UNIT - 4

ELECTROSTATICS

4.1 Fundamental Electrostatic Phenomena

Introduction

The branch of physics which deals with the electricity at rest is called electrostatics. In this chapter we deal with the characters and behaviours of charges. According to modern theory of electrification, when two bodies of different nature are rubbed together there is a transfer of electrons of outer-most orbits of one body to another body. The body which gains electrons is negatively charged and the other body which loses electrons is positively charged.

Properties of electric charge

i) Like charges repel one another and unlike charges attract each other.

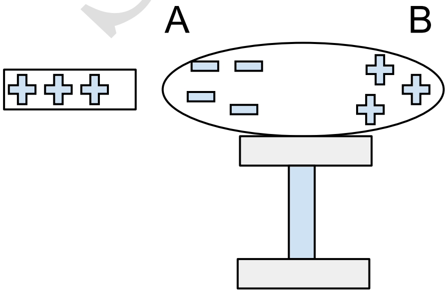
ii) Charge of any body is the integral multiples of the basic unit of charge which is known as quantization of charge.

iii) The total charge of an isolated system remains constant which is known as conservation of charge.

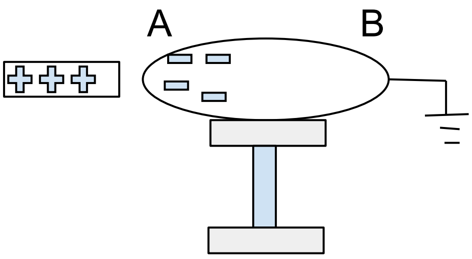
iv) Although it has direction, even then it does not follow laws of vector algebra. So, it is a scalar quantity.

4.2 Changing a Body by Induction

The temporary electrification of a body by bringing a charged body close to the body is called electrostatic induction. The charges in the charged body which cause the other body to be charged are called inducing charges. Similarly, the charges developed in the uncharged body by induction are called induced charges. For charging a body negatively by induction, following steps should be followed;

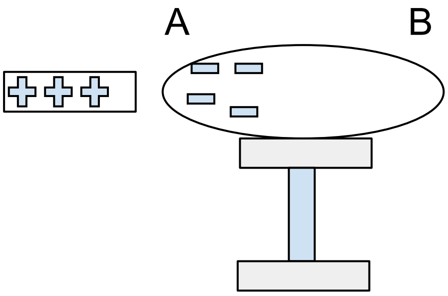


i) If a positively charged glass rod is brought near a body AB, the end A of the body acquires bound negative charge and another end B acquires free positive charge due to induction as shown in figure.

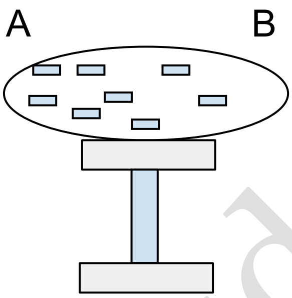


ii) The body AB is earthed with the help of the metal wire. Here free positive charge flows to the earth.

iii) The earthing is removed keeping the glass rod still in its position as shown in figure.



iv) Finally, the positive charged glass rod is removed away from the body AB. The bound negative charge spreads over the whole surface of the body AB as shown in figure. Hence the body AB becomes. negatively charged by induction.



Surface density of charge

The distribution of charges on a surface is characterized by surface charge density at the point on the surface. The surface charge density of a charged conductor is defined as the charge per unit surface area of the conductor. If the charge q is distributed on surface area A of a conductor, the surface charge density (δ) is given by:

$$\delta = \left(\frac{q}{A}\right)$$

4.3 Electric Field and Potential

Coulomb's law

It states that, "the magnitude of force between two charges is directly proportional to the product of the two charges and inversely proportional to the square of the distance between the charges". Consider two charges q_1 and q_2 separated by a distance r. Then, according to Coulomb's law, the force (F) between the charges is:

i) Directly proportional to q_1 and q_2.

i.e $F \alpha q_1 q_2$..................(i)

ii) Inversely proportional to r

i.e $F \alpha \frac{1}{r^2}$..............(ii)

From (i) and (ii):

$F \alpha \frac{q1\, q2}{r^2}$

$F = \frac{q1\, q2}{r^2}$

Where k is the proportionality constant whose value depends upon the medium in which the changes are placed.

