Exam Total
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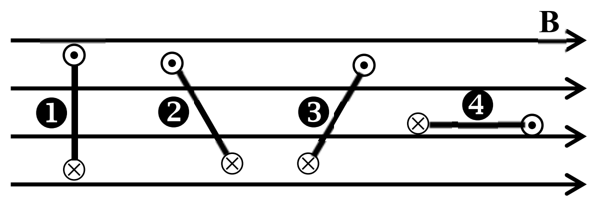
PHYS 2135 Exam II
October 16, 2018

Name: ___________________________ Section: _________

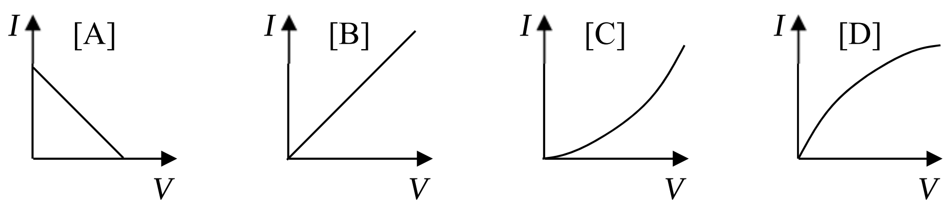
For questions 1-5, select the best answer. For problems 6-9, solutions must begin with an Official Starting Equation, when appropriate. Work must be shown to receive credit. Calculators are not allowed.

(8) ___D_____ 1. Two light bulbs are both rated for 110V operation. One bulb is 100W and the other is 40W. They are wired in parallel with a 110V source. The 100W bulb burns out. What happens next?
[A] The current flowing through the 40W bulb goes to zero.
[B] The voltage across the 40W bulb decreases but does not decrease to zero.
[C] The current flowing through the 40W bulb increases to 10/4 of its initial value.
[D] None of the above.

(8) ___D_____ 2. The diagram shows a side view of four loops in a uniform magnetic field. All four loops are identical. For which loop is the potential energy of the magnetic dipole equal to zero.?
[A] ❶ [B] ❷
[C] ❸ [D] ❹



(8) ___B_____ 3. A resistor with resistance R obeys Ohm's law. It is connected to a variable voltage source and the current through the resistor as a function of applied voltage is measured. Which plot (A, B, C, or D) best describes the results of the measurements?



(8) ___D_____ 4. A vertical straight wire of length L, carries a current I upward from the ground. The earth's magnetic field, which is directed towards the north, exerts a force on the wire. The direction of the force on the wire is towards the
[A] north [B] south [C] east [D] west.

(8) _________ 5. Free point problems often involve animals because
[A] they are found in fields.
[B] we lack resistance against them.
[C] they have the capacity to charge.
[D] of unknown reasons, the subject of current research.

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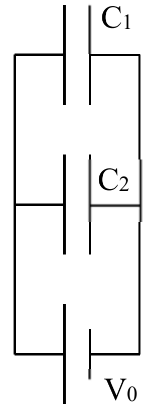
6. Two capacitors with capacitance $C_1 = C$ and $C_2 = 2C$ are connected across a potential difference V_0 as shown. **Express answers in terms of given quantities. Simplify when possible.**

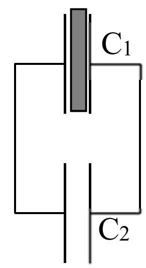


(10) (a) Calculate the charge on each capacitor.

$C = \frac{Q}{V}$ $\quad Q_1 = C_1V_1 \quad Q_2 = C_2V_2$

$\boxed{Q_1 = CV_0} \quad \boxed{Q_2 = 2CV_0}$

(10) (b) After the *battery is disconnected*, a dielectric with dielectric constant $K = 4$ is inserted into capacitor C_1 completely filling the space between the capacitor plates. Calculate the charge on each capacitor now.



$$C_{1f} = \kappa C_1$$
$$C_{1f} = 4C$$

$$Q_{T0} = Q_{Tf}$$
$$CV_0 + 2CV_0 = C_{1f}V_f + C_2V_f$$
$$3CV_0 = (4C + 2C)V_f$$
$$\frac{3CV_0}{6C} = V_f$$
$$\frac{1}{2}V_0 = V_f$$

$$Q_{1f} = C_{1f}V_f$$
$$Q_{1f} = 4C\left(\frac{1}{2}V_0\right)$$
$$\boxed{Q_{1f} = 2CV_0}$$
$$Q_{2f} = C_{2f}V_f$$
$$Q_{2f} = 2C\left(\frac{1}{2}V_0\right)$$
$$\boxed{Q_{2f} = CV_0}$$

