Lesson-1

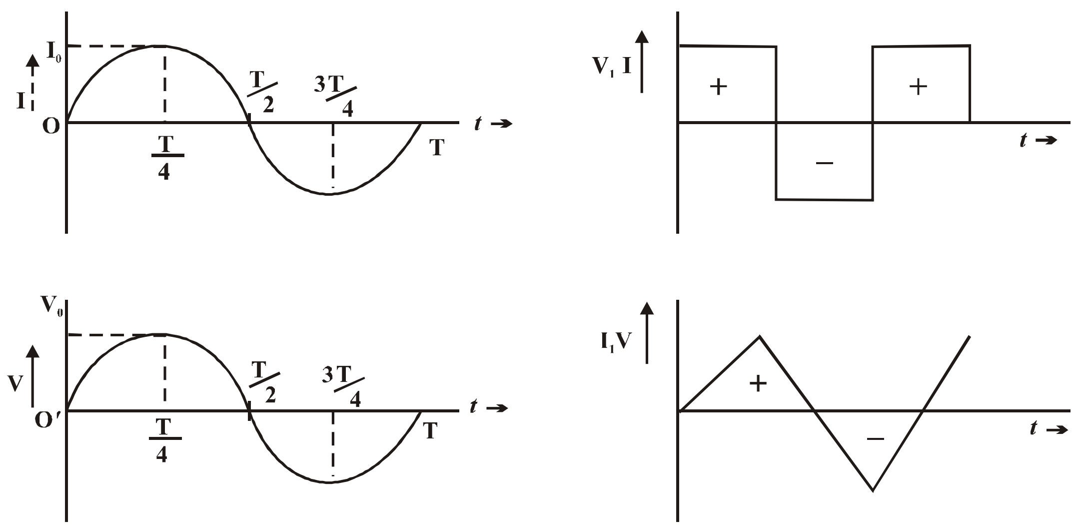
ALTERNATING CURRENT

Alternating Current and Voltage

An alternating current or voltage is that variation of current or voltage respectively whose magnitude and direction vary periodically and continuously with time. For current or voltage to be alternating (i) magnitude should be constant (ii) alternate half cycle is positive and half negative. The simplest type of alternating current I and voltage V have a sinusoidal variation whose instantaneous value is given by

$$I = I_0 \sin(\omega t + \phi)$$
$$V = V_0 \sin(\omega t + \phi)$$

where ϕ is initial phase graphs of some of the alternating current and voltage cases:



(a) Sinusoidal (b) Non sinusoidal

Where I_0 and V_0 denote the peak values of the current and e.m.f. respectively and ω is the angular frequency.

The time period T of alternating current is given by $T = \frac{2\pi}{\omega}$.

The frequency f, of alternating current is given by $f = \frac{1}{T} = \frac{\omega}{2\pi}$.

Average value of alternating current: The average value of current over time t is defined as

$$I_{avg} = \frac{\int_0^t i\,dt}{\int_0^t dt}$$ where i is intantaneous value of the current.

For sinusoidal variation of current and voltages

Case I: Average value over complete cycle = $\dfrac{\int_0^T i_0 \sin(\omega t + \phi)\, dt}{\int_0^T dt} = 0$

Similarly $V_{avg} = 0$

Case II: Average value over half cycle

$$i_{avg} = \frac{\int_0^{T/2} i_0 \sin(\omega t + \phi)\, dt}{\int_0^{T/2} dt} = \frac{2\, I_0}{\pi}$$

Similarly $V_{avg} = \dfrac{2\, V_0}{\pi}$

Effective Current and Voltage : Since the average value over a time period of sinusoidal alternating current or voltage is zero, a D.C. ammeter or voltmeter does not show any deflection for alternating current circuits. Therefore alternating current ammeter or voltmeters are used which measure the average or effective values of the current and voltage and are based on 'measuring' the root mean square values of current and voltage. The root mean square value of an alternating current is that steady current which when passed through a resistor will produce the same amount of heat as the actual alternating current shall develop when passed for the same time. It is denoted by I_{rms}

The magnitude of I_{rms} is given by

$$I^2_{rms} = \frac{\int_0^T I^2\, dt}{\int_0^T dt} = \frac{\int_0^T I_0^2 \sin^2(\omega t) dt}{\int_0^T dt} = \frac{I_0^2}{2}$$

$\therefore$ $\mathbf{I_{eff}} = \mathbf{I_{rms.}} = \dfrac{I_0}{\sqrt{2}} = 0.707\ I_0$ Where I_0 is the peak value of the current.

Similarly $\mathbf{V}_{eff}$ or $\mathbf{V}_{rms.} = \dfrac{V_0}{\sqrt{2}} = 0.707\ \mathbf{E_0}$

Power in Alternating Current Circuit:

Average power in alternating current circuit over time t is defined as

$$P_{avg} = \frac{\int_0^t V\, i\, dt}{\int_0^t dt}$$

where V and i are instantaneous values of voltage and current respectively

Let $\quad V = V_0 \sin \omega t$

$\quad i = i_0 \sin(\omega t - \phi)$

Average power over a cycle

$$P_{avg} = \frac{\int_0^T V_0\, i_0 \sin \omega t \sin(\omega t - \phi)\, dt}{\int_0^T dt}$$

$$= \frac{V_0\, i_0 \int_0^T \left(\sin^2 \omega t \cos \phi - \frac{1}{2} \sin 2\omega t \sin \phi\right) dt}{T}$$

$$= \frac{1}{2} V_0 i_0 \cos \phi = V_{rms} \cdot i_{rms} \cos \phi$$

The term $\cos \phi$ is known as power factor.

It is said to be leading if current leads voltage, lagging if current lags voltage. Thus, a power factor of 0.5 laging means current lags the voltage by 60° (as $\cos^{-1} 0.5 = 60°$). The product of V_{rms} and i_{rms} gives the apparent power. While the true power is obtained by multiplying the apparent power by the power factor $\cos \phi$. Thus,

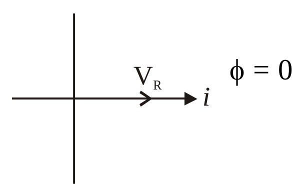
$\quad$ Apparent power = $V_{rms} \times i_{rms}$

and $\quad$ True power = apparent power × power factor

For $\phi = 0°$, the current and voltage are in phase. The power is thus, maximum (= $V_{rms} \times i_{rms}$). For $\phi = 90°$, the powr is zero. The current is then stated wattless. Such a case will arise when resistance in the circuit is zero. The circuit is purely inductive or capacitive. The case is similar to that of a frictionless pendulum, where the total work done by gravity upon the pendulum in a cycle is zero.

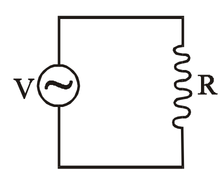
Alternating current through different circuits

(1) Purely Resistive Circuit :



If $\quad V = V_0 \sin(\omega t)$

$$I = \frac{V}{R} = \frac{V_0}{R} \sin(\omega t) = I_0 \sin(\omega t)$$



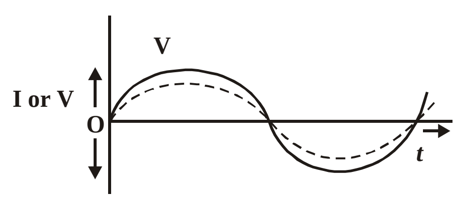
Both voltage and curent are in same phase.

Instantancous Power dissipated = P = VI

$\quad = V_0 I_0 \sin^2 (\omega t)$

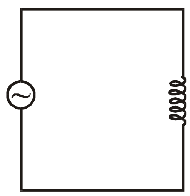
Average power dissipated over a cycle

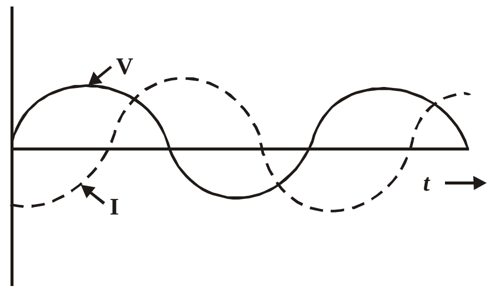
$$= \bar{P} = \frac{1}{T}\int_0^T P\, dt = \frac{V_0 I_0}{2} = \frac{V_0}{\sqrt{2}} \cdot \frac{I_0}{\sqrt{2}}$$



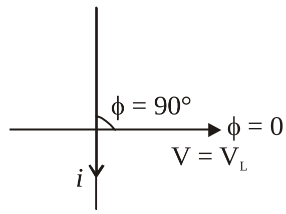
$$\Rightarrow \quad \bar{P} = V_{rms} \cdot I_{rms.}$$

(2) Purely Inductive Circuit





Let $V = V_0 \sin \omega t$



$$V - L\frac{dI}{dt} = 0$$

$$I = I_0 \sin(\omega t - \pi/2)$$

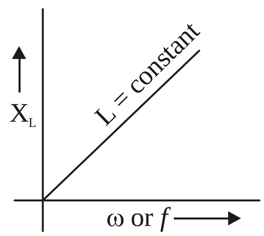
$$I_0 = \frac{V_0}{\omega L} \Rightarrow V_{rms} = (\omega L)I_{rms}$$

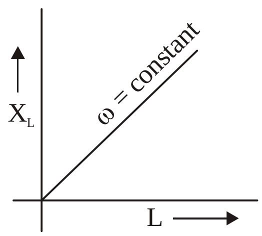
Therefore, in purely inductive circuit

(*i*) the current lags behind the voltage in phase by $\pi/2$, and

(*ii*) the quantity ωL is a measure of the effective opposition offered to the flow of an alternating current by an inductor. It is denoted by X_L and is called inductive reactance :

$$X_L = \omega L$$





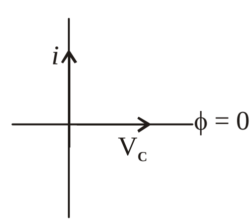
Thus inductance offers larger opposition to a.c. of higher frequency than to a.c. of lower frequency. Also the average power consumed by an purely inductive circuit in a cycle is zero :

$$\mathbf{P} = 0 \qquad \because \phi = 90°$$

Since the current flows without any power loss, it is called wattless current. During one quarter cycle, when the current increases, energy is stored in the inductance in the form of magnetic energy and during the next quarter, when the current decreases, this energy is transferred back to the source. An inductance coil with a high value of reactance and low resistance has got the property of opposing alternating current without any significant power loss. Such a coil is called a choke coil.

