İzmir Kâtip Çelebi University
Department of Engineering Sciences
Phy102 Physics II
Midterm Examination
November 04, 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		20
1B		15
2		20
3		20
4		10
5		15
TOTAL		100

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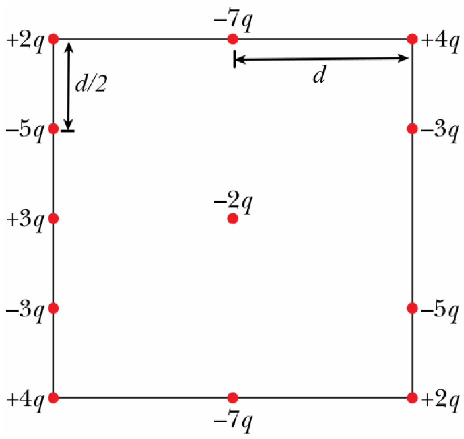
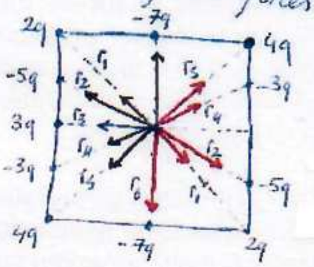
1. A) In the figure below, a central particle of charge $-2q$ is surrounded by a square array of charged particles, separated by either distance d or $d/2$ along the perimeter of the square.



i What are the magnitude and direction of the net electrostatic force on the central particle due to the other particles? (**Hint: Some forces on the central particle cancel each other!**)

ii What is the work you need to apply to bring central particle to its place from infinity?

i) Some of the forces cancel each other!



$$\vec{F} = k\frac{|q_1||q_2|}{r^2}\hat{r}, \quad \vec{F}_{net} = \sum_{i=1}^{11} \frac{k|-2q||q_i|}{r_i^{2}}\hat{r}_i \quad 3$$

$$\vec{F}_{net} = k|-2q|\left(\frac{|2q|}{r_1^2}\hat{r}_1 + \frac{|-5q|}{r_2^2}\hat{r}_2 + \frac{|3q|}{r_3^2}\hat{r}_3 + \frac{|-3q|}{r_4^2}\hat{r}_4 + \frac{|4q|}{r_5^2}\hat{r}_5 + \frac{|-7q|}{r_6^2}\hat{r}_6\right.$$

$$6 \quad \left.\frac{|2q|}{r_1^2}(-\hat{r}_1) + \frac{|-5q|}{r_2^2}(-\hat{r}_2) + \frac{|-3q|}{r_4^2}(-\hat{r}_4) + \frac{|4q|}{r_5^2}(-\hat{r}_5) + \frac{|-7q|}{r_6^2}(-\hat{r}_6)\right)$$

only survival force is due to 3q.

$$\rightarrow \vec{F}_{net} = \frac{k|-2q||3q|}{r_3^2}\hat{r}_3 = k\frac{6q}{d^2}(-\hat{x}) = \boxed{\frac{1}{4\pi\varepsilon_0}\frac{6q^2}{d^2}(-\hat{x})} \quad 2$$

ii) To bring the central particle. First find the potential present at that central point. Potential is a scalar quantity. No cancellation as force vectors. $V = k\frac{q}{r}$

$$V_{net} = \sum_{i=1}^{11} V_i = k\left(\frac{-7q-7q+3q}{d} + \frac{+4q+4q+2q+2q}{d\sqrt{2}} + \frac{-5q-5q-3q-3q}{[d^2+(d/2)^2]^{1/2}}\right) \quad 2$$

$$2 \quad = \frac{q}{4\pi\varepsilon_0}\left(\frac{-11}{d} + \frac{12}{d\sqrt{2}} + \frac{-16}{d\sqrt{5}/2}\right) = \frac{q}{4\pi\varepsilon_0 d}\left(-11+6\sqrt{2}-32/\sqrt{5}\right) = \frac{q}{4\pi\varepsilon_0 d}(-16.8)$$

$$= \frac{-4.2q}{\pi\varepsilon_0 d}$$

1 Now find the required potential energy (or work)

$$W = \underset{(qV)}{\Delta U} = (U_f - \underset{0 \text{ at infinity}}{U_i}) = U_f = (-2q)\left(\frac{-4.2q}{\pi\varepsilon_0 d}\right) = \boxed{\frac{8.4q}{\pi\varepsilon_0 d}} \quad 2$$

2

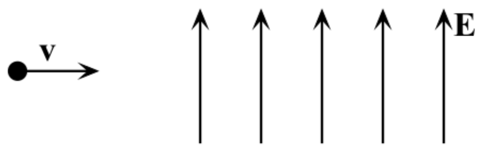
B) A proton moves at $4.50 \times 10^5\ m/s$ in the horizontal direction. It enters a uniform vertical electric field with a magnitude of $9.60 \times 10^3\ N/C$.

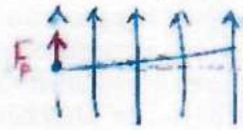
Ignoring any gravitational effects, find

i the time required for the proton to travel 5.00 cm horizontally,

ii the vertical displacement during that time,

iii the horizontal and vertical components of the velocity after the proton has traveled 5.00 cm horizontally.





$v = 4.5 \times 10^5\ m/s$ & $E = 9.6 \times 10^3\ N/C$

(uniform)

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

$a = a_y$ & $a_x = 0$ } acceleration ⇜ force

$qE = ma$

i) $v_x = v_{0x} = v = \frac{\Delta x}{\Delta t}$ (1) $\rightsquigarrow \Delta t = \frac{5 \times 10^{-2}\ m}{4.5 \times 10^5\ m/s} = 1.11 \times 10^{-7}\ s = \underline{\underline{111\ ns}}$ (1) (1)

ii) $a_y m_p = q_p E$ (2) $\rightarrow a_y = \frac{q_p E}{m_p} = \frac{(1.6 \times 10^{-19}\ C)(9.6 \times 10^3\ N/C)}{(1.67 \times 10^{-27}\ kg)} = 9.21 \times 10^{11}\ m/s^2$ (1) (1) (1)

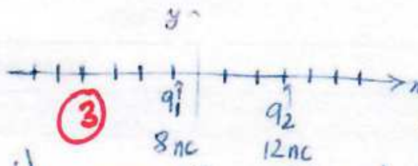
$y = y_0 + v_{0y} t + \frac{1}{2} a_y t^2$ (1) $\rightsquigarrow y - y_0 = h = \frac{1}{2} a_y t^2 = \frac{1}{2}(9.21 \times 10^{11}\ m/s^2)(1.11 \times 10^{-7}\ s)^2$ (1) (1)

$= 5.68 \times 10^{-3}\ m = \underline{\underline{5.68\ mm}}$

iii) $v_x = v_{0x} = 4.5 \times 10^5\ m/s$ (1)

$v_y = v_{0y} + a_y t = a_y t = (9.21 \times 10^{11}\ m/s^2)(1.11 \times 10^{-7}\ s) = \underline{\underline{1.02 \times 10^5\ m/s}}$ (1) (1) (1)

2. A positive point charge q_1=8 nC is on the x-axis at x_1= -1 m, a second positive point charge q_2=12 nC is on the x-axis at x_2=3 m. Find the net electric field (a) at point A on the x-axis at x=6 m, and (b) at point B on the x-axis at x=2 m.



3

i) $E(x=6m)=?$

ii) $E(x=2m)=?$

i) $\longrightarrow E_{q_1}$, $\longrightarrow E_{q_2}$

$$E(x=6m)=\sum_{i=1}^{2} E_{q_i}(x=6m) = E_{q_1}(x=6m) + E_2(x=6m)$$ 3

3

$$= k\frac{|q_1|}{(7m)^2} + k\frac{|q_2|}{(3m)^2} = \left(8.99\times10^{9}\frac{N}{C^2}m^2\right)\left(\frac{8\times10^{-9}C}{49m^2}+\frac{12\times10^{-9}C}{9m^2}\right)$$

$$= 13.45\ N/C \rightsquigarrow \boxed{\vec{E}(x=6m)=13.45\ N/C\ \hat{i}}$$ 3

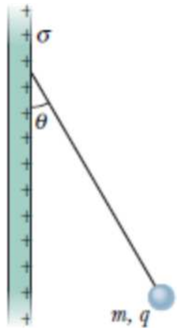
ii) $E(x=2m)=?$

$\longrightarrow E_{q_1}$, $\longleftarrow E_{q_2}$ 4

$$E(x=2m)=k\frac{|q_1|}{(9m^2)} - k\frac{|q_2|}{1m^2} = 8.99\times10^{9}\frac{N}{C^2}m^2\left(\frac{8\times10^{-9}C}{9m^2}-\frac{12\times10^{-9}C}{1m^2}\right)$$

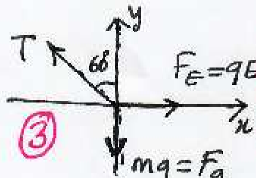
$$= -99.9\ N/C \rightarrow \boxed{\vec{E}(x=2m)= 99.9\ N/C\ (-\hat{i})}$$ 4

3. A small, nonconducting ball of mass $m = 2 \times 10^{-6}\ kg$ and charge $q = 4.0 \times 10^{-8}\ C$ (distributed uniformly through its volume) hangs from an insulating thread that makes an angle $\theta = 30°$ with a vertical, uniformly charged **nonconducting sheet** (shown in cross section).



Considering the gravitational force on the ball and assuming the sheet extends far vertically and into and out of the page, **calculate the surface charge density** σ **of the sheet. Hint: The ball is in equilibrium (stationary)**.

$m = 2\times10^{-6}$ kg (non-conducting)
$q = 4\times10^{-8}$ C uniform distribution
non-conducting sheet, $\sigma = ?$
$E = \frac{\sigma}{2\varepsilon_0}$ (if hanged)

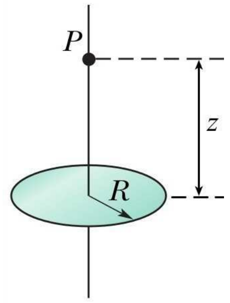


$F_E = qE$ (3) $T\cos 60° - mg = ma_y = 0$
(3)
(3) $qE - T\sin 60° = ma_x = 0$
hangs ⇝ stationary
now, eliminate T

$\rightsquigarrow qE - \left(\frac{mg}{\cos 60°}\right)\sin 60° = 0$ (3) $\rightsquigarrow qE = mg\tan 60° \rightsquigarrow q\frac{\sigma}{2\varepsilon_0} = mg\tan 60° \rightsquigarrow \sigma = \frac{2mg\varepsilon_0\tan 60°}{q}$

$\rightsquigarrow \sigma = \frac{2mg\varepsilon_0\tan 60°}{q}$ (3) $= \frac{2(2\times10^{-6}\,kg)(9.8\,m/s^2)(8.85\times10^{-12}\,C^2/Nm^2)\tan 60°}{(4\times10^{-8}\,C)}$ (2) $= \boxed{15\times10^{-9}\,C/m^2}$ (2) (1)

4. The electric potential at any point on the central axis of a uniformly charged disk is



$$V = \frac{\sigma}{2\epsilon_0}\left(\sqrt{z^2+R^2} - z\right)$$

Starting with this expression, derive an expression for the electric field at any point on the axis of the disk.

