Physics 111 Homework Solutions Collected on Wednesday 9/17/14

Friday, September 12, 2014
Chapter 14
Questions

14.3 If an equal magnitude charge is placed at the midpoint between two other charges (whether those charges are positive or negative) the charge at the midpoint is in stable equilibrium since the forces on this charge are equal in magnitude and oppositely directed. If the two charges are positive and the third charge is also positive and is displaced slightly to one side along the line jointing the two positive charges the third charge will oscillate back and forth exactly as a mass on a spring. If the third charge has an opposite sign and the charge is displaced to one side it will continue to move toward the charge to which it was displaced. If all charges are positive and the midpoint charge is displaced off of the line perpendicular to the line the displaced charge will move away to infinity. If the midpoint charge is of opposite charge and is displaced off of the line perpendicular to the line the displaced charge will oscillate about the line joining the two charges exactly like a mass on a spring.

14.4 Coulomb's Law

a. Of the distance between the charges is doubled the force decreases by a factor of 4.
b. If the charge of one is halved the force decreases by a factor of 2.
c. If the sign of both charges were changed nothing happens to the magnitude or direction of the force.
d. If the sign of one of the charges were changed nothing happens to the magnitude but the direction of the force reverses.
e. If the distance between the charges are doubled and one of the charges is halved then the force decreases by a factor of 8.

Multiple-Choice

14.2 B

Problems

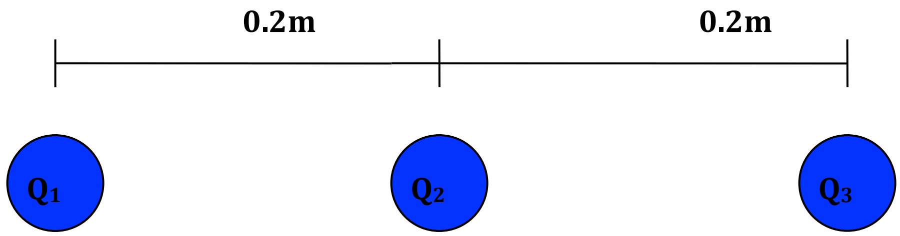
14.3 We equate the weight of a proton to the electrostatic force. We have

$$m_p g = \frac{ke^2}{r^2} \rightarrow r = \sqrt{\frac{ke^2}{m_p g}} = \sqrt{\frac{9\times10^9 \frac{Nm^2}{C^2}\times\left(1.6\times10^{-19}C\right)^2}{1.67\times10^{-27}kg\times9.8\frac{m}{s^2}}} = 0.12m$$

14.5 The centripetal force is given by Coulomb's Law and we have

$$\frac{ke^2}{r^2} = m_e\frac{v^2}{r} \rightarrow v = \sqrt{\frac{ke^2}{m_e r}} = \sqrt{\frac{9\times10^9 \frac{Nm^2}{C^2}\times\left(1.6\times10^{-19}C\right)^2}{9.11\times10^{-31}kg\times0.53\times10^{-10}m}} = 2.2\times10^6\frac{m}{s}$$

14.9. The forces on each charge are the vector sum of all of the forces on a charge due to the other charges separately. The magnitudes of the forces are given by Coulomb's law and the directions are obtained from the diagram.



$$\vec{F}_{net,1} = \vec{F}_{1,2} + \vec{F}_{1,3} = \left(-k\frac{Q_1 Q_2}{r_{1,2}^2} - k\frac{Q_1 Q_3}{r_{1,3}^2} \right)\hat{i}$$

$$= -\left(9\times10^9 \tfrac{\mathrm{Nm}^2}{\mathrm{C}^2}\right)\left(2\times10^{-6}\mathrm{C}\right)^2\left(\frac{1}{(0.2\mathrm{m})^2} + \frac{1}{(0.4\mathrm{m})^2} \right)\hat{i}$$

$$= \text{-}1.13\mathrm{N}\hat{i}$$

$$\vec{F}_{net,2} = \vec{F}_{2,1} + \vec{F}_{2,3} = \left(-k\frac{Q_2 Q_1}{r_{2,1}^2} + k\frac{Q_2 Q_3}{r_{2,3}^2} \right)\hat{i}$$

$$= \left(9\times10^9 \tfrac{\mathrm{Nm}^2}{\mathrm{C}^2}\right)\left(2\times10^{-6}\mathrm{C}\right)^2\left(+\frac{1}{(0.2\mathrm{m})^2} - \frac{1}{(0.2\mathrm{m})^2} \right)\hat{i}$$

