IGCSE/GCE O-LEVEL

Electric Quantities

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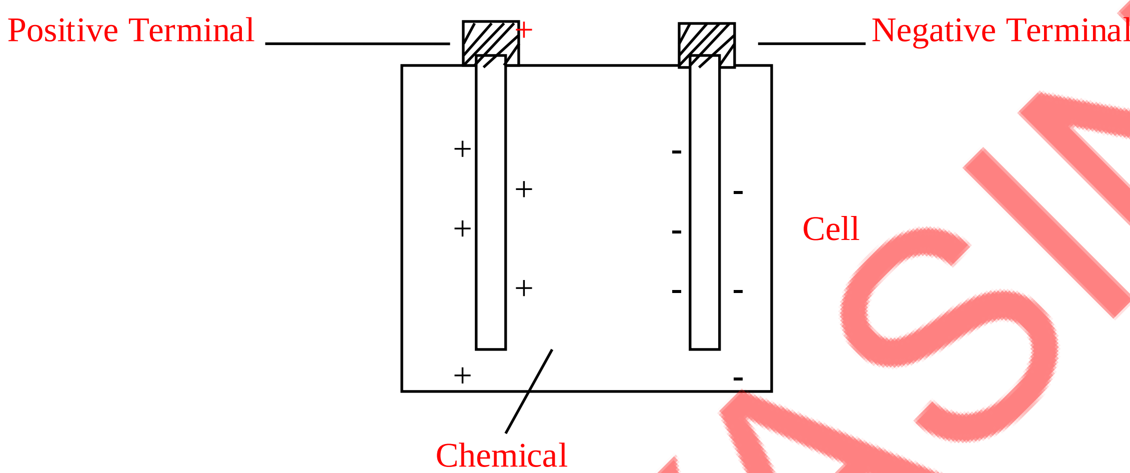
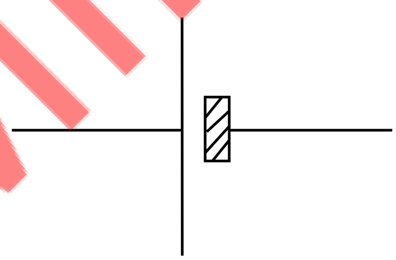
CELL

A source of Electrical Energy is called a cell.



- A cell has chemical in it.
- Cell converts chemical energy into electrical energy.
- There are two rods placed in the cell.
- One of the rod is positively charged and is called positive terminal and other rod is negatively charged and is called negative terminal.

Symbol



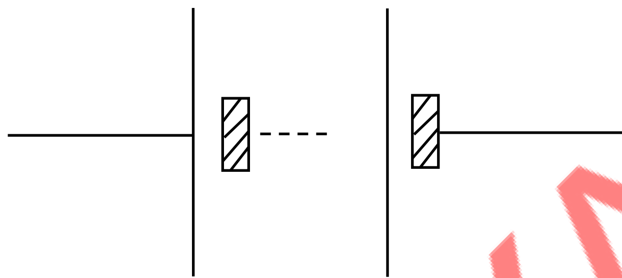
The bigger line represents positive terminal and smaller line represents negative terminal of the cell.

Battery

Combination of two or more than two cells is called battery.

- If two or more than two cells are connected in series or parallel then arrangement is called a battery.

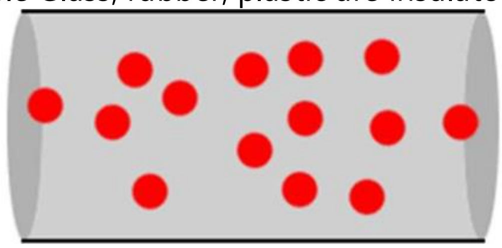
Symbol



Insulator

A material which does not have free electrons in it is called an insulator.

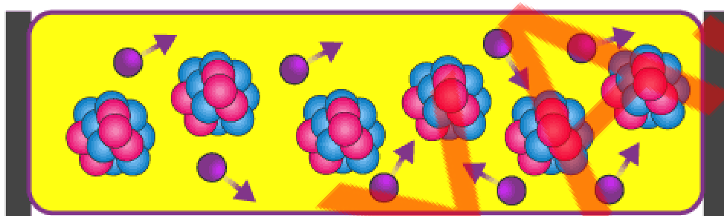
- For example Glass, rubber, plastic are insulators.



Conductor

A material which has free electrons in it is called a conductor.

- For example all the metals are conductor.



