WJEC (Wales) Physics GCSE

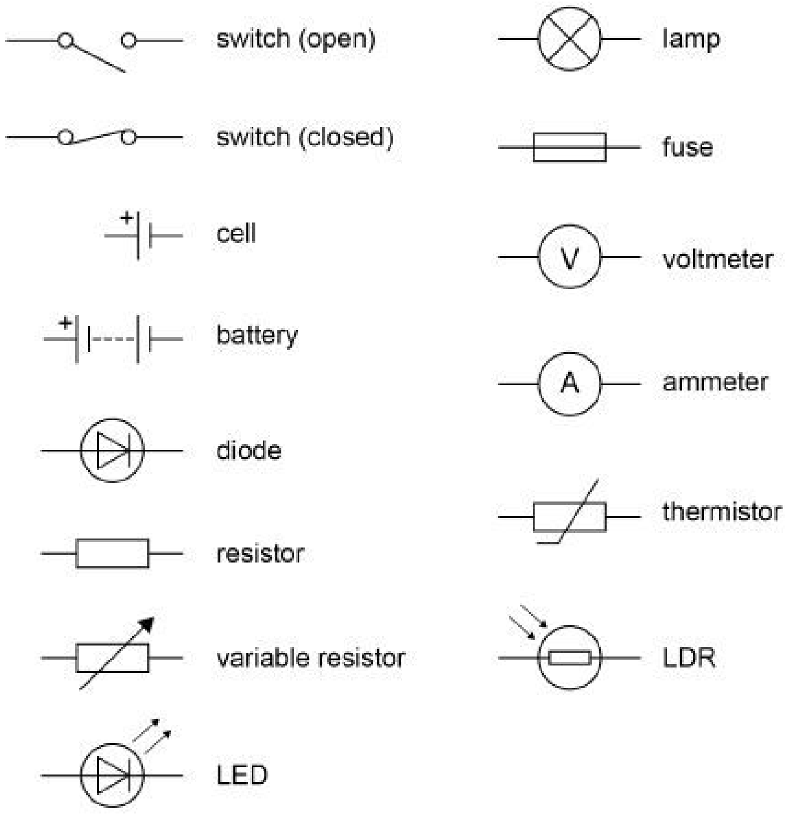
1.1: Electric Circuits

Detailed Notes

(Content in **bold** is for higher tier **only**)

Circuit Symbols

Symbols are used to represent the different **components** of electrical circuits.

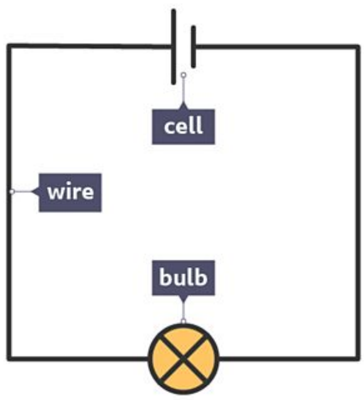


Common electrical circuit symbols (studyrocket.co.uk)

Types of Circuit

Series

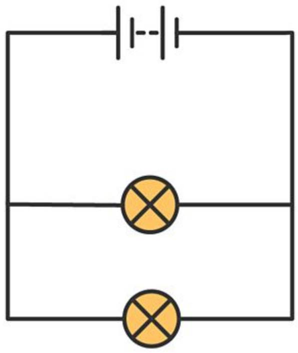
A series circuit is a **closed** electrical system with a **single path** for current to flow. This current is the **same everywhere** in the circuit and the **sum of voltages** across all components in the circuit is equal to the supply voltage.



A simple series circuit (bbc.co.uk)

Parallel

A parallel circuit is a **branched** electrical system with **multiple paths** (branches) for current to flow along. The total current at a circuit junction equals the **sum of current** along each of the branches. The voltage across each branch is the **same**.



A simple parallel circuit (bbc.co.uk)

Current, Voltage & Resistance

Current

Current (I) is the **flow of electrical charge** in a circuit. The greater the rate of flow of charge (Q), the greater the current:

$$Q = It$$

Q is charge flow in coulombs (C), I is the current in amperes (A) and t is the time in seconds (s)

In a single closed loop such as a series circuit, current has the **same value** at any point and can be measured in series, using an **ammeter**. The current through a component depends on both the resistance (R) of the component and the potential difference (V) across the component.

Voltage

Voltage is also referred to as **potential difference** (p.d.) and is a measure of the 'force' required to move current around the circuit. It is measured as a **change in voltage** between two parts of a circuit (circuit segment), such as before and after a component.

The voltage within a segment is measured in **parallel** with the segment, using a voltmeter. The total p.d. across the circuit can be increased by increasing the number of source **cells**.

