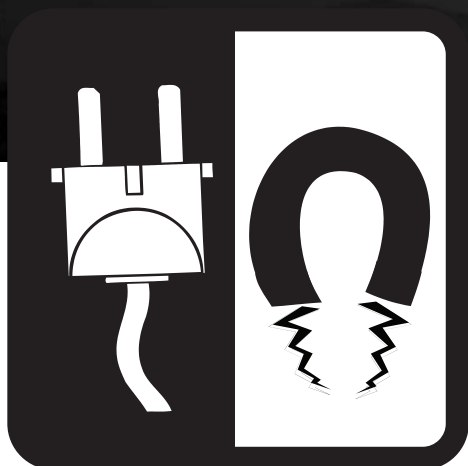


ElectroWorks

Student Guide





Electricity

Atomic Structure

Everything in the universe is made of **atoms**—every star, every tree, every animal. The human body is made of atoms. Air and water are, too. Atoms are the building blocks of the universe. Atoms are so small that millions of them would fit on the head of a pin.

Atoms are made of even smaller particles. The center of an atom is called the **nucleus**. It is made of particles called **protons** and **neutrons**. The protons and neutrons are very small, but **electrons** are much, much smaller. Electrons move around the nucleus a great distance from the nucleus. If the nucleus were the size of a tennis ball, the atom would be the size of the Empire State Building. Atoms are mostly empty space. All diagrams in this booklet are not drawn to scale. To do so would require a book as big as your classroom!

If you could see an atom, it would look a little like a tiny center of spheres surrounded by giant invisible clouds.

Electrons are found in the invisible clouds on **energy levels**. They are held in these levels by an electrical force. The protons and electrons of an atom are attracted to each other. They both carry an electrical charge.

Protons have a positive charge (+) and electrons have a negative charge (-). The strength of the positive charge of the protons is equal to the strength of the negative charge of the electrons. Opposite charges attract each other.

When an atom is neutral, it has an equal number of protons and electrons. The neutrons carry no charge and their number can vary. Neutrons help hold the nucleus together.

Elements

An **element** is a substance in which all of the atoms have the same number of protons. The number of protons in an atom determines the kind of atom or element it is, and the atom's properties.

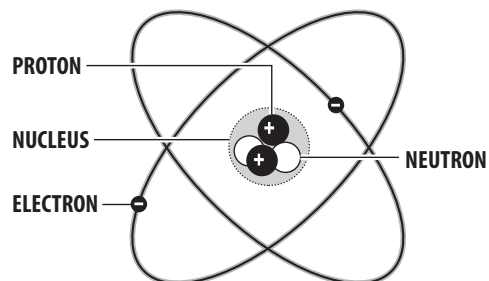
Most atoms of hydrogen, for example, have one proton and one electron, with no neutrons. Most atoms of carbon have six protons, six electrons, and six neutrons.

Electrons

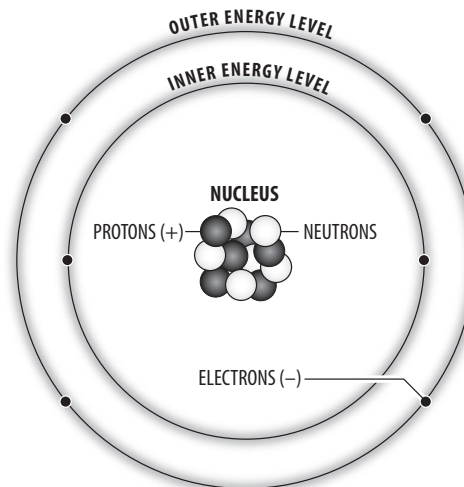
The electrons usually remain in their energy levels—well-defined regions at a specific distance from the nucleus. The energy level closest to the nucleus can hold a maximum of two electrons. The next level can hold up to eight. Other levels can hold even more.

Electrons require energy to be able to escape their attraction to the nucleus. Electrons closer to the nucleus require more energy to be removed from the atom than those farther away from the nucleus. If these outer electrons get just a little extra energy, they can escape to other atoms. In a conductor, electrons are able to move from atom to atom. When the movement of electrons is in mostly one direction through an object, the movement is called **electricity**.

Atom



Carbon Atom



A carbon atom has six protons and six neutrons in the nucleus, two electrons in the inner energy level, and four electrons in the outer energy level.

Several Common Elements

ELEMENT	SYMBOL	PROTONS	ELECTRONS	NEUTRONS
Hydrogen	H	1	1	0
Lithium	Li	3	3	4
Carbon	C	6	6	6
Nitrogen	N	7	7	7
Oxygen	O	8	8	8
Magnesium	Mg	12	12	12
Copper	Cu	29	29	34
Silver	Ag	47	47	60 or 62
Gold	Au	79	79	118

Electricity

Electricity has been moving in the world since clouds formed on Earth. Lightning is a form of electricity. It is electrons moving from one cloud to another or jumping from a cloud to the ground.

Have you ever felt a shock when you touched an object after walking across a carpet? A stream of electrons jumped from you to that object. When electrons build up on an object, this is called **static electricity**.

Have you ever made your hair stand up straight by rubbing a balloon on it? If so, you rubbed some electrons off of your hair on to the balloon. This leaves your hair positively charged, and the balloon negatively charged. Your hair stands up when it is near the balloon because opposite charges attract. Your hair will still stand up when the balloon is not near it. Why? If opposite charges attract each other, like charges repel. Each hair is positively charged and repels the hair next to it, trying to get as far away as possible. The concept of opposites attracting is very important when discussing electricity.

Magnets

In most objects the molecules that make up the substance have atoms with electrons that spin in random directions. They are scattered evenly throughout the object. **Magnets** are different—they are made of molecules that have north- and south-seeking poles.

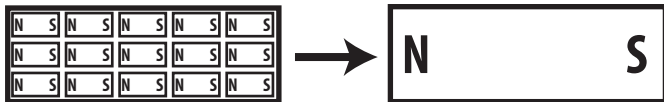
The molecules in a magnet are arranged so that most of the north-seeking poles point in one direction and most of the south-seeking poles point in the other.

Spinning electrons create small **magnetic fields** and act like microscopic magnets or micro-magnets. In most objects, the electrons located around the nucleus of the atoms spin in random directions throughout the object. This means the micro-magnets all point in random directions cancelling out their magnetic fields. Magnets are different—most of the atoms' electrons spin in the same direction which means the north- and south-seeking poles of the micro-magnets they create are aligned. Each micro-magnet works together to give the magnet itself a north- and south-seeking pole. Because the micro-magnets in a magnet are fixed and not able to move around, we call it a permanent magnet.

A magnet is labeled with north (N) and south (S) poles. By definition, a magnetic field in a magnet flows from the north pole to the south pole.

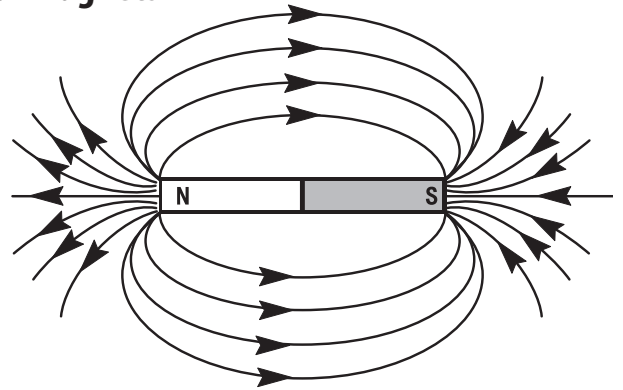
Have you ever held two magnets close to each other? They don't act like most objects. If you try to push the south poles together, they repel each other. Two north poles also repel each other, just like with two positively charged objects.

Permanent Magnet Showing Micro-Magnets



There are really millions and millions of micro-magnets working together in a magnet to create the north and south-seeking poles.

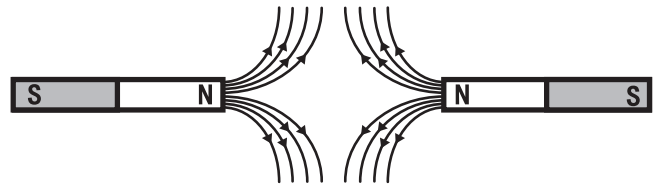
Bar Magnets



Magnets can be made of molecules, but they can also be made of alloys, which are different types of atoms that are not chemically bonded together, or even pure metals.

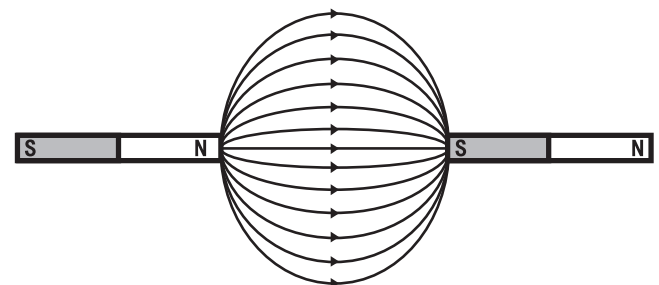
Like Poles

Like poles of magnets (N-N or S-S) repel each other.

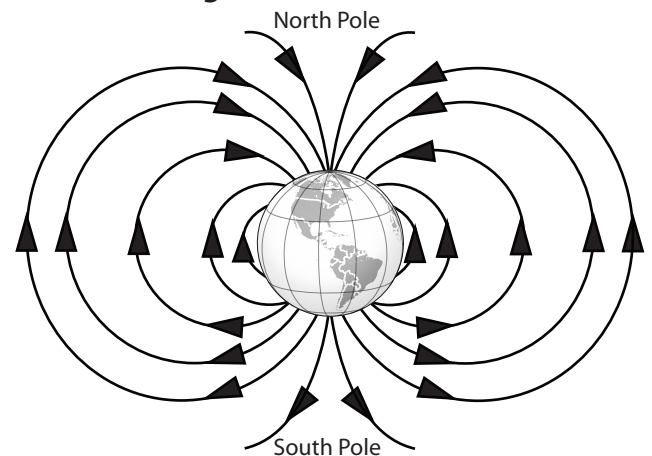


Opposite Poles

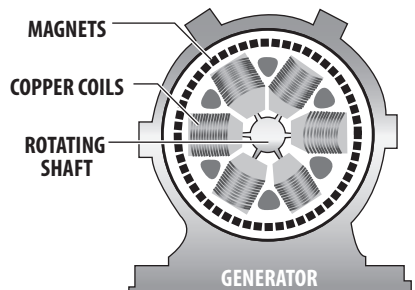
Opposite poles of magnets (N-S) attract each other.



Earth with Magnetic Field



Generator



The copper coils spin inside a ring of magnets. This creates an electric field, producing electricity.

Turn one magnet around and the north and the south poles are attracted to each other. The magnets come together with a strong force. Just like protons and electrons, opposites attract.

Electromagnetism

A magnetic field can be used to produce electricity. In fact, magnetism and electricity are really two permanently related parts of one force, called **electromagnetism**. Every time there is a change in a magnetic field, an **electric field** is produced. Every time there is a change in an electric field, a magnetic field is produced.

We can use this relationship to produce electricity. Some metals, like copper, have electrons that are loosely held. They can be pushed from their shells by moving magnets. If a coil of copper wire is moved in a magnetic field, or if magnets are moved around a coil of copper wire, an electric current is generated in the wire.

Electric current can also be used to produce magnets. Around every current-carrying wire is a magnetic field, created by the uniform motion of electrons in the wire.

Producing Electricity at a Power Plant

Power plants use huge turbine generators to make the electricity that we use in our homes and schools. Power plants use many fuels to spin a **turbine**. They can burn coal, oil, or natural gas to make steam to spin a turbine. They can split atoms of uranium to heat water into steam. They can also use the power of rushing water from a dam or the energy in the wind to spin the turbine.

