Kuwait University **Physics Department**

جامعة الكويت
KUWAIT UNIVERSITY

Physics 102
Midterm-1 Examination

Summer Semester 2025
July 5, 2025

Time: 12:00 p.m. – 1:30 p.m.

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

Section: …………………………………… Serial number: …………………………

Instructors: Drs. Al-Mumin, Lajko, & Vagenas

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

Problems	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 you solutions in details.

1. Three charges $q_1 = 3$ nC, $q_2 = 7$ nC and $q_3 = -5$ nC are placed on the *xy*-plane, as shown. What is the net force vector $\vec{F}_{net}$ on q_1? **[4 points]**

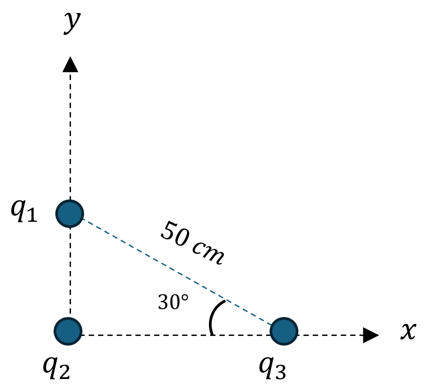
$$F_{12} = \frac{kq_1q_2}{r_{12}^2} = 3.02 \times 10^{-6}\text{N}$$

$$F_{13} = \frac{kq_1q_3}{r_{13}^2} = 5.4 \times 10^{-7}\text{N}$$

$$\Sigma F_y = F_{12} - F_{13}\sin(30) = 2.75 \times 10^{-6}\text{ N}$$

$$\Sigma F_x = F_{13}\cos(30) = 4.7 \times 10^{-7}\text{ N}$$

$$\vec{F}_{net} = +4.7 \times 10^{-7}\text{N}\,\hat{\imath} + 2.75 \times 10^{-6}\text{ N}\,\hat{\jmath}$$



2. Three uniformly charged infinite parallel lines with $\lambda_1 = -6$ nC/m, $\lambda_2 = -3$ nC/m, and λ_3 are fixed on *xy*-plane as shown. If $\vec{E}_{net} = 100$ N/C $\hat{\imath}$ at *the origin*, what is the value and sign of λ_3? **[5 points]**

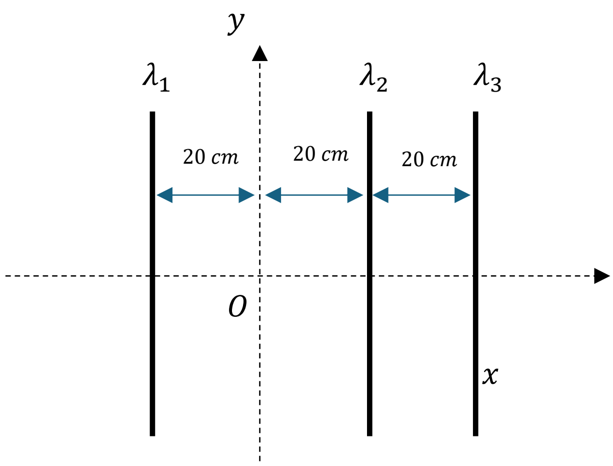
$$\vec{E}_1 = \frac{2k\lambda_1}{r_1} = -540\frac{\text{N}}{\text{C}}\hat{\imath}$$

$$\vec{E}_2 = \frac{2k\lambda_2}{r_3} = 270\frac{\text{N}}{\text{C}}\hat{\imath}$$

$$\vec{E}_{net} = 100\hat{\imath} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3, \quad \vec{E}_3 = 370\frac{\text{N}}{\text{C}}\,\hat{\imath}$$

$$|\lambda_3| = \frac{E_2 r}{2k} = 8.22 \times 10^{-9}\frac{\text{C}}{\text{m}}$$

$$\lambda_3 = -8.22 \times 10^{-9}\frac{\text{C}}{\text{m}}$$



3. A line charge of length $L = 0.5\text{m}$ with charge $Q = 10\ \mu\text{C}$ distributed uniformly along its length, lies along the y-axis at distance $a = 0.4$ m from the origin, as shown. Derive the formula for the electric field at the origin due to the line charge. Determine the magnitude and direction of $\vec{E}$ at the origin. **[5 points]**

