Magnetism
May 02

6 (a) Two similar coils **A** and **B** of insulated wire are wound on to a soft-iron core, as illustrated in Fig. 6.1.

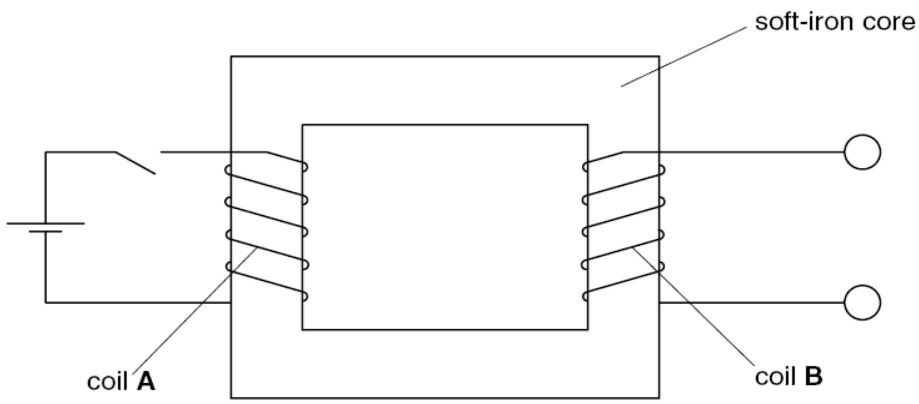


Fig. 6.1

When the current I in coil **A** is switched on and then off, the variation with time t of the current is shown in Fig. 6.2.

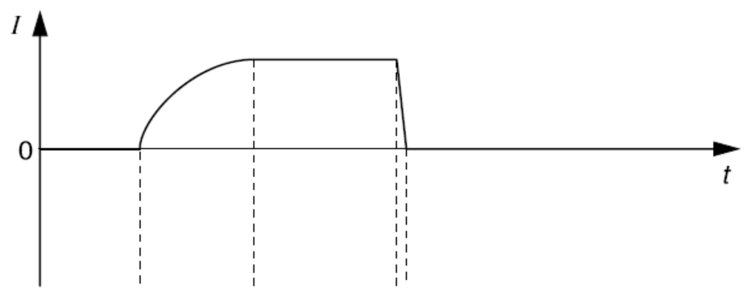


Fig. 6.2

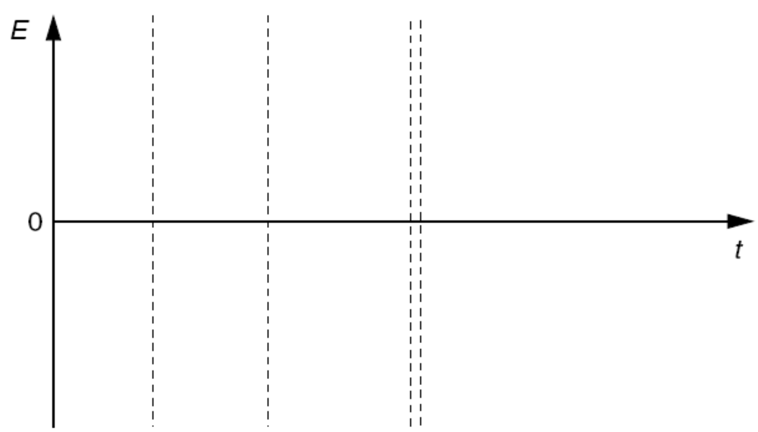


Fig. 6.3

On Fig. 6.3, draw a graph to show the variation with time t of the e.m.f. E induced in coil **B**. [3]

Nov 02

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 $4.5 \times 10^6\,\mathrm{m\,s^{-1}}$, 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.

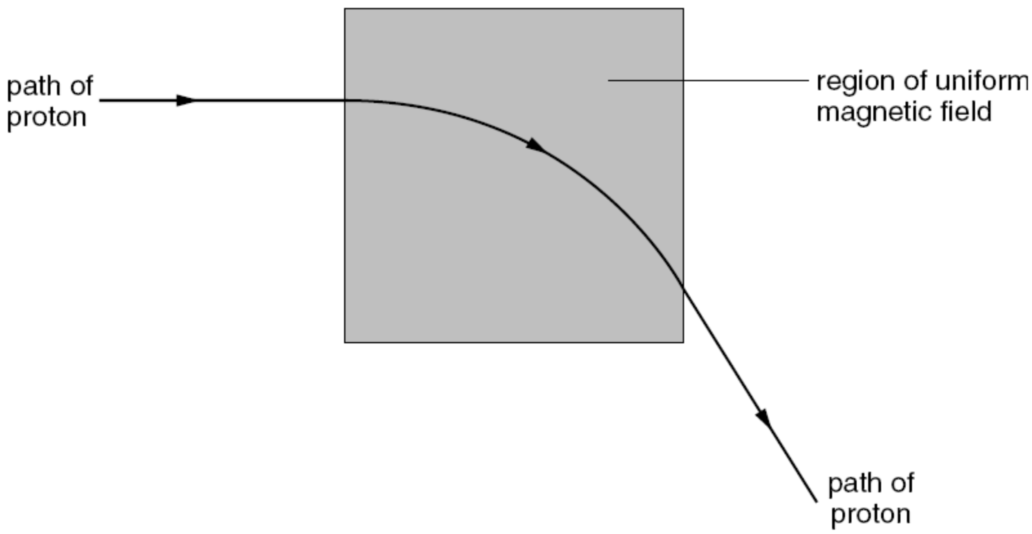


Fig. 6.1

(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]

