ELECTROMAGNETIC INDUCTION

Challenging **MCQ** questions by The Physics Cafe

Compiled and selected by The Physics Cafe

1 **(a)** Define *magnetic flux* in a coil.

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.... [1]

(b) Electrical transformers are widely used in industries and there are various types of transformers suited for different applications. Fig. 4.1 illustrates a modified version of a 3-legged core transformer.

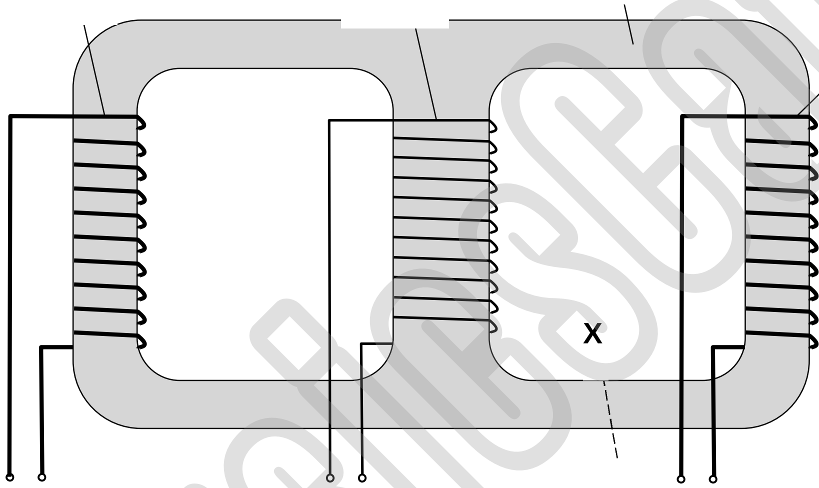

Fig. 4.1

The terminals of coil **B** is connected to a 240 V r.m.s. AC source.

The ratio of the number of turns of wire in the coils of coil **A** : **B** : **C** is 2 : 13 : 1.

(i) With reference to the laws of electromagnetic induction, explain why a potential difference is produced across the terminals of coil **C**.

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.... [2]

(ii) The magnetic flux produced by coil **B** is ϕ_B and the magnetic flux through coil **C** is ϕ_C. State the relation between ϕ_B and ϕ_C.

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(iii) Determine the peak output potential difference across the terminals of coil **C**.

potential difference = ………………………….. V [2]

(iv) Due to impact on the transformer, a gap is formed in the soft iron core along the dashed line labelled **X** as shown in Fig. 4.1. State and explain how the gap affects the maximum e.m.f. induced in coil **C**.

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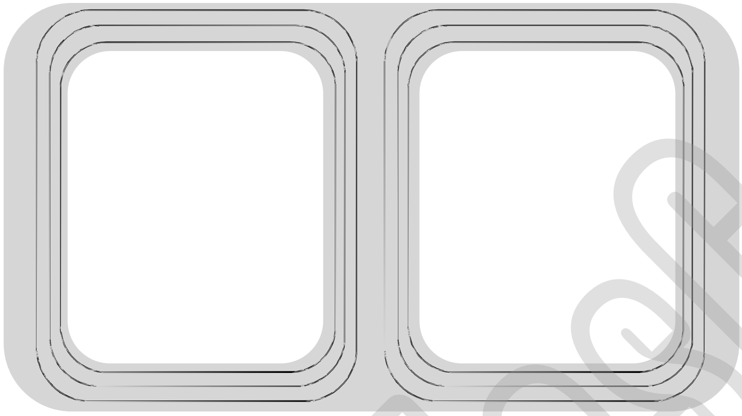
Ans **(a)** Magnetic flux ϕ through a coil is defined as the product of the magnetic flux density normal to the coil surface, B_N and the area A of the coil surface. [B1]

(b) **(i)** Coil B, connected to AC source, produces a magnetic field that is varying with time sinusoidally. This results in a varying magnetic flux through coil B and hence a varying magnetic linkage through coil C. [M1]
By Faraday's law, an emf is induced in coil C due to changing magnetic flux linkages through coil C. [A1]

(ii) $\phi_B = 2\phi_C$ [A1]



Notes:
The magnetic flux produced by coil B will distribute and flow equally through coil A and coil C. (By geometry of the soft iron core)
Students wrongly state the turn ratio of coil B to coil C.