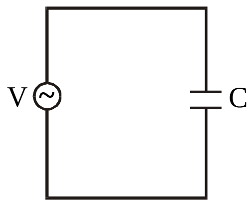
(3) Purely Capacitive Circuit

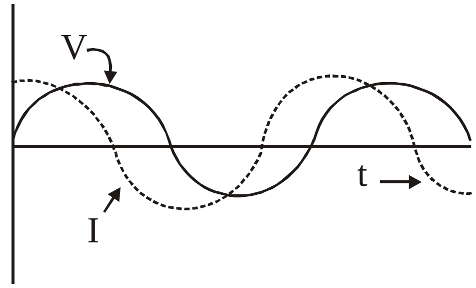
If $V = V_0 \sin \omega t$, $Q = CV = CV_0 \sin(\omega t)$



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

$\therefore \qquad I = I_0 \sin(\omega t + \pi/2)$





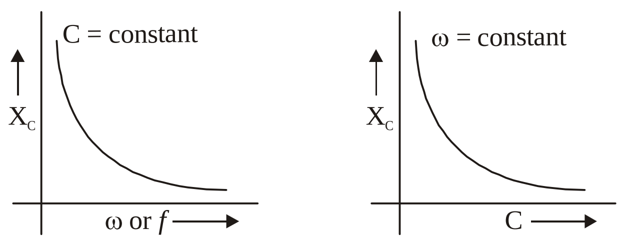
where $I_0 = (\omega C)\, V_0 \qquad \Rightarrow V_{rms} = \left(\frac{1}{\omega C}\right) I_{rms}$

It shows that in a purely capacitor circuit

(*i*) the current leads the voltage in phase by $\pi/2$,

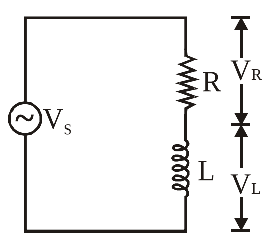
(*ii*) the quantity $(1/\omega C)$ is a measure of the effective opposition offered to the flow of an alternating current by capacitor. It is denoted by X_C and is called capacitive reactance.

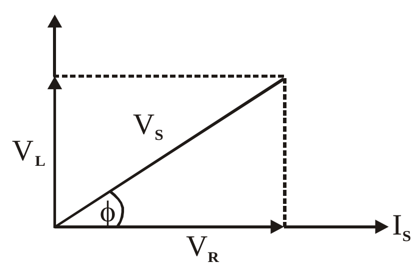
$$X_C = 1/\omega C$$



As $X_C \propto 1/\omega$, a capacitor offers smaller opposition to a.c. of higher frequency than to a.c. of lower frequency. The average power is zero. During one quarter cycle, energy is stored in the capacitor in the form of electrostatic field, and this energy is delivered back to the source during the next quarter cycle.

(4) The LR Series Circuit





If V_R, V_L and V_S are the r.m.s. voltages across R, L and the a.c. source respectively. Then

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

$$= I_S \sqrt{R^2 + X_L^2} \qquad \text{where } I_S \text{ is r.m.s. value of source current.}$$

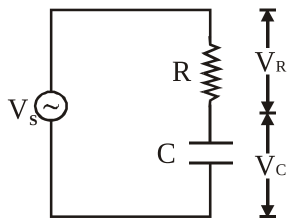
The total opposition to the current is called impedance and it is denoted by **Z.**

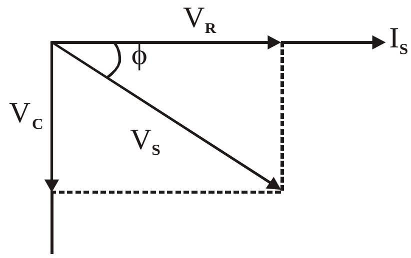
$$Z = \frac{V_S}{I_S} = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + \omega^2 L^2}$$

The phase angle ϕ by which the applied voltage leads the current is

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

(5) The RC Series Circuit





If V_S, V_R and V_C are r.m.s. voltage across source, resistance and capacitor respectively

$$V_S = \sqrt{V_R^2 + V_C^2} = I_S = \sqrt{R^2 + X_C^2}$$

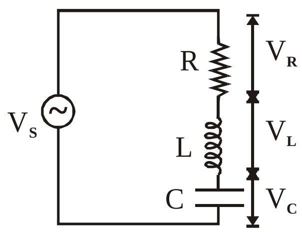
Impedence of circuit, $$Z = \frac{V_S}{I_S} = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \frac{1}{\omega^2 C^2}}$$

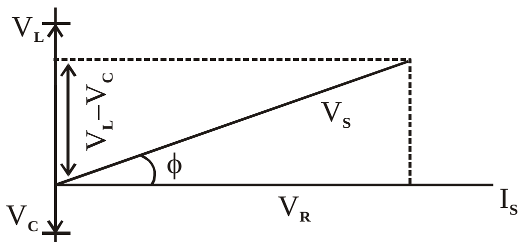
V_S leads I_S by $$\phi = \tan^{-1}\left(\frac{X_C}{R}\right) = \tan^{-1}\left(\frac{1}{\omega CR}\right)$$

The current leads the applied voltage by angle ϕ.

(6) The LCR Series Circuit

For LCR seeries circuit,





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

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

V_S leads I_S by $$\varphi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right) = \tan^{-1}\left(\frac{\omega L - \frac{1}{\omega C}}{R}\right)$$

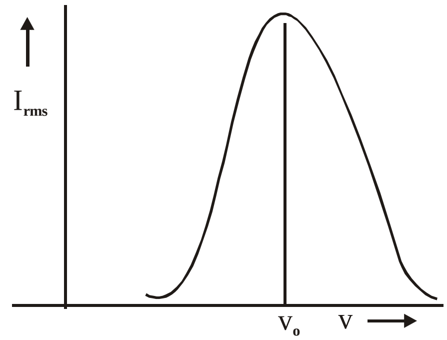
Power in LCR Circuit = $$P = V_{rms} I_{rms} \cos f = V_{rms} I_{rms} \frac{R}{Z} = V_R I_{rms}$$

Where $\cos\phi$ is called the power factor of the LCR circuit.

Resonance in LCR series circuit

At a particular angular frequency ω_0 of the source, when $X_L = X_C$ or $\omega_0 L = \frac{1}{\omega_0 C}$, the impedance of circuit becomes minimum and equal to R and, therefore, the current will be maximum. The circuit is then said to be in resonance. The resonant angular frequency ω_0 and frequency v_0 are given by

$$\omega_0 = \frac{1}{\sqrt{LC}}, \quad v_0 = \frac{1}{2\pi\sqrt{LC}}$$



The variation of r.m.s. current with the frequency of the applied voltage is shown in the figure. If the applied voltage consists of a number of frequency components, the current will be large for the component having frequency v_0.

The Q factor of an LCR series circuit is given by $Q = \frac{\omega_0 L}{R}$

A direct current flows uniformly throughout the cross-section of the conductor. An alternating current, on the other hand, flows mainly along the surface of the conductor. This effect is known as skin effect. The reason is that when a.c. flows through a conductor, the flux changes in the inner part of the conductor are higher.

SOLVED EXAMPLES

Ex.1 What is average and r.m.s. current over half cycle if instantaneous current is given by

$$i = 4\sin\omega t + 3\cos\omega t.$$

Sol.: Given $i = 4\sin\omega t + 3\cos\omega t.$

$$= 5\left(\frac{4}{5}\sin\omega t + \frac{3}{4}\cos\omega t\right)$$

$$= 5\sin(\omega t + \alpha) \qquad \text{where } \cos\alpha = \frac{4}{5}$$

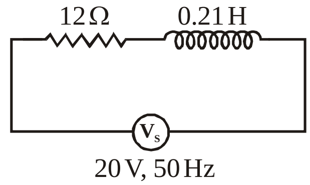
Comparing with $i = i_0\sin(\omega t + \phi)$

$$i_0 = 5\,\text{A}$$

$$\Rightarrow \qquad i_{rms} = \left(\frac{5}{\sqrt{2}}\right)\text{A}$$

$$i_{avg} = \left(\frac{10}{\pi}\right)\text{A}$$

Ex.2 A 0.21 H inductor and a 12 Ω resistor are connected in series to a 20 V, 50 Hz ac source. Calculate the current in the circuit and the phase angle between the current and the source voltage.



