THE FIRST BOOK OF ELECTRICITY

SAM & BERYL EPSTEIN

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This edition published 2025
by Living Book Press

ISBN: 978-1-76153-424-9 (hardcover)
978-1-76153-425-6 (softcover)

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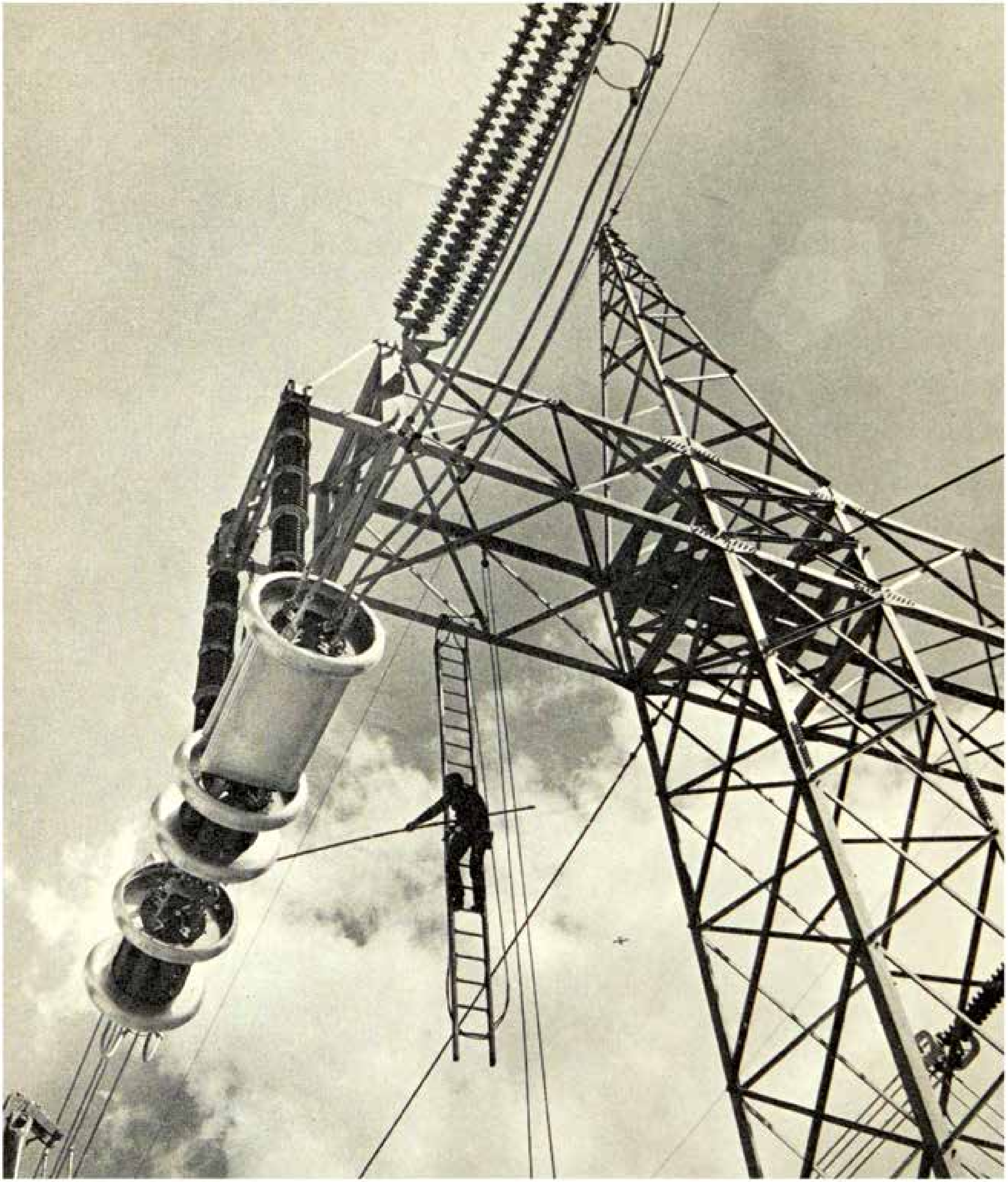


This man high in the sky is connecting wires to carry electric power across the countryside. (Westinghouse Photo)

ELECTRICITY—WHAT WE KNOW

About 150 years ago, men learned how to make electricity flow in a current so that it could do useful work, but the strange thing is that even today no one knows for certain exactly what electricity is. Though there are still many things we do not know concerning electricity, we have managed to learn a great deal about it.

We know that no one can see electricity, just as no one can see the wind.

We know that electricity is like the wind in another way, too. The wind is a force—a form of energy. So is electricity. Even if we can't see the wind, we can see what it does. It bends trees, turns windmills, and pushes sailboats over the water. We can see the work electricity does, too, even if we can't see the electricity itself. Electricity runs motors, lights lamps, and does many other helpful things.

We know how to make electricity in great quantities and very cheaply.

We know how to send it quickly from one place to another along wires.

We know how to measure electricity's strength.

We know how to control it.

TURN ON THE ELECTRICITY

We use electricity in many ways.

We use it to give us bright lights. We use electricity to produce heat for such things as stoves, toasters, flatirons, and heaters. We use it to melt ores for making iron and steel and many other things.

Electricity turns motors that run refrigerators, vacuum cleaners, sewing machines, and many other kinds of machinery. Electric motors supply the power for many of our trains. Electric motors start our automobile engines.

Electricity serves us in a thousand ways.

It is not the only kind of power that works for us. We also use the power from steam engines, waterwheels, diesel and gasoline engines, and windmills. But electric power does things no other power can do. Only electricity can give us electric lights. Only electricity can run a radio or a television set, or take X-ray pictures. Only electricity can operate telephone and telegraph systems.

