Kuwait University **Physics Department**

Physics 102
Final Examination

Fall Semester 2010-2011
January 17, 2011

Time: 11:00 am – 1:00 pm

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

Instructors: Drs. Abdel Karim, Davis, Farhan, Lajko, Rakhshani, Razee, and Sharma

---

(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)
$N_A = 6.02 \times 10^{22}$	(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

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

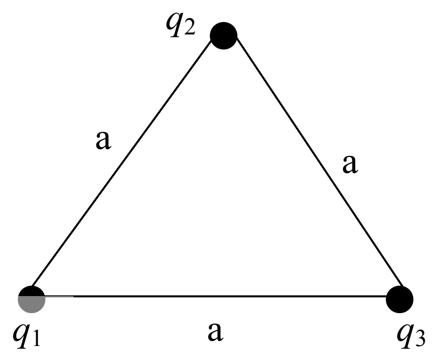
For use by Instructors only

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

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

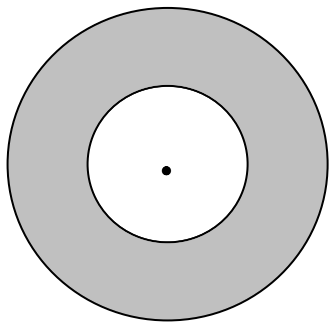
PART I. Solve the following problems. Show your solutions in detail.

1. Three point charges $q_1 = q_2 = 2\ \mu C$ and $q_3 = -2\ \mu C$ are located on the vertices of an equilateral triangle with sides $a = 0.30$ cm. What is the magnitude of the net force acting on the charge q_2? **[4 points]**



$$F_{21} = F_{23} = \frac{k|q_1||q_2|}{a^2} = 4\times10^3\ \text{N} \qquad [1]$$
$$F_y = F_{21}\sin 60° - F_{23}\sin 60° = 0 \qquad [1]$$
$$F_x = F_{21}\cos 60^o + F_{23}\cos 60°$$
$$= 2F_{21}\cos 60° = 4\times10^3\ \text{N} \qquad [1]$$
$$F = \sqrt{F_x^2 + F_y^2} = 4\times10^3\ \text{N} \qquad [1]$$

2. A spherical shell with inner radius $a = 1.0$ m and outer radius $b = 2.0$ m has a uniform volume charge density $\rho = 3\times10^{-6}$ C/m^3. What is magnitude of the electric field at 1.5 m from the center of the sphere? **[3 points]**



$$\oint \vec{E}.d\vec{A} = \frac{q_{encl}}{\varepsilon_0} = \frac{\rho V}{\varepsilon_0} \qquad [1]$$
$$E.4\pi r^2 = \frac{\rho.(4\pi/3)(r^3 - a^3)}{\varepsilon_0} \qquad [1]$$
$$E = \frac{\rho(r^3 - a^3)}{3\varepsilon_0 r^2} = 1.2\times10^5\ \text{N/C} \qquad [1]$$

3. A charged ring of radius $R = 0.3$ m with the centre located at the origin has $Q = 6$ μC distributed uniformly. A charged particle $q = 2$ μC ($m = 3.6 \times 10^{-6}$ kg) is released at $x = 0.5$ m. What is the speed of the particle when it reaches the point $x = 1.0$ m?

[3 points]

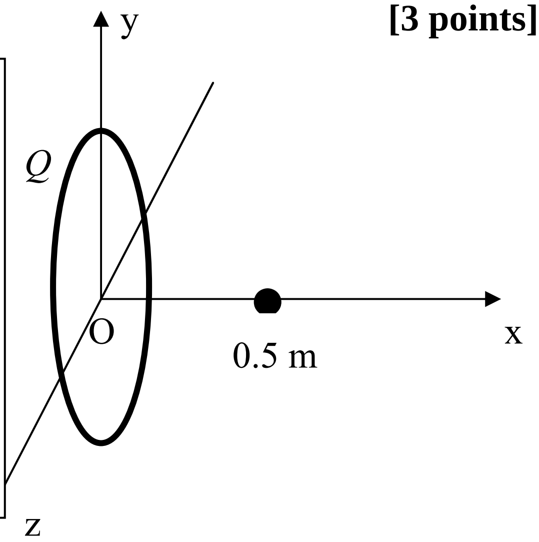
$$\Delta K = -\Delta U = q\Delta V$$

$$\frac{1}{2}mv^2 - 0 = -q(V_f - V_i) \qquad [1]$$

$$= -q\left(k\frac{Q}{\sqrt{R^2 + x_f^2}} - k\frac{Q}{\sqrt{R^2 + x_i^2}}\right)$$

