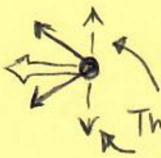
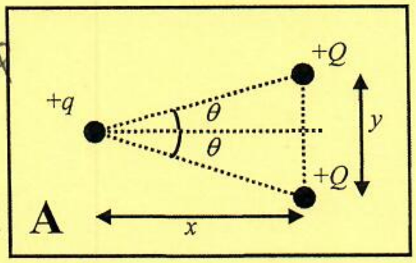
1. Consider the following two arrangements of point charges fixed in space.

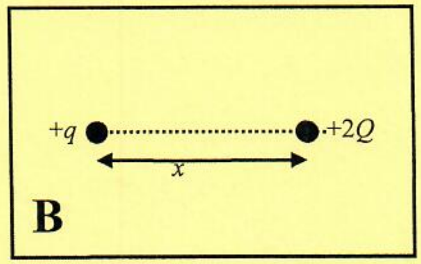
a)



+Q

These +Q components





$|\vec{E}|$

b) F on q

+2q

Is the magnitude of the electric force on $+q$ due to the two $+Q$ charges in case A *greater than*, *less than*, or *equal to*, the magnitude of the electric force on $+q$ due to the single $+2Q$ charge in case B?

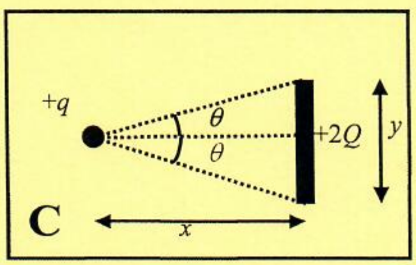
(a) (1 point) Write *greater than*, *less than*, or *equal to*: B

(b) (4 points) Carefully explain your reasoning. Please be sure to include ALL reasons you can think of:

→ FORCE DIAGRAM

From a) above +Q & +Q have X and Y components and the Y components cancel so at the final analysis Even though Q+Q=2Q The Force with charges on the Y axis at different points in Less in Force diagram b) The Force on q in Horizontal from 2Q & has no Y components that Cancel!

Now consider a third arrangement consisting of the $+q$ charge with a charged insulating rod having length y and charge $+2Q$ distributed uniformly along it.



WE ARE COMPARING C, A & B

Rank the magnitude of the electric force on the $+q$ in case C with that in case A and case B. [For example, if you thought the force was strongest in case A, with B next strong, and with C the weakest, write A>B>C.]

(c) (1 point) **Your** rank:

We KNOW B > A So Is C In between? C has its charge spread on the Y AXIS.

The +2Q Portion in the Middle does not have Big components in Y So $\vec{F}$ in Horizontal More

B > C > A

2. In Figure **A**, a positive charge $+Q$ is placed at the center of a cube. In Figure **B**, this same positive charge is moved upwards, closer to the upper surface of the cube.

Figure A

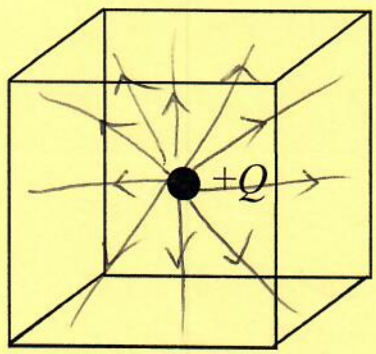
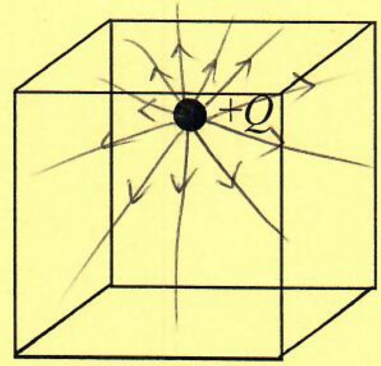


Figure B



A. Consider the total electric flux Φ_{cube} passing outward through the cube:
Is Φ_{cube} in Figure **A** greater than/equal to/ less than Φ_{cube} in Figure **B**. (2 pts)
Explain The Total flux IS EQUAL FOR FIGURE B THE TOP (UPPER) SURFACE HAS A LOT OF FLUX DUE TO PROXIMITY OF THE CHARGE (NEAR TOP) BUT IT EVENS OUT

