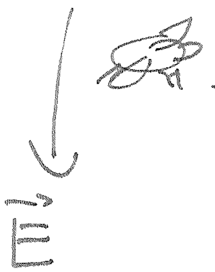
Physics 152, HW #2

Mastering Physics: 7 Questions from Chapter 20

Two written problems

20.58



Bee (I swear!)

$m = 0.1g$, $q = +18pC = 18\times10^{-12}C$
$= 1.8\times10^{-11}C$

$E = 100 N/C$

a) What is ratio of F_e to weight?
↑ electric force

$$F_e = |q|E = (1.8\times10^{-11}C)(100N/C) = 1.8\times10^{-9}N$$

$w = mg$ but mass in kilogram, $m = 0.1g \times \frac{kg}{1000g} = 1\times10^{-4}kg$

$$w = (1\times10^{-4}kg)(9.8m/s^2) = 9.8\times10^{-4}N$$

$$\Rightarrow \frac{F_e}{w} = \frac{1.8\times10^{-9}N}{9.8\times10^{-4}N} = 1.8367\times10^{-4} = 1.8\times10^{-6}$$

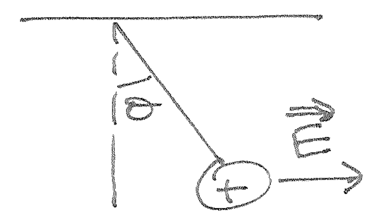
b) to suspend bee, $F_e = w \Rightarrow |q|E = mg$

$$\Rightarrow (1.8\times10^{-11}C)E = 9.8\times10^{-4}N \Rightarrow E = \frac{9.8\times10^{-4}N}{1.8\times10^{-11}C} = 5.444\times10^{7}N/C$$

$\approx 5.4\times10^{7}N/C$
↑ 54 million N/C

c) direction? Bee has positive charge, so $\vec{E}$ needs to be upwards so $\vec{F_e}$ is up ↑$\vec{F_e}$ ↓$\vec{w}$

20.66



$m = 2g = 2g \times \frac{kg}{1000g} = 0.002\,kg$

$q = 25\,nC = 25(1\times10^{-9}C) = 2.5\times10^{-8}C$

$E = 2.4\times10^{5}\,N/C$

What is θ?

3 forces on BALL: $\vec{F}_e$, $\vec{w}$, Tension: $\vec{T}$

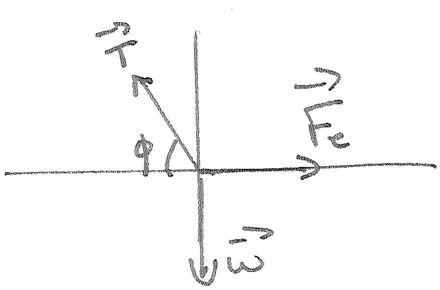
↑ electric force

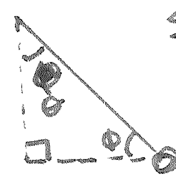
Positive charge $\Rightarrow$ $\vec{F}_e$ in same direction as $\vec{E}$ = $\vec{F}_e$ to right

$F_e = |q|E = (2.5\times10^{-8}C)(2.4\times10^{5}N/C) = 6\times10^{-3}N = 0.006\,N$

$\vec{w}$ always down, $w = mg = (0.002kg)(9.8\,m/s^2) = 0.0196\,N$

$\vec{T}$ at angle ϕ





so $\theta + \phi + 90° = 180°$

$\Rightarrow$ ~~[crossed out]~~

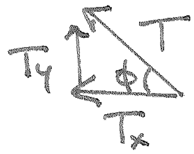
$\theta = 90° - \phi$

BALL not moving $\Rightarrow \Sigma F_x = 0,\ \Sigma F_y = 0$

$\Sigma F_x = 0 \Rightarrow T_x + F_{e,x} + \cancel{w_x}^{0} = 0$

$\Rightarrow T_x + F_e = 0$

Using a non-standard angle, so have to put negative signs in by hand.



