CAMBRIDGE INTERNATIONAL AS & A LEVEL PHYSICS · 9702

PHYSICS



EXAM QUESTION PACK

20 MAGNETIC FIELDS

SCORE	PERCENTAGE
/	%

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Chapter 13

Electromagnetic induction

STEMUP.CO.UK

293. 9702_m21_qp_42 Q: 9

(a) Define *magnetic flux linkage*.

.....

.....

..... [2]

(b) A solenoid of diameter 6.0 cm and 540 turns is placed in a uniform magnetic field as shown in Fig. 9.1.

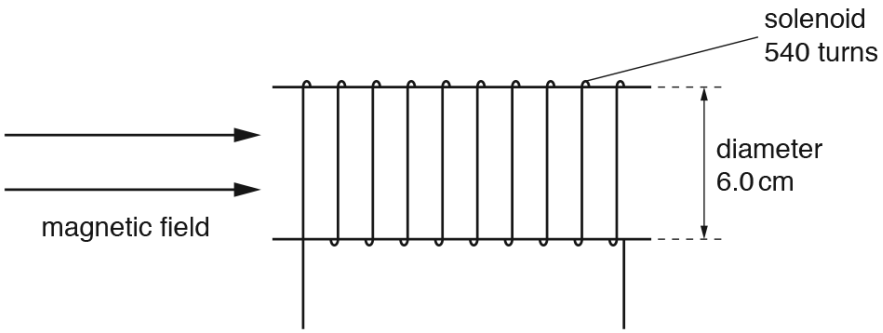


Fig. 9.1

The variation with time *t* of the magnetic flux density is shown in Fig. 9.2.

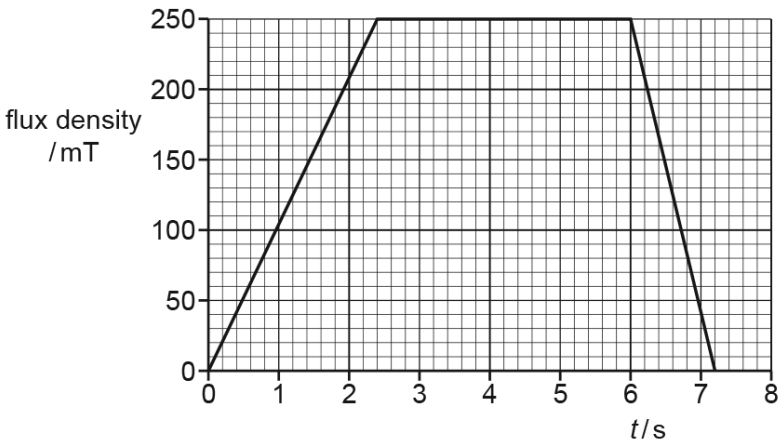


Fig. 9.2

Calculate the maximum magnitude of the induced electromotive force (e.m.f.) in the solenoid.

e.m.f. = ... V [3]

(c) A thin copper sheet X is supported on a rigid rod so that it hangs between the poles of a magnet as shown in Fig. 9.3.

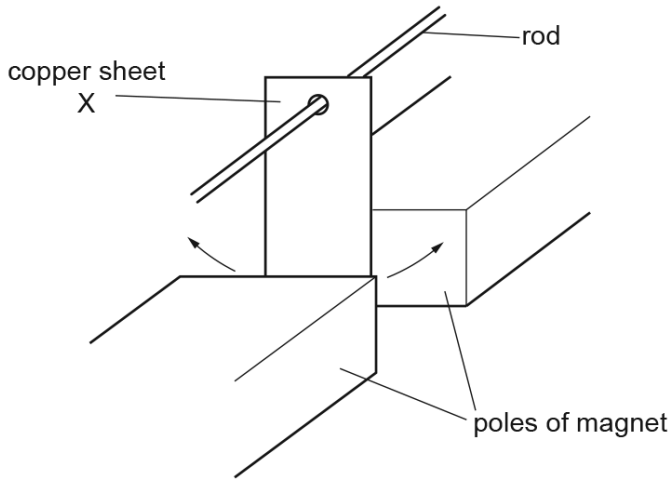


Fig. 9.3

Sheet X is displaced to one side and then released so that it oscillates. A motion sensor is used to record the displacement of X.

A second thin copper sheet Y replaces sheet X. Sheet Y has the same overall dimensions as X but is cut into the shape shown in Fig. 9.4.

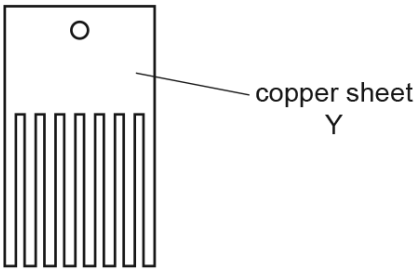


Fig. 9.4

The motion sensor is again used to record the displacement.

The graph in Fig. 9.5 shows the variation with time *t* of the displacement *s* of each copper sheet.

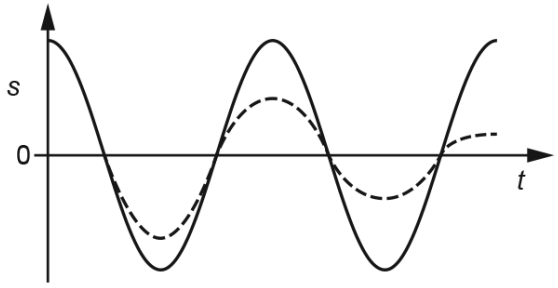


Fig. 9.5

(i) State the name of the phenomenon illustrated by the gradual reduction in the amplitude of the dashed line.

..... [1]

(ii) Deduce which copper sheet is represented by the dashed line. Explain your answer using the principles of electromagnetic induction.

.....

.....

.....

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.....

..... [4]

[Total: 10]

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294. 9702_s21_qp_41 Q: 10

(a) State Lenz's law.

.....

.....

..... [2]

(b) A metal ring is suspended from a fixed point P by means of a thread, as shown in Fig. 10.1.

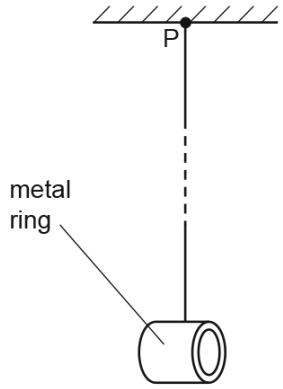


Fig. 10.1

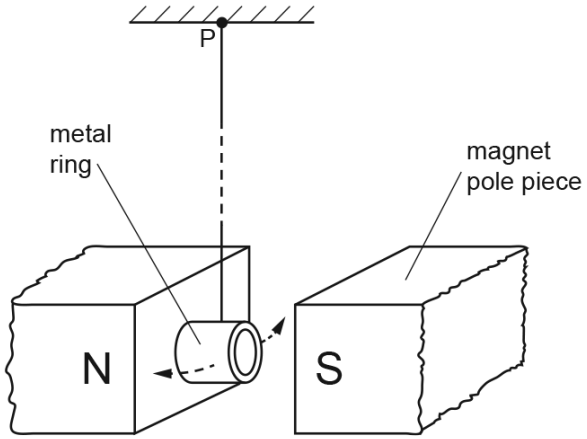


Fig. 10.2

The ring is displaced a distance *d* and then released. The ring completes many oscillations before coming to rest.

The poles of a magnet are now placed near to the ring so that the ring hangs midway between the poles of the magnet, as shown in Fig. 10.2.

The ring is again displaced a distance *d* and then released.
Explain why the ring completes fewer oscillations before coming to rest.

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..... [4]

(c) The ring in **(b)** is now cut so that it has the shape shown in Fig. 10.3.



Fig. 10.3

Explain why, when the procedure in **(b)** is repeated, the cut ring completes more oscillations than the complete ring when oscillating between the poles of the magnet.

.....

.....

.....

.....

..... [3]

[Total: 9]

295. 9702_s21_qp_42 Q: 9

(a) State **two** situations in which a charged particle in a magnetic field does **not** experience a force.

1. .....

.....

2. .....

.....

[2]

(b) A loosely coiled metal spring is suspended from a fixed point, as shown in Fig. 9.1.

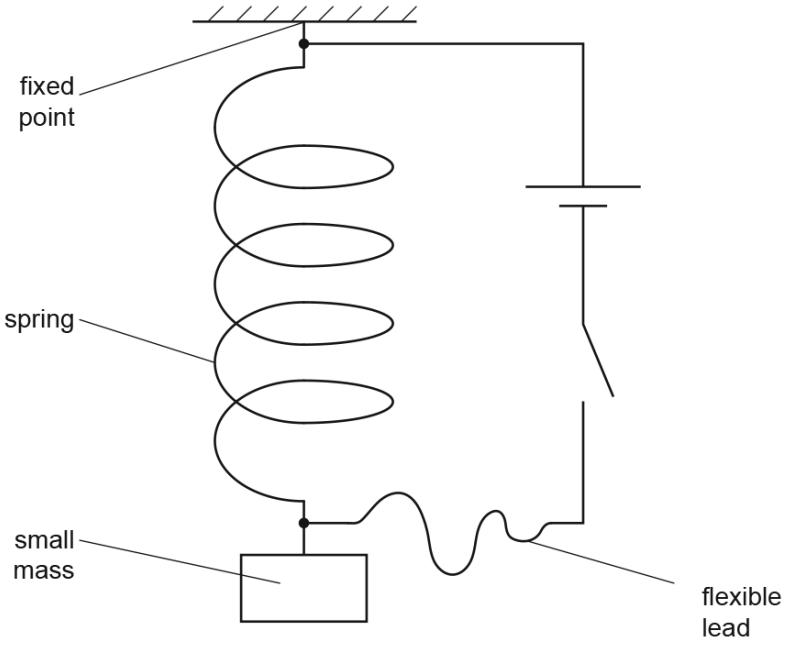


Fig. 9.1

Electrical connections are made to the ends of the spring by means of a flexible lead.

The length of the spring is measured before the switch is closed and then again after the switch is closed.

When the switch is closed, a magnetic field is set up around each coil of the spring.

By reference to these magnetic fields, explain why there is a change in length of the spring. State whether the spring extends or contracts.

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..... [4]

(c) With the switch in **(b)** closed, the small mass on the free end of the spring is now made to oscillate vertically.

Use the principles of electromagnetic induction to explain why small fluctuations in the current in the spring are found to occur.

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..... [3]

[Total: 9]

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296. 9702_s21_qp_43 Q: 10

(a) State Lenz's law.

.....

.....

..... [2]

(b) A metal ring is suspended from a fixed point P by means of a thread, as shown in Fig. 10.1.

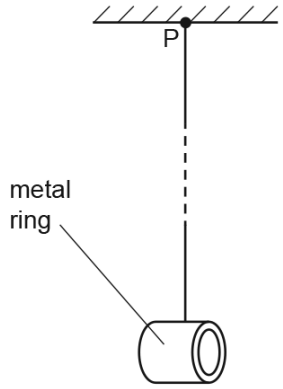


Fig. 10.1

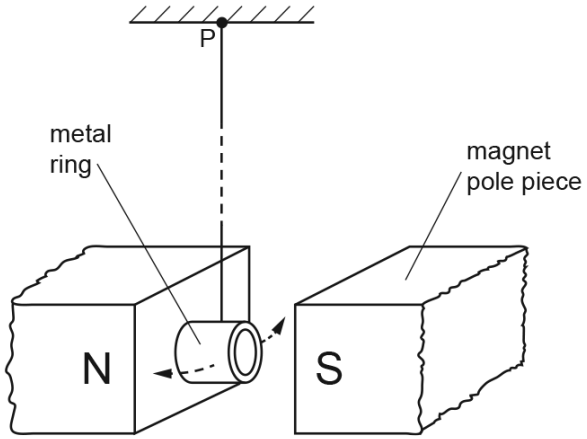


Fig. 10.2

The ring is displaced a distance *d* and then released. The ring completes many oscillations before coming to rest.

The poles of a magnet are now placed near to the ring so that the ring hangs midway between the poles of the magnet, as shown in Fig. 10.2.

The ring is again displaced a distance *d* and then released.
Explain why the ring completes fewer oscillations before coming to rest.

.....

.....

.....

.....

.....

..... [4]

(c) The ring in **(b)** is now cut so that it has the shape shown in Fig. 10.3.



Fig. 10.3

Explain why, when the procedure in **(b)** is repeated, the cut ring completes more oscillations than the complete ring when oscillating between the poles of the magnet.

.....

.....

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.....

..... [3]

[Total: 9]

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297. 9702_m20_qp_42 Q: 3

(a) A body undergoes simple harmonic motion.

The variation with displacement x of its velocity v is shown in Fig. 3.1.

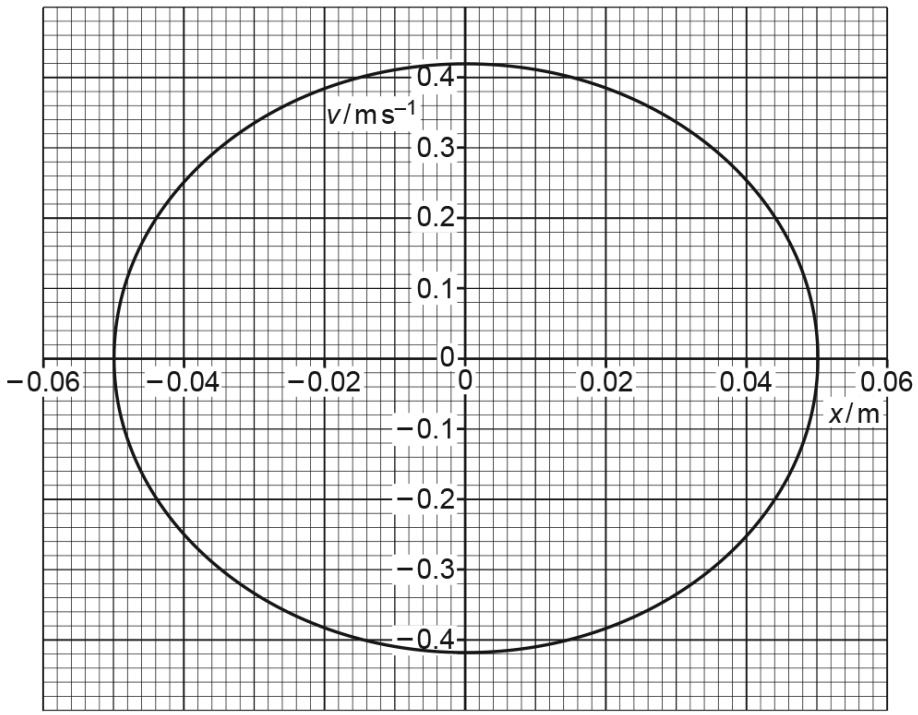


Fig. 3.1

(i) State the amplitude x_o of the oscillations.

x_o = ... m [1]

(ii) Calculate the period T of the oscillations.

T = ... s [3]

(iii) On Fig. 3.1, label with a P a point where the body has **maximum** potential energy. [1]

(b) A bar magnet is suspended from the free end of a spring, as shown in Fig. 3.2.

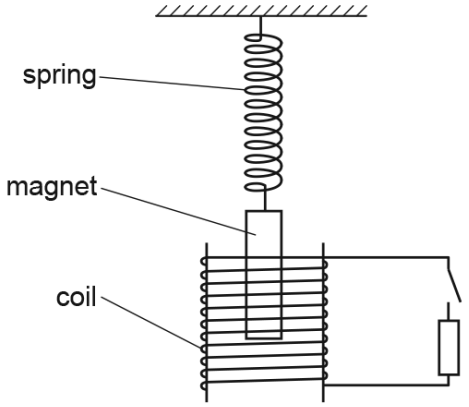


Fig. 3.2

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. The magnet oscillates with simple harmonic motion.

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

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..... [2]

(ii) The switch is now closed. Explain why the oscillations of the magnet are damped.

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..... [3]

[Total: 10]

298. 9702_s20_qp_41 Q: 9

(a) A coil of wire is situated in a uniform magnetic field of flux density *B*.
The coil has diameter 3.6 cm and consists of 350 turns of wire, as illustrated in Fig. 9.1.

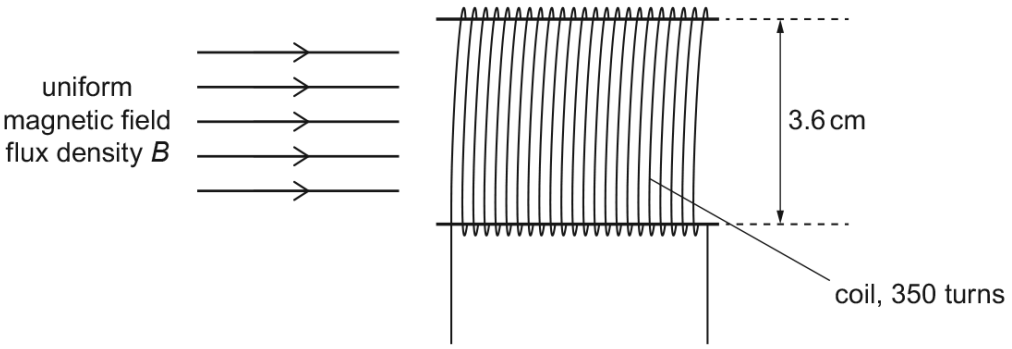


Fig. 9.1

The variation with time t of B is shown in Fig. 9.2.

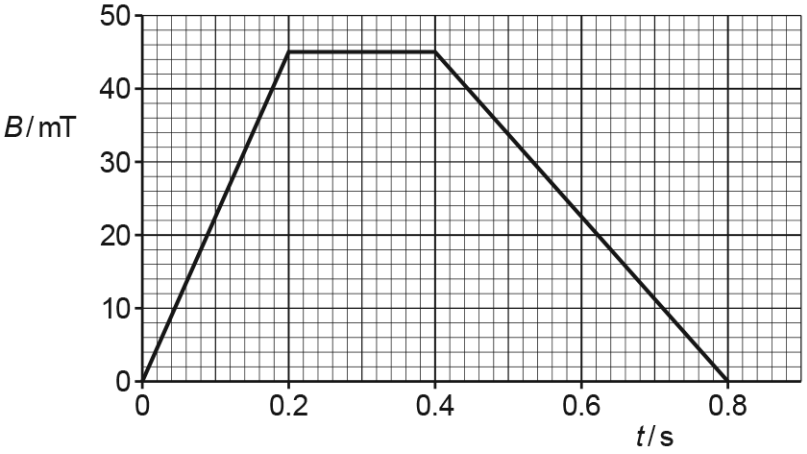


Fig. 9.2

(i) Show that, for the time $t = 0$ to time $t = 0.20\,s$, the electromotive force (e.m.f.) induced in the coil is 0.080 V.

[2]

(ii) On the axes of Fig. 9.3, show the variation with time t of the induced e.m.f. E for time $t = 0$ to time $t = 0.80\,s$.

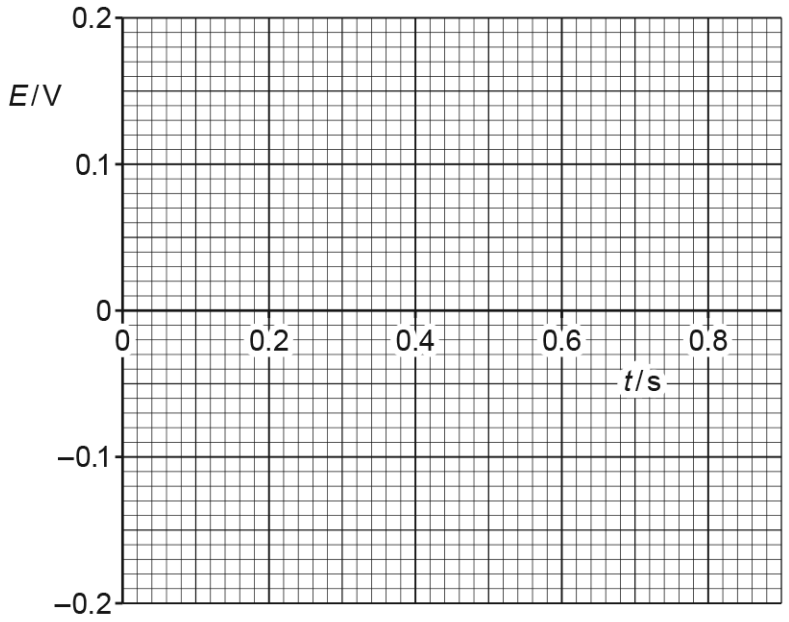


Fig. 9.3

[4]

(b) A bar magnet is held a small distance above the surface of an aluminium disc by means of a rod, as illustrated in Fig. 9.4.

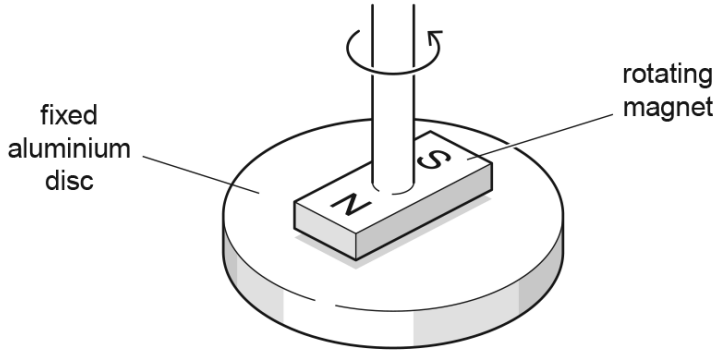


Fig. 9.4

The aluminium disc is supported horizontally and held stationary.

The magnet is rotated about a vertical axis at constant speed.

Use laws of electromagnetic induction to explain why there is a torque acting on the aluminium disc.

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.....

.....

.....

.....

..... [4]

[Total: 10]

299. 9702_s20_qp_43 Q: 9

(a) A coil of wire is situated in a uniform magnetic field of flux density B.
The coil has diameter 3.6 cm and consists of 350 turns of wire, as illustrated in Fig. 9.1.

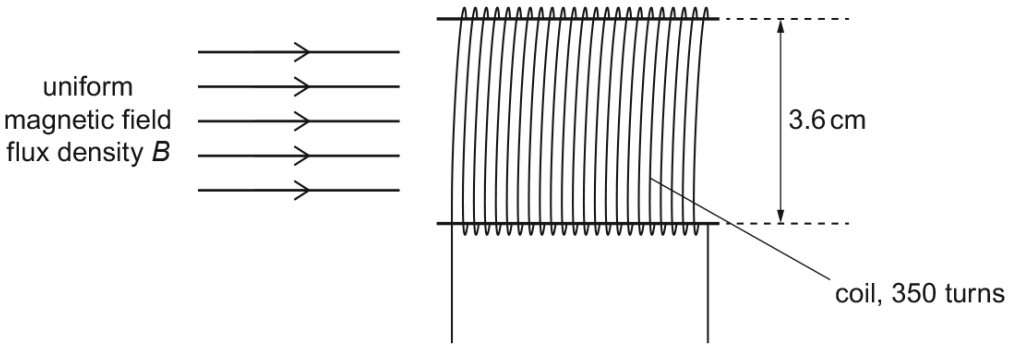


Fig. 9.1

The variation with time t of B is shown in Fig. 9.2.

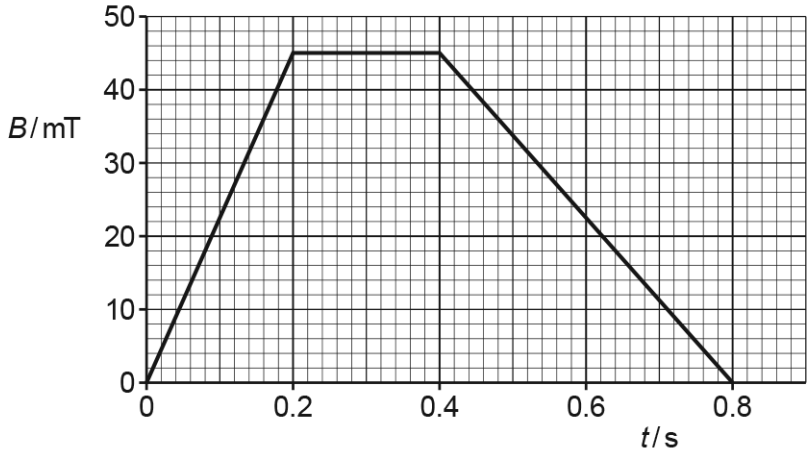


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[2]

(ii) On the axes of Fig. 9.3, show the variation with time t of the induced e.m.f. E for time $t = 0$ to time $t = 0.80\,s$.

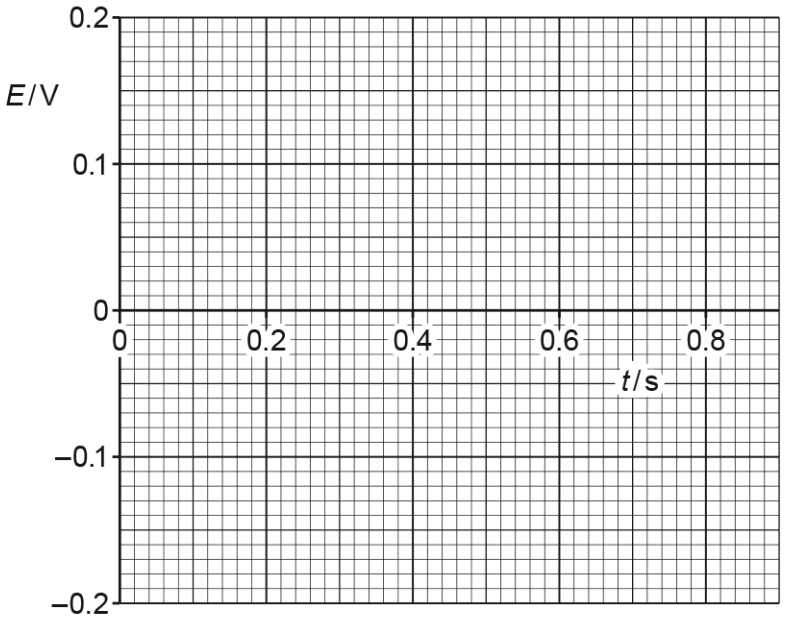


Fig. 9.3

[4]

(b) A bar magnet is held a small distance above the surface of an aluminium disc by means of a rod, as illustrated in Fig. 9.4.

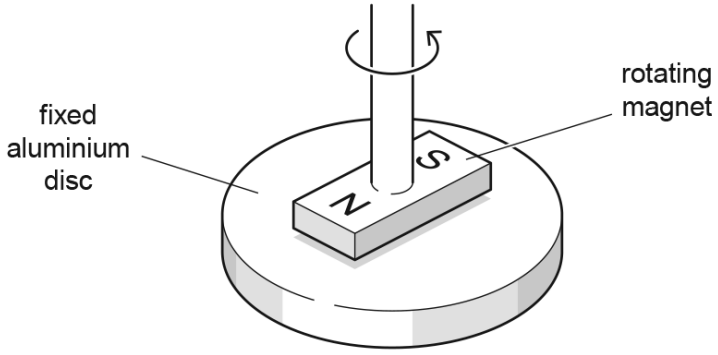


Fig. 9.4

The aluminium disc is supported horizontally and held stationary.

The magnet is rotated about a vertical axis at constant speed.

Use laws of electromagnetic induction to explain why there is a torque acting on the aluminium disc.

.....

.....

.....

.....

.....

..... [4]

[Total: 10]

300. 9702_m19_qp_42 Q: 10

(a) A cross-section through a current-carrying solenoid is shown in Fig. 10.1.

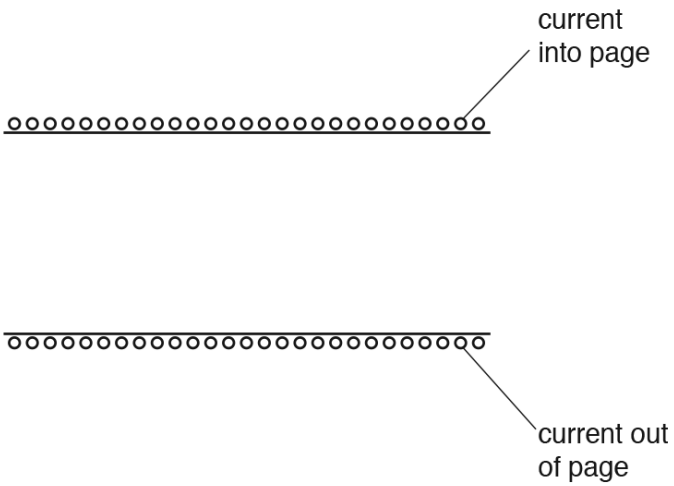


Fig. 10.1

On Fig. 10.1, draw field lines to represent the magnetic field inside the solenoid. [3]

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

.....

.....

..... [2]

(c) A coil of insulated wire is wound on to a soft-iron core.

The coil is connected in series with a battery, a switch and an ammeter, as shown in Fig. 10.2.

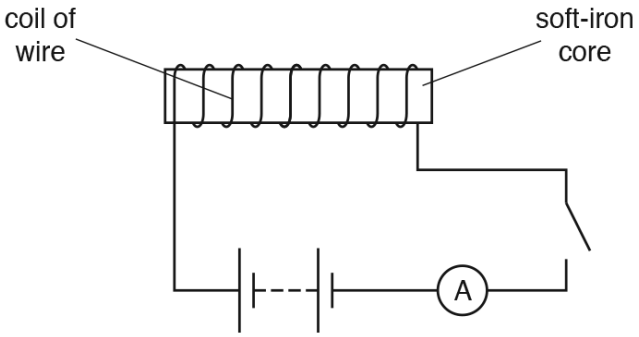


Fig. 10.2

Use laws of electromagnetic induction to explain why, when the switch is closed, the current increases **gradually** to its maximum value.

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.....

..... [3]

[Total: 8]

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301. 9702_s19_qp_41 Q: 8

A solenoid is connected in series with a battery and a switch, as illustrated in Fig. 8.1.

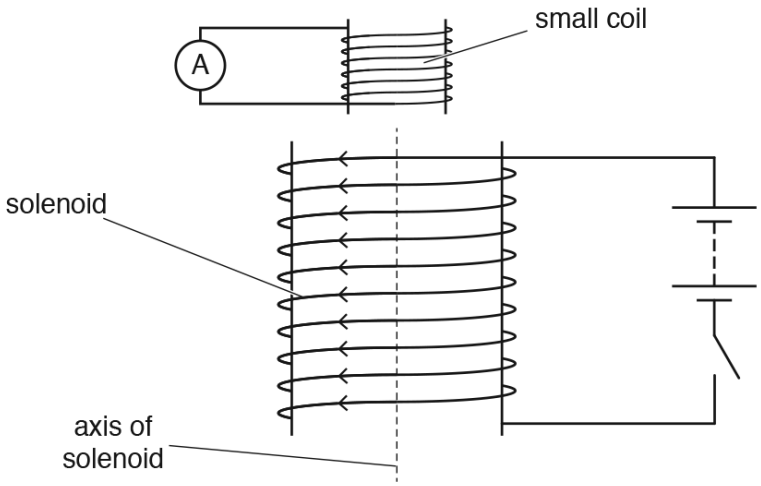


Fig. 8.1

A small coil, connected to a sensitive ammeter, is situated near one end of the solenoid.

As the current in the solenoid is switched on, there is a changing magnetic field inside the solenoid.

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

.....

..... [1]

(ii) On Fig. 8.1, draw an arrow on the axis of the solenoid to show the direction of the magnetic field inside the solenoid. Label this arrow P. [1]

(b) As the current in the solenoid is switched on, there is a current induced in the small coil. This induced current gives rise to a magnetic field in the small coil.

(i) State Lenz's law.

.....

.....

..... [2]

(ii) Use Lenz's law to state and explain the direction of the magnetic field due to the induced current in the small coil. On Fig. 8.1, mark this direction with an arrow inside the small coil.

.....

.....

.....

..... [3]

(c) The small coil has an area of cross-section $7.0 \times 10^{-4}\,m^2$ and contains 75 turns of wire.

A constant current in the solenoid produces a uniform magnetic flux of flux density 1.4 mT throughout the small coil.

The direction of the current in the solenoid is reversed in a time of 0.12 s.

Calculate the average e.m.f. induced in the small coil.

e.m.f. = ...V [3]

[Total: 10]

302. 9702_s19_qp_43 Q: 8

A solenoid is connected in series with a battery and a switch, as illustrated in Fig. 8.1.

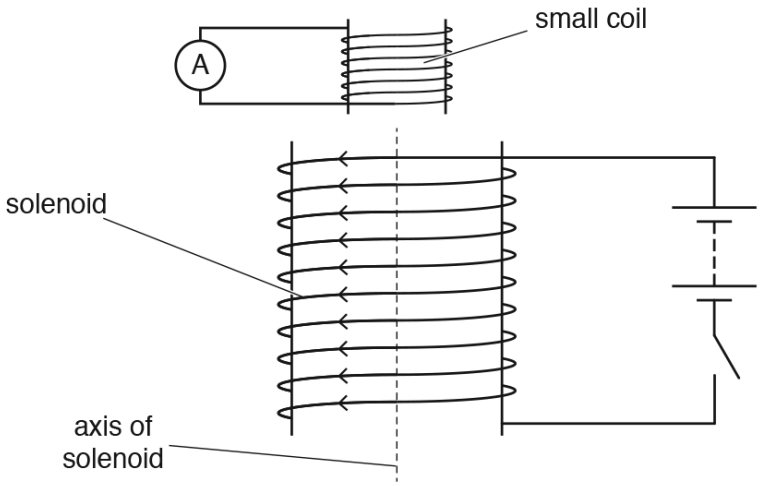


Fig. 8.1

A small coil, connected to a sensitive ammeter, is situated near one end of the solenoid.

As the current in the solenoid is switched on, there is a changing magnetic field inside the solenoid.

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

.....

..... [1]

(ii) On Fig. 8.1, draw an arrow on the axis of the solenoid to show the direction of the magnetic field inside the solenoid. Label this arrow P. [1]

(b) As the current in the solenoid is switched on, there is a current induced in the small coil. This induced current gives rise to a magnetic field in the small coil.

(i) State Lenz's law.

.....

.....

..... [2]

(ii) Use Lenz's law to state and explain the direction of the magnetic field due to the induced current in the small coil. On Fig. 8.1, mark this direction with an arrow inside the small coil.

.....

.....

.....

..... [3]

(c) The small coil has an area of cross-section $7.0 \times 10^{-4}\,m^2$ and contains 75 turns of wire.

A constant current in the solenoid produces a uniform magnetic flux of flux density 1.4 mT throughout the small coil.

The direction of the current in the solenoid is reversed in a time of 0.12 s.

Calculate the average e.m.f. induced in the small coil.

e.m.f. = ...V [3]

[Total: 10]

303. 9702_m18_qp_42 Q: 10

(a) (i) Define *magnetic flux*.

.....

.....

.....[2]

(ii) State Faraday's law of electromagnetic induction.

.....

.....

.....

.....[2]

(b) A solenoid has a coil C of wire wound tightly about its centre, as shown in Fig. 10.1.

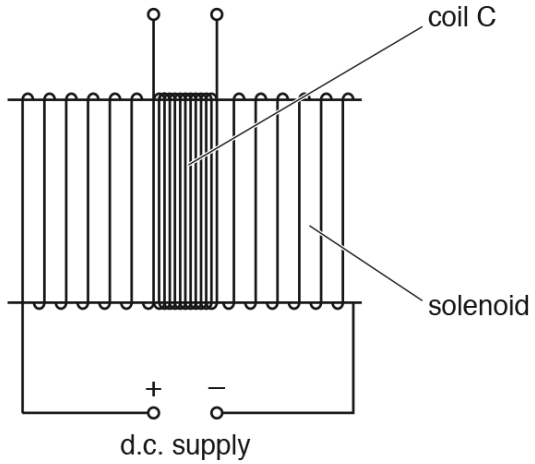


Fig. 10.1

The coil C has 96 turns.

The uniform magnetic flux Φ (in weber) in the solenoid is given by the expression

$$\Phi = 6.8 \times 10^{-6} \times I$$

where I is the current (in amperes) in the solenoid.

Calculate the average electromotive force (e.m.f.) induced in coil C when a current of 3.5 A is reversed in the solenoid in a time of 2.4 ms.

e.m.f. = ... V [2]

(c) The d.c. supply in Fig. 10.1 is now replaced with a sinusoidal alternating supply.

Describe qualitatively the e.m.f. that is now induced in coil C.

.....

.....

.....[2]

[Total: 8]

304. 9702_s18_qp_41 Q: 10

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

.....

.....

.....

.....[2]

(b) A coil of insulated wire is wound on to one end of a ferrous core and connected to a battery, as shown in Fig. 10.1.

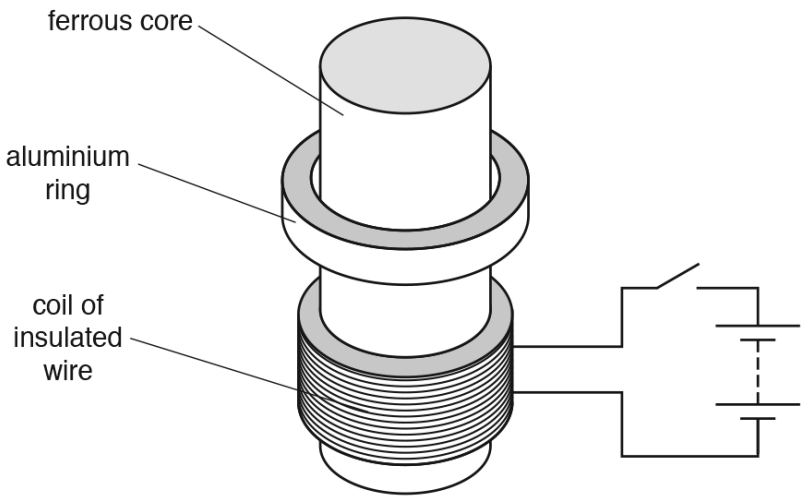


Fig. 10.1

An aluminium ring is placed on the core. The ring can move freely along the length of the core.

The switch is initially open.

Use Faraday's law and Lenz's law to explain why the aluminium ring jumps upwards when the switch is closed.

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.....[4]

[Total: 6]

305. 9702_s18_qp_42 Q: 9

(a) State what is meant by the *magnetic flux linkage* of a coil.

.....

.....

.....

.....[3]

(b) A coil of wire has 160 turns and diameter 2.4 cm. The coil is situated in a uniform magnetic field of flux density 7.5 mT, as shown in Fig. 9.1.

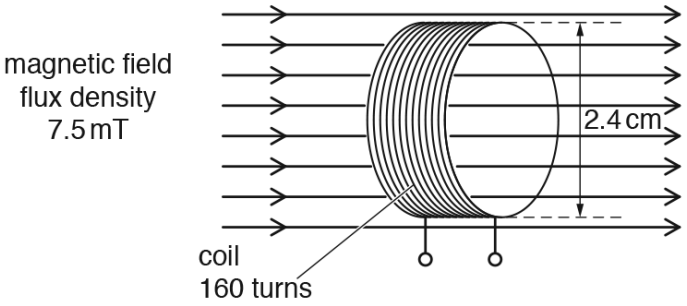


Fig. 9.1

The direction of the magnetic field is along the axis of the coil.

The magnetic flux density is reduced to zero in a time of 0.15 s.

Show that the average e.m.f. induced in the coil is 3.6 mV.

[2]

The magnetic flux density B in the coil in **(b)** is now varied with time t as shown in Fig. 9.2.

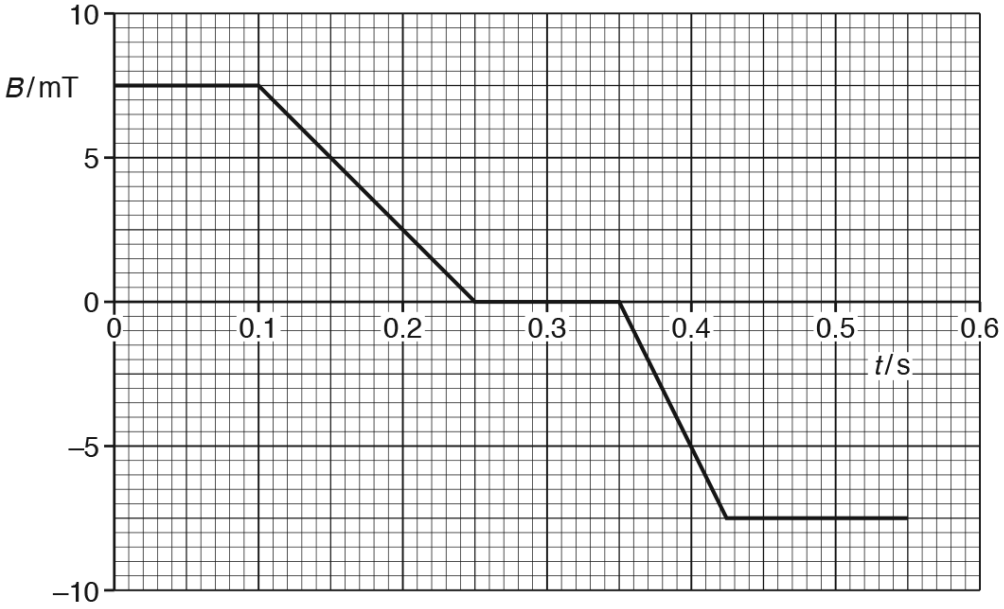


Fig. 9.2

Use data in **(b)** to show, on Fig. 9.3, the variation with time t of the e.m.f. E induced in the coil.

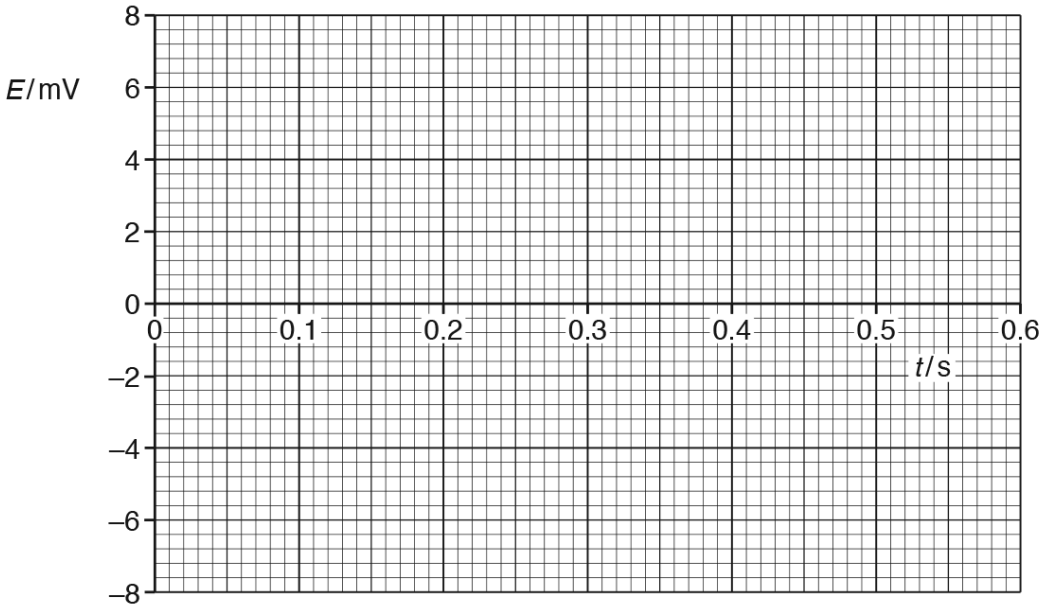


Fig. 9.3

[4]

[Total: 9]

306. 9702_s18_qp_43 Q: 10

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

.....

.....

.....

.....[2]

(b) A coil of insulated wire is wound on to one end of a ferrous core and connected to a battery, as shown in Fig. 10.1.