The turbine is attached to a shaft in the **generator**. Inside the generator are magnets and coils of copper wire. The generator can be designed in two ways. The turbine can spin coils of wire inside magnets, or can spin magnets inside coils of wire. In either design, the electrons move from one copper atom to another inside the wire because as the magnetic field moves, the electrons also move.

In the diagram at the top of the page, coils of copper wire are attached to the turbine shaft. The shaft spins the coils of wire inside huge magnets. The magnet on one side of a coil has its north pole to the front. The magnet on the other side has its south pole to the front.

The magnetic fields around these magnets push and pull electrons in the copper wire as the wire spins. This causes the electrons to move through the copper wire creating an electric current or electricity.

The electricity created in a generator then travels to an **inverter** where it is converted from direct current (DC) into alternating current (AC). The AC electricity carries energy to our houses. Electricity moves through wires very fast. In just one second, electricity can travel around the world seven times.

Other Ways To Produce Electricity

Electricity can also be produced in other ways. A solar cell turns **radiant energy** into electricity. A battery turns **chemical energy** into electricity.

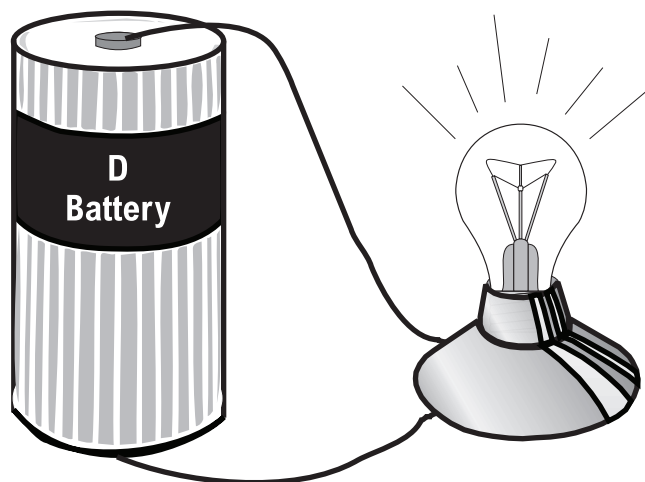
A **battery** produces electricity using two different metals in a chemical solution. A chemical reaction between the metals and the chemicals frees more electrons in one metal than in the other.

One end of the battery is attached to one of the metals; the other end is attached to the other metal. The end that frees more electrons develops a positive charge and the other end develops a negative charge. If a wire is attached from one end of the battery to the other, electrons flow through the wire to balance the electrical charge.

Loads

A **load** is a device that does work or performs a job. If a load—such as a light bulb—is placed along the wire, the electricity can do work as it flows through the wire. In the picture below, electrons flow from the end of the battery with a surplus of electrons (the negative end) through the wire to the light bulb. The electricity flows through the wire in the light bulb and back to the battery. Any device placed in a circuit to do work is called a load. The light bulb in a flashlight is a load. A television plugged into a wall outlet is also a load.

Battery and Bulb



Circuits

Electricity travels in closed loops, or **circuits**. It must have a complete path before the electrons can move. If a circuit is open, the electrons cannot flow. When we flip on a light switch, we close a circuit. The electricity flows from the electric wire through the light and back into the wire. When we flip the switch off, we open the circuit. No electricity flows to the light.

When we turn on the TV, electricity flows through wires inside the set, producing pictures and sound. Sometimes electricity runs **motors**—in washers or mixers. Electricity does a lot of work for us. We use it many times each day.

In the United States, we use electricity to light our homes, schools, and businesses. We use it to warm and cool our homes and help us clean them. Electricity runs our TVs, DVD players, video games, and computers. It cooks our food and washes the dishes. It mows our lawns and blows the leaves away. It can even run our cars.

Conductors and Insulators

Have you ever wondered why some materials are used more often in electrical devices than others? It is because some objects conduct electricity better. A **conductor** is a material in which the outer electrons are not held as tightly as they are in other materials. When electrons are able to flow easily from atom to atom in an object, we call the object a conductor. If the electrons are not able to easily move around, we call the substance an **insulator**. Most metals make good conductors, with silver and copper being the best. Most non-metals are poor conductors. Substances such as plastic and rubber are good insulators and are used to coat wires used in electrical circuits.

Measuring Electricity

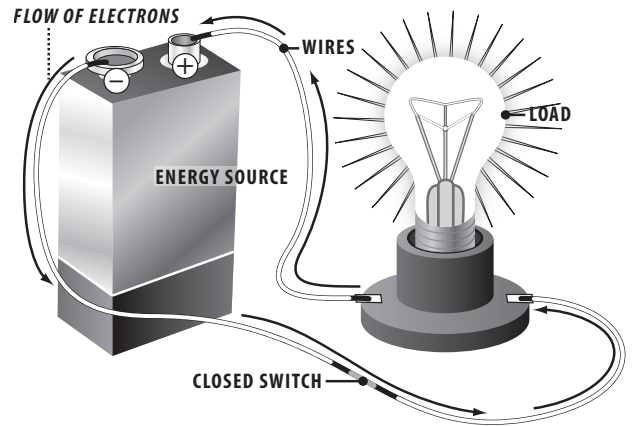
Electricity makes our lives easier, but it can seem like a mysterious force. Measuring electricity can be confusing because we cannot see it. We are familiar with terms such as **watt**, **volt**, and **amp**, but we often do not have a clear understanding of these terms. We buy a 60-watt light bulb, a tool that needs 120 volts, or a vacuum cleaner that uses 8.8 amps, and we don't think about what those units mean.

Using the flow of water as an analogy can make electricity easier to understand. The flow of electrons in a circuit is similar to water flowing through a hose. If you could look into a hose at a given point, you would see a certain amount of water passing that point each second. The amount of water depends on how much pressure is being applied—how hard the water is being pushed. It also depends on the diameter of the hose. The harder the pressure and the larger the diameter of the hose, the more water passes each second. The flow of electrons through a wire depends on the electrical pressure pushing the electrons and on the cross-sectional area of the wire.

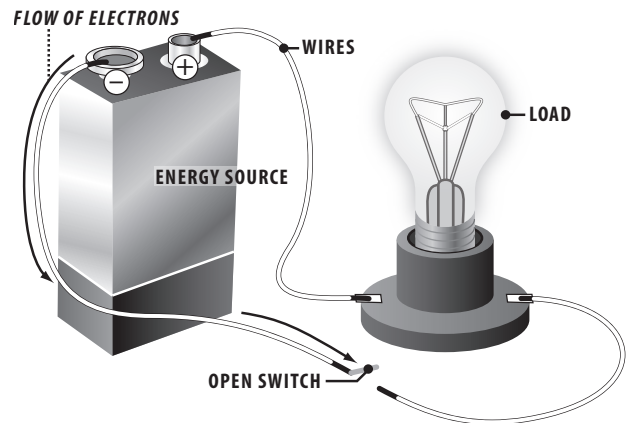
▪ Voltage

The pressure that pushes electrons in a circuit is called **voltage**. Using the water analogy, if a tank of water were suspended one meter above the ground with a one-centimeter pipe coming out of the bottom, the water pressure would be similar to the force of a shower. If the same water tank were suspended 10 meters above the ground, the force of the water would be much greater, possibly enough to hurt you.

Electrical Circuits

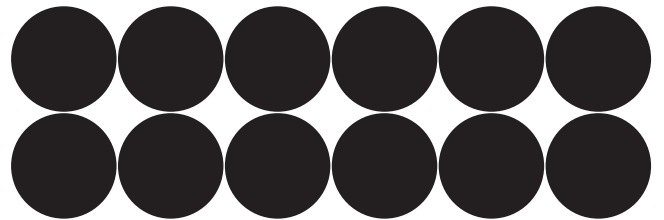


A closed circuit is a complete path allowing electricity to flow from the energy source to the load.

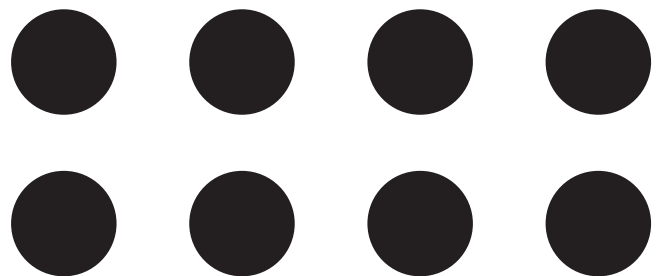


An open circuit has a break in the path. There is no flow of electricity because the electrons cannot complete the circuit.

Good Conductor



Good Insulator



Voltage (V) is a measure of the pressure applied to electrons to make them move. It is a measure of the strength of the current in a circuit and is measured in volts (V). Just as the 10-meter tank applies greater pressure than the 1-meter tank, a 10-volt power supply (such as a battery) would apply greater pressure than a 1-volt power supply.

A, AA, AAA, C, and D batteries are all 1.5-volt; they apply a small amount of voltage or pressure for lighting small flashlight bulbs. A car usually has a 12-volt battery—it applies more voltage to push current through circuits to operate the radio or defroster. The standard voltage of wall outlets is 120 volts—a dangerous amount of voltage. An electric clothes dryer is usually wired at 240 volts—a very dangerous voltage.

▪ Electric Current

The flow of electrons can be compared to the flow of water. The water current is the number of molecules flowing past a fixed point; **electric current** is the number of electrons flowing past a fixed point in a certain amount of time.

Current is measured in amperes or amps (A). One ampere is 6.25×10^{18} electrons per second passing through a circuit. With water, as the diameter of the pipe increases, so does the amount of water that can flow through it. With electricity, conducting wires take the place of the pipe. As the cross-sectional area of the wire increases, so does the amount of electric current (number of electrons) that can flow through it.

▪ Resistance

Resistance (R) is a property that slows the flow of electrons—the current. Using the water analogy, resistance is something that slows water flow—a smaller pipe or fins on the inside of the pipe. In electrical terms, the resistance of a conducting wire depends on which metal the wire is made of and its diameter. Copper, aluminum, and silver—metals used in conducting wires—all have different resistance.

Resistance is measured in units called **ohms** (Ω). There are devices called resistors, with set resistances, that can be placed in circuits to reduce or control the current flow. Every load in a circuit has resistance.

