Fuzail

A capacitor C is charged using a supply of e.m.f. 8.0V. It is then discharged through a resistor R.
The circuit is shown in Fig. 5.1.

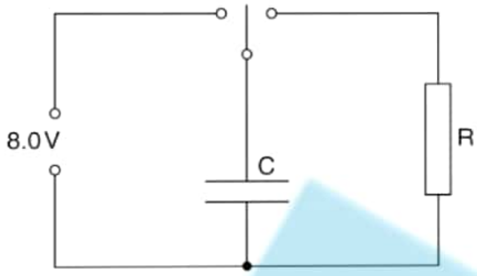


Fig. 5.1

The variation with time t of the potential difference V across the resistor R during the discharge of the capacitor is shown in Fig. 5.2.

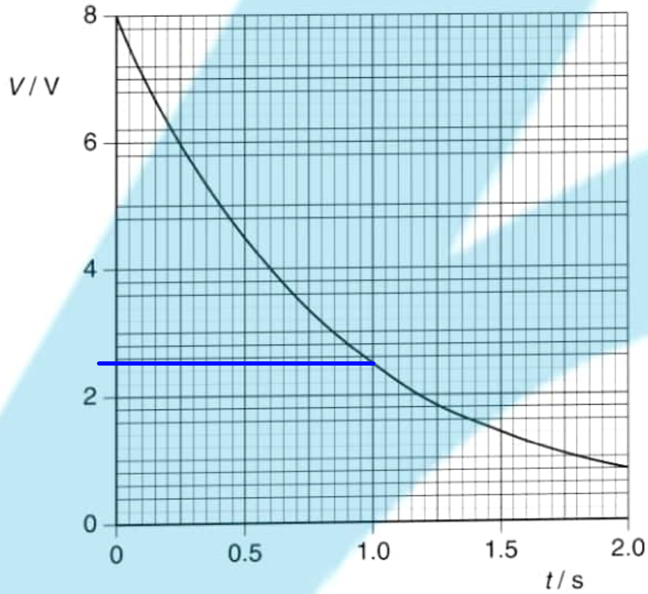


Fig. 5.2

(a) During the first 1.0s of the discharge of the capacitor, 0.13J of energy is transferred to the resistor R.
Show that the capacitance of the capacitor C is 4500 μF.

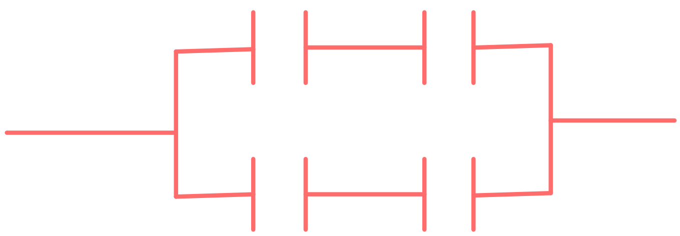
$E = \frac{1}{2}CV^2$

$C = \frac{E}{0.5V^2} \quad \frac{0.13}{0.5(8^2 - 2.5^2)} \approx 4500\,\mu F$

[3]

(b) Some capacitors, each of capacitance 4500 μF with a maximum working voltage of 6V, are available.

Draw an arrangement of these capacitors that could provide a total capacitance of 4500 μF for use in the circuit of Fig. 5.1.



[2]

(a) Define *electric field strength.*

electric force per unit positive charge.

.... [1]

(b) An isolated metal sphere is to be used to store charge at high potential. The charge stored may be assumed to be a point charge at the centre of the sphere. The sphere has a radius of 25 cm. Electrical breakdown (a spark) occurs in the air surrounding the sphere when the electric field strength at the surface of the sphere exceeds $1.8 \times 10^4\,\mathrm{V\,cm^{-1}}$.

(i) Show that the maximum charge that can be stored on the sphere is $12.5\,\mu\mathrm{C}$.

$1.8\times10^4 = \frac{kQ}{.25^2}$

$Q = \frac{1.8\times10^4 \times 0.25^2}{k}$

$= 12.5\,\mu C$

[2]

(ii) Calculate the potential of the sphere for this maximum charge.

$V = \frac{kQ}{r} = \frac{9\times10^9 \times 1.25\times10^{-7}}{.25}$

$= 4500$

potential = 4500 V [2]

(a) On the axes of Fig. 2.1, sketch the variation with distance from a point mass of the gravitational field strength due to the mass.

