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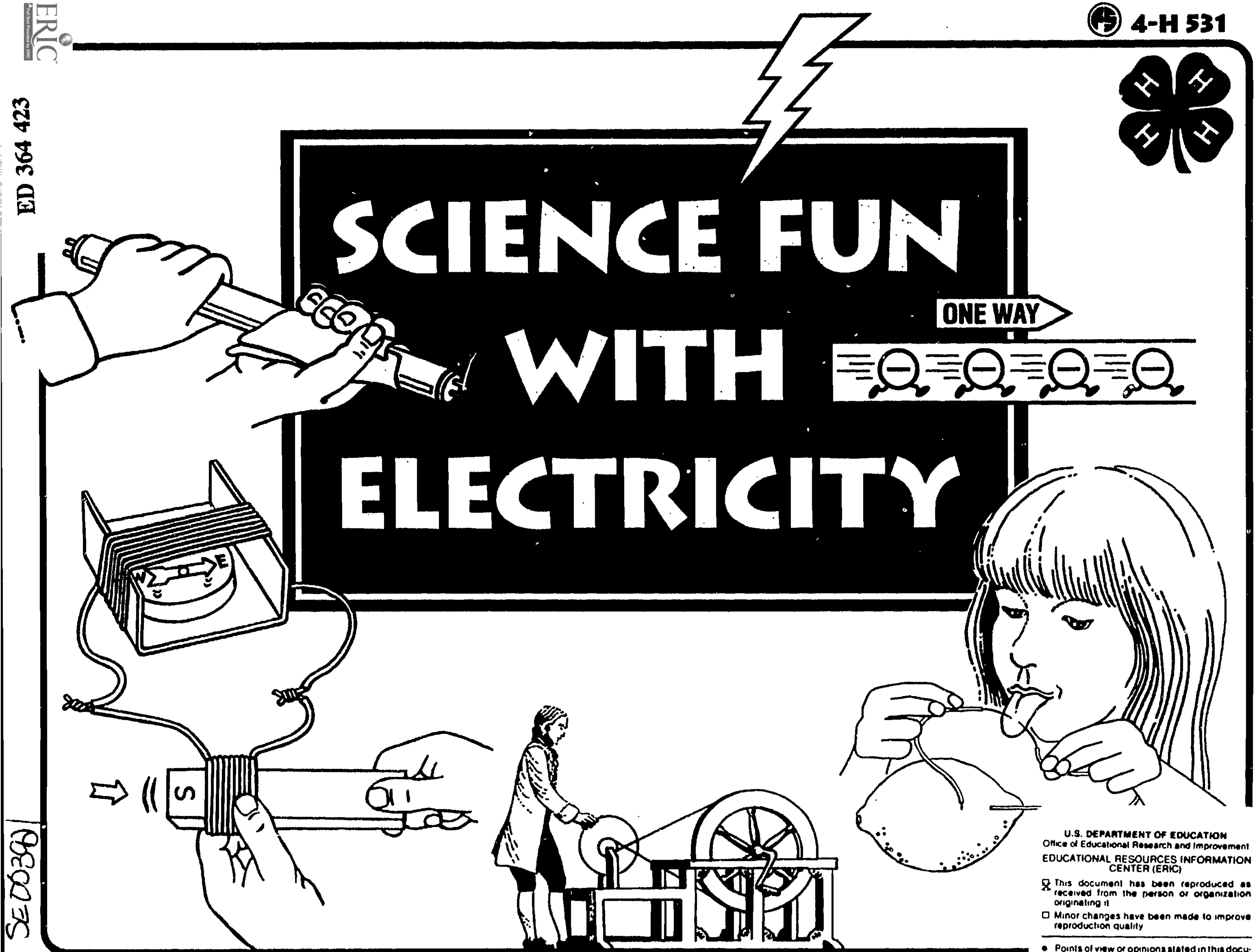
ABSTRACT

This project manual is written for 4-H member children who are in the fifth grade or older. This project is designed to familiarize members with the scientific history concerning the discovery and application of electric energy through the 1800's. Readers can conduct experiments similar to the ones performed by the scientists and inventors of that day. Topics include static electricity, current electricity, electromagnetism, electromagnets, electric generation, electric motors, and electric light. (PR)

4-H 531

SCIENCE FUN WITH ELECTRICITY



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Science Fun With Electricity

. . . Discoveries and Innovations

BY ROBERT L. HORTON, PH.D.

Extension 4-H Specialist, Science Education, The Ohio State University

This book is dedicated to my daughters Christy, Carrie and the kids of the neighborhood for their invaluable curiosity and willingness to try.

Development of this project was supported by the National Center for Science Teaching and Learning under grant #R117Q00062 from the Office of educational Research and Improvement, U.S. Department of Education

Additional technical support provided by Randall Reeder, Extension Specialist, Agricultural Engineering, The Ohio State University

THE NATIONAL CENTER FOR SCIENCE TEACHING & LEARNING

Member Project Guide

Project Background

This beginning level project is written for members who are in the fifth grade or older. Younger members may take this project under the supervision of an adult. Due to the technical nature of the project, members may focus on a few of the Activities per year. This will allow the individual to explore thoroughly each experiment and Digging Deeper Activity. It will also help reduce the costs associated with completing all the experiments and activities in one year.

This project is designed to familiarize members with the scientific history concerning the discovery and application of electric energy through the 1800's. Members will conduct experiments similar to the ones performed by the scientists and inventors of that day.

As members move through the manual they will note that the experiments have been organized chronologically to their place in history. This allows the members, like earlier scientists, to build upon previous discoveries.

Members should also note the timeline which runs through the book. It provides a graphic representation of the historical development of electricity. Note that once the basics of electricity had been learned, inventors like Edison and Morse quickly appeared on the scene to apply this new knowledge. This is evident by the abundance of dates and events toward the end of the 19th century as compared to the beginning. In fact things were happening so fast that only a fraction of the important events are listed.

Check your county project guidelines for additional requirements for taking this project, especially if you choose to participate in county project judging or prepare an exhibit for the fair. Members who complete this project are encouraged to move to the next level of 4-H electric energy projects.

Project Guidelines

1. Complete the Planning Section of this guide (steps 1-4).
2. Explore each of the Project Interest Areas.
3. Complete at least one of the experiments for each Interest Area selected. Digging Deeper Activities are optional.
4. Build a DC motor from scratch or from a kit. See page 20 for details.
5. Take part in at least two Organized Project Activities.
6. Become involved in at least two Citizenship/Leadership activities.

PLANNING YOUR PROJECT

Steps 1 and 2
PROJECT INTEREST AREAS AND ACTIVITIES

Explore each of the Project Interest Areas listed. Plan to complete at least one of the experiments in each Interest Area. Digging Deeper Activities are optional. Have your parent or advisor initial and date what you complete.

Date Completed	Interest Areas and Activities
	1. STATIC ELECTRICITY, *page 8*
____________	**Experiment 1** — Charge a Balloon
____________	**Experiment 2** — Static Electricity Light
	2. CURRENT ELECTRICITY, *page 10*
____________	**Experiment 3** — Tongue Test
____________	**Digging Deeper** — Getting Electricity From a Lemon
____________	**Digging Deeper** — Potato Polarity Indicator
	3. ELECTROMAGNETISM, *page 12*
____________	**Experiment 4** — Magnetic Field Around a Current Carrying Wire
____________	**Experiment 5** — Making a Galvanscope
	4. ELECTROMAGNET, *page 15*
____________	**Experiment 6** — Make an Electromagnet
____________	**Digging Deeper** — Polarity Check
____________	**Digging Deeper** — Magnetize a Screwdriver
	5. ELECTRIC GENERATON, *page 17*
____________	**Experiment 7** — Induce Current From a Magnet
____________	**Digging Deeper** — AC/DC Detection
	6. ELECTRIC MOTOR, *page 19*
____________	**Activity** — Magnetic Force
____________	**Experiment 8** — Build a DC Electric Motor
	7. ELECTRIC LIGHT, *page 22*
____________	**Experiment 9** — Light a Coiled Strand of Wire

Step 3
Organized Project Activities

Select two of the organized project activities listed below, and plan your involvement in the Report of Organized Activities chart. Before starting your project write your choices in the section labeled Plan To Do. Once you have taken part in an activity, record what you did and when. Organized Activities may be added or changed at any time.

Sample Organized Activities

Demonstration	Speech
County Judging	Illustrated Talk
Tour	Project Meetings
Project Exhibit	Workshop
Field Trip	Radio/TV Presentation
Mall Show	Short Course

Report of Organized Activities

Plan To Do	Date Completed	Interest Areas and Activities
Demonstration	Date: 5/28	What I Did: Showed club members how my D C electric motor worked

Step 4
Leadership/Citizenship Activities

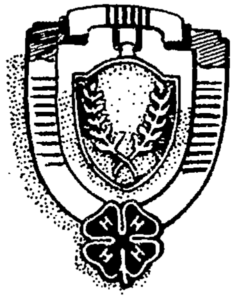
Check the activities you wish to do or plan your own in the space provided. Do at least two. Keep track of your progress by marking the date (month and year) when you are through. Leadership/Citizenship activities may be added or changed at any time.

Plan	to Do	When I Finished
		Leadership/Citizenship Activities
☐	______	Encourage someone to take an electric project.
☐	______	Help someone with his or her electric project.
☐	______	Organize an electric safety clinic in your community.
☐	______	Invite someone to talk to your club on electricity.
☐	______	Prepare and exhibit or poster about electricity.
☐	______	Teach someone something you learned about electricity.
☐	______	Encourage a friend to join 4-H.
☐	______	Apply something you learned about electricity to benefit your family.
☐	______	Help a member prepare his or her electric project for judging.
☐	______	Help a member prepare an electric exhibit for the county fair.
☐	______	Plan your own activities here. ______

Project Review

Once you complete what you planned, arrange for local project review. This review can take part with your parent, project advisor or interested adult. It may also be part of a more comprehensive member evaluation at a time agreed upon by club members. Such evaluations are designed to help you evaluate what you learned as well as your growth as a 4-H member. Members who take part in this level of evaluation can receive special membership and project achievement awards like ribbons, pins and certificates.