B. Consider the electric flux Φ_{bottom} passing outward through the shaded bottom face of the cube:
Is Φ_{bottom} in Figure **A** $\boxed{\text{greater than}}$/equal to/ less than Φ_{bottom} in Figure **B**. (2 pts)
Explain OOPS

GREATER THAN

The charge CENTRALLY LOCATED IN A HAS MORE FLUX THAN CHARGE IN B THAT IS FARTHER AWAY

C. Focusing on **Figure A** where the charge **Q** is right smack in the center and given that Q is 1 Coulomb. What is the flux through the bottom surface with the correct units? (2 pts) $Q = 1C$

Electric flux $= \frac{q_{enc}}{\epsilon_0}$ (FOR THE CUBE)

$$\underbrace{\oint_S \vec{E} \cdot d\vec{A}}_{\text{Total flux}} = \frac{q_{enc}}{\underbrace{\epsilon_0}_{8.85 \times 10^{-12} \frac{C^2}{Nm^2}}}$$

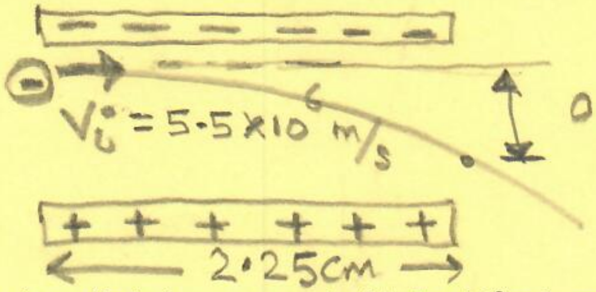
Total flux from 6 sides $= \frac{Q}{\epsilon_0} = \frac{1C}{8.85 \times 10^{-12} \frac{C^2}{Nm^2}}$

$= 1.13 \times 10^{11} \frac{Nm^2}{C}$

FOR ONE SIDE Flux $= \frac{1.13 \times 10^{11} \frac{Nm^2}{C}}{6}$

FOR ONE SIDE $\boxed{\Phi_E = 3.77 \times 10^{10} \frac{Nm^2}{C}}$

The particle is repelled by (–) plate must be an Electron



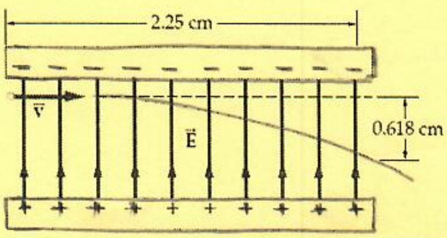
m_e (mass of electron) $= 9.11 \times 10^{-31}$ Kg

3. A **particle** has a speed of 5.5 x 10^6 m/s as it enters two conducting plates with a uniform electric field. It is deflected 0.618 cm from the horizontal as it exits the capacitor. (6 pts)

Is this particle an electron or a proton? Explain (1 pt) Attracted by positive Plate

Find the Electric field inside the two plates. (5 pts) (mass of electron/proton in equation sheet)

The Electric field is that of a capacitor (or a parallel plate)



If we Knew the Area Charge density σ then $\boxed{E = \sigma/\epsilon_0}$

But since we do not we will have to use Kinematics & The Relationship $\boxed{F = qE}$ — (a)

In the x: $\Delta x = V_{xi} \Delta t$ — (1) $\longrightarrow$ 2.25×10^{-2} m $= 5.5 \times 10^6$ m/s Δt

Y: $\Delta y = V_{yi} \Delta t + \frac{1}{2} a_y \Delta t^2$ (2)

