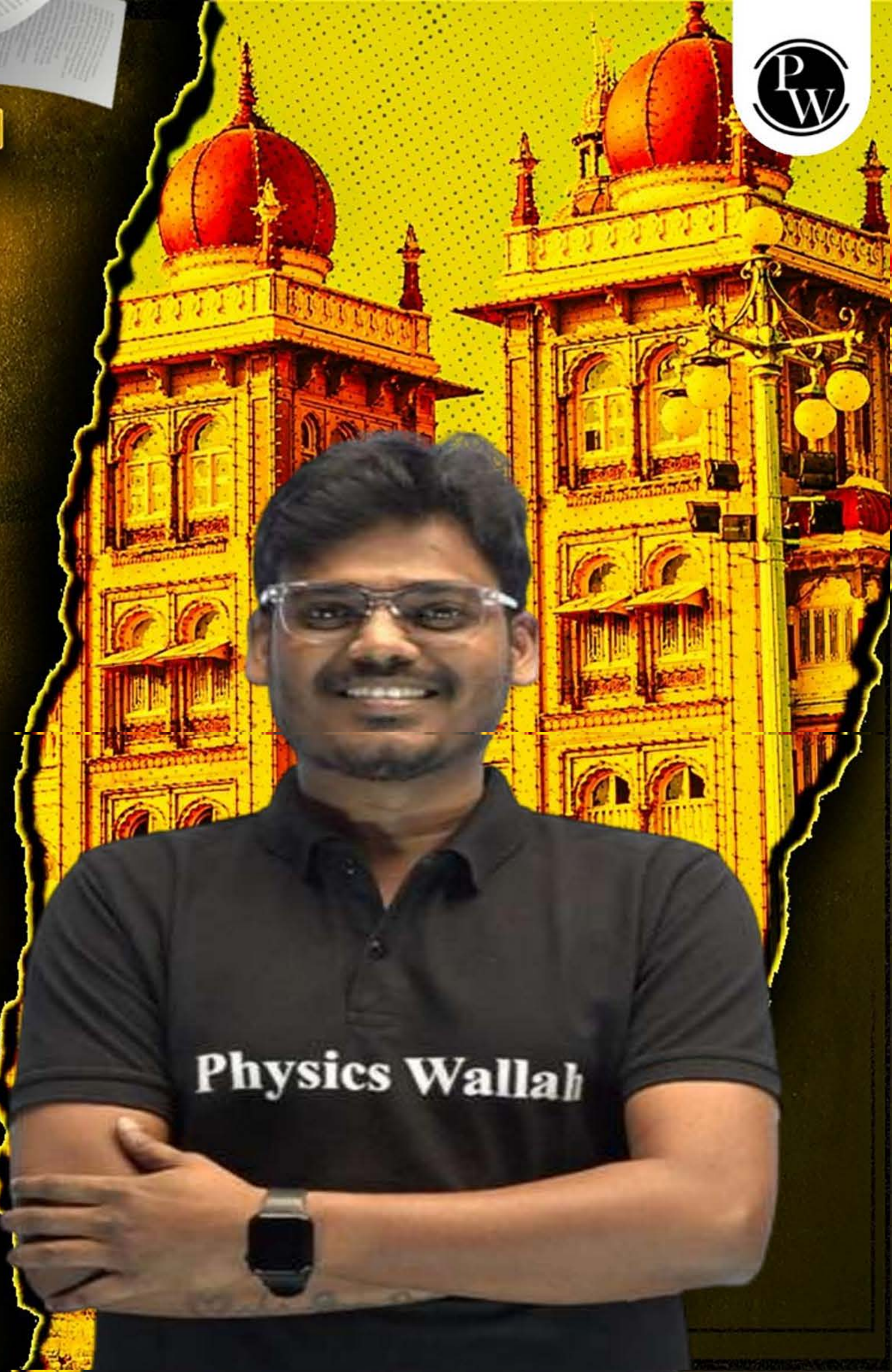
ULTIMATE KCET

CRASH COURSE 2026

PHYSICS | Lecture : 01

ALTERNATING CURRENT AND ELECTROMAGNETIC WAVES

By – AK SIR



Recap *of previous lecture*

1. TORQUE ON A CURRENT CARRYING COIL IN A MAGNETIC FIELD
2. CONVERSION OF A GALVANOMETER INTO AMMETER AND VOLTMETER
3. BAR MAGNET AND MAGNETIC FIELD LINES
4. QUESTIONS

Topics *to be covered*

1. RMS VALUES OF AC & AC AND DC
2. DIFFERENT TYPES OF AC CIRCUIT
3. LCR-RESONANT CIRCUIT
4. ELECTROMAGNETIC WAVES

KCET analysis of chapter - Marks weightage

Year	Topic
2025 (2Q)	RMS Value of voltage and frequency, Series LCR
2024(3Q)	LCR circuit, Resonance frequency and LCR Graph
2023(3Q)	Quality factor, Transformer and Phase difference in LCR
2022(3Q)	Impendence of LCR, Energy stored in LC and R.M.S current
2021(3Q)	Current in LCR, Oscillating LC (2)

KCET analysis of chapter - Marks weightage

Year	Topic
2020(3Q)	R.M.S values of LCR, Power factor R-L and Resonant frequency of L-C
2019(2Q)	Peak Values of R.M.S and Power dissipated in L-R
2018(5Q)	Graph of inductive reactance, Current through AC, Power dissipated LCR, Transformer and R.M.S Values of AC
2017(3Q)	Time lag-LCR, Inductance and Transformer
2016(4Q)	Average value of AC, Current AC, Source voltage-LCR and Power dissipated in AC
2015(3Q)	Efficiency of transformer, Resonance-LCR and Power dissipated in a pure inductor

RMS VALUES

Root mean square values

From last class: AC Generator.

In India

↳ 220V
↳ f = 50Hz } AC

$e = e_0 \sin\omega t$

$V = V_0 \sin\omega t$

$I = \frac{V}{R} = \frac{V_0 \sin\omega t}{R}$

$I = I_0 \sin\omega t$

$V_0 = NAB\omega$

$I_0 = \frac{NAB\omega}{R}$

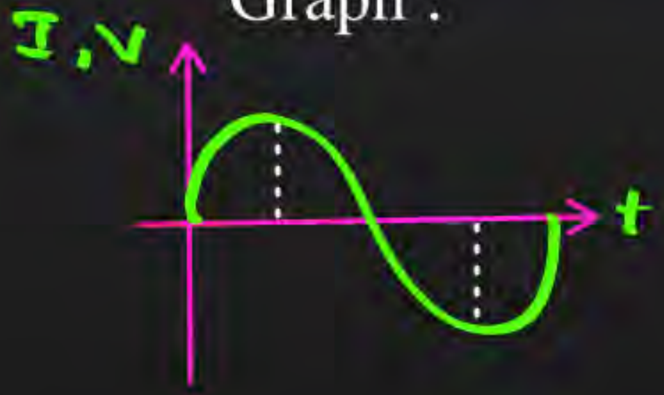
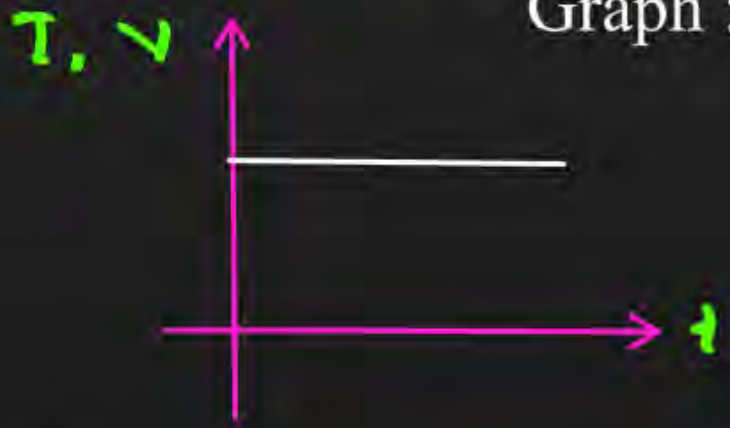
RMS Values

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

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

V_0, I_0 – peak value of voltage & current

AC and DC

Alternating Current (AC)	Direct current
Graph : 	Graph : 
Can be Generated by using AC Generator.	Can be Generated by using DC Generator, Battery, solar panels.
Inverter converts DC into AC.	Rectifier converts AC into DC.
Can be controlled using Transformer.	Cannot be controlled using Transformer

Question

In Karnataka, the normal domestic power supply AC is 220 V, 50 Hz. Here, 220 V and 50 Hz refer to

(A) peak value of voltage and frequency

(B) rms value of voltage and frequency

(C) mean value of voltage and frequency

(D) peak value of voltage and angular frequency

Question

A multimeter reads a voltage of a certain AC source as 100 V . What is the peak value of voltage of AC source?

$V_{rms} = 100V$

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

$V_0 = \sqrt{2} \times V_{rms} = 1.41 \times 100$

$V_0 = 141 V$

(A) 200 V

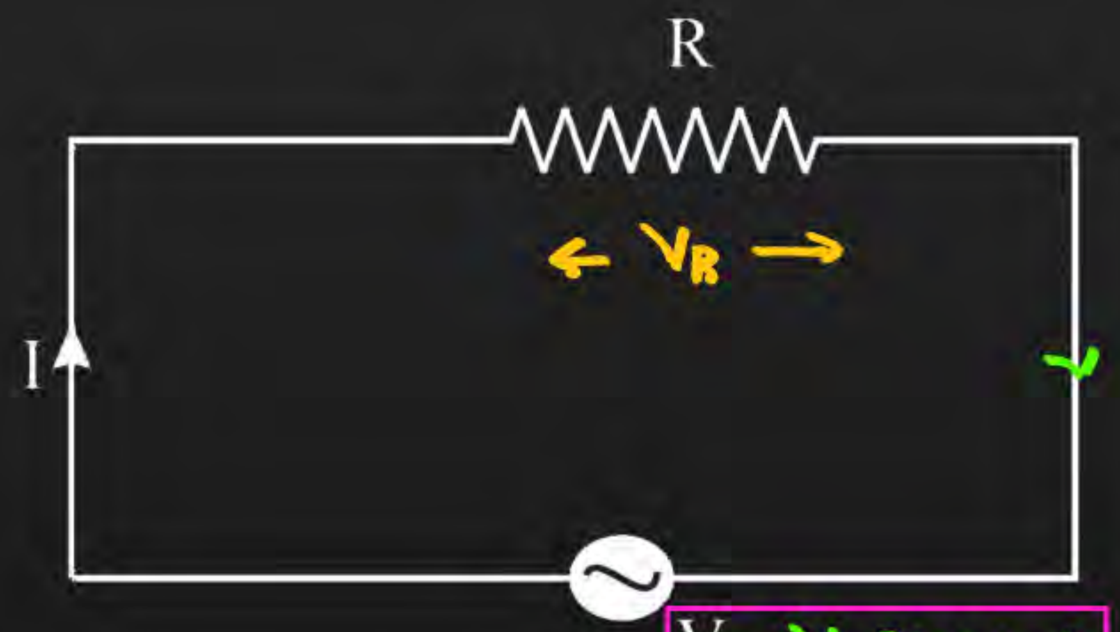
(B) 100 V

(C) 141.4 V

(D) 400 V

$y = A\sin(\omega t \pm \phi)$

AC Voltage applied to pure Resistance (R)



