Previous Years' CBSE Board Questions

7.2 AC Voltage Applied to a Resistor

VSA (1 mark)

1. The peak value of emf in ac is E_0. Write its (i) rms (ii) average value over a complete cycle. *(Foreign 2011)*

2. Define the term 'rms value of the current'. How is it related to the peak value? *(AI 2010C)*

SA I (2 marks)

3. An alternating voltage given by $V = 140 \sin 314t$ is connected across a pure resistor of 50 Ω. Find
   (i) the frequency of the source.
   (ii) the rms current through the resistor. *(AI 2012)*

7.4 AC Voltage Applied to an Inductor

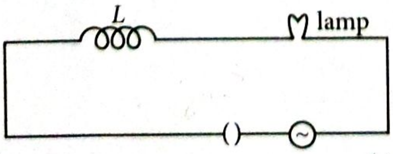
VSA (1 mark)

4. When an ac source is connected across an inductor, show on a graph the nature of variation of the voltage and the current over one complete cycle. *(Delhi 2012C)*

SA II (3 marks)

5. (i) When an AC source is connected to an ideal inductor show that the average power supplied by the source over a complete cycle is zero.

   (ii) A lamp is connected in series with an inductor and an AC source. What happens to the brightness of the lamp when the key is plugged in and an iron rod is inserted inside the inductor? Explain.



(AI 2016)

6. An ac voltage, $V = V_0 \sin \omega t$, is applied across a pure inductor L. Obtain an expression for the current I in the circuit and hence obtain the
   (i) inductive reactance of the circuit, and
   (ii) the 'phase', of the current flowing, with respect to the applied voltage. *(AI 2010C)*

LA (5 marks)

7. Show that in an ac circuit containing a pure inductor, the voltage is ahead of current by $\pi/2$ in phase. *(2/5, AI 2011)*

7.5 AC Voltage Applied to a Capacitor

VSA (1 mark)

8. Define capacitive reactance. Write its S.I. units. *(Delhi 2015)*

9. Plot a graph showing variation of capacitive reactance with the change in the frequency of the ac source. *(AI 2015C)*

10. A reactive element, in an a.c. circuit, causes the current flowing (i) to lead in phase by $\pi/2$, (ii) to lag in phase by $\pi/2$ with respect to the applied voltage. Identify the element in each case. *(Delhi 2010C)*

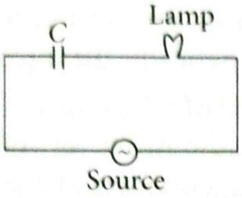
SA I (2 marks)

11. Show that the current leads the voltage in phase by $\pi/2$ in an ac circuit containing an ideal capacitor. *(Foreign 2014)*

12. A lamp is connected in series with a capacitor. Predict your observation when this combination is connected in turn across (i) ac source and (ii) a dc battery. What change would you notice in each case if the capacitance of the capacitor is increased? *(Delhi 2012C)*

13. An electric lamp having coil of negligible inductance connected in series with a capacitor and an ac source is glowing with certain brightness. How does the brightness of the lamp change on reducing the

(i) capacitance, and (ii) the frequency? Justify your answer.

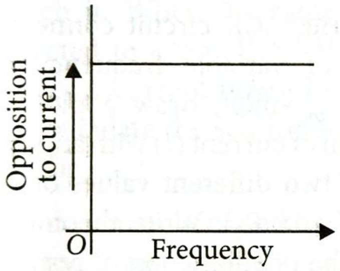


(Delhi 2010)

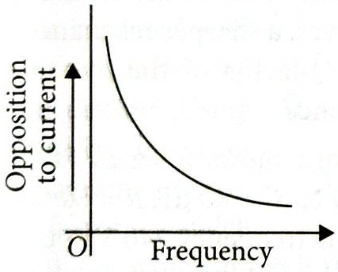
SA II **(3 marks)**

14. A lamp is connected in series with a capacitor. Predict your observations when the system is connected first across a dc and then an ac source. What happens in each case if the capacitance of the capacitor is reduced? *(Delhi 2013C)*

15. The graphs (i) and (ii) shown in the figure represent variation of opposition offered by the circuit elements, *X* and *Y*, respectively to the flow of alternating current *vs* the frequency of the applied emf. Identity the elements *X* and *Y*.



(i)



(ii)

(2/3, AI 2012C)

LA **(5 marks)**

16. A device *X* is connected across an ac source of voltage $V = V_0 \sin\omega t$. The current through *X* is given as $I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$.

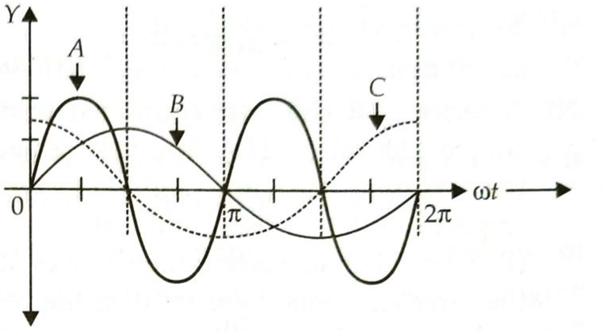
(a) Identify the device *X* and write the expression for its reactance.

(b) Draw graphs showing variation of voltage and current with time over one cycle of ac, for *X*.

(c) How does the reactance of the device *X* vary with frequency of the ac? Show this variation graphically.

(d) Draw the phasor diagram for the device *X*. *(2018)*

17. 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:



(a) Identify the device '*X*'.

(b) Which of the curves *A*, *B* and *C* represent the voltage, current and the power consumed in the circuit? Justify your answer.

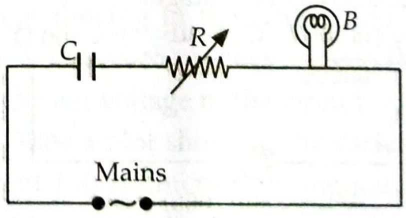
(c) How does its impedance vary with frequency of the ac source? Show graphically.

(d) Obtain an expression for the current in the circuit and its phase relation with ac voltage. *(AI 2017)*

7.6 AC Voltage Applied to a Series LCR Circuit

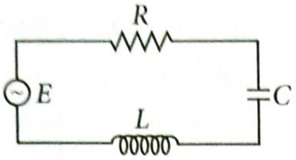
SA I **(2 marks)**

18. 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? *(Delhi 2014)*

19. The figure shows a series LCR circuit connected to a variable frequency 200 V source with $L = 50$ mH, $C = 80$ μF and $R = 40\ \Omega$.
Determine
(i) the source frequency which derives the circuit in resonance;
(ii) the quality factor (Q) of the circuit.



(AI 2014C)

20. A series LCR circuit is connected to an ac source (200 V, 50 Hz). The voltages across the resistor, capacitor and inductor are respectively 200 V, 250 V and 250 V.
(i) The algebraic sum of the voltages across the three elements is greater than the voltage of the source. How is this paradox resolved?
(ii) Given the value of the resistance of R is 40 Ω, calculate the current in the circuit. *(Foreign 2013)*

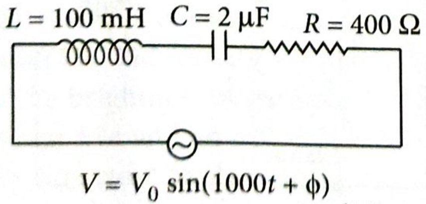
21. Calculate the quality factor of a series LCR circuit with $L = 2.0$ H, $C = 2$ μF and $R = 10\ \Omega$. Mention the significance of quality factor in LCR circuit. *(Foreign 2012)*

22. Write the expression for the impedance offered by the series combination of resistor, inductor and capacitor connected to an ac source of voltage $V = V_0 \sin \omega t$.

Show on a graph the variation of the voltage and the current with 'ωt' in the circuit. *(AI 2012C)*

SA II **(3 marks)**

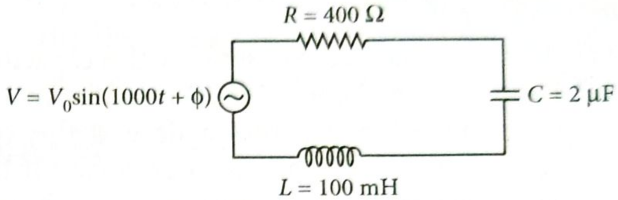
23. Find the value of the phase difference between the current and the voltage in the series LCR circuit shown below. Which one leads in phase: current or voltage?



(2/3, Delhi 2017)

24. An inductor L of inductive reactance X_L is connected in series with a bulb B and an ac source. How would brightness of the bulb change when
(i) number of turn in the inductor is reduced,
(ii) an iron rod is inserted in the inductor and (iii) a capacitor of reactance $X_C = X_L$ is inserted in series in the circuit. Justify your answer in each case. *(Delhi 2015)*

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

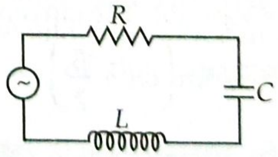


(2/3, AI 2015)

26. A source of ac voltage $V = V_0 \sin\omega t$ is connected to a series combination of a resistor 'R' and a capacitor 'C'. Draw the phasor diagram and use it to obtain the expression for (i) impedance of the circuit and (ii) phase angle. *(AI 2015C)*

27. In a series LCR circuit connected to an ac source of variable frequency and voltage $V = V_m \sin\omega t$, draw a plot showing the variation of current (I) with angular frequency (ω) for two different values of resistance R_1 and $R_2 (R_1 > R_2)$. Write the condition under which the phenomenon of resonance occurs. For which value of the resistance out of the two curves, a sharper resonance is produced? Define Q-factor of the circuit and give its significance. *(Delhi 2013)*

28. The figure shows a series LCR circuit with $L = 10.0$ H, $C = 40$ μF, $R = 60\ \Omega$ connected to a variable frequency 240 V 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 inductor at resonance.



