DRGP Institute

Chapter 7

Alternating Current

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BOARD- 2013

1. The voltage applied in an alternating LCR series circuit is 220V. If $R = 8\Omega$, $X_C = X_L = 6\Omega$ then find value of the following-
   a. rms value of voltage
   b. Impedance of circuit [1 Mark]

⇒ $V_{rms} = 220V$

$R = 8\Omega$

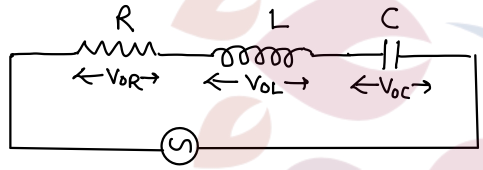
$X_L = 6\Omega \quad X_C = 6\Omega$

$Z = \sqrt{R^2 + (X_L - X_C)^2} \quad \{X_L = X_C\}$

$Z = \sqrt{(8)^2} = 8\Omega$

2. Draw the phasor diagram of series LCR circuit with AC voltage source. Derive value of impedance of this circuit. [4Marks]

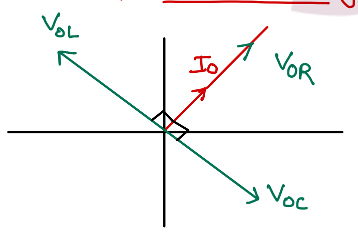
⇒



AcSource

Suppose there are resistance (R), inductance (L) & capacitance (C) connected in series with applied AC source.

A. Phasor Diagram -



Phase difference b/w V_{oR} & I_o zero.

– V_{oL} leads I_o by $\pi/2$ angle.

– V_{oc} Lags I_o by $\pi/2$ angle.

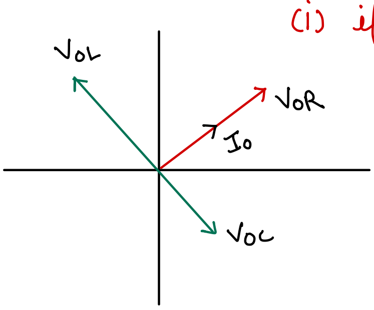
→ There are three possible situation

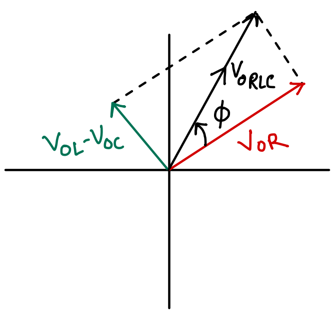
(i) $X_L > X_C$ or $V_{oL} > V_{oc}$

(ii) $X_C > X_L$ or $V_{oc} > V_{oL}$

(iii) $X_L = X_C$

(i) if $X_L > X_C$ or $V_{oL} > V_{oc}$ -





→ V_{oRLC} leads current by ϕ angle.

(A) Impedance of RLC -

In $\triangle OAB$ $\quad V_{oRLC}^2 = V_{oR}^2 + (V_{oL} - V_{oc})^2$

$= (I_o R)^2 + (I_o X_L - I_o X_C)^2$

$= I_o^2 R^2 + I_o^2 (X_L - X_C)^2$

$= I_o^2 [R^2 + (X_L - X_C)^2]$

$$\frac{V_{0RLC}}{I_0} = \sqrt{R^2+(X_L-X_C)^2}$$

$$\boxed{Z_{RLC} = \sqrt{R^2+(X_L-X_C)^2}}$$

phase difference –

$$\tan\phi = \frac{V_{0L}-V_{0C}}{V_{0R}}$$

$$\phi = \tan^{-1}\left(\frac{X_L-X_C}{R}\right)$$

Note – if $X_C > X_L$

$$Z_{RLC} = \sqrt{R^2+(X_C-X_L)^2}, \quad \phi = \tan^{-1}\left(\frac{X_C-X_L}{R}\right)$$

if $X_C = X_L$

$$Z_{RLC\,(min)} = R, \quad \phi = 0^\circ$$

BOARD - 2013 (Supp)

