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

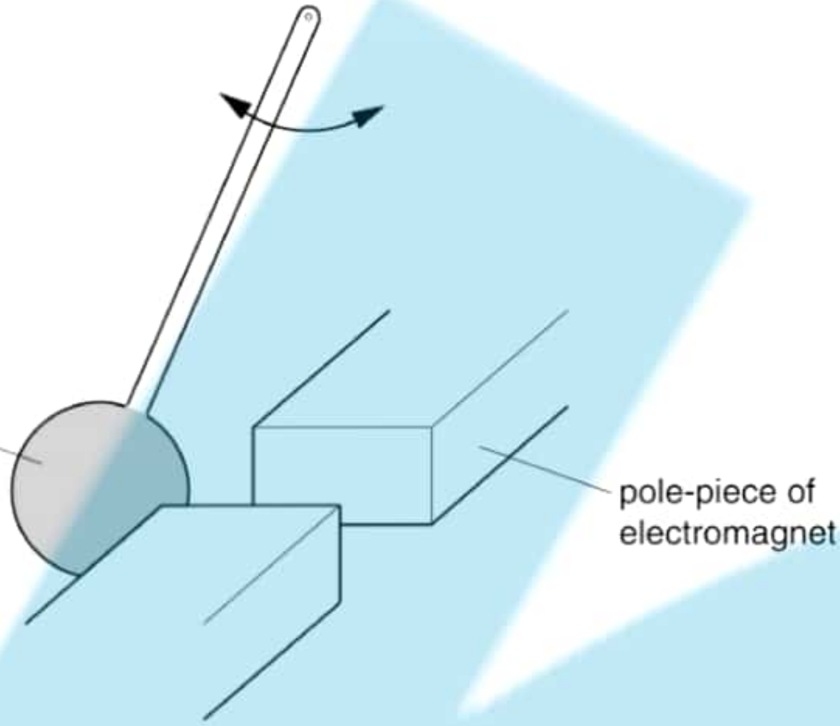

Fig. 5.1

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.

The induced emf is proportional to the rate of change of flux linkage, as the metal disc moves between the magnet, the flux is changing thus emf is induced

[2]

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

The magnetic field in the disc is not constant so different emf is induced at different parts of the disc, so there is a pd, thus eddy currents

[2]

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

eddy currents will give rise to thermal energy in the disk, this energy is coming from the oscillation of the disk, and depend on the amplitude of oscillation

[3]

(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.

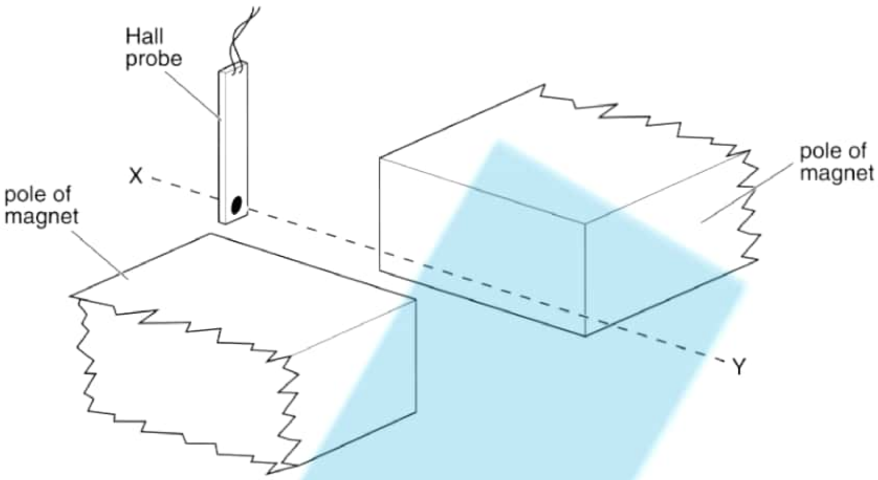

Fig. 5.1

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.

