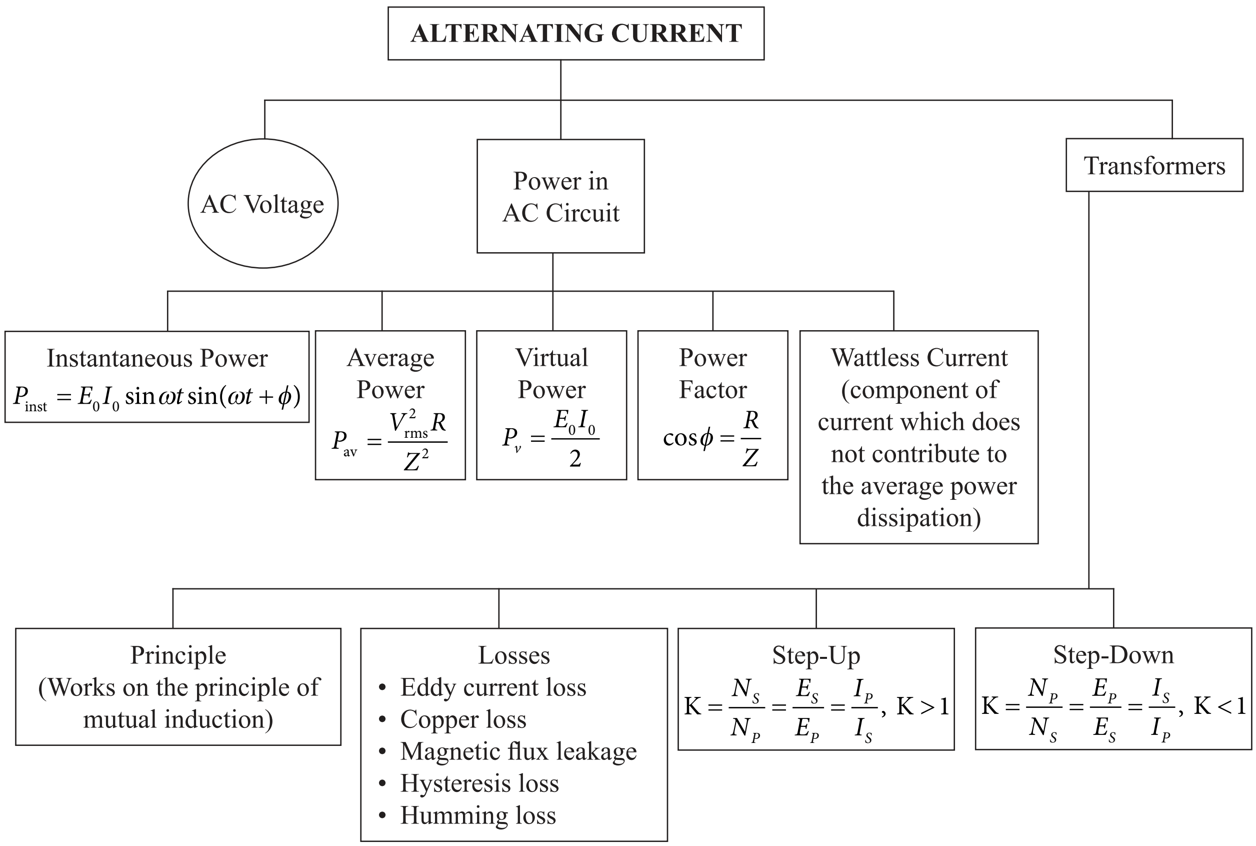
CHAPTER | 7 |

Alternating Current

Syllabus

- **AC Voltage:** Introduction; AC voltage applied to a resistor; Phasors; AC voltage applied to an inductor; AC voltage applied to a capacitor, resistive-inductive circuit, resistive-capacitive circuit, inductive-capacitive circuit; AC voltage applied to a series LCR circuit; Resonance; LC oscillations.
- **Power in AC Circuit:** Introduction, instantaneous power, average power, virtual power, power factor.
- **Transformers:** Introduction, principle, types of transformers, losses in transformers.

MIND MAP



Mind Map 1: Alternating at a Glance

AC VOLTAGE

AC voltage applied to a resistor
- emf: $E = E_0 \sin\omega t$
- current: $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$
- peak value of current: $I_0 = \frac{E_0}{R}$

AC voltage applied to a inductor
- emf: $E = E_0 \sin\omega t$
- current: $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$
- peak value of current: $I_0 = \frac{E_0}{2\pi\nu L}$

AC voltage applied to an capacitor
- emf: $E = E_0 \sin\omega t$
- current: $I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$
- peak value of current: $I_0 = E_0 (2\pi\nu) C$

Phasors
(diagrams representing alternating current and voltage of same frequency as vectors or phasors with phase angle between them)

Resistive-inductive circuit
- emf: $E = \sqrt{V_R^2 + V_L^2}$
- current: $I = I_0 \sin(\omega t - \phi)$
- peak value of current: $I_0 = \frac{V_0}{\sqrt{R^2 + 4\pi^2\nu^2L^2}}$
- Impedance: $Z = \sqrt{R^2 + 4\pi^2\nu^2L^2}$
- Phase difference: $\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$

Resistive-capacitive circuit
- emf: $E = \sqrt{V_R^2 + V_C^2}$
- current: $I = I_0 \sin(\omega t + \phi)$
- peak value of current: $I_0 = \frac{V_0}{\sqrt{R^2 + \frac{1}{4\pi^2\nu^2C^2}}}$
- Impedance: $Z = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$
- Phase difference: $\phi = \tan^{-1}\left(\frac{1}{\omega CR}\right)$

Inductive-capacitive circuit
- emf: $E = V_L - V_C$
- current: $I = I_0 \sin\left(\omega t \pm \frac{\pi}{2}\right)$
- peak value of current: $I_0 = \frac{V_0}{\left(\omega L - \frac{1}{\omega C}\right)}$
- Impedance: $Z = X_L - X_C = X$
- Phase difference: $\phi = 90°$

AC voltage applied to a series LCR circuit
- emf: $V = \sqrt{V_R^2 + (V_L - V_C)^2}$
- current: $I = I_0 \sin(\omega t \pm \phi)$
- peak value of current: $I_0 = \frac{E_0}{Z}$
- Impedance: $Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$
- Phase difference: $\phi = \tan^{-1}\left(\frac{\omega L - \frac{1}{\omega C}}{R}\right)$

Resonance
- The necessary condition for resonance is $X_L = X_C$
- Resonance frequency: $\nu = \frac{1}{2\pi\sqrt{LC}}$

LC oscillations
(The frequency of energy oscillations is given by) $\nu = \frac{1}{2\pi\sqrt{LC}}$

Mind Map 2: AC Voltage at a Glance

RECAP

AC Voltage

Introduction

- An alternating quantity (current *I* or voltage *V*) is one whose magnitude changes continuously with time between zero and a maximum value and whose direction reverses periodically.
- The electric mains supply in our homes and offices is a voltage that varies like a sine function with time. Such a voltage is called **alternating voltage.**
- The current that changes its magnitude and polarity at regular intervals of time is called an **alternating current (AC).**
- AC voltage is preferred over Direct Current (DC) voltage as AC voltages can be easily and efficiently converted from one voltage to the other by means of transformers.
- Alternating current obeys Ohm's law and Joule's law.
- In AC circuits, the direction of current is not indicated.

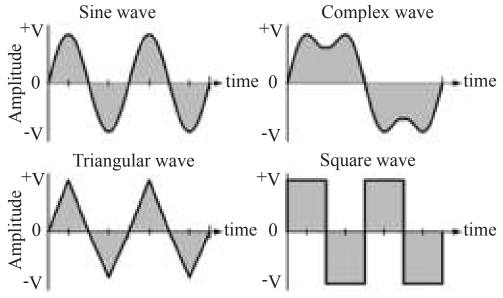


Figure: Alternating current

- **Instantaneous value**
  - At any instant the value of emf (voltage) or current in an AC circuit is called instantaneous value.
  - The instantaneous value of emf (voltage) is represented by *E* and current is represented by *I*. Its value may be zero.
  - Instantaneous value depends upon time and varies simple harmonically in the circuit.
- **Peak value**
  - The positive or negative maximum value of current in one cycle of alternating current is called peak value of current.
  - Peak value of voltage is represented by E_0 and that of current by I_0.
- **Mean value or average value**
  - Mean value is the average of instantaneous value of current or voltage in one cycle.
  - The mean value of alternating voltage or current in one full cycle is zero i.e.,

$$\bar{E} = \frac{1}{T}\int_0^T E dt = 0; \text{and } \bar{I} = \frac{1}{T}\int_0^T I dt = 0$$

- **Mean square value ($\bar{E}^2$ or $\bar{I}^2$)**
  - Mean square value is the average of square of instantaneous value in one cycle.
  - Mean square value of voltage is,

$$\bar{E}^2 = \frac{1}{T}\int_0^T E^2 dt = \frac{E_0^2}{2}$$

and mean square value of current is,

$$\bar{I}^2 = \frac{1}{T}\int_0^T I^2 dt = \frac{I_0^2}{2}$$

- **Root mean square (rms) value**
  - Root of mean of square of emf or current in an AC circuit for one full cycle is called root mean square value (rms value). The rms value of emf (voltage) is represented by E_{rms} and rms value of current is represented by I_{rms}. Thus,

$$E_{rms} = \sqrt{\bar{E}^2}$$

and,

$$I_{rms} = \sqrt{\bar{I}^2}$$

  - The square of instantaneous value of voltage or current is always positive. Therefore rms value is not zero.

- The rms value of voltage for one full cycle is,

$$E_{\text{rms}} = \sqrt{(\overline{E^2})} = \sqrt{\left(\frac{E_0^2}{2}\right)} = \frac{E_0}{\sqrt{2}} = 0.707E_0$$

and rms value of current for one full cycle is,

$$I_{\text{rms}} = \sqrt{(\overline{I^2})} = \sqrt{\left(\frac{I_0^2}{2}\right)} = \frac{I_0}{\sqrt{2}} = 0.707I_0$$

In general,

$$\text{rms value} = \frac{\text{peak value}}{\sqrt{2}}$$

- **Peak to peak value**
  - Peak to peak value is the sum of the magnitude of positive and negative peak values.
  - Peak to peak value,

$$= E_0 + E_0 = 2E_0 = 2\sqrt{2}E_{\text{rms}} = 2.828E_{\text{rms}}$$

- **Form factor and peak factor**
  - The ratio of rms value of AC to its average during half cycle is known as form factor.
  - The ratio of peak value and rms value is called peak factor.
- **Impedance *(Z)***
  - Impedance is the opposition offered by AC circuits to the flow of alternating current through it.
  - It is equal to the ratio of magnitudes of the alternating voltage and the current.

  Thus,

$$|Z| = \frac{|E|}{|I|} = \frac{E_{\text{rms}}}{I_{\text{rms}}} = \frac{E_0}{I_0}$$

- **Reactance *(X)***
  - Reactance is the opposition offered by inductor or capacitor or both to the flow of alternating current through it.
  - The reactance is represented by X and,

$$X = \frac{E}{I} = \frac{E_{\text{rms}}}{I_{\text{rms}}} = \frac{E_0}{I_0}$$

  - Reactance is of the two types:
    - **Inductive reactance (X_L)**
      - Inductive reactance,

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

      For DC,

      $\nu = 0, X_L = 0$
    - **Capacitive reactance (X_C)**
      - Capacitive reactance,

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

      For DC,

      $\nu = 0, X_L = \infty$
- **Admittance *(Y)***
  - Admittance is the reciprocal of impedance.

$$\left(Y = \frac{1}{Z}\right)$$

- **Susceptance *(S)***

- Susceptance is the reciprocal of reactance.

$$\left(S = \frac{1}{X}\right)$$

- Susceptance is of the two types:
  - **Inductive susceptance (S_L)**

$$S_L = \frac{1}{X_L} = \frac{1}{2\pi\nu L}$$

  - **Capacitive susceptance (S_C)**

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

- **Conductance *(G)***
  - Conductance is the reciprocal of resistance of a circuit.

$$\therefore \text{ Conductance} = \frac{1}{\text{Resistance}} \quad \text{or,} \quad G = \frac{1}{R}$$

  - The unit of conductance is $(\text{ohm})^{-1}$ or mho.

AC voltage applied to a resistor

- A pure resistance R is connected to an alternating source of emf. Suppose at time t, emf applied to the circuit is,

$$E = E_0 \sin\omega t$$

- According to Ohm's law, at time t the current in the circuit due to this emf will be,

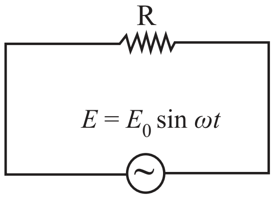


Figure: AC circuit with R

$$I = \frac{E}{R} = \frac{E_0}{R}\sin\omega t; \text{ or, } I = I_0 \sin\omega t$$

where, $I_0 = \frac{E_0}{R}$ is the maximum or peak value of current.

Phasors

- **Phase difference:** Suppose, the emf and current in a circuit are $E = E_0 \cos \omega t$ and $I = I_0 \cos (\omega t + \phi)$. Then ϕ is called the phase difference between E and I.
  If ϕ is positive, then the current is said to lead the emf by phase angle ϕ. If ϕ is negative, then the current is said to lag behind the emf by phase angle ϕ.
- **Phasor Diagram**
  - Phasor diagrams are diagram representing alternating current and voltage of same frequency as vectors or phasors with the phase angle between them.
  - Phasors are the arrows rotating in the anti-clockwise direction i.e. they are rotating vectors but they represents scalar quantities.
  - Length of the vector must be equal to the peak value of alternating voltage or current.
  - In certain circuits when current reaches its maximum value after emf becomes maximum then current is said to lag behind emf.
  - When current reaches its maximum value before emf reaches its maximum then current is said to lead the emf.

