1.)

a) $\vec{E} = \frac{\vec{F}}{q} = \frac{\langle -1, 2, 0 \rangle}{5 \times 10^{-6}} = \langle -2, 4, 0 \rangle \times 10^{5} \frac{N}{C}$

$\vec{E} = \langle -2, 4, 0 \rangle \times 10^{5} \frac{N}{C}$

b) $\vec{F} = q\vec{E} = (-2 \times 10^{-6}) \langle -2, 4, 0 \rangle \times 10^{5}$ N

$\vec{F} = \langle 0.4, -0.8, 0 \rangle$ N

c) $|\vec{E}| = \frac{1}{4\pi\epsilon_0} \frac{|q|}{|\vec{r}|^2}$

$|\vec{r}|^2 = \frac{1}{4\pi\epsilon_0} \frac{|q|}{\vec{E}}$

$|\vec{r}| = \sqrt{\frac{1}{4\pi\epsilon_0} \frac{|q|}{|\vec{E}|}}$

$\vec{E} = \langle -2, 4, 0 \rangle \times 10^{5} \frac{N}{C}$

$|\vec{E}| = \sqrt{(4 + 16) \times 10^{10}} \frac{N}{C} = 4.47 \times 10^{5} \frac{N}{C}$

$|q| = 10^{-6}$ C

$|\vec{r}| = 0.1419 \ldots$ m

2

a) 1 + 3 are possible

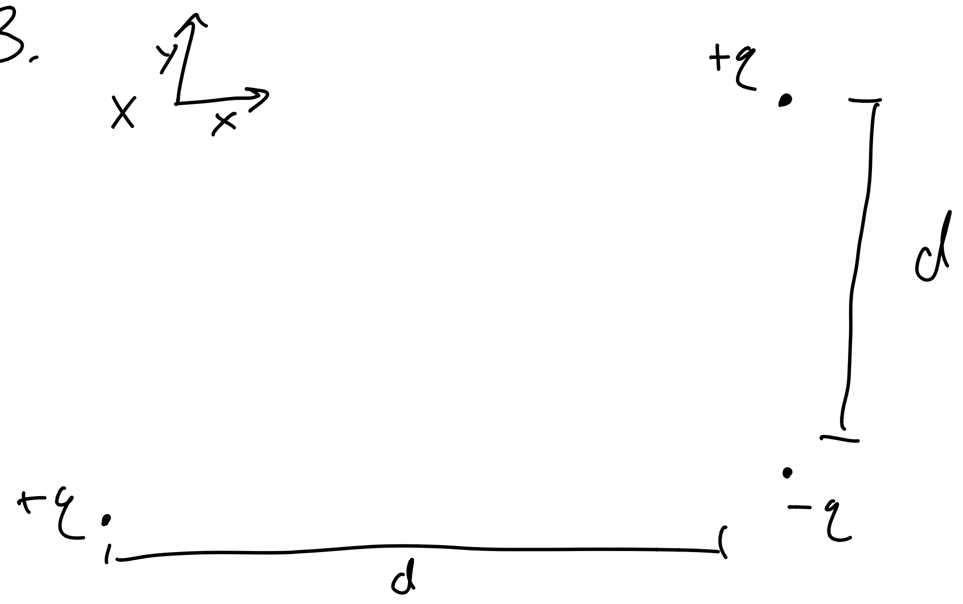
b) Diagram 1

c) 1 + 4 are true

d) Repulsion. An object can be attracted even if it is neutral.

A neutral object can never be repelled by a charged one.

3.



a) Set top left corner as origin.

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

$\vec{E}_1 = \vec{E}_{\text{TOP RIGHT}}$

$\vec{E}_2 = \vec{E}_{\text{BOT RIGHT}}$

$\vec{E}_3 = \vec{E}_{\text{BOT LEFT}}$

$\vec{E}_1$:

$q = +q$

$\vec{r}_{obs} = \langle 0, 0 \rangle$

$\vec{r}_{src} = \langle d, 0 \rangle$

$\vec{r} = \langle -d, 0 \rangle$

$|\vec{r}| = d$

$\hat{r} = \langle -1, 0 \rangle$

$$\vec{E}_1 = \frac{1}{4\pi\epsilon_0}\frac{q}{d^2}\langle -1, 0\rangle$$

$\vec{E}_2$: $q = -q$

$$\vec{r}_{obs} = (0, 0\rangle$$

$$\vec{r}_{src} = \langle d, -d\rangle$$

$$\vec{r} = \langle -d, d\rangle$$

$$|\vec{r}| = \sqrt{2}\, d$$

$$\hat{r} = \left\langle -\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}\right\rangle$$

$$\vec{E}_2 = \frac{-1}{4\pi\epsilon_0}\frac{q}{2d^2}\left\langle -\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}\right\rangle$$

$$\vec{E}_2 = \frac{1}{2}\frac{1}{4\pi\epsilon_0}\frac{q}{d^2}\left\langle \frac{\sqrt{2}}{2}, -\frac{\sqrt{2}}{2}\right\rangle$$

$\vec{E}_3$: $q = +q$

$$\vec{r}_{src} = \langle 0, -d\rangle$$

$$\vec{r} = \langle 0, d\rangle$$

$$|\vec{r}| = d$$

$$\hat{r} = \langle 0, 1\rangle$$

$$\vec{E}_3 = \frac{1}{4\pi\epsilon_0}\frac{q}{d^2}\langle 0, 1\rangle$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0}\frac{q}{d^2}\langle -1, 0\rangle$$

$$+\frac{1}{2}\frac{1}{4\pi\epsilon_0}\frac{q}{d^2}\left\langle \frac{\sqrt{2}}{2}, -\frac{\sqrt{2}}{2}\right\rangle$$

$$+\frac{1}{4\pi\epsilon_0}\frac{q}{d^2}\langle 0, 1\rangle$$

$$= \left\langle -\frac{1}{4\pi\epsilon_0}\frac{q}{d^2} + \frac{1}{4\pi\epsilon_0}\frac{q}{d^2}\frac{\sqrt{2}}{4}, \frac{1}{4\pi\epsilon_0}\frac{q}{d^2} - \frac{1}{4\pi\epsilon_0}\frac{q}{d^2}\frac{\sqrt{2}}{4}\right\rangle$$

$$= \frac{1}{4\pi\epsilon_0}\frac{q}{d^2}\left\langle \frac{\sqrt{2}}{4} - 1, 1 - \frac{\sqrt{2}}{4}\right\rangle$$

$$= \frac{(9\times10^9)(2\times10^{-6})}{(0.45)^2}\langle -0.65, 0.65\rangle$$

$$\vec{E} = \langle -5.77, 5.77\rangle \times 10^4 \ \frac{N}{C}$$

b)

$$V = V_1 + V_2 + V_3$$

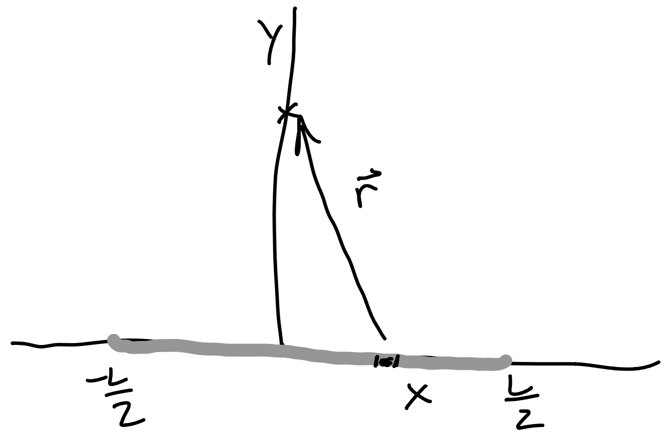
$$r_1 = d, \ r_2 = \sqrt{2}\,d, \ r_3 = d$$

$$V = \frac{q}{4\pi\epsilon_0}\frac{1}{d}\left(1 - \frac{1}{\sqrt{2}} + 1\right) = \frac{q}{4\pi\epsilon_0}\frac{1}{d}\left(2 - \frac{\sqrt{2}}{2}\right)$$

$$V = 5.17 \times 10^4 \ V$$

4.

