DC Electrical Conductivity

Electrical conductivity (& other electrical properties) is one of the most important and distinguishing properties of metals, compared to other materials.

Ohm's Law: $\boxed{V = IR}$

When an electric field is applied across a metal, a current will flow:

$$\vec{j} = \sigma \vec{E} = \frac{1}{\rho} \vec{E}$$

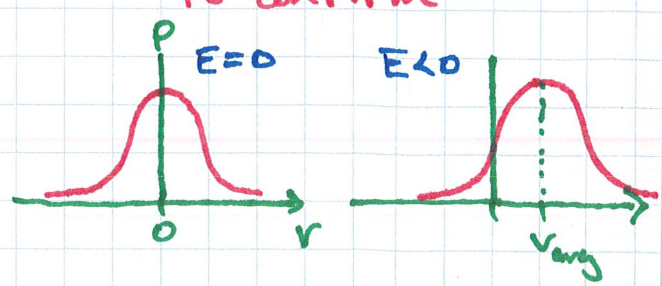
- $\vec{j}$ → current density ($A \cdot m^{-2}$)
- σ → conductivity ($S \cdot m^{-1}$, $\Omega^{-1} \cdot m^{-1}$)
- ρ → resistivity ($\Omega \cdot m$)
- $\vec{E}$ → applied electric field ($V \cdot m^{-1}$)

- electrons will travel w/ avg. drift velocity $\bar{v}$:

$$\therefore \vec{j} = -ne\vec{v}$$

→ check units to confirm

- w/o E-field, $\bar{v}_{avg.} = 0$



- Between collisions:

$$F = ma = qE \qquad (a = v/t)$$

$$\therefore v = \frac{-eEt}{m}$$

Recall avg. time between collisions is τ:

$$\vec{v}_{avg} = -\frac{e\vec{E}\tau}{m}$$

$$\vec{j} = \frac{ne^2\tau}{m}\vec{E}$$

$$\sigma = \frac{ne^2\tau}{m}$$

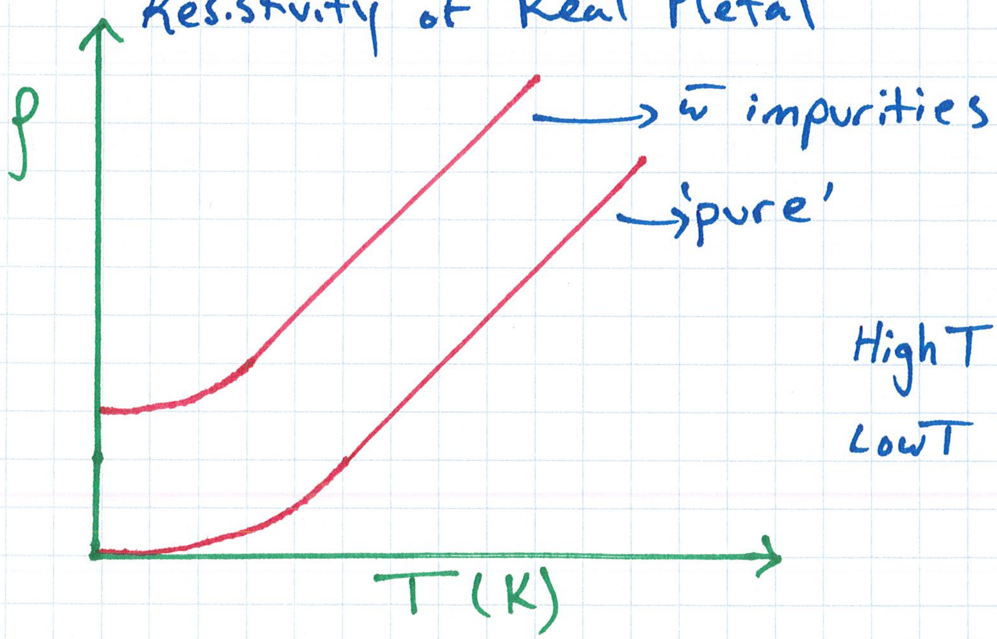
So what is τ??

→ no explicit formulation of τ in Drude Model

$$\tau = \frac{m}{\rho n e^2}$$

can measure ρ to estimate τ

Resistivity of Real Metal



High T: $\rho \propto T$

Low T: $\rho \sim$ const.

→ Does T-dependence make sense if $\bar{e}$'s collide with ions?

ion spacing ~ 4 Å

e.g. Ag: 273 K → $\ell \approx 44$ Å

77 K → $\ell \approx 120$ Å

Equation of Motion

- Consider the time-dependance of the current density:

$$j = -\frac{ne}{m}\vec{p}(t) \qquad \bar{p}(t) = m\bar{v}(t)$$

- Consider collision probability (dt/τ) and external force $f(t)$.

Result: (Problem set #1)

$$\frac{d\,p(t)}{dt} = -\frac{p(t)}{\tau} + f(t)$$

- collisions (τ) introduce damping term ($\propto$ velocity) to eqn of motion.