

Q1.

- 5 An α -particle and a β -particle are both travelling along the same path at a speed of $1.5 \times 10^6 \text{ m s}^{-1}$.

Use

They then enter a region of uniform magnetic field as shown in Fig. 5.1.

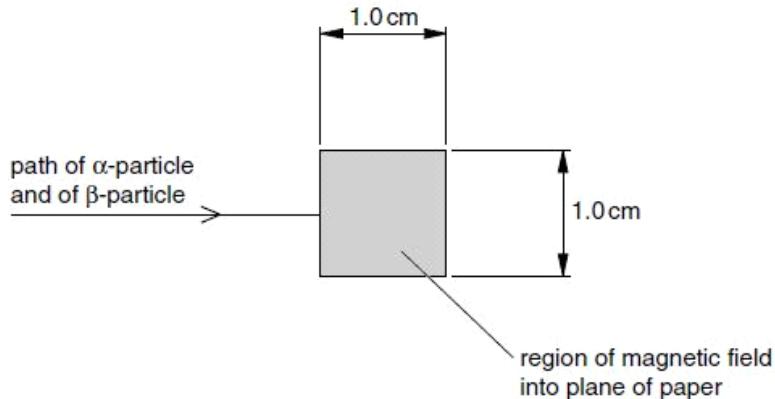


Fig. 5.1

The magnetic field is normal to the path of the particles and is into the plane of the paper.

- (a) Show that, for a particle of mass m and charge q travelling at speed v normal to a magnetic field of flux density B , the radius r of its path in the field is given by

$$r = \frac{mv}{Bq}.$$

(b) Calculate the ratio

$$\frac{\text{radius of path of the } \alpha\text{-particle}}{\text{radius of path of the } \beta\text{-particle}}$$

ratio = [3]

(c) The magnetic field has flux density 1.2 mT. Calculate the radius of the path of

(i) the α -particle,

radius = m

(ii) the β -particle.

radius = m
[3]

(d) The magnetic field extends over a region having a square cross-section of side 1.0 cm (see Fig. 5.1). Both particles emerge from the region of the field.

On Fig. 5.1,

- (i) mark with the letter A the position where the emergent α -particle may be detected,
(ii) mark with the letter B the position where the emergent β -particle may be detected.
[3]

Q2.

- 6 An ideal iron-cored transformer is illustrated in Fig. 6.1.

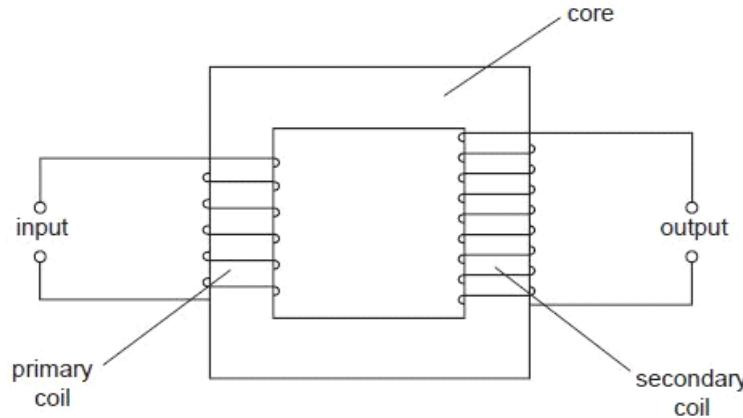


Fig. 6.1

(a) Explain why

- (i) the supply to the primary coil must be alternating current, not direct current,

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.....
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[2]

- (ii) for constant input power, the output current must decrease if the output voltage increases.

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.....
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[2]

- (b) Fig. 6.2 shows the variation with time t of the current I_p in the primary coil. There is no current in the secondary coil.

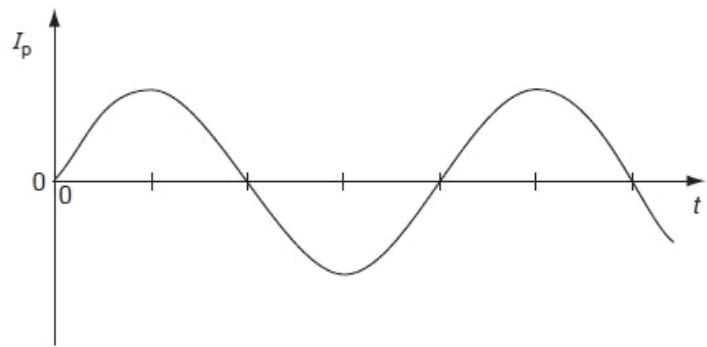


Fig. 6.2

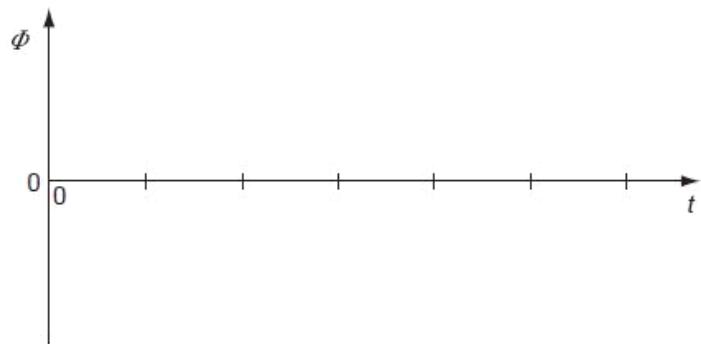


Fig. 6.3

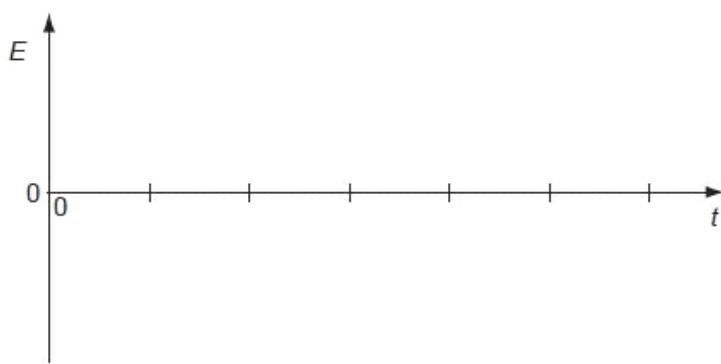


Fig. 6.4

- (i) Complete Fig. 6.3 to show the variation with time t of the magnetic flux Φ in the core. [1]
- (ii) Complete Fig. 6.4 to show the variation with time t of the e.m.f. E induced in the secondary coil. [2]
- (iii) Hence state the phase difference between the current I_p in the primary coil and the e.m.f. E induced in the secondary coil.

phase difference = [1]

Q3.

- 6 Two long, straight, current-carrying conductors, PQ and XY, are held a constant distance apart, as shown in Fig. 6.1.



Fig. 6.1

The conductors each carry the same magnitude current in the same direction.

A plan view from above the conductors is shown in Fig. 6.2.



Fig. 6.2

- (a) On Fig. 6.2 draw arrows, one in each case, to show the direction of
- (i) the magnetic field at Q due to the current in wire XY (label this arrow B), [1]
 - (ii) the force at Q as a result of the magnetic field due to the current in XY (label this arrow F). [1]

- (b) (i) State Newton's third law of motion.

.....
.....
.....

[1]

- (ii) Use this law and your answer in (a)(ii) to state the direction of the force on wire XY.

.....
.....

[1]

- (c) The magnetic flux density B at a distance d from a long straight wire carrying a current I is given by

$$B = 2.0 \times 10^{-7} \times \frac{I}{d}$$

Use this expression to explain why, under normal circumstances, wires carrying alternating current are not seen to vibrate. Make reasonable estimates of the magnitudes of the quantities involved.

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.....

[4]

Q4.

- 8 A proton is moving with constant velocity v . It enters a uniform magnetic field that is normal to the initial direction of motion of the proton, as shown in Fig. 8.1.

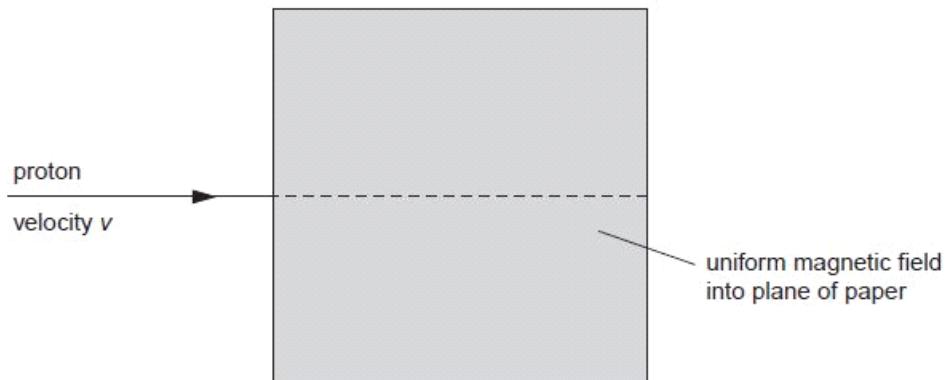


Fig. 8.1

A uniform electric field is applied in the same region as the magnetic field so that the proton passes undeviated through the fields.

- (a) On Fig. 8.1, draw an arrow labelled E to show the direction of the electric field. [1]
- (b) The proton is replaced by other particles. The electric and magnetic fields remain unchanged.

State and explain the deviation, if any, of the following particles in the region of the fields.

- (b) The proton is replaced by other particles. The electric and magnetic fields remain unchanged.

State and explain the deviation, if any, of the following particles in the region of the fields.

- (i) an α -particle with initial velocity v

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.....
.....
.....

[3]

- (ii) an electron with initial velocity $2v$

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.....
.....
.....

[3]

Q5.

- 6 A small rectangular coil ABCD contains 140 turns of wire. The sides AB and BC of the coil are of lengths 4.5 cm and 2.8 cm respectively, as shown in Fig. 6.1.

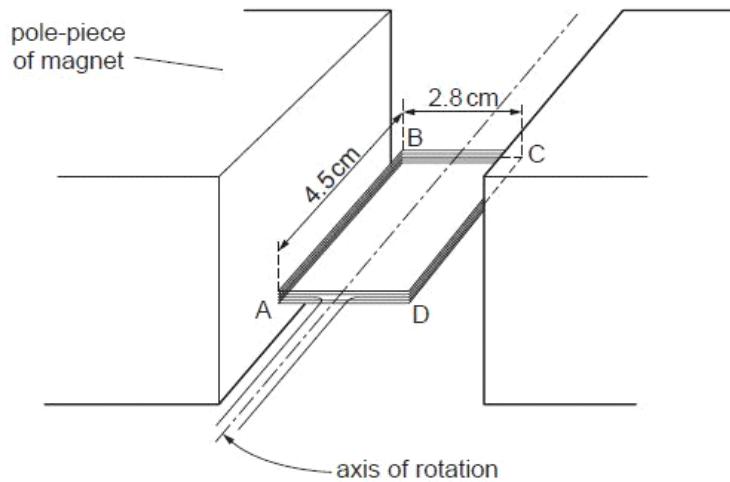


Fig. 6.1

The coil is held between the poles of a large magnet so that the coil can rotate about an axis through its centre.

The magnet produces a uniform magnetic field of flux density B between its poles. When the current in the coil is 170 mA, the maximum torque produced in the coil is 2.1×10^{-3} Nm.

- (a) For the coil in the position for maximum torque, state whether the plane of the coil is parallel to, or normal to, the direction of the magnetic field.

[1]

- (b) For the coil in the position shown in Fig. 6.1, calculate the magnitude of the force on

- (i) side AB of the coil,

force = N [2]

(ii) side BC of the coil.

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force = N [1]

- (c) Use your answer to (b)(i) to show that the magnetic flux density B between the poles of the magnet is 70 mT.

[2]

- (d) (i) State Faraday's law of electromagnetic induction.

.....
.....
..... [2]

- (ii) The current in the coil in (a) is switched off and the coil is positioned as shown in Fig. 6.1.
The coil is then turned through an angle of 90° in a time of 0.14 s.
Calculate the average e.m.f. induced in the coil.

e.m.f. = V [3]

Q6.

- 6 (a) Define the tesla.

Ex:

[3]

- (b) A large horseshoe magnet produces a uniform magnetic field of flux density B between its poles. Outside the region of the poles, the flux density is zero. The magnet is placed on a top-pan balance and a stiff wire XY is situated between its poles, as shown in Fig. 6.1.

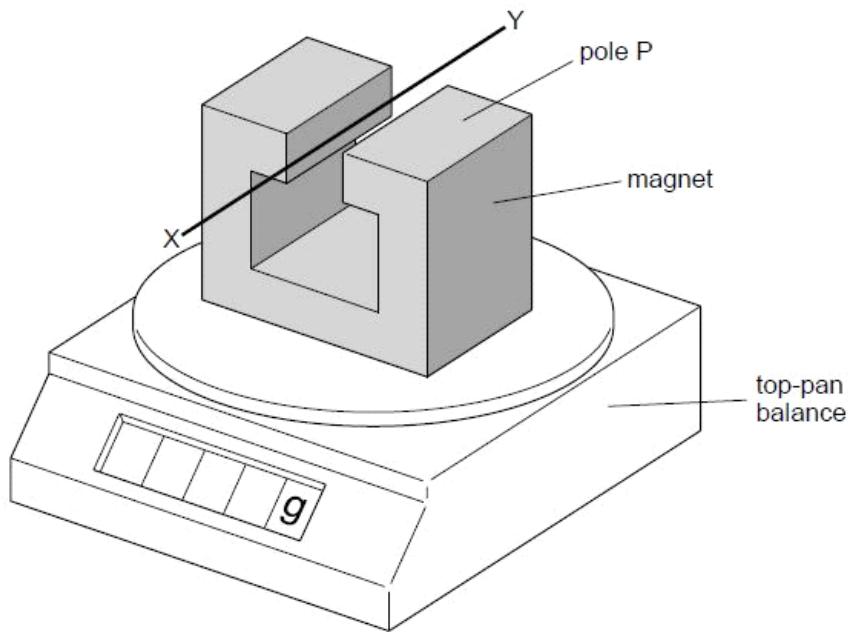


Fig. 6.1

The wire XY is horizontal and normal to the magnetic field. The length of wire between the poles is 4.4 cm.

A direct current of magnitude 2.6A is passed through the wire in the direction from X to Y.

The reading on the top-pan balance increases by 2.3g.

- (i) State and explain the polarity of the pole P of the magnet.

.....
.....
.....
.....

[3]

- (ii) Calculate the flux density between the poles.

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$$\text{flux density} = \dots \text{ T} [3]$$

- (c) The direct current in (b) is now replaced by a very low frequency sinusoidal current of r.m.s. value 2.6A.

Calculate the variation in the reading of the top-pan balance.

$$\text{variation in reading} = \dots \text{ g} [2]$$

Q7.

- 7 You are provided with a coil of wire, a bar magnet and a sensitive ammeter.

Outline an experiment to verify Lenz's law.

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[6]

Q8.

- 5 (a) A constant current is maintained in a long straight vertical wire. A Hall probe is positioned a distance r from the centre of the wire, as shown in Fig. 5.1.

