Kuwait University **Physics Department**

Physics 102

First Midterm Examination

Fall Semester (2010 - 2011)
November 7, 2010

Time: 6:30 – 8:30 PM

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

Instructors: Drs. AbdelKarim, Davis, Farhan, Lajko, Rakhshani, Razi 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)
$N_A = 6.02 \times 10^{23}$	(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

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

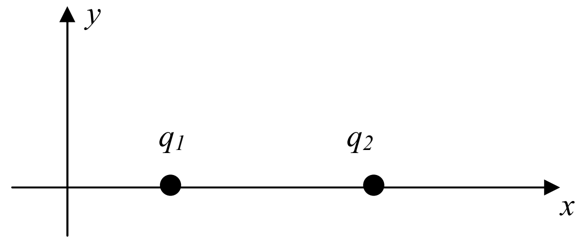
For use by Instructors only

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. Point charges q_1 = +8.0 nC and q_2 = -2.0 nC are held along the x-axis at x_1 = 1.0 m and x_2 = 3.0 m, respectively. A point charge Q is in equilibrium (experiences no net force) in the x-y plane. Find its coordinates. **[4 points]**

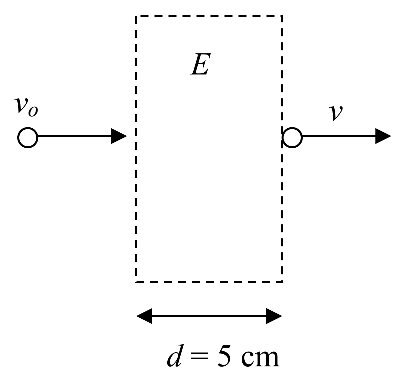


- Must be along the x-axis and closer to q_2 [1]
- $k|q_1|/(x-1)^2 = k|q_2|/(x-3)^2 \rightarrow (x-3)/(x-1) = \pm 1/2 \rightarrow x = 5$ m and $x = 2.33$ m [2]
- x = 2.33 m is not acceptable, so x = 5 m [1]

2. An electron enters the region of a uniform electric field, E, with an initial velocity of magnitude v_o = 9×10 ^{6} m/s. It leaves the field with a velocity of magnitude v = 3×10 ^{6} m/s in the same direction, as shown below. Find the magnitude and direction of the field. **[4 points]**

- Taking v direction along +x-axis, then

  $v^2 - v_o^2 = 2a_x d \rightarrow a_x = -7.2\text{x}10^{14}$ m/s^2 [1]
- taking $a_x = -eE_x/m \rightarrow E_x = +4.1\text{x}10^3$ N/C [2]
- $E = 4.1\text{x}10^3$ N/C & direction: to the right [1]

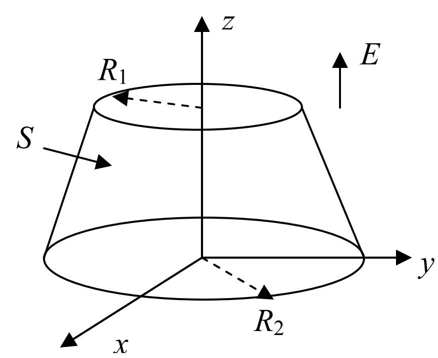


3. $N = 3.13\text{x}10^9$ electrons have been removed from a conducting ball. The largest magnitude of the electric field produced by the ball is 5000 N/C. What is the radius of the ball? **[3 points]**

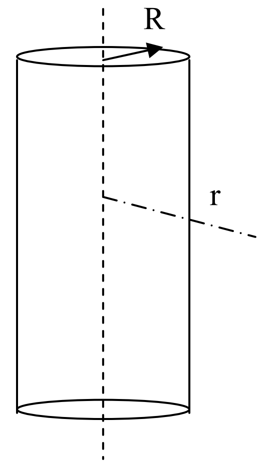
- Q = +Ne = +0.50 nC [1]
- Largest E corresponds to r = R [1]
- $R = [k|Q|/E]^{1/2} = 0.03$ m [1]

4. A truncated conical object is placed in a uniform electric field (*E* = 500 N/C along +z direction) as shown in the figure. The radii of the two circular faces are $R_1 = 7.0$ cm and $R_2 = 10.0$ cm. What is the electric flux through the conical surface S? **[3 points]**

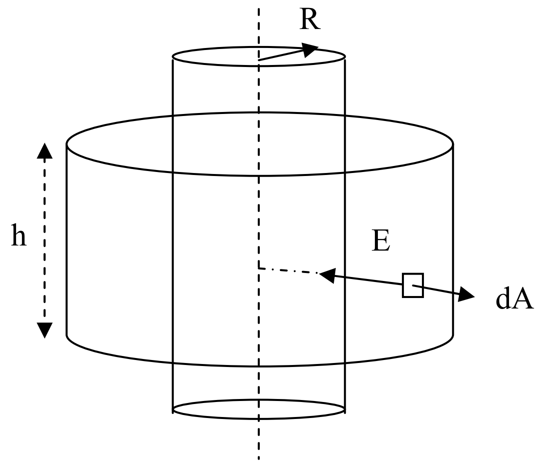
- $\Phi_{top} + \Phi_{bot} + \Phi_S$ = net enclosed charge/$\varepsilon_o = 0$ [1]
- $\Phi_S = \pi E\,(R_2^2 - R_1^2)$ [1]
- $\Phi_S = +8.0$ N.m^2/C [1]



