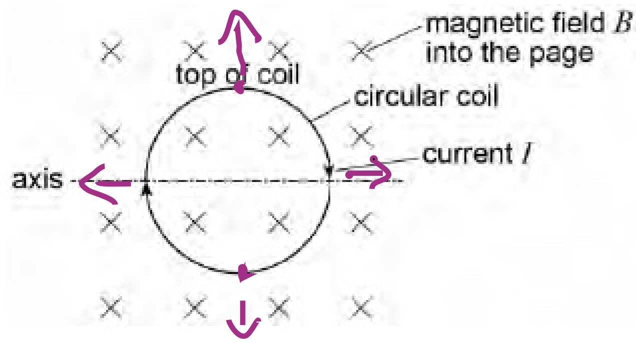
1 The diagram shows a clockwise current I in a circular coil placed in a uniform magnetic field B with the plane of the coil perpendicular to the magnetic field.



What is the effect on the coil of the interaction between the current and the magnetic field?

A It rotates about the axis with the top moving out of the page.

B It rotates about the axis with the top moving into the page.

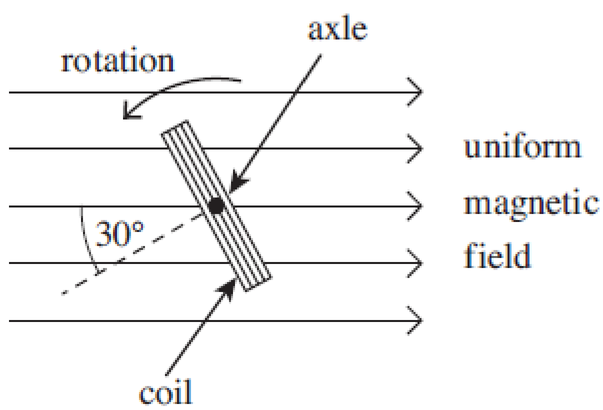
C It causes an increase in the diameter of the coil. ✓

D It causes a decrease in the diameter of the coil.

(Total 1 mark)

2 A rectangular coil is rotating anticlockwise at constant angular speed with its axle at right angles to a uniform magnetic field. **Figure 1** shows an end-on view of the coil at a particular instant.

Figure 1



(a) At the instant shown in **Figure 1**, the angle between the normal to the plane of the coil and the direction of the magnetic field is 30°.

(i) State the minimum angle, in degrees, through which the coil must rotate from its position in **Figure 1** for the emf to reach its maximum value.

angle 60 degrees

(1)

(ii) Calculate the minimum angle, in radians, through which the coil must rotate from its position in **Figure 1** for the flux linkage to reach its maximum value.

2π rads = 360°

$\frac{2\pi}{360} \times 150$

angle $\frac{5}{6}\pi$ radians

(2)

(b) **Figure 2** shows how, starting in a different position, the flux linkage through the coil varies with time.

(i) What physical quantity is represented by the gradient of the graph shown in **Figure 2**?

ε induced (magnitude)

(1)

(ii) Calculate the number of revolutions per minute made by the coil.

T = 40ms ⇒ f = 25

revolutions per minute 25×60 = 1500

(2)

