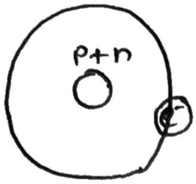
Electricity

Atom → Proton, Neutron } Bounded; → Electron → Revolving (sub-atomic particles)



Proton → +ve, $m_p = 1.67 \times 10^{-27}$ kg, $+1e = +1.6 \times 10^{-19}$ C

Electron → −ve, $m_e = 9.1 \times 10^{-31}$ kg, $-1e = -1.6 \times 10^{-19}$ C

Neutron → Changeless

⊙ Electric Charge

- Charge is the property associated with matter due to which it produces and experience electrical and magnetic effects. The excess or deficiency of electrons in a body gives the concept of charge.

  S.I Unit of charge - ampere second or Coulomb

  Practical Unit of charge - ampere × hour = (3600 C) and faraday

$$1 F = 96500 C$$

⇒ Types of Electric Charge

Charge (q)
- Positive ⇓ Deficiency of electrons
- Negative ⇓ Excess of electrons

⇒ Properties of Electric Charge

- Charge is a Scalar quantity.
- Charge is transferable.
- Charge is always associated with mass.
- When body is given positive charge, its mass decreases
- When body is given negative charge, its mass increases.
- Charge is quantized.
- Charge is conserved.
- Charge is invariant (Charge on a body does not change whatever be its speed.)
- Accelerated charge radiates energy.
- Like charges repel while unlike charges attract each other.

Properties of Electric charge

1) Quantisation of charge : Electric charge on a body is always an integral multiple of the smallest discrete value of charge (quanta of charge). A quanta of charge is the magnitude of charge which has a value. (1.6×10^{-19} C).

- Charge on an e^- is negative and that on proton is positive but both are equal in magnitude i.e., 1.6×10^{-19} C.

So charge on a body can be written as

$$\boxed{Q = \pm ne}$$ where $n = 1, 2, 3 \ldots$ { Remember n cannot be fractional }

2) Conservation of charge : for an isolated system (collection of matter), charge is always conserved. It can neither be neither be created nor be destroyed but can be transferred from one body to another.

3) Invariance of charge : Charge invariance refers to the fixed value of the charge of a particle regardless of its speed. for eg. an electron has a charge i.e., 1.6×10^{-19} C which is independent of its speed.

4) Additivity of charge : for an isolated system, the net charge is the algebraic sum of all the charges present in the system.

PARTICLE	CHARGE	MASS
PROTON	$+1.6 \times 10^{-19}$ C	1.6×10^{-24} g
NEUTRON	0	1.6×10^{-24} g
ELECTRON	-1.6×10^{-19} C	9.1×10^{-28} g
α - particle	$+3.2 \times 10^{-19}$ C	6.64×10^{-24} g

Q-1) A body is given +1C charge. How many electrons & protons are added or removed from the body.

$Q = ne$

∴ number of e^-s removed are, $n = \frac{Q}{e} = \frac{1\,C}{1.6 \times 10^{-19}} = 6.25 \times 10^{18}$.

Q-2) From the given set of charges, which charge is/are not possible?

a) 3.2×10^{-20} C (b) 6.4×10^{-18} C (c) 0.8×10^{-16} C (d) 12.8×10^{-19} C

⇒ from $Q = ne$

$n = \frac{3.2 \times 10^{-20}}{1.6 \times 10^{-19}}$

$= 2 \times 10^{-1}$

$= \frac{2}{10} = \frac{1}{5}$

⇒ $Q = ne$

$n = \frac{6.4 \times 10^{-18}}{1.6 \times 10^{-19}}$

$= 4 \times 10^{1}$

$= 40$

⇒ $Q = ne$

$n = \frac{0.8 \times 10^{-16}}{1.6 \times 10^{-19}}$

$= \frac{1}{2} \times 1000$

$= 500$

⇒ $Q = ne$

$n = \frac{12.8 \times 10^{-19}}{1.6 \times 10^{-19}}$

$= 8$

∴ b, c & d are possible as the value of n is an integer but in ⓐ it is in fraction, not possible.

