Exam Total
/200

PHYS 2135 Exam II

March 20, 2018

Name: ___________________________

Recitation Section: _______________

Five multiple choice questions, 8 points each. Choose the best or most nearly correct answer. For questions 6-9, solutions must begin with a correct OSE. You must show work to receive full credit for your answers. **Calculators are NOT allowed.**

(8) __**D**__ 1. A parallel plate capacitor is fully charged. It remains connected to the battery, and the plates are moved further apart. Which quantity remains unchanged?

[A] capacitance
[B] electric field
[C] charge
[D] potential difference

(8) __**C**__ 2. The potential difference across a length of wire is decreased. Which of the following does **not** decrease as well?

[A] Electric field in the wire
[B] Current through the wire
[C] Resistance of the wire
[D] Power dissipated in the wire

(8) __**B**__ 3. An ideal voltmeter has _______ resistance. An ideal ammeter has ______ resistance.

[A] infinite, infinite
[B] infinite, zero
[C] zero, infinite
[D] zero, zero

(8) __**A**__ 4. The time constant of an RC circuit is the time it takes

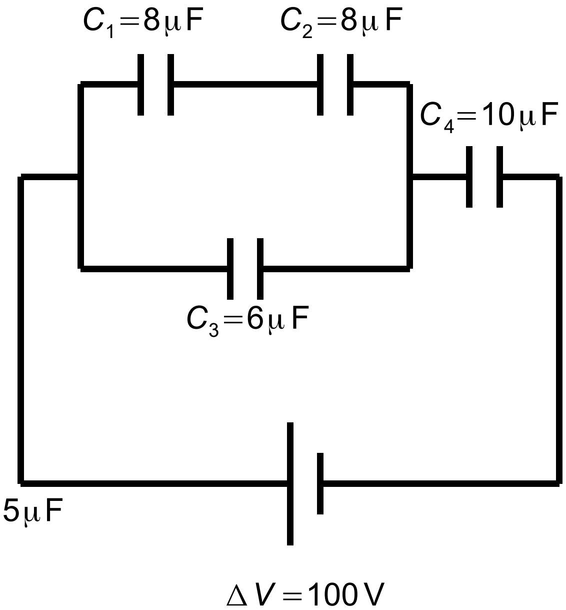
[A] for the current to decrease to 37% of its initial value.
[B] for the current to drop to zero.
[C] for the current to reach its maximum value.
[D] for the capacitor to be completely charged.

(8) ________ 5. If magnetic charges were discovered at S&T,

[A] those whose science knowledge is current would be attracted to Rolla.
[B] S&T would push back against others who claimed to find the same charges.
[C] it would be an outstanding discovery in the field.
[D] there would be a significant increase in our potential.

/40

6. In the capacitor circuit shown C_1 = C_2 = 8 μF, C_3 = 6 μF, C_4 = 10 μF, and ΔV = 100 V.



(20) (a) Find the equivalent capacitance of this circuit.

$$C_{12} = \left(\frac{1}{C_1} + \frac{1}{C_2}\right)^{-1} = \left(\frac{1}{8\,\mu F} + \frac{1}{8\,\mu F}\right)^{-1} = \left(\frac{2}{8\,\mu F}\right)^{-1} = 4\,\mu F$$

$$C_{123} = C_{12} + C_3 = 4\,\mu F + 6\,\mu F = 10\,\mu F$$

$$C_T = \left(\frac{1}{C_{123}} + \frac{1}{C_4}\right)^{-1} = \left(\frac{1}{10\,\mu F} + \frac{1}{10\,\mu F}\right)^{-1} = \left(\frac{2}{10\,\mu F}\right)^{-1} = 5\,\mu F$$

$$\boxed{C_T = 5\,\mu F}$$

(10) (b) Find the potential difference V_4 across capacitor C_4.

