Kuwait University **Physics Department**

جامعة الكويت
KUWAIT UNIVERSITY

Physics 102
Midterm-1 Examination

Summer Semester 2026
June 30, 2026

Time: 6:30 p.m. – 8:00 p.m.

Name: …… Student ID No: ……

Section: …… Serial No.: ……

Instructors: Drs. Abdul Mohsen, Alaa, Elias, Peter, & Yahya.

Fundamental constants

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

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

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

$|e| = 1.60 \times 10^{-19}\ \text{C}$ (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)

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

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

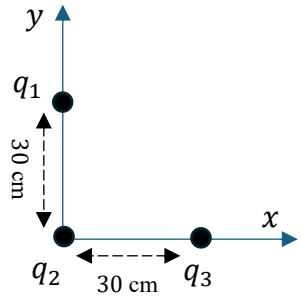
Ques.	1	2	3	4	5	6	Questions	Total
Marks								

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 $q_1 = 50\ \mu C$, $q_2 = -10\ \mu C$, and $q_3 = -30\ \mu C$ are placed on the *xy*-plane, as shown below. Calculate the net force vector $\vec{F}$ on q_3. **[4 points]**



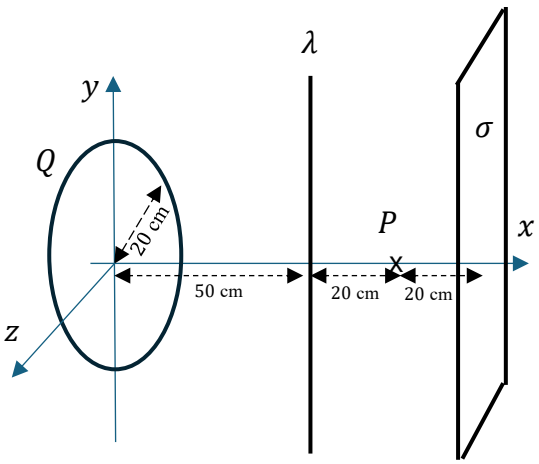
$$|\vec{F}_{13}| = \frac{k|q_1 q_3|}{(r_{13})^2} = \frac{9\times10^{-9}\times50\times10^{-6}\times30\times10^{-6}}{0.424^2}\,\text{N} = 75\ \text{N}$$

$$|\vec{F}_{23}| = \frac{k|q_2 q_3|}{(r_{23})^2} = \frac{9\times10^{-9}\times10\times10^{-6}\times30\times10^{-6}}{0.3^2}\,\text{N} = 30\ \text{N}$$

$$\vec{F}_{13} = -|\vec{F}_{13}|\cos(45)\ \hat{\imath} + |\vec{F}_{13}|sin(45)\hat{\jmath} = (-53\ \text{N}\ \hat{\imath} + 53\ \text{N}\ \hat{\jmath})$$

$$\vec{F}_{net} = \vec{F}_{13} + \vec{F}_{23} = (-23\ \text{N})\ \hat{\imath} + (53\ \text{N})\ \hat{\jmath}$$

2. A ring of radius $R = 20$ cm in the yz-plane is centred at the origin and carries a charge $Q = 20$ nC uniformly distributed along it. An infinitely long line parallel with the y-axis with uniform linear charge density $\lambda = 30\ \text{nC/m}$, and an infinite sheet in the yz-plane with uniform surface charge density σ are located, as shown below. If $\vec{E}_{net} = 0$ at point P, what is the value and sign of σ?
[5 points]



$$\vec{E}_{\lambda,P} = \frac{\lambda}{2\pi\epsilon_0 x_1} = \frac{30\times10^{-9}}{2\pi\epsilon_0 0.2}\,\text{N}\ \hat{\imath} = 2697\ \text{N}\ \hat{\imath}$$

$$\vec{E}_{Q,P} = \frac{kQx_2}{(x_2^2+a^2)^{3/2}} = \frac{9\times10^9\times20\times10^{-9}\times0.7}{(0.7^2+0.2^2)^{3/2}}\,\text{N}\ \hat{\imath} = 326\ \text{N}\ \hat{\imath}$$

$$\vec{E}_{net} = \vec{E}_{\lambda,P} + \vec{E}_{Q,P} + \vec{E}_{\sigma,P} = 0 \rightarrow \vec{E}_{\sigma,P} = -3023\ \text{N/C}\ \hat{\imath}$$

$$|\vec{E}_{\sigma,P}| = \frac{|\sigma|}{2\epsilon_0} = 3023\,\frac{\text{N}}{\text{C}} \rightarrow \sigma = +5.35\times10^{-8}\ \text{C/m}^2$$

