INDUCTOR
TRANSIENT RESPONSE

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TOPIC OUTLINE

RL Circuit

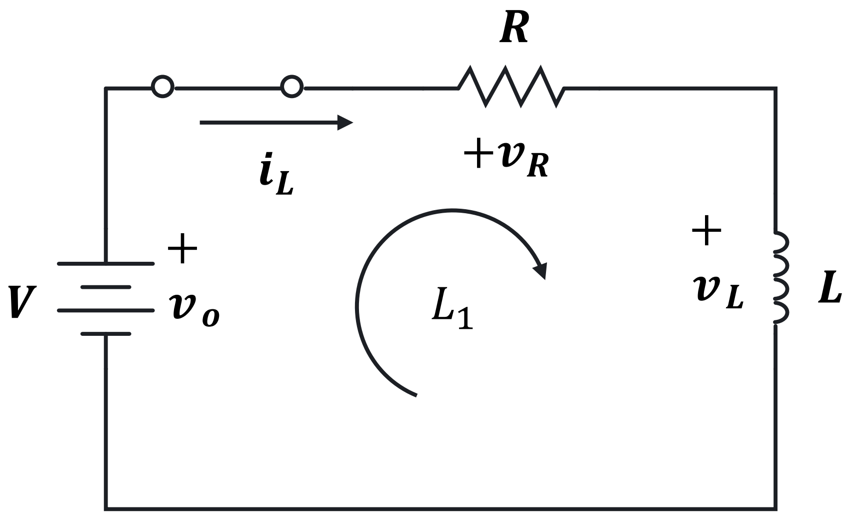
Energizing an Inductor

De-energizing an Inductor

Transient Response

ENERGIZING AN INDUCTOR

RL CIRCUIT



KVL @ L_1:

$$-v_o + v_R + v_L = 0$$

$$v_R + v_L = v_o$$

$$i_L R + v_L = v_o \qquad ; v_L = L\frac{d}{dt}i_L$$

$$i_L R + L\frac{d}{dt}i_L = v_o$$

$$\frac{d}{dt}i_L + \frac{R}{L}i_L = \frac{v_o}{L}$$

... first-order ODE

$$i_L = \frac{v_o}{R}\left(1 - e^{-\frac{R}{L}t}\right)$$

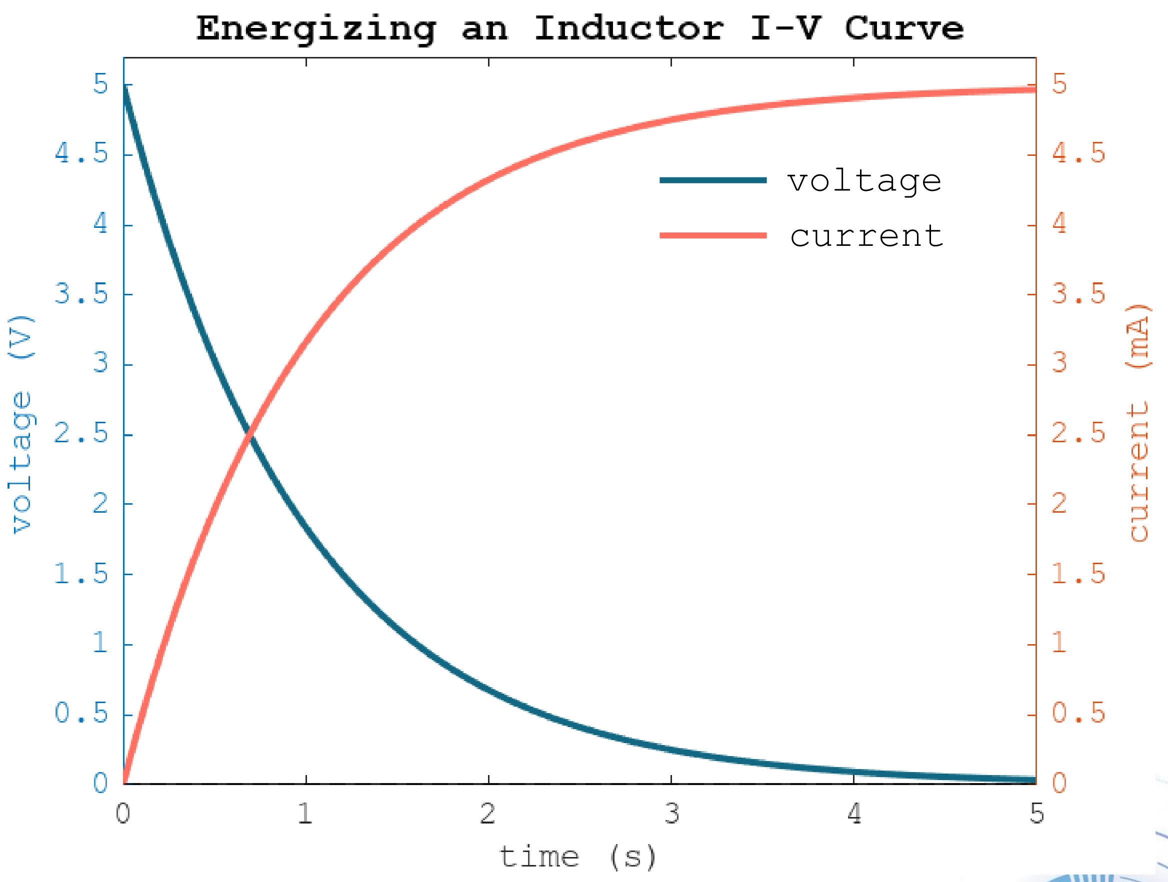
INDUCTOR CURRENT

Energizing equation:

$$i_L(t) = \frac{v_o}{R}\left(1 - e^{-\frac{t}{\tau}}\right)$$

where: $\tau = \frac{L}{R}$

The **current** through the inductor **starts at zero** and exponentially increases to $\frac{v_o}{R}$ amperes (maximum current).