(Delhi 2012)

29. A series LCR circuit is connected to an ac source. Using the phasor diagram, derive the expression for the impedance of the circuit.

Plot a graph to show the variation of current with frequency of the source, explaining the nature of its variation. *(AI 2012)*

30. A 100 μF capacitor in series with a 40 Ω resistance is connected to a 100 V, 60 Hz supply. Calculate (i) the reactance, (ii) the impedance and (iii) maximum current in the circuit. *(AI 2011C)*

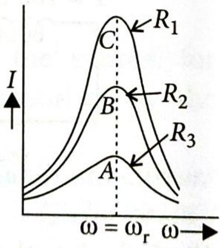
LA (5 marks)

31. (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 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. *(Delhi 2019)*

32. (a) What do you understand by 'sharpness of resonance' for a series *LCR* resonant circuit?



How is it related with the quality factor '*Q*' of the circuit? Using the graphs given in the diagram, explain the factors which affect it. For which graph is the resistance (*R*) minimum?

(b) A 2 μF capacitor, 100 Ω resistor and 8 H inductor are connected in series with an *ac* source. Find the frequency of the *ac* source for which the current drawn in the circuit is maximum. If the peak value of emf of the source is 200 V, calculate the (i) maximum current and, (ii) inductive and capacitive reactance of the circuit at resonance. *(AI 2019)*

33. 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 ? *(3/5, Delhi 2016)*

34. A 2 μF capacitor, 100 Ω resistor and 8 H inductor are connected in series with an ac source

(i) What should be the frequency of the source such that current drawn in the circuit is maximum? What is this frequency called?

(ii) If the peak value of emf of the source is 200 V, find the maximum current.

(iii) Draw a graph showing variation of amplitude of circuit current with changing frequency of applied voltage in a series *LCR* circuit for two different values of resistance R_1 and R_2 ($R_1 > R_2$).

(iv) Define the term 'Sharpness of Resonance'. Under what condition, does a circuit become more selective? *(Foreign 2016)*

35. (a) A series *LCR* circuit is connected to an ac source of variable frequency. Draw a suitable phasor diagram to deduce the expressions for the amplitude of the current and phase angle.

(b) Obtain the condition of resonance. Draw a plot showing the variation of current with the frequency of a.c. source for two resistances R_1 and R_2 ($R_1 > R_2$). Hence define the quality factor, Q and write its role in the tuning of the circuit. *(Delhi 2014C)*

36. (a) Using phasor diagram for a series *LCR* circuit connected to an ac source of voltage $V = V_0 \sin \omega t$, derive the relation for the current flowing in the circuit and the phase angle between the voltage across the resistor and the net voltage in the circuit.

(b) Draw a plot showing the variation of the current *I* as a function of angular frequency 'ω' of the applied ac source for the two cases of a series combination of (i) inductance L_1, capacitance C_1 and and resistance R_1 and (ii) inductance L_2, capacitance C_2 and resistance R_2 where $R_2 > R_1$. Write the relation between

L_1, C_1 and L_2, C_2 at resonance. Which one, of the two, would be better suited for fine tuning in a receiver set? Give reason. *(Foreign 2013)*

37. (a) An ac source of voltage $V = V_0 \sin \omega t$ is connected across a series combination of an inductor, a capacitor and a resistor. Use the phasor diagram to obtain the expression for (i) impedance of the circuit and (ii) phase angle between the voltage and the current.

(b) A capacitor of unknown capacitance, a resistor of 100 Ω and an inductor of self inductance $L = (4/\pi^2)$ henry are in series connected to an ac source of 200 V and 50 Hz, Calculate the value of the capacitance and the current that flows in the circuit when the current is in phase with the voltage. *(AI 2013C)*

38. Derive an expression for the impedance of a series *LCR* circuit connected to an ac supply of variable frequency.

Plot a graph showing variation of current with the frequency of the applied voltage.

Explain briefly how the phenomenon of resonance in the circuit can be used in the tuning mechanism of a radio or a TV set. *(Delhi 2011)*

39. Explain
(i) Resistance,
(ii) Reactance and
(iii) Impedance *(Delhi 2011C)*

7.7 Power in AC Circuit : The Power Factor

VSA (1 mark)

40. Define 'quality factor' of resonance in series *LCR* circuit. What is its SI unit? *(Delhi 2016)*

41. The power factor of an ac circuit is 0.5. What is the phase difference between voltage and current the circuit? *(Foreign 2016)*

42. Why is the use of ac voltage preferred over dc voltage? Give two reasons. *(AI 2014)*

43. Define the term wattless current. *(Delhi 2011)*

SA I (2 marks)

44. In series *LCR* circuit obtain the conditions under which (i) the impedance of the circuit is minimum and (ii) wattless current flows in the circuit. *(Foreign 2014)*

45. A resistor '*R*' and an element '*X*' are connected in series to an ac source of voltage. The voltage is found to lead the current in phase by $\pi/4$. If '*X*' is replaced by another element '*Y*', the voltage lags behind the current by $\pi/4$.

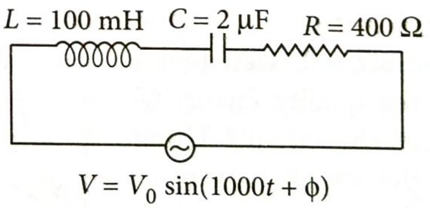
(i) Identify elements '*X*' and '*Y*'.

(ii) When both '*X*' and '*Y*' are connected in series with '*R*' to the same source, will the power dissipated in the circuit be maximum or minimum? Justify your answer. *(Foreign 2013)*

46. A light bulb is rated 100 W for 220 V ac supply of 50 Hz. Calculate
(i) the resistance of the bulb;
(ii) the rms current through the bulb. *(AI 2012)*

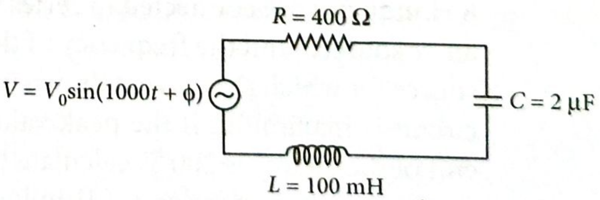
SA II (3 marks)

47. 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.



(1/3, Delhi 2017)

48. 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.



(1/3, AI 2015)

49. A circuit containing an 80 mH inductor and a 250 mF capacitor in series connected to a 240 V, 100 rad/s supply. The resistance of the circuit is negligible.

(i) Obtain rms value of current.

(ii) What is the total average power consumed by the circuit? *(Delhi 2015C)*

50. A voltage $V = V_0 \sin\omega t$ is applied to a series LCR circuit. Derive the expression for the average power dissipated over a cycle. Under what condition is

(i) no power dissipated even though the current flows through the circuit,

(ii) maximum power dissipated in the circuit? *(AI 2014)*

51. (a) 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 $\frac{1}{2}i_m^2 R$.

(b) A light bulb is rated at 100 W for a 220 V ac supply. Calculate the resistance of the bulb. *(AI 2013)*

52. When an ac source is connected to an ideal capacitor show that the average power supplied by the source over a complete cycle is zero. *(2/3, Delhi 2013C)*

53. Prove that an ideal capacitor, in an ac circuit does not dissipate power. *(AI 2011)*

54. A series LCR circuit is connected to a 220 V variable frequency (ac) supply. If $L = 10$ mH, $C = \left(\frac{400}{\pi^2}\right)\mu$F and $R = 55\ \Omega$.

(a) Find the frequency of the source, for which the average power absorbed by the circuit is maximum.

(b) Calculate the value of maximum current amplitude. *(Delhi 2010C)*

LA (5 marks)

55. In 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 P_1/P_2. *(2/5, Delhi 2016)*

56. (a) A voltage $V = V_0 \sin\omega t$ applied to a series LCR circuit drives a current $i = i_0 \sin\omega t$ in the circuit. Deduce the expression for the average power dissipated in the circuit.

(b) For circuits used for transporting electric power, a low power factor implies large power loss in transmission. Explain.

(c) Define the term 'Wattless current'. *(Delhi 2012C)*

57. (a) An alternating voltage $V = V_m \sin\omega t$ applied to a series LCR circuit drives a current given by $i = i_m \sin(\omega t + \phi)$. Deduce an expression for the average power dissipated over a cycle.

(b) For circuits used for transporting electric power, a low power factor implies large power loss in transmission. Explain.

(c) Determine the current and quality factor at resonance for a series LCR circuit with $L = 1.00$ mH, 1.00 nF and $R = 100\ \Omega$ connected to an ac source having peak voltage of 100 V. *(Foreign 2011)*

58. A series LCR circuit is connected to an ac source having voltage $V = V_m \sin\omega t$. Derive the expression for the instantaneous current I and its phase relationship to the applied voltage. Obtain the condition for resonance to occur. Define 'power factor'. State the conditions under which it is (i) maximum and (ii) minimum. *(Delhi 2010)*

7.9 Transformers

VSA (1 mark)

59. Why is the core of a transformer laminated? *(Delhi 2013C)*

60. Mention the two characteristic properties of the material suitable for making core of a transformer. *(AI 2012)*

61. What is the function of a step-up transformer? *(AI 2011C)*

SA I (2 marks)

62. 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? *(AI 2012)*

LA (5 marks)

63. (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 0.5 Ω 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. *(Delhi 2019)*

64. (a) Draw a labelled diagram of a step-up transformer. Obtain the ratio of secondary to primary voltage in terms of number of turns and currents in the two coils.

(b) A power transmission line feeds input power at 2200 V to a step-down transformer with its primary windings having 3000 turns. Find the number of turns in the secondary to get the power output at 220 V. *(Delhi 2017)*

65. (i) Draw a labelled diagram of a step-down transformer. State the principle of its working.

