22.
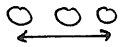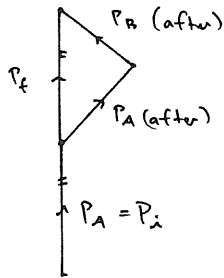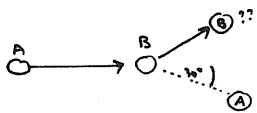

Take the velocity vectors as the distance between 3 images (as above)

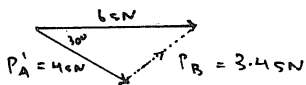By measurement $\vec{P_i} = \vec{P_f}$
∴ The law holds.

23.

$P_i = P_A = 2.0 \times 3.0 = 6.5N \rightarrow$
∴ $P_f = 6.0$ s $N \rightarrow$

$P_B = 3.45N = mV$
∴ $3.4 = 3.0 \times V$
∴ $V = \frac{3.4}{3.0}$
$V = 1.13$ ms^{-1}

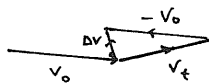**24.**

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

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

∴ $\vec{P_A} = 3m \times 2 = 6m$
$\vec{P_B} = m \times 2.3 = 2.3m$
∴ A has the biggest momentum

(3)

ie $\Delta V = V_t - V_0$

(4)

Before collision

P_i total $= 8m$
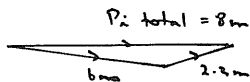
After collision
$P_A' = 3m \times 1.8 = 5.4m$
$P_B' = m \times 2.7 = 2.7m$

$P_f = 8m$
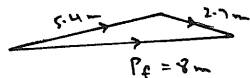
Momentum is conserved.

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

∴ $F = \frac{9 \times 10^9 \times 1.44 \times 10^{-6} \times 2.0 \times 10^{-6}}{(1.2)^2}$

$F = 0.018N$ attraction.

(2) (a) $F \propto \frac{1}{d^2}$
∴ double distance, ¼ the force.
$F_{new} = 0.0045N$

(b) $0.30m$ is ¼ distance
∴ F is 16 times the size
$F = 16 \times 0.018$
$= 0.288 N$

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

$F = \frac{9 \times 10^9 \times 1.6 \times 10^{-19} \times 1.6 \times 10^{-19}}{(5.32 \times 10^{-11})^2}$

$F = 8 \times 10^{-8}$ Newtons.

(2) The attraction force is a centripetal force.
∴ $F = \frac{mv^2}{r}$

∴ $8 \times 10^{-8} = \frac{9.11 \times 10^{-31} \times v^2}{5.32 \times 10^{-11}}$

∴ $v = \sqrt{\frac{8 \times 10^{-8} \times 5.32 \times 10^{-11}}{9.11 \times 10^{-31}}}$

$v = 2.2 \times 10^6$ ms^{-1}.

3. (1) $F \propto \frac{1}{d^2}$
∴ double distance, ¼ the force.
∴ $F_{new} = \frac{6.0 \times 10^{-7}}{4}$
$= 1.5 \times 10^{-7} N$

(2) $3.6 \times 10^{-6} N$ is 6 times the force.
∴ $\frac{F_1}{F_2} = \frac{d_2^2}{d_1^2}$
∴ $\frac{F_1}{6F_1} = \frac{d_2^2}{d_1^2}$
∴ $d_1^2 = 6 d_2^2$
∴ $d_1 = \sqrt{6} d_2$
∴ new distance $= \frac{10}{\sqrt{6}}$
$= 4.1 cm$

(3) $F \propto q_1 q_2$
∴ double one charge will double the force
∴ $F_2 = 1.2 \times 10^{-6} N$

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

$1.0 \times 10^{-6} = \frac{9 \times 10^9 \times 2.0 \times 10^{-6} \times 6.0 \times 10^{-6}}{d^2}$

∴ $d = \sqrt{\frac{9 \times 10^9 \times 2 \times 10^{-6} \times 6 \times 10^{-6}}{1.0 \times 10^{-6}}}$
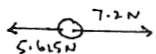
$d = 328 m$.

5. Force between A & C
$F = \frac{1}{4\pi\varepsilon_0} \frac{q_1 q_2}{d^2}$

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

$F = 7.2 N$ repulsion.