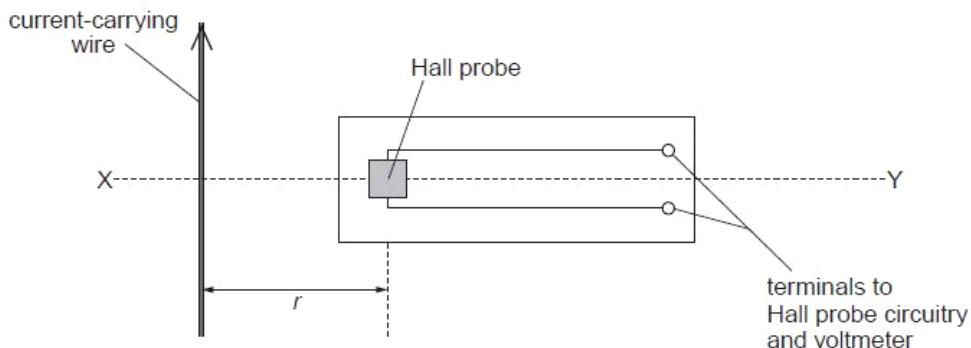


Fig. 5.1

- (i) Explain why, when the Hall probe is rotated about the horizontal axis XY, the Hall voltage varies between a maximum positive value and a maximum negative value.

.....
.....
.....

[2]

- (ii) The maximum Hall voltage V_H is measured at different distances r . Data for V_H and the corresponding values of r are shown in Fig. 5.2.

V_H / V	r / cm
0.290	1.0
0.190	1.5
0.140	2.0
0.097	3.0
0.073	4.0
0.060	5.0

Fig. 5.2

It is thought that V_H and r are related by an expression of the form

$$V_H = \frac{k}{r}$$

where k is a constant.

1. Without drawing a graph, use data from Fig. 5.2 to suggest whether the expression is valid.

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[2]

2. A graph showing the variation with $\frac{1}{r}$ of V_H is plotted.

State the features of the graph that suggest that the expression is valid.

.....
.....
.....

[1]

- (b) The Hall probe in (a) is now replaced with a small coil of wire connected to a sensitive voltmeter. The coil is arranged so that its plane is normal to the magnetic field of the wire.

- (i) State Faraday's law of electromagnetic induction and hence explain why the voltmeter indicates a zero reading.

.....
.....
.....

[3]

- (ii) State three different ways in which an e.m.f. may be induced in the coil.

1.

.....

2.

.....

3.

[3]

Q9.

- 7 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 $930 \mu\text{T}$. Initially, the particles are travelling at right-angles to the magnetic field. The path of a single particle is shown in Fig. 7.1.

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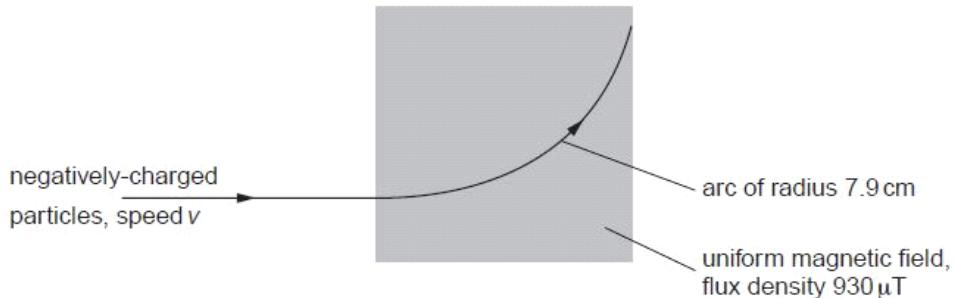


Fig. 7.1

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 ,

$$v = \dots \text{ m s}^{-1} [3]$$

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

$$\text{ratio} = \dots \text{ C kg}^{-1} [3]$$

Q10.

- 6 (a) A uniform magnetic field has constant flux density B . A straight wire of fixed length carries a current I at an angle θ to the magnetic field, as shown in Fig. 6.1.

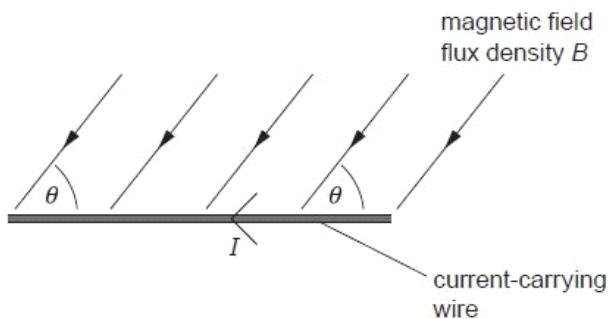


Fig. 6.1

- (i) The current I in the wire is changed, keeping the angle θ constant.
On Fig. 6.2, sketch a graph to show the variation with current I of the force F on the wire.

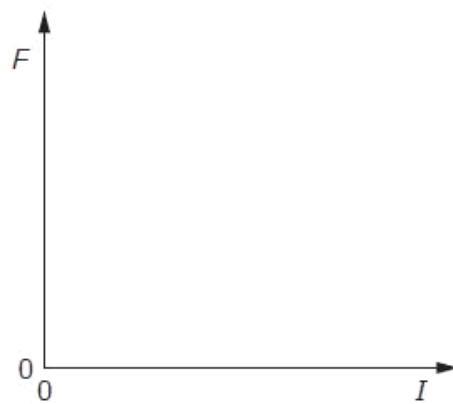


Fig. 6.2

[2]

- (ii) The angle θ between the wire and the magnetic field is now varied. The current I is kept constant.

On Fig. 6.3, sketch a graph to show the variation with angle θ of the force F on the wire.

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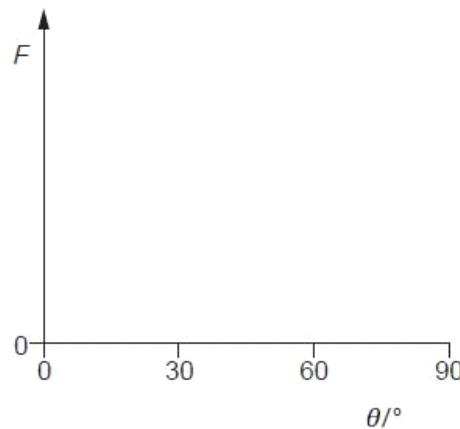


Fig. 6.3

[3]

- (b) A uniform magnetic field is directed at right-angles to the rectangular surface PQRS of a slice of a conducting material, as shown in Fig. 6.4.

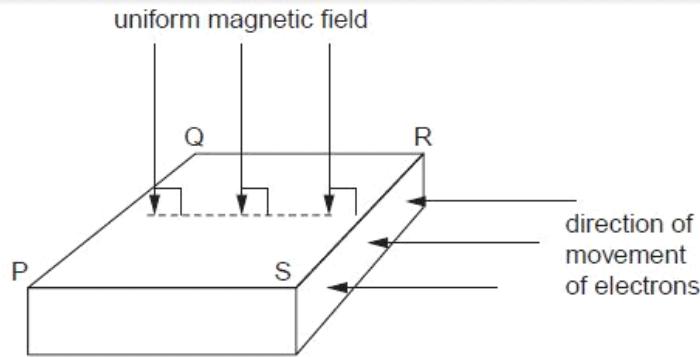


Fig. 6.4

Electrons, moving towards the side SR, enter the slice of conducting material. The electrons enter the slice at right-angles to side SR.

- (i) Explain why, initially, the electrons do not travel in straight lines across the slice from side SR to side PQ.

.....
.....
..... [2]

- (ii) Explain to which side, PS or QR, the electrons tend to move.

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.....
..... [2]

Q11.

- 5 (a) State what is meant by a *magnetic field*.

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- (b) A charged particle of mass m and charge $+q$ is travelling with velocity v in a vacuum. It enters a region of uniform magnetic field of flux density B , as shown in Fig. 5.1.

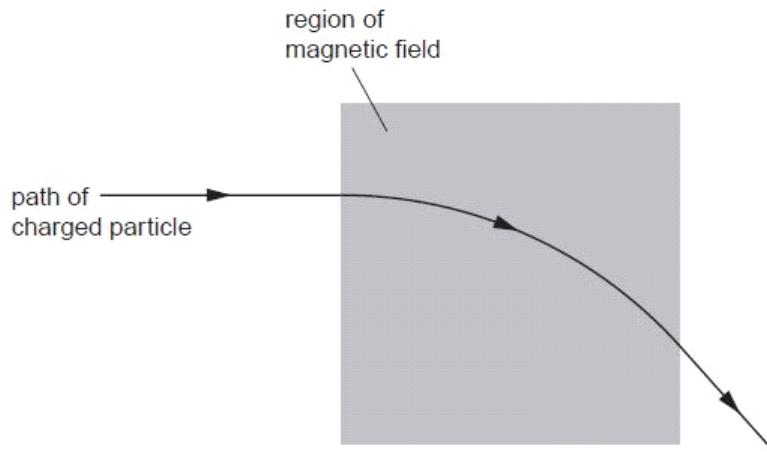


Fig. 5.1

The magnetic field is normal to the direction of motion of the particle. The path of the particle in the field is the arc of a circle of radius r .

- (i) Explain why the path of the particle in the field is the arc of a circle.

.....
.....
.....
.....

[2]

- (ii) Show that the radius r is given by the expression

$$r = \frac{mv}{Bq}.$$

[2]

- (c) A thin metal foil is placed in the magnetic field in (b).

A second charged particle enters the region of the magnetic field. It loses kinetic energy as it passes through the foil. The particle follows the path shown in Fig. 5.2. Ex

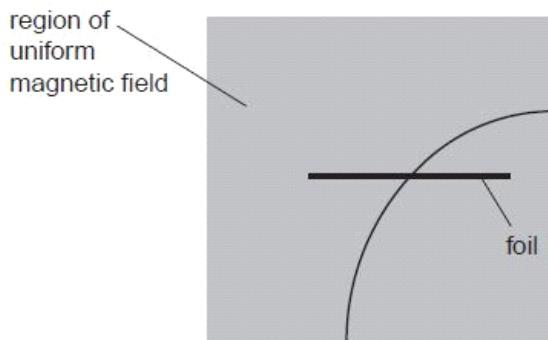


Fig. 5.2

- (i) On Fig. 5.2, mark with an arrow the direction of travel of the particle.

[1]

- (ii) The path of the particle has different radii on each side of the foil.
The radii are 7.4 cm and 5.7 cm.
Determine the ratio

$$\frac{\text{final momentum of particle}}{\text{initial momentum of particle}}$$

for the particle as it passes through the foil.

ratio = [2]

Q12.

- 5 A bar magnet is suspended vertically from the free end of a helical spring, as shown in Fig. 5.1.

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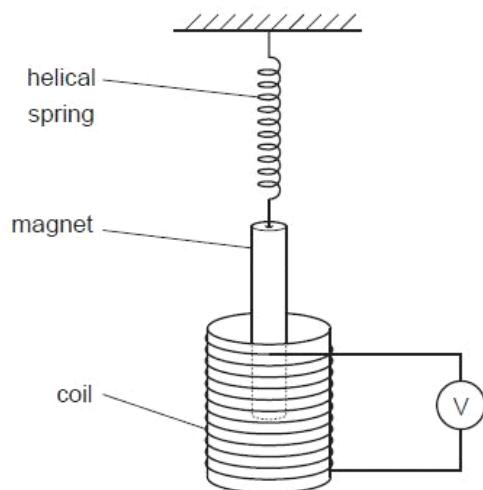


Fig. 5.1

One pole of the magnet is situated in a coil. The coil is connected in series with a high-resistance voltmeter.
The magnet is displaced vertically and then released.
The variation with time t of the reading V of the voltmeter is shown in Fig. 5.2.

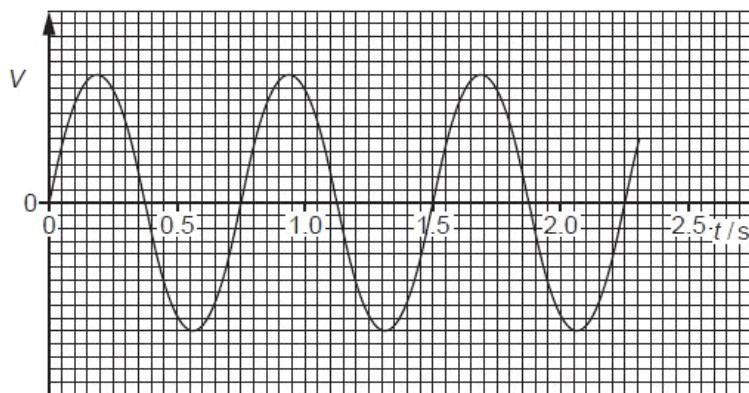


Fig. 5.2

- (a) (i) State Faraday's law of electromagnetic induction.

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.....
..... [2]

- (ii) Use Faraday's law to explain why

1. there is a reading on the voltmeter,

..... [1]

2. this reading varies in magnitude,

..... [1]

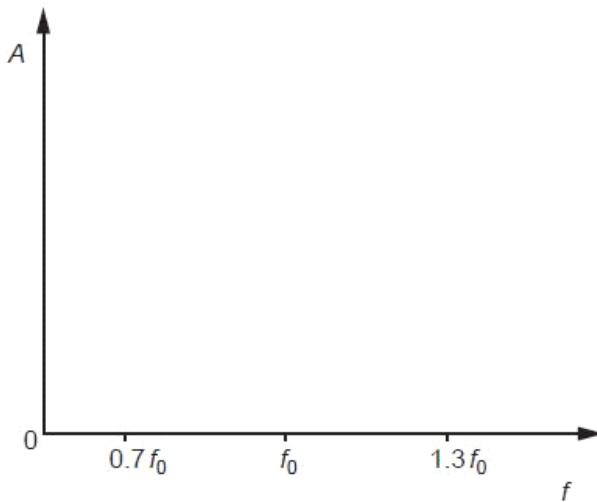
3. the reading has both positive and negative values.

..... [1]

- (b) Use Fig. 5.2 to determine the frequency f_0 of the oscillations of the magnet.

$$f_0 = \dots \text{Hz} \quad [2]$$

- (c) The magnet is now brought to rest and the voltmeter is replaced by a variable frequency alternating current supply that produces a constant r.m.s. current in the coil. The frequency of the supply is gradually increased from $0.7f_0$ to $1.3f_0$, where f_0 is the frequency calculated in (b). On the axes of Fig. 5.3, sketch a graph to show the variation with frequency f of the amplitude A of the new oscillations of the bar magnet.



[2]

Fig. 5.3

- (d) (i) Name the phenomenon illustrated on your completed graph of Fig. 5.3.

..... [1]

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- (ii) State one situation where the phenomenon named in (i) is useful.

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[1]

Q13.

- 7 Two long straight parallel copper wires A and B are clamped vertically. The wires pass through holes in a horizontal sheet of card PQRS, as shown in Fig. 7.1.

