Alternating Current

1. The reactance of a capacitor of capacitance C connected to an ac source of frequency ω is 'X'. If the capacitance of the capacitor is doubled and the frequency of the source is tripled, the reactance will become: (2024)

(A) X/6

(B) 6X

(C) 2X/3

(D) 3X/2

Ans. (A) X/6

2. An inductor, a capacitor and a resistor are connected in series with an ac source $v = v_m \sin \omega t$. Derive an expression for the average power dissipated in the circuit. Also obtain the expression for the resonant frequency of the circuit. (2024)

Ans. Deriving an expression for the average power dissipated in series LCR circuit

Obtaining expression for the resonant frequency

$$v = v_m \sin\omega t$$
$$i = i_m \sin(\omega t+\varphi)$$

$$\text{Power, } P = v\, i = (v_m \sin\omega t) \times [i_m \sin(\omega t+\varphi)]$$
$$= \frac{v_m i_m}{2}[\cos\varphi - \cos(2\omega t+\varphi)]$$

The average power over a cycle is given by the average of the two terms in RHS of eqn (1). It is only the 2nd term which is time dependent. It's average is zero. Therefore,

$$P = \frac{v_m i_m}{2}\cos\varphi$$

$$P = V\, I \cos\varphi$$
OR
$$P = I^2 Z \cos\varphi$$

At resonance, $X_C = X_L$

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

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

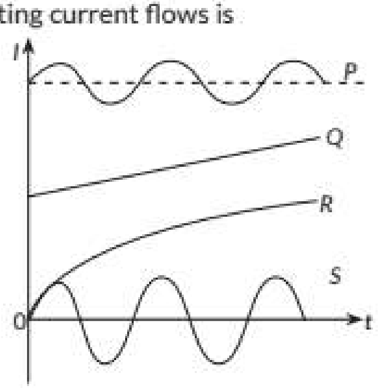
$$\Rightarrow \qquad \upsilon = \frac{1}{2\pi\sqrt{(LC)}}$$

Previous Years' CBSE Board Questions

7.1 Introduction

MCQ

1. The figure shows variation of current (I) with time (t) in four devices P, Q, R and S. The device in which an alternating current flows is



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

SA I (2 marks)

7. An ac source of emf $V = V_0 \sin \omega t$ is connected to a capacitor of capacitance C. Deduce the expression for the current (I) flowing in it. Plot the graph of (i) V vs ωt, and (ii) I vs ωt. *(2020)*

OR

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

SA II (3 marks)

8. The figure shows the graphical variation of the reactance of a capacitor with frequency of ac source.

(a) P (b) Q (c) R (d) S *(2023)*

7.2 AC Voltage Applied to a Resistor

MCQ

2. The rms current in a circuit connected to a 50 Hz ac source is 15 A. The value of the current in the circuit $\left(\frac{1}{600}\right)$s after the instant the current is zero, is

(a) $\frac{15}{\sqrt{2}}$ A (b) $15\sqrt{2}$ A

(c) $\frac{\sqrt{2}}{15}$ A (d) 8 A *(Term I 2021-22)*

7.5 AC Voltage Applied to a Capacitor

MCQ

3. An ac voltage $v = v_0 \sin\omega t$ is applied to a series combination of a resistor R and an element X. The instantaneous current in the circuit is $I = I_0 \sin\left(\omega t + \frac{\pi}{4}\right)$. Then which of the following is correct?

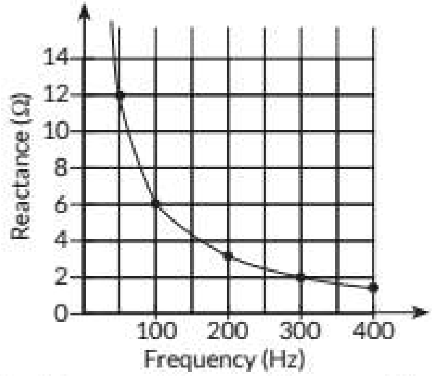
(a) X is a capacitor and $X_C = \sqrt{2}R$
(b) X is an inductor and $X_L = R$
(c) X is an inductor and $X_L = \sqrt{2}R$
(d) X is a capacitor and $X_C = R$ *(2023)*

VSA (1 mark)

4. What is the impedance of a capacitor of capacitance C in an ac circuit using source of frequency n Hz? *(2020)* R

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

reactance of a capacitor with frequency of ac source.



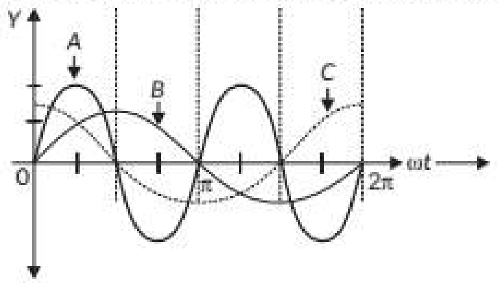
(a) Find the capacitance of the capacitor.
(b) An ideal inductor has the same reactance at 100 Hz frequency as the capacitor has at the same frequency. Find the value of inductance of the inductor.
(c) Draw the graph showing the variation of the reactance of this inductor with frequency. *(2020)* Ap

LA (5 marks)

9. 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)*

10. 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

15. The voltage across a resistor, an inductor, and a capacitor connected in series to an ac source are 20 V, 15 V and 30 V respectively. The resultant voltage in the circuit is
(a) 5 V (b) 20 V (c) 25 V (d) 65 V *(Term I 2021-22)*

16. A circuit is connected to an ac source of variable frequency. As the frequency of the source is increased, the current first increases and then decreases. Which of the following combinations of elements is likely to comprise the circuit?
(a) L, C and R (b) L and C
(c) L and R (d) R and C *(Term I 2021-22)*

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) Ev

7.6 AC Voltage Applied to a Series *LCR* Circuit

MCQ

11. Which of the following statements about a series *LCR* circuit connected to an ac source is correct?
(a) If the frequency of the source is increased, the impedance of the circuit first decreases and then increases.
(b) If the next reactance $(X_L - X_C)$ of circuit becomes equal to its resistance, then the current leads the voltage by 45°.
(c) At resonance, the voltage drop across the inductor is more than that across the capacitor.
(d) At resonance, the voltage drop across the capacitor is more than that across the inductor.
(2023)

12. What is the ratio of inductive and capacitive reactance in an ac circuit?
(a) $\omega^2 LC$ (b) LC^2 (c) $\frac{LC}{\omega^2}$ (d) $\omega^2 L$
(2023)

13. In a circuit the phase difference between the alternating current and the source voltage is $\frac{\pi}{2}$. Which of the following cannot be the element(s) of the circuit?
(a) only *C* (b) only *L*
(c) *L* and *R* (d) *L* or *C*
(Term I 2021-22)

14. The impedance of a series *LCR* circuit is
(a) $R + X_L + X_C$ (b) $\sqrt{\frac{1}{X_C^2} + \frac{1}{X_L^2} + R^2}$
(c) $\sqrt{X_L^2 - X_C^2 + R^2}$ (d) $\sqrt{R^2 + (X_L - X_C)^2}$
(Term I 2021-22)

17. A 15 Ω resistor, an 80 mH inductor and a capacitor of capacitance *C* are connected in series with a 50 Hz ac source. If the source voltage and current in the circuit are in phase, then the value of capacitance is
(a) 100 μF (b) 127 μF (c) 142 μF (d) 160 μF
(Term I 2021-22)

18. A 300 Ω resistor and a capacitor of $\left(\frac{25}{\pi}\right)$μF are connected in series to a 200 V – 50 Hz ac source. The current in the circuit is
(a) 0.1 A (b) 0.4 A (c) 0.6 A (d) 0.8 A
(Term I 2021-22)

19. The selectivity of a series *LCR* a.c. current is large, when
(a) *L* is large and *R* is large
(b) *L* is small and *R* is small
(c) *L* is large and *R* is small
(d) *L* = *R*
(2020)

VSA (1 mark)

20. What is the value of impedance of a resonant series *LCR* circuit? *(2020)* R

21. A series combination of an inductor (*L*), capacitor (*C*) and resistor (*R*) is connected across an ac source of emf of peak value E_0 and angular frequency (ω). Plot a graph to show variation of impedance of the circuit with angular frequency (ω). *(2020)*

SA I (2 marks)

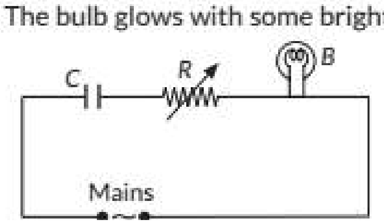
22. An inductor *L* = 0.4 H, a capacitor *C* = 10 μF and a resistor *R* = 400 Ω are connected in series to an ac source *V* = 40 sin (1000 *t* + π/3) volt.
Calculate the
(a) impedance of the circuit, and
(b) peak value of current. *(2020C)*

23. Explain the term 'sharpness of resonance in ac circuit. *(1/2, 2020)* U

OR

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

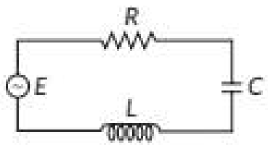
24. A capacitor '*C*', a variable resistor '*R*' and a bulb '*B*' are connected in series to the ac mains in circuit as shown. The bulb glows with some brightness.



29. A resistance *R* and a capacitor *C* are connected in series to a source $V = V_0 \sin \omega t$.
Find :
(a) The peak value of the voltage across the (i) resistance and (ii) capacitor.
(b) The phase difference between the applied voltage and current. Which of them is ahead ?
(2020)

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)*

25. 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 Ω.



Determine

(i) the source frequency which derives the circuit in resonance;

(ii) the quality factor (Q) of the circuit.