(iii)
$$\varepsilon_B = -\frac{d\Phi_B}{dt} = -N_B\frac{d\phi_B}{dt}$$
$$\varepsilon_C = -\frac{d\Phi_C}{dt} = -N_C\frac{d\phi_C}{dt}$$

$$\frac{d\phi_B}{dt} = 2\frac{d\phi_C}{dt}$$ [M1]
$$\frac{\varepsilon_B}{N_B} = 2\frac{\varepsilon_C}{N_C}$$
$$\frac{240}{13} = 2\frac{\varepsilon_C}{1}$$
$$\varepsilon_C = 9.23 \text{ V}$$
Peak output $V_C = 9.23\sqrt{2} = 13.1\,\text{V}$

[A1]

(iv) Since soft iron has a gap, the magnetic flux through coil C will be reduced and hence the rate of change of magnetic flux linkage through coil C will be lowered. [M1]
By Faraday's law, induced emf in coil C is proportional to the rate of change of mangetic flux linkages, hence the induced emf will be lower. [A1]

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

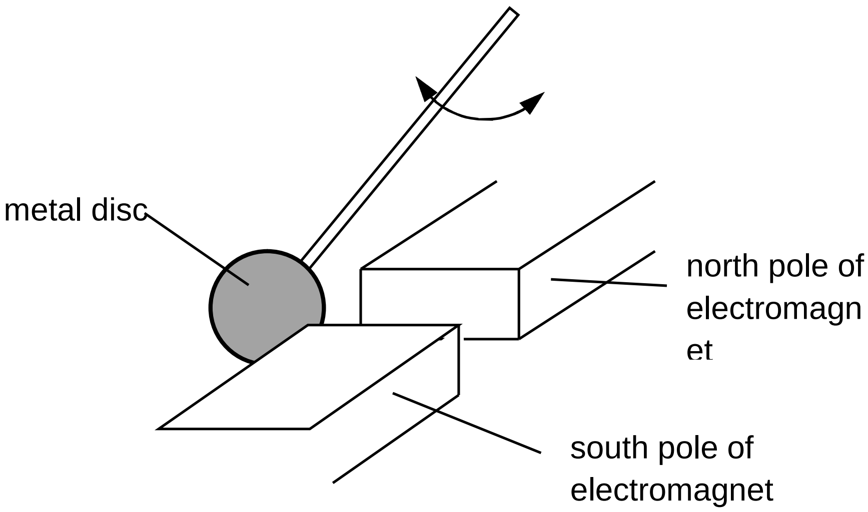


Fig. 5.1

When the electromagnet is switched on, the disc comes to rest after 12 s.

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

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(b) An enlarged diagram of the disc as it is leaving the magnetic field is shown in Fig. 5.2. The direction of the magnetic field is shown in the diagram. The dotted circle indicates one possible path of the eddy current generated.

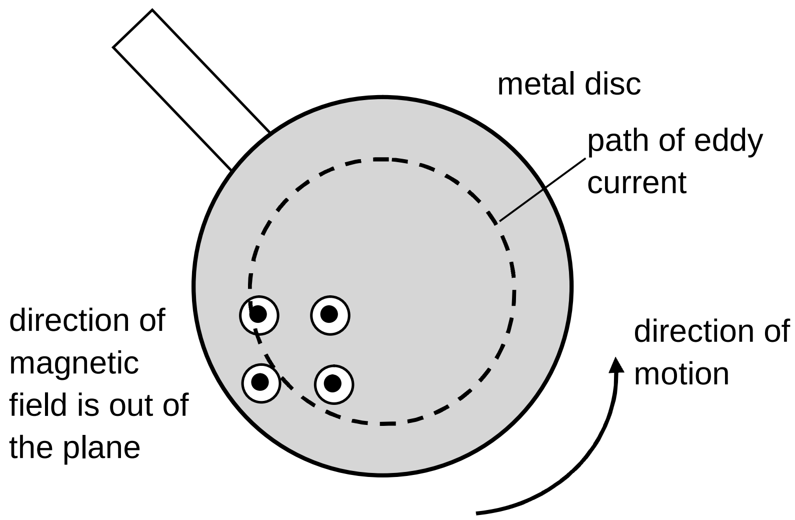

Fig. 5.2

(i) State Lenz's law of electromagnetic induction.

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(ii) Indicate on the dotted path in Fig. 5.2 the direction of the eddy current as the disc is leaving the electromagnet. [1]

(iii) Use Lenz's law to explain why eddy currents induced in the metal disc are in the direction as indicated in **(b)(ii)**.

