Short Answer Questions – II (PYQ)

Q. 1. Show that the current leads the voltage in phase by π/2 in an ac circuit containing an ideal capacitor. [CBSE (F) 2014]

Ans. The instantaneous voltage,

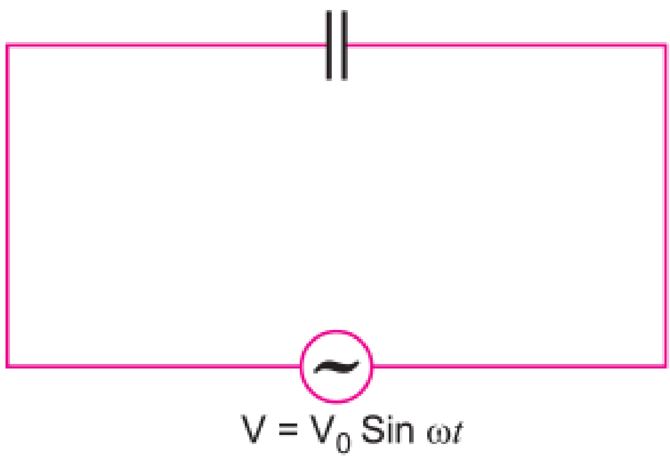
$V = V_0 \sin \omega t$ … (i)

Let q be the charge on capacitor and I, the current in the circuit at any instant, then instantaneous potential difference,

$$V = \frac{q}{c} \quad \ldots (ii)$$

From (i) and (ii)

$$\frac{q}{C} = V_0 \sin \omega t \quad \Rightarrow \quad q = CV_0 \sin \omega t$$



The instantaneous current,

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

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

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

Hence, the current leads the applied voltage in phase by π/2

Q. 2. In a series LCR circuit, obtain the conditions under which [CBSE (F) 2014]

(i) The impedance of the circuit is minimum, and
(ii) Wattless current flows in the circuit.

Ans. (i) Impedance of series LCR circuit is given by

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

For the impedance, Z to be minimum

$$X_L = X_C$$

(ii)

$$\text{Power } P = V_{rms} I_{rms} \cos \varphi$$

$$\text{When } \varphi = \frac{\pi}{2}$$

$$\text{Power} = V_{\text{rms}} I_{\text{rms}} \cos \frac{\pi}{2} = 0$$

Therefore, wattless current flows when the impedance of the circuit is purely inductive or purely capacitive.

In another way we can say,

For wattless current to flow, circuit should not have any ohmic resistance (R= 0)

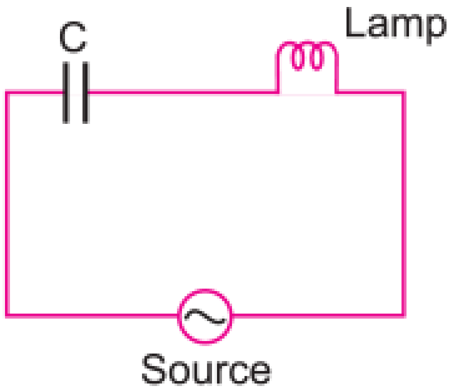
Q. 3. State the underlying principle of a transformer. How is the large scale transmission of electric energy over long distances done with the use of transformers?
[CBSE (AI) 2012]

Ans. The principle of transformer is based upon the principle of mutual induction which states that due to continuous change in the current in the primary coil an emf gets induced across the secondary coil. At the power generating station, the step up transformers step up the output voltage which reduces the current through the cables and hence reduce resistive power loss. Then, at the consumer end, a step down transformer steps down the voltage.

Hence, the large scale transmission of electric energy over long distances is done by stepping up the voltage at the generating station to minimise the power loss in the transmission cables.

Q. 4. An electric lamp connected in series with a capacitor and an ac source is glowing with of certain brightness. How does the brightness of the lamp change on reducing the

(i) Capacitance and



(ii) Frequency? [CBSE Delhi 2010, (North) 2016]

Ans. (i)

When capacitance is reduced, capacitive reactance $X_C = \frac{1}{\omega C}$ increases, hence impedance of circuit

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

increases and so current $I = \frac{V}{Z}$ decreases. As a result the **brightness of the bulb is reduced.**

(ii) When frequency decreases; capacitive reactance $X_c = \frac{1}{2\pi\nu c}$ increases and hence impedance of circuit increases, so current decreases. As a result brightness of bulb is reduced.

Q. 5. State the principle of working of a transformer. Can a transformer be used to step up or step down a d.c. voltage? Justify your answer. [CBSE (AI) 2011]

Ans. Working of a transformer is based on the principle of mutual induction. Transformer cannot step up or step down a dc voltage.

Reason: No change in magnetic flux.

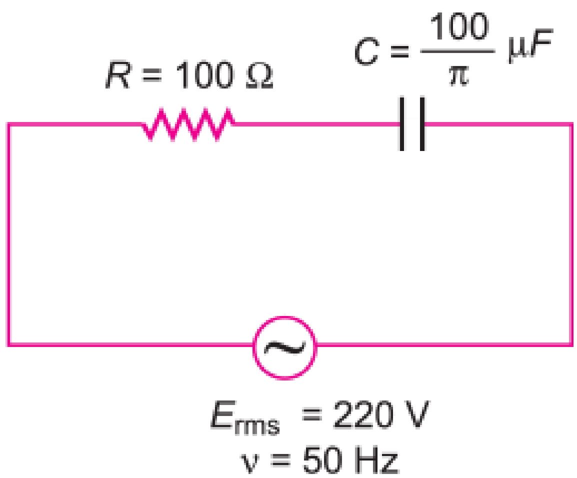
Explanation: When dc voltage source is applied across a primary coil of a transformer, the current in primary coil remains same, so there is no change in magnetic flux associated with it and hence no voltage is induced across the secondary coil.

