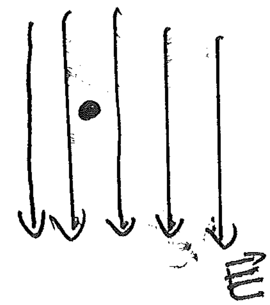
Physics 161, HW #1

#1 : a) WHAT CHARGE to KEEP 2.15g PARTICLE STATIONARY IN A DOWNWARD 950N/C ELECTRIC FIELD?

$$M = 2.15g = 2.15g \times \frac{Kg}{1000g} = .00215Kg$$



FORCES ON PARTICLE :

DOWNWARD GRAVITY, $\vec{F_g} = M\vec{g}$

ELECTRIC FORCE, $\vec{F_e} = q\vec{E}$

$\Sigma\vec{F} = \vec{F_g} + \vec{F_e}$. STATIONARY $\Rightarrow \Sigma\vec{F} = 0$

$\Rightarrow \underline{\vec{F_e} = -\vec{F_g}}$

$\Rightarrow \vec{F_e}$ IS UPWARD

$\vec{F_e}$ opposite to $\vec{E}$ $\Rightarrow$ $\boxed{q \text{ MUST BE NEGATIVE}}$

$$F_e = F_g \Rightarrow |q|E = Mg \Rightarrow |q| = \frac{Mg}{E} = \frac{(.00215Kg)(9.8m/s^2)}{950N/C}$$

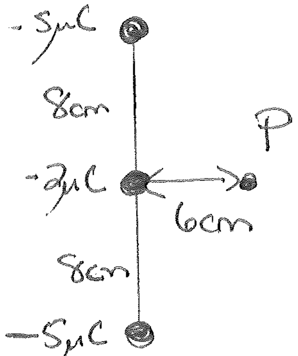
$$\Rightarrow \boxed{|q| = 2.2179 \times 10^{-5}C = 2.22 \times 10^{-5}C = 22.2\mu C}$$

b) What Electric field to keep proton stationary?

$F_e = F_g$ AGAIN $\Rightarrow \underline{|q|E = Mg} \Rightarrow E = \frac{Mg}{|q|}$. For proton, $M = 1.67 \times 10^{-27}kg$

$q = 1.6 \times 10^{-19}C \Rightarrow \boxed{E = \frac{(1.67\times10^{-27}kg)(9.8m/s^2)}{1.6\times10^{-19}C} = 1.02\times10^{-7}N/C}$

#2

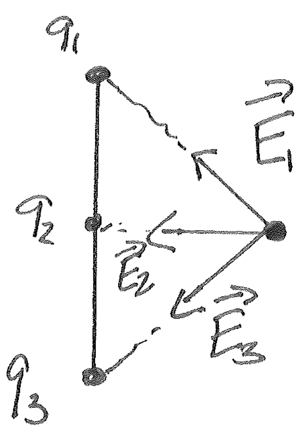


Find magnitude and direction $\vec{E}$ at P.

at P, $\vec{E}$ has 3 contributions

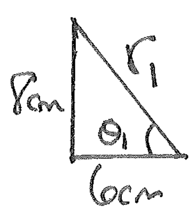
$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3$$

let $q_1 = -5\mu C \leftarrow$ upper, $q_2 = -2\mu C$, $q_3 = -5\mu C \leftarrow$ lower



$\vec{E}$ points in $\vec{F}$'s direction if test charge positive, q_1, q_2, q_3 All Negative

$\vec{E}_1$:



$$E_1 = \frac{1}{4\pi\epsilon_0} \frac{|q_1|}{r_1^2}$$

$$r_1^2 = (8cm)^2 + (6cm)^2 = (.08m)^2 + (.06m)^2 = .01m^2$$

$$\Rightarrow E_1 = \frac{(8.99 \times 10^9 N \cdot m^2/C^2)(5 \times 10^{-6} C)}{.01m^2} = 4.495 \times 10^6 N/C$$

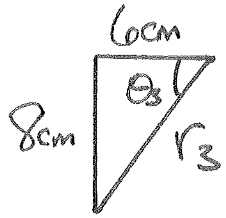
$\vec{E}_1$ at angle, $\theta_1 = \tan^{-1}\left(\frac{8}{6}\right) = 53.13°$