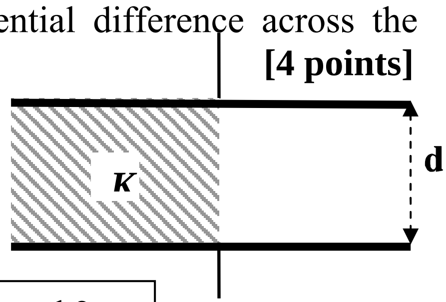
$$= 8.2 \times 10^{-2} \text{ J} \qquad [1]$$

$$v = \sqrt{\frac{2 \times 8.2 \times 10^{-2}}{3.6 \times 10^{-6}}} = 2.1 \times 10^2 \text{ m/s} \qquad [1]$$



4. An air-filled parallel-plate capacitor $C = 16$ μF is charged to $V = 16$ V and the battery is disconnected. The half of the space between the plates is now filled with a dielectric material $K = 5$, as shown. What is the potential difference across the capacitor plates now?

[4 points]



Considering the two compartments of the capacitor as 1 and 2:

with air: $V_1 = V_2 = V \Rightarrow \sigma_1 = \sigma_2$ and $Q = (\sigma_1 + \sigma_2)A/2$

With the dielectric: $V_1^K = V_2^K \Rightarrow \frac{\sigma_1^K}{K} = \frac{\sigma_2^K}{1} \Rightarrow \sigma_1^K = 5\sigma_2^K$

And $Q = (\sigma_1^K + \sigma_2^K)A/2 = 6\sigma_2^K \times A/2 = 3\sigma_2^K A$

$$V_2^K = \frac{\sigma_2^K d}{\varepsilon_0} = \frac{Qd}{3A\varepsilon_0} = \frac{1}{3}\frac{Q}{C_0} = \frac{1}{3}V = \frac{16}{3} = 5.3 \text{ V}$$

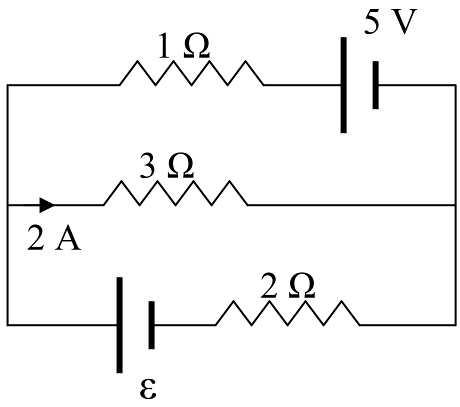
An easier solution is: Consider the two compartments as two capacitors C_1 and C_2 in parallel.

$$C_1 = \frac{K\varepsilon_0 A/2}{d} = \frac{5}{2}C = 40 \text{ μF and } C_2 = \frac{\varepsilon_0 A/2}{d} = \frac{C}{2} = 8 \text{ μF}$$

$$C' = C_1 + C_2 = 40 + 8 = 48 \text{ μF}$$

New potential difference $V' = \frac{Q}{C'} = \frac{CV}{C'} = \frac{16}{48} \times V = \frac{V}{3} = 5.3$ V

5. In the circuit given, the current through the 3 Ω resistor is 2 A. What is the e.m.f. of the battery ε? **[3 points]**



Upper loop: clockwise

$I_1 \cdot 1 - 5 + 2 \times 3 = 0 \quad \Rightarrow I_1 = -1\text{ A}$ [1]

