Physics 2135 Exam 2

March 22, 2016

Exam Total

200 / 200

Printed Name: ____**Key**____

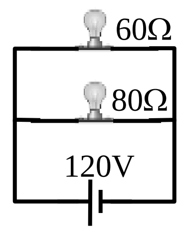
Rec. Sec. Letter: __**N/A**__

Five multiple choice questions, 8 points each. Choose the **best** or **most nearly correct** answer.

__B__ 1. An air-filled parallel plate capacitor is connected across a potential difference V_0 and fully charged. The capacitor is then disconnected from the circuit. After that, the separation between the plates is doubled. Which of the following best describes the change that results?

[A] The charge stored on the capacitor decreases.
[B] The potential difference across the plates increases.
[C] The capacitance of the capacitor increases.
[D] The electric energy stored in the capacitor decreases.

__A__ 2. A light bulb having 60 Ω resistance and a light bulb having 80 Ω resistance are connected in parallel across a 120 V power line. Which statement is true?



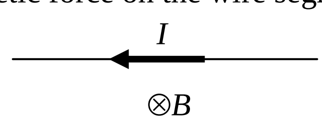
[A] The 60 Ω bulb glows brighter and draws a larger current than the 80 Ω bulb.
[B] The 60 Ω bulb glows brighter and draws the same current as the 80 Ω bulb.
[C] The 80 Ω bulb glows brighter and draws a larger current than the 60 Ω bulb.
[D] The 80 Ω bulb glows brighter and draws the same current as the 60 Ω bulb.

__C__ 3. The magnetic potential energy of a magnetic dipole $\vec{\mu}$ in a uniform magnetic field is maximum when

[A] $\vec{\mu}$ is parallel to $\vec{B}$ [B] $\vec{\mu} \perp \vec{B}$ [C] $\vec{\mu}$ is antiparallel to $\vec{B}$.

__C__ 4. A straight wire segment carries a current *I*. The wire segment is in a region where there is a uniform magnetic field *B* as shown. What is the direction of the magnetic force on the wire segment?

[A] ⊗ [B] ↑
[C] ↓ [D] ⊙



ABCD 5. What is causing the dog to levitate?

[A] Magnetism. [B] Physics.
[C] The Mind of Dr. Pringle. [D] Magic.

__40__ /40 for page 1

6. (20 points total) A light bulb is connected across a constant potential difference V_0. When it is first turned on at 20 °C the light bulb filament carries a current I_0. After several minutes, the light bulb filament reaches a temperature of 820°C and carries a current of 0.20 I_0.

(a) (10 points) Calculate the temperature coefficient of resistivity of the light bulb filament material. Start with OSE's and show all steps in your derivation of the final result.

$V_0 = I_0 R_0 = 0.20 I_0 R_{820}$

$\Rightarrow R_{820} = 5 R_{20}$

$\rho_{820} = \rho_{20}\left[1+\alpha(T-T_0)\right]$

$\frac{R_{820} \cancel{A_{820}}}{\cancel{L_{820}}} = \frac{R_{20} \cancel{A_{20}}}{\cancel{L_{20}}}\left[1+\alpha(820-20)\right]$

$\frac{R_{820}}{R_{20}} = 1 + 800\alpha$ assuming A, L do not change with T

$5 = 1 + 800\alpha$

$\alpha = \frac{4}{800} = \boxed{0.005\ (°C)^{-1}}$

(b) (10 points) Calculate the percentage change in the energy per second dissipated by the light bulb as the temperature rises from 20 °C to 820°C.

$\frac{P_{820} - P_{20}}{P_{20}} = \frac{0.20 I_0 V_0 - I_0 V_0}{I_0 V_0} = \frac{0.2 - 1}{1} = -0.8 \Rightarrow \boxed{80\%\ \text{decrease}}$ or -80%

You can also use $P = \frac{V^2}{R}$ but the algebra is more difficult

7. (20 points total) A 4.00 μF parallel-plate capacitor is charged with a 9.0 V battery. The air-filled distance between the plates is 2.0 cm.

(a) (10 points) Calculate the energy stored in the capacitor.