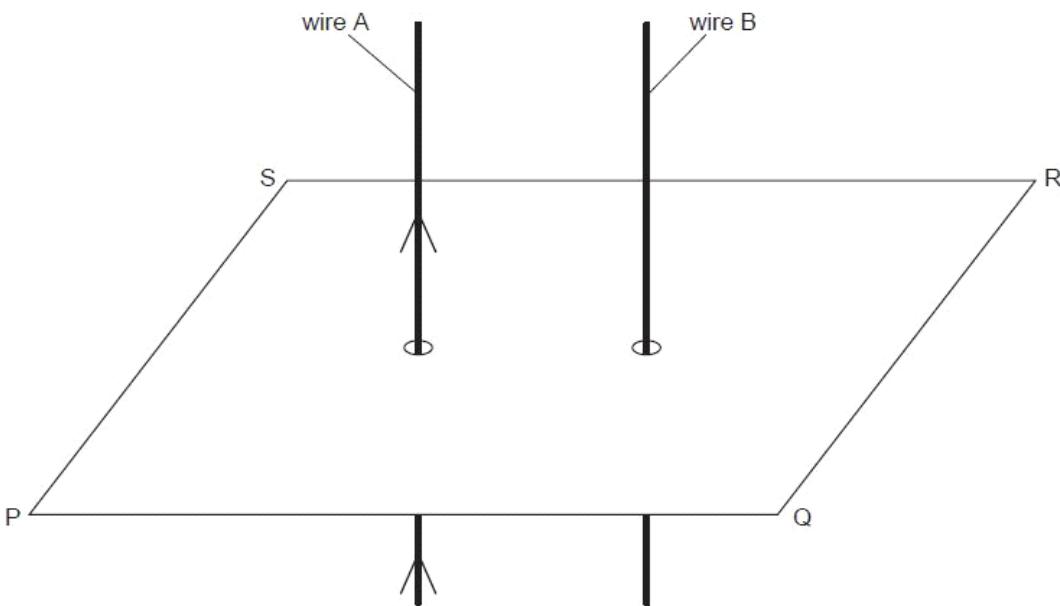


Fig. 7.1

- (a) There is a current in wire A in the direction shown on Fig. 7.1.
On Fig. 7.1, draw four field lines in the plane PQRS to represent the magnetic field due to the current in wire A. [3]
- (b) A direct current is now passed through wire B in the same direction as that in wire A.
The current in wire B is larger than the current in wire A.
- (i) On Fig. 7.1, draw an arrow in the plane PQRS to show the direction of the force on wire B due to the magnetic field produced by the current in wire A. [1]
- (ii) Wire A also experiences a force. State and explain which wire, if any, will experience the larger force.

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.....
.....

[2]

- (c) The direct currents in wires A and B are now replaced by sinusoidal alternating currents of equal peak values. The currents are in phase.
Describe the variation, if any, of the force experienced by wire B.

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.....
.....
.....

[3]

Q14.

- 5 (a) Define the *tesla*.

[3]

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- (b) A horseshoe magnet is placed on a balance. A stiff metal wire is clamped horizontally between the poles, as illustrated in Fig. 5.1.

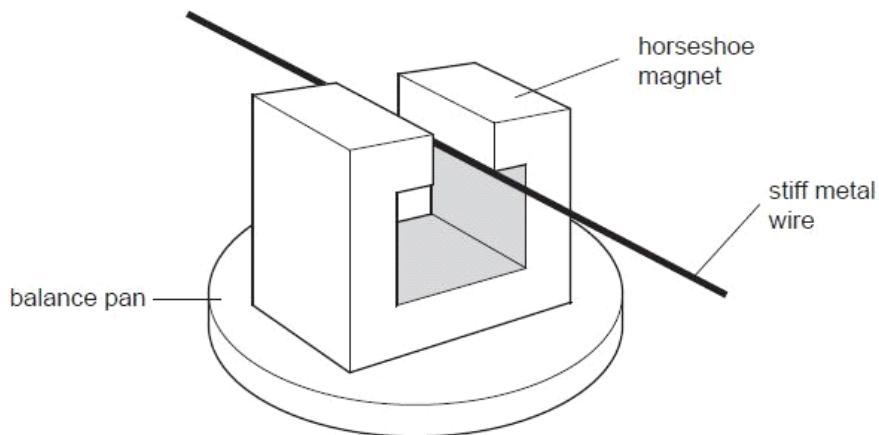


Fig. 5.1

The magnetic flux density in the space between the poles of the magnet is uniform and is zero outside this region.

The length of the metal wire normal to the magnetic field is 6.4 cm.

When a current in the wire is switched on, the reading on the balance increases by 2.4 g.
The current in the wire is 5.6 A.

- (i) State and explain the direction of the force on the wire due to the current.

[3]

- (ii) Calculate the magnitude of the magnetic flux density between the poles of the magnet.

Ex:

$$\text{flux density} = \dots \text{ T} [2]$$

- (c) A low frequency alternating current is now passed through the wire in (b).
The root-mean-square (r.m.s.) value of the current is 5.6 A.

Describe quantitatively the variation of the reading seen on the balance.

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.....

[2]

Q15.

- 5 (a) Define the *tesla*.

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[2]

- (b) A long solenoid has an area of cross-section of 28 cm^2 , as shown in Fig. 5.1.

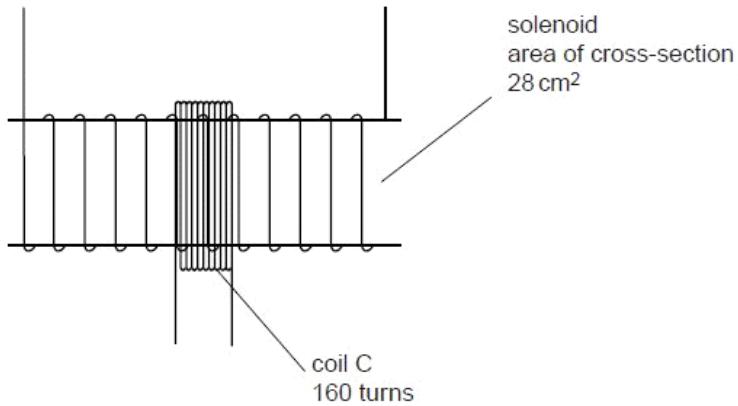


Fig. 5.1

A coil C consisting of 160 turns of insulated wire is wound tightly around the centre of the solenoid.

The magnetic flux density B at the centre of the solenoid is given by the expression

$$B = \mu_0 n I$$

where I is the current in the solenoid, n is a constant equal to $1.5 \times 10^3 \text{ m}^{-1}$ and μ_0 is the permeability of free space.

Calculate, for a current of 3.5A in the solenoid,

- (i) the magnetic flux density at the centre of the solenoid,

flux density = T [2]

- (ii) the flux linkage in the coil C.

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$$\text{flux linkage} = \dots \text{Wb} [2]$$

- (c) (i) State Faraday's law of electromagnetic induction.

.....
.....
..... [2]

- (ii) The current in the solenoid in (b) is reversed in direction in a time of 0.80 s.
Calculate the average e.m.f. induced in coil C.

$$\text{e.m.f.} = \dots \text{V} [2]$$

Q16.

- 5 (a) Define the *tesla*.

.....
.....
..... [2]

- (b) Two long straight vertical wires X and Y are separated by a distance of 4.5 cm, as illustrated in Fig. 5.1.

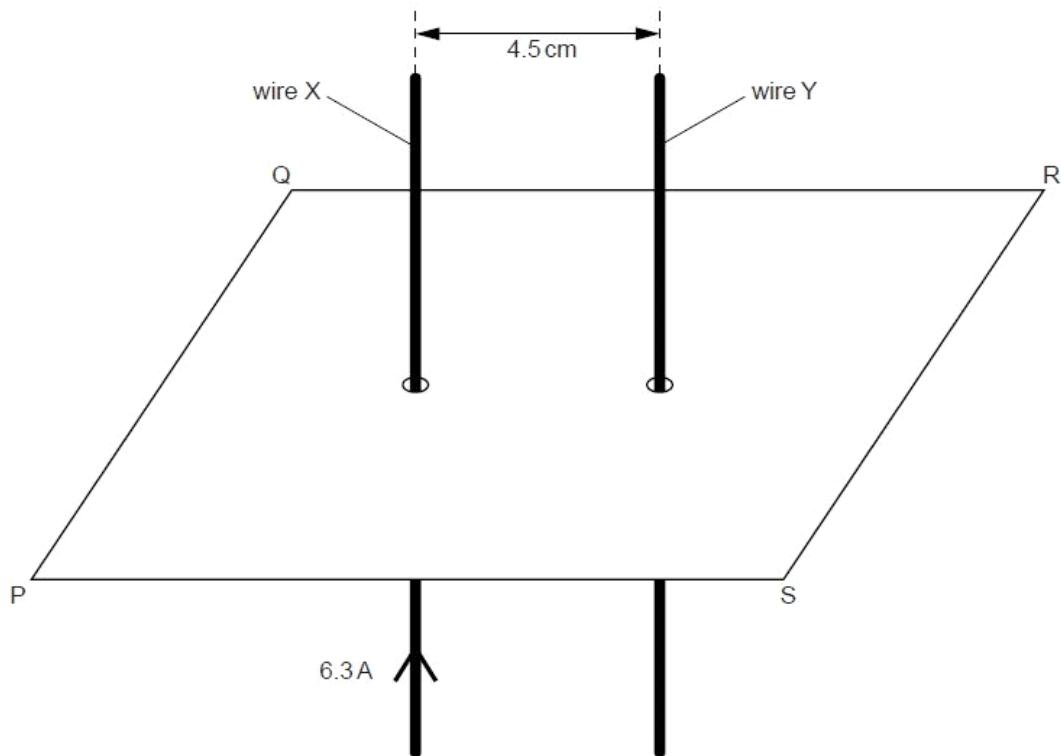


Fig. 5.1

The wires pass through a horizontal card PQRS.

The current in wire X is 6.3 A in the upward direction. Initially, there is no current in wire Y.

- (i) On Fig. 5.1, sketch, in the plane PQRS, the magnetic flux pattern due to the current in wire X. Show at least four flux lines. [3]

- (ii) The magnetic flux density B at a distance x from a long straight current-carrying wire is given by the expression

$$B = \frac{\mu_0 I}{2\pi x}$$

where I is the current in the wire and μ_0 is the permeability of free space.

Calculate the magnetic flux density at wire Y due to the current in wire X.

flux density = T [2]

- (iii) A current of 9.3 A is now switched on in wire Y. Use your answer in (ii) to calculate the force per unit length on wire Y.

force per unit length = N m⁻¹ [2]

- (c) The currents in the two wires in (b)(iii) are not equal.

Explain whether the force per unit length on the two wires will be the same, or different.

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.....
..... [2]

Q17.

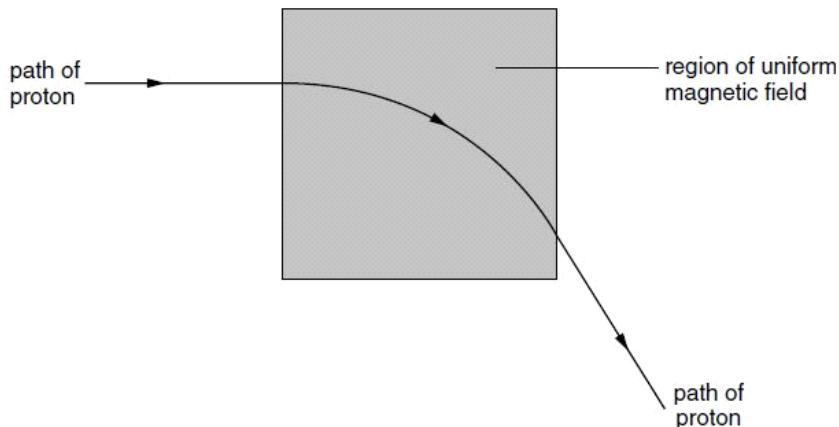
- 6 (a) A charged particle may experience a force in an electric field and in a magnetic field.

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State two differences between the forces experienced in the two types of field.

1.
-
2.
- [4]

- (b) A proton, travelling in a vacuum at a speed of $4.5 \times 10^6 \text{ m s}^{-1}$, enters a region of uniform magnetic field of flux density 0.12 T . The path of the proton in the field is a circular arc, as illustrated in Fig. 6.1.



- (i) State the direction of the magnetic field.

.....

- (ii) Calculate the radius of the path of the proton in the magnetic field.

$$\text{radius} = \dots \text{ m}$$

[4]

(c) A uniform electric field is now created in the same region as the magnetic field in Fig. 6.1, so that the proton passes undeviated through the region of the two fields.

- (i) On Fig. 6.1 mark, with an arrow labelled E, the direction of the electric field.
- (ii) Calculate the magnitude of the electric field strength.

$$\text{field strength} = \dots \text{ V m}^{-1}$$

[3]

(d) Suggest why gravitational forces on the proton have not been considered in the calculations in (b) and (c).

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[1]

Q18.

7 A metal wire is held taut between the poles of a permanent magnet, as illustrated in Fig. 7.1.

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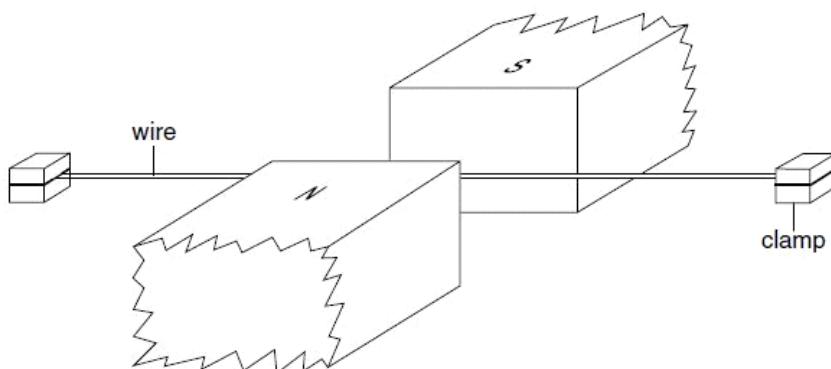


Fig. 7.1

A cathode-ray oscilloscope (c.r.o.) is connected between the ends of the wire. The Y-plate sensitivity is adjusted to 1.0 mV cm^{-1} and the time base is 0.5 ms cm^{-1} .

The wire is plucked at its centre. Fig. 7.2 shows the trace seen on the c.r.o.

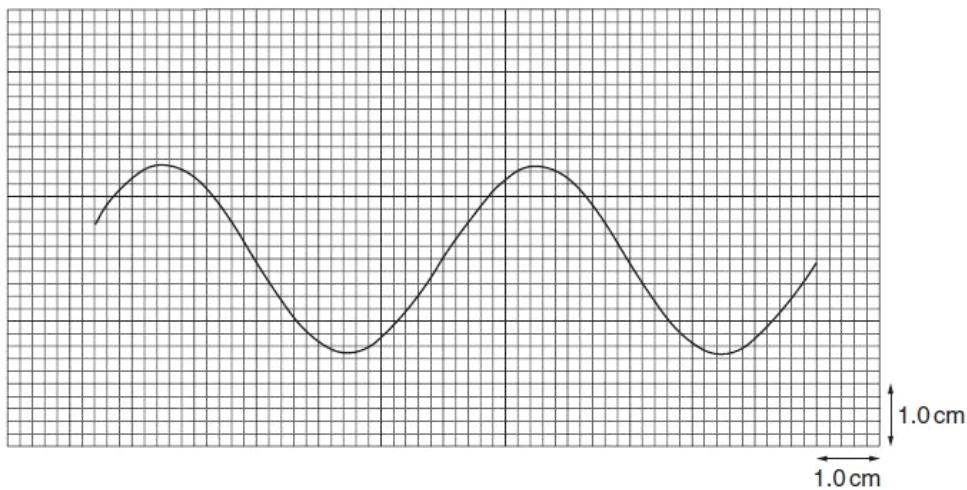


Fig. 7.2

(a) Making reference to the laws of electromagnetic induction, suggest why

- (i) an e.m.f. is induced in the wire,

.....
.....
.....

