Phys 1B
Solutions
Summer 2010

Week 1 CH 15

1) $F = k_e \cdot \frac{|q_1||q_2|}{r^2}$

$k_e = 8.99 \cdot 10^9 \, Nm^2/C^2$

$q_1 = 4.5 \cdot 10^{-9} C$

$q_2 = 2.8 \cdot 10^{-9} C$

$r = 3.2m$

Plugging these values in will give:

$F = 1.1 \cdot 10^{-8} N$

the force is attractive because opposite charges

5a) $F = k_e \cdot \frac{|q_1||q_2|}{r^2}$

$k_e = 8.99 \cdot 10^9 \, Nm^2/C^2$

$q_1 = 2 \cdot e = 3.2 \cdot 10^{-19} C$
elementary charge.

$q_2 = 2 \cdot e = 3.2 \cdot 10^{-19} C$

$r = 5 \cdot 10^{-15} m$

$F = 37 N$

the force is repulsive (like charges)

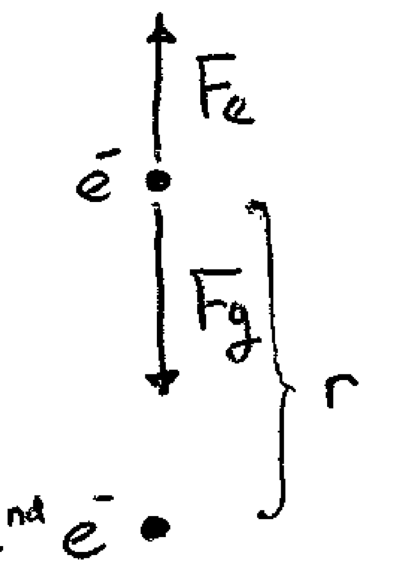
b) $F = m \cdot a \Rightarrow a = F/m$

$F = 36.8N$

$m = 4.0026u = 4.0026 \cdot 1.66 \cdot 10^{-27} kg = 6.64 \cdot 10^{-27} kg$
mass of 1 amu

$a = 5.54 \cdot 10^{27} \, m/s^2$

8) 1^{st} draw a free body diagram



Now the forces cancel. Hence,

$F_e = F_g$

$F_e = k_e \frac{|q_1||q_2|}{r^2}$ $\quad F_g = mg$

$k_e = 8.99 \cdot 10^9\ Nm^2/C^2$

$q_1 = -1.602 \cdot 10^{-19} C$

$q_2 = -1.602 \cdot 10^{-19} C$

$r =$ wanted

$m = 9.11 \cdot 10^{-31} kg$ (mass of electron)

$g = 9.80\ m/s^2$

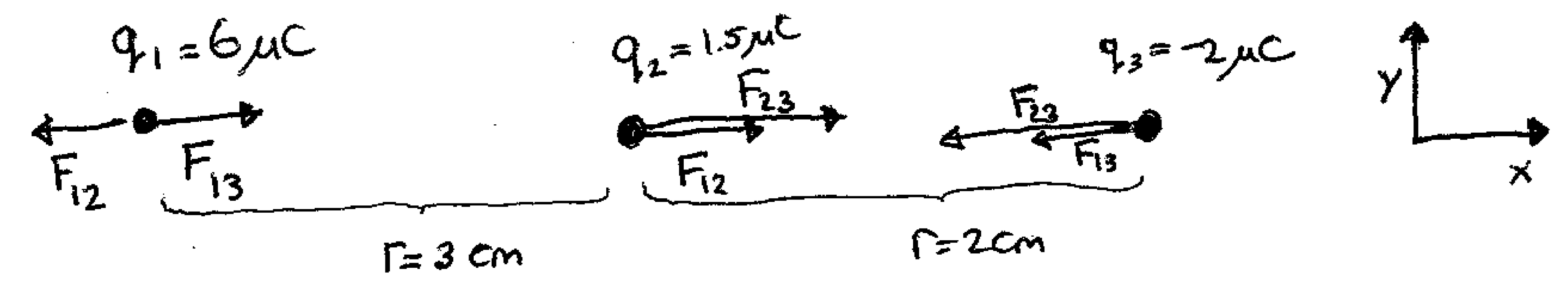
$k_e \frac{|q_1||q_2|}{r^2} = mg$

$r = \sqrt{\frac{k_e |q_1||q_2|}{mg}}$

$r = 5.08 m$

10) Each charge "feels" two forces from the other charges

1^{st} draw a free body diagram:



By Newton's third law, $F_{12} = -F_{21}$ so their magnitudes are equal.

Hence, need to find F_{12}, F_{23}, F_{13} and add them accordingly.

F_{12}: $q_1 = 6.00 \cdot 10^{-6} C$, $q_2 = 1.50 \cdot 10^{-6} C$, $r_{12} = 3 \cdot 10^{-2} m$ $\Big\}$ $F_{12} = 89.9 N$

F_{13}: $q_1 = 6.00 \cdot 10^{-6} C$, $q_3 = -2.00 \cdot 10^{-6} C$, $r_{13} = 5 \cdot 10^{-2} m$ $\Big\}$ $F_{13} = 43.2 N$

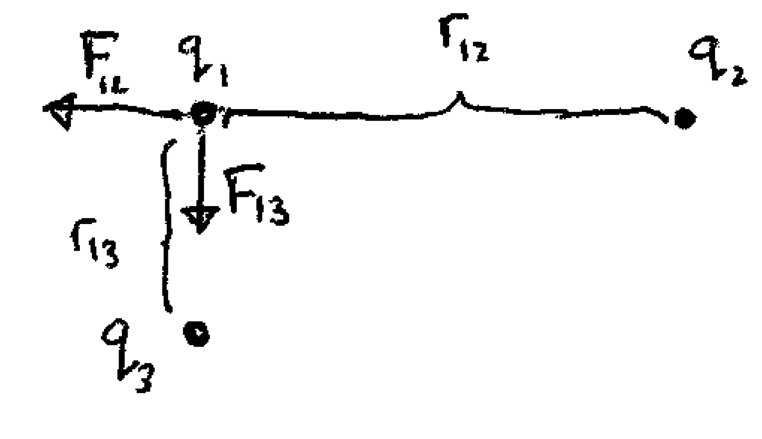
F_{23}: $q_2 = 1.5 \cdot 10^{-6} C$, $q_3 = -2 \cdot 10^{-6} C$, $r_{23} = 2 \cdot 10^{-2} m$ $\Big\}$ $F_{23} = 67.4 N$

