CHARGE and COLOMB'S LAW

Study of stationary electric charges at rest is known as **electrostatics**.

Electric Charge :

i) It is a fundamental property of matter and never found free.

ii) There are two kinds of charges namely positive and negative. If a body has excess of electrons, it is said to be **negatively charged** and if it is deficient in electrons, it is said to be **positively charged**.

iii) Benzamin Frankline introduced the concept of positive and negative charges.

iv) Repulsion is the sure test for the detection of a charge.

v) In S.I. system the unit of charge is **coulomb.**

vi) Charge is **scalar quantity**.

vii) Like charges repel and un-like charges attract.

viii) Charge is conserved. It can neither be created nor destroyed. It can only be transferred from one object to other.

ix) Charge is quantised. The smallest charge is associated with electron (–) and proton (+) is 1.6×10^{-19} coulomb.

x) All charges in nature exist as integral multiples of electron charge. q = n.e. n $\rightarrow$ Integer

xi) A coulomb is equivalent to a charge of 6.243×10^{18} electrons.

xii) When a body is positively charged, its mass slightly decreases

xiii) When a body is negatively charged, its mass slightly increases.

xiv) In the case of a conductor, its charge spreads over the entire outer surface and in the case of an insulator, its charge is localised

xv) Charge given to a conductor always resides on the outer surface of the conductor only.

Charging of bodies :

i) The process of making a neutral body into a charged body is known as **electrification**

ii) Electrification is universal phenomenon

iii) A body can be charged by any one of the following three ways :

(a) friction (b) contact and

(c) electrostatic induction

Charging by friction :

i) The electricity (i.e., transfer of electrons) that is produced due to friction is called **frictional electricity**

ii) When we rub two neutral bodies, there will be some transfer of electrons from one body to the other due to structural modifications because of the frictional forces acting on them.

iii) In this method one of the bodies acquires a negative charge while the other gets a positive charge, both of which are equal in magnitude.

Eg: a) When a glass rod is rubbed with silk cloth, glass acquires positive charge and silk cloth acquires negative charge. Electrons are removed from glass rod and are added to silk cloth.

b) When an ebonite rod is rubbed with fur cloth, ebonite rod acquires negative charge and fur cloth acquires positive charge. Electrons are transferred from fur cloth to ebonite rod.

iv) The list of substances called electric series given below is arranged in such a manner that if any two of them rubbed together, the one occurring earlier would be positively charged.

1. Glass	2. Flannel	3. Wool
4. Silk	5. Sealing wax	6. Hard metal
7. Hard rubber	8. Resin	9. Sulphur, etc.

Eg: If we select glass and silk, glass will acquire a positive charge while silk will get a negative charge when glass rod is rubbed with silk

Charging by contact :

i) A neutral body can be charged by making contact with a charged body.
ii) Here the body will acquire a charge that is the same as that of the charging body.
iii) Thus by contact a similar charge is formed on both the bodies.
iv) In this method first body's charge decreases.

Charging by electrostatic induction :

i) Induction always precedes attraction
ii) Polarisation of charges in a body when a charged body is present near that is called **induction**.
iii) In induction, a charged body is brought near an uncharged body. Then the uncharged body acquires a charge opposite in sign to that of the charged body.

Induced charge on dielectric slab of dielectric constant K is $q^1 = -q\left[1-\frac{1}{K}\right]$.

For metals K = □□□□□ $q^1 = -q$.

iv) Without a decrease in the charge of the body, which induces by the method of induction, bodies can be charged continuously.

Conductors , insulators and semiconductors:

i) A body in which electric charge can easily flow through is called **conductor** (e.g. metals).
ii) A body in which electric charge cannot flow is called **insulator** or **dielectric**. (e.g. glass, wool, rubber, plastic, etc.)
iii) Substances which are intermediate between conductors and insulators are called **semiconductors**.(e.g. silicon, germanium, etc)

Electroscope :

i) An **electroscope** is used to detect the charge on a body.
ii) **Pith ball electroscope** is used to detect a charge and to know the nature of the charge.
iii) **Gold leaf electroscope** which was invented by Bennet detects a charge and the nature of the charge and determines the quantity of the charge.

Coulomb’s law :

i) The force of attraction or repulsion between two charged bodies is directly proportional to the product of their charges and inversely proportional to the square of the distance between them.

ii) It acts along the line joining the two charges considered to be point charges.

iii) $F \propto \dfrac{q_1 q_2}{d^2}$

iv) $F = \dfrac{1}{4\pi\varepsilon_o\varepsilon_r} \cdot \dfrac{q_1 q_2}{d^2}$ (or) $F = \dfrac{1}{4\pi\varepsilon_o K} \cdot \dfrac{q_1 q_2}{d^2}$ (or) $F = \dfrac{1}{4\pi\varepsilon} \cdot \dfrac{q_1 q_2}{d^2}$

a) where ε is **absolute permittivity**,
K or ε_r is the **relative permittivity** or **specific inductive capacity** and ε_o is the **permittivity of free space**.

