Solutions

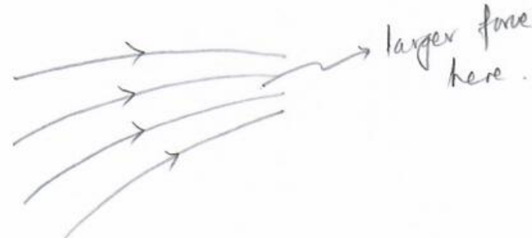
PHYS-205B-001 (Midterm Exam 01) (Fall 2023)

Problem 1

Zero.

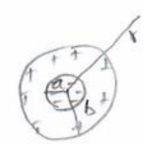
Problem 2

The density of electric field lines is a measure of the strength of electric field. Since $\vec{F} = q\vec{E}$, regions with denser lines will have larger magnitude of force.



Problem 3

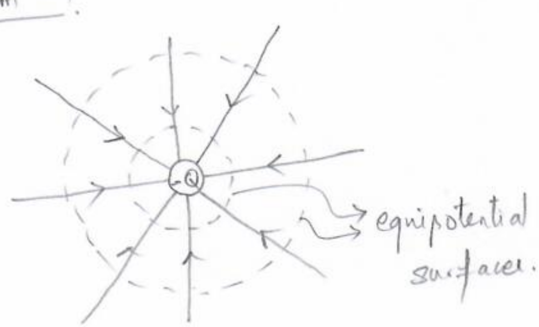
$$\oint \vec{E} \cdot d\vec{a} = \frac{-16Q + 17Q}{\epsilon_0} \quad \text{for } r > b$$



$$E(4\pi r^2) = \frac{Q}{\epsilon_0}$$

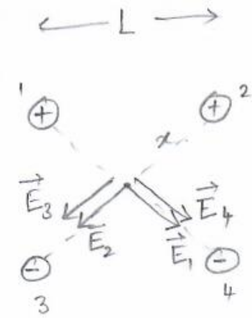
$$\Rightarrow \quad \vec{E} = \frac{Q}{4\pi\epsilon_0 r^2}\hat{r} \quad \text{for } r > b.$$

Problem 4



equipotential surfaces are perpendicular to electric field lines.

Problem 5



$x = \frac{L}{\sqrt{2}}$

$$\vec{E}_1 = \frac{kq}{(L/\sqrt{2})^2}\left[+\cos 45\,\hat{i} - \sin 45\,\hat{j}\right]$$

$$= \frac{2kq}{L^2}\left[+\frac{1}{\sqrt{2}}\,\hat{i} - \frac{1}{\sqrt{2}}\,\hat{j}\right]$$

$$\vec{E}_4 = \frac{2kq}{L^2}\left[+\frac{1}{\sqrt{2}}\,\hat{i} - \frac{1}{\sqrt{2}}\,\hat{j}\right] = \vec{E}_1$$

$$\vec{E}_2 = \frac{2kq}{L^2}\left[-\frac{1}{\sqrt{2}}\,\hat{i} - \frac{1}{\sqrt{2}}\,\hat{j}\right]$$

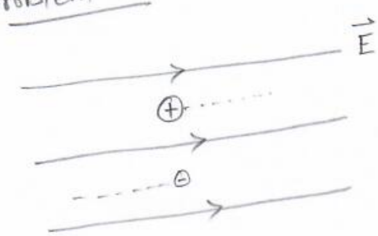
$$\vec{E}_3 = \frac{2kq}{L^2}\left[-\frac{1}{\sqrt{2}}\,\hat{i} - \frac{1}{\sqrt{2}}\,\hat{j}\right] = \vec{E}_2$$

$$\vec{E}_{tot} = \frac{2kq}{L^2}\left[0\,\hat{i} - \frac{4}{\sqrt{2}}\,\hat{j}\right] = -\hat{j}\,\frac{8}{\sqrt{2}}\,\frac{kq}{L^2}$$

magnitude: $\frac{8}{\sqrt{2}}\frac{kq}{L^2}$

direction: along $-\hat{j}$

Problem 6



$$a_p = \frac{eE}{m_p} \qquad a_e = \frac{eE}{m_e}$$

$$V_p = V_{pi} + a_p\,\Delta t$$

$$V_e = V_{ei} + a_e\,\Delta t$$

$$\frac{V_e}{V_p} = \frac{\left(\frac{eE}{m_e}\Delta t\right)}{\left(\frac{eE}{m_p}\Delta t\right)} = \frac{m_p}{m_e}$$

Problem 7

$+Q = q_2$

$-Q = q_1$

$+Q = q_3$

$$U = U_{12} + U_{23} + U_{31}$$

$$= +\frac{kq_1q_2}{L} + \frac{kq_2q_3}{L} + \frac{kq_3q_1}{L}$$

$$= -\frac{kQ^2}{L} + \frac{kQ^2}{L} - \frac{kQ^2}{L}$$

$$= -\frac{kQ^2}{L}$$