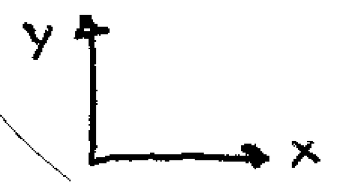
The Netforce on the charges is then:

1^{st} charge: $F_{13} - F_{12} = -46.7 N$ $\quad$ 2^{nd} charge: $F_{12} + F_{23} = 157$[illegible]N $\quad$ 3^{rd} charge: $-F_{13} - F_{23} = -111 N$

− means to the left $\quad$ + means to the right

11)

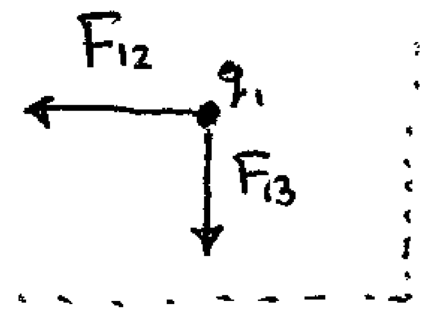




$$F = k_e \frac{|q_1||q_2|}{r^2}$$

F_{12} : $r_{12} = 0.3\,m$, $q_1 = 5\cdot10^{-9}C$, $q_2 = 6\cdot10^{-9}C$ } $F_{12} = 3.00\cdot10^{-6}N$

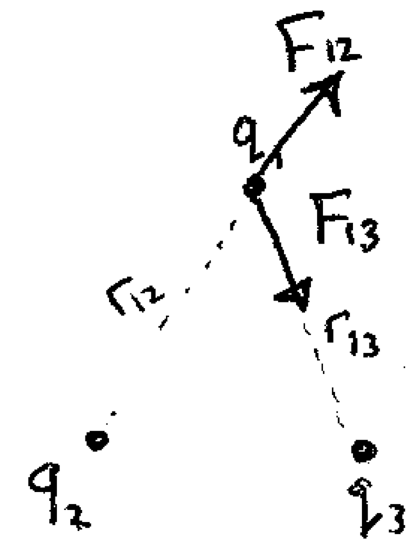
F_{13} : $r_{13} = 0.1m$, $q_1 = 5\cdot10^{-9}C$, $q_3 = -3\cdot10^{-9}C$ } $F_{13} = 1.35\cdot10^{-5}N$

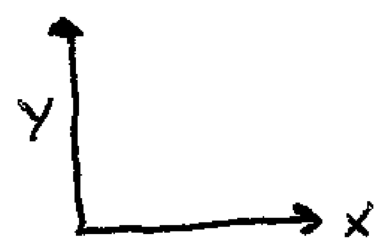


adding these forces vectorially gives:

$$F = (-3\cdot10^{-6}N, -1.35\cdot10^{-5}N) = 1.38\cdot10^{-5}N \text{ at } 257^\circ \text{ from } +x\text{-axis.}$$

13)

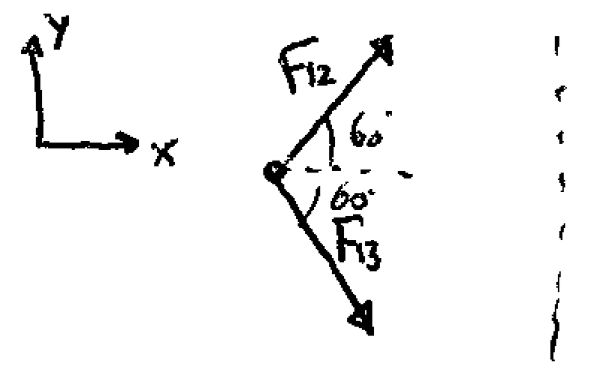




$$F = k_e \frac{|q_1||q_2|}{r^2}$$

F_{12} : $r_{12} = 0.5m$, $q_1 = 7\cdot10^{-6}C$, $q_2 = 2\cdot10^{-6}C$ } $F_{12} = 0.503N$

F_{13} : $r_{13} = 0.5m$, $q_1 = 7\cdot10^{-6}C$, $q_3 = -4\cdot10^{-6}C$ } $F_{13} = 1.01N$



decompose the vectors into x, y components.

$F_{12x} = 0.503N\cdot\cos(60^\circ) = 0.252N$ $\qquad$ $F_{13x} = 1.01N\cdot\cos(60^\circ) = 0.505N$

$F_{12y} = 0.503N\cdot\sin(60^\circ) = 0.436N$ $\qquad$ $F_{13y} = 1.01N\cdot\sin(60^\circ) = 0.875N$

