Name: Jake Bobowski Student Number: Sol'ns

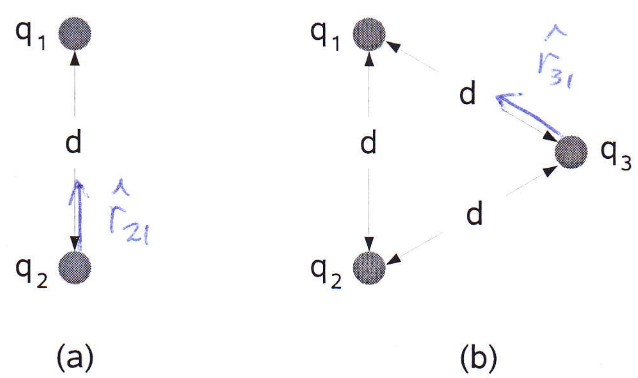
Phys 102 Sec. 002 Assignment 1

January 2011

Print this document and answer the questions in the space provided. Place a box around your final answer. Due Wednesday, January 26 @ 9:30 am.

1. **Coulomb's Law... (10 marks)**

Part (a) of the figure shows two charges, q_1 and q_2 held a fixed distance d apart. (a) What is the magnitude and direction of the electrostatic force that acts on q_1? Assume that $q_1 = q_2 = 20.0$ μC and $d = 1.50$ m. (b) A third charge $q_3 = 20.0$ μC is brought in and placed as shown in part (b) of the figure. Now what is the magnitude and direction of the electrostatic force on q_1? Give your answers using vector notation: $\vec{F} = F_x\,\hat{\imath} + F_y\,\hat{\jmath}$.



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(a)

$$\vec{F}_{21} = \frac{k_e q_1 q_2}{d^2}\hat{r}_{21} = k_e \frac{q_1 q_2}{d^2}\hat{j}$$ (2)

$q_1 = q_2 = 20.0\,\mu C$

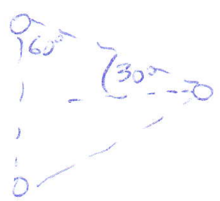
$d = 1.50\ m$

$k_e = 8.99\times10^9 \frac{N}{C^2}m^2$

$\therefore \vec{F}_{21} = 1.60\,N\,\hat{j}$ (2)

(b) $\vec{F}_{21}$ same as part (a) (1)

$$\vec{F}_{31} = \frac{k_e q_1 q_3}{d^2}\hat{r}_{31} \qquad |\vec{F}_{31}| = 1.60\,N$$ (1)



$F_{31,x} = -|\vec{F}_{31}|\cos 30° = -1.38\,N$ (1)

$F_{31,y} = |\vec{F}_{31}|\sin 30° = 0.799\,N$ (1)

$\therefore \vec{F}_{net} = -1.38\,N\,\hat{i} + (1.60\,N + 0.799\,N)\,\hat{j}$

$\vec{F}_{net} = -1.38\,N\,\hat{i} + 2.40\,N\,\hat{j}$ (2)

