Circuit Board Electrics

Experiment with electricity & making circuits

Issued by

Caution: Adult supervision required
WHAT IS IN YOUR KIT?
BE SURE YOU HAVE ALL THE PARTS SHOWN HERE. NOTE: SOME PARTS MAY BE PACKED INSIDE THE PLASTIC JAR. YOU WILL ALSO NEED 4 "AA" BATTERIES.
THINGS YOU WILL NEED TO GET OR USE:
- Tape
- Penny, Dime, Quarter
- Paper, Wood, Plastic
- Metal Spoon
- Key
- Book
- Ceramic Cup
- Salt
- Vinegar (optional)
- Lemon Juice (optional)
- Towel or Paper Towel
- Thin Thread.

MAKING A CIRCUIT

CIRCUIT: THE PATH ALONG WHICH ELECTRICITY TRAVELS.

PUT THE PARTS IN A BOWL

Open the plastic envelopes that hold the parts to your kit. Empty the parts into a bowl.

Your kit contains a lot of little parts. Keep them in the bowl if you’re not using them. That way you won’t lose anything.

PUT FRESH BATTERIES INTO THE BATTERY HOLDER

1. Insert 4 fresh “AA” batteries into the battery holder. Look carefully at the information printed on the holder to find which way the batteries should point.

2. After you have put the batteries in place, check to make sure that they were inserted correctly. The flat end of each battery rests against a spring. Batteries on one side of the holder point in the opposite direction from batteries on the other side.

BATTERY WARNING:
- Do not mix alkaline, standard (carbon-zinc) and rechargeable batteries (nickel hydride).
- Do not mix old and new batteries.
- Non-rechargeable batteries are not to be recharged.
- Rechargeable batteries are to be removed from the appliance before being charged (if removable).
- Rechargeable batteries are only to be charged under adult supervision (if removable).
- Exhausted batteries are to be removed.
- The supply terminals are not to be short-circuited.
- As recommended, only batteries of the same or equivalent type are to be used.
- Batteries are to be inserted with the correct polarity.
PUT THE BATTERY HOLDER ONTO THE CIRCUIT BOARD

1. GET SOME TAPE AND STICK THE BATTERY HOLDER TO THE TOP OF THE CIRCUIT BOARD (FIG. 1)

Be sure that the battery wires are in the position shown in the drawing before you stick the holder onto the circuit board.

PUT A BULB ONTO THE BOARD

1. SCREW A BULB INTO A BULB HOLDER. IF THE BULB IS ALREADY IN PLACE, MAKE SURE IT IS SCREWED IN TIGHTLY.

3. Reach under the board and open the brads so they hold the bulb holder and bulb firmly in place.

**FIG. 2**

This is a circuit diagram, of Fig. 2.
PUT TWO CONNECTORS ONTO THE BOARD

1. Slip a washer and a spring onto a brad, as shown in the drawing (Fig. 3a). Make sure the washer goes on first.
2. Put the brad into the board approximately in the position marked Connector A in Fig. 2. Push it about 2/3 of the way into the board. Hold it at this position, reach under the circuit board, and open the brad. You have just made a temporary connector. You should be able to push the washer down away from the head of the brad, and the spring should push it back up again when you let go.
3. Make another temporary connector the same way and put it into the board at the position marked Connector B.

PUT A SWITCH ONTO THE BOARD

1. Attach the flat switch to the board with a temporary connector. To do this, first slip a washer onto a brad, then slip a spring onto it, then slip the brad through the hole in the switch. Put the brad into the fifth hole below Connector A, push it about 2/3 of the way into the board, and open the brad. This is your switch connector. (See Fig. 3c.)
2. Push down on the washer of Connector A. Slip the tip of the nearest wire from the light bulb between the washer and the head of the brad. Be sure that just the wire goes in, not the insulation covering it. When you let go, the spring should hold the tip of the wire in place. (Fig. 3b).

2. Put the other bulb wire into Connector B.
3. Put a battery wire into Connector B.
4. Put the other battery wire into the Switch Connector. Your circuit is now complete. Check it against the drawing of Fig.2 on Page 5.

CHECK THE UNDERSIDE OF THE BOARD

This is a very important step! Turn the circuit board over and look at the brads. The brads must never touch each other! If the brads are touching, turn them so they do not touch. You'll learn why later.

SLIP THE WIRES INTO THE CONNECTORS

1. Push down on the washer of Connector A. Slip the tip of the nearest wire from the light bulb between the washer and the head of the brad. Be sure that just the wire goes in, not the insulation covering it. When you let go, the spring should hold the tip of the wire in place. (Fig. 3b).
2. Put the other bulb wire into Connector B.
3. Put a battery wire into Connector B.
4. Put the other battery wire into the Switch Connector. Your circuit is now complete. Check it against the drawing of Fig.2 on Page 5.

TURN YOUR LIGHT ON AND OFF

Move the switch so that it touches Connector A. This is the ON position of your switch. Your light bulb should light up! (If it doesn't, check your connections. One of them is probably loose. Or check to make sure your bulb is screwed all the way into the bulb holder).

Move the switch away from the connector. The light goes off.

