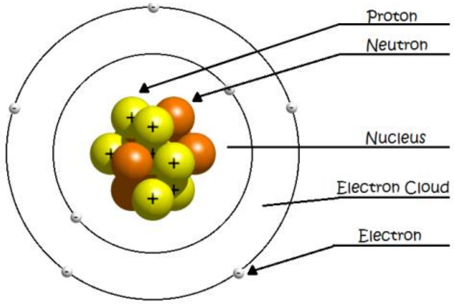
Characteristics of Electricity

Grade 9 Science
Ms. Hayduk

Review of the Atom



What is Electricity?

Electricity is caused by the **movement of electrons**.

They are the only subatomic particle that can move freely. Protons and neutrons are stuck in the nucleus of the atom.

Electric Charges

The word charge means either:

- An **excess of electrons**; or,
- A **shortage of electrons**.

Something that has too many electrons has a **negative charge**. If it doesn't have enough electrons, it has a **positive charge**.

Something that has no charge is **neutral**.

Electric Charges

It's important to remember that all objects have protons (+) and electrons (-) in them.

Charge	What It Means
Positive	**More protons than electrons (lost electrons)**
Negative	**More electrons than protons (gained electrons)**
Neutral	**Equal number of electrons and protons**

Law of Attraction and Repulsion

All charged objects follow specific rules:

1. **Opposite** charges (+ and -) **attract** each other.
2. **Like** charges (+ and + or – and -) **repel**.
3. **Charged** objects (+ or -) **attract neutral** objects.

Conductors and Insulators

Conductors are materials that **easily let electrons move through them**.

The electrons are not strongly attracted to the nucleus in each atom of the substance, so they can **move freely**.

Examples of good conductors are **copper, aluminum and other metals**.

Conductors and Insulators

Insulators are materials that are **poor conductors**.

In these substances, the electrons are **too strongly attracted** to the nucleus of each atom, so they do not move around much.

Examples of good insulators are **rubber, wood and plastic**.

What is Static Electricity?

Static electricity is the **build up of charge on the surface of an object**.

It is called **static** because it is **does not move**, unless it is given a path to escape.

Static Charges on Conductors and Insulators

Charges build up more easily on **insulators**, since the charge cannot move through the object.

In fact, charges can only build up on a conductor if it is on top of an insulator, so the charge cannot "escape" from the conductor, like on a **Van de Graaff generator**.

Formation of Static Charges

Static electricity is formed by **friction**.

When two objects are rubbed together, electrons are **transferred** from one to the other. This gives one object a **positive charge** and one object a **negative charge**.

Electron Affinity

Electron affinity of a substance tells **how strongly it will hold on to its electrons**.

When they are rubbed together, something with a **high** electron affinity will steal electrons from something with a **lower** electron affinity.

Electron Affinity

The **triboelectric series** is a list of substances in order of how strongly they will hold on to their electrons.

Substances listed as **positive** will give away electrons easily, and listed as **negative** will steal electrons easily. These types of items are all **insulators**.

Neutral substances do not hold static charges well. Often, these are **conductors**.

Example 1: Electron Affinity

Rub a piece of acrylic with silk. What is the charge on the acrylic?

Example 2: Electron Affinity

Rub your hair with a rubber balloon. What is the charge on your hair?

Example 3: Electron Affinity

Rub a piece of glass with rayon. What is the charge on the glass?

Transfer of Static Charges

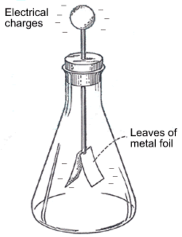
There are three main ways to transfer charges between two objects.

Friction is the first way, and is important because it is the only way to create a static charge between two neutral objects.

The other methods are **conduction** and **induction**.

Electroscopes

An electroscope is an instrument used to **detect static charges**. For a neutral electroscope, the leaves will move apart if a charged object is brought near the ball.



Electroscopes

To determine the charge on an object:

1. Charge the electroscope by contact (conduction) with the unknown object.
2. Bring an object with a known charge close to the electroscope – if the leaves move closer together, it is the **opposite charge**. If they separate, they are the **same charge**.

Charging by Friction

Rubbing two insulating objects together

One object will "pick up" elections from the other, making one positively charged and one negatively charged.

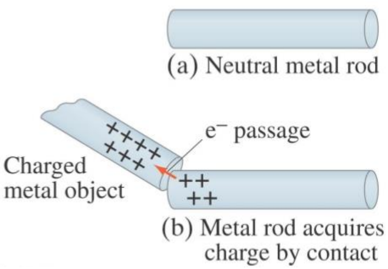
The object that attracts electrons is based on the triboelectric series.

Charging by Conduction

Transferring a charge by touching a charged and a neutral object together

Whichever object has the most negative charge will transfer its electrons to the other, giving both objects the same charge.

