CAMBRIDGE INTERNATIONAL A LEVEL • PHYSICS 9702

Topical Questions

Unit 20: Magnetic Fields and Electromagnetic Induction

Past Papers 2021 – 2025

QUESTION PAPER 32 Questions

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Question 1

(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.

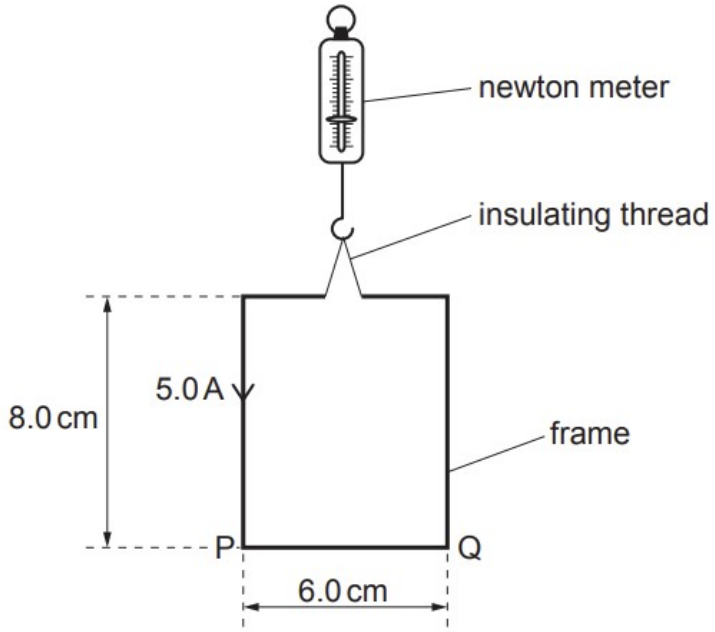


Fig. 8.1

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.

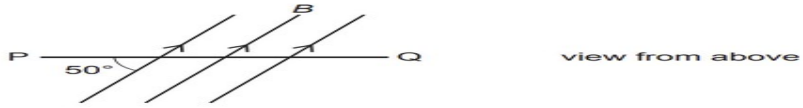


Fig. 8.2

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

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

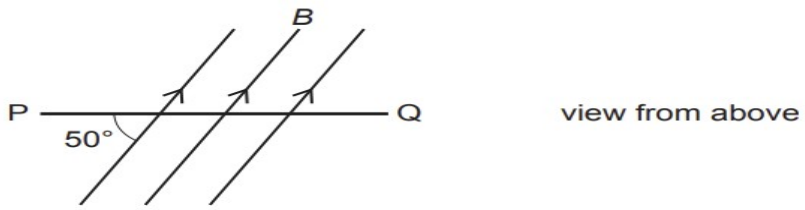


Fig. 8.2

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]

Question 2

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]

Question 3

Fig. 10.1 shows a simple laminated iron-cored transformer consisting of a primary coil of 25 000 turns and a secondary coil of 625 turns.

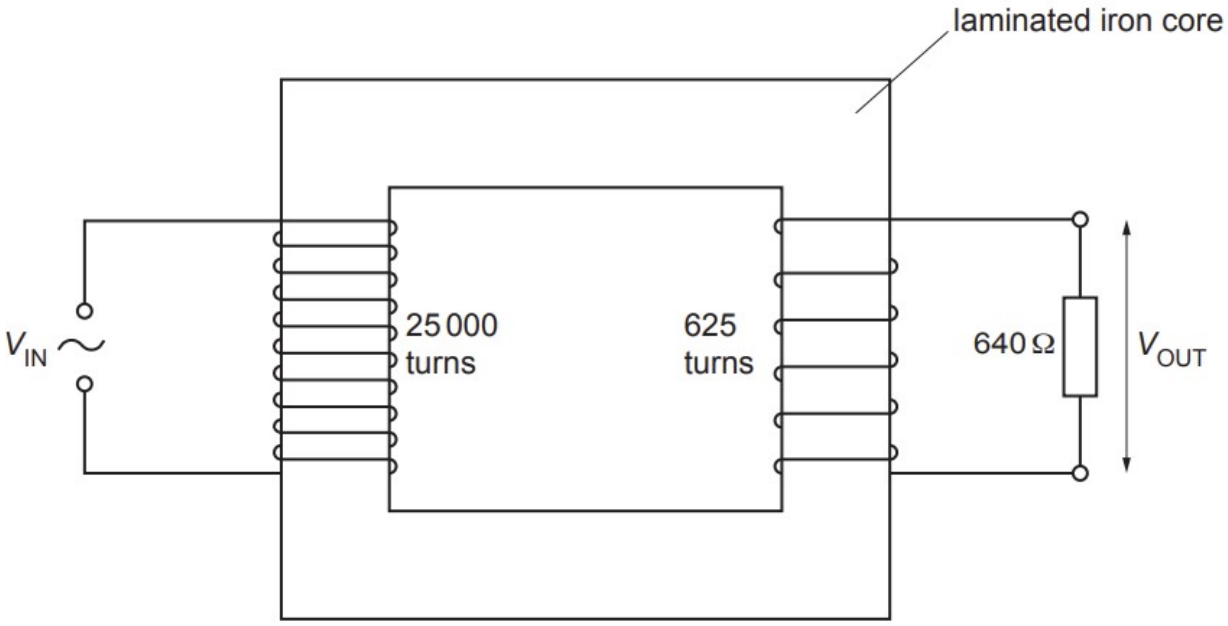


Fig. 10.1

The output potential difference (p.d.) V_{OUT} is applied to a load resistor of resistance 640 Ω.

(a) (i) State the function of the iron core.

.....

..... [1]

(ii) Explain why the iron core is laminated.

.....

.....

..... [2]

(b) The input p.d. V_{IN} is a sinusoidal alternating voltage of peak value 12 kV and period 40 ms.

(i) Calculate the maximum value of V_{OUT}.

maximum V_{OUT} = ... V [1]

(ii) Calculate the root-mean-square (r.m.s.) current in the load resistor.

r.m.s. current = ... A [1]

(iii) On Fig. 10.2, sketch the variation with time t of the power P dissipated in the load resistor for time $t = 0$ to $t = 40$ ms. Assume that $P = 0$ when $t = 0$.

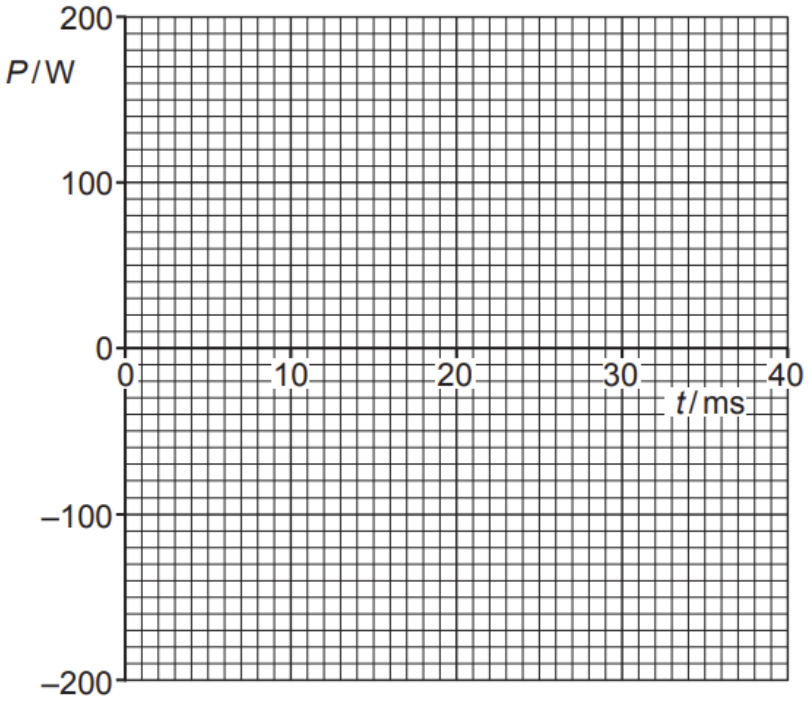


Fig. 10.2

[3]

(c) Explain, with reference to Fig.10.2, why the mean power in the load resistor is 70 W.

.....

.....

.....

..... [2]

[Total: 10]

Question 4

(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.

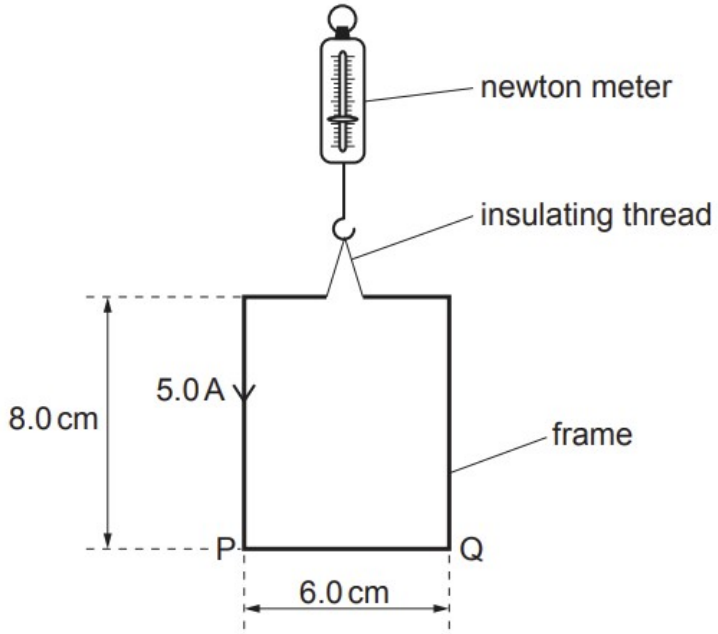
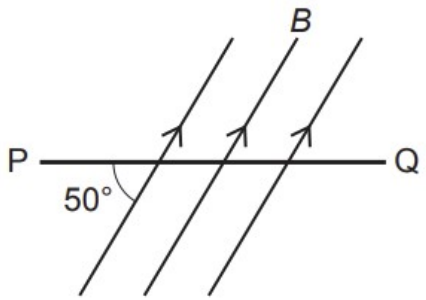


Fig. 8.1

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



view from above

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]

Question 5

(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.

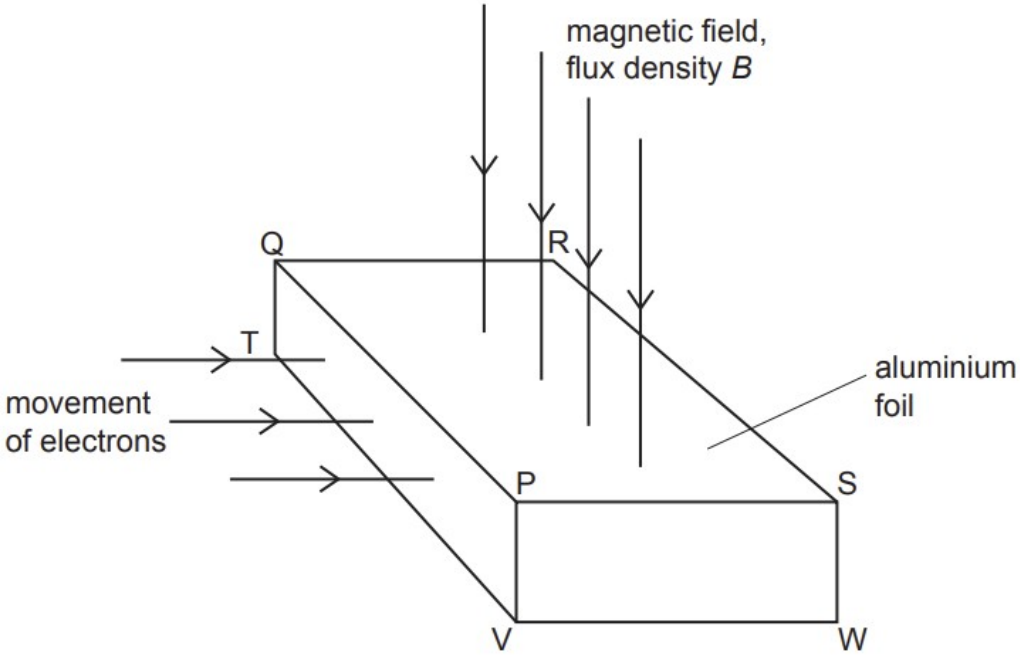


Fig. 9.1

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]

Question 6

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.

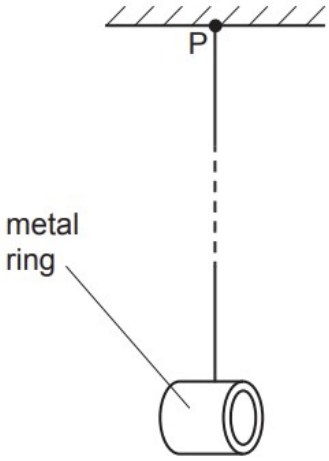


Fig. 10.1

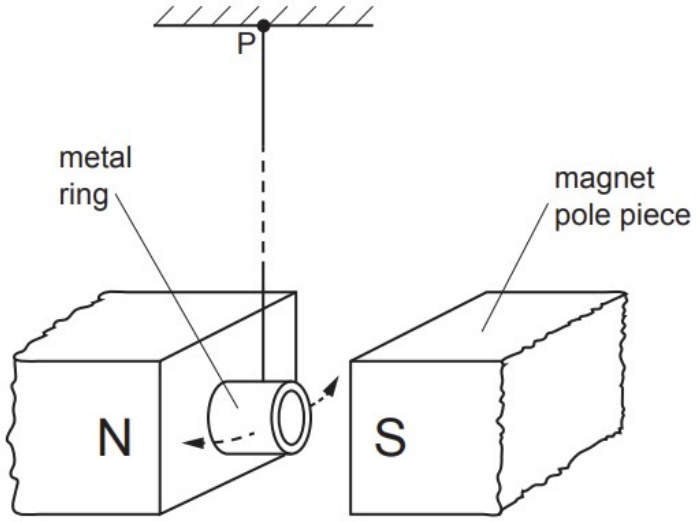


Fig. 10.2

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.

