

New

SURE SHOT QUESTIONS 2026

Chapter – 07 (Questions)

Alternating Current

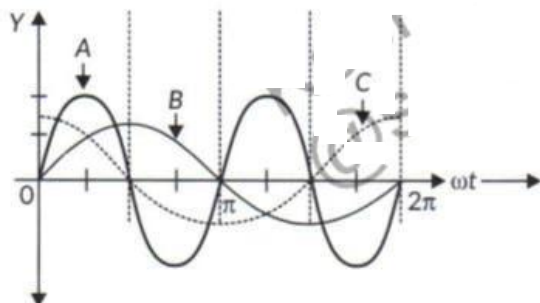
Questions

1. A device X is connected across an ac source of voltage $V = V_0 \sin \omega t$. The current through X is

$$i = i_0 \sin \left(\omega t + \frac{\pi}{2} \right).$$

- Identify the device X and write the expression for its reactance.
- Draw graphs showing variation of voltage and current with time over one cycle of ac, for X.
- How does the reactance of the device X vary with frequency of the ac? Show this variation graphically.
- Draw the phasor diagram for the device X.

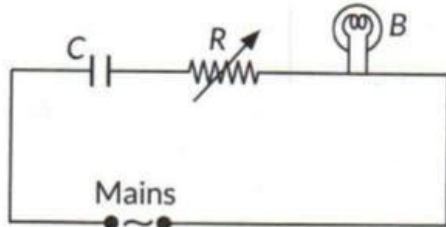
2. A device 'X' is connected to an ac source $V = V_0 \sin \omega t$. The variation of voltage, current and power in one cycle is shown in the following graph:



- Identify the device 'X'.
 - Which of the curves A, B and C represent the voltage, current and the power consumed in the circuit? Justify your answer.
 - How does its impedance vary with frequency of the ac source? Show graphically.
 - Obtain an expression for the current in the circuit and its phase relation with ac voltage.
3. (a) In a series LCR circuit connected across an ac source of variable frequency, obtain the expression for its impedance and draw a plot showing its variation with frequency of the ac source.
(b) What is the phase difference between the voltages across inductor and the capacitor at resonance in the LCR circuit?
- (c) When an inductor is connected to a 200 V dc voltage, a current of 1A flows through it. When the same inductor is connected to a 200 V, 50 Hz ac source, only 0.5 A current flows. Explain, why? Also, calculate the self inductance of the inductor.
4. With the help of a labelled diagram, explain the working of a step – up transformer. Give reasons to explain the following:
(i) The core of the transformer is laminated.
(ii) Thick copper wire is used in windings.
5. (a) Draw the diagram of a device which is used to decrease high ac voltage into a low ac voltage and state its working principle. Write four sources of energy loss in this device.
(b) A small town with a demand of 1200 kW of electric power at 220 V is situated 20 km away from an electric plant generating power at 440 V. The resistance of the two wire line carrying power is 0.5Ω per km. The town gets the power from the line through a 4000 – 220 V step – down transformer at a substation in the town. Estimate the line power loss in the form of heat.
6. Distinguish between reactance and impedance of an ac circuit. Show that an ideal inductor in an ac circuit does not dissipate any power.
7. A resistor of 30Ω and a capacitor of $\frac{250}{\pi} \mu F$ are connected in series to a 200 V, 50 Hz ac source. Calculate (i) the current in the circuit, and (ii) voltage drops across the resistor and the capacitor. (iii) Is the algebraic sum of these voltages more than the source voltage? If yes, solve the paradox.
8. An ac source of emf $V = V_0 \sin \omega t$ is connected to a capacitor of capacitance C. Deduce the expression for the current (I) flowing in it. Plot the graph of (i) V vs ωt , and (ii) I vs ωt .
- OR

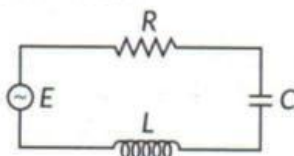
Show that the current leads the voltage in phase by $\pi/2$ in an ac circuit containing an ideal capacitor.

9. A capacitor 'C', a variable resistor 'R' and a bulb 'B' are connected in series to the ac mains in circuit as shown. The bulb glows with some brightness.



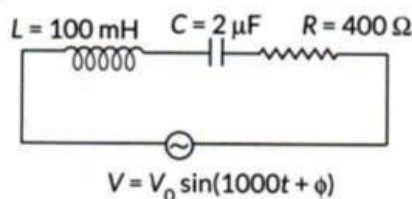
How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same; (ii) the resistance R is increased keeping the same capacitance?

10. The figure shows a series LCR circuit connected to a variable frequency 200 V source with $L = 50 \text{ mH}$, $C = 80 \mu\text{F}$ and $R = 40 \Omega$.



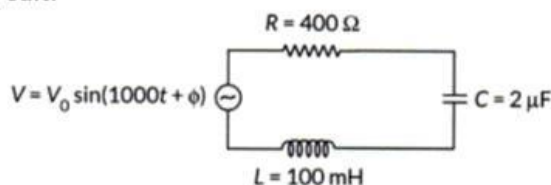
Determine

- The source frequency which drives the circuit in resonance.
 - The quality factor (Q) of the circuit.
11. Find the value of the phase difference between the current and the voltage in the series LCR circuit shown below. Which one leads in phase: current or voltage?



OR

Determine the value of phase difference between the current and the voltage in the given series LCR circuit.



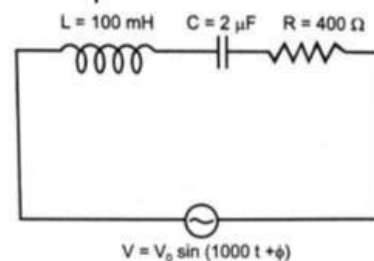
12. A lamp is connected in series with a capacitor. Predict your observation when this combination is connected in turn across
- ac source and
 - a dc battery. What change would you notice in each case if the capacitance of the capacitor is increased?

13. When an inductor is connected to 200 V dc voltage, a current of 1 A flows through it. When the same inductor is connected to a 200 V, 50 Hz ac source, only 0.5 A current flows. Explain, why? Also, calculate the self inductance of the inductor.