Charging by Conduction



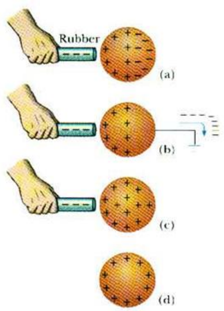
Charging by Induction

Bringing one charged and one neutral object close together without touching

The charged object attracts or repels the electrons in the other, causing a temporary charge in the neutral object.

If the newly charged object is **grounded** while a charge is induced, it will have the opposite charge of the other object.

Charging by Induction



Grounding

Grounding means **giving electrons a path to or from a charged object**.

Grounding happens when a charged object is touched by a conductor that is also connected to the ground. The object will become neutral.

For a **negatively** charged object, the extra electrons move into the ground. For a **positively** charged object, electrons are drawn up into the object.

Electrical Safety

- Handle batteries carefully. They contain corrosive chemicals that can cause burns.
- Do not connect the two battery terminals together – you will create a short circuit.
- Do not use bare connecting wires.
- **Triple check** a circuit before closing the switch.
- Disconnect or turn off the power source before you connect wires in a circuit.
- Do not leave circuits on and unattended.

What is Current Electricity?

Current electricity is caused by **the movement of electrons through a conducto**r.

Unlike static electricity, which can only discharge once after it has build up on a surface, current electricity will continue to flow as long as certain conditions are met.

Conditions for Current

Conditions required for the flow of current electricity:

- There must be an **energy source** providing a supply of electrons (e.g. a battery).
- There must be a complete path (a **circuit**) for the electrons to flow through.

Circuits

An electrical circuit must contain:

1. **An energy source**
2. **A conductor (to move electrons)**
3. **A load (something that is using the electrical energy)**

A circuit without a load is called a **short circuit**, and is very dangerous because it can get very hot.

Parts of a Circuit

<u>Batteries</u>

Batteries are **energy sources** in a circuit, and provide the electrons to move through and create electrical energy.

Batteries have a positive and negative terminal. Both terminals must be connected into the circuit for electricity to flow.

Electrons **repel away** from the negative terminal **towards** the positive terminal.

Parts of a Circuit

Switches

A switch is a section of a circuit that can **easily open and close to complete the circuit**. When it is open, the electrons stop flowing through the circuit because there is no path for them to go.

The electrons "wait" in the circuit until the switch is closed (like water in a tap), when they can start to move again.

A circuit does not need a switch!

Parts of a Circuit

An **open circuit** is a circuit where the switch is not pushed down to be part of the circuit.

A **closed circuit** is a circuit where the switch is down and the circuit is complete.

Parts of a Circuit

Resistors

Resistors are used to **convert electrical energy to other forms of energy**. Resistor is the general term for any kind of load that is using electrical energy, like a lamp, a toaster or a TV.

They are called resistors because they are designed to **limit the flow of electricity**.

Circuit Symbols

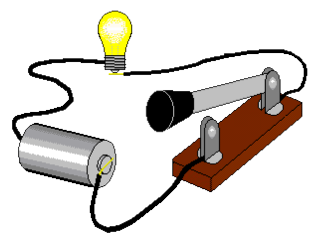
Element	Symbol
Wire	——
Wire (overlapping)	—┼—
Battery	—||—
Lamp	—⊗—

Circuit Symbols

Element	Symbol
Switch (open)	—•/ •—
Switch (closed)	—•—•—
Resistor	—/\/\/\/—
Voltmeter	—(V)—
Ammeter	—(A)—

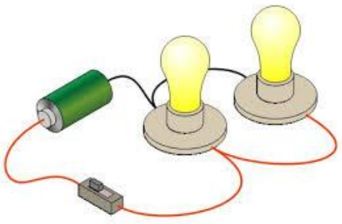
Example 1: Circuit Symbols

Draw a circuit diagram for the following circuit:



Example 2: Circuit Symbols

Draw a circuit diagram for the following circuit:



Charge

Charge refers to the **amount of negativity** produced by the electrons in an area.

It is measured in **coulombs** (C) and has the variable **Q**.

One coulomb is equal to the amount of charge on 6.25×10^{18} electrons.

What is Current?

Current is **the movement of charge** through a circuit. More specifically, it is the amount of charge that passes a specific point in a circuit every second.

Analogy: if you were to describe the current of water in a river, it would be the number of litres of water that pass a point every second.

Current

Current is measured in **amperes**, or amps (A). It has the variable **I**.

Current can be measured using an **ammeter**. It needs to be connected **in series**, so that it is part of the circuit and the current flows through it.

Galvanometers also measure current, but are only used for very small amounts of current.

Potential and Kinetic Energy

Potential energy is energy that not currently "doing" anything but could, at some point, do something.

Kinetic energy is energy that is in **motion**.

Energy can be converted between potential and kinetic energy, but it cannot be "used up", created or destroyed. This is called the **Law of Conservation of Energy**.

Energy is measured in Joules (J).

Electrical Potential Energy

In a circuit, electrical potential energy is the electrical energy stored in a battery. It cannot be converted to kinetic energy (electrical energy) until the battery is connected into a circuit.