T_x to left $\Rightarrow -T_x + F_e = 0$

$\Rightarrow T_x = F_e = 0.006\,N$

$\sum F_y = 0 \Rightarrow T_y + \cancel{F_{e,y}}^{\,0} + w_y = 0 \Rightarrow T_y - w = 0$

$\Rightarrow T_y = w = 0.0196\,N$

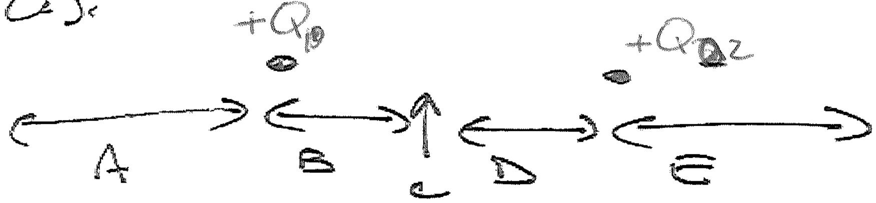
$\tan\phi = \frac{T_y}{T_x}$ (From triangle above) $\Rightarrow \tan\phi = \frac{0.0196\,N}{0.006\,N} = 3.266\ldots$

$\Rightarrow \phi = \tan^{-1}(3.2666\ldots) = 72.979° \approx 73°$

$\theta = 90° - \phi = 90° - 73° = 17°$

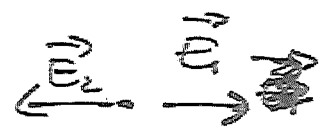
Electric Field Conceptual Question

a).



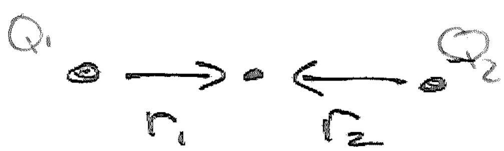
in what region is $E = 0$

If there was another positive charge it will feel repulsion from both. Label charges Q_1 and Q_2

in the region in between them : 

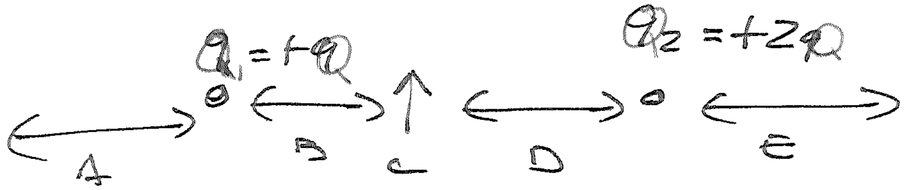
opposite directions ⇒ can cancel

Since $Q_1 = Q_2 = Q$ ⇒ equal distance from both in order to make $E_1 = E_2$

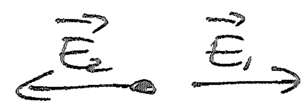


So point C works.

b)

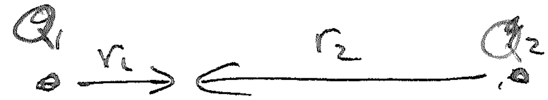


Both positive $\Rightarrow$ Region in Between will gives opposite Electric fields



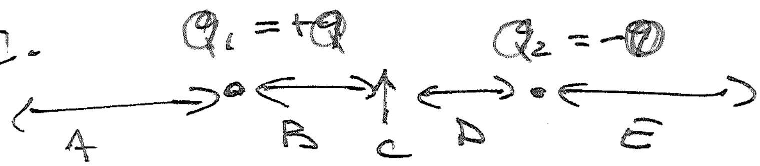
point charges $\Rightarrow$ $E = \frac{K|Q|}{r^2}$ $\Rightarrow$ Farther Away = smaller field

to make $E_1 = E_2$ we have to be farther Away From q_2 to compensate for its LArger charge



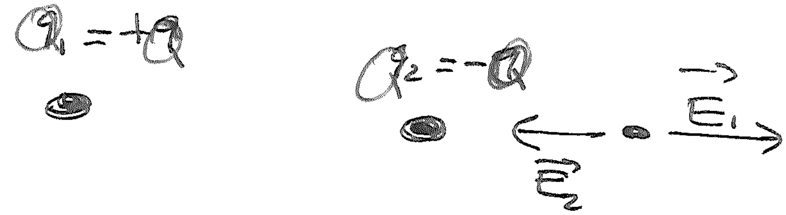
So Region B

C.