a)



density: $\lambda = \frac{Q}{L}$

$$dq = \lambda dx = \frac{Q}{L} dx$$

$$\vec{r}_{obs} = \langle 0, y, 0 \rangle$$

$$\vec{r}_{src} = \langle x, 0, 0 \rangle$$

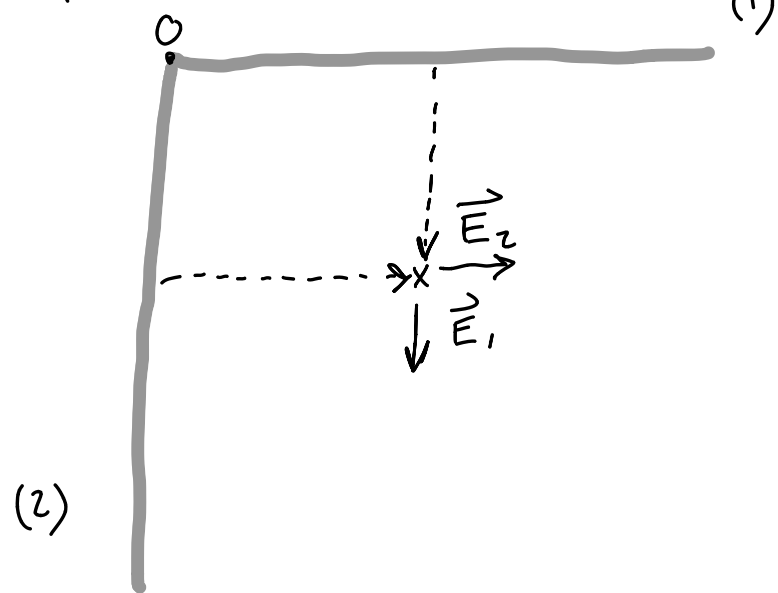
$$\vec{r} = \langle -x, y, 0 \rangle$$

$$|\vec{r}| = \sqrt{x^2 + y^2}$$

$$d\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{Q}{L} \frac{dx}{(x^2+y^2)^{3/2}} \langle -x, y, 0 \rangle$$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{Q}{L} \int_{-\frac{L}{2}}^{\frac{L}{2}} \frac{dx}{(x^2+y^2)^{3/2}} \langle -x, y, 0 \rangle$$

b)



$$\vec{E}_{Rod} = \frac{1}{4\pi\epsilon_0}\left[\frac{Q}{y\sqrt{y^2+(L/2)^2}}\right]\hat{y}$$

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

$$\vec{E}_1 = -\frac{1}{4\pi\epsilon_0}\left[\frac{Q}{L/2\sqrt{(L/2)^2+(L/2)^2}}\right]\hat{y}$$

$$\vec{E}_2 = \frac{1}{4\pi\epsilon_0}\left[\frac{Q}{L/2\sqrt{(L/2)^2+(L/2)^2}}\right]\hat{x}$$

$$\sqrt{(L/2)^2+(L/2)^2} = \sqrt{L^2/2} = \frac{\sqrt{2}}{2}L$$

$$\left(\frac{L}{2}\right)\left(\frac{L}{2}\sqrt{2}\right) = \left(\frac{L}{2}\right)^2\sqrt{2} = \frac{L^2}{4}\sqrt{2}$$

$$\vec{E}_1 = \frac{-1}{4\pi\epsilon_0} \frac{Q}{L^2/4\sqrt{2}} \hat{y} = \frac{-1}{4\pi\epsilon_0} \frac{4\sqrt{2}\,Q}{2L^2} = \frac{-1}{4\pi\epsilon_0} \frac{Q}{L^2} 2\sqrt{2}\,\hat{y}$$

$$\vec{E}_2 = \frac{1}{4\pi\epsilon_0} \frac{Q}{L^2} 2\sqrt{2}\,\hat{x}$$

$$\vec{E} = \frac{2\sqrt{2}}{4\pi\epsilon_0} \frac{Q}{L^2} \langle 1, -1 \rangle$$

$$L = 0.04 \text{ m}$$

$$Q = 6 \times 10^{-6} \text{ C}$$

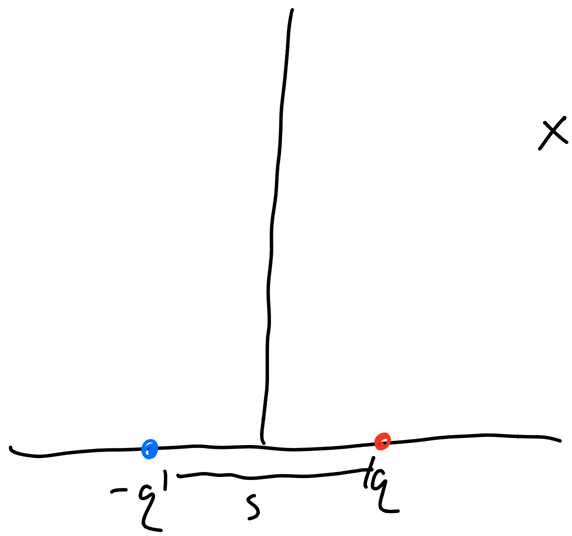
$$\vec{E} = \langle 9.55, -9.55 \rangle \times 10^{7} \frac{N}{C}$$

