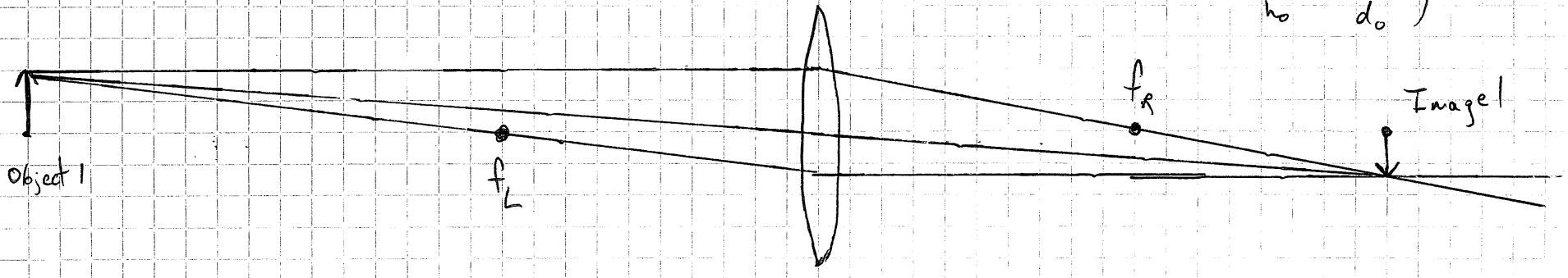
1)

Grid spacing = 3 cm horizontally
0.5 cm vertically

Image distance ~ 54 cm via this method (actual answer from $\frac{1}{s} + \frac{1}{s'} = \frac{1}{f}$ is 50 cm)

Image height ~ -0.7 cm (actual answer is -0.67 cm via $\frac{h_i}{h_o} = \frac{-d_i}{d_o}$)



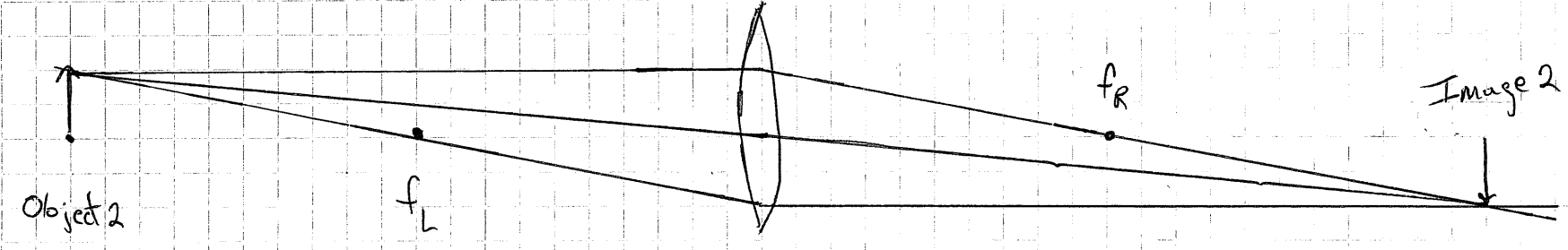
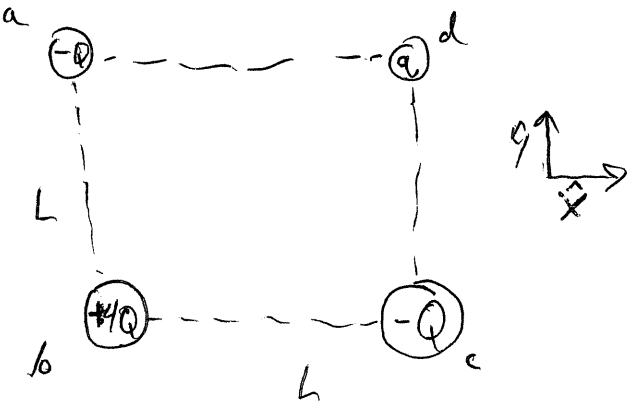


Image distance ~ 63 cm (actual answer is 60 cm)
Image height ~ 1 cm (actual answer 1 cm)