Any point on the axis of disk → z-direction

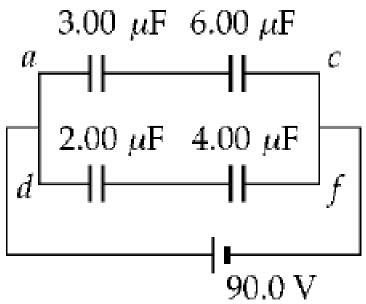
$$E = -\frac{\partial V}{\partial z} = -\frac{\partial}{\partial z}\left[\frac{\sigma}{2\varepsilon_0}\left((z^2+R^2)^{1/2} - z\right)\right]$$

(4)

$$= \frac{-\sigma}{2\varepsilon_0}\left[\frac{1}{2}(z^2+R^2)^{-1/2}2z - 1\right] \quad (3)$$

$$\boxed{= \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{z}{\sqrt{z^2+R^2}}\right]} \quad (3)$$

5. For the system of capacitors shown in Figure;



Find

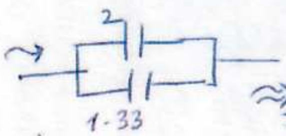
i the equivalent capacitance of the system,

ii the charge on each capacitor,

iii the potential across each capacitor.

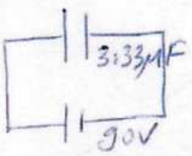
i) $C_{equ} = ?$ 3 || 6 || — $\sim \frac{1}{C_{ac}} = \frac{1}{3\mu F} + \frac{1}{6\mu F} \Rightarrow C_{ac} = 2\,\mu F$

2 || 4 || — $\sim \frac{1}{C_{df}} = \frac{1}{2\mu F} + \frac{1}{4\mu F} \Rightarrow C_{df} = 1.33\,\mu F$ 2

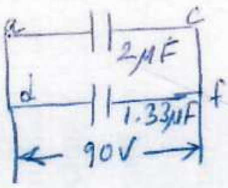


$\Rightarrow C_{equ} = 3.33\,\mu F$ 2 1

ii)



$C = \frac{Q}{V} \sim Q = C_{equ} * V = (3.33 \times 10^{-6} F)\, 90V = 299.7\,\mu C$ 2 (total charge)

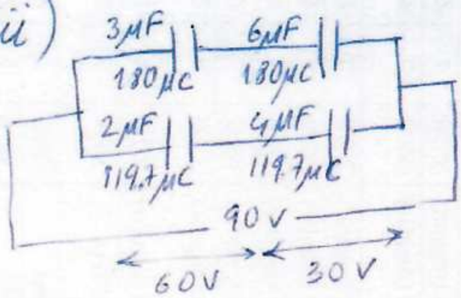


2

$Q_{ac} = (2\mu F)\, 90V = 180\,\mu C = q_a = q_c$

$Q_{df} = (1.33\mu F)\, 90V = 119.7\,\mu C = q_d = q_f$ 2

iii)



$V_a = \frac{q_a}{C_a} = \frac{180\mu C}{3\mu F} = \boxed{60V}$ 1

$V_c = \frac{180\mu C}{6\mu F} = \boxed{30V}$ 1

$V_d = \frac{119.7\mu C}{2\mu F} \simeq \boxed{60V}$ 1

$V_f = \frac{119.7\mu C}{4\mu F} \simeq \boxed{30V}$ 1

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

NAME-SURNAME:

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ID:

DEPARTMENT:

INSTRUCTOR:

DURATION: 90 minutes

◇ **Answer all the questions.**
◇ **Write the solutions explicitly and clearly. Use the physical terminology.**
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Question	Grade	Out of
1A		10
1B		10
2		20
3		20
4		20
5		20
TOTAL		100

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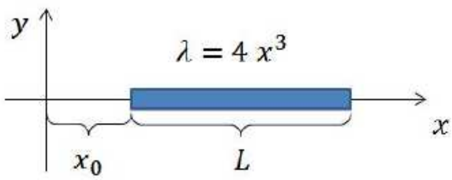
1. A) A non-uniform positive line charge of length $L = 1.0\ m$ is put along the x-axis as shown in the figure, where $x_0 = 2.0\ m$. The linear charge density is given by $\lambda(x) = 4x^3\ C/m^4$.



i Find the total charge on the rod.

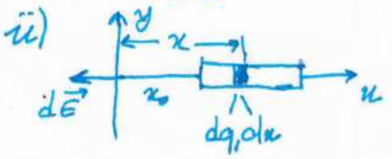
ii Find the magnitude and direction of the total electric field, E, created by the line charge at the origin by using integration.

i) $\lambda(x) = 4x^3\ C/m^4$ $\quad \frac{Q}{L} = \lambda = \frac{dq}{dx}$

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

3 1 1

ii)



$dq = \lambda(x)dx$

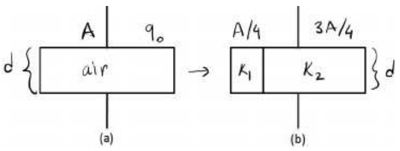
$dE = k\frac{dq}{x^2}$

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

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

3 1 1

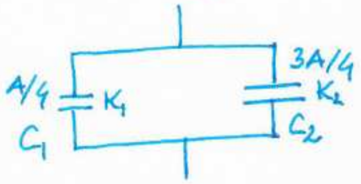
B) A parallel plate capacitor has the surface area **A** and the plate to plate distance **d** and **air filled** between the plates (see the Figure (a)). It has the capacitance C_0 and it is initially charged to q_0. Then the region under the area A/4 and the area 3A/4 are filled with dielectrics $\kappa_1 = 8$ 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) $C_0 = \varepsilon_0 \frac{A}{d}$



$K_1 = 8$ & $K_2 = 4$

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

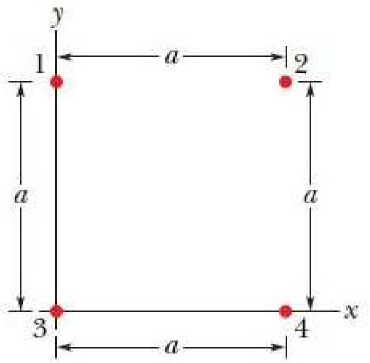
$C_{new} = C_1 + C_2 = K_1 \varepsilon_0 \frac{A/4}{d} + K_2 \varepsilon_0 \frac{3A/4}{d}$ 3

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

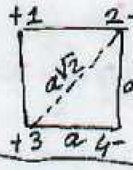
$q_1 = 100\times10^{-9}C$

$q_2 = -q_1$

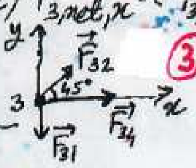
$q_3 = 200\times10^{-9}C$

$q_4 = -q_3$

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



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



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

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

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

$$= \boxed{0.169N}$$ 1 1

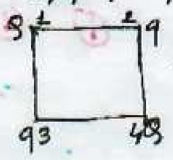
$$F_{3,net,y} = \frac{k|q_3|}{a^2}\left(\frac{|q_2|}{2}\frac{\sqrt{2}}{2} - |q_1|\right) = \frac{8.99\times10^{9}Nm^2/C^2(200\times10^{-9}C)}{(5\times10^{-2}m)^2}\left(|100\times10^{-9}C|\frac{\sqrt{2}}{4} - |100\times10^{-9}C|\right)$$

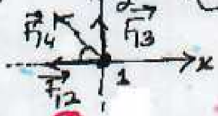
$$= \boxed{-0.046N}$$ 1 1

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

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

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





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

$$\rightsquigarrow \frac{Q}{q} = -\frac{4}{\sqrt{2}} = -2\sqrt{2} = \boxed{-2.83}$$ 2

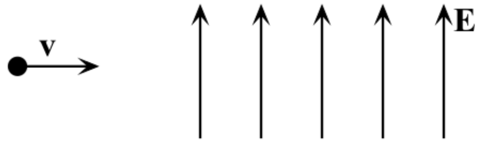
3. A proton moves at $4.5 \times 10^5\ m/s$ in the horizontal direction. It enters a uniform vertical electric field with a magnitude of $9.6 \times 10^3\ N/C$.

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.



$v = 4.5 \times 10^5\ m/s$ & $E = 9.6 \times 10^3\ N/C$ (uniform)

$v = v_{0x}$ & $v_{0y} = 0$
$a = a_y$ & $a_x = 0$

Constant $\vec{E}$ ~ constant acceleration ⇐ force

$qE = ma$

i) $v_x = v_{0x} = v = \frac{\Delta x}{\Delta t}$ (1) $\rightsquigarrow \Delta t = \frac{5 \times 10^{-2}\ m}{4.5 \times 10^5\ m/s} = 1.11 \times 10^{-7}\ s = \underline{\underline{111\ ns}}$ (1) (1)

ii) $a_y m_p = q_p E$ (2) $\rightarrow a_y = \frac{q_p E}{m_p} = \frac{(1.6 \times 10^{-19}\ C)(9.6 \times 10^3\ N/C)}{(1.67 \times 10^{-27}\ kg)}$ (1) $= 9.21 \times 10^{11}\ m/s^2$ (1) (1)

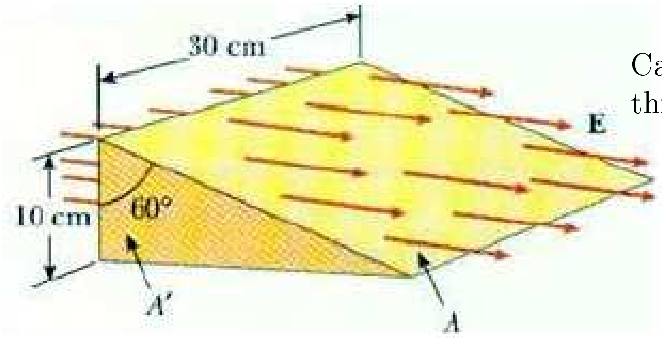
$y = y_0 + v_{0y} t + \frac{1}{2} a_y t^2$ (1) $\rightsquigarrow y - y_0 = h = \frac{1}{2} a_y t^2 = \frac{1}{2}(9.21 \times 10^{11}\ m/s^2)(1.11 \times 10^{-7}\ s)^2$ (1) (1)

$= 5.68 \times 10^{-3}\ m = \underline{\underline{5.68\ mm}}$

iii) $v_x = v_{0x} = 4.5 \times 10^5\ m/s$ (1)

$v_y = v_{0y} + a_y t = a_y t$ (1) $= (9.21 \times 10^{11}\ m/s^2)(1.11 \times 10^{-7}\ s) = \underline{\underline{1.02 \times 10^5\ m/s}}$ (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

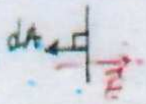
$\Phi_{is} = \oint E \cos 60° dA = E A \cos 60$ 2

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

$= 0.06m^2$ 2

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

ii) entire surface

2 

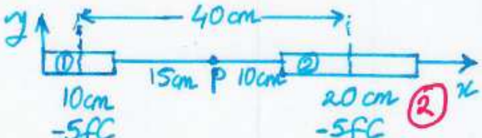
$\Phi_{es} = \oint E \cos 180° dA = -(7.80 \times 10^4 N/C)(0.1m)(0.3m)$ 2

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

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

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

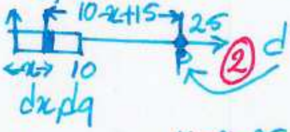
5. Two non-conductive rods are located on x-axis. The first rod has a length of 10 cm and the second one has a length 20 cm. A charge of $q = -5 \times 10^{-15}$ C is uniformly distributed along the each length. The distance between the centres of the rods is 40 cm. Find the **magnitude of the electric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



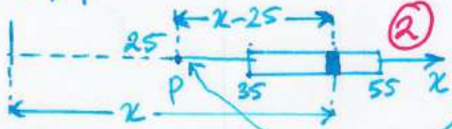
2

uniform distribution, $\lambda = Q/L$

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



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



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

İzmir Kâtip Çelebi University
Department of Engineering Sciences
Phy102 Physics II
Midterm Examination
April 22, 2024 17:45 – 19:15
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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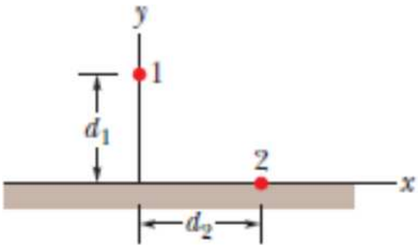
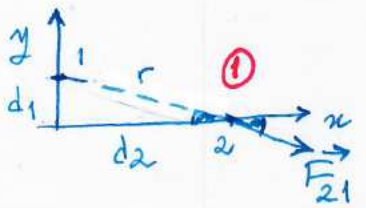
1. A) In figure given below, particle 1 of charge $q_1 = 4e$ is above a floor by distance $d_1 = 2.00\ mm$ and particle 2 of charge $q_2 = 6e$ is on the floor, at distance $d_2 = 6.00\ mm$ horizontally from particle 1.