And electricity is the only kind of power that can easily be produced in one place and used somewhere else, possibly hundreds of miles away.

Without electric power how would we run a vacuum cleaner or a washing machine? We might have to use a separate steam or gasoline engine for each of these things. It would be a nuisance to tend the steam engines or to keep the gasoline engines cleaned and filled with gas and oil.

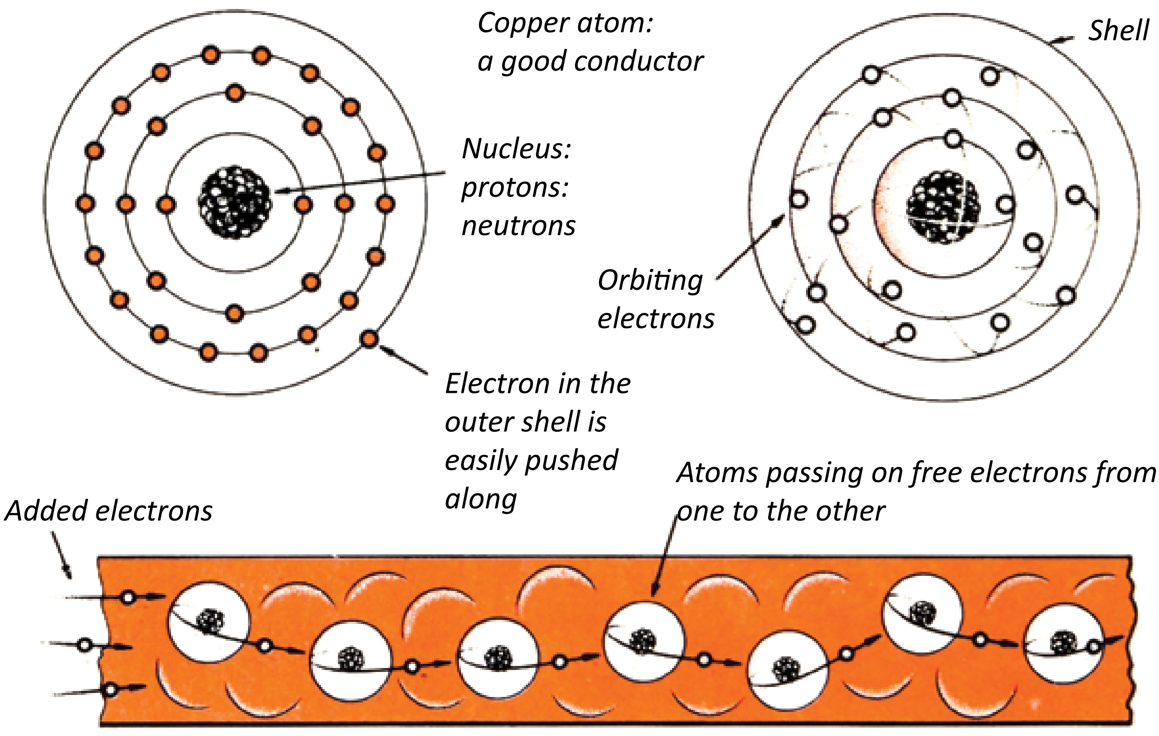
Without electricity, how dark this street would be at night! (Ewing Galloway Photo)

Electric power saves all that work and trouble. The engines that make our electricity can be miles away from our homes. We never hear them. We do not have to take care of them. All we do is to plug an electric cord into a wall socket, and our vacuum cleaner or washing machine has the power it needs to go to work for us.

ELECTRICITY—WHAT IS IT?

Although scientists do not know exactly what electricity is, they have figured out some things about how it works.

They now think that everything in the world is made up of very, very tiny particles called "atoms." These atoms are made up of even tinier little pieces called "electrons," "protons," and "neutrons." It is the electrons that make the force we call electricity.



Conductor (copper wire)

Scientists believe that electrons make electricity in this way. Suppose that you have a piece of wire. That wire is made up of millions and millions of atoms. Each atom has its own protons, neutrons, and electrons. The little protons and neutrons stick very tightly to their atoms, but the electrons can be moved quite easily from one atom to the next.

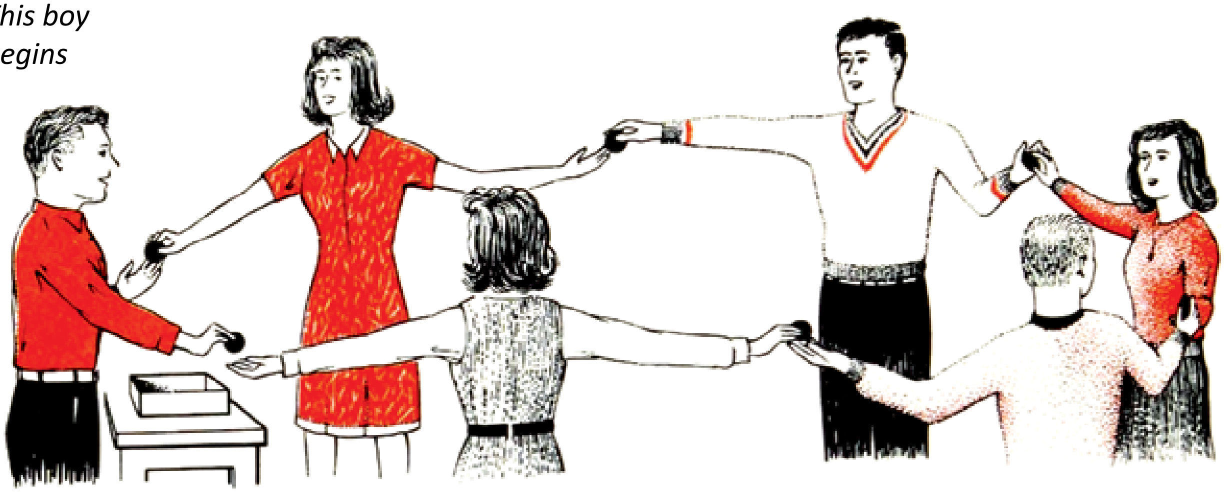
Now suppose that an extra electron is added to the first atom at one end of the wire. That extra electron will have to make room for itself, so it pushes one electron away from the first atom. The pushed-off electron jumps to the second atom. Now this atom has an extra electron, so the extra electron jumps to the third atom. This happens all the way down the wire.