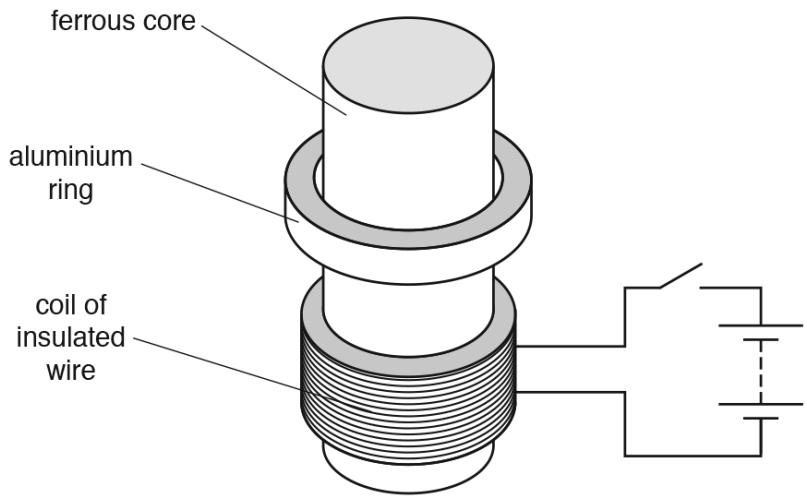


Fig. 10.1

An aluminium ring is placed on the core. The ring can move freely along the length of the core.

The switch is initially open.

Use Faraday's law and Lenz's law to explain why the aluminium ring jumps upwards when the switch is closed.

.....

.....

.....

.....

.....

.....

.....[4]

[Total: 6]

307. 9702_w18_qp_41 Q: 9

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

.....

.....

.....[2]

(b) A solenoid S is wound on a soft-iron core, as shown in Fig. 9.1.

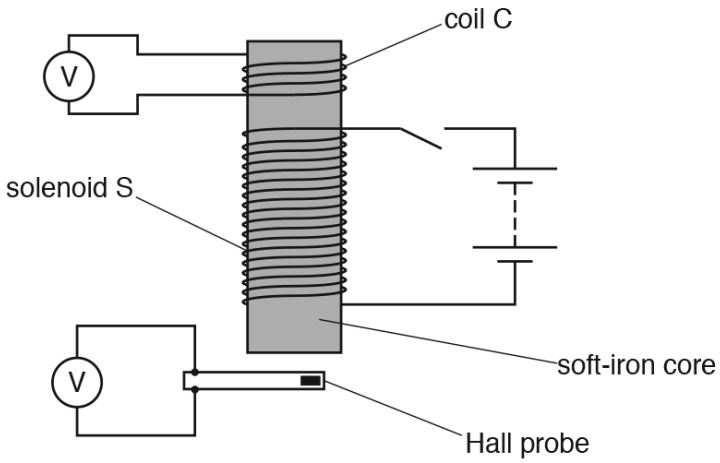


Fig. 9.1

A coil C having 120 turns of wire is wound on to one end of the core. The area of cross-section of coil C is 1.5 cm^2.

A Hall probe is close to the other end of the core.

When there is a constant current in solenoid S, the flux density in the core is 0.19 T. The reading on the voltmeter connected to the Hall probe is 0.20 V.

The current in solenoid S is now reversed in a time of 0.13 s at a constant rate.

(i) Calculate the reading on the voltmeter connected to coil C during the time that the current is changing.

reading = ... V [2]

(ii) Complete Fig. 9.2 for the voltmeter readings for the times before, during and after the direction of the current is reversed.

	before current changes	during current change when current is zero	after current changes
reading on voltmeter connected to coil C/V	.....	.....	.....
reading on voltmeter connected to Hall probe/V	0.20	.....	.....

Fig. 9.2

[4]

[Total: 8]

308. 9702_w18_qp_42 Q: 9

(a) A Hall probe is placed near one end of a solenoid that has been wound on a soft-iron core, as shown in Fig. 9.1.

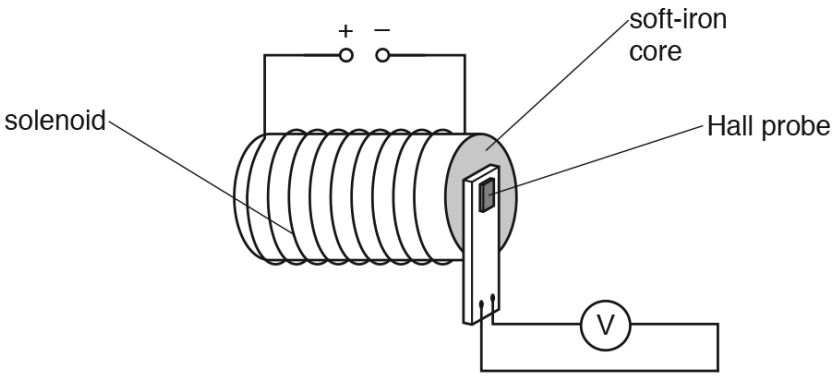


Fig. 9.1

The current in the solenoid is switched on.
The Hall probe is rotated until the reading V_H on the voltmeter is maximum.

The current in the solenoid is then varied, causing the magnetic flux density to change.
The variation with time t of the magnetic flux density B at the Hall probe is shown in Fig. 9.2.

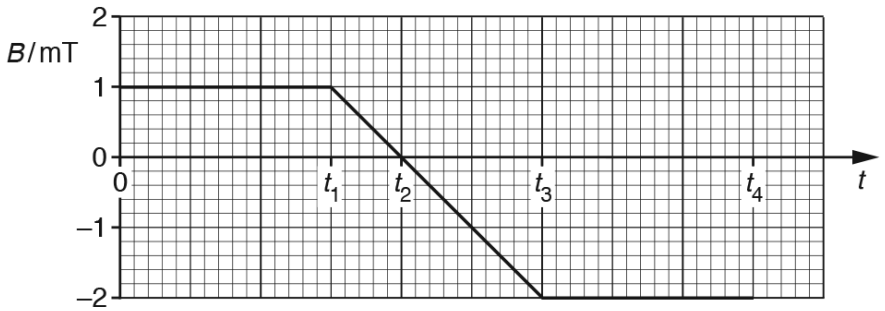


Fig. 9.2

At time $t = 0$, the Hall voltage is V_0.
On Fig. 9.3, draw a line to show the variation with time t of the Hall voltage V_H for time $t = 0$ to time $t = t_4$.

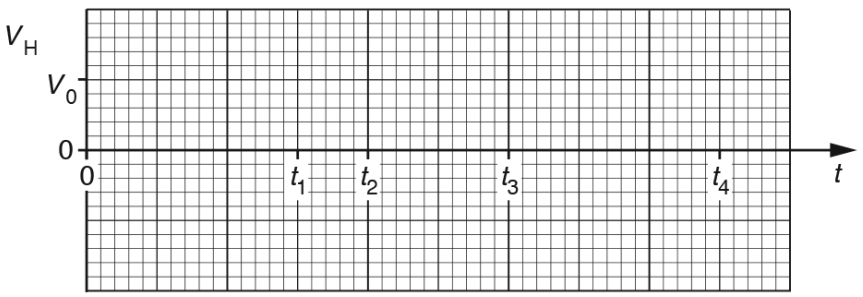


Fig. 9.3

[2]

(b) The Hall probe in **(a)** is now replaced by a small coil of wire connected to a sensitive voltmeter, as shown in Fig. 9.4.

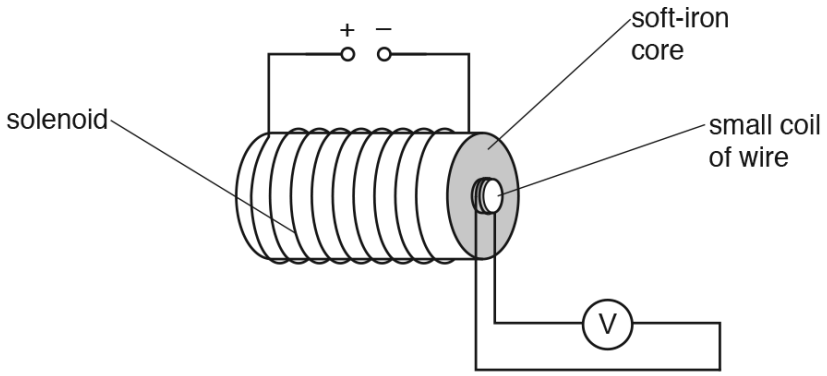


Fig. 9.4

The magnetic flux density, normal to the plane of the small coil, is again varied as shown in Fig. 9.2.

On Fig. 9.5, draw a line to show the variation with time t of the e.m.f. E induced in the small coil for time $t = 0$ to time $t = t_4$.

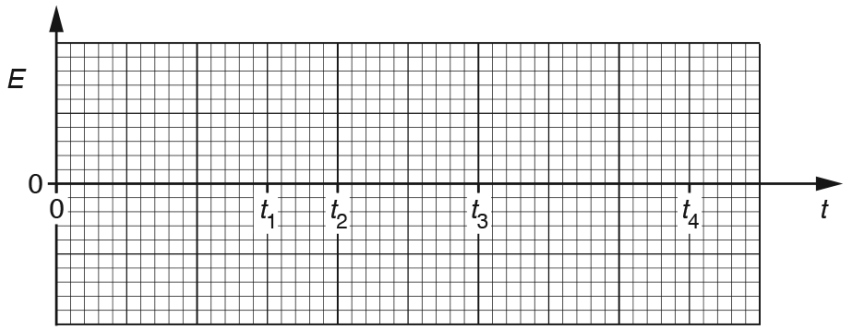


Fig. 9.5

[3]

[Total: 5]

309. 9702_w18_qp_43 Q: 9

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

.....

.....

.....[2]

(b) A solenoid S is wound on a soft-iron core, as shown in Fig. 9.1.

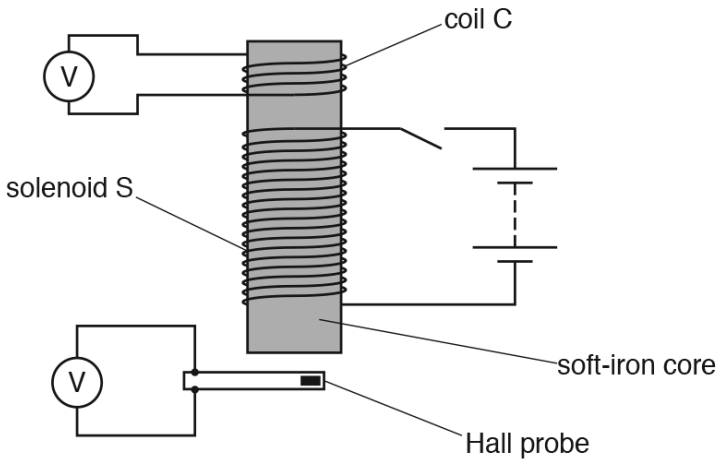


Fig. 9.1

A coil C having 120 turns of wire is wound on to one end of the core. The area of cross-section of coil C is 1.5 cm^2.

A Hall probe is close to the other end of the core.

When there is a constant current in solenoid S, the flux density in the core is 0.19 T. The reading on the voltmeter connected to the Hall probe is 0.20 V.

The current in solenoid S is now reversed in a time of 0.13 s at a constant rate.

(i) Calculate the reading on the voltmeter connected to coil C during the time that the current is changing.

reading = ... V [2]

(ii) Complete Fig. 9.2 for the voltmeter readings for the times before, during and after the direction of the current is reversed.

	before current changes	during current change when current is zero	after current changes
reading on voltmeter connected to coil C/V	.....	.....	.....
reading on voltmeter connected to Hall probe/V	0.20	.....	.....

Fig. 9.2

[4]

[Total: 8]

---

310. 9702_s17_qp_42 Q: 3

A bar magnet of mass 250 g is suspended from the free end of a spring, as illustrated in Fig. 3.1.

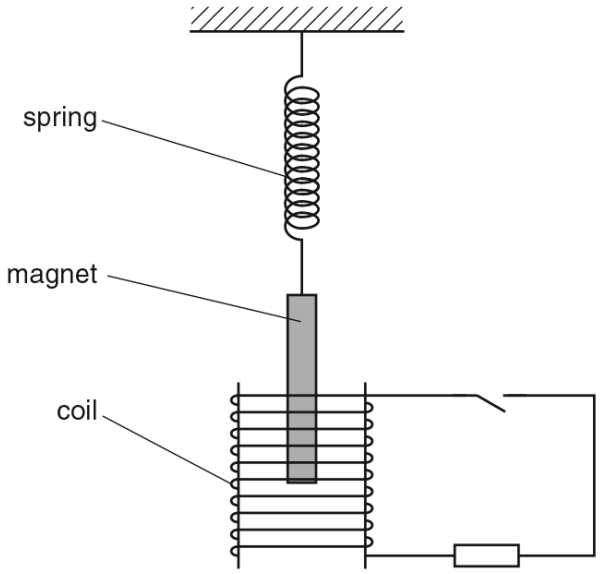


Fig. 3.1

The magnet hangs so that one pole is near the centre of a coil of wire.

The coil is connected in series with a resistor and a switch. The switch is open.

The magnet is displaced vertically and then allowed to oscillate with one pole remaining inside the coil. The other pole remains outside the coil.

At time $t = 0$, the magnet is oscillating freely as it passes through its equilibrium position. At time $t = 6.0$ s, the switch in the circuit is closed.

The variation with time t of the vertical displacement y of the magnet is shown in Fig. 3.2.

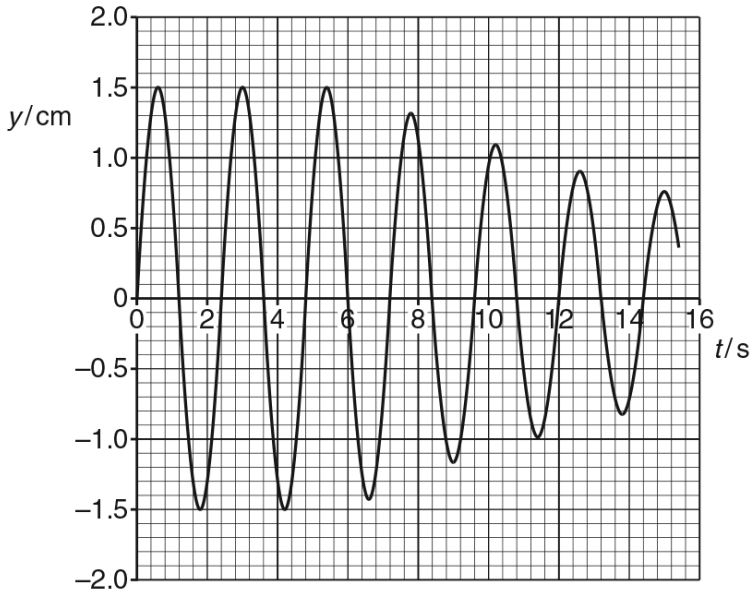


Fig. 3.2

(a) For the oscillating magnet, use data from Fig. 3.2 to calculate, to two significant figures,

(i) the frequency f,

$f =$ ..... Hz [2]

(ii) the energy of the oscillations during the time $t = 0$ to time $t = 6.0\,s$.

energy = ... J [3]

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

.....

.....

.....

.....[2]

(ii) Use Faraday's law and energy conservation to explain why the amplitude of the oscillations of the magnet reduces after time $t = 6.0\,s$.

.....

.....

.....

.....

.....

.....[3]

[Total: 10]

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311. 9702_w17_qp_41 Q: 5

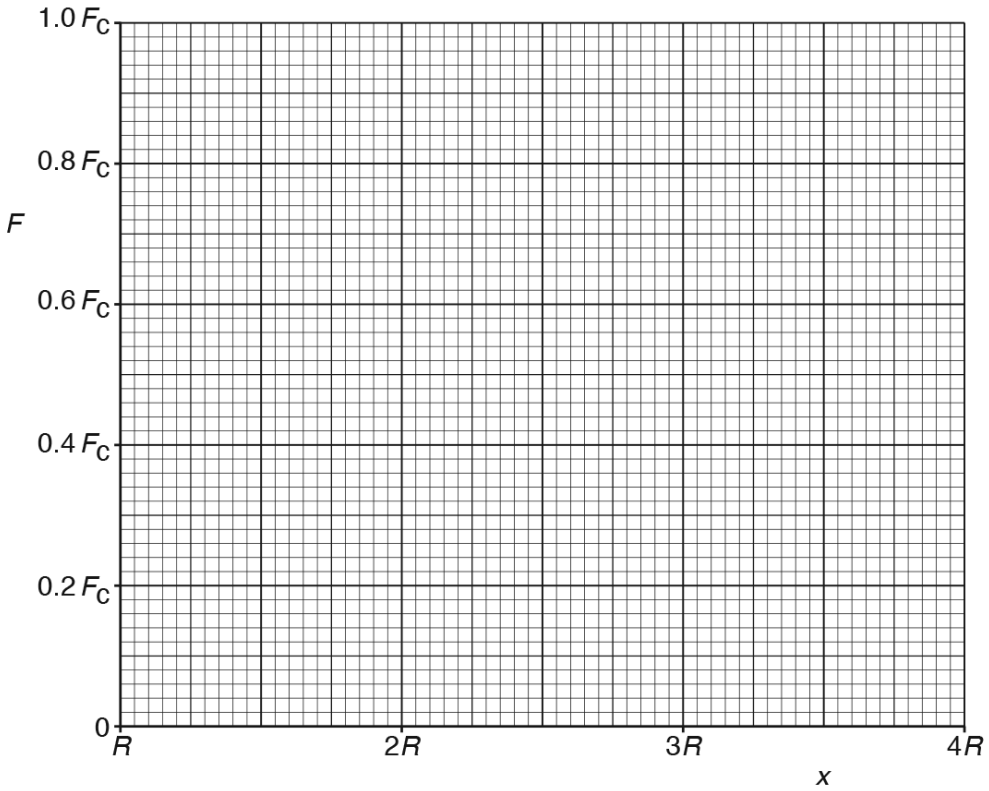
(a) (i) State Coulomb's law for the force between two point charges.

.....

..... [1]

(ii) Two point charges are situated in a vacuum and separated by a distance R. The force between the charges is F_C.

On Fig. 5.1, sketch a graph to show the variation of the force F between the charges with separation x for values of x from $x = R$ to $x = 4R$.



[3]

Fig. 5.1

(b) Two coils C and D are placed close to one another, as shown in Fig. 5.2.

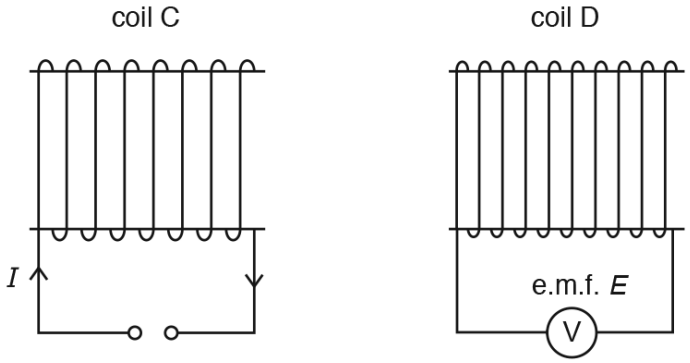


Fig. 5.2

The variation with time t of the current I in coil C is shown in Fig. 5.3.

On Fig. 5.4, show the variation with time t of the e.m.f. E induced in coil D for time $t = 0$ to time $t = t_5$.

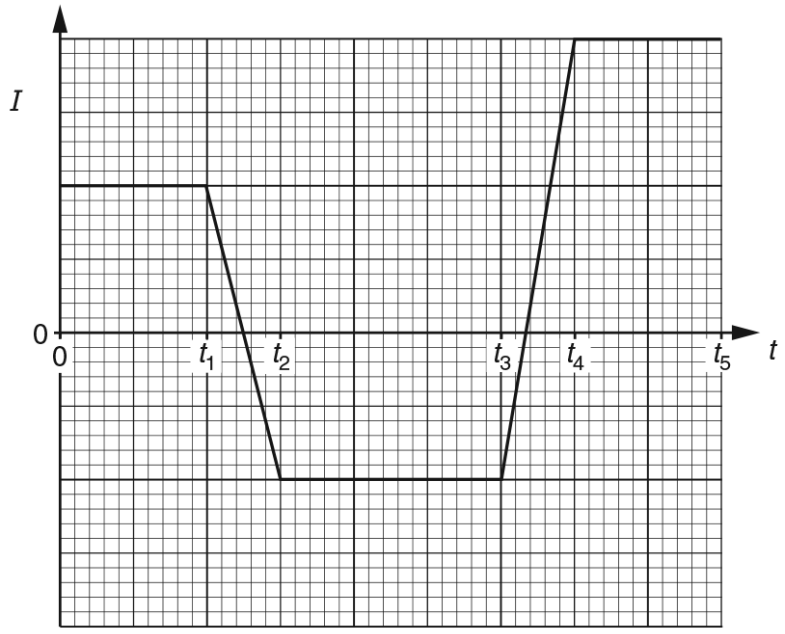


Fig. 5.3

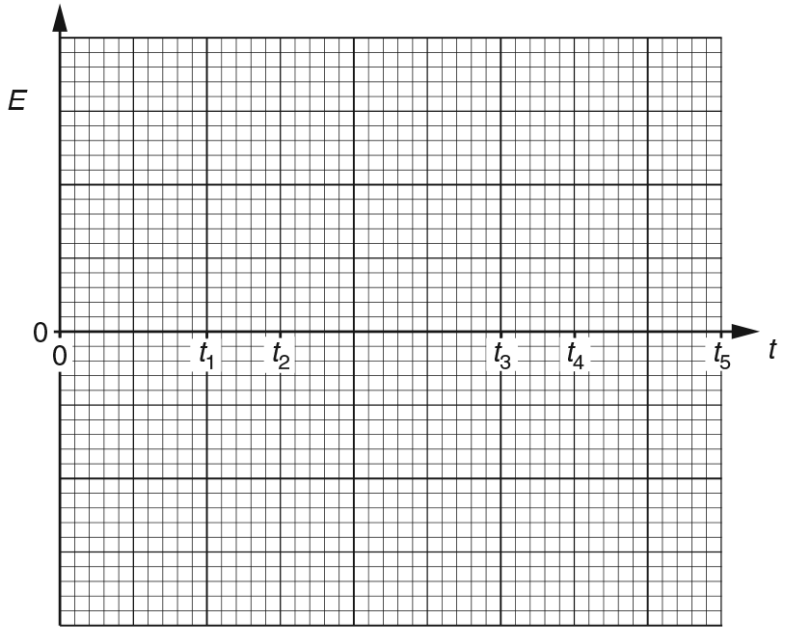


Fig. 5.4

[4]

[Total: 8]

312. 9702_w17_qp_43 Q: 5

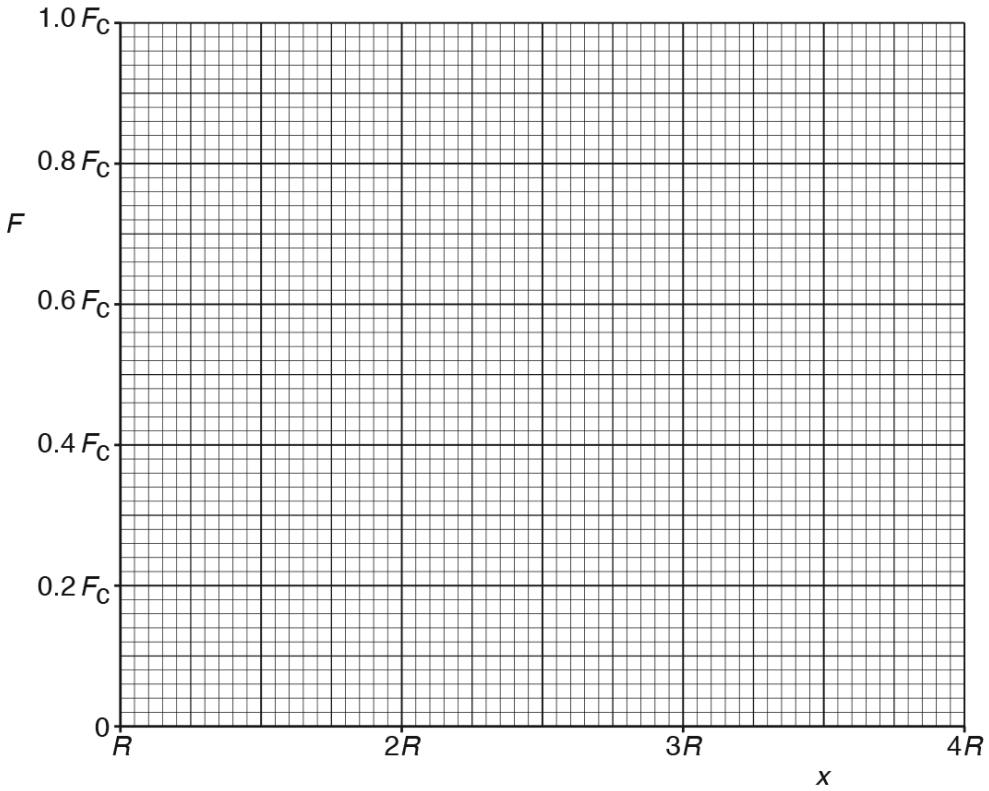
(a) (i) State Coulomb's law for the force between two point charges.

.....

..... [1]

(ii) Two point charges are situated in a vacuum and separated by a distance R. The force between the charges is F_C.

On Fig. 5.1, sketch a graph to show the variation of the force F between the charges with separation x for values of x from $x = R$ to $x = 4R$.



[3]

Fig. 5.1

(b) Two coils C and D are placed close to one another, as shown in Fig. 5.2.

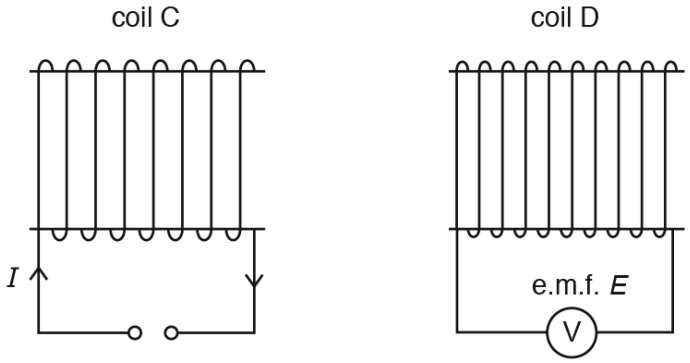


Fig. 5.2

The variation with time t of the current I in coil C is shown in Fig. 5.3.

On Fig. 5.4, show the variation with time t of the e.m.f. E induced in coil D for time $t = 0$ to time $t = t_5$.

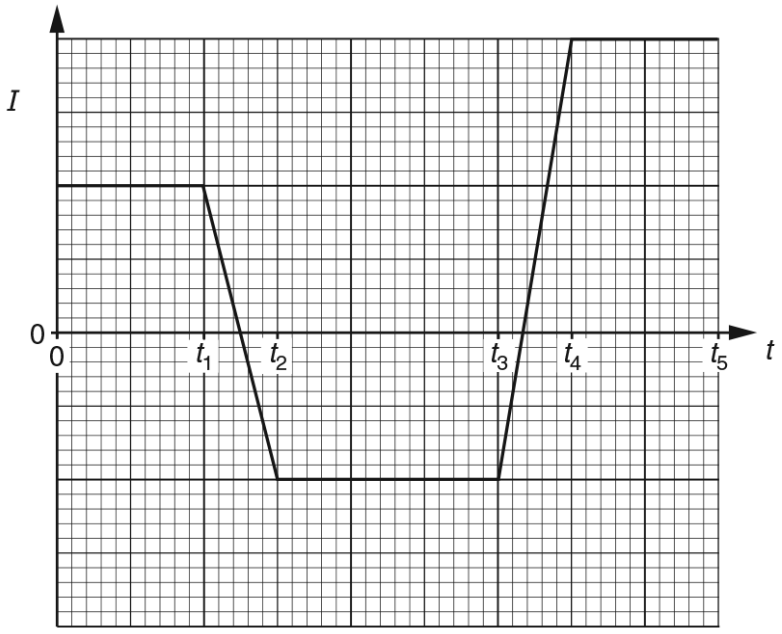


Fig. 5.3

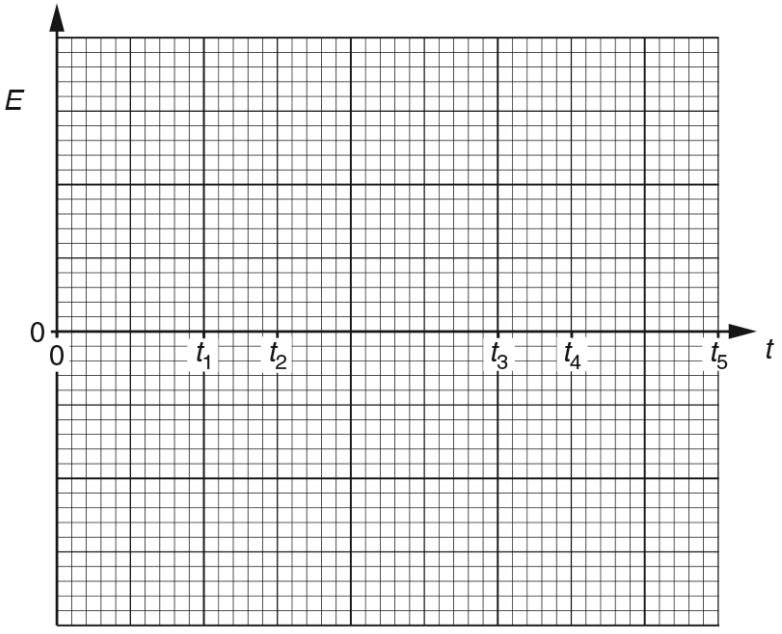


Fig. 5.4

[4]

[Total: 8]

313. 9702_m16_qp_42 Q: 10

A small coil of wire is situated in a non-uniform magnetic field, as shown in Fig. 10.1.

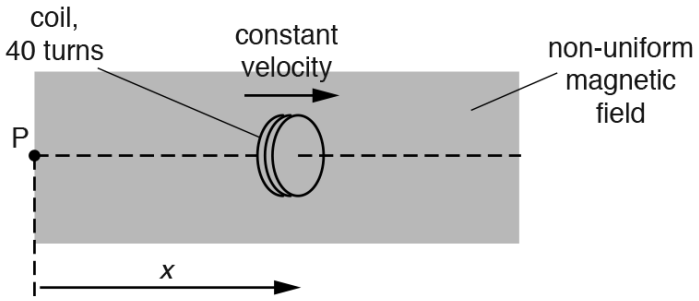


Fig. 10.1

The coil consists of 40 turns of wire and moves with a constant speed in a straight line. The coil has displacement x from a fixed point P.

The variation with x of the magnetic flux Φ in the coil is shown in Fig. 10.2.

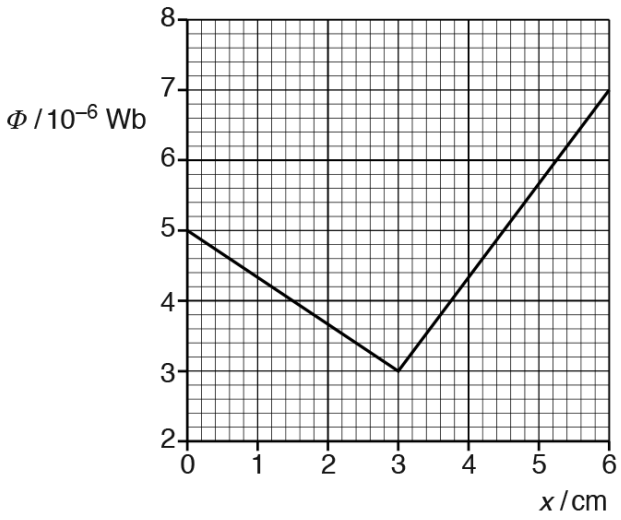


Fig. 10.2

(a) The coil is moved at constant speed between point P and the point where $x = 3.0\,\text{cm}$.

(i) Calculate the change in magnetic flux linkage of the coil.

change in flux linkage = ... Wb [1]

(ii) The e.m.f. induced in the coil is 5.0×10^{-4} V. Determine the speed of the coil.

speed = ... $m\,s^{-1}$ [2]

(b) On Fig. 10.3, sketch the variation with x of the e.m.f. E induced in the coil for values of x from $x = 0$ to $x = 6.0$ cm.

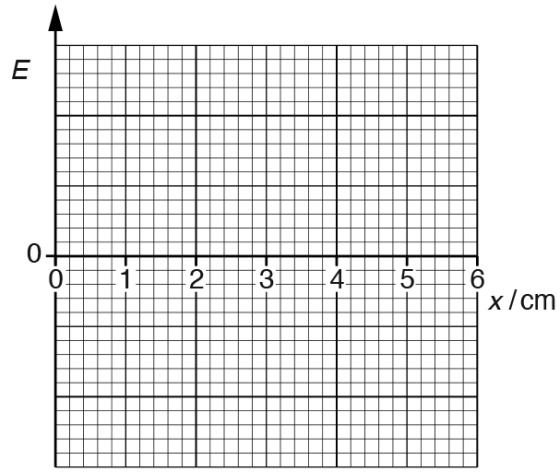


Fig. 10.3

[2]

[Total: 5]

314. 9702_w16_qp_41 Q: 9

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

.....

.....

.....

..... [2]

(b) The diameter of the cross-section of a long solenoid is 3.2 cm, as shown in Fig. 9.1.

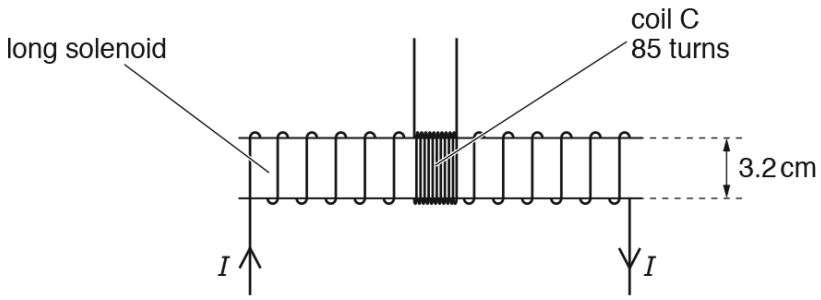


Fig. 9.1

A coil C, with 85 turns of wire, is wound tightly around the centre region of the solenoid.

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

$$B = \pi \times 10^{-3} \times I$$

where I is the current in the solenoid in ampere.

Show that, for a current I of 2.8 A in the solenoid, the magnetic flux linkage of the coil C is 6.0×10^{-4} Wb.

[1]

(c) The current I in the solenoid in **(b)** is reversed in 0.30 s.

Calculate the mean e.m.f. induced in coil C.

e.m.f. = ... mV [2]

(d) The current I in the solenoid in **(b)** is now varied with time t as shown in Fig. 9.2.

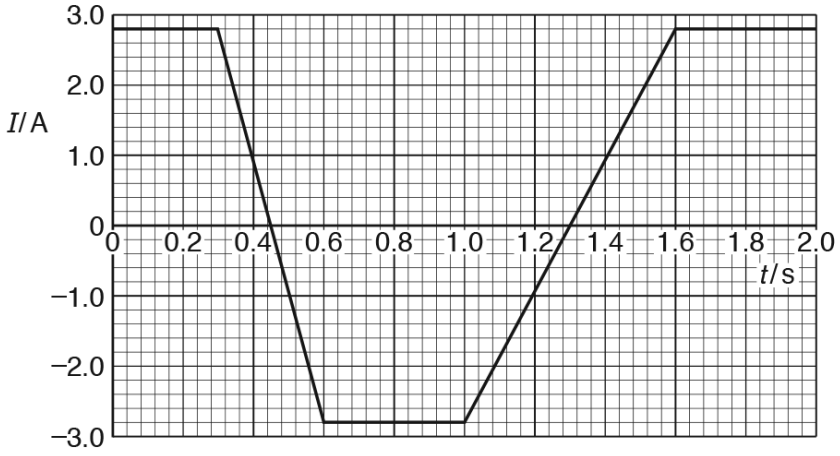


Fig. 9.2

Use your answer to **(c)** to show, on Fig. 9.3, the variation with time t of the e.m.f. E induced in coil C.

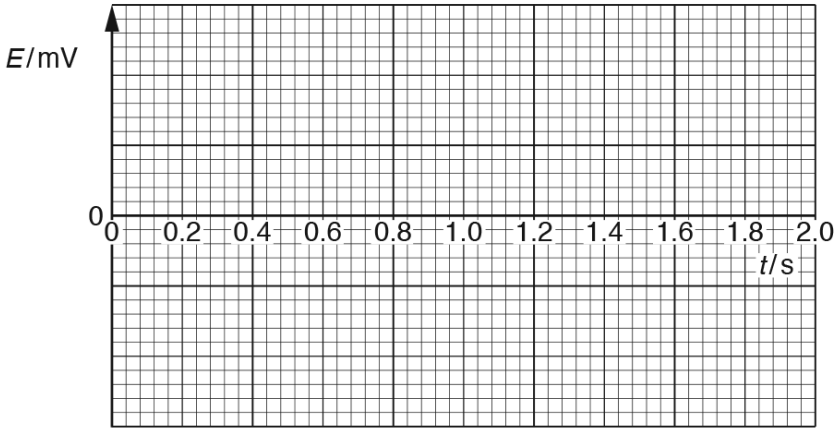


Fig. 9.3

[4]

[Total: 9]

315. 9702_w16_qp_43 Q: 9

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

.....

.....

.....

..... [2]

(b) The diameter of the cross-section of a long solenoid is 3.2 cm, as shown in Fig. 9.1.

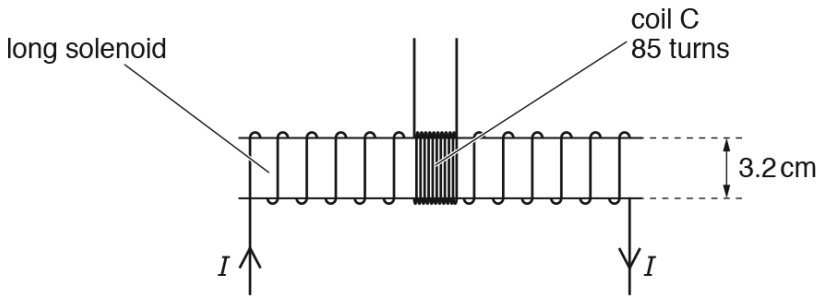


Fig. 9.1

A coil C, with 85 turns of wire, is wound tightly around the centre region of the solenoid.

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

$$B = \pi \times 10^{-3} \times I$$

where I is the current in the solenoid in ampere.

Show that, for a current I of 2.8 A in the solenoid, the magnetic flux linkage of the coil C is 6.0×10^{-4} Wb.

[1]

(c) The current I in the solenoid in **(b)** is reversed in 0.30 s.

Calculate the mean e.m.f. induced in coil C.

e.m.f. = ... mV [2]

(d) The current I in the solenoid in **(b)** is now varied with time t as shown in Fig. 9.2.

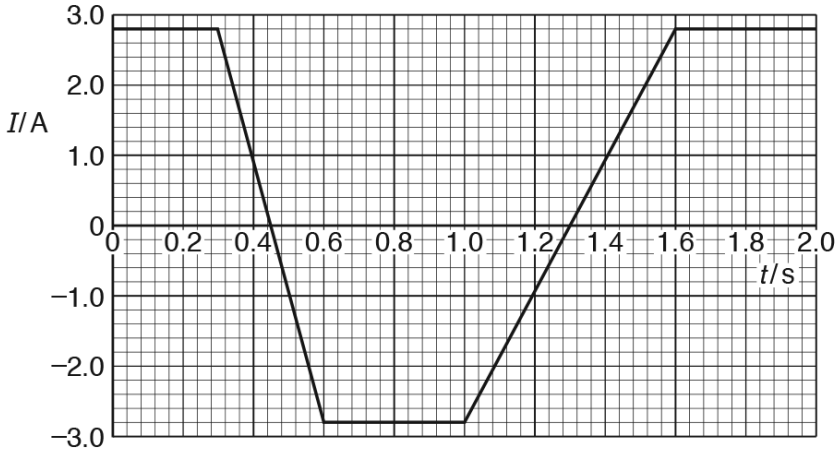


Fig. 9.2

Use your answer to **(c)** to show, on Fig. 9.3, the variation with time t of the e.m.f. E induced in coil C.

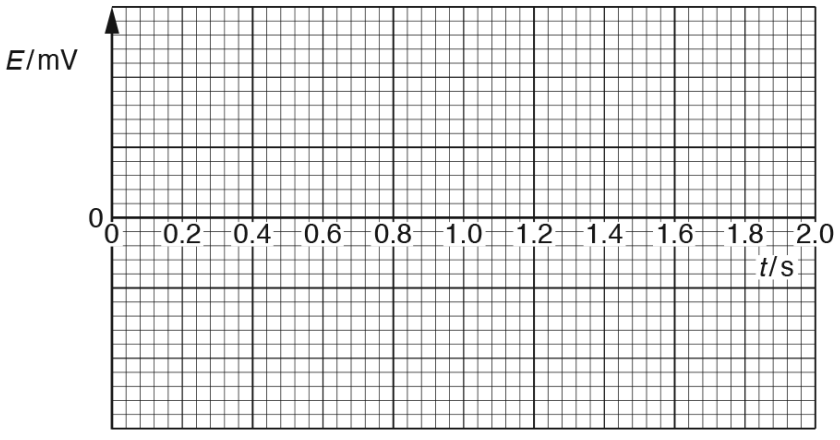


Fig. 9.3

[4]

[Total: 9]

Chapter 12

Magnetic fields

STEMUP.CO.UK

251. 9702_w21_qp_41 Q: 8

(a) Define the *tesla*.

.....

.....

..... [2]

(b) A stiff metal wire is used to form a rectangular frame measuring 8.0 cm × 6.0 cm. The frame is open at the top, and is suspended from a sensitive newton meter, as shown in Fig. 8.1.

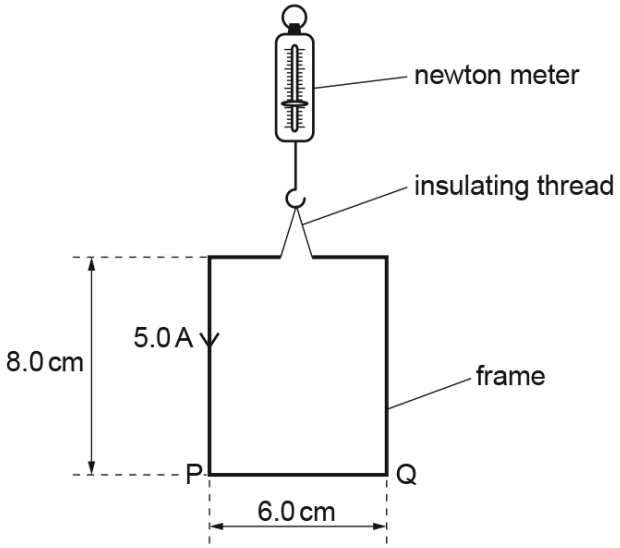


Fig. 8.1

The open ends of the frame are connected to a power supply so that there is a current of 5.0 A in the frame in the direction indicated in Fig. 8.1.

The frame is slowly lowered into a uniform magnetic field of flux density *B* so that all of side PQ is in the field. The magnetic field lines are horizontal and at an angle of 50° to PQ, as shown in Fig. 8.2.

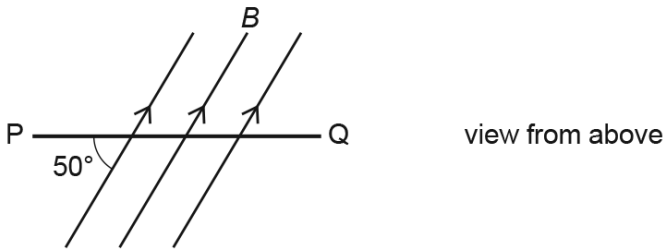


Fig. 8.2

When side PQ of the frame first enters the magnetic field, the reading on the newton meter changes by 1.0 mN.

(i) Determine the magnetic flux density B, in mT.

B = ... mT [2]

(ii) State, with a reason, whether the change in the reading on the newton meter is an increase or a decrease.

.....

.....

..... [1]

(iii) The frame is lowered further so that the vertical sides start to enter the magnetic field.

