Kuwait University **Physics Department**

Physics 102

First Midterm Exam
Second Semester (2008-2009)

April 16, 2009 (6.00- 7:30 p.m.)

Name: ………………………… Student No: ………………..

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(Fundamental constants)

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

Prefixes of units

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

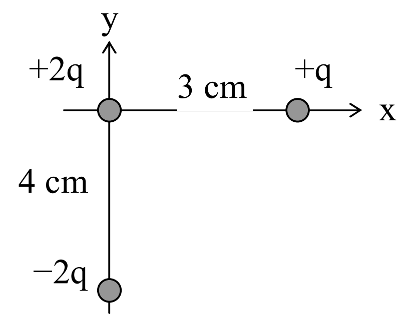
For use by Instructors only

Problem	1	2	3	4	5	6	7	8	Total
Marks									

Question	1	2	3	4	5	6	7	8	Total
Marks									

Part I: Solve the following problems

1. Three charges are located in the x-y plane as shown in the figure. What is the magnitude of the resultant force on the charge +q = 1 nC ? **[3 points]**



$$\vec{F}_1 = \frac{k|q.2q|}{(0.03)^2}\hat{i} = 2.0\times10^{-5}\,\hat{i}\ N$$

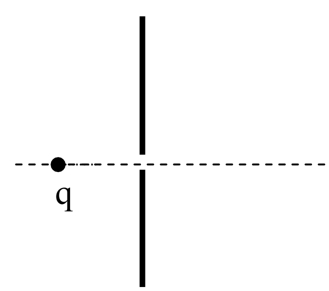
$$\vec{F}_2 = \frac{k|q.(-2q)|}{(0.05)^2}\left[-0.6\hat{i} - 0.8\,\hat{j}\right]$$

$$= \left[-4.32\times10^{-6}\,\hat{i} - 5.76\times10^{-6}\,\hat{j}\right] N$$

$$\vec{F} = \vec{F}_1 + \vec{F}_2 = \left[1.568\times10^{-5}\,\hat{i} - 5.76\times10^{-6}\,\hat{j}\right] N$$

$$F = 1.67\times10^{-5}\ N$$

2. A point charge (q = −1 mC and mass m = 2 × 10^{-6} kg) moving with a velocity v = 2.0 ×10^3 m/s enters the region between two oppositely charged parallel plates through a hole in the positive plate. If the plates are 0.10 m apart and the charge stops just before hitting the negative plate, what is the magnitude of the electric field between the plates? **[2 points]**



$$0 - v^2 = -2ax \rightarrow a = \frac{v^2}{2x} = 2.0\times10^{7}\ m/s^2$$

$$|q|E = ma \rightarrow E = \frac{ma}{|q|}$$

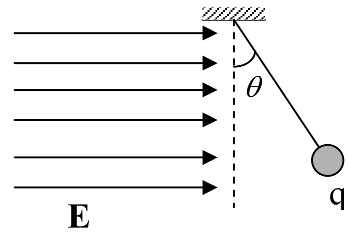
$$= 4.0\times10^{4}\ \frac{N}{C}$$

OR

$$0 - \frac{1}{2}mv^2 = -q\Delta V = -q(-Ed)$$

$$\rightarrow E = -\frac{mv^2}{2q} = 4.0\times10^{4}\ \frac{N}{C}$$

3. A small ball of mass 1.02 g and charge q is suspended by a light string and placed in a uniform electric field $E = 10^6$ N/C. If the ball is in equilibrium at $\theta = 45^o$, find the charge on the ball. **[2 points]**



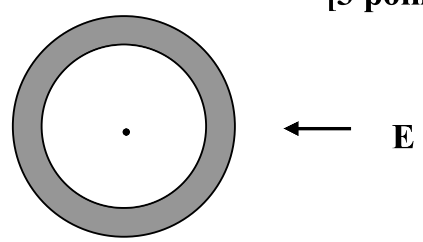
Obviously q > 0

T sin θ = qE

T cos θ = mg

$$\tan\theta = \frac{qE}{mg} \rightarrow q = \frac{mg\tan\theta}{E} = 1.0\times10^{-8}\ C$$