- If a conductor is connected to the cell then negative terminal of cell will repel the free electrons and positive terminal will attract the free electrons of the conductor.
- Electrons will start moving in the conductor or in other words we can say that electrons will start flowing through the conductor or charge will start flowing through the conductor.
- Flow of charge through a conductor is called an electric current

Electric Current

Rate of flow of charge through a conductor

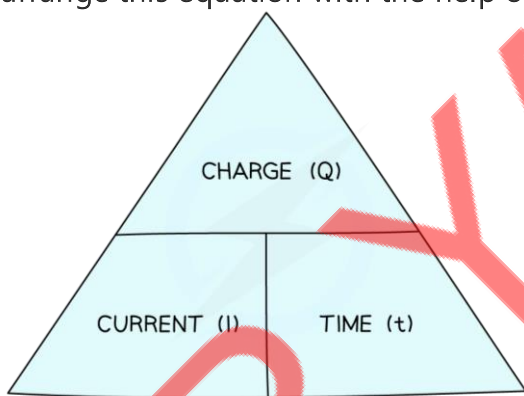
Or

Amount of charge passing through the conductor in unit time is called an electric current.

Electric Current = $\frac{\text{Charge}}{\text{time}}$

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

- We can rearrange this equation with the help of the formula triangle:



Unit of Electric Current

Unit of electric current is Ampere

Ampere = $\frac{\text{Coulomb}}{\text{Second}}$

A = $\frac{C}{S}$

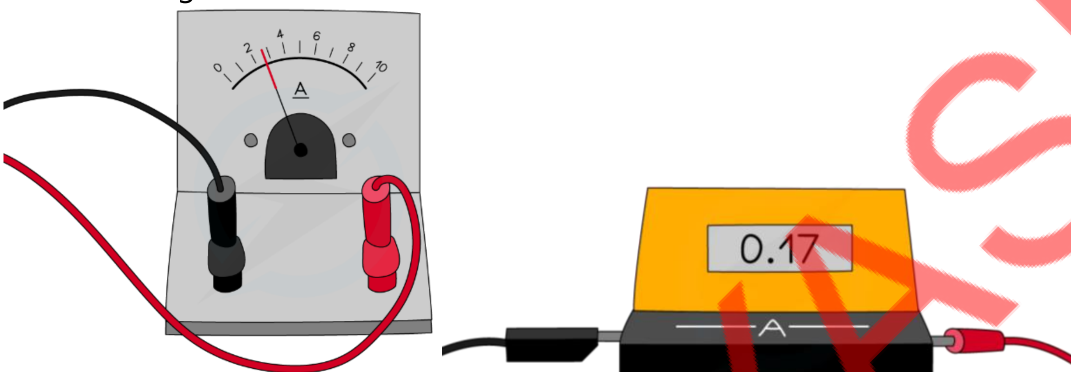
Ammeter

A device which is used to measure the current is called an ammeter.

Types of Ammeter

There are two types of ammeter

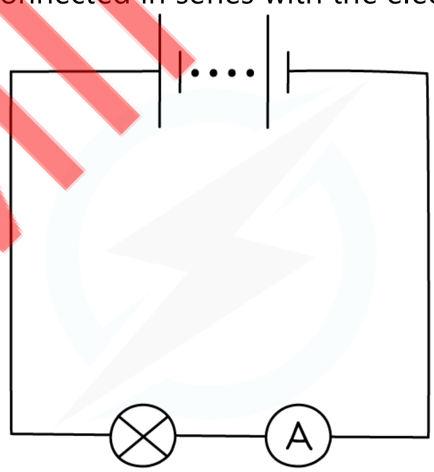
- Analogue ammeter
- Digital ammeter



Symbol

Ammeter is represented by the following symbol.

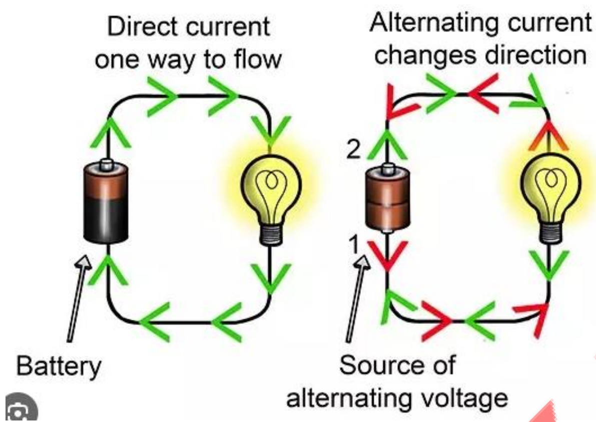
Ammeter is always connected in series with the electrical component.



Types of Current

There are two types of current.

