# SNS COLLEGE OF TECHNOLOGY

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## Department of Biomedical Engineering

**Course Name: 23BMT201 & Circuit Analysis**

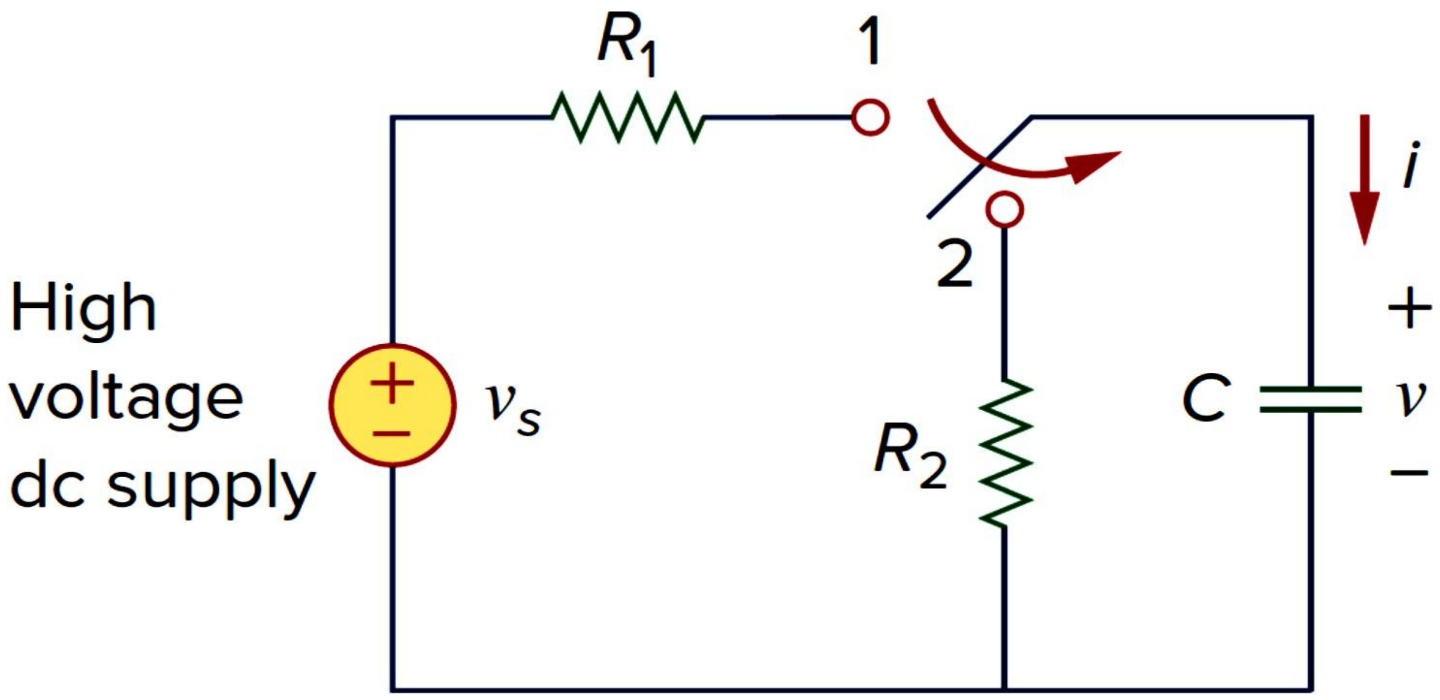
**I Year : II Semester**

**Unit IV –TRANSIENT RESPONSE FOR DC AND AC CIRCUITS**

**Topic :** Step Response of RL Circuits

# Real Life Applications – Photo Flash


Digital Camera Flash Light utilizes a RC circuit to create a short duration high current pulse to energize the flash light.