This is the OFF position of your switch. Always turn the switch off when you finish an experiment. If you leave it on, the batteries will run down, and some of the connections may get uncomfortably hot.
Back on pg. 5 below the drawing of the setup you just made (Fig. 2) is a simplified diagram of the same setup. It is called a circuit diagram.

A circuit diagram shows only the path of the electricity and the electrical devices in that path. It leaves out everything else. It doesn’t show the circuit board, or all the connectors you put together, or all the twists and turns of the wire, or the holders for the different electrical devices.

Anybody who works with electricity should learn how to read a circuit diagram. It’s not hard. Look at the circuit diagram again. See if you can identify the symbols for:

- the batteries
- the bulb
- the switch, in an open position

Most important, compare the circuit diagram with the more complicated drawing above it. Notice how the circuit diagram gives you the same information about the electrical devices and the electrical circuit as the drawing does, only in a much simpler form.
When you moved the switch to the ON position, you made a circuit - a path along which electricity could flow. Electricity flowed out from the batteries, through all your connections, and back to the batteries again. And since the path of the electricity went through the bulb, the bulb lit up.

When you moved your switch to the OFF position, you made a gap in the path. You broke the circuit. Electricity couldn't flow, and the light went off.

Every time you turn on something that runs by electricity, you are making a circuit. Every time you turn it off, you are breaking a circuit. This is true both with battery-powered toys and with the appliances in your house.

You usually can't see the circuit you are making and breaking. The electric wires are hidden inside an appliance or inside the walls of your house. But they are there. When you turn a switch on, you are making a circuit - either with batteries or with a far-away electric company as the power source. All your switch does is make the circuit or break the circuit.

Whenever an electrical device doesn't work when you turn it on, the most probable cause is a break in the circuit somewhere!

Part of the device or the switch may be burned out, breaking the circuit. An electrical connection may be loose somewhere, breaking the circuit. If someone repairs the connection, the device usually works again.
MAKE A TEMPORARY SHORT CIRCUIT

Short Circuit: A circuit connection (usually a wire) that prevents one or more electrical devices in the circuit from working.

1. Take your circuit board and move the switch to the on position. The light bulb lights up, of course.
2. Leave the switch in the on position. Touch one end of a wire to Connector A and the other end to Connector B. You have made a short circuit. What happens?
3. Take the wire away. What happens?
4. Turn the switch to off.

MAKE ANOTHER SHORT CIRCUIT

1. With the switch in the off position, slip one end of the wire into Connector A and the other end into Connector B. You have made a short circuit (Fig. 4).
2. Move the switch to the on position. What happens?
3. Keep the switch in the on position for 10 seconds, or while you count to 10 slowly. Then move the switch to the off position.
4. Touch one of the connectors. Does the connector feel warm or cold.
MAKE OTHER SHORT CIRCUITS

1. REMOVE THE SHORT-CIRCUIT WIRE FROM CONNECTORS A AND B.
2. MOVE THE SWITCH TO THE ON POSITION. THE LIGHT BULB LIGHTS.
3. TOUCH ONE END OF THE WIRE TO CONNECTOR B AND THE OTHER END TO THE SWITCH CONNECTOR - THE BRAD AT THE END OF THE SWITCH. WHAT HAPPENS?
4. TOUCH ONE END OF THE WIRE TO CONNECTOR A AND THE OTHER END TO THE SWITCH CONNECTOR. WHAT HAPPENS?
5. WHICH EXPERIMENT MADE A SHORT CIRCUIT? WHICH DID NOT? THE CIRCUIT DIAGRAMS (FIG. 5) SHOULD SHOW YOU.
What Your Experiments Showed

You made a short circuit in two different ways:

- You made a short circuit when you switched the light on, touched two connectors with the two ends of a wire, and the light went off.
- You made a short circuit when you attached a wire between two connectors, moved the switch to on, and the light didn’t light.

To understand what happened, you should understand that we use electricity to do work. Running an appliance is work. Even lighting a light bulb is work.

But electricity is lazy! If it can find a path to flow through without doing any work, it will.

When you make a short circuit, you are making a path for the electric current that it can follow without doing any work. So the current follows that path and the light bulb doesn’t light.

Another thing. In a short circuit, the current flows out of the batteries with almost no resistance. The battery rapidly loses its charge and goes dead.

But even when electricity flows through a short circuit, it actually does a little work after all. It heats the wires and connectors that it flows through. They can get very hot. You felt this when you let electricity flow through a short circuit and then touched one of the connectors.
Testing Conductors and Insulators

Conductor - Something that an electric current can flow through - like the wires in your kit.

Insulator - Something that electricity can't flow through - like the plastic covering on the wires.

This is why a short circuit is dangerous! If a short occurs in an appliance or in the wiring in your home, the wires heat up. The short circuit can cause a fire.

In the last experiment, you learned that whenever an electrical device doesn't work when you turn it on, the most probable cause is a loose connection or some other break in the circuit somewhere. But if the problem isn't a break in the circuit, it may be a short circuit.

If an electrical device doesn't work when you turn it on, turn it off again! Get someone to unplug it! Short circuits are dangerous!

You will learn how electricians protect against fire caused by short circuits later in this booklet.
You can make a tester (Fig. 6) that you can use to test things to see if they are conductors or insulators.

