Physics 2135 Exam 2

October 20, 2015

Exam Total

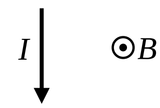
200 / 200

Printed Name: **Key**

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

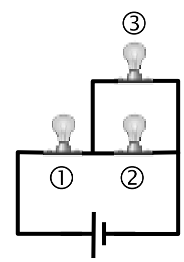
Five multiple choice questions, 8 points each. Choose the **best** or **most nearly correct** answer.

B 1. 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?



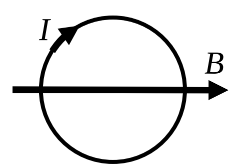
[A] ⊗ [B] ←
[C] → [D] ⊙

A 2. Three identical light bulbs are connected to a battery as shown in the figure to the right. Which light bulb will dissipate the most power?



[A] bulb ① [B] bulb ②
[B] bulb ③ [D] all three bulbs will dissipate the same power

B 3. A circular current loop has an area of $A = 200\ \text{cm}^2$ and is oriented so that the plane of the loop is parallel to a constant magnetic field $B = 0.6$ T. The magnitude of the torque acting on the current loop is 0.024 m·N. What is the current *I* in the loop?



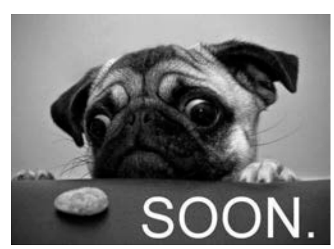
[A] 1 A [B] 2 A
[C] 4 A [D] 0 A

C 4. A charged particle moves through a region of space that has both a uniform electric field and a uniform magnetic field. In order for the particle to move through this region at a constant velocity,

[A] the electric and magnetic fields must point in the same direction
[B] the electric and magnetic fields must point in opposite directions
[C] the electric and magnetic fields must point in perpendicular directions
[D] the answer depends on the sign of the particle's electric charge.

ABCD 5. When will I get a picture of a levitating dog on my Physics 2135 exam?

[A] soon [B] exam 3
[C] ask Dr. Parris [D] the answer is always magnetism



40 /40 for page 1

6. (40 points total) An air-filled parallel-plate capacitor consists of two square plates of length *L* and plate separation *d*. It is charged to an initial voltage V_0.

(a) (10 points) Calculate the energy U_0 stored in the capacitor in terms of *L*, *d*, V_0, and constants.

$$C_0 = \frac{\epsilon_0 A}{d} = \frac{\epsilon_0 L^2}{d} \quad K=1 \text{ for air}$$

$$U_0 = \frac{1}{2} C_0 V_0^2 = \frac{1}{2}\left(\frac{\epsilon_0 L^2}{d}\right) V_0^2 = \boxed{\frac{\epsilon_0 L^2 V^2}{2d}}$$

(b) (20 points) The capacitor is disconnected from the voltage source. After that, an insulator having a dielectric constant κ>1 is inserted between the plates of the capacitor. The dielectric material fills the space between the plates. Find the energy U_1 stored in the capacitor after the dielectric is inserted. Express your answer in terms of *L*, *d*, V_0, κ, and constants.

$$Q_1 = Q_0 \text{ (disconnected)} \quad C_1 = \frac{K\epsilon_0 A}{d} = \frac{K\epsilon_0 L^2}{d} = KC_0$$

$$U_1 = \frac{Q_1^2}{2C_1} = \frac{Q_0^2}{2C_1} = \frac{C_0^2 V_0^2}{2C_1} = \frac{C_0^2 V_0^2}{2KC_0} = \frac{C_0 V_0^2}{2K}$$

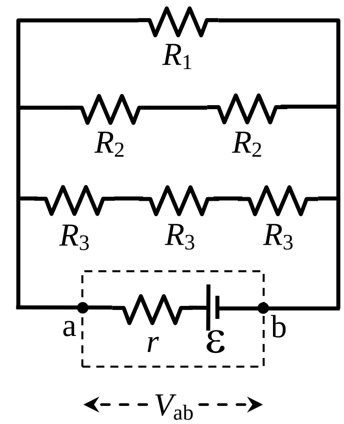
$$U_1 = \frac{\left(\frac{\epsilon_0 L^2}{d}\right) V_0^2}{2K} = \boxed{\frac{\epsilon_0 L^2 V_0^2}{2Kd}}$$

(c) (10 points) The potential difference V_1 between the capacitor plates after the dielectric has been inserted is (circle one below)

less than V_0 | equal to V_0 | greater than V_0

40 /40 for page 2

7. (40 points total) Consider the circuit shown. The **terminal voltage** of the battery is V_{ab}=120 V.



(a) (20 points) Each resistor dissipates 100W. Calculate R_1, R_2, and R_3. Clearly indicate any OSEs you use.

R_1 branch: $R_{eq} = R_1 \Rightarrow V_1 = V_{ab}$

R_2 branch: $R_{eq} = 2R_2 \Rightarrow V_2 = V_{ab}/2$

R_3 branch: $R_{eq} = 3R_3 \Rightarrow V_3 = V_{ab}/3$

$P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P}$ $\quad R_1 = \frac{120^2}{100} = \boxed{144\,\Omega}$

$R_2 = \frac{60^2}{100} = \boxed{36\,\Omega}$

$R_3 = \frac{40^2}{100} = \boxed{16\,\Omega}$

(b) (10 points) If the battery has an internal resistance of r = 0.8 Ω, what is its emf?