Nov 02

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

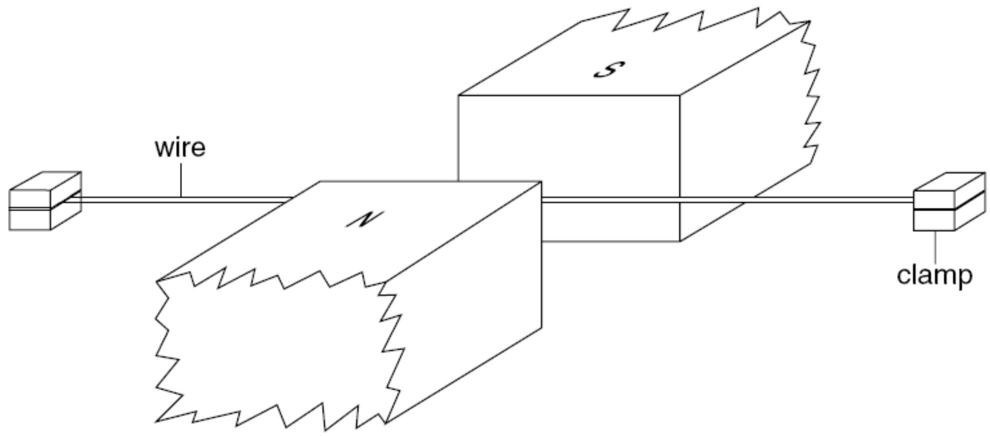


Fig. 7.1

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

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

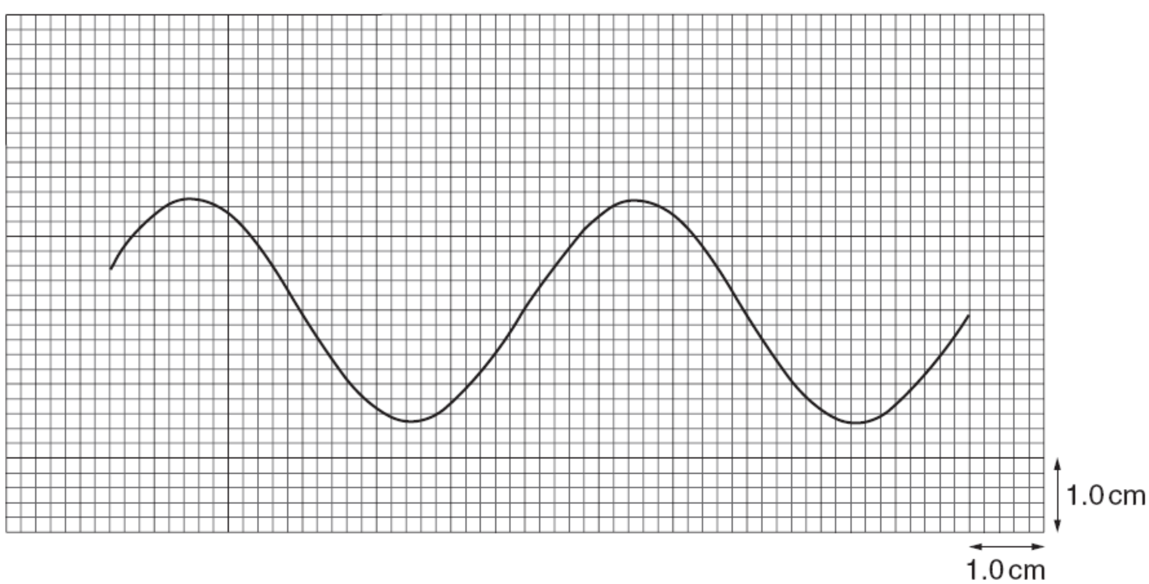


Fig. 7.2

(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]

May 03

3 An aluminium sheet is suspended from an oscillator by means of a spring, as illustrated in Fig. 3.1.

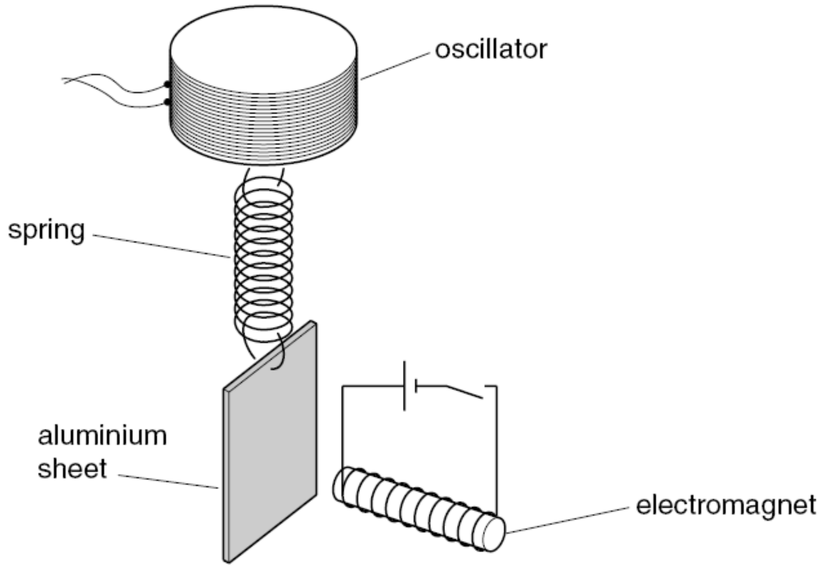
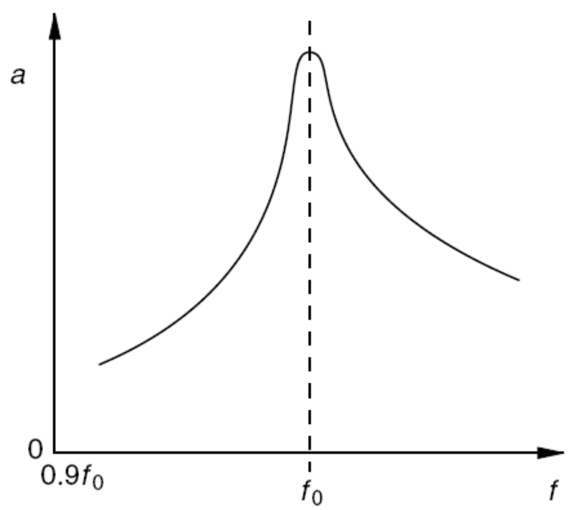


Fig. 3.1

An electromagnet is placed a short distance from the centre of the aluminium sheet.

The electromagnet is switched off and the frequency *f* of oscillation of the oscillator is gradually increased from a low value. The variation with frequency *f* of the amplitude *a* of vibration of the sheet is shown in Fig. 3.2.