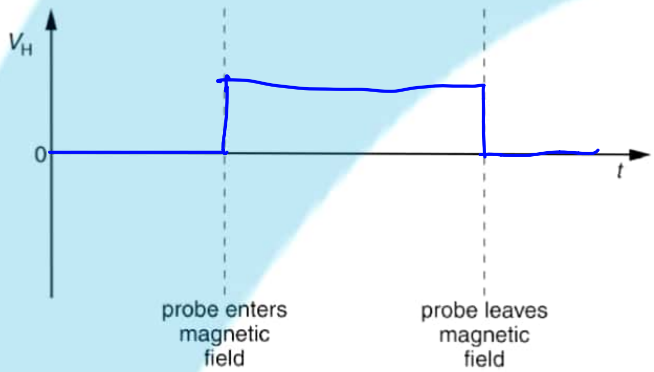

Fig. 5.2

[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.

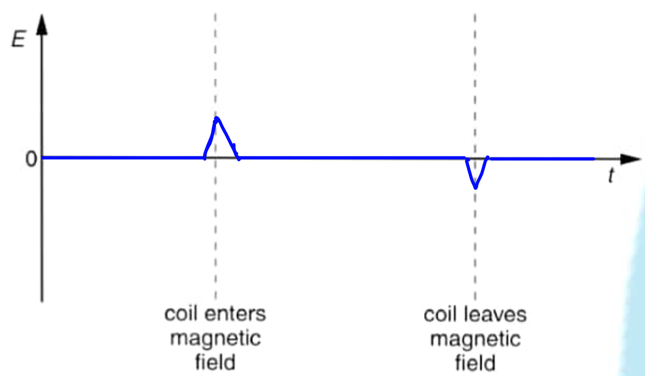

Fig. 5.3

[3]

For Examiner's Use

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

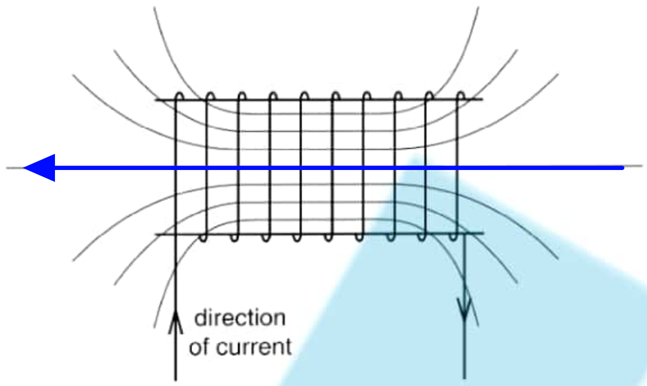

Fig. 5.1

(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.

lines are more spaced out at the ends [1]

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

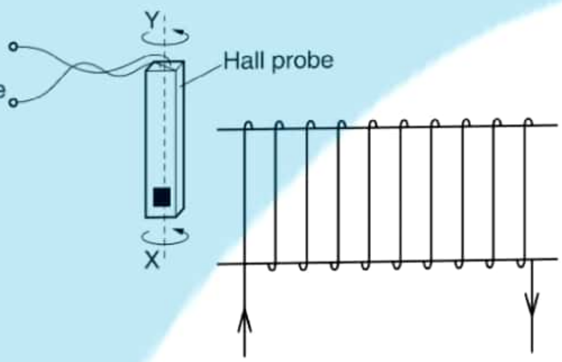

Fig. 5.2

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

The hall voltage depends on the angle such that it is maximum when the M field is normal to the plane of the probe and 0 when parallel [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. move the coil left to right constantly

2. rotate the coil constantly

3. constantly vary current in solenoid or use ac [3]

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

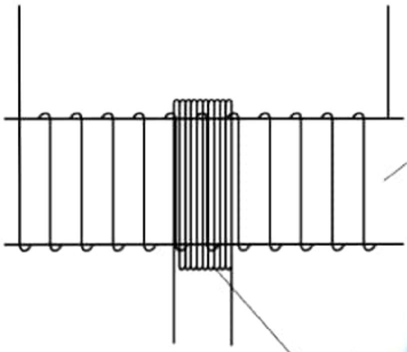

Fig. 5.1

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,

$B = 4\pi \times 10^{-7} \times 1.5 \times 10^3 \times 3.5$

6.6×10^{-3}

flux density = 6.6×10^{-3} T [2]

(ii) the flux linkage in the coil C.

$6.6 \times 10^{-3} \times 160 \times \frac{28}{100^2} = 2.95 \times 10^{-3}$

flux linkage = 3×10^{-3} 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.

