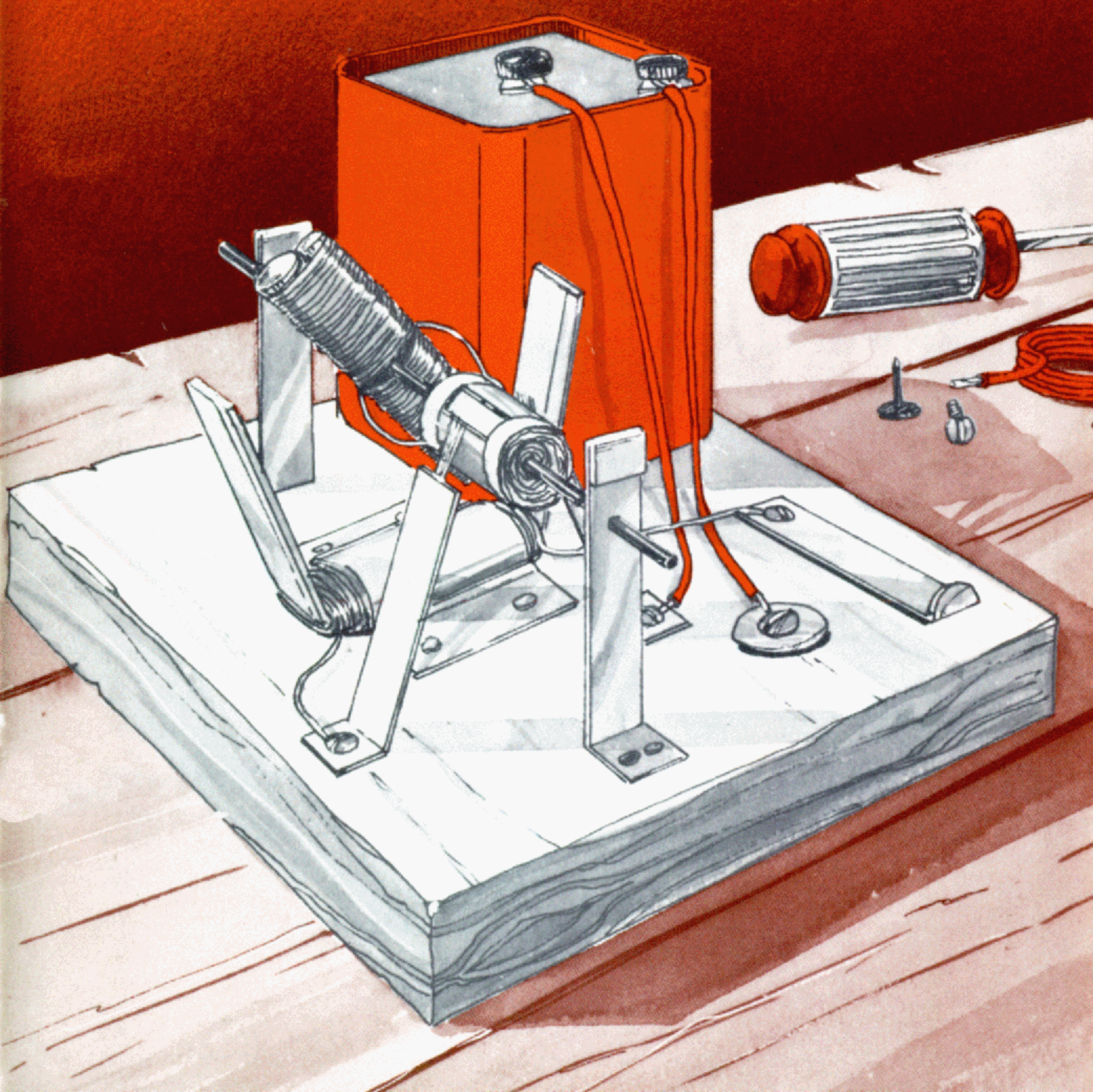
Selected Experiments and Projects

...from Edison



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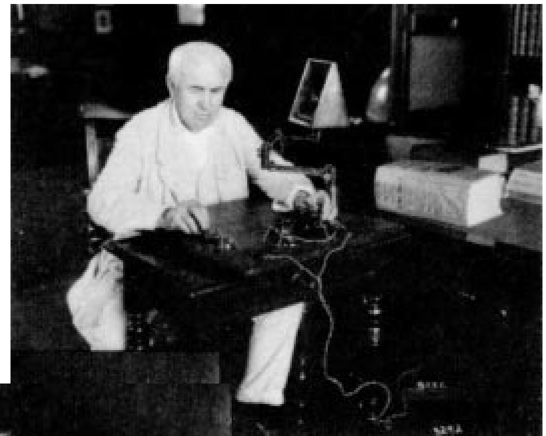

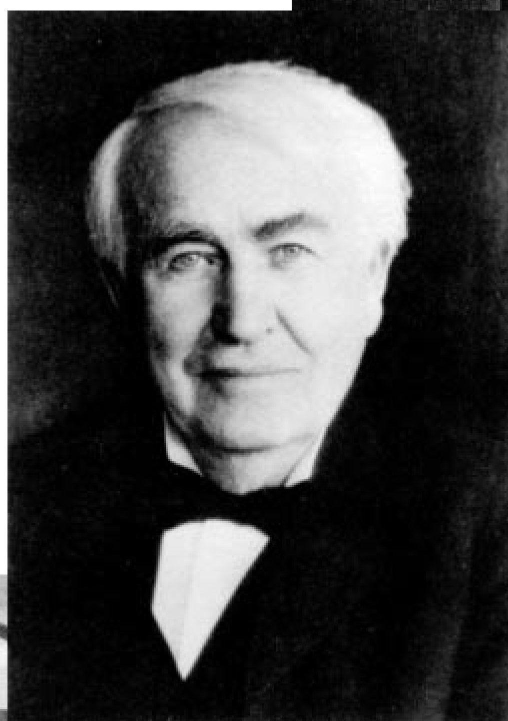

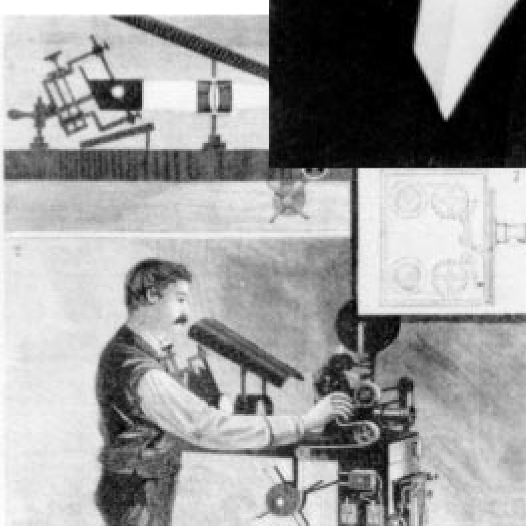

Selected Experiments and Projects

... from Edison

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INTO THE SECOND CENTURY OF LIGHT

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THOMAS ALVA EDISON FOUNDATION
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ADVANCING SCIENCE, TECHNOLOGY AND ENGINEERING EDUCATION

Charles Edison
1890-1969
Son of Thomas Alva Edison

TO THE YOUNG PEOPLE OF AMERICA

The initial publication run of this, the eighth in the "Edison Experiments" series, was made possible by a grant from the Charles Edison Fund, named for a departed dear friend.

Charles Edison, like his father before him, Thomas Alva, was a man of manifold interests and energies. Although not scientifically oriented in the manner of his father, Charles was, nonetheless, a successful experimenter in his own right.

He introduced innovations into government as Secretary of the Navy and Governor of New Jersey; he initiated social reforms and advanced techniques in the businesses he headed; and he gave unstintingly of his time, talents and treasury to bettering the future while preserving the best of the past.

Thomas Edison left with us 1,093 patents, most of which are still being used in the service of man. As Charles Edison once remarked, his father would have been very pleased by this, but it would have given him far greater satisfaction to know that his name was being used as an inspiration to young men and women to follow in his footsteps.

I urge you to consider these areas for your career. Science and engineering offer excitement and great personal fulfillment. They are, after all, superb vehicles for the improvement of life for mankind.