- Study of electricity is divided into two parts :-
  i) Static electricity : deals with physical effects produced by charges at rest.
  ii) Current electricity : deals with physical effects produced by charges in motion.

⦿ CONDUCTORS AND INSULATORS

- Those substances which allow electric charges to flow through them.
  eg) copper, silver, Graphite, aq. solutions of salt. etc.
- Those substances which do not allow charges to flow through them. They can be charged by friction (by rubbing with other body).
  eg) Rubber, Glass, Plastic, wood etc.

⦿ ELECTRIC CURRENT (CHARGES IN MOTION)

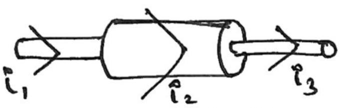
- The rate of flow of charges through any cross-section of a conductor is called electric current. If a net charge Q passes through a cross-section in time t, the current is :-

$$I = \frac{Q}{t} = \frac{\text{charge}}{\text{time}}$$

· S.I Unit → Ampere (A).

Q → Define 1 Ampere.
1 Ampere is the amount of current flowing in the circuit if 1C of charge moves across it in 1s.

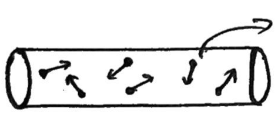
- Conventionally, direction of current is taken to be in the direction of flow of positive charge or opposite to the direction of flow of electrons.
- A conductor remains uncharged when current flows through it.
- For a given conductor, the current flowing through it does not vary as its cross-sectional area varies.



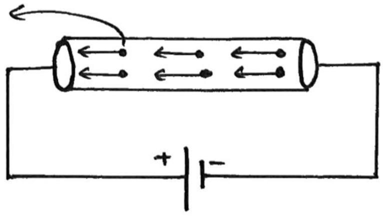
$i_1 = i_2 = i_3$ (conservation of charge)

- When one ampere current flows through a conductor, then 6.25×10^{18} electrons per second flow across any cross-section of the conductor.
- Electric current in a conductor is set up due to the organized motion of free electrons on applying an external source. (cell or battery)

free electrons



A conductor without a source (random motion)

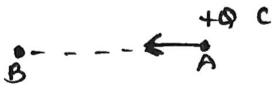


A conductor with a source. (organized motion)

⊙ ELECTRIC POTENTIAL AND POTENTIAL DIFFERENCE

- for flow of charges in a conducting metallic wire, the gravity of course has no role to play. The e⁻s move only due to difference of electric potential difference.
- Electric potential may be defined as the amount of work done in bringing a unit positive charge from infinity to a point under consideration.
- Electric potential difference between two points in an electric circuit may be defined as the amount of work done to move a unit positive charge from one point to another. Thus when a charge Q is moved from point A to point B in an electric circuit, W_{AB} is done, then potential difference between them is

$$V_B - V_A = \frac{W_{AB}}{Q}$$

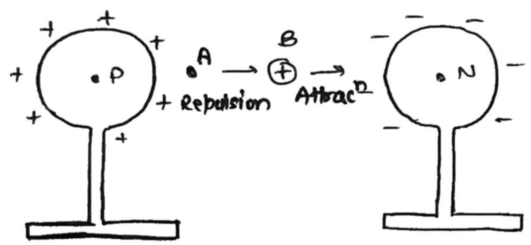


- Electric potential is a scalar quantity. [S.I Unit = Volt (V)]
- one volt → 1 V is the potential difference between two points when 1 J of work is done to move a charge of 1 Coulomb from one point to the other.

$$1 \text{ volt} = \frac{1 \text{ Joule}}{1 \text{ coulomb}}$$

⊙ FLOW OF CHARGE

- consider two metallic spheres P and N, carrying equal amounts of positive and negative charge. A positive charge particle is attracted by the negatively charged sphere N and repelled by the positively charged particle / sphere P. So to move the charge towards point A, one has to apply a force on it towards the left. Thus the work done is positive. Hence the potential difference $V_A - V_B$ is positive. It means $V_A > V_B$.