Ohm's Law

George Ohm, a German physicist, discovered that in many materials, especially metals, the current that flows through a material is proportional to the voltage. In the substances he tested, he found that if he doubled the voltage, the current also doubled. If he reduced the voltage by half, the current dropped by half. The resistance of the material remained the same. This relationship is called **Ohm's Law**, and can be written in three simple formulas. If you know any two of the measurements, you can calculate the third using this formula:

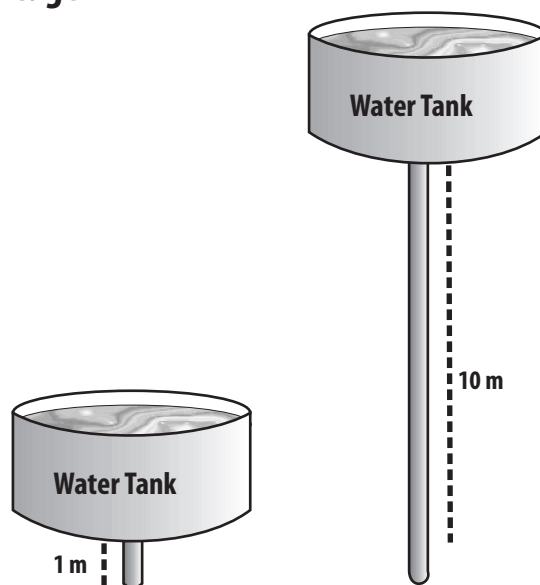
$$V = I \times R$$

Where V = Voltage (V)

I = Current (A)

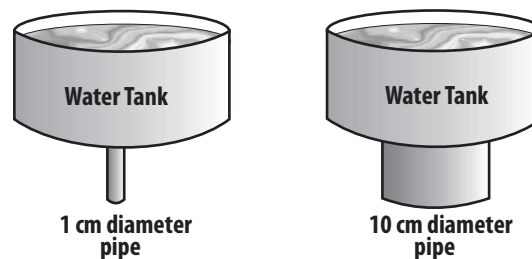
and R = Resistance (Ω)

Voltage



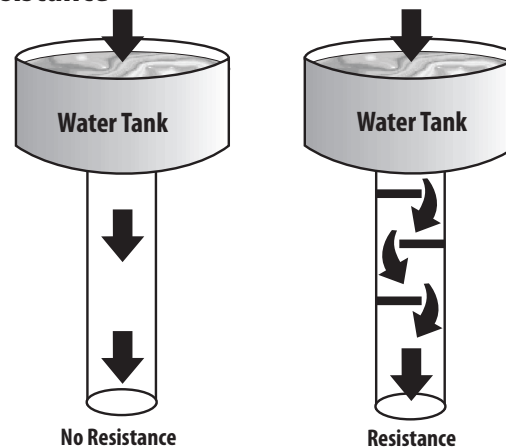
Voltage (V) is a measure of the pressure applied to electrons to make them move. It is a measure of the strength of the current in a circuit and is measured in volts (V).

Current



The water current is the number of molecules flowing past a fixed point.

Resistance



Resistance is something that slows water flow—a smaller pipe or fins on the inside of the pipe.

▪ Electric Power

Power (P) is a measure of the rate of doing work or the rate at which energy is converted. Electric power is the rate at which electricity is transformed.

Using the water analogy, electric power is the combination of the water pressure (voltage) and the rate of flow (current) that results in the ability to do work. A large pipe carries more water (current) than a small pipe. Water at a height of 10 meters has much greater pressure (voltage) than at a height of one meter. The power of water flowing through a 1-centimeter pipe from a height of one meter is much less than water through a 10-centimeter pipe from 10 meters.

Electric power is defined as the rate at which electricity is converted to another form of energy. It is the amount of electricity required to start or operate a load for one second. Electric power is measured in watts (W). The formula for electric power is:

$$P = V \times I$$

Where P = Power (W)

I = Current (A)

and V = Voltage (V)

▪ Electrical Energy and Power

Electrical energy introduces time to electric power. In the water analogy, it would be the amount of water falling through the pipe over a period of time, such as an hour. When we talk about using power over time, we are talking about using energy. Using our water example, we could look at how much work could be done by the water in the time that it takes for the tank to empty.

The electrical energy that an appliance transforms can only be determined if you know how long (time) it uses electric power at a specific rate (power). To find the amount of energy converted, you multiply the rate of energy use (measured in watts) by the amount of time (measured in hours) that it is being used. Electrical energy is measured in **watt-hours (Wh)**.

$$EE = P \times t$$

Where EE = electrical energy (Wh)

P = power (W)

and t = time (h)

When we look at electric power, we are talking about the rate that electrical energy is being transformed.

You would not say you used 100 watts of light energy to read your book, because watts represent the rate at which you used the energy, not the total energy used while reading. The amount of energy used would be calculated by multiplying the rate by the amount of time you read. If you read for five hours with a 100 watt bulb, for example, you would use the formula as follows:

$$\text{Electrical Energy} = \text{Power} \times \text{Time}$$

$$EE = P \times t$$

$$EE = (100 \text{ W}) \times (5 \text{ h})$$

$$EE = 500 \text{ Wh}$$

One watt-hour is a very small amount of electrical energy. Usually, we measure electric power in larger units called kilowatt-hours (kWh) or 1,000 watt-hours (kilo means *thousand*). A kilowatt-hour is the unit that utilities use when billing most customers.

Ohm's Law

- Voltage = current x resistance

$$V = I \times R \quad \text{or} \quad V = A \times \Omega$$

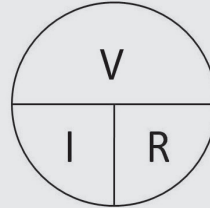
- Current = voltage / resistance

$$I = V / R \quad \text{or} \quad A = V / \Omega$$

- Resistance = voltage / current

$$R = V / I \quad \text{or} \quad \Omega = V / A$$

Formulas for Measuring Efficiency



V = I x R The formula pie works for any three variable equation. Put your finger on the variable you want to solve for and the operation you need is revealed.

I = V/R

R = V/I

Electric Power



The average cost of kilowatt-hour of electricity for residential customers is about \$0.12. To calculate the cost of reading with a 100 W bulb for 5 hours, change the watt-hours into kilowatt-hours, then multiply the kilowatt-hours used by the cost per kilowatt-hour, as shown below:

$$500 \text{ Wh} \times \frac{1 \text{ kWh}}{1,000 \text{ Wh}} = 0.5 \text{ kWh}$$

$$0.5 \text{ kWh} \times \$0.12/\text{kWh} = \$0.06$$

It would cost only six cents to read for 5 hours using a very bright, 100 W bulb.

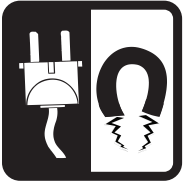


Key Words for Electricity

Instructions: Complete the sentences with the correct key word from the list below. Each word will be used once.

atoms	electricity	magnet	protons
attract	electrons	neutrons	repel
battery	element	north pole	south pole
circuit	generator	nucleus	static electricity
electrical charges	load	outer energy level	turbine

1. All of the atoms in a(n) _____ have the same number of protons.
2. The center of an atom is the _____.
3. In a(n) _____, a chemical reaction produces electricity.
4. Magnetic fields flow from the _____ of a magnet.
5. The particles in the nucleus of an atom that carry no charge are _____.
6. Opposite poles of a magnet _____ each other.
7. A device that does work in a circuit is called a(n) _____.
8. _____ is simply moving electrons.
9. Protons and electrons carry equal and opposite _____.
10. In some elements, electrons can be pushed from the atom's _____.
11. Electrons that jump from one object to another are called _____.
12. The _____ of atoms are positively charged.
13. Magnetic fields flow to the _____ of a magnet.
14. Two south poles of a magnet will _____ each other.
15. In a power plant, a(n) _____ spins a coil of wire in the generator.
16. _____ are tiny particles spinning far from the nucleus of the atom.
17. Electricity in a closed loop is called a(n) _____.
18. A(n) _____ has huge magnets and coils of wire to produce electricity.
19. The building blocks of all matter are called _____.
20. An object with properties that can affect the motion of electrons is a(n) _____.



Key Words for Measuring Electricity

Instructions: Complete the sentences with the correct key word from the list below. Words may be used more than once.

amperes
current
volts
watts

load
resistance
voltage
pressure

power
watt-hours
ohm's law
ohms

resistor
electrical energy

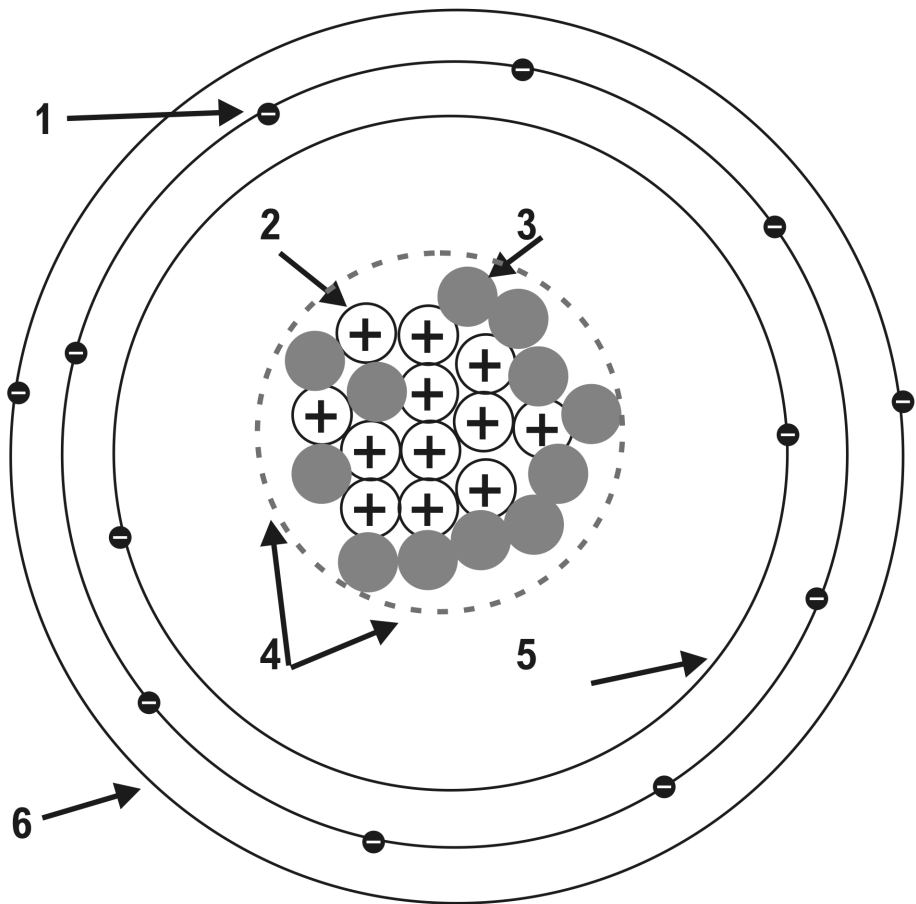
1. The property of a material that slows the flow of electrons is _____ .
2. Electric power is measured in _____ .
3. The amount of _____ depends on the electrical pressure and the cross-sectional area of the conducting wire.
4. The relationship between voltage and current is called _____ .
5. Electric current is measured in _____ .
6. A device designed to control current with a specific resistance is a(n) _____ .
7. Electrical energy is measured in _____ .
8. Electrical pressure is called _____ .
9. A device in a circuit that does work is a(n) _____ .
10. The rate of doing work is called _____ .
11. Resistance is measured in _____ .
12. Voltage is the electrical _____ applied to electrons to move them.
13. Voltage is measured in _____ .
14. The number of electrons flowing between two points in a certain amount of time is the _____ .
15. Current multiplied by resistance equals _____ .
16. Voltage multiplied by current equals _____ .
17. Power multiplied by time equals _____ .
18. Power divided by voltage equals _____ .
19. An appliance in a circuit is called a(n) _____ .



Atomic Structure

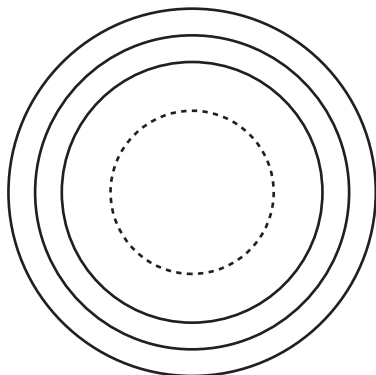
Below is a model of an atom of magnesium (Mg). Magnesium is a silvery white metal that has 12 protons, 12 electrons, and 12 neutrons in its most stable isotope. Number the words on the left with the correct part of the atom in the diagram.