$\underline{\vec{E}_2}$: Easiest : $E_2 = \frac{1}{4\pi\epsilon_0}\frac{|q_2|}{r_2^2}$ $\quad r_2 = 6\text{cm} = .06\text{m}$

$$\vec{E}_2 = \frac{(8.99\times10^9\,\text{N}\cdot\text{m}^2/\text{C}^2)(2\times10^{-6}\,\text{C})}{(.06\text{m})^2} = 4.9944\times10^6\,\text{N/C}$$

$\vec{E}_2$ at $180°$, i.e. $\xleftarrow{\vec{E}_2}$

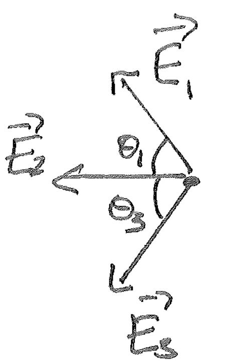
$\underline{\vec{E}_3}$: Same Numbers as $\vec{E}_1$



$E_3 = \frac{1}{4\pi\epsilon_0}\frac{|q_3|}{r_3^2}$ $\quad r_3^2 = (8\text{cm})^2 + (6\text{cm})^2 = (.08\text{m})^2 + (.06\text{m})^2 = .01\text{m}^2$

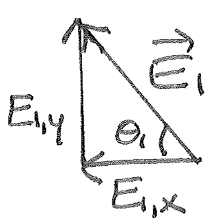
$$\Rightarrow E_3 = 4.495\times10^6\,\text{N/C}$$

$$\theta_3 = \tan^{-1}\left(\frac{8}{6}\right) = 53.13°$$



$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 \Rightarrow E_x = E_{1,x} + E_{2,x} + E_{3,x}$$

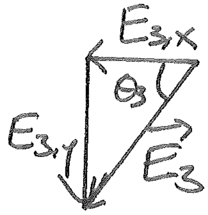
Make to left positive $\Rightarrow E_{2,x} = E_2 = 4.9944\times10^6\,\text{N/C}$



$$E_{1,x} = E_1\cos\theta_1 = 4.495\times10^6\,\text{N/C}\cos 53.13° = 2.697\times10^6\,\text{N/C}$$

$$E_{1,y} = E_1\sin\theta_1 = 4.495\times10^6\,\text{N/C}\sin 53.13° = 3.596\times10^6\,\text{N/C}$$

For $\vec{E_3}$, same components but $E_{3,y}$ in opposite direction to $E_{1,y}$ $\Rightarrow$ make $E_{3,y}$ negative



$$E_{3,x} = E_{1,x} = 2.697 \times 10^6\ N/C$$

$$E_{3,y} = -E_{1,y} = -3.596 \times 10^6\ N/C$$

$$E_x = E_{1,x} + E_{2,x} + E_{3,x} = 2.697 \times 10^6\ N/C + 4.9944 \times 10^6\ N/C + 2.697 \times 10^6\ N/C$$

$$\Rightarrow E_x = 1.03884 \times 10^7\ N/C$$

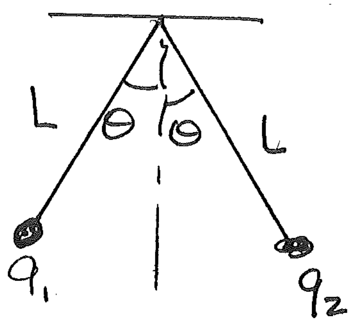
$E_y = E_{1,y} + E_{2,y} + E_{3,y}$. $E_{2,y} = 0$, $E_{3,y} = -E_{1,y}$

$$\Rightarrow E_y = 0$$

$\Rightarrow E = E_x = 1.03884 \times 10^7\ N/C$ only E_x

$$\Rightarrow \boxed{\vec{E} = 1.03884 \times 10^7\ N/C \text{ at } 180^\circ}$$

#3



$M = 15g = .015\,Kg$

$L = 1.2m$

WHEN $q_1 = q_2 = q$, BOTH NEGATIVE,

$\theta = 25°$

a) DRAW FREE BODY DIAGRAM FOR EACH MASS.