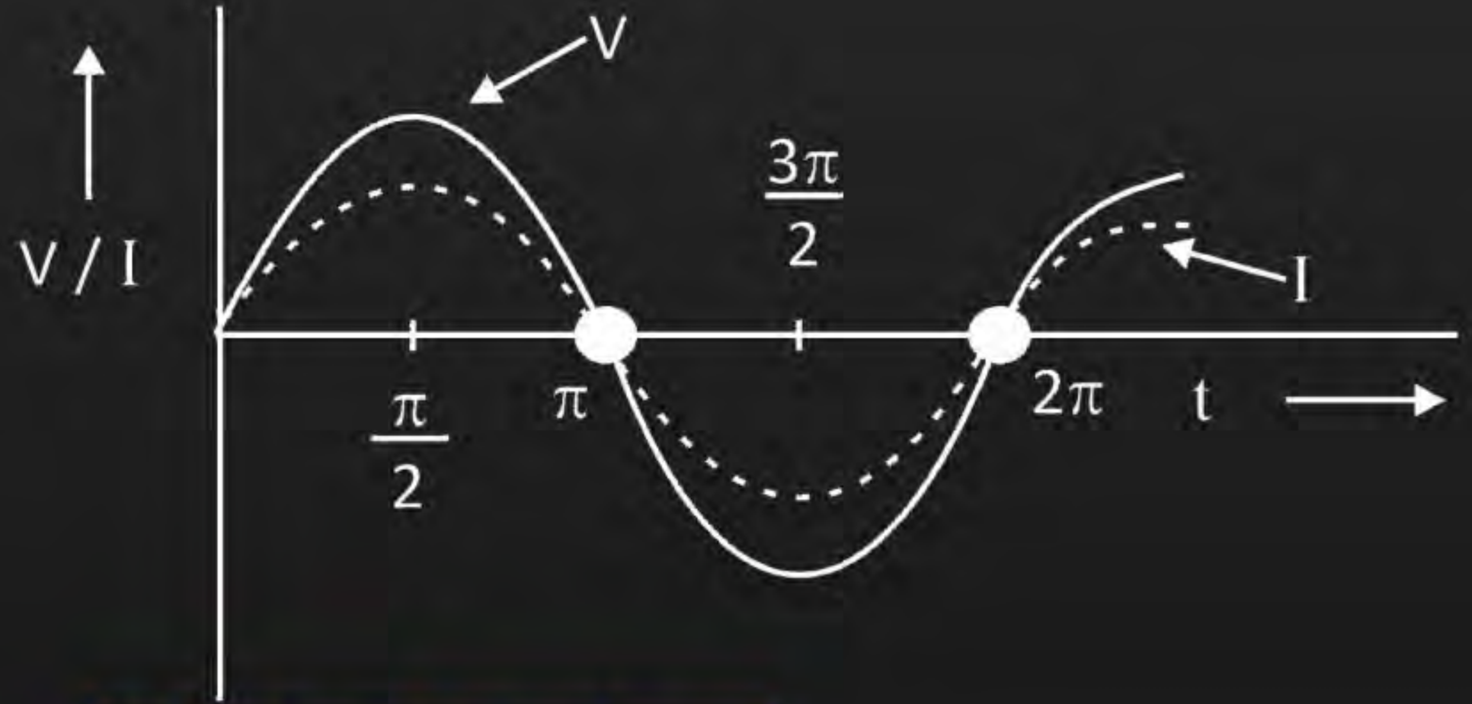
$V = V_0 \sin\omega t$

$I = \frac{V}{R}$

$I = \frac{V_0 \sin\omega t}{R}$

$I = I_0 \sin\omega t$

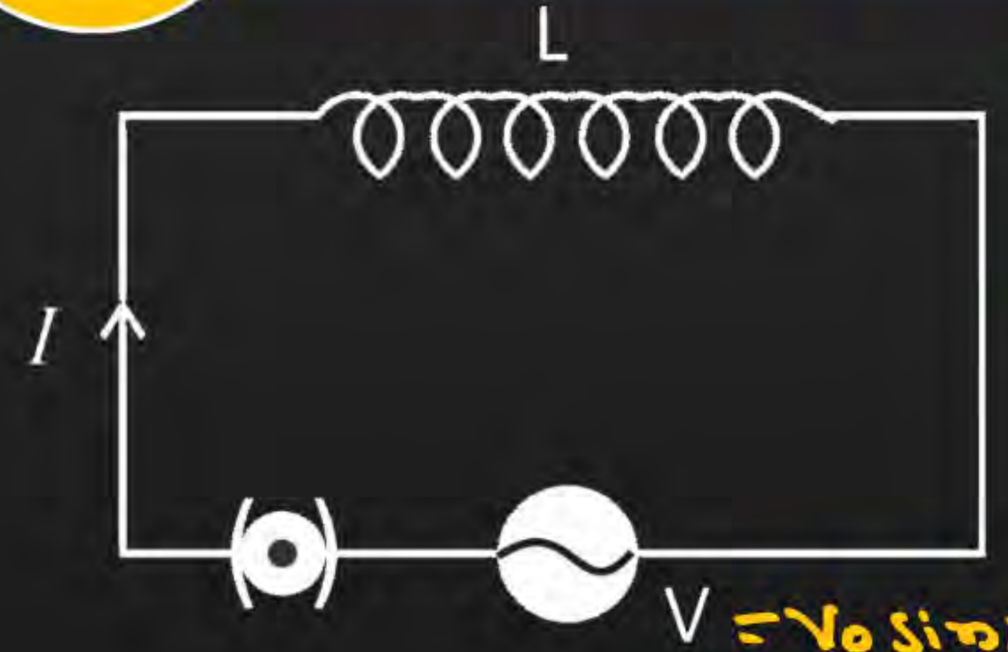
V & I both are in phase i.e $\phi = 0^\circ$



Phasor Diagram

$\phi = 0^\circ$

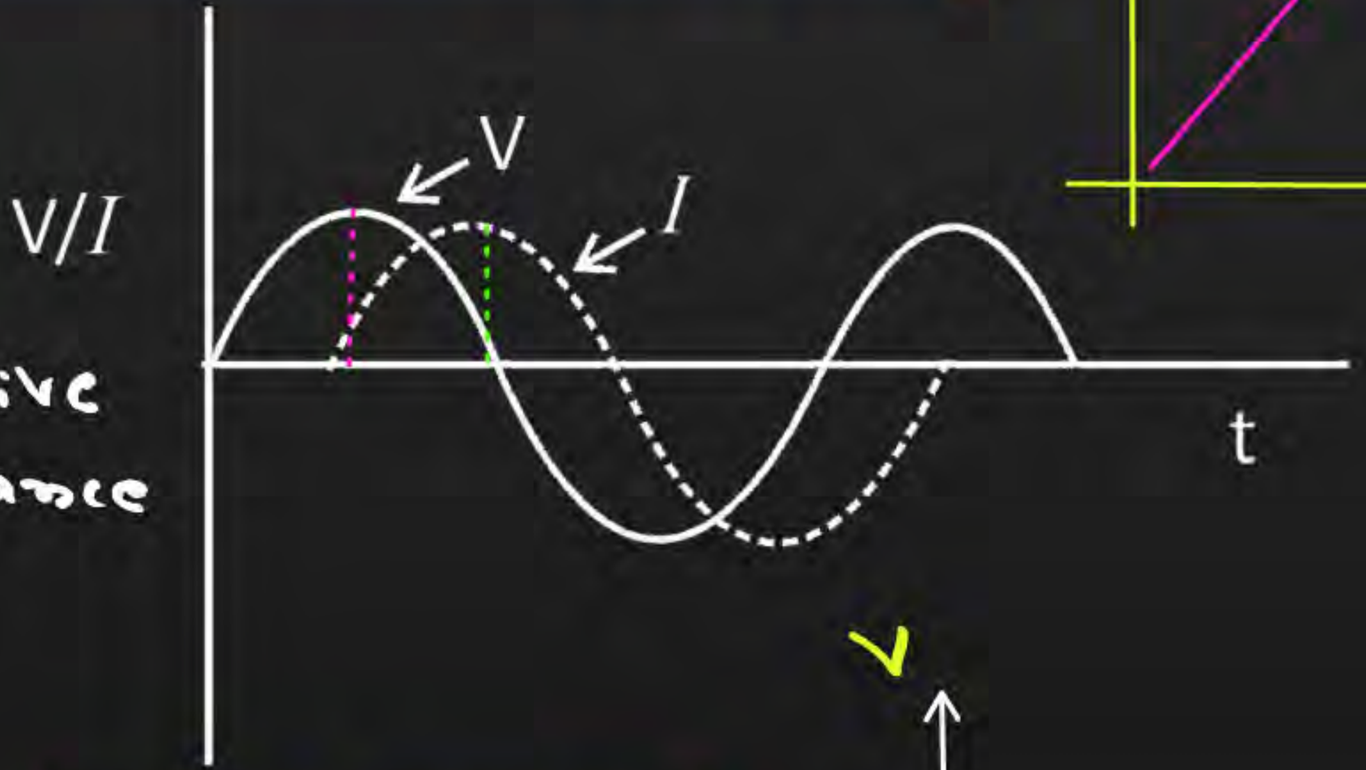
AC Voltage applied to pure Inductor (L)

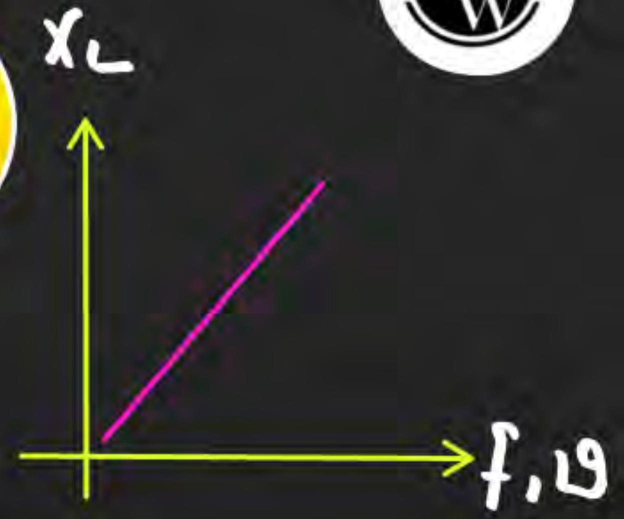


$V = V_0 \sin \omega t$

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

$X_L \rightarrow$ Inductive Reactance





$$I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$$

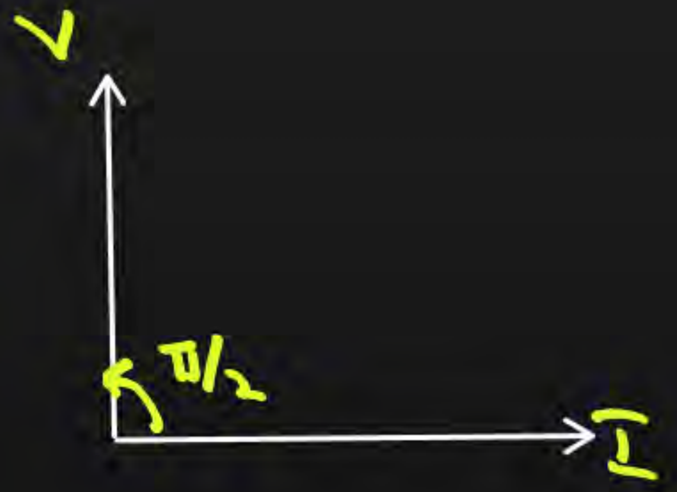
phase Difference

$$\phi = \pi/2$$

→ V Leads I by $\frac{\pi}{2}$

→ I lags V by $\frac{\pi}{2}$.

Phasor Diagram



$$X_L = \omega L = 2\pi f L$$

↳ unit – Ohm.

Question

Which of the following, represents the variation of inductive reactance (X_L) with the frequency of voltage sources (v)?

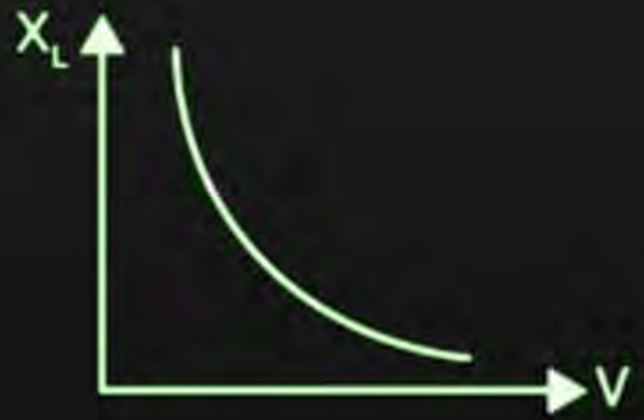
$\nu = f$

A

B

C

D



$X_L = \omega L$

$X_L = 2\pi f L$

$X_L \propto f$

$X_L \propto \nu$

Question

X_L I_0

What is the inductive reactance of a coil if the current through it is 20 mA and voltage across it is 100 V

V_0

$$X_L = \frac{V_{rms}}{I_{rms}}$$

$$I_0 = \frac{V_0}{X_L} \Rightarrow X_L = \frac{V_0}{I_0}$$

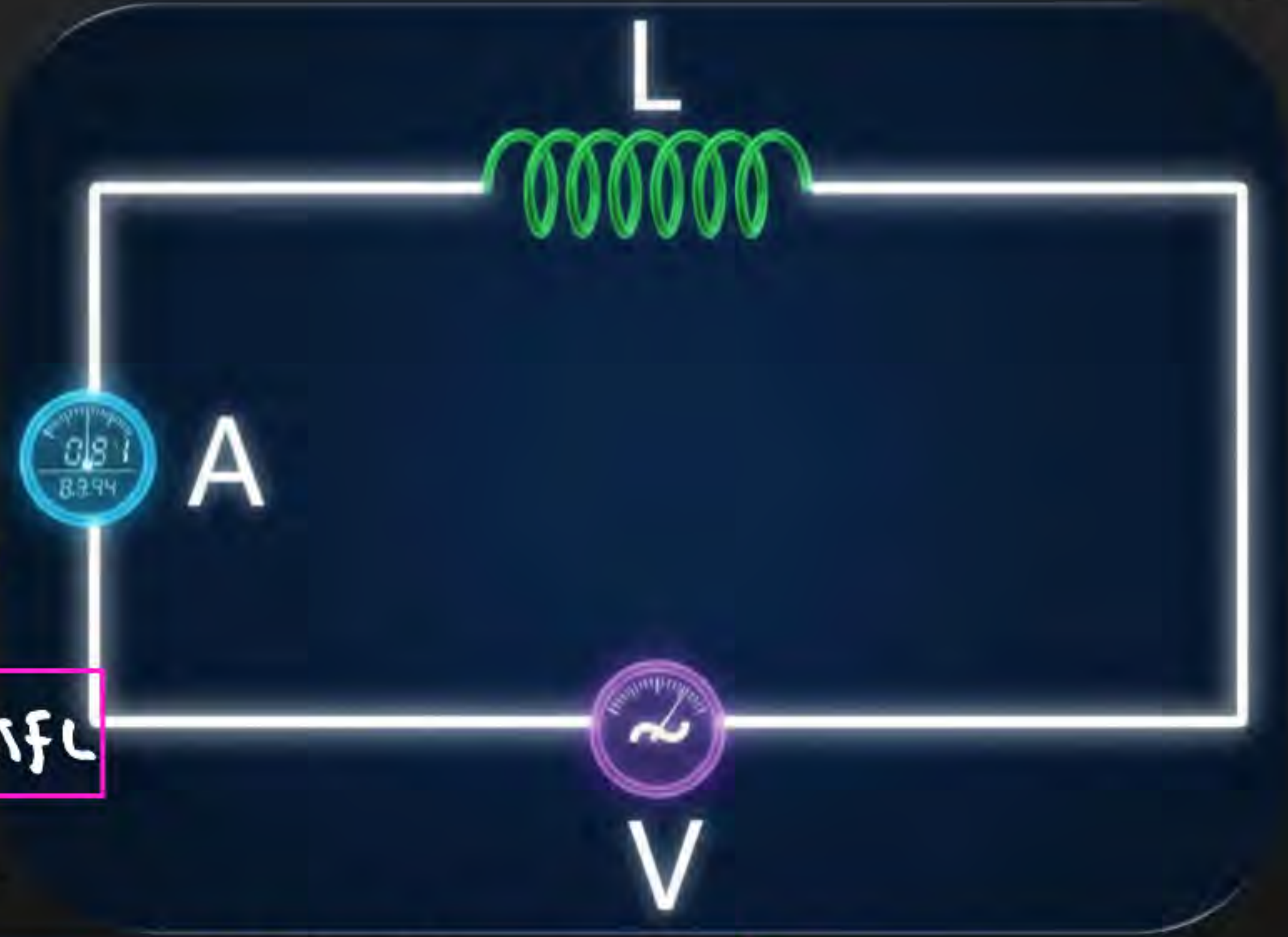
$$X_L = \frac{100}{20 \times 10^{-3}} = 5 \times 10^3$$

$$X_L = 5000\,\Omega$$

Question

$X_L = \frac{V_{rms}}{I_{rms}} = \frac{V_0}{\sqrt{2}} \times \frac{1}{I_{rms}} = \frac{50\sqrt{2}}{\sqrt{2}} \times \frac{1}{2} = 25\Omega$

In given circuit applied voltage $V = 50\sqrt{2}\sin(100\pi t)$ volt and ammeter reading is 2A ($\hookrightarrow I_{rms}$) then calculate value of L ?



