Coulomb's Law

Coulomb's Law states that the force between two point charges $Q1$ and $Q2$ is directly proportional to the product of the charges and inversely proportional to the square of the distance between them. Point charge is a hypothetical charge located at a single point in space. It is an idealised model of a particle having an electric charge.

Mathematically, $F = \frac{kQ_1Q_2}{R^2}$, where k is the proportionality constant.

In SI units, $Q1$ and $Q2$ are expressed in Coulombs(C) and R is in meters.

Force F is in Newtons (N) and $k = \frac{1}{4\pi\varepsilon_0}$ is called the permittivity of free space.

(We are assuming the charges are in free space. If the charges are any other dielectric medium, we will $\varepsilon = \varepsilon_0 \varepsilon_r$ instead where ε_r is called the relative permittivity or the dielectric constant of the medium).

Therefore $F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{R^2}$ .... (2.1)

As shown in the Figure 1.1 let the position vectors of the point charges

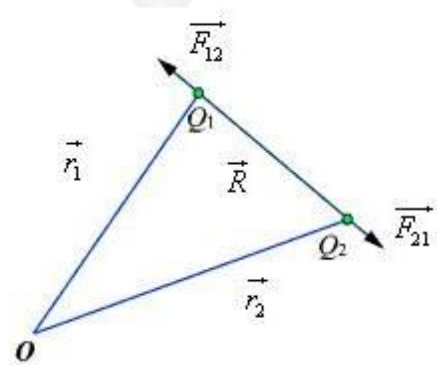

Fig 1.1: Coulomb's Law
(www.brainkart.com/subject/Electromagnetic-Theory_206/)

$\vec{r}_1$ $\vec{r}_2$ $\overrightarrow{F_{12}}$

$Q1$ and $Q2$ are given by and . Let represent the force on $Q1$ due to charge $Q2$.

The charges are separated by a distance of $R = \left|\vec{r_1} - \vec{r_2}\right| = \left|\vec{r_2} - \vec{r_1}\right|$. We define the unit vectors as

$$\widehat{a_{12}} = \frac{\left(\vec{r_2} - \vec{r_1}\right)}{R} \qquad \widehat{a_{21}} = \frac{\left(\vec{r_1} - \vec{r_2}\right)}{R}$$

.... (2.2)

$\vec{F_{12}}$ can be defined as .

$$\vec{F_{12}} = \frac{Q_1 Q_2}{4\pi\varepsilon_0 R^2}\widehat{a_{12}} = \frac{Q_1 Q_2}{4\pi\varepsilon_0 R^2}\frac{\left(\vec{r_2} - \vec{r_1}\right)}{\left|\vec{r_2} - \vec{r_1}\right|^3}$$

due to charge $Q2$ can be calculated and if $\vec{F_{21}}$ represents this force then we can write

$$\vec{F_{21}} = -\vec{F_{12}}$$

When we have a number of point charges, to determine the force on a particular charge due to all other charges, *we apply principle of superposition*. If we have N number of charges

$Q1, Q2, ...QN$ located respectively at the points represented by the position vectors $\vec{r_1}$,

,...... $\vec{r_N}$, the force experienced by a charge Q located at $\vec{r}$ is given by,

$$\vec{F} = \frac{Q}{4\pi\varepsilon_0}\sum_{i=1}^{N}\frac{Q_i\left(\vec{r} - \vec{r_i}\right)}{\left|\vec{r} - \vec{r_i}\right|^3}$$

...................................(2.3)