

Exercise walk-through

19.2

Induction (full D.4, HL)

International Baccalaureate · IB Diploma · Physics · HL

Fields · 2.1

Reasoning

A field describes a force effect at positions in space. A current-carrying conductor in a magnetic field can experience a force. Electromagnetic induction occurs when magnetic flux linkage changes. induction: Creation of emf by changing flux linkage; transformer : A device transferring energy between coils through changing flux.

Fields · 4.1

Reasoning

State the known values and their units. Choose the relation because its assumptions fit this case, then rearrange before substitution. Known: a transformer has 200 primary turns, 50 secondary turns and 12 V primary voltage. For an ideal transformer, $V_s/V_p = N_s/N_p$. $V_s = V_p N_s/N_p = 12 \times 50/200 = 3.0$ V. Real transformers also dissipate energy.

A changing flux makes an emf

- 1 Set the model** A 50-turn coil has flux per turn $8.7 \times 10^{-3} \text{ Wb}$, falling to zero uniformly in 0.10 s.
- 2 Calculate** Average emf magnitude = $N|\Delta\Phi|/\Delta t = 50(8.7 \times 10^{-3})/0.10 = 4.35 \text{ V}$.

Decision

Lenz's law sets the direction: the induced effect opposes the change in flux, not necessarily the original field.

Exercises 2.1·2.3

2.1 Define magnetic flux and state the angle used in $\Phi = BA \cos \theta$. [2]

2.2 State Lenz's law and explain why it is a consequence of energy conservation. [2]

2.3 A rod of length 0.15 m moves at 3.0 m/s perpendicular to a 0.40 T field. Calculate the induced emf. [2]

Exercises 2.1·2.3

2.1 Define magnetic flux and state the angle used in $\Phi = BA \cos \theta$. [2]

2.1 The product of field strength and the perpendicular component of area it crosses: field through the surface; θ is the angle between the field and the normal to the surface.

2.2 State Lenz's law and explain why it is a consequence of energy conservation. [2]

2.2 The induced current's field opposes the change in flux that produces it; the opposition means work must be done to keep the change going, and that work is exactly the electrical energy delivered – without opposition the induced current would create energy from nothing.

2.3 A rod of length 0.15 m moves at 3.0 m/s perpendicular to a 0.40 T field. Calculate the induced emf. [2]

2.3 $\varepsilon = BLv = 0.40 \times 0.15 \times 3.0 = 0.18 \text{ V}$.

Exercises 2.4·3.1

2.4 State two changes that increase the peak emf of a coil rotating in a uniform magnetic field. [2]

3.1 A single loop of area 0.020 m^2 lies with its plane perpendicular to a 0.50 T field. Calculate the flux through it; then, if the loop is pulled out of the field in 0.040 s , calculate the average induced emf. [4]

Exercises 2.4·3.1

2.4 State two changes that increase the peak emf of a coil rotating in a uniform magnetic field. [2]

2.4 Any two of: stronger field B ; more turns N ; larger area A ; faster rotation ω – since $\varepsilon_0 = NBA\omega$.

3.1 A single loop of area 0.020 m^2 lies with its plane perpendicular to a 0.50 T field. Calculate the flux through it; then, if the loop is pulled out of the field in 0.040 s , calculate the average induced emf. [4]

3.1 Plane perpendicular to the field means $\theta = 0$ to the normal: $\Phi = BA = 0.50 \times 0.020 = 1.0 \times 10^{-2} \text{ Wb}$; $\varepsilon = \Delta\Phi/\Delta t = 1.0 \times 10^{-2}/0.040 = 0.25 \text{ V}$.

Exercises 3.2-3.3

3.2 A bar magnet hangs on a spring above a coil. The magnet oscillates, and the coil's ends are connected through a small lamp. Explain, using Lenz's law, why the magnet's oscillation dies away faster when the lamp circuit is closed than when it is open. [4]

3.3 A rectangular coil of 200 turns and area 0.025 m^2 rotates at 25 rev/s in a 0.30 T field. Calculate the angular frequency and the peak emf, and describe how the output changes if the rotation rate is doubled. [5]

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3.2 The moving magnet changes the flux through the coil, inducing an emf that drives current through the lamp; by Lenz's law the current's field opposes the magnet's motion, an upward or downward force against it at every phase; the mechanical energy of oscillation converts to electrical energy and then to heat and light in the lamp; with the circuit open no current flows, no opposing force acts, and only the spring's own damping remains.

3.3 A rectangular coil of 200 turns and area 0.025 m^2 rotates at 25 rev/s in a 0.30 T field. Calculate the angular frequency and the peak emf, and describe how the output changes if the rotation rate is doubled. [5]

3.3 $\omega = 2\pi f = 2\pi \times 25 = 157 \text{ rad/s}$; $\varepsilon_0 = NBA\omega = 200 \times 0.30 \times 0.025 \times 157 = 236 \approx 240 \text{ V}$; doubling the rotation rate doubles both the output frequency and the peak emf to about 470 V .

Exercise 3.4

3.4 A generator supplies more power when turned faster. Explain this in terms of Faraday's law and the energy the driving source must supply. [3]

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3.4 Faster rotation raises the rate of flux change, so Faraday's law gives a larger emf and the generator drives more current and power; by Lenz's law the larger current pushes a stronger opposing force on the coils; the source must supply the extra mechanical work against that opposition – energy in equals electrical energy out plus losses.