.....

.....

.....

.....

..... [3]

[Total: 9]

Question 7

(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.

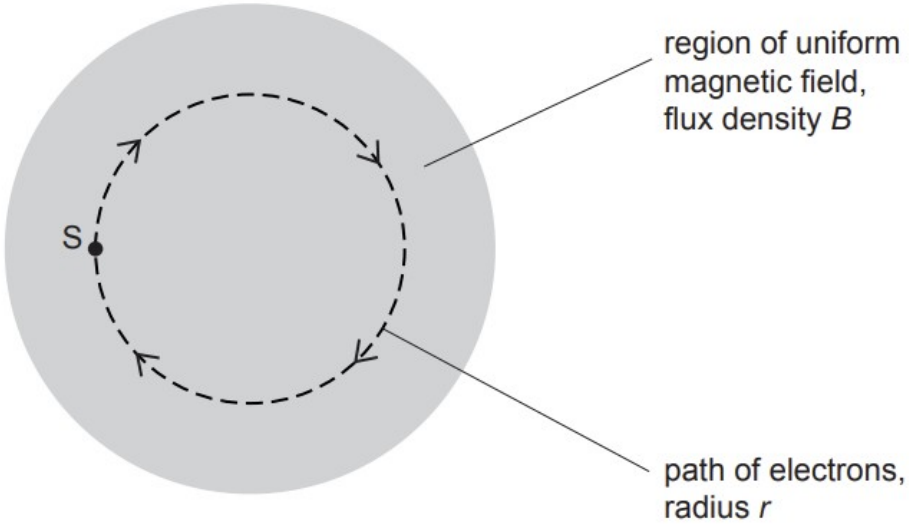


Fig. 8.1

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

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

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]

Question 8

(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.

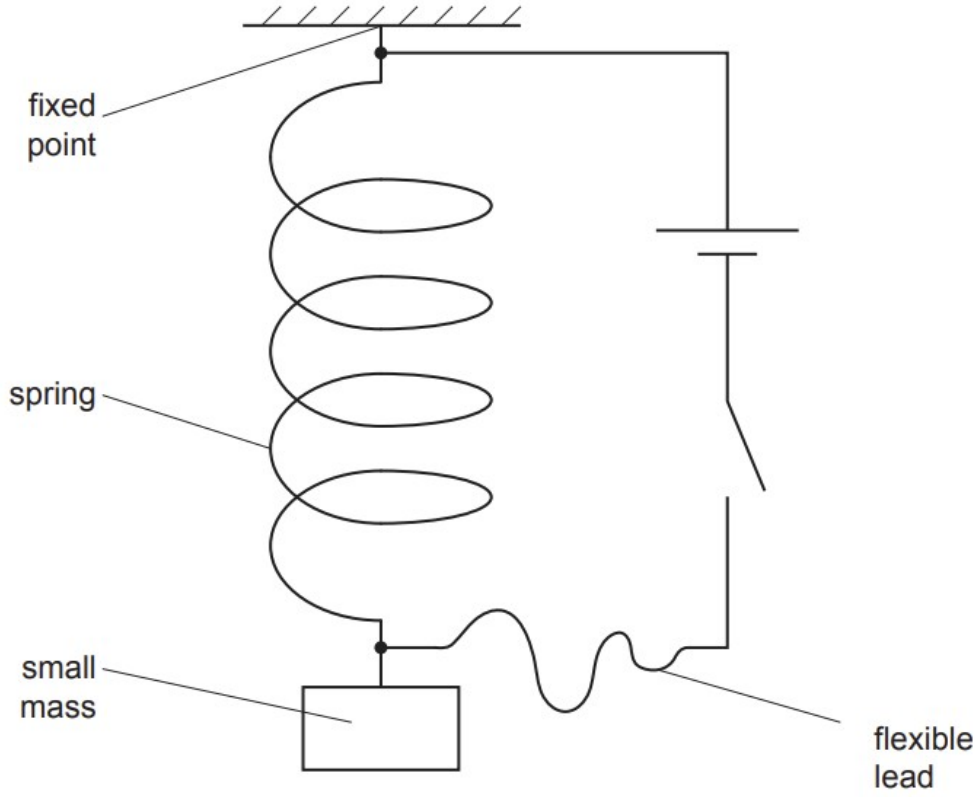


Fig. 9.1

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.

.....

.....

.....

..... [3]

[Total: 9]

Question 9

(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.

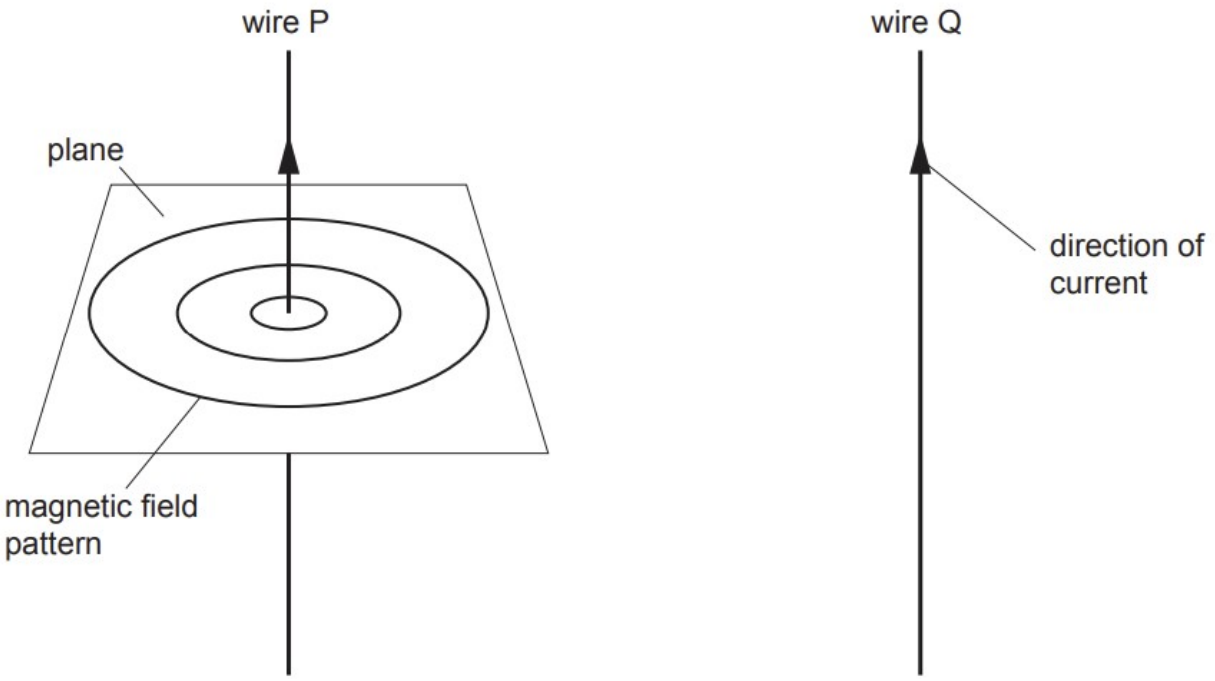


Fig. 8.1

(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]

Question 10

(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.

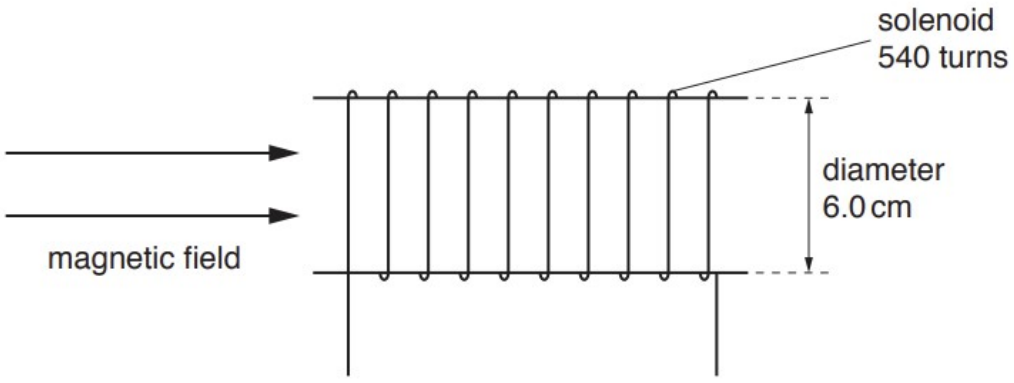


Fig. 9.1

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

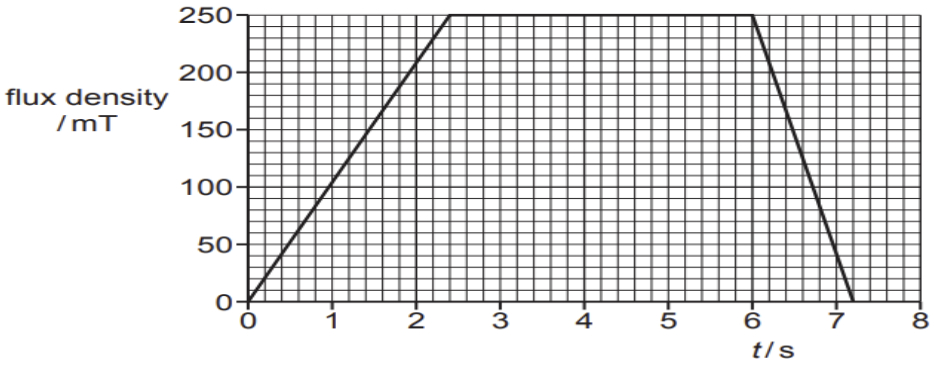


Fig. 9.2

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

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

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

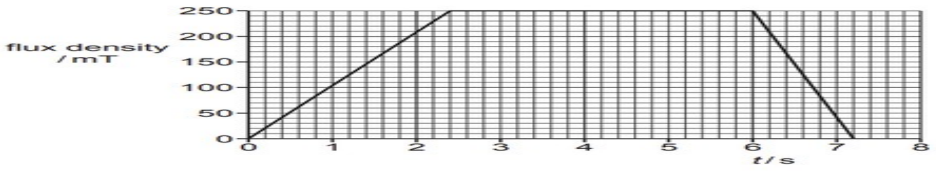


Fig. 9.2

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.

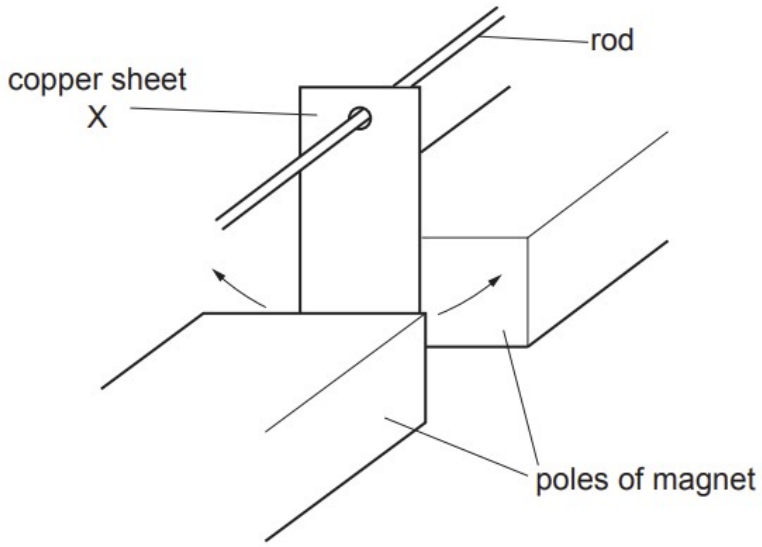


Fig. 9.3

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.

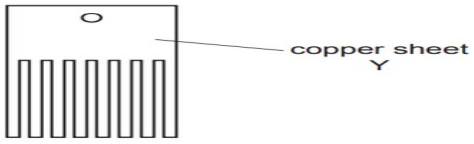


Fig. 9.4

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.

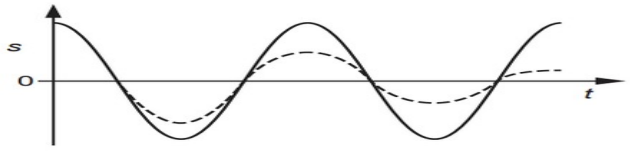


Fig. 9.5

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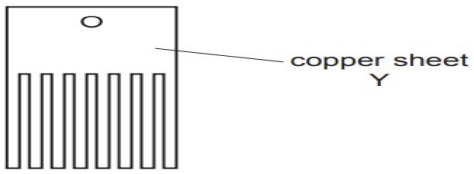


Fig. 9.4

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.

