns the domains in the piece of iron.

Another Mysterious Force?

The Greek philosopher Thales of Miletus (640-546 B.C.) is credited with first reporting the attraction that results when amber is rubbed against fur. For a long time, this curious effect was associated only with amber, but over time other substances were found to behave in a similar manner. Glass, for example, seemed to have a related but opposite property. Gradually, people realized that there were two kinds of electricity. The rubbed-glass kind was called "vitreous" and the rubbed-amber kind was called "resinous."

Little more was discovered about the mysterious attraction until Sir William Gilbert (1540-1603) conducted a series of electrical experiments and published the results in his book *De Magnete* around the turn of the seventeenth century. His work reawakened the interest of other natural philosophers in this mysterious phenomenon.

In the two hundred years following Gilbert's contributions, great advances were made in understanding electricity. Scientific investigators built devices that could collect static charge, which greatly facilitated experimentation. In 1733, the French engineer Charles Coulomb (1736-1806) devised a method to measure charge and then succeeded in describing the force between the opposing charges in elegant mathematical terms. Once scientists were able to make precise measurements of the mysterious force, progress in harnessing it was swift. In 1800, Allesandro Volta (1745-1827) developed the "voltaic pile," the first charge-storing device capable of supplying a consistent current. In 1819, the Dane Hans Christian Oersted (1777-1851) discovered that a magnetic field is created by an electric current, proving that electricity and magnetism are related. In 1821, Michael Faraday, (1791-1867) an English chemist and physicist, found that a changing magnetic field can produce a current in a nearby conductor. This discovery enabled him to invent the first electric generator and motor.

With the mutual relationships of magnetism and electricity established, the masterful work of James Clerk Maxwell (1831-1879) showed the precise nature of the interactions and

Appendix E - Science Resources *(continued)*

Electricity and Magnetism

the relative strength of the two forces. The essence of his work is contained in the mathematical expressions known as "Maxwell's Equations," which became the cornerstone of the field of electromagnetism. Maxwell's work in this area is often compared to that of Newton in the area of mechanics. Maxwell's Equations are accurate even when applied in the new context of Einstein's Theory of Special Relativity. Indeed, Maxwell–along with Lorenz and Fitzgerald–laid the groundwork for Einstein's relativity theories decades later.

Electricity

Electricity is one of the most common and fundamental components of nature, but is often one of the least understood. Electricity holds the molecules of our bodies together, makes all living and non-living chemical processes possible, and is a basic part of all radiation from radio waves to cosmic rays. Since the mid-1900s, it has also been a primary means of transferring energy from one place to another.

There are two types of electrical charges, positive and negative. All objects contain electrical charges. When the number of positive and negative charges are nearly equal, the object is described as neutral. Some materials (conductors) allow their charges to move about more freely, while others (insulators) hold their charges tightly. Both conductors and insulators can become charged, but charges move in and out of conductors much more easily than they move in and out of insulators.

Electric charges exert forces on one another. Unlike charges attract each other, while like charges repel each other. The effects of these forces may be observed and measured.

Current Electricity

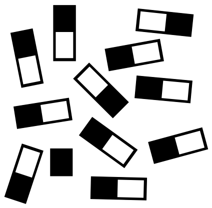
Charges must move or flow to make it possible for electricity to do work. This flow of charge is called an "electric current." When an electric current moves through a conductor, a magnetic field is produced around the conductor. Also, when a conductor, such as a wire, moves through a magnetic field, charges flow in the conductor. These principles allow scientists and inventors to design motors and electric generators that use magnets, conductors and electric current.

Static Electricity

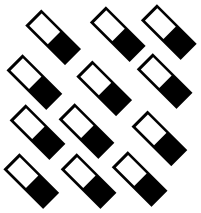
Static electricity is electrical charge which is not moving. When 2 objects rub against each other, electrons can be transferred from one object to the other. When this happens, the object that gains the electrons becomes slightly more negatively charged and the object that receives the electrons becomes slightly more positive. As long as they are far enough apart that the charge can not move from one object to the other, they remain charged with static electricity. Since they have opposite charges, the objects are attracted to each other. Once they come close enough together, the charge moves from the more negative object to the more positive object. The ionized air that results provides a path for the transfer of charge to the small sphere. As the electrons move, the light and heat energy given off creates a spark.

What is a magnet?

A magnet is a piece of metal or stone in which the tiny magnetic domains line up to form a larger magnetic field.



Whenthe domains are in random order, the material remains non-magnetic.



When the domains line up with all their north poles pointing in the same direction, a magnet is formed.

Each magnet has both a north pole and a south pole. These poles are the strongest points in the magnet's field. When one magnet is near another magnet, a force exists between the magnets. When the north pole is near another magnet's south pole, the force is attractive. If like poles are near each other (north/north or south/south), the force between the poles is repulsive.

The force between two magnets can be felt even when

Appendix E - Science Resources *(continued)*

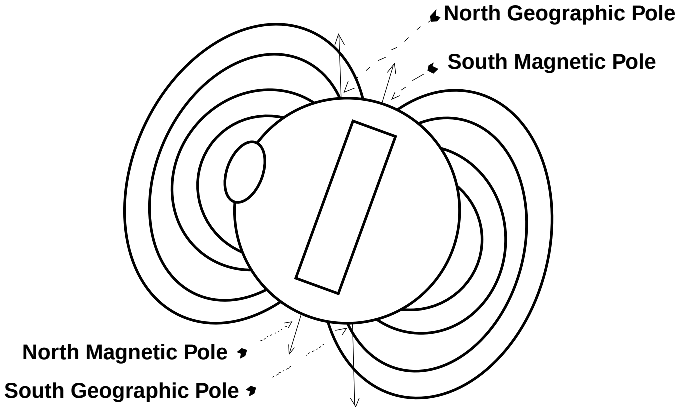
Electricity and Magnetism

substances such as paper, air or glass are positioned between the magnets. A magnet also exerts a force on other magnetic materials, such as lodestone, cobalt and iron. The magnet induces an alignment of the magnetic domains in these materials that temporarily gives them the properties of a magnet.

A compass needle points north because the Earth is a magnet; its North geographic pole is a magnetic South pole. The Earth's magnetic axis is not quite parallel to its geographic axis (the axis of rotation), so a compass reading deviates somewhat from geographic north; this deviation, which varies with location, is called "magnetic declination." *

A Sketch of the Earth's Magnetic Field

A compass placed at any point in this field would point in the direction of the field line at that point. Representing the Earth's field as that of a tilted bar magnet is only a crude approximation of the actual, fairly complex, field of configuration.



