Lecture 13, Feb 8, 2023

Electric Flux Density and Polarization

- $D = \varepsilon_r \varepsilon_0 \vec{E} = \varepsilon_r \varepsilon_0 (\vec{E}_0 - \vec{E}_p), \varepsilon_r = \chi_e + 1, \vec{P} = \varepsilon_0 \chi_e \vec{E} = \varepsilon_0 (\varepsilon_r - 1)\vec{E}$
- $\chi_e = \dfrac{\rho_{sb}}{\varepsilon_0 (E_0 - E_p)} = \dfrac{\rho_{sb}}{\rho_s - \rho_{sb}}$
- $\varepsilon_r = \chi_e + 1 = \dfrac{\rho_s}{\rho_s - \rho_{sb}}$
- $\vec{D} = \left(\dfrac{\rho_s}{\rho_s - \rho_{sb}}\right) \varepsilon_0 \left(\dfrac{\rho_s}{\varepsilon_0} - \dfrac{\rho_{sb}}{\varepsilon_0}\right) = \rho_s$
  - Note this is for a flat plate capacitor
- In the end the electric flux density relates only to the free charge, but the electric field relates to both free and bound charge
- Therefore $\vec{D} = \varepsilon_0 \varepsilon_r \vec{E} = \varepsilon_0 \vec{E} + \vec{P}$
  - Note $\vec{D}$ is not something *changed* by polarization; rather it is the total field $\vec{E}$ that changes
  - The combination of changing $\vec{E}$ and polarization $\vec{P}$ produces a constant $\vec{D}$, unaffected by dielectric changes
- $\vec{D}$ is the *electric flux density* or *electric displacement vector*
  - $\vec{D}$ is completely material independent
  - $\vec{D}$ represents the flow, or flux, of the "presence" of charge – it is connected only to the source of the field (i.e. the free charges)
    - This is why $\oiint_S \vec{D} \cdot \mathrm{d}\vec{S} = Q_{enc}$
- $\vec{E}$ is the *electric field intensity*
  - It relates to the total charge, both free and bound
  - $\vec{E}$ comes from the electric force per unit charge
  - $\vec{E}$ represents the effects of the entire field with all of its charges/forces