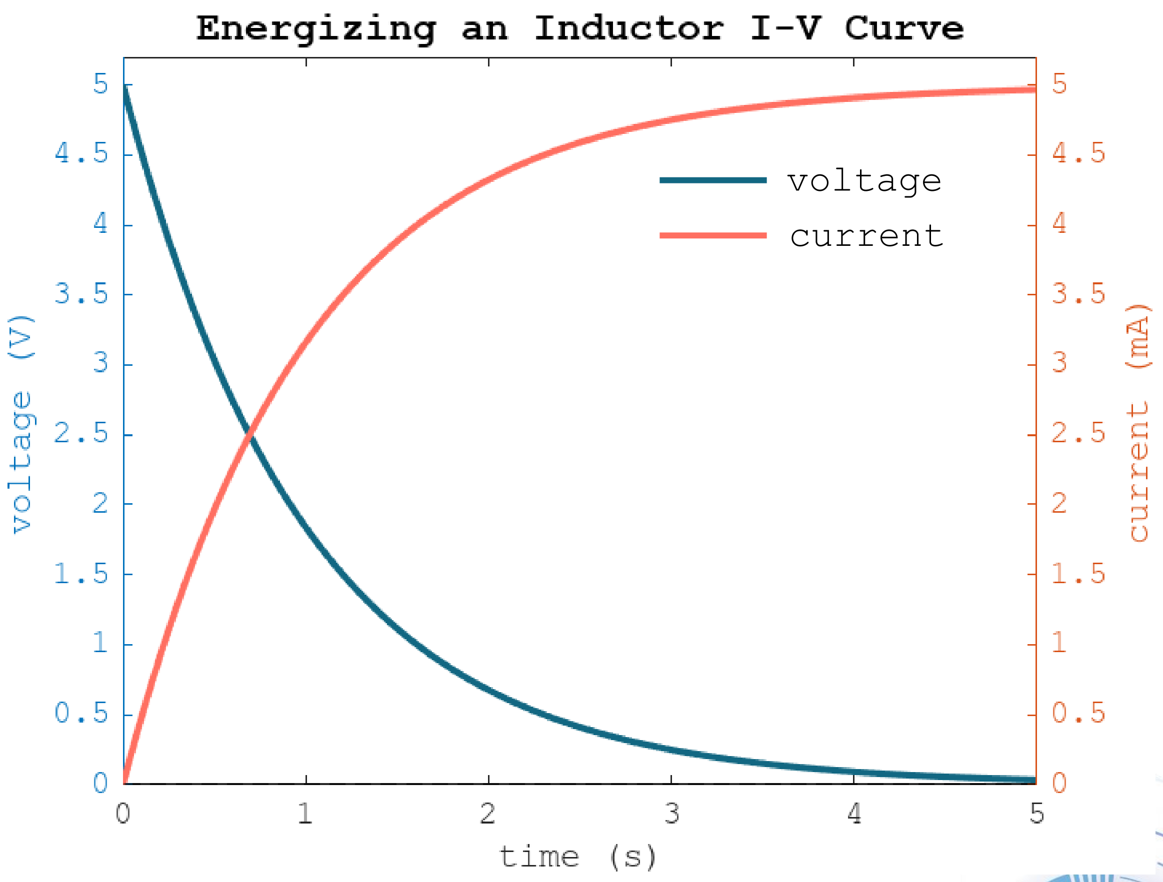
INDUCTOR VOLTAGE

Energizing equation:

$$v_L(t) = v_o e^{-\frac{t}{\tau}}$$

where: $\tau = \frac{L}{R}$

The **voltage** across the inductor instantly jumps to its **maximum value** of v_o volts then decays exponentially to zero.



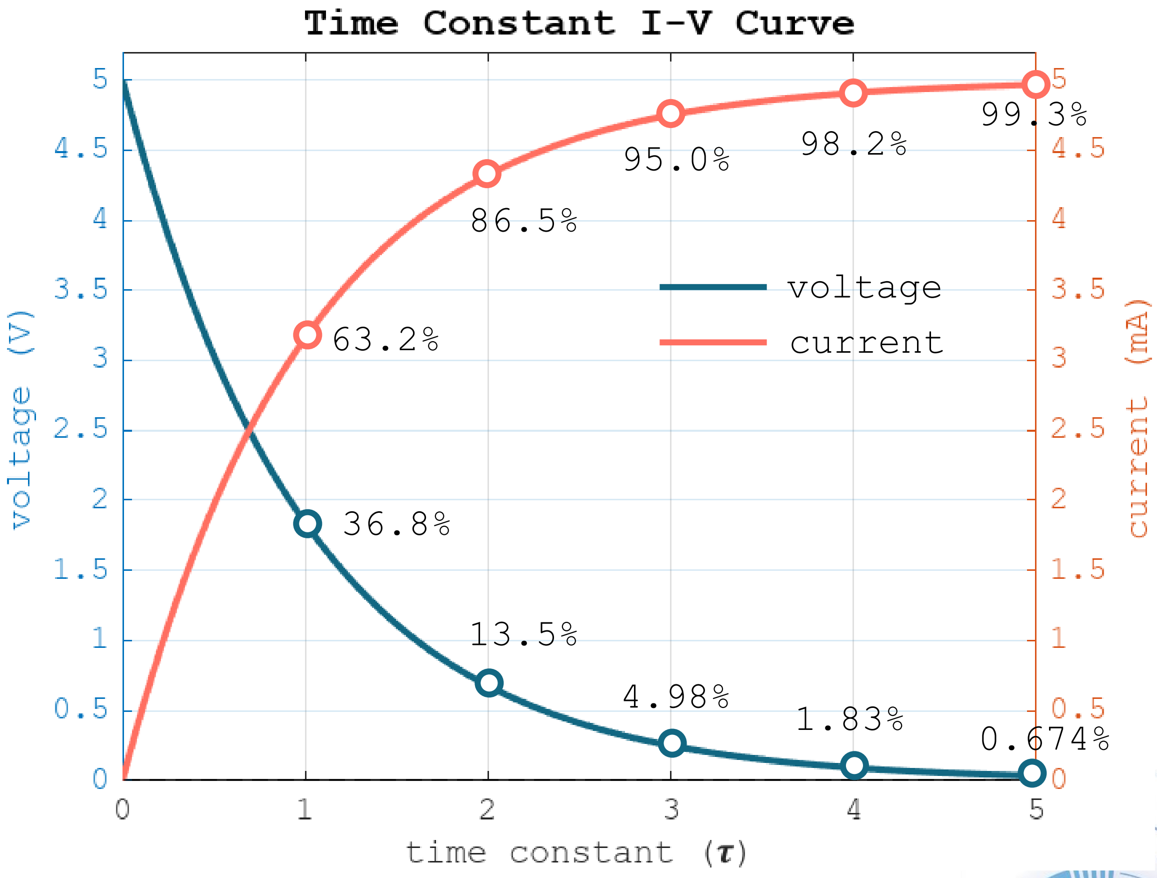
TIME CONSTANT

The **time constant** τ is a measure of how quickly an inductor energizes or de-energizes in an RL circuit.

