CURRENT OF ELECTRICITY

Electric current: Electric current is the flow of charge carriers and is measured in units of amperes (A) or amps.

Charge at a point: Product of the current at that point and the time for which the current flows,

$$Q = It.$$

Coulomb: Charge flowing per second pass a point at which the current is one ampere.

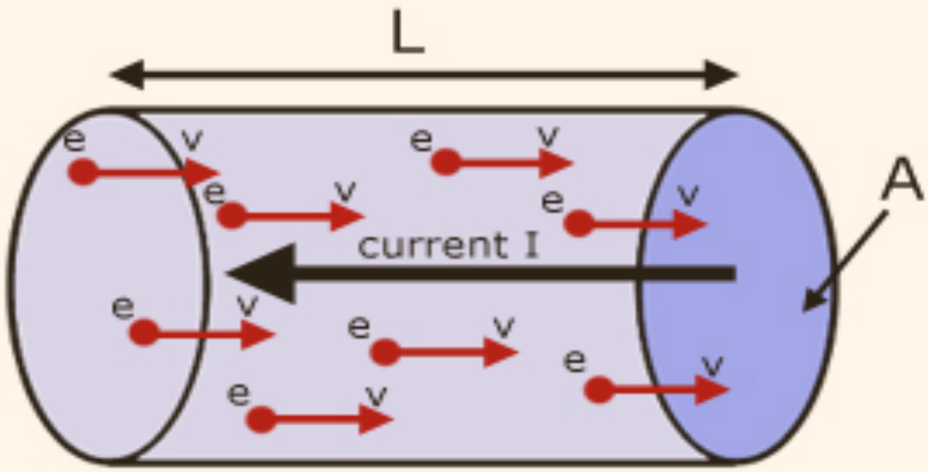
Charge is quantized: Values of charge are not continuous, they are discrete. All charges are multiples of charge of 1e: 1.6×10^{-19}C

Potential Difference: The potential difference across a component in a circuit is defined as the energy transferred per unit charge flowing from one point to another.

Current-Carrying Conductors

In a conductor, current is due to the movement of charge carriers. These charge carriers can be negative or positive, however the current is always taken to be in the same direction. In conductors, the charge carrier is usually free electrons.

Deriving a formula for current:



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

$$Volume\ of\ container = LA$$

$$Number\ of\ free\ electrons = nLA$$

$$Total\ charge\ in\ container = Q = nLAq$$

$$\therefore I = \frac{nLAq}{t} = \frac{nLAq}{L/v} \qquad \because t = \frac{L}{v}$$

$$I = Anvq$$

Where,

L = length of conductor

A = cross-sectional area of conductor

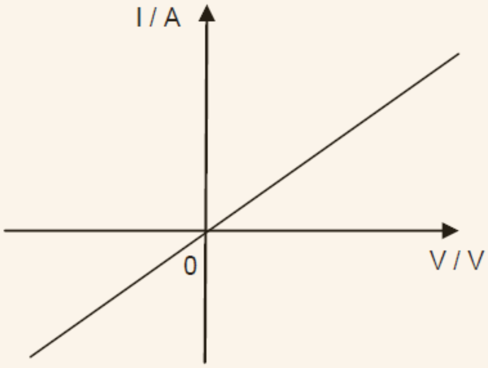
n = no. free electrons per unit volume

q = charge on 1 electron

v = average electron drift velocity

Current-P.D Relationships

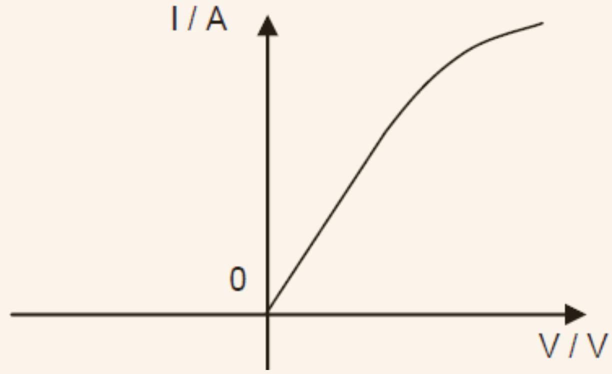
Metallic Conductor:



Ohmic conductor

V/I ratio constant

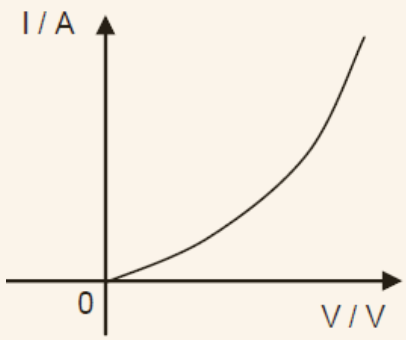
Filament Lamp:



