[May/June 2008]

1 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.

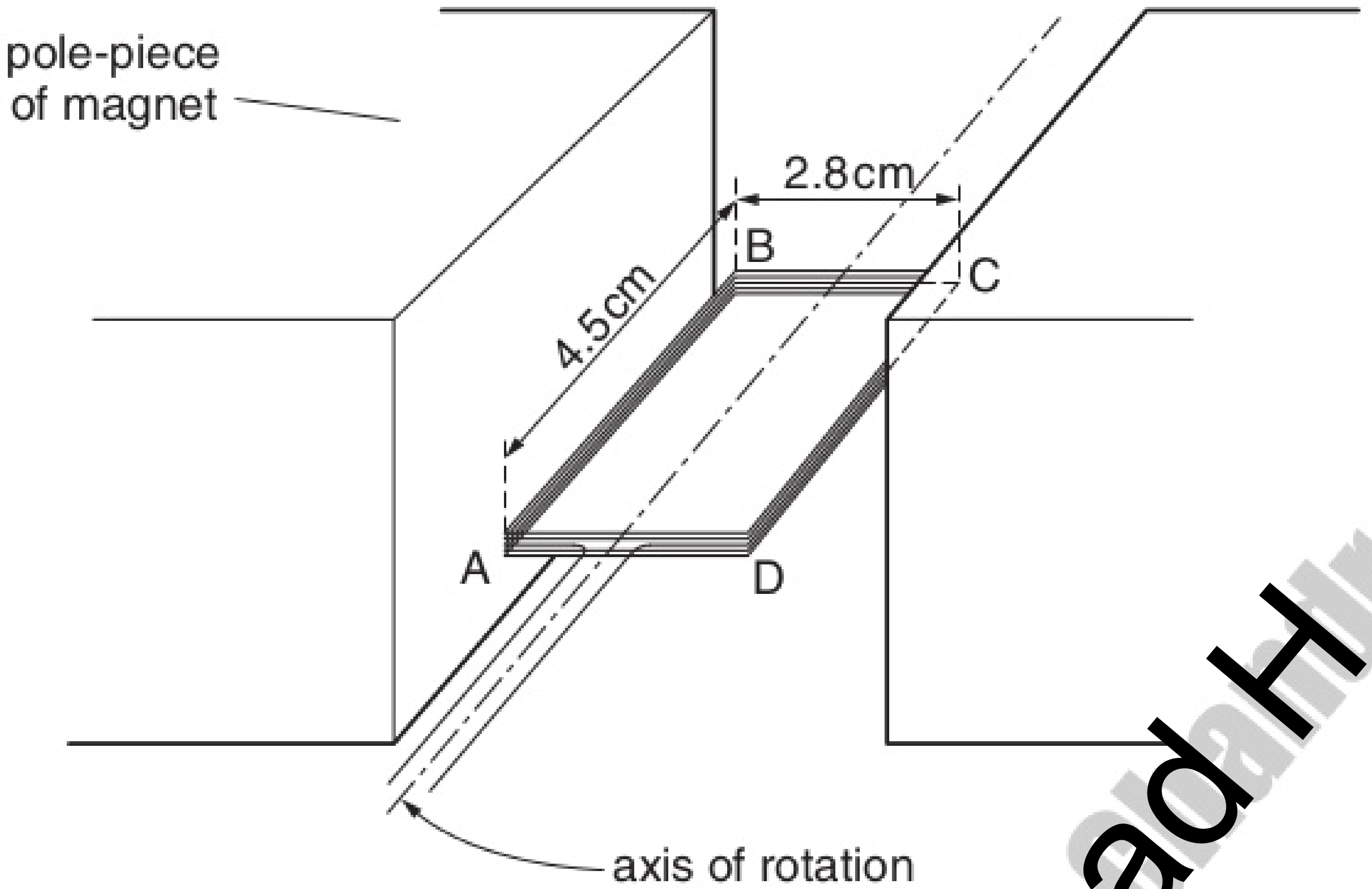


Fig. 6.1

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]

[November/December 2007]

2 **(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.

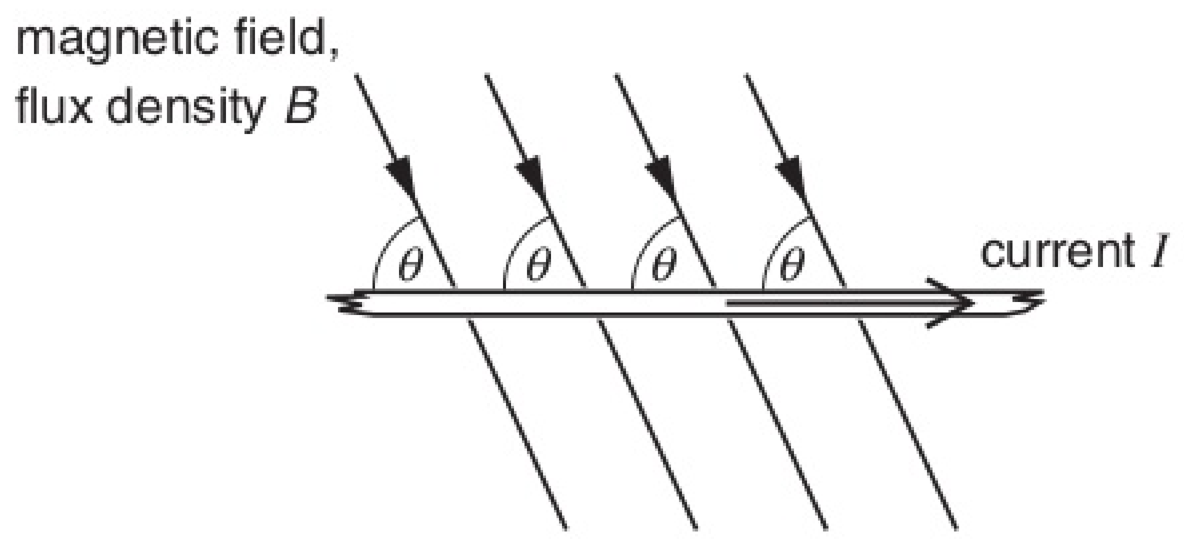


Fig. 6.1

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.

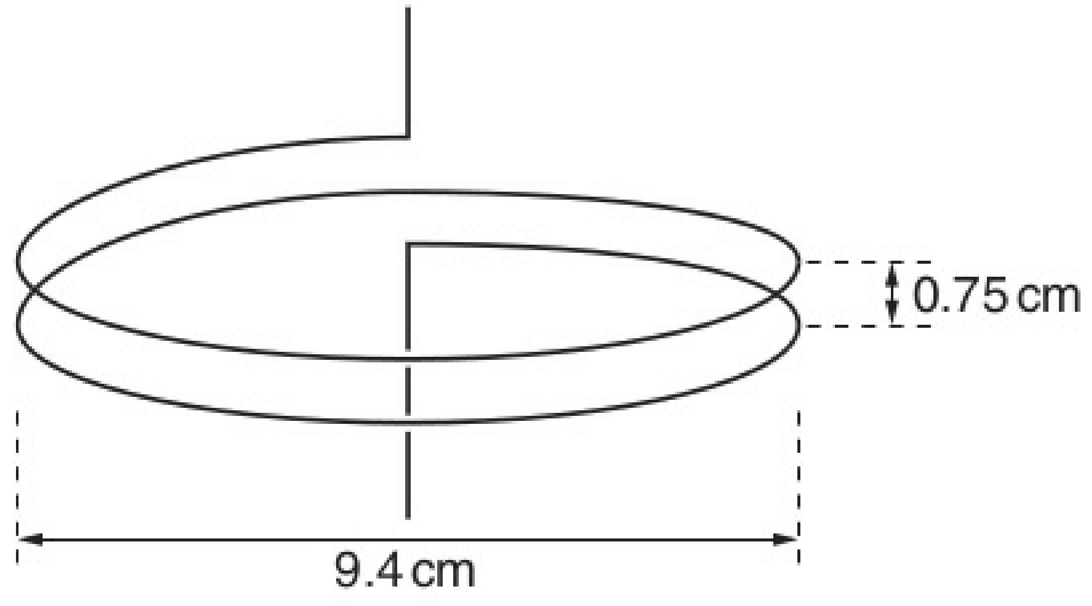


Fig. 6.2

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 0.26g 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/June 2003]

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

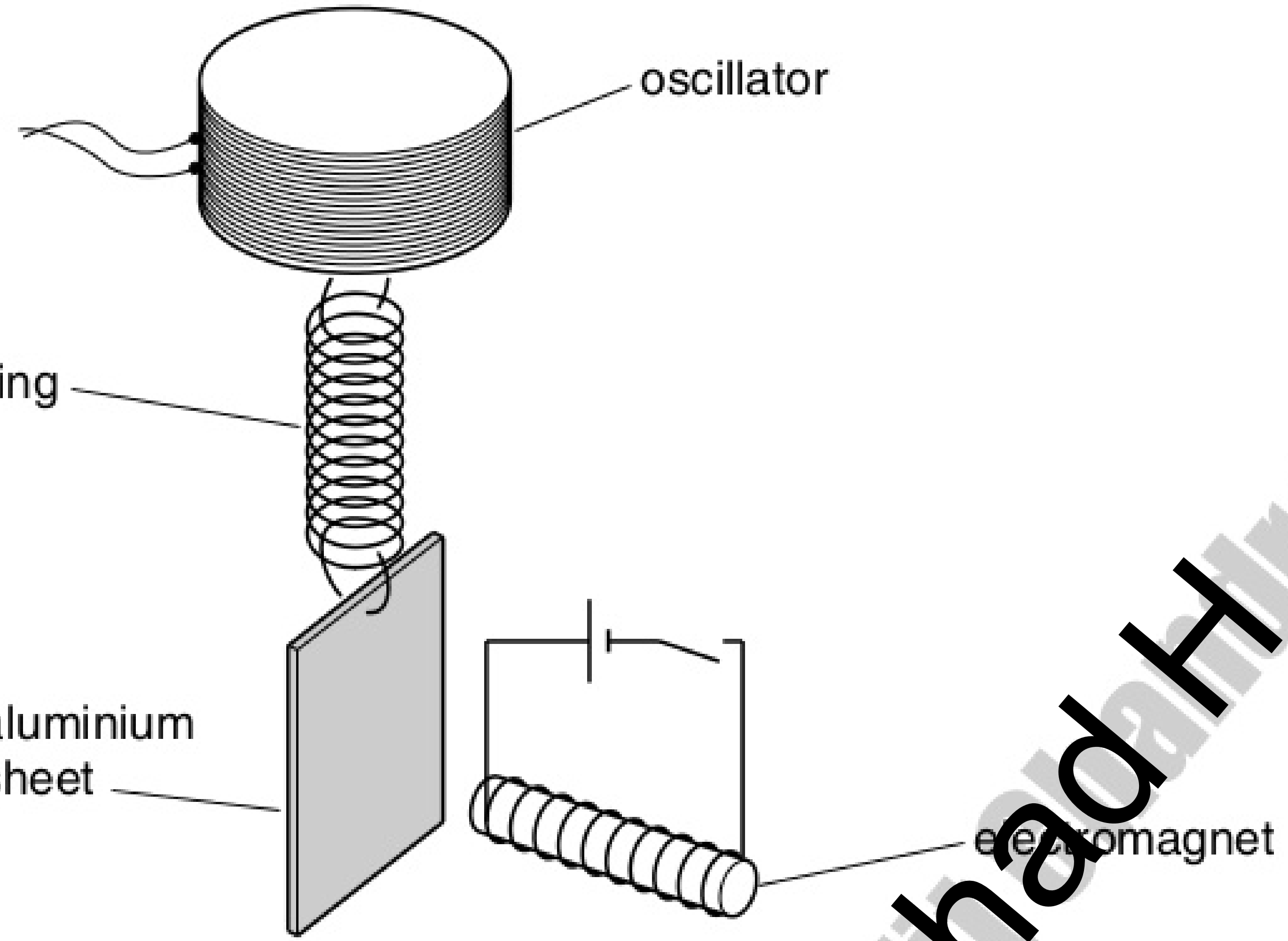


Fig. 3.1

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.

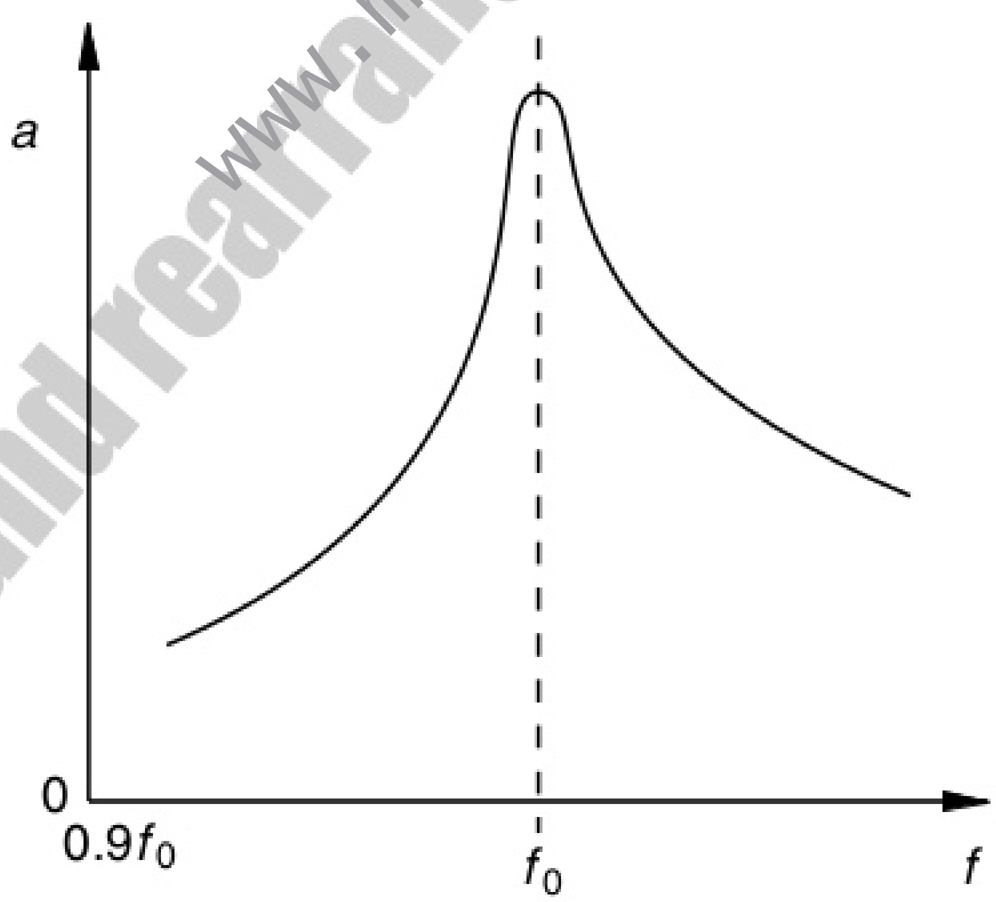


Fig. 3.2

A peak on the graph appears at frequency f_0.

(a) Explain why there is a peak at frequency f_0.

....

....

.... [2]

(b) The electromagnet is now switched on and the frequency of the oscillator is again gradually increased from a low value. On Fig. 3.2, draw a line to show the variation with frequency f of the amplitude a of vibration of the sheet. [3]

(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]

[November/December 2004]

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.

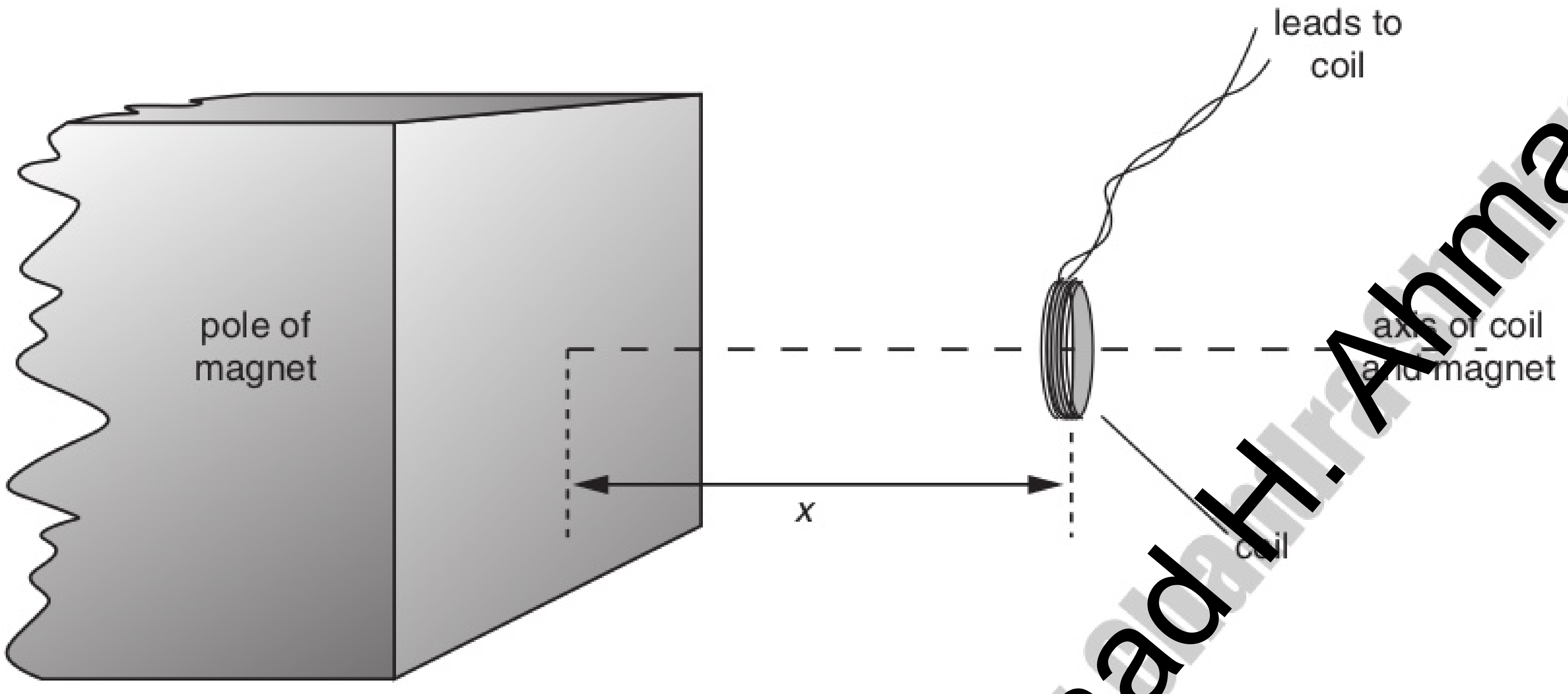


Fig. 4.1

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.

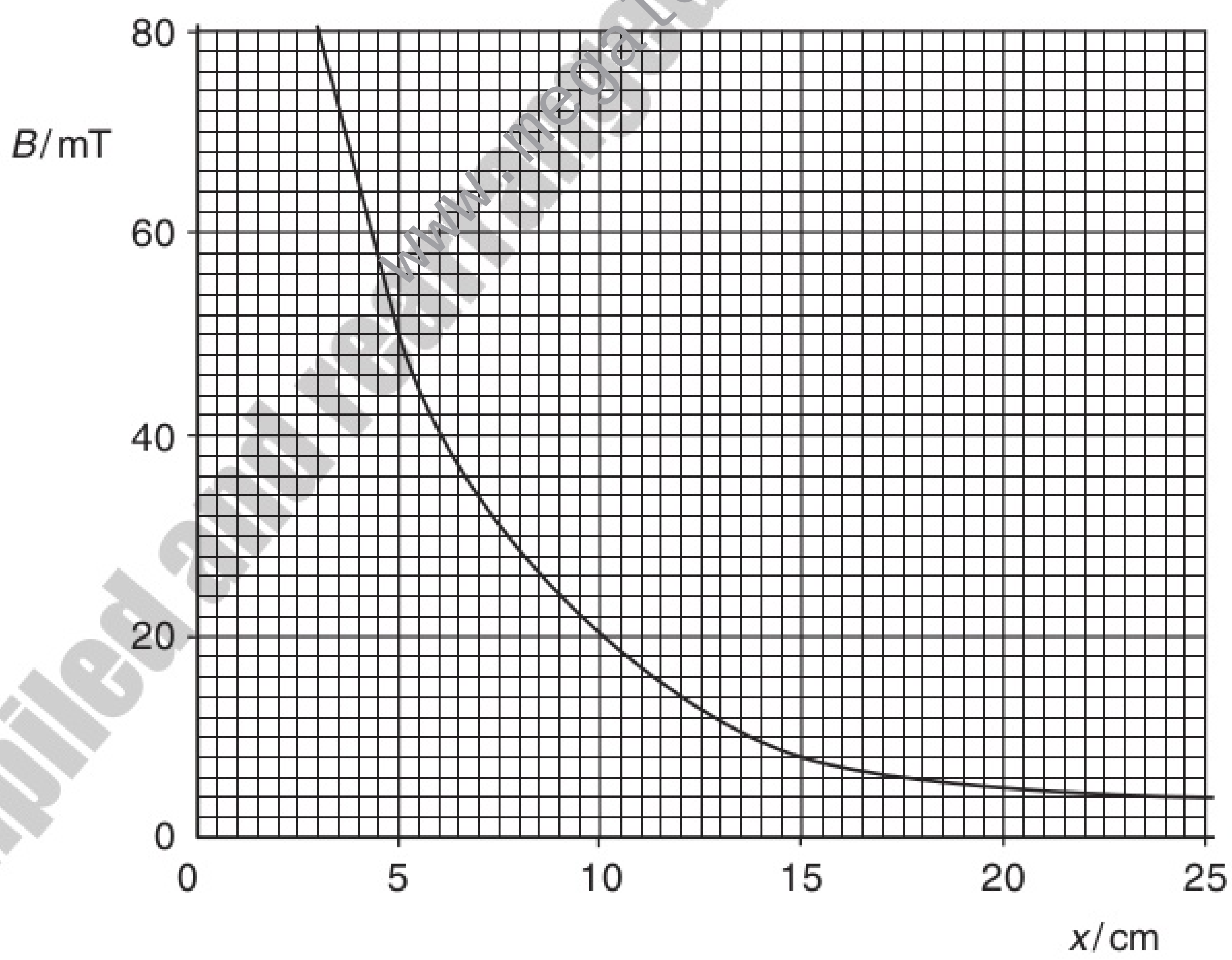


Fig. 4.2

(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]

For Examiner's Use

[November/December 2006]

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

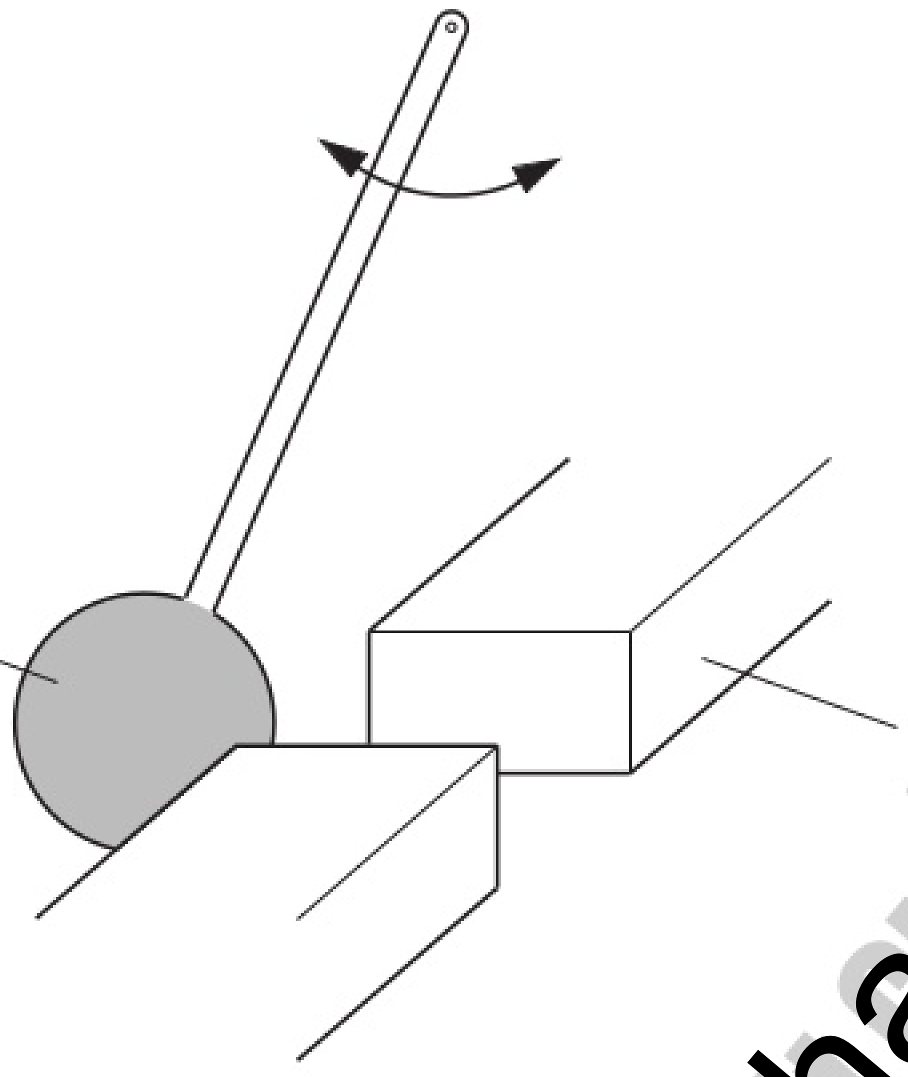


Fig. 5.1

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/June 2004]

6 **(a)** Explain, in terms of heating effect, what is meant by the *root-mean-square (r.m.s.) value* of an alternating current.

....

....

.... [2]

(b) State the relation between the peak current I_0 and the r.m.s. current I_{rms} of a sinusoidally-varying current.

.... [1]

(c) The value of a direct current and the peak value of a sinusoidal alternating current are equal.

(i) Determine the ratio

$$\frac{\text{power dissipation in a resistor of resistance } R \text{ by the direct current}}{\text{power dissipation in the resistor of resistance } R \text{ by the alternating current}}.$$

ratio = ... [2]

(ii) State one advantage and one disadvantage of the use of alternating rather than direct current in the home.

advantage ....

....

disadvantage ....

.... [2]

(d) A current I varies with time t as shown in Fig. 5.1.

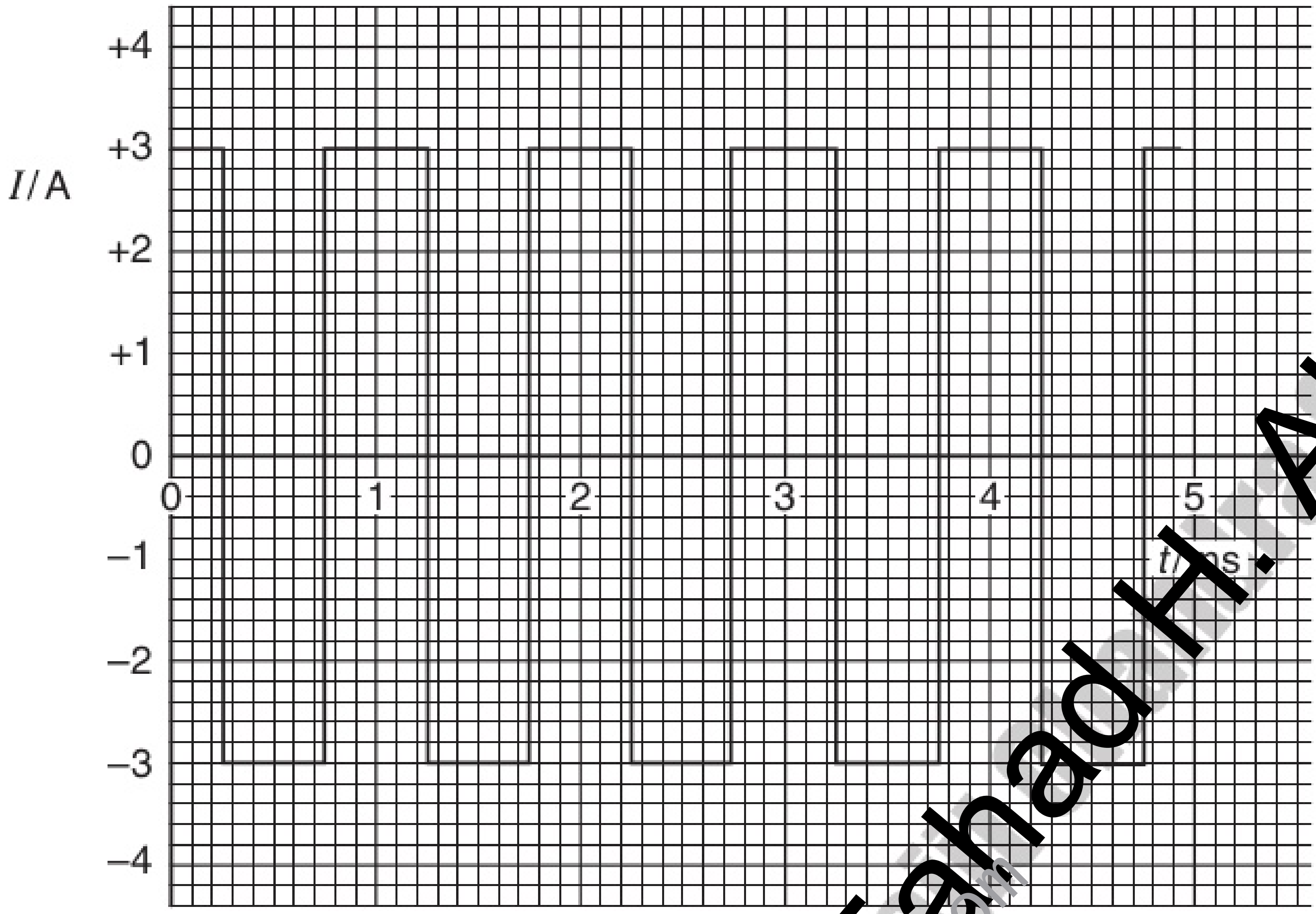


Fig. 5.1

For this varying current, state

(i) the peak value,

peak value = ... A [1]

(ii) the r.m.s. value.

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

For Examiner's Use

[May/June 2007]

7 An ideal transformer has 5000 turns on its primary coil. It is to be used to convert a mains supply of 230 V r.m.s. to an alternating voltage having a peak value of 9.0 V.

(a) Calculate the number of turns on the secondary coil.

number = ... [3]

(b) The output from the transformer is to be full-wave rectified. Fig. 4.1 shows part of the rectifier circuit.

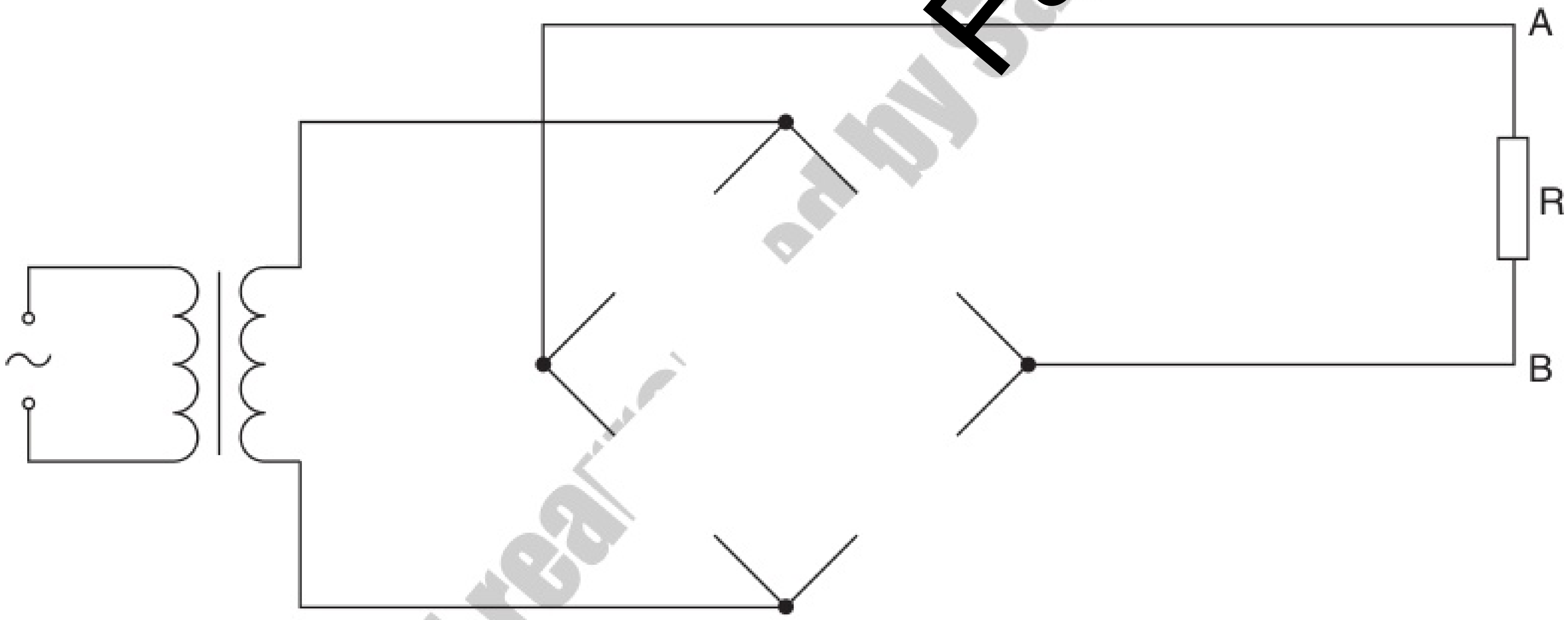


Fig. 4.1

On Fig. 4.1, draw

(i) diode symbols to complete the diagram of the rectifier such that terminal A of the resistor R is positive with respect to terminal B, [2]

(ii) the symbol for a capacitor connected to provide smoothing of the potential difference across the resistor R. [1]

(c) Fig. 4.2 shows the variation with time *t* of the smoothed potential difference *V* across the resistor R.