Sol.: Impedance $Z = \sqrt{R^2 + (\omega L)^2}$

$$= \sqrt{(12)^2 + (2 \times 3.14 \times 50 \times 0.21)^2}$$

$$= \sqrt{(12)^2 + (65.94)^2}$$

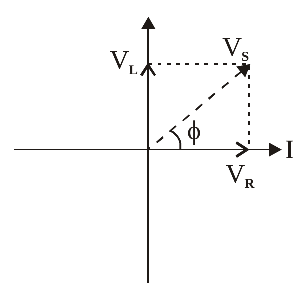
$$= 67\ \Omega$$

$$\text{Current } I_{rms} = \frac{V_{rms}}{Z} = \frac{220}{67} = \mathbf{3.28\ A}$$

$$\text{Phase angle } \phi = \tan^{-1}\left(\frac{\omega L I}{IR}\right) = \tan^{-1}\left(\frac{65.94}{12}\right)$$

$$= \tan^{-1}(5.495)$$

$$= \mathbf{78.69^0}.$$



Ex.3 A resistance R, an inductance L and capacitor C are connected in series with an AC supply where R = 16Ω, inductive reactance X_L = 24Ω and capacitive reactance X_C = 12Ω . If the current in the circuit is 5 ampere find

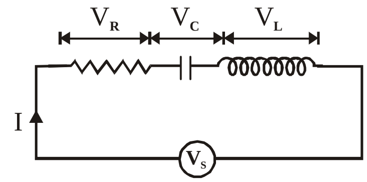
(a) P.D. across R, L and C

(b) impedance of circuit,

(c) voltage of AC supply and

(d) phase angle.

Sol.: (a) $V_R = 5 \times 16 = 80$ V, $V_L = I \times \omega L = 5 \times 24 = 120$V, $V_C = \dfrac{I}{C\omega} = 5 \times 12 = 60$V



(b) $Z = \sqrt{R^2 + \left(\omega L - \dfrac{1}{C\omega}\right)^2} = \sqrt{(16)^2 + (24-12)^2} = 20\Omega$

(c) $E = IZ = 5 0 \times 20 = 100$ V

(d) $\phi = \tan^{-1}\left(\dfrac{\omega L - \dfrac{1}{\omega C}}{R}\right) = \tan^{-1}\left(\dfrac{24-12}{16}\right) = \tan^{-1}(0.75) = 36°46'$

Ex.4 A current of 4 A flows in a coil when connected to a 12 V dc source. If the same coil is connected to a 12 V, 50 rad/s ac source, a current of 2.4 A flows in the circuit. Determine the inductance of the coil. Also find the power developed in the circuit if a 2500 μF condenser is connected in series with the coil.

Sol.: Resistance of the coil, $R = \dfrac{12}{4} = 3\Omega$ ($\because$ Resistance of inductor in de circuit is zero)

Impedance of the coil, $Z = \dfrac{12}{2.4} = 5\Omega$

Now $Z^2 = R^2 + \omega^2 L^2$ *or* $L = \dfrac{\sqrt{Z^2 - R^2}}{\omega} = \dfrac{4}{50} = \mathbf{0.08\,H}$

Reactance of the capacitor $X_c = \dfrac{1}{\omega C} = \dfrac{1}{50 \times 2500 \times 10^{-6}} = 8\Omega$

$\therefore$ When capacitor is connected in series,

$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{3^2 + (8-4)^2} = 5\,\Omega$

Power factor, $\cos\phi = \dfrac{R}{Z} = \dfrac{3}{5}$

Power developed $P = I^2_{rms} Z \cos\phi = (2.4)^2 \times 3 = $ **17.28 W**.

Ex.5 A 100 V a.c source of frequency 500 Hz is connected to a series LCR circuit with L = 8.1 mH, C = 12.5 μF and R = 10 Ω. Find the potential difference across the resistance.

Sol.: Inductive reactance, $X_L = 2\pi \times 500 \times 8.1 \times 10^{-3} = 25.434\,\Omega$

Capacitive reactance, $X_C = \dfrac{10^6}{2\pi \times 500 \times 12.5} = 25.478\Omega$

$\Rightarrow$ $X_L = X_C$

This is the condition of resonance. This means that total potential drop occurs across the resistance only.

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

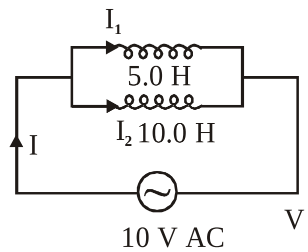
$V_R = $ **100 V**.

Ex.6 Two inductances of 5.0 H and 10.0 H are connceted in parallel circuit. Find the equivalent inductance and r.m.s. voltage in each inductor and in mains circuit when connected to a source of 10 V AC.

Sol.: Let $E = E_0 \sin \omega t$

$$I = I_0 \sin(\omega t - \frac{\pi}{2}) = \frac{E_0}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right) \quad \text{(since current legs by } \frac{\pi}{2}\text{)}$$

where L is equivalent inductance of circuit.



$$I_1 = \frac{E_0}{\omega L_1}\sin\left(\omega t - \frac{\pi}{2}\right),\ I_2 = \frac{E_0}{\omega L_2}\sin\left(\omega t - \frac{\pi}{2}\right)$$

$\because$ $I = I_1 + I_2$

$$\frac{E_0}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right) = \frac{E_0}{\omega L_1}\sin\left(\omega t - \frac{\pi}{2}\right) + \frac{E_0}{\omega L_2}\sin\left(\omega t - \frac{\pi}{2}\right)$$

$\Rightarrow$ $$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} = \frac{1}{5} + \frac{1}{10} = \frac{15}{50} = \frac{3}{10}$$

i.e., $$L = \frac{10}{3} H$$

$$I_{rms} \text{ in } L_1 = \frac{V}{\omega L_1} = \frac{10}{2\pi \times 50 \times 5} = \frac{1}{50\pi},\ I_{rms} \text{ in } L_2 = \frac{V}{\omega L_2} = \frac{10}{2\pi \times 50 \times 10} = \frac{1}{100\pi}$$

$$I_{rms} \text{ in circuit } = \frac{1}{50\pi} + \frac{1}{100\pi} = \frac{3}{100\pi}$$

Ex.7 A 750 hertz, 20 V source is connected to a resistance of 100 ohm, an inductance of 0.1803 henry and a capacitance of 10 microfarad all in series. Calculate the time in which the resistance (thermal capacity = 2 joule / °C) will get heated by 10 °C ?

Sol.: Inductive reactance, $X_L = \omega L = 2 \times 3.14 \times 750 \times 0.1803 = 849.2\ \Omega$

Capacitive reactance, $$X_C = \frac{1}{\omega C} = \frac{1}{2 \times 3.14 \times 750 \times 10 \times 10^{-6}} = 21.23\Omega$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(100)^2 + (849.2 - 21.23)^2} = 834\ \Omega$$

Power dissipated $= V_{rms} \cdot i_{rms} \cos\phi = \frac{V^2_{rms}}{Z^2} R = \left(\frac{20}{834}\right)^2 \times 100 = \mathbf{0.0575\ W}$.

Heat required by wire to get heated by 10°C

$H = 2.0 \times 10 = 20$ J,

$\because$ $H = P \times t$

$\Rightarrow$ $$t = \frac{H}{P} = \frac{20}{0.0574} = 348 \text{ second.}$$

Ex.8 A series LCR circuit containing a resistance of 120 Ω has angular resonance frequency 4×10^5 rad s^{-1}**.** At resonance, the voltage across resistance and inductance are 60 V and 40 V respectively. Find the values of L and C. At what frequency the current in the circuit lags the voltage by 45°?

Sol.: For resistance; $V_R = I_{rms} R$

or $I_{rms} = \dfrac{V_R}{R} = \dfrac{60}{120} = 0.5\,A$

For inductor

$V_L = I_{rms}\,\omega_0 L$

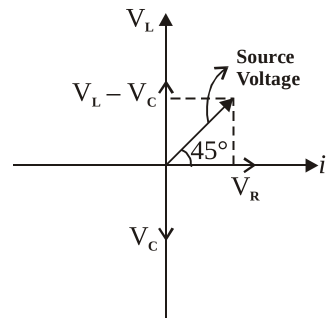
or $40 = 0.5 \times 4 \times 10^5 \times L$

or $L = \mathbf{2 \times 10^{-4}\ H}$

$\because$ at resonance, $X_L = X_C$ or $\omega L = \dfrac{1}{\omega C}$

$\Rightarrow$ $C = \dfrac{1}{\omega^2 L} = \dfrac{1}{(4 \times 10^5)^2 \times 2 \times 10^{-4}} = \mathbf{(1/32)\ \mu F}$

When the current lags behind the voltage by 45^0,



$\tan 45° = \dfrac{V_L - V_C}{V_R} = \dfrac{\omega L - (1/\omega C)}{R}$

$\Rightarrow$ $\omega L - \dfrac{1}{\omega C} = R$ $\left(\because C = \dfrac{1}{\omega_0^2 L}\right)$

$\Rightarrow$ $\omega L - \dfrac{\omega_0^2 L}{\omega} = R$

$\Rightarrow$ $\omega^2 L - \omega_0^2 L = 2\omega$

$\Rightarrow$ $2 \times 10^{-4}\,\omega^2 - 120\omega - (4 \times 10^5)^2 \times 2 \times 10^{-4} = 0$

$\Rightarrow$ $\omega^2 - 6 \times 10^5\,\omega - (4 \times 10^5)^2 = 0$

Taking roots,

$\omega = 8 \times 10^5, -2 \times 10^5$

Rejecting the negative root,

$\omega = \mathbf{8 \times 10^5}$ Hz

Ex.9 A LCR circuit has L = 10 mH, R = 3 ohm and C = 1μF connected in series to a source of 15 cos (ωt) volt. Calculate the current amplitude and the average power dissipated per cycle at a frequency that is 10% lower than the resonant frequency.