- proton _____
- electron _____
- neutron _____
- inner energy level _____
- nucleus _____
- outer energy level _____

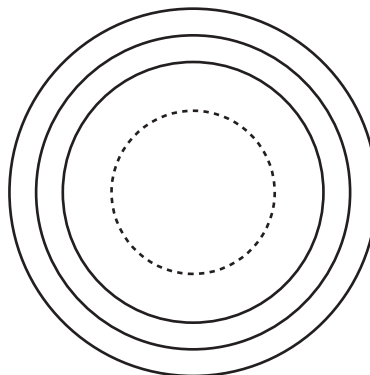


Magnesium—24

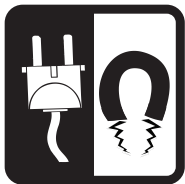
Draw the protons, neutrons, and electrons on the atoms below. Be sure to put the electrons in the correct energy levels. Lithium has three protons and four neutrons. Nitrogen has seven protons and seven neutrons.



Lithium—7



Nitrogen—14



Static Electricity

Background

An electroscope is a device that shows the presence of an electric charge on an object. An electric charge can be a build-up of electrons on an object, producing a negative (-) charge. It could also be a loss of electrons, producing a positive (+) charge on an object. The electroscope you are using is a glass container with a rubber stopper holding a metal rod. At the bottom of the metal rod is a hook that holds two strips of foil. If an electrically charged object touches the metal ball at the top, the charge will flow down the metal rod, through the hook, and into the strips of foil. Both pieces of foil will develop the same charge and push away from each other. Let's use the electroscope to explore ways of producing electric charges.

Questions

- What kinds of materials lose electrons easily?
- What kinds of materials attract electrons easily?

Materials

- | | | |
|----------------|-------------------------------------|-------------------------------|
| ▪Electroscope | ▪Plastic marking pen | ▪Piece of construction paper |
| ▪Piece of wool | ▪Plastic ruler | ▪Scissors with plastic handle |
| ▪Piece of tape | ▪Piece of plastic transparency film | ▪Balloon |
| ▪Wooden pencil | ▪Metal spoon | ▪Aluminum foil (in strips) |

Preparation

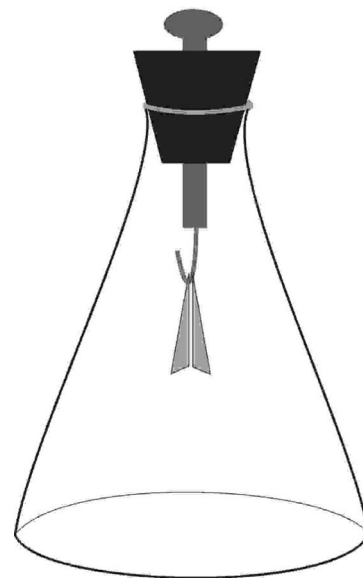
- Blow up the balloon and tie it.
- Roll the construction paper into a tube and tape it.

Hypothesis

Read the procedure and record your hypothesis.

Procedure

1. Look at the list of objects in the data table. Check the first column if you think it will hold a charge.
2. Test each object by rubbing it quickly with the piece of wool, then holding it close to the ball on the electroscope.
3. Check the second column for each object that produces a charge on the electroscope.
4. Produce a charge on the electroscope and touch your finger to the ball. Observe the foil strips.



Data

Record your observations.

Object	I predict this object will hold a charge	This object produced a charge on the electroscope with wool	This object produced a charge on the electroscope with foil
Wooden pencil			
Plastic marking pen			
Plastic ruler			
Piece of plastic transparency			
Metal spoon			
Piece of construction paper			
Scissors with plastic handle			
Balloon			

** Conclusion

For each question, make sure you support your answer with experimental evidence. In other words, what about the experiment you just did verifies your answer?

1. Were you surprised by any of the objects that produced an electric charge?
2. Why did you rub the objects with a piece of wool? Would a piece of aluminum foil produce the same results? Try it and see.
3. Describe how the aluminum foil affected the charge on the objects.
4. Why did the foil strips stay charged when you touched the electroscope? How long did the charge stay on the electroscope?



Make a Battery

Background

We use batteries everyday. They produce electricity to operate flashlights, cameras, and many other devices. Batteries usually have two kinds of metal placed in chemical solutions. The solutions cause chemical reactions in the metals, freeing electrons. One metal loses more electrons than the other. The metal that loses more electrons is the positive (+) end or terminal of the battery. The other metal is the negative (-) terminal of the battery. If we make a closed circuit with the battery, we can produce electricity. When electrons flow through a wire, heat is produced. We can sometimes feel that heat in battery operated devices. We can also measure the flow of electricity with an ammeter, which measures electric current.

Question

- Can any liquid be used in a battery?

Materials

- 2 Zinc electrodes
- 2 Copper electrodes
- 6 D Batteries
- 2 Alligator clips
- 1 Measuring cup
- 1 Electrical meter (ammeter)
- 1 Beaker of distilled water
- Aluminum foil
- Salt

Preparation

- Fold the piece of aluminum foil several times lengthwise to make a thick foil strip. Cut this foil strip in half, so that you have two 25 cm strips. Cut one again so that you have a 10 cm and a 15 cm strip.

Hypothesis

Read the procedure and record your hypothesis.

Procedure

- Attach the 10 cm strip to the terminals (ends) of the battery with tape, as shown in Diagram 1. Hold the strip in your fingers for 15 seconds. Observe any change in the temperature of the strip. Attach the 15 cm strip to the battery and feel the strip. Do the same thing with the 25 cm strip.
- Attach the alligator clips to the leads on the meter. Attach the clip with the red label to a zinc electrode and the other clip to a copper electrode. Observe the meter. Place the electrodes in the beaker of water so they are NOT touching (Diagram 2). Observe the meter. Remove the electrodes.
- Add 5 cm³ of salt to the water and stir. Place the electrodes in the salt water so they are NOT touching and observe the meter. Add another 5 cm³ of salt, stir, and observe the meter. Touch the electrodes together and observe the meter.
- Place two copper electrodes on one clip and two zinc electrodes on the other in the salt solution and observe the meter.
- Place one copper electrode on each clip and observe the meter.

NOTE: 1 cm³ = 1 mL

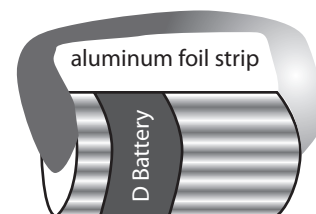


Diagram 1

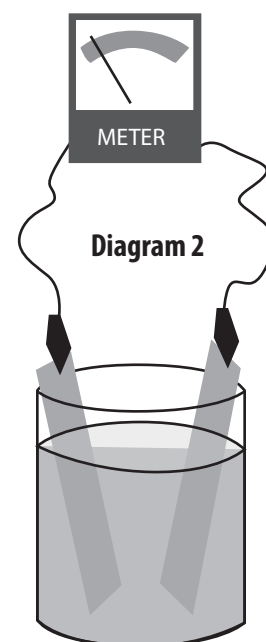


Diagram 2

Data

Record your observations.

Conditions	Meter Reading and/or Observations
10 cm aluminum foil on battery	
15 cm aluminum foil on battery	
25 cm aluminum foil on battery	
Copper and zinc in plain water	
Copper and zinc in water with 5 cm ³ salt	
Copper and zinc in water with 10 cm ³ salt	
2 Copper and 2 zinc pieces in water with 10 cm ³ salt	
2 pieces of copper, one at each wire, in water with 10 cm ³ salt	

**** Conclusion**

For each question, make sure you support your answer with experimental evidence. In other words, what about the experiment you just did verifies your answer?

1. Using the D battery, could you feel any heat produced by the electricity in the foil strips? Which length of foil got hotter? Why?

2. Did the metal electrodes produce electricity before they were placed in water? Was this apparatus a battery? Did the metal electrodes produce electricity when they were placed in water? In salt water? Was this apparatus a battery? Which solution made a better battery? What happened when the metal electrodes were touching in the salt solution?

3. How did increasing the amount of metal affect the meter? What happened when both electrodes were made of the same metal? Why?



Magnets and Compasses

Background

Did you know the Earth is a giant magnet? The Earth has north and south poles just like a magnet has north and south poles. The whole Earth has a magnetic field around it. The needle of a compass always points to the north because the needle is a magnet, too. You can turn an ordinary needle into a magnet by stroking it with a magnet, rearranging the electrons in the needle. You can demagnetize the needle by dropping or striking it several times.

Questions

- What kinds of materials are magnetic?
- Is one end of a magnet stronger than another?

Materials

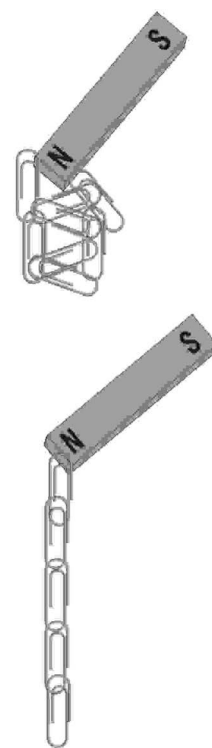
- 2 Bar magnets
- 1 Horseshoe magnet
- 6 Ring magnets
- 1 Student compass
- 1 Large sewing needle
- Wood disk
- Pencil or straw
- Paper clips
- Tape
- Bowl of water

Hypothesis

Read the procedure and record your hypothesis.

Procedure

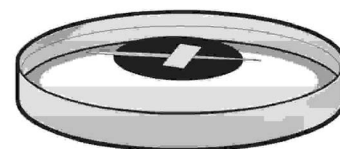
1. Hold the needle firmly on the end with the eye. Hold one end of a bar magnet with your other hand. Stroke the needle with the magnet from the eye end to the pointed end—in one direction only—about 25 times.
2. Tape the needle to the wood disk and float it in the water with the needle on top. Observe the direction that the needle points. Compare it to the direction of the needle of the compass. The compass will always point north.
3. Examine the two bar magnets. Try to push the north (N) poles of the bar magnets together, then the two south (S) poles. Now place the N pole of one magnet next to the S pole of the other. Observe how the magnets attract and repel each other.
4. Examine the horseshoe magnet. Observe how it is different from the bar magnets. Determine the N and S poles of the horseshoe magnet using a bar magnet.
5. Examine the ring magnets. See if you can determine their N and S poles. Stack the ring magnets on a pencil or straw so that they repel each other.
6. Put the paper clips in a pile on the table. See how many paper clips the N pole of a bar magnet can lift. Now try the S pole. Try the other bar magnet to determine if it has the same magnetic force as the first. See if a magnet can lift as many paper clips end to end—in a line—as it can if they are bunched together.
7. Place both bar magnets together N pole to S pole. See how many paper clips the magnets together can lift.
8. See how many paper clips the horseshoe magnet and the ring magnets can lift.



Data

Record your observations below.

1. Needle rubbed on magnet:
2. Direction of needle on disc compared to compass needle:
3. North pole → north pole interaction:
North pole → south pole interaction:
4. How are the poles of the horseshoe magnet aligned? Draw a diagram.



5. How are the poles of the ring magnets aligned? Draw a diagram.

6. Number of paper clips lifted by one magnet, north pole: _____

Number of paper clips lifted by one magnet, south pole: _____

Other bar magnet's strength, compared to the first: smaller larger same

Number of paper clips lifted by one magnet, when clips are in a line: _____

7. Number of paper clips lifted by two magnets together N to S. _____

8. Number of paper clips lifted by horseshoe magnet: _____

Number of paper clips lifted by one ring magnet: _____

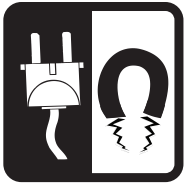
**** Conclusion**

For each question, make sure you support your answer with experimental evidence. In other words, what about the experiment you just did verifies your answer?