$V = V_0 \sin \omega t$

$V_0 = 50\sqrt{2}$ V $\quad \omega = 100\pi$ rad/s

$I = \frac{V}{R} = \frac{V}{X_L} \Rightarrow X_L = \frac{V}{I} = \frac{V_0}{I_0}$

$I_{rms} = \frac{I_0}{\sqrt{2}} \quad I_0 = \sqrt{2} I_{rms} = \sqrt{2} \times 2$ A

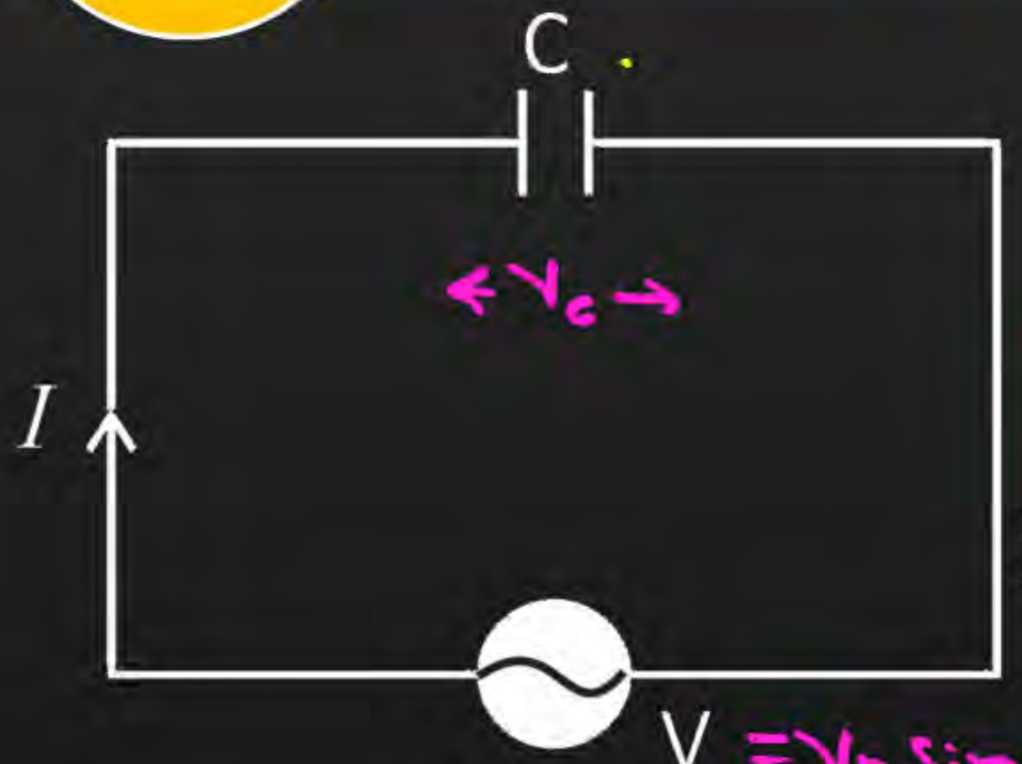
$X_L = \frac{50\sqrt{2}}{2\sqrt{2}} = 25\Omega$

$X_L = \omega L = 2\pi f L$

$25 = 100\pi \times L$

$L = \frac{1}{4\pi} = \frac{1}{4 \times 3.14} = 0.080$ H $= 80$ mH

AC Voltage applied to pure Capacitor (C)



$V = V_0 \sin \omega t$

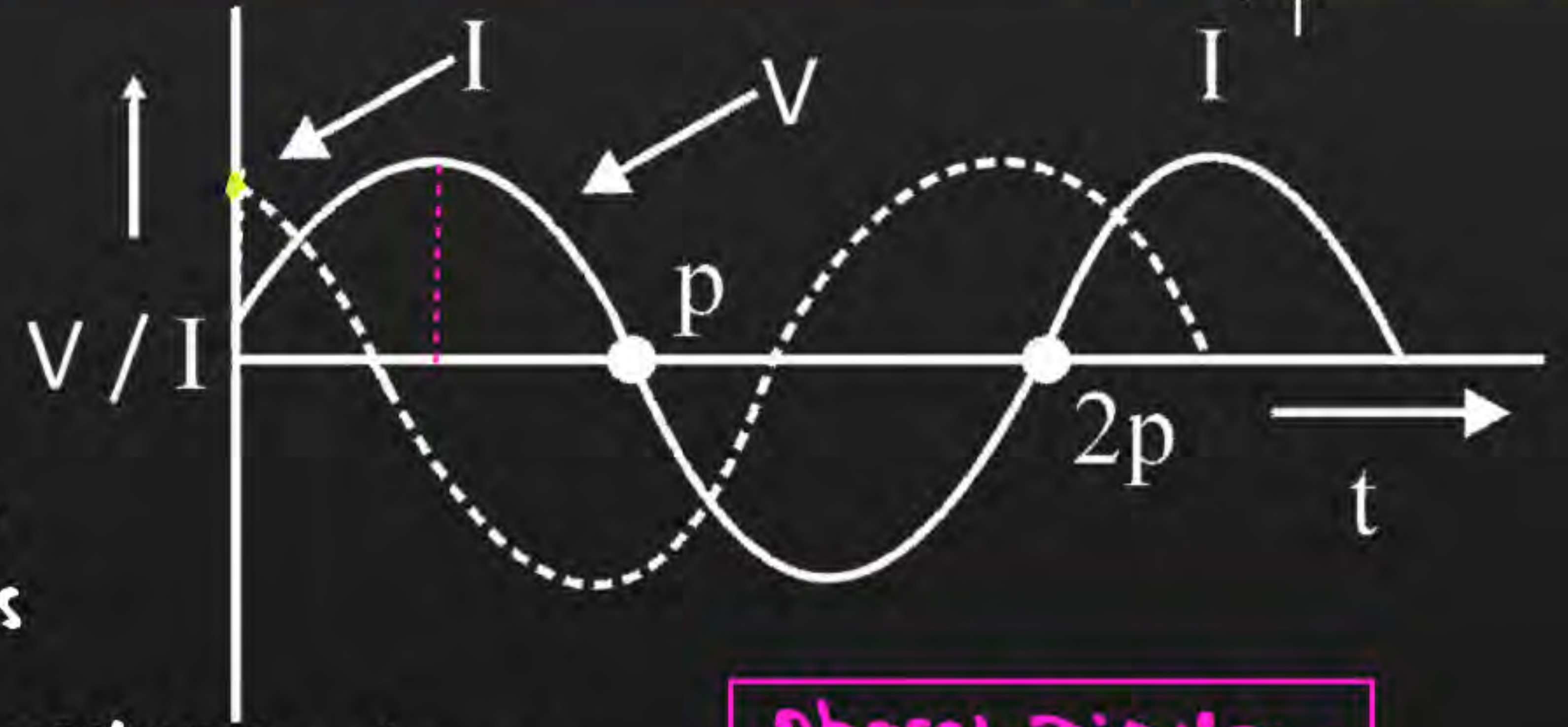
$$I_0 = \frac{V_0}{X_C}$$

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

OR

$$X_C = \frac{V_{rms}}{I_{rms}}$$

X_C - capacitive reactance



$$X_C \propto \frac{1}{f} \propto \frac{1}{\omega}$$

$$I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$$

→ V lags I by $\frac{\pi}{2}$

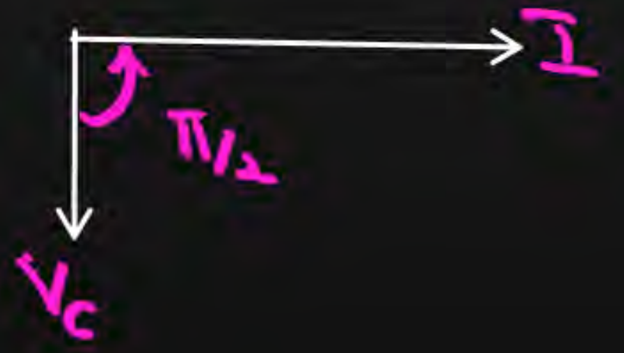
→ I leads V by $\frac{\pi}{2}$

$$X_C = \frac{1}{\omega C}$$

$$X_C = \frac{1}{2\pi f C}$$

⇒ Unit Ohm (Ω)

Phasor Diagram



Question

$p \to 10^{-12}$ F

A capacitor of 50 pF is connected to an a.c. source of frequency 1kHz. Calculate its reactance.

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$$

$$X_C = \frac{1}{2 \times 3.14 \times 10^{3} \times 50 \times 10^{-12}}$$

$$X_C = \frac{1}{314 \times 10^{-9}} = 0.00318 \times 10^{9}$$

$$X_C = 3.18 \times 10^{6}\ \Omega$$

Question

$I = \frac{V}{R} = \frac{V}{X_C} = \frac{V_{rms}}{X_C}$

A capacitor of capacitance 10μ F is connected to an AC ammeter. If the source voltage varies as $V = 50\sqrt{2}\sin 100t$, the reading of the ammeter is

$V = V_0 \sin \omega t$

$V_0 = 50\sqrt{2}\ V$

$\omega = 100\ rad/s$

$C = 10\mu F$

$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{50\sqrt{2}}{\sqrt{2}} = 50V$

(A) 50 mA

(B) 70.7 mA

(C) 5.0 mA

(D) 7.07 mA

$I_{rms} = \frac{V_{rms}}{X_C}$

$X_C = \frac{1}{\omega C} = \frac{1}{100 \times 10 \times 10^{-6}} = \frac{1}{10^3}$

$X_C = 10^3\ \Omega$

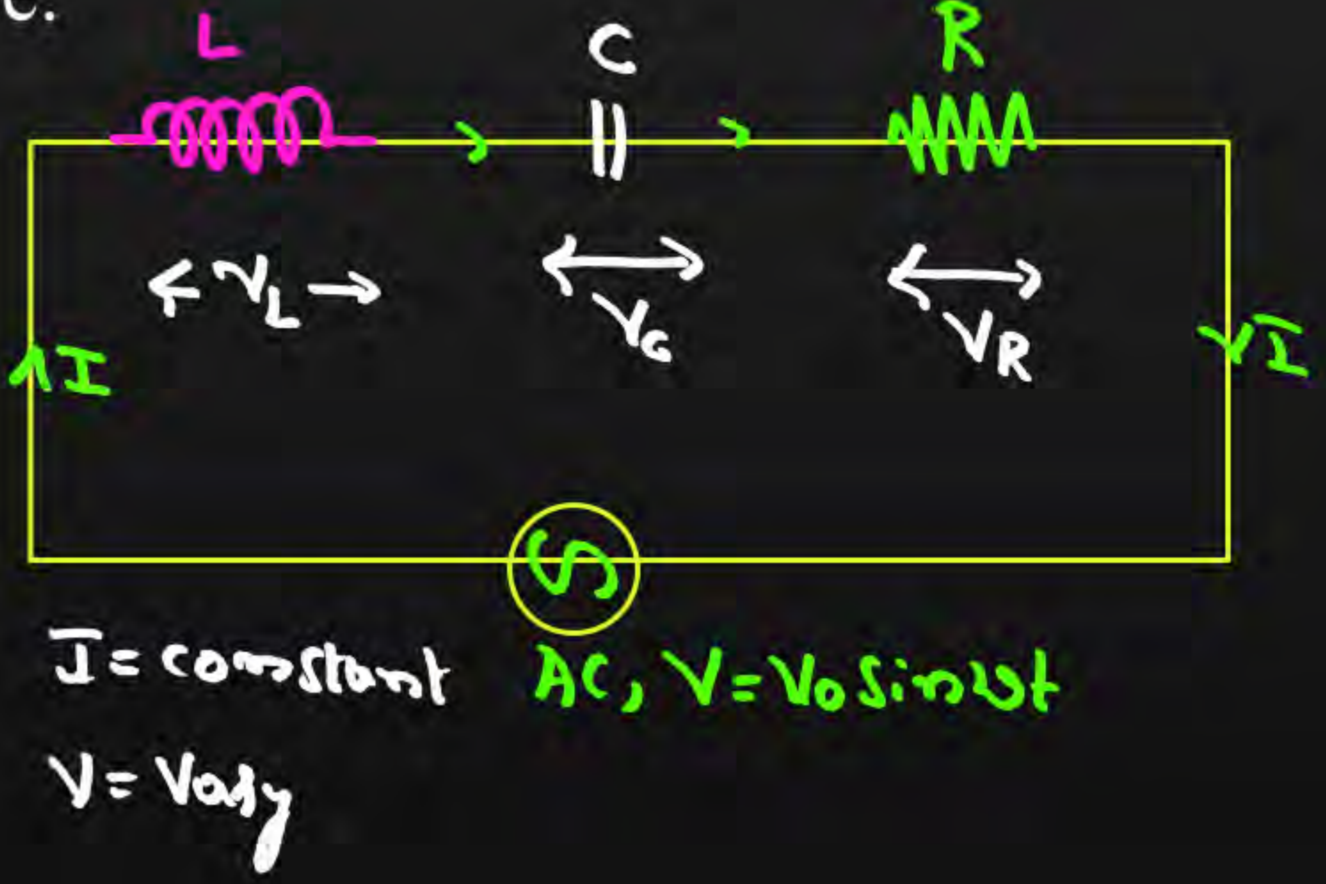
$I_{rms} = \frac{V_{rms}}{X_C} = \frac{50}{10^3} = 50 \times 10^{-3}\ A$