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

$$= 1.6 \times 10^{-14} \langle 9.55, -9.55 \rangle \times 10^{7} \text{ N}$$

$$\vec{F} = 1.52 \times 10^{-11} \langle 1, -1 \rangle \text{ N}$$

5.



$$p = qs \Rightarrow q = p/s$$

$$q = \frac{6\times10^{-30}}{4\times10^{-12}} = 1.5\times10^{-18}$$

$$\vec{E} = \vec{E}_+ + \vec{E}_-$$

$$\vec{r}_{src+} = \langle s/2, 0, 0\rangle$$

$$\vec{r}_{src-} = \langle -s/2, 0, 0\rangle$$

$\vec{E}_+$

$$\vec{r}_{obs} = \langle 8, 5, 0\rangle \times10^{-12}\ m$$

$$\vec{r}_{src} = \langle 2, 0, 0\rangle \times10^{-12}\ m$$

$$\vec{r} = \langle 6, 5, 0\rangle \times10^{-12}\ m$$

$$|\vec{r}| = \sqrt{36+25} \times 10^{-12}\ m$$

$$|\vec{r}| = 7.81 \times 10^{-12}\ m$$

$$\vec{E}_+ = \frac{kq}{r^2}\hat{r} = \frac{kq}{r^3}\vec{r}$$

$$= \frac{(9\times10^{9})(1.5\times10^{-18})}{(7.81\times10^{-12})^3}\langle 6,5,0\rangle \times 10^{-12}$$

$$\vec{E}_+ = \langle 1.70, 1.42\rangle \times 10^{14}\ \frac{N}{C}$$

$\vec{E}_-$: $\vec{r}_{obs} = \langle 8,5,0\rangle \times 10^{-12}\ m$

$$\vec{r}_{src} = \langle -2,0,0\rangle \times 10^{-12}\ m$$

$$\vec{r} = \langle 10,5,0\rangle \times 10^{-12}\ m$$

$$|\vec{r}| = 1.118 \times 10^{-11}\ m$$

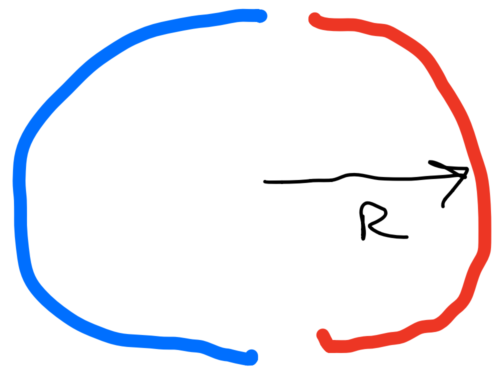
$$\vec{E}_- = \frac{kq}{r^2}\hat{r} = \frac{kq}{r^3}\vec{r}$$

$$= \frac{-(9\times10^{9})(1.5\times10^{-18})}{(1.18\times10^{-11})^3}\langle 10,5,0\rangle\times10^{-12}$$