Formula:

$$\tau = \frac{L}{R}$$

unit: second



EXERCISE

A $\mathbf{50}\ \boldsymbol{mH}$ inductor is connected to a $\mathbf{12}\ \boldsymbol{V}$ DC power supply through a resistor of $\mathbf{500}\ \boldsymbol{\Omega}$. Determine the **time** it takes for the inductor to charge to $\mathbf{95\%}$ of its maximum current.

Solution:

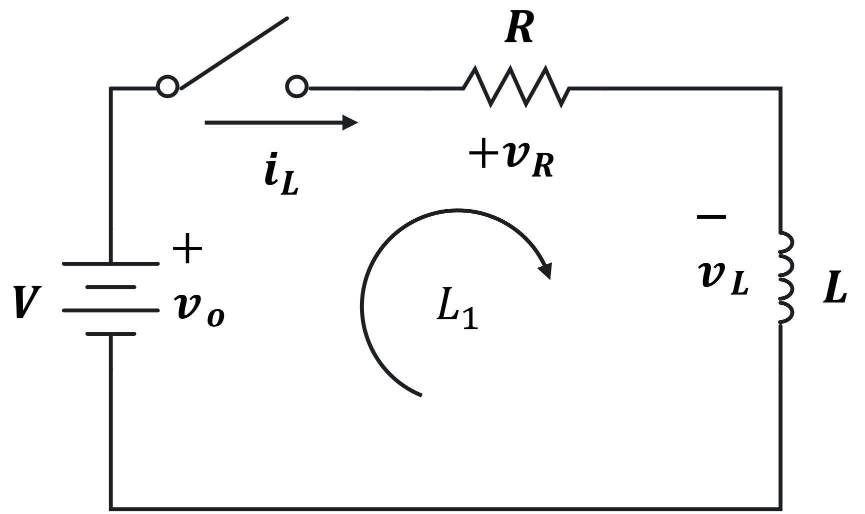
EXERCISE

A $\mathbf{50}\ \boldsymbol{mH}$ inductor is connected to a $\mathbf{12}\ \boldsymbol{V}$ DC power supply through a resistor of $\mathbf{500}\ \boldsymbol{\Omega}$. Determine the **current** through the inductor after $\mathbf{300}\ \boldsymbol{\mu s}$ of charging.

Solution:

DE-ENERGIZING AN INDUCTOR

RL CIRCUIT



KVL @ L_1:

$$v_R - v_L = 0$$

$$i_L R - v_L = 0 \qquad ; v_L = L\frac{d}{dt}i_L$$

$$i_L R - L\frac{d}{dt}i_L = 0$$

$$\frac{d}{dt}i_L - \frac{R}{L}i_L = 0$$

... first-order ODE

$$i_L = \frac{v_o}{R}e^{-\frac{R}{L}t}$$

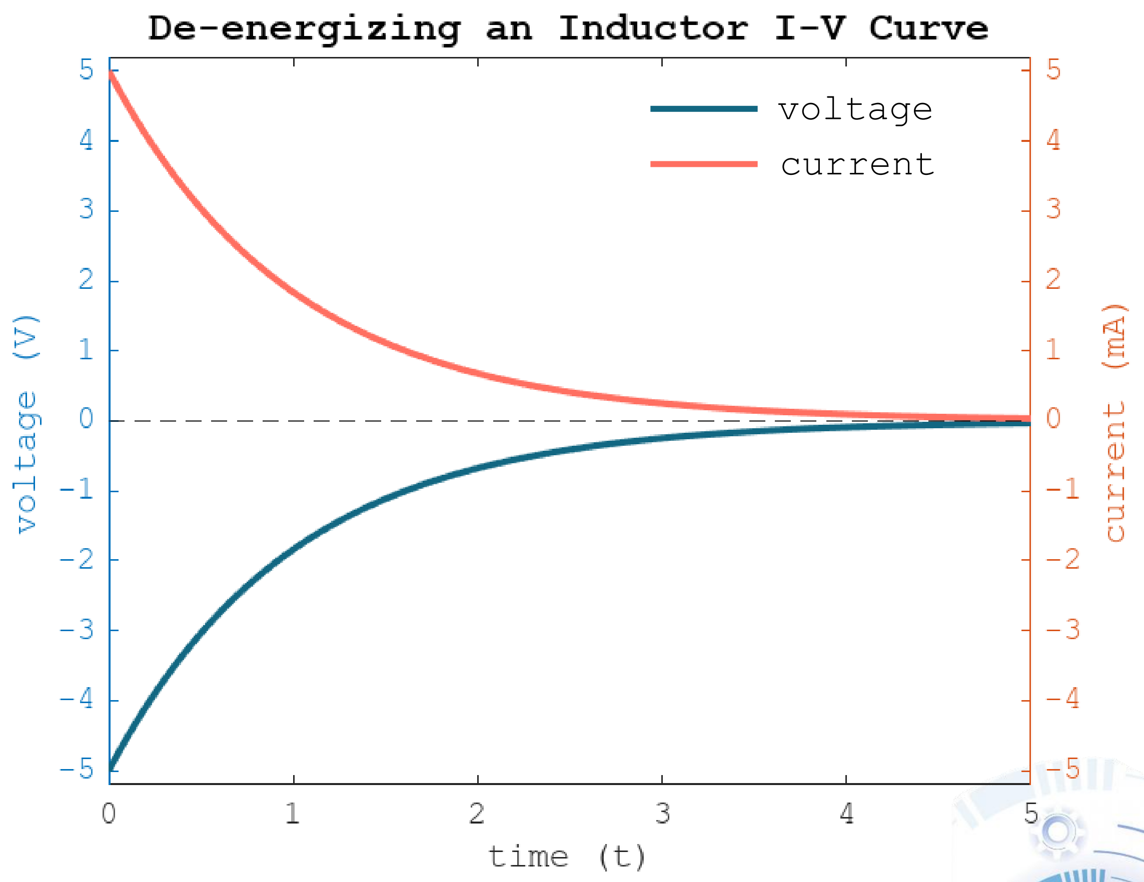
INDUCTOR CURRENT

De-energizing equation:

$$i_L(t) = \frac{v_o}{R} e^{-\frac{t}{\tau}}$$

where: $\tau = \frac{L}{R}$

The **current** through the inductor starts at its maximum value $\frac{v_o}{R}$ amperes then decays exponentially to **zero**.



