Solutions

Each answer shows the steps, then the **result**.

2.1

- the plane is perpendicular to the field, so the full area links the flux

$$N\Phi = NBA = 150 \times 0.25\ \text{T} \times 4.0 \times 10^{-3}\ \text{m}^2 = \mathbf{0.15}\ \text{Wb}$$

2.2

- divide the change in flux linkage by the time

$$|E| = \frac{\Delta(N\Phi)}{\Delta t} = \frac{0.15\ \text{Wb}}{0.20\ \text{s}} = \mathbf{0.75}\ \text{V}$$

2.3

- from 0 to 2.0 s: a **constant** e.m.f., of one sign
- from 2.0 to 3.0 s: **zero**
- from 3.0 to 4.0 s: **constant**, of the **opposite** sign and **twice** the earlier magnitude, because the same flux change happens in half the time

2.4

- as the magnet enters, the flux linkage through the coil **increases**; as it leaves, the flux linkage **decreases**
- the gradient $\dfrac{\mathrm{d}(N\Phi)}{\mathrm{d}t}$ therefore has **opposite signs**, so the induced e.m.f. does too

2.5

- the magnet **accelerates** under gravity, so it is moving faster as it leaves than as it entered
- the same change of flux linkage therefore happens in a **shorter time**, giving a **larger** e.m.f. that lasts for **less** time – the two areas remain equal

2.6

- when the **plane of the coil is perpendicular to the field** – that is, when the flux linkage is a **maximum**
- at that instant the flux linkage is momentarily **not changing**, so $\dfrac{\mathrm{d}(N\Phi)}{\mathrm{d}t} = 0$ and the induced e.m.f. is zero

3.1 B

- with the plane of the coil perpendicular to the field, the full area links the flux, so the flux linkage is at its **maximum**
- a maximum is a turning point, so the flux linkage is momentarily constant and the e.m.f. is **zero**. **A** is the standard error: the e.m.f. follows the *rate of change*, not the flux

3.2

(a)

- as the magnet falls, the magnetic flux linking each part of the copper tube **changes**
- an e.m.f. is induced, and because copper is a conductor a current – an **eddy current** – flows in the tube wall
- by **Lenz's law** the current is in the direction that **opposes the change** producing it
- so the tube exerts an **upward force** on the falling magnet, which nearly balances its weight, and the magnet falls slowly at almost constant speed

(b)

- an e.m.f. is still induced in the plastic, because the changing flux does not care what the material is
- but plastic is an **insulator**, so no current flows, there is no opposing force, and the magnet falls freely under gravity

3.3

(a)

- the maximum flux linkage is NBA, with the plane of the coil perpendicular to the field

$$N\Phi_{\text{max}} = 250 \times 85 \times 10^{-3}\ \text{T} \times 1.8 \times 10^{-3}\ \text{m}^2 = \mathbf{3.8 \times 10^{-2}}\ \text{Wb}$$

(b)

- the **plane of the coil is perpendicular to the field** (the normal to the coil is along the field)
- at that instant the induced e.m.f. is **zero**

(c)

- flux linkage: a **cosine** curve, starting at its maximum 3.8×10^{-2} Wb, through zero, to -3.8×10^{-2} Wb and back
- e.m.f.: a **sine** curve of the same period
- the e.m.f. curve is a **quarter of a cycle** ahead: its zeros are at the peaks of the flux-linkage curve, and its peaks are at the zeros

(d)

- substitute into $E_0 = 2\pi f\, NBA$, using the flux linkage from part (a)

$$E_0 = 2\pi \times 50\ \text{Hz} \times 3.8 \times 10^{-2}\ \text{Wb} = \mathbf{12}\ \text{V}$$

(e)

- the peak e.m.f. **doubles**, to about 24 V, because $E_0 = 2\pi f NBA$ is proportional to f
- the period **halves**, to 1.0×10^{-2} s, because $T = 1/f$; both changes follow from the same doubling of f