3. What is the avg value of power over a one cycle in AC circuit? [1]

⇒ $P_{avg} = V_{rms} I_{rms} \cos\phi$

4. Define power factor. Find its value if the circuit – [3]
   (i) Purely inductive
   (ii) Series LCR resonance

⇒ Ratio of avg. power & virtual power is called Power factor.

$$\cos\phi = \frac{P_{avg}}{P_{vir}}$$

(i) for pure resistance $\phi = 0$ $\cos\phi = 1$
(ii) for pure inductive / capacitive $\phi = 90^\circ$ $\cos\phi = 0$
(iii) In Series LCR Resonance
$\phi = 0$ $\cos\phi = 1$

BOARD - 2014

5. Draw a curve showing variation in AC with feequency in LCR resonance circuit. obtain expression of band width. 1+2 = 3

BOARD - 2015

6. write the average value of current over a complete cycle of current.

⇒ zero

7. Match the following :- (6 × 1/2 = 3)

	Column I		Column II
i)	Resonant frequency	a)	$VI\cos\phi$
ii)	Quality factor	b)	$\frac{1}{2}LI^2$
iii)	Average power	c)	$\frac{1}{\sqrt{LC}}$
iv)	Impedance	d)	$\sqrt{R^2+(X_L-X_C)^2}$
v)	Magnetic potential energy	e)	$\frac{-E}{\left(\frac{dI}{dt}\right)}$
vi)	Coefficient of self-induction	f)	$\frac{w_0L}{R}$

⇒ Resonant frequency – $1/\sqrt{LC}$
Quality factor – $\omega_0 L/R$
Average power – $VI\cos\phi$
Impedance – $\sqrt{R^2+(X_L-X_C)^2}$
Magnetic potential Energy – $\frac{1}{2}LI^2$
Coefficient of self-inductance – $-E/(dI/dt)$

BOARD- 2016

8. A light bulb is rated at 100 w for 220V supply. Find peak voltage of source.

⇒ $V_{rms} = 220\ V$

$V_{rms} = \frac{V_0}{\sqrt{2}}$

$V_0 = \sqrt{2} \times 220V$

$V_0 = 311$ volts

BOARD- 2017

9. write any two energy loss occuring in transformers. How can these be minimised? why does electric power is transmitted at high voltage upto large distance? [3 Marks]

⇒ Energy loss in transformer –
1. Copper Loss
2. Eddy current Loss
3. Flux leakage
4. Hysteressis loss

1. Copper Loss – Due to resistance of Cu wire of transformer coils, heat produces.

→ To reduce Cu loss we make transformer coil with thick wire of Cu.

2. Flux leakage – 100% flux of primary coil can't be linked with secondary coil. So, there is flux leakage.

→ To reduce flux leakage, make sec. coil over the primary coil.

Reason of High voltage upto Large distance - To reduce energy loss during transmission over long distances.

$$P = VI$$

at constant power

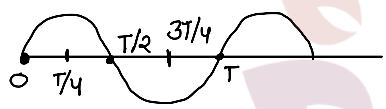
$$I \propto \frac{1}{V}$$

at High voltage current is low so, I^2Rt is less.

BOARD - 2018

10. Find the time taken by AC attain zero from its peak value. The frequency of AC is 50 Hz. (1 Mark)

⇒



Time taken by AC attain zero from its peak - T/4

$$t = T/4 \quad -①$$

$$T = \frac{1}{f} = \frac{1}{50} = 0.02$$

put value -

$$t = \frac{0.02}{4}$$

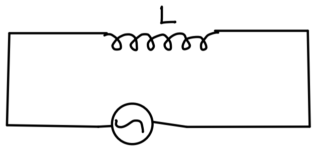
$$t = 0.005 \text{ sec}$$

11. (i) write one merit & demerit of AC in compare to DC.
(ii) Obtain following in pure inductive AC circuit -
a. Instant value of current
b. Reactance of circuit
c. Peak value of current.
d. Draw curve for power in pure inductive

⇒ **AC v/s DC** - Ⓐ **Merit** - Transmission to remote place is easy & cheap compare to DC.

