Physics 122

Worksheet - Electric Charge and Coulomb's Law

Electric Charge

1\. $N = ?$
$q = 25C$
$e = 1.60 \times 10^{-19} C$

$q = Ne$

$N = \frac{q}{e}$

$N = \frac{25}{1.60 \times 10^{-19}}$

$N = 1.6 \times 10^{20}$

The number of electrons needed is 1.6×10^{20}.

2\. $q = ?$
$N = 1.88 \times 10^{19}$
$e = 1.60 \times 10^{-19} C$

$q = Ne$

$q = 1.88 \times 10^{19} \times 1.60 \times 10^{-19}$

$q = 3.01 C$

The electrons have 3.01C of charge.

Coulomb's Law - 2 Charges

1\. q_1, q_2, d, F $\quad$ * $F_n \rightarrow$ new force

a) $F_n = \frac{k q_1 q_2}{(4d)^2}$

$F_A = \frac{1}{16} F$

b) $F_n = k \frac{(\frac{1}{2} q_1)(3 q_2)}{d^2}$

$F_n = \left[\frac{3}{2}\right]\left[\frac{k q_1 q_2}{d^2}\right] = \frac{3}{2} F$

c) $F_n = \frac{k q_1 (2 q_2)}{(3d)^2}$

$F_n = \left[\frac{2}{9}\right]\left[\frac{k q_1 q_2}{d^2}\right] = \frac{2}{9} F$

d) $F_n = \frac{k (\frac{1}{2} q_1)(\frac{1}{4} q_2)}{(\frac{1}{4} d)^2}$

$F_n = 2F$

2. $q_1 = 1.8 \times 10^{-6} C$
$q_2 = 1.0 \times 10^{-6} C$
$r = 0.040 m$
$F = ?$

$$F = k\frac{q_1 q_2}{r^2}$$
$$F = \frac{(9.0\times10^{9})(1.8\times10^{-6})(1.0\times10^{-6})}{(0.040)^2}$$
$$F = 10 N$$

The magnitude of the force is 10N.

3. $q_1 = 4.0 \times 10^{-6} C$
$F = 7.2 N$
$r = 0.050 m$
$q_2 = ?$

q_1 ⊖
F repulsion
q_2 ⊖

$$F = k\frac{q_1 q_2}{r^2}$$
$$Fr^2 = k q_1 q_2$$
$$q_2 = \frac{Fr^2}{kq_1}$$
$$q_2 = \frac{(7.2)(0.050)^2}{(9.0\times10^{9})(4.0\times10^{-6})}$$
$$q_2 = 5.0 \times 10^{-7} C$$

The second charge has a magnitude of $5.0\times10^{-7}C$ and is negatively charged.

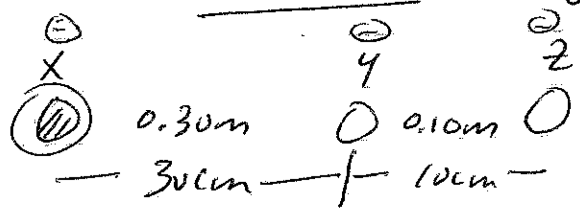
4. $r = ?$
$q_1 = 1.0 \mu C = 1.0\times10^{-6} C$
$q_2 = 1.0 \mu C = 1.0\times10^{-6} C$
$F = 440 N.$

$$F = k\frac{q_1 q_2}{r^2}$$
$$r = \sqrt{\frac{k q_1 q_2}{F}}$$
$$r = \sqrt{\frac{(9.0\times10^{9})(1.0\times10^{-6})(1.0\times10^{-6})}{440}}$$
or
$$r = \sqrt{\frac{(9.0\times10^{9})(1.0\times10^{-6})^2}{440}}$$
$$r = 4.5\times10^{-3} m.$$

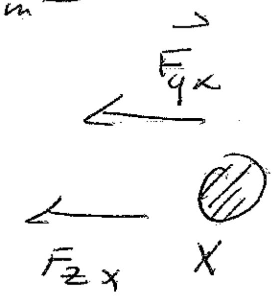
The two charges are $4.5\times10^{-3} m$ apart.

Coulomb's Law - 3 Charges

1.



