Kuwait University **Physics Department**

Physics 102

Second Midterm Examination

Spring Semester (2009 - 2010)

May 15, 2010

Time: 12:00 – 2:00 PM

Name…………………………………..Student No………………………

Instructors: Drs. AbdelKarim, Afroosheh,Davis, Jassar, Kokaj, Lajko, Marafi, Rakhshani, Razee, Sharma and Zaher

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(Fundamental constants)

$k = \frac{1}{4\pi\varepsilon_o} = 9.0\times10^9\ N.m^2/C^2$	(Coulomb constant)
$\varepsilon_o = 8.85 \times 10^{-12}\ C^2/(N\cdot m^2)$	(Permittivity of free space)
$\mu_0 = 4\pi \times 10^{-7}$ T .m/A	(Permeability of free space)
$\lvert e \rvert = 1.60 \times 10^{-19}$ C	(Elementary unit of charge)
$N_A = 6.02 \times 10^{23}$	(Avogadro's number)
$g = 9.8$ m/s^2	(Acceleration due to gravity)
$m_e = 9.11 \times 10^{-31}$ kg	(Electron mass)
$m_p = 1.67 \times 10^{-27}$ kg	(Proton mass)

Prefixes of units

m = 10^{-3}	μ = 10^{-6}	n = 10^{-9}	p = 10^{-12}
k = 10^{3}	M = 10^{6}	G = 10^{9}	T = 10^{12}

For use by Instructors only

Prob.	1	2	3	4	5	6	7	8	Total
Marks									

Ques.	1	2	3	4	5	6	7	8	Total
Marks									

PART I. Solve the following problems. Show your solutions in detail.

1. An air –filled capacitor consists of two parallel plates, each with an area of 7.6 cm^2, separated by a distance of 1.8 mm. If a potential difference of 20 V is applied across the plates, calculate the energy stored in the capacitor.

$$C = \varepsilon_o A / d = 3.7 \ PF$$

$$U = \frac{1}{2} C V^2 = 74.7 \ nJ$$

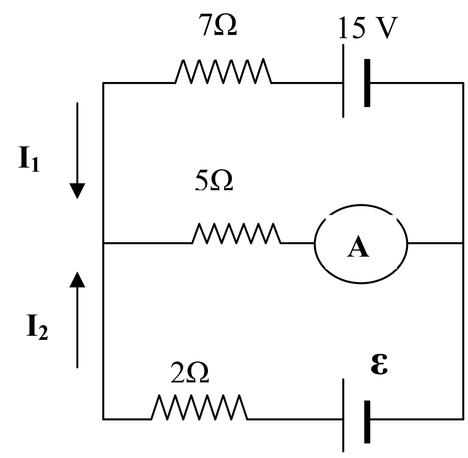
2. Suppose you want to install a heating wire that will convert electric energy to heat at a rate of 300 W for a current of 1.5 A. The resistivity of the wire is $5x10^{-7}$ Ωm, and its diameter is 0.3 mm. What must be the length of the wire?

$$P = R I^2 \rightarrow R = 133.3 \ \Omega$$

$$A = \pi D^2 / 4 = 7.1 \times 10^{-8} \ m^2$$

$$R = \rho l / A \rightarrow l = 18.9 \ m$$

3. The ammeter in the circuit shown reads 2A. Find the values of I_1, I_2, and ε.



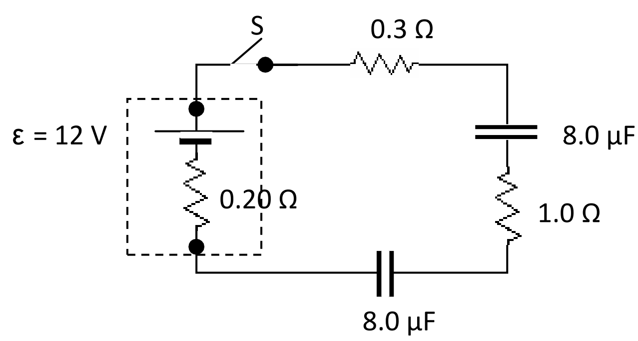
Current through 5-Ω resistor: $I_3 = I_1 + I_2 = 2A$ to the right

Upper loop : $15 - 7 I_1 - 5I_3 = 0 \rightarrow I_1 = 5/7\ A$

$I_2 = 9/7\ A$

Lower loop: $\varepsilon - 2I_2 - 5I_3 = 0 \rightarrow \varepsilon = 12.6\ V$

4. At time $t = 0$ the switch S is closed in the circuit shown. What is the terminal voltage of the battery at $t = 12\ \mu s$?

