Kuwait University

Physics Department

General Physics II

PHY 102

جامعة الكويت
KUWAIT UNIVERSITY

First Midterm Examination
Summer Semester 2023 – 2024

June 29, 2024
Time: 2:30 – 4:00 PM

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

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

Instructors: Drs. Alfailakawi, Lajko, and Vagenas

<u>Fundamental constants</u>

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

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

For use by Instructors only

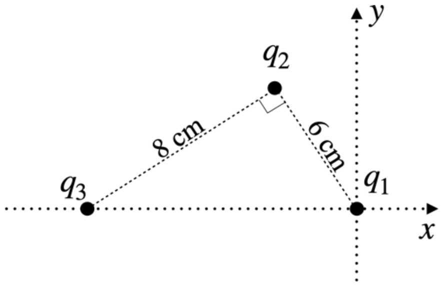
Problems	1	2	3	4	5	6	7	8	**Questions**	**Total**
Marks										

Instructions to the Students:

1. Mobile 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 detail.

1. Three point charges $q_1 = 20$ nC, $q_2 = -15$ nC, and $q_3 = 10$ nC are placed on the *xy*-plane, as shown in the figure. Find the net electric force $\vec{F}_3$ acting on q_3. **[4 points]**



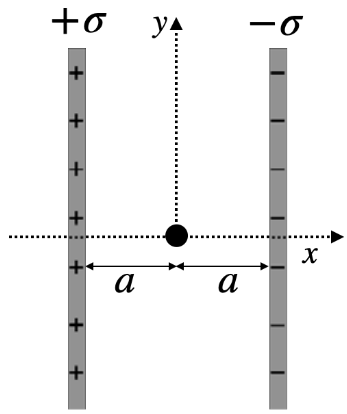
$r_{13} = 10$ cm

$\overrightarrow{F_1} = \frac{kq_1q_3}{r_{13}^2}(-\hat{\imath}) = 1.8 \times 10^{-4}$ N$(-\hat{\imath})$

$\overrightarrow{F_2} = \frac{kq_2q_3}{r_{23}^2}\left(0.8(+\hat{\imath}) + 0.6(+\hat{\jmath})\right) = 1.69 \times 10^{-4}$ N$(+\hat{\imath})$ + 1.27×10^{-4} N$(+\hat{\jmath})$

$\overrightarrow{F_3} = \overrightarrow{F_1} + \overrightarrow{F_2} = 1.1 \times 10^{-5}$ N$(-\hat{\imath}) + 1.27 \times 10^{-4}$ N$(+\hat{\jmath})$

2. A proton is released from rest at the origin between two oppositely charged parallel plates with uniform surface charge density $+\sigma = +17.7\ \text{nC/m}^2$ and $-\sigma = -17.7\ \text{nC/m}^2$. Calculate the kinetic energy that the proton acquires when it reaches the plate. Take *a* = 10 cm. **[4 points]**



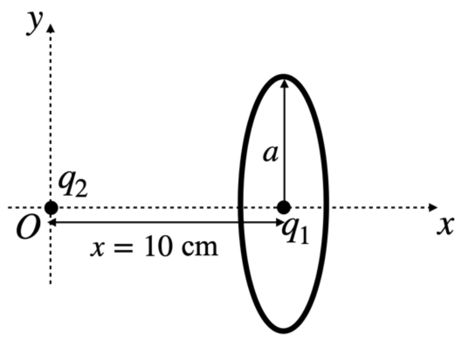
$\vec{E} = \frac{\sigma}{\varepsilon_0} = 2000$ N/C$(+\hat{\imath})$

$F = qE = ma \Rightarrow a = \frac{qE}{m} = 1.92 \times 10^{11}\text{m/s}^2$

$v_x^2 = v_{0x}^2 + 2a\Delta x \Rightarrow v_x = 1.96 \times 10^5$ m/s

$K = \frac{1}{2}mv_x^2 = 3.2 \times 10^{-17}$J

3. A positive charge $Q = 5$ nC is distributed uniformly over a ring of radius $a = 5$ cm. A point charge $q_1 = -10$ nC is placed at the center of that ring as shown in the figure. Calculate the net electric force $\vec{F}_2$ acting on charge $q_2 = +5$ nC placed at the origin O. **[4 points]**



