

AQA Physics A-level

Topic 5: Electricity

Key Points

Current

Current is defined as the **rate of flow of charge** in a circuit. It is measure in Amperes. You should be aware of two different ways of describing current flow:

1. **Electron flow** is from negative to positive and is the direction that electrons actually flow in a circuit
2. **Conventional current flow** is from positive to negative and is more commonly used to describe direction

As an equation, current is defined as:

$$I = \frac{\Delta Q}{\Delta t}$$

1 Ampere is the current flow when 1 Coulomb of charge passes a point each second.

Potential Difference

Potential difference is equal to the **work done** per **coulomb** of charge travelling in a circuit. As an equation this is defined as:

$$V = \frac{W}{Q}$$

It is measured in **Volts**, where 1 Volt is equal to 1 Joule of work being done by each Coulomb of charge.

To measure the potential difference over a specific component, a voltmeter can be used. It should be connected in **parallel** over the component.

An **ideal voltmeter** has **infinite resistance**, so that no current is drawn from the circuit.

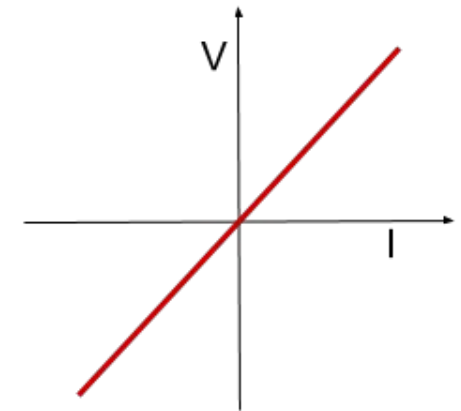
Resistance

Resistance is a measure of how difficult it is for current to flow in a circuit. It is **directly** proportional to the **potential difference** in a circuit, and **inversely** proportional to the **current** flow. As an equation it is defined as:

$$R = \frac{V}{I}$$

It is measured in **Ohms**.

An **ohmic conductor** is a conductor through which the current flow is directly proportional to potential difference, when held at a **constant temperature**.



Resistivity

The resistance of a material depends on several different factors. They are:

1. **Cross sectional area** - the greater the area, the easier the passage of electrons
2. **Length** - the longer the length, the harder it is to send a current through it
3. **Resistivity** - a property of the material that is assumed under standard conditions

Combining these factors allows an equation for resistivity to be formed:

$$\rho = \frac{RA}{L}$$

The unit for resistivity is **Ωm** .

Superconductors and Semiconductors

Superconductors are materials which have **zero resistivity** at and below a **critical temperature**. This temperature differs for each material, but currently are too low to be usefully used. If materials with high enough critical temperatures can be developed, they could be used in electricity transmission to **reduce energy loss** as well as in the production of **strong magnetic fields**.

Semiconductors are components for which the resistance changes depending on **external conditions**. The two main types you need to know about are:

1. **Light Dependant Resistors** are light sensitive components - when light intensity increases, their resistance decreases
2. **Thermistors** are temperature sensitive components - when the temperature increases, their resistance decreases

Power

Power is defined as the **rate of energy transfer**. It can be calculated using:

$$P = \frac{W}{t}$$

It can also be defined by combining the above equation with the equations defining potential difference, resistance and current to give:

$$P = I V = I^2 R = \frac{V^2}{R}$$

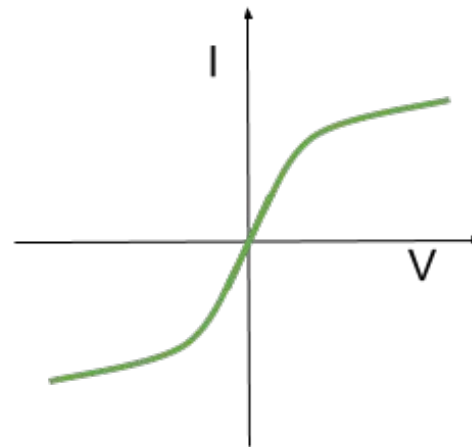
The unit of power is the **Watt**, where 1 Watt is the power dissipated when 1 joule of energy is transferred each second.

I-V Characteristics

You should be familiar with the two I-V characteristics below, as well as with the straight-line ohmic conductor graph.