Now, if we imagine A positive charge, it will be repelled by Q_1 And attracted by Q_2. to get oppositely directed fields we Need to be to the Right of Q_2 or to left of Q_1

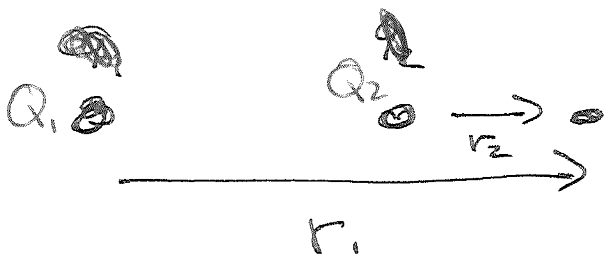
Right of q_2



Here $\vec{E}_2$ to Left AND $\vec{E}_1$ to Right.

But we Also NEED $E_1 = E_2$. Since $E = \frac{k|Q|}{r^2}$

that means that $r_1 = r_2$

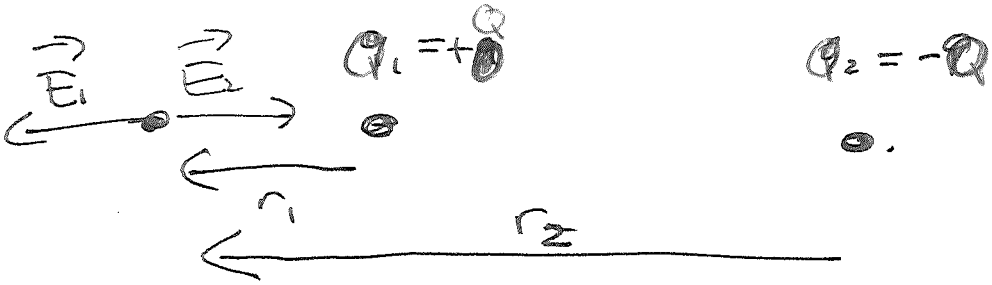


to the Right of q_2

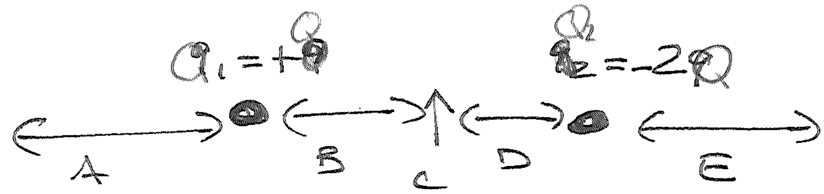
All r_2's are smaller than r_1's $\Rightarrow$

Nowhere

Left of Q_1

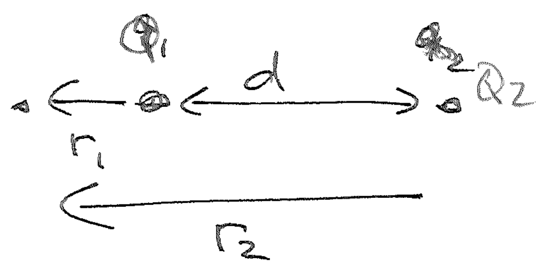


Over here All r_1's are smaller than r_2's $\Rightarrow$ **Nowhere** d.)



As in part c, either to Right of Q_2 or to the left of Q_1 will give opposite directions for $\vec{E}_1$ AND $\vec{E}_2$.

Now, we need a bigger distance from Q_2 to compensate for its larger charge.



So Region A will work

e.) Now, we can be more precise

$$E_1 = E_2 \Rightarrow \frac{k|Q_1|}{r_1^2} = \frac{k|Q_2|}{r_2^2} \Rightarrow \frac{k(Q)}{r_1^2} = \frac{k(2Q)}{r_2^2}$$

$$\Rightarrow r_2^2 = 2r_1^2 \Rightarrow r_2 = \sqrt{2r_1^2} = \sqrt{2}\, r_1$$

Let d be the distance between the charges (on the figure

d is 4 units.)

$r_2 - r_1 = d \Rightarrow \sqrt{2}\, r_1 - r_1 = d \Rightarrow (\sqrt{2} - 1) r_1 = d$

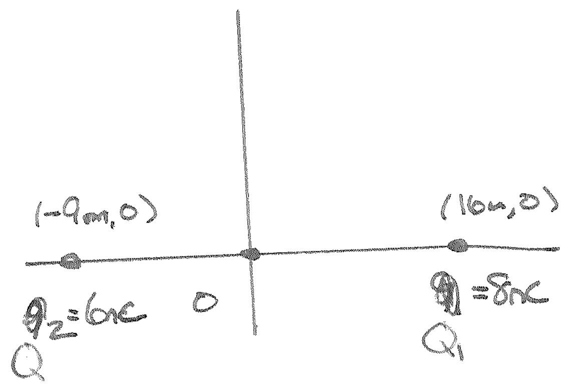
$\Rightarrow r_1 = \dfrac{d}{(\sqrt{2}-1)} = \dfrac{d}{0.4142} = 2.414\, d$