AC voltage applied to an inductor

- A pure inductor L is connected to an alternating source of emf. Suppose at time t, emf applied to the circuit is,

$$E = E_0 \sin\omega t$$

- An alternating current I flowing in the circuit is given as,

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

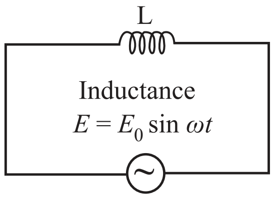


Figure: AC circuit with L

where,

$$I_0 = \frac{E_0}{X_L} = \frac{E_0}{\omega_L} = \frac{E_0}{2\pi \nu L}$$

I_0 is the peak value of I.

AC voltage applied to a capacitor

- A pure capacitor C is connected to an alternating source of emf. Suppose at time t, emf applied to the circuit is,

$$E = E_0 \sin \omega t$$

- Since applied emf is periodic, so the charge stored on the plates of the capacitor will also be periodic, as a result an alternating current flows through the capacitor,

$$q = CE = CE_0 \sin wt$$

$$\therefore \quad I = \frac{dq}{dt} = wCE_0 \cos wt$$

or, $$I = I_0 \cos wt$$

where $$I_0 = wCF_0$$

but, $$\cos wt = \sin\left(wt + \frac{\pi}{2}\right)$$

$$\therefore \quad I = I_0 \sin\left(wt + \frac{\pi}{2}\right)$$

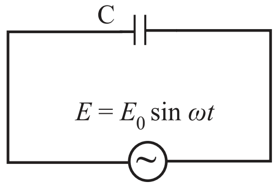


Figure: AC circuit with C

where, $$I_0 = \frac{E_0}{X_c} = \omega CE_0 = E_0(2\pi\nu)C$$

I_0 is the peak value of I.

Resistive-inductive circuit (RL-circuit)

- A RL series circuit consists basically of an inductor of inductance. L connected in series with a resistor of resistance R.
- The applied voltage E can be given as,

$$E = \sqrt{V_R^2 + V_L^2}$$

- Voltage V_R and current I are in phase but the voltage V_L leads the current by an angle π/2. Thus, the phase difference between V_R and V_L will be π/2 or 90°.
- The voltage leads the current by an angle,

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

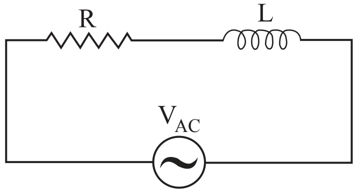


Figure: RL series circuit

- Impedance (Z) of the circuit is given as,

$$Z = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + \omega^2 L^2} = \sqrt{R^2 + 4\pi^2 \nu^2 L^2}$$

- The current I in the circuit is given as,

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

where,

$$I_0 = \frac{E_0}{Z} = \frac{E_0}{\sqrt{R^2 + X_L^2}} = \frac{V_0}{\sqrt{R^2 + 4\pi^2 \nu^2 L^2}}$$

I_0 is the maximum or peak value of current I.

Resistive-capacitive circuit (RC-circuit)

- A RC circuit is a circuit with a resistor (R) and a capacitor (C) connected in series.
- The applied voltage E can be given as,

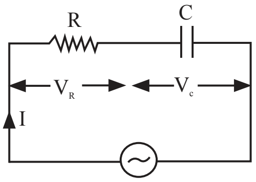


Figure: RC series circuit

$$E = \sqrt{V_R^2 + V_C^2}$$

- Voltage V_R and I are in phase while V_C will lag behind the current I by $\frac{\neq}{2}$ or 90°.
- The voltage lags behind the current by an angle,

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

- The impedance (Z) of the circuit is given as,

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

- The current I in the circuit is given as,

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

where, $I_0 = \frac{E_0}{Z} = \frac{V_0}{\sqrt{R^2 + X_C^2}} = \frac{V_0}{\sqrt{R^2 + \frac{1}{4\pi^2 v^2 C^2}}}$

I_0 is the maximum or peak value of current I.

Inductive-capacitive circuit (LC-circuit)

- A LC circuit is a circuit with a resistor (R) and a capacitor (C) connected in series.
- The applied voltage E can be given as,

$$E = V_L - V_C$$

where, V_L is voltage across L and V_C is voltage across C.
- The phase difference ϕ between the applied voltage E and current I is given as, $\phi = 90°$.
- The impedance (Z) of the circuit is given as,

$$Z = X_L - X_C = X$$

- The current I in the circuit is given as,

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

where, $I_0 = \frac{E_0}{Z} = \frac{E_0}{X_L - X_C} = \frac{V_0}{\omega L - \frac{1}{\omega C}}$

I_0 is the maximum or peak value of current I.

AC voltage applied to a series LCR circuit

- A coil of inductance L, capacitor of capacitance C, and a resistor of resistance R are connected in series and an alternating emf $E = E_0 \sin\omega t$ is applied to this combination.
- The equation for the voltage in the circuit is,

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

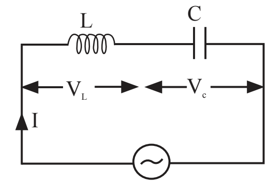


Figure: LC series circuit

- V_R and I are in phase, voltage V_L leads the current I by an angle $\frac{\neq}{2}$, voltage V_C lags behind the current by an angle $\frac{\neq}{2}$. Thus, V_L and V_C will be opposite in phase.

- Phase angle,

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

- The impedance (*Z*) of the circuit is,

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

- In series combination, the current *I* remains the same while the vector sum of potential difference across these components will be equal to the applied emf. The equation for current is given as,

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

where, $I_0 = \frac{E_0}{Z}$

- If net reactance is inductive, circuit behaves as RL circuit and if the net reactance is capacitive, it behaves as RC circuit.

Resonance

- **Series Resonance Circuit**
  - A series LCR-circuit, which admits maximum current corresponding to a particular angular frequency ω_0 of the AC source, is called series resonant circuit and the angular frequency ω_0 is called the resonant angular frequency.
  - For resonance to occur, net reactance should be zero, i.e.,

$$X = X_L - X_C = 0$$

$$\therefore \quad X_L = X_C$$

  - At resonance,

$$X_L = X_C \Rightarrow Z_{\min} = R$$

i.e., circuit behaves as resistive circuit.

$$V_L = V_C \Rightarrow \quad V = V_R$$

i.e., whole applied voltage appears across the resistance.

    - Current in the circuit is maximum and it is,

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

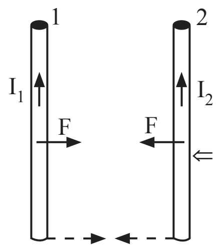


Figure: Two straight and parallel current-carrying conductors

  - **Resonant frequency (Natural frequency)**
    At resonance, $X_L = X_C$

$$\therefore \ \omega_0 L = \frac{1}{\omega_0 C}; \quad \therefore \omega_0 = \frac{1}{\sqrt{LC}} \text{rad/s}; \quad \therefore \nu_0 = \frac{1}{2\pi\sqrt{LC}} \text{ Hz (or cps)}$$

(Resonant frequency doesn't depend upon the resistance of the circuit)

- **Parallel Resonance Circuit**
  - **Parallel LCR Circuit:** The LCR parallel circuit, which allows no current to flow corresponding to a particular angular frequency ω_0 of the AC source, is called LCR-parallel resonant circuit and angular frequency ω_0 is called the resonant angular frequency.
  - At resonance,
    - The current is,

$$I_C = I_L \Rightarrow I_{\min} = I_R$$

    - The susceptance is given as,

$$\frac{V}{X_C} = \frac{V}{X_L} \Rightarrow S_C = S_L \Rightarrow \Sigma S = 0$$

- Impedance is given as,

$$Z_{max} = \frac{V}{I_R} = R$$

- Resonant frequency is given as,

$$\Rightarrow \nu = \frac{1}{2\pi\sqrt{LC}}$$

- **Parallel LC circuits:** If inductor (L) has resistance (R) and it is connected in parallel with capacitor (C).
  - Maximum impedance is given as,

$$Z_{max} = \frac{1}{Y_{min}} = \frac{L}{CR}$$

  - Current through the circuit is minimum and,

$$I_{min} = \frac{V_0 CR}{L}$$

  - Susceptance is given as, $S_L = S_C$

$$\therefore \quad \frac{1}{X_L} = \frac{1}{X_C}$$

$$\Rightarrow \quad X = \infty$$

  - Resonant frequency,

$$\omega_0 = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} \ \frac{\text{rad}}{\text{sec}}; \text{or, } \nu_0 = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} \text{ Hz}$$

(Condition for parallel resonance is $R < \sqrt{\frac{L}{C}}$)

LC Oscillations

- The electric current and the charge on the capacitor in the circuit undergo electrical LC oscillations when a charged capacitor is connected to an inductor. The electrical energy stored in the capacitor is its initial charge which is named as q_m.

$$U_E = \frac{1}{2}\frac{q_m^2}{C}$$

- Frequency of oscillation is given by,

$$\nu = \frac{1}{2\pi\sqrt{LC}} \text{ Hz} \quad \left(\because \omega = \frac{1}{\sqrt{LC}}\right)$$

- If the resistance of the circuit is zero, no energy is dissipated as heat.
- The parallel combination of inductor of inductance L and capacitor of capacitance C is called as tank circuit.

Power in AC Circuit

Introduction

- In an electric circuit, the rate of dissipation of power or the work done by the current in one second is called power of the circuit.
- In AC circuits, since there is some phase angle between voltage and current, therefore power is defined as the product of voltage and that component of the current which is in phase with the voltage. Thus, $P = VI \cos \phi$; where V and I are rms values of voltage and current.
- Unit of power is watt or joule/s.

Instantaneous power

- Instantaneous power is the power in an AC circuit at any instant.
- Suppose in a circuit $E = E_0 \sin \omega t$ and $I = I_0 \sin(\omega t + \phi)$

  $\therefore$ Instantaneous power,

$$P_{\text{inst}} = EI = E_0 I_0 \sin \omega t \sin(\omega t + \phi)$$

Average power

- The average of instantaneous power in an AC circuit over a full cycle is called average power.
- Average power is given by,

$$P_{\text{av}} = E_{\text{rms}} I_{\text{rms}} \cos\phi = \frac{E_0}{\sqrt{2}} \frac{I_0}{\sqrt{2}} \cos\phi = \frac{1}{2} E_0 I_0 \cos\phi = I_{\text{rms}}^2 R = \frac{V_{\text{rms}}^2 R}{Z^2}$$

Virtual power

- The product of virtual voltage and virtual current in the circuit is called virtual power.
- Virtual power $= E_{\text{rms}} \cdot I_{\text{rms}}$

$$\therefore \quad P_v = \frac{E_0 I_0}{2}$$

Power factor

- Power factor is the ratio of true power to apparent power of an ac circuit,

$$\cos\phi = \frac{\text{True power}}{\text{Apparent power}}$$

- Power factor is also equal to the ratio of the resistance and the impedance of the AC circuit.

  Thus, $\cos\phi = \dfrac{R}{Z}$

- Power factor depends upon the nature of the components used in the circuit.
- In pure resistive circuit, $\cos \phi = 1$.
- In pure inductive circuit, $\cos \phi = 0$.
- In pure conductive circuit, $\cos \phi = 0$.
- In RL circuit,

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

- In RC circuit,

$$\cos\phi = \frac{R}{\sqrt{R^2 + X_C^2}}$$

- In LC circuit, $\cos \phi = 0$.
- At resonance, $X_L = X_C$

$$\therefore \quad Z = R$$

$$\text{and,} \quad \phi = 0^\circ$$

$$\cos\phi = 1$$

Wattless current

- The component of current which does not contribute to the average power dissipation is called wattless current.
- In an AC circuit, $R = 0$, then, $\cos \phi = 0$, so, $P_{\text{av}} = 0$ i.e., in resistance-less circuit the power consumed is zero. Such a circuit is called the wattless circuit and the current flowing is called the wattless current.

- The average of wattless power is zero because the average of second component of instantaneous power for a full cycle is zero.

$$E_0 \sin \omega t \left(I_0 \sin\phi\right) \sin\left(\omega t - \frac{\pi}{2}\right) = 0$$

Transformers

Introduction

- Transformer is a device used for converting low alternating voltage at high current into high voltage at low current and vice-versa, through mutual induction.
- It can increase or decrease either voltage or current but not both simultaneously.
- Transformer does not change the frequency of input alternating current.
- There is no electrical connection between the winding but they are linked magnetically.

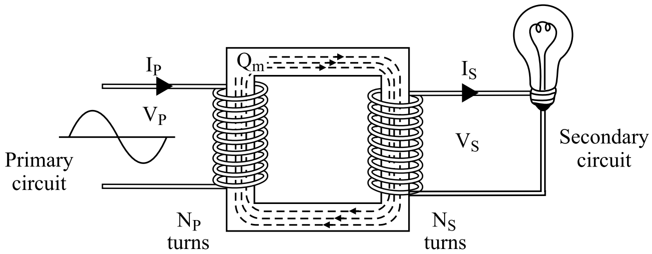


Figure: Transformer

- Effective resistance between primary and secondary winding is infinite.
- If N_P = number of turns in primary
  N_S = number of turns in secondary
  V_P = applied (input) voltage to primary
  V_S = Voltage across secondary (load voltage or output)
  e_P = induced emf in primary
  e_S = induced emf in secondary
  In an ideal transformer there is no loss of power,

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

$$so,\ V_S I_S = V_P I_P$$

$$V_P \approx e_P; V_S \approx e_S$$

Hence, $\dfrac{e_S}{e_P} = \dfrac{N_S}{N_P} = \dfrac{V_S}{V_P} = \dfrac{I_P}{I_S} = \text{k}$

- The efficiency of the transformer is given by,

$$\eta = \frac{\text{Output power}}{\text{Input power}}$$

Principle and working

- It works on the principle of mutual induction i.e., if two coils are inductively coupled and when current or magnetic flux is changed through one of the two coils, then induced emf is produced in the other coil.
- It consists of two coils wound on the same core.
- The alternating current passing through the primary creates a continuously changing flux through the core. The changing flux induces an alternating emf in the secondary. To minimize eddy currents, the soft iron core is laminated.

