Electromagnetic Induction

Question paper 1

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Electromagnetic Induction
Sub Topic	
Paper Type	Theory
Booklet	Question paper 1

Time Allowed:	**69 minutes**
Score:	**/57**
Percentage:	**/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

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

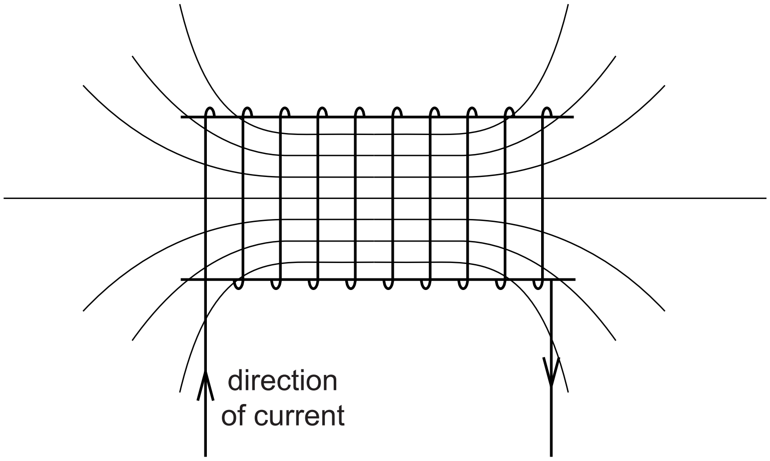


Fig. 5.1

(i) On Fig. 5.1, draw arrows on the field lines to show the direction of the magnetic field. [1]

(ii) State the feature of Fig. 5.1 that indicates that the magnetic field strength at each end of the solenoid is less than that at the centre.

.... [1]

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

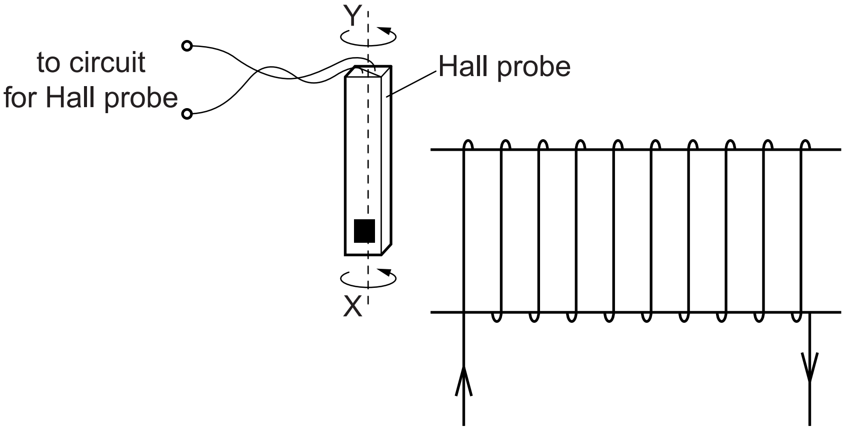


Fig. 5.2

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

....

....

.... [2]

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

....

....

.... [2]

(ii) The Hall probe in **(b)** is replaced by a small coil of wire connected to a sensitive voltmeter.
State three different ways in which an e.m.f. may be induced in the coil.

1. ....

....

2. ....

....

3. ....

....

[3]

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

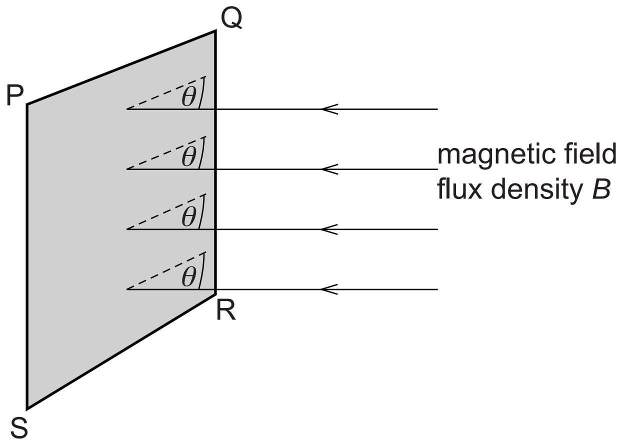


Fig. 5.1

The plane PQRS has area *A*.