Sol.: Resonant frequency $\omega_{\mathbf{R}} = 1/\sqrt{(LC)}$.

Here, $L = 10\ mH = 10 \times 10^{-3}\ H$

and $C = 1\ \mu F = 1 \times 10^{-6} F$.

$$\therefore \quad \omega_R = \sqrt{\left(\frac{1}{(10\times10^{-3})(1\times10^{-6})}\right)} = \mathbf{10^4\ /sec.}$$

Now, 10% less frequency will be

$$\omega = 10^4 - 10^4 \times \frac{10}{100} = 9\times10^3\ /\text{sec}.$$

At this frequency,

$$X_L = \omega L = \times\ 9 \times 10^3 \times (10 \times 10^{-3}) = 90 \text{ ohm}$$

$$X_C = \frac{1}{\omega C} = \frac{1}{(9\times10^3)(1\times10^{-6})} = 111.11 \text{ ohm}$$

$$\therefore \quad Z = \sqrt{[R^2 + (X_L - X_C)^2]} = \sqrt{[(3)^2 + (90 - 111.11^2)]} = 21.32 \text{ ohm}$$

Current amplitude $= I_0 = \frac{E_0}{Z} = \frac{15}{21.32} = 0.704$ amp.

Average power, $P = \frac{1}{2}E_0 I_0 \cos\phi$; where $\cos\phi = \frac{R}{Z} = \frac{3}{21.32} = 0.141$

$$P = \frac{1}{2}\times15\times0.704\times0.141 = 0.744 \text{ watt}.$$

OBJECTIVE QUESTIONS

1. A 10 μ F capacitor is connected across a 200 V, 50 Hz a.c. supply. The peak current through the circuit is

(a) 0.6 amp (b) $0.6\sqrt{2}$ amp (c) $(0.6/\sqrt{2})$ amp (d) $(0.6\ \pi/2)$ amp.

2. In a L R circuit the a.c. source has voltage 220 V and the potential difference across the inductance is 176 volts. The potential difference across the resistance will be

(a) 44 V (b) 396 V (c) 132 V (d) $\sqrt{[(250\times176)]}$ V

3. An a.c. voltage source $E = 200\sqrt{2}$ sin 100 t is connected across a circuit containing an a.c. ammeter and capacitor of capacity 1μF. the reading of ammeter is

(a) 10 mA (b) 20 mA (c) 40 mA (d) 80 mA

4. A 12 Ω resistor and a 0.21 henry inductor are connected in series to an a.c. source operating at 20 volt, 50 cycle. The phase angle between the current and source voltage is

(a) $\tan^{-1}\sqrt{3}$ (b) $\tan^{-1}\left(\frac{1}{\sqrt{3}}\right)$ (c) $\tan^{-1}(5.5)$ (d) $\tan^{-1}(1)$

5. In order to obtain a time constant of 10 seconds in an R.C. circuit containing a resistance of 10^3 Ω, the capacity of the condenser should be

(a) 10 μF (b) 100 μF (c) 1000 μF (d) 10000 μF

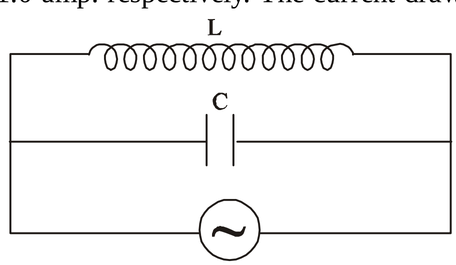
6. An A.C. series circuit contains 40 Ω of resistance and 30 Ω of inductive reactance. Then the impedance of circuit is

(a) 70 Ω (b) 10 Ω (c) 50 Ω (d) 70 Ω

7. A group of electric lamps having a total power rating of 1000 watt is supplied by an a.c. voltage $E = 200 \sin(310\,t + 60^0)$. Then the r.m.s. value of the circuit current is

(a) 10 amp (b) $10\sqrt{2}$ amp (c) 20 amp (d) $20\sqrt{2}$ amp.

8. In the alternating current circuit shown in following figure, the currents through the inductor and the capacitor are 1.2 amp and 1.0 amp. respectively. The current drawn from the generator is



(a) 0.4 amp. (b) 0.2 amp. (c) 1.0 amp. (d) 1.2 amp.

9. An alternating voltage $E=200\sqrt{2}$ sin 100 t, where V is in volt and t in seconds, is connected to a series combination of 1 μF capacitor and a 10 kΩ resistor through an ac ammeter. The reading of the ammeter will be

(a) $\sqrt{2}$ mA (b) $10\sqrt{2}$ mA (c) 2 mA (d) 20 mA

10. An inductor of 1 henry is connected across a 220 V, 50 Hz supply. The peak value of the curent is approximately

(a) 0.5 A (b) 0.7 A (c) 1 A (d) 1.4 A

11. An inductive coil has a resistance of 100 Ω. When an ac signal of frequency 1000 Hz is applied to the coil, the voltage leads the current by 45°. The inductance of the coil is

(a) $\frac{1}{10\pi}$ (b) $\frac{1}{20\pi}$ (c) $\frac{1}{40\pi}$ (d) $\frac{1}{60\pi}$

12. An LCR series circuit consists of a resistance of 10 Ω, a capacitance of reactance 60 Ω and an inductor coil. The circuit is found to resonate when put across a 300 V, 100 Hz supply. The inductance of the coil is (take $\pi = 3$).

(a) 0.1 H (b) 0.01 H (c) 0.2 H (d) 0.02 H

13. When 100 V dc is applied across a coil, a current of 1 A flows through it. When 100 V ac of 50 Hz is applied across the same coil, only 0.5 A flows. the resistance and inductance of the coil are (take $\pi^2 = 10$).

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

14. In an ac circuit V = 100 sin (100 t) volt and I = 100 sin (100 t + $\pi/3$) mA. The power dissipated in the circuit is

(a) 10^4 W (b) 10 W (c) 2.5 W (d) 5 W

15. An electric bulb which runs at 80 V dc and consumes 10 A current is connected across a 100 V, 50 Hz ac supply. The inductance of the choke required so that it consumes rated power, is (take $\pi = 3$).

(a) 0.01 H (b) 0.02 H (c) 0.04 H (d) 0.08 H

16. The tuning circuit of a radio receiver has a resistance of 50 Ω, an inductor of 10 mH and a variable capacitor. A 1 MHz radio wave produces a potential difference of 0.1 mV. The value of the capacitor to produce resonance is (take π^2=10).

(a) 2.5×10^{-12} F (b) 5.0×10^{-12} F (c) 2.5×10^{-11} F (d) 5.0×10^{-11} F

17. The impedance of a circuit consists of 3 Ω resistance and 4 Ω reactance. The power factor of the circuit is

(a) 0.4 (b) 0.6 (c) 0.8 (d) 1.0

18. 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

19. A resistance R, an inductance L and a capacitance C are connected in series across an ac source of angular frequency ω. If the resonant frequency is ω_0, then the current will lag behind the voltage if

(a) $\omega < \omega_0$ (b) $\omega > \omega_0$ (c) $\omega = \omega_0$ (d) $\omega < 0$

20. An LCR series circuit containing a resistance of 120Ω has angular resonance frequency 4×10^5 rad s^{-1}. At resonance the voltage across resistance and inductance are 60 V and 40 V respectively. The values of L and C are

(a) 0.2 mH, 1/32 μF (b) 0.4 mH, 1/16 μF (c) 0.2 mH, 1/16 μF (d) 0.4 mH, 1/32 μF

21. In an L-R circuit, the value of L is $(0.4/\pi)$ henry and the value of R is 30 ohm. If in the circuit, an alternating emf of 200 volt at 50 cycles per second is connected, the impedance of the circuit and current will be :

(a) 11.4 ohm, 17.5 ampere (b) 30.7 ohm, 6.5 ampere

(c) 40.4 ohm, 5 ampere (d) 50 ohm, 4 ampere.

22. An inductor 20×10^{-3} Henry, a capacitor $100\mu F$ and a resistor 50Ω are connected in series across a source of EMF V = 10 sin 314t. If resistance is removed from the

circuit and the value of inductance is doubled, then the variation of current with time in the new circuit is –

(a) 0.52 cos 314 t (b) 0.52 sin 314 t (c) $0.52 \sin (314\,t + \pi/3)$ (d) None of these

23. A coil having an inductance of $1/\pi$ henry is connected in series with a resistance of 300Ω. If 20 volt from a 200 cycle source are impressed across the combination, the value of the phase angle between the voltage and the current is :

(a) $\tan^{-1}(5/4)$ (b) $\tan^{-1}(4/5)$ (c) $\tan^{-1}(3/4)$ (d) $\tan^{-1}(4/3)$

24. An A.C. source is in series with R and L. If respective potential drops are 200 V and 150 V and 150 V, what is the applied voltage ?