Resistance

The components of electrical circuits can **restrict the flow of current** in a circuit. This effect is known as resistance. The units of resistance are **Ohms** (Ω). Current, potential difference and resistance are related and can be calculated using the equation:

$$V = IR$$

V is voltage in volts (V), I is the current in amperes (A) and R is the resistance in ohms (Ω)

Total resistance in a circuit varies depending on whether the components are connected in series or parallel. Adding components in **series increases** the total resistance, as it is the **sum** of separate resistances:

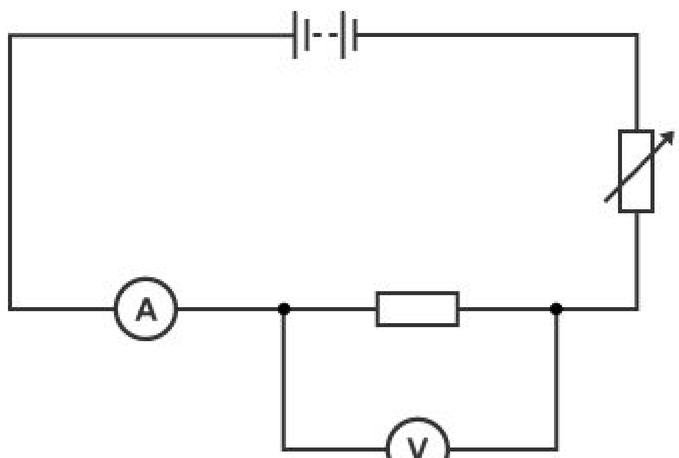
$$R_T = R_1 + R_2 + \ldots$$

Adding components in **parallel reduces** the total resistance in a circuit. **This total resistance can also be calculated as the sum of the reciprocals of each component resistance:**

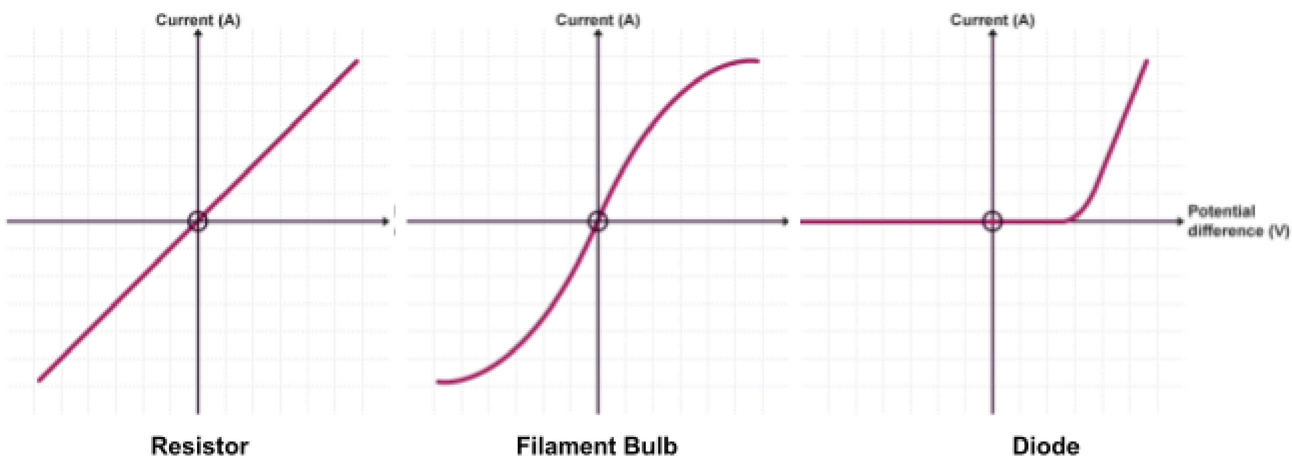
$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \ldots$$

Resistors

Resistance of a component can be investigated by monitoring the current flow through it and potential difference across it. This is done using a **variable resistor** within the circuit that can change the voltage and current.



A circuit to investigate how current changes with voltage for a component (bbc.co.uk)



Characteristic current-voltage curves for common components (bbc.co.uk)

By taking regular measurements of voltage and current across a component for different applied resistances in the variable resistor, a **current-voltage graph** can be produced.

If the current through the component is **directly proportional** to the potential difference across it, the resistance of the component (V/I) is constant. This is the case for an ordinary resistor, hence ordinary resistors can be described as **ohmic conductors**.

The resistance of components such as lamps, diodes, thermistors and LDRs, however, is **not constant** and changes with the current flow through it. This produces a **non-linear** current-voltage graph.