Figure 2

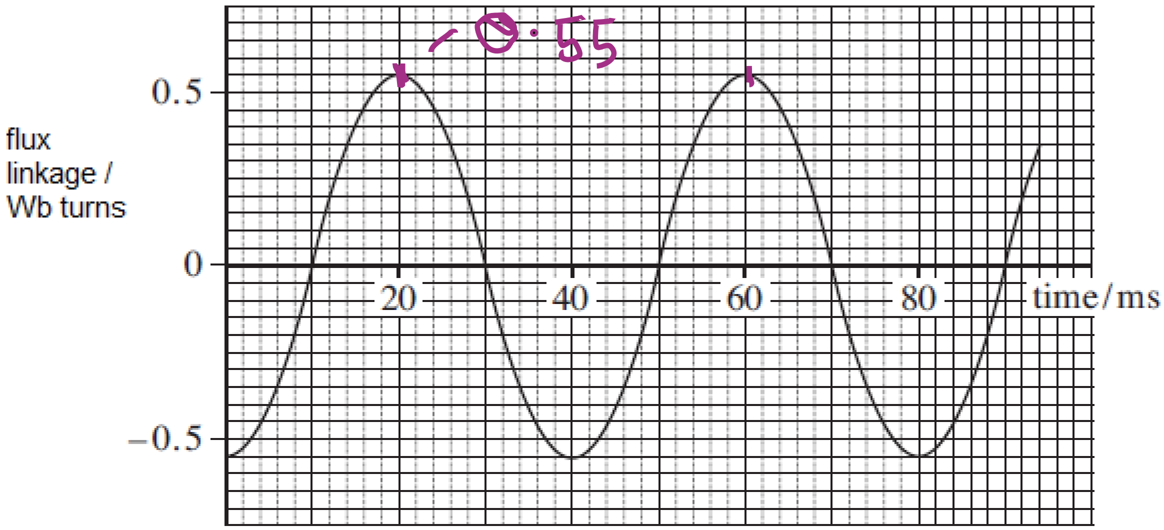
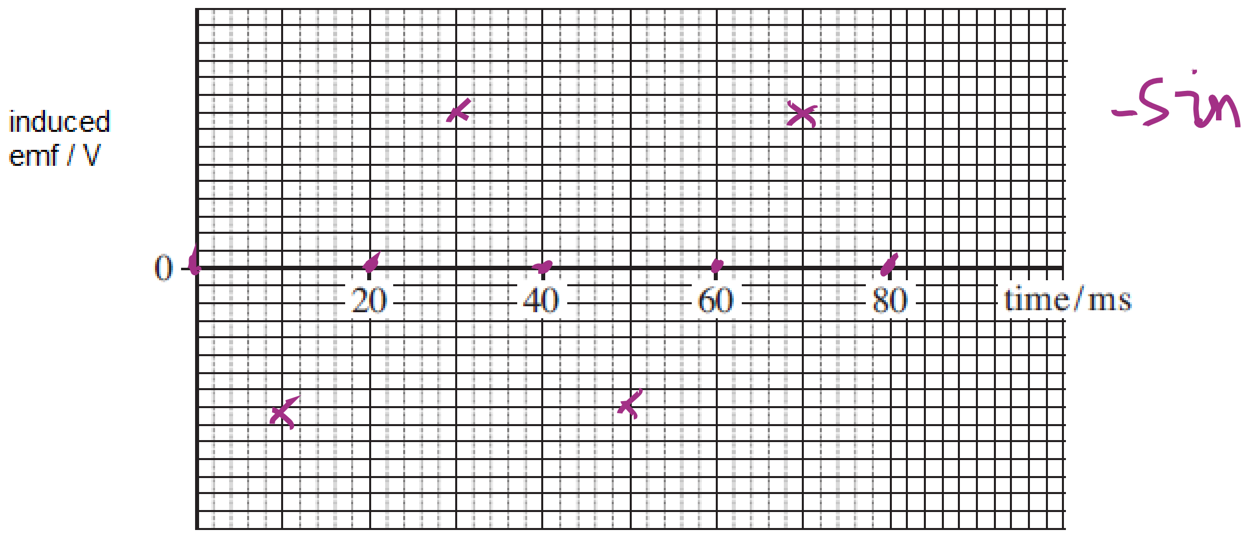


Figure 3



(iii) Calculate the peak value of the emf generated.

$N\phi = BAN = 0.55$ Wb turns

and $\mathcal{E} = BAN\omega \sin(\omega t) \Rightarrow$ peak $= BAN\omega$

$\omega = \frac{2\pi}{T} = \frac{2\pi}{40\,ms}$

peak emf 86.4 V

(3)

(c) Sketch a graph on the axes shown in **Figure 3** above to show how the induced emf varies with time over the time interval shown in **Figure 2**.

(2)

(d) The coil has 550 turns and a cross-sectional area of $4.0 \times 10^{-3} m^2$.

