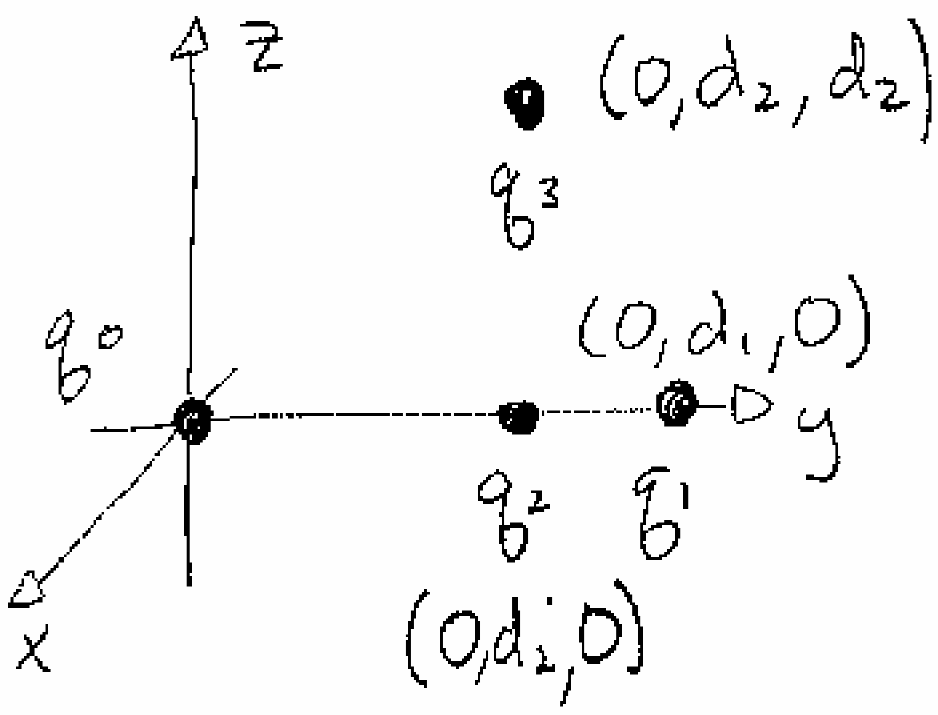
Coulomb's Law Tutorial

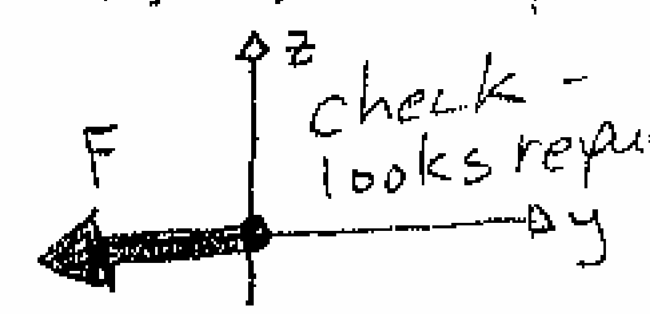


$$\vec{F}_{01} = \frac{kq_1q_0}{r^2}\hat{r} = \frac{kq_1q_0}{|\vec{r}|^2}\frac{\vec{r}}{|\vec{r}|}$$

$$= \frac{kq_1q_0}{d_1^2}\left(\frac{(0-0)\hat{\imath} + (0-d_1)\hat{\jmath} + (0-0)\hat{k}}{d_1}\right)$$