Walker Cisler

Walker L. Cisler
Chairman and Chief Executive Officer
Thomas Alva Edison Foundation

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NOTE: You need various metal strips to do Experiments 2, 3, 9, and 10. These can be cut from a large coffee or juice can. The easiest way to do this is to remove the bottom first. Then cut along the seam, and flatten the can. Watch out for those sharp and jagged edges.

Be sure to scrape the metal clean when making electrical connections.

Good luck with your projects.

THOMAS EDISON
AN AMERICAN FOLK HERO

Back in the 19th century, even though America was still in its infant stages, we were regarded as the most inventive nation in the world. Samuel Morse had invented the telegraph, Alexander Graham Bell the telephone, Cyrus McCormick the reaper, Elias Howe the sewing machine, Charles Goodyear vulcanized rubber, George Eastman photographic roll film . . . even Abraham Lincoln had patented an invention of a novel riverboat.

But all through this revolutionary period of technical progress, the accomplishments of Thomas Alva Edison placed him head and shoulders above all other inventors.

Edison was a driving, self-taught American who used his intellect and burning curiosity to become perhaps the most productive inventor known to history. To the people of his time, he grew to be one of their greatest folk heroes. He was the man who was forever “making things.”

Along with hundreds of other contributions, Edison gave us the phonograph, motion picture camera, nickel-iron battery, electric railroad, multiplex telegraph, carbon microphone, and, of course, the electric light. Truly he belongs among the great builders of our country, now celebrating the 200th anniversary of its existence.

As a Bicentennial tribute to the master inventor, the Thomas Alva Edison Foundation is publishing this newest experiment booklet. It contains selected, revised experiments from Foundation booklets now out of print. Most of the experiments and projects relate directly to Edison's more famous inventions. The others deal with some of the scientific principles he used in achieving the 1093 inventions he gave us.

REPRODUCING SOUND THE EDISON WAY

From his early youth, Edison was hard of hearing. Perhaps that's why he devoted much of his time to the study of sound. He knew that the vibrations of the human eardrum, which is really a diaphragm, were communicated to the inner ear and that this caused the sensation of sound.

His experiments with megaphones, vibrating diaphragms, and the telephone transmitter were all stepping stones to his invention of the phonograph in 1877.

Edison's phonograph reproduced sound as follows: a pick-up stylus tracking the grooves of a recording (Edison used tin foil wrapped around a cylinder) vibrated in accordance with the sound impressions in those grooves. Being attached to a diaphragm, the stylus caused the diaphragm to vibrate at the same rate. The diaphragm then emitted sound waves, which were made audible by a mechanical horn. Let's see if we can reproduce sound the way Edison did.

Experiment 1

A Phonograph Pick-Up

Materials: Frozen juice can. Aluminum foil. Small cork. Sewing needle. Phonograph record (don't use a good one). Smooth cardboard. Ballpoint cartridge.

HORN AND DIAPHRAGM. First, remove the bottom of the juice can with a can opener. Then stretch a piece of aluminum foil tightly over either opening, folding the foil edges down the sides of the can and securing the foil with a strong rubber band. Try to get this diaphragm as taut as you can.

STYLUS. To make the stylus, carefully tap the needle through the cork until the eye end is flat with the cork surface. Glue the back of the cork to the center of the diaphragm. You have just built a mechanical sound pick-up.

WHAT'S THIS I HEAR? With the can opening next to your ear, lightly scrape your finger against the stylus. Pretty loud, isn't it? Now, holding the pickup at an angle, let the needle rest lightly in the grooves of your record. Well I'll be a caveman's cousin. That's music coming out of the can.

SEEING SOUND. You can also demonstrate the vibrations that sound creates by converting your pick-up to a recorder. Do this by replacing the needle with the ballpoint cartridge. Then cut a round piece of smooth cardboard the size of your phonograph turntable. Punch a hole in the middle, and place it on the turntable. Start the machine. As you hold the pen gently on the cardboard, make various sounds into the can. Note the wavy line caused by the vibrations of the diaphragm as the sounds from your voice strike it.

THE TELEGRAPH RELAY

You've heard of a relay, haven't you? It's an electromechanical device that allows a weak force to control a much stronger force. For example, a relay allows a switch in a safe low-voltage circuit to open or close a higher-voltage circuit.

In the telegraph system that Edison operated and helped develop, the current flowing in the line between two distance stations was too weak to operate the sounder. The sounder is what made the coded clicks that the operator would translate into a message. So to activate the sounder, a relay was used.

Here's how it worked: The telegraph line was connected to a coil in the relay having many turns of wire around an iron core. When current flowed through the coil, meaning that a message was coming in, the coil became an electromagnet. The resulting magnetism caused two contacts in the relay to close. These contacts were part of a separate circuit that included the sounder and its own power supply. How the click intervals varied indicated what the message was.

Building and testing an electromechanical relay will give you a clearer picture of this operation. In your setup, imagine the telegraph key (really a kind of on-off switch) to be miles away and the relay located at your end of the line. A light bulb will serve as the sounder.

Experiment 2
The Relay in Action

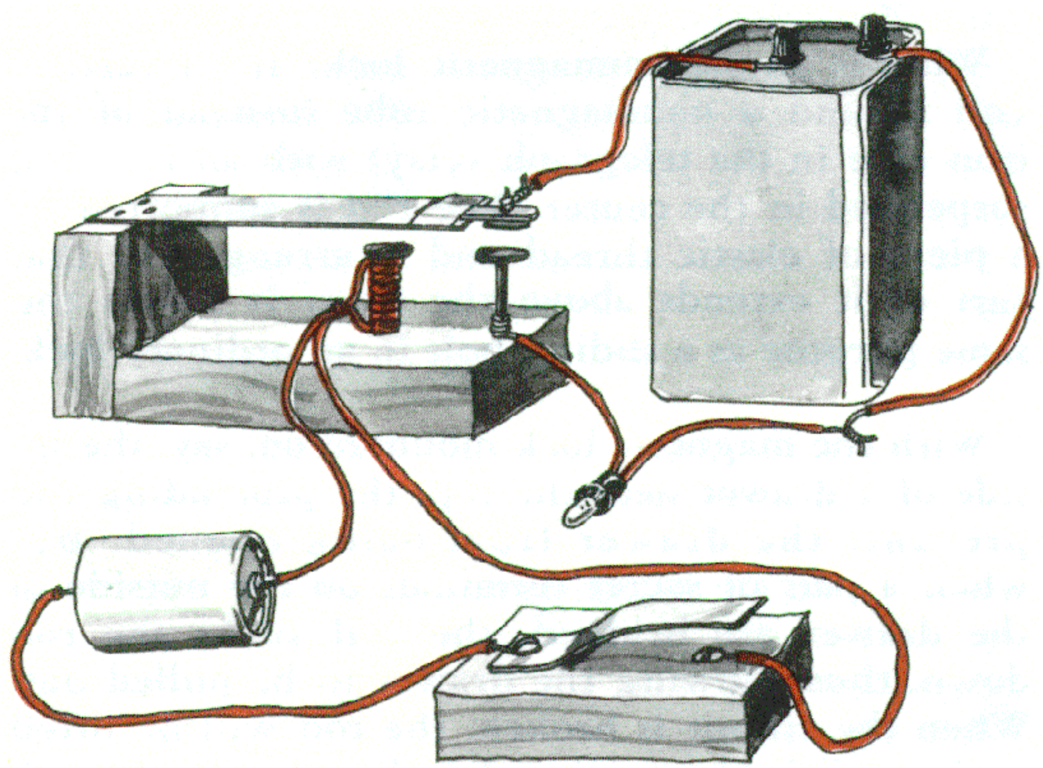
Materials: 2 wood blocks 4” by 2” by ¾”. A wood block 2” by 2” by ¾”. Some nails, including 2 roofing nails l-1/2” long. 12’ of hookup wire. Metal strips. Popsicle stick. Thumb tack. 1-l/2-volt flashlight battery. 6-volt battery. 6-volt bulb. Bulb socket (the kind with wires already attached).

RELAY FRAME. Using the drawing as a guide, nail the wood blocks together to form the frame. Then install a roofing nail about l-1/2” from the open end. The top of the nail should be slightly below the top of the upright wood block. Also, mark a spot l/4” from the open end for the other roofing nail, but don‘t pound that nail in yet.

