Investigating Electrical Energy Workshop

QUT Extreme Engineering

Introduction

This workshop is designed for grades 6-7, to give them some hands-on experience in building and testing electrical circuits. A clip circuit kit is used, so no soldering or playing with exposed wires is required. The activities are preceded by a PowerPoint presentation to introduce the topic, in preparation for the activities.

In this booklet, some background information on electricity and circuits is provided, followed by the content of the QUT Extreme Engineering school workshop.

Glossary

Battery	A chemical factory that stores chemical potential energy
Circuit	A complete or continuous loop which conducts electricity and has an energy source, like a battery
Charge	A physical property of particles
Conductor	A material that allows electricity to flow along it easily
Current	The flow of charge through a conductor
Electricity	A form of energy resulting from charged particles
Insulator	A material that does not allow electricity to flow along it easily
Parallel circuit	A circuit in which there is more than one path for the electricity to flow along
Series circuit	A circuit in which there is only one path for the electricity to flow along
Switch	A device that completes or breaks a circuit, to control the flow of electricity in a circuit
Terminal (battery)	The positive and negative ends of a battery to which the conductor (wire) is connected.
Voltage	The difference in electrical charge between two points in a circuit

The difference between voltage and current

Voltage can be thought of as the ability to cause current to flow in a conductor. A good analogy is to think of a tap – voltage is like the tap water pressure, current is like the flow rate of water, and the tap is like the switch. The greater the voltage in a circuit, the greater the current will be.

Background information

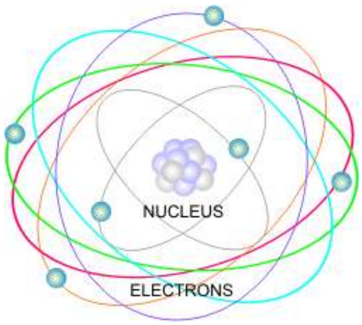
Science of Electricity Basics

Everything Is Made of Atoms

In order to understand electricity, we need to know something about atoms. Everything in the universe is made of atoms — every star, every tree, every animal. The human body is made of atoms. Air and water are, too. Atoms are the building blocks of the universe. Atoms are so small that millions of them would fit on the head of a pin.

Atoms Are Made of Even Smaller Particles

The centre of an atom is called the **nucleus**. It is made of particles called **protons** and **neutrons**. The protons and neutrons are very small, but electrons are much, much smaller. **Electrons** spin around the nucleus in shells a great distance from the nucleus. If the nucleus were the size of a tennis ball, the atom would be the size of the Empire State Building. Atoms are mostly empty space.

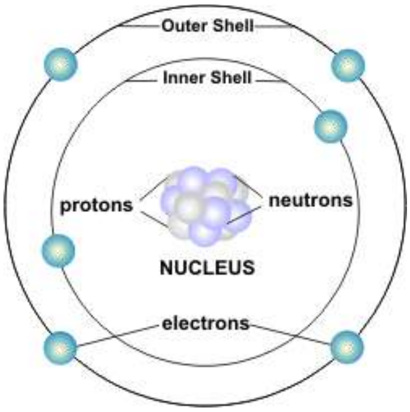


If you could see an atom, it would look a little like a tiny center of balls surrounded by giant invisible bubbles (or shells). The electrons would be on the surface of the bubbles, constantly spinning and moving to stay as far away from each other as possible. Electrons are held in their shells by an electrical force.

The protons and electrons of an atom are attracted to each other. They both carry an **electrical charge**. Protons have a positive charge (+) and electrons have a negative charge (-). The positive charge of the protons is equal to the negative charge of the electrons. Opposite charges attract each other. An atom is in balance when it has an equal number of protons and electrons. The neutrons carry no charge and their number can vary.

The number of protons in an atom determines the kind of atom, or **element**, it is. An element is a substance consisting of one type of atom (the Periodic Table shows all the known elements), all with the same number of protons. Every atom of hydrogen, for example, has one proton, and every atom of carbon has six protons. The number of protons determines which element it is.

Electricity Is the Movement of Electrons Between Atoms



Electrons usually remain a constant distance from the nucleus in precise **shells**. The shell closest to the nucleus can hold two electrons. The next shell can hold up to eight. The outer shells can hold even more. Some atoms with many protons can have as many as seven shells with electrons in them.

The electrons in the shells closest to the nucleus have a strong force of attraction to the protons. Sometimes, the electrons in an atom's outermost shells do not. These electrons can be pushed out of their orbits. Applying a force can make them move from one atom to another. These moving electrons are electricity.

