Kuwait University **Physics Department**

Physics 102

First Midterm Examination
Spring Semester (2011-12)

March 31, 2012

Time: 12.00 to 1.30 p.m.

Name…………………………………… Student No…………………

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

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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

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

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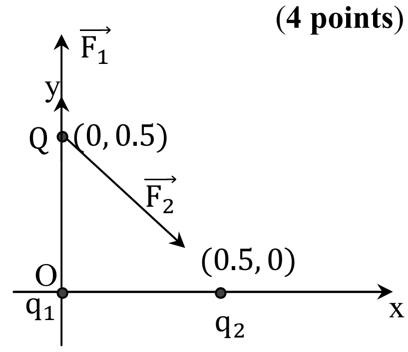
Prob.	1	2	3	4	5	6	7	8	Total
Marks									

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

1. A charge $q_1 = 80.0\ \mu C$ is placed at the origin and a charge $q_2 = -50.0\ \mu C$ is at $(0.50\ m, 0)$. Calculate the magnitude of the electrostatic force on a third charge ($Q = +70.0\ \mu C$) placed at $(0, 0.50\ m)$. **(4 points)**



$$\vec{F_1} = \frac{k\,|Qq_1|}{(0.5)^2}\ \hat{j} = 202.0\,\hat{j}\ N$$

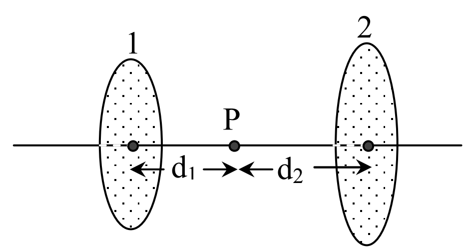
$$\vec{F_2} = \frac{k\,|Qq_2|}{(0.71)^2}\left[\frac{0.5}{0.71}\,\hat{i} - \frac{0.5}{0.71}\,\hat{j}\right]$$

$$= (45.0\,\hat{i} - 45.0\,\hat{j})\ N$$

$$\vec{F} = \vec{F_1} + \vec{F_2} = (45.0\,\hat{i} + 157\,\hat{j})N$$

$$F = 163\ N$$

2. Two discs of radii $R_1 = 2$ cm & $R_2 = 3$ cm respectively are placed parallel to each other & have a common symmetry axis as shown. The discs carry charges distributed uniformly with equal surface charge densities σ. Point P is at a distance $d_1 = 1$ cm from the center of disc 1. Determine its distance d_2 from the center of disc 2 if the electric field at P is to be zero. **(4 points)**



$$E_1 = E_2$$

$$\rightarrow \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{d_1}{\sqrt{d_1^2 + R_1^2}}\right] = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{d_2}{\sqrt{d_2^2 + R_2^2}}\right]$$

$$\frac{d_1}{\sqrt{d_1^2 + R_1^2}} = \frac{d_2}{\sqrt{d_2^2 + R_2^2}} \rightarrow \frac{d_1^2}{d_1^2 + R_1^2} = \frac{d_2^2}{d_2^2 + R_2^2}$$

$$\rightarrow 0.2 = \frac{d_2^2}{d_2^2 + R_2^2} \rightarrow 0.2\,R_2^2 = 0.8\,d_2^2$$

$$\rightarrow d_2 = \frac{R_2}{2} = 1.5\ cm$$

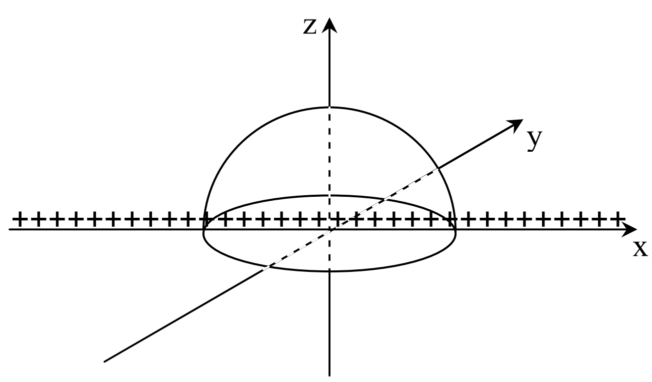
3. A point charge ($q = -8.0$ mC) moves in a region where the only force acting on it is electrostatic. The charge is released from rest at point A. If the kinetic energy of the particle at point B is 4.8 J, calculate the potential difference $V_A - V_B$. **(3 points)**

$$\Delta K = q\,(V_A - V_B)$$

$$\rightarrow 4.8 = -8 \times 10^{-3}\,(V_A - V_B)$$

$$\rightarrow V_A - V_B = -600\ V$$

4. Charge with uniform linear charge density of 4.0 nC/m is distributed along the entire x-axis. Consider a hemispherical surface of radius $a = 5.0$ cm, centered on the origin. Calculate the electric flux through this surface. **(4 points)**