ELECTROMAGNET. Put about 100 turns of wire around the first roofing nail, leaving enough wire to make circuit connections. Keep the wire turns close together. When finished, twist the loose ends together so they won’t come apart. Now you can drive the second roofing nail in.

CONTACT ARM. For this you’ll have to cut a 4” by 1” metal strip. Next, tape a piece of the popsicle stick to the end of the strip. Have the stick extend l/2” beyond the strip. Near the end of the stick, press in the thumb tack, with the head on the same side as the strip. Make sure the head is scraped clean. Then nail the strip to the frame so that the tack head is directly above the outermost roofing nail.

TELEGRAPH KEY. Make this from the last wood block and a metal strip 4” by l/2”. Bend the strip as shown. Use round-head screws for the terminals. Now you can connect all the parts to see the relay in action.



A MESSAGE COMES IN. Note that when the low-voltage telegraph key is depressed (from miles away, remember?), the nail becomes an electromagnet and pulls the strip down. This closes the higher-voltage circuit, lighting the bulb. When the key is released, the electromagnetic field collapses, the strip springs upward, and the bulb circuit opens.

THE RELAY COIL IN A FUN PROJECT

Edison used the relay principle in many of his inventions. It's easy to see why. This principle has thousands of applications.

Remember we mentioned a coil in the relay having many turns of wire around an iron core? We're going to use a coil similar to this in a fun project on the secret electromagnetic lock.

What is an electromagnetic lock? It's a vertical coil around a nonmagnetic tube (instead of the iron core in the telegraph relay) with an iron rod suspended in the center. The rod is supported by a piece of elastic thread and is arranged so that part of it extends above the tube. It serves the same purpose as a sliding bolt in an ordinary lock.

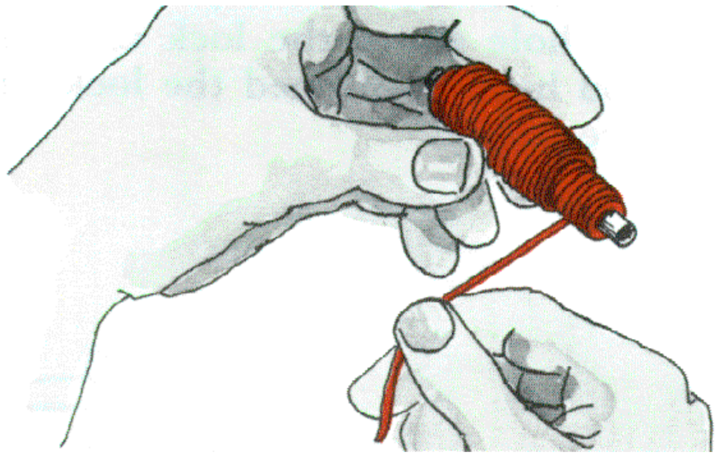
With the magnetic lock mounted on, say, the inside of a drawer near the top, the protruding rod prevents the drawer from being opened. But when a pair of secret terminals on the outside of the drawer are bridged, the coil yanks the rod down, thus allowing the drawer to be pulled out. When the circuit is broken, the rod will be lifted to its original position by the elastic thread. Power for the electromagnetic lock is supplied by a 6-volt battery kept inside the drawer.

Experiment 3

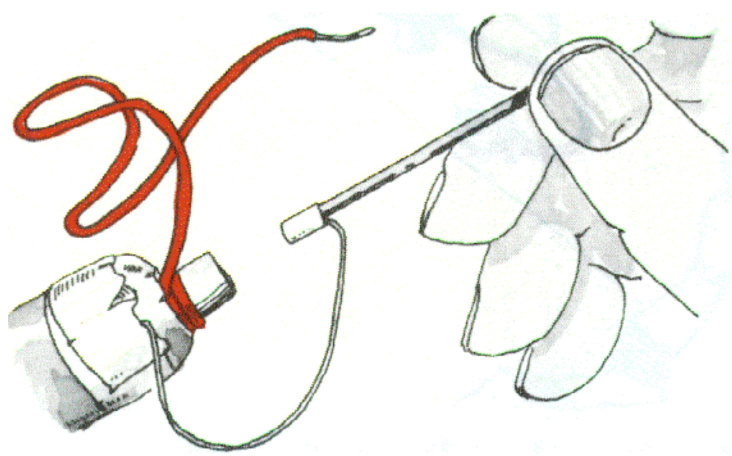
A Secret Drawer Lock

Materials: 1/4" nonmagnetic tubing 2-1/2" long. 35' of hook-up wire. An 8-penny nail. Elastic thread. Metal strip. 4 small nails. 2 machine screws with nuts. 6-volt battery.

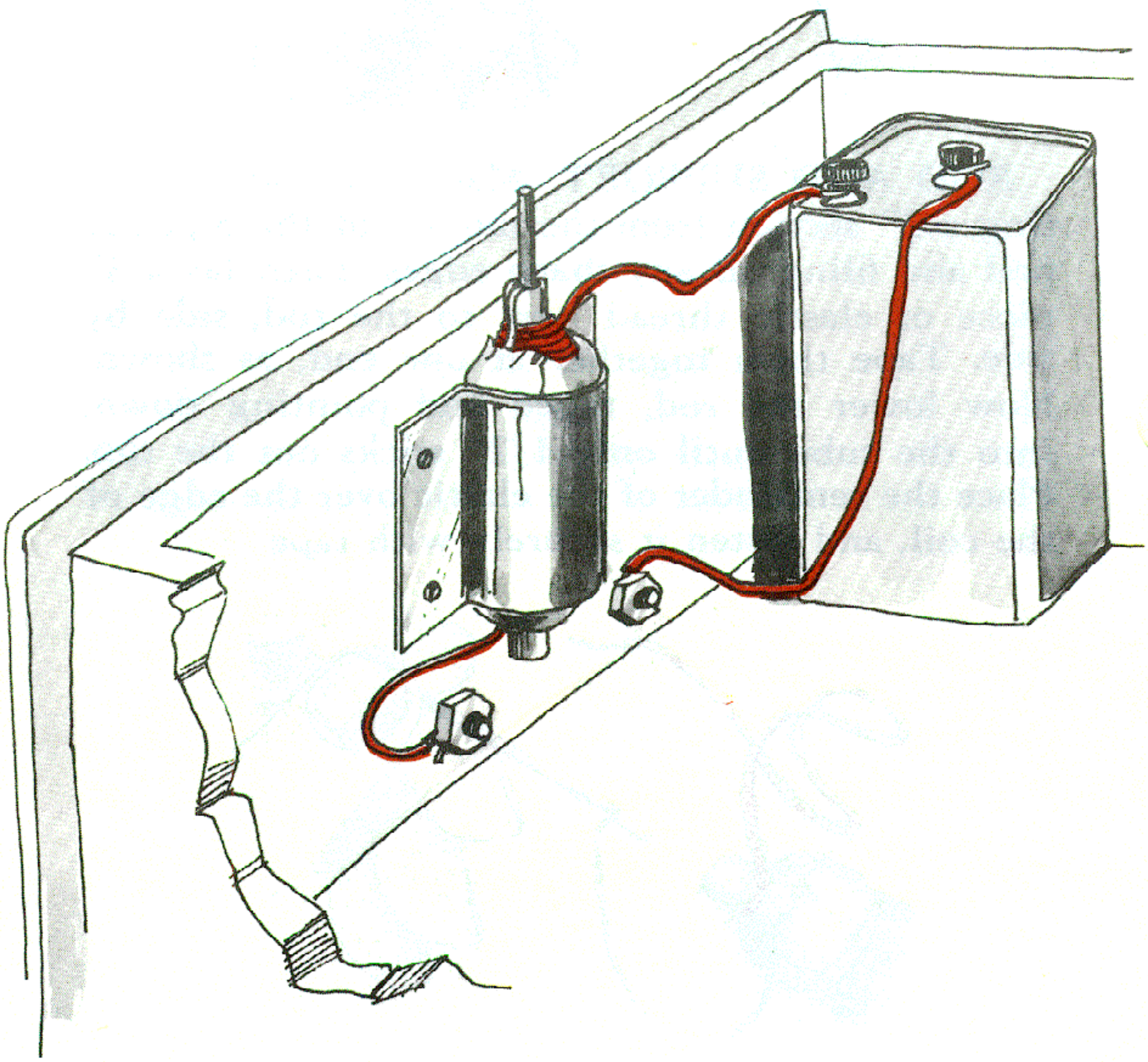
COIL. For the tubing, use copper or aluminum. Wind about 300 turns of wire around the tubing. When you've finished, wrap some tape around the entire assembly so it won't come apart.



