* Electric charges :- The gravitational force of attraction between two electrons placed 1 cm apart is

$$F_G = \frac{G m_1 m_2}{r^2}$$

$$= \frac{6.67 \times 10^{-11} \times (9.1 \times 10^{-31})^2}{(10^{-2})^2} \text{ N}$$

$$= 5.5 \times 10^{-67} \text{ N.}$$

But an electron is found to repel another electron at 1 cm with a force of .

$$F_E = 2.3 \times 10^{-24} \text{ N}$$

This extra force is called the electric force. The electric force is very large as compared to the gravitational force. The electron must have some additional property, apart from their mass, which is responsible for the electric force. This additional property is known as charge. Just as masses are responsible for the gravitational force, charges are responsible for the electric force.

** Charges are of two types
(a) Positive charge : lesser number of electrons than number of protons.

(b) Negative charge: More number of electrons than number of protons.

*Note: Only electrons are responsible for a substance to be charged and not the protons.

** Properties of charge:-

(i) Like charges repel while unlike charge attract each other

(ii) Charge is quantized in nature, i.e the magnitude of charge possessed by different objects is always an integral multiple of charge of electron (or proton) i.e the charge of any object

$Q = \pm ne$ n is an integer.

where $n = 1, 2, 3, 4 \ldots\ldots$

(iii) The minimum possible charge that can exist in nature is the charge of electron which has a magnitude of $e = 1.6 \times 10^{-19} C$. This is also known as quantum of charge or fundamental charge.

(v) The charge of an isolated system is conserved. It is possible to create or destroy charged particles but it is not possible to create or destroy net charge.

* S.I unit of charge is coulomb
* cgs unit of charge is e.s.u. (stat coulomb).

$$1 \text{ coulomb} = 3 \times 10^{9} \text{ esu.}$$

** Coulomb's law :- The force of interaction between any two points are directly proportional to the product of the charges and inversly proportional to the square of the distance between them. The force act along the line joining the two points. If q_1 and q_2 are the two charges seperated by the distance r then the force acting between the two charges is given by

$$F \propto \frac{q_1 q_2}{r^2}$$

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

where $K = \frac{1}{4\pi \epsilon_0 \epsilon_r}$

$\because \epsilon_r$ = relative permittivity

$$\frac{1}{4\pi \epsilon_0} = 9 \times 10^{9} \ N m^2 \ \text{coulomb}^{-2}$$

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

*** Factors affecting coulomb's law :-

* Electric force between two charges not depends upon the neighbouring charges.

* When two charges (Q_1, Q_2) are placed some distance apart. Neutral point is nearer to the smaller charge and in between Q_1 and Q_2 if charges are like and away from smaller charge if charges are unlike.

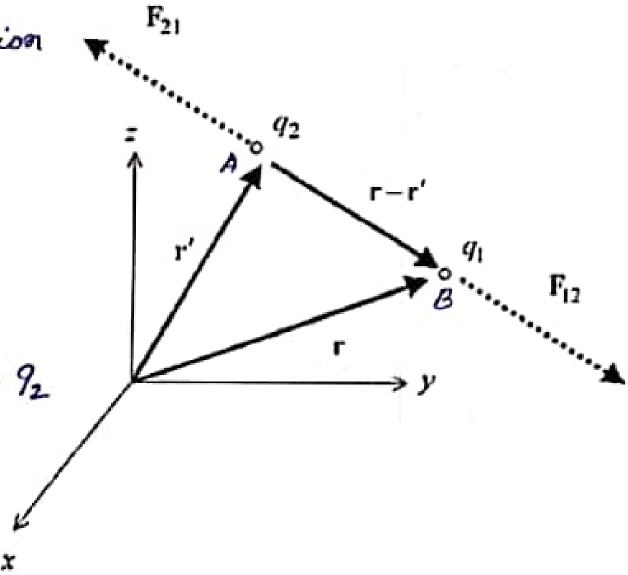
* This law is valid only for stationary charges and cannot be applied for moving charges.

* This law is valid only if the distance between two charges is not less than 10^{-15} m.

** Coulomb's law in vector form:–

$$\vec{F}_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{|\vec{r}-\vec{r}'|^2}\hat{r}_{21} \longrightarrow (1)$$

$\hat{r}_{21}$ unit vector along the direction $\vec{AB}$.



Now $|\vec{r}-\vec{r}'|\,\hat{r}_{21} = \vec{r}-\vec{r}'$

$\therefore (1) \Rightarrow \vec{F}_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{|\vec{r}-\vec{r}'|^3}\,(\vec{r}-\vec{r}')$

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

Similarly

$$\vec{F}_{21} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{|\vec{r}-\vec{r}'|^2}\hat{r}_{12}$$

$$= \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{|\vec{r}-\vec{r}'|^2}(-\hat{r}_{21}) = -\vec{F}_{12}$$

$\Rightarrow \vec{F}_{21} = -\vec{F}_{12}$

$\vec{F}_{21}$ force on charge q_2 due to q_1.

** Force between multiple charges (Superposition principle):–

Superposition principle states that the total force on any charge due to a number of other charges at rest is the vector sum of all the forces on the charge due to other charges, taken one at a time. The force due to individual charges are unaffected due to the presence of other charges.