Q. 6. A resistor of 100 Ω and a capacitor of 100/π μF are connected in series to a 220 V, 50 Hz a.c. supply.

(i) Calculate the current in the circuit.

(ii) Calculate the (rms) voltage across the resistor and the capacitor. Do you find the algebraic sum of these voltages more than the source voltage? If yes, how do you resolve the paradox? [CBSE Chennai 2015]

Ans. (i)



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

$$= \frac{1}{2\pi \times 50 \times \frac{100}{\pi}\mu F} = 100\Omega$$

$$\text{Impedance of the circuit, } Z = \sqrt{R^2 + X_C^2}$$

$$= \sqrt{(100)^2 + (100)^2} = 100\sqrt{2}$$

$$\text{Current in the circuit } I_{rms} = \frac{E_{rms}}{Z} = \frac{220}{100\sqrt{2}} = 1.55\ A$$

(ii) Voltage across resistor, VR = I_{rms} R

=1.55 × 100 = 155V

Voltage across capacitor, VC = I_{rms} × C =1.55 × 100V = 155 V

The algebraic sum of voltages across the combination is

$V_{rms} = V_R + V_C$ $=155V + 155V = 310V$

While Vrms of the source is 220 V. Yes, the voltages across the combination is more than the voltage of the source. The voltage across the resistor and capacitor are not in phase.

This paradox can be resolved as when the current passes through the capacitor, it leads the voltage V_C by phase $\frac{\pi}{2}$ So, voltage of the source can be given as

$$V_{\mathrm{rms}} = \sqrt{V_R^2 + V_C^2}$$

$$= \sqrt{(155)^2 + (155)^2}$$

$$= 155\sqrt{2} = 220\ V$$

Q. 7. A capacitor of unknown capacitance, a resistor of 100 Ω and an inductor of self-inductance L = ($\frac{4}{\pi^2}$) henry are connected in series to an ac source of 200 V and 50 Hz. Calculate the value of the capacitance and impedance of the circuit when the current is in phase with the voltage. Calculate the power dissipated in the circuit.
[CBSE South 2016]

Ans.

$$\text{Capacitance,}\ \ C = \frac{1}{L\omega^2}$$

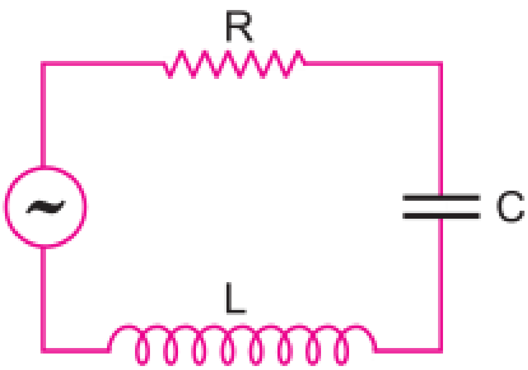
$$= \frac{1}{\frac{4}{\pi^2}(2\pi\times 50)^2} F = \frac{1}{40000} F = 2.5\ \times\ 10^{-5} F$$

Since V and I are in same phase

Impedance = Resistance = 100Ω

$$\text{Power dissipated}\ \ = \frac{E_{\mathrm{rms}}^2}{2} = \frac{(200)^2}{100} W = 400W$$

Q. 8. The figure shows a series LCR circuit with L = 5.0 H, C = 80 μF, R = 40 Ω connected to a variable frequency 240V source. Calculate.



(i) The angular frequency of the source which drives the circuit at resonance.
(ii) The current at the resonating frequency.
(iii) The rms potential drop across the capacitor at resonance. [CBSE Delhi 2012]

Ans. (i) We know

$$\omega_r = \text{Angular frequency at resonance} = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5\times80\times10^{-6}}} = 50 \ \text{rad}/s$$

(ii)

$$\text{Current at resonance, } I_{\text{rms}} = \frac{V_{\text{rms}}}{R} = \frac{240}{40} = 6 \ A$$

(iii) V_{rms} across capacitor

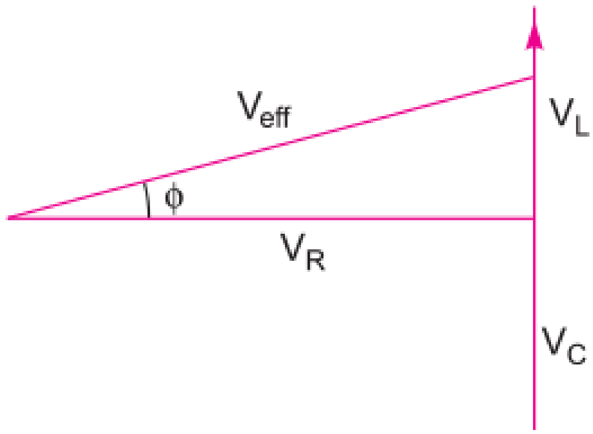
$$I_{\text{rms}} = I_{\text{rms}} X_C = 6 \times \frac{1}{50\times80\times10^{-6}} = \frac{6\times10^6}{4\times10^3} = 1500 \ V$$

Q. 9. Given the value of the resistance of R is 40Ω, calculate the current in the circuit.
[CBSE (F) 2013]

Ans. Given R = 40Ω, so current in the LCR circuit.

