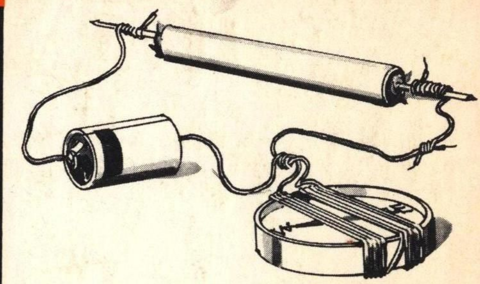
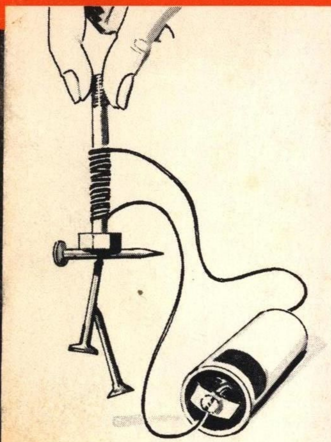
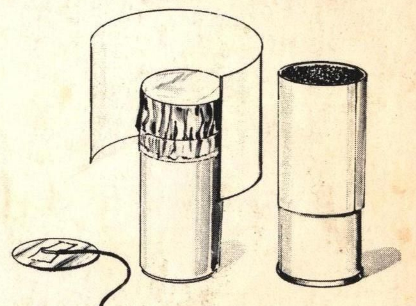
EDISON EXPERIMENTS



Carbon Particles Experiment



Build Your Own Magnet



Build A Transmitter

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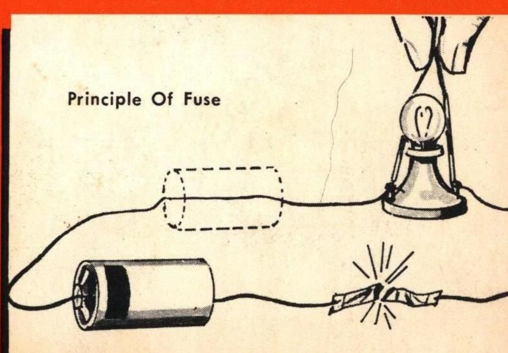
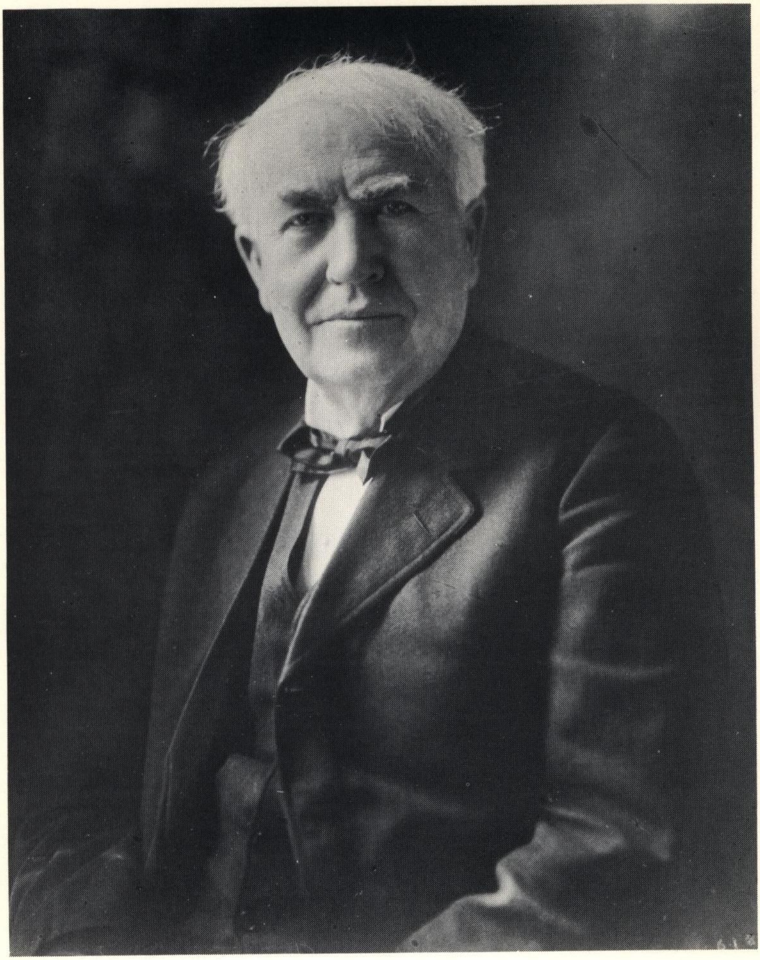




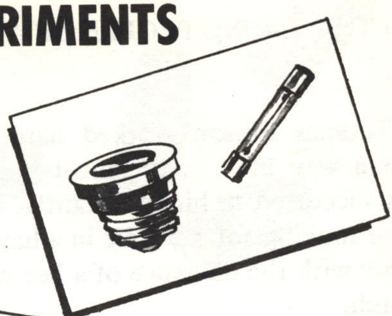
it is said of . . .

thomas a. edison

"he has led no armies into battle — he has conquered no countries — yet he wields a power the magnitude of which no warrior ever dreamed . . . this democratic, kindly, modest man has bestowed upon the human race blessings instead of bondage, service instead of serfdom, construction instead of conquest . . . he is humanity's friend."

arthur j. palmer

EDISON EXPERIMENTS

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Text by:
ROBERT F. SCHULTZ

Publication of the
THOMAS ALVA EDISON FOUNDATION
2000 Second Avenue, Detroit, Michigan 48226

TO THE YOUNG PEOPLE OF AMERICA

Thomas Edison worked hard at experimenting. To him, it was a way life . . . the most positive way of testing the ideas that occurred to him constantly. It was said of Edison that if he were looking for a needle in a haystack, he would examine each straw with the diligence of a bee until he found the object of his search.

This booklet, based on Edison's work, is designed to give you some idea of the experiments Edison performed to achieve a few of his many inventions, and developments.

We hope that by following Edison's methods of invention, you may learn the crucial importance of thorough experimental work. We hope that doing these simple investigations will be pleasant, so that you will also know some of the satisfaction most scientists find in their work.

Today our country, as well as the entire world, needs young men and women with the kind of imagination, courage, and willingness to work hard that enabled Edison to conquer so many unknown fields. If your interests lead you to one of the scientific or technical fields, you will have not only the excitement and challenge of a demanding career but the knowledge that you are helping your country at a time when you are greatly needed.

Walker Cisler

Walker L. Cisler, President of the Thomas Alva Edison Foundation. Mr. Cisler is Chairman of the Board of The Detroit Edison Company and one of America's leading authorities on electric power and the development of peaceful uses of atomic energy. He is active in many educational endeavors including the Engineers Joint Council and the National Academy of Engineering of which he is a founding member. Mr. Cisler also serves as a trustee of a number of colleges and is a member of the Executive Committee of the Freedoms Foundation.

The Famous Carbon Buttons

Most people think of Thomas Edison as an inventor of mechanical and electrical devices. But he was more than an inventor. He was a discoverer as well. And many of his great contributions were not devices; they were observations . . . observations that blossomed because of his keen mind and curiosity about the unusual.

One unusual thing that particularly interested Edison was the way pressure affected the electrical resistance of a mass of carbon particles. Like others before him, Edison noticed that when current flowed through such a mass, applied pressure allowed more current to flow. And when the pressure was removed, the flow decreased. (As we shall see, this observation later led to Edison's development of the telephone transmitter.)

CARBON IN TUBES

He learned about this property of carbon in 1873. At that time he was looking for a way to speed up the transmission of telegraph messages over the 3000-mile long transatlantic cable. To run experiments, he had to produce in the laboratory an electrical resistance comparable to that of the cable. He tried pressing finely ground graphite in glass tubes and inserting wires in the graphite at both ends. By connecting many of these tubes end to end, he hoped to approximate the resistance of the cable.