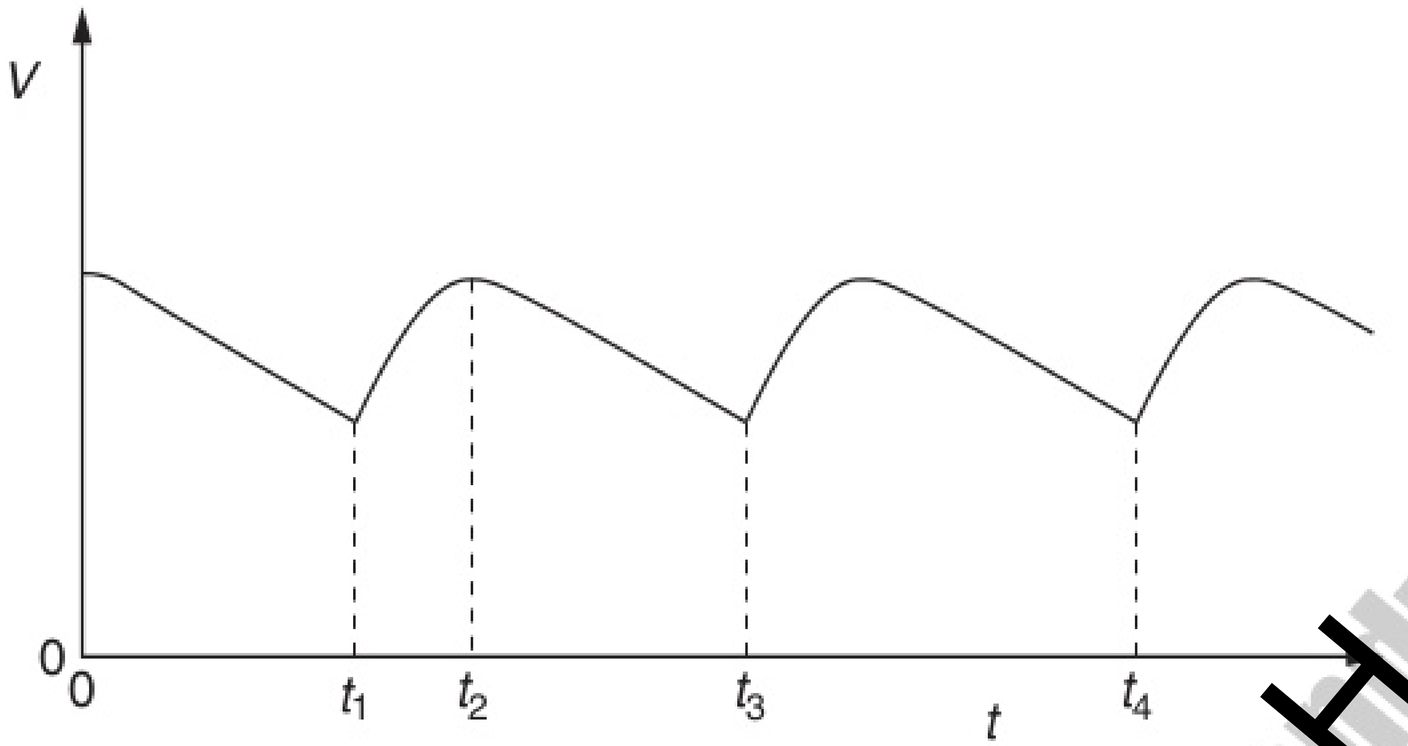


Fig. 4.2

(i) State the interval of time during which the capacitor is being charged from the transformer.

from time .... to time .... [1]

(ii) The resistance of the resistor R is doubled. On Fig. 4.2, sketch the variation with time *t* of the potential difference *V* across the resistor. [2]

[November/December 2002]

8 (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.

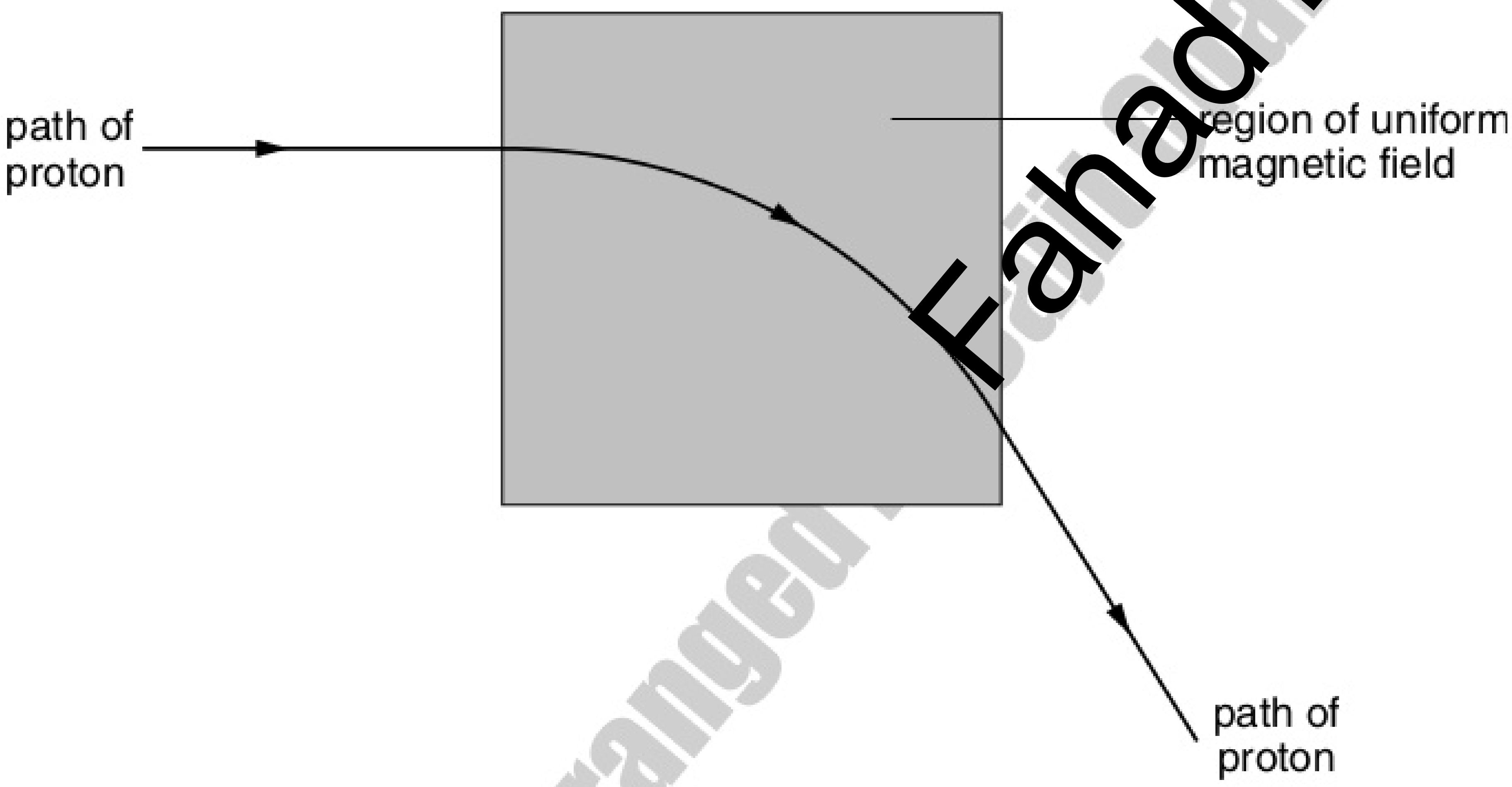


Fig. 6.1

(i) State the direction of the magnetic field.

.... [1]

(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]

[November/December 2004]

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

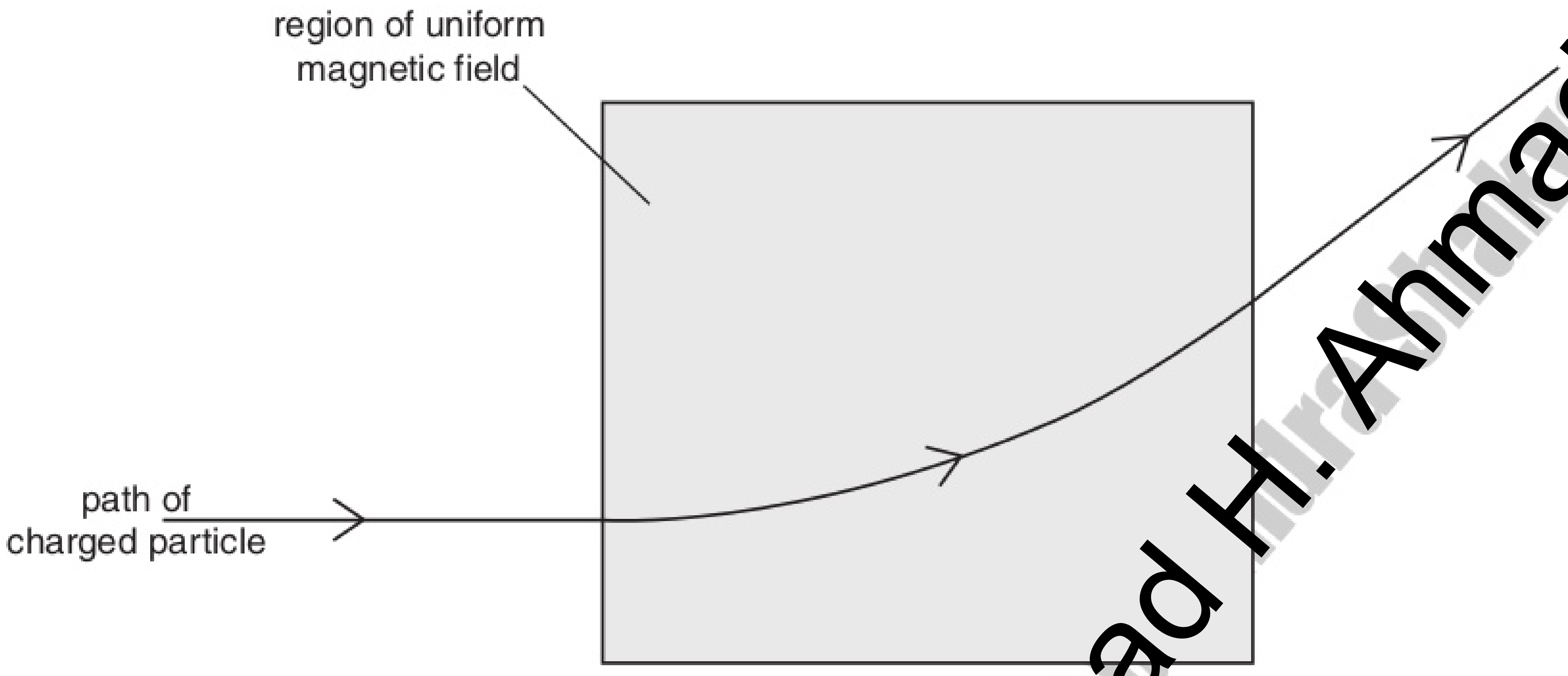


Fig. 5.1

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

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

(c) **(i)** The particle in **(b)** has charge $1.6 \times 10^{-19}\,\mathrm{C}$. 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]

[November/December 2005]

10 **(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.

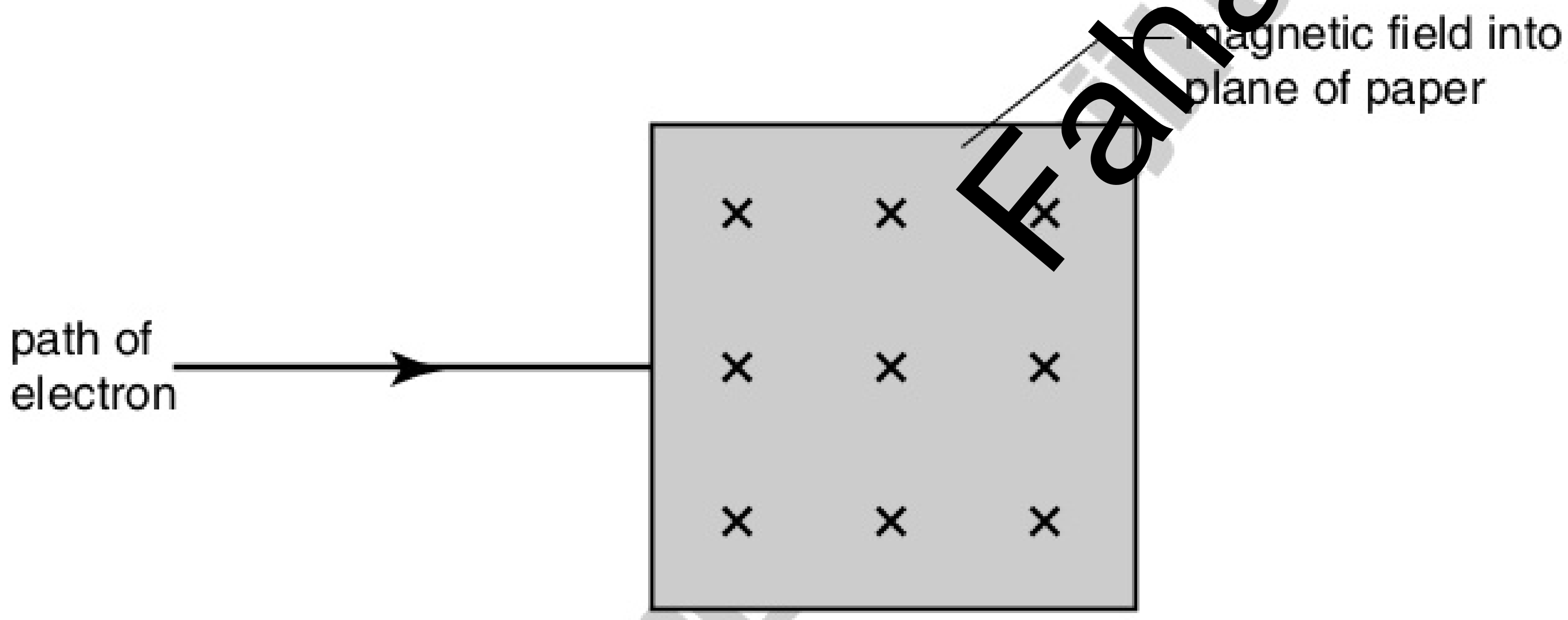


Fig. 5.1

(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]

For Examiner's 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]

For Examiner's Use

[May/June 2002]

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

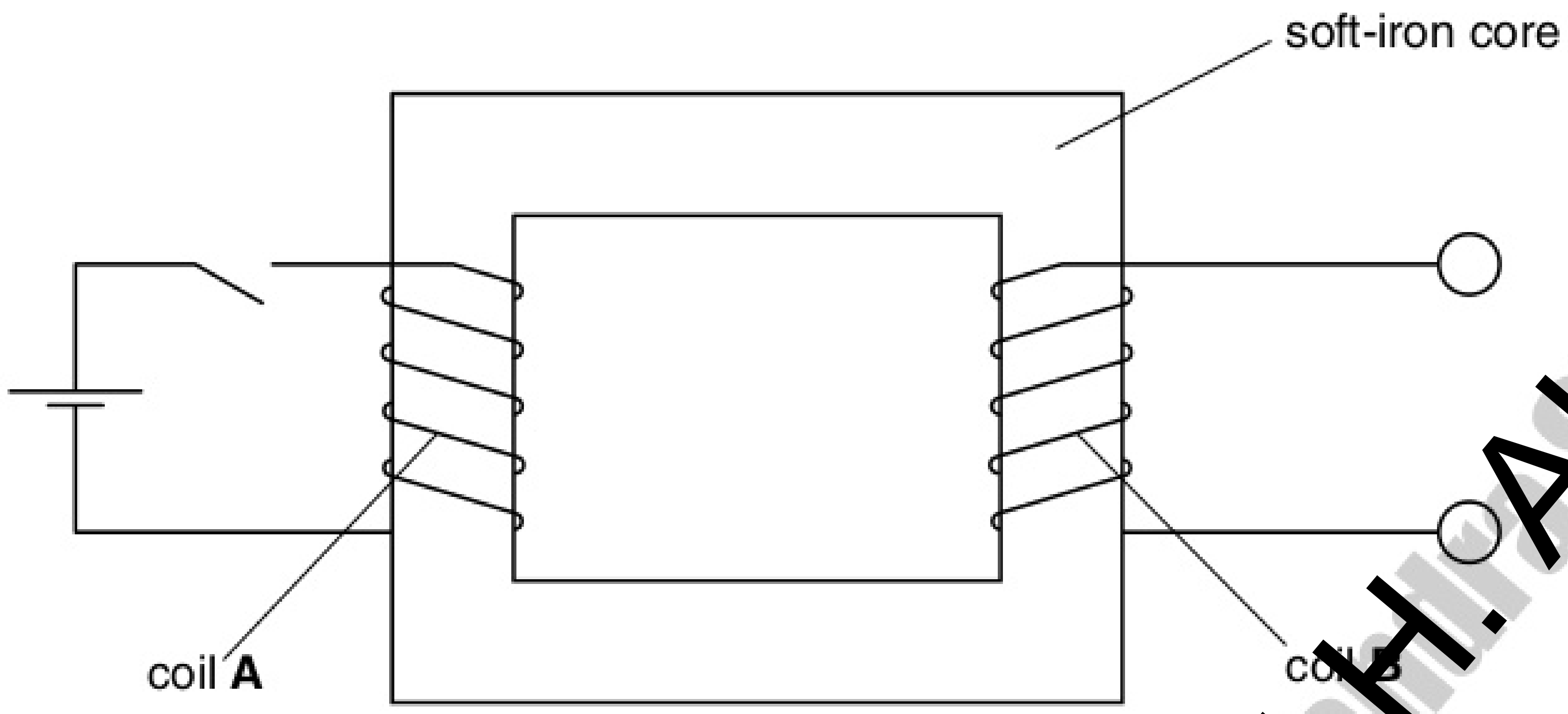


Fig. 6.1

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.

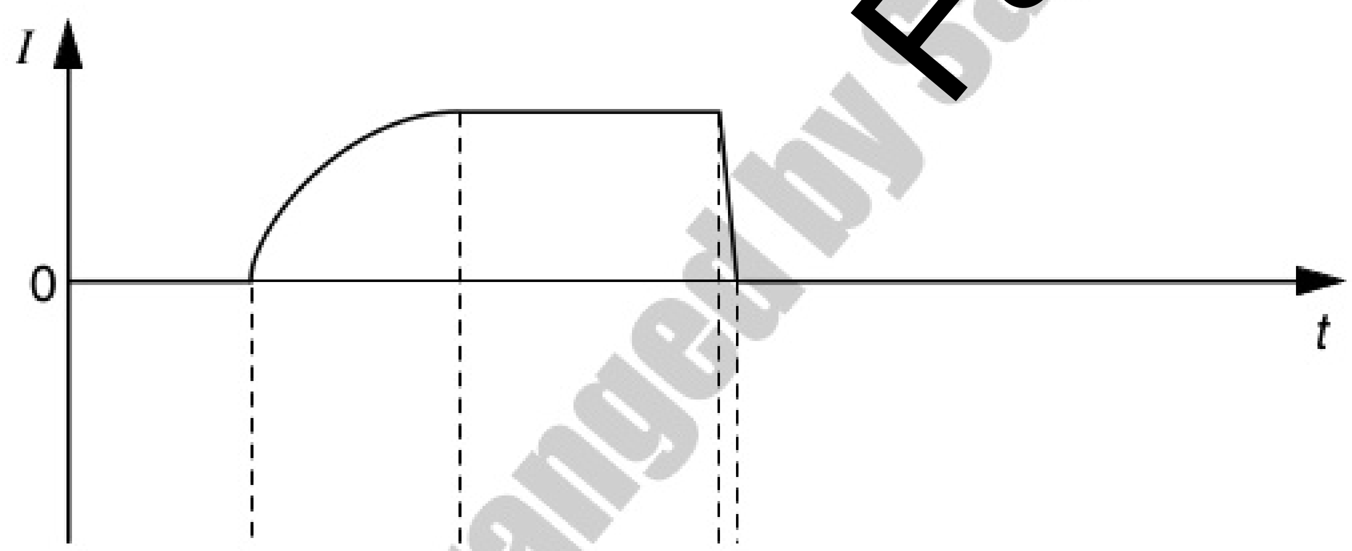


Fig. 6.2

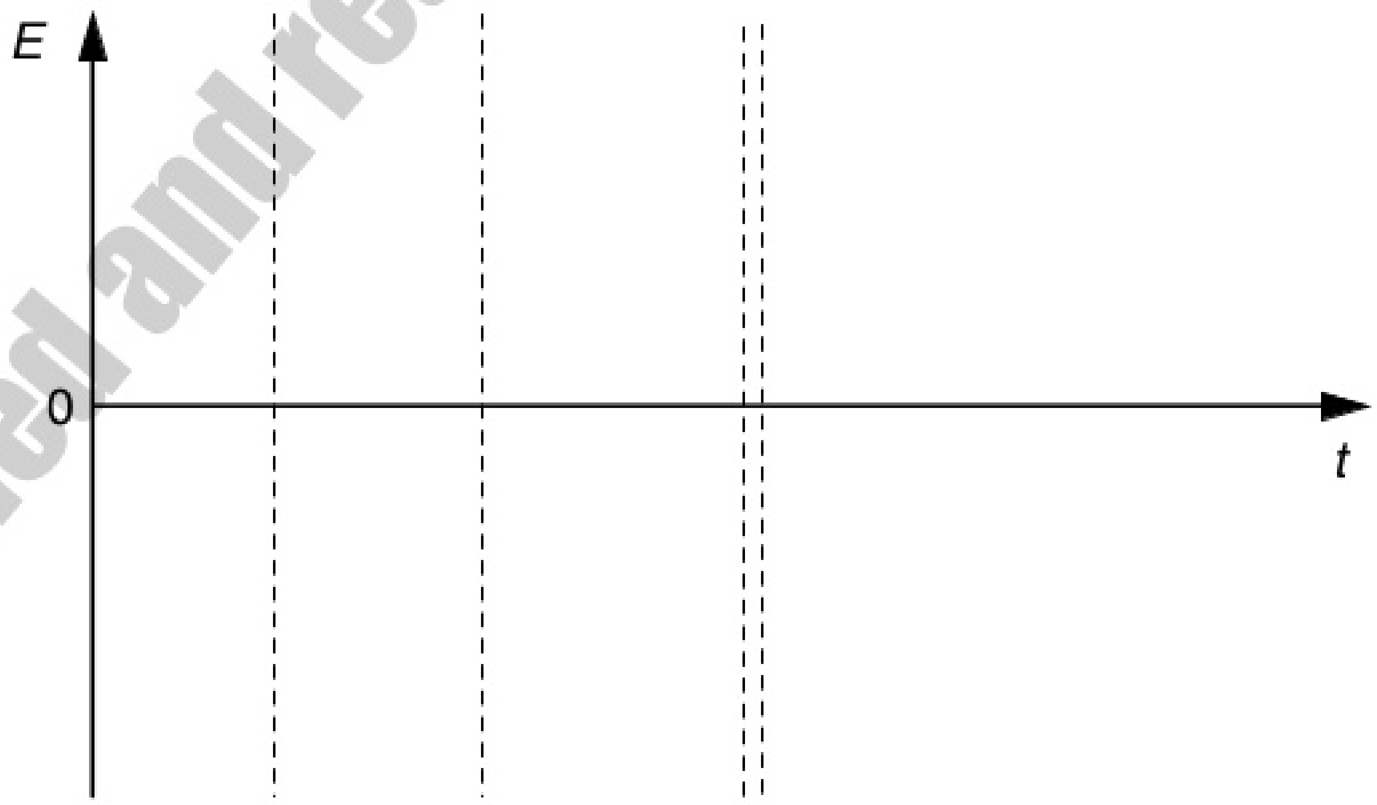


Fig. 6.3

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]

(b) Fig. 6.4 is the circuit of a bridge rectifier.

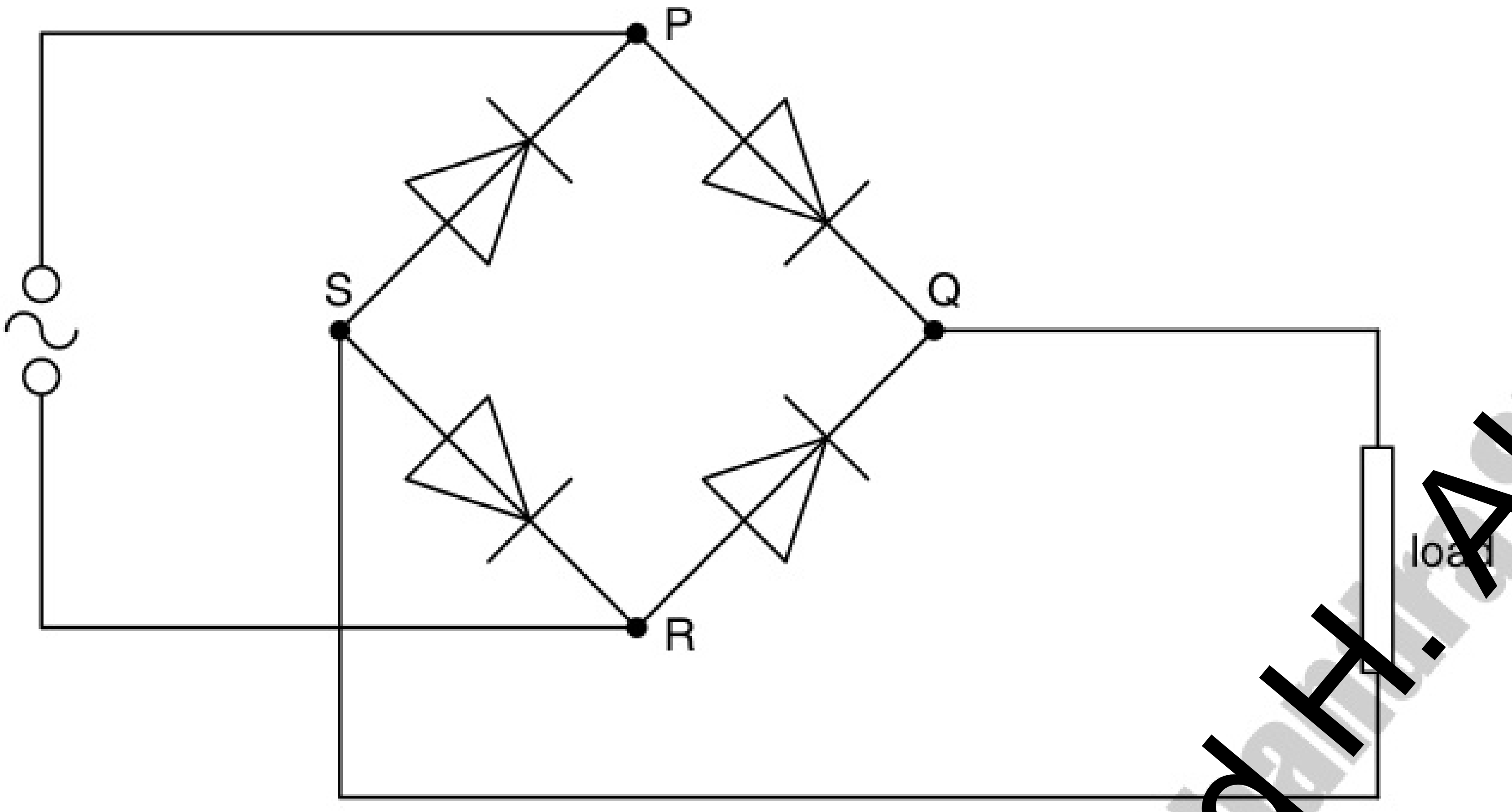


Fig. 6.4

An alternating supply connected across PR has an output of 6.0 V r.m.s.

(i) On Fig. 6.4, circle those diodes that are conducting when R is positive with respect to P. [1]

(ii) Calculate the maximum potential difference between points Q and S, assuming that the diodes are ideal.

potential difference = ... V [2]

(iii) State and explain how a capacitor may be used to smooth the output from the rectifier. You may draw on Fig. 6.4 if you wish.

....

....

....[3]

For Examiner's Use

[May/June 2005]

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

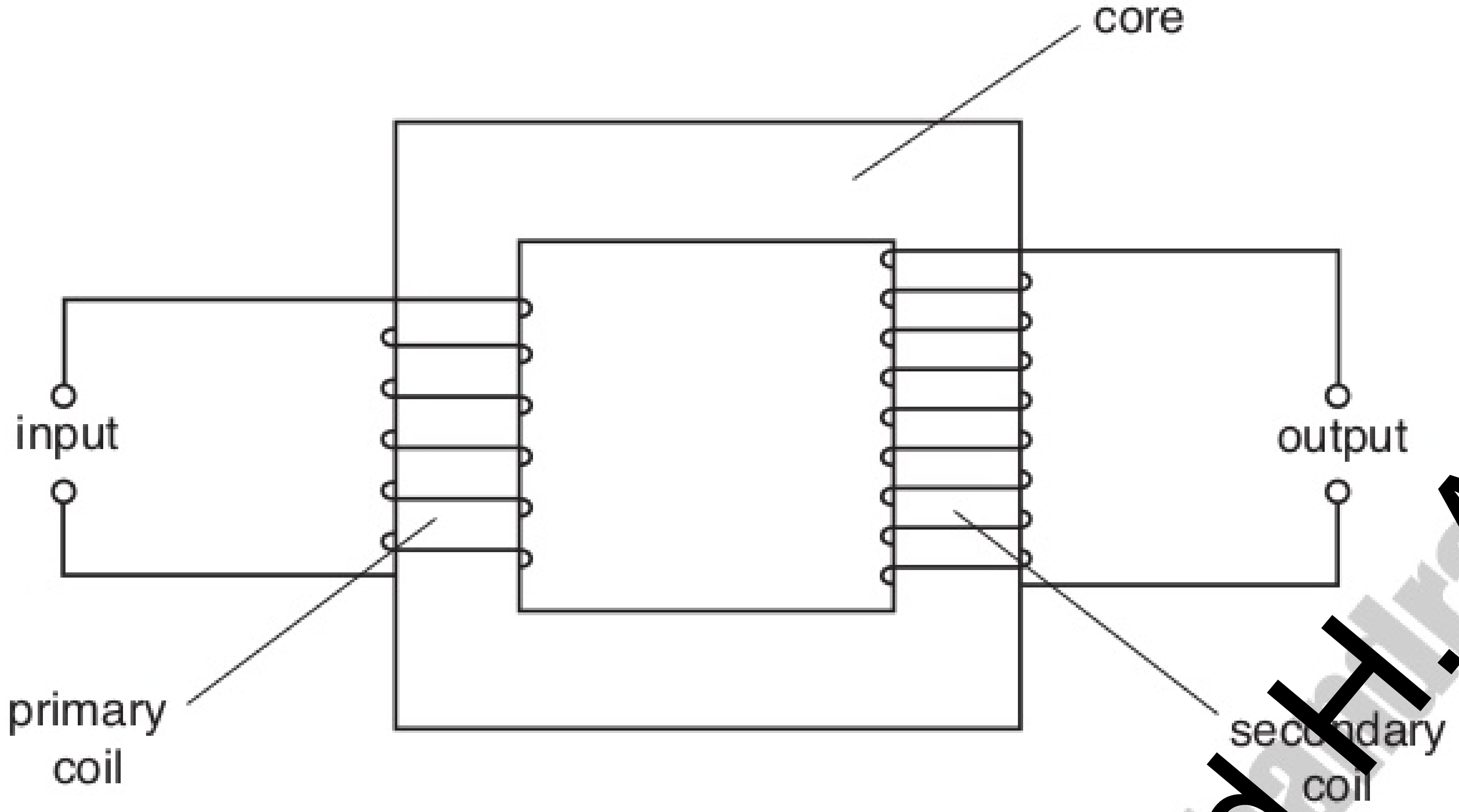


Fig. 6.1

(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.

