Exercise walk-through

Circuits with Resistors and Inductors (LR Circuits) ▪ 13.5

eXercise

You must be able to

- describe the **growth** and **decay** of current in an LR circuit
- explain how an inductor **opposes changes** in current
- define the **time constant** 时间常数 $\tau = \frac{L}{R}$
- analyse the **initial** and **steady-state** behaviour

Method — Growth and decay

$$I(t) = \frac{\varepsilon}{R}\left(1 - e^{-t/\tau}\right) \text{ (rising)}, \qquad I(t) = I_0\, e^{-t/\tau} \text{ (falling)}.$$

Method — Time constant

$\tau = \dfrac{L}{R}$ sets how quickly the current settles.

Method — Start and steady state

At $t = 0$ the inductor **opposes** the sudden change, so the current is 0 (it acts like a break); at steady state it passes current freely (like a plain wire), and $I = \varepsilon / R$.

Practice 2.1 ▪ 2 marks

Find the time constant of a 0.40 H inductor and a $20\ \Omega$ resistor.

Solution 2.1

Method: Time constant

Worked steps

$$\tau = \frac{L}{R} = \frac{0.40}{20} = 0.020 \text{ s} \quad \text{M1} \; \text{A1}.$$

Practice 2.2 ▪ 1 mark

State the current in an LR circuit immediately after the switch closes.

Solution 2.2

Worked steps

zero (the inductor opposes the sudden change) B1.

Practice 2.3 ▪ 1 mark

State the steady-state current for an emf of 12 V and $R = 6.0\ \Omega$.

Solution 2.3

Method: Start and steady state

Worked steps

$$I = \frac{\varepsilon}{R} = \frac{12}{6.0} = 2.0 \text{ A}$$ B1.

Exam-style 3.1 ▪ 1 mark

The time constant of an LR circuit is

A RC

B L/R

C LR

D R/L

Solution 3.1

Method: Time constant

A RC

B L/R ✓

C LR

D R/L

Worked steps

B.

Exam-style 3.2 ▪ 1 mark

At $t = 0$ in an LR circuit, an inductor behaves like

A a plain wire

B a break (no current)

C a battery

D a capacitor

Solution 3.2

Method: Start and steady state

A a plain wire

B a break (no current) ✓

C a battery

D a capacitor

Worked steps

B.

Exam-style 3.3 ▪ 2 marks

An LR circuit has $\varepsilon = 10$ V, $R = 5.0\ \Omega$, and $L = 0.25$ H.
(a) Find the time constant.
(b) Find the final (steady-state) current.

Solution 3.3

Worked steps

(a) $\tau = \dfrac{L}{R} = \dfrac{0.25}{5.0} = 0.050$ s M1 A1. (b) $I = \dfrac{\varepsilon}{R} = \dfrac{10}{5.0} = 2.0$ A M1 A1.