$\Delta t = \dfrac{2.25 \times 10^{-2}\text{ m}}{5.5 \times 10^6 \text{ m/s}}$

$\Delta t = 4.09 \times 10^{-9}$ s

Using Equation 2 $\Delta y = 0.618 \times 10^{-2}$ m

$V_{yi} = 0$ $a_y = ?$

$\Delta y = \cancel{V_{yi} \Delta t}^{\,0} + \frac{1}{2} a_y \Delta t^2$

-0.618×10^{-2} m $= \frac{1}{2} a_y (4.09 \times 10^{-9} s)^2$

$a_y = \dfrac{-0.618 \times 10^{-2}\text{ m}}{(0.5)(4.09 \times 10^{-9} s)^2} = -7.39 \times 10^{14}$ m/s^2 ↓ (Downward)

$\vec{F}_{net} = m_e \vec{a}_y = qE$ from Equation (a)

$\vec{E} = \dfrac{m_e \vec{a}_y}{q} = \dfrac{9.11 \times 10^{-31} \text{ Kg} * -7.39 \times 10^{14} \frac{m}{s^2}}{1.6 \times 10^{-19} C} = -4207.7$ N/C

$\vec{E} = \langle 0, -4208, 0 \rangle$ N/C

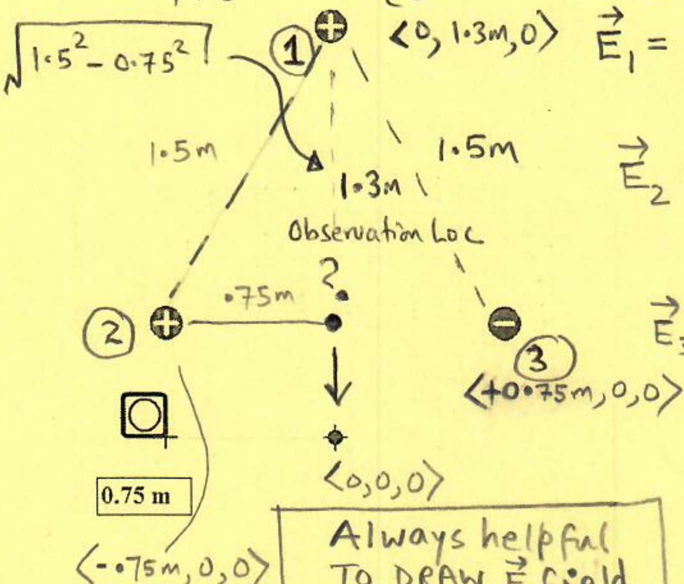
Question 4

Source charge

A student is tinkering with PHET simulation and creates 3 point charges to form an equilateral triangle of side *1.5m* as shown in Figure below. The point charges have a magnitude of 1 nC each.

$K = \frac{1}{4\pi\epsilon_0} = 9\times10^9 \frac{Nm^2}{C^2}$

- Since they are Point charges $\vec{E} = \left(\frac{1}{4\pi\epsilon_0}\right)\frac{q}{|\vec{r}|^2}\hat{r}$
- USE SUPERPOSITION To find $\vec{E}_{net}$



$\vec{E}_1 = \frac{Kq}{(1.3m)^2}\hat{r}_1 \sim \langle 0,-1,0\rangle$

$\vec{E}_2 = \frac{Kq}{(0.75m)^2}\langle 1,0,0\rangle$

will be POSITIVE

$\vec{E}_3 = \frac{K(-q)}{(0.75m)^2}\langle -1,0,0\rangle$

$E_{1Y} = \frac{9\times10^9 \frac{Nm^2}{C^2}\, 1\times10^{-9}C}{(1.3m)^2} = -5.33 N/C$

Downward

(The Z & X components are Zero)

$E_{2X} = \frac{9\times10^9 \frac{Nm^2}{C^2}\cdot 1\times10^{-9}C}{(0.75m)^2} = 16.0 N/C$

$E_{3X} = \frac{9\times10^9 \frac{Nm^2}{C^2}\, 1\times10^{-9}C}{(.75m)^2} = 16.0 N/C$

Always helpful TO DRAW $\vec{E}$ field vectors.

