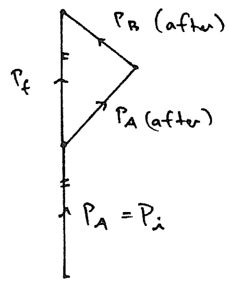
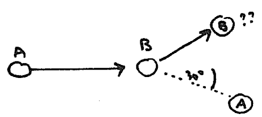
22.  Take the velocity vectors as the distance between 3 images (as above)



By measurement $\vec{P_i} = \vec{P_f}$

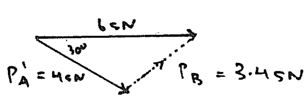
$\therefore$ The Law holds.

23.



$P_i = P_A = 2.0 \times 3.0 = 6\text{sN} \rightarrow$

$\therefore P_f = 6.0\text{sN} \rightarrow$



$P_B = 3.4\text{sN} = mV$

$\therefore 3.4 = 3.0 \times V$

$\therefore V = 3.4/3.0$

$V = 1.13 \text{ ms}^{-1} \nearrow$

24.

(1) No. It is moving with constant speed in a straight line $\therefore$ not accelerating $\therefore$ no force

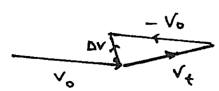
(2) Use the velocity vector as the distance between 3 images

$\therefore \vec{P_A} = 3m \times 2 = 6m$

$\vec{P_B} = m \times 2.3 = 2.3m$

$\therefore$ A has the biggest momentum

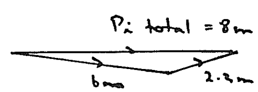
(3)



ie $\Delta V = V_f - V_0$

(4)

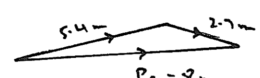
Before collision



after collision

$P_A' = 3m \times 1.8 = 5.4m$

$P_B' = m \times 2.7 = 2.7m$



Momentum is conserved.

1. (1) Coulombic force

$\therefore F = \frac{\frac{1}{4\pi\varepsilon_0} q_1 q_2}{d^2}$

$\therefore F = \frac{9\times10^9 \times 1.44\times10^{-6} \times 2.0\times10^{-6}}{(1.2)^2}$

$F = 0.018\text{N}$ attraction.

(2) (a) $F \propto 1/d^2$

$\therefore$ double distance, 1/4 the force.

$F_{new} = 0.0045\text{N}$

(b) 0.30m is 1/4 distance

$\therefore$ F is 16 times the size

$F = 16 \times 0.018$

$= 0.288 \text{ N}$

(c) Same magnitude force now repulsion.

(3) Equal and opposite forces as per Newton's Third Law.

(4) as $F = ma$, need the mass of q_2

2. (1) $F = \frac{\frac{1}{4\pi\varepsilon_0} q_1 q_2}{d^2}$

$F = \frac{9\times10^9 \times 1.6\times10^{-19} \times 1.6\times10^{-19}}{(5.32\times10^{-11})^2}$

$F = 8\times10^{-8}$ Newtons.

(2) The attraction force is a centripetal force.

$\therefore F = \frac{mv^2}{r}$

$\therefore 8\times10^{-8} = \frac{9.11\times10^{-31} \times v^2}{5.32\times10^{-11}}$

$\therefore v = \sqrt{\frac{8\times10^{-8} \times 5.32\times10^{-11}}{9.11\times10^{-31}}}$

$v = 2.2\times10^6 \text{ ms}^{-1}$.

3. (1) $F \propto 1/d^2$

$\therefore$ double distance, 1/4 the force.

$\therefore F_{new} = \frac{6.0\times10^{-7}}{4}$

$= 1.5\times10^{-7}\text{N}$

(2) $3.6\times10^{-6}\text{N}$ is 6 times the force.

$\therefore \frac{F_1}{F_2} = \frac{d_2^2}{d_1^2}$

$\therefore \frac{F_1}{6F_1} = \frac{d_2^2}{d_1^2}$

$\therefore d_1^2 = 6 d_2^2$

$\therefore d_1 = \sqrt{6}\, d_2$

$\therefore$ new distance $= \frac{10}{\sqrt{6}}$

$= 4.1\text{cm}$

(3) $F \propto q_1 q_2$

$\therefore$ double one charge will double the force

$\therefore F_3 = 1.2\times10^{-6}\text{N}$

4. $F = \frac{\frac{1}{4\pi\varepsilon_0} q_1 q_2}{d^2}$

$1.0\times10^{-6} = \frac{9\times10^9 \times 2.0\times10^{-6} \times 6.0\times10^{-6}}{d^2}$

$\therefore d = \sqrt{\frac{9\times10^9 \times 2\times10^{-6} \times 6\times10^{-6}}{1.0\times10^{-6}}}$

$d = 328\text{ m}$.

