PHYS-203B, 2016 Fall, Midterm Exam 1

Solutions

Prob. 1

initial : $Q_A = Q$ $\quad Q_B = Q$ $\quad Q_c = 0$

c touches A : $Q_A = \frac{Q+0}{2} = \frac{Q}{2}$ $\quad Q_B = Q$ $\quad Q_c = \frac{Q+0}{2} = \frac{Q}{2}$.

c touches B : $Q_A = \frac{Q}{2}$ $\quad Q_B = \frac{Q+\frac{Q}{2}}{2} = \frac{3}{4}Q$ $\quad Q_c = \frac{Q+\frac{Q}{2}}{2} = \frac{3}{4}Q$

$F = \frac{kQ^2}{R^2}$

Answers: (a) $\frac{Q}{2}$

(b) $\frac{3}{4}Q$

(c) $F' = \frac{k\left(\frac{Q}{2}\right)\left(\frac{3}{4}Q\right)}{R^2} = \frac{3}{8}\frac{kQ^2}{R^2} = \frac{3}{8}F$

Prob. 2

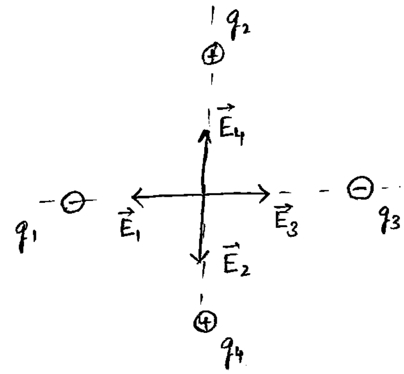
$$F = \frac{kq^2}{r^2}$$

$$4.0\,N = \frac{\left(8.99\times10^9\ \frac{Nm^2}{C^2}\right) q^2}{(2.0\ m)^2}$$

$$q^2 = \frac{4.0 \times 2.0^2}{8.99\times10^9}\ C^2 = 1.78\times10^{-9}\ C^2.$$

$$q = 4.22\times10^{-5}\ C = 0.422\ \mu C.$$

Prob. 3



$$\vec{E}_1 = -\frac{k|q_1|}{L^2}\hat{i} + 0\hat{j}$$

$$\vec{E}_2 = 0\hat{i} - \frac{k|q_2|}{L^2}\hat{j}$$

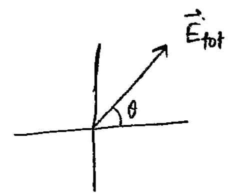
$$\vec{E}_3 = +\frac{k|q_3|}{L^2}\hat{i} + 0\hat{j}$$

$$\vec{E}_4 = 0\hat{i} + \frac{k|q_4|}{L^2}\hat{j}$$

$$\vec{E}_{tot} = \frac{k(|q_3|-|q_1|)}{L^2}\hat{i} + \frac{k(|q_4|-|q_2|)}{L^2}\hat{j}$$

$$= \frac{8.99\times10^9 \times (3.0-1.0)\times10^{-6}}{(1.00\times10^{-1})^2}\hat{i} + \frac{8.99\times10^9 \times (4.0-2.0)\times10^{-6}}{(1.00\times10^{-1})^2}\hat{j}$$

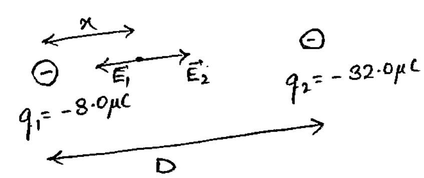
$$= 1.798\times10^6\,\frac{N}{C}\,\hat{i} + 1.798\times10^6\,\frac{N}{C}\,\hat{j}$$



magnitude: $|\vec{E}_{tot}| = \sqrt{(1.798\times10^6)^2 + (1.798\times10^6)^2} = 2.54\times10^6\,\frac{N}{C}$

direction: $\theta = \tan^{-1}\left(\frac{1.798\times10^6}{1.798\times10^6}\right) = 45^\circ$

Prob. 4



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

$$\frac{\cancel{k}|q_1|}{x^2} = \frac{\cancel{k}|q_2|}{(D-x)^2}$$

→ Argue that the solution will be in between the charges.

$$(D-x)^2 = 4.0\,x^2$$

$$D - x = \pm 2.0\,x$$

$$D = \pm 2.0x + x$$

$x = +3.33\,\text{cm}$ or $x = -10.0\,\text{cm}$

↳ rule out because $x > 0$.

