

## PHY217 UNIVERSITY PHYSICS II

### Solutions for Homework Assignment 2 of 09/03/2009

#### Chapter 21 of text

#### Question 1:

In all the four situations, for the electron to be in equilibrium, the magnitude of the attractive force on it due to a positive charge should be equal to the magnitude of the repulsive force on it due to a negative charge. A charge of **smaller magnitude acting at a smaller distance** gives the same amount of force as **a charge of larger magnitude acting from a larger distance from the electron**. Therefore the electron should be closer to charge of magnitude  $q$  and farther from charge of magnitude  $3q$  to achieve equilibrium. This is only possible for situations (a) and (b) in the figure.

#### Question 7:

#### Strategy:

Find **separately** the net force on the central particle of charge  $-q$  due to the outer ring and then the inner ring.

Outer ring:

Charge  $+4q$  situated and another charge  $+4q$  situated diametrically opposite to each other exert zero net force on central charge  $-q$ . Same holds for the four  $-2q$  charges on the outer ring. Net force due to outer ring on charge  $-q$  is then zero.

Inner ring:

Pairs of charges  $-7q$  each and  $-q$  each give zero net force on central charge  $-q$ . Therefore the net force on  $-q$  is **ONLY** due to the charge  $+2q$  situated on the inner ring at a distance of  $r$  from  $-q$ .

Magnitude of force  $F = \frac{k \times q \times 2q}{r^2}$  and the force is attractive on  $-q$  towards  $2q$ .

### Problems from Chapter 21 of text

3. The magnitude of the mutual force of attraction at  $r = 0.120$  m is

$$F = k \frac{|q_1||q_2|}{r^2} = 8.99 \times 10^9 \text{ N} \cdot \text{m}^2/\text{C}^2 \frac{3.00 \times 10^{-6} \text{ C} \cdot 1.50 \times 10^{-6} \text{ C}}{(0.120 \text{ m})^2} = 2.81 \text{ N}.$$

14.

(a) According to the graph, when  $q_3$  is very close to  $q_1$  (at which point we can consider the force exerted by particle 1 on 3 to dominate) there is a (large) force in the positive  $x$  direction. This is a repulsive force, then, so we conclude  $q_1$  has the same sign as  $q_3$ . Thus,  $q_3$  is a positive-valued charge.

(b) Since the graph crosses zero and particle 3 is *between* the others,  $q_1$  must have the same sign as  $q_2$ , which means it is also positive-valued. We note that it crosses zero at  $r = 0.020$  m (which is a distance  $d = 0.060$  m from  $q_2$ ). Using Coulomb's law at that point, we have

$$\frac{1}{4\pi\epsilon_0} \frac{q_1 q_3}{r^2} = \frac{1}{4\pi\epsilon_0} \frac{q_3 q_2}{d^2} \Rightarrow q_2 = \left(\frac{d}{r}\right)^2 q_1 = \left(\frac{0.060 \text{ m}}{0.020 \text{ m}}\right)^2 q_1 = 9.0 q_1$$

Or  $q_2/q_1 = 9.0$ .

48. This problem demonstrates conservation of charge nicely.

In experiment 1, sphere C (initial charge 0) first touches sphere A (initial charge  $4Q$ ) and they divide up their total charge,  $+4Q$  equally between them. Thus,

sphere A and sphere C each acquire charge  $+2Q$ . Then, sphere C touches B (initial charge  $-6Q$ ) and those spheres split up their total charge,  $+2Q + (-6Q) = -4Q$  equally between them so that B ends up with charge equal to  $-2Q$ . The force of attraction between A and B is therefore,

$$F_1 = \frac{k \times 2Q \times 2Q}{d^2} \text{ with negative sign for } F_1$$

In experiment 2, sphere C initially touches sphere B and they each get charged to  $-3Q$ . Then sphere C touches sphere A and they share their total charge  $-3Q + 4Q = 1Q$  equally and sphere A ends up with  $+\left(\frac{1}{2}\right)Q$ . Now the force between B and A is

$$F_2 = \frac{k \times \frac{1}{2}Q \times 3Q}{d^2} \text{ with negative sign for } F_2$$

Ratio of electrostatic force between A and B =  $\frac{F_2}{F_1} = \frac{3}{8} = 0.375$

57.

The mass of an electron is  $m = 9.11 \times 10^{-31}$  kg, so the number of electrons in a collection with total mass  $M = 75.0$  kg is

$$n = \frac{M}{m} = \frac{75.0 \text{ kg}}{9.11 \times 10^{-31} \text{ kg}} = 8.23 \times 10^{31} \text{ electrons.}$$

The total charge of the collection is

$$q = -ne = -8.23 \times 10^{31} \cdot 1.60 \times 10^{-19} \text{ C} = -1.32 \times 10^{13} \text{ C.}$$