İzmir Kâtip Çelebi University
Department of Engineering Sciences
Phy102 Physics II
Midterm Examination
April 16, 2025 08:30 – 10:00
Good Luck!

NAME-SURNAME:

SIGNATURE:

ID:

DEPARTMENT:

INSTRUCTOR:

DURATION: 90 minutes

◇ **Answer all the questions.**
◇ **Write the solutions explicitly and clearly. Use the physical terminology.**
◇ **You are allowed to use Formulae Sheet.**
◇ **Calculator is allowed.**
◇ **You are not allowed to use any other electronic equipment in the exam.**

Question	Grade	Out of
1A		10
1B		10
2		20
3		20
4		20
5		20
TOTAL		100

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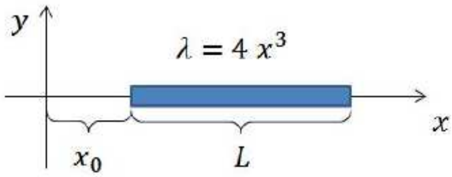
1. A) A non-uniform positive line charge of length $L = 1.0\ m$ is put along the x-axis as shown in the figure, where $x_0 = 2.0\ m$. The linear charge density is given by $\lambda(x) = 4x^3\ C/m^4$.



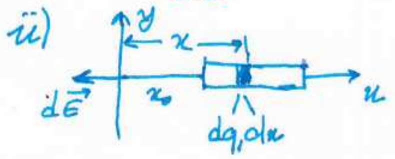
i Find the total charge on the rod.

ii Find the magnitude and direction of the total electric field, E, created by the line charge at the origin by using integration.

i) $\lambda(x) = 4x^3\ C/m^4$ $\quad\Big|\quad Q = \int dq = \int_{x_0}^{x_0+L} \lambda(x)dx = \int_2^3 4x^3 dx = x^4\Big|_2^3 = \underline{\underline{65\ C}}$

$\frac{Q}{L} = \lambda = \frac{dq}{dx}$ $\qquad$ 3 $\qquad$ 1 1

ii)



$dq = \lambda(x)dx$

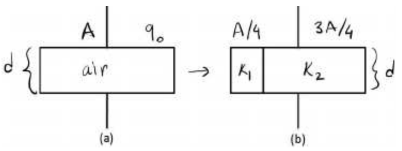
$dE = k\frac{dq}{x^2}$ $\quad\Big|\quad E = \int dE = \int_{x_0}^{x_0+L} k\frac{4x^3 dx}{x^2} = 4k\int_2^3 x\,dx$

3

$= 2k(3^2 - 2^2) = 10k = \underline{\underline{8.99\times 10^{10}\ N/C}}$

1 1

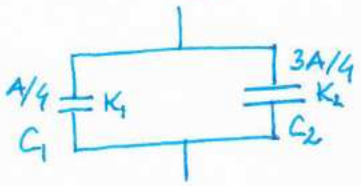
B) A parallel plate capacitor has the surface area **A** and the plate to plate distance **d** and **air filled** between the plates (see the Figure (a)). It has the capacitance C_0 and it is initially charged to q_0. Then the region under the area A/4 and the area 3A/4 are filled with dielectrics $\kappa_1 = 8$ and $\kappa_2 = 4$ respectively as seen in the Figure (b).



i Find the new capacitance in terms of C_0.

ii Find the the new electrostatic energy, U, of the dielectric capacitor in terms of U_0 if U_0 is the energy stored in the air filled capacitor.

i) $C_0 = \varepsilon_0 \frac{A}{d}$



$K_1 = 8$ & $K_2 = 4$

$U = \frac{q^2}{2C} = \frac{1}{2}CV^2$

$C_{new} = C_1 + C_2 = K_1 \varepsilon_0 \frac{A/4}{d} + K_2 \varepsilon_0 \frac{3A/4}{d}$

3

$= 2\varepsilon_0 \frac{A}{d} + 3\varepsilon_0 \frac{A}{d} = \underline{\underline{5C_0}}$ 2

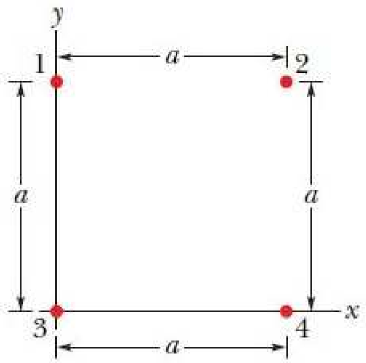
ii) $U_0 = \frac{1}{2}\frac{q_0^2}{C_0}$, q_0 is conserved

3

$U_{new} = \frac{1}{2}\frac{q_0^2}{C_{new}} = \frac{1}{2}\frac{q_0^2}{5C_0} = \frac{U_0}{5}$ //

2

2. In Figure, four particles form a square. The particles have charges $q_1 = 100\ nC$, $q_2 = -100\ nC$, $q_3 = 200\ nC$, $q_4 = -200\ nC$, and distance $a = 5.0\ cm$.



i What are the x and y components of the net electrostatic force on particle 3?

ii If the charges were $q_1 = q_4 = Q$ and $q_2 = q_3 = q$. What is Q/q if the net electrostatic force on particles 1 and 4 is zero?