Suggest what effect this will have on the frame.

.....

.....

..... [1]

[Total: 6]

252. 9702_w21_qp_43 Q: 8

(a) Define the *tesla*.

.....

.....

..... [2]

(b) A stiff metal wire is used to form a rectangular frame measuring 8.0 cm × 6.0 cm. The frame is open at the top, and is suspended from a sensitive newton meter, as shown in Fig. 8.1.

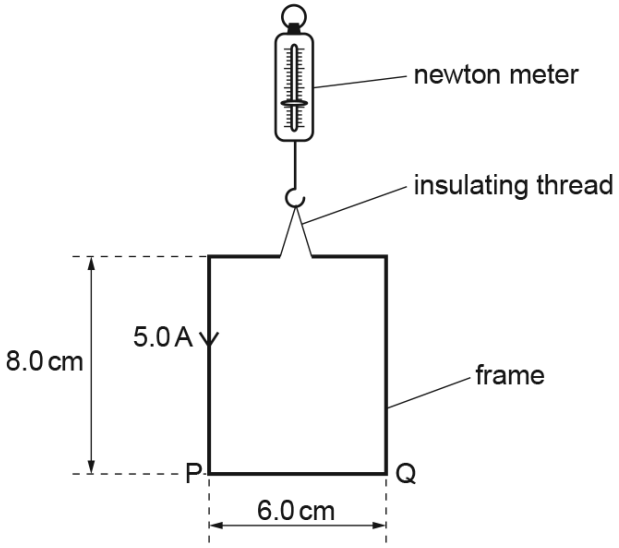


Fig. 8.1

The open ends of the frame are connected to a power supply so that there is a current of 5.0 A in the frame in the direction indicated in Fig. 8.1.

The frame is slowly lowered into a uniform magnetic field of flux density *B* so that all of side PQ is in the field. The magnetic field lines are horizontal and at an angle of 50° to PQ, as shown in Fig. 8.2.

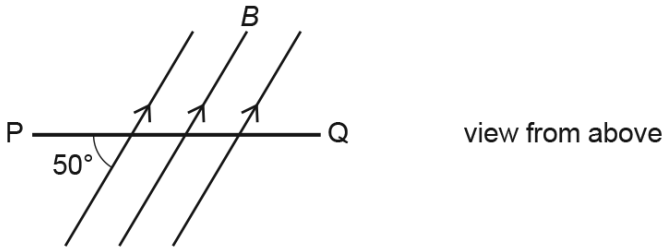


Fig. 8.2

When side PQ of the frame first enters the magnetic field, the reading on the newton meter changes by 1.0 mN.

(i) Determine the magnetic flux density B, in mT.

B = ... mT [2]

(ii) State, with a reason, whether the change in the reading on the newton meter is an increase or a decrease.

.....

.....

..... [1]

(iii) The frame is lowered further so that the vertical sides start to enter the magnetic field.

Suggest what effect this will have on the frame.

.....

.....

..... [1]

[Total: 6]

253. 9702_s20_qp_41 Q: 8

(a) Define the *tesla*.

.....

.....

.....

..... [3]

(b) A magnet produces a uniform magnetic field of flux density *B* in the space between its poles.

A rigid copper wire carrying a current is balanced on a pivot. Part PQLM of the wire is between the poles of the magnet, as illustrated in Fig. 8.1.

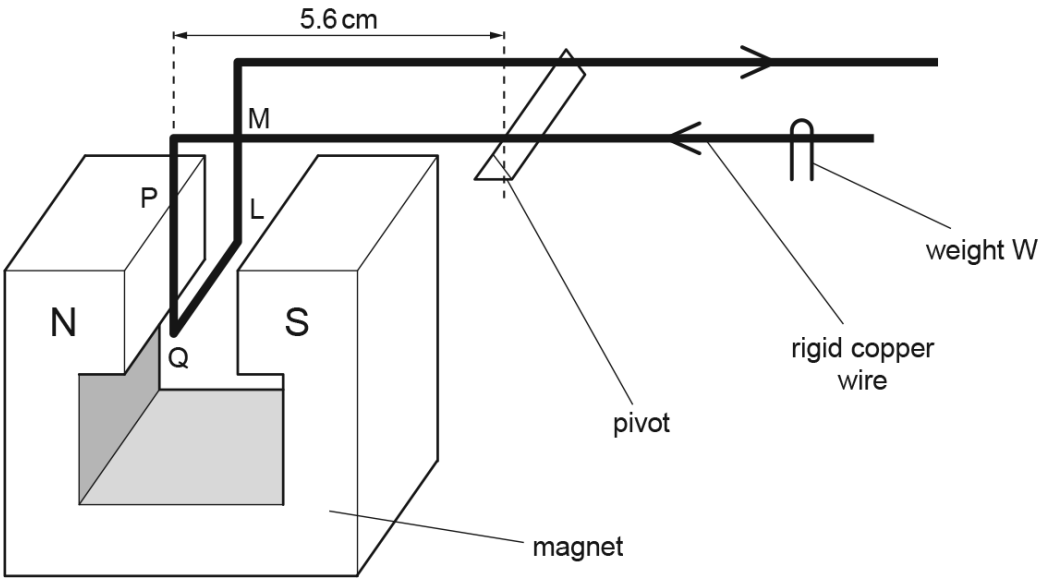


Fig. 8.1 (not to scale)

The wire is balanced horizontally by means of a small weight W.

The section of the wire between the poles of the magnet is shown in Fig. 8.2.

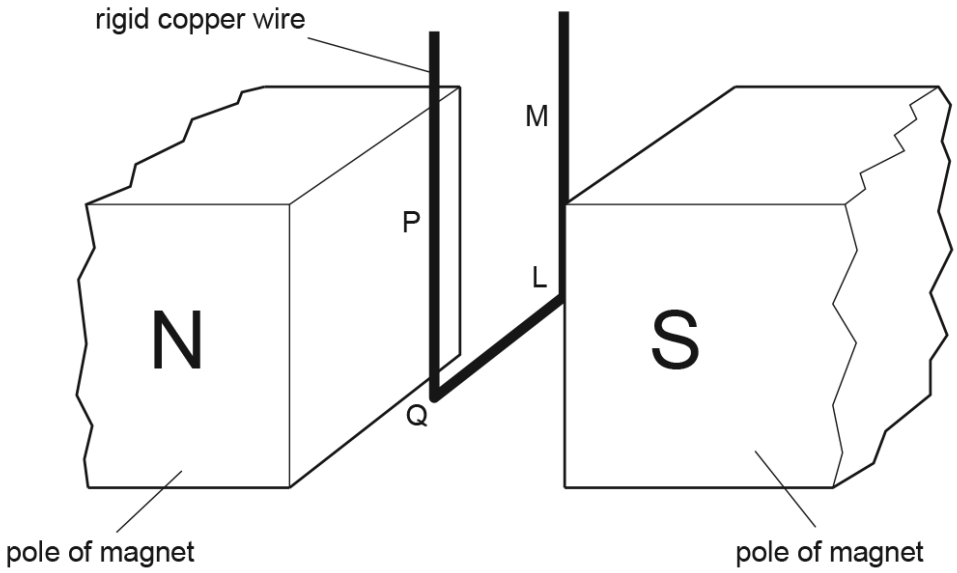


Fig. 8.2 (not to scale)

Explain why:

(i) section QL of the wire gives rise to a moment about the pivot

.....

.....

.....

..... [3]

(ii) sections PQ and LM of the wire do not affect the equilibrium of the wire.

.....

.....

.....

..... [2]

(c) Section QL of the wire has length 0.85 cm.

The perpendicular distance of QL from the pivot is 5.6 cm.

When the current in the wire is changed by 1.2 A, W is moved a distance of 2.6 cm along the wire in order to restore equilibrium. The mass of W is 1.3×10^{-4} kg.

(i) Show that the change in moment of W about the pivot is 3.3×10^{-5} N m.

[2]

(ii) Use the information in **(i)** to determine the magnetic flux density B between the poles of the magnet.

B = ... T [3]

[Total: 13]

254. 9702_s20_qp_43 Q: 8

(a) Define the *tesla*.

.....

.....

.....

..... [3]

(b) A magnet produces a uniform magnetic field of flux density *B* in the space between its poles.

A rigid copper wire carrying a current is balanced on a pivot. Part PQLM of the wire is between the poles of the magnet, as illustrated in Fig. 8.1.

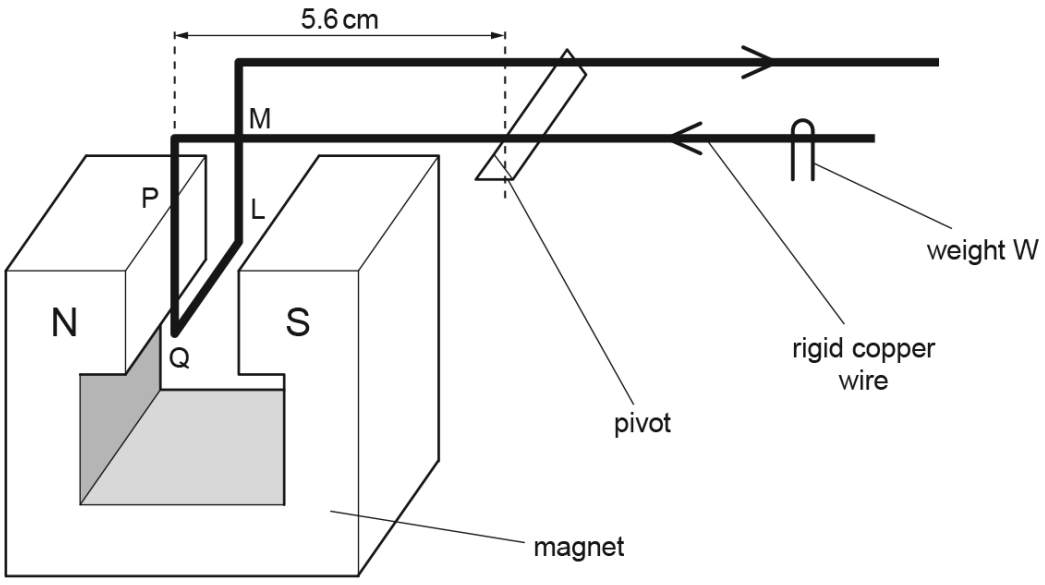


Fig. 8.1 (not to scale)

The wire is balanced horizontally by means of a small weight W.

The section of the wire between the poles of the magnet is shown in Fig. 8.2.

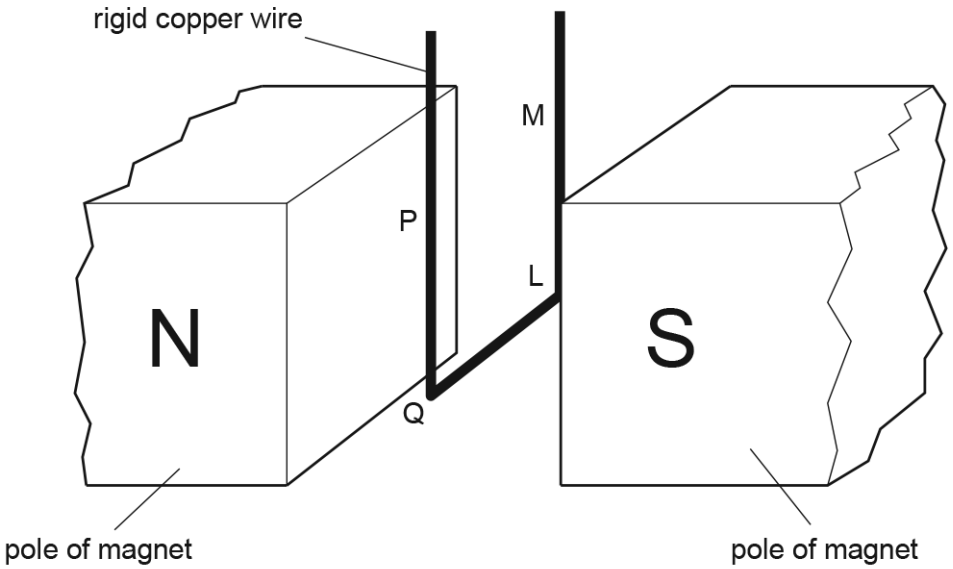


Fig. 8.2 (not to scale)

Explain why:

(i) section QL of the wire gives rise to a moment about the pivot

.....

.....

.....

..... [3]

(ii) sections PQ and LM of the wire do not affect the equilibrium of the wire.

.....

.....

.....

..... [2]

(c) Section QL of the wire has length 0.85 cm.

The perpendicular distance of QL from the pivot is 5.6 cm.

When the current in the wire is changed by 1.2 A, W is moved a distance of 2.6 cm along the wire in order to restore equilibrium. The mass of W is 1.3×10^{-4} kg.

(i) Show that the change in moment of W about the pivot is 3.3×10^{-5} N m.

[2]

(ii) Use the information in **(i)** to determine the magnetic flux density B between the poles of the magnet.

B = ... T [3]

[Total: 13]

255. 9702_s18_qp_41 Q: 9

A rigid copper wire is held horizontally between the pole pieces of two magnets, as shown in Fig. 9.1.

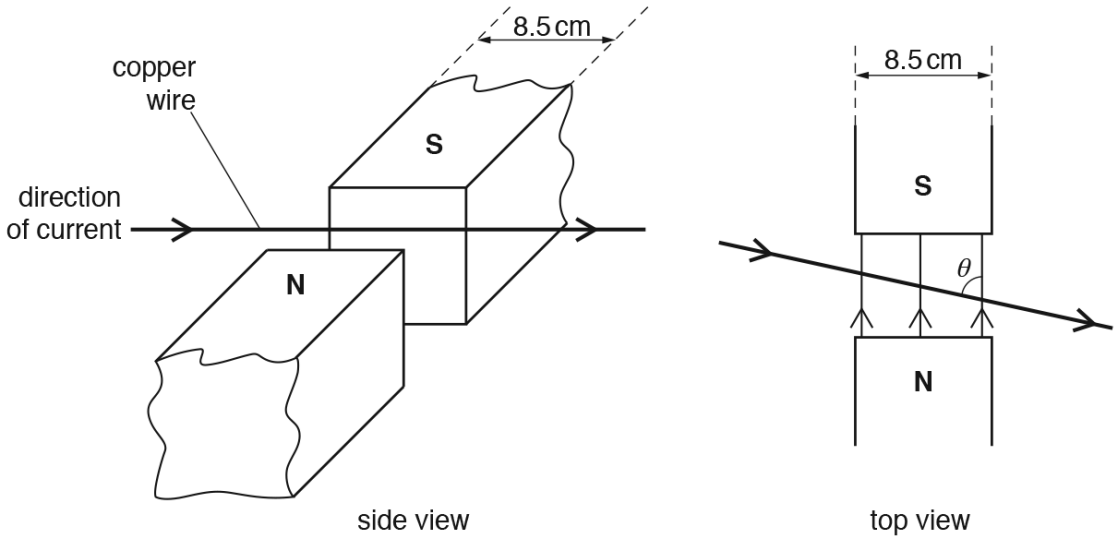


Fig. 9.1

The width of each pole piece is 8.5 cm.
The uniform magnetic flux density B in the region between the poles of the magnets is 3.7 mT and is zero outside this region.
The angle between the wire and the direction of the magnetic field is θ.
The current in the wire is in the direction shown on Fig. 9.1.

(a) By reference to the **side** view of Fig. 9.1, state and explain the direction of the force on the **magnets**.

.....

.....

.....

.....[2]

(b) The constant current in the wire is 5.1 A.

(i) For angle θ equal to 90°, calculate the force on the wire.

force = ... N [2]

(ii) The angle θ is changed to 60°.

The length of wire in the magnetic field is $\left(\frac{8.5}{\sin 60°}\right)$ cm.

Calculate the force on the wire.

force = ... N [1]

(c) The constant current in the wire is now changed to an alternating current of frequency 20 Hz and root-mean-square (r.m.s.) value 5.1 A.

The angle between the wire and the direction of the magnetic field is 90°.

On Fig. 9.2, sketch a graph to show the variation with time t of the force F on the wire for two cycles of the alternating current.

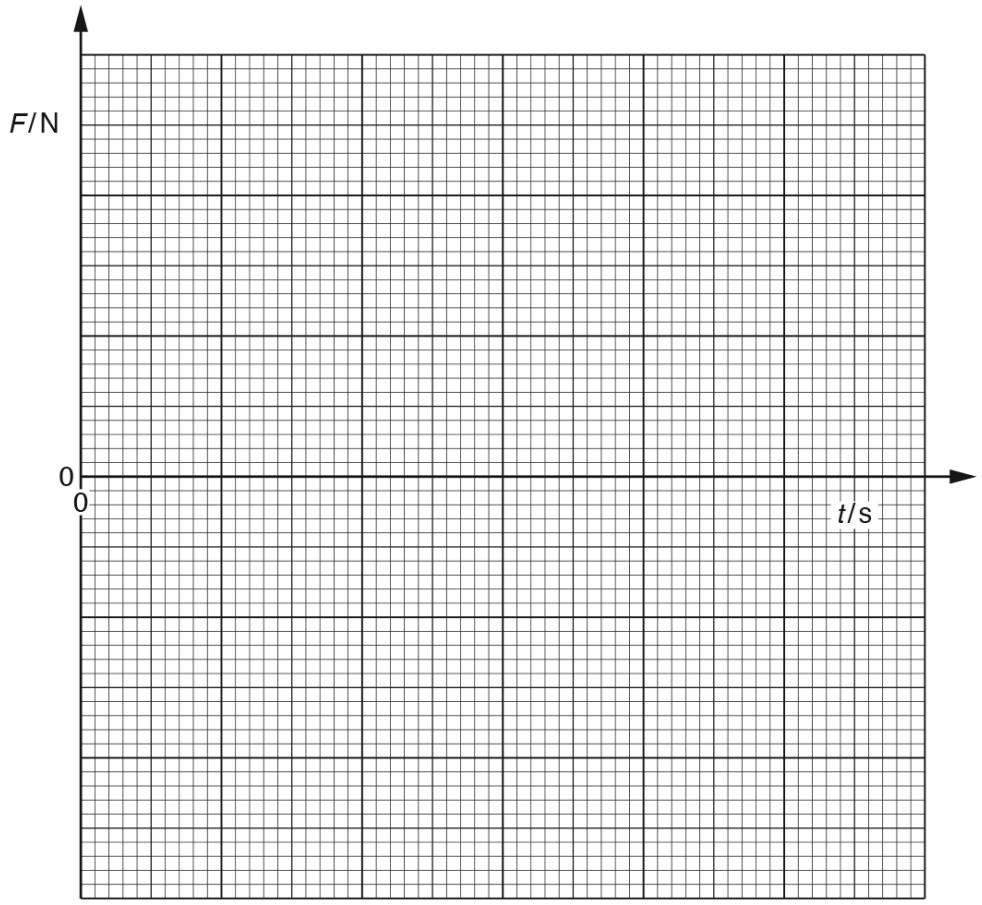


Fig. 9.2

[3]

[Total: 8]

256. 9702_s18_qp_43 Q: 9

A rigid copper wire is held horizontally between the pole pieces of two magnets, as shown in Fig. 9.1.

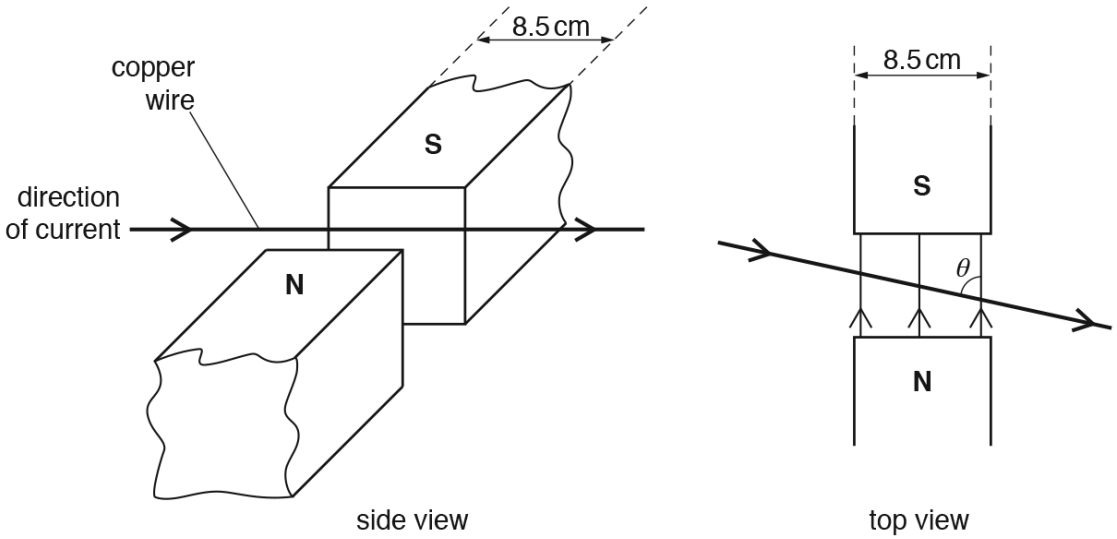


Fig. 9.1

The width of each pole piece is 8.5 cm.
The uniform magnetic flux density B in the region between the poles of the magnets is 3.7 mT and is zero outside this region.
The angle between the wire and the direction of the magnetic field is θ.
The current in the wire is in the direction shown on Fig. 9.1.

(a) By reference to the **side** view of Fig. 9.1, state and explain the direction of the force on the **magnets**.

.....

.....

.....

.....[2]

(b) The constant current in the wire is 5.1 A.

(i) For angle θ equal to 90°, calculate the force on the wire.

force = ... N [2]

(ii) The angle θ is changed to 60°.

The length of wire in the magnetic field is $\left(\frac{8.5}{\sin 60°}\right)$ cm.

Calculate the force on the wire.

force = ... N [1]

(c) The constant current in the wire is now changed to an alternating current of frequency 20 Hz and root-mean-square (r.m.s.) value 5.1 A.

The angle between the wire and the direction of the magnetic field is 90°.

On Fig. 9.2, sketch a graph to show the variation with time t of the force F on the wire for two cycles of the alternating current.

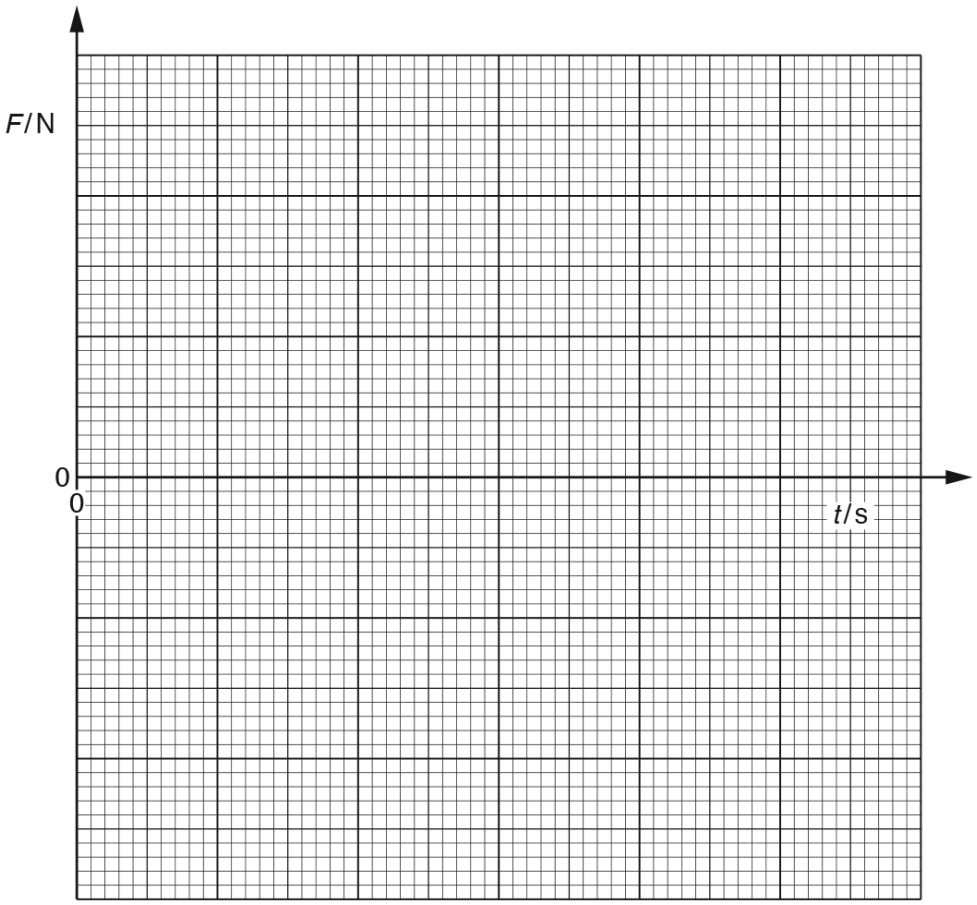


Fig. 9.2

[3]

[Total: 8]

257. 9702_w18_qp_42 Q: 8

(a) Define *magnetic flux density*.

.....

.....

.....

.....[3]

(b) A stiff copper wire is balanced horizontally on a pivot, as shown in Fig. 8.1.

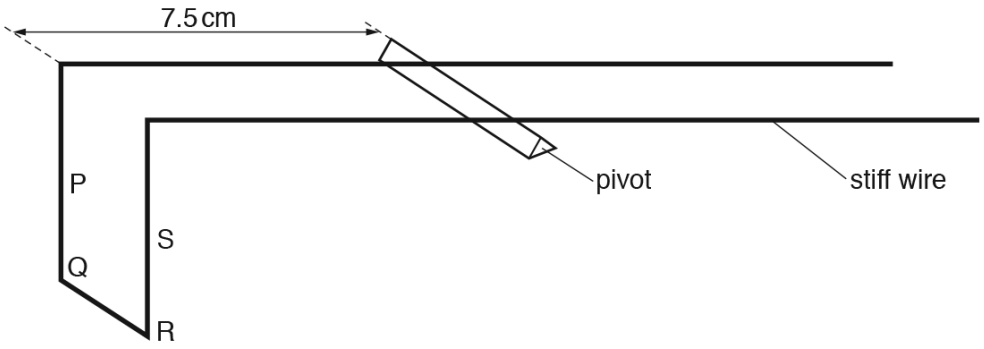


Fig. 8.1

Sections PQ, QR and RS of the wire are situated in a uniform magnetic field of flux density *B* produced between the poles of a permanent magnet.
The perpendicular distance of PQRS from the pivot is 7.5 cm.

When a current of 2.7 A is passed through the wire, a small mass of 45 mg is placed a distance 8.8 cm from the pivot in order to restore the balance of the wire, as shown in Fig. 8.2.

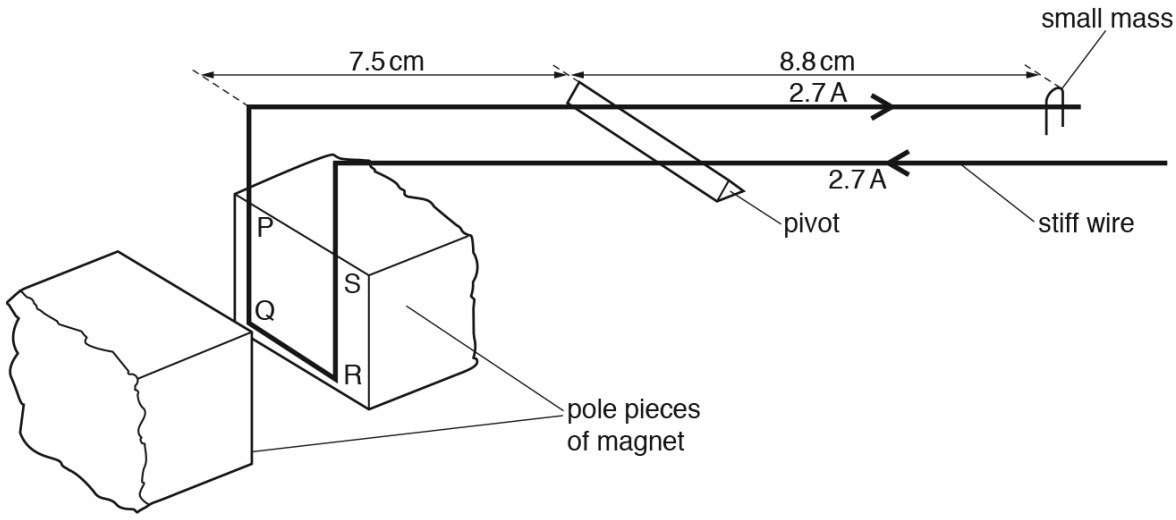


Fig. 8.2

(i) Explain why, when the current is switched on, the current in the sections PQ and RS of the wire does not affect the balance of the wire.

.....

.....

.....[2]

(ii) The length of section QR of the wire is 1.2 cm.
Calculate the magnetic flux density *B*.

B = ... T [3]

[Total: 8]

258. 9702_w16_qp_42 Q: 9

A stiff wire is held horizontally between the poles of a magnet, as illustrated in Fig. 9.1.

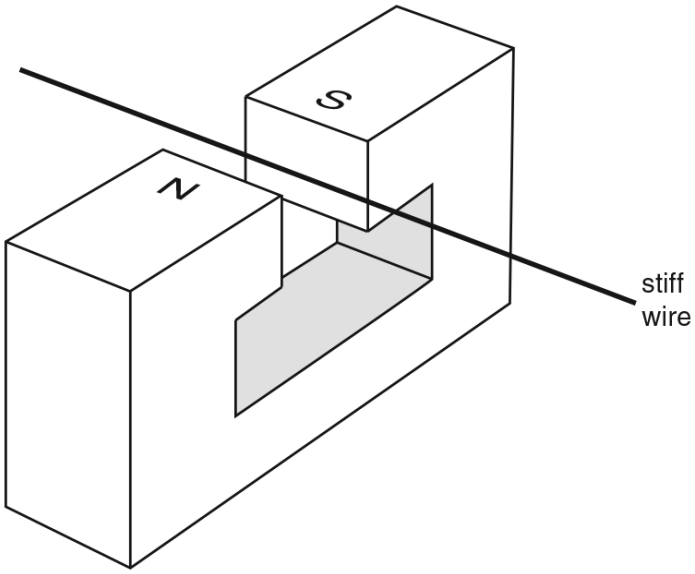


Fig. 9.1

When a constant current of 6.0 A is passed through the wire, there is an additional downwards force on the magnet of 0.080 N.

(a) On Fig. 9.1, draw an arrow on the wire to show the direction of the current in the wire.
Explain your answer.

.....

.....

.....

.....[3]

(b) The constant current of 6.0 A is now replaced by a low-frequency sinusoidal current.
The root-mean-square (r.m.s.) value of this current is 2.5 A.

Calculate the difference between the maximum and the minimum forces now acting on the magnet.

difference = ... N [4]

[Total: 7]

259. 9702_s21_qp_41 Q: 9

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

.....

.....

..... [2]

(b) A rectangular piece of aluminium foil is situated in a uniform magnetic field of flux density *B*, as shown in Fig. 9.1.

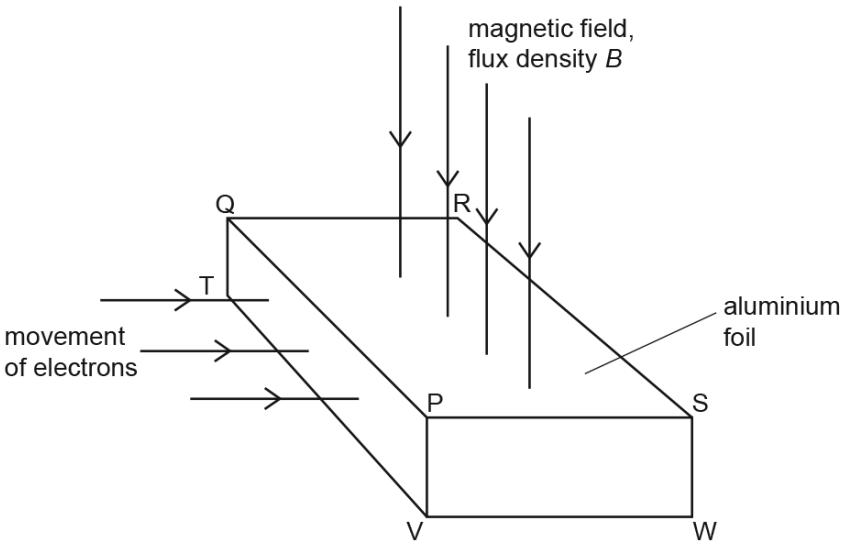


Fig. 9.1

The magnetic field is normal to the face PQRS of the foil.

Electrons, each of charge $-q$, enter the foil at right angles to the face PQTV.

(i) On Fig. 9.1, shade the face of the foil on which electrons initially accumulate. [1]

(ii) Explain why electrons do not continuously accumulate on the face you have shaded.

.....

.....

.....

..... [3]

(c) The Hall voltage V_H developed across the foil in **(b)** is given by the expression

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

where I is the current in the foil.

(i) State the meaning of the quantity n.

.....

..... [1]

(ii) Using the letters on Fig. 9.1, identify the distance t.

..... [1]

(d) Suggest why, in practice, Hall probes are usually made using a semiconductor material rather than a metal.

.....

..... [1]

[Total: 9]

---

260. 9702_s21_qp_42 Q: 8

(a) Define *magnetic flux density*.

.....

.....

..... [2]

(b) Electrons, each of mass m and charge q, are accelerated from rest in a vacuum through a potential difference V.

Derive an expression, in terms of m, q and V, for the final speed v of the electrons. Explain your working.

[2]

(c) The accelerated electrons in **(b)** are injected at point S into a region of uniform magnetic field of flux density B, as illustrated in Fig. 8.1.

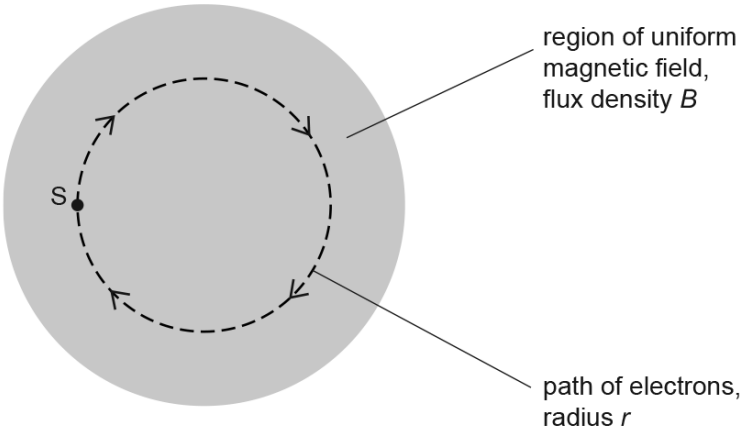


Fig. 8.1

The electrons move at right angles to the direction of the magnetic field. The path of the electrons is a circle of radius r.

(i) Show that the specific charge $\frac{q}{m}$ of the electrons is given by the expression

$$\frac{q}{m} = \frac{2V}{B^2 r^2}.$$

Explain your working.

[2]

(ii) Electrons are accelerated through a potential difference V of 230 V. The electrons are injected normally into the magnetic field of flux density 0.38 mT.
The radius r of the circular orbit of the electrons is 14 cm.

Use this information to calculate a value for the specific charge of an electron.

specific charge = ... $C\,kg^{-1}$ [2]

(iii) Suggest why the arrangement outlined in **(ii)**, using the same values of B and V, is not practical for the determination of the specific charge of α-particles.

.....

.....

..... [2]

[Total: 10]

261. 9702_s21_qp_43 Q: 9

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

.....

.....

..... [2]

(b) A rectangular piece of aluminium foil is situated in a uniform magnetic field of flux density *B*, as shown in Fig. 9.1.

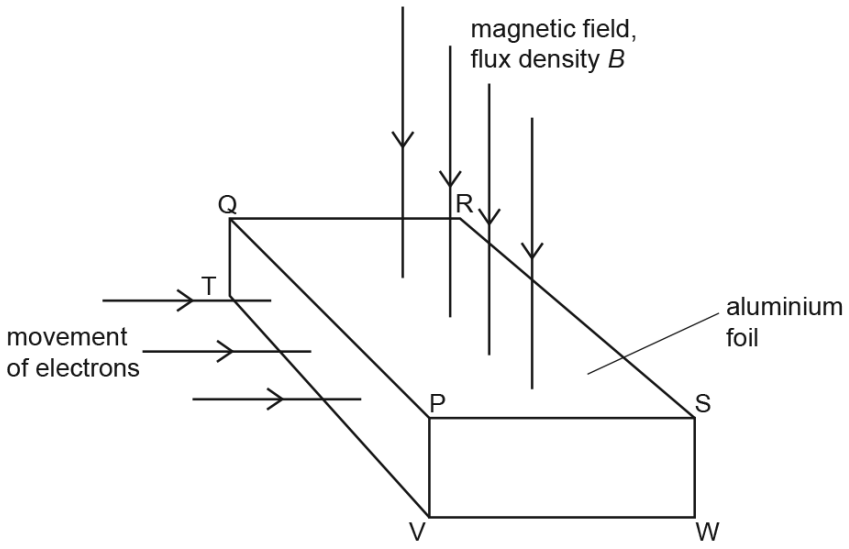


Fig. 9.1

The magnetic field is normal to the face PQRS of the foil.

Electrons, each of charge $-q$, enter the foil at right angles to the face PQTV.

(i) On Fig. 9.1, shade the face of the foil on which electrons initially accumulate. [1]

(ii) Explain why electrons do not continuously accumulate on the face you have shaded.

.....

.....

.....

..... [3]

(c) The Hall voltage V_H developed across the foil in **(b)** is given by the expression

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

where I is the current in the foil.

(i) State the meaning of the quantity n.

.....

..... [1]

(ii) Using the letters on Fig. 9.1, identify the distance t.

..... [1]

(d) Suggest why, in practice, Hall probes are usually made using a semiconductor material rather than a metal.

.....

..... [1]

[Total: 9]

---

262. 9702_m20_qp_42 Q: 8

(a) Explain what is meant by a *magnetic field*.

.....

.....

.....

..... [1]

(b) The apparatus shown in Fig. 8.1 is used in an experiment to find the magnetic flux density *B* between the poles of a horseshoe magnet. Assume the magnetic field is uniform between the poles of the magnet and zero elsewhere.

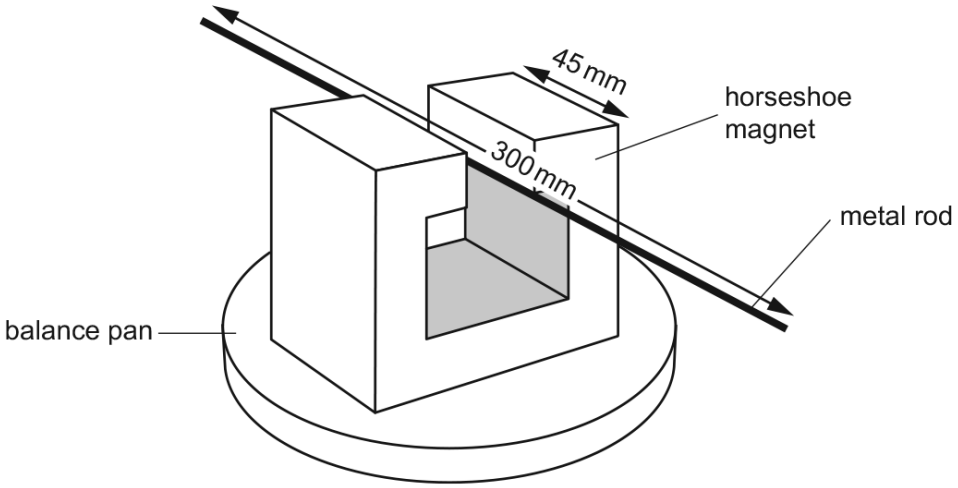


Fig. 8.1

The rigid metal rod of length 300 mm is fixed in position perpendicular to the direction of the magnetic field. The poles of the magnet are both 45 mm long. There is a current in the rod that causes a force on the rod. The balance is used to determine the magnitude of the force.

The variation with current *I* of the force *F* on the rod is shown in Fig. 8.2.

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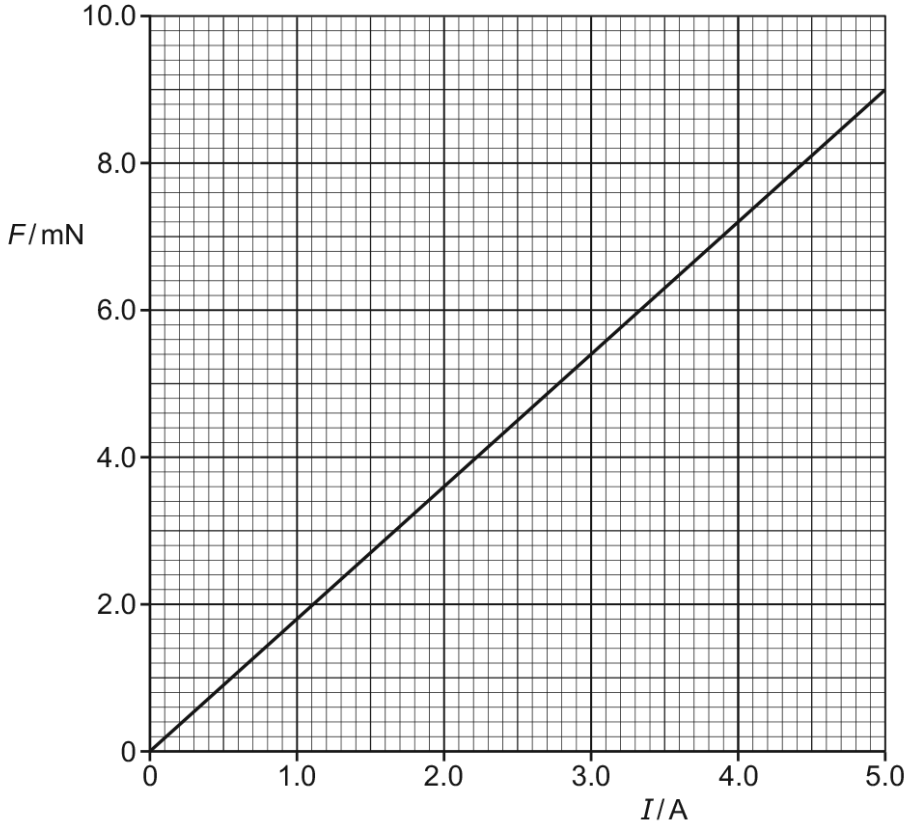


Fig. 8.2

Calculate the magnetic flux density *B*.

B = ... T [2]

(c) In a different experiment, electrons are accelerated through a potential difference and then enter a region of magnetic field. The magnetic field is into the plane of the paper and is perpendicular to the direction of travel of the electrons, as illustrated in Fig. 8.3.

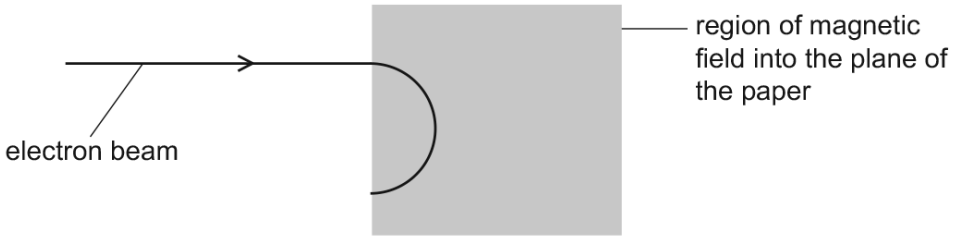


Fig. 8.3

(i) Explain why the electrons follow a circular path when inside the region of the magnetic field.

.....

.....

.....

..... [3]

(ii) State the measurements needed in order to determine the charge to mass ratio, e/m_e, of an electron.

.....

.....

..... [2]

[Total: 8]

263. 9702_s20_qp_42 Q: 9

(a) An electron is travelling at speed v in a straight line in a vacuum. It enters a uniform magnetic field of flux density 8.0×10^{-4} T. Initially, the electron is travelling at right angles to the magnetic field, as illustrated in Fig. 9.1.