In addition, you may want to take part in county project judging. However, this level of evaluation determines "how well" you did on your project by assigning you a "project grade." You will also be compared against the achievements of others in order to determine "the best" in your project area, as well as possible state fair participation. For more information refer to 4-H 956, 4-H Member Recognition Program, or contact your local Extension office for specific county project judging information.



Congratulations to...

For successfully planning and completing the

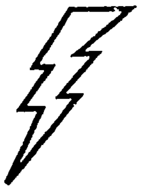
BEGINNING LEVEL 4-H PROJECT

Offered by Ohio State University Extension

date

THE OHIO STATE UNIVERSITY EXTENSION

1 Static Electricity



When any two different materials come into contact, tiny particles of electricity called "electrons" move from one to the other. This gives both materials an electric charge. Objects that gain electrons become negative while objects that lose electrons become positive.

The simple act of flicking a switch to turn on a lamp in a dark room is the result of centuries of investigation and experimentation. The science of electricity, the power that lights and heats our homes, operates complex machinery and produces convenience and entertainment for millions of people, began more than 2,000 years ago in ancient Greece. There, a scientist by the name of Thales of Miletus, born in 640 BC, observed an unusual property of amber, a plastic type of material commonly used for jewelry. When rubbed briskly with fur, the amber would attract bits of cloth, wool and fur.

What the Greeks observed was something called "static electricity." "Static" means "still," or "not moving." This early Greek discovery also provided the basis for the word "electricity." Their name for amber was "electron." Try Experiments 1 & 2 to explore this discovery.

Experiment 1

Charge a Balloon

Try this experiment to observe static electricity at work.

You will need:

Rubber balloon
Piece of wool or fur

Inflate the balloon, tie its neck securely and rub it quickly against a piece of wool. Now hold the balloon against the wall. It will stick.

Explanation

Rubbing the balloon removed some of the free electrons from the wool. This gave the balloon a negative charge and the wool a positive charge. When the charged balloon was brought in contact with the uncharged wall, it exchanged electrons with the wall, causing it to stick.

Question

Explain what happens when you get "static shock" in the winter after walking across a carpeted area. Why does this happen more in the winter than in the summer? What type of charge are you giving off, negative or positive? ______________________

____

____

Timeline

▲ **640 BC**
Thales of Miletus discovers static electricity.

Experiment 2

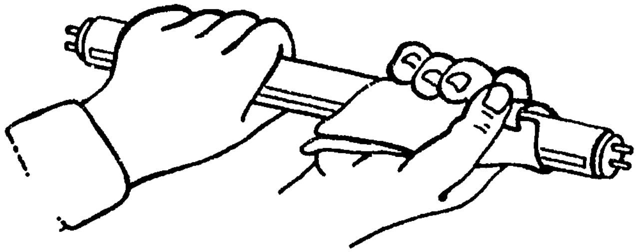
Static Electricity Light

Try this experiment to observe the power of static electricity.

You will need:

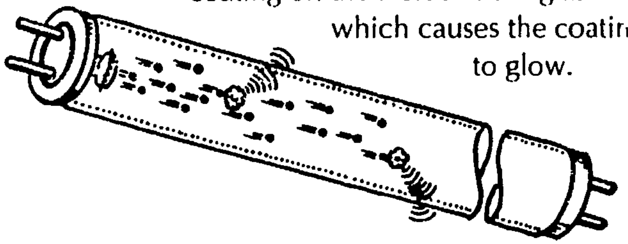
Fluorescent tube
Piece of wool
Dark room

In a dark room, rapidly rub the tube with the wool cloth as shown below. The tube will try to light.



Explanation

The friction between the wool and the glass tube caused electrons to strike and dislodge electrons from atoms in the gas inside the tube. When these dislodged electrons try to get back into their atoms, they give off ultraviolet rays. These rays strike a phosphor coating on the inside of the glass tube, which causes the coating to glow.



It wasn't until 1600 that practical progress began with static electricity. In that year, English physician William Gilbert described the static attraction in amber. Later that century (1663), Otto Van Guericke built one of the first static electric machines. This was followed in 1745 by the invention of the Leyden Jar by Dutch mathematician named Pieter van Musschenbroek. He covered a thin glass jar inside and out with metal foil. Through the wrapping, he inserted a brass rod with a hook at top. A chain provided contact with the inner foil and the ground. Musschenbroek found the device would **store electrical charges.** This was a very important discovery because before this time no method had been found for storing static charges.

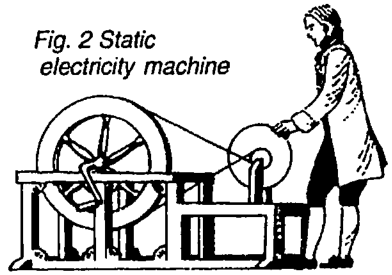


Fig. 2 Static electricity machine

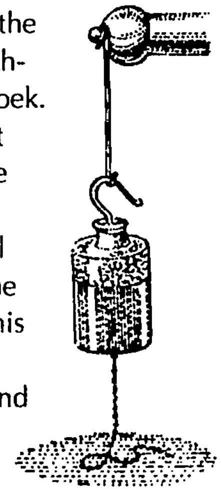


Fig. 3 Leyden Jar Stores electrical charges

An equally important discovery occurred in 1787 by an English scientist named Abraham Bennet. In that year Bennet perfected what he called the "electroscope." An electroscope has two strips of metal foil hanging inside a glass vessel. A charged amber rod touching the metal ball on top of the instrument causes the leaves to repel each other. This instrument was useful for determining the presence of electrostatic charges as well as determining the polarity of the charges.

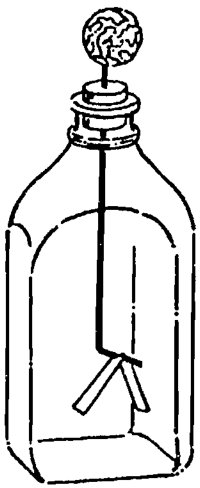


Fig. 4 Electroscope

1296 AD Petrus Peregrinus discovers properties of magnetism.

1600 The word "electricity" coined from the Greek word "electron" by William Gilbert.

1663 Otto Van Guericke builds the first static electric machine.

2 CURRENT ELECTRICITY

Inside the battery is a carbon rod and zinc container to produce an electric charge. A current flows if the rod and container are connected. When the chemicals are used up, the battery goes dead.

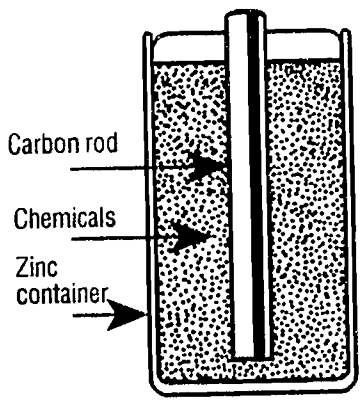


Fig. 5 Zinc carbon battery

In 1786, Luigi Galvani observed how a frog's legs moved when exposed to a strong static charge. He also observed that when he touched the legs with copper and zinc instruments, they also moved. He concluded that the action had something to do with the "static electricity trapped in the frog." Although his conclusion was wrong, his work made other scientists aware of this unusual occurrence.

In 1800, Alessandro Volta, an Italian physics professor discovered why the frog's legs moved. He determined that Galvani's discovery was **a new form of electricity** which he called **"current electricity."** This type of electricity was generated from the chemical action of moisture in the frog coupled with the copper and zinc instruments.

Further experimentation led Volta to produce the **first source of continuous current electricity — the battery**. He made it of stacked copper and zinc plates separated by paper or cloth that had been soaked in a salt solution. This early source of battery power was referred to as a "voltaic cell." Try Experiment 3 and the two Digging Deeper Activities to explore this discovery.

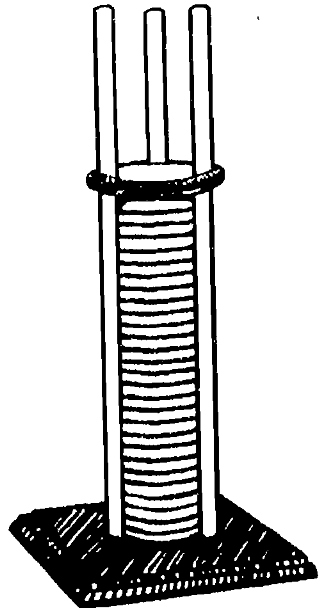
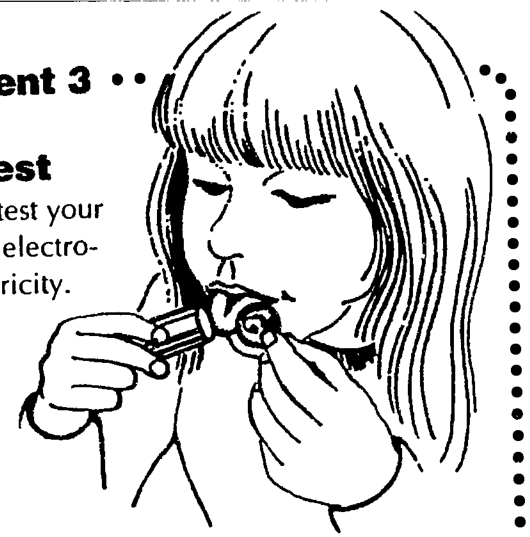


Fig. 6 Voltaic cell

Experiment 3

Tongue Test

Make and test your own source of electro-chemical electricity.