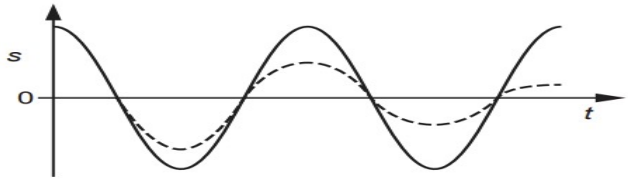


Fig. 9.5

(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.

.....

.....

.....

.....

.....

..... [4]

[Total: 10]

Question 11

6 A small solenoid of area of cross section $1.6 \times 10^{-3}\,m^2$ is placed inside a larger solenoid of area of cross-section $6.4 \times 10^{-3}\,m^2$, as shown in Fig. 6.1.

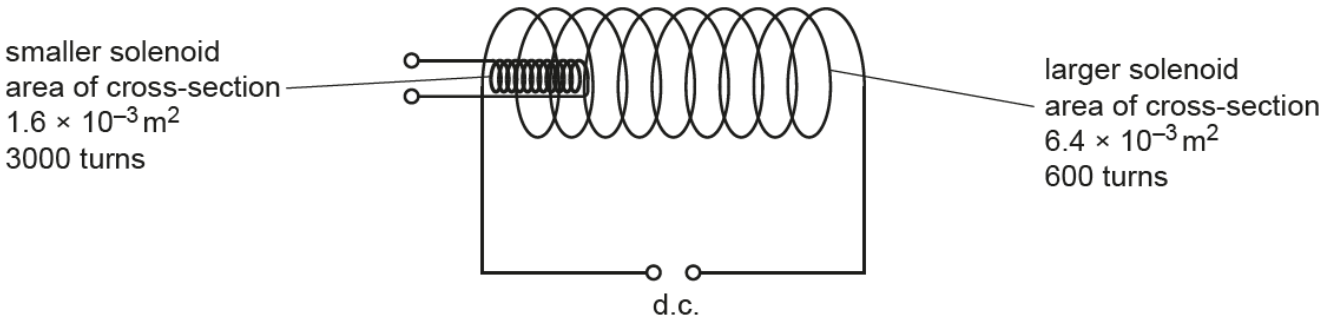


Fig. 6.1 (not to scale)

The larger solenoid has 600 turns and is attached to a d.c. power supply to create a magnetic field.

The smaller solenoid has 3000 turns.

(a) Compare the magnetic flux in the two solenoids.

.....

.....

..... [1]

(b) Compare the magnetic flux linkage in the two solenoids.

.....

.....

..... [1]

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

.....

.....

..... [2]

(ii) The terminals of the smaller solenoid are connected together. The smaller solenoid is then removed from inside the larger solenoid.

With reference to magnetic fields, explain why a force is needed to remove the smaller solenoid.

.....

.....

.....

.....

.....

..... [3]

[Total: 7]

Question 12

(a) Define magnetic flux.

.....

.....

..... [2]

(b) A square coil of wire of side length 12 cm consists of 8 insulated turns. The coil is stationary in a uniform magnetic field. The plane of the coil is perpendicular to the magnetic field, as shown in Fig. 6.1.

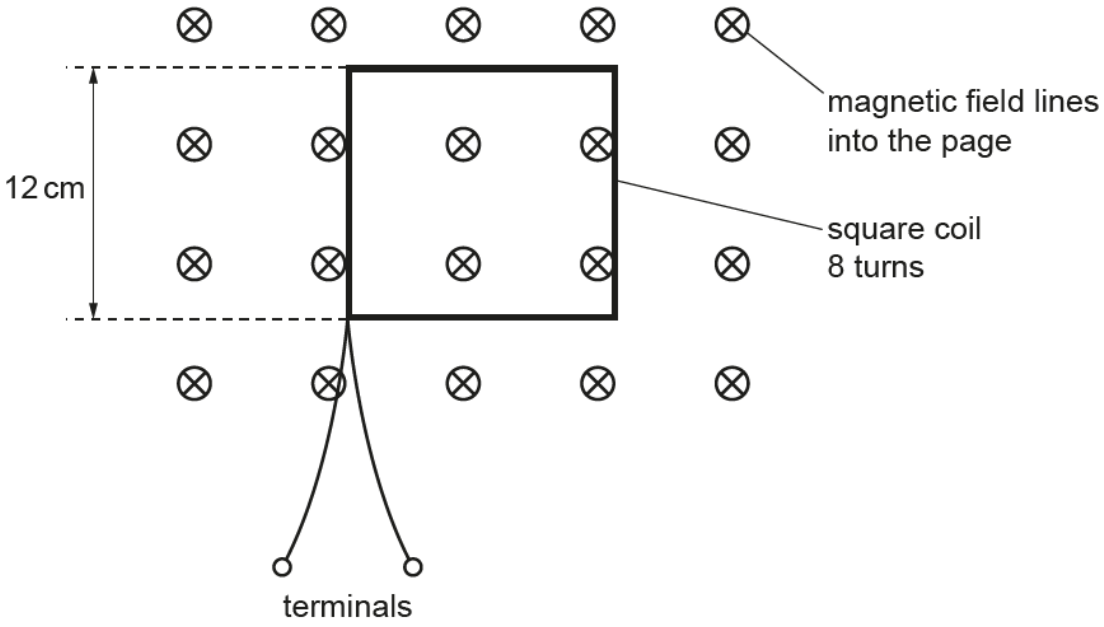


Fig. 6.1

The flux density *B* of the magnetic field varies with time *t* as shown in Fig. 6.2.

Fig. 6.1

The flux density B of the magnetic field varies with time t as shown in Fig. 6.2.

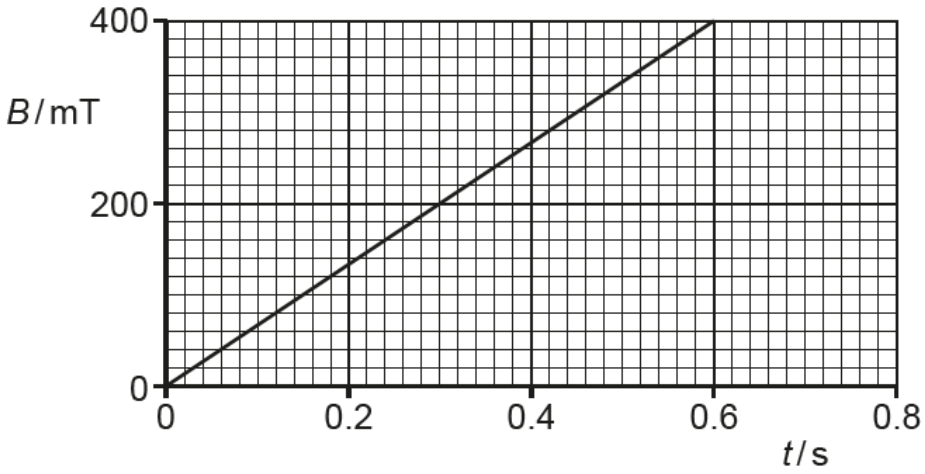


Fig. 6.2

(i) Determine the magnetic flux linkage inside the coil at time t = 0.60 s. Give a unit with your answer.

magnetic flux linkage = ... unit ..... [3]

(ii) State how Fig. 6.2 shows that the electromotive force (e.m.f.) E induced across the terminals between t = 0 and t = 0.60 s is constant.

..... [1]

(iii) Calculate the magnitude of E.

E = ... V [2]

(c) The procedure in **(b)** is repeated, but this time the terminals of the coil are connected together.

State and explain the effect on the coil of connecting the terminals together during the change of magnetic flux density shown in Fig. 6.2.

.....

.....

.....

..... [3]

[Total: 11]

Question 13

(a) State the **two** conditions that must be satisfied for a copper wire, placed in a magnetic field, to experience a magnetic force.

1 .....

.....

2 .....

.....

[2]

(b) A long air-cored solenoid is connected to a power supply, so that the solenoid creates a magnetic field. Fig. 6.1 shows a cross-section through the middle of the solenoid.

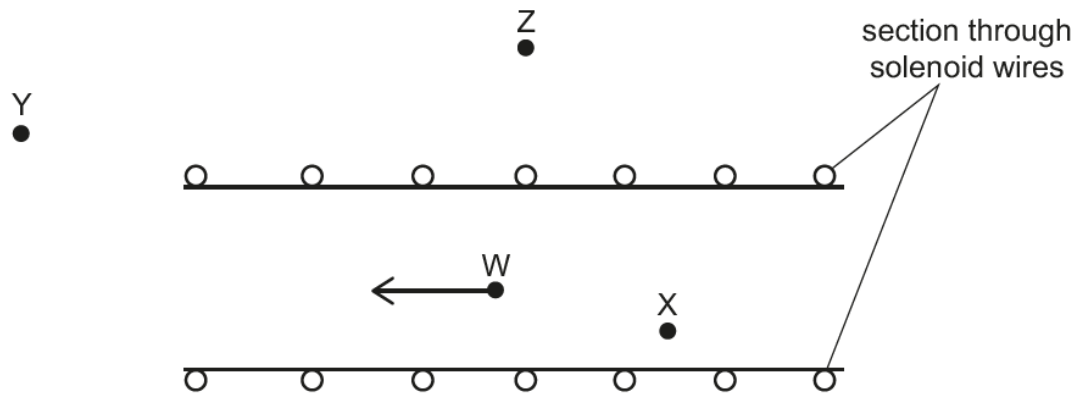


Fig. 6.1

The direction of the magnetic field at point W is indicated by the arrow. Three other points are labelled X, Y and Z.

Fig. 6.1

The direction of the magnetic field at point W is indicated by the arrow. Three other points are labelled X, Y and Z.

(i) On Fig. 6.1, draw arrows to indicate the direction of the magnetic field at each of the points X, Y and Z. [3]

(ii) Compare the magnitude of the flux density of the magnetic field:

- at X and at W .....

.....

- at Y and at Z. .....

.....

[2]

(c) Two long parallel current-carrying wires are placed near to each other in a vacuum.

Explain why these wires exert a magnetic force on each other. You may draw a labelled diagram if you wish.

.....

.....

.....

..... [3]

[Total: 10]

Question 14

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

.....

.....

..... [2]

(b) Two coils are wound on an iron bar, as shown in Fig. 7.1.

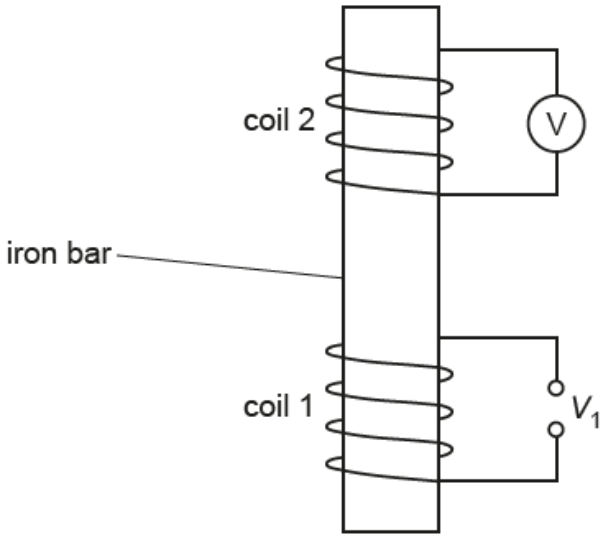


Fig. 7.1

Coil 1 is connected to a potential difference (p.d.) V_1 that gives rise to a magnetic field in the iron bar.

Fig. 7.2 shows the variation with time t of the magnetic flux density B in the iron bar.

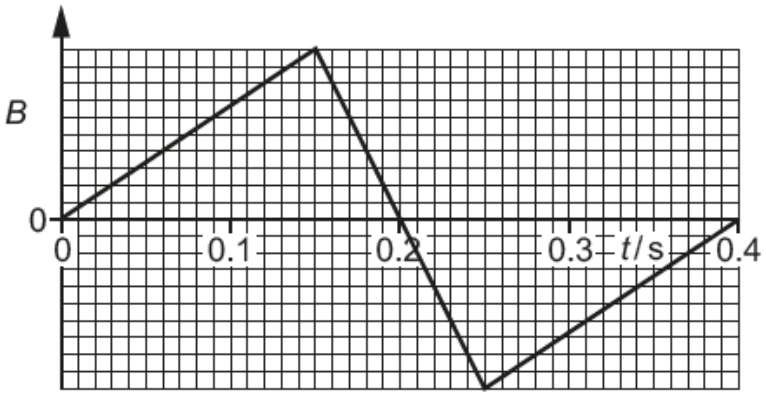


Fig. 7.2

A voltmeter measures the electromotive force (e.m.f.) V_2 that is induced across coil 2.

On Fig. 7.3, sketch the variation with t of V_2 between $t = 0$ and $t = 0.40$ s.

