ELECTRICAL DEVICES & CIRCUITS

COURSE CODE: NEEE 101
VENUE: NLHC-G3
TIME: 09.00 AM-09.50 AM

COURSE INSTRUCTOR: PROF. SOUMYABRATA BARIK

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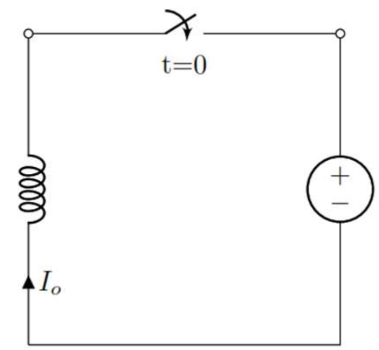
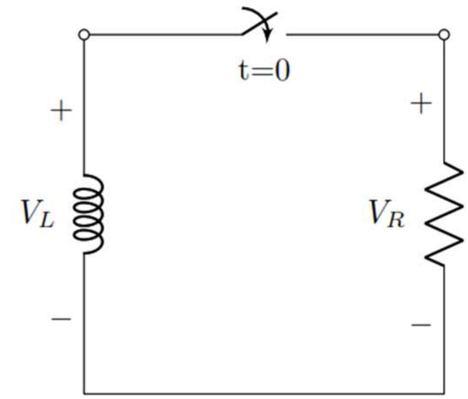
BEHAVIOR OF L IN THE CIRCUIT

- In an inductor the current can not change instantaneously.
- Let us consider the following circuits. Here, the initial current flowing through the inductor is I_0 before the switch is on.
- If $I_0 = 0$, then just after switching i.e., $@t = 0^+$ the inductor will behave like an open circuit.
- If $I_0 \neq 0$, then just after switching i.e., $@t = 0^+$ the inductor will behave like a current source of magnitude I_0.
- At $@t = \infty$, the inductor will behave like a short circuit as $v = L\frac{di}{dt} = 0$.



SOURCE FREE RESPONSE (R-L CIRCUIT)

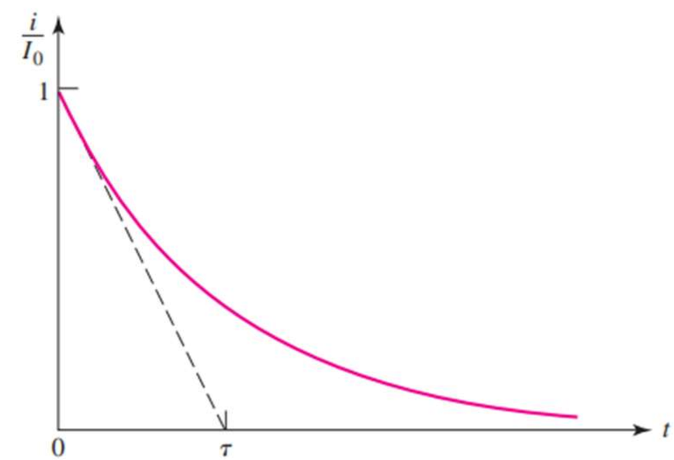


- If the current flowing through the series path is $i(t)$ and the initial current of the inductor is $i_L(t = 0^+) = I_0$, then the differential equation will be

$$\frac{di(t)}{dt} + \frac{R}{L} i(t) = 0$$

- The expression of current is

$$i(t) = I_0 e^{-\frac{R}{L}t}$$



- The ratio $\frac{L}{R}$ is also known as time constant (τ) of the circuit. This is the time required by the circuit for $\frac{i}{I_0}$ drop to zero with a constant decreasing rate of $\frac{R}{L}$.

Ref. William H. Hayt Jr, Jack E. Kemmerly and Steven M. Durbin, "Engineering Circuits Analysis", McGraw Hill publishers

BEHAVIOR OF C IN THE CIRCUIT

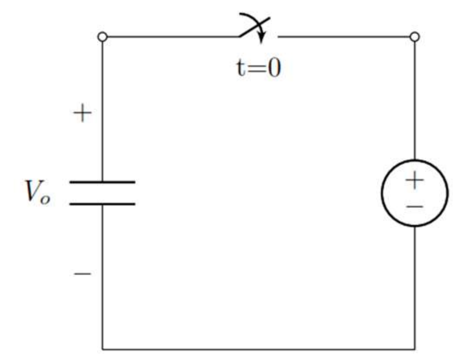
- In a capacitor the voltage can not change instantaneously.

