

Answers

Module 1: AC Voltage and Current

A.7.1.1 (D) 220 V is the rms value of voltage.

A.7.1.2 (D)

$$\text{We have, } R = \frac{V^2}{P} = \frac{(220)^2}{25} \Omega = 1936 \Omega$$

$$\begin{aligned} V_m &= \sqrt{2} V_{RMS} = \sqrt{2} \times 220 \\ &= 311 \text{ V} \end{aligned}$$

$$I_{RMS} = \frac{P}{V_{RMS}} = \frac{25}{220} = 0.1136 \text{ A.}$$

A.7.1.3 (C)

$$I = I_0 \sin \omega t$$

$$I_{RMS} = 1 \text{ A}$$

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

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

$$\therefore \omega = 2\pi f = 100\pi$$

$$\text{At } t = \frac{1}{400} \text{ s, } \omega t = \frac{\pi}{4}$$

$$\therefore I = I_0 \sin \omega t = \sqrt{2} \sin \frac{\pi}{4} = 1 \text{ A}$$

A.7.1.4. (A), (C)

- (A)** In each cycle, the direction of AC is reversed twice.
- (B)** Incorrect. Transformers work on the principle of mutual induction which requires time varying magnetic flux; this variation takes place in AC hence transformer work on AC.



(C) Magnetic effect can not be used to define AC ampere as the field varies both in magnitude as well as direction. AC ampere must be defined in terms of some property that is independent of the direction of current. Joule's heating effect is such property and hence it is used to define rms value of AC.

(D) Incorrect. rms value of AC = $\frac{I_m}{\sqrt{2}} = 0.707 I_m$

I_m = peak value of AC.

A.7.1.5 (A), (C) & (D)

(A) $P = VI$

$V = \frac{P}{I}$ for given power $V \propto \frac{1}{I}$

Hence for high alternating voltages I will be smaller.

(B) $R = \rho \frac{l}{A}$

Thinner wire will have more resistance and hence higher power loss.

A = Area of cross-section.

If A decreases, R increases. Thus the heat loss increases

$$\therefore H = I^2 R t$$

(C) $P = I^2 R$

Hence lower current implies lesser power loss.

(D) Voltage can be reduced easily at the receiving end using step-down transformers.

A.7.1.6 (A)

(A) $P = I_m^2 R \sin^2 \omega t$

$$\bar{P} = \langle I_m^2 R \sin^2 \omega t \rangle$$

Square of the AC current will always give positive values. Hence instantaneous and average power are always positive.

(B) Instantaneous power is always positive in purely resistive circuit because $P = I_m^2 R \sin^2 \omega t$ Hence the statement is false.

(C) $P = I_m^2 R \sin^2 \omega t$ and $\bar{P} = \langle I_m^2 R \sin^2 \omega t \rangle$ are both positive hence statement is false.

(D) $\langle P \rangle = \langle I_m^2 R \sin^2 \omega t \rangle$

$$= I_m^2 R \langle \sin^2 \omega t \rangle$$

$$= \frac{1}{2} I_m^2 R$$

Average power cannot be zero. Hence this statement is also false.

A.7.1.7. (A) & (B) are correct.

$$I_{av} = \frac{\int_0^T I(t) dt}{T}$$

$$I_{av} = \frac{\int_0^T I_m \sin \omega t \cdot dt}{T}$$

Because $\langle I(t) \rangle = \frac{\int_0^T I(t) dt}{T}$

Because $\int_0^T \sin \omega t dt = 0$

So, $I_{av} = 0$,

(B) $I_{av} = \frac{\int_0^{\frac{T}{2}} I(t) dt}{\frac{T}{2}} = 0.637 I_m$

Here $I(t) = I_0 \sin \omega t$

(C) Average value of AC for a complete cycle is zero. So, option (C) is incorrect.

