

EE468G NOTES (4)

Conductors:

There are free charges

Conduction current: $\vec{J} = \sigma \vec{E}$ (General Ohm's law)

σ : conductivity [S/m]

Insider perfect conductor: $\sigma = \infty$, $\vec{E} = 0$, $\vec{J} = 0$,

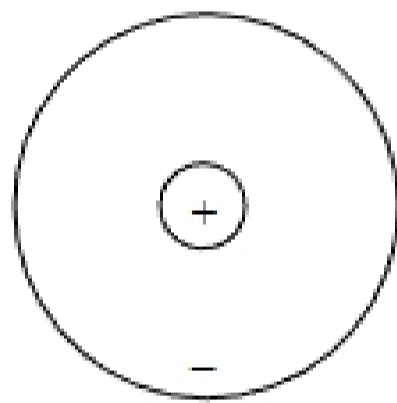
Power dissipation:

$$P = \int_V \sigma |\vec{E}|^2 dV$$

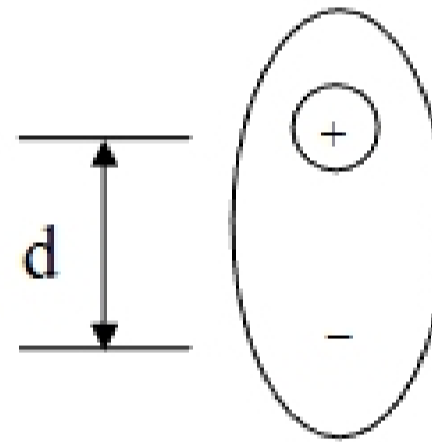
Dielectrics:

Charges are tightly bound to individual nuclei.

Then can only move a fraction of an atomic distance in a electric field.



Un-polarized
molecule



Polarized
molecule

For isotropic dielectric, the polarization vector is related to electric field by

$$\vec{P} = \epsilon_0 \chi_e \vec{E}, \quad \chi_e : \text{Susceptibility (no unit)}$$

Charges associated with the polarization vector:

$$\rho_{VP} = -\nabla \cdot \vec{P}, \quad [\text{C/m}^3]$$

$$\rho_{SP} = \hat{n} \cdot \vec{P}, \quad [\text{C/m}^2]$$

Maxwell's equation in dielectric material

$$\nabla \cdot \epsilon_0 \vec{E} = \rho_V + \rho_{VP} = \rho_V - \nabla \cdot \vec{P}$$

$$\nabla \cdot \epsilon_0 \vec{E} + \nabla \cdot \vec{P} = \rho_V$$

$$\nabla \cdot [\epsilon_0 \vec{E} + \vec{P}] = \rho_V$$

Let $\vec{D} = \epsilon_0 \vec{E} + \vec{P}$, then we have

$$\nabla \cdot \vec{D} = \rho_V, \quad \rho_V \text{ ---- Free-charge density.}$$

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

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

$\epsilon = \epsilon_0 \epsilon_r$ is the dielectric permittivity

ϵ_r is the relative permittivity.

Air is very close to free-space, hence, for air, $\epsilon_{r, \text{air}} \approx 1$