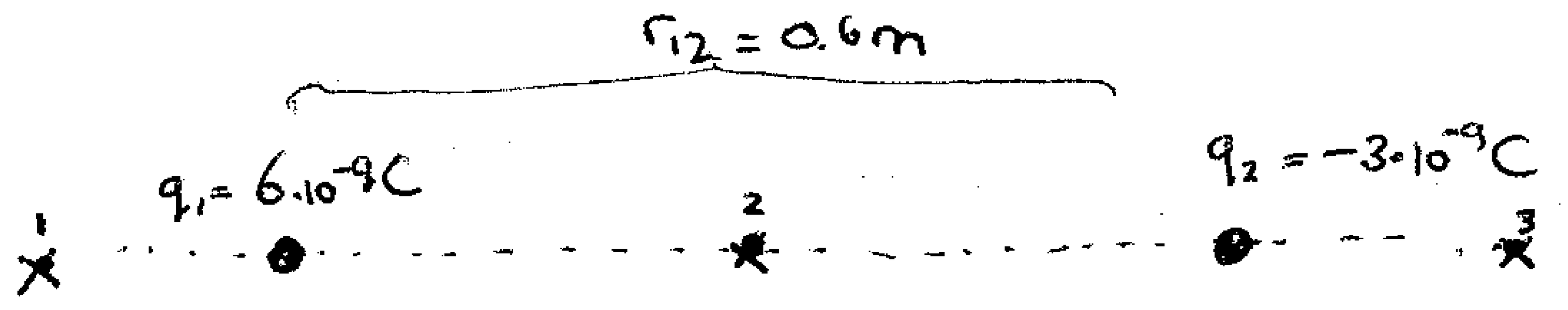
Now add the components vectorially (note that F_{13y} points in the negative direction).

$$F = (0.252+0.505,\ 0.436-0.875) = (0.757N, -0.439N) = 0.875N \text{ at } -30.1^\circ \text{ from } +x\text{-axis}$$

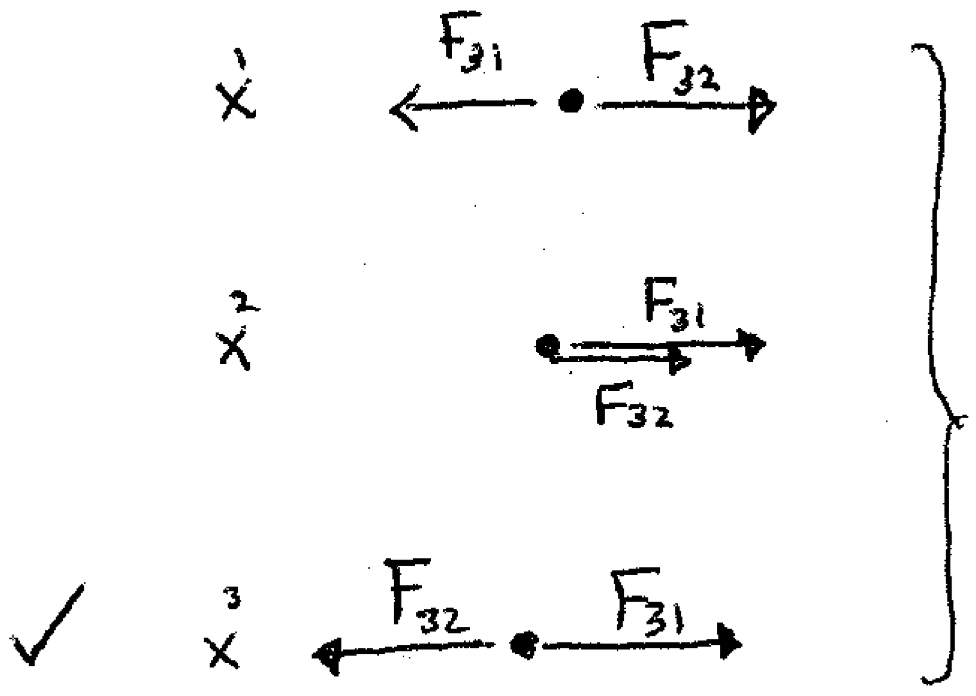
Note: to get the last equalities in the answer use:

$$F = \sqrt{F_x^2 + F_y^2} \quad \text{and} \quad \theta = \tan^{-1}(F_y/F_x).$$

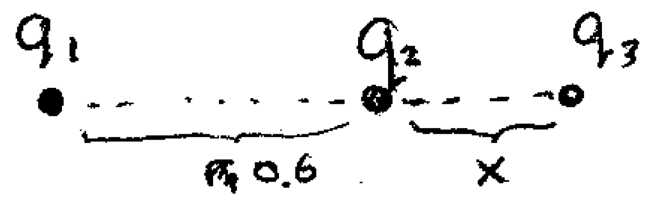
16)



First need to see in what position you have to place the third charge For the Forces to cancel on it the two forces need to point in opposite directions if the charge 3 is put at :



need to choose position 3 not position 1 because to have the forces to be equal the weaker charge needs to be closer.



F_{31} : $q_1 = 6 \cdot 10^{-9}C$

$q_3 = \cancel{8}\,12 \cdot 10^{-9}C$

$r_{31} = (0.6 + x)m$

F_{32}: $q_2 = -3 \cdot 10^{-9}C$

$q_3 = 12 \cdot 10^{-9}C$

$r_{23} = x\,m$

$$\frac{\cancel{k_e}\,|q_1|\cancel{|q_3|}}{r_{31}^2} = \frac{\cancel{k_e}\,|q_2|\cancel{|q_3|}}{r_{23}^2} \Rightarrow \frac{r_{23}^2}{r_{31}^2} = \frac{|q_2|}{|q_1|} :$$

$$\frac{x^2}{(0.6+x)^2} = \frac{1}{2} \Rightarrow (0.6+x)^2 = 2x^2 \Rightarrow x^2 - 1.2x - 0.36 = 0 \qquad X = 1.4\cancel{9}5\,m$$

The charge needs to be placed 1.45m ~~left~~ ~~away~~ right of the $-3 \cdot 10^{-9}C$ charge.

48a) $F = k_e \cdot \frac{|q_1||q_2|}{r^2}$

$q_1 = 1.602\cdot10^{-9}C$
$q_2 = -1.602\cdot10^{-9}C$
$r = 0.53\cdot10^{-10}m$

$\Big\}$ $F = 8.21\cdot10^{-8}N$ this is the force acting on each particle (note the force is attractive).