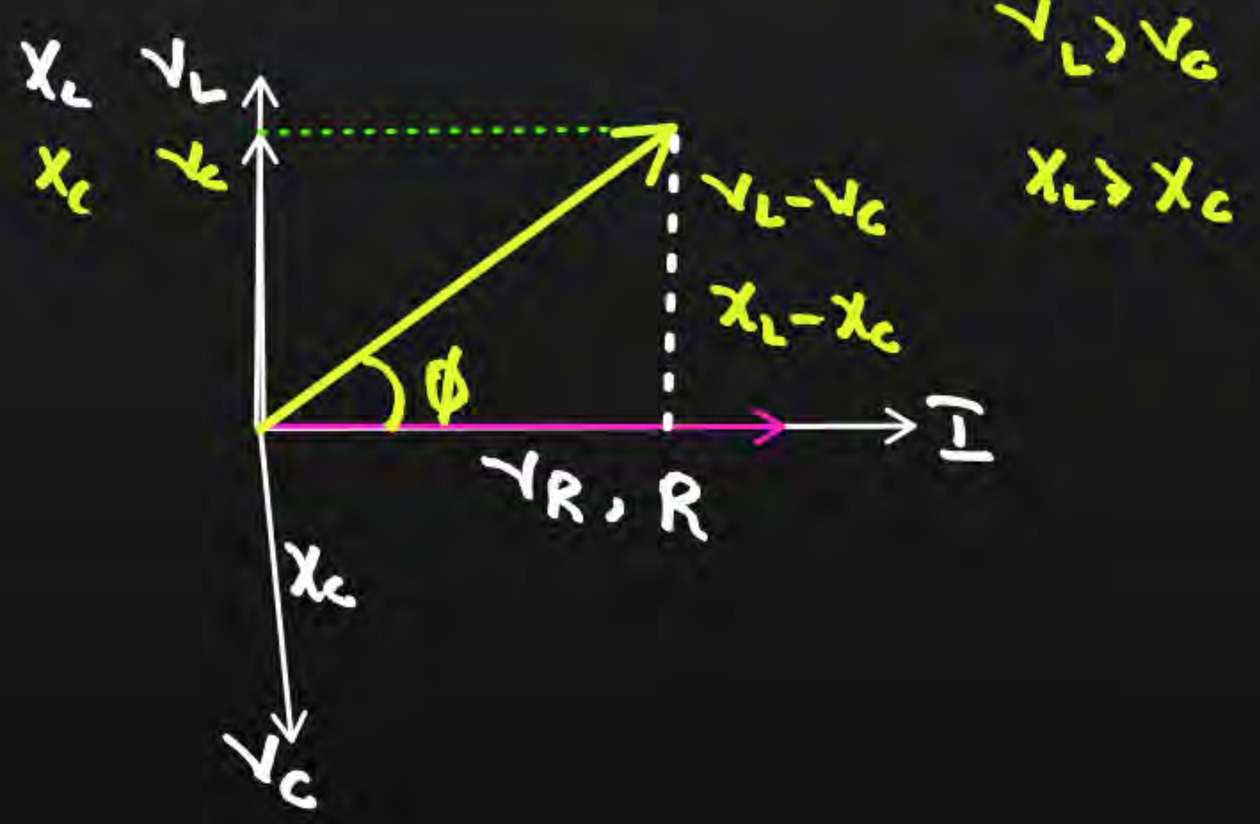
$I_{rms} = 50\ mA$

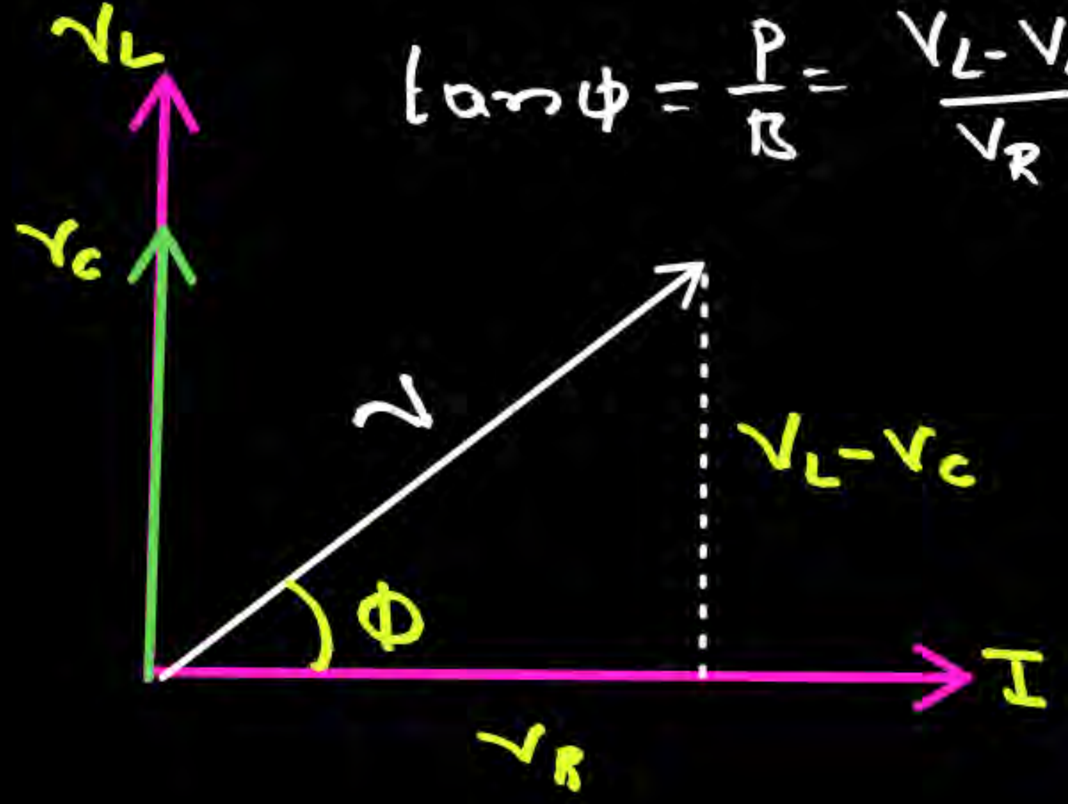
Series LCR Circuit

L-C-R series circuit

A circuit containing a series combination of an resistance R, a coil of inductance L and a capacitor of capacitance C, connected with a source of alternating e.m.f. of peak value E_0, as shown in figure.



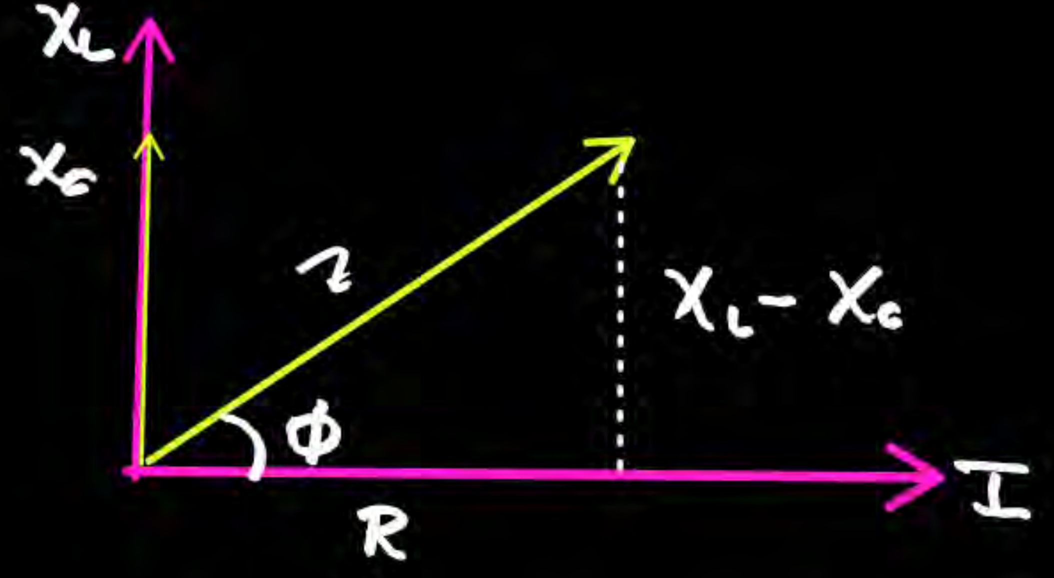




$$\tan\phi = \frac{P}{B} = \frac{V_L - V_C}{V_R}$$

$$V^2 = V_R^2 + (V_L - V_C)^2$$

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$



Impendence = Total Resistance

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

Power Factor

$$\cos\phi = \frac{B}{H} = \frac{R}{Z}$$

$$\tan\phi = \frac{P}{B} = \frac{X_L - X_C}{R}$$

$$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$$

$V_L > V_C$

$X_L > X_C$

Question

For the given LCR-series circuit. Find out applied source voltage of ac.

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$V = \sqrt{(40)^2 + (50-20)^2}$$

$$V = \sqrt{1600 + 900}$$

$$\boxed{V = \sqrt{2500} = 50V}$$

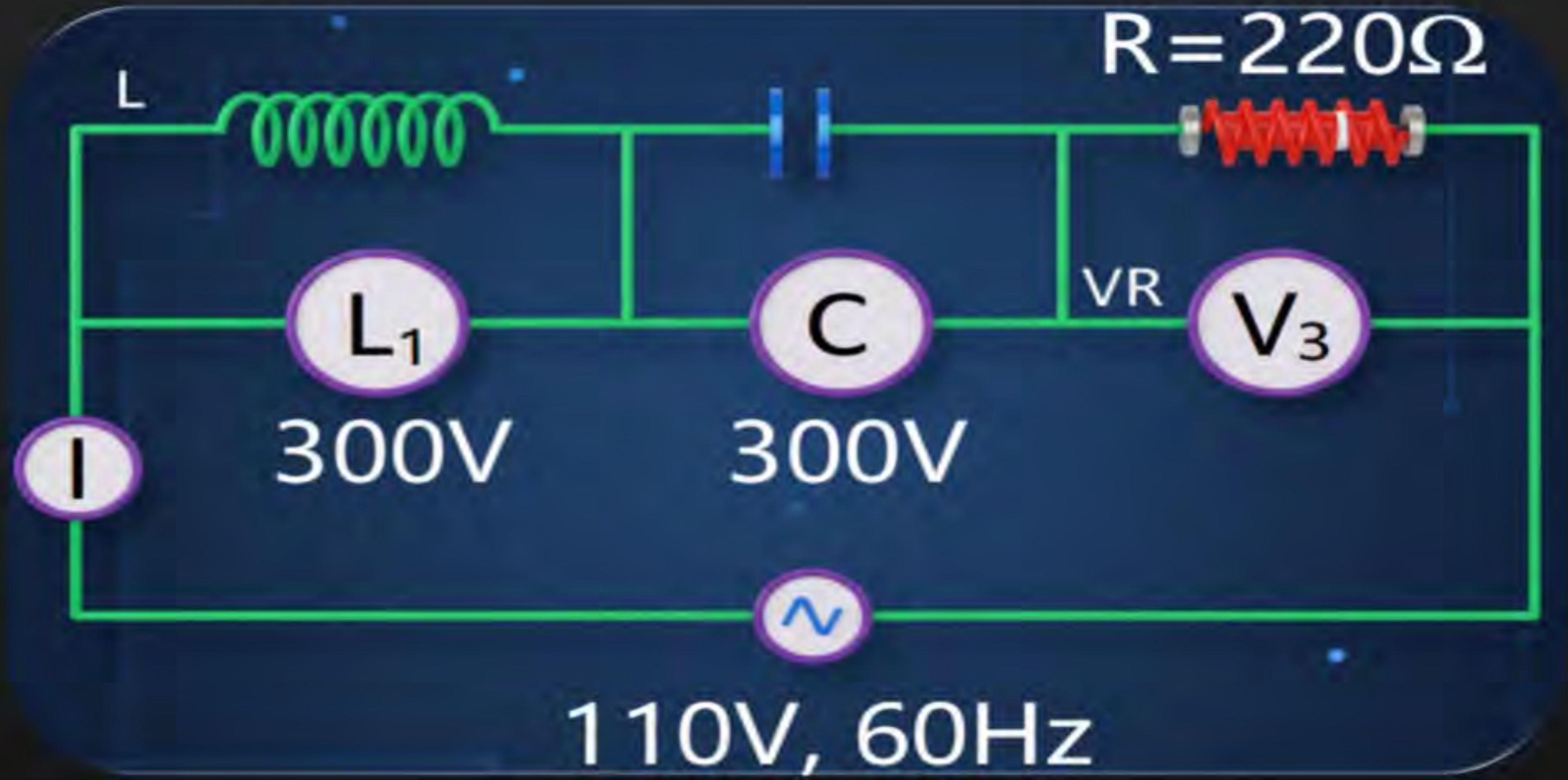
Question

A capacitor, a resistor and a inductor are connected in series to an ac-source of 110 V and frequency 60Hz. Find reading of voltmeter V3 and ammeter in the given LCR-series circuit.

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$110 = \sqrt{V_3^2 + (300-300)^2}$$

$$110 = \sqrt{V_3^2} \Rightarrow V_3 = 110V$$



I = constant, I across R

$$I = \frac{V}{R} = \frac{V_3}{R} = \frac{110}{220} = 0.5\,A$$

Question

Find out the impedance of given circuit.

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

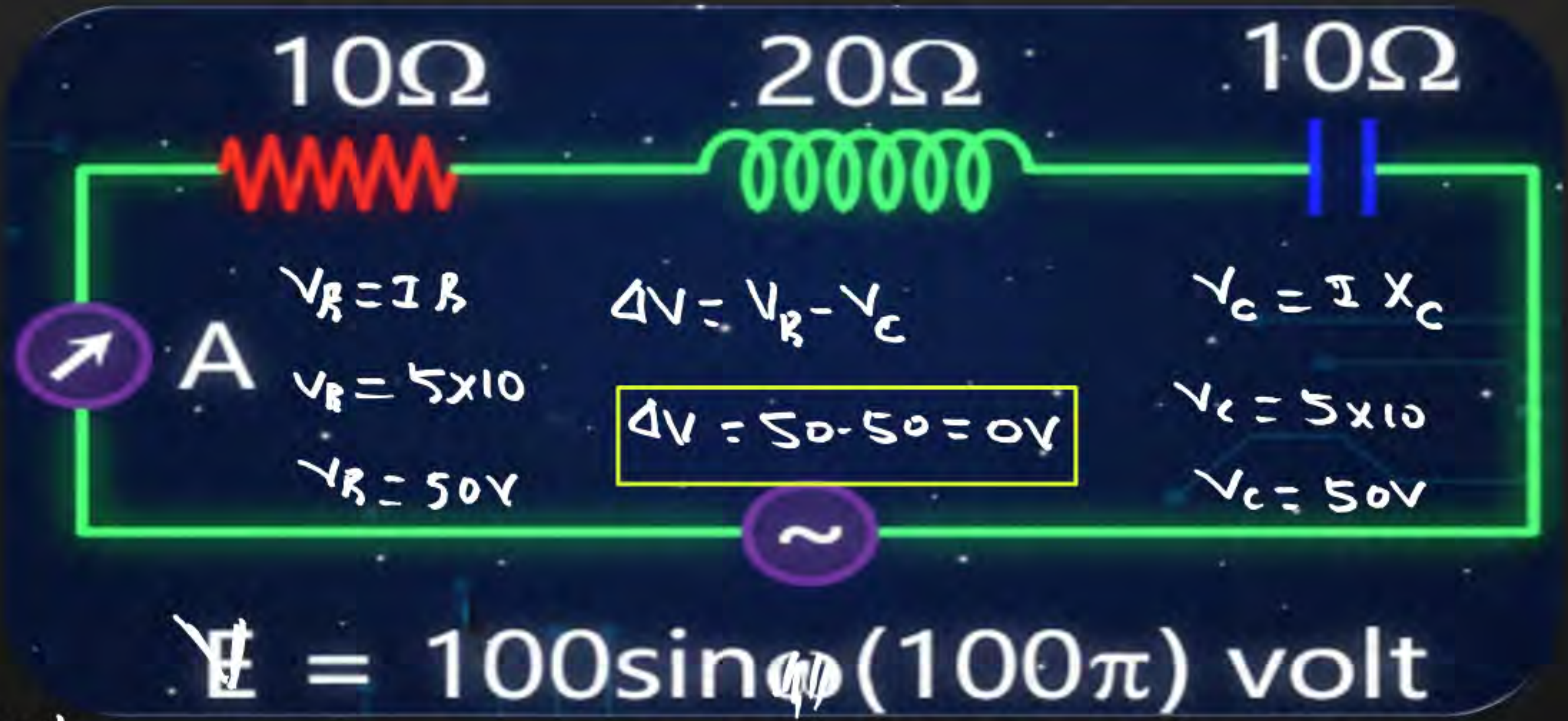
$$Z = \sqrt{(4)^2 + (9-6)^2}$$

$$Z = \sqrt{16+9} = \sqrt{25}$$

$$\boxed{Z = 5\,\Omega}$$

Question

Find out reading of A.C. ammeter and also calculate the potential difference across, resistance and capacitor