- Let us consider the following circuits. Here, the initial voltage of the capacitor is V_0 before the switch is on.

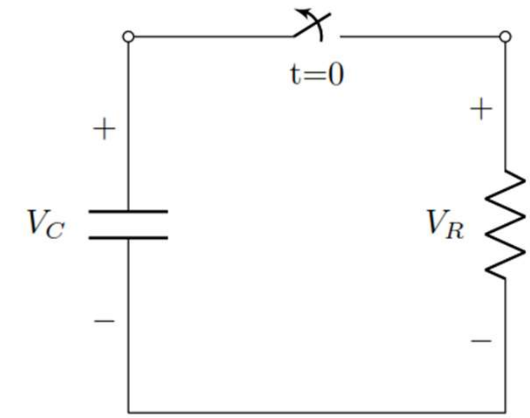
- If $V_0 = 0$, then just after switching i.e., $@t = 0^+$ the capacitor will behave like a short circuit.

- If $V_0 \neq 0$, then just after switching i.e., $@t = 0^+$ the capacitor will behave like a voltage source of magnitude V_0.

- At $@t = \infty$, the capacitor will behave like an open circuit as $i = C\frac{dv}{dt} = 0$.



SOURCE FREE RESPONSE (R-C CIRCUIT)



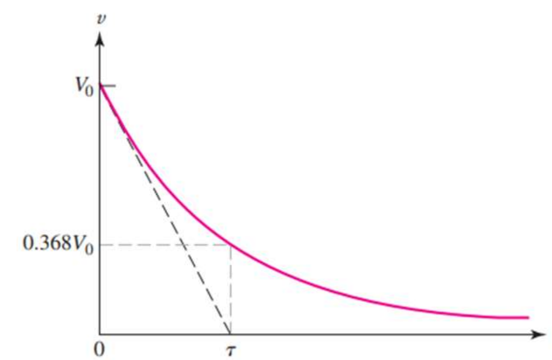
- If the voltage across the capacitor is $v(t)$ and the initial voltage of the capacitor is $v_c(t=0^+) = V_0$, then the differential equation will be

$$\frac{dv(t)}{dt} + \frac{1}{RC}v(t) = 0$$

- The expression of current is

$$v(t) = V_0 e^{-\frac{1}{RC}t}$$

- The product RC is also known as time constant (τ) of the circuit. This is the time required by the circuit for $\frac{v}{V_0}$ drop to zero with a constant decreasing rate of $\frac{1}{RC}$.



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Forced Response

- Let us consider a general first order differential equation as below

$$\frac{di}{dt} + Pi = Q$$

- The integrating factor as $e^{\int Pdt} = e^{Pt}$. The solution of that differential equation is

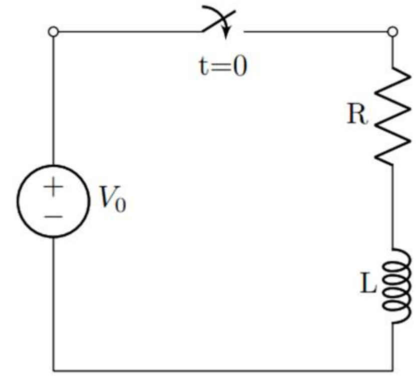
$$i(t) = Ae^{-Pt} + e^{-P} \int Qe^{Pt}dt$$

- Here the first term is known as the natural response (Complementary Response), whereas the second term is the forced response (Particular Integral).

RESPONSE OF CIRCUITS WITH L, C

- Analysis of a circuit with inductor or capacitor depends on the solution of integrodifferential equations.
- Solution of the integrodifferential equation provides the response of the circuit.
- Source free response is also known as the **natural response/transient response**.
- An inductor or a capacitor can not store the energy forever.
- The energy dissipated into heat energy due to the presence of resistance intrinsically associated with the inductor and capacitor.
- Mathematically, natural response is also known as **complementary function**.
- When an independent source is applied to a circuit, part of the response will resemble the nature of the particular source.
- This part of response is known as **forced response/particular solutions**.
- Total response=Natural response+ Forced Response=Complementary Solution+ Particular Solution

FORCED RESPONSE (R-L CIRCUIT)