(a) 250 V (b) 50 V (c) 150 V (d) 200 V

25. The value of current in two series LCR circuits at resonance is same when connected across a sinusoidal voltage source. Then –

(a) both circuits must be having same value of capacitance and inductor

(b) in both circuits ratio of L and C will be same

(c) for both the circuits X_L/X_C must be same at that frequency

(d) both circuits must have same impedance at all frequencies.

26. When 100V D.C. is applied across a solenoid a current of 1A flows in it. When 100V A.C. is applied across the same coil, the current drops to 0.5 A. If the frequency of the A.C. source is 50 Hz the impedance and inductance of the solenoid are –

(a) $100\,\Omega$, 0.93 H (b) $200\,\Omega$, 1.0 H (c) $100\,\Omega$, 0.86 H (d) $200\,\Omega$, 0.55 H

27. If in a series L-C-R circuit, the voltage across R, L and C are V_R, V_L and V_C respectively, then the voltage of applied AC source must be :

(a) $V_R + V_L + V_C$ (b) $\sqrt{[(V_R)^2 + (V_L - V_C)^2]}$ (c) $V_R + V_C - V_L$ (d) $[(V_R + V_L)^2 + V_C^2]^{1/2}$

28. The p.d. across an instrument in an a.c. circuit of frequency f is V and the current flowing through it is I such that

V = 5 cos πft(B) volt and I = 2 sin (2 πft) amp. The power dissipate in the instrument is :

(a) zero (b) 10 watt (c) 5 watt (d) 2.5 watt.

29. In an A.C. circuit, maximum value of voltage is 423 volt. Its effective voltage is :

(a) 323 V (b) 340 V (c) 400 V (d) 300 V.

30. Resonance frequency of a circuit is f. If the capacitance is made 4 times the initial value, then the resonance frequency will become :

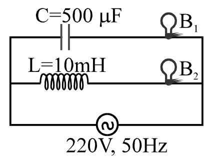
(a) f/2 (b) 2f (c) f (d) f/4

MORE THAN ONE CORRECT CHOICE

31. The symbols L, C, R represent inductance, capacitance and resistance respectively. Dimension of frequency are given by the combination :

(a) 1/RC (b) R/L (c) $1/\sqrt{LC}$ (d) C/L

32. In the circuit shown in the figure, if both the bulbs B_1 and B_2 are identical



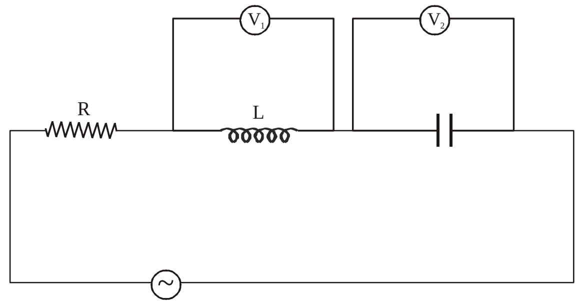
(a) their brightness will be the same

(b) B_2 will be brighter than B_1

(c) as frequency of supply voltage is increased, brightness of B_1 will increase and that of B_2 will decrease

(d) only B_2 will glow because the capacitor has infinite impedance

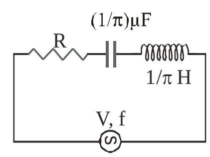
33. In the circuit shown, resistance R = 100Ω, inductance $L = \frac{2}{\pi}H$ and capacitance $C = \frac{8}{\pi}\mu F$ are connected in series with an ac source of 200 volt and frequency 'f'. If the readings of the hot wire voltmeters V_1 and V_2 are same then–



(a) f = 250 π Hz (b) f = 125 Hz

(c) current through R is 2A (d) $V_1 = V_2 = 1000$ volt

34. In the AC circuit shown below, the supply voltage has a constant rms value V but variable frequency f. At resonance, the circuit :



(a) has a current i given by I = V/R

(b) has a resonance frequency 500 Hz

(c) has a voltage across the capacitor which is 180° out of phase with that across the inductor

(d) has a current given by $I = \frac{V}{\sqrt{R^2 + \left(\frac{1}{\pi} + \frac{1}{\pi}\right)^2}}$

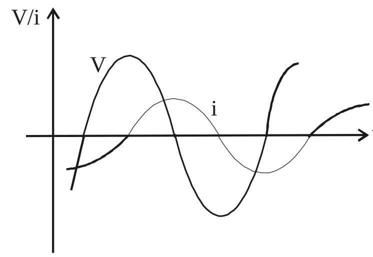
35. An A. C. source producing $V = V_0\sin\omega t + V_0\sin2\omega t$ is connected in series with a box, containing either capacitor or inductor and resistance. The current found in the circuit is :

$i = i_1\sin(\omega t + \phi_1) + i_2\sin(2\omega t + \phi_2)$. Here ϕ_1 and ϕ_2 may be positive or negative.

(a) if $i_1 > i_2$, box has inductor and resistor (b) if $i_1 > i_2$, box has capacitor and resistor

(c) if $i_2 > i_1$ box has inductor and resistor (d) if $i_2 > i_1$ box has capacitor and resistor

36. Graph shows variation of source emf V and current i in a series RLC circuit, with time



(a) To increase the rate at which energy is transferred to the resistive load, L should be decreased

(b) To increase the rate at which energy is transferred to the resistive load, C should be decreased

(c) The circuit is more inductive than capacitive

(d) The current leads the emf in the circuit

37. A light bulb is rated at 200 W for a 220 V supply. Then the resistance of the bulb and the peak voltage of the source are

(a) 242 Ω (b) 252 Ω (c) 211 V (d) 311 V

38. An LCR circuit has L = 10 mH, R = 3 Ω and C = 1 μF connected in series to a source of 15 cos ωt V. Then the current amplitude and the average power dissipated per cycle at a frequency that is 10% lower than the resonance frequency will be

(a) 0.704 A (b) 0.242 A (c) 5.16×10^{-4} J/cycle (d) 3.11×10^{-4} J/cycle

39. A resistor of 200Ω and a capacitor of 15.0 μF are connected in series to a 220 V, 50 Hz ac source. Then the impedance and rms current will be

(a) 0.704 A (b) 0.755 A (c) 291.5 Ω (d) 391.5 Ω

40. A pure inductor of 50.0 mH is connected to a source of 220 V. Find the inductive reactance and rms current in the circuit if the frequency of the source is 50 Hz.

(a) 14.01 A (b) 10.755 A (c) 15.7 Ω (d) 17.5 Ω

MISCELLANEOUS ASSIGNMENT

Comprehension-1

The a.c. generator which is one of the most important applications of the phenomenon of electromagnetic induction converts mechanical energy into electrical energy. A rectangular coil consisting of a large number of turns of copper wire would over a soft iron core is rotated between the pole pieces of a permanent strong magnet. The magnetic flux through the coil changes continuously with time, thus producing induced emf given by

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

When a load resistor R is connected across the terminals, a current I flows through the circuit.

$$I = \frac{E}{R} = \frac{E_0}{R} \sin \omega t = I_0 \sin \omega t$$

Where $I_0 = E_0/R$. Such a current is called a.c. or alternating current.

1. In an a.c. generator, a coil of area A and having N turns rotates in a magnetic field B. The magnetic flux through the coil is

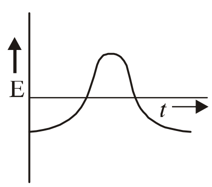
(a) maximum equal to NAB when the plane of the coil is perpendicular to the magnetic field.

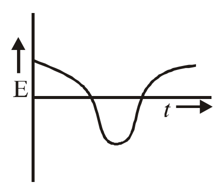
(b) zero when the plane of the coil is parallel to the field.

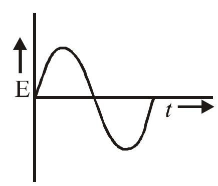
(c) 1/2 NAB when the plane of the coil makes an angle of 60° with the field.

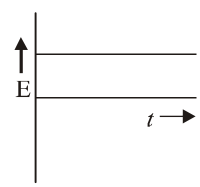
(d) 1/4 NAB when the plane of the coil makes an angle of 30° with the field.

2. In an a.c. generator, initially (*i.e.* at $t = 0$) the plane of the coil is normal to the magnetic field. Which graph shown in the figure represents the variation of induced emf E with time t ?

(a) 

(b) 

(c) 

(d) 

3. In an a.c. generator, the peak value of the induced emf depends upon the

(a) frequency of rotation of the coil

(b) area of the coil

(c) number of turns in the coil

(d) strength of the magnetic field

4. In an a.c. generator

(a) the coil is wound over a soft iron core in order to increase the flux.

(b) an electromagnetic field with an alternating current in used.