(a) State

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

....

.... [1]

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

.... [1]

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

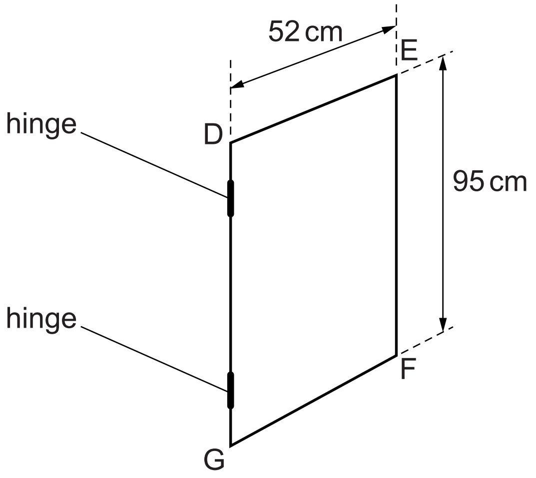


Fig. 5.2

The frame is hinged along the vertical edge DG.
The horizontal component B_H of the Earth's magnetic field is 1.8×10^{-5} T. For the closed window, the frame is normal to the horizontal component B_H.
The window is opened so that the plane of the window rotates through 90°.

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

....

....[1]

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

change in flux linkage = ... Wb [2]

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

....

....

....[2]

(ii) The window in **(b)** is opened in a time of 0.30 s.
Use your answer in **(b)(ii)** to calculate the average e.m.f. induced in the window frame.

e.m.f. = ... V [1]

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

between side .... and side .... [1]

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

....

....

.... [2]

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

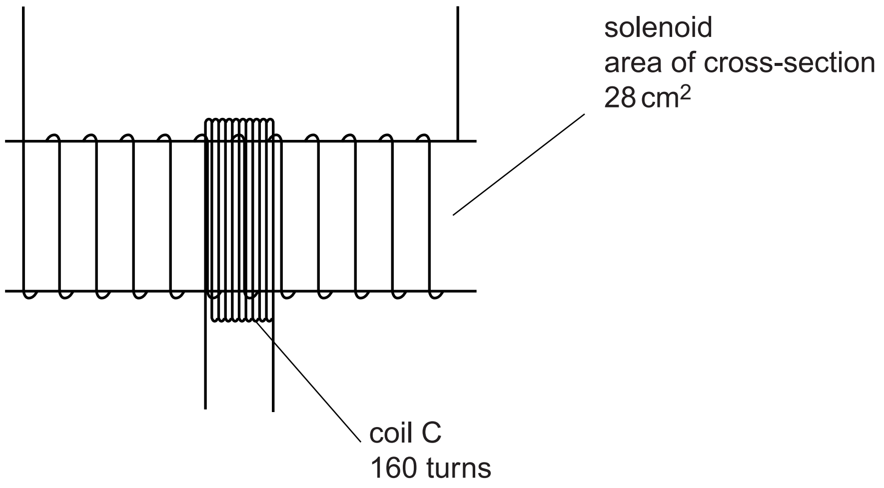


Fig. 5.1

A coil C consisting of 160 turns of insulated wire is wound tightly around the centre of the solenoid.
The magnetic flux density B at the centre of the solenoid is given by the expression

$$B = \mu_0 n I$$

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

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

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

flux density = ... T [2]

(ii) the flux linkage in the coil C.

flux linkage = ... Wb [2]

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

....

....

....[2]

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

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

4 **(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.