$U_0 = \frac{1}{2} C_0 V_0^2 = \frac{1}{2}(4 \times 10^{-6})(9)^2 = 162 \times 10^{-6} = \boxed{162\ \mu J}$

(b) (10 points) The capacitor **is disconnected from the battery**, and a material with dielectric constant $\kappa = 3.0$ is inserted between the plates. Find the electric field between the plates of the capacitor.

Q stays the same

$Q_0 = C_0 V_0 = Q_1 = C_1 V_1$

$C_0 V_0 = \kappa C_0 V_1 = 3 C_0 V_1$

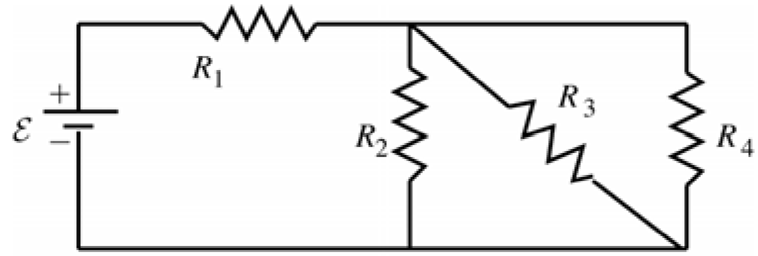
$\Rightarrow V_1 = \frac{1}{3} V_0$

$\Delta V = Ed$ and d does not change

$E_1 = \frac{V_1}{d} = \frac{\frac{1}{3} V_0}{0.02} = \frac{9}{0.06} = \boxed{150\ \frac{V}{m}}$ or $\frac{N}{C}$

40 /40 for page 2

8. (40 points total) In the circuit shown, $R_1 = 300\ \Omega$, $R_2 = 200\ \Omega$, $R_3 = 300\ \Omega$ and $R_4 = 600\ \Omega$. In this configuration, the power supply (which has negligible internal resistance) provides 1 W of power to the rest of the circuit. **Put your answers, with units, in the boxes provided.**



(a) (10 points) Find the equivalent resistance of the resistors connected across the power supply.

$$\frac{1}{R_{234}} = \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} = \frac{1}{200} + \frac{1}{300} + \frac{1}{600} = \frac{3+2+1}{600} = \frac{6}{600} \Rightarrow R_{234} = 100\,\Omega$$

$$R_{eq} = R_1 + R_{234} = 300 + 100 = 400\,\Omega$$

R_{eq} = $400\,\Omega$

(b) (10 points) Find the emf ε of the power supply.

$$P = \frac{\varepsilon^2}{R} \Rightarrow \varepsilon = \sqrt{PR} = \sqrt{1(400)} = 20\text{V}$$

ε = 20 V

(c) (20 points) Find the voltage across the resistor R_1, and the power dissipated by that resistor.

$$P = I\varepsilon$$
$$I = \frac{P}{\varepsilon} = \frac{1}{20} = 0.05\text{A}$$

OR

$$\varepsilon = I R_{eq}$$
$$I = \frac{\varepsilon}{R_{eq}} = \frac{20}{400} = 0{,}05\text{A}$$

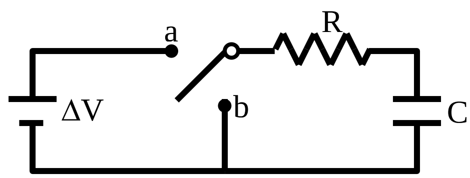
$$V_1 = I R_1 = (0.05)(300)$$
$$= 15\text{V}$$

$$P_1 = I_1^2 R_1 = (0.05)^2(300) = 0.75\text{W}$$

V_1 = 15V	P_1 = 0.75W

40 /40 for page 3

9. (40 points total) In the circuit shown, the uncharged capacitor has a capacitance of C=10μF and the resistor has a resistance of R=20Ω. The voltage source provides ΔV=12 V.



(a) (5 points) At t=0, the switch is thrown to position a. What is the current through the resistor immediately after the switch is thrown to position a?

loop rule: $\Delta V - IR - V_c = 0$

$V_{c0} = 0$ (initially uncharged)

$I_0 = \frac{\Delta V}{R} = \frac{12}{20} = \boxed{0.6A}$

OR

$I(t) = \frac{dQ(t)}{dt} = \frac{d}{dt}\left[Q_f\left(1-e^{-t/RC}\right)\right]$

$= -Q_f\left(e^{-t/RC}\right)\left(-\frac{1}{RC}\right) = \frac{C\Delta V}{RC}e^{-t/RC}$

$I(0) = \frac{\Delta V}{R}e^{-0} = \frac{12}{20} = \boxed{0.6 A}$

(b) (20 points) How long does it take before the current through the resistor is one third of its maximum value? Begin with the OSE for the time dependent charge and derive an expression for the time dependent current.