$$= \langle -9.66\ ,\ -4.83, 0\rangle \times 10^{13}\ \frac{N}{C}$$

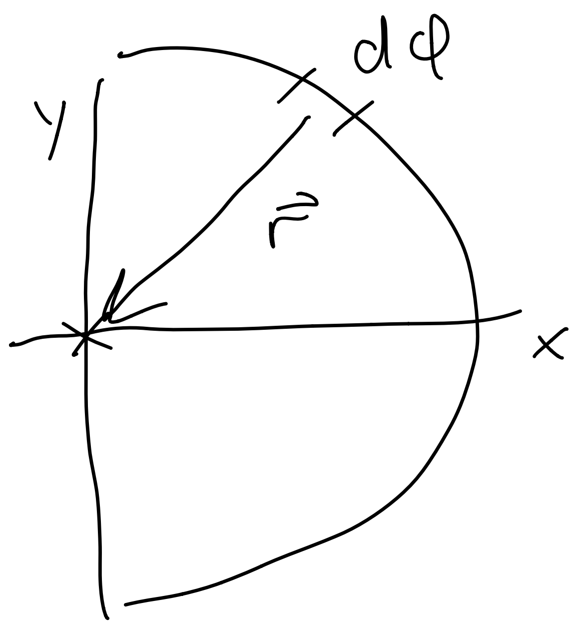
$$\boxed{\vec{E} = \langle 7.34\ ,\ 9.37\ \rangle \times 10^{13}\ \frac{N}{C}}$$

6.



Superposition of
2 half-rings

$\vec{E}_{half-ring}$:



$$\vec{r}_{obs} = \langle 0, 0, 0 \rangle$$

$$\vec{r}_{src} = \langle R\cos\phi, R\sin\phi, 0 \rangle$$

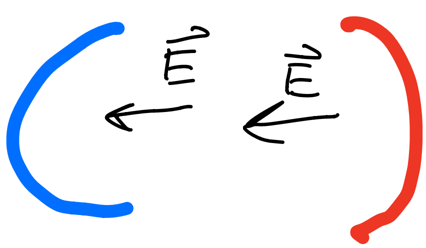
$$\vec{r} = \langle -R\cos\phi, -R\sin\phi, 0 \rangle$$

$$dq = \frac{Q}{\pi} d\phi$$

$$d\vec{E} = \frac{-1}{4\pi\epsilon_0} \frac{Q}{\pi} \frac{d\phi}{R^2} \left(\cos\phi, \sin\phi \right)$$

$$\vec{E} = \frac{-1}{4\pi\epsilon_0} \frac{Q}{\pi} \frac{1}{R^2} \left\langle \underbrace{\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \cos\phi \, d\phi}_{2}, \underbrace{\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \sin\phi \, d\phi}_{0} \right\rangle$$

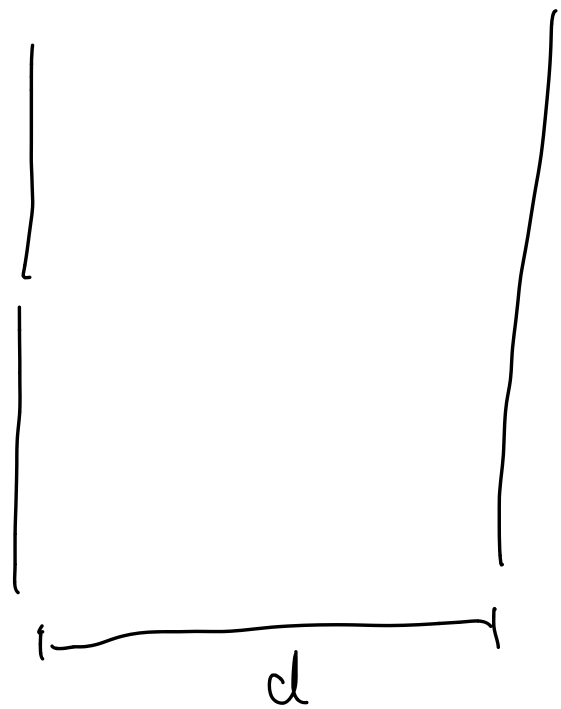
$$\vec{E} = \frac{-1}{4\pi\epsilon_0} \frac{2Q}{\pi R^2} \hat{x}$$



$$\vec{E} = -\frac{4Q}{4\pi\epsilon_0} \frac{Q}{\pi R^2} \hat{x}$$

$$\vec{E} = \frac{-1}{4\pi\epsilon_0} \frac{2Q}{\pi R^2} \left(\hat{x} + \hat{x} \right)$$

7.