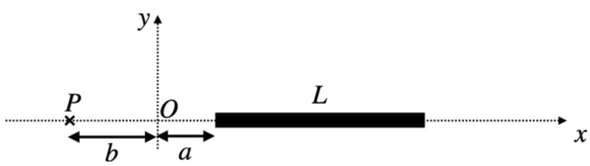
$\vec{E}_{point} = \frac{k|q_1|}{r^2}\,(+\hat{\imath}) = 9000\,\frac{\text{N}}{\text{C}}\,(+\hat{\imath})$

$\vec{E}_{ring} = \frac{kQx}{(a^2+x^2)^{3/2}}\,(-\hat{\imath}) = 3219.94\,\frac{\text{N}}{\text{C}}\,(-\hat{\imath})$

$\vec{E}_{net} = \vec{E}_{point} + \vec{E}_{ring} = 5780\,\frac{\text{N}}{\text{C}}\,(+\hat{\imath})$

$\vec{F}_{q_2} = q_2\vec{E}_{net} = 2.89 \times 10^{-5}\ \text{N}\,(+\hat{\imath})$

4. A charge $Q = 30\ \mu$C is uniformly distributed along a rod of length $L = 1.0$ m on the x-axis, as shown. Calculate the electric field at point P. Take $a = 10$ cm, $b = 20$ cm. **[4 points]**



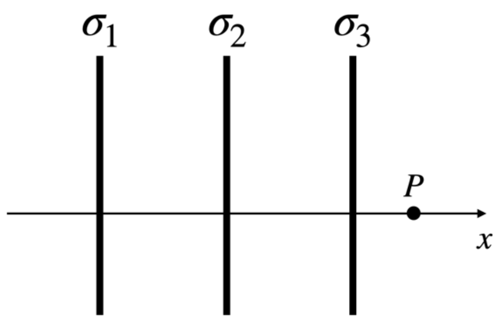
$\lambda = \frac{Q}{L}$

$d\vec{E} = \frac{kdQ}{r^2}(-\hat{\imath}) = \frac{k\lambda dx}{(x+b)^2}(-\hat{\imath})$

$\vec{E} = \int_a^{a+L} \frac{k\lambda dx}{(x+b)^2}(-\hat{\imath}) = k\lambda\left[\frac{1}{x+b}\right]_a^{a+L}(-\hat{\imath})$

$\vec{E} = 6.92 \times 10^5\ \text{N/C}(-\hat{\imath})$

5. Three large sheets carry uniform surface charge densities $\sigma_1 = +1.77\ \mathrm{C/m^2}$, $\sigma_2 = +0.885\ \mathrm{C/m^2}$, and $\sigma_3 = -3.54\ \mathrm{C/m^2}$. Find the net electric field $\vec{E}$ at point *P*. **[4 points]**

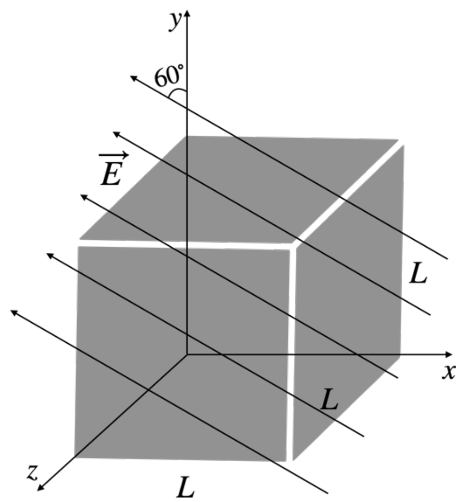


$$\vec{E}_p = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$$

$$\vec{E}_p = \frac{\sigma_1}{2\varepsilon_0}(+\hat{\imath}) + \frac{\sigma_2}{2\varepsilon_0}(+\hat{\imath}) + \frac{\sigma_3}{2\varepsilon_0}(+\hat{\imath})$$

