ALTERNATING CURRENT

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JEE (Advance) Syllabus

AC

JEE (Main) Syllabus

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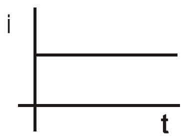
Note: ✍ Marked Questions can be used for Revision.

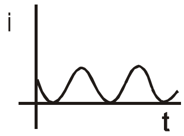
ALTERNATING CURRENT

1. AC AND DC CURRENT :

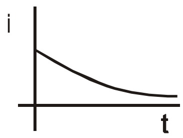
A current that changes its direction periodically is called alternating current (AC). If a current maintains its direction constant it is called direct current (DC).



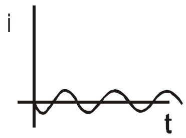
constant dc



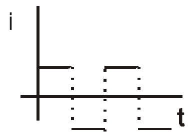
periodic dc



variable dc



ac



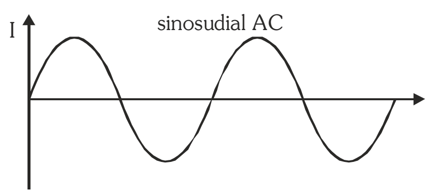
ac

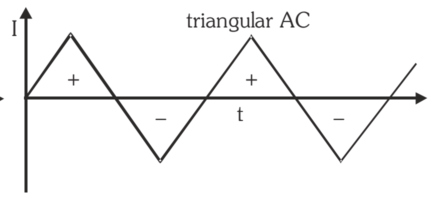
If a function suppose current, varies with time as $i = I_m \sin(\omega t+\phi)$, it is called sinusoidally varying function.Here I_m is the peak current or maximum current and i is the instantaneous current. The factor $(\omega t+\phi)$ is called phase. ω is called the angular frequency, its unit rad/s.Also $\omega = 2\pi f$ where f is called the frequency, its unit s^{-1} or Hz. Also frequency f = 1/T where T is called the time period.

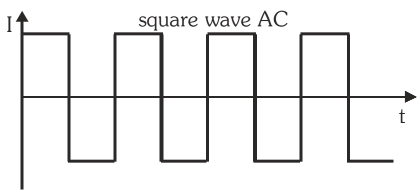
CONDITION REQUIRED FOR CURRENT/ VOLTAGE TO BE ALTERNATING

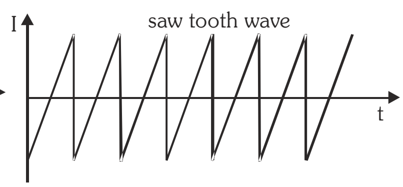
- Amplitude is constant
- Alternate half cycle is positive and half negative

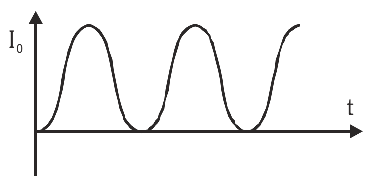
The alternating current continuously varies in magnitude and periodically reverses its direction.











Not AC (direction not change)

2. AVERAGE VALUE :

The mean value of A.C over any half cycle (either positive or negative) is that value of DC which would send same amount of charge through a circuit as is sent by the AC through same circuit in the same time.

average value of current for half cycle $< I > = \dfrac{\int_0^{T/2} I dt}{\int_0^{T/2} dt}$

Average value of $I = I_0 \sin \omega t$ over the positive half cycle :

$$I_{av} = \frac{\int_0^{\frac{T}{2}} I_0 \sin\omega t \, dt}{\int_0^{\frac{T}{2}} dt} = \frac{2I_0}{\omega T}\left[-\cos\omega t\right]_0^{\frac{T}{2}} \Rightarrow = \frac{\mathbf{2I_0}}{\pi}$$

$< \sin \theta > = < \sin 2\theta > = 0$
$< \cos \theta > = < \cos 2\theta > = 0$
$< \sin \theta \cos \theta > = 0$
$< \sin^2 \theta > = < \cos^2 \theta > = \frac{1}{2}$

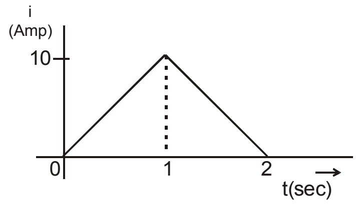
- For symmetric AC, average value over full cycle = 0,
  Average value of sinusoidal AC

MAXIMUM VALUE

- $I = a \sin\theta \Rightarrow I_{Max.} = a$
- $I = a + b \sin\theta \Rightarrow I_{Max.} = a + b$ (if a and b > 0)
- $I = a \sin\theta + b \cos \theta \Rightarrow I_{Max.} = \sqrt{a^2 + b^2}$
- $I = a \sin^2 \theta \Rightarrow I_{Max.} = a \ (a > 0)$

SOLVED EXAMPLE

Exercise 1. Find the average value of current shown graphically, from t = 0 to t = 2 sec.



Solution : From the i – t graph, area from t = 0 to t = 2 sec

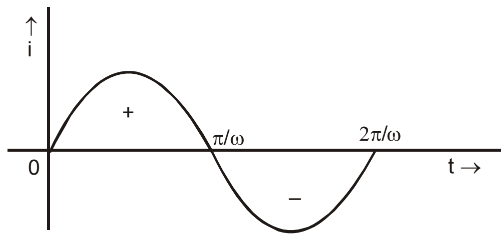
= × 2 × 10 = 10 Amp. sec.

$\therefore$ Average Current = $\frac{10}{2}$ = 5 Amp.

Example 2. Find the average value of current from t = 0 to t = if the current varies as $i = I_m \sin \omega t$.

Solution :

$$<i> = \frac{\int_0^{\frac{2\pi}{\omega}} I_m \sin\omega t dt}{\frac{2\pi}{\omega}} = \frac{\frac{I_m}{\omega}\left(1 - \cos\omega\frac{2\pi}{\omega}\right)}{\frac{2\pi}{\omega}} = 0$$



It can be seen graphically that the area of i – t graph of one cycle is zero.

$\therefore$ < i > in one cycle = 0.

Example 3. Show graphically that the average of sinusoidally varying current in half cycle may or may not be zero

Solution :

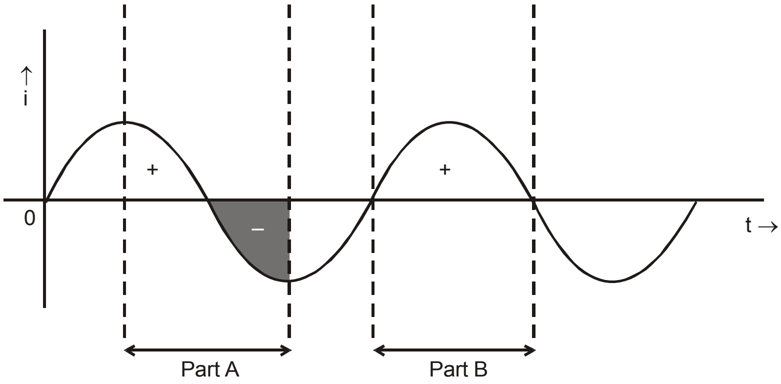


Figure shows two parts A and B, each half cycle. In part A we can see that the net area is zero
$\therefore$ < i > in part A is zero.
In part B, area is positive hence in this part $\langle i \rangle \neq 0$.