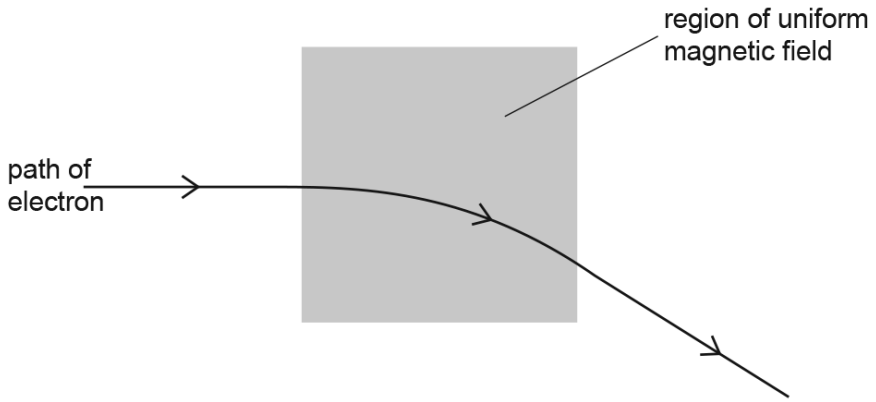


Fig. 9.1

The path of the electron in the magnetic field is an arc of a circle of radius 6.4 cm.

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

.....

.....

..... [2]

(ii) Show that the speed v of the electron is $9.0 \times 10^{6}\,\text{m s}^{-1}$.

[3]

(b) A uniform electric field is now applied in the same region as the magnetic field.

The electron passes undeviated through the region of the two fields, as illustrated in Fig. 9.2.

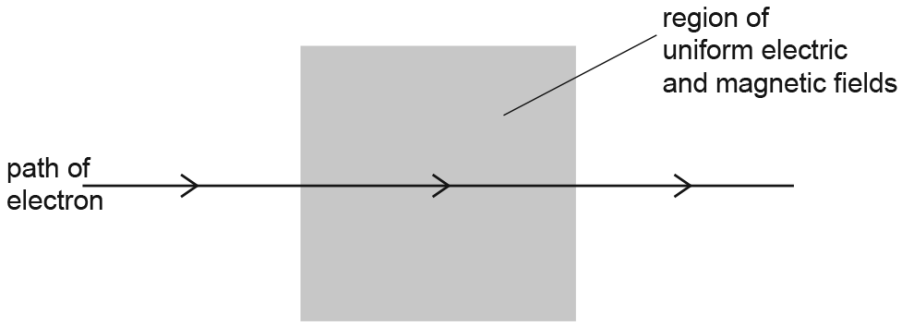


Fig. 9.2

(i) On Fig. 9.2, mark with an arrow the direction of the uniform electric field. [1]

(ii) Use data from **(a)** to calculate the magnitude of the electric field strength.

field strength = ... NC^{-1} [2]

(c) The electron in **(b)** is now replaced by an α-particle travelling at the same speed v along the same initial path as the electron.

Describe and explain the shape of the path in the region of the magnetic and electric fields.

.....

.....

..... [2]

[Total: 10]

264. 9702_s19_qp_42 Q: 8

An electron is travelling in a vacuum at a speed of $3.4 \times 10^7\,\text{m s}^{-1}$. The electron enters a region of uniform magnetic field of flux density 3.2 mT, as illustrated in Fig. 8.1.

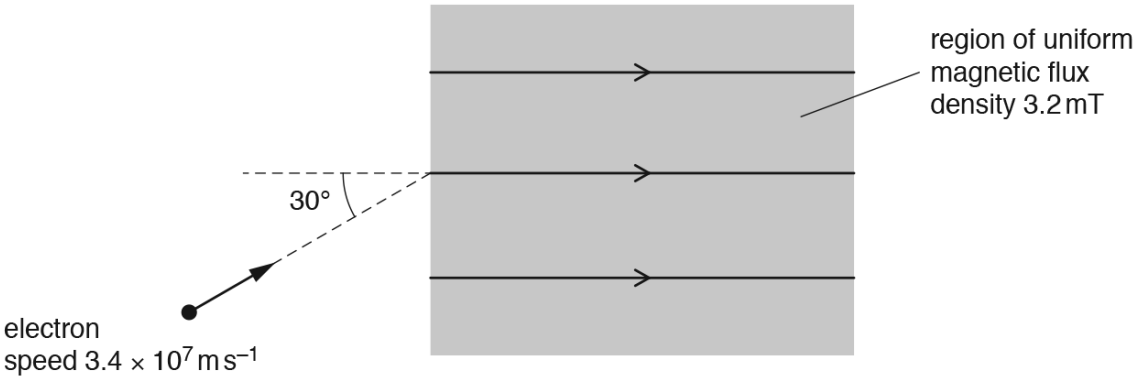


Fig. 8.1

The initial direction of the electron is at an angle of 30° to the direction of the magnetic field.

(a) When the electron enters the magnetic field, the component of its velocity v_N normal to the direction of the magnetic field causes the electron to begin to follow a circular path.

Calculate:

(i) v_N

v_N = ... m s^{-1} [1]

(ii) the radius of this circular path.

radius = ... m [3]

(b) State the magnitude of the force, if any, on the electron in the magnetic field due to the component of its velocity along the direction of the field.

.....[1]

(c) Use information from **(a)** and **(b)** to describe the resultant path of the electron in the magnetic field.

.....

.....[1]

[Total: 6]

265. 9702_w19_qp_42 Q: 8

Electrons enter a rectangular slice PQRSEFGH of a semiconductor material at right-angles to face PQFE, as shown in Fig. 8.1.

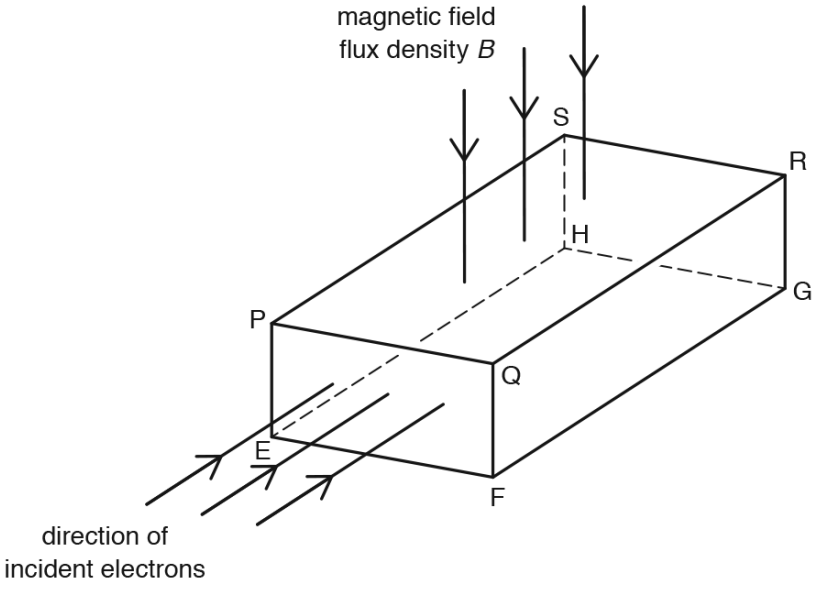


Fig. 8.1

A uniform magnetic field of flux density B is directed into the slice, at right-angles to face PQRS.

(a) The electrons each have charge $-q$ and drift speed v in the slice.

State the magnitude and the direction of the force due to the magnetic field on each electron as it enters the slice.

.....

.....

..... [2]

(b) The force on the electrons causes a voltage V_H to be established across the semiconductor slice given by the expression

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

where I is the current in the slice.

(i) State the two faces between which the voltage V_H is established.

face ..... and face ..... [1]

(ii) Use letters from Fig. 8.1 to identify the distance t.

..... [1]

(c) Aluminium ($^{27}_{13}Al$) has a density of 2.7 g cm^{-3}. Assume that there is one free electron available to carry charge per atom of aluminium.

(i) Show that the number of charge carriers per unit volume in aluminium is 6.0×10^{28} m^{-3}.

[2]

(ii) A sample of aluminium foil has a thickness of 0.090 mm. The current in the foil is 4.6 A.

A uniform magnetic field of flux density 0.15 T acts at right-angles to the foil.

Use the value in **(i)** to calculate the voltage V_H that is generated.

V_H = ... V [2]

[Total: 8]

266. 9702_m18_qp_42 Q: 9

A thin slice of conducting material has its faces PQRS and VWXY normal to a uniform magnetic field of flux density *B*, as shown in Fig. 9.1.

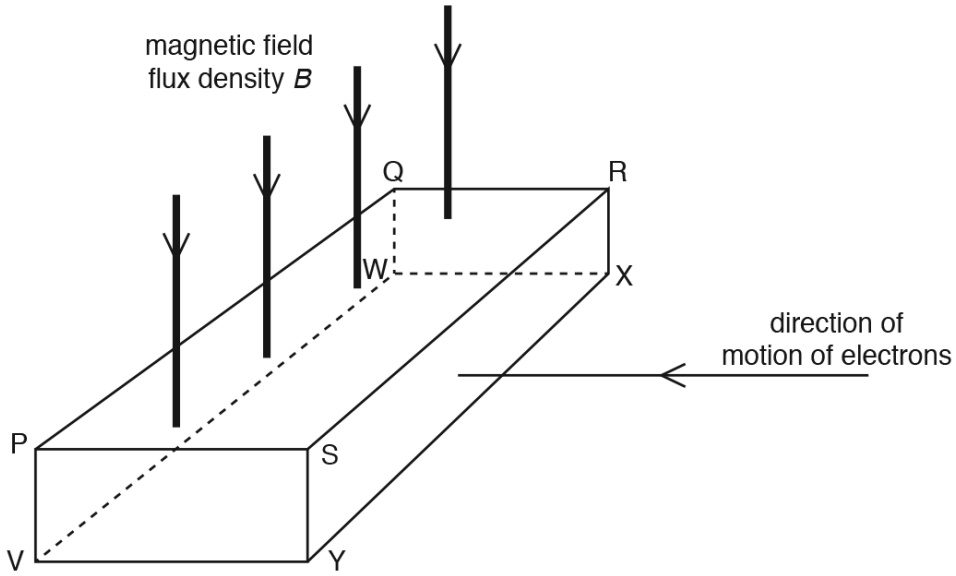


Fig. 9.1

Electrons enter the slice at right-angles to face SRXY.

A potential difference, the Hall voltage V_H, is developed between two faces of the slice.

(a) (i) Use letters from Fig. 9.1 to name the two faces between which the Hall voltage is developed.

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

(ii) State and explain which of the two faces named in **(a)(i)** is the more positive.

.....

.....[2]

(b) The Hall voltage V_H is given by the expression

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

(i) Use the letters in Fig. 9.1 to identify the distance t.

.....[1]

(ii) State the meaning of the symbol n.

.....

.....[1]

(iii) State and explain the effect, if any, on the polarity of the Hall voltage when negative charge carriers (electrons) are replaced with positive charge carriers, moving in the same direction towards the slice.

.....

.....

.....[2]

[Total: 7]

---

267. 9702_s18_qp_42 Q: 8

(a) Explain how a uniform magnetic field and a uniform electric field may be used as a velocity selector for charged particles.

.....

.....

.....

.....[3]

(b) Particles having mass m and charge $+1.6 \times 10^{-19}$ C pass through a velocity selector. They then enter a region of uniform magnetic field of magnetic flux density 94 mT with speed $3.4 \times 10^{4}\,\text{m s}^{-1}$, as shown in Fig. 8.1.

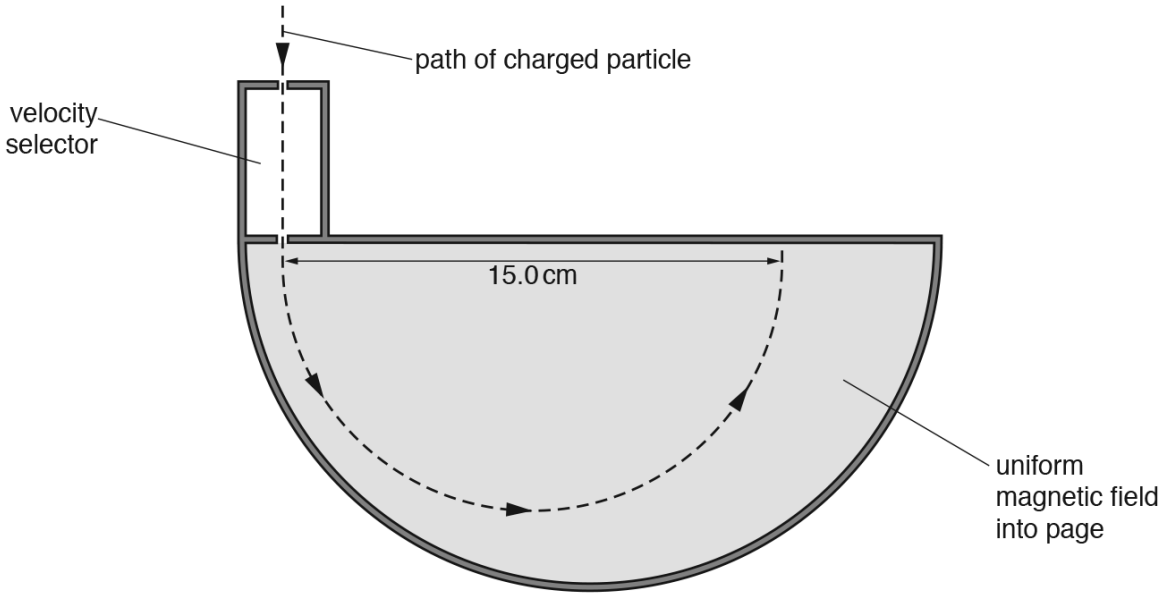


Fig. 8.1

The direction of the uniform magnetic field is into the page and normal to the direction in which the particles are moving.

The particles are moving in a vacuum in a circular arc of diameter 15.0 cm.

Show that the mass of one of the particles is 20 u.

[4]

(c) On Fig. 8.1, sketch the path in the uniform magnetic field of a particle of mass 22 u having the same charge and speed as the particle in **(b)**. [2]

[Total: 9]

268. 9702_w18_qp_41 Q: 8

(a) Explain what is meant by a *magnetic field*.

.....

.....

.....[2]

(b) A particle has mass m, charge $+q$ and speed v.

The particle enters a uniform magnetic field of flux density B such that, on entry, it is moving normal to the magnetic field, as shown in Fig. 8.1.

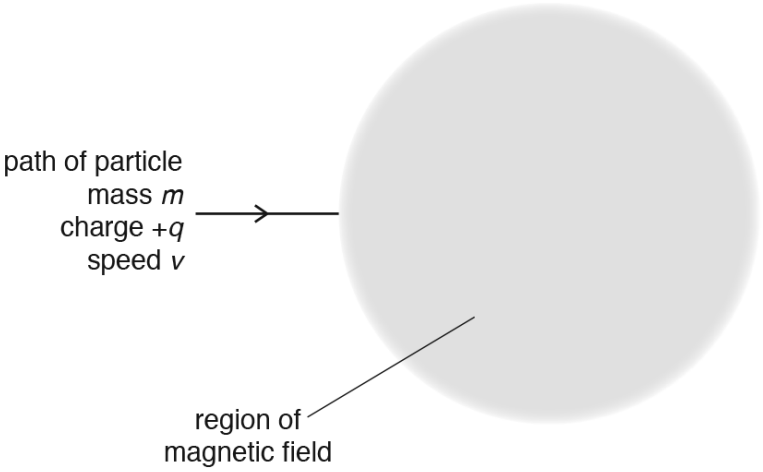


Fig. 8.1

The direction of the magnetic field is perpendicular to, and into, the plane of the paper.

(i) On Fig. 8.1, draw the path of the particle through, and beyond, the region of the magnetic field. [3]

(ii) There is a force acting on the particle, causing it to accelerate.
Explain why the speed of the particle on leaving the magnetic field is v.

.....

.....

.....[1]

(c) The particle in **(b)** loses an electron so that its charge becomes $+2q$. Its change in mass is negligible.

Determine, in terms of v, the initial speed of the particle such that its path through the magnetic field is unchanged. Explain your working.

speed = ... [3]

[Total: 9]

---

269. 9702_w18_qp_43 Q: 8

(a) Explain what is meant by a *magnetic field*.

.....

.....

.....[2]

(b) A particle has mass m, charge $+q$ and speed v.

The particle enters a uniform magnetic field of flux density B such that, on entry, it is moving normal to the magnetic field, as shown in Fig. 8.1.

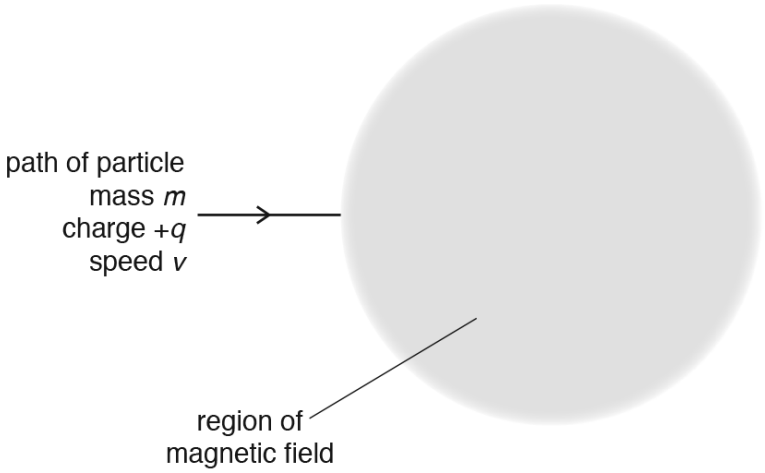


Fig. 8.1

The direction of the magnetic field is perpendicular to, and into, the plane of the paper.

(i) On Fig. 8.1, draw the path of the particle through, and beyond, the region of the magnetic field. [3]

(ii) There is a force acting on the particle, causing it to accelerate.
Explain why the speed of the particle on leaving the magnetic field is v.

.....

.....

.....[1]

(c) The particle in **(b)** loses an electron so that its charge becomes $+2q$. Its change in mass is negligible.

Determine, in terms of v, the initial speed of the particle such that its path through the magnetic field is unchanged. Explain your working.

speed = ... [3]

[Total: 9]

---

270. 9702_m17_qp_42 Q: 8

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

.....

.....

.....[2]

(b) A particle of charge $+q$ and mass m is travelling in a vacuum with speed v. The particle enters, at a right angle, a uniform magnetic field of flux density B, as shown in Fig. 8.1.

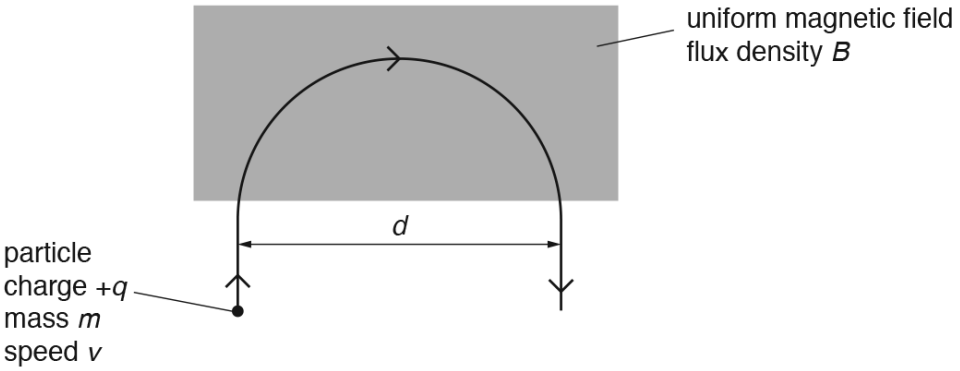


Fig. 8.1

The particle leaves the field after following a semi-circular path of diameter d.

(i) State the direction of the magnetic field.

.....[1]

(ii) Explain why the speed of the particle is not affected by the magnetic field.

.....

.....

.....[2]

(iii) Show that the diameter d of the semi-circular path is given by the expression

$$d = \frac{2mv}{Bq}.$$

[2]

(iv) Use the expression in **(b)(iii)** to show that the time T_F spent in the field by the particle is independent of its speed v.

[2]

[Total: 9]

---

271. 9702_s17_qp_41 Q: 7

An electron having charge $-q$ and mass m is accelerated from rest in a vacuum through a potential difference V.
The electron then enters a region of uniform magnetic field of magnetic flux density B, as shown in Fig. 7.1.

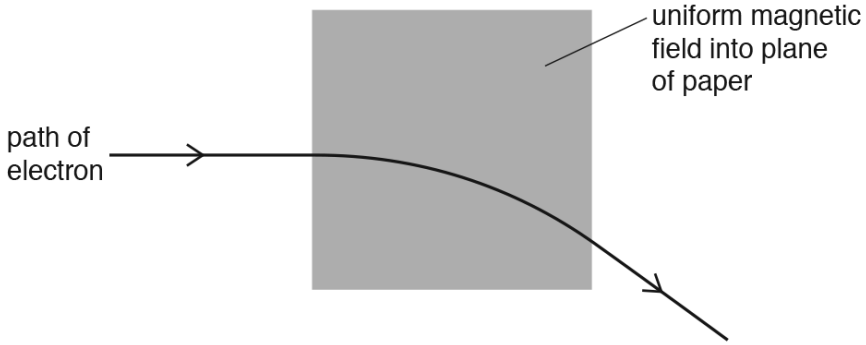


Fig. 7.1

The direction of the uniform magnetic field is into the plane of the paper.
The velocity of the electron as it enters the magnetic field is normal to the magnetic field.
The radius of the circular path of the electron in the magnetic field is r.

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

.....

.....

.....

.....[3]

(b) Show that the magnitude p of the momentum of the electron as it enters the magnetic field is given by

$$p = \sqrt{(2mqV)}.$$

[2]

(c) The potential difference V is 120 V. The radius r of the circular arc is 7.4 cm.

Determine the magnitude B of the magnetic flux density.

B = ... T [3]

(d) The potential difference V in **(c)** is increased. The magnetic flux density B remains unchanged.

By reference to the momentum of the electron, explain the effect of this increase on the radius r of the path of the electron in the magnetic field.

.....

.....

.....[2]

[Total: 10]

272. 9702_s17_qp_42 Q: 9

A Hall probe is placed near to one end of a current-carrying solenoid, as shown in Fig. 9.1.

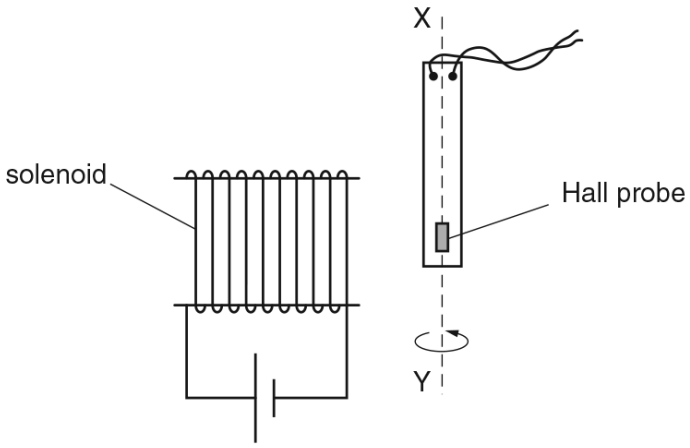


Fig. 9.1

The probe is rotated about the axis XY and is then held in a position so that the Hall voltage is maximum.

(a) Explain why

(i) a Hall probe is made from a *thin slice* of material,

.....

.....

.....[2]

(ii) in order for consistent measurements of magnetic flux density to be made, the current in the probe must be constant.

.....

.....[1]

(b) The probe is now rotated through an angle of 360° about the axis XY.
At angle $\theta = 0$, the Hall voltage V_H has maximum value V_{MAX}.

On Fig. 9.2, sketch the variation with angle θ of the Hall voltage V_H for one complete revolution of the probe about axis XY.

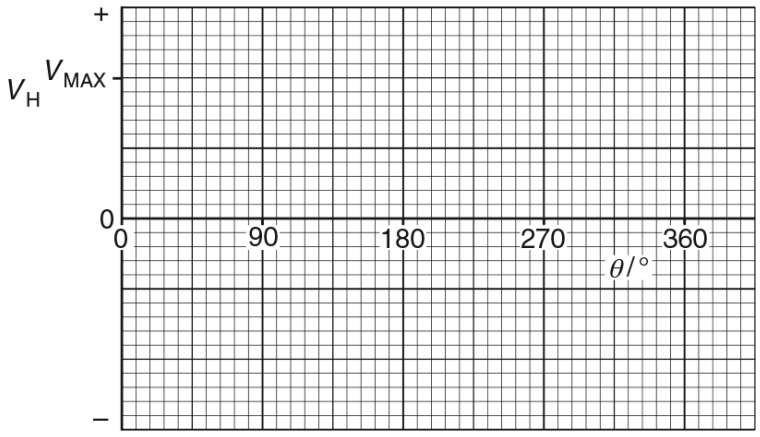


Fig. 9.2

[3]

[Total: 6]

273. 9702_s17_qp_43 Q: 7

An electron having charge $-q$ and mass m is accelerated from rest in a vacuum through a potential difference V.
The electron then enters a region of uniform magnetic field of magnetic flux density B, as shown in Fig. 7.1.

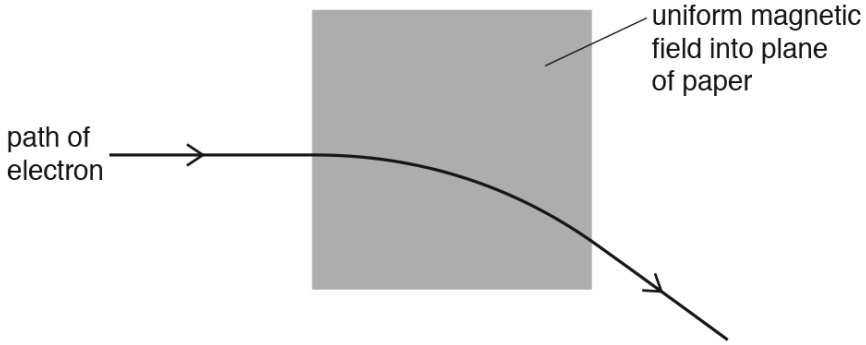


Fig. 7.1

The direction of the uniform magnetic field is into the plane of the paper.
The velocity of the electron as it enters the magnetic field is normal to the magnetic field.
The radius of the circular path of the electron in the magnetic field is r.

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

.....

.....

.....

.....[3]

(b) Show that the magnitude p of the momentum of the electron as it enters the magnetic field is given by

$$p = \sqrt{(2mqV)}.$$

[2]

(c) The potential difference V is 120 V. The radius r of the circular arc is 7.4 cm.

Determine the magnitude B of the magnetic flux density.

B = ... T [3]

(d) The potential difference V in **(c)** is increased. The magnetic flux density B remains unchanged.

By reference to the momentum of the electron, explain the effect of this increase on the radius r of the path of the electron in the magnetic field.

.....

.....

.....[2]

[Total: 10]

---

274. 9702_w17_qp_41 Q: 8

A thin slice of conducting material is placed normal to a uniform magnetic field of flux density *B*, as shown in Fig. 8.1.

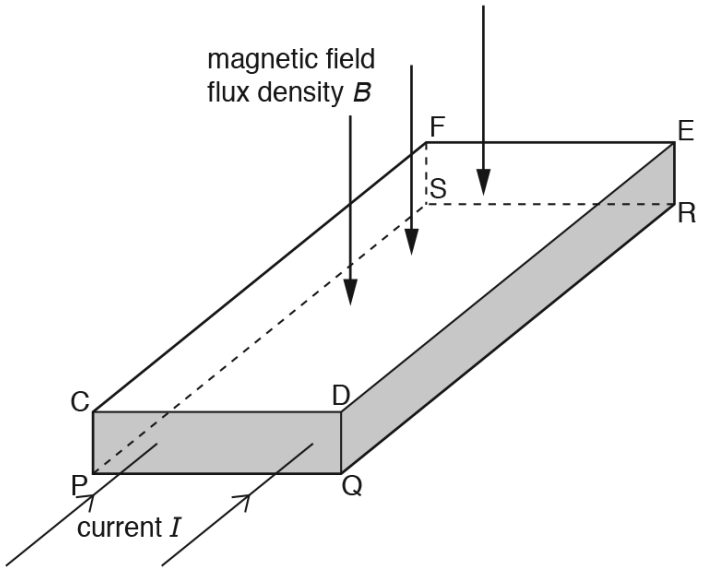


Fig. 8.1

The magnetic field is normal to face CDEF and to face PQRS.

A current I passes through the slice and is normal to the faces CDQP and FERS.

A potential difference, the Hall voltage V_H, is developed across the slice.

(a) State the faces between which the Hall voltage V_H is developed.

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

(b) The current I is produced by charge carriers, each of charge $+q$ moving at speed v in the direction of the current. The number density of the charge carriers is n.

(i) Derive an expression relating the Hall voltage V_H to v, B and d, where d is one of the dimensions of the slice.

[3]

STEMUP.CO.UK

(ii) Use your answer in **(b)(i)** and an expression for the current I in the slice to derive the expression

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

Explain your working.

[2]

(c) Suggest why the Hall voltage is difficult to detect in a thin slice of copper.

.....

.....

..... [2]

[Total: 8]

275. 9702_w17_qp_42 Q: 8

A thin slice of conducting material is placed normal to a uniform magnetic field, as shown in Fig. 8.1.

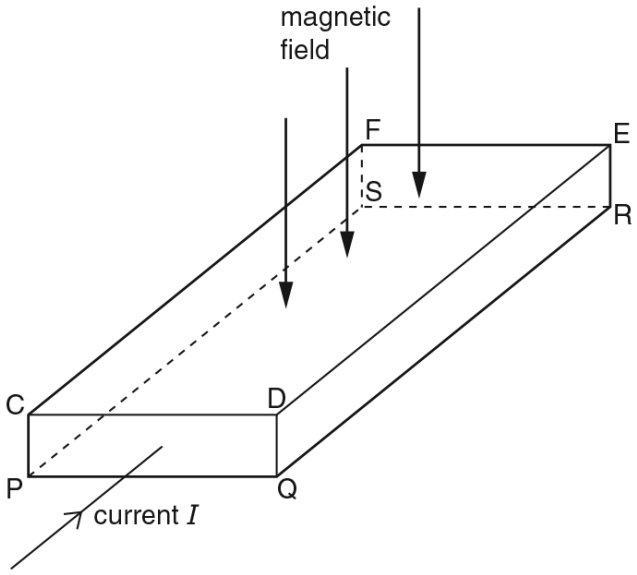


Fig. 8.1

The magnetic field is normal to face CDEF and to face PQRS.

The current I in the slice is normal to the faces CDQP and FERS.

A potential difference, the Hall voltage V_H, is developed across the slice.

(a) (i) State the faces between which the Hall voltage V_H is developed.

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

(ii) Explain why a constant voltage V_H is developed between the faces you have named in **(i)**.

.....

.....

.....

.....

.....

.....

.....[4]

(b) Two slices have similar dimensions. One slice is made of a metal and the other slice is made of a semiconductor material.

For the same values of magnetic flux density and current, state which slice, if either, will give rise to the larger Hall voltage. Explain your reasoning.

.....

.....

.....

.....[2]

[Total: 7]

---

276. 9702_w17_qp_42 Q: 9

(a) State what is meant by a *field of force*.

.....

.....

.....[2]

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

.....

.....

.....

.....

.....

.....[4]

(c) A beam of charged particles enters a region of uniform magnetic and electric fields, as illustrated in Fig. 9.1.



Fig. 9.1

The direction of the magnetic field is into the plane of the paper. The velocity of the charged particles is normal to the magnetic field as the particles enter the field.

A particle in the beam has mass *m*, charge +*q* and velocity *v*. The particle passes undeviated through the region of the two fields.

On Fig. 9.1, sketch the path of a particle that has

(i) mass *m*, charge +2*q* and velocity *v* (label this path Q), [1]

(ii) mass *m*, charge +*q* and velocity slightly larger than *v* (label this path V). [2]

[Total: 9]

277. 9702_w17_qp_43 Q: 8

A thin slice of conducting material is placed normal to a uniform magnetic field of flux density *B*, as shown in Fig. 8.1.

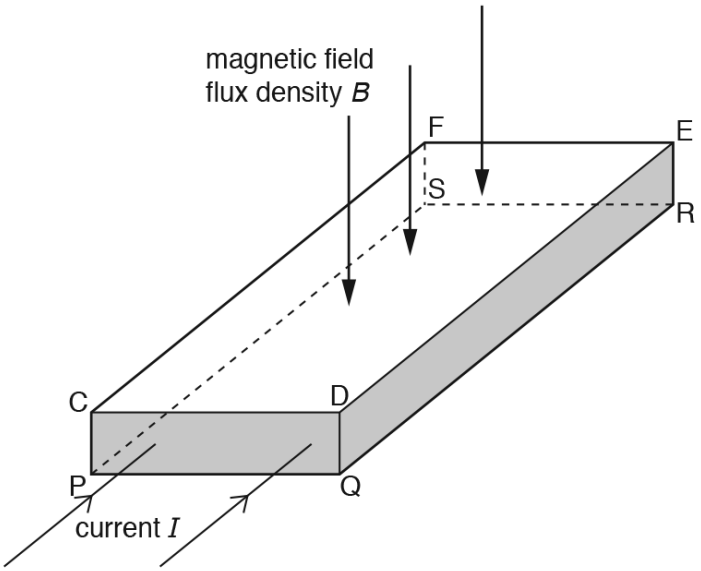


Fig. 8.1

The magnetic field is normal to face CDEF and to face PQRS.

A current I passes through the slice and is normal to the faces CDQP and FERS.

A potential difference, the Hall voltage V_H, is developed across the slice.

(a) State the faces between which the Hall voltage V_H is developed.

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

(b) The current I is produced by charge carriers, each of charge $+q$ moving at speed v in the direction of the current. The number density of the charge carriers is n.

(i) Derive an expression relating the Hall voltage V_H to v, B and d, where d is one of the dimensions of the slice.

[3]

(ii) Use your answer in **(b)(i)** and an expression for the current I in the slice to derive the expression

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

Explain your working.

[2]

(c) Suggest why the Hall voltage is difficult to detect in a thin slice of copper.

.....

.....

..... [2]

[Total: 8]

278. 9702_w16_qp_41 Q: 7

(a) Explain what is meant by a *field of force*.

.....

..... [1]

(b) State the type of field, or fields, that will give rise to a force acting on

(i) a moving uncharged particle,

..... [1]

(ii) a stationary charged particle,

..... [1]

(iii) a charged particle moving at an angle to the field or fields.

.....

..... [1]

(c) An electron, mass m and charge $-q$, is moving at speed v in a vacuum. It enters a region of uniform magnetic field of flux density B, as shown in Fig. 7.1.

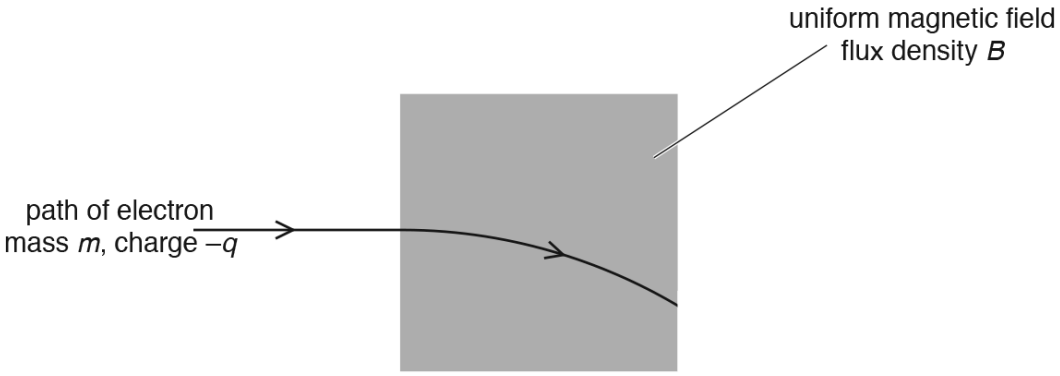


Fig. 7.1

Initially, the electron is moving at right-angles to the direction of the magnetic field.

(i) Explain why the path of the electron in the magnetic field is the arc of a circle.

.....

.....

.....

.....

..... [3]

(ii) Derive an expression, in terms of the radius r of the path, for the linear momentum of the electron. Show your working.

[2]

[Total: 9]

---

279. 9702_w16_qp_43 Q: 7

(a) Explain what is meant by a *field of force*.

.....

..... [1]

(b) State the type of field, or fields, that will give rise to a force acting on

(i) a moving uncharged particle,

..... [1]

(ii) a stationary charged particle,

..... [1]

(iii) a charged particle moving at an angle to the field or fields.

.....

..... [1]

(c) An electron, mass m and charge $-q$, is moving at speed v in a vacuum. It enters a region of uniform magnetic field of flux density B, as shown in Fig. 7.1.

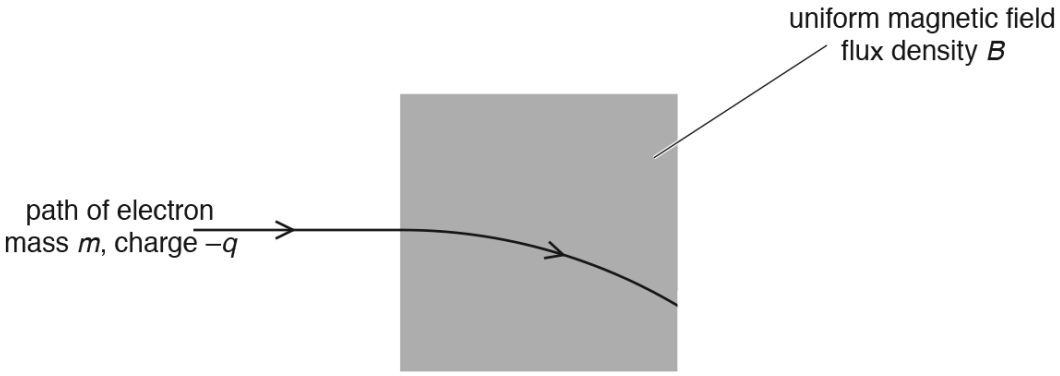


Fig. 7.1

Initially, the electron is moving at right-angles to the direction of the magnetic field.

(i) Explain why the path of the electron in the magnetic field is the arc of a circle.

.....

.....

.....

.....

..... [3]

(ii) Derive an expression, in terms of the radius r of the path, for the linear momentum of the electron. Show your working.

[2]

[Total: 9]

---

280. 9702_w21_qp_42 Q: 8

Two long straight parallel wires P and Q carry currents into the plane of the paper, as shown in Fig. 8.1.



Fig. 8.1

The current in P is I and the current in Q is $2I$.

(a) (i) On Fig. 8.1, draw an arrow to show the direction of the magnetic field at wire Q due to the current in wire P. Label this arrow B. [1]

(ii) On Fig. 8.1, draw another arrow to show the direction of the force acting on wire Q due to the current in wire P. Label this arrow F. [1]

(b) (i) State, with a reason, how the magnitude of the force acting on wire P compares with the magnitude of the force acting on wire Q.

.....

.....

.....

..... [2]

(ii) State how the direction of the force on wire P compares with the direction of the force on wire Q.

.....

..... [1]

[Total: 5]

281. 9702_w19_qp_41 Q: 8

(a) A long straight vertical wire carries a current I. The wire passes through a horizontal card EFGH, as shown in Fig. 8.1 and Fig. 8.2.

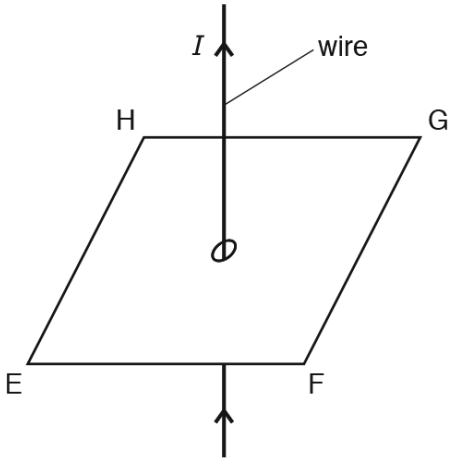


Fig. 8.1

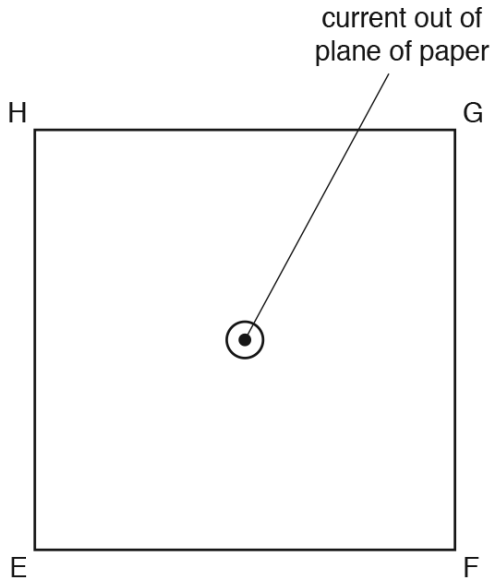


Fig. 8.2 (view from above)

On Fig. 8.2, draw the pattern of the magnetic field produced by the current-carrying wire on the plane EFGH. [3]

(b) Two long straight parallel wires P and Q are situated a distance 3.1 cm apart, as illustrated in Fig. 8.3.

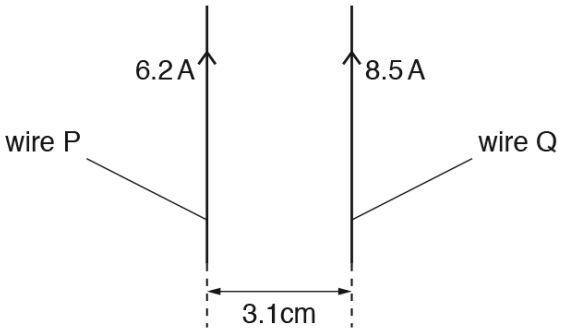


Fig. 8.3

The current in wire P is 6.2 A. The current in wire Q is 8.5 A.

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

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

where μ_0 is the permeability of free space.

Calculate:

(i) the magnetic flux density at wire Q due to the current in wire P

flux density = ... T [2]

(ii) the force per unit length, in $N\,m^{-1}$, acting on wire Q due to the current in wire P.

force per unit length = ... $N\,m^{-1}$ [2]

(c) The currents in wires P and Q are different in magnitude.

State and explain whether the forces per unit length on the two wires will be different.

.....

.....

..... [2]

[Total: 9]

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282. 9702_w19_qp_43 Q: 8

(a) A long straight vertical wire carries a current I. The wire passes through a horizontal card EFGH, as shown in Fig. 8.1 and Fig. 8.2.

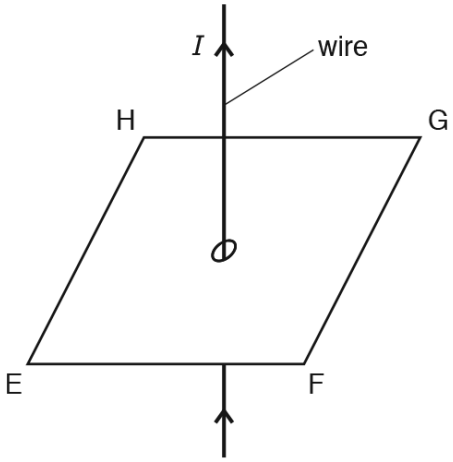


Fig. 8.1

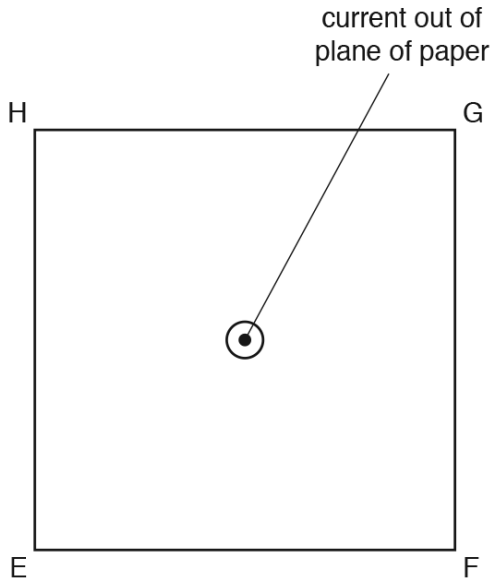


Fig. 8.2 (view from above)

On Fig. 8.2, draw the pattern of the magnetic field produced by the current-carrying wire on the plane EFGH. [3]

(b) Two long straight parallel wires P and Q are situated a distance 3.1 cm apart, as illustrated in Fig. 8.3.

