Chapter 21 Electric Charge & Electric Field

I] Assignments

Quest: 4, 6, 8, 9, 11, 17, 19, 21

Prob: 1, 3, 5, 6, 10, 12, 13*, 14, 19, 21, 24, 26, 28, 32, 34, 36, 40, 41, 45, 56, 57, 59, 62, 63, 68, 70, 76, 80, 82, 85, 88

II] Solution to Selected Problems

21-3) $Q_1 = 25\,\mu C = 2.5\times10^{-5}C$,

$Q_2 = 2.5\,mC = 2.5\times10^{-3}C$, $r_{12} = 0.28m$

$\therefore F_{21} = k\dfrac{Q_1Q_2}{r_{12}^2} = 9.0\times10^{9}\dfrac{N\cdot m^2}{C^2}\,\dfrac{2.5\times2.5\times10^{-5-3}C^2}{(0.28m)^2}$

$= 9.0\times\dfrac{2.5^2}{0.28^2}\times10^{9-8}N = 717\,N$

21-6) When the 2 particles are r_0 apart $F_0 = 3.2\times10^{-2}N$, Now $r = r_0/8$. $F = ?$

A) Long Version.

$\dfrac{F}{F_0} = \dfrac{kQ_1Q_2/r^2}{kQ_1Q_2/r_0^2} = \left(\dfrac{r_0}{r}\right)^2 = (8)^2 = 64$

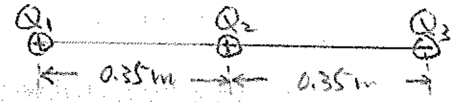
$\therefore F = 64F_0 = 64\times3.2\times10^{-2}N = 2.05\,N$

B) Alternative approach.

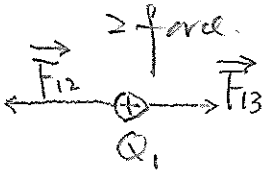
$\left.\begin{array}{l} F \propto 1/r^2 \\ r = \frac{1}{8}r_0 \end{array}\right\}$ in your mind!

$\therefore F = \dfrac{1}{(\frac{1}{8})^2}F_0 = 64F_0 = \underline{\qquad}$.

21-12)

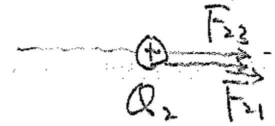


Hint: On every charge there are two forces, one each from the other 2 charges. First, determine the direction of the 2 force. e.g.



$\because Q_1Q_2 > 0$, repulsive
$Q_1Q_3 < 0$ attractive

21-12) Continued



$\because Q_1Q_2 > 0$ repulsive
$Q_2Q_3 < 0$ attractive

Let's cal the total force on Q_1

$\vec{F}_1 = \vec{F}_{12} + \vec{F}_{13}$ & $\vec{F}_{13}\rightarrow$, $\vec{F}_{12}\leftarrow$

$\therefore F_1 = F_{13} - F_{12}$

$= k\left[\dfrac{|Q_1Q_3|}{r_{13}^2} - \dfrac{|Q_1Q_2|}{r_{12}^2}\right]$

$= 9.0\times10^{9}\dfrac{N\cdot m^2}{C^2}\left[\dfrac{75\times85}{(.70m)^2} - \dfrac{75\times48}{(.35m)^2}\right]10^{-12}C^2$

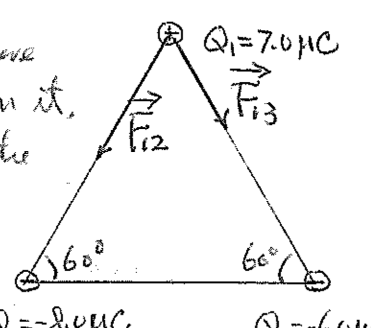
$= 9.0\times10^{9}N\left[1.30\times10^{4} - 2.94\times10^{+4}\right]\times10^{-12}$

$= 9.0\times10^{-3}N\left[1.64\times10^{4}\right] = 14.8\times10^{4-3}N = 148\,N$

"$-$" $\vec{F}_1$ is toward the left.

