Kuwait University **Physics Department**

Physics 102
Final Examination

Spring Semester 2011-2012
May 30, 2012

Time: 11:00 am – 1:00 pm

Name……………………………. Student No………………………

Instructors: Drs. Abdelkarim, Afrousheh, Davis, Farhan, Habib, Kokaj, Lajko, Marafi, Razee, & Sharma

---

(Fundamental constants)

$k = \frac{1}{4\pi\varepsilon_o} = 9.0 \times 10^9 \text{ N.m}^2/\text{C}^2$	(Coulomb constant)
$\varepsilon_o = 8.85 \times 10^{-12}\ \text{C}^2/(\text{N}\cdot\text{m}^2)$	(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)
$g = 9.8\ \text{m/s}^2$	(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

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

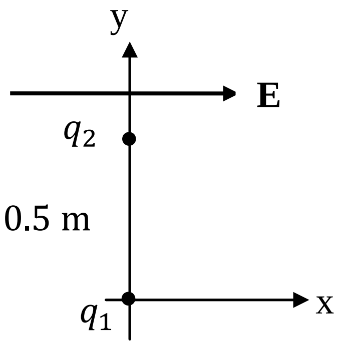
For use by Instructors only

Prob.	1	2	3	4	5	6	7	8	9	10	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 $q_1 = 2.0$ μC and $q_2 = -6.0$ μC as shown are inside a uniform electric field $\vec{E} = 4.0\times10^4\ \hat{i}$ V/m. Charge q_1 is fixed and q_2 is released. What is the magnitude of the initial acceleration of q_2, if its mass is 5×10^{-6} kg? **[4 Points]**



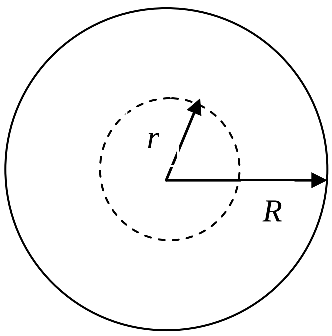
$F_1 = (kq_1q_2)/0.5^2 = 0.43$ N [1]

$F_2 = q_2E = 0.24$ N [1]

$F = \sqrt{F_1^2 + F_2^2} = 0.49$ N [1]

$a = F/m = 9.8 \times 10^4$ m/s^2 [1]

2. A uniformly charged *insulating* sphere has a radius R = 60 cm. The electric flux through a concentric sphere of radius r = 30 cm is -3.54×10^5 Nm^2/C. What is the magnitude of the electric field on the surface of the charged sphere? **[4 Points]**



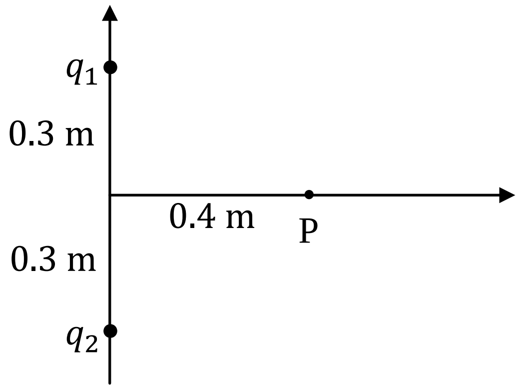
$q' = \varphi\varepsilon_0 = 3.1\,\mu\text{C}$ [1]

$\rho = \dfrac{q'}{4/3\pi r^3} = 27.7\,\mu\text{C/m}^3$ [1]

$Q = \rho.4/3\pi R^3 = 25.1\,\mu\text{C}$ [1]

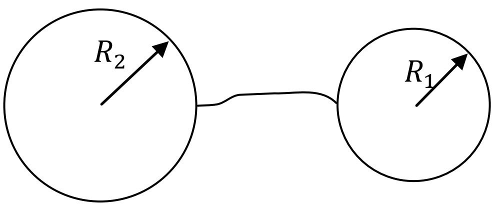
$E = kQ/R^2 = 6.3\times10^5$ N/C [1]

3. The two point charges $q_1 = 12.0$ nC and $q_2 = -3.0$ nC are held fixed. A proton is released from rest at point P. What is the maximum speed achieved by the proton?
[4 Points]



$V = V_1 + V_2 = 216-54 = 162$ V [2]
$qV = 1/2mv^2$ [1]
$v = 1.8 \times 10^5$ m/s [1]

4. After two conducting spheres of radius $R_1 = 0.25$ m and $R_2 = 0.40$ m are connected by a conducting wire, the surface charge density on sphere 1 is $\sigma_1 = 7.5\,\mu\text{C/m}^2$. What is the electric potential on the surface of sphere 2? **[3 Points]**

