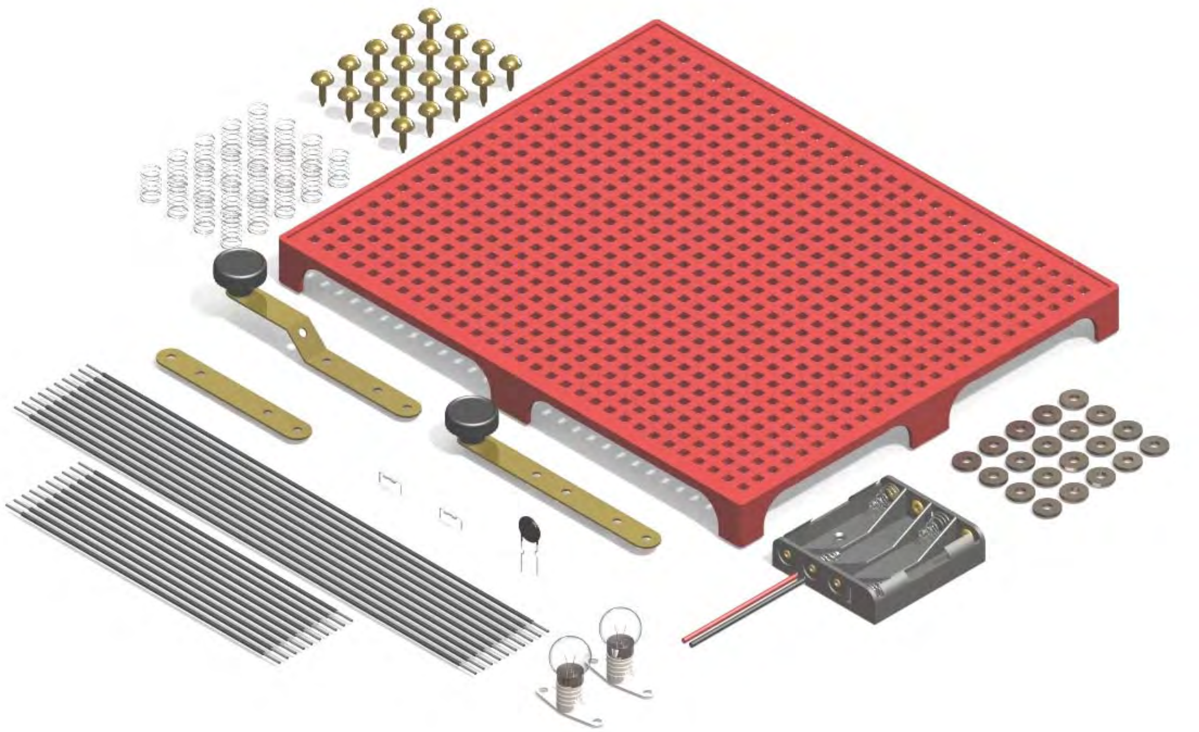
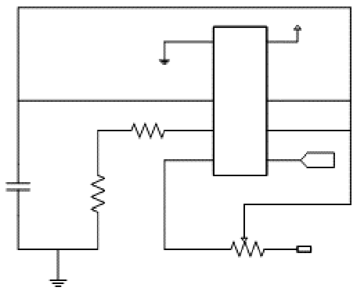
615-4068 (10-132) Electricity Kit



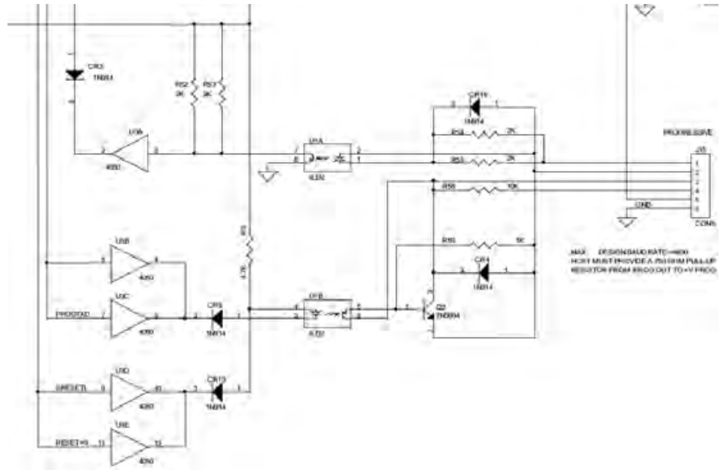
Warning: Although this device is designed to be as safe as possible, it does use electricity and has a risk of shock. Please exercise caution while operating this kit and never use anything other than the included 4 AAA cell battery pack as

Introduction: What is electricity? All atoms are partially made up of an elementary particle known as an electron. These electrons can sometimes be induced to leave their host atoms and move to another atom nearby. Metal atoms are particularly good at this. When metal atoms bond together, the outermost electrons on each atom form a "sea" or a "cloud" of electrons that flow freely from atom to atom. This flow of electrons is called electricity, but it is useless unless guided. If an electrical current is applied to a metal, the electrons in the metal will flow, carrying the electrical current with them.

Electrical circuits are essential for our modern civilization. They control lights across continents, keep planes flying through the air, and manage global communication. They also do more mundane things like control the flow of electricity in flashlights or doorbells. Regardless of their function, all electrical circuits have certain things in common.
Most analog circuits are linear: that is, the electricity follows a clear path, with various operations at different points. Most analog circuits are fairly easy to understand. Digital circuits are often far more complex: some can only be analyzed with the aid of specialized software. *Note: this kit deals with analog circuits*. Consider the difference between a buzzer and a computer's motherboard for a good example of this.