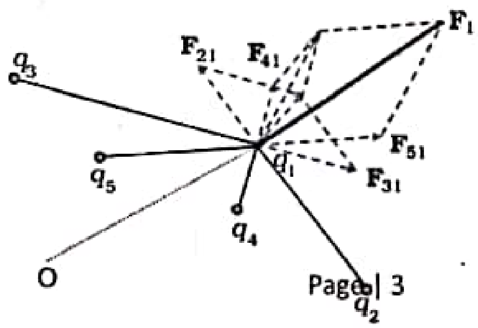
Force on q_1 due to the charge q_2 is $\vec{F}_{12}$

$$\vec{F}_{12} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12}$$

Similarly, force on q_1 due to q_3 is $\vec{F}_{13}$

$$\vec{F}_{13} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_3}{r_{13}^2}\hat{r}_{13}$$

and So on



∴ The net force $\vec{F_1}$ on the charge q_1 due to all other charges is given by

$$\vec{F_1} = \vec{F_{12}} + \vec{F_{13}} + \vec{F_{14}} + \cdots + \vec{F_{1n}}$$

$$\therefore \vec{F_1} = \frac{1}{4\pi\epsilon_0}\left\{ \frac{q_1 q_2}{r_{12}^2}\hat{r}_{12} + \frac{q_1 q_3}{r_{13}^2}\hat{r}_{13} + \cdots + \frac{q_1 q_n}{r_{1n}^2}\hat{r}_{1n} \right\}$$

$$\vec{F_1} = \frac{q_1}{4\pi\epsilon_0}\sum_{i=1}^{n}\frac{q_i}{r_{1i}^2}\hat{r}_{1i}$$

** Dielectric constant :—

Let two charge particles q_1 and q_2 are seperated by a distance 'r' in a medium of permittivity ϵ. Then the force acting between the two charge particles is

$$\vec{F_m} = \frac{1}{4\pi\epsilon}\frac{q_1 q_2}{r^2}\hat{r} \longrightarrow (1)$$

If the same two charge particles are held at the same distance in vacuum then the force between the same particles is

$$\vec{F_0} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}\hat{r} \longrightarrow (2)$$

Now

$$(2) \div (1) \Rightarrow \frac{\vec{F_0}}{\vec{F_m}} = \frac{\epsilon}{\epsilon_0} = \epsilon_r$$

ϵ_r is called relative electrical permittivity of the medium or dielectric constant of the medium.

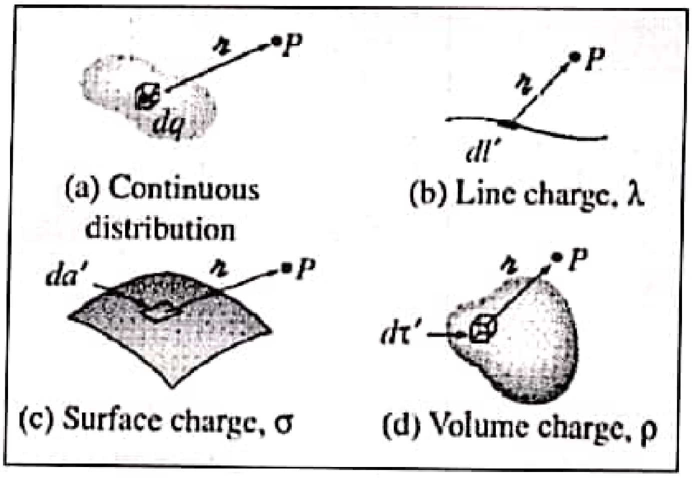
Hence,

Dielectric constant of a medium is the ratio of absolute electrical permittivity of the medium to the absolute permittivity of free space.

Dielectric constant of a medium may also defined as the ratio of force of interaction between two charges seperated by a certain distance in air/vacuum to the force of attraction repulsion between the same two charges, held in the same distance apart in the medium.

Dielectric constant depends only on the nature of medium.

** Continous charge distribution :-



*Linear charge distribution: When the charges are distributed linearly, the total charge dq over a small length dl' is given by

$$dq = \lambda dl'$$

where λ is the line charge density. unit of λ : Cm^{-1}

* Surface charge distribution : when the charges are distributed uniformly over a surface, then the total charge dq over the small area da' is given by

$$dq = \sigma ds'$$

where σ is the surface charge density, unit of σ is Cm^{-2}.

* Volume charge distribution :- When the charges are distributed uniformly over a volume $d\tau'$, then the total charge over the volume $d\tau'$ is given by

$$dq = \rho d\tau'$$

where ρ is the volume charge density, unit of ρ is Cm^{-3}.

** Electric field :- A charge produces something called an electric field in the space around it and this electric field exerts a force on any charge placed on it.

The electric field due to a given charge is the space around the charge in which electrostatic force of attraction or repulsion due to the charge can be experienced by any other charge.

* Note :- 1. For measuring $\vec{E}$ practically a test charge (+ve) of magnitude much less than the source charge should be used.

* Note : 2 Electric force on a charge in uniform E is constant and hence acceleration is constant, so equation of motion can be used as

$$a = qE/m$$

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