So for $d = 4$ units $\Rightarrow r_1 = 2.414\,(4) = 9.66$

So 9.66 units to left of q_1 is the place where

$E = 0$

Electric Field Due to Two Point Charges

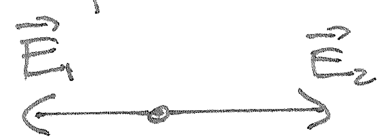


a) Find $\vec{E}$ at O

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

($\vec{E}_1$ due to q_1, $\vec{E}_2$ due to q_2)

a Positive CHARge at O would be pushed to RIGHT by q_2 AND to left by Q_1 $\Rightarrow$



$\Rightarrow E_x = E_2 - E_1$, $E_y = 0$

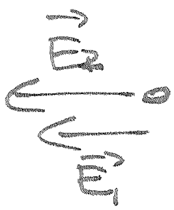
$$E = \frac{k|q|}{r^2} \Rightarrow E_1 = \frac{(9\times10^9 N\cdot m^2/C^2)(8\times10^{-9}C)}{(16m)^2} = 0.28125 N/C$$

$$E_2 = \frac{(9\times10^9 N\cdot m^2/C^2)(6\times10^{-9}C)}{(9m)^2} = 0.6667 N/C$$

$\therefore E_x = +.6667 N/C - 0.28125 N/C = 0.38542 N/C = 0.385 N/C$

$E_y = 0$

b) if $q_2 = -6\,nC$ $\Rightarrow$ Positive charge at O would be pulled to left by q_2 (AND q_1 still)



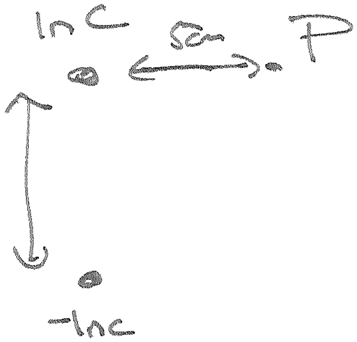
same magnitude because same distance

$\Rightarrow$ $E_x = -E_2 - E_1 = -0.6667\,N/c - 0.28125\,N/c$

$= -0.94792\,N/c = -0.950\,N/c$

$E_y = 0$ still

20.46



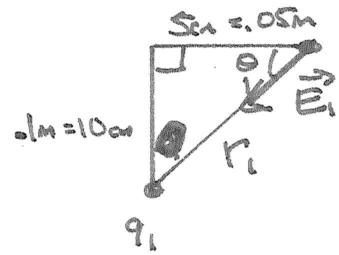
What is $\vec{E}$ at P?

Let $Q_1 = -1nC = -1\times10^{-9}C$

$Q_2 = +1nC = +1\times10^{-9}C$

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

$$E_1 = \frac{K|Q_1|}{r_1^2}$$



a positive charge at P is attracted to q_1

$$r_1^2 = (.1m)^2 + (.05m)^2$$
$$= 0.0125m^2$$

[illegible]

$$\tan\theta = \frac{.1m}{.05m} = 2 \Rightarrow \theta = \tan^{-1}(2) = 63.435°$$

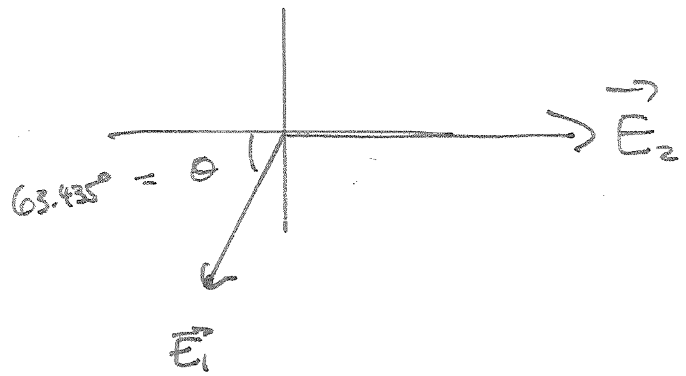
$$E_1 = \frac{(9\times10^9 N\cdot m^2/c^2)(1\times10^{-9}c)}{0.0125m^2} = 720N/c$$

$$E_2 = \frac{K|Q_2|}{r_2}$$

a positive charge at P would be repelled by q_2

$r_2 = .05m$

$$E_2 = \frac{(9\times10^9 N\cdot m^2/c^2)(1\times10^{-9}c)}{(.05m)^2} = 3600N/c$$



