Physics 122
Date: 10/21/15

Questions?
Announcements/Reminders

Exam 2 – Friday. Arrive 15 min. early if you can.

- This week recitation: Have your cheat sheets for exam2 ready!
- Written HW#9 due on Monday, Oct 26 by 9 am.
- MP HW#9 – Due Monday, Oct 26, by 11:59 pm.
- Written HW#10 due on Friday, Oct 30 by 9 am.
- MP HW#10 – Due Friday, Oct 30, by 11:59 pm.
Last class ...

Electron current, current, current density, ...

Today...

Conductivity, resistivity, resistance and resistors.
Last class summary

**Drift speed**

\[ v_d = \frac{eE}{m} \tau \]

**Electron current, units [electrons/s]**

\[ i_e = n_e A v_d = n_e A \frac{eE}{m} \tau \]

**Current (I), units [A]**

\[ I = \frac{dQ}{dt} \]

- For steady current:

\[ Q = I \Delta t \]

\[ I = i_e e \]

\[ I = n_e e v_d e A \]

**Current density, units [A/m^2]**

\[ J = \frac{I}{A} \]

\[ J = n_e e v_d \]
Example (Problem 30.11 in the text)

In an integrated circuit, the current density in a 2.5 \( \mu m \times 75 \mu m \)-wide gold film is 7.5 \( \times 10^5 \frac{A}{m^2} \). How much charge flows through the film in 15 minutes?

\[
J = 7.5 \times 10^5 \frac{A}{m^2}
\]

\[
A = 2.5 \mu m \times 75 \mu m = 187.5 \times 10^{-12} m^2
\]

\[
Q = ?
\]

\[
\Delta t = 15 \text{ min}
\]

\[
Q = I \Delta t \quad \text{and} \quad I = JA
\]

\[
\Rightarrow Q = JA \Delta t = 7.5 \times 10^5 \frac{A}{m^2} \times 187.5 \times 10^{-12} m^2 \times 15 \times 60 \text{ s}
\]
\[ Q = 127 \, \text{C} \]
Conservation of current and Kirchhoff's Junction Law

\[ I_0 = I_1 + I_2 \]

\[ \sum I_{in} = \sum I_{out} \]
\[ I_3 = I_4 + I_5 + I_c \]

\[ I_1 + I_2 = I_3 \]
Conductivity

\[ J = n_e e v_d \]

\[ \sigma = \frac{n_e e^2 \tau}{m} \]

\[ J = n_e e \frac{eE}{m} \tau \]

\[ J = \left( \frac{n_e e^2 \tau}{m} \right) E \]

Conductivity \( \sigma \)

units \( \sigma \): \( \frac{A}{m^2 \cdot V} = \frac{A}{mV} \)

\[ \sigma = \frac{1}{\rho} \]

\[ \sigma = \frac{m}{n_e e^2 \tau} \]

Resistivity
Example (Stop-to-Think)

\[ J = \frac{I}{A} \]

\[ A = \pi r^2 \]
\[ A_1 = \pi (2r)^2 = 4A \]

\[ J_a = \frac{I}{A} \quad ; \quad J_b = \frac{2I}{A} = 2J_a \]
\[ J_c = \frac{2I}{4A} = \frac{1}{2} J_a \quad \text{and} \quad J_d = \frac{I}{A} = J_a \]

\[ J_b > J_a = J_d > J_c \]

* Current requires \( \Delta V \) (E)
how strong is $E$ in the cond?

$E = \frac{\Delta V}{L}$

$\Delta V = V_+ - V_-$

$I = JA = 6EA = 6A \frac{\Delta V}{L} = \frac{A}{S} \frac{\Delta V}{L}$
**Resistance**

\[ R = \frac{\rho L}{A} \]

Unit: \([\Omega]\) Ohm

\[ \varepsilon \Omega_{\text{m}} \]

**Ohm's Law**

\[ I = \frac{\Delta V}{R} \]
Ohmic materials:

\[ R = \frac{1}{\text{slope}} \]

\[ \Delta V \]

Ohm's Law good...

* Resistors
  - used to "regulate" current in circuits
- ideal conductors: \( R = 0 \)
- ideal insulator: \( R = \infty \)
Example (Problem 30.31 in the text)

a) How long must a 0.60-mm-diameter aluminum wire be to have a 0.50 A current when connected to the terminals of 1.5 V battery?

b) What is the current if half this length?

\[
\begin{align*}
\text{a)} & \quad L, \Delta V = 1.5 V \\
& \quad I = 0.50 A \\
& \quad d = 0.60 \text{ mm} \\
& \quad S = 2.8 \times 10^{-8} \Omega m \\
\end{align*}
\]

\[
I = \frac{\Delta V}{R} = \frac{\Delta V}{S L / A} = \frac{(\Delta V)A}{S L} \checkmark
\]

\[
I = \frac{\Delta V \pi (d/2)^2}{S L} \Rightarrow L = \frac{\Delta V \pi (d/2)}{IS}
\]
\[ \Rightarrow L = 3.0 \text{ mm} \]

\[ L \rightarrow \frac{L}{2} \]

\[ L_1 = \frac{(\Delta V) \pi \left( \frac{d}{2} \right)^2}{8 I_1} \Rightarrow I_1 = \frac{2 \Delta V d \left( \frac{d}{2} \right)^2}{75} \]

\[ \Rightarrow I_1 = 1.0 \text{ A} \]

\[ \text{\underline{I}_1 = 2 I} \]