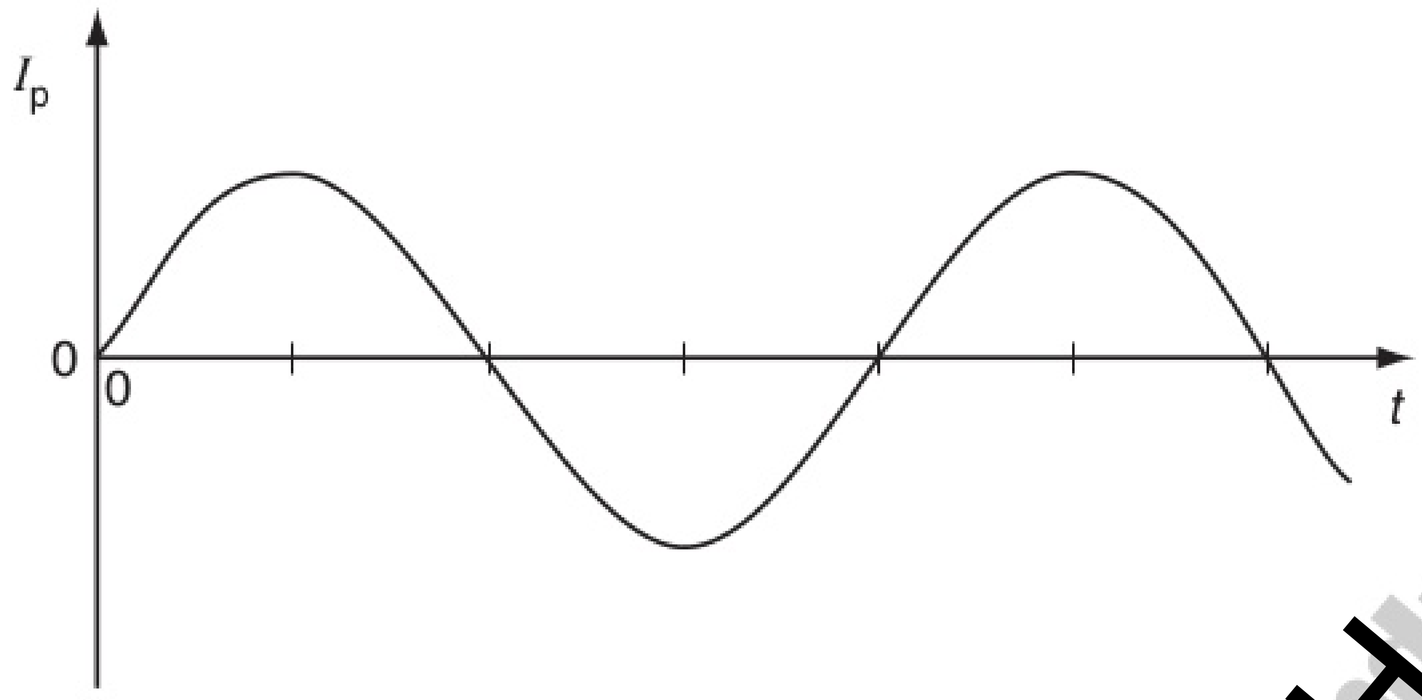


Fig. 6.2

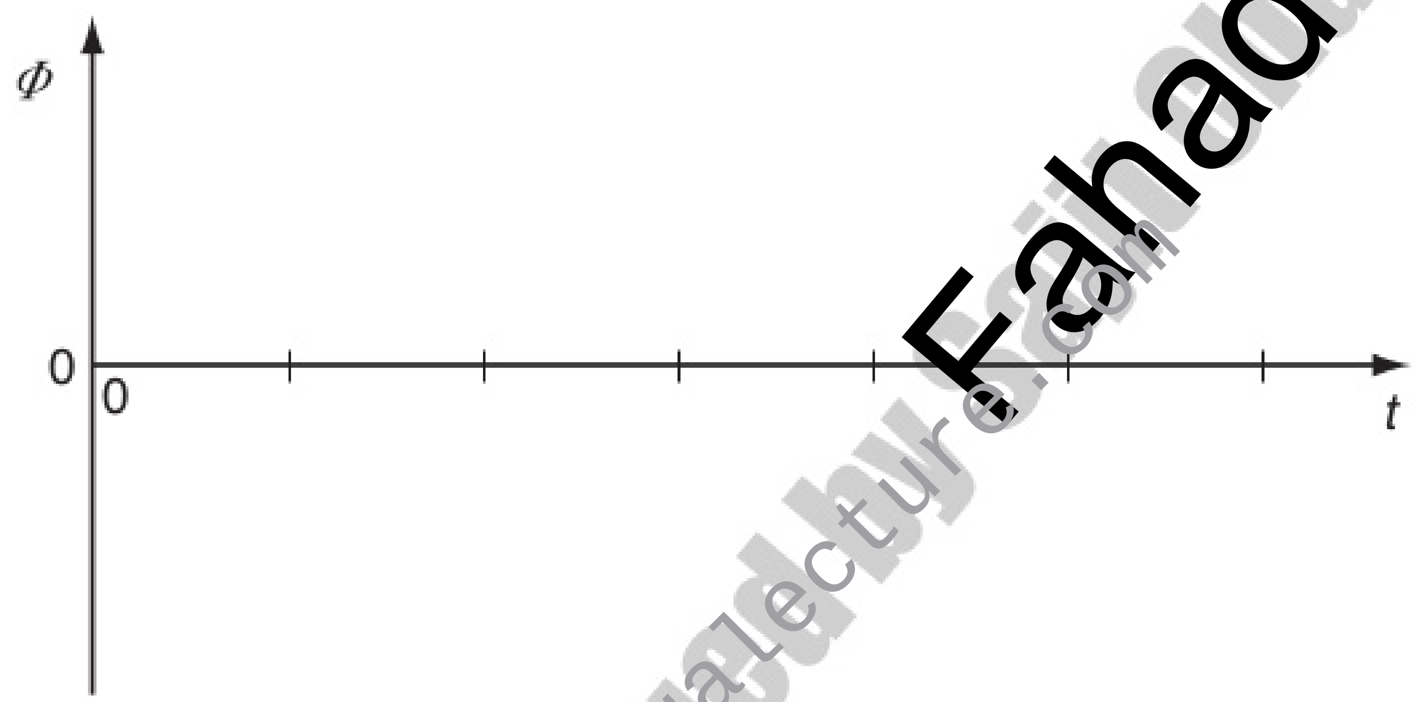


Fig. 6.3

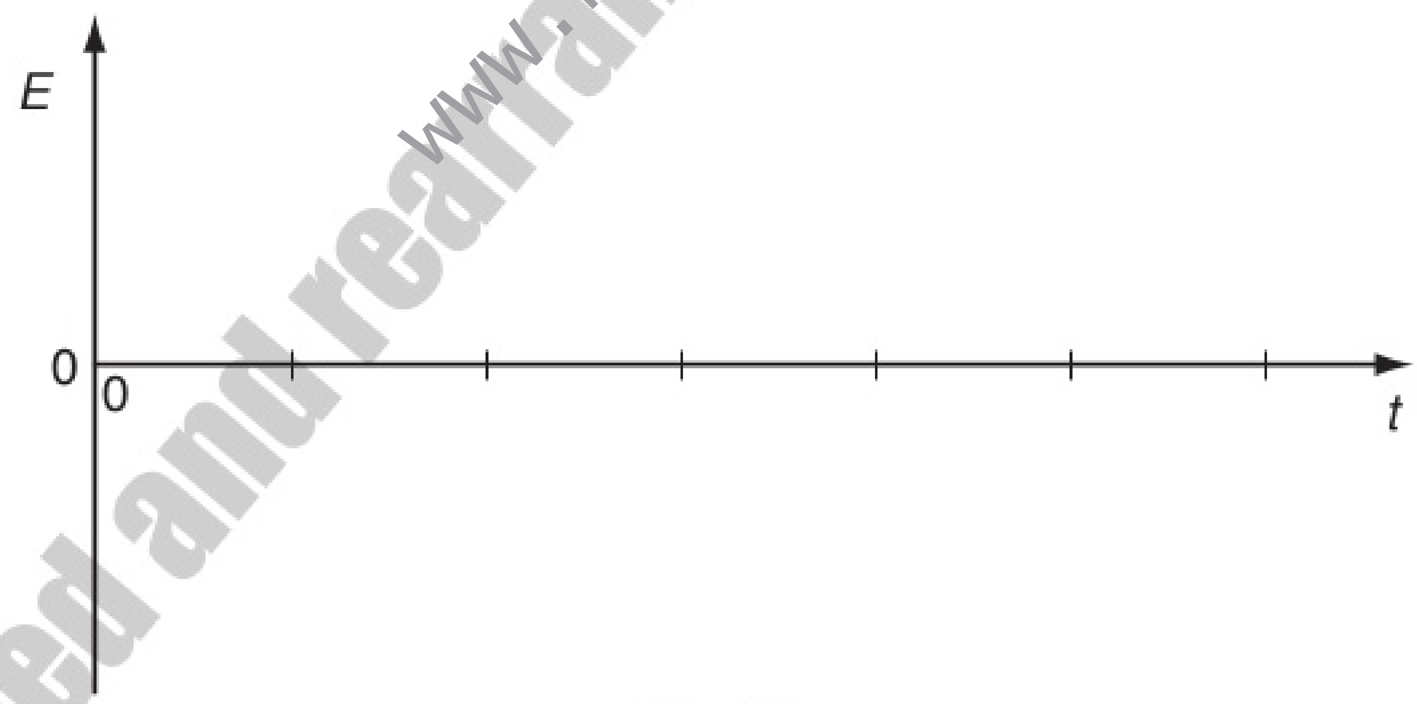


Fig. 6.4

(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]

[May/June 2006]

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

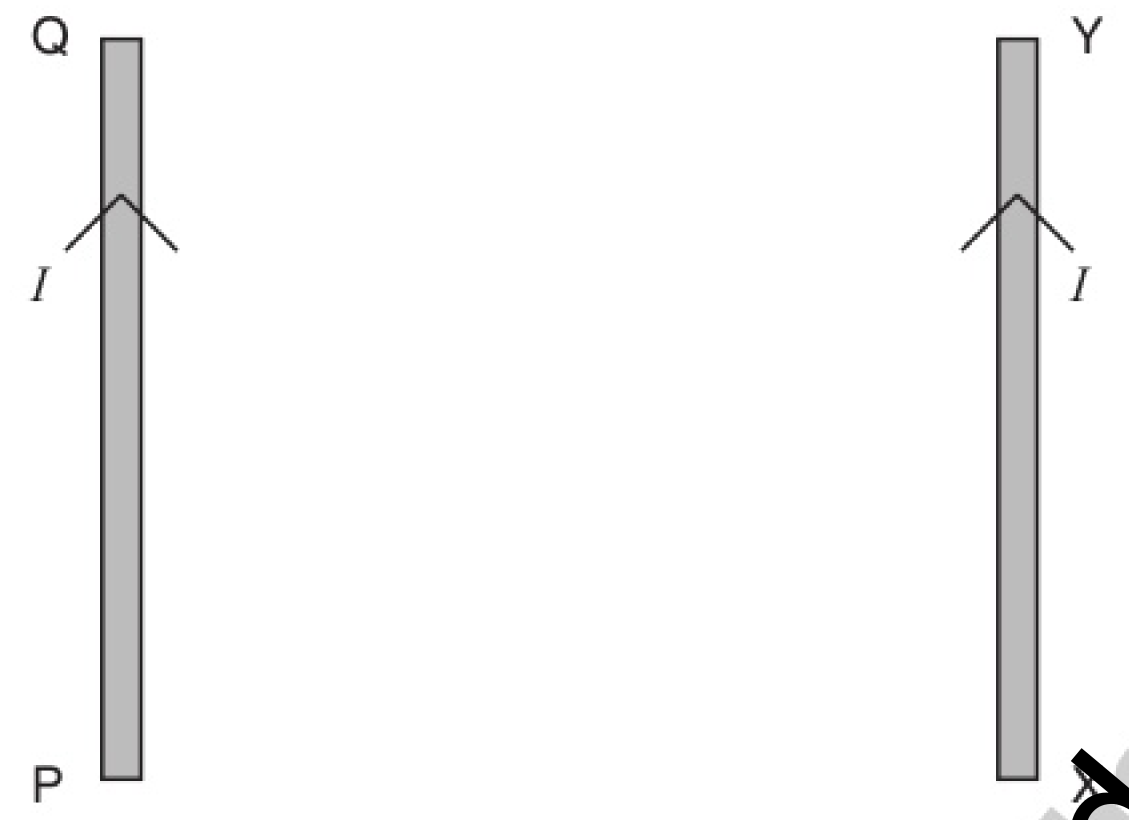


Fig. 6.1

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 X.

....

.... [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]

[November/December 2002]

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

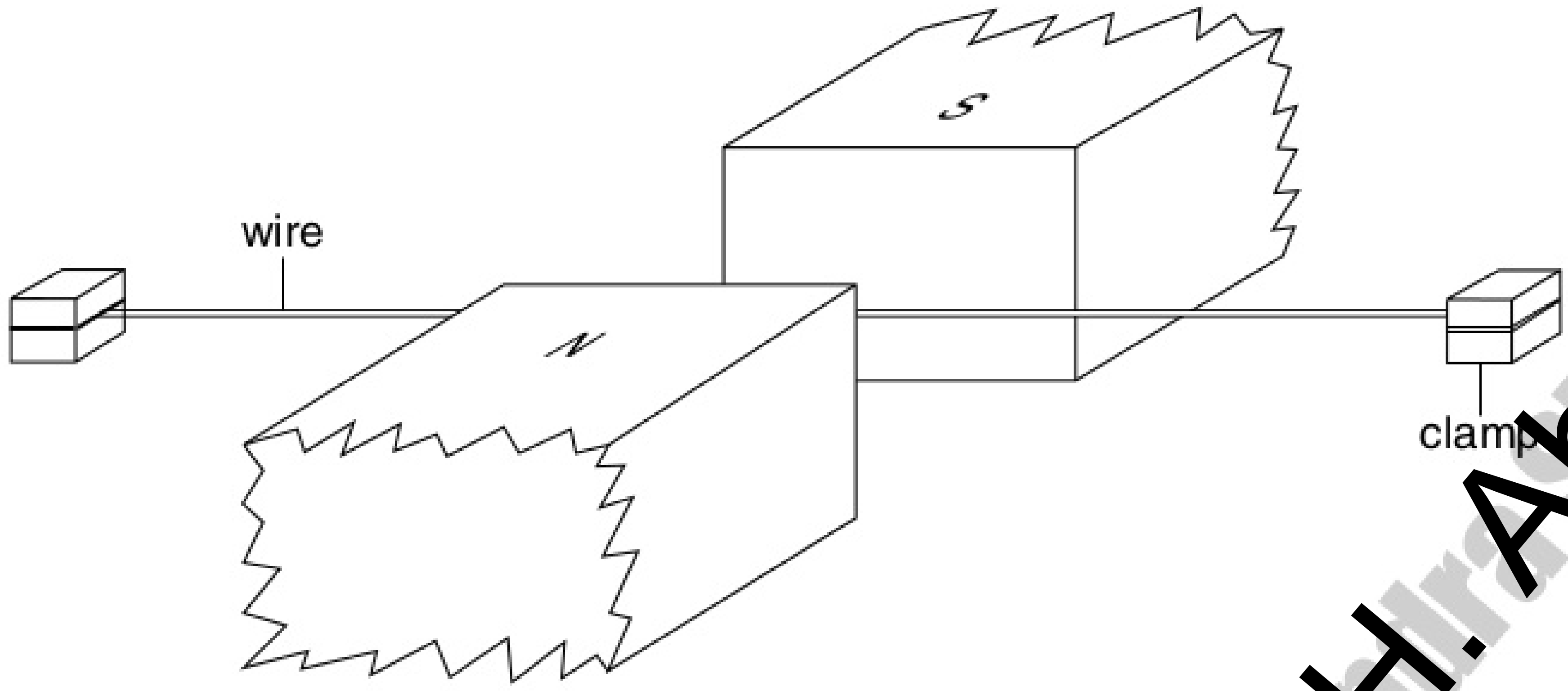


Fig. 7.1

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.

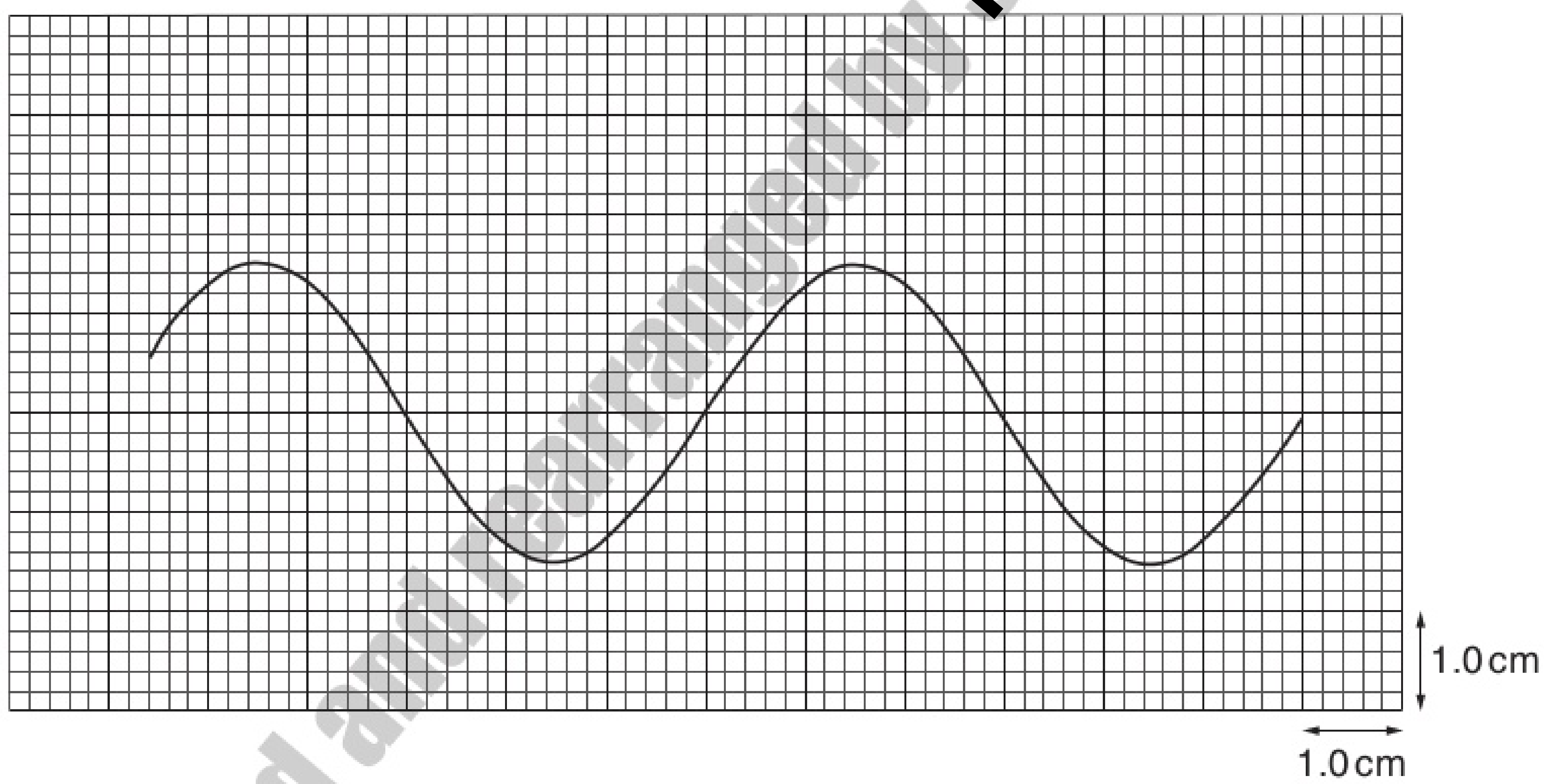


Fig. 7.2

(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]

[November/December 2005]

16 **(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.

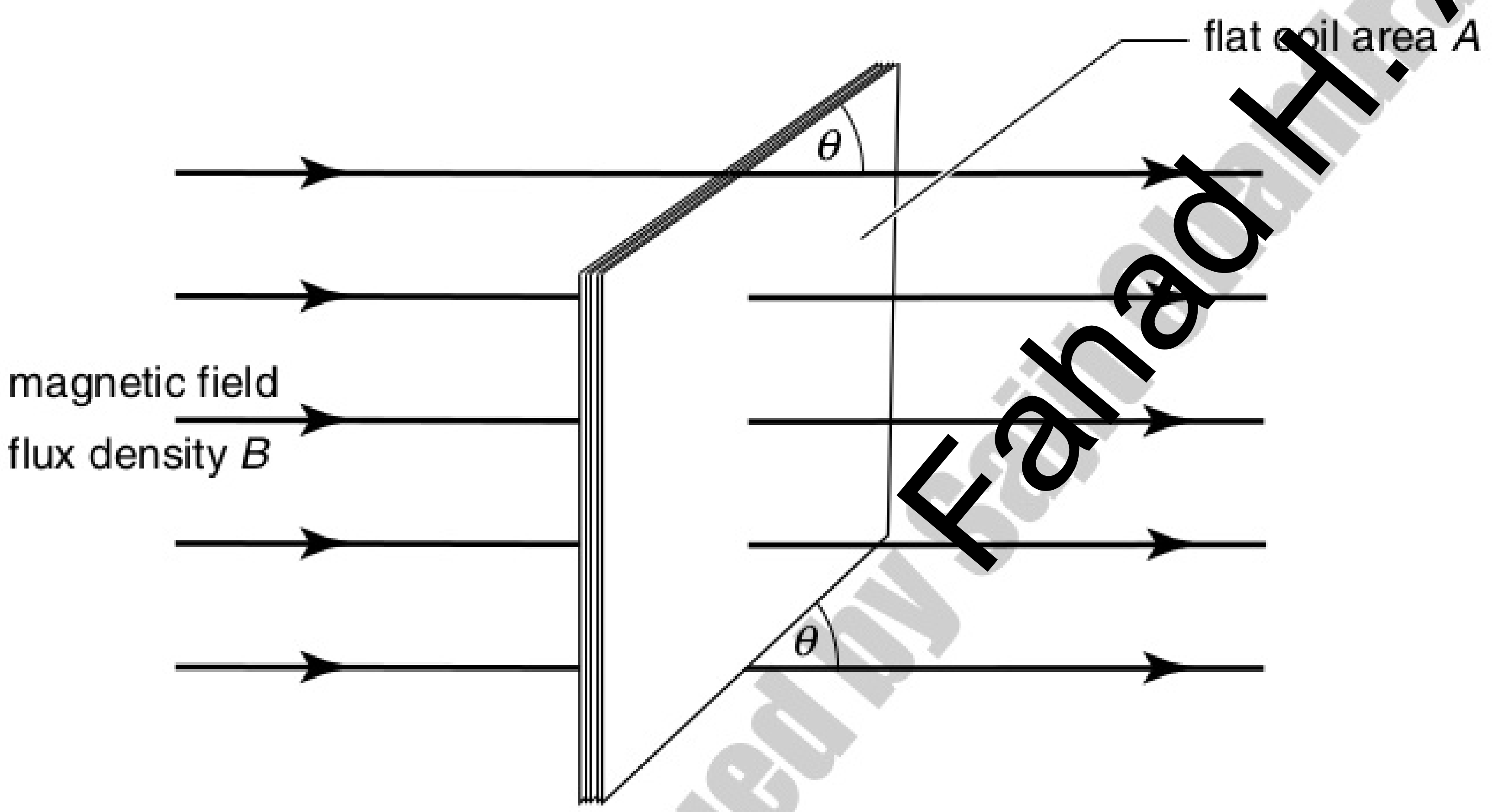


Fig. 6.1

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.

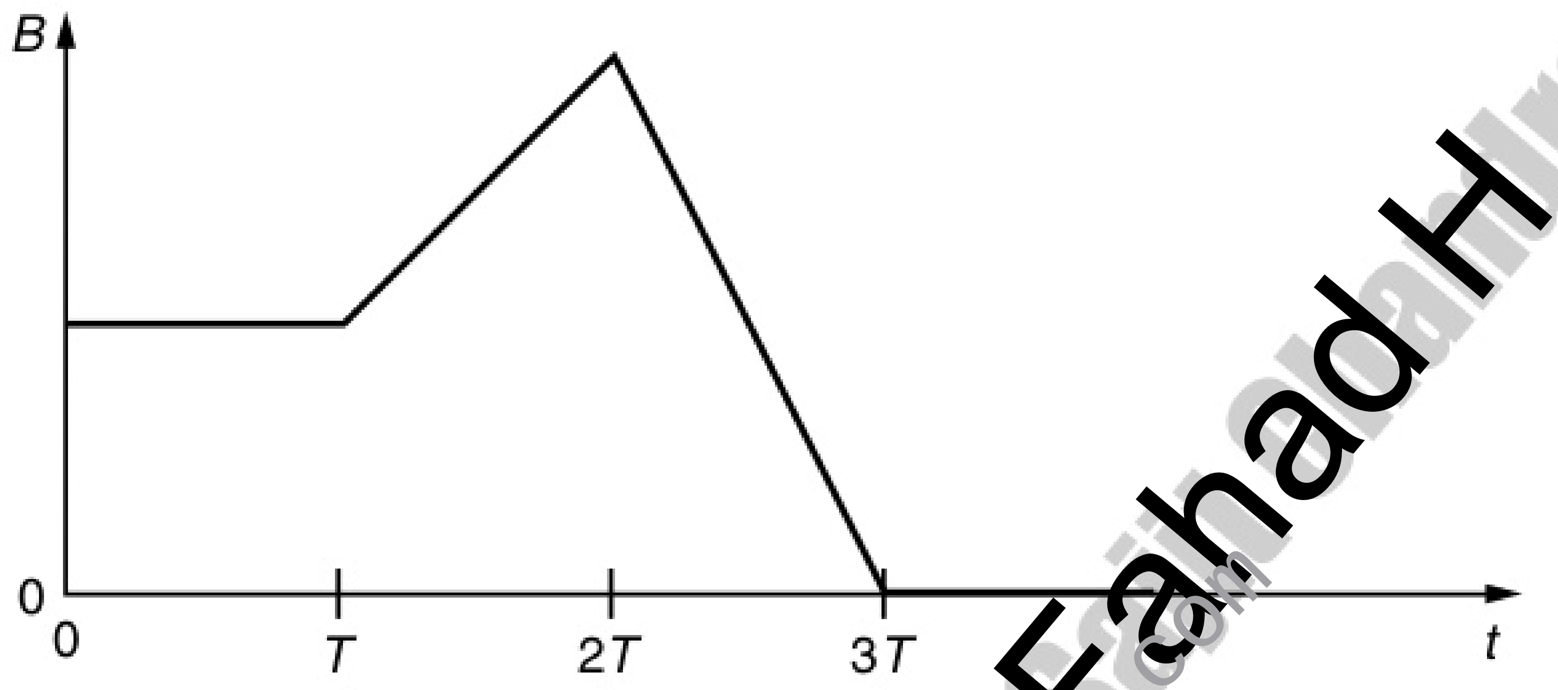


Fig. 6.2

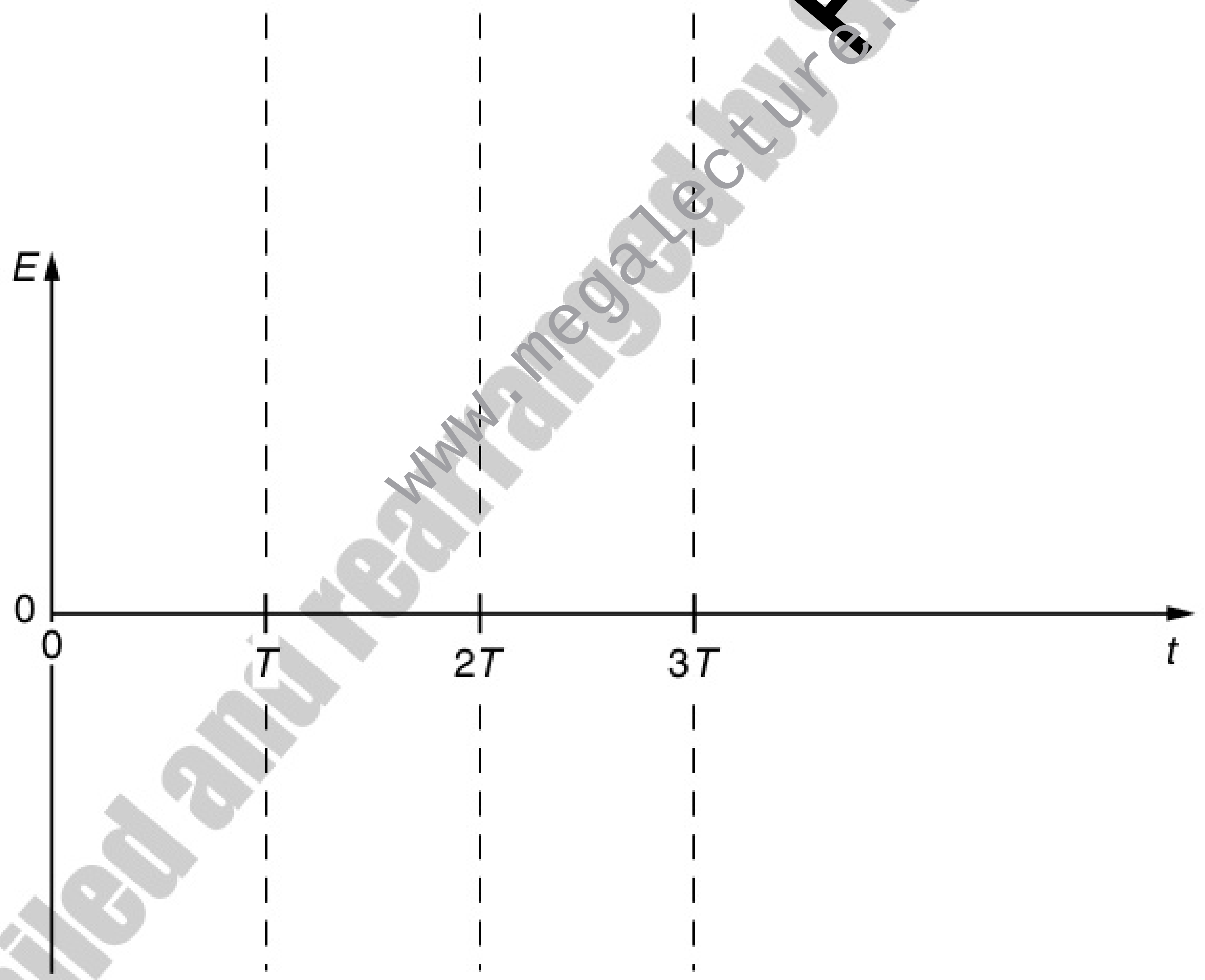


Fig. 6.3

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

[November/December 2008]

For Examiner's Use

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

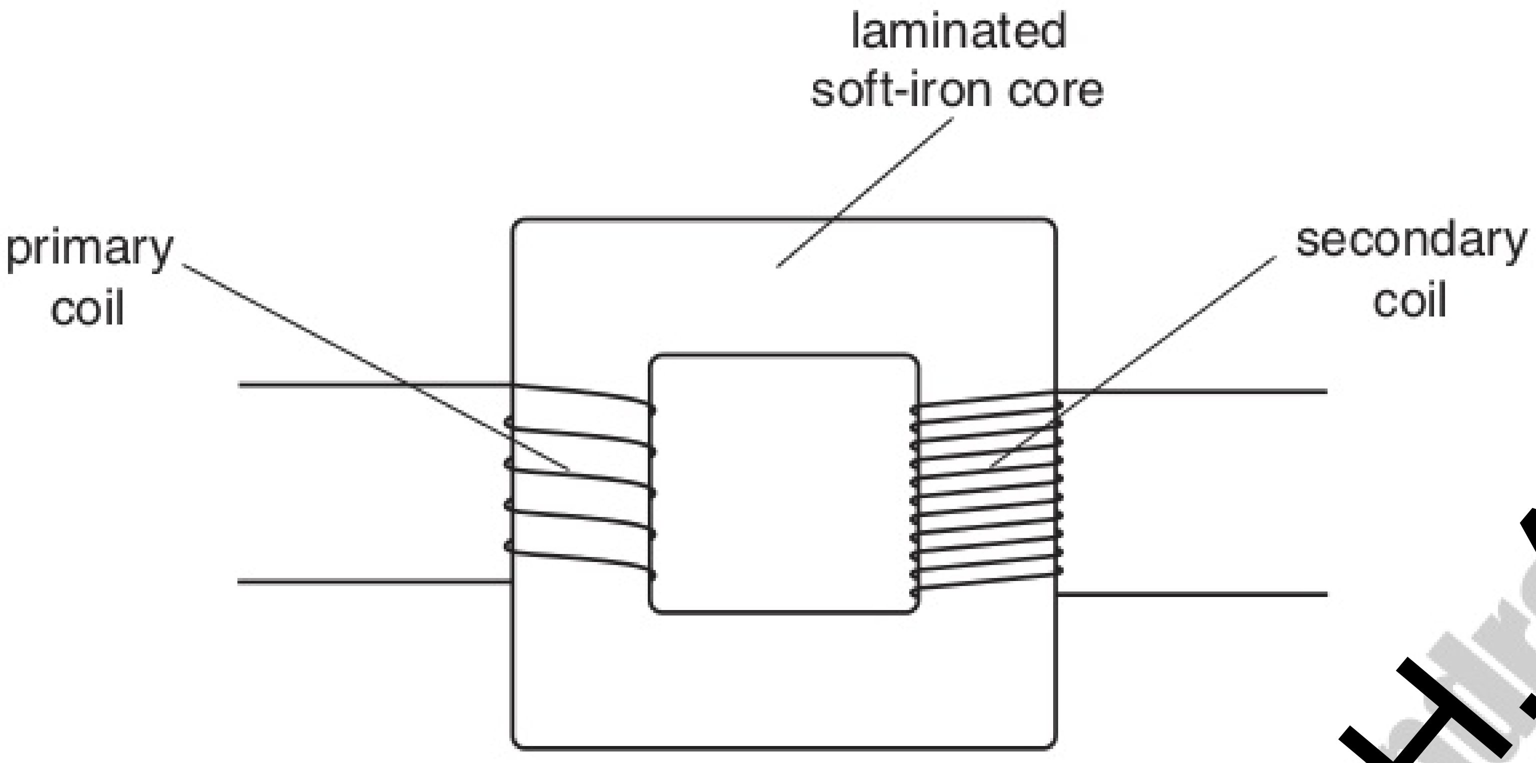


Fig. 6.1

(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]

For Examiner's Use

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

1. ....