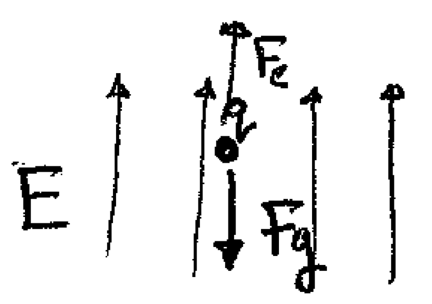
b) If the force causes centripetal acceleration, then

$F = mv^2/r \Rightarrow v = \sqrt{\frac{rF}{m}}$

$r = 0.53\cdot10^{-10}m$
$F = 8.21\cdot10^{-8}N$
$m = 9.11\cdot10^{-31}kg$

$\Big\}$ $V = 2.19\cdot10^{6}m/s$ This is about 1% the speed of light!

17)



$E = 610 N/C$
$q = 24\cdot10^{-6}C$
$g = 9.8 m/s^2$

$\Big\}$ $E = F/q$ $\quad F_e = qE$ $\quad F_g = mg$ $\quad F_e = F_g \Rightarrow qE = mg$

$m = qE/g = 1.49$ grams

20a) $F_e = qE = ma \quad a = qE/m$

$q = 1.602\cdot10^{-19}C$
$E = 300 N/C$
$m = 9.11\cdot10^{-31}kg$

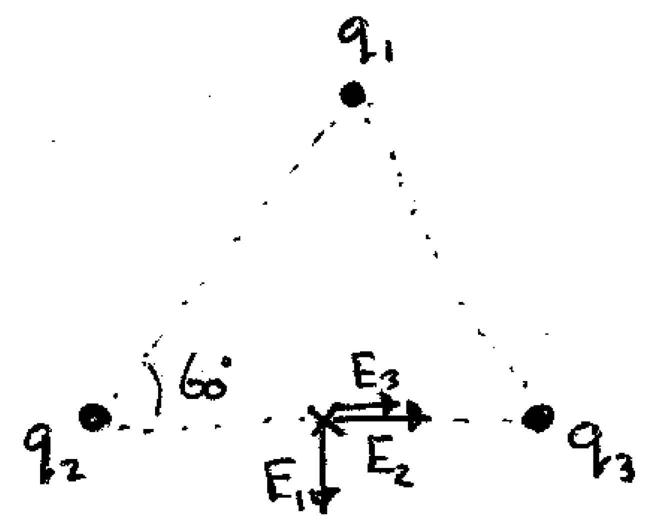
$\Big\}$ $a = 5.28\cdot10^{13} m/s^2$

b) Use $V_f = V_o + at$

$V_o = 0 m/s$
$a = 5.28\cdot10^{13} m/s^2$
$t = 1\cdot10^{-8}s.$

$\Big\}$ $V_f = 5.28\cdot10^{5} m/s$

24)



$$E = \frac{k_e|q|}{r^2}$$

$q_1 = 3\cdot10^{-9}\,C$

$r = 0.5\cdot \sin 60 = 0.433\,m$

$E_1 = 144\,N/C$

$q_2 = 8\cdot10^{-9}\,C$

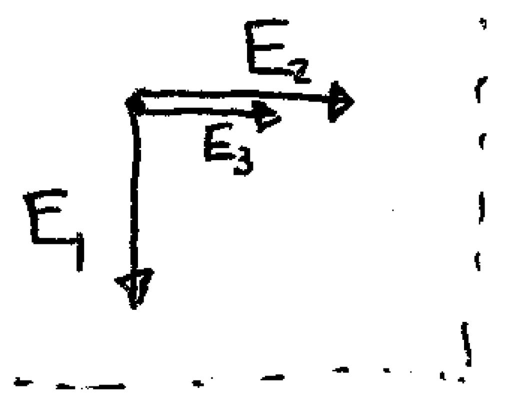
$r = 0.250\,m$

$E_2 = 1150\,N/C$

$q_3 = 5\cdot10^{-9}\,C$

$r = 0.250\,m$

$E_3 = 719\,N/C$

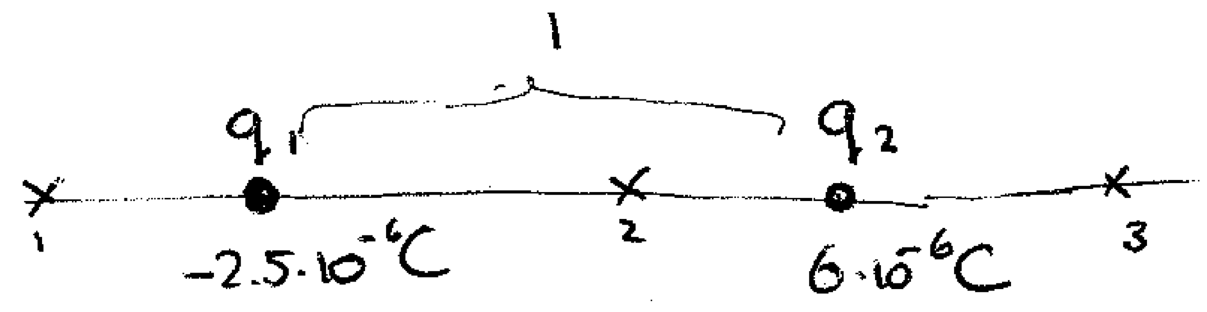


adding these up vectorially will give:

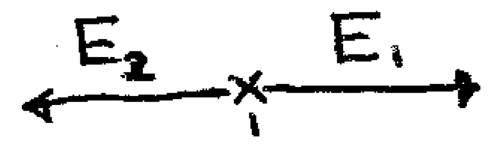
$E = (1869\,N/C;\ 144\,N/C) = 1870\,N/C$ at $-4.41°$ below $+x$-axis.

note: We always use a <u>positive</u> test charge.