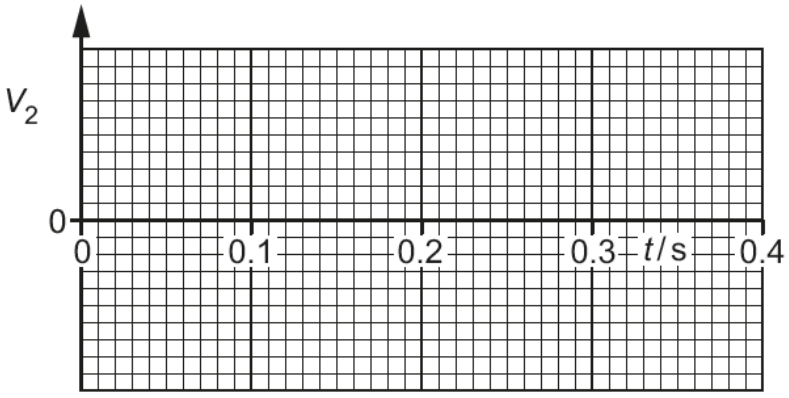


Fig. 7.3

[4]

(c) Coil 2 in **(b)** is now replaced with a copper ring that rests loosely on top of coil 1. The supply to coil 1 is replaced with a cell and a switch that is initially open, as shown in Fig. 7.4.

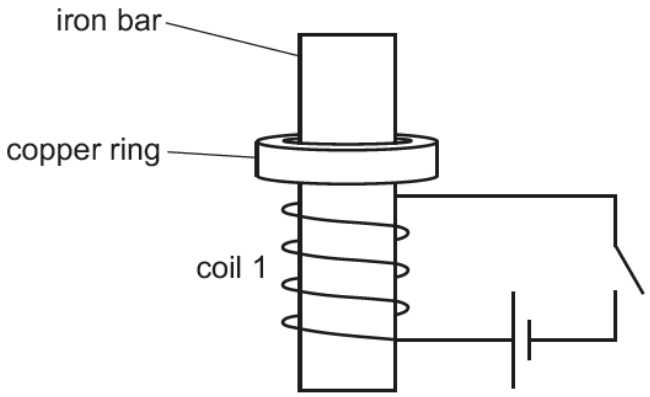


Fig. 7.4

(i) The switch is now closed. As it is closed, the copper ring is observed to jump upwards.

Explain why this happens.

.....

.....

.....

..... [3]

(ii) Suggest, with a reason, what would be the effect of repeating the procedure in **(c)(i)** with the terminals of the cell reversed.

.....

..... [1]

[Total: 10]

Question 15

Fig. 6.1 shows a thin slice of semiconducting material used in a Hall probe.

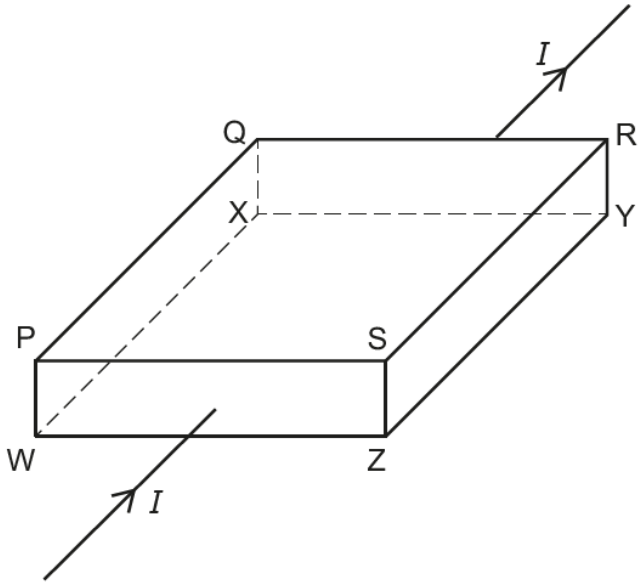


Fig. 6.1 (not to scale)

Current I passes through the slice in the direction shown.

The slice is placed in a uniform magnetic field of flux density B, so that two of its faces are perpendicular to the magnetic field.

A steady Hall voltage V_H is developed between face PQXW and face SRYZ.

(a) (i) Use the letters in Fig. 6.1 to identify the faces that are perpendicular to the magnetic field.

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

(ii) Explain how the steady Hall voltage V_H is developed between faces PQXW and SRYZ.

.....

.....

.....

.....

..... [3]

(b) The magnitude of V_H is given by the equation

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

(i) State the meaning of the symbols n, t and q. You may refer to the letters in Fig. 6.1.

n: .....

t: .....

q: .....

[3]

(ii) Suggest, with reference to the equation, why the slice of the material used in a Hall probe is thin.

.....

.....

..... [2]

[Total: 9]

Question 16

(a) Define magnetic flux density.

.....

.....

.....

..... [3]

(b) An insulated rectangular coil of wire, consisting of 40 turns, is suspended in a cradle from a newton meter, as shown in Fig. 7.1.

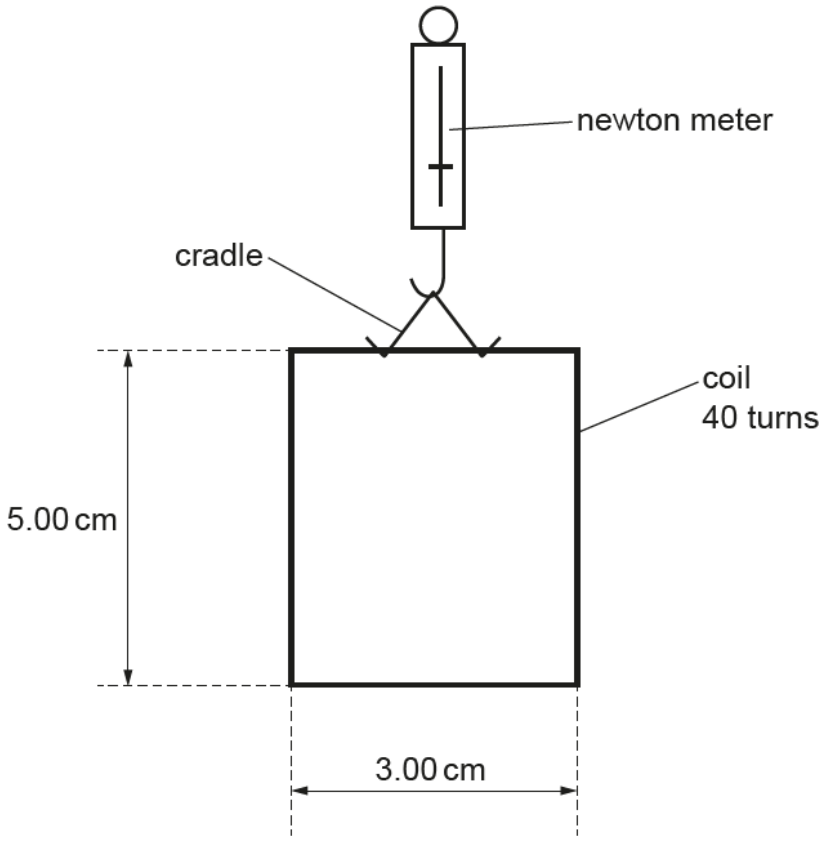


Fig. 7.1

The vertical sides of the coil have a length of 5.00 cm and the horizontal sides have a length of 3.00 cm. The initial reading on the newton meter is 0.563 N.

A U-shaped magnet rests on a top-pan balance that is set to a reading of 0.00 g.
The lower edge of the coil is lowered into the region between the poles of the U-shaped magnet, as shown in the side view in Fig. 7.2.

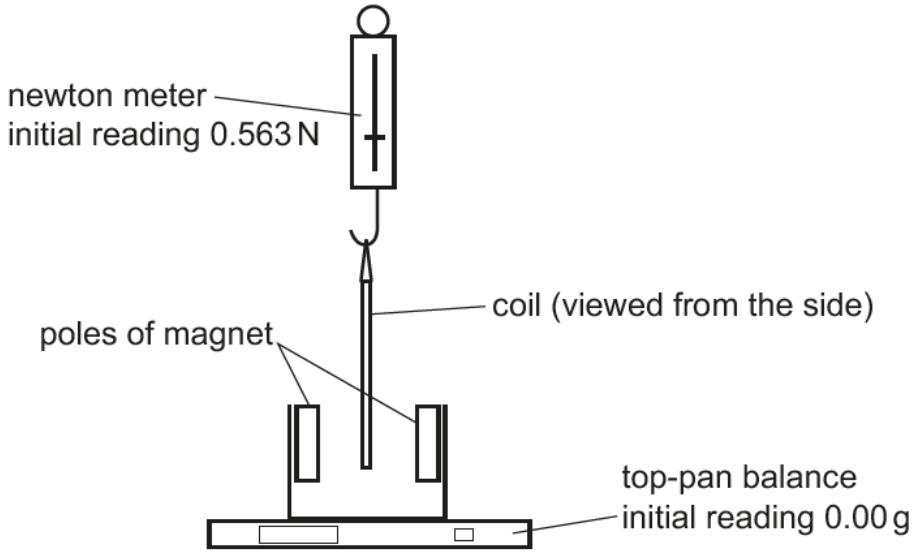


Fig. 7.2

The magnetic field in the region between the poles is uniform.
The lower edge of the coil is entirely within the uniform magnetic field.

A current of 3.94 A is now passed through the coil. This causes the reading on the top-pan balance to change to 2.16 g.

(i) Explain why the current causes a vertical force to act on the coil.

.....

.....

..... [2]

(ii) Determine, to three significant figures, the flux density *B* of the uniform magnetic field.

B = ... T [3]

(iii) Determine what is now the reading on the newton meter. Explain your reasoning.

reading = ... N [2]

[Total: 10]

Question 17

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

.....

.....

..... [2]

(b) Two coils of insulated wire are wound on an iron bar, as shown in Fig. 8.1.

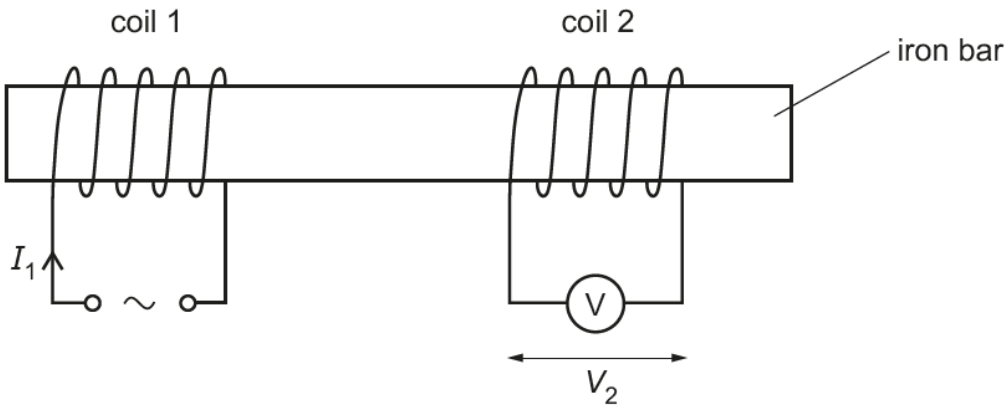


Fig. 8.1

There is a current I_1 in coil 1 that varies with time t as shown in Fig. 8.2.

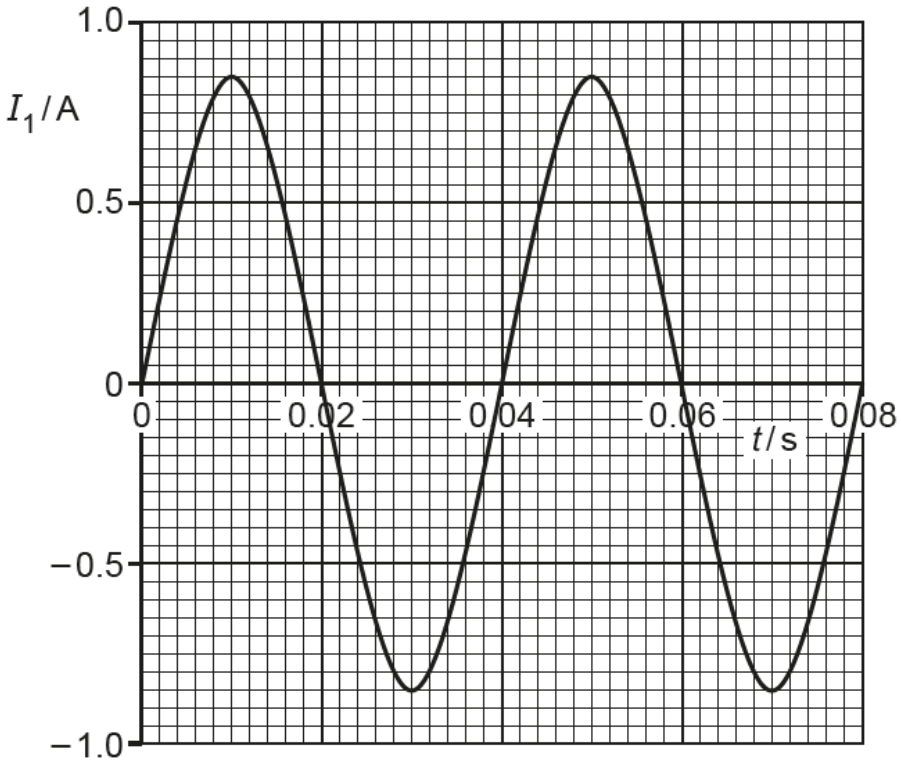


Fig. 8.2

(i) The variation with t of I_1 can be represented by the equation

$$I_1 = X \sin Yt$$

where X and Y are constants.

