Kuwait University جامعة الكويت KUWAIT UNIVERSITY •1966• **Physics Department**

Physics 102
Midterm-1 Examination

Fall Semester 2025
October 25, 2025

Time: 11:00 a.m. – 12:30 p.m.

Name: …………………………………… Student ID No: …………………………

Section: …………………………………… Serial No.: …………………………

Instructors**:** Drs. Abdul Mohsen, Yahya, Lajko, Sharma, & Vagenas

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Fundamental constants

$k = \dfrac{1}{4\pi\varepsilon_o} = 9.0\times10^9\ \mathrm{N.m^2/C^2}$ (Coulomb constant)

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

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

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

$N_A = 6.02 \times 10^{23}$ (Avogadro's number)

$g = 9.8\ \mathrm{m/s^2}$ (Acceleration due to gravity)

$m_e = 9.11 \times 10^{-31}\ \mathrm{kg}$ (Electron mass)

$m_p = 1.67 \times 10^{-27}\ \mathrm{kg}$ (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

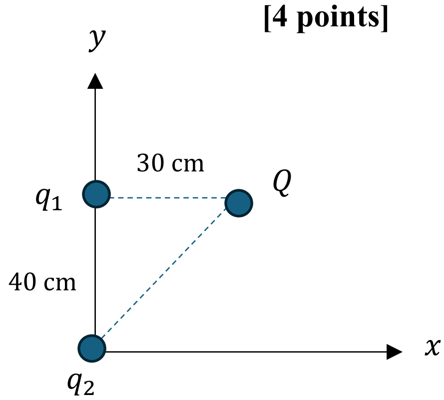
Ques.	1	2	3	4	5	6	7	8	Questions	Total
Marks										

Important:

1. Mobiles or other electronic devices are **strictly prohibited** during the exam.
2. Programmable calculators, which can store equations, are not allowed.
3. **Cheating incidents will be processed according to the university rules.**

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

1. Three charges $q_1 = -20\ \mu\text{C}$, $q_2 = +30\ \mu\text{C}$, and $Q = -40\ \mu\text{C}$ are placed on the *xy*-plane. Calculate the net force $\vec{F}_{net}$ on Q. **[4 points]**



$$F_1 = \frac{k|q_1||Q|}{r_{12}^2} = \frac{9\times10^9\times20\times10^{-6}\times40\times10^{-6}}{0.30^2} = 80.0\ \text{N}$$

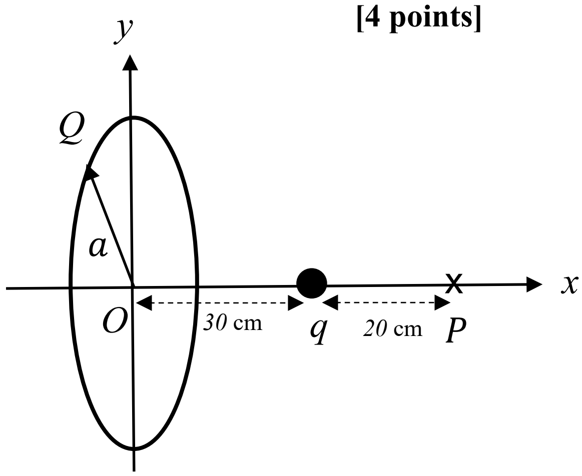
$$F_2 = \frac{k|q_2||Q|}{r_{13}^2} = \frac{9\times10^9\times30\times10^{-6}\times40\times10^{-6}}{0.50^2} = 43.2\ \text{N}$$

$$\vec{F}_x = F_1\,\hat{\imath} - F_2\cos\theta\ \hat{\imath} = 80\,\hat{\imath} - 43.2\times\frac{0.30}{0.50}\ \hat{\imath} = \ 54.1\ \text{N}\ \ \hat{\imath}$$

$$\vec{F}_y = -F_2\sin\theta\ \ \hat{\jmath} = -43.2\times\frac{0.40}{0.50}\ \hat{\jmath}\ \ = -34.6\ \text{N}\,\hat{\jmath}$$

$$\vec{F}_{net} = (54.1\,\hat{\imath} - 34.6\,\hat{\jmath})\ \text{N}$$

2. A uniformly charged ring (with charge Q = 50 nC and radius a = 0.24 m) with its axis along the *x*-axis has its center at origin. A charge q = −20 nC is located at distance 30 cm from the center, as shown. What is the net electric field $\vec{E}_{net}$ at point *P*? **[4 points]**