I knew $|\vec{r}|^2 = \left(\sqrt{(0-0)^2 + (0-d_1)^2 + (0-0)^2}\right)^2 = d_1 \cdot d_1$

a) $= \frac{kq_1q_0}{d_1^2}(-\hat{\jmath})$ (or $-\hat{y}$)



check - looks repulsive

$$\vec{F}_{02} = \frac{k(-q_2)q_0}{d_2^2}(-\hat{\jmath}) \qquad \vec{F}_{\text{tot on } 0} = \vec{F}_{01} + \vec{F}_{02}$$

b) $= \left(\frac{kq_2q_0}{d_2^2} - \frac{kq_1q_0}{d_1^2}\right)\hat{\jmath}$

(final direction depends on $|q_2/q_1|$)

c) For $\vec{F}_{tot} = 0$, $\vec{F}_{01} + \vec{F}_{02} = 0$

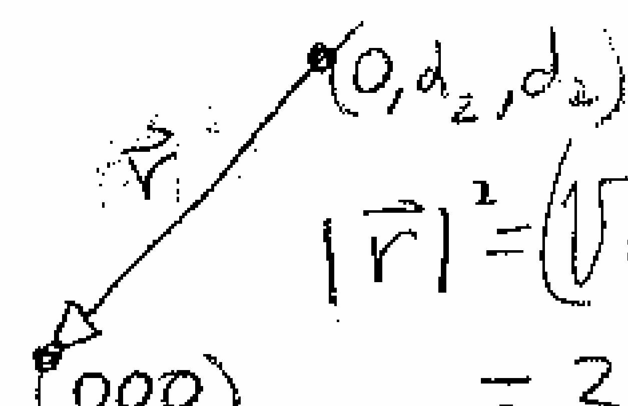
or $\vec{F}_{01} = -\vec{F}_{02}$

$$\frac{kq_1q_0}{d_1^2}(-\hat{\jmath}) = -\frac{k(-q_2)q_0}{d_2^2}(-\hat{\jmath})$$

$$\Rightarrow \frac{q_1}{d_1^2} = \frac{q_2}{d_2^2} \text{ or } \frac{q_1}{q_2} = \frac{d_1^2}{d_2^2}$$

$$\text{so } \frac{d_1}{d_2} = \sqrt{\frac{q_1}{q_2}}$$

d) $\vec{F}_{03} = \frac{kq_3q_0}{|\vec{r}|^2}\hat{r} = \frac{kq_3q_0}{|\vec{r}|^2}\frac{\vec{r}}{|\vec{r}|}$



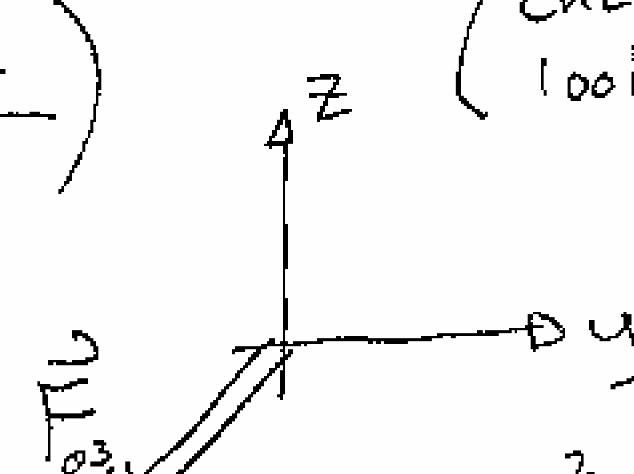
$$|\vec{r}|^2 = \left(\sqrt{(0-0)^2 + (0-d_2)^2 + (0-d_2)^2}\right)^2 = 2d_2^2$$

$$\vec{F}_{03} = \frac{kq_3q_0}{2d_2^2}\left(\frac{(0-0)\hat{\imath} + (0-d_2)\hat{\jmath} + (0-d_2)\hat{k}}{\sqrt{2}\,d_1}\right)$$

$$= \frac{kq_3q_0}{2d_2^2}\left(-\frac{\hat{\jmath}}{\sqrt{2}} - \frac{\hat{k}}{\sqrt{2}}\right)$$

or $-\hat{z}$

(check - looks repulsive!)



in z y plane

Charged Aluminum Spheres

$$\#\text{ electrons in a sphere} = \frac{(0.0250\,\text{kg})}{\left(\frac{26.982\,g}{\text{mole}}\cdot\frac{1\,\text{kg}}{1000\,g}\right)}\cdot\frac{6.02\times10^{23}\,\text{atoms}}{\text{mole}}\cdot\frac{13\,e\text{'s}}{\text{atom}}$$