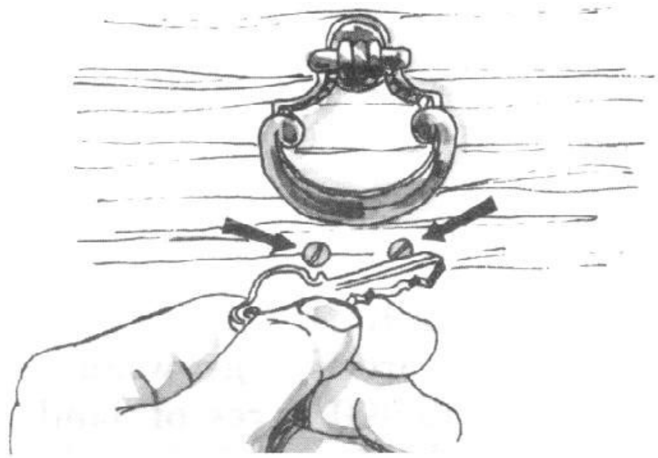
ROD AND SUPPORT. Make the rod by cutting a 2" section from the middle of the 8-penny nail and filing off any sharp edges. Then lay a 3" piece of elastic thread next to the rod, side by side. Tape them together at one end, as shown. Now lower the rod, taped end pointing down, into the tube until only l/2" sticks out the top. Place the remainder of the elastic over the edge of the coil, and fasten it securely with tape.



INSTALLING THE LOCK. Cut a metal strip 3" by l-1/2", and form it around the coil. Bend the ends outward, and punch two holes in each end to receive the nails. Before mounting the lock, energize the coil and measure the distance the rod drops. Suppose it drops l/4”. This means you should locate the lock on the drawer so that the rod exends l/4” into the space above the top of the drawer. If there is no space, you will have to gouge a small hole above the lock to receive the rod. When you have positioned the lock properly, nail it in place.



CONNECTING THE CIRCUIT. The battery and lock are connected in series with two terminals (machine screws) that come through the drawer from the outside. Wires from the coil and battery are attached to these screw terminals with nuts.



Anything metallic that can touch both outside terminals at once will be your “electric key.” It could be a coin, a scout knife, a metal-edged ruler. Of course, touching the terminals and pulling on the drawer will have to be done at the same time. And it should be done quickly, to conserve the battery.

FREE ADVICE. Here’s an idea on how to disguise the outside terminals. You could attach some sort of *nonconducting* (cardboard, wood, plastic) emblem or nameplate to the drawer front and use decorative screws as terminals. But even if you do nothing special with the screws, no one is likely to guess the secret of how the drawer is locked or what must be done to open it.

Incidentally, when the battery inside the drawer starts to weaken and can’t quite pull the rod all the way down, you can still open the drawer by applying 6 volts (in the right + to – direction) to the outside terminals, But don’t let the battery die, for then you will have a little problem on your hands.

EDISON'S ORE SEPARATOR

While we're still on the subject of electromagnetism, let's take a look at one of Thomas Edison's inventions based directly on this principle. It's his magnetic ore separation process.

Edison's reason for developing this process was to separate low-grade iron ore from the worthless material found with it. In the 1880s, a general belief was that iron ore was growing scarce. Edison had access to 19,000 acres of land that contained, in his words, "over 200 million tons of low-grade iron ore." He thought that it would be a simple matter to extract the iron and sell it at a good price. And that's what he set out to do.

It was no small operation. His iron mine and ore-processing plant at Ogdensburg, New Jersey, had miles of conveyors, giant rollers that could crush piano-size rocks, and the largest steam shovel in America.

The heart of the whole system was a towering structure that housed the ore separator. In this building, powdered rock was hoisted to the top and allowed to fall past a series of screens and large magnets. The iron was deflected by the magnets into receiving bins; the sand dropped straight down to be carried away.

We can easily make a model of this separator using sand and iron filings as the ore mixture. But we can demonstrate the identical principle in a less messy and more relevant way with the slug (counterfeit coin) rejector.

Experiment 4

Rejecting Counterfeit Coins

Materials: Iron bolt 2” long with nut and 2 washers. 20’ of hookup wire. Thin, stiff cardboard 10” by 12”. Telegraph key from Experiment 2. Various coins and coin-sized washers (slugs). 6-volt battery.

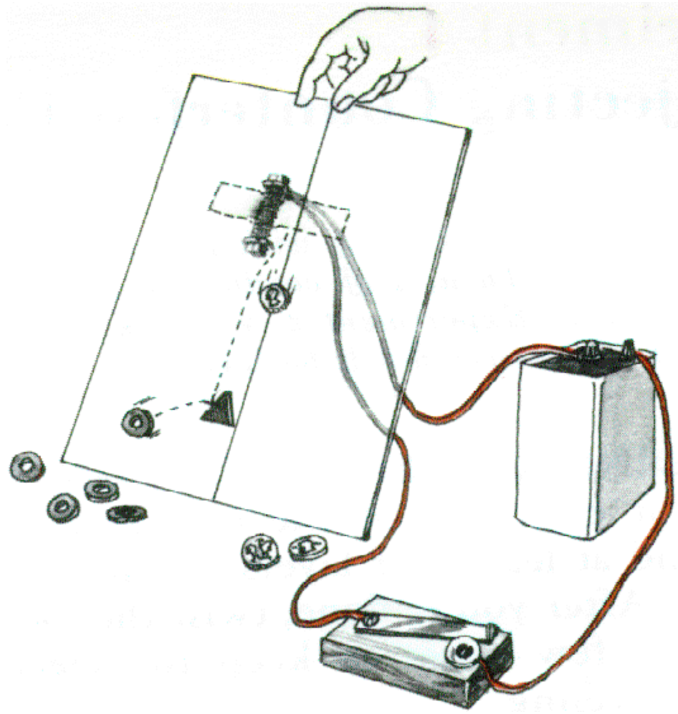
WINDING THE ELECTROMAGNET. Place a washer at each end of the bolt and engage the nut. Wind at least four layers of wire between the washers. After you’re done, twist the loose lengths of wire a few times to keep the electromagnet from unraveling.

PREPARING THE SETUP. First, put marks on the cardboard to indicate front, back, top, and bottom. Then draw a centerline down the length of both the front and back. Also draw a parallel line on the back l/2” to the right of the centerline. Tape the electromagnet on this parallel line about l/3 of the way from the top.

On the front, glue an A-shaped piece of wood as a divider. Locate it a few inches from the bottom, and position the peak l/4” away from the centerline, toward the electromagnet.

Now we’re going to convert the telegraph key to a switch. Very simple. Just cut a 3/4” metal disc, make a hole in the center, and put it under the free screw. Also straighten the arm, and bend the end upward. The switch will be “on” when the arm is wedged under the disc.

HEY MA, IT WORKS. After connecting the circuit, prop the cardboard against something sturdy at about a 45^{o} angle. From the top of the



centerline, let several coins and slugs (washers) slide down the cardboard. If our slug rejector is working properly (bet you forgot to close the switch), all the slugs will be attracted to the electromagnet side of the divider, and all the coins will drop straight down . . . somewhat like in Edison's ore separator.

That's because magnetism affects iron but not copper or nickel (or sand). Modern coin vending machines detect slugs in a similar manner.

THE MOVIES THANKS TO EDISON

During the middle years of his life, Thomas Edison's interest focused mainly on his secret "toy," the motion picture camera. He could see no practical future for it. Yet he could not bring himself to abandon the project. Perhaps he felt it was a logical extension of his work on the phonograph, which he had invented years earlier and was still improving.

In 1888, Edison filed a document with the U.S. Patent Office stating: “I am experimenting upon an instrument which does for the eye what the phonograph does for ear . . . . This apparatus I call a Kinetoscope.”

The Kinetoscope offered the first motion picture show in history. With it, the viewer could look through a peephole and see a sequence of stop-and-go photographs that gave the illusion of continuous motion. Persistence of vision made this illusion possible.