(D) Average value of AC for half cycle is $0.637 I_m$

A.7.1.8 (B)

The inductive reactance,

$$X_L = 2\pi\nu L = 2 \times 3.14 \times 50 \times 50 \times 10^{-3} \Omega$$

$$= 15.7 \Omega$$

the rms current in the circuit is

$$I = \frac{V}{X_L} = \frac{220 \text{ V}}{15.7 \Omega} \approx 14 \text{ A}$$

A.7.1.9 (A)

The capacitive reactance $X_C = 1/\omega C$

∴ The rms current in A is

$$I = \frac{V}{X_C} = \frac{220 \text{ V}}{106.16} = 2.07 \text{ A}$$

The peak current is $I_m = \sqrt{2}I = 1.414 \times 2.07 = 2.92 \text{ A}$

So, This current oscillates between + 2.92 A and -2.92 A

A.7.1.10 (B) 3.45 A

$$X_C = \frac{1}{2\pi\nu C} = \frac{1}{2 \times 3.14 \times (50 \text{ Hz}) \times (50 \times 10^{-6} \text{ F})}$$

$$= 63.7 \Omega$$

$$\text{The rms current is } I = \frac{V}{X_C} = \frac{220 \text{ V}}{63.7 \Omega} = 3.45 \text{ A}$$

Module 2: AC Circuits with Frequency Dependent Components

A.7.2.1. (C)

(i) 220 V is the rms value of the voltage of given A.C we know that the peak value of voltage is $\sqrt{2}$ times the r.m.s value of voltage

$\therefore$ peak value of voltage $= 220\sqrt{2}$ V

(ii) The angular frequency ω of A.C is

$$\omega = 2\pi\nu$$

Given $\omega = 100\pi$; therefore $\nu = 50$ Hz

A.7.2.2 (D)

Let R ; and W denote the resistance and power rating of the bulb respectively. V is the rms value of applied AC we have

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

$$\therefore R = \frac{200 \times 200}{50} = 800 \Omega$$

$$I = \text{rms value current drawn by bulb} = \frac{V}{R} = \frac{200}{800} = \left(\frac{1}{4}\right) \text{ A}$$

A.7.2.3 (A)

Case(i) $I = 0.1$ A; $t = t_1$

$$\therefore \frac{1}{2} = \sin(120\pi t_1)$$

$$\text{or } \frac{\pi}{6} = 120\pi t_1$$

$$\therefore t_1 = \left(\frac{1}{720}\right) \text{ s}$$

Case(ii) $I = 0.174$ A $= \frac{\sqrt{3}}{2} \times 0.2$ A at $t = t_2$

$$\therefore \frac{\sqrt{3}}{2} = \sin(120\pi t_2)$$

$$\text{or } \frac{\pi}{3} = 120\pi t_2$$

$$\therefore t_2 = \left(\frac{1}{360}\right) \text{ s}$$

$$\begin{aligned} \text{obviously } (t_2 - t_1) &= \frac{1}{360} - \frac{1}{720} \\ &= \left(\frac{1}{720}\right) \text{ s} \end{aligned}$$

A.7.2.4 (B) (i) A DC (direct-current) ammeter cannot detect on A.C current. Due to inertia the pointer of D.C

ammeter does not move. It shows zero deflection.

- (ii) An AC instrument shows r.m.s value of current/voltage The r.m.s value of given current is 40 mA, therefore the reading of the AC ammeter is 40 mA.

A.7.2.5 (D)

Option (D) shows maximum value of voltage among all options. Transmission at high voltage and low current is economic and hence necessary to minimise the loss of power as heat.

