My Book of

Electrical Experiments

Experiments help us to understand what is going on in the world. Just holding a ball in our hand and then letting it drop to the floor will give information about gravity and how the ball behaves when it hits the ground. Does it bounce? Does it sink into the ground? Do we know why?

The picture above shows electrical sparks jumping between the clouds and the ground. Our electrical experiments will help us understand why.

Electricity is essential to the way we live – but it can also be dangerous if we do not treat it with respect. The experiments suggested are safe but only with the low voltage batteries suggested. **DO NOT TRY THEM WITH ELECTRICITY FROM THE WALL PLUGS.**
Electrical Experiments

Experiments are a way to ask questions to help us understand how things work. We must look carefully and make measurements to help us do this.

This is a picture of a thunderstorm. What do we call the sparks going between the thunderclouds and the ground? Is it lightning?

Do you know why there is loud thunder when this happens? Does the spark heat the air very quickly making it expands very fast causing this loud noise?

The clouds have static electricity on them and the sparks carry a very large electric current between the clouds and the ground.

If you rub your feet on a nylon carpet in cold dry weather, your body may get an electric charge. If you then touch a metal doorknob, a spark may jump from your hand and you will feel a shock. It will also make a tiny noise.
Can we do some experiments to see how Static Electricity behaves?

Balloons are good things to use for this.

The girl has rubbed the balloon on her hair and the balloon now has a static electrical charge. Her hair has an opposite charge.

Do you see how these two opposite charges attract each other? Her hair is being pulled to the balloon because of this and the balloon is being pulled to the hair.

Use a balloon and try this experiment for yourself. Do you get the same result?

Try rubbing the balloon with some dry cloth made from wool or nylon. Does this also attract your hair?
When we get results from an experiment, we try to understand what they are telling us and then ask some new questions.

The picture below gives an answer to how the things we rub together get different charges: one positive (+) and the other negative (-). Electrons are negative (-).

**Static Electricity**

Where do charges come from?

When a balloon rubs a piece of wool...

Electrons are pulled from the wool to the balloon.

The balloon has more electrons than usual.

The balloon: – charged,
The wool: +charged

Do you understand the answer?

Electrons are part of the atoms that make balloon and the wool. The atoms are too big to be easily moved by just rubbing. The small electrons are pulled from the wool to the balloon and it then gets a negative charge.
Now take two balloons tied to long pieces of thin string. Can they come close enough to touch each other?

Now rub each of them with the same type of cloth and then bring them close to each other. Do they attract each other or push each other apart?

If they push each other apart like the two red balloons in the picture what can this mean?

From the experiment with our hair, we found that if two things have opposite charges they attract each other.

By rubbing our balloons with the same sort of cloth, we would expect to give them the same sort of charge. Now our experiment shows they push each other away.

Is our experiment telling us that same charges repel each other? Here are some pictures to help us remember these results.
Different materials hold on to their electrons more or less strongly.
The picture below shows this for some more materials.

Can you find **Rubber** and **Wool** in the list? One is on the blue, (-), negative side and the other on the red, (+), positive side. They are quite close together.
The further the thing in the picture are apart, the bigger the charge rubbing them together makes.
Can you try rubbing some other pairs together?
Electrical Circuits & Currents

The Balloon experiments separated electrical charges using rubbing and they then stayed in one place.

The sparks we made showed that these charges can sometimes move and make an electric current.

We should do some Experiments to find out how to make a current and use it for making interesting things.

Do you have a flashlight? Have you ever looked inside to see what it is made of? Can you name the things you saw? Here is a picture that might help.

![Diagram of a flashlight with labeled parts: Case, Switch, Bulb, Spring, Dry Cells, Reflect, Protective Glass, Red Line.]

Did you find all of the things shown in the picture?

The Dry Cell Battery stores electricity; the Bulb only makes light when Currents pass through it; the Switch can stop or let the current pass and the red line, the spring and the case finish the Electrical Circuit which takes the electron current where we want it to go.
The Circuit in the flashlight is metal and the electrical current is due to electrons moving in the metal because the Battery **Voltage** pushes them.

If the switch is open, electrons cannot go all around the circuit and the bulb will not give light.

Electrons have a negative charge and are attracted to the positive (+) side of the battery and repelled by the negative side (-) of the battery. This is shown by the arrows in the picture above where they also go through the lamp.

This board has the things needed for a circuit except for the connecting wires. Can you say what each thing is?
Batteries

A Battery is needed to provide the voltage and electrons for the electric current. The Battery has both positive and negative sides made from different metals with a conducting material between them.

Let us make one from Copper and Zinc metals and a lemon. Push the metals through the lemon skin so that they do not touch each other.