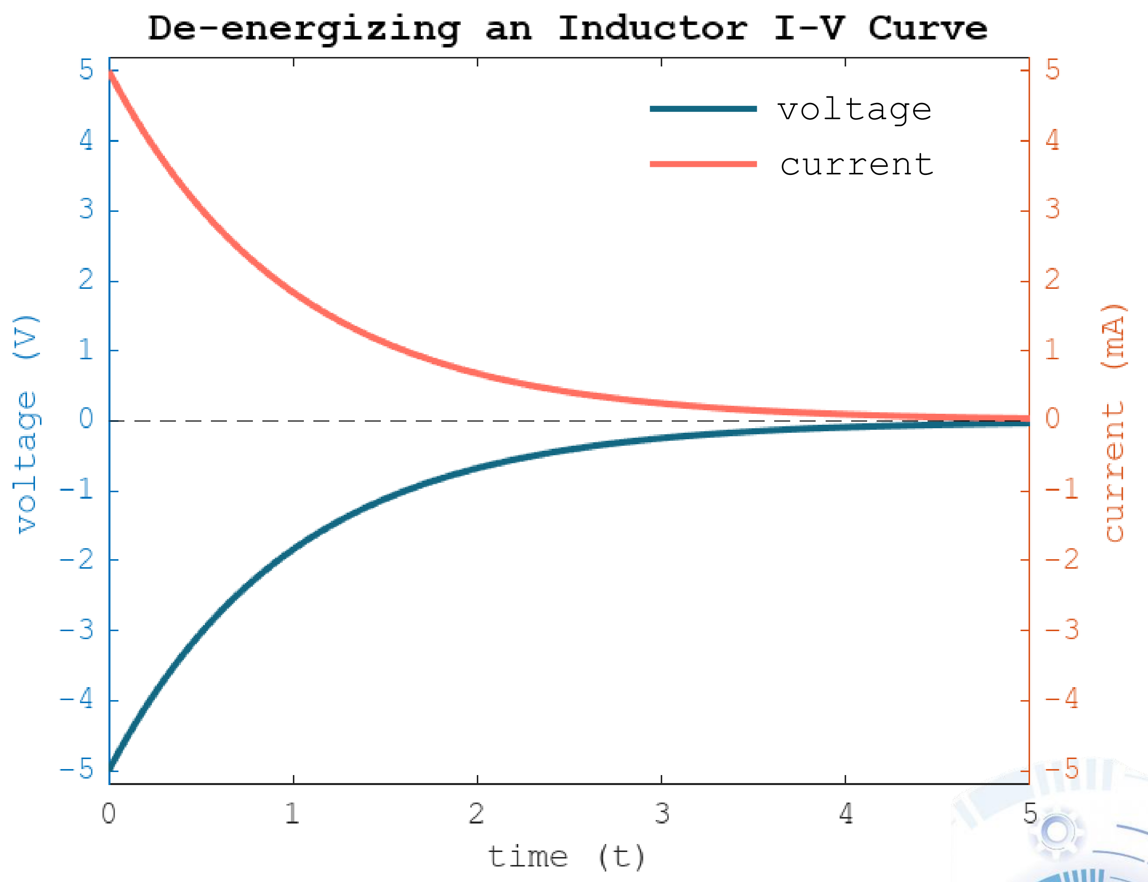
INDUCTOR VOLTAGE

De-energizing equation:

$$v_L(t) = -v_o e^{-\frac{t}{\tau}}$$

where: $\tau = \frac{L}{R}$

The **voltage** across the inductor instantly jumps to its maximum value, but in opposite direction of $-v_o$ volts then decays exponentially to **zero**.



