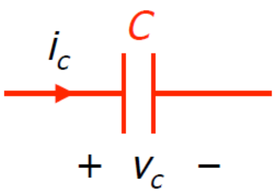
ELECTRICAL SCIENCE-II
(15B11EC211)

ELECRTICAL SCIENCE-2 (15B11EC211)

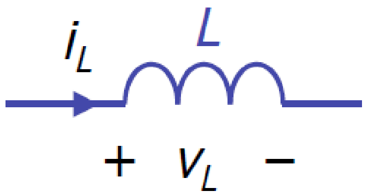
At the end of the course, students will be able to:

S.No.	Course Outcomes	Cognitive levels/Blooms taxonomy
CO1	Study and analyze the complete response of the first order and second order circuits with energy storage and/or non-storage elements.	Analyzing (C4)
CO2	Understand two-port network parameters and study first order, second order passive filters.	Understanding (C2)
CO3	Study the properties of different types of semiconductors, PN junction diode, zener diode and analyze diode applications.	Analyzing (C4)
CO4	Study the characteristics, operation of bipolar junction transistor (BJT) and its biasing, stability aspects.	Understanding (C2)

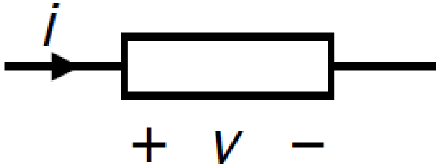
constitutive relation of C,L, R



$$i_c = C\frac{dv_c}{dt}$$



$$v_L = L\frac{di_L}{dt}$$



$$v = i\,R$$

- If a circuit has one C or L then ***circuit becomes dynamic*** **means**
  - Its behaviour is a function of time.
    - Its behaviour is described by a (set of) differential equation(s).
      - It has a transient response as well as a steady state.
- Resistive circuits have no transient
  - When the switch is turned on, the voltage across R becomes V **immediately (in zero time).**

RL and RC circuits are called first-order circuits

Steady State and Transient Response Content

- The Simple *RL* Circuit.
  - Concept of Time Constant.
  - Meaning of Time Constant.
  - Growth of Current in Series *RL* Circuit.
- The Simple *RC* Circuit.
  - Discharging of a Capacitor.
  - Charging of a Capacitor.
- Comparison between *RC* and *RL* Circuits.

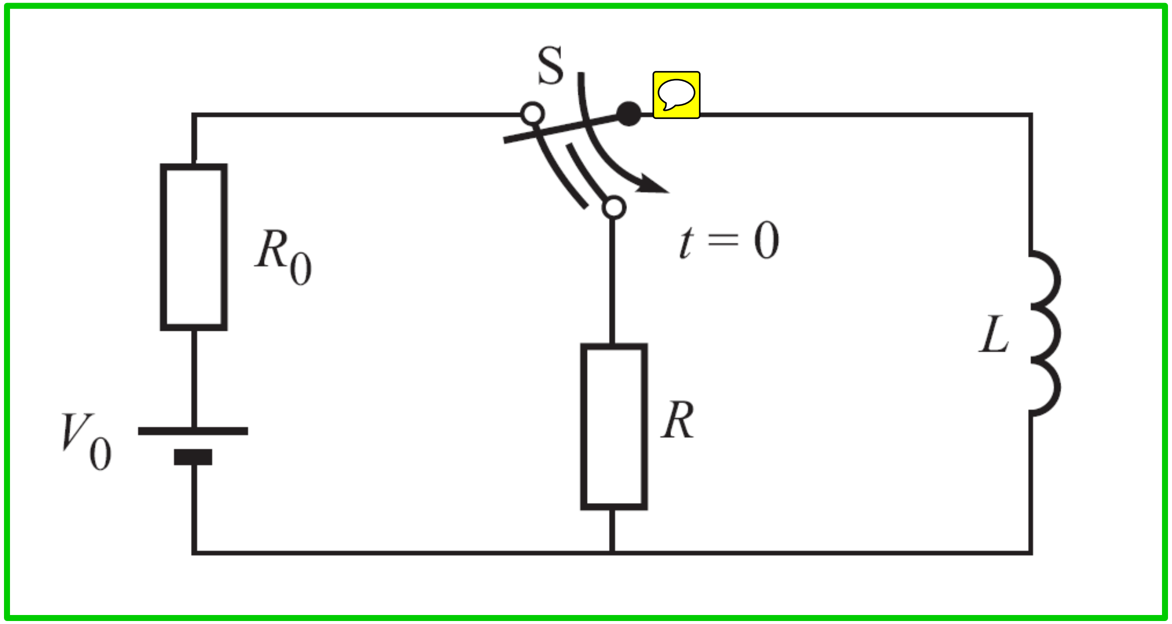
Steady State

- Both the inductance and capacitance are energy-storing elements.
- When connected to a dc source, energy starts flowing to these elements.
- Initially the rate of flow of energy is high, but as more and more energy is stored, the rate of flow decreases.
- When maximum possible energy has been stored, the flow of energy stops altogether. We say that the circuit has reached its ‘steady state’.