Complete Buzzer Schematic

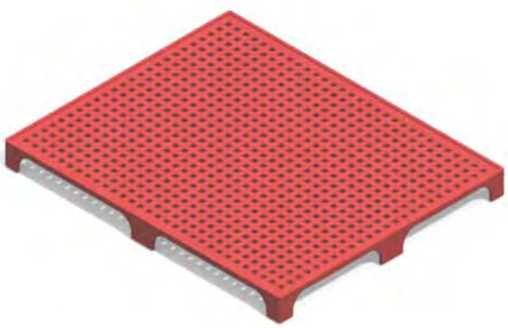


Small Portion of a Motherboard Schematic

With our set, you'll be able to construct a variety of circuits. You'll learn about: switches, series and parallel circuits, lights, short circuits, electrolysis, conductors and insulators, fuses, Morse code, and resistance.

Description: Our set contains the following components (images not to scale):

Circuit Board base



4 AAA Cell Battery Holder

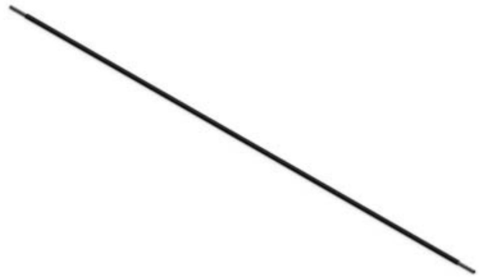
Brass Strip

Light bulbs with holders (2)

Switch

Fuse

Long Wires (10)



Short Wires (10)

Morse code key

Resistors (2)

Springs (20)

Brad Pins (or Paper Clips - 20)

Washers (20)

Because of the large number of small parts in this kit, it is recommended you use a bin, box or similar container to hold them when not is use. The box the kit was shipped in is useful for this purpose.

Operation:

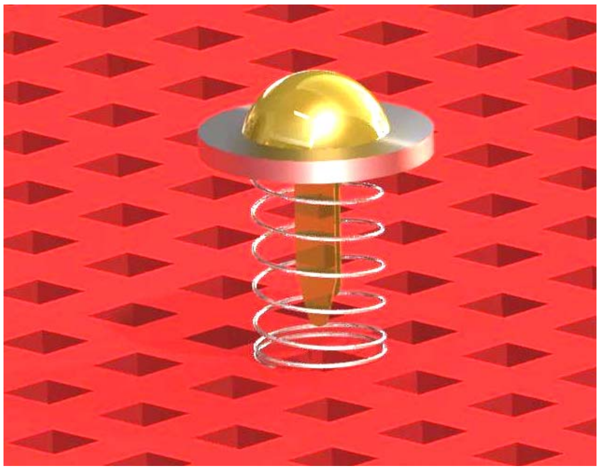
Start by attaching the battery holder to the circuit board. There are two ways to do this. First option is to use the included brads to affix it to the circuit board. Make sure you insert the heads of the brads from the bottom of the circuit board and then flatten their tabs into the bottom of the battery holder wells. If the brads are installed from the top down (with their heads in the battery wells) the AAA batteries will not fit correctly into the holder. A second good way to do this is to use double-sided adhesive tape. In either case, make sure that the wires can reach as much of the circuit board as possible.

Your battery holder accepts four AAA batteries. Always use the same type of battery and never mix rechargeable with alkaline or old batteries with new. It will need all four batteries in order for the kit will work properly.

▸ Caution! ◂

When not in use, one battery should be removed so that if the ends of the wires from the battery holder come in contact, they will not short out the batteries.

Making quick connect connectors:

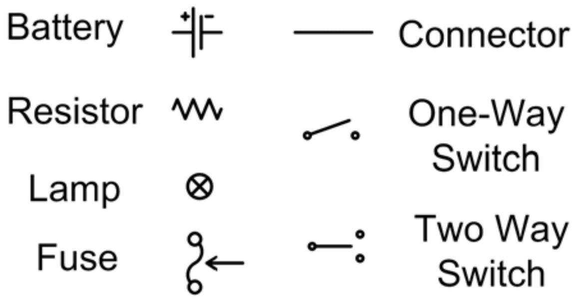


In order to quickly and easily wire up the following electrical experiments, there is one type of connector that will be utilized repeatedly, the quick connector. A quick connector consists of one brad, one spring and one washer. These are combined as shown on the right. Insert the brad pin into the washer, then into a spring and finally into the board. Do not completely compress the spring. Spread the brad legs out under the board. You can now easily depress the washer slightly to insert a wire or two as needed.

Circuit Diagrams (Schematics):

Circuit diagrams have many names. They can be called electrical schematics, wiring diagrams or even elementary diagrams. A circuit diagram is a pictorial representation of components in a device. It does not necessarily show the proper arrangement of the components, but rather the signal connections between them. All of the following experiments have Schematics along with them for you to study. Make sure that you understand how the two relate to each other and that you see how much simpler the circuit diagram is when compared to the actual assembled experiment.

Component symbols used in this kit are:



There are many other symbols used when making circuit diagrams, this kit only introduces a few for you to begin with.
Experiments and Activities:

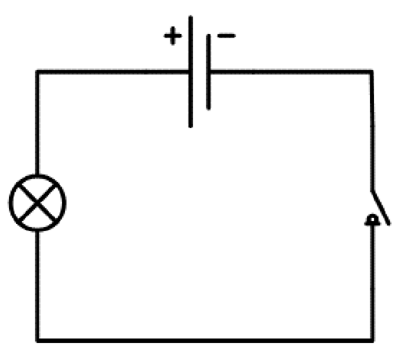
Switches: For the first activity, make a simple circuit that powers a light and is controlled by a switch. Start by putting one of the bulbs into a bulb holder, and then attach it to the board with brads. To make the switch, you will need the following:

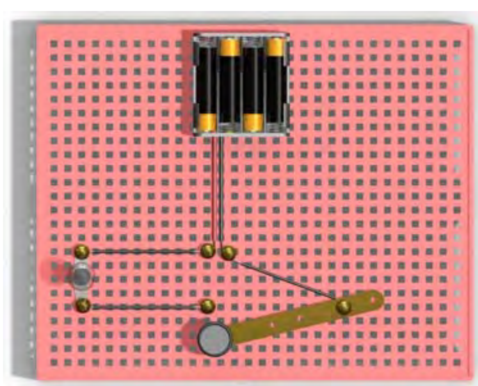
1. The switch
2. Six brads
3. Three short wires
4. Six washers
5. Six springs