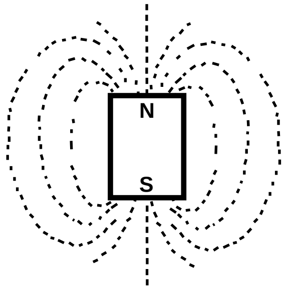
Currents and Magnets:

Can Electrical Current Create a Magnet?

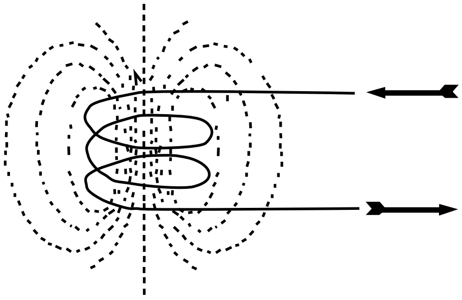
Any moving charge has a magnetic field associated with it. This connection between electricity and magnetism can be utilized to make a magnet from moving charges or current.

What's the connection?

Charges have the ability to move through a conductor. This movement of charge is called "current." In this exhibit, the wire acts as the conductor. As the current moves through the wire, a magnetic field is produced around every point of the wire. When the wire is shaped into a coil, the fields around the individual windings combine. This makes a magnetic field that looks like the magnetic field around a permanent bar magnet.



Bar Magnet



Electromagnet

The study of electricity cannot be separated from the study of magnetism. Whenever electrons are in motion, a magnetic field exists. Both electricity and magnetism have been studied by scientists for hundreds of years.

**University Physics: Seventh Edition.* Francis W. Sears, Mark W. Zemansky and Hugh D. Young. pp. 684. Addison-Wesley Pub. Co. 1987.

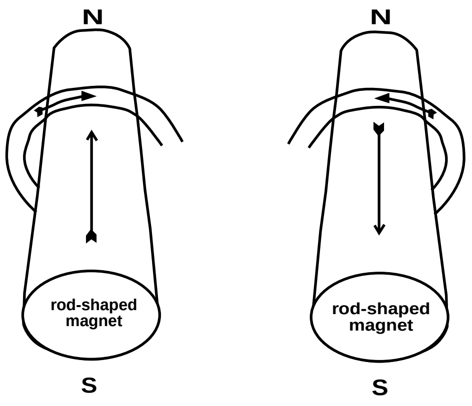
Appendix E - Science Resources *(continued)*

Electricity and Magnetism

Magnets and Currents:

Can a Magnet Create an Electrical Current?

When a rod-shaped magnet is moved in and out of a coil of wire, the changing magnetic field that this creates causes electrons in the wire to move. Mechanical energy (the back and forth motion of the rod) is converted into electrical energy in the form of current. The electrical field produced by the action of the magnet is always at right angles to the changing magnetic field. So, as the magnetic rod moves forward, the electric current flows in one direction. As the rod reverses direction, the current flows in the opposite direction. (See the diagram below.)



A current that periodically reverses direction is known as "alternating current." The electrical energy available in most homes is alternating current.

Simple Motor: Electricity in Motion

Electric motors are found in all kinds of machinery and consumer goods, from computers and refrigerators to CD players and electric drills. Electricity is used to power these devices primarily because it is a convenient and economical method of moving energy from one place to another. Surprisingly, electrical energy in itself is rarely the desired end product. Electrical energy must usually be converted into another form of energy, such as motion. Electric motors convert electrical energy into kinetic energy. The key to this conversion is the connection between electricity and magnetism.

In this simple motor, the magnetic field close to the magnet is strong. The rotating coil is made up of many turns of wire. Each turn of wire that carries current produces a magnetic field and each additional field intensifies the overall magnetic field around the coil. With this increased magnetic field, the force pushing the coil away from the permanent magnet is much greater.
In an actual motor, this increased force allows a lot more work to be done.

Glossary

AC (alternating current) – an electric current in which electrons move back and forth in a regular repeating cycle.

atom – a unit of matter, the smallest unit of an element consisting of a positively-charged nucleus surrounded by a system of electrons.

battery – two or more connected cells that produce a direct current by converting chemical energy into electrical energy. (See definition of "cell.")

capacitor – a device used for storing electric charge.

cell – a single unit for the conversion of chemical energy into electrical energy, usually consisting of a container with electrodes and an electrolyte.

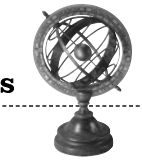
charge – the ability to push or pull possessed by the protons and electrons in atoms.

coil – a wound spiral of two or more turns of insulated wire.

compass – any of various instruments used to show direction. -especially one consisting of a magnetic needle swinging freely on a pivot and pointing to the magnetic north.

conduction (transferred charge) – movement of electric charge through the direct contact of two materials without perceptible motion of the materials.

conductor – a substance through which heat or electricity can flow readily.



Appendix E - Science Resources *(continued)*

Electricity and Magnetism

current – the flow or rate of flow of electric charge in a conductor or medium between two points, usually measured in units of amperes.

DC (direct current) – an electric current in which electrons move in only one direction.

domain – a group of atoms that align themselves in each other's fields.

earth ground – a conductor that is attached to the earth which can freely accept or give up electrons.

electric generator – a device that converts kinetic energy into electrical current. Moving parts of the generator cause changes in a magnetic field that induce an electric current in a conductor.

electric motor – a device that converts electrical energy into kinetic energy, using the flow of current to generate a magnetic field that attracts or repulses the motor's moving parts.

electrode – a solid electric conductor through which an electric current enters or leaves an electrolytic cell or other medium.

electrolyte – a chemical compound that ionizes when dissolved or molten to produce an electrically conductive medium.

electron – the relatively small, easily moved particle in an atom that carries a charge that is called "negative."

electromagnet – a soft iron core surrounded by a coil of wire that temporarily becomes a magnet when an electric current flows through the wire.

electrophorus – an apparatus for generating static electricity.

energy – the capacity for doing work and overcoming resistance.

ground – a reference point like the zero mark on a ruler. Its voltage is zero. All other voltage is measured against this point, providing a common reference point for everyone. (Earth ground may be established by driving a long metal rod into the earth.)

induction – the separation of charge of an isolated conducting object by bringing a charged body near it. –also, charging by the proximity of a charged body near a momentarily grounded, isolated conducting body.

insulator – a substance through which heat or electricity cannot flow readily.

ion – an atom that has become charged by gaining or losing one or more electrons.

joule – a unit of electrical energy equal to the work done when a current of one ampere is passed through a resistance of one ohm for one second.

kilowatt – a unit of power equal to 1,000 watts.