(c) the output is always taken across a load resistor

(d) the mechanical energy of the rotating coil is converted into electrical energy

Comprehension-2

In a series LCR circuit with an ideal ac source of peak voltage $E_0 = 50V$, frequency $v = \frac{50}{\pi}$ Hz and $R = 300\Omega$. The average electric field energy stored in the capacitor and average magnetic energy stored in the coil are 25 mJ and 5 mJ respectively. The value of RMS current in the circuit is 0.1 A. Then find :

5. Capacitance (C) of capacitor-

(a) 10μF (b) 15μF (c) 20μF (d) None of these

6. Inductance (L) of inductor-

(a) 0.25 Henry (b) 0.5 Henry (c) 1 Henry (d) 2 Henry

7. The sum of rms potential difference across each of the three elements-

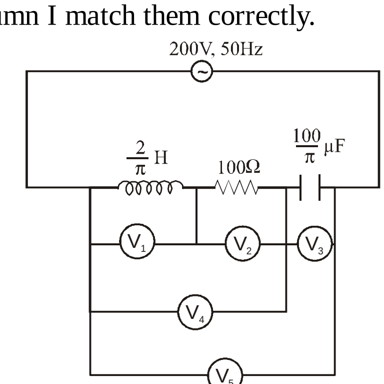
(a) 50 volt (b) $50\sqrt{2}$ volt (c) $\frac{50}{\sqrt{2}}$ volt (d) None of these

8. A circuit containing a 0.1 H inductor and a 50 μF capacitor in series is connected to a 230 volt, 100/π Hz supply. The resistance of the circuit is negligible.

	Column I		Column II
A.	Current amplitude	(p)	$23\sqrt{2}$
B.	Average power transferred to inductor	(q)	zero
C.	Average power transferred to capacitor	(r)	23
D.	rms value of current	(s)	460

9. For the circuit shown column II give data for quantities given in column I match them correctly.

	Column I		Column II
A.	Reactance of circuit	(p)	$100\sqrt{2}$
B.	Impedance of circuit	(q)	100
C.	Current	(r)	200
D.	V_2 reading	(s)	$\sqrt{2}$



10 In an L-C-R series circuit $R = \sqrt{5}$ W, $X_L = 9$W and $X_C = 7$W. If applied voltage in the circuit is 50 volt then find impedance of the circuit in ohm.

11. The resistance (R) in a series LCR – circuit is 24Ω, while the reactance of the inductor (L) and the capacitor (C) are 2Ω and 28Ω respectively at a certain frequency. The total impedance (Z) of the circuit, if the frequency is halved, is nearly $10n$ Ω. Find the value of n.

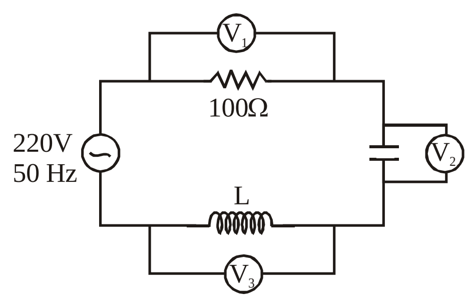
12. A choke coil is needed to operate an arc lamp at 250 V (rms) and 50 Hz. The lamp has an effective resistance of 15Ω when running at 10 A (rms). The inductance of the choke coil is ($n/10\pi$) H. Find the value of n.

13. The sinusoidal voltage wave changes from 0 to maximum value of 100 volt. The voltage when the phase angle is 30º is 10 n volt. Find the value of n.

14. A circuit draws a power of 550 watt from a source of 220 volt, 50 Hz. The power factor of the circuit is 0.8 and the current lags in phase behind the potential difference. To make the power factor of the circuit as 1.0, capacitance 15n μF will have to be connected with it. Find the value of n.

15. A series LCR circuit containing a resistance of 120 Ω has angular resonance frequency 4×10^5 rad s^{-1}. At resonance the voltages across resistance and inductance are 60 V and 40 V respectively. At $n \times 10^5$ rad/s frequency the current in the circuit lags the voltage by 45º. Find the value of n.

16. A series L-C-R circuit is connected to an AC source of 220 V and 50 Hz as shown in figure. If the readings of the three voltmeters V_1, V_2 and V_3 are 65 V, 415 V and 204 V respectively, the value of the capacitor C is n μF. Find the value of n.



17. A resistance R and inductance L and a capacitor C all are connected in series with an AC supply. The resistance of R is 16 ohm and for a given frequency, the inductive reactance of L is 24 ohm and capacitive reactance of C is 12 ohm. If the current in the circuit is 5 amp. The impedance of the circuit is 5n ohm. Find the value of n.

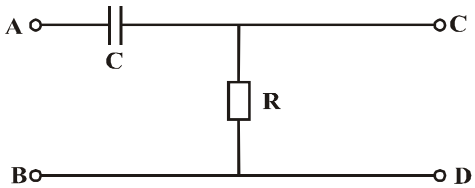
18. A 750 Hz., 20 V source is connected to a resistance of 100 ohm, an inductance of 0.1803 henry and a capacitance of 10 microfarad all in series. After 2.9 n minutes time the resistor (thermal capacity 2 J/ºC) is heated by 10ºC. Find the value of n.

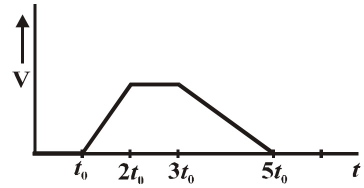
19. A sinusoidal voltage of peak value 283 V and frequency 50 Hz is applied to a series LCR circuit in which R = 3Ω, L = 25.48 mH, and C = 796 μF. The impedance of the circuit is n Ω. Find the value of n.

PREVIOUS YEAR QUESTIONS

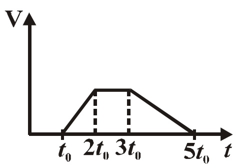
IIT-JEE/JEE-ADVANCE QUESTIONS

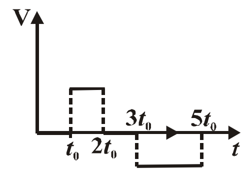
1. A varying voltage is applied to the terminals AB as shown in figure, such that the voltage across capacitor plates varies as shown in the figure below.

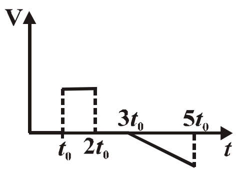


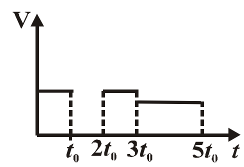


The time dependence of voltage across the terminals C and D is

(a)


(b)


(c)


(d)


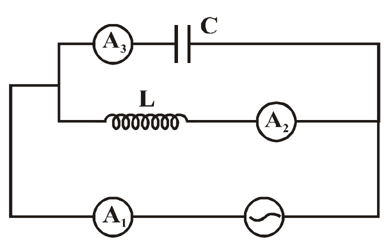
2. For the circuit shown in the figure the ammeter A_2 reads 1.6 A, ammeter A_3 reads 0.4. Then

(a) The ammeter A_1 reads 2A

(b) The ammeter A_1 reads 1.2 A

(c) $f = \dfrac{\pi}{\sqrt{LC}}$

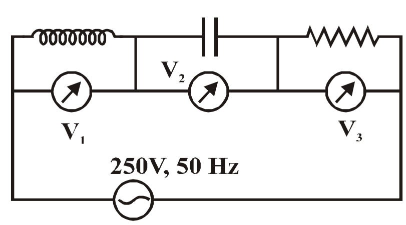
(d) $\omega_0 = \dfrac{3}{\sqrt{LC}}$



3. A charged capacitor discharges through a resistance R with time constant τ. The two are now placed in series across an AC source of angular frequency $\omega = \dfrac{1}{\tau}\cdot$ The impedance of the circuit will be

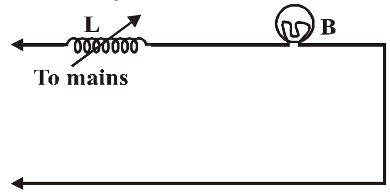
(a) $\dfrac{R}{\sqrt{2}}$ (b) R (c) $\sqrt{2}R$ (d) 2R

4. An A.C. supply of 250 V, 50 Hz is connected to an inductance L, capacitance C and resistance R in series. V_1 and V_2 are A.C. voltmeters connected across L, and C respectively. If their readings are 300 V and 150 V respectively, the reading of the voltmeter V_3 across R will be



(a) 100 V (b) 150 V (c) 200 V (d) 250 V

5. The mains electrical supply is 220 V at 50 Hz, the light bulb is rated at 220 V, 1100 W. What L_{max} is required if the rate of energy dissipation in the light bulb is to be reduced by a factor of 5 from its upper limit of 1100 W?



(a) 0.69 H (b) 0.28 H

(c) 0.38 H (d) 0.56 H

6. An electric lamp designed for operation on 110 V AC is connected to a 220 V AC supply, through a choke coil of inductance 2H, for proper operation. The angular frequency of the AC is $100\sqrt{10}$ rad/s. If a capacitor is to be used in place of the choke coil, its capacitance must be

(a) 1 μF (b) 2 μF (c) 5 μF (d) 10 μF

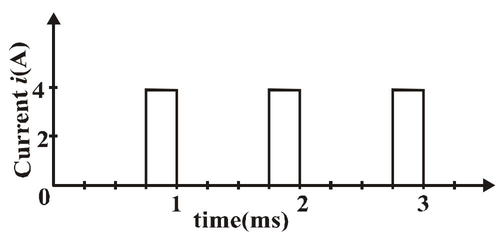
7. A resistance R draws P power when connected to an AC source. If an inductance is now placed in series with the resistance, such that the impedance of the circuit becomes Z, the power drawn will be

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

8. If the instantaneous current in a circuit is given by $i = 2\cos(\omega t - \phi)$ amperes, the r.m.s. value of the current is

(a) 2 ampere (b) $\sqrt{2}$ ampere (c) $2\sqrt{2}$ ampere (d) zero ampere

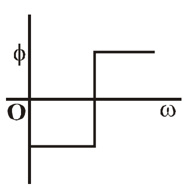
9. The figure shows (in part) the variation with time of periodic current, the root mean square current is

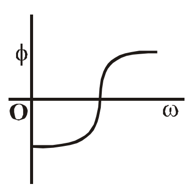


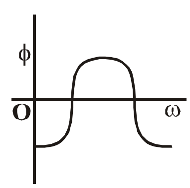
(a) 1 A (b) $\frac{1}{3}$ A

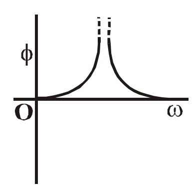
(c) 2 A (d) $\frac{2}{3}$ A

10. An inductor and a capacitor are joined in series to an AC source. The frequency of AC is gradually increased. The phase difference φ between the emf and the current is plotted against the angular frequency ω. Which of the following best represents the resulting curve?