14. A small town with a demand of 1200 kW of electric power at 220V is situated 20 km away from an electric plant generating power at 440 V. the resistance of the two wire line carrying power is 0.5Ω per km. the town gets the power from the line through a 4000-220 V step-down transformer at a sub-station in the town. Estimate the line power loss in the form of heat.

15. A device X is connected across an ac source of voltage $V = V_0 \sin \omega t$. The current through X is given as $I = I_0 \sin \left(\omega t + \frac{\pi}{2} \right)$
- Identify the device X and write the expression for its reactance.
 - Draw graphs showing variation of voltage and current with time over one cycle of ac, for X.
 - How does the reactance of the device X vary with frequency of the ac? Show this variation graphically.
 - Draw the phasor diagram for the device X.

16. (a) Find the value of the phase difference between the current and the voltage in the series LCR circuit shown below. Which one leads in phase: current or voltage?
- (b) Without making any other change, find the value of the additional capacitor C_1 , to be connected in parallel with capacitor C, in order to make the power factor of the circuit unity.



17. The power factor of an ac circuit is 0.5. What is the phase difference between voltage and current in the circuit?

18. Define rms value of AC & derive an expression for it.

19. Why is the use of ac voltage preferred over dc voltage? Give two reasons.

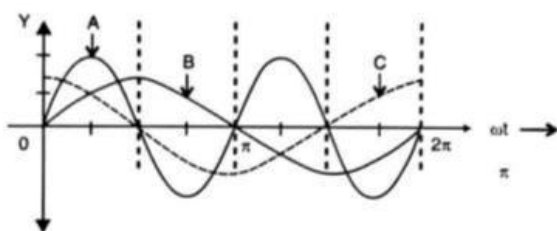
20. Show that the current leads the voltage in phase by $\pi/2$ in an a.c. circuit containing an ideal capacitor & also show that the average power supplied by the source over a complete cycle is Zero in this circuit.

21. (i) Prove that current flowing through an ideal inductor connected across ac source, lags the voltage in phase by $\frac{\pi}{2}$.

(ii) An inductor of self-inductance 100mH and a bulb are connected in series with ac source of rms voltage 10 V, 50Hz. It is found that effective voltage of the circuit leads the current in phase by $\frac{\pi}{4}$. Calculate the inductance of the inductor used and average power dissipated in the circuit, if a current of 1A flows in the circuit.

22. Obtain the expression for the energy density of magnetic field B produced in the inductor.

23. A device 'X' is connected to an ac source $V = V_m \sin \omega t$. The variation of voltage, current and power in one cycle is shown in the following graph:

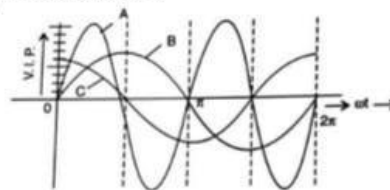


- identify the device 'X'.
- Which of the curves A, B and C represent the voltage, current and the power consumed in the circuit? Justify your answer.
- How does its impedance vary with frequency of the ac source? Show graphically.
- Obtain an expression for the current in the circuit and its phase relation with ac voltage.

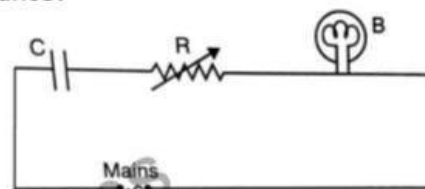
24. A device 'X' is connected to an ac source $V = V_0 \sin \omega t$. The variation of voltage, current and power in

one complete cycle is shown in the following figure.

- Which curve shows power consumption over a full cycle?
- Identify the device 'X'



25. A capacitor 'C', a variable resistor 'R' and a bulb 'B' are connected in series to the ac mains in circuit as shown. The bulb glows with some brightness. How will the glow of the bulb change if (i) a dielectric slab is introduced between the plates of the capacitor, keeping resistance R to be the same; (ii) the resistor R is increased keeping the same capacitance?



26. A 200 mH (pure) inductor and a $5 \mu F$ (pure) capacitor are connected one by one, across a sinusoidal ac voltage source of $V = [70.7 \sin(1000t)]$ voltage. Obtain the expressions for the current in each case.

27. An ac voltage $V = V_m \sin \omega t$ is applied to a series LCR circuit. Obtain an expression for the current in the circuit and voltage. What is resonance frequency?

28. An ac source of voltage $V = V_0 \sin \omega t$ is connected to a series combination of L, C and R. Use the phasor diagram to obtain expressions for impedance of the circuit and phase angle between voltage and current. Find the condition when current will be in phase with the voltage. What is the circuit in this condition called?

(ii) In a series LR circuit $X_L = R$ and power factor of the circuit is P_1 . When capacitor with capacitance C such that $X_L = X_C$ is put in series, the power factor becomes P_2 . Calculate $\frac{P_1}{P_2}$

29. (i) Describe, with the help of a suitable diagram, the working principle of a step-up transformer. Obtain the relation between input and output voltages in terms of the number of turns of primary and secondary windings and the currents in the input and output circuits.

(ii) Given the input current 15 A and the input voltage of 100 V for a step-up transformer having 90% efficiency, find the output power and the voltage in the secondary if the output current is 3 A.

30. You are given three circuit elements X, Y and Z. When the element X is connected across an *a.c.* source of a given voltage, the current and the voltage are in the same phase. When the element Y is connected in series with X across the source,

Voltage is ahead of the current in phase by $\frac{\pi}{4}$. But the current is ahead of the voltage in phase by $\frac{\pi}{4}$ when Z is connected in series with X across the source. Identify the circuit elements X, Y and Z.

When all the three elements are connected in series across the same source, determine the impedance of the circuit.

Draw a plot of the circuit versus the frequency of applied source and mention the significance of this plot

New

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Chapter – 07 (Solutions)

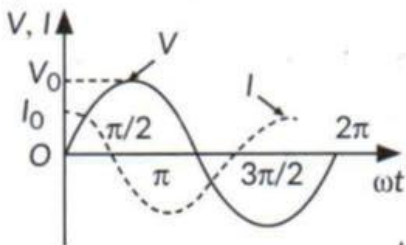
Alternating Current

Solutions

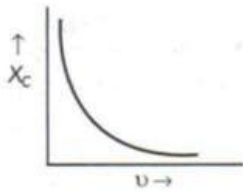
1. Ans. (a) Here device X is a capacitor.

Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi\nu C}$

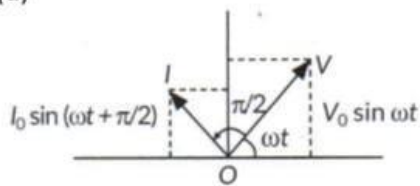
(b) In pure capacitive circuit current leads voltage by $\frac{\pi}{2}$.



(c) The capacitive reactance varies inversely with the frequency. As ν increases, X decreases. Graph shows the variation of X_C with ν .



(d)



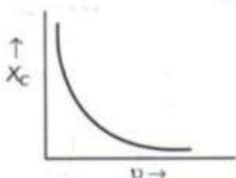
2. Ans. (a) Device X is a capacitor.

(b) B → Voltage (Because it is sine wave)

C → Current (Because current leads voltage by $\pi/2$)

A → Power (Average power over one cycle is zero)

(c) The capacitive reactance varies inversely with the frequency. As ν increases, X decreases. Graph shows the variation of X_C with ν .



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

$$C = \frac{q}{V}$$

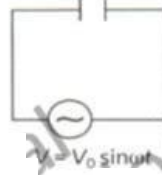
$$q = CV_0 \sin \omega t$$

$$i = \frac{dq}{dt} = \frac{d}{dt}(CV_0 \sin \omega t)$$

$$= \omega CV_0 \cos \omega t$$

$$= \frac{V_0}{\frac{1}{\omega C}} \cos \omega t$$

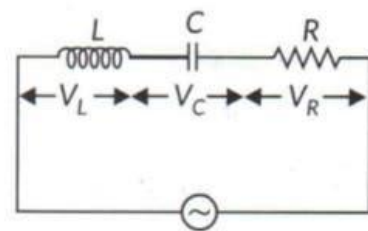
$$i = \frac{V_0}{X_C} \sin \left(\omega t + \frac{\pi}{2} \right) \text{ or } i = i_0 \sin \left(\omega t + \frac{\pi}{2} \right)$$



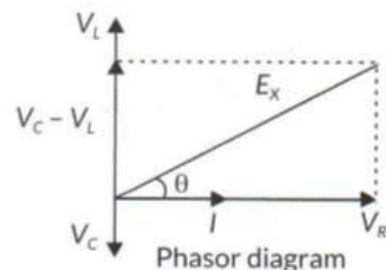
In pure capacitive circuit current leads voltage by $\frac{\pi}{2}$.

3. Ans. (a) AC circuit containing inductor, capacitor and resistor in series [Series LCR circuit]

If I is the current in the circuit containing inductor of inductance L , capacitor of capacitance C and resistor of resistance R in series, then the voltage drop across the inductor is $V_L = I \times X_L$



Which leads current I by phase angle of $\pi/2$, and voltage drop across the capacitor is $V_C = I \times X_C$



Which lags behind current I by phase angle of $\pi/2$, and voltage drop across the resistor is $V_R = IR$

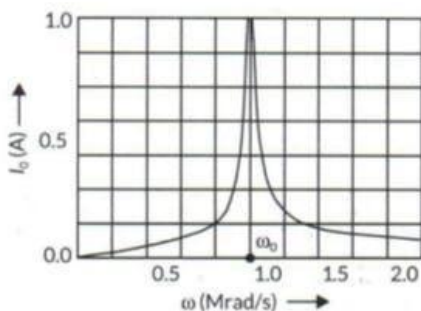
Which is in phase with current I . So the net voltage E , across the circuit is

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

$$\text{or } E = I\sqrt{R^2 + (X_L - X_C)^2} \text{ or } E = IZ$$

Where Z is the effective resistance offered by ac circuit containing inductor, capacitor and resistor in series, known as impedance in series LCR circuit. Hence in series LCR circuit, phase difference ϕ between the current I and the voltage E is

$$\tan\phi = \frac{X_L - X_C}{R} = \frac{\omega L - \frac{1}{\omega C}}{R}$$



With increase in ω , current first increases (upto ω_0) and then decreases.

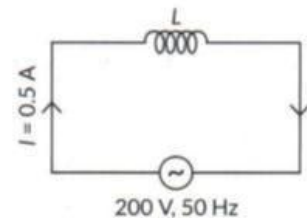
(b) At resonance, $X_L = X_C$

$$\therefore \tan\phi = \frac{X_L - X_C}{R} = 0$$

$$\therefore \phi = 0^\circ$$

\therefore There is no phase difference between voltage across inductor and capacitor at resonance in the LCR circuit.

(b) Whenever an inductor is connected to an a.c. source then it produces inductive reactance as impedance, that reduces the amount of current flowing through it. When inductor is connected flow in a circuit is 1 A and when in same inductor is connected to a.c. source, current will be reduced so, we can say that power consumption is more in case of d.c. circuit.



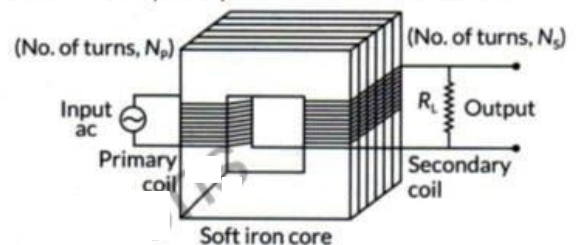
Here, $I = 0.5A$, $V = 200V$, $\nu = 50Hz$

\therefore Inductive reactance, $X_L = \omega L = 2\pi\nu L$

$$\text{Also, } I = \frac{V}{X_L} \text{ or } 0.5 = \frac{200}{2 \times 3.14 \times 50 \times L}$$

$$\Rightarrow L = \frac{200}{0.5 \times 2 \times 3.14 \times 50} = 1.27H$$

4. Ans. Step - up transformer (or transformer) is based on the principle of mutual induction.



An alternating potential (V_p) when applied to the primary coil induced an emf in it.

$$\varepsilon_p = -N_p \frac{d\phi}{dt}$$

If resistance of primary coil is low $V_p = \varepsilon_p$.