Ⓑ **Demerit** - High peak voltage ($V_0 = \sqrt{2} V_{rms}$) so safety concern.

Pure Inductance - 1. **Circuit Diagram** -



2. **Alternating Voltage** -

$$V = V_0 \sin\omega t \quad - ①$$

3. **Alternating Current** -

$$|e| = L\frac{dI}{dt} \quad - ②$$

$|e| = V = V_0 \sin\omega t$ — ③

from ② & ③

$$V_0 \sin\omega t = L\frac{dI}{dt}$$

$$dI = \frac{V_0}{L} \sin\omega t\, dt$$

$$\int dI = \frac{V_0}{L} \int \sin\omega t\, dt$$

$$I = \frac{V_0}{L}\left[-\frac{\cos\omega t}{\omega}\right]$$

$$I = \frac{V_0}{\omega L}(-\cos\omega t)$$

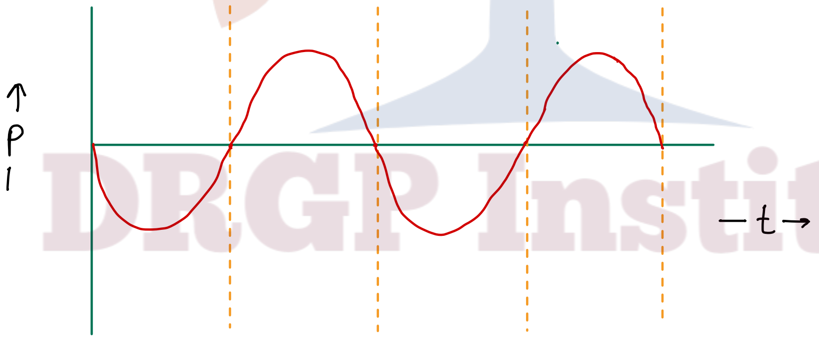
$$\left\{ \begin{array}{l} \cos\omega t = \sin(\pi/2 - \omega t) \\ -\cos\omega t = \sin(\omega t - \pi/2) \end{array} \right\}$$

$$I = \frac{V_0}{\omega L} \sin(\omega t - \pi/2) \qquad \left\{ I = \frac{V_0}{X_L} \right\} \quad \{X_L = \omega L\}$$

$$I = I_0 \sin(\omega t - \pi/2)$$

(i) Instant value –
(ii) Reactance – $X_L = \omega L$
(iii) Peak current – $I_0 = \frac{V_0}{X_L}$

Note :- phase difference $= \pi/2$
{Current lags voltage by $\pi/2$}.



BOARD :- 2018 (Supp.)

12. The value of AC voltage & current in a LCR circuit are given by – [2 Marks]

$V = 210 \sin 200t$

$I = 7 \sin(200t - \pi/3)$

find Impedance & frequency

⇒ $V_m = 210 \sin 200t$, $I = 7 \sin(200t - \pi/3)$

$V_0 = 210$ volt

$I_0 = 7$ A

(i) Impedance – $Z = \frac{V_0}{I_0} = \frac{210}{7} = 30\Omega$

(ii) $V = 210 \sin 200t$ compare it $V = V_0 \sin \omega t$

$$\omega = 200$$
$$2\pi n = 200$$
$$n = \frac{200}{2 \times 3.14}$$
$$n = 31.8 \text{ Hz}$$

BOARD:- 2019

13. write the relationship b/w rms value & peak value of AC.

