Grade 12 Physics, Explained

Unit 18 · Electromagnetic Induction

ANSWER KEY · FOR TEACHERS

Full marks 34

Give the marks for the points in the marking scheme; an answer in other words that says the same is right.

1 Key words

1. electromagnetic induction
2. Lenz's law
3. motional
4. eddy currents
5. laminated
6. self-induction
7. henrys
8. mutual induction

Each carries 0.5 mark. K · 4

2 Label the diagram

1. axis
2. coil
3. slip rings
4. brushes

Each carries 0.5 mark. K · 2

3 Multiple choice

i. **c.** 3.6 V A · 1

$\varepsilon = N\frac{\Delta\Phi}{\Delta t} = \frac{150 \times 40 \times 10^{-4} \times (0.35 - 0.05)}{0.05} = 3.6$ V. (4.2 V comes from using 0.35 T instead of the change.)

ii. **a.** 0.6 V A · 1

$\varepsilon = Blv = 0.25 \times 0.8 \times 3 = 0.6$ V.

iii. **b.** a quarter as large U · 1

$L = \mu_0 N^2 A/l$: L $\propto$ N^2, so halving N gives a quarter of L.

iv. **c.** 0.18 J A · 1

E = ½LI^2 = ½ × 0.040 × 3^2 = 0.18 J.

v. **b.** eddy currents in the frame stop the pointer swinging to and fro U · 1

When the coil swings, eddy currents in the frame oppose the motion (electromagnetic damping), so the pointer comes to rest at its reading quickly: a dead-beat galvanometer.

4 Short answers

a. MARKING SCHEME U · 2

- ✓ Opposing the change means work must be done to make it, and the work becomes the electrical energy.
- ✓ If it helped the change, energy would be created from nothing.

b. MARKING SCHEME U · 2

- ✓ Higher voltage means a smaller current for the same power.
- ✓ The loss I^{2}R falls (as 1/n^2).

c. MARKING SCHEME U · 2

- ✓ Slip rings replaced by a split ring (commutator).
- ✓ It swaps the connections each time the e.m.f. reverses, so the outside current is one way.

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5 Long answer

ANSWER U · 4

Let the coil's normal make an angle $\theta = \omega t$ with the field. The flux linkage is $N\Phi = NBA\cos \omega t$. By Faraday's law $\varepsilon = -\frac{d(N\Phi)}{dt} = NBA\omega \sin \omega t$. It is greatest when $\sin \omega t = 1$, that is when the plane of the coil is parallel to the field (the flux is then zero but changing fastest), and its greatest value is $\varepsilon_0 = NBA\omega$.

MARKING SCHEME

- ✓ Flux linkage NBA cos ωt, with $\theta = \omega t$.
- ✓ $\varepsilon = -d(N\Phi)/dt$.
- ✓ $\varepsilon = NBA\omega \sin \omega t$.
- ✓ Greatest, NBAω, when the plane of the coil is parallel to the field.

6 Numerical problems

a. **ANSWER** A · 3

i. $\omega = 2\pi \times 50 = 314$ rad/s; $\varepsilon_0 = NBA\omega = 100 \times 0.4 \times (0.08 \times 0.05) \times 314 = \mathbf{50\ V}$.

ii. The plane at 30° to the field puts the normal at 60°: $\varepsilon = \varepsilon_0 \sin 60° = \mathbf{44\ V}$.

MARKING SCHEME

- ✓ $\omega = 314$ rad/s.
- ✓ $\varepsilon_0 = 50$ V.
- ✓ $\varepsilon = 44$ V (the angle from the normal is 60°).

b. **ANSWER** A · 4

i. $L = \frac{\mu_0 N^2 A}{l} = \frac{4\pi \times 10^{-7} \times 1000^2 \times 6.0 \times 10^{-4}}{0.50} = \mathbf{1.5\ mH}$.

ii. $\varepsilon = L\frac{\Delta I}{\Delta t} = 1.51 \times 10^{-3} \times \frac{2.0}{5.0 \times 10^{-3}} = \mathbf{0.60\ V}$.

iii. $E = \frac{1}{2}LI^2 = \frac{1}{2} \times 1.51 \times 10^{-3} \times 2.0^2 = \mathbf{3.0 \times 10^{-3}\ J}$.

MARKING SCHEME

- ✓ $L = \mu_0 N^2 A/l$.
- ✓ L = 1.5 mH.
- ✓ $\varepsilon = 0.60$ V.
- ✓ E = 3.0 mJ.

c. **ANSWER** A · 3

$N_S = N_P \times \frac{E_S}{E_P} = 1150 \times \frac{12}{230} = \mathbf{60\ turns}$.

Ideal, so the input power is 6.0 W too: $I_P = 6.0 \div 230 = \mathbf{0.026\ A}$ (the secondary current is $6.0 \div 12 = 0.5$ A).

MARKING SCHEME

- ✓ $N_S = 60$ turns.
- ✓ Input power = output power for an ideal transformer.
- ✓ $I_P = 0.026$ A.

7 Think

ANSWER HA · 3

As it moves, an e.m.f. Blv drives a current round the rod, rails and resistor. The force BIl on the current in the rod opposes the motion (Lenz's law), so the rod slows down; as it slows, the e.m.f., the current and the force get smaller, so it slows more and more gently until it stops. Its kinetic energy becomes heat in the resistor (and the rod), I^2R.

MARKING SCHEME

- ✓ The induced current gives a force BIl against the motion (Lenz's law).
- ✓ The rod slows down, more gently as it slows, and stops.
- ✓ Its kinetic energy becomes heat in the resistance.

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8 Activity: Demonstrating Lenz's law (Activity 18.3)

(not marked)

WHAT STUDENTS SHOULD FIND

The needle moves one way as the magnet approaches and the other way as it leaves, and the directions swap with the S pole. The coil's near end always becomes a pole that opposes the motion: a north pole facing an approaching N pole (repelling it), a south pole facing a retreating N pole (attracting it). You do work either way, as Lenz's law says.

See it at Science Playground

Exhibits and plants at the center, Bhaktapur, that go with this unit. Book a class visit at science-playground.com/booking.

- **Magnetic Braking** (exhibit): Drop the magnet down the copper tube: the currents it induces make magnetic fields that oppose its motion, Lenz's law, so it drifts down slowly.

Marks by level	Knowledge	Understanding	Application	Higher ability	Total
Marks	6	12	13	3	**34**