Using the diagram of the quick connector on the previous page and the wiring diagrams on the next page as a reference, assemble one quick connector and use it to attach one lead from the battery back to a short wire. Assemble a second and use this one to attach the other end of the short wire to one leg of the lamp holder. Make another identical assembly leading from the other bulb holder leg and terminate this with a quick connector that has nothing else attached to it. Returning to the battery pack; making sure that the two leads (or the two installed brads) from the battery pack do not touch each other, attach another quick connector with a short wire and the other battery lead. From this you will need to count either eight or ten holes to install the one end of the switch. This fixed end of the switch also has the free end of the short wire you just installed attached to it. The switch should be able to swivel around the brad at the end.

Congratulations, you have constructed an electrical circuit! The batteries will light the bulb unless you interrupt the flow of electricity by disconnecting the switch. Don't leave the switch closed and the bulb lit for a very long time as it will drain the batteries and might possibly make some of the components or connections hot. Always turn off an experiment when you are done with it.

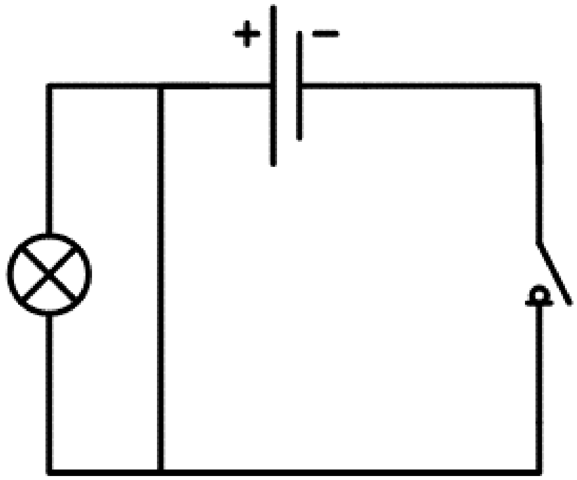
Electrical Schematic and Image of experiment setup:

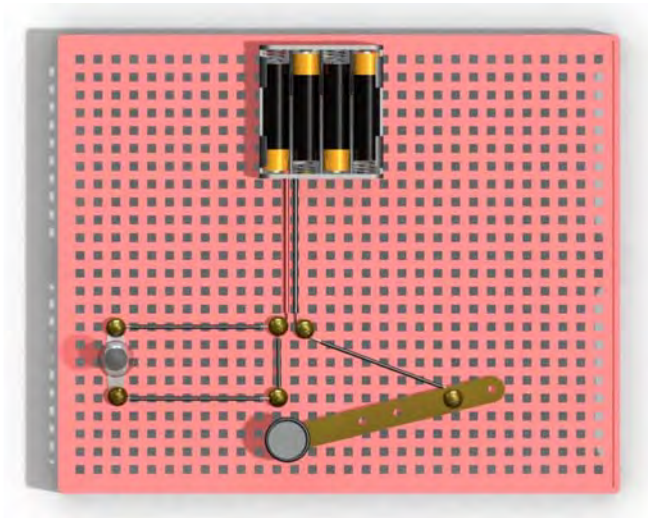




How does electricity work? Electricity is the flow of elemental particles called electrons. Some materials allow electrons to move very freely. Copper wire is good at this, so it conducts the electricity to the light bulb very well. When the switch is turned off, the electricity no longer has any wire to move through. Air is a very poor conductor, so the electricity cannot reach the light bulb. Thus, the switch can control whether or not electricity can reach the light bulb.

Short Circuits: Shorts are an instance where electricity flows along a path it's not supposed to. Using the same circuit you assembled in the previous activity, take a short wire and put it between the two connectors by the bulb, not the switch. See the following schematic and diagram.



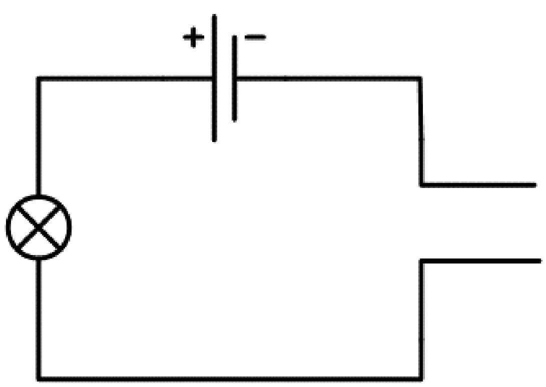


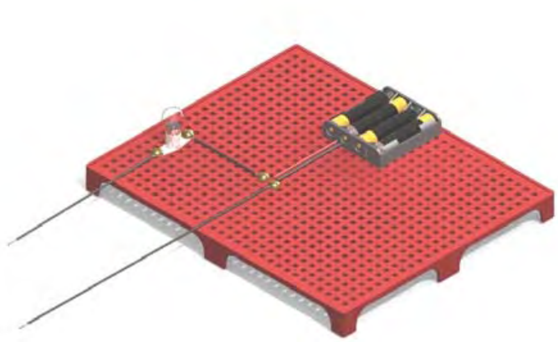
What happens when you turn the switch to the on position? Leave the switch on for a few seconds, and then turn it off. Do not leave it connected for more than a few seconds. Feel the connectors. Are they warm or cold?

What has happened here? As you learned in the last activity, electricity needs certain materials, called conductors, to flow from one spot to another. However, electricity doesn't like having to do more work than it absolutely needs to. It will always seek a course that gives it as little trouble as possible, called the path of least resistance. If the wire between the connectors has less resistance than the wire in the light bulb, the electricity will flow along that wire and ignore the light bulb entirely. This is precisely what happens.