$V_R = IR$

$V_R = 5\times10$

$V_R = 50V$

$\Delta V = V_R - V_C$

$\Delta V = 50 - 50 = 0V$

$V_C = IX_C$

$V_C = 5\times10$

$V_C = 50V$

$I_{rms} = \frac{V_{rms}}{Z}$

$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{100}{\sqrt{2}}$ V

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

$Z = \sqrt{(10)^2 + (20-10)^2}$

$Z = \sqrt{100 + 100}$

$Z = 10\sqrt{2}\ \Omega$

$I_{rms} = \frac{100}{\sqrt{2}\times 10\sqrt{2}}$

$I_{rms} = \frac{10}{2} = 5A$

$V = V_0 \sin \omega t$

$V_0 = 100V,\ \omega = 100\pi$ rad/s

Question

In LCR circuit with an AC source R = 300 ohm, C = 20 μF, L = 1.0 H, Vrms = 50V and $f = \frac{50}{\pi}$ Hz. Find RMS current in the circuit.

$$I_{rms} = \frac{V_{rms}}{Z}$$

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

$$X_L = \omega L = 2\pi f L$$

$$X_C = 2\pi \times \frac{50}{\pi} \times 1$$

$X_L = 100\,\Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} = \frac{1}{2\pi \times \frac{50}{\pi} \times 20 \times 10^{-6}} = \frac{1}{2000 \times 10^{-6}}$$

$X_C = 0.5 \times 10^3 = 500\,\Omega$

$$Z = \sqrt{(300)^2 + (100 - 500)^2}$$

$$Z = \sqrt{90000 + 160000}$$

$$Z = \sqrt{250000}$$

$Z = 500\,\Omega$

$$I_{rms} = \frac{50}{500} = \frac{1}{10}$$

$I_{rms} = 0.1$ A

$I_{rms} = 100$ mA

Question

A sinusoidal voltage produced by an AC generator at any instant t is given by an equation V = 311 sin(314t). The rms value of voltage and frequency are respectively

$V = V_0 \sin(\omega t)$

$\omega = 314$

(A) 220 V, 50 Hz

(B) 200 V, 100 Hz

(C) 220 V, 100 Hz

(D) 200 V, 50 Hz

$V_0 = 311\,V$

$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{311}{1.414}$

$V_{rms} = 220\,V$

$\omega = 2\pi f$

$f = \frac{\omega}{2\pi} = \frac{314}{2 \times 3.14} = \frac{100}{2} = 50$

$f = 50\,Hz$

Question

A series LCR circuit containing an AC source of 100V has an inductor and a capacitor of reactance's 24Ω and 16Ω respectively. If a resistance of 6Ω is connected in series, then the potential difference across the series combination of inductor and capacitor will be

(A) 8 V

(B) 40 V

(C) 80 V

(D) 400 V

$X_L = 24\Omega$

$X_C = 16\Omega$

$R = 6\Omega$

$I = \frac{V}{Z}$

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

$Z = \sqrt{(6)^2 + (24-16)^2}$

$Z = \sqrt{36+64} = \sqrt{100} = 10\Omega$

$Z = 10\Omega$

$I = \frac{100}{10}$

$I = 10A$

$V_L = I X_L = 10 \times 24 = 240V$

$V_C = I \times X_C = 10 \times 16 = 160V$

$\Delta V = V_L - V_C = 240 - 160$

$\Delta V = 80V$

Question

In a series L-C-R circuit, $R = 300\Omega, L = 0.9\text{H}, C = 2.0\mu\,\text{F}$ and $\omega = 1000\text{rad/s}$. then impedance of the circuit is

(A) 900Ω

(B) 500Ω

(C) 400Ω

(D) 1300Ω

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(300)^2 + (900-500)^2}$$

$$X_L = \omega L = 1000 \times 0.9$$

$$X_L = 900\Omega$$

$$X_C = \frac{1}{\omega C} = \frac{1}{1000 \times 2 \times 10^{-6}} = \frac{10^{+3}}{2}$$

$$X_C = 500\Omega$$

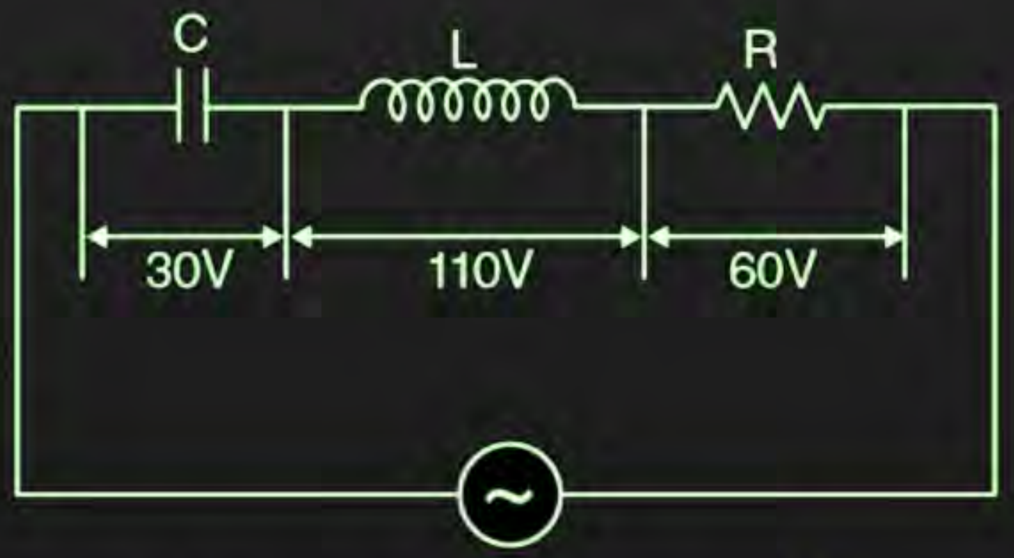
$$= \sqrt{90000 + 160000}$$

$$= \sqrt{250000}$$

$$Z = 500\Omega$$

Question

In the given circuit the peak voltage across C, L and R are $30\ \mathrm{V}, 110\ \mathrm{V}$ and $60\ \mathrm{V}$, respectively. The rms value of the applied voltage is



(A) 100 V

(B) 200 V

(C) 70.7 V

(D) 141 V

$$V_0 = \sqrt{V_R^2 + (V_L - V_C)^2}$$

$$V_0 = \sqrt{(60)^2 + (110-30)^2}$$

$$V_0 = \sqrt{3600 + 6400}$$

$$V_0 = \sqrt{10000}$$

$$V_0 = 100\ \mathrm{V}$$

$$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{100}{\sqrt{2}} = 70.7\ \mathrm{V}$$

Question

L C

An inductance of $\left(\frac{200}{\pi}\right)$ mH, a capacitance of $\left(\frac{10^{-3}}{\pi}\right)$ F and a resistance of 10Ω are connected in series with an AC source 220 V, 50 Hz. The phase angle of the circuit is

(A) $\frac{\pi}{6}$

(B) $\frac{\pi}{4}$

(C) $\frac{\pi}{2}$

(D) $\frac{\pi}{3}$

$X_L = \omega L = 2\pi f L$

$X_L = 2\pi \times 50 \times \frac{200}{\pi} \times 10^{-3}$

$X_L = 20000 \times 10^{-3}$

$X_L = 20\,\Omega$

$X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} = \frac{1}{2\pi \times 50 \times \frac{10^{-3}}{\pi}} = 10^1 = 10\,\Omega$

$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$

$\tan\phi = \frac{20-10}{10} = \frac{10}{10}$

$\tan\phi = 1$

$\tan\phi = \tan 45^\circ = \tan(\pi/4)$

$\phi = \pi/4$

Series LCR Resonance Circuit

Resonance

A circuit is said to be resonant when the natural frequency of circuit is equal to frequency of the applied voltage.

Note : For resonance both L and C must be present in circuit.

There are two types of resonance :

(i) Series Resonance – Resonance is a condition where current is maximum in circuit.

(ii) Parallel Resonance - Resonance is a condition where current is manimum in circuit.

Series LCR Resonance Circuit

(a) At Resonance

i. Reactance of 'L' and 'C' ⟶ $X_L = X_C$

ii. Voltage across 'L' and 'C' ⟶ $V_L = V_C$

iii. Phase difference, Ø ⟶ 0°

iv. Impendence ⟶ $Z_{min} = R$

v. Current ⟶ $I = \frac{V}{Z} = \frac{V_R}{R}$, $Z_{min} \rightarrow I_{max}$

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

$\tan\phi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R}$

$\phi = 0^\circ$

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

$Z = R$

Series LCR Resonance Circuit

(b) Resonant frequency

$$X_L = X_C$$

$$\omega L = \frac{1}{\omega C}$$

$$\omega^2 = \frac{1}{LC}$$

$$\omega = \frac{1}{\sqrt{LC}}$$

Angular Frequency

$$\omega = 2\pi f$$

$$f_r = \frac{\omega}{2\pi} = \frac{1}{2\pi\sqrt{LC}}$$

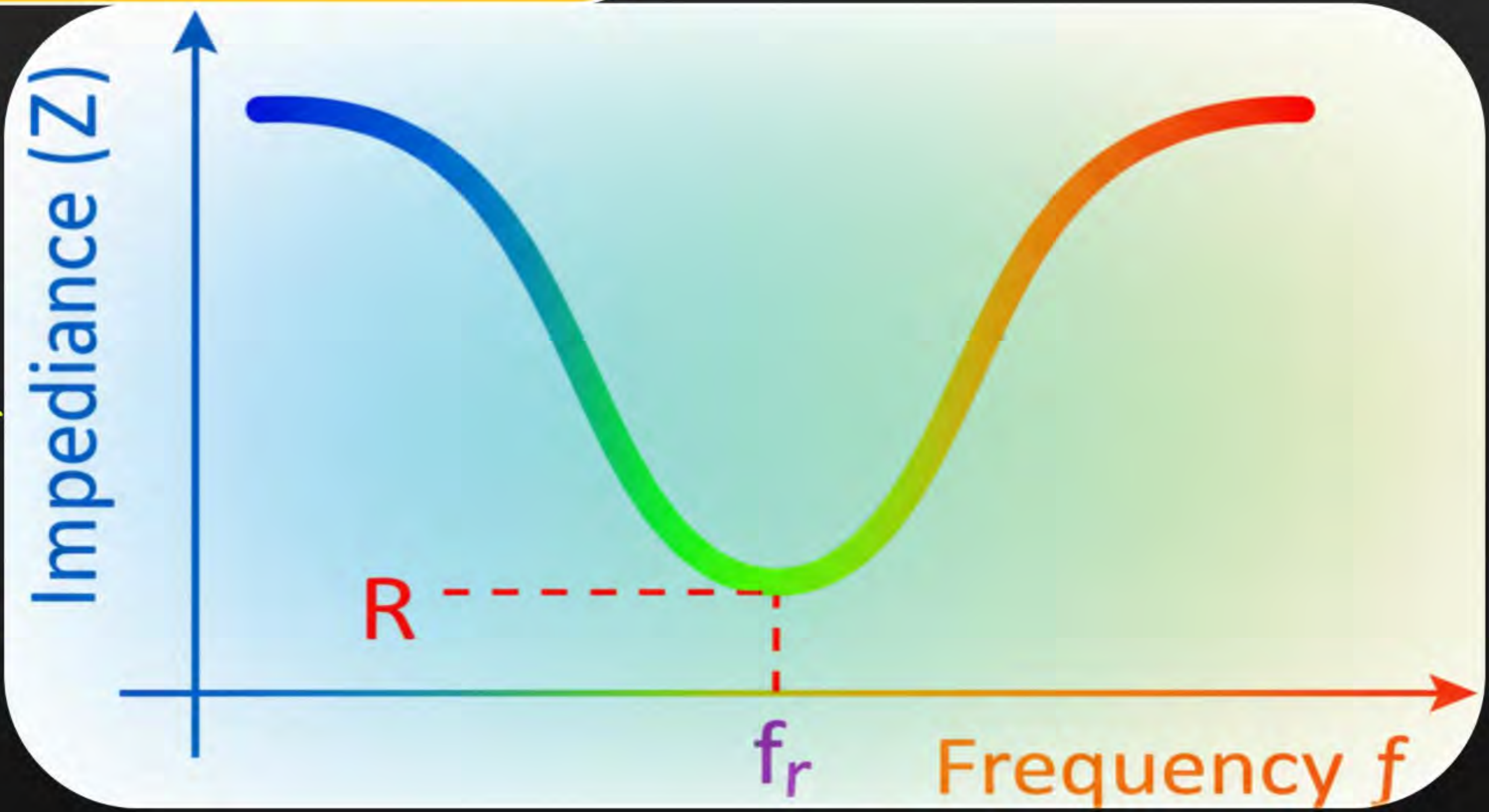
Series LCR Resonance Circuit

(c) Variation of 'Z' with 'f'