Use Fig. 8.2 to determine the values of X and Y. Give units with your answers.

X = ... unit .....

Y = ... unit .....

[3]

(ii) The current in coil 1 gives rise to a magnetic field in the iron bar.
Assume that the flux density of this magnetic field is proportional to I_1.

An alternating electromotive force (e.m.f.) is induced across coil 2. The p.d. across coil 2 is measured using the voltmeter and has a root-mean-square (r.m.s.) value of 4.6 V.

On Fig. 8.3, sketch a line to show the variation with t of V_2 between t = 0 and t = 0.08 s.

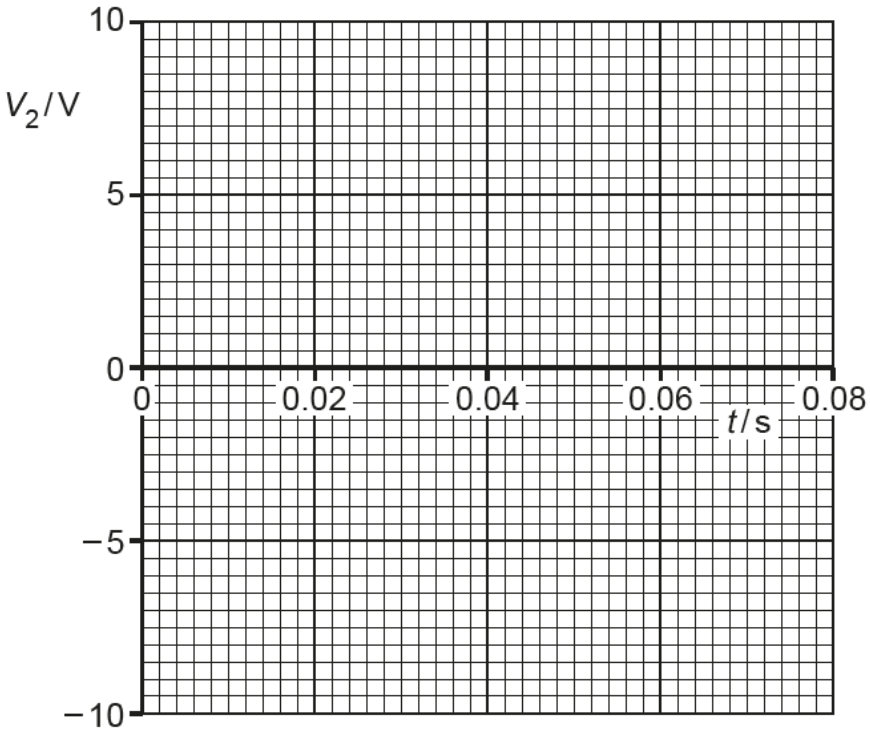


Fig. 8.3

[3]

(iii) Use the laws of electromagnetic induction to explain the shape of your line in **(b)(ii)**.

.....

.....

.....

..... [3]

[Total: 11]

Question 18

(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]

(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.

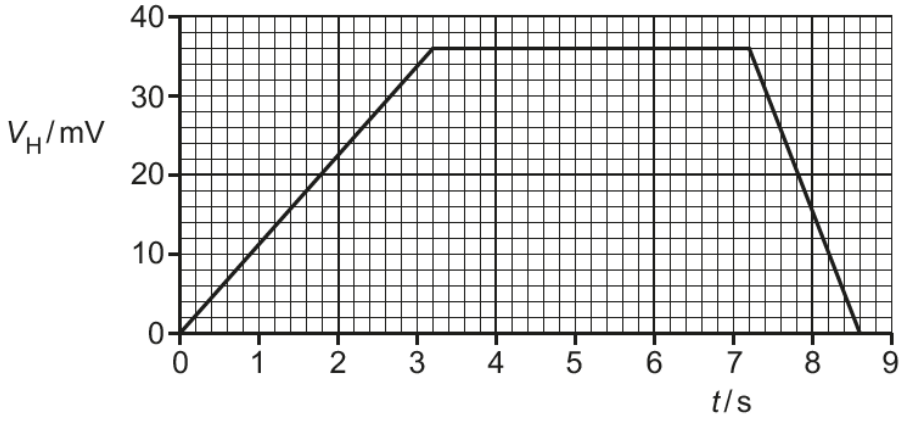


Fig. 6.1

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]

Question 19

(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.

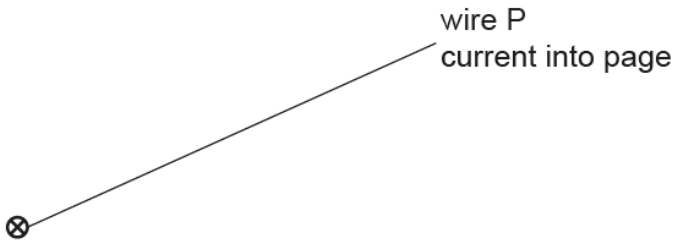


Fig. 6.1

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.

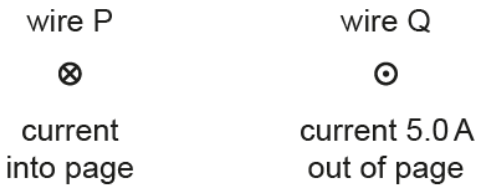


Fig. 6.2

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]

(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]

Question 20

A heavy aluminium disc has a radius of 0.36 m. The disc rotates with the wheels of a vehicle and forms part of an electromagnetic braking system on the vehicle.

In order to activate the braking system, a uniform magnetic field of flux density 0.17 T is switched on. This magnetic field is perpendicular to the plane of rotation of the disc, as shown in Fig. 6.1.

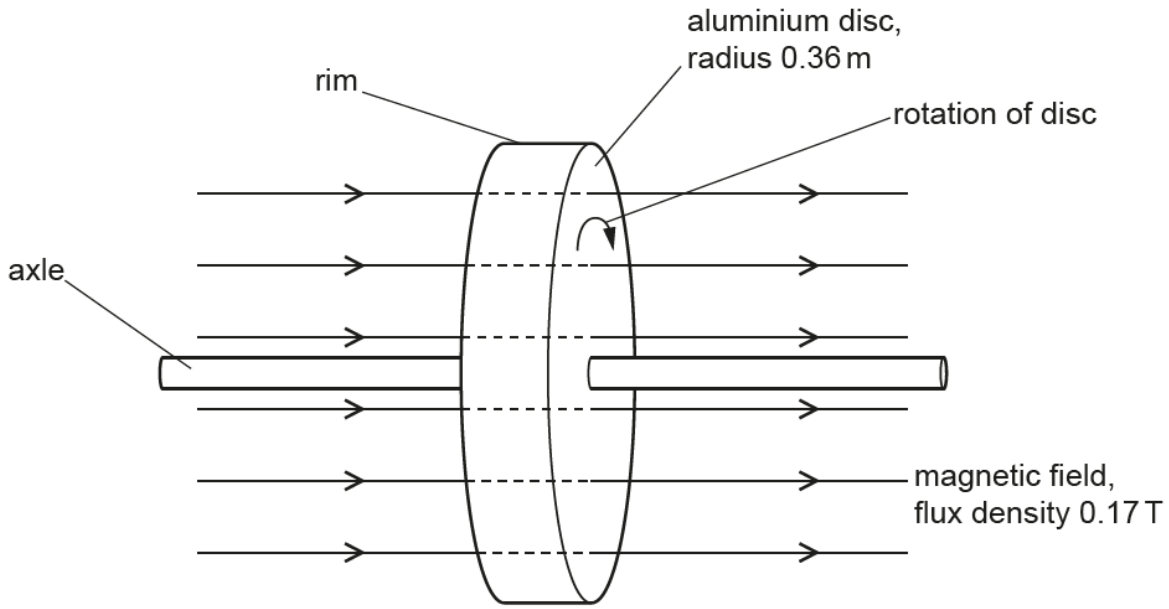


Fig. 6.1

(a) (i) Define magnetic flux.

.....

.....

..... [2]

(ii) Calculate the magnetic flux through the disc. Give a unit with your answer.

magnetic flux = ... unit ..... [2]

(b) The disc is rotating at a rate of 25 revolutions per second.

Calculate the magnitude of the electromotive force (e.m.f.) induced between the axle and the rim of the disc.

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

(c) The axle and the rim are connected into an external circuit that enables the energy of the rotation of the disc to be stored for future use. The direction of rotation is shown in Fig. 6.1.

Use Lenz's law of electromagnetic induction to determine whether the current in the disc is from the rim to the axle or from the axle to the rim. Explain your reasoning.

.....

.....

.....

.....

..... [3]

[Total: 10]

Question 21

(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.

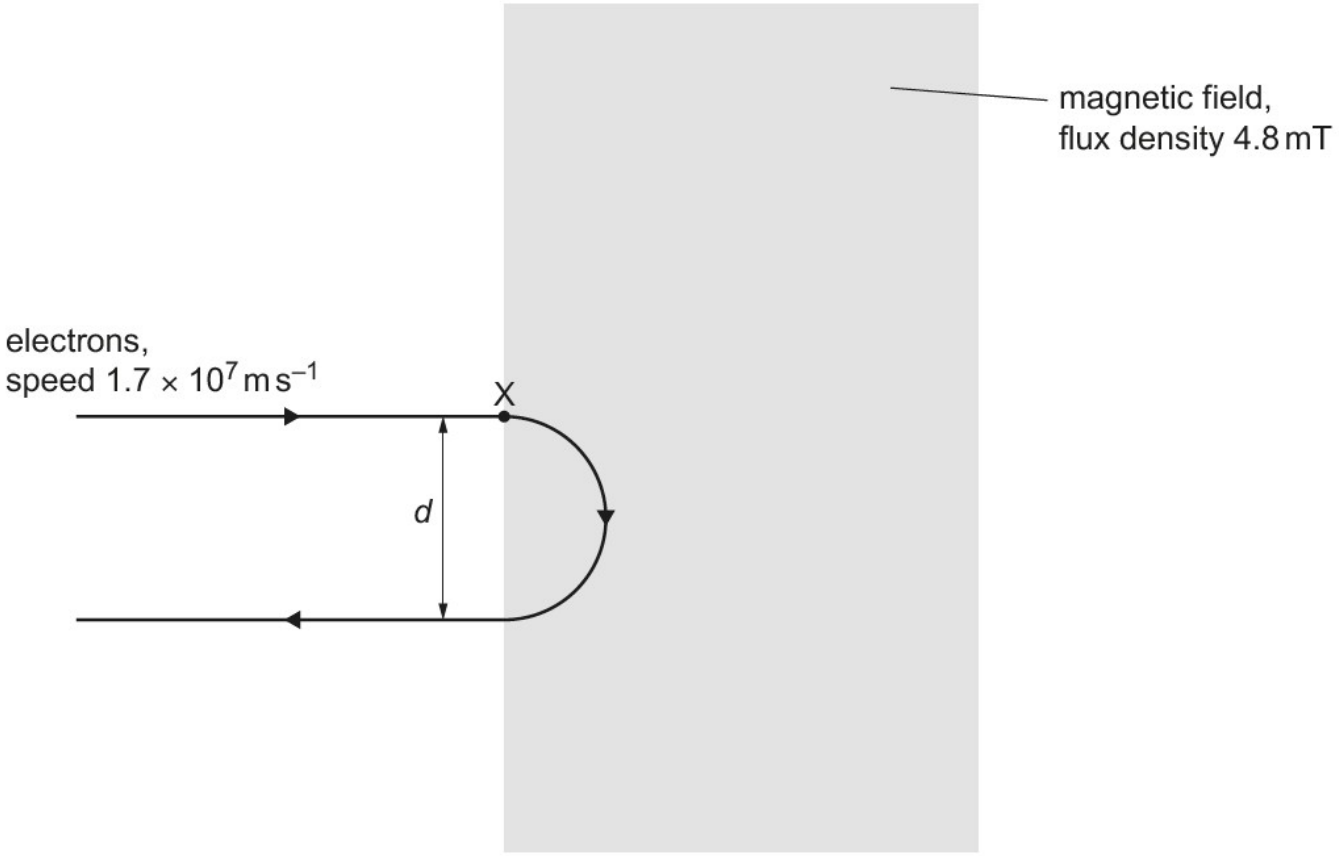


Fig. 6.1

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

(i) State the direction of the magnetic field.

.....

..... [1]

(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 3.4×10^{7} 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]

Question 22

(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.