(ii) Express the turn ratio in terms of voltages.

(iii) Find the ratio of primary and secondary currents in terms of turn ratio in an ideal transformer.

(iv) How much current is drawn by the primary of a transformer connected to 220 V supply when it delivers power to a 110 V – 550 W refrigerator ? *(AI 2016)*

66. (i) Write the function of a transformer. State its principle of working with the help of a diagram. Mention various energy losses in this device.

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

(a) number of turns in secondary

(b) current in primary

(c) voltage across secondary

(d) current in secondary

(e) power in secondary *(Delhi 2016)*

67. (a) Draw a schematic arrangement for winding of primary and secondary coil in a transformer when the two coils are would on top of each other.

(b) State the underlying principle of a transformer and obtain the expression for the ratio of secondary to primary voltage in terms of the

(i) number of secondary and primary windings and

(ii) primary and secondary currents.

(c) Write the main assumption involved in deriving the above relations.

(d) Write any two reasons due to which energy losses may occur in actual transformers. *(AI 2014C)*

68. (a) Explain with the help of a labelled diagram, the principle and working of a transformer. Deduce the expression for its working formula.

(b) Name any four causes of energy loss in an actual transformer. *(AI 2013C)*

69. (a) State the principle of a step-up transformer. Explain, with the help of a labelled diagram, its working.

(b) Describe briefly any two energy losses, giving the reasons for their occurrence in actual transformers. *(Foreign 2012)*

70. (i) With the help of a labelled diagram, describe briefly the underlying principle and working of a step up transformer.

(ii) Write any two sources of energy loss in a transformer.

(iii) A step up transformer converts a low input voltage into a high output voltage. Does it violate law of conservation of energy? Explain. *(Delhi 2011)*

71. A power transmission line feeds power at 2200 V with a current of 5 A to step down transformer with its primary winding having 4000 turns. Calculate the number of turns and the current in the secondary in order to get output power at 220 V. *(2/5, Foreign 2011)*

72. (a) Draw a schematic diagram of a step-up transformer. Explain its working principle.

Assuming the transformer to be 100% efficient, obtain the relation for (i) the current in the secondary in terms of the current in the primary, and (ii) the number of turns in the primary and secondary windings.

(b) Mention two important energy losses in actual transformers and state how these can be minimized. *(Delhi 2011C)*

73. Draw a schematic diagram of a step-up transformer. Explain its working principle. Deduce the expression for the secondary to primary voltage in terms of the number of turns in the two coils. In an ideal transformer,

how is this ratio related to the currents in the two coils?
How is the transformer used in large scale transmission and distribution of electrical energy over long distances? *(AI 2010)*

74. A step down transformer operates on a 2.5 kV line. It supplies a load with 20 A. The ratio of the primary winding to the secondary is 10 : 1. If the transformer is 90% efficient, calculate:
(i) the power output,
(ii) the voltage, and
(iii) the current in the secondary.
(3/5, Foreign 2010)

Detailed Solutions

1. E_0 = peak value of emf

(i) rms value $[E_{\text{rms}}] = \dfrac{E_0}{\sqrt{2}}$

(ii) average value $[E_{av}]$ = zero

2. Root Mean Square value of the current : The root mean square (rms) value of ac is defined as the value of steady current, which when passed through a resistance for a given time would produce the same amount of heat as is produced by the alternating current in the same resistance in same time. It is denoted by I_{rms}.

$$\therefore \quad I_{\text{rms}} = \frac{I_0}{\sqrt{2}} = 0.707 I_0$$

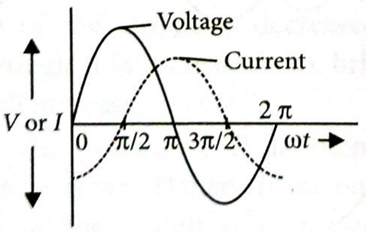
3. (i) $2\pi\upsilon = 314 \text{ rad s}^{-1} \Rightarrow \upsilon = 50 \text{ Hz}$

(ii) $i_{\text{rms}} = \dfrac{V_{\text{rms}}}{R}$ where $V_{\text{rms}} = \dfrac{V}{\sqrt{2}}$

$$= \frac{140}{\sqrt{2} \times 50} = 1.98 \text{A} \approx 2\text{A}$$

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

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



5. (i) As $P_{av} = V_{rms} I_{rms} \cos\phi$

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

$\therefore \quad \phi = \pi/2 \quad$ so, $\quad P_{av} = V_{rms} I_{rms} \cos \pi/2$

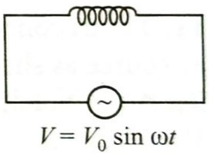
or $\quad P_{av} = V_{rms} I_{rms} \times 0.$ or $P_{av} = 0.$

(ii) Brightness of the lamp decreases. It is because when iron rod is inserted inside the inductor, its inductance L increases, thereby increasing its inductive reactance X_L and hence impedance Z of the circuit. As $I_{rms} = \dfrac{V_{rms}}{Z}$, so, this decreases the current I_{rms} in the circuit and hence the brightness of lamp.

6. The instantaneous ac potential difference across the ends of an inductor of inductance is

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

If I is the instantaneous current through L at instant t,



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

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

Integrating both sides,

$$I = \frac{V_0}{L}\int_0^t \sin\omega t dt = \frac{V_0}{L}\left[\frac{-\cos\omega t}{\omega}\right]_0^t$$

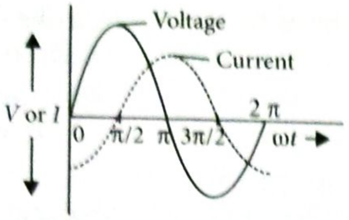
$$\text{or } I = \frac{-V_0}{\omega L}\cos\omega t \text{ or } I = \frac{V_0}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right) \quad \text{...(ii)}$$

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

where, $I = \dfrac{V_0}{\omega L}$ is the amplitude of the current.

(i) The quantity ωL in $I = \dfrac{V_0}{\omega L}$ is analogous to the resistance and is called inductive reactance denoted by X_L.
$X_L = \omega L = 2\pi\upsilon L$

(ii) from eqns (i) and (ii), it is clear that, in an ac circuit containing inductance, current lags voltage by $\pi/2$.



7. *Refer to answer 6.*

8. Capacitive reactance is the resistance offered by a capacitor to flow of ac through it. It is denoted by X_C.

Mathematically,

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

Where υ = frequency of ac source

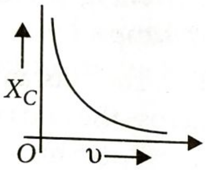
C = capacitance of the capacitor.

Ohm (Ω) is the SI unit of capacitive reactance.

9. Showing variation of capacitive reactance with the change in the frequency of the AC source.

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

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



10. In case (i), reactive element is capacitor and in case (ii), reactive element is inductor.

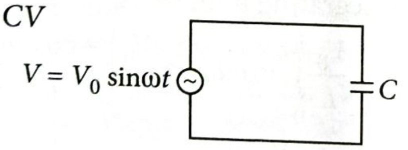
11. Let us consider a capacitor C connected to an ac source as shown in the figure.

Let the ac voltage applied be

$$V = V_0 \sin\omega t \qquad \text{...(i)}$$

$$\therefore \quad V = \frac{q}{C} \text{ or } q = CV$$

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

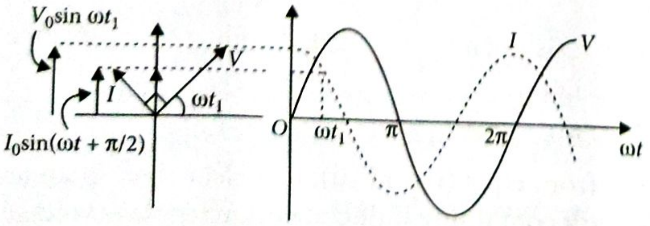


$$I = \frac{d}{dt}(CV_0 \sin\omega t) = \omega C V_0 \cos\omega t = I_0 \cos\omega t$$

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

where,

$$I_0 = \omega C V_0 = \frac{V_0}{\frac{1}{\omega c}} = \text{current amplitude.}$$



Hence, the current leads the voltage in phase by $\pi/2$

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

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

13. When AC source is connected, the capacitor offers capacitive reactance $X_C = \frac{1}{\omega C} = \frac{1}{2\pi\upsilon C}$.

The current flows in the circuit and the lamp glows.

(i) On reducing capacitance C, X_C increases so current in the circuit reduces. Therefore, the brightness of the bulb reduces.

(ii) On reducing frequency υ, X_C increases so current in the circuit reduces. Therefore, the brightness of the bulb reduces.

14. For dc, capacitor is an open circuit because $X_C = \frac{1}{\omega C} = \infty$, the lamp will not glow at all, even if C is reduced. For ac, the lamp will glow because capacitor conducts ac. If C is reduced, the reactance X_C will increase and the brightness of the lamp will decrease further.

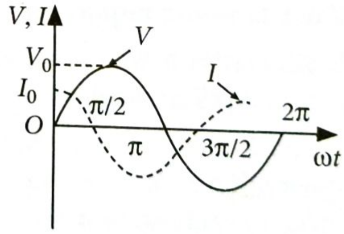
15. (i) Element X is a pure resistor because opposition to current is independent of frequency.

(ii) $X_C = \frac{1}{\omega C} = \frac{1}{2\pi\upsilon C}$, graph of X_C and υ is a rectangular hyperbola. Therefore element Y is capacitor.

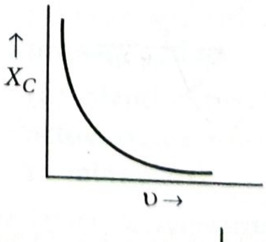
16. (a) Here device X is a capacitor.