⇒ $$I_{rms} = \frac{I_0}{\sqrt{2}}$$

14. In LCR AC circuit $R = 100\Omega$, $X_L = 100\Omega$ & $X_C = 100\Omega$ write the value of Impedance.

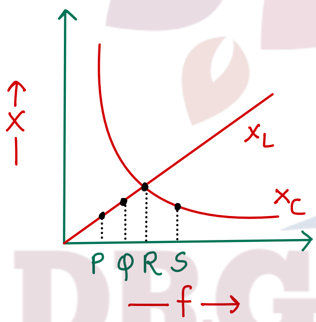
⇒ $$Z = \sqrt{R^2 + (X_L - X_C)^2}$$
$$Z = \sqrt{(10)^2 + (100-100)^2}$$
$$Z = 10\Omega$$

15. Draw vector diagram (Phasor diagram) of LCR circuit and derive value of impedance.

BOARD:- 2020

16. In a given diagram, write a point showing resonant state.

⇒



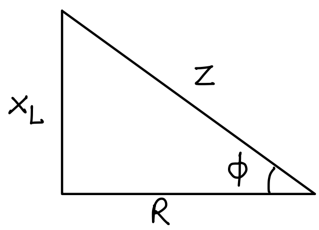
R = Resonant state ($X_L = X_C$)

17. The power factor of a coil is 0.707 at frequency 50 Hz. If frequency is doubled, then calculate the power factor of coil. [2 Marks]

⇒ $\cos\phi_1 = 0.707$ at $f_1 = 50\text{Hz}$

if $f_2 = 100\text{ Hz}$ $\cos\phi_2 = ?$

$$\cos\phi_1 = R/Z = 0.707$$
$$\cos\phi_1 = 1/\sqrt{2} = \cos\pi/4$$
so,
$$\phi_1 = \pi/4$$
$$\tan\phi_1 = \tan 45^\circ$$
$$\tan\phi_1 = 1 \quad -①$$



$$\tan\phi_1 = \frac{X_L}{R}$$

$$\frac{\tan\phi_1}{\tan\phi_2} = \frac{X_{L_1}}{X_{L_2}} = \frac{\omega_1 L}{\omega_2 L} = \frac{2\pi n_1 L}{2\pi n_2 L}$$

$$\frac{\tan\phi_1}{\tan\phi_2} = \frac{n_1}{n_2}$$

$$\tan\phi_2 = \frac{n_2}{n_1} \times \tan\phi_1$$

$$\tan\phi_2 = \frac{n_2}{n_1}$$

given $n_2 = 2n_1$ $n_1 = 50Hz$

$n_2 = 100Hz$

$$\tan\phi_2 = \frac{2}{1} \begin{matrix}\rightarrow P \\ \rightarrow B\end{matrix}$$

So $H = \sqrt{2^2+1^2} = \sqrt{5}$

$$\cos\phi_2 = \frac{B}{H}$$

$$\cos\phi_2 = \frac{1}{\sqrt{5}}$$

18. The voltage and current in an A.C are $V = 50 \sin 314t$ and $I = 10 \sin(314t + \pi/4) A$

Calculate (i) wattless current

(ii) Root mean square voltage.

⇒ (i) Wattless current – Not in syllabus $I_{w.L} = I_{rms} \sin\phi$

(ii) $V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{50}{\sqrt{2}} = 50 \times 0.707 = 35.35$ Vot

BOARD- 2021

19. The I_{rms} in AC is $\sqrt{2}A$. Find its peak value.

⇒ $I_0 = \sqrt{2} I_{rms} = \sqrt{2}(\sqrt{2}) = 2A$

20. A transformer steps up 220 V to 2200 V. If number of turns in secondary coil is 1000 then calculate number of turns in primary coil.