1. Remove the brad that holds your switch in place and take the switch off the circuit board.

2. Put a temporary connector into the circuit board where the switch brad was. Follow the directions for making temporary connectors on page 6. This is Connector C.

3. Slip an end of one long wire into Connector A. Slip an end of the other long wire into Connector C. These wires are called probes (Fig. 6).

4. Test your tester by touching the ends of the two probes together. The light bulb should light up. If it doesn’t, check your connections.

Test different things to see whether they are conductors or insulators. Just touch the ends of your probes to the object.

- If the bulb lights brightly, the object is a good conductor.
- If the bulb lights dimly, the object is a poor conductor.
- If the bulb doesn’t light at all, the object is an insulator.

Use your tester to test each of the following items:

<table>
<thead>
<tr>
<th>OBJECT</th>
<th>GOOD CONDUCTOR</th>
<th>BAD CONDUCTOR</th>
<th>INSULATOR</th>
</tr>
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<tbody>
<tr>
<td>A PENNY</td>
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<tr>
<td>A DIME</td>
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<tr>
<td>A QUARTER</td>
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<tr>
<td>A PIECE OF PAPER</td>
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<tr>
<td>SOMETHING WOOD</td>
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<tr>
<td>SOMETHING PLASTIC</td>
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</tbody>
</table>
What Your Experiments Showed

You should have found that metal is a good conductor of electricity. The best conductors are silver, copper, gold, and aluminum. The commonest conductors, used in electric wires, are copper and aluminum. They are used instead of silver and gold because they are much less expensive. Paper, plastic, wood, and ceramics are insulators.

Test Water

CAUTION: ADULT SUPERVISION REQUIRED FOR THIS ACTIVITY!

1. Make two small holes in the plastic jar lid about 1/2 inch (1.5 cm) apart.

2. Push 2 brads through the holes.

3. Fill the jar about 3/4 full with water and snap the lid onto the jar. The brads should be in water.

4. Touch the ends of your probes to the split pins (Fig. 7). Look at the bulb. Does it light up? Is water a conductor or an insulator?

<table>
<thead>
<tr>
<th>OBJECT</th>
<th>GOOD CONDUCTOR</th>
<th>BAD CONDUCTOR</th>
<th>INSULATOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>A metal spoon</td>
<td></td>
<td></td>
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<tr>
<td>A ceramic cup</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>A key</td>
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<td>A book</td>
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TEST SALT WATER

1. Take the lid off the jar. Add about half a teaspoon of salt to the water. Stir the water until most of the salt is dissolved.

2. Snap the lid back onto the jar.

3. Connect the ends of your probes to the split pins. Look at the bulb again. Does it light up? Is salt water a conductor or an insulator?

4. You may wish to try other liquids, like vinegar or lemon juice. Are they conductors?

WHAT YOUR EXPERIMENTS SHOWED

You should find that when you use pure water in the jar, the light bulb doesn’t light. Pure water is a very poor conductor of electricity.

When you use salt water, or vinegar, or lemon juice in the jar, the light bulb lit up, but not as brightly as when you used a metal conductor. Salt water, vinegar, and lemon juice are conductors though not as good as metal.

WARNING:

Batteries don’t have much power, but the electric current in your home has a lot more power behind it! It can use water as a conductor! Never touch any electric wall switch or electric appliance when you or your hands are wet! The electricity in your home can injure or even kill you if it passes through your body.

MAKING A FUSE

CAUTION: ADULT SUPERVISION REQUIRED FOR THIS ACTIVITY!

Fuse: A safety device placed in an electric circuit. When the circuit has too much electricity in it, the fuse blows and breaks the circuit.
Prepare the Fuse Jar

1. Empty out all the liquid from your jar. Dry the inside of the jar, and the brads too. Make sure there is no moisture in the jar or on the brads.

2. Get your piece of steel wool and pull a small tuft from it. Twist it so that it no longer feels fuzzy, but is like a single piece of thick, soft wire. Slip the ends into the legs of the brads in the jar lid, so that it forms a bridge between them.

3. Put the lid back on the jar and snap it shut firmly (Fig. 8).

Prepare the Circuit Board

1. Remove Connector C and its probe from the circuit board. Leave the other probe attached to Connector A.

2. Put the switch back on the board the way you did in the first series of experiments - making a circuit.

3. Check your circuit by moving the switch to the on position. The light bulb should light up. Then move the switch back to off.

4. Remove the light bulb wire from Connector A and connect it to a brad in the jar lid. Place it between the legs of the brad.

5. Connect the probe from Connector A to the other brad in the jar lid. Your circuit board should now look like the drawing (Fig. 9) on page 18.

6. Look carefully at the circuit diagram. What is the symbol for a fuse?
1. Move the switch to on. Keep it there. What happens?

WHAT YOUR EXPERIMENT SHOWED

When you switched the current on, the steel wool glowed brightly for a moment. Then it burned out. At the same time, the light bulb went off.

Whenever current passes through a conductor, it makes heat. You found this out in the second series of experiments. - short circuits. Some metals heat up so quickly and so much that they glow red and then white. They melt or vaporize if too strong a current is passed through them. This happened to the steel wool.