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

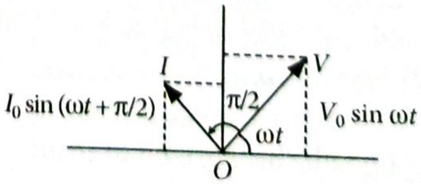
(b)



(c)



(d)



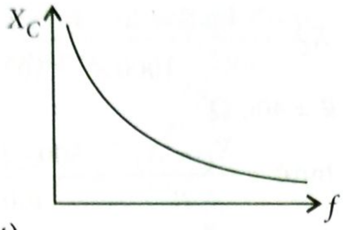
17. (a) Device X is capacitor.

(b) $B \rightarrow$ Voltage (Because it is sine wave)

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

$A \rightarrow$ Power (Average power over one cycle is zero)

(c) $X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi f C}$



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

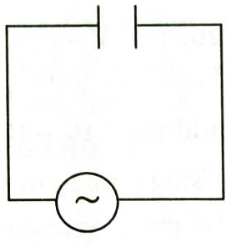
$C = \dfrac{q}{V}$

$q = CV_0 \sin\omega t$

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

$= \omega C V_0 \sin\omega t$

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



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

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

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

18. For the RC circuit,

Impedance, $Z = \sqrt{R^2 + (1/\omega C)^2}$

Current, $I = \dfrac{\varepsilon_0}{Z}$ ... (i)

Case 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.

Case II : The resistance R is increased and capacitance is same. Hence, from equation (i), impedance of the circuit is increased and the current flowing through it is decreased. So, brightness of the bulb will decrease.

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

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

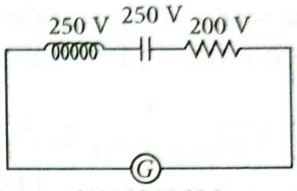
$$\omega = \frac{10^3}{2} = 500 \text{ rad s}^{-1} \Rightarrow \upsilon = \frac{500}{2\pi} = 80 \text{ Hz}$$

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

20. (i) From given parameter $V_R = 200$ V, $V_L = 250$ V and $V_C = 250$ V$\cdot V_{\text{eff}}$ should be given as

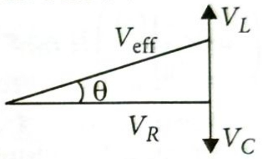
$V_{\text{eff}} = V_R + V_L + V_C$

$= 200 \text{ V} + 250 \text{ V} + 250 \text{ V} = 700\text{V}$



(250 V, 50 Hz)

However, $V_{\text{eff}} > 200$ V of the ac source. This paradox can be solved only by using phasor diagram, as given below :



$$(V_{\text{eff}}) = \sqrt{V_R^2 + (V_L - V_C)^2}$$

Since $V_L = V_C$

so $V_{\text{eff}} = V_R = 200$ V

(ii) Given $R = 40\ \Omega$, so current in the LCR circuit.

$$I_{\text{eff}} = \frac{V_{\text{eff}}}{R} = \frac{200}{40} = 5 \text{ A} \quad [X_L = X_C \text{ or } Z = R]$$

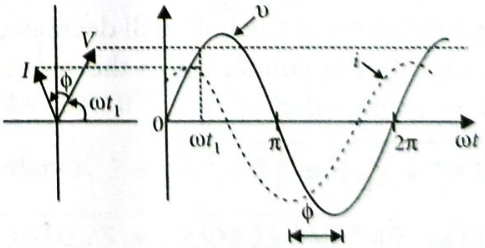
21. We have, $Q = \dfrac{1}{R}\sqrt{\dfrac{L}{C}} = \dfrac{1}{10}\sqrt{\dfrac{2}{2 \times 10^{-6}}} = 100$

It signifies the sharpness of resonance.

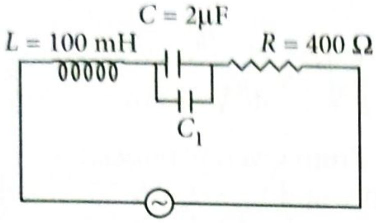
22. Impedance offered by series LCR circuit,

$$Z = \sqrt{R^2 + (X_C - X_L)^2}, \quad V = \sqrt{V_R^2 + (V_C - V_L)^2}$$

As V_C and V_L are the voltages applied across capacitor C and inductor L. V_C or V_L may be greater than V. The situation may be shown in figure, where $V_C > V$.



23. (i) Given : $V = V_0 \sin(1000t + \phi)$, $R = 400\ \Omega$, $L = 100$ mH, $C = 2\ \mu F$



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

The standard equation is given as

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

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

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

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

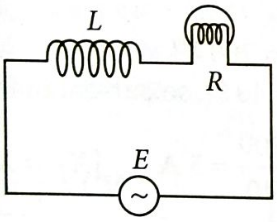
$$\phi = \tan^{-1}\frac{X_C - X_L}{R}$$

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

$$\phi = 45°$$

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

24. Inductive reactance, $X_L = \omega L$



Impedance of the circuit,

$$Z = \sqrt{X_L^2 + R^2} = \sqrt{\omega^2 L^2 + R^2}$$

(i) When the number of turns in a inductor coil decreases then its inductance L decreases. So, the net impedance of the circuit decreases and current through the bulb (circuit) increases. Hence brightness (I^2R) of bulb increases.

(ii) When an iron rod is inserted in the inductor, then its inductance L increases. So, Z will increase and current through the bulb will decrease. Hence, brightness of the bulb will decrease.

(iii) A capacitor is connected in the series in the circuit, so its impedance,

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

$$Z = R \quad (\because X_L = X_C)$$

This is the case of resonance so maximum current will flow through the circuit. Hence brightness of the bulb will increase.

25. Here, $V = V_0 \sin(1000t + \phi)$

On comparing with $V = V_0 \sin(\omega t + \phi)$

$\omega = 1000$ rad s^{-1}

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

$$X_C = \frac{1}{\omega C} = \frac{1}{1000 \times 2 \times 10^{-6}} = \frac{1}{2 \times 10^{-3}} = 500\ \Omega$$

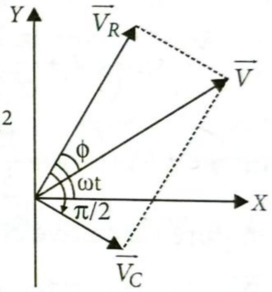
$R = 400\ \Omega$

$$\tan\phi = \frac{X_C - X_L}{R} = \frac{500-100}{400} = \frac{400}{400}$$

$$\phi = \tan^{-1}\left(\frac{400}{400}\right) = \tan^{-1}(1) = 45°$$

26. (i) $V = V_0 \sin\omega t$ ...(i)

From diagram, by parallelogram law of vector addition, $\vec{V_R} + \vec{V_C} = \vec{V}$



Using pythagorean theorem, we get

$$V^2 = V_R^2 + V_C^2 = (IR)^2 + (IX_C)^2$$

$$V^2 = I^2(R^2 + X_C^2)$$

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

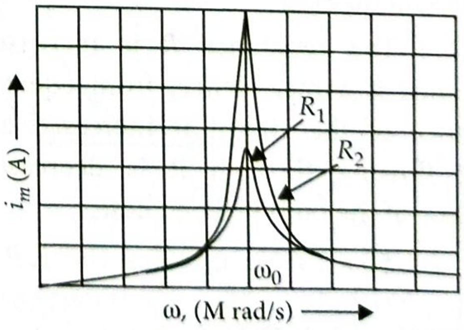
where, $Z = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \dfrac{1}{\omega^2 C^2}}$

Z = impedance.

The phase angle ϕ between resultant voltage and current is given by

$$\tan\phi = \frac{V_C}{V_R} = \frac{IX_C}{IR} = \frac{X_C}{R} = \frac{1/\omega C}{R} = \frac{1}{\omega RC}$$

27. Figure shows the variation of i_m with ω in a LCR series circuit for two values of resistance R_1 and $R_2 (R_1 > R_2)$,



The condition for resonance in the LCR circuit is,

$$X_L = X_C \Rightarrow \omega_0 L = \frac{1}{\omega_0 C} \Rightarrow \omega_0 = \frac{1}{\sqrt{LC}}$$

We see that the current amplitude is maximum at the resonant frequency. Since $i_m = V_m / R$ at resonance, the current amplitude for case R_2 is sharper to that for case R_1.

Quality factor or simply the *Q*-factor of a resonant *LCR* circuit is defined as the ratio of voltage drop across the resistance at resonance.

$$Q = \frac{V_L}{V_R} = \frac{\omega L}{R}$$

Thus finally, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

The *Q* factor determines the sharpness at resonance as for higher value of *Q* factor the tuning of the circuit and its sensitivity to accept resonating frequency signals will be much higher.