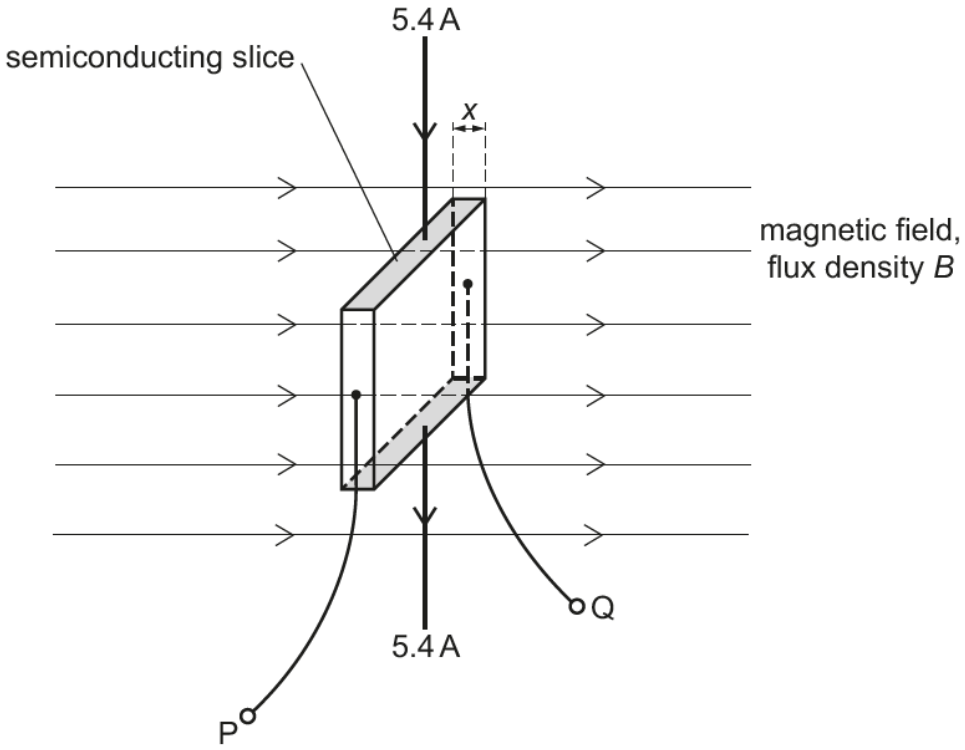


Fig. 7.1

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.

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

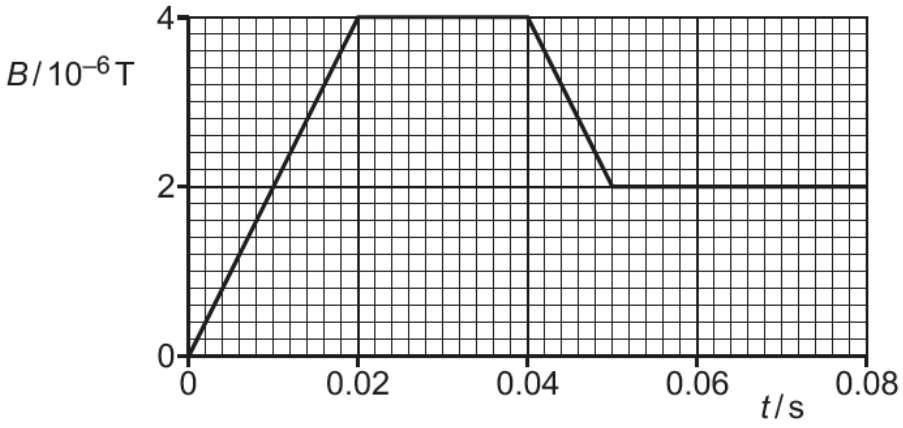


Fig. 7.2

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

[1]

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

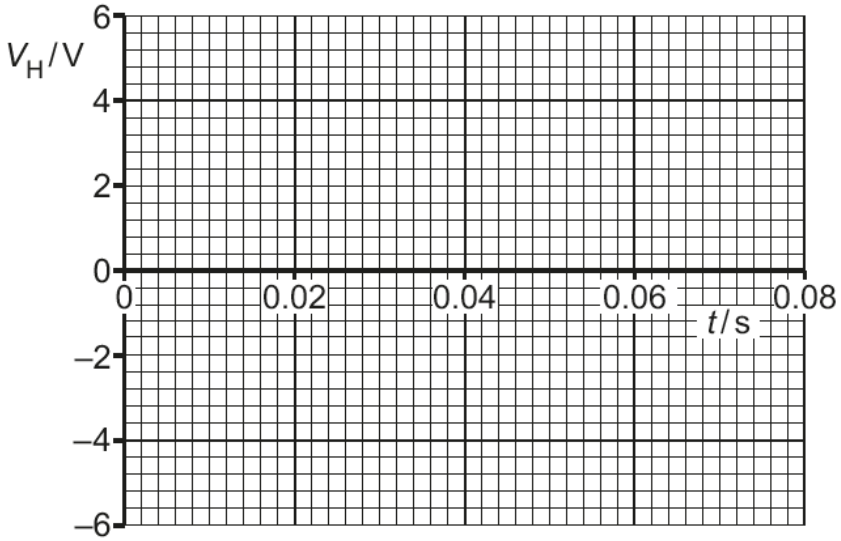


Fig. 7.3

[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 $t = 0.080\,s$.

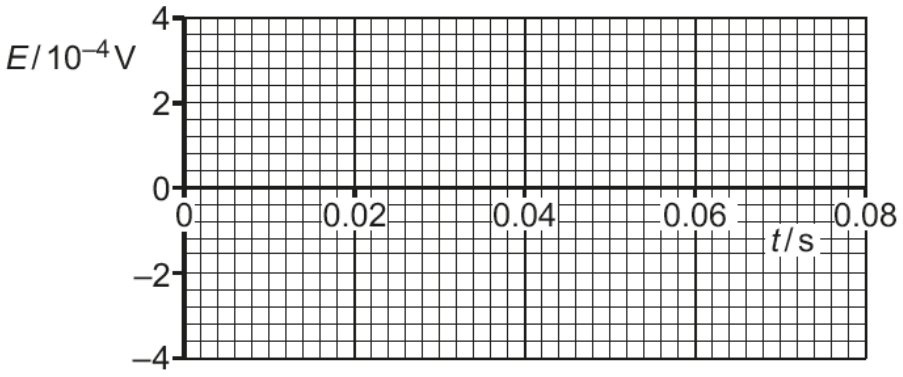


Fig. 7.4

[4]

[Total: 11]

Question 23

(a) An object travels in a circle at constant speed.

State the names of **two** quantities that vary during the motion of the object.

1 .....

2 .....

[2]

(b) A charged particle of mass m and with charge q enters a region of uniform magnetic field, perpendicular to the field lines. The magnetic flux density is B.

The particle travels in a circle with period T and radius r.

(i) By considering the magnetic force acting on the particle, show that

$$B = \frac{2\pi m}{qT}.$$

[3]

(ii) The particle is an alpha particle. The period of the circular motion is 2.5 μs.

Calculate B.

B = ... T [2]

(iii) A second alpha particle is in the same uniform field. It travels in a circle of radius $2r$.

State and explain how the periods of the motion of the two particles compare.

.....

.....

..... [1]

(iv) The speed of the alpha particle in **(b)(ii)** is $1.1 \times 10^6\,\text{m s}^{-1}$. An electric field is applied so that this particle now moves with constant velocity.

Use your answer in **(b)(ii)** to calculate the electric field strength E. Give the unit with your answer.

E = ... unit ..... [2]

[Total: 10]

Question 24

(a) A small coil C has 64 turns and cross-sectional area 0.71 cm^2. The coil is placed inside a solenoid as shown in Fig. 6.1.

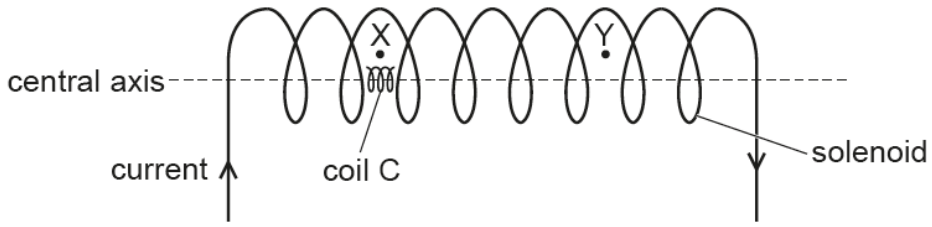


Fig. 6.1

The centre of coil C is on the central axis of the solenoid.

(i) There is a constant current in the solenoid.
Coil C is moved through the solenoid from position X to position Y.

On Fig. 6.2, sketch a line to show the variation of the magnetic flux linkage in coil C with position as it moves from X to Y.

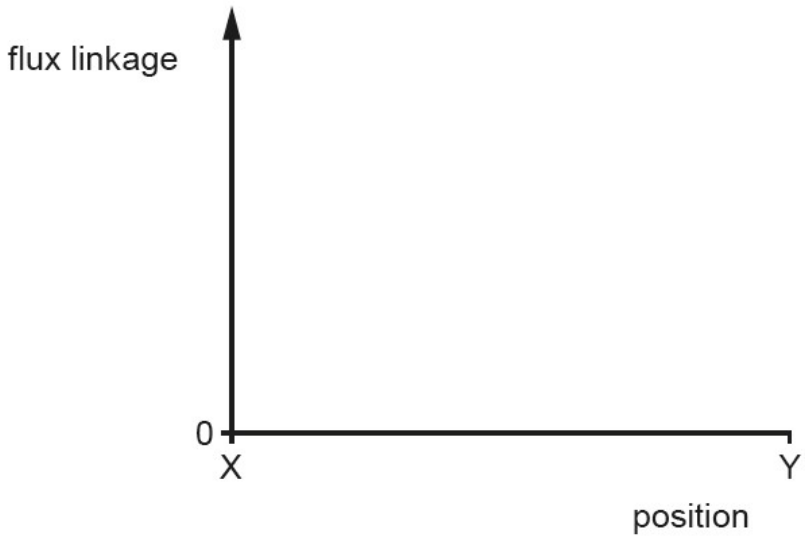


Fig. 6.2

[1]

(ii) Explain the shape of your line in **(a)(i)**.

.....

.....

.....

..... [2]

(iii) Coil C is now held stationary at X. The current in the solenoid varies so that the magnetic flux density *B* at X varies from time 0 to time 4*t* as shown in Fig. 6.3.

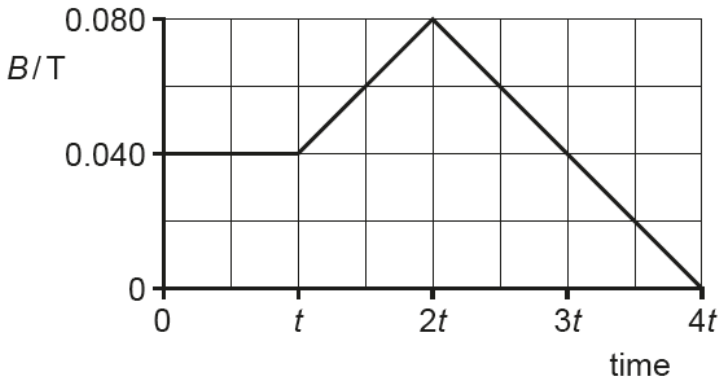


Fig. 6.3

Calculate the maximum magnetic flux linkage in coil C.

flux linkage = ... Wb [2]

(iv) On Fig. 6.4, sketch a line to show the induced electromotive force (e.m.f.) E in coil C from time 0 to time $4t$.

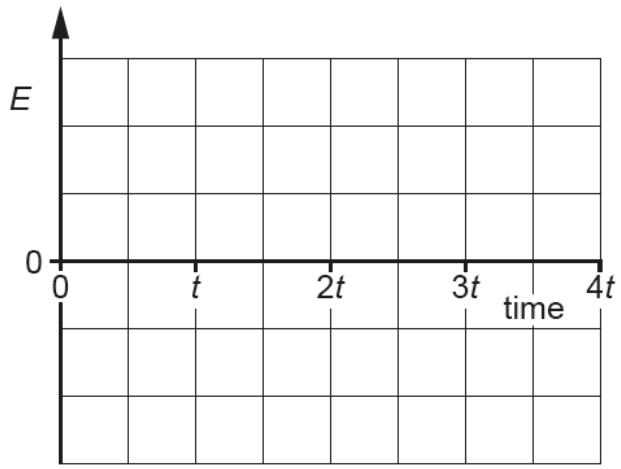


Fig. 6.4

[3]

(b) A metal spring rests on a smooth table. The turns of the spring are equally spaced. The ends of the spring are connected to a d.c. power supply, as shown in Fig. 6.5.

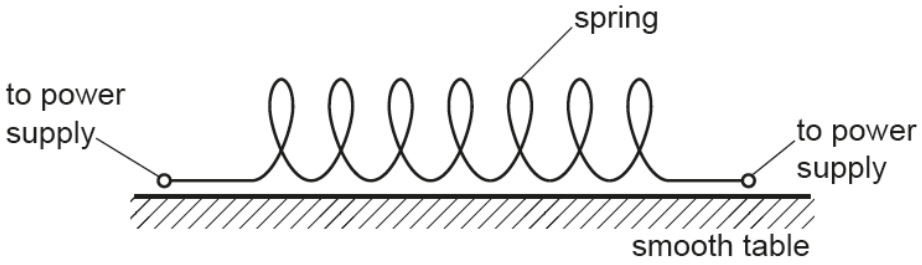


Fig. 6.5

The spring is connected to the d.c. power supply using flexible leads. The spring is not under tension.

The spring is connected to the d.c. power supply using flexible leads. The spring is not under tension.

With reference to magnetic fields, describe and explain the change in the distance between the turns of the spring when the power supply is first switched on.

.....

.....

.....

.....

..... [3]

[Total: 11]

Question 25

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

.....

.....

..... [2]

(b) Fig. 7.1 shows a coil at rest in a uniform magnetic field that is parallel to the axis of the coil.

