COULOMB'S LAW:

Charles-Augustin de coulomb discovered this law, which states that the force between two Static point charges is inversely proportional to the square of the distance between the Charges and is directly proportional to the product of the magnitude of the two charges and the force acts along the line joining the two charges.

Mathematically, if Q_1 and Q_2 are two point charges separated by distance r, then the Electrostatic force between them is,

$$F \propto Q_1 Q_2 \quad \text{... (1)}$$

$$F \propto \frac{1}{r^2} \quad \text{... (2)}$$

By combining the equation and equation, we get,

$$F \propto \frac{Q_1 Q_2}{r^2}$$

$$F = \frac{k_e Q_1 Q_2}{r^2}$$

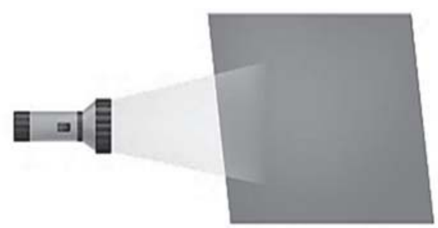
Where k_e is the proportionality constant known as coulomb's constant the electrostatic force (f) as defined looks similar to the gravitational force between two masses defined by, $F = \frac{GM_1M_2}{r^2}$. The comparison between the expression of the electrostatic force and the gravitational force is given.

Quantity	Electrostatic force	Gravitational force
Expression of force	$F = \frac{GM_1M_2}{r^2}$	$F = \frac{k_e Q_1 Q_2}{r^2}$
Applicability	Force of interaction between static point charges	Force of interaction between masses
Nature	Attractive or repulsive	Always attractive
Comparable strength	Stronger	Weaker
Nature of proportionality constant	It can be shielded that means depends on the medium	Universal

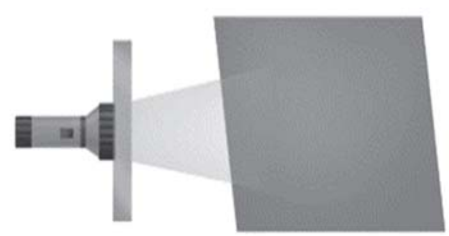
Coulomb's constant:

It does not matter where the masses are; be it at the ground, underwater, or even outer space, the gravitational force is always the same, but it is not true for the electrostatic force. It is different in different mediums.

Consider that a light beam from a torch is falling on a surface as shown in the figure.



Now, if the medium is changed, i.e., we put something in between the torch and the surface (say a glass slab), the intensity of light falling on the surface gets reduced.



Similarly, the electrostatic force also varies with the medium, and the way it varies is given by the constant ke we saw earlier. From this discussion it may seem to you that it is not a constant after all. Then why is it known as a constant? It is because it is constant for a given medium.

The coulomb constant k_e is defined as $k_e = \frac{1}{4\pi\varepsilon}$ where ε is known as the permittivity of the medium, and it is the deciding factor of the coulomb's constant.

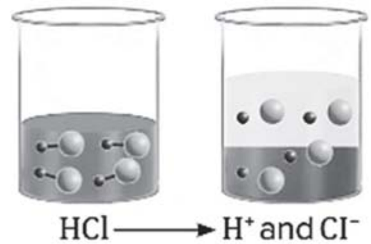
In the case of vacuum, the permittivity of the medium is given by,

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

Therefore, the value of coulomb constant at vacuum is, $k_e = 9 \times 10^9 Nm^2C^{-2}$

Relative Permittivity:

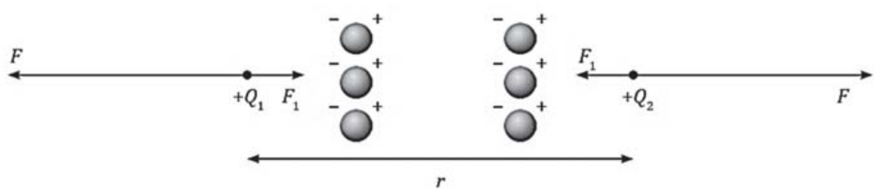
If the permittivity of vacuum is denoted by ε_0 and the permittivity of any medium is denoted by ε, then the relative permittivity (or dielectric constant) of the given medium is defined by the following expression: $\varepsilon_r = \frac{\varepsilon}{\varepsilon_0}$



The physical significance of the relative permittivity or the dielectric constant is the ability of a medium to ionise whatever is put inside it. For example, when hydrochloric acid (HCL) is mixed with water, the hcl molecule gets ionised as H^+ and Cl^- because the dielectric constant for water is 81. Hence, the electrostatic force between the ions is reduced by 81.

Force experienced by two point charges placed in a medium:

It may seem that the force between two point charges placed in a medium other than the vacuum changes from what was the force between them in vacuum. However, this statement is incomplete. The correct statement is that the force between two charges placed in a medium other than vacuum does not change from what was the force between them in vacuum, but the force experienced by each charge alone in totality changes. To understand this statement clearly, let us consider the scenario shown in the figure.



In This Figure, The Yellow Particles Are The Charged Particles Of The Medium. Here, F is The Force on Q_1 Due To Q_2 and Vice Versa, And F_1 Is the Force on the Charges by the Medium.

Therefore, the net force on the charge is,

$$F_{net} = (F - F_1) < \frac{k_e Q_1 Q_2}{r^2}$$