Kuwait University **Physics Department**

Physics 102
Final Examination

Summer Semester (2009 - 2010)
August 08, 2010

Time: 5:00 – 7:00 PM

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

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(Fundamental constants)

$k = \dfrac{1}{4\pi\varepsilon_o} = 9.0\times10^{9}\ N\cdot m^2/C^2$	(Coulomb constant)
$\varepsilon_o = 8.85 \times 10^{-12}\ C^2/(N\cdot m^2)$	(Permittivity of free space)
$\mu_0 = 4\pi \times 10^{-7}\ T\cdot m/A$	(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

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

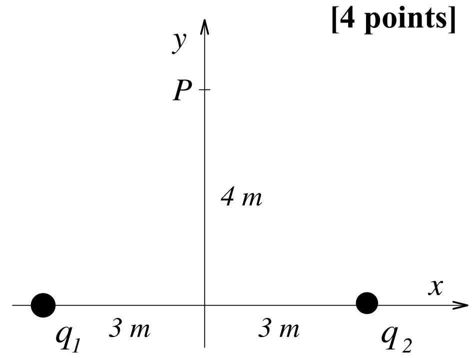
For use by Instructors only

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. Two point charges $q_1 = 1\ \mu$C, $q_2 = -1\ \mu$C lie along the x-axis as shown. Find the magnitude of electric field at point P. **[4 points]**

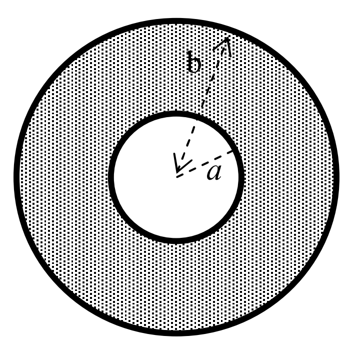


$$\vec{E}_1 = \frac{k|q|}{r^2}\frac{3}{r}\hat{i} + \frac{k|q|}{r^2}\frac{4}{r}\hat{j} \qquad \vec{E}_2 = \frac{k|q|}{r^2}\frac{3}{r}\hat{i} - \frac{k|q|}{r^2}\frac{4}{r}\hat{j}$$

$$r = \sqrt{3^2 + 4^2} = 5m$$

$$\vec{E}_{net} = 2E_{1x} = 432\ \ N/C$$

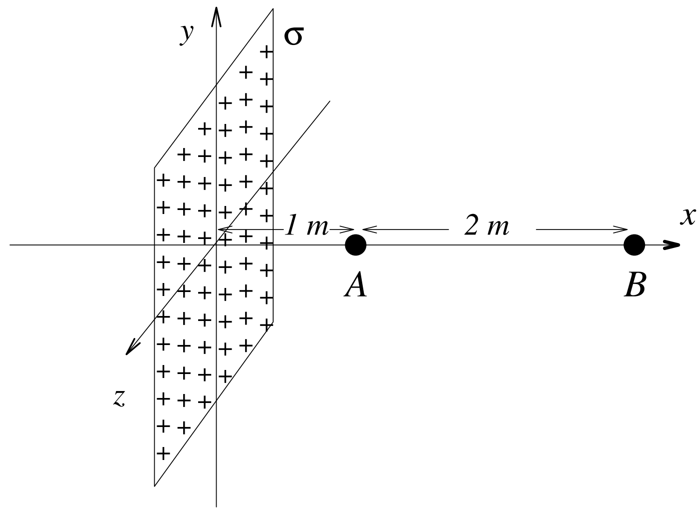
2. A hollow spherical shell with inner radius $a = 30$ cm and outer radius $b = 70$ cm has uniform volume charge density ρ. The magnitude of electric field 50 cm from the center of the shell is $E = 2$ N/C. Calculate the magnitude of ρ. **[4 points]**



$$\oint \overline{E} \cdot d\overline{A} = E4\pi r^2 = \frac{\rho \frac{4}{3}\pi(r^3 - a^3)}{\varepsilon_0} \Rightarrow \rho = \frac{E3r^2\varepsilon_0}{(r^3 - a^3)} = 1.35\times 10^{-10}\, C/m^3$$

3. An infinite, non-conducting sheet with uniform surface charge density $\sigma = 3.54\times10^{-11}$ C/m^2 is in the y-z-plane. A particle with charge $q = 2$ μC and mass $m = 4\times10^{-6}$ kg is released from rest at point A.

