Electricity

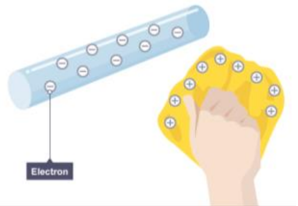
Static Electricity

Electrical conductor: electrical charges can move through it.
Electric insulator: electrical charges can not move through it.
Many insulators can be charged by friction.

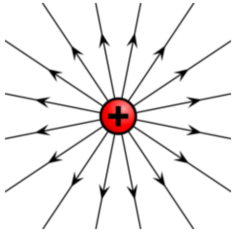
- Charges which are the same **repel.**
- Charges which are different **attract.**

All electrostatic effects are caused by the movement of negatively charged **electrons.**

When a polythene rod is rubbed with a duster it becomes **charged** and can attract tiny pieces of paper**. Electrons move from the duster to the polythene** making the polythene negatively charged.



If an acetate rod is rubbed with a dus**ter, electrons move from the acetate to the duster** making the acetate rod positively charged.



Electric Fields

An **electric field** is a region where a force acts on a charged particle. A charge that is close to the centre will feel a stronger force of attraction or repulsion than one that is further away. The strength of an electric field gets weaker as the distance from the charge increases

The atoms and molecules of gases in the air contain positive and negative charges. Air does not conduct electricity, however, when there is a strong electric field the atoms and molecules in the air break apart to form **charged ions**. When the electric field becomes strong enough the charged ions move, causing a **spark.** This is how **lightning strikes.**

Electric current

Current (I) is the flow of charge (flow of electrons) through a wire. It will only flow if there is a complete circuit and a potential difference (V). *Figure 1(a)* shows a metal wire with no charge flowing. *Figure 1(b)* shows a metal wire when a charge is applied. **Potential difference (V)** is the driving force that pushes the charge around. **Resistance (R)** is anything that slows the current down.

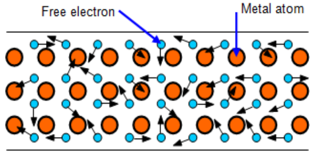


Figure 1(a)

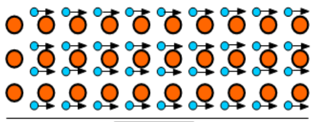
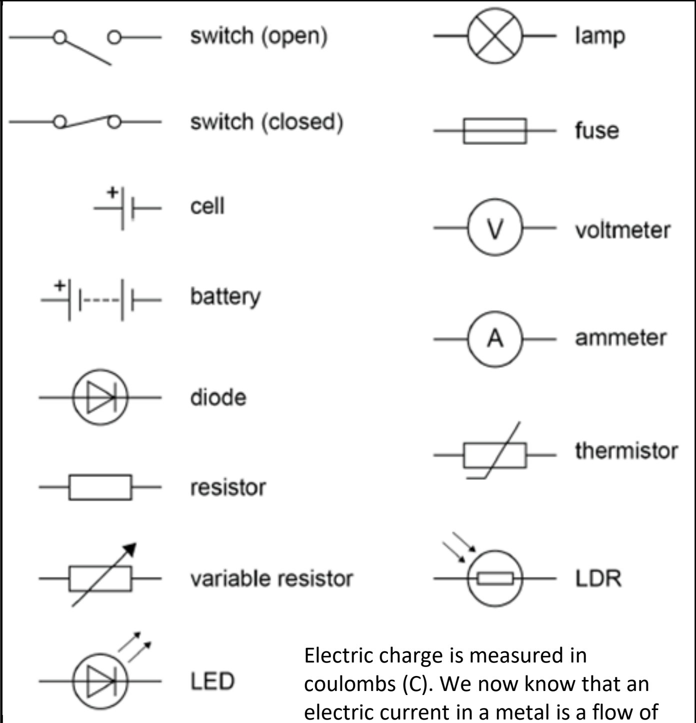
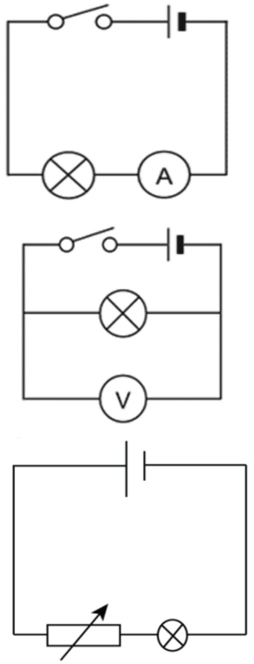