Somewhere in your home you have a box containing fuses (or automatic switches called circuit breakers that do the same job.) The fuses in the box are made of a short length of very thin wire in a glass or ceramic housing. There is a fuse or a circuit breaker in every circuit in your home. The fuse protects the circuit from overheating. This can happen for two reasons:
Too many appliances are plugged into the circuit. They use too much current. The wires in the circuit heat up.

The insulation on two electric wires that are close to each other wears through. The wires touch each other and a short circuit results.

In either case, the fuse heats up, too. The fuse blows before the electricity can cause a fire. Electricity stops flowing in the circuit, and a fire is prevented.

Something Else That Your Experiment Showed

When electricity passes through a wire, it heats the wire. If you choose the right kind of wire, it gets white hot and gives off light. You saw this when you made your fuse. It glowed for a moment before it burned out. You not only made a fuse. You also made a light bulb!

Of course, your light bulb burned out in less than a second. Real light bulbs don’t do this. Here’s why:

• Burning is the process of heating something until it combines with a gas in the air called oxygen.

• If the wire in the bulb has no oxygen around, won’t burn.

• Bulb makers prevent bulbs from burning either by taking all the air out of the bulb or by putting in some other gas that doesn’t burn.

Electrolysis: (pronounced uh-lek-trah-luh-sis) Producing a chemical change by passing an electric current through a solution, like a salt solution.

Set Up the Experiment

Set up Experiment D from Testing Conductors again. This is the experiment where you passed an electric current through salt water. (Page 15-16)

You can use the same setup that you used for the fuse experiment – without the steel wool, of course. Just put the salt water in the jar and, when you are ready, close the switch.

Leave the switch on and keep the experiment running for 3 minutes.
WATCH CAREFULLY

1. Look through the side of the jar. The jar is made of a cloudy plastic, but you should notice the following:
   ✽ Nothing much happens for about a minute.
   ✽ After a minute or so, you will see a cloudy green-gray substance slowly forming in the water.
   ✽ This change takes place near only one of the brads.
   ✽ You can’t see the next change, but if the jar were clear, you would notice tiny bubbles forming on the other brad.

WARNING:

You have made a chemical in the salt water. Now it contains harmful chemicals. Do not drink it! Never drink or eat anything you use in an experiment or that is produced by an experiment! It may be poisonous! Always wash your hands after doing experiments with chemicals!

CLEAN THE JAR

After 3 minutes, remove the probes from the brad. Empty the stuff in the jar into the sink or toilet. Wash out the jar. Then wash your hands.

LOOK AT THE BRADS

Notice any changes in the color of the brads? Did only one brad change color, or did both?

WHAT YOUR EXPERIMENT SHOWED

This is an easy experiment to do. But to understand what happened is not so easy.

Here’s a quick explanation:
   ✽ The electricity caused chemical changes both in the salt water and in one of the brads.
   ✽ The greenish-gray sludge comes from a chemical combination of the metal in the brad with part of the salt in the water.
The bubbles that form on the other brad are hydrogen gas, the lightest gas in the universe. The hydrogen came from splitting the water molecules; water is made of the gases hydrogen and oxygen.

You’ll find a more complete explanation later in the book on page 36.

As you saw, in this experiment electric current brought about a chemical change. Using electricity to split molecules and make chemical changes is called electrolysis, which means “loosening or splitting with electricity.”

Electrolysis was discovered very shortly after the invention of the battery. Today, electrolysis is often used by scientists to make or study new chemicals. It is also widely used to make the chemicals that are used in our factories and industries.

Another common use is to put a metal coating on an object. This is called electroplating. If you had used a silver salt instead of table salt in the water, the brad would have been plated with silver when you passed electricity through it.

**Light Bulbs in Series and in Parallel**

You know that when a circuit is broken, electricity doesn’t flow, and you know that turning a switch to the off position breaks the flow of electricity in that device.

But think of all the lights and appliances in your home. When we turn one of them off, why don’t all the others go off, too?

The following experiments will show why.

**Experiment with Two Light Bulbs in Series**

1. Add the second light bulb in your kit to your circuit board setup. You’ll also need to insert a new connector, Connector C, between the bulbs. Follow the illustration and the circuit diagram (Fig. 10) on page 22. Putting two light bulbs in a row like this is called putting them in series.

2. Switch the switch to on. What happens to the light bulbs?

3. Compare the brightness of each bulb in the series circuit to the brightness of one bulb alone. Do this by keeping the switch on and then touching one end of a wire to Connector B and the other end to Connector C. You have created a short circuit around Bulb 2. (An electrician would say that you “shorted out” Bulb 2.) The electricity bypasses Bulb 2 and goes through Bulb 1 only. Which is brighter - a single bulb in a circuit, or 2 bulbs in series?
4. With the switch still on, unscrew Bulb 2 from the series circuit. What happens?