$$\vec{E}_p = -\,5 \times 10^{10}\mathrm{N/C}\ (+\hat{\imath})$$

6. A cube of sides *L* = 10 cm as shown in the figure, is placed in a space with a uniform electric field. The magnitude of the electric field is $3 \times 10^3\mathrm{N/C}$ and it is parallel to *xy*-plane at an angle of 60° from the y-axis. What is the electric flux though each of the faces (left, right, top, bottom, front and back) of the cube? **[4 points]**



$$\Phi_E = \vec{E} \cdot \vec{A} = EA\cos\phi$$

$$\Phi_{front+back} = E\,L^2\cos 90° = 0$$

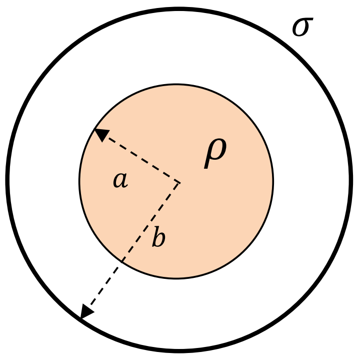
$$\Phi_{left} = E\,L^2\cos 30° = +25.98\ \frac{Nm^2}{C}$$

$$\Phi_{right} = E\,L^2\cos 150° = -25.98\ \frac{Nm^2}{C}$$

$$\Phi_{top} = E\,L^2\cos 60° = +15\ \frac{Nm^2}{C}$$

$$\Phi_{bottom} = E\,L^2\cos 120° = -15\ \frac{Nm^2}{C}$$

7. A non-conducting sphere has radius a =25 cm and it is concentric with a spherical surface of radius b = 40 cm. The sphere has a uniform volume charge density $\rho = 100\ \mathrm{nC/m^3}$ and outer spherical surface has a uniform surface charge density σ. At a distance 50 cm from the center, the magnitude of the electric field is 50 N/C and it points towards the center. Find the value of σ. **[4 points]**

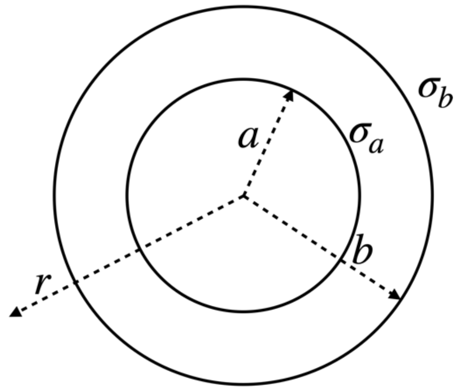


$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{enc.}}{\varepsilon_0}$$

$$E\ 4\pi r^2 = \frac{\rho \frac{4}{3}\pi a^3 + \sigma\ 4\pi b^2}{\varepsilon_0}$$

$$\sigma = -3.95 \times 10^{-9}\ \mathrm{C/m^2}$$

8. Two concentric spherical surfaces have radii a = 5 cm and b = 8 cm, and uniform surface charge densities $\sigma_a = +7\ \mathrm{nC/m^2}$, and $\sigma_b = -10\ \mathrm{nC/m^2}$, respectively. Find the magnitude and direction (inward or outward) of the electric field at a distance r = 10 cm from the center. **[4 points]**



$$\oint \vec{E} \cdot d\vec{A} = \frac{Q_{enc.}}{\varepsilon_0}$$

$$E\ 4\pi r^2 = \frac{\sigma_a(4\pi a^2) + \sigma_b(4\pi b^2)}{\varepsilon_0}$$

$$Q_{enc.} = \sigma_a(4\pi a^2) + \sigma_b(4\pi b^2) = -0.584\ \mathrm{nC}$$

$$E = 525.4\ \mathrm{N/C}$$

$\vec{E}$ is inward.

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

1. The electric field at a point in space is the measure of

   a) the electric force per unit charge at that point.

   b) the electric force on any charge at that point.

   c) the electric force per unit mass at that point.

   d) the total charge at that point.

