(j) Linear Dielectrics (Susceptibility, Permittivity, Dielectric Constant)

For any substances, the polarization is proportional to the field provided $\vec{E}$ is not too strong:

$$\vec{P} \propto \vec{E} \Rightarrow \vec{P} = \varepsilon_0 \chi_e \vec{E}$$

(Materials that obey this relation are called linear dielectrics)

The constant of proportionality, χ_e is called the ***electric susceptibility*** of the medium. The value of χ_e depends on the microscopic structure of the substance and also on external conditions such as temperature.

In linear media we have

$$\vec{D} = \varepsilon_0 \vec{E} + \vec{P} = \varepsilon_0 \vec{E} + \varepsilon_0 \chi_e \vec{E} = \varepsilon_0 \vec{E}\ (1+\chi_e) = \varepsilon \vec{E}, \quad where \quad \varepsilon = \varepsilon_0 (1+\chi_e)$$

This new constant ε is called the permittivity of the material.

Also $\varepsilon_r = \dfrac{\varepsilon}{\varepsilon_0} = (1+\chi_e)$ is called ***relative permittivity*** or ***dielectric constant***, of the material.

Energy in Dielectric System

$$W = \frac{1}{2} \int_{all\ space} \left(\vec{D} \cdot \vec{E}\right) d\tau \qquad \text{where } \vec{D} = \varepsilon \vec{E}$$