(AI 2014C) An

SA II (3 marks)

26. A resistor of 30 Ω and a capacitor of $\frac{250}{\pi}$ μF are connected in series to a 200 V, 50 Hz ac source. Calculate (i) the current in the circuit, and (ii) voltage drops across the resistor and the capacitor. (iii) Is the algebraic sum of these voltages more than the source voltage? If yes, solve the paradox. *(2023)*

27. A series LCR circuit with R = 20 Ω, L = 2 H and C = 50 μF is connected to a 200 volts ac source of variable frequency. What is (i) the amplitude of the current, and (ii) the average power transferred to the circuit in one complete cycle, at resonance? (iii) Calculate the potential drop across the capacitor. *(2023)*

28. (i) In an LCR series circuit connected to an ac source, the voltage and the current are in the same phase. If the capacitor is filled with a dielectric, will the current lead or lag behind or remain in phase with the voltage ? Explain.

(ii) In the circuit, why is the rms value of net voltage not equal to the sum of voltage drops across individual elements ?

(iii) Draw a graph showing variation of the impedance of the circuit with the frequency of the applied voltage. *(2020C)*

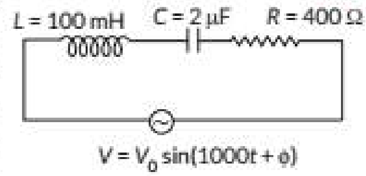
30. A resistor R and an inductor L are connected in series to a source $V = V_0 \sin \omega t$. Find the

(a) peak value of the voltage drops across R and across L

(b) phase difference between the applied voltage and current. Which of them is ahead?

(2020) An

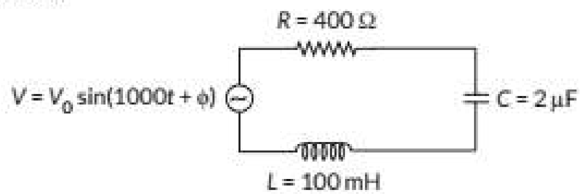
31. Find the value of the phase difference between the current and the voltage in the series LCR circuit shown below. Which one leads in phase: current or voltage?



(2/3, Delhi 2017)

OR

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



(2/3, AI 2015)

32. 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,

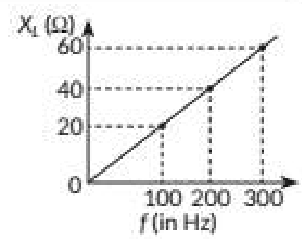
(ii) an iron rod is inserted in the inductor and

(iii) a capacitor of reactance $X_C = X_L$ is inserted in series in the circuit. Justify your answer in each case. *(Delhi 2015)*

33. 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)* Ev

LA (5 marks)

34. The variation of inductive reactance (X_L) of an inductor with the frequency (f) of the ac source of 100 V and variable frequency is shown in the figure.



(i) Calculate the self-inductance of the inductor.

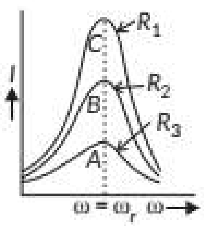
(ii) When this inductor is used in series with a capacitor of unknown value and a resistor of 10 Ω at 300 s^{-1}, maximum power dissipation occurs in the circuit. Calculate the capacitance of the capacitor. *(2/5, 2020)* Cr

35. (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)*

36. (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)* Cr

37. 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)* Ev

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

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

39. (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)* Ap

7.7 Power in AC Circuit : The Power Factor

MCQ

Question number 40 is Assertion (A) and Reason (R) type question. Two statements are given – one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer from the codes (a), (b), (c) and (d) as given below.

40. **Assertion (A) :** When three electric bulbs of power 200 W, 100 W and 50 W are connected in series to a source, the power consumed by the 50 W bulb is maximum.

Reason (R) : In a series circuit, current is the same through each bulb, but the potential difference across each bulb is different.

(a) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).
(b) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).
(c) Assertion (A) is true, but Reason (R) is false.
(d) Assertion (A) is false and Reason (R) is also false. *(2023)*

41. When an alternating voltage $E = E_0 \sin\omega t$ is applied to a circuit, a current $I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$ flows through it. The average power dissipated in the circuit is

(a) $E_{rms} I_{rms}$ (b) $E_0 I_0$
(c) $\frac{E_0 I_0}{\sqrt{2}}$ (d) Zero *(Term I 2021-22)*

42. The power factor of a series *LCR* circuit at resonance

(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 ($R_1 > R_2$).

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

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

SA I (2 marks)

46. A resistor *R* and an inductor *L* are connected in series to a source of voltage $V = V_0 \sin \omega t$. The voltage is found to lead current in phase by $\pi/4$. If the inductor is replaced by a capacitor *C*, the voltage lags behind current in phase by $\pi/4$. When *L*, *C* and *R* are connected in series with the same source,
Find the :
(i) average power dissipated and
(ii) instantaneous current in the circuit. *(2020)*

47. In a series *LCR* circuit, $V_L = V_C \neq V_R$. What is the value of power factor for this circuit? *(1/2, 2020)*

48. 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)* An

SA II (3 marks)

49. An alternating current $I = 14 \sin (100\pi t)$. A passes through a series combination of a resistor of 30 Ω and and inductor of $\left(\frac{2}{5\pi}\right)$H. Taking $\sqrt{2} = 1.4$, calculate the
(i) rms value of the voltage drops across the resistor and the inductor and
(i) power factor of the circuit. *(2023)*

50. (a) An ac circuit as shown in the figure has an inductor of inductance *L* and a resistor of resistance *R* connected in series. Using the phasor diagram, explain why the voltage in the

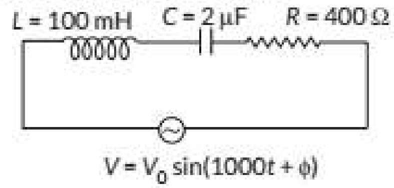
will be
(a) 1 (b) 0 (c) 1/2 (d) $1/\sqrt{2}$
(2020) R

VSA (1 mark)

43. An alternating current $I = (10 \text{ A}) \sin (100\pi t)$ is passed through a resistor of 20 Ω. What is the average power consumed by the resistor over a complete cycle ? *(AI 2021C)*

(a) name the circuit element *Y*.
(b) calculate the rms value of current, if rms value of voltage is 141 V.
(c) what will happen if the ac source is replaced by a dc source? *(2019)*

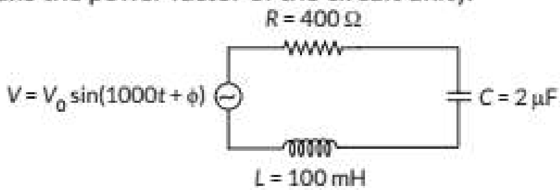
52. Without making any other change, find the value of the additional capacitor C_1, to be connected in parallel with the capacitor *C*, in order to make the power factor of the circuit unity.



(1/3, Delhi 2017)

OR

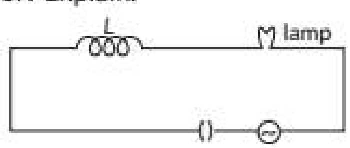
Calculate the value of the additional capacitor which may be joined suitably to the capacitor *C* that would make the power factor of the circuit unity.



(1/3, AI 2015)

53. (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.

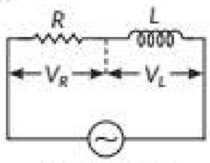


(AI 2016)

circuit will lead the current in phase.

(b) The potential difference across the resistor is 160 V and that across the inductor is 120 V. Find the effective value of the applied voltage. If the effective current in the circuit be 1.0 A, calculate the total impedance of the circuit.

(c) What will be the potential difference in the circuit when direct current is passed through the circuit?



$\varepsilon = \varepsilon_0 \sin \omega t$ *(2019)*

51. An ac circuit consists of a series combination of circuit elements X and Y. The current is ahead of the voltage in phase by $\pi/4$. If element X is a pure resistor of 100 Ω,

54. 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)* Ap

55. 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)*

LA (5 marks)

56. Show that an ideal inductor does not dissipate power in an ac circuit. *(2/5, 2020)* Ap

57. 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)* An

7.8 Transformers*

MCQ

58. The core of a transformer is laminated to reduce the effect of
(a) flux leakage (b) copper loss
(c) hysteresis loss (d) eddy current.
(Term I 2021-22)

VSA (1 mark)

59. Laminated iron sheets are used to minimize _____ currents in the core of a transformer. *(2020)* R

SA II (3 marks)

60. (i) An LCR series circuit is connected to an ac source. If the angular resonant frequency of the circuit is ω_0, will the current lead or lag behind or be in phase with the voltage when $\omega < \omega_0$ and why ?
(ii) We cannot step up a de voltage using a transformer. Why ?
(iii) On what principle does a metal detector work ?
(AI 2021C)

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)* Ev

65. (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)* Ev

66. (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)

67. (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.

61. In a step-up voltage transformer, explain giving reasons, the following facts :
(a) The output current is less than the input current.
(b) The iron core is laminated.
(c) The input power is more than the output power. *(AI 2020C)*

62. Explain with the help of a diagram, the working of a step-down transformer. Why is a laminated iron core used in a transformer? *(AI 2020C)*

LA (5 marks)

63. With the help of a labelled diagram, explain the working of a step-up transformer. Give reasons to explain the following :
(i) The core of the transformer is laminated.
(ii) Thick copper wire is used in windings. *(3/5, 2020)*

64. (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

(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)*

68. (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)*

**In this topic, the subtopic eddy current has been deleted from current CBSE syllabus. But, it has been asked as subparts of some previous years questions. Thus, we are keeping it in those questions.*

CBSE Sample Questions

7.2 AC Voltage Applied to a Resistor

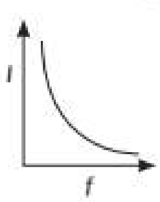
VSA (1 mark)

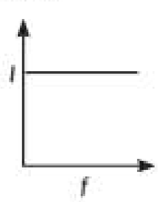
1. An alternating current from a source is given by $i = 10\sin 314t$. What is the effective value of current and frequency of source? *(2020-21)*

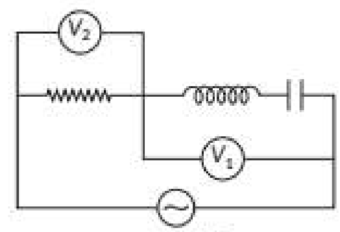
7.5 AC Voltage Applied to a Capacitor

MCQ

2. Which of the following graphs represent the variation of current (I) with frequency (f) in an AC circuit containing a pure capacitor?