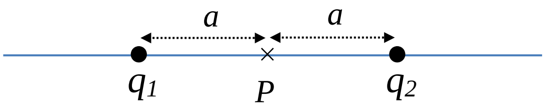
2. If two point charges q_1 and q_2 are fixed on the x-axis at a distance $2a$ the net electric field is zero at point P. Which statement is correct for the charges?

   a) $q_1 + q_2 = 0$.

   b) $q_1 > q_2 > 0$.

   c) $q_1 = q_2$.

   d) $q_1 > |q_2|$.



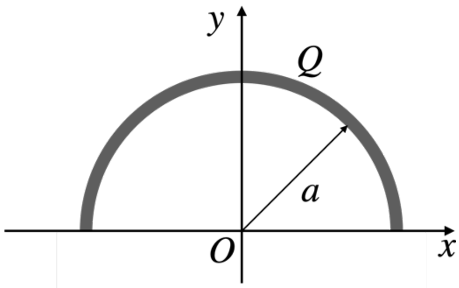
3. A positive charge is uniformly distributed around a semicircle. The electric field produced at the origin is in

   a) the +*x*-direction.

   b) the –*x*-direction.

   c) the +*y*-direction.

   d) the –*y*-direction.



4. Which statement is true about electric field lines?

   a) Electric field lines are always straight.

   b) Electric field lines do not intersect with each other.

   c) Electric field lines are always parallel to each other.

   d) Electric field lines are always perpendicular to each other.

5. A charge Q is uniformly distributed through a cube of side L. The volume charge density of the cube is:

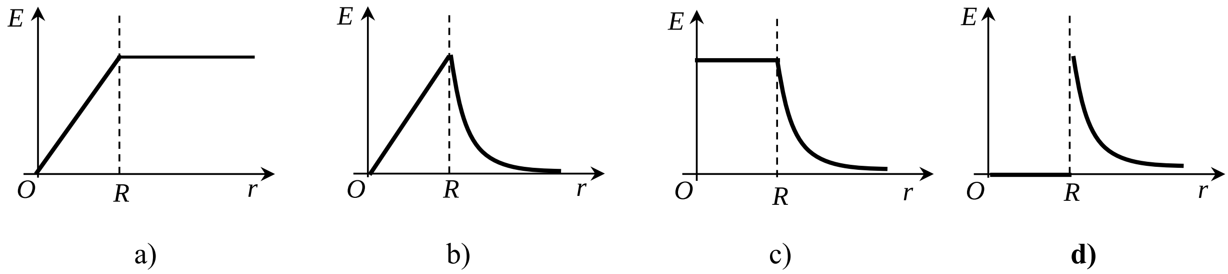
   a) $\rho = \frac{Q}{L^2}$.

   b) $\boldsymbol{\rho = \frac{Q}{L^3}}$.

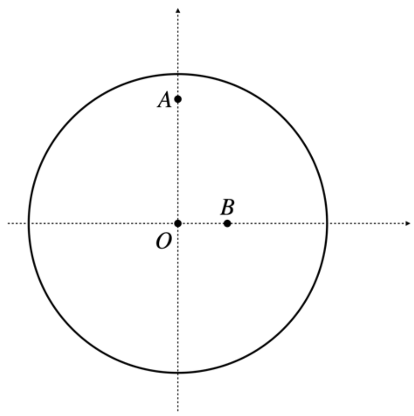
   c) $\rho = \frac{Q}{6L^2}$.

   d) $\rho = \frac{Q}{(2L)^3}$.

6. Which of the following figures shows the electric field magnitude E as a function of the distance r for a uniformly charged conducting sphere of radius R?



7. The figure shows a spherical conductor with total charge Q. Which relation is correct for the magnitude of electric field at points A and B?



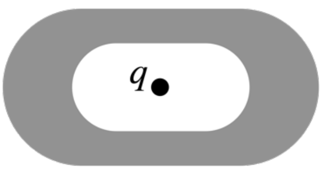
   a) $E_A > E_B$.

   b) $E_A < E_B$.

   c) $E_A + E_B > 0$.

   d) $\boldsymbol{E_A = E_B}$.

8. A conductor has a net charge of 20 nC and a point charge q = +5 nC is placed in its cavity, as shown in the figure. The charge on the outer surface of the conductor is:



   a) 25 nC.

   b) 15 nC.

   c) 10 nC.

   d) 5 nC.