Although the tubes did give the resistance he needed, Edison could not keep the resistance constant. He found that the slightest pressure on the end of a tube, even a vibration in the wires, varied the resistance. When he saw that the arrangement would not be suitable, he temporarily halted his experiments with the graphite.

GRAPHITE FOR VOICE TRANSMISSION

However he did not forget this experience. Four years later, when he was seeking a way to transmit voice vibrations by means of a diaphragm, he remembered the curious behavior of the graphite. And he felt he could turn this behavior to his advantage.

He put a stick of graphite in an electrical circuit and adjusted the graphite so it would lightly touch a spring attached to the diaphragm. When a person spoke, changing pressure waves would vibrate the diaphragm, which transferred its movements to the spring and then to the graphite. Current passing through the graphite and into a receiver would thus vary in accordance with the sounds of the speaker's voice.

With this graphite, along with other materials he tried including tufts of graphite-coated silk, Edison achieved a high degree of sensitivity. Even a whisper and the touch of a finger could be picked up. Yet the sounds, although loud enough, were not clear. So he continued his search for a better material.

LAMPBLACK CARBON BUTTON

One night he happened to be distracted from his work by an excessive smoking of his kerosene lamp. Glancing at the lamp he noticed how intense the carbon deposits were on the inside of the glass. True to his nature, he began wondering if this carbon would help in his voice transmitting experiments. As soon as the lamp had cooled, he scraped off the soot and pressed it into a little cake. This cake, the first of his famous "carbon buttons," greatly improved the clearness of the voice sounds.

Soon he set up banks of smoking lamps in what he called his carbon factory. Assistants were kept busy gathering the lampblack and pressing it into buttons. Edison used these buttons in many ways. But none was as dramatic as his carbon transmitter, which helped make possible the modern telephone. His transmitter was, in fact, a microphone.

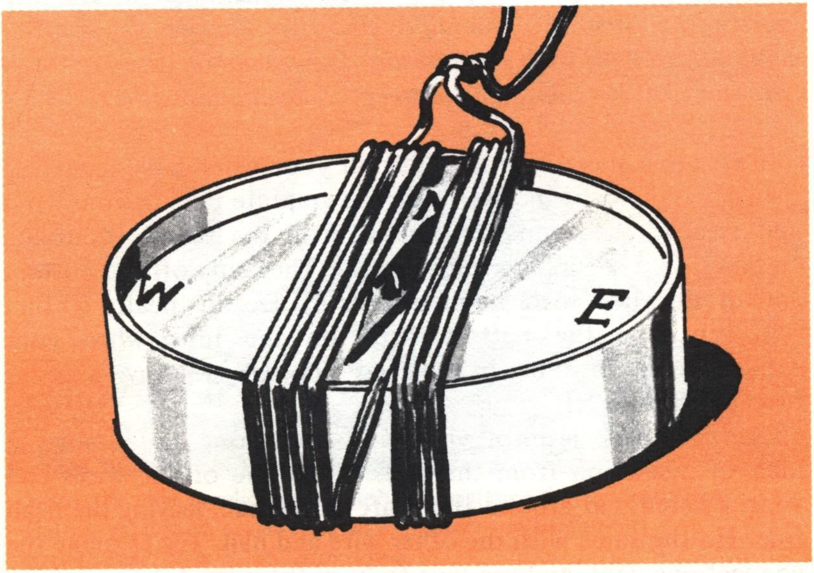
The experiments that follow will enable you to check some of carbon's properties for yourself. They may also give you some idea of how Edison carried out his endless search for the solution to whatever problem he tackled.

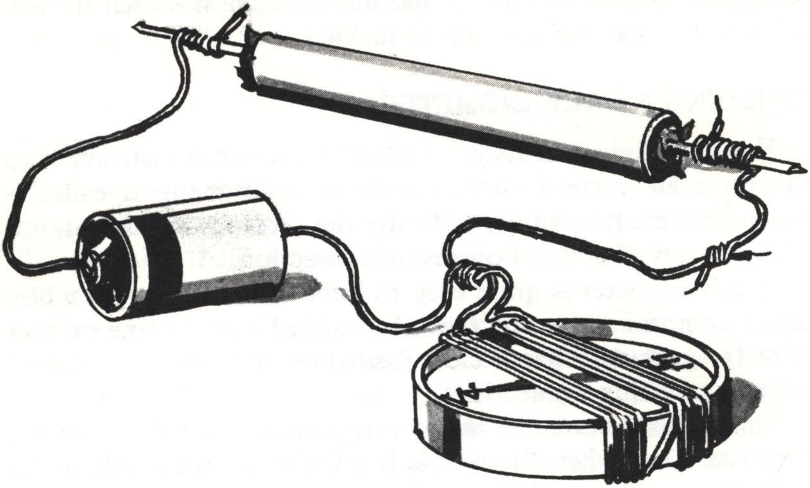
BUILDING A GALVANOMETER

For these experiments you will need a sensitive instrument to detect small current flows. Such an instrument is called a galvanometer. It not only indicates the presence of current, but it also shows when the flow reverses direction.

A galvanometer is quite easy to build. All you need is a boy scout compass and a few feet of insulated wire or fine magnet wire (magnet wire has a clear insulation that must be scraped off when making connections).

Simply wrap several turns of wire around the N-S axis of the compass. Thus when the needle is pointing to the north, it will be hidden by the coil of wire. Whenever current passes through the coil, it will create a magnetic field. The field will tend to attract the needle toward the E-W axis. You can tell how strong the current is by how much the needle swings. And you can tell that current is flowing in the opposite direction when the needle swings to the other side.





EXPERIMENT 1: Edison's Carbon Tubes

MATERIALS: *Tube of dry powdered graphite (most hardware and department stores carry plastic squeeze tubes of graphite lubricant). Small non-metallic tube (use the one the graphite came in). 2 nails with wide heads. Paper napkin. 2 or 3 feet of wire (any kind). Flashlight battery. Galvanometer.*

First lay a sheet of newspaper on your work table. Graphite is black and can be messy. Grasp the graphite tube in your hand and remove the spout by pushing with the thumb. Pour the graphite on a separate sheet of paper. Then snip off the bottom end of the tube with a pair of scissors. Do this neatly so that you can tape the bottom back on the tube when your experimenting is done. In that way you will still have a useful tube of graphite left.

Next cut two pieces of wire about a foot long, and remove an inch of insulation from the ends. Take one of the wires and wrap a bared end around the shaft of the nail, leaving the head free. Do the same with the other wire and nail. Try to make the connections tight, and use tape to keep them in place.

Then wrap napkin strips around the nail shafts – enough so that each nail fits snugly (head first) into the tube openings. With one nail in place, pour the graphite back into the tube. Leave room for the second nail; then close the tube with that nail.

Now connect the tube and galvanometer to the battery, as shown. Tape will hold the battery wires in place. Note that when the circuit connections are completed, current begins flowing, as indicated by the compass needle. If the needle doesn't move, check all connections. You may have to scrape some of the surfaces clean to make good contact. See what happens when you push the nails deeper into the graphite. Also, tap on one of the nails to make it vibrate, and observe the reading.

This experiment shows what Edison found out about the carbon particles . . . that a mass of such particles is sensitive to movement and has a variable electrical resistance.

Since you will be using the same basic circuit in the next four experiments, study the set-up so that you can make connections quickly and correctly.

One of the first candid photographs in existence that actually shows Thomas A. Edison conducting an experiment in his famous West Orange, New Jersey laboratory.

