Dielectrics

Definition - The dielectrics are non-conductors of electricity (electrical insulators) because they do not possess free charges.
The electrical conductivity of the dielectrics is either very small or zero.

examples :- ceramics, mica, resins, asbestos, wood, glass etc.

Molecular theory : Dielectrics

The dielectric becomes polarized in the presence of electric field. The effect of electric field is to separate positive and negative charges of the entire volume of dielectric and create electric dipoles. This effect is called polarization of dielectric.

An electric dipole is made up of two equal positive and negative charges, separated by a small distance. If q is magnitude of charge and dl is the separation, then electric dipole moment is given by

$$p = q\,dl$$

✓ dipole moment is a vector quantity.

✓ Unit = Coulomb-meter.

If each of particle in a solid possesses a dipole moment, then the net/total dipole moment will be the sum of moments of all dipoles.

✓ The polarization 'P' in a solid is defined as dipole moment per unit volume, ie.

$$P = \frac{p}{V}$$

(a) Types of dielectrics :-

(i) Non-Polar dielectrics :-

A molecule in which the centre of positive and negative charge coincide is called non-polar molecule and do not possess any electric dipole moment.

Examples :- CO_2, CCl_4, H_2, N_2, O_2 etc.

(ii) Polar dielectrics :-

A molecule in which centres of positive and negative charges do not coincide but separated by a small distance, is called polar molecule.

Polar molecules work as electric dipoles and have dipole moment.

Examples: HCl, H_2O, $CHCl_3$ etc.

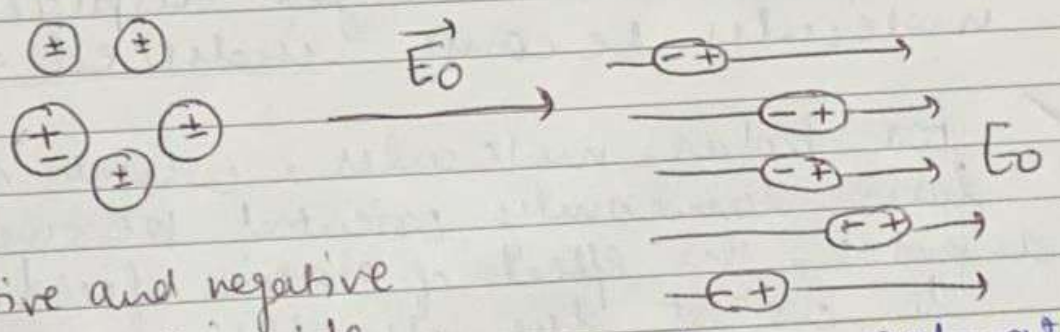
HCl ⇒ H^+ (positive charge)

Cl^- (equal negative charge)

Thus HCl molecule has a dipole moment at every instant and is a polar molecule.

(b) Polarization in dielectrics :-

(i) Polarization in non-polar dielectrics :-

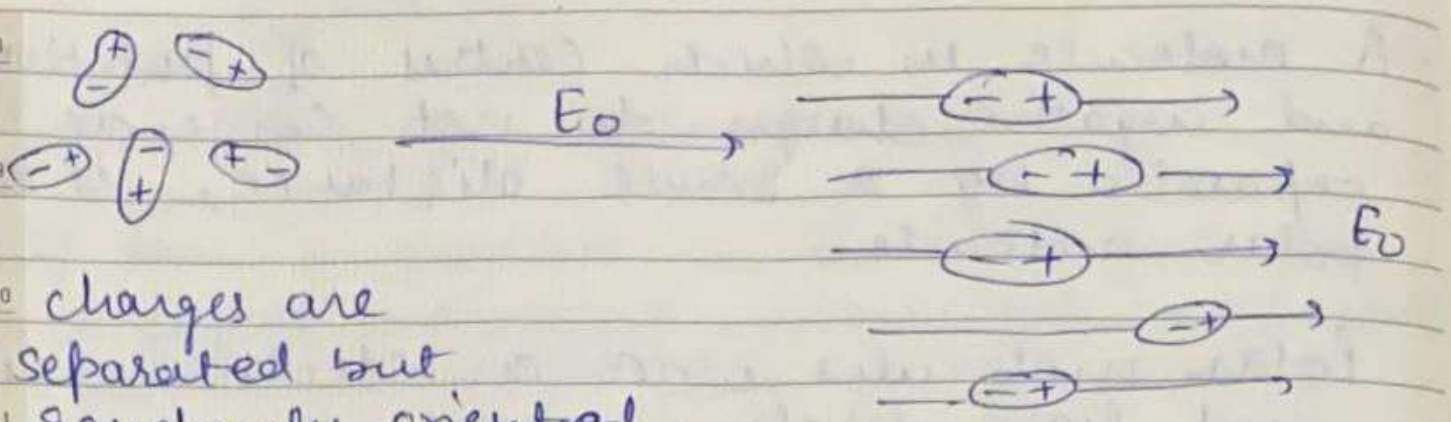


Positive and negative charges coincide.