5. Force between A & C

$F = \frac{\frac{1}{4\pi\varepsilon_0} q_1 q_2}{d^2}$

$F = \frac{9\times10^9 \times 20\times10^{-6} \times 10\times10^{-6}}{(0.5)^2}$

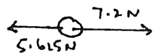
$F = 7.2\text{ N}$ repulsion.

Force between B & C

$$F = \frac{9\times10^9 \times 10\times10^{-6} \times 10\times10^{-6}}{(0.4)^2}$$

$F = 5.625$ N repulsion

$\therefore$ resultant force on C



$\therefore F_R = 1.575$ N towards B.

6. Force between A & B

$$F = \frac{\frac{1}{4\pi\varepsilon_0} q_1 q_2}{d^2}$$

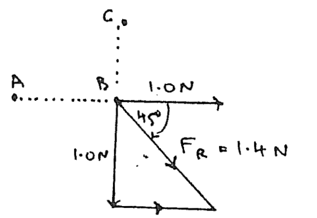
$$= \frac{9\times10^9 \times (2.10\times10^{-6})^2}{(.2)^2}$$

$= 1.0$ Newton repulsion

Force between B & C

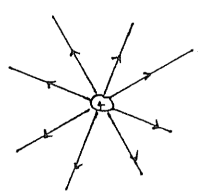
$= 1.0$ N repulsion.

$\therefore$ Resultant force on B



Resultant force on B $= 1.4$ N at 45° as shown.

7(1)



$$\vec{E} = \frac{\frac{1}{4\pi\varepsilon_0} q_1}{d^2} = \frac{9\times10^9 \times 0.5}{(3)^2}$$

$\vec{E}_1 = 5.0\times10^{10}$ Nc^{-1} outwards

(2) 90 cm is 3 times the distance. as $E \propto 1/d^2$, the field at 90 cm will be $1/9^{th}$ E_1

$\therefore E_2 = 5.5\times10^9$ Nc^{-1} $\rightarrow$

(3) 10 cm is 1/3 distance

$\therefore \vec{E}_3$ is 9 times E_1

$E_3 = 4.5\times10^{11}$ Nc^{-1} outwards.

8. (1) $\vec{E} = \frac{\frac{1}{4\pi\varepsilon_0} q_1}{d^2}$

$$\vec{E}_1 = \frac{9\times10^9 \times 1.1\times10^{-8}}{(0.2)^2}$$

$\vec{E}_1 = 2475$ Nc^{-1} outwards.

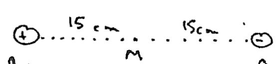
(2) $\vec{F} = \vec{E}q$

$\therefore F = 2475 \times 1.6\times10^{-19}$

$F = 3.96\times10^{-16}$ N attraction.

(3) $F = 3.96\times10^{-16}$ N repulsion.

9. (1)



Electric field strength at M due to q_1

$$\vec{E} = \frac{\frac{1}{4\pi\varepsilon_0} q_1}{d^2}$$

$$= \frac{9\times10^9 \times 3.0\times10^{-7}}{(.15)^2}$$

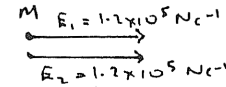
$E_1 = 1.2\times10^5$ Nc^{-1} $\rightarrow$

Electric field strength at M due to q_2

$E_2 = 1.2\times10^5$ Nc^{-1} $\rightarrow$

9(1) Vector addition of the two fields gives the resultant field strength at M.

$\therefore$



$\therefore \vec{E}$ resultant $= 2.4\times10^5$ Nc^{-1} towards q_2

9 (2) $\vec{F} = \vec{E}q$ $[He^{2+}]$

$\therefore F = 2.4\times10^5 \times 3.2\times10^{-19}$

$F = 7.68\times10^{-14}$ N towards q_2

10. (1) Magnitude of the electric field at X due to A

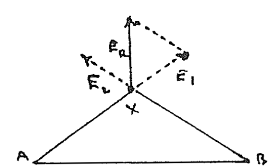
$$E_1 = \frac{\frac{1}{4\pi\varepsilon_0} q_1}{d^2} = \frac{9\times10^9 \times 2\times10^{-6}}{(.283)^2}$$

$E_1 = 2.25\times10^5$ Nc^{-1}

Similarly E_2 due to B at X is $E_2 = 2.25\times10^5$ Nc^{-1}

Vector addition gives the resultant field at X.