This jumping of electrons from one atom to the next is what we call electricity. Electricity is a stream of electrons racing in one direction from one atom to the next. Sometimes we say that electricity races along like a stream of water. That's why we call it *current* electricity. It's something like a rushing current of water.

Before we can make electrons rush along in a stream, though, we must have some way of adding the extra electrons that start things moving. And we must not only start the electrons moving, but we must also keep them moving. Only moving electrons will give us a current of electricity.

We must also give the electrons a good road to travel on. If they do not have that, they will not move. If they do not move, we will have no electricity.

This boy begins



MAKING ELECTRICITY

Imagine an "electricity game." Any number can play, but let's suppose there are six players. In that case, they need a small box and six pennies, or raisins, or six of anything else that can be handed around easily. One player stands behind the box and the other five stand in a circle that starts and ends at the box. Every player in the circle has one penny. The sixth penny is in the box.

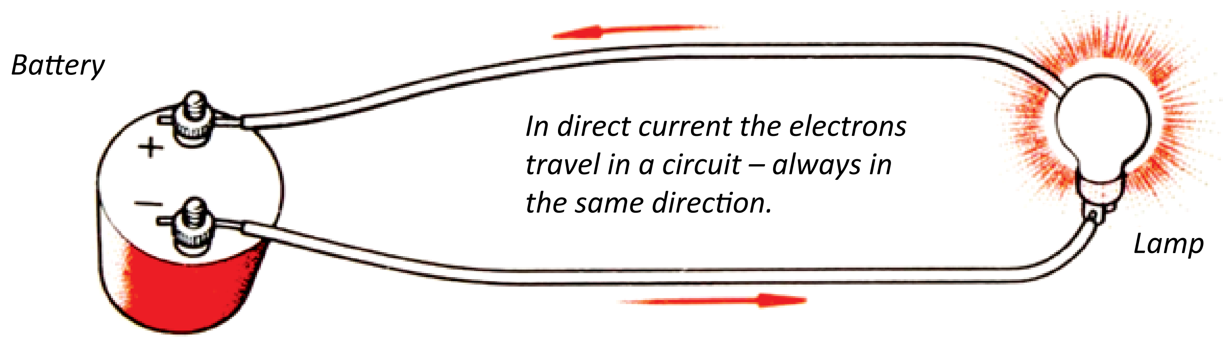
Imagine that every player in the circle is an atom, and his penny is an electron. The sixth player—the one behind the box—is the starter.

This game has some rules that must be followed. No atom can have more than one electron at a time. No atom is allowed to throw away an electron. An atom can only pass electrons on to the next atom, or to the box. And an atom must never hand an electron back to the atom it came from, once things are in motion.

Now every player, or atom, in the circle has one electron. So has the box. We say everything is in balance. No electrons are moving. No electricity is being made. But we want to make electricity, so we give the starter a signal.

The starter takes the penny out of the box and hands it to the player on his right, who is the first atom. Now things are out of balance. The box has no electrons, and the first atom has two. He quickly passes his extra electron to the second atom, who passes his extra electron to the third atom, who passes his to the fourth atom, who passes his to the fifth atom. The fifth atom has only one place to get rid of his extra electron. He puts it into the box, and everything is back in balance once more.

But the starter doesn't leave things in balance. He takes the electron out of the box and starts it going around the circle again. If he does that over and over, the electrons keep moving around the circle.



In direct current the electrons travel in a circuit – always in the same direction.

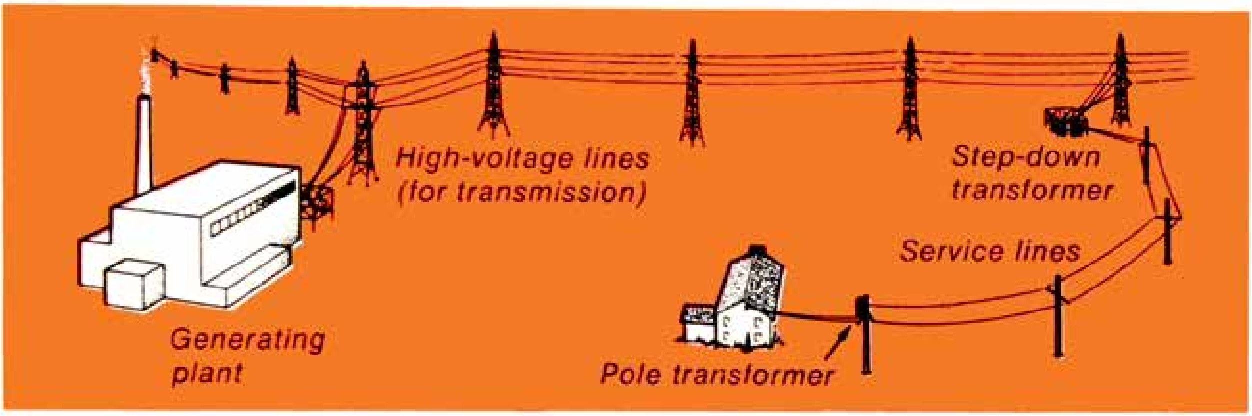
If the starter always starts the electron moving by handing it to the player on his right, the extra electron will always travel around the circle in the same direction. When electrons travel in the same direction all the time they produce the kind of electricity that we call "direct current"—because it always runs in the same direction.