Non-ohmic conductor

Volt ↑, Temp. ↑, Vibration of ions ↑, Collision of ions with e$^-$ ↑, Resistance ↑

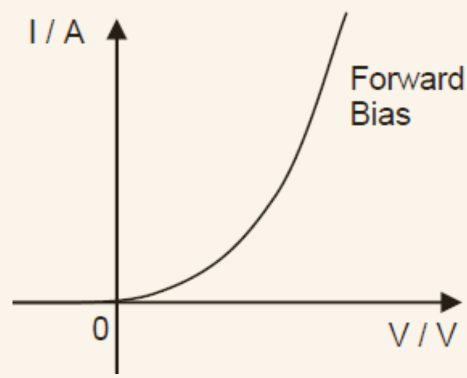
Thermistor:



Non-ohmic conductor

Volt ↑, Temp. ↑, Released e$^-$ ↑, Resistance ↓

Semi-Conductor Diode:



Non-ohmic conductor

Low resistance in one direction & infinite resistance in opposite

Ohm's law: The current in a component is proportional to the potential difference across it provided physical conditions (e.g. temp) stay constant.

Resistance

Resistance: Resistance is defined as the **opposition** to current. For a given potential difference: The higher the resistance the lower the current.

The resistance R of a conductor is defined as the ratio of the potential difference V across to the current I in it.

$$V = IR$$

Resistance is measured in ohm.

Resistivity: Resistivity is the resistance of a material of unit cross- sectional area and unit length. It is a property that describes the extent to which a material opposes the flow of electric current through it.

$$R = \frac{\rho L}{A}$$

D.C Circuits

Electromotive Force: The electromotive force (e.m.f) is the amount of chemical energy converted to electrical energy per coulomb of charge (C) when charge passes through a power supply. It is also the potential difference across the cell when no current is flowing.

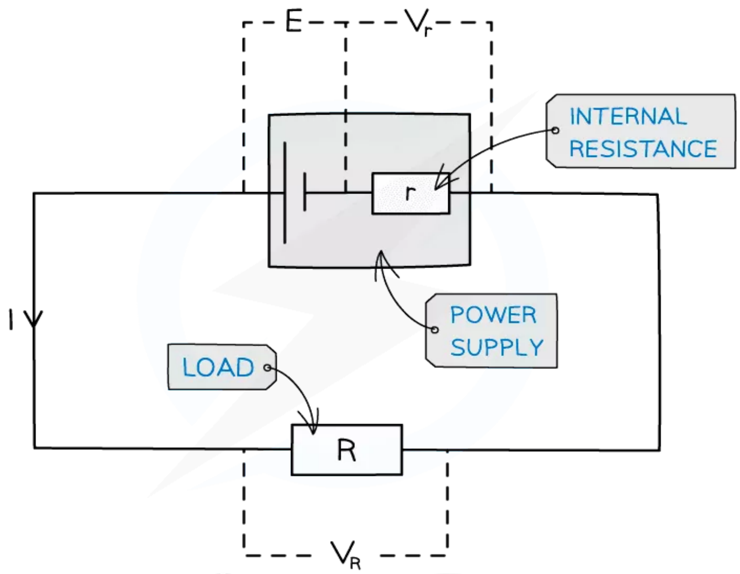
e.m.f is measured in Volts (V).

Potential Difference : Potential difference is the difference in the amount of energy that charge carriers have between two points in a circuit. It is the amount oof electrical energy converted to other form of energy per coulomb of charge when passes through a electrical component.

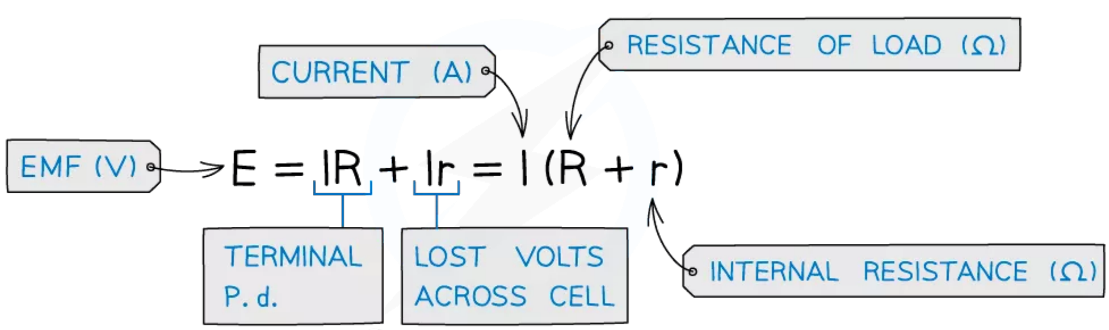
It is also measured in Volts(V)

Internal Resistance: All power supplies have some resistance between their terminals. This is called internal resistance (*r*). This internal resistance causes the charge circulating to dissipate some electrical energy from the power supply itself. This is why the cell becomes warm after a period of time.