1/proton

$$= 7.25\times10^{24}\,e\text{'s}$$

Q tot has to stay the same Taking away electrons is like giving the sphere + charge

$$① \xrightarrow{\text{move } n \text{ electons}} ②$$

$$q_1 = n_{electrons}(1.6\times10^{-19}C)$$

$$q_2 = n_{electrons}(-1.6\times10^{-19}C)$$

$$|F| = \left|\frac{k q_1 q_2}{r^2}\right| = \frac{k}{r^2}\left|n_{electrons}(1.6\times10^{-19}C)\right|^2$$

$$\sqrt{\frac{|F|r^2}{k(1.6\times10^{-19}C)^2}} = \sqrt{n^2_{electrons}} = n_{electrons}$$

$$= \sqrt{\frac{1.0\times10^4\,N\cdot(0.80\,m)^2}{\left(8.99\times10^9\,\frac{Nm^2}{C^2}\right)(1.6\times10^{-19}C)^2}} = 5.27\times10^{15}$$

c) Fraction $= 5.27\times10^{15}/7.25\times10^{24} = 7.27\times10^{-10}$

(7.26×10^{-10} w/o rounding 1st)

(21.19)

$q_1 = -1.05\,nC$ $\quad q_3 = +4.75\,nC$ $\quad q_2 = 3.90\,nC$

$\hat{r}_{13}$ $\quad \hat{r}_{23}$

$-0.560\,m$ $\quad -0.410\,m$ $\quad 0$

$\longrightarrow \hat{j}$

$\hat{r}_{13} = \hat{j}$

$\hat{r}_{23} = -\hat{j}$

$$= \frac{k q_2 q_3}{r_{23}^2}\hat{r}_{23}$$

$$= \frac{(8.99\times10^9\,N\frac{m^2}{C^2})(3.90\,\underset{10^{-9}}{nC})(+4.75\,\underset{10^{-9}}{nC})}{(-0.410m - 0)^2}(-\hat{j})$$

$$= 9.907\times10^{-7}\,N(-\hat{j})$$

$$\vec{F}_{13} = \frac{k q_1 q_3}{r_{13}^2}\hat{r}_{13}$$

$$= \frac{(8.99\times10^9\,\frac{Nm^2}{C^2})(-1.05\,\underset{10^{-9}}{nC})(+4.75\,\underset{10^{-9}}{nC})}{(-0.410m-(-0.560m))^2}\hat{j}$$

$$= 1.993\times10^{-6}\,N(-\hat{j})$$

check #1 $\quad$ expect

$-|q_1|$ $\quad +|q_3|$ $\quad +|q_2|$ $\quad$ both in $\hat{j}$ $\quad$ (yes)