   What is the speed of the particle at point B? **[4 points]**



$$-\Delta U = \Delta K \Rightarrow -q\Delta V = \frac{mv^2}{2} \Rightarrow v = \sqrt{\frac{2q|\Delta V|}{m}}$$

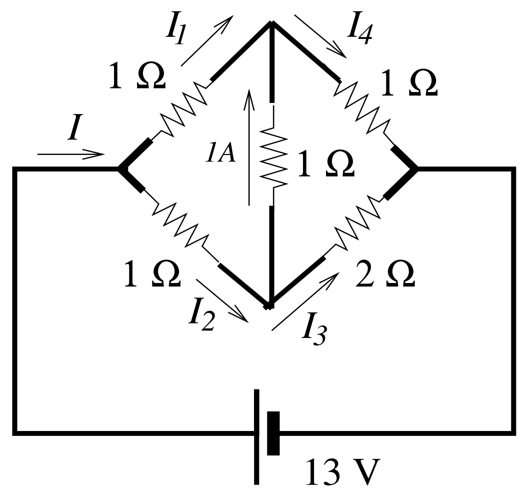
with $\Delta V = -\frac{\sigma d}{2\varepsilon_0}$ *so* $v = 2\ m/s$

4. Two conducting spheres have radii $R_1 = 60$ cm, $R_2 = 30$ cm and charges $Q_1 = 120$ μC and $Q_2 = 0$ C. If the two spheres are connected with a thin wire, what will be the electric potential energy stored on the smaller sphere after the equilibrium is established? **[4 points]**

$$Q_1 = Q_1^{fin} + Q_2^{fin}\ (Eq.1) \quad and \quad V_1 = V \Rightarrow \frac{Q_1^{fin}}{C_1} = \frac{Q_2^{fin}}{C_2} = \frac{Q_1^{fin}}{R_1} = \frac{Q_2^{fin}}{R_2}\ (Eq.2)$$

From (Eq.1) and (Eq.2) $Q_2^{fin} = 40\mu C \Rightarrow\Rightarrow U = \frac{Q^2}{2C} = 24J$

5. Find the current supplied by the 13-V battery to the circuit, if the current in the middle resistance is *1* A, as shown. **[6 points]**



Currents, as shown, and junction rules can be assigned:

$I = I_1 + I_2$

$I_1 + 1A = I_4$

$I_2 - 1A = I_3$

Loops rules, for instance in the middle left and right loops, by using the above junction rules:

$$-I_1 1\Omega + 1A1\Omega + I_2 1\Omega = 0$$

$$-1A1\Omega - (I_1 + 1A)1\Omega + (I_2 - 1A)2\Omega = 0$$

$\Downarrow$

$I_1 = 6A \qquad I_2 = 5A.$

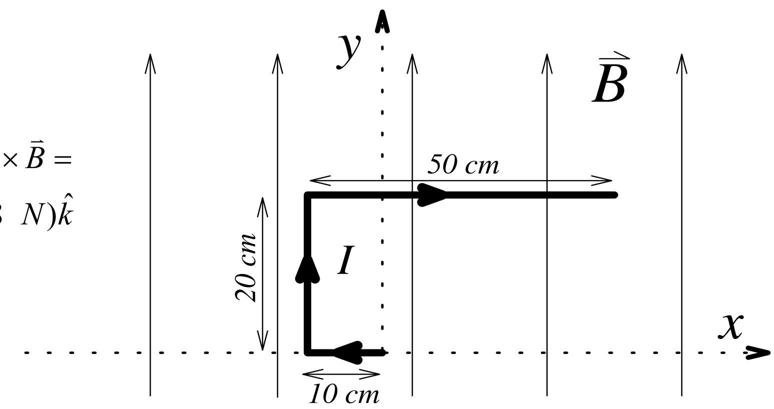
$\Rightarrow I = I_1 + I_2 = 11A$

6. A point charge $q = 2\ \mu C$ enters a region of a uniform magnetic field of $\vec{B} = (0.5\ \ T)\hat{j}$ with velocity $\vec{v} = (4\times10^5 m/s)\hat{i} + (5\times10^4 m/s)\hat{j}$. Find the electric field $\vec{E}$ that keeps the particle on a straight path inside this region. **[3 points]**

$$\vec{F}_{net} = \vec{F}_E + \vec{F}_B = 0 \Rightarrow \vec{F}_E = -\vec{F}_B \Rightarrow \vec{E} = -\vec{v}\times\vec{B} \Rightarrow$$

