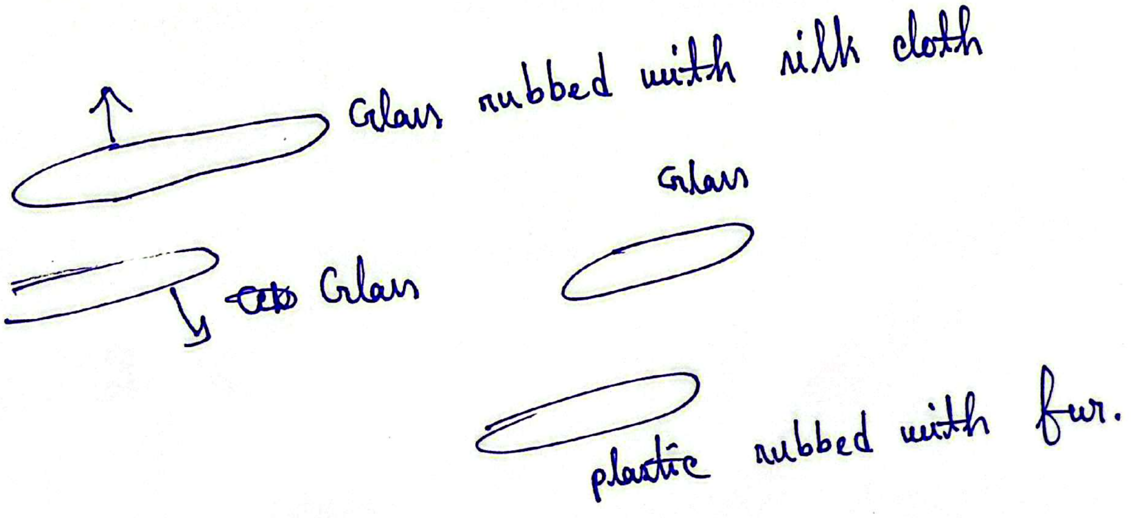
Electric Charge and Coulomb's Law

* Charge is fundamental / intrinsic property of fundamental Particles.
* The attraction between the comb and the hair is a result of some physical entity being transferred from one to the other when they rub together, with the same physical entity being transferred back again to neutralize the attraction when they come into contact. This physical entity is called ~~charge.~~ electric charge.
* As there are two kinds of forces, we conclude that there are two kinds of charges. (Unit coulomb)
* positive and negative charge.
* Charges of the same signs repel one another, and charges of the opposite sign attract one another.



Quantization of Charge: Experiments show ~~that~~ the electric charge always exists only in ~~quantity~~ quantities that are integer multiples of a certain elementary quantity of charge e. That is,

$$q = ne \quad , \quad n = 0, \pm 1, \pm 2, \pm 3 \cdot \cdots$$

$$e = 1.602 \times 10^{-19} \, C. \; [\text{Elementary Charge}]$$

Conservation of Charge: In any process occuring in an isolated system the net initial charge must equal the net final charge.

$$\Sigma q = \cancel{0} \text{ constant or } \cancel{q} \; q_i = q_f .$$

Conductors and Insulators:

⇒ Conductors are materials through which charge can move rather freely.

⇒ Insulators are materials through which charge can not move freely.

Coulomb's Law:

$$|\vec{F}| = K \frac{|q_1 q_2|}{r^2} \quad \text{[From Experiment]}$$

q_1 and q_2 are the magnitudes of the charges.

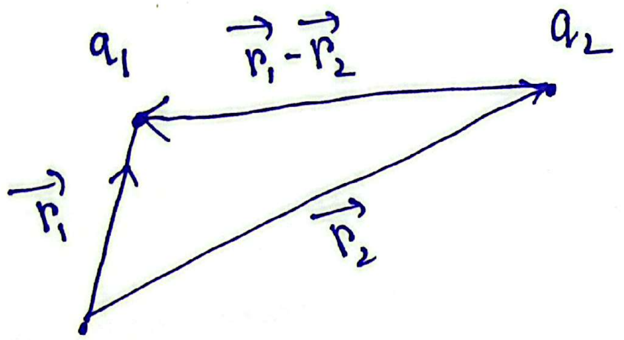
r = distance bet^n the charges.