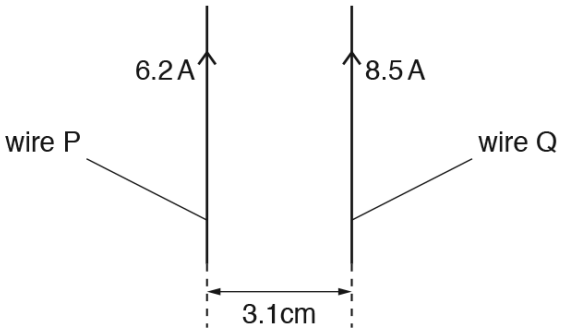


Fig. 8.3

The current in wire P is 6.2 A. The current in wire Q is 8.5 A.

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

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

where μ_0 is the permeability of free space.

Calculate:

(i) the magnetic flux density at wire Q due to the current in wire P

flux density = ... T [2]

(ii) the force per unit length, in $N\,m^{-1}$, acting on wire Q due to the current in wire P.

force per unit length = ... $N\,m^{-1}$ [2]

(c) The currents in wires P and Q are different in magnitude.

State and explain whether the forces per unit length on the two wires will be different.

.....

.....

..... [2]

[Total: 9]

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283. 9702_m21_qp_42 Q: 8

Two long straight wires P and Q are parallel to each other, as shown in Fig. 8.1. There is a current in each wire in the direction shown.

The pattern of the magnetic field lines in a plane normal to wire P due to the current in the wire is also shown.

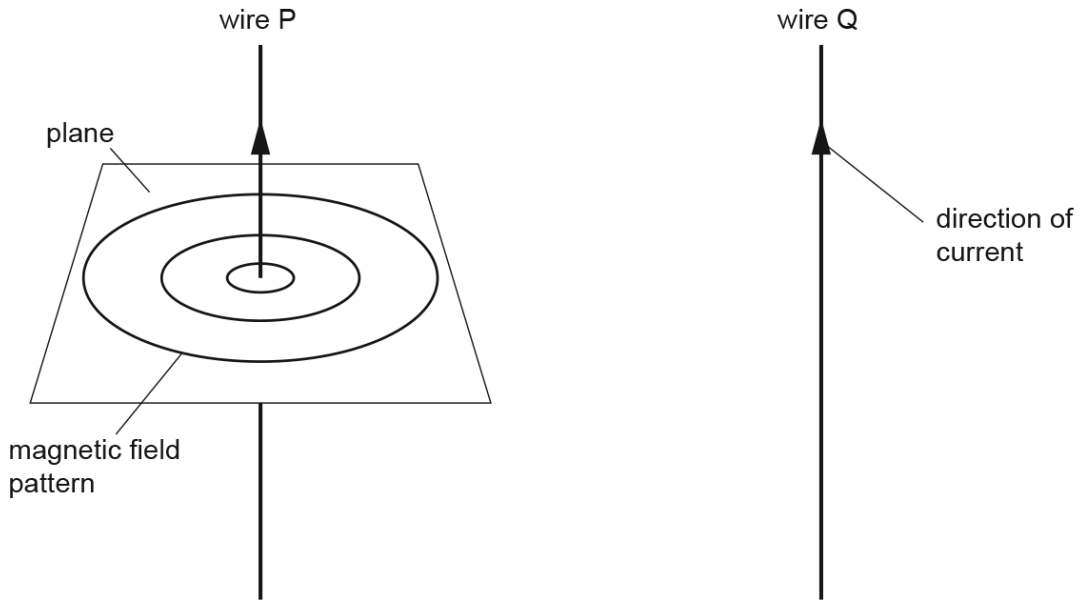


Fig. 8.1

(i) Draw arrows on the magnetic field lines in Fig. 8.1 around wire P to show the direction of the field. [1]

(ii) Determine the direction of the force on wire Q due to the magnetic field from wire P.

..... [1]

(iii) The current in wire Q is less than the current in wire P.

State and explain whether the magnitude of the force on wire P is less than, equal to, or greater than the magnitude of the force on wire Q.

.....

.....

..... [2]

(b) Nuclear magnetic resonance imaging (NMRI) is used to obtain diagnostic information about internal structures in the human body.

Radio waves are produced and directed towards the body. The radio waves affect the protons within the body.

(i) Explain why radio waves are used.

.....

.....

..... [2]

(ii) Explain why the radio waves are applied in pulses.

.....

.....

..... [2]

[Total: 8]

284. 9702_s19_qp_41 Q: 9

Nuclear magnetic resonance imaging (NMRI) is used to obtain diagnostic information about internal body structures.

State, during the use of NMRI, the function of:

(a) the large constant magnetic field

.....

.....

.....

.....

..... [3]

(b) the non-uniform magnetic field.

.....

.....

.....

.....

..... [2]

[Total: 5]

285. 9702_s19_qp_43 Q: 9

Nuclear magnetic resonance imaging (NMRI) is used to obtain diagnostic information about internal body structures.

State, during the use of NMRI, the function of:

(a) the large constant magnetic field

.....

.....

.....

.....

..... [3]

(b) the non-uniform magnetic field.

.....

.....

.....

.....

..... [2]

[Total: 5]

286. 9702_w19_qp_41 Q: 9

Diagnosis using nuclear magnetic resonance imaging (NMRI) requires the use of a non-uniform magnetic field superimposed on a constant magnetic field of large magnitude.

Explain the purpose of:

(a) the large constant magnetic field

.....

.....

.....

.....

..... [2]

(b) the non-uniform magnetic field.

.....

.....

.....

.....

..... [2]

[Total: 4]

287. 9702_w19_qp_43 Q: 9

Diagnosis using nuclear magnetic resonance imaging (NMRI) requires the use of a non-uniform magnetic field superimposed on a constant magnetic field of large magnitude.

Explain the purpose of:

(a) the large constant magnetic field

.....

.....

.....

.....

..... [2]

(b) the non-uniform magnetic field.

.....

.....

.....

.....

..... [2]

[Total: 4]

288. 9702_s17_qp_41 Q: 8

Explain the main principles behind the use of nuclear magnetic resonance imaging (NMRI) to obtain information about internal body structures.

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.....[8]

[Total: 8]

289. 9702_s17_qp_43 Q: 8

Explain the main principles behind the use of nuclear magnetic resonance imaging (NMRI) to obtain information about internal body structures.

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.....[8]

[Total: 8]

290. 9702_w16_qp_41 Q: 8

Explain the main principles behind the use of nuclear magnetic resonance imaging (NMRI) to obtain diagnostic information about internal body structures.

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..... [8]

[Total: 8]

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291. 9702_w16_qp_42 Q: 10

Explain the function of the non-uniform magnetic field that is superimposed on a large uniform magnetic field in diagnosis using nuclear magnetic resonance imaging (NMRI).

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.....[4]

[Total: 4]

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292. 9702_w16_qp_43 Q: 8

Explain the main principles behind the use of nuclear magnetic resonance imaging (NMRI) to obtain diagnostic information about internal body structures.

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..... [8]

[Total: 8]

Q1.

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

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

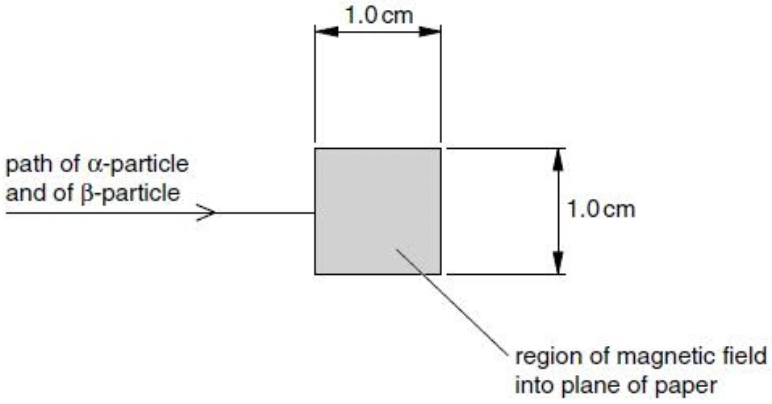


Fig. 5.1

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.

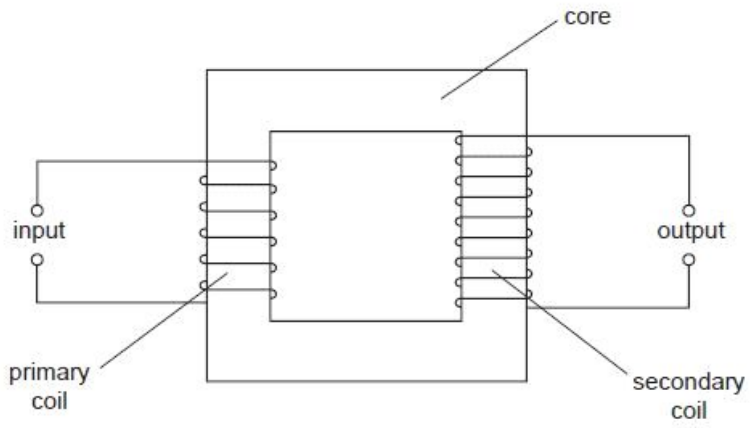


Fig. 6.1

(a) Explain why

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

.....

.....

.....[2]

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

.....

.....

.....[2]

Use

(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.

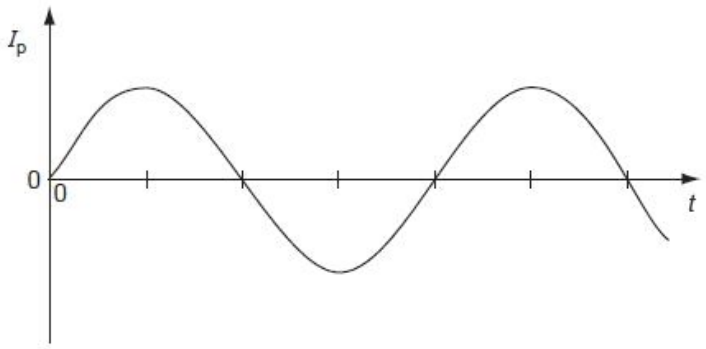


Fig. 6.2

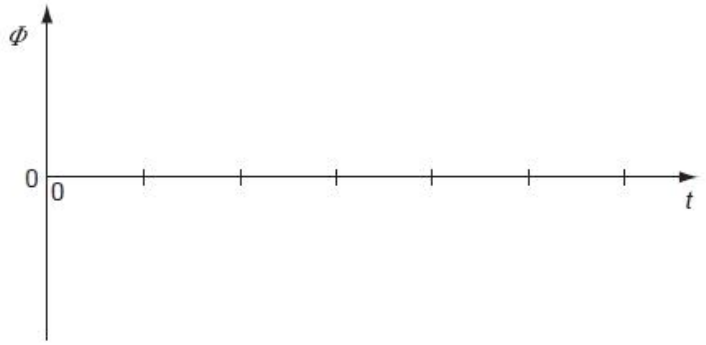


Fig. 6.3

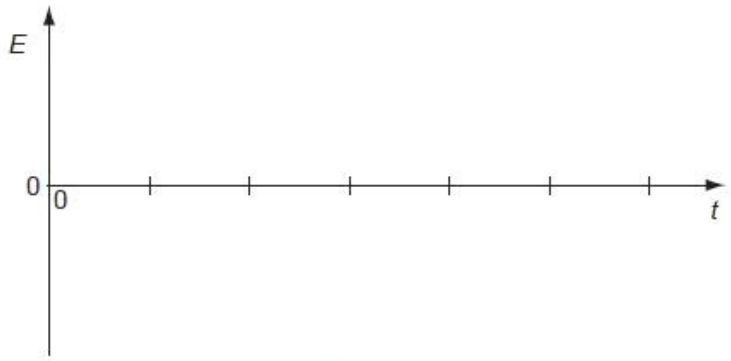


Fig. 6.4

(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 wire 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.

.....

.....

.....

.....

..... [4]

Q4.

Use

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.

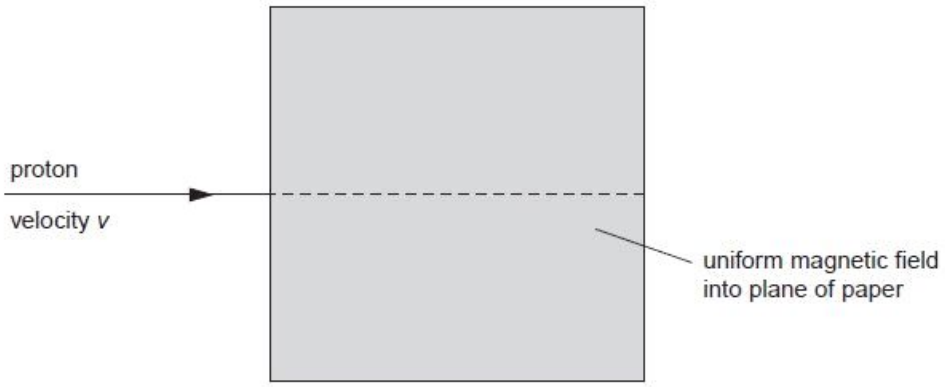


Fig. 8.1

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

.....

.....

.....

..... [3]

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

.....

.....

.....

..... [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.

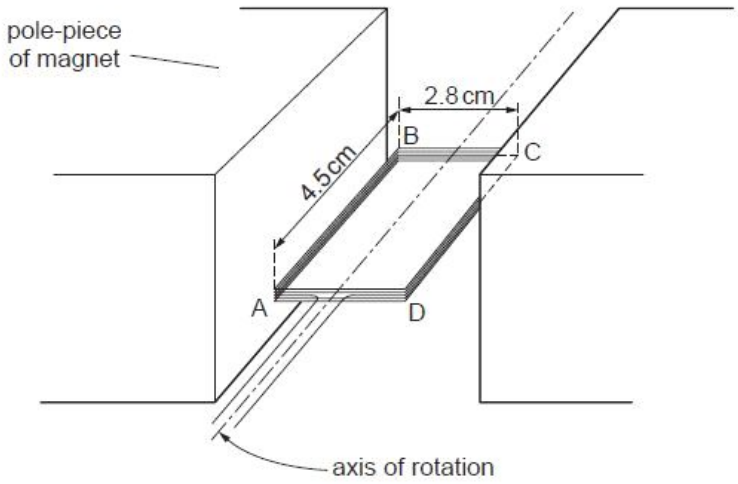


Fig. 6.1

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} N m.

(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.

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*.

.....

.....

.....

..... [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.

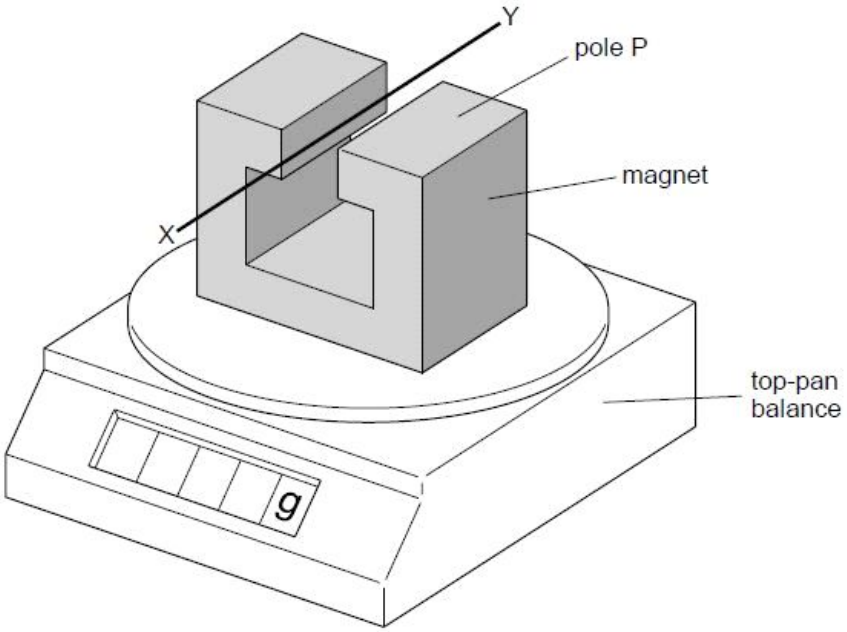


Fig. 6.1

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 2.6 A is passed through the wire in the direction from X to Y.
The reading on the top-pan balance increases by 2.3 g.

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

.....

.....

.....

..... [3]

(ii) Calculate the flux density between the poles.

Fo Exami Us

flux density = ... T [3]

(c) The direct current in **(b)** is now replaced by a very low frequency sinusoidal current of r.m.s. value 2.6 A.
Calculate the variation in the reading of the top-pan balance.

variation in reading = ... 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.

E

.....

.....

.....

.....

.....

.....

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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.

For Examin Use

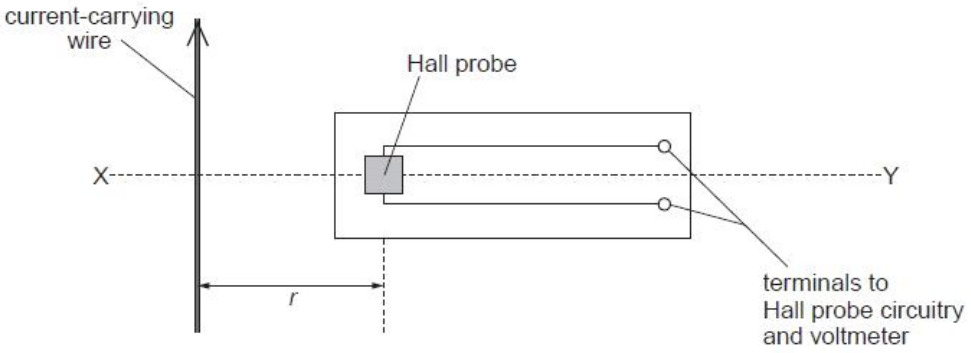


Fig. 5.1

(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.

[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 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.

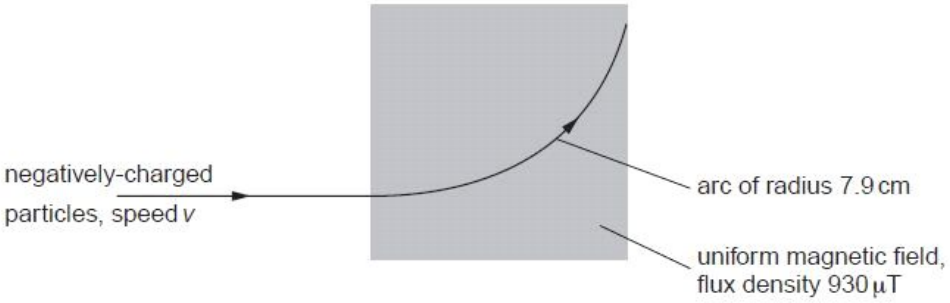


Fig. 7.1

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,

v = ... m s^{-1} [3]

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

ratio = ... 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.

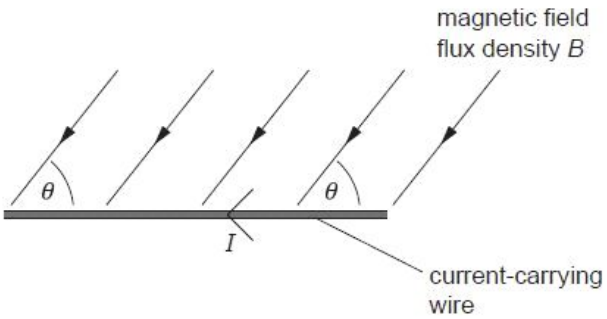


Fig. 6.1

(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.

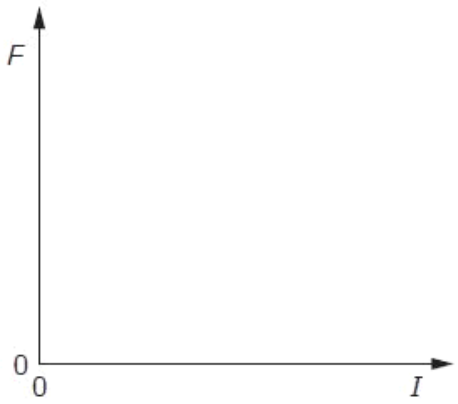


Fig. 6.2

[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.

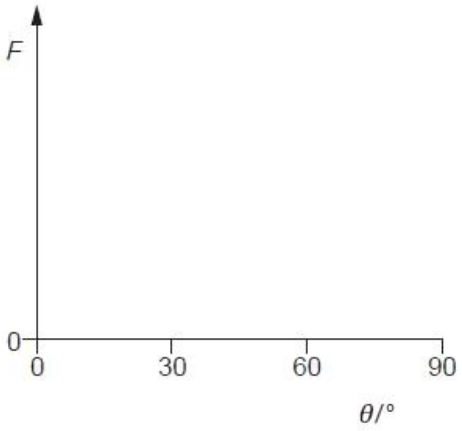


Fig. 6.3 [3]

(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.

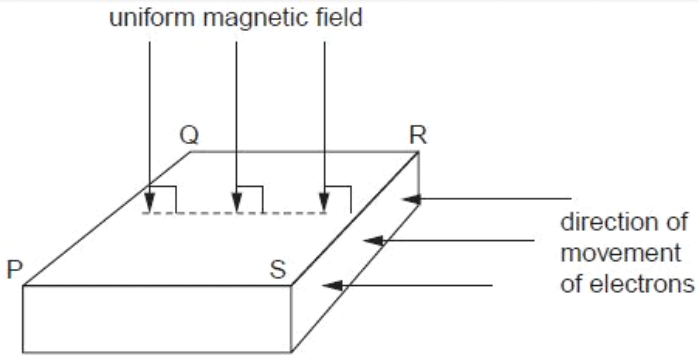


Fig. 6.4

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.

.....

.....

..... [2]

Q11.

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

.....

.....

.....[2]

(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.

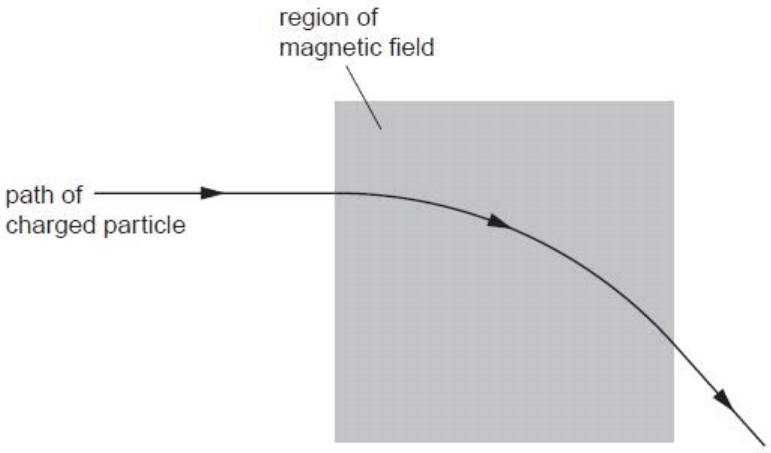


Fig. 5.1

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.

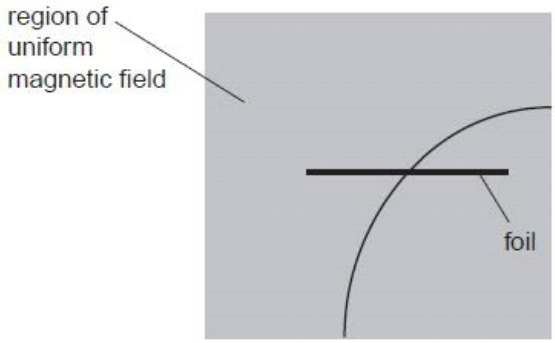


Fig. 5.2

(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.

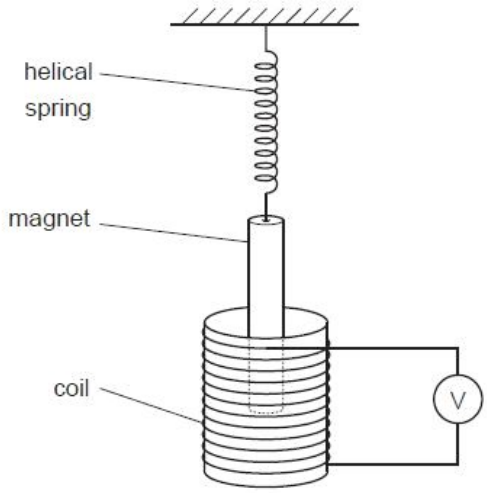


Fig. 5.1

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.

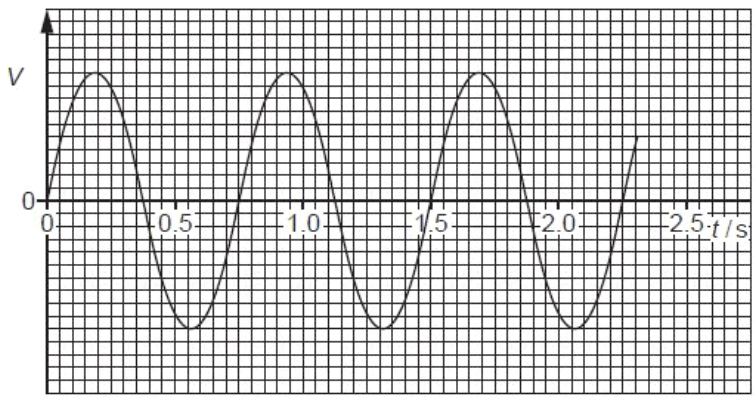


Fig. 5.2

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

.....

.....

..... [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.

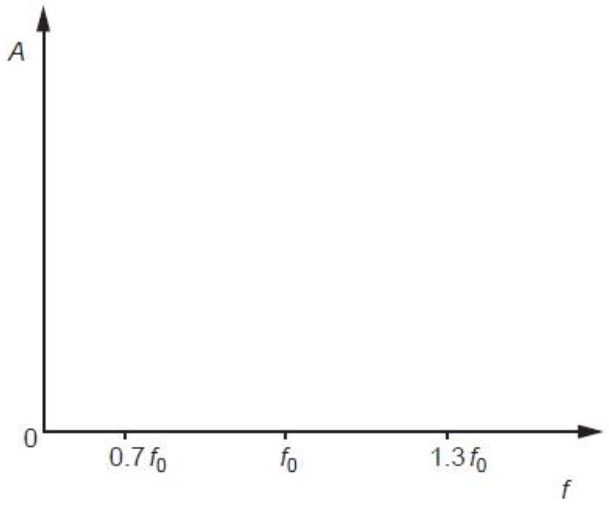
.....

..... [1]

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

f_0 = ... Hz [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.

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..... [1]

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

.....

..... [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.

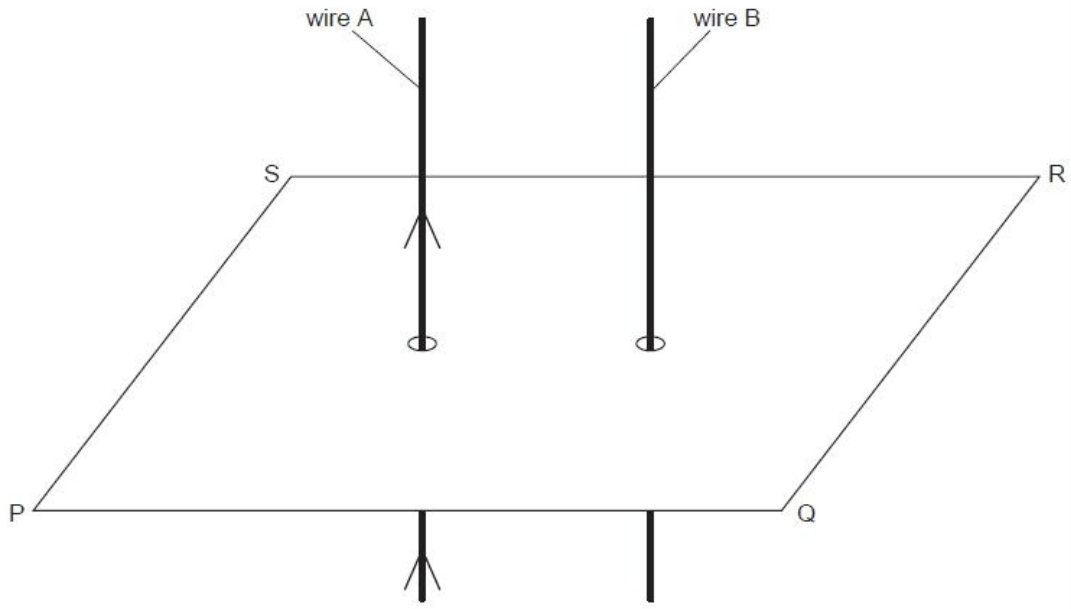


Fig. 7.1

(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.

.....

.....

..... [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.

.....

.....

.....

..... [3]

Q14.

5 **(a)** Define the *tesla*.

.....

.....

.....

.....[3]

(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.

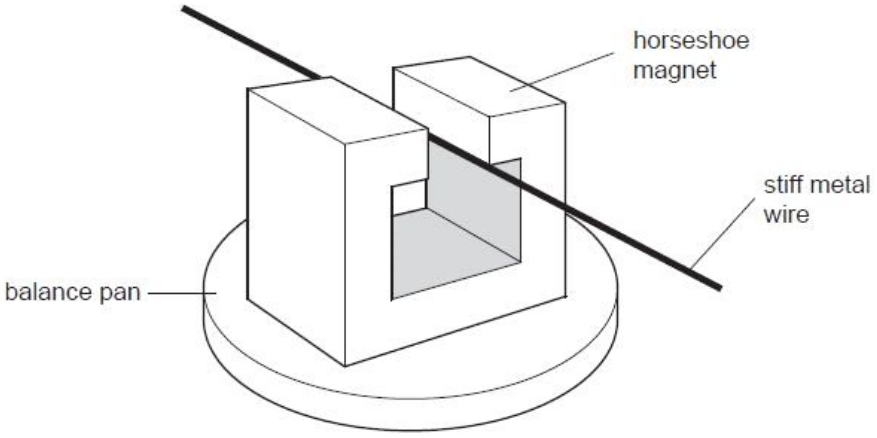


Fig. 5.1

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.

flux density = ...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.

.....

.....

.....

.....[2]

Q15.

5 **(a)** Define the *tesla*.

.....

.....

.....[2]

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

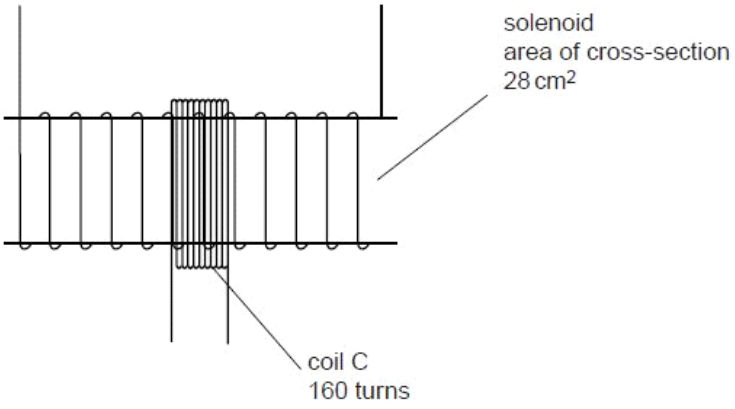


Fig. 5.1

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 $1.5 \times 10^3 m^{-1}$ and μ_0 is the permeability of free space.

Calculate, for a current of 3.5 A 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.

flux linkage = ... 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.

e.m.f. = ... 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.

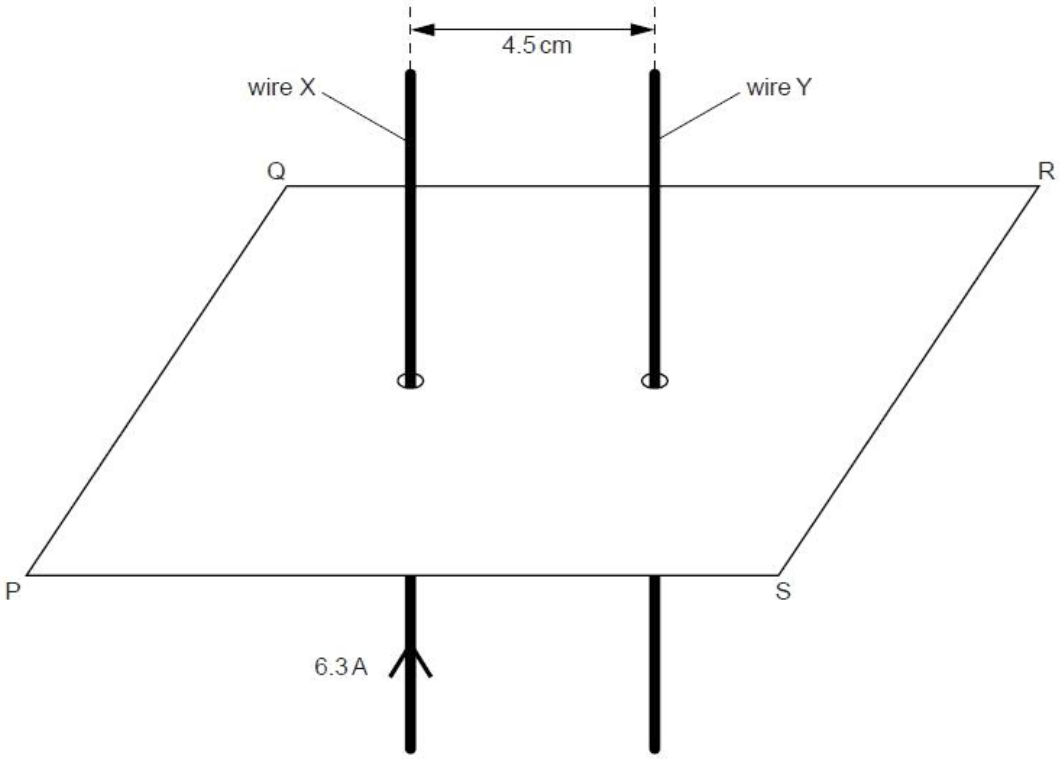


Fig. 5.1

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]

For Examiner Use

(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 = ... Nm^{-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.

.....

.....

..... [2]

Q17.

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

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

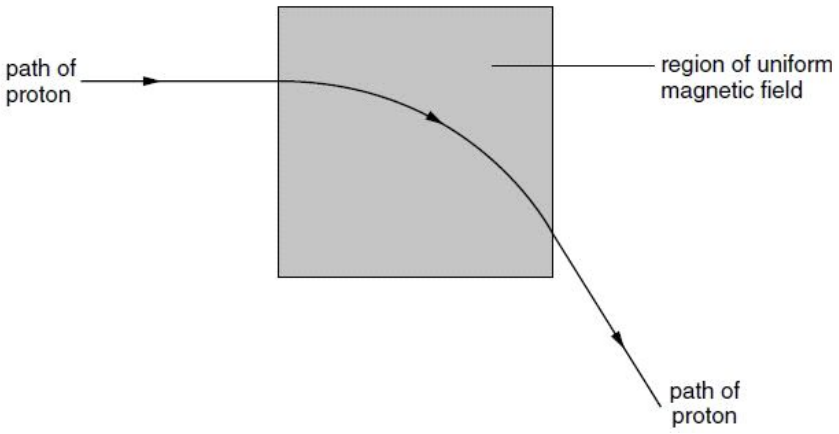
1. .....

.....

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.

radius = ... 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.

field strength = ... $V\,m^{-1}$
[3]

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

.....

.....[1]

Q18.

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

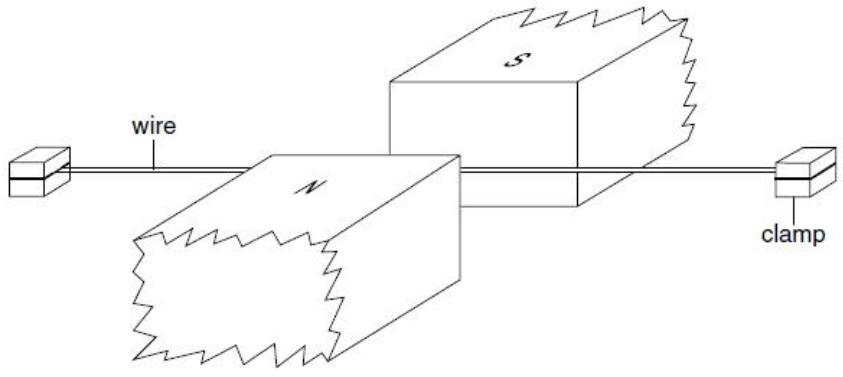


Fig. 7.1

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.

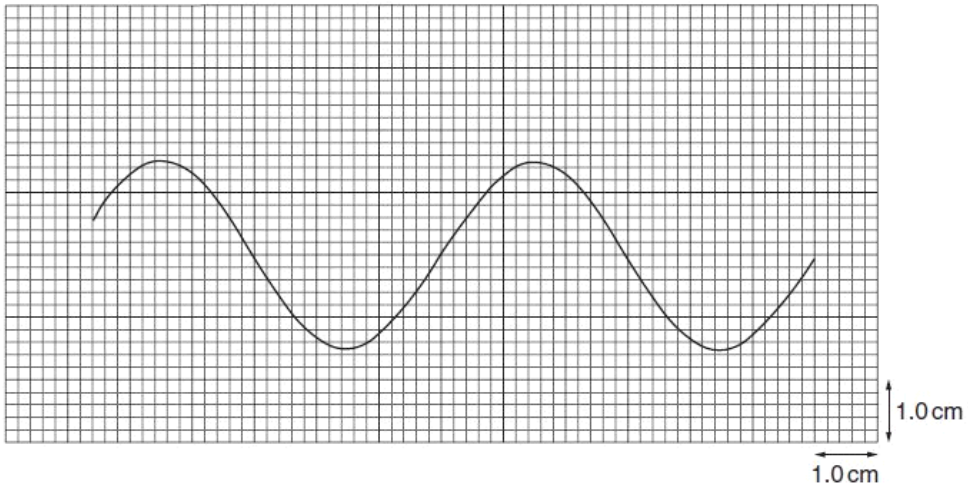


Fig. 7.2

(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 × 60 cm, as illustrated in Fig. 5.1.

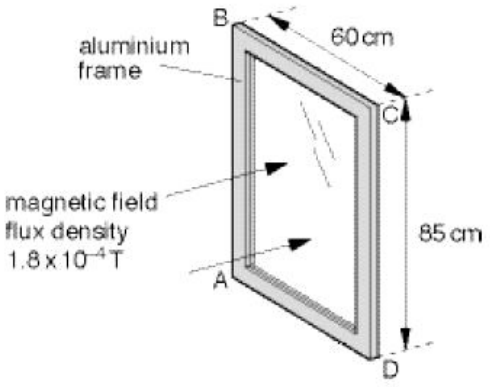


Fig. 5.1

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.

magnetic flux = ... Wb [2]

Use

(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,

change = ... Wb

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

e.m.f. = ... 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.

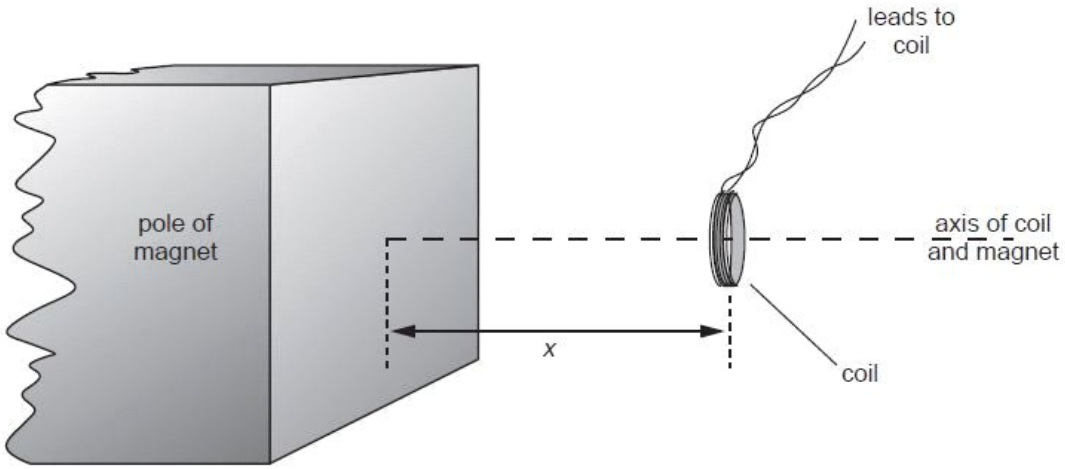


Fig. 4.1

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.

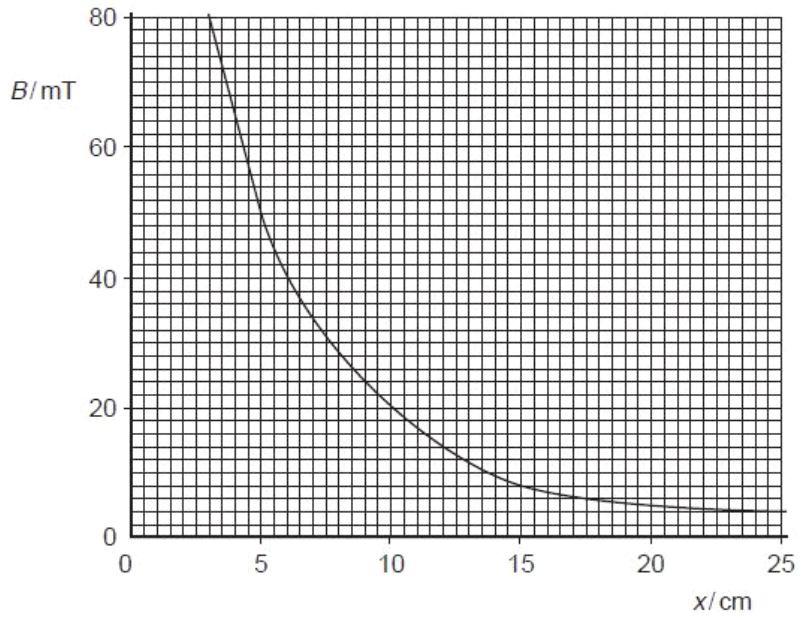


Fig. 4.2

(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 $x = 5.0$ cm to $x = 15.0$ cm in a time of 0.30 s. Calculate

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

change = ... Wb [2]

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

e.m.f. = ... 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.

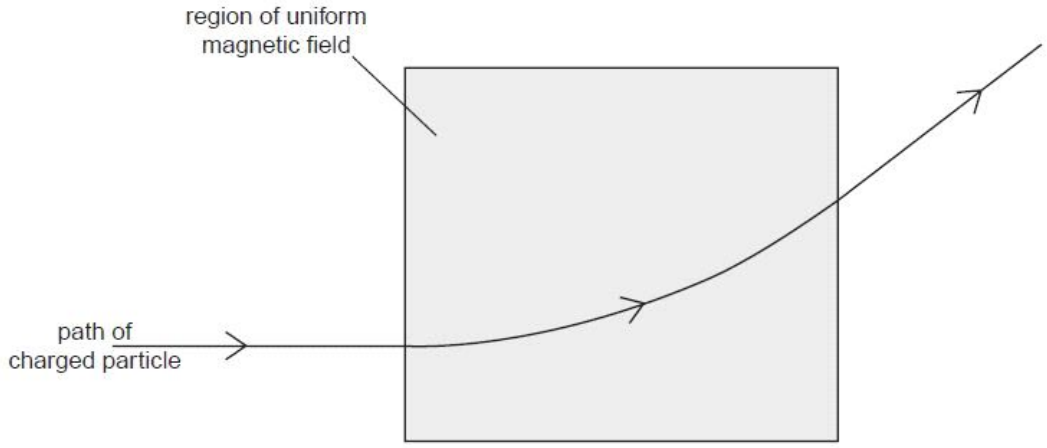


Fig. 5.1

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 $8.2 \times 10^6\,m\,s^{-1}$. Calculate the specific charge of the particle.

specific charge = ... $C\,kg^{-1}$ [2]

(c) (i) The particle in **(b)** has charge $1.6 \times 10^{-19}\,C$. 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 $1.2 \times 10^4\,V$.
Show that the final speed of the electron is $6.5 \times 10^7\,m\,s^{-1}$.