....

2. ....

.... [2]

For Examiner's Use

18 **(a)** Define the *tesla*. [May June 2009]

....

....

....

.... [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.

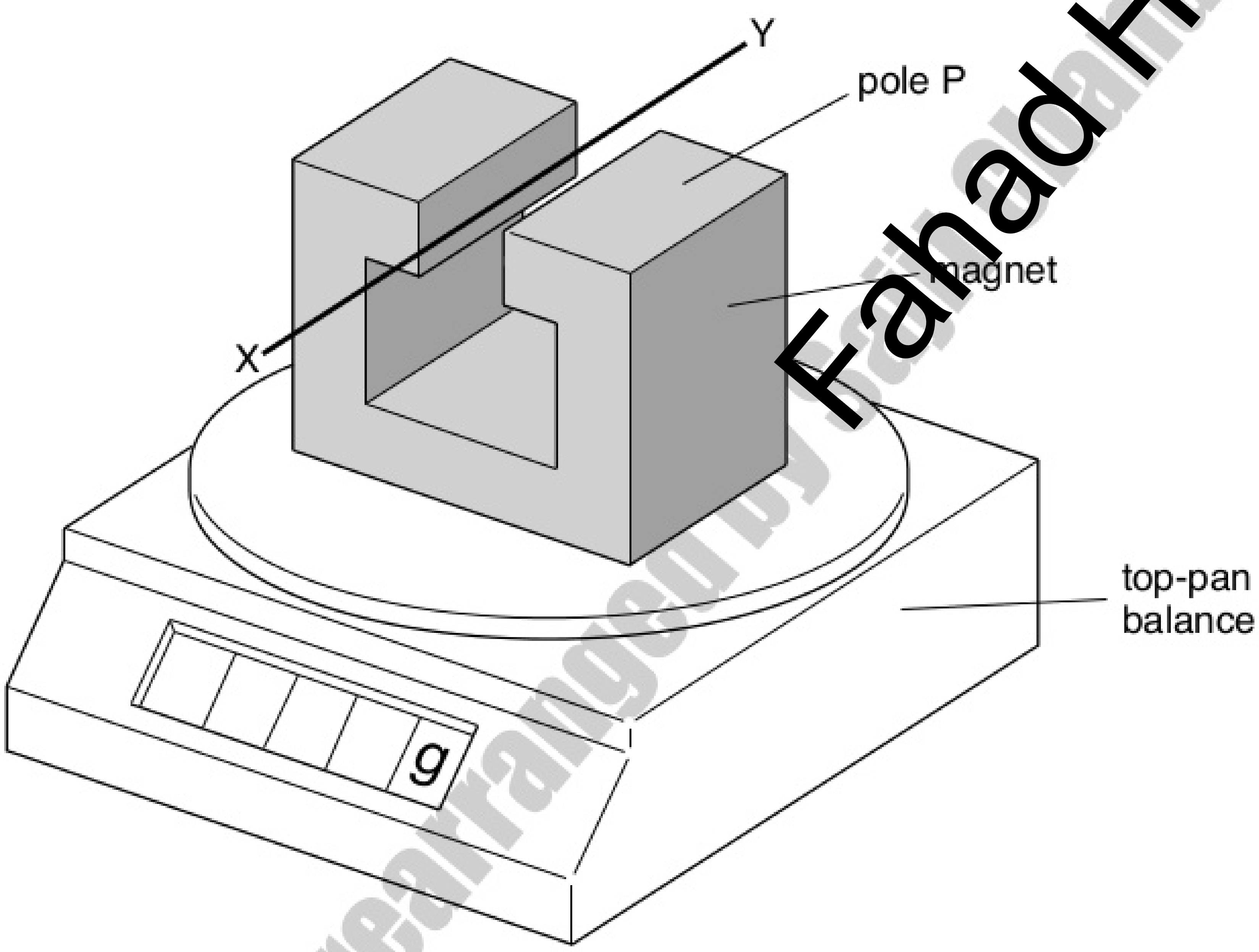


Fig. 6.1

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 June 2009]

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

Outline an experiment to verify Lenz's law.

For Examiner's Use

....

....

....

....

....

....

....

.... [6]

[October November 2009]

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

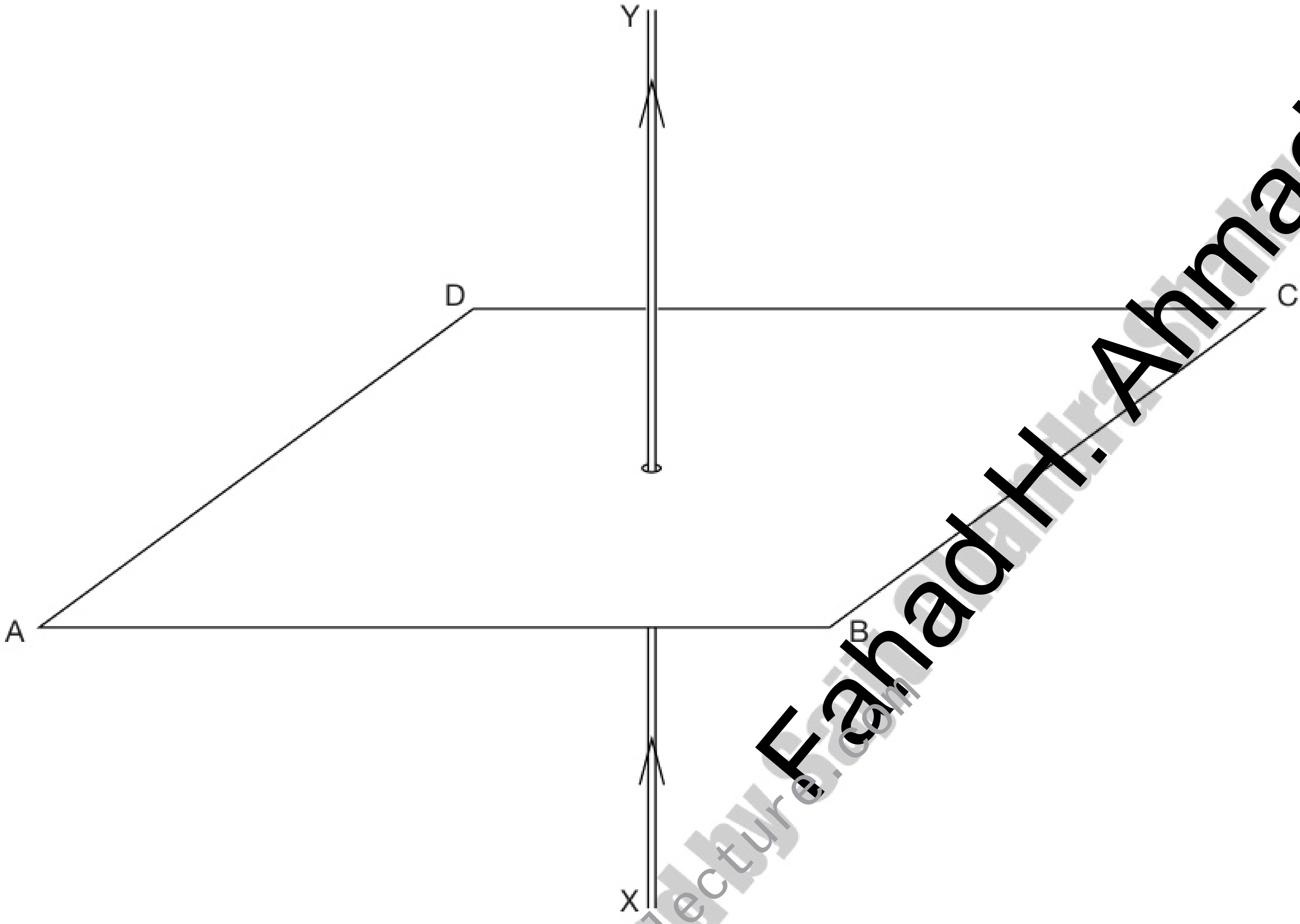


Fig. 6.1

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

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

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

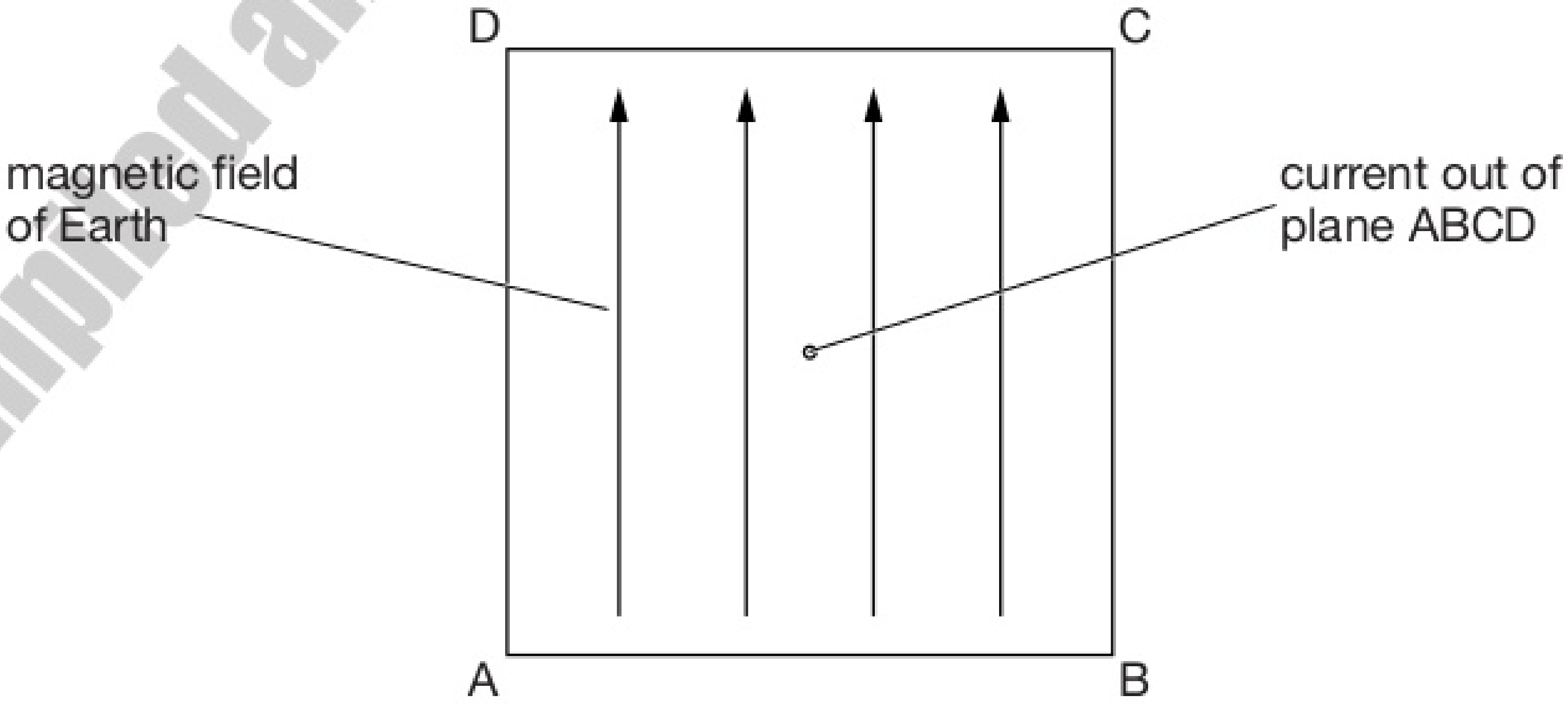


Fig. 6.2

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

(i) On Fig. 6.2, mark with the letter P a point where the magnetic field due to the current-carrying wire could be equal and opposite to that of the Earth. [1]

(ii) For a long, straight wire carrying current I, the magnetic flux density B at distance r from the centre of the wire is given by the expression

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

where μ_0 is the permeability of free space.

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

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

flux density = ... T [2]

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

Determine the new current in the wire.

current = ... A [2]

21 A sinusoidal alternating voltage is to be rectified. [October November 2009]

For Examiner's Use

(a) Suggest one advantage of full-wave rectification as compared with half-wave rectification.

....

....

(b) The rectification is produced using the circuit of Fig. 7.1.

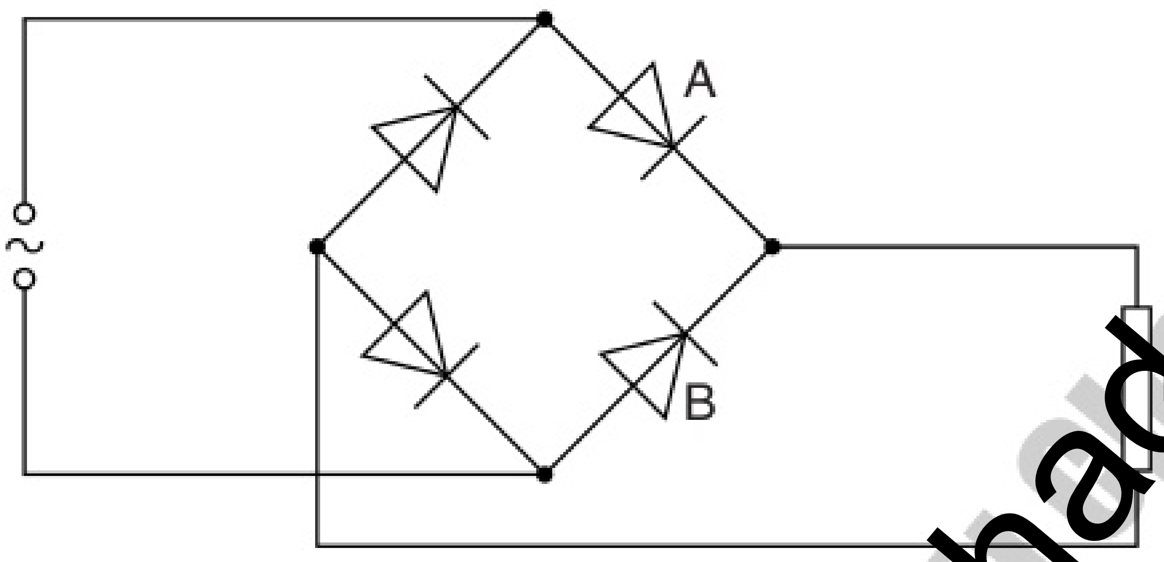


Fig. 7.1

All the diodes may be considered to be ideal.

The variation with time t of the alternating voltage applied to the circuit is shown in Fig. 7.2 and in Fig. 7.3.

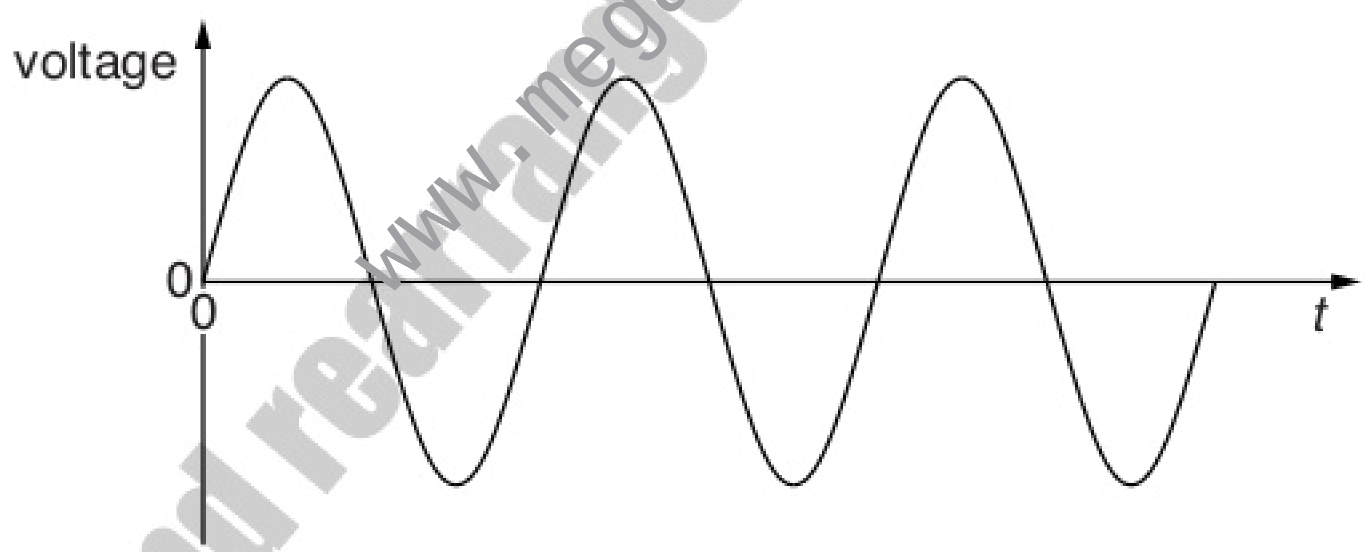


Fig. 7.2

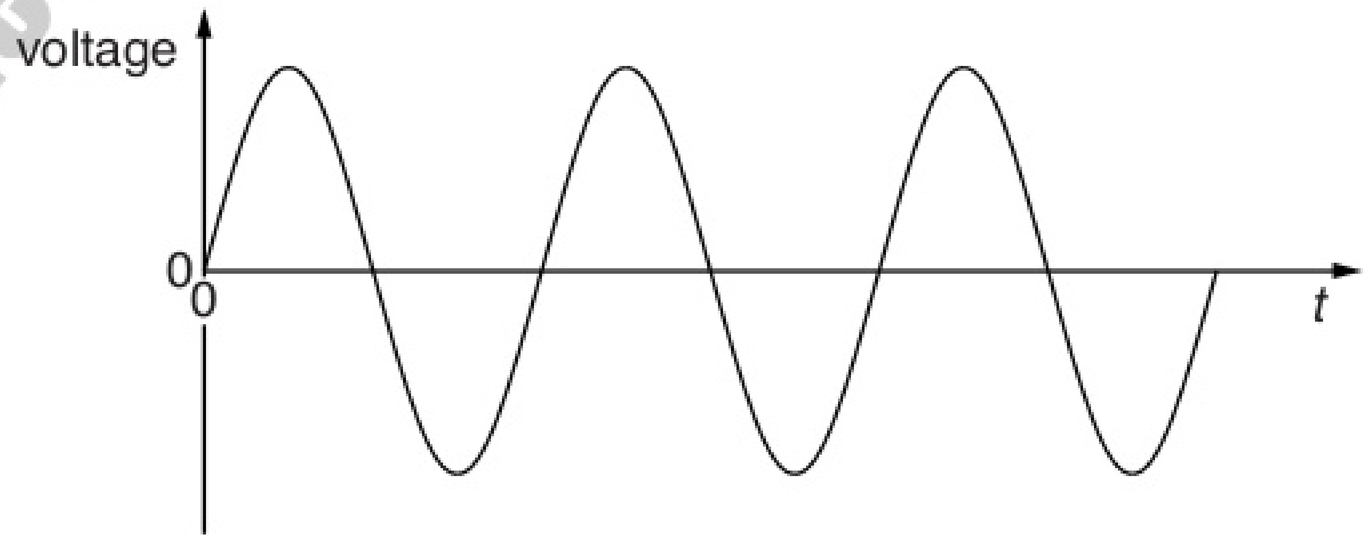


Fig. 7.3

(i) On the axes of Fig. 7.2, draw a graph to show the variation with time *t* of the potential difference across diode A. [1]

(ii) On the axes of Fig. 7.3, draw a graph to show the variation with time *t* of the potential difference across diode B. [1]

(c) (i) On Fig. 7.1, draw the symbol for a capacitor, connected into the circuit so as to provide smoothing. [1]

(ii) Fig. 7.4 shows the variation with time *t* of the smoothed potential difference across the resistor R in Fig. 7.1.

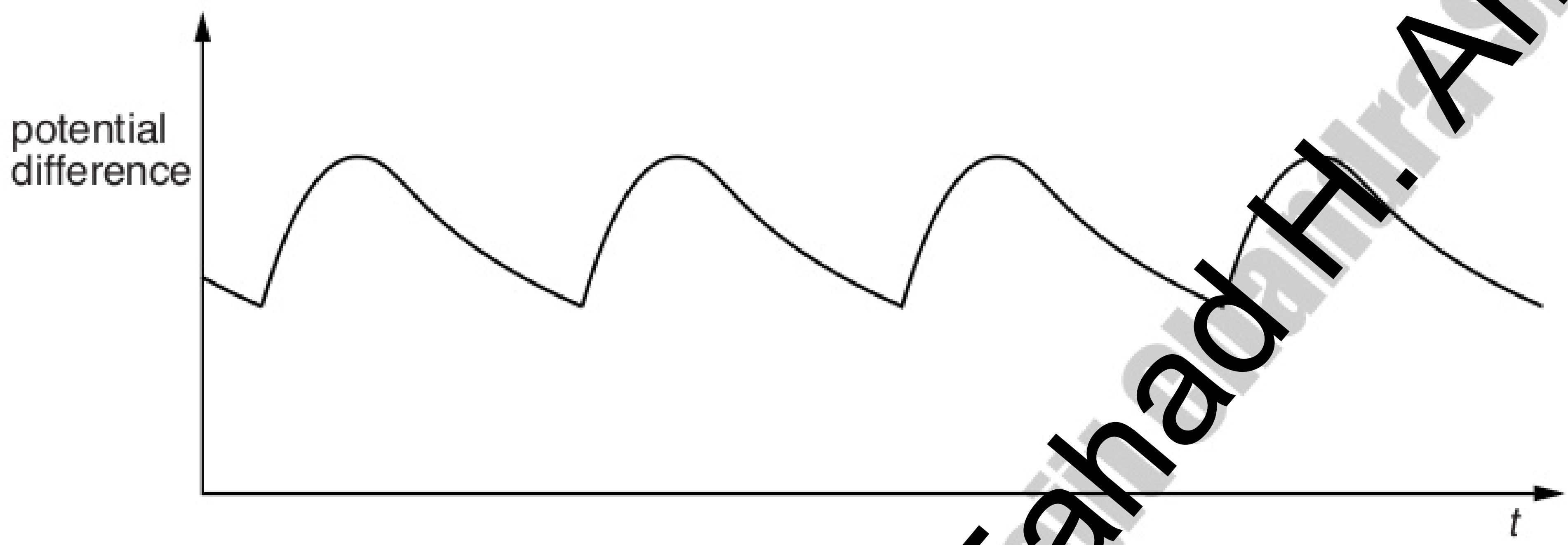


Fig. 7.4

1. State how the amount of smoothing may be increased.

....

.... [1]

2. On Fig. 7.4, draw the variation with time *t* of the potential difference across resistor R for increased smoothing. [2]

[October November 2009]

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

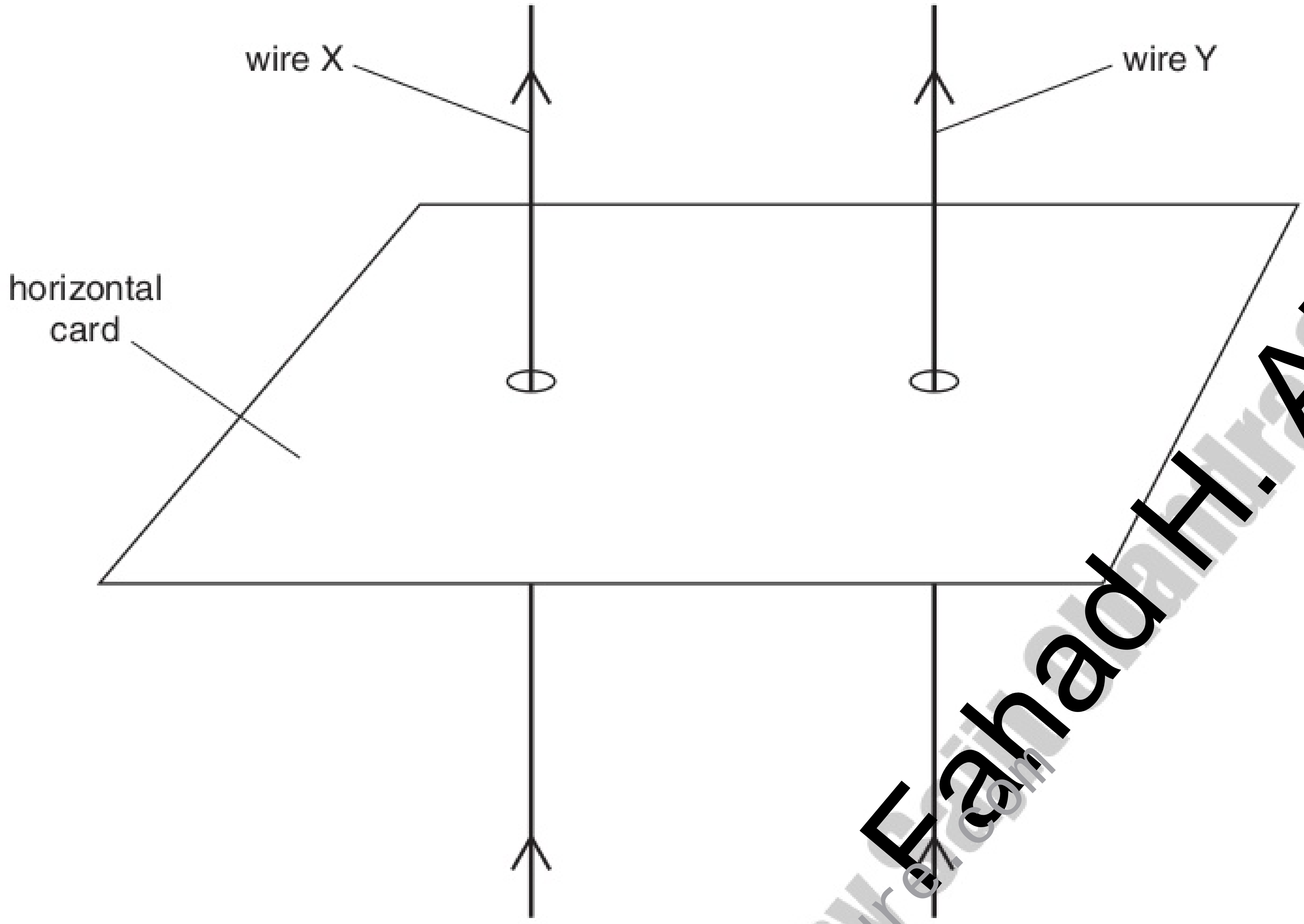


Fig. 5.1

The current in each wire is in the upward direction.

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

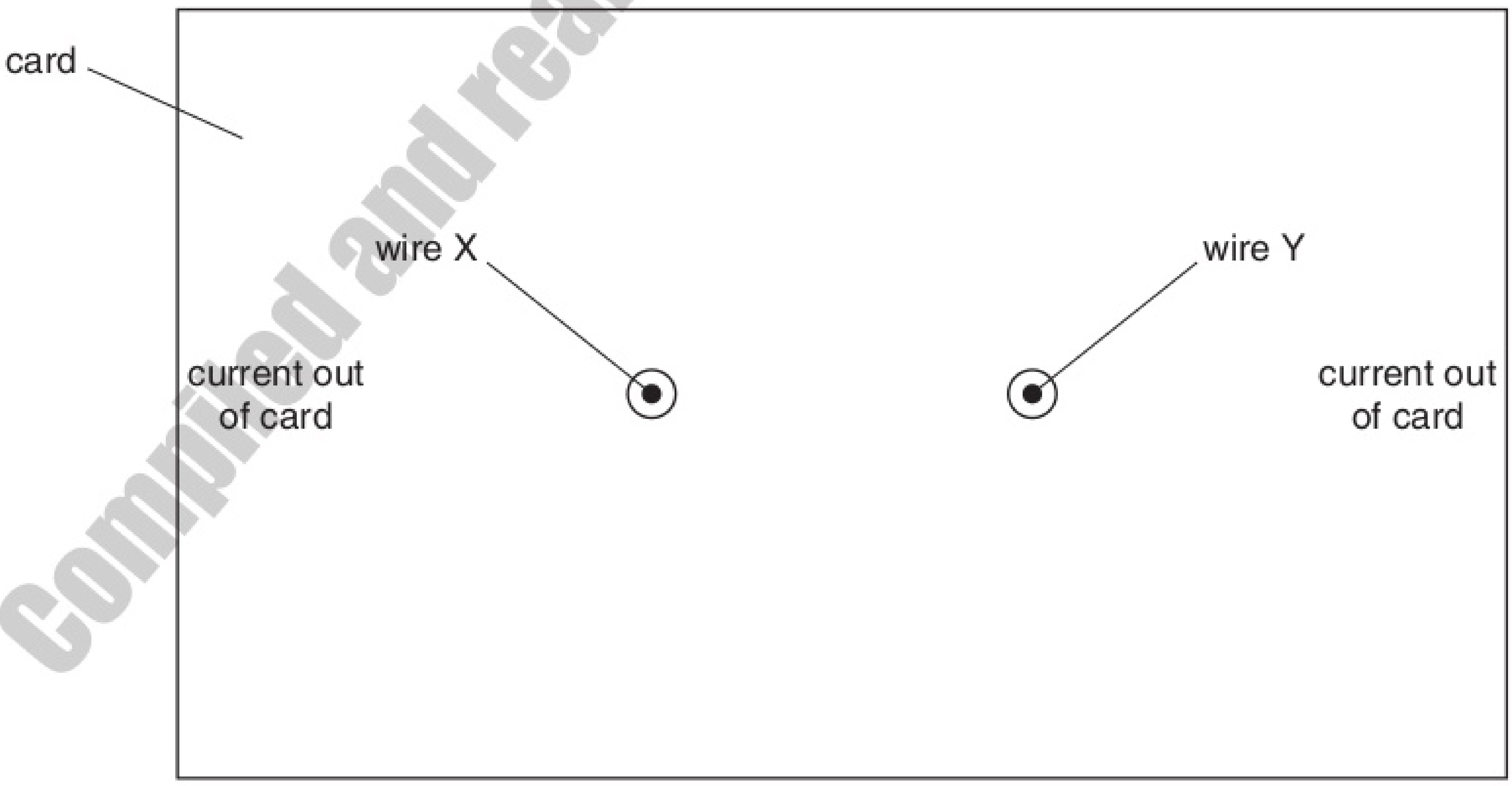


Fig. 5.2 (not to scale)

(a) On Fig. 5.2,

(i) draw four field lines to represent the pattern of the magnetic field around wire X due solely to the current in wire X, [2]

(ii) draw an arrow to show the direction of the force on wire Y due to the magnetic field of wire X. [1]

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

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

where μ_0 is the permeability of free space.