Types of transformers

- There are two types of transformer:
  - **Step-up transformer:** In step-up transformer, the no. of turns in secondary coil (N_S) is greater than the number of turns in primary coil (N_P) i.e., $N_S > N_P$. It converts a low voltage at high current into a high voltage at low current.

- **Step-down transformer:** The number of turns in secondary coil (N_S) is less than that in primary coil (N_P) i.e., $N_S < N_P$. It converts a high voltage at low current into a low voltage at high current.

Losses in transformers

- **Eddy current loss:** In actual iron cores, despite of lamination, eddy current are produced. The magnitude of eddy current may however be small. But a part of energy is lost as the heat produced in the iron core.
- **Copper loss:** In practice, the coils of the transformer possess resistance. So, a part of the energy is lost due to the heat produced in the resistance of the coil.
- **Magnetic flux leakage:** The coupling between the coils is seldom perfect. So, whole of the magnetic flux produced by the primary coil is not linked up with the secondary coil.
- **Hysteresis loss:** The alternating current flowing through the coils magnetizes and demagnetizes the iron core again and again. Therefore, during each cycle of magnetization, some energy is lost due to hysteresis.
- **Humming loss:** Due to the passage of alternating current, the core of the transformer starts vibrating and produces loss of electrical energy in the form of humming sound.

PRACTICE TIME

AC Voltage

1. Alternating current cannot be measured by DC ammeter because:
(a) AC is virtual
(b) AC changes its direction
(c) AC cannot pass through DC ammeter
(d) Average value of complete cycle is zero

2. The alternating current of equivalent value of $\frac{I_0}{\sqrt{2}}$ is:
(a) rms current
(b) DC current
(c) Peak current
(d) all of these

3. In an AC circuit $I = 100\sin 200\pi t$. The time required for the current to achieve its peak value will be:
(a) $\frac{1}{200}$ s (b) $\frac{1}{400}$ s
(c) $\frac{1}{100}$ s (d) $\frac{1}{300}$ s

4. The resistance of a coil for DC is in Ω. In AC, the resistance:
(a) Will be zero (b) Will remain same
(c) Will increase (d) Will decrease

5. The ratio of mean value over half cycle to rms value of AC is:
(a) $\sqrt{2}:1$ (b) $2:\neq$
(c) $2\sqrt{2}:\neq$ (d) $\sqrt{2}:\neq$

6. The peak value of an alternating emf E given by $E = E_0 \cos\omega t$ is 10 V and its frequency is 50 Hz. At time $t = \frac{1}{600}$ s, the instantaneous emf is:
(a) $5\sqrt{3}$ V (b) 5 V
(c) 10 V (d) 1 V

7. The domestic power supply works on 220 V, then the voltage amplitude of emf as mentioned for the safe operation of component in circuit is:
(a) 220 V (b) 440 V
(c) 155.6 V (d) 311 V

8. When an AC voltage of 220 V is applied to the capacitor C, then:
(a) The current is in phase with the applied voltage
(b) Power delivered to the capacitor per cycle is zero
(c) The maximum voltage between plates is 220 V
(d) The charge on the plate is not in phase with the applied voltage

9. The frequency of an alternating voltage is 50 cps and its amplitude is 120 V. Then the rms value of voltage is:
(a) 56.5 V (b) 70.7 V
(c) 101.3 V (d) 84.8 V

10. A 40 Ω electric heater is connected to a 200 V, 50 Hz mains supply. The peak value of electric current flowing in the circuit is approximately:
(a) 10 A (b) 5 A
(c) 7 A (d) 2.5 A

11. In the case of an inductor:
(a) Voltage leads the current by $\frac{\neq}{4}$

(b) Voltage leads the current by $\frac{\neq}{3}$

(c) Voltage leads the current by $\frac{\neq}{2}$

(d) Voltage lags the current by $\frac{\neq}{2}$

12. A resistance of 20 Ω is connected to a source of an alternating potential $V = 220\sin(100\pi t)$. The time taken by the current to change from its peak value to rms value is:

(a) 2.5×10^{-3} s (b) 25×10^{-3} s

(c) 0.25 s (d) 0.2 s

13. The rms value of an AC of 50 Hz is 10 A. The time taken by the alternating current in reaching from zero to maximum value and the peak value of current will be:

(a) 1×10^{-2} s and 7.07 A

(b) 2×10^{-2} s and 14.14 A

(c) 5×10^{-3} s and 14.14 A

(d) 5×10^{-3} s and 7.07 A

14. Determine the rms value of the emf given by,

$$E\text{ (in V)} = 8\sin(\omega t) + 6\sin(2\omega t)$$

(a) $10\sqrt{2}$ V (b) 10 V

(c) $5\sqrt{2}$ V (d) $7\sqrt{2}$ V

15. An alternating current of frequency f is flowing in a circuit containing a resistor of resistance R and a choke of inductance L in series. The impedance of this circuit is:

(a) $R + 2\pi fL$ (b) $\sqrt{R^2 + L^2}$

(c) $\sqrt{R^2 + 2\pi fL}$ (d) $\sqrt{R^2 + 4\pi^2 f^2 L^2}$

16. A generator produces a voltage that is given by $V = 240\sin 120t$ V, where t is in seconds. The frequency and rms voltage are nearly:

(a) 19 Hz and 120 V

(b) 19 Hz and 170 V

(c) 60 Hz and 240 V

(d) 754 Hz and 170 V

17. The instantaneous voltage through a device of impedance 20 Ω is $e = 80\sin 100\pi t$. The effective value of the current is:

(a) 1.732 A (b) 2.828 A

(c) 3 A (d) 4 A

18. An alternating voltage is connected in series with a resistance R and an inductance L. If the potential drop across the resistance is 200 V and across the inductance is 150 V, then the applied voltage is:

(a) 250 V (b) 300 V

(c) 350 V (d) 500 V

19. A 15 μF capacitor is connected to 220 V, 50 Hz source. Find the capacitive reactance and the rms current.

(a) 212.1 Ω; 1.037 A (b) 212.1 Ω; 2.037 A

(c) 412.1 Ω; 1.037 A (d) 412.1 Ω; 2.037 A

20. In an AC circuit an alternating voltage $V = 200\sqrt{2}\sin 100t$ V is connected to a capacitor of capacity 1 μF. The rms value of the current in the circuit is:

(a) 10 mA (b) 20 mA

(c) 100 mA (d) 200 mA

21. A resistor and a capacitor are connected in series with an AC source. If the potential drop across the capacitor is 5 V and that across resistor is 12 V, applied voltage is:

(a) 5 V (b) 12 V

(c) 13 V (d) 17 V

22. An alternating voltage given as $V = 100\sqrt{2}\sin 100t$ V is applied to a capacitor of 1 μF. The current reading of the ammeter will be equal to ______ mA.

(a) 40 (b) 20

(c) 10 (d) 80

23. The voltage of an AC supply varies with time (t) as $V = 120\cdot\sin 100\pi t\cdot\cos 100\pi t$. The maximum voltage and frequency respectively are:

(a) 60 V, 100 Hz (b) 60 V, 200 Hz

(c) 120 V, 100 Hz (d) $\frac{120}{\sqrt{2}}$ V, 100 Hz

[***Hint:*** $V = V_{max}\sin 2\pi\nu t$]

24. A 120 V AC source is connected across a pure inductor of inductance 0.70 H. If the frequency of the AC source is 60 Hz, the current passing through the inductor is:

(a) 0.355 A (b) 0.455 A

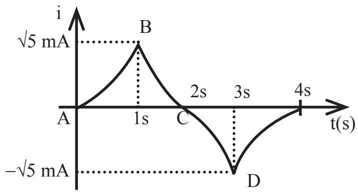
(c) 3.55 A (d) 4.55 A

25. The reactance of capacitor at 50 Hz is 10 Ω. What will be its reactance at 200 Hz?

(a) 2.5 Ω (b) 10 Ω

(c) 20 Ω (d) 40 Ω

26. Figure shows one cycle of an alternating current with the segments AB, BC, CD, and DE being symmetrical and parabolic. The root mean square value of this current over one cycle is x mA, find x.



(a) 4 mA (b) 3 mA
(c) 2 mA (d) 1 mA

27. In an LR circuit, the value of L is $\left(\frac{0.4}{\pi}\right)$ H and the value of R is 30 Ω. If in the circuit, an alternating emf of 200 V at 50 cps is connected, the impedance of the circuit and current will be:
(a) 50 Ω, 4 A (b) 40.4 Ω, 5 A
(c) 30.7 Ω, 6.5 A (d) 11.4 Ω, 17.5 A

28. An alternating emf, $E = 300\sin(100\pi t)$ V is applied to a pure resistance of 100 Ω. Calculate rms current through the circuit.
(a) 1.121 A (b) 2.121 A
(c) 3.121 A (d) 4.121 A

29. Same current is flowing in two alternating circuits. The first circuit contains only inductance and the other contains only a capacitor. If the frequency of the emf of AC is increased, the effect on the value of the current will be:
(a) Increases in both the circuits
(b) Decreases in both the circuits
(c) Increases in the first circuit and decreases in the other
(d) Decreases in the first circuit and increases in the other

30. In an AC circuit the voltage applied is $E = E_0 \sin \omega t$. The resulting current in the circuit is $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$. The power consumption in the circuit is given by:
(a) $P = \frac{E_0 I_0}{2}$ (b) $P = \frac{E_0 I_0}{\sqrt{2}}$
(c) $P = \sqrt{2} E_0 I_0$ (d) $P = 0$

31. A 10 μF capacitor is connected across a 200 V, 50 Hz AC supply. The peak current through the circuit is:
(a) 0.6 A
(b) $\frac{0.6}{\sqrt{2}}$ A
(c) $0.6\frac{\neq}{2}$ A
(d) $0.6\sqrt{2}$ A

32. In an LCR series AC circuit, the voltage across each of the components, L, C and R is 50 V. The voltage across the LC combination will be:
(a) 0 V (b) 50 V
(c) $50\sqrt{2}$ V (d) 100 V

33. A resistance of 300 Ω and an inductance of $\frac{1}{\neq}$ H are connected in series to an AC voltage of 20 V and 200 Hz frequency. The phase angle between the voltage and current is:
(a) $\tan^{-1}\frac{3}{2}$ (b) $\tan^{-1}\frac{4}{3}$
(c) $\tan^{-1}\frac{3}{4}$ (d) $\tan^{-1}\frac{2}{5}$

34. Find the capacitive reactance of 10 μF capacitor, when it is part of a circuit, whose frequency is 100 Hz.
(a) 159.2 Ω (b) 412.1 Ω
(c) 612.1 Ω (d) 812.1 Ω
[***Hint:*** *Take π = 3.14.*]

35. In a series LCR circuit, the emf leads current. Now the driving frequency is decreased slightly.

	Column I		Column II
A	Current amplitude	(i)	Increases
B	Phase constant	(ii)	Decreases
C	Power developed in resistor	(iii)	Remains same
D	Impedance	(iv)	May increase or decrease

Match column I and column II and choose the correct combination from the given options.
(a) A-(ii), B-(iii), C-(iv), D-(i)
(b) A-(i), (ii), B-(ii), C-(iii), (iv), D-(i)
(c) A-(i), B-(ii), C-(i), D-(ii)
(d) A-(i), B-(iii), C-(i), D-(i), (ii)

36. The resonant frequency of a circuit is f. If the capacitance is made 4 times the initial values, then the resonant frequency will become:
(a) $\frac{f}{2}$ (b) f
(c) $2f$ (d) $\frac{f}{4}$

37. A coil of 10 Ω and 10 mH is connected in parallel to a capacitor of 0.1 μF. The impedance of the circuit at resonance is:

(a) 10^3 (b) 10^6

(c) 10^2 (d) 10^4

38. An inductance of negligible resistance whose reactance is 22 Ω at 200 Hz is connected to 200 V, 50 Hz power line. The value of inductance is:

(a) 17.5 H (b) 1.75 H

(c) 0.175 H (d) 0.0175 H

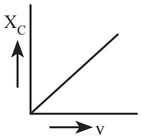
[***Hint:*** *Take* $\pi = \frac{22}{7}$.]

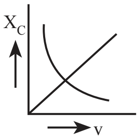
39. For a series LCR circuit $R = X_L = 2X_C$. The impedance of the circuit and phase difference between V and I respectively will be:

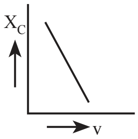
(a) $\sqrt{5}R,\ \tan^{-1}\left(\frac{1}{2}\right)$ (b) $\frac{\sqrt{5}R}{2},\ \tan^{-1}\left(\frac{1}{2}\right)$

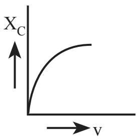
(c) $\sqrt{5}X_C,\ \tan^{-1}(2)$ (d) $\frac{\sqrt{5}R}{2},\ \tan^{-1}(2)$

40. Which of the following curves correctly represent the variation of capacitive reactance (X_C) with frequency (v)?

(a)


(b)


(c)


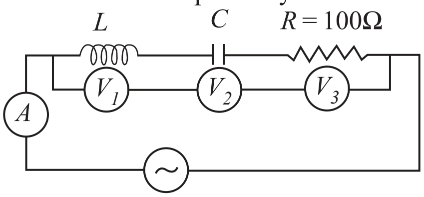
(d)


41. In the non-resonant circuit, what will be the nature of the circuit for frequencies higher than the resonant frequency?