Junction rule: $I_1 + I_2 = 2$

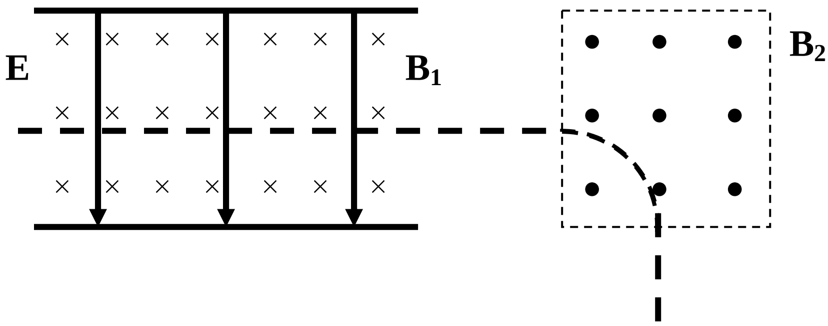
$\Rightarrow I_2 = 2 - I_1 = 2 - (-1) = 3\text{ A}$ [1]

Lower loop: clockwise

$-2 \times 3 - 3 \times 2 + \varepsilon = 0$

$\Rightarrow \varepsilon = 12\text{ V}$ [1]

6. A charged particle (q = 8.0 μC and m = 1.2 ×10^{-9} kg) is traveling straight in crossed fields E = 360 V/m and B_1 = 0.15 T. Then it enters perpendicular to a uniform magnetic field B_2 = 1.8 T. It comes out of the field as shown. How much distance does it travel inside the field B_2? **[4 points]**



$qE = qvB_1$ [1]

$v = \dfrac{E}{B_1} = 2400\text{ m/s}$ [1]

$r = \dfrac{mv}{qB_2} = 0.20\text{ m}$ [1]

$s = \dfrac{2\pi\text{ r}}{4} = 0.31\text{ m}$ [1]

7. A conducting wire of length *a* carrying a current *I* lies along the y-axis as shown.

(a) Write down the magnitude of the magnetic field dB at the point P due the infinitesimal element *dy* of the wire. **[1 point]**

$$dB = \frac{\mu_0 I}{4\pi}\frac{dy \sin\theta}{r^2}$$

(b) Using the formula sin θ = sin (π−θ), obtain the expression for dB in terms of *x*, *y* and *dy*. **[1 point]**

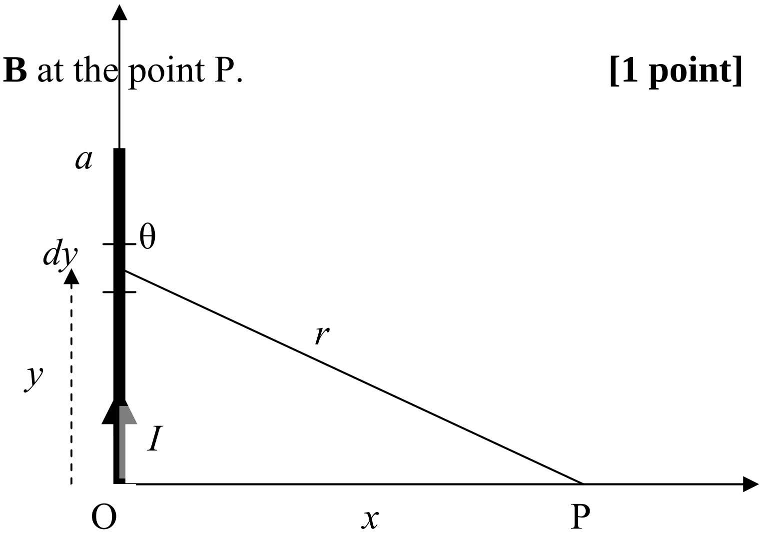
$$dB = \frac{\mu_0 I}{4\pi}\frac{x dy}{(x^2 + y^2)^{3/2}}$$

(c) Write down the integral for the resultant magnetic field B produced at P due to the whole wire. **[1 point]**

$$B = \frac{\mu_0 I}{4\pi}\int_0^a \frac{x dy}{(x^2 + y^2)^{3/2}}$$

(d) Draw the direction of the field **B** at the point P. **[1 point]**

Direction of B: Into the page



8. A conducting loop with the sides *a* and *b* is perpendicular to a uniform magnetic field B = 1.2 T as shown. It is pulled completely out of the field in 0.23 s. If the loop has a resistance of 3.6 Ω, what is the magnitude and direction of the average current induced during the pull out? Given, *a* = 0.20 m, *b* = 0.30 m. **[3 points]**

$$\Delta\Phi = \Phi_f - \Phi_i = 0 - Bab = -7.2\times10^{-2}\text{ Wb} \quad [1]$$