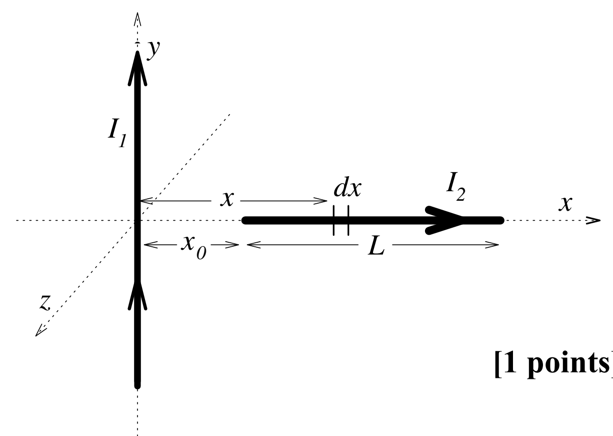
$$\vec{E} = -(4\times10^5 m/s)\hat{i} + (5\times10^4 m/s)\hat{j})\times 0.5T\hat{j} = (-2\times10^5 N/C)\hat{k}$$

7. A bent wire, as shown in the figure, carrying a current of *3* A is in uniform magnetic field $\vec{B} = (4\ T)\,\hat{j}$. Find the magnetic force vector acting on the wire. **[3 points]**



$$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 = I\vec{L}_1 \times \vec{B} + I\vec{L}_2 \times \vec{B} + I\vec{L}_3 \times \vec{B} =$$
$$= (-IL_1B + 0 + IL_3B)\hat{k} = I(L_3 - L_1)B\hat{k} = (4.8\ \ N)\hat{k}$$

8. An infinitely long straight wire carrying a current I_1 lies along the *y*-axis. A straight wire of length *L* carrying a current I_2 lies along the *x*-axis as shown.



(a) Write down a formula for the magnetic field vector $\vec{B}_1$ due to I_1 at distance x from the wire. Use the unit vectors $\hat{i},\ \hat{j},\ \hat{k}$. **[1 points]**

$$\vec{B}_1 = -\frac{\mu_0 I_1}{2\pi x}\hat{k}$$

(b) Use the general expression $d\vec{F} = Id\vec{L} \times \vec{B}$ and the result in (a) to find a vector expression for the force acting on segment *dx* of the wire along the *x*-axis. **[1 points]**

$$d\vec{F} = I_2(dx\hat{i}) \times \left(-\frac{\mu_0 I_1}{2\pi x}\hat{k}\right) = \frac{\mu_0 I_2 I_1 dx}{2\pi x}\hat{j}$$

(c) Write down an integral expression of the total force $\vec{F}$ acting on the wire with I_2 and integrate it. **[2 points]**

$$\vec{F} = \int d\vec{F} = \int_{x_0}^{x_0+L} \frac{\mu_0 I_2 I_1 dx}{2\pi x}\hat{j} = \frac{\mu_0 I_2 I_1}{2\pi}\ln\left(\frac{x_0 + L}{x_0}\right)\hat{j}$$

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

1. The magnitude of the electric force between two point charges is F, if they are a distance d_1 apart. If the distance is changed to d_2, the force decreases to F/2. The ratio $\frac{d_1}{d_2}$ is

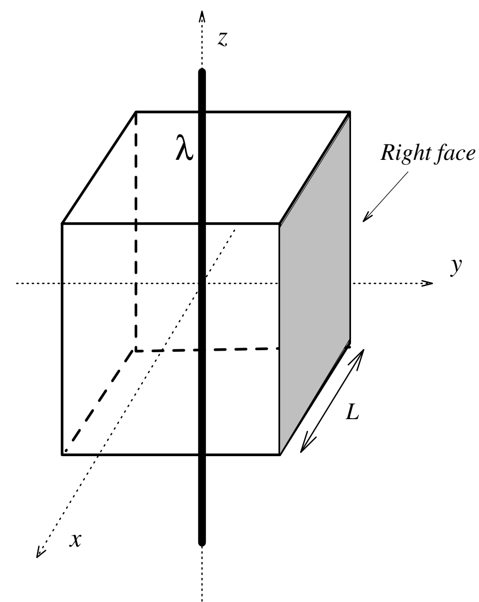
   (a) 2.

   (b) $\sqrt{2}$.

   (c) $1/2$.

   (d) $1/\sqrt{2}$. Ans.