Think of the "work" that the electricity needs to do as being related to the resistance. It's just like when you are pedaling a bicycle along a flat road and then you have to go up a hill (resistance). Pedaling up the hill requires more work, work which you probably don't want to do and would avoid if possible. More resistance means more work needs to be done. The high resistance of the wire in the light bulb (normally made from a small diameter tungsten wire and called a filament) is also what causes it to glow brightly and make light. In some light bulbs it is extremely hot, somewhere in the range of 3100-5400°F (1700-3000°C), but the wire is encased in a glass bulb with an inert gas surrounding it. This special gas helps to keep the filament from burning out immediately.

Conductors and Insulators: For this experiment, you will use the same circuit as before, with one modification. Remove the switch and attach a long wire to the brad that goes to the battery pack. Next, free the switch end of the wire that was coming from the bulb and going to the switch. See the following picture and schematic for better detail.





These wires should remain unattached to anything. You will also need a variety of items: some coins (a penny and any other silver coin), something made of plastic, a piece of wood, something ceramic, silverware and paper. You can test any other material you like. To test these or any other object, simply place the object between the two exposed wires.

An object is said to be conductive if it allows electricity to flow through it. When you tested the materials, some were good conductors, some were poor conductors, and some were insulators. An object is said to be an insulator if it does not conduct electricity. The good conductors caused the bulb to burn brightly, the poor conductors produced a dim bulb, and the insulators allowed no electricity at all to reach the bulb. Which of the objects you tested were good conductors, poor conductors, or insulators? Do they have any similarities? Now that you have some experience with materials and their conductivity, test some more materials but before you do, try to guess whether they will conduct electricity or not.

Some materials, called superconductors, have no resistance to electricity. This means that the amount of current at the source is the same amount that reaches the end of the wire, with nothing lost as heat. Unfortunately these materials are expensive, and must be cooled to very low temperatures, usually a few Kelvin, which increases the cost of their use even more. A few Kelvin means temperatures that would be over 200° below zero Celsius (-250°C) or over 450° below zero Fahrenheit (-450°F). These extremely low temperatures are normally obtained through the use of liquid nitrogen. If superconductors can ever be found that work at or near room temperature, the world as we know it will change dramatically.

Conductivity of liquids: This will use the same circuit you constructed to test solid objects. Fill a cup with some water and then place the free ends of the two wires into the water making sure they don't touch each other. Does the light bulb illuminate? Repeat the experiment, this time using salt water. What are your results?

If done properly, you should have noticed that pure water is an insulator, whereas salt water is a conductor. This is because water by itself is an insulator, but dissolved salt puts ions into the water. These ions are electrically charged and can carry electricity. Some tap water may even have enough dissolved sediments to conduct electricity. Water, even pure water, is not a perfect insulator. A powerful enough current can pass through even pure water. This is why it is generally a bad idea to use electricity in wet environments. You can also try this experiment using other liquids, such as lemon juice, vinegar, milk, oil or any other safe to handle material. Try to guess what the results will be before performing the experiments.

The following experiment should only be performed under adult supervision!

Electrolysis: For this experiment, use the same setup as the previous experiment. Fill a container (do not use a cup or glass that you will ever drink from) with concentrated salt water (very salty water). Attach brads to each of the free ends of the wires. Put the brads into the very salty water, making sure they do not touch each other. Close the switch. For about a minute, nothing much will happen however, after some time, a grey-green substance will start forming in the water. This substance appears to be coming from one of the brads. You may be unable to see it, but the other brad will be covered in small bubbles. What is happening?

The electricity flowing through the salt water caused a chemical change in one of the brads and the water. The grayish greenish stuff comes from the combination of the metal in the brad and the salt water. On the other brad, bubbles of hydrogen formed. Since hydrogen is the lightest element, these bubbles quickly escape into the air.

Note: Never touch the grey-green substance on the brads. Never drink the salt water used in this experiment. Wash all the brads, the container and the ends of the wires that came in contact with the water with large amounts of water. Wash your

Optional and more advanced: A Deeper Look into Electrolysis:
Electrolysis is a method which uses electricity to separate chemically bonded compounds. In general, the items required to perform electrolysis are:

- Two pieces of metal, these are called electrodes (the brads)
- A liquid that has ions which are free to move about called an electrolyte (the salt water)
- A source of direct current (a battery or set of batteries, for our experiment)

The most important feature of electrolysis is the modification of ions and atoms through the addition or subtraction of electrons. The way it works is this: a DC (Direct Current) electrical current is applied to the two electrodes, one electrode will be positive and the other will be negative. The positive electrode will attract negatively charged ions (also called anions) from the electrolyte and the negative electrode will attract positively charged ions (called cations) from the electrolyte. The applied electrical current allows this exchange to take place. A solid (like a block of salt) would not allow this exchange to happen because the ions are not free to move like they can in a liquid.

Once the ions reach the electrodes, electrons will either be released or absorbed by the ions and atoms. Some of the atoms and ions become charged and these will pass into the electrolyte and those that become uncharged, separate from the electrolyte.

Remember that for this experiment we have the following materials:
The electrodes, in this electricity kit, are made from brass. Brass is an alloy (a combination) of copper (Cu) and zinc (Zn).

The liquid we use for this experiment is salt water. The chemical formula for salt is NaCl where Na is Sodium and Cl is chloride. The chemical formula for water (as you may well know by now) is H_2O where H is hydrogen and O is oxygen. When you mix salt into the water it dissolves. When the salt dissolves it separates into ions of chlorine and sodium. These ions are now free to combine with other ions to make something else.

When the electricity is applied to the setup, it supplies the energy required to separate the rest of the molecules and to bring them together as new ones.

The sodium will combine with the oxygen to create sodium hydroxide or lye (2NaOH).
The chlorine combines with the copper to create copper chloride ($CuCl_2$).
There is also a gas released, the lightest gas in the universe, hydrogen (H).