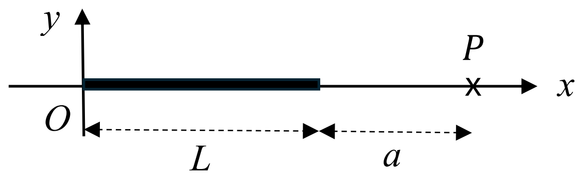


$$\vec{E}_{ring} = k\frac{|Q|x}{(0.5^2+a^2)^{\frac{3}{2}}}\ \hat{\imath} = 1.32\times10^3\,\frac{\text{N}}{\text{C}}\hat{\imath}$$

$$\vec{E}_q = k\frac{|q|}{(0.2)^2}(-\,\hat{\imath}) = \ -4.50\ \times\ 10^3\,\frac{\text{N}}{\text{C}}\hat{\imath}$$

$$\vec{E}_{net} = \vec{E}_{ring} + \ \vec{E}_q = 1.32\times10^3\,\frac{\text{N}}{\text{C}}\hat{\imath}\ -4.50\ \times\ 10^3\,\frac{\text{N}}{\text{C}}\hat{\imath}$$
$$= -3.18\ \times\ 10^3\,\frac{\text{N}}{\text{C}}\hat{\imath}$$

3. A line charge of length $L = 0.30$ m, with charge $Q = 15.0$ nC distributed uniformly along its length, lies along the x-axis, as shown. Derive the electric field $\vec{E}$ at point P that is at distance $a = 0.20$ m from the line charge. **[4 points]**



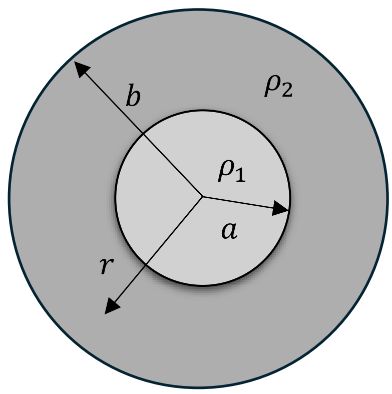
$$d\vec{E} = \frac{k|dQ|}{r^2}(\hat{\imath}) = \frac{k\lambda dx}{(L+a-x)^2}(\hat{\imath})$$

$$\vec{E} = \int_0^L \frac{k|\lambda|dx}{(L+a- x)^2}(\hat{\imath}) = -\int_{L+a}^{a} \frac{k|\lambda|dx\prime}{x\prime^2}(\hat{\imath})$$

$$= k\lambda \left[\frac{1}{x\prime}\right]_{L+a}^{a} = k\lambda\left[\frac{1}{a} - \frac{1}{a+L}\right] = k\frac{|Q|}{a(a+L)}(\hat{\imath})$$

$$\vec{E} = 1.35 \times 10^3 \text{ N/C } (\hat{\imath})$$

4. A sphere of radius $a = 4$ cm has a uniform volume charge density $\rho_1 = 5\ \text{nC/m}^3$ and a concentric spherical shell of inner radius a, and outer radius $b = 9$ cm has a uniform volume charge density $\rho_2 = -13\ \text{nC/m}^3$. Find the magnitude and direction of the electric field at a distance $r = 7$ cm. **[4 points]**