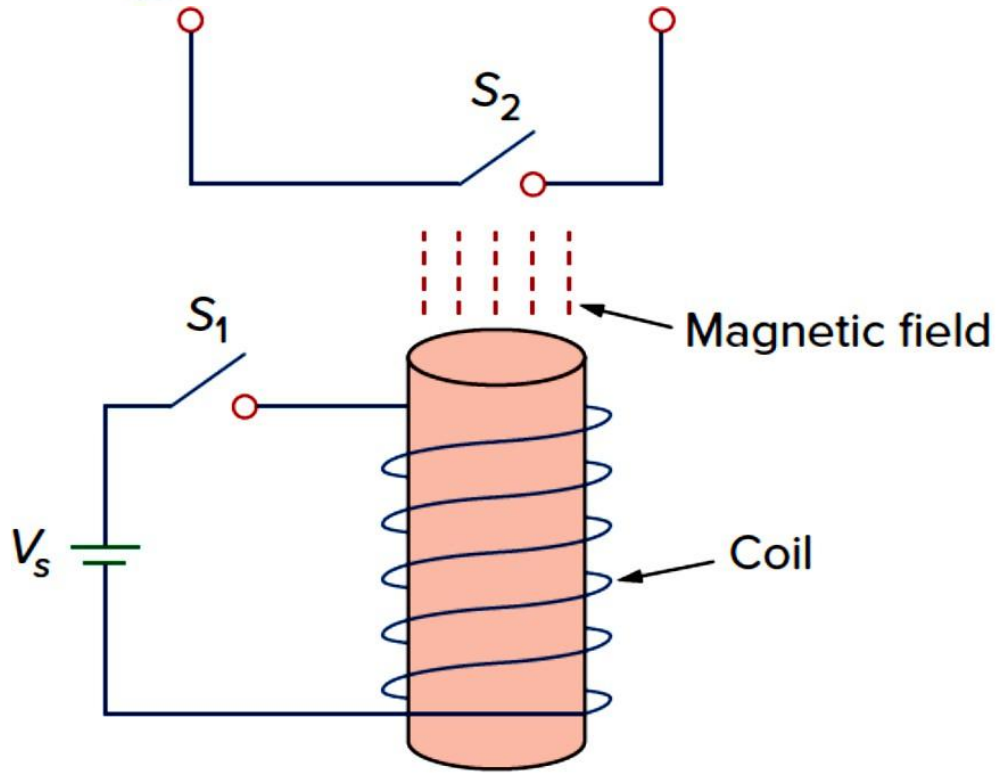


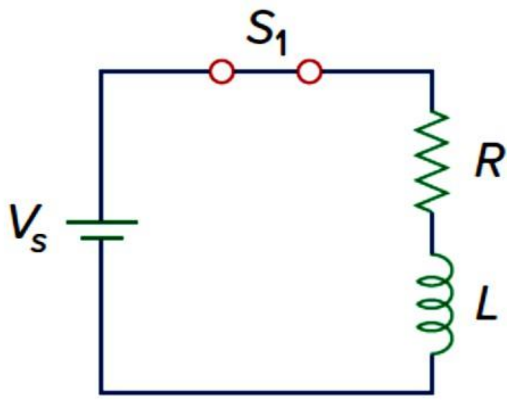

Circuit for a flash unit providing slow charge in position 1 and fast discharge in position 2 ($R_1 >> R_2$ ).

# Real Life Applications – Relay Circuits



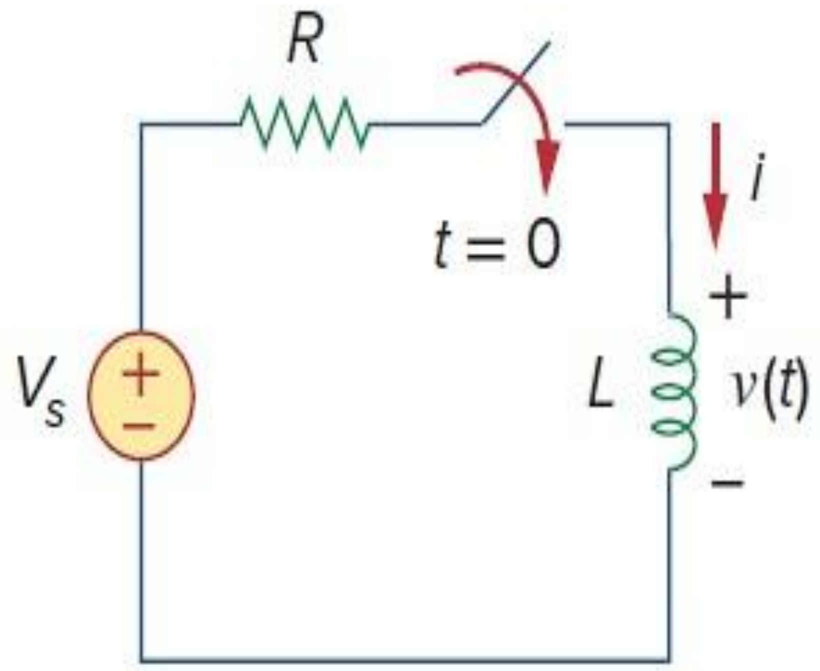
Relay coil is nothing but an RL circuit used to control the switching of another circuit