(a) 

(b) 

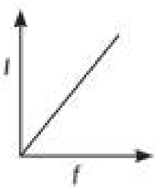


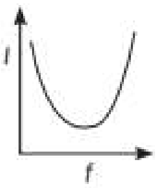
$50\sqrt{2}\sin\omega t$

(a) 30 V (b) 58 V (c) 29 V (d) 15 V *(2022-23)*

6. A 20 volt AC is applied to a circuit consisting of a resistance and a coil with negligible resistance. If the voltage across the resistance is 12 volt, the voltage across the coil is
(a) 16 V (b) 10 V
(c) 8 V (d) 6 V *(Term I 2021-22)*

7. The instantaneous values of emf and the current in a series ac are $E = E_0\sin\omega t$ and $I = I_0\sin(\omega t + \pi/3)$

(c) 

(d) 

(Term I 2021-22) (U)

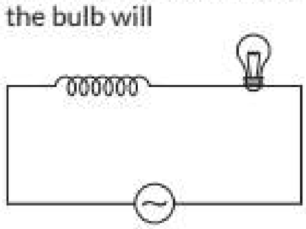
SA II (3 marks)

3. An a.c. source generating a voltage $\varepsilon = \varepsilon_0 \sin \omega t$ is connected to a capacitor of capacitance C. Find the expression for the current I flowing through it. Plot a graph of ε and I versus ωt to show that the current is ahead of the voltage by $\pi/2$. *(2022-23)*

7.6 AC Voltage Applied to a Series LCR Circuit

MCQ

4. An iron cored coil is connected in series with an electric bulb with an AC source as shown in figure. When iron piece is taken out of the coil, the brightness of the bulb will



(a) decrease (b) increase
(c) remain unaffected (d) fluctuate *(2022-23)*

5. If the reading of the voltmeter V_1 is 40 V, then the reading of voltmeter V_2 is

respectively, then it is
(a) Necessarily a *RL* circuit
(b) Necessarily a *RC* circuit
(c) Necessarily a *LCR* circuit
(d) Can be *RC* or *LCR* circuit *(Term I 2021-22)* (Ap)

8. An alternating voltage source of variable angular frequency 'ω' and fixed amplitude 'V' is connected in series with a capacitance C and electric bulb of resistance R(inductance zero). When 'ω' is increased
(a) the bulb glows dimmer
(b) the bulb glows brighter
(c) net impedance of the circuit remains unchanged
(d) total impedance of the circuit increases.
(Term I 2021-22) (Ap)

SA II (3 marks)

9. An ac voltage $V = V_0 \sin \omega t$ is applied across a pure inductor of inductance L. Find an expression for the current i, flowing in the circuit and show mathematically that the current flowing through it lags behind the applied voltage by a phase angle of $\pi/2$. Also draw graphs of V and i versus ωt for the circuit. *(2022-23)*

LA (5 marks)

10. (a) Derive the expression for the current flowing in an ideal capacitor and its reactance when connected to an ac source of voltage $V = V_0 \sin\omega t$.
(b) Draw its phasor diagram.

(c) If resistance is added in series to capacitor what changes will occur in the current flowing in the circuit and phase angle between voltage and current. *(2020-21)* (Ev)

7.7 Power in AC Circuit: The Power Factor

MCQ

11. A sinusoidal voltage of peak value 283 V and frequency 50 Hz is applied to a series *LCR* circuit in which $R = 3\ \Omega$, $L = 25.48$ mH and $C = 796\ \mu$F, then the power dissipated at the resonant condition will be
(a) 39.70 kW (b) 26.70 kW
(c) 13.35 kW (d) zero
(Term I 2021-22) (Ap)

of transformers. The voltage output of the generator is stepped-up. It is then transmitted over long distances to an area sub-station near the consumers. There the voltage is stepped down. It is further stepped down at distributing sub-stations and utility poles before a power supply of 240 V reaches our homes.

(i) Which of the following statement is true?
(a) Energy is created when a transformer steps up the voltage.
(b) A transformer is designed to convert an AC voltage to DC voltage.
(c) Step-up transformer increases the power for transmission.
(d) Step-down transformer decreases the AC voltage.

(ii) If the secondary coil has a greater number of turns than the primary,

7.8 Transformers

MCQ

12. Which among the following, is not a cause for power loss in a transformer
   (a) eddy currents are produced in the soft iron core of a transformer
   (b) electric flux sharing not properly done in primary and secondary coils
   (c) humming sound produced in the transformers due to magnetostriction
   (d) primary coil is made up of a very thick copper wire. *(Term I 2021-22)*

CASE BASED (4 marks)

13.

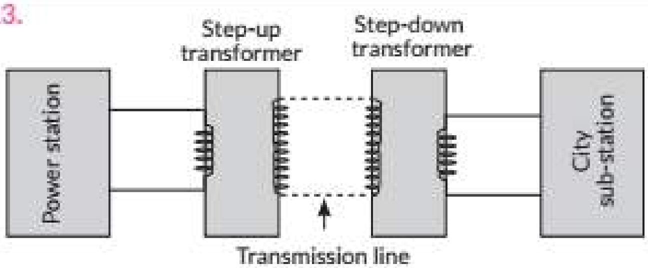


Figure : Long distance power transmissions

The large-scale transmission and distribution of electrical energy over long distance is done with the use

(a) the voltage is stepped-up ($V_s > V_p$) and arrangement is called a step-up transformer
(b) the voltage is stepped-down ($V_s < V_p$) and arrangement is called a step-down transformer
(c) the current is stepped-up ($I_s > I_p$) and arrangement is called a step-up transformer
(d) the current is stepped-down ($I_s < I_p$) and arrangement is called a step-down transformer.

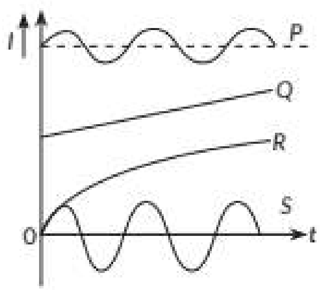
(iii) We need to step-up the voltage for power transmission, so that
   (a) the current is reduced and consequently, the I^2R loss is cut down
   (b) the voltage is increased, the power losses are also increased
   (c) the power is increased before transmission is done
   (d) the voltage is decreased so V^2/R losses are reduced.

(iv) A power transmission line feeds input power at 2300 V to a step down transformer with its primary windings having 4000 turns. The number of turns in the secondary in order to get output power at 230 V are
   (a) 4 (b) 40 (c) 400 (d) 4000
   (Term I 2021-22) Ev

Detailed SOLUTIONS

Previous Years' CBSE Board Questions

1. (d) There are four devices connected with different sources.
In alternating current, the current changes its magnitudes sinusoidally with time and passing through origin.



Here, it is clear that Q and R are not alternating current flow.
Here, S-device shows the variation of current with time and P-device's current does not passing through origin.
Hence, option (d) is correct.

2. (a): Here, I_{rms} = 15 A, f = 50 Hz, $t = \frac{1}{600}$ s
The equation of current is

$$I = I_0 \sin(\omega t) = I_{rms}\sqrt{2}\sin(2\pi f t)$$

So, $I = 15\sqrt{2}\sin\left(2\times\pi\times 50\times\frac{1}{600}\right)$

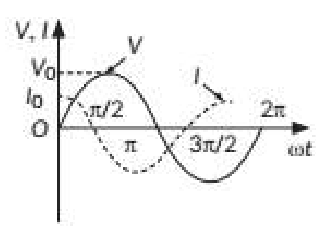
$$I = 15\sqrt{2}\sin\left(\frac{\pi}{6}\right) = \frac{15\sqrt{2}}{2} \Rightarrow I = \frac{15}{\sqrt{2}}\text{A}$$

Key Points
- The alternating voltage and current are measured and specified in terms of their r.m.s. value.

3. (d) Given, voltage, $v = v_0 \sin\omega t$ is applied to a series

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

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

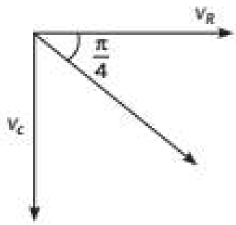


combination of a resistor R and an element X.
Also, instantaneous current in the circuit,

$$I = I_0 \sin\left(\omega t + \frac{\pi}{4}\right)$$

Since, current is leading the voltage with phase difference $\frac{\pi}{4}$. So, capacitor must be present in the given circuit.

Thus, the circuit must be RC.



$\because \quad \tan\frac{\pi}{4} = \frac{v_c}{v_r}$

or $\quad v_c = v_R \quad$ or $\quad X_c = R$

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

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

$$Z = \sqrt{2}R$$

Hence, X is a capacitor and $X_c = R$. So, option (d) is correct.

4. Impedance of a capacitor,

$Z = X_C = \frac{1}{\omega C} = \frac{1}{2\pi n C}$, where n is the frequency of source.

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

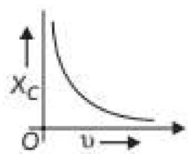
Mathematically, $X_C = \frac{1}{2\pi\upsilon C}$

where υ = frequency of ac source

C = capacitance of the capacitor.