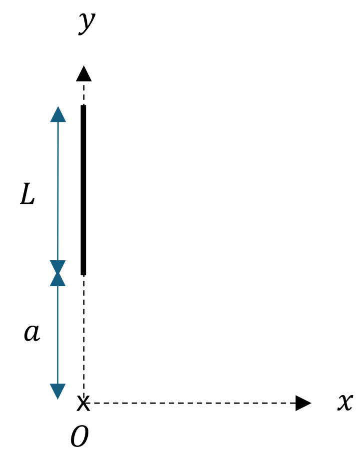
$$\lambda = \frac{Q}{L} = \frac{10 \times 10^{-6}}{0.5} = 2 \times 10^{-5}\ \text{C/m}$$

$$d\vec{E} = \frac{k|dQ|}{r^2}(-\hat{\jmath}) = \frac{k|\lambda|dy}{y^2}(-\hat{\jmath})$$

$$\vec{E}_{net} = \int_a^{a+L} \frac{k|\lambda|dy}{y^2}(-\hat{\jmath})$$

$$= k|\lambda|\left(\frac{1}{a} - \frac{1}{a+L}\right)(-\hat{\jmath})$$

$$\vec{E}_{net} = -2.5 \times 10^5\ \frac{\text{N}}{\text{C}}\ \hat{\jmath}$$



4. A sphere of radius $a = 5$ cm has a uniform volume charge density $\rho_1 = -20\ \text{nC/m}^3$ and a concentric spherical shell of inner radius a, and outer radius $b = 10$ cm has a uniform volume charge density $\rho_2 = 15\ \text{nC/m}^3$. Find the magnitude and direction of the net electric field $\vec{E}$ at distance $r = 8$ cm from the center. **[5 points]**

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

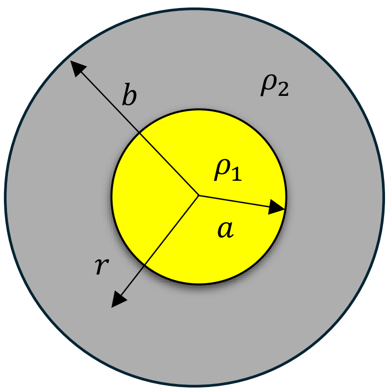
$$A = 4\pi r^2 = 0.0804\ \text{m}^2$$

$$q_{enc} = Q_a + Q_r$$

$$Q_a = \rho_1 \frac{4}{3}\pi a^3 = -1.05 \times 10^{-11}\ \text{C}$$

$$Q_r = \rho_2 \frac{4}{3}\pi(r^3 - a^3) = 2.43 \times 10^{-11}\ \text{C}$$

$$E = \frac{q_{enc}}{A\epsilon_0} = 19.4\frac{\text{N}}{\text{C}},\ outward$$



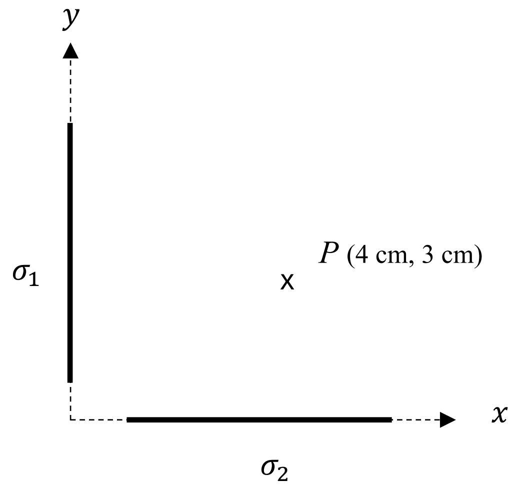
5. Two uniformly charged infinite sheets are placed perpendicular to *xy*-plane as shown below. Sheet 1 has $\sigma_1 = 12\ \mathrm{nC/m^2}$, and sheet 2 has $\sigma_2 = 8\ \mathrm{nC/m^2}$. Calculate the magnitude and direction of the net electric field at point *P*. **[4 points]**

$$\vec{E}_1 = \frac{\sigma_1}{2\epsilon_0} = 678\frac{\mathrm{N}}{\mathrm{C}}\hat{\imath}$$