Column 1

Force between B & C

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

$F = 5.625 \text{ N repulsion}$
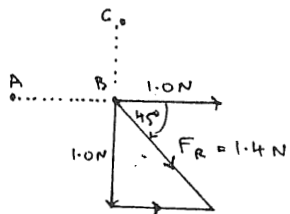
∴ resultant force on C

5.625N   7.2N

∴ $F_R = 1.575 \text{ N towards B.}$

6. Force between A & B

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

$$= \frac{9 \times 10^9 \times (2.10 \times 10^{-6})^2}{(2)^2}$$
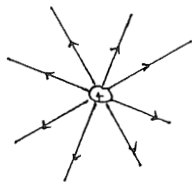
$= 1.0 \text{ Newton repulsion}$

Force between B & C
$= 1.0 \text{ N repulsion.}$

∴ Resultant force on B

C

A   B   1.0N

45°

1.0N $F_R = 1.4 \text{ N}$

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

7(1)

$$\vec{E_3} = \frac{1}{4\pi\varepsilon_0} \frac{q_1}{d^2} = \frac{9 \times 10^9 \times 0.5}{(3)^2}$$

$\vec{E_1} = 5.0 \times 10^{10} \text{ Nc}^{-1} \text{ outwards}$

Column 2

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

∴ $E_2 = 5.5 \times 10^9 \text{ Nc}^{-1} \rightarrow$

(3) 10 cm is $\frac{1}{3}$ distance
∴ $\vec{E_3}$ is 9 times E_1

$E_3 = 4.5 \times 10^{11} \text{ Nc}^{-1} \text{ outwards.}$

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

$$\vec{E_1} = \frac{9 \times 10^9 \times 1.1 \times 10^{-8}}{(0.2)^2}$$

$\vec{E_1} = 2475 \text{ Nc}^{-1} \text{ outwards.}$
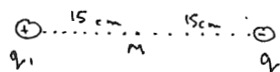
(2) $\vec{F} = \vec{E} q$

∴ $F = 2475 \times 1.6 \times 10^{-19}$

$F = 3.96 \times 10^{-16} \text{ N}$
      attraction.

(3) $F = 3.96 \times 10^{-16} \text{ N}$
      repulsion.

9. (1)

15 cm   15 cm
① .... ⊙
q_1 M q_2
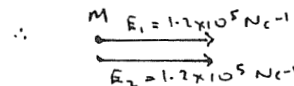
Electric field strength at M
due to q_1

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

$$= \frac{9 \times 10^9 \times 3.0 \times 10^{-7}}{(.15)^2}$$

$E_1 = 1.2 \times 10^5 \text{ Nc}^{-1} \rightarrow$

Electric field strength at M
due to q_2

$E_2 = 1.2 \times 10^5 \text{ Nc}^{-1} \rightarrow$

Column 3

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

∴   M $E_1 = 1.2 \times 10^5 \text{ Nc}^{-1}$
→
$E_2 = 1.2 \times 10^5 \text{ Nc}^{-1}$

∴ $\vec{E}$ resultant $= 2.4 \times 10^5 \text{ Nc}^{-1}$
towards q_2

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

∴ $F = 2.4 \times 10^5 \times 3.2 \times 10^{-19}$

$F = 7.68 \times 10^{-14} \text{ N towards}$
      q_2

10. (1)
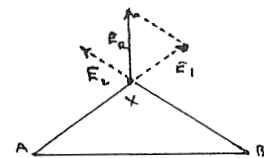Magnitude of The
electric field at X due to A
$$\vec{E_1} = \frac{1}{4\pi\varepsilon_0} \frac{q_1}{d^2} = \frac{9 \times 10^9 \times 2 \times 10^{-6}}{(.283)^2}$$

$\vec{E_1} = 2.25 \times 10^5 \text{ Nc}^{-1}$

Similarly E_2 due to B at X
is $E_2 = 2.25 \times 10^5 \text{ Nc}^{-1}$

Vector addition gives The
resultant field at X.

Scale: 1cm ≡ $1 \times 10^5 \text{ Nc}^{-1}$

$\vec{E_R}$ (by scale diagram)
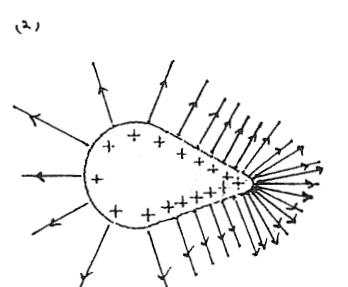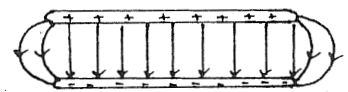$= 3.18 \times 10^5 \text{ Nc}^{-1}$
perpendicular to the line between
A & B.

