PHYS-207 (8) (Kaldon-52328) **Name ______S O L U T I O N__________**

WMU - Spring 2003

Exam 1A - 100,000 points + 20,000 ☆ points **Book Title ____________________________________**

01/29/2003•Rev.A5

State Any Assumptions You Need To Make – Show All Work – Circle Any Final Answers
Use Your Time Wisely – Work on What You Can – Be Sure to Write Down Equations
Feel Free to Ask Any Questions ☐☆2a ☐☆2b ☐☆2c ☐☆2e

EXAM 1 [FORM - A]
PHYS-207 (KALDON-8)

SPRING 2003

WMU

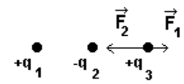
$k = 8.988 \times 10^9 \; N \cdot m^2 / C^2$

$\varepsilon_0 = 8.85 \times 10^{-12} \; C^2 / N \cdot m^2$

$e = 1.602 \times 10^{-19} \; C$

Random Problem Title (50,000 points)

1.) Three charges, $|q| = 4.00 \times 10^{-6}\, C$, are rigidly arranged in line with spacing $a = 10.0\, cm = 0.100\, m$ as shown. (a) Find the vector electric force, $\vec{F}_E$, acting on the charge at the right.



$$F_1 = \frac{kq_1q_3}{r^2} = \frac{kq^2}{(2a)^2} = \frac{\left(8.988\times10^9 \frac{N\cdot m^2}{C^2}\right)\left(4.00\times10^{-6}C\right)^2}{(0.200m)^2}$$

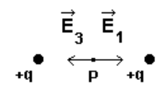
$$= 3.595N$$

$$F_2 = \frac{kq_2q_3}{r^2} = \frac{-kq^2}{a^2} = -4F_1 = -14.38N$$

$$F_{net} = F_1 + F_2 = 3.595N - 14.38N = -10.79N$$

$$\vec{F}_E = -10.79N\,\hat{i} = 10.79N@180°$$

(b) The center charge at point P is removed. Find the electric field vector, $\vec{E}_{total}$, at the center point P.

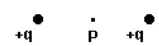


By Symmetry:

$$\vec{E}_1 = -\vec{E}_3$$

$$So\ \vec{E}_{total} = 0$$

(c) Find the electric potential, V, at the center point P.



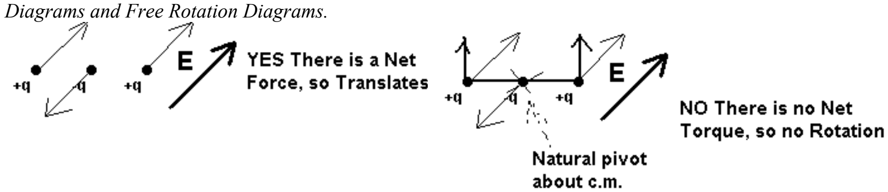
V is a scalar, so the two V's do NOT cancel each other.

$$V_1 = \frac{kq_1}{r} = \frac{\left(8.988\times10^9 \frac{N\cdot m^2}{C^2}\right)\left(4.00\times10^{-6}C\right)}{(0.200m)}$$

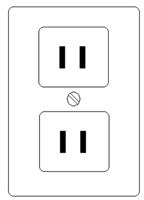
$$= 179{,}800 volts$$

$$V_{total} = 2V_1 = 2(179{,}800 volts) = 359{,}600 volts$$

(d) In a constant electric field, applied everywhere, show whether these three charges, rigidly held together, will translate or rotate in the applied E-field, where $\vec{E} = 150.\ {}^{N}\!/_{C}\ @45°$. *Hint: Think Free Body Diagrams and Free Rotation Diagrams.*



(e) The two main slots of an electrical outlet in the United States are 1.00 cm apart. However, you never see sparks shooting between the slots when the potential difference is 125 volts. At what minimum voltage will you see sparks in dry air?