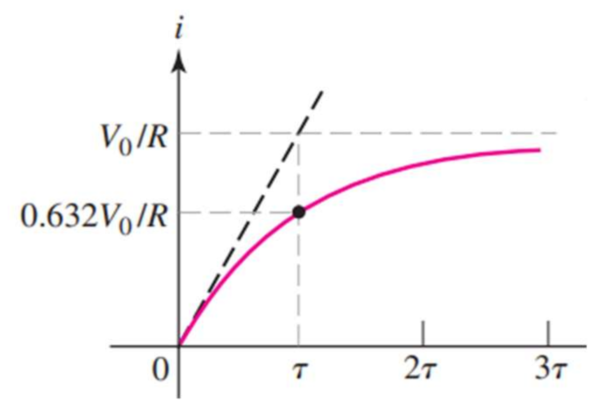
- If the current flowing through the series path is $i(t)$ and the initial current of the inductor is $i_L(t = 0^+) = 0$, then the differential equation will be

$$\frac{di(t)}{dt} + \frac{R}{L}i(t) = \frac{V_0}{L}$$

- The expression of current is

$$i(t) = \frac{V_0}{R}\left(1 - e^{-\frac{R}{L}t}\right)$$

- The ratio $\frac{L}{R}$ is also known as time constant (τ) of the circuit. This is the time required by the circuit for $\frac{i}{I_0}$ drop to zero with a constant decreasing rate of $\frac{R}{L}$.



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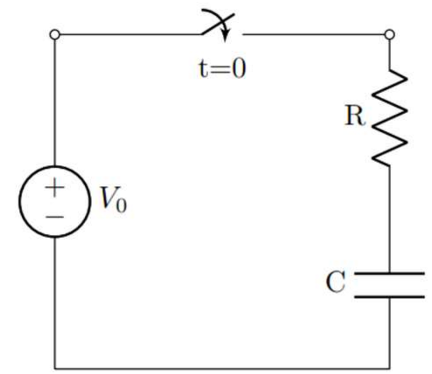
FORCED RESPONSE (R-C CIRCUIT)



- If the voltage across the capacitor is $v(t)$ and the initial voltage of the capacitor is $v(t = 0^+) = 0$, then the differential equation will be

$$Ri + \frac{1}{C}\int idt = V_s$$

- The expression of current is

$$v(t) = V_0\left(1 - e^{-\frac{t}{RC}}\right)$$

- The product RC is also known as time constant (τ) of the circuit. This is the time required by the circuit for $\frac{v}{V_0}$ drop to zero with a constant decreasing rate of $\frac{1}{RC}$.

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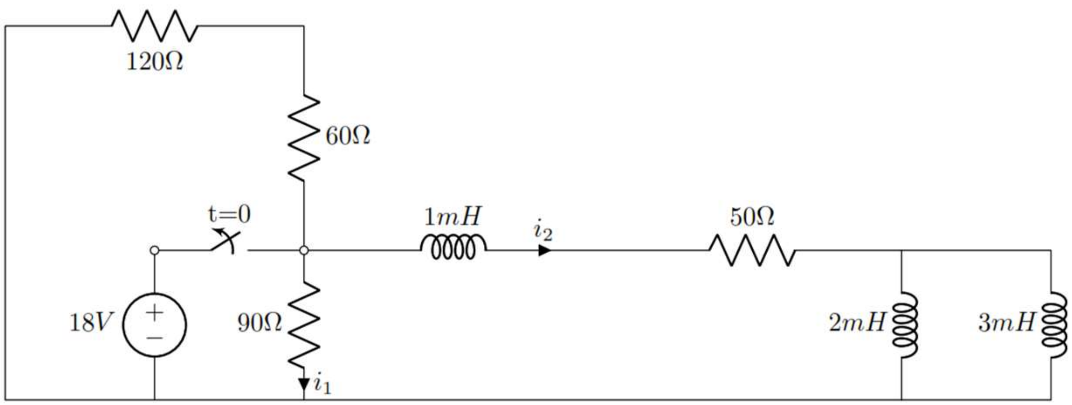
SOURCE FREE RESPONSE (R-L CIRCUIT)

Problem-1:

The given circuit was at steady state before the switch is turned off. Determine $i_1(0^-), i_2(0^-)$.

After the switch is off, determine the expression of $i_1(t), i_2(t)$ for $t > 0$.