- Alternating current (A.C)
- Direct current (D.C)

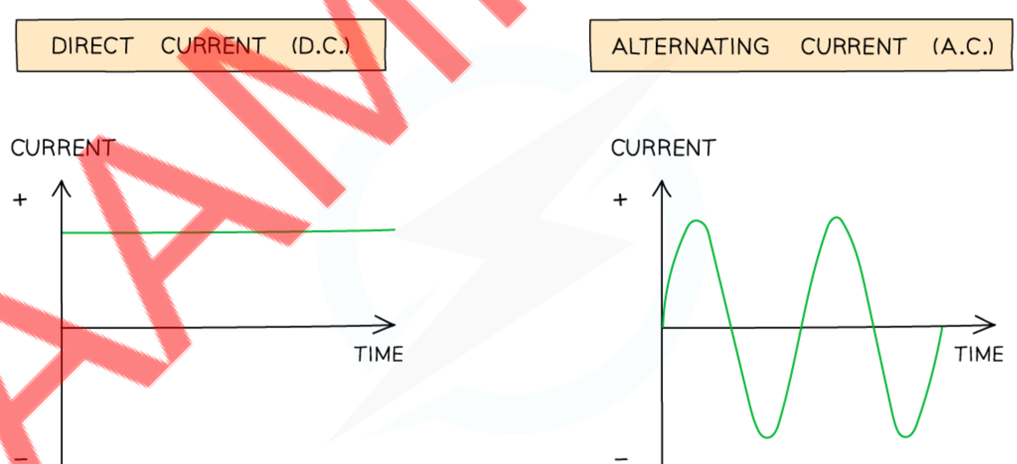


Alternating Current (A.C)

Current in which direction of flow of current reverses after every half cycle.
Main electricity generator produce alternating current.

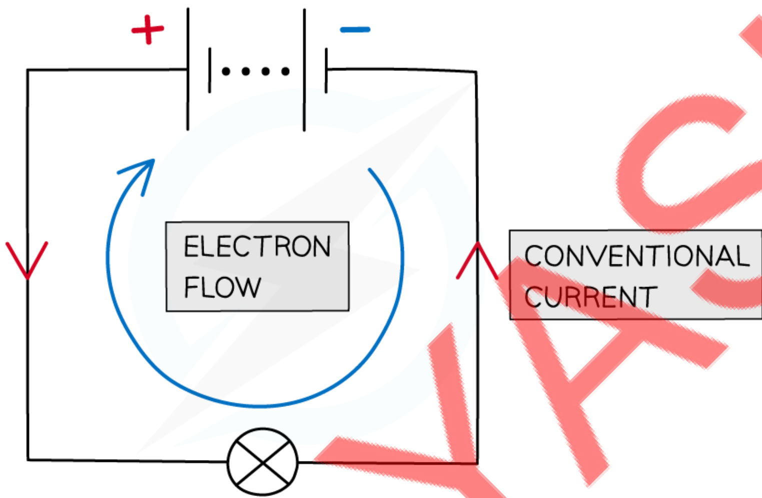
Direct Current (D.C)

Current in which direction of flow of current remains unchanged.
Cell and battery produce direct current



Conventional Current

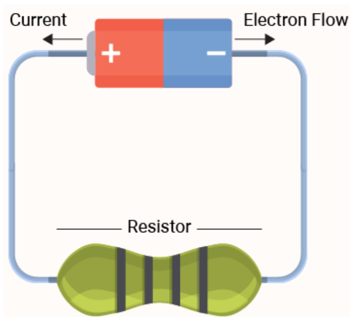
- In a metal, current is caused by a flow of electrons
- Electrons are negatively charged
- This means that the **electrons flow from negative to positive**
- **Conventional current**, however, is still defined as going from **positive to negative**

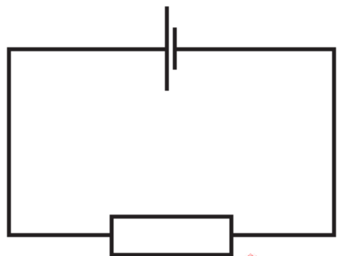


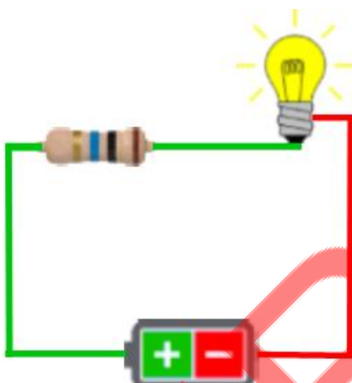
Electric Circuit

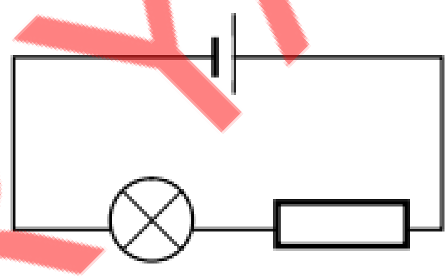
If an electric component is connected to the cell or a combination of two or more than two electric components is connected to the battery then whole arrangement is called an electric circuit.

