Kuwait University **Physics Department**

Physics 102

First Midterm Examination
Summer Semester (2011-12)

July 1, 2012

Time: 6:00 PM to 7:30 PM

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)
$\varepsilon_o = 8.85 \times 10^{-12}\ C^2/(N \cdot m^2)$	(Permittivity of free space)
$\mu_0 = 4\pi \times 10^{-7}$ T .m/A	(Premeability 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

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

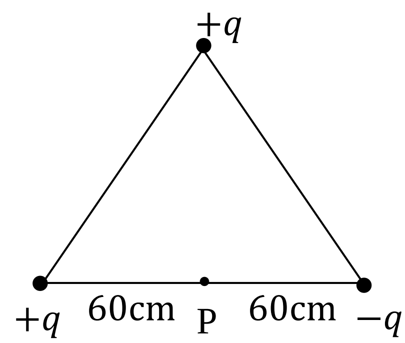
For use by Instructors only

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. Three point charges are at the corners of an equilateral triangle. If $q = 20$ μC what is the magnitude of the net electric force on a proton located at point P?

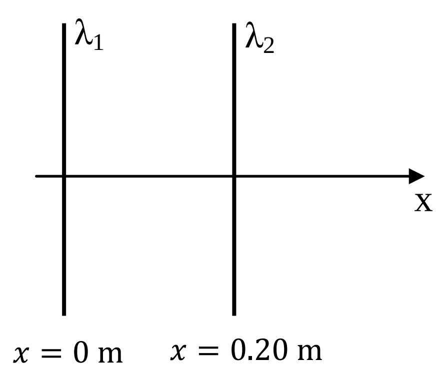


$$F_1 = F_2 = \frac{kqe}{(0.60)^2} = 8.0\times10^{-14}\ \text{N}$$

$$F_3 = \frac{kqe}{(1.2^2 - 0.6^2)} = 2.7\times10^{-14}\ \text{N}$$

$$F = \sqrt{(2F_1)^2 + F_3^2} = 1.6\times10^{-13}\ \text{N}$$

2. Two long charged rods with linear charge densities $\lambda_1 = +6$ μC/m and $\lambda_2 = -4$ μC/m are parallel to the y-axis, as shown. Where on the x-axis is the electric field zero?



$$E_1 = E_2$$

$$\frac{2k\lambda_1}{x} = \frac{2k\lambda_2}{x - 0.2}$$

$$x = 0.6\ \text{m}$$

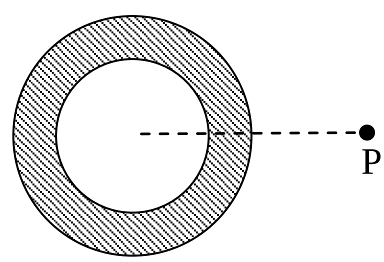
3. An electron moving with a velocity $\overrightarrow{v_0} = (4.5 \times 10^6 \mathrm{m/s})\hat{\imath}$ enters a uniform electric field $\vec{E} = (4.0\ \mathrm{N/C})\hat{\imath}$. What is the velocity of the electron 4 μs after entering the field?

$$\vec{a} = \frac{q\vec{E}}{m} = -7.0\times10^{11}\ \hat{\mathrm{i}}\ \ \mathrm{m/s}^2$$

$$\vec{v} = \vec{v}_0 + \vec{a}t = 4.5\times10^{6}\ \ \hat{\mathrm{i}} - 7.0\times10^{11}\ \hat{\mathrm{i}}\times 4\times10^{-6}$$

$$= 1.7\times10^{6}\ \hat{\mathrm{i}}\ \ \mathrm{m/s}$$

4. Electric charge is distributed uniformly in the volume of a spherical shell with inner radius a = 15 cm and outer radius b = 25 cm, as shown. The electric flux through the outer surface of the shell is $-5.0 \times 10^3\ \mathrm{Nm^2/C}$. What is the magnitude and direction of the electric field at point P that is 45 cm from the centre of the shell?