$$V_p = -N_p \frac{d\phi}{dt}$$

i.e.,

as same flux is linked with the secondary coil with the help of soft iron core due to mutual induction, emf is induced in it.

$$\varepsilon_s = -N_s \frac{d\phi}{dt}$$

If output circuit is open $V_s = \varepsilon_s$

$$V_s = -N_s \frac{d\phi}{dt}$$

$$\text{Thus } \frac{V_s}{V_p} = \frac{N_s}{N_p}$$

For an ideal transformer, $P_{out} = P_{in}$

$$\Rightarrow I_s V_s = I_p V_p$$

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

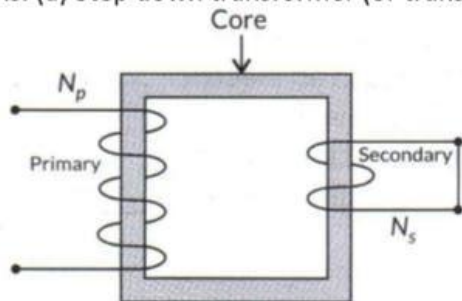
For step - up transformer, $\frac{N_s}{N_p} > 1$

In case of dc voltage, flux does not change. Thus no emf is induced in the circuit.

(i) The core of the transformer is laminated to reduce eddy current losses.

(ii) Thick copper wire is used in winding of transformers because of its low resistivity i.e., low resistance.

5. Ans. (a) Step down transformer (or transformer):



Principle: When the current flowing through the primary coil changes, an emf is induced in the secondary coil due to the change in magnetic flux linked with it i.e., it works on the principle of mutual induction.

There are number of energy losses in a transformer,

- (i) Copper losses due to Joule's heating produced across the resistances of primary and secondary coils. It can be reduced by using copper wires.
- (ii) Hysteresis losses due to repeated magnetization and demagnetization of the core of transformer. It is minimized by using soft iron core, as area of hysteresis loop for soft iron is small and hence energy loss also becomes small,
- (iii) Iron losses due to eddy currents produced in soft iron core. It is minimized by using laminated iron core.
- (iv) Flux losses due to flux leakage or incomplete flux linkage and can be minimised by proper coupling of primary and secondary coils.

(b) Power required, $P = 1200 \text{ kW} = 1200 \times 10^3 \text{ W}$

Total resistance of two wire lines,

$$R = 2 \times 20 \times 0.5 = 20 \Omega$$

$$E_v = 4000 \text{ volt}$$

$$\text{As, } P = E_v I_v \therefore 1200 \times 10^3 = 4000 \times I_v$$

$$\Rightarrow I_v = \frac{1200 \times 10^3}{4000} = 300 \text{ A}$$

Where I_v is the rms value of current.

Line power loss in the form of heat is,

$$= (I_p)^2 \times \text{Resistance of wire line}$$

$$= (300)^2 \times 20 = 1800 \text{ kW}$$

6. Ans. Reactance : The non-resistive opposition to the flow of current is called reactance. It may be inductive or capacitive.

Inductive reactance, $X_L = \omega L = 2\pi fL$

$$\text{Capacitive reactance, } X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC}$$

Its SI unit is ohm (Ω).

Impedance : It is the effective resistance of an ac circuit containing any two or all the three elements, resistor (R), inductor (L) and capacitor (C). It plays same role in AC circuit as resistance plays in dc circuit.

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

Its S.I. unit is also ohm (Ω).

$$\text{As } P_{av} = V_{rms} I_{rms} \cos \phi$$

In ideal inductor, current I_{rms} lags behind applied voltage V_{rms} by $\pi/2$.

$$\text{So, } P_{av} = V_{rms} I_{rms} \cos \pi/2 \quad (\because \phi = \pi/2)$$

$$\text{or } P_{av} = V_{rms} I_{rms} \times 0 \text{ or } P_{av} = 0.$$

7. Ans. (i) In R-C circuit, $V = IZ$, where 'V' is voltage, I is current and Z is impedance.

$$Z = \sqrt{R^2 + X_C^2}$$

Here, X_C is capacitive reactance

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

$$v = 50 \text{ Hz, } C = \frac{250}{\pi} \mu\text{F}$$

As frequency,

$$X_C = \frac{10^6}{2\pi \times 50 \times \frac{250}{\pi}} = 40 \Omega$$

Then,

$$Z = \sqrt{(30)^2 + (40)^2} = \sqrt{900 + 1600} = 50 \Omega$$

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

As,

$$I = \frac{200 \text{ V}}{50 \Omega} = 4 \text{ A}$$

(ii) Voltage drop across the resistor = $IR = 4 \times 30 = 120 \text{ V}$

Voltage drop across the capacitor = $IX_C = 4 \times 40 = 160 \text{ V}$

(iii) Total voltage drop = $120 + 160 = 280 \text{ V}$

120 V and 160 V are rms value of voltage and the sum of both i.e., 280 V is smaller than the source peak voltage.

8. Ans. $V = V_0 \sin \omega t, C = \frac{q}{V}$

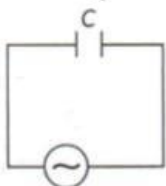
$$q = CV_0 \sin \omega t, i = \frac{dq}{dt} = \frac{d}{dt}(CV_0 \sin \omega t)$$

$$= \omega CV_0 \cos \omega t$$

$$= \frac{V_0}{\frac{1}{\omega C}} \cos \omega t$$

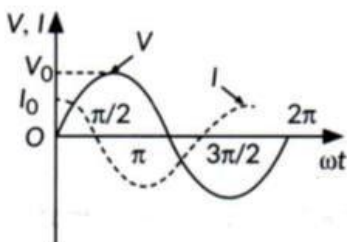
$$i = \frac{V_0}{X_C} \sin\left(\omega t + \frac{\pi}{2}\right)$$

$$\text{or } i = i_0 \sin\left(\omega t + \frac{\pi}{2}\right)$$



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

In pure capacitive circuit current leads voltage by $\frac{\pi}{2}$.