Scale: km $\equiv 1\times10^5$ Nc^{-1}



$\vec{E}_R$ (by scale diagram)

$= 3.18\times10^5$ Nc^{-1}

perpendicular to the line between A & B.

(2) $F = Eq$

$= 3.18\times10^5 \times 1.6\times10^{-19}$

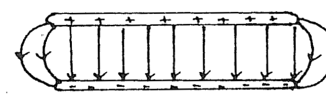
$\vec{F} = 5.09\times10^{-14}$ N in the direction of the resultant field.

11. The strength of the field is shown by the number of field lines in an area. more field lines $\Rightarrow$ stronger field.

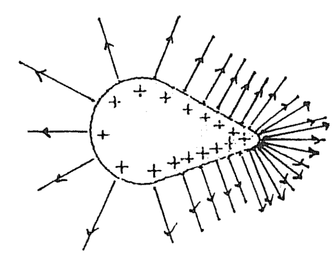
The direction of the field is shown by the arrows on the lines.

12.

(1)



(2)



(3) See text.

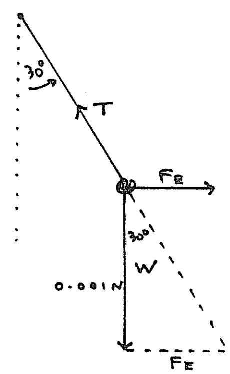
B (1) See text

(2) See text.

14. (1) towards the left.

(2) Field lines radiate from positive to negative.
$\therefore$ if the small charge is attracted to the right it must be negative.

(3)



(4) From the vector force diagram

$\tan 30° = F_E / 0.001$

$\therefore F_E = 0.001 \tan 30°$

$\therefore F_E = 0.006\ N$

(5) $\vec{F} = \vec{E}q$

$\therefore 0.006 = \vec{E} \times 3.0\times10^{-6}$

$\therefore \vec{E} = \dfrac{0.006}{3.0\times10^{-6}}$

$\vec{E} = 2\times10^{3}\ NC^{-1}$.

1. (1) See text

(2) $w.d = F \times \text{distance}$
$= \vec{E}q.d$
$= 2500 \times 2\times10^{-3} \times 0.1$
$= 0.5\ J.$

2. (1) $w.d = \Delta Vq$
$= 800 \times 1.6\times10^{-19}$
$= 1.28\times10^{-16}\ J.$

(2) $K = 1.28\times10^{-16}\ J$

(3) No. $E_k = \Delta Vq$ which is independent of mass

3. (1) $\vec{E} = \dfrac{\Delta V}{d} = \dfrac{200}{0.05}$

$= 4000\ Vm^{-1}$ towards the negative plate.

(2) ΔV changes to 300V

(a) $\therefore \vec{E} \propto \Delta V$
$\therefore \vec{E}$ increases.

(b) $\vec{E} \propto 1/d$ $\therefore$ doubled d halve $\vec{E}$.

4. (1) $a = F/m = \dfrac{Eq}{m}$

$a = \dfrac{25000 \times 1.6\times10^{-19}}{9.11\times10^{-31}}$

$= 4.39\times10^{15}\ ms^{-2}$

(2) $V_t = V_0 + at$

$\therefore 3.0\times10^{6} = V_0 + 4.39\times10^{15} t$

$\therefore t = 6.8\times10^{-10}\ s.$

5. (1) $\vec{E} = \dfrac{\Delta V}{d} = \dfrac{400}{0.1}$

$= 4000\ Vm^{-1}.$

(2) $\vec{F} = \vec{E}q$

$\therefore F = 4000 \times 1.6\times10^{-19}$
$= 6.4\times10^{-16}\ N.$ to the negative plate.

(3) $a = F/m = \dfrac{6.4\times10^{-16}}{1.673\times10^{-27}}$

$a = 3.8\times10^{11}\ ms^{-2}$

(4) $S = V_0 t + \frac{1}{2}at^2$

$\therefore S = \frac{1}{2} \times 3.8\times10^{11} \times t^2$

$\therefore t = \sqrt{\dfrac{2s}{a}} = \sqrt{\dfrac{2\times0.1}{3.8\times10^{11}}}$

$t = 7.2\times10^{-7}\ s.$

(5) $V_t = V_0 + at = 0 + at$

$\therefore V_t = 3.8\times10^{11} \times 7.2\times10^{-7}$
$= 2.74\times10^{5}\ ms^{-1}$

6. See text

7. (1) $\vec{F} = \vec{E}q = 200 \times 1.6\times10^{-19}$

$F = 3.2\times10^{-17}\ N$ to the positive plate

(2) $\vec{E} = \dfrac{\Delta V}{d}$ $\therefore \Delta V = \vec{E}d.$

$\therefore \Delta V = 200 \times 0.02$
$= 4$ Volts.