Calculate the flux density of the uniform magnetic field.

BAN = 0.55

$B = \frac{0.55}{AN}$

flux density 0.25 T

(2)

(Total 13 marks)

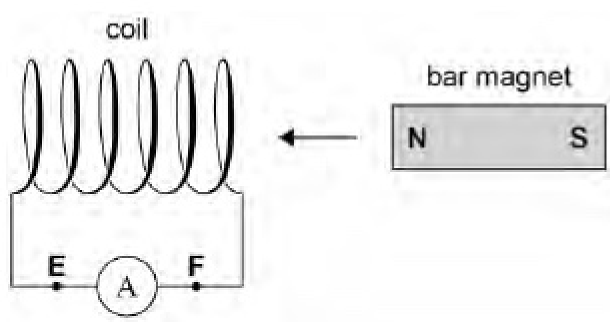
3 (a) State Lenz's law.

Direction of induced emf is such that it opposes the change which created it

(1)

(b) Lenz's law can be demonstrated using a bar magnet and a coil of wire connected to a sensitive ammeter as shown in **Figure 1**.

Figure 1



The bar magnet is moved towards the coil and is then brought to a halt.

State how the reading on the ammeter changes during this process.

Reading moves to a peak the speed of the magnet is increased from zero. As the magnet is bought to rest it falls back to zero (there is no change in the direction of the current)

(1)

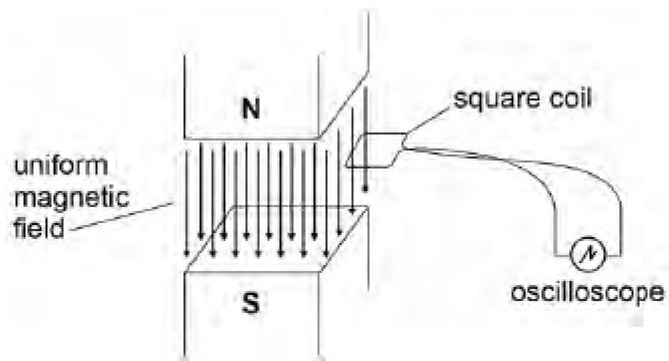
(c) During the demonstration an induced current is detected by the ammeter. The induced current is in the direction **E** to **F**.
Explain how this demonstrates Lenz's law.

Current flowing from E to F induces a N pole at the rhs of the coil. This opposes the magnetic field from the magnet, thereby opposing the change that produced it.

(2)

(d) **Figure 2** shows an arrangement for investigating induced emf.

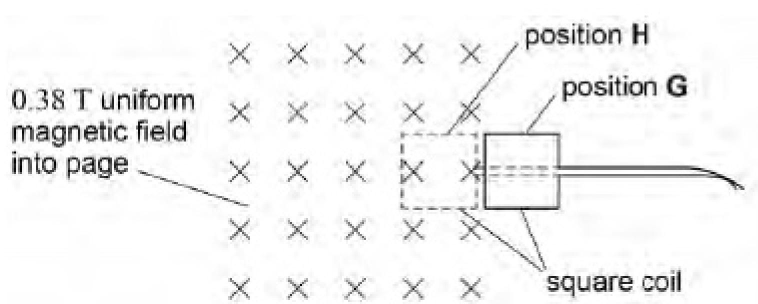
Figure 2



As shown, the uniform vertical magnetic field is confined to the gap between the poles of the magnet. The plane of the square coil is horizontal and is made of conducting wire. The coil consists of a single turn and is attached by flexible wire to an oscilloscope.

The oscilloscope gives a reading of 2.9×10^{-4} V when the coil is moved at uniform speed from position **G** outside the field to position **H** inside the field, as shown in **Figure 3**.

Figure 3



Length of side of square coil = 32 mm = L

Magnetic flux density of uniform magnetic field = 0.38 T

Calculate the time taken to move the coil from position **G** to position **H**.