(c) The frequency of the oscillator is now maintained at a constant value. The amplitude of vibration is found to decrease when the current in the electromagnet is switched on.

Use the laws of electromagnetic induction to explain this observation.

....

....

....

....

....

.... [4]

May 03

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.

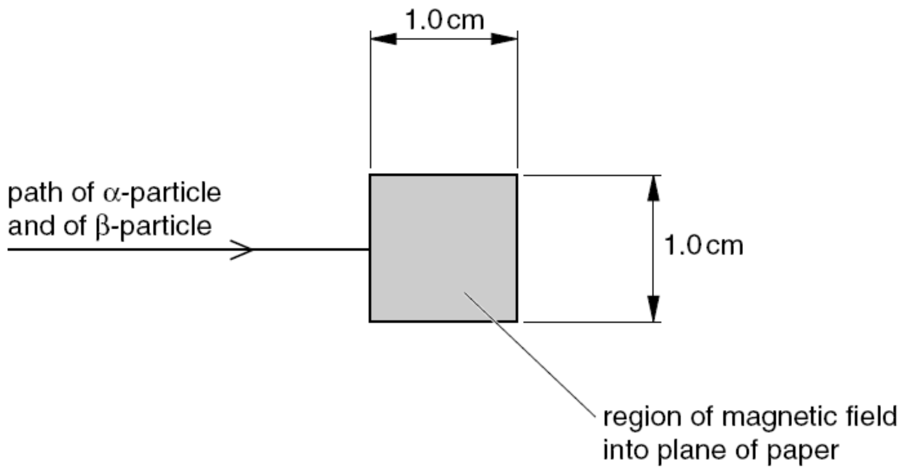


Fig. 5.1

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

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

[3]

(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]

Nov 03

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.

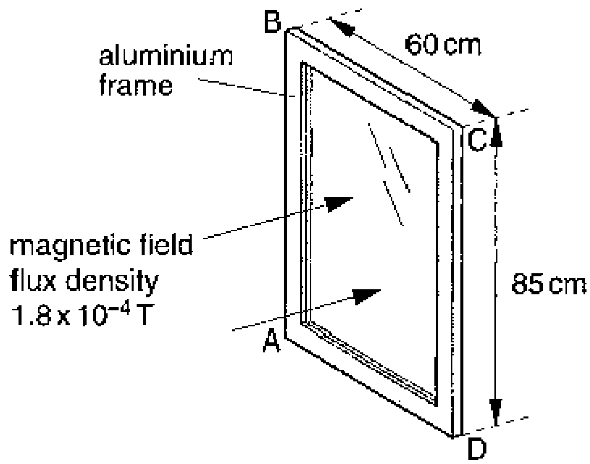


Fig. 5.1

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]

(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]

Nov 04

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.

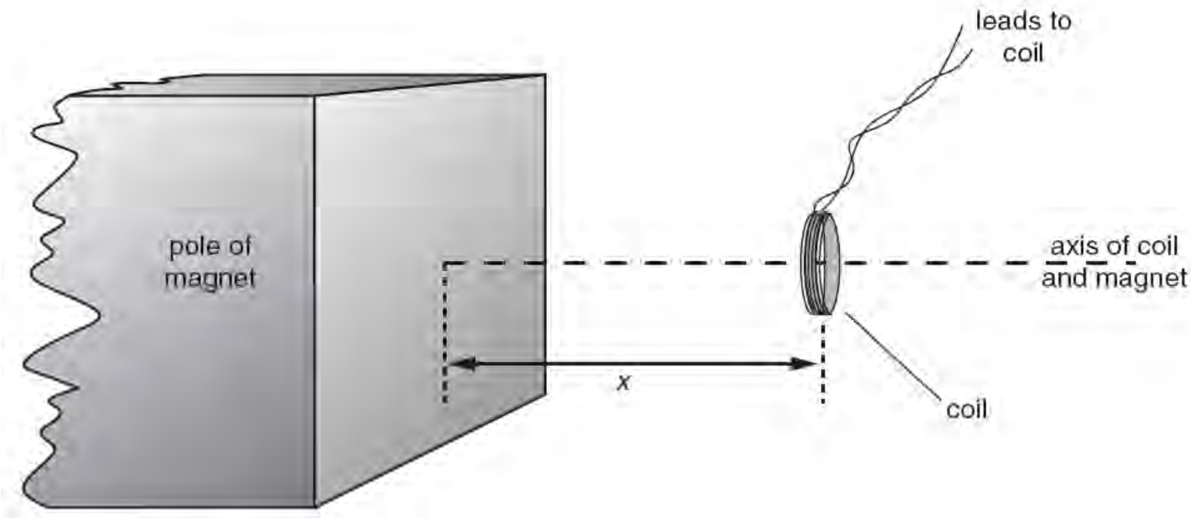


Fig. 4.1

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.

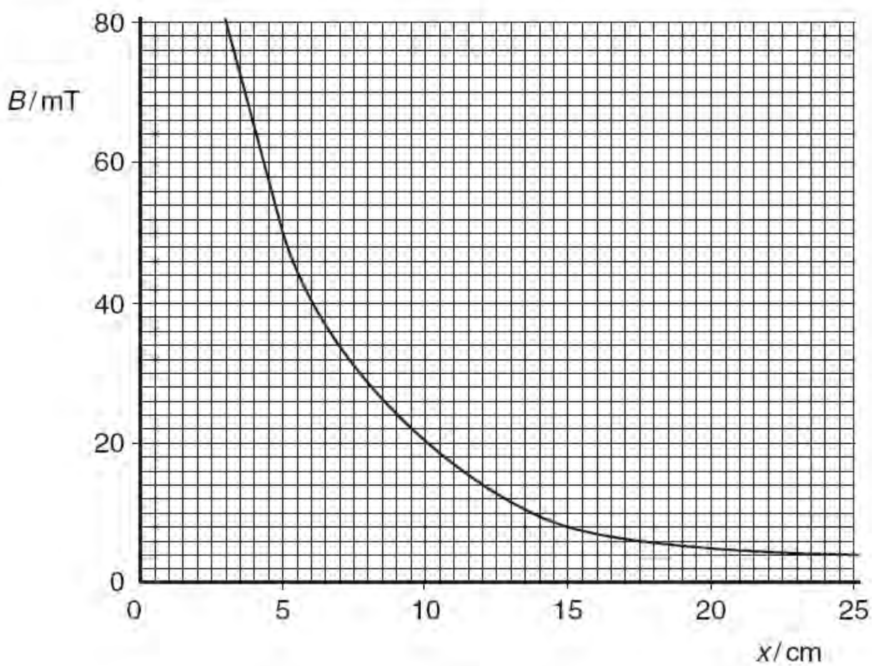


Fig. 4.2

(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]