$$\Phi_E = EA = \frac{q_{enc}}{\epsilon_0}$$

$$A = 4\pi r^2 = 0.0616m^2$$

$$q_{enc} = q_a + q_r$$

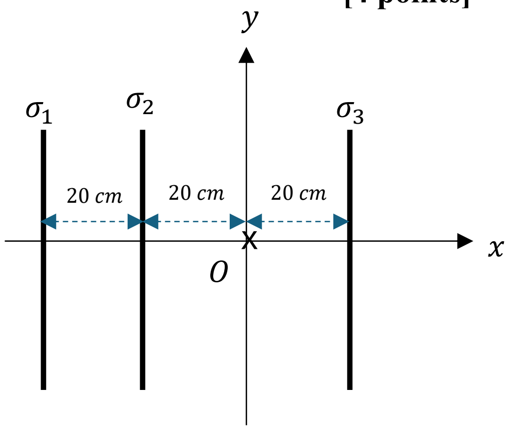
$$q_a = \frac{4}{3}\pi a^3 \rho_1 = 1.34 \times 10^{-12}\ \text{C}$$

$$q_r = \frac{4}{3}\pi(r^3 - a^3)\rho_2 = -1.52 \times 10^{-11}\ \text{C}$$

$$E = \frac{q_{enc}}{A.\epsilon_0} = \frac{-1.39\times10^{-11}}{0.0616\times8.85\times10^{-12}} = -25.4\ \text{N/C}$$

$$|E| = 25.4\ \text{N/C, inward}$$

5. Three uniformly charged infinite sheets are perpendicular to the x-axis, as shown below. Sheet 1 has $\sigma_1 = -10\ \mathrm{nC/m^2}$ and sheet 2 has $\sigma_2 = 4\ \mathrm{nC/m^2}$. If the net electric field is $\vec{E}_{net} = 440\ \mathrm{N/C}\ \hat{\imath}$ at point O, what is σ_3? **[4 points]**



$\vec{E}_{net} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$

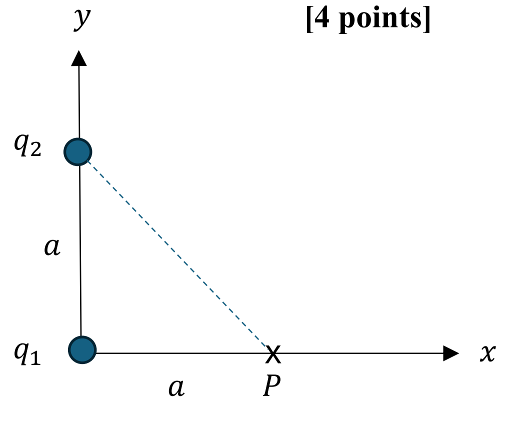
$440\ \hat{\imath} = -\frac{10\times10^{-9}}{2\epsilon_0}\hat{\imath} + \frac{4\times10^{-9}}{2\epsilon_0}\hat{\imath} + \vec{E}_3$

$\vec{E}_3 = 779\ \mathrm{N/C}\ \hat{\imath}$

$|\sigma_3| = 2\epsilon_0|\vec{E}_3| = 13.8 \times 10^{-9}\ \mathrm{C/m^2}$

$\sigma_3 = -13.8 \times 10^{-9}\ \mathrm{C/m^2}$

6. Two charges $q_1 = -8\ \mu\mathrm{C}$, and charge $q_2 = -4\ \mu\mathrm{C}$ are located on the xy-plane, as shown below (where $a = 3$ cm). What is the work done by the electric field to bring a *proton* from infinity to point P? **[4 points]**



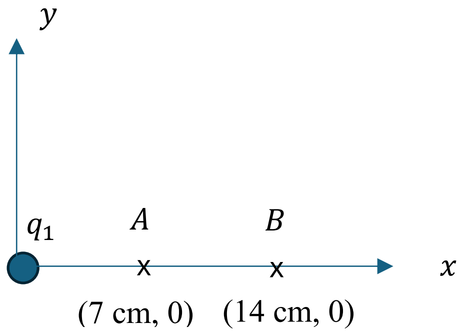
$W_{field} = -\Delta U = -(U_p - U_\infty)$

$U_p = |e|V_p = |e|\left(\frac{kq_1}{a} + \frac{kq_2}{\sqrt{2}a}\right) = -5.2 \times 10^{-13}\ \mathrm{J}$