What is the **x component of the electrostatic force on particle 2 due to particle 1**?



① $\vec F_{21} = F_{21,x}\,\hat i + F_{21,y}\,\hat j = |\vec F_{21}|\cos\theta\,\hat i - |\vec F_{21}|\sin\theta\,\hat j$

$F_{21,x} = ?$ ② $\dfrac{1}{4\pi\varepsilon_0}\dfrac{|q_2||q_1|}{r^2}$ $\dfrac{d_2}{r} = \dfrac{d_2}{\sqrt{d_1^2+d_2^2}}$ ②

$\Rightarrow F_{21,x} = k\dfrac{|q_2||q_1|}{d_1^2+d_2^2}\dfrac{d_2}{\sqrt{d_1^2+d_2^2}} = \dfrac{k(6e)(4e)\,d_2}{(d_1^2+d_2^2)^{3/2}}$ ② ② ①

$= 8.99\times10^{9}\dfrac{Nm^2}{C^2}\,\dfrac{24\times(1.602\times10^{-19}C)^2(6\times10^{-3}m)}{\left((2\times10^{-3}m)^2+(6\times10^{-3}m)^2\right)^{3/2}} = \boxed{1.31\times10^{-22}\,N}$

B) An electrometer is a device used to measure static charge-an unknown charge is placed on the plates of the meter's capacitor, and the potential difference is measured. What minimum charge can be measured by an electrometer with a capacitance of 50 pF and a voltage sensitivity of 0.15 V?

$C = 50\,pF$
$V = 0.15V = V_{min}$
$q_{min} = ?$

5 3

$q_{min} = V_{min} C = (0.15V)(50 \times 10^{-12} F) =$

$\boxed{q_{min} = 7.5\,pC}$

2

2. At some instant the velocity components of an electron moving between two charged parallel plates are $v_x = 3 \times 10^5\ m/s$ and $v_y = 5.0 \times 10^3\ m/s$. Suppose the electric field between the plates is given by $\vec{E} = (180N/C)\hat{j}$. In unit-vector notation, what are

   i the electron's acceleration in that field

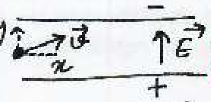
   ii the electron's velocity when its x coordinate has changed by 2.4 cm?

$\bar{e}$: electron

$v_x = 3\times10^5\ m/s = v_{0x}$

$v_y = 5\times10^3\ m/s = v_{0y}$

$\vec{E} = 180\ N/C\ \hat{j}$



2 i) $a = ?$ $\vec{F}_E = q\vec{E} = (1.6\times10^{-19}C)(180\ N/C)(-\hat{j})$ 2

$= 288\times10^{-19}N\,(-\hat{j})$ 1 1

$\Rightarrow m_e\vec{a} = \vec{F}_E \rightarrow \vec{a} = \dfrac{288\times10^{-19}N}{9.109\times10^{-31}kg}(-\hat{j}) = \boxed{3.16\times10^{13}\ m/s^2\,(-\hat{j})}$ 2 1 1

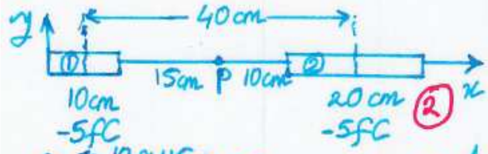
ii) $\Delta x = x - x_0 = 2.4\times10^{-2}m$ & no force acting on x direction 2

$\Rightarrow v_x = v_{0x}$ 1 & $v_y = v_{0y} + at$ 1 $\Rightarrow \dfrac{\Delta x}{\Delta t} = v_x \rightarrow \dfrac{\Delta x}{v_x} = \Delta t$

$\Rightarrow \Delta t = \dfrac{2.4\times10^{-2}m}{3\times10^5 m/s} = 8\times10^{-8}s$ 1 1 $\rightarrow v_y = 5\times10^3 m/s - (3.16\times10^{13} m/s^2)(8\times10^{-8}s) = \boxed{-2.52\times10^6 m/s}$ 1 1

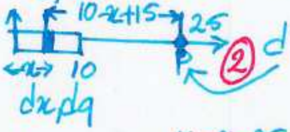
$\Rightarrow \boxed{\vec{v} = 3\times10^5 m/s\ \hat{i} + 2.52\times10^6 m/s\,(-\hat{j})}$ 2

3. 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 $\int dx/(x-A) = ln|-A+x| + C$)

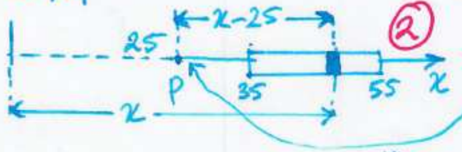


uniform distribution, $\lambda = Q/L$

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



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



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

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

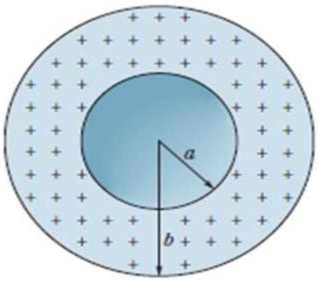
$$= \left(8.99\times10^9 \frac{Nm^2}{C^2}\right)\left(\frac{-5\times10^{-15}C}{10\times10^{-2}m}\right) ln(5/3) = \underline{\underline{-2.30\times10^{-4}V}} \quad (2)$$

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

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

$$\Rightarrow V_p = V_1 + V_2 = \boxed{-4.77\times10^{-4}V} \quad (2)$$

4. Figure shows a spherical shell with uniform volume charge density $\rho = 1.56 \times 10^{-9}\ C/m^3$, inner radius $a = 10\ cm$, and outer radius $b = 2.00a$.

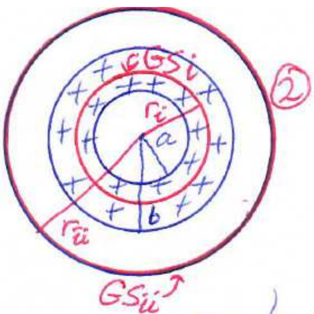


What is the magnitude of the electric field at radial distances

i $r = 1.5a$

ii $r = 3.00b$

Hints: Use Gauss' Law. Volume of the spherical shell: $\frac{4}{3}\pi(b^3 - a^3)$.



(2)

$\oint \vec{E}\cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$ (2), $\rho = \frac{q}{V} = \frac{q_{enc}}{V_{enc}}$ (2), $\vec{E} \parallel \vec{A}$ (2)

$\rho = 1.56\times10^{-9}\ C/m^3$

$a = 10\times10^{-2}\ m$

$b = 2a$

$r_i = 1.5a$

$r_{ii} = 3b$

$V_{ss} = \frac{4}{3}\pi(b^3 - a^3)$

i) $\oint \vec{E}\cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0} \rightsquigarrow E 4\pi r_i^2 = \frac{q_{enc}}{\varepsilon_0}$ $\}$ $q_{enc} = ?$

GS_i

$\rightsquigarrow q_{enc} = \rho V_{enc} = \rho \frac{4}{3}\pi(r_i^3 - a^3)$ (2)

$\rightsquigarrow E 4\pi r_i^2 = \rho \frac{4}{3}\frac{\pi(r_i^3 - a^3)}{\varepsilon_0}$ $\}$ $r_i = 1.5a$

$\Rightarrow E = \frac{\rho\, 4/3\,\pi}{4\pi\varepsilon_0}\frac{((1.5a)^3 - a^3)}{1.5a^2} = \frac{\rho a}{3\varepsilon_0}\left(\frac{2.375}{2.25}\right)$ (2) (1)

$E(r=1.5a) = \frac{(1.56\times10^{-9}\ C/m^3)(10\times10^{-2}\ m)}{3 * 8.85\times10^{-12}\ C^2/(Nm^2)}\left(\frac{2.375}{2.25}\right) = \boxed{6.20\ N/C}$ (1)

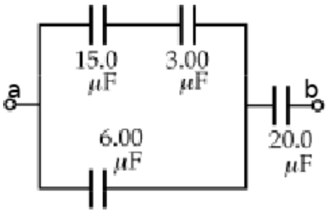
ii) $E 4\pi r_{ii}^2 = \frac{q_{enc}}{\varepsilon_0} \rightsquigarrow q_{enc} = \rho \frac{4}{3}\pi(b^3 - a^3)$ (2)

GS_{ii} $\rightsquigarrow E 4\pi r_{ii}^2 = \rho \frac{4}{3}\frac{\pi(b^3 - a^3)}{\varepsilon_0}$ $\}$ $r_{ii} = 3b$

$\Rightarrow E = \frac{\rho\, 4/3\,\pi}{4\pi\varepsilon_0}\frac{b^3 - a^3}{(3b)^2} = \frac{\rho\, 7a}{108\,\varepsilon_0}$ (1) (1)

$E(r=3b) = \frac{(1.56\times10^{-9}\ C/m^3)\, 7(10\times10^{-2}\ m)}{108 * 8.85\times10^{-12}\ C^2/(Nm^2)} = \boxed{1.14\ N/C}$ (2)

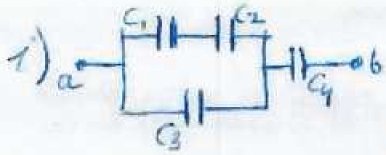
5. Four capacitors are connected as shown in Figure.



i Find the equivalent capacitance between points a and b.

ii Calculate the charge on each capacitor if $\Delta V_{ab} = 15.0\ V$.