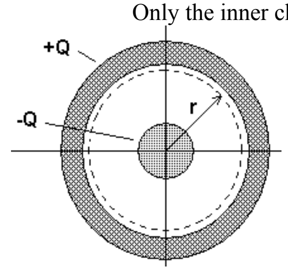


$$E_{max} = 3{,}000{,}000 V/m$$
$$V = E\,d = (3{,}000{,}000 V/m)(0.0100 m)$$
$$= 30{,}000\,volts$$

People's Revolutionary Star Problems Number Eight (50,000 points)

2.) ☆(a) The following system consists of (1) a solid conducting sphere of radius a and has a total charge $-Q$ and a thick-walled hollow sphere of inner radius b and outer radius c, which has a total charge $+Q$. Use Gauss' Law to find the magnitude of the E-field at a radius r, where $a < r < b$ as shown. *NOTE: You may evaluate the integrals by using the known equations for things like the surface area and volume of a sphere.*

Only the inner charge matters.



$$\Phi_E = \oint_{surface} \vec{E}\cdot d\vec{A} = \frac{q_{inside}}{\varepsilon_0}$$
$$= \int E\,dA = \frac{q_{inside}}{\varepsilon_0}$$
$$= E\int dA = \frac{-Q}{\varepsilon_0}$$
$$= E\left(4\pi r^2\right) = \frac{-Q}{\varepsilon_0}$$
$$E = \frac{-Q}{4\pi\,\varepsilon_0 r^2} = \frac{-k\,Q}{r^2}$$

☆(b) An electric field is given by $\vec{E} = (5250\,{}^{V}\!/_{m^2})\,x\,\hat{i}$. Use the integral definition of potential difference to find ΔV from the origin (x = 0, y = 0) to (x = 0.250 m, y = 0).

$$\Delta V = -\int \vec{E}\cdot d\vec{s}$$

$$\vec{E} = (5250\,{}^{V}\!/_{m^2})\,x\,\hat{i} \quad ; \quad d\vec{s} = dx\,\hat{i}$$
$$\Delta V = -\int \vec{E}\cdot d\vec{s}$$
$$= -\int_0^{0.250m} (5250\,{}^{V}\!/_{m^2})\,x\,\hat{i}\cdot dx\,\hat{i}$$
$$= -(5250\,{}^{V}\!/_{m^2})\int_0^{0.250m} x\,dx = -(5250\,{}^{V}\!/_{m^2})\left[\frac{x^2}{2}\right]_0^{0.250m}$$
$$= -(5250\,{}^{V}\!/_{m^2})\left(\frac{(0.250m)^2}{2}\right) = -164.1\,volts$$

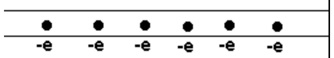
☆(c) Repeat (b) to find ΔV from the origin (x = 0, y = 0) to (x = 0, y = 0.250 m).

$$\vec{E} = (5250\,{}^{V}\!/_{m^2})\,x\,\hat{i} \quad ; \quad d\vec{s} = dy\,\hat{i}$$
$$\vec{E}\cdot d\vec{s} = 0 \quad \therefore \Delta V = 0$$

OR

$$\vec{E} = (5250\,{}^{V}\!/_{m^2})\,x\,\hat{i} \quad ; \quad \vec{E}(x=0) = 0$$
$$\vec{E}\cdot d\vec{s} = 0 \quad \therefore \Delta V = 0$$

(d) A very thin line of charge has $Q = -1.00 \times 10^{-4}\ C$, $L = 1.00\ m$. Since all real charges are made of electrons, then assuming the electrons are all evenly spaced single file along the line, find the distance d between each electron.



$$q = \pm Ne \quad ; \quad q = -Ne$$

$$N = \frac{-q}{e} = \frac{-(-1.00\times 10^{-4}\,C)}{1.602\times 10^{-19}\,C}$$

$$= 6.242\times 10^{14}$$

$$d = \frac{L}{N} \qquad \left(Technically,\ d = \frac{L}{N-1}\right)$$

$$= \frac{1.00m}{6.242\times 10^{14}} = 1.602\times 10^{-15}\,m$$

Oops! PTPBIP! This distance is about the size of the *nucleus* of an atom so this is too small.

☆(e) An electron starts at rest above an infinite sheet of charge ($\sigma = 1.38 \times 10^{-5}$ C/m²). Find the work due to the electric force to move the electron from $a = 5.00\ cm$ to infinity ($b = \infty$), by integrating $\int_a^b F_E(x)\,dx$. *You may use the electric field for a sheet of charge.*

$$W = \int_a^b F_E(x)\,dx \quad ; \quad F_E = qE \quad ; \quad E = \frac{\sigma}{2\varepsilon_0}$$

$$W = \int_a^\infty F_E(x)\,dx = \int_a^\infty \left(\frac{q\sigma}{2\varepsilon_0}\right)dx = \left(\frac{q\sigma}{2\varepsilon_0}\right)\int_a^\infty dx = \infty$$