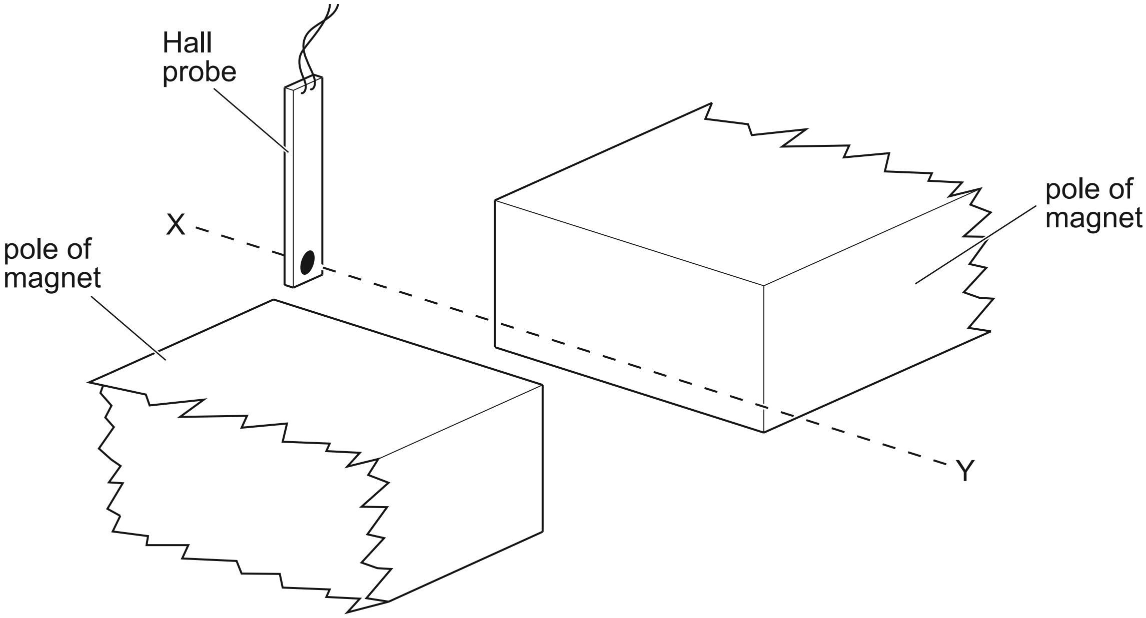


Fig. 5.1

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.

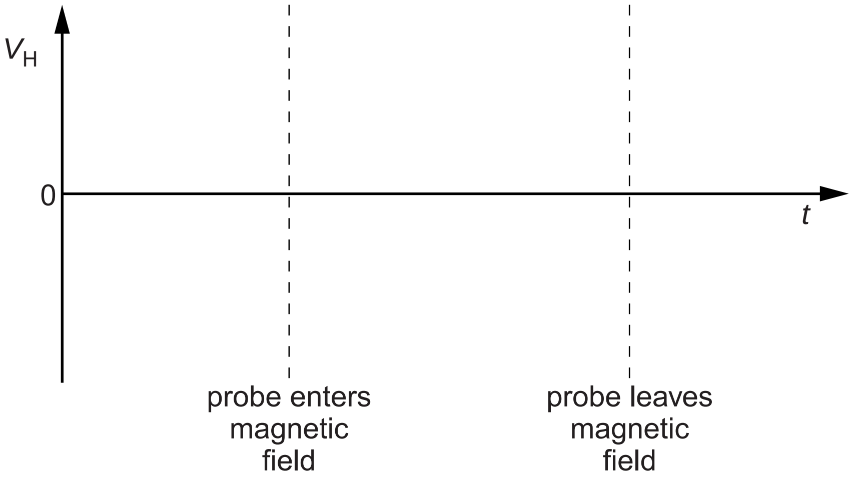


Fig. 5.2

[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.