LED – light emitting diode. –a semiconductor diode that converts applied voltage to light and is used in digital displays.

lodestone or **magnetite** – a naturally occurring magnet.

magnet – any piece of iron, steel, nickel or magnetite (lodestone) that has the property of attracting iron or steel. This property may be naturally present or artificially induced.

magnetic field – a region of space in which a magnetic force acts.

mechanical or **kinetic energy** – energy generated by motion.

potential energy – the energy of a particle or system of particles derived from position, or condition, rather than motion. A raised weight, a coiled spring and a charged battery have potential energy.

power – the time-rate at which work is done or at which energy is transferred.
– energy per unit time.

proton – the relatively large, usually unmoving particle in an atom that carries a charge that is called "positive."

resistance – the opposition of a body or substance to the electricity moving through it, usually resulting in the dissipation of energy in the form of heat.

semiconductor – a substance which has greater electrical conductivity than an insulator, but less than a good conductor.

static charge – a charge that is fixed or stationary.

transformer – a device used to transfer electric energy from one circuit to another, usually raising or lowering voltage as a result.

voltage – electrical potential energy.

Appendix E - Science Resources *(continued)*

Electricity and Magnetism

watt – a unit of power equal to one joule per second. A watt equals of a horsepower.

work – the transfer of energy from one physical system to another, especially the transfer of energy to a body by the application of a force that moves the body in the direction of the force. Work is calculated as the product of the force and the distance through which the body moves and may be expressed in joules, ergs and foot-pounds.

Electrical Measurements

coulomb – a unit of electric charge (first recorded use in 1881)

ampere – a unit of electric current (first recorded use in 1881)

volt – a unit of electric potential difference (first recorded use in 1873)

joule – a unit of electric energy (first recorded use in 1882)

ohm – a unit of electric resistance (first recorded use in 1870; proposed in 1861)

watt – a unit of electric power (first recorded use in 1882)

Reading List

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Appendix E - Science Resources *(continued)*

Electricity and Magnetism

From Archimedes to Einstein. Truan Reid and Patricia Fara. (Usborne Book of Scientists.) Usborne, EDC. 1993.

Safe and Simple Electrical Experiments. Rudolf F. Graf. Dover Publications Inc. 1964.

Other Resources

Delta Science Modules: *Electrical Circuits Kit* (gr. 3-5), *Electromagnetism Kit* (gr. 5-6) and *Electromagnetism Guide*. These modules contain all the materials needed to teach 4 weeks of creative hands-on electricity lessons to an entire class. Batteries and Guides included. Kits are available from Delta Education Hands on Science Catalog; P. O. Box 950; Hudson, NH 03051. Phone: 1-800-442-5444.

The American Heritage Dictionary of the English Language: Third Edition was especially helpful in defining scientific terms. The tables which appear under "measurement" are of particular interest.

The electrical supply in homes can be very dangerous because of the large supply of charged particles.

Never experiment with home electrical supplies or outlets.

Timeline of Great Discoveries about Electricity

600 B.C.	**Thales of Miletus** (640-546), Greek scientist and philosopher, discovers attractive power of charged amber.
1269 A.D.	**Petrus Peregrinus** discovers properties of magnetism and shows that like poles repel and unlike poles attract.
1492	**Christopher Columbus** shows that the declination of a compass needle varies for different parts of the world.
1600	**William Gilbert** describes the earth as having the properties of a huge magnet (explaining the behavior of the compass needle). Gilbert also introduced the word "electric."
1650	**Otto von Guericke**, German physicist, builds the first static machine.
1729	**Stephen Gray**, English electrical experimenter, develops the concept of conductors and non-conductors.
1733	**Charles Dufay** of Paris discovers that there are only two kinds of electricity and announces that like charges repel and unlike charges attract.
1747	**Benjamin Franklin** advances single fluid theory of electricity, originates "plus" and "minus" designations, and invents the lightning rod.
1785	**Charles Augustin de Coulomb**, French physicist, proves the law of inverse squares, and that the internal surface of a body cannot be charged with static electricity.
1800	**Allessandro Volta**, a physicist native to Lombardy, invents the voltaic pile, the first practical method of generating current.

Appendix E - Science Resources *(continued)*

Electricity and Magnetism

1819	**Hans Christian Oersted**, Danish physicist, discovers that a magnetic field is caused by electric current, proving that electricity and magnetism are related.
1820	**André Marie Ampère**, French physicist, shows the relationship between electricity and magnetism. Ampère also developed the solenoid.
1820	**Dominique François Jean Arago**, French physicist, discovers that a magnet can be made from an iron or steel bar placed inside a solenoid through which a current is flowing.
1821	**Michael Faraday**, English chemist and physicist, shows that the flow of current in a wire can cause a magnet to revolve around the wire, and that a current-carrying wire tends to revolve around a fixed magnet.
1827	**George Simon Ohm**, German physicist, discovers the mathematical relationship among current, voltage and resistance in an electric circuit.
1833	**Karl Friedrich Gauss**, German physicist and mathematician, develops an exact mathematical formula for the magnetic field.
1834	**Heinrich Friedrich Emil Lenz**, German-Russian physicist, establishes a method of determining the direction of an induced current in a circuit.
1840	**Samuel Morse**, American artist and inventor, invents the telegraph.
1859	**Gaston Plante**, French inventor, makes the first lead-acid storage cell for storing electrical energy.
1865	**James Clerk Maxwell**, Scottish physicist, explains mathematically the transmission of electric and magnetic fields through a medium.
1875	**Alexander Graham Bell**, American inventor, develops the electric telephone.
1879	**Thomas Edison**, American inventor, develops a dynamo, the incandescent lamp and many other electric devices.
1887	**Heinrich Rudolph Hertz**, German physicist, discovers the photoelectric effect. In 1888 Hertz also discovers that electricity may be transmitted by electromagnetic waves.
1888	**Nikola Tesla**, Serbian-born American engineer and inventor, discovers the principle of the rotating field on which the induction motor is based.
1895	**Guglielmo Marconi,** Italian inventor, begins experiments in wireless telegraphy.

Appendix E - Science Resources *(continued)*

Electricity and Magnetism

Balloon Attraction – A Static Electricity Game

Electricity is everywhere. All objects have electrical charges. The Earth, a desk, and even a human body carry electrical charges. Because charge cannot be seen, electrical effects often appear mysterious. This activity explores the effects of electricity and introduces some of the basic properties of electricity.

Purpose:

Students will observe the effect between two oppositely charged objects and the effect between two similarly charged objects.

Students will explore different materials and compare the amounts of charge generated between each material and the balloon.