9. Ans. For the RC circuit,

$$\text{Impedance, } Z = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$

$$\text{Current, } I = \frac{\mathcal{E}_0}{Z} \dots\dots\dots(i)$$

(i) When a dielectric slab is introduced between the plates of the capacitor, then its capacitance increases. Hence, from equation (i), impedance of the circuit is decreased and the current through it is increased. So, brightness of the bulb will increase.

(ii) When the resistance R is increased and capacitance is same, then from equation (i), impedance of the circuit is increased and the current flowing through it is decreased. So, brightness of the bulb will decrease.

10. Ans. (i) $L = 50 \times 10^{-3} \text{ H}, C = 80 \times 10^{-6} \text{ F}, R = 40 \Omega$

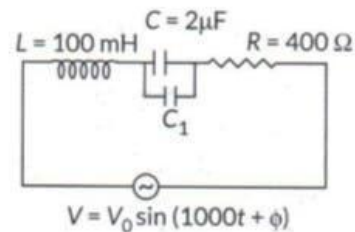
$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{50 \times 10^{-3} \times 80 \times 10^{-6}}}$$

$$\omega = \frac{10^3}{2} = 500 \text{ rads}^{-1} \Rightarrow v = \frac{500}{2\pi} = 80 \text{ Hz}$$

$$(ii) Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{40} \sqrt{\frac{50 \times 10^{-3}}{80 \times 10^{-6}}} = \frac{1}{40} \times \sqrt{625} = 0.625$$

11. Ans. Given L

$$V = V_0 \sin(1000t + \phi), R = 400 \Omega, L = 100 \text{ mH}, C = 2 \mu\text{F}$$



The standard equation is given as

$$V = V_0 \sin(\omega t + \phi) \therefore \omega = 1000$$

$$X_L = \omega L = 1000 \times 100 \times 10^{-3} = 10^2 = 100 \Omega$$

$$\therefore X_C = \frac{1}{\omega C} = \frac{1}{1000 \times 2 \times 10^{-6}} = 500 \Omega$$

Phase difference between the current and the voltage in the series LCR circuit is given as,

$$\phi = \tan^{-1} \frac{X_C - X_L}{R}$$

$$\therefore \phi = \tan^{-1} \left(\frac{500 - 100}{400} \right) = \tan^{-1}(1)$$

$$\phi = 45^\circ$$

Since, $X_C > X_L$, therefore current leads in phase.

12. Soln. (i) On increasing capacitance, current will increase. It also increases the brightness of bulb.

(ii) There will no flow of current and hence bulb will not glow.

13. Soln. Since the reactance of an inductor is zero for d.c. circuit. Therefore, the current decreases for the same inductor when it is connected with an a.c. source.

When inductor is connected in a.c. circuit:

$$V = 200 \text{ V}$$

$$f = 50 \text{ Hz}$$

$$i = 0.5 \text{ A}$$

$$i = \frac{V}{R} = \frac{V}{X_L} = \frac{V}{\omega L}$$

$$0.5 = \frac{200}{2\pi \times 50L} [\because \omega = 2\pi f]$$

$$L = \frac{200}{100 \times 0.5 \times 3.14} = \frac{4}{3.14} = 1.27 \text{ H}$$

14. Soln. Length of wire line = $20 \times 2 = 40 \text{ km}$

$$\text{Resistance of wire line, } r = 40 \times 0.5 = 20 \Omega$$

$$\text{Power to be supplied} = 1200 \text{ kW} = 1200 \times 10^3 \text{ W}$$

$$\text{Voltage at which power supplied} = 4000 \text{ V}$$

Since, $P = VI$

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

$$\Rightarrow I = \frac{1200 \times 10^3}{4000}$$

$$= 300 \text{ A}$$

Therefore, line power loss

$$= I^2 \times R$$

$$= (300)^2 \times 200$$

$$= 1800000 \text{ w}$$

\therefore Line power loss in the form of heat is 18000

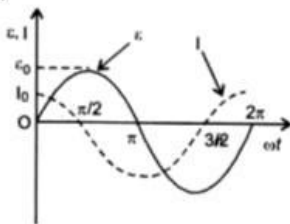
Kw

15. Soln. $V = V_0 \sin \omega t; I = I_0 \sin \left(\omega t + \frac{\pi}{2} \right)$.

(a) Since current leads the voltage by $\frac{\pi}{2}$ radians, X is a capacitor.

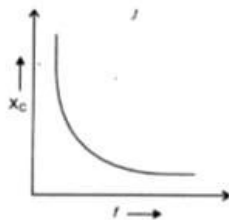
Capacitive reactance, $X_C = \frac{1}{2\pi fC}$ where, $\omega =$ angular velocity, C = capacitance.

(b)

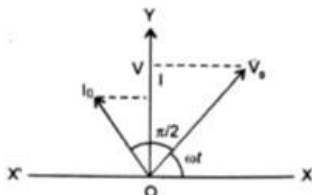


(c) Capacitive reactance varies inversely with frequency as $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

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



(d)



16. Soln.

(a) Given:

$$L = 1000 \times 10^{-3} \text{ H}$$

$$C = 2 \times 10^{-6} \text{ F}$$

$$R = 400 \Omega$$

$$\omega = 1000$$

Now, $X_L = \omega L$

$$X_L = (1000 \times 100 \times 10^{-3}) \Omega$$

$$X_L = 100 \Omega$$

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

$$= \frac{1}{1000 \times 2 \times 10^{-6}}$$

$$= \frac{10^6}{2 \times 10^3}$$

$$X_C = \frac{1000}{2} = 500 \Omega$$

Here $X_C > X_L$ so, the current will lead.

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

$$= \frac{100 - 500}{400}$$

$$\tan \phi = -\frac{400}{400}$$

$$\tan \phi = -1$$

$$\Rightarrow \text{phase angle } \phi = -45^\circ$$

(b) For unity power factor,

$$X_L = X_C$$

$$\omega L = \frac{1}{\omega C_{eq}}$$

$$C_{eq} = \frac{1}{\omega^2 L}$$

$$C_{eq} = \frac{1}{(1000)^2 \times 100 \times 10^{-3}} = 10 \mu\text{F}$$

Now, $C_{eq} = C + C_1$

$$10 = 2 + C_1$$

$$C_1 = 8 \mu\text{F}$$

17. Soln. $\cos \phi = \frac{1}{2} \Rightarrow \phi = \cos^{-1} \left(\frac{1}{2} \right) = \cos^{-1} \left(\frac{1}{2} \right) = 60^\circ = \frac{\pi}{3}$

\therefore Phase difference between current and voltage = $\frac{\pi}{3}$.