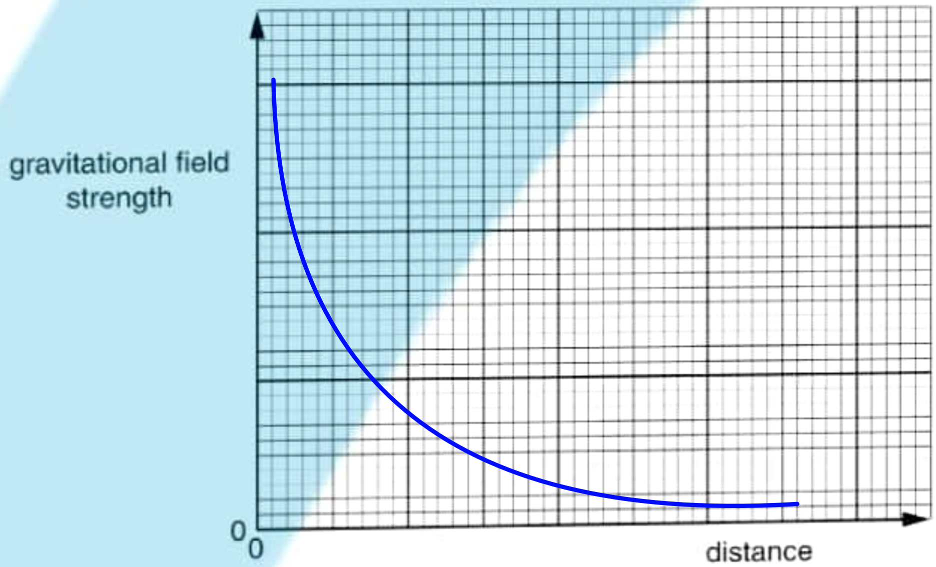
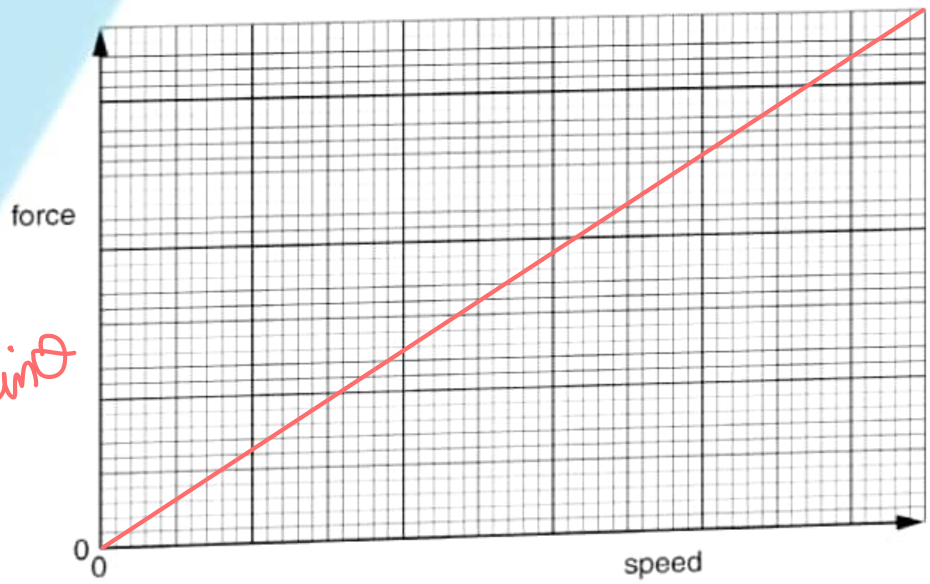


Fig. 2.1

[2]

(b) On the axes of Fig. 2.2, sketch the variation with speed of the magnitude of the force on a charged particle moving at right-angles to a uniform magnetic field.



$f = BqV\sin\theta$

$f \propto V$

Fig. 2.2

[2]

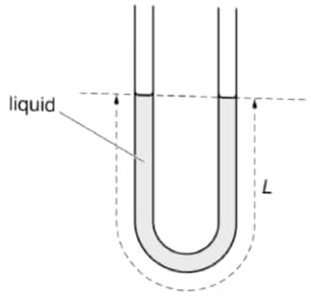


Fig. 3.1

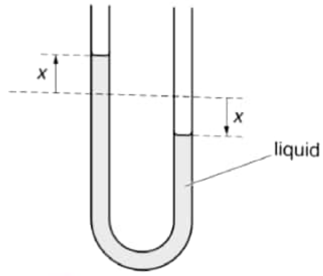


Fig. 3.2

The total length of the column of liquid in the tube is L.

