BASIC PROPERTIES OF ELECTRIC CHARGE

If the sizes of charged bodies are **very small** as compared to the **distances** between them, we treat them as **point charges**. All the charge content of the body is assumed to be concentrated at one **point** in space.

Additivity of charges

Charge has **magnitude but no direction**, similar to the **mass**. However, there is one difference between mass and charge. Mass of a body is always **positive** whereas a charge can be either **positive or negative**. Proper signs have to be used while adding the charges in a system.

The total charge of the system is the algebraic sum of the individual charges of the system

Charge is conserved

Within an **isolated** system consisting of **many charged bodies**, due to **interactions** among the bodies, charges may get **redistributed** but it is found that the **total charge** of the isolated system is **always conserved**

Quantisation of charge

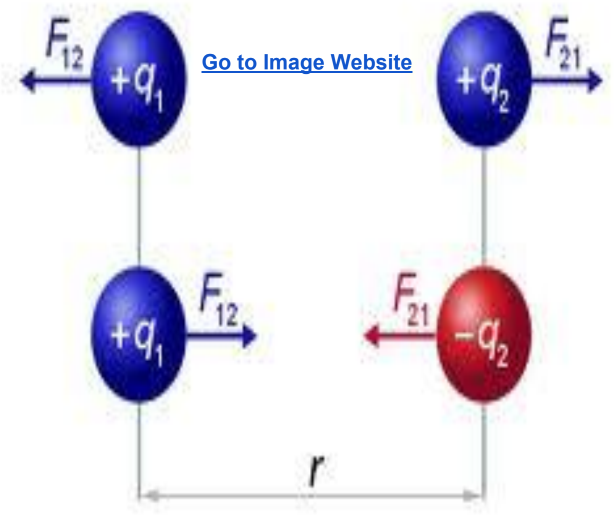
Experimentally it is established that all free charges are **integral multiples** of a basic unit of charge denoted by **e**. Thus charge q on a body is always given by $q = ne$, $n = 1, 2, 3 \ldots\ldots\ldots$

$$e = 1.602192 \times 10^{-19}\ C$$

The **basic unit of charge** is the charge that an **electron** or **proton** carries. By **convention**, the charge on an **electron** is taken to be **negative**; therefore charge on an electron is written as **–e** and that on a proton as **+e**.

If the protons and electrons are the only basic charges in the universe,all the **observable charges** have to be **integral multiples of e**.

COULOMB'S LAW



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$$F_{12} = F_{21} = k\frac{q_1 q_2}{r^2}$$

Coulomb measured the **force** between **two point charges** and found that it varied **inversely** as the *square of the distance* between the charges and was d**irectly proportional** to the *product of the magnitude of the two charges* and acted along the line joining the two charges.

ε_0 is the Permittivity of the free space

$$F = \frac{1}{4\pi\varepsilon_0} \frac{|q_1 q_2|}{r^2}$$

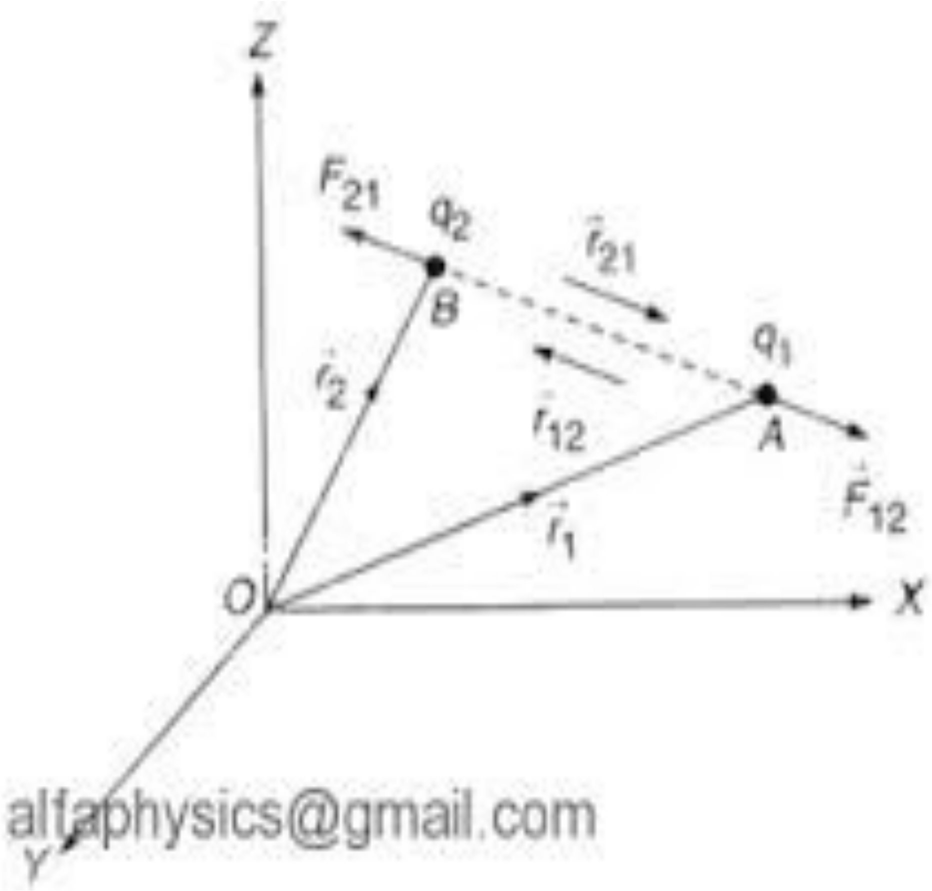
$\varepsilon_0 = 8.854 \times 10^{-12}\ C^2\ N^{-1}\ m^{-2}$

