InkPhysics

ANSWER BOOK

Electromagnetic induction: Faraday and Lenz

Magnetic fields · Year 13

AQA 3.7.5.4 · CIE 20.5.4, 20.5.5 · OCR A 6.3.3(c), 6.3.3(d)(i), 6.3.3(e)

19 questions · 52 marks

NAVY EDITION

SECTION A · Warm-up

A1 The magnitude of the induced emf equals the rate of change of flux linkage (1); emf = $N\,\Delta\Phi/\Delta t$ (1). [2]

A2 emf = $\Delta(N\Phi)/\Delta t$ = 0.60/0.20 (1)
emf = 3.0 V (1) [2]

A3 The direction of the induced current (or emf) is such as to oppose the change in flux that produces it (1). [1]

A4 The volt: a rate of change of flux linkage of 1 Wb-turn per second induces an emf of 1 V (1). [1]

A5 The emf is zero (1); the induced emf equals the rate of change of flux linkage, and here the flux linkage is not changing (1). [2]

SECTION B · Standard

B1 emf = Blv = 0.25 × 0.30 × 4.0 (1)
emf = 0.30 V (1) [2]

B2 emf = $NA\Delta B/\Delta t$ (1)
= 200 × 0.01 × (0.50 - 0.10)/0.40 (1)
emf = 2.00 V (1) [3]

B3 emf = $\Delta(N\Phi)/\Delta t$ = 0.80/0.010 (1)
emf = 80 V (1) [2]

B4 If the induced current acted to aid the change in flux, the change would reinforce itself and electrical energy would be produced from nothing (1). The induced current instead opposes the change, so work must be done against the opposing force to keep the change going (1); this work input is the source of the electrical energy generated, consistent with energy conservation (1). [3]

B5 emf = $N\Delta\Phi/\Delta t$ = $250 \times 3.2 \times 10^{-4}/0.040$ (1)
emf = 2.0 V (1)
I = emf/R = 2.0/4.0 = 0.50 A (1) [3]

B6 [3]

emf = $Blv = 45 \times 10^{-6} \times 60 \times 250$ (1)
emf = 0.68 V (1)
The wings sweep out a horizontal area, so only the flux of the vertical component passes through the area swept; the horizontal component lies in the plane of sweep and contributes no flux (1)

B7 [2]

While the current in A grows, the flux it produces through B is changing, so an emf is induced in B and the meter deflects (1); once the current in A is steady, the flux through B is constant, so there is no rate of change of flux linkage and no emf (1).

B8 [3]

Entering, the flux linkage increases at a steady rate, so a constant emf is induced (1); fully inside, the flux linkage is constant, so the emf is zero (1); leaving, the flux linkage falls at the same rate, so the emf has the same magnitude but the opposite sense (1).

SECTION C · Stretch

C1 [3]

$\omega = 2\pi f = 2\pi \times 50$ (1)
peak emf = $BAN\omega = 0.30 \times 0.02 \times 100 \times (2\pi \times 50)$ (1)
peak emf = 188.5 V (1)

C2 [4]

emf = $Blv = 0.40 \times 0.20 \times 3.0 = 0.24$ V (1)
$I = \text{emf}/R = 0.24/2.0 = 0.12$ A (1)
Applied force balances the opposing magnetic force: $F = BIl$ (1)
$F = 0.40 \times 0.12 \times 0.20 = 0.0096$ N (1)

C3 [3]

As the magnet enters, the flux linkage of the coil increases (1); the induced current flows so that the top face of the coil becomes a north pole, opposing the approaching north pole (1). As the magnet leaves, the flux falls, so the current reverses to attract the receding magnet (1).

C4 [4]

$\omega = 2\pi f = 2\pi \times 50 = 314$ rad s^{-1} (1)
Peak emf of P = $BAN\omega = 0.35 \times 2.5 \times 10^{-3} \times 200 \times 314 = 55.0$ V (1)
Peak emf of Q = $0.35 \times 1.2 \times 10^{-3} \times 350 \times 314 = 46.2$ V (1)
Only P reaches 50 V, so coil P should be chosen (1)

C5 [3]

The emf equals the rate of change of flux linkage, not the flux linkage itself (1); face-on, the flux linkage is at its maximum but momentarily not changing, so the emf is zero (1); edge-on, the flux linkage is passing through zero at its greatest rate, so the emf is a maximum (1).

C6 As the plate swings, the flux through each region of the plate changes as it enters and leaves the field (1). By Faraday's law, emfs are induced in the plate (1), driving circulating (eddy) currents within the metal (1). By Lenz's law these currents flow so as to oppose the change producing them, so the forces on them oppose the plate's motion whichever way it swings (1). The opposing force decelerates the plate, so the oscillation dies away quickly (1). The plate's kinetic energy is transferred to internal energy in the aluminium by the eddy currents flowing through its resistance (1). [6]