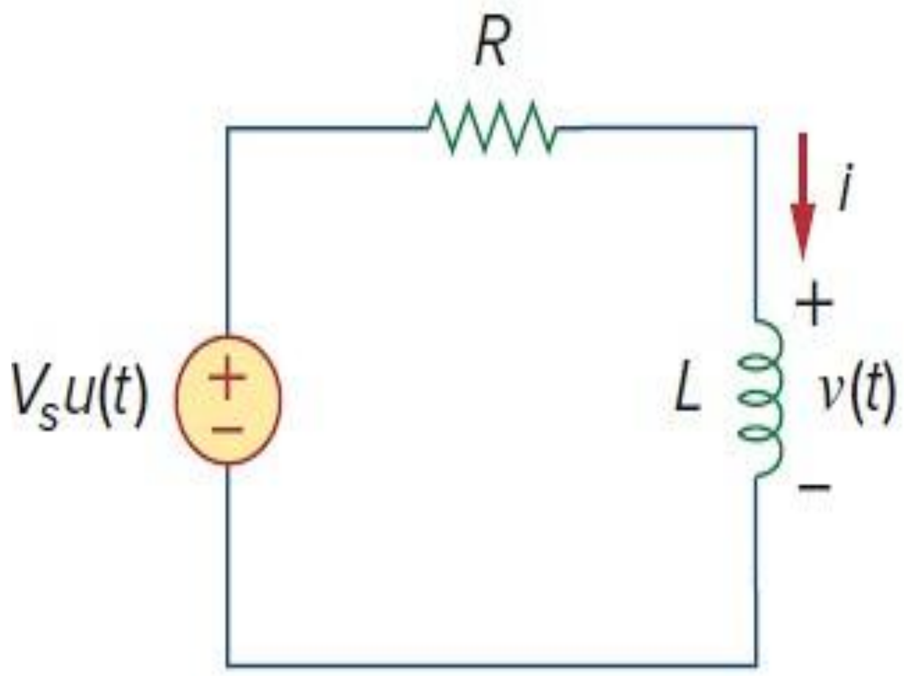



# Step Response of an RL Circuit

When a DC source is suddenly turned on, the source voltage or current can be modelled as a step function



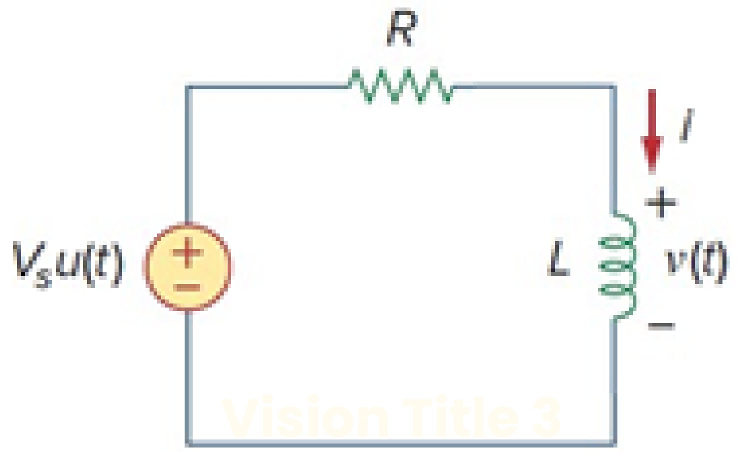

(a)




(b)