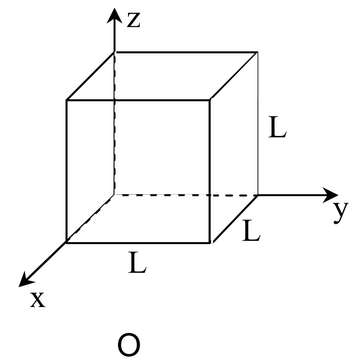


$$\Phi_E = \frac{1}{2}\,\frac{\lambda\,(2a)}{\varepsilon_o}$$

$$= \frac{\lambda a}{\epsilon_o} = 22.6\ \frac{N.m^2}{C}$$

5. A cube of edge L = 10 cm has charge inside it & is located as shown in figure. The electric field is given by $\vec{E} = (2 + 30\,z)\,10^5\,\hat{k}\,N/C$. Calculate the amount of charge inside the cube.

$\phi_{left} = \phi_{right} = \phi_{front} = \phi_{rear} = 0$ **(4 points)**



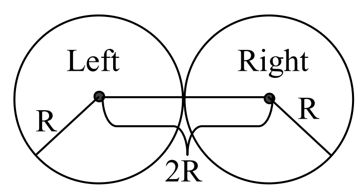
$$\phi_{top} = \vec{E}\Big|_{z=0.1} \cdot (0.1)^2\,\hat{k} = 5 \times 10^3\ \frac{N.m^2}{C}$$

$$\phi_{bot} = \vec{E}\Big|_{z=0} \cdot (0.1)^2(-\hat{k}) = -2 \times 10^3\ \frac{N.m^2}{C}$$

$$\phi_E = 3 \times 10^3\ \frac{N.m^2}{C}$$

$$Q_{enc} = \varepsilon_o\,\phi_E = 2.66 \times 10^{-8} C$$

6. Two insulating spheres of equal radii, R = 12 cm, are barely touching. They carry charges distributed inside them with equal volume charge density $\rho = 17.7 \times 10^{-9}\ cm^{-3}$. Calculate the magnitude of the electric field at the center of the right sphere.
(Hint: Use the principle of superposition) **(4 points)**



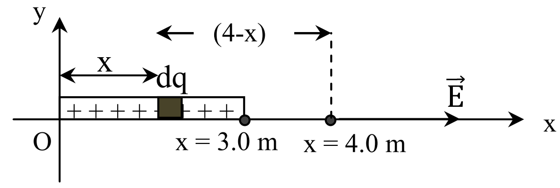
$$E_{Right} = 0$$

$$E_{Left} = \frac{kQ}{(2R)^2}$$

$$Q = \frac{4\pi}{3}\,R^3\rho = 1.28 \times 10^{-10}\ C$$

$$E = E_{Right} + E_{Left} = 20\ N/C$$

7. Charge is distributed uniformly with linear charge density $\lambda = 6.7\ \text{nC/m}$ along a rod on the x-axis extending from x = 0 to x = 3.0 m. **Derive an expression** for the electric field at x = 4.0 m & obtain a numerical value for its magnitude. **(5 points)**



$$d\vec{E} = \frac{k\,|\lambda|\,dx}{(4-x)^2}\ \hat{\imath}$$

$$\vec{E} = k\,|\lambda| \int_0^3 \frac{dx}{(4-x)^2}\ \hat{\imath} = k\,|\lambda| \left(\frac{1}{4-x}\right)\Bigg|_0^3\ \hat{\imath}$$

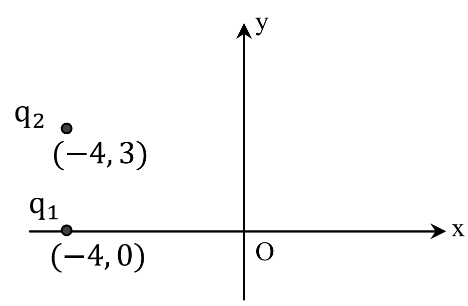
$$= \frac{3k\,|\lambda|}{4}\ \hat{\imath} = 45\,\hat{\imath}\ \frac{N}{C}$$