$U_\infty = 0$

$W_{field} = -U_p = 5.2 \times 10^{-13}\ \mathrm{J}$

7. A charge $q_1 = -3\ \mu\text{C}$ is fixed at the origin. If $q_2 = -6\ \mu\text{C}$ moves with the initial velocity $\vec{v}_i = 350\,\frac{\text{m}}{\text{s}}\,\hat{\imath}$ at point A and the final velocity $\vec{v}_f = 700\,\frac{\text{m}}{\text{s}}\,\hat{\imath}$ at point B, calculate the mass of q_2. **[4 points]**

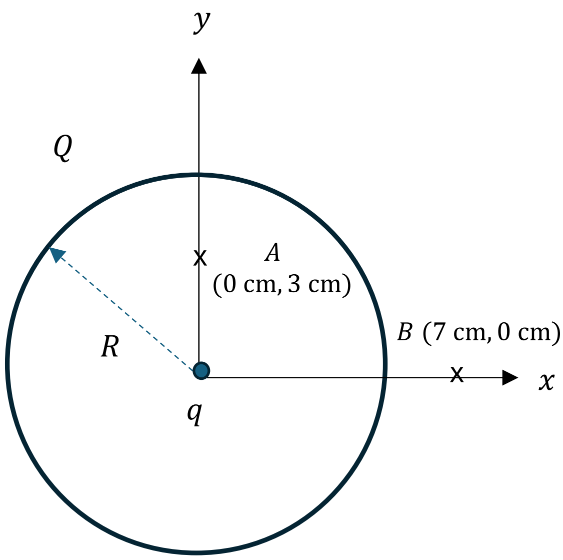


$$E_A = E_B \rightarrow K_A + U_A = K_B + U_B$$

$$\frac{1}{2}mv_i^2 + \frac{kq_1q_2}{r_A} = \frac{1}{2}mv_f^2 + \frac{kq_1q_2}{r_B}$$

$$m = \frac{2kq_1q_2\left(\frac{1}{r_A}-\frac{1}{r_B}\right)}{(v_f^2-v_i^2)} = 6.3 \times 10^{-6}\ \text{kg}$$

8. A conducting thin spherical shell of radius $R = 5$ cm is centered at the origin of the *xy*-plane and has an electric charge $Q = 20$ nC. A point charge $q = -15$ nC is located at the center of the shell. Calculate the potential difference $V_A - V_B$. **[4 points]**



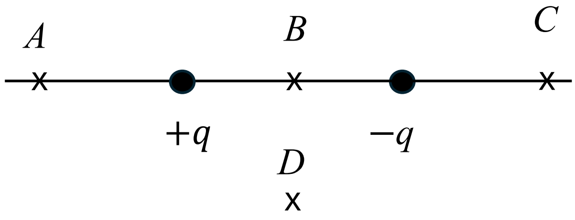
$$V_A = \frac{kQ}{R} + \frac{kq}{r_A} = -900\ \text{V}$$

$$V_B = \frac{kQ}{r_b} + \frac{kq}{r_b} = 643\ \text{V}$$

$$V_A - V_B = -1543\ \text{V}$$

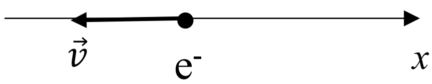
Part II. Conceptual Questions (each carries 1 point). Tick the best answer.

1. Two charges $+q$ and $-q$ are placed along the x-axis, as shown. At which point is the magnitude of the net electric field largest?



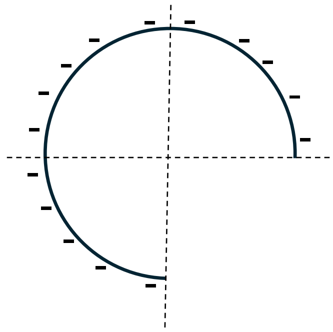
a) A.
b) B. (ans)
c) C.
d) D.

2. An electron is moving with velocity $\vec{v}$ in the $-x$ direction. Which of the applied electric fields below *may* stop the electron?