Although today’s motion picture equipment is vastly superior to what Edison developed, persistence of vision is still necessary for it to work. What is persistence of vision? It is the tendency of the eye to continue seeing an object for about l/l0 of a second after the object disappears. Here’s a simple experiment to demonstrate the effect.

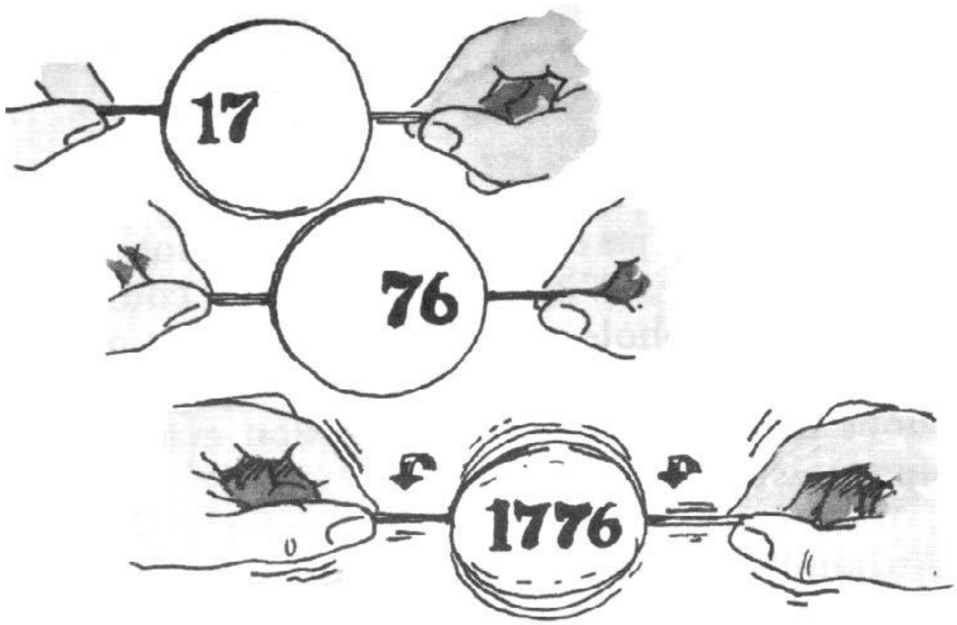
Experiment 5

The Spirit of 1776

Materials: 2” disc of cardboard. 12” of string. Glue.

SETTING THE STAGE. On the left half of the disc draw a large 17. Flip the disc over in bottom-to-top fashion, and draw a large 76 on the right half. After laying a thin bead of glue across either side in the horizontal direction, stretch the string firmly and place it on the glue.

SEEING IS BELIEVING. When the glue has dried, twirl the disc rapidly back and forth with the string. Thanks to the persistence of vision we all have, you will see our country’s birthyear as a complete number. In addition, you will see what lies directly behind the disc, which would nor-



mally be blocked out.

In developing his motion picture camera, Edison used not only the persistence of vision effect but certain optical principles as well. One of these explains how a camera sees an image, as shown in the next experiment.

Experiment 6

A Pinhole Camera

Materials: Large coffee can with plastic lid (the semiclear type). Large dark cloth.

BASIC CAMERA. It's amazing how simple a camera can be, as you're about to find out. To make one, punch a hole about the size of a penny in the bottom of the coffee can. Do it in the center. Then cover this hole with a disc of thin cardboard, taping it down around the edges. Now pierce a hole in the disc with a pin, put the plastic lid on top of the can . . . and there's your camera, ready to go.

SCREEN AND LIGHT SHIELD. The plastic lid is our viewing screen. However for you to be able to see the projected image of what you aim at, the screen has to be shielded from light. For this purpose, drape the dark cloth over your head and the camera, the way some photographers do.

A TOPSY-TURVY WORLD. Aim the camera at something bright about 10’ away. Hold the screen a foot or so from the eye. Note that what you see on the screen will be upside down. This is because light travels in straight lines. The light from the top of the object travels through the pinhole and lands on the bottom of the screen. Similarly, light from the bottom of the object strikes the top of the screen.

WHO TURNED ON THE LIGHTS?

What do most people think of when they hear the name Thomas Edison? The light bulb, of course. Invented by Edison in 1879, it was the most practical source of artificial light produced by man since the beginning of time. In the early 1800s, scientists in both the United States and Europe had experimented with hundreds of incandescent electric lights. But they couldn't get any of them to work, except perhaps for brief periods, until Edison succeeded.

As hard as it was to develop, the incandescent electric light is basically a simple device. It consists of a coiled filament within a glass enclosure from which the air has been removed.

The principle on which it is based is that a glowing filament gives off both heat and light. The hotter the filament, the brighter the light. Edison's main problem was to find the right material to use for the filament. But he also had to create a good vacuum to prevent the filament from burning up.

After finding that carbon filaments worked best, he managed to make the filament last longer and longer by removing more and more air from the bulb. We're going to try something similar in this experiment on the light bulb.

Experiment 7

Edison's Electric Light

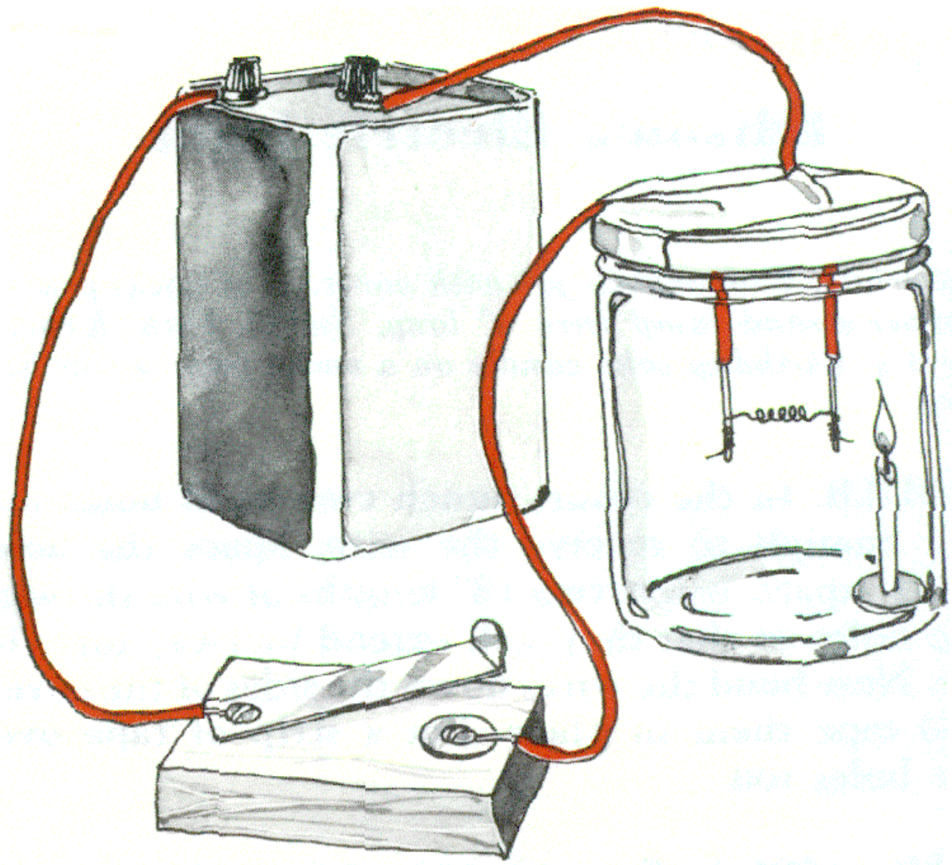
Materials: Wide-mouth jar with cover. 4' of hookup wire. Copper-strand lamp wire 4" long. Switch from Experiment 4. Birthday cake candle on a small base. 6-volt battery.

BULB. In the cover, punch two small holes just big enough to receive the wire. Space the holes l-1/2" apart. Insert two 18" lengths of wire through the holes so that they will extend halfway into the jar. Now bend the wires down the sides of the cover, and tape them in place. Put a strip of tape over the holes too.

FILAMENT. Remove one copper strand from the lamp wire. Wind it several times around a nail. Slip the coiled filament off the nail, and connect it to the two wires coming from the cover.

