Kuwait University Physics Department

Physics 102
First Midterm Exam

Fall Semester 2022/23
October 29, 2022

Time: 12:00 – 1:30 p.m.

Name……………………………………. Student No.……………….

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

Instructors: Drs. Afrousheh, Al-Failakawi, Farhan, Lajko, & 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)

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

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

$|e| = 1.60 \times 10^{-19}$ 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

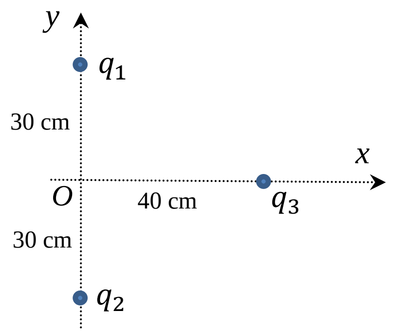
Prob.	1	2	3	4	5	6	7	8	Total
Marks									

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 point charges $q_1 = -4\ \mu C,\ q_2 = q_3 = 4\ \mu C$ are placed on the *xy*-plane, as shown. Calculate the *x* and *y* components of the net electric force $\vec{F}_3$ acting on q_3. **[4 points]**

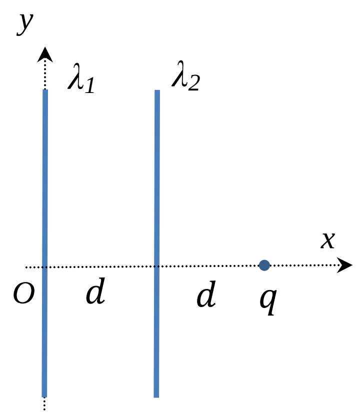


$$r_{13} = \sqrt{(0.3m)^2 + (0.4m)^2} = 0.5\ m \qquad [1]$$

$$F_{3,x} = F_{13,x} + F_{23,x} = -k\frac{|q_1 q_3|}{r_{12}^2}\cos(\theta) + k\frac{|q_2 q_3|}{r_{23}^2}\cos(\theta) = 0 \qquad [1]$$

$$F_{3,y} = F_{13,y} + F_{23,y} = 2k\frac{|q_1 q_3|}{r_{13}^2}\sin(\theta) = 2k\frac{|q_1 q_3|}{r_{13}^2}\frac{3}{5} = 0.69N; \qquad [2]$$

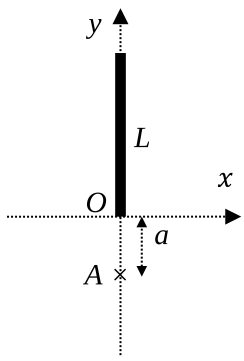
2. Two infinitely long linear uniform charge densities $\lambda_1 = -8$ nC/m, $\lambda_2 = 2$ nC/m are fixed on the *xy*-plane and a point charge $q = 2\mu C$ of mass $m = 0.1$ g is released on the x-axis, as shown. If $d = 0.2$ m, calculate the initial acceleration vector of charge q. **[4 points]**



$$\vec{E}_{net} = \vec{E}_1 + \vec{E}_2 = \frac{\lambda_1}{2\pi\varepsilon_0 2d}\hat{\imath} + \frac{\lambda_2}{2\pi\varepsilon_0 d}\hat{\imath} = 180\ \frac{\text{N}}{\text{C}}(-\hat{\imath}) \qquad [2]$$

$$\vec{F}_{net} = q\vec{E}_{net} \Rightarrow \vec{a} = \frac{\vec{F}_{net}}{m} = 3.6\ \frac{m}{s^2}(-\hat{\imath}) \qquad [2]$$

3. Charge $Q = -60$ nC is uniformly distributed along a rod of length $L = 2.0$ m fixed on the y-axis, as shown. Calculate the electric field vector $\vec{E}_A$ at point A. Given $a = 0.2$ m. **[5 points]**