(a) Inductive (b) Resistive

(c) Capacitive (d) None of the above

42. In the given circuit the reading of voltmeter V_1 and V_2 are 300 V each. The reading of the voltmeter V_3 and ammeter A are respectively:



220 V, 50H_Z

(a) 100 V and 2 A (b) 150 V and 2.2 A

(c) 220 V and 2 A (d) 220 V and 2.2 A

43. How does the current in an RC circuit vary when the charge on the capacitor builds up?

(a) It decreases linearly

(b) It increases linearly

(c) It decreases exponentially

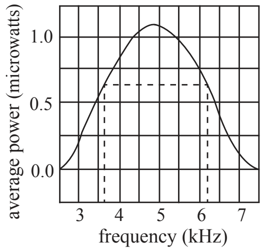
(d) It increases exponentially

44. In a circuit L, C and R are connected in series with an alternating voltage source of frequency f. The current leads the voltage by 45°. The value of C is:

(a) $\frac{1}{\pi f(2\pi fL + R)}$ (b) $\frac{1}{\pi f(2\pi fL - R)}$

(c) $\frac{1}{2\pi f(2\pi fL + R)}$ (d) $\frac{1}{2\pi f(2\pi fL - R)}$

45. The plot given below is of the average power delivered to an LCR circuit versus frequency. The quality factor of the circuit is:



(a) 2 (b) 0.4

(c) 5 (d) 6

46. The impedance in a circuit containing a resistance of 1 Ω and an inductance of 0.1 H in series for AC of 50 Hz is:

(a) $\sqrt{10}$ (b) $10\sqrt{10}$

(c) 100 (d) $100\sqrt{10}$

47. In an LCR series circuit connected to an AC source, the supply voltage is $V = V_0 \sin\left(100\pi t + \frac{\pi}{6}\right)$. $V_L = 40$ V, $V_R = 40$ V, $Z = 5$ Ω, and $R = 4$ Ω.

	Column I		Column II
A	Peak current (in A)	(i)	$10\sqrt{2}$
B	V_0 (in V)	(ii)	$50\sqrt{2}$
C	Effective value of applied voltage (in V)	(iii)	50
D	X_C (in Ω)	(iv)	1

Match column I and column II and choose the correct combination from the given options.

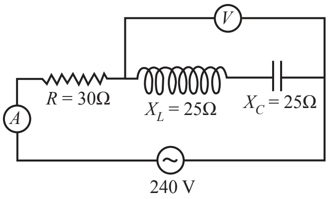
(a) A-(i), B-(ii), C-(iii), D-(iv)

(b) A-(ii), B-(iii), C-(i), D-(iv)

(c) A-(iv), B-(iii), C-(ii), D-(i)

(d) A-(iv), B-(i), C-(iii), D-(ii)

48. In the circuit shown in figure neglecting source resistance the voltmeter and ammeter reading will respectively be:

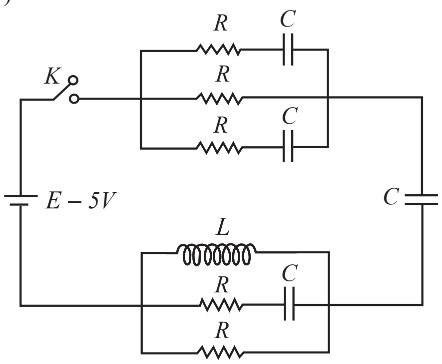


(a) 0 V, 3 A (b) 0 V, 8 A
(c) 150 V, 3 A (d) 150 V, 6 A

49. In a LR circuit, the value of L is $\frac{0.4}{\neq}$ H and the value of R is 30 Ω. If in the circuit, an alternating emf of 200 V at 50 cps is connected, the impedance of the circuit and current will be:

(a) 11.4 Ω, 17.5 A (b) 30.7 Ω, 6.5 A
(c) 40.4 Ω, 5 A (d) 50 Ω, 4 A

50. Find the current passing through battery immediately after key (K) is closed. It is given that initially all the capacitors are uncharged. (Given that: $R = 6\ \Omega$ and $C = 4\ \mu F$)



(a) 1 A (b) 2 A
(c) 3 A (d) 5 A

51. One 10 V, 60 W bulb is to be connected to 100 V line. The required induction coil has self-inductance of value (f = 50 Hz)

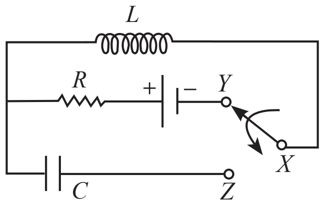
(a) 1.62 mH (b) 16.2 mH
(c) 0.052 H (d) 2.42 H

52. A current of 1 A flows through a coil, when a 100 V DC is applied to it. But a current of 0.5 A flows through the same coil, when a 100 V AC of frequency 50 Hz is applied. The resistance and inductance of the coil are given by:

(a) 50 |, $\sqrt{0.2}$ H (b) 50 |, $\sqrt{0.3}$ H
(c) 100 |, $\sqrt{0.2}$ H (d) 100 |, $\sqrt{0.3}$ H

[***Hint:*** *Take $\pi^2 = 10$*]

53. In the circuit shown, the symbols have their usual meanings. The cell has emf E. X is initially joined to Y for a long time. Then, X is joined to Z. The maximum charge on C at any later time will be:



(a) $\frac{E\sqrt{LC}}{R}$ (b) $\frac{E\sqrt{LC}}{2R}$
(c) $\frac{E}{R\sqrt{LC}}$ (d) $\frac{ER}{2\sqrt{LC}}$

54. An ac circuit contains a resistance R, capacitance C and inductance L in series with a source of emf $e = e_0 \sin(wt + £)$. The current through the circuit is maximum when:

(a) $\omega^2 = LC$ (b) $\omega L = \frac{1}{\omega C}$
(c) $R = L = C$ (d) $\omega = LCR$

55. A series circuit contains a resistor of 20 Ω, a capacitor and an ammeter of negligible resistance. It is connected to a source of 220 V - 50 Hz. If the reading of the ammeter is 2.5 A, calculate reactance of the capacitor.

(a) 23.7 Ω (b) 63.7 Ω
(c) 85.7 Ω (d) 92.7 Ω

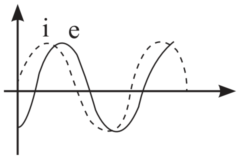
56. A charged 30 μF capacitor is connected to a 27 mH inductor. The angular frequency of free oscillations of the circuit is:

(a) 1.1×10^3 rad s^{-1} (b) 2.1×10^3 rad s^{-1}
(c) 3.1×10^3 rad s^{-1} (d) 4.1×10^3 rad s^{-1}

57. The frequency of the output signal becomes ______ times by doubling the value of the capacitance in the LC oscillator circuit.

(a) $\frac{1}{2}$ (b) 2
(c) $\sqrt{2}$ (d) $\frac{1}{\sqrt{2}}$

58. When an AC source of emf $e = e_0 \sin(100t)$ is connected across a circuit, the phase difference between the emf e and the current i in the circuit is observed to be $\frac{\neq}{4}$, as shown in the diagram. If the circuit consists possibly only of RC or RL or LC in series, find the relationship between the two elements:



(a) $R = 1$ kΩ, $C = 10$ μF
(b) $R = 1$ kΩ, $C = 1$ μF
(c) $R = 1$ kΩ, $L = 10$ H
(d) $R = 1$ kΩ, $L = 1$ H

59. The frequency at which 9 mH inductor and 10 μF capacitor will have same reactance is:
(a) 0.33 kHz (b) 0.53 kHz
(c) 5.3 kHz (d) 50 kHz

60. The ratio of induced emf in a coil of 50 turns and area A oscillating at frequency 50 Hz to that in a coil of 100 turns and same area oscillating at frequency 100 Hz is:
(a) 0.25 (b) 0.50
(c) 0.50 (d) 1

61. A coil of 40 H inductance is connected in series with a resistance of 8 Ω and the combination is joined to the terminals of a 2 V battery. The time constant of the circuit is:
(a) $\frac{1}{5}$ s (b) 5 s
(c) 20 s (d) 40 s

62. A 16 μF capacitor is charged to 20 V. The battery is then disconnected and a pure 40 mH coil is connected across the capacitor so that LC oscillations are set up. The maximum current in the coil is:
(a) 0.2 A (b) 0.4 A
(c) 2 A (d) 40 mA

63. In an LR circuit $f = 50$ Hz, $L = 2$ H, $E = 5$ V, $R = 1$ Ω then energy stored in inductor is:
(a) 25 J (b) 50 J
(c) 100 J (d) None of the above

64. A lamp of 220 V and 100 W is first connected in DC circuit of 200 V and then in AC circuit of 200 V. It will light brighter in:
(a) AC circuit
(b) DC circuit
(c) DC or AC circuit depending on the nature of filament
(d) None of these

65. A circuit has a resistance of 11 Ω, an inductive reactance of 25 Ω and a capacitive resistance of 18 Ω. It is connected to an AC source of 260 V and 50 Hz. The current through the circuit (in A) is:
(a) 11 (b) 15
(c) 18 (d) 20

66. In an LCR circuit, the sharpness of resonance depends on:
(a) Resistance (R)
(b) Capacitance (C)
(c) Inductance (L)
(d) All of these

67. An LCR circuit contains $R = 50$ Ω, $L = 1$ mH and $C = 0.1$ μF. The impedance of the circuit will be minimum for a frequency of:
(a) $2\pi \times 10^5$ s^{-1} (b) $2\pi \times 10^6$ s^{-1}
(c) $\frac{10^5}{2\pi}$ s^{-1} (d) $\frac{10^6}{2\pi}$ s^{-1}

Power in AC circuit

68. The power factor of LCR circuit at resonance is:
(a) Zero (b) 0.5
(c) 0.707 (d) 1

69. A series LCR arrangement with $X_L = 80$ Ω, $X_C = 50$ Ω, $R = 40$ Ω is applied across AC source of 200 V. Choose the correct options.
(i) Wattless current = 3.2 A
(ii) Power current = 3.2 A
(iii) Power factor = 0.6
(iv) Impedance of circuit = 50 Ω
(a) (i), (ii), and (iii) are correct
(b) (i) and (ii) are correct
(c) (ii), and (iv) are correct
(d) (i) and (iii) are correct

70. The average power dissipation in a pure capacitor in AC circuit is:
(a) CV^2 (b) $2CV^2$
(c) $\frac{CV^2}{2}$ (d) Zero

71. In a circuit, the reactance X and resistance R are equal. What is the power factor?
(a) $\frac{1}{2}$ (b) 1
(c) $\frac{1}{\sqrt{2}}$ (d) $\sqrt{2}$

72. In a series resonant circuit, having L, C, and R as its elements, the resonant current is i. The power dissipated in circuit at resonance is:
(a) Zero (b) i^2R
(c) $i^2\omega L$ (d) $\frac{i^2R}{\left(\omega L - \frac{1}{\omega C}\right)}$

73. The average power lost per cycle of AC is given by:

(a) $\frac{1}{2}E_0 I_0 \times \theta$ (b) $\frac{1}{2}E_0 I_0 \sin\theta$

(c) $\frac{1}{2}E_0 I_0 \cos\theta$ (d) $\frac{1}{2}E_0 I_0 \tan\theta$

74. The values of resistance and inductive reactance of a choke coil are 8 Ω and 6 Ω respectively. What is the power factor of the coil?

(a) 0.3 (b) 0.4

(c) 0.6 (d) 0.8

75. The power factor in a circuit connected to an AC. The value of power factor is:

(a) Unity when the circuit contains an ideal resistance only

(b) Unity when the circuit contains an ideal capacitance only

(c) Unity when the circuit contains an ideal inductance only

(d) Zero when the circuit contains an ideal resistance only

76. What will be the phase difference between virtual voltage and virtual current, when the current in the circuit is wattless?

(a) 45° (b) 60°

(c) 90° (d) 180°

77. In which of the following cases, the power factor is not equal to 1:

(a) $L = C$ (b) $Z = R$

(c) $X_L = X_C$ (d) $S_C = S_L$

78. In an AC circuit the voltage applied is $E = E_0 \sin\omega t$. The resulting current in the circuit is $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$. The power consumption in the circuit is given by:

(a) Zero (b) $P = \frac{E_0 I_0}{2}$

(c) $P = \frac{E_0 I_0}{\sqrt{2}}$ (d) $P = \sqrt{2}E_0 I_0$

79. In a series LCR circuit alternating emf (e) and current (i) are given by the equation $v = v_0 \sin\omega t,\ i = i_0 \sin\left(\omega t + \frac{\pi}{3}\right)$.

The average power dissipated in the circuit over a cycle of AC is:

(a) Zero (b) $\frac{v_0 i_0}{2}$

(c) $\frac{v_0 i_0}{4}$ (d) $\frac{\sqrt{3}}{2} v_0 i_0$

80. In an AC circuit, the current flowing in inductance is $I = 5\sin(100t - \pi/2)$ A and the potential difference is $V = 200\sin(100t)$ V. The power consumption is equal to:

(a) Zero (b) 20 W

(c) 40 W (d) 1000 W

81. The power factor in an AC series LR circuit is:

(a) $\frac{L}{R}$ (b) $\sqrt{R^2 + L^2\omega^2}$

(c) $R\sqrt{R^2 + L^2\omega^2}$ (d) $\frac{R}{\sqrt{R^2 + L^2\omega^2}}$

82. A circuit has a resistance of 30 Ω and inductive reactance of 40 Ω in series. They are connected to an AC source of peak voltage 200 V. The power factor is:

(a) $\frac{1}{5}$ (b) $\frac{2}{5}$

(c) $\frac{3}{5}$ (d) $\frac{4}{5}$

83. Two coils A and B are connected in series across a 240 V, 50 Hz supply. The resistance of A is 5 Ω and the inductance of B is 0.02 H. The power consumed is 3 kW and the power factor is 0.75. The impedance of the circuit is:

(a) 0.144 Ω (b) 1.44 Ω

(c) 14.4 Ω (d) 144 Ω

84. An AC supply gives 30 V_{rms}. which passes through 10 Ω resistance. The power dissipated in it is:

(a) $45\sqrt{2}$ W (b) $90\sqrt{2}$ W

(c) 45 W (d) 90 W

85. The average power dissipated in AC circuit is 2 W. If a current flowing through a circuit is 2 A and impedance is 1 Ω, what is the power factor of the AC circuit?