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

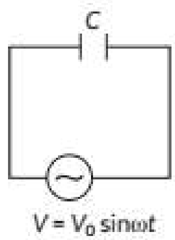
6. Showing variation of capacitive reactance with the change in the frequency of the AC source.



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

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

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



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

$= \omega C V_0 \cos\omega t$

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

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

8. (a) Capacitive reactance, $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$

From graph, for $X_C = 12\ \Omega$, $f = 50$ Hz

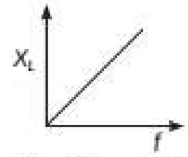
$\therefore \quad 12 = \frac{1}{2 \times 3.14 \times 50 \times C} \Rightarrow C = 265\ \mu F$

(b) Inductive reactance, $X_L = \omega L = 2\pi f L$

For $f = 100$ Hz, $X_C = X_L = 6\ \Omega$

$\therefore \quad 6 = 2 \times 3.14 \times 100 \times L \Rightarrow L = 9.6$ mH

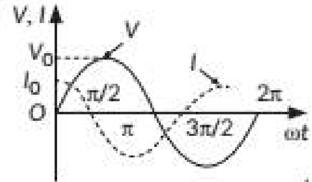
(c)



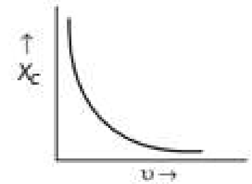
9. (a) Here device X is a capacitor.

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

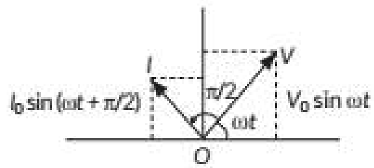
(b) In pure capacitive circuit current leads voltage by $\frac{\pi}{2}$.



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



(d)



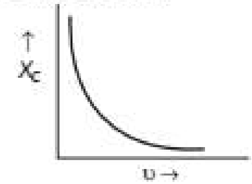
10. (a) Device X is a capacitor.

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



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

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

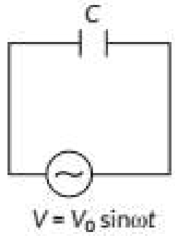
$q = CV_0 \sin\omega t$

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

$= \omega CV_0 \cos\omega t$

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

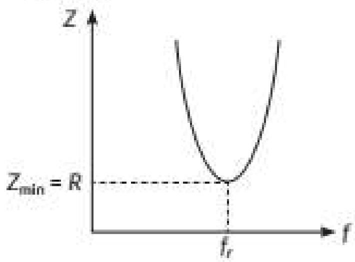
$i = \frac{V_0}{X_C}\sin\left(\omega t + \frac{\pi}{2}\right)$ or $i = i_0 \sin\left(\omega t + \frac{\pi}{2}\right)$



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

11. **(a):** Impedance (Z) *versus* frequency (f) is shown below:

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



12. **(a):** $X_L = \omega L$, $X_C = \frac{1}{\omega C}$

$\frac{X_L}{X_C} = \frac{\omega L \times \omega C}{1} = \omega^2 LC$

13. **(c):** Given, the phase difference, is $\phi = \frac{\pi}{2}$ (between source voltage and alternating current)

Phase difference of $\pi/2$ is possible when L or C is present. So, L and R cannot be present.

14. **(d)**

15. **(c):** Voltage across resistor, $V_R = 20$ V

Voltage across inductor, $V_L = 15$ V

Voltage across capacitor, $V_C = 30$ V

The resultant voltage is given by

$V = \sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{20^2 + (15-30)^2} = 25$ V

16. **(a):** In an a.c. circuit containing L, R and C, the impedance is

$Z = \sqrt{R^2 + (X_L - X_C)^2}$; $X_L = 2\pi f L$, $X_C = \frac{1}{2\pi f C}$

We know, $I = \frac{V}{Z}$.

When frequency increases, the current first increases and then decreases.

17. **(b):** Here: resistance, $R = 15\ \Omega$, inductance, $L = 80$ mH, capacitance = C, frequency, $f = 50$ Hz

When, the current and voltage are in same phase,

So, $X_L = X_C$

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

18. **(b):** Here, resistance, $R = 300\ \Omega$,

capacitance, $C = \frac{25}{\pi}\mu$F

$X_C = \frac{1}{2\pi\upsilon C} = \frac{1}{2\pi \times 50 \times \frac{25}{\pi}} \times 10^6 = 400$ F

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

$Z = \sqrt{300^2 + 400^2} = 500\ \Omega$

Current, $I = \frac{V}{Z} = \frac{200}{500} = 0.4$ A

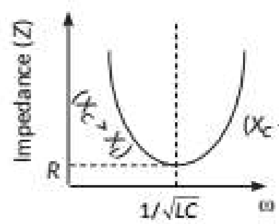
19. **(c):** Selectivity depends on the quality factor,

$Q = \frac{\omega_0 L}{R}$.

20. Impedance of a resonant series LCR circuit,

$Z = \sqrt{R^2 + (X_L - X_C)^2} = R$ $\quad$ [$\because X_L = X_C$ at resonance]

21.



22. Given, $L = 0.4$, $C = 10\ \mu$F, $R = 400\ \Omega$ are connected in series to an ac source $V = 40 \sin(1000t + \pi/3)$ volt.

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

$\because V = 40 \sin\left(1000t + \frac{\pi}{3}\right)$

$\therefore \omega = 1000$, $R = 400\ \Omega$

$X_L = \omega L = 1000 \times 0.4\ \Omega = 400\ \Omega$

$X_C = \frac{1}{\omega_L} = \frac{1}{10^3 \times 10 \times 10^{-6}}\Omega = 100\ \Omega$

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

$= \sqrt{(400)^2 + (400-100)^2}\ \Omega = \sqrt{400^2 + (300)^2}\ \Omega$

Impedance $(Z) = 500\ \Omega$

(b) Now, peak value of current, we have,

Impedance $(Z) = 500\ \Omega$

$I_{rms} = \frac{V_{rms}}{Z}$, $V_0 = 40$ V

$V_{rms} = \frac{V_0}{\sqrt{2}} = \frac{40}{\sqrt{2}}$ V

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

$I_{rms} = \frac{40}{\sqrt{2}} \times \frac{1}{500}$ Amp.

So, $I_{peak} = \sqrt{2} \times I_{rms}$

$$C = \frac{1}{4\pi^2 f^2 L} = \frac{1}{4 \times (3.14)^2 \times 50^2 \times 80 \times 10^{-3}}$$

$C = 1.27 \times 10^{-4}$ F = 127 μF

23. 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 resonant angular frequency to the bandwidth of the circuit.

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

It is a dimensionless quantity.

24. For the RC circuit,

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

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

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

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

Answer Tips

- When dielectric material with dielectric constant K is introduced between the plates of the capacitor, it increases the capacitance of the capacitor by K times.

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

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

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

Here, X_C is capacitive reactance

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

$$= \sqrt{2} \times \frac{40}{\sqrt{2}} \times \frac{1}{500} \text{ Amp.}$$

I_{peak} = 0.08 Amp. = 80 mA

Voltage drop across the capacitor = $I X_C$

= 4 × 40 = 160 V

(iii) Total voltage drop = 120 + 160 = 280 V

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

27. Given, $R = 20\ \Omega$, L = 2H, C = 50 μF

V_{rms} = 200 V

(i) At resonance, the frequency of the supply power equals the natural frequency of the given LCR circuit.

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

At resonance, $X_L = X_C = \omega L = \frac{1}{\omega C}$

$\Rightarrow \quad \omega = \frac{1}{\sqrt{LC}} = 100$ rads

$\therefore \quad Z = R = 20\ \Omega$

Current in the circuit, $I = \frac{V}{Z} = \frac{200 V}{20\ \Omega}$

$\therefore \quad I = 10$ A

(ii) The average power transferred to circuit in one complete cycle $P = VI$

= 200 × 10 = 2000 W

(iii) Potential drop across the capacitor

$$= I \times \frac{1}{\omega C} = 10 \times \frac{10^6}{100 \times 50} = 2000 \text{ V}$$

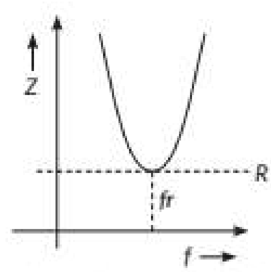
28. (i) In a LCR circuit, if we increase the capacitance of a capacitor then $X_L < X_C$, tan θ become negative.

Therefore, θ is negative.

Hence, current leads the voltage by a phase angle ϕ and circuit is capacitance dominated circuit.

(ii) In series LCR circuit, the voltage across the inductor is 180° out of phase with voltage across the capacitor. While voltage acrosses L and C are 90° out of phase with voltage across R. Hence they are added taking account of their direction.

(iii) Graph between variation of impedance and frequency in circuit.



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

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

29. Here, a resistance R and capacitor C connected in

As frequency, $\upsilon = 50$ Hz; $C = \frac{250}{\pi}\mu F$

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

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

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

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

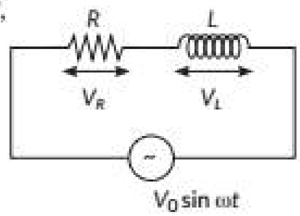
(ii) Voltage drop across the across the resistor = IR = 4 × 30 = 120 V

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

$\phi = \tan^{-1}\left(\frac{1}{\omega RC}\right)$

In RC series circuit the current leads the applied voltage.

30. (a) (i) Peak voltage across R, $V_R = I_0R$

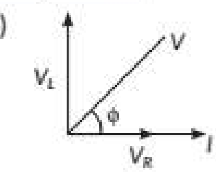


$V_R = \frac{V_0}{\sqrt{R^2 + X_L^2}}R$

(ii) Peak voltage across, L

$V_L = \frac{V_0 X_L}{\sqrt{R^2 + X_L^2}}$

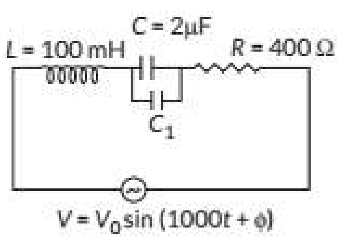
(b)



Phase difference $\phi = \tan^{-1}\left(\frac{V_L}{V_R}\right) = \tan^{-1}\left(\frac{X_L}{R}\right)$

Voltage leads in $R - L$ circuit as shown in figure.

