Chapter 11
Electricity

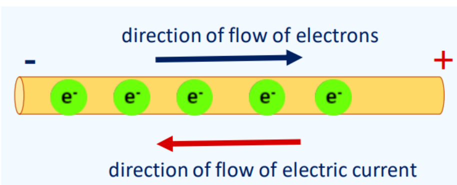
- **Electricity** is a form of energy used to run a variety of electrical and electronic appliances like bulb, camera, fridge, computer, etc.

- **Charge (Q)** is a basic property of a particle(matter). It may be positive or negative. Like charges repel each other. Unlike charges attract each other.
  SI unit of charge is coulomb (C)
  Charge on 1 electron = - 1.6×10^{-19} C
  No. of electrons in 1 coulomb = 6.25×10^{18}

Electric Current (I)

- **Electric Current (I):** The rate of flow of electric charge is known as electric current.
- Current = $\frac{\text{Charge}}{\text{Time}}$ $\Rightarrow \mathbf{I = \frac{Q}{T}}$
- S. I. unit of current is ampere (A)
- **1 ampere**: If one coulomb of charge flows through a conductor in one second, then the current flowing through the conductor is known as 1 ampere.
- 1 ampere = 1 coulomb/1 second
- 1 milliampere(mA) = 10^{-3} A
- 1 microampere(μA) = 10^{-6} A
- Current is measured by Ammeter. Its symbol is

- Ammeter has low resistance and always connected in series.
- Electrons flow from negative terminal of a battery (or cell) to positive terminal, whereas current flows from positive terminal of a battery to negative terminal.



Potential Difference

- **Potential Difference (V):** Potential difference is defined as the work done to move a unit charge from one point to another.
- Potential Difference = $\frac{\text{Work done}}{\text{Charge}}$ $\Rightarrow \mathbf{V = \frac{W}{Q}}$
- S. I. unit of Potential difference is Volt (V)
- **1 Volt:** 1 volt is the potential difference between two points if 1 J of work has to be done in taking 1 C charge from one point to another.
- 1 volt = 1 joule/1 coulomb
- **Voltmeter** is used to measure the potential difference. It has high resistance and always connected in parallel. Symbol is

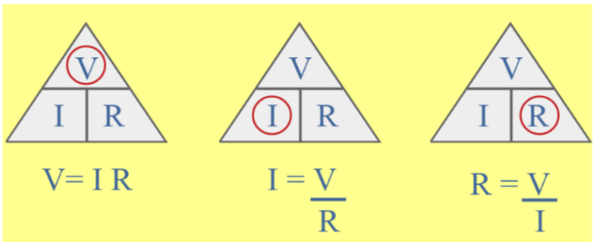
- **Battery** (or cell) is a device which can be used to create potential difference.

Ohm's Law

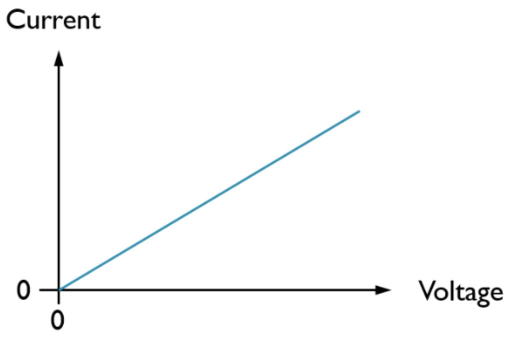
Ohm's Law states that **the current flowing through a conductor is directly proportional to the potential difference** (provided that the temperature and other physical conditions remain unchanged).

$\Rightarrow V \propto I$ $\Rightarrow V = IR$

Where, R is a constant called **resistance**.



V-I graph for Ohm's law



Resistance (R)

Resistance is the property of conductor which opposes the flow of electric current through it.

- SI unit of resistance is **ohm**(Ω)
- **1 ohm**: One ohm is defined as that resistance of an object when a current of 1 ampere flows through an object having a potential difference of 1 Volt.
- 1 ohm = 1 volt/1ampere
- Device that resists the flow of electric current in a circuit is called resistor.
- **Rheostat** (variable resistor) is a device used to control the current by changing the resistance (without changing the potential difference).

