DEPARTMENT OF PHYSICS AND NANOTECHNOLOGY
SRM INSTITUTE OF SCIENCE AND TECHNOLOGY

18PYB101J-Electromagnetic Theory, Quantum Mechanics, Waves and Optics

Module I Lecture-13

Relationship Between Polarizability, Permittivity and Dielectric constant, Polar and Non Polar Dielectrics

Dielectric Materials

- Dielectric materials are also called as insulators.
- In dielectric materials**, all the electrons are tightly bound to their parent molecules** and there are **no free charges**. In addition, the forbidden energy band gap (e.g.) for dielectric materials is more than 3eV.
- Not possible for the electrons in the valence band to excite to the conduction band, by crossing the energy gap, even with normal voltage or thermal energy.

SRM
Institute of Science and Technology

Active and Passive Dielectrics

- *The dielectric materials can be classified into active and passive dielectric materials.*
- *i. Active dielectrics*

When a dielectric material is kept in an external electric field, if it actively accepts the electricity, then it is known as active dielectric material. Thus, active dielectrics are the dielectrics, which can easily adapt themselves to store the electrical energy in it.

Eg: Piezoelectric and ferroelectric

- *ii. Passive dielectrics*

Passive dielectrics are the dielectrics, which restrict the flow of electrical energy in them. So, these dielectrics act as insulators.

Examples: All insulating materials such as glass, mica, rubber etc.,

i. Non-Polar Dielectrics

- *There is no permanent dipole existence in the absence of electric filed*

- *Eg: H_2, N_2, O_2, CO_2*

ii. Polar dielectrics

- *There is existence of permanent dipole in the absence of electric filed*

- *Examples: H_2O, HCl, CO*

SRM
Institute of Science and Technology

Basic Definitions in Dielectrics

Electric Field

- **The region around the charge within which its effect is felt or experienced is known as electric field.**
- **The electric field is assumed to consist of imaginary electric lines of force. These lines of force originate from the positive charges and terminate to the negative charges .**

Electric field strength or electric field intensity (E)

Electric field strength at any point is defined as the force experienced by an unit positive charge placed at the point. It is denoted by ‘E’.

‘q’ - magnitude of the charge in coulombs

‘f’ - force experienced by that charge in Newton,

electric field strength (E)

Its unit is Newton / Coulomb (or) volt / meter.

Electric flux

It is defined as the total number of electric lines of force passing through a given area in the electric field. (Emanated from the positive charge). Unit: Coulomb

Electric flux density or electric displacement vector (D =Ø/A)

It is defined as the number of electric lines of force passing normally through an unit area of cross section in the field.

Its unit is Coulomb / m^2

Dielectric Constant

The dielectric constant or relative permittivity of a material determines its dielectric characteristics. It is the ratio of the permittivity of the medium and the permittivity of free space

$$\varepsilon_r = \varepsilon/\varepsilon_0$$

➢Electric Polarization

(The process of creating or inducing diploes in DEM)

➢Consider an atom. We know that it is electrically neutral. Furthermore, the centre of the negative charge of the electrons coincides with the positive nuclear charge, which means that the atom has no net dipole moment.

➢However, when this atom is placed in an external electric field, the centre of the positive charge is displaced along the field direction while the centre of the negative charge is displaced in the opposite direction.

➢When a dielectric material is placed inside an electric field, such dipoles are created in all the atoms inside.

Polarizability (α)

When the electric field strength 'E' is increased, the strength of the induced dipole is also increased. Thus, the induced dipole moment is proportional to the intensity of the electric field.

$$\mu \propto E$$

$$\mu = \alpha E$$

Polarization vector

The dipole moment per unit volume of the dielectric material is called *polarization vector.*

$$P = N\mu$$

Unit: Coulomb / m2

'μ' - average dipole moment per molecule and

'N' - number of molecules per unit volume

SRM
Institute of Science and Technology

Relation between P, ε_0 , ε_r and E

The polarization 'P' is related to the electric flux density D as,

$$D = \varepsilon_0 E + P$$

Since $D = \varepsilon_0 \varepsilon_r E$, the above relation becomes,

$$\varepsilon_0 \varepsilon_r E = \varepsilon_0 E + P$$

(or) $$P = \varepsilon_0 \varepsilon_r E - \varepsilon_0 E$$

i.e. $$P = \varepsilon_0 (\varepsilon_r - 1) E$$