Example 4. Find the average value of current $i = I_m \sin \omega t$ from (i) t = 0 to $t = \frac{\pi}{\omega}$ (ii) $t = \frac{\pi}{2\omega}$ to $t = \frac{3\pi}{2\omega}$.

Solution : (i) $\langle i \rangle = \frac{\int_0^{\pi/\omega} I_m \sin \omega t dt}{\frac{\pi}{\omega}} = \frac{\frac{I_m}{\omega}\left(1 - \cos \omega \frac{\pi}{\omega}\right)}{\frac{\pi}{\omega}} = \frac{2I_m}{\pi}$ (ii) $\langle i \rangle = \frac{\int_{\pi/2\omega}^{3\pi/2\omega} I_m \sin \omega t dt}{\frac{\pi}{\omega}} = 0.$

Example 5. Current in an A.C. circuit is given by $i = 2\sqrt{2} \sin(\pi t + \pi/4)$, then the average value of current during time t = 0 to t = 1 sec is:

Solution : $\langle i \rangle = \frac{\int_0^1 i\, dt}{1} = 2\sqrt{2} \int_0^1 \sin\left(\pi t + \frac{\pi}{4}\right) = \frac{4}{\pi}$ **Ans.**

3. ROOT MEAN SQUARE VALUE :

It is value of DC which would produce same heat in given resistance in given time as is done by the alternating current when passed through the same resistance for the same time.

$$I_{rms} = \sqrt{\frac{\int_0^T I^2 dt}{\int_0^T dt}}$$ rms value = Virtual value = Apparent value

rms value of $I = I_0 \sin \omega t$:

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

$$= I_0 \sqrt{\frac{1}{T}\int_0^T \left[\frac{1-\cos 2\omega t}{2}\right] dt} = I_0 \sqrt{\frac{1}{T}\left[\frac{t}{2} - \frac{\sin 2\omega t}{2\times 2\omega}\right]_0^T} = \frac{I_0}{\sqrt{2}}$$

- If nothing is mentioned then values printed in a.c circuit on electrical appliances, any given or unknown values, reading of AC meters are assumed to be RMS.

SOLVED EXAMPLE

Example 6. Find the rms value of current from t = 0 to $t = \frac{2\pi}{\omega}$ if the current varies as $i = I_m \sin \omega t$.

Solution : $$i_{rms} = \sqrt{\frac{\int_0^{\frac{2\pi}{\omega}} I_m^2 \sin^2 \omega t dt}{\frac{2\pi}{\omega}}} = \sqrt{\frac{I_m^2}{2}} = \frac{I_m}{\sqrt{2}}$$

Example 7. If $I = 2\sqrt{t}$ ampere then calculate average and rms values over t = 2 to 4 s

Solution: $$\langle I \rangle = \frac{\int_2^4 2\sqrt{t}.dt}{\int_2^4 dt} = \frac{4}{3}\frac{(t^{\frac{3}{2}})_2^4}{(t)_2^4} = \frac{2}{3}\left[8 - 2\sqrt{2}\right]$$ and

$$I_{rms} = \sqrt{\frac{\int_2^4 (2\sqrt{t})^2 dt}{\int_2^4 dt}} = \sqrt{\frac{\int_2^4 4t\, dt}{2}} = \sqrt{2\left[\frac{t^2}{2}\right]_2^4} = 2\sqrt{3}\text{ A}$$

Example 8. If $E = 20 \sin (100\pi t)$ volt then calculate value of E at $t = \frac{1}{600}$ s

Solution: At $t = \frac{1}{600}$ s $E = 20 \text{ Sin} \left[100\pi \times \frac{1}{600}\right]$

$$= 20 \sin \left[\frac{\pi}{6}\right] = 20 \times \frac{1}{2} = 10\text{V}$$

Example 9. Find the rms value of current $i = I_m \sin \omega t$ from (i) $t = 0$ to $t = \frac{\pi}{\omega}$ (ii) $t = \frac{\pi}{2\omega}$ to $t = \frac{3\pi}{2\omega}$.

Solution : (i) $i_{rms} = \sqrt{\dfrac{\int_0^{\pi/\omega} I_m^2 \sin^2 \omega t dt}{\frac{\pi}{\omega}}} = \sqrt{\dfrac{I_m^2}{2}} = \dfrac{I_m}{\sqrt{2}}$ (ii) $<i> = \sqrt{\dfrac{\int_{\pi/2\omega}^{3\pi/2\omega} I_m^2 \sin^2 \omega t\, dt}{\frac{\pi}{\omega}}} = \sqrt{\dfrac{I_m^2}{2}} = \dfrac{I_m}{\sqrt{2}}$

Note:

- The r m s values for one cycle and half cycle (either positive half cycle or negative half cycle) is same.
- From the above two examples note that for sinusoidal functions **rms value** (Also called **effective value**) **=**

$\dfrac{\text{peak value}}{\sqrt{2}}$ or $\mathbf{I_{rms} = \dfrac{I_m}{\sqrt{2}}}$

Example 10. Find the effective value of current $i = 2 \sin 100\pi t + 2 \cos (100\pi t + 30°)$.

Solution : The equation can be written as $i = 2 \sin 100\pi t + 2 \sin (100\pi t + 120°)$
so phase difference $\phi = 120°$

$I_m)_{res} = \sqrt{A_1^2 + A_2^2 + 2A_1A_2 \cos\phi}$

$= \sqrt{4 + 4 + 2 \times 2 \times 2\left(-\frac{1}{2}\right)}$ = 2, so effective value or rms value = $2/\sqrt{2} = \sqrt{2}$ A

4. AC SINUSOIDAL SOURCE :

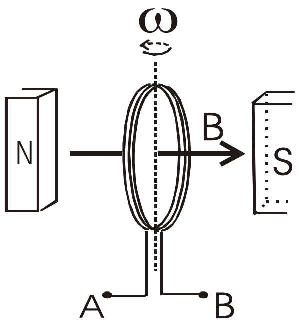


Figure shows a coil rotating in a magnetic field. The flux in the coil changes as $\varphi = NBA \cos (\omega t + \phi)$. Emf induced in the coil, from Faraday's law is $\frac{-d\varphi}{dt} = N B A \omega \sin (\omega t + \phi)$. Thus the emf between the points A and B will vary as $E = E_0 \sin (\omega t + \phi)$. The potential difference between the points A and B will also vary as $V = V_0 \sin (\omega t + \phi)$. The symbolic notation of the above arrangement is A—(~)—B. We do not put any + or – sign on the AC source.

5. PHASOR AND PHASOR DIAGRAM

A diagram representing alternating current and voltage (of same frequency) as vectors (phasor) with the phase angle between them is called phasor diagram.

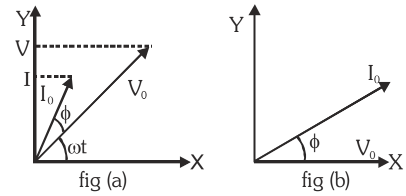


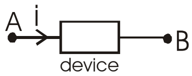
fig (a) fig (b)

Let $V = V_0 \sin \omega t$

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

In figure (a) two arrows represents phasors. The length of phasors represents the maximum value of quantity. The projection of a phasor on y-axis represents the instantaneous value of quantity

6. POWER CONSUMED OR SUPPLIED IN AN AC CIRCUIT:



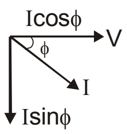
Consider an electrical device which may be a source, a capacitor, a resistor, an inductor or any combination of these. Let the potential difference be $V = V_A - V_B = V_m \sin\omega t$. Let the current through it be $i = I_m \sin(\omega t + \phi)$. Instantaneous power P consumed by the device $= V\,i = (V_m \sin \omega t)\,(I_m \sin(\omega t + \phi))$

$$\text{Average power consumed in a cycle} = \frac{\int_0^{\frac{2\pi}{\omega}} P\,dt}{\frac{2\pi}{\omega}} = \frac{1}{2} V_m I_m \cos \phi$$

$$= \frac{V_m}{\sqrt{2}} \cdot \frac{I_m}{\sqrt{2}} \cdot \cos \phi = V_{rms} I_{rms} \cos \phi.$$

Here $\cos \phi$ is called **power factor**.