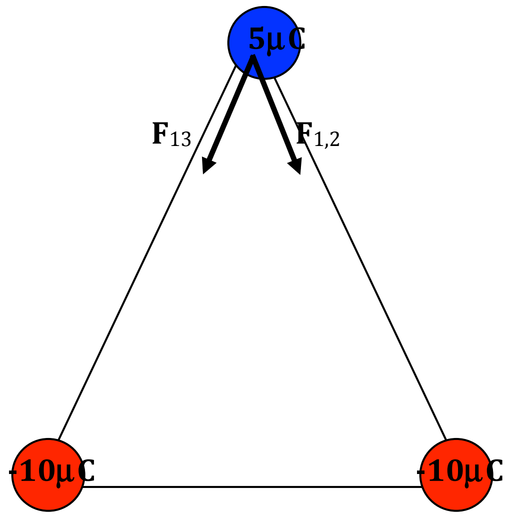
$$= 0\mathrm{N}\hat{i}$$

$$\vec{F}_{net,3} = \vec{F}_{3,1} + \vec{F}_{3,2} = \left(+k\frac{Q_3 Q_1}{r_{3,1}^2} + k\frac{Q_3 Q_2}{r_{3,2}^2} \right)\hat{i}$$

$$= +\left(9\times10^9 \tfrac{\mathrm{Nm}^2}{\mathrm{C}^2}\right)\left(2\times10^{-6}\mathrm{C}\right)^2\left(\frac{1}{(0.4\mathrm{m})^2} + \frac{1}{(0.2\mathrm{m})^2} \right)\hat{i}$$

$$= +1.13\mathrm{N}\hat{i}$$

14.10



To calculate the net force we break of the forces into their respective x- and y-components. For the net force in the x-direction we find:

$F_{Net,x} = F_{1,2}\cos 60 - F_{1,3}\cos 60 = 0, \text{since } |\mathrm{F}_{1,2}| = |\mathrm{F}_{1,3}|.$

For the net force in the y-direction we find:

$$F_{Net,y} = -F_{1,2}\sin 60 - F_{1,3}\sin 60 = -2\left(9\times10^{9}\ \tfrac{Nm^2}{C^2}\right)\frac{\left(5\times10^{9}\,C\right)\left(10\times10^{9}\,C\right)}{(0.5m)^2}\frac{\sqrt{3}}{2}$$

$$= -3.12\text{N}.$$

Therefore the net force is 3.12N in the -y-direction.
Note: The charges can be cycled to different corners of the triangle. The magnitude of the net force will be the same but the direction will change.

Monday, September 15, 2014
Chapter 14
Questions

14.2 Since objects are charged each will exert equal and opposite forces on each other. If the test charge is massive then its acceleration will be small and both charges will move around in the field of the other. If on the other hand the test charge is small, its acceleration is very large and the test charge will be experience the largest change in motion and can be used to map out the electric field of the other charges.

Multiple-Choice

14.8 C

Problems

14.7 Assuming as standard Cartesian coordinate system and applying Newton's 2nd law we have for the vertical forces ,

$\sum F_y: \; F_T \cos 30 - F_W = 0 \rightarrow F_T = \frac{mg}{\cos 30} = \frac{0.02kg \times 9.8 \frac{m}{s^2}}{\cos 30} = 0.226N$ while for the horizontal forces

$$\sum F_x: \; -F_T \sin 30 + F_E = 0 \rightarrow F_E = k\frac{Q^2}{r^2} = F_T \sin 30$$

$$\rightarrow Q = \sqrt{\frac{F_T r^2 \sin 30}{k}} = \sqrt{\frac{0.226N \times (0.5m)^2 \times \sin 30}{9\times 10^9 \frac{Nm^2}{C^2}}} = 1.77\times 10^{-6} C = 1.77\mu C$$

Thus the total charge on the electroscope is twice this value or *3.6mC*.

14.8 To determine the amount of charge on either the moon or the Earth, equate the gravitational force law to the electric force law. This produces

$$F_G = F_E \rightarrow \frac{GM_E M_M}{r^2} = \frac{kQ_E Q_M}{r^2} = \frac{kQ^2}{r^2} \rightarrow Q = \sqrt{\frac{G}{k} M_E M_M} =$$

$$Q = \sqrt{\left(\frac{6.67\times 10^{-11} \frac{Nm^2}{kg^2}}{9\times 10^9 \frac{Nm^2}{C^2}}\right) \times 7.35\times 10^{22} kg \times 5.98\times 10^{24} kg} = 5.7\times 10^{13} C.$$