Nov 04

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

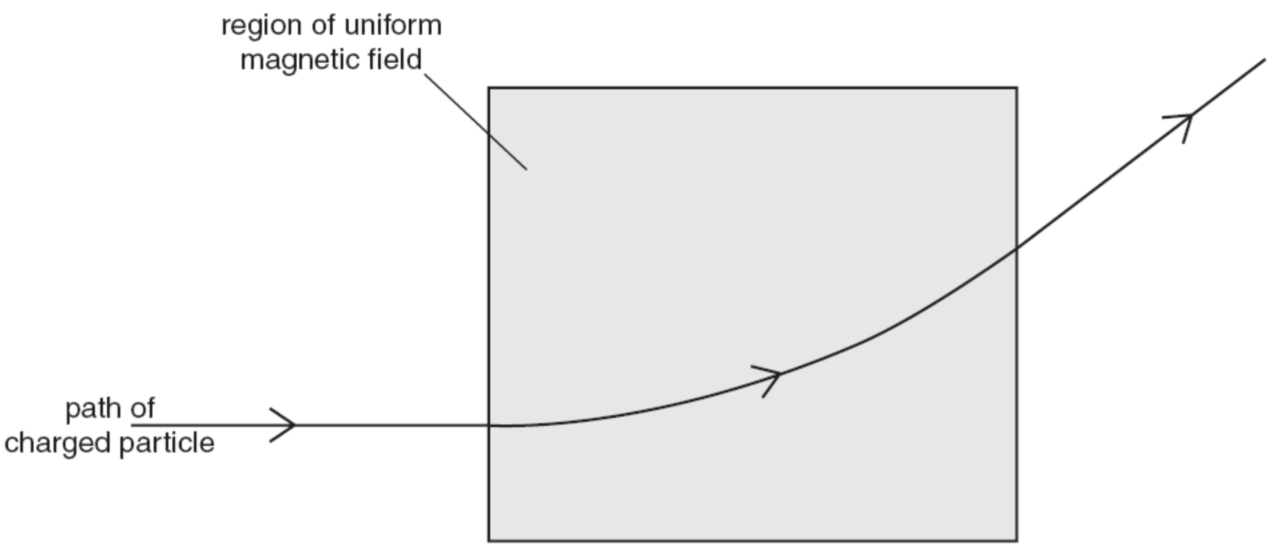


Fig. 5.1

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]

May 05

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

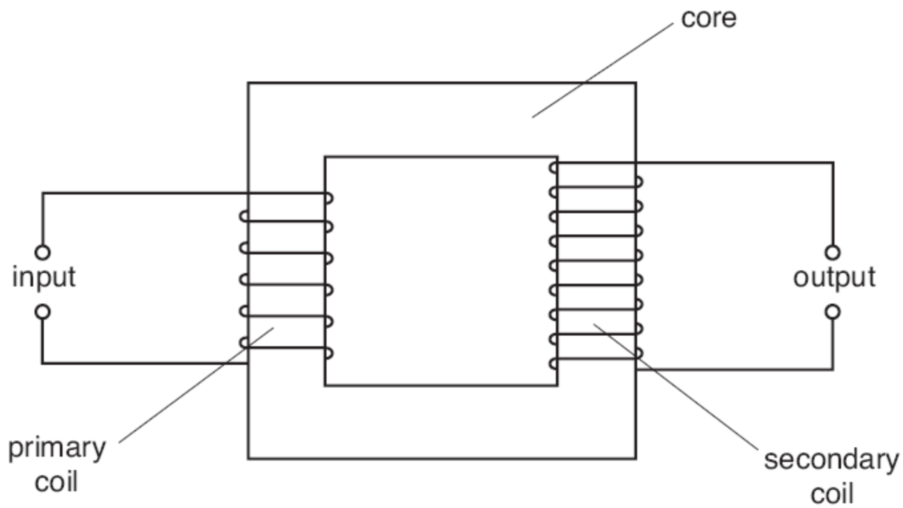


Fig. 6.1

(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]

(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.

