Lecture 9 — Dielectrics

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- Capacitance

$$C = \frac{\varepsilon_r \varepsilon_o A}{d}$$

  - ε_o represents the permittivity of free space
  - ε_r is the permittivity of a dielectric material
  - A is the cross-sectional area of the plates
  - d is the distance between plates
  - C represents the effective capacitance
  - Add in parallel, divide in series

- Dielectric Strength
  - When the electric field in the dielectric reaches a critical value called the dielectric strength, the medium suffers a dielectric breakdown where a large current flows across the plates

- Dielectric Theory
  - p is the electric dipole moment (measure of electrostatic effect of opposite charges displaced by a): $p = Qa$
  - Power dissipation in a capacitor occurs and is also frequency dependent

- Polarizability
  - Polarizability is defined as:

$$p = \alpha E$$

  - The induced dipole moment is called the electronic polarizability, α_e

- The electronic polarization may be written as:

$$p_e = \left(\frac{Z^2e^2}{\beta}\right)$$

- We can find susceptibility as:

$$\chi_e = \frac{1}{\varepsilon_o}N\alpha_e$$

- The two are related through:

$$\varepsilon_r = 1 + \chi_e$$

- Clausius-Mossotti Equation
  - Taking:

$$p = \alpha_e E$$
$$P = \chi_e \varepsilon_o E$$
$$\varepsilon_r = 1 + \chi_e$$

  - We combine all of the relationships to get:

$$\frac{\varepsilon_r - 1}{\varepsilon_r + 2} = \frac{N\alpha_e}{3\varepsilon_o}$$

- Relaxation
  - The rate of polarization change may be written as:

$$\frac{dp}{dt} = -\frac{p}{\tau} + \frac{\alpha_d(o)}{\tau}E_o e^{j\omega t}$$

  - We can solve to obtain:

$$p = \alpha_d(\omega)E_o e^{j\omega t}$$