If you have taken any algebra classes, you may be familiar with algebraic equations such as:

$$y = mx + b$$

Chemical formulas are different in one important way: when chemical formulas are written, both sides of the equation must be equal at all times. For this experiment, we have:

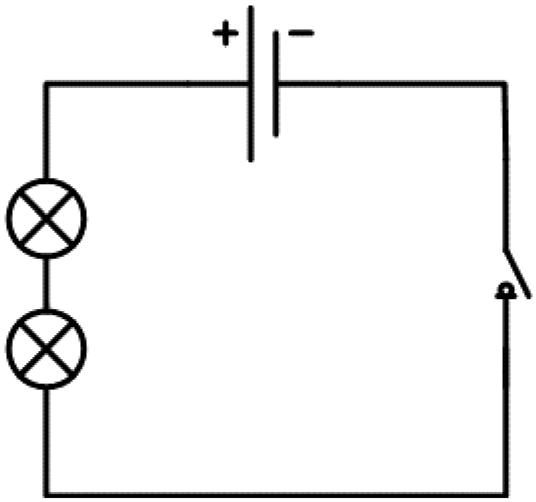
$$\mathbf{2H_2O + Cu + 2NaCl \rightarrow H_2 + 2NaOH + CuCl_2}$$

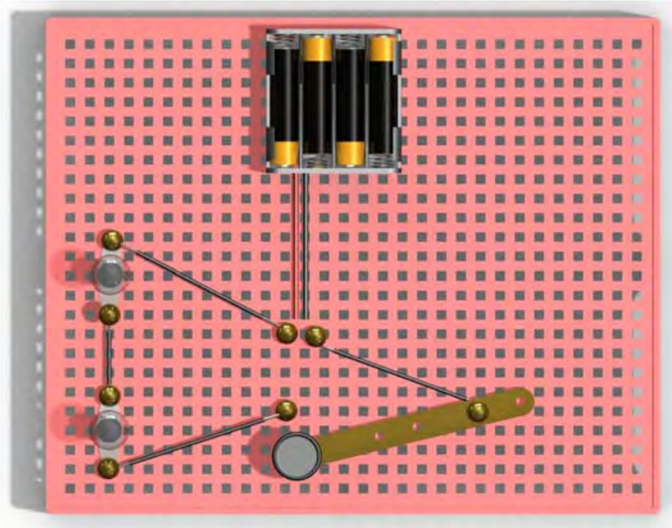
The → sign means “yields” or “becomes”.

Remember: Never touch the grey-green substance on the brads, this is the copper chloride. Never drink the salt water used in this experiment. The experiment will not create enough copper chloride or sodium hydroxide to be dangerous, but care should be exercised regardless. Wash all the brads, the container and the ends of the wires that came in contact with the water with large amounts of water. Wash your hands thoroughly after completing this experiment.

Series and Parallel circuits: Think about what you have learned about switches. When the switch is turned off, the light goes off. Why then, do some lights in your school stay on when a switch is flipped? The secret lies in the type of circuit.

Series circuits:
It’s time to build another circuit. Using your circuit setup from the first experiment, we need to add a second light bulb. For the first setup, the light bulb will be added in the same path as the first, rather like a chain. The two bulbs should be in a row on the circuit. This is called ***series***. When a set of electrical components are connected <u>in series, they have the same current</u>. We will see what this means once the circuit is completely wired. See the following schematic and picture for more detail.



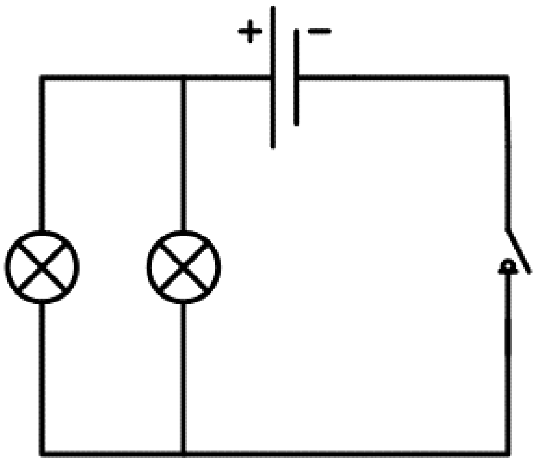


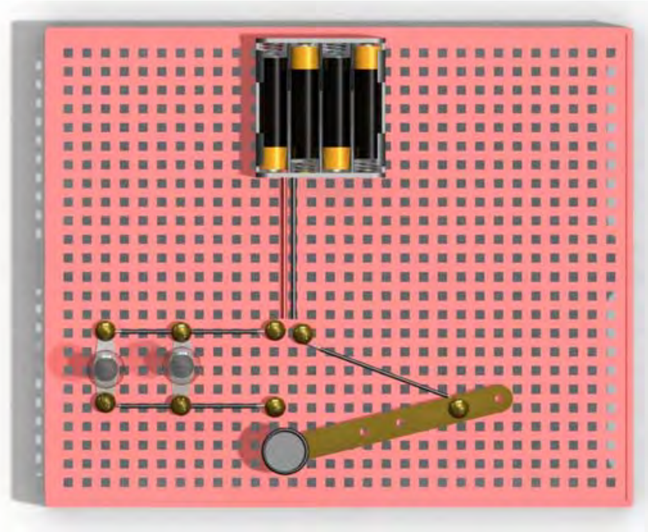
Turn the switch on. What happens? Also, try removing one of the bulbs by unscrewing it from the socket. Make sure the switch is off before you remove the bulb! Turn the switch on. What is the result?

You will notice that two bulbs in series are less bright than one bulb standing alone. This is because the same amount of current now has to light up two bulbs, making each dimmer. The two bulbs have effectively doubled the resistance in the system. The current is divided between the two bulbs so both bulbs glow less brightly. Think of the current in the wire as being like water in a garden hose. If you have just the end of the hose open then the water will gush out, but if a hole is cut into the hose, the water comes out from the end of the hose less strongly. Although the amount of water running through the hose is the same, it now has two separate places to exit the hose. The more openings, the less strongly the water flows through each hole and the same is true for electricity, the more resistances (or, in our case light bulbs), the less strongly they glow.

