Class 12 Physics · Chapter 6: Electromagnetic Induction

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. The current in a coil is being decreased steadily. The self-induced emf in the coil [1]

(a) acts opposite to the current, helping it to fall

(b) is zero, because the current is decreasing and not increasing

(c) is equal to the emf of the source driving the current

(d) acts in the same direction as the current, opposing its decrease

Answer: (d) The self-induced (back) emf $\varepsilon = -L\, dI/dt$ opposes any change in the current. When the current falls, the emf tries to keep it flowing, so it acts in the direction of the current.

2. A closed metal ring is pulled away, along the axis, from the north pole of a bar magnet that is held fixed. As seen from the magnet's side, the induced current in the ring is [1]

(a) anticlockwise

(b) zero, because the magnet is at rest

(c) clockwise

(d) clockwise at first and then anticlockwise

Answer: (c) Only relative motion matters, so the flux through the ring decreases as for a receding magnet. To oppose the decrease the ring's near face becomes a south pole, attracting the magnet; a current that is clockwise as seen from that face makes it a south pole.

3. A long solenoid with an air core has a self-inductance of 2.0 mH. It is filled completely with a material of relative permeability 400, everything else unchanged. Its self-inductance becomes [1]

(a) 0.0050 H

(b) 0.80 H

(c) 0.040 H

(d) 320 H

Answer: (b) $L = \mu_r \mu_0 n^2 A l$, so L is multiplied by μ_r: $400 \times 2.0 \times 10^{-3}$ H = 0.80 H. 0.0050 H divides by μ_r; 0.040 H uses $\sqrt{\mu_r}$; 320 H uses μ_r^2.

4. The flux through each turn of a 200-turn coil falls steadily from 5.0 mWb to 1.0 mWb in 0.20 s. The magnitude of the emf induced in the coil is [1]

(a) 4.0 V

(b) 6.0 V

(c) 0.020 V

(d) 0.80 V

Answer: (a) $\varepsilon = N\,\Delta\Phi/\Delta t = 200 \times (5.0 - 1.0) \times 10^{-3} / 0.20 = 4.0$ V. 6.0 V adds the two fluxes instead of subtracting; 0.020 V leaves out N; 0.80 V forgets to divide by the time.

5. The weber, the SI unit of magnetic flux, is the same as [1]

(a) V s^{-1}

(b) V s

(c) T m^{-2}

(d) A m^2

Answer: (b) From Faraday's law $\varepsilon = -d\Phi_B/dt$, flux = emf × time, so 1 Wb = 1 V s. It is also 1 T m^2, not T m^{-2}.

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6. In a simple ac generator, what is the role of the slip rings and brushes? What energy conversion takes place in the generator? [2]

The ends of the rotating coil are joined to slip rings that turn with it; fixed brushes press on the rings and carry the current to the external circuit without the wires twisting. The generator converts mechanical energy (of whatever turns the armature) into electrical energy.

- slip rings and brushes connect the rotating coil to the external circuit (1)
- mechanical energy to electrical energy (1)

7. The current through an inductor of 0.50 H is raised from 2.0 A to 6.0 A. Find the increase in the energy stored in it. Where does this energy come from? [2]

$U = \tfrac{1}{2}LI^2$. $\Delta U = \tfrac{1}{2} \times 0.50 \times (6.0^2 - 2.0^2) = 0.25 \times 32 = 8.0$ J. The source does this work against the back emf while the current rises; it is stored as magnetic energy.