$X \Rightarrow q_x = (-)5.0\times10^{-6}C$
$Y \Rightarrow q_y = (-)3.0\times10^{-6}C$
$Z \Rightarrow q_z = (-)2.0\times10^{-6}C$



$F_{yx} = \frac{k q_y q_x}{r^2}$

$F_{yx} = \frac{(9.0\times10^{9})(3.0\times10^{-6})(5.0\times10^{-6})}{(0.30)^2}$

$F_{yx} = 1.50\times10^{0}\ N$

$F_{yx} = 1.50\ N$

$F_{zx} = \frac{k q_z q_x}{r^2}$

$F_{zx} = \frac{(9.0\times10^{9})(2.0\times10^{-6})(5.0\times10^{-6})}{(0.40)^2}$

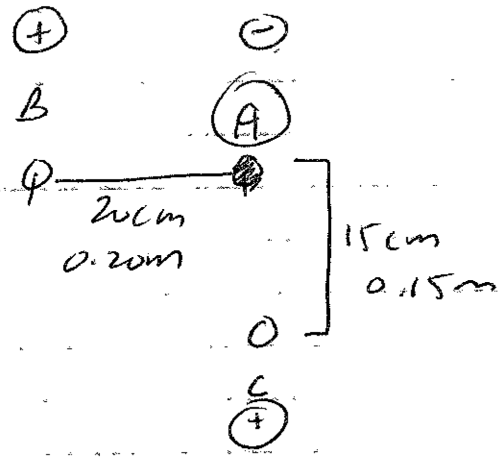
$F_{zx} = 0.563\ N$

$\vec{F}_{net} = -1.50 + (-0.563)$

$\vec{F}_{net} = -2.1N$

The net force on q_x is 2.1N left.

2. $q_A = (-)\,4.0\,\mu C = (-)\,4.0\times10^{-6}\,C$
$q_B = 5.0\,\mu C = 5.0\times10^{-6}\,C$
$q_C = 3.0\,\mu C = 3.0\times10^{-6}\,C$



$F_{BA} = \frac{k\,q_B\,q_A}{r^2}$

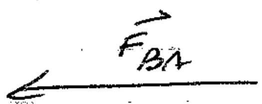
$F_{BA} = \frac{(9.0\times10^{9})(5.0\times10^{-6})(4.0\times10^{-6})}{(0.20)^2}$

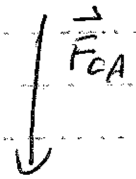
$F_{BA} = 4.50\ N$

$F_{CA} = \frac{k\,q_C\,q_A}{r^2}$

$F_{CA} = \frac{(9.0\times10^{9})(3.0\times10^{-6})(4.0\times10^{-6})}{(0.15)^2}$

$F_{CA} = 4.80\ N$





$\vec{F}_{BA_x} = -4.50N$

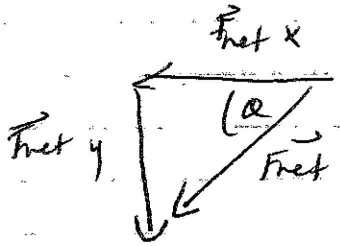
$\vec{F}_{BA_y} = 0\ N$

$\vec{F}_{CA_x} = 0\ N$

$\vec{F}_{CA_y} = -4.80N$

$\vec{F}_{net\,x} = -4.50 + 0 = -4.50\,N$

$\vec{F}_{net\,y} = 0 - 4.80 = -4.80N$



$F_{net} = \sqrt{4.50^2 + 4.80^2}$

$F_{net} = 6.6\ N$

$\tan\theta = \frac{4.80}{4.50}$

$\theta = 47°$

The net force on A is 6.6N, 47° S of W.

Mandatory

1. $r = ?$

$q_1 = q_2 = 1.60 \times 10^{-19} C$

$F = 1.80 \times 10^{-10} N$

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

$$F = \frac{k q^2}{r^2}$$

$$r = \sqrt{\frac{k q^2}{F}}$$

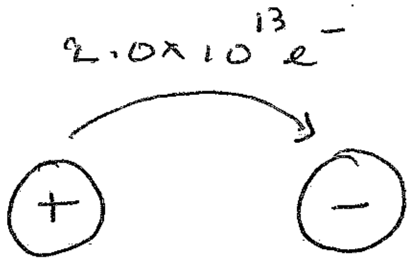
$$r = \sqrt{\frac{(9.0 \times 10^9)(1.60 \times 10^{-19})^2}{1.80 \times 10^{-10}}}$$

$$r = 1.1 \times 10^{-9} m$$

The two electrons are $1.1 \times 10^{-9} m$ apart.