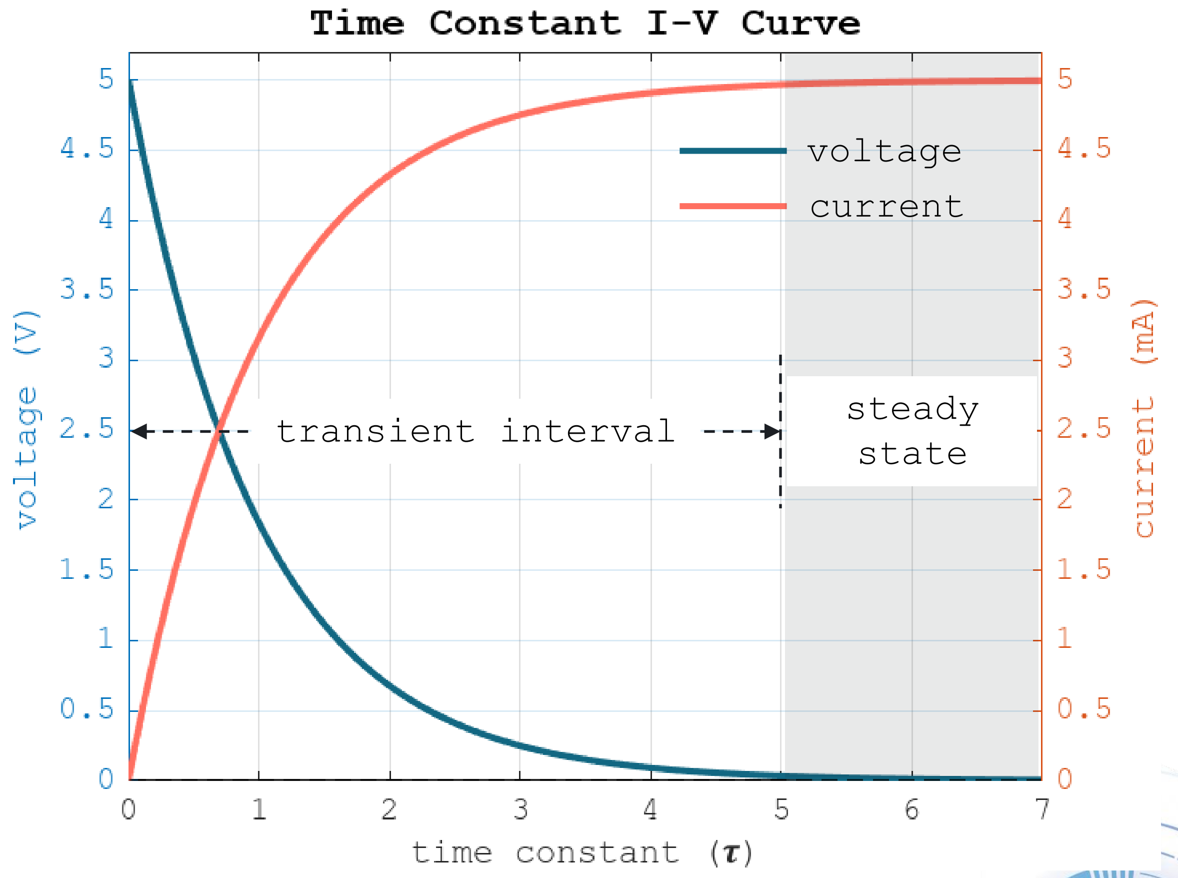
EXERCISE

A $\mathbf{100}\ \boldsymbol{mH}$ inductor is initially charged to $\mathbf{6}\ \boldsymbol{V}$. It is then disconnected from the power supply and discharged through a resistor of $\mathbf{500\ \Omega}$. Determine the **current** through the inductor after $\mathbf{0.02}\ \boldsymbol{s}$ of discharging.

Solution:

TRANSIENT RESPONSE

The **transient response** of an inductor describes the time-dependent changes in current through the inductor and the voltage across it. The transient phase is typically considered to last for approximately **five time constants** 5τ after which the system is assumed to have reached steady-state conditions.



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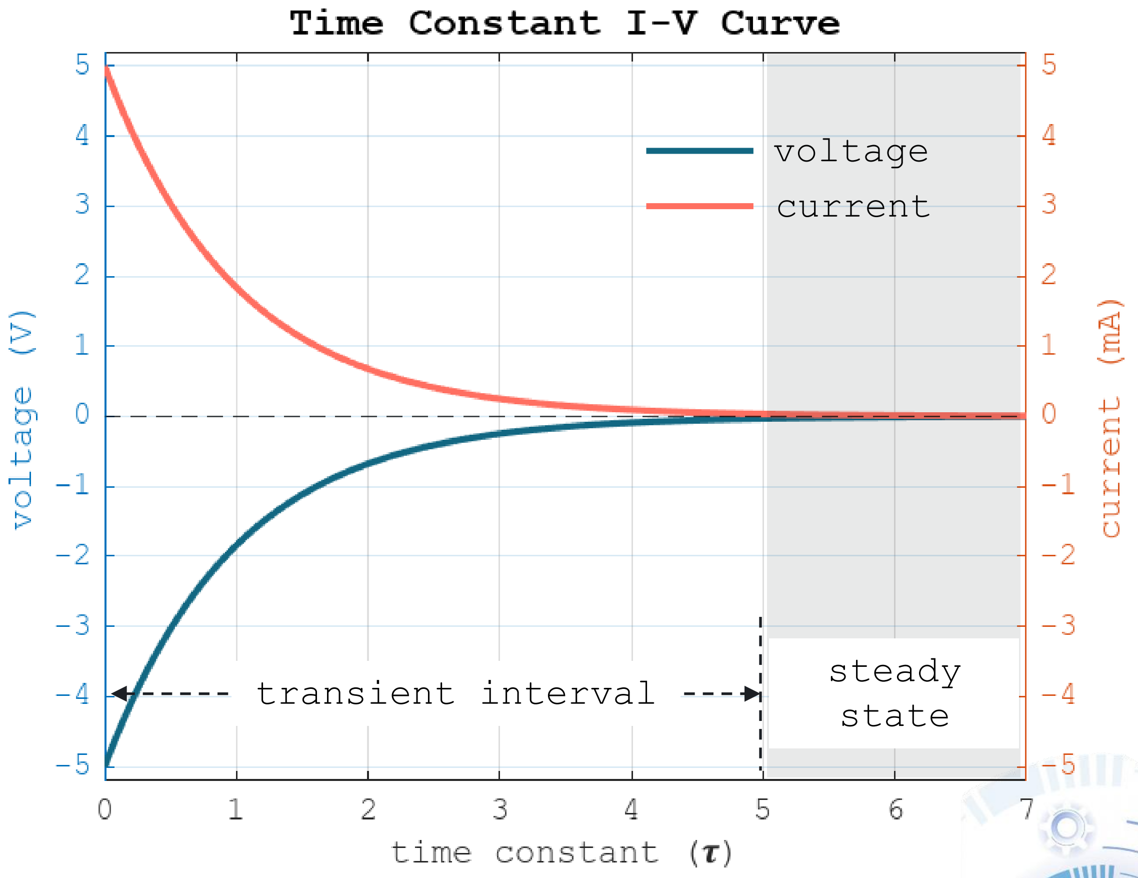

LABORATORY