$q_1 = 100\times10^{-9}C$

$q_2 = -q_1$

$q_3 = 200\times10^{-9}C$

$q_4 = -q_3$

$a = 5\times10^{-2}m$

i) $F_{3net,x}$ & $F_{3net,y}$? $\vec{F}_{3,net} = \sum_{i=1}^{3} \vec{F}_{3i} = \vec{F}_{31}+\vec{F}_{32}+\vec{F}_{34}$ (2)

(3) $\rightsquigarrow F_{3net,x} = |\vec{F}_{34}| + |\vec{F}_{32}|\cos 45$ (1)

$\rightsquigarrow F_{3net,y} = |\vec{F}_{32}|\sin 45 - |\vec{F}_{31}|$ (1)

$$F_{3net,x} = k\frac{|q_3||q_4|}{a^2} + k\frac{|q_3||q_2|}{(a\sqrt{2})^2}\frac{\sqrt{2}}{2} = \frac{k|q_3|}{a^2}\left(|q_4| + \frac{|q_2|}{2}\frac{\sqrt{2}}{2}\right) = \frac{8.99\times10^{9}Nm^2/C^2(200\times10^{-9}C)}{(5\times10^{-2}m)^2}\left(|-200\times10^{-9}C| + |-100\times10^{-9}C|\frac{\sqrt{2}}{4}\right) = \boxed{0.169N}$$ (1) (1)

$$F_{3net,y} = \frac{k|q_3|}{a^2}\left(\frac{|q_2|}{2}\frac{\sqrt{2}}{2} - |q_1|\right) = \frac{8.99\times10^{9}Nm^2/C^2(200\times10^{-9}C)}{(5\times10^{-2}m)^2}\left(|100\times10^{-9}C|\frac{\sqrt{2}}{4} - |100\times10^{-9}C|\right) = \boxed{-0.046N}$$ (1) (1)

ii) $q_1 = q_4 = Q$, $q_2 = q_3 = q$, $Q/q = ?$

$|\vec{F}_{1net}| = 0 \rightsquigarrow F_{1net,x} = 0$ & $F_{1net,y} = 0$ (2)

$|\vec{F}_{4net}| = 0$ $(|\vec{F}_{14}|\cos 45 + |\vec{F}_{12}|)(-\hat{i})$ $(|\vec{F}_{13}| + |\vec{F}_{14}|\sin 45)(\hat{j})$

(3)

$$0 = \frac{k|q_1|}{a^2}\left(\frac{|q_4|}{2}\frac{\sqrt{2}}{2} + |q_2|\right) - \frac{kQ}{a^2}\left(Q\frac{\sqrt{2}}{4} + q\right)$$ (2)

$$\Rightarrow \frac{Q}{q} = -\frac{4}{\sqrt{2}} = -2\sqrt{2} = \boxed{-2.83}$$ (2)

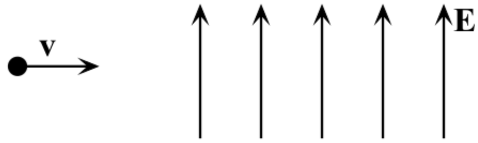
3. A proton moves at $4.5 \times 10^5\ m/s$ in the horizontal direction. It enters a uniform vertical electric field with a magnitude of $9.6 \times 10^3\ N/C$.

Ignoring any gravitational effects, find

i the time required for the proton to travel 5 cm horizontally,

ii the vertical displacement during that time,

iii the horizontal and vertical components of the velocity after the proton has traveled 5 cm horizontally.



$v = 4.5\times10^5\ m/s$ & $E = 9.6\times10^3\ N/C$ (uniform)

$v = v_{0x}$ & $v_{0y} = 0$ } Constant $\vec{E}$ ~ constant acceleration ~ force

$a = a_y$ & $a_x = 0$

$qE = ma$

i) $v_x = v_{0x} = v = \frac{\Delta x}{\Delta t}$ 2 ~ $\Delta t = \frac{5\times10^{-2}\ m}{4.5\times10^{5}\ m/s} = 1.11\times10^{-7}\ s = 111\ ns$ 1 1

ii) $a_y m_p = q_p E$ 2 ~ $a_y = \frac{q_p E}{m_p} = \frac{(1.6\times10^{-19}\ C)(9.6\times10^{3}\ N/C)}{(1.67\times10^{-27}\ kg)} = 9.21\times10^{11}\ m/s^2$ 2 1 1