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

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

force per unit length = ... $N m^{-1}$ [4]

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

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

....

....

.... [2]

23 An ideal transformer is illustrated in Fig. 6.1. [October November 2009]

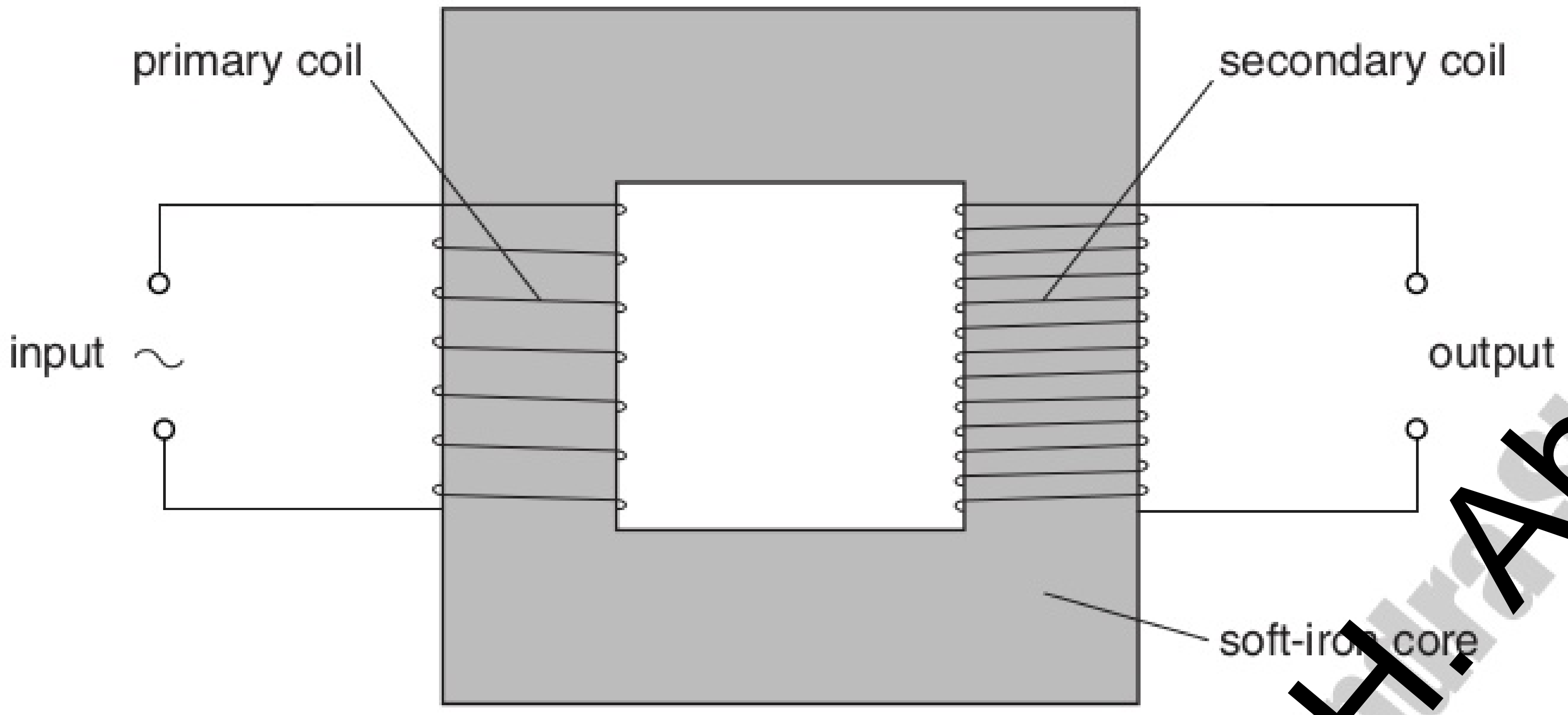


Fig. 6.1

(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.

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

(i) alternating voltage, ...

.... [1]

(ii) high voltage. ....

.... [1]

For Examiner's Use

24 **(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.

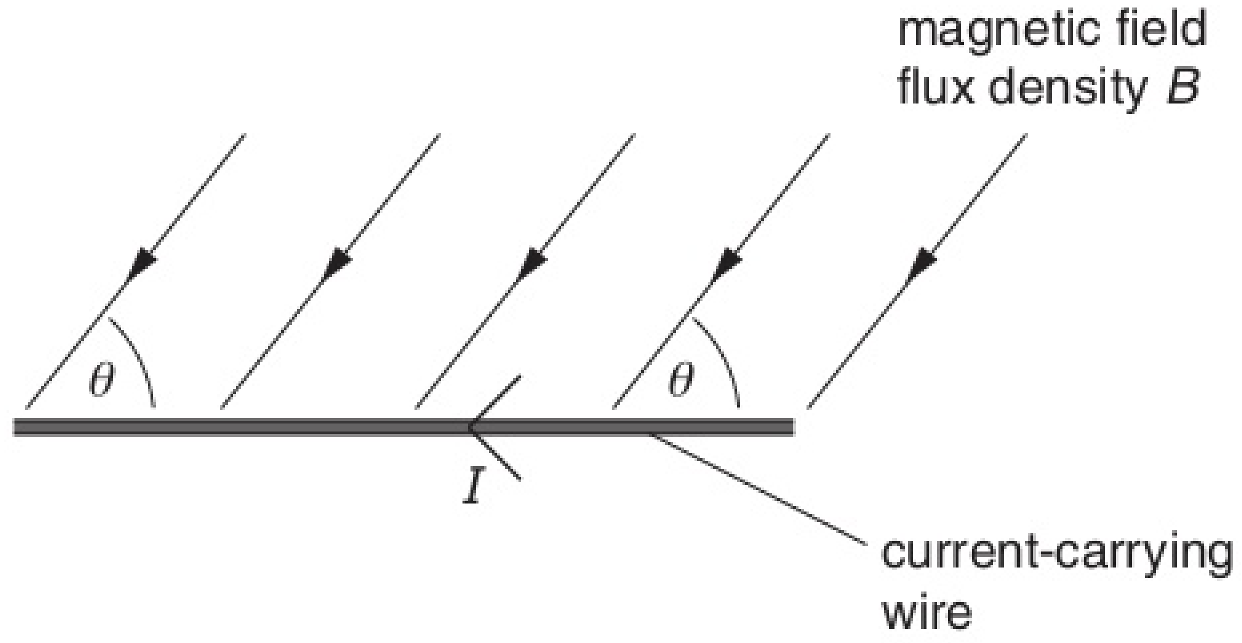


Fig. 6.1

(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.

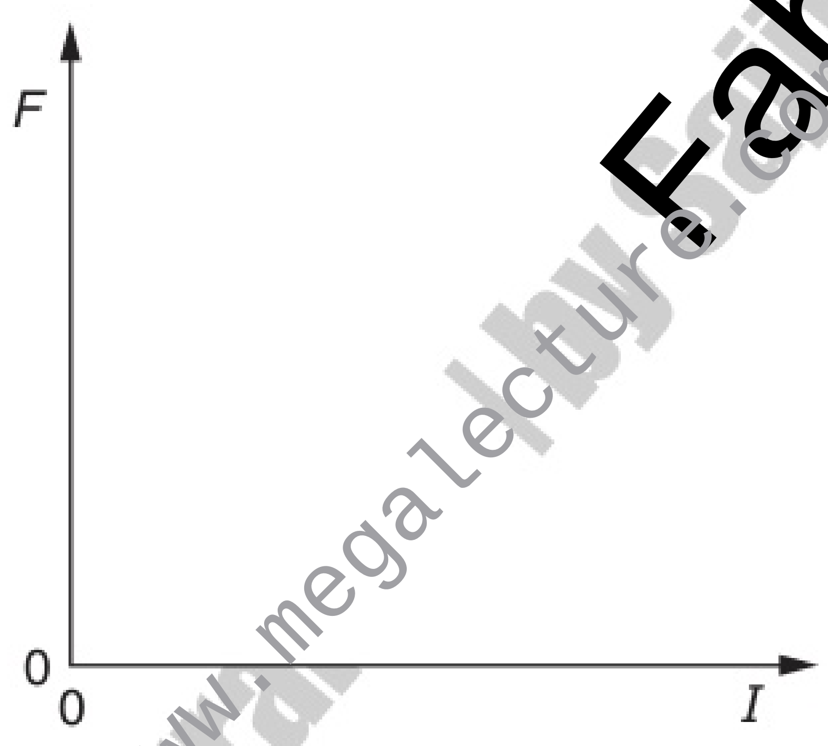


Fig. 6.2

[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.

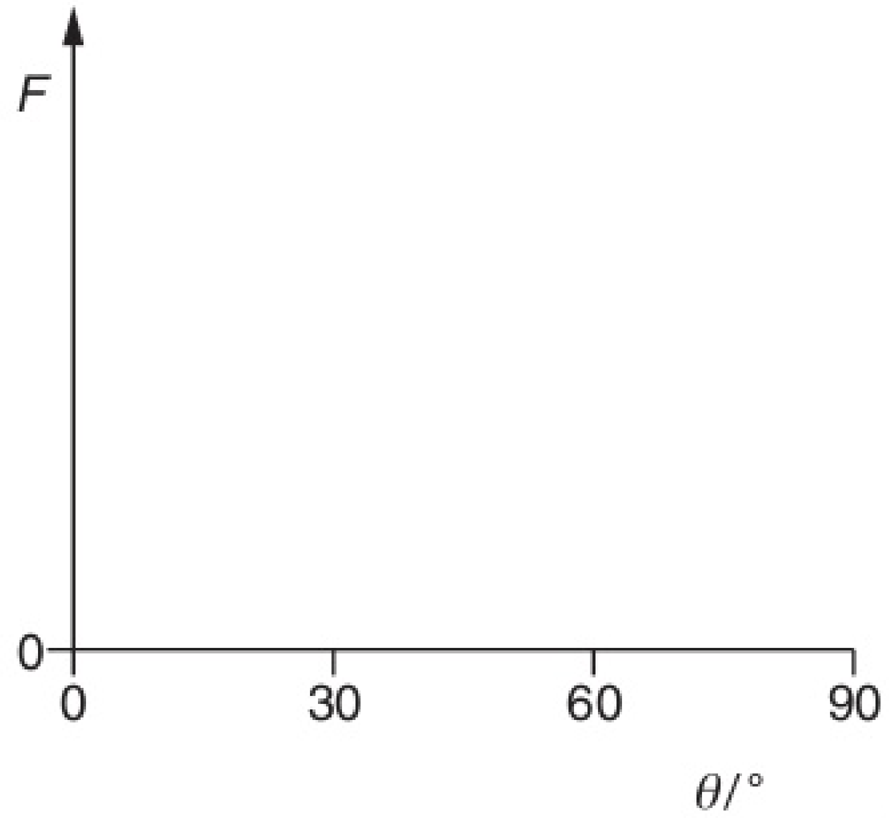


Fig. 6.3 [3]

(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.

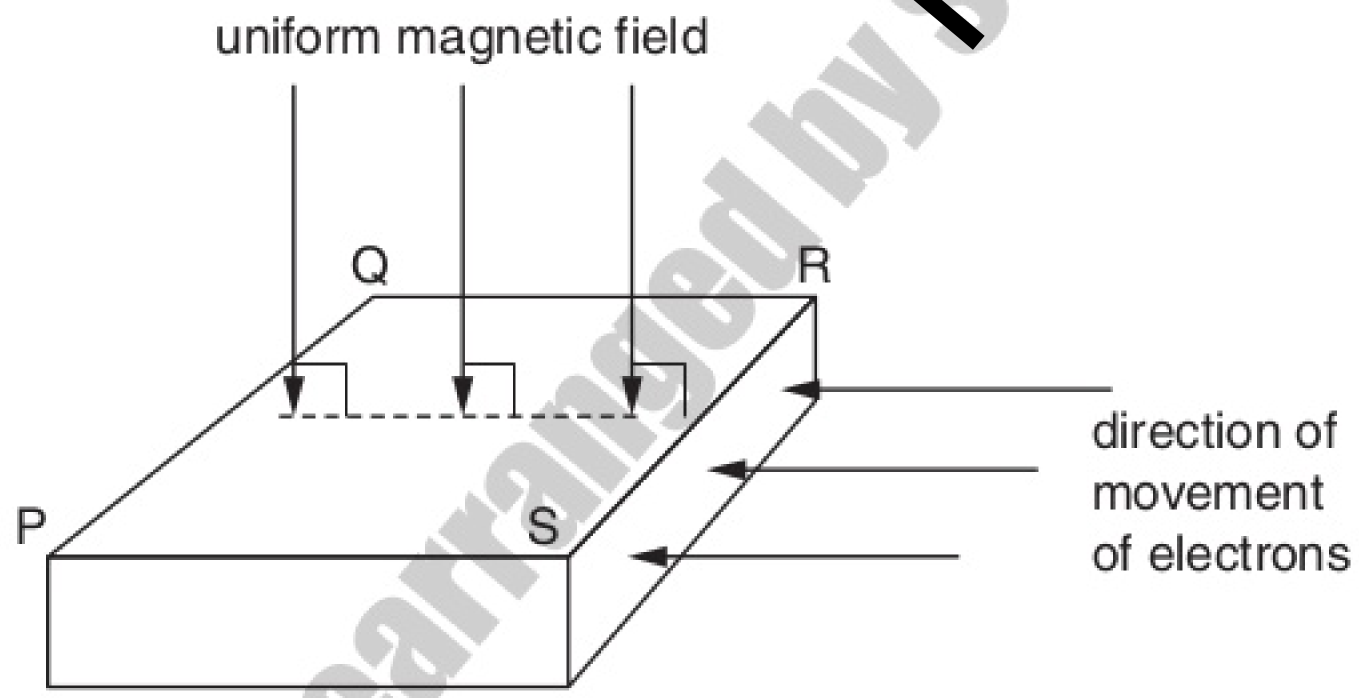


Fig. 6.4

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]

For Examiner's Use

25 **(a)** Explain what is meant by the *root-mean-square* (r.m.s.) value of an alternating voltage.

....

....

.... [2]

(b) An alternating voltage V is represented by the equation

$$V = 220 \sin(120\pi t),$$

where V is measured in volts and t is in seconds.

For this alternating voltage, determine

(i) the peak voltage,

peak voltage = ... V [1]

(ii) the r.m.s. voltage,

r.m.s. voltage = ... V [1]

(iii) the frequency.

frequency = ... Hz [1]

(c) The alternating voltage in **(b)** is applied across a resistor such that the mean power output from the resistor is 1.5 kW.

Calculate the resistance of the resistor.

resistance = ... Ω [2]

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

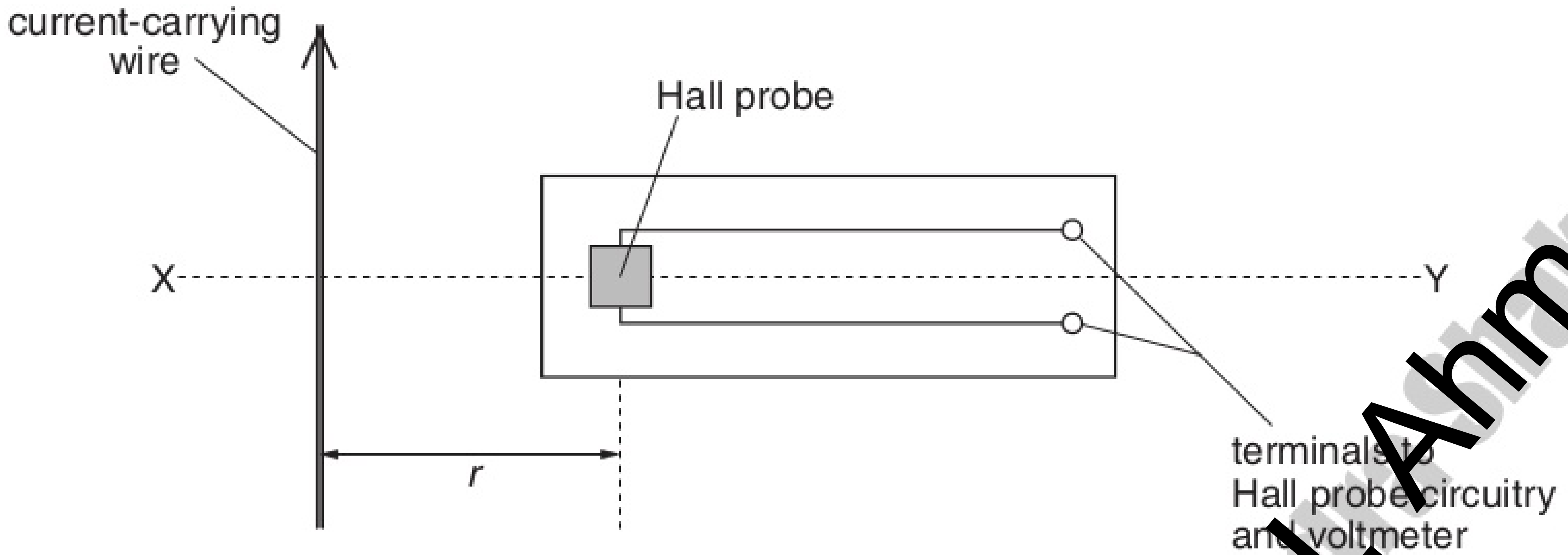


Fig. 5.1

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

....

....

.... [2]

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

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

Fig. 5.2

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

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

where *k* is a constant.

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

[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]

27 A student is asked to design a circuit by which a direct voltage of peak value 9.0V is obtained from a 240V alternating supply.
The student uses a transformer that may be considered to be ideal and a bridge rectifier incorporating four ideal diodes.
The partially completed circuit diagram is shown in Fig. 6.1.

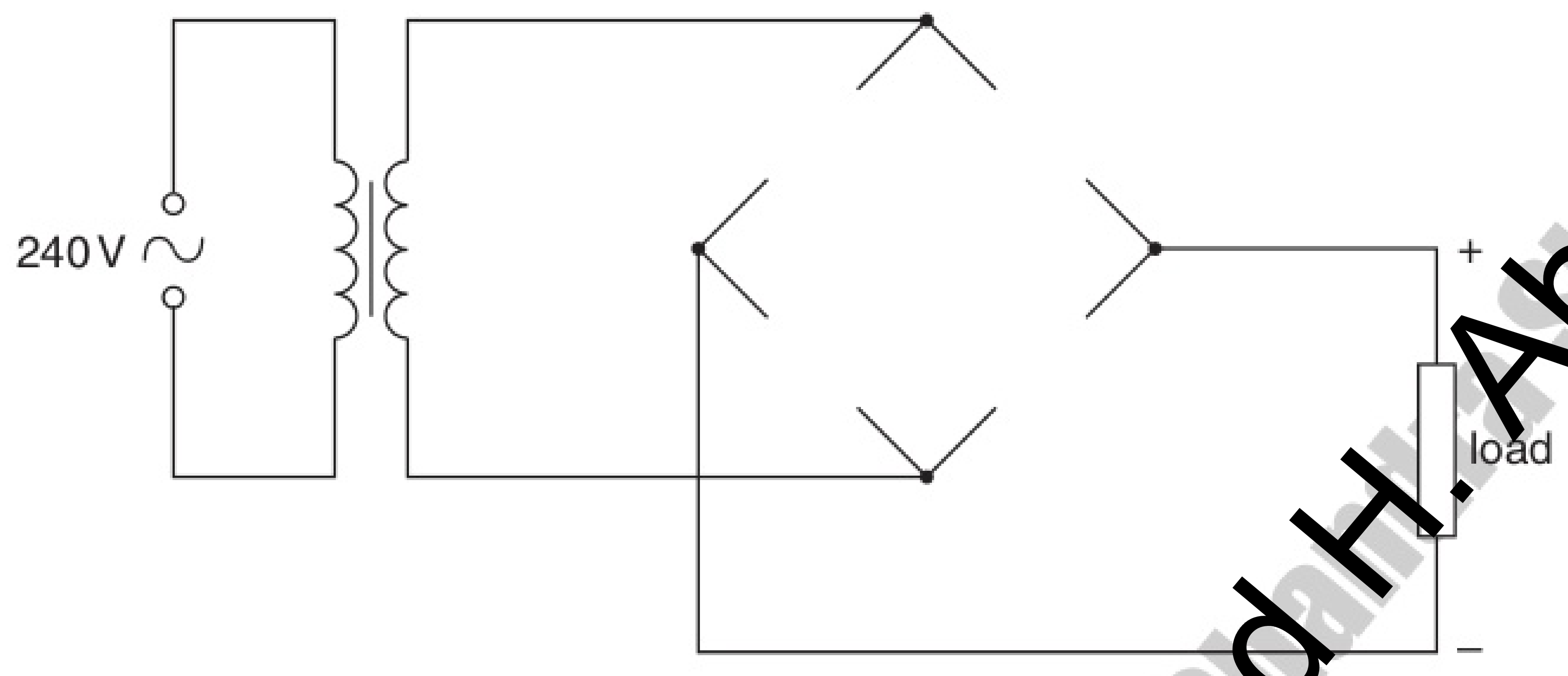


Fig. 6.1

(a) On Fig. 6.1, draw symbols for the four diodes so as to produce the polarity across the load as shown on the diagram. [2]

(b) Calculate the ratio

$$\frac{\text{number of turns on the secondary coil}}{\text{number of turns on the primary coil}}.$$

ratio = ... [3]

For Examiner's Use

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

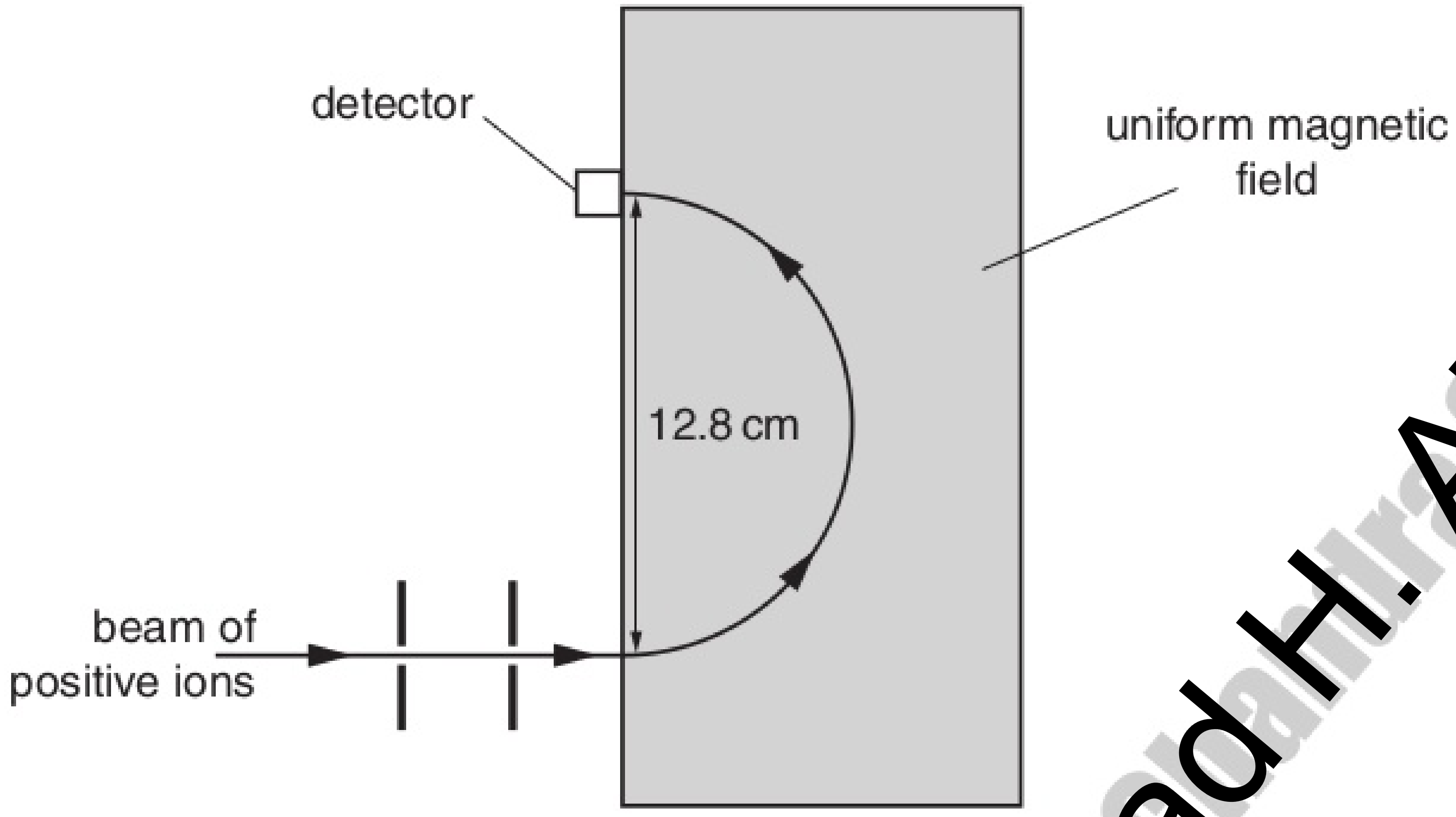


Fig. 5.1

The ions, travelling with speed $1.40 \times 10^5\,m\,s^{-1}$, 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]

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

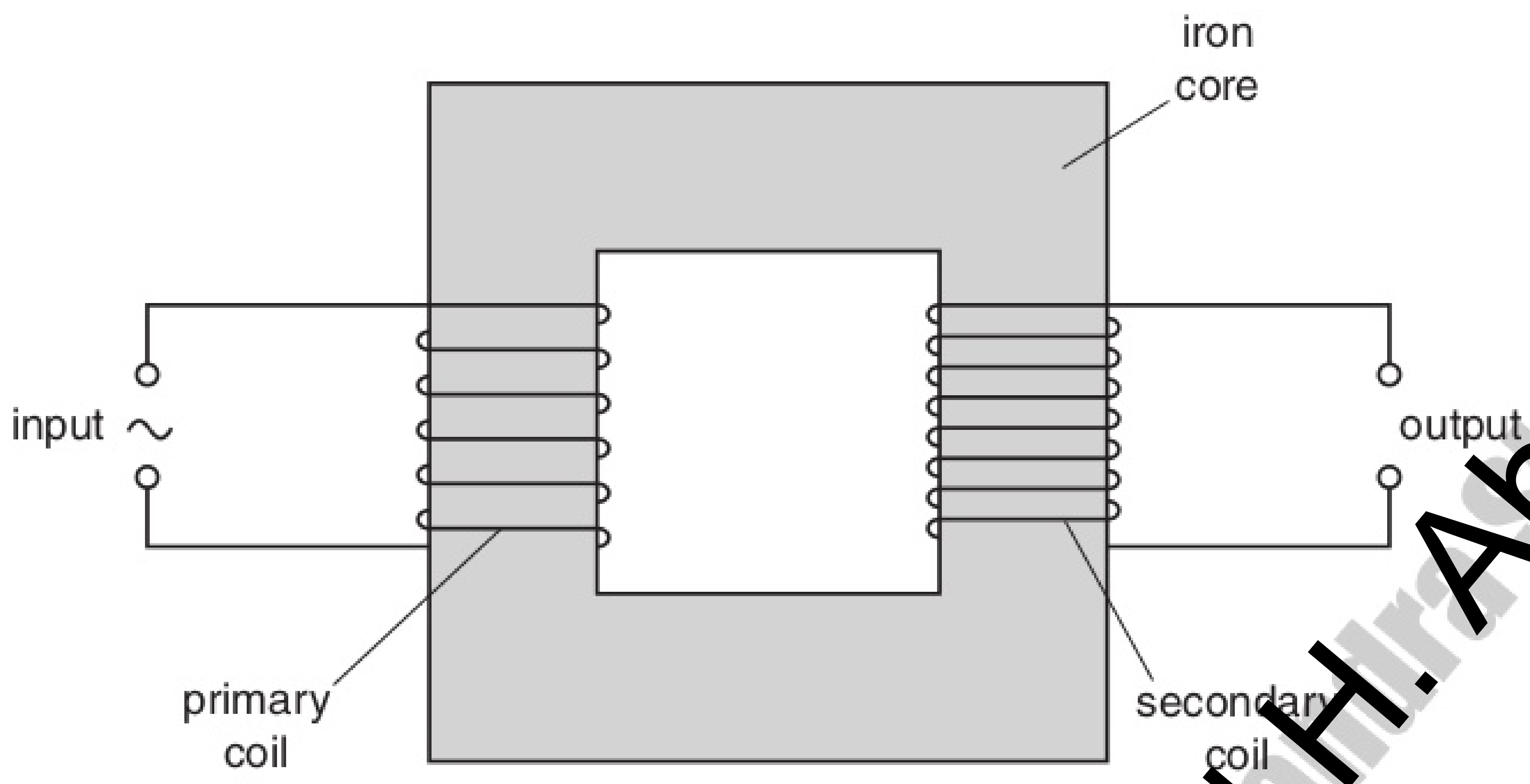


Fig. 6.1

(a) (i) State why the primary and secondary coils are wound on a core made of iron.

....

....

....[1]

(ii) Suggest why thermal energy is generated in the core when the transformer is in use.

....

....

....

....[3]

(b) The root-mean-square (r.m.s.) voltage and current in the primary coil are V_P and I_P respectively.
The r.m.s. voltage and current in the secondary coil are V_S and I_S respectively.

For Examiner's Use

(i) Explain, by reference to direct current, what is meant by the *root-mean-square* value of an alternating current.

....

....

