# Electric Properties Continued….

## ❖ Dielectric Properties

Dielectric properties of materials are defined as a molecular property which is fundamental in all the materials that are capable of impending electron movement resulting in polarization within the material on exposure to an external electric field.

- Non –conducting materials are divided into two categories:
  - (i) Insulator
  - (ii) Dielectrics
- **Insulator:** If the main function of non-conducting material is to provide electrical insulation then material is called as an insulator.
- **Dielectrics:** If the main function of non-conducting material is storage of charge then material is called dielectric.
- Dielectrics are non-conductors which can be can be polarized by application of an electric field. When a dielectric is placed in an electric field, electric charges slightly shift from their average equilibrium positions, causing dielectric polarization. Because of dielectric polarization, positive charges are displaced toward the field and negative charges shift in the opposite direction. This creates an internal electric field that reduces the overall field within the dielectric itself.

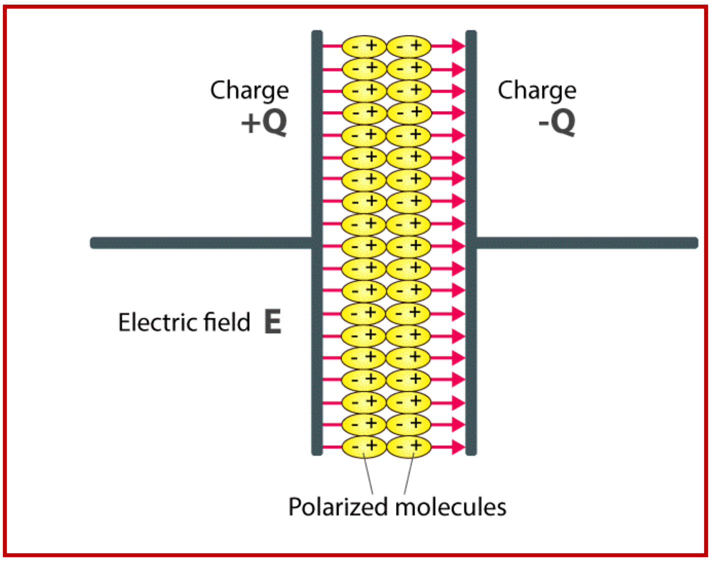


***Figure 1: Polarisation of dielectric molecules when the electric field is applied.***

- If a dielectric is composed of weakly bonded molecules, those molecules not only become polarized but also reorient so that their symmetry axis aligns to the field.
- Ideally, dielectric material does not exhibit electrical conductivity when an electric field is applied. But practically, all dielectrics do exhibit some conductivity, which generally increases with increase in temperature and applied field.
- The study of dielectric properties is concerned with the storage and dissipation of electric and magnetic energy in materials. In practice, most dielectric materials are solid. Examples include porcelain (ceramic), mica, glass, plastics, and the oxides of various metals.
- Dielectrics are employed as insulation for wires, cables, and electrical equipment, as polarizable media for capacitors, in apparatus used for the propagation or reflection of electromagnetic waves, and for a variety of artifacts, such as rectifiers and semiconductor devices, piezoelectric transducers, dielectric amplifiers, and memory elements.
- Some liquids and gases can serve as good dielectric materials. Dry air is an excellent dielectric and is used in variable capacitors.
- **Properties of Dielectric Material**
  (i) The energy gap in the dielectric materials is very large.
  (ii) The temperature coefficient of resistance is negative and the insulation resistance is high.
  (iii) The dielectric materials have high resistivity.
  (iv) The attraction between the electrons and the parent nucleus is very strong.
  (v) The electrical conductivity of these materials is very low as there are no free electrons to carry current.
- **Parameters of Dielectrics**
  (i) Dielectric constant / Permittivity (ε)
  (ii) Electric dipole moment (p)
  (iii) Polarizability (α)
  (iv) Polarization (P)