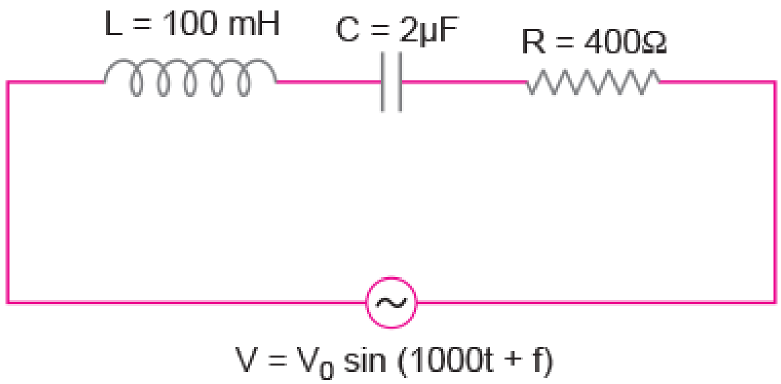
$$I_{\text{eff}} = \frac{V_{\text{eff}}}{R} \qquad [X_L = X_C \quad \text{or} \quad Z = R]$$

$$= \frac{200}{40} = 5A$$



Q. 10. (i) 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?

(ii) Without making any other change, find the value of the additional capacitor, C_1, to be connected in parallel with the capacitor C, in order to make the power factor of the circuit unity. [CBSE Delhi 2017]



Ans.

i. Inductive reactance,

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

Capacitive reactance,

$X_C = \frac{1}{\omega C} = \left(\frac{1}{1000 \times 2 \times 10^{-6}}\right)\Omega = 500\Omega$

Phase angle,

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

$\tan\varphi = \frac{100 - 500}{400} = -1$

$\varphi = -\frac{\pi}{4}$ As $X_C > X_L$, (phase angle is negative), hence current leads voltage.

ii. To make power factor unity

$X_C = X_L$ (where C = net capacitance of parallel combination)

$\frac{1}{\omega C'} = 100$

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

$\therefore$ $C' = 10\mu F$

$\because$ $C' = C + C_1$

$\Rightarrow$ $10 = 2 + C_1$ $\Rightarrow C_1 = 8\mu F$

Q. 11. Answer the following question :

(i) For a given ac, $i = i_m \sin \omega t$, show that the average power dissipated in a resistor R over a complete cycle is $\frac{1}{2} i_m^2 R.$

(ii) A light bulb is rated at 100 W for a 220 V ac supply. Calculate the resistance of the bulb. [CBSE (AI) 2013]

Ans. (i) Average power consumed in resistor R over a complete cycle

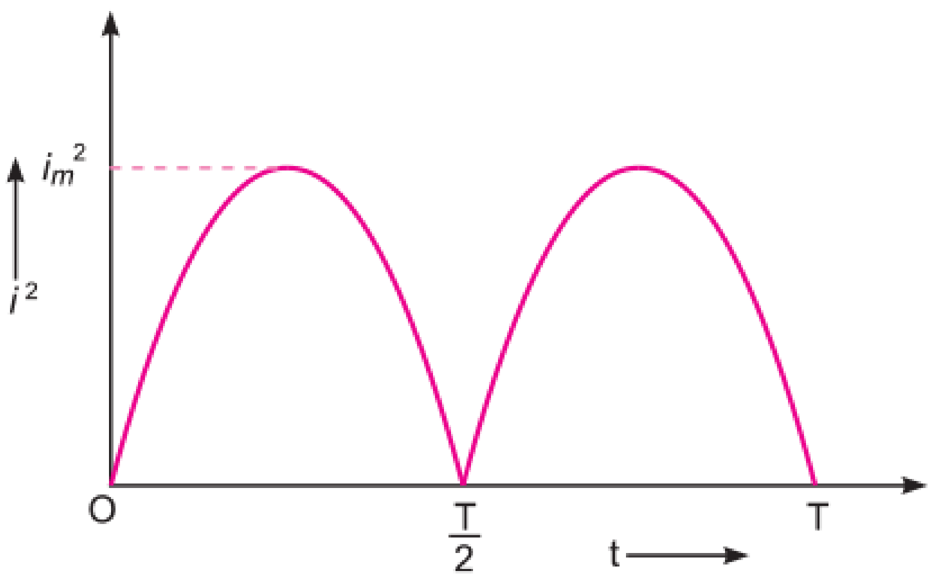
$$P_{a\nu} = \frac{1}{\int_0^T dt} \cdot \int_0^T i^2 R \ dt$$

$$= \frac{i_m^2 R}{T} \int_0^T \sin^2 \omega t \ dt \qquad ...(i)$$

$$= \frac{i_m^2 R}{2T} \int_0^T (1 - \cos 2 \omega t) \ dt$$

$$= \frac{i_m^2 R}{2T} \left[\int_0^T dt - \int_0^T \cos 2 \omega t \ dt \right] \qquad ...(ii)$$

$$= \frac{i_m^2 R}{2T} [T - 0] = \frac{i_m^2 R}{2}$$



(ii)

In case of ac

$$P_{a\nu} = \frac{V_{\text{rms}}^2}{R} = \frac{V_{\text{eff}}^2}{R}$$

$$R = \frac{V_{\text{rms}}^2}{P} = \frac{220 \times 220}{100} = 484 \, \Omega$$

Q. 12. Determine the current quality factor at resonance for a series LCR circuit with L = 1.00 mH, C= 1.00 nF and R=100Ω connected to an ac source having peak voltage of 100 V. [CBSE (F) 2011]

Ans.

$I_V = ?,\ Q = ?$

$L = 1.00\ \text{mH} = 1\times10^{-3}\ \text{H},\ C = 1.00\ \text{nF} = 1\times10^{-9}\ \text{F},\ R = 100\Omega,\ E_0 = 100\ \text{V}$

$$I_0 = \frac{E_0}{\sqrt{R^2+\left(\omega L - \frac{1}{\omega C}\right)^2}} = \frac{E_0}{Z} \qquad \left\{\begin{array}{l}\text{at resonance } \omega L = \frac{1}{\omega c} \\ \text{Hence } Z = R\end{array}\right\}$$

$$\therefore \qquad I = \frac{V}{R} = \frac{100}{100}$$

$$I_\nu = \frac{I_0}{\sqrt{2}} = \frac{1}{\sqrt{2}} \times \frac{\sqrt{2}}{2} = \frac{1.44}{2} = 0.707\ A \qquad [\therefore I_0 = 1\text{A}]$$

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{1}{100}\sqrt{\frac{1.0\times10^{-3}}{1.0\times10^{-9}}} = \frac{1}{100}\times10^3 = 10$$

Q. 13. A circuit is set up by connecting inductance L = 100 mH, resistor R = 100 Ω and a capacitor of reactance 200 Ω in series. An alternating emf of 150 $\sqrt{2}$ V, 500/π Hz is applied across this series combination. Calculate the power dissipated in the resistor.
[CBSE (F) 2014]

Ans.