Figure 1(b)





Electric charge is measured in coulombs (C). We now know that an electric current in a metal is a flow of electrons from negative to positive Electric charge can be calculated using the following equation:

$$Q = It$$

Charge flow (coulombs, C); Current (A); Time (s)

Current is measured in **amps (A)** using an ammeter which must be connected in series with the component.
Potential difference is measured in **volts (V)** using a voltmeter that must be placed in parallel to the component.

Where there is a current, electrons collide with the atoms of the conductor causing **resistance**.
When electrons are 'pushed' around a circuit by a battery, they bump into to metal ions in the resistor
Resistance is measured in **ohms (Ω)**.

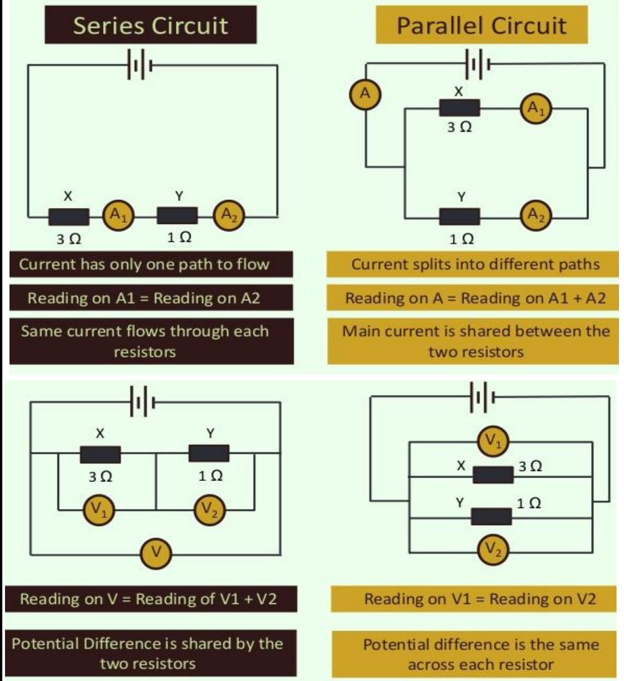
Current (*I*), resistance (*R*) and potential difference (*V*) are linked by the equation:

$$V = IR$$

All the electrical appliances in a home are connected in a parallel circuit. If they were connected in series you would need to switch on every single appliance in order to watch TV.

Series circuits:
The potential difference is shared between the components. The same current flows through each component.

Parallel circuits:
The potential difference is of the power supply is the same as across each component. The current is shared between components.



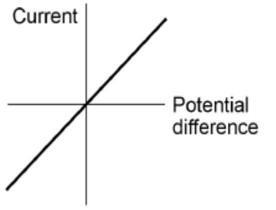
Circuits can be used to test and measure components by connecting a component between two **terminals. Voltmeters have a very high resistance**, which means only a small current flows through a voltmeter. **Ammeters have a very low resistance.** You can change the current by altering the resistance of a variable resistor.

For resistors in a series, the total potential difference is the sum of the potential differences across the resistors and the current is the same through all the resistors. **The total resistance is the sum of all the resistors.**

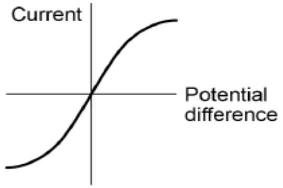
For resistors in parallel, the potential difference across each resistor is identical, but the total current is the sum of the currents that pass through each of the resistors.

Resistance

ohmic conductor: (at a constant temperature)
The current through an ohmic conductor (wire or resistor) at a constant temperature is directly proportional to the potential difference across the resistor. This means that the **resistance remains constant** as the current changes.

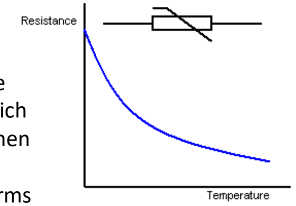


Filament lamp: The resistance of a filament lamp increases as the temperature of the filament increases. When an electric charge flows through a filament lamp it transfers some energy to the internal energy store of the filament and it heats up.

