UNIT 1

Electrostatics

ELECTRIC CHARGE

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

Properties of Charge

- Charge is a scalar quantity.
- **Charge is transferable :** If a charged body is put in contact with an uncharged body, the uncharged body becomes charged due to transfer of electrons from one body to the other.
- **Charge is always associated with mass,** *i.e.*, charge can not exist without mass though mass can exist without charge. So, the presence of charge itself is a convincing proof of existence of mass.
- **Quantization of charge :** Total charge on a body is always an integral multiple of a basic unit of charge denoted by e and is given by $q = ne$ where n is any integer, positive or negative and $e = 1.6\times10^{-19}$ C.
- The quantisation of charge was first suggested by Faraday. It was experimentally demonstrated by Millikan in 1912.
- The basic unit of charge is the charge that an electron or proton carries . By convention the charge on electron is $-e$ (-1.6×10^{-19} C) and charge on proton is $+e$ (1.6×10^{-19} C).
- **Additivity of charge :** Total charge of a system is the algebraic sum (*i.e.* sum is taking into account with proper signs) of all individual charges in the system.
- **Conservation of charge :** Total charge of an isolated system remains unchanged with time. In other words, charge can neither be created nor be destroyed. Conservation of charge is found to hold good in all types of reactions either chemical or nuclear.
- **Charge is invariant :** Charge is independent of the frame of reference.
- Like charges repel each other while unlike charges attract each other.
- **Methods of charging :** A body can be charged by
  - Friction
  - Induction
  - Conduction
- Charging by induction is preferred because one charged body can be used to charge any number of uncharged bodies without any loss of charge. If q be the source of charge, then charge induced on a body of dielectric constant K is given by

$$q' = -q\left(1-\frac{1}{K}\right)$$

For metals, $K = \infty \quad \therefore \quad q' = -q$

i.e., charges induced are equal and opposite only in case of conductors. In general, magnitude of induced charge is less than that of inducing charge.

Illustration 1

10^{12} α-particles (Nuclei of helium) per second falls on a neutral sphere. Find the time in which sphere gets charged by 2 μC.

Soln. : Number of α-particles falls in t second = $10^{12}t$

Charge on α-particle = $+2e$, So

Charge incident in time $t = (10^{12}t)(2e)$

$\because$ Given charge is 2 μC

$\therefore \quad 2\times10^{-6} = (10^{12}t)(2e)$

$$\Rightarrow \quad t = \frac{10^{-18}}{1.6\times10^{-19}} = 6.25 \text{ sec}$$

COULOMB'S LAW

- It states that the electrostatic force of interaction (repulsion or attraction) between two electric charges q_1 and q_2 separated by a distance r, is directly proportional to the product of the charges and inversely proportional to the square of the distance between them and acts along the straight line joining two charges.

  i.e., $F = K\dfrac{q_1q_2}{r^2}$

  where $K = \dfrac{1}{4\pi\varepsilon_0} = 9\times10^9$ N m^2 C^{-2}

  is the proportionality constant and

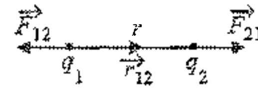
  $\varepsilon_0 = 8.854\times10^{-12}$ C^{2}N^{-1}m^{-1}

  is permittivity of free space.

  Coulomb's law in vector form

  $\vec{F}_{12}$ = force on q_1 due to q_2

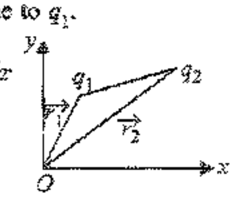
  $$= K\frac{q_1q_2}{r^2}\hat{r}_{21}$$



  $\vec{F}_{21} = \dfrac{Kq_1q_2}{r^2}\hat{r}_{21}$ = force on q_2 due to q_1.

  Here, $\hat{r}_{12}$ is unit vector from q_1 to q_2.

  Coulomb's law in terms of positive vector



  $$\vec{F}_{12} = K\frac{q_1q_2}{|\vec{r}_1-\vec{r}_2|^3}(\vec{r}_1-\vec{r}_2)$$