5. Put Bulb 2 back in its socket and switch everything off.

**What Your Experiment Showed**

- You should have found the following things about two bulbs wired in series:
  - Two light bulbs in series are not as bright as one light bulb alone. This is because the “push” that the batteries give to the electric current remains the same, but now the current has to light up two bulbs.
  - As you can see from the circuit diagram, if you remove a bulb, you break the circuit, and so the other bulb also goes out. It doesn’t matter which one you remove. The other also goes out.
EXPERIMENT WITH 2 LIGHT BULBS IN PARALLEL

1. Make a new setup with the 2 light bulbs. Take the wire ends out of Connector C and remove this connector. Put one wire into Connector A and the other into Connector B, exactly the way the diagram shows (Fig. 11).

FIG. 11

Putting two light bulbs side by side in a circuit like this is called wiring them in parallel.

2. Switch the switch on. What happens to the light bulbs?
3. Again, compare the brightness of each bulb in the parallel circuit to the brightness of one bulb alone. Do this by disconnecting both bulb 2 wires from the connectors. Which is brighter - a single bulb in a circuit, or two bulbs in parallel? Which is brighter, two bulbs in parallel, or two bulbs in series?

4. Reconnect bulb 2. With the switch on, unscrew bulb 2 from the parallel circuit. What happens?

5. Put bulb 2 back and switch everything off.

WHAT YOUR EXPERIMENT SHOWED

Look carefully at your circuit board and at the circuit diagram. At first they may not look the same at all. But if you look at them carefully, you will understand how they show the same kind of circuit. The labeling on the circuit diagram should help you.

Notice that in a parallel circuit, the path of the electricity splits in two, and then joins the two paths again. Some of the current goes in one path, through bulb 1. The rest goes in the other path, through bulb 2. This is very different from a series circuit, where there is only one path for the electricity to follow.

You should have noticed the following things about a parallel circuit:

🗗 Bulbs wired in parallel are brighter than bulbs wired in series!

🗗 When two light bulbs are wired in parallel, each bulb is nearly as bright as one bulb wired by itself. (Surprisingly, in a parallel circuit like this one, each of the branches draws the same amount of electricity as the one path of an ordinary circuit.)

🗗 When you remove one bulb from one branch of a parallel circuit, the other branch of the circuit is not broken, so the other bulb stays lit. This is why appliances in your home are wired in parallel, not in series.

Some of the electricity in the circuit is wasted in heating up the wires and the connectors. If there were no waste, each light bulb in the parallel circuit would be just as bright as a single light bulb.

You don’t get the extra brightness for free. The circuit is now lighting two bulbs at nearly full brightness, so it is using two times the amount of current as a circuit with only one bulb. The batteries will wear out more quickly.
MAKE A TWO-WAY SWITCH

WITH A SMALL CHANGE IN YOUR PARALLEL CIRCUIT, YOU CAN MAKE A TWO-WAY SWITCH. THE SWITCH WILL TURN ON EITHER BULB, BUT NOT BOTH AT ONCE.

1. MAKE A NEW TEMPORARY CONNECTOR (CONNECTOR D) ON THE OTHER SIDE OF THE SWITCH FROM CONNECTOR A. TAKE THE WIRE FROM BULB 2 OUT OF CONNECTOR A AND INSERT IT IN CONNECTOR D. FOLLOW THE DIAGRAM TO MAKE SURE EVERYTHING IS CORRECT (FIG. 12). AND CHECK UNDER THE CIRCUIT BOARD TO MAKE SURE THE BRADS ARE NOT TOUCHING!

YOU NOW HAVE A TWO-WAY SWITCH
BATTERIES IN SERIES AND IN PARALLEL

MAKE A BATTERY TESTER

1. REMOVE ONE OF THE BULBS AND HOLDERS FROM THE CIRCUIT BOARD.

2. TAKE THE BRASS STRIP WITH THE TWO HOLES IN IT. PUT THE END OF A BULB WIRE INTO A HOLE AND WRAP THE END AROUND THE BRASS STRIP SO THAT IT MAKES A GOOD ELECTRICAL CONTACT.

3. PUT THE OTHER BULB WIRE END BETWEEN THE LEGS OF A BRAD. WRAP THE WIRE END AROUND THE BRAD SO THAT IT, TOO, MAKES A GOOD ELECTRICAL CONTACT.

YOUR TESTER IS NOW COMPLETE. IT SHOULD LOOK LIKE THE ONE IN THE DRAWING (FIG. 13A).

TEST WITH ONE BATTERY


2. TURN THE BATTERY UPSIDE DOWN SO THAT THE BUMP IS ON THE BRASS STRIP. TOUCH THE AT END WITH THE BRAD. WHAT HAPPENS?

WHAT YOUR EXPERIMENTS SHOWED

USING ONE BATTERY GAVE A VERY WEAK GLOW TO YOUR LIGHT BULB.

\[ \text{Look at the side of the battery. It's marked 1.5 volts. Volts are the push that the battery gives to the electric current flowing through the bulb. 1.5 volts isn't much of a push.} \]

A weak push means that not much electric current goes through the bulb. So it's not very bright.
CURRENT, BY THE WAY, IS MEASURED IN UNITS CALLED AMPERES, OR AMPS FOR SHORT. (THEY ARE NAMED AFTER ANDRE AMPERE, AN EARLY SCIENTIST WHO STUDIED ELECTRICITY.)

