1. Nov/2021/Paper_22/No.2

A charged oil drop is in a vacuum between two horizontal metal plates. A uniform electric field is produced between the plates by applying a potential difference of 1340 V across them, as shown in Fig. 2.1.

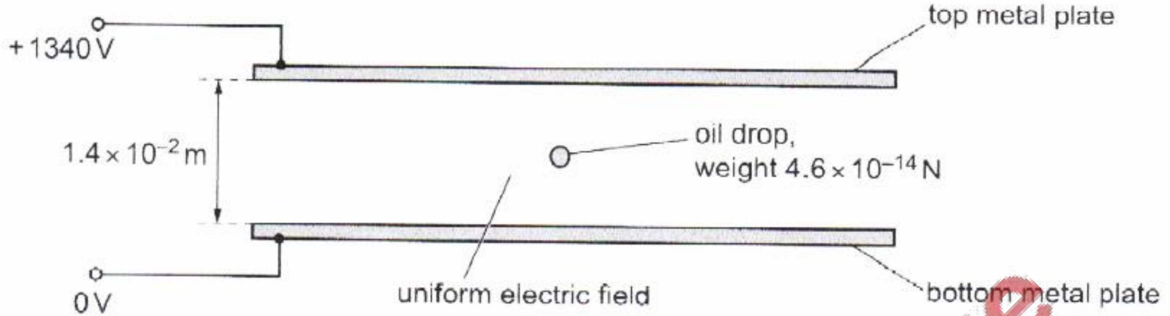


Fig. 2.1

The separation of the plates is 1.4×10^{-2} m.

The oil drop of weight 4.6×10^{-14} N remains stationary at a point mid-way between the plates.

(a) **(i)** Calculate the magnitude of the electric field strength.

$E = \frac{V}{d}$ or $E = \frac{F}{q}$

$= \frac{1340\,V}{1.4 \times 10^{-2}\,m}$

$= 95714\ NC^{-1}$

$E = 9.6 \times 10^{4}\ NC^{-1}$

unit of E can be NC^{-1} or Vm^{-1}

electric field strength = 9.6×10^{4} N C^{-1} [2]

(ii) Determine the magnitude and the sign of the charge on the oil drop.

$E = \frac{F}{q}$

$q = \frac{F}{E}$

F = weight of oil drop

$= 4.6 \times 10^{-14}$ N

$q = \frac{4.6 \times 10^{-14} \cancel{N}}{9.6 \times 10^{4} \cancel{N} C^{-1}}$

$= 4.79 \times 10^{-19}$ C.

$\approx 4.8 \times 10^{-19}$ C

magnitude of charge = 4.8×10^{-19} C

sign of charge negative (-ve).

oil drop is stationary, meaning its been attracted by the top metal plate which is positive. So charge can only be (-ve). [3]

(b) The electric potentials of the plates are instantaneously reversed so that the top plate is at a potential of 0 V and the bottom plate is at a potential of +1340 V. This change causes the oil drop to start moving downwards.

(i) Compare the new pattern of the electric field lines between the plates with the original pattern.

- Field is still uniform but direction of field is upwards (from +ve to -ve) [2]

(ii) Determine the magnitude of the resultant force acting on the oil drop. ↙R.F

$R.F = \text{Weight} + (F = Eq)$

$F = 4.8\times10^{-19} \times 9.6\times10^{4}$

$F = 4.608\times10^{-14}\,N$

$\text{Weight} = 4.6\times10^{-14}\,N$

$\therefore F = \text{weight} + F$

$= 4.6\times10^{-14} + 4.608\times10^{-14}$

$= 9.208\times10^{-14}\,N$

resultant force = ...9.2×10^{-14}........ N [1]

(iii) Show that the magnitude of the acceleration of the oil drop is $20\,m\,s^{-2}$.

$a = \frac{F}{m}$

$m = \frac{W}{g}$

$m = \frac{4.6\times10^{-14}\,N}{9.81}$

$= 4.69\times10^{-15}\,kg$

$\therefore a = \frac{9.2\times10^{-14}\,N}{4.69\times10^{-15}\,kg}$

$= 19.62\,ms^{-2}$

$a = 20\,ms^{-2}.$

[2]

(iv) Assume that the radius of the oil drop is negligible.

Use the information in **(b)(iii)** to calculate the time taken for the oil drop to move to the bottom metal plate from its initial position mid-way between the plates.

$S = ut + \frac{1}{2}at^2$

but $ut = 0$, since $u = 0$

$\frac{1}{2}gt^2 = S$

$t^2 = \frac{2S}{a}$

but $S = \frac{1.4\times10^{-2}}{2} = 0.7\times10^{-2}\,m$

$t^2 = \frac{2\times0.7\times10^{-2}}{19.62}$

$t = \sqrt{7.14\times10^{-4}}$

$= 2.67\times10^{-2}\,s$

time = ...2.67×10^{-2}........ s [2]

(c) The oil drop in **(b)** starts to move at time $t = 0$. The distance of the oil drop from the bottom plate is x.

On Fig. 2.2, sketch the variation with time t of distance x for the movement of the drop from its initial position until it hits the surface of the bottom plate. Numerical values of t are not required.