(a) 

(b) 

(c) 

(d) 

11. An AC voltage source of variable angular frequency ω and fixed amplitude V_0 is connected in series with a capacitance C and an electric bulb of resistance R (inductance zero). When ω is increased

(a) the bulb glows dimmer (b) the bulb glows brighter

(c) total impedance of the circuit is unchanged (d) total impedance of the circuit increases

12. A series R-C circuit is connected to AC voltage source. Consider two cases; (A) when C is without a dielectric medium and (B) when C is filled with dielectric of constant 4. The current I_R through the resistor and voltage V_C across the capacitor are compared in the two cases. Which of the following is/ are true?

(A) $I_R^A > I_R^B$ (B) $I_R^A < I_R^B$ (C) $V_C^A > V_C^B$ (D) $V_C^A < V_C^B$

13. A series R-C combination is connected to an AC voltage of angular frequency ω = 500 radian/s. If the impedance of the R-C circuit is $R\sqrt{1.25}$, the time constant (in millisecond) of the circuit is

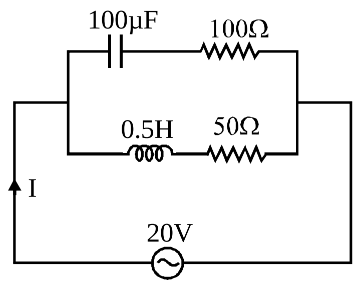
14. In the given circuit, the AC source has ω = 100 rad/s. Considering the inductor and capacitor to be ideal, the correct choice (s) is (are)

(a) The current through the circuit I is 0.3 A

(b) The current through the circuit, I is $0.3\sqrt{2}$ A

(c) The voltage across 100 Ω resistor = $10\sqrt{2}$ V

(d) The voltage across 50 Ω resistor = 10 V



Paragraph for Question 15 to 16

A thermal power plant produces electric power of 600 kW at 4000 V, which is to be transported to a place 20 km away from the power plant for consumers usage. It can be transported either directly with a cable of large current carrying capacity or by using a combination of step-up and step-down transformation at the two ends. The drawback of the direct transmission is the large energy dissipation. In the method using transformers, the dissipation is much smaller. In this method, a step-up transformer is used at the plant side so that the current is reduced to a smaller value. At the consumers end, a step down transformer is used to supply power to the consumers at the specified lower voltage. It is reasonable to assume that the power cable is purely resistive and the transformers are ideal with a power factor unity. All the currents and voltages mentioned are rms values.

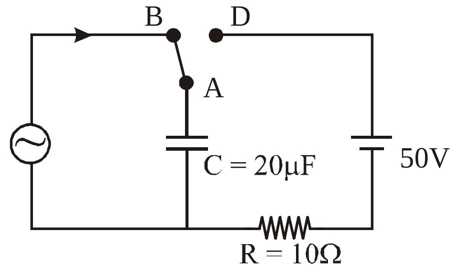
15. If the direct transmission method with a cable of resistance 0.4 Ω km^{-1} is used, the power dissipation (in %) during transmission is

(a) 20 (b) 30 (c) 40 (d) 50

16. In the method using the transformers, assume that the ratio of the number of turns in the primary to that in the secondary in the step-up transformer is 1 : 10. If the power to the consumers has to be supplied at 200 V, the ratio of the number of turns in the primary to that in the secondary in the step-down transformer is

(a) 200 : 1 (b) 150 : 1 (c) 100 : 1 (d) 50 : 1

17. At time $t = 0$, terminal A in the circuit shown in the figure is connected to B by a key and an alternating current $I(t) = I_0\cos(\omega t)$, with $I_0 = 1A$ and $\omega = 500$ rad s^{-1} starts flowing in it with the initial direction shown in the figure. At $t = \frac{7\pi}{6\omega}$, the key is switched from B to D. Now onwards only A and D are connected. A total charge Q flows from the battery to charge the capacitor fully. If C = 20 μF, R = 10 Ω and the battery is ideal with emf of 50V, identify the correct statement (s)



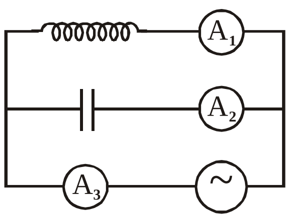
(a) Magnitude of the maximum charge on the capacitor before $t = \frac{7\pi}{6\omega}$ is 1×10^{-3} C

(b) The current in the left part of the circuit just before $t = \frac{7\pi}{6\omega}$ is clockwise

(c) Immediately after A is connected to D, the current in R is 10A

(d) $Q = 2 \times 10^{-3}$ C

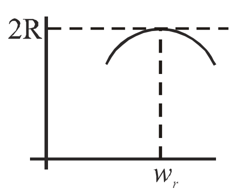
DCE QUESTIONS

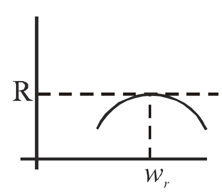
1. 

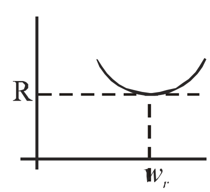
at resonance which ammeter reads 0.

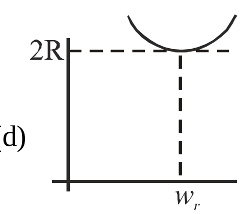
(a) A_1 (b) A_2
(c) A_3 (d) all three A_1, A_2 & A_3

2. In an LCR circuit, the graph between resonance frequency, w_r and impedance z is

(a) 

(b) 

(c) 

(d) 

3. In a series LCR circuit, resonant frequency depends on

(a) $\frac{L}{C}$ (b) $\sqrt{LC}$ (c) $\frac{1}{\sqrt{LC}}$ (d) $\sqrt{\frac{L}{C}}$

4. In a LR circuit, L = 20 H, E = 5 volts, R = 1 Ω, what is the energy stored in inductor?

(a) 50 J (b) 25 J (c) 100 J (d) none of these

5. Average power generated in an inductor connected to an AC source is

(a) $\frac{1}{2}Li^2$ (b) Li^2 (c) zero (d) none of these

6. For EM wave propagating along x axis has E_{max} = 30 V/m. What is maximum value of magnetic field?

(a) 10^{-7} tesla (b) 10^{-8} tesla (c) 10^{-9} tesla (d) 10^{-6} tesla

7. In LCR circuit if resistance increases quality factor

(a) increases finitely (b) decreases finitely (c) remains constant (d) none of these

8. Direction of EM wave is given by

(a) $\vec{E} \times \vec{B}$ (b) $\vec{B} \times \vec{E}$ (c) $\vec{E}$ (d) $\vec{B}$

MAINS QUESTIONS

1. Alternating current can not be measured by D.C. ammeter because

(a) Average value of current for complete cycle is zero

(b) A.C. changes direction

(c) A.C. can not pass through D.C. Ammeter (d) D.C. Ammeter will get damaged

2. In an LCR series a.c. circuit, the voltage across each of the components, L, C and R is 50 V. The voltage across the LC combination will be

(a) 100 V (b) $50\sqrt{2}$ V (c) 50 V (d) 0 V

3. In a LCR circuit capacitance is changed from C to 2C. For the resonant frequency to remain unchanged, the inductance should be changed from L to

(a) L/2 (b) 2L (c) 4 L (d) L/4

4. In a series resonant LCR circuit, the voltage across R is 100 volts and R = 1 kΩ with C = 2 μF. The resonant frequency ω is 200 rad/s. At resonance the voltage across L is

(a) 2.5×10^{-2} V (b) 40 V (c) 250 V (d) 4×10^{-3} V

5. In an AC generator, a coil with N turns, all of the same area A and total resistance R, rotates with frequency ω in a magnetic field B. The maximum value of emf generated in the coil is

(a) N.A.B.R.ω (b) N.A.B (c) N.A.B.R (d) N.A.B.ω

6. In an a.c. 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) $P = \sqrt{2}\, E_0\, I_0$ (c) $P = \frac{E_0 I_0}{\sqrt{2}}$ (d) P = zero

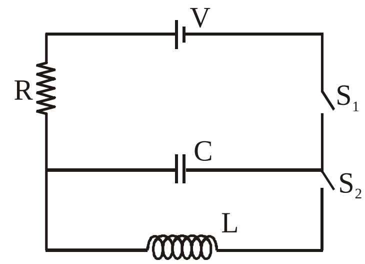
7. In a series LCR circuit R = 200Ω and the voltage and the frequency of the main supply is 220 V and 50 Hz respectively. On taking out the capacitance from the circuit the current lags behind the voltage by 30°. On taking out the inductor from the circuit the current leads the voltage by 30°. The power dissipated in the LCR circuit is

(a) zero W (b) 242 W (c) 305 W (d) 210 W

8. A fully charged capacitor C with initial charge q_0 is connected to a coil of self inductane L at t = 0. The time at which the energy is stored equally between the electric and the magnetic field is

(a) $\pi\sqrt{LC}$ (b) $\frac{\pi}{4}\sqrt{LC}$ (c) $2\pi\sqrt{LC}$ (d) $\sqrt{LC}$

9. In an LCR circuit as shown below both switches are open initially. Now switch S_1 is closed, S_2 kept open. (q is charge on the capacitor and $\tau = RC$ is capacitive time constant). Which of the following statement is correct?