Static Electricity Exists in Nature

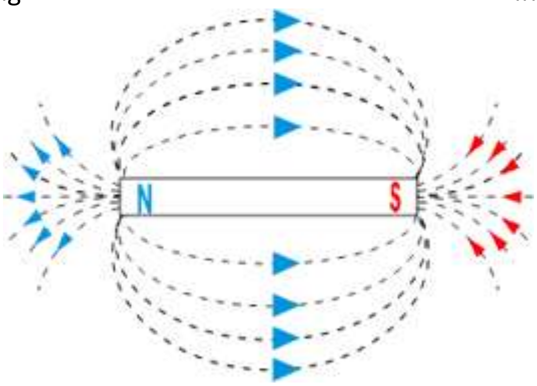
Lightning is a form of electricity. It is electrons moving from one cloud to another or jumping from a cloud to the ground. Have you ever felt a shock when you touched an object after walking across a carpet? A stream of electrons jumped to you from that object. This is called **static electricity**.

Have you ever made your hair stand straight up by rubbing a balloon on it? If so, you rubbed some electrons off the balloon. The electrons moved into your hair from the balloon. They tried to get far away from each other by moving to the ends of your hair. They pushed against each other and made your hair move — they repelled each other. Just as opposite charges attract each other, like charges repel each other.

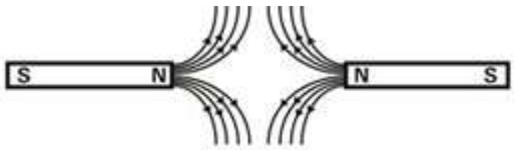
Magnets and Electricity

The spinning of the electrons around the nucleus of an atom creates a tiny magnetic field. Most objects are not magnetic because their electrons spin in different, random directions, and cancel out each other.

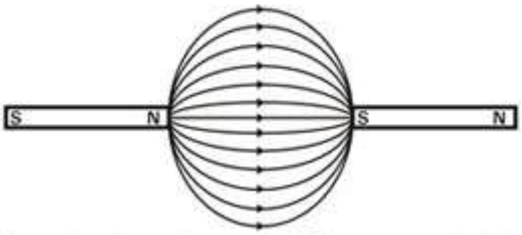
Magnets are different; the molecules in magnets are arranged so that their electrons spin in the same direction. This arrangement of atoms creates two poles in a magnet, a North-seeking pole and a South-seeking pole.



Magnetic Field Around a Bar Magnet



Like poles of magnets (N-N or S-S) repel each other.



Opposite poles of magnets (N-S) attract each other.

Source: National Energy Education Development Project (Public Domain)

Magnets Have Magnetic Fields

The magnetic force in a magnet flows from the North pole to the South pole. This creates a **magnetic field** around a magnet.

Have you ever held two magnets close to each other? They don't act like most objects. If you try to push the South poles together, they repel each other. Two North poles also repel each other.

Turn one magnet around, and the North (N) and the South (S) poles are attracted to each other. Just like protons and electrons — opposites attract.

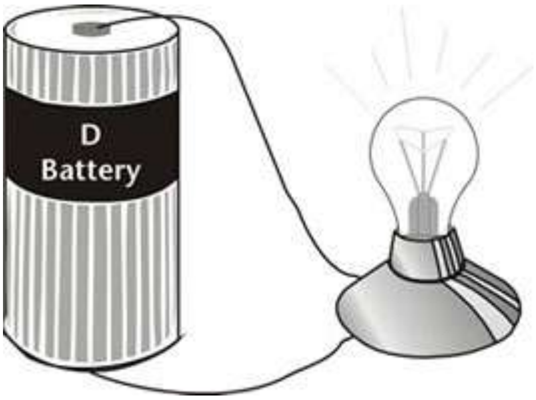
Magnetic Fields Can Be Used To Make Electricity

Properties of magnets can be used to make electricity. Moving magnetic fields can pull and push electrons. Metals such as copper have electrons that are loosely held. So electrons in copper wires can easily be pushed from their shells by moving magnets.

By using moving magnets and copper wire together, electric generators create electricity. Electric generators essentially convert kinetic energy (the energy of motion) into electrical energy.

Batteries, Circuits, & Transformers

Batteries Produce Electricity



Source: National Energy Education Development Project (Public Domain)

A battery produces electricity using two different metals in a chemical solution. A chemical reaction between the metals and the chemicals frees more electrons in one metal than in the other. One end of the battery is attached to one of the metals; the other end is attached to the other metal.

The end that frees more electrons develops a positive charge and the other end develops a negative charge. If a wire is attached from one end of the battery to the other, electrons flow through the wire to balance the electrical charge.

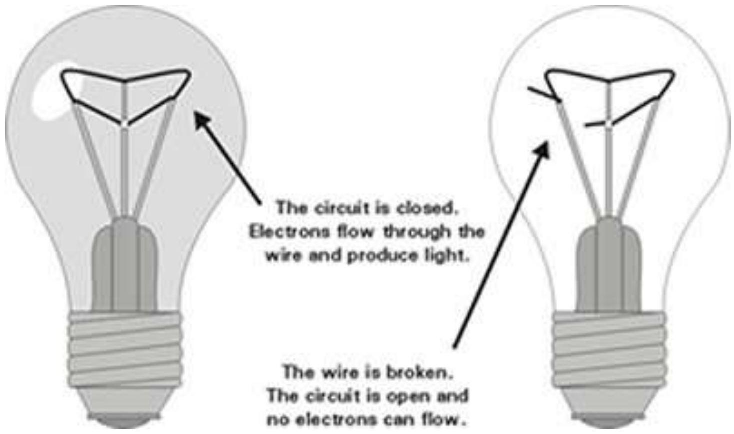
A load is a device that does work or performs a job. If a load — such as a light bulb — is placed along the wire, the electricity can do work as it flows through the wire. Electrons flow from the negative end of the battery through the wire to the light bulb. The electricity flows through the wire in the light bulb and back to the positive end of the battery.