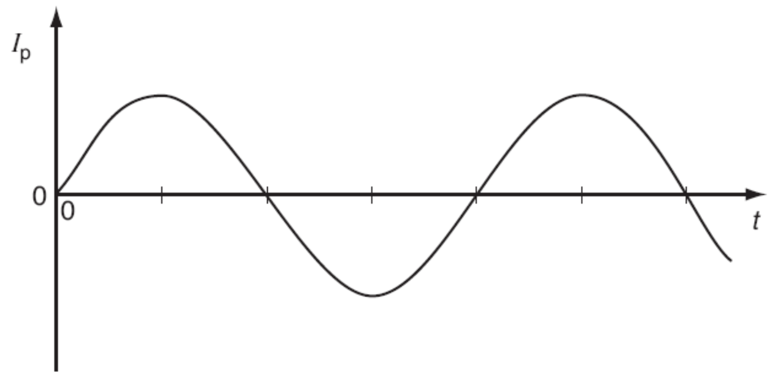


Fig. 6.2

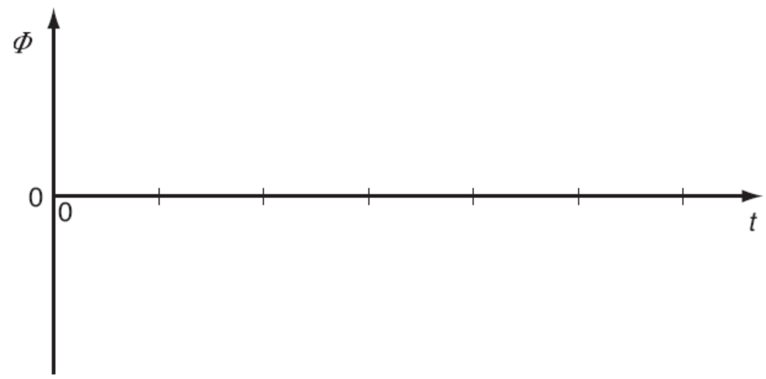


Fig. 6.3

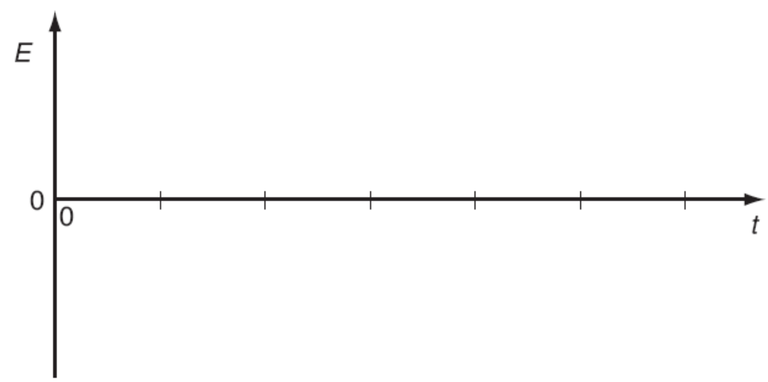


Fig. 6.4

(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]

Nov 05

5 **(a)** An electron is accelerated from rest in a vacuum through a potential difference of 1.2×10^4 V.
Show that the final speed of the electron is 6.5×10^7 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.

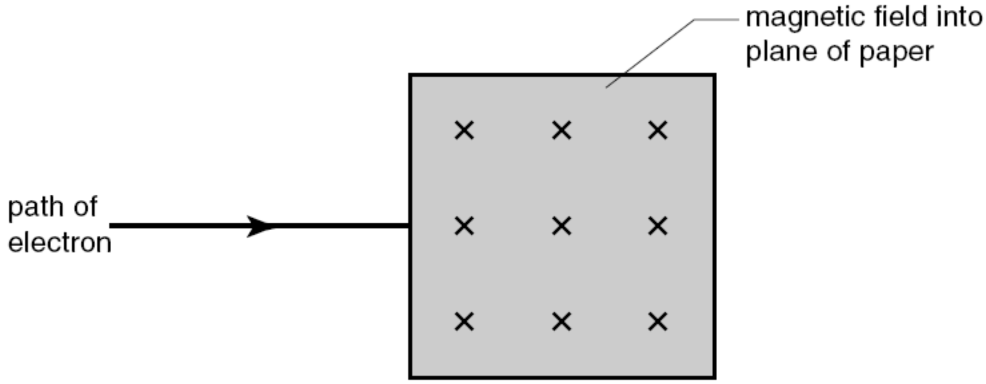


Fig. 5.1

(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]

(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]

Nov 05

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.

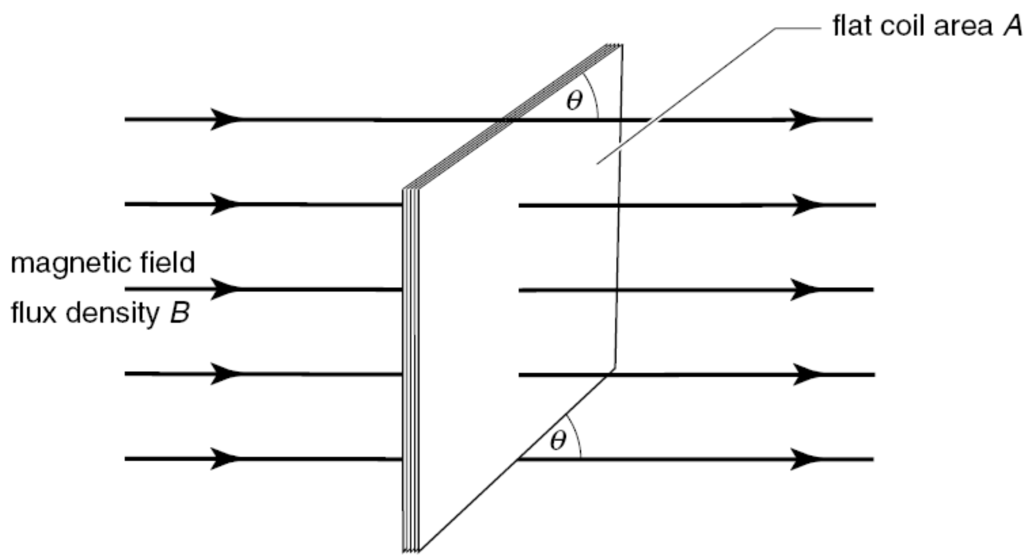


Fig. 6.1

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.