Here, $L = 100 \times 10^{-3}$ H, $R = 100\ \Omega$, $X_C = 200\ \Omega$, $V_{rms} = 150\sqrt{2}$ V

$\nu = \frac{500}{\pi}$ Hz .

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

$= 2\pi\frac{500}{\pi} \times 100 \times 10^{-3} = 100.$

Impedance of circuit

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

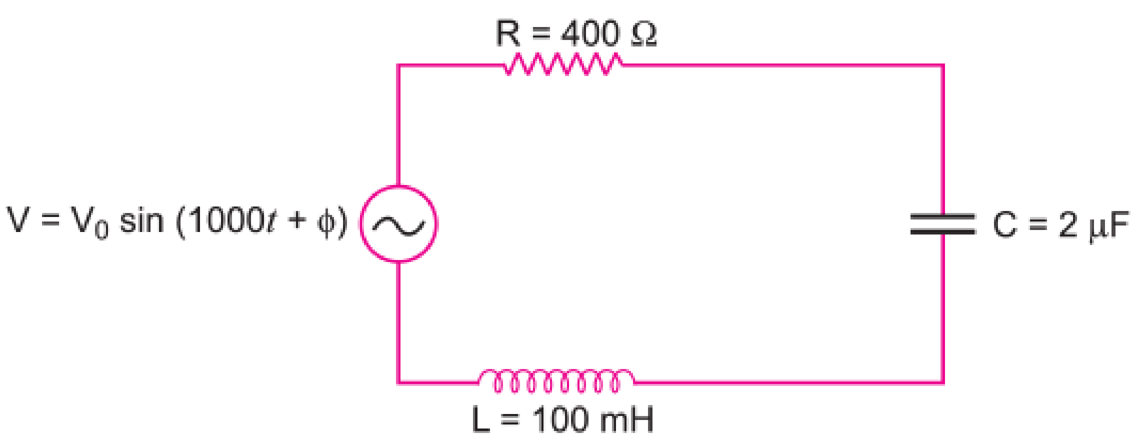
$= \sqrt{(100)^2 + (200-100)^2} = \sqrt{20000} = 100\sqrt{2}$

$I_{\text{rms}} = \frac{V_{\text{rms}}}{Z} = \frac{150\sqrt{2}}{100\sqrt{2}} = \frac{3}{2}$

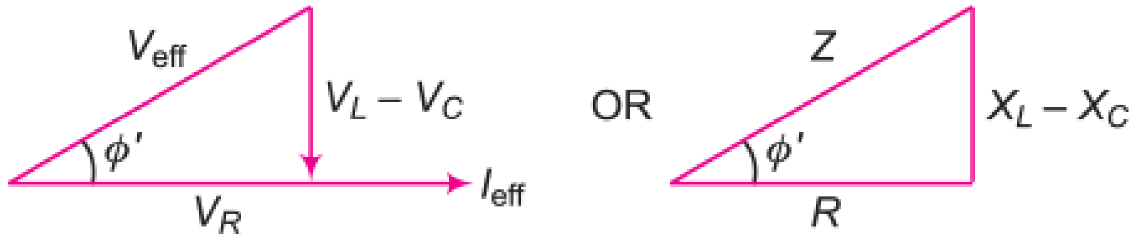
Power dissipated $(I_{\text{rms}})^2\ R = \frac{9}{4} \times 100 = 225W$

Q. 14. (a) Determine the value of phase difference between the current and the voltage in the given series LCR circuit.

(b) Calculate the value of the additional capacitor which may be joined suitably to the capacitor C that would make the power factor of the circuit unity.
[CBSE Allahabad 2015]



Ans. (a) From phasor diagrams,



Phase angle, $\tan\varphi = \frac{X_L - X_C}{R}$

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

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

$\therefore \qquad \tan\varphi' = \frac{500 - 100}{400} = 1 \qquad \Rightarrow \qquad \varphi' = 45^o$

The phase angle between the current and applied voltage is

$45^o \left(= \frac{\pi}{4}\right)$

b. If power factor of the circuit is unity. It means the series LCR would be in resonance. It is possible, if another capacitor C is used in the circuit.

So, $\qquad X_C' = X_L \qquad \Rightarrow \frac{1}{\omega C'} = \omega L$

$\Rightarrow \qquad C' = \frac{1}{\omega^2 L} = \frac{1}{(1000)^2 \times 100 \times 10^{-3}} = 10^{-5} F \quad \Rightarrow C' = 10\ \mu F$

Since $C' > C$, so an additional capacitor of 8 μF would be connected in parallel to the capacitor of $C = 2$ μF

Q. 15. The primary coil of an ideal step up transformer has 100 turns and transformation ratio is also 100. The input voltage and power are 220 V and 1100 W respectively. Calculate

(a) The number of turns in the secondary coil.

(b) The current in the primary coil.

(c) The voltage across the secondary coil.

(d) The current in the secondary coil.

