ELEMENTS OF ELECTRICAL ENGINEERING

Course Code : UE25EE141A/B

PES UNIVERSITY

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ELEMENTS OF ELECTRICAL ENGINEERING

Analysis of Single-Phase AC circuits with R Load , L Load and C Load

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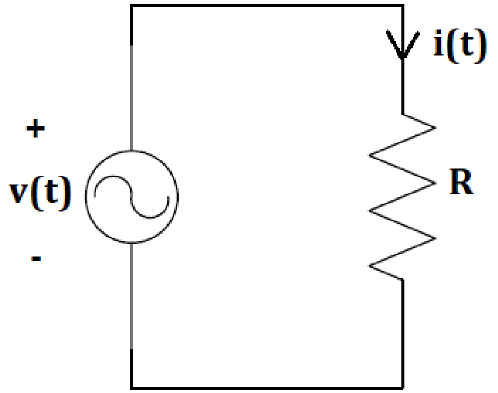
Response of Resistive Load to Sinusoidal Supply



Let the supply voltage be $v(t) = V_m \sin(\omega t)$

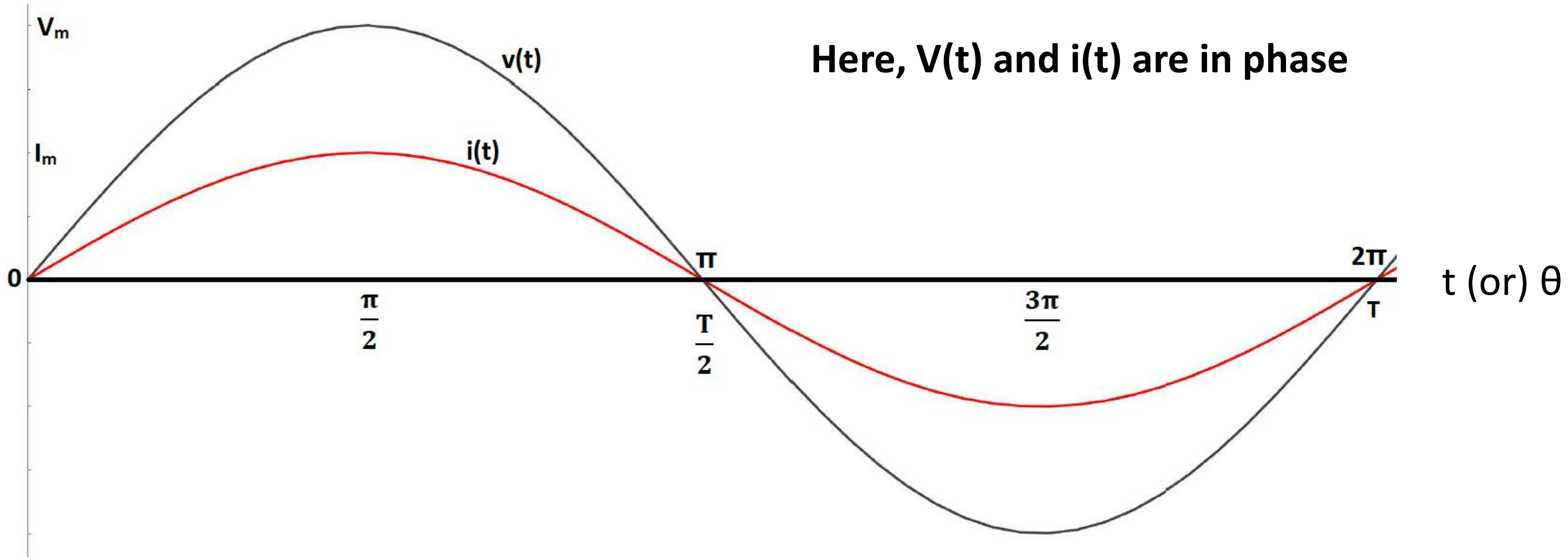
where, V_m is the peak value of voltage

By Ohm's Law, $i(t) = \dfrac{v(t)}{R}$

Hence current will be of the form, $i(t) = I_m \sin(\omega t)$

where, $I_m = \dfrac{V_m}{R}$ is the peak value of current

Response of Resistive Load to Sinusoidal Supply

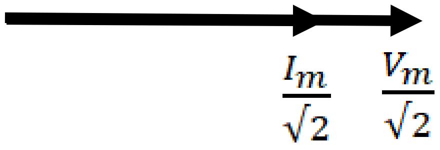


Here, V(t) and i(t) are in phase

$v(t) = V_m \sin(\omega t) \quad \Rightarrow \quad \bar{V} = \frac{V_m}{\sqrt{2}} \angle 0^\circ$

$i(t) = I_m \sin(\omega t) \quad \Rightarrow \quad \bar{I} = \frac{I_m}{\sqrt{2}} \angle 0^\circ$

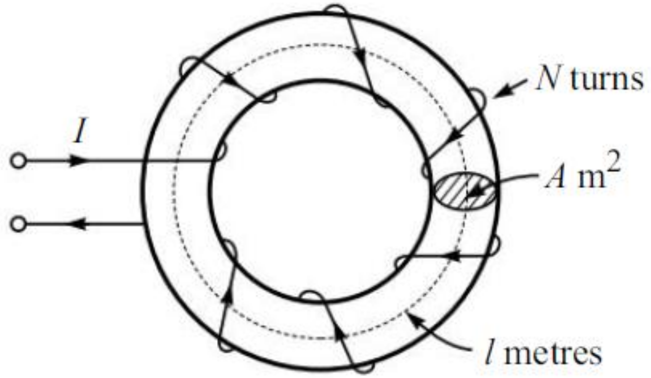
Phasor Diagram:



Impedance, $Z = \bar{V}/\bar{I} = R\angle 0^\circ = R \ \Omega$

Inductor & the concept of inductance

An inductor is obtained by winding the conductor into a coil.



A current carrying coil sets up a magnetic field around it.

Magnetic field is expressed as magnetic flux ϕ around the coil.

$$\text{Magnetic flux } \phi = \frac{\text{Magnetomotive Force}}{\text{Reluctance}} = \frac{N*I}{S}$$

$$\text{Where, } S = \text{Reluctance} = \frac{\text{length}}{(\text{Permeability*Area})}$$

Inductor & the concept of inductance

Magnetic flux, ϕ is directly proportional to the current in the inductor coil.

i.e., $\phi \propto i$

i.e., $N\phi \propto i$

Where, $N\phi$ is called **flux linkages** denoted by ψ

Therefore, ψ is proportional to i

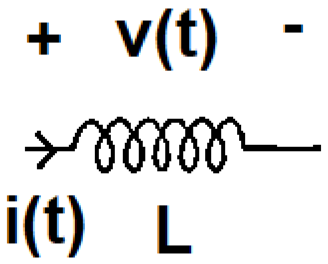
$\Rightarrow \psi = Li$

Where, L is the proportionality constant called ‘Inductance’ of the inductor.

$$L = \frac{\psi}{i} = \frac{N\phi}{i}$$

Inductance is measured in Henrys (H)

Voltage – Current relationship in an inductor



The voltage across the terminals of an inductor is directly proportional to rate of change of flux linkages.