2. $r = 0.64 m$

$F = ?$



$q = Ne$

$q = 2.0 \times 10^{13} (1.60 \times 10^{-19})$

$q = 3.20 \times 10^{-6} C$

$q_1 = q_2 = q$

$$F = \frac{k q^2}{r^2}$$

$$F = \frac{(9.0 \times 10^9)(3.20 \times 10^{-6})^2}{(0.64)^2}$$

$$F = 2.3 \times 10^{-1} N$$

The magnitude of the force between the spheres is $2.3 \times 10^{-1} N$

3. $q_1 = q$
$q_2 = 3q$
$r = 24cm = 0.24m$
$F = 72N$

$q_2 = ?$

$$F = k\frac{q_1 q_2}{r^2}$$
$$F = \frac{k(3q^2)}{r^2}$$
$$Fr^2 = 3kq^2$$
$$q = \sqrt{\frac{Fr^2}{3k}}$$
$$q = \sqrt{\frac{(72)(0.24)^2}{3(9.0\times10^9)}}$$
$$q = 1.2\times10^{-5} C$$

$$q_2 = 3q = 3.6\times10^{-5} C$$

The charge on q_2 is $3.6\times10^{-5}C$.

4. $F = 8.0N$
⊖ , ⊕

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

$$F_n = \frac{kq_1q_2}{(4r)^2}$$
$$F_n = \frac{1}{16}\left[\frac{kq_1q_2}{r^2}\right]$$
$$F_n = \frac{1}{16}(8.0)$$
$$F_n = 0.50 N$$

The new force of attraction will be 0.50N.

5. $q_1 = (+)\,6.0\,\mu C$
$q_2 = (-)\,2.0\,\mu C$
$F = 2.0\,N$

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

$$r = \sqrt{\frac{k q_1 q_2}{F}}$$

$$r = \sqrt{\frac{(9.0\times10^9)(6.0\times10^{-6})(2.0\times10^{-6})}{2.0}}$$

$r = 0.232\,m$

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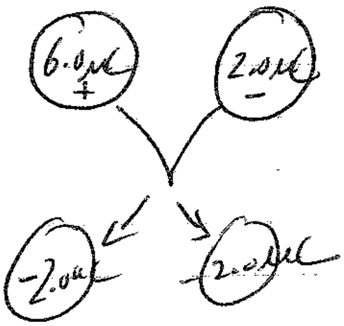
new
$q_1 = 2.0\,\mu C$
$q_2 = 2.0\,\mu C$
$r = 2(0.232m)$
$r = 0.464m$



$$F = \frac{(9.0\times10^9)(2.0\times10^{-6})^2}{(0.464)^2}$$

$F = 0.17\,N$

or

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new
$q_{1_n} = \frac{1}{3} q_1$
$q_{2_n} = q_2$
$r_n = 2r$

$$F_n = \frac{k\left(\frac{q_1}{3}\right)(q_2)}{(2r)^2}$$

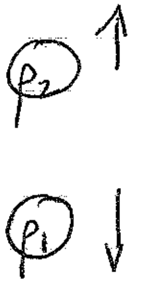
$$F_n = \frac{1}{12} F$$

$$F_n = \frac{1}{12}(2.0)$$

$F_n = 0.17\,N$

The new force will have a magnitude of 0.17 N.

6.



$F = W_p = (1.67 \times 10^{-27})(9.80)$

$F = 1.637 \times 10^{-26} N$

$F = \frac{kq^2}{r^2}$

$q_1 = q_2 = 1.60 \times 10^{-19} C$

$r = \sqrt{\frac{kq^2}{F}}$

$r = \sqrt{\frac{(9.0 \times 10^9)(1.60 \times 10^{-19})^2}{1.637 \times 10^{-26}}}$

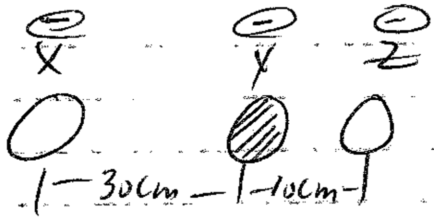
$r = 0.12 m$

The second proton must be placed 0.12 m above the first.

