Kuwait University **Physics Department**

جامعة الكويت
KUWAIT UNIVERSITY

Physics 102
Midterm 1 Examination

Fall Semester 2023
October 28, 2023

Time: 12:00 – 1:30 p.m.

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

Instructors: Drs. Alfailakawi, Hadipour, Lajko, Sharma, & Vagenas

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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 ·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}	μ = 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

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

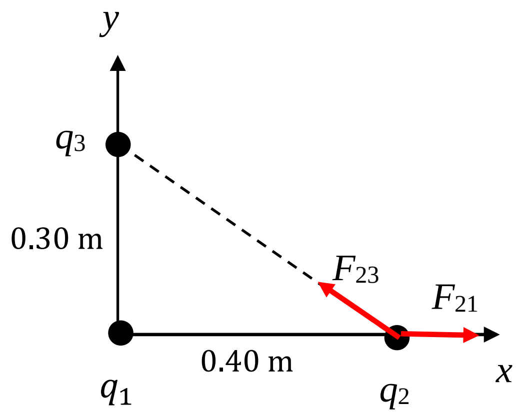
Ques.	1	2	3	4	5	6	7	8	Total
Marks									

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.**

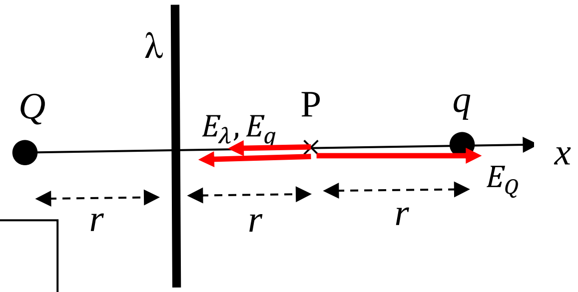
PART I. Solve the following problems. Show your solutions in detail.

1. Three charges $q_1 = -4.0$ μC, $q_2 = -5.0$ μC and $q_3 = 6.0$ μC are placed as shown. What is the magnitude and direction of the net force on q_2? **[5 points]**



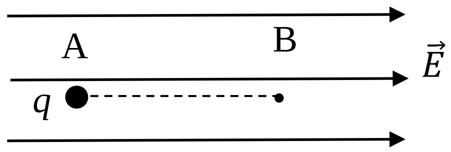
$$F_{21} = k\frac{|q_2||q_1|}{r_{21}^2} = \frac{9\times10^9\times5.0\times10^{-6}\times4.0\times10^{-6}}{(0.40)^2} = 1.13 \text{ N}$$
$$F_{23} = k\frac{|q_2||q_3|}{r_{23}^2} = \frac{9\times10^9\times5.0\times10^{-6}\times6.0\times10^{-6}}{(0.50)^2} = 1.08 \text{ N}$$
$$F_x = F_{12} - F_{23}\cos\theta = 1.13 - 1.08\times\frac{0.40}{0.50} = 0.27 \text{ N}$$
$$F_y = F_{23}\sin\theta = 1.08\times\frac{0.30}{0.50} = 0.65 \text{ N}$$
$$F = \sqrt{F_x^2 + F_y^2} = 0.70 \text{ N}$$
$$\phi = \tan^{-1}\frac{F_y}{F_x} = 67.4°$$

2. A uniformly charged infinite line with $\lambda = -2.40$ nC/m is perpendicular to the x-axis as shown. Charges q and Q are located as shown. If $q = 0.12$ nC, what should be the magnitude and sign of Q, so that the net electric field at point P is zero? Given, $r = 1.8$ cm. **[4 points]**



$$E_\lambda = \frac{2k|\lambda|}{r} = \frac{2\times9\times10^9\times2.40\times10^{-9}}{0.018} = 2400 \text{ N/C}$$
$$E_q = k\frac{q}{r^2} = \frac{9\times10^9\times0.12\times10^{-9}}{(0.018)^2} = 3333 \text{ N/C}$$
$$E_Q - E_\lambda - E_q = 0$$
$$E_Q = E_\lambda + E_q = k\frac{Q}{(2r)^2} = 5733 \text{ N/C}$$
$$Q = 0.83 \text{ nC}$$

