Lecture 11, Feb 3, 2023

Effect of Electric Field on Materials

- If an external electric field is applied to a material, then "excess" or "mobile" charges will be pushed along by the field
- Based on the amount of mobile charges, most materials fall into 3 categories: conductors, semiconductors, and dielectrics (insulators)
  - In a conductor the band gap is very small so very little energy is needed to promote an electron to the conduction band
  - In a dielectric the band gap is quite large, so a lot of energy is needed for conduction
- The movement of charges creates a current I; we can define a *current density* J so that $I = \iint_S \vec{J} \cdot \mathrm{d}\vec{S}$
  - $\vec{J}$ has units of $\mathrm{A/m^2}$

Equation

The relationship between current density and an electric field causing the current is

$$\vec{J} = \sigma \vec{E}$$

where σ is the conductivity of the material

- This is known as Ohm's law in microscopic (point) form
- Conductivity characterizes how easily a current flows within that material
  - Later we see $\sigma = \frac{N_e e^2 \tau}{m_e}$ where N_e is the electron density and τ is the mean free time
  - In general σ goes down as temperature goes up as τ decreases when the atoms become more energetic
- Resistivity is the inverse of conductivity, $\rho = \frac{1}{\sigma}$ with units of $\Omega\,\mathrm{m}$
- Properties of perfect conductors and dielectrics:
  - In a perfect conductor, $\sigma \to \infty$, so no applied field is needed for current to flow, and *there is always zero electric field*
  - In a perfect insulator, $\sigma \to 0$, so there is never any current; the electric field can be anything but the material will not respond
- A perfect conductor will have the same potential everywhere on its surface, so all perfect conducting surfaces are equipotential; therefore the electric field is always perpendicular to them