2)



$$\vec{F}_{ad} = \frac{-Qq}{4\pi\varepsilon_0 |\vec{r}_{ad}|^2}\hat{r}_{ad} \qquad \vec{r}_{ad} = L\hat{x}$$

$$\hat{r}_{ad} = \hat{x}$$

$$|r_{ad}| = L$$

$$= \frac{-Qq}{4\pi\varepsilon_0 L^2}\hat{x}$$

Similarly $\vec{F}_{cd} = \frac{-Qq}{4\pi\varepsilon_0 L^2}\hat{y}$

$$\vec{F}_{bd} = \frac{4Qq}{4\pi\varepsilon_0 |\vec{r}_{bd}|^2}\hat{r}_{bd} \qquad \vec{r}_{bd} = L\hat{x} + L\hat{y}$$

$$\hat{r}_{bd} = \frac{1}{\sqrt{2}}(\hat{x}+\hat{y})$$

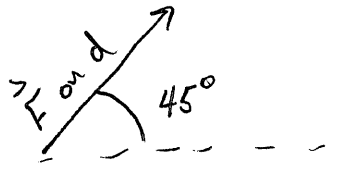
$$|\vec{r}_{bd}| = \sqrt{2}L$$

$$= \frac{4Qq}{2\pi\varepsilon_0 L^2}\cdot\frac{1}{\sqrt{2}}(\hat{x}+\hat{y})$$

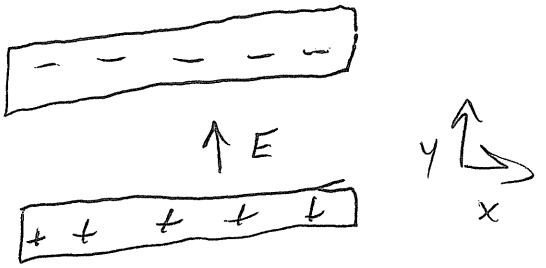
$$\Rightarrow \vec{F}_{on\ d} = \vec{F}_{ad} + \vec{F}_{bd} + \vec{F}_{cd} = \frac{Qq}{4\pi\varepsilon_0 L^2}(\sqrt{2}-1)(\hat{x}+\hat{y})$$

$$\text{i.e. } |\vec{F}_{on\ d}| = \frac{Qq}{4\pi\varepsilon_0 L^2}(\sqrt{2}-1)(\sqrt{2})$$

and



3)a) Inside a capacitor the electric field is approximately constant. It is directed straight up



Let the electric field strength be E.

The force on an electron inside the capacitor will be eE (directed downward) where e is the charge on the electron.

Gravitational force here will be negligible.

Therefore the electron will accelerate downward with acceleration $a_e = \frac{Ee}{m_e}$

The time from launch to impact is

$\frac{2V_{oy}}{a_e}$ and the horizontal distance travelled

is $d_x = \frac{2V_{oy}}{a_e} \cdot V_{ox}$ $\qquad V_{oy} = V_{ox} = \frac{V}{\sqrt{2}}$ ($V = 5.10^6$ m/s as given in problem)

$(d_x = 4.10^{-2}\ m) \Rightarrow d_x = \frac{V^2}{a_e} = \frac{V^2 m_e}{Ee} \Rightarrow E = \frac{V^2 m_e}{e d_x}$

3a (cont.) $\Rightarrow E = \boxed{3.56 \cdot 10^{3}\ N/C}$ (directed up)

3 b) time of flight (t_f) $= \frac{d_x}{v_{0x}} = \frac{\sqrt{2}\, d_x}{v}$

time to top of arc $= \frac{t_f}{2} = \frac{\sqrt{2}}{2} \frac{d_x}{v}$

displacement in y-direction to top of arc (d_y)

$$d_y = \frac{v_{0y} + v^y_{\text{top of arc}}}{2} \cdot \left(\frac{t_f}{2}\right) \qquad v^y_{\text{top of arc}} = 0$$

$$d_y = \frac{v}{4\sqrt{2}} \cdot t_f = \frac{v}{4\sqrt{2}} \cdot \frac{\sqrt{2}\, d_x}{v} = \frac{d_x}{4} = \boxed{1\ cm}$$