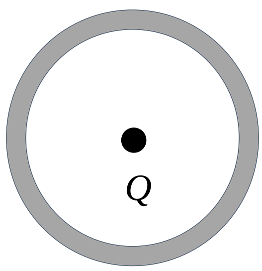
3. A point charge q with mass $m = 5.2 \times 10^{-6}$ kg enters at point A with velocity $\vec{v}_0 = 50.0\,\hat{\imath}$ m/s in the region of a uniform electric field $\vec{E} = 6.3 \times 10^3\,\hat{\imath}$ N/C. The particle stops momentarily at point B which is 10.0 cm from A. What is the magnitude and sign of the charge q? **[3 points]**



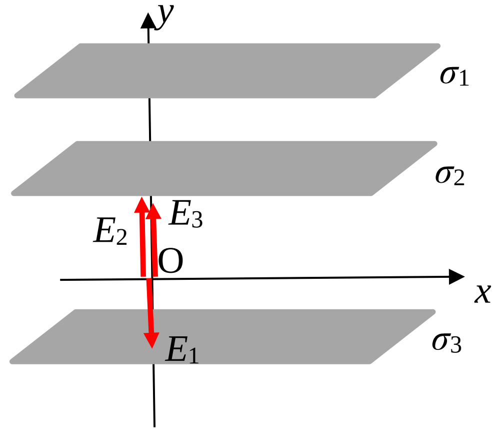
$$v^2 = v_0^2 + 2a\Delta x \rightarrow 0 = (50.0)^2 + 2a \times 0.10$$
$$a = -1.25 \times 10^4 \text{ m/s}^2$$
$$\vec{F} = q\vec{E} = m\vec{a}$$
$$q \times 6.3 \times 10^3\,\hat{\imath} = 5.2 \times 10^{-6} \times -1.25 \times 10^4\hat{\imath}$$
$$q = -\frac{5.2\times10^{-6}\times-1.25\times10^4}{6.3\times10^3} = -10.3\ \mu\text{C}$$

4. A conducting spherical shell of outer radius R = 20.0 cm has a surface charge density $\sigma = 4.3$ μC/m². When a charge $Q = -2.5$ μC is brought to the centre of the shell, what is the magnitude and direction of the electric field at a point 25.0 cm from the centre of the shell? **[4 points]**

$$\oint \vec{E}.d\vec{A} = \frac{q_{encl}}{\varepsilon_0}$$
$$E.4\pi r^2 = \frac{(Q+4\pi R^2.\sigma)}{\varepsilon_0}$$
$$E = k\frac{(Q + 4\pi R^2.\sigma)}{r^2}$$
$$= \frac{9\times10^9\times(-2.5\times10^{-6}+4\pi(0.20)^2\times4.3\times10^{-6})}{(0.25)^2}$$
$$= -4.9 \times 10^4 \text{ N/C}$$
directed radially inwards.



5. Three uniformly charged large sheets with surface charge densities $\sigma_1 = +9.7\ \text{nC/m}^2$, $\sigma_2 = -\,13.7\ \text{nC/m}^2$ and $\sigma_3 = +15.7\ \text{nC/m}^2$ are perpendicular to the y-axis, as shown below. Find the net electric field $\vec{E}$ at the point O. **[4 Points]**



