Kuwait University **Physics Department**

Physics 102

First Midterm Examination
Spring Semester (2022 - 2023)
March 20, 2023

Time: 6:30 – 8:00 PM

Name.................................... Student ID.....................

Section No..................... Serial No.....................

Instructors: Drs. Afrousheh, Alfailakawi, Hadipour, Lajko, Sharma and Vagenas.

Fundamental constants

$k = \frac{1}{4\pi\varepsilon_o} = 9.0 \times 10^9 \text{ N.m}^2/\text{C}^2$ (Coulomb constant)

$\varepsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/(\text{N}\cdot\text{m}^2)$ (Permittivity of free space)

$\mu_0 = 4\pi \times 10^{-7}$ T .m/A (Permeability of free space)

$|e| = 1.60 \times 10^{-19}$ C (Elementary unit of charge)

$N_A = 6.02 \times 10^{23}$ (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)

$1\ eV = 1.6 \times 10^{-19}\ J$

Prefixes of units

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

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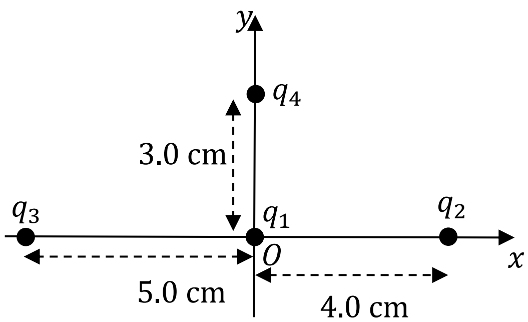
Prob.	1	2	3	4	5	6	7	8	Questions	Total
Marks										

Part I. Solve the following problems. Show your solutions in detail.

1. Four point charges are placed on x and y axes as shown. If $q_1 = +3.0\ \mu\text{C}$, $q_2 = +4.0\ \mu\text{C}$, $q_3 = -1.5\ \mu\text{C}$, and $q_4 = +5.0\ \mu\text{C}$. Find the net electric force $\vec{F}$ acting on charge q_1. **[4 points]**



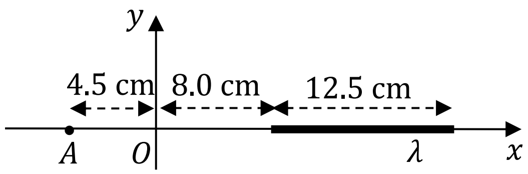
$$\vec{F}_{21} = k\frac{q_1 q_2}{r_{12}^2}(-\hat{\imath}) = -(67.5\ \text{N})\hat{\imath}$$

$$\vec{F}_{31} = k\frac{q_1 q_3}{r_{13}^2}(\hat{\imath}) = -(16.2\ \text{N})\hat{\imath}$$

$$\vec{F}_{41} = k\frac{q_1 q_4}{r_{14}^2}(-\hat{\jmath}) = -(150\ \text{N})\hat{\jmath}$$

$$\vec{F}_1 = -(83.7\ \text{N/C})\hat{\imath} - (150\ \text{N})\hat{\jmath}$$

2. A thin rod of length $L = 12.5$ cm with a uniform charge density of $\lambda = +1.2\ \text{nC/m}$ is placed along the x-axis as shown. Calculate the electric field of the rod at point A. **[4 points]**



$$\vec{E} = \int_{0.125}^{0.25} k\frac{\lambda dx}{x^2}(-\hat{\imath})$$

$$= k\lambda\left(-\frac{1}{x}\right)_{0.125}^{0.25}(-\hat{\imath})$$

$$= -(43.2\ \text{N/C})\hat{\imath}$$

3. An electron is moving at a velocity of $\vec{v} = (5.0 \times 10^6 \text{ m/s})\hat{\imath}$. Find the uniform electric field that can stop the electron in a distance of 5.0 cm. **[3 Points]**