28. Here, $L = 10.0$ H, $C = 40\ \mu\text{F} = 40 \times 10^{-6}$ F

$R = 60\ \Omega$, $V_{\text{rms}} = 240$ V

(i) At resonance the angular frequency of the source is

$$\omega_r = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(10.0)(40\times 10^{-6})}} = \frac{1}{2\times 10^{-2}} = 50 \text{ rad s}^{-1}$$

(ii) At resonating frequency

Impedance, $Z = R \qquad (\because\ X_L = X_C)$

The rms current at resonance

$$\therefore\ I_{\text{rms}} = \frac{V_{\text{rms}}}{Z} = \frac{V_{\text{rms}}}{R} = \frac{240 \text{ V}}{60\ \Omega} = 4 \text{ A}$$

(iii) The inductive reactance is

$X_L = \omega_r L = 50 \times 10.0 = 500\ \Omega$

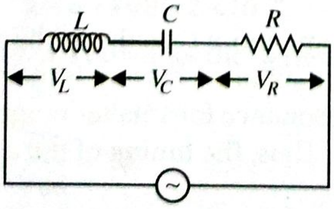
The rms potential drop across inductor at resonance,

$(V_{\text{rms}})_L = I_{\text{rms}} \times X_L = (4 \text{ A})\ (500\ \Omega) = 2000$ V

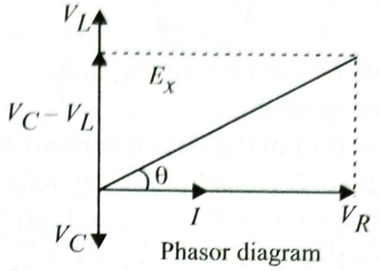
29. AC circuit containing inductor, capacitor and resistor in series [Series *LCR* circuit]

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 $V_C = I \times X_C$



Phasor diagram

which lags behind current *I* by phase angle of $\pi/2$, and voltage drop across the resistor is

$V_R = I\,R$

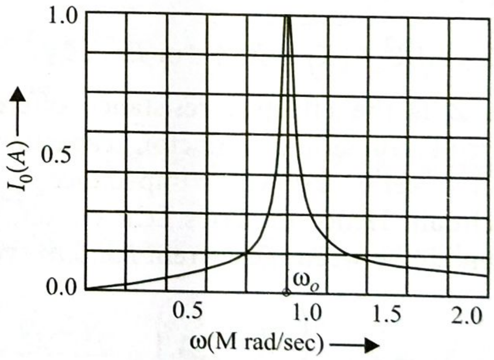
which is in phase with current *I*. So the net voltage *E*, across the circuit is

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

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

$$\tan\phi = \frac{X_L - X_C}{R} = \frac{\left(\omega L - \dfrac{1}{\omega C}\right)}{R}$$



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

30. (i) Reactance, $X_C = \frac{1}{2\pi f C}$

$$= \frac{1}{2\times 3.14\times 60\times 10^{-4}} = \frac{1}{.03768} = 26.5\ \Omega$$

(ii) Impedance, $Z = \sqrt{R^2 + X_C^2} = \sqrt{40^2 + 26.5^2}$

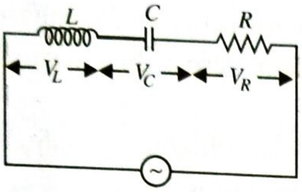
$= \sqrt{1600 + 702.25} = \sqrt{2302.25} = 47.98 = 48\ \Omega$

(iii) $V_{eff} = 100$ V

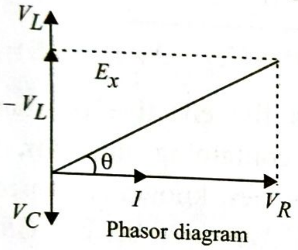
$$I_0 = \frac{V_0}{Z} = \frac{\sqrt{2}V_{eff}}{Z} = \frac{1.414 \times 100}{48} = 2.95 \text{ A}.$$

31. (a) AC circuit containing inductor, capacitor and resistor in series.

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 $V_C = I \times X_C$



Phasor diagram

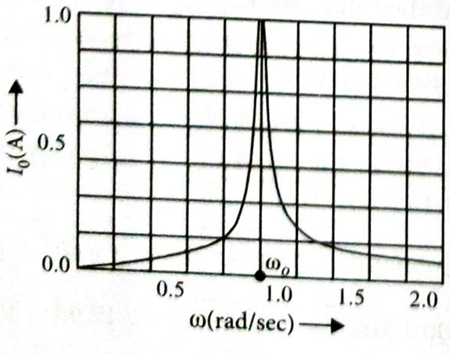
which lags behind current I by phase angle of $\pi/2$, and voltage drop across the resistor is $V_R = IR$ which is in phase with current I. So the net voltage E, across the circuit is

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

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

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



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

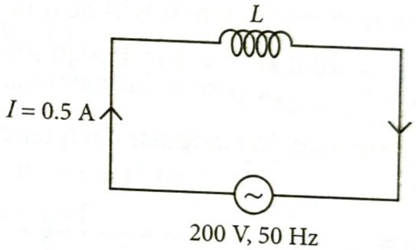
(b) At resonance, $X_L = X_C$

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

$\therefore \quad \phi = 0°$

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

(c) 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 to d.c. voltage, current 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, $I = 0.5$ A, $V = 200$ V, $\upsilon = 50$ Hz

$\therefore$ Inductive reactance,

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

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

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

32. Sharpness of resonance : It is defined as the ratio of the voltage developed across the inductance (L) or capacitance (C) at resonance to the voltage developed across the resistance (R).

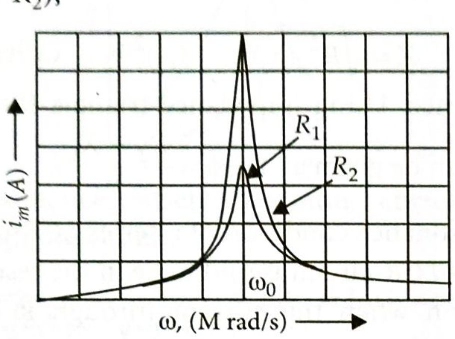
$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

It may also be defined as the ratio of resonance angular frequency to the bandwidth of the circuit

$$Q = \frac{\omega_r}{2\Delta\omega}$$

Circuit become more selective if the resonance is more sharp, maximum current is more, the circuit is close to resonance for smaller range of ($2\Delta\omega$) of frequencies. Thus, the tuning of the circuit will be good.

Figure shows the variation of i_m with ω in a *LCR* series circuit for two values of resistance R_1 and $R_2 (R_1 > R_2)$,



The condition for resonance in the *LCR* circuit is,

$$X_L = X_C \Rightarrow \omega_0 L = \frac{1}{\omega_0 C} \Rightarrow \omega_0 = \frac{1}{\sqrt{LC}}$$

We see that the current amplitude is maximum at the resonant frequency. Since $i_m = V_m / R$ at resonance, the current amplitude for case R_2 is sharper to that for case R_1.

Quality factor or simply the *Q*-factor of a resonant *LCR* circuit is defined as the ratio of voltage drop across the resistance at resonance.

$$Q = \frac{V_L}{V_R} = \frac{\omega L}{R}$$

Thus finally, $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

The *Q* factor determines the sharpness at resonance as for higher value of *Q* factor the tuning of the circuit and its sensitivity to accept resonating frequency signals will be much higher. At resonance, current in *ac* series *LCR* circuit is maximum, and depends only on the ohmic resistance *R* of the circuit. Thus if the ohmic resistance *R* of series *LCR* circuit is low, then large current flows in circuit at resonance. So graph *C* *i.e.* resistance R_1 has minimum value.

(b) To draw maximum current from a series *LCR* circuit, the circuit at particular frequency $X_L = X_C$.

The frequency of the source will be

$$\upsilon = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2 \times 3.14\sqrt{8 \times 2 \times 10^{-6}}} = 39.80 \text{ Hz}$$

This frequency is known as the series resonance frequency.

(i) $I_0 = \frac{E_0}{R} = \frac{200}{100} = 2\,\text{A}$

(ii) Inductive reactance, $X_L = \omega L = 2\pi\upsilon L$
$= 2 \times 3.14 \times 39.80 \times 8 \simeq 2000\ \Omega$

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

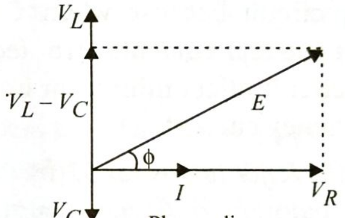
$$= \frac{1}{2 \times 3.14 \times 39.80 \times 2 \times 10^{-6}} = 2000\ \Omega$$

33. 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

$V_C = I \times X_C$



Phasor diagram

which lags behind current *I* by phase angle of $\pi/2$, and voltage drop across the resistor is

$V_R = IR$

which in phase with current *I*. So the net voltage *E* across the circuit is (using phasor diagram)

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

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

or $E = IZ$

where $Z = \sqrt{R^2 + (X_L - X_C)^2}$ is known as impedance.

Phase angle between voltage and current, is given by

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

A series *LCR* circuit has its natural angular frequency

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

and natural (resonating) frequency $\upsilon = \frac{1}{2\pi\sqrt{LC}}$

when the applied ac in the circuit has this frequency the series *LCR* circuit offers minimum impedance *i.e.*, only '*R*' and current at this frequency is maximum. In the case of resonance, voltage and current are in same phase.

Above mentioned condition is known as condition of resonance. In this condition

(i) Inductive and capacitive reactances are equal

$X_L = X_C$

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

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

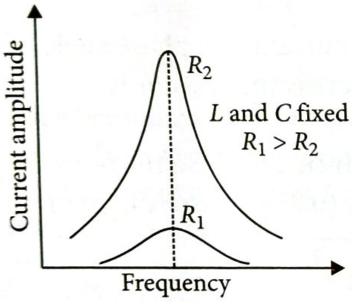
(ii) Potential drop across inductor and capacitor are equal.

$V_L = V_C$

(iii) The series resonant circuit is also called an acceptor circuit because when a number of different frequency currents are fed into the circuit, the circuit offers minimum impedance to natural frequency current.