2. An infinite line of charge with uniform charge density λ lies along the symmetry axis of a cube of side length L, as shown. The electric flux through the right face of the cube is



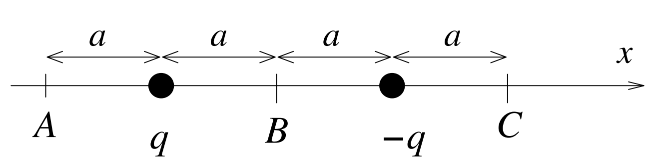
   (a) $\frac{\lambda L}{4\varepsilon_0}$. Ans.

   (b) $\frac{6\lambda L}{\varepsilon_0}$.

   (c) $\frac{\lambda L}{6\varepsilon_0}$.

   (d) $\frac{\lambda L}{\varepsilon_0}$.

3. Point charges $q(>0)$ and $-q$ are placed along the x-axis, as shown. Which relation is correct?



   (a) $V_C > V_B > V_A$.

   (b) $V_A > V_B > V_C$. Ans.

   (c) $V_C > V_A > V_B$.

   (d) $V_A > V_C > V_B$.

4. A capacitor is connected to a battery and has charge Q when it is fully filled with a material of dielectric constant K. If the battery remains connected, but the dielectric material is taken out, what will be the charge on the plates?

   (a) KQ.

   (b) Q.

   (c) Q/K. Ans.

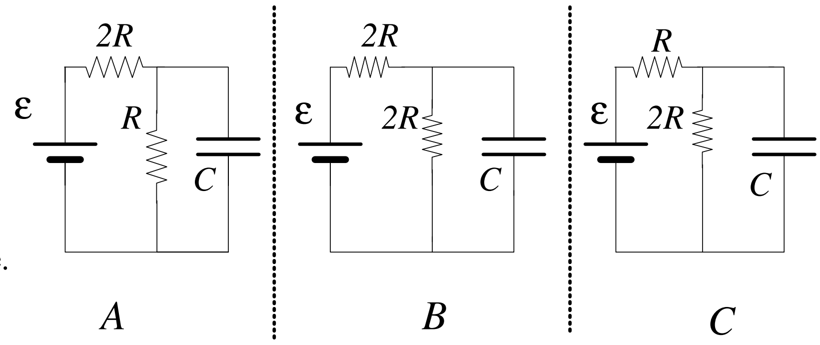
   (d) $Q(K+1)$.

5. A voltage is applied to the two ends of a cylindrical wire. If the diameter of the wire is doubled and the applied voltage is halved, the current through the wire

   (a) will be double the initial current.   Ans.
   (b) will not change.
   (c) will be half the initial current.
   (d) will be four times the initial current.

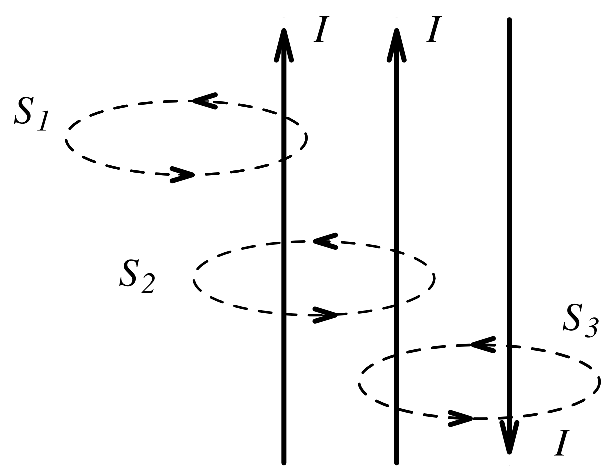
6. In which circuit is the final charge of the capacitor the highest?

   (a) *A*.
   (b) *B*.
   (c) *C*.   *Ans*
   (d) All capacitors have the same final charge.



7. The three wires in this figure are infinitely long and carrying identical magnitude of current *I* as shown. S_1, S_2, S_3 are circular loops. The integral $\oint \vec{B}\cdot d\vec{l}$ is the largest on circle

   (a) S_1.
   (b) S_2.   Ans.
   (c) S_3.
   (d) The curve integrals are the same on each circles.



8. Two charged particles q_1 and q_2 with identical masses and speeds separately enter a region of a uniform magnetic field. In the magnetic field, both particles follow semicircular paths with radii *R* and *2R*, as shown. The relation of the charges is

   (a) $q_1 = -2q_2$ Ans..
   (b) $q_1 = 2q_2$.
   (c) $-2q_1 = q_2$.
   (d) $2q_1 = q_2$.