**Analysis:** The response is the sum of the transient response and the steady-state response, $i = i_t + i_{ss}$

# Step Response of an RL Circuit




- Transient response is always a decaying exponential,

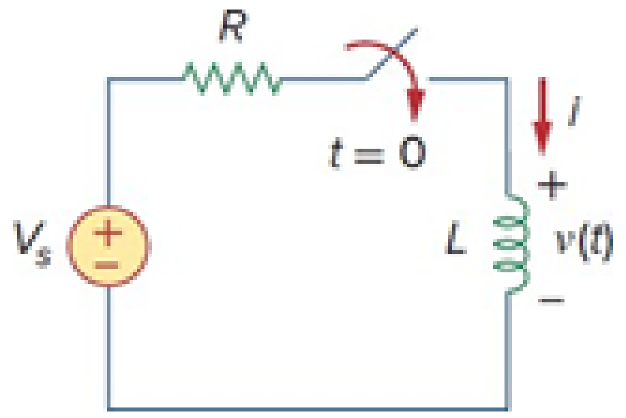
$$i_t = Ae^{-\frac{t}{\tau}};\ \tau = \frac{L}{R}$$

- The steady-state response is the value of the current a long time after the switch is closed (practically after ~5 time constants).
- The transient response essentially dies out after ~5$\tau$ and the inductor effectively becomes a short circuit (voltage across it is zero).
- The entire source voltage $V_s$ appears across $R$. Thus, the steady-state response is

$$i_{ss} = \frac{V_s}{R};\quad i = Ae^{-\frac{t}{\tau}} + \frac{V_s}{R}$$

# Step Response of an RL Circuit

- Determine the constant $A$ from the initial value of $i$.
- Let $I_0$ be the initial current through the inductor.

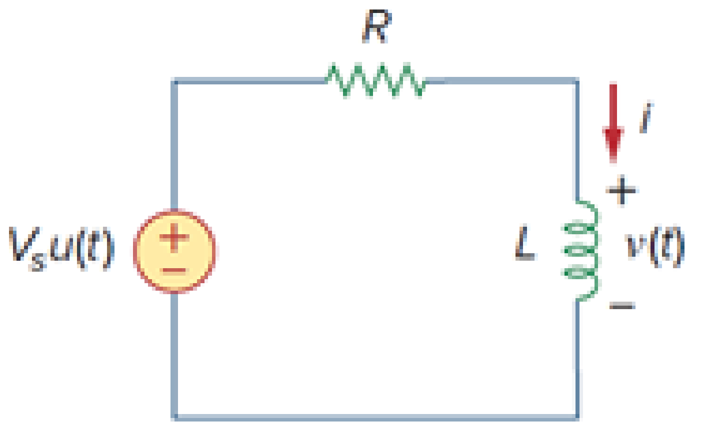



(a)

$$i(0^+) = i(0^-) = I_0$$

At $t = 0$, $I_0 = A + \frac{V_s}{R}$

$$A = I_0 - \frac{V_s}{R}$$




(b)

On substitution,

$$i(t) = \frac{V_s}{R} + (I_0 - \frac{V_s}{R})e^{-\frac{t}{\tau}}$$

This is the complete response of the RL circuit

$$i(t) = i(\infty) + [i(0) - i(\infty)]e^{-t/\tau}$$

where, $i(0)$ and $i(\infty)$ are the initial and final values of $i$, respectively.

# Step Response of an RL Circuit

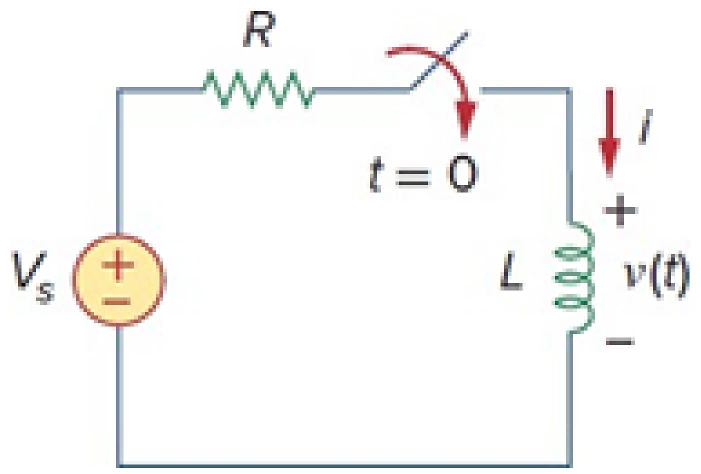
If the switching takes place at time $t = t_0$ instead of $t = 0$,