A cell can be thought of as a source of e.m.f with an internal resistance connected in series. This is shown in the circuit diagram below:

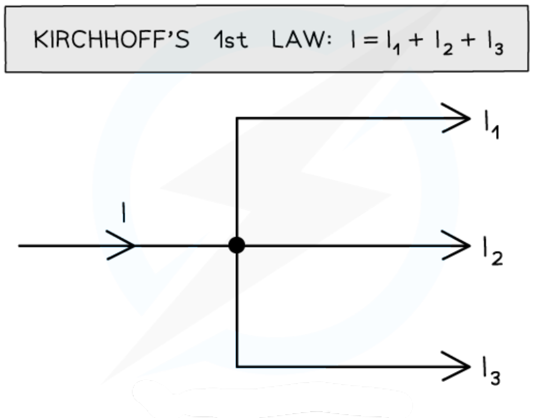


- V_R is the **terminal potential difference.** This is the voltage available in the circuit.
- V_r is the **lost volt** due to internal resistance.
- E is the sum of these potential differences, giving the equation below:



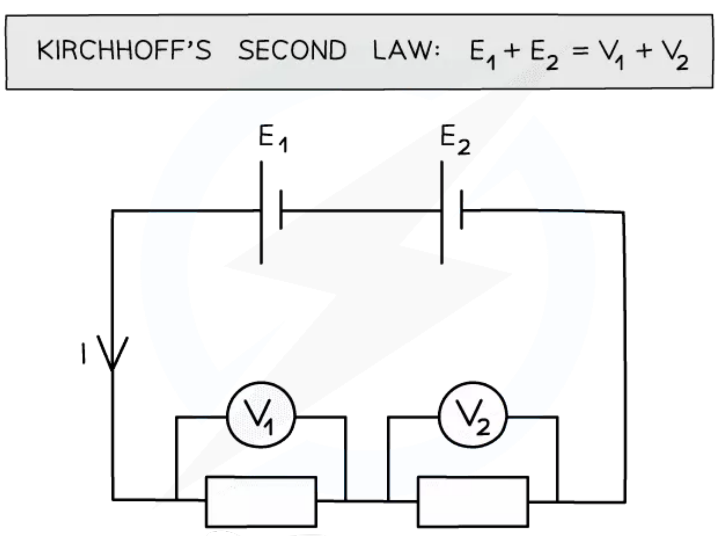
Kirchhoff's 1st Law: Kirchhoff's first law states that: The sum of the currents entering a junction always equal the sum of the currents out of the junction.

This is a consequence of conservation of charge – current shouldn't decrease or increase in a circuit when it splits

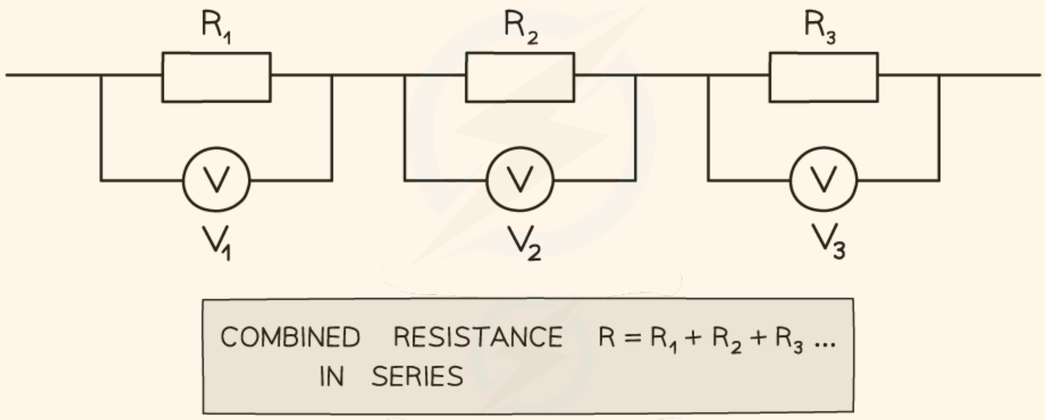


Kirchhoff's 2nd Law: Kirchhoff's second law states that: The sum of the e.m.f's in a closed circuit equals the sum of the potential differences across that circuit. This is a consequence of conservation of energy.