Removing one bulb turns off the system completely because the connection is broken. Cheap Christmas tree bulbs are wired in series; which is why the entire strand (or long sections of a strand) fails if one is missing or has blown out.

Parallel circuits:
For an experiment in parallel circuits, we need to move the second bulb so that it is taking electricity from the wire at the same time as the first bulb. When a set of electrical components are connected in parallel, they have the same voltage. Using the various wires and connectors at your disposal, reconnect the circuit as shown in the following diagram.





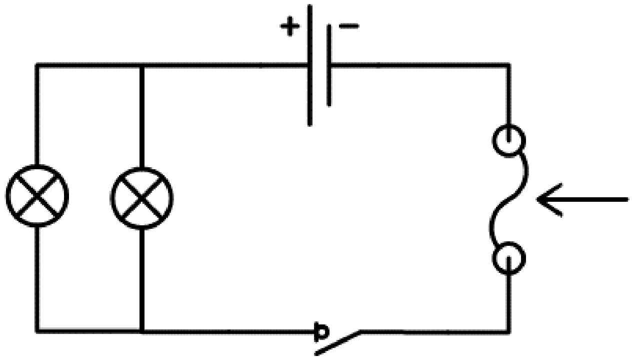
This is a ***parallel*** circuit.
Flip the switch on. What happens? Remove one of the bulbs (again, make sure the switch is off before you remove the bulb.). What happens now?

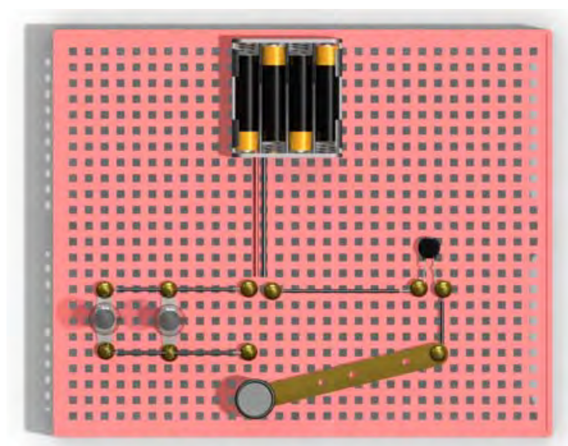
You will notice something interesting: the bulbs in parallel are brighter than those in series. This is because the voltage is the same across the bulbs. Also, when a bulb is removed, the other bulb stays lit. This is because the wires to one bulb bypass the other, essentially making two circuits connected to the same power source. Most everything in your house is wired in parallel with the exception of one component. Can you guess what this component is? The answer follows the next paragraph.

Unfortunately, the light from the extra bulb isn't free. The drain on the battery is twice as strong. It is a little harder to use the garden hose analogy here because you must imagine that the amount of water coming through the hose (equivalent to the electrical current) isn't limited by the size of the hose, it will always remain constant. The current is broken up into two legs; it travels through the two bulbs and then rejoins on the other side. If more and more bulbs were added to this circuit in parallel the drain on the batteries would increase with each bulb added. The bulbs would all glow the same brightness as each other, but the batteries would have a shorter and shorter life span with each bulb added.

The one common component that must be wired in series is a *fuse.* By wiring fuses in series, when they are blown (or tripped in the case of a circuit breaker, like the ones in your house), they will shut off the power flowing to everything in that circuit. A very handy feature indeed.

Fuses: For this activity, use the parallel circuit that was just used in the last experiment. You will need to slightly change the wiring as shown below. Take the wire coming from the battery pack and the wire from the switch and connect these as shown, with the quick connectors, each to one leg of the resettable fuse. It may be necessary to bend apart the legs of the fuse. This is ok, just don't repeatedly bend them or they may break from fatigue.





Turn the switch on and leave it in the on position. What happens?

You should have noticed the lights will dim and go out after a few seconds. Why? Except for superconductors, all conductors turn part of the electricity into heat. For some materials, this heat is enough to melt or vaporize the material. For the special fuse that is enclosed with this kit, when used during normal operation, numerous carbon paths within the fuse (a special substance called a polymer) allow the device to conduct electricity. As current through this special resettable fuse reaches its rated threshold, the polymer material begins to heat causing the polymer to expand. The resulting expansion breaks the carbon chains to reduce the current through the circuit to a small leakage current. In other words, there is no path for the electricity to flow through anymore. This is why the bulbs slowly dim and then go out. Once the switch is turned off the material will cool down and electricity will be able to flow once again.

If you have brand new AAA batteries, this fuse may trip with only one bulb in the circuit. Try different configurations such as replacing one bulb with a resistor, both bulbs with resistors, or more complex series and parallel circuits. Try to guess from your past experience what will happen before performing your experiments. Specifically, try the experiment with the two bulbs in series. Looking back at what remains constant in a given circuit, why does the fuse not blow with two bulbs in series?

Fuses are important because they will automatically disrupt a circuit if too much electricity is applied to it or if a short occurs. This is a very important safety feature as fuses help prevent fires and personal injury that might occur if the insulation is accidently stripped from electrical wires or if some connections become loose and wires move from where they should be.

Series and parallel used functionally: With your newly acquired knowledge of series and parallel circuits, we will now set up a device to test batteries in both configurations. To start with, we will make a simple battery tester. This battery tester is portable so the red base will not be used, no components will be attached to it. Required for this experiment will be:

- The brass strip
- Two wires (any length)
- One light bulb in its holder
- One brass brad

Wire these together and place the battery into the setup as shown. What happens when the brad touches the top of the battery? Turn the battery over and test with the button top of the battery touching the brass strip and the flat part of the battery touching the brad. Is there any difference in brightness of the bulb between the two orientations?