$$\vec{E}_2 = \frac{\sigma_2}{2\epsilon_0} = 452\frac{\mathrm{N}}{\mathrm{C}}\hat{\jmath}$$

$$|E_{net}| = \sqrt{452^2 + 678^2} = 815\frac{\mathrm{N}}{\mathrm{C}}$$

$$Direction: \theta = \tan^{-1}\left(\frac{452}{678}\right) = 33.7°$$



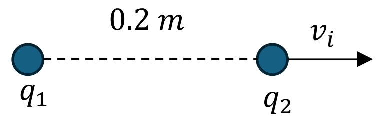
6. A charge $q_1 = 8\ \mu\mathrm{C}$ is held at rest. Another charge $q_2 = 4\ \mu\mathrm{C}$ with mass $m = 8 \times 10^{-6}$ kg moves with initial speed $v_i = 350\ \mathrm{m/s}$ away from q_1 when it is at distance 0.2 m. What is the speed of q_2 when it reaches distance 0.7 m away from q_1. **[4 points]**

$$K_i + U_i = K_f + U_f$$

$$\frac{1}{2}mv_i^2 + \frac{kq_1q_2}{r_i} = \frac{1}{2}mv_f^2 + \frac{kq_1q_2}{r_f}$$

$$v_f = \sqrt{\frac{2}{m}[\frac{1}{2}mv_a^2 + kq_1q_2\left(\frac{1}{r_i} - \frac{1}{r_f}\right)]}$$

$$v_f = 616\ \frac{\mathrm{m}}{\mathrm{s}}$$



7. A charge $q_1 = -12\ \mu C$ is located at the origin. A charge $q_2 = 5\ \mu C$ is located 10 cm away from the origin on the x-axis. What is the external work needed to move a charge $q_3 = 3\ \mu C$ from point A to point B?

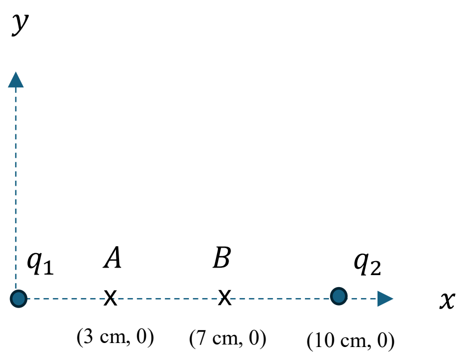
[4 points]

$$W_{ext} = \Delta U = q_3(V_B - V_A)$$

$$V_A = \frac{kq_1}{(r_1)_A} + \frac{kq_2}{(r_2)_A} = -2.96 \times 10^6\ \text{V}$$

$$V_B = \frac{kq_1}{(r_1)_B} + \frac{kq_1}{(r_2)_B} = -4.24 \times 10^4\ \text{V}$$

$$W_{ext} = 8.75\ \text{J}$$



8. A conducting sphere of radius $R = 5$ cm is centered at the origin of xy-plane and has an electric charge $Q = 50\ \mu C$. Calculate the potential difference $V_A - V_B$.

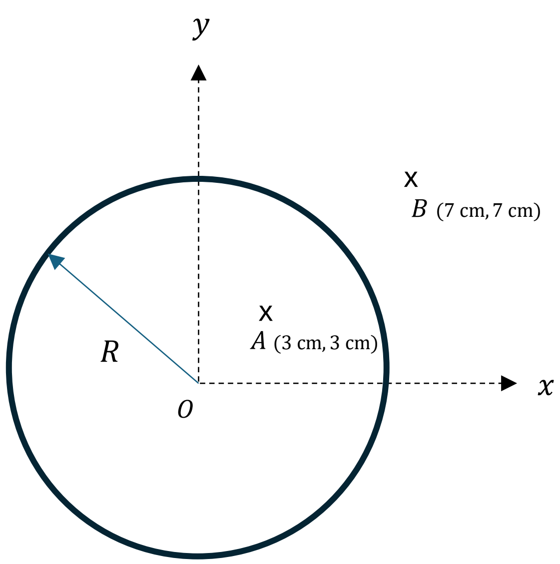
[4 points]

$$V_A = \frac{kQ}{R} = 9 \times 10^6\ \text{V}$$

$$r = \sqrt{0.07^2 + 0.07^2} \cong 10\ \text{cm}$$

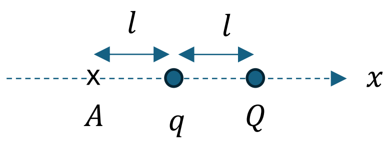
$$V_B = \frac{kQ}{r} = 4.5 \times 10^6\ \text{V}$$

$$V_A - V_B = 4.5 \times 10^6\ \text{V}$$



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. If the net electric field is equal to zero at point A, then Q must be