8. Two point charges $q_1 = 4\ \mu C$ & $q_2 = 5\ \mu C$ are located at $(-4, 0)$cm & $(-4, 3)$cm respectively. Calculate the work done by an external force to move a charge $q_3 = 2\ \mu C$ slowly from infinity & place it at the origin O. **(4 points)**

$$W_{ext} = \Delta U = q_3\left(\frac{kq_1}{0.04} + \frac{kq_2}{0.05}\right)$$

$$= 2 \times 10^{-6}\,(9.0 \times 10^5 + 9.0 \times 10^5)$$

$$= 3.6\ \text{J}$$

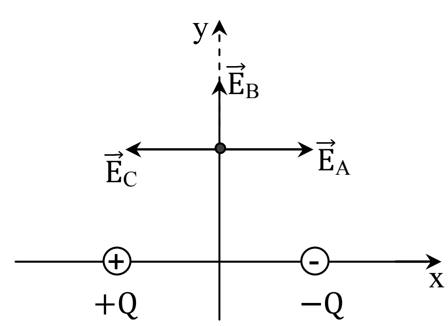


Conceptual Questions. Tick the best answer. Each question carries one point.

1. Which one of the following statements is **not** true?
   - ✓ a) Only conductors can be electrically charged.
   - b) A charged object can attract a neutral object.
   - c) Two unequal charges exert forces of equal magnitude on each other.
   - d) The electric field of a point charge exists everywhere in space.

2. If a positive charge Q is placed inside the cavity of a hollow isolated conductor that is originally uncharged & the charge does not touch that conductor at any time. Which of the following statements is true?
   - a) The inside surface of the conductor will become positively charged.
   - ✓ b) The outside surface of the conductor will become positively charged.
   - c) Both the inner & outer surfaces of the conductor will remain neutral.
   - d) Both the inner & outer surfaces of the conductor will become positively charged.

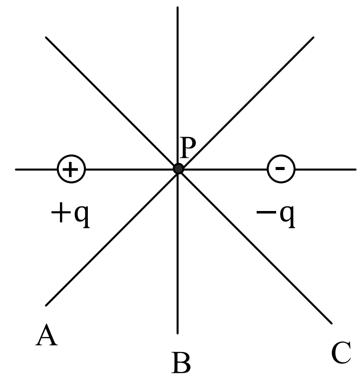
3. Two point charges, $+Q$ & $-Q$, are located at $x = \pm 1$ m on the x-axis as shown. Which vector best represents the direction of the electric field at a point along the y-axis?
   - ✓ a) $\vec{E}_A$.
   - b) $\vec{E}_B$.
   - c) $\vec{E}_C$.
   - d) The electric field at that point is zero.



4. A hollow metallic sphere of radius 10 cm is charged so that the potential at its surface is 5 V. The potential at the centre of the sphere is
   - a) 0 .
   - ✓ b) 5 V.
   - c) 50 V.
   - d) Equal to the potential at distance of 20 cm from the centre of the sphere.

5. A vertical cylinder of radius R & length L contains a charge Q uniformly distributed throughout its volume. The flux through the curved side of the cylinder is $3\,Q/4\varepsilon_o$. What is the flux through the top end of the cylinder?
   - a) $3\,Q/4\varepsilon_o$.
   - ✓ b) $Q/8\varepsilon_o$.
   - c) $Q/4\varepsilon_o$.
   - d) 0.

6. The point P in the figure lies halfway between point charges $+q$ & $-q$. The solid lines marked A, B & C represent three planes that are perpendicular to the paper. Which of these planes is an equipotential surface?
(All angles in the figure are equal)



a) A.
b) B.
c) C.
d) A & C.

7. Two conducting spheres of radii R_1 & R_2 initially carrying charges Q_1 & Q_2 respectively, are connected by a wire. When equilibrium is reached which of the following is true?

a) The charges on the spheres are equal.
b) The electric fields at the surfaces of spheres are equal.
c) The potentials of the two spheres are equal.
d) The spheres give rise to equal potentials at all points of space.

8. The figure shows three very large parallel insulating sheets positively charged with uniform & identical surface charge densities. In which regions shown is the magnitude of the electric field maximum?

a) A & B.
b) B & C.
c) A & C.
d) A & D.