i.e., $v(t) \propto \frac{d}{dt}(\psi)$

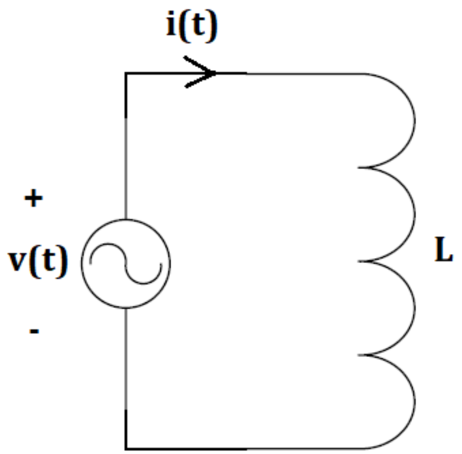
$$v(t) = \frac{d}{dt}(\psi) = \frac{d}{dt}(N\phi) = N\frac{d\phi}{dt} = \frac{d}{dt}(Li) = L\frac{di}{dt}$$

i.e., voltage v(t) is related to current i(t) as $v(t) = L\frac{di(t)}{dt}$

Therefore, i(t) can be expressed as

$$i(t) = \frac{1}{L}\int v(t)dt$$

Response of Pure Inductive Load to Sinusoidal Supply



Let the supply voltage be $v(t) = V_m \sin(\omega t)$

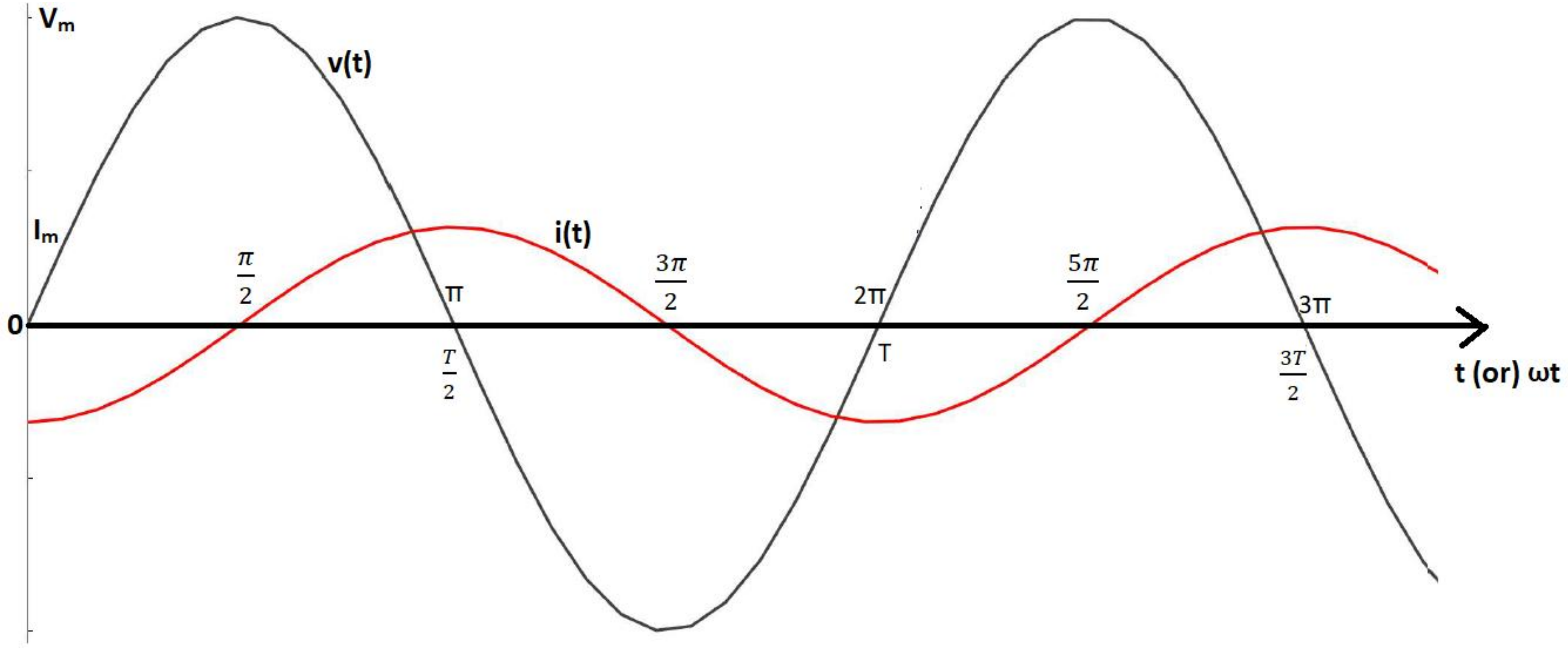
In a pure inductor, $i(t) = \dfrac{1}{L}\int v(t)dt$