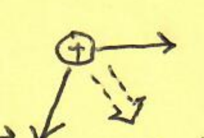
(a) Find the Net Electric field at 0.75m (between the two bottom charges) (5 pts)

$\vec{E}$	X	Y
E_1	0	−5.33 N/C
E_2	16.0 N/C	0
E_3	16.0 N/C	0
$\vec{E}_{net}$	32 N/C	−5.33 N/C

$\vec{E}_{net} = \langle 32, -5.33, 0\rangle \frac{N}{C}$

PART B:

b)



Find $\vec{E}_{net}$ at Lower Left & then Multiply by q_2

$\vec{F} = q_2\vec{E}_{net}$

$\langle 0,0,0\rangle$ $\langle 1.5,0,0\rangle$

(b) What is the Net Force exerted by the two charges on the lower left charge? (5 pts)

$\vec{E}_3 = \frac{K(-q)}{(1.5m)^2}\langle -1,0,0\rangle = \frac{16.0 N/C}{4} = \langle 4,0,0\rangle \frac{N}{C}$

$\vec{E}_1 = \frac{K(q)}{(1.5m)^2}\langle -0.5, -.866, 0\rangle = \langle -2, -3.46, 0\rangle \frac{N}{C}$

For E_1 obsloc − Source Loc = $\vec{r}_1$

$\vec{r}_1 = \langle 0,0,0\rangle - \langle .75m, 1.3m, 0\rangle$

$\vec{r}_1 = \langle -.75, -1.3, 0\rangle m$

$\hat{r}_1 = \frac{\vec{r}}{|\vec{r}_1|} = \frac{\langle -.75, -1.3, 0\rangle m}{\sqrt{.75^2 + 1.3^2}}$

$\hat{r}_1 = \langle -.499, -0.866, 0\rangle$

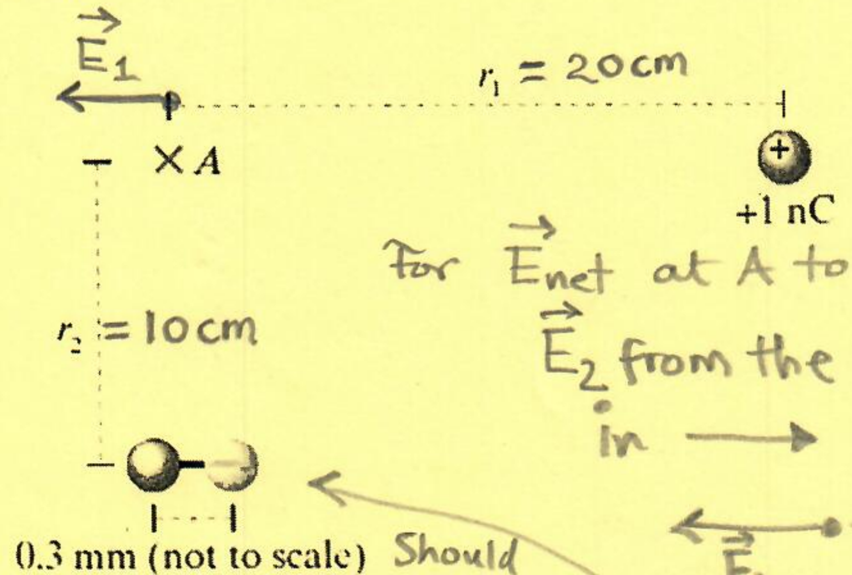
$\vec{F}_{net} = q\,\vec{E}_{net}$

$\vec{E}_1 + \vec{E}_3 = \vec{E}_{net} = \langle 2, -3.46, 0\rangle N/C$

$\vec{F}_{net} = \langle 2\times10^{-9}N, -3.46\times10^{-9}N, 0\rangle$

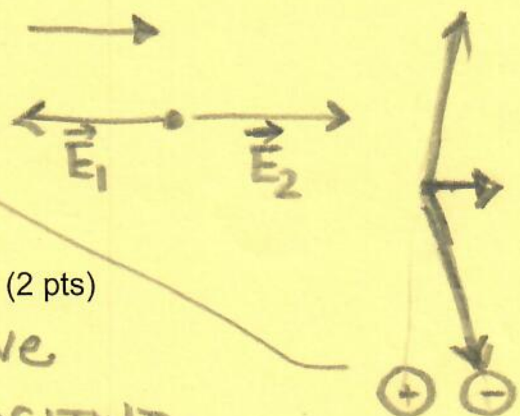
Dipole problem

5. A charge of +1nC (1X 10^{-9}C) and a dipole with charges +q and -q separated by 0.3 mm a net field at a location A that is equal to zero. r1= 20 cm and r2= 10 cm