Electricity Travels in Circuits

Electricity travels in closed loops, or circuits. It must have a complete path before the electrons can move. If a circuit is open, the electrons cannot flow. When we flip on a light switch, we close a circuit. The electricity flows from an electric wire, through the light bulb, and back out another wire.

When we flip the switch off, we open the circuit. No electricity flows to the light. When we turn a light switch on, electricity flows through a tiny wire in the bulb. The wire gets very hot. It makes the gas in the bulb glow. When the bulb burns out, the tiny wire has broken. The path through the bulb is gone.

When we turn on the TV, electricity flows through wires inside the TV set, producing pictures and sound. Sometimes electricity runs motors — in washers or mixers. Electricity does a lot of work for us many times each day.



Source: National Energy Education Development Project (Public Domain)

Transformers Help To Move Electricity Efficiently Over Long Distances

To solve the problem of sending electricity over long distances, William Stanley developed a device called a transformer. The transformer allowed electricity to be efficiently transmitted over long distances. This increased delivery range made it possible to supply electricity to homes and businesses located far from the electric generating plant.

The electricity produced by a generator travels along cables to a transformer, which changes electricity from low voltage to high voltage. Electricity can be moved long distances more efficiently using high voltage. Transmission lines are used to carry the electricity to a substation. Substations have transformers that change the high voltage electricity into lower voltage electricity. From the substation, distribution lines carry the electricity to homes, offices, and factories, which require low voltage electricity.

Measuring Electricity

Electricity Is Measured in Watts and Kilowatts

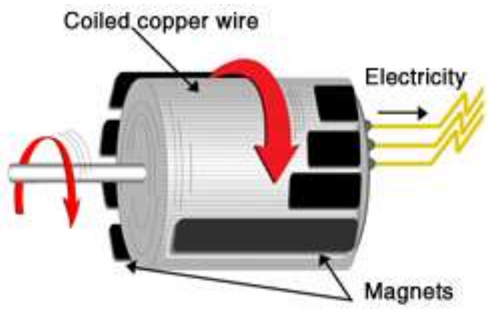
Electricity is measured in units of power called watts. It was named to honour James Watt, the inventor of the steam engine. One watt is a very small amount of power. It would require nearly 750 watts to equal one horsepower. A kilowatt is the same as 1,000 watts.

Electricity Use Over Time Is Measured in Kilowatthours

A kilowatthour (kWh) is equal to the energy of 1,000 watts working for one hour. The amount of electricity a power plant generates or a customer uses over a period of time is measured in kilowatthours (kWh). Kilowatthours are determined by multiplying the number of kilowatts required by the number of hours of use.

For example, if you use a 40-watt light bulb for 5 hours, you have used 200 watthours, or 0.2 kilowatthours, of electrical energy.

How Electricity is Generated



Turbine Generator

Source: adapted from Energy For Keeps (Public Domain)

A generator is a device that converts mechanical energy into electrical energy. The process is based on the relationship between magnetism and electricity. In 1831, scientist Michael Faraday discovered that when a magnet is moved inside a coil of wire, electrical current flows in the wire.

A typical generator at a power plant uses an electromagnet — a magnet produced by electricity — not a traditional magnet. The generator has a series of insulated coils of wire that form a stationary cylinder. This cylinder surrounds a rotary electromagnetic shaft. When the electromagnetic shaft rotates, it induces a small electric current in each section of the wire coil. Each section of the wire becomes a small, separate electric conductor. The small currents of individual sections are added together to form one large current. This current is the electric power that is transmitted from the power company to the consumer.

An electric utility power station uses either a turbine, engine, water wheel, or other similar machine to drive an electric generator — a device that converts mechanical or chemical energy to electricity. Steam turbines, internal-combustion engines, gas combustion turbines, water turbines, and wind turbines are the most common methods to generate electricity.

Steam turbine power plants powered by coal and nuclear energy produce about 70% of the electricity used in the United States. These plants are about 35% efficient. That means that for every 100 units of primary heat energy that go into a plant, only 35 units are converted to useable electrical energy.