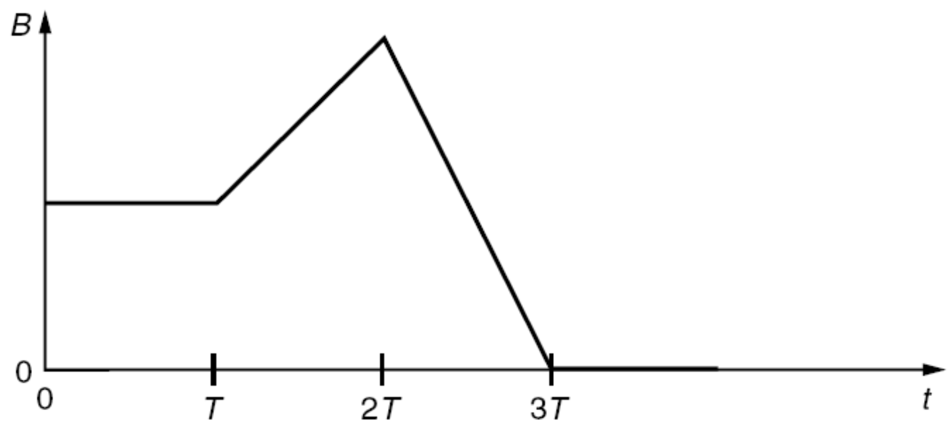


Fig. 6.2

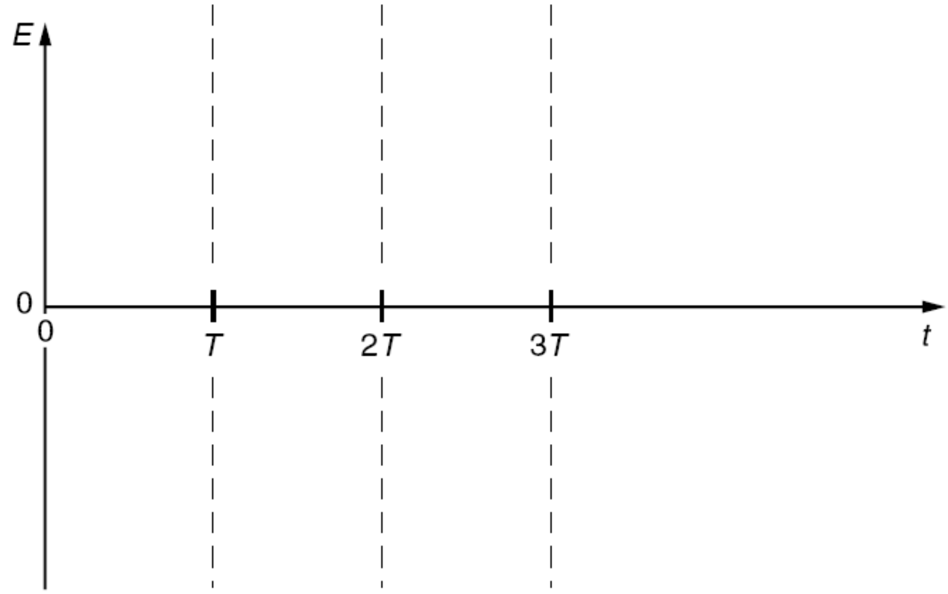


Fig. 6.3

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

May 06

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

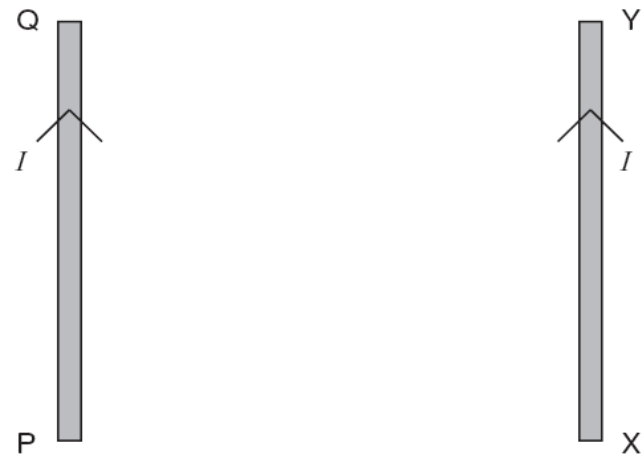


Fig. 6.1

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]

May 06

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.

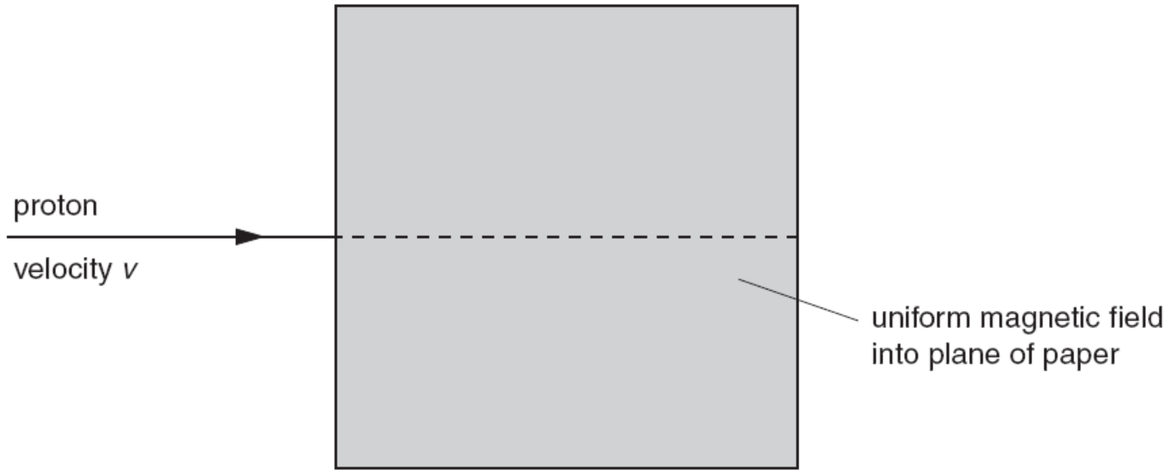


Fig. 8.1

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.

(i) an α-particle with initial velocity v

....

....

....

.... [3]

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

....

....

....

.... [3]

Nov 06

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

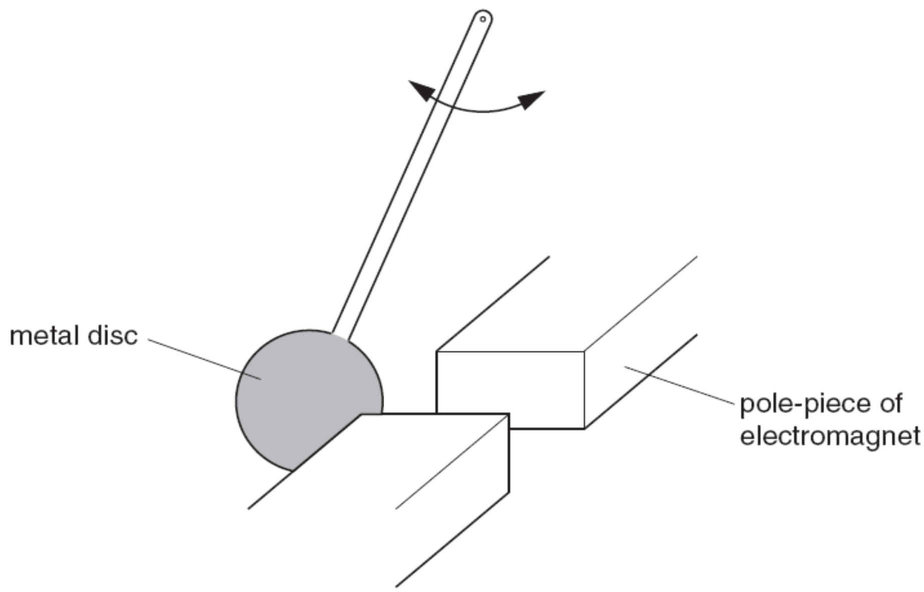


Fig. 5.1

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

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

....

