

Electric Circuits

Unit Of Charge

- Charge measured in C (Coulomb)
- 1 Coulomb = 6.24×10^{18} electrons

Quantization of charges

experiment : "[Millikan oil drop experiment](#)"

$$e = 1.6 \times 10^{-19} C$$

- $e \rightarrow$ Elementary charge

Volt vs E.M.F. vs P.D.

Volt : Energy Per Coulomb (Unit of E.M.F. & P.D.)

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

E.M.F. (Electro Motive Force) : Energy given by the power supply to rotate the whole circuit

P.D. (Potential Difference) : energy consumed between 2 points per unit of charge

Current (I)

It is the rate of flow of charge

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

- $Q \rightarrow$ Charge in Coulomb
- Measured in A (Ampere)

$$I = neAv$$

- $n \rightarrow$ Charge Density : Number of free electrons per unit volume
 - Measured in $\# m^{-3}$
- $e \rightarrow$ Elementary Charge
- $A \rightarrow$ Cross-sectional Area Of The Wire
- $v \rightarrow$ Drift Velocity

Resistance (R)

- Measured in Ω (Ohm)

Resistors in Series

- Similar to [Capacitors](#) in parallel
- $R_T = R_1 + R_2 + R_3 + \dots$

Resistors in Parallel

Connected in parallel : Components are connected directly to the supply voltage and the current is divided between them.

- Similar to Capacitors in series
- $\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \dots$
- Total Resistor < Least Resistor
- For 2 Resistors in parallel
 - $R_T = \frac{R_1 \times R_2}{R_1 + R_2}$
- Resistors have the same P.D. across them

The resistance of a conductor depends on 4 properties :

1. The length of the conductor (l)

$$R \propto l$$

2. The cross-sectional area of the conductor (A)

$$R \propto \frac{1}{A}$$

$$R \propto \frac{1}{d^2}$$

3. The nature of the material (ρ)

$$R \propto \rho$$

4. The temperature of the conductor

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

Resistivity (ρ)

It is the resistance between the opposite faces of a m^3 of that material

- Measured in Ωm

$$\rho = \frac{A \times R}{l}$$

Ohm's Law

$$V = IR$$

Components Of An Electric Circuit

Ammeter : It is a device used to measure the electric current

- It is connected in series
- Has very low resistance

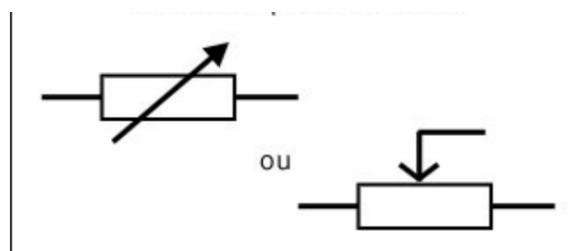
Voltmeter : It is a device to measure potential difference (P.D.) between 2 points

- It is connected in parallel
- Has very high resistance

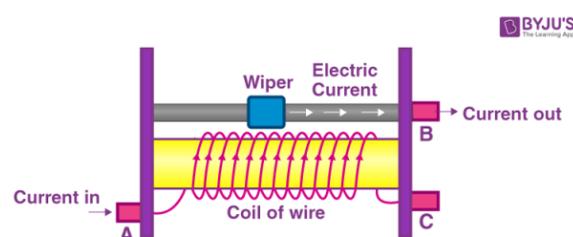
Variable Resistor (Rheostat)

A resistor with adjustable resistance

- Symbols



- How it looks in a real circuit



An Experiment to determine the resistance of a fixed resistor

1. Place an ammeter in series and a voltmeter across the resistor
2. measure the resistance of the resistor
3. place another variable resistor in the circuit, change the voltage of the power supply
4. Before closing the switch, adjust the variable resistor to it's maximum value, to obtain the minimum current
5. change the voltage and current in the circuit, and measure the resistance across the fixed resistor
6. plot a graph V against I with the readings