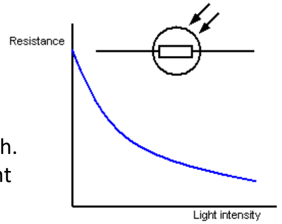


Sensors are components which detect changes.

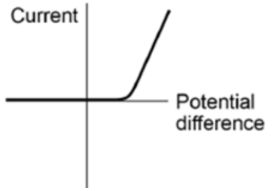
Thermistor: a temperature-dependent resistor. As the temperature increases, the resistance decreases. Made from a semi-conductor, which can conduct more easily when heated. Can be used in household heaters, fire alarms and fish tanks.



Light dependent resistor (LDR): When there are low light levels, resistance is high. Resistance decreases as light level increases.

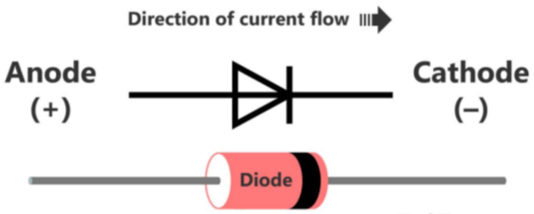


Diode: The current through a diode flows in one direction only. The diode has a very high resistance in the reverse direction.

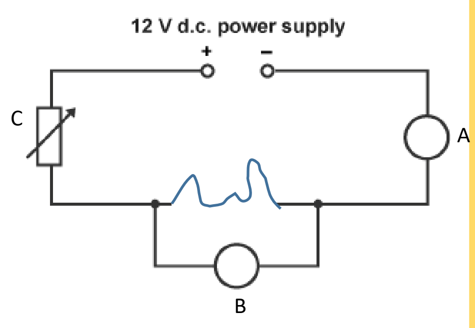


Length of a wire

Resistance increases as the length of a wire increases- the increase in resistance is directly proportional to the length of the wire.



Worked example:
The diagram below shows a circuit used to investigate the resistance of a thin piece of wire.



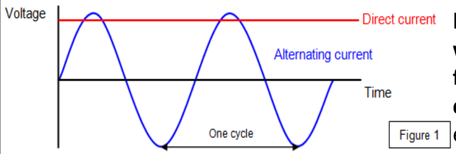
1) Name the three components in the circuit labelled A, B and C.
A is an ammeter, B is a voltmeter and C is a variable resistor.

2) Give the purpose of component C.
It is used to change the potential difference across the thin wire.

3) The student recorded the potential difference across the thin wire and the current passing through it. She plotted her results on a graph. Explain what variable she should plot on each axis.
Potential difference should be plotted on the x-axis because it is the independent variable, and current is plotted on the y-axis because it is the dependent variable.

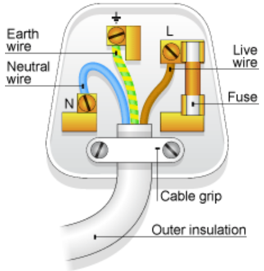
4) The student increased the potential difference to 12 V. Explain what you think would have happened.
The wire gets hot because of the large current passing through it. Large currents transfer lots of energy.

5) Explain how you would expect the graph to look if the wire had been replaced by a filament lamp.
The line would initially be straight but then curve with a shallower gradient as the temperature of the filament increases.



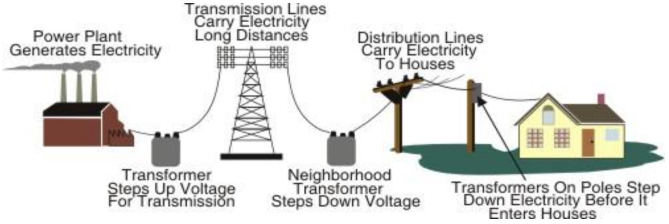
AC/DC: A cell or battery has **direct current (d.c), where the current always flows in the same direction**. In mains electricity, the current alternates, or changes direction (a.c)

Three-pin plug: the live wire carries a high potential difference into and around the house. There is no current in the **neutral wire** until an electrical appliance is connected. The **fuse** in the plug is always connected to the live wire. The fuse will melt and switch off the circuit if the current is too high. The **earth wire** is a safety wire which connects to the metal case of an appliance in case it becomes charged, providing a low-resistance path to the ground.