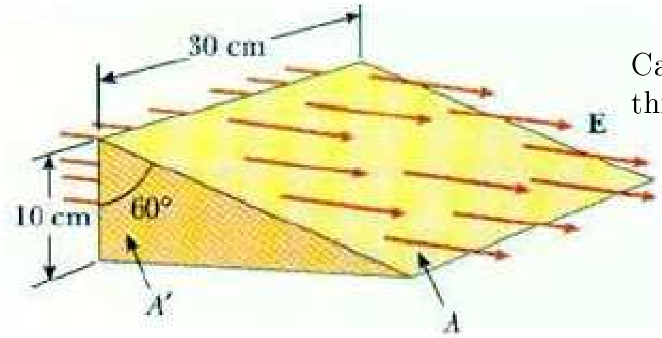
$y = y_0 + v_{0y} t + \frac{1}{2} a_y t^2$ 2 ~ $y - y_0 = h = \frac{1}{2} a_y t^2 = \frac{1}{2}(9.21\times10^{11}\ m/s^2)(1.11\times10^{-7}\ s)^2$ 1 1

$= 5.68\times10^{-3}\ m = 5.68\ mm$

iii) $v_x = v_{0x} = 4.5\times10^{5}\ m/s$ 2

$v_y = v_{0y} + a_y t = a_y t = (9.21\times10^{11}\ m/s^2)(1.11\times10^{-7}\ s) = 1.02\times10^{5}\ m/s$ 2 1 1

4. Consider a closed triangular box resting within a horizontal electric field of magnitude $E = 7.80 \times 10^4\ N/C$ as shown in figure given below.



Calculate the **electric flux** through

i the **inclined surface**.

ii the entire surface of the box.

$\Phi = \oint \vec{E} \cdot d\vec{A}$ (3)

i) Inclined surface

$\Phi_{is} = \oint E \cos 60° dA = E A \cos 60$ (2)

Area: $\cos 60 = \frac{10cm}{hyp} \rightarrow hyp = 20\,cm \Rightarrow A = (0.2m)(0.3m) = 0.06\,m^2$ (2)

$\Phi_{is} = (7.80 \times 10^4\ N/C)(0.06m^2)\cos 60 = \underline{2340\ Nm^2/C}$ (1)

ii) entire surface

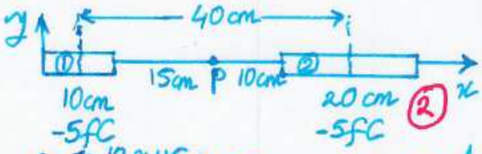
(2) dA ← E $\quad \Phi_{es} = \oint E \cos 180° dA = -(7.80 \times 10^4\ N/C)(0.1m)(0.3m)$ (2)

$= \underline{-2340\ N m^2/C}$ (1) (1)

(2) $\Rightarrow \Phi = \Phi_{is} + \Phi_{es} + \underbrace{\int E \cos 90\, dA}_{\text{side surfaces}} = \underline{0}$ (2) (2)

OR Closed surface, # of in = # of out ⇒ It is $\underline{\underline{zero}}$

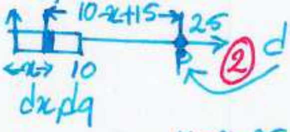
5. Two non-conductive rods are located on x-axis. The first rod has a length of 10 cm and the second one has a length 20 cm. A charge of $q = -5 \times 10^{-15}\ C$ is uniformly distributed along the each length. The distance between the centres of the rods is 40 cm. Find the **magnitude of the electric potential** at the middle of the distance between the centres of the rods. (Hints: $\int dx/(A-x) = -ln|A-x| + C$ and $\int dx/(x-A) = ln|-A+x| + C$)



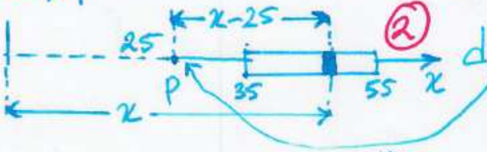
2

uniform distribution, $\lambda = Q/L$

$\lambda_1 = \frac{-5\times10^{-15}C}{10\times10^{-2}m}$, $\lambda_2 = \frac{-5\times10^{-15}C}{20\times10^{-2}m}$ 2



2 $dV_1 = k\frac{\lambda_1 dx}{(10-x+15)}$, $V_1 = \int dV_1 = k\lambda_1 \int_0^{10} \frac{dx}{(25-x)}$ 3



2 $dV_2 = k\frac{\lambda_2 dx}{x-25}$, $V_2 = k\lambda_2 \int_{35}^{55} \frac{dx}{(x-25)}$ 3

$\Rightarrow V_1 = k\lambda_1\left(-ln|25-x|\Big|_0^{10}\right) = k\lambda_1(-ln15 + ln25) = k\lambda_1 ln(5/3)$

$= \left(8.99\times10^9 \frac{Nm^2}{C^2}\right)\left(\frac{-5\times10^{-15}C}{10\times10^{-2}m}\right) ln(5/3) = \underline{\underline{-2.30\times10^{-4}V}}$ 2

$V_2 = k\lambda_2\left(ln|-25+x|\Big|_{35}^{55}\right) = k\lambda_2(ln30 - ln10) = k\lambda_2 ln3$

$= \left(8.99\times10^9 \frac{Nm^2}{C^2}\right)\left(\frac{-5\times10^{-15}C}{20\times10^{-2}m}\right) ln3 = \underline{\underline{-2.47\times10^{-4}V}}$ 2

$\Rightarrow V_P = V_1 + V_2 = \boxed{-4.77\times10^{-4}V}$ 2