(a) 0 (b) 0.5

(c) 1 (d) $\frac{1}{\sqrt{2}}$

86. A resistance R draws power P when connected to an AC source. If an inductance is now placed in series with the resistance, such that the impedance of the circuit becomes Z, the power drawn will be:

(a) P (b) $P\left(\frac{R}{Z}\right)$

(c) $P\sqrt{\frac{R}{Z}}$ (d) $P\left(\frac{R}{Z}\right)^2$

Transformers

87. A transformer is employed to:
(a) Convert DC into AC
(b) Convert AC into DC
(c) Obtain a suitable DC voltage
(d) Obtain a suitable AC voltage

88. The loss of energy in the form of heat in the iron core of a transformer is:
(a) Copper loss (b) Iron loss
(c) Mechanical loss (d) None of these

89. The core of any transformer is laminated so as to:
(a) Make it light weight
(b) Make it robust and strong
(c) Increase the secondary voltage
(d) Reduce the energy loss due to eddy currents

90. If the coils of transformer are made up of thick wires, then:
(a) Joule's heating loss is increased
(b) Joule's heating loss is reduced
(c) Eddy current loss will be more
(d) Magnetic flux leakage is reduced

91. A step up transformer has transformation ratio 5:3. What is voltage in secondary if voltage in primary is 60 V?
(a) 60 V (b) 180 V
(c) 20 V (d) 100 V

92. A transformer is used to light up a 100 W, 110 V lamp from a 220 V supply. If the supply current is 0.5 A, the efficiency of the transformer is very near to:
(a) 30% (b) 45%
(c) 60% (d) 90%

93. A transformer has 50 turns in the primary and 100 in the secondary. If the primary is connected to a 220 V DC supply, what will be the voltage across the secondary?
(a) 19 V (b) 30 V
(c) 62 V (d) 0 V

94. The primary of a transformer has 400 turns while the secondary has 2000 turns. If the power output from the secondary at 1000 V is 12 kW, what is the primary voltage?
(a) 200 V (b) 400 V
(c) 300 V (d) 500 V

95. A step-down transformer is used on a 1000 V line to deliver 20 A at 120 V at the secondary coil. If the efficiency of the transformer is 80% the current drawn from the line is:
(a) 0.3 A (b) 3 A
(c) 30 A (d) 24 A

96. A current of 5 A is flowing at 220 V in the primary coil of a transformer. If the voltage produced in the secondary coil is 2200 V and 50% of power is lost, then the current in the secondary coil will be:
(a) 0.025 A (b) 0.25 A
(c) 2.5 A (d) 5 A

97. Input power at 22000 V is to be stepped down to 220 V by a transformer with a winding of 4400 turns in the primary. What should be the number of turns in the secondary of the transformer?
(a) 44 (b) 200
(c) 220 (d) 440

98. A step-down transformer has 50 turns on secondary and 1000 turns on primary winding. If a transformer is connected to 220 V, 1 A AC source, what is output current of the transformer?
(a) 2 A (b) 20 A
(c) 100 A (d) $\frac{1}{20}$ A

99. The output voltage of a transformer connected to 220 V line is 1100 V at 2 A current. Its efficiency is 100%. The current coming from the line is:
(a) 11 A (b) 22 A
(c) 10 A (d) 20 A

100. A transformer having efficiency of 90% is working on 200 V and 3 kW power supply. If the current in the secondary coil is 6 A, the voltage across the secondary coil and the current in the primary coil respectively are:
(a) 300 V, 15 A (b) 450 V, 13.5 A
(c) 450 V, 15 A (d) 600 V, 15 A

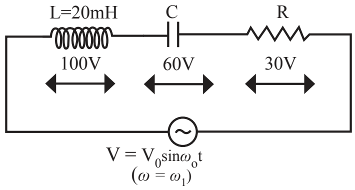
HIGH-ORDER THINKING SKILL

AC Voltage

1. An alternating emf of angular frequency ω is applied across an inductance. The instantaneous power developed in the circuit has an angular frequency:
(a) ω (b) 2ω
(c) $\frac{\omega}{2}$ (d) $\frac{\omega}{4}$

2. An alternating voltage $E = 200\sqrt{2}\sin(100t)$ is connected to a 1 μF capacitor through an AC ammeter. The reading of the ammeter shall be:
(a) 40 mA (b) 20 mA
(c) 80 mA (d) 10 mA

3. Consider the LCR circuit shown below connected to an AC source of constant peak voltage V_0 and variable frequency ω_0. The value of L is 20 mH. For a certain value $\omega_0 = \omega_1$, rms voltage across L, C, R are shown in the diagram. At $\omega_0 = \omega_2$, it is found that rms voltage across resistance is 50 V. Then the value of ω_2, is:



(a) 50 Hz

(b) $\sqrt{\frac{5}{3}}\omega_1$

(c) $\sqrt{\frac{3}{5}}\omega_1$

(d) cannot be calculated from given data

Power in AC Circuit

4. A series LR circuit is connected to an ac source of frequency ω and the inductive reactance is equal to $2R$. A capacitance of capacitive reactance equal to R is added in series with L and R. The ratio of the new power factor to the old one is:

(a) $\sqrt{\frac{2}{3}}$ (b) $\sqrt{\frac{3}{2}}$

(c) $\sqrt{\frac{2}{5}}$ (d) $\sqrt{\frac{5}{2}}$

5. A coil has an inductance of 0.7 H and is joined in series with a resistance of 220 Ω. When the alternating emf of 220 V at 50 Hz is applied to it then the phase through which current lags behind the applied emf and the wattless component of current in the circuit will be respectively:

(a) 30°, 1 A (b) 30°, 1.5 A

(c) 45°, 0.5 A (d) 60°, 1.5 A

6. An LCR series circuit with a resistance of 100 Ω is connected to an ac source of 200 V (rms) and angular frequency 300 rad/s. When only the capacitor is removed, the current lags behind the voltage by 60°. When only the inductor is removed the current leads the voltage by 60°. The average power dissipated is:

(a) 400 W (b) 200 W

(c) 100 W (d) 50 W

Transformers

7. 1 MW power is to be delivered from a power station to a town 15 km away. One uses a pair of Cu wires of radius 0.4 cm for this purpose. Calculate the fraction of ohmic losses to power transmitted if a step-up transformer is used to boost the voltage to 11000 V, power transmitted, then a step-down transformer is used to bring voltage to 220 V.
(Pcu = 1.7×10^{-8} SI unit)

(a) 1.5% (b) 1.8%

(c) 3.6% (d) 8.5%

8. A step-down transformer is connected to 2400 volts line and 80 A of current is found to flow in output load. The ratio of the turns in primary and secondary coil is 20:1. If transformer efficiency is 100%, then the current flowing in primary coil will be:

(a) 1.5 A (b) 4 A

(c) 20 A (d) 1600 A

NCERT EXEMPLAR PROBLEMS

AC Voltage

1. If the rms current in a 50 Hz AC circuit is 5 A, the value of the current $\frac{1}{300}$ s after its value becomes zero is:

(a) $5\sqrt{2}$ A (b) $5\sqrt{\frac{3}{2}}$ A

(c) $\frac{5}{6}$ A (d) $\frac{5}{\sqrt{2}}$ A

2. An alternating current generator has an internal resistance R_g and an internal reactance X_g. It is used to supply power to a passive load consisting of a resistance R_g and a reactance X_L. For maximum power to be delivered from the generator to the load, the value of X_L is equal to:

(a) zero (b) X_g.

(c) $-X_g$. (d) R_g.

3. When a voltage measuring device is connected to AC mains, the meter shows the steady input voltage of 220 V. This means:

(a) Input voltage cannot be AC voltage, but a DC voltage.

(b) maximum input voltage is 220 V.

(c) the meter reads not v but $\langle v^2 \rangle$ and is calibrated to read $\sqrt{\langle v^2 \rangle}$.

(d) the pointer of the meter is stuck by some mechanical defect.

4. To reduce the resonant frequency in an LCR series circuit with a generator:
   (a) the generator frequency should be reduced.
   (b) another capacitor should be added in parallel to the first.
   (c) the iron core of the inductor should be removed.
   (d) dielectric in the capacitor should be removed.

5. Which of the following combinations should be selected for better tuning of an LCR circuit used for communication?
   (a) $R = 20\ \Omega, L = 1.5\ \text{H}, C = 35\ \mu\text{F}$.
   (b) $R = 25\ \Omega, L = 2.5\ \text{H}, C = 45\ \mu\text{F}$.
   (c) $R = 15\ \Omega, L = 3.5\ \text{H}, C = 30\ \mu\text{F}$.
   (d) $R = 25\ \Omega, L = 1.5\ \text{H}, C = 45\ \mu\text{F}$.

Power in AC Circuit

6. An inductor of reactance 1 Ω and a resistor of 2 Ω are connected in series to the terminals of a 6 V (rms) AC source. The power dissipated in the circuit is:
   (a) 8 W (b) 12 W
   (c) 14.4 W (d) 18 W

Transformers

7. The output of a step-down transformer is measured to be 24 V when connected to a 12 W light bulb. The value of the peak current is:
   (a) $\frac{1}{\sqrt{2}}$ A (b) $\sqrt{2}$ A
   (c) 2 A. (d) $2\sqrt{2}$ A

ASSERTION AND REASONS

Directions: In the following questions, a statement of assertion is followed by a statement of reason. Mark the correct choice as:
(a) If both assertion and reason are true and reason is the correct explanation of assertion.
(b) If both assertion and reason are true but reason is not the correct explanation of assertion.
(c) If assertion is true but reason is false.
(d) If both assertion and reason are false.

AC Voltage

1. **Assertion:** AC is more dangerous in use than DC.

   Reason: It is because the peak value of DC is greater than indicated value.

2. **Assertion:** Average value of AC over a complete cycle is always zero.

   Reason: Average value of AC is always defined over half cycle.

3. **Assertion:** The alternating current lags behind the emf by a phase angle of $\frac{\neq}{2}$, when AC flows through an inductor.

   Reason: The inductive reactance increases as the frequency of AC source decreases.

4. **Assertion:** Capacitor serves as a block for DC and offers an easy path to AC.

   Reason: Capacitive reactance is inversely proportional to frequency.

5. **Assertion:** In series LCR resonance circuit, the impedance is equal to the ohmic resistance.

   Reason: At resonance, the inductive reactance exceeds the capacitive reactance.

6. **Assertion:** An alternating current shows magnetic effect.

   Reason: Alternating current varies with time.

7. **Assertion:** In series LCR circuit resonance can take place.

   Reason: Resonance takes place if inductance and capacitive reactance are equal and opposite.

8. **Assertion:** AC is more dangerous than DC.

   Reason: Frequency of AC is dangerous for human body.

Power in AC Circuit

9. **Assertion:** Power factor correction is must in heavy machinery.

   Reason: A low power factor implies larger power loss in transmission.

10. **Assertion:** Choke coil is preferred over a resistor to adjust current in an AC circuit.

    Reason: Power factor for inductance is zero.

11. Assertion: When AC circuit contain resistor only, its power is minimum.

Reason: Power of a circuit is independent of phase angle.

Transformers

12. Assertion: The power is produced when a transformer steps up the voltage.

Reason: In an ideal transformer VI = constant.

13. Assertion: A transformer cannot work on DC supply.

Reason: DC changes neither in magnitude nor in direction.

14. Assertion: A laminated core is used in transformers to increase eddy currents.

Reason: The efficiency of a transformer increases with increase in eddy currents.

15. Assertion: Soft iron is used as a core of transformer.

Reason: Area of hysteresis is loop for soft iron is small.

16. Assertion: A given transformer can be used to step-up or step-down the voltage.

Reason: The output voltage depends upon the ratio of the number of turns of the two coils of the transformer.

ANSWER KEY

Practice Time

1	(d)	2	(a)	3	(b)	4	(c)	5	(c)	6	(a)	7	(d)	8	(b)	9	(d)	10	(c)
11	(c)	12	(a)	13	(c)	14	(c)	15	(d)	16	(b)	17	(b)	18	(a)	19	(a)	20	(b)
21	(c)	22	(c)	23	(a)	24	(b)	25	(a)	26	(d)	27	(a)	28	(b)	29	(d)	30	(d)
31	(d)	32	(a)	33	(b)	34	(a)	35	(c)	36	(a)	37	(d)	38	(d)	39	(b)	40	(b)
41	(c)	42	(d)	43	(c)	44	(c)	45	(a)	46	(b)	47	(a)	48	(b)	49	(d)	50	(a)
51	(c)	52	(d)	53	(a)	54	(b)	55	(c)	56	(a)	57	(d)	58	(a)	59	(b)	60	(a)
61	(b)	62	(b)	63	(d)	64	(a)	65	(d)	66	(d)	67	(c)	68	(d)	69	(c)	70	(d)
71	(c)	72	(b)	73	(c)	74	(d)	75	(a)	76	(c)	77	(a)	78	(a)	79	(c)	80	(a)
81	(d)	82	(c)	83	(c)	84	(d)	85	(b)	86	(d)	87	(d)	88	(b)	89	(d)	90	(b)
91	(d)	92	(d)	93	(d)	94	(a)	95	(b)	96	(b)	97	(a)	98	(b)	99	(c)	100	(c)

High-Order Thinking Skill

1	(b)	2	(b)	3	(c)	4	(d)	5	(c)	6	(a)	7	(d)	8	(b)

NCERT Exemplar Problems

1	(b)	2	(c)	3	(c)	4	(b)	5	(c)	6	(c)	7	(a)

Assertion and Reason

1	(a)	2	(b)	3	(c)	4	(a)	5	(c)	6	(b)	7	(a)	8	(a)	9	(b)	10	(a)
11	(d)	12	(a)	13	(a)	14	(d)	15	(a)	16	(a)								

HINTS AND EXPLANATIONS

Practice Time

1 (d) In DC ammeter, a coil is free to rotate in the magnetic field of a fixed magnet. If an alternating current is passed through such a coil, the torque will reverse its direction each time the current changes direction and the average value of the torque will be zero.