Should be (–)

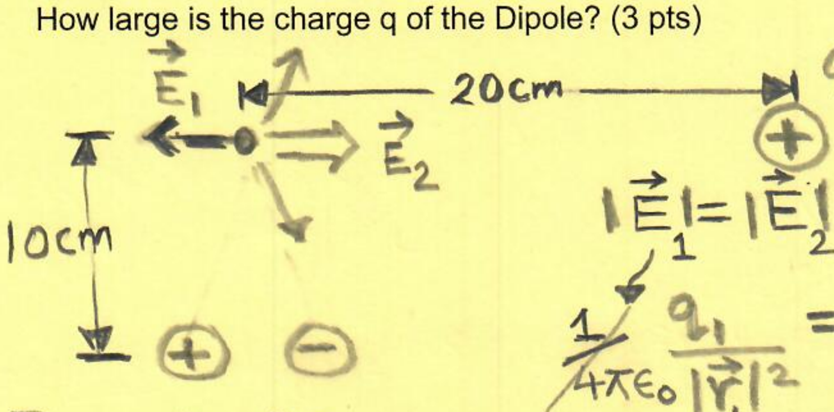
For $\vec{E}_{net}$ at A to be zero we need $\vec{E}_2$ from the Dipole to point in →



Which end of the Dipole is positively charged? (2 pts)

The Right side is Negative & LEFT SIDE IS POSITIVE.

How large is the charge q of the Dipole? (3 pts)



Let me use the Magnitude

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

$$\cancel{\frac{1}{4\pi\epsilon_0}} \frac{q_1}{|\vec{r}_1|^2} = \cancel{\frac{1}{4\pi\epsilon_0}} \frac{q_2 s}{r_2^3}$$

cancel $\frac{1}{4\pi\epsilon_0}$ on Both sides

$$E_{2\perp} = \frac{1}{4\pi\epsilon_0} \frac{qs}{r_2^3}$$

Perpendicular

$$q_2 = \frac{q_1}{r_1^2} \frac{r_2^3}{s} = \frac{1nc\,(10cm)^3}{(20cm)^2\, 0.3mm} * \frac{10mm}{1cm} = 83.3nC$$

$$\boxed{q_2 = 83.3nC}$$

6. Your pet squirrel-Ali repeatedly rubs against your cotton slacks on a dry day , the charge transfer between the squirrel fur and the cotton leaves you with an excess -4.00 μC. (5 pts)

a) How many electrons are transferred between you and the squirrel? You will gradually discharge but if instead of waiting, you immediately reach toward the faucet, a painful spark can suddenly appear as your fingers near the faucet.
(1 pt)

$-4.00\mu C = Q = N * e$ → charge of an Electron

$-4.00\times10^{-6} C = N * -1.6\times10^{-19} C$ ← No. of electrons

$N = \cancel{-4.00\times10^{-6} C} / \cancel{-1.6\times10^{-19} C} = 2.5\times10^{13}$ Electrons

b) In that spark, do electrons flow from you to the faucet or vice versa? Explain.
(1 pt)

Electrons flow from me to the Faucet
Faucet is a conductor And I have excess Electrons

(POLARIZATION)

Faucet

c) Just before the spark appears, what charge is on the faucet? Why?
(1 pt)