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

$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$

$Z = \sqrt{R^2 + \left(2\pi f L - \frac{1}{2\pi f C}\right)^2}$



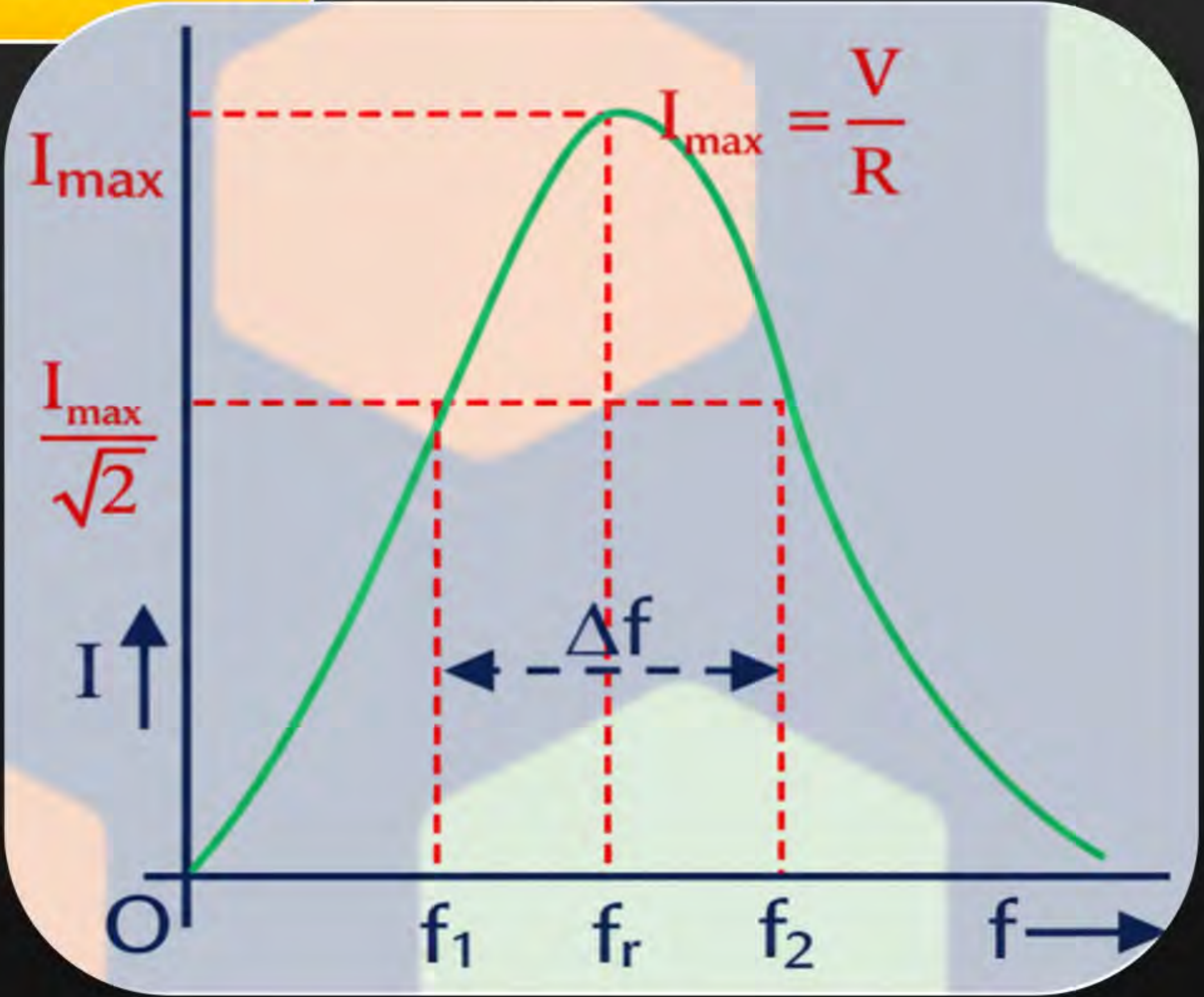
Series LCR Resonance Circuit

(d) Variation of 'I' with 'f'

as f increase, Z first decreases then increase
as f increase, I first increase then decreases

$$I = \frac{V}{Z}$$

$$Z = \sqrt{R^2 + \left(2\pi f L - \frac{1}{2\pi f C}\right)^2}$$



Question

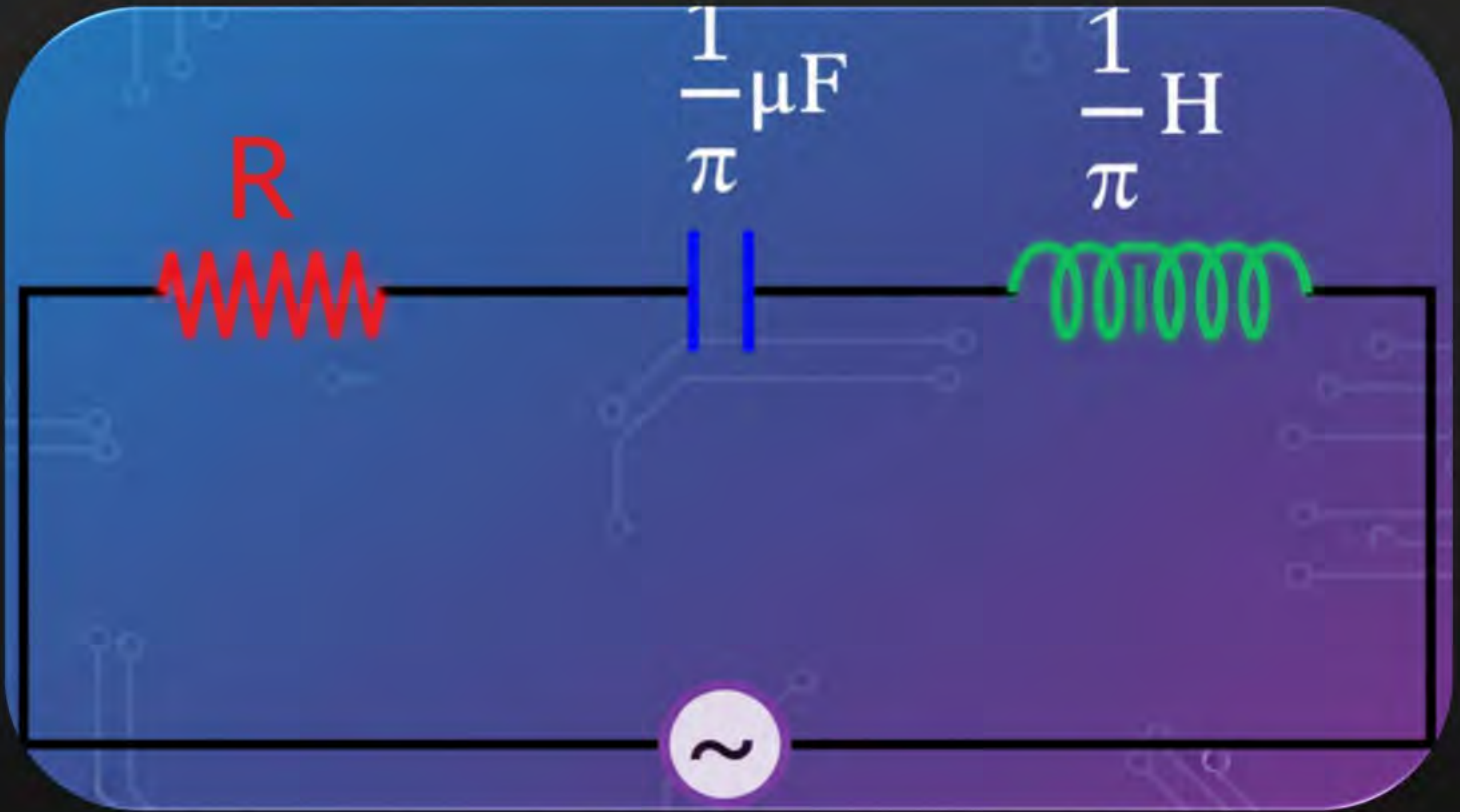
For what frequency the voltage across the resistance R will be maximum.

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$f = \frac{1}{2\pi\sqrt{\frac{1}{\pi} \times \frac{1}{\pi} \times 10^{-6}}}$$

$$f = \frac{1}{2\pi \times \frac{1}{\pi} \times 10^{-3}} = 0.5 \times 10^{3}$$

$$\boxed{f = 500\ Hz}$$



Question

P $\quad V \Rightarrow V_{rms}$

A light bulb is rated at 100W for a 220 V supply. Find

(a) the resistance of the bulb;

(b) the peak voltage of the source; and

(c) the rms current through the bulb.

(a) Resistance

$$P = \frac{V^2}{R}$$

$$R = \frac{V^2}{P} = \frac{(220)^2}{100}$$

$$\boxed{R = 484\,\Omega}$$

(b) $V_{rms} = \frac{V_0}{\sqrt{2}}$

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

$$V_0 = 1.414 \times 220$$

$$\boxed{V_0 = 311\,V}$$

(c) $I_{rms} = \frac{V_{rms}}{R}$

$$I_{rms} = \frac{220}{484}$$

$$\boxed{I_{rms} = 0.45\,A}$$

Question

In series $L - C - R$ circuit at resonance, the phase difference between voltage and current is

A. Zero

B. π

C. $\frac{\pi}{4}$

D. $\frac{\pi}{2}$

Question

A series resonant AC circuit contains a capacitance 10^{-6} F and an inductor of 10^{-4}H. The frequency of electrical oscillations will be

(A) 10 Hz

(B) $\frac{10^5}{2\pi}$ Hz

(C) $\frac{10}{2\pi}$ Hz

(D) 10^5 Hz

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$f = \frac{1}{2\pi\sqrt{10^{-4} \times 10^{-6}}} = \frac{1}{2\pi \times 10^{-5}}$$

$$f = \frac{10^5}{2\pi} \text{ Hz}$$

Question

In the given circuit, the resonant frequency is

(A) 15.92 Hz

(B) 159.2 Hz

(C) 1592 Hz

(D) 15910 Hz

$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14\sqrt{0.5 \times 10^{-3} \times 20 \times 10^{-6}}}$

$f = \frac{1}{6.28\sqrt{10^{-8}}} = \frac{1}{6.28 \times 10^{-4}}$

$f = 0.159235 \times 10^{4}$

$f = 1592.35\,Hz$

Question

In an $L-C-R$ circuit, at resonance

A. The current is minimum

B. The current and voltage are in phase

C. The current leads the voltage by $\frac{\pi}{2}$

D. The impedance is maximum

Power in AC

$P = IV = VI$

Power in ac-circuit

The rate of doing work or the amount of energy transferred by a circuit per unit time is known as power in AC circuits.

It is used to calculate the total power required to supply a load.

Types

1. Instantaneous power ✓
2. Average power ✓
3. RMS Power ✓

Average power

power factor.

$$\cos\phi = \frac{R}{Z}$$

$$P = V_{rms} I_{rms} \cos\phi$$ ✓

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

$$P = \frac{V_0 I_0}{2} \cdot \cos\phi$$

AC circuit

(i) $R \Rightarrow \phi = 0^\circ$ $\quad P = V_{rms} I_{rms} \neq 0$

(ii) $L \Rightarrow \phi = 90^\circ$, $\quad P = 0$

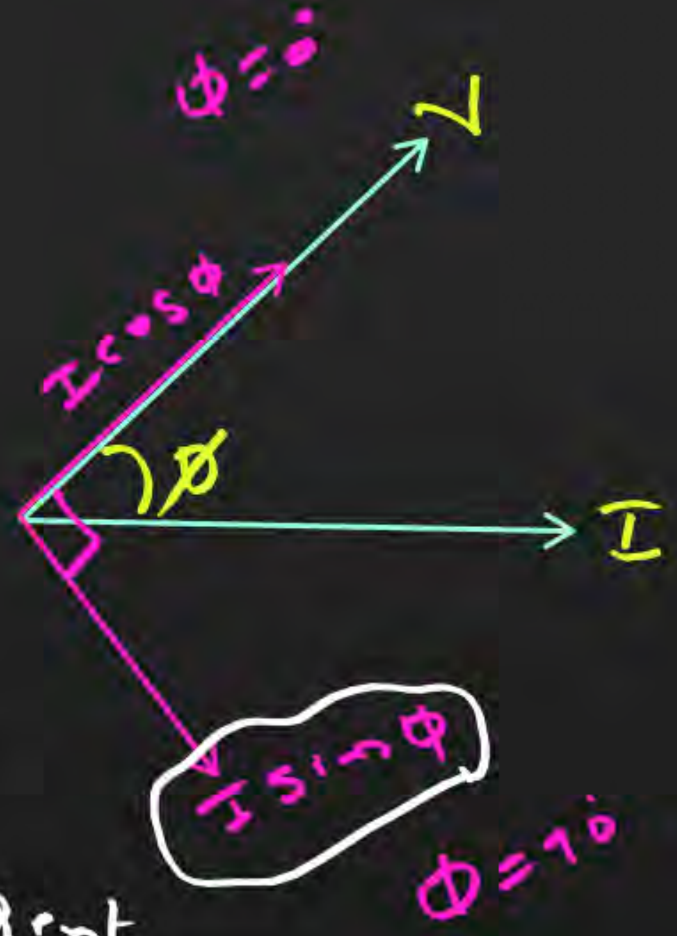
(iii) $C \Rightarrow \phi = 90^\circ$ $\quad P = 0$

RMS Power

$$P_{rms} = V_{rms} I_{rms}$$

$I\cos\phi \rightarrow$ watt current

$I\sin\phi \rightarrow$ wattless current



Wattless current : That component of current in ac-circuit which is not active.

Note : $Icos\emptyset$ is the activity component of current because it is in phase with applied voltage But $Isin\emptyset$ is the component which is inactive, called as wattless current because it is in $\frac{\pi}{2}$ phase with applied voltage

Power factor

$$\cos\phi = \frac{R}{Z}$$

1. Watt full Power: Average power is also known as watt full power

2. Wattless Power : That component of current in ac-circuit which is not active.

Question

$\cos\phi = \cos 0^\circ$
$= 1 \rightarrow$ unity

In an A.C. circuit V and I are given by V = 100 sin(100 t) V and I = 100 sin(100t + π/3) mA

Find power dissipated in the circuit ?