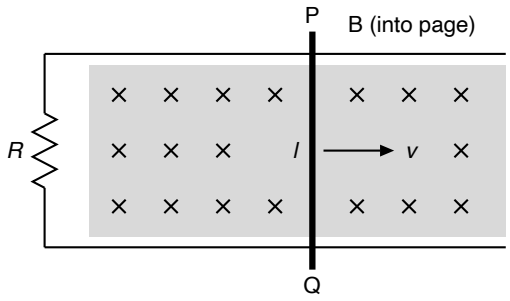
- $\Delta U = \tfrac{1}{2}L(I_2^2 - I_1^2) = 8.0$ J (1)
- work done by the source against the back emf (1)

8. Why is self-inductance called the electrical inertia of a coil? Which quantities in $\tfrac{1}{2}LI^2$ play the parts of mass and velocity in $\tfrac{1}{2}mv^2$? [2]

The self-induced (back) emf opposes any change in the current, growth or decay, just as inertia opposes any change in velocity. In $U = \tfrac{1}{2}LI^2$, the inductance L plays the part of mass m and the current I that of velocity v.

- back emf opposes both growth and decay of current, as inertia opposes change of velocity (1)
- L corresponds to m and I to v (1)

9. In the arrangement shown, the rod PQ, 0.60 m long, moves to the right at 4.0 m s^{-1} on the rails through a uniform field of 0.25 T directed into the page. (a) Find the Lorentz force on a free electron in the rod and its direction. (b) Using the work done per unit charge, find the emf of the rod. (c) Which end of the rod is at the higher potential? [3]



(a) $F = evB = 1.6 \times 10^{-19} \times 4.0 \times 0.25 = 1.6 \times 10^{-19}$ N. For a positive charge, v × B (right × into page) points up the rod towards P; an electron, being negative, is pushed towards Q. (b) Moving a charge q along the rod the force does work W = qvBl, so $\varepsilon = W/q = Blv = 0.25 \times 0.60 \times 4.0 = 0.60$ V. (c) Electrons collect at Q, so P is at the higher potential (the induced current flows from Q to P inside the rod, anticlockwise round the circuit, opposing the rising flux).

- $F = evB = 1.6 \times 10^{-19}$ N, electron pushed towards Q (1)
- $\varepsilon = W/q = Blv = 0.60$ V (1)
- P at higher potential (1)

10. An aluminium ring rests on the top of a vertical coil wound on a soft-iron core. When the switch in the coil's circuit is closed, the ring jumps up. (a) Explain why. (b) Why does it fall back while the switch is kept closed? (c) What would happen if the ring had a narrow cut in it? [3]

(a) Closing the switch makes the coil's current, and the flux through the ring, rise sharply (the iron core makes the flux large). By Lenz's law the induced current in the ring opposes this rise: its field is opposite to the coil's, so the ring is repelled and jumps. (b) Once the current is steady the flux stops changing, the induced current dies away, there is no repulsion and gravity pulls the ring back. (c) With a cut the ring is an open circuit: an emf appears across the cut but no current flows, so there is no force and the ring does not jump.

- rising flux induces a current opposing it, so the ring is repelled (1)
- steady current, no change of flux, no induced current (1)
- cut ring: emf only, no current, so no jump (1)

11. A coil of N turns, each of area A, rotates at a constant angular speed ω about an axis perpendicular to a uniform field B. (a) Show that the emf induced is ε = NBAω sin ωt, taking the plane of the coil perpendicular to B at t = 0. (b) State the positions of the coil in which the emf is maximum and zero, with a reason. [3]

(a) At time t the area vector makes θ = ωt with B, so $\Phi_B = BA\cos\omega t$ per turn. $\varepsilon = -N\,d\Phi_B/dt = -NBA\,d(\cos\omega t)/dt = NBA\omega\sin\omega t$. (b) ε is maximum, $\varepsilon_0 = NBA\omega$, at θ = 90° and 270°, when the plane of the coil is parallel to B: the flux is zero but changing fastest. ε is zero at θ = 0° and 180°, when the plane is perpendicular to B: the flux is maximum and momentarily not changing.

- $\Phi_B = NBA\cos\omega t$ written (1)
- $\varepsilon = -N\,d\Phi/dt = NBA\omega\sin\omega t$ (1)
- maximum when plane parallel to B, zero when perpendicular, with the rate-of-change reason (1)