Only the leading edge of the coil cuts any field lines so l=32mm

$d = v\Delta t$ $\quad V = 2.9\times10^{-4}$ V

Area of flux cut $\Rightarrow L \times v \times \Delta t$

$\Delta\phi = BA \Rightarrow \Delta\phi = BLv\Delta t$

time = ____________________ s

(2)

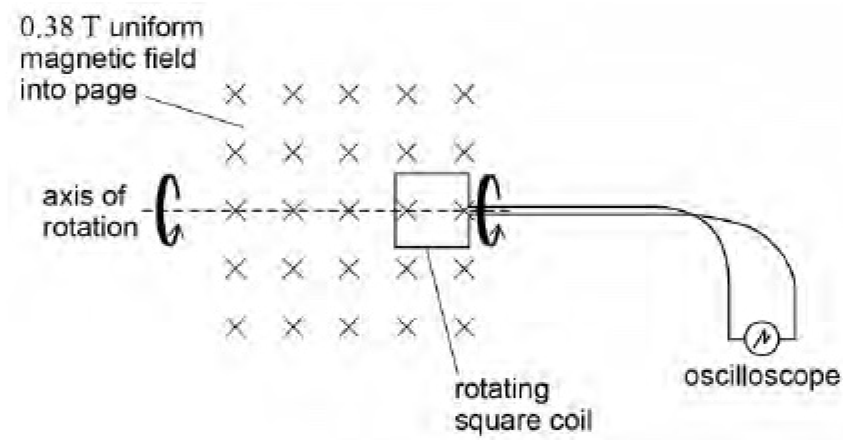
$\mathcal{E} = N\frac{\Delta\phi}{\Delta t} \Rightarrow \mathcal{E} = \frac{BLv\Delta t}{\Delta t}$

$\frac{\mathcal{E}}{BL} = v \Rightarrow v = 0.024$ ms

$t = \frac{32\times10^{-3}}{0.024} = 1.3$ s

(e) The square coil is rotated through 360° at a constant angular speed about the horizontal axis shown in **Figure 4**.

Figure 4



Calculate the angular speed of the coil when the maximum reading on the oscilloscope is 5.1 mV

$\varepsilon = BAN\omega \sin \omega t$ 1

$A = (32\text{mm})^2$

$\frac{5.1 \times 10^{-3}}{BAN} = \omega$

$B = 0.38$

$n = 1$

angular speed = 13 rad s^{-1}

(2)

(Total 8 marks)

4

A transformer has an efficiency of 80%
It has 7000 turns on its primary coil and 175 turns on its secondary coil. When the primary of the transformer is connected to a 240 V ac supply, the secondary current is 8.0 A

What are the primary current and secondary voltage?

	Primary current / mA	Secondary voltage / V	
A	250	6.0	⬭
B	160	6.0	⬭
C	250	9600	⬭
D	160	9600	⬭

(Total 1 mark)

$n_p = 7000$ $n_s = 175$

$V_p = 240V$ $I_s = 8A$

$P_s = 0.8 P_p$

$V_s \times 8 = 0.8 \times 240 \times I_s \Rightarrow I = 1/4$

$\frac{V_s}{N_s} = \frac{V_p}{N_p} \Rightarrow V_s = 6$

Mark schemes

1 **C** **[1]**

2 (a) (i) 60 (degrees) ✓ 1

(ii) angle required is 150° ✓

which is 5π / 6 [**or** 2.6(2)] (radians) ✓

Correct answer in radians scores both marks.

2

(b) (i) (magnitude of the induced) emf ✓

Accept "induced voltage" or "rate of change of flux linkage", but not "voltage" alone.

1

(ii) frequency $\left(=\frac{1}{T}\right)=\frac{1}{40\times10^{-3}}$ ✓ (= 25 Hz)

no of revolutions per minute = 25 × 60 = 1500 ✓

1500 scores both marks.

Award 1 mark for 40s → 1.5 rev min^{-1}.

