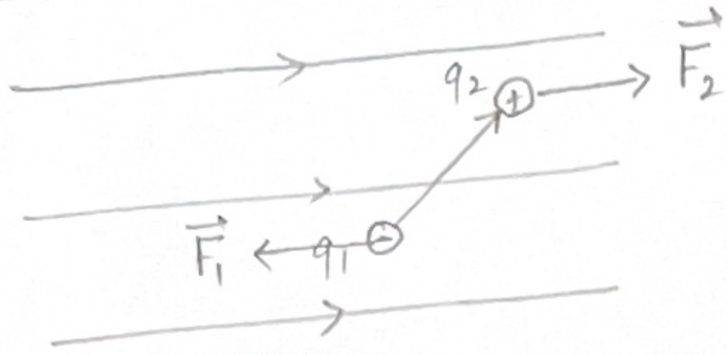
Solution

PHYS-205B-002 (Midterm Exam 01) Spring 2025

Problem 1



$q_1 = -q_2$

$\vec{F}_{tot} = \vec{F}_1 + \vec{F}_2$

$= q_1 \vec{E} + q_2 \vec{E}$

$= (q_1 + q_2) \vec{E}$

$= 0$

no force

Problem 2

$F = \frac{k Q_A Q_B}{r^2} = \frac{k Q^2}{r^2}$

$Q_A = Q \quad Q_B = Q \quad Q_C = 0$

$Q_A' = \frac{Q}{2} \quad Q_B' = Q \quad Q_C' = \frac{Q}{2}$

$Q_A'' = \frac{Q}{2} \quad Q_B'' = \frac{3}{4}Q \quad Q_C'' = \frac{3}{4}Q$

$F'' = \frac{k Q_A'' Q_B''}{r^2} = \frac{k \left(\frac{1}{2}Q\right)\left(\frac{3}{4}Q\right)}{r^2}$

$= \frac{3}{8} \frac{kQ^2}{r^2}$

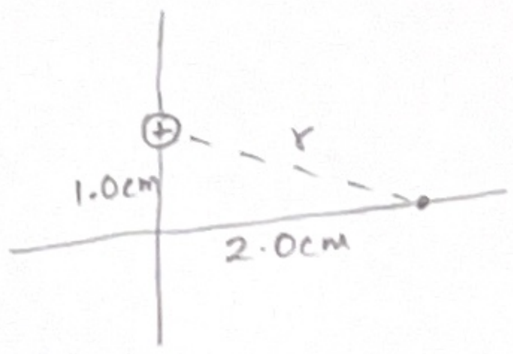
$= \frac{3}{8} F$

Problem 3

$|\vec{E}| = \frac{k q}{r^2}$

$= \frac{(9.0 \times 10^9)(1.0 \times 10^{-9})}{5.0 \times 10^{-4}}$

$= 1.8 \times 10^4 \ \frac{N}{C}$



$r^2 = (1.0)^2 + (2.0)^2$

$= 5.0\ cm^2$

$= 5.0 \times 10^{-4}\ m^2$

Problem 4

$$\Phi_E = \frac{Q_{enclosed}}{\epsilon_0} = \frac{-3.5\times10^{-9}\,C}{8.9\times10^{-12}\,\frac{C^2}{Nm^2}} = -390\,\frac{N}{C}\,m^2$$

Problem 5

$$\vec{F}_{21} = \frac{kq^2}{L^2}\left[\cos 60\,\hat{i} + \sin 60\,\hat{j}\right]$$

$$= \frac{kq^2}{L^2}\left[\frac{1}{2}\,\hat{i} + \frac{\sqrt{3}}{2}\,\hat{j}\right]$$

$$\vec{F}_{23} = \frac{kq^2}{L^2}\left[-\frac{1}{2}\,\hat{i} + 0\,\hat{j}\right]$$

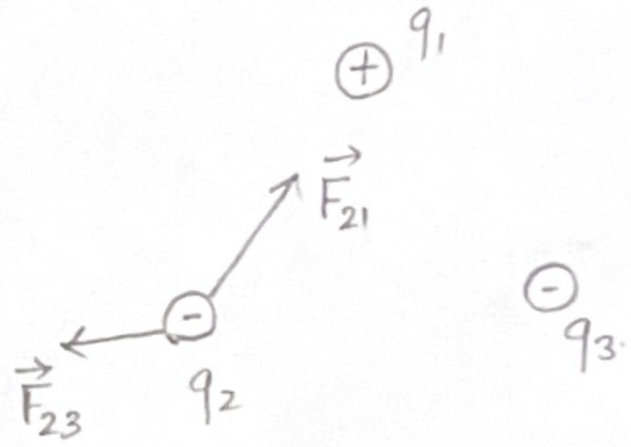
$$\vec{F}_{tot} = \frac{kq^2}{L^2}\left[0\,\hat{i} + \frac{\sqrt{3}}{2}\,\hat{j}\right] = \hat{j}\,\frac{\sqrt{3}}{2}\,\frac{kq^2}{L^2}$$