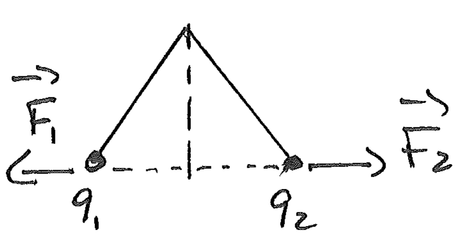
FORCES ON q_1: gravity DOWN, $W = Mg = (.015kg)(9.8m/s^2)$

$\Rightarrow W = .147N$

TENSION, $\vec{T}_1$ along string (SEE NEXT PAGE)

Electric FORCE: $\vec{F}_1$. q_1, q_2 BOTH NEGATIVE $\Rightarrow$ Repulsion

EQUAL L, EQUAL θ $\Rightarrow$ q_1, q_2 AT SAME HEIGHT & LINE Connecting THEIR CENTERS IS HORIZONTAL.



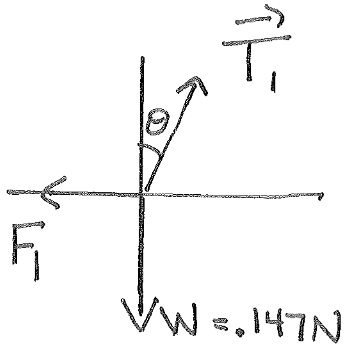
Repulsion $\Rightarrow$ $\vec{F}_1$ to LEFT

(AND q_2 HAS $\vec{F}_2$ to RIGHT)

Direction of $\vec{T}_1$:

THE TWO VERTICAL DASHED ARE parallel, Angles DRAWN here are equal BECAUSE opposite interior Angles (OR DRAW yourself SOME RIGHT TRIANGLES)

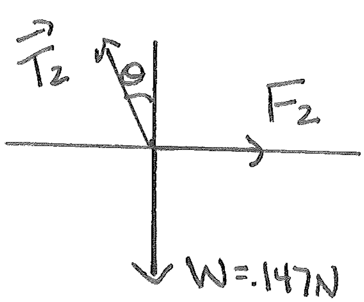
q_1's free BODY DIAGRAM



$\theta = 25°$

Forces on q_2, same $m \Rightarrow$ same $\vec{W} = .147N$, DOWN, electric force $\vec{F}_2$ to right, Tension $\vec{T}_2$ Along string $\Rightarrow \vec{T}_2$ at θ

q_2's f.b.d.



$\theta = 25°$

b) FIND VALUE of q.

WE KNOW TWO Things: (1) MASSES at rest $\Rightarrow$ NET Force is ZERO.

$$\Rightarrow \sum F_x = 0$$

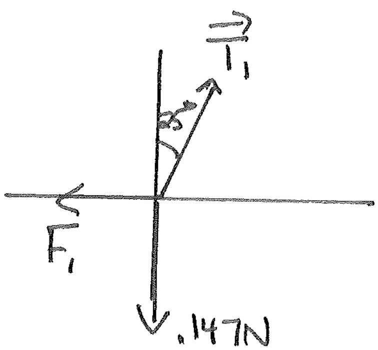
SUM of Force's x-components,

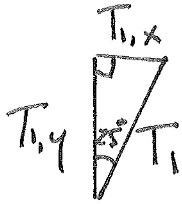
$$\sum F_y = 0$$

sum of y-components

(2) $F_1 = F_2 = \frac{1}{4\pi\epsilon_0}\frac{|q_1||q_2|}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{(q)(q)}{r^2} = \frac{1}{4\pi\epsilon_0}\frac{q^2}{r^2}$

Look at q_1's f.b.d. (WE get SAME INFO from q_2's)





$T_{1,x} = T_1 \sin 25°$

$T_{1,y} = T_1 \cos 25°$

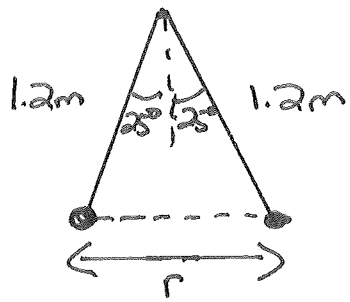
$$\sum F_y = 0 \Rightarrow T_1 \cos 25° - .147\text{N} = 0 \Rightarrow T_1 = \frac{.147\text{N}}{\cos 25°} = .1622\text{N}$$