Transient Response

- If we switch off the source, or switch over the network to another source, the circuit starts attaining another ‘steady state’.
- The time taken by the circuit to change over from one steady-state condition to another steady-state condition is called *transient time*.
- The response of the circuit during this time is known as *transient response*.

The Simple *RL* Circuit



At t = 0-, a steady current that has been flowing in the circuit,

$$I_0 = \frac{V_0}{R_0}$$

For $t > 0+$, applying KVL,

$$v_R + v_L = 0 \quad \text{or} \quad Ri + L\frac{di}{dt} = 0 \quad \text{or} \quad \frac{di}{dt} + \frac{R}{L}i = 0$$

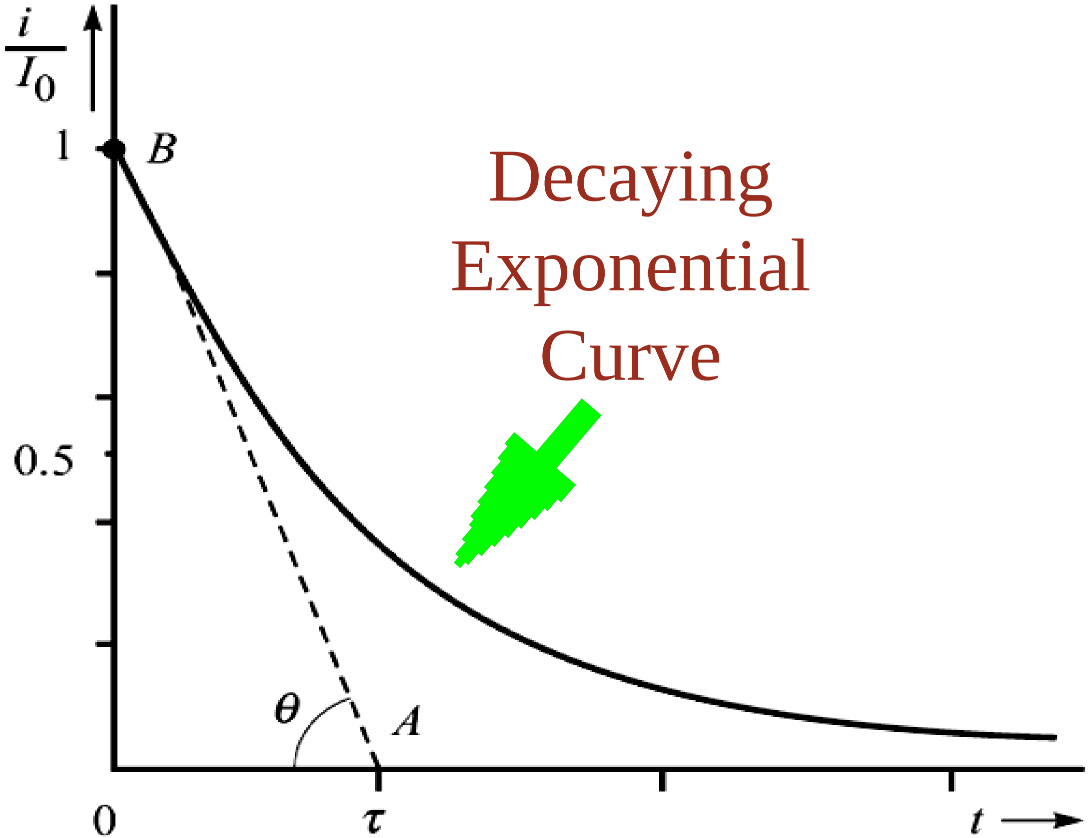
Re-writing the equation to separate variables and then integrating,

$$\frac{di}{i} = -\frac{R}{L}dt$$

$$\int_{I_0}^{i(t)} \frac{1}{i}di = \int_0^t \left(-\frac{R}{L}\right)dt \quad \text{or} \quad \ln i\Big|_{I_0}^{i} = -\frac{R}{L}t\Big|_0^t$$

$$\text{or} \quad \ln i - \ln I_0 = -\frac{R}{L}(t-0)$$

or $$i(t) = I_0 e^{-Rt/L}$$



At $t = 0+$, the current is I_0. As time increases, the current decreases and approaches zero.

Concept of Time Constant

- From equation, we see that with larger L/R ratio, the current takes longer to decay.
- By doubling L/R, the "width" of the curve also doubles.
- The "width" is proportional to L/R.
- Instead of "width", we use the concept of "time constant (τ).
- *It is the time that would be required for the current to drop to zero if it continued to drop at its initial rate.*

The initial rate of decay

$$= \text{ the slope of line AB}$$

$$= \frac{d}{dt}(i/I_0)\Big|_{t=0} = -\frac{R}{L}e^{-Rt/L}\Big|_{t=0} = -\frac{R}{L}$$

From triangle OAB,

$$\tan\theta = \frac{1}{\tau} \quad \Rightarrow \quad \frac{1}{\tau} = \frac{R}{L} \quad \text{or} \quad \tau = \frac{L}{R}$$

- The ratio L/R must have the units of time.