3. A sphere of radius $a = 4$ cm has a uniform volume charge density $\rho_1 = 5\ \text{nC/m}^3$. 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 distance $r = 6$ cm from the centre. **[5 points]**

$$\Phi = \oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$$

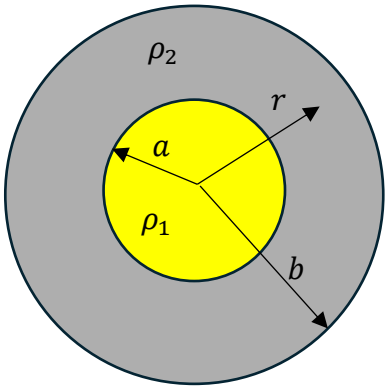
$$q_a = \rho_1 \left(\frac{4}{3}\pi a^3\right) = \mathbf{1.34 \times 10^{-12}\ C}$$

$$q_r = \rho_2 \left(\frac{4}{3}\pi (r^3 - a^3)\right) = \mathbf{-8.28 \times 10^{-12}\ C}$$

$$q_{enc} = q_a + q_r = \mathbf{-6.94 \times 10^{-12} C}$$

$$E = \frac{|q_{enc}|}{4\pi r^2 \epsilon_0} = \frac{|-6.94\times10^{-12} C|}{4\pi (0.06)^2 (8.85\times10^{-12})}\ \mathbf{N/C} = \mathbf{17.3\ N/C}$$

$$|\vec{E}| = \mathbf{17.3\ N/C},\ \textbf{direction: inward}$$

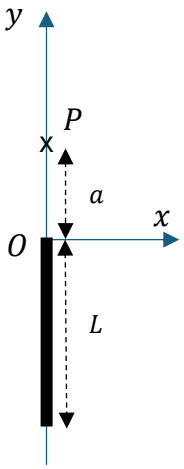


4. A line charge of length $L = 0.5$ m with charge $Q = -20$ μC distributed uniformly along its length, lies along the y-axis. Derive the electric field $\vec{E}$ at point P at distance $a = 0.20$ m from the origin. **[5 points]**

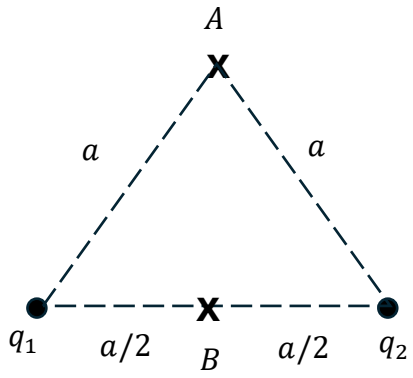
$$\lambda = \frac{Q}{L} = \mathbf{-40 \times 10^{-6}\ C/m}$$

$$\vec{E} = \int_a^{a+L} \frac{k\,|\lambda|\,dy}{y^2}(-\hat{j}) = \frac{k\,|\lambda|}{y}\Big|_a^{a+L}(\hat{j})$$

$$\vec{E} = \mathbf{(9 \times 10^9)(40 \times 10^{-6})}\left(\frac{1}{0.7} - \frac{1}{0.2}\right)\mathbf{N/C}\,\hat{j} = \mathbf{-1.29 \times 10^6\ N/C}\,\hat{j}$$



5. Two charges $q_1 = 4$ nC and $q_2 = -6$ nC are located, as shown. How much work is done by the electric field when a third charge $q_3 = -3$ nC moves from point *A* to point *B*? Given $a = 30$ cm. **[5 points]**

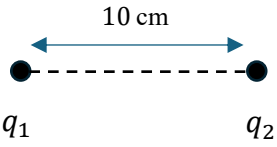


$$V_A = \frac{kq_1}{a} + \frac{kq_2}{a} = -60\ \text{V}$$

$$V_B = \frac{kq_1}{(a/2)} + \frac{kq_2}{(a/2)} = -120\ \text{V}$$

$$W_{field} = -q_3\Delta V = -q_3(V_B - V_A) = -180 \times 10^{-9}\ \text{J}$$

6. Two charged particles of $q_1 = q_2$, with masses $m_1 = 4 \times 10^{-6}$ kg and $m_2 = 6 \times 10^{-6}$ kg, are initially at rest at distance 10 cm apart. While charge q_1 remains rest, charge q_2 is released from rest and moves with speed $v = 800$ m/s when it is 30 cm away from q_1. Find the value of the charge q_1 and q_2. **[4 points]**



$$E_i = E_f \Rightarrow U_i = U_f + K_f$$

$$\frac{kq^2}{r_i} = \frac{kq^2}{r_f} + \frac{1}{2}m_2v_2^2$$

$$q^2 = \frac{1}{2}\frac{(6\times10^{-6})(800)^2}{9\times10^9(\frac{1}{0.1}-\frac{1}{0.3})} = 3.2 \times 10^{-11}\ \text{C}^2$$

$$q = q_1 = q_2 = 5.66 \times 10^{-6}\ \text{C}$$

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

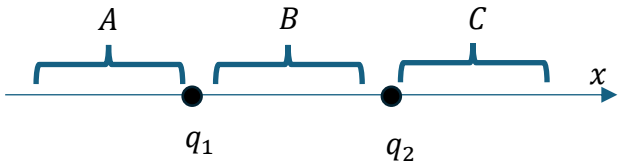
1. Two charges $q_1 = 2q_2$ are placed on the x-axis. The net electric field on the x-axis will be equal to zero in

a) region A.

b) region B, closer to q_1.

c) region B, closer to q_2. √

d) region C.