[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.

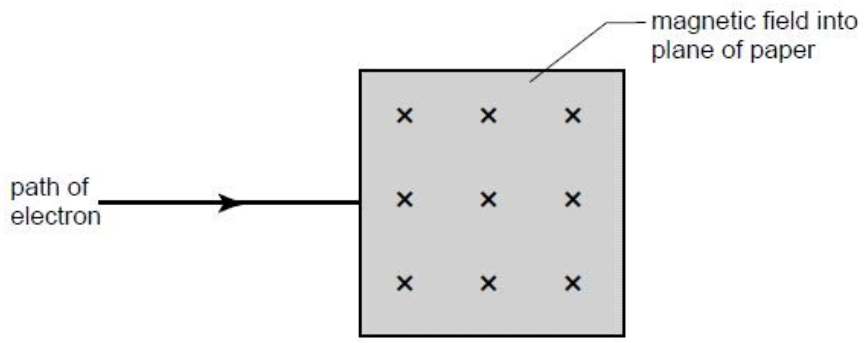


Fig. 5.1

(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]

Use

(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.

Use

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.

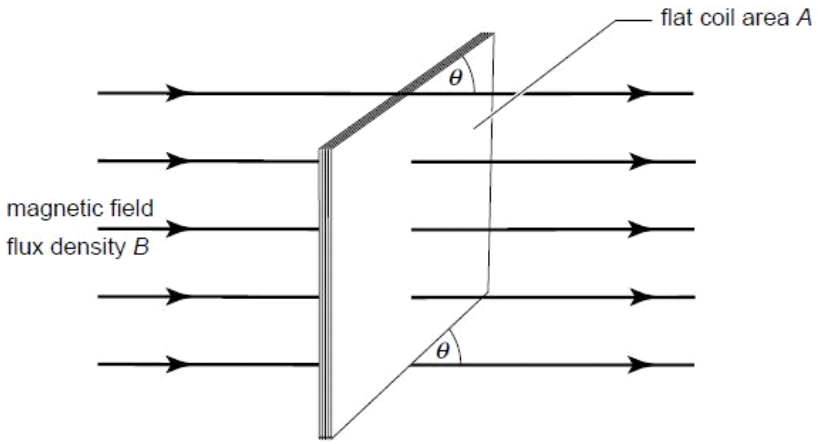


Fig. 6.1

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.

.....

.....

..... [2]

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

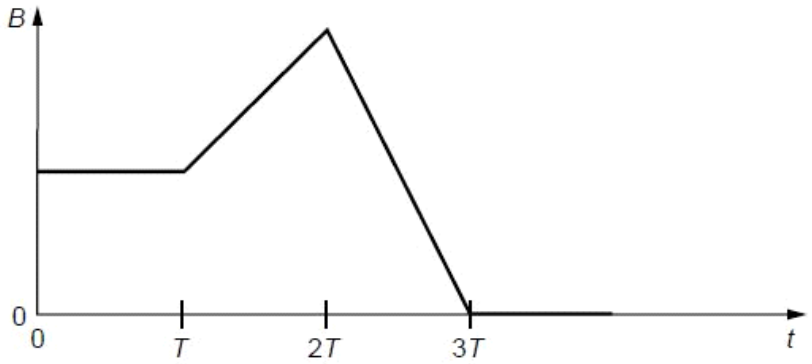


Fig. 6.2

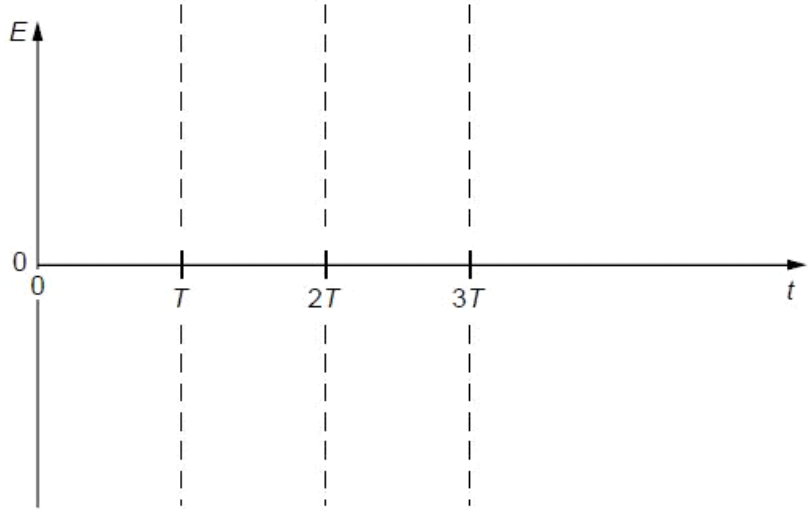


Fig. 6.3

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.

use

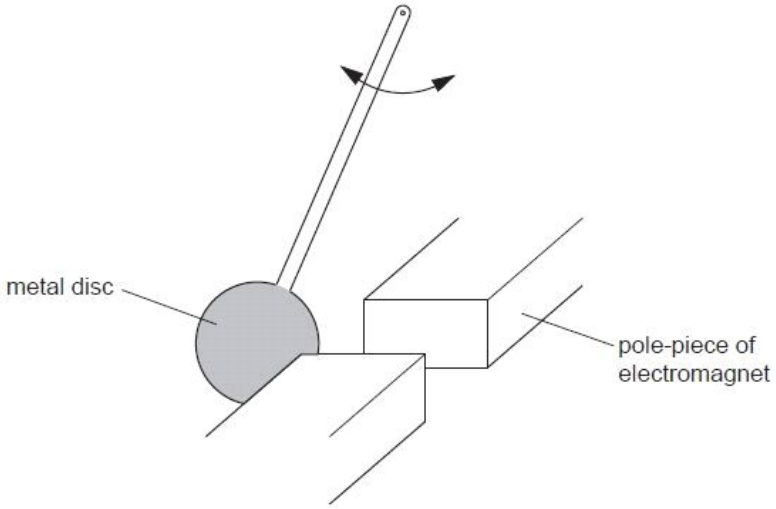


Fig. 5.1

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.

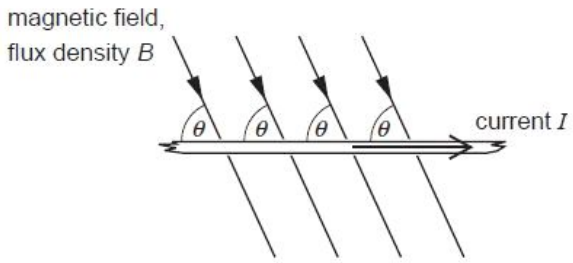


Fig. 6.1

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.

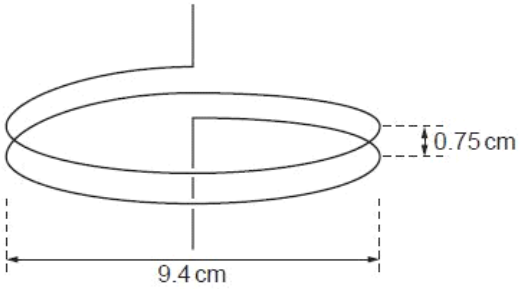


Fig. 6.2

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*.

For Examiner 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.

For Examiner Use

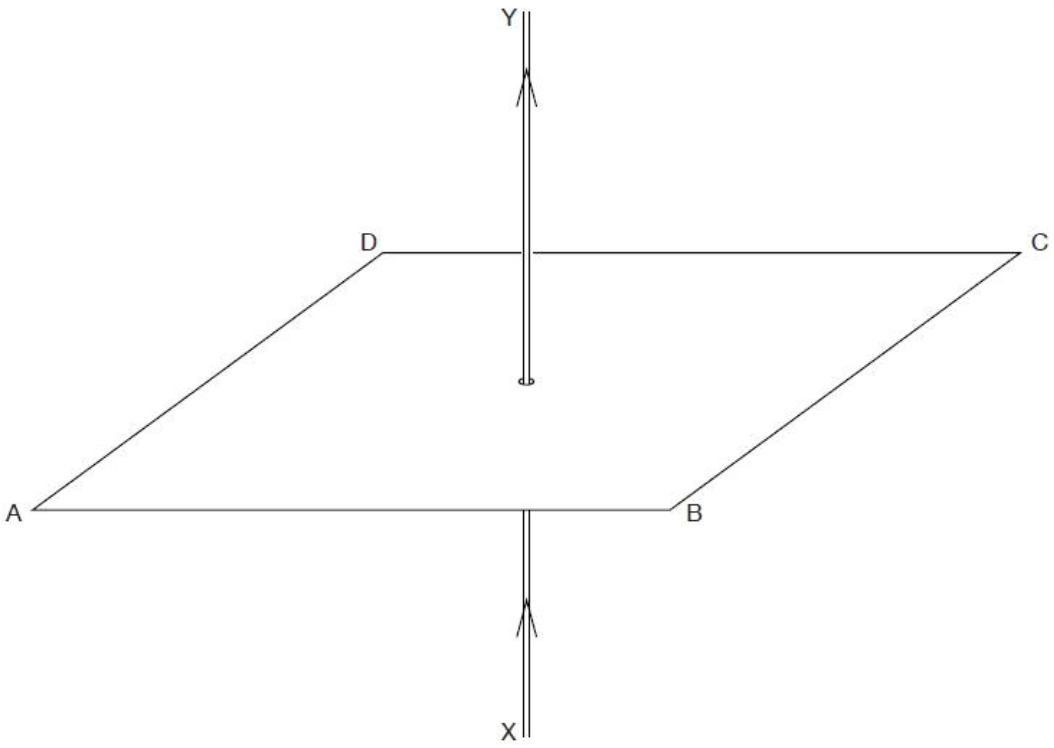


Fig. 6.1

(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.

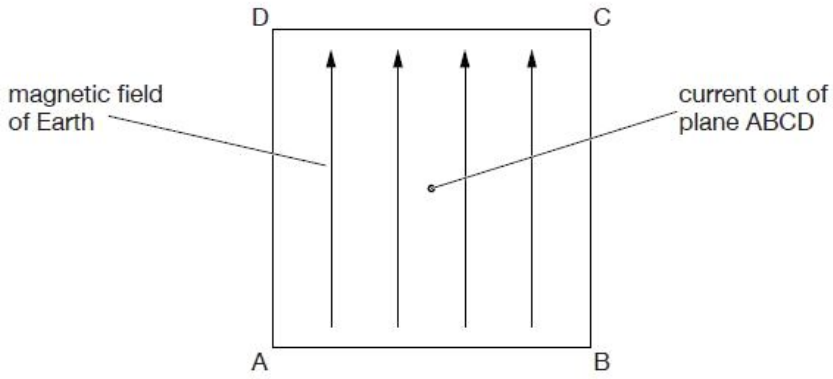


Fig. 6.2

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]

For Examiner Use

(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.

For Examin Use

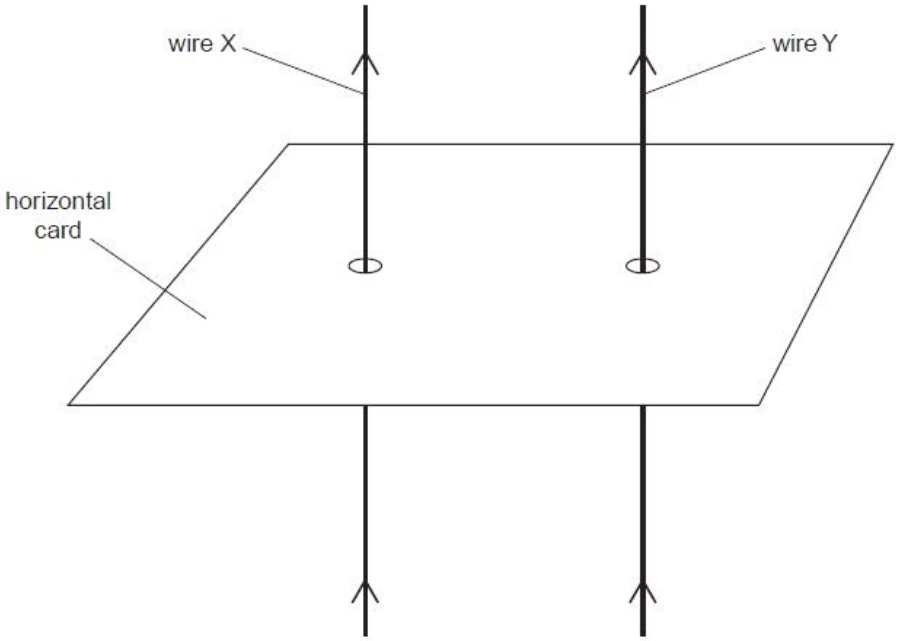


Fig. 5.1

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.

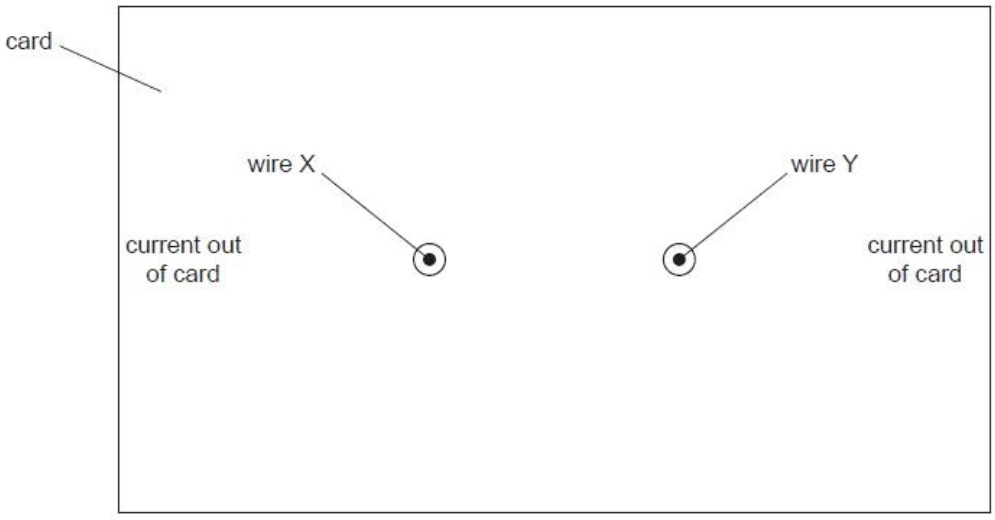


Fig. 5.2 (not to scale)

(a) On Fig. 5.2,

For Examiner Use

(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

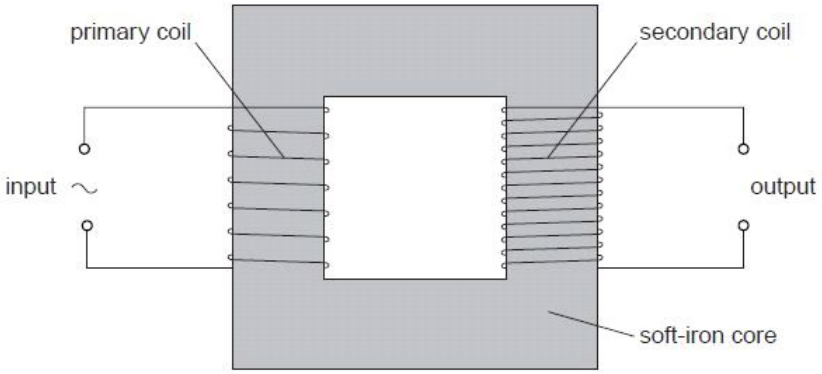


Fig. 6.1

(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.

For Examin Use

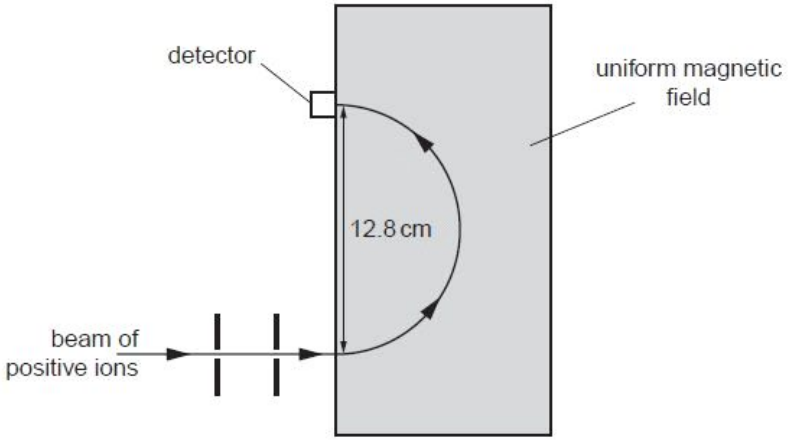


Fig. 5.1

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

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

.....[1]

(b) The ions have mass 20 u and charge $+1.6 \times 10^{-19}$ 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.

For Examiner's 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.

For Examiner's Use

5 The poles of a horseshoe magnet measure 5.0 cm × 2.4 cm, as shown in Fig. 5.1.

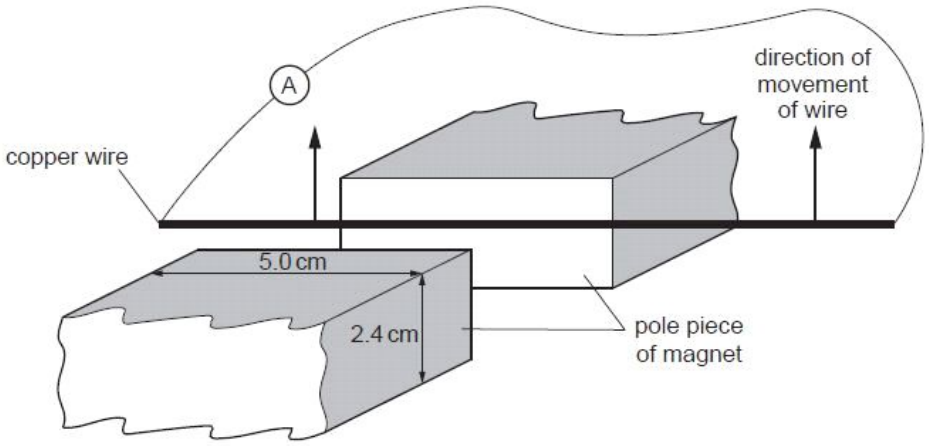


Fig. 5.1

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 0.12 Ω. A student moves the wire at a constant speed of 1.8 m s^{-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.

magnetic flux = ... 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.

e.m.f. = ... V [3]

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

For Examiner's 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.

For Examiner's Use

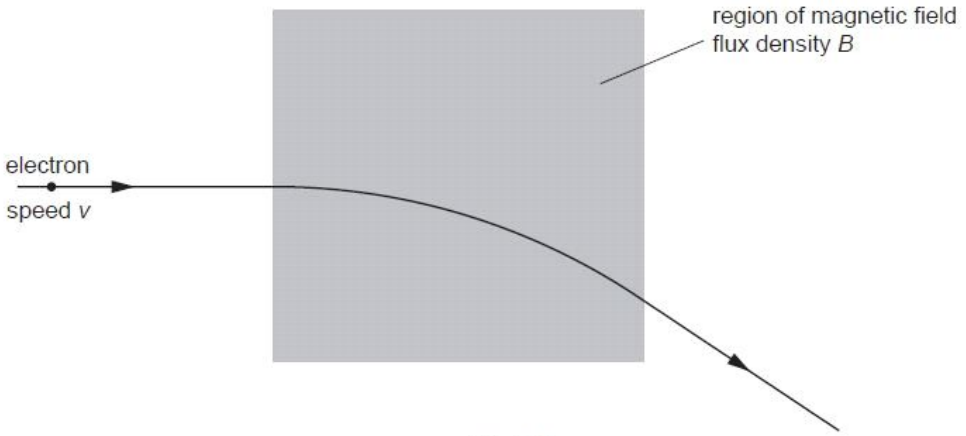


Fig. 7.1

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.

For Examiner's Use

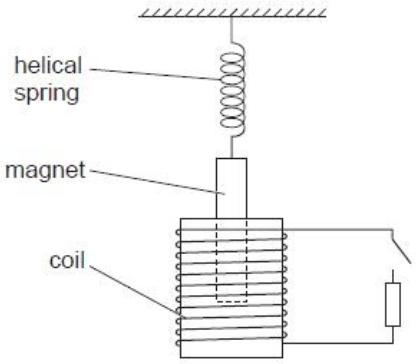


Fig. 3.1

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.

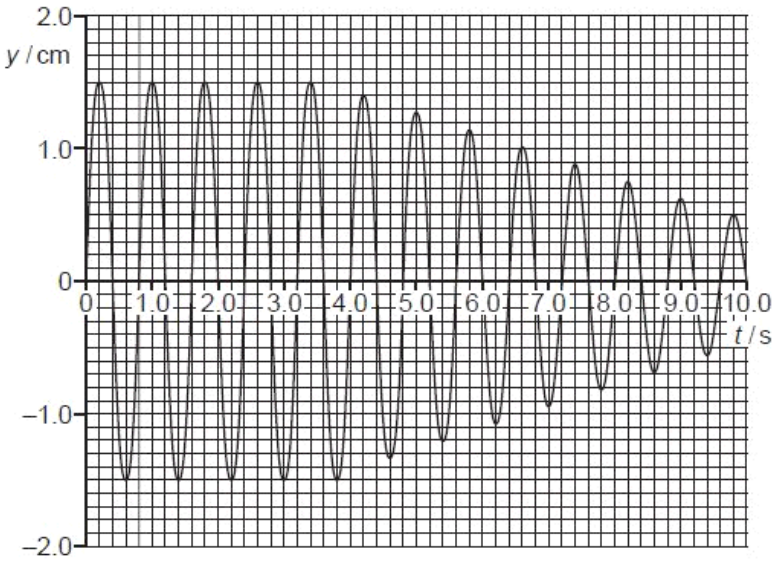


Fig. 3.2

At time t = 4.0 s, the switch is closed.

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

.....

.....

.....[2]

(ii) Explain why, after time t = 4.0 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.

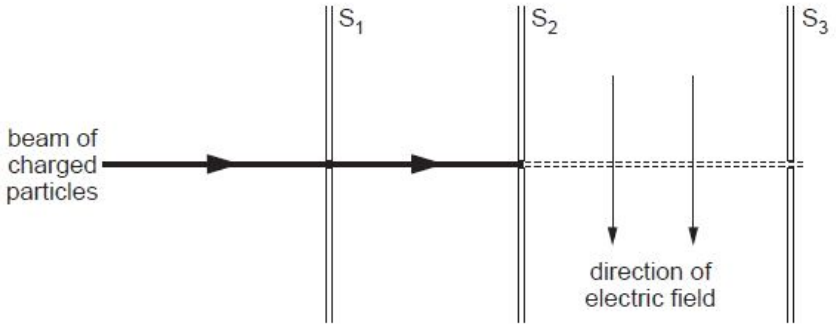


Fig. 5.1

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*.

For Examin 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.

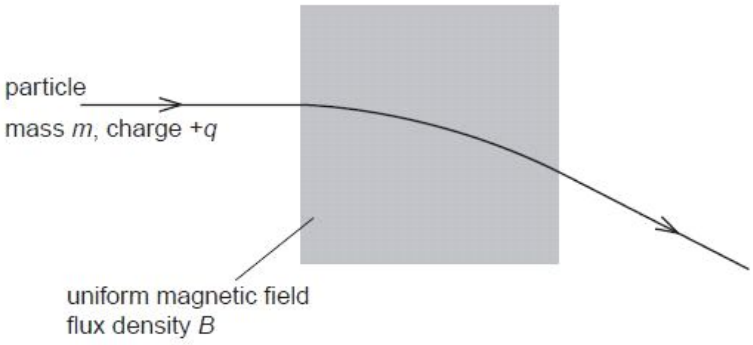


Fig. 6.1

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.

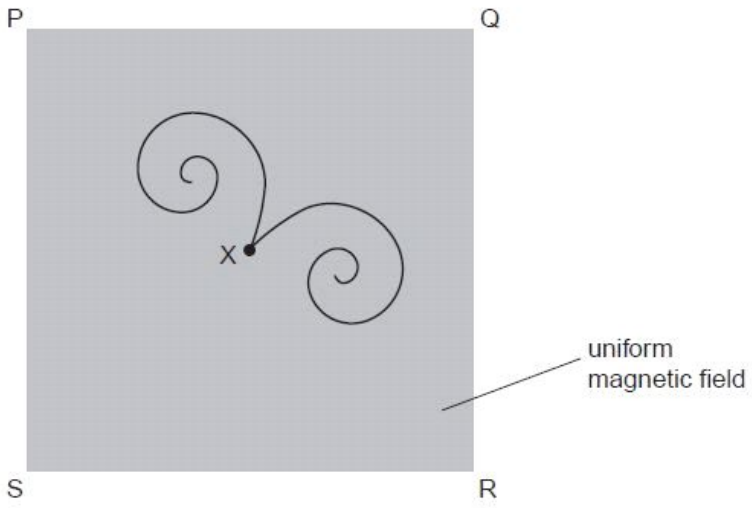


Fig. 6.2

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

1. the charges on the two particles,

.....

.....

..... [2]

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.

For Examiner's 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.

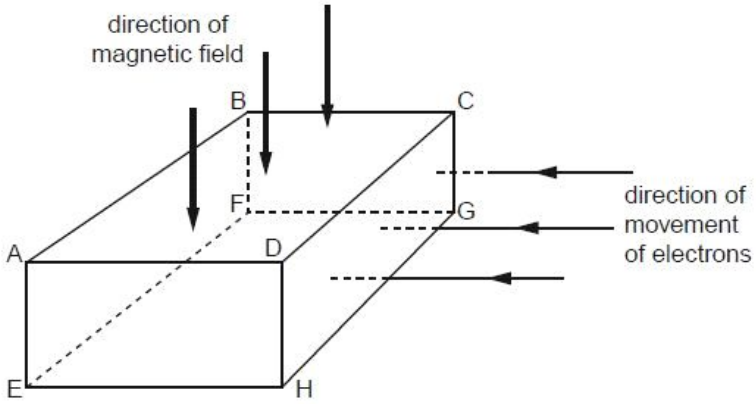


Fig. 6.1

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.

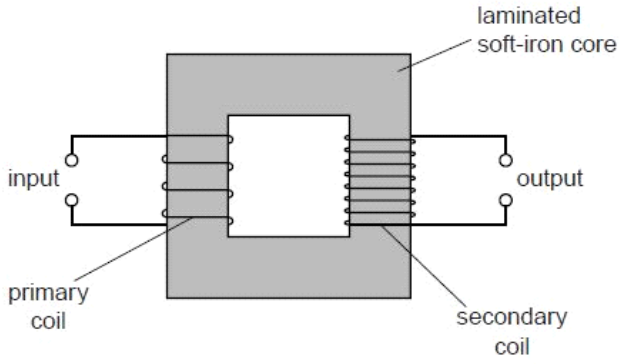


Fig. 7.1

(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.

For Examiner's Use

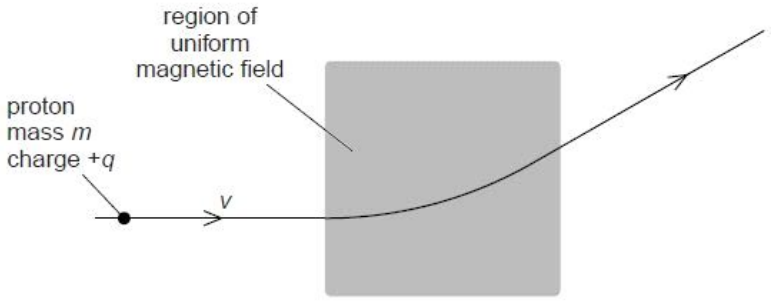


Fig. 4.1

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.

For Examiner 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.

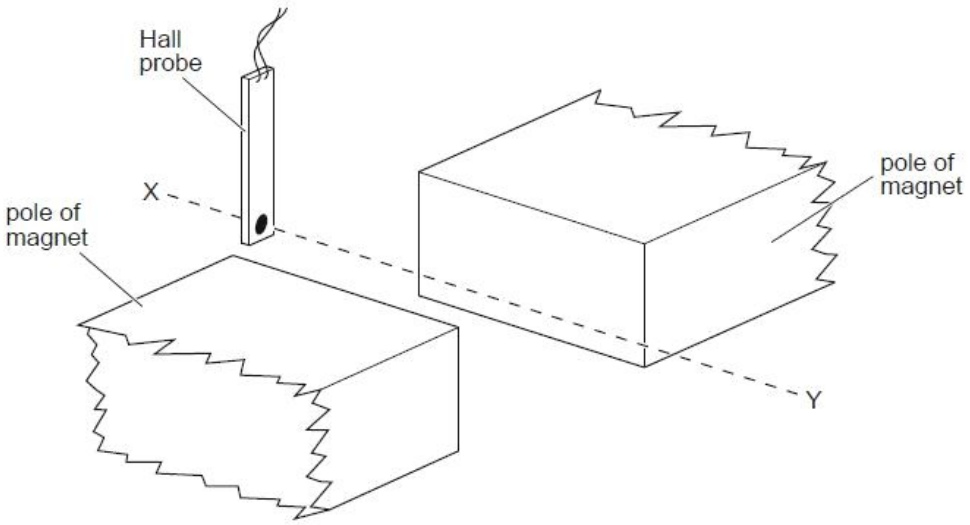


Fig. 5.1

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.

For Examiner's Use

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.

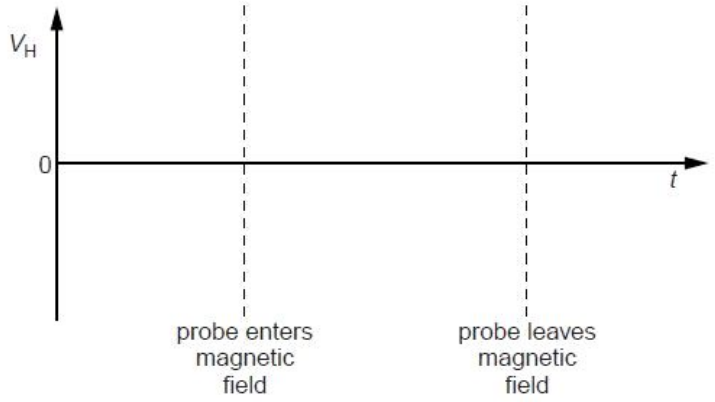


Fig. 5.2

[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.

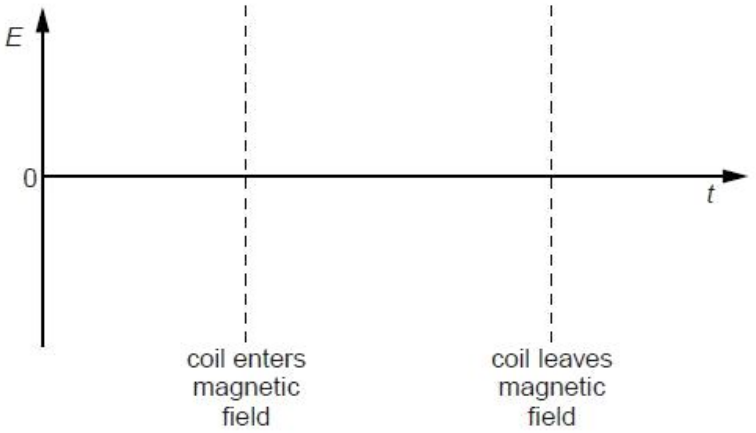


Fig. 5.3

[3]

Q40.

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

For Examiner's Use

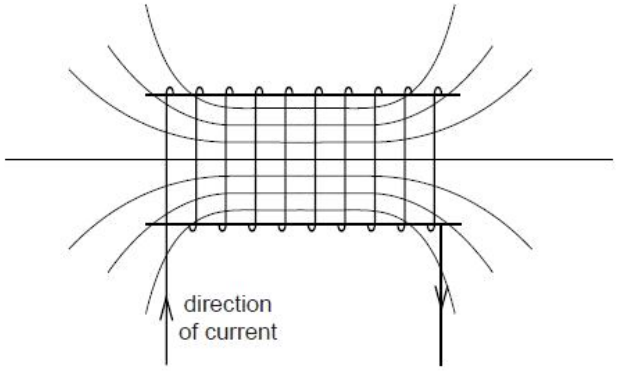


Fig. 5.1

(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.

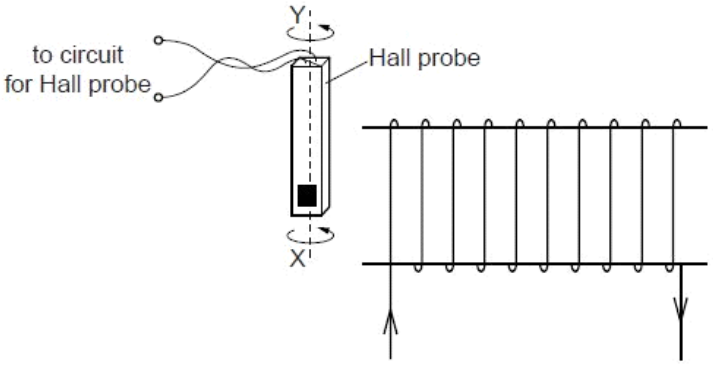


Fig. 5.2

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°.

For Examiner Use

(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 $2.0 \times 10^7\,\text{m s}^{-1}$. 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

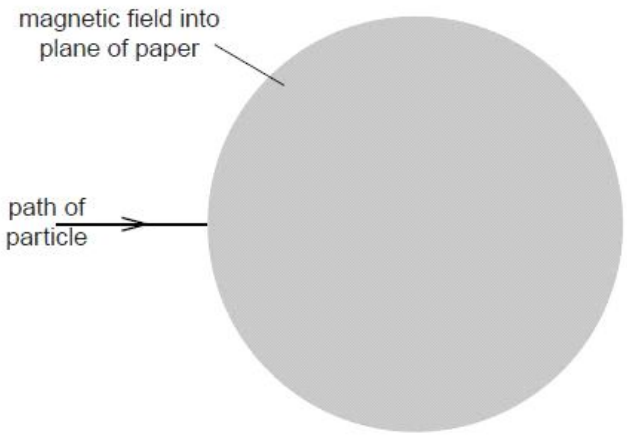


Fig. 6.1

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 from the field. [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.

For Examiner's Use

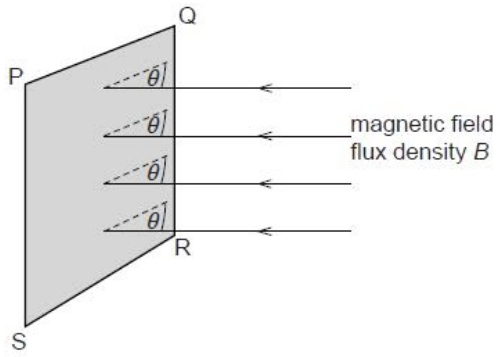


Fig. 5.1

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.

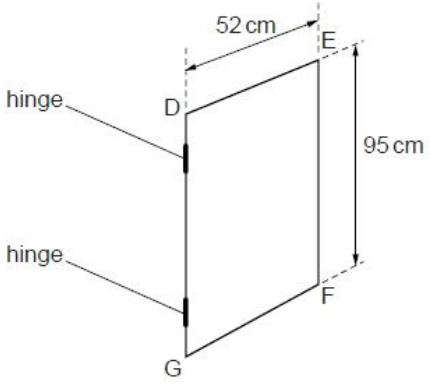


Fig. 5.2

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

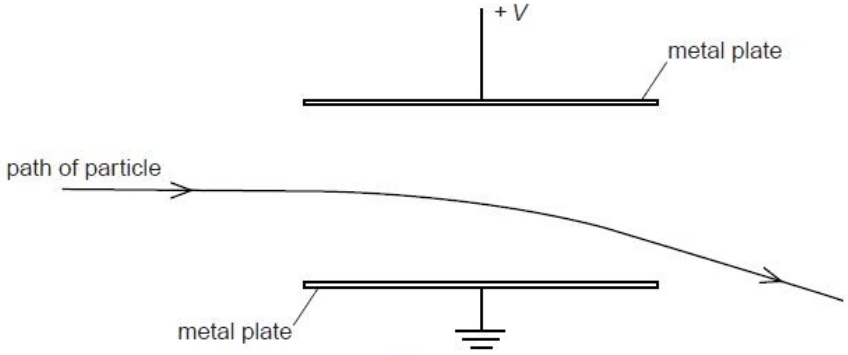


Fig. 6.1

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.

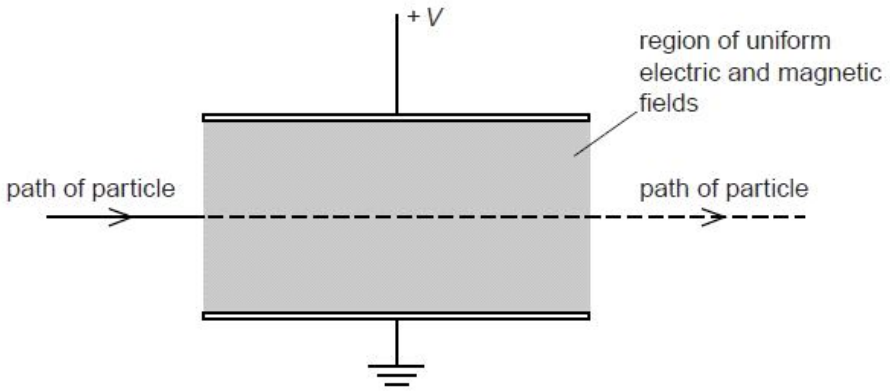


Fig. 6.2

(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.

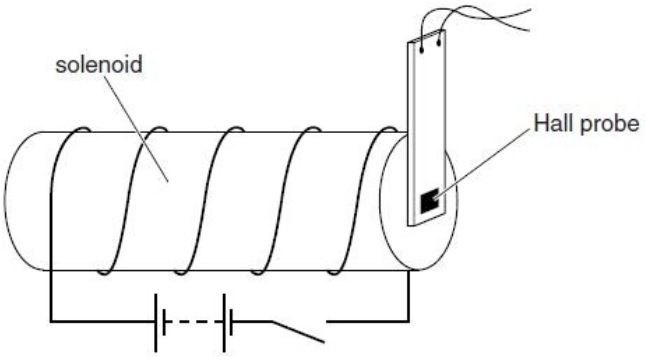


Fig. 7.1

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.

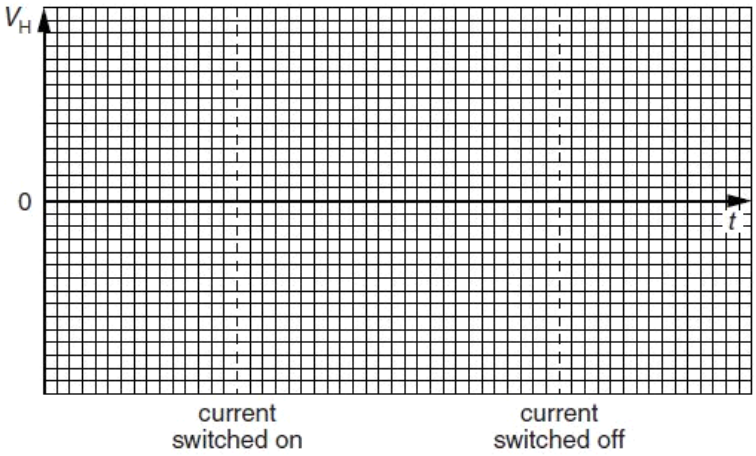


Fig. 7.2

[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.

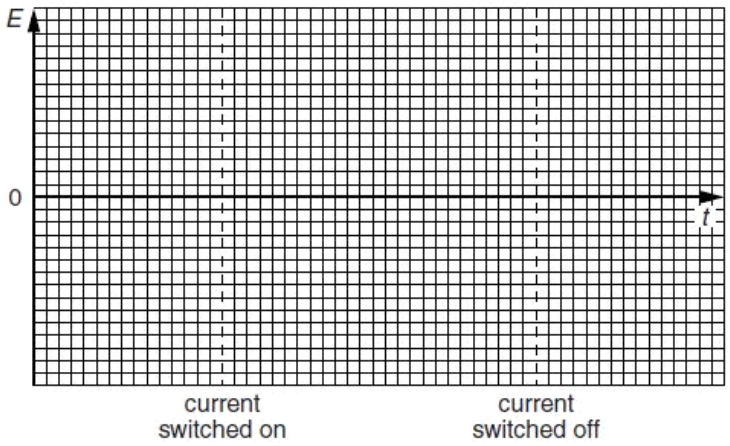


Fig. 7.3

[3]

Q45.

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

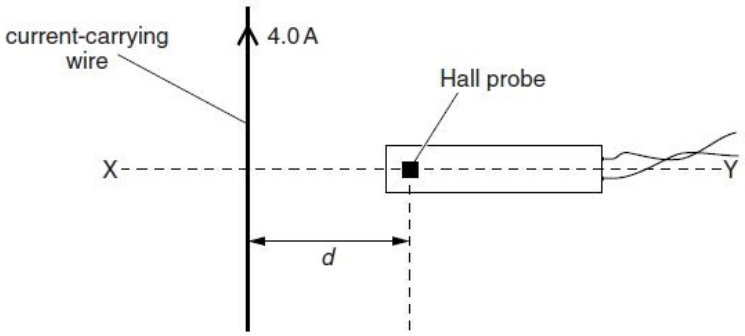


Fig. 5.1

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.

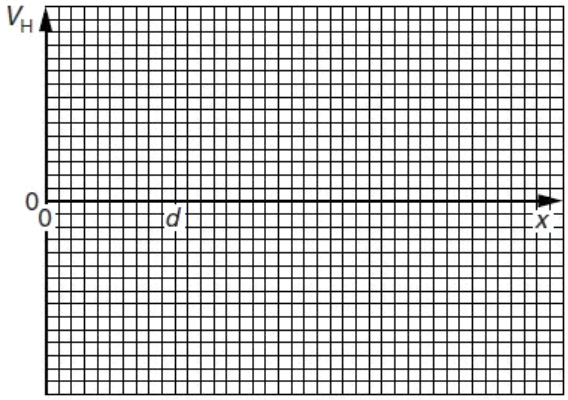


Fig. 5.2

[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.

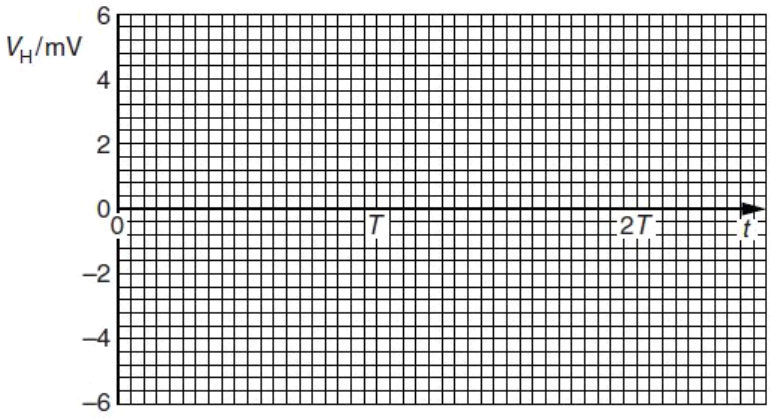


Fig. 5.3

[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 $9.6 \times 10^4\,m\,s^{-1}$. 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.