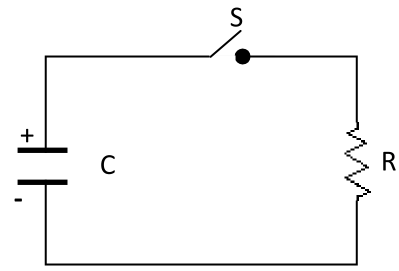


$\tau = RC = 1.5 \times 4 \times 10^{-6} = 6\ \mu s$

$I = \frac{\varepsilon}{R} e^{-t/\tau} = \frac{12}{1.5} e^{-2} = 1.1\ A$

$V_T = \varepsilon - rI = 12 - 0.2x1.1 = 11.8\ V$

5. In the circuit shown, C = 4.6 μF and R = 25 Ω. The capacitor initially has a charge of magnitude 3.5 nC on its plates. After switch S is closed what will be the current in the circuit at the instant that 70% of the energy stored in the capacitors is lost?

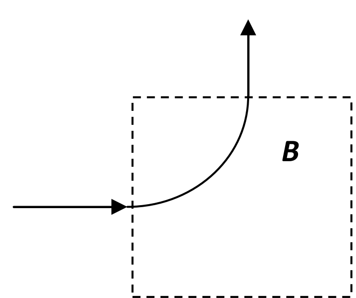


$$U = \frac{q^2}{2C} = U_o e^{\frac{-2t}{\tau}}$$

$$0.3\,U_o = U_o e^{\frac{-2t}{\tau}} \rightarrow e^{\frac{-t}{\tau}} = \sqrt{0.3}$$

$$I = \frac{q_o}{\tau} e^{-t/\tau} = 16.7\,\mu A$$

6. A proton enters and then leaves a region of the uniform magnetic field $\boldsymbol{B}$, which is perpendicular to the plane of paper, as shown below. The proton travels a distance of 2.0 cm in 10 μs inside the field. Find the magnitude and the direction (outward or inward) of $\boldsymbol{B}$.



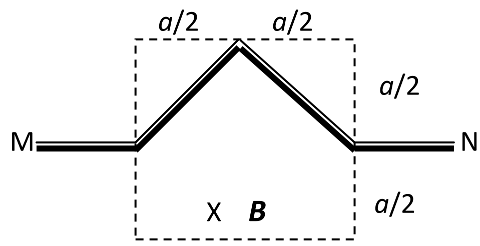
$\vec{B}$ is inward

$$v = l/t = 2000\,m/s$$

$$R = \frac{2}{\pi} l = 1.27 \times 10^{-2}\,m$$

$$B = mv/eR = 1.64\ mT$$

7. Wire MN with resistance 0.2 Ω carrying a current I passes through a region of uniform magnetic field as shown ($\boldsymbol{B}$ = 0.7 T, into the page; a = 20 cm). It experiences a net downward magnetic force of 2.1 N. Calculate the potential difference $V_M - V_N$.



$$\vec{F} = I\left(\vec{L} \times \vec{B}\right)$$

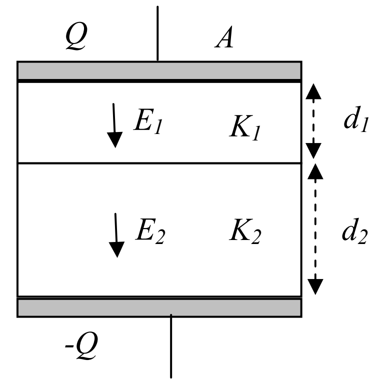
Since the net force in downward, the direction of current is from N to M

$$I = \frac{F}{aB} = 15\,A$$

$$V_M - V_N = -RI = -3V$$

8. The figure shows a parallel-plate capacitor with plate area A and charge Q. It is filled with two slabs of different dielectric constants K_1 and K_2 and thicknesses d_1 and d_2.