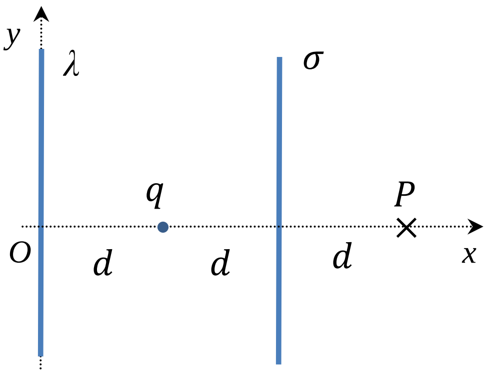
$d\vec{E}_A = \frac{kdQ}{r^2}(-\hat{j}) = \frac{k\lambda dy}{(y+a)^2}(-\hat{j})$; $\lambda = \frac{dQ}{dL} = \frac{Q}{L}$ [2]

$\vec{E}_A = \int_{source} d\vec{E}_A = -\int_0^L \frac{k\lambda dy}{(y+a)^2}\hat{j} = -k\lambda\left[-\frac{1}{y+a}\right]_0^L \hat{j} =$ [2]

$\vec{E}_A = 1227\ \frac{\text{N}}{\text{C}}\ \hat{j}$ [1]

4. An infinitely long linear uniform charge density $\lambda = 4$ nC/m and an infinitely large surface charge density σ are perpendicular to the x-axis, as shown. A point charge $q = -8$ nC is also placed on the x-axis. If the net electric field at point P is zero and $d = 0.2$ m, calculate the magnitude and sign of σ.

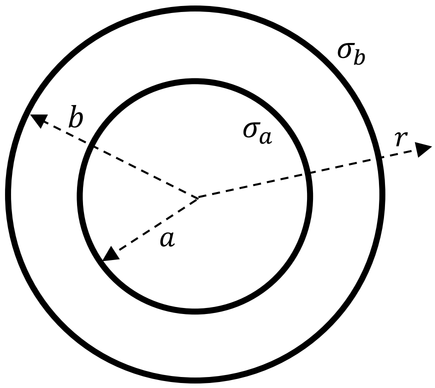
[4 points]



$\vec{E}_P = \vec{E}_\lambda + \vec{E}_q + \vec{E}_\sigma = 0 \Rightarrow \vec{E}_\sigma = -\vec{E}_\lambda - \vec{E}_q$ [1]

$\frac{\sigma}{2\varepsilon_0}\hat{\imath} = -\frac{\lambda}{2\pi\varepsilon_0 3d}\hat{\imath} - k\frac{q}{(2d)^2}\hat{\imath} \Rightarrow \sigma = 5.84\ \text{nC/m}^2$ [3]

5. Two concentric thin spherical surfaces have radii $a = 3$ cm and $b = 6$ cm and uniform surface charge densities $\sigma_a = 20$ nC/m^2, and $\sigma_b = -20$ nC/m^2.What is the magnitude and direction of the electric field at a radial distance of 8 cm from the center? **[4 points]**

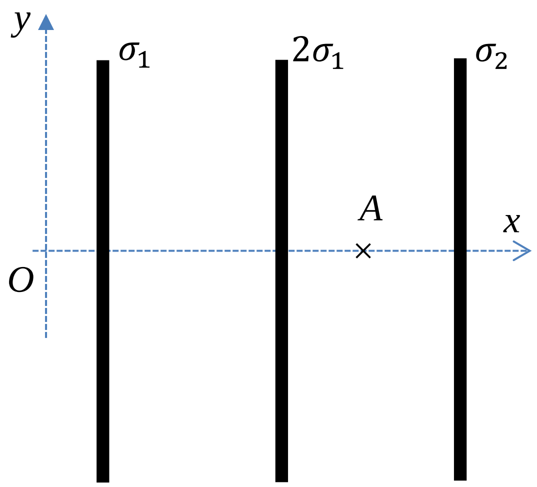


$$\oint \vec{E} \cdot \overrightarrow{dA} = \frac{Q_{encl}}{\varepsilon_0}$$

$$E_{0.08m} 4\pi (0.08m)^2 = \frac{\sigma_a 4\pi a^2 + \sigma_b 4\pi b^2}{\varepsilon_0}$$ [2]

$$E_{0.08m} = \frac{\sigma_a 4\pi a^2 + \sigma_b 4\pi b^2}{\varepsilon_0 4\pi (0.08m)^2} = 953 \frac{\text{N}}{\text{C}},\ inward$$ [2]