Example









Electric circuit is further divided into two parts

- Internal Circuit
- External Circuit

Internal Circuit

A cell or battery of an electric circuit is called internal circuit.

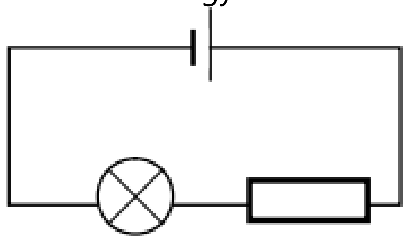
External Circuit

Combination of all the components other than cell or battery in an electric circuit is called external circuit.

So

Electric Circuit	=	External Circuit	+	Internal Circuit

In an electric circuit, cell provides electrical energy and all the other components convert that energy into any other form of the energy.



Let's say EMF of cell is 10V, P.D across resistor is 4V and P.D across bulb is 6V.
It means

$10V = \frac{10J}{IC}$ $6V = \frac{6J}{IC}$ $4V = \frac{4J}{1C}$

- It means that cell will provide 10J of electrical energy to the unit charge.
- Since P.D of resistor is 4V then it means that resistor will take 4J of energy from unit charge and then convert it into heat energy.
- Since P.D of bulb is 6V therefore bulb will take 6J energy from unit charge and convert it into light energy.
- So in an electric circuit, cell provides electrical energy and charge transfers electrical energy from cell to electric components.
- If we say that EMF of cell is 10V then it means that 10J of energy will be provided by the cell to the unit charge and on the basis of this energy unit charge will move round the complete circuit.

Electromotive Force (E.M.F)

Work done in moving unit charge round the complete circuit is called E.M.F.

$$\text{E.M.F} = \frac{\text{Work done}}{\text{Charge}}$$

Unit

$$\text{Volt} = \frac{\text{Joule}}{\text{coulomb}}$$

Potential Difference (P.D)

Work done in moving unit charge round external circuit only (through an electric component) is called potential difference across the electric component

$$\text{Potential difference} = \frac{\text{Work done}}{\text{charge}}$$

Unit

$$\text{Volt} = \frac{\text{Joule}}{\text{coulomb}}$$

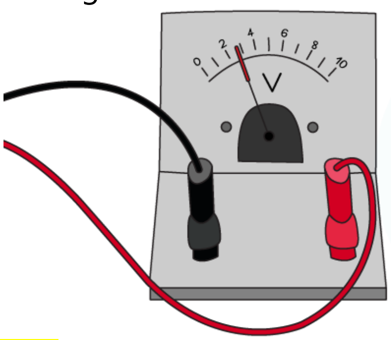
Voltmeter

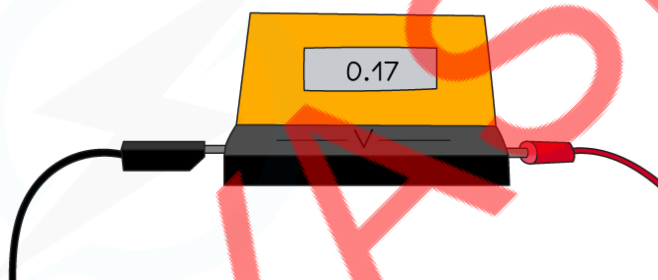
A device which is used to potential difference across the electrical component is called voltmeter.

Types of Voltmeter

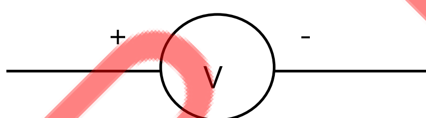
There are two types of voltmeter.