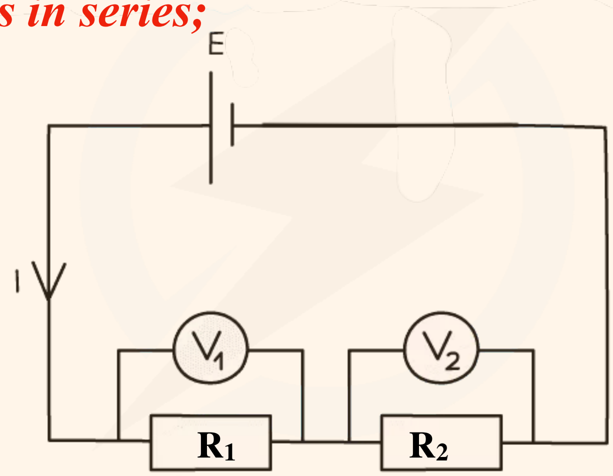
Below is a circuit explaining Kirchhoff's second law with the sum of the voltages in the closed series circuit equal to the sum of the e.m.f's:



Resistance in Series: When two or more components are connected in series: The combined resistance of the components is equal to the sum of individual resistances.



Derivation of resistors in series;



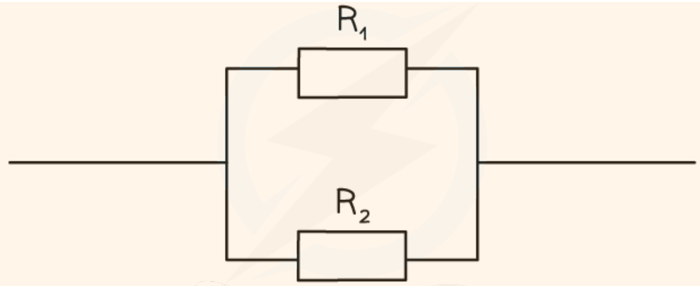
From Kirchhoff's 2nd Law:

$$E = V_1 + V_2$$
$$IR_t = IR_1 + IR_2$$

Current constant therefore cancel:

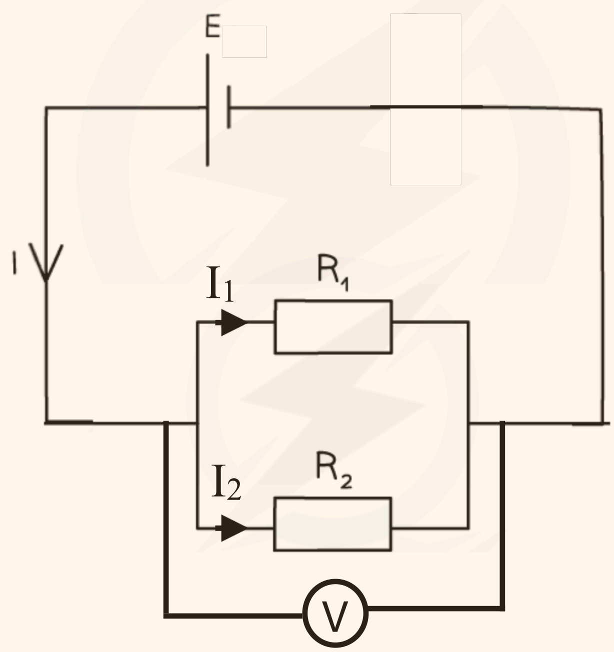
$$R_t = R_1 + R_2$$

Resistance in Parallel: When two or component are connected in parallel: The reciprocal of the combined resistance is the sum of the reciprocals of the individual resistances.



COMBINED RESISTANCE IN PARALLEL $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \cdots$

Derivation of resistors in parallel;



From Kirchhoff's 1st Law:

$$I = I_1 + I_2$$

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

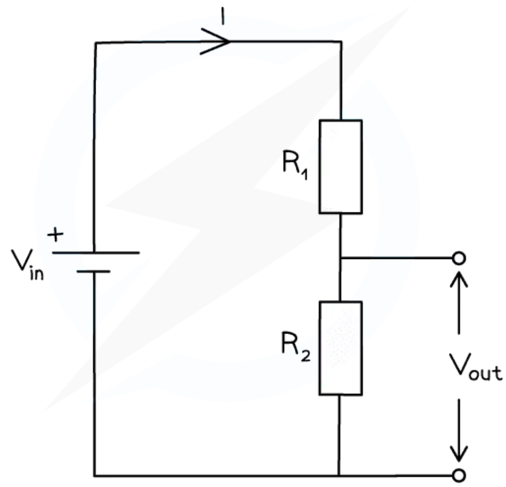
Voltage constant therefore cancel:

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

Potential Divider

Potential dividers are circuits which produce an output voltage as a **fraction** of its input voltage. This splits the potential difference of a power source between two components.

POTENTIAL DIVIDER EQUATION: $V_{out} = \frac{R_2}{R_1 + R_2} V_{in}$



Usage of a thermistor at R_1:

- Resistance decreases with increasing temperature.
- Can be used in potential divider circuits to monitor and control temperatures.

Usage of an LDR at R_1:

- Resistance decreases with increasing light intensity.
- Can be used in potential divider circuits to monitor light intensity.