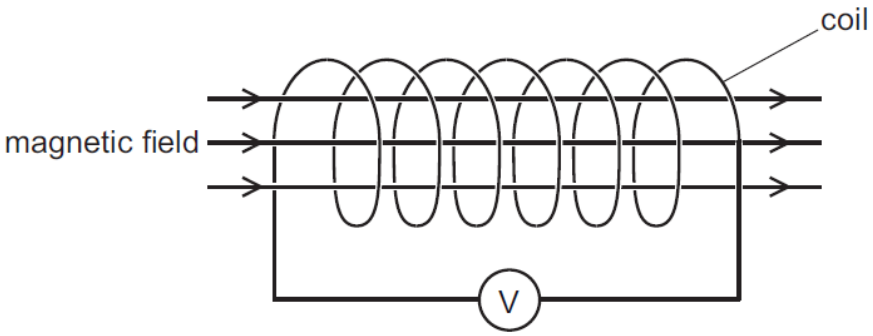


Fig. 7.1

The coil is connected to a centre-zero voltmeter.

The coil is connected to a centre-zero voltmeter.

The flux density B of the uniform magnetic field varies with time t as shown in Fig. 7.2.

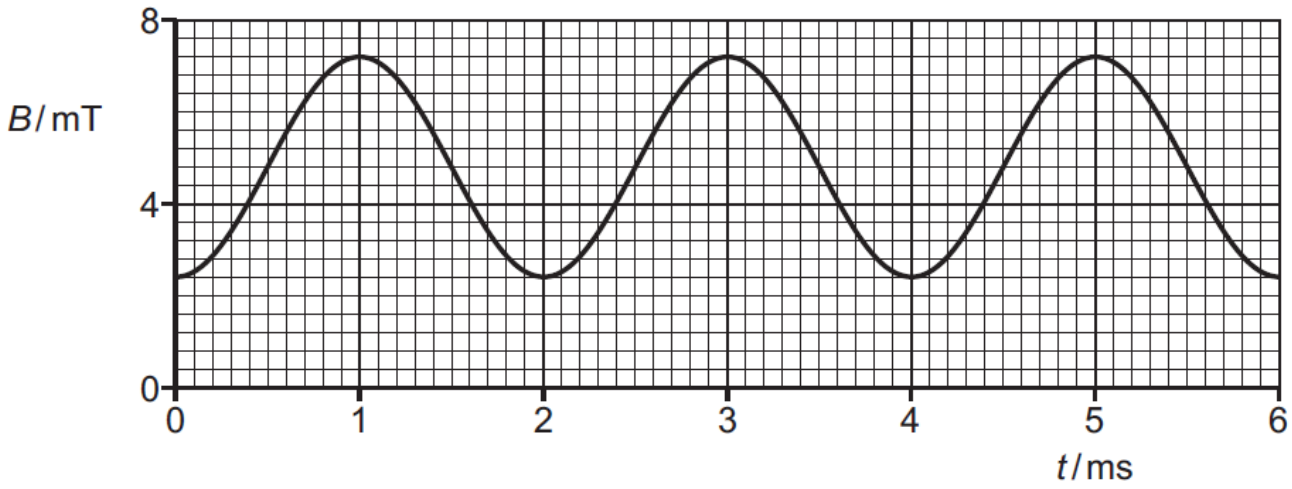


Fig. 7.2

The coil consists of 340 turns, each of cross-sectional area $3.2 \times 10^{-4}\,m^2$.

(i) Calculate the maximum magnetic flux through **one** turn of the coil.

maximum magnetic flux = ... Wb [2]

(ii) Determine the maximum rate of change of magnetic flux linkage in the coil.

maximum rate of change of flux linkage = ... $Wb\,s^{-1}$ [3]

(iii) State the maximum electromotive force (e.m.f.) V_0 induced across the coil.

V_0 = ... V [1]

(iv) On Fig. 7.3, sketch the variation of the e.m.f. V induced across the coil with t from $t = 0$ to $t = 6.0$ ms.

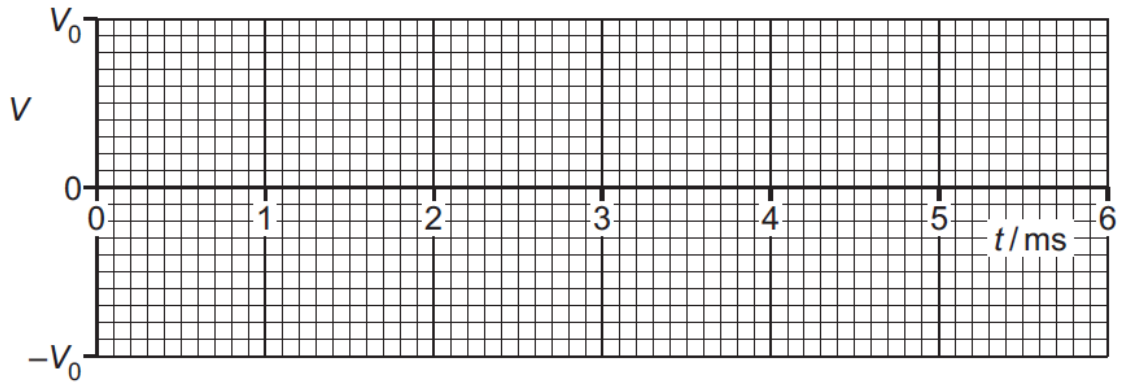


Fig. 7.3

[3]

(v) The variation of V with t can be described by

$$V = A \sin Bt$$

where A and B are constants.

Determine the values of A and B. Give units with your answers.

A = ... unit .....

B = ... unit .....

[3]

[Total: 14]

Question 26

(a) Define magnetic flux density.

.....

.....

..... [2]

(b) A long, straight wire carries a current into the page, as shown in Fig. 7.1.



Fig. 7.1

On Fig. 7.1, draw four field lines to represent the magnetic field around the wire due to the current in it. [3]

(c) Two identical wires X and Y are placed parallel to each other. The wires both carry current into the page, as shown in Fig. 7.2.



Fig. 7.2

(i) Explain why the two wires exert a magnetic force on each other.

.....

.....

.....

..... [2]

(ii) On Fig. 7.2, draw an arrow to show the direction of the magnetic force exerted on wire X. Label your arrow F. [1]

(iii) The current in X is double the current in Y.

State how the magnetic force exerted on wire Y compares with the magnetic force exerted on wire X.

.....

.....

..... [2]

(iv) The direction of the current in both wires is now reversed.

State, with a reason, the effect of this change on the direction of the force on wire X.

.....

..... [1]

[Total: 11]

Question 27

An electric field and a magnetic field are used to form a velocity selector. Charged particles, called ions, pass into a region of uniform electric and magnetic fields that is between parallel plates, as shown in Fig. 6.1.

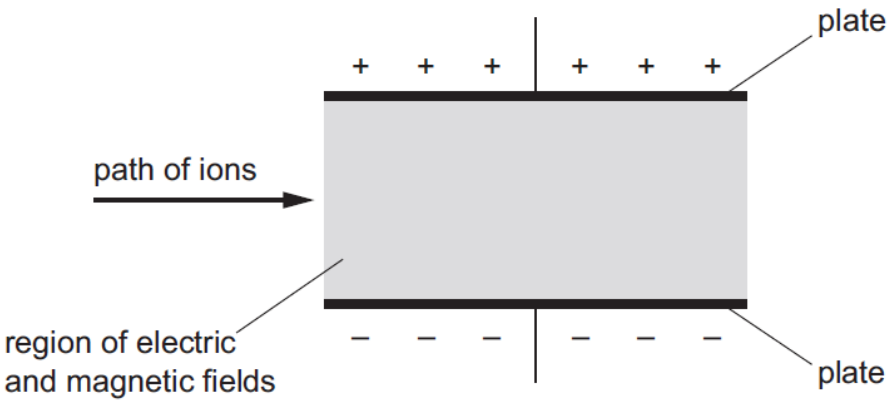


Fig. 6.1

(a) The potential difference (p.d.) between the plates of the velocity selector is V. The separation of the plates is d and the magnetic flux density is B.

Show that the speed u of ions that pass undeviated through the velocity selector is given by

$$u = \frac{V}{Bd}.$$

[2]

(b) Positive ions with kinetic energy 4.1×10^{-17} J and mass 3.2×10^{-27} kg pass undeviated through the velocity selector when V is equal to 980 V and d is equal to 3.6×10^{-2} m.

Determine B.

B = ... T [3]

(c) A proton passes undeviated through the velocity selector.

An alpha particle enters the velocity selector at the same speed as the proton.

State how the expression in **(a)** predicts that the alpha particle also passes undeviated through the velocity selector.

.....

..... [1]

(d) By reference to Fig. 6.1 and to the forces acting on a positive ion, determine the direction of the magnetic field. Explain your reasoning.

.....

.....

.....

.....

.....

..... [3]

(e) The positive ions in **(b)** enter the velocity selector with greater kinetic energy.

On Fig. 6.1, sketch the path of these ions. [2]

[Total: 11]

Question 28

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

.....

.....

..... [2]

(b) A metal rod is accelerated uniformly from rest in a uniform magnetic field as shown in Fig. 7.1.

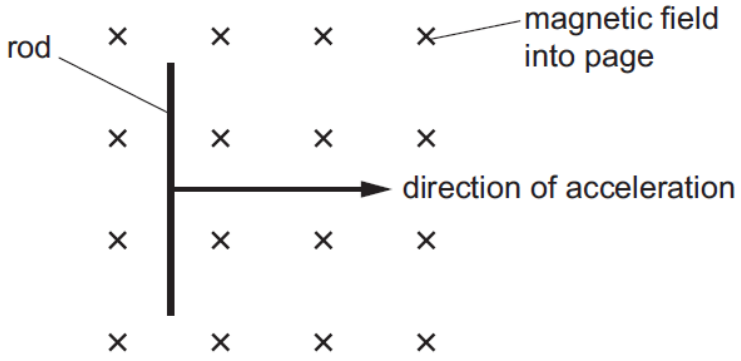


Fig. 7.1

The rod has length l and the flux density of the magnetic field is B.

An electromotive force (e.m.f.) is induced in the rod. The variation with time t of the induced e.m.f. E is shown in Fig. 7.2.

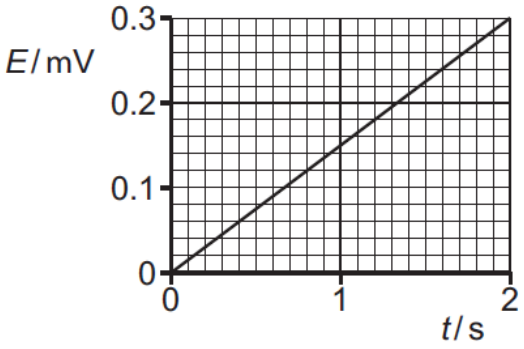


Fig. 7.2

(i) Explain how Fig. 7.2 shows that E is proportional to the velocity v of the rod.

.....

.....

..... [2]

(ii) Use Faraday's law to show that the variation of E with time t is given by

$$E = Blat$$

where a is the acceleration of the rod.

[3]

(iii) The length of the rod is 0.45 m. The acceleration a of the rod is $7.8\,m\,s^{-2}$.

Determine the value of B.

B = ... T [2]

[Total: 9]

Question 29

(a) Define magnetic flux density.

.....

.....

..... [2]

(b) A particle of mass *m* and charge +*Q* moves at speed *v* into a region where there is a uniform magnetic field, as shown in Fig. 7.1.

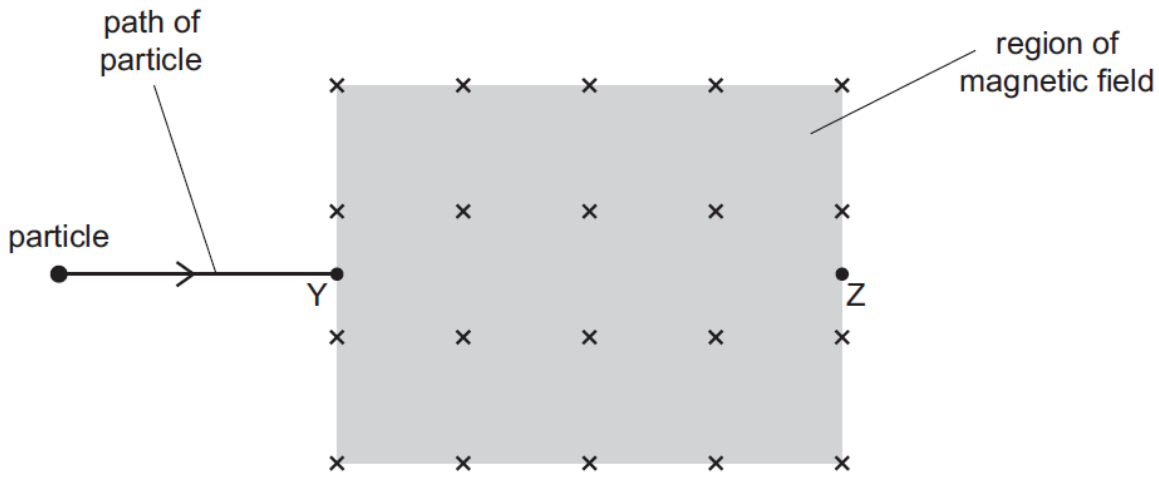


Fig. 7.1

The uniform magnetic field is into the page and has flux density *B*. The particle enters the region of the field at point Y.