4. A conducting spherical shell of outer radius 18 cm has a surface charge density $\sigma = 7.35\ \mu C/m^2$. When a point charge Q is brought to the centre of the shell, the electric field at a distance of 30 cm from the centre is 4×10^5 V/m pointing radially inwards. What is the value of Q? **[3 points]**



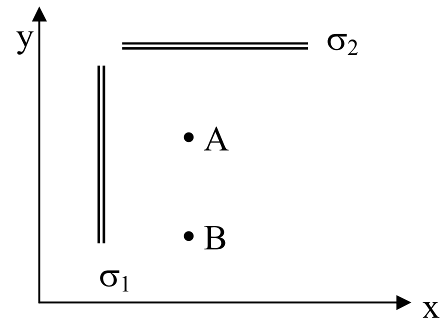
$\vec{E}$ inward, so $\phi_E < 0$

$$-4\pi r^2 E = \frac{Q + 4\pi b^2\sigma}{\varepsilon_o}$$

$$\rightarrow Q = -4\pi\varepsilon_o r^2 E - 4\pi\varepsilon_o b^2\sigma$$

$$= -7.0\times10^{-6}\ C$$

5. Two large sheets with surface charge densities $\sigma_1 = +1.77$ nC/m^2 and $\sigma_2 = +0.885$ nC/m^2 are perpendicular to the xy-plane as shown in the figure. How much work is done on a charge q = 2.5 μC to move a distance 20 cm from the point A to B in the xy-plane? **[3 points]**



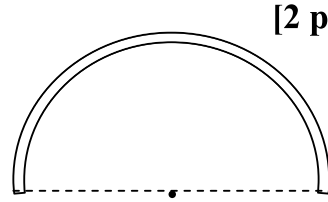
$\vec{E}_1$ has no contribution to the work

$$\vec{E}_2 = \frac{\sigma_2}{2\varepsilon_o}\left(\hat{j}\right)$$

$$\Delta\vec{l} = -0.2\ \hat{j}$$

$$W = -\Delta V = q\,\vec{E}.\Delta\vec{l} = q\frac{\sigma_2}{2\varepsilon_o}\left(0.2\right) = 2.5\times10^{-5}\ J$$

6. A plastic rod with a linear charge density −0.5 μC/m is bent into a semicircle of radius 30 cm as shown in the figure. What is the electric potential at the centre of the semicircle, if V=0 is at infinity. **[2 points]**



$$V = \frac{kQ}{a}$$

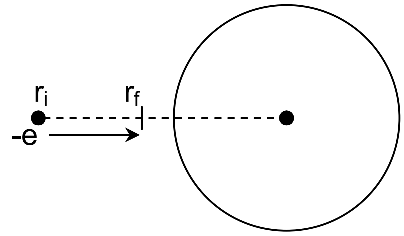
$$= \frac{k\left(\lambda\pi a\right)}{a}$$

$$= k\lambda\pi = -1.4\times10^{4}\ V$$

7. An electron outside a conducting sphere (radius = 1 .0 m) with a charge +10 C has an electric potential energy of −10 nJ. When the electron is released from rest, what is its kinetic energy after it has moved by 20 cm? **[3 points]**

$$v_i = \frac{-k\,Qe}{r_i}$$

$$\rightarrow r_i = -\frac{kQe}{V_i} = 1.44\,m$$



Upon release the electron moves <u>towards</u> sphere.

$$K = -(U_f - U_i) \qquad \rightarrow r_f = 1.24\,m$$

$$= -\frac{kQe}{r_f} + U_i = 1.6\times10^{-9}\ J$$

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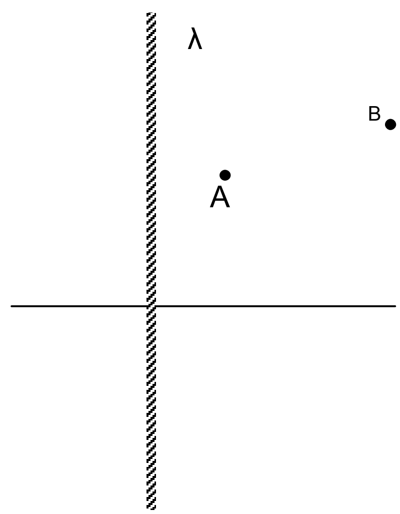
8. An infinite line of charge with the linear charge density λ = +4 nC/m is along the y-axis. What is the potential difference $V_A - V_B$ between the two points A (1 m, 2 m) and B (5 m, 4 m)? **[3 points]**