34. *(i) and (ii) Refer to answer 32(b).*

(iii)



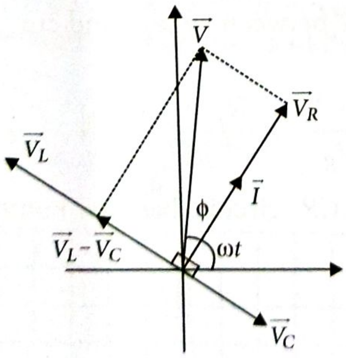
(iv) *Refer to answer 32(a).*

35. (a) AC source, $V = V_0 \sin\omega t$

Voltage across resistor of resistance R, $V_R = IR$

Voltage across inductor of inductance L, $V_L = IX_L$

Voltage across capacitor of capacitance C, $V_C = IX_C$

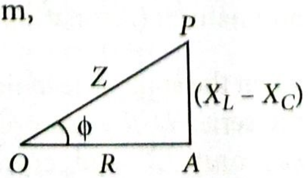


Using Pythagorean theorem,

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

$$V^2 = I^2R^2 + I^2(X_L - X_C)^2$$

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



$$\therefore \quad I_0 = \frac{V_0}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{V_0}{Z}$$

where, $Z = \sqrt{R^2 + (X_L - X_C)^2}$ is called its impedance. Using impedance triangle the phase angle can be given as $\tan\phi = \frac{X_L - X_C}{R}$

(b) Resonance condition of a series LCR-circuit : A series LCR-circuit is said to be in the resonance condition when the current through it has its maximum value.

The current amplitude I_0 for a series LCR-circuit is given by

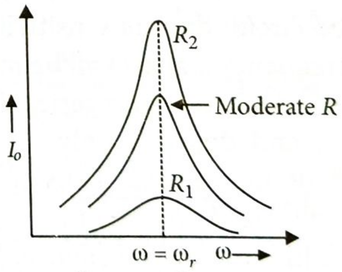
$$I_0 = \frac{V_0}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$$

Clearly, I_0 becomes zero both for $\omega \to 0$ and $\omega \to \infty$. The value of I_0 is maximum when

$$\omega L - \frac{1}{\omega C} = 0 \text{ or } \omega = \frac{1}{\sqrt{LC}}$$

Then impedance, $Z = \sqrt{R^2 + (\omega L - \omega L)^2} = R$

Clearly, the impedance is minimum. The current and voltage are in the same phase and the current in the circuit is maximum. This condition of the LCR-circuit is called resonance condition.



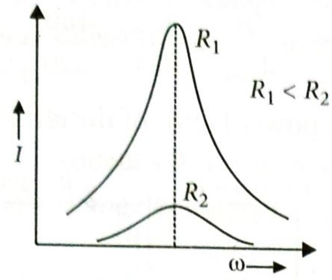
The Q-factor of a series resonant circuit is defined as the ratio of the resonant frequency to the difference in two frequencies taken on both sides of the resonant frequency such that at each frequency, the current amplitude becomes $\frac{1}{\sqrt{2}}$ times the value at resonant frequency.

36. (a) *Refer to answer 35(a).*

$I = I_0 \sin(\omega t - \phi)$ For $V_L > V_C$ or $X_L > X_C$

$I = I_0 \sin(\omega t + \phi)$ For $V_L < V_C$ or $X_L < X_C$

(b) Variation of the current I as a function of angular frequency ω.



At resonance, when maximum current flows through the circuit.

$$\omega_r = \frac{1}{\sqrt{L_1C_1}} = \frac{1}{\sqrt{L_2C_2}} \Rightarrow L_1C_1 = L_2C_2 \Rightarrow \frac{L_1}{L_2} = \frac{C_2}{C_1}$$

For fine tuning in the receiver set, combination L_1C_1 and R_1 is better because maximum current flows through the circuit.

37. (a) *Refer to answer 35(a).*

(b) $L = \frac{4}{\pi^2}\,\text{H}, \upsilon = 50\ \text{Hz}, R = 100\ \Omega, V = 200\ \text{V}$

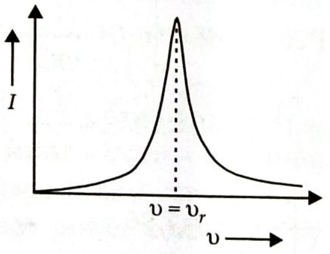
$$\because\ X_L = X_C \text{ or } \omega L = \frac{1}{\omega C}$$

$$C = \frac{1}{\omega^2 L} = \frac{1}{4\pi^2\upsilon^2 \times L} = \frac{1}{4\pi^2 \times 50 \times 50 \times \frac{4}{\pi^2}}$$

$$= \frac{1}{2500 \times 16} = \frac{1}{40000} = 2.5 \times 10^{-5}\ \text{F} = 25\ \mu\text{F}$$

$$I = \frac{V}{Z} = \frac{V}{R} = \frac{200}{100} = 2\ \text{A}$$

38. *Refer to answer 35(a).*



The practical application of series resonance circuit is in radio and T.V. receiver sets. The antenna of a radio/T.V. intercepts signals from many broadcasting stations. To receive one particular radio station/T.V. channel, we tune our receiver set by changing the capacitance of a capacitor in the tuning circuit of the set such that resonance frequency of the circuit becomes equal to the frequency of the desired station. Therefore, resonance occurs. The amplitude of current with the frequency of the signal from the desired station becomes maximum and it is received in our set.

39. (i) Resistance : The property due to which a conductor resists the flow of electrons through it, is called resistance of the conductor. It is measured by the ratio of potential difference between the ends of the conductor to the current flowing through it. If an alternating current is passed through a resistor, the current and voltage are in the same phase.

(ii) Reactance : The opposition offered by an inductor or a capacitor or both to the flow of ac through it, is called reactance.

There are two types of reactance :

(i) Capacitive reactance (X_C)

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi\upsilon C} \Rightarrow X_C \propto \frac{1}{\upsilon}$$

(ii) Inductive reactance (X_L)

$X_L = \omega L = 2\,\pi\,\upsilon L$ ∴ [$\upsilon \rightarrow$ Frequency of ac]
[$L \rightarrow$ inductance of the inductor]

$X_L \propto \upsilon$

(iii) Impedance : The total opposition offered by *LCR* circuit to the flow of alternating current is called impedance. It is denoted by Z and is given by

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

The impedance of an ac circuit plays the same role as resistance in dc circuit.

40. The quality factor (Q) of resonance in series *LCR* circuit is defined as the ratio of voltage drop across inductor (or capacitor) to the applied voltage,

i.e., $Q = \frac{V_L}{V_R} = \frac{I_0X_L}{I_0R} = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 CR}$

It is an indicator of sharpness of the resonance. Quality factor has no unit.

41. Power factor, $\cos\phi = 0.5$

$\cos\phi = \cos 60° \Rightarrow \phi = 60°$

Phase difference = 60°

42. (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 the choke coil.

(iv) ac is easier to generate.

43. The current which consumes no power for its maintenance (*i.e.*, power factor is zero) in the circuit is called wattless current.

44. (i) The impedance of a series LCR circuit is given by

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

Z will be minimum when $\omega L=\frac{1}{\omega C}$ *i.e.*, when the circuit is under resonance. Hence, for this condition, Z will be minimum and will be equal to R.

(ii) Average power dissipated through a series LCR circuit is given by

$P_{av}=EI\cos(\phi)$

where E = rms value of alternating voltage

I = rms value of alternating current

ϕ = phase difference between current and voltage

For wattless current, the power dissipated through the circuit should be zero *i.e.*,

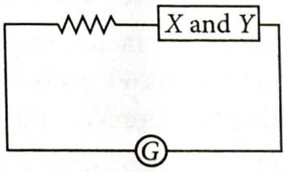
$\cos(\phi)=0$

$$\Rightarrow \quad \phi=\frac{\pi}{2}$$

Hence, the condition for wattless current is that the phase difference between the current and voltage should be $\pi/2$ and the circuit is purely inductive or purely capacitive.

45. (i) In $R-L$ series combination, voltage leads the current by phase $\phi=\frac{\pi}{4}$. It means element X is an inductor (with reactance equal to R). In RC series combination, voltage lags behind the current by phase $\phi=\frac{\pi}{4}$. So element Y is a capacitor (with reactance equal to R).

(ii) If both elements X and Y are connected in series with R, then power dissipation in the combination can be given as



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

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

Here, $X_L=X_C=R$. So, $\cos\phi=1$

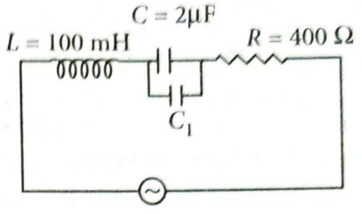
Hence, $P=V_{rms}I_{rms}$ (Maximum)

46. (i) $P=\frac{V^2}{R}$

$$100=\frac{(220)^2}{R}\Rightarrow R=\frac{220\times220}{100}=484\ \Omega$$

(ii) $i_{rms}=\frac{V_{rms}}{R}$ or $\frac{P}{V_{rms}}=\frac{220}{484}$ or $\frac{100}{220}=0.45$ A

47. To make power factor of the circuit unity,



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

$X_C=X_L$

$$\frac{1}{\omega(C+C_1)}=100\Rightarrow\frac{1}{1000(C+C_1)}=100$$

or $C+C_1=\frac{1}{10^5}$

or $C_1=10^{-5}-C=10^{-5}-0.2\times10^{-5}=0.8\times10^{-5}$

$\Rightarrow C_1=8\ \mu F$

48. For unity power factor, $X_L=X_C$

$$\omega L=\frac{1}{\omega C'} \qquad [\because C'=C+C'']$$

$$C'=\frac{1}{\omega^2L}=\frac{1}{(1000)^2\times100\times10^{-3}}=10^{-5}\,F=10\ \mu F$$

$\because \quad C'=C+C''$

$C''=C'-C=10-2=8\ \mu F$

So required capacitor is 8 μF which is added in parallel with the given capacitor.