a) $W = \Delta K = \frac{1}{2} m_p v_f^2$

$\Delta U = -W = q \Delta V$

$\Delta V = -\frac{1}{2} \frac{m_p v_f^2}{q}$

$\Delta V = -4.7 \times 10^{-2}$ V

$\Delta V = -47$ mV

b) $\Delta V = -\vec{E} \cdot \Delta x$

$|\Delta V| = |\vec{E}||d|$

$|\vec{E}| = \frac{|\Delta V|}{d} = \frac{0.047}{0.0005} = 94 \frac{N}{C}$

$\vec{E} = 94 \frac{N}{C}$

righ to left

c) $\left|\vec{E}_{capacitor}\right| = \frac{\frac{Q}{A}}{\epsilon_0}$

$E A \epsilon_0 = Q$

$Q = (94)(4 \times 10^{-4})(8.85 \times 10^{-12})$

$Q = 3.32 \times 10^{-13}\ C$

Negative is on the right plate

d) $K_i = \frac{1}{2} m_e v_i^2$

$W = -\Delta U = -q\Delta V$

$= e\Delta V$

$= -(e)(0.047)$

$K_f = K_i + W = 2.92\times10^{-19} - 7.52\times10^{-21}$

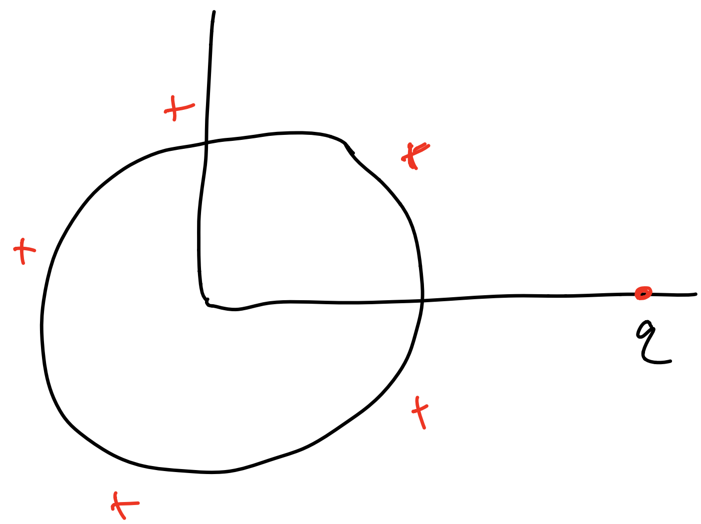
$K_f = 2.84\times10^{-19}$ J

$= \frac{1}{2} m_e v_f^2$

$v_f = \sqrt{\frac{2K_f}{m_e}}$

$v_f = 7.90\times10^{5}\ \frac{m}{s}$

8.



a) $\vec{E} = \vec{E}_{shell} + \vec{E}_{pt}$

$r < R \Rightarrow \vec{E}_{shell} = 0$

$\vec{r}_{obs} = \langle 0, y, 0 \rangle$

$\vec{r}_{src} = \langle d, 0, 0 \rangle$

$\vec{r} = \langle -d, y, 0 \rangle$

$|\vec{r}| = \sqrt{d^2 + y^2}$

$$\vec{E} = \frac{1}{4\pi\epsilon_0} \frac{q}{(d^2+y^2)^{3/2}} \langle -d, y \rangle$$

$q = 8 \times 10^{-6}\ C$

$d = 1.5 \times 10^{-2}\ m$

$y = 5 \times 10^{-3}\ m$

$$\vec{E} = \langle -2.73, 0.91 \rangle \times 10^{8}\ \frac{N}{C}$$

b)

$$\vec{E} = \vec{E}_{shell} + \vec{E}_{pt}$$

$$\vec{E}_{shell} = \frac{KQ}{.05^2}\hat{y} = \langle 0, 1.8 \rangle \times 10^{7}\ \frac{N}{C}$$

$\vec{E}_{pt}$:

$$\vec{E}_{pt} = \frac{1}{4\pi\epsilon_0} \frac{q}{(d^2+y^2)^{3/2}} \langle -d, y \rangle$$

$y = 5 \times 10^{-2}\ m$

$$\vec{E}_{pt} = \langle -0.76, 2.5 \rangle \times 10^{7}\ \frac{N}{C}$$

$$\vec{E} = \langle -0.76, 4.3 \rangle \times 10^{7} \ \frac{N}{C}$$

c) $\vec{E}_{net} = 0$

d) $\vec{E}_{net} = \vec{E}_{pt} + \vec{E}_{pol} = 0$

$$\vec{E}_{pol} = -\vec{E}_{pt}$$

$$\vec{E}_{pol} = \langle 2.73, -0.91 \rangle \times 10^{8} \ \frac{N}{C}$$