Standard Angle for $\vec{E}_1$ is $180° + 63.435° = 243.435°$

$$E_x = E_{1,x} + E_{2,x} = 720\,N/C \cos 243.435° + 3600\,N/C$$

$$\Rightarrow E_x = 720\,N/C\,(-.4472) + 3600\,N/C = 3278\,N/C$$

$$E_y = E_{1,y} + E_{2,y} = 720\,N/C \sin 243.435° + 0$$

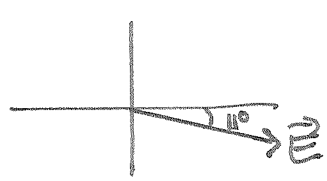
$$\Rightarrow E_y = 720\,N/C\,(-0.8944) = -643.99 \approx -643\,N/C$$

$$E = \sqrt{E_x^2 + E_y^2} = \sqrt{(3278\,N/C)^2 + (643\,N/C)^2} = 3340\,N/C = 3300\,N/C$$

to 2 sig figs

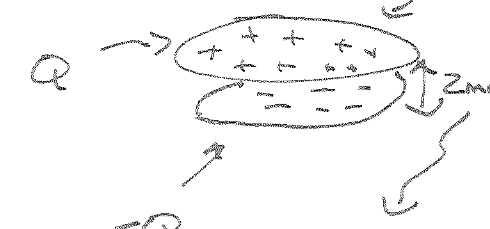
E_x is positive, E_y is negative $\Rightarrow$ 4th Quadrant, so Calculator OK $\Rightarrow \theta = \tan^{-1}\left(\frac{E_y}{E_x}\right) = \tan^{-1}\left(-\frac{643}{3340}\right) = -10.897°$

$= -11°$



Note: Mastering wants Angle Below Horizontal, so just enter 11°.

20.60



diameter = 1.5cm = 0.015m

$\Rightarrow$ radius $= \frac{0.015m}{2} = 0.0075m$

$Q = 15nC = 1.5\times10^{-8}C$

$2mm \times \frac{m}{1000mm} = .002m$

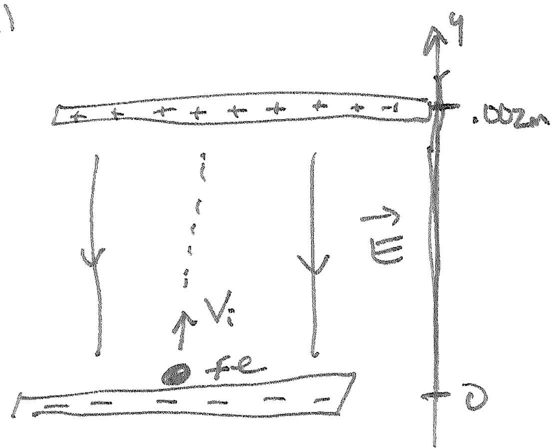
a) electric field between plates? Parallel-Plate $\Rightarrow E = \frac{Q}{\epsilon_0 A}$

Circular disks $\Rightarrow A = \pi(\text{radius})^2 = \pi(0.0075m)^2 = 0.0001767m^2$

$$\Rightarrow E = \frac{1.5\times10^{-8}C}{\left(8.85\times10^{-12}\frac{C^2}{N\cdot m^2}\right)(0.0001767m^2)} = 9.59\times10^{6}N/C = 9.6\times10^{6}N/C$$

unit: $\frac{C}{\frac{C^2}{N\cdot m^2}\cdot m^2} = C\cdot\frac{N}{C^2} = N/C$

b)



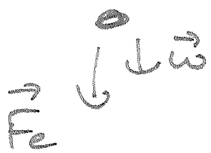
What V_i for proton to barely reach positive plate

$\vec{E}$ points from positive to negative

$\Rightarrow$ Downward in this picture

Proton is positive $\Rightarrow$ Downward $\vec{F_e}$ on it

$\vec{F}_e = |q|E = (1.6\times10^{-19}\,C)(9.59\times10^{6}\,N/C) = 1.5346\times10^{-12}\,N$



Should we include gravity?