$\hookrightarrow P = \frac{V_0 I_0}{2} \cdot \cos\phi$

$\phi = \frac{\pi}{3} = 60^\circ$

$P = \frac{100 \times 100 \times 10^{-3}}{2} \times \cos 60^\circ$

$P = \frac{10}{2} \times \frac{1}{2} = \frac{5}{2}$

$P = 2.5\,W$

Question

A series R - L - C (R =10Ω, X_L= 20Ω, X_C = 20Ω) circuit is supplied by V=10 sinωt V. Find power dissipation in circuit.

$$I = \frac{V_0}{Z} = \frac{V_0}{R} = \frac{10}{10} = 1$$

$X_L = X_C \Rightarrow$ Resonant $\phi = 0°$

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

$$P = \frac{10 \times I_0}{2} \times \cos 0°$$

$$P = 5 I_0$$

$$P = 5 \times 1 = 5W$$

Question

In the series L-C-R circuit, the power dissipation is Through

(A) R

(B) L

(C) C

(D) Both L and C

Question

In an AC circuit, V and I are given by $V = 150\sin(150t)$ volt and $I = 150\sin\left(150t + \frac{\pi}{3}\right)$ amp. The power dissipated in the circuit is

$\phi = \frac{\pi}{3} = 60^\circ$

(A) 106 W

(B) 150 W

(C) 5625 W

(D) zero

$P = \frac{I_0 V_0}{2} \cdot \cos\phi$

$P = \frac{150 \times 150}{2} \times \cos 60^\circ$

$P = \frac{150 \times 150}{2 \times 2} = 5625 W$

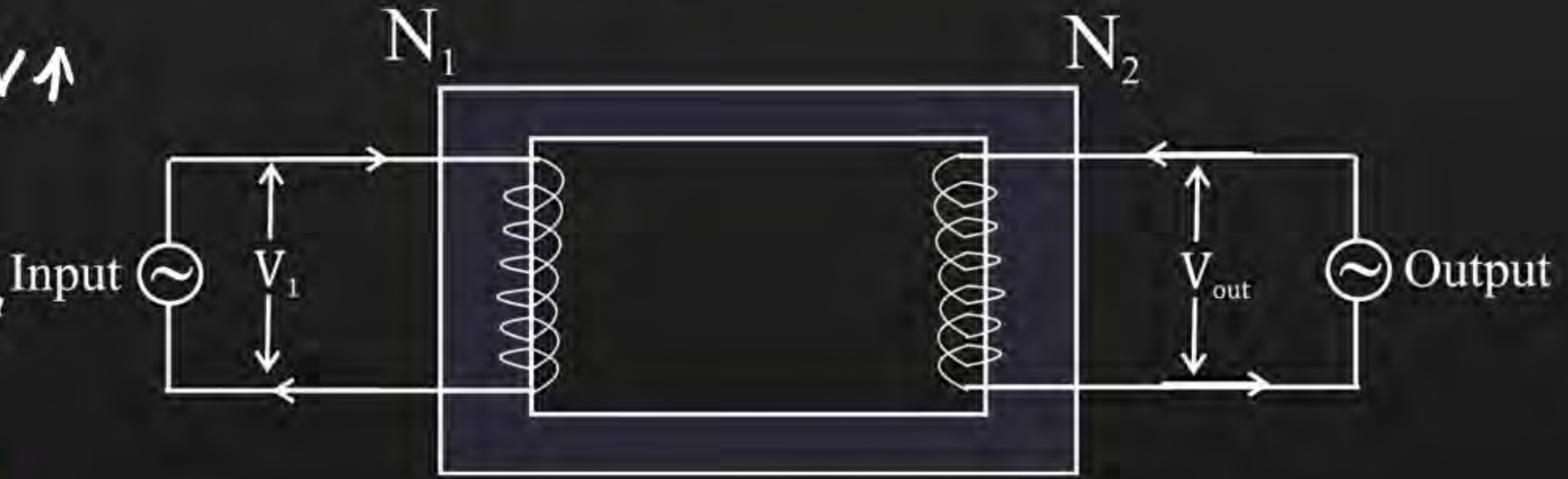
Transformers

Transformer - It is device to increase or decrease the AC voltage.

Types -

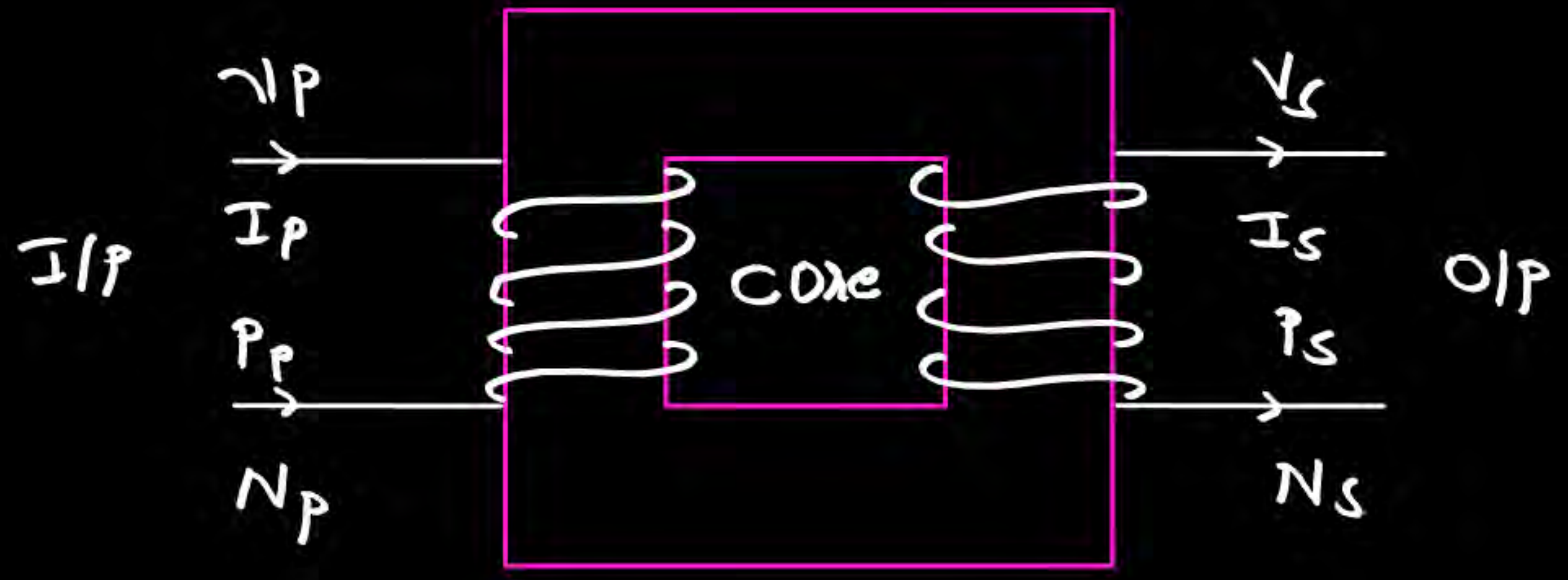
(i) Step up Tx => V↑

(ii) Step down Tx => V↓



Working Principle - Mutual Induction

It consist of two coils wound over soft iron core as shown in the figure. When current in the primary coil is changed the flux linked to the secondary coil also changes. Consequently, an emf is induced in the secondary coil due to Faraday law of EMI.



$\eta < 100\% \quad \eta < 1$

practical transformer

$$\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s} = \eta$$

$$\eta = \frac{P_o}{P_i} = \frac{P_s}{P_p}$$

$$P = VI$$

$$e = -N\frac{d\phi}{dt}$$

$$\frac{N_s}{N_p} = \frac{V_s}{V_s} = \frac{I_p}{I_s}$$

Ideal transformer.

$\eta = 100\%$

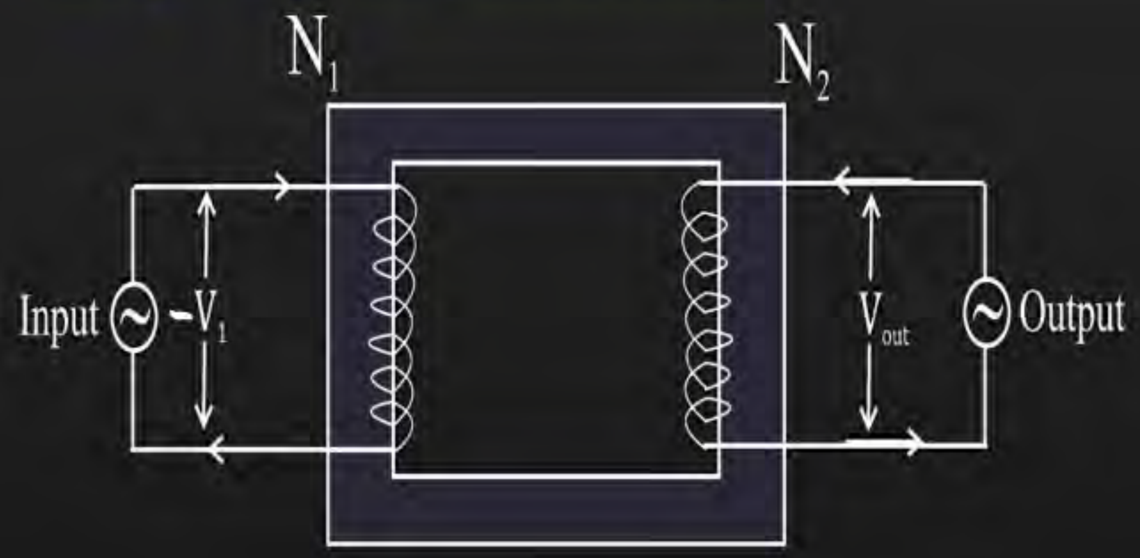
$\eta = 1$

$P_i = P_o$

$P_p = P_s$

Transformers

Step Up Transformer



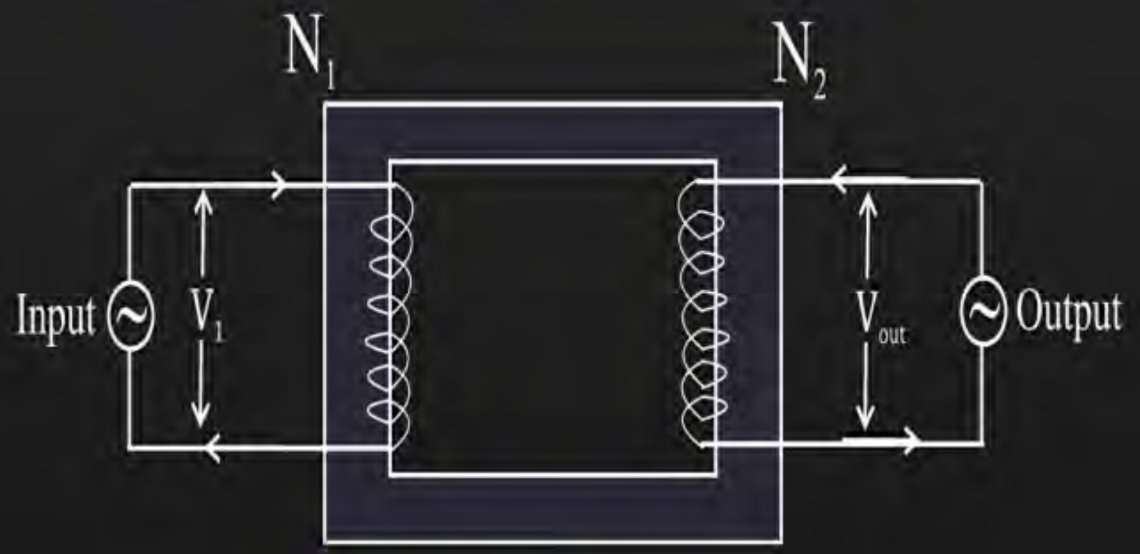
$V_s > V_p$

$N_s > N_p$

$I_p > I_s$

$\eta = \frac{N_s}{N_p} > 1$

Step down Transformer



$N_s < N_p$

$V_s < V_p$

$I_s > I_p$

$\eta = \frac{N_s}{N_p} < 1$

Energy loss in Transformers

(i) Flux Leakage: There is always some flux leakage; that is, not all of the flux due to primary passes through the secondary, It is due to poor design of the core or the air gaps in the core. It can be reduced by winding the primary and secondary coils one over the other.

(ii) Resistance of the windings: The wire used for the windings has some resistance and so, energy is lost due to heat produced in the wire (I^2R). In high current, low voltage windings, these are minimised by using thick wire. $R = \rho \frac{l}{A}$ $R \propto \frac{1}{A}$ $A\uparrow$ $R\downarrow$

(iii) Eddy currents: The alternating magnetic flux induces eddy currents in the iron core and causes heating. The effect is reduced by using a laminated core.

Question

An ideal transformer has a turns ratio of 10 . When the primary is connected to 220 V , 50 Hz as source, the power output is

(A) 10 times the power input

(B) $\frac{1}{10}$ th the power input

(C) equal to power input

(D) zero

Question

A step-up transformer operates on a 230 V line and a load current of 2 A. The ratio of primary and secondary windings is 1:25. Then, the current in the primary is

(A) 25 A

(B) 50 A

(C) 15 A

(D) 12.5 A

V_p, I_s, I_p

$$\frac{N_p}{N_s} = \frac{1}{25}$$

$$\frac{N_s}{N_p} = \frac{V_s}{V_p} = \frac{I_p}{I_s}$$

$$\frac{N_s}{N_p} = \frac{I_p}{I_s} \Rightarrow \frac{25}{1} = \frac{I_p}{2}$$

$$I_p = 50 A$$

Question

The output of a step down transformers is measured to be 48 V when connected to a 12 W bulb. The value of peak current is

A) $\frac{1}{\sqrt{2}} A$

B) $\sqrt{2}$ A

C) $\frac{1}{2\sqrt{2}} A$

D) $\frac{1}{4} A$

$V = 48V$

$P = 12W$

$P = IV$

$I = \frac{P}{V}$

$I_{rms} = \frac{12}{48} = \frac{1}{4} A$

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

$I_0 = \sqrt{2} \times I_{rms} = \sqrt{2} \times \frac{1}{4}$

$I_0 = \sqrt{\frac{2}{16}} = \frac{1}{\sqrt{8}} = \frac{1}{\sqrt{4 \times 2}} = \frac{1}{2\sqrt{2}}$

$I_0 = \frac{1}{2\sqrt{2}} A$

Question

A step down transformer has 50 turns on secondary and 1000 turns on primary winding. If a transformer is connected to 220 V, 1 A AC source, what is output current of the transformer

N_s N_p V_p I_p I_s

(A) $\frac{1}{20}A$

(B) $20\,A$

(C) $100\,A$

(D) $2\,A$

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

$$\frac{50}{1000} = \frac{1}{I_s}$$

$$I_s = 20\,A$$

Question

$\eta = \frac{N_S}{N_P} = 3$ $\quad \eta$

For a transformer, the turns ratio is 3 and its efficiency is 0.75. The current flowing in the primary coil is 2 A (I_P) and the voltage applied to it is 100 V (V_P). Then the voltage and the current flowing in the secondary coil are... Respectively