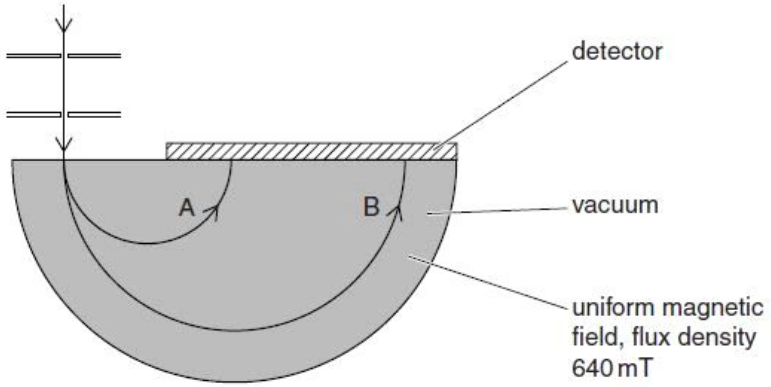


Fig. 6.1

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 $+1.6 \times 10^{-19}\,C$.

(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 2.6×10^{-3} T, as shown in Fig. 6.1.

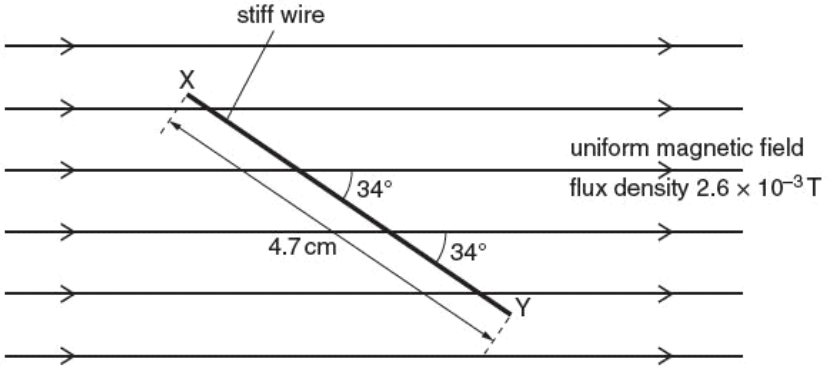


Fig. 6.1

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]

Electromagnetic Induction - 2020 A2

1. Nov/2020/Paper_41/No.9

(a) Define *magnetic flux*.

.....

.....

..... [2]

(b) A simple transformer consists of two coils of wire wound on a soft-iron core, as illustrated in Fig. 9.1.

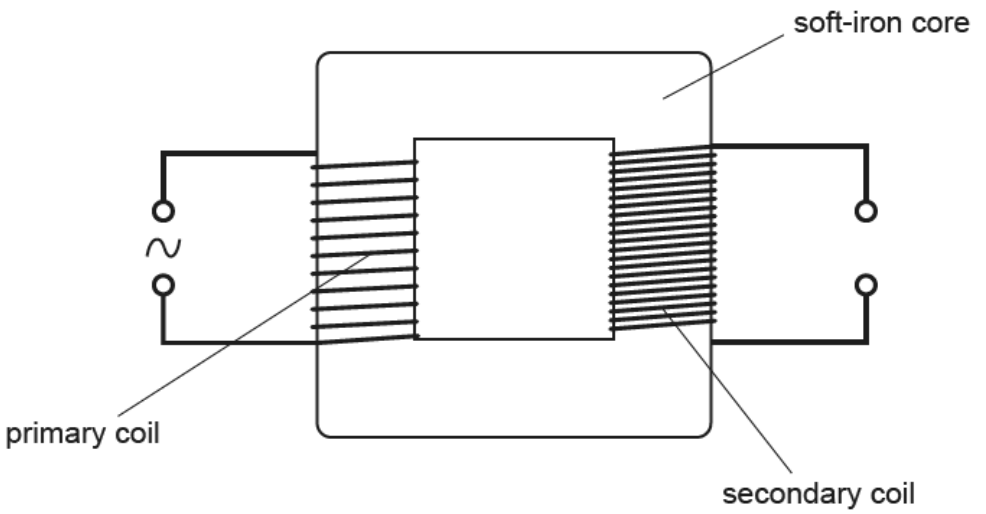


Fig. 9.1

There is a sinusoidal current in the primary coil.

Explain:

(i) how this current gives rise to an induced electromotive force (e.m.f.) in the secondary coil

.....

.....

.....

.....

..... [3]

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(ii) why the e.m.f. induced in the secondary coil is not constant.

.....

.....

.....

..... [2]

(c) Explain why the soft-iron core in **(b)** is laminated.

.....

.....

..... [2]

[Total: 9]

2. Nov/2020/Paper_42/No.9

(a) A small coil is placed close to one end of a solenoid connected to a power supply. The plane of the small coil is normal to the axis of the solenoid, as illustrated in Fig. 9.1.

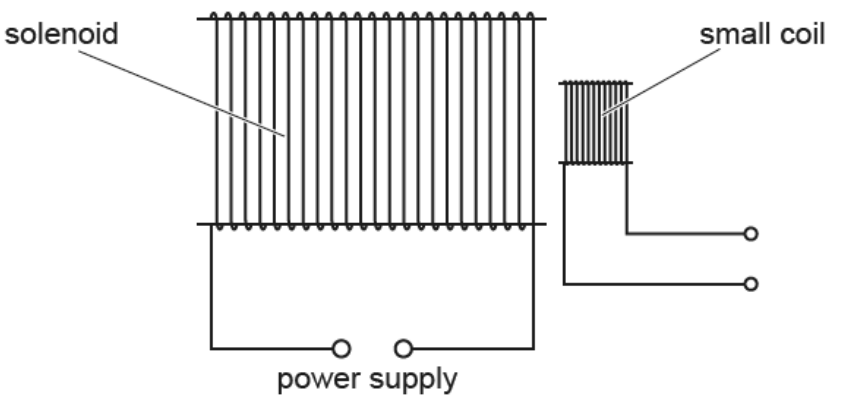


Fig. 9.1

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The power supply causes the current I in the solenoid to vary with time t as shown in Fig. 9.2.

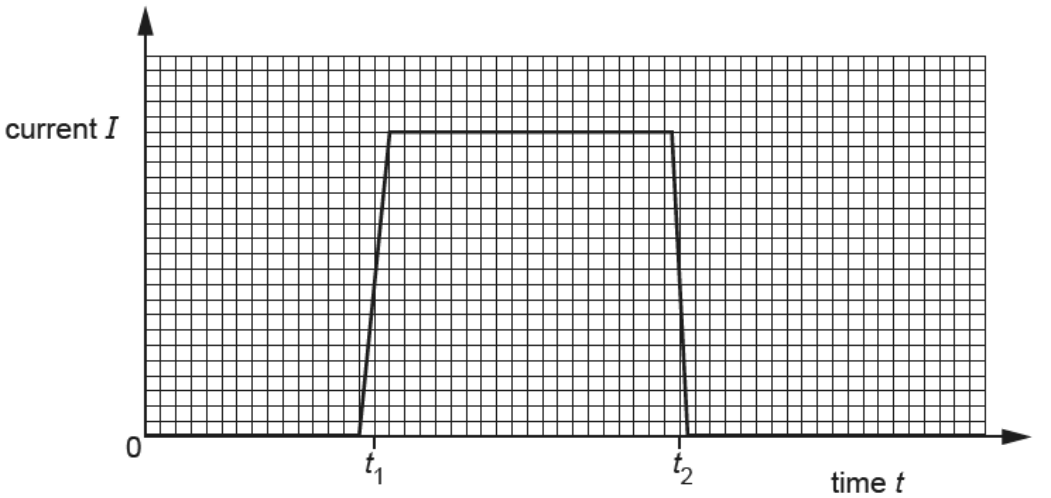


Fig. 9.2

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

.....

.....

..... [2]

(ii) On the axes of Fig. 9.3, sketch a graph to show the variation with time t of the electromotive force (e.m.f.) induced in the small coil.

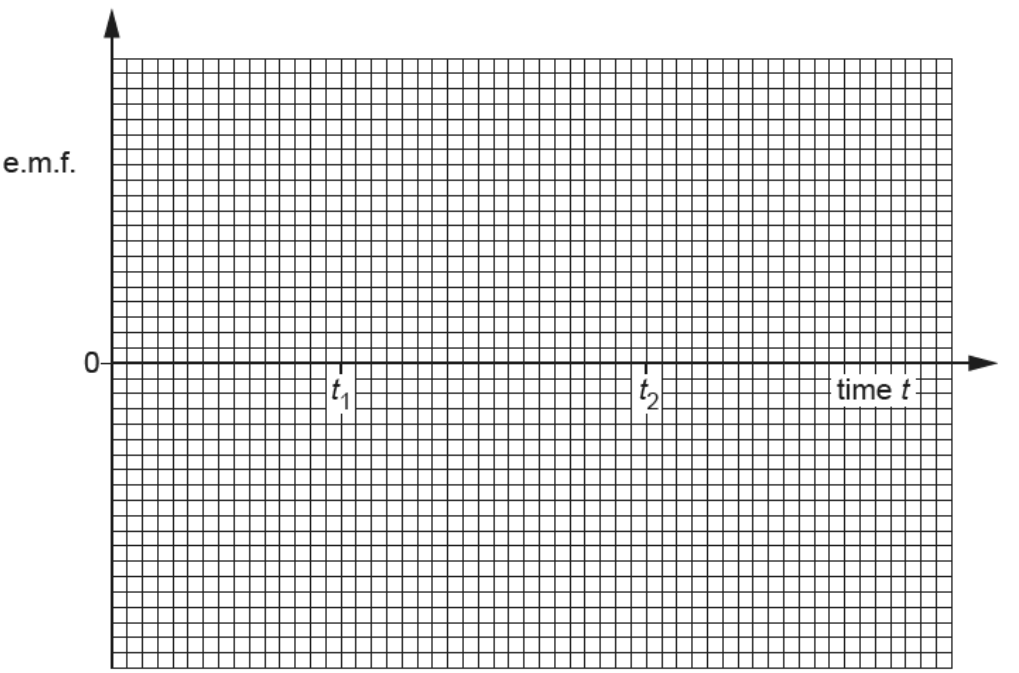


Fig. 9.3

[4]

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(b) The small coil in **(a)** is now replaced by a Hall probe.

The Hall probe is positioned so that the reading for the probe is a maximum.

The current I in the solenoid varies again as shown in Fig. 9.2.

On the axes of Fig. 9.4, sketch a graph to show the variation with time t of the reading V_H of the probe.

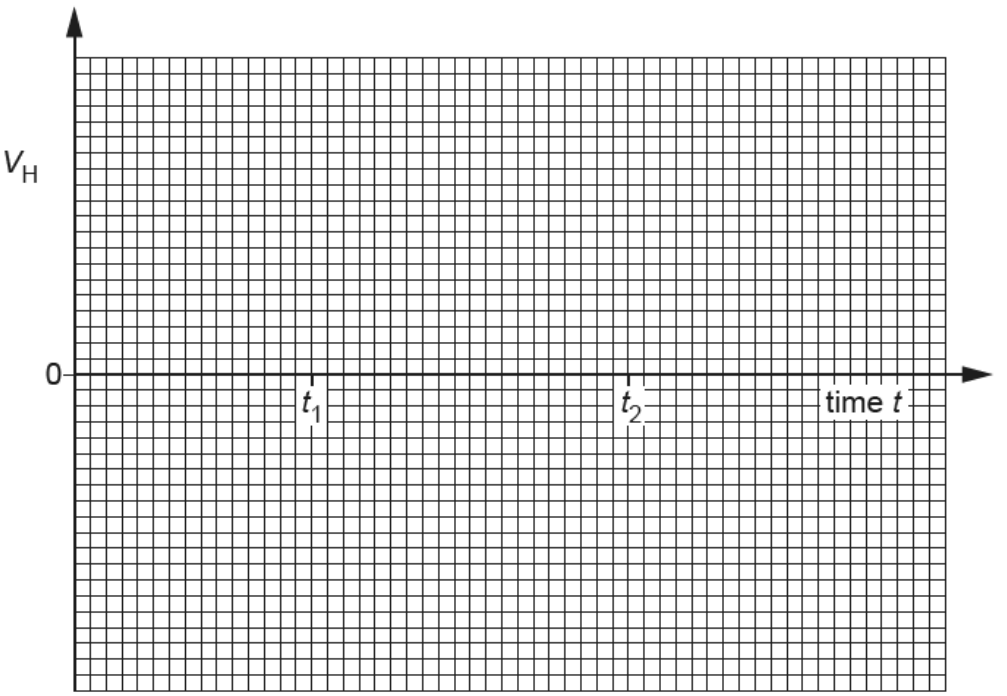


Fig. 9.4

[2]

[Total: 8]

3. June/2020/Paper_41/No.9

(a) A coil of wire is situated in a uniform magnetic field of flux density B.
The coil has diameter 3.6 cm and consists of 350 turns of wire, as illustrated in Fig. 9.1.

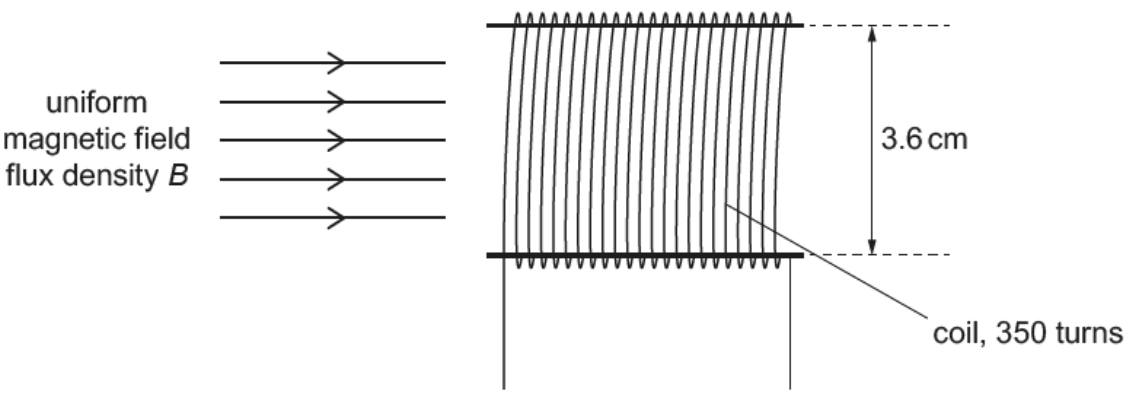


Fig. 9.1

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The variation with time t of B is shown in Fig. 9.2.

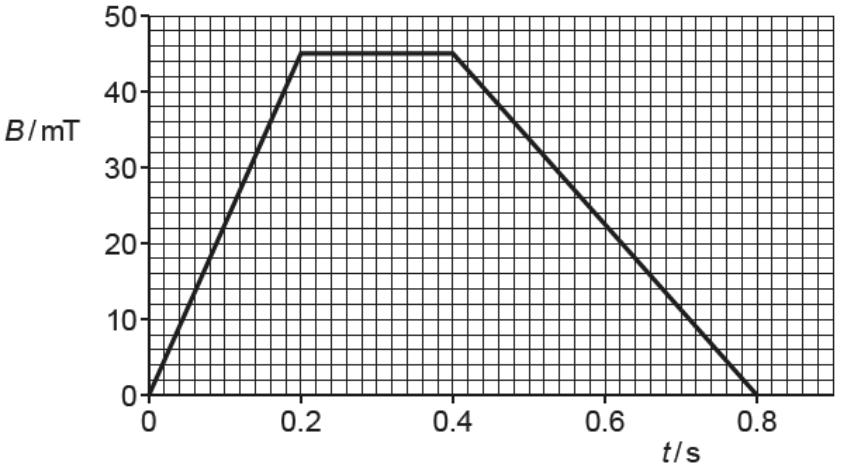


Fig. 9.2

(i) Show that, for the time $t = 0$ to time $t = 0.20\,s$, the electromotive force (e.m.f.) induced in the coil is 0.080 V.

[2]

(ii) On the axes of Fig. 9.3, show the variation with time t of the induced e.m.f. E for time $t = 0$ to time $t = 0.80\,s$.

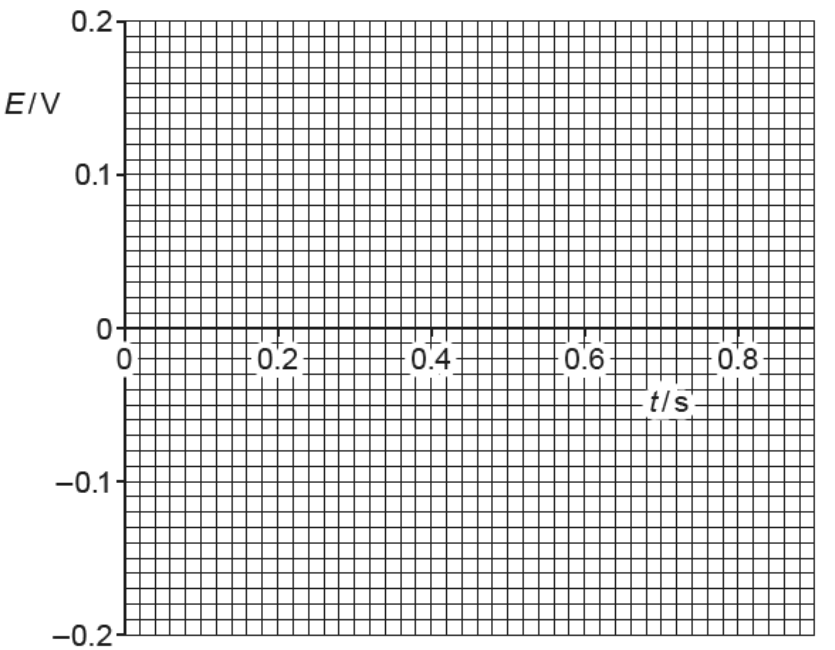


Fig. 9.3

[4]

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(b) A bar magnet is held a small distance above the surface of an aluminium disc by means of a rod, as illustrated in Fig. 9.4.

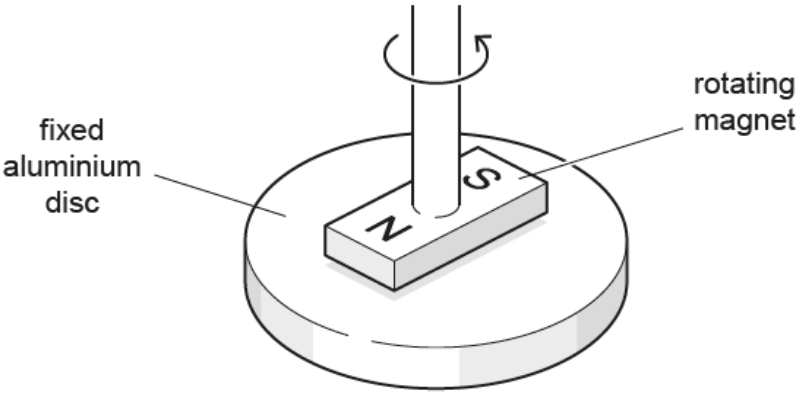


Fig. 9.4

The aluminium disc is supported horizontally and held stationary.

The magnet is rotated about a vertical axis at constant speed.

Use laws of electromagnetic induction to explain why there is a torque acting on the aluminium disc.

.....

.....

.....

.....

.....

..... [4]

[Total: 10]

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4. June/2020/Paper_42/No.10

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

.....

.....

..... [2]

(b) A simple iron-cored transformer is illustrated in Fig. 10.1.

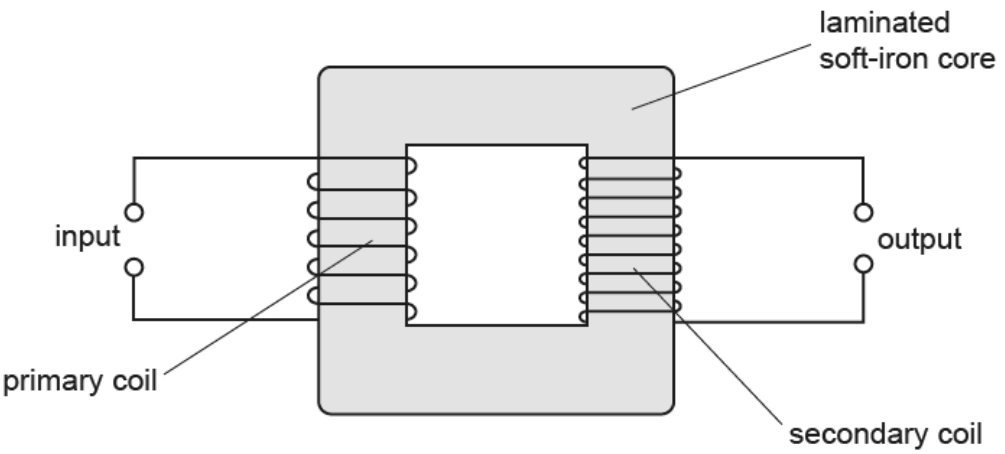


Fig. 10.1

(i) State **one** function of a transformer.

.....

..... [1]

(ii) A sinusoidal alternating current in the primary coil gives rise to a varying magnetic flux linking the secondary coil.

Use Faraday's law to explain why the output from the transformer is an electromotive force (e.m.f.) that is alternating.

.....

.....

.....

.....

..... [3]

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(iii) State why the soft-iron core of the transformer is laminated.

.....

..... [1]

[Total: 7]

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1. Nov/2020/Paper_41/No.8

A slice of a conducting material has its face QRLK normal to a uniform magnetic field of flux density *B*, as illustrated in Fig. 8.1.

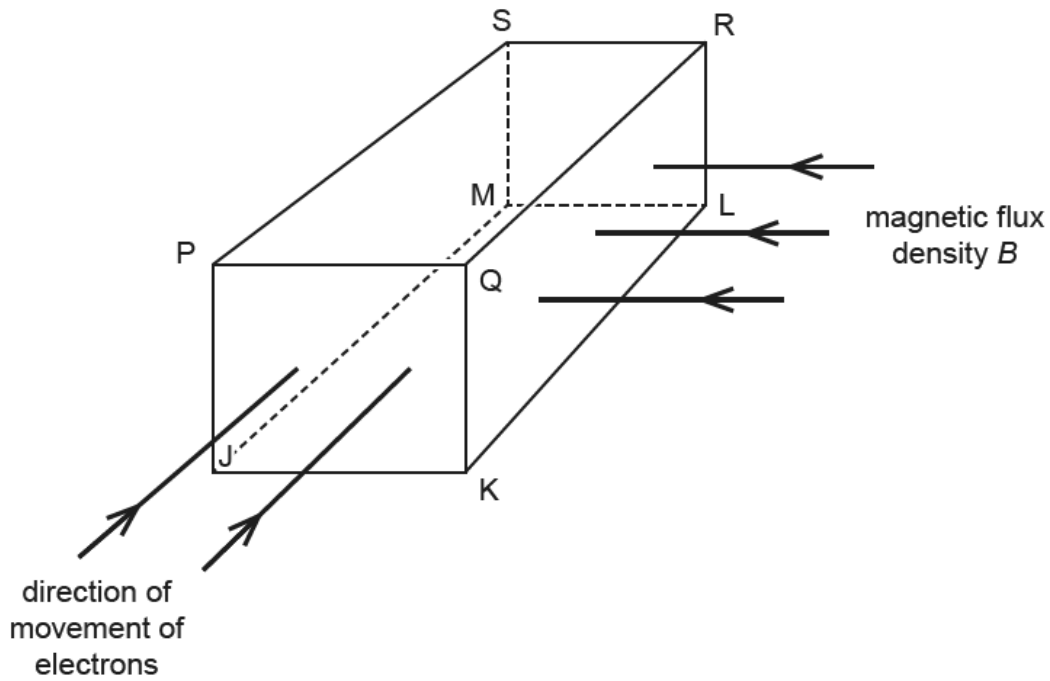


Fig. 8.1

Electrons enter the slice travelling perpendicular to face PQKJ.

(a) For the free electrons moving in the slice:

(i) state the direction of the force on an electron due to movement of the electron in the magnetic field

.....

..... [1]

(ii) identify the faces, using the letters on Fig. 8.1, between which a potential difference is developed.

face ..... and face ..... [1]

(b) Explain why the potential difference in **(a)(ii)** reaches a maximum value.

.....

.....

..... [2]

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(c) The number of free electrons per unit volume in the slice of material is $1.3 \times 10^{29}\,m^{-3}$.
The thickness PQ of the slice is 0.10 mm.
The magnetic flux density B is 4.6×10^{-3} T.

Calculate the potential difference across the slice for a current of 6.3×10^{-4} A.

potential difference = ... V [2]

(d) The slice in **(c)** is a metal.

By reference to your answer in **(c)**, suggest why Hall probes are usually made using semiconductors rather than metals.

.....

.....

..... [2]

[Total: 8]

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2. Nov/2020/Paper_42/No.10

(a) A long straight vertical wire A carries a current in an upward direction.
The wire passes through the centre of a horizontal card, as illustrated in Fig. 10.1.

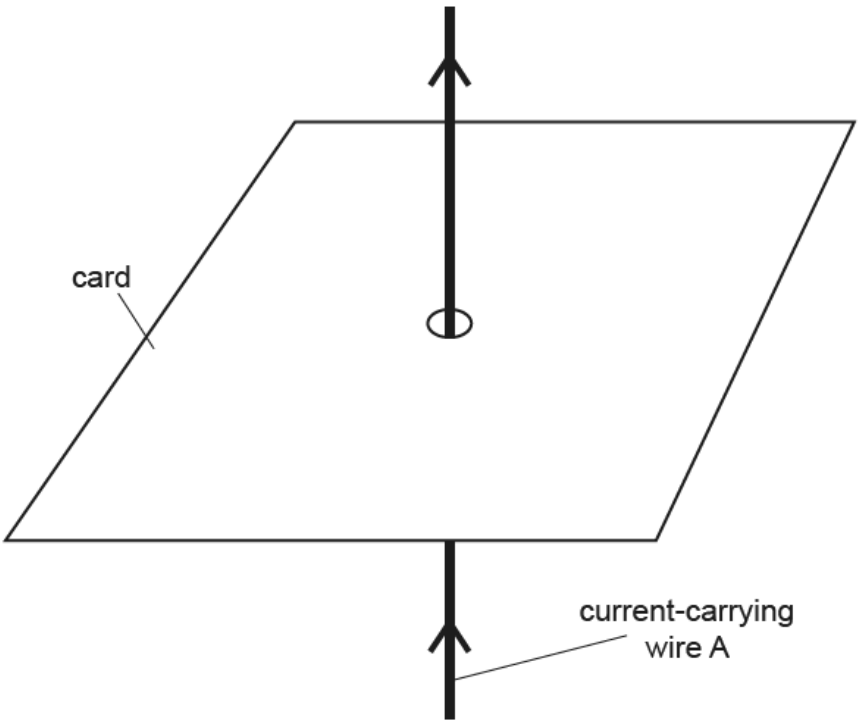


Fig. 10.1

The card is viewed from above. The card is shown from above in Fig. 10.2.

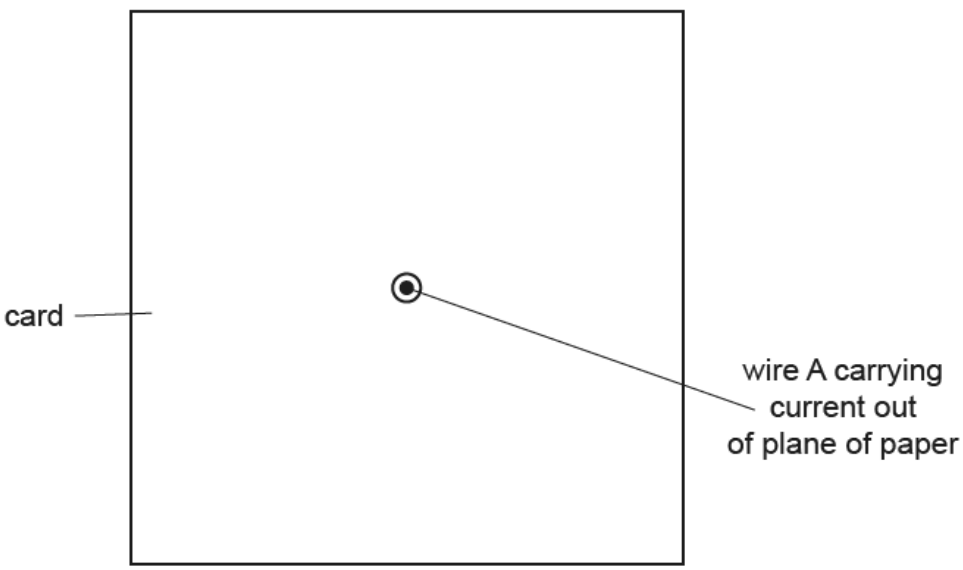


Fig. 10.2

On Fig. 10.2, draw four lines to represent the magnetic field produced by the current-carrying wire. [3]

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(b) Two wires A and B are now placed through a card. The two wires are parallel and carrying currents in the same direction, as illustrated in Fig. 10.3.

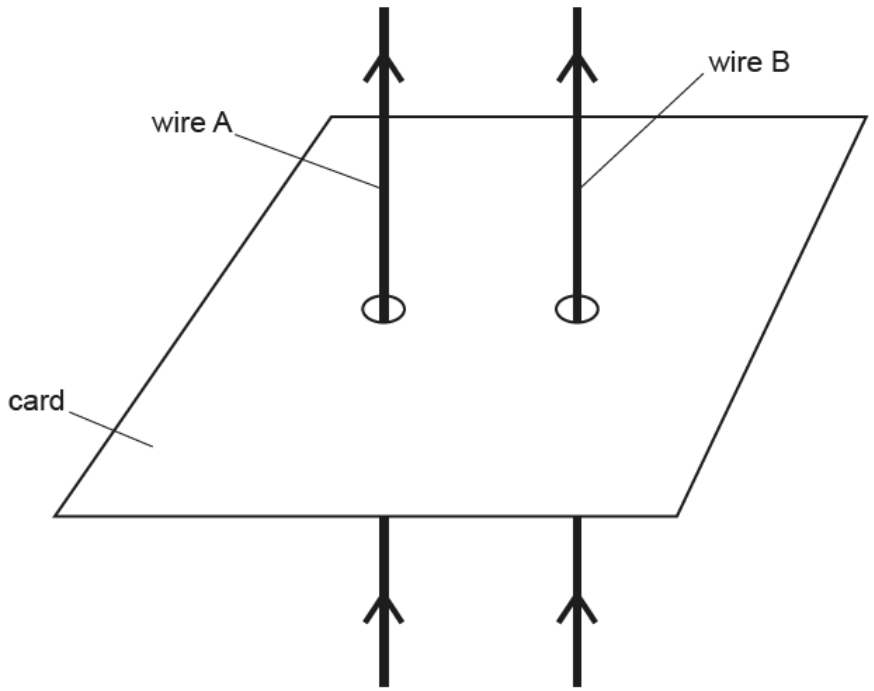


Fig. 10.3

(i) Explain why a magnetic force is exerted on each wire.

.....

.....

.....

..... [2]

(ii) State the directions of the forces.

.....

..... [1]

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

Explain whether the magnetic forces on the two wires are equal in magnitude.

.....

.....

..... [1]

[Total: 7]

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3. June/2020/Paper_41/No.8

(a) Define the *tesla*.

.....

.....

.....

..... [3]

(b) A magnet produces a uniform magnetic field of flux density *B* in the space between its poles.

A rigid copper wire carrying a current is balanced on a pivot. Part PQLM of the wire is between the poles of the magnet, as illustrated in Fig. 8.1.

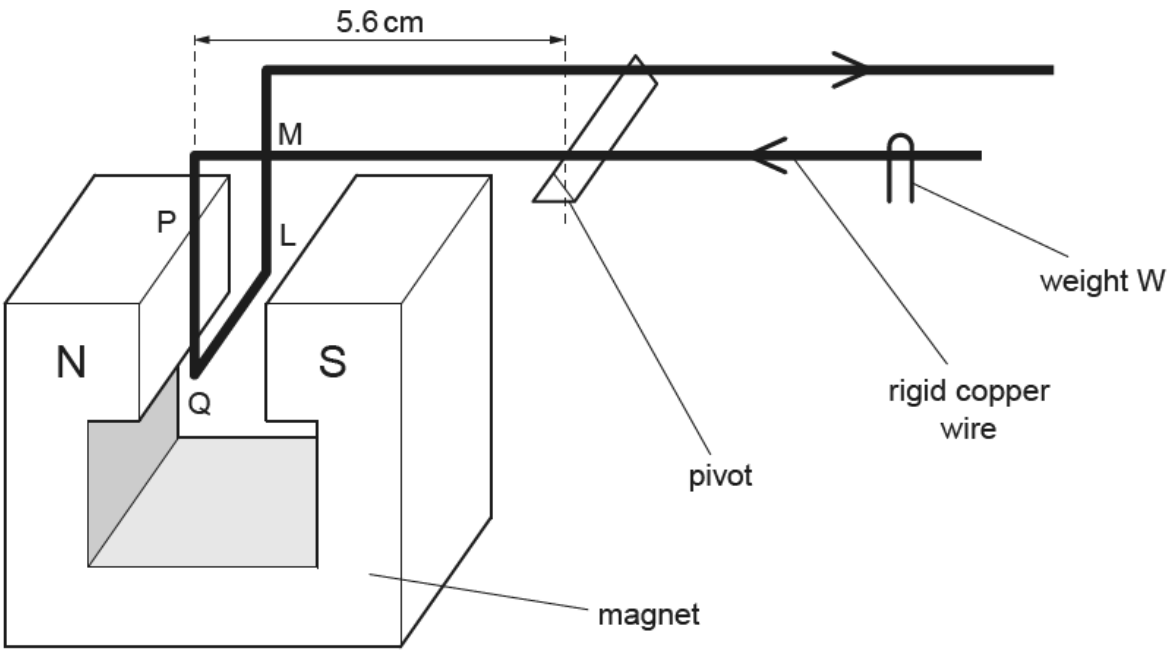


Fig. 8.1 (not to scale)

The wire is balanced horizontally by means of a small weight W.

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The section of the wire between the poles of the magnet is shown in Fig. 8.2.

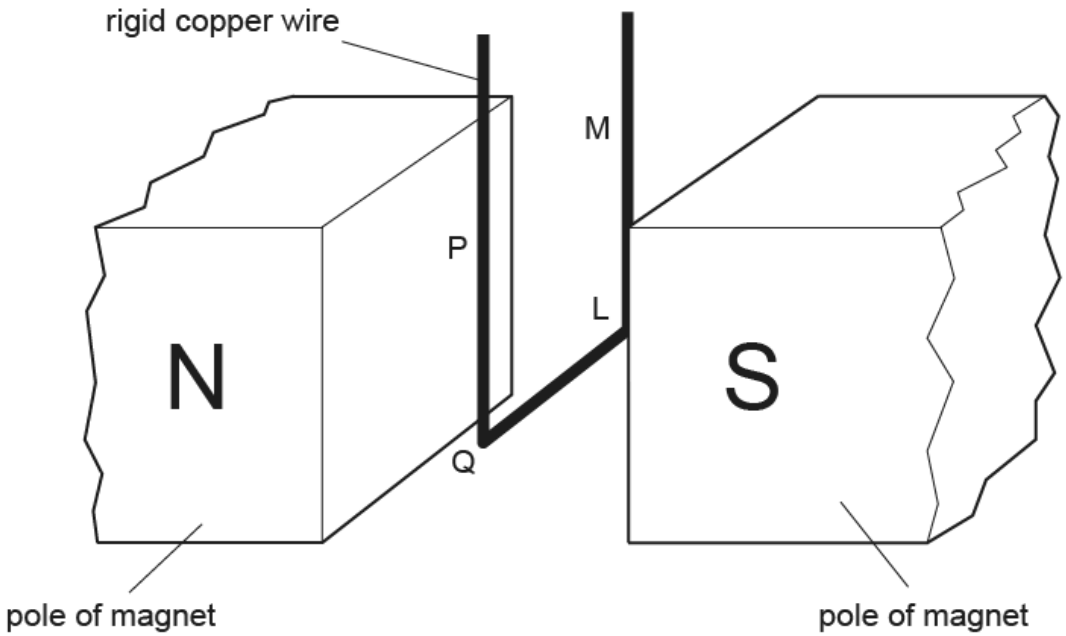


Fig. 8.2 (not to scale)

Explain why:

(i) section QL of the wire gives rise to a moment about the pivot

.....

.....

.....

..... [3]

(ii) sections PQ and LM of the wire do not affect the equilibrium of the wire.

.....

.....

.....

..... [2]

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(c) Section QL of the wire has length 0.85 cm.

The perpendicular distance of QL from the pivot is 5.6 cm.

When the current in the wire is changed by 1.2 A, W is moved a distance of 2.6 cm along the wire in order to restore equilibrium. The mass of W is 1.3×10^{-4} kg.

(i) Show that the change in moment of W about the pivot is 3.3×10^{-5} N m.

[2]

(ii) Use the information in **(i)** to determine the magnetic flux density B between the poles of the magnet.

B = ... T [3]

[Total: 13]

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4. June/2020/Paper_42/No.9

(a) An electron is travelling at speed v in a straight line in a vacuum. It enters a uniform magnetic field of flux density 8.0×10^{-4} T. Initially, the electron is travelling at right angles to the magnetic field, as illustrated in Fig. 9.1.

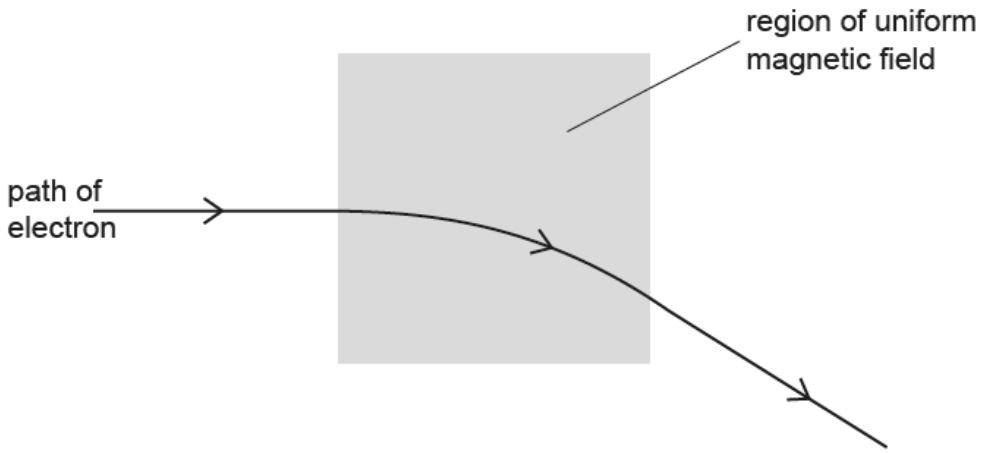


Fig. 9.1

The path of the electron in the magnetic field is an arc of a circle of radius 6.4 cm.

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

.....

.....

..... [2]

(ii) Show that the speed v of the electron is $9.0 \times 10^{6}\,\text{m s}^{-1}$.

[3]

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(b) A uniform electric field is now applied in the same region as the magnetic field.

The electron passes undeviated through the region of the two fields, as illustrated in Fig. 9.2.

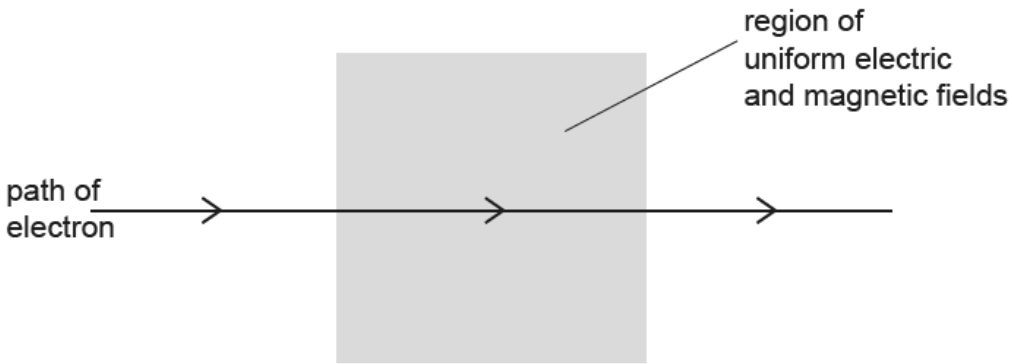


Fig. 9.2

(i) On Fig. 9.2, mark with an arrow the direction of the uniform electric field. [1]

(ii) Use data from **(a)** to calculate the magnitude of the electric field strength.

field strength = ... NC^{-1} [2]

(c) The electron in **(b)** is now replaced by an α-particle travelling at the same speed v along the same initial path as the electron.

Describe and explain the shape of the path in the region of the magnetic and electric fields.

.....

.....

..... [2]

[Total: 10]

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5. March/2020/Paper_42/No.8

(a) Explain what is meant by a *magnetic field*.

.....

.....

.....

..... [1]

(b) The apparatus shown in Fig. 8.1 is used in an experiment to find the magnetic flux density B between the poles of a horseshoe magnet. Assume the magnetic field is uniform between the poles of the magnet and zero elsewhere.

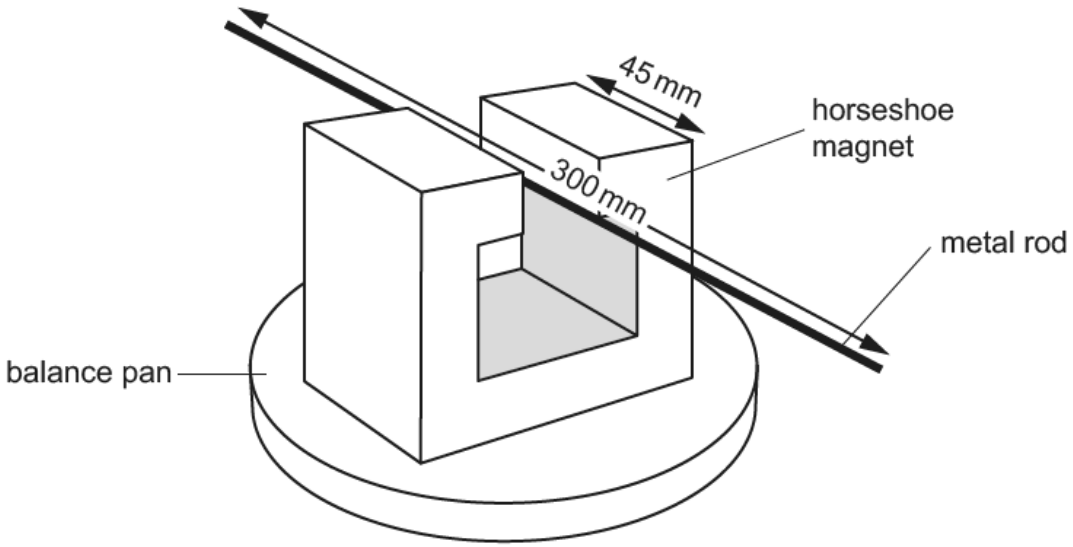


Fig. 8.1

The rigid metal rod of length 300 mm is fixed in position perpendicular to the direction of the magnetic field. The poles of the magnet are both 45 mm long. There is a current in the rod that causes a force on the rod. The balance is used to determine the magnitude of the force.

The variation with current I of the force F on the rod is shown in Fig. 8.2.