$w = mg = (1.67\times10^{-27}\,kg)(9.8\,m/s^2) = 1.6366\times10^{-26}\,N$

$\Rightarrow$ w about 100 trillion times smaller than F_e

So no.

F_e only force $\Rightarrow \sum F_y = ma_y \Rightarrow -F_e = ma_y$

$$\Rightarrow a_y = \frac{-F_e}{m} = \frac{-1.5346\times10^{-12}\,N}{1.67\times10^{-27}\,kg} = -9.189\times10^{14}\,m/s^2$$

Constant acceleration $\Rightarrow$ ~~[illegible]~~ $(V_f)_y^2 = (V_i)_y^2 + 2a_y(y_f - y_i)$

If it barely makes it $(V_f)_y = 0$

$y_f = 0.002\,m,\ y_i = 0$

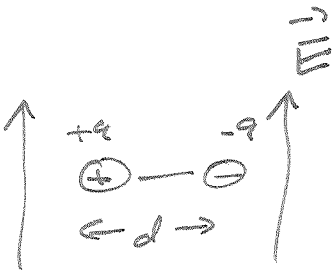
$\Rightarrow 0 = (V_i)_y^2 + 2(-9.189\times10^{14}\,m/s^2)(0.002\,m) \Rightarrow (V_i)_y^2 = 3.676\times10^{12}\,m^2/s^2$

$\Rightarrow (V_i)_y = \sqrt{3.676\times10^{12}\,m^2/s^2} = 1.9172\times10^{6}\,m/s$

$= 1.9\times10^{6}\,m/s$

↑ about 2 million m/s!

20.37 Carbon Monoxide is Dipole



$q = 3.4 \times 10^{-21} C$

$d = 0.11 nm = 0.11 (1 \times 10^{-9} m) = 1.1 \times 10^{-10} m$

$E = 15000 N/C$

a) What is net force? Positive charge has $\vec{F}_+$ in same direction as $\vec{E}$, Negative charge has $\vec{F}_-$ in opposite direction

⇒

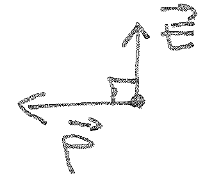
$F = |q|E \Rightarrow F_+ = F_-$, so two forces cancel and $F_{net} = 0$,

By the way, with these force Dipole would Rotate Clockwise.

b) What is torque? From lecture: $\tau = pE \sin \phi$

Dipole moment: $p = qd = (3.4 \times 10^{-21} C)(1.1 \times 10^{-10} m) = 3.74 \times 10^{-31} C \cdot m$

$\vec{p}$ points from ⊖ to ⊕ ⇒

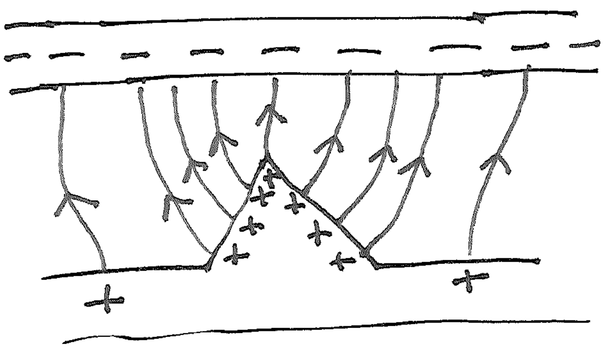


So $\phi = 90°$

$\Rightarrow \tau = (3.74 \times 10^{-31} C \cdot m)(15000 N/C) \sin 90° = 5.61 \times 10^{-27} N \cdot m$

$= 5.6 \times 10^{-27} N \cdot m$

Written Question #1



a.) There should be more charge on the high point. There the positive charges are closer to the negative charges ⇒ greater attractive force.

Overall you should have the same # of charges on each since we're told they are equal and opposite.

b.) Conductors ⇒ Field lines should be at 90° to each surface.

They go from + to − ⇒ upward.

there should be more lines on the high point since more charges ⇒ greater field. (The easiest way to do this is to start a field line from each positive charge that you drew.)

c.) High point has larger field ⇒ larger force, so more likely place for lightning to strike.

Written Question #2

① Conductors ⇒ Field Lines at 90° to all surfaces (including Sphere.)

② Sphere will polarize since it has free electrons. Originally Neutral ⇒ Equal # of positives and Negatives on each side. These "extra" charges have to be on the surface ⇒ on left and Right.

③ Field Lines go from + to −