The zinc and copper will partly dissolve in the acid lemon juice. Zinc atoms lose two electrons to dissolve and these can go through the wire to the copper plate so that it can add more copper atoms to that plate. The voltage moving the electrons is about one Volt with the copper (+) and the zinc (-). Volta’s first battery (pile) is shown in the other picture. He invented it in 1800!
This picture shows how the electrons can move in a circuit to light a bulb and how the charged atoms (ions) move in the electrolyte to the battery electrodes.

Take a glass jar and two metal plates from the kit. Put vinegar in the jar and use a Multimeter to measure the voltage between the plates when they are in the vinegar.

Is there a voltage if the plates are the same metal? Keep the copper electrode and use other metals for the second one. Does the voltage change? Now use different liquids – salt water, lemon juice – and measure the voltage for each one.
Circuits

For electrons to be able to move, a complete circuit is needed. The circuit materials must be conductors and metals are normally used.

The picture shows two wires that can be part of a circuit with clip connectors on each end. They are covered in red or black plastic to insulate them from other conductors.

Can you use them to clip to other things in the circuit? Do not clip one wire between the two ends of a battery! This will make a Short Circuit, damage the battery, and make the wire very hot.

Look at the picture and try to connect wires to the battery in the way it shows.

Did you find that the light bulb only gave light when the circuit was connected to both ends of the battery?

Not connecting the red wire acts like a switch and makes an open circuit so electrons cannot go from one battery electrode to the other.
If we have more than one light bulb, the circuit may be made in different ways. Experiment with the first two. In this picture the bulbs are connected to each other so the battery current passes through them one after the other. A Series circuit. The more bulbs there are the less light each will give.

The second picture shows how to connect each bulb directly to the battery so that each can get the current it needs to be bright. This is a Parallel circuit.

Put a switch in each circuit. Where?

What we do not want is a Short circuit where the current does not pass through the bulb but goes on a low Resistance path between the battery electrodes. The short circuit wire will get hot, the bulb will not give any light and the battery will get hot and be damaged. Do not try this last experiment!
Experiments that will help us understand what goes on in a circuit can be made using a **Multimeter**.

This can measure **Voltage**, $V$; **Resistance**, $R$ or $\Omega$; and **Current**, $I$, in Volts, Ohms and Amps.
Set it on the **Voltage scale, V**, and use its probes to measure the voltage across each of the things in the circuit. Put one probe on each side of the component.

Do this once with the **Switch** turned off and again with the switch turned on. Do you get the same answer?

Write the numbers down and see if they are the same each time. Which ones change and which ones stay the same?

Now we can use the Multimeter to measure the **Resistance** of the things in the circuit. To do this, take the **battery** out of the circuit or turn the switch OFF.
Change the Multimeter to measure **Resistance** in Ohms, \( \Omega \).

**Measuring Resistance**

Set multimeter to the proper Ohms range. Measure across the component being tested. Power must be off or removed from the circuit.

Place the Multimeter probes on either side of the thing being measured and the scale will show its resistance in Ohms, \( \Omega \).

To see that the meter is working properly, hold its two probes so that their tips touch. What number shows on the meter? If it is **0.00**, the meter is working properly.

What is the resistance of the switch when it is on or off? What is the resistance of the light bulb? If there is another resistor or bulb in the circuit what is its resistance value?
Now we will measure the current flowing in the circuit. The battery must be connected before we do this and the meter set to Amps. The probes of the meter must be connected into the circuit not just touching it.

**Measuring Current**

Set multimeter to the proper $A_{DC}$ range. Circuit flow must go through the meter.

What current do you measure with the switch OFF? Does this change when you turn the switch ON? How big is the ON current? Does the light shine? Here is a table to show the things you measured.

<table>
<thead>
<tr>
<th>Quantities</th>
<th>Abbreviations</th>
<th>Units</th>
<th>Symbols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>V</td>
<td>Volts</td>
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</tr>
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<td>Current</td>
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<td>Amperes</td>
<td>A</td>
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<td>Resistance</td>
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<td>Ohms</td>
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The man who did the first experiments measuring voltage, resistance and current is shown in the picture.

**Georg Simon Ohm** found that they are related to each other and the rule he discovered in 1827 is now known as Ohm’s Law: \( V = I \times R \)

\[ \text{Voltage} = \text{Current} \times \text{Resistance} \]

The triangles shown in the picture below give the three ways this law can be used to get the size of the thing in the circle if the size of the other two things are known. Wow! It really is a useful triangle.

\[ V = I \times R \]

\[ I = \frac{V}{R} \]

\[ R = \frac{V}{I} \]

Can you get someone to help you see if your measurements of the light-bulb circuit voltage, resistance and current agree with these results?
The picture below is of a resistance that can be changed by moving the slider on the top. It is a **Rheostat**.

The second picture shows how wires should be connected to it to make a variable resistance in a battery circuit with a switch. Use the circuit board to do this.