QUT Extreme Engineering workshop activities

There are four activities in this workshop, to explore the basics of electrical circuits. The first three are run simultaneously, and the fourth is done as an extension or challenge activity. The activities are:

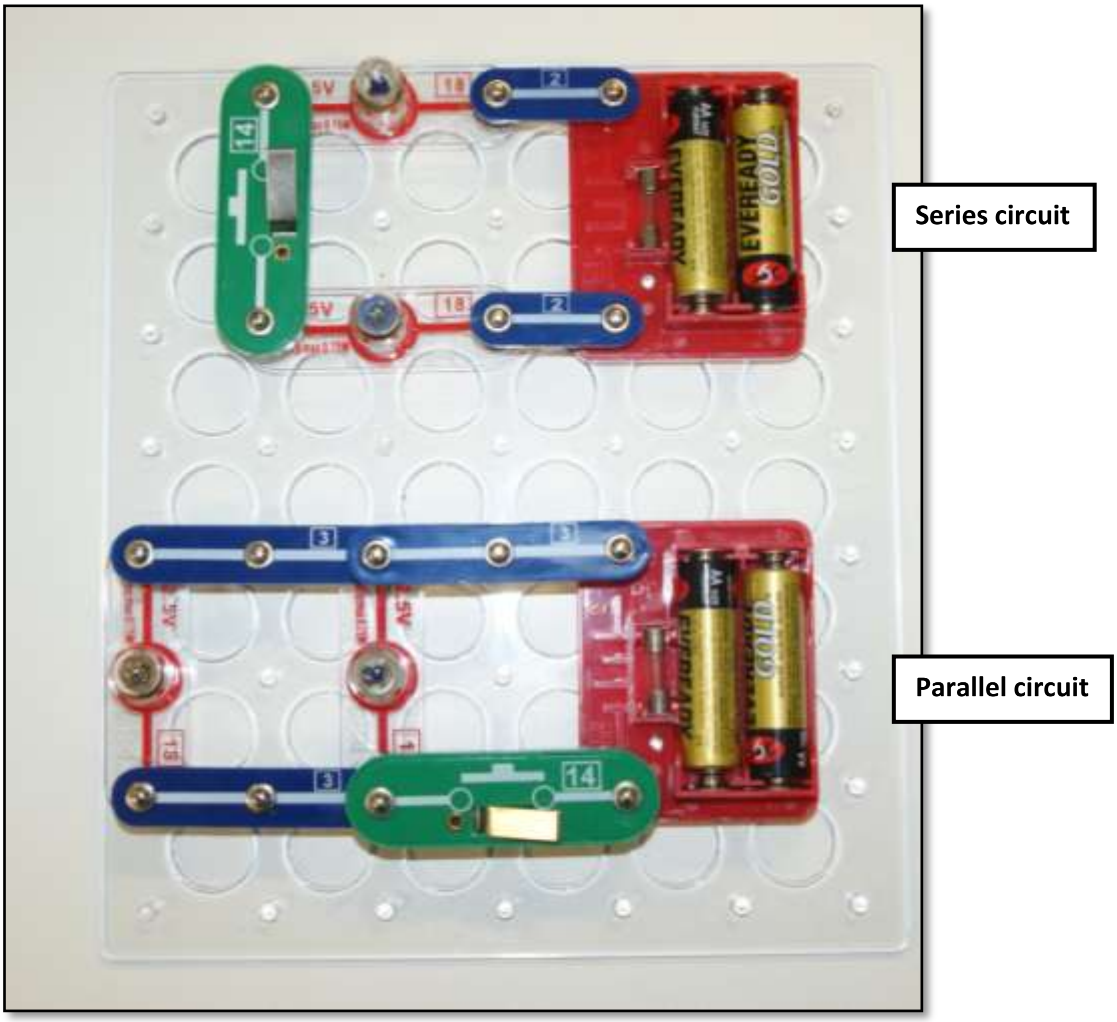
1. **Series and parallel circuits**
   - Students build a series circuit and parallel circuit and explore the differences between the two
2. **Batteries in series, and batteries in parallel**
   - Students observe circuits which have already been built, and use a multimeter to measure voltage at certain points in the circuit to understand how the arrangement of batteries affects the voltage
3. **Conductivity testing**
   - Students build a simple circuit to test some supplied materials to see if they are conductors or insulators, and they can test some materials of their own
4. **Build your own circuit**
   - Students are given a choice of circuits to build, which are more complex than the previous 3 and involve different electrical components

Students are provided with worksheets to fill out during the workshop. It is designed to reiterate what they have learnt, and to build a little further on that knowledge. The questions refer to the activities, requiring them to record their observations, and then to formulate possible explanations for these observations.

The activity instructions and worksheet are provided in the next section of this booklet.

Activity 1:

Series circuit vs Parallel circuit



For this activity, you will be setting up both circuits A and B on one large base. Use the picture above to assemble the circuits. If you need more detailed instructions, turn this page over!