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

$$\vec{E} = 548.0(-\hat{\jmath}) + 774.0(\hat{\jmath}) + 887.0(+\hat{\jmath})$$

$$\vec{E} = 1113(+\hat{\jmath})\ \text{N/C}$$

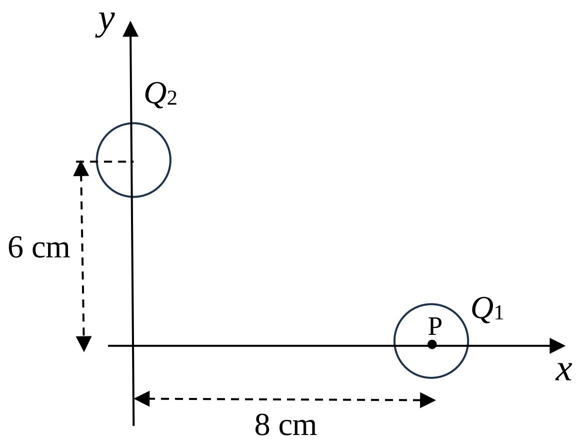
6. Two identical conducting spheres with charges $Q_1 = Q_2 = 20.0\ \text{nC}$ and radii $R_1 = R_2 = 1.0\ \text{cm}$ are placed on the xy plane, as shown in the figure. Calculate the net electric potential at point P located at center of the first sphere. Assume that the potential is zero at infinity. **[4 points]**

$$d = \sqrt{(0.06)^2 + (0.080)^2} = 0.100\ \text{m}$$

$$V_1 = k\frac{Q_1}{R_1} \Longrightarrow V_1 = 18000\ \text{V}$$

$$V_2 = k\frac{Q_2}{d} \Longrightarrow V_2 = 1800\ \text{V}$$

$$V_P = V_1 + V_2 = 19800\ \text{V}$$

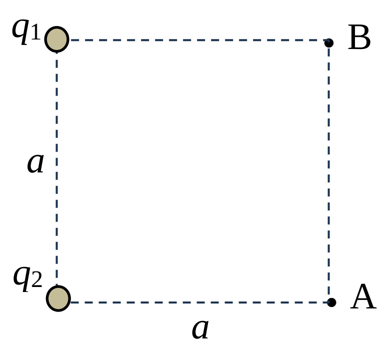


7. Two point charges, $q_1 = +25.0$ nC and $q_2 = -25.0$ nC, have identical masses $m = 3.0 \times 10^{-7}$ kg. They are released from rest when they were 100.0 cm apart. Find their speed when they are 50.0 cm from each other. **[4 Points]**

$$K_f - K_i = -(U_f - U_i)$$
$$2\left(\frac{1}{2}mv^2\right) - 0 = \frac{kq_1q_2}{r_1} - \frac{kq_1q_2}{r_2}$$
$$mv^2 = \frac{kq_1q_2}{1.0} - \frac{kq_1q_2}{0.50}$$
$$= -5.63 \times 10^{-6} + 1.13 \times 10^{-5}$$
$$= 5.63 \times 10^{-6}$$
$$v = 4.33 \text{ m/s}$$

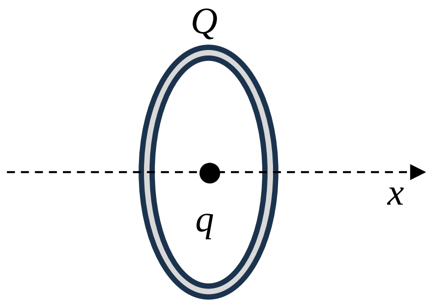
8. In the figure, two point charges $q_1 = +6.0$ nC, $q_2 = +3.0$ nC are placed at the corners of a square of side a = 5.0 cm, as shown. Calculate the work done to move a third charge $q_3 = +4.0$ nC from point A to point B. **[4 Points]**

$$W = \Delta U = q\Delta V$$
$$V_A = \frac{kq_1}{\sqrt{2}a} + \frac{kq_2}{a}$$
$$= 763.7 + 540.0 = 1303.7 \text{ V}$$
$$V_B = \frac{kq_1}{a} + \frac{kq_2}{\sqrt{2}a}$$
$$= 1080.0 + 381.8 = 1461.8 \text{ V}$$
$$W = 6.3 \times 10^{-7} \text{J}$$



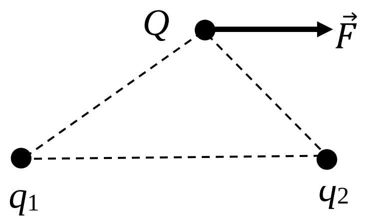
PART II : Conceptual Questions (each carries 1 point). Tick the best answer.

