

EXAM 2

1

Name: _____ unid: u _____

Discussion TA (circle): Adam Bill Doug Eric

- A. [7 pts.] A plate carries a charge of $-4.1 \mu\text{C}$, while a rod carries a charge of $+2.4 \mu\text{C}$. How many electrons must be transferred from the plate to the rod, so that both objects have the same charge?

Before touching plate and rod, Electron transferred on rod
 $Q_p = -4.1 \mu\text{C}, Q_r = +2.4 \mu\text{C}$
 After touching charge is same
 $Q = \frac{Q_p + Q_r}{2} = \frac{(-4.1 + 2.4) \mu\text{C}}{2} = -0.85 \mu\text{C}$
 $n = \frac{Q_p - Q}{e} = \frac{-3.25 \mu\text{C}}{-1.6 \times 10^{-19} \text{C}} = 2.03 \times 10^{13} \text{ electrons}$

- B. [5 pts.] Two charges attract each other with a force of 2.0 N. What will be the force if the distance between them is reduced to one-ninth of its original value?

$q_1 \xrightarrow{r} q_2$ $q_1 \xrightarrow{r/9} q_2$

$$F_{12} = \frac{kq_1q_2}{r^2} \quad F'_{12} = \frac{kq_1q_2}{(r/9)^2}$$

$$F'_{12} = 81 \left(\frac{kq_1q_2}{r^2} \right) = 81 F_{12} = 81 \times 2 \text{ N}$$

$F'_{12} = 162 \text{ N}$

- C. [7 pts.] Two parallel plate capacitors have circular plates. The magnitude of the charge on these plates is the same. However, the electric field between the plates of the first capacitor is $2.10 \times 10^5 \text{ N/C}$, while the field within the second capacitor is $5.80 \times 10^5 \text{ N/C}$. Determine the ratio r_2/r_1 of the plate radius for the second capacitor to the plate radius for the first capacitor.

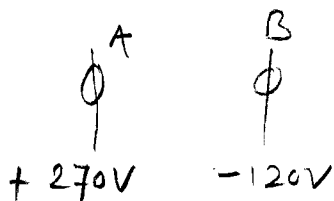
Electric field between the parallel plate capacitors is

$$E = \frac{\sigma}{\epsilon_0} = \frac{Q}{A\epsilon_0}$$

$$\frac{E_1}{E_2} = \frac{r_2^2}{r_1^2} \Rightarrow \frac{r_2}{r_1} = \sqrt{\frac{E_1}{E_2}}$$

$$E_1 = \frac{Q}{\pi r_1^2 \epsilon_0} \quad E_2 = \frac{Q}{\pi r_2^2 \epsilon_0} = \sqrt{\frac{2.10 \times 10^5 \text{ N/C}}{5.80 \times 10^5 \text{ N/C}}} = 0.6017$$

- D. [6 pts.] Point A is at a potential of +270 V, and point B is at a potential of -120 V. An α -particle is a helium nucleus that contains two protons and two neutrons; the neutrons are electrically neutral. An α -particle starts from rest at A and accelerates toward B. When the α -particle arrives at B, what kinetic energy (in electron volts) does it have?



$$W = -q(\Delta V)$$

$$= -2e(-120 \text{ V} - 270 \text{ V})$$

$$= -2e(-390 \text{ V})$$

$W = 780 \text{ eV}$

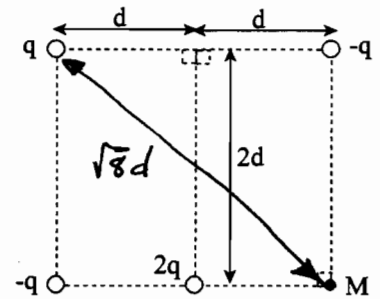
EXAM 2

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Name: Key unid: u _____

Discussion TA (circle): Adam Bill Doug Eric

A. [10 pts.] What is the potential at point M in the figure to the right caused by the four charges? Use $q = 3.0 \mu\text{C}$ and $d = 10 \text{ cm}$.



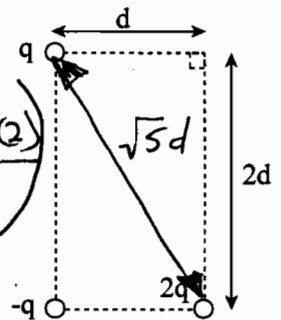
$$V = \sum \frac{kq}{r} = \frac{kq}{d} \left(\frac{1}{\sqrt{8}} - \frac{1}{2} + \frac{2}{1} - \frac{1}{2} \right)$$

$$= \frac{kq}{d} \left(1 + \frac{1}{\sqrt{8}} \right)$$

$$= \frac{(8.99 \text{ E}9 \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}) (3 \text{ E}-6 \text{ C}) \left(1 + \frac{1}{\sqrt{8}} \right)}{(0.1 \text{ m})} = 365,053 \text{ Volts}$$

$$\frac{\text{N}}{\text{C}} = \frac{\text{Newton}}{\text{Coulomb}} = \text{Volt}$$