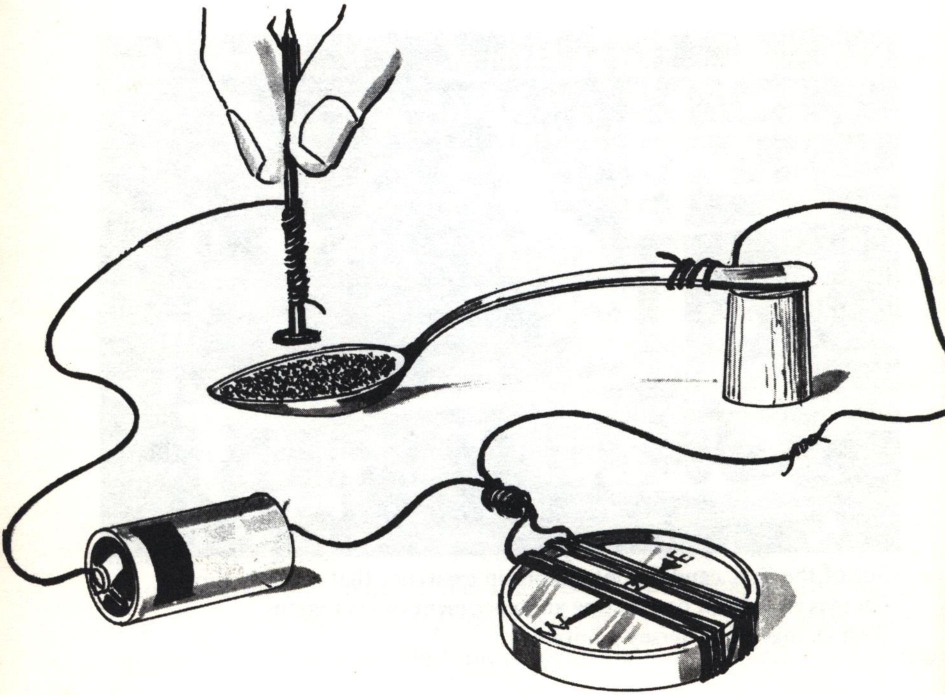
EXPERIMENT 2: The Carbon Button

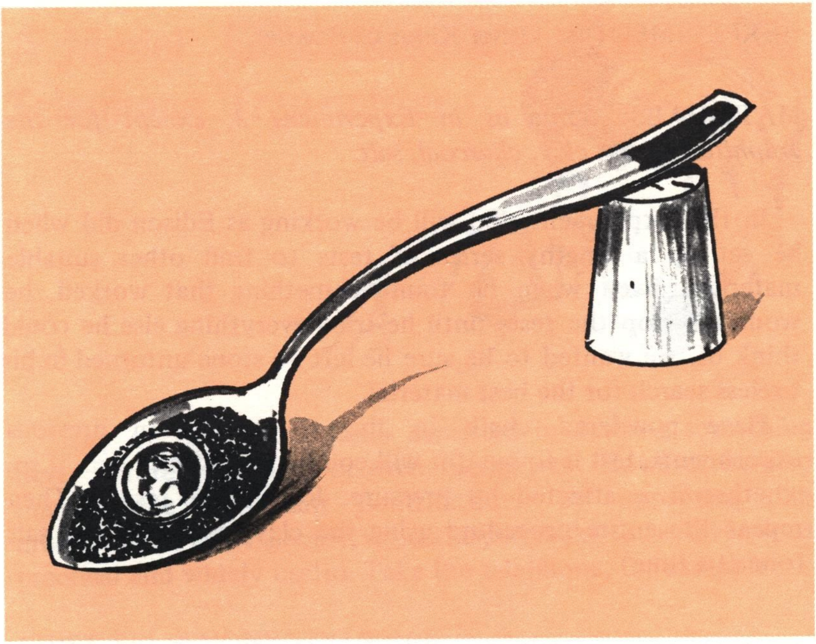
MATERIALS: *Same as in Experiment 1, except substitute a tablespoon for the tube.*

Remove the tube from the circuit, and take a nail off one of the wires (leave the other nail on). Tie the end of the free wire around the spoon handle; secure it with tape.

Prop something under the spoon handle to make the container part level. Fill the container with graphite and tap the graphite gently with a flat stick. This will be our carbon button for this experiment.

Now touch the nail to the graphite, not too deep or you'll hit the spoon and get a false reading. Try touching several areas on the graphite. Current should flow each time. The moving needle of the galvanometer will tell you when this happens, proving once again that carbon conducts electricity.





EXPERIMENT 3: The Carbon Transmitter Principle

MATERIALS: *Same as in Experiment 2, plus a dime.*

Place the dime on the graphite. Make sure that the coin does not contact the spoon. Now with the nail, touch the dime lightly. Note how much the galvanometer needle swings. Then press down on the dime with the nail. Again check the galvanometer. The needle should have swung farther, indicating that more current flowed.

With this experiment, you have demonstrated the basic principle used by Edison in his carbon transmitter. It is the same principle used in the mouthpiece of our telephones today. Pressure waves caused by your voice act on a diaphragm in the telephone (just as the pressure from the nail acted on the dime). The resulting vibrations vary the current passing through the carbon. These electrical variations correspond to the sound waves of your voice.

EXPERIMENT 4: Other Kinds of Powder

MATERIALS: *Same as in Experiment 2, except for the graphite. Chalk, clay, charcoal, salt.*

In this experiment you will be working as Edison did when he set up a lengthy series of tests to find other suitable materials. Even when he found something that worked, he wouldn't stop the tests until he tried everything else he could think of. He wanted to be sure he left no stone unturned in his tireless search for the best material.

Place powdered chalk in the spoon. As in previous experiments, test it to see if it will conduct electricity and, if so, whether it is affected by pressure. Record the results. Then repeat the entire procedure using the clay, charcoal, and salt (one at a time).

EXPERIMENT 5: Testing Seeds

MATERIALS: *Same as in Experiment 4, except for the test samples. Various fruit and vegetable seeds (dry).*

It's surprising how far Edison went in his material searches. Along with the different powders, particles, and granules, he even tried seeds. Among them were pumpkin, cantaloupe, and caraway seeds. He also investigated fruit pits such as those from wild cherries and peaches.

You too may want to try these items, as well as seeds from the apple, orange, grapefruit, and tomato. Perhaps in looking around for additional specimens, you may think of something the master inventor overlooked (if it existed in his time).

A Model Telephone Transmitter

Many of Edison's exploits consisted in devising something never before attempted or even thought of. However he also made some important contributions by improving the inventions of other people, which helped make those inventions practical and widely useful. Take the telephone, for example.

FIRST TELEPHONE TOO WEAK

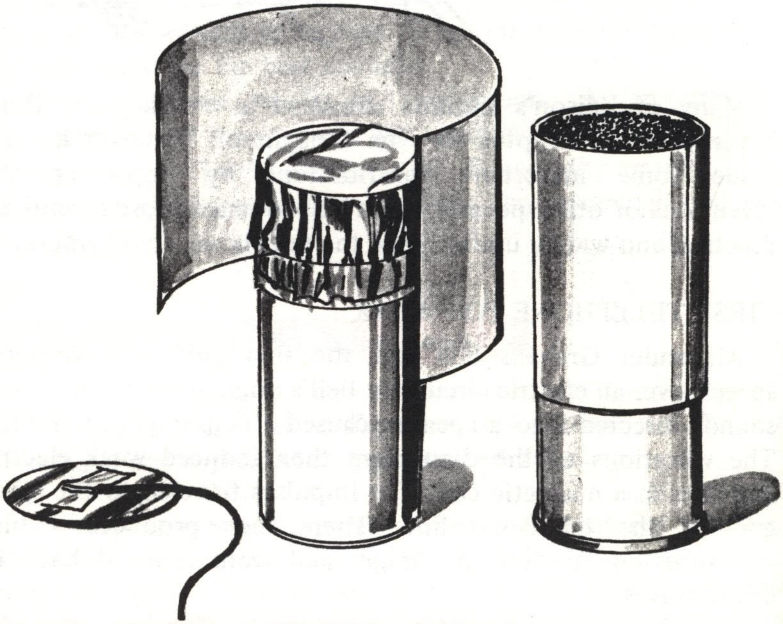
Alexander Graham Bell was the first person to transmit speech over an electric circuit. In Bell's original telephone, voice sounds directed into a speaker caused a diaphragm to vibrate. The vibrations of the diaphragm then induced weak electric impulses in a magnetic coil. The impulses traveled to the other end of the telephone line. There they produced similar vibrations in another diaphragm and were changed back to sound waves.

