MT-01, prob 1

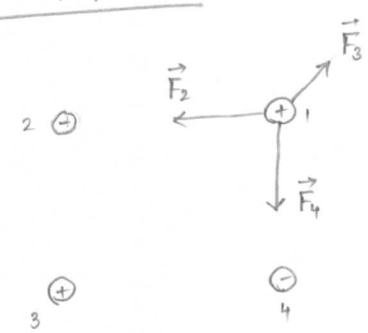
$$F_E = \frac{ke^2}{r^2}$$

$$F_G = \frac{G\, m_e m_p}{r^2}$$

$$\frac{F_E}{F_G} = \frac{ke^2}{G m_e m_p} = \frac{8.9\times10^{9}\times(1.6\times10^{-19})^2}{(6.7\times10^{-11})(9.1\times10^{-31})\times(1.67\times10^{-27})}$$

$$= 2.2\times10^{39}$$

MT-01, prob 2



$$|\vec{F_2}| = |\vec{F_4}| = \frac{kQ^2}{L^2}$$

$$|\vec{F_3}| = \frac{kQ^2}{2L^2}$$

$\cos 45 = \sin 45 = \frac{1}{\sqrt{2}}$

$$\vec{F_2} = -\frac{kQ^2}{L^2}\,\hat{i} + 0\,\hat{j}$$

$$\vec{F_4} = 0\,\hat{i} - \frac{kQ^2}{L^2}\,\hat{j}$$

$$\vec{F_3} = \frac{kQ^2}{2L^2}\frac{1}{\sqrt{2}}\,\hat{i} + \frac{kQ^2}{2L^2}\frac{1}{\sqrt{2}}\,\hat{j}$$

$$\vec{F_{tot}} = \vec{F_1} + \vec{F_2} + \vec{F_3}$$

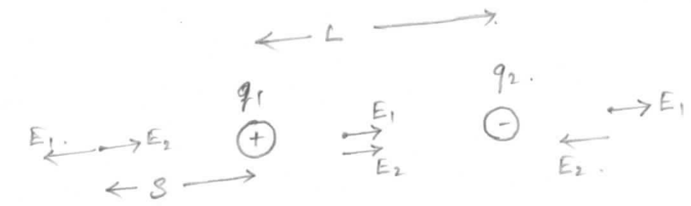
$$= \frac{kQ^2}{L^2}\left(\frac{1}{2\sqrt{2}} - 1\right)\hat{i} + \frac{kQ^2}{L^2}\left(\frac{1}{2\sqrt{2}} - 1\right)\hat{j}$$

$$|\vec{F_{tot}}| = \frac{kQ^2}{L^2}\sqrt{2}\left(1 - \frac{1}{2\sqrt{2}}\right)$$

$$= \frac{kQ^2}{L^2}\left(\sqrt{2} - \frac{1}{2}\right)$$

Direction : pointing towards charg 3 along the diagonal of square, which makes 45° with its sides.

MT-01, prob 3



Argue that it is to the left of q_1.

$q_1 = 2q$
$q_2 = -8q$

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

$$\frac{k|q_1|}{s^2} = \frac{k|q_2|}{(L+s)^2}$$

$$\sqrt{\frac{|q_2|}{|q_1|}} = 2$$

$$L + s = \pm\sqrt{\frac{|q_2|}{|q_1|}}\, s$$

$$L + s = \pm 2s.$$

$$s = L, \ -\frac{L}{3}$$

$-\frac{L}{3}$ → unphysical.

Answer:
$x = -L$, which is distance L to the left of q_1.

MT-01, prob 4

acceleration $= a = \frac{qE}{m}$ and $V_f = V_i + a\,\Delta T$

$$V_e = \frac{eE}{m_e}\Delta t \qquad \frac{V_e}{V_p} = \frac{m_p}{m_e} \sim 1835$$

$$V_p = \frac{eE}{m_p}\Delta t$$

Thus, electron gains higher speed.

MT-01, prob 5

$$\vec{E} = -\hat{i}\left[\frac{kq}{a^2} + \frac{kq}{(2a)^2} + \frac{kq}{(3a)^2} + \cdots\right]$$

$$= -\hat{i}\,\frac{kq}{a^2}\left[1 + \frac{1}{2^2} + \frac{1}{3^2} + \cdots\right]$$

$$= -\hat{i}\,\frac{kq}{a^2}\,\frac{\pi^2}{6}$$

It will be in $+\hat{i}$ direction if charges are assumed negative.

MT-01, prob 6

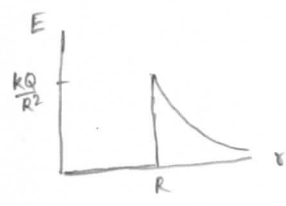
$\vec{E} = 14\hat{i} + 20\hat{j} + 16\hat{k}$ units $= \frac{N}{C}$.

$\vec{A} = 2\hat{k}$ units $= m^2$.

$\phi_E = \vec{E}\cdot\vec{A} = 16 \times 2 \ \frac{N}{C}m^2 = 32 \ \frac{N}{C}m^2$

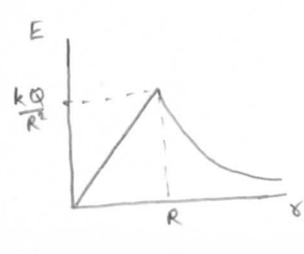
MT-01, prob 7

(a)



$$E = \begin{cases} 0, & \text{if } r < R, \\ \frac{kQ}{r^2}, & \text{if } R < r. \end{cases}$$

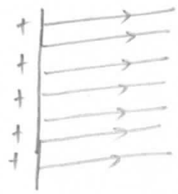
(b)



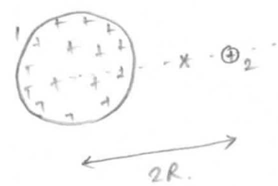
$$E = \begin{cases} \frac{kQ}{R^2}\frac{r}{R}, & \text{if } r < R, \\ \frac{kQ}{r^2}, & \text{if } R < r. \end{cases}$$

MT-01, prob 8

$$E = \frac{\sigma}{2\epsilon_0} = \frac{8\times 10^{-6}\ \frac{C}{m^2}}{2\times 8.85\times 10^{-12}\ \frac{C^2}{N m^2}} = 4.5\times 10^{5}\ \frac{N}{C}$$



MT-01, prob 9



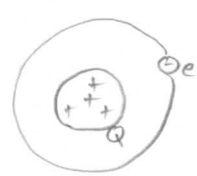
$$\vec{E}_1 = \frac{kQ}{\left(\frac{3}{2}R\right)^2}\ \hat{i}$$

$$\vec{E}_2 = -\frac{kQ}{\left(\frac{1}{2}R\right)^2}\ \hat{i}$$

$$\vec{E}_{tot} = \hat{i}\ \frac{4kQ}{R^2}\left(\frac{1}{9}-1\right)$$

$$|\vec{E}_{tot}| = 4\frac{kQ}{R^2}\frac{8}{9} = \frac{32}{9}\frac{kQ}{R^2}$$

MT-01, prob 10



$$\frac{kQe}{r^{\cancel{2}}} = \frac{m_e v^2}{\cancel{r}}$$

$$Q = \frac{m_e v^2 r}{ke}$$

$$= \frac{9.1\times 10^{-31}\times (2.99\times 10^{5})^2\times 9.5\times 10^{-3}}{8.9\times 10^{9}\times 1.6\times 10^{-19}}$$

$$= 5.43\times 10^{-13}\ C$$