- Analogue ammeter
    - Digital ammeter

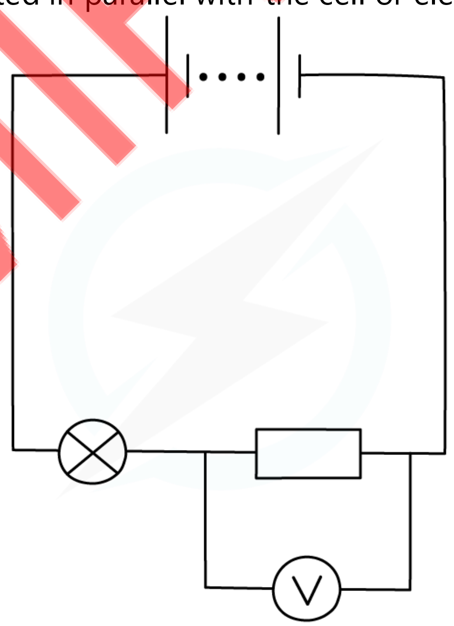




Symbol

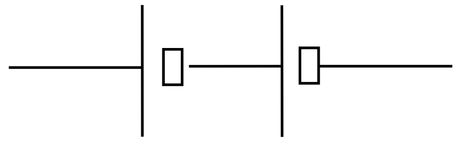


Voltmeter is always connected in parallel with the cell or electric component.



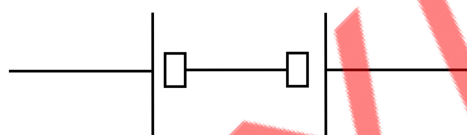
Combinations of Cell

1. Supporting Series Combination

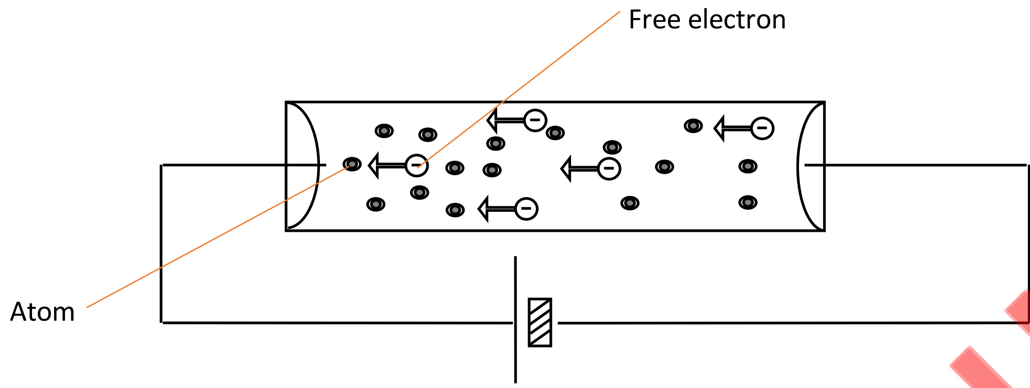


- If unlike terminals two cells are connected to each other then such a combination is called supporting series combination.
- In supporting series combination resultant EMF is found by adding the EMF of two cells.

2. Opposing Series Combination



- If like terminals of two cells are connected to each other then such a combination is called opposing series combination.
- In opposing series combination resultant EMF is found by subtracting the EMF of two cells.



- When free electron pass through the conductor then they continuously collides with the atoms of conductor and therefore experiences opposition / hindrance to flow.
- This opposition / hindrance experienced by the free electron to flow through the conductor is called resistance.

Resistance

Hindrance offered by the conductor to flow of charge is called resistance

Or

Opposition offered by the conductor to flow of charge is called resistance

Effect of temp on resistance of conductor

- If we increase the temp of conductor then vibration of atoms of conductor will increase
- Collisions of electron (charge) with the atoms will increase
- Resistance will increase.

Resistance

Potential difference to current ratio for a conductor is called its resistance.