27)



just as problem 16) the point needs to be at the outside closest to the weakest charge. i.e at position 1.



$$E_1 = \frac{k|q|}{r^2} \qquad E_1 = E_2 \Rightarrow \frac{k_e|q_1|}{r_1^2} = \frac{k_e|q_2|}{r_2^2} \Rightarrow \frac{r_2^2}{r_1^2} = \frac{|q_2|}{|q_1|}$$

$r_2 = (1+x)\,m$

$r_1 = x\,m$

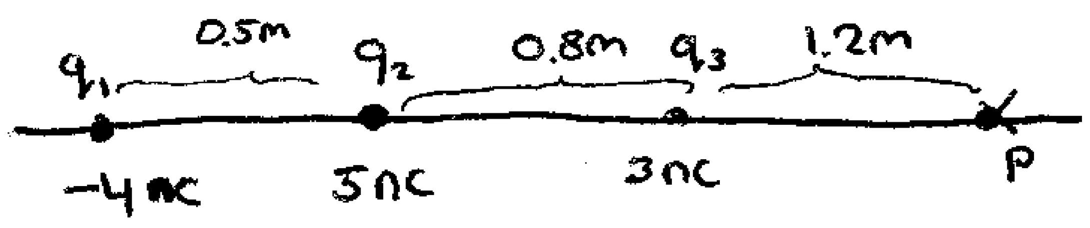
$q_1 = -2.5\cdot10^{-6}\,C$

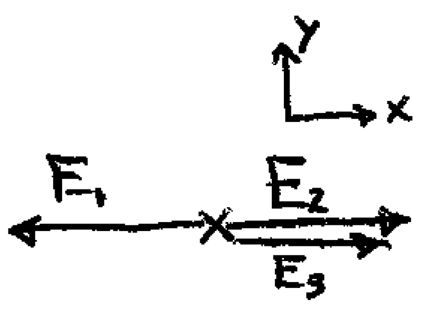
$q_2 = 6\cdot10^{-6}\,C$

$$\frac{(1+x)^2}{x^2} = \frac{6\cdot10^{-6}}{2.5\cdot10^{-6}} = 2.4 \Rightarrow (1+x)^2 = 2.4x^2$$

$$1.4x^2 - 2x - 1 = 0 \Rightarrow x = 1.8\,m$$ to the left of the $-2.5\,\mu C$ charge.

49)





$$E = \frac{k_e|q|}{r^2}$$

E_1: $q_1 = -4\cdot10^{-9}\,C$

$r = 2.5\,m$

$E_1 = 5.8\,N/C$

E_2: $q_2 = 5\cdot10^{-9}\,C$

$r = 2\,m$

$E_2 = 11\,N/C$

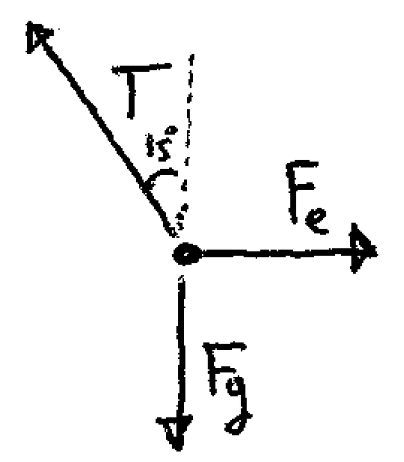
E_3: $q_3 = 3\cdot10^{-9}\,C$

$r = 1.2\,m$

$E_3 = 19\,N/C$

$E = E_2 + E_3 - E_1 = 24\,N/C$ to the left.

50) Draw a free body diagram :



The ball is not moving therefore $\Sigma F_x = 0$, and $\Sigma F_y = 0$

decompose T: $T_x = T\sin(15°)$; $T_y = T\cos(15°)$

$F_e = T\sin(15°)$ (x-direction)

$F_g = T\cos(15°)$ (y-direction)

To get rid of T divide the two equations by each other:

$$\frac{F_e}{F_g} = \frac{T\sin(15°)}{T\cos(15°)} = \tan(15°)$$

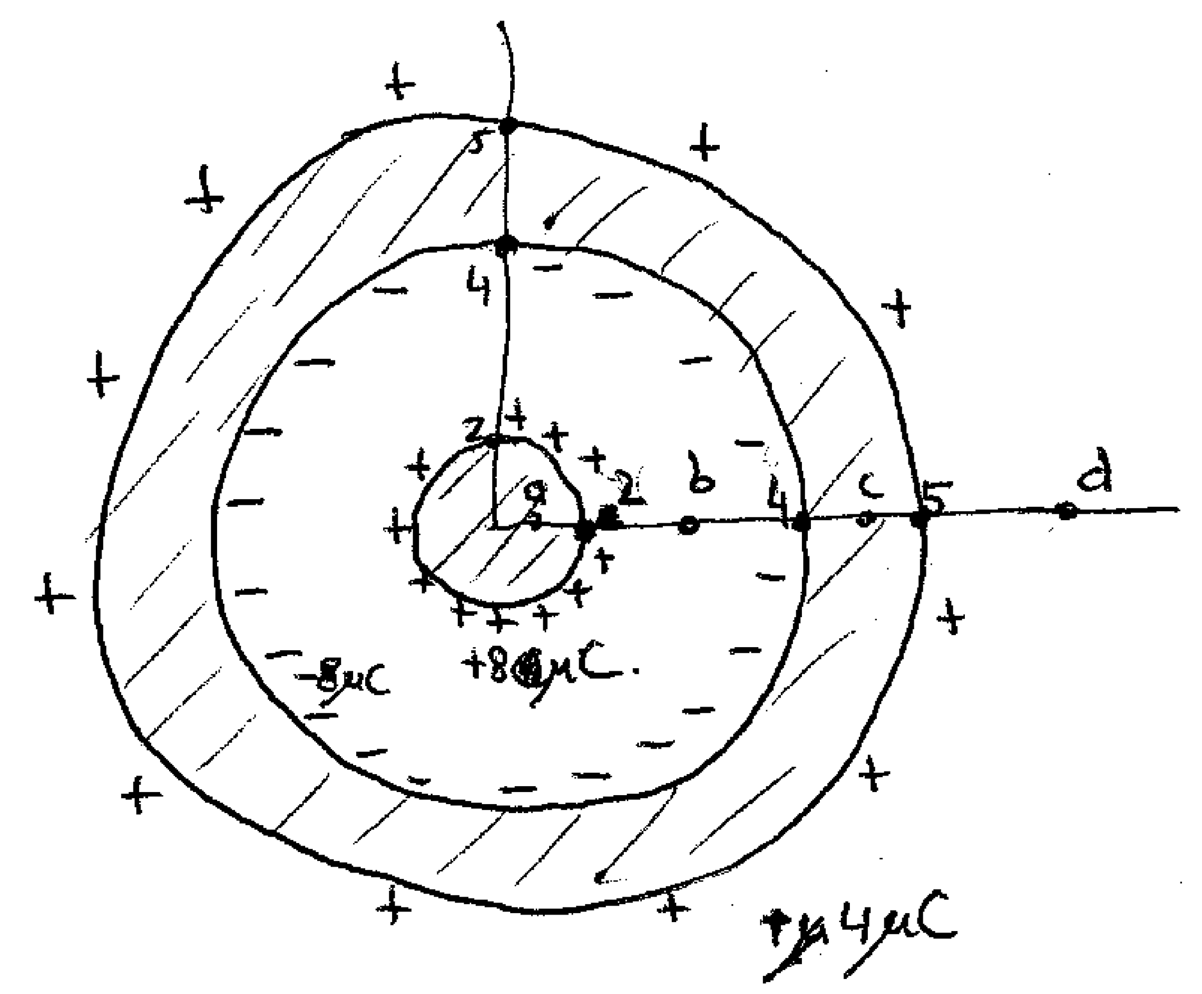
now $F_e = qE$, and $F_g = mg$

$$\left.\right\} \quad qE = mg\tan(15°)$$

$$q = mg\tan(15°)/E$$

$m = 2\cdot10^{-3}\,kg$, $g = 9.8\,m/s^2$ $E = 1\cdot10^{3}\,N/C$ $\Rightarrow$ $q = 5.25\cdot10^{-6}\,C = 5.25\,\mu C$

53)



Charges redistribute in such a way that the field inside a conductor is 0.

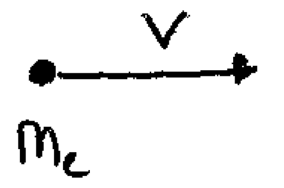
By Gauss' law the charge that is needed is the net charge inside the Gaussian surface of the given radius

a) $E = 0$ there is no net charge inside a radius of 1

b) $Q = 8\,\mu C$ $r = 3\,cm$ $E = k_e Q/r^2 = 7.99\cdot10^{7}\,N/C$

c) $E = 0$ again inside a conductor the net charge $= 0$

d) $Q = 4\,\mu C$ $r = 7\,cm$ $E = k_e Q/r^2 = 7.34\cdot10^{6}\,N/C$

63a) 

$KE = \frac{1}{2}mv^2 \qquad V = \sqrt{\frac{2KE}{m}}$

$KE = 1.60 \times 10^{-17}\,J \quad m = 9.11 \cdot 10^{-31}\,kg \; \} \; V = 5.93 \cdot 10^{6}\,m/s$

The constant E-field provides a constant force, i.e. a constant acceleration

use the following formula from phys IA:

$V_f^2 - V_0^2 = 2 \cdot a \cdot \Delta x \qquad V_f = 0 \quad V_0 = 5.93 \cdot 10^6\,m/s \quad \Delta x = 0.1\,m \; \} \; a = \frac{V_f^2 - V_0^2}{2\Delta x} = -1.76 \cdot 10^{14}\,m/s^2$

The electric field causes this acceleration. i.e. $F_e = ma \quad F_e = -1.60 \cdot 10^{-16}\,N$

$E = F_e/q \qquad q = -1.60 \cdot 10^{-19}\,C \qquad E = 1000\,N/C$

b) Using another formula for uniform acceleration: $V_f = V_0 + at$

with $V_f = 0\,m/s \quad V_0 = 5.93 \cdot 10^6\,m/s \quad a = -1.76 \cdot 10^{14}\,m/s^2$ gives

$t = \frac{V_f - V_0}{a} = 3.37 \cdot 10^{-8}\,s.$

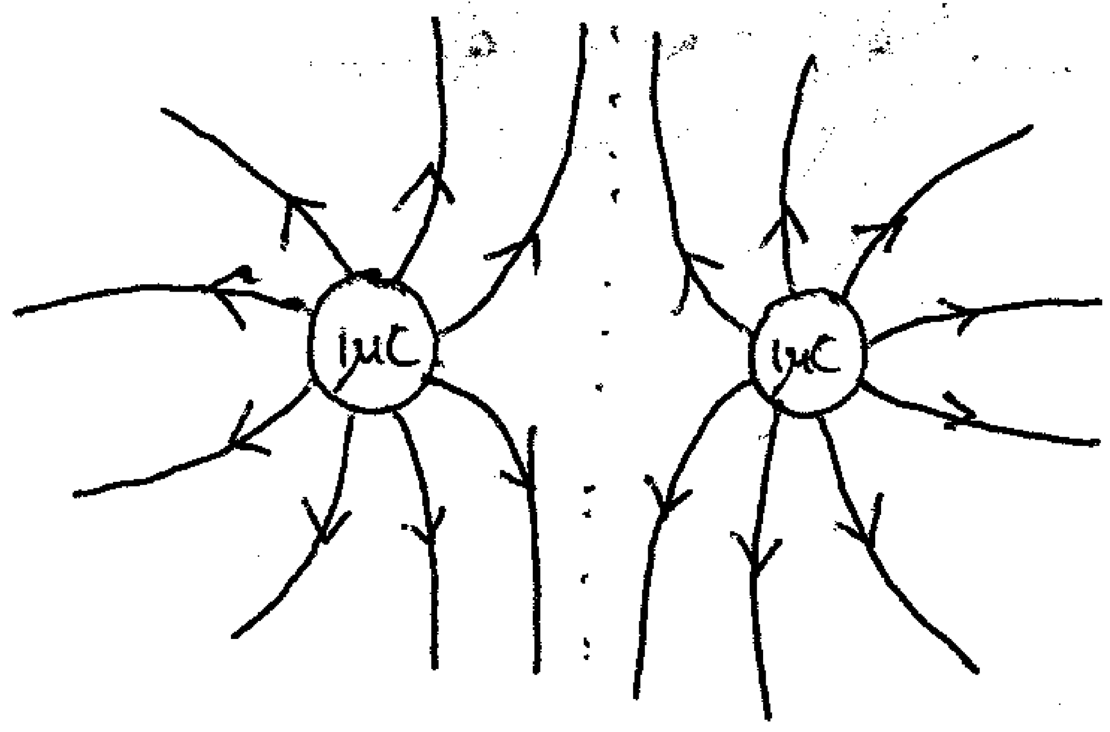
c) Since the E-field is still there, the electrons will continue to experience the force, and thus acceleration. They therefore will move backward and continue to accelerate