18. Soln. Root mean square or virtual or effective value of a.c. It is defined as that value of a direct current which produces the same heating effect in a given resistor as is produced by the given

alternating current when passed for the same time. It is denoted by I_{rms} , I_v or by I_{eff} .

Relation between the effective and peak value of a.c. Suppose an alternating current $I = I_0 \sin \omega t$ be passed through a circuit of resistance R. Then the amount of heat produced in small time dt will be

$$dH = I^2 R dt$$

If T is the time period of a.c., then heat produced in one complete cycle will be

$$H = \int_0^T I^2 R dt$$

Let I_{eff} be the effective value of a.c. Then heat produced in time T must be

$$H = I_{eff}^2 RT$$

$$\therefore I_{eff}^2 RT = \int_0^T I^2 R dt \text{ or } I_{eff}^2 = \frac{1}{T} \int_0^T I^2 dt$$

But $\frac{1}{T} \int_0^T I^2 dt$ is the mean of the squares of the instantaneous values of a.c. over one complete cycle, hence the effective or virtual value of a.c. equals its root mean square value, i.e.,

$$I_{eff} = I_{rms} = \sqrt{\frac{1}{T} \int_0^T I^2 dt}$$

$$\text{Now } \int_0^T I^2 dt = \int_0^T I_0^2 \sin^2 \omega t dt$$

$$\begin{aligned} &= I_0^2 \int_0^T \frac{1 - \cos 2\omega t}{2} dt \\ &= \frac{I_0^2}{2} \left[t - \frac{\sin 2\omega t}{2\omega} \right]_0^T \\ &= \frac{I_0^2}{2} \left[(T - 0) - \frac{1}{2\omega} \left(\sin \frac{4\pi}{T} t \right) \right]_0^T \\ &= \frac{I_0^2}{2} \left[T - \frac{1}{2\omega} (\sin 4\pi - \sin 0) \right] \\ &= \frac{I_0^2}{2} [T - 0] = \frac{I_0^2 T}{2} \end{aligned}$$

$$\therefore I_{eff} \text{ or } I_{rms} = \sqrt{\frac{1}{T} \cdot \frac{I_0^2 T}{2}}$$

$$\text{Or } I_{eff} \text{ or } I_{rms} = \frac{1}{\sqrt{2}} I_0 = 0.707 I_0$$

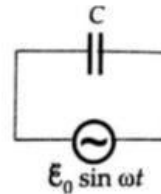
Thus the effective or rms value of an a.c. is $\frac{1}{\sqrt{2}}$ times its peak value.

19. Soln. Any two of the following (or any other correct) reactions:

- (i) ac can be transmitted with much lower energy losses as compared to dc.
- (ii) ac voltage can be adjusted (stepped-up or stepped down) as per requirement.

- (iii) ac current in a circuit can be controlled using (almost) wattless devices like choke coil.
- (iv) ac is easier to generate.

20. Soln. A.C. circuit containing only a capacitor. As shown in fig. consider a pure capacitor C connected across a source of alternating emf ϵ given by



$$\epsilon = \epsilon_0 \sin \omega t \quad \dots\dots\dots(1)$$

Due to the continuous charging and discharging of the capacitor plates, a continuous but alternating current exists in the circuit.

At any instant,

P.D. across the capacitor plates = Applied emf

$$\text{i.e., } V = \epsilon = \epsilon_0 \sin \omega t$$

\therefore Current at any instant is

$$I = \frac{dQ}{dt} = \frac{d}{dt} (C \epsilon_0 \sin \omega t) = \omega C \epsilon_0 \cos \omega t$$

$$\text{Or } I = I_0 \cos \omega t = I_0 \sin(\omega t + \pi/2) \quad \dots\dots\dots(2)$$

Where $I_0 = \omega C \epsilon_0 = \frac{\epsilon_0}{1/\omega C}$ = the current amplitude.

Phase relationship between ϵ and I. On comparing equations (1) and (2), we find that in a capacitive a.c. circuit, the current leads the voltage or the voltage lags behind the current in phase by $\pi/2$ radian. The phase relationship between ϵ and I is shown graphically in fig. We see that the current reaches its maximum value earlier than the voltage by one-fourth of a period.

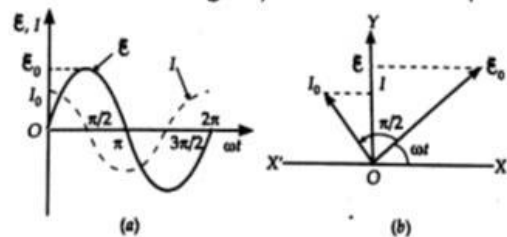
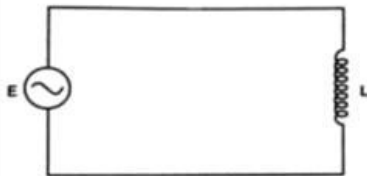


Fig. shows the phasor diagram for a capacitive a.c. circuit. The phasor $\vec{\epsilon}$ makes an angle ωt with X-axis in anticlockwise direction. As the current leads the emf in phase by $\pi/2$ rad, so the current phasor \vec{I} makes an angle $\pi/2$ rad with phasor $\vec{\epsilon}$ in anticlockwise direction.