The column of liquid is displaced so that the change in height of the liquid in each arm of the U-tube is x, as shown in Fig. 3.2.

The liquid in the U-tube then oscillates with simple harmonic motion such that the acceleration a of the column is given by the expression

$$a = -\left(\frac{2g}{L}\right)x$$

where g is the acceleration of free fall.

(a) Calculate the period T of oscillation of the liquid column for a column length L of 19.0 cm.

$a = \omega^2 x$

$\omega^2 = \frac{2g}{L}$

$\frac{4\pi^2}{T^2} = \frac{2g}{L}$

$T = \sqrt{\frac{4\pi^2 L}{2g}} = \sqrt{\frac{4\pi^2 0.19}{2 \times 9.81}}$

$= 0.618$

$T =$ 0.62 s [3]

9

(b) The variation with time t of the displacement x is shown in Fig. 3.3.

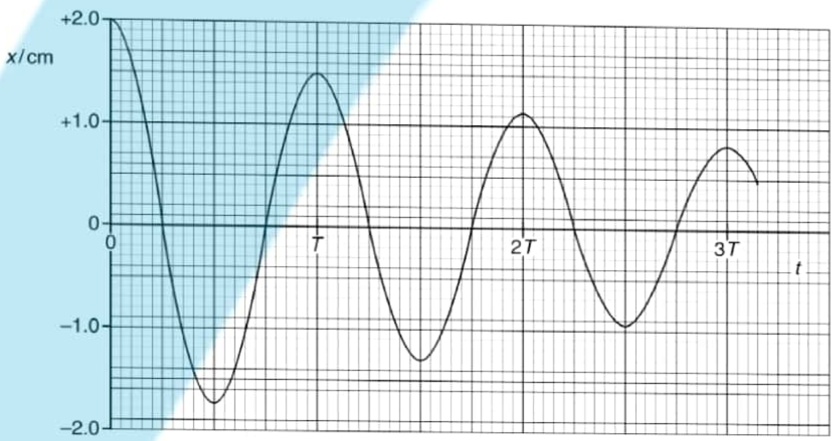


Fig. 3.3

The period of oscillation of the liquid column of mass 18.0 g is T.

The oscillations are damped.

(i) Suggest one cause of the damping.

friction against the walls of the tube

[1]

(ii) Calculate the loss in total energy of the oscillations during the first 2.5 periods of the oscillations.

Initial $\frac{1}{2} m \omega^2 x_0^2$ $\quad \omega = \frac{2\pi}{T}$

$\frac{0.018 \times 4\pi^2 \times 0.02^2}{2T^2} = \frac{7.2 \times 10^{-6}\, 4\pi^2}{2T^2}$

Final $\frac{0.018 \times 4\pi^2 \times 0.009^2}{2T^2} = \frac{1.458 \times 10^{-6}\, 4\pi^2}{2T^2}$

$L - M = \frac{2.2668 \times 10^{-4}}{2(6.18)^2}$

$= 2.967 \times 10^{-6}$

energy loss = 2.9×10^{-6} J [3]

Negatively-charged particles are moving through a vacuum in a parallel beam. The particles have speed v.

The particles enter a region of uniform magnetic field of flux density 930 μT. Initially, the particles are travelling at right-angles to the magnetic field. The path of a single particle is shown in Fig. 7.1.