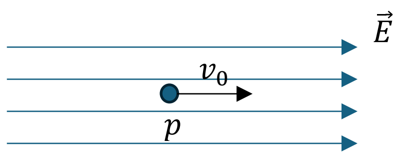
a) $2q$.

b) $4q$.

c) $-2q$.

d) $-4q$.

2. A particle is *slowing* down as it moves along the direction of the electric field. The charge of the particle is



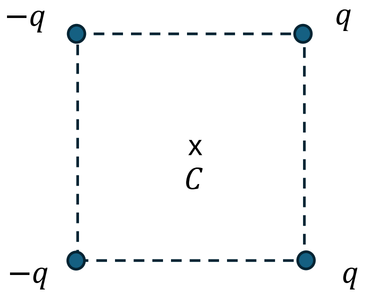
a) neutral.

b) positive.

c) negative.

d) undetermined.

3. Four charges are located at the vertices of a square. What is the direction of the electric field at point C (at the center of the square)?



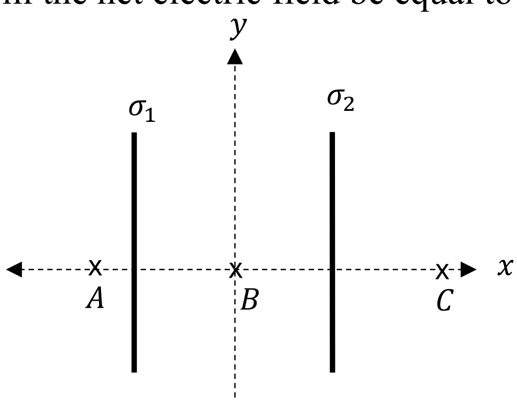
a) ←

b) ↑

c) →

d) ↓

4. Two uniformly charged infinite sheets σ_1 and σ_2 are placed perpendicular to the xy-plane, as shown. If $\sigma_1 = -\sigma_2$, at which point(s) will the net electric field be equal to zero?



a) A.

b) B.

c) B & C.

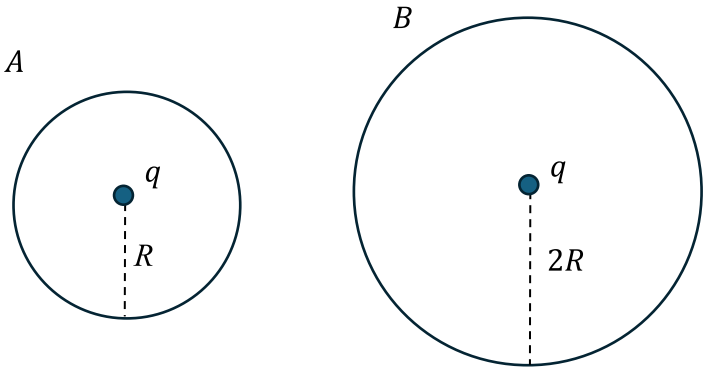
d) A & C.

5. The magnitude of the electric field inside a uniformly charged *non-conducting* sphere is

a) proportional to $1/r$.
b) proportional to $1/r^2$.
c) proportional to r.
d) constant.

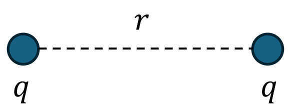
6. What is the electric flux through sphere A compared to sphere B?

a) $\Phi_A = \Phi_B$
b) $\Phi_A = 4\Phi_B$
c) $\Phi_A = \frac{1}{4}\Phi_B$
d) $\Phi_A = \frac{1}{8}\Phi_B$



7. If we decrease the distance between two identical positive charges, the work done by the electric field is

a) positive.
b) negative.
c) zero.
d) undetermined.



8. Initially, we have two charges that are equal in magnitude and have opposite signs, as shown below. By adding an extra charge Q at point O, the total energy of the system will

a) increase.
b) decrease.
c) remain the same.
d) depend on the sign of Q.