But the starter doesn't have to play this way. He can start the game by first giving the electron to the player on his right. Then, when the electron returns to the box, the starter can hand it to the player on his left for the next trip around the circle. The third time he can hand it to the player on his right again, and the fourth time to the player on his left. In other words, the electron will take turns, going around the circle first to the right and then to the left. When the game is played this way, we say that the electron "alternates." This is just another way of saying that the electron "takes turns."

(When electrons alternate they make the kind of electricity we call "alternating current.")

It is important that the players stand in a circle with the first and last players beside the starting box. If they were to stand in a straight line, only the first player would be near the starter. The last player would not be near the box and he would not be able to put his extra electron into it. Then the box would have no electron. The starter would not have one to hand to the first player again. The race of electrons would be over.

A real current of electricity works in this same way. It must travel in a circle. Of course, it doesn't have to travel in a perfectly round circle. But the electrons must be allowed to return to where they started. Engineers say that electricity travels in a "circuit." If the circuit is broken at any point and the electrons can't get back to the starter, they stop moving. Then there is no current of electricity.



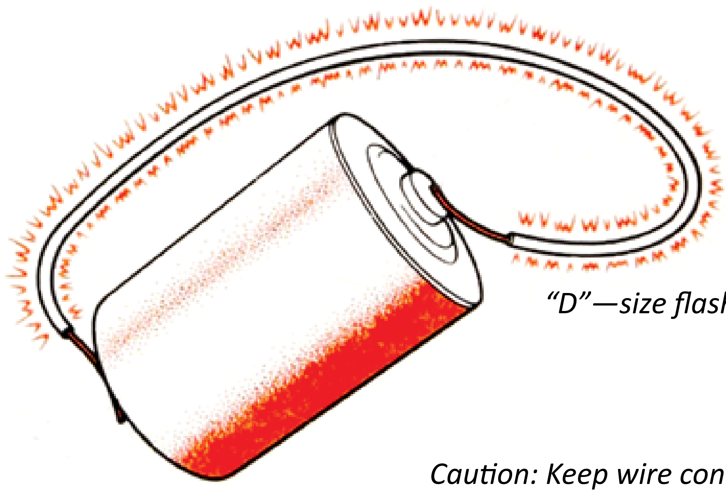
Electricity travels in a circuit along wires from the generating plant.

Electricity also has to have a starter to put things out of balance—to pile up extra electrons where they shouldn't be, so that they will start racing around to put things back in balance once more.

But, with electricity, we don't call it a starter. We call it a "battery" or a "generator." Batteries and generators are things that make—or "generate"—electricity. They start electrons racing through a circuit. Batteries always make the electrons move in one direction, so batteries always produce direct current. Generators can be made so as to produce either direct current or alternating current, whichever is wanted. Mostly, these days, the electricity we use in our homes is alternating current.

In our game each atom had one extra electron. But if a battery or generator pushed only one extra electron at a time into a circuit it would make very little electricity. Batteries can push many extra electrons at one time. The big generators that supply our homes and factories with electricity can jam so many extra electrons through a circuit that a tremendous quantity of electricity is made.

BATTERIES AND GENERATORS—HOW THEY WORK



Touch wire to button at one end, and zinc case at the other

"D"—size flashlight battery

Caution: Keep wire connected for very short time

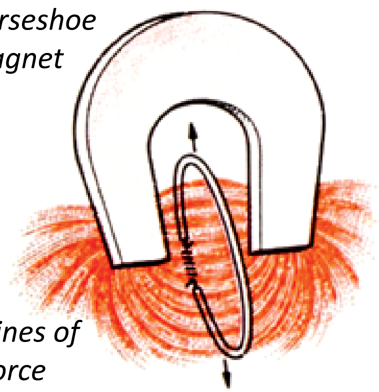
A battery—like the one in your flashlight, for example—has chemicals inside that start electrons moving. If you connect one end of a piece of wire to the zinc shell of a flashlight battery, and the other end to the brass button on top, you give the electrons a complete path, or circuit. Then the chemicals inside the battery start pushing electrons through the zinc shell into one end of the wire. The electrons rush through the wire and back into the battery through the brass button. You can't see them, but you will feel the wire grow warm. It is being warmed by the electricity that is flowing through it—the electricity that is being made by the rushing electrons.

A generator makes electricity by means of coils of wire and magnets. Most of us have seen how a magnet draws an iron nail to itself and holds on to it. Magnets attract iron and steel.

Every magnet has two ends, called “poles.” The power, or force, of a magnet comes out of these poles. It is as if the magnet had lines of power reaching out from it—lines no one can see.

But though we cannot see this power we know it is there because we see it attract the nail. We call the magnet’s strange invisible power its “lines of force.”

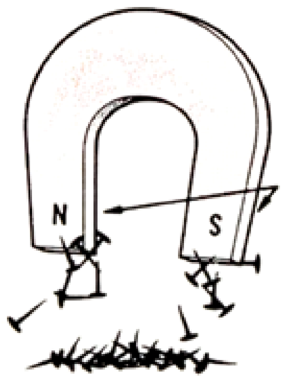
Horseshoe Magnet



Lines of force

A flow of electrons occurs in a continuous loop of wire moving up and down through the magnet’s field.