....

....

.... [2]

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

....

....

.... [2]

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

....

....

....

.... [3]

May 07

7 A magnet is suspended vertically from a fixed point by means of a spring, as shown in Fig. 7.1.

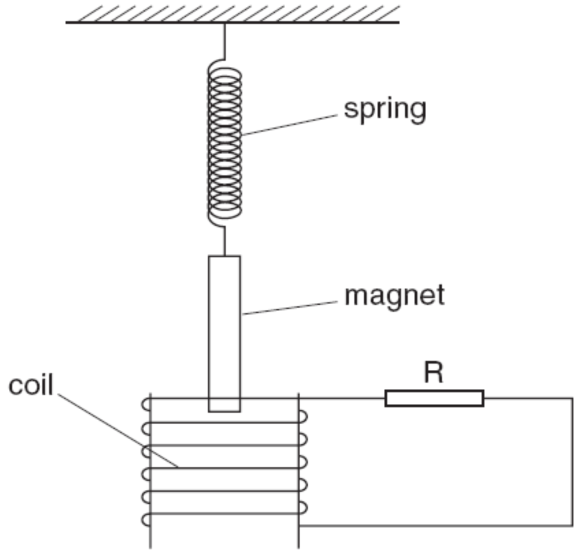


Fig. 7.1

One end of the magnet hangs inside a coil of wire. The coil is connected in series with a resistor R.

(a) The magnet is displaced vertically a small distance *D* and then released.
Fig. 7.2 shows the variation with time *t* of the vertical displacement *d* of the magnet from its equilibrium position.

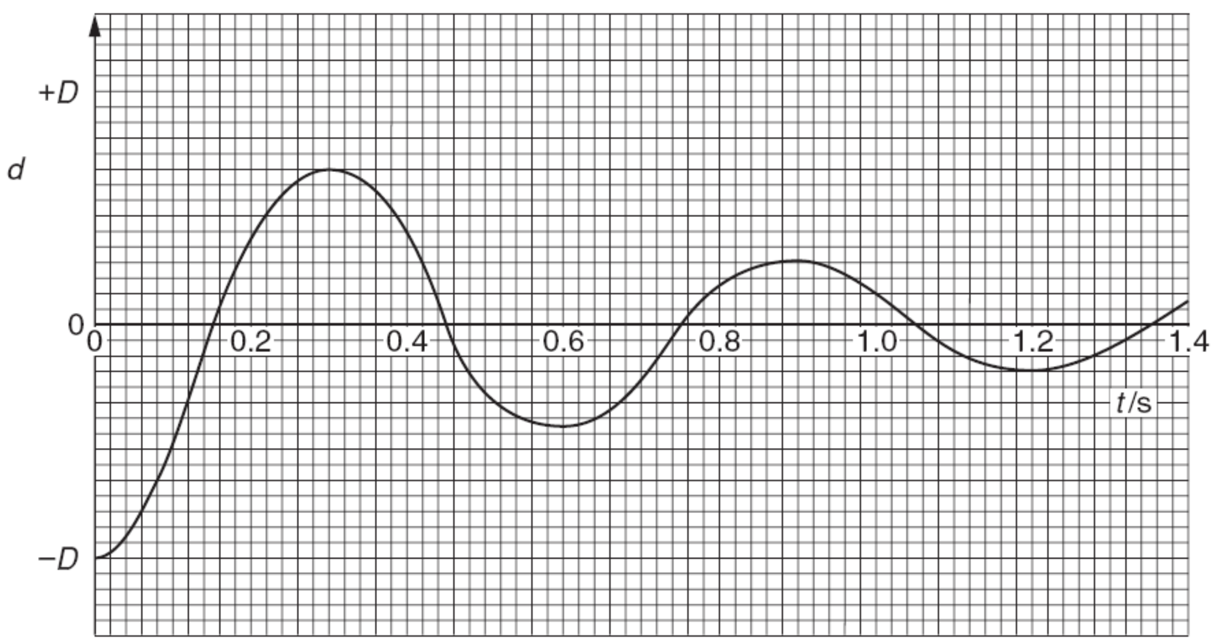


Fig. 7.2

(i) State and explain, by reference to electromagnetic induction, the nature of the oscillations of the magnet.

....

....

....

....

....

.... [5]

Nov 07

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.

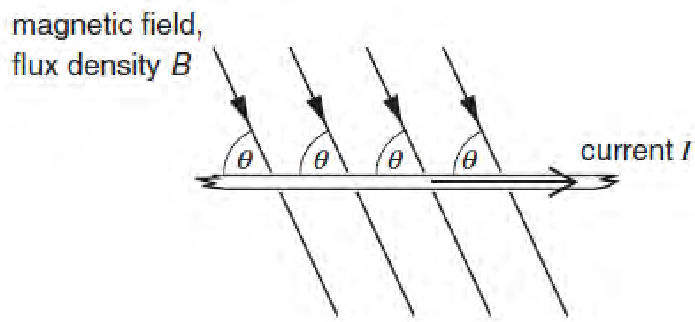


Fig. 6.1

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.