7. $q_x = (-) 5.0 \mu C = -5.0 \times 10^{-6} C$

$q_y = (-) 3.0 \mu C = -3.0 \times 10^{-6} C$

$q_z = (-) 2.0 \mu C = -2.0 \times 10^{-6} C$

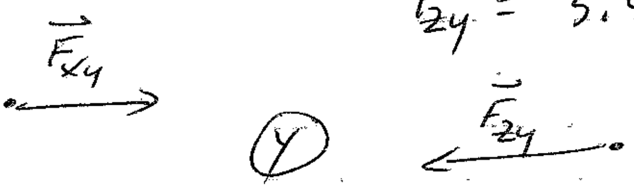


$F_{xy} = 1.50 N$ (previously calculated)

$F_{zy} = \frac{k q_z q_y}{r^2}$

$F_{zy} = \frac{(9.0 \times 10^9)(2.0 \times 10^{-6})(3.0 \times 10^{-6})}{(0.10)^2}$

$F_{zy} = 5.40 N$

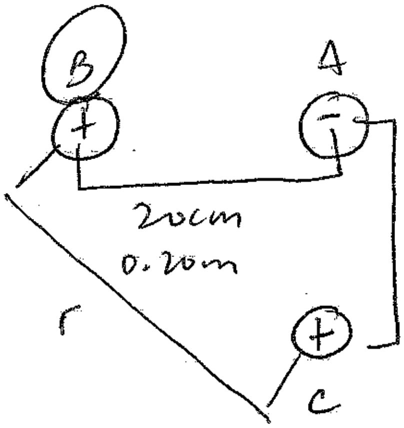


$\vec{F}_{net} = +1.50 - 5.40$

$F_{net} = -3.9 N$

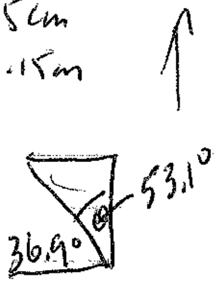
The net force on Y is 3.9 N, left.

8. $q_A = (-)\ 4.0 \times 10^{-6} C$
$q_B = (+)\ 5.0 \times 10^{-6} C$
$q_C = (+)\ 3.0 \times 10^{-6} C$



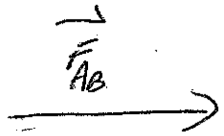
$\tan\theta = \frac{0.20}{0.15}$

$\theta = 53.1°$



$r = \sqrt{0.20^2 + 0.15^2}$
$r = 0.250\ m$

$F_{AB} = 4.50\ N$
(previously calculated)

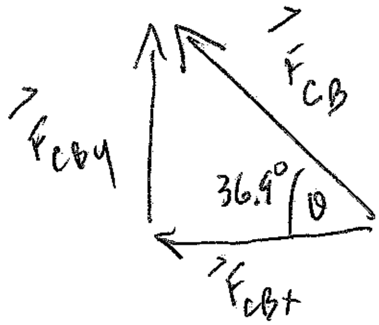


$\vec{F}_{ABx} = +4.50 N$
$\vec{F}_{ABy} = 0 N$

$F_{CB} = \frac{k q_C q_B}{r^2}$

$F_{CB} = \frac{(9.0 \times 10^9)(3.0 \times 10^{-6})(5.0 \times 10^{-6})}{(0.250)^2}$

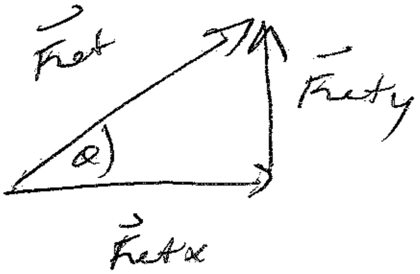
$F_{CB} = 2.16\ N$



$\vec{F}_{CBx} = -2.16 \cos 36.9° = -1.73 N$
$F_{CBy} = +2.16 \sin 36.9° = +1.30 N$

$\vec{F}_{net\,x} = +4.50 - 1.73 N = 2.77 N$

$\vec{F}_{net\,y} = 0 + 1.30 N = 1.30 N$



$F_{net} = \sqrt{2.77^2 + 1.30^2}$
$F_{net} = 3.1 N$

$\tan\theta = \frac{1.30}{2.77}$
$\theta = 25°$

The net force on B is 3.1 N, 25° N of W.