But the electric impulses were weak. Consequently, the speech carried only faintly and was difficult to hear and understand. Furthermore, the weak impulses limited Bell's range to only a few miles at best.

EDISON IMPROVES VOICE TRANSMISSION

Edison helped make Bell's telephone a practical success by introducing the carbon transmitter. With his transmitter, Edison did not have to depend on the voice alone for the strength of the electric impulses. He used a carbon button to vary the flow of current from a storage battery. The current flowed from the battery to the carbon button in the transmitter, through an induction coil, and then back to the battery. The induction coil boosted the voltage of the impulses produced by the voice vibrations.

These reinforced impulses were then put on the main line where they could travel great distances yet still be heard clearly. Edison gave credit to his deafness for the improvements he made in the telephone. He said, "I *had* to improve the transmitter so I could hear it."



EXPERIMENT 6: Build a Transmitter

MATERIALS: *ALL-METAL frozen-juice can (or can of similar size.) Aluminum foil. Thin cardboard. Tape. A foot of wire. Graphite from Experiment 1 (carbon granules would be better, if you know where to get some).*

First, we'll have to make a mouthpiece to talk into. The frozen-juice can will serve that purpose. Remove the top and bottom of the can with a rotary opener, to keep the edges smooth. Save one of the lids. Cut a circle of aluminum foil a little larger than the can opening, and fasten the foil tightly over the can with tape. This will be our diaphragm.

Next, attach a bared end of the one-foot length of wire to the shiny side of the juice-can lid. Use cellophane tape to hold the wire down. If you can solder the wire on, so much the better. It is important that the wire connect to the shiny side, because the other side is coated and will not conduct electricity.

To hold the carbon, wrap a sheet of cardboard around the end of the can having the diaphragm. With about a half inch of cardboard extending above the diaphragm, tape the cardboard to the can. Make sure the overlapping edge of cardboard is taped too, so the graphite can't spill out.

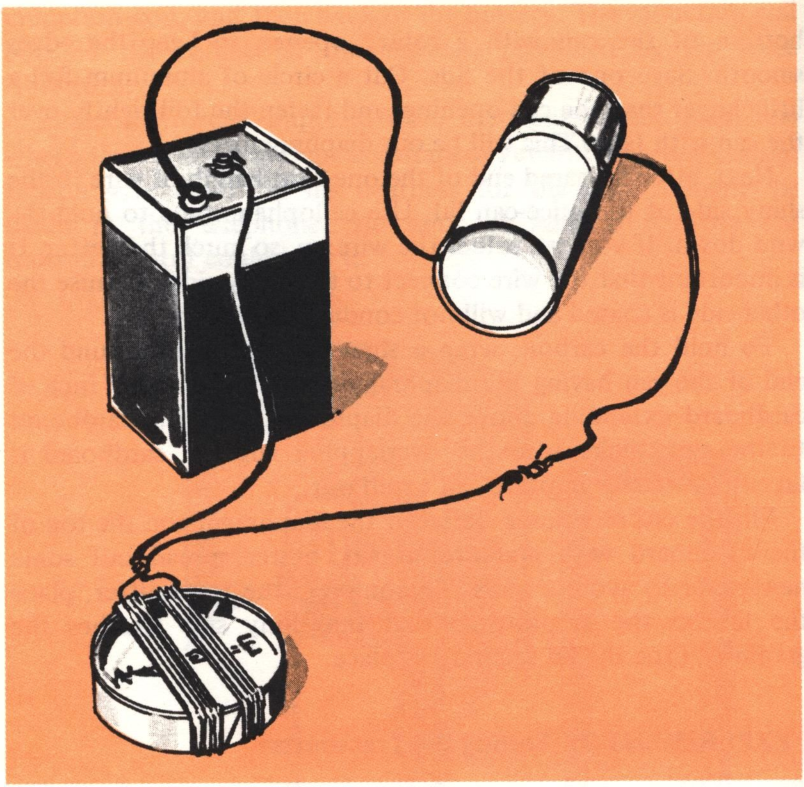
Fill the entire volume between the diaphragm and the top of the cardboard with graphite. Again, better spread out some newspaper to avoid a mess. To complete the transmitter, place the lid on the graphite so that the shiny side touches the graphite. Tape the lid securely in place.

EXPERIMENT 7: Testing the Transmitter

MATERIALS: *Transmitter from Experiment 6. A foot of wire. Galvanometer from Experiment 1. 6-volt battery.*

Connect the circuit as shown on page 12. Before taping (or soldering) the wire to the side of the can, scrape that spot on the can down to the bare metal. Good, tight connections are always important. It is also important that the compass lie flat, so the needle can move freely. Have the needle pointing to N at the start. When the connections are completed, the needle should move away from N and stay there. If it doesn't, check the connections and shake or tap the can a couple of times.

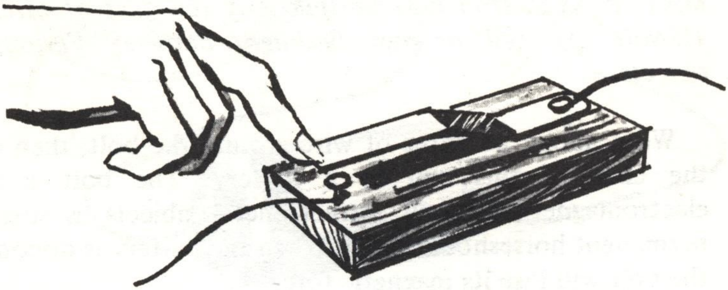
Once the needle moves, we can begin the test. Make any kind of *loud* noise – shout, whistle, growl – and watch the needle. It should move back and forth. That's because the sound waves from your voice vibrate the diaphragm and cause a varying pressure on the carbon. And, as you learned in Experiment 1,



varying pressure on carbon varies its electrical resistance, which changes the current flow. If you're not getting results, try laying the can on its side and tapping it once or twice. Maybe you're not making a loud enough noise.

This experiment illustrates, once again, the principle of Edison's carbon transmitter, which made possible long-distance telephone usage.

Edison Telegraph Experiments



Originally the telegraph was a simple system for sending messages along a wire by means of electric impulses. For more than 40 years in the mid-1800's it served as man's fastest means of long distance communication. It was the reason the famous Pony Express ended.

When young Edison became interested in the telegraph, it could transmit only one message at a time on any one wire. And since the telegraph had been playing such a vital role in our country's economic growth, the system couldn't keep up with the flood of messages pouring in. Edison wanted to develop a system that could carry more than one message at the same time.

He began studying all that he could on the subject. He experimented endlessly. As a result he not only made major improvements to the existing duplex which handled two messages simultaneously, but he invented the quadruplex which handled four. Modern telegraph systems, of course, go far beyond this capability. But for that period, 1874, four messages at once was quite an accomplishment.