Magnet raises steel nails up through the air, each becoming magnetized in turn

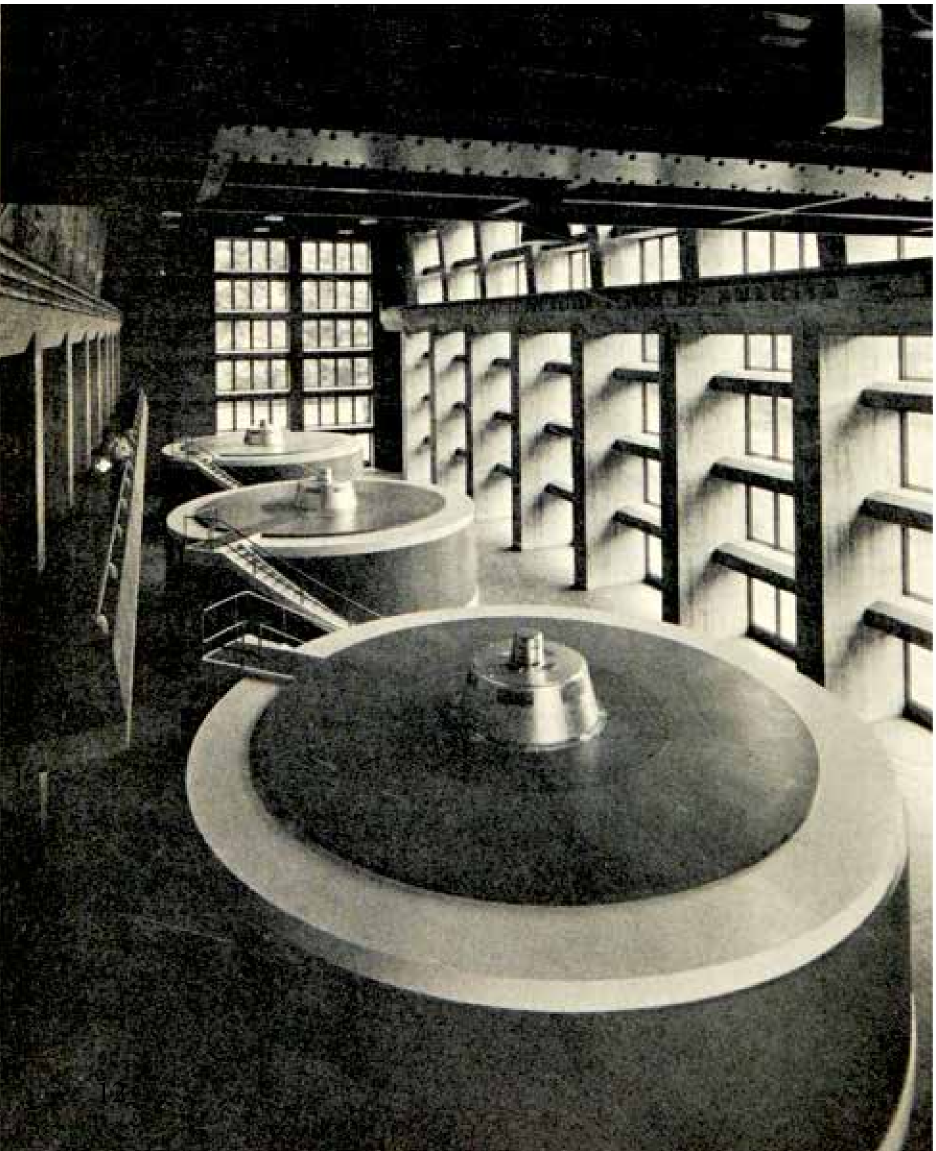


Poles: north and south

There is an odd thing about the magnet’s lines of force. If you pass a loop of wire through them, electrons start racing through the wire.

No one seems to know exactly why this should happen, but it does. Engineers say the wire loop is "cutting the magnet's lines of force."

But if the wire loop stands still, the electrons will stand still, too. To keep the electrons racing, something must keep moving the wire loop through the lines of force. It is a generator's job to do this.



The inside of the powerhouse at TVA's Fontana Dam, showing three enormous generators. (Tennessee Valley Authority Photo)

If a generator used only a single loop of wire it would make only tiny amounts of electricity, so it has a long rod called a shaft. On this are *thousands* of loops of wire, wound into coils. When the shaft is spun around, the coils spin, too. They spin in between the poles of very strong magnets. By merely turning around and around, the coils of wire keep cutting through the powerful lines of force, and electrons race through the coils.

Sometimes it is easier to attach the magnets to the shaft and spin them instead of spinning the coils. It doesn't really make any difference which do the spinning—the coils or the magnets. So long as the coils keep cutting the magnets' lines of force, electricity will be produced in the coils.

The coils are connected to a circuit. Electrons race through the circuit, too, making a current of electricity.