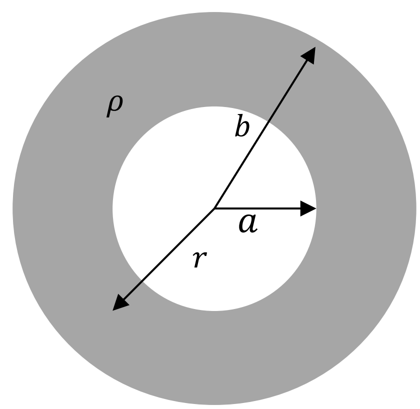
$$\vec{a} = -\frac{v_0^2}{2\Delta x}\hat{\imath} = -(2.5 \times 10^{14} \text{ m}/s^2)\hat{\imath}$$

$$\vec{F} = m\vec{a} = -(2.275 \times 10^{-16} \text{ N})\hat{\imath}$$

$$\vec{E} = \frac{\vec{F}}{-e} = (1422 \text{ N/C})\hat{\imath}$$

4. A non-conducting spherical shell with inner radius $a = 40$ cm and outer radius $b = 70$ cm is uniformly charged. If the electric field at a distance of $r = 55$ cm from its center is $30\,\text{N/C}$ pointing inward, calculate the volume charge density ρ of the sphere. **[4 points]**

$$\oint \vec{E} \cdot d\vec{A} = -4\pi r^2 E = \frac{Q_{enc}}{\varepsilon_0}$$

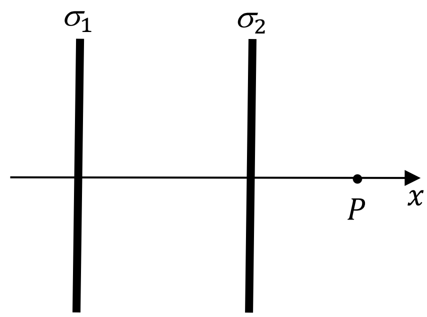


$$Q_{enc} = -\frac{(0.55)^2 \times 30}{9 \times 10^9} = -1 \times 10^{-9} \text{ C}$$

$$\rho = \frac{Q_{enc}}{\frac{4\pi}{3}(r^3 - a^3)}$$

$$\rho = \frac{-3 \times 1 \times 10^{-9}}{4 \times 3.14 \times (0.166 - 0.064)} = -2.34\,\text{nC/m}^3$$

5. Two uniformly charged parallel infinite plates are perpendicular to x-axis as shown. The surface charge density on one plate is $\sigma_1 = 15.0\ \mathrm{nC/m^2}$ and the net electric field at point P is given as $\vec{E} = -(1000\ \mathrm{N/C})\hat{\imath}$. Find the surface charge density σ_2. **[4 points]**

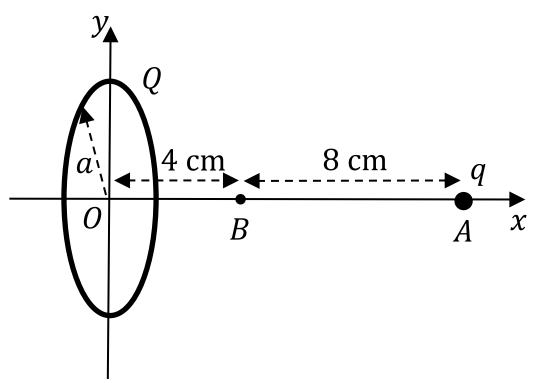


$$\vec{E}_P = E_1\hat{\imath} + E_2\hat{\imath} = -1000\hat{\imath}$$

$$\frac{\sigma_2}{2\epsilon_0}\hat{\imath} = -1000\hat{\imath} - \frac{\sigma_1}{2\epsilon_0}\hat{\imath}$$

$$\sigma_2 = -32.7\ \mathrm{nC/m^2}$$

6. A ring of uniform charge $Q = -50\ \mathrm{nC}$ and of radius $a = 6.0\ \mathrm{cm}$ is placed on the yz-plane and is centered at the origin. A point charge $q = 0.45\ \mu\mathrm{C}$ with a mass of $m = 1.5 \times 10^{-6}$ kg is released from rest at point A on the x-axis. Find the speed of the point charge when it is at point B. **[5 points]**