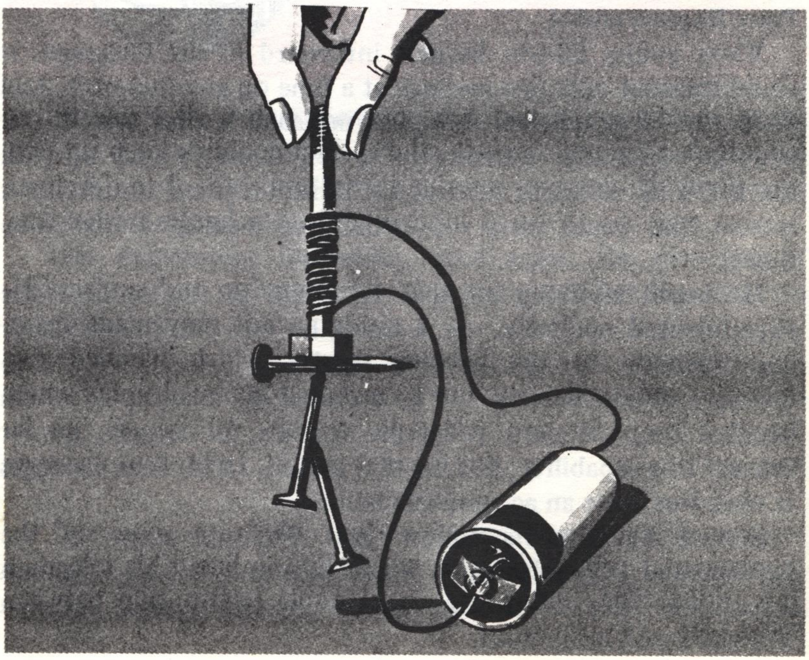
Several experiments follow that illustrate some of the fundamental principles upon which Edison based his telegraph inventions. They involve the inseparable relationship between electricity and magnetism.

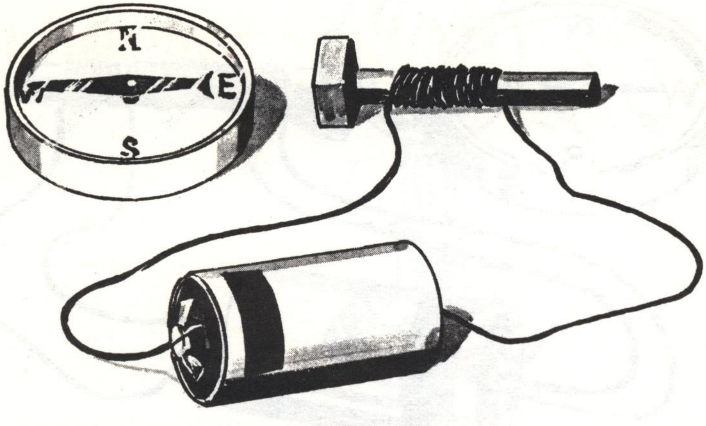
EXPERIMENT 8: Making an Electromagnet

MATERIALS: *Iron bolt or spike. A few feet of wire. Large 1½-volt dry cell or new flashlight battery. Various metal objects.*

Wind about 20 turns of wire around the bolt, then connect the ends of this coil to a battery. The bolt is now an electromagnet and will attract metal objects as surely as a permanent horseshoe magnet. When the battery is disconnected, the bolt will lose its magnetic force.

The strength of an electromagnet is determined in part by the number of turns of wire it has. The more turns of wire you put on, the stronger the electromagnet gets, within limits. With the right amount of turns, our small electromagnet will probably be able to pick up a hammer. Electromagnets can be made quite strong. For this reason they are used in scrap yards to lift large piles of metal.





EXPERIMENT 9: Magnetism and the Compass

MATERIALS: *Electromagnet from previous experiment. Compass.*

Place the compass on a flat surface with the needle pointing to N. Connect the electromagnet, and bring it near the compass. Note which way the needle deflects.

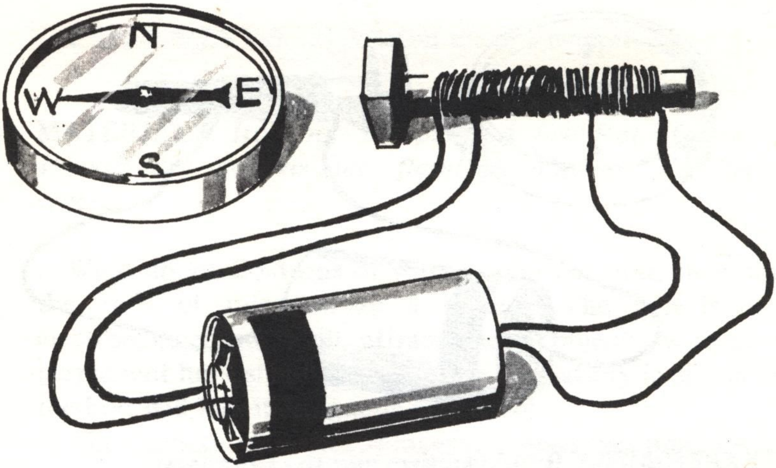
Now without moving the electromagnet, reverse the battery connections. The needle should deflect in the opposite direction.

You have just repeated the historic discovery of a Danish schoolteacher named Hans Christian Oersted. He concluded that since current in a wire deflected a compass, it must be producing magnetism. It was one of the most important discoveries of all time. The motor operates on this law of nature.

EXPERIMENT 10: Adding Another Coil

MATERIALS: *Same as in previous experiment, plus more wire.*

Wind another coil of wire around the bolt. Put on the same number of turns as before. Then connect the ends of the second coil to the same battery. With both coils energized, note what



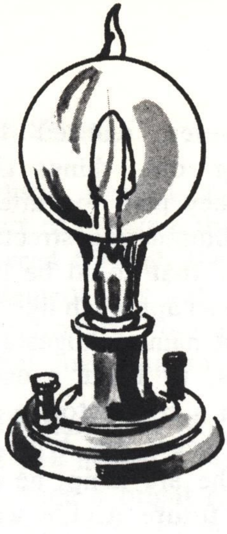
the compass does, if anything. Now reverse the connections on the second coil, and again check the compass.

Here's what happened. When the current in both coils traveled in the same direction, the compass needle deflected as it did with only one coil. When the current in the coils traveled in opposite directions, the compass needle did not move at all, or just slightly. That's because the magnetic fields set up by the coils were now aligned differently, and the fields opposed or balanced one another. This experiment demonstrates that you can control the magnetism of the bolt by reversing connections on either coil.

Through experiments like these, Edison found several methods of varying the magnetism in telegraph systems: change the direction of current flow through coils, change the amount of flow, change the direction in which coils were wound. He combined these methods so that two messages could be sent together over the same wire. That was the duplex.

He then arranged to have two messages sent from the home station to a distant station while, at the same time and on the same wire, two messages were coming in from the distant station . . . four messages simultaneously. That was the quadruplex.

Light From Heat



On October 21, 1879, after more than a year of intensive research, Thomas Edison began still another of his wire-in-a-bulb experiments. He, of course, was trying to invent the incandescent electric lamp (incandescent means *glowing with heat*). Already he had built and tested hundreds of such lamps. But he couldn't get any of them to work, at least not for very long.

This time, however, he succeeded. The lamp went on and stayed on for nearly two days (about 40 hours). That was the first practical incandescent lamp ever built. It was the most advanced electric light produced in the sixty years that inventors in both the United States and Europe had been working on electric lighting. In a manner of speaking, it was the great granddaddy of the lamp that today lights the entire civilized world.

EARLY WORK

The first experiments in electric lighting were made by Sir Humphry Davy in 1808, a few years after Volta invented the primary battery. Davy showed that electric current arcing across a small gap between two carbon rods produced a brilliant bluish-white light in that gap. This is the principle of the carbon-arc lamp used today in theater spotlights and motion picture projectors. Years after Davy's experiment, when scientists started becoming interested in electric lighting, carbon arcing was considered to be the best method to pursue.

Edison, however, realized that arc lamps had serious drawbacks. For one thing, they required high currents. Consequently they gave too intense a light to be suitable for anything but illuminating streets and factories. He wanted a softer light, one that could be brought into the home. That's why he favored an approach like the one taken back in 1820 by a Swiss scientist named Auguste De la Rive. De la Rive tried, without success, to make a useful electric lamp by passing current through a conductor in a glass-enclosed vacuum. Even though Edison knew this type of lamp would be harder to develop than the arc lamp, he nevertheless believed it had a more promising future. And he was right.