- As one move towards P, the work done increases. So the potential increases. And on moving towards N, the potential decreases.
- So the potential of P is higher than that of N.
- In general, a positively charged body is taken as higher than that of negatively charged body.
- Potential difference causes the charge to flow.

OHM'S LAW

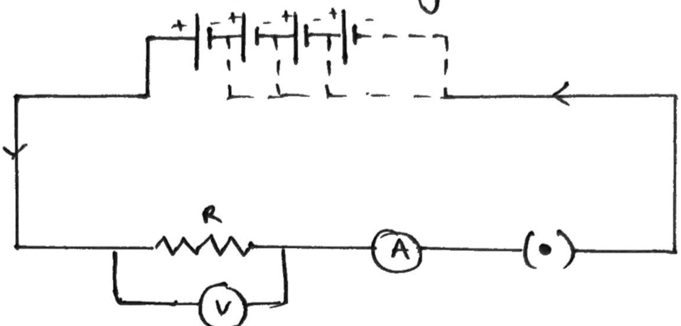
- If the physical quantity remain unchanged (such as temp.) the potential difference across the ends of a conductor is directly to the electric current flowing through it.

$V \propto I$

$\boxed{V = IR}$ where R is constant of proportionality and is called the resistance of the conductor. It resist the flow of charges through it.

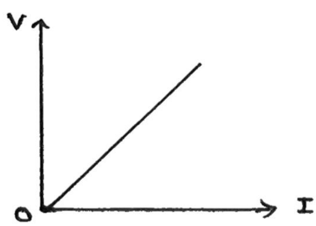
⇒ Verification of Ohm's law

- Setup an electrical circuit containing a resistor R, (eg metal wire)



- An Ammeter and Voltmeter is connected in the circuit so as to measure current across the resistor and the potential difference across it resp. Note down the value of A and V for the values of current through the resistance and potential difference across it.
- Connect more cells and repeat the procedure for different number of cells connected in the circuit.
- Find out the ratio of $\frac{V}{I}$ for every set of readings of the voltmeter and the ammeter. You will be getting the same ratio which is called the Resistance of the wire.
- By definition, the ratio $\frac{V}{I}$ is the electric resistance R of the conductor.

$R = \frac{V}{I}$ = constant
↓
straight line passing through origin.



- S.I Unit of Resistance is ohm. (Ω).
- The Resistance (R) of a conductor of uniform thickness depends on the length and area of cross-section.

$R \propto l$

$R \propto \frac{1}{A}$ ⇒ $R = \rho \frac{l}{A}$

ρ → 'Rho'
- Known as specific resistance or Resistivity of a conductor.

- Resistivity depends on nature of the material and not on its shape and size.
- Unit of Resistivity is Ω-m.

⊙ important points

1) Resistance of a material changes with its shape and size but its resistivity remains the same. Resistivity of different materials is different.

2) For a conductor, both resistance and resistivity increases with increase in temperature. The resistivity of various substances are related as :-

$$\rho_{insulator} > \rho_{semi\text{-}conductors} > \rho_{alloys} > \rho_{metals}$$

3) Range of resistivities :-

conductors – 10^{-8} to 10^{-6} Ωm
insulators – 10^{8} to 10^{16} Ωm
Semiconductors – 10^{-5} to 10^{-2} Ωm.

SOME IMP. ALLOYS
→ Constantan – Cu & Ni
→ Manganin – Cu, Mn, Ni
→ Nichrome – Ni, Cr, Mn, Fe

⊙ ELECTRICAL CIRCUITS

- A continuous or closed path of an electric current. It is a combination of some active and passive elements.
  - active: cell, battery, Generator
  - passive: ↳ Resistor, capacitor, inductor

⇒ SYMBOLS