## (i) Dielectric constant / Permittivity (ε)

It is defined as the ratio of electric flux density to electric field intensity i.e.,

$$\boldsymbol{\varepsilon = \frac{D}{E}}$$

Where, D is the electric flux density, Unit: Coulombs per metre squared ($C/m^2$)

E is the electric field intensity, Unit: Volt per metre (V/m)

Also,

$$\boxed{\varepsilon = \varepsilon_o \varepsilon_r}$$

Where, $\varepsilon_r$ is the relative permittivity of material (unit less quantity)

$\varepsilon_o$ is the permittivity of free space

$\varepsilon_o = 8.85 * 10^{-12}$ F/m

## (ii) Electric dipole moment (p)

- **Electric dipole:** Two opposite charges separated by a distance constitutes an electric dipole.
- **Electric dipole moment:** It is defined as the product of charge (q) and distance of separation (d) i.e.,

$$\boxed{p = qd}$$

- It is a vector quantity which is directed from negative (-ve) charge to positive (+ve) charge.

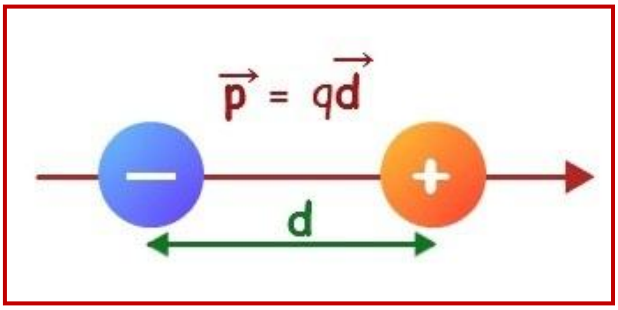


*Figure 2: Electric dipole moment*

- Units of electric dipole moment (p)
  1. Coulomb – metre (C-m)
  2. Debye

     1 Debye=$3.33*10^{-30}$C-m

## (iii) Polarizability(α)

As we know,

$$p \propto d \quad \text{-----------------------------(i)}$$

$$d \propto E \quad \text{-----------------------------(ii)}$$

From equation (i) and (ii) we can write:

$$p \propto E$$

$$\Rightarrow p = \alpha E$$

$$\Rightarrow \alpha = p/E$$

where, $\alpha$ is the polarizability of material

$$\alpha = p/E$$

$$\alpha = (C\text{-}m)/(V/m)$$

$$\alpha = (C/V).m^2$$

$$\alpha = F\text{-}m^2$$

Therefore, the unit of polarizability ($\alpha$) is $F\text{-}m^2$.

## (iv) Polarization (P)

- The phenomenon by which two opposite surfaces of dielectric become oppositely charged is known as polarization.
- Mathematically, it is given by dipole moment per unit volume i.e.,

P=Number of dipoles per unit volume * dipole moment

$$P = Np$$

Where, $N \Rightarrow$ Number of dipoles per unit volume ($1/m^3$)

$p \Rightarrow$ dipole moment (C-m)

- Therefore, unit for polarization is $C/m^2$

- **Total flux density**

Total flux density inside dielectric material under the influence of applied electric field, depends on two factors:

(i) Applied electric field

(ii) Polarization induced inside the material

i.e.,

$$D = \varepsilon_0 E + P \qquad \text{[1]}$$

where, $D \Rightarrow$ Total flux density

$\varepsilon_o E \Rightarrow$ Flux density due to applied electric field

$P \Rightarrow$ Flux density due to induced polarization

Also,

$$D = \varepsilon_0 \varepsilon_r E \qquad \text{[2]}$$

From equation [1] and [2] we get,

$$\varepsilon_o E + P = \varepsilon_o \varepsilon_r E$$

$$\Rightarrow P = \varepsilon_o(\varepsilon_r - 1)E$$

$$\Rightarrow P = \varepsilon_o \chi_e E$$

Where, $\chi_e$ is the dielectric susceptibility

$$\chi_e = \varepsilon_r - 1$$

$\chi_e$ is unit less quantity .