2

(iii) maximum flux linkage $(=BAN)$ = 0.55 (Wb turns) ✓

angular speed $\omega\left(=\frac{2\pi}{T}\right)=\frac{2\pi}{40\times10^{-3}}$ ✓ (= 157 rad s^{-1})

peak emf (= $BAN\omega$) = 0.55 × 157 = 86(.4) (V) ✓

[**or**, less accurately, use of gradient method ✓

{e.g $\varepsilon\left(=\frac{\Delta(N\Phi)}{\Delta t}\right)=\frac{0.5-(-0.5)}{(16-4)\times10^{-3}}=\frac{1.0}{12\times10^{-3}}$ } = 83 ($\pm$ 10) (V) ✓ ✓

(max 2 for (iii) for values between 63 and 72 V or 94 and 103V)]

3

(c) sinusoidal shape of constant period 40 ms ✓

Mark sequentially.

Graph must cover at least 80ms.

correct phase (i.e. starts as a minus sin curve) ✓

For 2nd mark, accept + sin curve.

Perfect sin curves are not expected.

2

(d) $BAN = 0.55 \therefore$ flux density $B = \dfrac{0.55}{4.0 \times 10^{-3} \times 550}$ ✓

= 0.25(0) (T) ✓

OR *by use of ε from (b)(iii) and f from (b)(ii) substituted in* $\varepsilon = BAN(2\pi f)$.

2

(Total 13 marks)

3 (a) The <u>direction</u> of the <u>induced emf</u> (when there is a change of flux linkage) is such that it will (try) <u>to oppose the change</u> (of flux) that is producing it ✓ owtte

A reference to emf is needed rather than induced current as this is dependent on a circuit. Ignore reference to current if emf is given.

1

(b) (The reading shows a dc) current flow which then becomes zero (when the magnet stops moving) ✓

The reading does not have to be steady. So reading increasing or pulsing up before falling to zero is okay. There should be no hint that the reading changes direction.

1

(c) (The induced current produces) a north pole on the right hand side of the coil ✓

which opposes the motion of the bar magnet

OR

and the two north poles repel each other

OR

to try to maintain the (small) magnetic field as the magnet approaches the coil (without this the magnet would increase the magnetic field beside the coil) ✓

The polarity of the coil may be shown on the diagram.

The two marks are independent but the second mark does not stand completely alone as it has to be said in context. EG 'Two North poles repel' on its own will not gain a mark.

2

(d) (Use of $\varepsilon = Blv$ as the straight leading edge of the coil is the only conductor that cuts the magnetic flux lines. Also using $v = s / t$)

$t = Bls/\varepsilon$ ✓

(There must be some evidence of use for the mark but the mark can come from substituting numbers, eg $t = 0.38 \times 0.032 \times 0.032 / 2.9 \times 10^{-4}$)

t = 1.3(4) (s)✓

OR

(Using $\varepsilon = (-)N\,\Delta\varphi/\Delta t$ then $\Delta t = \Delta(BA)/\varepsilon$)

$t = BA/\varepsilon$ ✓

(There must be some evidence of use for the mark but the mark can come from substituting numbers, eg. $t = 0.38 \times .032^2 / 2.9 \times 10^{-4}$)

t = 1.3(4) (s) ✓

Useful numbers BA = 3.89×10^{-4}

Although the first mark can come from substituting numbers the equation mark may be lost if it is obvious that the equation is not understood by the way substitutions are made (this does not include a simple AE slip). This loss of a mark is directed at the candidate who quotes several equations and happens to hit on the correct equation but fails to use it properly.

Failure to square the side length is a PE.

Answer only gains 2 marks.

2

(e) (using $\varepsilon = BAN\omega \sin \omega t$ which give a maximum value of $\varepsilon_{max} = BAN\omega$)

ω (= ε_{max}/BAN) = $5.1 \times 10^{-3} / (0.38 \times (0.032)^2$. ✓

ω = 13(.1) (rad s^{-1}) ✓

Candidates who cannot maximise/remove sin ωt *gain no marks.*

{may see $\omega = 5.1 \times 10^{-3} / 3.9 \times 10^{-4}$*}.*

2

[8]

4 **A**

[1]