Meaning of Time Constant

Determining the value of $i(t)/I_0$ at $t = \tau$, we have

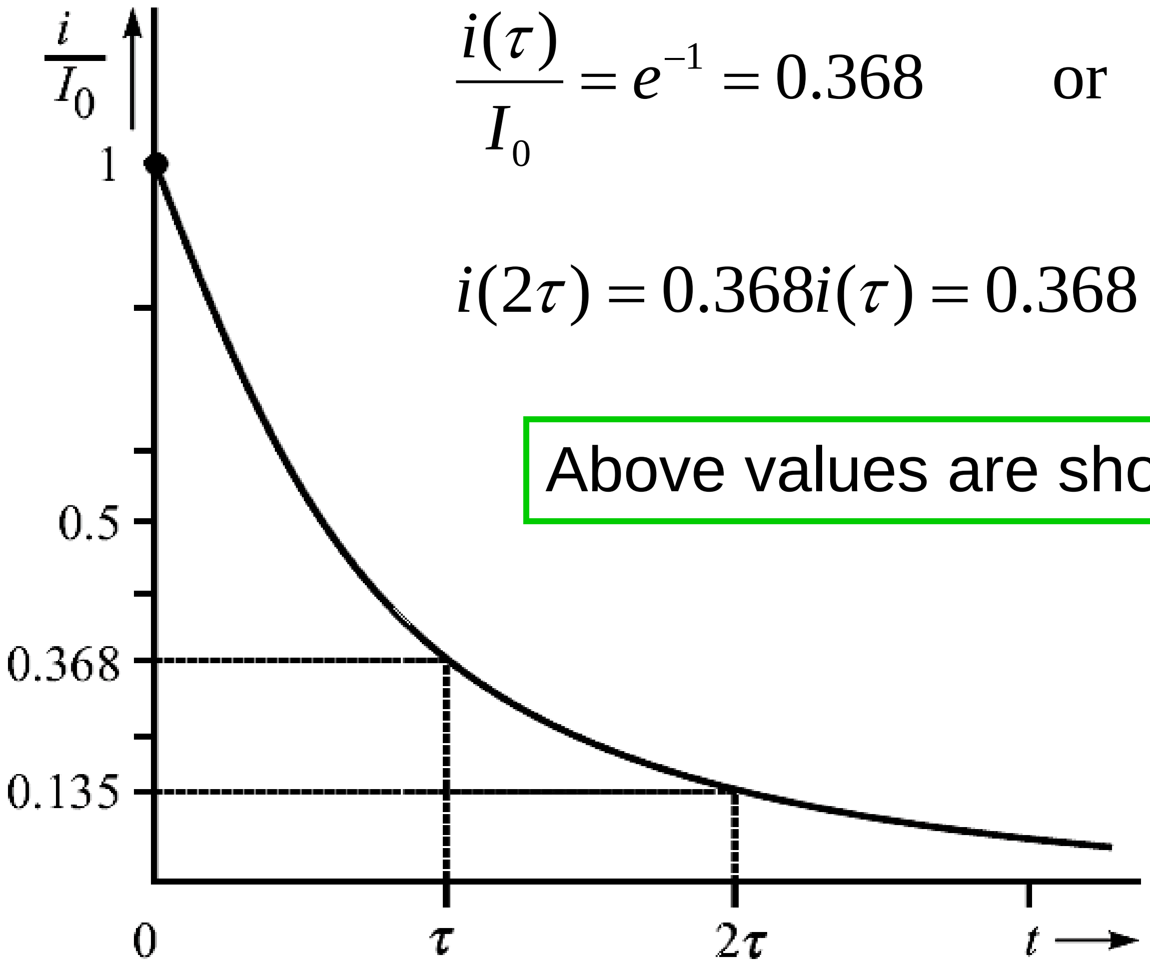
$$\frac{i(\tau)}{I_0} = e^{-1} = 0.368 \qquad \text{or} \qquad i(\tau) = 0.368 I_0$$

Thus, in one time constant the response drops to 36.8 % of its initial value. Hence,

$$i(2\tau) = 0.368 i(\tau) = 0.368 \times 0.368 I_0 = 0.1354 I_0$$

How long does it take for the current to decay to zero ?

Ans. : To answer this question, let us calculate



$$\frac{i(\tau)}{I_0} = e^{-1} = 0.368 \quad \text{or} \quad i(\tau) = 0.368 I_0$$

$$i(2\tau) = 0.368 i(\tau) = 0.368 \times 0.368 I_0 = 0.1354 I_0$$

Above values are shown on the graph.

$$
\begin{aligned}
i(3\tau) &= 0.0498 I_0, \\
i(4\tau) &= 0.0183 I_0, \\
i(5\tau) &= 0.0067 I_0, \\
\cdots \quad & \cdots \quad \cdots
\end{aligned}
$$

- It takes about **five time constants** for the current to decay to zero.
- At the end of this time interval, the current is less than one percent of its original value.