Another reason Edison chose the incandescent lamp over the arc lamp was that arc lamps had to be connected in series. In other words, they had to be connected so that they all went on or off at the same time. This was economically necessary to keep the total current flow from being too high. Obviously, such a scheme – although fine for lighting streets – would not be acceptable in the house.

SUBDIVISION OF LIGHT

After visiting another inventor doing work on the carbon-arc lamp, Edison wrote in his record book, "In all electric lights heretofore obtained, the intensity of the light was very great . . . . I came home and made experiments two nights in succession. I discovered the necessary secret, so simple that anyone might understand it. It suddenly came to me, like the secret of the speaking phonograph . . . the subdivision of light."

What did he mean, the subdivision of light? He had in mind a lighting system, fed by a central power station, in which the current (to make light) was subdivided into a number of main branches and house circuits. A high-resistance lamp in any circuit would draw a small amount of current and thus give off a mild light. It could also be switched on or off without affecting other lamps. Edison reasoned that if gas jets could be individually controlled in a house, why couldn't the same thing be done with electric lamps. This concept was totally unlike that being worked out by the arc-lamp inventors.

LAMP MUST HAVE HIGH RESISTANCE

For his system, then, Edison needed a lamp with a high-resistance filament (the part of the lamp that lights up). In such a lamp, current being forced through the filament with sufficient voltage makes the filament very hot . . . hot enough to glow brightly. The heat comes from the resistance of the wire to the passage of electrons that make up the current. It is frictional heat.

The resulting light is no different than that from any hot glowing object. For example if you heated a wire with a torch, it would glow first a dull red, then a bright cherry red, then orange, yellow, and finally white (if it lasted that long without burning up). In the wire, as in an incandescent lamp, the highest temperature produces the brightest light.

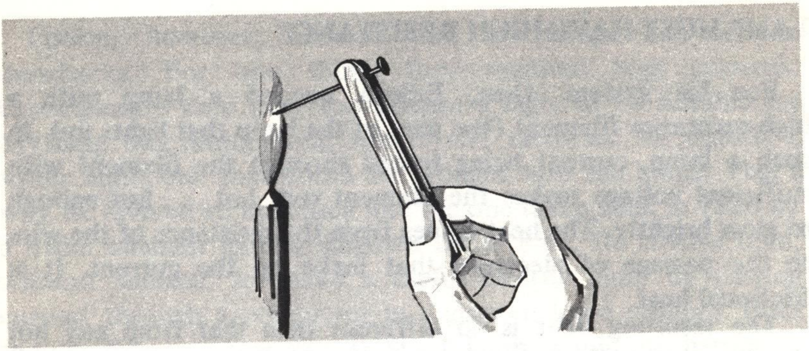
The amount of heat, and therefore the light, given off by an incandescent lamp depends on the kind of material in the filament, the thickness of the filament, and the voltage. If the voltage is kept the same, more light will be produced by a fine filament than by a heavier filament of the same material. With either filament, raising the voltage will increase lamp brightness.

So Edison's task was to find the right combination of conditions that would permit a filament to glow brightly without burning up too soon. Here are some experiments that may help you appreciate the problems he faced. They may also give you a better understanding of how the incandescent lamp works and the kind of branched electric circuit Edison envisioned for putting these lamps in the home.

EXPERIMENT 11: Heat Produces Light

MATERIALS: *Straight pin or needle. Flame source (gas burner or candle).*

With two sticks, hold the pin point in the flame. Notice the pin changing color. Soon it will glow. It won't glow very much, though, unless you have a very hot flame. But at least the experiment demonstrates that if an object is hot enough, it will



begin to emit light. The hotter it gets, the more light it will give off.

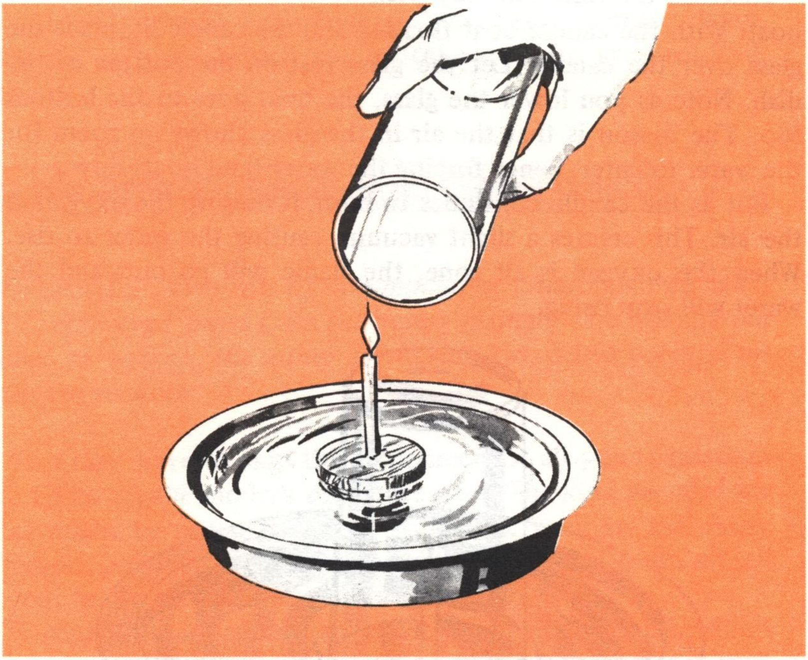
To produce a useful amount of light by incandescence, an object would have to be capable of getting white hot without melting. Edison realized this. That's why he naturally turned to carbon at the start.

He was quite familiar with the properties of that material and knew it had a very high melting point (6420° F). However, he wasn't entirely successful with carbon at first. For reasons unknown to him at the time, the carbon filament tended to burn out at the fairly low temperature of about 2900° F. He then investigated thousands of possibilities.

Of all the metals Edison tried, platinum seemed to produce the best results. Platinum melts at 3220°F. His extensive work with platinum resulted in some lamps that burned for an hour or two. These were patented. Yet they were far from what he wanted, in addition to being quite expensive.

As he began learning more about materials and lamp requirements, he returned to carbon. Much experimenting and study followed on fine carbon filaments. It was this work that eventually led Edison to the first successful incandescent lamp. That lamp had a filament made of ordinary cotton sewing thread packed with powdered carbon and baked solid. Later, Edison found that bamboo made better filaments, and he sent expeditions to many parts of the world to find the best bamboo. He finally ended up using a bamboo grown in the Orient. Up to that time, Edison had examined no less than 6000 vegetable growths for the right filament properties.

The material used as the filament in today's lamps is tungsten. Edison was not able to experiment with this metal because at that time it was too unworkable to be made into filaments. Tungsten has the highest melting point of all metals, a sizzling 6100°F. No wonder our incandescent lamps shine with such brilliance.



EXPERIMENT 12: How Air Affects Burning

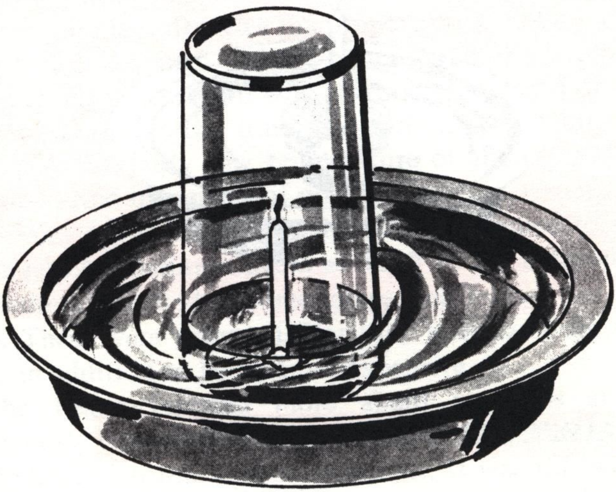
MATERIALS: *Birthday cake candle. Candle base. Soup dish or pie plate. Drinking glass.*

In general, nothing can burn itself up without air, that is, without the oxygen in the air. The following experiment will prove that point. In a minute you'll see how this fact relates to the incandescent lamp.