You will need:

1 zinc carbon battery *(general purpose type)*
Copper penny *(Best if minted before 1980 due to high copper content)*
Hand tools

With help from an adult, take apart a zinc carbon battery. Wash the container thoroughly. Place the container and the clean copper penny on your tongue. Touch the coin and container together. You will feel a tingling sensation. Move them apart and it stops.

Explanation

The container is made of zinc. If zinc and copper are placed in salty water and connected together, a small electric current flows between them. Your saliva is slightly salty, so the coin and container produce a weak current. You feel this current because your tongue is very sensitive.

1729 Stephen Gray discovers the idea of conductors vs non-conductors.

1733 Charles Du Fay discovers that like charges repel and unlike attract.

1745 Pieter Van Musschenbrock develops the Leyden Jar; static electricity can now be built up and stored.

Digging Deeper

Getting Electricity From a Lemon

Try making electricity from a natural power source.

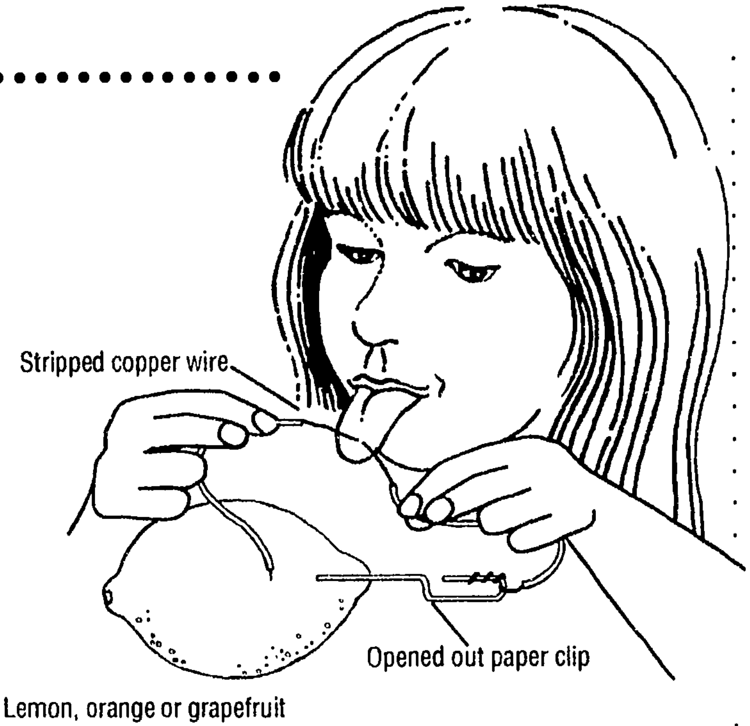
You will need:

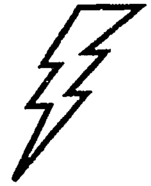
Lemon
Paper clip
12 feet 22-gauge insulated wire, single strand

Another form of a voltaic cell can be made by using a lemon. This cell consists of two electrodes, separated and immersed in an electrolyte. Two different materials are used for the electrodes so the electrolyte (lemon juice) will act more on one electrode than it does on the other and produce a potential difference between them.

Here is how to make the cell: Roll the lemon on a hard surface with your palm to break up some of the tissue. Straighten the paper clip, and push it about half way into the lemon. Clean the insulation off the wire, and push it into the lemon near the paper clip. Both wires should be close to each other but should not be touching inside or outside the lemon. If you have any difficulty inserting the wire, first make a hole with the paper clip so it may be inserted more easily.

To find whether the lemon is a source of electricity, touch your tongue to the ends of the two wires that come from the lemon. You will taste slight acidity. You may even feel a slight tingling. This is the same sensation you can experience by touching your tongue to the terminals of a 9 volt (transistor) battery. You may also try this experiment with an orange or any other citrus fruit.





In 1750, Ben Franklin originated the terms "positive" and "negative" for electrical polarity. He is said to have discovered the bi-pole (+/-) nature of electricity during his experiments with lightning. His lighting experiments also led way to his invention of the lightning rod.

1750
Ben Franklin gives + and - designations to electricity and invents lightning rod.

1786
Galvani inadvertently discovers "current electricity" while experimenting with frog.

Electricity can also be generated from heat and is called thermoelectricity. In 1821 Thomas J. Seebeck, a German physicist, observed that an electric current is generated when copper and iron wires are joined and their junction point heated.

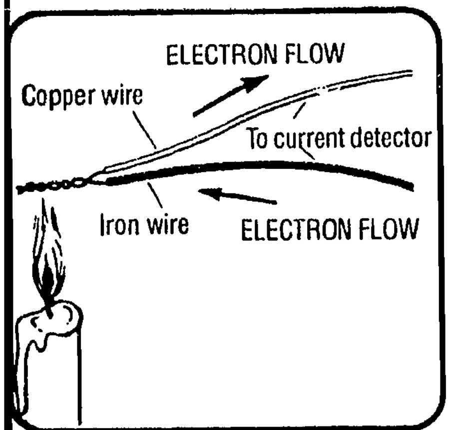
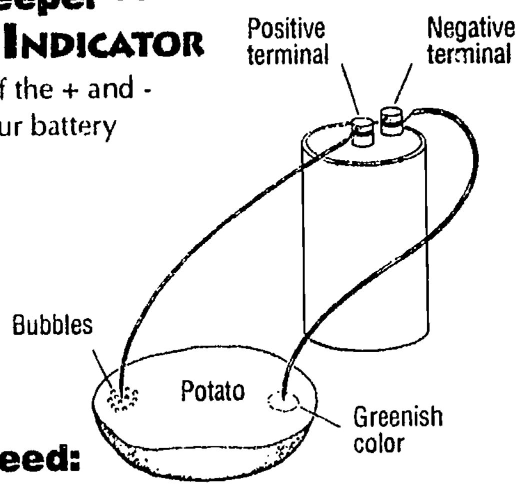


Fig. 9 Thermoelectricity

Digging Deeper

Polarity Indicator

Test to see if the + and - markings on your battery are correct.



You will need:

One potato
Four feet 22-gauge insulated wire, single strand
1 6-volt lantern battery

Sometimes it may be necessary to determine the polarity of a storage battery, such as one in an automobile or boat, because the markings have become obscured. When this happens, a potato may be used.

Slice the potato in half. Connect leads from both terminals of the battery to the potato as illustrated. Put the wires about one inch apart so that they do not touch inside or outside of the potato. Also make sure the part of each wire which goes into the potato has all the insulation removed.

In a short time, green discoloration will be noticed around one of the wires. At the same time there may be some bubbling *(or no indication of any activity at all)* at the other wire. The discoloration is around the lead going to the negative terminal. The other wire, where the bubbles appear, goes to the positive terminal.

3 Electromagnetism

The effects of Volta's discovery on the scientific world were immediate. At last, scientists had a continuous source of electricity with which to work. In 1819, a Danish scientist, Hans Christian Oersted, discovered that

Experiment 4

Magnetic Field Around a Current Carrying Wire

Try this simple experiment to see how a current carrying wire gives off a magnetic field.

You will need:

Wire hanger
Cardboard
Compass
2 feet of 22-gauge insulated wire, single strand
1 6-volt lantern battery

Make a stand from a wire hanger as illustrated in Figure 10. Scrape the coating off the hanger for about an inch at either end. Cut a piece of cardboard at least eight inches square with a hole in the middle and draw three concentric circles on it. These should be spaced about one inch apart with the inner circle about two inches from the wire. Center the board on the stand so it stays about half way up without slipping. A little tape will help hold it in position.

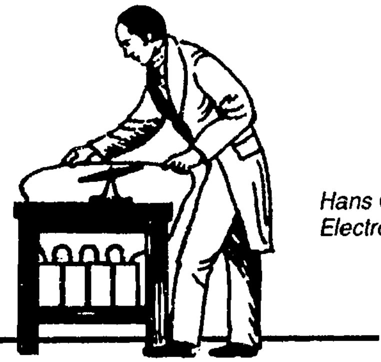
1787 Bennet invents "electroscope" to detect polarity of static electric charges.

1800 Volta's invention of first practical storage battery, the "Voltaic Pile."

1808 Dumphry Davy creates "arc light" from a reflected spark.

1819 Oersted discovers magnetic field is caused by electric current.

a compass held near a wire carrying current from a battery would move the needle. This was the discovery of electromagnetism. Try experiment 4 to further explore this discovery.



Hans Christian Oersted's Electromagnetism experiment

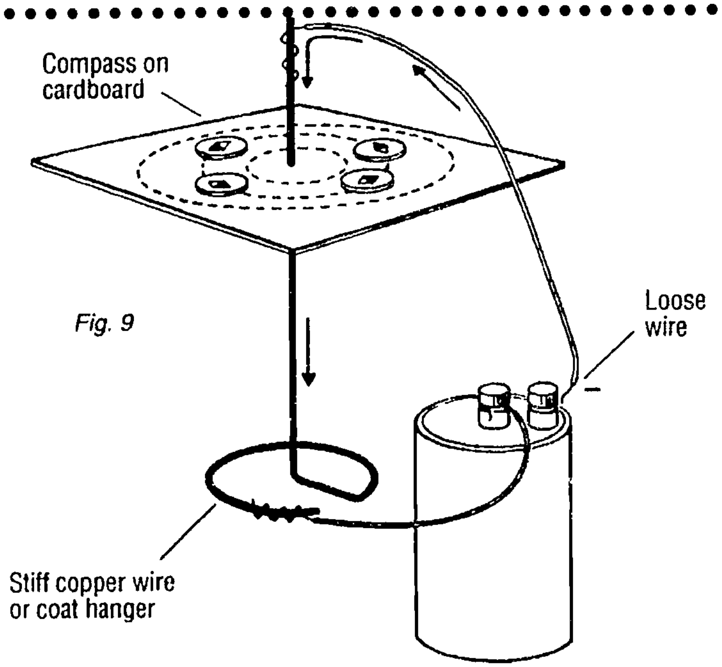


Fig. 9

Connect the stand with a wire to one terminal of the battery as shown. Lay the compass on any spot on the first circle and connect the loose wire to the other battery terminal. The compass needle will align itself with the circle. Try moving the compass to different spots on the circle or other circles.