1A Series circuit

Components needed

2 x 2.5v lamp holder [#18]	2 x AA 1.5v batteries
2 x bulb	1 x press switch [#14]
1 x battery unit [#19]	2 x two-snap connector [#2]

Instructions:

1. Connect the battery holder onto the base (positive terminal at the top)
2. Connect the bulb holders onto the base, to the left of the battery holder, as shown
3. Connect the bulb holders to the battery holder using the two-snap connectors
4. Connect the bulb holders together with the press switch as shown
5. Press the switch to see your circuit work!
6. Unscrew one of the bulbs and press the switch to see what happens

1B Parallel circuit

Components needed

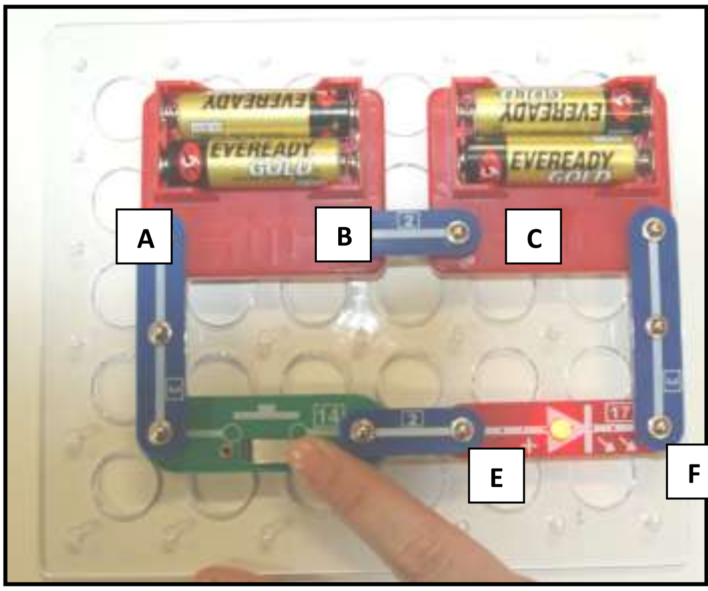
2 x 2.5v lamp holder [#18]	1 x press switch [#14]
2 x bulb	2 x one-snap connector [#1]
1 x battery unit [#19]	3 x three-snap connector [#3]
2 x AA 1.5v batteries	

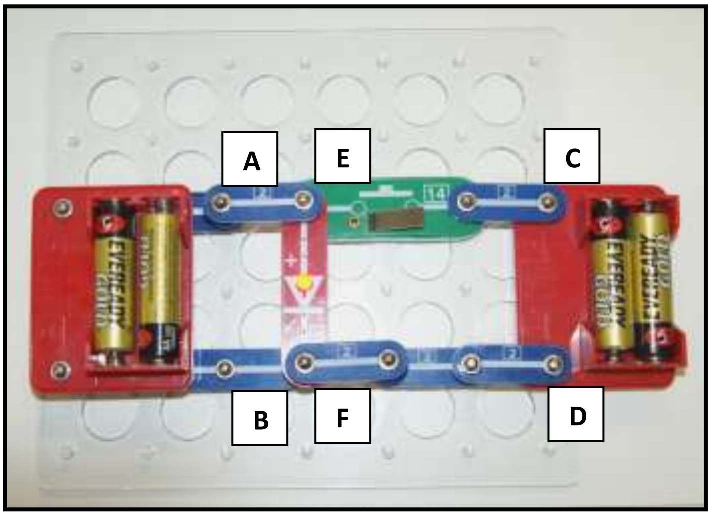
Instructions:

1. Connect the battery holder onto the base (positive terminal at the top)
2. Connect the bulb holders onto the base, to the left of the battery holder, as shown
3. Place the two one-snap connectors onto the battery terminal connectors
4. Connect the bulb holders and the batter holder using the three-snap connecters, as shown
5. Connect the right bulb holder and battery holder with the press switch
6. Press the switch to see your circuit work!
7. Unscrew one of the bulbs and press the switch to see what happens

Activity 2:

Batteries in series vs. Batteries in parallel





For this activity, you will be measuring the voltage of the circuits at different points, as marked on the pictures. To do this, use the multimeters provided – they have 2 probes, which you will need to place on the two points of measurement. Write the measurements on your worksheets.

