Physics 2220
Spring Semester 2008
George A Williams

EXAM 1

1

Name: ______________________ unid: u _ _ _ _ _ _ _ _

Discussion TA (circle): Justin Mahamadou Mike Will

<u>REPORT ALL NUMBERS TO THREE SIGNIFICANT FIGURES!</u>
<u>Use the conversion constants and data given on the front page.</u>

(a) Calculate the magnitude of the electric force between two protons (charge = +e) a distance 4.00×10^{-13}m apart.

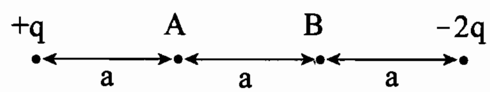
$$F = k_e \frac{|e|^2}{r^2} = 9\times10^{9}\,\frac{(1.6\times10^{-19})^2}{(4\times10^{-13})^2} = \boxed{1.44\times10^{-3}\ N}$$

(b) Use the binomial expansion to calculate the coefficient of the x^3 term for the expression $(1 - x)^{-7/3}$.

coefficient of x^3 $\rightarrow \boxed{\frac{455}{81}}$

$$(1-x)^{-7/3} \simeq 1 + \frac{7}{3}x + \frac{(-\frac{7}{3})(-\frac{7}{3}-1)}{2}x^2 \boxed{- \frac{(-7/3)(-7/3-1)(-7/3-2)}{6}} x^3 + \cdots$$

(c) For the arrangement shown, what is the potential difference $V_A - V_B$?



$$V_A - V_B = \left(\frac{kq}{a} - \frac{k2q}{2a}\right) - \left(\frac{kq}{2a} - \frac{2kq}{a}\right) = \frac{3kq}{2a}.$$

(d) A very long thin wire has a total charge of Q = $+3.75 \times 10^{-6}$ C. Its total length is 57.0 m. Calculate the magnitude of the electric field a distance 3.72 mm away from the center of the wire, nowhere near either end.

$$E = \frac{\lambda}{2\pi\epsilon_0 d} \quad \text{where } \lambda = \frac{Q}{L} \Rightarrow E = \frac{3.75\times10^{-6}}{2\pi(8.85\times10^{-12})\times57\times3.72\times10^{-3}} = \boxed{3.18\times10^{5}\ N/C}$$

(e) An electron is accelerated from rest through a potential difference of 137 volts. Calculate the velocity of the electron.

$$\Delta U = \frac{1}{2}mv^2 \Rightarrow v = \sqrt{\frac{2eV}{m}} = \sqrt{\frac{2\times1.6\times10^{-19}\times137}{9.11\times10^{-31}}} = \boxed{6.93\times10^{6}\ m/s}$$

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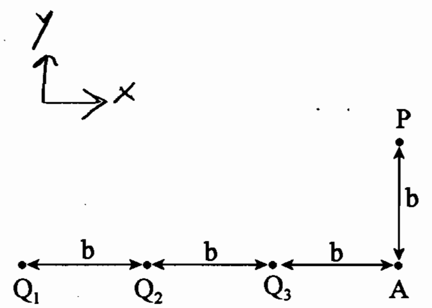
Three point charges are along the x-axis a distance b apart, as shown in the drawing. Point A is b from Q_3 along the x-axis, and P is directly above A at a distance b.

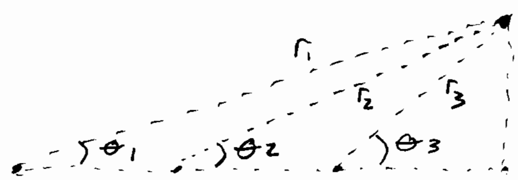


(a) Calculate the x-component of the electric field at point P. (Numerical answer.)

(b) Calculate the electric potential (in volts) at point P due to the three charges.

$Q_1 = +4.50\ \mu C$; $Q_2 = -2.75\ \mu C$; $Q_3 = -1.22\ \mu C$; $b = 7.00 \times 10^{-3}$ m

a) $\vec{E}_{tot} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$



$$E_{tot,x} = E_{1,x} + E_{2,x} + E_{3,x}$$

$$= E_1 \cos\theta_1 + E_2 \cos\theta_2 + E_3 \cos\theta_3$$

$$= \frac{kQ_1}{r_1^2}\cos\theta_1 + \frac{kQ_2}{r_2^2}\cos\theta_2 + \frac{kQ_3}{r_3^2}\cos\theta_3$$

$r_1 = \sqrt{(3b)^2 + b^2} = b\sqrt{10}$

$r_2 = \sqrt{(2b)^2 + b^2} = b\sqrt{5}$

$r_3 = \sqrt{b^2 + b^2} = b\sqrt{2}$

$$= \frac{kQ_1}{10b^2}\left(\frac{3}{\sqrt{10}}\right) + \frac{kQ_2}{5b^2}\left(\frac{2}{\sqrt{5}}\right) + \frac{kQ_3}{2b^2}\left(\frac{1}{\sqrt{2}}\right)$$