B. [15 pts.] What is the electrostatic potential energy of the three-charge configuration shown to the right?



$$U_E = \sum \frac{kq_1 q_2}{r} = \frac{kq^2}{d} \left(\frac{(1)(2)}{\sqrt{5}} + \frac{(-1)(1)}{2} + \frac{(-1)(2)}{1} \right)$$

$$= \frac{kq^2}{d} \left(\frac{2}{\sqrt{5}} + \frac{-1}{2} - 2 \right)$$

$$= \frac{(8.99 \text{ E}9 \frac{\text{N}\cdot\text{m}^2}{\text{C}^2}) (3 \text{ E}-6 \text{ C})^2 \left(\frac{2}{\sqrt{5}} - \frac{5}{2} \right)}{(0.1 \text{ m})} = -1.299 \text{ J}$$

$$\text{N}\cdot\text{m} = \text{Joule}$$

EXAM 2

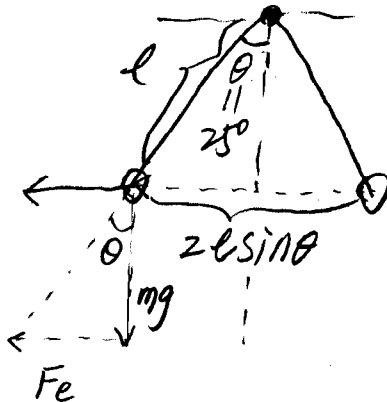
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Name: Famin

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Discussion TA (circle): Adam Bill Doug Eric

- A. [12 pts.] Two identical small insulating balls are suspended by separate 0.32 m threads that are attached to a common point on the ceiling. Each ball has a mass of 7.80×10^{-4} kg. Initially the balls are uncharged and hang straight down. They are then given identical positive charges and, as a result, they spread apart with an angle of 50° between the threads. What is the charge on each ball?



$$mg \tan \theta = \frac{q^2}{4\pi\epsilon_0 (2l \sin \theta)^2} = F_e$$

$$q = 2l \sin \theta \left(4\pi\epsilon_0 mg \tan \theta \right)^{\frac{1}{2}}$$

$$= 2 \times 0.32 \text{ m} \sin 25^\circ \sqrt{\frac{7.8 \times 10^{-4} \text{ kg} \cdot 9.8 \text{ m/s}^2 \tan 25^\circ}{8.99 \times 10^9 \text{ N}\cdot\text{m}^2/\text{C}^2}}$$

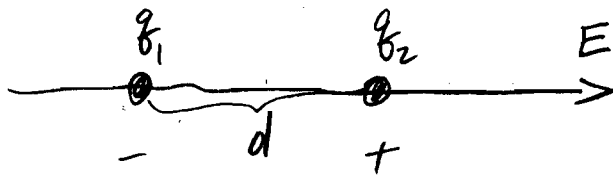
$$= 1.7 \times 10^{-7} \text{ C}$$

$$= 170 \text{ nC}$$

- B. [13 pts.] Two particles are in a uniform electric field whose value is $+2700 \text{ N/C}$. The mass and charge of particle 1 are $m_1 = 2.90 \times 10^{-5} \text{ kg}$ and $q_1 = -9.0 \mu\text{C}$, while the corresponding values for particle 2 are $m_2 = 3.00 \times 10^{-5} \text{ kg}$ and $q_2 = +12.0 \mu\text{C}$. Initially the particles are at rest. The particles are both located on the same electric field line but are separated from each other by a distance d . When released, they accelerate but always remain at this same distance from each other. Find the separation distance d .

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3.B



For particle 1: $m_1 a = q_1 (E - k \frac{q_2}{d^2})$ (1)

2: $m_2 a = q_2 (E + k \frac{q_1}{d^2})$ (2)

$$\frac{(1)}{m_1} = \frac{(2)}{m_2} \Rightarrow \frac{q_1}{m_1} (E - k \frac{q_2}{d^2}) = \frac{q_2}{m_2} (E + k \frac{q_1}{d^2})$$

$$\left(\frac{q_1}{m_1} - \frac{q_2}{m_2} \right) E = \left(\frac{k q_1 q_2}{m_2} + \frac{k q_1 q_2}{m_1} \right) \frac{1}{d^2}$$