1. A uniformly charged ring of radius R has a charge Q. A charge q is placed at the centre of the ring. The force experienced by the charge q is:



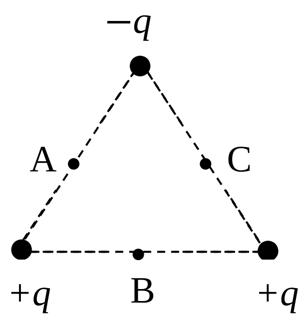
a) $F = k\frac{qQ}{R^2}$.
b) $F = 0$. (ans)
c) $F = k\frac{qQ}{(2R)^2}$.
d) None of the above.

2. Three point charges are placed at the vertices of a triangle as shown. The net force on the positive charge Q is $\vec{F}$, as shown. The charges q_1 and q_2 must be:



a) $q_1 > 0,\ q_2 > 0$.
b) $q_1 < 0,\ q_2 > 0$.
c) $q_1 > 0,\ q_2 < 0$. (ans)
d) $q_1 < 0,\ q_2 < 0$.

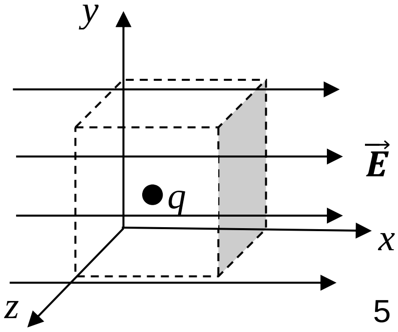
3. Three point charges are located at the vertices of an equilateral triangle, as shown. Points A, B and C are the midpoints of the sides. At which midpoint is the magnitude of the net electric field the smallest?



a) A
b) B (ans)
c) C
d) All have the same magnitude.

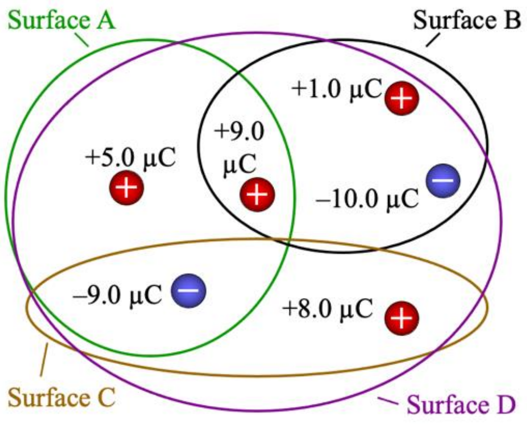
4. A cube of side L with a charge q at its centre is inside a uniform electric field $\vec{E}$ that is directed along the x-axis, as shown. What is the total electric flux through the cube?

a) $EL^2 + q/\varepsilon_0$
b) $2EL^2$
c) 0
d) q/ε_0 (ans)



5. The figure shows six point charges. Four Gaussian surfaces each enclose part of this plane. Which Gaussian surface has zero electric flux?

a) Surface A
b) **Surface B (ans)**
c) Surface C
d) Surface D



6. The electric charge on a charged conductor is

a) uniformly distributed throughout the volume.
b) distributed entirely on the outer surface. (ans)
c) distributed throughout the volume depending upon the shape of the conductor.
d) confined to the center of the conductor.

7. A point charge $+q$ is released from rest in a region where $\vec{E} \neq 0$. There is no other force acting on the charge. As the charge moves in this region, its electric potential energy

a) remains the same.
b) increases.
c) decreases. (ans)
d) will decrease then after some time will increase.

8. Where an electric field line crosses an equipotential surface, the angle between the electric field line and the equipotential surface is

a. 0°.
b. between 0°and 90°.
c. 90° . (ans)
d. between 90°and 180°.