$$= \frac{-V_m}{\omega L}\cos(\omega t)$$

$$= I_m \sin(\omega t - 90°)$$

where, $I_m = \dfrac{V_m}{\omega L}$ is the peak value of current

Response of Pure Inductive Load to Sinusoidal Supply



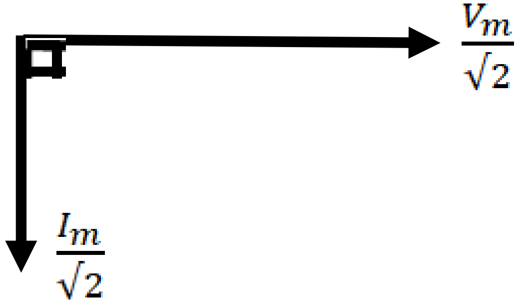
In a pure inductor, current **lags** voltage by 90°

Response of Pure Inductive Load to Sinusoidal Supply

$v(t)=V_m \sin(\omega t) \Rightarrow \bar{V} = \frac{V_m}{\sqrt{2}}\angle 0^\circ$

$i(t)=I_m \sin(\omega t-90^\circ) \Rightarrow \bar{I} = \frac{I_m}{\sqrt{2}}\angle -90^\circ$

Phasor Diagram:

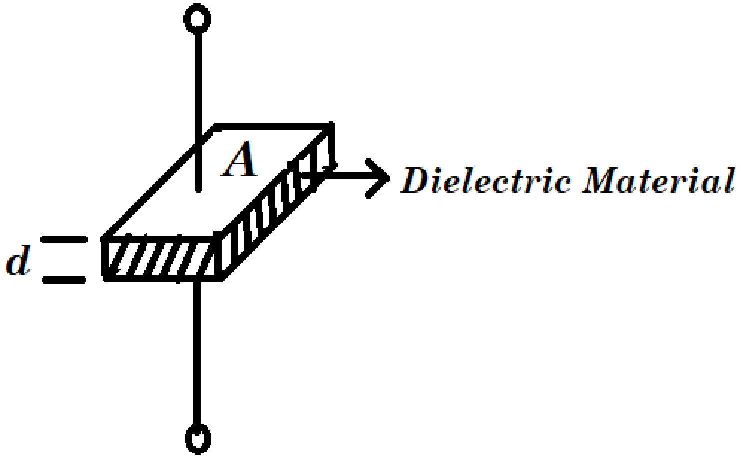


$$Z = \frac{\bar{V}}{\bar{I}} = \frac{\frac{V_m}{\sqrt{2}}\angle 0^\circ}{\frac{I_m}{\sqrt{2}}\angle -90^\circ} = \omega L\angle 90^\circ = jX_L \quad \Omega$$

Where, $X_L=\omega L$ is called '**Inductive Reactance**'

Capacitor & the concept of Capacitance

A Capacitor is obtained by placing a dielectric medium between the conducting plates.