7. resistance is the gradient $V = IR$

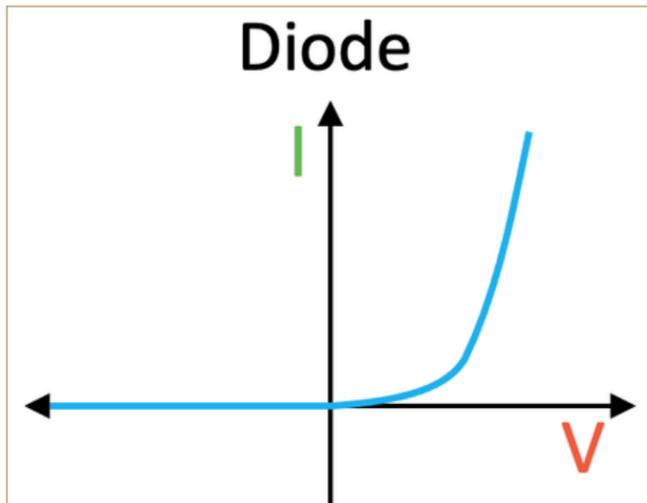
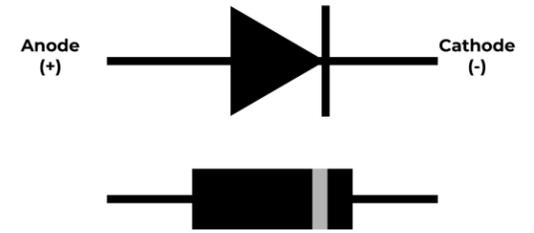
Note :

If the $V \times I$ graph is a straight line passing through the origin in the first and third quarter, It is an **Ohmic Device**

Non-Ohmic Devices

Diode (Rectifier)

- It is made of a semiconductor material
- Allows current to flow in just one direction



To get the resistance of the diode at a point, calculate $\frac{I}{V}$ At that point without calculating the gradient

Effect of Temperature of Temperature

In Metals

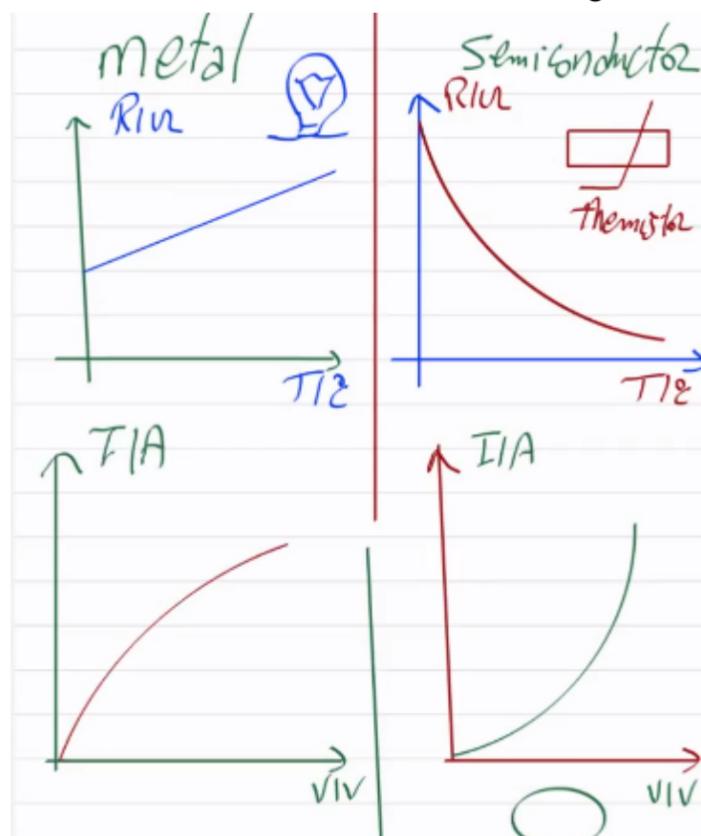
Example : Filament Lamps

Heating increases the **Kinetic Energy** of the electrons, leading them to collide more frequently with the atoms

In Semiconductors

Example : Thermistor

Heating increases the number of electrons in the semiconductor allowing more free electrons move



Power

Rate of Energy transfer

- Measured in **W**

$$P = IV$$

$$P = I^2R$$

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

Uses of $P = IV$

- Power Generated
- Power Consumed
- Normal Current: Current in the lamp at normal operation

Uses of $P = I^2R$

- Power Loss

Uses of $P = \frac{V^2}{R}$

- Resistance of a Device

Internal Resistance of a Power Supply

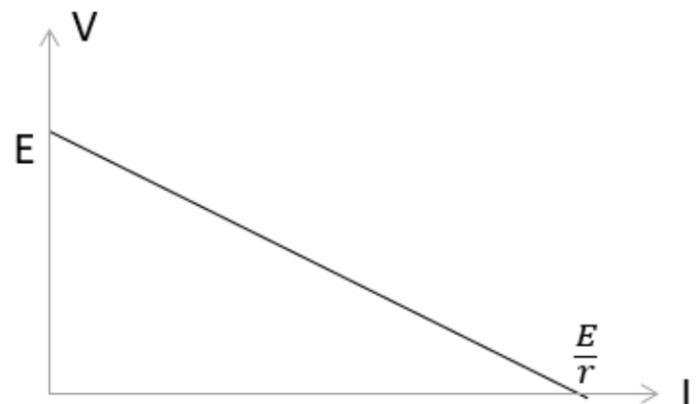
$$V = E - Ir$$

- V → Voltage across the power supply
- E → E.M.F. Supplied by the power supply
- r → Internal resistance of the power supply
- I → Current in the circuit