attractive $\quad$ repulsive

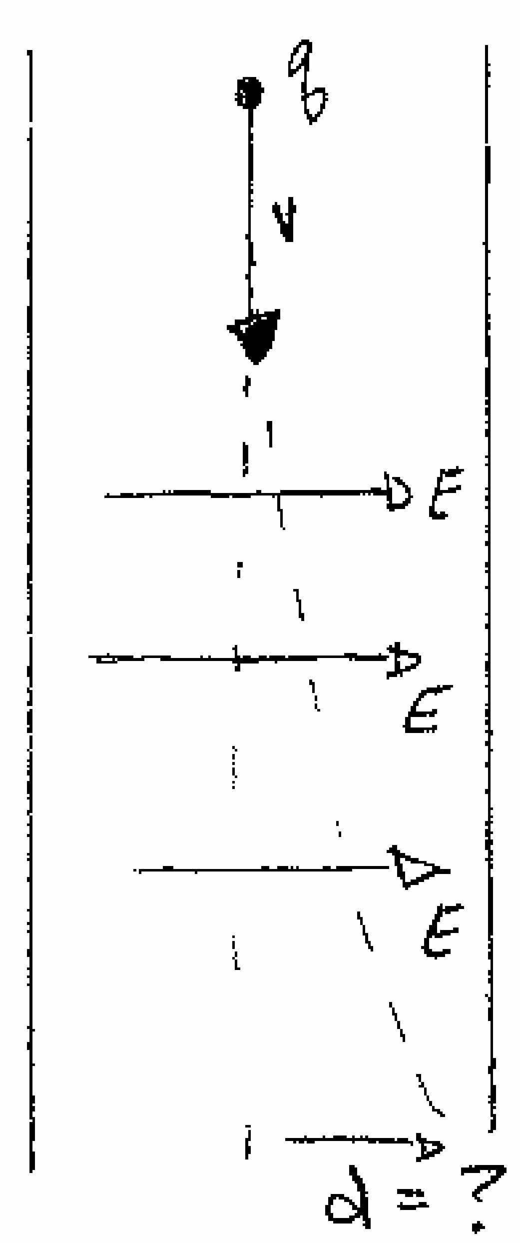
check #2

$$\text{expect } |F_{23}|/|F_{13}| = \frac{|q_2|}{|q_1|}\frac{r_{13}^2}{r_{23}^2} = \frac{3.90}{1.05}\frac{(0.15m)^2}{(0.410)^2} = 0.5$$

(yes)

$$\vec{F}_{tot} = (9.907\times10^{-7}N + 1.993\times10^{-6}N)\hat{j}$$

$$= 2.98\times10^{-6}\,N\,\hat{j}$$



inkdrop radius = r (I tuned it sideways)
density = ρ
charge = q

21.82

1) know the time spent between the plates is D_0/v

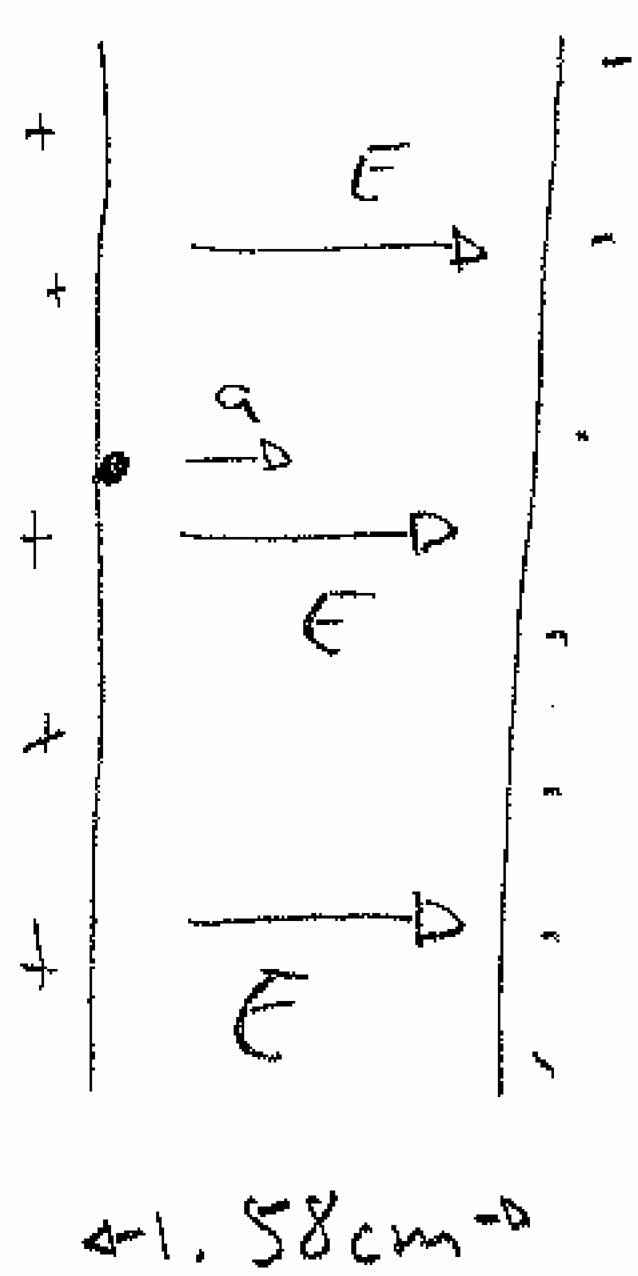
2) The acceleration the drop experiences is $\frac{qE}{m} = \frac{qE}{\frac{4}{3}\pi r^3 \rho}$