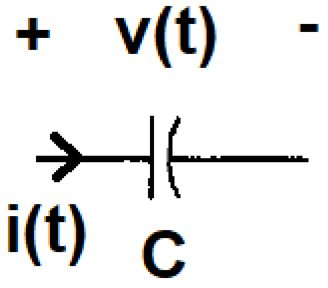
Capacitance, C $= \dfrac{\varepsilon A}{d}$ Farad

Where, A is the area of each of the plates in m^2

d is the distance between the plates in m

ε is the permittivity of the dielectric medium in F/m

Voltage – Current relationship in a Capacitor



The charge on the plates of a capacitor is directly proportional to the voltage across its terminals.

i.e., $q(t) \propto v(t) \Rightarrow q(t) = Cv(t)$

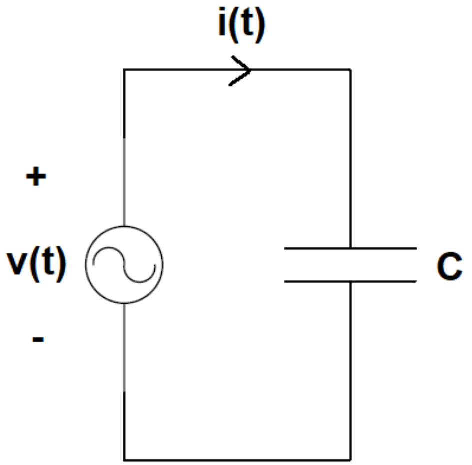
The constant of proportionality 'C' is called Capacitance of the Capacitor.

Hence, current, $i(t) = \dfrac{dq(t)}{dt} = C\dfrac{dv(t)}{dt}$

Therefore, v(t) can be expressed as

$$v(t) = \frac{1}{C}\int i(t)dt$$

Response of Pure Capacitor to Sinusoidal Supply



Let the supply voltage be $v(t) = V_m \sin(\omega t)$

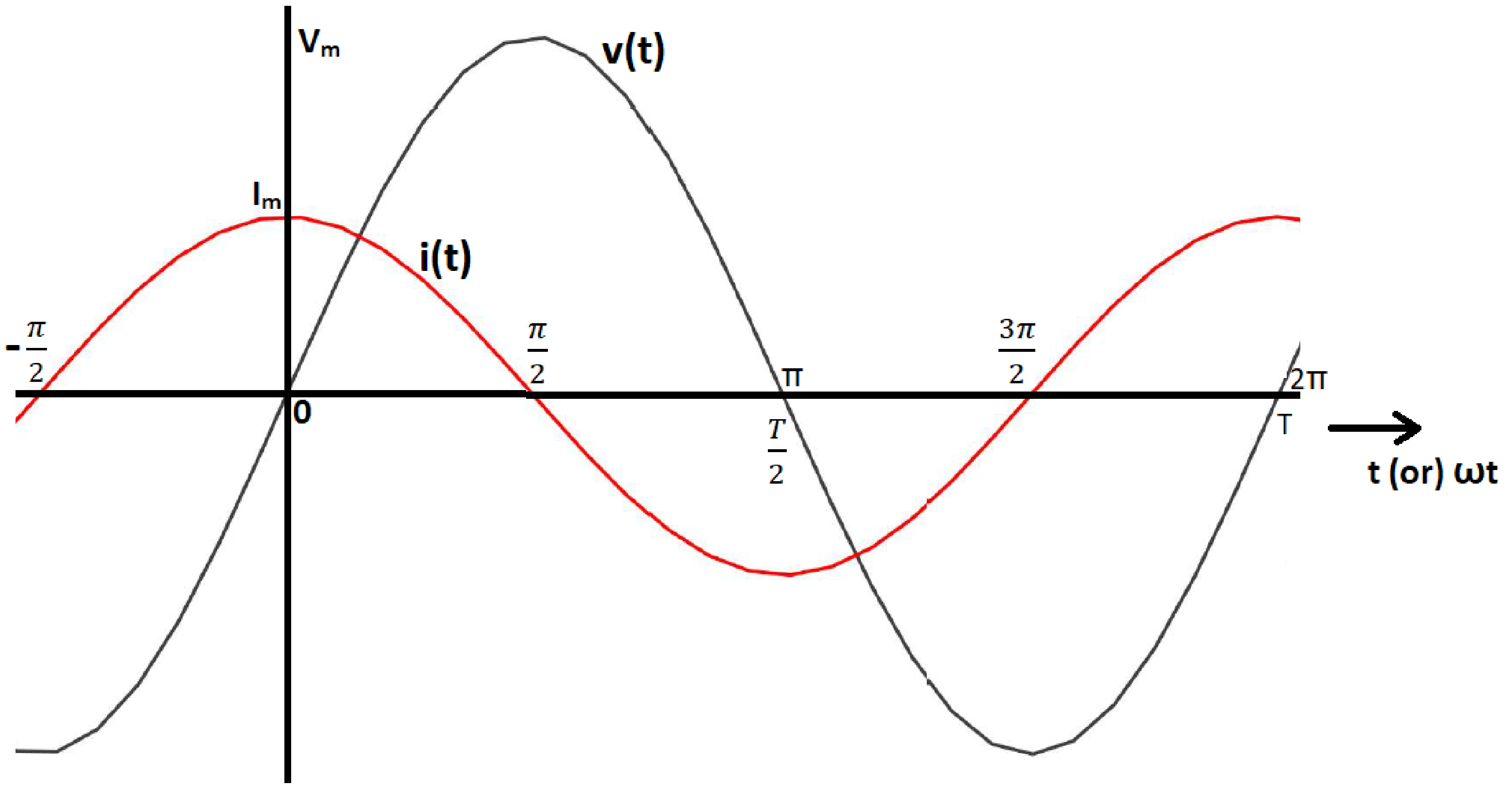
In a pure capacitor, $i(t) = C\dfrac{dv(t)}{dt}$