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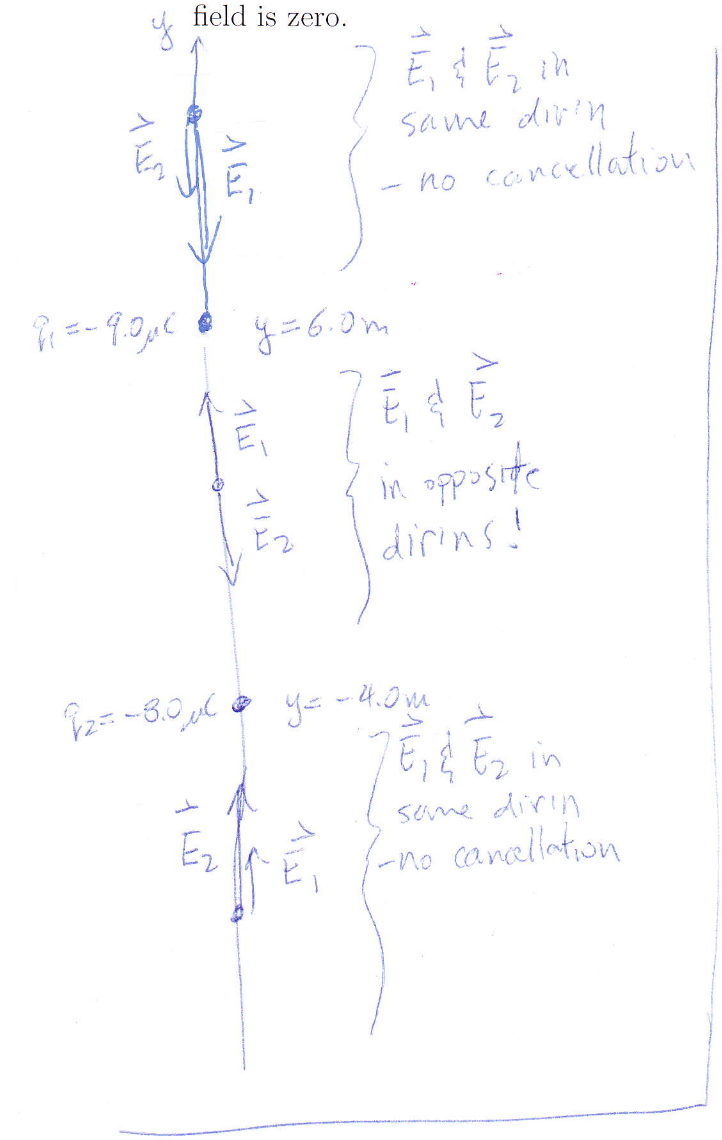
2. **Electric Field... (10 marks)**

Two point charges lie along the y-axis. A charge $q_1 = -9.0$ μC is at $y = 6.0$ m, and a charge of $q_2 = -8.0$ μC is at $y = -4.0$ m. Locate the point (other than infinity) at which the total electric field is zero.



between $-4.0 < y < 6.0$ m require $|\vec{E}_1| = |\vec{E}_2|$ for zero total $\vec{E}$-field (2)

$$|\vec{E}_1| = \frac{k_e q_1}{(6.0\text{m} - y)^2} \qquad |\vec{E}_2| = \frac{k_e q_2}{(y-(-4.0\text{m}))^2} \quad (2)$$

$$\frac{k_e q_1}{(6-y)^2} = \frac{k_e q_2}{(y+4)^2} \Rightarrow \frac{9.0\,\mu C}{(6-y)^2} = \frac{8.0\,\mu C}{(y+4)^2}$$

$$\therefore\ 9(y+4)^2 = 8(6-y)^2$$

$$9(y^2+8y+16) = 8(y^2-12y+36)$$

$$9y^2+72y+144 = 8y^2-96y+288$$

or $y^2 + 168y - 144 = 0$ (2)

$$y = \frac{-b \pm \sqrt{b^2-4ac}}{2a} \quad (2)$$

$$\therefore\ y = \frac{-168 \pm \sqrt{2.88\times10^4}}{2} = \frac{-168 \pm 169.7}{2}$$

clearly need to take the pos. root.

$\therefore\ y = 0.85$m (2)

can verify that $|\vec{E}_1| = |\vec{E}_2|$ ~~when~~ for $y = 0.85$m.

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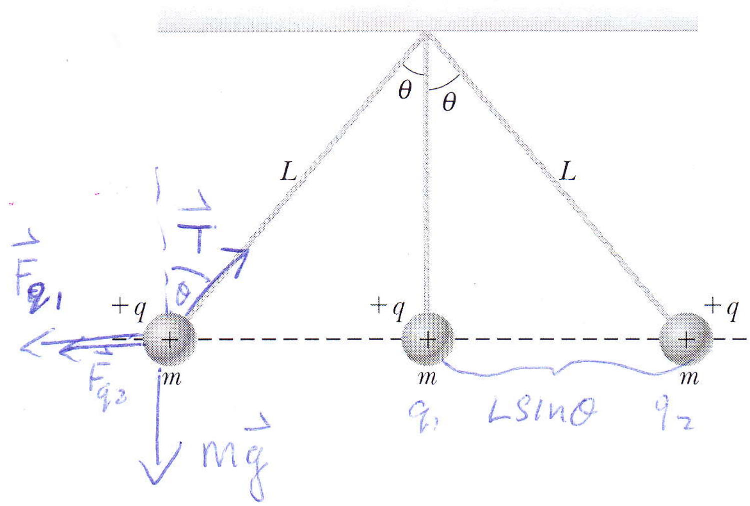
3. **Forces in Equilibrium... (10 marks)**