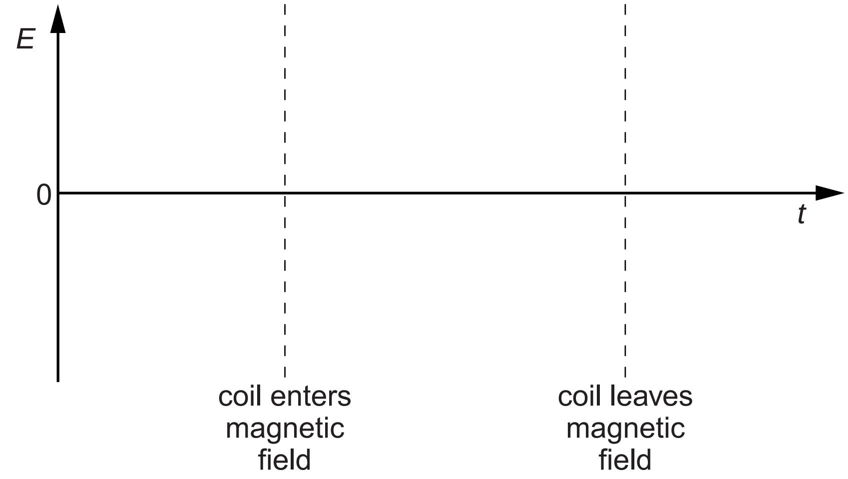


Fig. 5.3

[3]

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

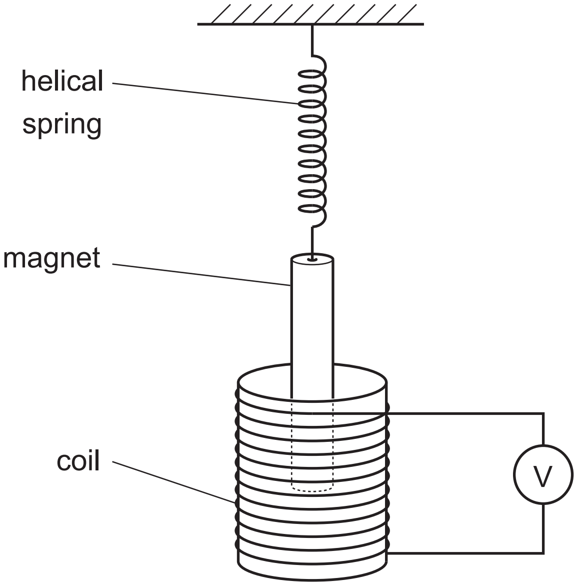


Fig. 5.1

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

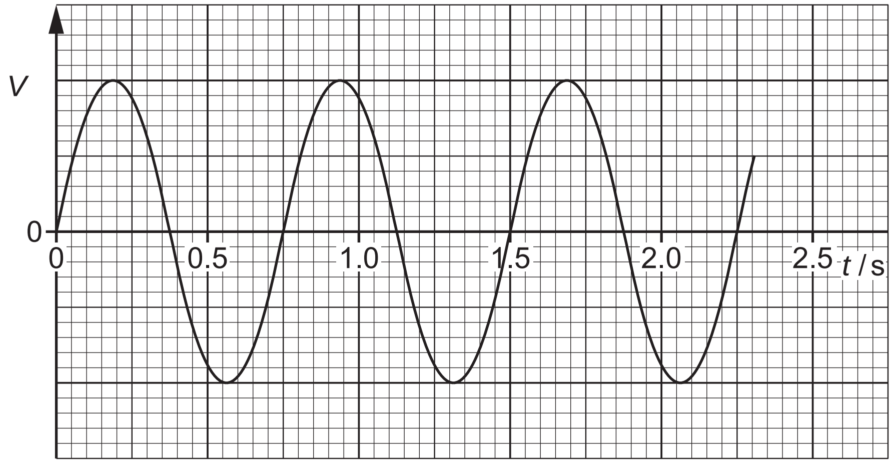


Fig. 5.2

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

....

....

.... [2]

(ii) Use Faraday's law to explain why

1. there is a reading on the voltmeter,

....

.... [1]

2. this reading varies in magnitude,

....