$\frac{2 \times 2.95 \times 10^{-3}}{0.8} = 7.375 \times 10^{-3}$

e.m.f. = 7.4×10^{-3} V [2]

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

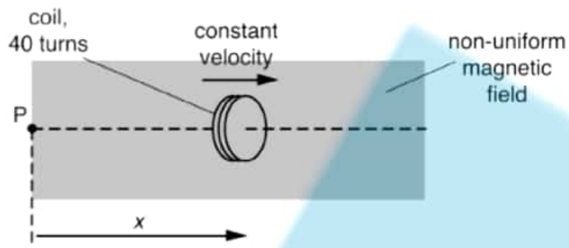

Fig. 10.1

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

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

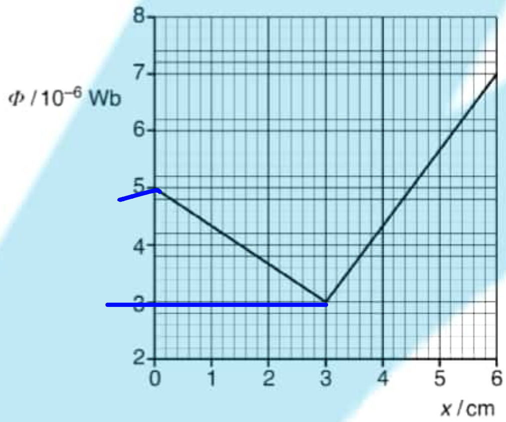

Fig. 10.2

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

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

$(5-3) \times 10^{-6} = 2 \times 10^{-6} \times 40$

change in flux linkage = ... 8.0×10^{-5} .... Wb [1]

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

$5 \times 10^{-4} = \dfrac{8 \times 10^{-5}}{T}$

$\left(\dfrac{\frac{3}{100}}{0.16}\right) = 0.1875$

emf $= \dfrac{d\Phi}{T}$

$T = \dfrac{8 \times 10^{-5}}{5 \times 10^{-4}} = 0.16$ s

$T = \dfrac{d\Phi}{\text{emf}}$

speed = ... 0.19 .... m s^{-1} [2]

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

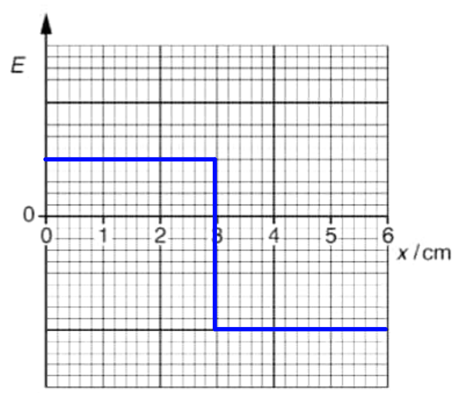

Fig. 10.3

[2]

[Total: 5]

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

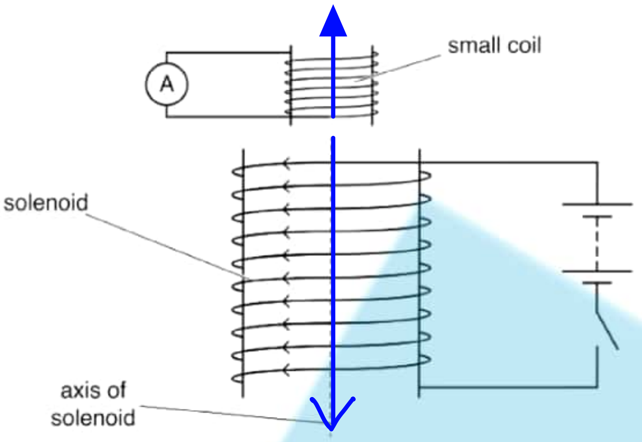

Fig. 8.1

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

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

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

....

.... [1]

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

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

(i) State Lenz's law.

Direction of induced current is such that it opposes the change causing it.

.... [2]

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

The magnetic field in the solenoid is increasing, the magnetic field in the coil will be in the opposite direction to oppose this. [3]

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

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

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

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

$$emf = 2 \times \left(\frac{7 \times 10^{-4} \times 75 \times 1.4 \times 10^{-3}}{0.12} \right)$$

$$1.225 \times 10^{-3}$$

e.m.f. = ... 1.2×10^{-3} .... V [3]

[Total: 10]