3) $d = \frac{1}{2} a t^2$

$$d = \frac{1}{2}\left(\frac{qE}{\frac{4}{3}\pi r^3 \rho}\right)\left(\frac{D_0}{v}\right)^2$$

$$2d\left(\frac{v}{D_0}\right)^2 \frac{\frac{4}{3}\pi r^3 \rho}{E} = q$$

proton between plates



same deal $d = \frac{1}{2}\left(\frac{qE}{m}\right) t^2$

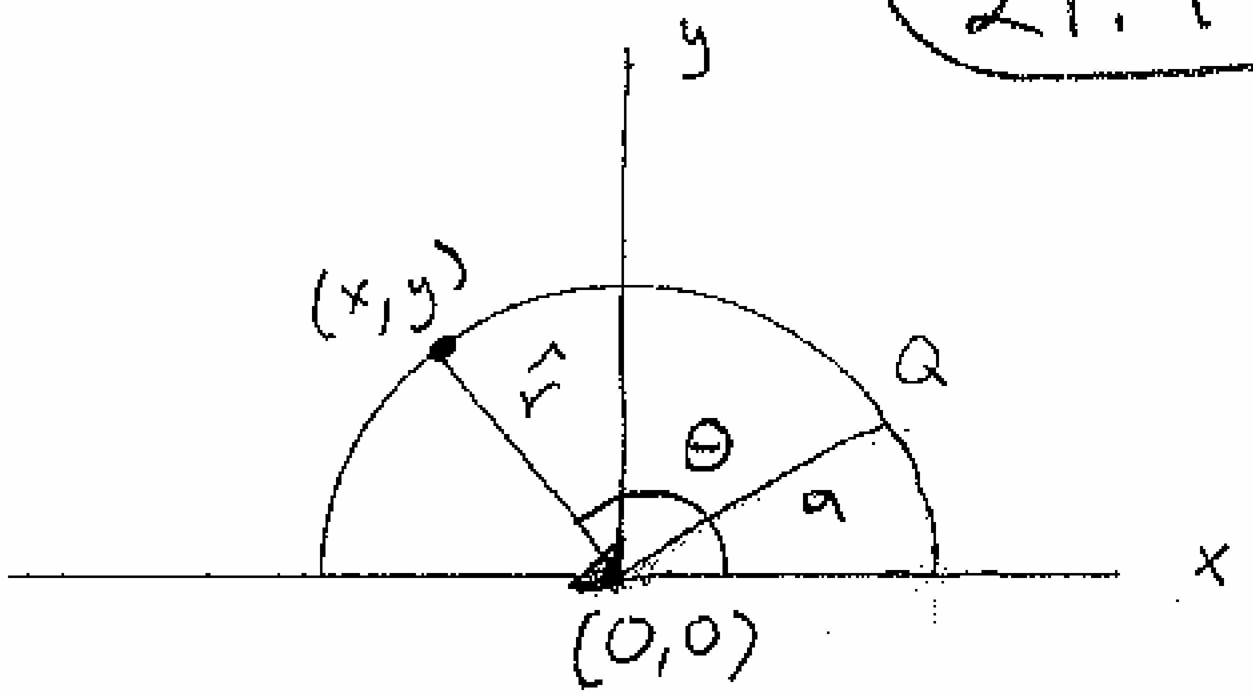
$$E = \frac{2md}{q t^2} = \frac{2(1.67\times10^{-27}\,kg)(0.0158\,m)}{1.60\times10^{-19}\,C\,(1.55\times10^{-6}\,s)^2}$$

$$\cancel{= 137.3 \frac{kg\,m}{C\,s^2}} \qquad 1N = kg\,m/s^2$$

$$v = at = \frac{qE}{m} t = \frac{q}{m} t \left(\frac{2md}{q t^2}\right) = \frac{2d}{t}$$