$$\vec{E} = \frac{\lambda}{2\pi\varepsilon_o x}\hat{i}\ ,\ d\vec{l} = dx\,\hat{i} + dy\,\hat{j}$$

$$V_A - V_B = \int_A^B \vec{E}\cdot d\vec{l}$$

$$\int_A^B \frac{\lambda}{2\pi\varepsilon_o x}\,dx$$

$$= \frac{\lambda}{2\pi\varepsilon_o}\ \ln x\Big|_1^5 = 1.16\times10^2\,V$$

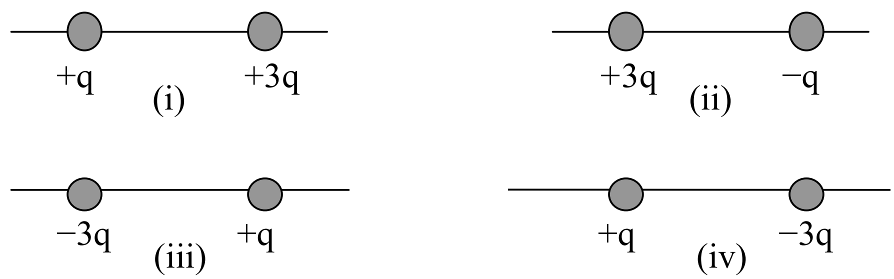


Part II: Conceptual questions. Tick the best answer.
Each question carries 1 point.

1. Three identical conducting spheres A, B, and C initially have charges of $+8Q$, $+4Q$, and $-8Q$, respectively. Thin conducting wire connects two balls at a time in the following sequence: (1) balls A and B, then (2) balls A and C. The final charge on ball A is:

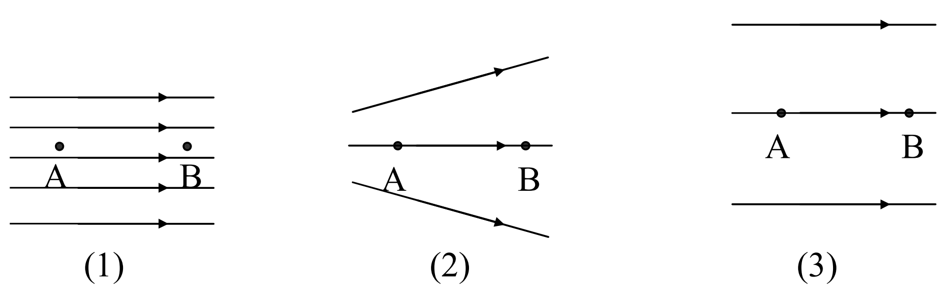
(a) zero
✓ (b) $-Q$
(c) $-4Q$
(d) $-8Q$.

2. The figure shows four different arrangements of two point charges. In which situation is there a point to the left of the arrangement where an electron will be in equilibrium?