LIGHTING UP THE DARK (WELL, NOT QUITE). Screw the cover on the jar. This is our "lamp." Next, connect the lamp in series with the switch and the battery. Turn the lamp on and start counting. The filament will begin to glow. If it continues glowing for more than 15 seconds, open the switch. Otherwise you'll drain the battery. Try a shorter filament. Keep doing this until you find a length that burns for just a few seconds. When you do, put on a new filament of this length.

Now we're going to remove some of the air from the lamp. Put the candle inside the jar and ignite it. There turn out the room lights. While the candle is burning, close the jar tightly. When the candle goes out, which means it has used up a



lot of the air, turn the lamp on once again. Hopefully, the filament will glow a little longer this time. Letting it glow in the dark will produce a rather dramatic effect.

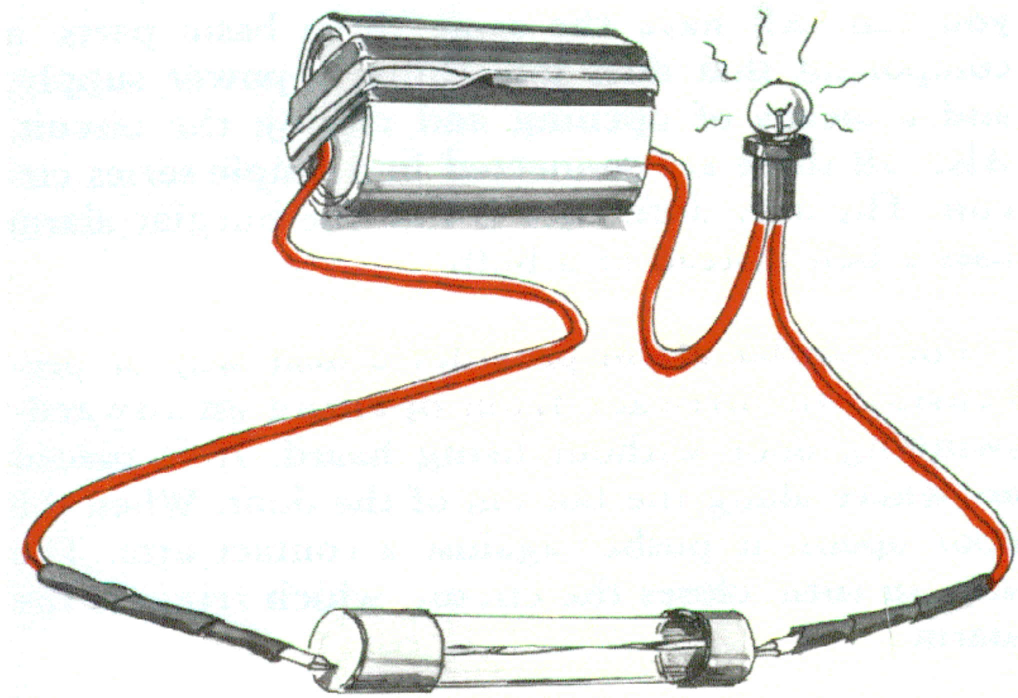
Experiment 8

A Light-Bulb Indicator

Materials: 2 long thin nails. 2' of hookup wire. Bulb socket from Experiment 2. Screw-type flashlight bulb. Flashlight battery. Some tape.

We mentioned that the electric light bulb is a simple device. Well in addition, it operates in the simplest of circuits. An example is the light-bulb indicator you are about to put together.

ASSEMBLING THE INDICATOR. Actually there's not much to assemble, as you can see. All you do is hook the light bulb and battery in series and attach the circuit ends to the nails. Make all connections by soldering. But if you have no soldering equipment, use tape. Also cover the nails and nail connections with tape, leaving only the tips exposed.



WHAT DO WE DO WITH IT? Lots of things. For example you can use it in science experiments to learn whether or not different materials and liquids are good conductors of electricity.

You can also use it to check items like flashlight bulbs or glass-tube fuses, as shown. Some of these fuses have wires so thin you can hardly see them. If you touched the indicator nails to the ends of such a fuse and the bulb lit up, you'd know the fuse is OK.

But whatever you do, *never* use it on anything that is connected to a voltage source (but then you don't need to be told not to stick your finger in a beehive, do you?).

REPLACING THE BULB WITH A BELL

Similar to both your light-bulb indicator and home-made electric light is the portable burglar alarm on page 25. Can you see the similarity? Sure you can. All have the same three basic parts: a component that does something, a power supply, and a means of opening and closing the circuit. Also, all three are connected in a simple series circuit. The only difference is that the burglar alarm uses a bell instead of a bulb.

The burglar alarm provides a neat way of preventing an intruder from opening an inward-swinging door without being heard. It is placed anywhere along the bottom of the door. When the door opens, it pushes against a contact arm. The arm, in turn, closes the circuit, which triggers the alarm.

Experiment 9

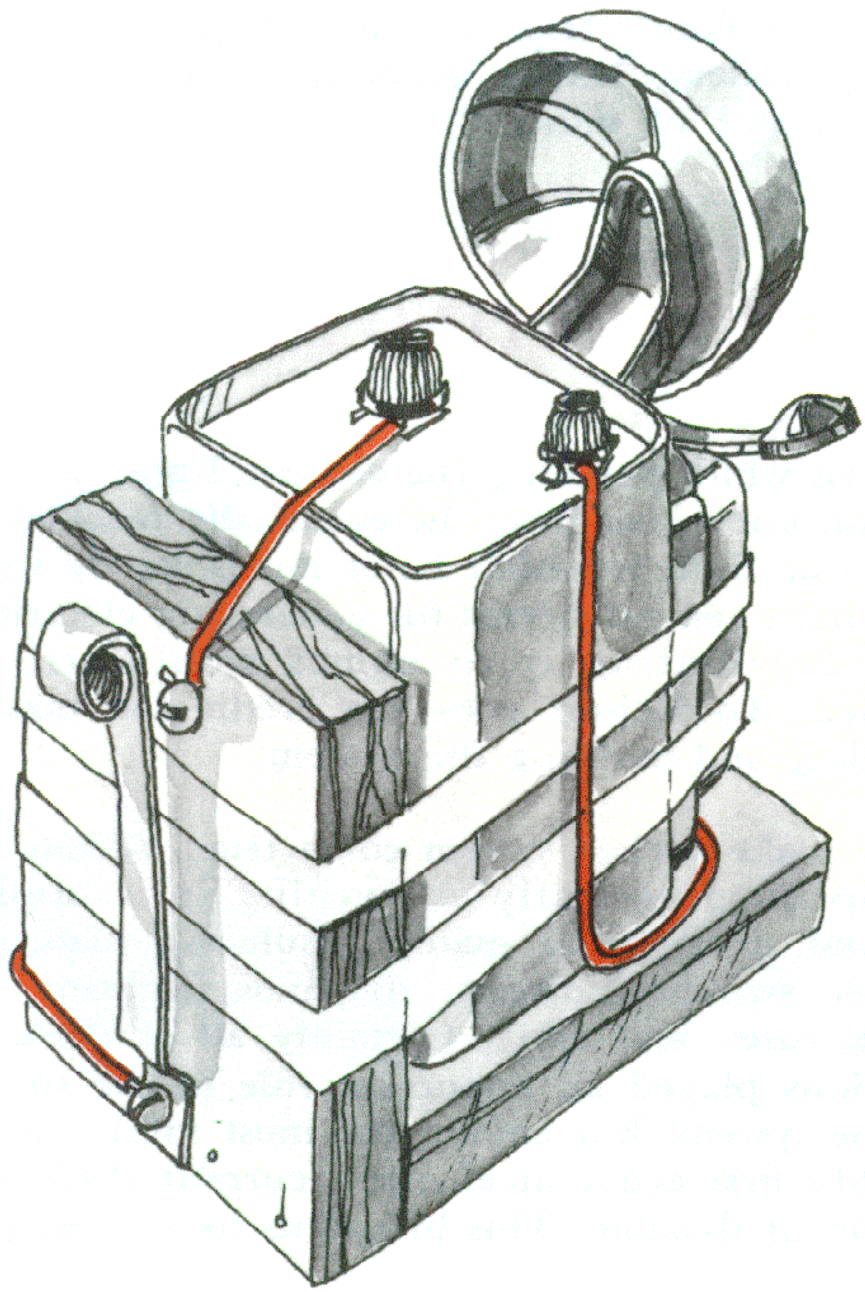
A Portable Burglar Alarm

Materials: 2 wood blocks 4” by 3” by 3/4”. 3 nails. Metal strip. 2 round-head screws. 2’ of hookup wire. Doorbell. 6-volt battery.

