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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**
4. Grading in surface charge density leads to field in the center of the wire. **Clicker fig19.19.**
5. Steady state of a current flow in a circuit
    a. One loop: i maintains the same value throughout
    b. Node: $i_{in}=i_1+i_2$
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:

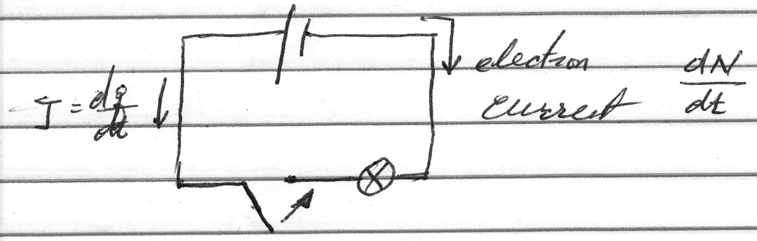
Midterm 2: Class average is 67.

- Reminder: How to determine the letter grade you made for this midterm?
    - Find you scaled score which is located near the bottom of the grading page.
    - Two letter grades for each exam:
        - letter grade-1 based on % cutoffs.
        - Letter grade-2 based on scaled score cutoffs.
    - 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.

ig 20 Electric field + electric circuit

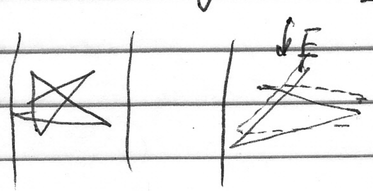
Simple circuit



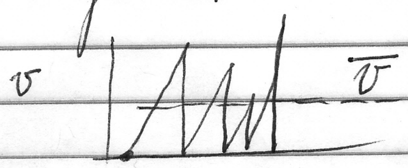
~~Def~~ Drift velocity:

$E = 0$ Random motion

$E > 0$ Steady drift



upward drift.



$$v = a t_c = \frac{eE}{m} t_c = \left(\frac{e t_c}{m}\right) E = uE$$

u mobility

v vs E

Trim

→ clicker 23.1

Electron number current:

$$i = \frac{dN}{dt} = \frac{nA\Delta L}{\Delta t} = nAv = nAuE$$

Drude model: $i = nAuE$

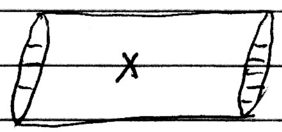
clicker 23-2

Surface charge distribution:

Grading in the surface charge distribution

$\Rightarrow$ electric field inside of the wire.

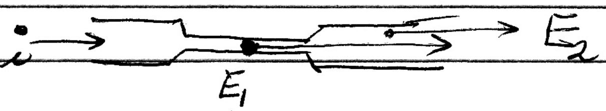
checker 19.19



If $i = \text{const} \Rightarrow E = \text{const}$ in the circuit.

$\Rightarrow$ ~~Surface charge distribution with gradient throughout the circuit.~~

$i = nAv = nAuE$,



for steady i, with same material $nu = \text{const}$

$AE = \text{const}$.

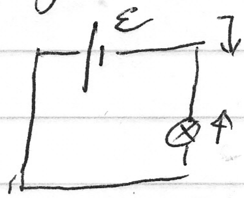
Smaller is A, Bigger is E.

If $A_1 \ll A_2$
$E_1 \gg E_2$

Solving circuit problem:

Given: Battery emf and circuits solve for E + i across each element of the circuit.

Example 1:

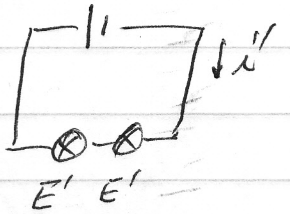


loop again:

$$\mathcal{E} - EL = 0 \quad , \quad E = \frac{\mathcal{E}}{L} \equiv E_0$$

$$i = nAv = nAuE = nAu\frac{\mathcal{E}}{L} \equiv i_0$$

Example 2:



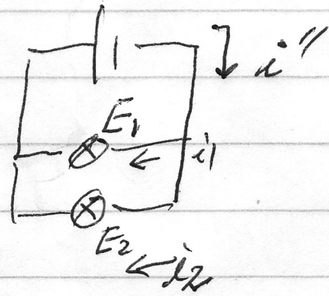
$$\mathcal{E} - E'L - E'L = 0$$

$$\therefore E' = \frac{\mathcal{E}}{2L} = \frac{E_0}{2}$$

$$i' = nAuE' = nAu\frac{\mathcal{E}}{2L} = \frac{i_0}{2}$$

$$\therefore E' = \frac{E_0}{2} \text{, and } i' = \frac{i_0}{2}$$

Example 3:



$$\mathcal{E} - E_1L = 0$$

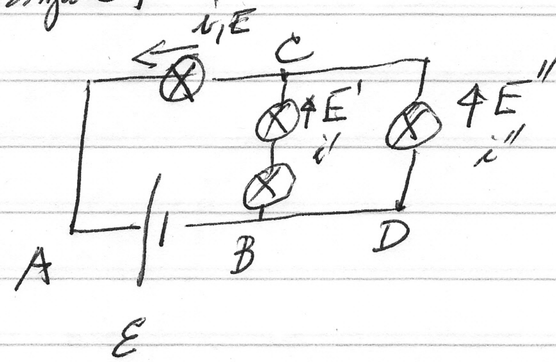
$$\mathcal{E} - E_2L = 0$$

$$i_1 = nAuE_1 = nAu\frac{\mathcal{E}}{L} = i_0$$

$$i_2 = i_0$$

$$\therefore i'' = 2i_0 \quad , \quad E_1 = E_2 = E_0$$

Example 4



ABCA: $\mathcal{E} - 2E'L - EL = 0$ (1)

ABDCA: $\mathcal{E} - E''L - EL = 0$ (2)

Node eqn: $i = i' + i''$ (3)

$\Downarrow$

$$\begin{cases} i = nAuE \\ i' = nAuE' \\ i'' = nAuE'' \end{cases}$$ ∴ Node eqn $\Rightarrow E = E' + E''$ (4)

3 eqns & 3 unknowns.

Solve for E', E'', E. Express all E's in term of E''

$2E' = E''$, $E' = \frac{E''}{2}$

$E = E' + E'' = \frac{3}{2}E''$

(1): $\mathcal{E} - E''L - \frac{3}{2}E''L = \mathcal{E} - \frac{5}{2}E''L = 0$, $E'' = \frac{2}{5}\frac{\mathcal{E}}{L}$

$E' = \frac{E''}{2} = \frac{1}{5}\frac{\mathcal{E}}{L}$. $E = E' + E'' = \frac{3}{2}E'' = \frac{3}{5}\frac{\mathcal{E}}{L}$.