BATTERIES ARE MARKED WITH A + ON TOP (WHERE THE BUMP IS) AND (SOMETIMES) A - ON OR NEAR THE BOTTOM. THE TOP WITH THE BUMP IS CALLED THE POSITIVE END AND THE FLAT BOTTOM IS THE NEGATIVE END.

IN A CIRCUIT, ELECTRICITY FLOWS FROM THE NEGATIVE END OF THE BATTERY TO THE POSITIVE END.

WHEN YOU TURNED YOUR BATTERY UPSIDE DOWN, THE ELECTRICITY FLOWED THE OTHER WAY. BUT NOTHING NEW HAPPENED. IN THE CIRCUITS IN THIS KIT, IT DOESN'T MAKE ANY DIFFERENCE WHICH WAY THE ELECTRICITY FLOWS. (IT DOES MAKE A DIFFERENCE IN SOME CIRCUITS - INSIDE RADIOS AND TV SETS, FOR EXAMPLE.)

TEST BATTERIES IN SERIES

1. Stack 2 batteries on the brass strip. You now have two batteries connected in series (Fig. 14). Test, the way the diagram shows. What happens? How is the result different from your test with only one battery?

2. Turn both batteries upside down and test again. What happens?

3. Hold the two batteries upside down and test again. What happens?

4. Hold the two batteries so that the two flat ends are touching (negative to negative). Test again. What happens?

WHAT YOUR EXPERIMENT SHOWED

STACKING BATTERIES IN SERIES ADDS VOLTAGE. SO WHEN YOU HAVE 2 BATTERIES IN SERIES Sending electricity through the bulb, you have double the push that you have with only 1 battery. The batteries send twice as much current through the bulb, and it burns brighter.

TWO 1.5 VOLT BATTERIES IN SERIES EQUALS 3 VOLTS. (1.5 VOLTS X 2 = 3 VOLTS)

WHEN YOU STACK BATTERIES IN SERIES, YOU HAVE TO STACK THEM SO THAT THE POSITIVE END OF ONE TOUCHES THE NEGATIVE END OF THE OTHER. IF YOU DON'T DO THIS, YOU HAVE THE BATTERIES TRYING TO SEND ELECTRICITY IN OPPOSITE DIRECTIONS, AND NOTHING HAPPENS.
TEST BATTERIES IN PARALLEL

1. REST 2 BATTERIES SIDE BY SIDE ON THE BRASS STRIP AND TOUCH THE TOP BUMPS OF BOTH OF THEM WITH THE BRAD. YOU NOW HAVE 2 BATTERIES IN PARALLEL. (FIG. 15). WHAT HAPPENS? HOW DOES THE LIGHT OF THE BULB COMPARE TO THE LIGHT WHEN THE BATTERIES ARE IN SERIES?

2. TURN 1 OF THE BATTERIES UPSIDE DOWN AND TEST AGAIN. WHAT HAPPENS?

3. PUT THE BATTERIES BACK IN THE BATTERY HOLDER.

WHAT YOUR EXPERIMENTS SHOWED

2 BATTERIES IN PARALLEL DON’T GIVE ANY MORE “PUSH” TO THE CURRENT THAN 1 BATTERY DOES. SO THE BULB DIDN’T BURN ANY BRIGHTER.

❖ WHAT’S THE ADVANTAGE OF BATTERIES IN PARALLEL? BATTERIES IN PARALLEL LAST 2 TIMES AS LONG.

NOW LOOK AT ALL YOU LEARNED FROM YOUR EXPERIMENTS WITH THE BATTERY TESTER!

❖ VOLTS ARE THE PUSH THAT THE BATTERY GIVES TO THE ELECTRIC CURRENT IT PUTS OUT. AMPERES OR AMPS ARE THE AMOUNT OF CURRENT IN A CIRCUIT.

❖ BATTERIES IN SERIES ADD VOLTAGE—ELECTRICAL PUSH. THE MORE BATTERIES YOU PUT IN SERIES, THE BRIGHTER THE BULB SHINES.

❖ BATTERIES IN PARALLEL DON’T ADD VOLTAGE. (BUT PUTTING BATTERIES IN PARALLEL MAKES THEM LAST TWICE AS LONG.)

❖ BATTERIES IN SERIES MUST BE POSITIVE TO NEGATIVE. IF YOU STACK THEM POSITIVE TO POSITIVE, OR NEGATIVE TO NEGATIVE, THEY DON’T WORK.

❖ CURRENT IN A CIRCUIT MOVES FROM NEGATIVE TO POSITIVE.

RESISTANCE

YOU KNOW THAT VOLTAGE IS WHAT PUSHES ELECTRIC CURRENT (AMPS) THROUGH A CIRCUIT. BUT EVERY CIRCUIT CONTAINS SOME RESISTANCE TO THE FLOW OF THE CURRENT. RESISTANCE CAN BE IN A BULB, THE WIRES OF A CIRCUIT, OR AS YOU WILL SEE, A RESISTOR.
In this section, you will do some experiments with a resistor.

Resistor: A device added to a circuit to add resistance to it. The main reason is to control the flow of electric current.

Experiment with a Resistor and a Bulb in Series

1. Connect a resistor into the circuit in series with a light bulb. Follow the diagram carefully (Fig. 16). What happens to the light when you turn on the switch? Leave the switch on for only a few seconds, then turn it off.