1)



$C_{12} = \frac{C_1C_2}{C_1+C_2} = \frac{(15\times10^{-6}F)(3\times10^{-6}F)}{18\times10^{-6}F} = 2.5\times10^{-6}F$ 3

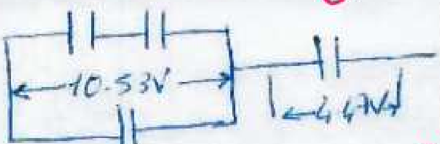
$C_{123} = C_{12}+C_3 = 2.5\times10^{-6}F + 6\times10^{-6}F = 8.5\times10^{-6}F$ 3

$C_{eqv} = C_{1234} = \frac{C_{123}C_4}{C_{123}+C_4} = \frac{(8.5\times10^{-6}F)(20\times10^{-6}F)}{28.5\times10^{-6}F} = 5.97\times10^{-6}F = 5.97\mu F$ 3

ii) $C=\frac{Q}{V} \rightarrow Q_{eqv}=Q_{1234}=C_{eqv}V = 5.97\times10^{-6}F\times15V = \boxed{89.47\mu C}$ 3

$\rightarrow Q_4 = Q_{123} = Q_{eqv} = 89.47\mu C$ 1 $\rightarrow V_4 = \frac{89.47\mu C}{20\mu F} = 4.47\ V \leftarrow$ 4 1 1

$\rightarrow$



1 10.53V ← 3 $\rightarrow Q_3 = C_3V_3 = \boxed{63.18\mu C}$ 3

$Q_{12} = C_{12}V = (2.5\times10^{-6}F)\,10.53V = Q_1 = Q_2$

$\rightarrow Q_1 = Q_2 = \boxed{2.63\mu C}$ 1 1

$\Rightarrow V_1 = \frac{Q_1}{C_1} = \frac{2.63\mu C}{15\mu F} = 1.75V$ 1 ← 1

$V_2 = \frac{Q_1}{C_2} = 8.78V \leftarrow$ 2 1

İzmir Kâtip Çelebi University
Department of Engineering Sciences
Phy102 Physics II
Midterm Examination
November 10, 2022 17:00 – 18:30
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		15
1B		15
2		20
3		20
4		20
5		20
TOTAL		110

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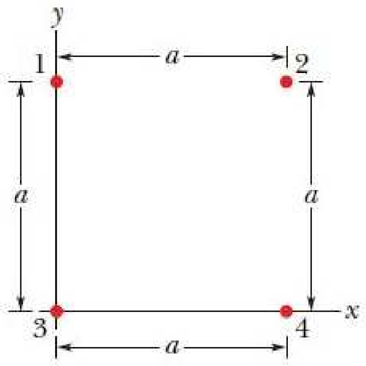
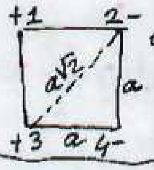
1. A) In Figure, four particles form a square. The particles have charges $q_1 = 100\ nC,\ q_2 = -100\ nC,\ q_3 = 200\ nC,\ q_4 = -200\ nC$, and distance $a = 5.0\ cm$.



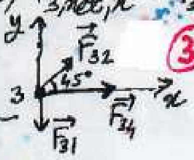
i What are the x and y components of the net electrostatic force on particle 3?

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



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

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

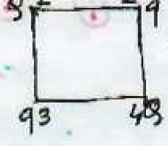
$$F_{3,net,x} = k\frac{|q_3||q_4|}{a^2} + k\frac{|q_3||q_2|}{(a\sqrt{2})^2}\frac{\sqrt{2}}{2} = \frac{k|q_3|}{a^2}\left(|q_4| + \frac{|q_2|}{2}\frac{\sqrt{2}}{2}\right) = \frac{8.99\times10^{9}Nm^2/C^2\,(200\times10^{-9}C)}{(5\times10^{-2}m)^2}\left(|-200\times10^{-9}C| + |-100\times10^{-9}C|\frac{\sqrt{2}}{4}\right)$$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

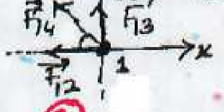
$$F_{3,net,y} = \frac{k|q_3|}{a^2}\left(\frac{|q_2|}{2}\frac{\sqrt{2}}{2} - |q_1|\right) = \frac{8.99\times10^{9}Nm^2/C^2\,(200\times10^{-9}C)}{(5\times10^{-2}m)^2}\left(|100\times10^{-9}C|\frac{\sqrt{2}}{4} - |100\times10^{-9}C|\right)$$
$$= \boxed{-0.046N}$$ 1 1

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

$|\vec{F}_{1net}| = 0 \rightsquigarrow F_{1,net,x} = 0$ & $F_{1,net,y} = 0$ 2
$|\vec{F}_{4,net}| = 0$

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





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

$$\rightsquigarrow \frac{Q}{q} = -\frac{4}{\sqrt{2}} = -2\sqrt{2} = \boxed{-2.83}$$ 2

B) The density of conduction electrons in aluminum is $2.1\times10^{29}\ m^{-3}$. What is the drift velocity in an aluminum conductor that has a 2.0 μm by 3.0 μm rectangular cross section and when a 32.0 mA current flows through the conductor?

$n = 2.1\times10^{29}\,m^{-3}$

$i = 32\times10^{-3}\,A$

$A = (2\times10^{-6}\,m)(3\times10^{-6}\,m)$

$v_d = ?$

$\vec{J} = ne\vec{v}_d$

3 $J = nev_d$

3 $J = \frac{i}{A}$

$\frac{i}{A} = nev_d$

$\Rightarrow v_d = \frac{i}{Ane} =$ 4 $\frac{32\times10^{-3}\,A}{(2\times10^{-6}\,m)(3\times10^{-6}\,m)(2.1\times10^{29}\,m^{-3})(1.602\times10^{-19}\,C)}$

$= \boxed{0.016\ m/s}$

3 2

$\frac{A}{m^2 m^{-3} C} \sim \frac{C/s}{m^2 m^{-3} C} \sim m/s$

unit check

2. At some instant the velocity components of an electron moving between two charged parallel plates are $v_x = 3 \times 10^5\ m/s$ and $v_y = 5.0 \times 10^3\ m/s$. Suppose the electric field between the plates is given by $\vec{E} = (180N/C)\hat{j}$. In unit-vector notation, what are

   i the electron's acceleration in that field

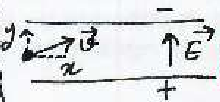
   ii the electron's velocity when its x coordinate has changed by 2.4 cm?

$\bar{e}$: electron

$v_x = 3\times10^5\ m/s = v_{0x}$

$v_y = 5\times10^3\ m/s = v_{0y}$

$\vec{E} = 180\ N/C\ \hat{j}$



(2) i) $a = ?$ (2) $\vec{F}_E = q\vec{E} = (1.6\times10^{-19}C)(180\ N/C)(-\hat{j})$

$= 288\times10^{-19} N(-\hat{j})$ (1) (1)

$\Rightarrow m_e\vec{a} = \vec{F}_E$ (2) $\rightarrow \vec{a} = \frac{288\times10^{-19} N}{9.109\times10^{-31} kg}(-\hat{j}) = \boxed{3.16\times10^{13}\ m/s^2(-\hat{j})}$ (1) (1)

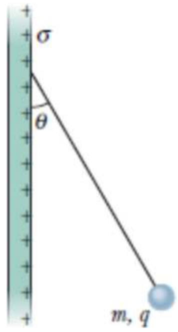
ii) $\Delta x = x - x_0 = 2.4\times10^{-2} m$ & no force acting on x direction (2)

$\Rightarrow v_x = v_{0x}$ (1) & $v_y = v_{0y} + at$ (1) $\Rightarrow \frac{\Delta x}{\Delta t} = v_x \rightarrow \frac{\Delta x}{v_x} = \Delta t$

$\Rightarrow \Delta t = \frac{2.4\times10^{-2} m}{3\times10^5 m/s} = 8\times10^{-8} s$ (1) (1) $\rightarrow v_y = 5\times10^3 m/s - (3.16\times10^{13} m/s^2)(8\times10^{-8} s) = \boxed{-2.52\times10^6 m/s}$ (1) (1)

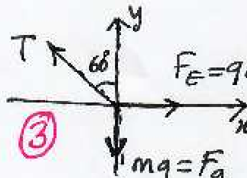
$\Rightarrow \boxed{\vec{v} = 3\times10^5 m/s\ \hat{i} + 2.52\times10^6 m/s(-\hat{j})}$ (2)

3. A small, nonconducting ball of mass $m = 2 \times 10^{-6}\ kg$ and charge $q = 4.0 \times 10^{-8}\ C$ (distributed uniformly through its volume) hangs from an insulating thread that makes an angle $\theta = 60°$ with a vertical, uniformly charged **nonconducting sheet** (shown in cross section).



Considering the gravitational force on the ball and assuming the sheet extends far vertically and into and out of the page, **calculate the surface charge density** σ **of the sheet.** (**Hint: The ball is in equilibrium (stationary).**)

$m = 2\times10^{-6}$ kg (non-conducting)
$q = 4\times10^{-8}$ C uniform distribution
non-conducting sheet
$E = \frac{\sigma}{2\varepsilon_0}$ $\sigma = ?$ (if hanged)



3

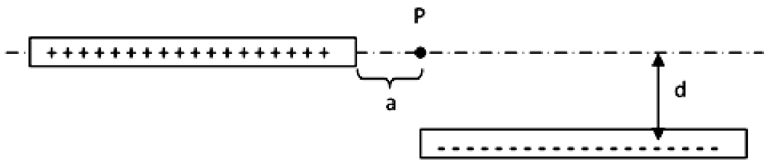
$F_E = qE$ 3 $T\cos 60° - mg = ma_y = 0$
3 $qE - T\sin 60° = ma_x = 0$
hangs → stationary

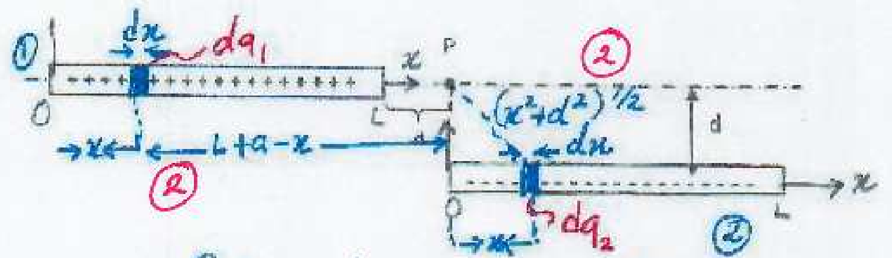
now, eliminate T

$\rightarrow qE - \left(\frac{mg}{\cos 60°}\right)\sin 60° = 0$ 3 $\rightarrow qE = mg\tan 60° \rightarrow q\frac{\sigma}{2\varepsilon_0} = mg\tan 60° \rightarrow \sigma = \frac{2mg\varepsilon_0\tan 60°}{q}$

$\rightarrow \sigma = \frac{2mg\varepsilon_0\tan 60°}{q}$ 3 $= \frac{2(2\times10^{-6}\,kg)(9.8\,m/s^2)(8.85\times10^{-12}\,C^2/N m^2)\tan 60°}{(4\times10^{-8}\,C)}$ 2 $= \boxed{15\times10^{-9}\,C/m^2}$ 2 1

4. Two very thin non-conducting rods are placed together as shown. Both rods have lengths of L and they carry uniform charges of $+q$ and $-q$ over their lengths. Find the potential at point P at a distance a and d from the positively and negatively charged rods as shown. Don't perform integration.





$$V_{1\,at\,P} = \int dV = \int \frac{1}{4\pi\varepsilon_0}\frac{dq_1}{r_1}$$

$dq_1 = \lambda\, dx$ 3

$r_1 = L + a - x$

$$V_{2\,at\,P} = \int dV = \int \frac{1}{4\pi\varepsilon_0}\frac{dq_2}{r_2}$$

3 $dq_2 = -\lambda\, dx$

$r_2 = \sqrt{x^2 + d^2}$

$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

$dV = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r}$ 2

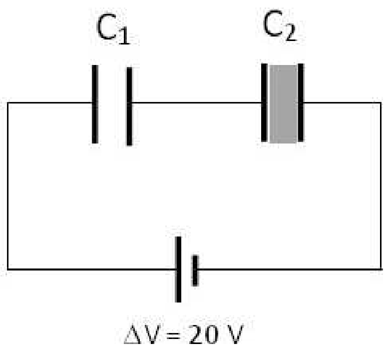
$dq = ?$

$dq = \lambda\, dx$ 2

$$\boxed{V_{tot} = V_{1\,at\,P} + V_{2\,at\,P}} = \boxed{\frac{\lambda}{4\pi\varepsilon_0}\left(\int_0^L \frac{dx}{(L+a-x)} - \int_0^L \frac{dx}{\sqrt{x^2+d^2}}\right)}$$