5. A very long cylindrical object with radius R = 4.0 cm carrying a uniform volume charge density of ρ = -8.0 nC/m^3 is shown. Using the Gauss' law, calculate the magnitude of electric field, E, at a distance r = 9.0 cm from the axis of the cylinder. Draw a suitable Gaussian surface and also show vectors $d\vec{A}$ and $\vec{E}$ **[4 points]**



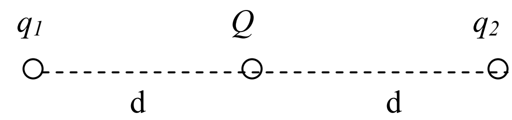
- Diagram & correct directions for vectors dA and E [2]
- $\oint \vec{E} d\vec{A} = q_{in} / \varepsilon_o \rightarrow -2\pi rhE = \pi R^2 h\rho/\varepsilon_o$ [1]
- E = 8.0 N/C [1]



6. A <u>conducting</u> spherical shell with the inner and outer radii of a = 5.0 cm and b = 12.0 cm carries a total charge of -1.6 nC. a) Draw the shell and show the position of charges. b) What is the electric potential, V, at the center of the shell? (Take V = 0 at infinity) **[3 points]**

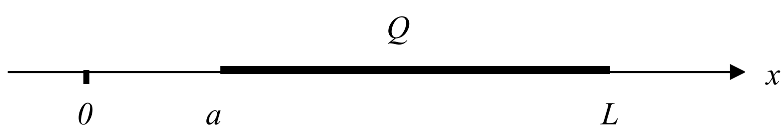
- Drawing the shell & showing charges on the outer surface [1]
- $V_{center} = V_{outer\ surface} = kq/b = -120.0$ V [2]

7. The system shown below consists of three point charges Q, q_1 = +3 nC and q_2 = -4 nC. Find Q if the total electrostatic potential energy of the system U = 0. (Assume U = 0 when the charges are infinitely far apart). **[3 points]**



- $U = kq_1q_2/2d + (kq_1/d + kq_2/d)Q$ [2]
- $U = 0 \rightarrow Q = -6.0$ nC [1]

8. Charge Q is distributed uniformly along the x-axis from $x = a$ to $x = L$. Calculate the electric potential V at the origin in terms of parameters Q, a and L. (Take V = 0 at infinitely) **[4 points]**



- $dV = k\lambda dx/x$ [1]
- $\lambda = Q/(L-a)$ [1]
- $V = \int_a^L dV = kQ\ln(L/a)/(L-a)$ [2]

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

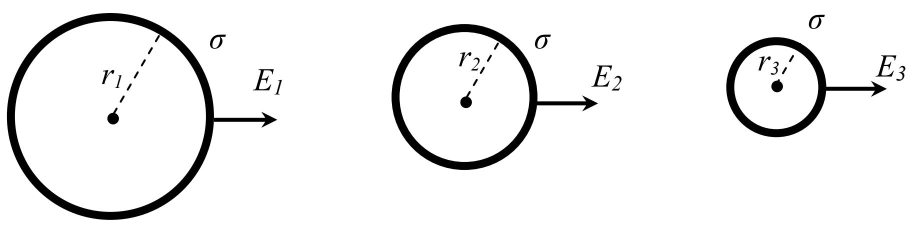
1. The figure shows three conducting spherical shells with the same surface charge density σ but different radii $r_1 > r_2 > r_3$. The electric fields E_1, E_2 and E_3 at the surface of these shells are related as

   a) $E_1 > E_2 > E_3$

   b) $E_1 < E_2 < E_3$

   c) $E_1 = E_2 = E_3 \neq 0$

   d) $E_1 = E_2 = E_3 = 0$



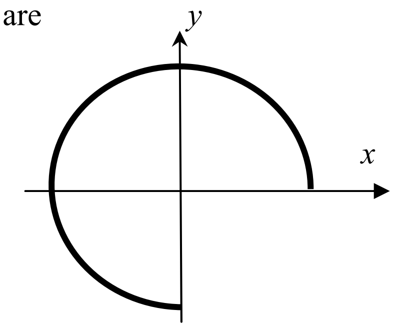
2. A positive charge is distributed uniformly on a circular wire shown below. The wire is in the *x-y* plane and centered at the origin. The two components of the electric field at the origin are