2 (a) We know that,

$$\text{rms current} = \frac{I_0}{\sqrt{2}}$$

3 (b) The current takes $\frac{T}{4}$ s to reach the peak value.

In the given question,

$$\frac{2\pi}{T} = 200\pi$$

$$\Rightarrow \ T = \frac{1}{100} \text{ s}$$

$\therefore$ Time to reach the peak value $= \frac{1}{400}$ s

4 (c) The coil is having inductance L besides the resistance R. Hence, for AC its effective resistance $\sqrt{R^2 + X_L^2}$ will be larger than its resistance R for DC.

5 (c) We know that,

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

$$\text{and, } I_{\text{m}} = \frac{2I_0}{\pi}$$

$$\therefore \ \frac{I_{\text{m}}}{I_{\text{rms}}} = \frac{2\sqrt{2}}{\pi}$$

6 (a) We know that,

$$E = E_0 \cos\omega t$$

$$= E_0 \cos\frac{2\pi t}{T}$$

$$= 10\cos\frac{2\pi \times 50 \times 1}{600}$$

$$= 10\cos\frac{\pi}{6}$$

$$= 5\sqrt{3} \text{ V}$$

7 (d) Peak value,

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

$$= 220\sqrt{2}$$

$$= 311 \text{ V}$$

8 (b) When an AC voltage of 220 V is applied to a capacitor C, the charge on the plates is in phase with the applied voltage.

As the circuit is pure capacitive so, the current developed leads the applied voltage by a phase angle of 90°. Hence, power delivered to the capacitor per cycle is,

$$P = V_{\text{rms}} I_{\text{rms}} \cos 90^\circ$$

$$= 0$$

9 (d) We know that,

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

$$= \frac{120}{1.414}$$

$$= 84.8 \text{ V}$$

10 (c) Since,

$$I_{\text{rms}} = \frac{E_{\text{rms}}}{R}$$

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

$$= 5 \text{ A}$$

$$\therefore \ \text{I}_0 = \text{I}_{\text{rms}}\sqrt{2}$$

$$= 7.07 \text{ A}$$

11 (c) In an inductor voltage leads the current by $\frac{\neq}{2}$ or current lags the voltage by $\frac{\neq}{2}$.

12 (a) Peak value to rms value means, current becomes $\frac{1}{\sqrt{2}}$ times.

If peak is at $t = 0$, current is of the form,

$$I = I_0 \cos 100\pi t$$

$$\Rightarrow \frac{1}{\sqrt{2}} \times I_0 = I_0 \cos 100\pi t$$

$$\Rightarrow \ \cos\frac{\pi}{4} = \cos 100\pi t$$

$$\Rightarrow \ t = \frac{1}{400} \text{ s}$$

$$= 2.5 \times 10^{-3} \text{ s}$$

13 (c) Time taken by the current to reach the maximum value,

$$t = \frac{T}{4}$$

$$= \frac{1}{4\nu}$$

$$= \frac{1}{4 \times 50}$$

$$= 5 \times 10^{-3} \text{ s}$$

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

$$= 10\sqrt{2}$$

$$= 14.14 \text{ A}$$

14 (c) According to question,

$$E = 8\sin\omega t + 6\sin 2\omega t$$

$$\Rightarrow \quad E_0 = \sqrt{8^2 + 6^2}$$

$$= 10 \text{ V}$$

$$E_{\text{rms}} = \frac{10}{\sqrt{2}}$$

$$= 5\sqrt{2} \text{ V}$$

15 (d) We know that,

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

$$X_L = \omega L$$

and, $\omega = 2\pi f$

$$\therefore \quad Z = \sqrt{R^2 + 4\pi^2 f^2 L^2}$$

16 (b) Given,

$$V = 240\sin 120t \text{ V}$$

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

$$V_0 = 240 \text{ V}$$

$$\omega = 120 \text{ rad/s}$$

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

$$= \frac{240}{\sqrt{2}}$$

$$= 169.7$$

$$\approx 170 \text{ V}$$

$$\omega = 2\pi f$$

$$f = \frac{\omega}{2\pi}$$

$$= \frac{120}{2\pi}$$

$$= 19 \text{ Hz}$$

17 (b) Given,

$$e = 80\sin 100\pi t \quad \ldots(i)$$

Standard equation of instantaneous voltage is given by,

$$e = e_m \sin\omega t \quad \ldots(ii)$$

Compare (i) and (ii), we get,

e_m = 80 V where e_m is the voltage amplitude.

Current amplitude,

$$I_m = \frac{e_m}{Z}$$

$$= \frac{80}{20} = 4 \text{ A}$$

where Z = impendence.

$$I_{\text{rms}} = \frac{4}{\sqrt{2}}$$

$$= \frac{4\sqrt{2}}{2}$$

$$= 2\sqrt{2}$$

$$= 2.828 \text{ A}$$

18 (a) The applied voltage is given by,

$$V = \sqrt{V_R^2 + V_L^2}$$

$$V = \sqrt{(200)^2 + (150)^2} = 250 \text{ V}$$

19 (a) We know that,

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

$$= \frac{1}{2\pi v C}$$

$$= \frac{1}{2 \times \frac{22}{7} \times 50 \times 15 \times 10^{-6}}$$

$$= 212.1 \ \Omega$$

$$I_{\min} = \frac{E_{\text{rms}}}{X_C}$$

$$= \frac{220}{212.1}$$

$$= 1.037 \text{ A}$$

20 (b) We know that,

$$V_{\text{rms}} = \frac{200\sqrt{2}}{\sqrt{2}}$$

$$= 200 \text{ V}$$

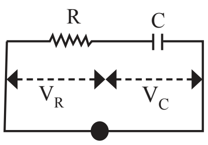
$$I_{\text{rms}} = \frac{V_{\text{rms}}}{X_C} = \frac{V_{rms}}{1/WC}$$

$$= \frac{200}{\frac{1}{100 \times 10^{-6}}}$$

$$= 2 \times 10^{-2}$$

$$= 20 \text{ mA}$$

21 (c)



Let the applied voltage be V.
Here,

$$V_R = 12 \text{ V}$$

$$V_C = 5 \text{ V}$$

$$V = \sqrt{V_R^2 + V_C^2}$$

$$= \sqrt{(12)^2 + (5)^2}$$

$$= 13 \text{ V}$$

22 (c) An AC ammeter shows rms value of current.

$$\therefore \quad i_{rms} = \frac{V_{rms}}{Z} = \frac{V_0}{\sqrt{2}X_C} = \frac{100\sqrt{2}}{\sqrt{2}\frac{1}{\omega C}} = 100\omega C$$

(Compare $V = 100\sqrt{2}\sin 100t$ with $V = V_0 \sin\omega t$)

$$\therefore \quad i_{rms} = 100\times100\times10^{-6} = 0.01 \text{ A} = 10 \text{ mA}$$

23 (a) According to question,

$$V = 120\sin 100\pi t \cos 100\pi t$$

$$\Rightarrow \quad V = 60\sin 200\pi t$$

$$\therefore \quad V_{max} = 60 \text{ V}$$

and $\quad v = 100$ Hz

24 (b) Since,

$$Z = X_L = 2\pi\times60\times0.7$$

$$\therefore \quad i = \frac{L}{Z} = \frac{120}{2\pi\times60\times0.7} = 0.455 \text{ A}$$

25 (a) We know that,

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

$$\Rightarrow \quad X_C \propto \frac{1}{v}$$

$$\frac{X'_C}{X_C} = \frac{v}{v'} = \frac{50}{200} = \frac{1}{4}$$

$$X'_C = \frac{X_C}{4} = \frac{10}{4} = 2.5\ \Omega$$

26 (d) rms value over one cycle = rms value over AB.

$$0 \le t \le 15$$

$$i(t) = \sqrt{5t^2 c}$$

$$i_{rms} = \sqrt{\langle i^2 \rangle} = \sqrt{\frac{5\int_0^1 t^4 dt}{\int_0^1 dt}} = 1 \text{ mA}$$

27 (a) We know that,

$$Z = \sqrt{R^2 + X_L{}^2} = \sqrt{R^2 + (2\pi f L)^2} = \sqrt{(30)^2 + \left(2\pi\times50\times\frac{0.4}{\pi}\right)^2} = \sqrt{900+1600} = 50\ \Omega$$

$$i = \frac{V}{Z} = \frac{200}{50} = 4 \text{ A}$$

28 (b) We know that,

$$E = E_0 \sin\omega t$$

and, $E_0 = 300$ V

$$I_0 = \frac{E_0}{R} = \frac{300}{100} = 3 \text{ A}$$

From formula,

$$I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{3}{\sqrt{2}} = \frac{3\sqrt{2}}{2} = 1.5\times\sqrt{2} = 1.5\times1.414 = 1.121 \text{ A}$$

$$\therefore \quad I_{rms} = 2.121 \text{ A}$$

29 (d) For the first circuit,

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

$\therefore$ Increase in ω will cause a decrease in I.
For the second circuit,

$$I = \frac{V}{\sqrt{R^2 + \frac{1}{\omega^2 C^2}}}$$

$\therefore$ Increase in ω will cause an increase in I.

30 (d) We know that power consumed in AC circuit is given by,

$$P = E_{\text{rms}} I_{\text{rms}} \cos\phi$$

Here,

$$E = E_0 \sin\omega t$$

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

which implies that the phase difference,

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

$$\therefore\ P = E_{\text{rms}} I_{\text{rms}} \cos\frac{\pi}{2}$$

$$= 0\ ...\left(\because \cos\frac{\pi}{2} = 0\right)$$

31 (d) Since,

$$I_{\text{rms}} = E_{\text{rms}} \omega C \qquad \left[\because I = \frac{V}{X_C}\right]$$

$$= 200 \times 2\pi \times 50 \times 10 \times 10^{-6}\ \text{A}$$

$$\cong 0.6\ \text{A}$$

$$\therefore\ I_0 = I_{\text{rms}} \times \sqrt{2}$$

$$\therefore\ I_0 = 0.6 \times \sqrt{2}\ \text{A}$$

32 (a) Since the phase difference between L & C is π.
$\therefore$ Net voltage difference across LC

$$= 50 - 50$$
$$= 0$$

33 (b) Phase angle,

$$\tan\phi = \frac{\omega L}{R}$$

$$= \frac{2\pi \times 200}{300} \times \frac{1}{\pi}$$

$$= \frac{4}{3}$$

$$\therefore\quad \phi = \tan^{-1}\frac{4}{3}$$

34 (a) We know that,

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

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

$$= \frac{1}{2 \times 3.14 \times 100 \times 10^{-5}}$$

$$= 159.2\ \Omega$$

35 (c) When the driving frequency is decreased slightly, the current amplitude increases, phase constant decreases, power developed in resistor increases, and impedance decreases.

36 (a) Since,

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

$$\Rightarrow\ f \propto \frac{1}{\sqrt{C}}$$

37 (d) At parallel resonance,

$$Z_{\max} = \frac{L}{RC}$$

$$= \frac{10 \times 10^{-3}}{10 \times 0.1 \times 10^{-6}}$$

$$= 10^4\ \Omega$$

38 (d) We know that,

$$X_L = \omega L$$

$$= 2\pi f L$$

$$\therefore\ L = \frac{X_L}{2\pi f}$$

$$= \frac{22 \times 7}{2 \times 22 \times 200}\ \text{H}$$

$$= 0.0175\ \text{H}$$

39 (b) Given :

$$R = X_L = 2X_C$$

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

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

$$= \sqrt{4X_C^2 + X_C^2}$$

$$= \sqrt{5}X_C$$

$$= \frac{\sqrt{5}R}{2}$$

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

$$= \frac{2X_C - X_C}{2X_C}$$

$$\tan\phi = \frac{1}{2}$$

$$\phi = \tan^{-1}\left(\frac{1}{2}\right)$$

40 (b) We know that,

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

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

41 (c) In non-resonant circuits, impedance

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

Z decreases i.e. current increases so circuit behaves as capacitive circuit.

42 (d) As $V_1 = V_2 = 300$ V,, resonance will take place.

$\therefore$ $V_3 = 220$ V

Current,

$$I = \frac{220}{100} = 2.2 \text{ A}$$

$\therefore$ reading of $V_3 = 220$ V

and reading of $A = 2.2$ A

43 (c) The current in RC circuit decreases both during charging as well as discharging.

44 (c) Since,

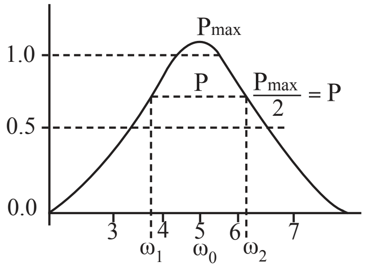
$$\tan\phi = \frac{X_C - X_L}{R}$$

$$\Rightarrow \quad \tan 45° = \frac{\frac{1}{2\pi fC} - 2\pi fL}{R}$$

$$\Rightarrow \quad C = \frac{1}{2\pi f(2\pi fL + R)}$$

45 (a) Quality factor of the circuit

$$= \frac{\omega_0}{\omega_2 - \omega_1} = \frac{5}{2.5} = 2.0$$



46 (b) We know that,

$$Z = \sqrt{R^2 + \omega^2 L^2}$$
$$= \sqrt{R^2 + 4\pi^2 f^2 L^2}$$
$$= \sqrt{1^2 + 4\times(10)(50)^2(0.1)^2}$$
$$\therefore \quad Z = \sqrt{1 + 1000}$$
$$= \sqrt{1001}$$
$$\approx 10\sqrt{10}$$

47 (a) A-(i):

$$I_{rms} = \frac{V_R}{R} = \frac{40}{4} = 10 \text{ A}$$
$$I_0 = \sqrt{2} I_{rms} = 10\sqrt{2} \text{ A}$$

B-(ii):

$$V_{rms} = iZ = 10 \times 5 = 50 \text{ V}$$
$$V_0 = \sqrt{2} V_{rms} = 50\sqrt{2} \text{ V}$$

C-(iii)

D-(iv): Now,

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

or $\quad 50^2 = 40^2 + (40 - V_C)^2$

$\therefore \quad V_C = 10$ V

and $\quad X_C = \frac{V_C}{i} = \frac{10}{10} = 1\ \Omega$

48 (b) The voltage V_L and V_C are equal and opposite so voltmeter reading will be zero.

