Physics 24 Test Preparation Homework #2

These problems are intended to help you verify your level of preparation for Test 2. They do not cover every topic you could be tested on.

Multiple Choice

1. An air-filled parallel-plate capacitor is charged by a battery. After it is fully charged it is disconnected from the battery and a dielectric is inserted between the plates. Which of the following is true?
   [A] The electric field between the plates increases and the energy stored increases.
   [B] The electric field between the plates is constant and the energy stored increases.
   [C] The electric field between the plates decreases and the energy stored decreases.
   [D] The electric field between the plates is constant and the energy stored decreases.

Problems

2. An electron with kinetic energy 1.20 keV moves in a circle in a plane perpendicular to a uniform magnetic field. The radius of the circular orbit is 25.0 cm.
   (a) Determine the speed, v, of the electron, and the period, T, of its motion.
   (b) Determine the magnitude of the magnetic field.

3. A 2.0 μF parallel-plate air-filled capacitor is connected across a 10 V battery.
   (a) Determine the charge on the capacitor and the energy stored in the capacitor.
   (b) An identical 2.0 μF parallel-plate air-filled capacitor is connected across a 5 V battery, and a dielectric slab with dielectric constant κ is inserted between the plates of the capacitor, completely filling the region between the plates, while the battery remains connected. The energy stored in this capacitor is four times that found in (a). Determine the dielectric constant κ and the charge on the capacitor after the dielectric is inserted.
   (c) Both capacitors are disconnected from the batteries used to charge them. The positively charged plates are then connected together, and the negatively charged plates are connected together. What is the charge on each capacitor and the energy stored in each capacitor?

4. A 4.60 μF capacitor is initially uncharged. It is connected in series with a switch of negligible resistance, a 7.50 kΩ resistor, and an emf of 125 volts and negligible internal resistance. Just after the switch is closed, what are the voltage drop across the capacitor, the voltage drop across the resistor, and the current through the resistor? At what time after the switch is closed will the current in the resistor be 10.0 mA?

5. For the resistor circuit shown, R₁ = 1.0 Ω, R₂ = 2.0 Ω, R₃ = 2.0 Ω, and R₄ = 2.0 Ω.
   (a) Find the equivalent resistance.
   (b) The power supply provides a potential difference of V₀ = 6 V. Determine the power dissipated by each of the four resistors.
2. a) \[ F_B = qBv \]  
\[ \vec{F}_B = m\frac{v^2}{2} \]  
so \[ v = \frac{m}{qBR} \]  
Now \[ \frac{1}{2}mv^2 = KE = (1.2 \times 10^3 \text{ eV}) (1.6 \times 10^{-19} \text{ J/eV}) \]  
\[ v = \sqrt{\frac{KE}{m}} \]  
\[ v = 2.05 \times 10^7 \text{ m/s} \]  
\[ T = \frac{2\pi R}{v} = \frac{2\pi (2.5)}{2.05 \times 10^{-8}} = 7.65 \times 10^{-8} \text{ s} \]  
\[ V = (\frac{9.11 \times 10^{-10}}{1.4 \times 10^{-19}}) (2.05 \times 10^3) = 4.67 \times 10^{-4} \text{ T} \]  

b) From above \[ B = \frac{mV}{(qBR)} = \frac{(9.11 \times 10^{-10}) (2.05 \times 10^3)}{(1.4 \times 10^{-19}) (2.5)} = 4.67 \times 10^{-4} \text{ T} \]  

3. a) \[ \frac{Q}{V} \Rightarrow Q_a = CV = (2 \times 10^{-6}) (10) = 2 \times 10^{-5} \text{ C} \]  
\[ V_a = \frac{1}{2}CV^2 = \frac{1}{2} (2 \times 10^{-6}) (10)^2 = 10^{-4} \text{ J} \]  

b) \[ V_b = \frac{1}{2} (KC)V_b^2 = K \frac{1}{2} C (\frac{V}{2})^2 = \frac{1}{4} \frac{K}{C} V_a \]  
Now \[ V_b = 4 V_a = \frac{1}{4} \frac{K}{C} V_a \Rightarrow [K = 16] \]
\[ Q_b = KCV_b = 16 C \frac{V}{2} = 8CV = 8 Q_a = 1.6 \times 10^{-4} \text{ C} \]

\[ Q_{\text{tot}} = Q_a + Q_b = 1.8 \times 10^{-4} \text{ C} = Q'_1 + Q'_2 \]  
Now \[ V'_1 = \frac{Q'_1}{K} = \frac{Q'_1}{C} = 16 Q_1 = Q_2 \]  
Thus \[ Q'_1 + 16Q'_2 = 1.8 \times 10^{-4} \text{ C} \Rightarrow Q'_1 = 1.06 \times 10^{-5} \text{ C} \]  
\[ Q'_2 = 1.69 \times 10^{-4} \text{ C} \]
\[ U'_1 = \frac{(Q'_1)^2}{2C} = 2.81 \times 10^{-5} \text{ J} \]  
\[ U'_2 = \frac{(Q'_2)^2}{2KC} = 4.46 \times 10^{-4} \text{ J} \]
4. a) \[ Q(t) = Q_f \left( 1 - e^{-t/\tau} \right) \]
\[ V_c(t) = qV_f \left( 1 - e^{-t/\tau} \right) \]
\[ V_c(0) = 0 \text{ V} \]
\[ V_R(0) + V_c(0) = E \Rightarrow V_R(0) = E = 125 \text{ V} \]
\[ I(t) = \frac{qV_f}{RC} e^{-t/\tau} \]
\[ I(0) = \frac{qV_f}{R} = \frac{125}{7.5 \times 10^{-3}} = 16.7 \times 10^{-2} \text{ A} = 1.67 \text{ mA} \]
b) \[ I(t) = 10.0 \text{ mA} \]
\[ t = -\frac{\ln(0.6)}{16.7 \times 10^{-2}} = 17.6 \text{ ms} \]

5. a) \[ R_1 \]
\[ R_2 \]
\[ R_3 \]
\[ R_4 \]
\[ V_0 \]
\[ \frac{1}{R_{23}} = \frac{1}{R_2} + \frac{1}{R_3} \]
\[ R_{23} = \frac{12 R_2 R_3}{R_2 + R_3} = 15 \Omega \]
\[ R_{123} = R_1 + R_{23} = 25 \Omega \]
\[ \frac{1}{R_{eq}} = \frac{1}{R_{123}} + \frac{1}{R_4} \]
\[ R_{eq} = \frac{R_{123} R_4}{R_{123} + R_4} = 15 \Omega \]

b) \[ V_0 \text{ = I}_{eq} R_{eq} \]
\[ I_{eq} = \frac{V_0}{R_{eq}} = 6 \text{ V} \]
\[ I_4 = I_{123} = 6 \text{ V} \]
\[ \frac{P_4}{I_4} = \frac{V_4^2}{R_4} = \frac{36}{2} = 18 \text{ W} \]
\[ I_{123} = \frac{V_{123}}{R_{123}} = \frac{6}{2} = 3 \text{ A} \]
\[ I_{eq} = I_{123} = I \Rightarrow P_1 = I^2 R_1 = 9(0.9) = 9 \text{ W} \]
\[ V_{12} = I_{123} R_{12} = 3(1) = 3 \text{ V} = V_2 = V_3 \]
\[ \frac{P_2}{I_2} = \frac{V_2^2}{2} = \frac{9}{2} \text{ W} \]
\[ P_3 = \frac{V_3^2}{R_3} = \frac{9}{2} \text{ W} \]