13.5 Circuits with Resistors and Inductors (LR Circuits)

Name: _____ Class: _____ Date: _____ **Total: 10 marks**

Objective

Build the skills to answer exam questions on **circuits with resistors and inductors (LR circuits)**.

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 $\tau = \dfrac{L}{R}$
- analyse the **initial** and **steady-state** behaviour

1 Worked examples

Study these first. Each one shows the method for a question type used later.

■ **Growth and decay**

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

■ **Time constant**

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

■ **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 $I = \varepsilon/R$.

2 Practice

2.1 Find the time constant of a 0.40 H inductor and a 20 Ω resistor. [2]

2.2 State the current in an LR circuit immediately after the switch closes. [1]

2.3 State the steady-state current for an emf of 12 V and $R = 6.0\ \Omega$. [1]

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3 Exam-style questions

3.1 The time constant of an LR circuit is [1]

- **A** RC
- **B** L/R
- **C** LR
- **D** R/L

3.2 At $t = 0$ in an LR circuit, an inductor behaves like [1]

- **A** a plain wire
- **B** a break (no current)
- **C** a battery
- **D** a capacitor

3.3 An LR circuit has $\varepsilon = 10$ V, $R = 5.0\ \Omega$, and $L = 0.25$ H.

(a) Find the time constant. [2]

(b) Find the final (steady-state) current. [2]

4 Go further

- work through the **13.5 Circuits with Resistors and Inductors (LR Circuits)** lesson on the **Learn** page;

- read the **Electromagnetic Induction** section of the AP Physics C: E&M handout on the **Know** page.

Solutions

2.1 $\tau = \dfrac{L}{R} = \dfrac{0.40}{20} = 0.020$ s.

2.2 zero (the inductor opposes the sudden change).

2.3 $I = \dfrac{\varepsilon}{R} = \dfrac{12}{6.0} = 2.0$ A.

3.1 **B**.

3.2 **B**.

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