Just Like the Drawing above the Faucet has (+) charge Due to Polarization

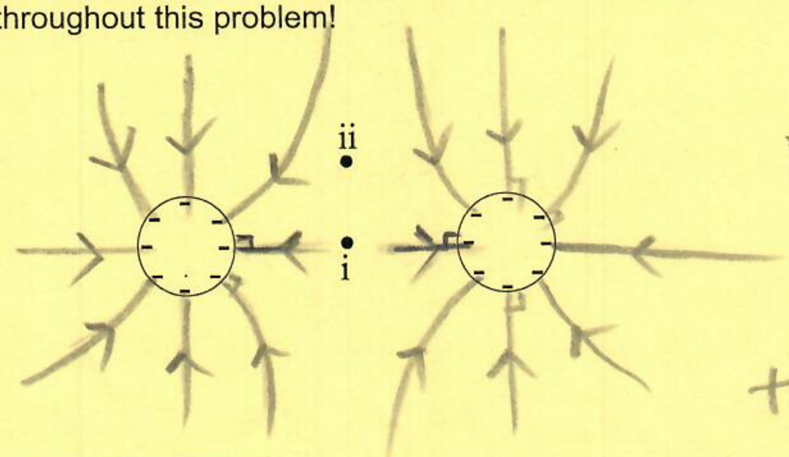
d) If, instead, Ali-the squirrel reaches a paw toward the faucet, which way do the electrons flow in the spark? Explain.(1 pt)

ALI IS Positively charged So Electrons flow from Faucet to ALI Polarization still but Negative charges on faucet

e) If you stroke Ali with a bare hand on a dry day, you should take care not to bring your fingers near the squirrel's nose or you will hurt it with a spark. Considering the squirrel hair/fur is an insulator, explain how the spark can appear.
(1 pt)

When you become (−) Negatively charged and Ali's Nose is wet, shiny & a Conductor. With Polarization & If you are charged up your (−) charges can discharge on Ali's nose which might hurt ouch!

Problem 7: Two identical large spherical conductors each carry identical charge -Q.
The points labeled i and ii are not charges, they are just points in space.
i is at the precise midpoint between the spheres. Point ii is directly above point i.
Neglect gravity throughout this problem!



Electric field Lines are $\perp$ on the surface of Spheres

a) *(4 pts)* Sketch Electric field lines in the figure above. (Remember, field lines are *lines with direction arrows,* not a bunch of little arrows at random points.)

b) (*4 pts*) Is the magnitude of the E field at point ii (shown in the figure) (***circle one!!)***

larger than, smaller than, the same as, ambiguous/undetermined

the magnitude of the E field at the point labeled i? Briefly, explain, using words and figures.

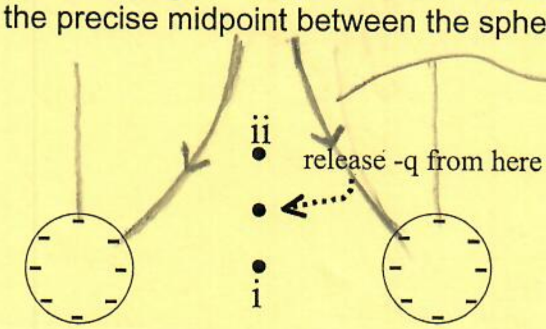
$\vec{E}$ at ii should point Downwards & ADDS up $\downarrow\downarrow = \Downarrow$

$\vec{E}$ at i is zero $\vec{E}_{net}$ $\leftarrow\bullet\rightarrow$ is zero

$|\vec{E}|_{at\ ii} > |\vec{E}|_{at\ i}$

Problem 7 (continued):

The figure from the previous page has been redrawn here with a small addition. (Recall, point i is at the precise midpoint between the spheres. Point ii is directly above point i.)



Using Electric field Lines

$-q$

c) *(4 pts)* If a *negative* test particle is released from a point directly *between* point i and point ii, (the middle black dot shown) which direction will it initially travel? Briefly, explain (with arrows in the figure above, and words below please). If the answer is ambiguous, explain why.

If the $\ominus$ charge was at i it would not move $\vec{E}_{net} = 0$. At a point between ii & i we need to find the Electric field Vector and from that Vector infer how the Force (Net force) on $-q$ acts

$\Downarrow$ $\vec{E}_{net}$ is Downward

But $\vec{F}_{net}$ Would act Upwards

$\vec{F}_{net} = q\vec{E}_{net}$

$q \leftarrow -q$

$\Uparrow$

The Charge Moves Upward!