$$\text{Resistance} = \frac{\text{Potential difference}}{\text{Current}}$$

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

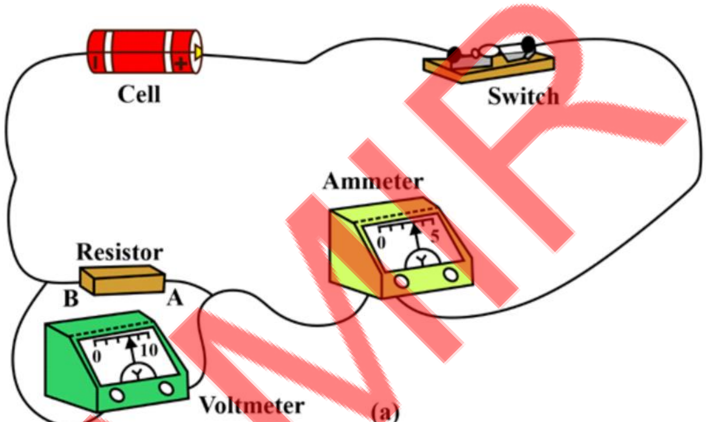
Unit

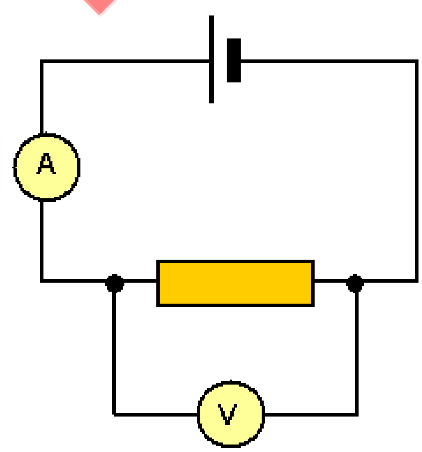
Unit of the resistance is ohm

$$\text{Ohm} = \frac{\text{Volt}}{\text{Ampere}}$$

$$\Omega = \frac{V}{A}$$

Determination of Resistance of a Conductor





- Connect the resistor with a cell with an open switch.
- Connect an ammeter in series with the resistor and voltmeter parallel to the bulb.
- Close the switch and note down the ammeter and voltmeter readings.
- Calculate the resistance of bulb using following expression.

$$\text{Resistance} = \frac{\text{Potential difference}}{\text{Current}}$$

Ohm's Law

Current flowing through a metal conductor is directly proportional to potential difference across its ends provided that temperature and other physical conditions are kept constant.

Potential difference α Current

$$V \propto I$$

$$\frac{V}{I} = \text{Constant}$$

This is mathematical expression for ohm's law.

Types of the conductor

There are two types of the conductor

1- Ohmic conductor

2- Non Ohmic conductor

Ohmic Conductor

A conductor which obeys Ohm's Law.

Or

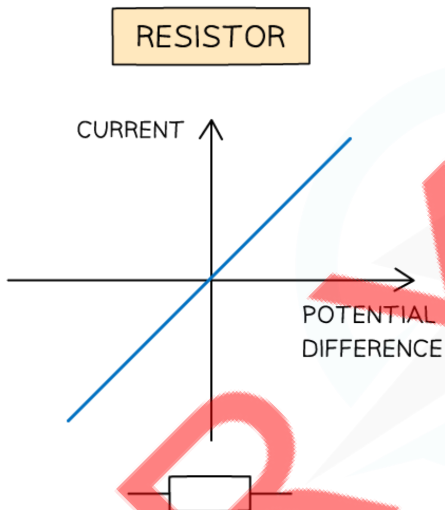
A conductor for which potential difference to current ratio remains constant

Or

A conductor for which Current-Voltage graph is straight line passing through origin is called ohmic conductor.

Example:

Carbon Resistor



Non-Ohmic Conductor

A conductor which does not obey ohm's law.

Or

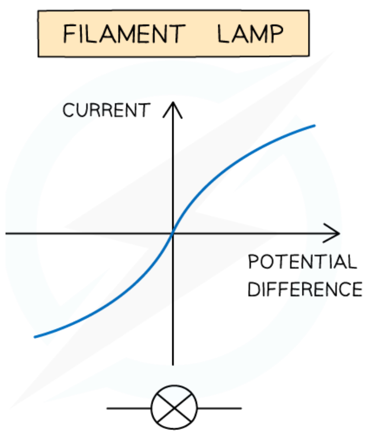
A conductor for which potential difference to current ratio does not remain constant.

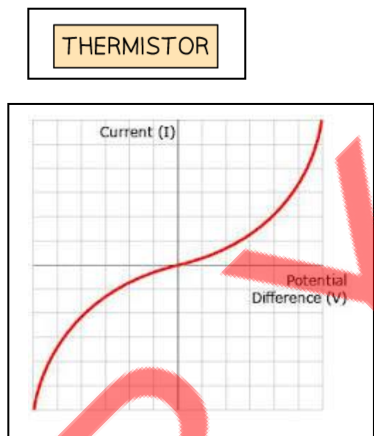
Or

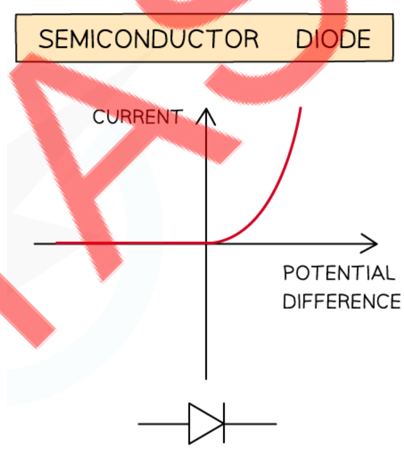
A conductor for Current-Voltage graph is not a straight line or not passing through the origin is called non-ohmic conductor.