For the candle base, any thin piece of wood about one and a half inches in diameter will do. Actually, you can use anything that floats, as long as the drinking glass will fit completely over it. In the center of the base, attach the candle. Do this by lighting the candle and letting some of the melted wax drip on the base. Then before the wax hardens, set the candle in place.

Next fill the dish half way with water, and launch the candle boat. With the candle boat floating and the candle lit, place the glass over the candle. Let the glass rest on the bottom of the dish. Note as you lower the glass, the boat goes to the bottom too. The reason is that the air in the glass allows no room for the water to enter, hence forcing the water (and boat) down.

But as the candle continues to burn, it uses up the oxygen in the air. This creates a slight vacuum, causing the water to rise. When the oxygen is all gone, the flame will go out; and the water will stop rising.



What does this experiment have to do with Edison's incandescent lamp? Mainly it suggests the harmful effect of oxygen on a lamp filament. For just as oxygen would allow the candle to consume itself, it would also allow a lamp filament to do the same. And as the lack of oxygen kept the candle from burning up, so does this lack of oxygen prevent a glowing filament from doing likewise.

From the beginning, Edison recognized the need for a vacuum. But getting a high enough vacuum was a problem. In his first successful lamp, all but a millionth part of the air in the bulb had been removed.

Nowadays, incandescent lamps are still practically free of oxygen. Those with a rating above 40 watts, however, contain a small amount of argon and neon. These inert gases help prevent the filament from vaporizing. They thus increase lamp efficiency and life, which for a 100-watt lamp averages 750 hours.

EXPERIMENT 13: Edison's Home Lighting System

MATERIALS: *Two sets of non-miniature Christmas tree lights with screw-type bases (one set having a single wire going from socket to socket, the other set having two wires going from socket to socket).*

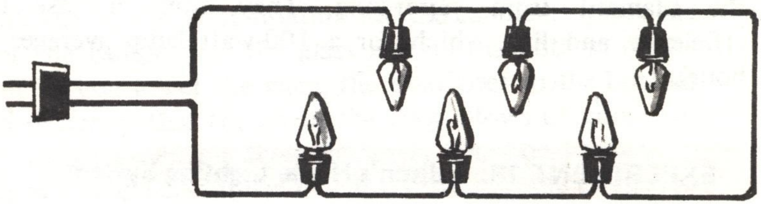
You may have to skip this experiment if all your Christmas tree lights are the modern miniature ones. The kind we need are what might be called the older style sets. They are still fairly common, however. We'll assume that you have such sets stored in your house or that you can borrow some.

In general, the sets look the same. Even when lit, they don't appear much different. But now loosen one of the bulbs in each set and notice what happens. In the single-wire set, all the bulbs go out. Whereas in the two-wire set, only the one you loosened goes out.

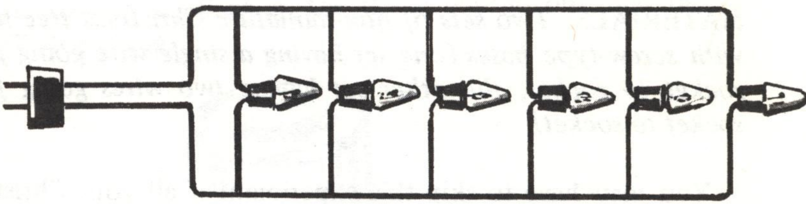
The single-wire set makes up a *series* circuit. All the lamps go on or off at the same time. If one burns out, they all go off. This is the way carbon-arc lamps had to be connected, and that's only one of the reasons Edison disliked that system. Imagine having to light up your whole house just to read the newspaper.

The two-wire set makes up a *parallel* circuit. Screwing any one bulb (or two, or three, etc.) in or out does nothing to the other lamps. If they are already on, they will stay on. If already off, they will stay off.

If the lamps in parallel were on a very long pair of wires and if each lamp was in a different room, you could see how nicely a person could control the lighting. This is the way Edison imagined his lamp would be wired up in a house. And this is pretty much the way it's done today.



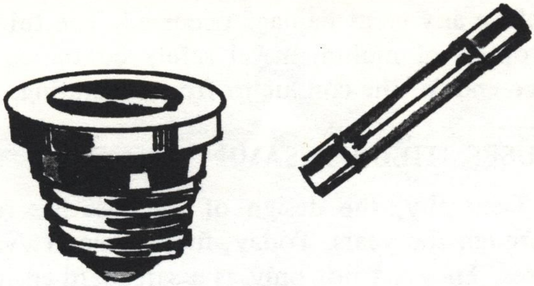
LAMPS IN SERIES



LAMPS IN PARALLEL

NOTE: Lamps designed for use in a series circuit can not be used in a parallel circuit, and vice versa.

The Fuse—An Electrical Safety Device



Edison's invention of the incandescent lamp, although a marvelous feat in itself, was only the first step in his grand plan for an electric light and power system. He also needed improved electric generators and controls, underground distribution mains, insulating materials, power switches, and meters to measure current. In addition, a whole family of lighting fixtures, sockets with switches, and service wiring for households had to be worked out. Otherwise, how could the incandescent lamp ever be used in the home? How could it fulfill its glorious promise of turning night into day?

PRINCIPLE OF FUSE

Undoubtedly the smallest, though not the least important, device in the entire system was the fuse. Something like an automatic safety switch, the fuse cuts off the current when it becomes high enough to cause a fire. Dangerously high currents in the main lines are the result of too many branch circuits being used at the same time (overloading the lines). Or they are the result of the "live" wire accidentally touching the ground wire or anything else that is grounded, such as a water pipe. This accidental touching is known as a "short circuit."

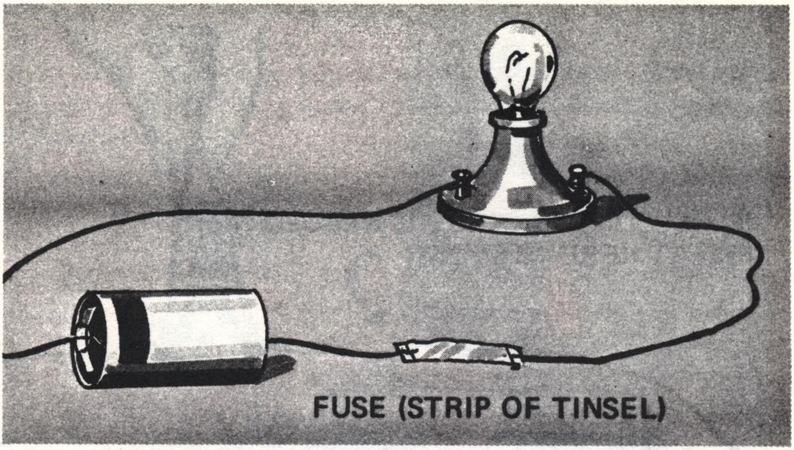
Edison's first fuse was patented on March 10, 1880, under the name "Safety Conductor for Electric-Lights." He intended that such a fuse be placed in the circuit of each lamp or other electrical device.

It consisted of a piece of thin, special wire enclosed in a tube made of a non-conducting material. The wire had a low melting point. When a short circuit developed, the heat of the high current would melt the fuse immediately – opening the circuit before any great damage occurred. The tube served to keep the droplets of molten metal safely contained and to prevent the two ends of the conductor from separating.

FUSES STILL THE SAME

Generally, the design of the fuse has remained unchanged through the years. Today, fuses come in a variety of shapes and sizes. They act not only as a safeguard against electrical fires in the home but also as a protector of expensive equipment such as in TV sets and automobiles. All of them, however, still work on Edison's melting-metal concept.

