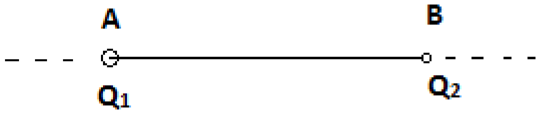
What is Coulomb's law?

It gives you the force of attraction or repulsion between two point charges.

Its characteristics:

It forms an action-reaction pair.

It is along the line joining the two charges, attractive or repulsive depending on the nature of the charges.



If Q_1 and Q_2 both are positive, force on Q_1 due to Q_2 will be along the line AB but directed from B to A.

Force on Q_2 due to Q_1 will also be along the line AB but directed from A to B.

These two forces will be equal in magnitude and opposite in direction.

The force on Q_1 or Q_2 will also depend on the medium in which these two charges are immersed. If they are in vacuum, this force is given by $F = \frac{1}{4\pi\varepsilon_0}\frac{Q_1Q_2}{d^2}$ where d is the separation between the two charges and ε_0 is the permittivity of free space with value 8.854×10^{-12}

(Permittivity is the ability of any medium to resist the formation of an electric field by any charge. It is a measure of how much electric field is generated per unit charge in that medium.)

If the charges are in air, we take the value of ε_0 to be almost same.

If the force between two charges kept at a certain distance in air is F, the force between them when kept at the same distance in any other medium is $\frac{F}{\varepsilon_r}$ where ε_r is the relative permittivity of the medium or also called as dielectric constant of the medium. (It is a measure of how easily an insulating material can be polarized under the influence of an electric field)

What is Electric field? It is a region or space in which a charge will experience an electrostatic force. It is a vector quantity.

Strength of the electric field at a point: It is the force experienced by a unit positive charge kept at that point. The magnitude and direction of the force is the same as that of the strength of the electric field. It is also called as Intensity of the electric field.

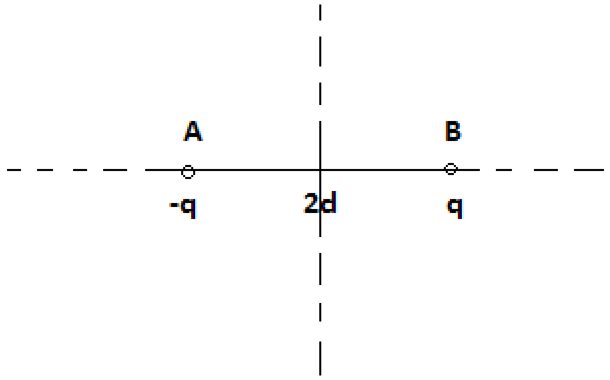
If the strength of the electric field at a point is E, then the force experienced by a charge Q placed at that point is QE.

Electric flux through a given area: It is the count of the number of lines of force through the area. As the lines of force are imaginary and cannot be literary counted, the mathematical approach for finding the flux through a given area is $\oint \vec{E}\cdot d\vec{s}$ where E is the intensity of the electric field, ds is the elemental area or small area. The special integral symbol indicates that it is not an integration to be carried along a line but along a surface.

Gauss's theorem: $\oint \vec{E}\cdot d\vec{s} = \frac{1}{\varepsilon_0}Q$ Remember that the E on the left hand side is the resultant electric field and the charge on the right hand side is only the charge enclosed by the Gaussian surface.

The Gaussian surface can be of any shape. Imagine a hollow cube with a charge Q placed in it. The flux coming out of the cube will be $\frac{1}{\varepsilon_0}Q$. If another charge Q_1 is placed outside the cube, the flux coming out of the cube will still remain the same as the contribution to the flux coming out of a closed surface by a charge outside the surface is zero. No doubt the electric field E in the first case will be only due to Q, but in the second case with another charge Q_1 placed outside, will be due to both Q and Q_1.

Electric dipole: Two equal and opposite charges held separated by a finite distance constitutes an electric dipole.



Points to be remembered: AB is the axial line. Line perpendicular to AB and passing through the midpoint of AB is called equatorial line.

Dipole moment: It is a vector quantity with magnitude q (2d) and direction from negative charge to positive charge. It is denoted by $\vec{p}$.

Find the field on the axial line and on the equatorial line using definition of electric field strength and Coulomb's law and check for yourself that if the distance of the point, from the midpoint of the dipole, where the field is written, is much larger than the distance 2d then, field on the axial line is double the field on the equatorial line. Also note that the direction of the field on the axial line is along the dipole moment and that on the equatorial line is opposite to the dipole moment.

Electric potential at a point: It is the work done by an external agent in bringing a unit positive charge from infinity to that point in the electric field without changing the kinetic energy.

Relation between electric field strength and potential at a point: $\vec{E} = -\frac{dV}{d\vec{r}}$

What is a Capacitor? It is a device in which electrostatic energy can be stored and retrieved.

A parallel plate capacitor has two large conducting plates with area A each, held separated by a small distance d (distance is small in comparison with the dimension of the plate) with one plate given a positive charge and the other an equal negative charge.

The electric field in between the plates is $\frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}$ where the two terms are contribution made by each plate. ($\sigma = \frac{Q}{A}$)

The potential difference between the two plates is $\frac{\sigma}{\varepsilon_0}(d)$

Force exerted by one plate on the other is, field created by the plate multiplied by the charge on the other. $\frac{\sigma}{2\varepsilon_0}Q$

If electric field in a region is E, the energy density (electrostatic potential energy per unit volume) in that region is $\frac{1}{2}\varepsilon_0 E^2$. In a given volume, the energy stored can be found by multiplying the energy density with the volume.

Hence the energy stored in between the two plates of a parallel plate capacitor is $\frac{1}{2}\varepsilon_0 E^2 (Ad)$.