(e) The power in the secondary coil. [CBSE Delhi 2016]

Ans.

a. Transformation ratio $r = \frac{\text{Number of turns in secondary coil } (N_s)}{\text{Number of turns in primary coil } (N_P)}$

Given $N_P = 100$, $r = 100$

$\therefore$ Number of turns in secondary coil, $N_S = rN_P = 100 \times 100 = 10{,}000$

b. Input voltage $V_P = 220$ V, Input power $P_{in} = 1100$ W

Current in primary coil $I_p = \frac{P_{in}}{V_P} = \frac{1100}{220} = 5A$

c. Voltage across secondary coil (V_S) is given by

$r = \frac{V_s}{V_P}$

$\Rightarrow V_S = rV_p = 100 \times 220 = 22{,}000 \text{ V} = \mathbf{22kV}$

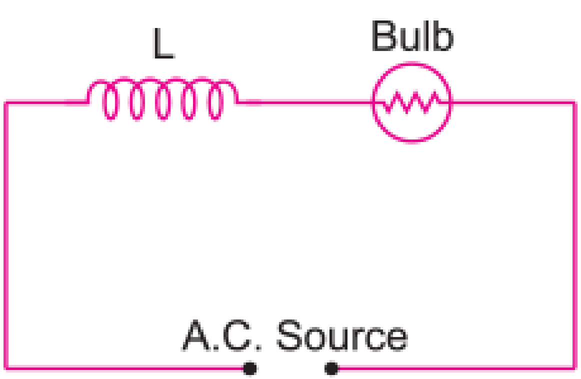
d. Current in secondary coil is given by

$r = \frac{I_P}{I_S} \quad \Rightarrow \quad I_S = \frac{I_P}{r} = \frac{5}{100} = 0.05\,A$

e. Power in secondary coil, $P_{out} = V_S I_S = 22 \times 10^3 \times 0.05 = \mathbf{1100\ W}$

Obviously power in secondary coil is same as power in primary. This means that the transformer is ideal, *i.e.* there are no energy losses.

Q. 16. An inductor L of reactance X_L is connected in series with a bulb B to an ac source as shown in figure. Explain briefly how does the brightness of the bulb change when (i) number of turns of the inductor is reduced (ii) an iron rod is inserted in the inductor and (iii) a capacitor of reactance $X_C = X_L$ is included in the circuit.
[CBSE Delhi 2014, 2015]



Ans. Brightness of the bulb depends on square of the Irms (i.e., I^2_{rms})

Impedance of the circuit, $Z = \sqrt{R^2 + (\omega L)^2}$

and Current in the circuit, $I = \frac{V}{Z}$

(i) When the number of turns in the inductor is reduced, the self-inductance of the coil decreases; so impedance of circuit reduces and so current in the circuit $\left(I = \frac{E}{Z}\right)$ increases. Thus the brightness of the bulb increases.

(ii) When iron (being a ferromagnetic substance) rod is inserted in the coil, its inductance increases and in turn, impedance of the circuit increases. As a result, a larger fraction of the applied ac voltage appears across the inductor, leaving less voltage across the bulb. Hence, brightness of the bulb decreases.

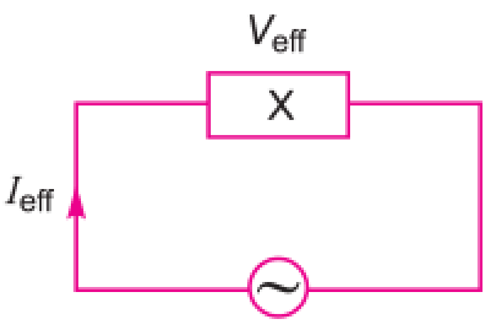
(iii) When capacitor of reactance $X_C = X_L$ is introduced, the net reactance of circuit becomes zero, so impedance of circuit decreases; it becomes Z = R; so current in circuit increases; hence brightness of bulb increases. Thus brightness of bulb in both cases **increases.**

Q. 17. 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 π/4. But the current is ahead of the voltage in phase by π/4 when Z is connected in series with X across the source. Identify the circuit elements X, Y and Z.

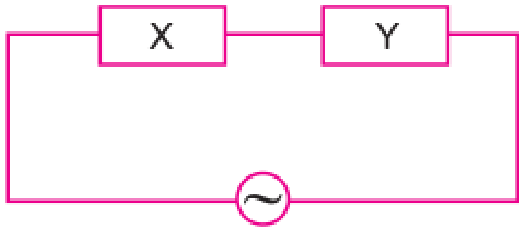
When all the three elements are connected in series across the same source, determine the impedance of the circuit.

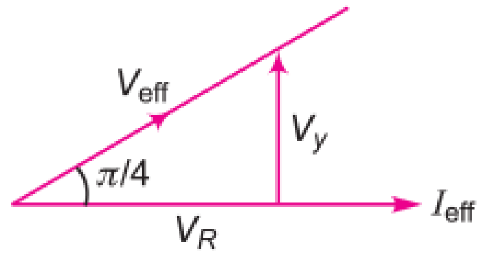
Draw a plot of the current versus the frequency of applied source and mention the significance of this plot. [CBSE Panchkula 2015]

Ans.

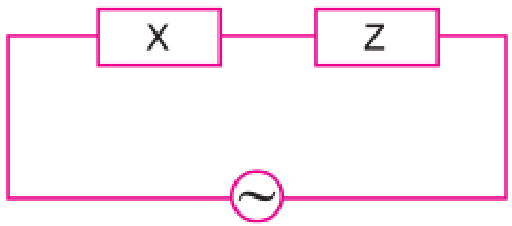


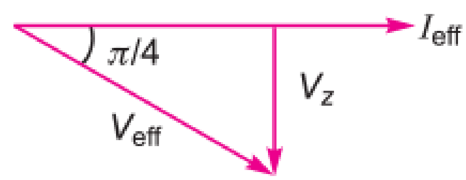
Since the phase angle between the current. I_{eff} and voltage drop V_{eff} is zero. Hence, the element X is a resistor.