FRAME AND CIRCUIT CONTACTS. After nailing the frame together, drive one of the screws part way into the vertical block about l/2” from the top. Then loop the bared end of a 6” length of wire around the screw, and finish driving the screw in.

Cut a strip of metal 5” by l/2”. After shaping the strip as illustrated, pierce a hole in the flat end. In a moment we will mount this contact arm at the bottom of the vertical block using the remaining screw. But first let's assemble the alarm.

TYING THINGS TOGETHER. Attach two 9" lengths of wire to the doorbell terminals. Put the battery on the wood base, and hold the doorbell against the back of the battery. Now for a compact package, tie the bell, the battery, and the vertical block together tightly with tape or cord.



FINAL STEPS. Screw on the contact arm. Then complete these circuit connections: Run one doorbell wire to the battery, the other doorbell wire to the contact arm, and a third line from the upper contact screw to the battery.

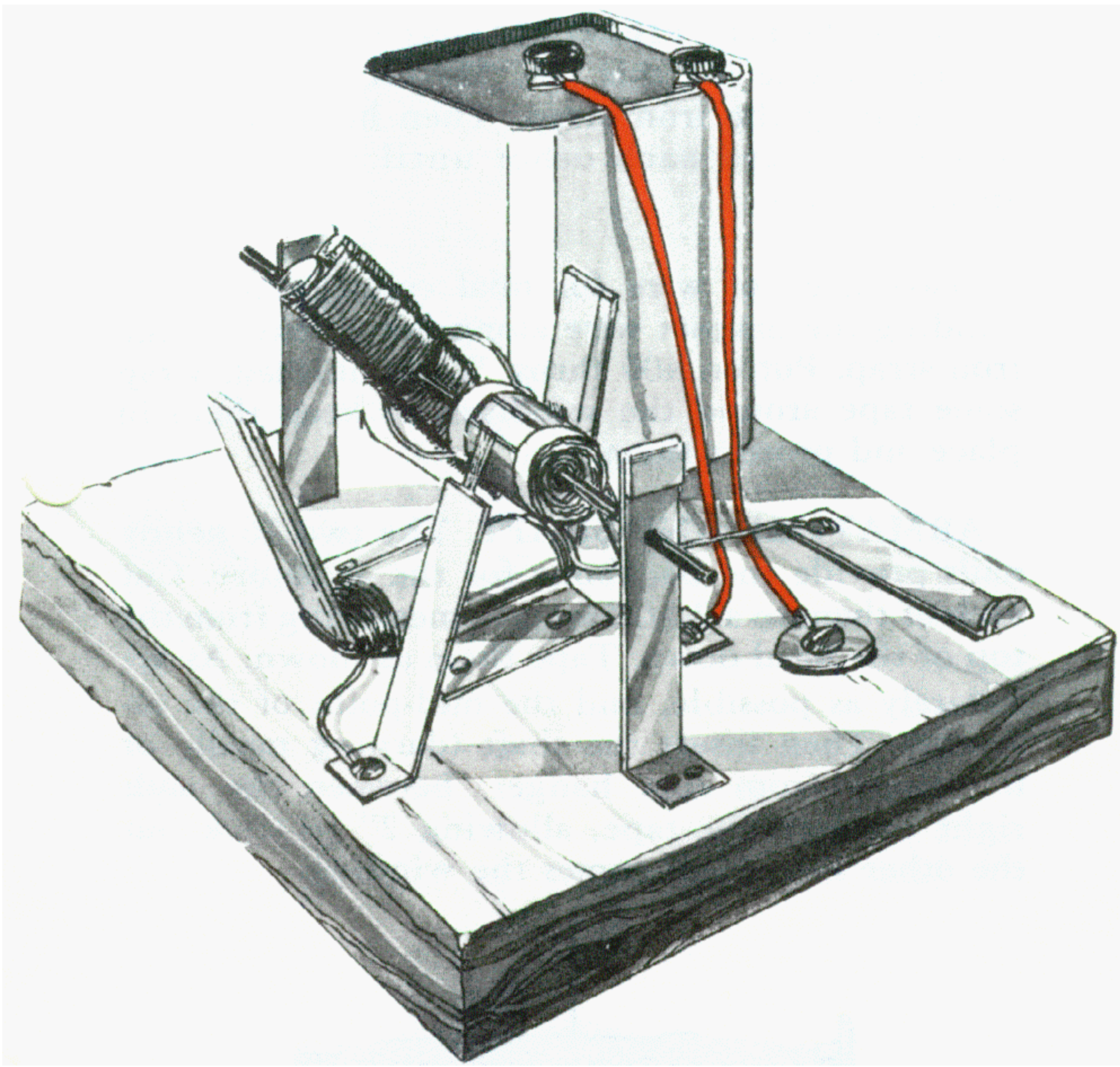
A WATCHDOG THAT NEVER SLEEPS. The system should work like a charm. Anyone opening a door that is booby trapped with this alarm will be in for quite a hair-raising surprise. Keep in mind, too, that this burglar alarm is truly portable. Since it has its own power supply, you can take it on family trips for use in hotels, motels, or house trailers. Maybe everyone will sleep with more peace of mind.

EDISON'S POWER GENERATING SYSTEM

Even while pursuing the electric light, Thomas Edison knew that when he eventually reached his goal, the light wouldn't be of much use by itself. An entire central system for generating electricity and distributing it to homes would still be needed. To Edison goes the credit for masterminding and building this system.

To make such a system come true, Edison had to invent practically everything in it: underground distribution mains, insulating materials, power switches, meters, dynamos, lighting fixtures, fuses, and more. Certainly all of these inventions played an important role in the success of the system. But among the most vital was the world's first economical direct-current (DC) generator, or dynamo. This brings us to our last project. The big one. It's a DC motor, which is essentially the same as a DC generator.

Experiment 10
A Speedy Electric Motor



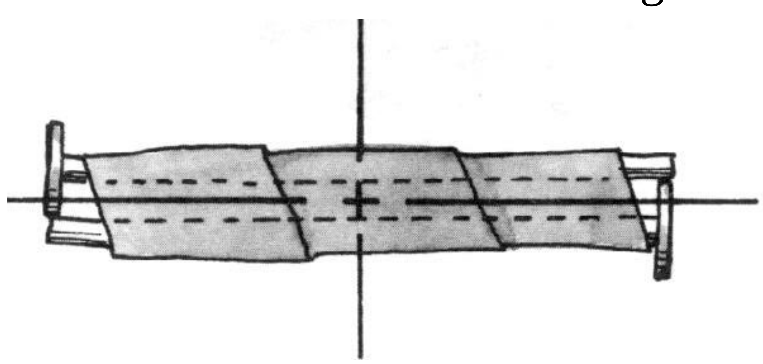
Materials: Strap iron 6" by 5/8" by 3/32" (or 1/8") 100' of. #24 magnet wire. Two 16-penny spikes. Tape 1" wide. Daring needle or piece of coat hanger. Various metal strips. Copper-strand lamp wire 2" long. Baseboard 7" by 6" by 3/4". 4 screws. Some nails. 1' hookup wire. 6-volt battery.

The motor we're going to build has four parts: the field magnet, armature, commutator, and a pair of brushes.

MAKING THE FIELD MAGNET. We're going to need a vise for this job. Measure 2" in from each end of the iron strap. Then bend these 2" sections toward each other until the ends are about 3" apart.

Leaving 6" of wire for final connections, start winding the magnet wire along the 2" base of the iron strap. Put on 400 turns. When finished, wrap some tape around the windings to keep them in place and protect them.

ARMATURE AND SHAFT. The two l6-penny nails provide the backbone for the armature. Cut each of them to a 2-1/2" length, measuring from the top of the head down. Tape them as shown. As accurately as possible, find the mid-point of the assembly. Then insert the shaft (darning needle or 6" length from coat hanger) between the nails right through the tape, allowing 2" to stick out the other side. Next comes the winding.



