Lecture: 23 (iq20) Microscopic picture of a circuit

1. A simple circuit: Macro vs micro descriptions
2. Drude model and drift velocity Clicker 23.1
3. Mechanical battery and steady decreasing surface charge density. Clicker 23-2
5. Steady state of a current flow in a circuit
   a. One loop: i maintains the same value throughout
   b. Node: $i_m = i_1 + i_2$
6. Examples
   a. Loop equations and node equations Kirchhoff’s rules.
   b. Simple circuit
   c. Example with a simple series connection
   d. Example with a simple parallel connection
   e. Example with 4 identical bulbs

Announcement:

Midterm 2: Class average is 67.
   o Reminder: How to determine the letter grade you made for this midterm?
     o Find you scaled score which is located near the bottom of the grading page.
     o Two letter grades for each exam:
       ▪ letter grade-1 based on % cutoffs.
       ▪ Letter grade-2 based on scaled score cutoffs.
     o The letter grade you have made for this exam is the higher of the two letter grades, if there is a difference.

Redo mt2: Due time this coming Sunday, 11:30pm, 3/10.
$i = \frac{dN}{dt}$

$E = 0$ Random motion

$E > 0$ Steady drift

$\mu = \frac{e \nu}{m}$

$v = at = \frac{eE}{m} t \nu = \left(\frac{e \nu}{m}\right) E = \nu E$

Drude model: $i = nA \nu E$

Clicker 3-2
Surface charge distribution:

Grading in the surface charge distribution

⇒ electron field inside the wire.

cross 1919

\[ i = \text{const} \Rightarrow E = \text{const} \text{ in the circuit.} \]

⇒ surface charge density is greatest throughout the circuit.

\[ i = nA r = nA u E, \]

\[ E_1 \rightarrow E_2 \]

for steady \( i \), with same material \( n = \text{const} \),

\[ AE = \text{const}. \]

Smaller \( A \) bigger \( \approx E \). \( \text{If} \ A_1 \ll A_2 \),

\[ E_1 \approx E_2. \]
Solving circuit problems

Given: Both ends and currents solve for \( E \) & \( i \) across each element of the circuit.

**Example 1:**

\[
\begin{align*}
\varepsilon - \varepsilon_L &= 0, \quad E = \frac{\varepsilon}{L} = E_0 \\
\dot{i} &= -\pi A \nu - \pi A \nu E = \pi A \frac{\varepsilon}{L} = \dot{i}_0
\end{align*}
\]

**Example 2:**

\[
\begin{align*}
\varepsilon - \varepsilon' - \varepsilon' &= 0 \\
\dot{i}' &= \pi A \nu \varepsilon' = \pi A \nu \frac{\varepsilon}{2L} = \frac{\dot{i}_0}{2} \\
\dot{E}' &= \frac{\varepsilon}{2L}, \text{ and } \dot{i}' = \frac{\dot{i}_0}{2}
\end{align*}
\]

**Example 3:**

\[
\begin{align*}
\varepsilon - \varepsilon_1 L &= 0 \\
\varepsilon - \varepsilon_2 L &= 0 \\
\dot{i}_1 &= \pi A \nu \varepsilon_1 = \pi A \nu \frac{\varepsilon}{L} = \dot{i}_0 \\
\dot{i}_2 &= \dot{i}_0 \\
\therefore \quad \dot{i}' &= 2\dot{i}_0, \quad \varepsilon_1 = \varepsilon_2 = \varepsilon_0
\end{align*}
\]
Example 4

\[ i_1 E \]

\[ \text{ABCBA: } E - 2E' - EL = 0 \quad (1) \]

\[ \text{ABDCA: } E - E' - EL = 0 \quad (2) \]

Node eqn: \[ i_1 = i' + i'" \quad (3) \]

\[ \begin{cases} 
  i_1 = -\text{mA}uE \\
  i' = -\text{mA}uE' \land \text{Node eqn } \Rightarrow E = E' + E'' \\
  i'" = -\text{mA}uE" 
\end{cases} \quad (4) \]

3 eqns + 3 unknowns.

Solve for \[ E, E', E" \] express all \[ E \] in terms of \[ E" \]

\[ 2E' = E" \quad \Rightarrow E' = \frac{E"}{2} \]

\[ E = E' + E" = \frac{3}{2}E" \]

(1): \[ E - E' - \frac{3}{2}E" = E - \frac{5}{2}E" = 0, \quad E" = \frac{2}{3}E \]

\[ E' = \frac{E"}{2} = \frac{1}{3}E" \quad \Rightarrow E = E' + E" = \frac{3}{2}E" = \frac{3}{3}E = \frac{E}{3} \]