Explanation

The results of this experiment indicate that

- the direction of the magnetic field is constant.
- the magnetic field is located all around the wire.
- the magnetic field spreads from the center similar to the pattern which forms when a pebble is thrown into a lake.

Question

What would happen to the strength of the electromagnetic field if the wire was looped through two or more times and then connected to the battery? ____________

____

____

Natural magnets called *loadstones* or *leading stones* were used by early explorers to find their way on sea voyages. The Greeks discovered this magnetic rock near the city of Magnesia. They named the rock "magnetite" for the city.

1820
Andre Ampre discovers relationship between electricity and magnetism.

1821
Faraday shows that electric energy could be converted into mechanical motion.

1821
Seebeck discovers that electric current can be produced when two dissimilar metals are joined and heated.

Oersted's discovery shows a direct **relationship between electricity and magnetism**. This was a important, because the only source of magnetism before that time was from natural magnets called loadstones. Based on Oersted's find, an instrument called a Galvanscope was soon perfected to detect electromagnetic current. Try Experiment 5 to further explore this discovery.

Experiment 5

Make a Galvanscope

Make a galvanscope to further explore the relationship between electricity and magnetism.

You will need:

Compass
Flashlight battery
3 x 4-inch piece of cardboard
10 feet of 22-gauge insulated wire, single strand

Fold two ends of the cardboard to form supports for the wire, then wrap the wire around the cardboard about 30 times (Figure 13.1). Leave about a foot of surplus wire for connections. Scrape about a half an inch of the insulation from each end of the wire. Place the compass on the cardboard and beneath the wire as shown in Figure 13.2. Turn the cardboard so the wires run east and west then connect them to the battery (Figure 13.3). When the ends of the wires are connected to the battery, the compass needle will be deflected nearly east and west, showing the current flow. This movement indicates the presence of an electromagnetic field within the coil.

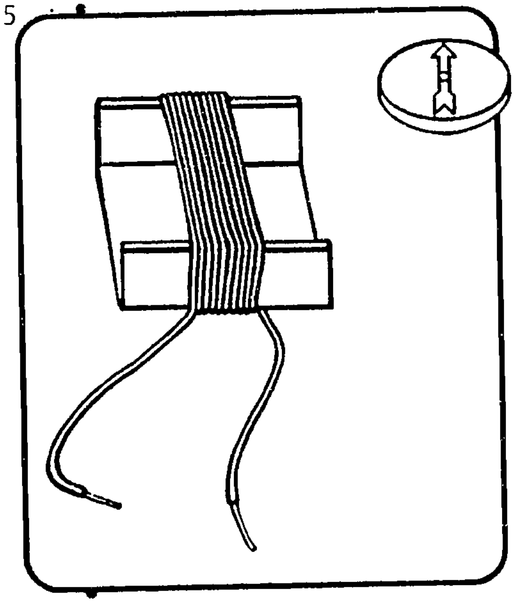


Fig. 13.1 Wrap the wire around the cardboard and remove the insulation from the ends.

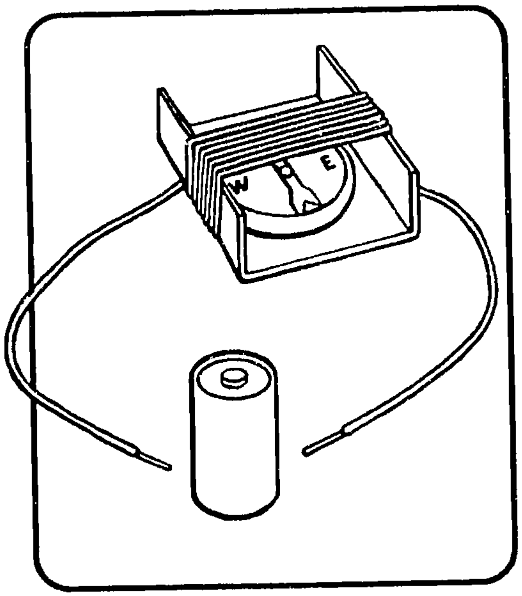


Fig. 13.2 Place the compass inside the coil of wire. Align the wires east and west.

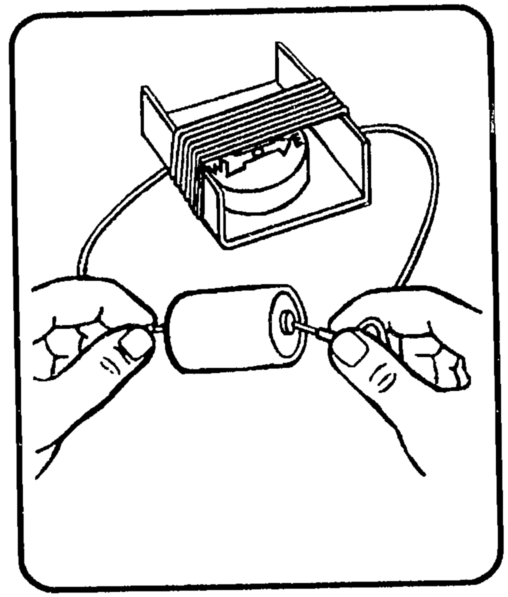


Fig. 13.3 Touch the wires to the battery and watch the compass needle. Also try reversing the wires to see what happens.

1825
William Sturgeon invents the electromagnet.

1827
George Ohm discovers relation between current, voltage and resistance.

1831
Faraday discovers generation of electricity by use of "Disk Dynamo."

4 Electromagnet

Without question, the greatest immediate practical application of Oersted's discovery (electromagnetism, 1819) was the eventual **invention of the electromagnet**. This was accomplished in 1825, when William Sturgeon of Woolrich, England wound copper wire around a bar of iron and made the first electromagnet. This invention made the telegraph, electric generator, and the electric motor possible. His magnet was made from a soft iron bar about 12-inches long and 1/2-inch in diameter bent into a "U" shape. Try Experiment 4 and the Digging Deeper to further explore this innovation.

Digging Deeper

Polarity Check

Check the polarity of your electromagnet with a compass. Hold your electromagnet one to two inches from the compass as shown in Figure 14.2. Remove the nail and recheck the polarity. Note the difference in the deflection time of the compass. When the nail was in place, all the available magnetic strength was funneled in and around the nail.

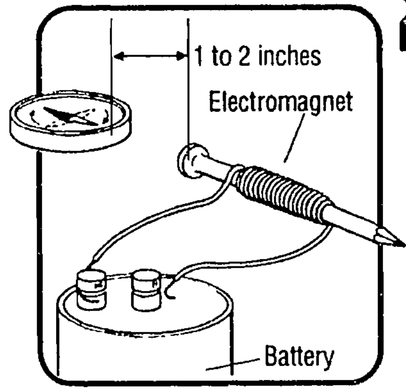
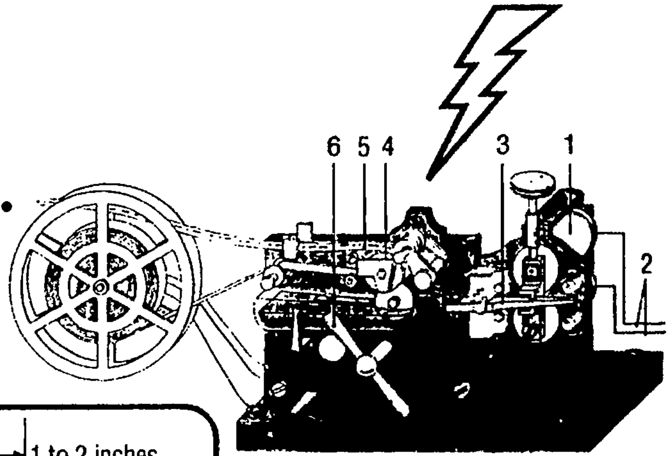


Fig. 14.2 Tap on terminal and watch electromagnet attract needle



Using a battery operated electromagnet, Samuel Morse invented the telegraph in 1837. The first long distance telegraph message, "What hath God wrought?" was sent from the U.S. Supreme Court in Washington D.C. on May 24, 1844 to Baltimore MD.

In an early Morse telegraph, electromagnetic coils (1) were energized by a current pulse transmitted through a telegraph line (2). The coils attracted a lever (3) that pressed an inked roller (4) against a moving paper strip (5) driven by a clockwork motor wound by a handle (6).

Experiment 6

Make an Electromagnet

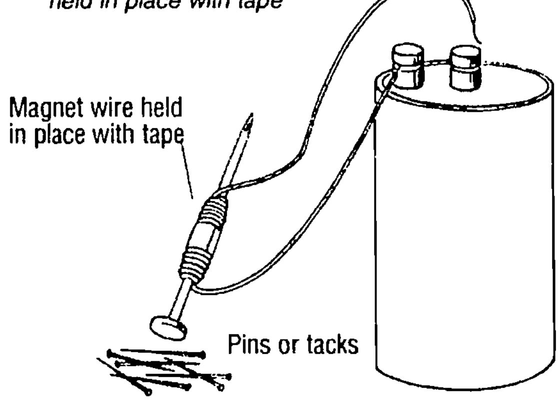
Experience the power of an electromagnet.

You will need:

- Large nail *(about three inches long)*
- 1 6-volt lantern battery
- 4 feet of 22-gauge insulated wire, single strand

Leaving a few inches of wire for a lead, wrap about 50 times around the nail as shown in Figure 14.1. Leave a little wire at the end for another lead. When the ends of the coil are connected to a battery, the electromagnet can pick up small nails and paper clips.