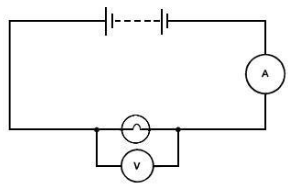
Voltage

Voltage is the **difference** in electrical potential energy between two points in a circuit. It measures **how much energy is used between one point and another**.

The units for potential energy are Joules/Coulomb (J/C), or volts (V).

A **voltmeter** is used to measure voltage. It is connected to two points in a circuit – not as part of a circuit, like an ammeter.

Voltmeter and Ammeter



Resistance

Resistance describes **how difficult it is for charge to move through an object or substance**.

Very good conductors have **low** resistance (e.g. wires) and insulators have **high** resistance.

For loads in a circuit, a higher resistance is better because resistance is what causes the load work. However, too high of a resistance can stop the circuit from working!

It is measured in **Ohms**, which have the symbol **Ω** (capital omega).

Units and Variables

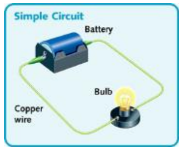
Measurement	Variable	Unit
Current	I	Amperes (A)
Voltage	V	Volts (V)
Resistance	R	Ohms (Ω)

Parallel and Series Circuits

A circuit with one power source and one load is called a **simple circuit**.

When more than one load is connected into a circuit, there are two ways to connect it:

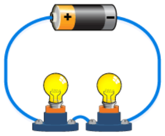
- In **series**
- In **parallel**



Series Circuits

Loads are connected one after another. The electricity must go through the first one to get to the second one.

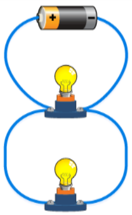
When one load is disconnected, the entire circuit will **stop working** because the electrons do not have a path back to the battery.



Parallel Circuits

Loads are connected separately to the battery. The electricity has a different path to each load.

When one load is disconnected, the other loads will **continue to receive electricity**.



Current and Voltage in Circuits

	Series	Parallel
Voltage	Voltage for each load when added will equal the voltage of the energy source	Same for all loads and energy sources
Current	Same at all points	Current for each path when added together will equal the current leaving the energy source

Ohm's Law

The resistance of a load in a circuit can be measured using a multimeter.

It can also be calculated if current and voltage are known using Ohm's Law:

Voltage = Current × Resistance

V = IR

Example 1: Ohm's Law

A light bulb is plugged into a wall outlet (220 V) and it uses 0.68 A. What is the light bulb's resistance?

Example 2: Ohm's Law

A stereo speaker has a resistance of 8.00 Ω. When it is operating at full power, it uses 35 V of electricity. What is the current drawn by the speaker?

Example 3: Ohm's Law

You have three 1.5 V batteries available to use. Your flashlight bulb needs 0.40 A and has a resistance of 8.75 Ω. How many batteries do you need to use to light the bulb?

Energy

Energy comes in many forms. Depending on its form, it can be used to move or make objects work.

There are many forms of energy, including:

Kinetic (movement)	Potential (stored)
Mechanical	Chemical
Electric	Magnetic
Radiant (light)	Thermal (heat)
Sound	

Energy Conversion

Electrical devices work by **converting electrical energy** into the energy needed by the device.

Energy is not always converted completely into the desired type of energy. Energy may be wasted by being converted into an unusable form.

Electrical energy is the **input** energy. Other forms are the **output** energy.

Example: Energy Conversion

What are the forms of input and output energy for a hair dryer?

Electrical Efficiency

The efficiency of an electrical device tells **how well the input energy is converted into useful output energy**.

For example, an incandescent bulb uses about 5% of the electrical energy it receives to make light, and the other 95% is converted to heat, so it has **5% efficiency**.

Power

Power is the **amount of energy used in a specific amount of time.**

Power is measured in **watts** (W) or **kilowatts** (kW). One watt is equal to one Joule per second:

1 W = 1 J/s

Household Electrical Energy

We generally measure electrical energy consumption in kilowatt-hours (kW·h), which is the amount of energy it uses in one hour.

If an appliance uses 20 kW of power when it's on for 15 minutes:

$$20 \text{ kW} \times 0.25 \text{ h} = 5 \text{ kW} \cdot \text{h}$$

Electrical Efficiency Rating

Most home appliances now come with an energy efficiency rating, which tells how well the appliance converts electrical energy when compared to other appliances with the same purpose.

Electrical Efficiency

Efficiency is usually calculated as a percentage:

$$\textbf{Percent Efficiency} = \frac{E_{out}}{E_{in}} \times \mathbf{100}$$

In this equation, the energy can be measured in Joules (J), watts (W) or kilowatt-hours (kW·h).

Example 1: Electrical Efficiency

A car produces 28 kJ of output energy from 125 kJ of fuel. What is the car’s efficiency?

Example 2: Electrical Efficiency

A microwave has an efficiency of 64%. It produces 700 W of power. How much energy is being input into the microwave?