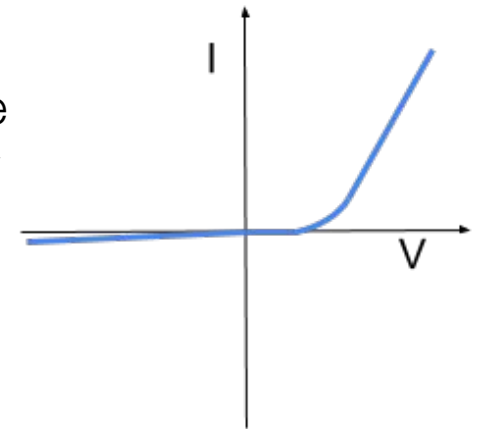
Filament Lamp

When a filament bulb is used, as current is increased, the **temperature** of the filament increases. This causes the **metal ions** to vibrate with more kinetic energy and consequently makes it harder for the **charge carriers** to pass through. This means the resistance **increases**.



Diode

Diodes are components that only let current flow through in **one direction**. In the opposite direction the resistance is very high and means current can't flow through. In the correct direction, diodes have a **threshold voltage** of around **0.6V**, after which current can flow through normally.



Series and Parallel Circuits

Series circuits are ones where all the components are part of the **same loop**.

You need to know that:

- The **current** is the same in all positions in a series circuit
- The **potential difference** over the loop is split between all the components, in the ratio of their resistances

Parallel circuits are ones where the components are in **adjacent loops**. You need to know that:

- The **potential difference** over each loop is the same
- The **current** is split between each branch and so is different in different parts of the circuit

Kirchoff's Laws

Energy and **charge** are **conserved** in circuits which means that e.m.f and current are too (as they're related to energy and charge).

Kirchoff's 1st Law:

The total current entering a junction is equal to the total current leaving it.

$$I_t = I_1 + I_2 + I_3 \dots$$

$$\frac{V}{R_t} = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3}$$

$$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

From this we can derive total resistance in a parallel circuit.

Kirchoff's 2nd Law:

The sum of e.m.f in any loop of the circuit is equal to the sum of the p.d's of each component.

$$\varepsilon = \sum IR$$

$$IR_t = IR_1 + IR_2 + IR_3 \dots$$

$$R_t = R_1 + R_2 + R_3 \dots$$

From this we can derive total resistance in a series circuit.

E.M.F and Internal Resistance

All power sources have a value for their EMF. **Electromotive force** can be defined as the amount of **energy** supplied by the **source** per unit charge. It is measured in Volts.

However, in reality, the **terminal potential difference** of the power source is **never equal** to this **EMF** value. This is because energy is **dissipated** within the source due to the cell's internal resistance.

Internal resistance can be described as the opposition to the flow of charge within a cell.

$$\varepsilon = IR + Ir$$

$$\varepsilon = V + rI$$

$$V = -rI + \varepsilon$$

$$y = mx + c$$

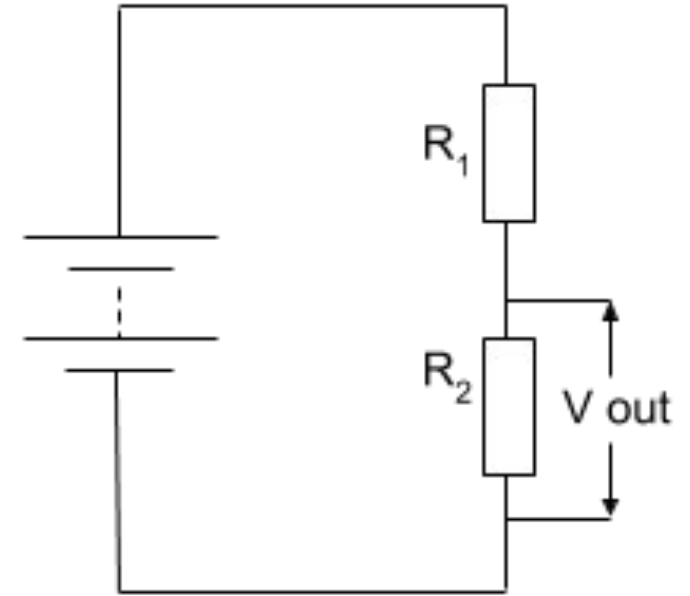
You can plot a graph of the terminal voltage against current. The y intercept will be the e.m.f and the gradient will be the negative internal resistance.

Potential Divider

A **potential divider** is a combination of two resistors in series, which results in the potential difference in the circuit being **split** into a specific **ratio**. By choosing the correct values of resistance for the resistors, a desired **V-Out** can be obtained.

A component's pd as a fraction of the total e.m.f must be equal to its resistance as a fraction of the total resistance:

$$\frac{P.D_1}{\Sigma \mathcal{E}} = \frac{R_1}{\Sigma R}$$



Variable resistors in a potential divider are used to change the voltage supplied to something to a suitable voltage without using a transformer. However, this method wastes power.

Detecting circuits can also be constructed by adding a semiconductor, such as an LDR, as the second resistance. This means that when light intensity increases, the V-Out over the LDR will drop below a certain desired level.