- (ii) the e.m.f. is alternating.

.....
.....
.....

[4]

- (b) Use Fig. 7.2 and the c.r.o. settings to determine the equation representing the induced alternating e.m.f.

equation: [4]

Q19.

- 5 (a) Define the tesla, the unit of magnetic flux density.

.....
.....
.....

[2]

- (b) The aluminium frame ABCD of a window measures 85 cm \times 60 cm, as illustrated in Fig. 5.1.

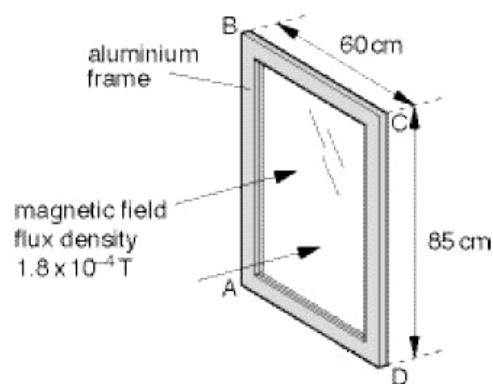


Fig. 5.1

The window is hinged along the edge AB.

When the window is closed, the horizontal component of the Earth's magnetic field, of flux density 1.8×10^{-4} T, is normal to the window.

- (i) Calculate the magnetic flux through the window.

$$\text{magnetic flux} = \dots \text{Wb} [2]$$

- (ii) The window is now opened in a time of 0.20 s. When open, the plane of the window is parallel to the Earth's magnetic field.

For the opening of the window,

1. state the change in flux through the window,

$$\text{change} = \dots \text{Wb}$$

2. calculate the average e.m.f. induced in side CD of the frame.

$$\text{e.m.f.} = \dots \text{V} [3]$$

- (iii) Suggest, with a reason, whether the e.m.f. calculated in (ii)2 gives rise to a current in the frame ABCD.

..... [1]

Q20.

- 4 A small coil is positioned so that its axis lies along the axis of a large bar magnet, as shown in Fig. 4.1.

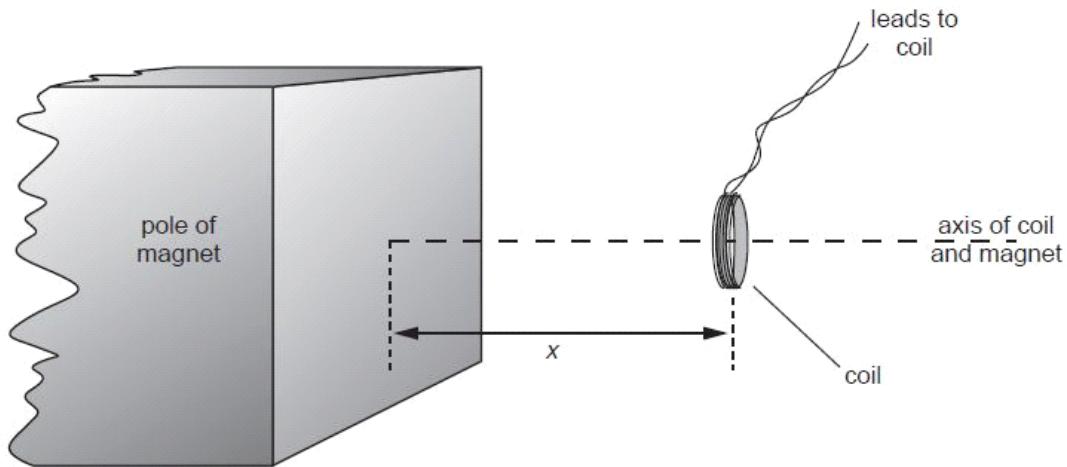


Fig. 4.1

The coil has a cross-sectional area of 0.40 cm^2 and contains 150 turns of wire.

The average magnetic flux density B through the coil varies with the distance x between the face of the magnet and the plane of the coil as shown in Fig. 4.2.

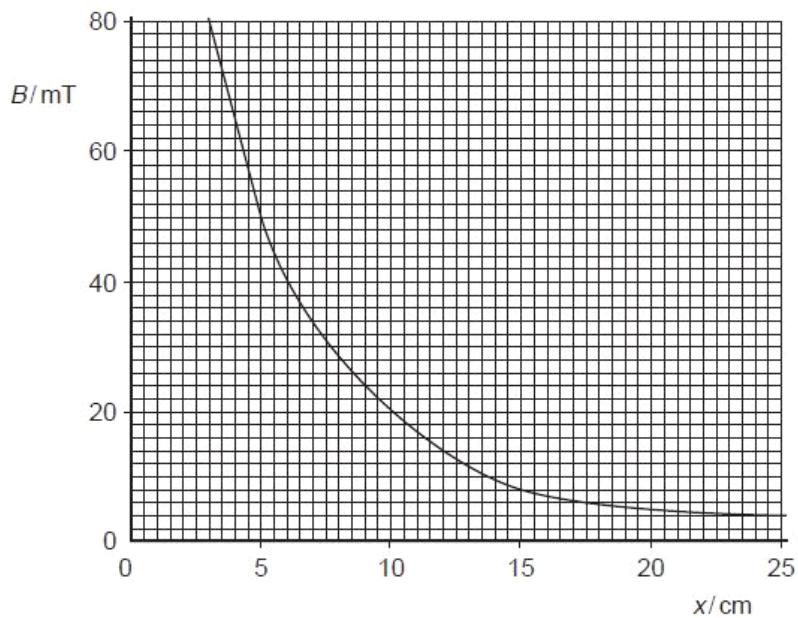


Fig. 4.2

- (a) (i) The coil is 5.0 cm from the face of the magnet. Use Fig. 4.2 to determine the magnetic flux density in the coil.

magnetic flux density = T

- (ii) Hence show that the magnetic flux linkage of the coil is 3.0×10^{-4} Wb.

[3]

- (b) State Faraday's law of electromagnetic induction.

.....
.....
.....

[2]

(c) The coil is moved along the axis of the magnet so that the distance x changes from $x = 5.0\text{ cm}$ to $x = 15.0\text{ cm}$ in a time of 0.30 s . Calculate

(i) the change in flux linkage of the coil,

$$\text{change} = \dots \text{Wb} [2]$$

(ii) the average e.m.f. induced in the coil.

$$\text{e.m.f.} = \dots \text{V} [2]$$

(d) State and explain the variation, if any, of the speed of the coil so that the induced e.m.f. remains constant during the movement in (c).

.....
.....
.....
.....

[3]

Q21.

- 5 A charged particle passes through a region of uniform magnetic field of flux density 0.74 T, as shown in Fig. 5.1.

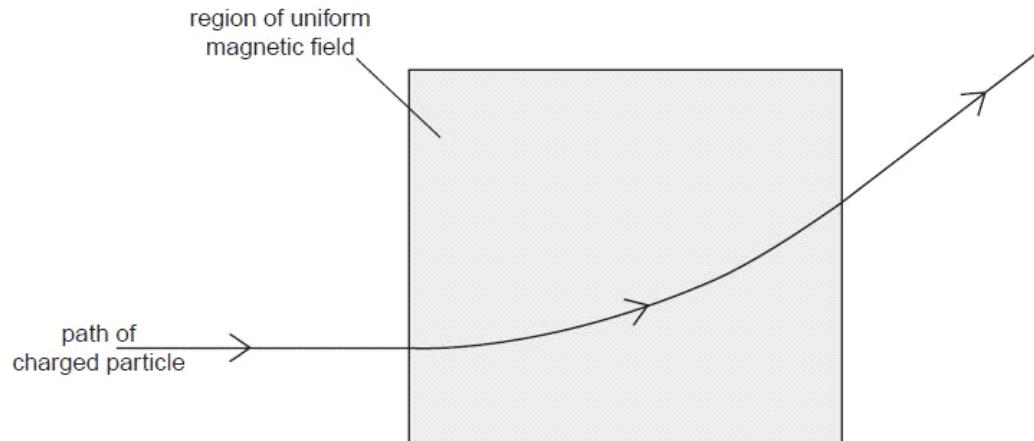


Fig. 5.1

The radius r of the path of the particle in the magnetic field is 23 cm.

- (a) The particle is positively charged. State the direction of the magnetic field.

..... [1]

- (b) (i) Show that the specific charge of the particle (the ratio $\frac{q}{m}$ of its charge to its mass) is given by the expression

$$\frac{q}{m} = \frac{v}{rB},$$

where v is the speed of the particle and B is the flux density of the field.

[2]

- (ii) The speed v of the particle is $8.2 \times 10^6 \text{ ms}^{-1}$. Calculate the specific charge of the particle.

use

specific charge = C kg^{-1} [2]

- (c) (i) The particle in (b) has charge $1.6 \times 10^{-19} \text{ C}$. Using your answer to (b)(ii), determine the mass of the particle in terms of the unified atomic mass constant u .

mass = u [2]

- (ii) The particle is the nucleus of an atom. Suggest the composition of this nucleus.

.....
..... [1]

Q22.

- 5 (a) An electron is accelerated from rest in a vacuum through a potential difference of $1.2 \times 10^4 \text{ V}$. Show that the final speed of the electron is $6.5 \times 10^7 \text{ m s}^{-1}$.

use

[2]

- (b) The accelerated electron now enters a region of uniform magnetic field acting into the plane of the paper, as illustrated in Fig. 5.1.

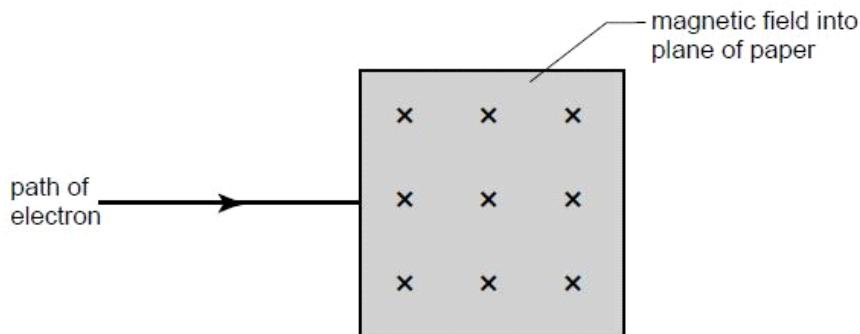


Fig. 5.1

- (i) Describe the path of the electron as it passes through, and beyond, the region of the magnetic field. You may draw on Fig. 5.1 if you wish.

path within field:

.....
path beyond field:

[3]

- (ii) State and explain the effect on the magnitude of the deflection of the electron in the magnetic field if, separately,

1. the potential difference accelerating the electron is reduced,

.....
.....
.....
.....
..... [2]

2. the magnetic field strength is increased.

.....
.....
.....
..... [2]

Q23.

- 6 (a) Define magnetic flux density.

[3]

- (b) A flat coil consists of N turns of wire and has area A . The coil is placed so that its plane is at an angle θ to a uniform magnetic field of flux density B , as shown in Fig. 6.1.

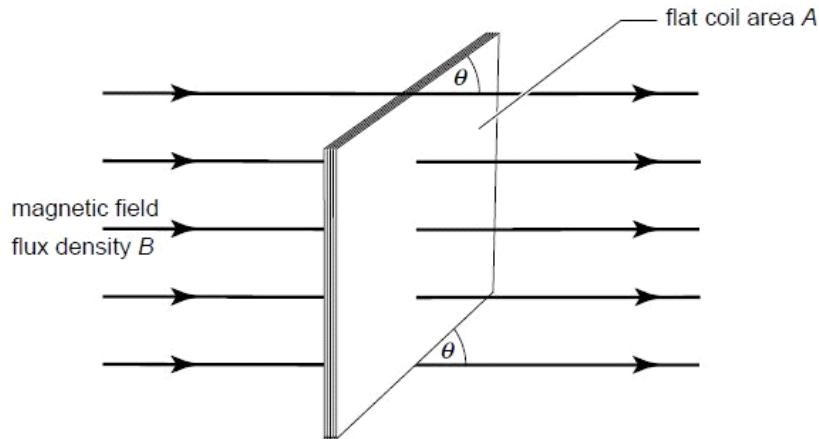


Fig. 6.1

Using the symbols A , B , N and θ and making reference to the magnetic flux in the coil, derive an expression for the magnetic flux linkage through the coil.

[2]

(c) (i) State Faraday's law of electromagnetic induction.

U

[2]

(ii) The magnetic flux density B in the coil is now made to vary with time t as shown in Fig. 6.2.

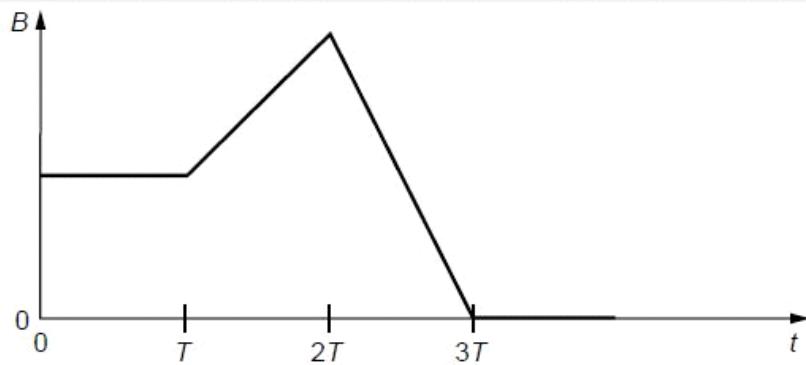


Fig. 6.2

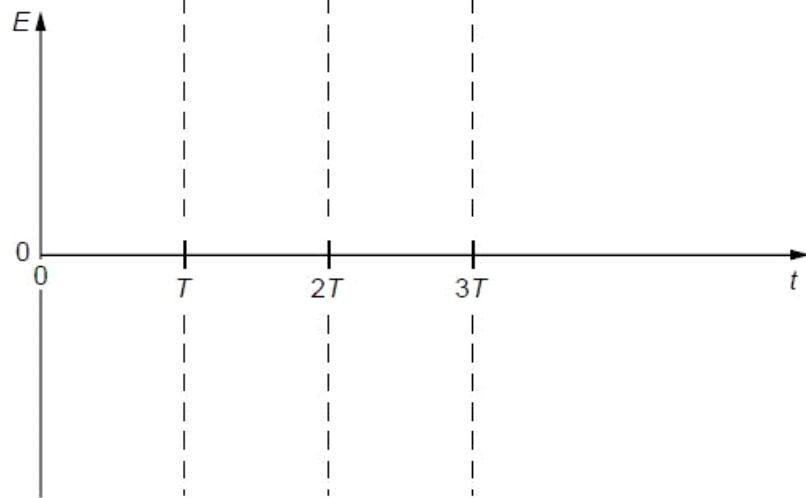


Fig. 6.3

On Fig. 6.3, sketch the variation with time t of the e.m.f. E induced in the coil. [3]

Q24.

- 5 A metal disc is swinging freely between the poles of an electromagnet, as shown in Fig. 5.1.