Fig. 14.1 Magnet wire held in place with tape



▲ *1833
Joseph Saxon of England invents first AC generator.

▲ *1834
William Sturgeon perfects DC generator through invention of split ring commutator.

▲ *1835
Davenport patent's the first DC electric motor (battery-powered).

Man-made magnets are aluminum, nickel and cobalt (alnico). Once electromagnetically charged this extremely hard metal will remain permanently magnetized, outlasting softer steel magnets.

Digging Deeper

Magnetize a Screwdriver

Use electromagentisim to magnetize a screwdriver.

You will need:

- 6-volt lantern battery
- Screwdriver
- 25 feet of 22-gauge insulated wire, single strand

Leave a length of wire for a lead, then wrap the wire around the shank of the screwdriver in even coils *(Figure 15.1)*. Use all the wire except for another short length for a lead. Remove the insulation from the ends of the leads *(Figure 15.2)*. Briefly touch the ends to the terminals of the battery *(Figure 15.3)*. This should magnetize the screwdriver.

Explanation

You have made a permanent magnet. The magnetic field of the coil aligns the molecules of the screwdriver into a magnet. (Fig. 15.6) *(You can accomplish the same thing by stroking the screwdriver with a bar magnet in a downward fashion.)* It will remain magnitized for a few hours, days or years depending on the materials from which it was made. The harder the material, the longer it will remain magnetized.

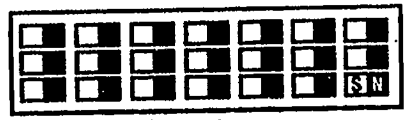


Fig. 15.6

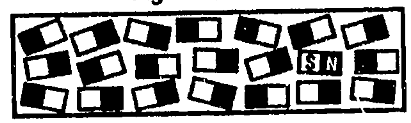


Fig. 15.7

To remove the charge, try striking the screwdriver with a hammer. (Fig. 15.5) This will jumble the atoms that were aligned in the magnetizing process. (Fig. 15.7)

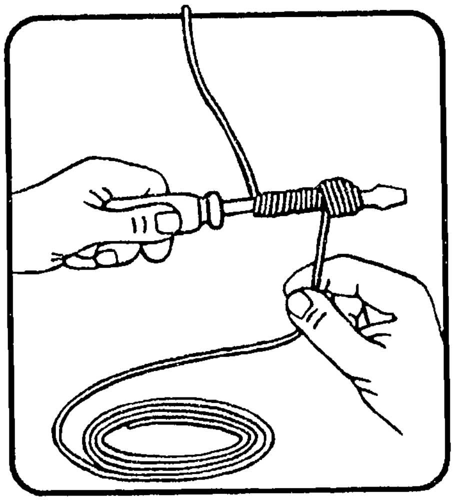


Fig. 15.1 Wrap wire

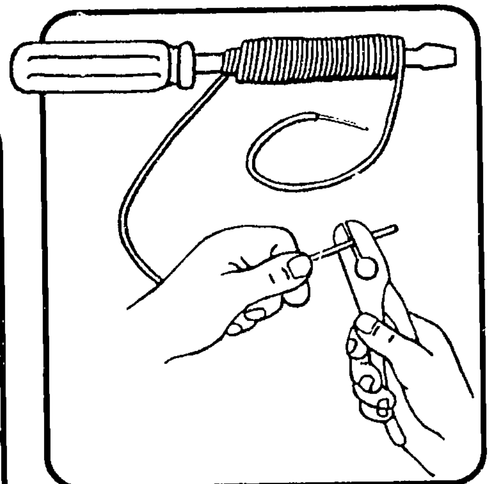


Fig. 15.2 Cut, leaving a leader

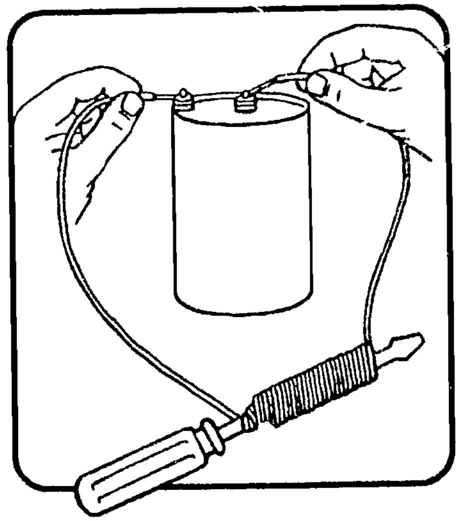


Fig. 15.3 Connect the wire to battery

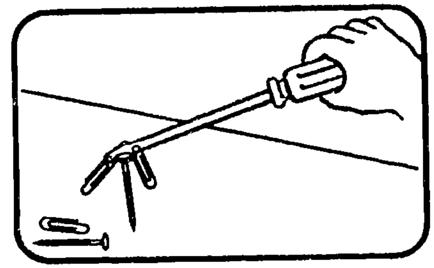


Fig. 15.4 Screwdriver becomes a charged magnet

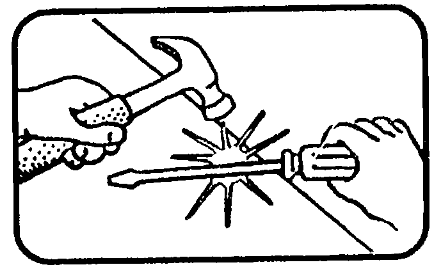


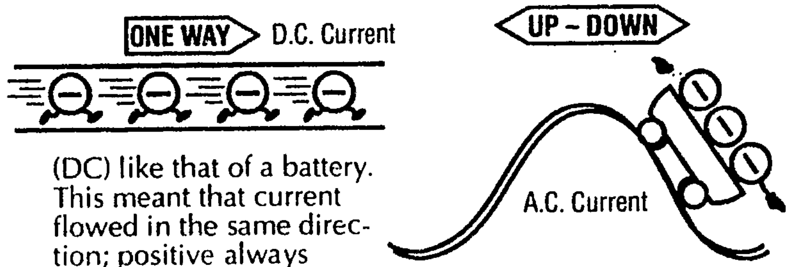
Fig. 15.5 Strike screwdrivier to disengage magnet

1837 Samuel Morse invents the telegraph.

1844 First long-distance telegraph system established between Washington, D.C. and Baltimore, Md.

5 Electric Generation

In 1831, while using a type of galvanscope, a young scientist named Michael Faraday made an important discovery. He found that a moving magnet would induce an electric current in the coil of his galvanscope. Faraday's discovery led to the rapid development of the **"dynamo electric machine"** or the electric generator. These early generators produced a simple direct current (DC) like that of a battery. This meant that current flowed in the same direction; positive always remained positive and negative always remained negative. Later generators produced an alternating current (AC). This meant that the current went back and forth, alternating the polarity of the poles. This allowed electricity to be transmitted over longer distances. Try Experiment 7 and the Digging Deeper Activity to explore this discovery further.



In the United States, AC current makes this turnabout 60 times each second. This 60-cycle standard allows electric clocks, electrical appliances and electric motors to operate consistently across the country.

Experiment 7

Induce Current From a Magnet

Use your galvanoscope to test the presence of electricity that you create.

You will need:

Bar magnet

10 feet of 22-gauge insulated wire, single strand (bell wire)

Galvanoscope

Wrap the wire around your fingers about 30 times to make a coil as shown in Figure 17.1. It should be a little larger than the bar magnet. Leave a length free at each end to make connections. Remove about a half inch of the insulation on each end and connect them to the galvanometer (see Figure 17.2). Move the bar magnet abruptly in and out of the center of the coil as shown in Figure 17.3.

Notice the direction of the movement of the needle. When the magnet is first pushed into the coil, the needle is deflected in one direction. When the magnet is removed, it moves in the other direction. The current changed directions (Figure 17.4). The current can be increased by using a stronger magnet, moving the magnet faster or adding more loops in the coil.

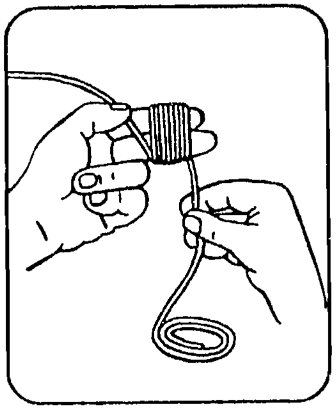


Fig.17.1 Make a coil of wire.

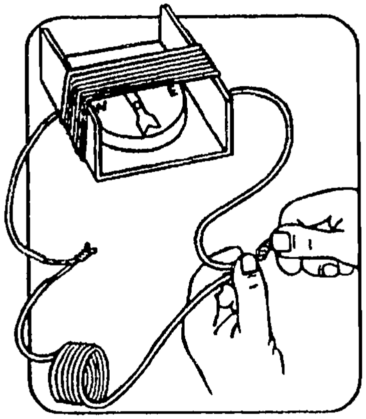


Fig. 17.2. Connect the coil to the coil with the compass.

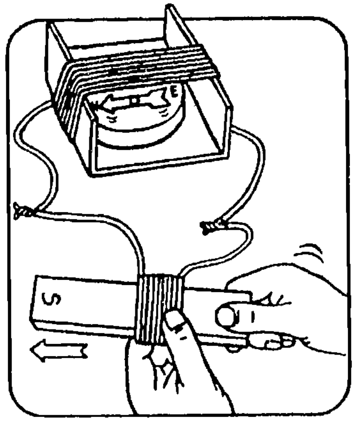


Fig. 17.3 Quickly push the magnet into the coil and watch the compass needle.