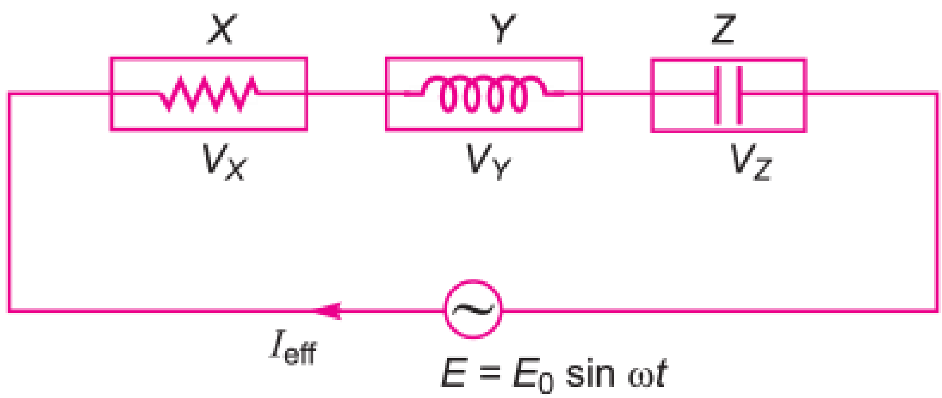


The voltage drop across the combination X and Y is ahead of the current flow. Hence, the element Y is an inductor.





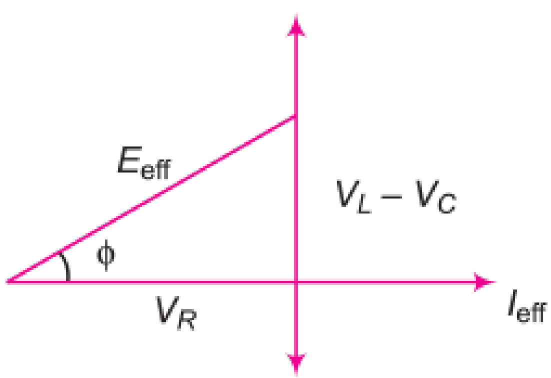
The voltage drop across the combination X and Z lags behind the current flow. Hence, the element Z is a capacitor.



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



$$|E_{eff}|^2 = v_R^2 + (V_L - V_C)^2 \quad ...(1)$$

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

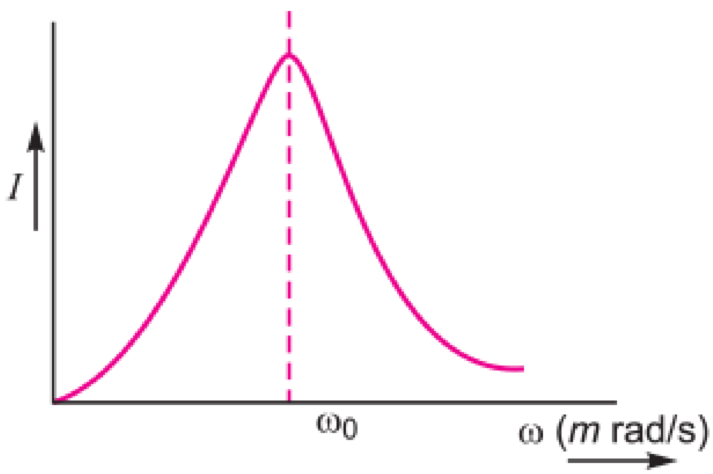
Since $E_{eff} = I_{eff} Z$ ...(2)

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 $I_{max} = \frac{V_{eff}}{R}$.
It is possible at $Z = R\left(\text{or } \omega_0 = \frac{1}{\sqrt{LC}}\right)$



Significance:

The resonance phenomenon is exhibit by the circuit only when both L and C are present in the circuit. When voltages across L and C cancel each other (on being out of phase).

The current in the circuit reaches to its maximum value and can be given as $\frac{V_{eff}}{R}$ So, we cannot have resonance in a R.L. or R.C. circuits.

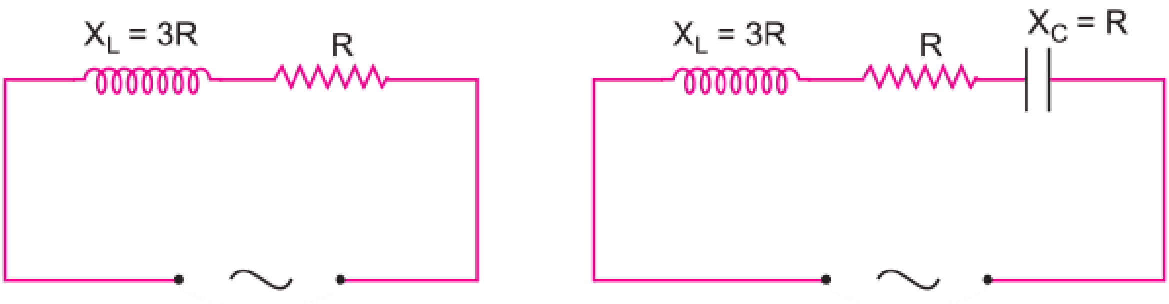
Short Answer Questions –II (OIQ)

Q. 1. Given below are two electrical circuits A and B. Calculate the ratio of power factor of circuit B to the power factor of circuit A.

Ans.

Power factor, $\cos\varphi = \frac{R}{Z}$

Impedance of circuit $A, Z_A = \sqrt{R^2 + X_L^2}$



(a) (b)

Impedance of circuit $B, Z_B = \sqrt{R^2 + (X_L - X_C)^2}$

Ratio of power factor of circuit B to that of A is

$$\frac{(\cos\varphi)_B}{(\cos\varphi)_A} = \frac{R/Z_B}{R/Z_A} = \frac{Z_A}{Z_B} = \frac{\sqrt{R^2 + X_L^2}}{\sqrt{R^2 + (X_L - X_C)^2}}$$

$$= \frac{\sqrt{R^2 + (3R)^2}}{\sqrt{\left[R^2 + \sqrt{(3R) - (R)^2}\right]}} = \frac{\sqrt{10}}{\sqrt{5}} = \sqrt{2}$$

Q. 2. Prove that the power dissipated in an ideal resistor connected to an ac source is $V_{\text{eff}}^2/R.$

Ans.