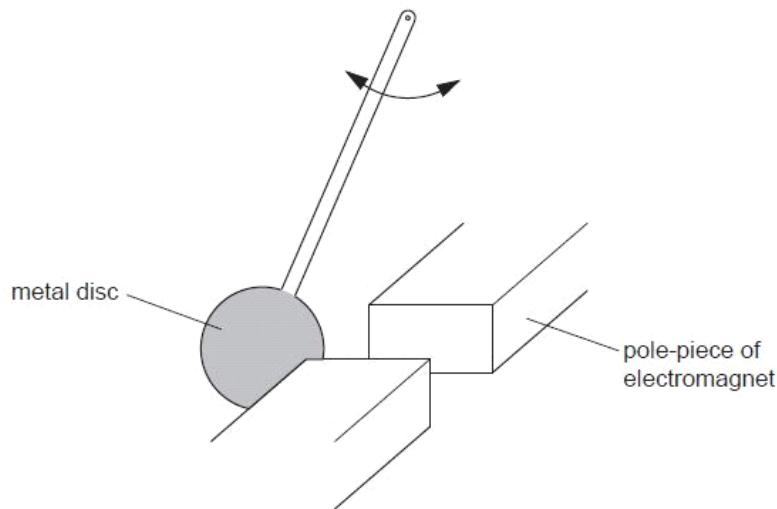


Fig. 5.1

When the electromagnet is switched on, the disc comes to rest after a few oscillations.

- (a) (i) State Faraday's law of electromagnetic induction and use the law to explain why an e.m.f. is induced in the disc.

.....
.....
.....
..... [2]

- (ii) Explain why eddy currents are induced in the metal disc.

.....
.....
..... [2]

- (b) Use energy principles to explain why the disc comes to rest after a few oscillations.

.....
.....
..... [3]

Q25.

- 6 (a) A straight conductor carrying a current I is at an angle θ to a uniform magnetic field of flux density B , as shown in Fig. 6.1.

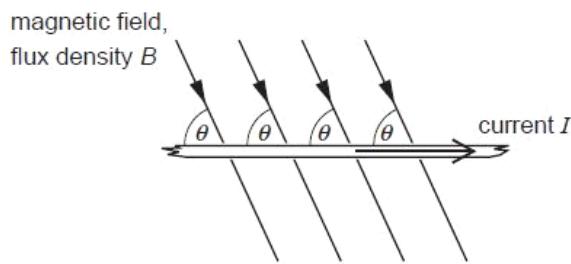


Fig. 6.1

The conductor and the magnetic field are both in the plane of the paper. State

- (i) an expression for the force per unit length acting on the conductor due to the magnetic field,

force per unit length = [1]

- (ii) the direction of the force on the conductor.

..... [1]

- (b) A coil of wire consisting of two loops is suspended from a fixed point as shown in Fig. 6.2.

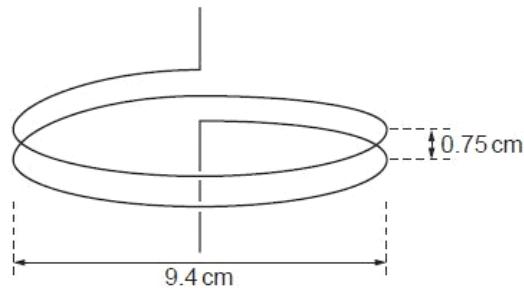


Fig. 6.2

Each loop of wire has diameter 9.4 cm and the separation of the loops is 0.75 cm.
The coil is connected into a circuit such that the lower end of the coil is free to move.

- (i) Explain why, when a current is switched on in the coil, the separation of the loops of the coil decreases.

.....
.....
.....
.....
.....

[4]

- (ii) Each loop of the coil may be considered as being a long straight wire.
In SI units, the magnetic flux density B at a distance x from a long straight wire carrying a current I is given by the expression

$$B = 2.0 \times 10^{-7} \frac{I}{x}$$

When the current in the coil is switched on, a mass of 0.26 g is hung from the free end of the coil in order to return the loops of the coil to their original separation.
Calculate the current in the coil.

current =A [4]

Q26.

- 8 (a) Describe what is meant by a *magnetic field*.

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Exam/
Use

[3]

- (b) A small mass is placed in a field of force that is either electric or magnetic or gravitational.

State the nature of the field of force when the mass is

- (i) charged and the force is opposite to the direction of the field,

[1]

- (ii) uncharged and the force is in the direction of the field,

[1]

- (iii) charged and there is a force only when the mass is moving,

[1]

- (iv) charged and there is no force on the mass when it is stationary or moving in a particular direction.

[1]

Q27.

- 6 The current in a long, straight vertical wire is in the direction XY, as shown in Fig. 6.1.

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Use

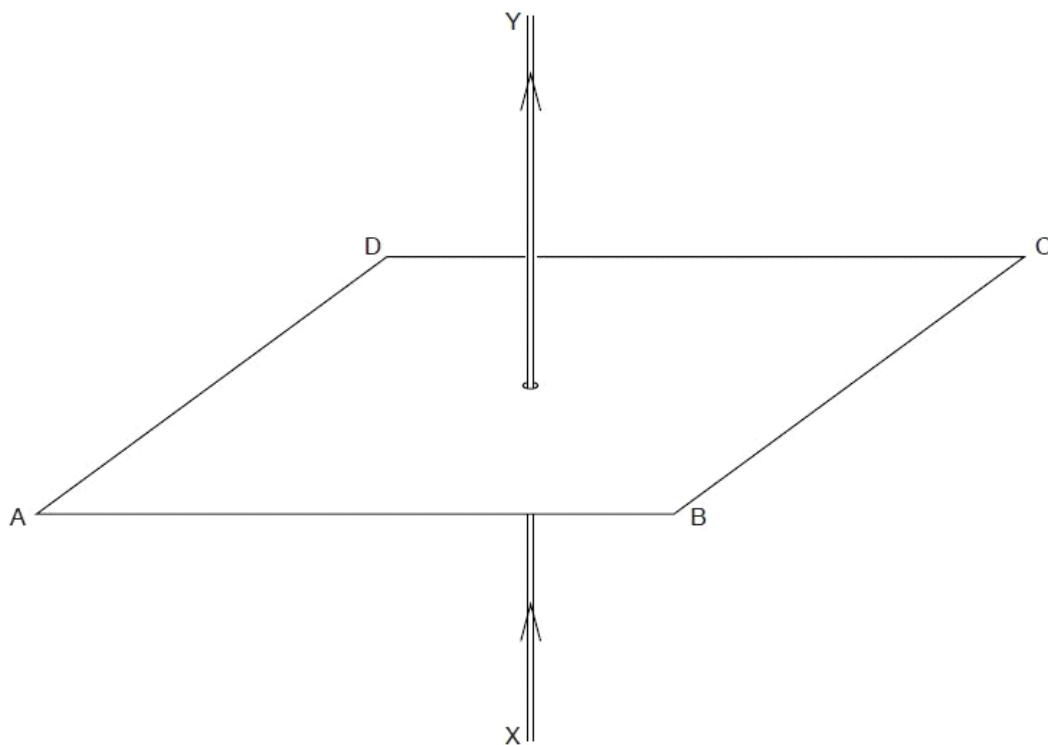


Fig. 6.1

- (a) On Fig. 6.1, sketch the pattern of the magnetic flux in the horizontal plane ABCD due to the current-carrying wire. Draw at least four flux lines. [3]

- (b) The current-carrying wire is within the Earth's magnetic field. As a result, the pattern drawn in Fig. 6.1 is superposed with the horizontal component of the Earth's magnetic field.

Fig. 6.2 shows a plan view of the plane ABCD with the current in the wire coming out of the plane.

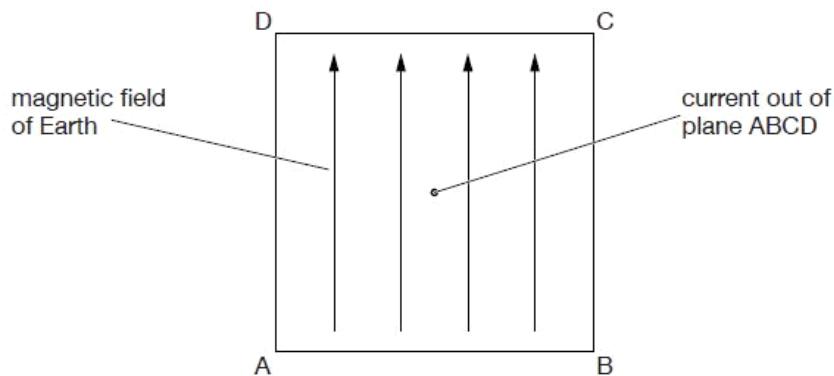


Fig. 6.2

The horizontal component of the Earth's magnetic field is also shown.

- (i) On Fig. 6.2, mark with the letter P a point where the magnetic field due to the current-carrying wire could be equal and opposite to that of the Earth. [1]
- (ii) For a long, straight wire carrying current I , the magnetic flux density B at distance r from the centre of the wire is given by the expression

$$B = \mu_0 \frac{I}{2\pi r}$$

where μ_0 is the permeability of free space.

The point P in (i) is found to be 1.9 cm from the centre of the wire for a current of 1.7 A.

Calculate a value for the horizontal component of the Earth's magnetic flux density.

flux density = T [2]

- (c) The current in the wire in (b)(ii) is increased. The point P is now found to be 2.8 cm from the wire.

Determine the new current in the wire.

current = A [2]

Q28.

- 5 Two long straight vertical wires X and Y pass through a horizontal card, as shown in Fig. 5.1.

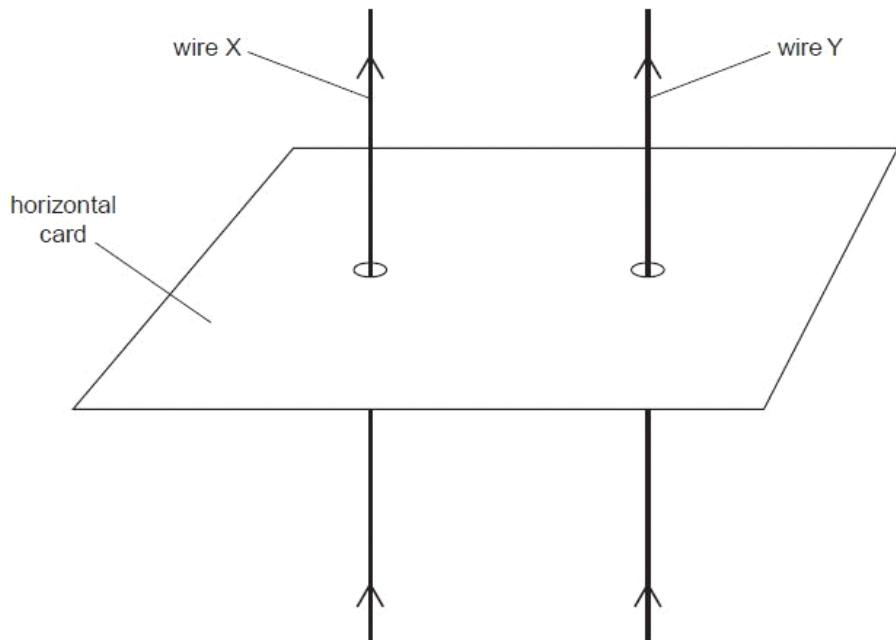


Fig. 5.1

The current in each wire is in the upward direction.

The top view of the card, seen by looking vertically downwards at the card, is shown in Fig. 5.2.

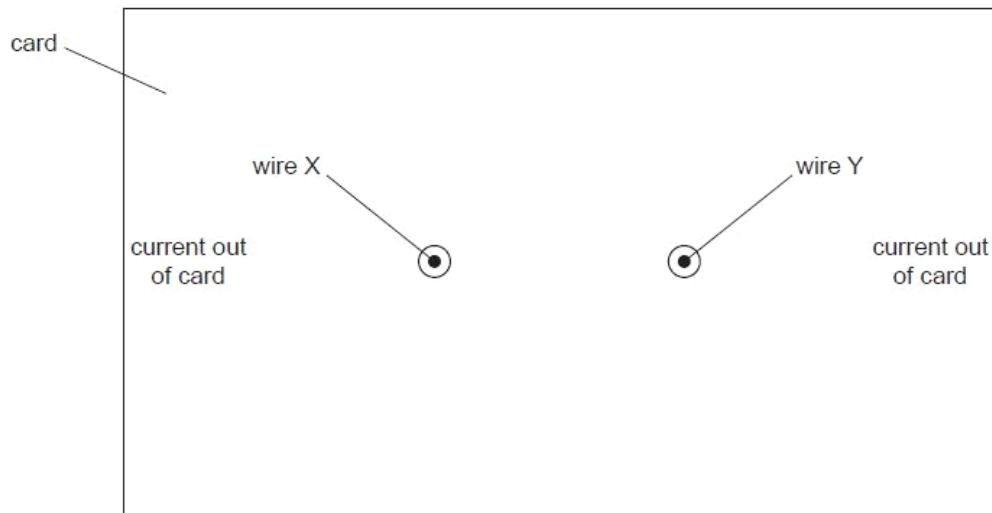


Fig. 5.2 (not to scale)

(a) On Fig. 5.2,

- (i) draw four field lines to represent the pattern of the magnetic field around wire X due solely to the current in wire X, [2]
- (ii) draw an arrow to show the direction of the force on wire Y due to the magnetic field of wire X. [1]

(b) The magnetic flux density B at a distance x from a long straight wire due to a current I in the wire is given by the expression

$$B = \frac{\mu_0 I}{2\pi x},$$

where μ_0 is the permeability of free space.

The current in wire X is 5.0 A and that in wire Y is 7.0 A. The separation of the wires is 2.5 cm.

- (i) Calculate the force per unit length on wire Y due to the current in wire X.

force per unit length = N m⁻¹ [4]

- (ii) The currents in the wires are not equal.

State and explain whether the forces on the two wires are equal in magnitude.

.....
.....
..... [2]

Q29.

- 6 An ideal transformer is illustrated in Fig. 6.1.

For Examiner's Use

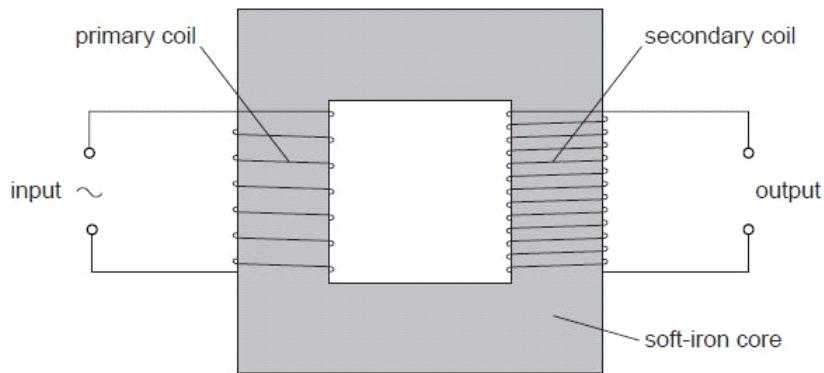


Fig. 6.1

- (a) (i) State Faraday's law of electromagnetic induction.

.....
.....
.....

[2]

- (ii) Use the law to explain why a transformer will not operate using a direct current input.

.....
.....
.....

[2]

- (b) (i) State Lenz's law.

.....
.....
.....

[2]

- (ii) Use Lenz's law to explain why the input potential difference and the output e.m.f. are not in phase.