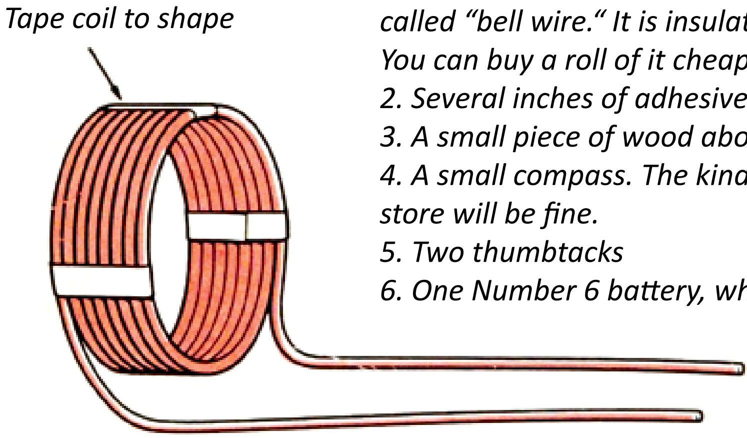
Generators may be small or they may be large. The generator in an automobile is only about six inches long and about six inches across. The generators in big powerhouses that supply entire cities with electricity are sometimes bigger than a house. The bigger a generator is, the more coils it will have and the stronger its magnets will be. And the bigger a generator is, the more electrons it will push into the circuit and the more electricity it will make. Or, as the engineers say, the more electricity it will "generate."

HOW TO MAKE AN ELECTRIC CURRENT DETECTOR

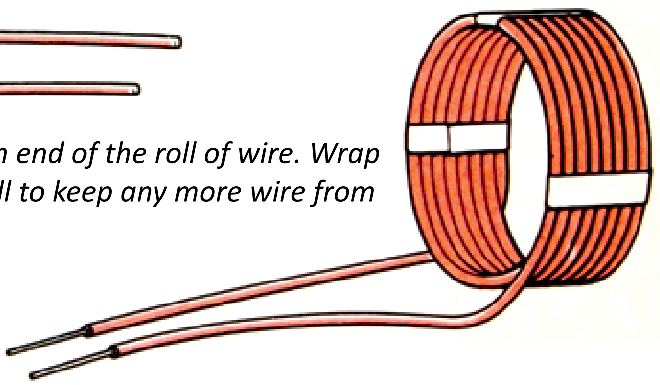
You can produce electricity with a battery you make yourself, you can make electricity with a magnet and a coil of wire, and you can do many other interesting electrical experiments. But first you will probably want to make an electric current detector to use in your experiments. This is a device that finds, or detects, the presence of even very small amounts of electric current.

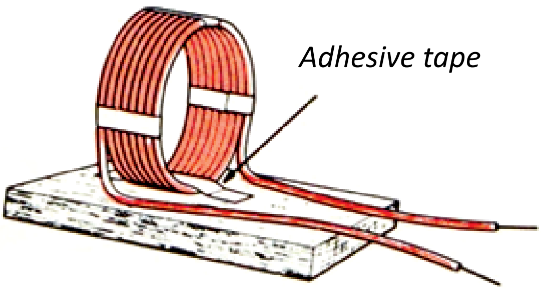
You will need:

1. A roll of insulated wire. A good variety to use is the kind called "bell wire." It is insulated by a coating of cotton or plastic. You can buy a roll of it cheaply in almost any hardware store.
2. Several inches of adhesive tape
3. A small piece of wood about 4 inches square
4. A small compass. The kind that can be bought in almost any toy store will be fine.
5. Two thumbtacks
6. One Number 6 battery, which you can buy in a hardware store



1. Unwind about 12 inches of wire from each end of the roll of wire. Wrap several rows of adhesive tape around the roll to keep any more wire from unwinding.

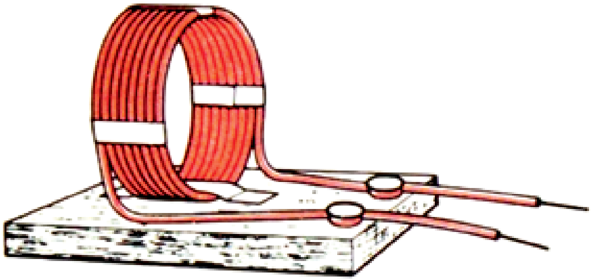


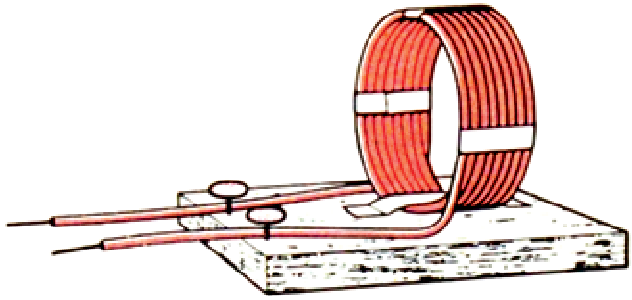


2. Scrape the covering, or insulation, from the ends of the wire so that one inch of bare copper shows.

3. Set the roll of wire upright on the block of wood, and fasten it in place with a strip of adhesive tape, as shown in the picture.

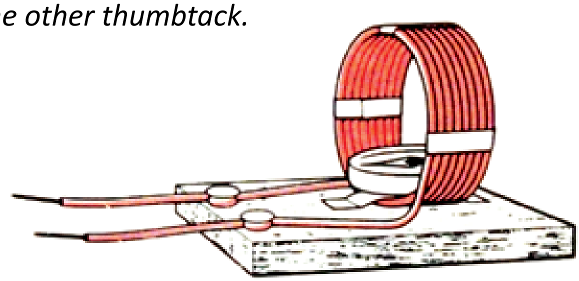
4. Push two thumbtacks into the wood block near one edge. The tacks should be about 2 inches apart. Do not push them all the way into the wood yet.