(a)

(b) Charges separated in the presence of electric field

(ii) Polarization in polar-dielectrics :-



charges are separated but randomly oriented in polar molecules

(a)

(b) orientation of the dipoles along the direction of electric field Eo.

So we can deduce, two points from the above two figures for polar and non-polar molecules.

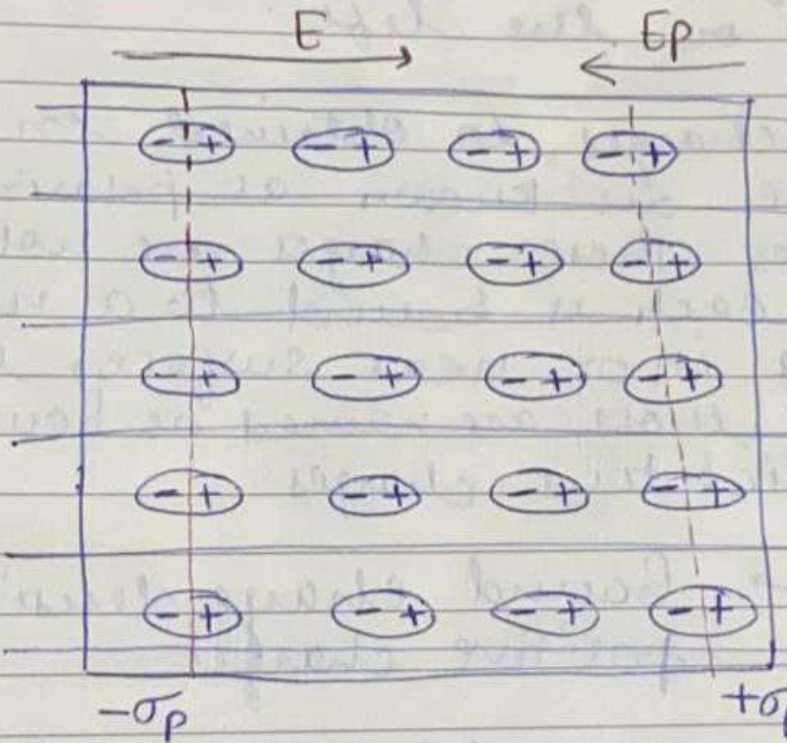
09 SUNDAY ✓ when a dielectric (polar or non-polar) is placed in an electric field, the charge centres of non-polar molecules get displaced & molecules become induced dipoles.

✓ for polar molecules, which already have randomly oriented permanent dipoles, the effect of electric field is to orient the dipoles along the

direction of electric field and increase their dipole moment. The stronger the field, the greater is the aligning effect.

" The phenomena of orientation of the induced dipoles or the permanent dipoles in an external electric field to set the axis of the dipoles along the field is called electric polarization ".

Behaviour of dielectric slab in the electric field :-



When a thin dielectric slab placed in an electric field, the slabs as a whole become polarised. Due to polarisation, molecules are oriented so that negative

charges are on left and positive charges are on the right. Thus leaving the net positive charge at right surface and net negative charge at the left surface.

Inside the medium, there is no extra charge in any given volume element.

The medium as a whole is electrically neutral and positive charge on right is equal in magnitude to the negative charge on the left.

The charges so obtained on the surface are known as polarization charges. These charges are not free but each is bound to a molecule lying in or near surface, that is why those are named as bound charges or fictitous charges.

$+\sigma_p \rightarrow$ Bound charge density of positive charges.

$-\sigma_p \rightarrow$ Bound/polarized charge density of negative charges.

These charges create their own electric field = E_p (left to right) and oppose the external applied field (E_0).

So resultant field $E < E_0$.

Thus the polarization of the dielectric reduces the electric field in its interior.

Dielectric constant :-

It is defined as the ratio of a capacitance of a capacitor with dielectric to the capacitance of the same capacitor without dielectric.

$$K = \frac{C_d}{C_0} = \frac{V_0}{V_d}$$

$K \rightarrow$ dielectric constant

It is also called the relative permitivity of the medium (ε_r).

$K > 1$ and independent of shape or dimensions of the capacitor but

Varies for different dielectric materials.

ε = permitivity of medium

$\varepsilon = \varepsilon_0 \varepsilon_r = \varepsilon_0 k$

$$\boxed{\varepsilon_r = k = \frac{\varepsilon}{\varepsilon_0}}$$