The bulbs that are included in this electricity kit are 6v and to operate at their optimal brightness, they need 6v of DC electricity to work correctly. The single battery that you have just tested with is only able to produce 1.5v, even less if the battery is not new or if it is a rechargeable battery. The light bulb still glows, but it does so very weakly.

Think back upon what you learned from the two previous experiments that dealt with *series* and *parallel* circuits, which do you expect to make the bulb glow more brightly? Your guess is called a scientific hypothesis. It is a reasoned estimate of what will happen based upon past experiences or observations. You now need to test your hypothesis and see if your guess was correct or not.

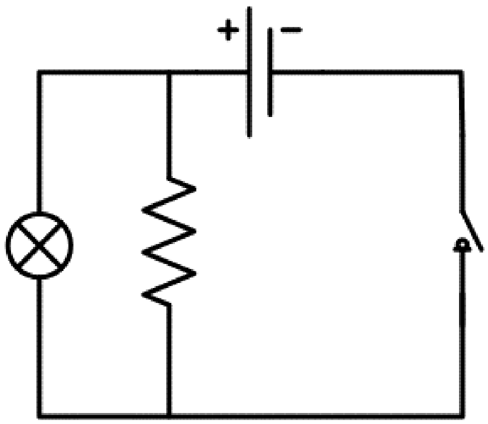
The series setup will look like this

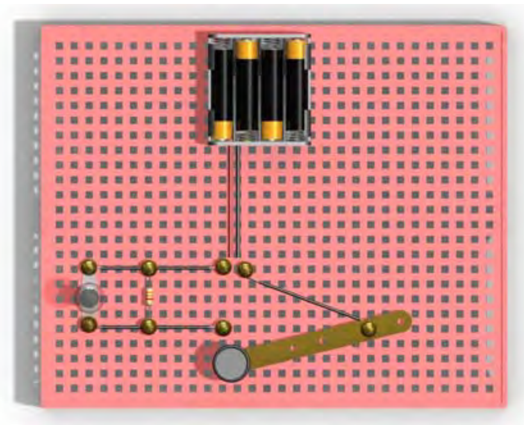
The parallel setup will look like this

Did your hypotheses turn out to be accurate? In series the two 1.5v batteries add their voltages to become 3v, and hence the bulb burns brighter. Batteries in parallel do not add their voltages so the bulb does not glow brighter. If you had the time to test how long the bulb would remain lit however, you would find that the bulb lit by the batteries in parallel would remain lit twice as long.

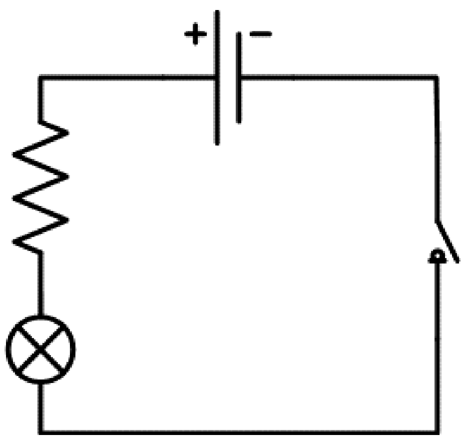
Resistance: Although it is the bane of all power transmission, resistance is an interesting phenomenon. Since our set does not utilize superconducting materials, there is already some resistance in the circuit. For this experiment, we will add more.

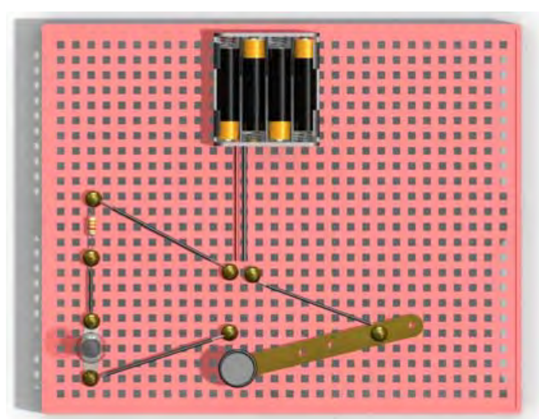
At this point you already have the circuit connected in parallel. Remove one of the light bulbs from the circuit (it matters not which is removed) and replace it with a resistor as shown below. Turn on the switch for a few seconds and then turn it off. Touch the resistor. What happens to the bulb and resistor?





Next, connect the resistor in series with the bulb and repeat the experiment.



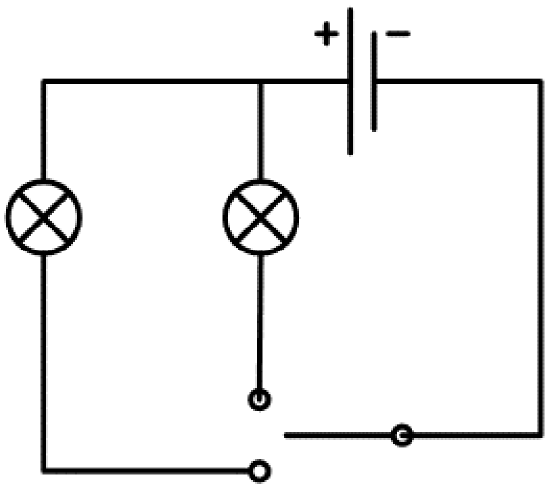


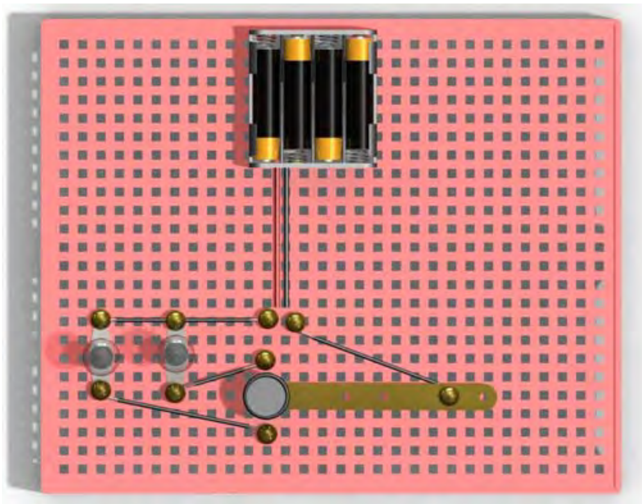
What are the results?