$$\Delta K = -\Delta U$$

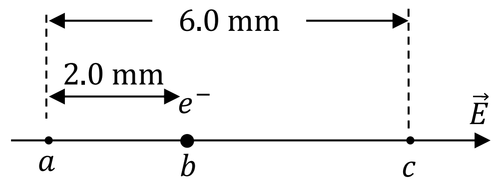
$$\frac{1}{2}mv^2 - 0 = -q(V_B - V_A)$$

$$V_A = \frac{kQ}{\sqrt{x^2+a^2}} = -3354\ \mathrm{V}$$

$$V_B = -6240\ \mathrm{V}$$

$$\frac{1}{2}mv^2 = 2886q \quad \rightarrow \quad v = 41.6\ \mathrm{m/s}$$

7. The three points a, b, and c are in a uniform electric field as shown. The potential difference between points a and c is $V_{ac} = 600$ V. How much work must be done on an electron by an external force to move it from point b to c? Write your answer in eV. **[4 Points]**

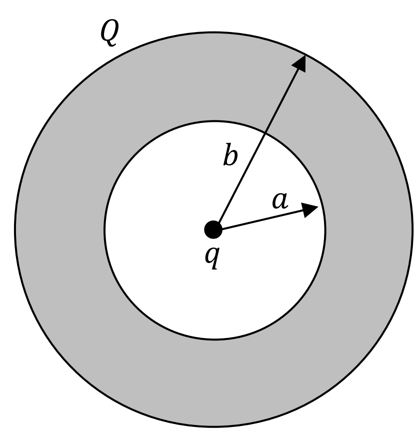


$$E = \frac{V_{ac}}{d} = \frac{600}{0.006} = 1 \times 10^5 \text{ V/m}$$

$$W_E = |q|Ed\cos 180^\circ = -eEd$$

$$W_{ext} = -W_E = eEd = 1 \times 1.0 \times 10^5 \times 0.004 = 400 \text{ eV}$$

8. A conducting spherical shell of inner radius $a = 4.0$ cm and outer radius $b = 6.0$ cm carries a net charge $Q = -10.0$ nC. A point charge $q = 5.0$ nC is placed at the center of the shell. Calculate the electric potential at a distance of 3.0 cm from the center of the shell. **[4 points]**



$$V = k\frac{q}{r} + k\frac{-q}{a} + k\frac{q+Q}{b}$$

$$V = -375 \text{ V}$$

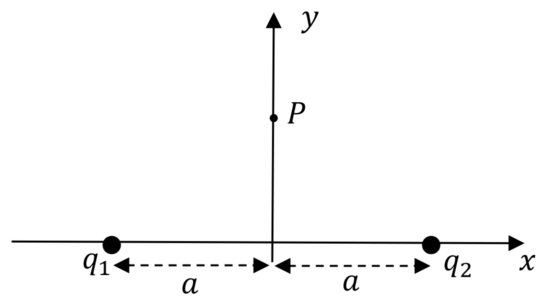
PART II : Conceptual Questions (each carries 1 point). Tick the best answer.

1. Which one of the following values can be the net charge of a free particle?

   a) 4.0×10^{-19} C.
   b) -4.0×10^{-19} C.
   c) 3.2×10^{-20} C.
   d) $\mathbf{3.2 \times 10^{-18}}$ C.

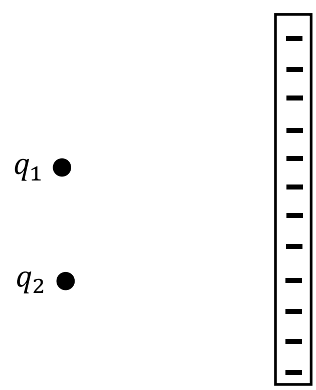
2. Two point charges q_1 and q_2 are placed on the x-axis as shown. The net electric field $\vec{E}$ at point P on y-axis

   a) is zero if $q_1 = q_2$.
   b) is zero if $|q_1| = |q_2|$.
   c) is zero if $q_1 = -q_2$.
   d) **is never zero**.