6. Three uniformly charged large sheets perpendicular to the x-axis have surface charge densities σ_1, $2\sigma_1$, and σ_2, as shown. If $\sigma_1 = 35.4$ nC/m^2 and the net electric field vector at point O is $\vec{E}_O = 0$, calculate the net electric field $\vec{E}_A$ at point A. **[4 points]**

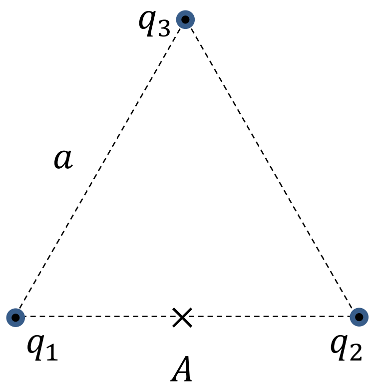


$$\vec{E}_O = \frac{\sigma_1}{2\varepsilon_0}(-\hat{\imath}) + \frac{2\sigma_1}{2\varepsilon_0}(-\hat{\imath}) + \frac{\sigma_2}{2\varepsilon_0}(-\hat{\imath}) = 0 \Rightarrow$$ [1]

$$\sigma_2 = -3\sigma_1 = -106.2 \text{ C/m}^2$$ [1]

$$\vec{E}_A = \frac{\sigma_1}{2\varepsilon_0}(\hat{\imath}) + \frac{2\sigma_1}{2\varepsilon_0}(\hat{\imath}) + \frac{\sigma_2}{2\varepsilon_0}(-\hat{\imath}) = 1.2 \times 10^4 \frac{\text{N}}{\text{C}}\ \hat{\imath}$$ [2]

7. Three small charges are $q_1 = q_2 = 4\ \mu C,\ q_3 = -4\ \mu C$ are fixed at vertices of an equilateral triangle of side length $a = 0.6$ m. If point charge q_3 of mass $m_3 = 3$ g is released from rest, what will be its speed at point A? **[3 points]**



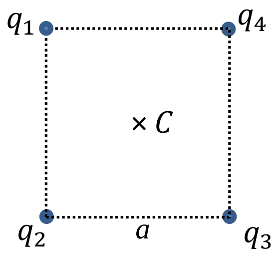
The mechanical energy conservation:

$$E_{in} = E_{fin} \Rightarrow U_{in}(q_3) = U_{fin}(q_3) + K_{fin}(q_3) \quad [1]$$

$$2k\frac{q_1q_3}{a} = 2k\frac{q_1q_3}{\frac{a}{2}} + \frac{mv^2}{2} \Rightarrow -2k\frac{q_1q_3}{a} = \frac{mv^2}{2} \quad [1]$$

$$v = \sqrt{\frac{-4kq_1q_3}{ma}} = 17.9 \text{ m/s} \quad [1]$$

8. Four point charges $q_1 = q_2 = 2\ \mu C,\ q_3 = -4\ \mu C,$ and $q_4 = 2\ \mu C$ are fixed at the vertices of a square of side length $a = 0.5$ m, as shown. If q_4 is moved from its original position to the center point C, calculate the work done by the electric field. **[4 points]**



$$W_E = -\Delta U$$

$$U_{in}(q_4) = k\frac{q_1q_4}{a} + k\frac{q_2q_4}{a\sqrt{2}} + k\frac{q_3q_4}{a} = -0.021 \text{ J} \quad [2]$$

$$U_{fin}(q_4) = 0 \quad [1]$$

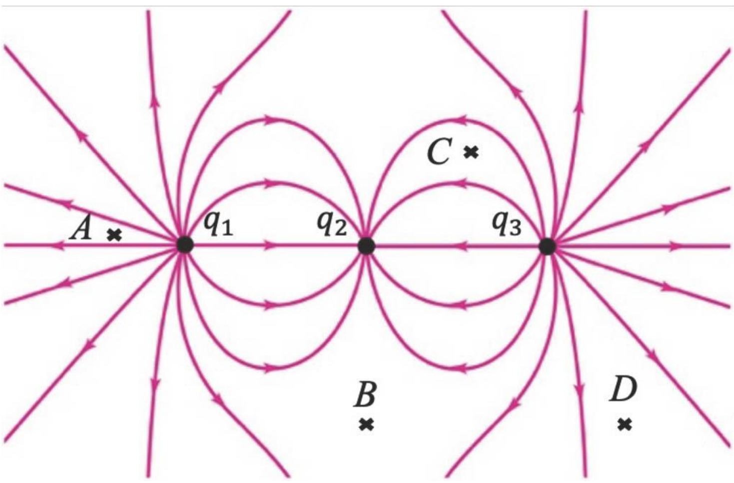
$$W_E = -\Delta U = -0.021 \text{ J} \quad [1]$$