Regardless of the method, you will notice that the resistor gets hot. This is because the electricity blocked by the resistor has to go somewhere, and it turns into heat. In series, the electricity must go through the resistor, so the bulb gets dimmer. In parallel, electricity can flow around the resistor, so the bulb stays as bright. However, some of the electricity will continue to go through the resistor, so it still gets warm.

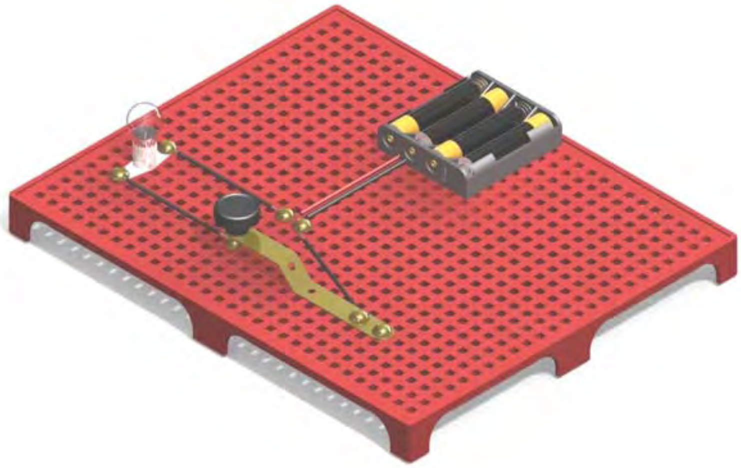
Practical applications of resistance are toaster ovens and dimmer switches. Light bulbs are a kind of resistor that gives off light and heat.

Constructing a Two-Way switch: There are instances when one switch is used to control different light bulbs or when one switch may make different settings on an appliance possible. Examples of this would be a fan (think of the Low, Medium and High settings), the temperature knob in your refrigerator and the intermittent switch on your family's car windshield wiper blades. While some of those examples use multiple position switches, we will make a two-way switch. It is a simple matter to alter the parallel circuit you just made to show how this new circuit would work. All that is required is rewiring one wire and adding a second wire and quick connector in such a way that the switch can reach both brads, though not at the same time. See the following diagrams for greater clarity:





Morse Code: You can also set up the electricity kit to be used as a Morse code transmitter. To do this, start with your original circuit. You will then replace the switch with the Morse key as shown below. If you have constructed your circuit properly, the light should illuminate when you tap the key and extinguish when you let go.



The schematic is exactly the same as the one for the first experiment since the Morse code key is just another type of switch, a special switch called a momentary switch. This means that the switch does not remain on when pressed. It toggles on and off each time it is pressed. Morse code was invented by Samuel Morse in the 1840's for use in telegraphs. This form of communication uses dots and dashes to relay letters. A dot is a quick pulse; a dash is a longer pulse. Each letter's code as follows is:

A= dot dash
B= dash dot dot dot
C= dash dot dash dot

N= dash dot
O= dash dash dash
P= dot dash dash dot

D= dash dot dot
E= dot
F= dot dot dash dot
G= dash dash dot
H= dot dot dot dot
I= dot dot
J= dot dash dash dash
K= dash dot dash
L= dot dash dot dot
M= dash dash

Q= dash dash dot dash
R= dot dash dot
S= dot dot dot
T= dash
U= dot dot dash
V= dot dot dot dash
W= dot dash dash
X= dash dot dot dash
Y= dash dot dash dash
Z= dash dash dot dot

For example, SOS is three dots, three dashes, three dots • • • — — — • • •

Understood = dot dot dot dash dot • • • — •
Period = dot dash dot dash dot dash • — • — • —
Question Mark = dot dot dash dash dot dot • • — — • •
Exclamation Mark = dash dot dash dot dash dash — • — • — —
Starting signal = dash dot dash dot dash — • — • —
Break = dash dot dot dot dash — • • • —
Error = dot dot dot dot dot dot dot dot • • • • • • • •
Wait = dot dash dot dot dot • — • • •
At sign (@) = dot dash dash dot dash dot • — — • — •
End of transmission = dot dot dot dash dot dash. • • • — • —

International Morse Code

1. A dash is equal to three dots.
2. The space between parts of the same letter is equal to one dot.
3. The space between two letters is equal to three dots.
4. The space between two words is equal to seven dots.

A	• —	U	• • —
B	— • • •	V	• • • —
C	— • — •	W	• — —
D	— • •	X	— • • —
E	•	Y	— • — —
F	• • — •	Z	— — • •
G	— — •		
H	• • • •		
I	• •		
J	• — — —		
K	— • —	1	• — — — —
L	• — • •	2	• • — — —
M	— —	3	• • • — —
N	— •	4	• • • • —
O	— — —	5	• • • • •
P	• — — •	6	— • • • •
Q	— — • —	7	— — • • •
R	• — •	8	— — — • •
S	• • •	9	— — — — •
T	—	0	— — — — —

Warranty and Parts:
We replace all defective or missing parts free of charge. Additional replacement parts may be ordered toll-free. We accept MasterCard, Visa, checks and School P.O.s. All products warranted to be free from defect for 90 days. Does not apply to accident, misuse or normal wear and tear. Intended for children 13 years of age and up. This item is not a toy. It may contain small parts that can be choking hazards. Adult supervision is required.

May we suggest:

611-2261 Conductivity Meter: Visually compare conductivity between different solutions. The green LED is numbered from 1-10 and will light up as the probes are dipped into solutions of salts or acids.