method 1: use $I = V/R$ & $V_{ab} = \varepsilon - Ir$

$I_1 = \frac{120}{144} = \frac{10}{12}$

$I_2 = \frac{120}{36+36} = \frac{10}{6}$

$I_3 = \frac{120}{3(16)} = \frac{10}{4}$

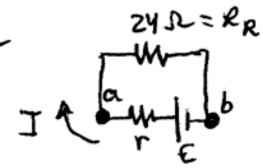
$I_{total} = I_1 + I_2 + I_3 = \frac{10+20+30}{12} = 5A$

$\varepsilon = V_{ab} + I_{total}\, r = 120 + 5(0.8) = \boxed{124\,V}$

method 2: calculate R_{eq} of R_1 R_2's & R_3's

$\frac{1}{R_{R's}} = \frac{1}{144} + \frac{1}{72} + \frac{1}{48} = \frac{6}{144}$

$R_{R's} = 24\,\Omega$



$V_{ab} = 120\,V \Rightarrow I = \frac{120}{24} = 5A$

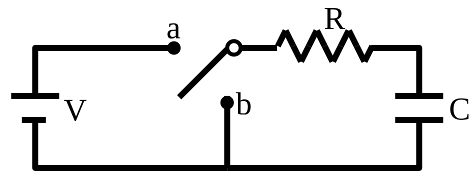
$\varepsilon = V_{ab} + Ir = \boxed{124\,V}$

(c) (10 points) A non-ideal ammeter is connected to measure the current passing through R_1. How does the power dissipated in R_1 change? (Circle one of the answers below.)

increases does not change decreases

40 /40 for page 3

8. (40 points total) In the circuit shown, R = 50 kΩ, V = 25 volts, and C = 10 μF. The capacitor is initially uncharged.



(a) (10 points) What is the initial current through the resistor immediately after the switch is set to position a?

Initially $V - V_R - \cancel{V_C}^{\,0} = 0 \Rightarrow V_R = IR = V$

OK to just start here → $I = \frac{V}{R} = \frac{25}{50{,}000} = \boxed{0.5\,mA}$

you can also take $I = \frac{dQ}{dt}$ and get same result

(b) (20 points) What is the voltage across the capacitor 1 second after the switch is set to a?

$Q(t) = Q_f\left(1 - e^{-t/RC}\right)$ $\qquad RC = (50\times10^3)(10\times10^{-6}) = 0.5\,s$

$CV(t) = CV\left(1 - e^{-t/RC}\right)$

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

$V(1) = 25\left(1 - e^{-1/0.5}\right) = 25(1 - 0.135) = \boxed{21.6\,V}$

(c) (10 points) The capacitor is allowed to fully charge. The switch is then set to position b. How much time elapses after the switch is set to position b until the charge stored in the capacitor is equal to one-fourth of its fully-charged value?

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

$\frac{1}{4}Q_0 = Q_0 e^{-t/RC}$

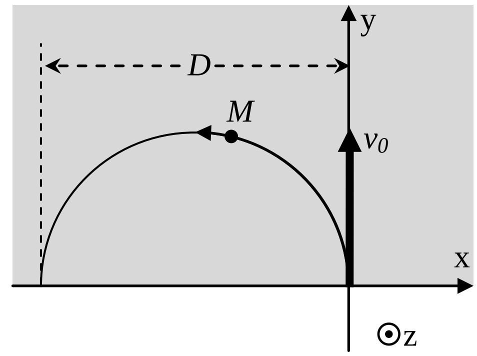
$\frac{1}{4} = e^{-t/RC}$

$\frac{-t}{RC} = \ln\frac{1}{4}$

$t = -RC\ln\left(\frac{1}{4}\right) = -0.5\ln\frac{1}{4} = \boxed{0.693\,s}$

40 /40 for page 4

9. (40 points total) A particle of mass M and positive charge Q enters a region (indicated by the shaded area) of uniform magnetic field, moving initially with a velocity $\vec{v} = v_0\hat{j}$. The particle moves in a circular path in the xy-plane and crosses the x-axis at $x = -D$.



(a) (5 points) What is the direction of the magnetic field?

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

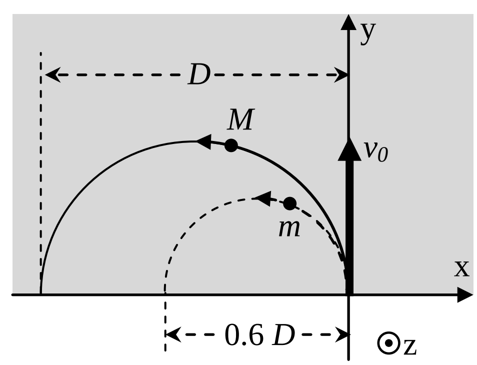
(b) (20 points) Begin with starting equations and calculate the magnitude of the magnetic field. Express your answer in terms of parameters given in the statement of the problem.

$\vec{F} = Q\vec{v}\times\vec{B} = M\vec{a}$ with $\vec{v} \perp \vec{B}$

$$Qv_0 B = \frac{Mv_0^2}{r} = \frac{Mv_0^2}{D/2} = \frac{2Mv_0^2}{D}$$

$$\boxed{B = \frac{2Mv_0}{QD}}$$

(c) (15 points) A second particle of unknown mass having the same charge Q and the same initial velocity $v_0\hat{j}$ moves in a circular path in the magnetic field region and crosses the x-axis at x = -0.6 D. Begin with starting equations or an equation you derived in part (b), and calculate the mass of the second particle. Express your answer in terms of M.



from part b $QB = \frac{mv}{r} \Rightarrow m = \frac{QrB}{v}$

$$m = \frac{Q\frac{1}{2}(0.6D)B}{v_0} = 0.6\frac{QDB}{2v_0} = \boxed{0.6\,M}$$

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