28 a) q_2 has 18 lines and q_1 has 6 lines

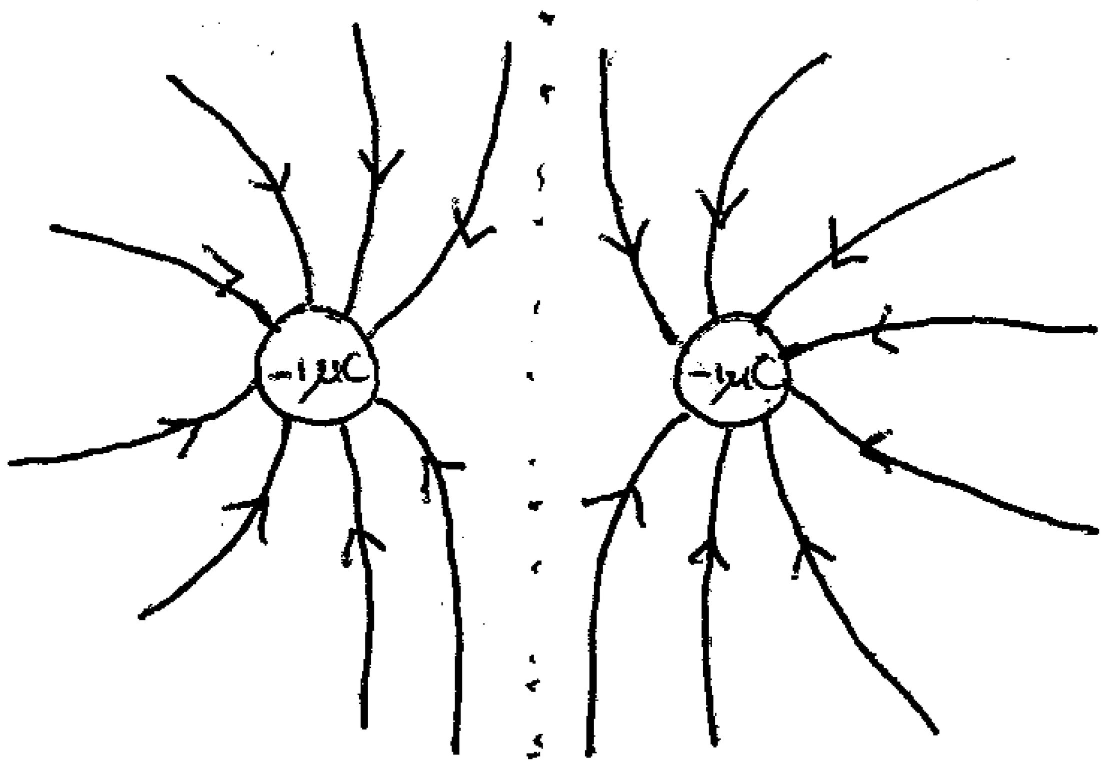
b) q_2 is positive (the lines leave q_2) q_1 is negative (the lines end at q_1)

therefore $q_1/q_2 = -6/18 = -1/3.$

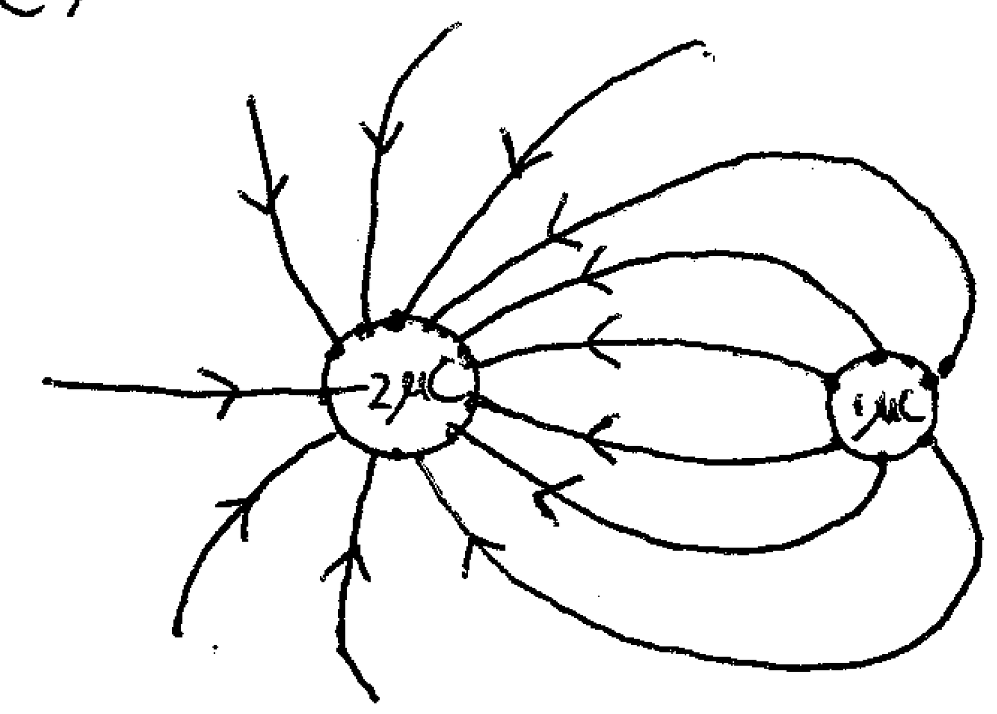
30 a)



b)



c)