Example:

1. Filament Lamp
2. Termistor
3. Diode



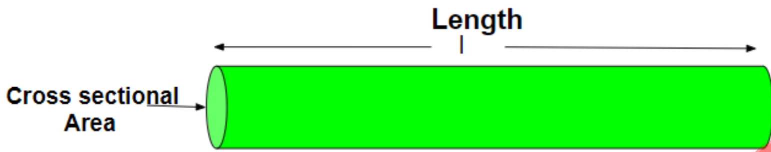




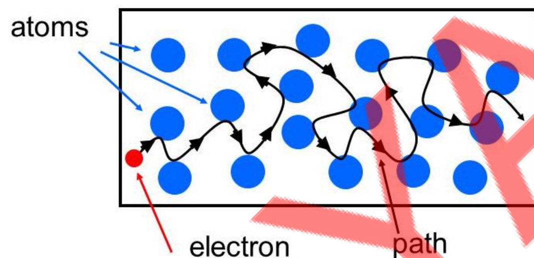
Resistance of a Conductor

Resistance of conductor depends upon two things

- the **length** of the conductor
- the **cross-sectional area** of the conductor
-

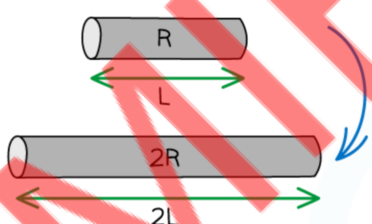


As electrons pass through a conductor, they collide with the atoms of the conductor, conductor offers resistance to the flow of electrons.



If the conductor is longer, each electron will collide with more atoms and so there will be more resistance: i.e longer a conductor, *greater* its resistance.

Resistance α Length

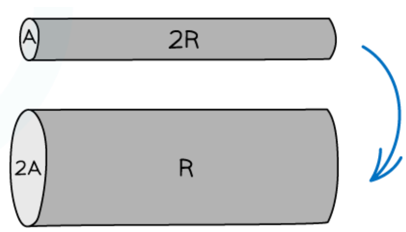


DOUBLING THE LENGTH OF A WIRE WILL DOUBLE THE RESISTANCE

If the conductor is thicker (greater diameter) there is more space for the electrons and so more electrons can flow: i.e thicker a conductor, *smaller* its resistance.

Resistance α 1/Area

DOUBLING THE CROSS−SECTIONAL AREA OF A WIRE WILL HALF THE RESISTANCE

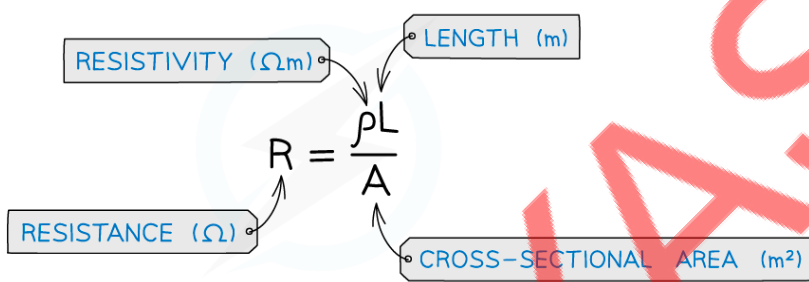


$$\text{Resistance} \quad \alpha \quad \frac{\text{Length}}{\text{Area}}$$

$$R \quad \alpha \quad \frac{L}{A}$$

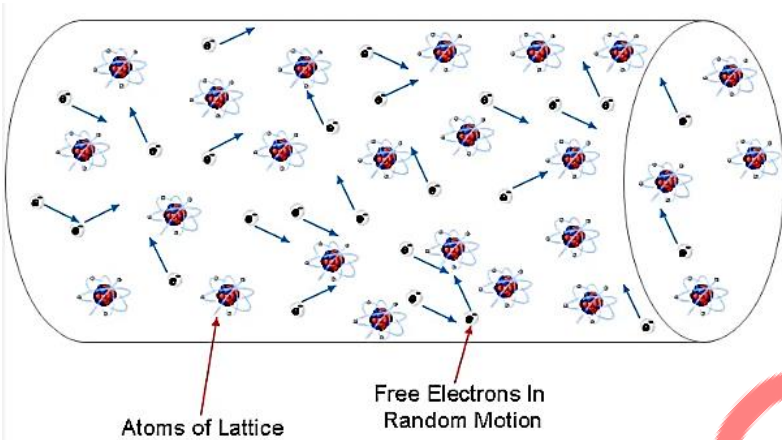
$$R = (\text{Constant}) \ \frac{L}{A}$$

$$R = (\text{Resistivity}) \ \frac{L}{A}$$



Difference between Resistance and Resistivity

Resistance	Resistivity
1. It is property of object	1. It is property of material
2. It depends upon shape and size of object	2. It does not depend upon shape and size of object
3. It does not remain constant for single object	3. It remains constant for single object
4. It has unit ohm	4. Its unit is ohm-meter