7. A light bulb has a resistance of 20 Ω when off (20 °C) and a resistance of 120 Ω when on (hot).

(20) If the temperature coefficient for the light bulb filament is $1/60\ (°\mathrm{C})^{-1}$ what is the operating temperature of the bulb? You may neglect thermal expansion of the filament. **A numerical answer is required.**

$$R = \rho\frac{L}{A}$$
$$R = \rho_0\frac{L}{A}[1 + \alpha(T - T_0)]$$
$$R = R_0[1 + \alpha(T - T_0)]$$
$$\frac{R}{R_0} = 1 + \alpha(T - T_0)$$
$$\frac{R}{R_0} - 1 = \alpha(T - T_0)$$
$$\frac{\frac{R}{R_0}-1}{\alpha} = T - T_0$$
$$\frac{\frac{R}{R_0}-1}{\alpha} + T_0 = T$$

$$\frac{\frac{120\Omega}{20\Omega}-1}{1/(60℃)} + 20℃ = T$$
$$\frac{6-1}{1/(60℃)} + 20℃ = T$$
$$5(60℃) + 20℃ = T$$
$$300℃ + 20℃ = T$$
$$\boxed{320℃ = T}$$

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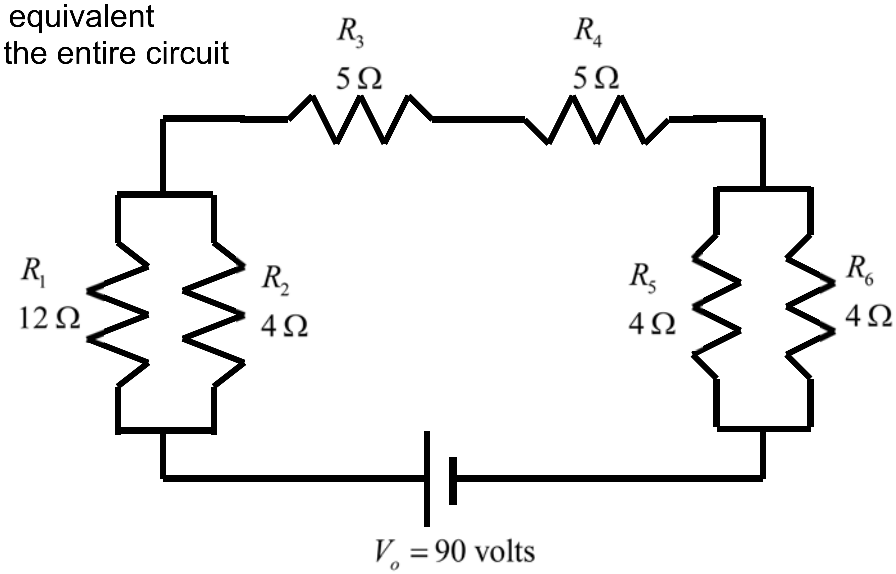
8. **Numerical answers are required for all parts of problem 8.**

(10) (a) Calculate the equivalent resistance of the entire circuit shown.



$$R_{12} = \left(\frac{1}{12\Omega} + \frac{1}{4\Omega}\right)^{-1} = 3\Omega$$

$$R_{56} = \left(\frac{1}{4\Omega} + \frac{1}{4\Omega}\right)^{-1} = 2\Omega$$

$$R_T = 3\Omega + 5\Omega + 5\Omega + 2\Omega$$

$$\boxed{R_T = 15\Omega}$$

(10) (b) Find the current I_3 in resistor R_3.

$$I_3 = I_T = \frac{V_T}{R_T} = \frac{90\text{V}}{15\Omega}$$

$$\boxed{I_3 = 6\text{A}}$$

(10) (c) Find the voltage V_1 across resistor R_1.

$$V_1 = V_{12} = I_{12}R_{12} = I_T R_{12} = (6\text{A})(3\Omega)$$

$$\boxed{V_1 = 18\text{V}}$$

(10) (d) Assume resistor R_5 has a cylindrical shape with a diameter of 6 mm, a length ℓ and is made out of Carbon. Estimate the length ℓ of the Carbon rod so that it has a resistance of $4\,\Omega$. The resistivity of Carbon $\rho = 3.6\times10^{-5}\,\Omega\cdot m$ and assume $\pi \approx 3$ for estimation purposes. **<u>A numerical answer of one significant figure is required</u>.**

$$R = \rho\frac{l}{A}$$

$$\frac{RA}{\rho} = l$$

$$\frac{R\pi r^2}{\rho} = l$$

$$\frac{(4\Omega)3\left(3\times10^{-3}\text{m}\right)^2}{3.6\times10^{-5}\Omega\text{m}} = l$$

$$\boxed{3\text{m} = l}$$

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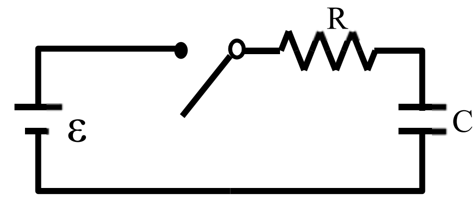
9. In the circuit shown, an uncharged capacitor with capacitance C and a resistor with resistance R are in series with a battery of emf Ɛ.