(3) Initial $K = 2.0eV$. As the electron enters the field its kinetic energy converts to potential energy.
$PE = 2.0eV$ when $K = 0$.
K is 2.0eV when the electron stops. But electron across the plate gains 4.0eV
$\therefore$ electron stops half way across

(4.) electron will slow down, stop, and then accelerate back to the hole in the plate.

(5) $a = F/m = \frac{3.2\times10^{-17}}{9.11\times10^{-31}}$

$a = 0.35\times10^{14}\ ms^{-2}$

Use $V_f^2 = V_0^2 + 2as$ to find 's':

$0 = 7\times10^{11} + 2\times(.35\times10^{14})s$

$\therefore s = 0.01\ m = 1\ cm$

(which of course, coincides with the answer in (3))

8. $E_n = \Delta Vq$

$= 10{,}000 \times 3.2\times10^{-19}$

$= 3.2\times10^{-15}\ J$

$\equiv 20{,}000\ eV$

9. A. — electrons are negative ∴ are attracted to the upper plate.

∴ parabolic path curving upwards.

10. (1) $E = \frac{\Delta V}{d} = \frac{400}{0.05}$

$\vec{E} = 8000\ Vm^{-1} \downarrow$

(2) $F = Eq = 8000\times1.6\times10^{-19}$

$= 1.28\times10^{-15}\ N$ to the positive plate.

(3) $a = \frac{F}{m} = \frac{1.28\times10^{-15}}{9.11\times10^{-31}}$

$a = 1.4\times10^{15}\ ms^{-2}$

(4) No force in the horizontal direction ∴ no acceleration ∴ no change of velocity.

(5) $time = \frac{0.20}{9.00\times10^{7}} = 2.2\times10^{-9}\ s.$

(6) $s = V_0t + \frac{1}{2}at^2$

$\therefore s = \frac{1}{2}at^2$

$= \frac{1}{2}\times 1.4\times10^{15}\times(2.2\times10^{-9})^2$

$\therefore s = 3.4\ mm$

11. (1) $E_n = \Delta Vq$

$E_n = 60{,}000\times1.6\times10^{-19}$

$= 9.6\times10^{-15}\ J.$

(2) Total $= 50\times9.6\times10^{-15}\ J$

$= 4.8\times10^{-13}\ J.$

(3) (a) $E_n \to K = \frac{1}{2}mv^2$

$\therefore 9.6\times10^{-15} = \frac{1}{2}\times1.673\times10^{-27}\ v^2$

$\therefore v = 3.39\times10^{6}\ ms^{-1}$

(b) E_n (4 traverses)

$= 38.4\times10^{-15}\ J$

$\therefore 38.4\times10^{14} = \frac{1}{2}\times1.673\times10^{-27}\ V^2$

$V = 6.77\times10^{6}\ ms^{-1}$

(4) If not evacuated protons will collide with air molecules — losing energy & ∴ slowing down ∴ changing the radius of curvature etc.

12. (1) $Wd = \Delta K$

$= 2.2\times10^{-17}\ J.$

(2) $K = \frac{2.2\times10^{-17}}{1.6\times10^{-19}} = 137.5\ eV$

13. $K = \frac{1}{2}mv^2$

$\therefore 6.1\times1.6\times10^{-19} = \frac{1}{2}\times9.11\times10^{-31}\ v^2$

$\therefore V = 1.46\times10^{6}\ ms^{-1}$

14. (1) A — negative

B — positive

(2) B has the larger mass.

The displacement vertical is given by $s = \frac{1}{2}at^2$. Now this is smaller for B. Because the time of flight in the plates is the same for A & B the acceleration (a) for B is less.

But each experiences the same force ($F = Eq$) ∴ m has the bigger mass ($F = ma$)

(3) Same time for each. No force in the horizontal direction for each particle ∴ both move at constant speed horizontally ∴ t is the same.

(4) Same force: ($F = Eq$) & q is the same for both.

(5) A — see (2)