- When electron pass through the conductor they continuously collide with atoms of conductor.
- Due to these collisions electron continuously loose energy which is then converted into any other form of energy.
- Usually it is converted into heat energy.
- Energy lost by the charges while passing through a conductor is called Energy dissipation and Energy lost by the charges in unit time while passing through a conductor is called Power dissipation.

Power Dissipation

Rate of loss of electrical energy by the charges while passing through a conductor is called power dissipation

Or

Electrical energy lost by charges in unit time while passing through a conductor is called power dissipation

Or

Electrical energy lost by the charges in one second while passing through the conductor is called power dissipation.

$$\text{Electrical Power} = \frac{\text{Energy}}{\text{Time}}$$

Or

$$\text{Electrical Power} = \frac{\text{Work done}}{\text{Time}}$$

$$P = VI$$

$$P = I^2 R$$

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

Energy Dissipation

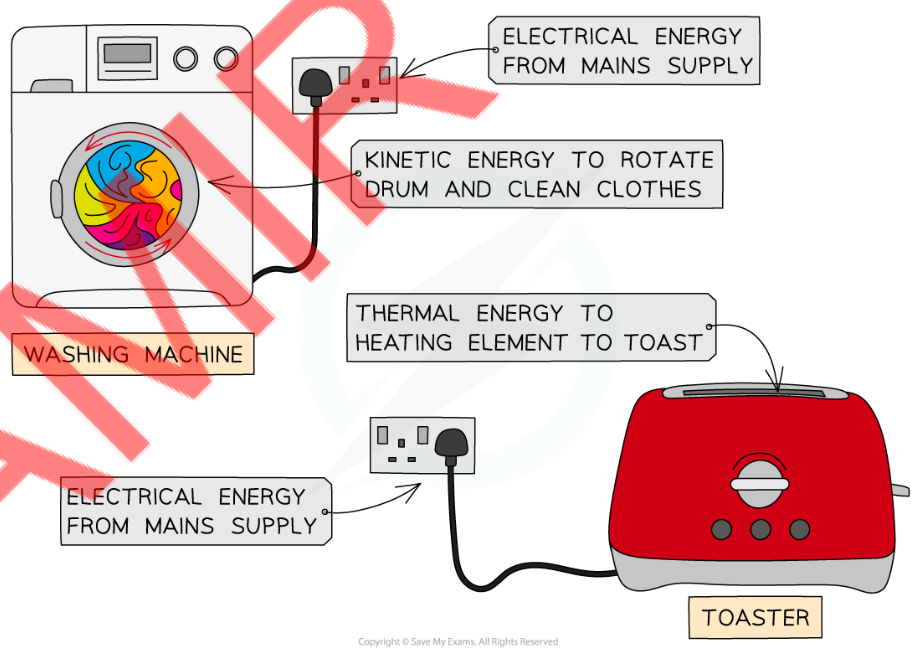
Total energy lost by the charges while passing through a conductor is called energy dissipation

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

Or $P = \frac{E}{T}$

So $E = Pt$

Therefore
$$E = VIt$$
$$E = I^2 Rt$$
$$E = \frac{V^2 t}{R}$$



The Kilowatt Hour (kWh)

A unit of energy equivalent to one kilowatt of power expended for one hour

- A unit of electrical energy used to measure the electrical energy consumed by an electrical device is called kilo watt-hour.
- It is represented by KWh.
- Energy is commonly measured in **kilowatt-hour (kW h)**, which is then used to calculate the cost of energy used

1KWh = 1×10^3 W x 3600S

= 3600×10^3 WS

= 3.6×10^6 J

Example

Filament Bulb

P = 2KW

t = 3 hours

Let say a bulb has power equal to 2 KW i.e 2000 W and it is used for 3 hours daily so total energy consumed by the bulb daily will be

Energy = 2 KW x 3 hour

= 6 KWh

Let say electricity price for one unit i.e one KWh is 5 rupees then

Cost of Electricity of bulb for one day = 6 x 30 = 30 Rupees

Now for whole month cost of using this bulb will be

Total Cost for one month = 30 x 30 = 900 Rupees