1. Which end of the needle is the N pole? If you stroked the needle in the other direction, would the N pole be on the needle's other end? Write your answer, then test it out.

2. Which magnet was the most powerful? How do you know?

3. Do you think the paper clips became magnetized to lift other paper clips? What evidence supports your answer?



Magnetic Fields

Background

Every magnet produces a field of force around it. This magnetic field attracts certain materials, such as iron. It can also affect the direction of a compass needle. The magnetic field demonstrator holds small pieces of iron—a metal that is attracted to a magnet—suspended in oil.

Question

Do different shaped magnets have different magnetic fields?

Materials

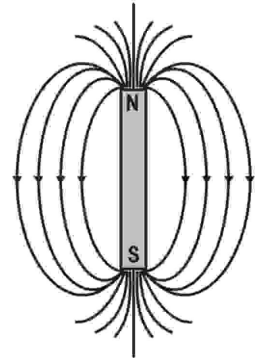
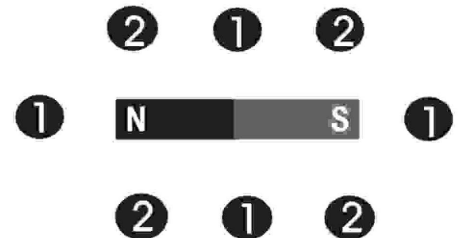
- 2 Bar magnets
- 1 Horseshoe magnet
- 1 Ring magnet
- 4 Student compasses
- 1 Magnetic field demonstrator (MFD)
- Overhead projector

Hypothesis

Read the procedure and record your hypothesis.

Procedure

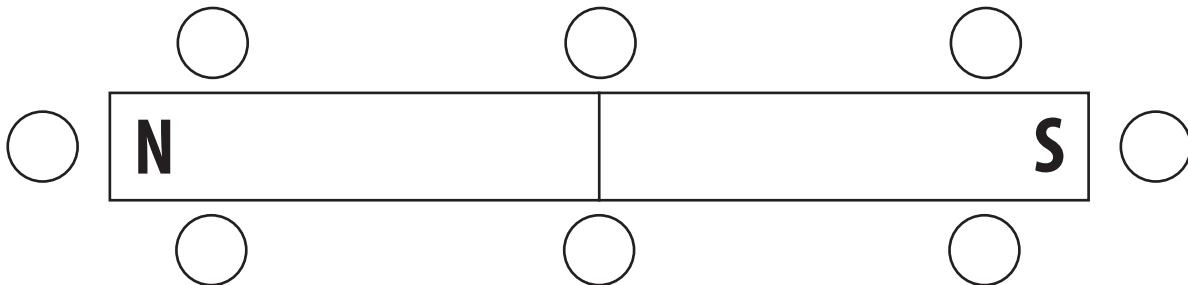
1. Arrange four compasses around a bar magnet, as shown in the diagram to the right. Place them at the positions marked as 1, far enough away from the magnet so that the compasses don't move toward the magnet. Make a diagram of the magnet and compasses, showing the N and S poles of the magnet and the direction that each compass needle points. Do the same placing the compasses at the 2 positions.
2. Arrange compasses first around the horseshoe magnet, then around a ring magnet, and make diagrams of these, too.
3. Shake the magnetic field demonstrator (MFD). Place a bar magnet on the projector and place the MFD on top of it. Observe the pattern of the iron filings. Make a diagram of the magnetic field of the magnet, as shown by the iron filings.
4. Shake the MFD. Place both bar magnets together on the projector with N and S poles together. Place the MFD on top of the magnets. Make a diagram of the magnetic field produced by the two magnets.
5. Shake the MFD and place it on the horseshoe magnet. Make a diagram of its magnetic field.
6. Shake the MFD and place it on the ring magnet. See if the magnetic field changes if you turn the ring magnet over. Draw a diagram of the magnetic field of the ring magnet.



Data

Draw what you observed.

Diagram the position of the compass needles when placed around the bar magnet:



Draw and diagram the position of the compass needles when placed around a horseshoe and ring magnet.

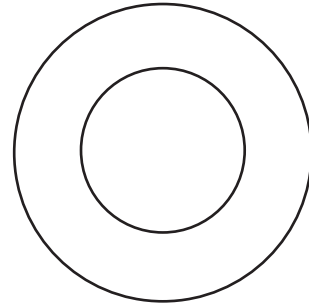
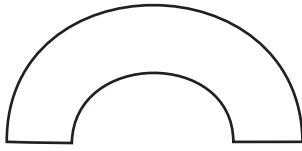
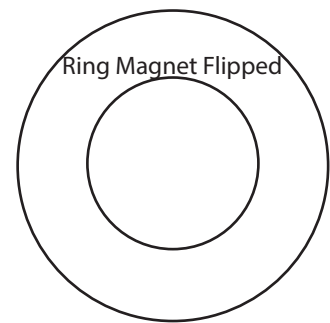
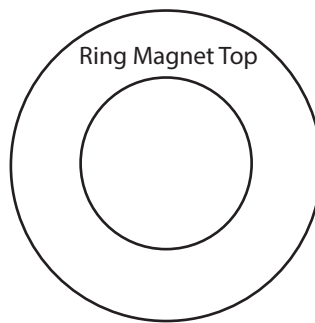
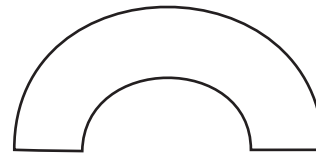
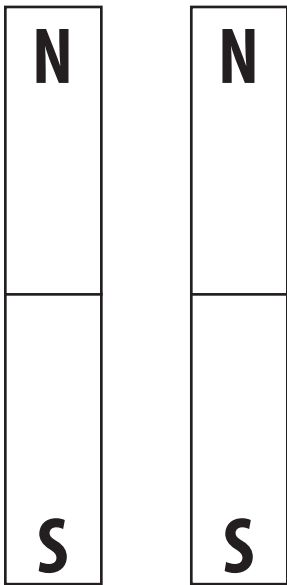


Diagram the magnetic field for each type of magnet below:

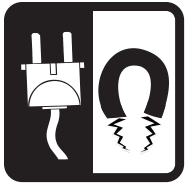


**** Conclusion**

For each question, make sure you support your answer with experimental evidence. In other words, what about the experiment you just did verifies your answer?

1. Do your diagrams of the compasses and the iron filings for each shape of magnet give you the same information? Compare them and see what you discover.

2. Which magnet has a magnetic field most like that of the Earth? Draw a diagram showing what the magnetic field of the Earth might look like.



Electromagnets 1

Background

Moving electrons—electricity—have a magnetic field around them. If we move electrons through a wire, the wire has a magnetic field around it. We can use moving electrons to make a magnet. This kind of magnet is called an electromagnet.

Question

▪What is an electromagnet?

Caution

If the wire begins to feel hot, detach it from the battery and allow it to cool before resuming the experiments. Only connect while testing batteries, not indefinitely. Batteries will get hot.

Materials

- 1 Piece of coated copper wire (1 meter long)
- 1 Large iron nail
- 1 9-Volt battery
- 1 Compass
- Paper clips
- Tape

Preparation

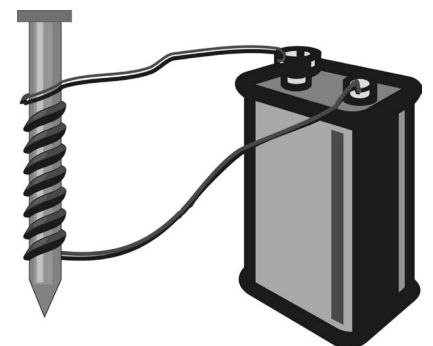
▪Check to see if the nail is magnetized by moving it over the compass. Does the needle of the compass move? If it moves, tap the nail on the floor several times and recheck.

Hypothesis

Read the procedure and record your hypothesis.

Procedure

1. Move the wire over the compass. Observe any movement of the compass needle. Does the compass detect a magnetic field around the wire?
2. Wrap the middle of the wire around the nail 10 times as shown in the picture below. Do not let the wires cross or touch each other; wrap the wire as if it were a spring.
3. Wrap the ends of the wire around the metal contacts on top of the battery to make a circuit, and tape in place like in the picture at the bottom of the page.
4. Move the compass near the wire wrapped nail. Observe the movement of the compass needle. Does the wrapped nail act like a magnet? Has the wrapped nail become an electromagnet?
5. Place a pile of paper clips on the table. Touch the nail to the paper clips and lift. See how many paper clips the nail can lift.
6. Carefully remove the nail from the coil of wire. See if the coil of wire can lift paper clips without the nail inside. Is the coil of wire an electromagnet?
7. Disconnect the coil of wire from the battery after observations are completed.
8. Move the compass over the nail. Did the nail become magnetized?



 **Data**

Record your observations.

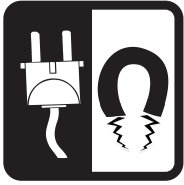
Conditions	Observations
Plain wire	Does the compass detect a magnetic field around the wire?
Wire, 10 turns around nail, connected to battery	Does the wrapped nail act like a magnet?
	Number of paper clips lifted:
Coil of wire, 10 turns, no nail, connected to battery	Does the coil of wire act like a magnet?
	Number of paper clips lifted:
Nail alone	Does the nail act like a magnet?

**** Conclusion**

For each question, make sure you support your answer with experimental evidence. In other words, what about the experiment you just did verifies your answer?

1. When you wrapped the wire around the nail, you intensified the magnetic field of the electrons flowing through the wire. Did the nail also become a magnet while it was in the wire?

2. Is the coiled wire an electromagnet without the nail inside? What experimental evidence supports your answer?



Electromagnets 2

Background

We have discovered that moving electrons have a magnetic field around them. In this experiment, we will investigate the variables that affect the force of electromagnets.

Question

What can be done to change or affect an electromagnet's strength?

Caution

If the wire begins to feel hot, detach it from the battery and allow it to cool before resuming the experiments. Only connect while testing batteries, not indefinitely. Batteries will get hot.

Materials

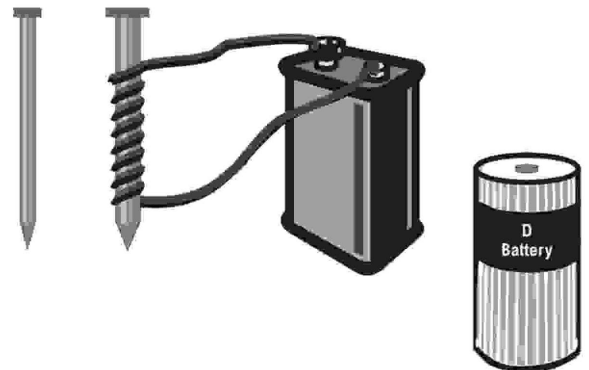
- 1 Piece of coated copper wire (1 meter long)
- 1 Large iron nail
- 1 Small iron nail
- 1 9-Volt battery
- 1 1.5-Volt battery (D battery)
- Paper clips
- Battery holder on circuit

Hypothesis

Read the procedure and record your hypothesis.

Procedure

1. Insert the large nail back into the coil of wire from the last experiment. Make sure there are 10 coils of wire on the nail, that they are not crossing, and reattach the wire to the 9-volt battery.
2. How many paper clips can the electromagnet lift?
3. Wrap the wire around the nail 10 more times, so that you have 20 coils of wire on the nail.
4. How many paper clips can the electromagnet lift?
5. Remove the ends of the wire from the 9-volt battery. Have someone hold the ends of the wire to the ends of the 1.5-volt battery.
6. How many paper clips can the electromagnet lift?
7. Carefully remove the large nail and insert the small nail into the coil of wire. Tighten the coils around the nail.
8. How many paper clips can the electromagnet lift?
9. Connect to the 9 volt battery.
10. How many paper clips can the electromagnet lift?
11. Remove 10 coils from the small nail so that there are only 10 coils of wire around it.
12. How many paper clips can the electromagnet lift?



