ENTRI

ELECTRIC CHARGE

- Electric Charge : Charge is the property associated with matter due to which it produces and experiences electrical and magnetic effects. The excess or deficiency of electrons in a body gives the concept of charge.

Properties of Charge

- Charge is a scalar quantity.
- Charge is transferable : If a charged body is put in contact with an uncharged body, the uncharged body becomes charged due to transfer of elecfrons from one body to the other.
- Charge is always associated with mass, i.e., charge can not exist without mass though mass can exist without charge. So, the presence of charge itselfis a convincing proofofexistence of mass.
- Quantization of charge : Total charge on a body is always an integral multiple ofa basic unit ofcharge denoted by e and is given by q = ne where n is any integer, positive or negative and e = 1.6 x C.
- The quantisation of charge was first suggested by Faraday. It was experimentally demonstrated by Millikan in 1912.
- The basic unit of charge is the charge that an electron or proton carries . By convention the charge on electron is —e (—1 .6 x 10-19 C) and charge on proton is +e (l .6 x 10-19 C).
- Additivity of charge : Total charge ofa system is the algebraic sum (i.e. sum is taking into account with proper signs) of all individual charges in the system.
- Conservation of charge : Total charge ofan isolated system remains unchanged with time. In other words, charge can neither be created nor be destroyed. Conservation of charge is found to hold good in all types ofreactions either chemical or nuclear.
- Charge is invariant : Charge is independent on the frame of reference.
- Like charges rgpel each other while unlike charges attract each other.

- Methods of charging :

A body can be charged by
Friction
Induction
Conduction

Charging by induction is preferred because one charged body can be used to charge any number ofuncharged bodies without any loss of charge. If q be the source of charge, then charge induced on a body of dielectric constant K is give

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

For metals, K $= \infty$ ∴

i.e., charges induced are equal and opposite only in case of conductors. In general, magnitude of induced charge is less than that of inducing charge.

Illustration 1

10^{12} a-particles (Nuclei of helium) per second falls on a neutral sphere. Find the time in which sphere gets charged by 2 mC.

Soln. : Number of a-particles fall o in t second = $10^{12}t$

Charge on a-panicle = +2e, So

Charge incident in time t = $(10^{12}t)(2e)$

∵ Given charge is 2 PC

∴ $2 \times 10^{-6} = (10^{12}t)\cdot(2e)$

$$t = \frac{10^{-18}}{1.6 \times 10^{-19}} = 6.25 \text{ sec}$$

COULOMB'S LAW

- It states that the electrostatic force of interaction (repulsion or attraction) between two electric charges qi and separated by a distance r, is directly proportional to the product ofthe charges and inversely proportional to the square ofthe distance between them and acts along the straight line joining two charges.

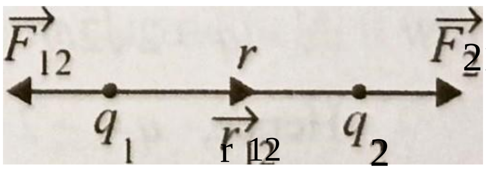
i.e., K 2

1 where K = 9 x 109 N m2 C-2

is the proportionality constant and % x 10-12 $C^2N^{-1}m^{-1}$ is permittivity of free space.

Couloinb's law in vector form

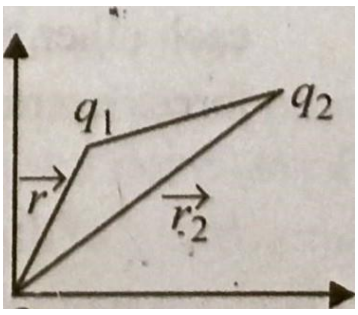
F12 = force on qi due to q_2



= K —ühl

21 — 2 r21 = force on due to qr

Here, r12 is unit vector from to (12. Y



Coulomb's law in terms of positive vector

$$\vec{F}_{12} = K \frac{q_1 q_2}{|\vec{r}_1 - \vec{r}_2|^3} (\vec{r}_1 - \vec{r}_2)$$

x o

lh -F2 1

- Comparison between Coulomb force and gravitational force are as follows :

  Coulomb force and gravitational force follow the same inverse square law.

  Coulomb force can be attractive or repulsive while gravitational force is always attractive.

  Coulomb force between the two charges depends on the medium between two charges while gravitational force is independent of the medium between the two bodies.

  fie ratio of coulomb force to the gravitational force between two protons at a same distance apart is

$$\frac{e^2}{4\pi\varepsilon_0 G m_p m_p} = 1.3 \times 10^{36}$$

Illustration 2

Electric force between two point charges and at rest is F. Now if a charge —q is placed next to . What will be the (a) force on q2 (b) total force on %?

Soln. : (a) As electric force between two body interaction i. e., force between two particles is independent of presence or absence of other particles, the force between % and will remain unchanged, i.e., F.

(b) An electric force is proportional to the magnitude of charges, total force on % will be given by

F' _ Chq' _ q' _ 0

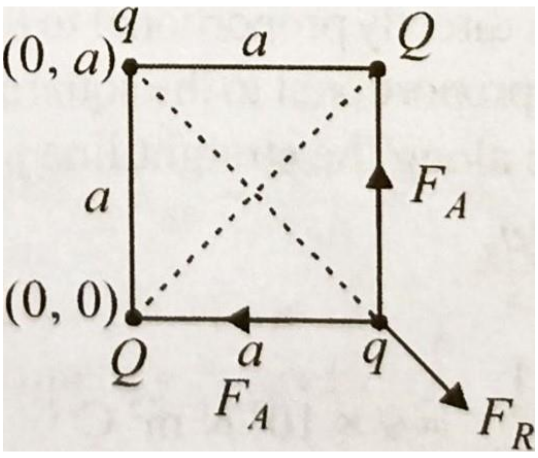
[as $q' = q + (-q) = 0$]

F Chq q q

Hence, the resultant force on % will be zero.

Illustration 3

For the system shown in figure. Find Q for which resultant force on q is zero.



Soln.: For force on q to be zero, charges q must be of opposite of nature.

Net attraction force on q due to Q = repulsion force due to q

$\sqrt{2}F_A = F_R \Rightarrow \sqrt{2}$ KQq _ Kq 2 a2 (Uäa)2

$$q = 2\sqrt{2}Q$$

Hence, q = 2UäQ