$$Q_4 = Q_T = C_T \Delta V = (5\,\mu F)(100\,V) = 500\,\mu C$$

$$V_4 = \frac{Q_4}{C_4} = \frac{500\,\mu C}{10\,\mu F} = 50\,V$$

$$\boxed{V_4 = 50\,V}$$

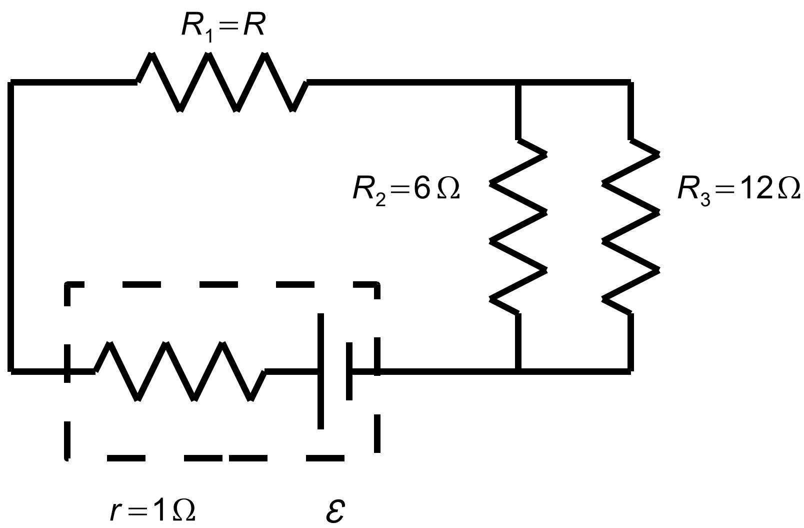
(10) (c) Find the total energy stored in this capacitor circuit.

$$U = \frac{1}{2} C_T (\Delta V)^2 = \frac{1}{2}(5\,\mu F)(100\,V)^2 = 0.025\,J$$

$$\boxed{U = 0.025\,J}$$

/40

7. In the circuit shown $R_1 = R$, $R_2 = 6\Omega$, $R_3 = 12\Omega$, $r = 1\Omega$.



(10) (a) If the current through R_3 is 1A, find the current I_2 through resistor R_2.

$$I_2 R_2 = V_2 = V_3 = I_3 R_3$$

$$I_2 = I_3 \frac{R_3}{R_2} \qquad \boxed{I_2 = 2\,\mathrm{A}}$$

$$I_2 = (1\,\mathrm{A}) \frac{12\,\Omega}{6\,\Omega}$$

(20) (b) If the power dissipated by resistor R_1 equals the total power dissipated by resistors R_2, and R_3, find the value of R.

$$I_1^2 R = P_1 = P_2 + P_3 = I_2^2 R_2 + I_3^2 R_3$$

$$I_1 = I_2 + I_3 = 2\,\mathrm{A} + 1\,\mathrm{A} = 3\,\mathrm{A} \qquad R = \frac{I_2^2 R_2 + I_3^2 R_3}{I_1^2} \qquad \boxed{R = 4\,\Omega}$$

$$R = \frac{(2\,\mathrm{A})^2 (6\,\Omega) + (1\,\mathrm{A})^2 (12\,\Omega)}{(3\,\mathrm{A})^2}$$

(10) (c) Find the emf, ε, of the battery.

$$R_{23} = \left(\frac{1}{R_2} + \frac{1}{R_3}\right)^{-1} = \left(\frac{1}{6\,\Omega} + \frac{1}{12\,\Omega}\right)^{-1} = 4\,\Omega$$

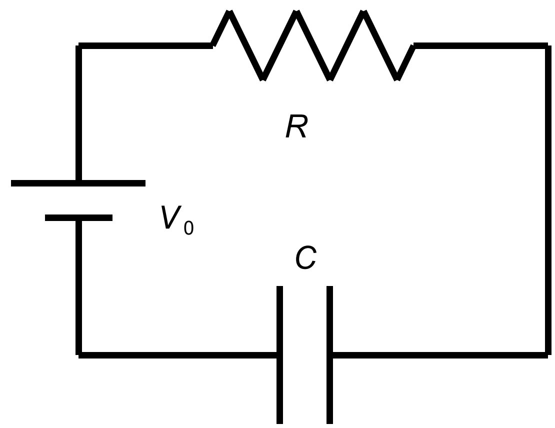
$$\mathcal{E} = I_T R_T = (3\,\mathrm{A})(9\,\Omega)$$

$$\boxed{\mathcal{E} = 27\,\mathrm{V}}$$

$$R_T = r + R_1 + R_{23} = 1\,\Omega + 4\,\Omega + 4\,\Omega = 9\,\Omega$$

/40

8. An uncharged capacitor with capacitance C, a resistor with resistance R, and a battery with voltage V_0 are connected in series as shown in the diagram at right.