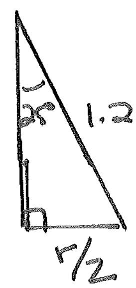
$$\sum F_x = 0 \Rightarrow T_1 \sin 25° - F_1 = 0 \Rightarrow F_1 = T_1 \sin 25° = \frac{.147\text{N}}{\cos 25°}\sin 25°$$

$$\Rightarrow F_1 = .147\text{N} \tan 25° = .06855\text{N}$$

(Looking at q_2 gives $T_2 = .1622\text{N}$ AND $F_2 = .06855\text{N}$)

Finally, use $F_1 = \frac{1}{4\pi\epsilon_0}\frac{q^2}{r^2}$ after finding r





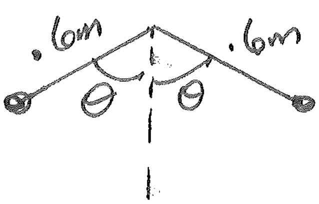
$\sin 25° = \frac{r/2}{1.2m}$

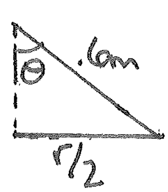
$\Rightarrow r = 2[1.2m \sin 25°]$

$= 2[.5071m] = 1.0142m$

$\Rightarrow .06855N = (8.99\times10^9 N\cdot m^2/C^2)\frac{q^2}{(1.0142m)^2}$ $\Rightarrow$ $\boxed{q = \sqrt{7.84\times10^{-12} m^2} = 2.8\times10^{-6} C = 2.8\,\mu C}$

(5) strings shortened to .6m, what is new angle θ





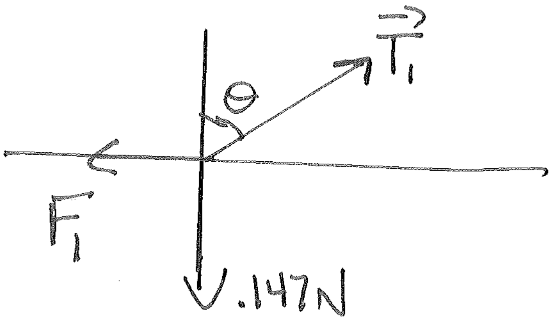
$\sin\theta = \frac{r/2}{.6m} \Rightarrow r = 2[.6m \sin\theta]$

$= 1.2m \sin\theta$

$\Rightarrow F_1 = \frac{(8.99\times10^9 Nm^2/C^2)(2.8\times10^{-6}C)^2}{(1.2m \sin\theta)^2} = \frac{.048945N}{\sin^2\theta}$

SAME f.b.d but NOW at θ, Still at rest so $\sum F_x = 0$

$\sum F_y = 0$



$\sum F_y = 0 \Rightarrow T_1 \cos\theta = .147N$

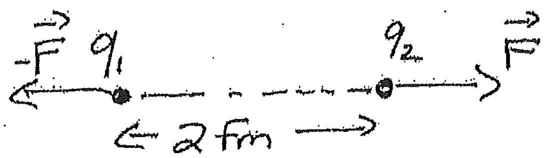
$\sum F_x = 0 \Rightarrow T_1 \sin\theta = F_1$

$$\Rightarrow \frac{.147N \sin\theta}{\cos\theta} = \frac{.0489456N}{\sin^2\theta} \Rightarrow \boxed{\frac{\sin^3\theta}{\cos\theta} = .333}$$

By TRIAL-AND-Error OR, MORE TRUTHFULLY, USING MATLAB to solve gives $\boxed{\theta = 39.4799° = 39.5°}$

#4

FIND Electric force BETWEEN Two protons, 2 fm Apart:



Two positive charges ⇒ Repulsion

protons ⇒ $q_1 = q_2 = +1.6\times10^{-19}C$

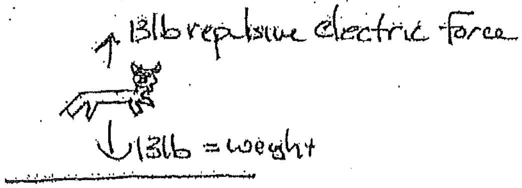
$r = 2\,fm = 2\times10^{-15}m$

$$F = \frac{1}{4\pi\epsilon_0}\frac{|q_1||q_2|}{r^2} = \frac{(8.99\times10^{9}\,N\cdot m^2/C^2)(1.6\times10^{-19}C)^2}{(2\times10^{-15}m)^2} \Rightarrow \boxed{F = 57.536N}$$