49. (i) Here, $L=80$ mH, $C=250$ mF, $\omega=100$ rad/sec, $V_{rms}=240$ V

$$\text{Reactance}=\left|\omega L-\frac{1}{\omega C}\right|$$

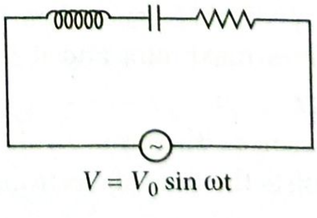
$$=\left|100\times80\times10^{-3}-\frac{1}{100\times250\times10^{-3}}\right|$$

$$=\left|8-\frac{1}{25}\right|=7.96$$

$$I_{rms}=\frac{V_{rms}}{\text{Reactance}}=\frac{240}{7.96}=30.15\text{ A}$$

(ii) The total average power consumed by circuit is zero.

50. The rate at which electrical energy is consumed in an electric circuit is called its power.



$V=V_0\sin\omega t$

Suppose in an ac circuit, voltage and current are having a phase difference ϕ.

$V = V_0 \sin \omega t$

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

Work done by source of emf in a small time dt with negligible change in current.

$dW = VI\,dt$

$dW = V_0 I_0 \sin \omega t \sin (\omega t - \phi) dt$

where $\sin(\omega t - \phi) = \sin \omega t \cos \phi - \cos \omega t \sin \phi$

$dW = V_0 I_0 [\sin^2 \omega t \cos \phi - \sin \omega t \cos \omega t \sin \phi] dt$

$$dW = V_0 I_0 \left[\left(\frac{1-\cos 2\omega t}{2}\right)\cos\phi - \frac{\sin 2\omega t}{2}\sin\phi\right]dt$$

Now total work done in a complete cycle

$$W = \frac{V_0 I_0}{2} \times$$

$$\left[\int_0^T \cos\phi\, dt - \cos\phi \int_0^T \cos 2\omega t\, dt - \sin\phi \int_0^T \sin 2\omega t\, dt\right]$$

we can solve $\int_0^T \cos 2\omega t\, dt = \int_0^T \sin 2\omega t\, dt = 0$

$$W = \frac{V_0 I_0}{2} \int_0^T \cos\phi\, dt = \frac{V_0}{\sqrt{2}} \frac{I_0}{\sqrt{2}} \cos\phi T$$

Thus power consumed over a cycle,

$$P = \frac{W}{T} = V_{rms} I_{rms} \cos\phi$$

(i) Minimum power : In an ac circuit containing pure L only current I lags behind the applied voltage V by phase angle $\pi/2$. So average power consumed by pure inductor 'L' in complete cycle of ac is then given by

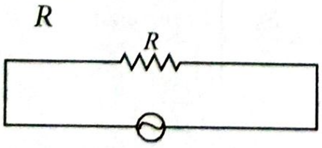
$P = V_{rms}\, I_{rms} \cos \pi/2 = 0$

(ii) Maximum power : In ac circuit containing R only both applied voltage V and current I are in same phase, so average power consumed by resistor R in complete cycle of a.c. is then given by

or $P = V_{rms}\, I_{rms} \cos 0° = V_{rms}\, I_{rms}$

$$P = \frac{V_{rms}^2}{R}$$

51.



Average power in one cycle, $P = \frac{W}{t} = \frac{\int_0^T Vi dt}{\int_0^T dt}$

where current and voltage are in same phase across resistance R.

If $i = i_m \sin\omega t$ then $V = V_m \sin\omega t$

$$\text{Hence, } P = \frac{V_m i_m \int_0^T \sin^2 \omega t dt}{\int_0^T dt}$$

$$P = \frac{V_m i_m}{T} \int_0^T \left(\frac{1-\cos 2\omega t}{2}\right) dt$$

$$P = \frac{V_m i_m}{2T}\left[\int_0^T dt - \int_0^T \cos 2\omega t\, dt\right]$$

$$P = \frac{V_m i_m}{2T}[T - 0] = \frac{V_m i_m}{2}$$

Also, $i_m = \frac{V_m}{R}$

So, $P = \frac{i_m^2 R}{2}$

(b) Bulb is rated at 100 W, 220 V ac supply.

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

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

52. In a circuit containing capacitor C, current leads the voltage by a phase angle of $\frac{\pi}{2}$.

$\therefore\ E = E_0 \sin \omega t$ then $I = I_0 \sin(\omega t + \frac{\pi}{2})$

$\therefore\ I = I_0 \cos \omega t$

Work done in one complete cycle is

$$W = \int_0^T EI\,dt = \int_0^T (E_0 \sin\omega t)(I_0 \cos \omega t) dt$$

$$= E_0 I_0 \int_0^T \sin\omega t \cos\omega t\, dt = E_0\, I_0 \int_0^T \frac{\sin 2\omega t}{2}\, dt$$

[∵ $\sin\theta = 2 \sin\theta \cos\theta$]

$$= \frac{E_0 I_0}{2}\left[-\frac{\cos 2\omega t}{2\omega}\right]_0^T = -\frac{E_0 I_0}{2}\left[\frac{\cos 2\omega T}{2\omega} - \frac{\cos 0}{2\omega}\right]$$

$$= -\frac{E_0 I_0}{2}\left[\frac{\cos 2.\frac{2\pi}{T}.T}{2\omega} - \frac{1}{2\omega}\right] = -\frac{E_0 I_0}{2}\left[\frac{\cos 4\pi}{2\omega} - \frac{1}{2\omega}\right]$$

$$= -\frac{E_0 I_0}{2}\left[\frac{1}{2\omega} - \frac{1}{2\omega}\right] = 0 \quad [\because \cos 4\pi = 1]$$

$\therefore$ Average power $= \frac{W}{T} = \frac{0}{T} = 0$

Hence, average power supplied to an ideal capacitor by the source over a complete cycle of ac is zero.

53. *Refer to answer 52.*

54. Here $L = 10\text{ mH} = 10 \times 10^{-3} = 10^{-2}\text{ H}$

$$C = \left(\frac{400}{\pi^2}\right)\mu\text{F} = \frac{400}{\pi^2} \times 10^{-6}\text{ F} = \frac{4}{\pi^2} \times 10^{-4}\text{ F}$$

$R = 55\ \Omega$

(a) The average power absorbed by the circuit is maximum at resonance.

$\therefore\ X_L = X_C$

$$2\pi\upsilon_0 L = \frac{1}{2\pi\upsilon_0 C}$$

$$4\pi^2\upsilon_0^2\, LC = 1$$

$$\upsilon_0^2 = \frac{1}{4\pi^2 LC}$$

$$\therefore\ \upsilon_0 = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{10^{-2} \times \frac{4}{\pi^2} \times 10^{-4}}}$$

$$= \frac{1}{2\pi \times \frac{2}{\pi} \times 10^{-3}} = \frac{10^3}{4} = \frac{1000}{4} = 250\text{ Hz}$$

(b) Maximum current amplitude is,

$$i_m = \frac{V_m}{R} = \frac{V_{rms}\sqrt{2}}{R} = \frac{220\sqrt{2}}{55} = 4\sqrt{2}\text{ A}$$

55. For LR circuit, $X_L = R$

Power factor, $P_1 = \cos\phi$

$$= \frac{R}{\sqrt{R^2 + X_L^2}} = \frac{R}{\sqrt{R^2 + R^2}} = \frac{1}{\sqrt{2}}$$

For LCR circuit, as C is put in series with LR circuit and, $X_L = X_C$

Power factor, $P_2 = \cos\phi$

$$= \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{R}{\sqrt{R^2 + (X_L - X_L)^2}} = \frac{R}{R} = 1$$

$$\text{Required ratio} = \frac{P_1}{P_2} = \frac{1}{\sqrt{2}}$$

56. (a) $V = V_0 \sin\omega t$ and $I = I_0 \sin\omega t$

Work done in small time dt will be

$dW = P\,dt = VI\,dt = V_0 I_0 \sin^2\omega t\,dt$

$$= \frac{V_0 I_0}{2}(1 - \cos 2\omega t)dt$$

The average power dissipated per cycle in the resistor will be

$$P_{av} = \frac{W}{T} = \frac{1}{T}\int_0^T dW$$

$$= \frac{V_0 I_0}{2T}\int_0^T (1 - \cos 2\omega t) = \frac{V_0 I_0}{2T}\left[t - \frac{\sin 2\omega t}{2\omega}\right]_0^T$$

$$= \frac{V_0 I_0}{2T}[(T - 0) - 0] = \frac{V_0 I_0}{2} = \frac{V_0^2}{2R}$$

or

$$P_{av} = \frac{V_0 I_0}{\sqrt{2}\sqrt{2}} = V_{rms} I_{rms} = \frac{V_{rms}^2}{R} \quad \left[\because \frac{V_0}{2} = V_{rms}\right]$$

(b) The power is $P = V_{rms}\, I_{rms} \cos\phi$. If $\cos\phi$ is small, then current considerably increases when voltage is constant. Power loss, is $I^2 R$. Hence, power loss increases.