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



The standard equation is given as

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

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

series to source, $V = V_0 \sin \omega t$.

(a) (i) Peak value of voltage across resistance

$I_0 = \frac{V_0}{Z} = \frac{V_0}{\sqrt{R^2 + X_C^2}}$

$V_R = I_0R = \frac{V_0R}{\sqrt{R^2 + X_C^2}}$

(ii) $V_C = I_0X_C = \frac{V_0X_C}{\sqrt{R^2 + X_C^2}}$

(b) Now, the phase difference between applied voltage and current

(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) When a capacitor is connected in series in the circuit, so its impedance is given by,

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

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

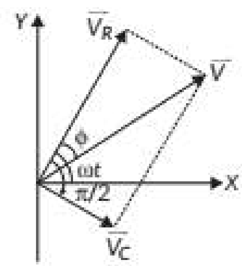
This is the case of resonance so maximum current will flow through the circuit. Hence brightness of the bulb will increase.

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

From diagram, by parallelogram law of vector addition,

$\overline{V_R} + \overline{V_C} = \overline{V}$

Using pythagoras 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, $Z = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \frac{1}{\omega^2 C^2}}$

Z = impedance.

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

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

34. (i) We know that, $X_L = \omega L = 2\pi f L$

$\Rightarrow L = \frac{X_L}{2\pi f} = \frac{20}{2 \times 3.14 \times 100} = 0.0318\ H = 31.8$ mH

(ii) For maximum power dissipation, $X_L = X_C$

$2\pi f L = \frac{1}{2\pi f C} \Rightarrow 2 \times 3.14 \times 300 \times 31.8 \times 10^{-3} = \frac{1}{2 \times 3.14 \times 300C}$

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

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

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

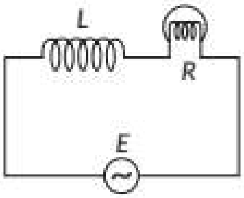
$$\therefore \quad \phi = \tan^{-1}\left(\frac{500-100}{400}\right) = \tan^{-1}(1)$$

$$\phi = 45°$$

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

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

Impedance of the circuit,



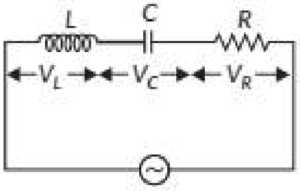
$$Z = \sqrt{X_L^2 + R^2} = \sqrt{\omega^2 L^2 + R^2}$$

(i) When the number of turns in an 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.

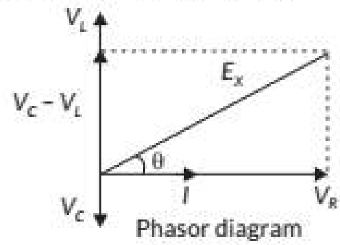
$\Rightarrow C = 8.8 \times 10^{-6}$ F = 8.8 μF

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

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



which leads current *I* by phase angle of π/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 π/2, and voltage drop across the resistor is $V_R = I\,R$,

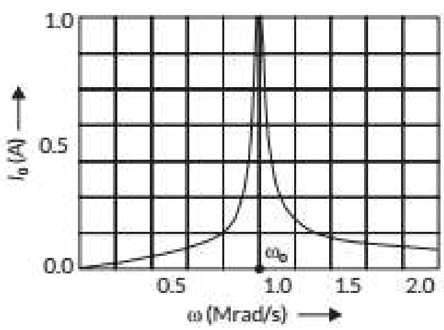
which is in phase with current *I*. So the net voltage *E*, across the circuit is

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

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

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

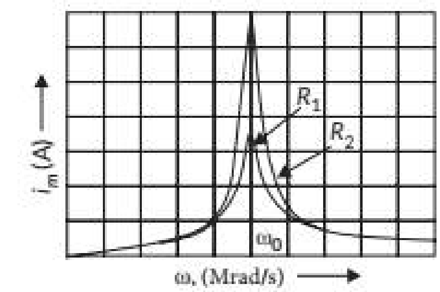
$$\tan\phi = \frac{X_L - X_C}{R} = \frac{\omega L - \frac{1}{\omega C}}{R}$$



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

Circuit become more selective if the resonance is more sharp, maximum current is more, the circuit is close to resonance for smaller range of (2Δω) 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

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

(b) At resonance, $X_L = X_C$

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

$$\therefore \quad \phi = 0°$$

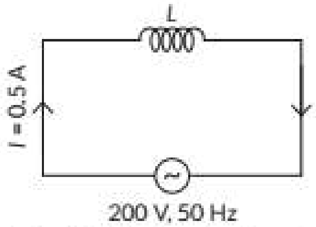
case R_1.

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.

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

∴ 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

∴ Inductive reactance, $X_L = \omega L = 2\pi\upsilon L$

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

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

36. (a) 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 resonant angular frequency to the bandwidth of the circuit.

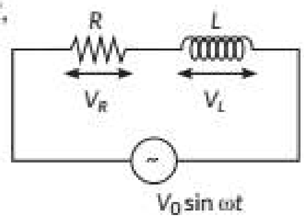
$$\phi = \tan^{-1}\left(\frac{X_C}{R}\right)$$

$$\phi = \tan^{-1}\left(\frac{1}{\omega RC}\right)$$

In RC series circuit the current leads the applied voltage.

30. (a) (i) Peak voltage across *R*,
$V_R = I_0 R$

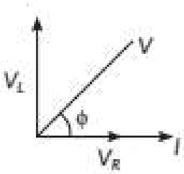
$$V_R = \frac{V_0}{\sqrt{R^2 + X_L^2}} R$$



(ii) Peak voltage across, *L*

$$V_L = \frac{V_0 X_L}{\sqrt{R^2 + X_L^2}}$$

(b)



Phase difference $\phi = \tan^{-1}\left(\frac{V_L}{V_R}\right) = \tan^{-1}\left(\frac{X_L}{R}\right)$

Voltage leads in *R* – *L* circuit as shown in figure.

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, $X_L = \omega L = 2\pi\upsilon L$
$= 2 \times 3.14 \times 39.80 \times 8 = 2000\ \Omega$

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

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

(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) When a capacitor is connected in series in the circuit, so its impedance is given by,

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

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

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

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

From diagram, by parallelogram law of vector addition,

$$\vec{V_R} + \vec{V_C} = \vec{V}$$

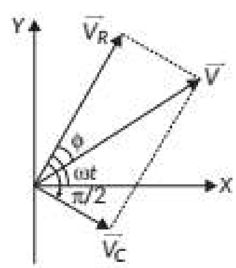
Using pythagoras theorem, we get

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

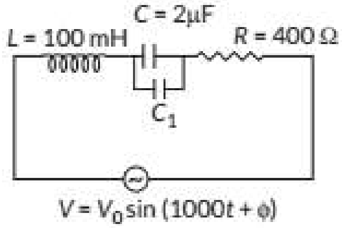
$V^2 = I^2(R^2 + X_C^2)$

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

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



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



The standard equation is given as

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

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

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

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

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

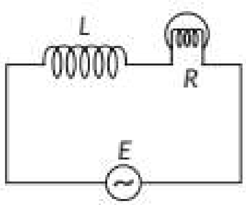
$$\therefore\ \phi = \tan^{-1}\left(\frac{500-100}{400}\right) = \tan^{-1}(1)$$

$\phi = 45°$

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

32. 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 an 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.

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 Z = impedance.

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

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

34. (i) We know that, $X_L = \omega L = 2\pi f L$

$$\Rightarrow L = \frac{X_L}{2\pi f} = \frac{20}{2 \times 3.14 \times 100} = 0.0318\ \text{H} = 31.8\ \text{mH}$$

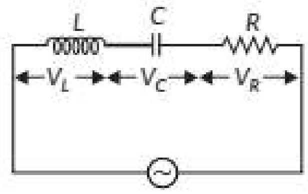
(ii) For maximum power dissipation, $X_L = X_C$

$$2\pi f L = \frac{1}{2\pi f C} \Rightarrow 2 \times 3.14 \times 300 \times 31.8 \times 10^{-3} = \frac{1}{2 \times 3.14 \times 300 C}$$

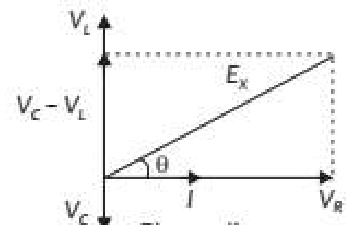
$\Rightarrow C = 8.8 \times 10^{-6}$ F $= 8.8\ \mu$F

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

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



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



Phasor diagram

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

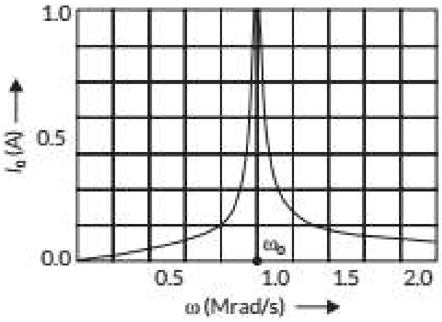
$$Q = \frac{\omega_r}{2\Delta\omega}$$

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 $R_2 (R_1 > R_2)$.