Gradient of the graph represents $-r$

$$y = mx + c$$

$$V = -rI + E$$



- The power of a Power Supply depends on both the internal and external resistance
- Maximum Power output when Internal resistance = External resistance

Kirchhoff's Laws

Kirchhoff's First Law

At any node, the sum of the current in = sum of the current out

$$\Sigma I_{in} = \Sigma I_{out}$$

Kirchhoff's Second Law

At any closed loop, Energy gained = Energy lost

$$\Sigma E.M.F. - \Sigma P.D. = 0$$

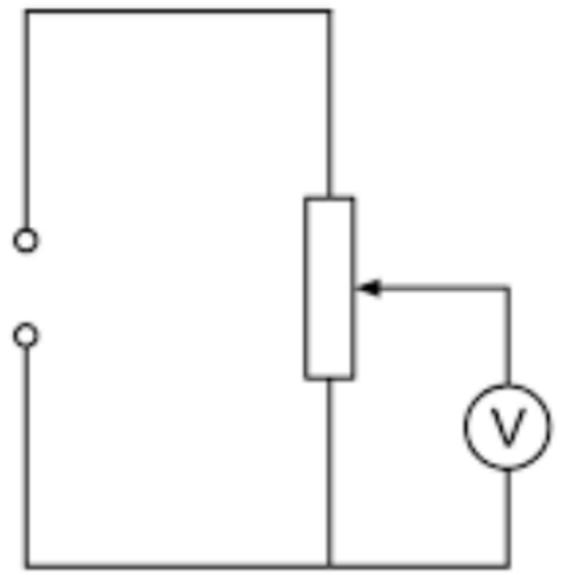
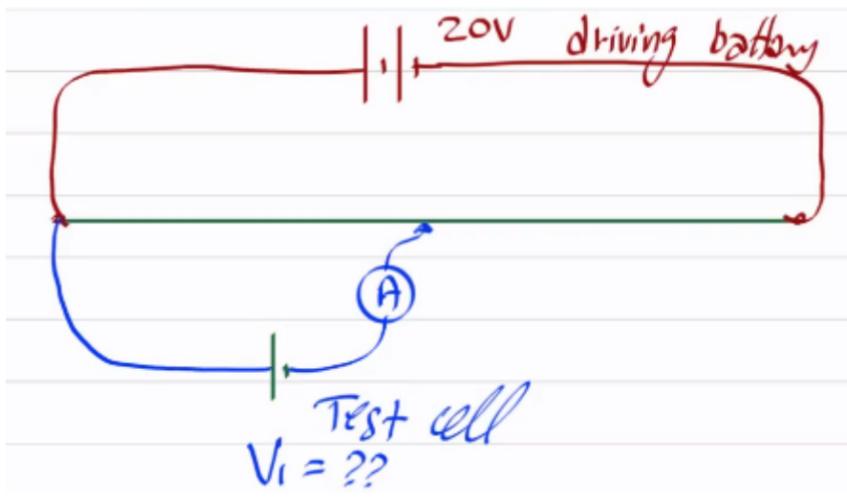
Potential divider

variable resistor connected to a power supply

- According to the position of the slider, the required voltage is gained
- Allows 0V to be across the Voltmeter

Potentiometer

Resistance wire that allows you to measure very low voltage



In this circuit the goal is to determine the E.M.F. of the cell V_1

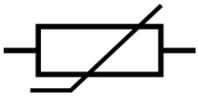
here the entire 20 Volts of the driving battery are consumed across the resistance wire

if the sensitive ammeter (or galvanometer) reads 0A at 40% of the length of the wire, that would mean that V_1 is exactly 40% of the Voltage of the driving battery

Thermistor

Semiconductor Resistor that decreases in resistance as temperature increases

- Symbol



LDR (Light Dependent Resistor)

Resistor that depends on level of intensity it's subjected to.

As light increases the resistance decreases

- Symbol

