2. When sphere three comes into contact with sphere one, they will evenly share the total charge.

$$Q_1 = \text{charge on sphere one and so forth.}$$

$$\text{given} Q_2 = Q_1$$

$$\text{fig(b) :sphere (1) now has } \frac{Q_1}{2}$$

$$\text{sphere (3) now has } \frac{Q_1}{2}$$

$$\text{fig(c) :Total charge} = Q_1 + \frac{Q_1}{2} = \frac{3Q_1}{2}$$

$$\text{sphere (2) now has } \frac{3Q_1}{4}$$

$$\text{sphere (3) now has } \frac{3Q_1}{4}$$

$$\text{Before :} F = \frac{kQ_1Q_2}{r^2} = \frac{kQ_1^2}{r^2}$$

$$\text{After :} F' = \frac{k}{r^2}\left(\frac{Q_1}{2}\right)\left(\frac{3Q_1}{4}\right) = \frac{3}{8}\left(\frac{kQ_1^2}{r^2}\right) = \frac{3}{8}F$$

5. The minus sign means attractive force.

$$F = \frac{1}{4\pi\pi_0}\frac{q_1q_2}{r^2}$$

$$F = \frac{(9\times10^9)(3\times10^{-6})(-1.5\times10^{-6})}{(.12)^2}$$

$$F = -2.8 \text{ Newtons}$$

6.

$$\text{a)} F = m_1a_1 = (6.3\times10^{-7})\left(7\frac{m}{\sec^2}\right) = 44.1\times10^{-7}\,n$$

$$F = \frac{(9\times10^9)Q^2}{(3.2\times10^{-3})^2} = 44.1\times10^{-7}\,n$$

$$Q^2 = 50.1\times10^{-22} \Rightarrow Q = 7.1\times10^{-11}\text{coulombs}$$

$$\text{b)} F = m_2a_2 = 44.1\times10^{-7}\,n$$

$$m_2\left(9\frac{m}{\sec^2}\right) = 44.1\times10^{-7}\,n$$

$$m_2 = 4.9\times10^{-7}\text{kg}$$

9. When they are connected with a wire, the spheres will evenly divide the total charge. Also, an attractive force is negative, and a repelling force is positive.

Beforewire :

$$\mathbf{F = -.108\ N = \frac{kQ_1Q_2}{(.05)^2}}$$

$$\mathbf{Q_1Q_2 = -\frac{108(.05)^2}{9\times10^9} = -3\times10^{-12}}$$

After wire :Total charge $\mathbf{= Q_1 + Q_2}$

Each sphere has $\mathbf{\frac{Q_1+Q_2}{2}}$.

$$\mathbf{F = .036\ N = \frac{k\left(\frac{1}{2}(Q_1+Q_2)\right)^2}{(.05)^2}}$$

$$\mathbf{(Q_1+Q_2)^2 = \frac{4(.05)^2(.036)}{9\times10^9}}$$

$$\mathbf{Q_1+Q_2 = \pm2\times10^{-6}}$$

$$\mathbf{Q_1Q_2 = -3\times10^{-12} \Rightarrow Q_1 = -\frac{3\times10^{-12}}{Q_2}}$$

$$\mathbf{Q_1+Q_2 = -\frac{3\times10^{-12}}{Q_2} + Q_2 = \pm2\times10^{-6}}$$

$$\mathbf{-3\times10^{-12} + Q_2^2 = \pm(2\times10^{-6})Q_2}$$

$$\mathbf{Q_2^2 \pm(2\times10^{-6})Q_2 - 3\times10^{-12} = 0}$$

One solution is :

$$\mathbf{(Q_2 + 3\times10^{-6})(Q_2 - 1\times10^{-6}) = 0}$$

all solutions:

$$\mathbf{Q_2 = \pm3\times10^{-6}\ \text{and}\ Q_1 = \mp1\times10^{-6}}$$

or

$$\mathbf{Q_1 = \pm3\times10^{-6}\ \text{and}\ Q_2 = \mp1\times10^{-6}}$$

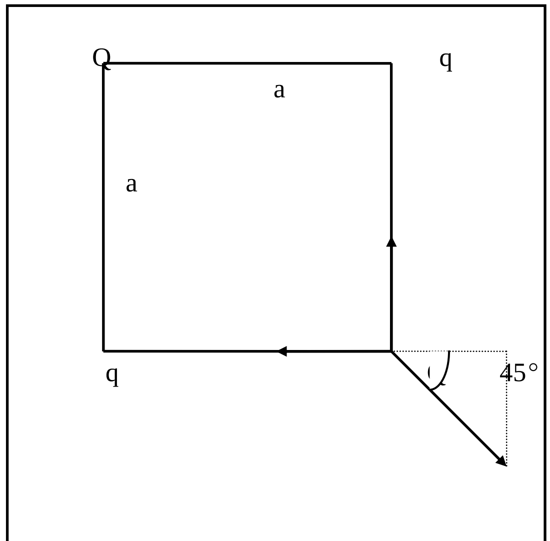
10. q has to have the opposite sign of Q.
Looking at x – components.

$$\sum F_x = \frac{kQ^2}{\left(\sqrt{2}a\right)^2}\cos\left(45^\circ\right) + \frac{kQq}{a^2} = 0$$

$$\frac{kQ^2}{\left(\sqrt{2}a\right)^2}\left(\frac{\sqrt{2}}{2}\right) = -\frac{kQq}{a^2}$$

$$\frac{\sqrt{2}Q}{4} = -q$$

This quantity holds for the y – components, also.



b) The magnitude of the attractive forces on q are the same as the attractive forces on Q. However the repulsive forces on q are proportional to q^2 and the repulsive forces on Q are proportional to Q^2. Suppose q is chosen to put Q in equilibrium. Since the same attractive force cannot balance both repulsive simultaneously, q is not in equilibrium.