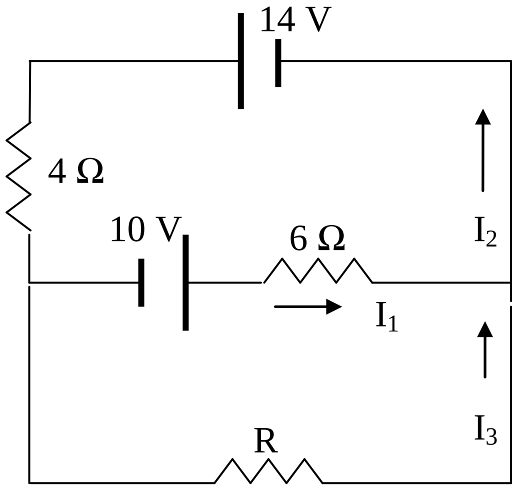


$E = \sigma/\varepsilon_0 = 8.5 \times 10^5$ V/m [1]
$V_2 = V_1 = ER_1 = 2.1\times 10^5$ V [2]

OR:

$Q_1 = \sigma_1.4\pi R_1^2 = 5.9\,\mu\text{C}$ [1]
$V_2 = V_1 = kQ_1/R_1 = 2.1\times 10^5$ V [2]

5. The power dissipated in the 6 Ω resistor is 26 W. What is the power dissipated in the resistor R? **[5 Points]**



$I_1 = \sqrt{P/6} = 2.08\ \text{A}$ [1]

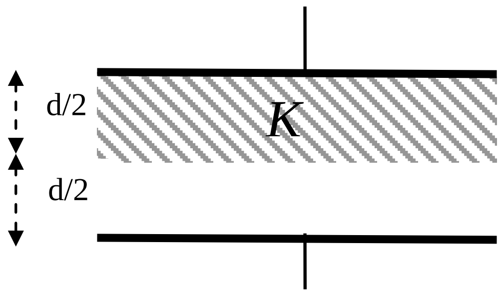
$4I_2 - 14 + 6I_1 - 10 = 0 \Rightarrow I_2 = 2.88\ \text{A}$ [1]

$I_3 = I_2 - I_1 = 0.8\ \text{A}$ [1]

$4I_2 - 14 + I_3 R = 0 \Rightarrow R = 3.1\Omega$ [1]

$P = I_3^2 R = 2.0\ \text{W}$ [1]

6. An isolated air-filled capacitor 12 μF has 150 μJ of energy stored in it. The capacitor is then half filled by a dielectric slab *K* = 3, as shown. What is the energy stored in the capacitor now? **[5 Points]**



$Q = 60\ \mu\text{C}$ [1]

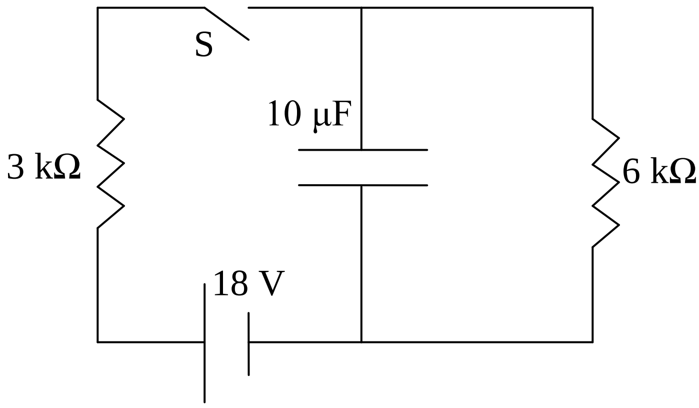
$C_1 = \dfrac{K\varepsilon_0 A}{d/2} = 72\ \mu\text{F}$ [1]

$C_2 = \dfrac{\varepsilon_0 A}{d/2} = 24\ \mu\text{F}$ [1]

$C_{\text{eq}} = 18\ \mu\text{F}$ [1]

$U_{\text{f}} = \dfrac{Q^2}{2C_{\text{eq}}} = 100\ \mu\text{J}$ [1]

7. In the circuit below, the capacitor is initially uncharged. A long time after closing the switch S, what is the charge on the capacitor? **[3 Points]**



Current in steady state:

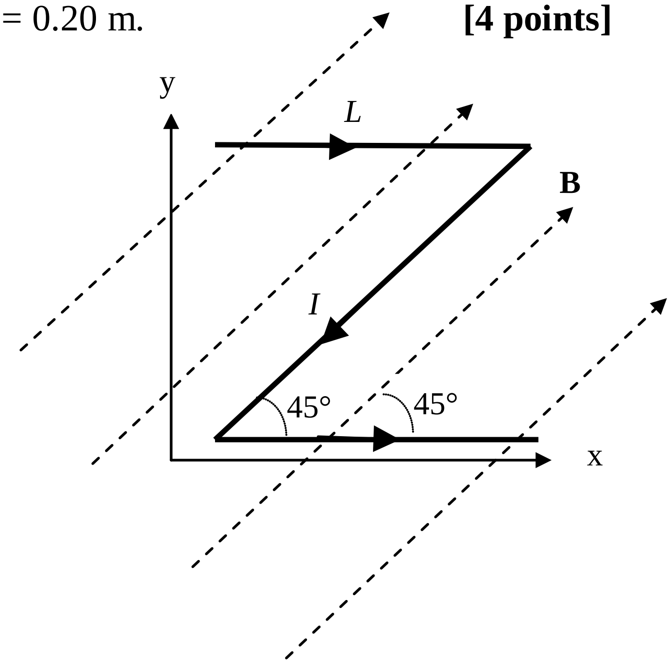
$$I = \frac{18\text{ V}}{(3+6)\text{ k}\Omega} = 2\text{ mA} \quad [1]$$

$$V_{6\Omega} = IR = 2\text{ mA}.6\text{k}\Omega = 12\text{ V} \quad [1]$$

$$Q_0 = CV_{6\Omega}$$

$$= 10\ \mu\text{F}.12\text{V} = 120\ \mu\text{C} \quad [1]$$

8. A wire of the shape as shown lies in the x-y plane in a uniform magnetic field B = 0.80 T. If the wire has a current I = 5 A, what is the magnitude and direction of the net magnetic force on the wire? Given, L = 0.20 m. **[4 points]**



$$F_1 = ILB\sin 45^\circ = 0.57\text{ N out of page} \quad [1]$$

$$F_2 = 0 \quad [1]$$

$$F_3 = ILB\sin 45^\circ = 0.57\text{ N out of page} \quad [1]$$

$$F_{net} = 1.14\text{ N out of page} \quad [1]$$

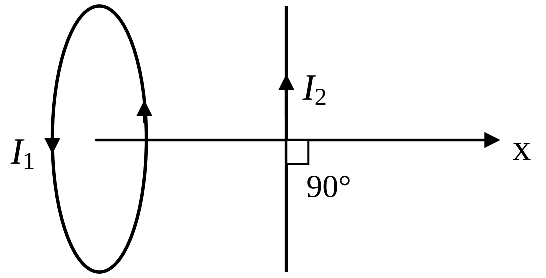
9. An electron has a velocity $\vec{v} = (32\,\hat{i} + 40\,\hat{j}) \times 10^3$ m/s as it enters a uniform magnetic field $\vec{B} = B_0\,\hat{i}$. The pitch of the helical path taken by the electron is 2.29 cm. What is the radius of the helix? **[4 points]**

$p = v_x T \Rightarrow T = 7.2 \times 10^{-7}$ s [1]

$T = \dfrac{2\pi\, m}{qB} \Rightarrow B = 5.0 \times 10^{-5}$ T [1]

$r = \dfrac{mv_\perp}{qB} = 4.6 \times 10^{-3}$ m [2]

10. A circular loop of radius 0.30 m with a current I_1 = 12 A lies perpendicular to the x-axis. A long wire with a current I_2 = 19 A is at a distance of 0.24 m from the loop as shown. What is the magnitude of the net magnetic field at the centre of the loop? **[4 points]**



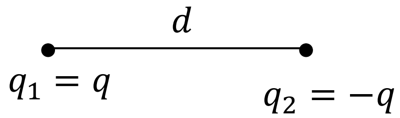
$B_1 = \dfrac{\mu_0 I_1}{2R} = 25.1\,\mu$T [1]

$B_2 = \dfrac{\mu_0 I_2}{2\pi\, r} = 15.8\,\mu$T [1]

$B = \sqrt{B_1^2 + B_2^2} = 29.7\,\mu$T [2]

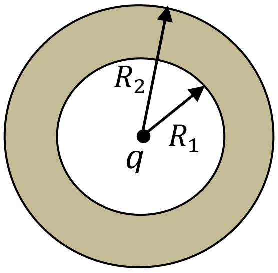
PART II: Conceptual Questions (1 point each). Tick the best answer:

1. The electrostatic force on charge q_1 below is $\vec{F}$. If the distance between the two charges is doubled, the electrostatic force on q_2 is



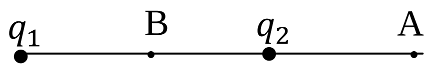
(a) $\vec{F}$
(b) $-\vec{F}/2$
(c) $2\vec{F}$
(d) $-\vec{F}/4$ (ans)

2. There is a point charge q inside a charged spherical shell. The electric field inside the shell (for $R_1 < r < R_2$)



(a) depends on the charge q if the shell is a conductor.
(b) depends on the charge q if the shell is an insulator. (ans)
(c) depends on the charge on the shell if the shell is a conductor.
(d) does not depend on the charge q in any case.