Data

Record your observations.

Conditions	Observations
Large nail, 10 coils of wire, connected to 9V battery	Number of paper clips lifted:
Large nail, 20 coils of wire, connected to 9V battery	Number of paper clips lifted:
Large nail, 20 coils of wire, connected to 1.5V battery	Number of paper clips lifted:
Small nail, 20 coils of wire, connected to 1.5V battery	Number of paper clips lifted:
Small nail, 20 coils of wire, connected to 9V battery	Number of paper clips lifted:
Small nail, 10 coils of wire, connected to 9V battery	Number of paper clips lifted:

***** Conclusion**

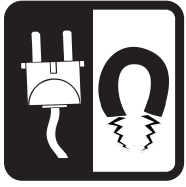
For each question, make sure you support your answer with experimental evidence. In other words, what about the experiment you just did verifies your answer?

1. How does the number of coils affect the strength of an electromagnet? How do you know?

2. How does the voltage of the battery affect the strength of an electromagnet? How do you know?

3. How does the size of the nail in the coil affect the strength of the electromagnet? How do you know?

4. What would you do to build a very strong electromagnet?



Circuits

Background

For electrons to flow through a wire, the wire must make a complete path or circle. This path is called a circuit. A battery produces electricity, or moving electrons, only when it is part of a circuit. You can add a switch to a circuit to open and close the path. A compass can help you determine if your circuit is completed or not. If it is complete, electricity will flow, creating an electric field and magnetic field to move the compass. You can also add a load to the circuit so that the electricity can do work as it flows through the circuit. A light bulb is an example of a load.

Question

How does a completed circuit affect a compass?

Materials

- 1 Battery holder with switch and light socket
- 1 D Battery
- 1 Light bulb
- 1 Student compass
- 3 Pieces of wire or alligator clips

Hypothesis

Read the procedure and record your hypothesis.

Procedure

- Place the battery in the battery holder. Using one wire, attach the ends of the wire to the terminals on the sides of the battery holder, as shown in Diagram 1. Use the compass to determine if you have completed a circuit. Are there electrons flowing through the wire? Disconnect.
- Add a switch to the circuit. Unhook one end of the wire from the battery holder and attach it to one of the terminals of the switch, as shown in Diagram 2. Attach a second wire to the other end of the switch and to the other end of the battery holder.
- Place the compass under one of the wires. Close the circuit by pushing on the switch until it touches the metal under it. Open and close the switch several times, observing the movement of the compass needle.
- Add a load to the circuit. Attach the light bulb to the circuit as shown in Diagram 3. You will need three wires. One wire is attached to the battery holder and the light bulb holder. The second wire is attached to the light bulb holder and the switch. The third wire is attached to the other terminal of the switch and the battery holder.
- Close the switch. Have you made a circuit? Does the light bulb glow?

Diagram 1

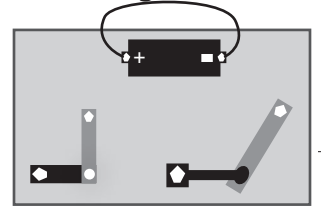
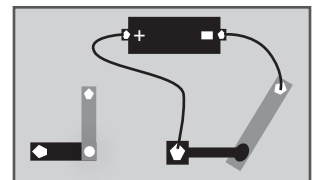
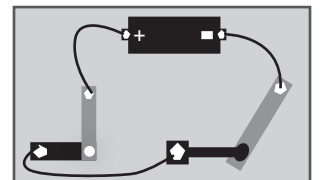


Diagram 2



circuit with switch

Diagram 3



circuit with switch and load

Data

Record your observations.

Conditions	Observations
Diagram 1 (Step 1)	Are there electrons flowing through the wire? How do you know?
Diagram 2 (Steps 2 and 3)	Movement of compass:
Diagram 3 (Steps 4 and 5)	Does the light bulb glow?

Conclusion

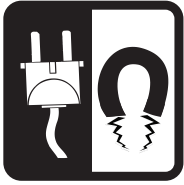
For each question, make sure you support your answer with experimental evidence. In other words, what about the experiment you just did verifies your answer?

1. In conductors, electrons are loosely bound and therefore easy to move. In insulators, electrons are tightly bound and therefore hard to move. Examine the switch. It is made of plastic and metal.

Which material is a better conductor?

Which material is an insulator?

2. Why do you think the copper wire is covered in a plastic coating?



Series Circuits 1

Background

There are many different ways to make circuits. You might want to connect several loads or power sources in one circuit. Computers have millions of circuits connected together. One way to connect power sources, loads, and switches is in a series circuit. In a series circuit, the electricity flows through all of the parts of the circuit in one loop.

Question

- How are loads affected when wired in series?

Materials

- 3 Battery holders with switches and light sockets
- 1 D Battery
- 3 Light bulbs
- 5 Pieces of wire or alligator clips

Hypothesis

Read the procedure and record your hypothesis.

Procedure

- Make a simple circuit with one power source, one switch, and one load as shown in Diagram 1. Observe the brightness of Light Bulb 1 when you close the switch.
- Make a series circuit with one power source, one switch, and two loads, as shown in Diagram 2. Connect the parts in this order: battery to switch; switch to Light Bulb 2; Light Bulb 2 to Light Bulb 1; Light Bulb 1 to battery.
- When you close the switch, observe how the light bulbs glow. Do they both glow as brightly as one bulb did? Does one bulb glow more brightly than the other?
- Make a series circuit with one power source, one switch, and three loads, as shown in Diagram 3. Connect the parts in this order: battery to switch; switch to Light Bulb 2; Light Bulb 2 to Light Bulb 3; Light Bulb 3 to Light Bulb 1; Light Bulb 1 to battery.
- When you close the switch, observe how the light bulbs glow.

Diagram 1

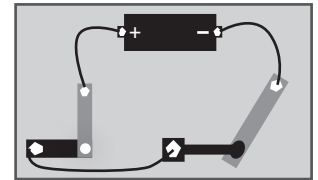


Diagram 2

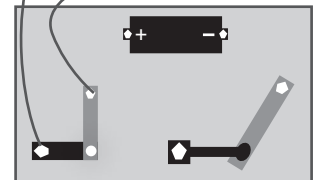
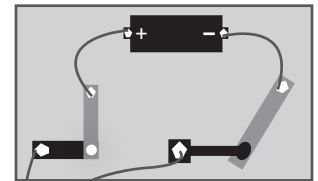
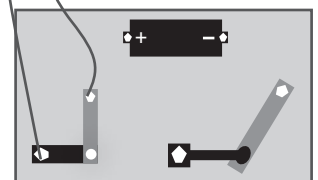
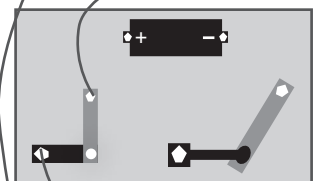
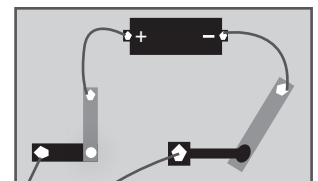
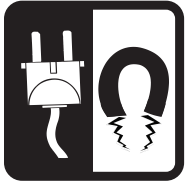


Diagram 3





Series Circuits 2

Background

In the first series circuits, you added loads (light bulbs) to the circuit. The amount of work that the loads could do decreased. In this experiment, you will add power sources (batteries) to the series circuit to see if the loads receive more power when the power sources and loads are connected in a series (one loop).

Question

- How will adding power sources affect loads wired in series?

Materials

- 3 Battery holders with switches and light sockets
- 3 Light bulbs
- 3 D Batteries
- 7 Pieces of wire or alligator clips

Hypothesis

Read the procedure and record your hypothesis.

Procedure

- First, close the switch in the circuit you made in Diagram 3 of *Series Circuits 1*. Observe the brightness of the bulbs.
- Make a series circuit with two power sources, one switch, and three loads, as shown in Diagram 4. Connect the parts in this order: Battery 1 (-) to Battery 2 (+); Battery 2 (-) to Switch 2; Switch 2 to Light Bulb 2; Light Bulb 2 to Light Bulb 3; Light Bulb 3 to Light Bulb 1; Light Bulb 1 to Battery 1 (+). Make sure you connect the negative end of Battery 1 (-) to the positive end of Battery 2 (+).
- When you close the switch, observe the brightness of the bulbs. Did their brightness change when you added another power source as compared to Diagram 3 of *Series Circuits 1* (Step 1 above)?
- Make a series circuit with three power sources, one switch, and three loads, as shown in Diagram 5. Connect the parts in this order: Battery 1 (-) to Battery 2 (+); Battery 2 (-) to Battery 3 (+); Battery 3 (-) to Switch 3; Switch 3 to Light Bulb 3; Light Bulb 3 to Light Bulb 2; Light Bulb 2 to Light Bulb 1; Light Bulb 1 to Battery 1 (+). Make sure you connect the negative end of one battery to the positive end of the other.
- When you close the switch, observe the brightness of the bulbs. Did their brightness change when you added another power source?

Data

Use the data table in *Series Circuits 1* on page 27 to record your observations.

Conclusion

- What happened to the brightness of the light as you added batteries to the circuit?
- Did adding power sources to the series circuit increase the power to the loads?
(power = voltage x current)

Diagram 4

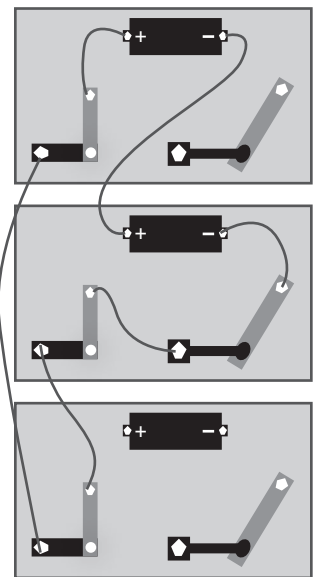
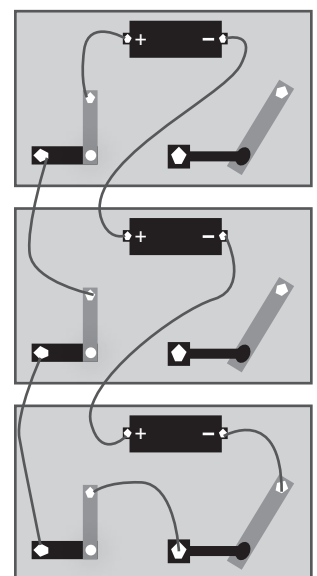
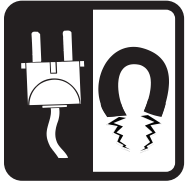


Diagram 5





Circuits

Background

For electrons to flow through a wire, the wire must make a complete path or circle. This path is called a circuit. A battery produces electricity, or moving electrons, only when it is part of a circuit. You can add a switch to a circuit to open and close the path. A compass can help you determine if your circuit is completed or not. If it is complete, electricity will flow, creating an electric field and magnetic field to move the compass. You can also add a load to the circuit so that the electricity can do work as it flows through the circuit. A light bulb is an example of a load.

Question

How does a completed circuit affect a compass?

Materials

- 1 Battery holder with switch and light socket
- 1 D Battery
- 1 Light bulb
- 1 Student compass
- 3 Pieces of wire or alligator clips

Hypothesis

Read the procedure and record your hypothesis.