21-13) Hints.

a) On each charge, there are 2 forces acting on it, one from each of the other 2 charges.



(b) The 2 forces on each charges do not line up. They are vectors. Add them up as vectors.

21-14) Given: $Q_1+Q_2=90.0\,\mu C=9.0\times10^{-5}C$

a) when $r_{12}=1.16\,m$, $F=12.0N$ repulsive

$\Rightarrow Q_1$ & Q_2 are like charges.

use $F=k\frac{|Q_1Q_2|}{r_{12}^2}$

$\therefore |Q_1Q_2|=|Q_1||Q_2|=\frac{F\cdot r_{12}^2}{k}$

$=\frac{12N\times(1.16m)^2}{9.0\times10^9\frac{N\cdot m^2}{C^2}}=1.79\times10^{-9}C^2$

$=1.79\times10^3(\mu C)^2$

Since $|Q_1|+|Q_2|=90\,\mu C$

$\therefore [|Q_1|+|Q_2|]^2-4|Q_1||Q_2|=(90^2-4\times1790)(\mu C)^2$

ie $[|Q_1|-|Q_2|]^2=940(\mu C)^2=(30.66\,\mu C)^2$

so: $|Q_1|+|Q_2|=90\,\mu C$ ····(1)

$|Q_1|-|Q_2|=30.66\,\mu C$ ···(2)

(1)+(2) $\Rightarrow 2|Q_1|=120.66\,\mu C$

ie: $|Q_1|=60.33\,\mu C$

so. $|Q_2|=(90-60.33)\mu C$

$=29.67\,\mu C$

Note: Q_1, Q_2 can be both "+" or both "−"

(b) when $r=1.16\,m$, $F=12.0N$ & attractive.

then Q_1 & Q_2 are unlike charges,

Let's consider Q_1 is "+" $\Rightarrow$ Q_2 is "−"

$\Rightarrow Q_1+Q_2=Q_1-|Q_2|=90\,\mu C$

& From $F=k\frac{|Q_1Q_2|}{r_{12}^2}$

We get $|Q_1Q_2|=Q_1|Q_2|=1790(\mu C)^2$

so $[Q_1+|Q_2|]^2=[Q_1-|Q_2|]^2+4|Q_1Q_2|$

$=[90^2+4\times1790](\mu C)^2=(1.526\times10^4)(\mu C)^2$

$=(123.5\,\mu C)^2$

21-14) Continued

ie: $Q_1+|Q_2|=123.5\,\mu C$ ····(3)

$Q_1-|Q_2|=90.0\,\mu C$ ····(4)

(3)+(4) $\Rightarrow 2Q_1=213.5\,\mu C$

so $Q_1=106.8\,\mu C$

& $|Q_2|=(123.5-106.8)\mu C=16.7\,\mu C$

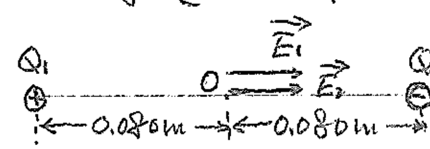
$\therefore Q_2=-16.7\,\mu C$

21-24) Use y (so $\hat{j}$) points up

Given $\vec{F}=-(8.4)\hat{j}\,N$ and $Q=-8.8\,\mu C$

so $\vec{E}=\vec{F}/Q=\frac{-8.4\hat{j}\,N}{-8.8\times10^{-6}C}$

$=9.55\times10^5\,\hat{j}\,\frac{N}{C}$ ($\Rightarrow$ points up)

21-32) 

Hints:

(a) Q_1 is "+", $\vec{E_1}$ points away from it

Q_2 is "−", $\vec{E_2}$ points toward it.