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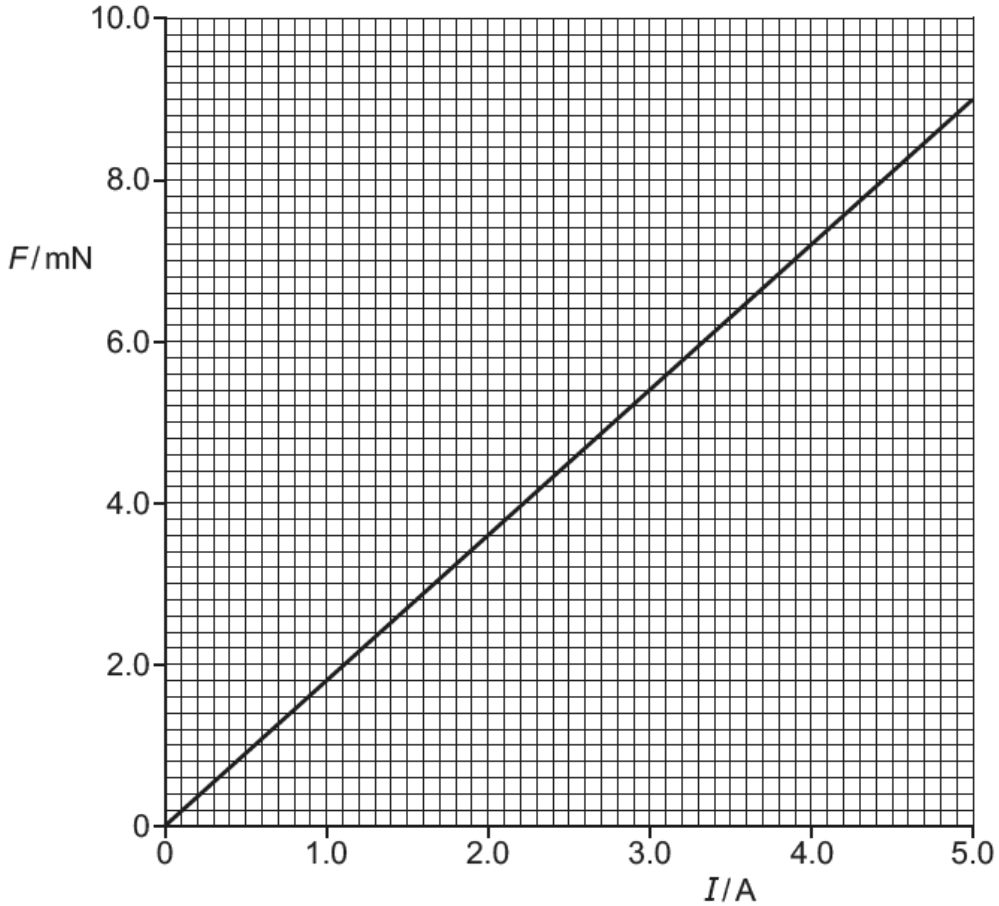


Fig. 8.2

Calculate the magnetic flux density *B*.

B = ... T [2]

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(c) In a different experiment, electrons are accelerated through a potential difference and then enter a region of magnetic field. The magnetic field is into the plane of the paper and is perpendicular to the direction of travel of the electrons, as illustrated in Fig. 8.3.

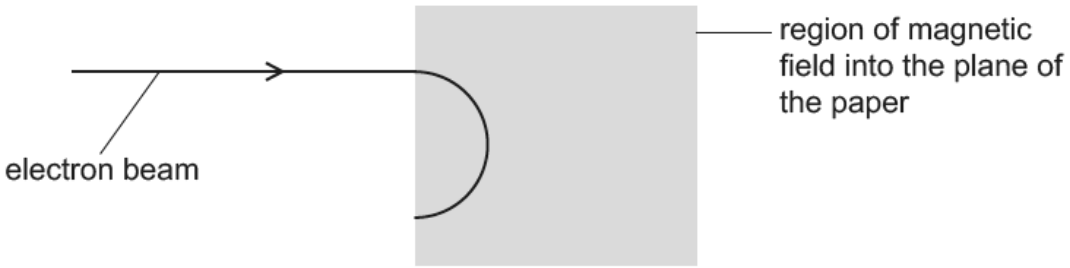


Fig. 8.3

(i) Explain why the electrons follow a circular path when inside the region of the magnetic field.

.....

.....

.....

..... [3]

(ii) State the measurements needed in order to determine the charge to mass ratio, e/m_e, of an electron.

.....

.....

..... [2]

[Total: 8]

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1. June/2021/Paper_41/No.10

(a) State Lenz's law.

.....

.....

..... [2]

(b) A metal ring is suspended from a fixed point P by means of a thread, as shown in Fig. 10.1.

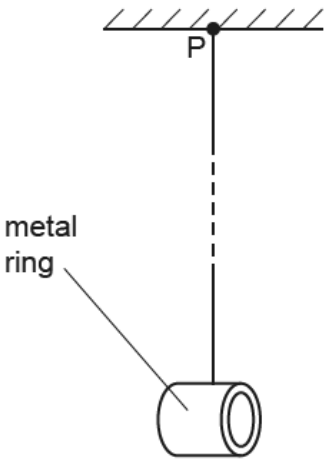


Fig. 10.1

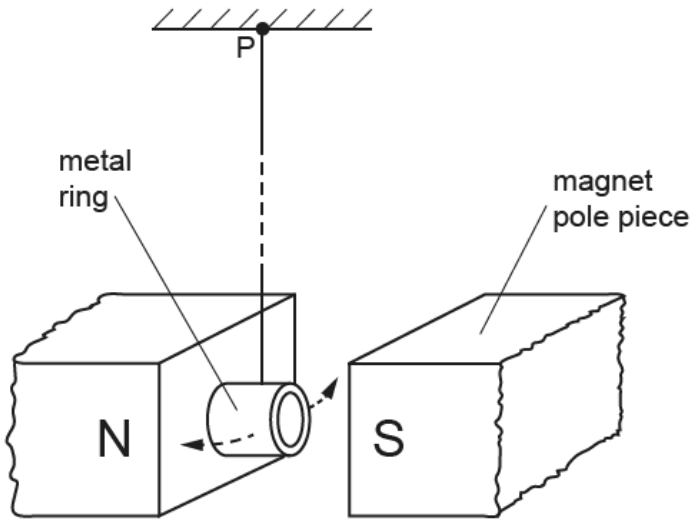


Fig. 10.2

The ring is displaced a distance *d* and then released. The ring completes many oscillations before coming to rest.

The poles of a magnet are now placed near to the ring so that the ring hangs midway between the poles of the magnet, as shown in Fig. 10.2.

The ring is again displaced a distance *d* and then released.
Explain why the ring completes fewer oscillations before coming to rest.

.....

.....

.....

.....

.....

..... [4]

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(c) The ring in **(b)** is now cut so that it has the shape shown in Fig. 10.3.



Fig. 10.3

Explain why, when the procedure in **(b)** is repeated, the cut ring completes more oscillations than the complete ring when oscillating between the poles of the magnet.

.....

.....

.....

.....

..... [3]

[Total: 9]

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2. June/2021/Paper_42/No.9

(a) State **two** situations in which a charged particle in a magnetic field does **not** experience a force.

1. .....

.....

2. .....

.....

[2]

(b) A loosely coiled metal spring is suspended from a fixed point, as shown in Fig. 9.1.

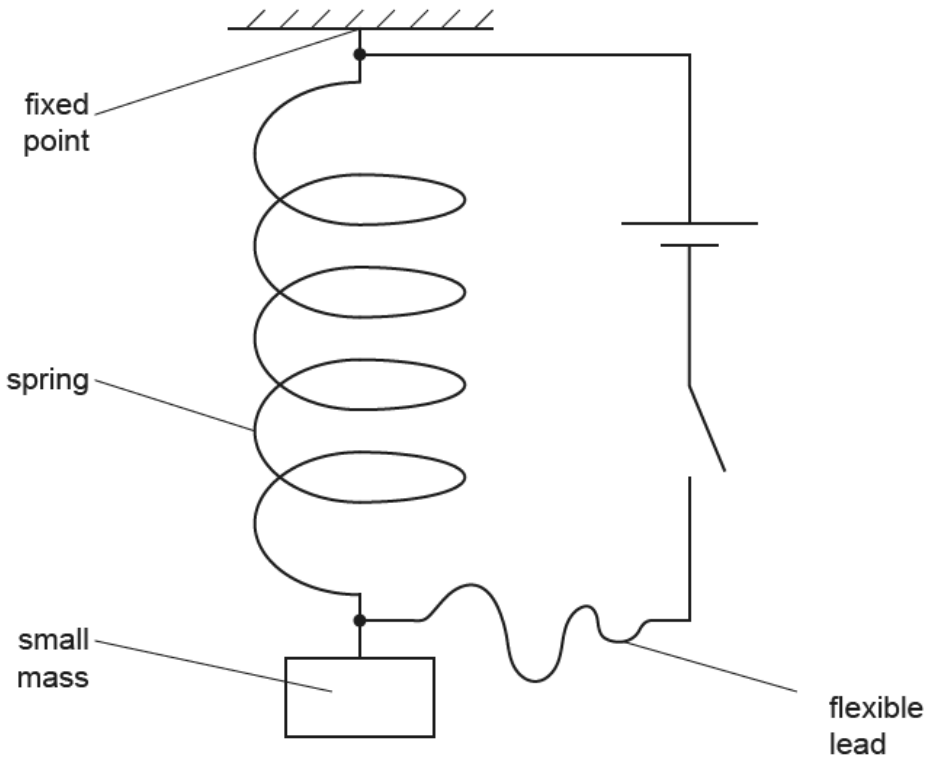


Fig. 9.1

Electrical connections are made to the ends of the spring by means of a flexible lead.

The length of the spring is measured before the switch is closed and then again after the switch is closed.

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When the switch is closed, a magnetic field is set up around each coil of the spring.

By reference to these magnetic fields, explain why there is a change in length of the spring. State whether the spring extends or contracts.

.....

.....

.....

.....

.....

..... [4]

(c) With the switch in **(b)** closed, the small mass on the free end of the spring is now made to oscillate vertically.

Use the principles of electromagnetic induction to explain why small fluctuations in the current in the spring are found to occur.

.....

.....

.....

..... [3]

[Total: 9]

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3. March/2021/Paper_42/No.9

(a) Define *magnetic flux linkage*.

.....

.....

..... [2]

(b) A solenoid of diameter 6.0 cm and 540 turns is placed in a uniform magnetic field as shown in Fig. 9.1.

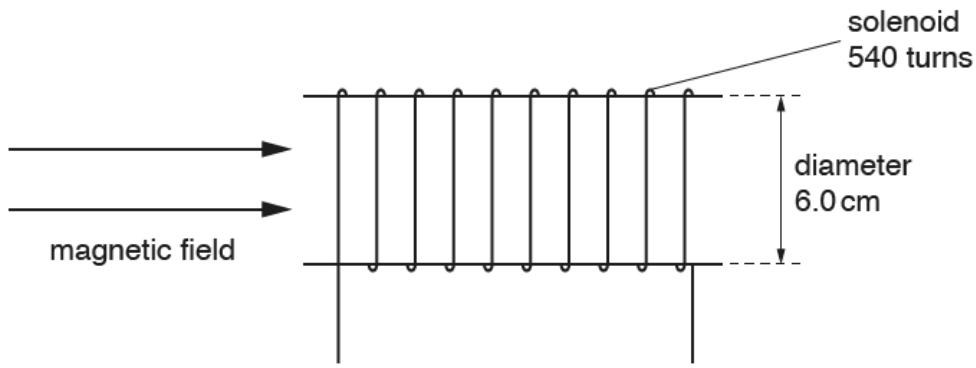


Fig. 9.1

The variation with time *t* of the magnetic flux density is shown in Fig. 9.2.

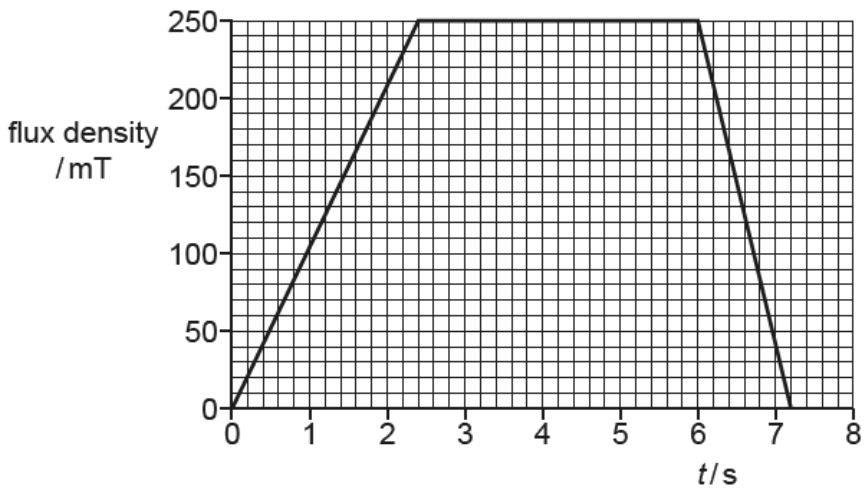


Fig. 9.2

Calculate the maximum magnitude of the induced electromotive force (e.m.f.) in the solenoid.

e.m.f. = ... V [3]

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(c) A thin copper sheet X is supported on a rigid rod so that it hangs between the poles of a magnet as shown in Fig. 9.3.

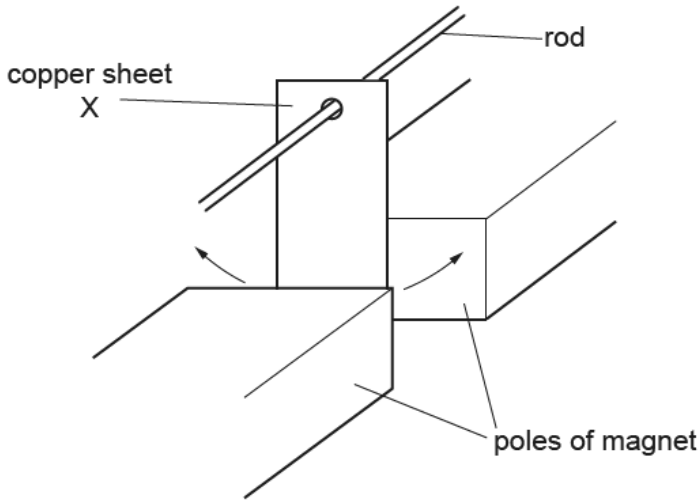


Fig. 9.3

Sheet X is displaced to one side and then released so that it oscillates. A motion sensor is used to record the displacement of X.

A second thin copper sheet Y replaces sheet X. Sheet Y has the same overall dimensions as X but is cut into the shape shown in Fig. 9.4.

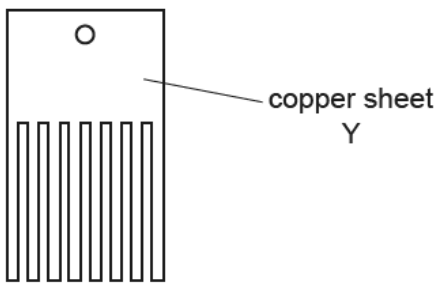


Fig. 9.4

The motion sensor is again used to record the displacement.

The graph in Fig. 9.5 shows the variation with time *t* of the displacement *s* of each copper sheet.

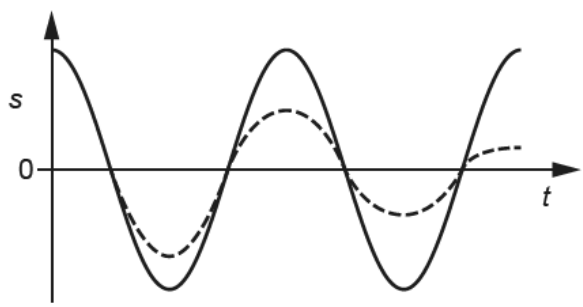


Fig. 9.5

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(i) State the name of the phenomenon illustrated by the gradual reduction in the amplitude of the dashed line.

..... [1]

(ii) Deduce which copper sheet is represented by the dashed line. Explain your answer using the principles of electromagnetic induction.

.....

.....

.....

.....

.....

..... [4]

[Total: 10]

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1. Nov/2021/Paper_41/No.8

(a) Define the *tesla*.

.....

.....

..... [2]

(b) A stiff metal wire is used to form a rectangular frame measuring 8.0 cm × 6.0 cm. The frame is open at the top, and is suspended from a sensitive newton meter, as shown in Fig. 8.1.

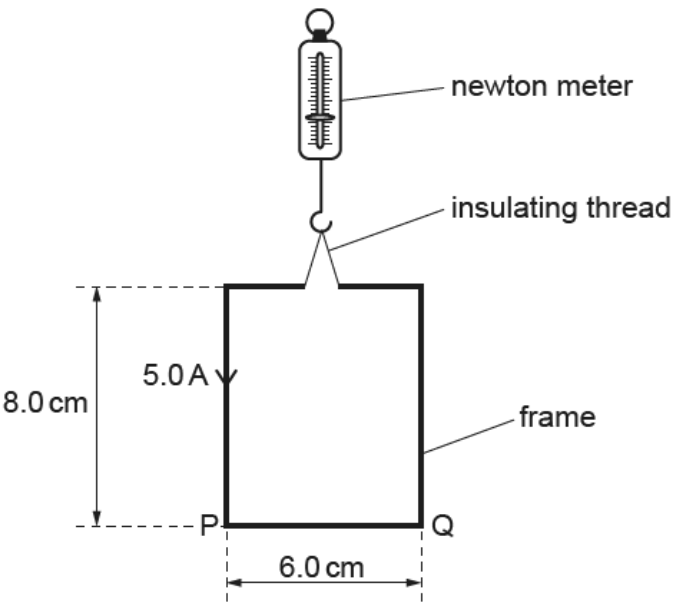


Fig. 8.1

The open ends of the frame are connected to a power supply so that there is a current of 5.0 A in the frame in the direction indicated in Fig. 8.1.

The frame is slowly lowered into a uniform magnetic field of flux density *B* so that all of side PQ is in the field. The magnetic field lines are horizontal and at an angle of 50° to PQ, as shown in Fig. 8.2.

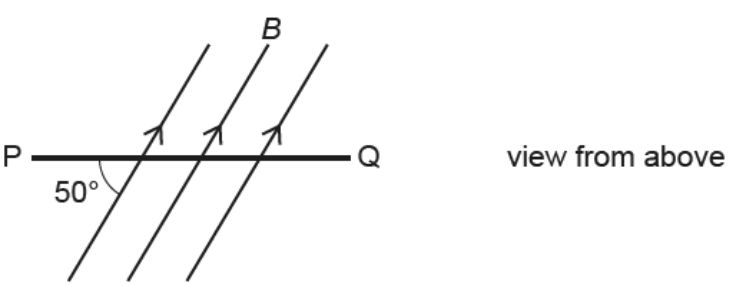


Fig. 8.2

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When side PQ of the frame first enters the magnetic field, the reading on the newton meter changes by 1.0 mN.

(i) Determine the magnetic flux density B, in mT.

B = ... mT [2]

(ii) State, with a reason, whether the change in the reading on the newton meter is an increase or a decrease.

.....

.....

..... [1]

(iii) The frame is lowered further so that the vertical sides start to enter the magnetic field.

Suggest what effect this will have on the frame.

.....

.....

..... [1]

[Total: 6]

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2. Nov/2021/Paper_42/No.8

Two long straight parallel wires P and Q carry currents into the plane of the paper, as shown in Fig. 8.1.



Fig. 8.1

The current in P is I and the current in Q is $2I$.

(a) (i) On Fig. 8.1, draw an arrow to show the direction of the magnetic field at wire Q due to the current in wire P. Label this arrow B. [1]

(ii) On Fig. 8.1, draw another arrow to show the direction of the force acting on wire Q due to the current in wire P. Label this arrow F. [1]

(b) (i) State, with a reason, how the magnitude of the force acting on wire P compares with the magnitude of the force acting on wire Q.

.....

.....

.....

..... [2]

(ii) State how the direction of the force on wire P compares with the direction of the force on wire Q.

.....

..... [1]

[Total: 5]

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3. June/2021/Paper_41/No.9

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

.....

.....

..... [2]

(b) A rectangular piece of aluminium foil is situated in a uniform magnetic field of flux density *B*, as shown in Fig. 9.1.

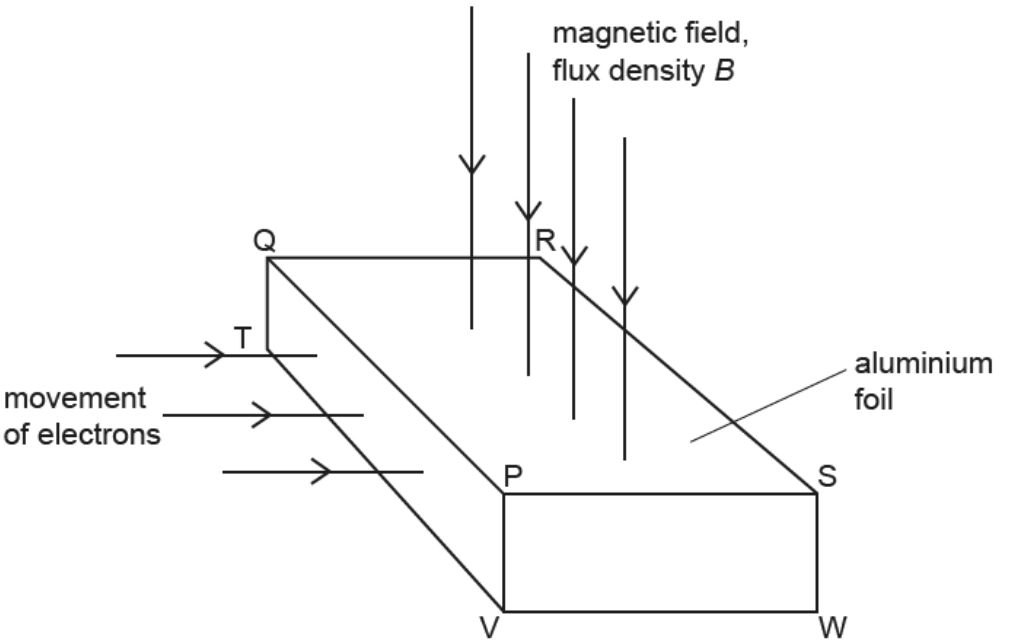


Fig. 9.1

The magnetic field is normal to the face PQRS of the foil.

Electrons, each of charge $-q$, enter the foil at right angles to the face PQTV.

(i) On Fig. 9.1, shade the face of the foil on which electrons initially accumulate. [1]

(ii) Explain why electrons do not continuously accumulate on the face you have shaded.

.....

.....

.....

..... [3]

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(c) The Hall voltage V_H developed across the foil in **(b)** is given by the expression

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

where I is the current in the foil.

(i) State the meaning of the quantity n.

.....

..... [1]

(ii) Using the letters on Fig. 9.1, identify the distance t.

..... [1]

(d) Suggest why, in practice, Hall probes are usually made using a semiconductor material rather than a metal.

.....

..... [1]

[Total: 9]

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4. June/2021/Paper_42/No.8

(a) Define *magnetic flux density*.

.....

.....

..... [2]

(b) Electrons, each of mass m and charge q, are accelerated from rest in a vacuum through a potential difference V.

Derive an expression, in terms of m, q and V, for the final speed v of the electrons. Explain your working.

[2]

(c) The accelerated electrons in **(b)** are injected at point S into a region of uniform magnetic field of flux density B, as illustrated in Fig. 8.1.

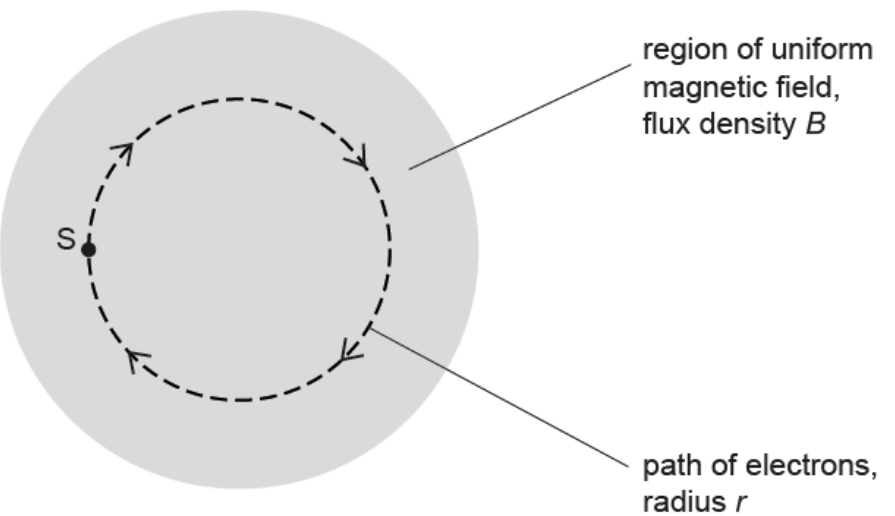


Fig. 8.1

The electrons move at right angles to the direction of the magnetic field. The path of the electrons is a circle of radius r.

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(i) Show that the specific charge $\frac{q}{m}$ of the electrons is given by the expression

$$\frac{q}{m} = \frac{2V}{B^2 r^2}.$$

Explain your working.

[2]

(ii) Electrons are accelerated through a potential difference V of 230 V. The electrons are injected normally into the magnetic field of flux density 0.38 mT.
The radius r of the circular orbit of the electrons is 14 cm.

Use this information to calculate a value for the specific charge of an electron.

specific charge = ... $C\,kg^{-1}$ [2]

(iii) Suggest why the arrangement outlined in **(ii)**, using the same values of B and V, is not practical for the determination of the specific charge of α-particles.

.....

.....

..... [2]

[Total: 10]

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5. March/2021/Paper_42/No.8

(a) Two long straight wires P and Q are parallel to each other, as shown in Fig. 8.1. There is a current in each wire in the direction shown.

The pattern of the magnetic field lines in a plane normal to wire P due to the current in the wire is also shown.

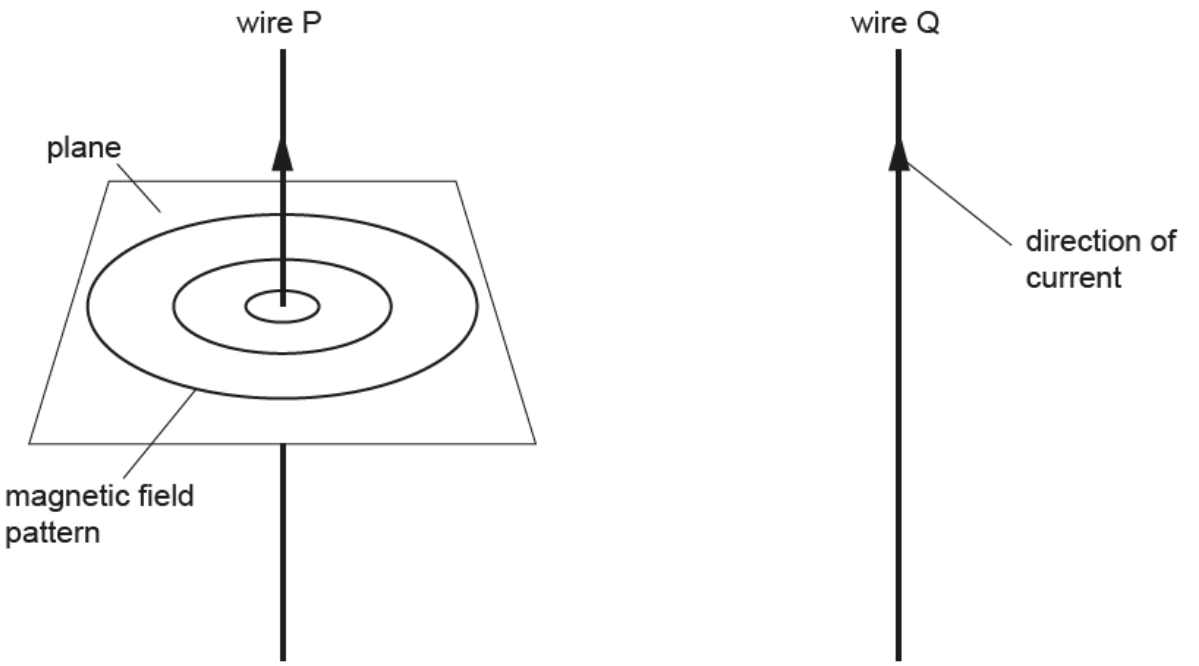


Fig. 8.1

(i) Draw arrows on the magnetic field lines in Fig. 8.1 around wire P to show the direction of the field. [1]

(ii) Determine the direction of the force on wire Q due to the magnetic field from wire P.

..... [1]

(iii) The current in wire Q is less than the current in wire P.

State and explain whether the magnitude of the force on wire P is less than, equal to, or greater than the magnitude of the force on wire Q.

.....

.....

..... [2]

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(b) Nuclear magnetic resonance imaging (NMRI) is used to obtain diagnostic information about internal structures in the human body.

Radio waves are produced and directed towards the body. The radio waves affect the protons within the body.

(i) Explain why radio waves are used.

.....

.....

..... [2]

(ii) Explain why the radio waves are applied in pulses.

.....

.....

..... [2]

[Total: 8]

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1. Nov/2023/Paper_9702/41/No.6

(a) Define magnetic flux density.

.....

.....

.....

..... [2]

(b) Electrons are moving in a vacuum with speed $1.7 \times 10^7\,m\,s^{-1}$. The electrons enter a uniform magnetic field of flux density 4.8 mT. Fig. 6.1 shows the path of the electrons.

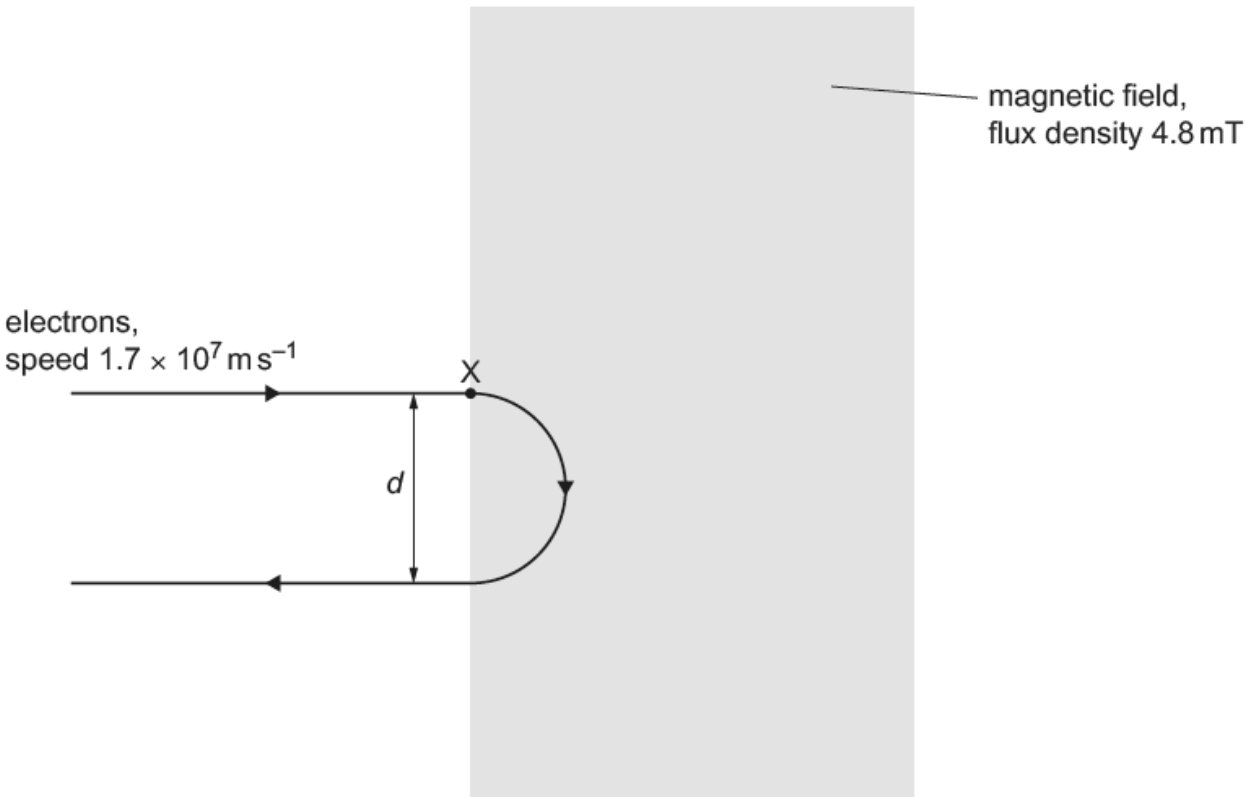


Fig. 6.1

The path of the electrons remains in the plane of the page.

(i) State the direction of the magnetic field.

.....

..... [1]

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(ii) Show that the magnitude of the force exerted on each electron by the magnetic field is 1.3×10^{-14} N.

[2]

(iii) On Fig. 6.1, draw an arrow to indicate the direction of the centripetal acceleration of the electron where it enters the magnetic field at point X. [1]

(iv) Use the information in **(b)(ii)** to calculate the distance *d* between the path of the electrons entering the magnetic field and the path of the electrons leaving it.

d = ... m [3]

(c) The electrons in **(b)** are replaced with positrons that are moving with speed $3.4 \times 10^{7}\,\text{m s}^{-1}$ along the same initial path as the electrons.
The positrons enter the magnetic field at point X on Fig. 6.1.

On Fig. 6.1, draw a line to show the path of the positrons through the magnetic field. [3]

[Total: 12]

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2. Nov/2023/Paper_9702/42/No.7

(a) A Hall probe containing a thin slice of semiconducting material is placed in a uniform magnetic field of flux density *B*. The largest faces of the slice are perpendicular to the magnetic field, as shown in Fig. 7.1.

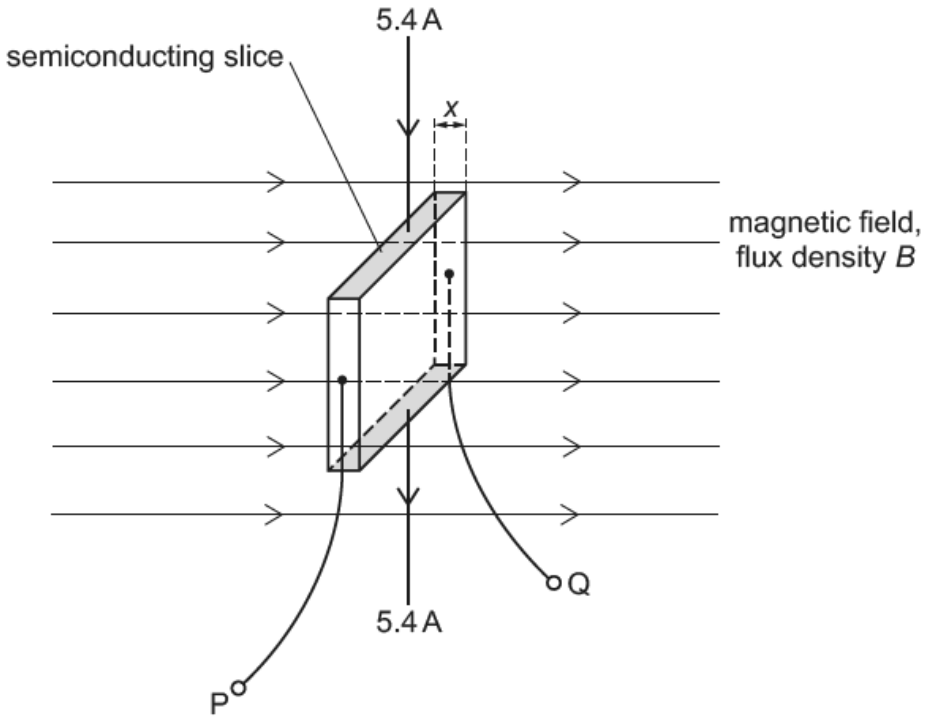


Fig. 7.1

The thickness *x* of the slice is 1.8 mm. The number density of charge carriers in the semiconducting material is $1.5 \times 10^{16}\,m^{-3}$.
A constant current of 5.4 A is passed through the slice between the shaded faces.
The Hall voltage V_H that is developed between the terminals PQ is recorded.

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Fig. 7.2 shows the variation with time t of B.

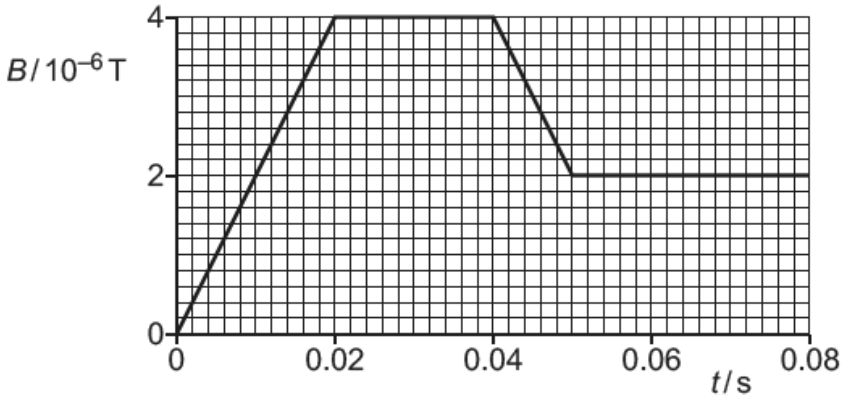


Fig. 7.2

(i) Show that, when B is equal to 4.0×10^{-6} T, the magnitude of V_H is 5.0 V.

[1]

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(ii) On Fig. 7.3, sketch the variation of V_H with t between $t = 0$ and $t = 0.080\,s$.

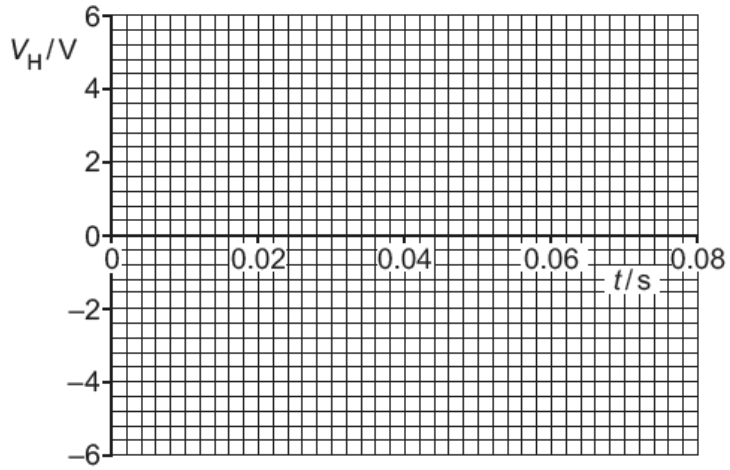


Fig. 7.3

[3]

(b) The Hall probe in **(a)** is replaced with a small flat coil that has 3000 turns. The cross-sectional area of the coil is $3.4 \times 10^{-4}\,m^2$.
The plane of the coil is perpendicular to the magnetic field. The electromotive force (e.m.f.) E induced between the terminals of the coil is recorded as B varies as shown in Fig. 7.2.

(i) Show that the magnitude of E at time $t = 0.010\,s$ is $2.0 \times 10^{-4}\,V$.

[3]

(ii) On Fig. 7.4, sketch the variation of E with t between $t = 0$ and $t = 0.080\,s$.

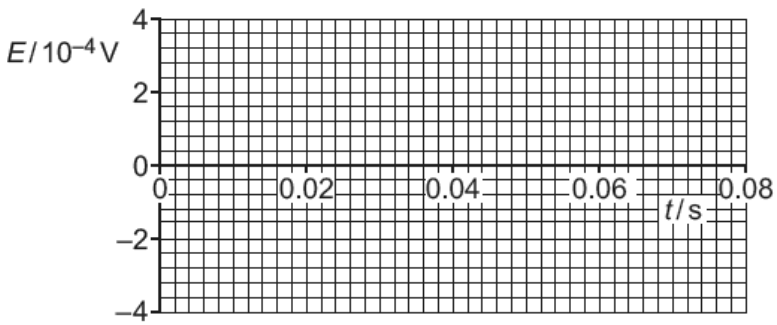


Fig. 7.4

[4]

[Total: 11]

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3. June/2023/Paper_9702/41/No.6

(a) State what is meant by a magnetic field.

.....

.....

..... [2]

(b) A long, straight wire P carries a current into the page, as shown in Fig. 6.1.

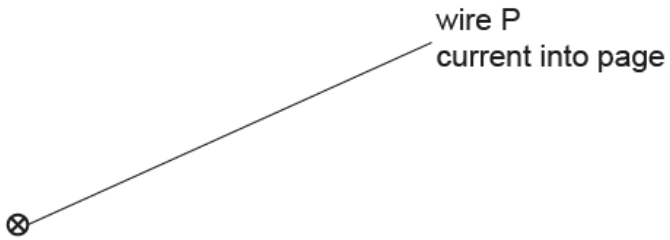


Fig. 6.1

On Fig. 6.1, draw four field lines to represent the magnetic field around wire P due to the current in the wire. [3]

(c) A second long, straight wire Q, carrying a current of 5.0 A out of the page, is placed parallel to wire P, as shown in Fig. 6.2.

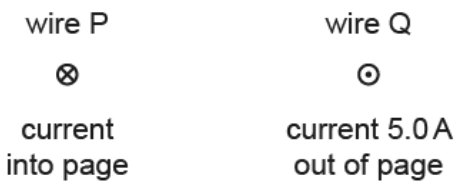


Fig. 6.2

The flux density of the magnetic field at wire Q due to the current in wire P is 2.6 mT.

(i) Calculate the magnetic force per unit length exerted on wire Q by wire P.

force per unit length = ... $N\,m^{-1}$ [2]

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(ii) State the direction of the force exerted on wire Q by wire P.

..... [1]

(iii) The flux density of the magnetic field at wire P due to the current in wire Q is 1.5 mT.

Determine the magnitude of the current in wire P. Explain your reasoning.

current = ... A [2]

[Total: 10]

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4. March/2023/Paper_9702/42/No.6

(a) A Hall probe is placed in a magnetic field. The Hall voltage is zero. The Hall probe is rotated to a new position in the magnetic field. The Hall voltage is now maximum.

Explain these observations.

.....

.....

..... [2]

(b) The formula for calculating the Hall voltage V_H as measured by a Hall probe is

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

Table 6.1 shows the value of n for two materials.

Table 6.1

material	n / m^{-3}
silicon	9.65×10^{15}
copper	8.49×10^{28}

(i) State the meaning of n.

.....

..... [1]

(ii) Explain why a Hall probe is made from silicon rather than copper.

.....

..... [1]

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(c) A Hall probe gives a maximum reading of 24 mV when placed in a uniform magnetic field of flux density 32 mT.

The same Hall probe is then placed in a magnetic field of fixed direction and varying flux density. The Hall probe is in a fixed position so that the angle between the Hall probe and the magnetic field is the same as when the Hall voltage was 24 mV.

The variation of the reading V_H on the Hall probe with time t from time $t = 0$ to time $t = 8.6$ s is shown in Fig. 6.1.

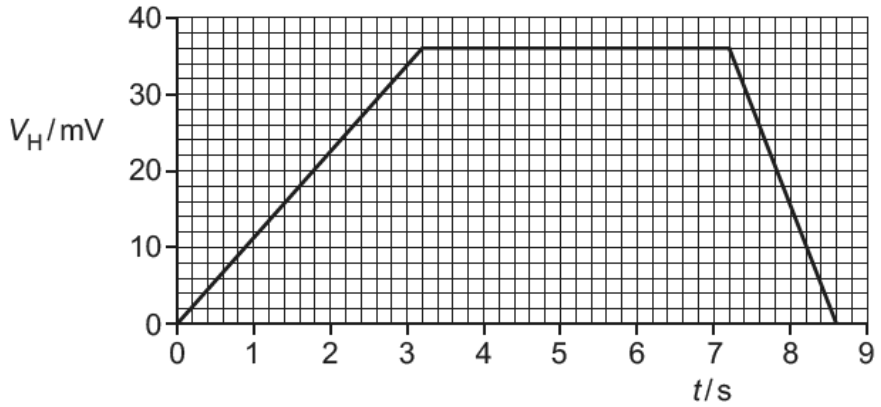


Fig. 6.1

A coil with 780 turns and a diameter of 3.6 cm is placed in this varying magnetic field. The plane of the coil is perpendicular to the field lines.

Calculate the magnitude of the maximum electromotive force (e.m.f.) induced in the coil in the time between $t = 0$ and $t = 8.6$ s.

e.m.f. = ... V [4]

[Total: 8]

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