$$= CV_m \omega \cos(\omega t)$$

$$= I_m \sin(\omega t + 90°)$$

Where, $I_m = V_m \omega C$ is the peak value of current

Response of Pure Capacitor to Sinusoidal Supply



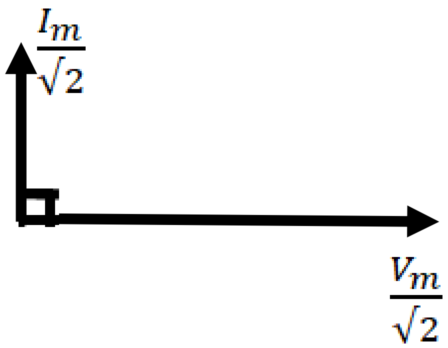
In a pure capacitor, current **leads** voltage by 90°

Response of Pure Capacitor to Sinusoidal Supply

$v(t)=V_m \sin(\omega t) \Rightarrow \bar{V} = \frac{V_m}{\sqrt{2}} \angle 0°$

$i(t)=I_m \sin(\omega t+90°) \Rightarrow \bar{I} = \frac{I_m}{\sqrt{2}} \angle 90°$

Phasor Diagram:



$$Z = \frac{\bar{V}}{\bar{I}} = \frac{\frac{V_m}{\sqrt{2}} \angle 0°}{\frac{I_m}{\sqrt{2}} \angle 90°} = \frac{1}{\omega C} \angle -90° = -jX_C \quad \Omega$$

Where, $X_C = \frac{1}{\omega C}$ is called '**Capacitive Reactance**'

Text Book & References

Text Book:

1. "Basic Electrical Engineering" S.K Bhattacharya, 1st Edition Pearson India Education Services Pvt. Ltd., 2017
2. "Basic Electrical Engineering", D. C. Kulshreshta, 2nd Edition, McGraw-Hill. 2019
3. "Special Electrical Machines" E G Janardanan, PHI Learning Pvt. Ltd., 2014

Reference Books:

1. "Engineering Circuit Analysis" William Hayt, Jack Kemmerly, Jamie Phillips and Steven Durbin, 10th Edition McGraw Hill, 2023

2. "Electrical and Electronic Technology" E. Hughes (Revised by J. Hiley, K. Brown & I.M Smith), 12th Edition, Pearson Education, 2016.

THANK YOU

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