Factors affecting the Resistance

Resistance of a conductor is:

(i) directly proportional to the length of conductor,

$R \propto l$ **...(i)**

(ii) inversely proportional to the area of cross-section,

$R \propto 1/A$ **...(ii)**

From (i) and (ii),

$$R \propto (l/A)$$
$$R = \rho.(l/A)$$

ρ(rho) is a constant of proportionality, it is called the electrical **resistivity** of the material of the conductor. Resistivity is a property of materials that measures how well or poorly they allow electricity to flow through them. It's like how some materials let electricity pass easily, while others make it more difficult. High resistivity means a material is a poor conductor, and low resistivity means it's a good conductor of electricity.

(iii) depend on nature of material (resistivity).

Resistivity(ρ): The electrical resistivity of a material is defined as the resistance of the material per unit length for unit cross-sectional area at a specified temperature**.** SI unit of resistivity is Ω m(ohm-metre).

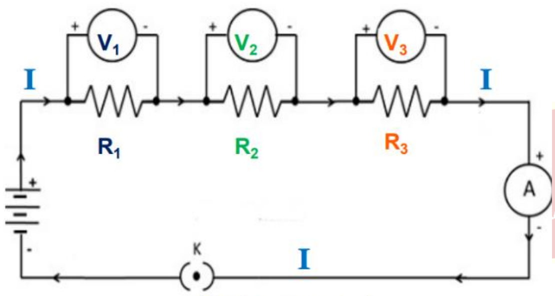
- Resistivity does not change with change in length or area of cross-section but it changes with change in temperature.
- Range of resistivity of metals and alloys is 10^{-8} to 10^{-6} Ωm.
- Range of resistivity of insulators is 10^{12} to 10^{17} Ωm.
- Resistivity of alloy is generally higher than that of its constituent metals.
- Alloys **do not oxidize (burn)** readily at high temperature, so they are commonly used in electrical heating devices.
- Copper and aluminium are used for electric wires as they have low resistivity.

Resistance of a system of resistors

Resistors are joined in two ways, i.e., in **series** and in **parallel**.

Resistors in Series

When resistors are joined from end to end, they are said to be in series combination



| Resistors in series |

When two or more resistors are connected in series:

- The **current** through the circuit remains the **same**.
- The **potential difference** becomes sum of the individual potential difference across each resistor.
- Total resistance of the circuit is the sum of individual resistances

Total resistance in series

In series combination, the current(I) remains the same, the potential difference(V) is different across each resistor.

From ohm's law,	When resistors are in series, potential difference gets added ,	Also the total potential difference in the circuit,
$V_1 = IR_1$ $V_2 = IR_2$ $V_3 = IR_3$ (i)	$V = V_1+V_2+V_3$ (ii)	$V = IR$ (iii)

From (i),(ii) & (iii)

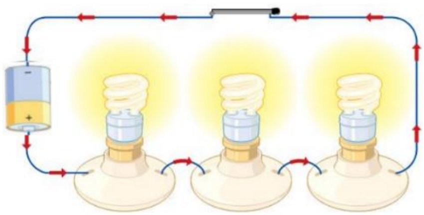
$V = V_1 + V_2 + V_3$

--> $IR = IR_1 + IR_2 + IR_3$

--> $R = R_1 + R_2 + R_3$

Total Resistance in series :

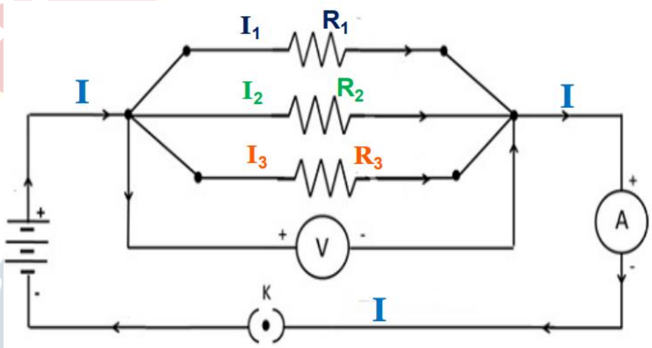
$R_s = R_1 + R_2 + R_3$



| Series connection of lamps |

Resistors in Parallel

A parallel circuit is a closed circuit in which the current divides into two or more paths before recombining to complete the circuit. Each device is connected in a separate path.