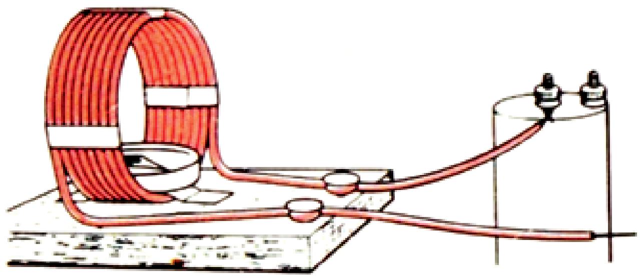




5. Wrap one of the ends of wire once around one of the thumbtacks, leaving about 10 inches of wire sticking out past the tack. Then force the tack all the way down into the wood, so that the wire is held in place. Do the same thing with the other end of wire, using the other thumbtack.

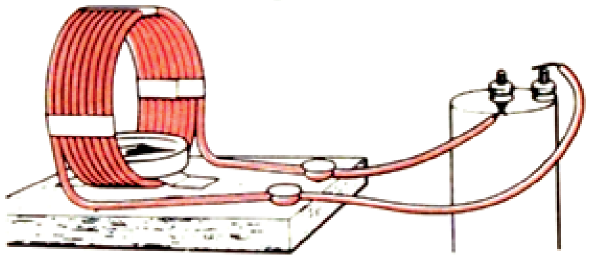
6. Set your compass inside the coil, as shown in the picture. Be sure that the compass is level, so that the needle can swing freely. Your electric current detector is now ready for use.





To test the current detector:

7. Connect one of the wires to the central terminal of the battery. Do this by loosening the screw in the center of the battery, wrapping the wire a few times around the bit of metal below the screw, then tightening the screw again to hold the wire in place.



8. Take the other wire of the detector and touch it to the side terminal of the battery—the second screw, near the edge of the battery. The compass needle will swing suddenly, as the electricity from the battery races through the coil of the detector.

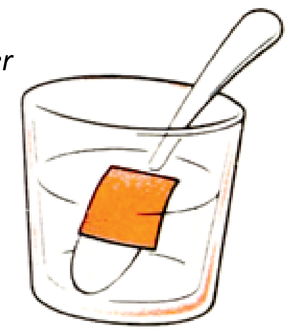
Your detector has detected the presence of the electric current flowing from the battery. The swinging of the compass needle proves that electricity is there. If your battery is dead—if there is no current flowing from it—the compass needle will not move.

HOW TO MAKE AN ELEVEN—CENT BATTERY

About 150 years ago an Italian scientist named Alessandro Volta discovered that he could produce current electricity by the use of two different metals and salt water or acid. Volta used copper and zinc as his metals, and vinegar as his acid. You can make a simple battery even more easily than Volta did, and prove for yourself how the chemical action of two different metals produces electricity.

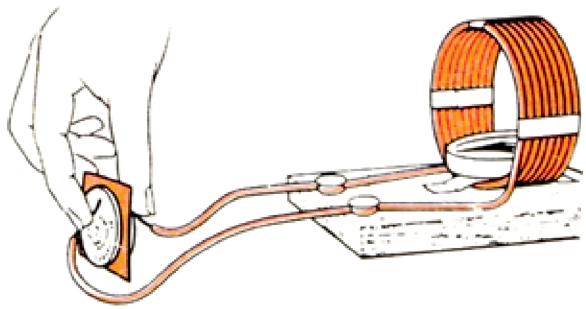
The battery you make will produce very little electricity, but it should be enough to move the needle of the compass in your current detector.

You will need:
1. A penny
2. A dime
3. A small piece of blotting paper about the size of a postage stamp
4. One teaspoonful of salt
5. One-half glass of water



1. Stir the salt in the water until it dissolves.

2. Soak the blotting paper in the salt water for a few seconds.



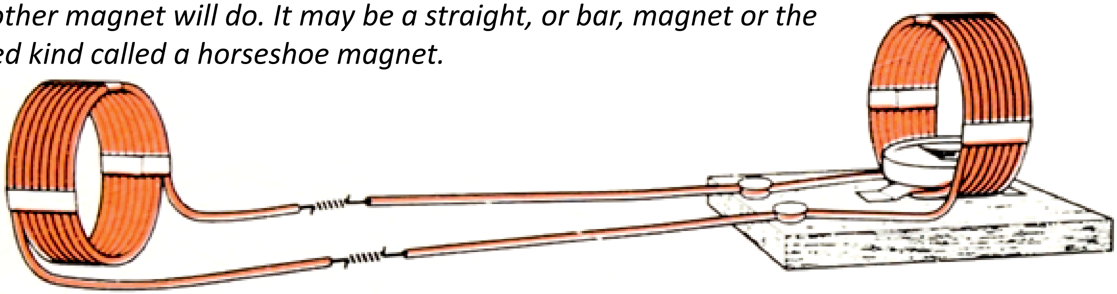
3. Put the wet blotting paper between the dime and the penny and squeeze the coins together. Then touch one wire of your current detector to the penny and the other wire to the dime. Watch closely and you will see the compass needle move as the electricity from your tiny battery rushes through the coil.

Flashlight batteries are very much like the one you have just made. Zinc and carbon are used instead of Volta's metals, and a chemical called "sal ammoniac" takes the place of the salt water you used. But your battery and a flashlight battery work in the same way.

