Unit 18 · Electromagnetic Induction

HARDER PRACTICE QUESTIONS · ANSWER KEY

Full marks 32

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

1 Spot the error

ANSWER U · 3

The **voltage** goes up in the ratio of the turns; the current goes down, since the power in equals the power out ($E_P I_P = E_S I_S$): $\frac{I_S}{I_P} = \frac{N_P}{N_S}$, so $I_S = 4.0 \times \frac{100}{2000} = \mathbf{0.20\ A}$. Her answer would give twenty times the voltage and twenty times the current, 400 times the power: energy from nothing.

MARKING SCHEME

- ✓ The error: the current ratio is the inverse of the turns ratio.
- ✓ From $E_P I_P = E_S I_S$.
- ✓ $I_S = 0.20$ A.

2 Read the data

ANSWER A · 4

0–0.2 s: $\varepsilon = 50 \times \frac{4 \times 10^{-3}}{0.2} = \mathbf{1.0\ V}$.

0.2–0.3 s: the flux doesn't change: **0**.

0.3–0.4 s: $50 \times \frac{4 \times 10^{-3}}{0.1} = \mathbf{2.0\ V}$, in the **opposite** direction (the flux is falling).

The graph is a step at 1.0 V, zero, then a step of 2.0 V on the other side of the axis.

MARKING SCHEME

- ✓ 1.0 V from 0 to 0.2 s.
- ✓ 0 from 0.2 to 0.3 s.
- ✓ 2.0 V from 0.3 to 0.4 s.
- ✓ Opposite sign in the last part, shown on the sketch.

3 Predict, then explain

MARKING SCHEME U · 3

- ✓ Solid plate: stopped quickly.
- ✓ Eddy currents oppose the motion (energy becomes heat).
- ✓ Slotted plate swings on: the slots cut the eddy currents' paths.

4 Show that

MARKING SCHEME A · 3

- ✓ $B = \mu_0 NI/l$ inside.
- ✓ Flux linkage $N\Phi = \mu_0 N^2 IA/l$.
- ✓ $L = N\Phi/I = \mu_0 N^2 A/l$.

5 Estimate it

ANSWER HA · 3

$\varepsilon = Blv = 34 \times 10^{-6} \times 1.5 \times 20 =$ **about 1 mV**.

No. The voltmeter's leads move with the car through the same field, so the same e.m.f. is set up along them, against the axle's; round the closed loop the e.m.f.s cancel and the voltmeter reads nothing. (The flux through the loop doesn't change.)

MARKING SCHEME

- ✓ $v = 20$ m/s and $\varepsilon = Blv$.
- ✓ About 1 mV.
- ✓ No: the leads move with it and have an equal opposing e.m.f. (no change of flux through the loop).

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

6 Which explanation fits?

MARKING SCHEME U · 2

- ✓ Muna: iron losses.
- ✓ No load means little current (small copper loss), but the core is still taken round its cycle.

7 Correct the misconceptions

ANSWER U · 3

1. An e.m.f. is induced only while the flux **changes**; a magnet held still gives none.
2. A transformer **does not** work on steady d.c.: the core's flux doesn't change, so no e.m.f. is induced in the secondary.
3. A turning coil's e.m.f. is greatest when the flux through it is **zero** (its plane along the field), where the flux changes fastest.

MARKING SCHEME

- ✓ Only a changing flux induces an e.m.f.
- ✓ No transformer action on steady d.c.
- ✓ The e.m.f. is greatest where the flux is zero and changing fastest.

8 Work backwards

ANSWER A · 3

At a steady speed the pull balances BIl: $I = \frac{F}{Bl} = \frac{0.050}{0.40 \times 0.50} = \mathbf{0.25\ A}$. $\varepsilon = Blv = 0.40 \times 0.50 \times 5.0 =$ 1.0 V, so $R = 1.0 \div 0.25 = \mathbf{4.0}\ \Omega$. Power $= Fv = 0.050 \times 5.0 = \mathbf{0.25\ W}$, the same as εI, all turned into heat in R.

MARKING SCHEME

- ✓ $I = F/(Bl) = 0.25$ A.
- ✓ $R = 4.0\ \Omega$.
- ✓ Power 0.25 W.

9 Design it

ANSWER A · 4

i. $I = 50\,000 \div 230 = 217$ A; loss $= I^2R = 217^2 \times 0.50 = \mathbf{2.4 \times 10^4\ W}$, nearly half the power.

ii. $I = 50\,000 \div 11\,000 = 4.5$ A; loss $= 4.5^2 \times 0.50 = \mathbf{10\ W}$.

iii. $N_S : N_P = 11\,000 : 230$, about **48 : 1**.

iv. A **step-down** transformer to bring it back to 230 V, because 11 kV is dangerous and homes' appliances need 230 V.

MARKING SCHEME

- ✓ About 24 kW lost at 230 V.
- ✓ About 10 W lost at 11 kV.
- ✓ Turns ratio about 48 : 1.
- ✓ A step-down transformer at the village, for safety and the appliances.

10 What if?

ANSWER HA · 2

i. M falls (to nearly zero): little of the first coil's flux now passes through the second's turns.

ii. M rises a lot: the iron carries far more flux, and guides nearly all of it from one coil through the other.

MARKING SCHEME

- ✓ Turned: M falls, less flux of one links the other.
- ✓ Iron core: M rises, the core carries more flux from one to the other.

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking

11 Make your own

ANSWER HA · 2

For example: “A coil of self-inductance 0.25 H carries a current of 2.0 A. How much energy is stored in its magnetic field?” $E = \frac{1}{2}LI^2 = \frac{1}{2} \times 0.25 \times 2.0^2 = 0.50$ J. Any problem whose numbers give $\frac{1}{2}LI^2 = 0.50$ J is right.

MARKING SCHEME

- ✓ A sensible problem.
- ✓ Solved correctly with $E = \frac{1}{2}LI^2$.

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	0	11	14	7	**32**

Science Playground, Katunje, Bhaktapur
Book a class visit: https://science-playground.com/booking