Note : $I\sin\phi$ is called "wattless current".



SOLVED EXAMPLE

Example 11. When a voltage $v_s = 200\sqrt{2} \sin (\omega t + 15^\circ)$ is applied to an AC circuit the current in the circuit is found to be $i = 2 \sin (\omega t + \pi/4)$ then average power concsumed in the circuit is

(A) 200 watt (B) $400\sqrt{2}$ watt (C) $100\sqrt{6}$ watt (D) $200\sqrt{2}$ watt

Solution : $P_{av} = v_{rms}\ I_{rms} \cos \phi$

$$= \frac{200\sqrt{2}}{\sqrt{2}}\ \frac{2}{\sqrt{2}} \cdot \cos (30^\circ) = 100\sqrt{6} \text{ watt}$$

7. SOME DEFINITIONS :

The factor **cos ϕ** is called **Power factor**.

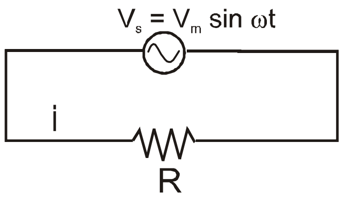
I_m sin ϕ is called **wattless current**.

Impedance Z is defined as $Z = \frac{V_m}{I_m} = \frac{V_{rms}}{I_{rms}}$

ωL is called **inductive reactance** and is denoted by X_L.

$\frac{1}{\omega C}$ is called **capacitive reactance** and is denoted by X_C.

8. PURELY RESISTIVE CIRCUIT:



Writing KVL along the circuit,

$V_s - iR = 0$

or $i = \frac{V_s}{R} = \frac{V_m \sin \omega t}{R} = I_m \sin \omega t$

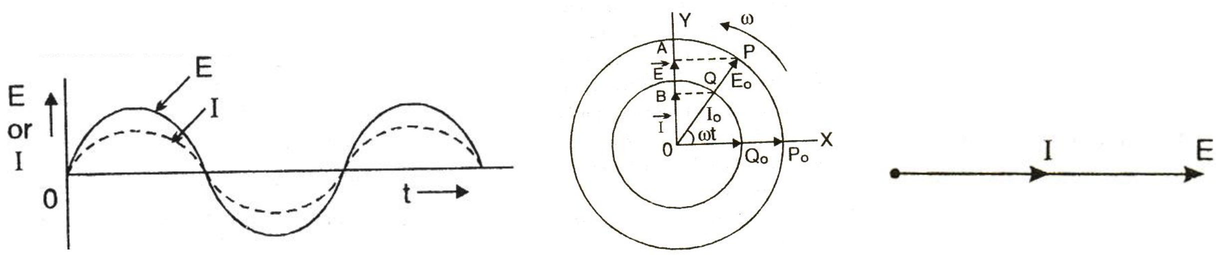
$\Rightarrow$ We see that the phase difference between potential difference across resistance, V_R and i_R is 0.

$I_m = \frac{V_m}{R}$

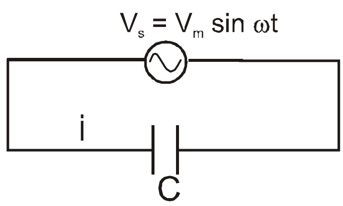
$\Rightarrow$ $I_{rms} = \frac{V_{rms}}{R}$

$\langle P \rangle = V_{rms} I_{rms} \cos \phi = \frac{V_{rms}^2}{R}$

Graph of E and I



9. PURELY CAPACITIVE CIRCUIT:

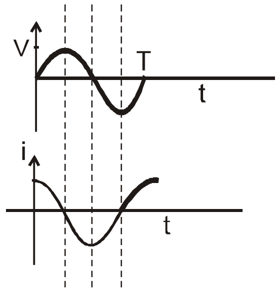


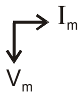
Writing KVL along the circuit,

$V_s - \frac{q}{C} = 0$

or $i = \frac{dq}{dt} = \frac{d(CV)}{dt} = \frac{d(CV_m \sin \omega t)}{dt} = CV_m \omega \cos \omega t = \frac{V_m}{1/\omega C} \cos \omega t = \frac{V_m}{X_C} \cos \omega t = I_m \cos \omega t.$

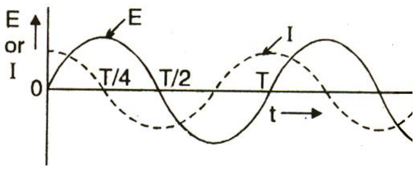
$X_C = \frac{1}{\omega C}$ and is called capacitive reactance. Its unit is ohm Ω.

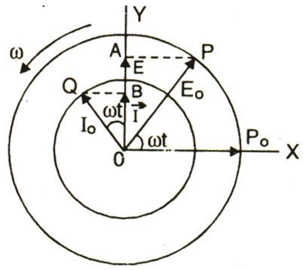


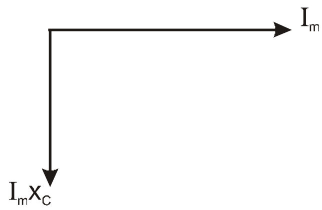
From the graph of current versus time and voltage versus time , it is clear that current attains its peak value at a time $\frac{T}{4}$ before the time at which voltage attains its peak value. Corresponding to $\frac{T}{4}$ the phase difference $= \omega\Delta t = \frac{2\pi}{T}\frac{T}{4} = \frac{2\pi}{4} = \frac{\pi}{2}$. i_C leads v_C by $\pi/2$ Diagrammatically (phasor diagram) it is represented as .

Since $\phi = 90^\circ$, $\langle P \rangle = V_{rms} I_{rms} \cos\phi = 0$

Graphical and vector representation of E and I is shown in the following figure

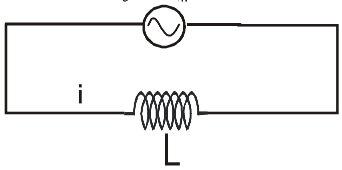






10. PURELY INDUCTIVE CIRCUIT:

$V_s = V_m \sin \omega t$



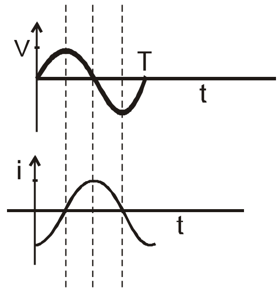
Writing KVL along the circuit,

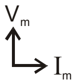
$V_s - L\frac{di}{dt} = 0 \quad \Rightarrow \quad L\frac{di}{dt} = V_m \sin \omega t$

$\int L\,di = \int V_m \sin\omega t\, dt \qquad i = -\frac{V_m}{\omega L}\cos\omega t + C$