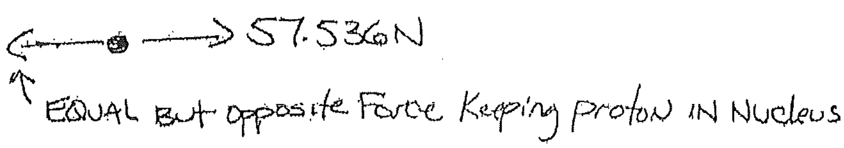
IN POUNDS? $1N = .2248\,lb$

$$\Rightarrow 57.536N \times \frac{.2248\,lb}{1N} = 12.934\,lb \approx 13\,lb$$ → DEFINITELY LArge enough for A person to feel

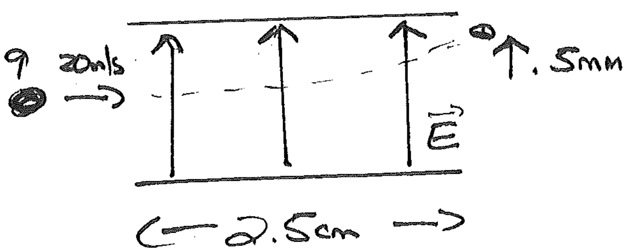
SO THIS FORCE Could levitate a 13lb BABY OR Chihuahua!



b) WHY DON'T PROTONS FLY OUT? → THEY MUST BE HELD IN PLACE BY ANOTHER Force! → THE strong force.



#5



$M = 1\times10^{-8}g = 1\times10^{-11}kg$

$2.5cm = .025m$

$.5mm = 5\times10^{-4}m$

$E = 9\times10^{4} N/C$

WHAT CHARGE q?

FIRST ASSUME GRAVITY IS NEGLIGIBLE. FIND q AND THEN ELECTRIC force to COMPARE with Weight to SEE IF THIS WAS REASONABLE.

ELECTRONS REMOVED $\Rightarrow$ positive CHARGE. VERTICAL ELECTRIC Field $\Rightarrow$ VERTICAL force. IGNORE All OTHER forces

$$\Rightarrow \sum F_y = qE, \quad \sum F_x = 0$$

$$2^{ND} \text{ LAW: } \sum F_y = Ma_y \Rightarrow qE = Ma_y \Rightarrow q = \frac{Ma_y}{E}$$

q, E constant $\Rightarrow$ Constant a_y, THEREFORE WE CAN USE

$$y = y_0 + V_{0,y}t + \tfrac{1}{2}a_y t^2. \quad y = 5\times10^{-4}m,\ y_0 = 0,\ V_{0,y} = 0$$

but NEED t

USE $\Sigma F_x = 0 \Rightarrow a_x = 0 \Rightarrow V_x = V_{0,x} = 20\,m/s$

$$x = x_0 + V_{0,x} t$$

$x = .025\,m,\ x_0 = 0 \ \therefore\ t = \frac{x}{V_{0,x}} = \frac{.025\,m}{20\,m/s} = .00125\,s$

$\therefore\ y = \cancel{y_0} + \cancel{V_{0,y} t} + \frac{1}{2} a_y t^2 \Rightarrow a_y = \frac{2y}{t^2} = \frac{2(5\times10^{-4}\,m)}{(.00125\,s)^2} = 640\,m/s^2$

AND SO $\boxed{q = \frac{(M a_y)}{E} = \frac{(1\times10^{-11}\,kg)(640\,m/s^2)}{9\times10^{4}\,N/C} = 7.11\times10^{-14}\,C}$

$\boxed{.0711\,pC}$

NOT MUCH!

FINALLY: $qE = (7.11\times10^{-14}\,C)(9\times10^{4}\,N/C) = 6.4\times10^{-9}\,N$

$$Mg = (1\times10^{-11}\,kg)(9.8\,m/s^2) = 9.8\times10^{-11}\,N$$

SO, $Mg \ll qE \Rightarrow$ OK TO IGNORE GRAVITY.