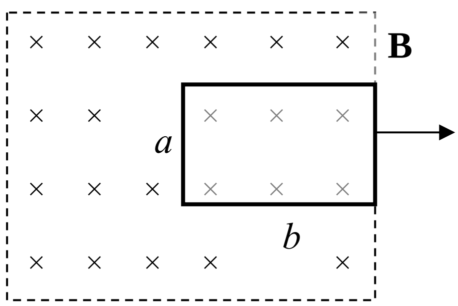
$$|\varepsilon| = \left|\frac{\Delta\Phi}{\Delta t}\right| = \frac{7.2\times10^{-2}}{0.23} = 0.31\text{ V} \quad [1]$$

$$I = \frac{\varepsilon}{R} = 8.6\times10^{-2}\text{ A} = 86\text{ mA} \quad [1]$$

OR:

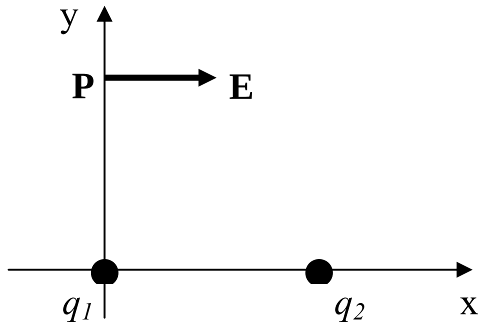
$$\varepsilon = BLv = Ba\times\frac{b}{t} = 0.31\text{V} \quad [1+1]$$

$$I = \frac{\varepsilon}{R} = 8.6\times10^{-2}\text{ A} = 86\text{ mA} \quad [1]$$



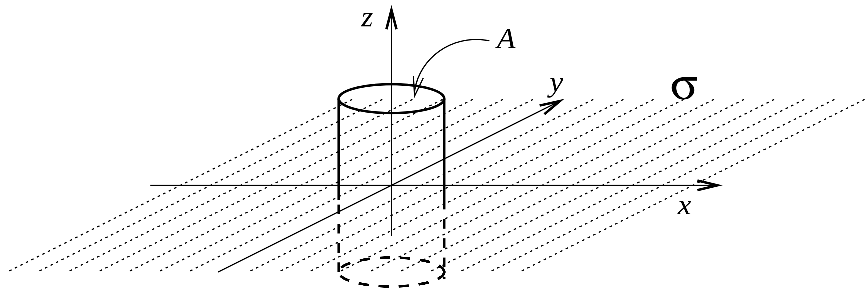
PART II: Conceptual Questions (each carries 1 point). Tick the best answer:

1. The net electric field at point P due to the charges q_1 and q_2 points along the +x-axis as shown. The signs of the charges are:



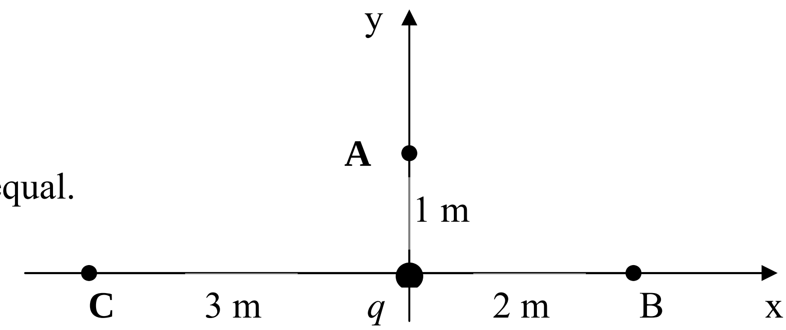
   a. $q_1 > 0$ and $q_2 > 0$.
   b. $q_1 < 0$ and $q_2 < 0$.
   c. $q_1 > 0$ and $q_2 < 0$. (Ans)
   d. $q_1 < 0$ and $q_2 > 0$.