3 3

5. The parallel plate capacitors in the given circuit have the same plate area A and plate separation d. The capacitance of the air-filled capacitor is $C_1 = 6.0\mu\ F$. A dielectric slab of dielectric constant $\kappa = 2.0$ is placed between the plates of the second capacitor as shown. The voltage across the combination of capacitors is $\Delta V = 20\ V$ and the capacitors are fully charged.



i Find the equivalent capacitance of the combination of capacitors.

ii Calculate the energy stored in each capacitor.

iii Calculate the electric field in the second capacitor if the area of the capacitor is $100\ cm^2$.

i) Capacitors C_1 & C_2 are in series. $C = \kappa \frac{\varepsilon_0 A}{d}$ 1

C_1 : air filled $\rightarrow \kappa = 1 \Rightarrow C_1 = \varepsilon_0 \frac{A}{d} = 6.0\mu F$

C_2 : dielectric slab $\rightarrow \kappa = 2 \Rightarrow C_2 = \kappa C_1 = 12.0\mu F$ 1

$\Rightarrow \frac{1}{C_{eqv}} = \frac{1}{C_1} + \frac{1}{C_2} \Rightarrow \frac{1}{C_{eqv}} = \frac{1}{6\mu F} + \frac{1}{12\mu F} = \frac{18}{72\mu F} \Rightarrow \boxed{C_{eqv} = 4\mu F}$

1 2 1 1

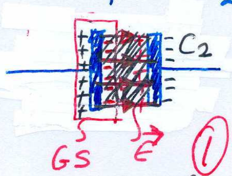
ii) In series $\rightarrow$ same charge on both capacitors 1

1 $q = q_1 = q_2$ & $\Delta V = 20\ V$ $\Big\}$ $C_{eqv} = \frac{q}{\Delta V} \rightarrow q = C_{eqv}\Delta V = (4\mu F)(20V) = \boxed{80\mu C}$ 1

$U = \frac{q^2}{2C}$ $\Big\{$ $U_1 = \frac{(80\mu C)^2}{2(6.0\mu F)} = \boxed{533.3\mu J}$ & $U_2 = \frac{(80\mu C)^2}{2\times(12\mu F)} = \boxed{266.6\mu J}$

1 1 1 1

iii)



1

$\varepsilon_0 \oint \kappa \vec{E} \cdot d\vec{A} = q$ 1

$\Rightarrow E = \frac{q}{\varepsilon_0 \kappa A} = \frac{80\times10^{-6}\ C}{(8.85\times10^{-12}\ F/m)(2.0)(10^{-2}\ m^2)} = \boxed{4.52\times10^{8}\ V/m}$

$A = 100\ cm^2 = 10^{-2}\ m^2$

2 1 1

İzmir Kâtip Çelebi University
Department of Engineering Sciences
Phy102 Physics II
Midterm Examination
November 11, 2021 17:00 – 18:30
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		15
1B		15
2		20
3		20
4		20
5		20
TOTAL		110

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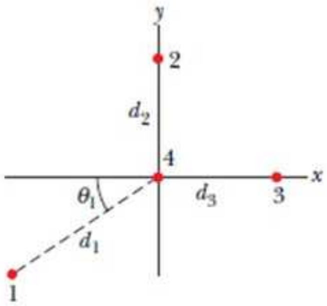
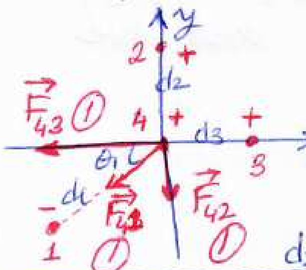
1. A) In figure, all four particles are fixed in the $xy-$plane, and $q_1 = -3.20 \times 10^{-19}\ C$, $q_2 = +3.20 \times 10^{-19}\ C$, $q_3 = +6.40 \times 10^{-19}\ C$, $q_4 = +3.20 \times 10^{-19}\ C$, $\theta_1 = 35.0°$, $d_1 = 3.00\ cm$ and $d_2 = d_3 = 2.00\ cm$.



What are the magnitude and direction of the net electrostatic force on particle 4 due to the other three particles?

Target particle: 4



$q_1 = -3.2 \times 10^{-19}\ C$
$q_2 = |q_1|$
$q_3 = 2|q_1|$
$q_4 = |q_1|$
$\theta_1 = 35°$
$d_1 = 3 \times 10^{-2}\ m$
$d_2 = d_3 = 2 \times 10^{-2}\ m$

$$\vec{F}_{4net} = \sum_{i=1}^{3} \vec{F}_{4i} = \vec{F}_{41} + \vec{F}_{42} + \vec{F}_{43} \quad 1$$

x & y - components

$$F_{4,net,x} = F_{43,x} + F_{41,x}$$
$$F_{4,net,y} = F_{42,y} + F_{41,y}$$

$$\Rightarrow F_{4net,x} = -F_{43} - |F_{41}| \cos 35$$
$$= -k\frac{|q_4||q_3|}{d_3^2} - k\frac{|q_4||q_1|}{d_1^2}\cos 35 \quad 1$$

$$F_{4net,y} = -F_{42} - |F_{41}| \sin 35° \quad 1$$
$$= -k\frac{|q_4||q_2|}{d_2^2} - k\frac{|q_4||q_1|}{d_1^2}\sin 35°$$

$$= -(8.99 \times 10^{9}\ Nm^2/C^2)(3.2 \times 10^{-19}\ C)^2\left(\frac{2}{(2 \times 10^{-2}\ m)^2} + \frac{\cos 35}{(3 \times 10^{-2}\ m)^2}\right) = \boxed{-5.44 \times 10^{-24}\ N} \quad 1 \quad 1$$

x-component

$$F_{4net,y} = -(8.99 \times 10^{9}\ Nm^2/C^2)(3.2 \times 10^{-19}\ C)^2\left(\frac{1}{(2 \times 10^{-2}\ m)^2} + \frac{\sin 35}{(3 \times 10^{-2}\ m)^2}\right) = \boxed{-2.89 \times 10^{-24}\ N} \quad 1 \quad 1$$

y-component

$$F_{4net} = \sqrt{F_{4net,x}^2 + F_{4net,y}^2} = \sqrt{(-5.44 \times 10^{-24}\ N)^2 + (-2.89 \times 10^{-24}\ N)^2} = \boxed{6.16 \times 10^{-24}\ N} \quad 1$$

1 magnitude

$$\tan\theta = \frac{F_{4net,y}}{F_{4net,x}} = \frac{-2.89 \times 10^{-24}}{-5.44 \times 10^{-24}} \leadsto \theta = \tan^{-1}\frac{-2.89}{-5.44} = \boxed{27.98 \approx 28°} \quad 1 \quad 1$$

$\boxed{\text{III. quadrant } \theta = 208°}$

1 angle

B) The density of conduction electrons in aluminum is $2.1 \times 10^{29}\ m^{-3}$. What is the drift velocity in an aluminum conductor that has a $2.0\ \mu m$ by $3.0\ \mu m$ rectangular cross section and when a 32.0 mA current flows through the conductor?

$n = 2.1 \times 10^{29}\ m^{-3}$
$i = 32 \times 10^{-3}\ A$
$A = (2 \times 10^{-6}\ m)(3 \times 10^{-6}\ m)$
$v_d = ?$

$\vec{J} = ne\vec{v}_d$

3 $J = nev_d$

3 $J = \frac{i}{A}$

$\frac{i}{A} = nev_d$

$$\Rightarrow v_d = \frac{i}{Ane} \overset{4}{=} \frac{32 \times 10^{-3}\ A}{(2 \times 10^{-6}\ m)(3 \times 10^{-6}\ m)(2.1 \times 10^{29}\ m^{-3})(1.602 \times 10^{-19}\ C)}$$

$$= \boxed{0.016\ m/s}$$

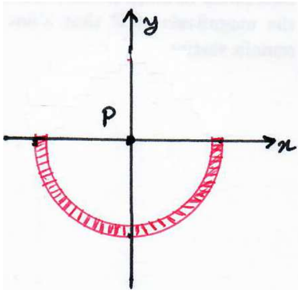
3 2

$$\frac{A}{m^2 m^{-3} C} \sim \frac{C/s}{m^2 m^{-3} C} \sim m/s$$

unit check

2. Semicircular wire shown in figure below has a non-uniform charge distribution $\lambda(\theta) = \lambda_0 Cos\theta$.

Find the electric field at point P in unit vector notation and in terms of total charge Q.
(Hint: $\int Cos^2 axdx = x/2 + Sin2ax/4a$)



$dE = \frac{k\,dq}{R^2} = \frac{k\lambda R d\theta}{R^2} = \frac{k\lambda d\theta}{R} \left\{ \lambda = \lambda_0 \cos\theta \right\} = \frac{k\lambda_0 \cos\theta}{R} d\theta$ 2 2

x-components are cancelling due to symmetry 2

$dE_y = |d\vec{E}|\cos\theta = \frac{k\lambda_0 \cos^2\theta\, d\theta}{R}$ 2 2 $\left\{ E_y = \int dE_y \right.$

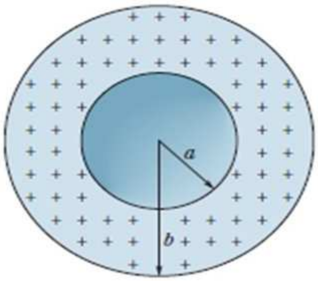
$E_y = E = \frac{k\lambda_0}{R}\int_{-\pi/2}^{\pi/2} \cos^2\theta\, d\theta = \frac{k\lambda_0}{R}\left(\frac{\theta}{2} + \frac{\sin 2\theta}{4}\right)\Big|_{-\pi/2}^{\pi/2}$ 2

$= \frac{k\lambda_0}{R}\frac{\pi}{2} \Rightarrow \vec{E} = \frac{k\lambda_0 \pi}{2R}(\hat{j})$ 2

in terms of Q $\left\{ Q = \int \lambda ds = \int_{-\pi/2}^{\pi/2} \lambda_0 \cos\theta R d\theta = \lambda_0 R \sin\theta \Big|_{-\pi/2}^{\pi/2} \right.$ 2 $= 2\lambda_0 R$

$\Rightarrow \vec{E} = \frac{1}{4\pi\epsilon_0}\frac{Q}{2R}\frac{\pi}{2R}\hat{j} = \boxed{\frac{Q}{16\pi\epsilon_0 R^2}\hat{j}}$ 2

3. Figure shows a spherical shell with uniform volume charge density $\rho = (1.56 \times 10^{-9}\ C/m^3$, inner radius $a = 10\ cm$, and outer radius $b = 2.00a$.

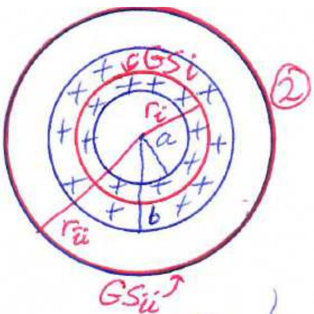


What is the magnitude of the electric field at radial distances

i $r = 1.5a$

ii $r = 3.00b$

Hints: Use Gauss' Law. Volume of the spherical shell: $\frac{4}{3}\pi(b^3 - a^3)$.