$\therefore E_0=E_1+E_2=586\,\frac{N}{C}$

(b) Since $E=k\frac{|Q|}{r^2}$ & $|Q_1|=|Q_2|$ & $r_1=r_2$

so. $E_1=E_2$ ie $2E_1=586\,\frac{N}{C}$

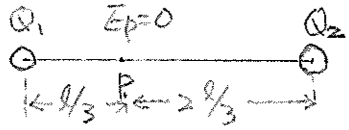
also $E_1=k\frac{|Q_1|}{(8\times10^{-2}m)^2}$

$\therefore |Q_1|=\frac{E_1\times6.4\times10^{-3}m^2}{k}$

$=\frac{293\frac{N}{C}\times6.4\times10^{-3}m^2}{9.0\times10^9\frac{N\cdot m^2}{C^2}}=0.208\times10^{-9}C$

$=0.208\,nC$

21-41)



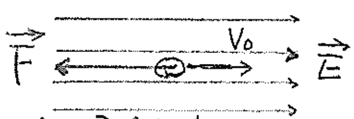
Given: at point P, $E_p = 0 = |\vec{E}_1 + \vec{E}_2|$

i.e.: $\vec{E}_1 = -\vec{E}_2 \Rightarrow$ Q_1, Q_2 are like charge.

$k\frac{Q_1}{r_1^2} = k\frac{Q_2}{r_2^2}$

i.e.: $Q_1/Q_2 = \frac{r_1^2}{r_2^2} = \frac{(l/3)^2}{(2l/3)^2} = \frac{1}{4}$

21-56)



Given: $\vec{V}_0 = 2.75\times10^{7}\,\hat{i}$ m/s

$\vec{E} = 1.14\times10^{4}\,\hat{i}$ N/C

$\vec{a} = \frac{\vec{F}}{m} = \frac{e\vec{E}}{m} = \frac{-1.6\times10^{-19}C \times 1.14\times10^{4}\,\hat{i}\,\frac{N}{C}}{9.11\times10^{-31}kg}$

$=(-\hat{i})\frac{1.6\times1.14}{9.11}\times10^{-19+4+31}\frac{N}{kg}$

$=(-\hat{i})0.203\times10^{16}\frac{m}{s^2} = (-\hat{i})2.03\times10^{15}\frac{m}{s^2}$

i.e.: $V_0 = 2.75\times10^{7}\frac{m}{s}$, $a = -2.03\times10^{15}\frac{m}{s^2}$

(a) use $\cancel{V^2} - V_0^2 = 2aD_{stop}$

$\therefore D_{stop} = \frac{0-V_0^2}{2a} = \frac{-(2.75\times10^{7}\frac{m}{s})^2}{-4.06\times10^{15}m/s^2}$

$= 0.186$ m

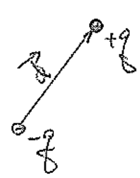
(b) When the electron returns to its starting point, $V = -V_0 = -2.75\times10^{7}\frac{m}{s}$

use $V - V_0 = at$

$\therefore t = \frac{V-V_0}{a} = \frac{(-2.75-2.75)\times10^{7}\frac{m}{s}}{-2.03\times10^{15}m/s^2}$

$= 2.71\times10^{-8}$ s

21-62)



Given $q = e = 1.60\times10^{-19}$C

$d = 0.68$ nm $= 6.80\times10^{-10}$ m

(a) $p = qd = 1.60\times10^{-19}C \times 6.80\times10^{-10}m = 10.88\times10^{-29}$ C·m

$= 1.09\times10^{-28}$ C·m

(b) $\sin\theta = 90°$ $\tau = pE\sin 90°$

21-62) continued

(b) $\therefore \tau = pE\sin 90° = 1.09\times10^{-28}C\cdot m \times 2.2\times10^{4}\frac{N}{C}\times1.0$

$= 2.39\times10^{-24}$ (N·m)

(c) when $\theta = 45°$ $\sin 45° = 0.707$

$\therefore \tau = pE\sin 45° = 2.39\times10^{-24}\times0.707$ (N·m)

$= 1.69\times10^{-24}$ (N·m)

(d) From parallel (ie $\theta_0 = 0$) to anti-parallel (ie $\theta = 180°$)

$W_{ext} = \Delta U = -(U - U_0)$

$= [-pE\cos\theta + pE\cos\theta_0]$

$= [-pE\cos180° + pE\cos0°]$

$= [pE + pE] = 2pE$

$= 2\times1.09\times10^{-28}(C\cdot m)\times2.2\times10^{4}\frac{N}{C}$

$= 4.78\times10^{-24}$ J.