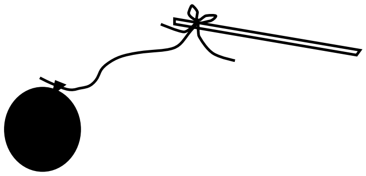
Materials:

Per person

- 1 inflated balloon
- 2 feet of string (silk or nylon thread works best)
- 1 stick or wooden dowel

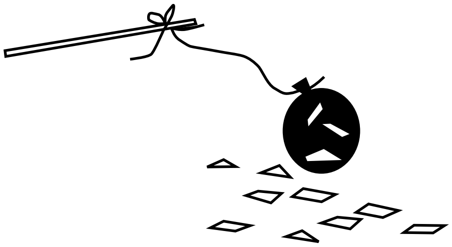
Per pair or group

- 40-50 small "fish" - (These can be cut-up pieces of paper, paper circles from a hole-punch or Styrofoam® packing peanuts.)
  (optional) - masking tape; pieces of wool; large, wide plastic tubs; or a plastic swimming pool



Procedure:

1. Tape or tie one end of the string onto the stick.
2. Tape or tie the other end of the string onto the balloon. Now you have your very own "electric" fishing pole.



Experiment A:

1. Put your fish into the fishing hole– the tub or pool. (You can use the floor or a table top as well.)
2. Holding your fishing pole over the fishing hole, try to pick up as many fish as you can on your balloon. How many fish did you catch? _____
3. Rub the balloon on your hair or a sweater. Try fishing again. How many fish did you catch? _____
4. Try several different rubbing procedures. (Try rubbing in one direction, both directions, try a different number of rubs or use different materials to rub the balloon, etc. Keep a record of what procedure was used as well as how many fish you caught each time.)

Experiment B:

1. Using two fishing poles, charge both balloons using the same method.
2. Hold the pole up so that the balloons are the same height and about two feet apart. (Make sure the balloons are held far away from your body.)

Appendix E - Science Resources *(continued)*

Electricity and Magnetism

3. Slowly move your poles together. What happens to the balloons?
4. Repeat experiment B and place one hand between the balloons. What happens to the balloons this time?

Extension:

1. Graph the number of fish caught using each procedure.
2. As a class categorize the methods into common groups and see which method appeared most successful throughout the class, chart your results.

For Your Information:

There are two kinds of electrical charges, negative and positive. We are not usually aware of the electricity in most objects because the numbers of positive and negative charges in them are nearly equal. However, if an object has more positive charges than negative charges, we say that the object is "positively charged." If an object has more negative charges than positive, we describe it as "negatively charged." An object has a neutral charge if there is a balance of positive and negative charges and there is no electrical current flowing through the object.

When the balloon is rubbed against a sweater or someone's hair, the balloon picks up electrons and becomes negatively charged. When the negatively charged balloon is brought near the neutrally charged fish, the electrons in the fish move away from the balloon. This leaves the part of the fish close to the balloon positively charged. The attraction between the negatively charged balloon and the positive charges in the fish causes the fish to "jump" to the surface of the balloon. When two objects are oppositely charged, they are attracted to one another.

When two objects are similarly charged, both with positive or both with negative charges, they will repel (or push away) from each other. When two negatively charged balloons are held close together, you can see the repulsion between the two.

Something to think about:

Lightning is a common electrical phenomenon that is produced by the attraction between unbalanced charges. Excessive negative charges in clouds cause the electrons in the ground below to move away from the surface of the Earth. This leaves the area of the ground near the surface with a positive charge. The negative charges in the clouds are attracted to this positive ground area and the result is the bright flash you see in the sky as the charges move.

Potato Power

Although most people think of electricity as something associated with batteries, wires and wall outlets, all living things – both plants and animals – produce weak electric currents. One of the first scientists to investigate electric currents in animals was the Italian physician Luigi Galvani (1737-1798). In the year 1750, he noticed that the muscle in a frog's leg would sometimes jerk convulsively when touched by a metal scalpel. Further experiments showed that the jerking took place when two different metals touched the frog's muscle at the same time. Galvani concluded from this experiment that there must be an "animal electricity" contained in the frog's body.

Another scientist of the time, Alessandro Volta (1745-1827), drew a different conclusion about the source of the electric charge. Volta believed that the jerking was caused by the electricity produced by the two different metals separated by the moist frog tissue. Some years later in 1800, Volta's experiments led to the invention of the "voltaic pile," or battery.

Purpose:

Students will make a simple battery using a potato and two different metal wires.

Students will understand that an electrical charge flows between two objects that have an unbalanced charge.

Materials:

Per student

1 6-inch length of non-insulated copper wire
1 paper clip
1 raw potato

Appendix E - Science Resources *(continued)*

Electricity and Magnetism

Procedure:

1. Insert one end of the copper wire into the potato.
2. Straighten out the paper clip and insert one end of it into the potato, close to the copper wire, but not touching it.
3. Touch the ends of the wire and the paper clip to your tongue.

Observations:

1. What did you feel?
2. Did you feel a faint tingling on your tongue, or experience a slightly acidic taste?

For Your Information:

These sensations are the result of an electric current that flows when your tongue completes the circuit between the copper wire and the paper clip.

When copper and aluminum are immersed in an ionic solution (the salty moisture in the potato), positive ions accumulate on one wire and negative ions on the other, creating a potential difference, or voltage. When the paper clip and the copper wire are connected with each other by a conducting solution, such as the moisture on your tongue, the charges move from one metal to the other through the potato, creating an electrical current. A device that works this way is called a battery.

Try these variations:

1. Try doing this experiment with a lemon, orange, tomato or grapefruit.

   Do you notice any difference in the intensity of feeling on your tongue?
2. What happens if you use two copper wires or two paper clips?

Something to Think About:
Was the voltaic pile the first battery?

In 1957, the German archaeologist Wilhelm König examined an object that dated from 250 to 244 B.C. (the era of the Parthian occupation of the Baghdad region). The object, about the size of a flashlight, seemed to be an electric battery. The only piece lacking was a conducting wire to connect the copper cylinder to the exterior, which could easily have become lost over the centuries. Scientists speculate that the ancient device might have been used in electroplating, the application of a thin coating of a metal to a different metal's surface.

Extension: Turn your potato green.

Slice a raw potato in half. Make two slits in the flat face of one potato half with a knife. Carefully clean two copper pennies and slide them halfway into the slits. Attach leads to both pennies. Attach one lead to the positive terminal of a battery and the other to the negative terminal. After 30 minutes to an hour, examine the potato. You will notice a greenish color around the penny connected to the positive terminal of the battery. The color comes from copper oxide, the same green coating that often builds up on copper statues in outdoor settings.

For Your Information:

The copper atoms on the penny attached to the positive terminal of the battery have given up electrons, resulting in a positive charge. (An atom that has a net electric charge is called an ion.) This change in charge causes a chemical change in the atoms. The positive copper ions are pushed away from the positive terminal and attracted by the negative terminal. You see this movement of copper ions as the green color that migrates from the penny into the potato.

Appendix E - Science Resources *(continued)*

Electric Circuits

A Science Museum of Virginia Activity
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In this activity, students investigate electric circuits. You can choose to do all or part of this series of activities.

