2-1) a. $\vec{F}_a = 0$ by symmetry

b. $\vec{F}_b = \vec{F}_a + \vec{F}_{-1}$ $\qquad \vec{F}_{-1} = \frac{1}{4\pi\varepsilon_0}\frac{(-q)Q}{r^2}\hat{y}$ opposite charge

$$= -\frac{1}{4\pi\varepsilon_0}\frac{qQ}{r^2}$$ By superposition

c. $\vec{F}_c = 0$

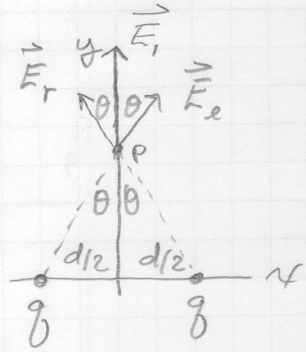
d. $\vec{F}_d = \vec{F}_c + \vec{F}_{-1b}$ $\qquad \vec{F}_{-1b} = \frac{1}{4\pi\varepsilon_0}\frac{(-q)(Q)}{r_d^2}\hat{r}_d$

By superposition

$r_d \equiv$ charge-center distance

$\hat{r}_d \equiv$ unit vector

2-2)



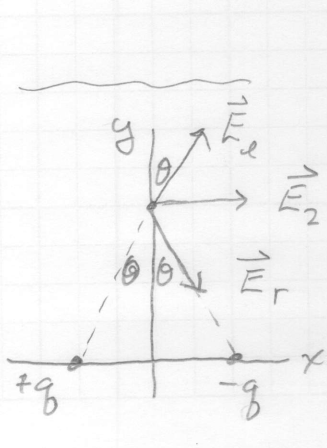
$\vec{E}_1 = \vec{E}_\ell + \vec{E}_r$

transverse components cancel so only use vertical part

$$\vec{E}_1 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q\cos\theta}{\left(\frac{d^2}{4}+y^2\right)} + \frac{q\cos\theta}{\left(\frac{d^2}{4}+y^2\right)}\right]\hat{y}$$

$$= \frac{1}{4\pi\varepsilon_0}\frac{2q}{\left(\frac{d^2}{4}+y^2\right)}\frac{y}{\sqrt{\frac{d^2}{4}+y^2}}\hat{y}$$

$$\vec{E}_1 = \frac{1}{4\pi\varepsilon_0}\frac{2qy}{\left(\frac{d^2}{4}+y^2\right)^{3/2}}\hat{y}$$



$\vec{E}_2 = \vec{E}_\ell + \vec{E}_r$

vertical components cancel

$$\vec{E}_2 = \frac{1}{4\pi\varepsilon_0}\left[\frac{q\sin\theta}{\left(\frac{d^2}{4}+y^2\right)} + \frac{q\sin\theta}{\left(\frac{d^2}{4}+y^2\right)}\right]\hat{x}$$

$$\sin\theta = \frac{d/2}{\left(\frac{d^2}{4}+y^2\right)^{1/2}}$$

$$= \frac{1}{4\pi\varepsilon_0}\,\frac{2q\,d/2}{\left(\frac{d^2}{4}+y^2\right)^{3/2}}\,\hat{x}$$

$$\vec{E}_2 = \frac{1}{4\pi\varepsilon_0}\,\frac{qd}{\left(\frac{d^2}{4}+y^2\right)^{3/2}}\,\hat{x}$$

for $\vec{E}_1$ and $y \gg d$

$$\vec{E}_1 \sim \frac{1}{4\pi\varepsilon_0}\,\frac{2q\cancel{y}}{y^{\cancel{3}\,2}}\,\hat{y} = \frac{1}{4\pi\varepsilon_0}\,\frac{2q}{y^2}\,\hat{y}$$

looks like a point charge.

for $\vec{E}_2$ and $y \gg d$

$$\vec{E}_2 \sim \frac{1}{4\pi\varepsilon_0}\,\frac{qd}{y^3}\,\hat{x} \sim 0$$

looks like a neutral object.