(10) (a) After the switch has been closed for a very long time what is the final charge on the capacitor and what is the total energy stored in it? **Express your answers in terms of Ɛ and C.**

$$C = \frac{Q}{V} \qquad U = \frac{1}{2}QV$$

$$Q_f = CV_f \qquad U_f = \frac{1}{2}Q_f V_f$$

$$\boxed{Q_f = C\mathcal{E}} \qquad \boxed{U_f = \frac{1}{2}C\mathcal{E}^2}$$

(15) (b) When the power dissipated by the resistor is equal to $\mathcal{E}^2/(9R)$, what is the energy stored in the capacitor? **Express your answer in terms of Ɛ and C.**

$$P = \frac{V_R^2}{R} = \frac{\mathcal{E}^2}{9R}$$

$$V_R = \frac{\mathcal{E}}{3}$$

$$\mathcal{E} - V_R - V_C = 0$$

$$\mathcal{E} - \frac{\mathcal{E}}{3} = V_C$$

$$\frac{2}{3}\mathcal{E} = V_C$$

$$U = \frac{1}{2}CV^2$$

$$U = \frac{1}{2}C\left(\frac{2}{3}\mathcal{E}\right)^2$$

$$\boxed{U = \frac{2}{9}C\mathcal{E}^2}$$

(15) (c) Determine the time after the switch is closed when the charge on the capacitor is $\frac{2}{3}$ of its final charge. **Express your answers using Ɛ, C, and R, as appropriate.**

$$Q = Q_f\left(1 - e^{-t/\tau}\right)$$

$$\frac{2}{3}Q_f = Q_f\left(1 - e^{-t/RC}\right)$$

$$\frac{2}{3} = 1 - e^{-t/RC}$$

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

$$-\frac{t}{RC} = \ln\left(\frac{1}{3}\right)$$

$$\boxed{t = -RC\ln\left(\frac{1}{3}\right)} \quad \text{or} \quad \boxed{t = RC\ln(3)}$$

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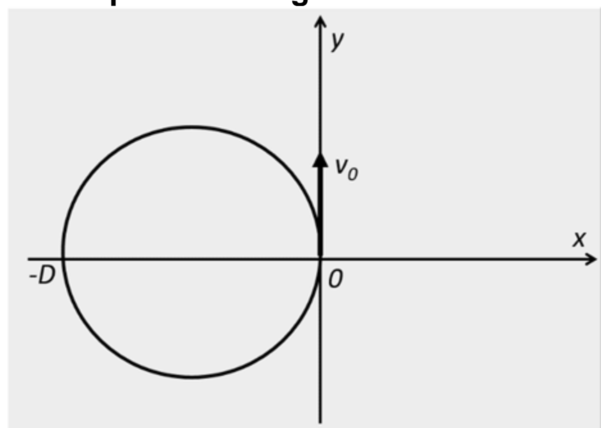
10. An electron of mass m_e and charge $-e$ enters a region (indicated by the shaded area) of uniform magnetic field, moving initially with a velocity $v = v_0$ along positive *y*-axis. The electron moves in a circular path in the *xy*-plane and crosses the *x*-axis at $x = -D$. **Express all answers for problem 10 in terms of parameters given in the statement of the problem.**



(15) (a) Begin with starting equations and calculate the magnitude of the magnetic field.

$$\vec{F} = q(\vec{E} + \vec{v} \times \vec{B})$$

$$|qvB| = \frac{mv^2}{r} \qquad r = \frac{D}{2}$$

$$\boxed{B = \frac{2m_e v_0}{eD}}$$

(5) (b) Which of the following is the direction of the magnetic field? [Circle the correct answer.]

[A]	$\hat{\imath}$	[B]	$\hat{\jmath}$	[C]	$\hat{k}$	[D]	Clockwise
[E]	$-\hat{\imath}$	[F]	$-\hat{\jmath}$	[G]	$-\hat{k}$	[H]	Counterclockwise

(10) (c) Calculate the magnitude of the magnetic flux through the area defined by the circular path.

$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

$$\Phi_B = \int B dA$$

$$\Phi_B = B \int dA$$

$$\Phi_B = BA$$

$$\Phi_B = \left(\frac{2m_e v_0}{eD}\right)\left[\pi\left(\frac{D}{2}\right)^2\right]$$

$$\boxed{\Phi_B = \frac{m_e v_0 \pi D}{2e}}$$

(10) (d) A positron (particle of mass m_e and charge $+e$) enters the same region with the same initial velocity $v = v_0$ along the positive *y*-axis. Find the position where the positron crosses the x-axis in its circular path.

$$\boxed{x = +D}$$

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