(Time required: Three class periods of 50 minutes)

Purpose:

Students will determine what makes a complete electric circuit and construct both series and parallel circuits.

Materials:

Per Student
- Electric Circuit Activity Sheet

Per Group
- battery holder
- D-cell battery
- 4 6-inch pieces of insulated copper wire
- 2 battery clips
- 2 light bulb holders
- 2 light bulbs

You can buy batteries at any good discount store. The rest of the materials listed above can be purchased from Delta Education at 1-800-442-5444 between 8 a.m. and 10 p.m. EST.

Prerequisite Skills and Knowledge:

Students should understand the following terms before beginning this activity.

conductors – Metals and other substances that allow the flow of electric current.

electron – The relatively tiny subatomic particle found outside the nucleus of an atom that carries a negative charge.

insulator – Substances that tend to block the flow of electric current, such as glass, amber, silk and wood.

circuit – A path through which electric current travels. A circuit requires a continuous, unbroken path on a conducting material. This material is often copper wire, because, like many metals, copper lets electric current flow through it very easily.

current – Moving electric charge.

power source – The driving force that pushes electric current around a circuit. Batteries are often used to provide this force.

resistance – The opposition of a substance to the current passing through it. Even good conductors, such as gold, silver, brass, aluminum and copper, offer some resistance to the movement of electrons.

Science Background:

Electricity is something everyone takes for granted, but which is often misunderstood. Many misconceptions are associated with this phenomenon, so check in with students often during this activity to make sure they understand what they are doing.

What is electricity? This is an excellent question. **Electricity**, a word familiar to everyone, can be defined as the movement of charged particles. However, the word can have so many different meanings that most scientists use the term “electric current” instead. The meaning of this term is more precise, which is essential in science communication. So, let’s begin again.

What is **electric current**? Electric current is the movement of charged particles. What must be available before charged particles can move? Charged particles must have a complete path available to them before current can flow. This path is called an **electric circuit**. Any device that uses electricity must be a part of this complete electric circuit before it can operate.

There are two basic types of electric circuits: series and parallel. In both types of circuits, a complete path beginning and ending with the power source (the battery in this activity) is necessary before current can flow and provide energy to the power users (the light bulbs in this activity). Any break in the

Appendix E - Science Resources *(continued)*

Electricity Circuits

path stops the movement of charges. The most common break in a circuit is an intentional one — the switch. When the switch is closed ("ON"), the path is complete and the power user (light bulb) works. When the switch is open ("OFF"), the path is broken and the power user (light bulb) won't work.

Getting Started:

Ask students to think about why a plug on an electrical device has two prongs. (Of course, some plugs have three prongs, but all plugs have at least two.) Accept all answers and if the students don't seem to know, tell them they should be able to answer this question before this activity is over!

(A circuit must provide a complete, unbroken path before charges can move from the power source through the power user and back to the power source. The two prongs provide a way for the current to come into the appliance that uses the electricity and also to return to the power source. A close look at most cords also reveals a doubled wire, for the same reason.)

Tips and Pointers:

- Have students work in groups of two, handing out only those materials needed for each step. Circulate around the room and give helpful hints or leading questions as needed.
- Check the batteries and bulbs before this activity to make sure that they are all working.

The Simple Circuit: Exercise 1

Review conductors and insulators with students before proceeding with this activity. Give each group a battery, one piece of wire, and one light bulb. Then go over the following questions, which are asked on the Electric Circuits Student Activity Sheet.

1. **Examine the wires you have been given. What kind of wire do you think you are using for this activity?**
   (It's a metal wire, often copper, which is an excellent conductor.)

   Is this material a conductor or a non-conductor?
   (It's a conductor.)

   Why is this important?
   (A circuit must be made of a conductor because conductors allow the movement of charge.)

   What kind of covering does the wire have?
   (It has a plastic coating.)

   Is this material a conductor or an insulator?
   (It's an insulator.)

   Why is it important for the wire to have a covering like this?
   (An insulating covering will keep the charge from making an accidental connection with another conductor, which could keep the electric circuit from working properly.)

2. **Examine your light bulb carefully. How is it constructed?**

   Draw a detailed picture of your light bulb. Label the insulators and conductors that make up the bulb. Be sure to notice the filaments inside the bulb.

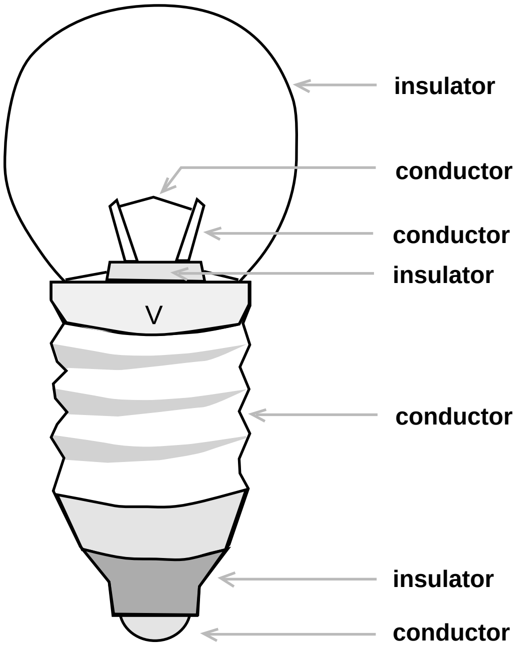
   (Compare the picture below to the drawings the students make. Did they notice most of the essential parts of the bulb? If lots of them missed important observations, you might have them compare drawings and then add to what they drew.

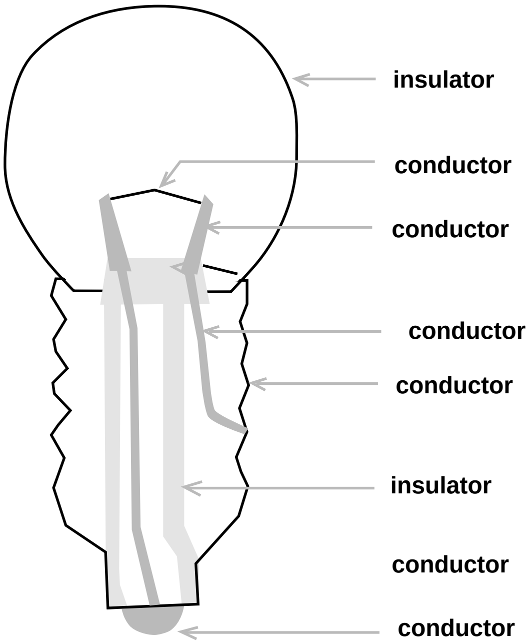
   Note the cut-away picture as well. A larger version of this is provided at the end of this activity. Use it to show the

Appendix E - Science Resources *(continued)*

Electricity Circuits

students what's happening underneath the metal covering at the base of the bulb. You can show it to them at this point in the activity, or you can ask the students to figure out what it must look like as an assessment exercise at the end of the lesson.)