A **filament lamp** has a characteristic curve as its **resistance increases with increased current**. When the current is increased, the number of charge carriers (electrons) passing through the component increases. As electrons pass through the filament lamp, they **collide** with the atoms in the filament, **transfering energy** to these atoms, which becomes converted to **heat and light energy**. Therefore, when the current travelling through the filament lamp is increased, more heat and light energy is produced. At an atomic scale, an increase in heat energy manifests as an increase in **vigour** with which **atoms vibrate**. This **restricts the flow of electrons** through the component, otherwise known as an increase in the resistance. This explains why the **resistance** (V/I ratio) **increases** as the **current** passing through the filament lamp is **increased** in the graph above.

Diodes produce a different characteristic curve to filament lamps, since current can only flow in **one direction** through them.

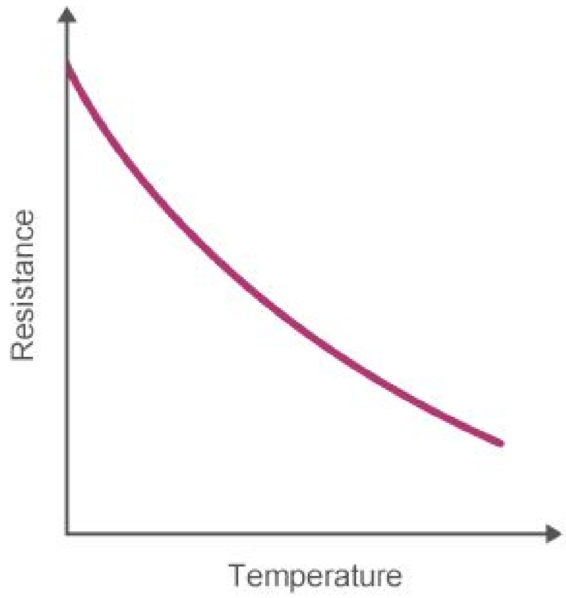
There are several different ways that resistance in a circuit can be affected:

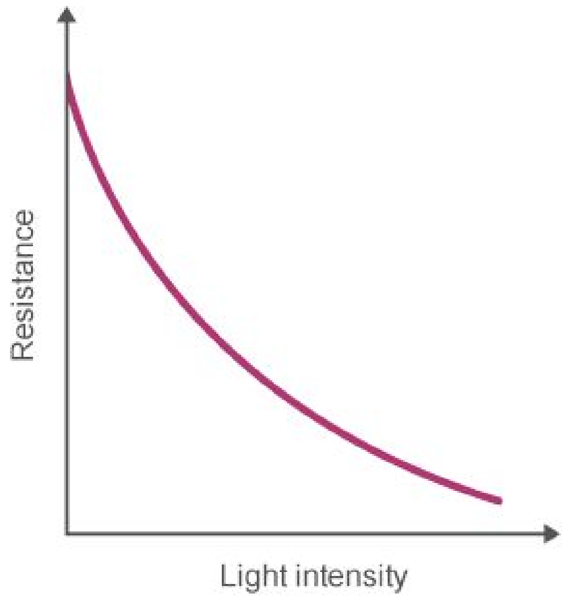
Temperature Variations
Even in wires and ordinary resistors (ohmic conductors), the **ongoing collision of electrons** with the atoms of the conducting material can result in **increased atomic vibration (heating)** over time. As a result the **resistance** of the material may **increase** the **longer** the circuit is active. This is why it is important to turn the power supply off in between readings when undertaking circuit-related experiments.

Thermistors are unusual in that their resistance decreases with increasing temperature. This feature means they are often used in temperature detectors and thermostats.

Length of Circuit
The greater the length, the greater the resistance as electrons have to make their way through **more resistor atoms**. Therefore the current flow is **reduced**.

Light Intensity
LDR (Light Dependent Resistor) have changing resistivity depending on the light level. The greater the intensity of light, the lower the resistance; therefore the resistance is greatest when it is dark. These are often used in automatic night lights.





Characteristic Resistance-Temperature and Resistance-Light-Intensity graphs for Thermisters (left) and LDRs (right) (bbc.co.uk)

Power

Power is the **energy transferred per unit time** and it is directly proportional to current and voltage.

$$E = Pt$$
$$P = IV$$

E is energy in joules (J) and P is power in watts (W)

Power loss in a component is proportional to resistance, and to the square of the current.

$$\boldsymbol{P = I^2R}$$

E is energy in joules (J) and P is power in watts (W)

The energy transferred from **chemical potential** in batteries to **electrical energy** in wires depends on the charge stored and potential difference. This energy is then transferred to any form of useful energy in the devices they power.

$$E = QV$$

E is energy in joules (J) and Q is charge flow in coulombs (C)