Part II. Multiple choice questions (each carries 1 point). Tick the best answer:

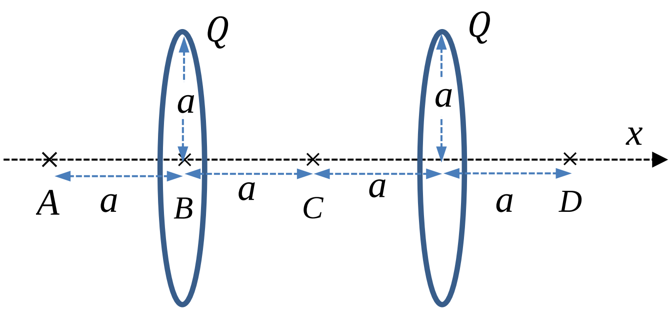
1. When two point charges q_1 and q_2 are at distance r the electric force acting on q_2 is $\vec{F}$. If the sign of one of the charges is changed then the force on q_2 is
   a) $\vec{F}$.
   b) $2\vec{F}$.
   c) $-2\vec{F}$.
   d) $-\vec{F}$. √

2. If an electron and a proton are moving in the same uniform electric field, which statement is correct for the magnitude of their acceleration?
   a) They have equal magnitude of acceleration.
   b) They have different magnitude of acceleration. √
   c) At small speeds the electron has smaller magnitude acceleration.
   d) Both accelerations are zero.

3. The figure shows the electric field lines due to three point charges $q_1, q_2,$ and q_3. Which point has the strongest electric field?
   a) Point *A*. √
   b) Point *B*.
   c) Point *C*.
   d) Point *D*.



4. Two charged rings with identical charges Q and radii a are placed along the x-axis as shown. At which point is the magnitude of electric field smallest?
   a) A.
   b) B.
   c) C. √
   d) D.



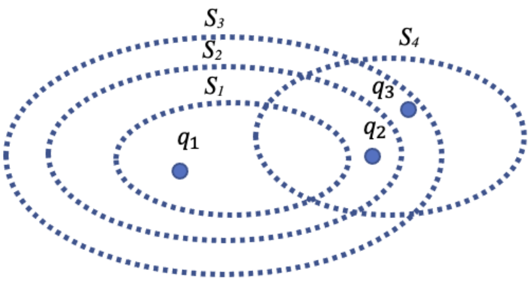
5. Point charges $q_1 = -2$ nC and $q_2 = q_3 = 2$ nC, and surfaces S_1, S_2, S_3, and S_4 are shown in the figure. Which surface has the largest electric flux?

a) S_1.

b) S_2.

c) S_3.

d) S_4. √



6. The electric field of a charged conducting sphere

a) is tangential to the surface inside and zero outside.

b) is tangential to the surface outside and zero inside.

c) is perpendicular to the surface inside and zero outside.

d) is perpendicular to the surface outside and zero inside. √

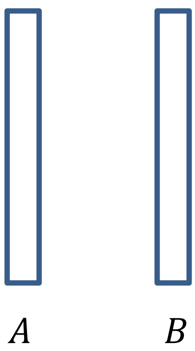
7. Two parallel very large charged conducting plates A, and B have charges Q and $-Q$, respectively. Which statement is correct for the location of the charges?

a) The charges are on the left surface of plate A and on the right surface of plate B.

b) The charges are on the left surface of plate A and on the left surface of plate B.

c) The charges are on the right surface of plate A and on the left surface of plate B. √

d) The charges are on the right surface of plate A and on the right surface of plate B.



8. Two point charges are fixed on the x-axis, as shown. A small charge Q is moved from infinity to point A without changing its kinetic energy. If $Q = q$, the work of the external force on Q is

a) positive.

b) negative. √

c) zero.

d) none of the above.