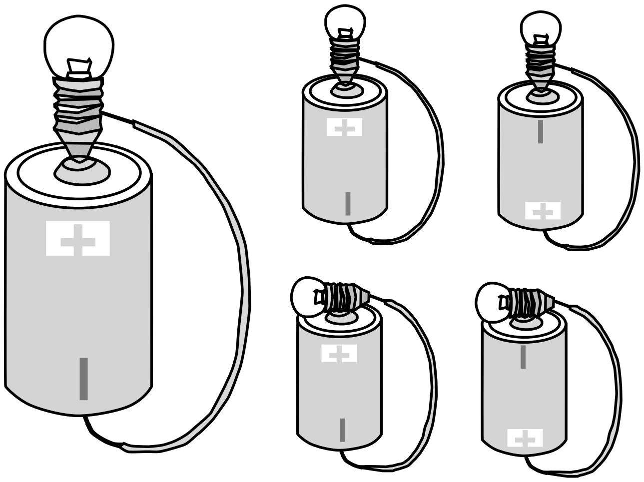




Once you have gone over these questions and the students have carefully examined the light bulb, give them the following challenge:

Can you produce a light with just a battery, a bulb and a wire?

(They should eventually come up with some version of a simple, or basic, circuit such as the one pictured on the left below. Other arrangements are possible and are pictured below on the right side of the page.)



Simple Circuit

(light bulb, battery and wire)

Have the students "draw" a picture of the arrangement of these components on their activity sheets.

How does it work? Electric current flows from the battery through the wire, up into the bottom of the light bulb, though the filament, back out though the side of the bulb and back to the battery. The circuit is complete and the bulb lights up.

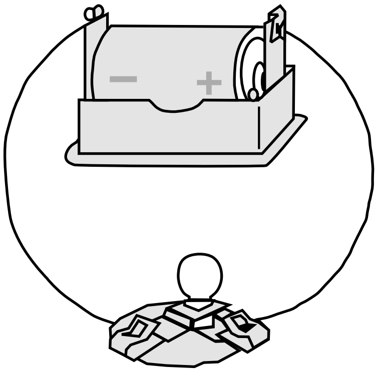
Give the students a bulb holder, a second piece of wire, a battery holder, and two battery clips. Challenge them to arrange these components so that the light bulb stays on. This simple circuit, which should look like the one pictured on the next page, has the same basic components as the one with just the wire, bulb and battery. The battery holder, clips and bulb

Appendix E - Science Resources *(continued)*

Electricity Circuits

holder have been added to make the circuits easier to manipulate. You may need to show the student how to use the battery clips and the bulb holders.

The battery clips flop over like bunny rabbit ears when they're properly positioned in the holders. Also, make sure the students notice how the bulb holder clips are connected to the bulb.

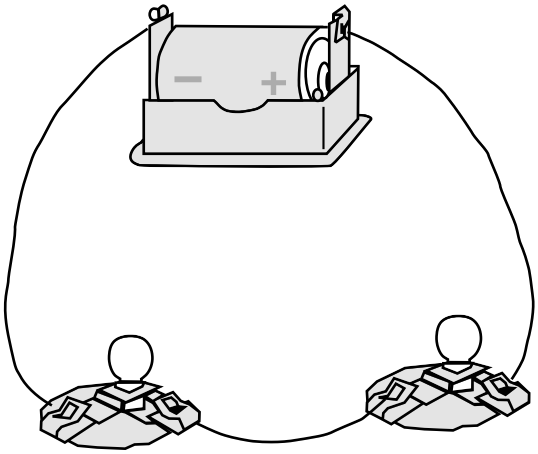


Simple Circuit

(light bulb, light bulb holder, battery, battery holder, 2 battery clips and 2 wires)

The Series Circuit: Exercise 2

Now give the students a second light bulb, a second bulb holder, and a third piece of wire and challenge them to light both light bulbs. Tell them that they should have only two wires coming from the battery. (This prevents them from making a parallel circuit at this step.) Once they have completed this task, ask them to draw a diagram of this circuit on their activity sheets. It should resemble the illustration below.



Series Circuit

Once they have finished, ask the following questions, which are listed on their activity sheets.

Once all of the bulbs are lit, write down a prediction — or hypothesis — about what will happen if one of the light bulbs is unscrewed from its holder.

(They may realize that the circuit will be broken and the bulbs won't work at this point, but if they don't, they will discover this to be the case when they test the hypothesis.)

Test your hypothesis. What happened?
(Both bulbs go out.)

Appendix E - Science Resources *(continued)*

Electricity Circuits

Why did this happen?
(The circuit was broken.)

What's going on?

In a series circuit, all the components of the circuit are connected one after the other in the same path. In other words, the path between the battery and light bulbs is one big circle connected by wires. It's possible to add additional components to the circuit, such as extra batteries, switches or bulbs, but any break in the circuit in any of these components causes the current to stop flowing. This is the disadvantage of series circuits.

A burnt-out light bulb is an example of a break in a circuit. If other light bulbs are in a series circuit with a burnt-out bulb, they won't light either because the movement of charges is stopped. Christmas lights are a good example of a series circuit — although newer strands may have an alternate path for electricity to flow through if a bulb burns out.

At this point, ask students to describe the way in which the components are arranged. It may helpful for the students to look at their previous diagrams. Try to get them to use the words "circle," "circular" or "circuit."

The word "circuit" comes from the Latin word *circuitus*, which means "to go around." Ask them to think of some other situations that are described by the word "circuit." (You might discuss circuit riders, lecture circuits and the downhill ski circuit. What do all these words have in common?)

If time permits, allow students some unstructured time to play with their electric circuits.

The Parallel Circuit: Exercise 3

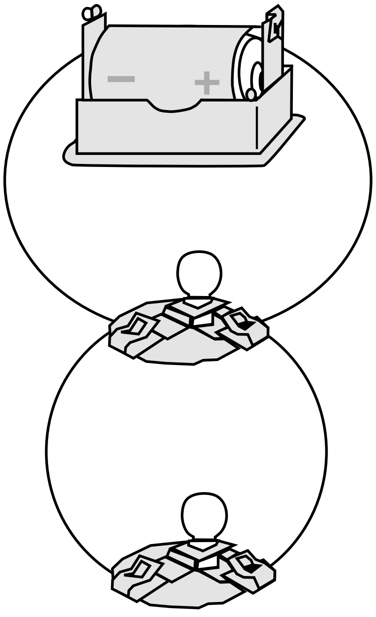
Give the students a fourth wire for this activity.