$\langle i \rangle = 0 \quad \Rightarrow \quad C = 0$

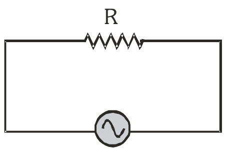
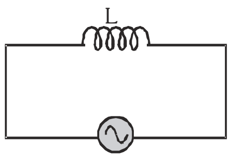
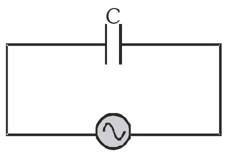
$\therefore\ i = -\frac{V_m}{\omega L}\cos\omega t \quad \Rightarrow \quad I_m = \frac{V_m}{X_L}$



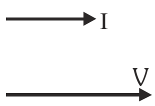
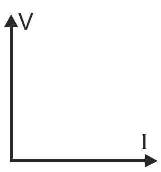
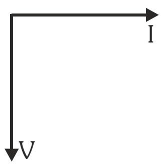
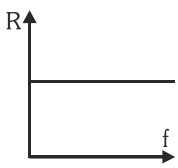
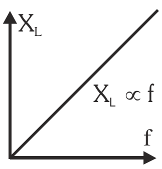
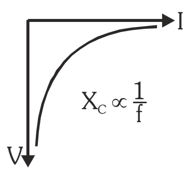
From the graph of current versus time and voltage versus time , it is clear that voltage attains its peak value at a time $\frac{T}{4}$ before the time at which current attains its peak value. Corresponding to $\frac{T}{4}$ the phase difference $= \omega\Delta t = \frac{2\pi}{T}\frac{T}{4} = \frac{2\pi}{4} = \frac{\pi}{2}$. Diagrammatically (phasor diagram) it is represented as  . i_L lags behind v_L by $\pi/2$.

Since $\phi = 90^o$, $<P> = V_{rms}I_{rms}\cos\phi = 0$

Summary :

TERM	**R**	**L**	**C**
Circuit			
Supply Voltage	$V = V_0 \sin \omega t$	$V = V_0 \sin \omega t$	$V = V_0 \sin \omega t$
Current	$I = I_0 \sin \omega t$	$I = I_0 \sin (\omega t - \frac{\pi}{2})$	$I = I_0 \sin (\omega t + \frac{\pi}{2})$
Peak Current	$I_0 = \frac{V_0}{R}$	$I_0 = \frac{V_0}{\omega L}$	$I_0 = \frac{V_0}{1/\omega C} = V_0\omega C$
Impedance (Ω)	$\frac{V_0}{I_0} = R$	$\frac{V_0}{I_0} = \omega L = X_L$	$\frac{V_0}{I_0} = \frac{1}{\omega C} = X_C$

$Z = \frac{V_0}{I_0} = \frac{V_{rms}}{I_{rms}}$ R = Resistance X_L=Inductive reactance. X_C=Capacitive reactance.

Phase difference	zero (in same phase)	$+\frac{\pi}{2}$ (V leads I)	$-\frac{\pi}{2}$ (V lags I)
Phasor diagram			
Variation of Z with *f*			

R does not depend on f		
G,S_L,S_C G=1/R = conductance.	$S_L = 1/X_L$	$S_C = 1/X_C$
(mho, seiman)	Inductive susceptance	Capacitive susceptance
Behaviour of deviceSame in	L passes DC easily	C - blocks DC
in D.C. and A.C A C and D C	(because X_L = 0) while	(because $X_C = \infty$) while
gives a high impedance	provides an easy path	
for the A.C. of high	for the A.C. of high	
	frequency ($X_L \propto f$)	frequency $\left[X_C \propto \frac{1}{f}\right]$
Ohm's law	V_R = IR $V_L = IX_L$ $V_C = IX_C$	

SOLVED EXAMPLE

Example 12. A capacitor of 50 pF is connected to an a.c. source of frequency 1kHz Calculate its reactance.

Solution: $X_C = \frac{1}{\omega C} = \frac{1}{2\pi\times10^3\times50\times10^{-12}} = \frac{10^7}{\pi}\ \Omega$

Example 13. An alternating voltage E = 200 $\sqrt{2}$ sin (100 t) V is connected to a 1μF capacitor through an ac ammeter (it reads rms value). What will be the reading of the ammeter?

Solution : Comparing E = 200 $\sqrt{2}$ sin (100 t) with E = E_0 sin ωt we find that,

$E_0 = 200\sqrt{2}$ V and ω = 100 (rad/s)

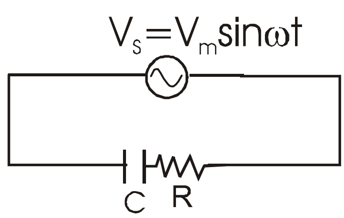
So, $X_C = \frac{1}{\omega C} = \frac{1}{100\times10^{-6}} = 10^4\,\Omega$

And as ac instruments reads rms value, the reading of ammeter will be,

$$I_{rms} = \frac{E_{rms}}{X_C} = \frac{E_0}{\sqrt{2}X_C} \quad \left[\text{as } E_{rms} = \frac{E_0}{\sqrt{2}}\right]$$

i.e. $I_{rms} = \frac{200\sqrt{2}}{\sqrt{2}\times10^4} = 20\text{mA}$ **Ans**

10. RC SERIES CIRCUIT WITH AN AC SOURCE :



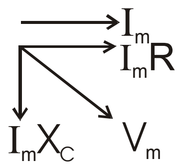
Let i = I_m sin (ωt + ϕ) $\Rightarrow$ V_R=iR= I_mR sin (ωt+ϕ)

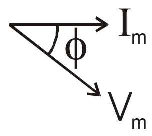
$V_C = (I_m X_C)\sin(\omega t + \phi - \frac{\pi}{2})$ $\Rightarrow$ $V_S = V_R + V_C$

or $V_m \sin(\omega t+\phi) = I_mR\sin(\omega t + \phi) + I_m X_C \sin(\omega t + \phi - \frac{\pi}{2})$

$$V_m = \sqrt{(I_mR)^2 + (I_mX_C)^2 + 2(I_mR)(I_mX_C)\cos\frac{\pi}{2}}$$

OR $I_m = \dfrac{V_m}{\sqrt{R^2 + X_C^2}}$ $\Rightarrow$ $Z = \sqrt{R^2 + X_C^2}$



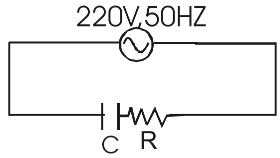


Using phasor diagram also we can find the above result.

$\tan\phi = \dfrac{I_m X_C}{I_m R} = \dfrac{X_C}{R}$.