.... [2]

(ii) Show that, for an ideal transformer,

$$\frac{V_S}{V_P} = \frac{I_P}{I_S}.$$

[2]

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

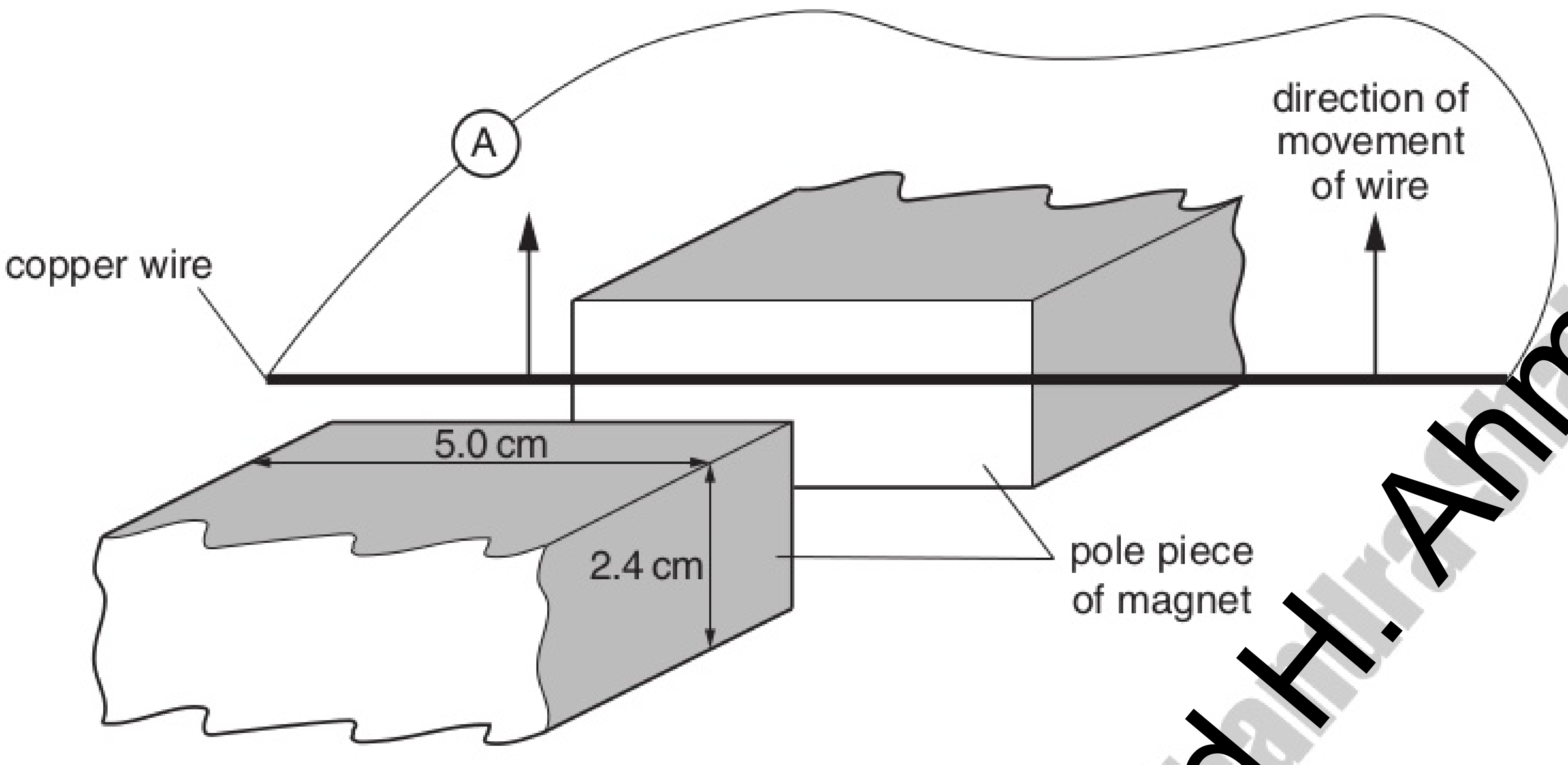


Fig. 5.1

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]

For Examiner's Use

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

[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]

6 The variation with time *t* of the current *I* in a resistor is shown in Fig. 6.1.

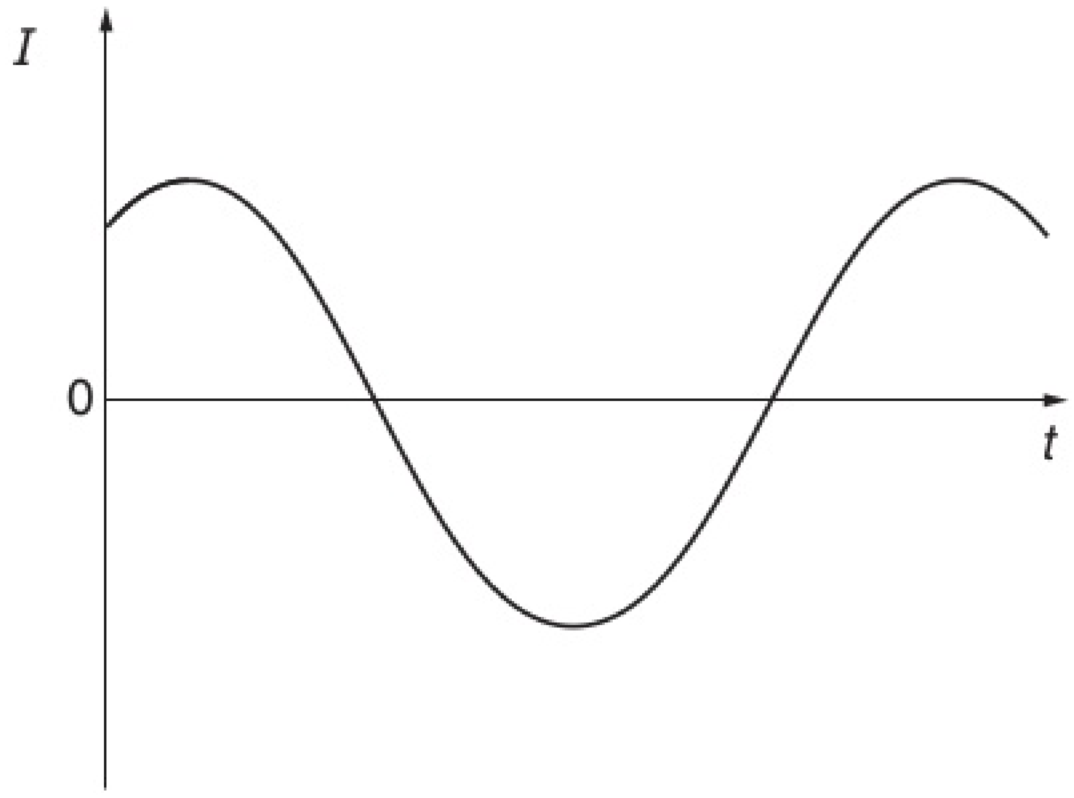


Fig. 6.1

The variation of the current with time is sinusoidal.

(a) Explain why, although the current is not in one direction only, power is converted in the resistor.

....

....

.... [2]

(b) Using the relation between root-mean-square (r.m.s.) current and peak current, deduce the value of the ratio

$$\frac{\text{average power converted in the resistor}}{\text{maximum power converted in the resistor}} .$$

ratio = ... [3]

6 A transformer is illustrated in Fig. 6.1.

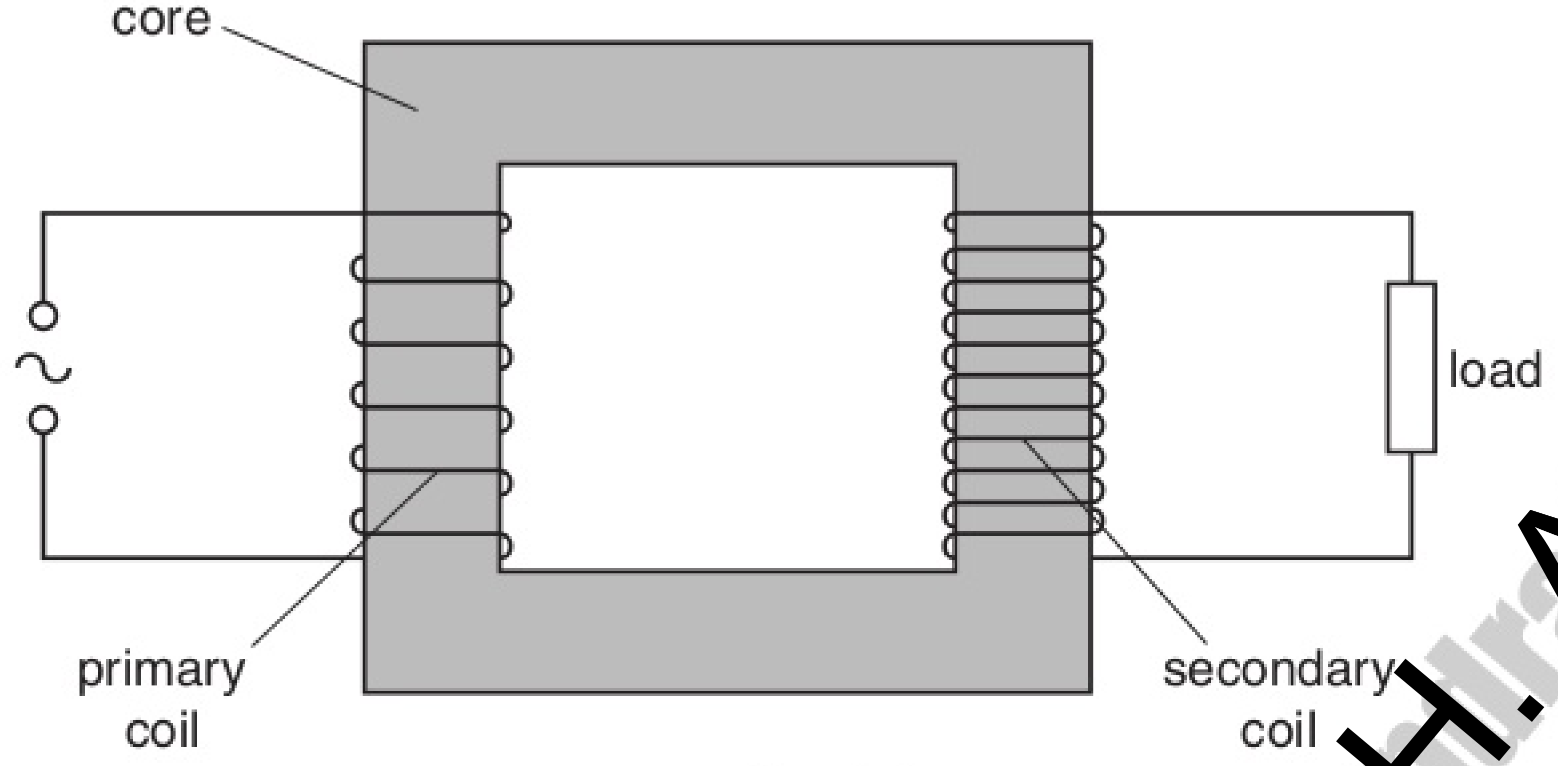


Fig. 6.1

(a) **(i)** Explain why the coils are wound on a core made of iron.

....

....[1]

(ii) Suggest why thermal energy is generated in the core.

....

....

....[2]

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

....

....

....[2]

(ii) Use Faraday's law to explain why the potential difference across the load and the e.m.f. of the supply are not in phase.

....

....

....

....[2]

For Examiner's Use

(c) Electrical energy is usually transmitted using alternating current. Suggest why the transmission is achieved using

(i) high voltages,

....

....

....[2]

(ii) alternating current.

....

....[1]

For Examiner's Use

6 An alternating current supply is connected in series with a resistor R, as shown in Fig. 6.1.

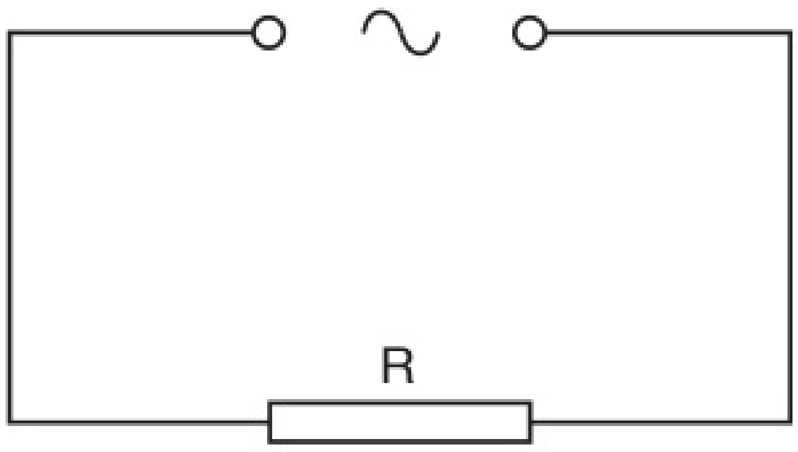


Fig. 6.1

The variation with time t (measured in seconds) of the current I (measured in amps) in the resistor is given by the expression

$$I = 9.9\sin(380t).$$

(a) For the current in the resistor R, determine

(i) the frequency,

frequency = ... Hz [2]

(ii) the r.m.s. current.

r.m.s. current = ... A [2]

For Examiner's Use

(b) To prevent over-heating, the mean power dissipated in resistor R must not exceed 400 W.
Calculate the minimum resistance of R.

resistance = ... Ω [2]

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

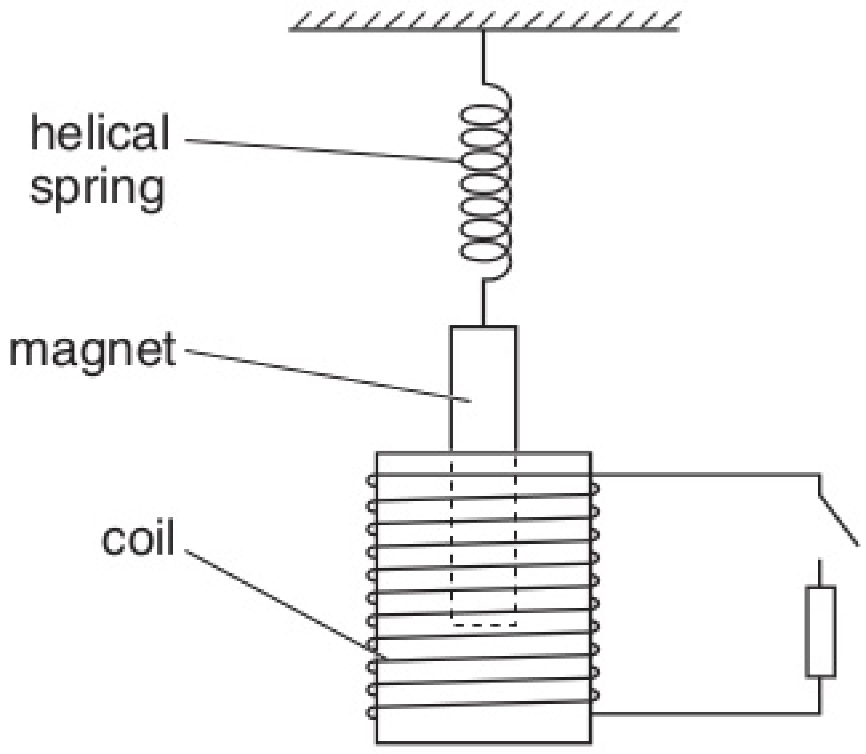


Fig. 3.1

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

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

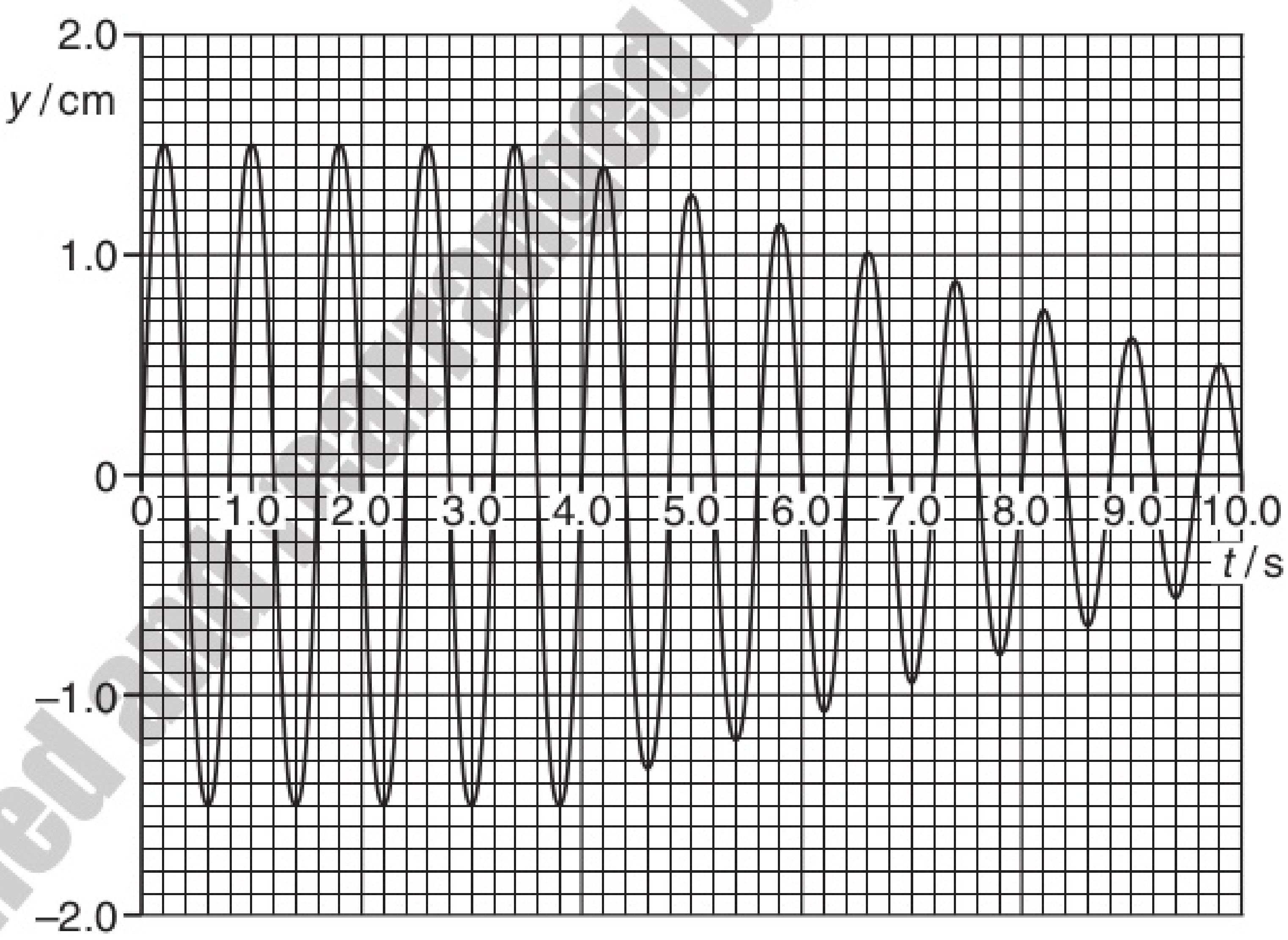


Fig. 3.2

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

(a) Use Fig. 3.2 to

(i) state the evidence for the magnet to be undergoing free oscillations during the period t = 0 to t = 4.0 s,

....

....[1]

(ii) state, with a reason, whether the damping after time t = 4.0 s is light, critical or heavy,

....

....

....[2]

(iii) determine the natural frequency of vibration of the magnet on the spring.

frequency = ... Hz [2]

(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]

For Examiner's Use

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.

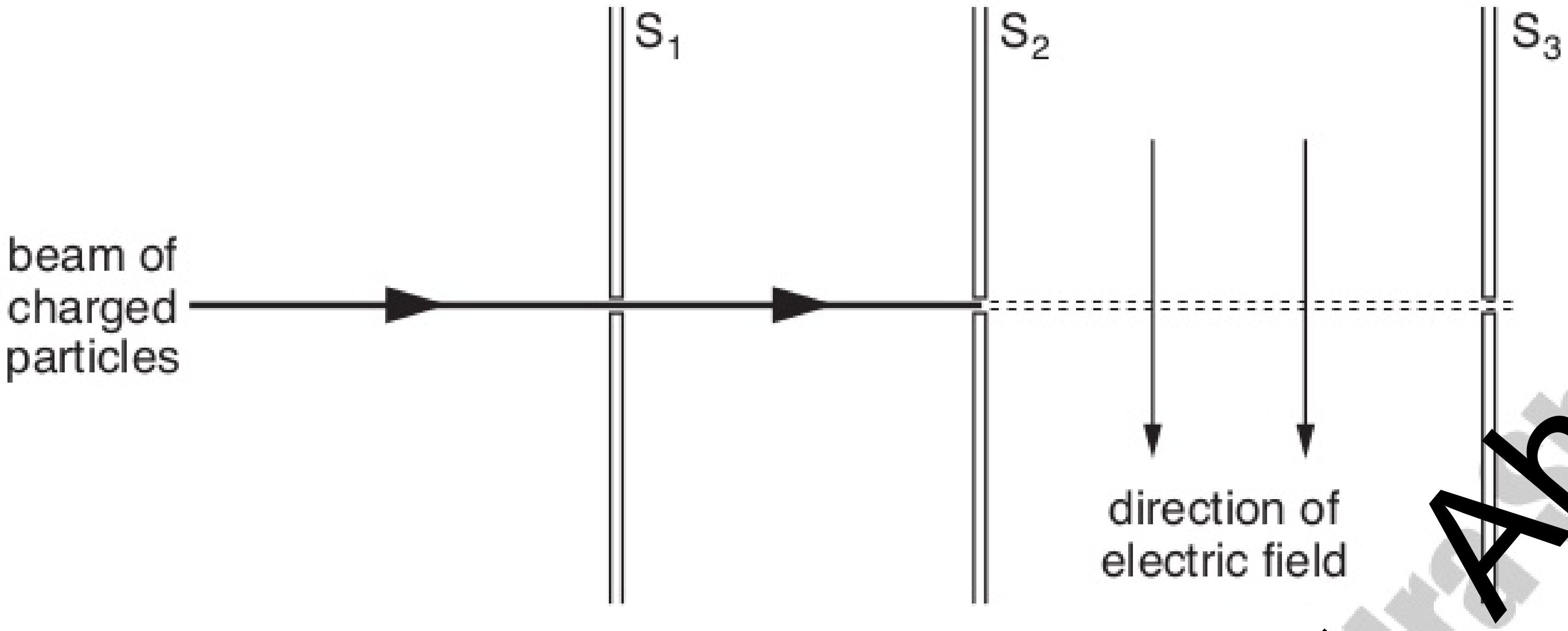


Fig. 5.1

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]

6 The variation with time t of the output V of an alternating voltage supply of frequency 50 Hz is shown in Fig. 6.1.

For Examiner's Use

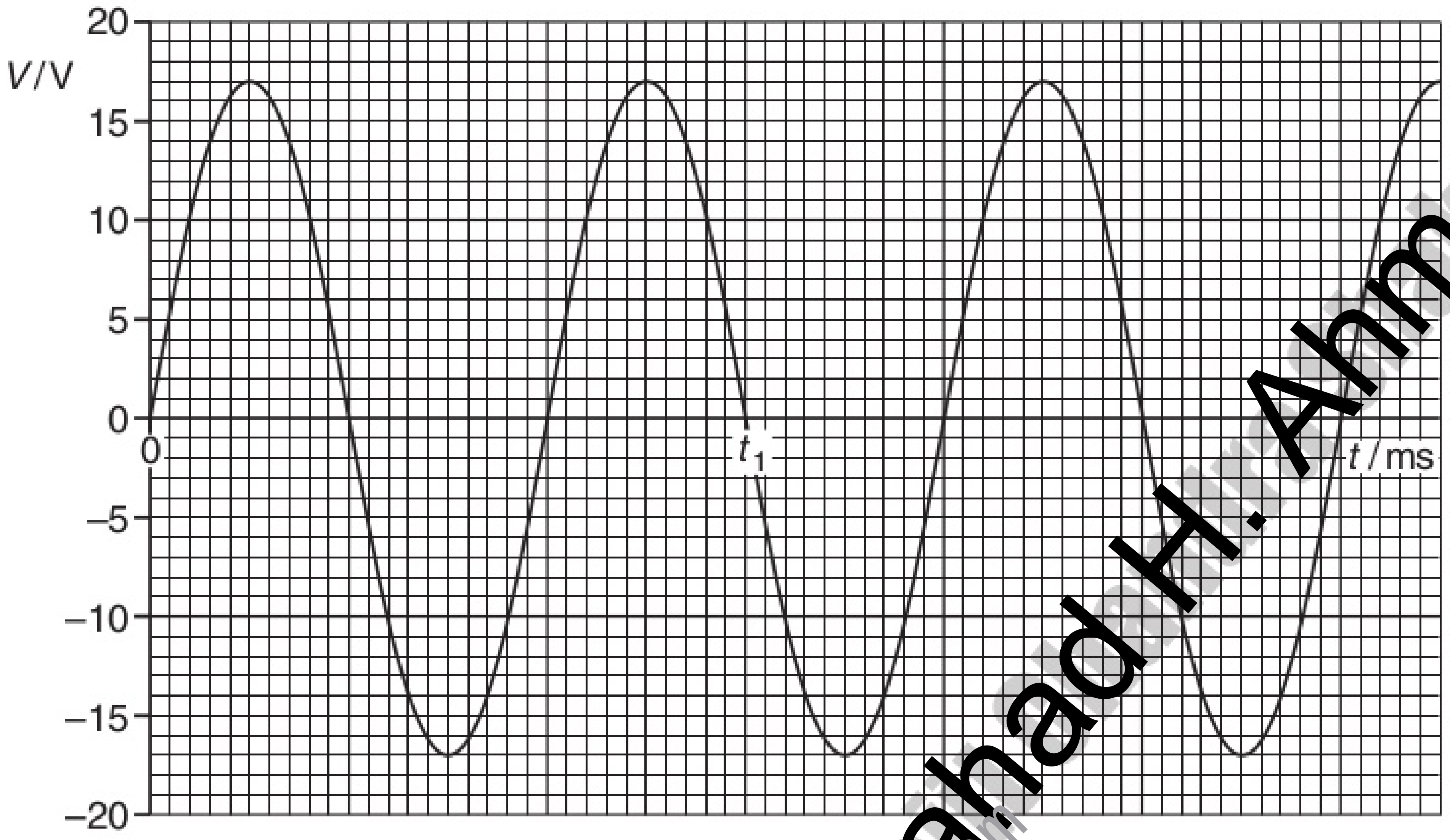


Fig. 6.1

(a) Use Fig. 6.1 to state

(i) the time t_1,

t_1 = ... s [2]

(ii) the peak value V_0 of the voltage,

V_0 = ... V [1]

(iii) the root-mean-square voltage V_{rms},

V_{rms} = ... V [1]

(iv) the mean voltage $<V>$.

$<V>$ = ... V [1]

For Examiner's Use

(b) The alternating supply is connected in series with a resistor of resistance 2.4 Ω. Calculate the mean power dissipated in the resistor.

power = ... W [2]

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

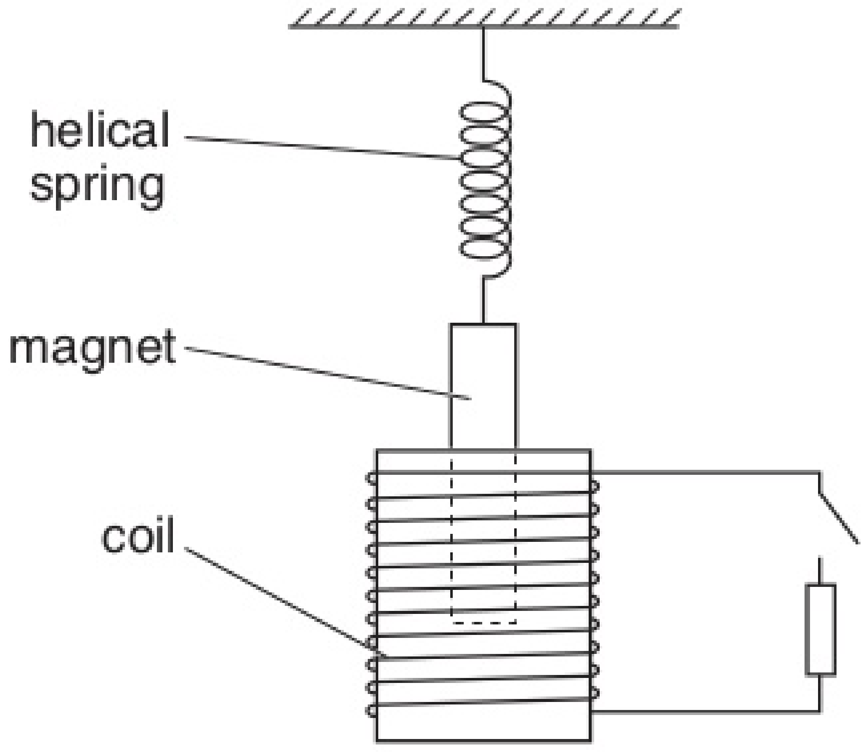


Fig. 3.1

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

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

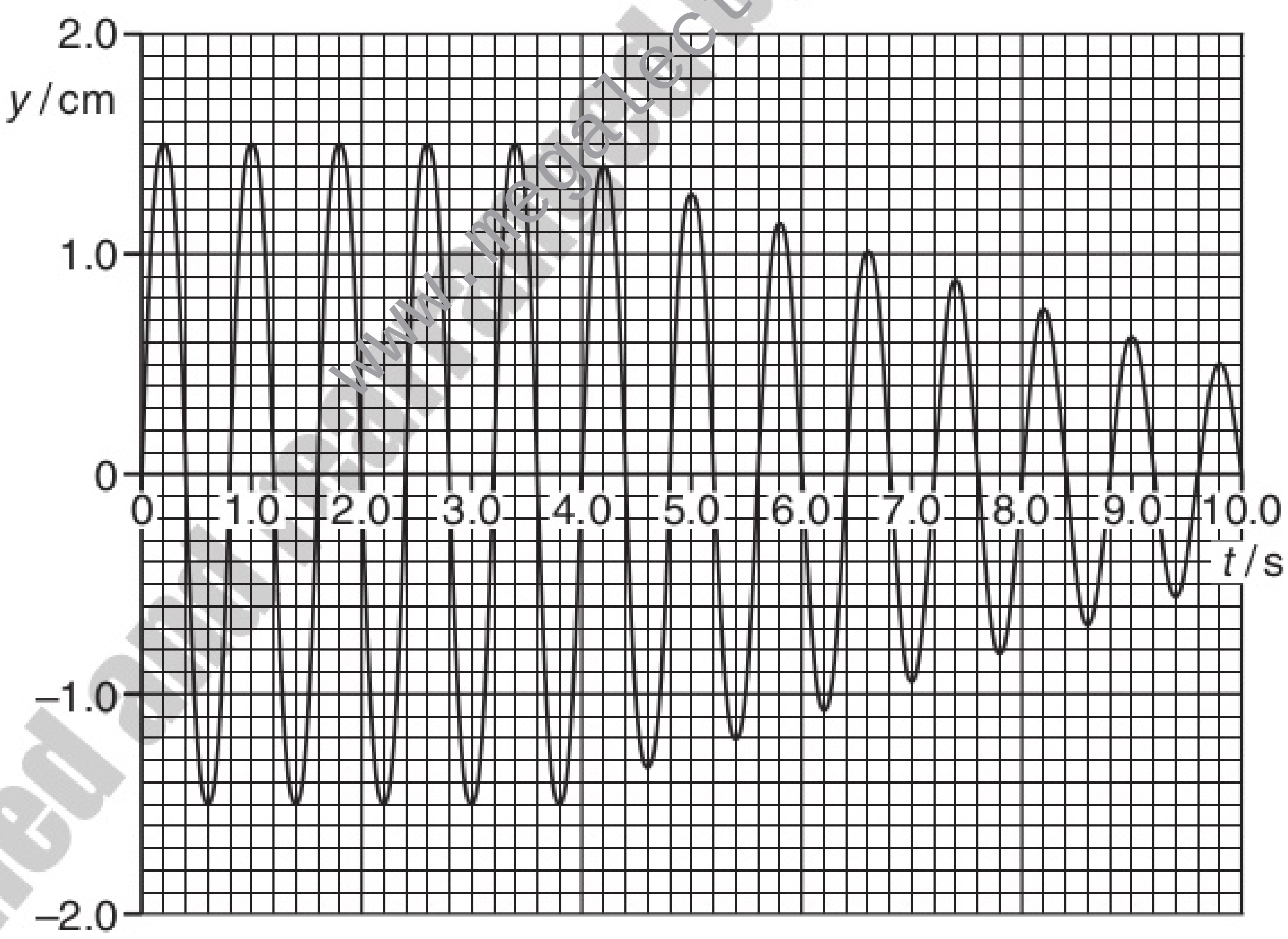


Fig. 3.2

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

(a) Use Fig. 3.2 to

(i) state the evidence for the magnet to be undergoing free oscillations during the period t = 0 to t = 4.0 s,

....

....

(ii) state, with a reason, whether the damping after time t = 4.0 s is light, critical or heavy,

....

....

....[2]

(iii) determine the natural frequency of vibration of the magnet on the spring.

frequency = ... Hz [2]

(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]

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.