Transformers: devices that can change the potential difference. Step-up transformers increase the potential difference. Step-down transformers decrease the potential difference

The National Grid: Collection of powers cables and transformers that connect power stations to factories and houses across Great Britain.



Energy and power
Power: the amount of energy transferred each second. The units are joules per second, or **watts (W).**
The amount of energy transferred by an appliance depends on its power and the length of time used.

Electrical energy, E = power, P x time, t
(joules, J) (watts, W) (seconds, S)

$E = Pt$

Worked example:
A 1500 W hairdryer is used for 5 minutes. Calculate the total energy transferred by the hairdryer.

E = Pt
= 1500 W x (5 x 60) s
= 450 000 J (or 450kJ)

When charge flows through a circuit, electrical work is done. We can calculate the amount of energy transferred by electrical work using the equation:

Energy transferred, E = charge flow, Q x potential difference, V
(joules) (coulombs, C) (volts, V)

$E = QV$

Worked example:
A charge of 50 C flows through a device with a potential difference across the device of 12 V.

E = QV
= 50 C x 12 V
= 600J

The power transfer in any component is related to the potential difference across it and the current passing through it. We can calculate power using the equation:

Power, P = potential difference, V x current, I
(watts, W) (volts, V) (amps, A)

$P = VI$

Worked example:
Jo boils a kettle of water to make a cup of tea. The kettle has a power rating of 2.4 kW. The mains supply is 230 V. Calculate the current in the kettle element.

P = IV (rearrange the equation to make I the subject)
I = P / V
= 2400 W / 230 V
= 10.4 A

When a current passes through a resistor, such as a kettle element, it has a heating effect. Work is done by the electrons which is transferred to thermal energy in the element.
As $V = IR$, so $P = (IR) \times I = I^2R$

Power, P = (current)², I^2 x resistance, R
(watts, W) (amps, A) (ohms, Ω)

$P = I^2 R$

Worked example:
Jo boils the same kettle with a power rating of 2.4 kW. The mains supply is 230 V. Calculate the resistance of the element.

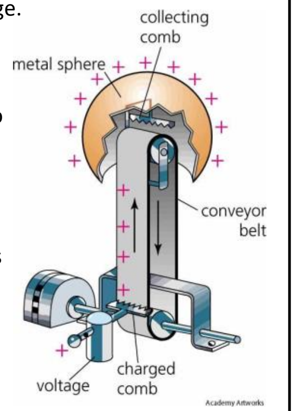
$R = P / I^2$
$= 2400 / (10.4)^2$
$= 22.2\ \Omega$

What's the difference between potential difference and current?

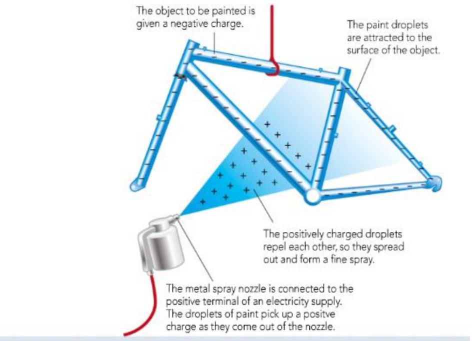
Current is a flow of charge. The size of the electrical current is the rate of flow of electrical charge. Potential difference is the work done in moving that charge. It is an indication of how much energy is transferred to a unit charge when charge moves between two points.

Uses of electrostatic charge
Van de Graffe generators produce a large electrostatic charge.

Small Van de Graaff generators can produce up to 100 000 V. The potential difference is very high, producing impressive effects but the discharge current is tiny, meaning it's safe to use .



Static electricity can be used in insecticide sprayers to make the spray spread out and also used in electrostatic paint spraying.



Electrostatic paint spraying

A more powerful appliance can transfer energy more quickly. **The total amount of energy is always conserved.** When energy is transferred from one store to another (e.g. Electrical → thermal), some energy may be dissipated to the energy store of the surroundings.