Identical to the fuse in purpose but not in operating principle is the circuit breaker. Many modern homes have circuit breakers instead of fuses. From the standpoint of use, they differ as follows: when a fuse "blows," it must be replaced with a new fuse; when a circuit breaker "kicks out," it can be reset by hand. The circuit breaker, then, is a sort of re-usable fuse.



EXPERIMENT 14: The Fuse in Action

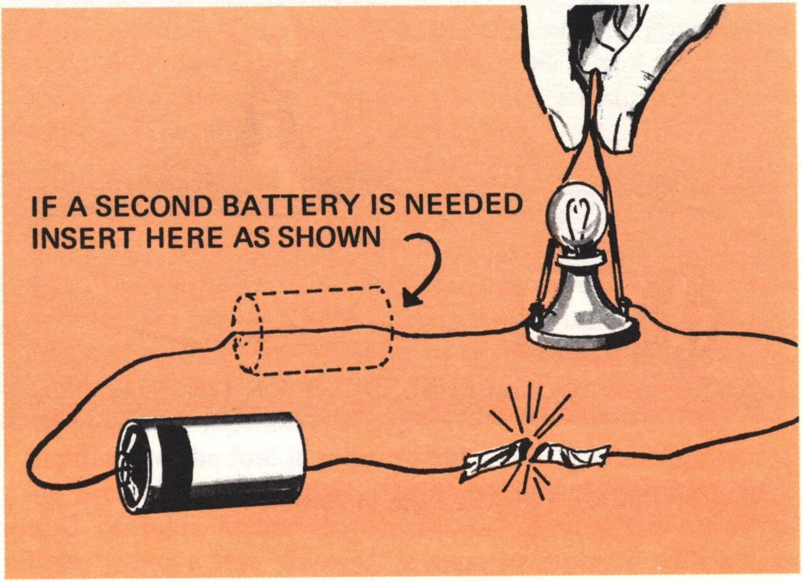
MATERIALS: *2 or 3 feet of common lamp wire. A strip of Christmas tree tinsel (silver icicle). Flashlight bulb and socket. Flashlight battery or dry cell (you may need 2 batteries).*

You can easily demonstrate how the fuse works. To build the fuse, cut the lamp wire in half. Then take one of these pieces and cut it in half again. Remove one-half inch of insulation from all six ends.

Lay the two small lengths of wire on a flat surface so that the wires are one straight line and an inch or less apart. We're going to connect a piece of tinsel across the one-inch gap. Use tape to make your connections, and be sure there is good contact between wire and tinsel at both ends. This will be our fuse.

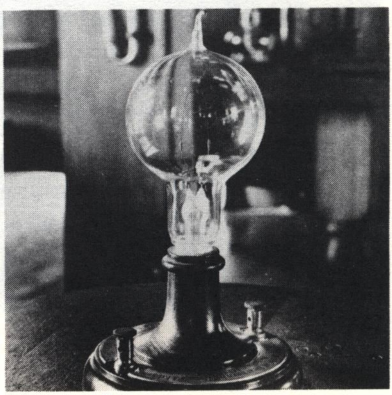
Now comes the test. Connect the fuse wires with the lamp and flashlight battery, as shown. Use tape to hold the wires to the battery ends. If everything is in order, the lamp will light.

To see the fuse in action, we'll have to produce a short circuit. Do this by touching the two terminals of the lamp socket at the same time with a pair of pliers or another piece of wire. That will allow the current to bypass the lamp, taking a short cut, you might say.

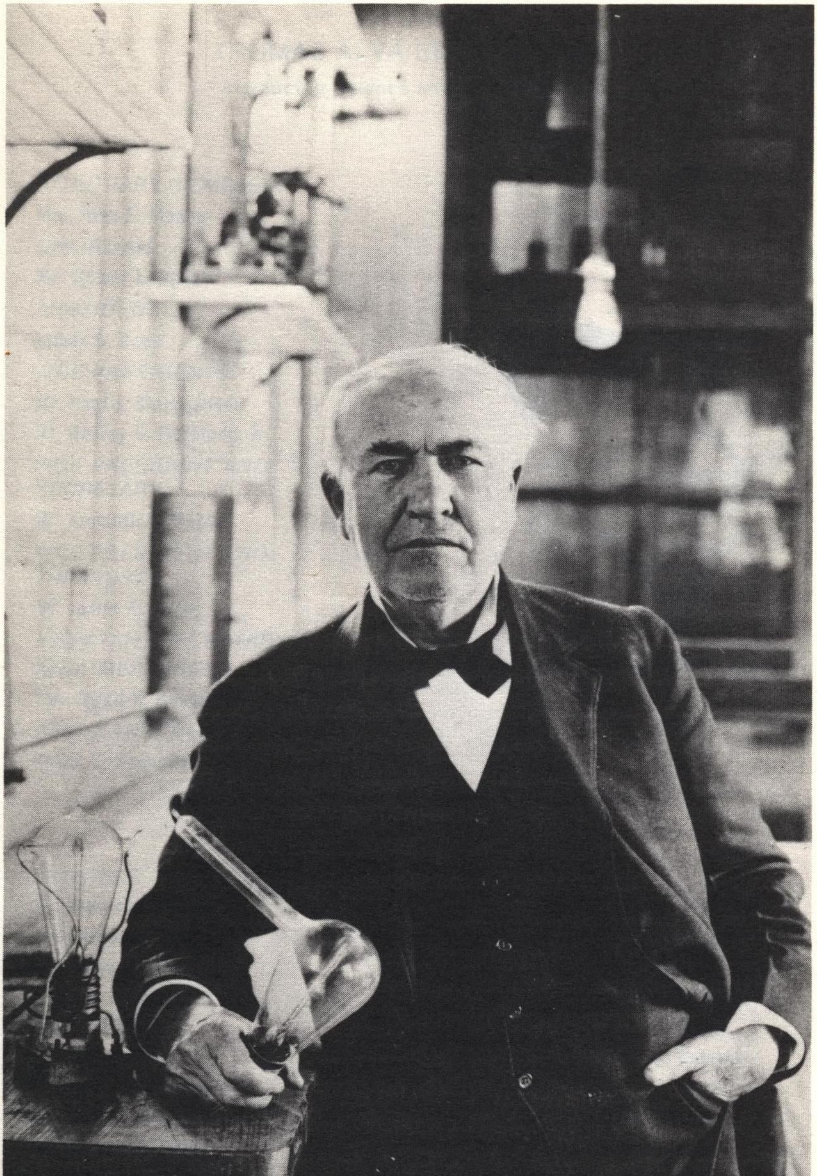


Without the lamp to act as a resistance, the current becomes much higher. The load will probably be more than the tinsel can carry. If so, the tinsel will overheat, melt, and open the circuit. However, you may have to use two batteries in series, depending on the thickness of the tinsel. If it weren't for our homemade fuse, the power source would spend itself in seconds.

We get this same kind of protection from our home fuses (or circuit breakers). Edison foresaw the possible dangers of electrical overloads and short circuits. That's why he felt the fuse was a necessary part of his system.



A replica of the first successful lamp, which was invented by Edison on October 19, 1879.



NOTES

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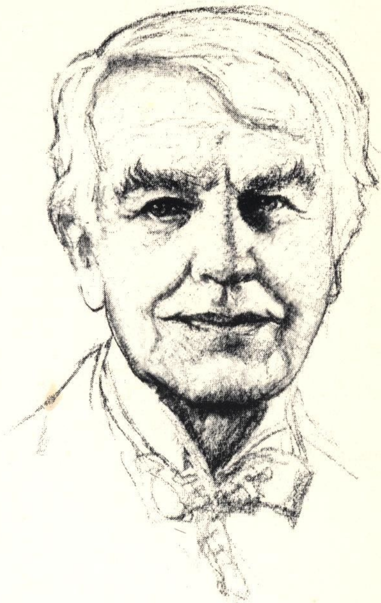

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