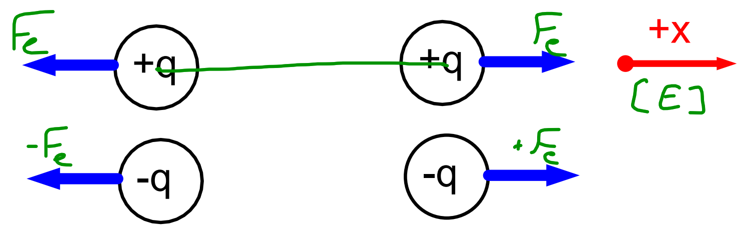
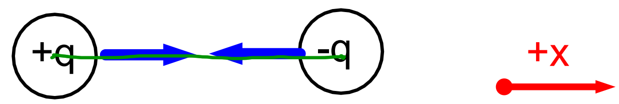
Electrostatics: Linear and 2D

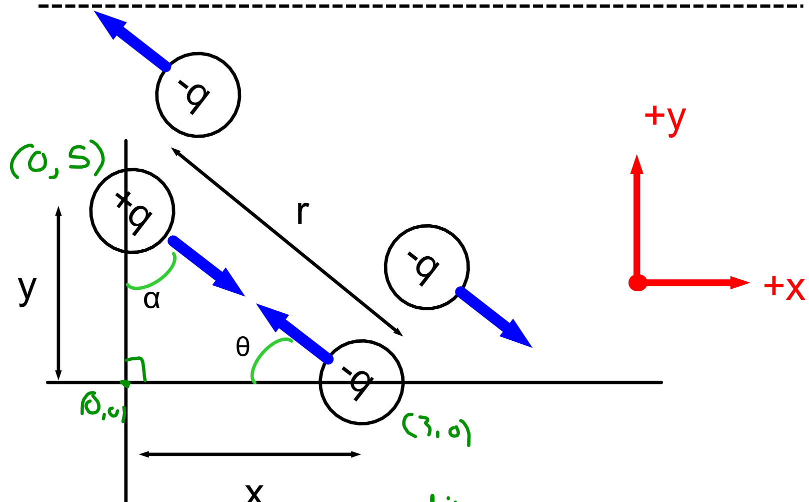
- Will now consider the electric force, F_e, to be a vector
  > Magnitude will now always be positive
  > Attractive/Repulsive will be used for the direction of the vector, along with basic geometry

$$F_e = \frac{k|q_1||q_2|}{r^2}$$

- Scenarios will, typically, involve looking at a particular charge in the situation and considering the net force acting on it







length $r^2=x^2+y^2$ direction $\tan(\theta)=y/x$, $\tan(\alpha)=x/y$, $\alpha=90^0-\theta$

- After magnitude calculated, direction will be determined by considering the angle the separation, r, makes with the axes and deciding if the direction is towards or away from the other charge(s), along this line
- Forces will have to be broken up into components when trying to find the Net Force

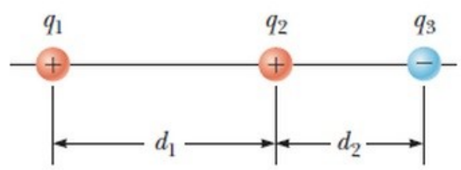
$$F_{Net,x} = F_{1x} + F_{2x} + \dots$$
$$F_{Net,y} = F_{1y} + F_{2y} + \dots$$

Linear and 2D Examples

Ex. 1: 2 charges, +2.3 μC on the left and -4.3 nC on the right, lie along the x-axis separated by a distance of 15 cm. What force does each charge experience? If each charge has a mass of 8.0 mg, what is the acceleration they each experience if they could move?

Ex. 2: 3 charges are lined up in the diagram given. What is the net force on the central charge? q_1 = 9.3 μC, q_2 = 6.7 μC, q_3 = -3.1 μC, d_1 = 15.0 nm, and d_2 = 10.0 nm.

q_2



Ex. 3: 2 carbon atom cores (no electrons) are located in a plane, aligned vertically separated by a distance of 5.0 pm. A stray electron is found 12.0 pm directly right of the lower carbon core. What is the net force the electron experiences?

Do practice problems 6-8, 10~~10~~ on page 640

WE WERE GOING TO USE THE TIME MACHINE TO PREVENT THE ROBOT APOCALYPSE, BUT THE GUY WHO BUILT IT WAS AN ELECTRICAL ENGINEER.

Ex 1

$q_1 = 2.3\,\mu C$

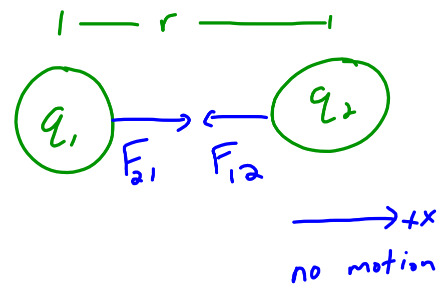
$q_2 = -4.3\,nC$

$r = 15\ cm$

$m = 8.0\ mg$

$\vec{F}_1 = ?$

$\vec{F}_2 = ?$



$$F_{12} = F_{21} = \frac{K|q_1||q_2|}{r^2}$$

$$F_{12} = \frac{(9.0\times10^{9}\,Nm^2/C^2)(2.3\times10^{-6}\,C)(4.3\times10^{-9}\,C)}{(15\times10^{-2}\,m)^2}$$

$$= 0.003956\ N$$

$\vec{F}_{12} = 0.0040\,N$ [left] or [W] or [-x]

$\vec{F}_{21} = 0.0040\,N$ [right] or [E] or [+x]

$$F_{12} = ma \longrightarrow a = \frac{F_{12}}{m}$$

$$= \frac{0.003956\,N}{8.0\times10^{-6}\,kg} = 494.5\ m/s^2$$

$\vec{a}_1 = 490\ m/s^2$ [right]