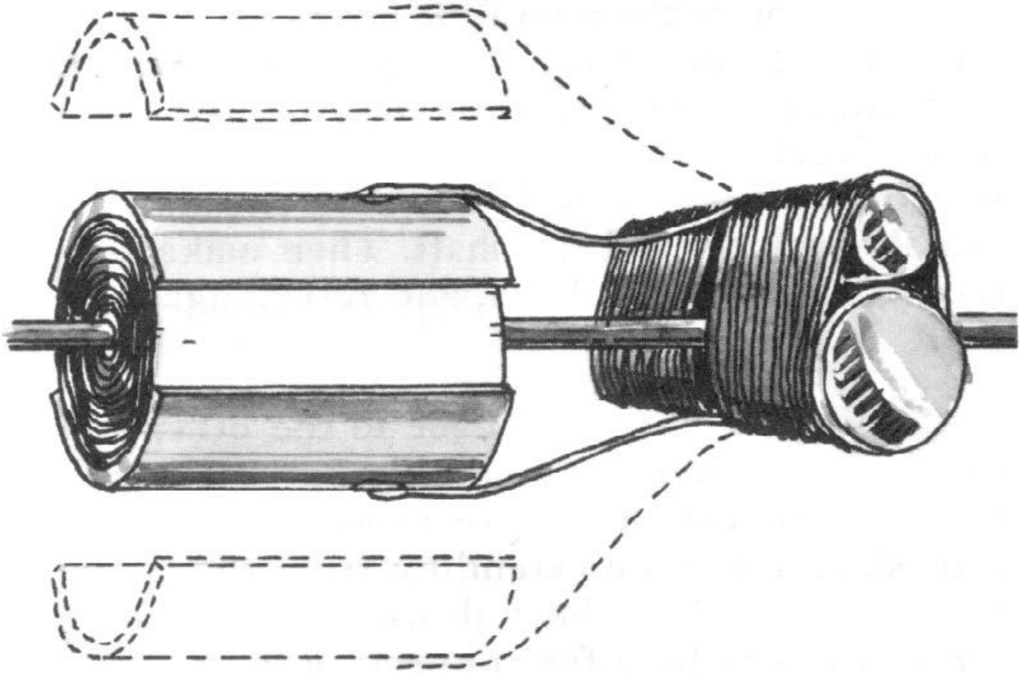
We will be putting on four layers of wire. Begin right next to the shaft. Leaving some wire for circuit connections, wind neatly toward the nail head. Keep each turn of the wire close to the preceding turn. Upon reaching the nail head, double back toward the shaft. Then make another trip to the same nail head, and return again to the shaft.

At this point we cross over to the other side of the armature *without changing our coiling direction*, and repeat the entire procedure. Two wire ends should now be extending from the center of the armature. Cut them down to about 2”, and scrape the tips bare for connecting to the commutator terminals. (Note: Magnet wire has a deceptively clear varnish-like insulation on it, which must always be scraped off when making a connection.)

THE COMMUTATOR. For the terminals, cut two 1” by l/2” metal strips. Shape them around any kind of l/2” diameter cylinder so that the length of the terminals runs with the length of the cylinder. Then if you can, solder the armature tips to the ends of the terminals. Otherwise, pierce each terminal with a small nail, loop an armature tip through the hole, and twist tightly.

Now we must build up the shaft diameter to hold the commutator terminals.. Do this by wrapping 1” tape on the longer end of the shaft about 3/4” from the armature. Keep wrapping until a l/2” diameter cylinder is formed.

After looping the excess wire around the armature, place the commutator terminals on the rolled tape as shown on page 30. The space between the long edges of the terminals should be equal on both sides of the commutator. And these



spaces should face the same direction the nails do. Put a thin strip of tape around each end of the commutator to keep it together. This completes the armature-commutator-shaft assembly. OK so far?

SUPPORTS FOR SHAFT AND BRUSHES. For the shaft supports, cut two strips 3-l/2" by l-1/4". Fold them in half so that the width is now 5/8". Bend a 3/4" segment 90^{o} for the base, and fold over about l/4" at the top for added stiffness. Standing each support vertically on a flat surface, measure 2" upward from the surface. Either drill or punch a hole at this point just big enough to receive the motor shaft. While you're at it, put a couple of holes in the base for the nails.

To make the brush holders, cut two strips 2-l/2" by l/2". In each one, bend a small segment for the base, and put a hole in the middle for a screw. Two 1" pieces of copper-strand wire will serve as the brushes. They should be soldered to the holders on the sides that will face the armature. with l/2” of copper extending above the holders. If soldering is not possible, try wrapping longer copper strands around the holders (scraped clean) and taping them on.

PUTTING THE MOTOR TOGETHER. Mount the motor parts on the baseboard as shown on page 27. When doing so:

- Secure the field magnet to the board with a 2-l/4” by 1” metal strip and nails.

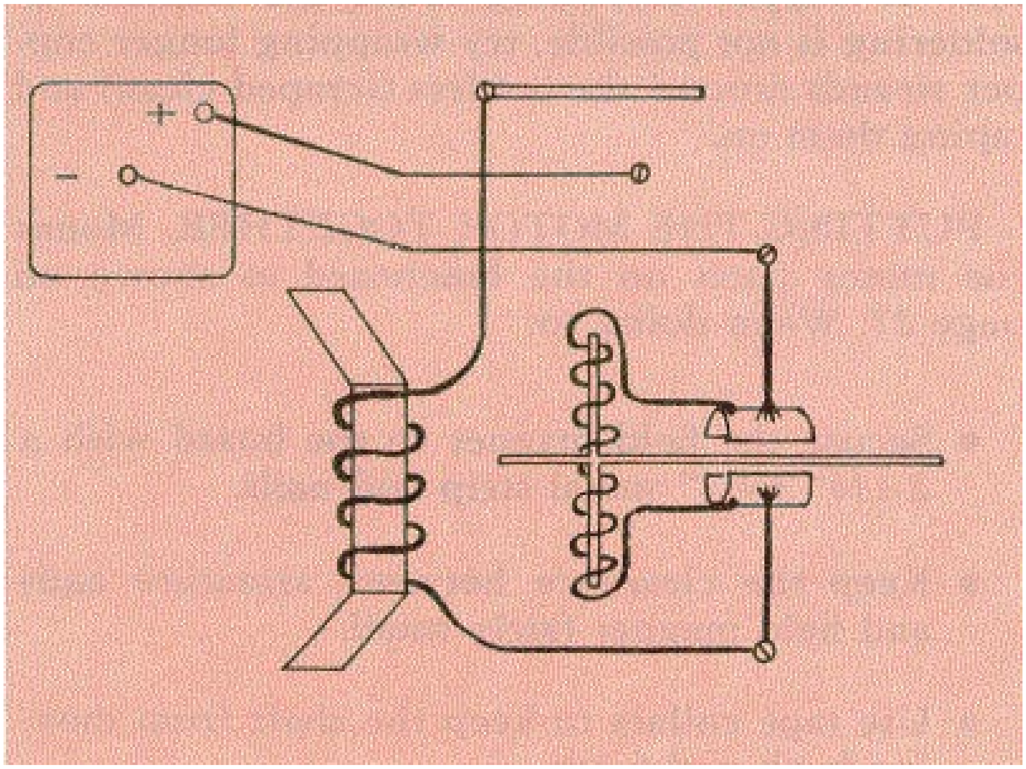
- Keep the clearance between armature ends and field magnet fairly small.

- Use tape collars to keep the shaft from moving back and forth.

- Mount the brush holders with screws. Adjust them until the copper strands are vertical. Also, fan out the strands for better contact with the commutator.

CONNECTING THE CIRCUIT. A good motor deserves a switch (and we didn’t build a junky motor, right?). Make the switch arm from a metal strip 4” by l/2”. Cut a 3/4” disc for the other contact. Use screws for the switch terminals.

In making the connections, follow the diagram on page 32 (as you can see, it’s a series circuit). Don’t forget that the clear insulation must be scraped off the ends of the magnet wire.



OK, START HER UP. Ready for the big moment? Let's keep our fingers crossed as we close the switch. You may have to give the armature a little push. If all the connections are good and nothing is binding the shaft, the motor should spring to life. Try adjusting brush pressure for better performance. A little oil in the shaft support holes will help too.

Just to see what our little workhorse can do, tie some thread around the shaft and let it hang over the edge of a table. See if the motor can lift, say, a lead pencil. Hey now, here's a possibility for your next science project in school.

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