(2)

$\oint \vec{E}\cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$ (2), $\rho = \frac{q}{V} = \frac{q_{enc}}{V_{enc}}$ (2), $\vec{E} \parallel \vec{A}$ (2)

$\rho = 1.56\times10^{-9}\ C/m^3$

$a = 10\times10^{-2}\ m$

$b = 2a$

$r_i = 1.5a$

$r_{ii} = 3b$

$V_{ss} = \frac{4}{3}\pi(b^3 - a^3)$

i) $\oint \vec{E}\cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0} \rightsquigarrow E\,4\pi r_i^2 = \frac{q_{enc}}{\varepsilon_0}$ } $q_{enc} = ?$

GS_i

$\rightsquigarrow q_{enc} = \rho V_{enc} = \rho\frac{4}{3}\pi(r_i^3 - a^3)$ (2)

$\rightsquigarrow E\,4\pi r_i^2 = \rho\frac{4}{3}\frac{\pi(r_i^3 - a^3)}{\varepsilon_0}$ } $r_i = 1.5a$

$\Rightarrow E = \frac{\rho\,4/3\,\pi}{4\pi\varepsilon_0}\,\frac{((1.5a)^3 - a^3)}{1.5a^2} = \frac{\rho a}{3\varepsilon_0}\left(\frac{2.375}{2.25}\right)$ (2) (1)

$E(r=1.5a) = \frac{(1.56\times10^{-9}\ C/m^3)(10\times10^{-2}\ m)}{3 * 8.85\times10^{-12}\ C^2/(Nm^2)}\left(\frac{2.375}{2.25}\right) = \boxed{6.20\ N/C}$ (1)

ii) $E\,4\pi r_{ii}^2 = \frac{q_{enc}}{\varepsilon_0} \rightsquigarrow q_{enc} = \rho\frac{4}{3}\pi(b^3 - a^3)$ (2)

GS_{ii} $\rightsquigarrow E\,4\pi r_{ii}^2 = \rho\frac{4}{3}\frac{\pi(b^3 - a^3)}{\varepsilon_0}$ } $r_{ii} = 3b$

$\Rightarrow E = \frac{\rho\,4/3\,\pi}{4\pi\varepsilon_0}\,\frac{b^3 - a^3}{(3b)^2} = \frac{\rho\,7a}{108\,\varepsilon_0}$ (1) (1)

(2) $E(r=3b) = \frac{(1.56\times10^{-9}\ C/m^3)\,7\,(10\times10^{-10}\ m)}{108 * 8.85\times10^{-12}\ C^2/(Nm^2)} = \boxed{1.14\ N/C}$

4. The electric potential at points in an xy plane is given by $V = 4x^2 - 2y^3$. **In unit vector notations**, what is the electric field at point (1m, 2m)?

$$V(x,y) = 4x^2 - 2y^3 \quad \& \quad E_s = -\frac{\partial V}{\partial s}$$

$$\vec{E} = -\frac{\partial V}{\partial x}\hat{i} - \frac{\partial V}{\partial y}\hat{j} = -8x\,\hat{i} + 6y^2\,\hat{j}$$

5 5

$$\vec{E}(x = 1m, y = 2m) = \boxed{-8\,\hat{i} + 24\,\hat{j}}$$

5 5

5. In figure below, the parallel plate capacitor of plate area $2 \times 10^{-2}\ m^2$ is filled with two dielectric slabs , each with thickness 2.00 mm. One slab has dielectric constant 3.00, and the other, 4.00 . **How much charge** does the 7.00V battery store on the capacitor?

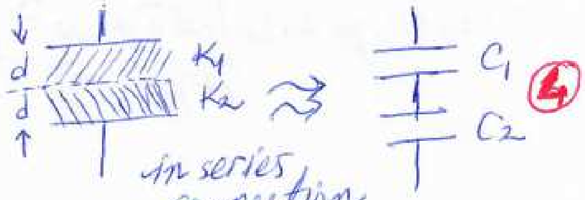
$A = 2\times10^{-2}\ m^2$

$d = 2\times10^{-3}\ m$

$K_1 = 3$ & $K_2 = 4$

$V = 7\ V$

$q = ?$



$C_1 = K_1 C_0 \overset{(3)}{=} K_1\, \varepsilon_0 \frac{A}{d} = 3\, \varepsilon_0 A/d$ (1)

$C_2 = K_2 C_0 \overset{(3)}{=} K_2\, \varepsilon_0 \frac{A}{d} = 4\, \varepsilon_0 A/d$ (1)

(1)

$\rightsquigarrow C_{eqv} = \frac{C_1 C_2}{C_1 + C_2} = \frac{12}{7}\, \varepsilon_0 A/d = \frac{12}{7}\left(8.85\times10^{-12}\ C^2/(N m^2)\right) \frac{2\times10^{-2}\ m^2}{2\times10^{-3}\ m}$

$= 1.52\times10^{-10}\ F$ (2) (1)

$\frac{C^2}{N m^2}\ \frac{m^2}{m} \sim F \sim \frac{Q}{V} = \frac{Q}{U/Q} = \frac{Q^2}{Fx}$

unit check

$C_{eqv} = \frac{Q}{V} \rightsquigarrow q = C_{eqv} V$ (1)

$= (1.52\times10^{-10}\ F)\ 7V = \boxed{1.06\times10^{-9}\ C}$ (2) (1)

İzmir Kâtip Çelebi University
Department of Engineering Sciences
Phy102 Physics II
Midterm Examination
November 03, 2019 15:30 – 17:30
Good Luck!

NAME-SURNAME:

SIGNATURE:

ID:

DEPARTMENT:

INSTRUCTOR:

DURATION: 120 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		15
1B		15
2		20
3		20
4		20
5		20
TOTAL		110

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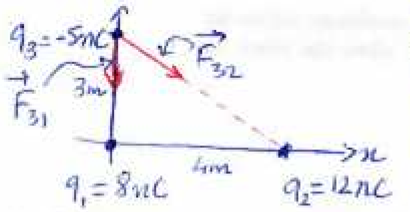
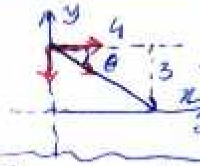
1. A) A point charge $q_1 = 8\ nC$ is at the origin and a second point charge $q_2 = 12\ nC$ is on the x-axis at x=4 m. Find the net electric force they exert on $q_3 = -5\ nC$ located on the y-axis at y=3.0 m in vector notation, magnitude and angle.



$\vec{F}_{3,net} = \vec{F}_{31} + \vec{F}_{32}$

$|\vec{F}_{31}| = k \dfrac{|q_3||q_1|}{r_{31}^2} = \left(9\times10^9 \dfrac{Nm^2}{C^2}\right) \dfrac{|5\times10^{-9}C||8\times10^{-9}C|}{(3m)^2}$

$= \underline{4\times10^{-8}N} \rightarrow \underline{\vec{F}_{31} = 4\times10^{-8}N(-\hat{j})}$



$\cos\theta = \frac{4}{5} = 0.8$

$\sin\theta = \frac{3}{5} = 0.6$

$|\vec{F}_{32}| = k \dfrac{|q_3||q_2|}{r_{32}^2} = \left(9\times10^9 \dfrac{Nm^2}{C^2}\right) \dfrac{|-5\times10^{-9}C||12\times10^{-9}C|}{(4m)^2}$

$= \underline{2.16\times10^{-8}N} \sim \vec{F}_{32} = ?$

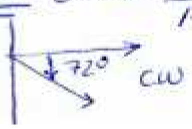
$F_{32,x} = |\vec{F}_{32}|\cos\theta = 2.16\times10^{-8}N \times 0.8 = 1.73\times10^{-8}N$

$F_{32,y} = |\vec{F}_{32}|\sin\theta = 2.16\times10^{-8}N \times 0.6 = 1.3\times10^{-8}N$

$\underline{\vec{F}_{32} = 1.7\times10^{-8}N\hat{i} + 1.3\times10^{-8}N(-\hat{j})}$

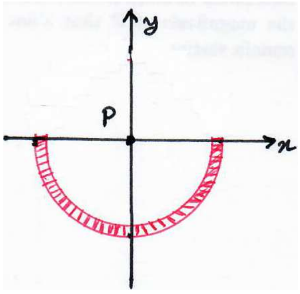
$\Rightarrow \vec{F}_{3,net} = (4.0\times10^{-8}(-\hat{j}) + 1.73\times10^{-8}N\hat{i} + 1.3\times10^{-8}(-\hat{j}))N = \underline{1.73\times10^{-8}N\hat{i} - 5.3\times10^{-8}\hat{j}}$

$|\vec{F}_{3,net}| = \sqrt{(1.73\times10^{-8}N)^2 + (-5.3\times10^{-8}N)^2} = \underline{5.6\times10^{-8}N}$ $\quad \theta = \tan^{-1}\dfrac{-5.3}{1.73} \cong -72^\circ$



B) Semicircular wire shown in figure below has a non-uniform charge distribution $\lambda(\theta) = \lambda_0 Cos\theta$.

Find the electric field at point P in unit vector notation and in terms of total charge Q.
(Hint: $\int Cos^2 ax dx = x/2 + Sin2ax/4a$)



2

$dE = \frac{k\,dq}{R^2} = \frac{k\lambda R d\theta}{R^2} = \frac{k\lambda d\theta}{R} \left\{ \lambda = \lambda_0 Cos\theta \right\} = \frac{k\lambda_0 Cos\theta}{R} d\theta$ 2

x-components are cancelling due to symmetry 2

$dE_y = |d\vec{E}| Cos\theta = \frac{k\lambda_0 Cos^2\theta d\theta}{R}$ 2 $\left\{ E_y = \int dE_y \right.$ 2

$E_y = E = \frac{k\lambda_0}{R} \int_{-\pi/2}^{\pi/2} Cos^2\theta d\theta = \frac{k\lambda_0}{R} \left(\frac{\theta}{2} + \frac{Sin2\theta}{4} \right) \Big|_{-\pi/2}^{\pi/2}$ 2

$= \frac{k\lambda_0}{R} \frac{\pi}{2} \rightsquigarrow \vec{E} = \frac{k\lambda_0 \pi}{2R} (\hat{j})$ 2

in terms of Q $\left\{ Q = \int \lambda ds = \int_{-\pi/2}^{\pi/2} \lambda_0 Cos\theta R d\theta = \lambda_0 R Sin\theta \Big|_{-\pi/2}^{\pi/2} \right.$ 2 $= 2\lambda_0 R$

$\Rightarrow \vec{E} = \frac{1}{4\pi\varepsilon_0} \frac{Q}{2R} \frac{\pi}{2R} \hat{j} = \boxed{\frac{Q}{16\pi\varepsilon_0 R^2} \hat{j}}$ 2

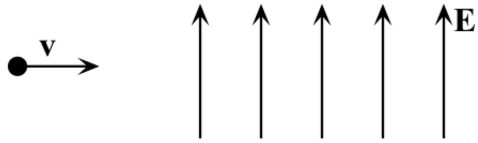
2. A proton moves at $4.5 \times 10^5\ m/s$ in the horizontal direction. It enters a uniform vertical electric field with a magnitude of $9.6 \times 10^3\ N/C$.