SOLVED EXAMPLE

Example 14. In an RC series circuit, the rms voltage of source is 200V and its frequency is 50 Hz.If R =100 Ω and C= $\dfrac{100}{\pi}$ μF, find



(i) Impedance of the circuit
(ii) Power factor angle
(iii) Power factor
(iv) Current
(v) Maximum current
(vi) voltage across R
(vii) voltage across C
(viii) max voltage across R
(ix) max voltage across C
(x) < P >
(xi) < P_R >
(xii) < P_C >

Solution : $X_C = \dfrac{10^6}{\dfrac{100}{\pi}(2\pi 50)} = 100\ \Omega$

(i) $Z = \sqrt{R^2 + X_C^2} = \sqrt{100^2 + (100)^2} = 100\sqrt{2}\ \Omega$

(ii) $\tan\phi = \dfrac{X_C}{R} = 1$ $\therefore \phi = 45^\circ$

(iii) Power factor= $\cos\phi = \dfrac{1}{\sqrt{2}}$

(iv) Current $I_{rms} = \dfrac{V_{rms}}{Z} = \dfrac{200}{100\sqrt{2}} = \sqrt{2}$ A

(v) Maximum current $= I_{rms}\sqrt{2} = 2A$

(vi) voltage across R=$V_{R,rms} = I_{rms}R = \sqrt{2} \times 100$ Volt

(vii) voltage across C=$V_{C,rms} = I_{rms}X_C = \sqrt{2} \times 100$ Volt

(viii) max voltage across R= $\sqrt{2}\ V_{R,rms}$= 200 Volt

(ix) max voltage across C= $\sqrt{2}\ V_{C,rms}$= 200 Volt

(x) $\langle P \rangle = V_{rms} I_{rms} \cos\phi = 200 \times \sqrt{2} \times \dfrac{1}{\sqrt{2}} = 200$ Watt

(xi) $\langle P_R \rangle = I_{rms}^2 R$ = 200 W

(x) $\langle P_C \rangle$ = 0

Example 15. In the above question if $V_s(t) = 220\sqrt{2}\ \sin(2\pi\, 50\, t)$, find (a) i (t), (b) v_R and (c) v_C (t)

Solution :
(a) $i(t) = I_m \sin(\omega t + \phi)$ $= \sqrt{2}\ \sin(2\pi\ 50\ t + 45^\circ)$

(b) $V_R = i_R \cdot R$ $= i(t)\,R$ $= \sqrt{2} \times 100 \sin(100\,\pi t + 45^\circ)$

(c) $V_C(t) = i_C X_C$ (with a phase lag of 90º) $= \sqrt{2} \times 100 \sin(100\,\pi t + 45 - 90)$

Example 16. An ac source of angular frequency ω is fed across a resistor R and a capacitor C in series. The current registered is I. If now the frequency of source is changed to ω/3 (but maintaining the same voltage), the current in the circuit is found to be halved. Calculate the ratio of reactance to resistance at the original frequency ω.

Solution : According to given problem,

$$I = \frac{V}{Z} = \frac{V}{[R^2 + (1/C\omega)^2]^{1/2}} \quad \text{... (1)}$$

and, $$\frac{I}{2} = \frac{V}{[R^2 + (3/C\omega)^2]^{1/2}} \quad \text{...(2)}$$

Substituting the value of I from Equation (1) in (2),

$$4\left(R^2 + \frac{1}{C^2\omega^2}\right) = R^2 + \frac{9}{C^2\omega^2}\ .\ \text{i.e.,}\ \frac{1}{C^2\omega^2} = \frac{3}{5}R^2$$

So that, $$\frac{X}{R} = \frac{(1/C\omega)}{R} = \frac{\left(\frac{3}{5}R^2\right)^{1/2}}{R} = \sqrt{\frac{3}{5}}$$ **Ans.**

Example 17. A 50 W, 100 V lamp is to be connected to an AC mains of 200 V, 50 Hz. What capacitance is essential to be put in series with the lamp ?

Solution: ∵ resistance of the lamp $R = \frac{V_s^2}{W} = \frac{(100)^2}{50}$ = 200 Ω and the maximum curent $I = \frac{V}{R} = \frac{100}{200} = \frac{1}{2}A$

∴ when the lamp is put in series with a capacitance and run at 200 V AC, from V = IZ

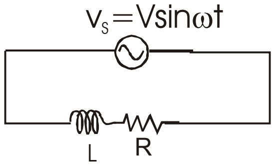
$Z = \frac{V}{I} = \frac{200}{\frac{1}{2}} = 400\Omega$ Now as in case of C–R circuit $Z = \sqrt{R^2 + \frac{1}{(\omega C)^2}}$,

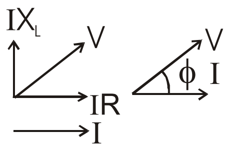
$$\Rightarrow R^2 + \frac{1}{(\omega C)^2} = (400)^2 \qquad \Rightarrow \frac{1}{(\omega C)^2} = 16\times10^4 - (200)^2 = 12\times10^4$$

$$\Rightarrow \frac{1}{\omega C} = \sqrt{12}\times10^2$$

$$\Rightarrow C = \frac{1}{100\pi\times\sqrt{12}\times10^2}F = \frac{100}{\pi\sqrt{12}}\mu F = 9.2\mu F$$

11. LR SERIES CIRCUIT WITH AN AC SOURCE :





From the phasor diagram

$$V = \sqrt{(IR)^2 + (IX_L)^2} = I\sqrt{(R)^2 + (X_L)^2} = I\,Z \quad \Rightarrow \tan\phi = \frac{IX_L}{IR} = \frac{X_L}{R}$$

SOLVED EXAMPLE

Example 18. A $\frac{9}{100\pi}$ H inductor and a 12 ohm resistance are connected in series to a 225 V, 50 Hz ac source. Calculate the current in the circuit and the phase angle between the current and the source voltage.

Solution : Here $X_L = \omega L = 2\pi f L = 2\pi \times 50 \times \frac{9}{100\pi} = 9\ \Omega$

So, $Z = \sqrt{R^2 + X_L^2} = \sqrt{12^2 + 9^2} = 15\ \Omega$

So (a) $I = \frac{V}{Z} = \frac{225}{15} = 15$ A **Ans**

and (b) $\phi = \tan^{-1}\left(\frac{X_L}{R}\right) = \tan^{-1}\left(\frac{9}{12}\right)$

$= \tan^{-1} 3/4 = 37°$

i.e., the current will lag the applied voltage by 37° in phase. **Ans**

Example 19. When an inductor coil is connected to an ideal battery of emf 10 V, a constant current 2.5 A flows. When the same inductor coil is connected to an AC source of 10 V and 50 Hz then the current is 2A. Find out inductance of the coil .

Solution : When the coil is connected to dc source, the final current is decided by the resistance of the coil .

$\therefore \quad r = \frac{10}{2.5} = 4\ \Omega$

When the coil is connected to ac source, the final current is decided by the impedance of the coil .

$\therefore \quad Z = \frac{10}{2} = 5\ \Omega$

But $Z = \sqrt{(r)^2 + (X_L)^2}$ $\qquad X_L^2 = 5^2 - 4^2 = 9$

$X_L = 3\ \Omega$

$\therefore \quad \omega L = 2\pi f L = 3$

$\therefore \quad 2\pi\, 50\, L = 3$

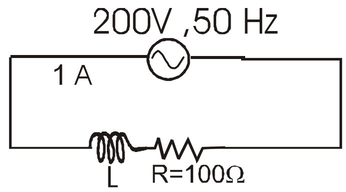
$\therefore \quad L = 3/100\pi$ Henry

Example 20. A bulb is rated at 100 V,100 W , it can be treated as a resistor .Find out the inductance of an inductor (called choke coil) that should be connected in series with the bulb to operate the bulb at its rated power with the help of an ac source of 200 V and 50 Hz.