$$= \hat{j}\,\frac{\sqrt{3}}{2}\,\frac{(9.0\times10^9)(1.0\times10^{-9})^2}{(3.0\times10^{-2})^2}\,\frac{N}{}$$

$$= \hat{j}\,8.7\,\mu N$$

magnitude: $8.7\,\mu N$

direction: along $\hat{j}$



Problem 6

$$a = \frac{qE}{m} = \frac{(1.6\times10^{-19})(9.1\times10^3)}{9.1\times10^{-31}} = 1.6\times10^{15}\,\frac{m}{s^2}$$

$\Delta x = 2.0\times10^{-2}\,m$

$\Delta t = \boxed{5.0\times10^{-9}\,s}$

$V_{ix} = 4.0\times10^6\,\frac{m}{s}$

$$\Delta t = \frac{\Delta x}{V_{ix}} = \frac{2.0\times10^{-2}}{4.0\times10^6} = 5.0\times10^{-9}\,s$$

$\Delta y = ?$

$\Delta t = \boxed{5.0\times10^{-9}\,s}$

$V_{iy} = 0$

V_{fy}

$a = -1.6\times10^{15}\,\frac{m}{s^2}$

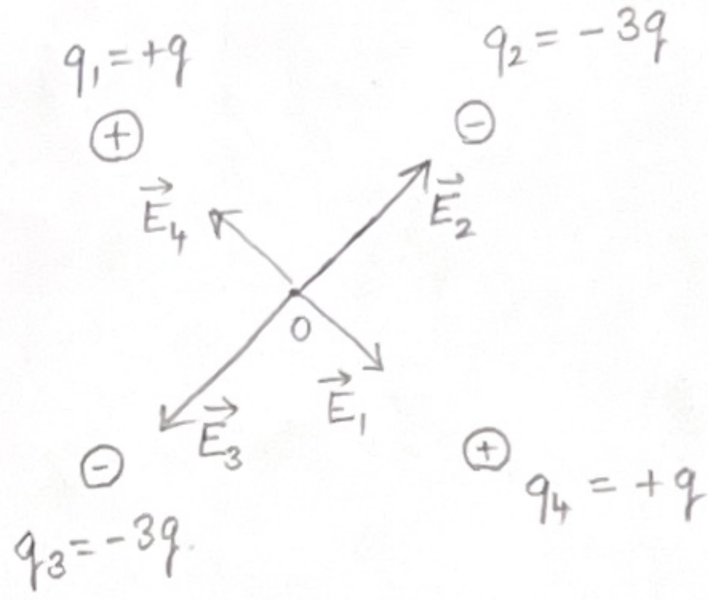
$$\Delta y = V_{iy}\,\Delta t + \frac{1}{2}\,a\,\Delta t^2$$

$$= 0 + \frac{1}{2}(-1.6\times10^{15})(5.0\times10^{-9})^2$$

$$= -0.020\,m$$

$$= -2.0\,cm$$

Problem 7



$$\vec{E}_1 + \vec{E}_4 = 0$$

$$\vec{E}_2 + \vec{E}_3 = 0$$

$$\Rightarrow \quad \vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \vec{E}_4 = 0$$

Explicitly,

$$\vec{E}_1 = \frac{kq}{a^2}\left[\cos 45\,\hat{i} - \sin 45\,\hat{j}\right] = \frac{kq}{a^2}\left[\frac{1}{\sqrt{2}}\,\hat{i} - \frac{1}{\sqrt{2}}\,\hat{j}\right]$$

$$\vec{E}_2 = 3\frac{kq}{a^2}\left[\cos 45\,\hat{i} + \sin 45\,\hat{j}\right] = \frac{kq}{a^2}\left[3\frac{1}{\sqrt{2}}\,\hat{i} + 3\frac{1}{\sqrt{2}}\,\hat{j}\right]$$

$$\vec{E}_3 = 3\frac{kq}{a^2}\left[-\cos 45\,\hat{i} - \sin 45\,\hat{j}\right] = \frac{kq}{a^2}\left[-3\frac{1}{\sqrt{2}}\,\hat{i} - 3\frac{1}{\sqrt{2}}\,\hat{j}\right]$$

$$\vec{E}_4 = \frac{kq}{a^2}\left[-\cos 45\,\hat{i} + \sin 45\,\hat{j}\right] = \frac{kq}{a^2}\left[-\frac{1}{\sqrt{2}}\,\hat{i} + \frac{1}{\sqrt{2}}\,\hat{j}\right]$$

$$\vec{E}_1 + \vec{E}_2 + \vec{E}_3 + \vec{E}_4 = 0$$