b) K or ε_r is also called as **dielectric constant** of the medium in which the two charges are placed.

v) a) **Relative permitivity of a material =** $\varepsilon_r = K = \dfrac{\text{Force between two charges in air}}{\text{Force between the same charges in the medium at the same distance}}$

$$\varepsilon_r = \frac{F_a}{F_m}$$

b) For air K = 1

c) For metals K = infinity

d) Force between 2 charges depends upon the nature of the intervening medium , where as gravitational force is independent of intervening medium.

vi) For air or vacuum, $F = \dfrac{1}{4\pi\varepsilon_o} \cdot \dfrac{q_1 q_2}{d^2}$

since for air or vacuum, $\varepsilon_r = K = 1$

vii) The value of $\dfrac{1}{4\pi\varepsilon_o}$ is equal to $9\text{x}10^9$ Nm^2/C^2.

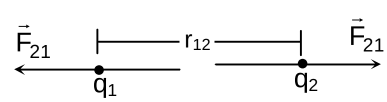
viii) A coulomb is that charge which repels an equal charge of the same sign with a force of $9\text{x}10^9$ N when the charges are one metre apart in vacuum.

ix) The value of ε_o is 8.86×10^{-12} C^2/Nm^2 (or) 8.86×10^{-12} Fm^{-1}

x) Coulomb force is conservative mutual and internal force.

xi) Coulomb force is true only for static charges.

Coulomb’s law in vector form :



1) $\vec{F}_{12} = \dfrac{1}{4\pi\epsilon_0} - \dfrac{q_1 q_2}{r_{12}^2}\hat{r}_{12}$; $\vec{F}_{12} = -\vec{F}_{21}$

Here F_{12} is force exerted by q_1 on q_2 and F_{21} is force exerted by q_2 on q_1.

2) Coulomb’s law holds for stationary charges only which are point sized.

3) This law obeys Newton’s third law $\left(\text{ie } \vec{F}_{12} = -\vec{F}_{21}\right)$.

Principle of Superposition of Electric Forces

Force on a charged particle due to a number of point charges is the resultant of forces due to individual point charges i.e. $\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ...$

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i) If the force between two charges in two different media is the same for different separations, $F = \frac{1}{K}\frac{1}{4\pi \in_0}\frac{q_1 q_2}{r^2}$ = constant .

ii) Kr^2 = constant or $K_1 r_1^2 = K_2 r_2^2$

iii) If the force between two charges separated by a distance 'r_0' in vacuum is same as the force between the same charges separated by a distance 'r' in a medium, $Kr^2 = r_0^2 \Rightarrow r = \frac{r_0}{\sqrt{k}}$

Applications

a) Two identical conductors having charges q_1 and q_2 are put to contact and then separated, then each have a charge equal to $\frac{q_1 + q_2}{2}$. If the charges are q_1 and $-q_2$, then each have a charge equal to $\frac{q_1 - q_2}{2}$.

b) Two spherical conductors having charges q_1 and q_2 and radii r_1 and r_2 are put to contact and then separated then the charges of the conductors after contact are

$$q_1 = \left(\frac{r_1}{r_1 + r_2}\right)(q_1 + q_2) \;\&\; q_2 = \left(\frac{r_2}{r_1 + r_2}\right)(q_1 + q_2).$$

c) The force of attraction or repulsion between two identical conductors having charges q_1 and q_2 when separated by a distance d is F. If they are put to contact and then separated by the same distance the new force between them is $F' = \frac{F(q_1 + q_2)^2}{4q_1 q_2}$

If charges are q_1 and $-q_2$ then $F' = \frac{F(q_1 - q_2)^2}{4q_1 q_2}$.

d) Between two electron separated by a certain distance $\frac{\text{Electrical force}}{\text{Gravitational force}} = 10^{42}$

Between two protons separated by a certain distance $\frac{\text{Electrical force}}{\text{Gravitational force}} = 10^{36}$

Between a proton and an electron separated by a certain distance $\frac{\text{Electrical force}}{\text{Gravitational force}} = 10^{39}$

e) The relationship between velocity of light, permeability of free space and permittivity of free space is given by the expression $c = 1/\sqrt{(\mu_o \varepsilon_o)}$.

f) If two identical balls each of mass m are hung by silk thread of length 'ℓ' from a same hook and carry similar charges q then.

g) The distance between balls = $\left[\frac{q^2 2\ell}{4\pi \epsilon_0 mg}\right]^{1/3}$

h) The tension in the thread = $\sqrt{(F)^2 + (mg)^2}$

i) If total system is kept in space then angle between threads is 180° and tension in thread is given by T = $\frac{1}{4\pi \epsilon_0} \frac{q^2}{4\ell^2}$

A charge Q is divided into q and (Q – q). Then electrostatic force between them is maximum when $\frac{q}{Q} = \frac{1}{2}$ (or) $\frac{q}{(Q-q)} = 1$