V_S, I_S

(A) 150 V, 1.5 A

(B) 300 V, 0.5 A

(C) 300 V, 1.5 A

(D) 150 V, 0.5 A

$$\eta = \frac{P_o}{P_i} = \frac{P_S}{P_P} = \frac{V_S I_S}{V_P I_P}$$

$$0.75 = \frac{V_S I_S}{100 \times 2}$$

$$75 \times 2 = V_S I_S$$

$$\boxed{V_S I_S = 150} \Rightarrow I_S = \frac{150}{300} = \frac{1}{2} = 0.5\,A$$

$$\frac{N_S}{N_P} = \frac{I_P}{I_S} = \frac{V_S}{V_P}$$

$$3 = \frac{V_S}{100} \Rightarrow V_S = 300\,V$$

Question

A transformer works on the principle of

(A) Self-induction

(B) Electrical inertia

(C) Mutual induction

(D) Magnetic effect of the electrical current

ELECTROMAGNETIC WAVES

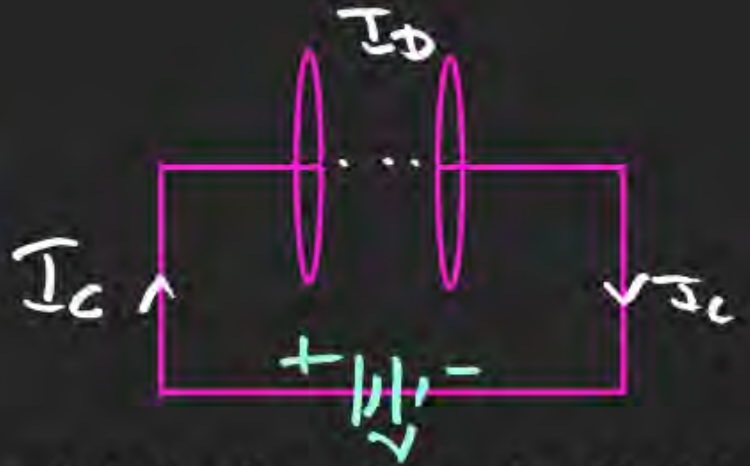
KCET analysis of chapter - Marks weightage

Year	Topic
2025 (1Q)	Wavelength range of EMWs
2024(1Q)	Force exerted by an electromagnetic wave
2023(1Q)	Ratio of Magnitude of Electric field and Magnetic field
2022(2Q)	Radiations deflected by Electric Field, Highest wavelength of EMW
2021(2Q)	Properties of EMW and Source of EMW

KCET analysis of chapter - Marks weightage

Year	Topic
2020(1Q)	Intensity and momentum
2019(2Q)	Direction of propagation of EMW and properties of EMW
2018	-
2017(1Q)	Direction of propagation of EMW
2016(2Q)	Uses of EM-Radiation and Magnetic field vector
2015	-

Displacement Current



$I_c = \frac{dq}{dt}$

The current which comes into existence in the region in which the electric field and the electric flux is changing with time is known as displacement current. It is expressed by

$$I_D = \varepsilon_0 \frac{d\phi_E}{dt}$$

$\oint \vec{B} \cdot d\vec{l} = \mu_0 I = 0$

$B = 0 \Rightarrow$ No defl

Where ϕ_E is the electric flux and I_D is the displacement current.

Need for Displacement Current

Ampere's circuital law for conduction current during charging of a capacitor was found inconsistent. Therefore, Maxwell modified Ampere's circuital law by introducing the concept of displacement current.

Maxwell's Equation

1. $\oint \vec{E} \cdot \overrightarrow{ds} = \frac{q_{in}}{\epsilon_0}$ - Guass Law of Electrostatics

2. $\oint \vec{B} \cdot \overrightarrow{ds} = 0$ - Gauss Law of Magnetism

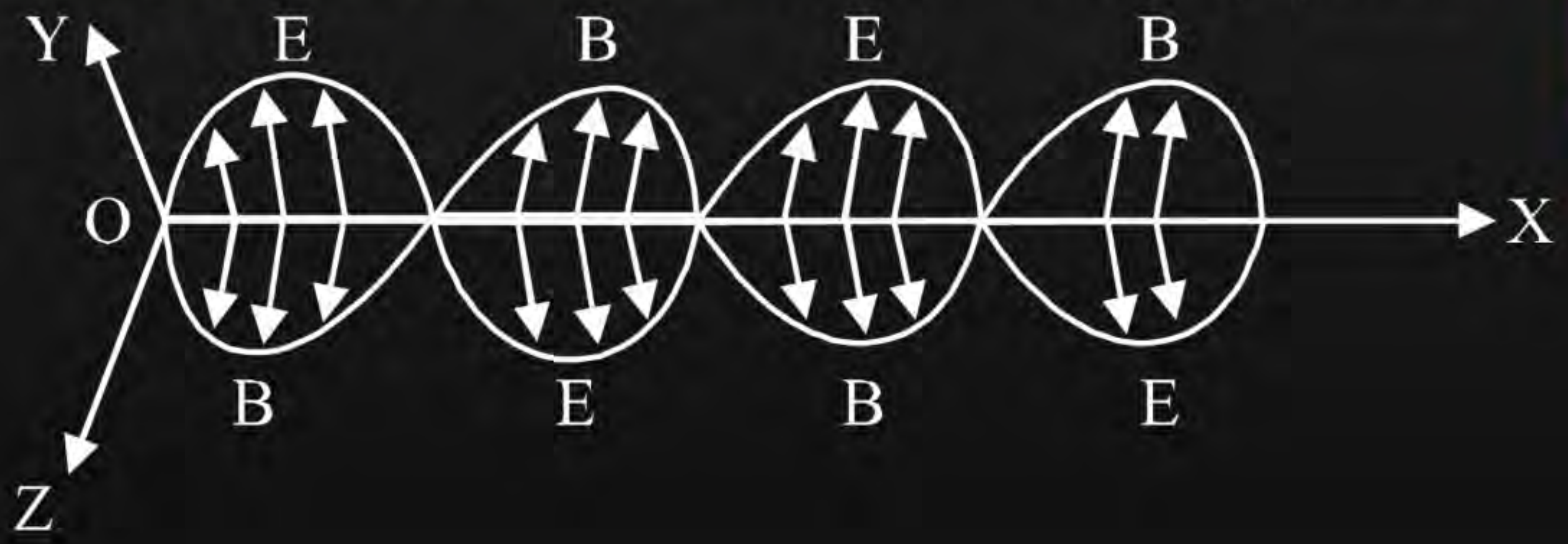
3. $\int \vec{E}\,\overrightarrow{dl} = -\frac{d\emptyset_B}{dt}$ - Faraday and Lenz's law

4. $\oint \vec{B} \cdot \overrightarrow{dl} = \mu_0 \left(i_C + \varepsilon_0 \frac{d\phi_E}{dt} \right)$ - Modified Maxwell's - Ampere's Circuital law

Electromagnetic Waves

An electromagnetic wave is a wave radiated by an accelerated or oscillatory charge in which varying magnetic field is the source of electric field and varying electric field is the source of magnetic field. Thus, two fields become source of each other and the wave propagates sinusoidally in a direction perpendicular to both the fields.

Electromagnetic waves are transverse in nature, i.e. electric and magnetic fields are perpendicular to each other and also perpendicular to the direction of wave propagation.



$$\vec{E} \times \vec{B} = \vec{c} = \vec{V}$$

$$\vec{E} \perp \vec{B} \perp \vec{V} \perp$$

Relation between magnitudes of $\vec{E}$ & $\vec{B}$ in a Free space

$\frac{E}{B} = C$ → Free space

$\frac{E_0}{B_0} = C$

$\frac{E}{B} = V$ → medium

$\frac{E_0}{B_0} = V$

Important Characteristics of EMW's

(i) The electromagnetic waves are produced by accelerated charge.

(ii) These waves do not require any material medium for propagation.

(iii) These waves travel in free space with the speed of light ($3.0 \times 10^8\ ms^{-1}$,()given by the relation

$$c = 1/\sqrt{\mu_0 \epsilon_0}$$

Light waves are electromagnetic.

(iv) The directions of variations of electric and magnetic fields are perpendicular to each other and also perpendicular to the direction of propagation. Thus, electromagnetic waves are transverse in nature.

(v) The variations in electric and magnetic fields occur simultaneously and the fields acquire their maximum values E_0 and B_0 at the same place and at the same time.

Electromagnetic Spectrum

* **Trick:** Raya's Mother Is Visiting Uncle Xovin Garden

λ_{max} →

R	M	I	V	U	X	G
↓	↓	↓	↓	↓	↓	↓
Radio	Micro	IR	Vissible	UV-rays	X-Ray	Gamma rays

λ_{min} (at the Gamma rays end)

f_{min} ← f_{max}

Question

The ratio of the magnitudes of electric field to the magnetic field of an electromagnetic wave is of the order of

$\frac{E}{B} = c = 3 \times 10^8$ m/s → Free space → c ✓

(A) $10^{-8}\ ms^{-1}$

(B) $10^{5}\ ms^{-1}$

(C) $10^{-5}\ ms^{-1}$

(D) $10^{8}\ ms^{-1}$

Question

Which of the following radiations is deflected by electric field?

All EMWs → Electrically Neutral

(A) Neutrons ✗

(B) γ-rays ✗

(C) α-particles ✓

(D) X-rays ✗

Question

Which of the following radiations of electromagnetic waves has the highest wavelength?

A. UV-rays

B. IR-rays

C. Microwaves

D. X-rays

Question

The source of electromagnetic wave can be a charge

(A) moving with a constant velocity

(B) moving in a circular orbit

(C) at rest

(D) moving parallel to the magnetic field

Question

An electromagnetic wave is travelling in x-direction with electric field vector given by, $E_y = E_0 \sin(kx - \omega t)j$. The correct expression for magnetic for magnetic field vector is

(A) $B_y = E_0 C \sin(kx - \omega t)\hat{j}$ ✗

(B) $B_y = E_0 C \sin(kx - \omega t)\hat{k}$

(C) $B_y = \dfrac{E_0}{C} \sin(kx - \omega t)\hat{j}$ ✗

(D) $B_y = \dfrac{E_0}{C} \sin(kx - \omega t)\hat{k}$

$\vec{E} \times \vec{B} = \vec{C} = \vec{V}$

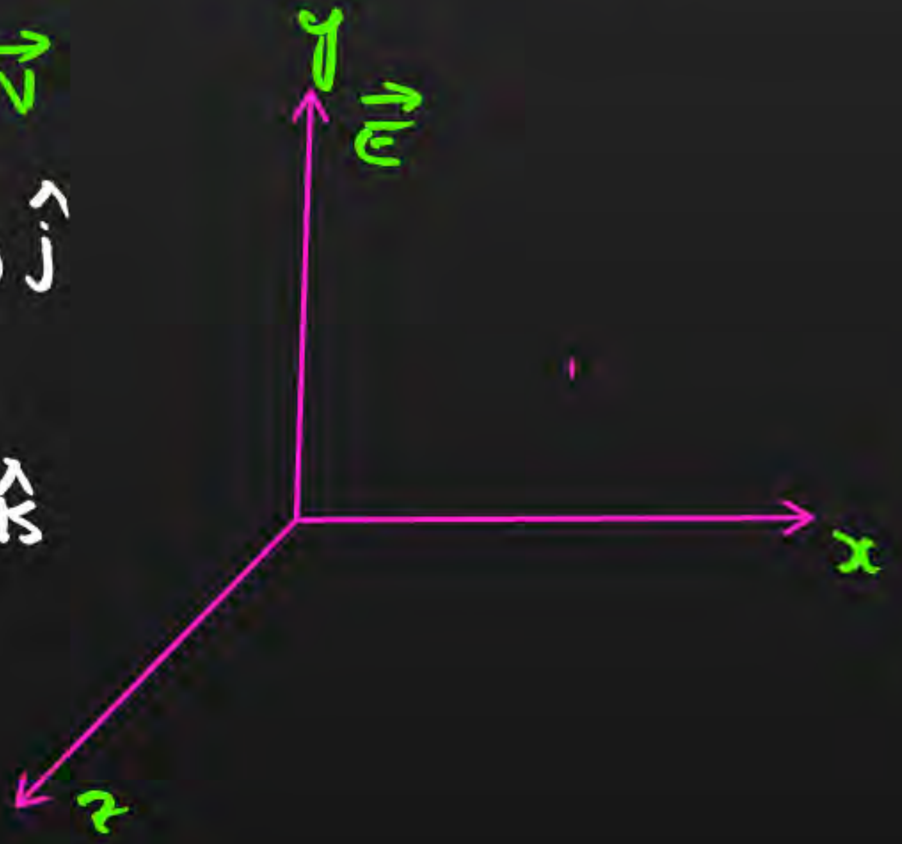
$\vec{E}_y = E_0 \sin(kx - \omega t)\hat{j}$

$\vec{B}_y = B_0 \sin(kx - \omega t)\hat{k}$

$E_0 = B_0 C$

$B_0 = \dfrac{E_0}{C}$

$\vec{B}_y = \dfrac{E_0}{C} \sin(kx - \omega t)\hat{k}$



Question

If E and B represent electric and magnetic field vectors of an electromagnetic wave, the direction of propagation of the wave is along

(A) $E \times B$

(B) $B \times E$

(C) E

(D) B

Question

Electromagnetic radiation used to sterilize milk is

A. X-rays

B. γ-rays

C. UV rays

D. Radio waves

Question

A plane electromagnetic wave of frequency 20 MHz travels through a space along x-direction. If the electric field vector at a certain point in space is 6 Vm^{-1}, what is the magnetic field vector at that point?

$\frac{E_0}{B_0} = c$

(A) 2×10^{-8}T

(B) $1/2 \times 10^{-8}$T

(C) T

(D) 1/2T

Question

X-rays, gamma rays and microwaves travelling in vacuum have

(A) same velocity and same frequency

(B) same wavelengths but different velocities

(C) same frequency but different velocities

(D) same velocity but different wavelengths

Question

The speed of electromagnetic wave in vacuum depends upon the source of radiation

A. increases as we move from y -rays to radio waves

B. decreases as we move from y-rays to radio waves

C. is same for all of them

D. None of the above

Question

If μ_0 is permeability of free space and ε_0 is permittivity of free space, the speed of light in vacuum is given by

(A) $\sqrt{\mu_0 \varepsilon_0}$

(B) $\sqrt{\mu_0/\varepsilon_0}$

(C) $\sqrt{1/\mu_0 \varepsilon_0}$

(D) $\sqrt{\varepsilon_0/\mu_0}$

Question

All components of the electromagnetic spectrum in vacuum have the same

$E = h\nu = hf$

(A) energy

(B) velocity

(C) wavelength

(D) frequency

Thank

You