Procedure

- Place the battery in the battery holder. Using one wire, attach the ends of the wire to the terminals on the sides of the battery holder, as shown in Diagram 1. Use the compass to determine if you have completed a circuit. Are there electrons flowing through the wire? Disconnect.
- Add a switch to the circuit. Unhook one end of the wire from the battery holder and attach it to one of the terminals of the switch, as shown in Diagram 2. Attach a second wire to the other end of the switch and to the other end of the battery holder.
- Place the compass under one of the wires. Close the circuit by pushing on the switch until it touches the metal under it. Open and close the switch several times, observing the movement of the compass needle.
- Add a load to the circuit. Attach the light bulb to the circuit as shown in Diagram 3. You will need three wires. One wire is attached to the battery holder and the light bulb holder. The second wire is attached to the light bulb holder and the switch. The third wire is attached to the other terminal of the switch and the battery holder.
- Close the switch. Have you made a circuit? Does the light bulb glow?

Diagram 1

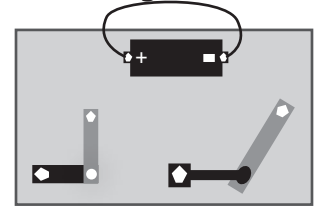
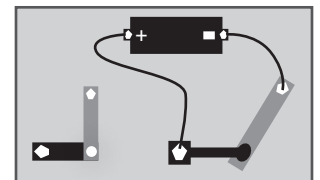
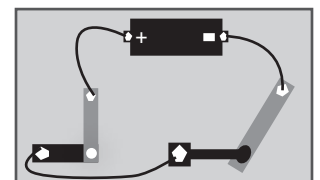


Diagram 2



circuit with switch

Diagram 3



circuit with switch and load

Data

Record your observations.

Conditions	Observations
Diagram 1 (Step 1)	Are there electrons flowing through the wire? How do you know?
Diagram 2 (Steps 2 and 3)	Movement of compass:
Diagram 3 (Steps 4 and 5)	Does the light bulb glow?

Conclusion

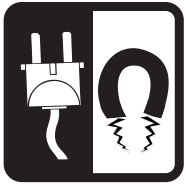
For each question, make sure you support your answer with experimental evidence. In other words, what about the experiment you just did verifies your answer?

1. In conductors, electrons are loosely bound and therefore easy to move. In insulators, electrons are tightly bound and therefore hard to move. Examine the switch. It is made of plastic and metal.

Which material is a better conductor?

Which material is an insulator?

2. Why do you think the copper wire is covered in a plastic coating?



Parallel Circuits

Background

In series circuits, electricity flows through all parts of the circuit in one loop. In parallel circuits, there are separate circuits within the larger circuit. If there is one power source and more than one load, each of the loads is connected to the power source separately. Part of the power goes to each load.

Question

How are parallel circuits different from series circuits?

Materials

- 3 Battery holders with switches and light sockets
- 1 D battery
- 9 Pieces of wire or alligator clips
- 3 Light bulbs

Hypothesis

Read the procedure and record your hypothesis.

Procedure

- First, make a simple circuit as shown in Diagram 1. Observe the brightness of Light Bulb 1 when you open and close the switch.
- Make a parallel circuit with one power source, two switches, and two loads, as shown in Diagram 2. Leave the first circuit as it is. Make a parallel circuit by connecting Battery 1 (-) with a second wire to Switch 2; Switch 2 to Light Bulb 2; Light Bulb 2 to Battery 1 (+).
- Close Switch 1 and observe the brightness of the light. Close Switch 2 and do the same. Now close both switches at the same time. Observe the brightness of the light bulbs.
- Make a parallel circuit with one power source, three switches, and three loads, as shown in Diagram 3. Leave the first two circuits as they are. Make a parallel circuit by connecting Battery 1 (-) with a third wire to Switch 3; Switch 3 to Light Bulb 3; Light Bulb 3 to Battery 1 (+).
- Close Switch 1 and observe the brightness of the light. Close Switches 1 and 2 and do the same. Now close all three switches at the same time. Observe the brightness of the light bulbs.

Diagram 1

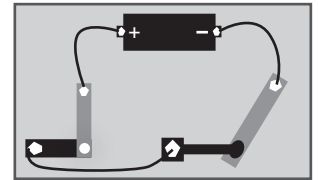


Diagram 2

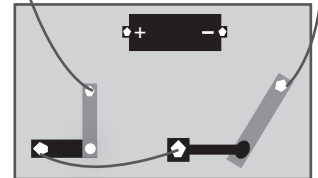
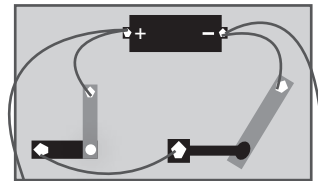
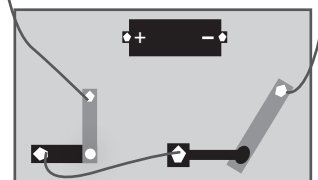
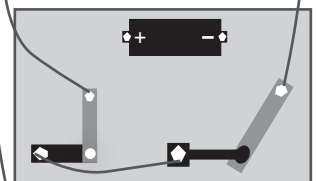
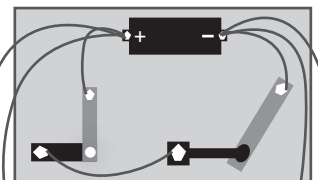


Diagram 3



Data

Record your observations.

Conditions	Observations
Diagram 1	How bright is the bulb?
Diagram 2, first switch only	How bright is the bulb?
Diagram 2, second switch only	How bright is the bulb?
Diagram 2, both switches	How bright are the bulbs?
Diagram 3, switch 1 only	How bright is the bulb?
Diagram 3, switches 1 and 2 closed	How bright are the bulbs?
Diagram 3, all switches closed	How bright are the bulbs?

**** Conclusion**

For each question, make sure you support your answer with experimental evidence. In other words, what about the experiment you just did verifies your answer?

1. If one of the light bulbs is unscrewed, will the other bulbs glow? Try it and see. Explain your observations.

2. Do you think the battery would last as long with three circuits as with one?



Mixed Circuits

Background

In this experiment, you will build circuits that have both series and parallel connections. You will connect the power sources in series circuits and the loads in parallel circuits.

Question

- How do loads behave in mixed circuits?

Materials

- 3 Battery holders with switches and light sockets
- 3 D Batteries
- 12 Pieces of wire or alligator clips
- 3 Light bulbs
- Colored pencils

Hypothesis

Read the procedure and record your hypothesis.

Procedure

- Make a mixed circuit with two batteries in series and two bulbs in parallel, as shown in Diagram 1. Connect the negative end of Battery 1 to the positive end of Battery 2. Connect the positive end of Battery 1 to both light bulbs. Connect the negative end of Battery 2 to Switch 2. Connect the other end of Switch 2 to both light bulbs at the unused connection point. Do not connect anything to Switch 1.
- Close Switch 2 and observe the brightness of the bulbs. Unscrew one of the bulbs and observe the brightness of the remaining bulb.
- Make a mixed circuit by connecting three batteries in series and three bulbs in parallel, as shown in Diagram 2. Connect the positive end of Battery 3 to the negative end of Battery 2, and the positive end of Battery 2 to the negative end of Battery 1. Connect the positive end of Battery 1 to Switch 1. Connect the other end of Switch 1 to all three bulbs. Connect the unused connections of all three bulbs to Switch 3. Connect the negative end of battery 3 to the unused end of Switch 3. Switch 2 will not be used. Close only Switch 3, leaving Switch 1 open. Observe.
- Close Switch 1 and observe the brightness of the bulbs. Unscrew one bulb and observe the brightness of the other two bulbs. Unscrew one of the remaining bulbs and observe the last bulb's brightness.

Diagram 1

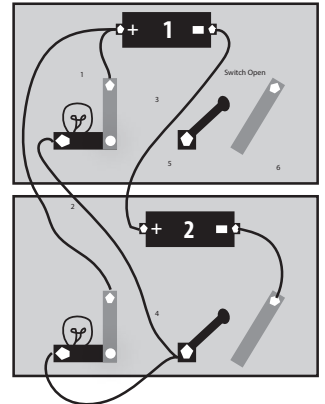
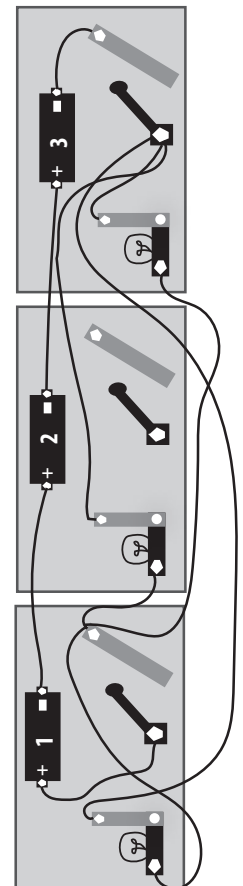


Diagram 2



 **Data**

Record your observations.

Conditions	Observations
Diagram 1, both bulbs	How bright are the bulbs?
Diagram 1, only one bulb	How bright is the bulb?
Diagram 2, all bulbs	How bright are the bulbs?
Diagram 2, one bulb removed	How bright are the remaining bulbs?
Diagram 2, two bulbs removed	How bright is the remaining bulb?

**** Conclusion**

For each question, make sure you support your answer with experimental evidence. In other words, what about the experiment you just did verifies your answer?

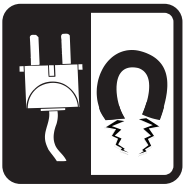
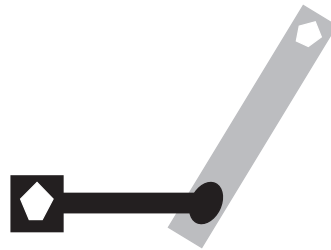
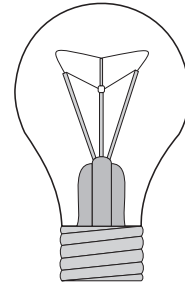
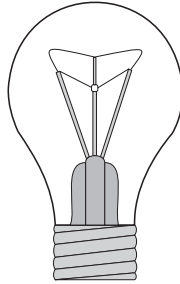
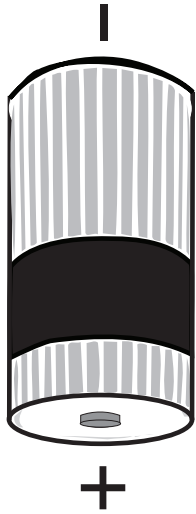
1. Could you tell that the power from the batteries was divided in the parallel circuits? What experimental evidence supports your answer?

2. If you wanted a string of lights to keep working if one of the bulbs burned out, would you wire the lights in series or parallel? Why?



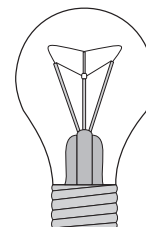
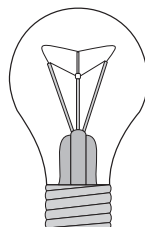
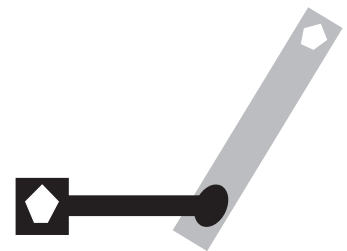
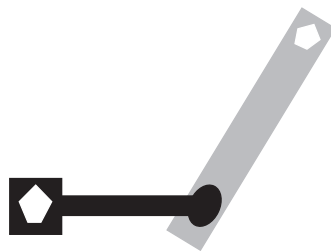
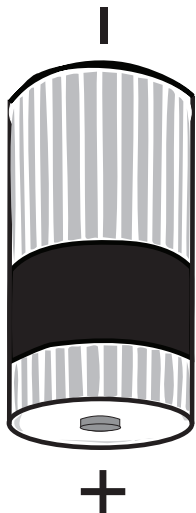
Circuit Worksheet 1

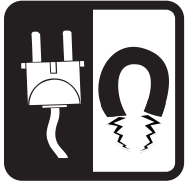
Instructions: Draw wires between all of the parts below to make a series circuit. Use different colored pencils to draw the different wires.