LCR circuit, phase difference ϕ between the current *I* and the voltage *E* is

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



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

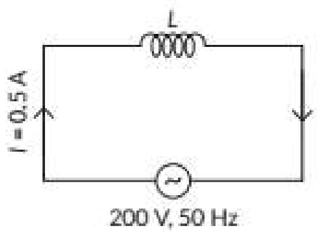
(b) At resonance, $X_L = X_C$

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

$\therefore$ $\phi = 0°$

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

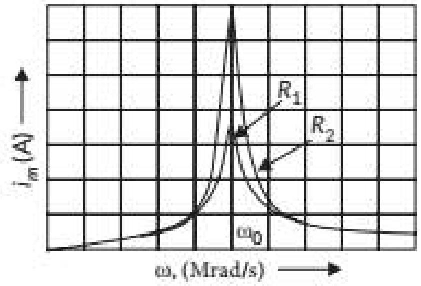
Also, $I = \frac{V}{X_L}$ or $0.5 = \frac{200}{2 \times 3.14 \times 50 \times L}$

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

36. (a) 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 resonant angular frequency to the bandwidth of the circuit.



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, $X_L = \omega L = 2\pi\upsilon L$
$= 2 \times 3.14 \times 39.80 \times 8 = 2000\ \Omega$

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

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

Key Points

- For resonance to be occurred in *LCR*-circuit, the presence of both capacitor (*C*) and inductor (*L*) necessary. Resonance cannot be obtained in *LR* and *LC* circuits.

37. If *I* is the current in the circuit containing inductor of inductance *L*, capacitor of capacitance *C* and resistor of resistance *R* in series, then the voltage drop across the inductor is

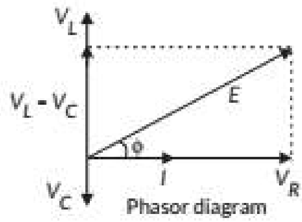
$V_L = I \times X_L$

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

$V_C = I \times X_C$

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

$V_R = IR$



which 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

$X_L = X_C$

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

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

Series *LCR* circuit offers minimum impedance *i.e.*, only '*R*' and current at this frequency is maximum.

(ii) Potential drop across inductor and capacitor are

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

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

$= 2 \times 3.14 \times 39.80 \times 8 = 2000\ \Omega$

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

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

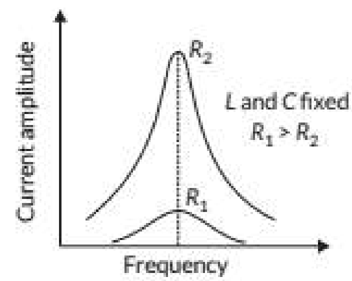
(i) The frequency of the source will be

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

This frequency is known as the series resonance frequency.

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

(iii)



(iv) 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 resonant angular frequency to the bandwidth of the circuit.

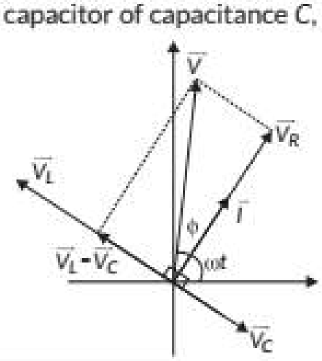
$$Q = \frac{\omega_r}{2\Delta\omega}$$

39. (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,

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.

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

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

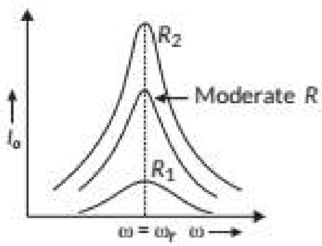
Clearly, I_0 becomes zero both for $\omega \to 0$ and $\omega \to \infty$.

The value of I_0 is maximum when

$\omega L-\frac{1}{\omega C}=0$ 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.

40. **(d):** As, $E = E_0\sin\omega t$, $I=I_0\sin\left(\omega t+\frac{\pi}{2}\right)$; $\phi=\frac{\pi}{2}$

Average power, $P = E_0I_0\cos\phi = E_0I_0\cos\frac{\pi}{2}=0$

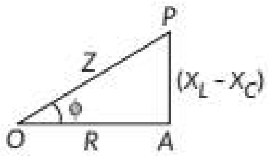
41. **(b):** Three electric bulbs of power 200 W, 100 W and 50 W connected in series.

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

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

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

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



$I_{rms}=\frac{I_0}{\sqrt{2}}=\frac{10}{\sqrt{2}}$ A

$V_{rms}=\frac{10}{\sqrt{2}}\times 20 \Rightarrow V_{rms}=100\sqrt{2}$

Power loss in once cycle $P = V_{rms}\cdot I_{rms}\cdot\cos\theta$

$=100\sqrt{2}\times\frac{10}{\sqrt{2}}\cos 0° \Rightarrow 1000$ W

44. Power factor, $\cos\phi = 0.5$; $\cos\phi = \cos 60° \Rightarrow \phi = 60°$

Phase difference = 60°

45. (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.

46. (i) Current $(I)=\frac{V}{Z}=\frac{V_0\sin\omega t}{\sqrt{R^2+(X_L-X_C)^2}}$

Instantaneous power dissipation $(P) = I^2R$

$P=\left[\frac{V_0\sin\omega t}{Z}\right]^2\times R=\frac{V_0\sin^2\omega t}{Z^2}R$

Average power dissipated in a cycle

$$\langle P\rangle=\frac{\int_0^{2\pi/\omega}P\,dt}{\int_0^{2\pi/\omega}dt}=\frac{V_0R}{2Z^2\times\frac{2\pi}{\omega}}\int_0^{2\pi/\omega}(1-\cos(2\omega t))dt$$

$\langle P\rangle = V_{rms}\cdot I_{rms}\cdot\cos(\phi)$

(ii) Instantaneous value of current in circuit,

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

at instantaneous value of time, $t = 0 \Rightarrow I=\frac{V}{R}$

$I = I_0\sin\omega t$

47. Power factor, $\cos\phi=\frac{R}{Z}$

Since, $V_L = V_C \Rightarrow X_L = X_C\ \therefore\ Z = R \Rightarrow \cos\phi = 1$

48. (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

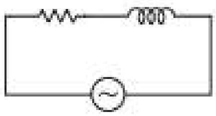
$\because$ We know that, $P \propto \frac{V^2}{R}$ or $R \propto \frac{1}{P}$

As we know that, $P = i^2R$. In a series circuit, the current remain same for all three electric bulbs, but resistance is maximum for 50 W bulbs.
Resistance of bulbs = 50 W > 100 W > 200 W.
In a series circuit potential difference across each bulb will be different.
It is not correct explanation of the assertion. Hence, option (b) is correct.

42. **(a):** Power factor, $\cos\phi = \frac{R}{Z} = 1$.

43. An alternating current $I = (10\text{ A})\sin(100\pi t)$
Here, $I_0 = 10$ Amp., $\phi = 0°$, $R = 20\ \Omega$
$V_{rms} = I_{rms} \times R$

49. $I = 14\sin(100\,\pi t)$



$R = 30\ \Omega$, $L = \frac{2}{5\pi}H, \sqrt{2} = 1.4$

Compare with $I = I_0 \sin\omega t$
$I_0 = 14$ A, $\omega = 100\,\pi$ rad/s

$X_L = \omega L = 100\pi \times \frac{2}{5\pi} = 40\Omega$

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

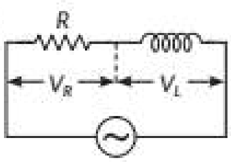
$Z = \sqrt{R^2 + L^2} = \sqrt{30^2 + 40^2} = 50\Omega$

(i) $I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{14}{1.4} = 10\text{A}$

Now, $V_R = I_{rms} \times R = 10 \times 30 = 300$ V
$V_L = I_{rms} \times X_L = 10 \times 40 = 400$ V

(ii) Power factor, $\cos\phi = \frac{R}{Z} = \frac{30}{50} = \frac{3}{5}$

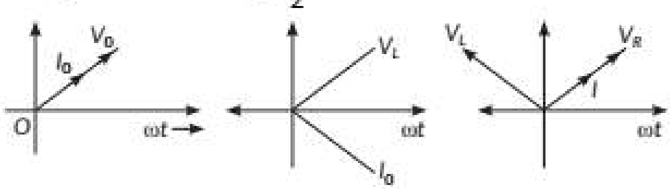
50. (a)



For the circuit, V and I are in phase in case of resistance while voltage lead current by $\frac{\pi}{2}$ across inductor. Thus for R-L circuit

$Z = \sqrt{R^2 + X_L^2}$ and $\tan\phi = \frac{X_L}{R}$

Voltage lead current by $\frac{\pi}{2}$.

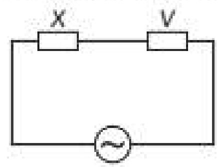


minimum and will be equal to R.
(ii) Average power dissipated through a series LCR circuit is given by
$P_{av} = EI\cos(\phi)$
where E = rms value of alternating voltage
I = rms value of alternating current
ϕ = phase difference between current and voltage
For wattless current, the power dissipated through the circuit should be zero *i.e.*,
$\cos(\phi) = 0$

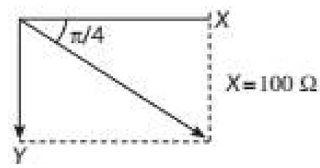
$\Rightarrow \phi = \frac{\pi}{2}$

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.

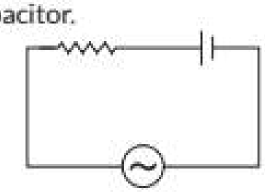
51. Here, a circuit having circuit element X and Y.
We know that the current is ahead of the voltage in phase by $\frac{\pi}{4}$.
So, phasor diagram:



$\varepsilon = \varepsilon_0 \sin\omega t$



(a) As current is ahead then circuit is capacitive.
Hence, Y is a capacitor.