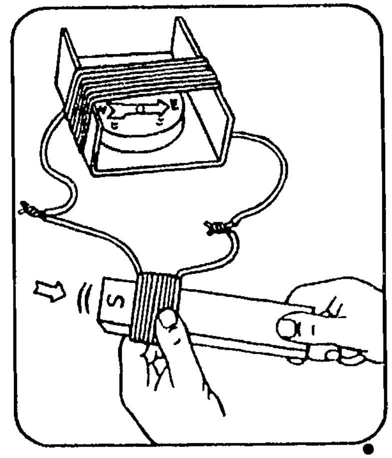


Fig. 17.4. Quickly withdraw the magnet and notice that the compass is deflected in the opposite direction.

1850
Manufacturing of wire by machine takes the place of "hand drawn" methods.

1873
Z'enobe Theophile Gramme demonstrated first DC motor to be powered by a generator.

1875
Alexander Bell develops the electric telephone.

When the first AC generator was invented in 1833 it was not fully understood how it could be useful.

Digging Deeper

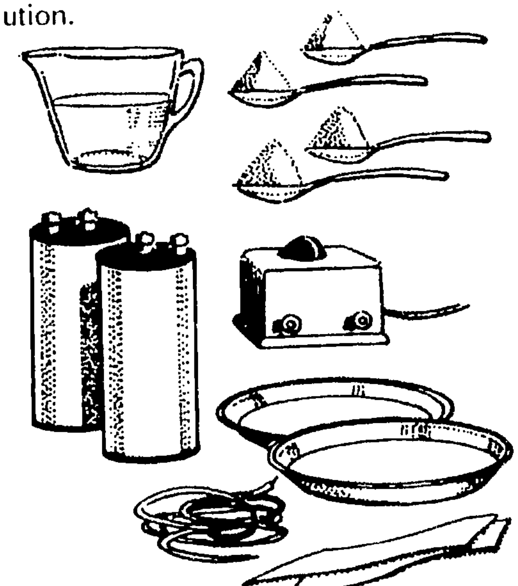
AC/DC Detection

Try this experiment to see for yourself how AC and DC currents differ.

You will need:

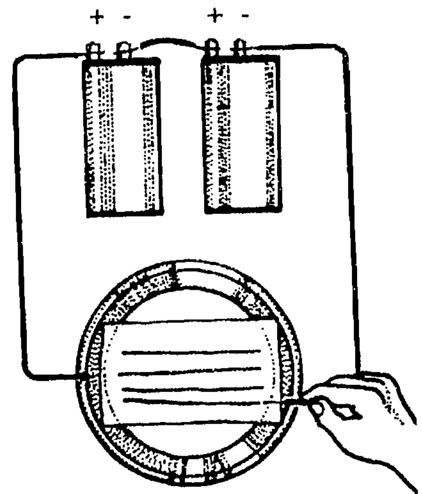
2 teaspoons cornstarch
$^{1}/_{2}$ cup water
2 teaspoons of potassium iodide *(obtain from pharmacy, or call NASCO at 1-800-558-9595)*
2 metal (non-aluminum) pie pans
8 feet bell wire
Measuring cup
2 6-volt lantern batteries
AC train transformer
Cloth strips

Mix two teaspoons of cornstarch in $^{1}/_{2}$-cup of water. Add two teaspoons of potassium iodide. Soak the strips of cloth in the solution.



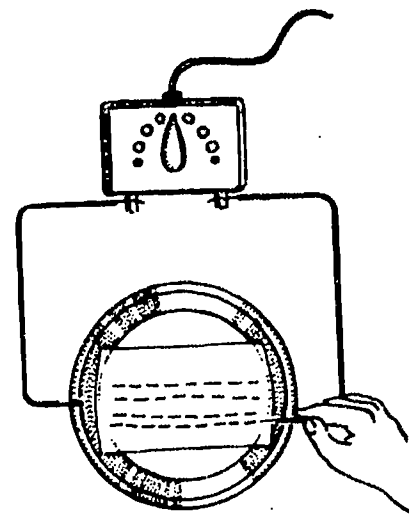
Direct Current

Wire the negative post of one battery to the positive post of the other battery. Turn a pie pan upside down, and connect a wire from the free negative post to the outer rim of the plate. Squeeze the solution out of one cloth and stretch the cloth over the plate. Attach a wire to the remaining positive post. Using the tip of this wire as a stylus, draw it across the cloth. A solid line will appear.



Alternating Current

Use an AC train transformer instead of batteries. Attach a wire from the low-voltage terminal to the rim of a pie plate. Spread a cloth saturated in solution on the plate. Connect a wire to the unused terminal of the transformer, and plug the transformer into an electric outlet. Holding the insulated part of the free wire, draw the wire quickly across the cloth. A broken line will form.



1878 First commercial telephone line set up in Somerville, Mass.

1879 Charles Scribner invents the knife switch.

1879 Edison invents the electric light bulb.

6 Electric Motor

Now that the generation of electromagnetism and reliable electric current had been discovered, inventors scrambled to harness these new powers. As early as 1835, an American scientist named Thomas Davenport patented the world's first **DC electric (battery-operated) motor**. This invention was based on another of Faraday's discoveries. In 1821, Faraday learned that electric current could create mechanical motion or a type of "moving magnet." His device was a wire (electric coil) which would rotate around a magnet when current was applied. However, unlike Faraday's invention, Davenport's motor utilized an electromagnet in place of a natural magnet, increasing the motor's potential power.

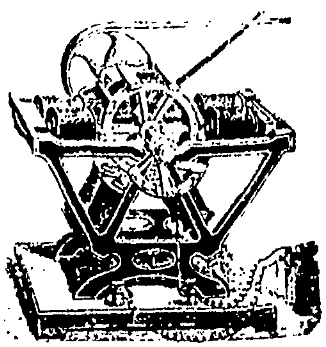


Fig. 20 Early D.C. Motor

A motor is simply two magnets working in opposition. The stationary magnet or electromagnet is called the **stator**, while the rotating electromagnet is called the **rotor** or armature. A basic electric motor consists of only four main parts: stator, rotor/armature, commutator and brushes.

There are two types of motors — those that operate on Direct Current (DC) and those that operate on Alternating Current (AC). A DC motor works because the spinning magnet keeps trying to line up opposite poles with the stationary magnets. With each half turn, the split contacts of the commutator function automatically to change the polarity of the rotor. (Fig. 21.1)

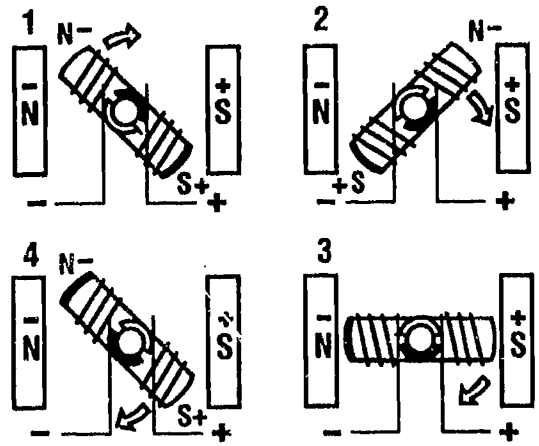
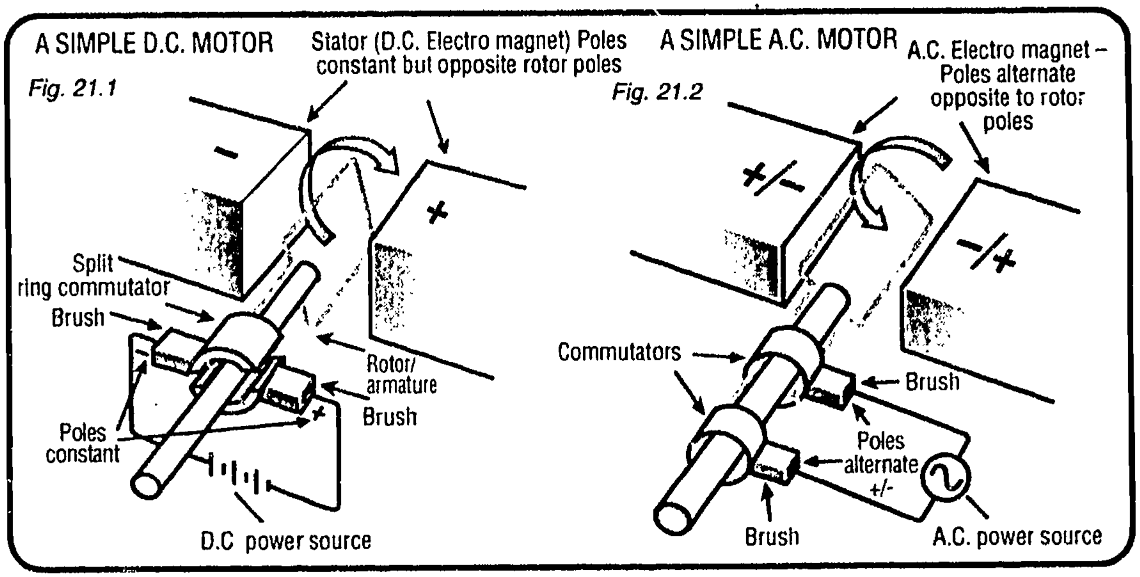


Fig. 21 Polarity change of rotor – D.C. motor

AC motors do not have split ring commutators. This is because Alternating Current reverses the polarity of the current automatically. Because of this, the commutator in an AC motor is set up as separate rings. (Figure 21.2) Try Experiment 8 to further explore the invention of the D.C. Motor.