Circuit Worksheet 2

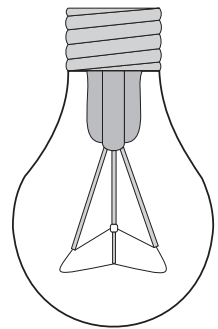
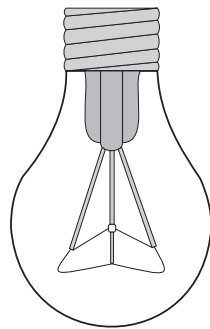
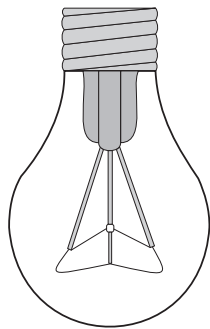
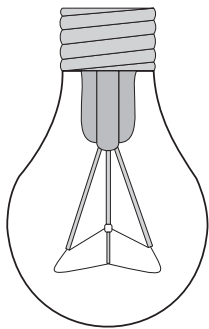
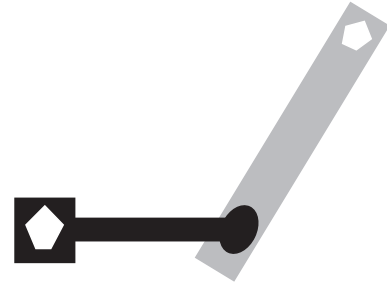
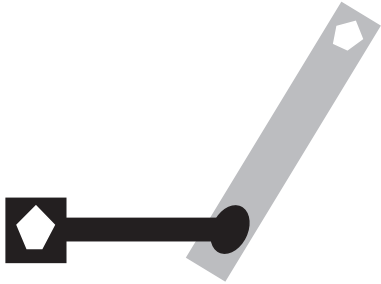
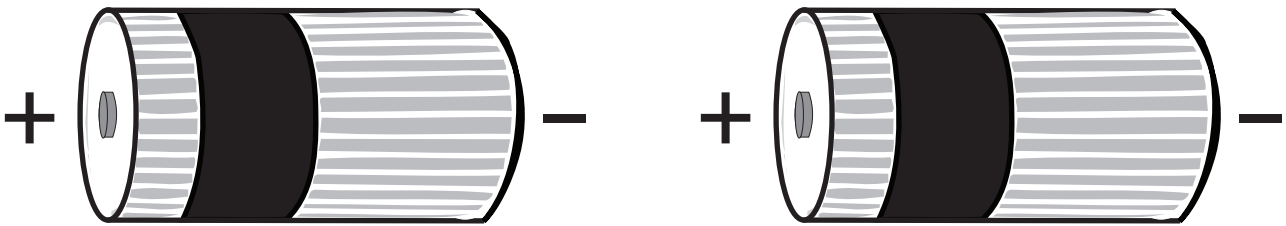
Instructions: Draw wires between all of the parts below to make parallel circuits. Use different colored pencils to draw the different wires.

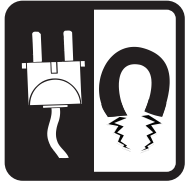




Circuit Worksheet 3

Instructions: Draw wires with different colored pencils to connect the batteries in series and the lights in parallel circuits.

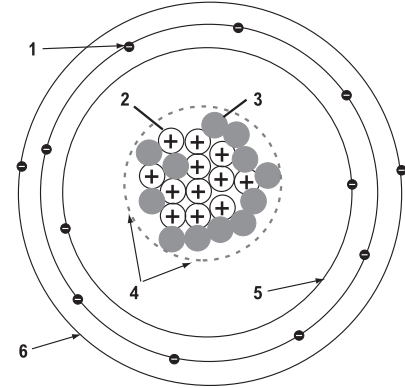




Review

1. Identify this atom, which has 29 protons, 29 electrons, and 35 neutrons. Circle the electrons that are loosely held and write the numbers to identify the following parts of the atom:

What is this atom? _____
electron _____
neutron _____
proton _____
nucleus _____
outer energy level _____
inner energy level _____



2. Circle the correct answer for each set of magnets below.

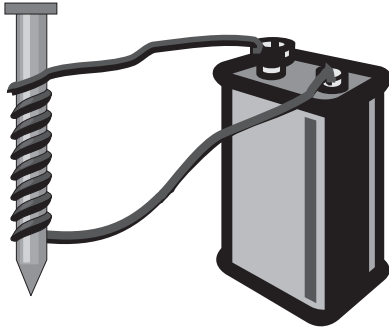


attract or repel

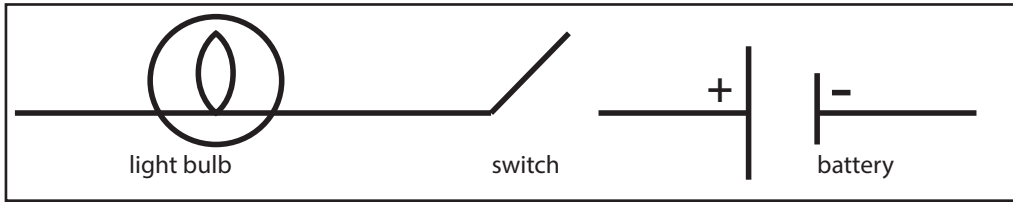


attract or repel

3. Explain what the device pictured below does.



Use these symbols to draw circuit diagrams:



4. Draw a series circuit with two batteries, one switch, and three light bulbs.

5. Draw a parallel circuit with a battery, two switches, and two light bulbs.

6. Draw a circuit with two batteries and one switch in series, and three light bulbs in parallel.



Sample Electricity Calculations

Example 1: Calculating Voltage

If household current is 6 amps and the resistance of an appliance is 20 ohms, calculate the voltage.
To solve for voltage, use the following equation: voltage = current x resistance ($V = I \times R$).

Example 2: Calculating Current

The voltage of most residential circuits is 120 V. If we turn on a lamp with a resistance of 60 ohms, what current would be required?
To solve for current, use the following equation: current = voltage / resistance ($I = V / R$).

Example 3: Calculating Resistance

A car has a 12-volt battery. If the car radio requires 0.5 amps of current, what is the resistance of the radio?
To solve for resistance, use the following equation: resistance = voltage / current ($R = V / I$).

Example 4: Calculating Power

If a 6 V battery pushes 2 A of current through a light bulb, how much power does the light bulb require?
To solve for power, use the following equation: power = voltage x current ($P = V \times I$).

Example 5: Calculating Voltage

If a 3 A blender uses 360 W of power, what is the voltage from the outlet?
To solve for voltage, use the following equation: voltage = power / current ($V = P / I$).

Example 6: Calculating Current

If a refrigerator uses power at a rate of 600 W when connected to a 120 V outlet, how much current is required to operate the refrigerator?
To solve for current, use the following equation: current = power / voltage ($I = P / V$).

Example 7: Calculating Electrical Energy and Cost

If a refrigerator uses power at a rate of 600 W for 24 hours, how much electrical energy does it use?
To solve for electrical energy, use the following equation: electrical energy = power x time ($EE = P \times t$).

If the utility charges \$0.12 a kilowatt-hour, how much does it cost to run the refrigerator for 24 hours?
To calculate cost, use the following equation: cost = electrical energy x price.



Measuring Electricity

TABLE 1

VOLTAGE	=	CURRENT	X	RESISTANCE
1.5 V	=	_____ A	x	3 Ω
_____ V	=	3 A	x	4 Ω
120 V	=	4 A	x	_____ Ω
240 V	=	_____ A	x	12 Ω

TABLE 2

POWER	=	VOLTAGE	X	CURRENT
27 W	=	9 V	x	_____ A
_____ W	=	120 V	x	1.5 A
45 W	=	_____ V	x	3 A
_____ W	=	120 V	x	2 A

TABLE 3

APPLIANCE	POWER	=	VOLTAGE	X	CURRENT
TV	180 W	=	120 V	x	_____ A
COMPUTER	40 W	=	120 V	x	_____ A
PRINTER	120 W	=	120 V	x	_____ A
HAIR DRYER	1,000 W	=	120 V	x	_____ A

TABLE 4

POWER	x	TIME	=	ELECTRICAL ENERGY (kWh)	X	PRICE	=	COST
5 kW	x	100 h	=	_____	x	\$ 0.12	=	\$ _____
25 kW	x	4 h	=	_____	x	\$ 0.12	=	\$ _____
1,000 W	x	1 h	=	_____	x	\$ 0.12	=	\$ _____



Glossary

amp or ampere	unit for measuring electric current
atom	the smallest unit of an element that retains the element's properties
battery	a device that transforms chemical energy into electrical energy
chemical energy	the energy stored within the chemical bonds of substances
circuit	a closed-loop pathway for electricity
conductor	a substance with electrons that can move around easily and transmit electrical energy
electric current	the rate at which electrical charges, usually electrons, flow past a certain point
electric field	the amount of electric force per electric charge; the greater the electric force, the stronger the electric field
electricity	electrons moving through an object
electromagnetism	name given to the fundamental force that ties magnetic fields and electric fields together
electron	very tiny, negatively charged, subatomic particle that moves around the nucleus of the atom
element	most basic of all substances; all other substances are made of various combinations of elements
energy level	region of space where an electron is most likely to be found
generator	a device that transforms circular motion into electrical energy
insulator	substance in which electrons cannot move easily
inverter	an electronic device that can change alternating current (AC) to direct current (DC)
load	device within an electric circuit that does work
magnet	object in which all magnetic domains are lined up in the same direction, and which responds to a magnetic field
magnetic field	region of space that is able to change the direction of a moving, charged particle
motor	a device that transforms electrical energy into circular motion
neutron	subatomic particle with no electric charge found in the nucleus of an atom
nucleus	the center of an atom where the vast majority of the atom's mass is found, and which contains the protons and neutrons
ohm	unit used to measure electric resistance
Ohm's Law	relationship between voltage, current, and resistance, that states the voltage across a load is proportional to the current flowing through the load of a circuit
power	the rate at which work is done; the rate at which energy is converted
proton	subatomic particle with a positive electric charge found in the nucleus of an atom
radiant energy	energy that travels through space in waves; light is an example of radiant energy
resistance	the degree to which an object will slow the flow of electrons
static electricity	build up of electrical charge on a surface
turbine	a device that changes linear motion into circular motion
volt	unit used to measure voltage, or electrical potential
voltage	the potential, or pressure, behind electrical charges
watt	unit used to measure power
watt-hour	unit used to measure electrical energy, calculated by multiplying power x time



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PECO
Pecos Valley Energy Committee
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United Way of Greater Philadelphia and Southern New Jersey
University of Nevada–Las Vegas, NV
University of Tennessee
University of Texas - Austin
University of Texas - Tyler
U.S. Department of Energy
U.S. Department of Energy–Hydrogen Program
U.S. Department of Energy–Office of Energy Efficiency and Renewable Energy
U.S. Department of Energy–Office of Fossil Energy
U.S. Department of Energy–Wind for Schools
U.S. Department of the Interior–Bureau of Land Management
U.S. Energy Information Administration
West Bay Exploration
Western Massachusetts Electric Company
W. Plack Carr Company
Yates Petroleum Corporation