3. Two positive point charges q_1 and q_2 of the same mass are released from rest at the same distance from a negatively charged infinite plate. The point charges have speeds v_1 and v_2 when they reach the plate. Which statement is correct?

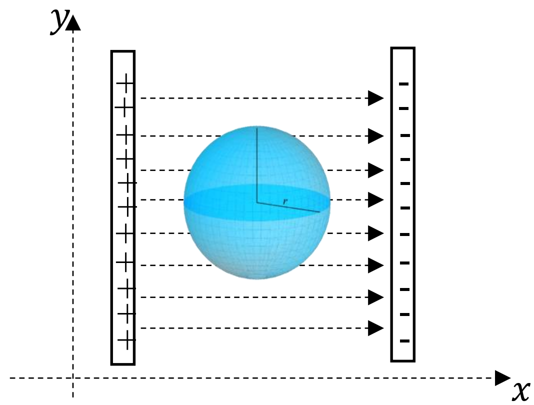
   a) $\boldsymbol{v_1 > v_2}$ **if** $\boldsymbol{q_1 > q_2}$.
   b) $v_1 > v_2$ if $q_1 < q_2$.
   c) $v_1 = v_2$ for any q_1 and q_2.
   d) any of the above depending on the charge of the plate.



4. Which statement is **wrong** about linear charge density λ?

   a) λ is a constant for a uniform charge distribution.
   b) $\boldsymbol{\lambda}$ **is a constant for any charge distribution**.
   c) λ is a constant for a uniformly charged infinite line.
   d) λ can be greater than the total charge of the line.

5. A conducting sphere is placed between two oppositely charged plates as shown. The electric field $\vec{E}$ inside the sphere is:



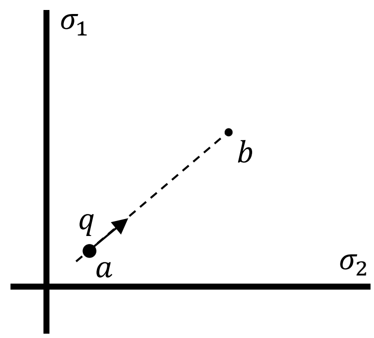
a) $\vec{E} = E\hat{\imath}$.

b) $\vec{E} = E(-\hat{\imath})$.

c) $\vec{E} = E_x\hat{\imath} + E_y\hat{\jmath}$.

d) $\vec{\boldsymbol{E}} = \mathbf{0}$.

6. A positive point charge q moves from point a to b near two positively charged infinite plates as shown. In this motion the electric potential energy of the point charge



a) decreases.

b) increases.

c) does not change.

d) does not change if $\sigma_1 = \sigma_2$.

7. Which one of the following **is not** the unit of electric field?

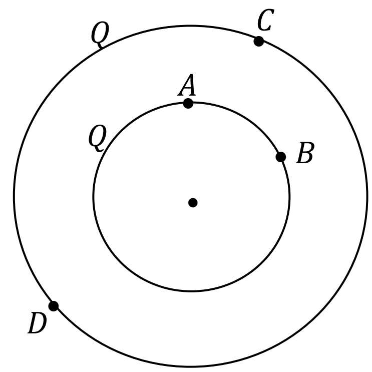
a) N/C.

b) V/m.

c) $\frac{J}{C \cdot m}$.

d) $\boldsymbol{\frac{J \cdot m}{C}}$.

8. Two concentric conducting spherical shells carry equal charges Q. A point charge q is moved between different points on these shells. Which statement is correct regarding the work done on q by the electric field?



a) $W_{A\to D} > W_{A\to C}$.

b) $\boldsymbol{W_{A\to D} = W_{A\to C}}$.

c) $W_{C\to D} > W_{A\to B}$.

d) $W_{C\to D} < W_{A\to B}$.