Name______________________________________

Physics 121 Quiz #5, February 12, 2016

Please show all work, thoughts and/or reasoning in order to receive partial credit. The quiz is worth 10 points total.

I affirm that I have carried out my academic endeavors with full academic honesty.

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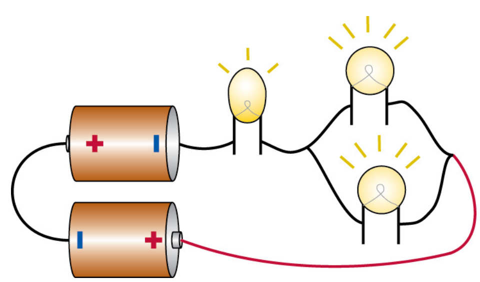
A thin filament light bulb is connected in series to two batteries (each rated at V_B) and 1.5×10^{18} electrons per second pass through the filament.

a. If the filament has a length L, what is the electric field in the thin filament bulb in terms of the battery potential and the length of the filament? (Hint: Use the loop rule.)

$$\Delta V_B + \Delta V_B + \Delta V_W = 0$$
$$2V_B - E_{thin}L = 0$$
$$E_{thin} = \frac{2V_B}{L}$$

b. Suppose now that you have the circuit wired below. The same two batteries (each of potential difference V_B) are connected in series to a thin filament bulb (the oval shaped bulb) and in parallel are two thick filament bulbs (the round circular bulbs.) Suppose that the filaments of each bulb are made out of the same material, the lengths of each filament are the same length, L, and that $A_{thin} = \frac{A_{thick}}{2}$. What is the relationship between the electric field in the thin bulb (E_{thin}) and the electric field in the thick bulb (E_{thick})? (Hint: Use the node rule and note that E_{thin} is not the same as what you calculated in part a.)



$$i_{thin} = i_{thick} + i_{thick} = 2i_{thick}$$
$$nA_{thin}\mu E_{thin} = 2nA_{thick}\mu E_{thick}$$
$$E_{thin} = 2\left(\frac{A_{thick}}{A_{thin}}\right)E_{thick} = 2\left(\frac{A_{thick}}{\frac{1}{2}A_{thick}}\right)E_{thick} = 4E_{thick}$$
$$E_{thin} = 4E_{thick}$$

c. Applying the loop rule to the circuit shown, determine expressions for E_{thin} and E_{thick} in terms of the potential difference of the batteries V_B and the length L of the bulb filaments.

$$\Delta V_B + \Delta V_B + \Delta V_{thin} + \Delta V_{thick} = 0$$
$$2V_B - E_{thin}L - E_{thick}L = 0$$
$$2V_B - 4E_{thick}L - E_{thick}L = 0$$
$$\therefore E_{thick} = \frac{2V_b}{5L} \quad \& \quad E_{thin} = 4\left(\frac{2V_b}{5L}\right) = \frac{8V_b}{5L}$$

d. What is the electron current that flows in the circuit? That is, what is i_{thin} for this circuit? (Hints: The electron current is not 1.5×10^{18} electrons per second, but related to it. There are many unknowns in the problem, namely n, μ, A_{thin}, L, and V_B. You can determine a value for all of the constants by using your result from part a.)

$$i_{thin} = nA_{thin}\mu E_{thin} = nA_{thin}\mu\left(\frac{8V_B}{5L}\right) \text{ and}$$

$$i_{thin} = 1.5\times10^{18} = nA_{thin}\mu E_{thin} = nA_{thin}\mu\left(\frac{2V_B}{L}\right)$$
$$\therefore \frac{nA_{thin}\mu V_B}{L} = \frac{1.5\times10^{18}}{2} = 0.75\times10^{18}$$

So, $i_{thin} = nA_{thin}\mu E_{thin} = \frac{8}{5}\left(\frac{nA_{thin}\mu V_B}{L}\right) = \frac{8}{5}\left(0.75\times10^{18}s^{-1}\right) = 1.2\times10^{18}s^{-1}$

e. What is the current I produced by the battery?