Let P be the power transmitted from A to B at transmission voltage V_T . Let I be the current in transmission cables we have $P = V_T I$

Transmission cable from A to B have a resistance R_C . The power lost as heat, in transmission is $I^2 R_C$

For a given value of R_C ; the transmission loss is less if transmission current I is small. For a fixed value of P ; transmission loss is minimum if I is minimum or V_T is maximum. Therefore $V_T = 20 \text{ kV}$

A.7.2.6 (A) and (C)

In pure resistive circuit current and applied voltage are in phase $\bar{P}$ = The average power consumed per cycle in AC circuit = $V_{rms} I_{rms} \cos\phi$ where $\cos\phi$ is the power factor of the circuit. For a pure resistive circuit

$$\bar{P} = V_{rms} I_{rms}$$

obviously The Power factor = $\cos\phi = 1$

The instantaneous power consumed is different at different moments of time.

A.7.2.7 (B) Given $I(t) = -0.5 \cos(100t)$

$$= 0.5 \sin\left(100t - \frac{\pi}{2}\right) \text{ A}$$

The current lags behind the applied p.d by $\frac{\pi}{2}$, therefore Z is an inductance. Let X_L be the reactance of inductance. We have

$$0.5 = \frac{10}{X_L}$$

$$\therefore X_L = 20 \Omega$$

A.7.2.8 (B) $L = 1 \text{ H}$, $R = 100 \Omega$, $\omega = 50 \text{ Hz}$

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

$$X_L = \omega L = 2\pi\nu L = 2 \times 3.14 \times 50 \Omega$$

$$100 \times 3.14 = 314 \Omega$$

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

$$= \sqrt{100^2 + 314^2}$$

$$= \sqrt{10000 + 98596}$$

$$= \sqrt{108596}$$

$$= 329.54 \Omega$$

A.7.2.9 (B)

$$\tan \phi = \frac{V_C}{V_R}$$

$$= \frac{IX_C}{IR} = \frac{X_C}{R} = \frac{1}{\omega CR} = \frac{1}{2\pi\nu CR} = \frac{1}{2 \times 3.14 \times 50 \times 10 \times 10^{-6} \times 100} = 3.18$$

$$\phi = \tan^{-1}(3.18)$$

So current leads the voltage by phase $\tan^{-1}(3.18)$. Refer Fig.A.7.2.1

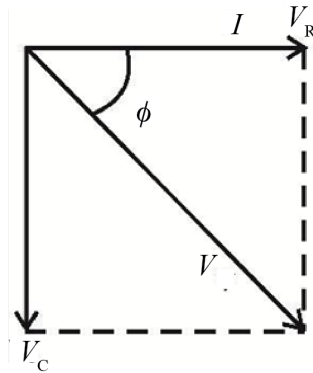


Fig.A.7.2.1

A.7.2.10 (A)

(i) For a resistance (R), the reactance $X = R$. X is independent of the frequency (ν) of applied AC. Therefore curve I is for resistance; therefore, element E_1 is a resistance.

(ii) For an inductance, L , the reactance X is

$$X = 2\pi\nu L$$

X v/s ν a graph is a straight line passing through the origin. This is curve II; therefore E_2 is an inductance.

(iii) For capacitor C , the reactance X is

$$X = \frac{1}{2\pi\nu C}$$

X v/s ν The graph is a rectangular hyperbola. This is curve III. Therefore element E_3 is a capacitor.

Module 3: Oscillation and Resonance in AC Circuit

A.7.3.1. (A)

Because $\frac{1}{\omega C} > \omega L$

$$X_C > X_L$$

$$IX_C > IX_L$$

$$V_C > V_L$$

Phase difference between V_R and $V_L + V_C$ must be $\frac{\pi}{2}$.

and current must lead the net voltage by phase ϕ . Hence only phasor diagram (A) is correct.

(B) Here phase difference between V_R and $V_L + V_C$ is less than $\frac{\pi}{2}$. It should be $\frac{\pi}{2}$.

Net voltage V is not represented correctly according to the parallelogram law of vector addition.

So, this phasor diagram is incorrect.

Hence the phasor diagram in option (B) is incorrect.

(C) Here also phase difference between V_R and $V_L + V_C$ is less than $\frac{\pi}{2}$. It should be $\frac{\pi}{2}$.