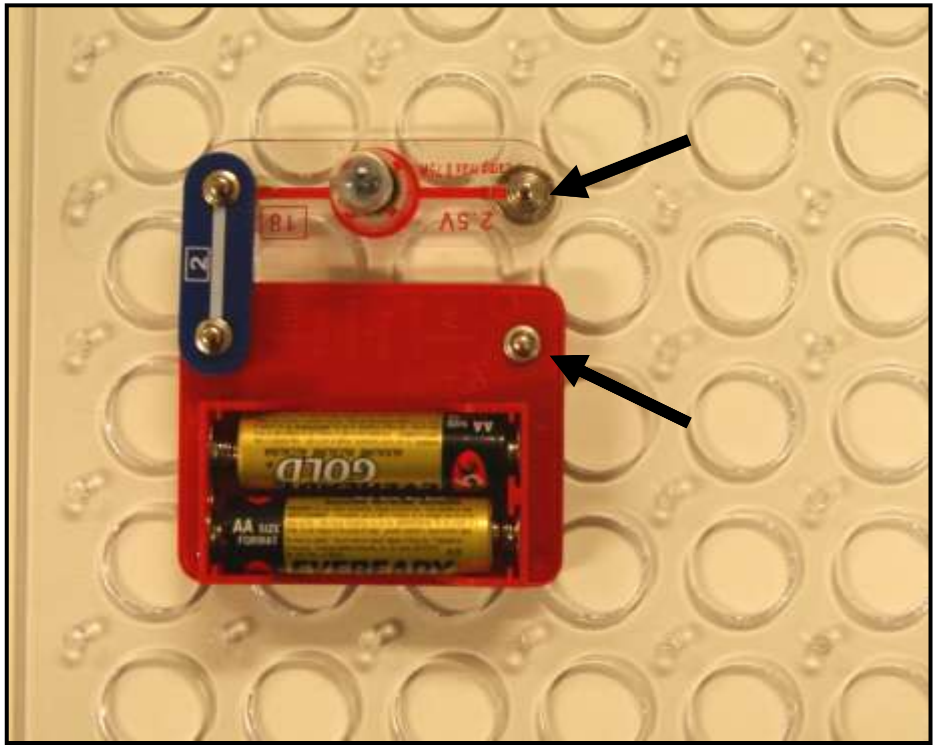
<u>Measure and record the voltage at these points on each circuit:</u>

A & B C & D A & D E & F

Activity 3: Conductivity testing

Components needed

1 x lamp holder [#18]	2 x AA 1.5v batteries
1 x bulb	1 x two-snap connector [#2]
1 x battery unit [#19]	Conductors and insulators



Instructions:

1. Place the battery holder onto the base, as shown
2. Place the bulb above the battery holder
3. Connect the bulb and battery holder using the two-snap connector
4. Connect the bulb and battery holders with the materials provided to determine if they are conductors or insulators

Remember: materials that allow electricity to pass through are conductors,

How do you know if the material you are testing is conducting electricity? The bulb will light up when you touch it to the circuit!

Materials that do not allow electricity to pass through are insulators

How do you know if the material you are testing is conducting electricity? The bulb will NOT light up when you touch it to the circuit!

5. Try some of your own items to see if they conduct or insulate.

Make your own electronic game sounds

Components required:

1 x 2-snap connector

3 x 3-snap connector

1 x 4-snap connector

1 x 5-snap connector

1 x slide switch (#14)

1 x press switch (#15)

1 x speaker (#20)

1 x sound circuit (#23)

1 x battery unit

2 x AA batteries

Group Instructions:

Nominate one person from your group to collect your components from the supply table.

Take this sheet to the supply table and your teacher or a presenter will help you to select the components you need for the basic circuit.

After you have built and tested the basic circuit, your nominated person can return to the supply table to get any components you need to modify your circuit, as per the instructions on the other side of this sheet.

56. Manually Activated Electronic Game Sounds

Assemble as illustrated. Use the slide switch[15] and the button switch[14] respectively or together to produce various sounds.

57. Magnetically Activated Electronic Game Sounds

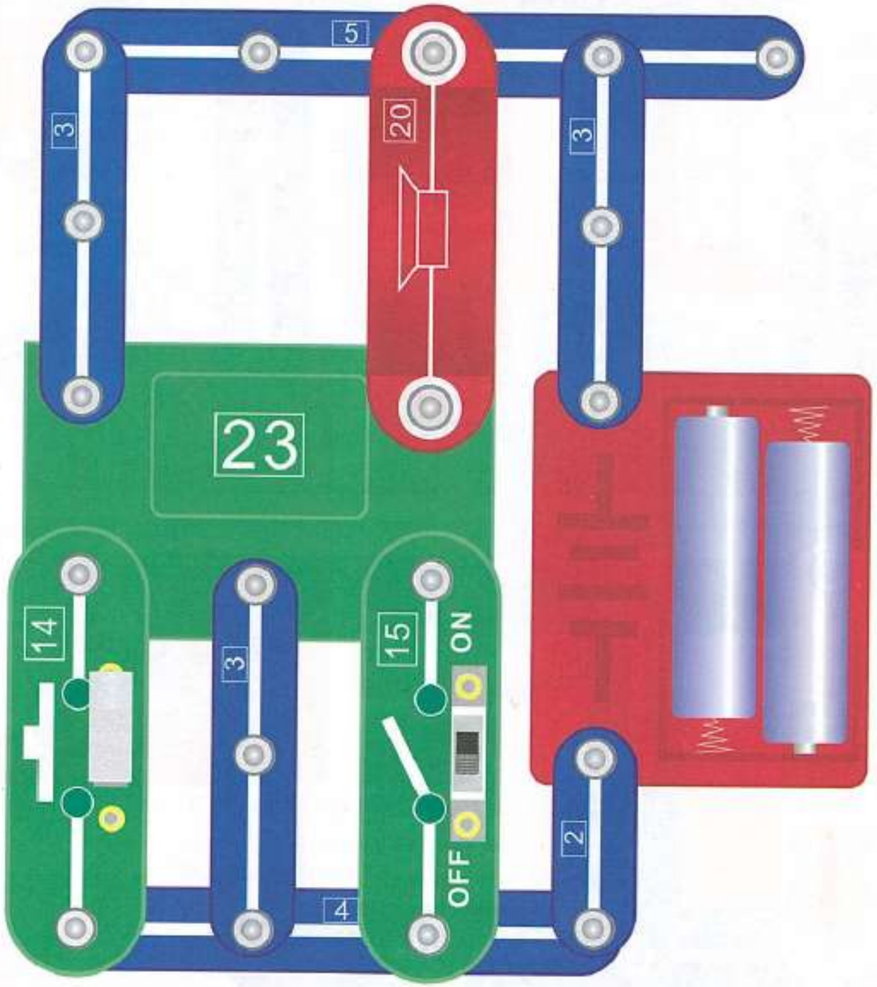
Replace the slide switch[15] with the reed relay[13]. Use the reed relay and the button switch respectively or together to produce various sounds.