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(c) State and explain how the time taken for the disc to come to rest will change if a metal of higher resistivity is used for the disc.

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Ans (a) Faraday's Law states that when there is a change in the magnetic flux linkage of a conductor, an e.m.f. is induced in it. The magnetic flux linkage linking the metal disc will increase and decrease respectively as it enters and exits the magnetic field of the electromagnet. Hence, an e.m.f. will be induced in the disc.

(b) (i) Lenz's Law states that the e.m.f. is induced in the direction such as to oppose the change in the flux linkage that is inducing it.

(ii)

(iii) As the metal disc is an electrical conductor, charges will be able to flow freely in the disc. As the disc leaves the magnetic field of the electromagnet, to oppose the decrease in magnetic flux linkage, magnetic flux density has to be induced in the same direction as the electromagnet's magnetic flux density. As such, the charges have to flow in a circular anti-clockwise direction to induce the magnetic flux density out of the plane.

(c) As the resistivity of the disc is higher, the resistance of the disc will be higher. This will decrease the magnitude of the eddy current induced and hence, the heat energy dissipated. As such, less kinetic energy will need to be converted to heat energy and this will cause the disc to come to rest in a longer time. (Candidates can also explain by commenting on the slower rate of heat dissipation.)

3 **(a)** Define *magnetic flux linkage.*

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.... [1]

(b) Fig. 5.1 shows a magnetic field of flux density 5.0×10^{-5} T passing through a short-circuited horizontal coil of wire. The field makes an angle of 60° with the plane of the coil. The coil has 400 turns, a resistance of 4.0 Ω and an area of 25 cm^2. After an initial push, the coil turns over once about the axis XY in the direction shown.

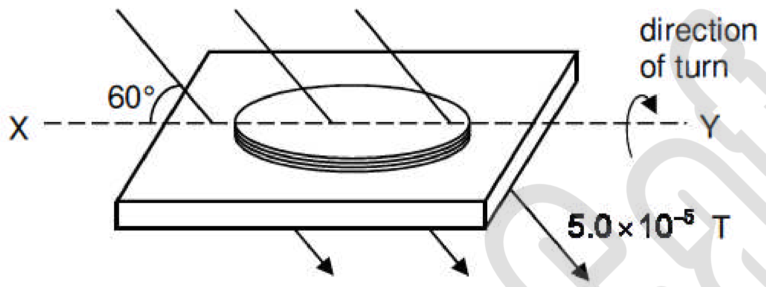

Fig. 5.1

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

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

(ii) Hence determine the total amount of charge that flows in the coil during the turn.

total charge = ... C [2]

(iii) On Fig. 5.1, indicate the direction of the induced current in the coil as it is being turned from the position shown. [1]

(iv) Explain why the coil slows down and stops after it turns over once. State the energy changes that take place.

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Ans (a) Magnetic flux linkage is the product of the magnetic flux density, the area of the coil normal to the magnetic field and the number of turns of the coil. B1

OR

Magnetic flux linkage is the product of the area of the coil, the magnetic flux density normal to the coil and the number of turns of the coil.

Reject the use of "magnetic field strength" instead of "magnetic flux density".

(b) (i) $\Phi = NBA = 400 \times 5.0 \times 10^{-5} \times \sin 60^{\circ} \times 25 \times 10^{-4}$ M1

$= 4.33 \times 10^{-5}$ Wb

$\Delta\Phi = \Phi_f - \Phi_i = [4.33 - (-4.33)] \times 10^{-5} = 8.66 \times 10^{-5}$ Wb (allow 2 sf) A1

Accept both positive and negative answers.
Deduct 1m for wrong version of cm² to m².

(ii) Average induced emf $E = \left| -\frac{\Delta\Phi}{\Delta t} \right|$ C1

Average current in the coil $I = \frac{E}{R} = \frac{\Delta\Phi}{R\Delta t}$

Total charge flowing in the coil

$Q = I\Delta t = \frac{\Delta\Phi}{R}$

$= \frac{8.66 \times 10^{-5}}{4.0}$

$= 2.17 \times 10^{-5}$ C (allow 2 sf and allow ecf) A1

(iii) Clockwise direction. B1

(iv) According to Lenz's Law, the induced current flows in a direction so as to oppose the change that produces it. This will result in a magnetic force that opposes the rotation of the coil. B1

Mechanical energy / kinetic energy is converted to electrical energy. B1