(D) Net Voltage V is not represented correctly according to the parallelogram law of vector addition

So, this phasor diagram is also incorrect.

A.7.3.2 (A)

In the graph, current lead the voltage by phase ϕ . Also given $Z > 1$

and $I = \frac{V}{Z}$.

So, length of phasor $I <$ length of phasor V

Hence option (A) is correct

(B) Here, from the phasor:

length of phasor $V <$ length of phasor I

this indicates $Z < 1$

So, option (B) is incorrect.

(C) From the graph, I is leading V but in the phasor diagram V is leading I . So, this phasor diagram is also not possible.

(D) From the phasor diagram length of phasor $V <$ length of phasor I . But from the graph length of phasor $V >$ Length of phasor I . So, this phasor diagram is not possible

A.7.3.3 (B)

In the graph, voltage leads the current by phase ϕ .

length of phasor $I <$ length of phasor V

$\therefore Z > 1$

hence, (B) is correct

(A) Option (A) is incorrect because length of phasor $V <$ Length of phasor I

(C) Option (C) is incorrect as I is leading V but from the graph, V is leading I .

(D) Option (D) is incorrect as the length of phasor $V <$ length of phasor I gives $Z < 1$

A.7.3.4 (C) Tuning takes place at resonance.

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

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

$$Z_{\min} = R$$

$$I = \frac{V}{Z_{\min}} = \frac{V}{R}$$

For better tuning in LCR circuits, current must be maximum.

I will be Max when R is minimum.

So, option (C) is correct.

Options (A), (B) & (D) are incorrect due to larger values of R than that in (C).

A.7.3.5 (A)

We see that the current amplitude is maximum at the resonant frequency. Since $I_m = \frac{V_m}{R}$ at resonance, the maximum current amplitude for case (i) is twice that of case (ii)

Hence, the value of R in case (i) will be half to that for case (ii).

Again, as per the graph the resonant frequency is 1 MHz.

$$\text{Also, } \omega_r = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{10^{-3} \times 10^{-9}}} = 10^6 \text{ rad/sec}$$

So, option (A) is correct

(B) In case (i) the value of R is double to that for case (ii). So, it is incorrect

$$\begin{aligned} \text{(C) Here } \omega_r &= \frac{1}{\sqrt{LC}} \\ &= \frac{1}{\sqrt{10^{-3} \times 10^{-6}}} = 10^4 \sqrt{10} \text{ rad/sec} \end{aligned}$$

From the given figure, $\omega_r = 1 \text{ Mrad/sec} = 10^6 \text{ rad/sec}$

Hence, option (C) is incorrect

(D) In case (i) the value of R is double that in case (ii) so it is also incorrect.

A.7.3.6 (C)

At very high frequencies

Capacitor $\approx$ short circuit due to very low capacitive reactance

$$\left(\because X_c = \frac{1}{\omega C} = \frac{1}{2\pi\nu C} \right)$$

and inductor $\approx$ open circuit

due to very high inductive reactance $\because X_L = \omega L = 2\pi\nu L$

Hence, option (C) is the correct effective equivalent circuit.

A.7.3.7 (D) Sharpness of resonance of *LCR* circuit is given by

$$Q = \frac{\text{Resonant angular frequency}}{\text{Bandwidth of series LCR circuit}}$$

$$= \frac{\omega_0}{2\Delta\omega}$$

$$\text{We know } \Delta\omega = \frac{R}{2L}$$

$$\text{So, } \frac{\omega_0}{2\Delta\omega} = \frac{\omega_0}{2 \times \frac{R}{2L}} = \frac{\omega_0 L}{R}$$