.....
.....
.....

[2]

- (c) Electrical energy is usually transmitted using alternating high voltages.

For
Examiner's
Use

Suggest one advantage, for the transmission of electrical energy, of using

- (i) alternating voltage,

[1]

- (ii) high voltage.

[1]

Q30.

- 5 Positive ions are travelling through a vacuum in a narrow beam. The ions enter a region of uniform magnetic field of flux density B and are deflected in a semi-circular arc, as shown in Fig. 5.1.

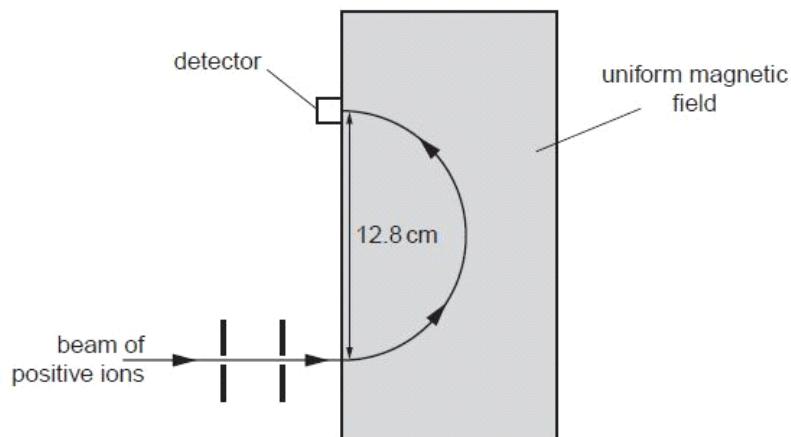


Fig. 5.1

The ions, travelling with speed $1.40 \times 10^5 \text{ ms}^{-1}$, are detected at a fixed detector when the diameter of the arc in the magnetic field is 12.8 cm.

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Use

- (a)** By reference to Fig. 5.1, state the direction of the magnetic field.

..... [1]

- (b)** The ions have mass 20 u and charge $+1.6 \times 10^{-19}\text{ C}$. Show that the magnetic flux density is 0.454 T . Explain your working.

[3]

- (c)** Ions of mass 22 u with the same charge and speed as those in **(b)** are also present in the beam.

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Use

- (i) On Fig. 5.1, sketch the path of these ions in the magnetic field of magnetic flux density 0.454 T . [1]
- (ii) In order to detect these ions at the fixed detector, the magnetic flux density is changed.
Calculate this new magnetic flux density.

magnetic flux density = T [2]

Q31.

- 5 The poles of a horseshoe magnet measure $5.0\text{ cm} \times 2.4\text{ cm}$, as shown in Fig. 5.1.

For Examiner's Use

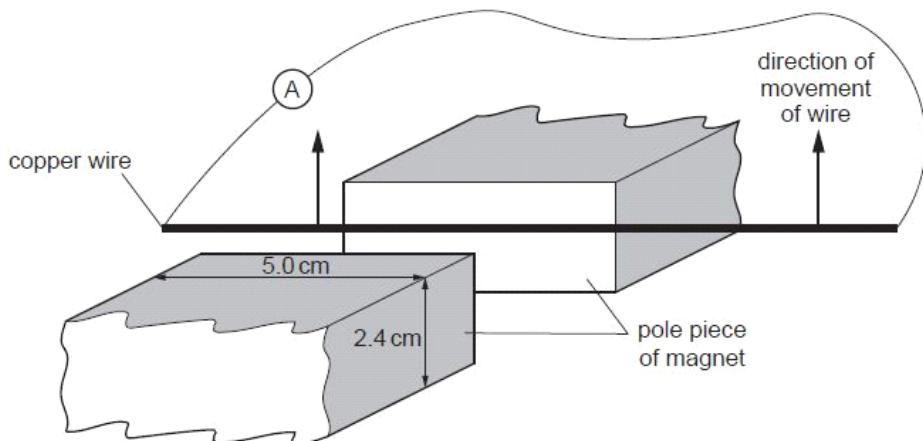


Fig. 5.1

The uniform magnetic flux density between the poles of the magnet is 89 mT . Outside the region of the poles, the magnetic flux density is zero.

A stiff copper wire is connected to a sensitive ammeter of resistance 0.12Ω . A student moves the wire at a constant speed of 1.8 ms^{-1} between the poles in a direction parallel to the faces of the poles.

- (a) Calculate the magnetic flux between the poles of the magnet.

$$\text{magnetic flux} = \dots \text{ Wb} [2]$$

- (b) (i) Use your answer in (a) to determine, for the wire moving between the poles of the magnet, the e.m.f. induced in the wire.

$$\text{e.m.f.} = \dots \text{ V} [3]$$

- (ii) Show that the reading on the ammeter is approximately 70 mA.

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Use

[1]

- (c) By reference to Lenz's law, a force acts on the wire to oppose the motion of the wire.
The student who moved the wire between the poles of the magnet claims not to have
felt this force.
Explain quantitatively a reason for this claim.

..... [3]

Q32.

- 7 Electrons are moving through a vacuum in a narrow beam. The electrons have speed v . The electrons enter a region of uniform magnetic field of flux density B . Initially, the electrons are travelling at a right-angle to the magnetic field. The path of a single electron is shown in Fig. 7.1.

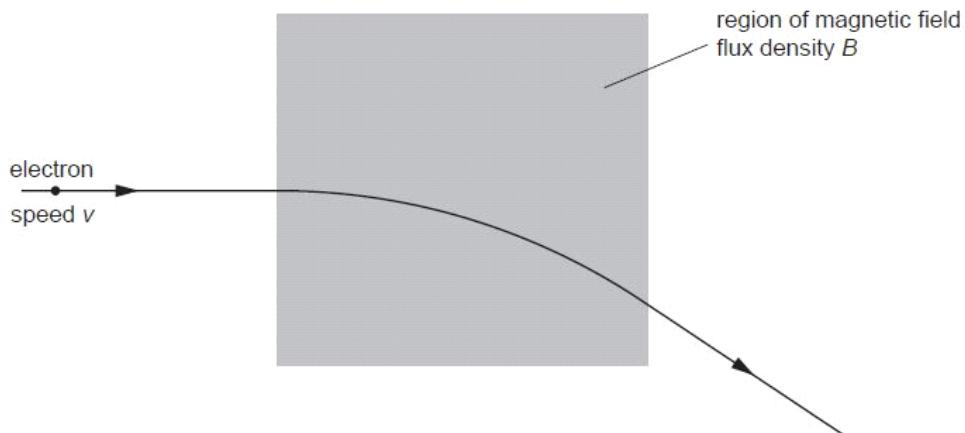


Fig. 7.1

The electrons follow a curved path in the magnetic field.

A uniform electric field of field strength E is now applied in the same region as the magnetic field.

The electrons pass undeviated through the region of the two fields.
Gravitational effects may be neglected.

- (a) Derive a relation between v , E and B for the electrons not to be deflected. Explain your working.

.....
.....
.....
.....
.....
.....

[3]

- (b) An α -particle has speed v and approaches the region of the two fields along the same path as the electron. Describe and explain the path of the α -particle as it passes through the region of the two fields.

.....
.....
.....
.....

[2]

Q33.

- 3 A bar magnet is suspended from the free end of a helical spring, as illustrated in Fig. 3.1.

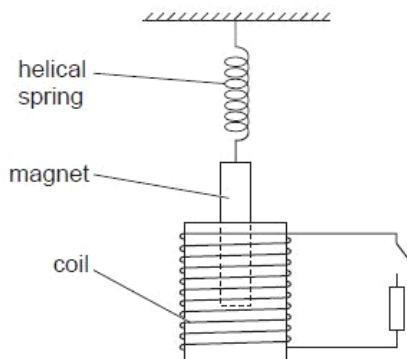


Fig. 3.1

One pole of the magnet is situated in a coil of wire. The coil is connected in series with a switch and a resistor. The switch is open.

The magnet is displaced vertically and then released. As the magnet passes through its rest position, a timer is started. The variation with time t of the vertical displacement y of the magnet from its rest position is shown in Fig. 3.2.

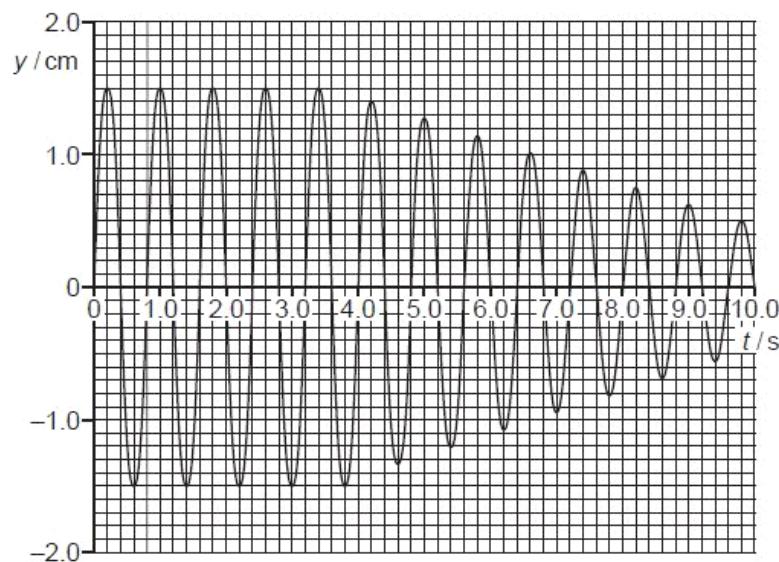


Fig. 3.2

At time $t = 4.0\text{ s}$, the switch is closed.

(b) (i) State Faraday's law of electromagnetic induction.

.....
.....

[2]

(ii) Explain why, after time $t = 4.0\text{ s}$, the amplitude of vibration of the magnet is seen to decrease.

.....
.....
.....
.....
.....

[4]

Q34.

- 5 Positively charged particles are travelling in a vacuum through three narrow slits S_1 , S_2 and S_3 , as shown in Fig. 5.1.

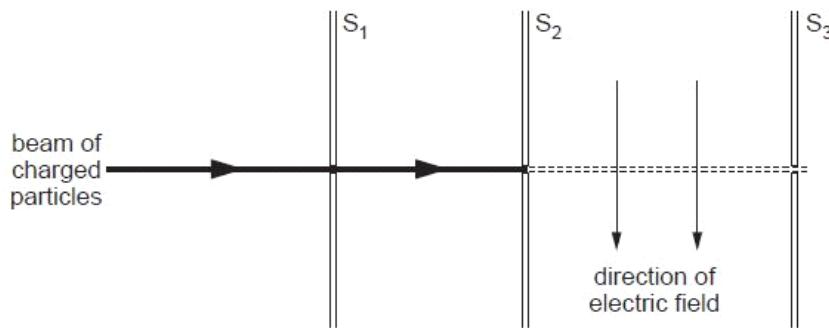


Fig. 5.1

Each particle has speed v and charge q .

There is a uniform magnetic field of flux density B and a uniform electric field of field strength E in the region between the slits S_2 and S_3 .

- (a) State the expression for the force F acting on a charged particle due to

- (i) the magnetic field,

..... [1]

- (ii) the electric field.

..... [1]

- (b) The electric field acts downwards in the plane of the paper, as shown in Fig. 5.1.

State and explain the direction of the magnetic field so that the positively charged particles may pass undeviated through the region between slits S_2 and S_3 .

.....
.....
..... [2]

Q35.

- 6 (a) Define the tesla.

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Use

[3]

- (b) A charged particle of mass m and charge $+q$ is travelling with velocity v in a vacuum. It enters a region of uniform magnetic field of flux density B as shown in Fig. 6.1.

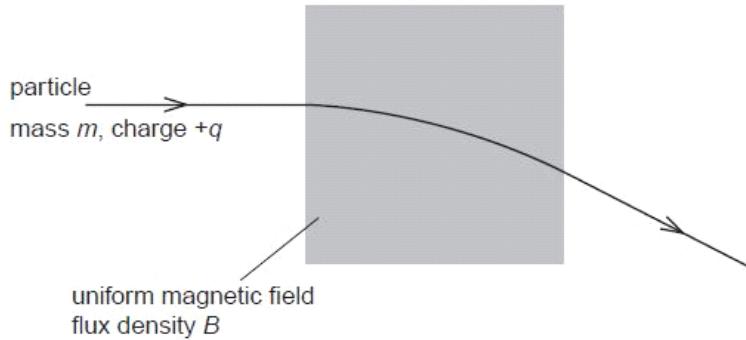


Fig. 6.1

The magnetic field is normal to the direction of motion of the particle. The path of the particle in the field is the arc of a circle of radius r .

- (i) Explain why the path of the particle in the field is the arc of a circle.

[2]

- (ii) Show that the radius r is given by the expression

$$r = \frac{mv}{Bq}.$$

[1]

- (c) A uniform magnetic field is produced in the region PQRS, as shown in Fig. 6.2.

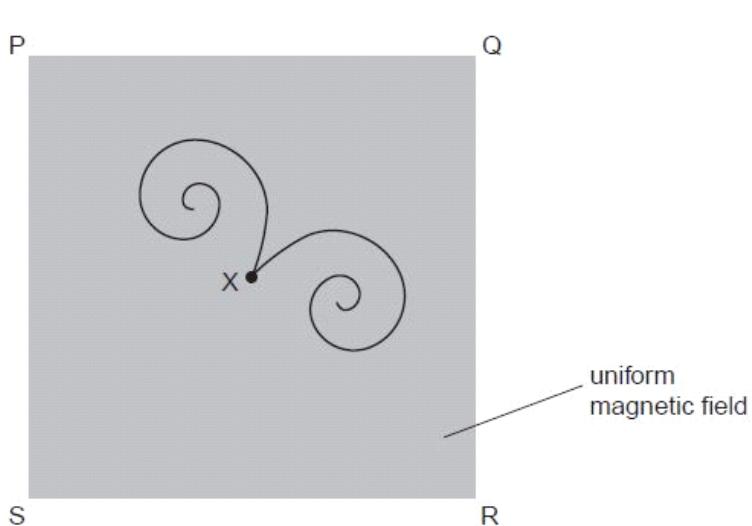


Fig. 6.2

The magnetic field is normal to the page.

At point X, a gamma-ray photon interaction causes two particles to be formed. The paths of these particles are shown in Fig. 6.2.

- (i) Suggest, with a reason, why each of the paths is a spiral, rather than the arc of a circle.

.....
.....
.....

[2]

- (ii) State and explain what can be deduced from the paths about

- the charges on the two particles,

.....
.....
.....

[2]

- the initial speeds of the two particles.

.....
.....
.....

[2]

Q36.

- 6 (a) (i) State the condition for a charged particle to experience a force in a magnetic field.

.....
.....

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Use

[2]

- (ii) State an expression for the magnetic force F acting on a charged particle in a magnetic field of flux density B . Explain any other symbols you use.

.....
.....

[2]

- (b) A sample of a conductor with rectangular faces is situated in a magnetic field, as shown in Fig. 6.1.