Power in ac circuit, $P = V_{rms}\, i_{rms} \cos \varphi$

As rms values of current and voltage are also called effective values *i.e.*

$$P = V_{eff}\, I_{eff} \cos \varphi \qquad \text{... (i)}$$

But $\qquad \cos \varphi = \text{power factor} = \frac{R}{Z}$

In a purely resistive circuit $Z = R$, $\cos \varphi = 1$

and $\qquad i_{\text{eff}} = \frac{V_{\text{eff}}}{Z} = \frac{V_{\text{eff}}}{R}$

Substituting these values in (i), we get

$$P = V_{\text{eff}} \cdot \frac{V_{\text{eff}}}{R} \times 1 = \frac{V_{\text{eff}}^2}{R}.$$

Q. 3. An inductor 200 mH, a capacitor 100 μF and a resistor 10Ω are connected in series to an a.c. source of 100 V, having variable frequency.

(i) At what frequency of the applied voltage will the power factor of the circuit be 1?
(ii) What will be the current amplitude at this frequency?
(iii) Calculate the Q-factor of the circuit.

Ans. (i) Since the power factor φ =1 it means the phase difference between voltage and the current is zero.

This is possible when

$$\text{wL} = \frac{1}{\omega C}$$

$$\omega^2 = \frac{1}{\text{LC}} \Rightarrow \nu = \frac{1}{2\pi\sqrt{\text{LC}}} = 35.58 \text{ Hz}$$

(ii)

$$\text{Current Amplitude, } I = \frac{V_{\text{eff}}}{Z} = \frac{V_{\text{eff}}}{R} = \frac{100}{10} = 10\ A \qquad (\because Z = R)$$

(iii)

$$\text{Quality factor, } Q = \frac{1}{R}\sqrt{\frac{L}{C}} = 4.47$$

Q. 4. An AC voltage V = Vm is applied across a:

(i) Series RC circuit in which capacitive reactance is ‘a’ times the resistance in the circuit.
(ii) Series RL circuit in which inductive reactance is ‘b’ times the resistance in the circuit.

Find the value of power factor of the circuit in each case.

Ans.

$$\text{Power factor } \cos\varphi = \frac{R}{Z}, \quad \text{when} \quad Z = \sqrt{R^2 + X^2}$$

i. $X = X_C = aR,$

$$\therefore \quad Z = \sqrt{R^2 + (\text{aR})^2} = R\sqrt{1 + a^2}$$

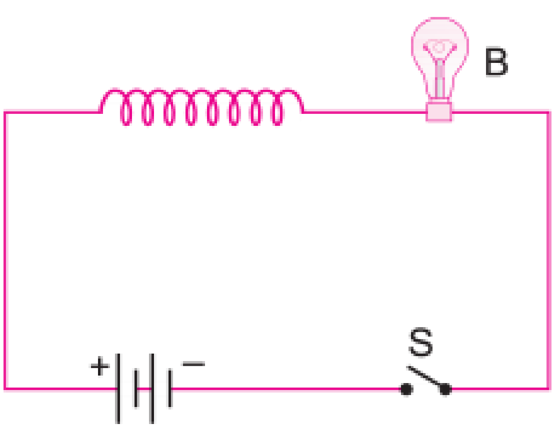
$$\therefore \quad \cos\varphi = \frac{R}{R\sqrt{1+a^2}} = \frac{1}{\sqrt{1+a^2}}$$

ii. $X = X_L = bR, \therefore$

$$Z = \sqrt{R^2 + (\text{bR})^2} = R\sqrt{1 + b^2}$$

$$\therefore \quad \cos\varphi = \frac{R}{R\sqrt{1+b^2}} = \frac{1}{\sqrt{1+b^2}}$$

Q. 5. Figure shows a light bulb (B) and iron cored inductor connected to a dc battery through a switch (S).



(i) What will one observe when switch (S) is closed?

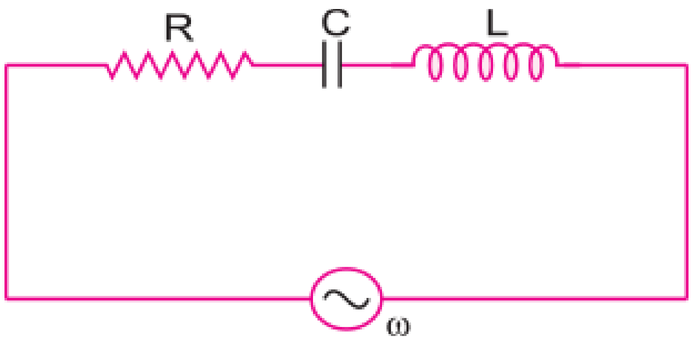
(ii) How will the glow of the bulb change when the battery is replaced by an ac source of rms voltage equal to the voltage of dc battery? Justify your answer in each case.

Ans. When switch S is closed, the bulb will give full brightness slowly, because inductor opposes the rise of current in the circuit depending on the value of ratio $\frac{L}{R}$.

(L = inductance, R = resistance of bulb).

(ii) When battery is replaced by an ac source, the inductor offers reactance (ωL) so impedance of circuit increases and the bulb will glow with less brightness.

Q. 6. In the circuit shown below R represents an electric bulb. If the frequency v = ($\frac{\omega}{2\pi}$) of the supply is doubled, how should the values of C and L be changed, so that the glow of bulb remains unchanged?



Ans. For same current value, the total impedance

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

must remain same.

Therefore, $\omega L - \frac{1}{\omega C}$ must remain same. As frequency (ω) is doubled, L and C must both be halved simultaneously.

Q. 7. When a circuit element 'X' is connected across an a.c. source, a current of $\sqrt{2}$ A flows through it and this current is in phase with the applied voltage. When another element 'Y' is connected across the same a.c. source, the same current flows in the circuit but it leads the voltage by $\frac{\pi}{2}$ radians.