A.7.3.8 (A) $Q = 12.5$

current will be minimum at resonance ($Z = R$)

$$I_{Max} = \frac{V}{Z} = \frac{V}{R}$$

$$R = \frac{220}{11} = 20 \, \Omega$$

Quality factor

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{20} \sqrt{\frac{2500 \times 10^{-3}}{40 \times 10^{-6}}}$$

$$Q = \frac{1}{20} \sqrt{\frac{2500000}{40}} = \frac{1}{20} = \frac{5 \times 100}{2} = \frac{25}{2} = 12.5$$

$$Q = 12.5$$

A.7.3.9 (C) required condition to attain maximum current in *LCR* series is resonance

$$\left[\omega_r \sqrt{\frac{1}{LC}} \right]$$

We have $\nu_1 = 25 \, \text{kHz}$

$$\nu_2 = 36 \, \text{kHz}$$

At given $I_1 = I_2$

$$\frac{V}{Z_1} = \frac{V}{Z_2}$$

$$\frac{V}{\sqrt{(\omega_1 L - \frac{1}{\omega_1 C})^2 + R^2}} = \frac{V}{\sqrt{(\frac{1}{\omega_1 C} - \omega_2 L)^2 + R^2}}$$

On comparing both side,

$$\omega_1 L - \frac{1}{\omega_1 C} = \frac{1}{\omega_2 C} - \omega_2 L$$

$$\omega_1 L + \omega_2 L = \frac{1}{\omega_2 C} + \frac{1}{\omega_1 C}$$

$$(\omega_1 + \omega_2)L = \frac{1}{C} \left[\frac{\omega_1 + \omega_2}{\omega_1 \omega_2} \right]$$

$$\omega_1 \omega_2 = \frac{1}{LC}$$

$$\sqrt{\omega_1 \omega_2} = \frac{1}{\sqrt{LC}}$$

$$\sqrt{\omega_1 \omega_2} = \omega_r$$

$$\sqrt{(2\pi\nu_1)(2\pi\nu_2)} = 2\pi\nu_r$$

$$\nu_r = \sqrt{\nu_1 \nu_2} = \sqrt{25 \text{ kHz} \times 36 \text{ kHz}} = 30 \text{ kHz}$$

At frequency of 30 kHz, current in the circuit is maximum

A.7.3.10 (C)

During LC oscillation when switch is closed

$t =$	0	$T/4$	$T/2$	$3T/4$	T
$U_E =$	Max	0	Max	0	Max
$U_B =$	0	Max	0	Max	0

Hence, option (C) is correct.

Module 4: Power in AC Circuit

A.7.4.1 (B)

$$P = 36 \text{ W}$$

$$V = 48 \text{ V}$$

$$I_{eff} = \frac{P}{V} = \frac{36}{48} = \frac{3}{4} \text{ A}$$

$$I_0 = I_{eff} \sqrt{2} = \frac{3}{4} \sqrt{2} \text{ A}$$

Hence, option (B) is correct

A.7.4.2 (A)

We know that $P = IV \cos \phi$ where $\cos \phi$ is the power factor.

If $\cos \phi$ is maximum ($= 1$) then, to supply a given power at a certain voltage, the current will be minimum. This leads to minimum power loss ($I^2 R$) in transmission.

So, option, (A) is correct

(B),(C) and (D) are incorrect as $\cos \phi < 1$

A.7.4.3 (B)

Average Power

$$<P> = VI \cos \phi \quad (7.4.1)$$

$$V_{eff} = \text{rms value of Voltage} = \frac{V_m}{\sqrt{2}}$$

$$I_{eff} = \text{rms value of Voltage} = \frac{I_m}{\sqrt{2}}$$

$$<P> = \frac{1}{2} I_m V_m = V_{eff} I_{eff} \cos \phi \quad (7.4.2)$$

$$\frac{1}{2} I_m V_m = \frac{1}{2} V_m I_m \cos \phi$$

$$\therefore \cos \phi = 1$$

A.7.4.4 (B)

$$V_P = 1100 \text{ V}$$

$$I_P = 10 \text{ A}$$

$$\text{Input power} = V_P \cdot I_P = 1100 \times 10 = 11000 \text{ W}$$

$$\text{efficiency } \eta = \frac{\text{output power}}{\text{input power}}$$

$$\begin{aligned} \therefore \text{output power} &= \eta \times \text{input power} \\ &= \frac{90}{100} \times 11000 \text{ W} \end{aligned}$$