$$i(t) = i(\infty) + [i(t_0) - i(\infty)]e^{-(t-t_0)/\tau}$$

If $I_0$=0,

$$i(t) = \begin{cases} 0 & t < 0 \\ \frac{V_s}{R}(1-e^{-\frac{t}{\tau}}) & t > 0 \end{cases}$$

$$i(t) = \frac{V_s}{R}(1-e^{-\frac{t}{\tau}})u(t)$$



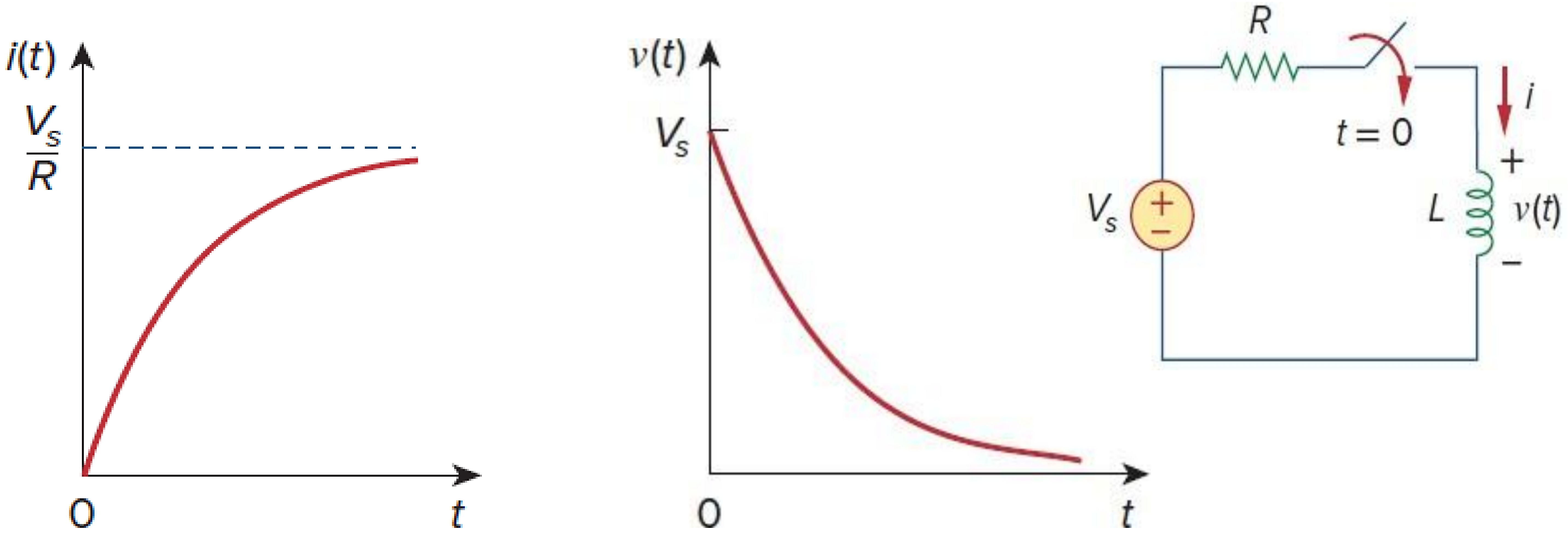

The voltage across the inductor is,

$$v(t) = L\frac{di}{dt} = \frac{V_s L}{\tau R}e^{-\frac{t}{\tau}}; \ \tau = \frac{L}{R} \quad t>0$$

$$v(t) = V_s e^{-\frac{t}{\tau}}u(t)$$

This is the step response of the RL circuit with no initial inductor current.

# Step Response of an RL Circuit




Step responses of an RL circuit with no initial inductor current