Now that students have recognized that a circuit must have a complete path in order to work, challenge students to create an electric circuit that has two light bulbs and one battery in which each light bulb works independently of the other.

This challenge may take a bit of thinking on the students' part. To make sure it is challenging, tell students they may have only one wire coming from the battery and one wire leading to the battery — all the light bulbs must come between those two wires.

Circulate around the classroom and ask the students to test their circuits for you to make sure each light bulb works independently of the other one.

Once this is accomplished, discuss and diagram an example of a parallel circuit for the class to compare to previous circuits. The diagrams should resemble the wiring pictured below.



Parallel Circuit

Appendix E - Science Resources *(continued)*

Electricity Circuits

What's going on?

A parallel circuit has several paths that current may travel through. Each individual path finds its way back to the battery. The advantage of a parallel circuit can be seen by considering the previous example of a burnt-out light bulb. If each light bulb is on its own path, even if one light bulb burns out, the other light bulbs will still have a complete path through which charges can flow. Homes are wired using parallel circuits.

Once the students have finished this task, go over the following questions that are asked on their activity sheets.

What makes this circuit different from the first one you built?
(If one light bulb is burnt out, the other one can still work.)

The circuit you built in Exercise 2 is called a series circuit. Using what you have learned, write a definition for a series circuit.
[A series circuit is one in which the current must pass through all the items in the circuit. Any break will make all the power users (bulbs) go out.]

The circuit you have just built in Exercise 3 is called a parallel circuit. Using what you have learned, write a definition for a parallel circuit.
[A parallel circuit is one in which there is more than one path for the current to take in the circuit. If one path (or loop) has a break in it, the other paths (or loops) can still provide a complete path for the current. Even if a single power user (bulb) wired in parallel ceases to work, the other power users (bulbs) still work.]

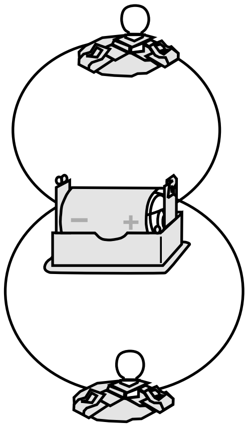
You might end the lesson by discussing the terms series and parallel. Why are these terms appropriate names for the types of circuits they describe?

If time permits, challenge students to see how additional batteries in series and in parallel affect the light bulbs in the circuit. Groups of students may combine their materials and work together in this part of the activity.

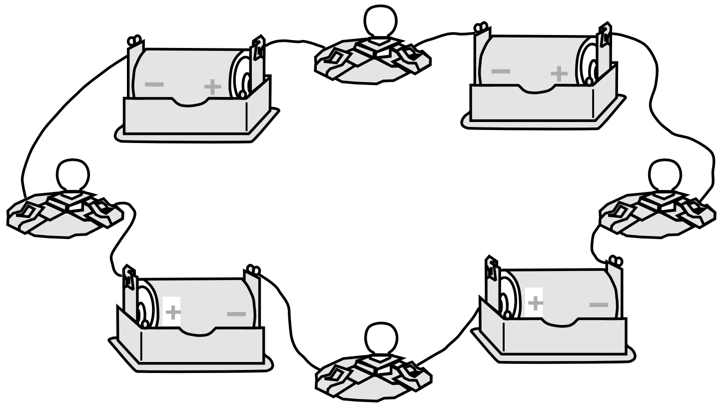
Here are a couple of pitfalls that might come up:

1. This diagram pictured here is a parallel circuit. It might, at first glance, seem to be two simple circuits that share a power source, but it's not! Since the current leaving the positive end of the battery can flow to either bulb, the circuit is really identical to the parallel circuit shown on Page 8.

   This parallel circuit uses more energy than a series circuit with the same number of bulbs — since the current here can flow more freely. Thus, a battery burning two bulbs in a parallel circuit burns out faster than one burning two bulbs in series.



2. Also note that when the students use more than one battery in a circuit, the positive and negative ends of the batteries must be properly aligned as shown in the series circuit pictured below.



Appendix E - Science Resources *(continued)*

Electricity Circuits

Integration Ideas:

Language Arts – Write a funny story about being transferred back in time 100 years and the problems this would create for a modern student.

Mathematics – Have students analyze an electric bill. Block certain parts of the statement and have students calculate total watt/hours used, cost per watt/hour, etc.

Social Studies – Investigate the effect on society of the development of electricity.

Extension:

With the students working in groups, ask them to compare the brightness of two bulbs in a parallel circuit to the two bulbs in a series circuit. The bulbs in the parallel circuit should be brighter. (See the explanation on Page 10.)

Assessment:

- Assess Student Activity Sheets.
- Ask students what type of circuit (series or parallel) they have in their homes and what the advantage of this type of circuit would be.

Appendix E - Science Resources *(continued)*

Electricity Circuits

Electric Circuits – Student Activity Sheet

The Simple Circuit: Exercise 1

Materials:

- 1 battery
- 1 light bulb
- 1 piece of wire

Examine the wires you have been given. What kind of wire do you think you are using for this activity?

Is this material a conductor or a non-conductor?

Why is this important?

What kind of covering does the wire have?

Is this material a conductor or an insulator?

Why is it important for the wire to have a covering like this?

Appendix E - Science Resources *(continued)*

Electricity Circuits

Examine your light bulb carefully. How is it constructed?

Draw a detailed picture of your light bulb. Label the insulators and conductors that make up the bulb. Notice the filaments inside the bulb.

Light Bulb

Using one wire, one battery and a light bulb, make the light bulb light up. Draw a picture of your circuit. Draw arrows, showing the path the current is taking in the circuit.

Simple Circuit

Appendix E - Science Resources *(continued)*

Electricity Circuits

Hint: If your bulb does not light up, there are several possibilities for what went wrong. Double-check the following:

- Is the battery good?
- Is the bulb good?
- Is your circuit complete?
- Do you have any places in the circuit where bare wires (or other conductors) cross or touch? (Two wires that overlap in the middle of the circuit change the pathway and current will not flow through the whole circuit. This is called a "short circuit" and often causes the circuit to become overheated or overloaded.)

Additional Materials:

- 1 wire
- 2 battery clips
- 1 battery holder
- I light bulb holder

Now, using two wires, one battery, two battery clips, one battery holder, one light bulb holder and a light bulb, make your light bulb light.

The Series Circuit: Exercise 2

Materials:

- 3 wires
- 1 battery
- 2 battery clips
- 1 battery holder
- 2 light bulb holders
- 2 light bulbs

Using three wires, one battery, two battery clips, one battery holder, two light bulb holders and two light bulbs, make your light bulbs light.

You may have only one wire coming from each end of the battery.