Also, $R = 30\ \Omega$

$X_L = X_C = 25\ \Omega$

So, $I = \frac{V}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{V}{R} = \frac{240}{30} = 8$ A

49 (d) We know that,

$$Z^2 = R^2 + X_L^2$$
$$\Rightarrow \quad Z^2 = (30)^2 + (2\pi fL)^2$$

$$= 900 + \left(2\pi \times 50 \times \frac{0.4}{\pi}\right)^2$$

$$= 900 + 1600$$

$$= 2500$$

$$\Rightarrow \quad Z = 50\ \Omega$$

$$\therefore \quad I = \frac{V}{Z} = \frac{200}{50} = 4\ \text{A}$$

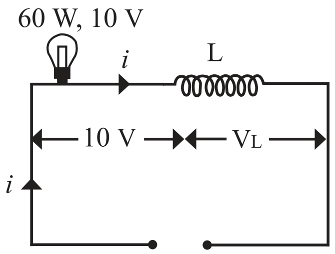
50 (a) According to the question,

$$R_{eq} = \frac{5R}{6}$$

$$\Rightarrow \quad I = \frac{6E}{5R} = 1\ \text{A}$$

51 (c) Current through the bulb,

$$I = \frac{P}{V} = \frac{60}{10} = 6\ \text{A}$$



$$V = \sqrt{V_R^2 + V_L^2}$$

$$(100)^2 = (10)^2 + V_L^2$$

$$\Rightarrow \quad V_L = 99.5\ \text{V}$$

Also, $V_L = IX_L$

$$= I \times (2\pi\nu L)$$

$$\Rightarrow \quad 99.5 = 6 \times 2 \times 3.14 \times 50 \times L$$

$$\Rightarrow \quad L = 0.052\ \text{H}$$

52 (d) For DC,

$$R = \frac{100}{1} = 100\ \Omega$$

For AC,

$$I = \frac{V}{\sqrt{R^2 + L^2\omega^2}}$$

$$\therefore \quad R^2 + L^2\omega^2 = \frac{V^2}{I^2}$$

$$\therefore \quad R^2 + L^2\omega^2 = \frac{100 \times 100}{\frac{1}{2} \times \frac{1}{2}} = 4 \times 10^4$$

$$\therefore \quad 4 \times 10^4 = (100)^2 + 4\pi^2 L^2 f^2$$

$$\therefore \quad 4 \times 10^4 = 10^4 (1 + 10L^2)$$

$$\therefore \quad 3 = 10L^2$$

$$\therefore \quad L = \sqrt{0.3}\ \text{H}$$

Thus,

$$R = 100\ \Omega$$

and $L = \sqrt{0.3}$ H

53 (a) Since,

$$\text{Current in inductor} = \frac{E}{R}$$

$$\therefore \quad \text{its energy} = \frac{1}{2}\frac{LE^2}{R^2}$$

Same energy is later stored in capacitor.

$$\frac{Q^2}{2C} = \frac{1}{2}\frac{LE^2}{R^2}$$

$$\Rightarrow \quad Q = \sqrt{LC}\frac{E}{R}$$

54 (b) When $\omega L = \frac{1}{\omega C}$, the circuit is in resonance.

Impedance is equal to resistance alone.

55 (c) Since,

$$Z = \frac{E_v}{1_v} = \frac{220}{2.5} = 88\ \Omega$$

As, $R^2 + X_C^2 = Z^2$

$$X_C = \sqrt{Z^2 - R^2} = \sqrt{88^2 - 20^2} = 85.7\ \Omega$$

56 (a) Here,

$$C = 30\ \mu\text{F} = 30 \times 10^{-6}\ \text{F}$$

$$L = 27\ \text{mH} = 27 \times 10^{-3}\ \text{H}$$

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

$$= \frac{1}{\sqrt{27 \times 10^{-3} \times 30 \times 10^{-6}}}$$
$$= \frac{1}{\sqrt{81 \times 10^{-8}}}$$
$$= \frac{10^4}{9}$$
$$= 1.1 \times 10^3 \text{ rad s}^{-1}$$

57 (d) Since,

$$v = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$$
$$\Rightarrow \quad v \propto \frac{1}{\sqrt{C}}$$

58 (a) Since current leads emf (as seen from the graph), Therefore, this is an RC circuit.

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

Here $\phi = 45^\circ$

$$\therefore \quad X_C = R \quad ...(X_L = 0 \text{ as there is no inductor})$$
$$\frac{1}{\omega C} = R$$
$$\Rightarrow \quad RC\omega = 1$$
$$\therefore \quad RC = \frac{1}{100} \text{ s}^{-1}$$

59 (b) We know that,

$$v_0 = \frac{1}{2\pi\sqrt{LC}}$$
$$= \frac{1}{2\pi\sqrt{9 \times 10^{-3} \times 10 \times 10^{-6}}}$$
$$= \frac{10}{18.84} \times 10^3 \text{ Hz}$$
$$= 0.530 \text{ kHz}$$

60 (a) We know that,

$$E \propto nAB\omega$$

Therefore,

$$\frac{E_1}{E_2} = \frac{n_1\omega_1}{n_2\omega_2}$$
$$= \frac{50 \times 50}{100 \times 100}$$
$$= 0.25$$

61 (b) Time constant is $\frac{L}{R}$

Given,

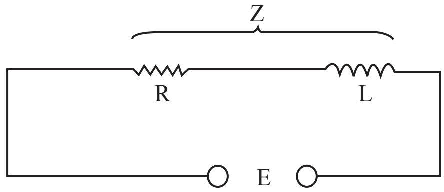
$$L = 40 \text{ H}$$
$$R = 8\ \Omega$$
$$\therefore \quad \tau = \frac{40}{8}$$
$$= 5 \text{ s}$$

62 (b) As the electric and magnetic fields share energy equally in an LC circuit,

$$\frac{1}{2}I^2 = \frac{1}{2}CV^2$$
$$\therefore \quad I = \left(\frac{CV^2}{L}\right)^{1/2}$$
$$= \left(\frac{16 \times 10^{-6} \times 20^2}{40 \times 10^{-3}}\right)^{1/2}$$
$$= 0.4 \text{ A}$$

63 (d) Given,

$L = 2$ H
$E = 5$ V
$R = 1$ W
$f = 50$ HZ



Energy in inductor,

$$= \frac{1}{2}LI^2$$
$$I = \frac{E}{Z}$$
$$I = \frac{5}{\sqrt{R^2 + (\omega L)^2}}$$
$$= \frac{5}{\sqrt{1 + 4\pi^2 \times 50^2 \times 4}}$$
$$= \frac{5}{\sqrt{1 + (200\pi)^2}}$$
$$= \frac{5}{200\pi}$$
$$\text{Energy} = \frac{1}{2} \times 2 \times \frac{5 \times 5}{200 \times 200\pi^2}$$
$$= 6.33 \times 10^{-5} \text{ J}$$

64 (a) In AC, the peak value is $\sqrt{2} \times 220$ V. So heating will be higher.

65 (d) We know that,

$$Z = \sqrt{R^2 + (X_L - X_c)^2}$$
$$= \sqrt{(11)^2 + (25 - 18)^2}$$
$$\cong 13\ \Omega$$

Current,

$$I = \frac{260}{13}$$
$$= 20 \text{ A}$$

66 (d) Since quality factor,

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

67 (c) Impedance of LCR circuit will be minimum at resonant frequency so,

$$v_0=\frac{1}{2\pi\sqrt{LC}}$$
$$=\frac{1}{2\pi\sqrt{1\times10^{-3}\times0.1\times10^{-6}}}$$
$$=\frac{10^5}{2\pi}\ \text{s}^{-1}$$

68 (d) At resonance, LCR circuit behaves as purely resistive circuit, for purely resistive circuit power factor = 1.

69 (c) Impedance,

$$Z=\sqrt{\left(X_L-X_C\right)^2+R^2}$$
$$=\sqrt{(80-50)^2+40^2}$$
$$=50\ \Omega$$

Power factor,

$$\cos\phi=\frac{R}{Z}$$
$$=\frac{40}{50}$$
$$=0.8$$

$$I_{\text{rms}}=\frac{V_{\text{rms}}}{Z}$$
$$=\frac{200\ \text{V}}{50\ \Omega}$$
$$=4\ \text{A}$$

Power current,

$$I_{\text{rms}}\cos\phi=4\times0.8$$
$$=3.2\ \text{A}$$

Wattless current,

$$I_{\text{rms}}\sin\phi=4\times0.6$$
$$=2.4\ \text{A}$$

70 (d) Average power in AC circuit is given by,

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

For pure capacitive circuit,

$\phi=90^\circ$, $\cos 90^\circ=0$

so, $P=0$

71 (c) Power factor,

$$\cos\phi=\frac{R}{Z}$$
$$=\frac{R}{\sqrt{R^2+X^2}}$$
$$=\frac{R}{\sqrt{2R^2}} \qquad [\because R=X]$$
$$=\frac{1}{\sqrt{2}}$$

72 (b) At resonance,

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

and $I=\dfrac{E}{R}$

So power dissipated in circuit is,

$$P=I^2R$$

73 (c) Average power lost/cycle

$$=E_vI_v\cos\theta$$
$$=\frac{E_0}{\sqrt{2}}\frac{I_0}{\sqrt{2}}\cos\theta$$
$$=\frac{1}{2}E_0I_0\cos\theta$$

74 (d) Power factor

$$=\frac{R}{\sqrt{R^2+X_L^2}}$$
$$=\frac{8}{\sqrt{8^2+6^2}}=\frac{8}{10}$$
$$=0.8$$

75 (a) We know that,

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

where Z is the impedance.

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

If there is only resistance then,

$$Z=R$$
$$\Rightarrow\quad \cos\phi=1$$

76 (c) If the current is wattless then power is zero. Hence phase difference,

$$\phi=90^\circ$$

77 (a) Power factor

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

78 (a) We know that power consumed in AC circuit is given by,

$$P = E_{\text{rms}} I_{\text{rms}} \cos\phi$$

Here,

$$E = E_0 \sin\omega t$$

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

which implies that the phase difference,

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

$$\therefore \quad P = E_{\text{rms}} I_{\text{rms}} \cos\frac{\pi}{2}$$

$$= 0 \quad \ldots\left(\because \cos\frac{\pi}{2} = 0\right)$$

79 (c) We know that,

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

$$= \left(\frac{v_0}{\sqrt{2}}\right)\left(\frac{I_0}{\sqrt{2}}\right)\left(\cos\frac{\pi}{3}\right)$$

$$= \frac{v_0 I_0}{4}$$

80 (a) Power,

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

In the given problem, the phase difference between voltage and current is $\frac{\neq}{2}$. Hence,

$$P = I_{\text{rms}} \times V_{\text{rms}} \times \cos\left(\frac{\pi}{2}\right)$$

$$= 0$$

81 (d) Power factor is given by,

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

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

82 (c) Power factor of an LR circuit,

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

$$= \frac{30}{\sqrt{(30)^2 + (40)^2}}$$

$$= \frac{30}{50}$$

$$= \frac{3}{5}$$

83 (c) We know that,

$$P = \frac{E_v^2 \cos\phi}{Z}$$

$$P = 3000 = \frac{(240)^2 (0.75)}{Z}$$

$$\Rightarrow \; Z = 14.4\ \Omega$$

84 (d) We know that,

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

$$= \frac{(30)^2}{10}$$

$$= 90\ \text{W}$$

85 (b) We know that,

$$P = VI\cos\phi$$

$$= I^2 Z \cos\phi$$

$$\therefore \; \cos\phi = \frac{P}{I^2 Z}$$

$$= \frac{2}{4 \times 1}$$

$$= 0.5$$

86 (d) For purely resistive circuit,

$$\text{Power, } P = \frac{V_{\text{rms}}^2}{R} \ldots(i)$$

When inductance is connected in series with resistance,

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

$$= V_{\text{rms}}\left(\frac{V_{\text{rms}}}{Z}\right)\left(\frac{R}{Z}\right) \quad \ldots\left(\because \cos\phi = \frac{R}{Z}\right)$$

$$= \frac{V_{\text{rms}}^2}{Z^2} R$$

$$P' = \frac{(PR)}{Z^2} R \quad \ldots\left(\text{from (i), } V_{\text{rms}}^2 = PR\right)$$

$$\therefore \; P' = \frac{PR^2}{Z^2}$$

87 (d) A transformer is a device to convert alternating current at high voltage into low voltage and vice versa.

88 (b) Iron loss is the energy loss in the form of heat due to the formation of eddy currents in the iron core of the transformer.

89 (d) The lamination on the core of the transformer increases its resistance which reduces eddy current.

90 (b) If thickness of wire is increased, its resistance decreases, which reduces heat loss.

91 (d) Transformation ratio,

$$k = \frac{V_S}{V_P}$$

$$\Rightarrow \; \frac{5}{3} = \frac{V_S}{60}$$

$$\Rightarrow \; V_S = 100\ \text{V}$$

92 (d) Input power $P_i = 220 \times 0.5 = 110$ W
Output power $P_o = 100$ W
Efficiency,

$$\frac{P_o}{P_i} \times 100\% = \frac{100}{110} \times 100\%$$
$$= 90.99\%$$
$$\approx 90\%$$

93 (d) A transformer does not work on DC. Therefore, voltage across the secondary will be zero.