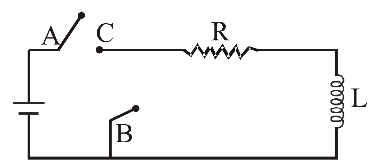
(a) At $t = 2\tau, q = CV(1-e^{-2})$

(b) At $t = \tau/2,\ q = CV(1-e^{-1})$

(c) Work done by the battery is half of the energy dissipated in the resistor

(d) At $t = \tau,\ q = CV/2$

10. In the circuit shown here, the point C is kept connected to point A till the current flowing through the circuit becomes constant. Afterward, suddenly, point C is disconnected from point A and connected to point B at time t = 0. Ratio of the voltage across resistance and the inductor at $t = L/R$ will be equal to



(a) –1 (b) $\frac{1-e}{e}$ (c) $\frac{e}{1-e}$ (d) 1

SUBJECTIVE PROBLEMS

1. Find the value of inductance which should be connected in series with a capacitance of 0.5 μF, a resistance of 10 ohms and an A.C. source of 50 caps so that the power factor of the circuit is unity.

2. A coil of resistance 60 ohms and inductance 3 henry is connected in series with a condenser of 4 μF and an a.c. supply of 200 volts and 50 c/s. Calculate

(a) the impedance of the circuit

(b) phase difference between current and voltage

(c) p.d. across the inductance coil, and

(d) p.d. across the capacitor

3. A 200 km long telegraph wire has a capacity of 0.014 μ F/km. If it carries an alternating current of frequency 5 KHz, find the value of the inductance which should be connected in series so that the impedance is minimum.

4. A circuit draws a power of 550 watt from a source of 220 Volt, 50 Hertz. The power factor of the circuit is 0.8 and the current lags in phase behind the potential difference. If the power factor of the circuit is to be increased to 1.0, find the value of capacitance which should be connected.

5. Prove that in a series LCR circuit, the frequencies f_1 and f_2 at which the current amplitude falls to $1/\sqrt{2}$ of the current at resonance are separated by an interval equal to $(R/2\pi L)$

6. A series circuit consists of a resistance, inductance and capacitance. The applied voltage and the current at any time t are respectively given by E=141.4 cos (3000t–10) and I=5 cos(3000t–550). If the inductance is 0.01 henry, find the values of the resistance and capacitance.

7. A 100 μ F capacitor in series with a 40Ω resistance is connected to a 110 V, 60 Hz supply. Find the maximum current in the circuit. Also find the time lag between the maximum current and maximum voltage.

8. A 20 volts 5 watt lamp is used on a.c. mains of 220 volts and 50 Hz. Find

(a) the values of

(*i*) capacitor and

(*ii*) inductor to be put in series with the lamp to run it.

(b) the value of pure resistance which should be connected in series with the lamp to run it.

9. A choke coil is required to operate an arc lamp at 160 V r.m.s. and 50 Hz. The arc lamp has an effective resistance of 5Ω when running at 10 A r.m.s. Find the inductance of the choke coil. If the same arc lamp is operated on 160 V d.c., find the additional resistance required and power loss if d.c. is used.

10. A series LCR circuit with L = 0.12 H, C = 480 nF and R = 23 Ω is connected to a 230 V variable frequency supply.

(a) What is the source frequency for which current amplitude is maximum? Find this maximum value of current.

(b) What is the source frequency for which average power absorbed by the circuit is maximum? Obtain the value of maximum power.

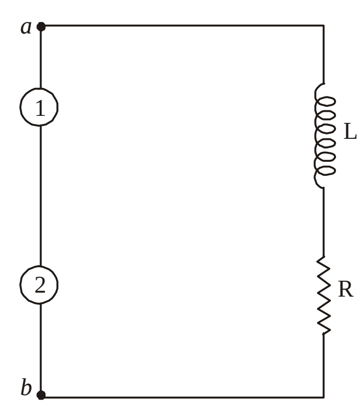
(c) For which frequencies of the source is the power transferred to the circuit half the power at resonant frequency?

(d) What is the Q factor of the circuit?

11. A box P and a coil Q are connected in series with an ac source of variable frequency. The e.m.f. of source is constant at 10 V. Box P contains a capacitance of 1μF in series with a resistance of 32 Ω. Coil Q has a self inductance 4.9 mH and a resistance of 68 Ω. The frequency is adjusted so that the maximum current flows in P and Q. Find the impedance of P and Q at this frequency. Also find the voltage across P and Q respectively.

12. An inductor 20×10^{-3} henry, a capacitor 100 μF and a resistor 50 W are connected in series across a source of e.m.f. $V = 10 \sin 314t$. Find the energy dissipated in the circuit in 20 minutes. If the resistance is removed from the circuit and the value of inductance is doubled then find the variation of current with time in the new circuit?

13. Two alternating-current generators in series are connected to a coil and a resistor as shown in the figure. The voltages across generators 1 and 2 are 6 V and 8 V, respectively. If the voltage between points *a* and *b* is 10 V, and the current in the circuit is 2A, calculate the phase difference between the voltages supplied by the two generators.



(a) What is the impedance of the circuit?

(b) If the power supplied to the coil is 12 W, calculate the resistance R and the inductive reactance of the coil X_L.

14. A coil of radius 100 cm has 490 turns and it lies in a vertical plane. The end of the coil are connected to an external resistor of 72 Ω. If the coil rotates about its vertical diameter at a speed of 3600 rpm, calculate the average power delivered to the resistor. The horizontal component of the earth's magnetic field is 0.2 oersted. Neglect the resistance and the inductance of the coil.

15. An alternating emf of angular frequency 400 radius per second is applied to a coil of inductance 20 mH and resistance 6 Ω.

(a) What should be the capacitance of a condenser placed in the circuit so as to make the power factor unity?

(b) Calculate the change in current due to the insertion of this condenser.

ANSWERS

Objectives Problems

1.	(b)	2.	(c)	3.	(b)	4.	(c)	5.	(c)
6.	(c)	7.	(b)	8.	(b)	9.	(b)	10.	(c)
11.	(b)	12.	(a)	13.	(d)	14.	(c)	15.	(b)
16.	(a)	17.	(b)	18.	(c)	19.	(b)	20.	(a)
21.	(d)	22.	(a)	23.	(d)	24.	(a)	25.	(c)
26.	(d)	27.	(b)	28.	(a)	29.	(d)	30.	(a)
31.	(a,b,c)	32.	(b,c)	33.	(b,c,d)	34.	(a,b,c)	35.	(a,d)
36.	(a,b,c)	37.	(a,d)	38.	(a,c)	39.	(b,c)	40.	(a,c)

Miscellaneous Assignment

1.	(a,b,c)	2.	(c)	3.	(a,b,c,d)	4.	(a,c,d)	5.	(c)
6.	(c)	7.	(d)	8.	A-(p); B-(q); C-(q); D-(r)				
9.	A-(q); B-(p); C-(s); D-(p)			10.	(3)	11.	(6)	12.	(1)
13.	(5)	14.	(5)	15.	(8)	16.	(5)	17.	(4)
18.	(2)	19.	(5						

Previous Year Questions

IIT-JEE/JEE-ADVANCE QUESTIONS

1.	(b)	2.	(b)	3.	(c)	4.	(c)	5.	(b)
6.	(c)	7.	(a)	8.	(b)	9.	(c)	10.	(a)
11.	(b)	12.	(b,c)	13.	(4)	14.	(a,c)	15.	(b)
16.	(a)	17.	(c,d)						

DCE QUESTIONS

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

MAINS QUESTIONS

1.	(b)	2.	(d)	3.	(a)	4.	(c)	5.	(d)
6.	(d)	7.	(b)	8.	(b)	9.	(a)	10.	(a)

Subjective Problems

1. 20.2 H
2. (a) 157.8 Ω (b) 67.7° (c) 1193 V (d) 1008.8 V
3. 0.36 mH
4. 75 μ F.
6. 20Ω, 33.3 μF
7. 3.24 amp, 1.55×10^{-3} second.
8. (a) (i) 4.0 μ F (ii) 2.53 H (b) 720 Ω.
9. 0.05 H, 11Ω, 1100 W.
10. (a) 4167 rad/sec., 14.14 amp (b) 4167 rad/sec, 2300 watt
    (c) 4263 rad/sec, 4071 rad/sec. (d) 21.74
11. P = 76 Ω, Q = 98 Ω; $\Delta V_P = 7.6$ V, $\Delta V_Q = 9.8$ V