⇒
$$\frac{E_s}{E_p} = \frac{N_s}{N_p}$$

$$\frac{2200}{220} = \frac{1000}{N_p}$$

$$\boxed{N_p = 100}$$

BOARD- 2022

BOARD:- 2023

21. Frequency of AC $I = 200 \sin(60\pi t + \pi/6)$

a. 120 Hz   b. 60 Hz

c. 90 Hz   d. 30 Hz

⇒ $I = 200 \sin(60\pi t + \pi/6)$

compare it with

$I = I_0 \sin(\omega t + \phi)$

$I = I_0 \sin(2\pi n t + \phi)$

$2\pi n = 60\pi$

$n = \frac{60}{2}$

$n = 30 \text{ Hz}$

22. Find the value of power coefficient for the following circuit-

(i) Pure capacitive circuit

(ii) Series LCR resonant circuit

⇒

Power factor - $\cos\phi = \frac{R}{Z}$

(i) for pure capacitive circuit

$\phi = 90°$

$\cos\phi = 0$

(ii) Series LCR resonant circuit

$R = Z$ {Because $X_L = X_C$}

$\cos\phi = 1$

23. Describe any three losses in transformer. How these can be minimised?

BOARD:- 2024

24. The mean value of AC in a complete cycle is-

⇒ Zero.

25. Prove that the peak value of AC is $\sqrt{2}$ times of I_{rms} value.

⇒

$I = I_0 \sin\omega t$

Squre both side -

$I^2 = I_0^2 \sin^2\omega t$

mean value -

$$\overline{I^2} = I_0^2 \, \overline{\sin^2 \omega t}$$

$$\overline{I^2} = I_0^2 \left(1/2\right)$$

$$\overline{I^2} = \frac{I_0^2}{2}$$

$$\sqrt{\overline{I^2}} = \sqrt{\frac{I_0^2}{2}}$$

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

$$\boxed{I_0 = \sqrt{2}\, I_{rms}}$$

26. $I = 4 \sin \omega t$ calculate average power.
$V = 200 \sin(\omega t + \pi/3)$

⇒ $P_{avg} = V_{rms} I_{rms} \cos\phi$

$$= \frac{V_0}{\sqrt{2}} \frac{I_0}{\sqrt{2}} \cos\phi$$

$V_0 = 200$, $I_0 = 4$
$\phi = \pi/3$

$$= \frac{200}{\sqrt{2}} \cdot \frac{4}{\sqrt{2}} \cos \pi/3$$

$$= 400 \times \frac{1}{2}$$

$$= 200 \text{ watt}$$

27. (i) Prove that the average power supplied to an inductor over one complete cycle is zero.
(ii) If in LCR AC $R = 24\Omega$, $X_L = 110\Omega$ & $X_C = 110\Omega$ calculate impedance.

⇒ (i) $P = VI$

$$P = V_0 \sin\omega t \cdot I_0 \sin(\omega t + \phi)$$

$$P = V_0 I_0 \sin \omega t \sin(\omega t + \phi)$$

$$P = V_0 I_0 \sin\omega t (\sin\omega t \cos\phi + \cos\omega t \sin\phi)$$

$$P = V_0 I_0 \sin^2 \omega t \cos\phi + V_0 I_0 \sin\omega t \cos\omega t \sin\phi$$

$$P_{avg} = \overline{P} = V_0 I_0 \overline{\sin^2\omega t} \cos\phi + V_0 I_0 \overline{\sin\omega t}\, \overline{\cos\omega t} \sin\phi$$

$$\left\{ \begin{array}{l} \overline{\sin^2 \omega t} = 1/2 \\ \overline{\sin\omega t} = \overline{\cos\omega t} = 0 \end{array} \right\}$$

$$P_{avg} = V_0 I_0 \left(\frac{1}{2}\right) \cos\phi + 0$$

$$P_{avg} = \frac{V_0}{\sqrt{2}} \cdot \frac{I_0}{\sqrt{2}} \cos\phi$$

$$P_{avg} = V_{rms} I_{rms} \cos\phi$$

for pure inductive circuit $\phi = 90^\circ$

$$P_{avg} = V_{rms} I_{rms} \cos 90^\circ$$

$$\boxed{P_{avg} = 0} \qquad \{\cos 90^\circ = 0\}$$

(ii)

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$Z = \sqrt{(24)^2 + (110 - 110)^2}$$

$$Z = \sqrt{(24)^2}$$

$$Z = 24\,\Omega$$