$I(t) = \frac{dQ(t)}{dt} = \frac{d}{dt}\left[Q_f\left(1-e^{-t/RC}\right)\right] = -Q_f\left(e^{-t/RC}\right)\left(-\frac{1}{RC}\right) = \frac{C\Delta V}{RC}e^{-t/RC} = I_0 e^{-t/RC}$

no need to re-derive if you did this above

solve for t when $I = I_0/3$

$\frac{I_0}{3} = I_0 e^{-t/RC}$

$\frac{1}{3} = e^{-t/RC}$

$-\frac{t}{RC} = \ln\frac{1}{3}$

$t = -RC\ln\frac{1}{3} = -20\left(10\times10^{-6}\right)\ln\frac{1}{3} = \boxed{220\,\mu s}$

(c) (15 points) After the capacitor is fully charged, the switch is thrown to position b. What is the charge on the capacitor at t= 0.3 ms after the switch is thrown to position b?

$Q = Q_0 e^{-t/RC}$

$Q_0 = C\Delta V = \left(10\times10^{-6}\right)(12) = 120\times10^{-6}$

$RC = 20\left(10\times10^{-6}\right) = 200\times10^{-6} = 0.2\times10^{-3} = 0.2\text{ ms}$

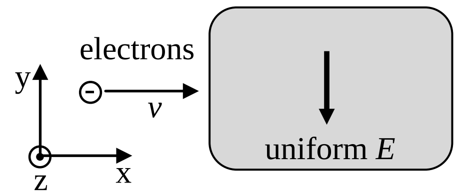
$Q(0.3ms) = \left(120\times10^{-6}\right)\exp\left(-\frac{0.3ms}{0.2ms}\right)$

$= 26.8\times10^{-6}$

$= \boxed{26.8\,\mu C}$

40 /40 for page 4

10. (40 points total) A beam of electrons of charge -*e* and mass *m* with random speeds in the +*x* direction enters a region containing a uniform electric field $\vec{E}$ pointing in the –*y* direction. We want to use a magnetic field $\vec{B}$ to make a velocity selector.



(a) (5 points) What direction should the magnetic field be to exert a force in the opposite direction of the force of the electric field?

Circle one: $+\hat{i}$ $-\hat{i}$ $+\hat{j}$ $-\hat{j}$ $+\hat{k}$ $-\hat{k}$

(b) (15 points) Starting with OSE's, derive an expression for the speed *v* of the particles that will be undeflected by the given electric and magnetic fields.

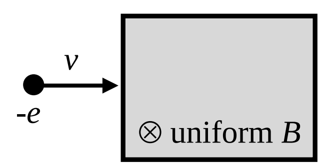
$\vec{F}_E = q\vec{E}$ and $\vec{F}_B = q\vec{v} \times \vec{B}$ $\quad$ $\vec{F}_E$ and $\vec{F}_B$ must be equal magnitude, opposite directions

$$F_E = F_B$$

$$|-e|E = |-e|vB$$

$$\boxed{v = \frac{E}{B}}$$

After the electrons with speed *v* leave the velocity selector, they enter a region of space where the only field present is a uniform magnetic field $\vec{B}$ different in magnitude from that of part (a) and pointing in the –*z* direction.



(c) (5 points) When they enter this new magnetic field region, the electrons begin to travel in a circle that is oriented (circle one below)

CLOCKWISE or COUNTERCLOCKWISE.

(d) (10 points) Starting with OSE's, derive an expression for the radius of the circle.

$$\vec{F}_B = q\vec{v} \times \vec{B} = m\vec{a}$$

$$|-e|vB = \frac{mv^2}{R}$$

$$R = \frac{mv^2}{evB} = \boxed{\frac{mv}{eB}}$$

(e) (5 points) What is the period of the motion?

$$T = \frac{2\pi R}{v} = \frac{2\pi mv}{veB} = \boxed{\frac{2\pi m}{eB}}$$

40 /40 for page 5