

Faraday's law, inductors and LR circuits

AP Physics C (Mechanics and E&M, calculus-based) · Test answers (mark scheme)

Marks follow the usual method, accuracy and explanation pattern. Full credit needs correct units and a clear link between the physics and the numbers.

Level: AP Physics C (Mechanics and E&M, calculus-based) · **Curriculum:** AP PC:E&M Unit 13

Question 1 Lenz's law (2 marks)

- The face nearest the magnet becomes a **north pole**, repelling the approaching magnet.
- Work must be done to push the magnet against this repulsion, and that work becomes electrical energy. If the pole were south, the magnet would accelerate and energy would be created from nothing.

Marking: 1 mark for the polarity, 1 mark for the energy argument.

Question 2 Flux and emf (3 marks)

- $\Phi = 0.20 \text{ t}^2 \text{ A}$, so $|\varepsilon| = N \text{ d}\Phi/\text{d}t = N \times 0.40 \text{ t} \times \text{A}$.
- $|\varepsilon| = 60 \times 0.40 \times 1.5 \times 8.0 \times 10^{-3} = \mathbf{0.29 \text{ V}}$ (0.288 V).

Marking: 1 mark for the derivative; 1 mark for substituting; 1 mark for the answer with unit.

Question 3 Solenoid inductance (2 marks)

- $L = \mu_0 N^2 A / \ell = (4\pi \times 10^{-7})(500)^2(3.0 \times 10^{-4})/0.25 = 3.77 \times 10^{-4} \text{ H} \approx \mathbf{0.38 \text{ mH}}$.
- $|\varepsilon| = L \text{ d}I/\text{d}t = 3.77 \times 10^{-4} \times 80 = \mathbf{0.030 \text{ V}}$.

Marking: 1 mark each part.

Question 4 LR rise (3 marks)

- $\tau = L/R = 0.60/30 = \mathbf{0.020 \text{ s}}$.
- $I_\infty = 6.0/30 = 0.20 \text{ A}$; $t = 2\tau$, so $I = 0.20 (1 - e^{-2}) = \mathbf{0.17 \text{ A}}$.

Marking: 1 mark for τ ; 1 for the final current and the 2τ idea; 1 for the answer.

Question 5 Energy store (2 marks)

- $I = \varepsilon/R = \mathbf{0.20 \text{ A}}$.

b. $U = \frac{1}{2}LI^2 = \frac{1}{2} \times 0.60 \times 0.040 = \mathbf{0.012\ J}.$

Marking: 1 mark each part.

Question 6 Explaining the delay (2 marks)

As the current starts to rise, the flux through the inductor grows. By Lenz's law an emf opposes the change, so the current cannot jump to its final value at once. **The lamp brightens as the current rises over several time constants.**

Marking: 1 mark for the self-induced emf opposing the change; 1 mark for the gradual rise.

Question 7 LC oscillator (3 marks)

a. $\omega = 1/\sqrt{LC} = 1/\sqrt{(10 \times 10^{-3} \times 4.0 \times 10^{-6})} = 1/\sqrt{(4.0 \times 10^{-8})} = \mathbf{5.0 \times 10^3\ rad/s}.$

b. $I_{\max} = \omega Q = 5.0 \times 10^3 \times 20 \times 10^{-6} = \mathbf{0.10\ A}.$

Marking: 1 mark for part (a); 1 mark for $I_{\max} = \omega Q$ (or an energy equation); 1 mark for the answer.

Question 8 Rod on rails (3 marks)

a. $\varepsilon = Blv = 0.40 \times 0.50 \times 3.0 = \mathbf{0.60\ V}; I = 0.60/2.0 = \mathbf{0.30\ A}.$

b. $F = BI\ell = 0.40 \times 0.30 \times 0.50 = \mathbf{0.060\ N}.$

Marking: 1 mark each for ε and I ; 1 mark for the force.