2. Look carefully at the circuit diagrams. What is the symbol for a resistor?
1. Connect a resistor into the circuit in parallel with the light bulb. Follow the diagram carefully (Fig. 17).

2. The wires from the resistor may not be long enough to reach between the two connectors the way the diagram shows. If you need to, take a short wire from your kit. Place it across one of the wires from the resistor and twist the two wires together. The combination should be long enough. Or move Connector B closer to A.

3. What happens to the bulb when you turn on the switch? Leave the switch on only a few seconds, then turn it off.

4. Very lightly, touch the resistor. What do you notice?
WHAT YOUR EXPERIMENTS SHOWED

A resistor resists the flow of electricity.

- You felt one result of resistance: heat.
- Another result can be light, for a light bulb is also a kind of resistor.
- When a resistor is connected in series with a light bulb, the bulb loses brightness.
- When a resistor is connected in parallel with a light bulb, however, the brightness of the light bulb is not dimmed. There is still a clear path for the current to take through the bulb without going through the resistor, and it does so.
- But current also goes through the resistor when it is in parallel. You can feel it. It gets hot.

There are many things in your home that work because of resistance: toasters, lamps, heaters, even a dimmer switch.

SENDING MESSAGES WITH MORSE CODE

You can use your Electricity Kit to send messages to any place where your light bulb can be seen. A special code, the International Morse Code, is used for this purpose.

PUT THE MORSE CODE KEY ONTO THE CIRCUIT BOARD

1. Take the switch key off the circuit board.
2. Count 8 holes down from Connector A. Slip a brad through the end hole of the Morse Code Key and into the 8th hole below Connector A. Do not open it yet.
3. Slip a spring under the hole in the middle of your Morse Code Key. Slip another brad through this hole, through the spring, and through the circuit board. Reach under the circuit board and open this brad.
4. Slip the loose battery wire through the legs of the first brad - the one at the end of the key. Reach under the board and spread the legs of the brad. Your setup should look like the diagram. (Fig. 18) ON PAGE 32.
5. Check under the circuit board. Make sure there are no brads touching.
6. Test your connection. You should be able to make the light blink on and off just by tapping the key.
Send Messages in Morse Code

Morse code uses two kinds of signals: very short ones (dots) and longer ones (dashes). Use a quick tap for a dot. Use a longer one for a dash. The complete code is shown below (Fig. 19)

You may want to practice sending messages to a friend who is some distance away from you. Now and then, change places with your friend so that both of you can practice coding and sending messages as well as receiving and decoding them.
Morse code used to be used to send messages by telegraph and by wireless (radio). It isn’t used much anymore, since radios can now send voices anywhere in the world.

### International Morse Code Table

<table>
<thead>
<tr>
<th>Letter</th>
<th>Code</th>
<th>Number</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>.-</td>
<td>1</td>
<td>Period (full stop)</td>
</tr>
<tr>
<td>B</td>
<td>-...</td>
<td>2</td>
<td>Question Mark (interrogation)</td>
</tr>
<tr>
<td>C</td>
<td>-.-.</td>
<td>3</td>
<td>Break</td>
</tr>
<tr>
<td>D</td>
<td>-..</td>
<td>4</td>
<td>Wait</td>
</tr>
<tr>
<td>E</td>
<td>.</td>
<td>5</td>
<td>End of Transmission</td>
</tr>
<tr>
<td>F</td>
<td>..-.</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>--.</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>H</td>
<td>---.</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>I</td>
<td>.-</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>-.</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>K</td>
<td>-.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>L</td>
<td>-.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>M</td>
<td>--</td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
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<td></td>
<td></td>
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<tr>
<td>O</td>
<td>---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>.-..</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Q</td>
<td>---.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R</td>
<td>-.--</td>
<td></td>
<td></td>
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<tr>
<td>S</td>
<td>..</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T</td>
<td>-....</td>
<td></td>
<td></td>
</tr>
<tr>
<td>U</td>
<td>.---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>...-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>W</td>
<td>.--.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>..-.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Y</td>
<td>.---</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Z</td>
<td>--.-</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Making a Room Alarm

You can use your circuit board to make a room alarm. It won’t make a noise, but it will light a light if anyone comes into a room where the circuit board is.

1. Set up your circuit board as shown in the drawing (Fig. 20). Basically, this is just the first circuit you made in this kit, only without a switch key.

2. Get a length of very thin thread that’s easy to break. Tie it around the brass strip and place the strip as shown in the diagram.

3. Test your alarm. Pull gently on the thread. The brass strip should be pulled into the contacts, and the light should light.

4. When everything tests OK, set up the alarm. Place it on the floor against the wall, near the door. Tape the end of the thread to the door so that when the door opens, the thread pulls the brass strip into the two contacts. You may want to put a weight on top of the circuit board so that the thread doesn’t pull it across the floor when the doors open. The thread breaks instead, but the light stays on.
5. Test your setup until it works the way you want it to. Remember that this is really just a demonstration! If someone goes into the room and turns the alarm on, the batteries will run down unless you turn it off.

Making a Puzzle Game

You can make an electric puzzle game with your circuit board. Just follow the directions below.