Solution : From the rating of the bulb , the resistance of the bulb is $R=\frac{V_{rms}^{2}}{P}=100\,\Omega$

For the bulb to be operated at its rated value the rms current through it should be 1A

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



$\therefore \quad 1 = \frac{200}{\sqrt{100^2+(2\pi 50 L)^2}}$

$L = \frac{\sqrt{3}}{\pi}$ H

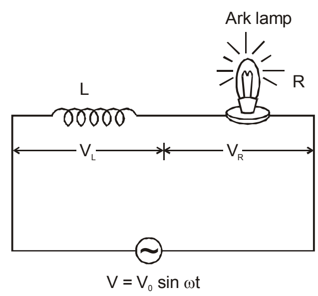
Example 21. A choke coil is needed to operate an arc lamp at 160 V (rms) and 50 Hz. The arc lamp has an effective resistance of 5 Ω when running of 10 A (rms). Calculate the inductance of the choke coil. If the same arc lamp is to be operated on 160 V (dc), what additional resistance is required? Compare the power losses in both cases.

Solution : As for lamp V_R = IR = 10 × 5 = 50 V, so when it is connected to 160 V ac source through a choke in series,

$V^2 = V_R^2 + V_L^2$, $\quad V_L = \sqrt{160^2 - 50^2} = 152$ V

and as, $V_L = IX_L = I\omega L = 2\pi f L I$

So, $L = \frac{V_L}{2\pi f I} = \frac{152}{2\times\pi\times 50\times 10} = 4.84 \times 10^{-2}$ H **Ans.**



Now the lamp is to be operated at 160 V dc; instead of choke if additional resistance r is put in series with it,

$V = I(R + r)$, i.e., 160 = 10(5 + r)

i.e., r = 11 Ω **Ans.**

In case of ac, as choke has no resistance, power loss in the choke
will be zero while the bulb will consume,

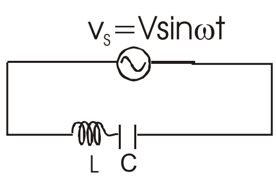
$P = I^2 R = 10^2 \times 5 = 500$ W

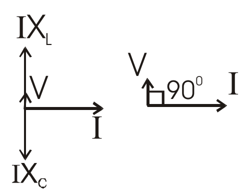
However, in case of dc as resistance r is to be used instead of choke, the power loss in the resistance r will be.

$PL = 10^2 \times 11 = 1100$ W

while the bulb will still consume 500 W, i.e., when the lamp is run on resistance r instead of choke more than double the power consumed by the lamp is wasted by the resistance r.

12. LC SERIES CIRCUIT WITH AN AC SOURCE :





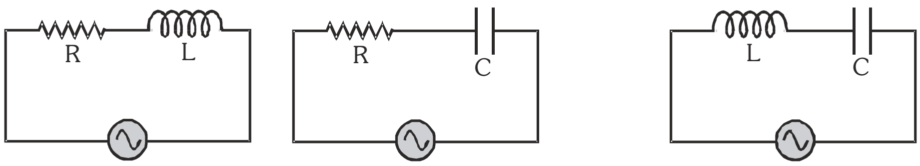
From the phasor diagram

$V = I|(X_L - X_C)| = I Z$ $\qquad \phi = 90^\circ$

COMBINATION OF COMPONENTS (R-L or R-C or L-C)

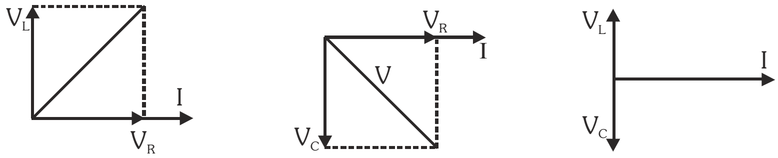
TERM **R-L** **R-C** **L-C**

Circuit



I is same in R & L I is same in R & C I is same in L & C

Phasor diagram



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

$V = V_C - V_L$ $(V_C > V_L)$

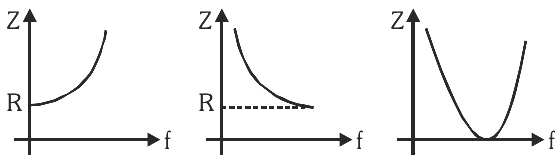
Phase difference V leads I (ϕ = 0 to $\frac{\pi}{2}$) V lags I ($\phi = -\frac{\pi}{2}$ to 0) V lags I ($\phi = -\frac{\pi}{2}$, if $X_C > X_L$)

in between V and I V leads I($\phi = +\frac{\pi}{2}$, if $X_L > X_C$)

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

Variation of Z as f$\uparrow$, Z $\uparrow$ as f$\uparrow$, Z$\downarrow$ as f$\uparrow$, Z first $\downarrow$ then$\uparrow$

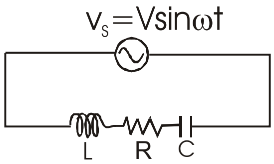
with f

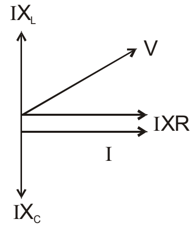


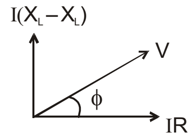
At very low f $\quad Z \simeq R$ $(X_L \to 0)$ $\quad Z \simeq X_C$ $\quad Z \simeq X_C$

At very high f $\quad Z \simeq X_L$ $\quad Z \simeq R$ $(X_C \to 0)$ $\quad Z \simeq X_L$

13. RLC SERIES CIRCUIT WITH AN AC SOURCE :







From the phasor diagram

$V=\sqrt{(IR)^2+(IX_L-IX_C)^2}=I\sqrt{(R)^2+(X_L-X_C)^2}=IZ$ $\qquad Z=\sqrt{(R)^2+(X_L-X_C)^2}$

$\tan\phi=\dfrac{I(X_L-X_C)}{IR}=\dfrac{(X_L-X_C)}{R}$

Resonance :

Amplitude of current (and therefore I_{rms} also) in an RLC series circuit is maximum for a given value of V_m and R , if the impedance of the circuit is minimum, which will be when X_L-X_C =0. This condition is called **resonance**.

(a) At Resonance

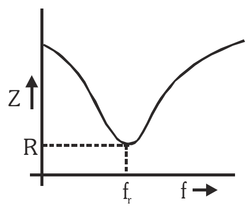
(i) $X_L = X_C$ (ii) $V_L = V_C$ (iii) $\phi = 0$ (V and I in same phase)

(iv) $Z_{min} = R$ (impedance minimum) (v) $I_{max} = \dfrac{V}{R}$ (current maximum)

(b) Resonance frequency

$\because \quad X_L = X_C \Rightarrow \omega_r L = \dfrac{1}{\omega_r C} \Rightarrow \omega_r^2 = \dfrac{1}{LC} \Rightarrow \omega_r = \dfrac{1}{\sqrt{LC}} \Rightarrow f_r = \dfrac{1}{2\pi\sqrt{LC}}$

(c) Variation of Z with f



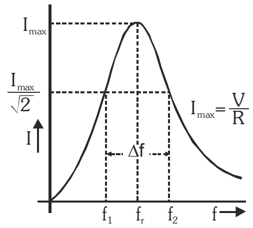
(i) If $f< f_r$ then $X_L < X_C$ circuit nature capacitive, φ (negative)

(ii) At $f = f_r$ then $X_L = X_C$ circuit nature, Resistive, φ = zero

(iii) If $f > f_r$ then $X_L > X_C$ circuit nature is inductive,φ (positive)

Variation of I with f as f increase, Z first decreases then increase

(d)



as f increase, I first increase then decreases

- At resonance impedance of the series resonant circuit is minimum so it is called 'acceptor circuit' as it most readily accepts that current out of many currents whose frequency is equal to its natural frequency. In radio or TV tuning we receive the desired station by making the frequency of the circuit equal to that of the desired station.