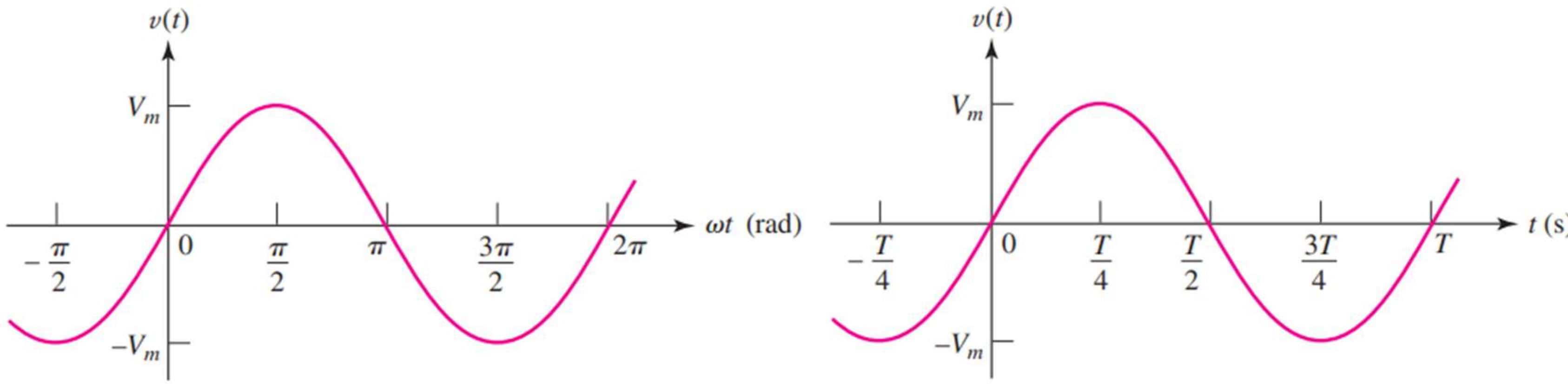


Ans:

$$\boldsymbol{i_1(0^-) = 200\ mA}$$
$$\boldsymbol{i_2(0^-) = 360\ mA}$$

$$\boldsymbol{i_1(t) = -240e^{-50{,}000t}\ mA}$$
$$\boldsymbol{i_2(t) = 360e^{-50{,}000t}\ mA}$$

CHARACTERISTICS OF SINUSOIDS



❖ A sinusoidally varying voltage function can be represented by $\mathrm{v}(t) = V_m \sin(\omega t)$

❖ The function repeats itself in every 2π radians. Therefore, period is 2π radians.

❖ Frequency $f = 1/T$

❖ We know $\omega T = 2\pi$

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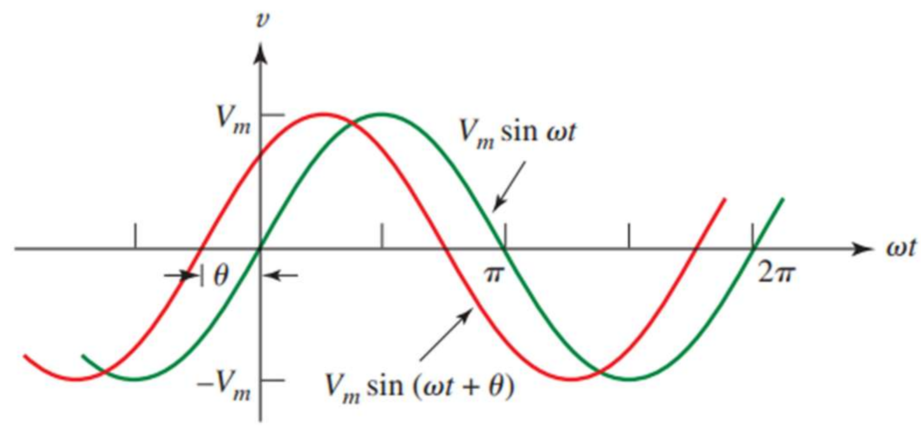
CONCEPTS OF LAGGING & LEADING

- More general form of sinusoids is $v(t) = V_m \sin(\omega t + \theta)$
- Here θ is the phase angle measured in radian. However, for representation purpose sometimes we use to express θ in degree.
- At $t = 0$, $v(t = 0) = V_m \sin\theta$
- Therefore, $V_m \sin(\omega t + \theta)$ sinusoid leads $V_m \sin(\omega t)$ sinusoid.



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