$$K = 9 \times 10^9 \ Nm^2/c^2 = \frac{1}{4\pi\epsilon_0}$$

$$\epsilon_0 = 8.85 \times 10^{-12} \ c^2/Nm^2$$

Permittivity of free space

Vector form:



$$\vec{r}_{12} = \vec{r}_1 - \vec{r}_2$$

$$\hat{r}_{12} = \frac{\vec{r}_{12}}{|\vec{r}_{12}|} = \frac{\vec{r}_1 - \vec{r}_2}{|\vec{r}_1 - \vec{r}_2|}$$

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

Force on particle 1 exerted by particle 2.

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

$$\cancel{\Phi_{21}} \ \hat{r}_{21} = \frac{\vec{r}_2 - \vec{r}_1}{|\vec{r}_2 - \vec{r}_1|}$$

$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} + \vec{F}_{14} + \cdots$$

$$= \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r_{12}^2} \hat{r}_{12} + \frac{1}{4\pi\epsilon_0} \frac{q_1 q_3}{r_{13}^2} \hat{r}_{13} + \cdots$$

$$= \frac{q_1}{4\pi\epsilon_0} \sum \frac{q_i}{r_{1i}^2} \hat{r}_{1i} .$$

Charge Problem Sol^n

1.) $$F_E = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_2}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{q^2}{r^2}$$

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

$$\therefore \frac{F_E}{F_g} = 3.1 \times 10^{35} .$$

2) Let the proton be placed at x distance from the origin.

$$F_{p1} = \frac{1}{4\pi\epsilon_0} \left| \frac{q_1 e}{x^2} \right|$$

$$F_{p2} = \frac{1}{4\pi\epsilon_0} \left| \frac{q_2 e}{(x-L)^2} \right|$$

$\therefore F_{p1} = F_{p2}$

$\Rightarrow \quad x = 2L$

3) $q = ne$

$\Rightarrow n = \frac{q}{e} = 3.$

4) For the first arrangement,

$$F_{12} = \frac{1}{4\pi\epsilon_0} \frac{|q_1 q_2|}{R^2} = 1.15 \times 10^{-24} \text{ N}.$$

$$\vec{F}_{12} = -(1.15 \times 10^{-24} \text{ N})\hat{i}$$

For the second arrangement,

$$F_{13} = \frac{1}{4\pi\epsilon_0} \frac{|q_1 q_3|}{(3/4 R)^2} = 2.05 \times 10^{-24} \text{ N}.$$

$$\vec{F}_{13} = (2.05 \times 10^{-24} \text{ N})\hat{i}$$

$$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13} = (9 \times 10^{-25} \text{ N})\hat{i}.$$

For the third arrangement,

$$F_{14} = \frac{1}{4\pi\epsilon_0} \frac{q_1 q_4}{(3/4 R)^2}$$

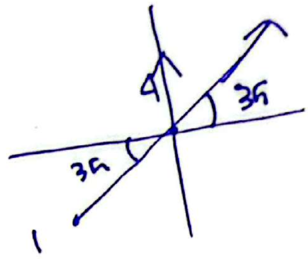
$$\vec{F}_{14} = F_{14} \cos\theta \, \hat{i} + F_{14} \sin\theta \, \hat{j}$$

$$= (1.025 \times 10^{-24} \text{ N})\hat{i} + (1.775 \times 10^{-24} \text{ N})\hat{j}$$

$$\therefore \vec{F}_1 = \vec{F}_{12} + \vec{F}_{14} = (-1.25 \times 10^{-25} \text{ N})\hat{i} + (1.178 \times 10^{-24} \text{ N})\hat{j}$$

5]

$$\vec{F}_4 = \vec{F}_{41} + \vec{F}_{42} + \vec{F}_{43}$$



$$\vec{F}_{41} = F_{41}\cos\theta\,\hat{i} + F_{41}\sin\theta\,\hat{j}$$

$$\vec{F}_{42} = F_{42}\,\hat{j}$$

$$\vec{F}_{43} = F_{43}\,\hat{i}$$

$\therefore \vec{F}_4$