21. Soln. (i)



$$\text{Induced emf } e = -L \frac{dI}{dt}$$

$$\text{Hence, Net voltage in the circuit} = V - L \frac{dI}{dt}$$

According to Kirchoff's Rule

$$V - L \frac{dI}{dt} = 0$$

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

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

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

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

$$\therefore i = i_m \sin \left(\omega t - \frac{\pi}{2} \right)$$

Hence current lags by $\frac{\pi}{2}$

(ii) Inductance of the inductor = 100 mH

Average power dissipation,

$$P = V_{rms} I_{rms} \cos \phi$$

$$= 10 \times 1 \times \cos \frac{\pi}{4}$$

$$= \frac{10}{\sqrt{2}} \text{ W}$$

$$= 5\sqrt{2} \text{ Watts (7.05 W)}$$

22. Soln. The instantaneous induced emf in an inductor when current changes through it

$$e = -L \frac{dI}{dt}$$

Hence, instantaneous applied voltage

$$e = V = L \frac{dI}{dt}$$

Work done $dW = V \cdot dq = VI dt$

$$\therefore dW = LI dI$$

$$\Rightarrow \int dW = \int_0^1 LI dI$$

$$W = \frac{1}{2} LI^2$$

Energy density, $(u) = \frac{\text{total energy stored}}{\text{volume}}$

$$u = \frac{\left(\frac{1}{2}\right)LI^2}{Al} = \frac{\frac{1}{2}(LI)I}{Al}$$

$$\text{Flux} = NBA = LI$$

$$\text{And } B = \frac{\mu_0 NI}{l} \Rightarrow I = \frac{Bl}{\mu_0 N}$$

$$\therefore u = \frac{\frac{1}{2}(NBA) \cdot \frac{Bl}{\mu_0 N}}{Al} = \frac{B^2}{2\mu_0}$$

23. Soln. (i) The device X is a capacitor

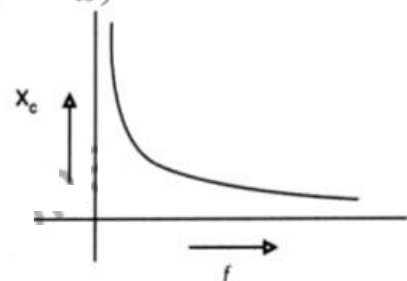
(ii) Curve B \longrightarrow voltage

Curve C \longrightarrow current

Curve A \longrightarrow power

Reason: The current leads the voltage in phase, by $\frac{\pi}{2}$, for a capacitor.

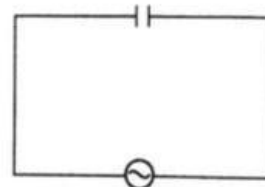
$$(iii) X_c = \frac{1}{\omega C} \left(X_c \propto \frac{1}{\omega} \right)$$



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

$$Q = VC = CV_0 \sin \omega t$$

$$I = \frac{dq}{dt} = \omega CV_0 \cos \omega t$$



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

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

Current leads the voltage, in phase, by $\frac{\pi}{2}$

24. Soln. (i) A, Power's frequency is double of current or Voltage frequency.

(ii) From the graph, the phase difference between V

and I is $\frac{\pi}{2}$ so device 'X' may be an inductor (L) or

capacitor (C) or series combination of L and C, but since the average power is zero so the device has to be capacitor.

25. Soln. (i) When a dielectric slab is introduced in between the plates of capacitor, its capacitance

will increase which tends to decrease the potential drop across the capacitor, i.e., $V = \frac{Q}{C}$. As a result of this potential drop across bulb will increase as they are connected in series, so the brightness of the bulb will increase.

(ii) As the resistance R increases, potential drop across the resistor will also increase which lead to decrease in potential drop across the bulb, since it is connected in series. Hence, the brightness of the bulb will decrease.

26. Soln. For the applied voltage

$$V = 70.7 \sin(1000t), \text{ we have}$$

$$V = 70.7 \text{ volts}$$

$$\omega = 1000 \text{ S}^{-1}$$

For the inductor

$$i_0 = \frac{V_0}{\omega L} = \frac{70.7}{1000 \times 200 \times 10^{-3}} \text{ A}$$

$$= 35.35 \times 10^{-2} \text{ A}$$

$$= 0.3535 \text{ A}$$

∴ Expression for current is

$$i = (0.3535) \sin\left(1000t - \frac{\pi}{2}\right)$$

For the capacitor

$$i_0 = \frac{V_0}{\left(\frac{1}{\omega C}\right)} = V_0 \cdot \omega C$$

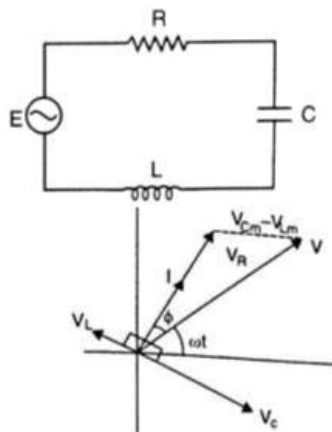
$$= 70.7 \times 1000 \times 5 \times 10^{-6} \text{ A}$$

$$= 353.5 \times 10^{-3} \text{ A} = 0.3535 \text{ A}$$

∴ Expression for current is

$$I = 0.3535 \sin\left(1000t + \frac{\pi}{2}\right)$$

27. Soln. (i) In a series LCR circuit shown,



From the phasor relation, voltages $V_L + V_R + V_C = V$, as V_C and V_L are along the same line and in opposite directions, so they will combine in single phasor $(V_C + V_L)$ having magnitude $|V_{Cm} - V_{Lm}|$. Since voltage V is shown as hypotenuse of right triangle with sides as V_R and $(V_C + V_L)$, so the Pythagorean Theorem results as:

$$V_m^2 = V_m^2 + (V_{Cm} - V_{Lm})^2$$

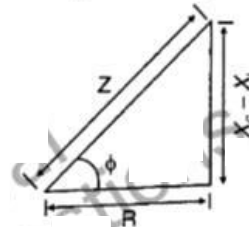
$$V_m^2 = (I_m R)^2 + (I_m X_C - I_m X_L)^2$$

$$V_m^2 = I_m^2 (R^2 + (X_C - X_L)^2)$$

Now current in the circuit:

$$I_m = \frac{V_m}{\sqrt{(R^2 + (X_C - X_L)^2)}}$$

$$I_m = \frac{V_m}{Z} \text{ as } Z = \sqrt{[R^2 + (X_C - X_L)^2]}$$



As phasor I is always parallel to phasor V_R , the phase angle ϕ is the angle between V_R and V and can be determine from figure.

