Electric Charge & Force

Charge

The charge is the property of matter due to which it produces and experiences electrical and magnetic effects. The study of electrical effect of charge at rest is called electrostatics.

The charge are produced on the body due to transfer of electrons. Positive charge results due to loss of electrons & negative charge results due to gain of electrons.

The SI unit of charge is coulomb and CGS units are esu and emu of charge. The relation among the units of charge is:

$$1 \text{ coulumb } = 3 \times 10^9 \text{ stat coulomb}$$
$$\text{esu of charge} = \frac{1}{10} \text{ emu of charge}$$

Properties of Charge

i. Charge is scalar and it is of two types: positive and negative. Hence it is added algebraically.
ii. Charge is transferable.
iii. Charge is always associated with mass: charge cannot exist without mass. Massless particle cannot bear charge equation photons.
iv. Charge is conserved: In an isolated system, the individual charge may charge but total charge cannot charge with time. This means, charge can neither be created nor be destroyed but transferred from one body to another.
v. Charge is quantized: The charge is always in the form of an integral multiple of electronic charge and never it's fraction.
   i.e. $q = \pm ne$
   where, n is an integer not fraction.
   $e = 1.6 \times 10^{-19} C$
   Recent theory predicts that there are particles called quarks, which carry ±e/3, ± echarges.
   This does not violet the quantization of charge as quarks do not exist in free states.
vi. Charge on the body does not change whatever be its speed.
vii. Accelerated charge radiates energy.
viii. Charge resides on outer surface of a conductor.

Induction

When a charged body is brought nearer to an neutral body, opposite charges are gathered at the nearer end, at the same instant, same charge is gathered at the farther end. This process is known as **electrostatic induction**.

Electrophorus is a device, which works on the principle of induction. It provides unlimited supply of charge. It is not a source of energy but is a device to convert mechanical energy to electrical energy. The principle of induction is used for charging GLE positively or negatively.

If q be the inducing charge, then the induced charge q' the body having dielectric constant K or ϵ_r is given by

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

for metal, $k = \infty, \quad q' = q$

This shows that the magnitudeof induced charge is less than that of inducing charge except for the conductors where the charges are equal and opposite.

According to Faraday's Ice-pail Experiment, on electrostatics induction:
Inducing charge = induced +ve charge
Inducing charge = induced –ve charge

Coulumb's Law

Force between two point charges at rest is given by:

$$F = K\frac{q_1 q_2}{r^2}$$

Where, r is distance between the charges. The value of constant K depends on system of units and medium present between charges.

In CGS, $K = 1$ so $F = \frac{q_1 q_2}{4\pi\epsilon_0 r^2}$ dyne.

In SI system, $K = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9$

So, $F = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}$ Newton.

Where $\epsilon_0 = 8.85 \times 10^{-12} C^2 N^{-1} m^{-2}$ or Farad/m is called permittivity of free space.

When charges are placed in medium, then force of attraction or repulsion can be given as:

$$F = \frac{1}{4\pi\epsilon_0\epsilon_r}\frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0 K}\frac{q_1 q_2}{r^2}$$

Where, $\epsilon_m = \epsilon_0 \quad \epsilon_r = \epsilon_0 K$

i.e. $K = \epsilon_r = \frac{\epsilon_m}{\epsilon_0}$ is called dielectric constant or relative permittivity of medium. Coulomb's force is two body interactions i.e. electrical force between two point charges is ndependent of presence or absence of other charges. So the principle of superposition is valid i.e. total force on a given charge is the vector sum of the individual forces exerted on the given charge by all the charges.

$$\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots\ldots + \vec{F}_n$$