Activity
Magnetic Force

See how a motor works using two bar magnets. First, try making them repel each other, then attract each other. What you are observing is the principle of magnetism. Each magnet has a north and south pole, just like the earth. The like poles (N/N, S/S) of the magnets repel each other, just as the opposite poles (S/N) of the magnets attract. That's why a motor works. The polarity of the stator and rotor poles are in constant opposition; providing the force that turns the rotor. (Fig 21)

1880
Edison patents the glass enclosed fuse.

1882
First DC municipal power plant put into operation.

1883
First electric street railroad was started in the U.S. in Baltimore, Md.

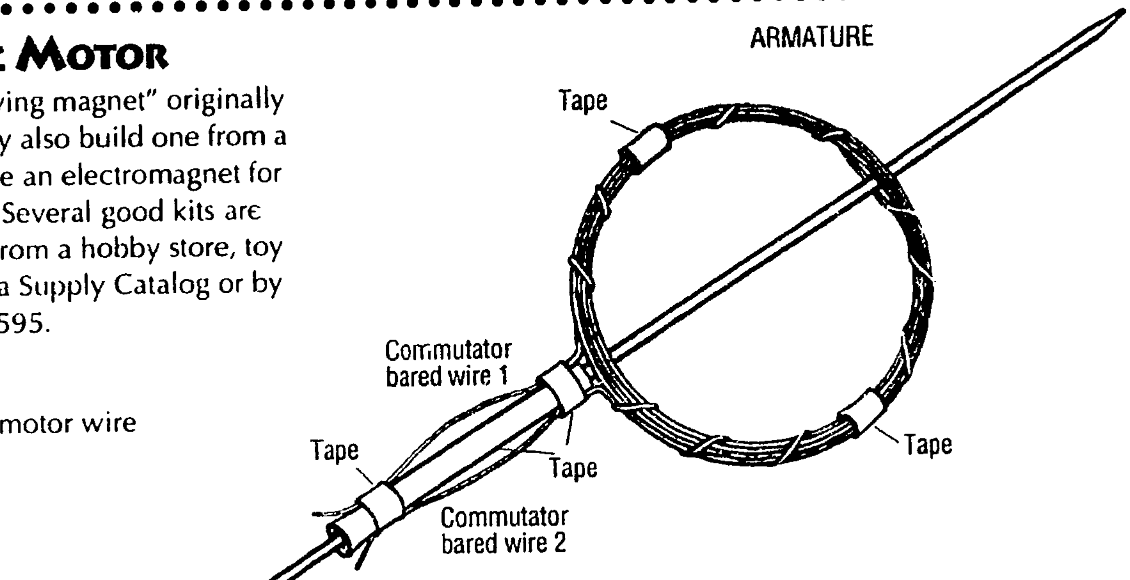
Experiment 8
BUILD A DC ELECTRIC MOTOR

Build the same type of "moving magnet" originally discovered by Faraday. You may also build one from a kit. This includes motors that use an electromagnet for the stator rather than a magnet. Several good kits are available and can be obtained from a hobby store, toy store, the Boy Scouts of America Supply Catalog or by calling NASCO at 1-800-558-9595.

Prior to 1873 all electric motors were battery powered. That is until Belgian scientist Z'enobe Theophile Gramme demonstrated that a motor could be powered by a generator.

You will need:

15 feet of 22 gauge electric motor wire
Tape
Thin plastic or wooden rod
1 6-volt lantern battery
Block of wood
4 nails
Bar magnet *(or electromagnet)*
Knife
Hammer
Broom handle



Using the copper wire, make a neat circular coil by winding 30 turns of the wire around a broom handle. Remove the coil and flatten its windings, to make a ring shape with projecting wire ends. Keep the coil in shape by binding it sparingly with little pieces of sticky tape.

Stick the coil on the rod as shown. Scrape away insulation from the ends of the wires projecting from the coil. Attach the ends of the bare wire on opposite sides of the rod, using thin bands of tape. The exposed wires are called commutator contacts (1 and 2) and the coil is called the armature.

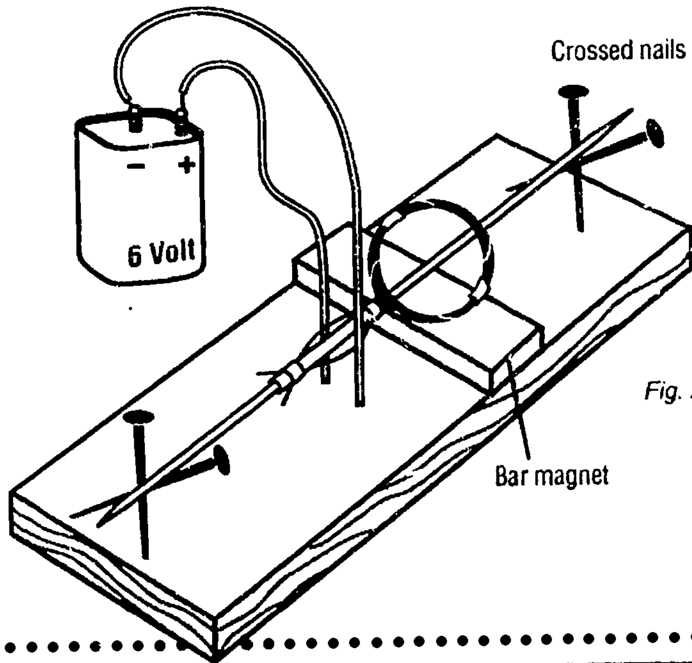


Fig. 24

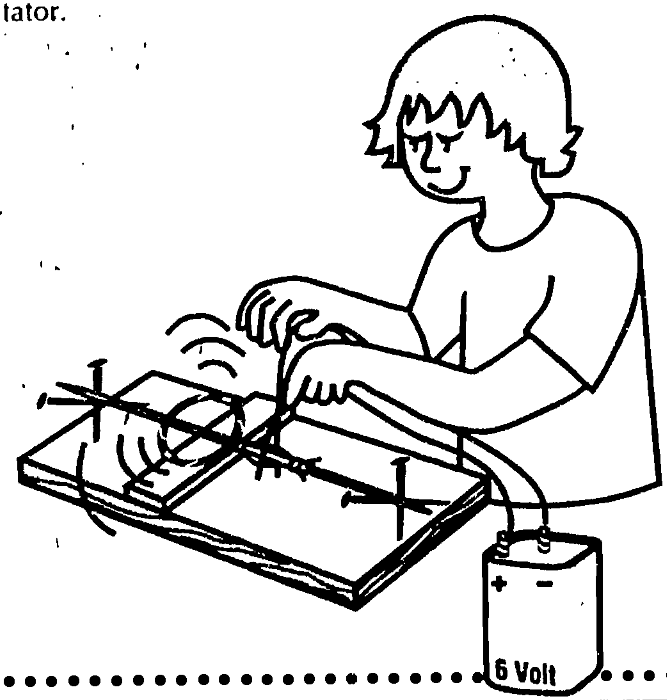
1885
Elihu Thomson invents the circuit breaker.

1886
Elihu Thomson patents the electrical welding system.

1886
First AC municipal power plant put into operation.

Mount the rod *(with its armature and commutator in place)* between two pairs of crossed nails on a block of wood. (See Figure 24.) Put a strong bar magnet just under the armature where it will not obstruct the armature as it is spun.

Make twin leads from thin wires and connect them to a 6-volt battery. Bare their other ends for about 2 inches to make brushes for the motor. Set the rod with commutator contacts 1 and 2 on a level. Touch the contacts with the sides of the brushes, which you hold vertically. The motor should start by itself and keep spinning. If not, have someone give the spindle a turn while you hold the brushes in place against the commutator.



What Can Go Wrong?

- Too much friction with the crossed nail bearings
- A badly-balanced armature coil
- Short-circuiting of current between wires 1 and 2 if they touch
- Poor battery connections
- The magnet placed too far away from the armature
- Insulation not scraped off of commutator wires

There are many kinds of motors. If you completed Experiment 8, you made a likeness of Faraday's experimental DC motor; since it operates on direct current. There are also motors which operate on AC (alternating current) and are used around the home and in businesses.

1888
Oliver Shallenberger invents electric meter.

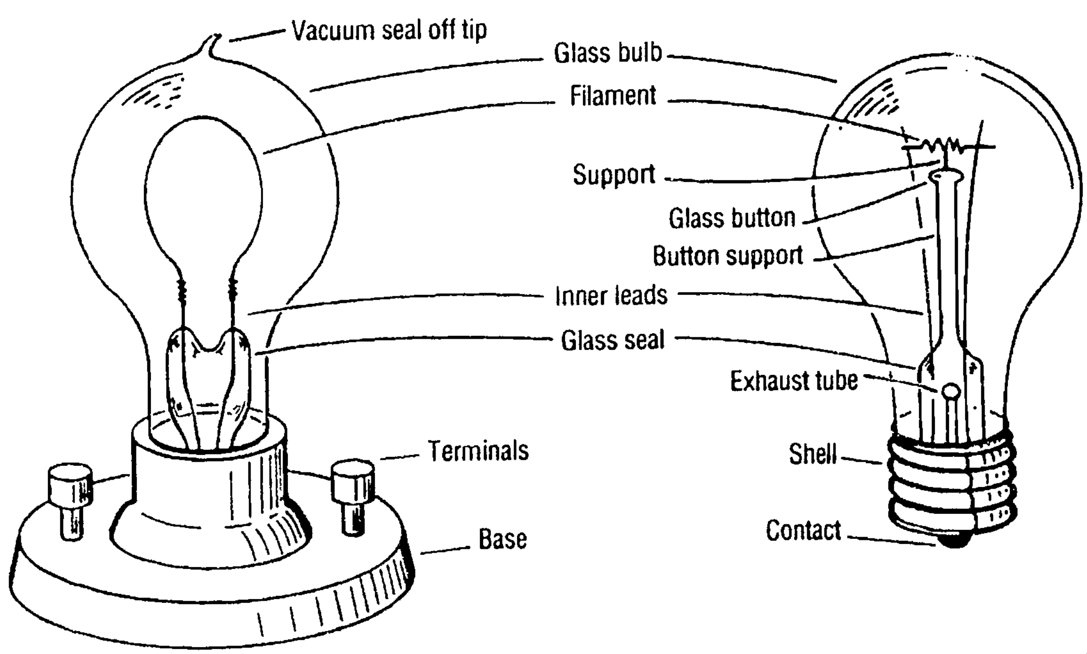
1888
American-born Nikola Telsa constructs first AC motor to be powered by a generator.