58. Light Activated Electronic Game Sounds

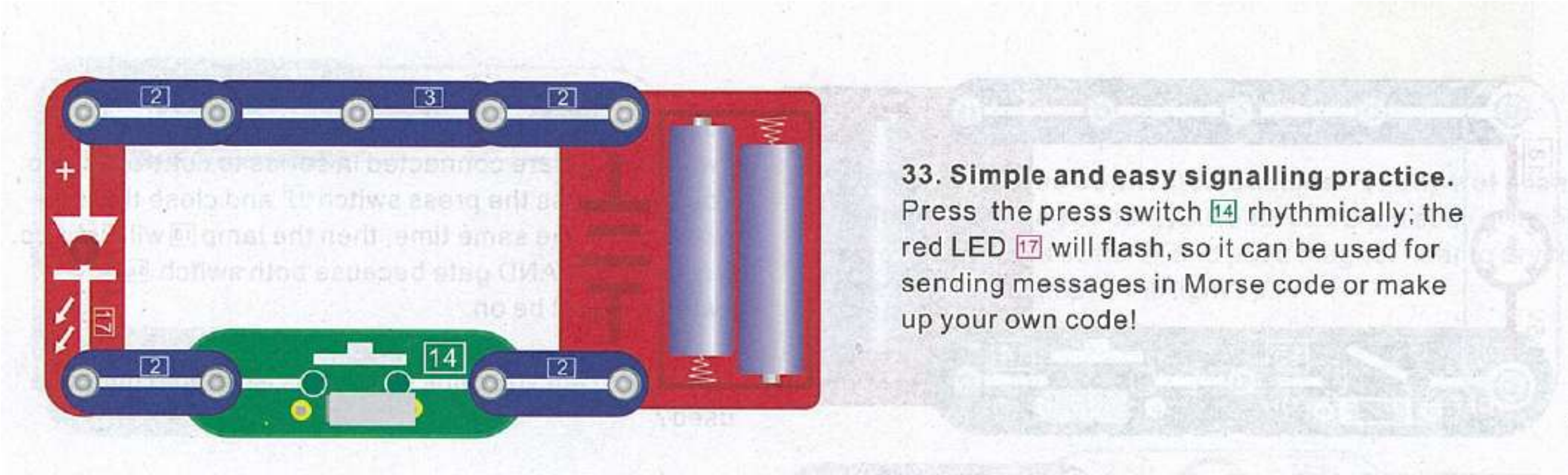
Replace the slide switch[15] with the photosensor[16]. Use the photosensor and the button switch respectively or together to produce various sounds.

59. Water Activated Electronic Game Sounds

Replace the button switch[14] with the touch plate[12]. Use the touch plate and the slide switch respectively or together to produce various sounds.



Make your own Morse Code signaller



Components Required:

4 x 2 snap connectors

1 x 3 Snap Connector

1 x battery unit

2 x AA batteries

1 x LED (#17)

1 x Press Switch (#14)

Group Instructions:

Nominate one person from your group to collect your components from the supply table. Take this sheet to the supply table and your teacher or a presenter will help you to select the components you need.

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	▬ ▬ ▬ ▬ ▬

Make your own sound effects circuit

Components required:

1 x 1-snap connector

4 x 2-snap connector

2 x 3-snap connector

1 x 4-snap connector

1 x 5-snap connector

1 x slide switch (#15)

1 x speaker (#20)

1 x alarm circuit (#22)