Appendix E - Science Resources *(continued)*

Electricity Circuits

Draw a picture of your circuit. Draw arrows showing the path the current takes in the circuit.

Simple Circuit

Once all of the bulbs are lit, write down a prediction — or hypothesis — about what will happen if one of the light bulbs is unscrewed from its holder.

Test your hypothesis. What happened?

Why did this happen?

Appendix E - Science Resources *(continued)*

Electricity Circuits

The Parallel Circuit: Exercise 3

Materials:

- 4 wires
- 1 battery
- 2 battery clips
- 2 battery holder
- 2 light bulb holders
- 2 light bulbs

Using four wires, one battery, two battery clips, one battery holder, two light bulb holders and two light bulbs, make your light bulb light.

You may have only one wire coming from each end of the battery. Wire the circuit so that you can unscrew one of the bulbs without the other going out.

Draw a picture of your circuit. Draw arrows showing the path the current takes in the circuit.

Parallel Circuit

Appendix E - Science Resources *(continued)*

Electricity Circuits

What makes this circuit different from the first one you built?

The circuit you built in Exercise 2 is called a **series circuit**. Using what you have learned, write a definition for a series circuit.

The circuit you have just completed in Exercise 3 is called a **parallel circuit**. Using what you have learned, write a definition for a parallel circuit.

Diagram of the Inside of a Light Bulb

Appendix E – Science Resources

Oobleck?

A Science Museum of Virginia Activity

This workshop introduces science processes using an investigation of the physical properties of a mysterious–and fun–gooey substance. This activity also gives you the opportunity to use science to help assess and build vocabulary. The use of the Dr. Seuss book can be a fun wrap-up for the activity, but it is an optional part of the activity.

(Time required: 45 minutes)

Purpose:

Students will observe physical properties, interpret and evaluate data, and make conclusions based on that data.

Materials:

- 3 16-oz. boxes of cornstarch
- green food coloring
- lots of old newspaper
- writing paper
- 4 small plastic bowls
- 1 large mixing bowl
- water
- paper towels
- pencils

- Optional: "Bartholomew and the Oobleck" by Dr. Seuss

Procedure:

1. Make these preparations in advance.
    A. Mix the Oobleck at least an hour before the class to allow time for adjusting the mixture. Prepare the Oobleck by adding 4 drops of green food coloring to 2 cups of water in a large mixing bowl. Then stir in 2 boxes of cornstarch. This makes enough Oobleck for 4 groups of about 8 students.
    (No, don't add that third box of cornstarch! It's for later. See "C" below.)

    B. Cover the work surface with newspaper. Provide paper towels, writing paper and a pencil for each student. You may also want to cover the floor with newspaper.

    C. Just before you start the activity, check the consistency of the Oobleck. Oobleck should flow when you tip the bowl and feel hard when you push on it. If it is too soupy, add more cornstarch. If it is too thick, add more water.

    D. Pour the Oobleck into 4 smaller bowls. Do not allow the students to "play" with the Oobleck until you have explained the activity.

2. Begin the activity.

    A. Explain that the students must conduct tests on it to determine the physical properties of an unknown substance. Assure them that this substance is safe to handle and examine. **Emphasize that it is never safe to taste or eat unknown substances!**

    B. Since the student's task is to investigate the properties of this substance, spend a few minutes discussing what physical properties are and how they are determined.

        1. A physical property is something that can be seen, heard, smelled, felt by the senses, or detected by instruments that enhance our senses (microscopes, telescopes, etc.).

        2. An experiment should include a repeatable sequence of steps that yield the same results each time. Observations need to be recorded clearly and accurately. Conclusions must be supported by observations.

    C. Ask the students to list the 5 senses and write each on the board or overhead. Leave blank space below each word for the words generated by observation.

Appendix E - Science Resources *(continued)*

Ooobleck?

Observations:

Divide the students into groups of 2 to 4 participants. Allow the groups to explore the properties of Oobleck for about 15 minutes. Encourage them to handle the Oobleck. Have them write down their observations. Encourage them to use a variety of words to describe each property.

List the properties the students observe and pick those which seem to describe the Oobleck best. Encourage discussion of the meaning of the words and why the word should be included. Stress that open discussion and the sharing of data is a vital part of science.

Conclusion:

Optional: Read the portion of "Bartholomew and the Oobleck" that describes Oobleck. Have the students decide if this substance is really Oobleck.

Discuss the differences between solids and liquids.
How does the workshop's Oobleck fit these descriptions?
(See the **For Your Information** section below.)

Clean Up!

Have the students help clean up by carefully rolling up the newspapers and throwing them away. A damp sponge will wipe up any remaining Oobleck. Do not mop up a large spill; use a sponge to absorb it. Once the Oobleck has dried, it can be vacuumed up. Do not pour Oobleck into the sink; it may clog the drain. Allow the Oobleck in the bowls to dry. Dry Oobleck can be thrown in the garbage.

For Your Information:

As you discuss the behavior of Oobleck and similar substances, the following definitions may be helpful.

fluid: A material which takes the shape of its container.

viscosity: The resistance of a fluid to flow. A material with a high viscosity does not flow easily. (Molasses is a good example.) A material with a low viscosity flows easily. (Water is a good example.)

Newtonian fluid: A fluid that becomes more viscous when cooled. (Cooking oil is a good example.)

non-Newtonian fluid: a fluid in which the viscosity is increased when the liquid is stirred or compressed. (Oobleck is a good example.)

The behavior of non-Newtonian fluids seems to be controlled by the interactions between molecules. Since it is difficult to determine what is happening at the molecular level, there are several theories that attempt to explain this behavior.

> One theory compares Oobleck to a mixture of sand and water in a squeezable plastic bottle. The grains of sand are packed closely together and water fills some of the spaces between them. When the bottle is squeezed slowly, the grains of sand slide against each other and the spacing between some of the grains increases. This allows more water into these spaces and provides lubrication, so that the grains can slide and flow past each other. When the bottle is squeezed quickly, there is not enough time for the water to enter the spaces and the friction between the grains resists the flow.
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> A second theory is based on the chemical structure of Oobleck. Cornstarch is made up of long chains of molecules called "polymers." It is suggested that when the mixture is compressed, these chains are stretched at right angles to the direction of compression and the molecules become "tangled." They are unable to slide against each other easily and the viscosity increases.
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> A third theory suggests that an electrical attraction is built up between the starch molecules as they rub against each other. The faster they rub together, the greater the attraction becomes, resulting in an increase in the viscosity.

An excellent discussion of this question was provided by Jearl Walker in two articles in "The Amateur Scientist" section of Scientific American: vol. 239, no. 5, pp. 186-198, November, 1978, and vol. 246, no. 1, pp. 174-180, January, 1982.