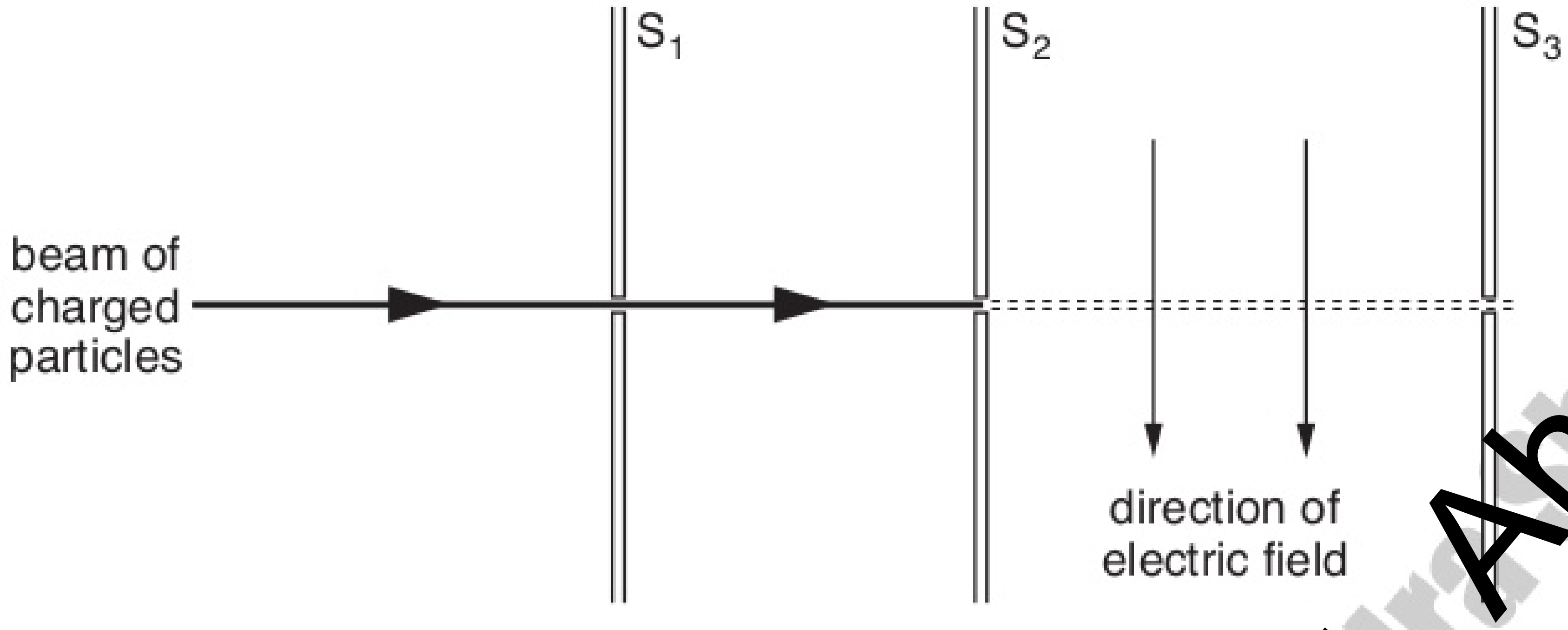


Fig. 5.1

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]

6 The variation with time t of the output V of an alternating voltage supply of frequency 50 Hz is shown in Fig. 6.1.

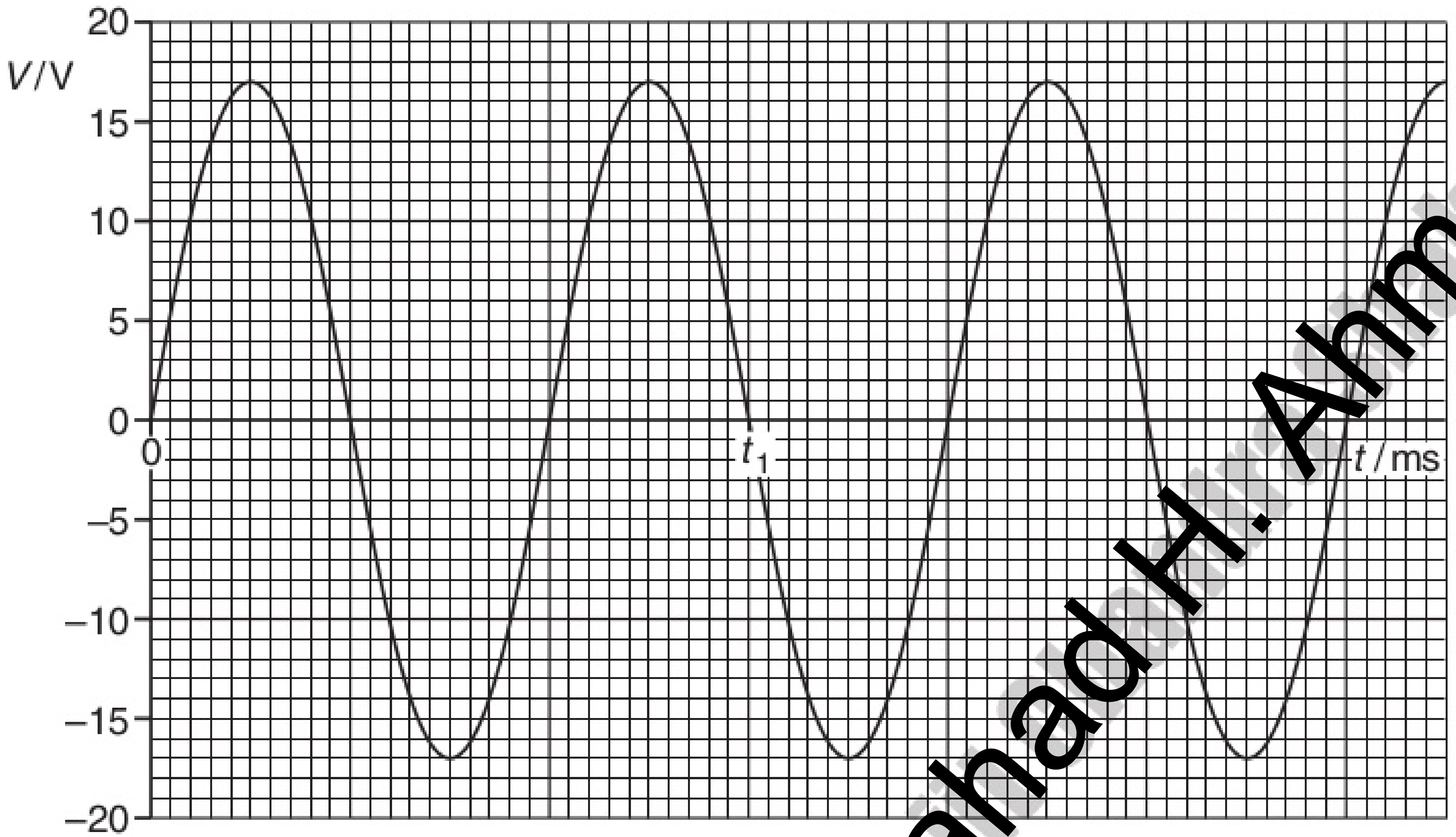


Fig. 6.1

(a) Use Fig. 6.1 to state

(i) the time t_1,

t_1 = ... s [2]

(ii) the peak value V_0 of the voltage,

V_0 = ... V [1]

(iii) the root-mean-square voltage V_{rms},

V_{rms} = ... V [1]

(iv) the mean voltage <V>.

<V> = ... V [1]

For Examiner's Use

(b) The alternating supply is connected in series with a resistor of resistance 2.4 Ω. Calculate the mean power dissipated in the resistor.

power = ... W [2]

5 The components for a bridge rectifier are shown in Fig. 5.1.

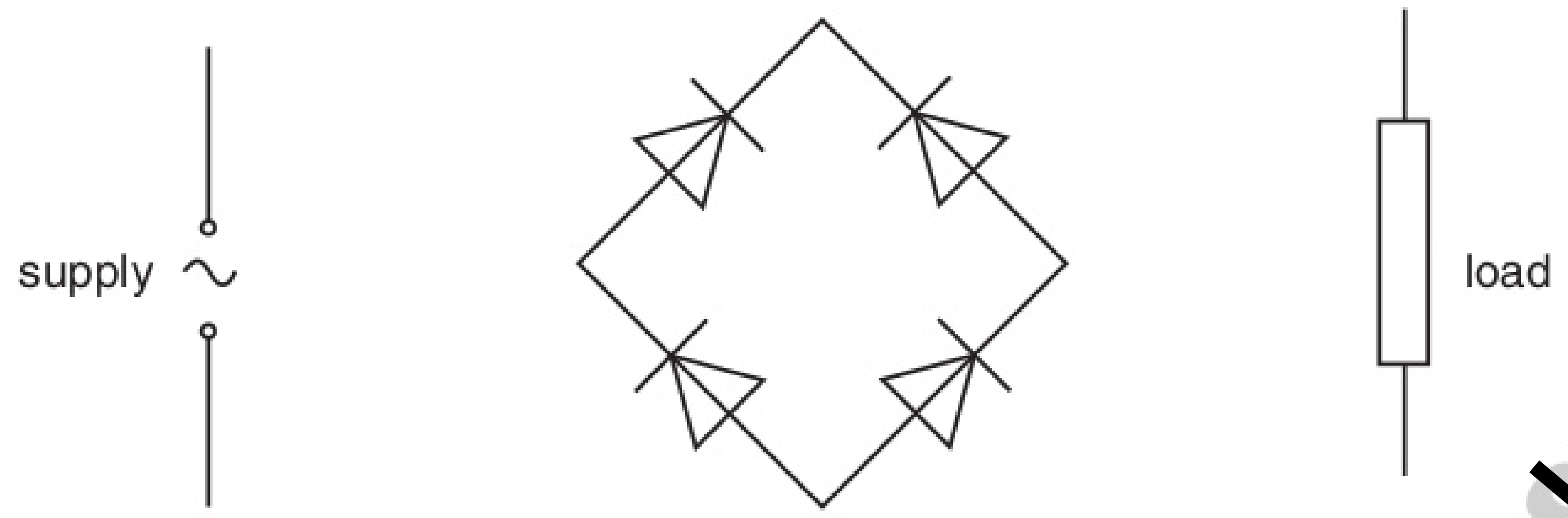


Fig. 5.1

(a) Complete the circuit of Fig. 5.1 by showing the connections of the supply and of the load to the diodes. [2]

(b) Suggest one advantage of the use of a bridge rectifier, rather than a single diode, for the rectification of alternating current.

....

.... [1]

(c) State

(i) what is meant by *smoothing*,

....

.... [1]

(ii) the effect of the value of the capacitance of the smoothing capacitor in relation to smoothing.

....

....

.... [2]

For Examiner's Use

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

....

....

....

.... [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.

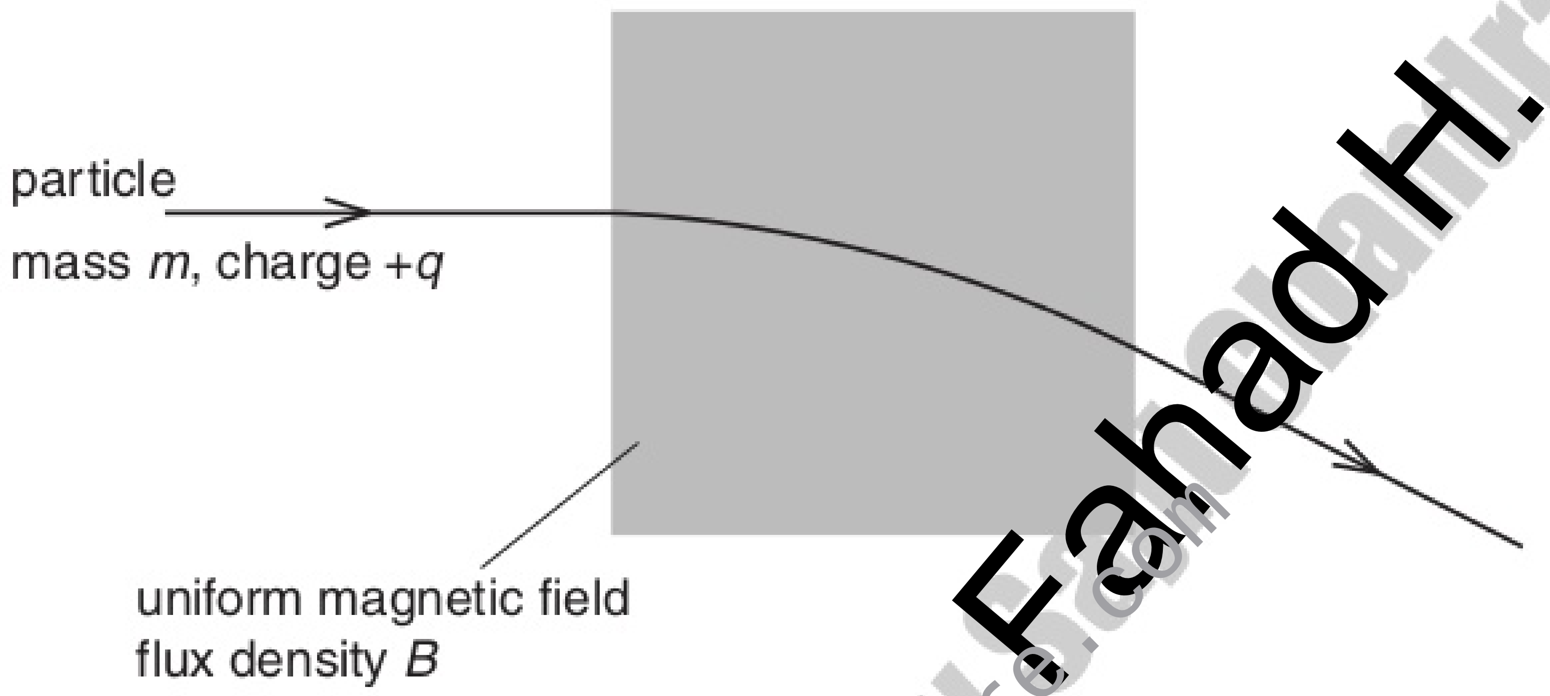


Fig. 6.1

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.

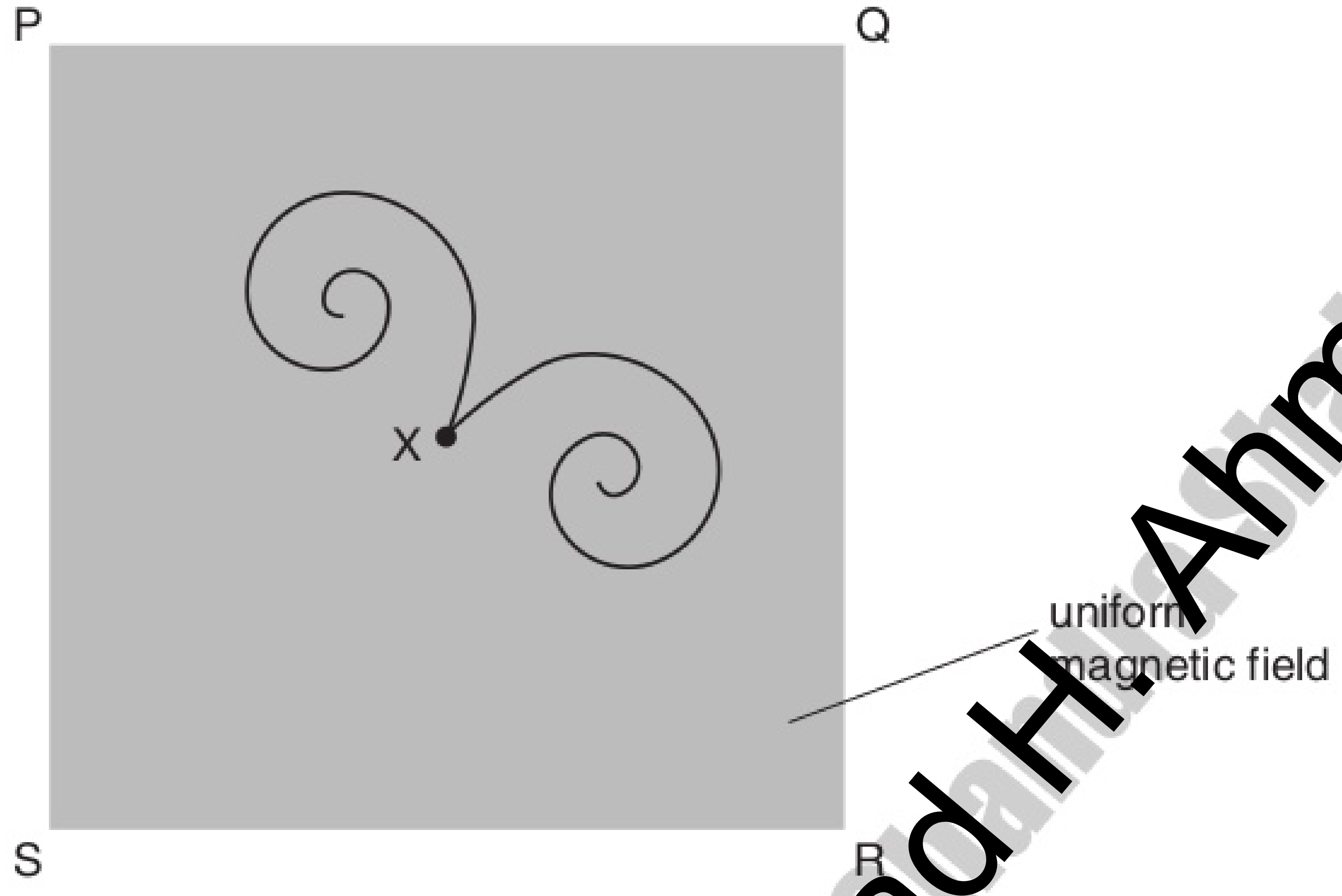


Fig. 6.2

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]

6 A sinusoidal alternating voltage supply is connected to a bridge rectifier consisting of four ideal diodes. The output of the rectifier is connected to a resistor R and a capacitor C as shown in Fig. 6.1.

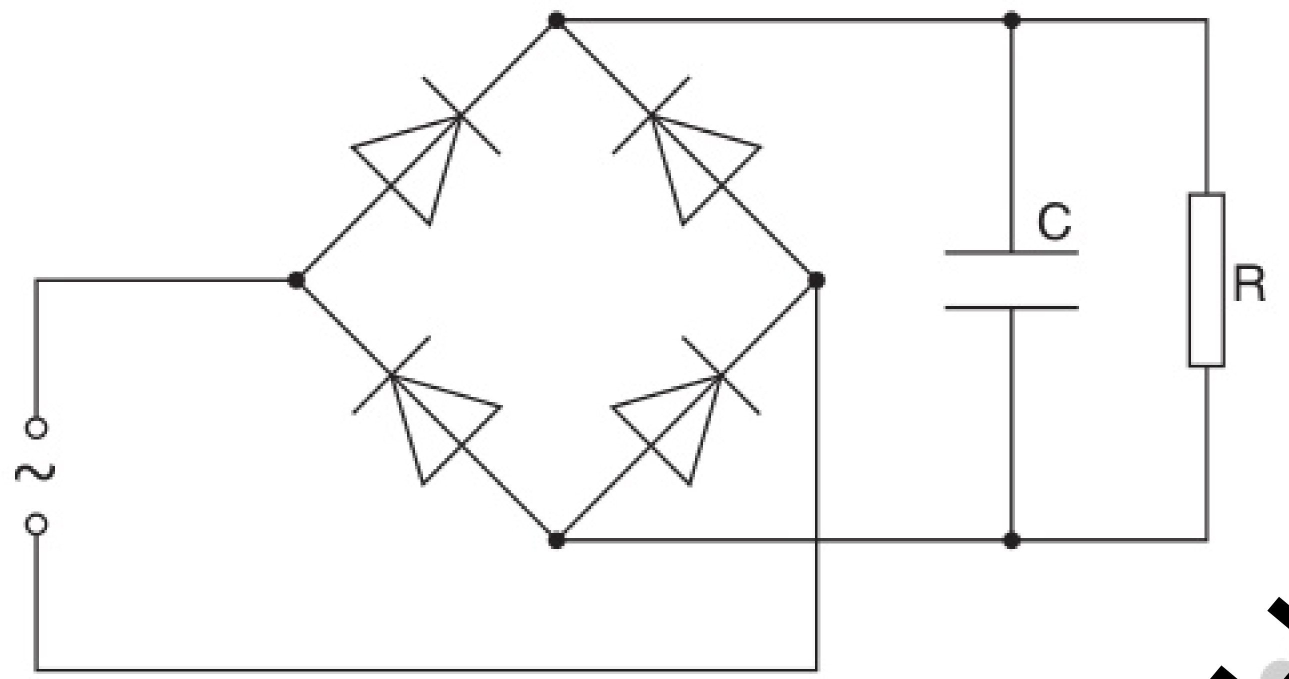


Fig. 6.1

The function of C is to provide some smoothing to the potential difference across R.
The variation with time *t* of the potential difference *V* across the resistor R is shown in Fig. 6.2.

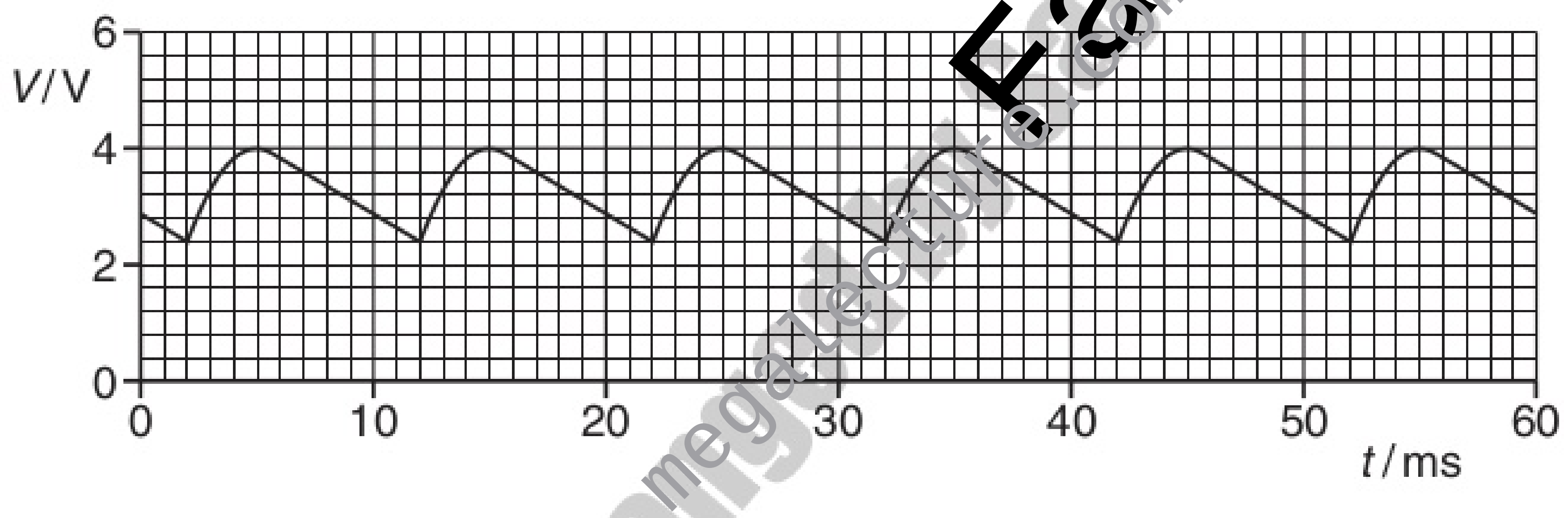


Fig. 6.2

(a) Use Fig. 6.2 to determine, for the alternating supply,

(i) the peak voltage,

peak voltage = ... V [1]

(ii) the root-mean-square (r.m.s.) voltage,

r.m.s. voltage = ... V [1]

(iii) the frequency. Show your working.

frequency = ... Hz [2]

(b) The capacitor C has capacitance 5.0 μF.
For a single discharge of the capacitor through the resistor R, use Fig. 6.2 to

(i) determine the change in potential difference,

change = ... V [1]

(ii) determine the change in charge on each plate of the capacitor,

change = ... C [2]

(iii) show that the average current in the resistor is 1.1×10^{-3} A.

[2]

For Examiner's Use

(c) Use Fig. 6.2 and the value of the current given in **(b)(iii)** to estimate the resistance of resistor R.

resistance = ... Ω [2]

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.

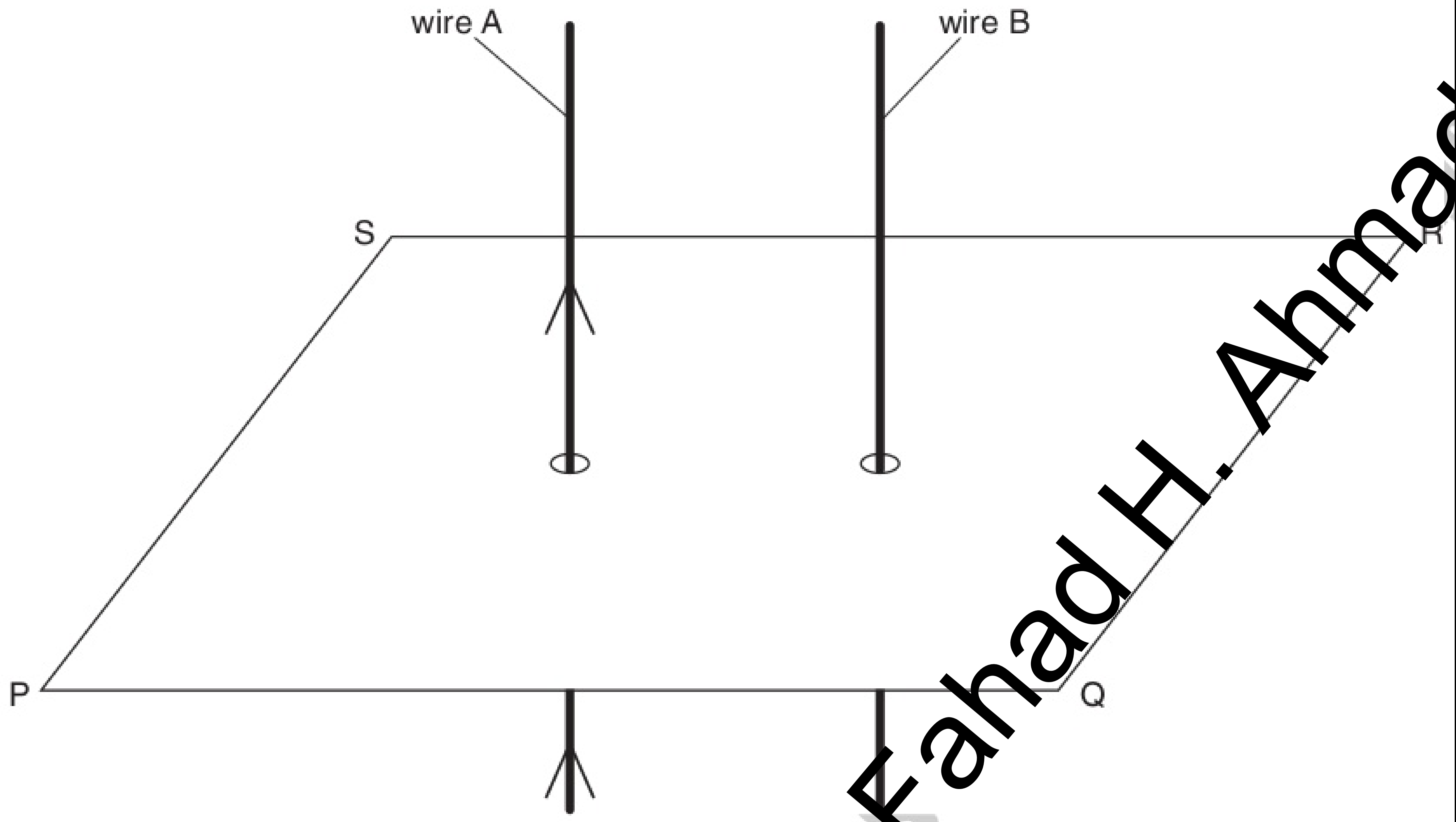


Fig. 7.1

(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]

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.

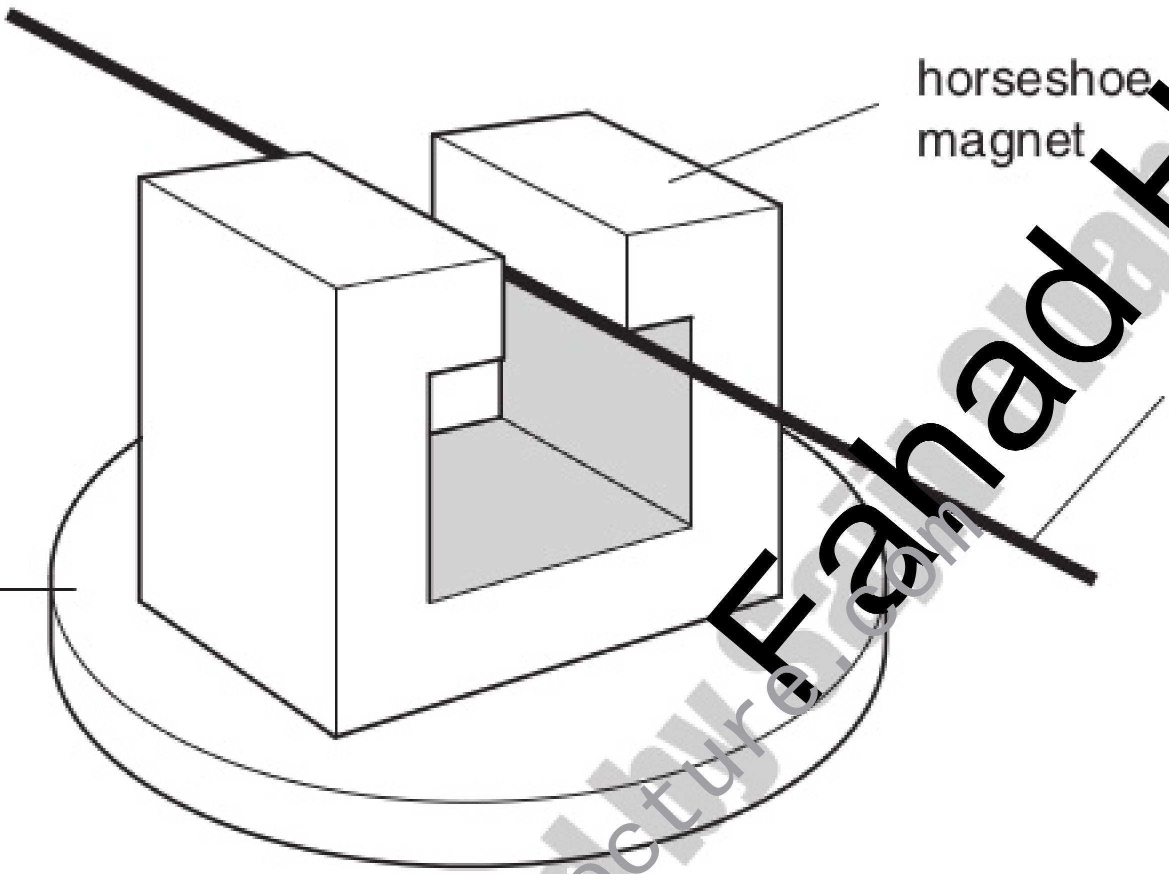


Fig. 5.1

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.

....

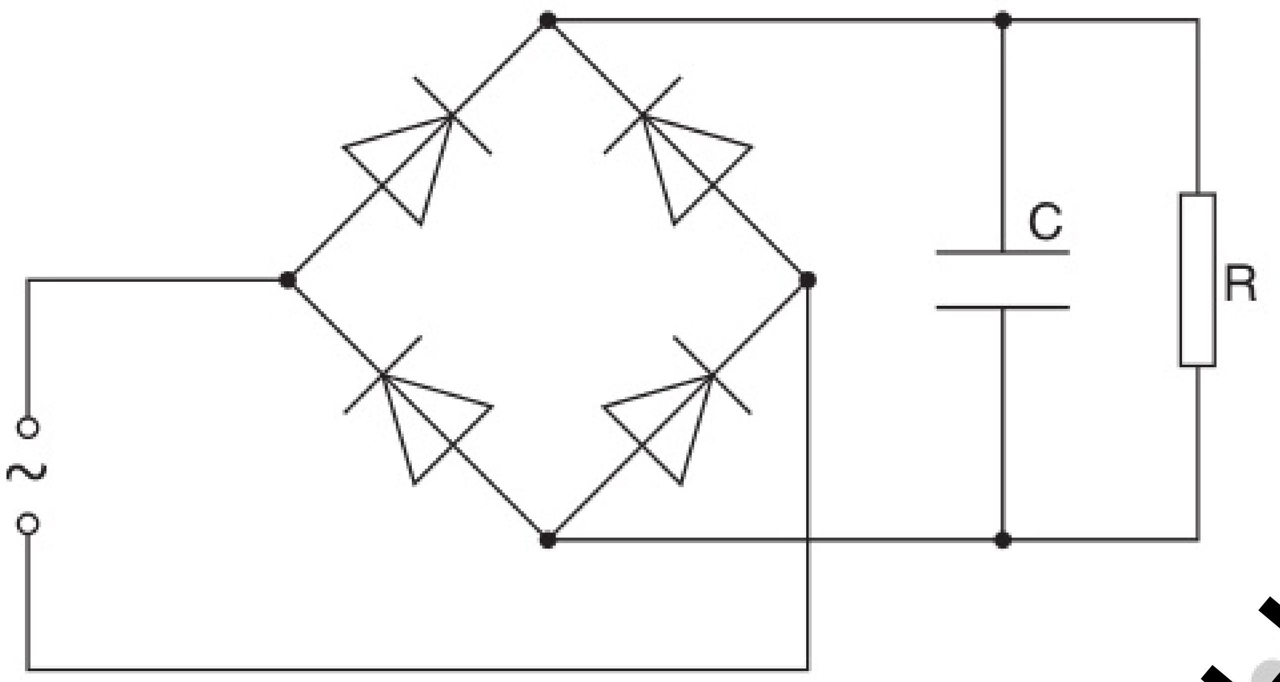
....

....

.... [2]

For Examiner's Use

6 A sinusoidal alternating voltage supply is connected to a bridge rectifier consisting of four ideal diodes. The output of the rectifier is connected to a resistor R and a capacitor C as shown in Fig. 6.1.



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The variation with time *t* of the potential difference *V* across the resistor R is shown in Fig. 6.2.