Column 4

(2) $F = E q$
$= 3.18 \times 10^5 \times 1.6 \times 10^{-19}$
$\vec{F} = 5.09 \times 10^{-14} \text{ N}$ in The
direction of The resultant
field.

11. The strength of the field
is shown by The number of
field lines ⊥ on area.
more field lines ⟹ stronger
field.
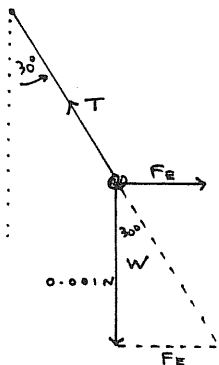The direction of the field
is shown by The arrows
on The lines.

12.
(1)

(2)

(3)   See text.

13.(1)   See text
(2)   See text.

14. (1) towards the left.

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

(3)

(4) From the vector force diagram

$\tan 30° = \dfrac{F_E}{0.001}$

∴ $F_E = 0.001 \tan 30°$

∴ $F_E = 0.006\,N$

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

∴ $0.006 = \vec{E} \times 3.0 \times 10^{-6}$

∴ $\vec{E} = \dfrac{0.006}{3.0 \times 10^{-6}}$

$\vec{E} = 2 \times 10^3\,Nc^{-1}.$

---

1. (1) See text

(2) $w \cdot d = F \times distance$
   $= \vec{E}q \cdot d$
   $= 2500 \times 2 \times 10^{-3} \times 0.1$
   $= 0.5\,J.$

2. (1) $w \cdot d = \Delta V q$
   $= 800 \times 1.6 \times 10^{-19}$
   $= 1.28 \times 10^{-16}\,J.$

(2) $K = 1.28 \times 10^{-16}\,J$

(3) No. $E_n = \Delta V q$ 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) ∴ $\vec{E} \propto \Delta V$
   ∴ $\vec{E}$ increases.

(b) $\vec{E} \propto \dfrac{1}{d}$ ∴ doubled d halve $\vec{E}$.

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

$a = \dfrac{25000 \times 1.6 \times 10^{-19}}{9.11 \times 10^{-31}}$

$= 4.39 \times 10^{15}\,ms^{-2}$

(2) $V_f = V_0 + at$
   ∴ $3.0 \times 10^6 = V_0 + 4.39 \times 10^{15} t$
   ∴ $t = 6.8 \times 10^{-10}\,s.$

5. (1) $\vec{E} = \dfrac{\Delta V}{d} = \dfrac{400}{0.1}$
   $= 4000\,Vm^{-1}.$

---

(2) $\vec{F} = \vec{E}q$
   ∴ $F = 4000 \times 1.6 \times 10^{-19}$
   $= 6.4 \times 10^{-16}\,N.$ to the negative plate.

(3) $a = \dfrac{F}{m} = \dfrac{6.4 \times 10^{-16}}{1.673 \times 10^{-27}}$
   $a = 3.8 \times 10^{11}\,ms^{-2}$

(4) $S = V_0 t + \frac{1}{2}at^2$
   ∴ $S = \frac{1}{2} \times 3.8 \times 10^{11} \times t^2$
   ∴ $t = \sqrt{\dfrac{2S}{a}} = \sqrt{\dfrac{2 \times 0.1}{3.8 \times 10^{11}}}$
   $t = 7.2 \times 10^{-7}\,s.$

(5) $V_f = V_0 + at = 0 + at$
   ∴ $V_f = 3.8 \times 10^{11} \times 7.2 \times 10^{-7}$
   $= 2.74 \times 10^5\,ms^{-1}$

6. See text

7. (1) $\vec{F} = \vec{E}q = 200 \times 1.6 \times 10^{-19}$
   $F = 3.2 \times 10^{-17}\,N$ to the positive plate

(2) $\vec{E} = \dfrac{\Delta V}{d}$ ∴ $\Delta V = \vec{E}d.$
   ∴ $\Delta V = 200 \times 0.02$
   $= 4\,Volts.$

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