94 (a) According to the question,

$$N_P = 400$$
$$N_S = 2000$$
and, $V_S = 1000$ V

We know,
$$\frac{V_P}{V_S} = \frac{N_P}{N_S}$$

$$V_P = \frac{V_S \times N_P}{N_S}$$
$$= \frac{1000 \times 400}{2000}$$
$$= 200 \text{ V}$$

95 (b) We know that,
$$\eta = \frac{E_S I_S}{E_P I_P}$$
Here,
$$\eta = 80\%$$
$$= \frac{80}{100}$$
$$E_S = 120 \text{ V}$$
$$I_S = 20 \text{ A}$$
$$E_P = 1000 \text{ V}$$
$$\therefore \frac{80}{100} = \frac{120 \times 20}{1000 \times I_P}$$
or, $I_P = 3$ A

96 (b) According to the question,
$$V_P = 220 \text{ V}$$
$$I_P = 5 \text{ A}$$
$$V_S = 2200 \text{ V}$$
$$P_S = \frac{P_P}{2}$$
$$I_S = ?$$
$$V_S I_S = \frac{V_P I_P}{2}$$

After putting the given value we will find,
$I_S = 0.25$ A

97 (a) For step down transformer,
We have,
$$N_P < N_S$$
Also, $\frac{N_S}{N_P} = \frac{E_S}{E_P}$
$$\Rightarrow \quad N_P = N_S \frac{E_P}{E_S}$$
Substituting,
$$E_P = 22000 \text{ V}$$
$$E_S = 4400 \text{ V}$$
$$N_S = 220$$
We get,
$N_P = 44$

98 (b) We know that,
$$\frac{N_S}{N_P} = \frac{V_S}{V_P}$$
$$\frac{50}{1000} = \frac{V_S}{220}$$
$$\Rightarrow \quad V_S = 11 \text{ V}$$
Now, $V_S I_S = V_P I_P$
$$11 \times I_S = 220 \times 1$$
$$\Rightarrow \quad I_S = 20 \text{ A}$$

99 (c) In a transformer, we have
$$E_S I_S = E_P I_P$$
$$\Rightarrow \quad I_P = \frac{E_S I_S}{E_P}$$
Substituting,
$$E_S = 1100 \text{ V}$$
$$E_P = 220 \text{ V}$$
$$I_S = 2 \text{ A}$$
We get,
$I_P = 10$ A

100 (c) Efficiency,
$$\eta = \frac{V_S I_S}{V_P I_P}$$
$$\Rightarrow \quad 0.9 = \frac{V_S (6)}{3 \times 10^3}$$
$$\Rightarrow \quad V_S = 450 \text{ V}$$
As, $V_P I_P = 3000$
so, $I_P = \frac{3000}{V_P}$
$$= \frac{3000}{200}$$
$$= 15 \text{ A}$$

High-Order Thinking Skill

1 (b) The instantaneous values of emf and current in inductive circuit are given by,

$$E = E_0 \sin\omega t$$

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

So,

$$P_{inst} = Ei$$

$$= E_0 \sin\omega t \times I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$$

$$= E_0 I_0 \sin\omega t\left(\sin\omega t \cos\frac{\pi}{2} - \cos\omega t \sin\frac{\pi}{2}\right)$$

$$= E_0 i_0 \sin\omega t \cos\omega t$$

$$= \frac{1}{2} E_0 i_0 \sin 2\omega t \quad ...(\because \sin 2\omega t = 2\sin\omega t\cos\omega t)$$

Hence, angular frequency of instantaneous power is 2ω.

2 (b) Reading of ammeter,

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

$$= \frac{V_0 \omega C}{\sqrt{2}}$$

$$= \frac{200\sqrt{2} \times 100 \times (1 \times 10^{-6})}{\sqrt{2}}$$

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

$$= 20 \text{ mA}$$

3 (c) If voltage across resistor is 50 V then this should be the resonance condition.

At resonance,

$$X_L = X_C$$

$$\omega_2 L = \frac{1}{\omega_2 C} \quad ...(i)$$

$$\omega_2 = \frac{1}{\sqrt{LC}}$$

Also, at $\omega = \omega_1$

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

$$= \frac{60}{X_C}$$

$$\frac{100}{\omega_1 L} = \frac{60}{\frac{1}{\omega_1 C}}$$

$$C = \frac{100}{\omega_1^2 L \times 60}$$

$$= \frac{5}{3\omega_1^2 L}$$

Put the V place of C in (i)

$$\omega_2 = \frac{1}{\sqrt{L \times \frac{5}{3\omega_1^2 L}}}$$

$$= \sqrt{\frac{3}{5}}\omega_1$$

4 (d) Power factor (old)

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

$$= \frac{R}{\sqrt{R^2 + (2R)^2}}$$

$$= \frac{R}{\sqrt{5}R}$$

Power factor (new)

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

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

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

$$\therefore \frac{\text{New power factor}}{\text{Old power factor}} = \frac{\frac{R}{\sqrt{2}R}}{\frac{R}{\sqrt{5}R}}$$

$$= \sqrt{\frac{5}{2}}$$

5 (c) According to question,

$$L = 0.7 \text{ H}$$

$$R = 220\,\Omega$$

$$E_0 = 220 \text{ V}$$

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

This is an LR circuit.

Phase difference,

$$X_L = 2\pi\nu L$$

$$= 2 \times \frac{22}{7} \times 50 \times 0.7$$

$$= 220\,\Omega$$

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

$$= \frac{\omega L}{R}$$

$$= \frac{2\pi\nu L}{R}$$

$$= \frac{220}{220}$$
$$= 1$$

or, $\phi = 45°$

Wattless component of current,

$$= I_0 \sin\phi$$
$$= \frac{I_0}{\sqrt{2}}$$
$$= \frac{1}{\sqrt{2}} \frac{E_0}{Z}$$
$$= \frac{1}{\sqrt{2}} \frac{220}{\sqrt{X_L^2 + R^2}}$$
$$= \frac{1}{\sqrt{2}} \frac{220}{\sqrt{220^2 + 220^2}}$$
$$= \frac{1}{2}$$
$$= 0.5 \text{ A}$$

6 (a) Since,

$$\tan\phi = \frac{X_L}{R} = \frac{X_C}{R}$$
$$\Rightarrow \tan 60° = \frac{X_L}{R} = \frac{X_C}{R}$$
$$\Rightarrow X_L = X_C = \sqrt{3}R$$

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

So, average power,

$$P = \frac{V^2}{R} = \frac{200 \times 200}{100} = 400 \text{ W}$$

7 (d) Given,

$$l = 30 \text{ km} = 30 \times 10^3 \text{ m}$$
$$r = 0.4 \text{ cm} = 0.4 \times 10^{-2} \text{ m}$$
$$\rho = 1.7 \times 10^{-8} \ \Omega\text{m}$$

So,

$$R = \frac{\rho l}{A} = \frac{1.7 \times 10^{-8} \times 30 \times 10^3}{3.14 \times (0.4 \times 10^{-2})^2} = 10.15 \ \Omega$$
$$P = 10^6 \text{ W}$$
$$V = 11000 \text{ V}$$
$$I = \frac{P}{V} = \frac{10^6}{11000} = \frac{10^3}{11} \text{ A}$$

Power loss,

$$I^2 R = \left(\frac{10^3}{11}\right)^2 \times 10.15 = 8.5 \times 10^4 \text{ W}$$
$$\frac{P_{\text{Lost}}}{P_{\text{Transmitted}}} \times 100\% = \frac{8.5 \times 10^4}{10^6} \times 100 = 8.5\%$$

8 (b) As we know that,

$$\frac{N_S}{N_P} = \frac{V_S}{V_P}$$
$$\Rightarrow \frac{1}{20} = \frac{V_S}{2400}$$
$$\Rightarrow V_S = 120 \text{ V}$$

For 100% efficiency,

$$V_S i_S = V_P i_P$$
$$\Rightarrow 120 \times 80 = 2400 i_P$$
$$\Rightarrow i_P = 4 \text{ A}$$

NCERT Exemplar Problems

1 (b) According to the question,

$$f = 50 \text{ Hz}$$
$$I_{\text{rms}} = 5 \text{ A}$$
$$t = \frac{1}{300} \text{ s}$$
$$I_0 = \sqrt{2}(I_{\text{rms}}) = 5\sqrt{2} = 5\sqrt{2} \text{ A}$$

From,

$$I = I_0 \sin\omega t$$
$$= 5\sqrt{2}\sin 2\pi ft$$
$$= 5\sqrt{2}\sin 2\pi \times 50 \times \frac{1}{300}$$
$$= 5\sqrt{2}\sin\frac{\pi}{3}$$
$$= 5\sqrt{2}\times\frac{\sqrt{3}}{2}$$
$$= 5\sqrt{\frac{3}{2}}\text{ A}$$

2 (c) For maximum power to be delivered from the generator (or internal reactance X_g) to the load (of reactance, X_L),
$\Rightarrow X_L + X_g = 0$ (The total reactance must vanish)

$$\Rightarrow \quad X_L = -X_g$$

3 (c) The voltmeter connected to AC mains calibrated to read rms value $\sqrt{<v^2>}$.

4 (b) Resonant frequency in an LCR circuit is given by,

$$v_0 = \frac{1}{2\pi\sqrt{LC}}$$

If L or C increases, the resonant frequency will reduce.

To increase capacitance, we must connect another capacitor parallel to it.

5 (c) We know quality factor should be high for better tuning.
Quality factor (Q) of an LCR circuit is,

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

where R is the resistance, L is the inductance and C is the capacitance of the circuit.

For high Q factor R should be low, L should be high and C should be low. These conditions are best satisfied by the values given in option (c).

6 (c) According to the question, $X_L = 1\ \Omega$, $R = 2\ \Omega$, $E_{\text{rms}} = 6$ V

Average power dissipated in the circuit,

$$P_{\text{av}} = E_{\text{rms}} I_{\text{rms}} \cos\phi \quad ...(i)$$

$$I_{\text{rms}} = \frac{E_{\text{rms}}}{Z}$$
$$Z = \sqrt{R^2 + X_L^2}$$
$$I_{\text{rms}} = \frac{6}{\sqrt{5}}\text{ A}$$
$$\cos\phi = \frac{R}{Z}$$
$$= \frac{2}{\sqrt{5}}$$
$$P_{\text{av}} = 6 \times \frac{6}{\sqrt{5}} \times \frac{2}{\sqrt{5}} \quad ...(\text{from (i)})$$
$$= \frac{72}{\sqrt{5}\sqrt{5}}$$
$$= \frac{72}{5}$$
$$= 14.4\text{ W}$$

7 (a) According to the problem output/secondary voltage $V_S = 24$ V

Power associated with secondary $P_S = 12$ W

$$I_S = \frac{P_S}{V_S}$$
$$= \frac{12}{24}$$
$$= 0.5\text{ A}$$

Amplitude of the current in the secondary winding,

$$I_0 = I_S\sqrt{2}$$
$$= (0.5)(1.414)$$
$$= 0.707$$
$$= \frac{1}{\sqrt{2}}\text{ A}$$

Assertion and Reasons

1 (a) AC is more dangerous in use than DC. It is because the peak value of AC is greater than indicated value.

2 (b) The mean or average value of alternating current or emf during a half cycle is given by,

$$I_m = 0.636 I_0$$
$$\text{or, } E_m = 0.636 E_0$$

During the next half cycle, the mean value of AC will be equal in magnitude but opposite in direction. For this reason the average value of AC over a complete cycle is always zero. So the average value is always defined over a half cycle of AC.

3 (c) When AC flows through an inductor current lags behind the emf, by phase of $\frac{\neq}{2}$, inductive reactance,

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

So when frequency increases correspondingly inductive reactance also increases.

4 (a) The capacitive reactance of capacitor is given by,

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

So this is infinite for DC ($f = 0$) and has a very small value for AC. Therefore a capacitor blocks DC.

5 (c) In series resonance circuit, inductive reactance is equal to capacitive reactance.

i.e., $\omega L = \frac{1}{\omega C}$

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

6 (b) Like direct current, an alternating current also produces magnetic field. But the magnitude and direction of the field goes on changing continuously with time.

7 (a) At resonant frequency,

$$X_L = \frac{X_C}{Z}$$
$$= R \text{ (minimum)}$$

Therefore, current in the circuit is maximum.

8 (a) The effect of AC on the body depends largely on the frequency. Low frequency currents of 50 to 60 Hz (cycles per second or cps), which are commonly used, are usually more dangerous than high frequency currents and are 3 to 5 times more dangerous than DC of same voltage and amperage (current). The usual frequency of 50 cps (or 60 cps) is extremely dangerous as it corresponds to the fibrillation frequency of the myocardium. This results in ventricular fibrillation and instant death.

9 (b) A heavy machinery requires a large power. The average power is given by,

$$P_{av} = E_{rms} I_{rms} \cos\phi$$

The required power can be supplied to the heavy machinery either by supplying larger current or by improving power factor. The first method is costly therefore second one is used.

10 (a) We can use a capacitor of suitable capacitance as a choke coil, because average power consumed per cycle in an ideal capacitor is zero. Therefore, like a choke coil, a condenser can reduce AC without power dissipation.

11 (d) The power of an AC circuit is given by,

$$P = EI\cos\phi$$

where $\cos\phi$ is power factor and ϕ is phase angle. In case of circuit containing resistance only, phase angle is zero and power factor is equal to one. Therefore power is maximum in case of circuit containing resistor only.

12 (a) Transformers cannot produce power, but it transfers from primary to secondary.

13 (a) Transformer works on AC only AC changes in magnitude as well as in direction.

14 (d) Large eddy currents are produced in non-laminated iron core of the transformer by the induced emf, as the resistance of bulk iron core is very small. By using thin iron sheets as core the resistance is increased. Laminating the core substantially reduces the eddy currents. Eddy current heats up the core of the transformer. More the eddy currents greater is the loss of energy and the efficiency goes down.

15 (a) Hysteresis loss in the core of transformer is directly proportional to the hysteresis loop area of the core material. Since soft iron has narrow hysteresis loop area, that is why soft iron core is used in the transformer.

16 (a) The ratio of the number of turns on each coil, called the turn ratio determines the ratio of the voltages.