(c) *Refer to answer 43.*

57. (a) $V = V_m \sin\omega t,\ i = i_m \sin(\omega t + \phi)$

and instantaneous power, $P = Vi$

$= V_m \sin\omega t\,.\,i_0 \sin(\omega t + \phi) = V_m\, i_m \sin\omega t \sin(\omega t + \phi)$

$$= \frac{1}{2} V_m i_m\, 2\sin\omega t\,.\,\sin(\omega t + \phi)$$

From trigonometric formula

$2\sin A \sin B = \cos(A - B) - \cos(A + B)$

$$\therefore \text{ Instantaneous power, } P = \frac{1}{2} V_m i_m [\cos(\omega t + \phi - \omega t) - \cos(\omega t + \phi + \omega t)]$$

$$P = \frac{1}{2} V_m i_m [\cos\phi - \cos(2\omega t + \phi)] \qquad \text{...(i)}$$

Average power for complete cycle

$$\overline{P} = \frac{1}{2} V_m i_m [\cos\phi - \overline{\cos(2\omega t + \phi)}]$$

For a complete cycle, $\overline{\cos(2\omega t + \phi)} = 0$

$\therefore$ Average power,

$$\overline{P} = \frac{1}{2} V_m i_m \cos\phi = \frac{V_0}{\sqrt{2}}\frac{i_0}{\sqrt{2}}\cos\phi = V_{rms} i_{rms} \cos\phi$$

(b) *Refer to answer 56 (b).*

(c) Given, $L = 1.00\text{ mH} = 1 \times 10^{-3}\text{ H}$,

$C = 1.00\text{ nF} = 1 \times 10^{-9}\text{ F}$

$R = 100\ \Omega,\ E_0 = 100\text{ V}$

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

$$\therefore\ I_0 = \frac{V}{R} = \frac{100}{100}, I_0 = 1\text{ A}$$

$$I_v = \frac{I_0}{\sqrt{2}} = \frac{1}{\sqrt{2}} = \frac{\sqrt{2}}{2} = \frac{1.414}{2} = 0.707\text{ A}$$

$I_v = 0.707$ A

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

$Q = 10$

58. *Refer to answer 35.*

Power factor : Power factor is defined as the ratio of true power to apparent power. It is denoted by $\cos\phi$

$$\therefore \quad \text{Power factor} = \cos\phi = \frac{R}{\sqrt{R^2+(X_L-X_C)^2}}$$

(i) Power factor is maximum when the circuit contains only R *i.e.* at resonance.

(ii) Power factor is minimum for purely inductive or capacitive circuit.

59. The core of transformer is laminated to reduce the energy losses due to eddy currents, so that its efficiency may remain nearly 100%.

60. Characteristic properties :

(a) Low coercivity/Low retentivity.

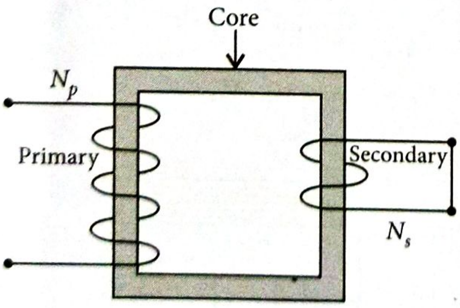
(b) Low hysteresis loss

61. A step-up transformer is used to convert a low voltage at high current into a high voltage at low current.

62. A transformer is based on 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.

Electric power generated at the power station, is stepped up to very high voltages by means of a step-up transformer and transmitted to a distant place. At receiving end, it is stepped down by a step down transformer.

63. (a) Step down 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, $P = 1200\text{ kW} = 1200\times10^3$ W

Total resistance of two wire lines, $R = 2\times20\times0.5$
$= 20\ \Omega$

$E_v = 4000$ volt

As, $P = E_v I_v \ \therefore\ 1200\times10^3 = 4000\times I_v$

$$\Rightarrow \quad I_v = \frac{1200\times10^3}{4000} = 300 \text{ A}$$

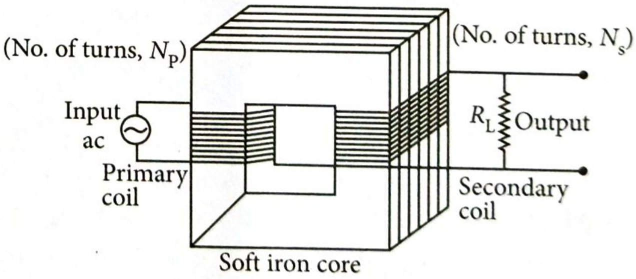
where I_v is the rms value of current.

Line power loss in the form of heat is,

$= (I_P)^2 \times$ Resistance of wire line

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

64. (a) 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 $V_p = e_p$.

$$i.e.,\ V_p = -N_p\frac{d\phi}{dt}$$

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 $V_s = \varepsilon_s$

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

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

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

$\Rightarrow I_s V_s = I_p V_p$

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

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

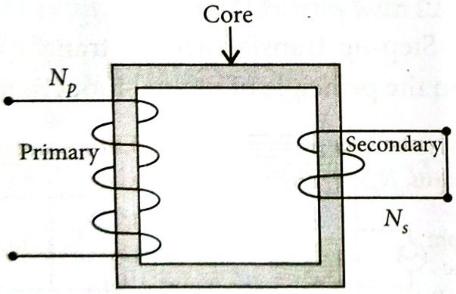
In case of dc voltage flux does not change. Thus no emf is induced in the circuit.

(b) $N_p = 3000$, $V_p = 2200$ V, $V_s = 220$ V, $N_s = ?$

As $\frac{V_s}{V_p} = \frac{N_s}{n_p}$ or, $N_s = \frac{N_p V_s}{V_p}$

$$\therefore N_s = \frac{3000 \times 220}{2200} = 300$$

65. (i) Step down 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.

For step down transformer,

$N_S < N_P$, hence $\varepsilon_s < \varepsilon_p$.

(ii) $\frac{\varepsilon_s}{\varepsilon_p} = \frac{N_s}{N_p}$

(iii) For an ideal transformer,

$$P_{in} = P_{out}$$

or $\varepsilon_p I_p = \varepsilon_s I_s \quad \therefore \quad \frac{I_p}{I_s} = \frac{\varepsilon_s}{\varepsilon_p} = \frac{N_s}{N_p}$

(iv) $P_{in} = P_{out} = 550$ W

or $\varepsilon_p I_p = 550$ or $220 \times I_p = 550$

$$I_p = \frac{550}{220} = \frac{5}{2} = 2.5 \text{ A}$$

66. (i) *Refer to answer 64(a).*

There are number of energy losses in a transformer.

(a) Copper losses due to Joule's heating produced across the resistances of primary and secondary coils. It can be reduced by using copper wires.

(b) 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.

(c) Iron losses due to eddy currents produced in soft iron core. It is minimized by using laminated iron core.

(d) Flux losses due to flux leakage or incomplete flux linkage and can be minimised by proper coupling of primary and secondary coils.

(ii) Here $N_P = 100$, $\frac{N_S}{N_P} = 100$

$\varepsilon_i = \varepsilon_P = 220$ V, $P_I = 1100$ W

(a) $N_P = 100 \therefore N_S = 10000$

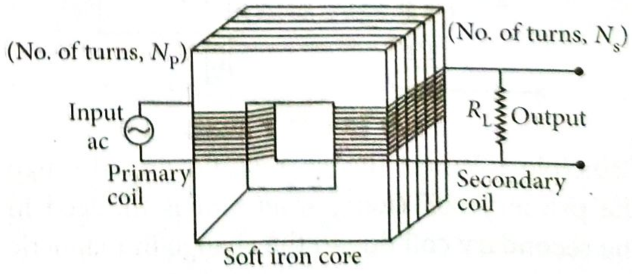
(b) $I_P = \frac{P_I}{\varepsilon_P} = \frac{1100}{220} = 5$ A

(c) $\varepsilon_S = \frac{N_S}{N_P} \times \varepsilon_P = 100 \times 220 = 22000$ V

(d) $I_S = \frac{P_O}{\varepsilon_S} = \frac{1100}{22000} = \frac{1}{20}$ A $\quad (\because P_O = P_I)$

(e) $P_S = P_O = P_I = 1100$ W.

67. (a)



(b) *Refer to answer 64(a).*

(c) The following three assumptions are involved

(i) The primary resistance and current are small.

(ii) The same flux links both with the primary and secondary windings as flux leakage from the core is negligibly small.

(iii) The terminals of the secondary are open or the current taken from it is small.

(d) *Refer to answer 66(i).*

68. *Refer to answer 66(i).*

69. *Refer to answer 66(i).*

70. (i) and (ii) *Refer to answer 66(i).*

(iii) Input power = Output power

$V_pI_p = V_sI_s$

when output voltage increases the output current automatically decreases to keep the power same. Thus, there is no violation of conservation of energy in a step up transformer.

71. $V_p = 2200$ V, $I_p = 5$ A, $N_p = 4000$

$V_s = 220$ V, $N_s = ?$ $I_s = ?$

$$\frac{V_s}{Vp} = \frac{I_P}{I_s} = \frac{N_s}{N_P}\ ;\ \frac{220}{2200} = \frac{5}{I_s} = \frac{N_s}{4000}$$

$$\frac{220}{2200} = \frac{5}{I_s} \Rightarrow \frac{1}{10} = \frac{5}{I_s}\ \therefore\ I_s = 50\text{ A}$$

$$\frac{5}{I_s} = \frac{N_s}{4000} \Rightarrow \frac{5}{50} = \frac{N_s}{4000}\ \therefore\ N_s = 400$$

72. *Refer to answer 66(i) and 67(i).*

73. *Refer to answer 64(a).*

Transformer is mainly used in long distance transmission of electrical energy. At the electric power producing station, a step-up transformer is used which increases the alternating voltage upto several kilo volts, thereby decreasing the electric current flowing through transmission wires. As Joule's heating is proportional to square of current, so this decreases the loss of electrical energy across transmission wires. Further a step-down transformer is used to decrease the alternating voltage at substation before distributing electrical energy for domestic use.

74. Given $V_p = 2.5$ kV $= 2.5 \times 10^3$ V, $I_p = 20$ A

Input power, $P_{in} = V_p\, I_p = 2.5 \times 10^3 \times 20$

$= 50 \times 10^3$ W $= 50$ kW

(i) $\eta = \dfrac{P_{out}}{P_{in}}$

Power output, $P_{out} = \eta P_{in} = 0.9 \times 50$ kW $= 45$ kW

(ii) Voltage across secondary

$$V_s = \frac{N_S}{N_P}V_P = \frac{1}{10} \times 2.5 \times 10^3\text{ V} = 250\text{ V}$$

(iii) Current in secondary

$$I_s = \frac{P_{out}}{V_s} = \frac{45 \times 10^3}{250} = 180\text{ A}$$