$$= 2\left(\frac{0.0158\,m}{1.55\times10^{-6}\,s}\right) = 20{,}389.5\ m/s$$

21.94



$$\hat{r} = \frac{(0-x)}{\sqrt{x^2+y^2}}\,\hat{i} + \frac{(0-y)}{\sqrt{x^2+y^2}}\,\hat{j}$$

$$x = a\cos\theta \qquad \sqrt{x^2+y^2} = a$$

$$y = a\sin\theta$$

$$\lambda = Q/\pi a$$

$$d\vec{E} = \frac{k\,dQ\,\hat{r}}{r^2}$$

$$= \frac{k\lambda a\,d\theta}{a^2}\left(-\cos\theta\,\hat{i} - \sin\theta\,\hat{j}\right)$$

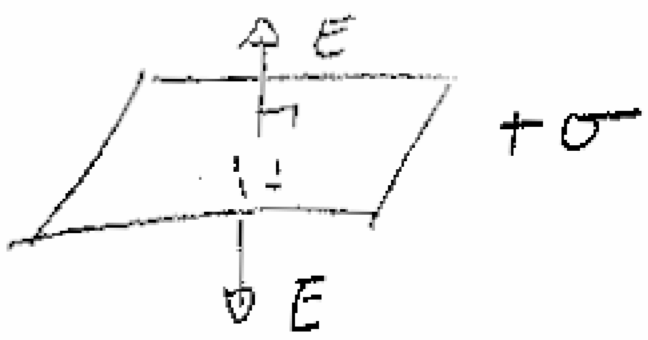
$$\vec{E} = \frac{k\left(\frac{Q}{\pi a}\right)a}{a^2}\left(-\int_0^{\pi}\cos\theta\,d\theta\,\hat{i} + \int_0^{\pi}\sin\theta\,d\theta\,\hat{j}\right)$$

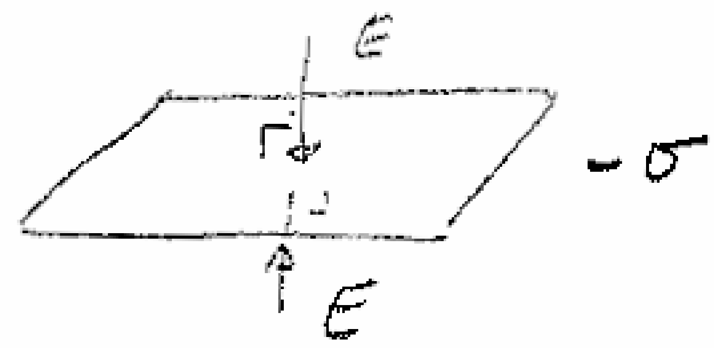
$$= \frac{kQ}{\pi a^2}\left(-\sin\theta\Big|_0^{\pi}\hat{i} + (-\cos\theta)\Big|_0^{\pi}\hat{j}\right)$$

