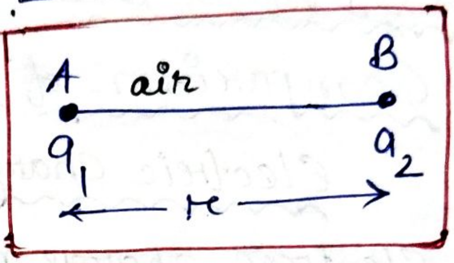
* Coulomb's law of Electric force:

It states that the force of attraction or repulsion between two stationary point charge is directly proportional to the product of the magnetudes of the two charges and inversely proportional to the square of the distance between them, ie.-



$F \propto |q_1||q_2|$

and $F \propto \frac{1}{r^2}$

Combining the above two factors-

$F \propto \frac{q_1 q_2}{r^2}$ r = distance betn the charges.

$\Rightarrow F = K \frac{q_1 q_2}{r}$ K = electrostatic force constant.

where-

$K = \frac{1}{4\pi\epsilon_0}$ ϵ_0 = electric permitivity of free space or air.

$= 9\times10^9 \, Nm^2/C^2$ $= 8.85\times10^{-12} \, C^2/Nm^2$

1 Coulomb: If $q_1 = q_2 = 1c$ and $r = 1m$

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

$\Rightarrow F = 9\times10^9 \times \frac{1\times1}{1^2}$

$\Rightarrow F = 9\times10^9 \, N$

~~So one coulomb is that amount of charge that repels and similar (equal) charge in vacuum at~~

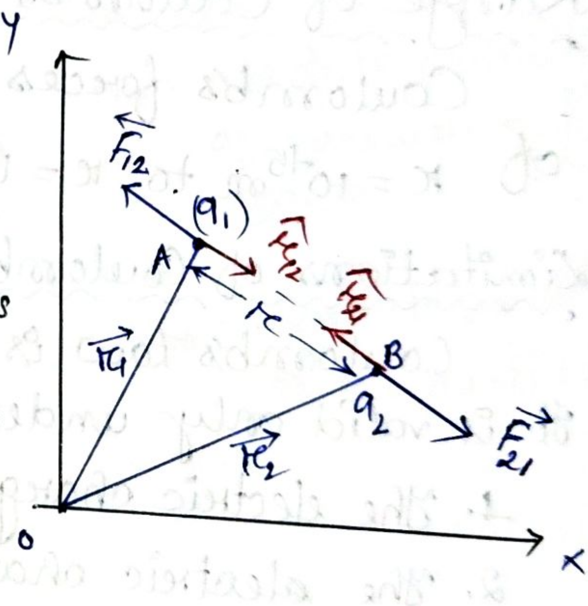
1 Coulomb:
So, one coulomb is that amount of charge that repels an equal and similar charge with a force 9×10^9 N when placed in vacuum at a distance of 1m from it.

1 e.s.u: One state coulomb is that charge which repels an identical charge in vacuum at a distance of 1cm with a force of 1 dyne.

$$1 \text{ coulomb} = 3\times10^9 \text{ state coulomb}$$

* Coulomb's law in vector form:

Consider two point charges q_1 and q_2 at points A and B respectively as shown in the fig.



In vector form, the Coulomb's force on the charge q_2 due to q_1 can be expressed as –

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

$$= \frac{K q_1 q_2}{r^2}\hat{r}_{12} \rightarrow (I)$$

Similarly, force on q_1 due to q_2 will be –

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

$$= \frac{K q_1 q_2}{r^2}\hat{r}_{21} \rightarrow (II)$$

Here $|\vec{r_{12}}| = |\vec{r_{21}}| = r$

$\hat{r}_{12}$ = unit vector in the direction from q_1 to q_2

and $\hat{r}_{21}$ = unit vector in the direction from q_2 to q_1

but $\hat{r}_{12} = -\hat{r}_{21}$

LHS $\vec{F}_{12} = \frac{Kq_1q_2}{r^2}\hat{r}_{21}$

$= \frac{Kq_1q_2}{r^2}(-\hat{r}_{12})$ [using equtⁿ ①]

$= -\frac{Kq_1q_2}{r^2}\hat{r}_{12}$

$$\Rightarrow \vec{F}_{12} = -\vec{F}_{21}$$ ← Newton's 3rd law from coulombs law.

Range of Coulomb's force:

Coulomb's forces can act over a range of $r = 10^{-15} m$ to $r = 10^{18} m$.

Limitations of Coulomb's law:

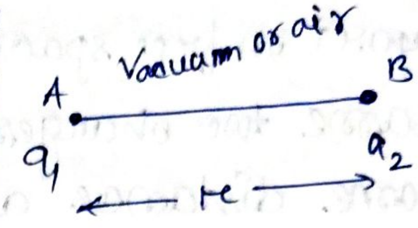
Coulomb's law is not applicable in all conditions. It is valid only under the following conditions –

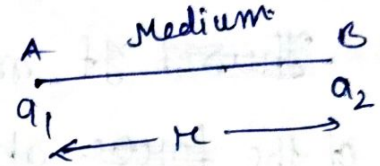
1. The electric charges must be at rest.
2. The electric charges must be point charges.
3. The separation between the charges must be greater than $10^{-15} m$ (the nuclear size) because for distance less than $10^{-15} m$ the strong nuclear force dominates the electrostatic force.

* Dielectric constant or relative permitivity :

Permitivity is a property of a medium which determines the electric force between two charges situated in that medium.

Let us first place two point charges q_1 and q_2 at a distance r in vacuum or air then the Coulomb's force betⁿ them will be -





~~$F = K q_1 q$~~

$$F_{vac} = \frac{1}{4\pi\epsilon_0} \cdot \frac{q_1 q_2}{r^2}$$

where -

ϵ_0 = absolute permitivity of vacuum or free space

Now, if the same two charges q_1 and q_2 are placed in a medium at a distance r then, the Coulomb's force betⁿ them will be -

$$F_{med} = \frac{1}{4\pi\epsilon_m} \frac{q_1 q_2}{r^2}$$

and -

ϵ_m = absolute permitivity of the medium.

Now -

$$\frac{F_{vac}}{F_{med}} = \frac{\frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2}}{\frac{1}{4\pi\epsilon_m} \frac{q_1 q_2}{r^2}}$$

$$\Rightarrow \frac{F_{vac}}{F_{med}} = \frac{1/\epsilon_0}{1/\epsilon_m}$$

$$= \frac{\epsilon_m}{\epsilon_0}$$

$= \epsilon_r$ or K

= dielectric constⁿ or relative permitivity of the medium.

Thus the dielectric constant or relative permittivity of a medium may be defined as the ratio of the force between two charges placed same distance apart in free space to the force between the same two charges when they are placed the same distance apart in the given medium.

or

~~Thus~~ It may also be defined as the ratio of the ~~force~~ absolute permittivity (ϵ_m) of the medium to the permittivity (ϵ_0) of free space.

$$\epsilon_r = K(\text{vacuum}) = 1$$

$$K(\text{air}) = 1.00054 \approx 1$$

$$K(\text{water}) = 80$$

* Similarities betn Electrostatic and Gravitational force

(i) Both forces obey inverse square law, $F \propto \frac{1}{r^2}$

(ii) Both are central force

(iii) Both are conservative force

(iv) Both forces can operate in vacuum.

Dissimilarities:

(i) Gravitational force is always attractive but electrostatic force maybe attractive or repulsive.

(ii) Gravitational force does not depends on the nature of the medium betn the masses but electrostatic force depends upon the medium betn the charges.

(iii) Electrostatic force ~~was~~ is much stronger than Gravitational force.