$\vec{a}_2 = 490\ m/s^2$ [left]

Ex 2

$q_1 = 9.3\,\mu C$

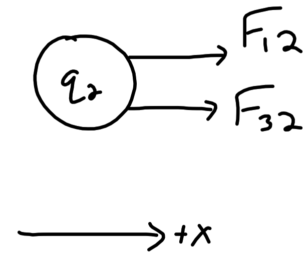
$q_2 = 6.7\,\mu C$

$q_3 = -3.1\,\mu C$

$d_1 = 15.0\ nm$

$d_2 = 10.0\ nm$

$\vec{F}_{net,2} = ?$



no motion

$$F_{12} = \frac{K|q_1||q_2|}{d_1^2}$$

$$= \frac{(9.0\times10^9\,Nm^2/C^2)(9.3\times10^{-6}C)(6.7\times10^{-6}C)}{(15.0\times10^{-9}m)^2}$$

$$= 2.4924\times10^{15}\ N$$

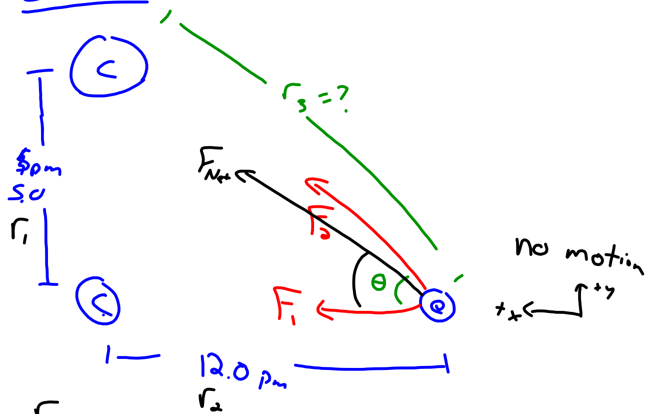
$$F_{32} = \frac{K|q_2||q_3|}{d_2^2} = \frac{(9.0\times10^9\,Nm^2/C^2)(6.7\times10^{-6}C)(3.1\times10^{-6}C)}{(10.0\times10^{-9}m)^2}$$

$$= 1.8693\times10^{15}\ N$$

$$F_{net,x,2} = F_{12} + F_{32} = 4.3617\times10^{15}\ N$$

$$\boxed{\vec{F}_{net,2} = 4.4\times10^{15}\ N\ [right]}$$

Ex 3)



$r_1 = 5.0\ pm$ $\qquad q_c = 6q_p = 6e$

$r_2 = 12.0\ pm$ $\qquad q_e = -1q_e = -1e$

$\vec{F}_{Net,e} = ?$ $\qquad e = 1.602 \times 10^{-19}\ C$

geometry stuff

$$r_3 = \sqrt{r_1^2 + r_2^2} = \sqrt{(5.0\,pm)^2 + (12.0\,pm)^2}$$

$$= 13.0\,pm$$

$$\theta = \tan^{-1}\left(\frac{r_1}{r_2}\right) = \tan^{-1}\left(\frac{5.0\,pm}{12.0\,pm}\right) = 22.62^\circ$$

$$F_1 = \frac{K|q_c||q_e|}{r_2^2} = \frac{K(6e)(e)}{r_2^2} = \frac{K(6e^2)}{r_2^2}$$

$$= \frac{(9.0\times10^9\,Nm^2/C^2)(6)(1.602\times10^{-19}\,C)^2}{(12.0\times10^{-12}\,m)^2}$$

$$= 9.624015 \times 10^{-6}\,N$$

$$F_2 = \frac{K q_e q_c}{r_3^2} = \frac{K(6e^2)}{r_3^2}$$

$$= \frac{(9.0\times10^9\,Nm^2/C^2)(6)(1.602\times10^{-19}\,C)^2}{(13\times10^{-12}\,m)^2}$$

$$= 8.20034 \times 10^{-6}\,N$$

$$F_{Net,x,e} = F_1 + F_{2x} = F_1 + F_2 \cos\theta$$

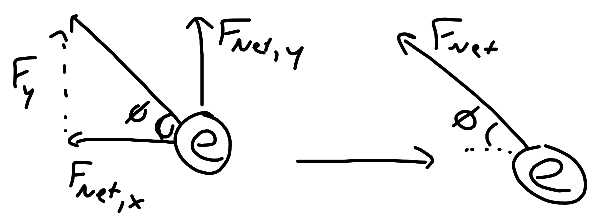
$$= 9.624015\times10^{-6}\,N + (8.20034\times10^{-6}\,N)\cos(22.62°)$$

$$= 1.719356\times10^{-5}\,N$$

$$= 17.19356\times10^{-6}\,N$$

$$F_{Net,y,e} = F_2 \sin\theta = (8.20034\times10^{-6}\,N)\sin(22.62°)$$

$$= 3.153979\times10^{-6}\,N$$



$$F_{Net} = \sqrt{(F_{Net,x})^2 + (F_{Net,y})^2}$$

$$= \sqrt{(17.19356\times10^{-6}\,N)^2 + (3.153979\times10^{-6}\,N)^2}$$

$$= 17.48044\times10^{-6}\,N$$

$$\phi = \tan^{-1}\left(\frac{F_{Net,y}}{F_{Net,x}}\right) = \tan^{-1}\left(\frac{3.153979\times10^{-6}\,N}{17.19356\times10^{-6}\,N}\right)$$

$$\phi = 10.39° = 10°$$

$$\boxed{\vec{F}_{Net} = 17.5\,\mu N\ [W\ 10°\ N]}$$