.... [1]

3. the reading has both positive and negative values.

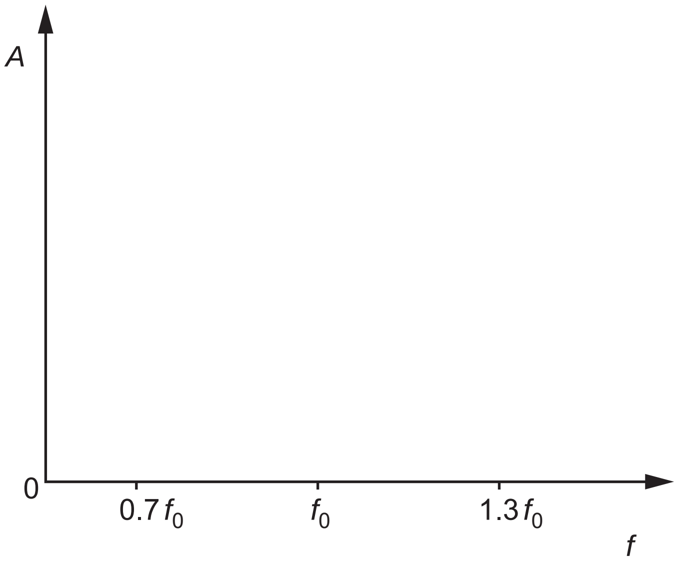
....

.... [1]

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

f_0 = ... Hz [2]

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



[2]

Fig. 5.3

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

.... [1]

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

....

.... [1]

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

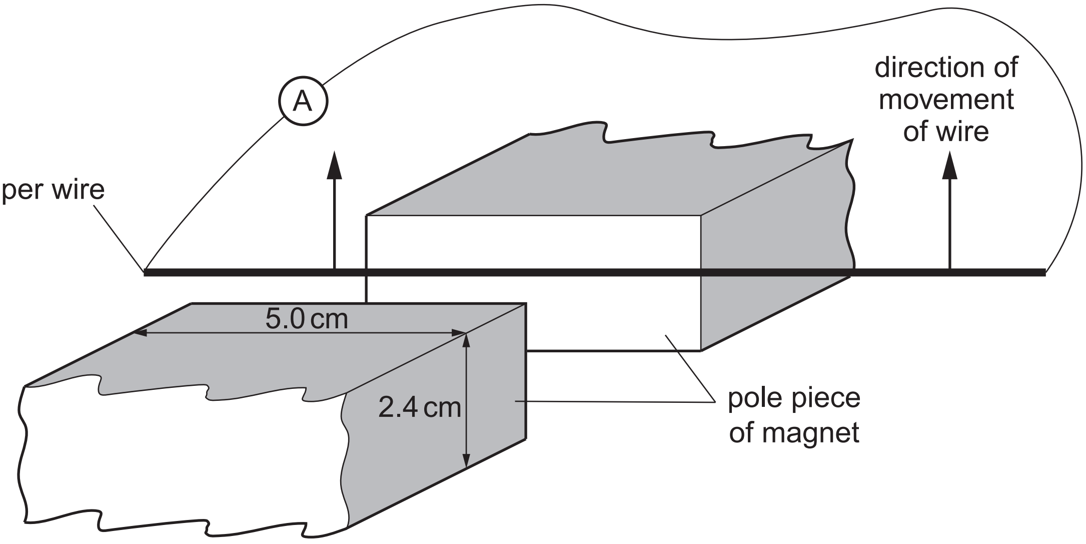


Fig. 5.1

The uniform magnetic flux density between the poles of the magnet is 89 mT. Outside the region of the poles, the magnetic flux density is zero.
A stiff copper wire is connected to a sensitive ammeter of resistance 0.12 Ω. A student moves the wire at a constant speed of 1.8 m s^{-1} between the poles in a direction parallel to the faces of the poles.

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

magnetic flux = ... Wb [2]

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

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

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

[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]