(i) State an expression, in terms of some or all of m, Q, B and v, for the magnetic force F that acts on the particle when it is at point Y.

F = ... [1]

(ii) On Fig. 7.1, draw an arrow at point Y to indicate the direction of the force in **(b)(i)**. [1]

(iii) On Fig. 7.1, draw a line to show a possible path for the particle through the region of the magnetic field. [1]

(c) **(i)** Explain how an electric field can be used with the magnetic field to ensure that the particle in **(b)** now passes through point Z.

.....

.....

.....

.....

..... [3]

(ii) Derive an expression for v in terms of B and the electric field strength E.

v = ... [2]

[Total: 10]

Question 30

A rectangular coil PQRS of wire is free to rotate about its axis XY, as shown in Fig. 6.1.

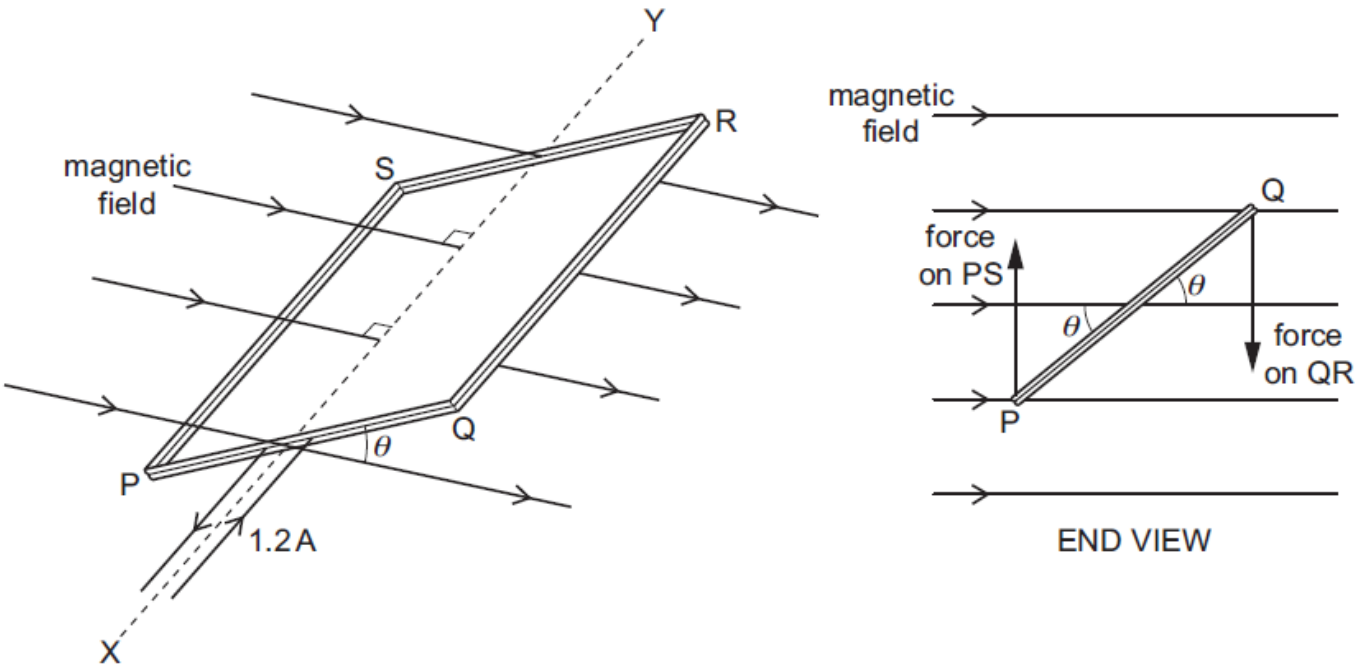


Fig. 6.1 (not to scale)

The coil has length QR of 5.4 cm, width PQ of 2.5 cm and has 190 turns of wire.
The plane of the coil is at an angle θ to a uniform magnetic field of flux density 5.2×10^{-3} T.
The axis XY of the coil is normal to the field.
The current in the coil is 1.2A.

(a) (i) Calculate the magnitude of the force on side QR of the coil.

force = ... N [3]

(ii) Use your answer in **(a)(i)** to show that the torque τ on the coil is given by

$$\tau = 1.6 \times 10^{-3} \cos\theta \text{ N m}.$$

[2]

(iii) Using the expression in **(a)(ii)** sketch, on the axes of Fig. 6.2, a graph to show the variation of the torque τ with angle θ for values of θ between 0 and 360°. Label the τ axis with an appropriate scale.

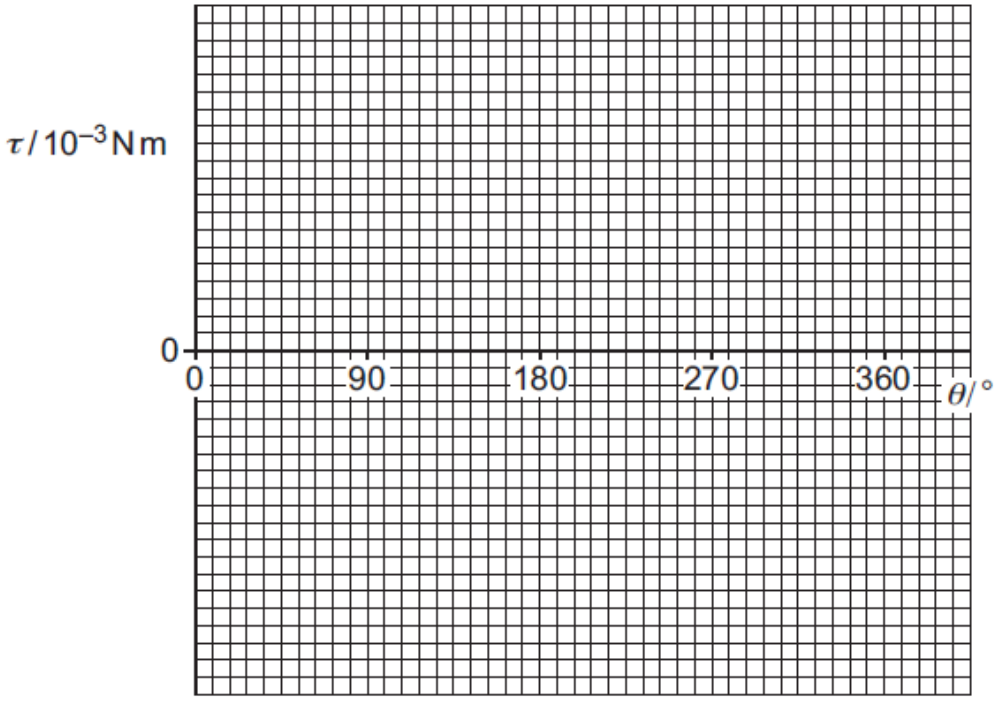


Fig. 6.2

[3]

(b) The coil is now replaced by an identical coil wound on a ferrous core.

Suggest, with a reason, how the torque on this coil compares with the torque on the original coil.

.....

.....

..... [2]

[Total: 10]

Question 31

A bar magnet is suspended from a spring. One pole of the magnet oscillates freely in a coil of wire, as shown in Fig. 7.1.

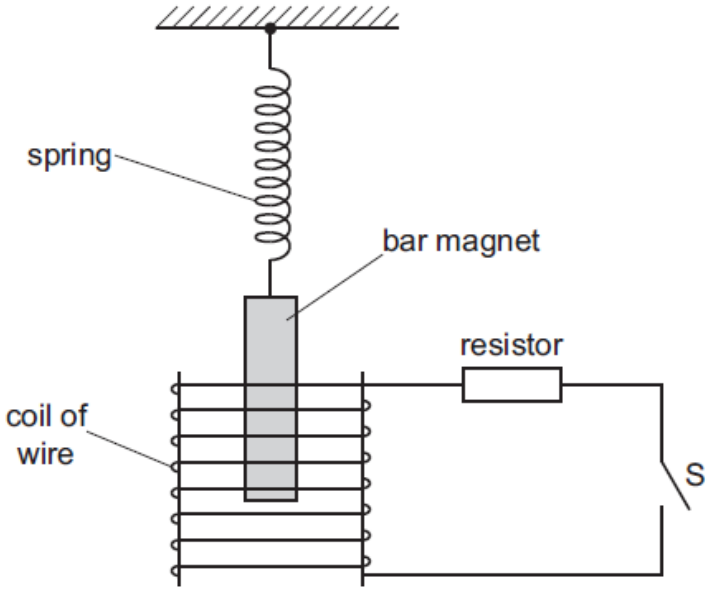


Fig. 7.1

The switch S is initially open.

(a) The switch S is now closed. As a result, the oscillations of the magnet are lightly damped.

(i) State what is meant by damping.

.....

.....

..... [2]

(ii) Describe what is observed to indicate that the damping is light.

.....

..... [1]

(iii) By reference to electromagnetic induction and to conservation of energy, explain why the oscillations are damped.

.....

.....

.....

..... [3]

(b) The procedure in **(a)** is repeated after replacing the resistor with one of greater resistance.

Suggest, with a reason, the effect of this change on the oscillations.

.....

.....

..... [2]

[Total: 8]

Question 32

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

.....

.....

..... [2]

(b) An aircraft is flying horizontally at constant speed v through the Earth's magnetic field, as shown in Fig. 7.1.

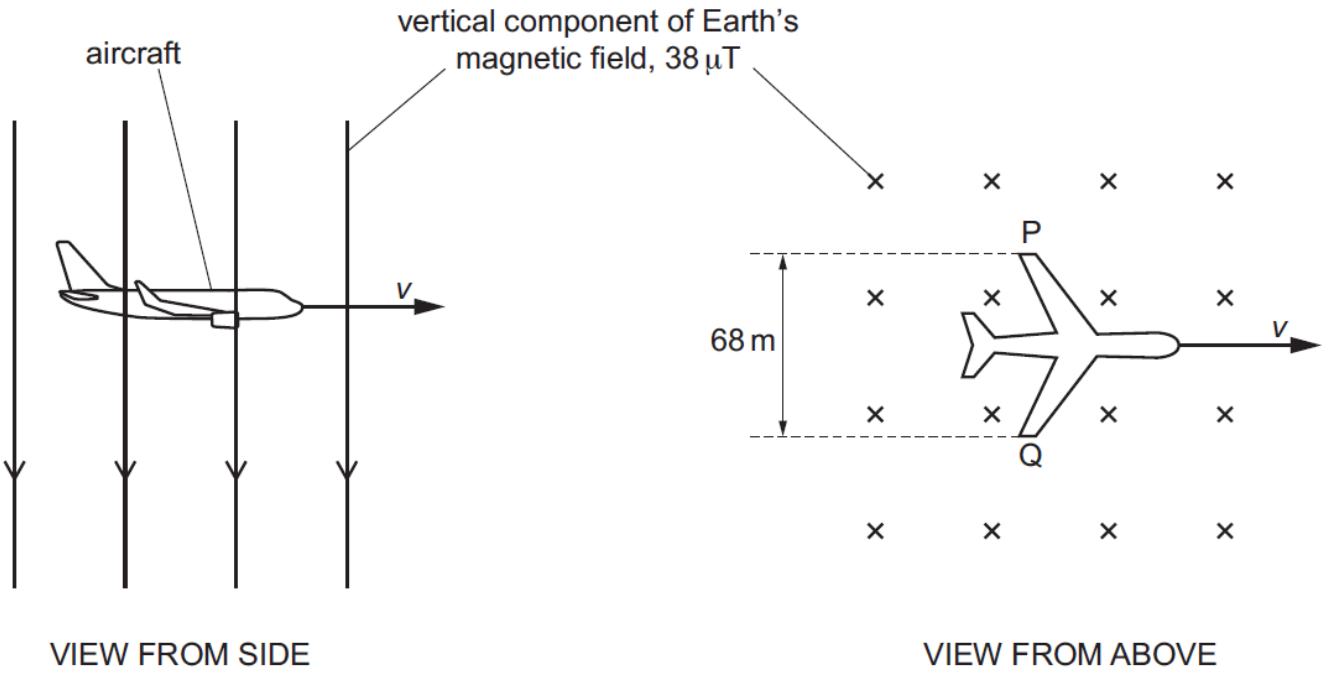


Fig. 7.1

At the location of the aircraft, the vertical component of the Earth's magnetic field is 38 μT towards the ground.

The distance between the wingtips P and Q of the aircraft is 68 m.

As the aircraft moves through the magnetic field, an electromotive force (e.m.f.) of 0.54 V is induced between the wingtips P and Q.

(i) Calculate the magnetic flux cut by the wings of the aircraft in a time of 15 s. Give a unit with your answer.

magnetic flux = ... unit ..... [2]

(ii) Determine the area of flux cut by the wings in a time of 15 s.

area = ...m^2 [2]

(iii) Use your answer in **(b)(ii)** to determine the speed *v* of the aircraft.

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

(iv) Use Lenz's law of electromagnetic induction to explain which of the wingtips P and Q is at the higher induced potential.

.....

.....

.....

.....

..... [3]

[Total: 11]

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