11.

$$F_{1-2} = \frac{9\times10^9\left(1\times10^{-7}\right)\left(2\times10^{-7}\right)}{\left(.05\right)^2}$$

F_{1-2} = **.072 Newtons**

$$F_{1-3} = \frac{9\times10^9\left(1\times10^{-7}\right)\left(2\times10^{-7}\right)}{\left(.071\right)^2}$$

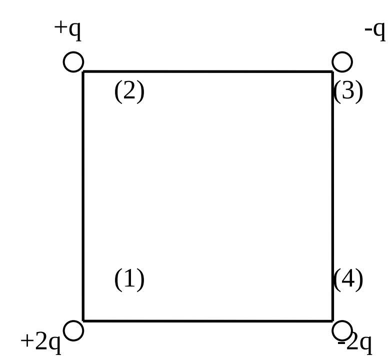
F_{1-3} = **.0357 Newtons**

$$F_{1-4} = \frac{9\times10^9\left(2\times10^{-7}\right)\left(2\times10^{-7}\right)}{\left(.05\right)^2}$$

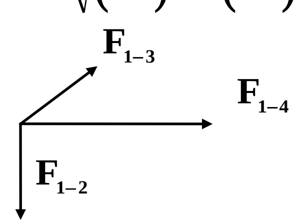
F_{1-4} = **.144 Newtons**

$$\sum F_x = .144 + .0357\cos\left(45^\circ\right) = .169 \text{ New}$$

$$\sum F_y = .072 - .0357\sin\left(45^\circ\right) = .047 \text{ New}$$



$$\text{diagonal} = \sqrt{\left(.05\right)^2 + \left(.05\right)^2} = .071$$



14. For the a) part, the two charges will have the same sign. That is, they will both be positive or both negative. For the b) part, they will have opposite signs. A subscript of one indicates the charge on the left, two is on the right.

a)We want $\mathbf{F_{1-Q} = F_{2-Q}}$

$$\mathbf{F_{1-Q} = \frac{kq_1Q}{\left(\frac{3a}{2}\right)^2} = F_{2-Q} = \frac{kq_2Q}{\left(\frac{a}{2}\right)^2}}$$

$$\mathbf{\frac{q_1}{9} = q_2 \text{ or } q_1 = 9q_2}$$

$$\mathbf{b)F_{1-Q} = \frac{kq_1Q}{\left(\frac{5a}{2}\right)^2} = -F_{2-Q} = -\frac{kq_2Q}{\left(\frac{a}{2}\right)^2}}$$

$$\mathbf{\frac{q_1}{25} = -q_2 \text{ or } q_1 = -25q_2}$$

19. **The third charge (Q) will be negative and placed colinear between charges +q and +4q. Let Q be a distance x from +q.**

$$F = \frac{kqQ}{x^2} = \frac{k(4q)Q}{(L-x)^2}$$

$$\frac{1}{x^2} = \frac{4}{(L-x)^2}$$

$$L^2 - 2Lx + x^2 = 4x^2$$

$$L^2 - 2Lx - 3x^2 = 0$$

$$(L+x)(L-3x) = 0$$

Need positive distance, so

$$L = 3x \Rightarrow x = \frac{L}{3}$$

$$F_{q-Q} = -F_{q-4q}$$

$$\frac{kqQ}{x^2} = -\frac{kq(4q)}{L^2}$$

$$\frac{Q}{\left(\frac{L}{3}\right)^2} = -\frac{4q}{L^2}$$

$$9Q = -4q$$

$$Q = -\frac{4}{9}q$$

27.

$$F = 3.7\times10^{-9} = \frac{(9\times10^9)Q^2}{(5\times10^{-10})^2}$$

$$Q^2 = 10.28\times10^{-38}$$

$$Q = 3.2\times10^{-19} = 2(1.6\times10^{-19})$$

$$b)\, Q = 2e$$

42.

$$\text{a)}\ \frac{F_x = T\sin\theta = \dfrac{kq^2}{x^2}}{F_y = T\cos\theta = mg}$$

$$\tan\theta = \frac{kq^2}{mgx^2}$$

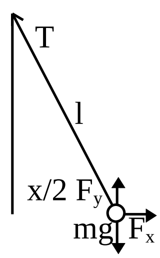
$$\text{approx } \tan\theta \approx \sin\theta = \frac{x/2}{l}$$

$$\frac{x}{2l} = \frac{kq^2}{mgx^2}$$

$$x^3 = \frac{kq^2(2l)}{mg}$$

$$\therefore x = \left(\frac{q^2\,2l}{4\pi\varepsilon_0 mg}\right)^{\frac{1}{3}}$$

$$\text{b)}.05 = \left(\frac{q^2\,2(1.20)}{4\pi\varepsilon_0\,(.01)(9.8)}\right)^{\frac{1}{3}}$$



$$.000125 = \left(\frac{q^2(1.20)}{5.4\times 10^{-12}}\right)$$

$$\frac{.000675}{1.2} = q^2$$

$$5.625\times 10^{-12} = q^2$$

$$5.6\times 10^{-16} = q$$

$$\text{so } q = \pm 2.4\times 10^{-8}$$

49.

$$q = \frac{1}{3}e = \left(\frac{1}{3}\right)\left(1.6\times 10^{-19}\right) = 5.33\times 10^{-20}$$

$$F = \frac{\left(9\times 10^{9}\right)\left(5.33\times 10^{-20}\right)^2}{\left(2.6\times 10^{-15}\right)^2}$$

$$F = 3.78 \text{ Newtons}$$