(20) (a) Derive an equation for the current through the resistor as a function of time. Start from OSEs and express your answer in terms of V_0, R, and C.

$$I = \frac{dQ}{dt}$$

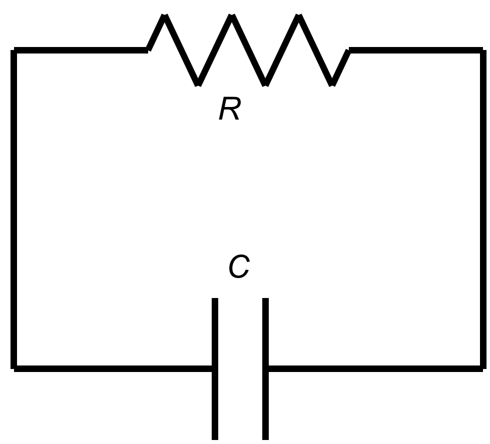
$$I = \frac{d}{dt} Q_f \left(1 - e^{-t/\tau}\right)$$

$$I = \frac{Q_f}{\tau} e^{-t/\tau}$$

$$I = \frac{Q_f}{RC} e^{-t/RC}$$

$$\boxed{I = \frac{V_0}{R} e^{-t/RC}}$$

(20) (b) After a while, the battery is removed from the circuit and the charge on the capacitor is found to be Q_i. The capacitor and resistor are then reconnected as shown in the diagram at right. Derive an equation for the energy stored in the capacitor as a function of time. Start from OSEs and express your answer in terms of Q_i, R, and C.



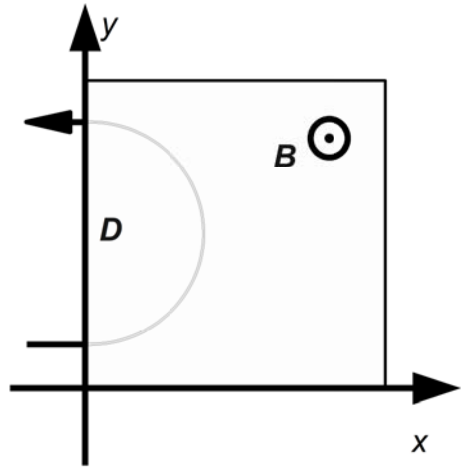
$$U = \frac{1}{2}\left(\frac{Q^2}{C}\right)$$

$$U = \frac{1}{2}\left(\frac{\left[Q_i e^{-t/\tau}\right]^2}{C}\right)$$

$$\boxed{U = \frac{1}{2}\left(\frac{Q_i^2}{C}\right) e^{-2t/RC}}$$

/40

9. A beam of particles having charge Q, mass m_0, moving with speed v_0 , enter a region which has a uniform magnetic field of unknown magnitude pointing out of the page ($+\hat{k}$). These particles are observed to follow the circular path shown in the figure with diameter D.



(5) (a) What is the sign of the charge of the particles (Circle one.)

negative positive

(10) (b) Starting with OSE, derive a formula for the magnitude of the magnetic field B in terms of the given variables.

$$|q(\vec{E}+\vec{v}\times\vec{B})|=\frac{mv^2}{R}$$

$$|Q|v_0B=\frac{m_0v_0^2}{D/2}$$

$$\boxed{B=\frac{2mv}{|Q|D}}$$

(10) (c) How much time does each particle spend in the region of magnetic field?

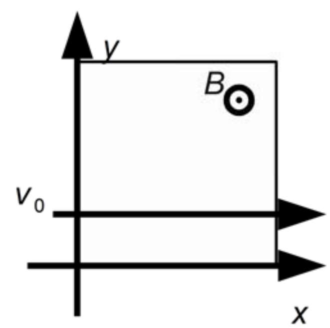
$$v=\frac{d}{t}$$

$$t=\frac{d}{v}$$

$$t=\frac{\pi D/2}{v_0}$$

$$\boxed{t=\frac{\pi D}{2v_0}}$$

(5) (d) Suppose we now want to use an electric field to make a velocity selector. What should be the direction of the electric field? (Circle one.)



$+\hat{i}$ $+\hat{j}$ $+\hat{k}$

$-\hat{i}$ $-\hat{j}$ $-\hat{k}$

(10) (e) Derive a formula for the magnitude of the electric field E for the velocity selector in terms of m_0, v_0, Q and D.

$$0=\vec{F}=q(\vec{E}+\vec{v}\times\vec{B})$$
$$E=vB$$

$$E=v_0\left(\frac{2m_0v_0}{qD}\right)$$

$$\boxed{E=\frac{2m_0v_0^2}{|Q|D}}$$

/40