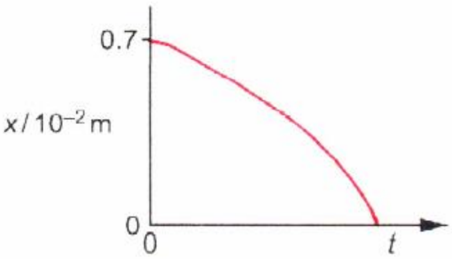


Fig. 2.2

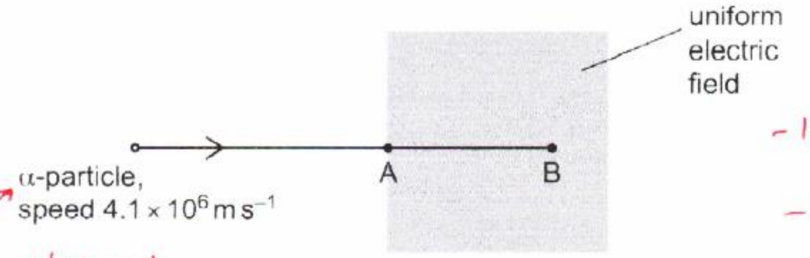
- Starts from $0.7\times10^{-2}\,m$ which is mid-way $\frac{1.4\times10^{-2}}{2} = 0.7\times10^{-2}\,m.$
- It accelerates from rest to an acceleration of $19.62\,ms^{-2}$
- So gradient will be increasing hence a curve.

[2]

[Total: 14]

2. Nov/2021/Paper_23/No.4

An α-particle moves in a straight line through a vacuum with a constant speed of $4.1 \times 10^6\,\mathrm{m\,s^{-1}}$.
The α-particle enters a uniform electric field at point A, as shown in Fig. 4.1.



+vely charged

– like charges repel
– Unlike charges attract.

↑ direction of field.

Fig. 4.1

The α-particle continues to move in the same straight line until it is brought to rest at point B by the electric field. The deceleration of the α-particle by the electric field is $2.7 \times 10^{14}\,\mathrm{m\,s^{-2}}$.

(a) State the direction of the electric field.

field is from right to left side .... [1]

(b) Calculate the distance AB.

$u = 4.1 \times 10^6\,\mathrm{m\,s^{-1}}$
$v = 0$
$a = 2.7 \times 10^{14}\,\mathrm{m\,s^{-2}}$
$s = ?$
$v^2 = u^2 + 2as$
but $v = 0$
$0 = u^2 + 2as$

for deceleration
$a = -2.7 \times 10^{14}\,\mathrm{m\,s^{-2}}$
$0 = 4.1 \times 10^6 - 2as$
$2as = u^2$
$s = \frac{u^2}{2a}$

$s = \frac{(4.1 \times 10^6)^2}{2 \times 2.7 \times 10^{14}}$
$= 0.03113$
$\simeq 0.031\,\mathrm{m}$
$\simeq 3.1\,\mathrm{cm}$

distance = ... 0.031 .... m [2]

(c) Calculate the electric field strength.

$E = \frac{F}{Q}$
$= \frac{ma}{Q}$ ← deceleration

charge on α-particle
$= +2 \times 1.6 \times 10^{-19}$.

mass of α-particle
$= (4 \times 1.66 \times 10^{-27})\,\mathrm{kg}$

$E = \frac{4 \times 1.66 \times 10^{-27} \times 2.7 \times 10^{14}}{2 \times 1.6 \times 10^{-19}}$
$= 5.6 \times 10^6\,\mathrm{N\,C^{-1}}$ or $\mathrm{V\,m^{-1}}$

Remember
α-particle is
$^{4}_{2}He^{2+}$ nucleus.
– 2 protons
– 2 neutrons.

electric field strength = ... 5.6×10^6 .... $\mathrm{V\,m^{-1}}$ [3]

(d) The α-particle is at point A at time $t = 0$.

On Fig. 4.2, sketch the variation with time t of the momentum of the α-particle as it travels from point A to point B. Numerical values are not required.

– α-particle is slowing down.

$p = mv$

when $v = 0$

then $p = 0$.

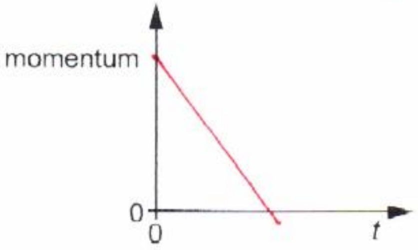


Fig. 4.2

$\frac{\Delta p}{t}$ = force.

[1]

(e) State the name of the quantity that is represented by the gradient of the graph in **(d)**.

force on the α- particle .... [1]

(f) A β^- particle now enters the electric field along the same initial path as the α-particle and with the same initial speed of $4.1 \times 10^6\,\mathrm{m\,s^{-1}}$.

(i) Calculate the kinetic energy, in J, of the β^- particle at point A.

$m_e = 9.11 \times 10^{-31}$ kg.

$v = 4.1 \times 10^6\,\mathrm{ms^{-1}}$

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

$= \frac{1}{2} \times 9.11 \times 10^{-31} \times (4.1 \times 10^6)^2$

$= 7.7 \times 10^{-18}$ J

kinetic energy = 7.7×10^{-18} .... J [3]

(ii) State and explain the differences between the electric force on the β^- particle in the electric field and the electric force on the α-particle in the electric field.

– Force on α and β will be opposite direction

– This is because the charge on the particle is opposite ($\alpha \to$ +ve, $\beta \to$ -ve).

– $\alpha \to +2$, $\beta \to -1$, so force on β will be half of force on α since field strength is same but β charge is half of α.

[3]

(iii) The β^- particle is produced by the decay of a nucleus. State the name of another lepton that is produced at the same time as the β^- particle.

electron antineutrino .... [1]

${}^1_0n \rightarrow {}^1_1p + {}^0_{-1}\beta^- + {}^0_0\bar{\nu}$

electron antineutrino

neutron changes to proton.

[Total: 15]