Solution to Midterm Exam 01 (PHYS-205B, 2015 Fall)

Prob. 1

$$1 \text{ gram of protons} = 1 \text{ gram} \; \frac{1 \text{ proton}}{1.67\times 10^{-27} \cancel{\text{grams}}} \qquad \text{kg} = 10^{3} \text{ grams.}$$

$$= 6 \times 10^{\cancel{26}} \text{ protons} \qquad 23$$

$$= 6 \times 10^{26\;\,23} \text{ proton} \; \frac{1.6\times 10^{-19}\,C}{1 \text{ proton}}$$

$$= \boxed{\cancel{1 \times 10^{8}\,C}} \qquad 1\times 10^{5}\,C$$

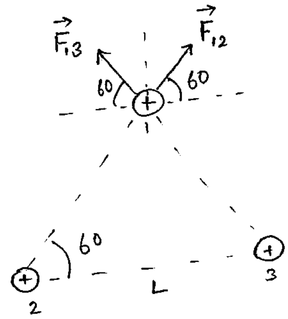
Prob. 2

(a) $$F = \frac{k q_1 q_2}{r^2} = \frac{8.99\times 10^{9} \times 3.0\times 10^{-6} \times 9.0\times 10^{-6}}{(10.0\times 10^{-2}\,m)^2} = 24\,N$$

(b) $$q_1' = q_2' = \frac{q_1 + q_2}{2} = \frac{+3.0\mu C - 9.0\mu C}{2} = -3.0\mu C$$

(c) Repulsive.

Prob. 3



$$|\vec{F}_{12}| = |\vec{F}_{13}| = \frac{k q^2}{L^2} = F_0$$

$$\vec{F}_{12} = F_0 \cos 60\ \hat{i} + F_0 \sin 60\ \hat{j}.$$

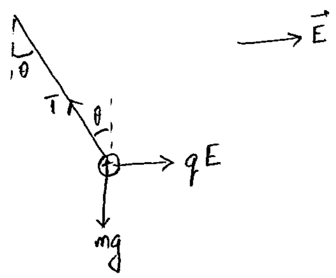
$$\vec{F}_{13} = -F_0 \cos 60\ \hat{i} + F_0 \sin 60\ \hat{j}$$

$$\vec{F}_{tot} = 0\ \hat{i} + 2F_0 \sin 60\ \hat{j}.$$

$$= 0\ \hat{i} + \sqrt{3}\, F_0\ \hat{j}$$

$$|\vec{F}_{tot}| = \sqrt{3}\, F_0 = \sqrt{3}\, \frac{k q^2}{L^2}.$$

Prob. 4



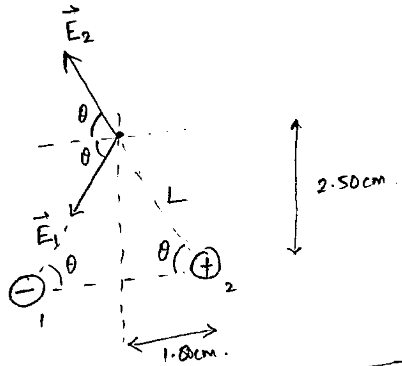
$$T \sin\theta = qE$$

$$T \cos\theta = mg$$

Thus,
$$\tan\theta = \frac{qE}{mg} = \frac{10.0\times10^{-6} \times 1.0\times10^{3}}{1.00\times10^{-3} \times 10.0} = 1.0$$

$$\Rightarrow \quad \theta = \tan^{-1}(1.0) = 45^\circ .$$

Prob. 5



$$L = \sqrt{1.00^2 + 2.50^2} = 2.69\text{ cm}$$

$$\theta = \tan^{-1}\left(\frac{2.50\text{cm}}{1.00\text{cm}}\right) = 68.2^\circ$$

$$E_0 = |\vec{E}_1| = |\vec{E}_2| = \frac{kq}{L^2} = \frac{8.99\times10^{9} \times 1.0\times10^{-9}\text{C}}{(2.69\times10^{-2})^2} = 1.24\times10^{4}\ \frac{N}{C}$$

$$\vec{E}_1 = -E_0\cos\theta\,\hat{i} - E_0\sin\theta\,\hat{j}$$

$$\vec{E}_2 = -E_0\cos\theta\,\hat{i} + E_0\sin\theta\,\hat{j}$$

$$\vec{E}_{tot} = -2E_0\cos\theta\,\hat{i} + 0\,\hat{j}$$

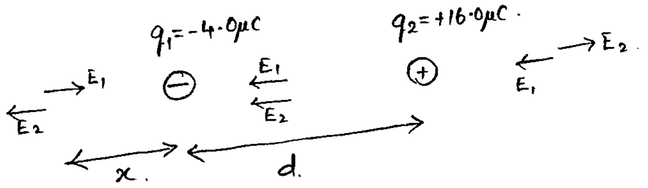
$$= -2\times1.24\times10^{4}\times\cos(68.2)\,\hat{i} + 0\,\hat{j}$$

$$= -9.9\times10^{3}\ \frac{N}{C}\ \hat{i}$$

magnitude is $9.9\times10^{3}\ \frac{N}{C}$

direction is along $-\hat{i}$ axis.

Prob. 6



Since $|q_1| < |q_2|$ and they are oppositely charge the zero-point will be on the left side of q_1.

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

$$\frac{k|q_1|}{x^2} = \frac{k|q_2|}{(d+x)^2}$$

$$d + x = \pm x \sqrt{\frac{|q_2|}{|q_1|}}$$

$$\sqrt{\frac{|q_2|}{|q_1|}} = \sqrt{\frac{16.0\mu C}{4.0\mu C}} = 2.0$$

$$10.0 + x = \pm 2.0x.$$

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

Since x by definition is positive $x = +10.0\text{cm}$ is the correct solution.

Prob. 7

$$a = \frac{q}{m}E = \frac{1.6\times10^{-19}}{9.1\times10^{-31}} \times 492 = 8.7\times10^{13}\ \frac{m}{s^2}$$

$$V_f = V_i + at$$
$$= 0 + 8.7\times10^{13} \times 47.2\times10^{-9}$$
$$= 4.1\times10^{6}\ \frac{m}{s}$$

Prob. 8

$$\vec{E} = \left(1.0\,\hat{i} + 2.0\,\hat{j}\right) \times 10^{3}\ \frac{N}{C}$$

$$\vec{A} = \left(0.080\,\hat{i} + 0\,\hat{j}\right)\ m^{2}$$

$$\phi_E = \vec{E} \cdot \vec{A}$$

$$= 1.0 \times 10^{3}\ \frac{N}{C} \times 0.080\,m^{2}$$

$$= 8.0 \times 10^{1}\ \frac{N}{C}\,m^{2}$$

Prob. 9

$$\phi_{tot} = \frac{Q}{\epsilon_0} = \frac{260 \times 10^{-6}\ C}{8.85 \times 10^{-12}\ \frac{C^2}{N m^2}} = 2.94 \times 10^{7}\ \frac{N}{C}\,m^{2}.$$

$$6\,\phi_{face} = \phi_{tot}$$

$$\phi_{face} = \frac{1}{6}\,\phi_{tot} = \frac{1}{6} \times 2.94 \times 10^{7} = 4.9 \times 10^{6}\ \frac{N}{C}\,m^{2}$$

Prob. 10

$$\phi_{tot} = \frac{Q_{enclosed}}{\epsilon_0}$$

Charge on a conductor resides on the surface. Thus, there is no charge enclosed inside the Gaussian sphere.

So, $\phi_{tot} = 0.$