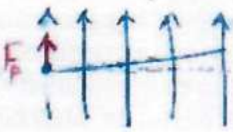
Ignoring any gravitational effects, find

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)

$v = v_x + v_y = 0$ Constant $\vec{E}$ ~ constant,

$a = a_y$ & $a_x = 0$ acceleration ~ force

$qE = ma$

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

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

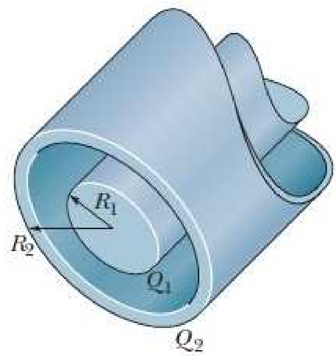
$y = y_0 + v_{0y}t + \frac{1}{2}a_y t^2$ (1) $\rightarrow y - y_0 = h = \frac{1}{2}a_y t^2 = \frac{1}{2}(9.21\times10^{11}\ m/s^2)(1.11\times10^{-7}\ s)^2$ (1) (1)

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

iii) $v_x = v_{0x} = 4.5\times10^5\ m/s$ (1)

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

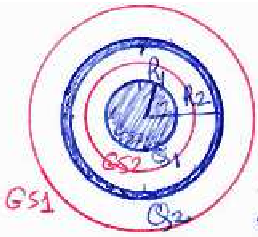
3. Figure below shows a section of a conducting rod of radius $R_1 = 1.30\ mm$ and length $L = 11.00\ m$ inside a thin-walled coaxial conducting cylindrical shell of radius $R_2 = 10.0R_1$ and the (same) length L. The net charge on the rod is $Q_1 = +3.40 \times 10^{-12}\ C$; that on the shell is $Q_2 = -2.00Q_1$



i What are the magnitude E and direction (radially inward or outward) of the electric field at radial distance $r = 2.00R_2$?

ii What are E and the direction at $r = 5.00R_1$?

iii What is the charge on the interior and exterior surface of the shell?



$R_1 = 1.30 \times 10^{-3} m$
$R_2 = 10.0 R_1 = 1.30 \times 10^{-2} m$
$L = 11.00 m$

$Q_1 = +3.40 \times 10^{-12} C$ (on rod)
$Q_2 = -2Q_1 = -6.80 \times 10^{-12} C$ (on shell)
$\oint \vec{E} d\vec{A} = \frac{q_{enc}}{\varepsilon_0}$ & cylindrical Gaussian surface

i) GS1: $r = 2R_2 \rightsquigarrow E\, 2\pi r L = \frac{Q_1 + Q_2}{\varepsilon_0} \Rightarrow E = \frac{3.4 \times 10^{-12} C - 6.8 \times 10^{-12} C}{2\pi\, 2 \times 1.30 \times 10^{-2} m\, 11m\, \varepsilon_0}$

$\vec{E}$ $\hat{r}_1$ $\rightsquigarrow E = -0.214\ N/C \rightsquigarrow |\vec{E}| = \underline{\underline{0.214\ N/C\ \&\ \text{inward}}}$

ii) GS2: $r = 5R_1 \rightsquigarrow E\, 2\pi r L = \frac{Q_1}{\varepsilon_0} \rightsquigarrow E = \frac{3.4 \times 10^{-12} C}{2\pi\, 5 \times 1.30 \times 10^{-3} m\, 11m\, 8.85 \times 10^{-12} C^2/Nm^2}$

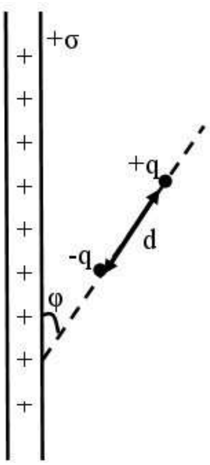
$\hat{r}_2$ $\vec{E}$ $\rightsquigarrow E = 0.855\ N/C \rightsquigarrow |\vec{E}| = \underline{\underline{0.855\ N/C\ \&\ \text{outward}}}$

iii) Q_1 $-Q_1$ $Q_2 - (-Q_1)$ $\rightarrow$ $3.4 \times 10^{-12} C$ $\underline{\underline{-3.4 \times 10^{-12} C}}$ $-6.8 \times 10^{-12} C - (-3.4 \times 10^{-12} C)$
rod {shell}
(outer) (inner) (outer)

$\underline{\underline{-3.4 \times 10^{-12} C}}$

sum up to $-6.8 \times 10^{-12} C$

4. An electric dipole of two opposite charges of magnitude $q = 1.50\ \mu C$, separated by a distance $d = 1.20\ cm$ is placed near an infinitely large plane of charge of uniform charge density $\sigma = 1.77\ \mu C/m^2$. The axis of the electric dipole makes an angle of $\varphi = 37°$ with the plane, as shown in the figure.

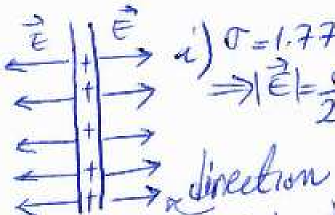


i Find the magnitude of the electric field due to the plane. Show its direction on the figure.

ii Calculate the magnitude of the electric dipole moment. Show its direction on the figure.

iii Calculate the magnitude of the torque acting on the electric dipole. Show its direction on the figure.

iv How much work must be done by an external agent to turn the electric dipole by 90° in clockwise direction?



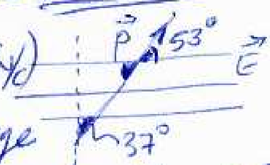
i) $\sigma = 1.77\times10^{-6}\ C/m^2$ & non-conducting plane (uniform charge density)

$\Rightarrow |\vec{E}| = \dfrac{\sigma}{2\varepsilon_0} = \dfrac{1.77\times10^{-6}\ C/m^2}{2\times8.85\times10^{-12}\ C^2/Nm^2} = \underline{10^5\ N/C}$ magnitude

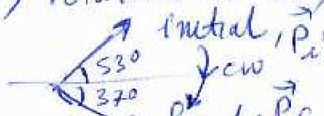
ii) $p = qd$ $\left\{ \ominus \xrightarrow[\vec{p}]{d} \oplus \right\}$ $p = 1.50\times10^{-6}\ C \times 1.20\times10^{-2}\ m = \underline{1.8\times10^{-8}\ Cm}$

iii) $\vec{\tau} = \vec{p}\times\vec{E} \Rightarrow |\vec{\tau}| = |\vec{p}||\vec{E}|\sin 53 = (1.8\times10^{-8}\ Cm)(10^5\ N/C)\sin 53$

$= 1.44\times10^{-3}\ Nm$ ⊗ into the page



iv) rotation in cw, 90°



$W_{ext} = -\Delta U = -U_f + U_i = U_i - U_f$ $\{U = \vec{p}\cdot\vec{E}$

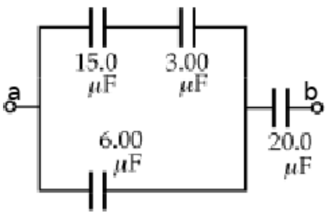
$= \vec{p}_i\cdot\vec{E} - \vec{p}_f\cdot\vec{E}$

$= |\vec{p}||\vec{E}|\cos 53 - |p||E|\cos 37°$

$= (1.8\times10^{-8}\ Cm)(10^5\ N/C)(\cos 53° - \cos 37°)$

$= \underline{-3.6\times10^{-4}\ J}$ $\quad J \equiv Nm$

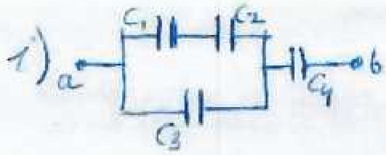
5. Four capacitors are connected as shown in Figure.



i Find the equivalent capacitance between points a and b.

ii Calculate the charge on each capacitor if $\Delta V_{ab} = 15.0\ V$.

1)



$C_{12} = \frac{C_1 C_2}{C_1 + C_2} = \frac{(15\times10^{-6}F)(3\times10^{-6}F)}{18\times10^{-6}F} = 2.5\times10^{-6}F$ (3)

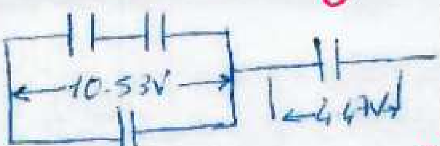
$C_{123} = C_{12} + C_3 = 2.5\times10^{-6}F + 6\times10^{-6}F = 8.5\times10^{-6}F$ (3)

$C_{eqv} = C_{1234} = \frac{C_{123} C_4}{C_{123} + C_4} = \frac{(8.5\times10^{-6}F)(20\times10^{-6}F)}{28.5\times10^{-6}F} = 5.97\times10^{-6}F = 5.97\mu F$ (3)

ii) $C = \frac{Q}{V} \rightarrow Q_{eqv} = Q_{1234} = C_{eqv} V = 5.97\times10^{-6}F \times 15V = \boxed{89.47\mu C}$ (3)

$\rightarrow Q_4 = Q_{123} = Q_{eqv} = 89.47\mu C$ (1) $\rightarrow V_4 = \frac{89.47\mu C}{20\mu F} = 4.47\ V \leftarrow$ (4) (1) (1)

$\rightarrow$



(1) $10.53V \leftarrow$ (3) $\rightarrow Q_3 = C_3 V_3 = \boxed{63.18\mu C}$ (3)

$Q_{12} = C_{12} V = (2.5\times10^{-6}F)\,10.53V = Q_1 = Q_2$

$\rightarrow Q_1 = Q_2 = \boxed{2.63\mu C}$ (1) (1)

$\Rightarrow V_1 = \frac{Q_1}{C_1} = \frac{2.63\mu C}{15\mu F} = 1.75V$ (1) $\leftarrow$ (1)

$V_2 = \frac{Q_1}{C_2} = 8.78V \leftarrow$ (2) (1)

İzmir Kâtip Çelebi University
Department of Engineering Sciences
Phy102 Physics II
Midterm Examination
November 06, 2018 16:30 – 18:30
Good Luck!

NAME-SURNAME:

SIGNATURE:

ID:

DEPARTMENT:

DURATION: 120 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		15
1B		15
2		20
3		20
4		20
5		20
TOTAL		110

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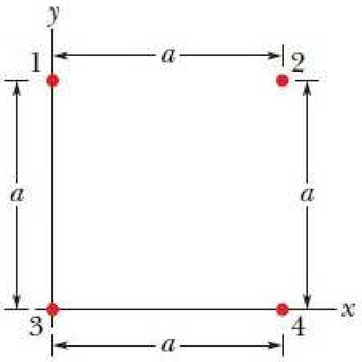
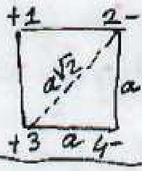
1. A) In Figure, four particles form a square.

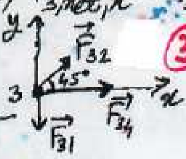


The particles have charges $q_1 = -q_2 = 100\ nC$ and $q_3 = -q_4 = 200\ nC$, and distance $a = 5.0\ cm$. What are the x and y components of the net electrostatic force on particle 3?

$q_1 = 100\times10^{-9}C$
$q_2 = -q_1$
$q_3 = 200\times10^{-9}C$
$q_4 = -q_3$
$a = 5\times10^{-2}m$



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



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

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

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

$$= \boxed{0.169N}$$ 1 1

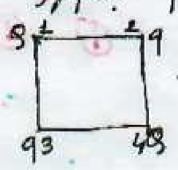
$$F_{3,net,y} = \frac{k|q_3|}{a^2}\left(\frac{|q_2|}{2}\frac{\sqrt{2}}{2} - |q_1|\right) = \frac{8.99\times10^{9}Nm^2/C^2(200\times10^{-9}C)}{(5\times10^{-2}m)^2}\left(|100\times10^{-9}C|\frac{\sqrt{2}}{4} - |100\times10^{-9}C|\right)$$

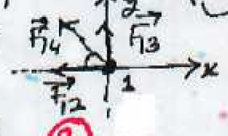
$$= \boxed{-0.046N}$$ 1 1

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

$|\vec{F}_{1,net}| = 0 \rightsquigarrow F_{1,net,x} = 0$ & $F_{1,net,y} = 0$ 2
$|\vec{F}_{4,net}| = 0$

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





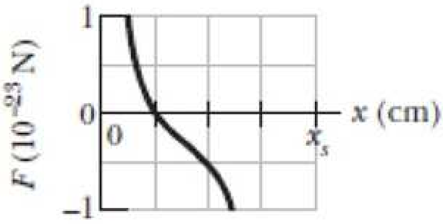
3

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

$$\rightsquigarrow \frac{Q}{q} = -\frac{4}{\sqrt{2}} = -2\sqrt{2} = \boxed{-2.83}$$ 2

B) In Figure (a), particle 1 (of charge q_1) and particle 2 (of charge q_2) are fixed in place on an x-axis, 8.00 cm apart. Particle 3 (of charge $q_3 = +8.00 \times 10^{-19}\ C$) is to be placed on the line between particles 1 and 2 so that they produce a net electrostatic force $F_{3,net}$ on it.