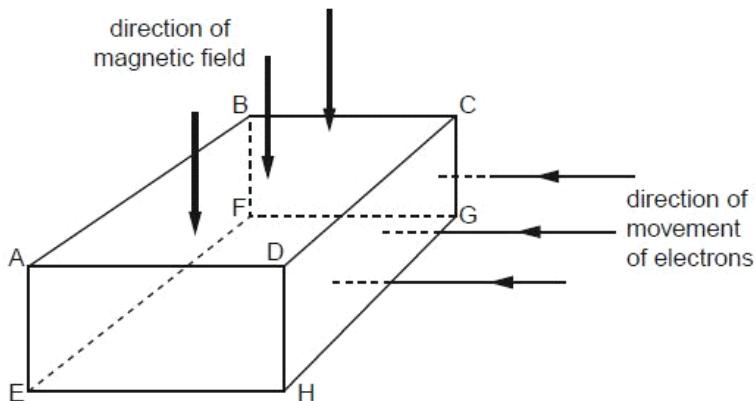


Fig. 6.1

The magnetic field is normal to face ABCD in the downward direction.

Electrons enter face CDHG at right-angles to the face. As the electrons pass through the conductor, they experience a force due to the magnetic field.

- (i) On Fig. 6.1, shade the face to which the electrons tend to move as a result of this force. [1]

- (ii) The movement of the electrons in the magnetic field causes a potential difference between two faces of the conductor.

Using the lettering from Fig. 6.1, state the faces between which this potential difference will occur.

face and face [1]

- (c) Explain why the potential difference in (b) causes an additional force on the moving electrons in the conductor.

[2]

Q37.

- 7 (a) State Lenz's law.

For
Examiner's
Use

[2]

- (b) A simple transformer with a soft-iron core is illustrated in Fig. 7.1.

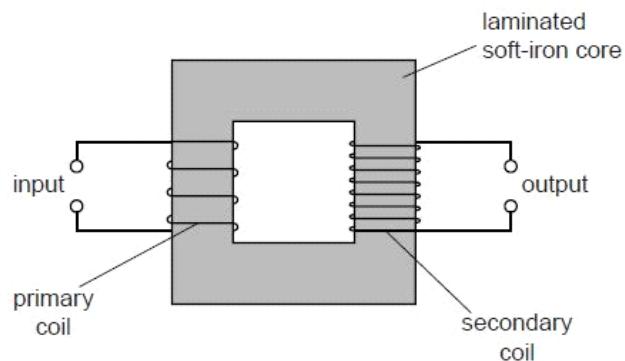


Fig. 7.1

(i) Explain why the core is

1. made of iron,

.....
.....

[1]

2. laminated.

.....
.....
.....

[2]

(ii) An e.m.f. is induced in the secondary coil of the transformer.
Explain how a current in the primary coil gives rise to this induced e.m.f.

.....
.....
.....
.....
.....

[4]

Q38.

- 4 A proton of mass m and charge $+q$ is travelling through a vacuum in a straight line with speed v . It enters a region of uniform magnetic field of magnetic flux density B , as shown in Fig. 4.1.

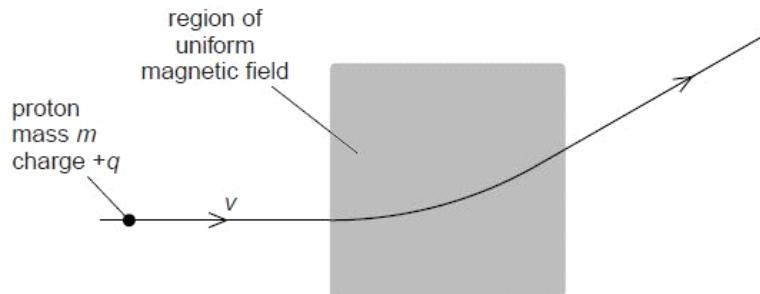


Fig. 4.1

The magnetic field is normal to the direction of motion of the proton.

- (a) Explain why the path of the proton in the magnetic field is an arc of a circle.

.....
.....
.....

[2]

- (b) The angular speed of the proton in the magnetic field is ω .

Derive an expression for ω in terms of B , q and m .

[4]

Q39.

- 5 (a) State the relation between magnetic flux density B and magnetic flux Φ , explaining any other symbols you use.

[2]

- (b) A large horseshoe magnet has a uniform magnetic field between its poles. The magnetic field is zero outside the space between the poles.
A small Hall probe is moved at constant speed along a line XY that is midway between, and parallel to, the faces of the poles of the magnet, as shown in Fig. 5.1.

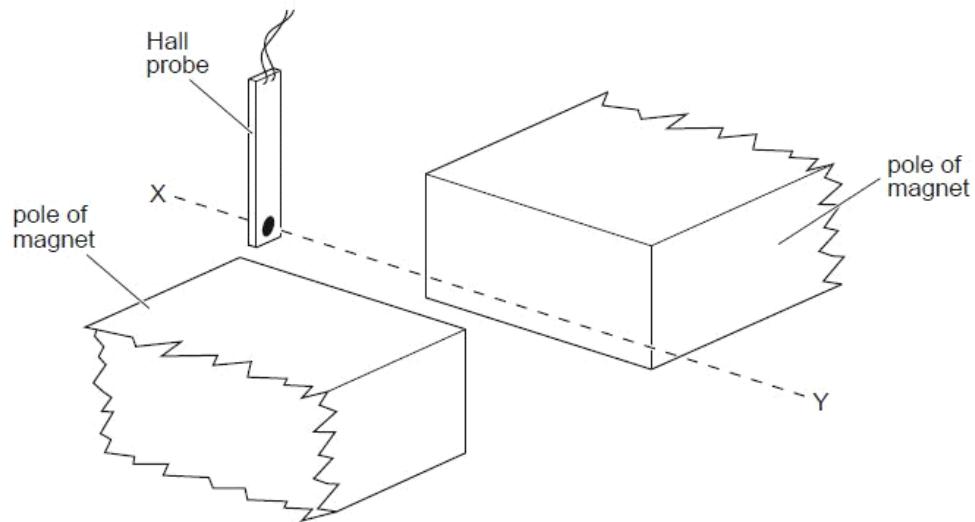


Fig. 5.1

An e.m.f. is produced by the Hall probe when it is in the magnetic field.
The angle between the plane of the probe and the direction of the magnetic field is not varied.

On the axes of Fig. 5.2, sketch a graph to show the variation with time t of the e.m.f. V_H produced by the Hall probe.

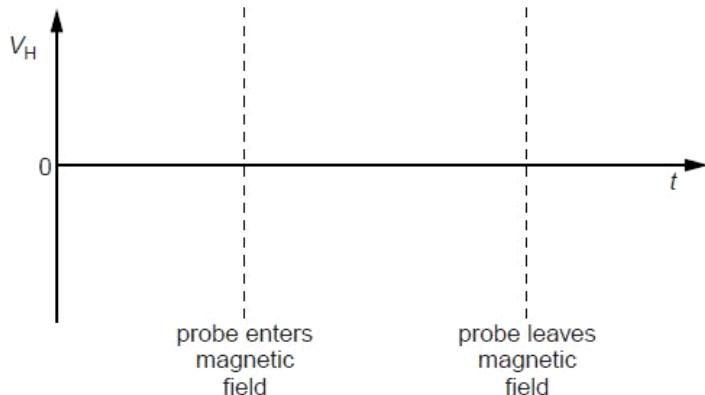


Fig. 5.2

[2]

- (c) (i) State Faraday's law of electromagnetic induction.

.....
.....
.....

[2]

- (ii) The Hall probe in (b) is replaced by a small flat coil of wire. The coil is moved at constant speed along the line XY. The plane of the coil is parallel to the faces of the poles of the magnet.

On the axes of Fig. 5.3, sketch a graph to show the variation with time t of the e.m.f. E induced in the coil.

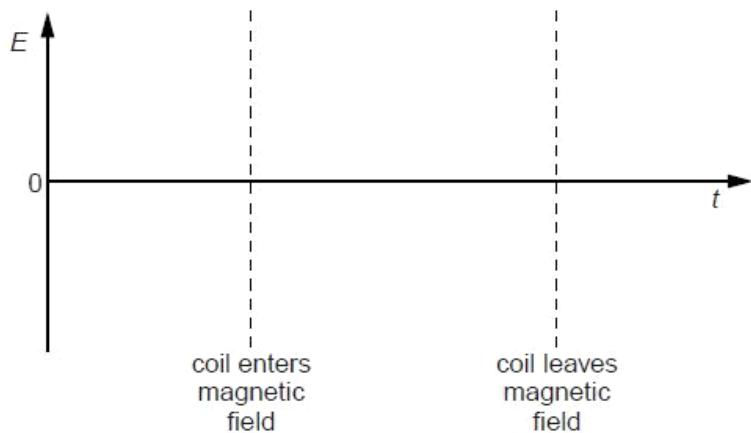


Fig. 5.3

[3]

Q40.

For
Examiner's
Use

- 5 (a) An incomplete diagram for the magnetic flux pattern due to a current-carrying solenoid is illustrated in Fig. 5.1.

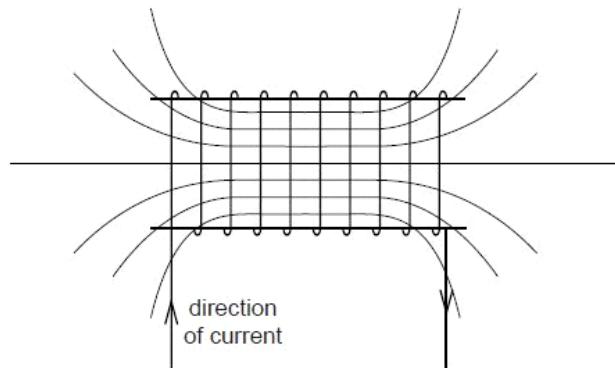


Fig. 5.1

- (i) On Fig. 5.1, draw arrows on the field lines to show the direction of the magnetic field. [1]
- (ii) State the feature of Fig. 5.1 that indicates that the magnetic field strength at each end of the solenoid is less than that at the centre.

..... [1]

- (b) A Hall probe is placed near one end of the solenoid in (a), as shown in Fig. 5.2.

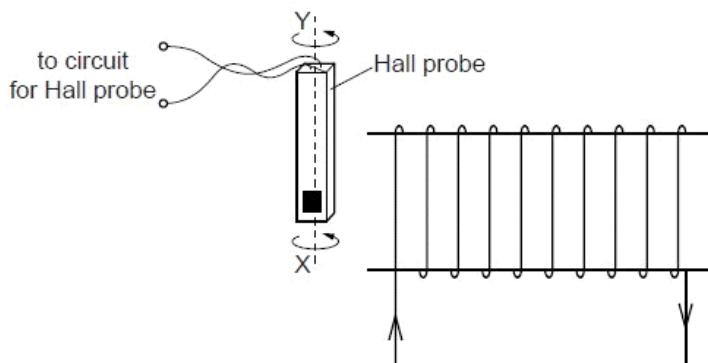


Fig. 5.2

The Hall probe is rotated about the axis XY. State and explain why the magnitude of the Hall voltage varies.

.....
.....
..... [2]

- (c) (i)** State Faraday's law of electromagnetic induction.

For
Examiner
Use

[2]

- (ii)** The Hall probe in **(b)** is replaced by a small coil of wire connected to a sensitive voltmeter.

State three different ways in which an e.m.f. may be induced in the coil.

1.

2.

3.

[3]

Q41.

- 6 A charged particle of mass m and charge $-q$ is travelling through a vacuum at constant speed v .

It enters a uniform magnetic field of flux density B . The initial angle between the direction of motion of the particle and the direction of the magnetic field is 90° .

- (a) Explain why the path of the particle in the magnetic field is the arc of a circle.

.....
.....
.....
.....

[3]

- (b) The radius of the arc in (a) is r .

Show that the ratio $\frac{q}{m}$ for the particle is given by the expression

$$\frac{q}{m} = \frac{v}{Br}.$$

[1]

- (c) The initial speed v of the particle is $2.0 \times 10^7 \text{ ms}^{-1}$. The magnetic flux density B is $2.5 \times 10^{-3} \text{ T}$.

The radius r of the arc in the magnetic field is 4.5 cm.

- (i) Use these data to calculate the ratio $\frac{q}{m}$.

ratio = C kg^{-1} [2]

- (ii) The path of the negatively-charged particle before it enters the magnetic field is shown in Fig. 6.1.

For
Examiner's
Use

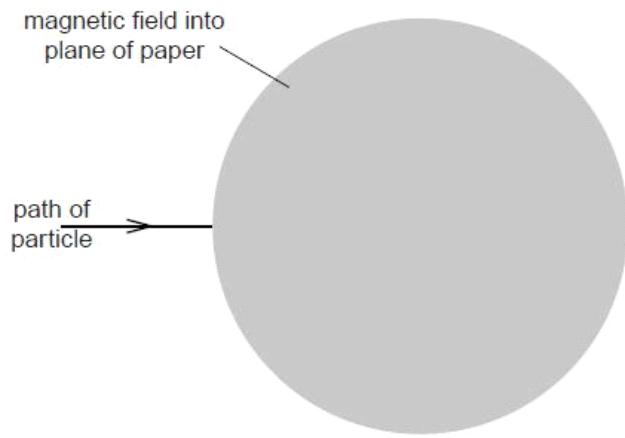


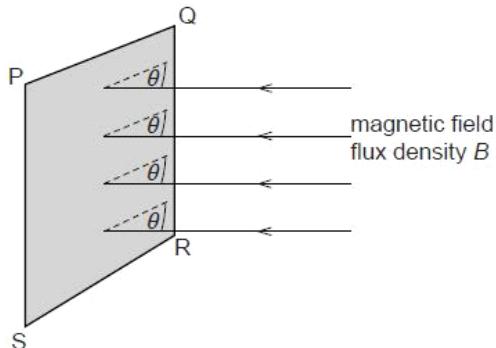
Fig. 6.1

The direction of the magnetic field is into the plane of the paper.

On Fig. 6.1, sketch the path of the particle in the magnetic field and as it emerges [2]

Q42.

- 5 A uniform magnetic field of flux density B makes an angle θ with a flat plane PQRS, as shown in Fig. 5.1.

**Fig. 5.1**

The plane PQRS has area A .

- (a) State

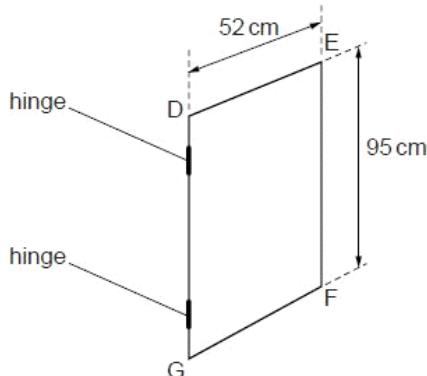
- (i) what is meant by a *magnetic field*,

..... [1]

- (ii) an expression, in terms of A , B and θ , for the magnetic flux Φ through the plane PQRS.

..... [1]

- (b) A vertical aluminium window frame DEFG has width 52 cm and length 95 cm, as shown in Fig. 5.2.

**Fig. 5.2**

The frame is hinged along the vertical edge DG.

The horizontal component B_H of the Earth's magnetic field is 1.8×10^{-5} T. For the closed window, the frame is normal to the horizontal component B_H .

The window is opened so that the plane of the window rotates through 90° .

- (i) Explain why, when the window is opened, the change in magnetic flux linkage due to the vertical component of the Earth's magnetic field is zero.

For
Examiner's
Use

..... [1]

- (ii) Calculate, for the window opening through an angle of 90° , the change in magnetic flux linkage.

change in flux linkage = Wb [2]

- (c) (i) State Faraday's law of electromagnetic induction.