Half power frequencies

The frequencies at which, power become half of its maximum value called half power frequencies

Band width = $\Delta f = f_2 - f_1$

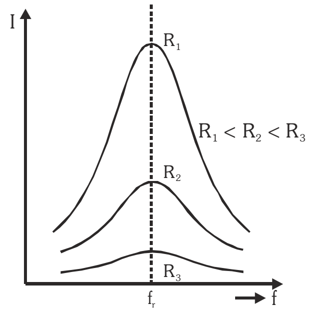
Quality factor Q : Q-factor of AC circuit basically gives an idea about stored energy & lost energy.

$$Q = 2\pi \frac{\text{maximum energy stored per cycle}}{\text{maximum energy loss per cycle}}$$

(i) It represents the sharpness of resonance.

(ii) It is unit less and dimension less quantity

(iii) $Q = \frac{(X_L)_r}{R} = \frac{(X_C)_r}{R} = \frac{2\pi f_r L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}} = \frac{f_r}{\Delta f} = \frac{f_r}{\text{band width}}$



Sharpness

Sharpness $\propto$ Quality factor

R decrease $\Rightarrow$ Q increases $\Rightarrow$ Sharpness increases

SOLVED EXAMPLE

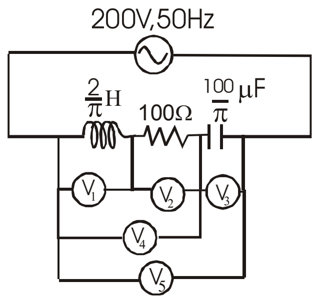
Example 18. In the circuit shown in the figure , find

(a) the reactance of the circuit .

(b) impedance of the circuit

(c) the current

(d) readings of the ideal AC voltmeters (these are hot wire instruments and read rms values).



Solution : (a) $X_L = 2\pi f L = 2\pi \times 50 \times \frac{2}{\pi} = 200\ \Omega$

$$X_C = \frac{1}{2\pi 50 \frac{100}{\pi} \times 10^{-6}} = 100\ \Omega$$

$\therefore$ The reactance of the circuit $X = X_L - X_C = 200 - 100 = 100\ \Omega$

Since $X_L > X_C$, the circuit is called inductive.

(b) impedance of the circuit $Z = \sqrt{R^2 + X^2} = \sqrt{100^2 + 100^2} = 100\sqrt{2}\ \Omega$

(c) the current $I_{rms} = \frac{V_{rms}}{Z} = \frac{200}{100\sqrt{2}} = \sqrt{2}$ A

(d) readings of the ideal voltmeter

V_1: $I_{rms}X_L = 200\sqrt{2}$ Volt

V_2: $I_{rms}R = 100\sqrt{2}$ Volt

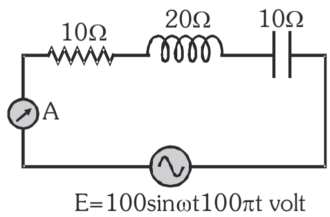
V_3: $I_{rms}X_c = 100\sqrt{2}$ Volt

V_4: $I_{rms}\sqrt{R^2 + X_L^2} = 100\sqrt{10}$ Volt

V_5: $I_{rms}Z = 200$ Volt ,which also happens to be the voltage of source.

Example 19. Find out reading of A C ammeter and also calculate the potential difference across, resistance and capacitor.

Solution: $Z = \sqrt{R^2 + (X_L - X_C)^2} = 10\sqrt{2}\ \Omega \quad \Rightarrow \quad I_0 = \frac{V_0}{Z} = \frac{100}{10\sqrt{2}} = \frac{10}{\sqrt{2}}$ A



∵ ammeter reads RMS value, so its reading = $\frac{10}{\sqrt{2}\sqrt{2}}$ = 5A

so $V_R = 5 \times 10 = 50$ V and $V_C = 5 \times 10 = 50$ V

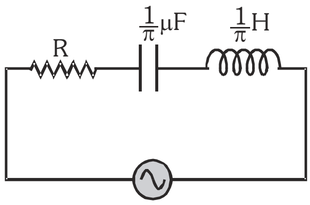
Example 20. In LCR circuit with an AC source R = 300 Ω , C = 20 μF, L = 1.0 H, E_{rms} = 50V and f = 50/π Hz. Find RMS current in the circuit.

Solution: $$I_{rms} = \frac{E_{rms}}{Z} = \frac{E_{rms}}{\sqrt{R^2 + \left[\omega L - \frac{1}{\omega C}\right]^2}} = \frac{50}{\sqrt{300^2 + \left[2\pi \times \frac{50}{\pi} \times 1 - \frac{1}{20 \times 10^{-6} \times 2\pi \times \frac{50}{\pi}}\right]^2}}$$

$$\Rightarrow \quad I_{rms} = \frac{50}{\sqrt{(300)^2 + \left[100 - \frac{10^3}{2}\right]^2}} = \frac{50}{100\sqrt{9+16}} = \frac{1}{10} = 0.1\text{A}$$

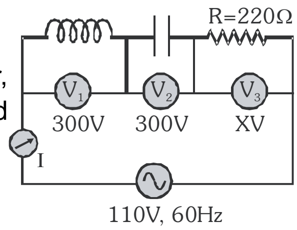
Example 21. For what frequency the voltage across the resistance R will be maximum.

Solution: It happens at resonance



$$f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{\frac{1}{\pi}\times 10^{-6}\times\frac{1}{\pi}}} = 500 \text{ Hz}$$

Example 22. A capacitor, a resistor and a 40 mH inductor are connected in series to an AC source of frequency 60Hz, calculate the capacitance of the capacitor, if the current is in phase with the voltage. Also calculate the value of X and I.



Solution: At resonance

$$\omega L = \frac{1}{\omega C},\ C = \frac{1}{\omega^2 L} = \frac{1}{4\pi^2 f^2 L} = \frac{1}{4\pi^2\times(60)^2\times 40\times 10^{-3}} = 176\mu F$$

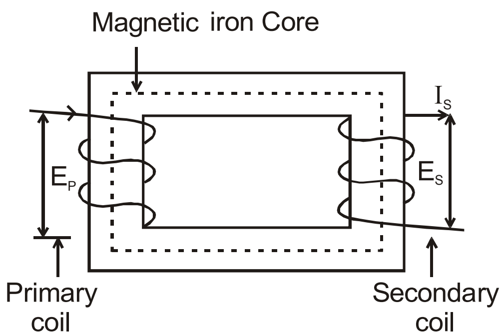
$V = V_R \Rightarrow$ X = 110 V and $I = \frac{V}{R} = \frac{110}{220} = 0.5\,A$

15. TRANSFORMER

A transformer changes an alternating potential difference from one value to another of greater or smaller value using the principle of mutual induction .Two coils called the primary and secondary windings,which are not connected to one another in any way , are wound on a complete soft iron core.When an alternating voltage E_P is applied to the primary , the resulting current produces a large alternating magnetic flux which links the secondary and induces an emf E_S in it.It can be shown that for an ideal transformer

$$\frac{E_s}{E_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s};$$

$\frac{N_s}{N_p}$ = turns ratio of the transformer.



E_S, N and I are the emf, number of turns and current in the coils.

$N_S > N_P \Rightarrow$ $E_S > E_P \rightarrow$ step up transformer.