2. The x-y plane has a uniform surface charge density σ. A cylinder with cross-sectional area A lies along the z-axis. The electric flux through the top face of the cylinder is



   a. 0.
   b. $\dfrac{\sigma A}{4\varepsilon_0}$.
   c. $\dfrac{\sigma A}{2\varepsilon_0}$. (Ans)
   d. $\dfrac{\sigma A}{\varepsilon_0}$.

3. Three points A, B, and C are around a point charge q (>0). The magnitude of the potential difference is the smallest between the points



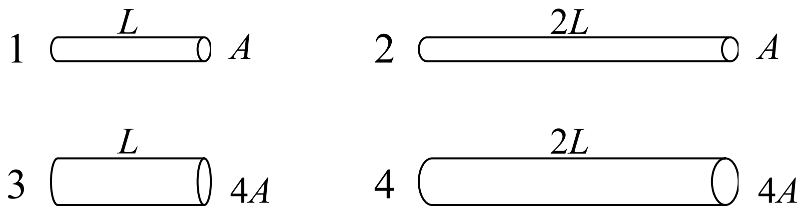
   a. A and B.
   b. B and C. (Ans)
   c. A and C.
   d. All potential differences are equal.

4. Two capacitors A and B are identical. Initially the capacitor A is charged so that it stores 8 J of energy, whereas the capacitor B is uncharged. The capacitors are then connected in parallel. The total energy on the capacitors is now:

   a. 16 J
   b. 8 J
   c. 4 J (Ans)
   d. 2 J

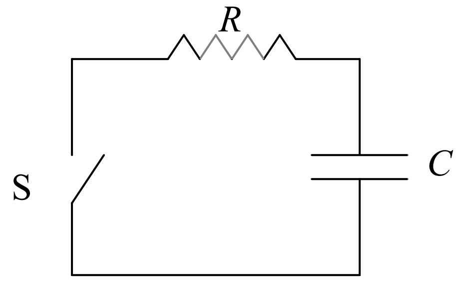
5. Four cylindrical wires are made of the same material. The length and the cross-section of the wires are shown in the figures. Rank the wires according to their resistance from the lowest to the greatest.

a. $R_3 < R_4 < R_1 < R_2$ (Ans)
b. $R_3 < R_2 = R_4 < R_1$
c. $R_2 < R_1 < R_4 < R_3$
d. $R_4 < R_2 < R_3 < R_1$

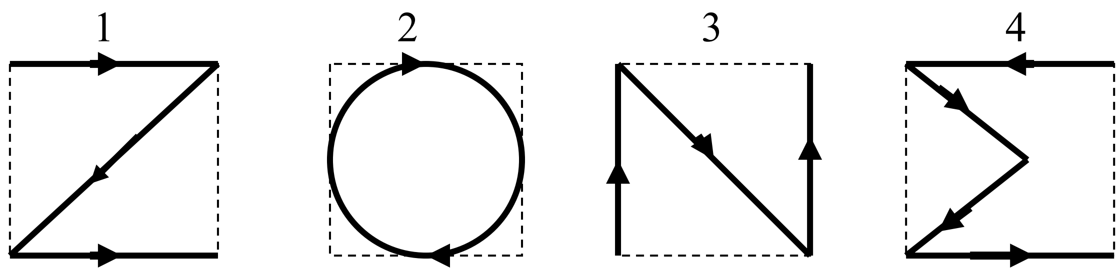


6. In the figure below, initially the capacitor is charged to a potential difference V_0 and the switch S is open. Immediately after the switch is closed, the current in the circuit is

a. 0.
b. V_0C.
c. V_0/R. (Ans)
d. $V_0/(2R)$.



7. Four elements of wires with the same current I are placed in a plane perpendicular to a uniform magnetic field B as shown in the figure. All the wires fit in a square of side L. Rank the wires according to the magnitude of the magnetic force.



a. 1 < 2 < 3 < 4
b. 2 < 3 < 1 < 4
c. 2 < 4 < 1 = 3 (Ans)
d. 3 < 4 < 2 < 1

8. Cross-sections of two long parallel wires with identical currents I but in opposite directions are shown. At which point is the magnetic field highest?

a. A
b. B (Ans)
c. C
d. D