For the first experiment turn the switch **off**, or **take out** the battery, and use the Multimeter on the **Ω scale** to measure the resistance between B and C.

Change the position of the sliding contact and see how the resistance changes. What position gives the biggest resistance? What gives the smallest? What are the measured resistance values?

Use a ruler to measure the position of the slider from one end (B) and the resistance for five positions (or more if you like). Can you write these down on some paper? Does the resistance get larger or smaller as the distance of the slider increases?
Here are two other circuits that use the Rheostat. The left one connects the battery to the A & B terminals and the Multimeter to the B & C terminals set to **Volts**. Use this for your first experiment.

How does the **Voltage** measured change if you change the position of the slider? Is it bigger or smaller than the Voltage of the battery?

Now make the second circuit. We want to measure **Current** and so the Multimeter must be on the **Amps** scale and the probe leads must both be in the Circuit.

Measure the current and see how it changes as the position of the slider changes. Put a light bulb in the circuit. Does its **brightness** change as you move the slider? Is the bulb brightest when the Amps in the circuit are the largest?

If you touch the bulb with your finger, does it feel warm? Do you know why?
The bulb gives light because electrons from the battery bump into the atoms and sides of the wire that is the filament of the bulb. This is normally Tungsten metal. This makes the wire very hot and it shines with a White light. If it is colder, the light looks more Red.

Did your second Rheostat experiment show you this?

The brighter the bulb the more electrical power, \( P \), it needs. This power is measured in Watts.

**Electrical Power**

Electrical power is directly related to the amount of current and voltage within a system.

\[
P = I \cdot V
\]

Power is measured in watts

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**Power equals Current times Voltage**

Can you use the multimeter to see if your experiments agree with this idea? You may need some help to play with the values you measure.

Do you think your measurements show that the more power the bulb gets the hotter it feels?
Currents and Magnets

When a current flows in a wire, it makes a Magnet.

The picture shows a wire that has been made into a long coil. When a current from a battery flows through the coil one end of the coil is like the North seeking pole of a magnet and the other end like the South seeking pole. When the current stops, the coil is no longer a magnet.

Our Earth also behaves like a magnet, probably because it has molten iron inside it that is moving as the Earth rotates about its axis.

The blue lines in the picture show the direction of the magnetic field, and look very much like the lines in the wire coil picture. A compass shows the direction of these lines, its red end looking for a South magnetic pole. The Geographical North Pole is a Magnetic South pole and the North Pole of our coil will point towards it if it is free to swing (just like the needle in a compass).
Here is another experiment you can try. Take an Iron nail or rod and wind an insulated copper wire around it as the picture shows. Keep the turns of the wire as close as possible and only wind in one direction.

To stop the wire unwinding, use some sticky tape to hold it to the rod. Make sure that the insulation is removed from the long free ends to make contact with your clip wires.

Use the multimeter to measure the resistance of the wire you have put on the rod. Use the circuit board to make the electrical circuit shown in the picture.

Find some iron paper clips that can be picked up with a magnet and see if your rod can pick them up if the switch is OFF. What did you discover?

Now turn the switch ON and try again. Has anything changed?

Pick up the rod and any paperclips that stick to it and turn the switch OFF. What happened? What does this tell you about the Electro-magnet? When does it work?
Here is a picture of how your experiment might look.

Here is a picture of what a **BIG** electromagnet looks like when it is picking up scrap metal. It needs a big crane to lift up, hold and move as much metal as this. Only magnetic materials can be lifted in this way.
In 1821, Michael Faraday was interested how a magnet would cause a wire with an electric current to behave.

His experiments made the first **Electric Motor**. This picture shows what is needed for our experiments. The glass or plastic cup holds salt water. A magnet is at the center of the cup and sticks out of the water. A long, straight copper conductor hangs freely from one electrode connected to the battery and dips into the water close to the magnet. Another electrode dips into the salt water and is connected to the other side of the battery through a switch.

With the switch open, nothing happens. When it is closed a current flows and the wire moves in a circle.

[Link to video](https://www.youtube.com/watch?v=MRFqYRHT3Wk)
Here is another way to make an Electric Motor.

A coil of insulated copper wire with scraped leads on either side sits between to copper supports.

A magnet is under the center of the coil, close but not stopping it rotate. Wires connect the copper supports to a battery.

When the battery is connected, the coil will rotate.

Which way does it turn?

What happens when you change the battery connections so the current go through the coil in the opposite way?

Now try turning the magnet upside down in the same position. What happens?

Now change the battery connections. What happens?

Use the fingers and thumb of your right hand to make the shape shown in the picture.

The Field is the magnetic field

Can this help you understand what your experiments have shown?
These experiments should have given you a lot about which to think.
Can you explain what happens to your friends?
Are there other experiments to do that might help you find out more?
Before trying anything, talk to someone to make sure that what you want to try is safe.