Prob. 5

$$a = \frac{qE}{m} = \frac{1.6\times10^{-19} \times 5.00\times10^{4}}{9.1\times10^{-31}} = 8.79\times10^{15}\ \frac{m}{s^2}.$$

$$V_f^2 - V_i^2 = 2a\,\Delta x.$$

$$0^2 - (6.00\times10^{6})^2 = 2\times(-8.79\times10^{15})\ \Delta x$$

$$\Delta x = 2.05\times10^{-3}\ m = 2.05\ mm$$

Prob. 6

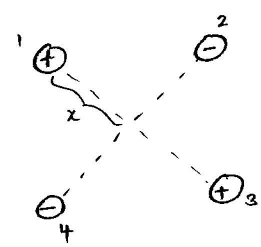
$$a = \frac{qE}{m} \qquad q_e = q_p$$

$$y = \frac{1}{2} a t^2$$

$$\Rightarrow \quad t = \sqrt{\frac{2y}{a}}$$

$$\frac{t_p}{t_e} = \frac{\sqrt{\frac{2y}{a_p}}}{\sqrt{\frac{2y}{a_e}}} = \sqrt{\frac{a_e}{a_p}} = \sqrt{\frac{\left(\frac{q_e E}{m_e}\right)}{\left(\frac{q_p E}{m_p}\right)}} = \sqrt{\frac{m_p}{m_e}} = \sqrt{1836} = 42.8$$

Prob. 7



$$V = V_1 + V_2 + V_3 + V_4$$

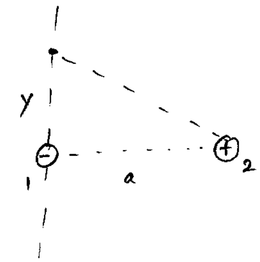
$$= +\frac{ke}{x} - \frac{ke}{x} + \frac{ke}{x} - \frac{ke}{x}$$

$$= 0$$

$$U = qV$$

$$= 0.$$

Prob. 8



$$V = V_1 + V_2 = 0$$

$$-\frac{kq}{y} + \frac{k\,2q}{\sqrt{a^2+y^2}} = 0$$

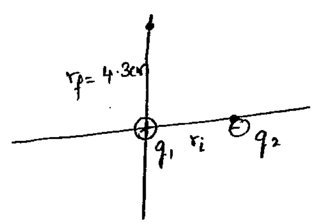
$$\frac{\cancel{k}\,2\cancel{q}}{\sqrt{a^2+y^2}} = \frac{\cancel{k}\cancel{q}}{y}$$

$$2y = \sqrt{a^2+y^2}$$

$$4y^2 = a^2 + y^2$$

$$3y^2 = a^2 \quad \Rightarrow \quad y = \pm\frac{a}{\sqrt{3}} = \pm\frac{2.0\text{ m}}{\sqrt{3}} = \pm 1.16\text{ m}$$

Prob. 9



$$U_i = \frac{k\,q_1 q_2}{r_i}$$

$$= \frac{8.99\times10^{9} \times 5.5\times10^{-8} \times (-2.3\times10^{-8})}{(3.5\times10^{-2})}$$

$$= -3.25\times10^{-4}\text{ J}$$

$$U_f = \frac{k\,q_1 q_2}{r_f}$$

$$= \frac{8.99\times10^{9} \times 5.5\times10^{-8} \times (-2.3\times10^{-8})}{(4.3\times10^{-2})}$$

$$= -2.65\times10^{-4}\text{ J}$$

$$U_f - U_i = (-2.65\times10^{-4}\text{ J}) - (-3.25\times10^{-4}\text{ J})$$

$$= 6.0\times10^{-5}\text{ J}$$