Lecture 24

Example Problem:

compare $i_1'$ with $i$

$E_1'L = \varepsilon$

$EL = \varepsilon$

$\therefore E_1' = E$ or for identical bulb: $i_1 = i$

$nAuE_1' = nAu\frac{\varepsilon}{L} = nAuE$
compare $i'_2$ vs $i$

Loop ABCA: \[ \mathcal{E} - 2E'_2L = 0 \]

\[ E'_2 = \frac{\mathcal{E}}{2L}, \quad E'_2 = \frac{E}{2}, \quad \text{or} \quad i'_2 = \frac{i}{2} \]

compare $i'$ with $i$, \[ i' = i_1 + i_2 = i + \frac{i}{2} = \frac{3i}{2} \]
Example Problem 2:

Change of local surface charge density leads to the local $E$ within the wire.

Of the following diagrams, which indicates the correct surface charge distribution of $+$’s and $-$’s on the circuit? Use the relation $\Delta V_i = I_i R_i$ (Ohm’s law) to assist in your qualitative reasoning.

**Inspection on wrong choices:**

- wrong sign, should be:
Inspection on wrong choices continued...

\[ R_1 = 25\Omega, \quad R_2 = 5\Omega \]

\[ \Delta V_1 = IR_1 \]

\[ \Delta V_2 = IR_2 \]

Picture has smaller charge density change across \( R_1 \). So \( \Delta V_1 < \Delta V_2 \)

This is contradictory to the given, \( R_1 > R_2 \)
Current flow should be clockwise,
i.e. from A to B, or at P, I is downward or $E_p$ is downward
The surface charge leads to $E_p$ upward which is inconsistent with CW current flows.

There is a potential difference between A and B.
This is inconsistent with set up where $V_A - V_B = 0$. 
Example Problem 3: Which of the following statements are true?

A steady-state current flows through the Nichrome wire in the circuit shown in the figure.

We discuss the first 4 statements here:

1. Incorrect. In the steady flow, $i = \text{const.}$, $E = \text{const.}$, but $E$ is not zero.

2. At $G$ and at $C$, the cross section is the same:
   \[ i_G = nA_G u E_G, \quad i_C = nA_C u E_C \]
   so $i_G = i_C$, and $E_G = E_C$

3. Correct by inspection

4. Incorrect. We need excess charges to generate $E$, in turn the excess in the wire.
Typical Homework Problem 4: Which of the following statements are true?

We discuss the first 2 statements:

1. Correct. Here \( i_e = i_O = i_c \) (steady flow within 1 loop)

\[
i_C = n A_c u E_C \\
i_D = n A_D u E_D
\]

\[
\therefore A_c E_C = A_D E_D, \quad E_D = \frac{A_C E_C}{A_D}
\]

Since ED is much bigger, the surface charge gradient must be larger also.

2. Yes. There is a steady current flow. The # of electrons pass through each point must be the same to avoid the pile up.
Ohm’s laws: conventional “macroscopic” ohm’s law are:

Ohm’s Law-1: \( J = \sigma E \)

Ohm’s Law-2: \( V = IR \)

How are the related to \( i = nA uE \)?

Define: \( I = |q| i = |q| nAuE. \)

So \( J = \frac{I}{A} = |q| nE = \sigma E \), or Ohm’s Law - 1 where the definition: \( \sigma = |q| nE \) is used.

Ohm’s Law-2 follows

\[
E = \frac{V}{L} = \frac{1}{\sigma} J = \rho \frac{I}{A}
\]

or

\[
V = \left( \frac{\rho L}{A} \right) I = RI, \quad \text{where} \quad R = \frac{\rho L}{A} \quad \text{is used.}
\]