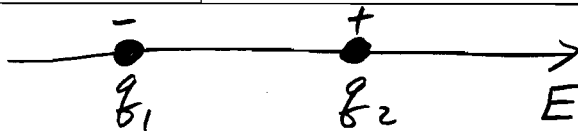
$$(m_2 q_1 - m_1 q_2) E = k q_1 q_2 (m_1 + m_2) \frac{1}{d^2}$$

$$d = \sqrt{\frac{k q_1 q_2 (m_1 + m_2)}{(m_2 q_1 - m_1 q_2) E}}$$

$$= \sqrt{\frac{8.99 \times 10^9 (2.9 \times 10^{-5} + 3.0 \times 10^{-5}) (-9 \times 10^{-6}) (12 \times 10^{-6})}{(3.0 \times 10^{-5}) (-9 \times 10^{-6}) - (2.9 \times 10^{-5}) (12 \times 10^{-6}) 2700}}$$

$$= 5.859 \text{ (m)}$$

For particle 1



$$F_1 = m_1 a = q_1 \left(E - k \frac{q_2}{d^2} \right)$$

$$\frac{1}{2} m_1 v^2 = F_1 s$$

where s is the distance

$$v^2 = 2s F_1 / m_1 \quad (1)$$

For particle 2:

$$F_2 = q_2 \left(E + k \frac{q_1}{d^2} \right)$$

$$\frac{1}{2} m_2 v^2 = F_2 s$$

$$v^2 = 2s F_2 / m_2 \quad (2)$$

$$E_{K(\text{total})} = \frac{1}{2} m_1 v_1^2 + \frac{1}{2} m_2 v_2^2 \\ = (q_1 + q_2) E$$

$$(1) = (2) \Rightarrow 2s \frac{F_1}{m_1} = 2s \frac{F_2}{m_2}$$

$$\frac{q_1}{m_1} \left(E - k \frac{q_2}{d^2} \right) = \frac{q_2}{m_2} \left(E + k \frac{q_1}{d^2} \right)$$

Solve for d

$$d = \sqrt{\frac{k q_1 q_2 (m_1 + m_2)}{(m_2 q_1 - m_1 q_2) E}}$$

$$= 5.859 \text{ (m)}$$

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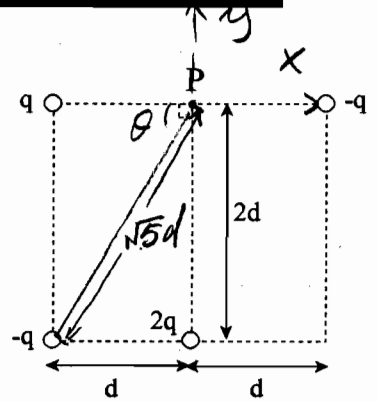
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Name: Famin

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Given the four charge configuration shown.



A. [18 pts.] What is the electric field at point P created by the four charges? Use $q = 3.0 \mu\text{C}$ and $d = 10 \text{ cm}$. Also remember that the electric field is a vector.

$$E_x = \frac{k(-q)}{5d^2} \cdot \cos\theta + \frac{kq}{d^2} - \frac{k(-q)}{d^2}$$

$$= \frac{kq}{d^2} \left(2 - \frac{1}{5\sqrt{5}} \right), \quad (\cos\theta = \frac{1}{\sqrt{5}})$$

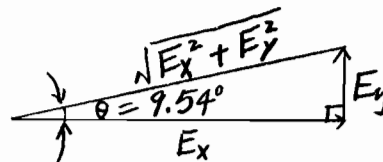
$$= \frac{8.99 \times 10^9 \cdot 3.0 \times 10^{-6}}{(0.1)^2} \cdot 1.91056 = 5.153 \times 10^6 \text{ (N/C)}$$

$$E_y = \frac{2q}{4\pi\epsilon_0(4d^2)} - \frac{q}{4\pi\epsilon_0(5d^2)} \sin\theta, \quad (\sin\theta = \frac{2}{\sqrt{5}})$$

$$= \frac{q}{4\pi\epsilon_0 d^2} \left(\frac{2}{4} - \frac{1}{5} \cdot \frac{2}{\sqrt{5}} \right) = \frac{8.99 \times 10^9 \cdot 3.0 \times 10^{-6}}{(0.1)^2} \cdot 0.3211 = 8.660 \times 10^5 \text{ (N/C)}$$

$$E = \sqrt{E_x^2 + E_y^2} = 5.225 \times 10^6 \text{ N/C}$$

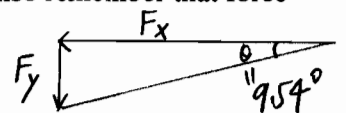
$$\theta = \tan^{-1} \frac{E_y}{E_x} = 9.54^\circ$$



B. [7 pts.] What is the force on a charge $q' = -1.9 \mu\text{C}$ if it is placed at point P? Also remember that force is a vector.

$$\vec{F} = q' E_x \hat{e}_x + q' E_y \hat{e}_y$$

$$= (-9.791 \hat{e}_x - 1.645 \hat{e}_y) \text{ N}$$



$$F = \sqrt{F_x^2 + F_y^2} = 9.928 \text{ N}, \quad \theta = \tan^{-1} \frac{F_y}{F_x} = 9.54^\circ$$