$$\tan \phi = \frac{V_{Cm} - V_{Lm}}{V_{Rm}}$$

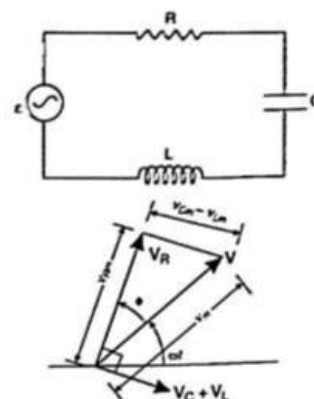
$$\tan \phi = \frac{X_C - X_L}{R}$$

(ii) Resonance Frequency

Frequencies at which the response amplitude is relative maximum are known as system's resonant frequencies. It is shown as:

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

28. Soln. (i)



From figure,

$$\vec{V} = \vec{V}_L + \vec{V}_R + \vec{V}_C$$

Where $|\vec{V}_R| = i_m R$

$$|\vec{V}_L + \vec{V}_C| = V_{Cm} - V_{Lm}$$

$$= i_m (X_C - X_L)$$

$$\Rightarrow V_m^2 = V_{Rm}^2 + (V_{Cm} - V_{Lm})^2$$

$$i_m^2 Z^2 = i_m^2 R^2 + i_m^2 (X_C - X_L)^2$$

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

From figure

$$\tan \phi = \frac{V_{Cm} - V_{Lm}}{V_{Rm}} = \frac{i_m (X_C - X_L)}{i_m R}$$

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

Condition for current and voltage are in phase:

$$V_L = V_C \text{ or } X_L = X_C$$

Circuit is called Resonant circuit.

(ii) Power factor

$$P_1 = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + R^2}}$$

$$= \frac{1}{\sqrt{2}} \text{ (as } X_L = R)$$

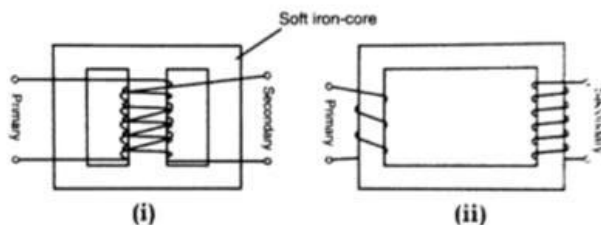
Power factor when capacitor C of Reactance $X_C = X_L$ is put in series in the circuit

$$P_2 = \frac{R}{Z} = \frac{R}{R} = 1$$

As $Z = R$ at resonance

$$\therefore \frac{P_1}{P_2} = \frac{\frac{1}{\sqrt{2}}}{1} = \frac{1}{\sqrt{2}}$$

29. Soln.



Working principle

Whenever current in one coil changes an emf gets induced in the neighbouring coil (Principle of mutual induction)

Voltage across secondary

$$V_s = e_s = -N_s \frac{d\phi}{dt}$$

Voltage across primary

$$V_p = e_p = -N_p \frac{d\phi}{dt}$$

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} \quad (\text{here } N_s > N_p)$$

In an Ideal transformer

Power Input = Power output

$$I_p V_p = I_s V_s$$

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

(ii) Input power,

$$P_i = I_i \times V_i = 15 \times 100 = 1500 \text{ W}$$

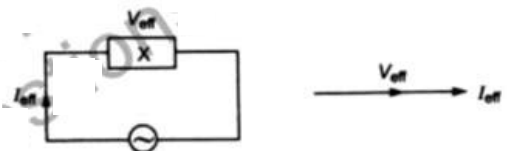
Power output

$$P_o = P_i \times \frac{90}{100} = 1350 \text{ W}$$

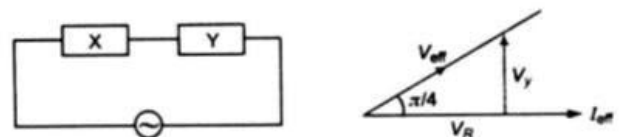
$$\Rightarrow I_o V_o = 1350 \text{ W}$$

$$\text{Output voltage, } V_o = \frac{1350}{3} \text{ V} = 450 \text{ V}$$

30. Soln



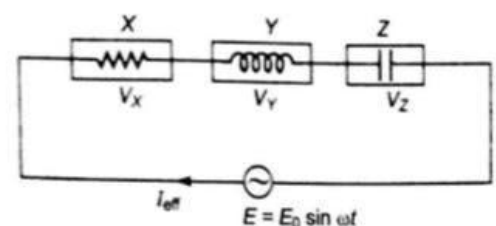
Since the phase angle between the current I_{eff} and voltage drop V_{eff} is zero. Hence, the element X is a resistor.



The voltage drop across the combination X and Y is ahead of the current flow. Hence, the element Y is ac inductor.



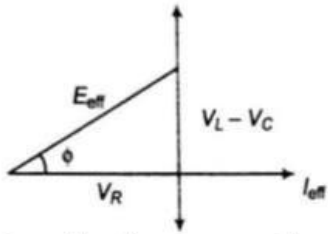
The voltage drop across the combination X and Z lags behind the current flow. Hence, the element Z is a capacitor.



Let I_{eff} be the current flows through each element X, Y and Z. The voltage V_X, V_Y and V_Z drop across the elements. However,

$$V_X + V_Y + V_Z > E_{eff}.$$

It is not possible. So, on plotting phasor diagram, we have



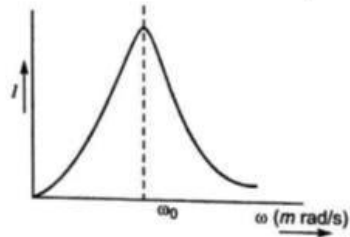
$$|E_{eff}|^2 = V_R^2 + (V_L - V_C)^2$$

$$E_{eff} = I_{eff} \sqrt{R^2 + (X_L - X_C)^2} \quad \dots\dots\dots(1)$$

$$\text{Since } E_{eff} = I_{eff} Z \quad \dots\dots\dots(2)$$

The impedance of the circuit can be given

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



The flow of the current in series LCR circuit varies as a function of frequency of a.c. source is shown in figure. Current amplitude is maximum at resonant frequency

ω_0 ; and can be given as $I_{max} = \frac{V_{eff}}{R}$. So, we can not

have resonance in a R.L. or R.C. circuits