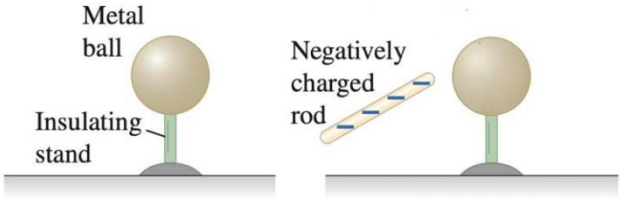
2. An uncharged metal ball is placed on an insulating stand. Then, a negatively charged rod is brought close to the ball. Which of the following statements is correct?

a) The ball is positively charged.

b) The ball is negatively charged.

c) The ball is still neutral. √

d) The rod is discharged.



3. Two positively charged particles of charges $q_1 > q_2$ and *identical* masses are released from rest. If $\vec{a}_1$ is the acceleration of q_1, and $\vec{a}_2$ is the acceleration of q_2, what is the magnitude and direction of the accelerations relative to each other?

a) $|\vec{a}_1| = |\vec{a}_2|$ and they show toward each other.

b) $|\vec{a}_1| > |\vec{a}_2|$ and they show toward each other.

c) $|\vec{a}_1| < |\vec{a}_2|$ and they show away from each other.

d) $|\vec{a}_1| = |\vec{a}_2|$ and they show away from each other. √

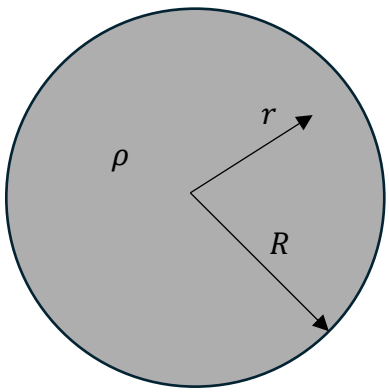
4. If r is the distance from the centre of a uniformly charged insulating sphere, the magnitude of the electric field inside the sphere is proportional to

a) r. √

b) r^2.

c) $1/r$.

d) $1/r^2$.



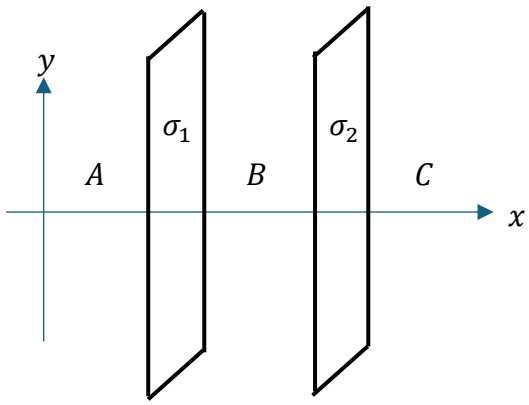
5. Two parallel infinite *sheets* of uniform surface charge density $\sigma_1 < 0$ and $\sigma_2 < 0$ are placed perpendicular to the xy-plane, as shown. If $|\sigma_1| > |\sigma_2|$, then the net electric field is

a) zero in region A.

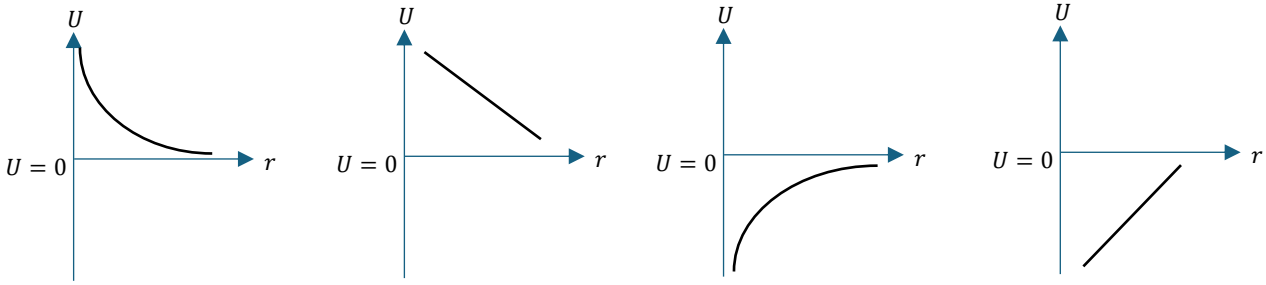
b) zero in region B.

c) zero in region C.

d) nowhere zero. √



6. Which plot shows the relationship between the potential energy U and the distance r between two opposite charges?



a) b) c) √ d)

7) If an electron is travelling in the opposite direction of a uniform electric field,

a) the *potential energy* increases and the *electric potential* increases.

b) the *potential energy* decreases and the *electric potential* decreases.

c) the *potential energy* increases and the *electric potential* decreases.

d) the *potential energy* decreases and the *electric potential* increases. √

8. Two negative charges q_1 and q_2 are placed on the x-axis, as shown. If we add a third negative charge q_3 between q_1 and q_2, the electric potential energy of the system will

a) increase. √

b) decrease.

c) stay the same.

d) undetermined.