$\varepsilon = \varepsilon_0 \sin\omega t$

(b) Now, we know that $V_{rms} = 141$ V

Impedance of circuit $(Z) = \sqrt{R^2 + X_C^2}$

$\because$ $R = 100\ \Omega$

$\frac{X_C}{R} = \frac{\tan\pi}{4}$

$X_C = R = 100\ \Omega$

So, $Z = \sqrt{100^2 + 100^2} \Rightarrow 100\sqrt{2}$

$I_{rms} = \frac{V_{rms}}{Z} = \frac{141}{100\sqrt{2}} \Rightarrow 0.997$ A

or $I_{rms} = 1$ A
(c) If source current is replaced by a dc source, there is no flow of electric current.

52. To make power factor of the circuit unity,
$X_C = X_L$

Across R Across L Across R-L

(b) We know that, I = 1.0 A, V_R = 160 V, V_L = 120 V

$V_R = 160\text{ V} = IR \Rightarrow R = \frac{160}{1} = 160\,\Omega$

$V_L = 160\text{ V} = IX_L \Rightarrow X_L = \frac{120}{1} = 120\,\Omega$

$\varepsilon_{net} = \sqrt{V_R^2 + V_L^2}$

$= \sqrt{(160)^2 + (120)^2} = \sqrt{25600 + 14400} = 200\text{ V}$

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

$Z = \sqrt{(160)^2 + (120)^2}$

$Z = \sqrt{25600 + 14400} = \sqrt{40000} = 200\,\Omega$

(c) In case of dc across circuit, inductor will act as a plane wire and potential drop will occur at $R\left(i.e., I = \frac{V_0}{R}\right)$ for intermediate time. But for the transition time there will be current drop across inductor.

(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 $I_{rms} = \frac{V_{rms}}{Z}$, so this decreases the current I_{rms} in the circuit and hence the brightness of lamp.

54. (i) Here, L = 80 mH, C = 250 mF, ω = 100 rad/sec, V_{rms} = 240 V

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

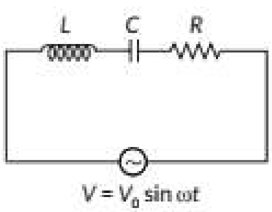
$= \left|100 \times 80 \times 10^{-3} - \frac{1}{100 \times 250 \times 10^{-3}}\right|$

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

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

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

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



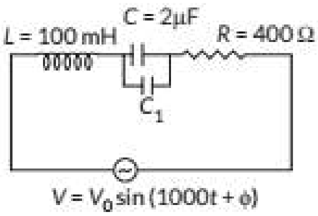
Suppose in an ac circuit, voltage and current are having a phase difference ϕ.

$V = V_0 \sin \omega t$

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

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

$dW = VI\,dt$



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

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

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

$\Rightarrow C_1 = 8\,\mu$F

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

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

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

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

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

or $P = V_{rms} I_{rms} \cos 0° = V_{rms} I_{rms}$ or $P = \frac{V_{rms}^2}{R}$

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

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

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

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

57. 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, $P_2 = \cos \phi$

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

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

58. (d): To reduce the eddy currents, the core of a transformer is laminated.

59. Laminated iron sheets are used to minimize eddy currents in the core of the transformer.

60. (i) In an LCR circuit,

Angular resonant frequency = ω_0

$\therefore$ applied voltage frequency = ω

$\because$ $(\omega < \omega_0)$

$X_C > X_L$

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

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

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

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

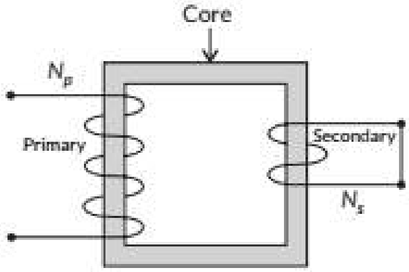
Thus power consumed over a cycle,

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

(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 ac is then given by



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

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

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

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

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, $\dfrac{V_s}{V_p} = \dfrac{N_s}{N_p}$

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

$\Rightarrow I_s V_s = I_p V_p$

When $X_C > X_L$, $\tan\phi$ is negative. Therefore, ϕ is negative. Hence, current leads the voltage by a phase angle ϕ. The ac circuit is capacitor dominated circuit.

(ii) When a dc voltage is applied to a primary coil of transformer, the current in primary coil remains constant. So, there is no change in magnetic flux linked with secondary coil. Therefore, voltage across the secondary is zero. Hence, we can not step up a dc voltage using a transformer.

(iii) Metal detector is work on the principle of electromagnetic induction.

61. (a) In a step up transformer, $I_p \propto \dfrac{I}{N_p}$

so, $\dfrac{I_p}{I_S} = \dfrac{N_S}{N_P}$

For step-up transformation $\dfrac{N_S}{N_P} > 1$

So, I_P (Input current) > I_S (Output current)

(b) The iron core is laminated to minimise eddy current.

(c) In a ideal transformer, the power remains same but in practice power loss due to the heating of coils, humming loss, magnetic flux leakage, hysteresis loss and eddy current.

62. **Step-down transformer :** Step down transformer is based on the principle of mutual induction.

If output circuit is open $V_s = \varepsilon_s$

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

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

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

$\Rightarrow I_s V_s = I_p V_p$

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

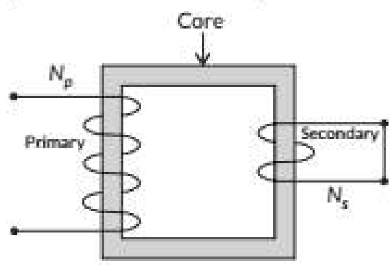
For step-up transformer, $\dfrac{N_s}{N_p} > 1$

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

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

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

64. (a) Step down transformer (or transformer) :

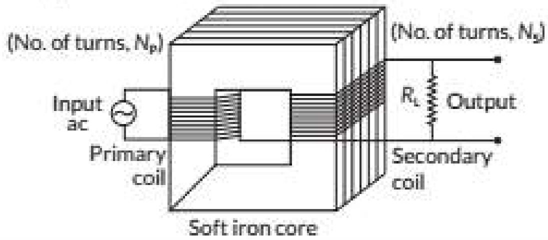


$\therefore \quad \frac{V_s}{V_p} = \frac{I_p}{I_s} = \frac{N_s}{N_p}$

For step-down transformer $\frac{N_S}{N_P} < 1$ and thus $I_P < I_S$ and $V_S < V_P$

The core of transformer laminate to reduce the eddy current and its increase the efficiency of transformer.

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



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

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

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

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.

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

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, $P = 1200$ kW $= 1200 \times 10^3$ W

Total resistance of two wire lines, $R = 2 \times 20 \times 0.5 = 20\,\Omega$

$E_v = 4000$ volt

As, $P = E_v I_v \quad \therefore\ 1200 \times 10^3 = 4000 \times I_v$

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

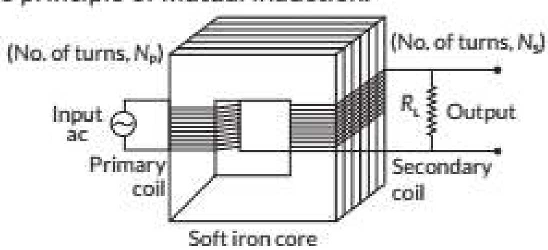
where I_v is the rms value of current.

Line power loss in the form of heat is,

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

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

65. (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 $V_p = \varepsilon_p$.

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

As same flux is linked with the secondary coil with the 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 $\varepsilon_p I_p = \varepsilon_s I_s \quad \therefore \ \frac{I_p}{I_s} = \frac{\varepsilon_s}{\varepsilon_p} = \frac{N_s}{N_p}$

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

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

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

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

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

$\Rightarrow \quad I_s V_s = I_p V_p$

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

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

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

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

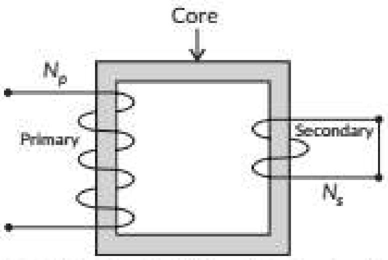
(ii) Thick copper wire is used in winding of transformers because of its low resistivity *i.e.*, low resistance.

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

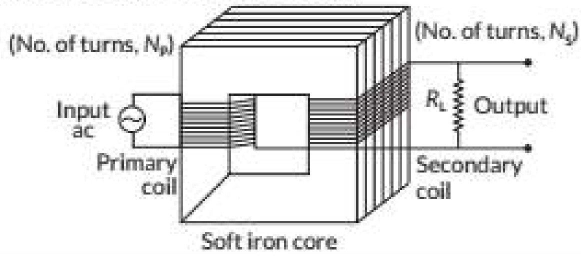
As, $\frac{V_s}{V_p} = \frac{N_s}{n_p}$ or, $N_s = \frac{N_p V_s}{V_p}$

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

66. (i) Step down transformer :



Principle : When the current flowing through the primary coil changes, an emf is induced in the secondary coil due



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

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

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

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, $P_{out} = P_{in} \Rightarrow I_s V_s = I_p V_p$

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

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

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

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

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

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

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

For an ideal transformer, $P_{out} = P_{in} \Rightarrow I_s V_s = I_p V_p$

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

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

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) $N_P = 100$ $\quad\therefore\ N_S = 10000$

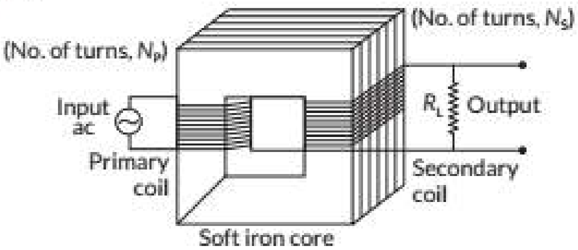
(b) $I_P = \frac{P_i}{\varepsilon_P} = \frac{1100}{220} = 5\,A$

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

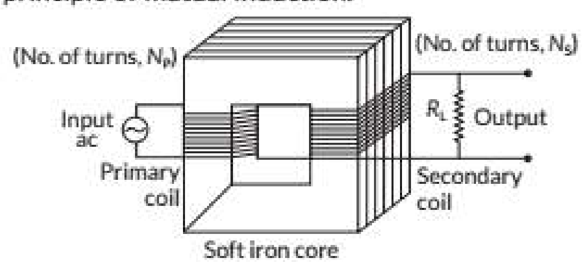
(d) $I_S = \frac{P_O}{\varepsilon_S} = \frac{1100}{22000} = \frac{1}{20}\,A$ $\qquad (\because P_O = P_i)$

(e) $P_S = P_O = P_i = 1100\ W$.

