2.5 DIELECTRIC POLARIZATION

Dipole described by its dipole moment$\boldsymbol{P}$. If $\boldsymbol{Q}$ is the charge and $\boldsymbol{l}$ is the vector (distance) from the negative to the positive charge, the dipole moment is given by

$$P = Q.l$$

If there are $\boldsymbol{n}$ dipole per unit volume ΔV ,then there are $n\Delta V$ dipoles and the total dipole moment is given by

$$P_{total} = \sum_{i=1}^{n\Delta V} P_i$$

Polarization is defined as dipole moment per unit volume

$$P = \lim_{\Delta V \to 0} \frac{1}{\Delta V} \sum_{i=1}^{n\Delta V} P_i \quad C/n^2$$

If the dipole is signed in random orientation, polarization $\boldsymbol{P}$ has zero values, whereas if dipoles are aligned in same direction polarization $\boldsymbol{P}$ has a significant value.

Consider a bound charge Q_b across a small element surface ds in dielectric containg non polar molecules .Then

$$Q_b = -\oint_s P\, ds$$

If $\boldsymbol{Q}$ is the free charge enclosed by the surface$\boldsymbol{S}$, the total enclosed charge is

$$Q_T = Q_b + Q$$

By Gauss’s law

$$Q_T = \oint_s \varepsilon_0 E.ds$$

The free charge enclosed

$$Q = Q_T - Q_b$$

Substitute Q_T and Q_b in above equation

$$Q = Q_T - Q_b$$

$$Q = \oint_s \varepsilon_0 E.ds - \left(-\oint_s P\, ds \right)$$

$$Q = \oint_s \varepsilon_0 E.ds + \oint_s P\, ds$$

$$Q = \oint_s (\varepsilon_0 E + P)\, ds$$

But

$$Q = \oint_s D.ds$$

Equate both the Q equation

$$\oint_s D.ds = \oint_s (\varepsilon_0 E + P)\, ds$$

$$D = (\varepsilon_0 E + P)$$

$$D = \varepsilon_0 E + P$$

Polarization P can be written as

$$P = \chi \varepsilon_0 E$$

Where χ is electric susceptibility

Substitute P expression in above equation

$$D = \varepsilon_0 E + P$$

$$D = \varepsilon_0 E + \chi \varepsilon_0 E$$

$$D = \varepsilon_0 E(1 + \chi)$$

Substitute

$$\varepsilon_R = 1 + \chi$$

$$D = \varepsilon_0 E \varepsilon_R$$

$$D = \varepsilon_0 \varepsilon_R E$$