If we put $q1 = q2 = 1$ C and $r = 1$ m
We get $F = 9 \times 10^9$ N

That is, 1 C is the charge that when placed at a distance of 1 m from another charge of the same magnitude in vacuum experiences an electrical force of repulsion of magnitude **9×10^9 N.**

One coulomb is evidently too **big** a unit to be used. In practice, electrostatics, one uses **smaller** units like 1 mC or 1 μC.

Coulomb's Law in Vector Form



$$r_{21} = r_2 - r_1$$

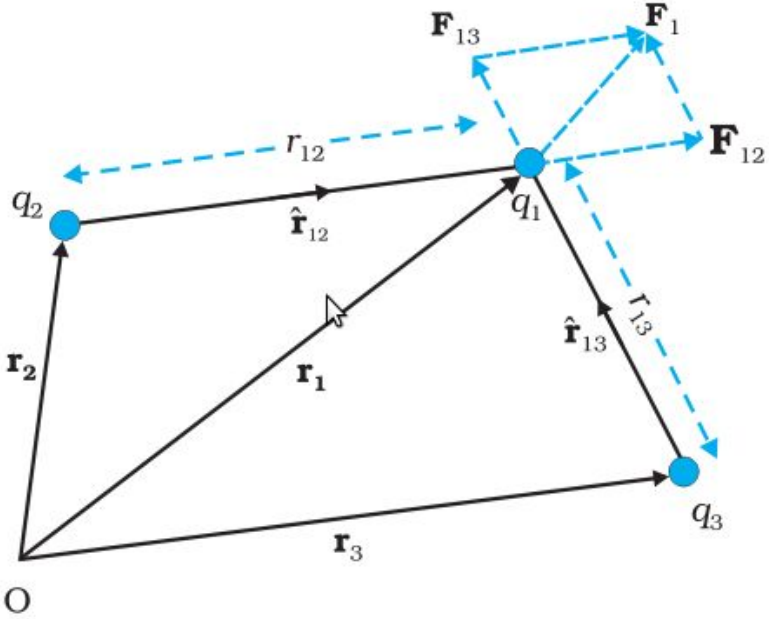
$$r_{12} = r_1 - r_2 = - r_{21}$$

$$\mathbf{F}_{21} = \frac{1}{4\pi\varepsilon_0} \frac{q_1 \, q_2}{r_{21}^2} \hat{\mathbf{r}}_{21}$$

Coulomb’s law agrees with the Newton’s third law

$$\mathbf{F}_{12} = \frac{1}{4\,\pi\,\varepsilon_0}\;\frac{q_1\;\;q_2}{r_{12}^2}\;\hat{\mathbf{r}}_{12} = -\mathbf{F}_{21}$$

FORCES BETWEEN MULTIPLE CHARGES



$$\mathbf{F}_1 = \mathbf{F}_{12} + \mathbf{F}_{13} + \ldots + \mathbf{F}_{1n}$$

$$= \frac{1}{4\pi\varepsilon_0}\left[\frac{q_1 q_2}{r_{12}^2}\hat{\mathbf{r}}_{12} + \frac{q_1 q_3}{r_{13}^2}\hat{\mathbf{r}}_{13} + \ldots + \frac{q_1 q_n}{r_{1n}^2}\hat{\mathbf{r}}_{1n}\right]$$

$$= \frac{q_1}{4\pi\varepsilon_0}\sum_{i=2}^{n}\frac{q_i}{r_{1i}^2}\hat{\mathbf{r}}_{1i}$$

All of electrostatics is basically a consequence of Coulomb's law and the superposition principle.