68. (a)



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



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

$$\varepsilon_P = -N_P \frac{d\phi}{dt}$$

If resistance of primary coil is low $V_P = \varepsilon_P$.

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 $V_s = \varepsilon_s$

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

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

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

(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) (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.

CBSE Sample Questions

1. Here, $I = 10\sin 314t$ ...(i)

We know, $I = I_0 \sin\omega t$ ...(ii)

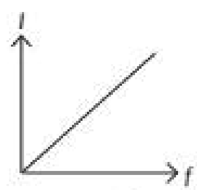
Compare eq. (i) and (ii), $I_0 = 10$

$I_{eff} = \frac{I_0}{\sqrt{2}} = \frac{10}{\sqrt{2}} = 7.07\,A$ **(1/2)**

$\omega = 314 = 3.14 \times 100 = 100\pi$

$\upsilon = \frac{\omega}{2\pi} = \frac{100\pi}{2\pi} = 50\,Hz$ **(1/2)**

2. (c) : In pure capacitor, $I = \frac{V}{X_C}$



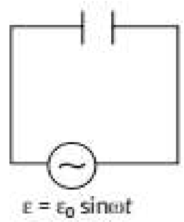
$\therefore\ I = \frac{V}{\frac{1}{2\pi fC}} = V \times 2\pi fC$

$\therefore\ I \propto f$ **(0.77)**

3. $\varepsilon = \varepsilon_0 \sin\omega t$; $C = \frac{q}{\varepsilon}$; $q = C\varepsilon_0 \sin\omega t$

$i = \frac{dq}{dt} = \frac{d}{dt}(C\varepsilon_0 \sin\omega t) = \omega C\varepsilon_0 \cos\omega t$

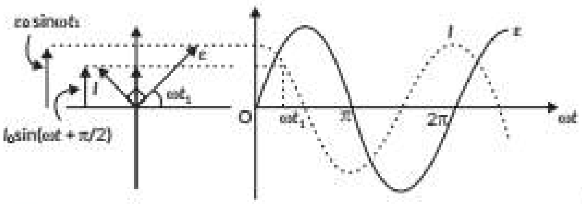
$= \frac{\varepsilon_0}{\frac{1}{\omega C}}\cos\omega t$; $i = \frac{\varepsilon_0}{X_C}\sin\left(\omega t + \frac{\pi}{2}\right)$



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

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

Where, $I_0 = \omega C \varepsilon_0 = \frac{\varepsilon_0}{\frac{1}{\omega C}}$ = current amplitude.



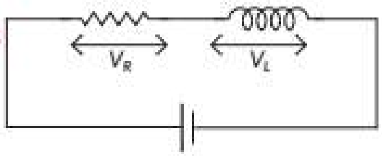
(1)

4. **(b):** When the current passes through the inductor, magnetic field is produced and it opposes the current flow. When the iron coil is removed, self-inductance of the coil decreases *i.e.*, the current flow will be increase and hence brightness of the bulb will increase. **(1)**

5. **(a):** $V_{rms} = \frac{50\sqrt{2}}{\sqrt{2}} = 50$

$V_2 = \sqrt{V_{rms}^2 - V_1^2} = \sqrt{(50)^2 - (40)^2} = 30\text{ V}$ **(1)**

6. **(a):**



V_R = effective voltage across R

$\therefore$ $V_R = I_{eff} \times R$

V_L = effective voltage across L

$V_L = I_{eff} \times L$

So, $V = \sqrt{V_R^2 + V_L^2} = \sqrt{I_{eff}^2 R^2 + I_{eff}^2 L^2}$

$20 = \sqrt{(12)^2 + V_L^2}$ or $(20)^2 = (12)^2 + V_L^2$

$\Rightarrow$ $400 = 144 + V_L^2$ $\Rightarrow$ $V_L = \sqrt{400 - 144} = \sqrt{256} = 16\text{ V}$ **(0.77)**

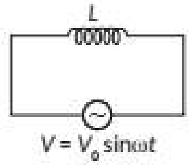
7. **(d):** As, $E = E_0 \sin\omega t$

$I = I_0 \sin\left(\omega t + \frac{\pi}{3}\right)$

As I can lead the voltage in RC and LCR circuit, so it can be RC or LCR circuit. **(0.77)**

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

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



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

Integrating both sides,

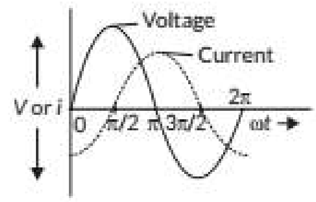
$i = \frac{V_0}{L}\int_0^t \sin\omega t\, dt = \frac{V_0}{L}\left[\frac{-\cos\omega t}{\omega}\right]_0^t$

or $i = \frac{-V_0}{\omega L}\cos\omega t$ or $i = \frac{V_0}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)$

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

where, $i_0 = \frac{V_0}{\omega L}$ is the amplitude of the current. **(2)**

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

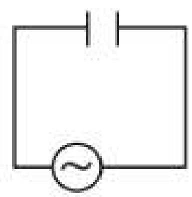


(1)

10. (a) $V = V_0 \sin\omega t$

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

$q = CV_0 \sin\omega t$



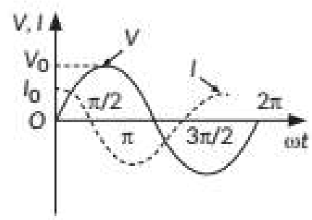
$i = \frac{dq}{dt} = \frac{d}{dt}(CV_0 \sin\omega t)$

$= \omega CV_0 \sin\omega t$

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

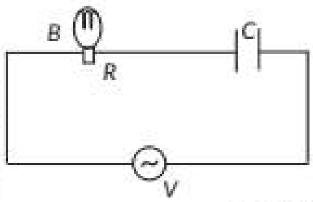
$i = \frac{V_0}{X_C}\sin\left(\omega t + \frac{\pi}{2}\right)$ or $i = i_0 \sin\left(\omega t + \frac{\pi}{2}\right)$

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



(2)

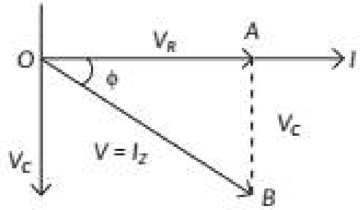
8. (b): $X_C = \frac{1}{2\pi fC} = \frac{1}{\omega C}$



When angular frequency ω increased, then impedance of circuit decreases and current increases. So, the bulb will glow brighter. (0.77)

9. Given that, applied ac Voltage, $V = V_0 \sin \omega t$ ...(i)

(c) Adding resistance R the circuit will behave as RC series ac circuit.



The vector sum of two voltage drop is equal to the applied voltage V(r.m.s value).

Now, $V_R = IR$ and $V_C = IX_C$

where $X_C = \frac{1}{2\pi I\Omega C}$

In ΔOAB,

$$V = \sqrt{(V_R)^2 + (V_C)^2} = \sqrt{(IR)^2 + (IX_C)^2}$$

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

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

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

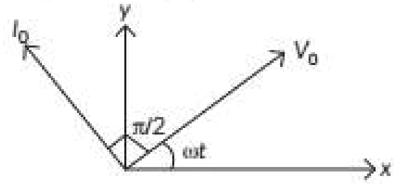
Phase angle, $\tan\phi = \frac{V_C}{V_R} = \frac{IX_C}{IR} = \frac{X_C}{R}$

or $\phi = \tan^{-1}\frac{X_C}{R}$ (2)

(b) Given, $V = V_0 \sin \omega t$

then $I = I_0 \sin (\omega t + \pi/r)$

Therefore, the phaser diagram is as shown below.



(1)

11. (c): Here : $V_0 = 283$ V, $f = 50$ Hz, $R = 3\ \Omega$, $L = 25.48$ mH

$C = 796\ \mu$F, $P|_{\text{at resonance}} = ?$

Power dissipated, $P = I^2R$

$$I = \frac{I_0}{\sqrt{2}} = \frac{1}{\sqrt{2}}\left(\frac{283}{3}\right) = 66.7 \text{ A}$$

$P = I^2R = (66.7)^2 \times 3 = 13.35$ kW (0.77)

12. (d): As primary coil made of thick copper wire has very low resistivity. Therefore power loss is negligible. Rest all options are reasons for power losses in a transformer. (0.77)

13. (i) (d) : Step-down transformer decreases the AC voltage. (0.77)

(ii) (a): $\because \frac{N_s}{N_p} = \frac{E_s}{E_p}$

i.e., number of turns of secondary coil are more than number of turns in primary coil then voltage is increased or stepped-up in secondary coil. So, it is called step-up transformer. (0.77)

(iii) (a): Current is reduced of voltage is stepped-up so corresponding I^2R losses are cut down. (0.77)

(iv) (c): Given, $E_i = 2300$ V, $E_0 = 230$ V, $N_p = 4000$, $N_s = ?$

$$\frac{E_i}{E_o} = \frac{N_p}{N_s} \Rightarrow \frac{2300}{230} = \frac{4000}{x}$$

$\Rightarrow$ $x = 400 = N_s$ = number of turns in the secondary coil (0.77)