$$\text{Output power} = 9900 \text{ W}$$

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

$$V_S = \frac{N_S}{N_P} \times V_P$$

$$V_S = \frac{1}{10} \times 1100 \text{ V}$$

$$V_S = 110 \text{ V}$$

A.7.4.5 (C)

$$\text{Input power} = 220 \times 0.5 = 110 \text{ W}$$

$$\text{Output power} = 100 \text{ W}$$

$$\begin{aligned} \therefore \text{efficiency of transformer} &= \frac{\text{output power}}{\text{input power}} \times 100\% \\ &= \frac{100}{110} \times 100 \\ &= 90.90\% \\ &\approx 91\% \end{aligned}$$

A.7.4.6 (A) Power dissipated

$$\begin{aligned} P &= E_{r.m.s} I_{r.m.s} \cos \phi \\ &= \frac{E_0}{\sqrt{2}} \cdot I_{r.m.s} \cos \phi \\ &= \frac{311.08}{1.414} \times 10 \times 0.6 \\ &= 1320 \text{ W} \end{aligned}$$

A.7.4.7 (C)

(A) At resonance,

$$\phi = 0$$

$$\therefore \cos \phi = 1$$

and $P = VI \cos \phi = VI = I^2 Z = I^2 R = \text{maximum}$

Hence statement (A) is correct.

(B)
$$I_{rms} = \frac{P}{V_{rms} \cos \phi}$$

Low $\cos \phi \Rightarrow$ large current $\Rightarrow$ large power loss

I.e. $P = I_{rms}^2 R$

So statement (B) is correct

(C) In purely resistive circuit,
 $\cos \phi = 1$

This result, $P = I^2 R = \text{max power loss}$

So, statement (C) is incorrect.

(D) In RL series circuit, when $R \ll \omega L$

Then,
$$\cos \phi = \frac{R}{Z} = \frac{R}{\sqrt{R^2 + \omega^2 L^2}} \approx \frac{R}{\omega L} \approx 0$$

As, $P = VI \cos \phi$

$$P \approx 0$$

Statement (D) is correct.

A.7.4.8 (A)

Resistance of two lines carrying current $= (10 + 10) \times 1 = 20 \Omega$

RMS current through the lines $= \frac{P}{V} = \frac{400 \times 10^3}{4000} \text{ A}$
 $= 100 \text{ A}$

Power loss through the lines $= I^2 R = (100)^2 \times 20 = 2,00,000 \text{ W} = 200 \text{ kW}$

$\therefore$ Total power must be supplied by the plant $= 400 + 200 = 600 \text{ kW}$

A.7.4.9 (B)

Power factor,

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

$$\approx \frac{R}{\omega L} \approx 0 \quad (\because \omega L = 2\pi \nu L = 2\pi \times 50 \times 50 \Omega, R = 0.01 \Omega \text{ and } \omega L \gg R)$$

A.7.4.10 (A)

Impedance of circuit

$$\begin{aligned}
 Z &= \sqrt{(X_L - X_C)^2 + R^2} \\
 &= \sqrt{(2.5 \, \Omega - 5.5 \, \Omega)^2 + (4 \, \Omega)^2} \\
 &= \sqrt{(-3)^2 + (4)^2} = 5 \, \Omega \\
 I &= \frac{V}{Z} \\
 &= \frac{10}{5} = 2 \, \text{A}
 \end{aligned}$$

Voltages -

$$\begin{aligned}
 V_R &= IR = 2 \times 4 = 8 \, \text{V} \\
 V_L &= IX_L = 2 \times 2.5 = 5 \, \text{V} \\
 V_C &= IX_C = 2 \times 5.5 = 11 \, \text{V}
 \end{aligned}$$



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