33 a) The conductor is neutral therefore both inside and outside have no charge

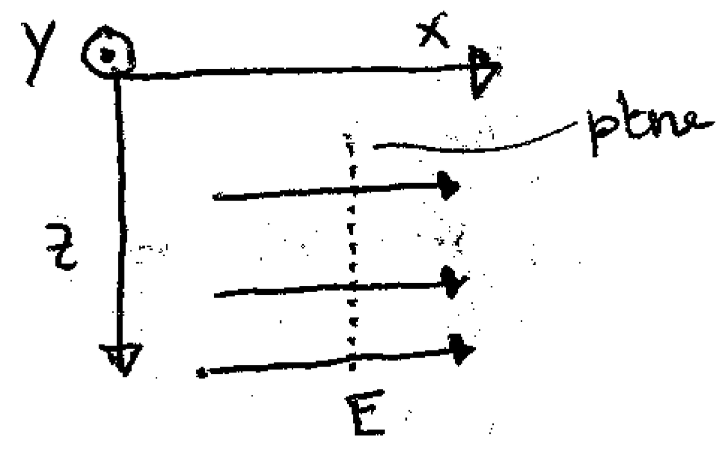
b) An equal amount of electrons will be "pulled" to the inside of the hollow conductor. Hence, this leaves an equal but positive charge on the outside:

$Q_{inside} = -5\mu C$ $Q_{outside} = +5\mu C$

c) When the ball touches the inside, the electrons on the inside will cancel the charge leaving

Q inside $= 0\mu C$ Q outside $= 5\mu C$

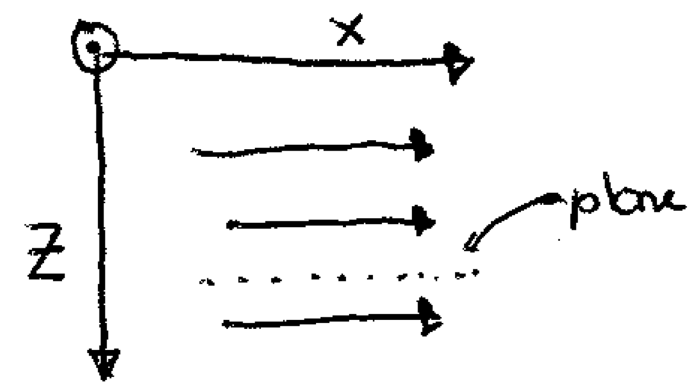
d) Nothing changes $Q_{inside} = 0\mu C$ Q outside $= 5\mu C$

39a) 

the plane is perpendicular to the field. ie

$\Phi_E = EA\cos\theta$ $\theta = 0$ $E = 3.5 \cdot 10^3\ N/C$ $A = 0.245\ m^2$

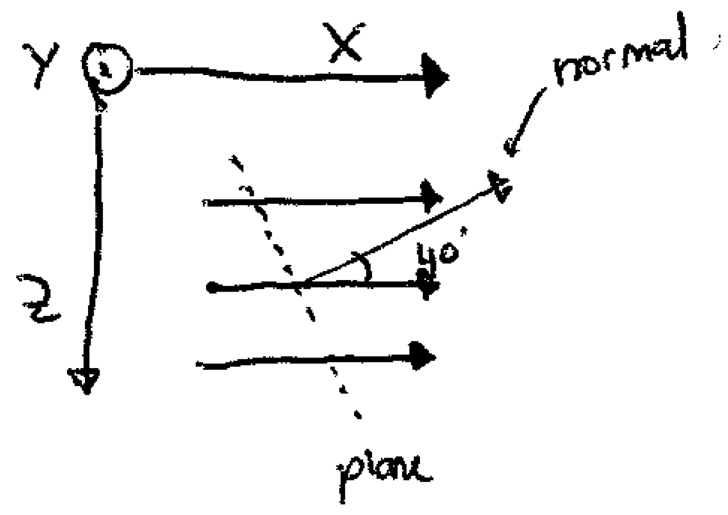
$\Phi_E = 858\ Nm^2/C$

b) 

the plane is parallel to the field i.e

$\Theta = 90°$ since $\cos(90°) = 0$

$\Phi_E = 0\ Nm^2/C$

c) 

the normal of the plane makes a 40° angle i.e.

$\Theta = 40°$ Hence, $E = 3.5 \cdot 10^3\ N/C$ $A = 0.245\ m^2$

$\Phi_E = 657\ Nm^2/C$

41) $\Phi_E = EA\cos\theta$ ϕ will be maximum when $\cos\theta = 1$ Hence,

$E = \Phi_E/A$ $\Phi_E = 5.2 \cdot 10^5\ Nm^2/C$ $A = \left(\frac{0.4}{2}\right)^2 \cdot \pi = 0.126\ m^2$

$E = 4.1 \cdot 10^6\ N/C$

43 a) By Gauss' law we can draw a Gaussian surface (a sphere) of radius r.

the flux through that surface must equal $EA = \Phi_E = Q_{inside}/\epsilon_0$

$A = 4\pi r^2$ Hence, $E = Q/4\pi\epsilon_0 r^2 = k_e Q/r^2$ Q is the charge inside the surface which is $-q+q = 0$ Hence $E = 0$ outside the shell.

b) inside the shell $Q = +q$ and thus $E = k_e q/r^2$ pointing outward since the charge is positive.