(a)



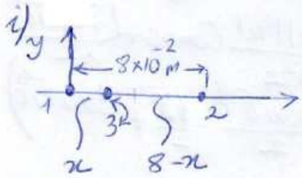
(b)

Figure (b) gives the x component of that force versus the coordinate x at which particle 3 is placed. The scale of the x axis is set by $x_s = 8.0\ cm$.

i What is the sign of charge q_1?

ii What is the ratio q_2/q_1?

i)



if − + − $\overleftarrow{F_{31}}\ \overrightarrow{F_{32}}$ ✓ but Figure(b)

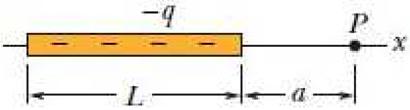
if + + + $\overleftarrow{F_{32}}\ \overrightarrow{F_{31}}$ ✓ when $x > 2$ repulsive force (positive value) → q_1 should be (+)

ii) $F_{3,net}(x=2) = 0 \rightarrow |F_{32}(x=2)| = |F_{31}(x=2)|$

$$k\frac{|q_3||q_2|}{(8-x)^2} = k\frac{|q_3||q_1|}{x^2} \quad \text{when } x = 2\times10^{-2}\ m$$

$$\frac{q_2}{(6\times10^{-2}\ m)^2} = \frac{q_1}{(2\times10^{-2}\ m)^2} \rightarrow \boxed{\frac{q_2}{q_1} = 9}$$

2. In the figure below, a nonconducting rod of length $L = 8.15\ cm$ has a charge $q = -4.23\ fC$ uniformly distributed along its length.



i What is the linear charge density of the rod?

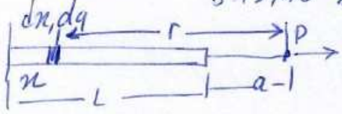
ii What are the magnitude and direction (relative to the $+x$-axis) of the electric field produced at point P, at distance $a = 12.0\ cm$ from the rod?

iii What is the electric field magnitude produced at distance $a = 50.0\ cm$ by the rod?

iv What is the electric field magnitude produced at distance $a = 50.0\ cm$ by <u>*a particle of charge*</u> $q = -4.23\ fC$ that replaces the rod?

i) $\lambda = \frac{Q}{L} = \frac{-4.23\times10^{-15}C}{8.15\times10^{-2}m} = \underline{\underline{-5.19\times10^{-14}C/m}}$

ii)



$\rightsquigarrow r = L+a-x$

$dE = k\frac{dq}{r^2} = k\frac{\lambda dx}{(L+a-x)^2}$ $\Big\}$ $E = \int_0^L dE$

$E_p = k\lambda\int_0^L \frac{dx}{(L+a-x)^2} = k\lambda \frac{1}{(L+a-x)}\Big|_0^L = k\lambda\left(\frac{1}{a} - \frac{1}{L+a}\right)$

$= 8.99\times10^9\frac{Nm^2}{C^2}\left(\underset{(-\hat{\imath})}{-5.19\times10^{-14}\frac{C}{m}}\right)\left(\frac{L}{a(L+a)}\right) = 4.67\times10^{-4}\frac{Nm}{C}$

$\Rightarrow$ $L = 8.15\times10^{-2}m$, $a = 12\times10^{-2}m$ $\Big\}$ $E_p = 4.67\times10^{-4}Nm/C\left(\frac{8.15\times10^{-2}m}{(12\times10^{-2}m)20.15\times10^{-2}m}\right) = \boxed{1.57\times10^{-3}\frac{N}{C}}$ $(\ )$

iii) $L = 8.15\times10^{-2}m$, $a = 50\times10^{-2}m$ $\Big\}$ $E_p = 4.67\times10^{-4}Nm/C\left(\frac{8.15\times10^{-2}m}{(50\times10^{-2}m)58.15\times10^{-2}m}\right) = \boxed{1.31\times10^{-4}N/C}$

iv) Point charge: $E_p = k\frac{|q|}{r^2} = 8.99\times10^9\frac{Nm^2}{C^2}\,\frac{4.23\times10\times10^{-15}C}{(50\times10^{-2}m)^2} = \boxed{1.54\times10^{-4}N/C}$

3. An infinitely long cylindrical insulating shell of inner radius a and outer radius b has a uniform volume charge density ρ. A line of uniform linear charge density λ, is placed along the axis of the shell. Determine the electric field in the following regions:

   i $r < a$

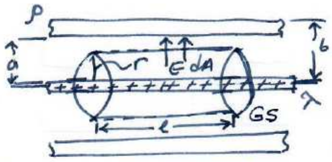
   ii $a < r < b$

   iii $r > b$

i) $r < a$

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

$E(2\pi r \ell) = \frac{Q_{enc}}{\varepsilon_0}$



$\boxed{E = \frac{\lambda}{2\pi \varepsilon_0 r}}$

$Q_{line} = \lambda \ell$

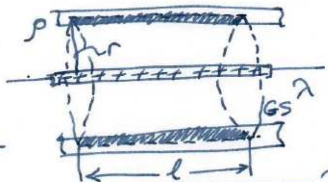
$Q_{cylinder} = \phi$ (shell theorem)

$\rightsquigarrow Q_{enc} = \lambda \ell + \phi$

ii) $a < r < b$

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

$E(2\pi r \ell) = \frac{Q_{enc}}{\varepsilon_0}$



$Q_{line} = \lambda \ell$

$Q_{cylinder} = \rho * \text{Volume}$

$= \rho * (\pi r^2 \ell - \pi a^2 \ell)$

$= \pi \ell \rho (r^2 - a^2)$

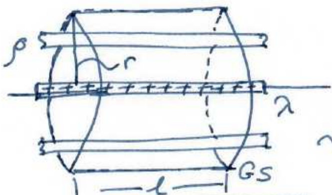
$\rightsquigarrow Q_{enc} = \lambda \ell + \pi \ell \rho (r^2 - a^2)$

$\boxed{E = \frac{\lambda + \rho \pi (r^2 - a^2)}{2\pi r}}$

iii) $r > b$

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

$E(2\pi r \ell) = \frac{Q_{enc}}{\varepsilon_0}$



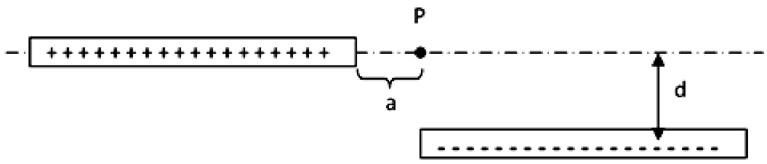
$Q_{line} = \lambda \ell$

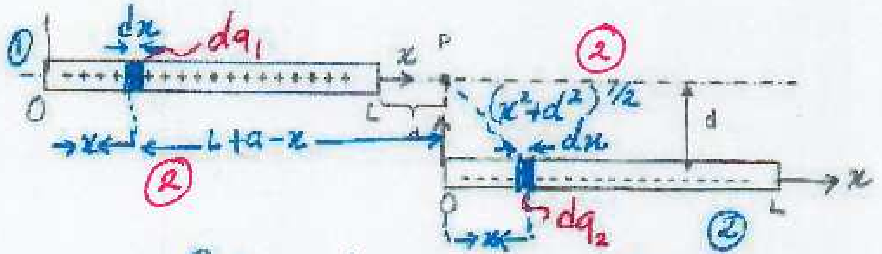
$Q_{cylinder} = \rho (\pi b^2 \ell - \pi a^2 \ell)$

$\rightsquigarrow Q_{enc} = \lambda \ell + \rho \ell \pi (b^2 - a^2)$

$\boxed{E = \frac{\lambda + \rho \pi (b^2 - a^2)}{2\pi r}}$

4. Two very thin non-conducting rods are placed together as shown. Both rods have lengths of L and they carry uniform charges of $+q$ and $-q$ over their lengths. Find the potential at point P at a distance a and d from the positively and negatively charged rods as shown. Don't perform integration.





$$V_{1\,at\,P} = \int dV = \int \frac{1}{4\pi\varepsilon_0}\frac{dq_1}{r_1}$$

$dq_1 = \lambda\, dx$ (3)

$r_1 = L+a-x$

$$V_{2\,at\,P} = \int dV = \int \frac{1}{4\pi\varepsilon_0}\frac{dq_2}{r_2}$$

(3) $dq_2 = -\lambda\, dx$

$r_2 = \sqrt{x^2+d^2}$

$V = \frac{1}{4\pi\varepsilon_0}\frac{q}{r}$

$dV = \frac{1}{4\pi\varepsilon_0}\frac{dq}{r}$ (2)

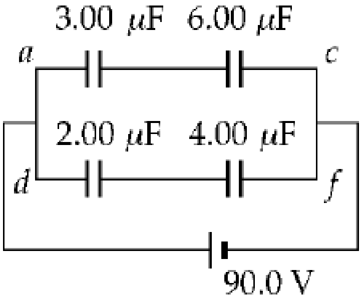
$dq = ?$

$dq = \lambda\, dx$ (2)

$$\boxed{V_{tot} = V_{1\,at\,P} + V_{2\,at\,P}} = \boxed{\frac{\lambda}{4\pi\varepsilon_0}\left(\int_0^L \frac{dx}{(L+a-x)} - \int_0^L \frac{dx}{\sqrt{x^2+d^2}}\right)}$$

(3) (3)

5. For the system of capacitors shown in Figure,



find

i the equivalent capacitance of the system,

ii the potential across each capacitor,

iii the charge on each capacitor.

i) $C_{eqv} = ?$ $3 \,||\, 6 \,||$ — $\sim \frac{1}{C_{ac}} = \frac{1}{3\mu F} + \frac{1}{6\mu F} \Rightarrow C_{ac} = 2\mu F$

$2 \,||\, 4 \,||$ — $\sim \frac{1}{C_{df}} = \frac{1}{2\mu F} + \frac{1}{4\mu F} \Rightarrow C_{df} = 1.33\mu F$ 2

$\Rightarrow C_{eqv} = 3.33\,\mu F$ 2 1

ii) $C = \frac{Q}{V} \sim Q = C_{eqv} \cdot V = (3.33\times 10^{-6} F)\, 90V = 299.7\,\mu C$ 2 (total charge)

$Q_{ac} = (2\mu F)\, 90V = 180\,\mu C = q_a = q_c$ 2

$Q_{df} = (1.33\mu F)\, 90V = 119.7\,\mu C = q_d = q_f$ 2

iii) $V_a = \frac{q_a}{C_a} = \frac{180\mu C}{3\mu F} = \boxed{60V}$ 1

$V_c = \frac{180\mu C}{6\mu F} = \boxed{30V}$ 1

$V_d = \frac{119.7\mu C}{2\mu F} \simeq \boxed{60V}$ 1

$V_f = \frac{119.7\mu C}{4\mu F} \simeq \boxed{30V}$ 1