Three identical point charges, each of mass $m = 0.100$ kg, hang from three strings as shown in the figure. If the lengths of the left and right strings are $L = 30.0$ cm and the angle is $\theta = 45°$, determine the value of q. *Use example 23.5 from the text as a guide.*

Calc. net force on left charge

(2)



y-component: For zero net force require

$$F_{net,y} = 0 = T\cos\theta - mg \Rightarrow T = \frac{mg}{\cos\theta}$$ (2)

x-component:

$$F_{net,x} = 0 = T\sin\theta - F_{q1} - F_{q2}$$ (2)

$$= \frac{mg\sin\theta}{\cos\theta} - \frac{k_e q^2}{(L\sin\theta)^2} - \frac{k_e q^2}{(2L\sin\theta)^2}$$

$$\therefore mg\tan\theta = \frac{k_e q^2}{L^2\sin^2\theta}\left(1 + \frac{1}{4}\right) = \frac{k_e q^2}{L^2\sin^2\theta}\frac{5}{4}$$ (2)

solve for q.

$$q^2 = \frac{4L^2 mg\tan\theta\sin^2\theta}{5k_e}$$

$L = 0.300$ m
$m = 0.100$ kg
$g = 9.80$ m/s²
$\theta = 45°$

(2) $\therefore q = 1.98\,\mu C$

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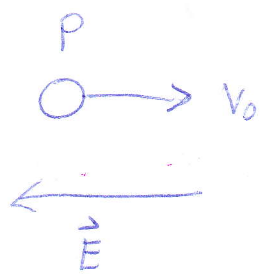
4. **Uniform Electric Field. . . (10 marks)**

A proton is projected in the positive x-direction into a region of a uniform electric field $\vec{E} = -6.00 \times 10^5\ \hat{\imath}$ N/C at time $t = 0$. The proton travels 7.00 cm as before coming to rest. Determine (a) the acceleration of the proton, (b) its initial speed, and (c) the time interval over which the proton comes to rest.



(a) Force on proton is $\vec{F} = q\vec{E} = m\vec{a}$ (2)

$q = 1.60 \times 10^{-19}$ C $m = 1.67 \times 10^{-27}$ kg

$\therefore \vec{a} = \frac{q}{m}\vec{E} = \boxed{-5.75 \times 10^{13}\ \frac{m}{s^2}\ \hat{\imath}}$ (2)

constant acceleration!

(b) $v^2 = v_0^2 + 2ad$ (1)

when proton comes to rest $v = 0$.

$\therefore v_0 = \sqrt{-2ad}$ $d = 0.0700$ m

(2) $\boxed{\therefore v_0 = 2.84 \times 10^6 \text{ m/s}}$ initially travelling to right.

$\therefore \vec{v}_0 = 2.84 \times 10^6$ m/s $\hat{\imath}$

(c) $v = v_0 + at$ (1)

$\therefore t = \frac{v - v_0}{a} = -\frac{v_0}{a} = \boxed{49.3 \text{ ns}}$ (2)

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5. **Electric Flux. . . (10 marks)**

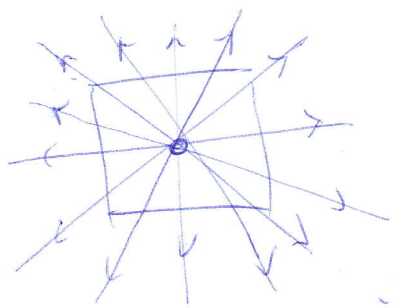
A charge of 1.70×10^2 μC is at the centre of a cube of edge 80.0 cm. No other charges are nearby. (a) Find the flux through the whole surface of the cube. (b) Find the flux through each face of the cube. (c) Would your answers to parts (a) or (b) change if the charge were not at the centre? Explain.