1. Set up your circuit board as shown in the drawing (Fig. 21). The main part of the setup has five rows of two brads each.
2. Under the board. Player 1 uses short wires to connect just one brad in every row. (Player 2 must not watch.) The last brad, one in Row 5, is connected to the battery wire, which is slipped under the circuit board through one of the holes. In the setup shown here, the brads that are connected are 1A, 2A, 3B, 4A and 5B. However, you can make your own setup.

3. Player 2 tries to guess which brad in each row is connected to the circuit. He or she uses the free bulb wire as a probe, touching one brad in each row with the tip of the wire. The bulb lights with each correct guess. The player's score is the number of correct guesses (out of 5).

4. Now Player 2 rewires the underside of the board, and Player 1 tries to guess.

5. The winner of the game is the player with the highest number of correct guesses.
What is Electricity?

- You probably know that everything in the world is made of tiny particles called atoms.
- The outside of an atom is made up of a cloud of even tinier electrical particles called electrons.
- In an electrical circuit, the voltage moves some of the electrons in the wire from atom to atom in the direction of the current flow. The negative end of the battery is "pushing" the electrons, and at the same time the positive end of the battery is attracting them.
- Of course, if there's a break in the circuit, the electrons don't move and current doesn't flow.
- Electric current flows fast, but the actual movement of the electrons is slow. Think of a long line of kids. The last one in line suddenly gives a push to the person in front of him or her, that person bumps into the next person, and so on all the way to the front of the line. The push traveled a long way, but nobody has really moved very far.

More About Electrolysis

Here's a more complete explanation of what happened in the electrolysis experiment you did earlier. First, you need to know several things: what water and salt are made of, what happens when you put salt into water, and what the brads are made of.

1. What is water?

- Water is a liquid made of two elements—hydrogen and oxygen.
- Both hydrogen and oxygen are gases. Hydrogen is the lightest gas in the world. Oxygen is a gas that is in the air. You breathe it. You need it to live.
- When two atoms of hydrogen combine chemically with one atom of oxygen, they make something new—a molecule of water.

2. What is salt?

- Salt is a chemical combination of two elements, just as water is. It's made of the element chlorine and the element sodium.
- Chlorine is a greenish poison gas. Sodium is a silvery metal that burns when it touches water!
When an atom of chlorine combines with an atom of sodium, it makes something completely new. The combination is ordinary table salt, which is neither a poison gas nor a metal.

3. What happens when you put it into water?

- The salt dissolves in the water. It seems to disappear.
- What actually happens is that the water splits the salt molecules! It breaks up each salt molecule into ions—that is, into atoms with an electric charge. (That’s one reason why you were able to pass an electric current through the water.) The water is now filled with sodium ions and chlorine ions.

4. What are the brads made of?

- The brads are coated with the metal brass. Brass is actually a mixture of two metals—zinc and copper.
- To make things simple, we’ll just pay attention to the copper.

5. Now let’s put it all together.

- The electricity provides the energy to split the rest of the molecules and to combine them into new substances.
- The split molecules of water, salt, and copper combine again this way:

A. Copper from one brad combines with the chlorine from the salt to make a new chemical called copper chloride. Copper chloride doesn’t dissolve well in water, so it makes the greenish-gray cloud near the brad.

B. Sodium from the salt combines with oxygen and part of the hydrogen in the water. It makes a new chemical called sodium hydroxide, or lye. Lye is a harsh chemical that is used to clean out drains and to make soap. Your experiment didn’t make enough to harm you, but be careful anyway. Wash your hands after the experiment.

C. There’s some hydrogen left over after the chemical combination of the water with the sodium. This hydrogen collects as bubbles near the other brad.

6. The chemical formula

A chemist would write what happens as a chemical formula:

\[ \text{Cu} + 2\text{H}_2\text{O} + 2\text{NaCl} \rightarrow \text{CuCl}_2 + 2\text{NaOH} + \text{H}_2 \]

Here’s what the formula means:

The formula uses special abbreviations for the names of the elements. (Some of these abbreviations come from the Latin language, so they may look strange.)
Cu means copper
O means oxygen
Na means sodium.
Cl means chlorine. Cl2 means 2 atoms of chlorine.

So the formula means this:

"An atom of copper (Cu) plus 2 molecules of water (H₂O) plus 2 molecules of salt (sodium - chloride - NaCl)

becomes

A molecule of copper chloride (CuCl₂) plus 2 molecules of sodium hydroxide (lye-NaOH) plus a molecule of hydrogen gas (H₂)."
LIGHT UP FRAME

1. Print out a picture

2. Make a light up circuit (Fig. 10 on page 22.)

3. Tape the back of the print out to frame

4. Connect the 4 pegs to the frame and the base

PRINT OUT

CONNECT THE 4 PEGS TO THE FRAME AND THE BASE

LIGHT IT UP!

4 Plastic Pegs

Make a light up circuit

Tape the back of the print out to frame

Connect the 4 pegs to the frame and the base

Light it up!

Dimensions:
6.25" x 4.5"
15.87cm x 11.43cm

Print out a picture

Print out

Connect the 4 pegs to the frame and the base

Light it up!