a) Express the electric fields E_1 and E_2 in terms of these parameters and ε_o (permittivity of free space).



$$E_1 = \frac{Q}{A\varepsilon_o K_1} \quad , \quad E_2 = \frac{Q}{A\varepsilon_o K_2}$$

b) Use the results in part a) to obtain the potential difference V across the plates.

$$V = E_1 d_1 + E_2 d_2 = Q\left(\frac{d_1}{A\varepsilon_o K_1} + \frac{d_2}{A\varepsilon_o K_2}\right)$$

c) Use the result in part b) to obtain the capacitance of the capacitor

$$C = \frac{Q}{V} = \frac{\varepsilon_o A}{\frac{d_1}{K_1} + \frac{d_2}{K_2}}$$

PART II: Conceptual Questions (each carries 1 mark). Circle the most proper answer:

1. Consider a charged and isolated air-filled parallel-plate capacitor. If the distance between the plates is increased by a factor of three, the energy stored in the capacitor

<u>a)</u> Increases three times.

b) Increases nine times.

c) Decreases three times.

d) Does not change.

2. The Kirchhoff's loop theorem is the consequence of the conservation law for

a) Momentum.

b) Charge.

<u>c)</u> Energy.

d) Rotational momentum.

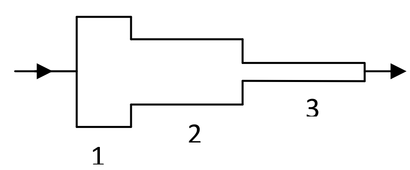
3. A steady current passes through a cylindrical conductor with a cross sectional view as shown. If the electron drift velocity is denoted by v_1, v_2 and v_3 in regions 1, 2 and 3, then

a) $v_1 = v_2 = v_3$

<u>b)</u> $v_1 < v_2 < v_3$

c) $v_1 > v_2 > v_3$

d) $v_1 < v_2 = v_3$



4. Four slabs with different dielectric constant K are placed between the plates of a charged and isolated parallel-plate capacitor. The induced surface charge density on the dielectric slab is the smallest for the slab with

a) $K = 5$

<u>b)</u> $K = 2$

c) $K = 6$

d) $K = 4$

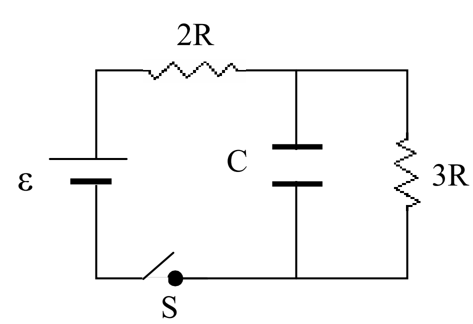
5. At time $t = 0$, when the switch S is closed, the current through the battery is I_o. A long time later ($t \to \infty$) the current is I. The ratio I_o/I is

a) 3/2

<u>b)</u> 5/2

c) 1/3

d) 1/5



6. The electric field E, the magnetic field B and the speed v of the charged particles which pass straight through a velocity selector are related as

   <u>a)</u> $B = E/v$

   b) $2E = v/B$

   c) $B = 2vE$

   d) $v = EB$

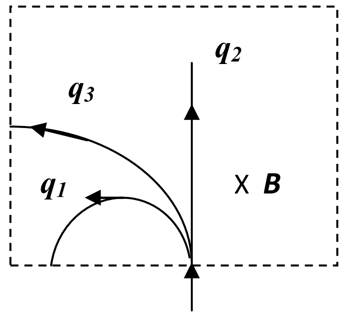
7. Three particles with identical mass and velocity but different charge (q_1, q_2, q_3) enter perpendicular to a uniform magnetic field ***B*** (into the page) and move in different paths as shown. One can conclude that

   a) $q_3 > q_1$

   b) $q_2 > q_3$

   <u>c)</u> $q_3 < q_1$

   d) $q_3 = q_1$



8. A wire carries current I in the x-y plane as shown. In the presence of a uniform magnetic field $\vec{B} = B\hat{j}$, the direction of the magnetic force acting on the wire is

   a) $\hat{i}$

   b) $\hat{j}$

   <u>c)</u> $\hat{k}$

   d) $\hat{i} + \hat{j}$