   a) $E_x > 0$ and $E_y < 0$

   b) $E_x > 0$ and $E_y > 0$

   c) $E_x < 0$ and $E_y > 0$

   d) $E_x < 0$ and $E_y < 0$



3. Point charges $q_1 = Q$ and $q_2 = -4Q$ are separated by distance *d*. If the magnitude of electrostatic force acting on q_1 is F_1 and on q_2 is F_2, then

   a) $F_1 = 4F_2$

   b) $F_2 = 4F_1$

   c) $F_1 = F_2$

   d) $F_1 = -F_2$

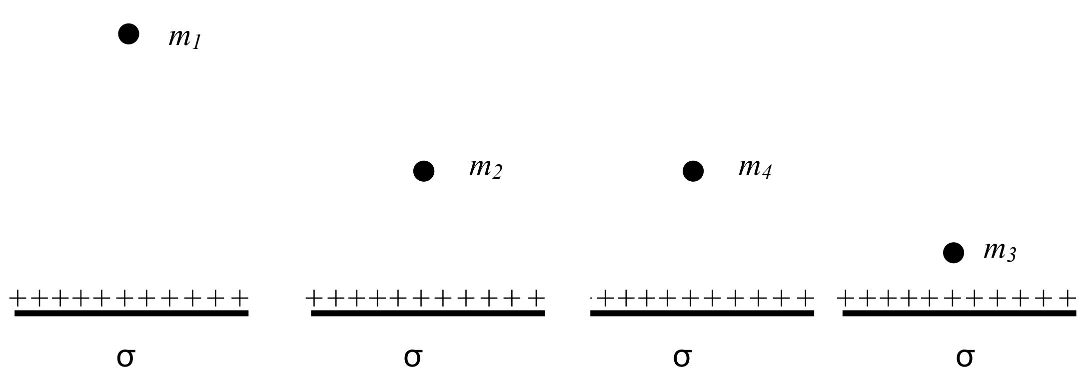
4. In the four figures shown below, each particle has the same charge q and is at rest over a large horizontal plate. The plates have the same surface charge density σ. The mass of the particles are related as

   a) $m_3 > m_2 = m_4 > m_1$

   b) $m_3 < m_2 = m_4 < m_1$

   c) $m_3 > m_2 > m_4 > m_1$

   d) $m_1 = m_2 = m_3 = m_4$



5. A uniform electric field is produced by charging uniformly

a) a very long bar

b) a very large plane

c) a conducting sphere

d) a non-conducting sphere

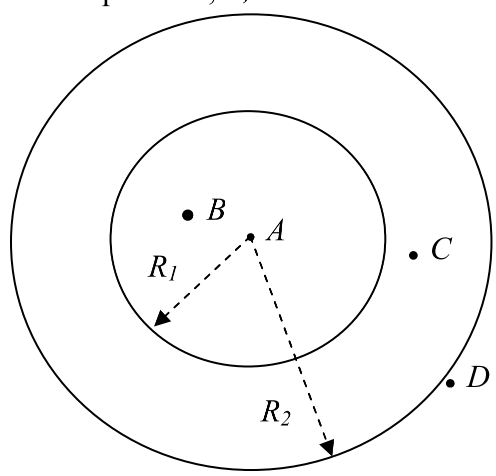
6. A positive charge is uniformly distributed in the spherical shell ($R_1 < r < R_2$) in the figure below. Taking the electric potential $V = 0$ at infinity, the electric potential at points A, B, C and D are such that

a) $V_A = V_B = V_C$

b) $V_A = V_B$

c) $V_C = V_D$

d) $V_C < V_D$



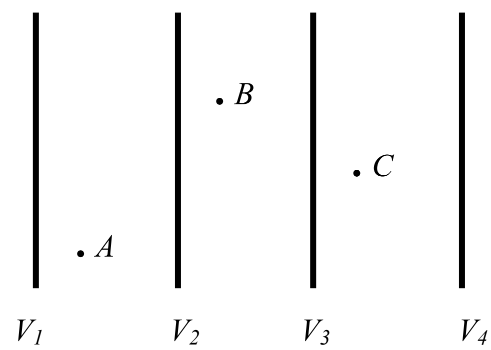
7. Four equipotential planes perpendicular to the plane of paper are shown below, where $V_1 < V_2 < V_3 < V_4$. The electric potential energy, U, of a negative charge Q ($Q < 0$) placed at points A, B and C are related as

a) $U_A < U_B = U_C$

b) $U_A = U_B = U_C$

c) $U_A < U_B < U_C$

d) $U_C < U_B < U_A$



8. In a region of electric field, charge Q is moved without acceleration from point A to point B along two paths with different lengths ($L_1 < L_2$) as shown. If the work done on Q is W_1 and W_2, respectively, then

a) $W_1 = W_2$

b) $W_1 > W_2$

c) $W_1 < W_2$

d) $W_1 = W_2$ only when the electric field is uniform