| Resistors in parallel |

When two or more resistors are connected in parallel:

- The **current** through the circuit is the sum of currents through each branch of the circuit.
- The **potential difference** across the two points of the circuit remains the **same**.
- The reciprocal of total resistance of the circuit is the sum of reciprocal of the individual resistances.

Total resistance in parallel

The current is different across the different branch of circuit, the potential difference remains the same.

From ohm's law,	When resistors are in parallel current gets added ,	Also the total current in the circuit,
$I_1 = V/R_1$ $I_2 = V/R_2$ $I_3 = V/R_3$ (i)	$I = I_1+I_2+I_3$ (ii)	$I = V/R$ (iii)

From (i),(ii) & (iii)

$I = I_1 + I_2 + I_3$

--> $V/R = V/R_1 + V/R_2 + V/R_3$

--> $1/R = 1/R1 + 1/R2 + 1/R3$

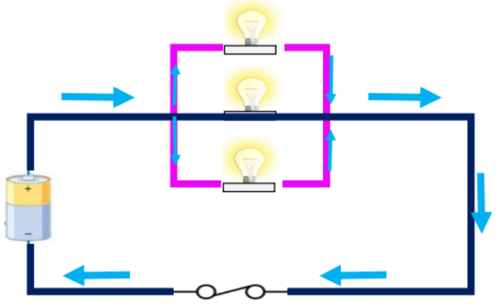
Total Resistance in parallel:

$$\frac{1}{Rp} = \frac{1}{R1} + \frac{1}{R2} + \frac{1}{R3}$$

Note: In parallel combination equivalent resistance is **less than** the value of the smallest individual resistance in the combination.

Advantages of Parallel Combination

- In series circuit, when one component fails, the circuit is broken and none of the component works.
- Different appliances have different requirement of current. This cannot be satisfied in series as current remains same.
- The total resistance in a parallel circuit is decreased.



| Parallel connection of bulbs |

Electric Power(P)

The rate of consumption of electric energy in an electrical circuit is known as electric power.

- **P = V x I**
- S.I. unit of power = Watt (W)
- 1 Watt = 1 volt × 1 ampere
- **Energy = Power x Time**
- Commercial **unit** of electric energy is **Kilo Watt hour (KWh)**
- 1 unit = 1 KWh = 3.6×10^6 Joules

Other formulas of power

- **Power** = $\frac{\textit{Energy Consumed}}{\textit{Time Taken}}$
- **Power = V^2 / R**
- **Power = I^2R**

Heating Effect of Electric Circuit

When an electric current passes through a conductor, the conductor becomes hot after some time and produces heat. This is called heating effect of electric current. For example, heating of electric iron, microwave oven, toaster, etc.

When an electric current passes through a conductor (such as a wire or a resistor), some of the electrical energy is transformed into heat energy.

This is explained by Joules law of heating.

Joule's Law of Heating Effect

Joule's law of heating states that the heat produced by a resistor is,

(i) directly proportional to square of current, **$H \propto I^2$**

(ii) directly proportional to resistance for a given current, **$H \propto R$**

(iii) directly proportional to time for which current flows through the conductor, **$H \propto t$**.

We get formula of heat: **$H = I^2Rt$**

Filament of electric bulb is made up of tungsten because it does not oxidise readily at high temperature it has high melting point.

Electric Fuse is a safety device that protects our electrical appliances in case of short circuit or overloading. It is made up of pure tin or alloy of copper and tin. It is always connected in series. Fuse has low melting point. Current capacity of fuse is slightly higher than that of the appliance.