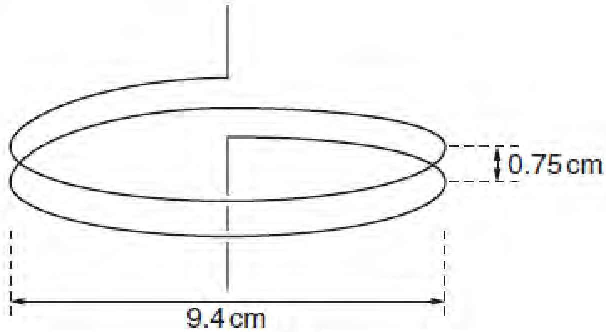


Fig. 6.2

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]

May 08

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.

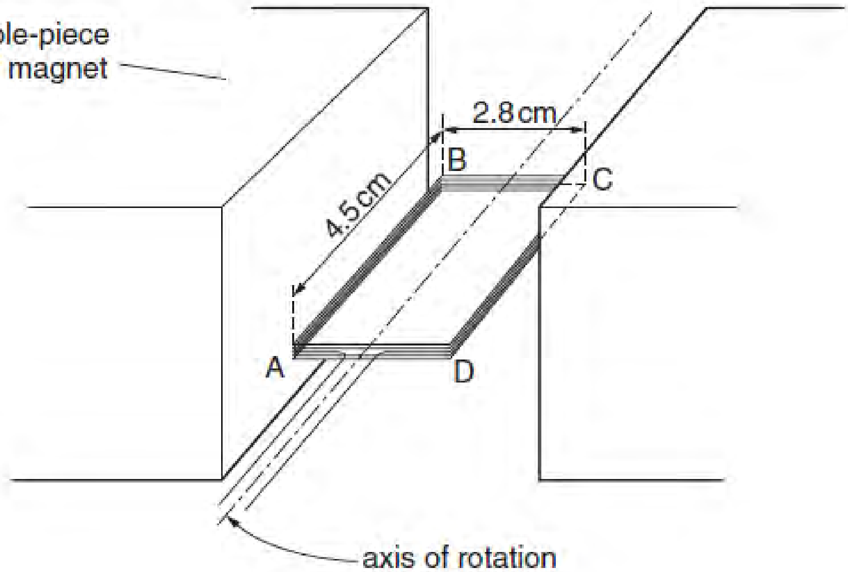


Fig. 6.1

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]

Nov 08

6 A simple iron-cored transformer is illustrated in Fig. 6.1.

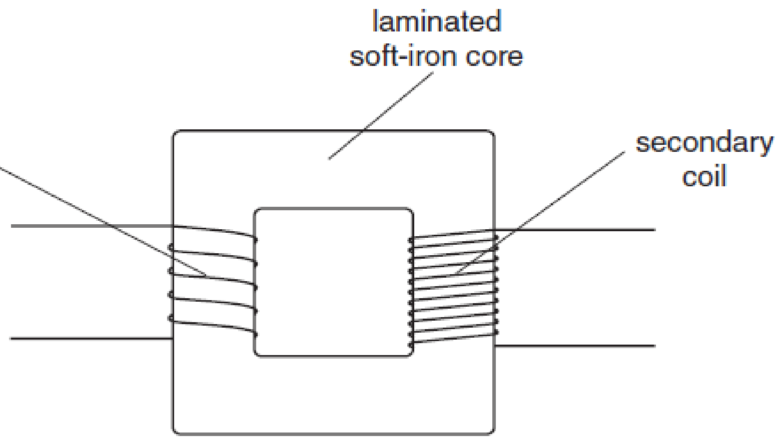


Fig. 6.1

(a) Suggest why the core is

(i) a continuous loop,

....

....[1]

(ii) laminated.

....

....

....[2]

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

....

....

....[2]

(ii) Use Faraday's law to explain the operation of the transformer.

....

....

....

....[3]

(c) State two advantages of the use of alternating voltages for the transmission and use of electrical energy.

1. ....

....

2. ....

.... [2]

Nov 08

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

....

....

....

....

....[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]

May 09

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.

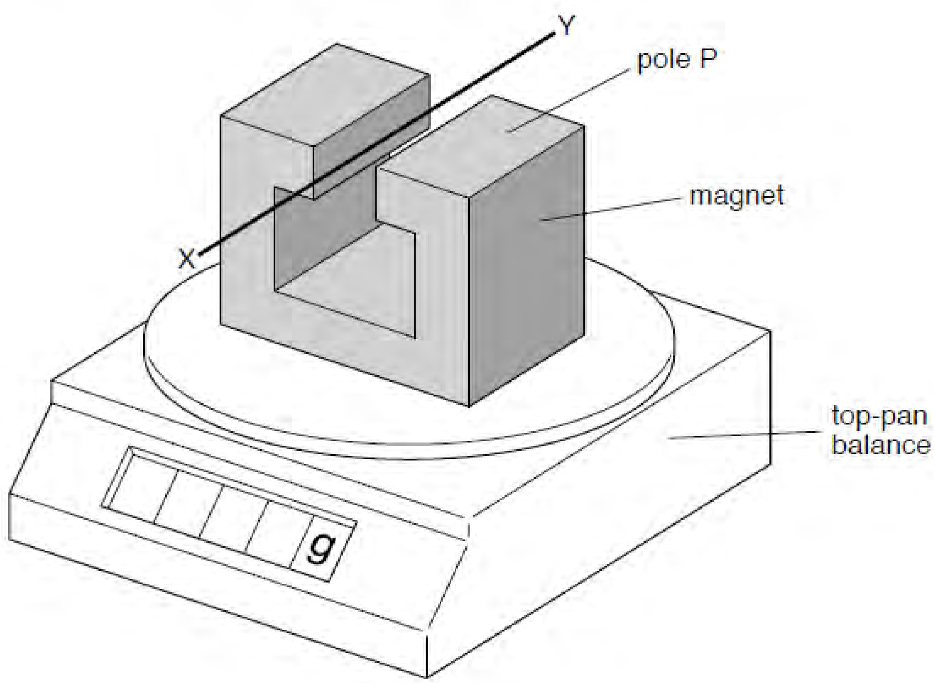


Fig. 6.1

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.

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]

May 09

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

Outline an experiment to verify Lenz's law.

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.... [6]