7 Electric Light

Probably one of the most significant electrical innovations of the century came by way of an inventor named Thomas Edison. Edison was attempting to create an inexpensive source of light using electricity from a D.C. generator. Until then, light was provided by candles and oil and gas lamps. Attempts were even made to create an arc-type lamp from a reflected metal spark. Edison and other inventors noted that if a coil strand of wire got hot from too much electric current, it glowed. The problem Edison and others faced was that the materials would eventually break or burn up from the heat.(Figure 25)

After testing more than 6,000 materials, Edison gave birth to the first electric light on October 21, 1879. He discovered that carbonized sewing thread mounted inside a glass bulb would glow continuously when the air was removed from the bulb and current applied. The lamp continued to burn for about 40 hours. In fact, it was only after Edison increased the voltage to the bulb that it burned out. Try experiment 9 to further explore this discovery.

Fig. 25 Comparison of Edison's first lamp with a modern incandescent type.



1892
First electric automobiles were put on the market.

1895
Guglielmo Marconi invents the wireless radio.

Experiment 9
Light a Coiled Strand of Wire

Experience the same challenge that Edison faced in creating the electric light.

You will need:

- Piece of wood
- 6 inches of 30-gauge wire
- 2 thumb tacks
- Small nail
- 2 6-volt lantern batteries
- 4 feet of 22-gauge insulated wire, single strand

Secure two lengths of bell wire with thumb tacks to a piece of wood as in Figure 26. Obtain a 6-inch length of a single strand of the wire used in a common power cord. You will have to cut apart an old power cord or ask for 6 inches of "zip" cord from the hardware store. Wind the strand of wire around a small-diameter nail to produce a coil of wire. Connect the free ends of this coil to the bell wire as shown.

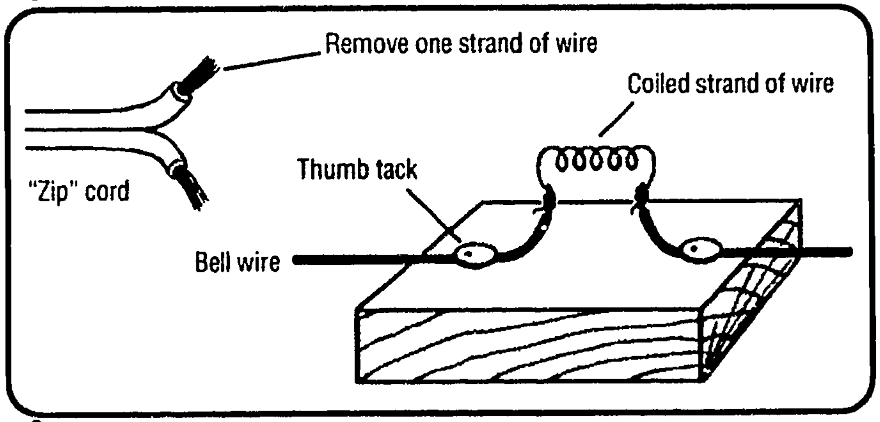


Fig. 26 Illuminated wire coil

Now connect the entire circuit to one 6-volt battery and watch what happens. The coil will heat, and the close turns of high-resistance wire produce enough heat to glow. Increase the voltage by wiring the batteries as shown Figure 26.1. Eventually this circut will fail because the intense heat will weaken the wire and cause it to break. BE VERY CAREFUL *WHEN DOING* THIS EXPERIMENT. THE HEAT PRODUCED *IS QUITE* HIGH AND CAN CAUSE SERIOUS BURNS *OR EVEN* CAUSE PAPER TO BURN.

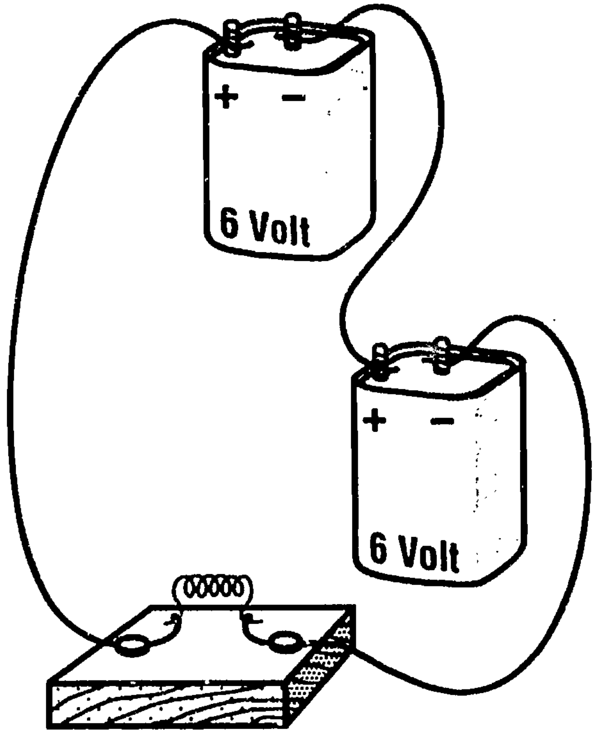


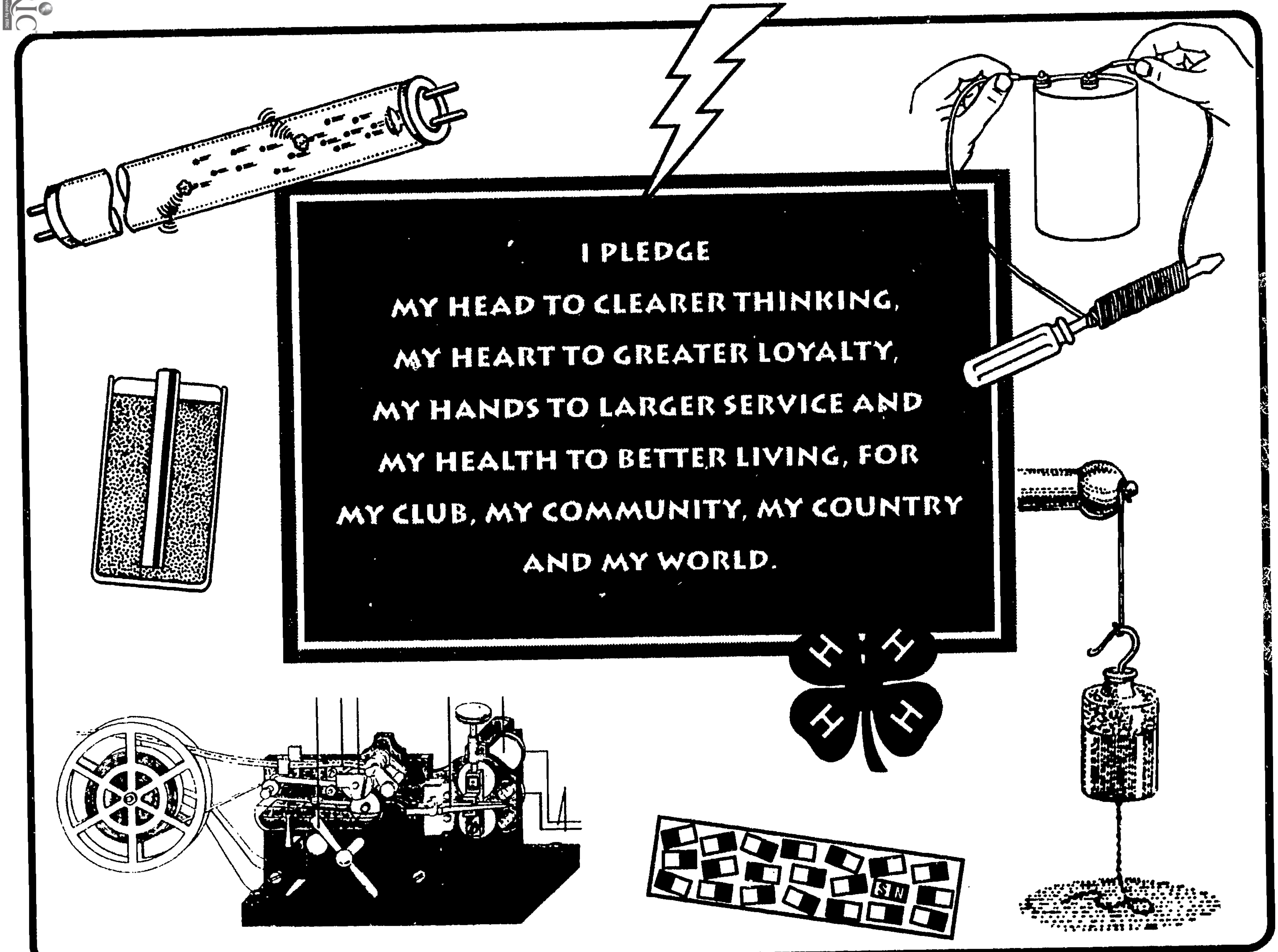
Fig. 26.1

GOING BEYOND

Now that you've completed this project, think about going beyond in the 4-H Electrical Energy Series. Unit 2 explores today's application of electricity in the home including wiring, lighting and switches. Unit 3 introduces you to the world of electronics. You may also wish to take Learning About Computers or Radio Controlled Vehicles as a companion to your 4-H electrical projects.

1896
Thomas Edison applies for patent on the fluorescent lamp.

1899
First ad for G.E. light bulbs appears in the *Saturday Evening Post* on February 4.


I PLEDGE
MY HEAD TO CLEARER THINKING,
MY HEART TO GREATER LOYALTY,
MY HANDS TO LARGER SERVICE AND
MY HEALTH TO BETTER LIVING, FOR
MY CLUB, MY COMMUNITY, MY COUNTRY
AND MY WORLD.
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