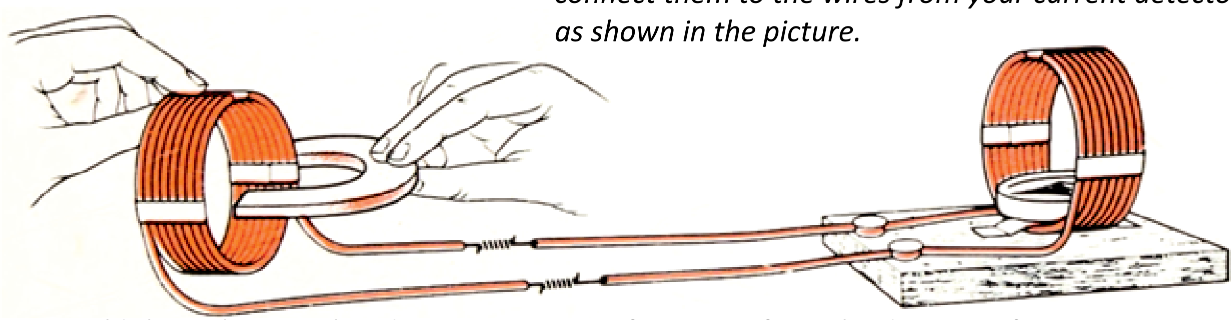
MAKING ELECTRICITY WITH A MAGNET AND A COIL OF WIRE

About one hundred years ago, a famous English scientist named Michael Faraday discovered that magnets and coils of wire could produce electricity. Faraday connected a coil of wire to an electric current detector. Then he thrust a magnet into the coil. As the magnet went into the coil, the detector's needle moved, proving that an electric current had passed through the detector.

To repeat this famous experiment, you will need:
1. Your current detector
2. Another coil of bell wire like the one you used to make the current detector
3. A magnet. A toy magnet from a toy shop or hardware store, or any other magnet will do. It may be a straight, or bar, magnet or the curved kind called a horseshoe magnet.



1. Unwind about 2 feet of wire from each end of the wire coil. Scrape the insulation from the ends and connect them to the wires from your current detector, as shown in the picture.



2. Hold the coil in your hand. Be sure it is two feet away from the detector. If you are using a bar magnet, thrust it into the center of the coil. If you are using a horseshoe magnet, hold it so that the coil passes between the ends of the magnet, as shown in the picture.

As the magnet ends pass the coil, watch the needle of the current detector. See how it moves, as electric current is generated by the moving magnet.

The more powerful your magnet is, the more electricity you will produce. But even a small horseshoe magnet will generate enough electricity to make the compass needle twitch.

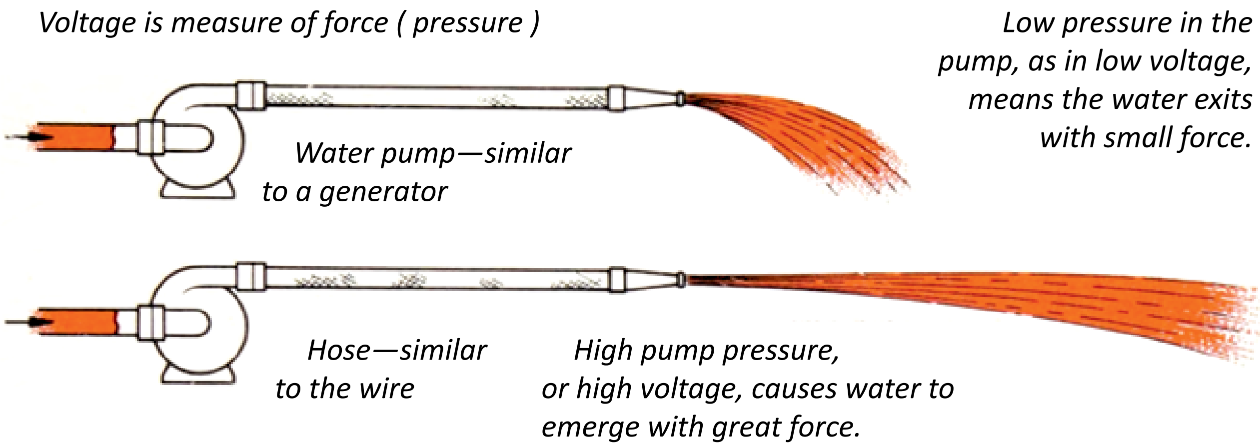
ALONG THE WIRES

Electricity will travel wherever we want it to go if we do two things. First, we must give it a complete circuit to travel through so that it can always come back to where it started. Second, the circuit must be made of something that the racing electrons can travel through easily.

Electrons can travel only along certain materials. We call these things "conductors" of electricity. Metals are conductors, although some metals are better conductors than others. Copper is a good conductor and so is aluminium. The wires we use to carry electricity from place to place are usually made of one of these two metals.

Some materials do not allow electrons to pass through, so, of course, no electricity can pass through them, either. These things that cannot be used as electrical roads are called "non-conductors," or "insulators." Glass, porcelain, rubber, plastic, and cotton are some of the insulators.

Insulators keep electricity in its place. Look at the cords that connect a lamp or a toaster to the wall socket in your house. You cannot see the copper wires inside because they have been covered with rubber, plastic, or cloth. If the wires did not have this insulator, the racing electrons would leave their roadway and go into your hand. You would be burned or shocked. The insulators on cords protect you. They keep electricity on the road it must travel to help, not harm, you.



MEASURING ELECTRICITY

When we want to measure the length of a road we use the word "mile." When we want to measure the weight of coal or sugar we use the words "ton" or "pound."

When we want to measure electricity we use the words "volt," "ampere," and "watt." Only people who know a great deal about electricity can understand these words perfectly. But all of us can understand some of the ways to use these words.

To make electricity, we must push electrons through a circuit. It takes pressure to do that, just as it takes pressure to push water through a pipe. We measure electric pressure in "volts." A little flashlight battery has a very low electric pressure—only 1 1/2 volts. It can push electrons around only a small circuit. The electric pressure in your home is probably 120 volts. This is plenty of pressure to push the electrons through the big circuits in your house. Sometimes we want to send electricity many miles over the power lines that stretch across the country on