$$I = |e|i = 1.6\times10^{-19}C\times1.2\times10^{18}s^{-1} = 0.192A$$

Physics 121 Equation Sheet

Electricity & Magnetism

$$\vec{F} = k\frac{Q_1Q_2}{r^2}\hat{r}; \quad \hat{r} = \frac{\vec{r}_o - \vec{r}_s}{|\vec{r}_o - \vec{r}_s|}$$

$$\vec{E} = \frac{\vec{F}}{q}$$

$$\vec{E}_Q = k\frac{Q}{r^2}\hat{r}$$

$$\vec{p} = q\vec{s} = \alpha\vec{E}$$

$$|\vec{E}_{\parallel}| = \frac{2kqs}{r^3};\ \text{dipole } r >> s$$

$$|\vec{E}_{\perp}| = \frac{kqs}{r^3};\ \text{dipole } r >> s$$

$$|\vec{E}_{rod}| = \frac{1}{4\pi\varepsilon_0}\left[\frac{Q}{r\sqrt{r^2 + \left(L/2\right)^2}}\right]; \quad |\vec{E}_{rod}| \sim \frac{1}{4\pi\varepsilon_0}\left(\frac{2Q}{rL}\right) \quad L >> r$$

$$|\vec{E}_{ring}| = \frac{1}{4\pi\varepsilon_0}\left[\frac{Qz}{\left(R^2 + z^2\right)^{\frac{3}{2}}}\right]$$

$$|\vec{E}_{disk}| = \frac{Q}{2\pi\varepsilon_0 R^2}\left[1 - \frac{z}{\sqrt{R^2 + z^2}}\right]; \quad |\vec{E}_{disk}| \sim \frac{Q}{2\varepsilon_0 A}\left[1 - \frac{z}{R}\right] \quad z << R; \quad |\vec{E}_{disk}| \sim \frac{Q}{2\varepsilon_0 A} \quad z << R$$

$$|\vec{E}_{capacitor}| \sim \frac{Q}{\varepsilon_0 A}; \quad |\vec{E}_{fringe}| \sim \frac{Q}{2\varepsilon_0 A}\left(\frac{s}{R}\right)$$

$$W = -q\Delta V = -\Delta U = \Delta K; \quad U = \sum_{i \neq j}\frac{kQ_iQ_j}{r_{ij}};$$

$$V_Q = \frac{kQ}{r}; \quad V_{Q's} = \sum_i \frac{kQ_i}{r_i}$$

$$\Delta V = -\int \vec{E} \cdot d\vec{r}$$

$$E_x = -\frac{\Delta V}{\Delta x}; \quad E_y = -\frac{\Delta V}{\Delta y}; \quad E_z = -\frac{\Delta V}{\Delta z}; \quad \vec{E} = -\left\langle \frac{dV}{dx}, \frac{dV}{dy}, \frac{dV}{dz} \right\rangle$$

$$Q = \left(\frac{\varepsilon_0 A}{s}\right)\Delta V$$

$$I = \frac{\Delta Q}{\Delta t} = i|e| = n|e|Av_d; \quad \vec{v}_d = \mu\vec{E}$$

$$\vec{B} = \frac{\mu_o}{4\pi}\left(\frac{q\vec{v} \times \hat{r}}{r^2}\right)$$

$$d\vec{B} = \frac{\mu_o I}{4\pi}\left(\frac{d\vec{l} \times \hat{r}}{r^2}\right)$$

$$|\vec{B}_{wire}| = \frac{\mu_o LI}{4\pi r\sqrt{\left(\frac{L}{2}\right)^2 + r^2}}; \quad |\vec{B}_{wire}| \approx \frac{\mu_o I}{2\pi r} \quad L >> r$$

$$|\vec{B}_{ring}| = \frac{\mu_o IR^2}{2\left(z^2 + R^2\right)^{\frac{3}{2}}}; \quad |\vec{B}_{ring}| \approx \frac{\mu_o IR^2}{2z^3} \quad z << R$$

Constants

$g = 9.8\,\frac{m}{s^2}$ $\qquad$ $1eV = 1.6 \times 10^{-19} J$

$1e = 1.6 \times 10^{-19} C$ $\qquad$ $\mu_o = 4\pi \times 10^{-7}\,\frac{Tm}{A}$

$k = \frac{1}{4\pi\varepsilon_o} = 9 \times 10^9\,\frac{Nm^2}{C^2}$ $\qquad$ $c = 3 \times 10^8\,\frac{m}{s}$

$\varepsilon_o = 8.85 \times 10^{-12}\,\frac{C^2}{Nm^2}$ $\qquad$ $h = 6.63 \times 10^{-34} Js$

$m_e = 9.11 \times 10^{-31} kg = \frac{0.511 MeV}{c^2}$

$m_p = 1.67 \times 10^{-27} kg = \frac{937.1 MeV}{c^2}$

$m_n = 1.69 \times 10^{-27} kg = \frac{948.3 MeV}{c^2}$

$1amu = 1.66 \times 10^{-27} kg = \frac{931.5 MeV}{c^2}$

$N_A = 6.02 \times 10^{23}$

$Ax^2 + Bx + C = 0 \rightarrow x = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$

$B_{Earth,H} = 2 \times 10^{-5} T$

Loop Rule: $\sum_i \Delta V_i = \sum_i E_i \Delta l_i = 0$

Node Rule: $\sum I_{in} = \sum I_{out}$