3. In the figure below, $q_1 < 0$ and $q_2 > 0$ and $|q_1| = |q_2|$. The work that must be done to move a point charge q from point A to point B (midway between q_1 and q_2) at *constant speed* is

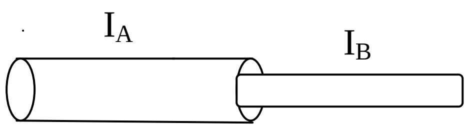


(a) positive if q is positive.
(b) negative if q is negative.
(c) negative if q is positive. (ans)
(d) always positive and is independent of the sign of q.

4. A light bulb connected to a voltage source has power output of 50 W. When it is connected to a source twice the voltage, the power output of the bulb

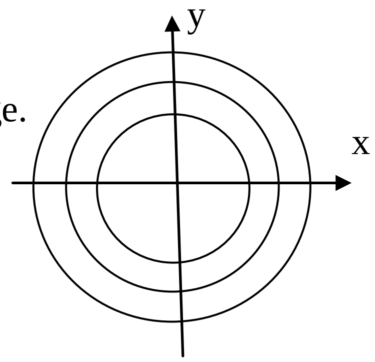
(a) will remain the same.
(b) will become double.
(c) will become four times. (ans)
(d) will become half.

5. Two conductors are joined as shown. The diameter of the left conductor is twice the diameter of the right one. Which statement is true?



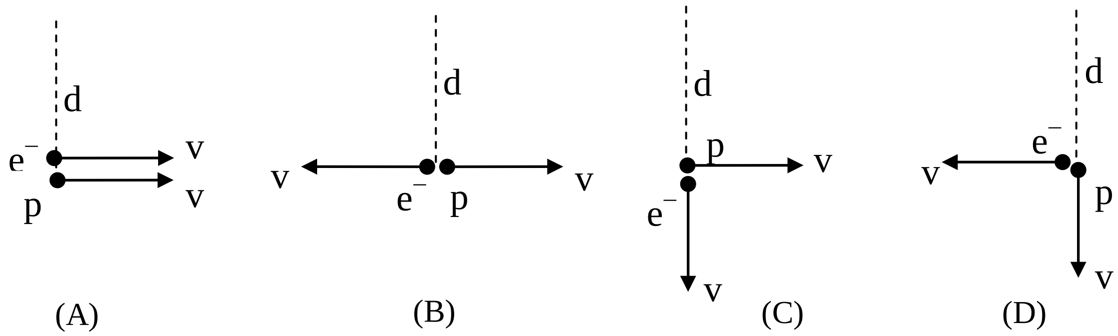
(a) $I_A = I_B$ (ans)
(b) $I_{AB} = I_A + I_B$
(c) $I_A = 2 I_B$
(d) $I_A = 0.5 I_B$

6. The circles in the figure show intersections of a few equipotential surfaces in the xy-plane. Which statement is ***not true***?



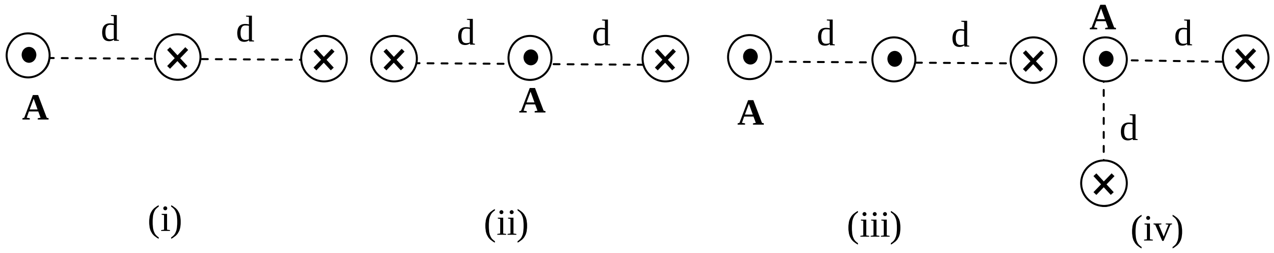
(a) The equipotential surfaces arise from a point charge.
(b) The equipotential surfaces arise from a long line of charge.
(c) The equipotential surfaces arise from a charged sphere.
(d) The equipotential surfaces arise from an infinite plane of charge. (ans)

7. In the diagrams below, an electron and a proton move with the same speed v at a given point. Rank the magnitude of magnetic field produced at a distance d, from greatest to smallest?



(a) A > B > C >D
(b) A > B > C = D
(c) B > A > C > D
(d) B > C = D > A (ans)

8. Three straight wires of equal length *L* carrying identical currents are shown in the following arrangements. In which case is the magnitude of the net force on the wire **A** the smallest?



(a) i
(b) ii (ans)
(c) iii
(d) iv