Linear Dielectrics

Susceptibility, Permittivity, Dielectric constan

The polarization of a dielectric ordinarily results from an electric field, which lines up the atomic or molecular dipoles. For many substances, the polarization is proportional to the field, provided $\vec{E}$ is not too strong:

$$\vec{P} = \epsilon_0 \chi_e \vec{E}$$

Here the constant of proportionality, χ_e is called the electric susceptibility of the medium. A factor of ϵ_0 has been extracted to make χ_e dimensionless. The value of χ_e depends on the microscopic structure of the substance of interest.

In case of linear media, we have the expression from dielectric displacement

$$\vec{D} = \epsilon_0 \vec{E} + \vec{P} = \epsilon_0 \vec{E} + \epsilon_0 \chi_e \vec{E} = \epsilon_0 (1 + \chi_e) \vec{E}$$

Also, for permittivity of a medium ϵ

$$\vec{D} = \epsilon \vec{E}$$

$$\therefore \quad \epsilon \vec{E} = \epsilon_0 (1 + \chi_e) \vec{E} \quad \text{or} \quad \boxed{\epsilon = \epsilon_0 (1 + \chi_e)}$$

If we remove ϵ_0 from the R.H.S. to become dimensionless quantity

$$1 + \chi_e = \frac{\epsilon}{\epsilon_0} = \epsilon_r$$

Here ϵ/ϵ_0 is called relative permittivity or dielectric constant of the material. It is also denoted by ϵ_r.

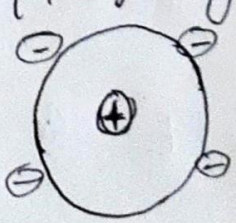
Mechanism of Polarization

There are three basic types of polarization that contribute to the total magnitude of polarization in a material have been identified as:

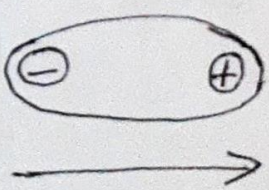
(i) Electronic Polarization
(ii) Ionic Polarization
(iii) Orientation polarization.

(i) Electronic polarization:

This type of polarization occurs due to the displacement of the positively charged nucleus and negatively charged electron cloud in opposite directions with in a dielectric material upon applying an external electric field.



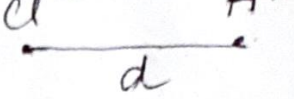
E = 0



E ≠ 0

Ionic Polarization

This type of polarization occurs in ionic materials. In an ionic bond when two different atoms join together there is transfer of electrons from one atom to another atom like HCl as shown in the figure. In presence of an applied electric field, the distance between the two poles increases. Hence, we get the polarization of the ionic materials.



Orientation Polarization

Orientation polarization occurs in dielectric materials which possess molecules with permanent dipole moment, for example, H_2O. In absence of an external electric field, the permanent dipoles are oriented randomly. such that they cancel the effects of each other. But under the influence of applied field each dipole undergo rotation so as to reorient along the field direction as shown. Thus the material becomes polarized and such type of polarization is called orientation polarization.