The value of k is $\frac{1}{4\pi E0}$

$F = \frac{1}{4\pi E0} \frac{q1q2}{r^2}$...........(iii)

Electric field and electric field intensity

An electric field is defined as the region where electric force can be experienced by point charge. The electric field intensity at a point in the space around a charge is defined as the electrostatic force experienced by a unit positive charge placed at the point. It is denoted by E and given by:

$E = \frac{q}{4\pi E0 r^2}$

Electric lines of force and flux

An electric line of force in an electric field is defined as the imaginary line along which a free unit positive charge moves. It starts from a positive charge and ends with a negative charge. The electric lines of force do not intersect each other. Similarly, the total number of electric lines of force passing through an area is called flux (ϕ). In fact, the electric field intensity (E) can be expressed in terms of flux.

i.e. $E = \frac{\phi}{A}$

Where, A is the area

Electric potential

Electric potential at a point is defined as the work done to bring a unit positive charge from infinity to the point inside the electric field. It is denoted by v and given by;

$v = \frac{q}{4\pi E0r}$

Potential difference

The potential difference between two points in an electric field is defined as the amount of work done in bringing a unit positive charge from one point to the other point.

Let P and Q be two points which are at distance r, and r_2 respectively from the charge +q place at point A as shown in figure. Then potential at P and Q be;

$Vp= \frac{q}{4\pi E0r}$

And $v_Q = \frac{q}{4\pi E0r1}$

Hence, potential difference between P and Q be;

$V_{PQ} = Vp-V_Q$

$V_{PQ} = \frac{q}{4\pi E0}\left(\frac{1}{r1} - \frac{1}{r2}\right)$

4.4 Capacitor

Introduction

The bodies which are specially designed for storing charge are called capacitors. Hence, it is a device to store charge. It consists of two conducting plates separated by an insulator or vacuum.

Capacitance of a capacitor

The capacitance of a capacitor is its ability to store charges. If q is the charge stored in a capacitor, when its potential difference is V, then, it is found that charge stored is directly proportional to potential difference.

i.e. $q \alpha V$

or, $q = CV$

Where C is the proportionality constant called capacitance of the capacitor. The unit of capacitance is called farad (F).

Uses of capacitor

There are many uses of capacitors. Some of them are given below;

- They can be used for storing charge.
- They can be used for increasing AC power.
- They are used in scientific investigation.

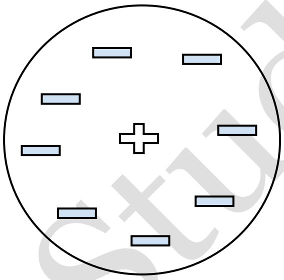
Dielectrics

Dielectrics are the substances which do not conduct electric charges but allow to induce charges on them when placed in an electric field. They are two types;

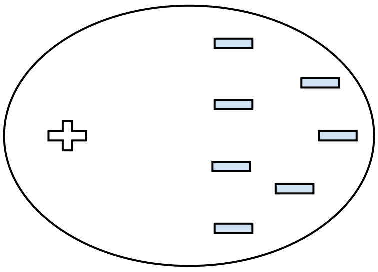
i) Polar dielectrics

ii) Non-polar dielectrics

If in a dielectric substance the centre of gravity of the positive charge in a molecule coincides with the centre of gravity of the negative charges in the molecules, then the dielectric is called non-polar dielectric. Similarly, if the centre of gravity of positive charges does not coincide with negative charges then the dielectric substances are called polar dielectrics.



Non-polar molecules



Polar molecules