$$= \frac{2kQ}{\pi a^2}\left(-\hat{j}\right)$$

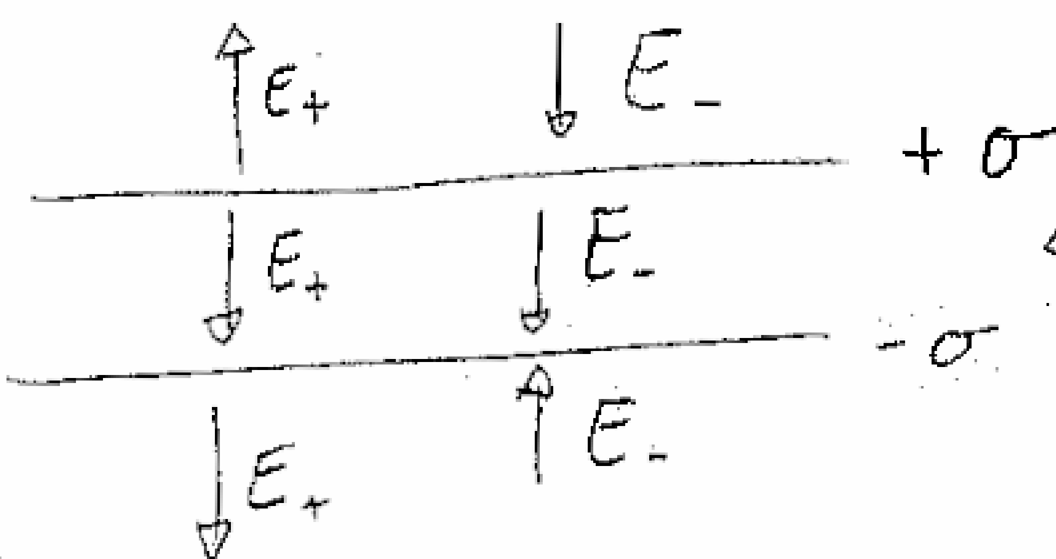
21.54

Infinite sheet of charge has $E = \sigma/2\varepsilon_0$ pointed perpendicular to sheet





expect



$E_{tot} = 0$

$E_{tot} = \left(\frac{\sigma}{2\varepsilon_0} + \frac{\sigma}{2\varepsilon_0}\right)$ down

$E_{tot} = 0$

Electric field vector drawing

similar to effect gravity has on a projectile

slowing down along horiz so

$\Longrightarrow F$

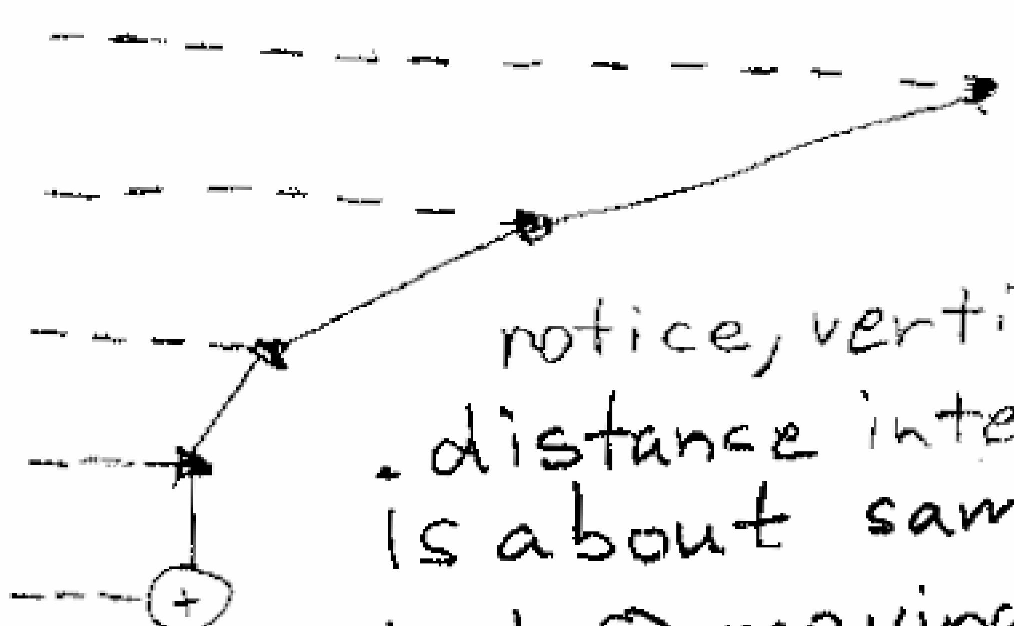
$\vec{F} = q\vec{E}$

+

so $\Longrightarrow E$

(B) Same but for $-q$

$\Longleftarrow E$



notice, vertical distance interval is about same, but ⊕ moving faster in $\longrightarrow$

so $E \longrightarrow$

(d) same deal, but here vertical speed is unchanged (slowing down in $-\hat{x}$, so $\Longrightarrow F$

& since q is ⊖ $\Longleftarrow E$