Homework Assignment #2 - Thursday June 16, 2005

1. (a) On a piece of graph paper (remember that some are available on the course web page) place a $-3\ \mu$C charge at the origin and a $+2\mu$C at the point $(x = 3.0$ m$, y = 0)$.

(b) Determine the magnitude of the electric forces acting on each of the two charges and sketch these forces on your diagram. Write down your force magnitudes below:

Magnitude of force on $-3\ \mu$C charge:

$F = k|q_1 q_2|/r^2 = (9 \times 10^9 \text{ N m}^2 \text{ C}^{-2})(3 \times 10^{-6} \text{ C})(2 \times 10^{-6} \text{ C})/(3.0 \text{ m})^2 = 6.0 \times 10^{-3} \text{ N}$

Magnitude of force on $+2\ \mu$C charge:

By Newton's third law, this must be the same: 6.0×10^{-3} N

2. Repeat for the following situations. You can use the same piece of graph paper if you plan out your scale properly and place the origin at a new position

(a) a $+3\ \mu$C charge at $(0, 2.0$ m$)$ and a $+2\ \mu$C at the point $(x = 3.0$ m$, y = 2.0$ m$)$

Magnitude of force on $+3\ \mu$C charge:

$F = k|q_1 q_2|/r^2 = (9 \times 10^9 \text{ N m}^2 \text{ C}^{-2})(3 \times 10^{-6} \text{ C})(2 \times 10^{-6} \text{ C})/(3.0 \text{ m})^2 = 6.0 \times 10^{-3} \text{ N}$

Magnitude of force on $+2\ \mu$C charge:

By Newton's third law, this must be the same: 6.0×10^{-3} N

(b) a $-4\ \mu$C charge at $(0, -2.0$ m$)$ and a $-2\ \mu$C at the point $(-3.0$ m$, -2.0$ m$)$

Magnitude of force on $-2\ \mu$C charge:

$F = k|q_1 q_2|/r^2 = (9 \times 10^9 \text{ N m}^2 \text{ C}^{-2})(4 \times 10^{-6} \text{ C})(2 \times 10^{-6} \text{ C})/(3.0 \text{ m})^2 = 8.0 \times 10^{-3} \text{ N}$

Magnitude of force on $-4\ \mu$C charge:

By Newton's third law, this must be the same: 8.0×10^{-3} N

3. On your old graph paper or a new one, place a $+3\ \mu$C charge at the origin and a charge of $+2\ \mu$C charge at the point $(x = 3.0$ m$, y = 4.0$ m$)$.

(a) Sketch the directions of the forces on each charge and determine their magnitudes.

Magnitude of force on $+3\ \mu$C charge:

The distance between the two charges is $\sqrt{(3.0 \text{ m})^2 + (4.0 \text{ m})^2} = 5.0$ m

$F = k|q_1 q_2|/r^2 = (9 \times 10^9 \text{ N m}^2 \text{ C}^{-2})(3 \times 10^{-6} \text{ C})(2 \times 10^{-6} \text{ C})/(5.0 \text{ m})^2 = 2.2 \times 10^{-3} \text{ N}$

Magnitude of force on $+3\ \mu$C charge:

By Newton's third law, this must be the same: 2.2×10^{-3} N

(b) Determine the x and y components of the forces on each charge. You can determine the necessary sines and cosines from the components of the displacement between the charges.

$+3\ \mu$C charge has force:

x component:

First, note that for the 3-4-5 right triangle formed by the force and sides parallel to the x and y axes, $\cos\theta = 3/5$ and $\sin\theta = 4/5$.

$F_x = F\cos\theta = -(2.16\times10^{-3}\text{ N})(3/5) = -1.3\times10^{-3}\text{ N}$

y component:

$F_y = F\sin\theta = -(2.16\times10^{-3}\text{ N})(4/5) = -1.7\times10^{-3}\text{ N}$

$+2\ \mu$C charge has force:

x component:

$F_x = +1.3\times10^{-3}$ N (the negative of F_x for the $+3\ \mu$C charge)

y component:

$F_y = +1.7\times10^{-3}$ N (the negative of F_x for the $+3\ \mu$C charge)

4. On your old graph paper or a new one, place the following charges:

A $+3\ \mu$C charge at the origin

A $-2\ \mu$C charge at (3.0 m, 0)

A $+3\ \mu$C charge at (0, 3.0 m)

Determine the x and y components of the two electric forces acting on the charge at the origin, and then determine the total electric force acting on it, giving it first in terms of its x and y components and then in terms of magnitude and direction. Write your answers below:

x component of total force:

The only force with an x component is the attractive force between the $+3\ \mu$C charge at the origin and the $-2\ \mu$C charge on the positive x axis; thus

$F_x = k|q_1q_2|/r^2 = (9\times10^9\text{ N m}^2\text{ C}^{-2})(3\times10^{-6}\text{ C})(2\times10^{-6}\text{ C})/(3.0\text{ m})^2$

$= +6.0\times10^{-3}\text{ N}$

y component of total force:

The only force with a y component is the repulsive force between the $+3\ \mu$C charge at the origin and the $+3\ \mu$C charge on the positive y axis; thus

$F_y = k|q_1q_2|/r^2 = -(9\times10^9\text{ N m}^2\text{ C}^{-2})(3\times10^{-6}\text{ C})(3\times10^{-6}\text{ C})/(3.0\text{ m})^2$

$= -9.0\times10^{-3}\text{ N}$

Magnitude of total force:

$F = \sqrt{(+6.0\times10^{-3}\text{ N})^2 + (-9.0\times10^{-3}\text{ N})^2} = 10.8\times10^{-3}\text{ N}$

Direction of total force:

The force is at an angle of $\theta = \tan^{-1}(-9.0/6.0) = \tan^{-1}(-1.5) = -56°$ (equivalent to $+304°$), close to a southeastern direction when north is the $+y$ direction and east is the $+x$ direction.

Sketch the electric force contributions and the total electric force on your diagram, and check that the results are consistent with your calculations.