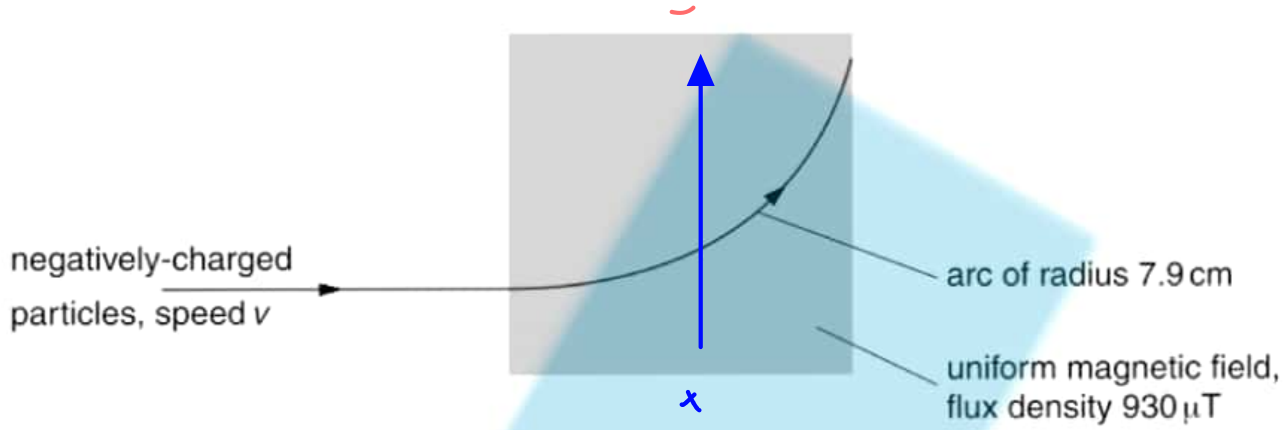


Fig. 7.1

The negatively-charged particles follow a curved path of radius 7.9 cm in the magnetic field.

A uniform electric field is then applied in the same region as the magnetic field. For an electric field strength of 12 kV m^{-1}, the particles are undeviated as they pass through the region of the fields.

(a) On Fig. 7.1, mark with an arrow the direction of the electric field. [1]

(b) Calculate, for the negatively-charged particles,

(i) the speed v,

$F_B = F_e$

$BqV = Eq$

$V = \frac{E\cancel{q}}{B\cancel{q}} = V = \frac{E}{B} = \frac{12 \times 10^3}{930 \times 10^{-6}} = 1.29 \times 10^7$

$v =$ ......1.29×10^7...... m s^{-1} [3]

(ii) the ratio $\frac{\text{charge}}{\text{mass}}$.

$\frac{\cancel{m}q}{m} = \frac{V}{B}$

$\frac{q}{m} = \frac{V}{BR}$

$= \frac{1.29 \times 10^7}{930 \times 10^{-6} \times 7.9}$

$\frac{q}{m} = 1.8 \times 10^{11}$

ratio = ...1.8×10^{11}...... C kg^{-1} [3]

A magnetic field of flux density B is normal to face PQRS of a slice of a conducting material, as shown in Fig. 9.1.

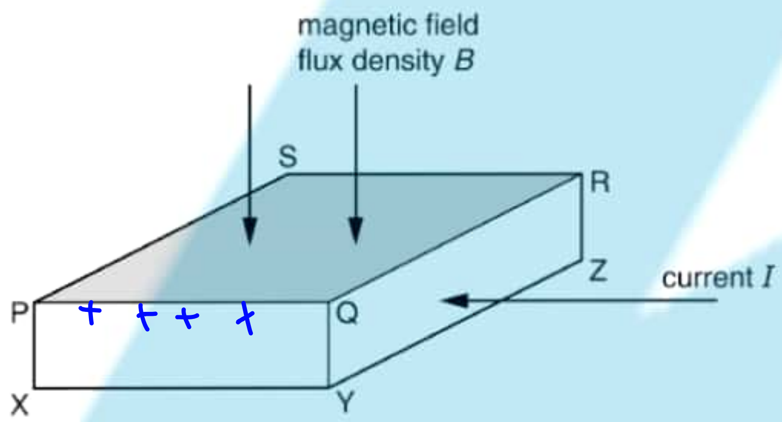


Fig. 9.1

A current I in the slice is normal to face QRZY of the slice.

The Hall voltage V_H across the slice is given by the expression

$$V_H = \frac{BI}{ntq}.$$

(a) **(i)** State what is represented by the symbol n.

number of charge carriers

.... [1]

(ii) The symbol t represents the length of one side of the slice. Use letters from Fig. 9.1 to identify t.

QY .... [1]

(b) **(i)** In general, the Hall voltage produced in a slice of a metal is very small. For a slice of the same dimensions with the same current and magnetic flux density, the Hall voltage produced in a semiconductor material is much larger. Suggest and explain why.

because there are less charge carriers

so value of n in $V_H = \frac{BI}{net}$ is smaller

$\therefore$ larger value of V_H. [2]

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