(a) $\Phi_E = \frac{q_{inside}}{\varepsilon_0}$ (Gauss's Law) (1)

$q_{inside} = 1.70 \times 10^2 \mu C$

$\therefore \Phi_E = 19.2 \times 10^6 \frac{N}{C} m^2$ (2)

(b) In 2-D picture looks like



By symmetry, same number of field lines cross each surface. (2)

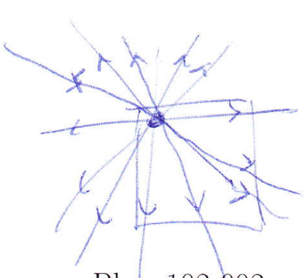
Cube has 6 surfaces,

$\therefore$ flux through each surface is $\frac{1}{6}$th of the total flux.

$\Phi_{E,face} = \frac{\Phi_E}{6} = 3.20 \times 10^6 \frac{N}{C} m^2$ (1)

(c) $\Phi_E = \frac{q_{inside}}{\varepsilon_0}$ Does not matter where q_{inside} is located – just that it is inside the cube. (2)

The total flux does not change. (a) is same.



When the charge is off centre, the number of $\vec{E}$-field lines crossing each face is no longer the same. $\therefore$ answer to (b) would change. (2)

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6. **Gauss's Law. . . (10 marks)**

A thin cylindrical shell of radius 7.00 cm and length 2.40 m has its charge uniformly distributed on its curved surface. The magnitude of the electric field at a point 19.0 cm radially outward from its axis (measured from the midpoint of the shell) is 36.0 kN/C. Find (a) the net charge on the shell and (b) the electric field at a point 4.00 cm from the axis, measured radially outward from the midpoint of the shell.

The surface area of curved part of cylinder is $2\pi RL$

$\therefore$ charge density is $\sigma = \frac{Q}{2\pi RL}$

(a) Apply Gauss's Law

Find flux through cylindrical surface radius $r > R$ & length l. By symmetry, $\vec{E}$ is radial (since $L >> r$).

$\therefore \int \vec{E}\cdot d\vec{A} = \int E dA = E\int dA = E\, 2\pi r l = \frac{q_{inside}}{\varepsilon_0}$ (3)

$q_{inside} = \sigma\, 2\pi R l = Q\frac{l}{L}$ (2)

$\therefore E\, 2\pi r l = \frac{Q l}{\varepsilon_0 L}$ or $Q = 2\pi r L \varepsilon_0 E$

$r = 0.190$ m
$L = 2.40$ m
$E = 36.0\times 10^3$ N/C

$\therefore Q = 0.913\ \mu C$ (1)

cont'd on back.

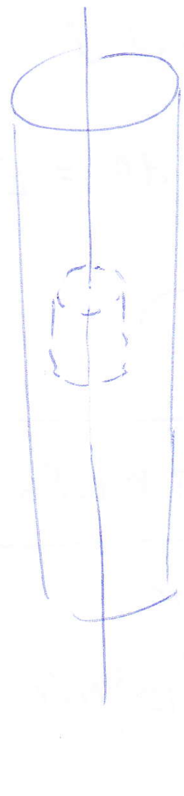
alternative sol'n to (a)

for $r > R$, cylindrical shell identical to long wire. (2)

For a long wire $E = 2k_e \frac{\lambda}{r} = \frac{2k_e}{r}\frac{Q}{L}$ (2)

$\therefore Q = \frac{rLE}{2k_e} = \boxed{0.913\,\mu C}$ (2)

(b) $r = 4.00$ cm is inside shell



$\therefore q_{inside} = 0$ (2)

by Gauss's Law

$$\int \vec{E}\cdot d\vec{A} = \frac{q_{inside}}{\varepsilon_0} = 0$$

area is not zero

$\boxed{\therefore \vec{E} = 0}$ (2)