1 x battery unit

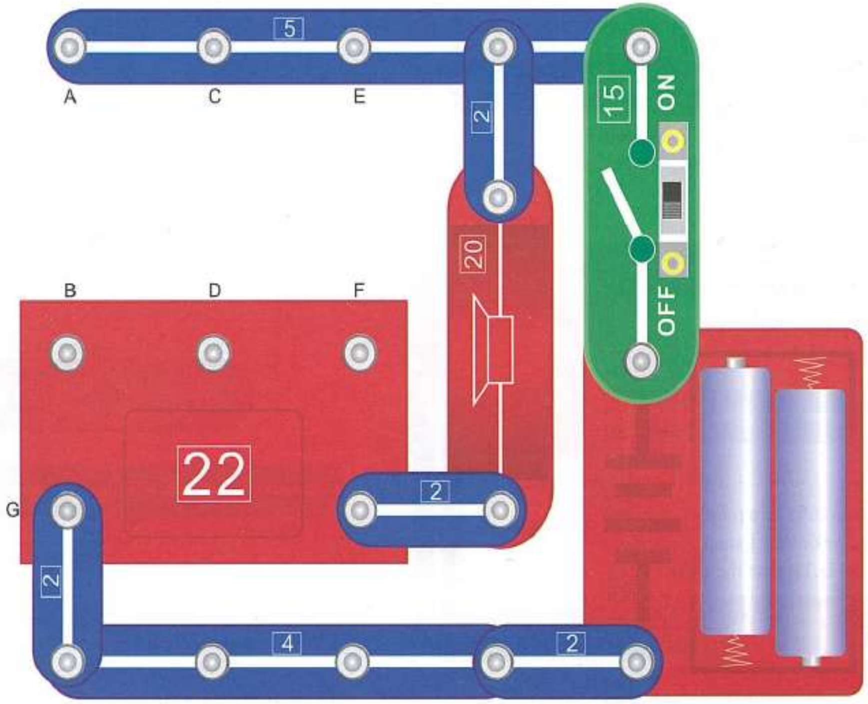
2 x AA batteries

Group Instructions:

Nominate one person from your group to collect your components from the supply table.

Take this sheet to the supply table and your teacher or a presenter will help you to select the components you need for the basic circuit.

After you have built and tested the basic circuit, your nominated person can return to the supply table to get any components you need to modify your circuit, as per the instructions on the other side of this sheet.



39. Police Siren

Assemble as illustrated. Connect points C and D with a 3-snap connector [3]. Turn on the slide switch [15]. The siren comes on.

40. Machine Gun

Use two 3-snap connectors [3] to join points CD and EF. Turn on the slide switch [15]. A machine gun sound is produced.

41. Fire Siren

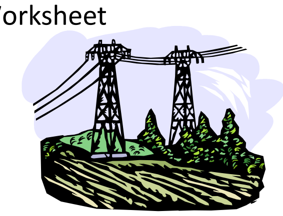
Use two 3-snap connectors [3] to join points AB and CD. Turn on the slide switch [15]. A fire siren sound is produced.

42. Ambulance Siren

Use a 3-snap connector [3] to join points C and D. Use a 2-snap connector [2] and a 1 snap connector [1] to join points B and G. Turn on the slide switch [15]. An ambulance siren sound is produced.

43. Electronic Game Sound

Use a 3-snap connector [3] to join points A and B. Turn on the slide switch [15]. An electronic game sound is produced.



Investigating Electrical Energy

1. Series vs. Parallel

Are the bulbs brighter in the series circuit or in the parallel circuit? Why do you think this is? ______

____

____

What happens in the series circuit when you unscrew one bulb? What about the parallel circuit?

____

____

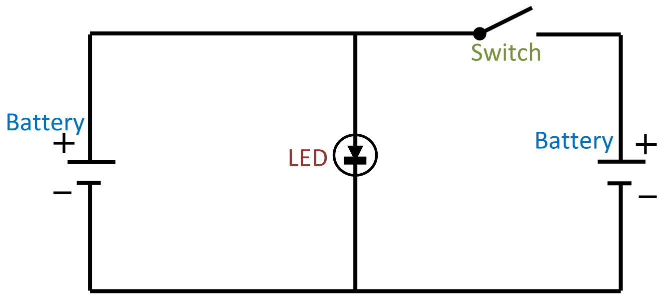
2. Voltage - batteries in series vs. batteries in parallel

Why did the LED light up in the parallel circuit when the switch was open? ____________________

____

____

Draw the path of the current in the diagram when the switch is left open (off).



		Series	Parallel
How many batteries are in the circuit?			
How many volts did you measure between these points?	**A** and **B** (one battery unit)		
	C and **D** (other battery unit)		
	A and **D** (both battery units)		
	E and **F** (LED)		

3. Conductivity testing

Material tested	Conductor or insulator?

4. Build your own circuit

What type of circuit did you build? ____

How do you think this circuit is used in everyday life? ____

Draw a diagram of your circuit in the box below and show the flow of current through your circuit.

Challenge questions

Name something that uses a *series circuit* in your home: ____________________________________

Name something that uses a *parallel circuit* in your home: __________________________________

What is an advantage of having batteries arranged in *series*? _________________________________

____

What is an advantage of having the batteries arranged in *parallel*? ____________________________

____

References

Background information taken from EIA (Energy Information Administration) Energy Kids website

http://www.eia.gov/kids/energy.cfm?page=electricity_science-basics

Further reading

www.electrickids.com.au/

http://www.ausgrid.com.au/education