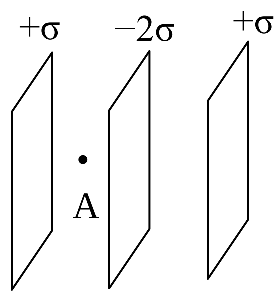
$$\Phi = \frac{q_{encl}}{\varepsilon_0}$$

$$q = \varepsilon_0\Phi = -4.4\times10^{-8}\ \mathrm{C}$$

$$E = k\frac{q}{r^2} = 1.97\times10^{3}\ \mathrm{N/C}$$

Towards the shell

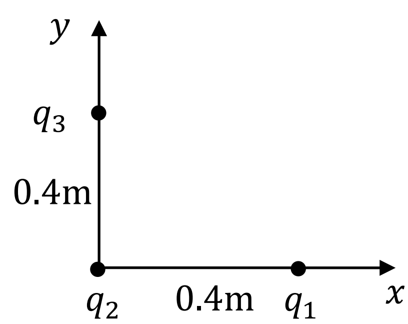
5. Three large sheets have uniform surface charge densities $+\sigma, -2\sigma$ and $+\sigma$, as shown. What is the magnitude and direction of the electric field at point A? Given, $\sigma = 8.85 \times 10^{-10}$ C/m^2.



$$\vec{E} = \frac{|\sigma|}{2\varepsilon_0}\hat{i} + \frac{|-2\sigma|}{2\varepsilon_0}\hat{i} + \frac{|\sigma|}{2\varepsilon_0}(-\hat{i})$$

$$= \frac{\sigma}{\varepsilon_0}\hat{i} = 100\,\hat{i} \text{ N/C}$$

6. Calculate the potential energy of the point charge q_1 in the figure. Given, $q_1 = -25$ nC, $q_2 = +45$ nC, and $q_3 = +30$ nC.



$$U_{12} = k\frac{q_1 q_2}{0.4} = -2.53 \times 10^{-5} \text{ J}$$

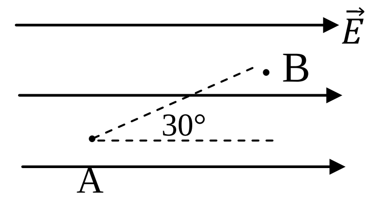
$$U_{13} = k\frac{q_1 q_3}{0.4\sqrt{2}} = -1.19 \times 10^{-5} \text{ J}$$

$$U_1 = U_{12} + U_{13} = -3.72 \times 10^{-5} \text{ J}$$

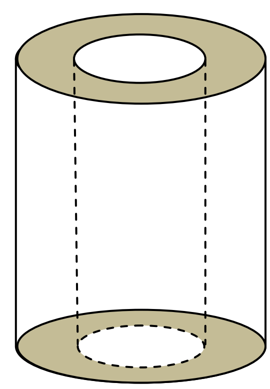
7. Work done on a charged particle q = 20 nC is 6.4 mJ when it moves from point A to point B in a uniform electric field **E**. If the distance between A and B is 0.30 m, what is the magnitude of the electric field **E**?

$$W = \vec{F}.\vec{d} = q\vec{E}.\vec{d} = qEd\cos\theta$$

$$E = \frac{W}{qd\cos\theta} = 1.23\times10^{6}\ \text{V/m}$$



8. A long *non-conducting* cylindrical shell with inner radius R_1 and outer radius R_2 has a uniform volume charge density ρ. In order to find out the electric field at a point r ($R_1 < r < R_2$):



(a) Draw a Gaussian surface through the point r.

(b) Obtain the charge enclosed by the Gaussian surface.

$$q_{encl} = \rho V = \rho\pi(r^2 - R_1^2)L$$

(c) Using the Gauss's law, obtain the electric field in terms of ρ, R_1, and ε_0.

$$\oint \vec{E}.d\vec{A} = \frac{q_{encl}}{\varepsilon_0}$$

$$E.2\pi rL = \frac{\rho\pi(r^2 - R_1^2)L}{\varepsilon_0}$$

$$E = \frac{\rho(r^2 - R_1^2)}{2\varepsilon_0 r}$$

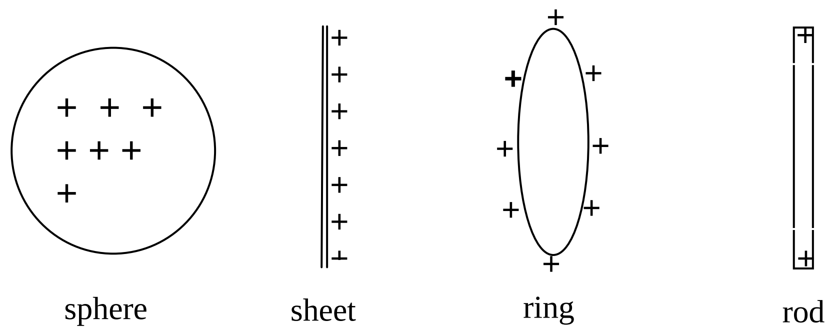
PART II: Conceptual Questions (1 point each). Tick the best answer.