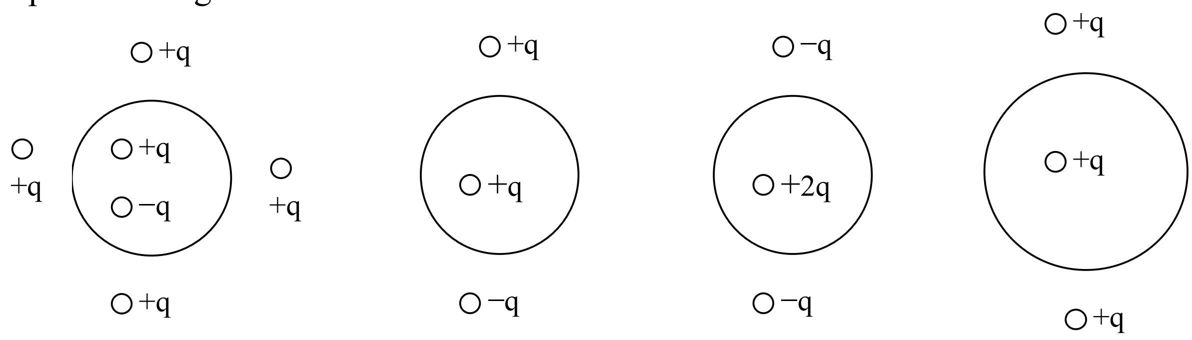
(a) i
(b) ii
(c) iii
✓ (d) iv

3. The figure shows three arrangements (1), (2), and (3) of the electric field lines. In each arrangement a proton is released from rest at point A. It reaches point B with a speed v_1, v_2, and v_3, respectively. If the separation between A and B is the same in all the arrangements, then which of the following relations is true?



(a) $v_2 > v_3 > v_1$
(b) $v_3 > v_2 > v_1$
✓ (c) $v_1 > v_2 > v_3$
(d) $v_1 = v_2 = v_3$

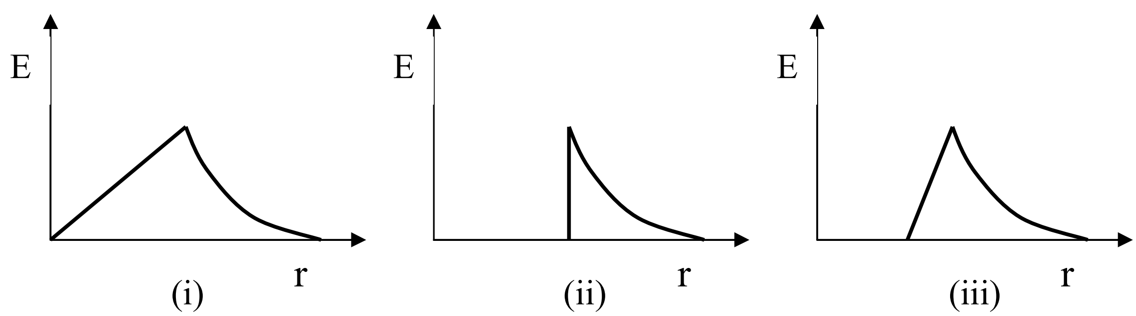
4. In the following figures, in which configuration is the electric flux through the sphere the highest?



(i) (ii) (iii) (iv)

(a) i
(b) ii
✓(c) iii
(d) iv

5. A sphere has a uniform charge density ρ. Which of the following diagram represents the electric field of the shell as a function of the distance r from the centre?

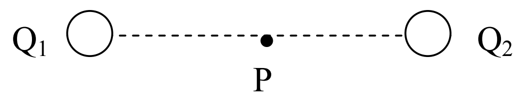


✓(a) i
(b) ii
(c) iii

6. If an electron and a proton are released inside an electric field, which statement is correct?

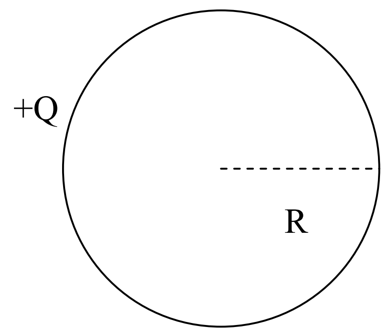
✓(a) Only the proton moves towards the lower electric potential.
(b) Only the electron moves towards the lower electric potential.
(c) Both of them move to the higher electric potential.
(d) Both of them move to the lower electric potential.

7. In the following figure, if the electric field at the point P midway between the two electric charges Q_1 and Q_2 is zero, then which of the following conclusions is *definitely* correct?



✔(a) Electric potential at point P is not zero.
(b) Electric potential at point P is positive.
(c) Electric potential at point P is negative.
(d) Electric potential at point P is zero.

8. A *conducting* sphere of radius R has a charge Q. A test charge q_0 is moved from the surface of the sphere to a half-radius point inside the sphere. The work done on the charge is:



(a) $k\dfrac{Qq}{R}$
(b) $k\dfrac{Qq}{(R/2)}$
(c) $k\dfrac{Qq}{2R}$
✔ (d) zero.