$\cos\theta_1 = \frac{3b}{r_1} = \frac{3}{\sqrt{10}}$

$$= \frac{k}{b^2}\left[\frac{3Q_1}{10\sqrt{10}} + \frac{2Q_2}{5\sqrt{5}} + \frac{Q_3}{2\sqrt{2}}\right]$$

$\cos\theta_2 = \frac{2b}{r_2} = \frac{2}{\sqrt{5}}$

$\cos\theta_3 = \frac{b}{r_3} = \frac{1}{\sqrt{2}}$

$$= \frac{(8.9876\times10^9)}{(7\times10^{-3})^2}\left[\frac{3(4.5\times10^{-6})}{10\sqrt{10}} + \frac{2(-2.75\times10^{-6})}{5\sqrt{5}} + \frac{(-1.22\times10^{-6})}{2\sqrt{2}}\right] = -9.10\times10^7\ \frac{N}{C}$$

b) $$V_{tot} = V_1 + V_2 + V_3 = \frac{kQ_1}{r_1} + \frac{kQ_2}{r_2} + \frac{kQ_3}{r_3} = \frac{k}{b}\left[\frac{Q_1}{\sqrt{10}} + \frac{Q_2}{\sqrt{5}} + \frac{Q_3}{\sqrt{2}}\right]$$

$$= \frac{(8.9876\times10^9)}{(7\times10^{-3})}\left[\frac{4.5\times10^{-6}}{\sqrt{10}} - \frac{2.75\times10^{-6}}{\sqrt{5}} - \frac{1.22\times10^{-6}}{\sqrt{2}}\right] = -8.60\times10^5\ V$$

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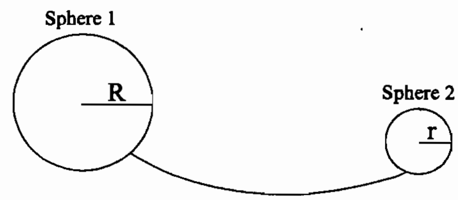
SHOW ALL WORK!!!!!
REPORT ALL NUMBERS TO THREE SIGNIFICANT FIGURES!
Use the conversion constants and data given on the front page.

Two conducting spheres are connected with a long wire. Sphere 1 has a radius of R = 17.0 cm and sphere 2 has a radius of r = 3.50 cm. A charge of 60.0 pC is placed on the system.



(a) What is the charge in picocoulombs on sphere 1?
(b) Find the potential of sphere 1 in volts.
(c) What is the value of the electric field a distance 2r from the center of sphere 2. Sphere 1 is very far away.

1.) $V_1(R) = V_2(r)$

$\frac{k_e q_1}{R} = \frac{k_e q_2}{r}$

$q_2 = \frac{r}{R} q_1$

$q_T = q_1 + q_2$

$q_T = q_1 + \frac{r}{R} q_1$

$q_1 = \frac{q_T}{(1+\frac{r}{R})}$

$\boxed{q_1 = 49.8\,pC}$

2.) $V_1(R) = \frac{k_e q_1}{R} = \boxed{2.63\,V}$

3.) $E(2r) = \frac{k_e q_2}{(2r)^2} = \boxed{18.7\,\frac{N}{C}}$

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Name: ELLIOTT unid: u _ _ _ _ _ _ _

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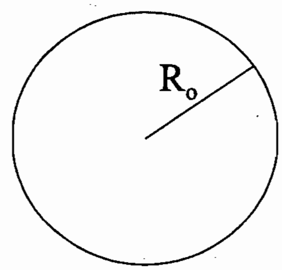
SHOW ALL WORK!!!!!
REPORT ALL NUMBERS TO THREE SIGNIFICANT FIGURES!
Use the conversion constants and data given on the front page.

A non-conducting sphere has a negative charge distribution that can be described by $\rho = Br^{7/2}$, where B is a constant.



(a) Calculate the total charge on the system.
(b) Calculate the magnitude of the electric field a distance $3R_o$ from the center of the sphere.
(c) Calculate the magnitude of the electric field at a point $R_o/4$ from the center of the sphere.
(d) In part (c) is the electric field directed inward or outward?

a) $Q_T = \int \rho(r)\, dV = \int_0^{R_o} B r^{7/2} (4\pi r^2)\, dr = 4\pi B \int_0^{R_o} r^{11/2} dr$

$= 4\pi B \frac{2}{13} R_o^{13/2} = \underline{\frac{8\pi B}{13} R_o^{13/2}}$

b) We may use $E = k \frac{Q_T}{r^2} = k \frac{8\pi B}{13} R_o^{13/2} \frac{1}{(3R_o)^2}$

$= \frac{8k B\pi}{117} R_o^{9/2}$

c) We must use Gauss Law

$E_r \cdot A = \frac{Q_{enc}}{\epsilon_o} \Rightarrow |E| 4\pi \left(\frac{R_o}{4}\right)^2 = \frac{1}{\epsilon_o} \frac{8}{13} B\pi \left(\frac{R_o}{4}\right)^{13/2}$

$E = \frac{2B}{13\epsilon_o} \left(\frac{R_o}{4}\right)^{9/2}$ or $\frac{8\pi B k}{13} \left(\frac{R_o}{4}\right)^{9/2}$

d) Inward