1. A charged rod is brought close to a small uncharged conducting ball. The net electric force acting on the ball

   a) is zero.
   b) is toward the rod. **(ans)**
   c) is away from the rod.
   d) none of the above.

2. Which charged object(s) may be a conductor?

   a) Sphere & sheet
   b) Sheet
   c) Ring & rod **(ans)**
   d) Sheet & ring

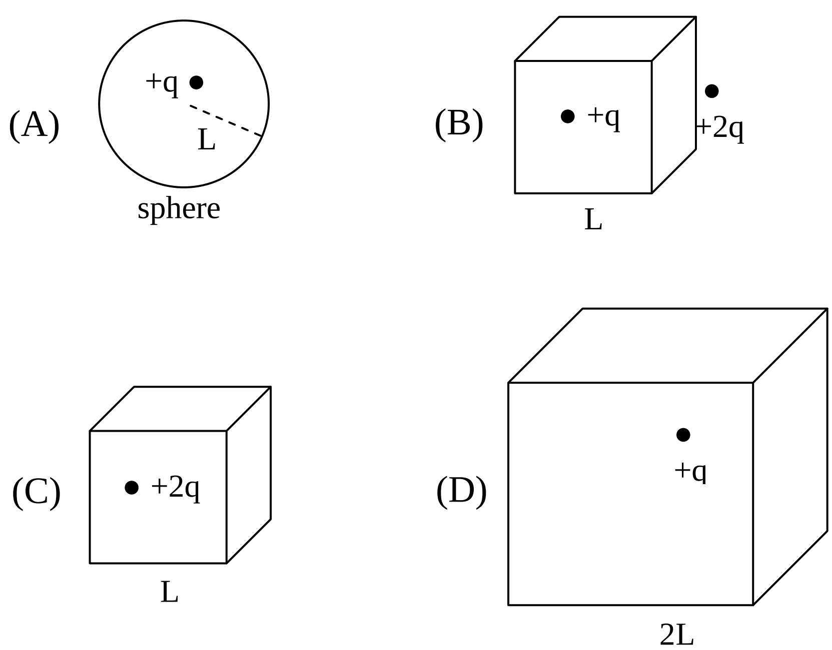


3. A *conducting* spherical shell has a net charge $-q$. A charge $+q$ is placed at the centre of the shell. How much is the charge on the outer surface of the shell?

   a) $+q$
   b) $-q$
   c) $+2q$
   d) zero **(ans)**

4. Various closed surfaces are shown. Through which closed surface is the electric flux greatest?

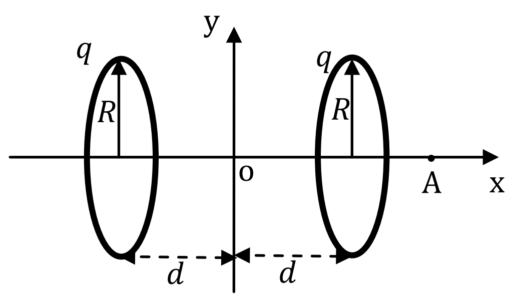
   a) A
   b) B
   c) C **(ans)**
   d) D



5. The electric field very close to the surface of a charged conductor

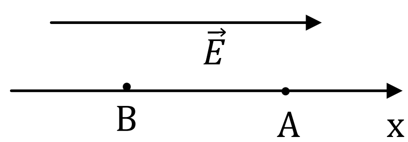
a) does not depend on the charge of the conductor.
b) is parallel to the surface of the conductor.
c) is perpendicular to the surface of the conductor. **(ans)**
d) is zero.

6. Electric charges $+q$ and $+q$ are uniformly distributed over two identical rings. Which statement is correct?



a) The electric field at the center of each ring is zero.
b) The electric field at the origin is zero. **(ans)**
c) The electric field at the origin points in +x direction.
d) The electric field at point A points in −x direction.

7. A negative point charge is moved from point A to B in a uniform electric field that is parallel to the x-axis. What can we say about the work done on the charge by the electric field and the potential energy of the charge?



a) The work done is positive and the potential energy increases.
b) The work done is negative and the potential energy decreases.
c) The work done is positive and the potential energy decreases. **(ans)**
d) The work done is zero and the potential energy is constant.

8. The two small spheres below are positively charged. In an experiment, charge q_1 is held in place and q_2 is released. If the final velocity of q_2 is to be doubled, charge q_1 must be changed to

a) $2q_1$
b) $q_1/2$
c) $4q_1$ **(ans)**
d) $q_1/4$