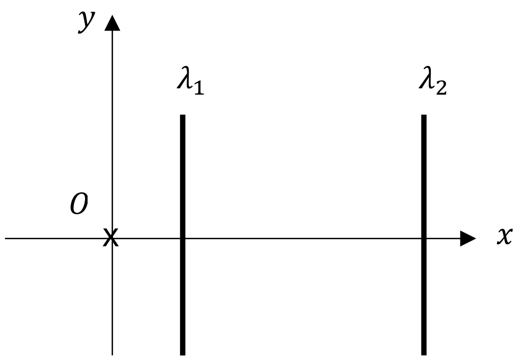
a) $\vec{E} = -E\ \hat{\imath}$. (ans)
b) $\vec{E} = \quad E\ \hat{\imath}$.
c) $\vec{E} = -E\ \hat{\jmath}$.
d) $\vec{E} = \quad E\ \hat{\jmath}$.

3. A negative charge is distributed uniformly along the circular arc as shown in the figure. What is the direction of the net electric field at *the center* of the arc?



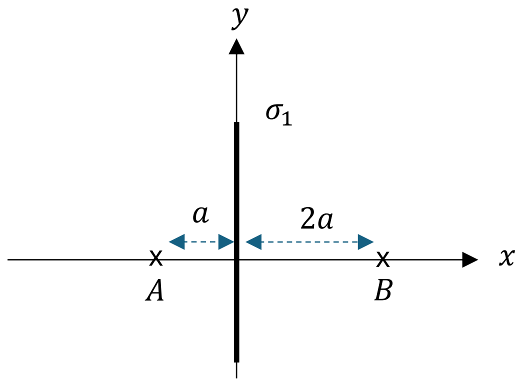
a) ←
b) ↘
c) ↖ (ans)
d) →

4. Two infinitely long wires carrying uniform linear charge densities $\lambda_1 > 0$ and λ_2 are placed on the xy-plane, as shown below. If the net electric field is *zero* at the origin O, then λ_2 must be



a) positive.
b) negative. (ans)
c) zero.
d) The same as λ_1.

5. An infinite sheet of a uniform surface charge σ_1 is placed perpendicular to the xy-plane, as shown. If the electric field at point A is $\vec{E}_A$, then the electric field at point B is



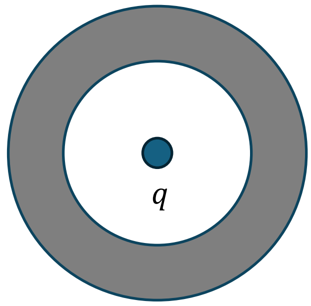
a) $\vec{E}_B = \vec{E}_A$.

b) $\vec{E}_B = -\vec{E}_A$. (ans)

c) $\vec{E}_B = \frac{\vec{E}_A}{2}$.

d) $\vec{E}_B = \frac{\vec{E}_A}{4}$.

6. A conducting shell carries $Q = 8$ nC on the outer surface. By adding a point charge $q = 2$ nC at the center of the charged conducting shell, what will be the charge on the outer surface of the conducting shell?



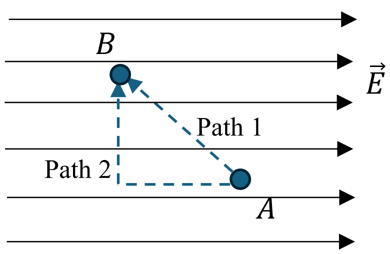
a) $q_{out} = 2$ nC.

b) $q_{out} = 6$ nC.

c) $q_{out} = 8$ nC.

d) $q_{out} = 10$ nC. (ans)

7. If q moves in a uniform electric field as shown. The work done by the electric field to move q from A and B via Path 1 is W_1, and Path 2 is W_2. What is the relationship between W_1 and W_2?



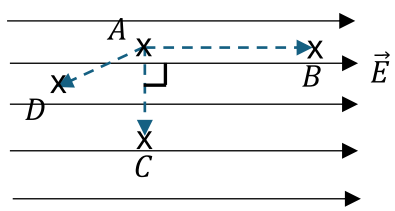
a) $W_1 > W_2$.

b) $W_1 < W_2$.

c) $W_1 = W_2$. (ans)

d) $W_1 = -W_2$.

8. For a uniform electric field, as shown below, which path has $\Delta V = 0$?



a) From A to B.

b) From A to C. (ans)

c) From A to D.

d) None