(i) Name the circuit element X and Y.
(ii) Find the current that flows in the circuit when the series combination of X and Y is connected across the same a.c. voltage.
(iii) Net impedance

Ans. (i) When circuit element is X, the current is in phase with the applied emf, this implies that X is **pure resistance.**

When circuit element Y is connected, the current leads the voltage by $\frac{\pi}{2}$ so **Y** is **pure capacitance.**

(ii)

$$\text{Resistance of } X = R; \ I = \frac{V}{R} \quad \text{or} \quad \sqrt{2} = \frac{V}{R} \qquad (i)$$

$$\text{Reactance of } Y, \ X_C = \frac{1}{\omega C}, I = \frac{V}{X_C} \Rightarrow \sqrt{2C} = \frac{V}{X_C} \qquad (ii)$$

This implies $X_C = R$

When R and C are connected in series across same voltage source, then

$$\text{Impedance } \ Z = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + R^2} = \sqrt{2}R \qquad (iii)$$

$\therefore$ Current in circuit $I = \frac{V}{Z} = \frac{V}{\sqrt{2}R}$

From (1), $\frac{V}{R} = \sqrt{2}, \therefore I = \frac{1}{\sqrt{2}} \times \sqrt{2} = 1A$

(iii)

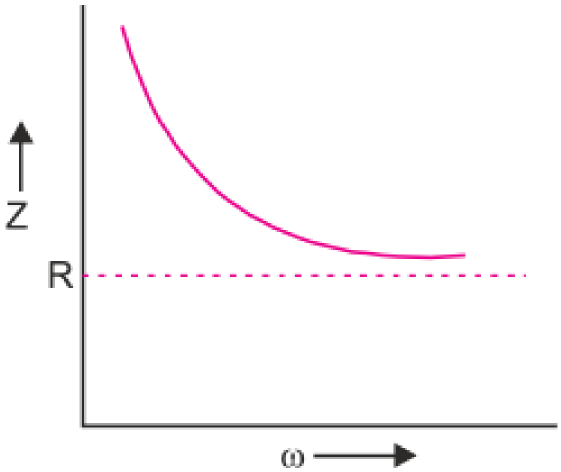
$$Z = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$$

i.e., impedance decreases with increase of angular frequency ω.

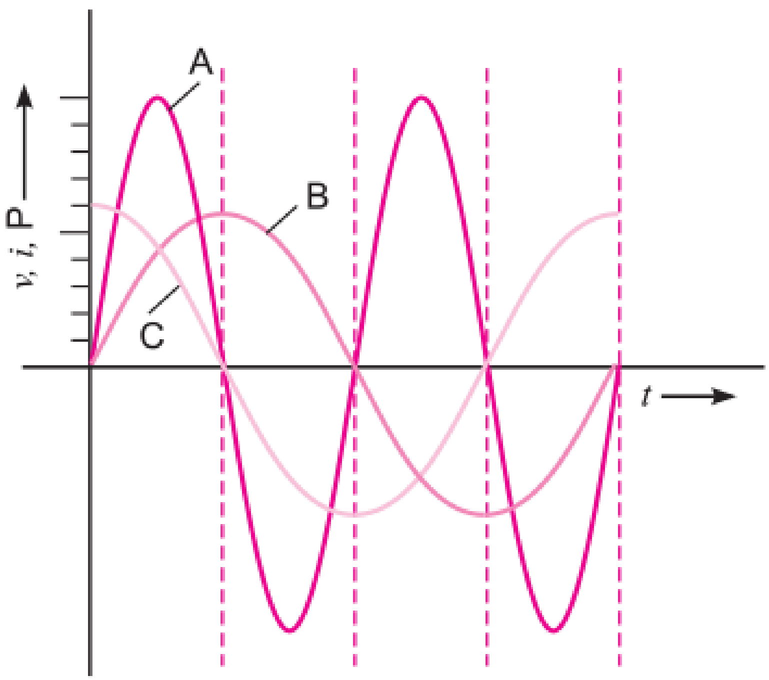
When ω = 0, Z = ∞

When ω = ∞, Z = R.

The graph of impedance Z versus ω is shown in fig.



Q. 8. A device ‘X’ is connected to an a.c. source. The variation of voltage, current and power in one complete cycle is shown in the figure.



(i) Which curve shows power consumption over a full cycle?

(ii) What is the average power consumption over a cycle?

(iii) Identify the device ‘X’. [NCERT Exemplar]

Ans. (i) A

(ii) Zero

(iii) L or C or LC

Q. 9. Answer the following question:

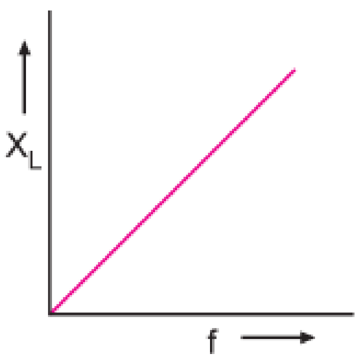
(i) Draw the graphs showing variation of inductive reactance and capacitive reactance with frequency of applied a.c. source.

(ii) Can the voltage drop across the inductor or the capacitor in a series LCR circuit be greater than the applied voltage of the a.c. source? Justify your answer.

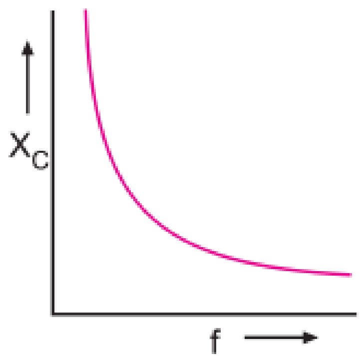
Ans. (i)

a. $X_L = w_L = 2\pi VL$; graph X_L of f and f is a straight line

b. $X_C = \frac{1}{\omega C} = \frac{1}{2\pi v C}$, graph of XC and f is a rectangular hyperbola as shown in figs.



(a)



(b)

(ii) Yes; because

As V_C and V_L have opposite faces, V_C or V_L may be greater than V. The situation may be as shown in figure where $V_C > V$