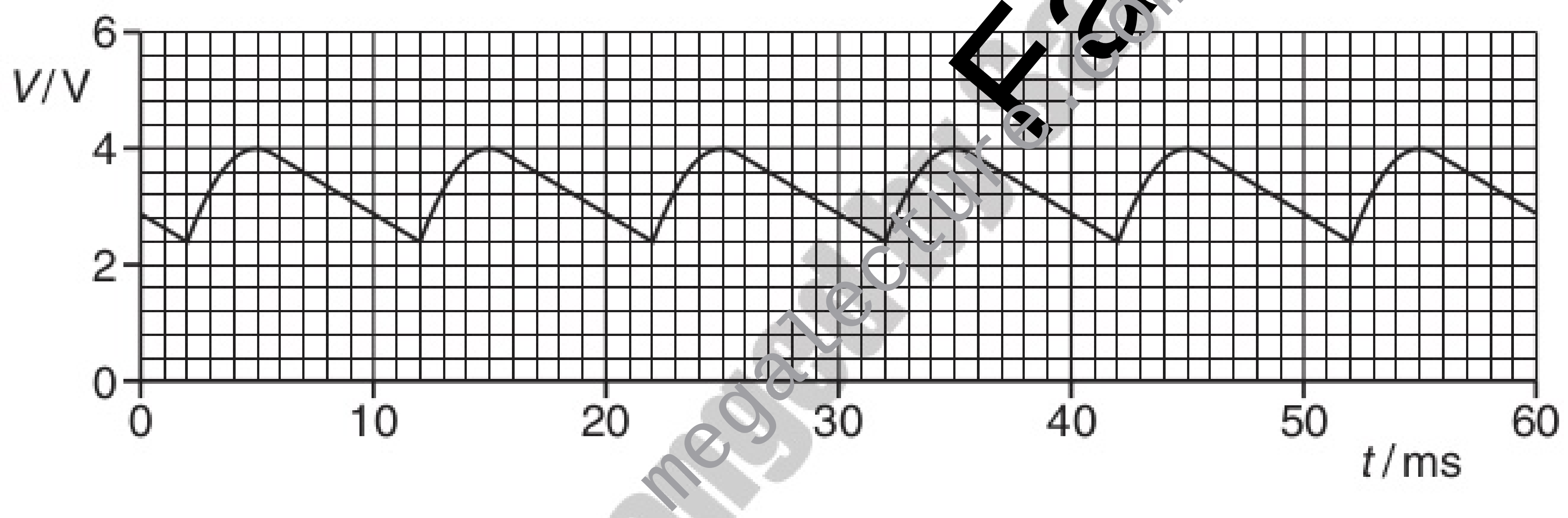

Fig. 6.2

(a) Use Fig. 6.2 to determine, for the alternating supply,

(i) the peak voltage,

peak voltage = ... V [1]

(ii) the root-mean-square (r.m.s.) voltage,

r.m.s. voltage = ... V [1]

For Examiner's Use

(iii) the frequency. Show your working.

frequency = ... Hz [2]

(b) The capacitor C has capacitance 5.0 μF.
For a single discharge of the capacitor through the resistor R, use Fig. 6.2 to

(i) determine the change in potential difference,

change = ... V [1]

(ii) determine the change in charge on each plate of the capacitor,

change = ... C [2]

(iii) show that the average current in the resistor is 1.1×10^{-3} A.

[2]

For Examiner's Use

(c) Use Fig. 6.2 and the value of the current given in **(b)(iii)** to estimate the resistance of resistor R.

resistance = ... Ω [2]

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.

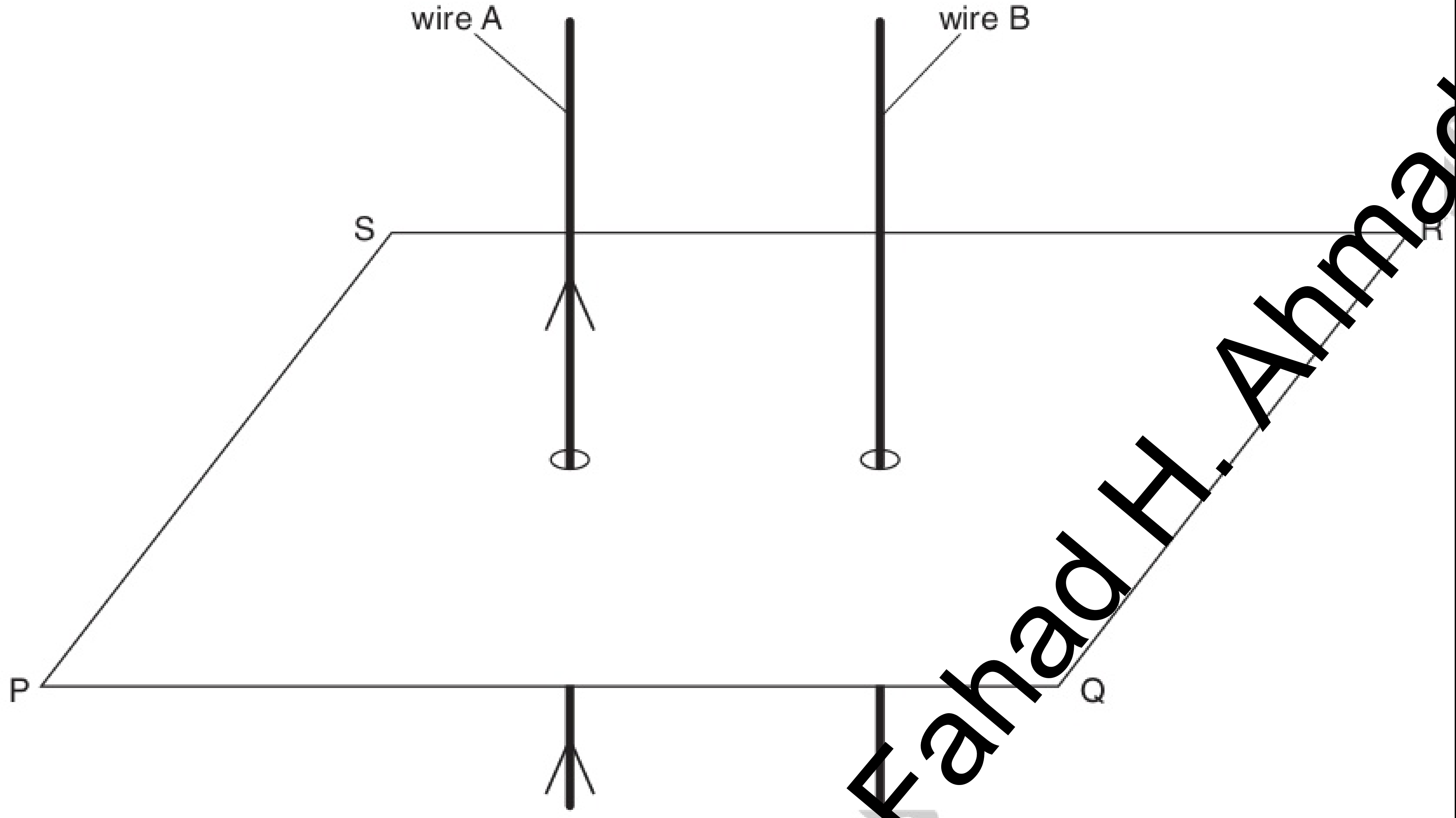

Fig. 7.1

(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]

For Examiner's Use

8 **(a)** Explain what is meant by a *photon*.

....

....

....

.... [3]

(b) An emission spectrum is seen as a series of differently coloured lines on a black background.

Suggest how this observation provides evidence for discrete electron energy levels in atoms.

....

....

....

.... [2]

7 (a) State Lenz's law.

....

....

.... [2]

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

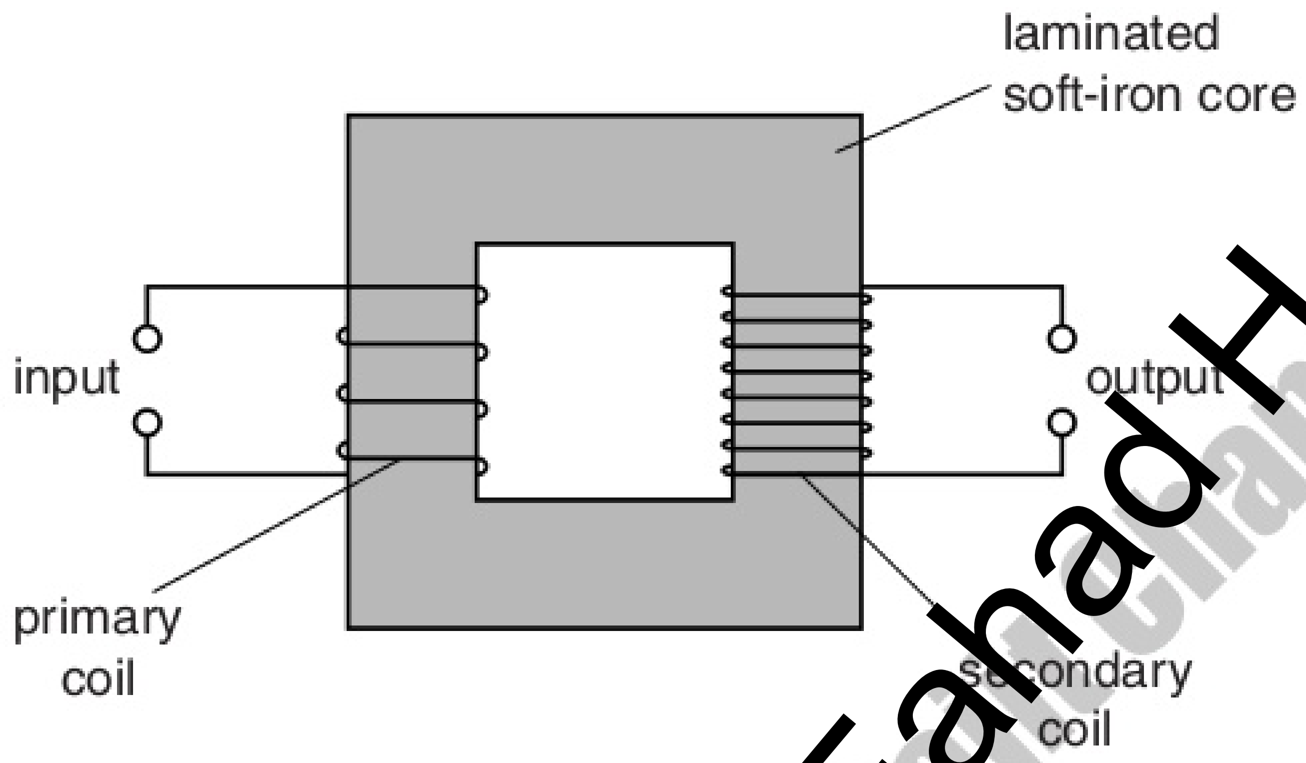

Fig. 7.1

(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]

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

....

....

.... [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.

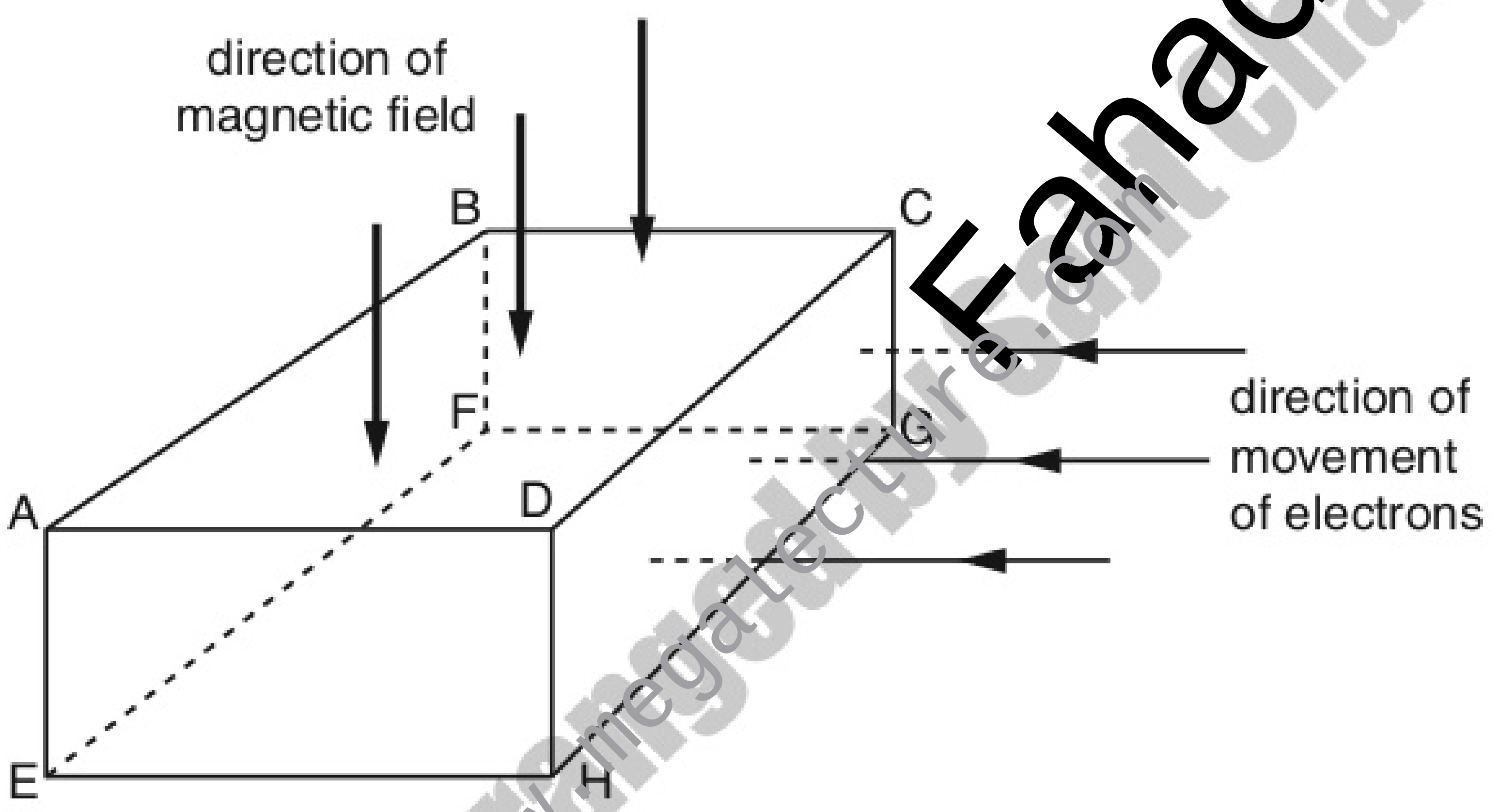

Fig. 6.1

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]

6 A bridge rectifier consists of four ideal diodes A, B, C and D, connected as shown in Fig. 6.1.

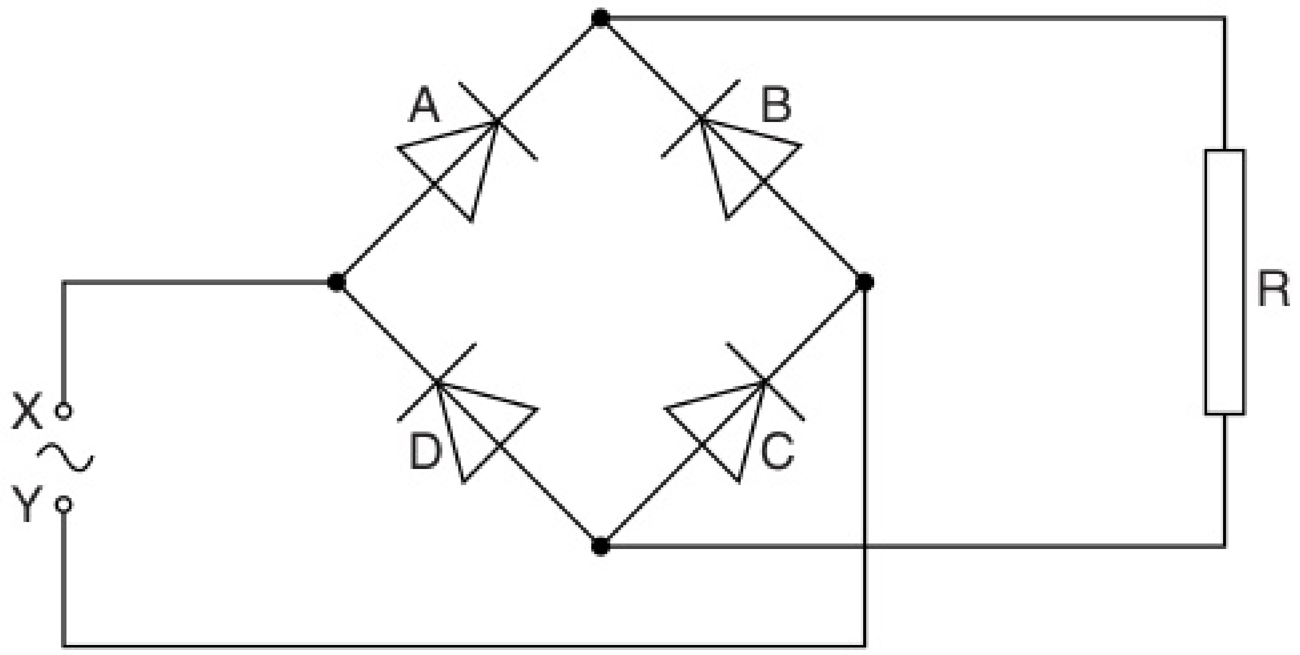

Fig. 6.1

An alternating supply is applied between the terminals X and Y.

(a) **(i)** On Fig. 6.1, label the positive (+) connection to the load resistor R. [1]

(ii) State which diodes are conducting when terminal Y of the supply is positive.

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

(b) The variation with time t of the potential difference V across the load resistor R is shown in Fig. 6.2.

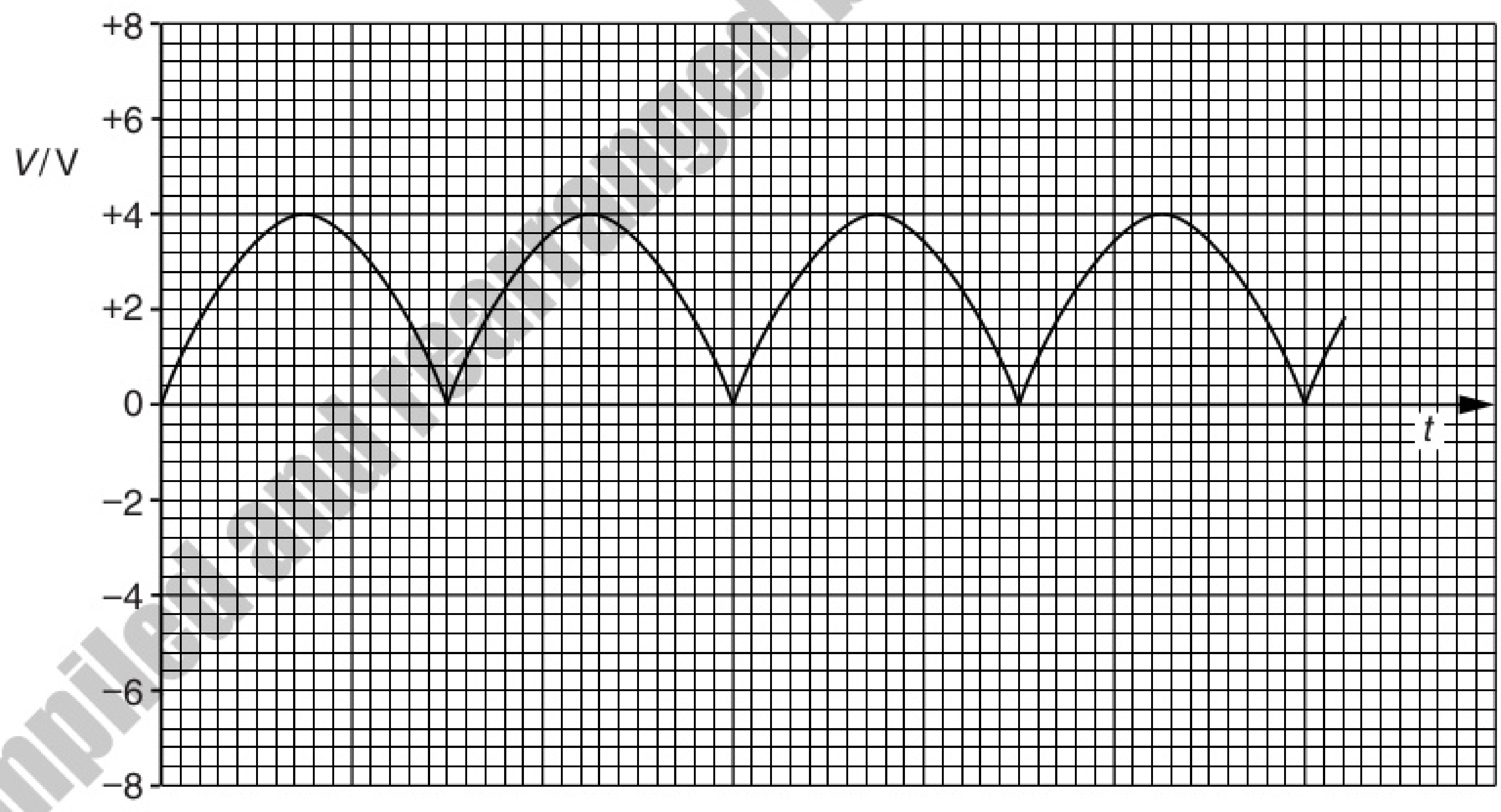

Fig. 6.2

The load resistor R has resistance 2700 Ω.

(i) Use Fig. 6.2 to determine the mean power dissipated in the resistor R.

power = ... W [3]

(ii) On Fig. 6.1, draw the symbol for a capacitor, connected so as to increase the mean power dissipated in the resistor R. [1]

(c) The capacitor in **(b)(ii)** is now removed from the circuit.
The diode A in Fig. 6.1 stops functioning, so that it now has infinite resistance.

On Fig. 6.2, draw the variation with time *t* of the new potential difference across the resistor R. [2]

For Examiner's Use

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

....

....

.... [2]

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

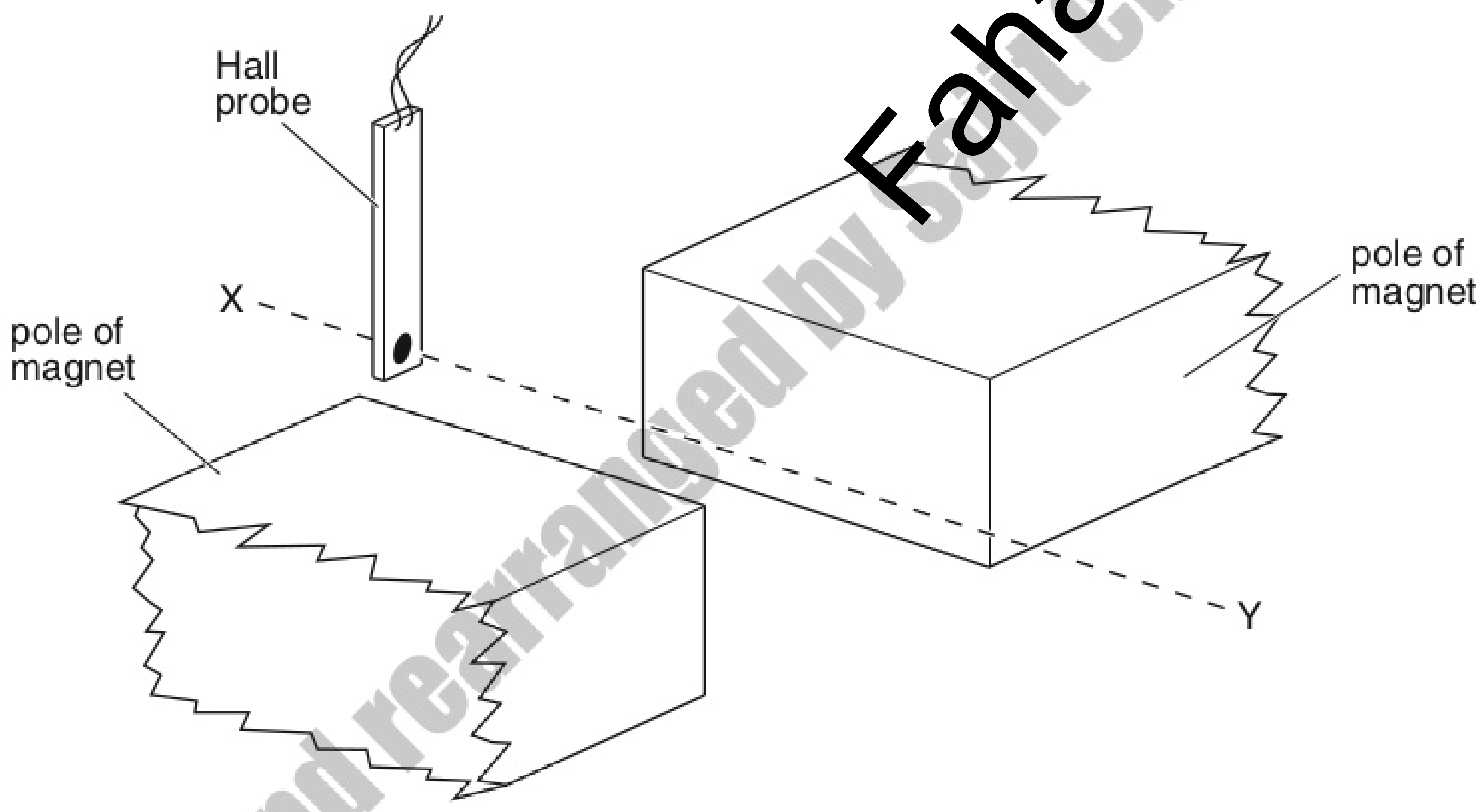

Fig. 5.1

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

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

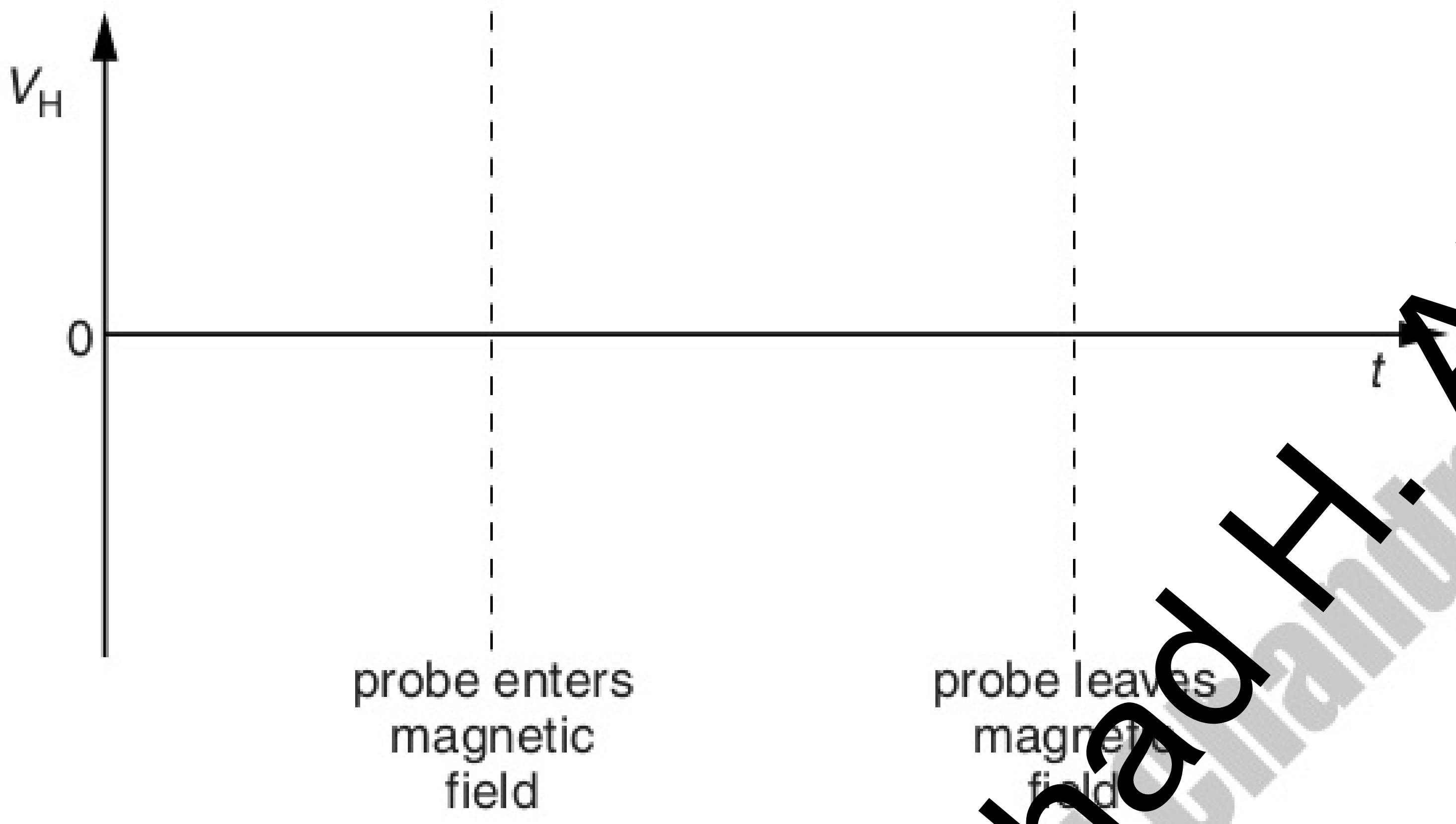

Fig. 5.2

[2]

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

....

....

.... [2]

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

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

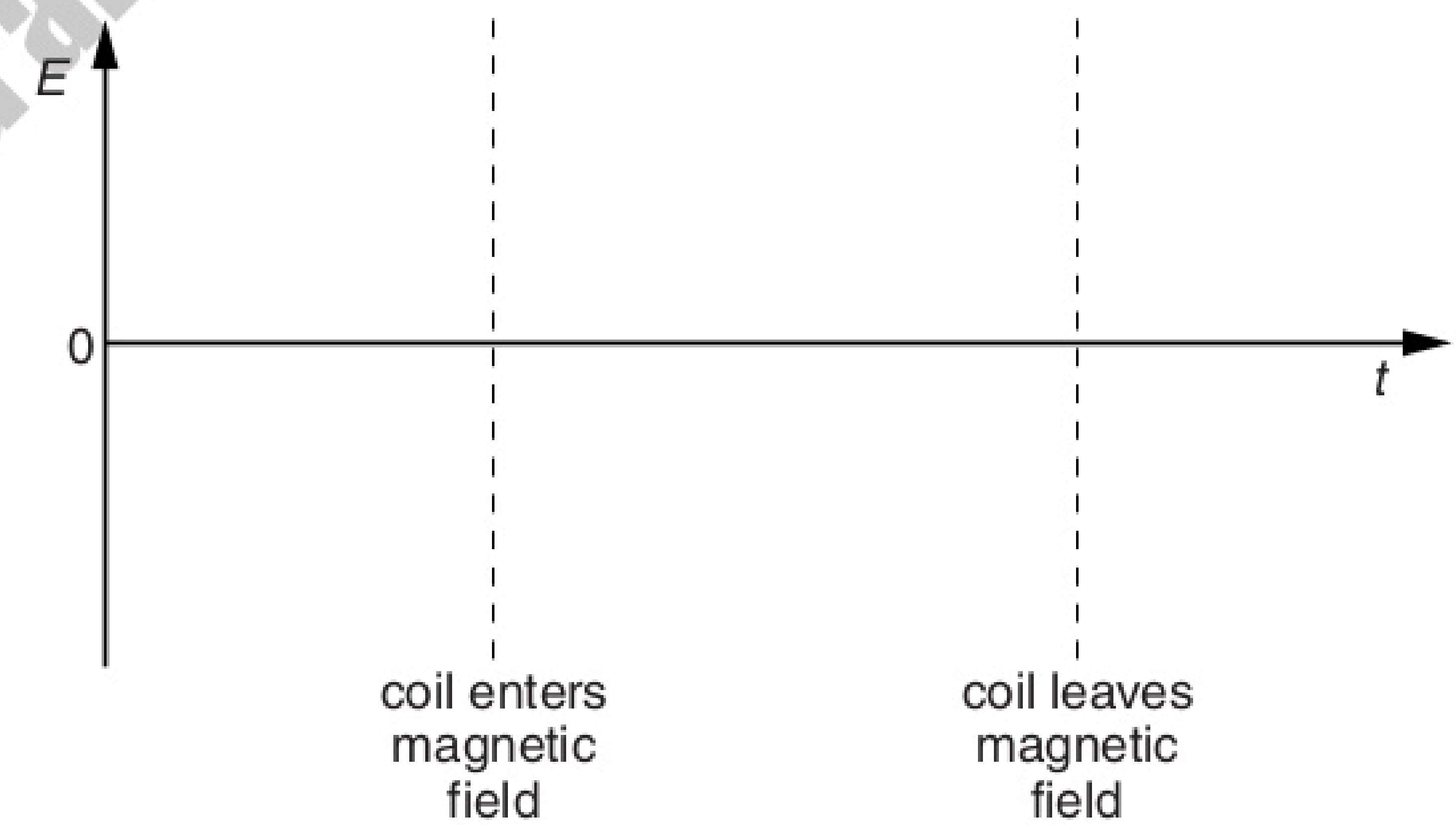

Fig. 5.3

[3]