.....
.....
..... [2]

- (ii) The window in (b) is opened in a time of 0.30 s.

Use your answer in (b)(ii) to calculate the average e.m.f. induced in the window frame.

e.m.f. = V [1]

- (iii) State the sides of the window frame between which the e.m.f. is induced.

between side and side [1]

Q43.

- 6** A particle has mass m and charge $+q$ and is travelling with speed v through a vacuum. The initial direction of travel is parallel to the plane of two charged horizontal metal plates, as shown in Fig. 6.1.

For
Examiner's
Use

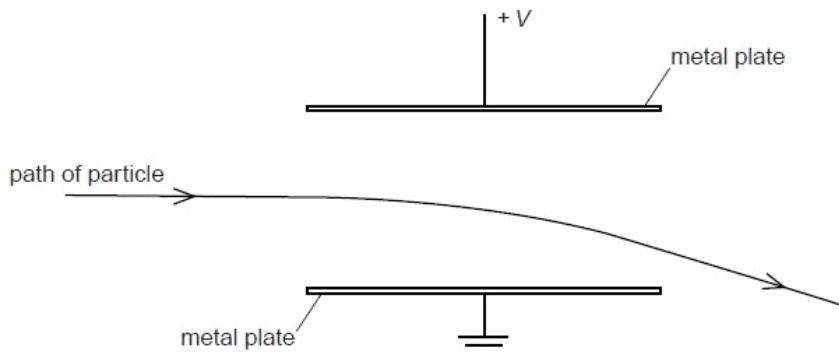


Fig. 6.1

The uniform electric field between the plates has magnitude $2.8 \times 10^4 \text{ V m}^{-1}$ and is zero outside the plates.

The particle passes between the plates and emerges beyond them, as illustrated in Fig. 6.1.

- (a) Explain why the path of the particle in the electric field is not an arc of a circle.

.....
.....
.....

[1]

- (b) A uniform magnetic field is now formed in the region between the metal plates. The magnetic field strength is adjusted so that the positively charged particle passes undeviated between the plates, as shown in Fig. 6.2.

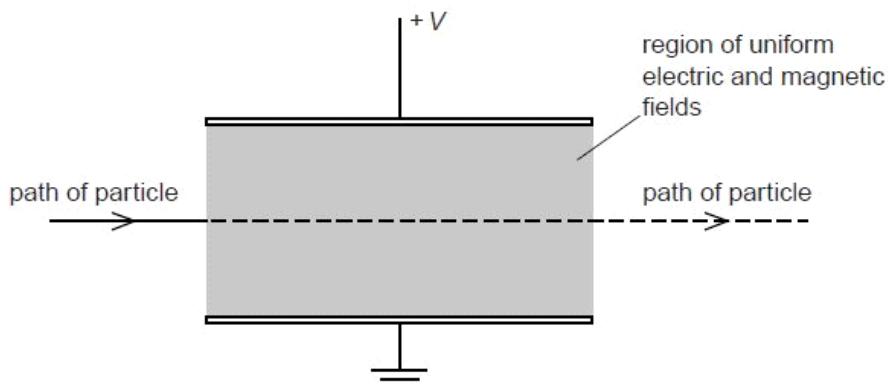


Fig. 6.2

- (i) State and explain the direction of the magnetic field.

.....
.....
.....

For
Examiner's
Use

[2]

- (ii) The particle has speed $4.7 \times 10^5 \text{ m s}^{-1}$.
Calculate the magnitude of the magnetic flux density.
Explain your working.

magnetic flux density = T [3]

- (c) The particle in (b) has mass m , charge $+q$ and speed v .
Without any further calculation, state the effect, if any, on the path of a particle that has

- (i) mass m , charge $-q$ and speed v ,

..... [1]

- (ii) mass m , charge $+q$ and speed $2v$,

..... [1]

- (iii) mass $2m$, charge $+q$ and speed v .

..... [1]

Q44.

- 7 A solenoid is connected in series with a battery and a switch. A Hall probe is placed close to one end of the solenoid, as illustrated in Fig. 7.1.

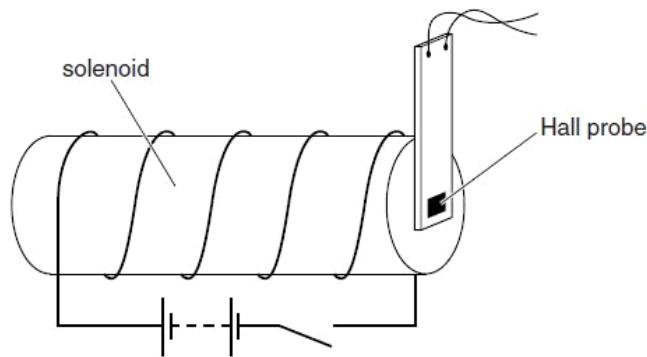


Fig. 7.1

The current in the solenoid is switched on. The Hall probe is adjusted in position to give the maximum reading. The current is then switched off.

- (a) The current in the solenoid is now switched on again. Several seconds later, it is switched off. The Hall probe is not moved.

On the axes of Fig. 7.2, sketch a graph to show the variation with time t of the Hall voltage V_H .

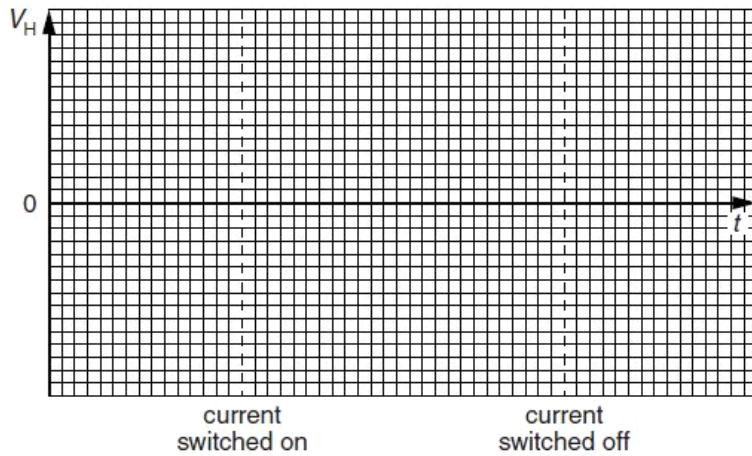


Fig. 7.2

[3]

- (b) The Hall probe is now replaced by a small coil. The plane of the coil is parallel to the end of the solenoid.

- (i) State Faraday's law of electromagnetic induction.

.....
.....
.....

[2]

- (ii) On the axes of Fig. 7.3, sketch a graph to show the variation with time t of the e.m.f. E induced in the coil when the current in the solenoid is switched on and then switched off.

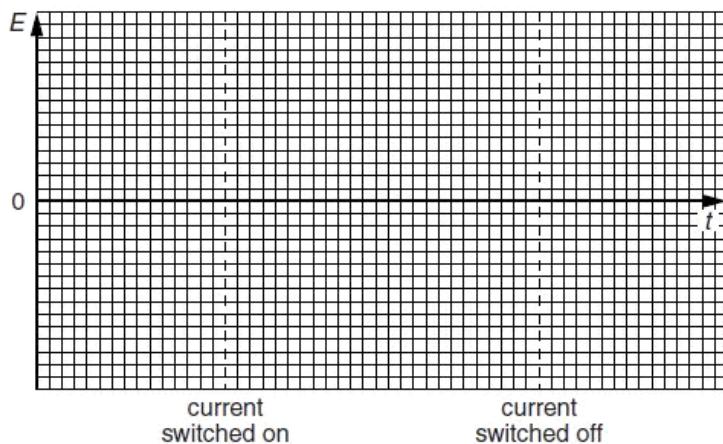


Fig. 7.3

[3]

Q45.

- 5 A Hall probe is placed a distance d from a long straight current-carrying wire, as illustrated in Fig. 5.1.

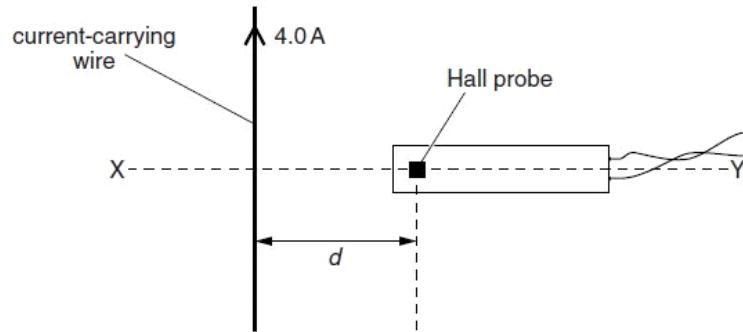


Fig. 5.1

The direct current in the wire is 4.0 A. Line XY is normal to the wire.

The Hall probe is rotated about the line XY to the position where the reading V_H of the Hall probe is maximum.

- (a) The Hall probe is now moved away from the wire, along the line XY.

On the axes of Fig. 5.2, sketch a graph to show the variation of the Hall voltage V_H with distance x of the probe from the wire. Numerical values are not required on your sketch.

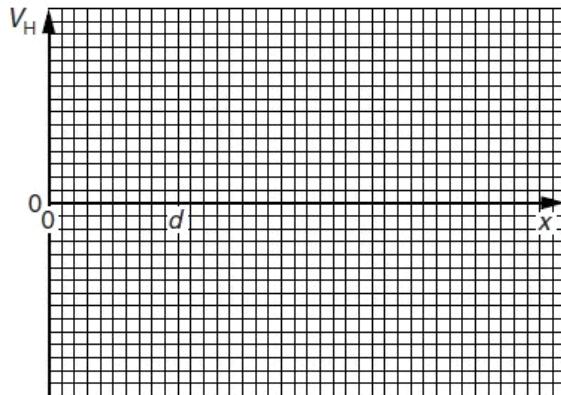


Fig. 5.2

[2]

- (b) The Hall probe is now returned to its original position, a distance d from the wire.
At this point, the magnetic flux density due to the current in the wire is proportional to the current.

For a direct current of 4.0 A in the wire, the reading of the Hall probe is 3.5 mV.
The direct current is now replaced by an alternating current of root-mean-square (r.m.s.) value 4.0 A. The period of this alternating current is T .

On the axes of Fig. 5.3, sketch the variation with time t of the reading of the Hall voltage V_H for two cycles of the alternating current. Give numerical values for V_H , where appropriate.

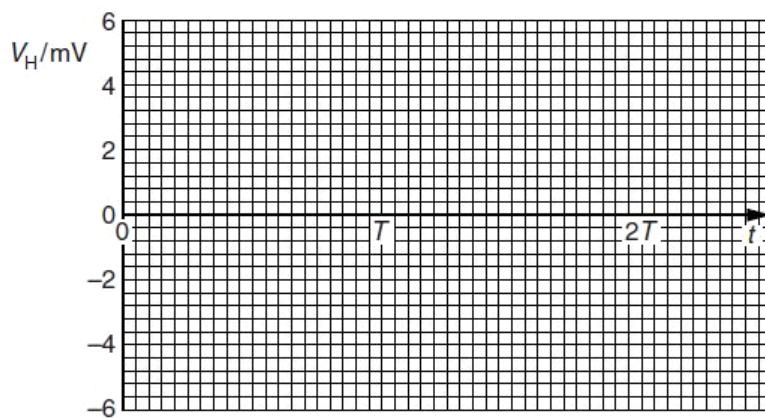


Fig.5.3

[3]

- (c) A student suggests that the Hall probe in (a) is replaced with a small coil connected in series with a millivoltmeter. The constant current in the wire is 4.0 A.
In order to obtain data to plot a graph showing the variation with distance x of the magnetic flux density, the student suggests that readings of the millivoltmeter are taken when the coil is held in position at different values of x .

Comment on this suggestion.

.....
.....
.....
..... [2]

Q46.

- 6 (a) Explain the use of a uniform electric field and a uniform magnetic field for the selection of the velocity of a charged particle. You may draw a diagram if you wish.

.....
.....
.....
..... [3]

- (b) Ions, all of the same isotope, are travelling in a vacuum with a speed of $9.6 \times 10^4 \text{ m s}^{-1}$. The ions are incident normally on a uniform magnetic field of flux density 640 mT. The ions follow semicircular paths A and B before reaching a detector, as shown in Fig. 6.1.

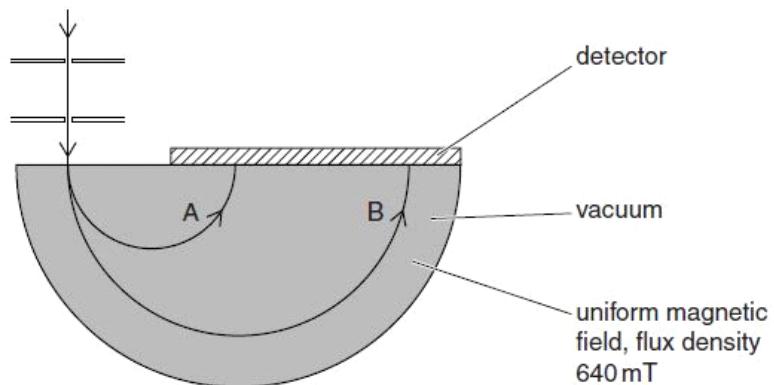


Fig. 6.1

Data for the diameters of the paths are shown in Fig. 6.2.

path	diameter/cm
A	6.2
B	12.4

Fig. 6.2

The ions in path B each have charge $+1.6 \times 10^{-19} \text{ C}$.

- (i) Determine the mass, in u, of the ions in path B.

mass = u [4]

- (ii) Suggest and explain quantitatively a reason for the difference in radii of the paths A and B of the ions.

.....
.....
.....
..... [3]

Q47.

- 6 A stiff straight copper wire XY is held fixed in a uniform magnetic field of flux density $2.6 \times 10^{-3} \text{ T}$, as shown in Fig. 6.1.

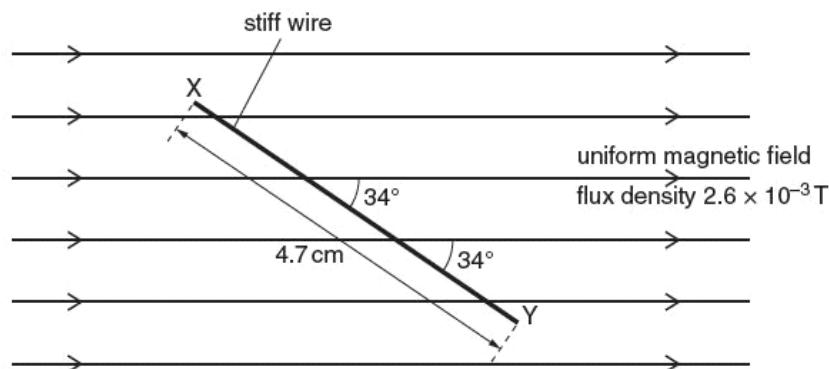


Fig. 6.1

The wire XY has length 4.7 cm and makes an angle of 34° with the magnetic field.

- (a) Calculate the force on the wire due to a constant current of 5.4 A in the wire.

force = N [2]

- (b) The current in the wire is now changed to an alternating current of r.m.s. value 1.7 A.

Determine the total variation in the force on the wire due to the alternating current.

variation in force = N [3]