$N_S < N_P \Rightarrow$ $E_S < E_P \rightarrow$ step down transformer.

Note : Phase difference between the primary and secondary voltage is π.

ENERGY LOSSES IN TRANSFORMER

Although transformers are very efficient devices, small energy losses do occur in them due to four main causes.

	Cause		Rectification
1.	**FLUX LEAKAGE :** Due to poor design and air gaps in the core, all the flux due to primary does not pass through the secondary.	1.	By winding the primary and secondary coil one over the other.
2.	**RESISTANCE OF THE WINDINGS:** Resistance of windings causes I^2 R loss.	2.	In high current, low voltage, these are minimised by using thick wire.
3.	**EDDY CURRENT:** The alternating magnetic flux induces eddy currents in the core and causes heating.	3.	By using laminated core it can be reduced.
4.	**HYSTERESIS** : Alternating magnetization of core causes hysteresis loss.	4.	It is kept minimum by using a magnetic material having low hysteresis loss. (e.g. soft iron)

MISCELLANEOUS SOLVED EXAMPLE

Problem 1. The peak voltage in a 220 V AC source is

(A) 220 V (B) about 160 V

(C) about 310 V (D) 440 V

Solution : $V_0 = \sqrt{2}\ V_{rms} = \sqrt{2} \times 220 \simeq 330$ V

Ans is (C)

Problem 2. An AC source is rated 220 V, 50 Hz. The average voltage is calculated in a time interval of 0.01 s. It

(A) must be zero (B) may be zero

(C) is never zero (D) is (220/√2)V

Solution : May be zero

Ans. is (B)

Problem 3. Find the effective value of current i = 2 + 4 cos 100 π t**.**

Solution : $I_{rms} = \left[\int_0^T \frac{(2+4\cos 100\pi t)^2 dt}{T}\right]^{1/2} = 2\sqrt{3}$

Problem 4. The peak value of an alternating current is 5 A and its frequency is 60 Hz. Find its rms value. How long will the current take to reach the peak value starting from zero?

Solution : $I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{5}{\sqrt{2}}$ A , $t = \frac{T}{4} = \frac{1}{240}$ s

Problem 5. An alternating current having peak value 14 A is used to heat a metal wire. To produce the same heating effect, a constant current i can be used where i is

(A) 14 A (B) about 20 A

(C) 7 A (D) about 10 A

Solution : $I_{RMS} = \frac{I_0}{\sqrt{2}} = \frac{14}{\sqrt{2}} \simeq 10$ **Ans. is (D)**

Problem 6. Find the average power concumed in the circuit if a voltage $v_s = 200\sqrt{2}$ sin ωt is applied to an AC circuit and the current in the circuit is found to be i = 2 sin (ωt + π/4) .

Solution : $P = V_{RMS} I_{RMS} \cos\phi = \frac{200\sqrt{2}}{\sqrt{2}} \times \frac{2}{\sqrt{2}} \times \cos\frac{\pi}{4} = 200$ W

Problem 7. A capacitor acts as an infinite resistance for

(A) DC (B) AC

(C) DC as well as AC (D) neither AC nor DC

Solution : $x_C = \frac{1}{\omega C}$ for DC $\omega = 0$. so, $x_C = \infty$

Ans. is (A)

Problem 8. A 10 μF capacitor is connected with an ac source $E = 200\sqrt{2}$ sin (100 t) V through an ac ammeter (it reads rms value) . What will be the reading of the ammeter?

Solution : $I_0 = \frac{V_0}{x_C} = \frac{200\sqrt{2}}{1/\omega C}$; $I_{RMS} = \frac{I_0}{\sqrt{2}} = 200$ mA

Problem 9. Find the reactance of a capacitor (C = 200 μF) when it is connected to (a) 10 Hz AC source, (b) a 50 Hz AC source and (c) a 500 Hz AC source.

Solution : (a) $x_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} \simeq 80\ \Omega$ for f = 10 Hz AC source,

(b) $x_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} \simeq 16\ \Omega$ for f = 50 Hz and

(c) $x_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} \simeq 1.6\ \Omega$ for f= 500 Hz.

Problem 10. An inductor (L = 200 mH) is connected to an AC source of peak current. What is the intantaneous voltage of the source when the current is at its peak value?

Solution : Because phase difference between volatage and current is π/2 for pure inductor.

So, **Ans. is zero**

Problem 11. An AC source producing emf $E = E_0[\cos(100\,\pi\, s^{-1})t + \cos(500\,\pi\, s^{-1})t]$is connected in series with a capacitor and a resistor. The current in the circuit is found to be $i = i_1 \cos[(100\,\pi\, s^{-1})t + \varphi_1]+i_2 \cos[(500\,\pi\, s^{-1})t+ \varphi_1]$

(A) $i_1 > i_2$ (B) $i_1 = i_2$

(C) $i_1 < i_2$ (D) the information is insufficient to find the relation between i_1 and i_2

Solution : Impedence z is given by $z = \sqrt{\left(\frac{1}{\omega C}\right)^2 + R^2}$

For higher ω, z will be lower so current will be higher

Ans is (C)

Problem 12. An alternating voltage of 220 volt r.m.s. at a frequency of 40 cycles/sec is supplied to a circuit containing a pure inductance of 0.01 H and a pure resistance of 6 ohms in series. Calculate (i) the current, (ii) potential difference across the resistance, (iii) potential difference across the inductance, (iv) the time lag, (v) power factor.

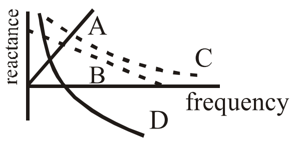
Solution : (i) $z = \sqrt{(\omega L)^2 + R^2} = \sqrt{(2\pi \times 40 \times 0.01^2)^2 + 6^2} = \sqrt{(42.4)}$

$I_{rms} = \frac{220}{z} = 33.83$ amp.

(ii) $V_{rms} = I_{rms} \times R = 202.98$ volts (iii) $\omega L \times I_{rms} = 96.83$ volts

(iv) $t = T\,\frac{\phi}{2\pi} = 0.01579$ sec (v) $\cos\phi = \frac{R}{Z} = 0.92$

Problem 13. Which of the following plots may represnet the reactance of a series LC combination ?



Answer : D

Problem 14. A series AC circuit has resistance of 4 Ω and a reactance of 3 Ω. the impedance of the circuit is

(A) 5 Ω (B) 7 Ω

(C) 12/7 Ω (D) 7/12 Ω

Solution : $Z = \sqrt{4^2 + 3^2} = 5\ \Omega$ **Ans. is (A)**

Exercise # 1

PART - I : SUBJECTIVE QUESTIONS

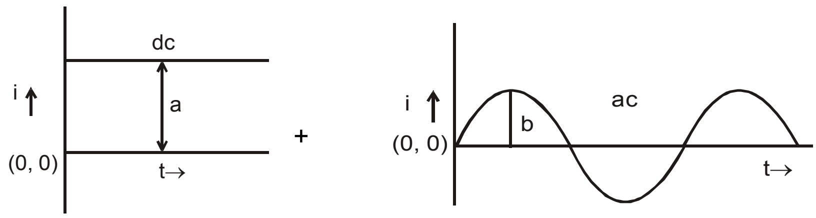
Section (A) : Average, peak and RMS value

A-1. The Equation of current in AC circuit is I = 4sin $\left[100\pi t + \frac{\pi}{3}\right]$A. Calculate.

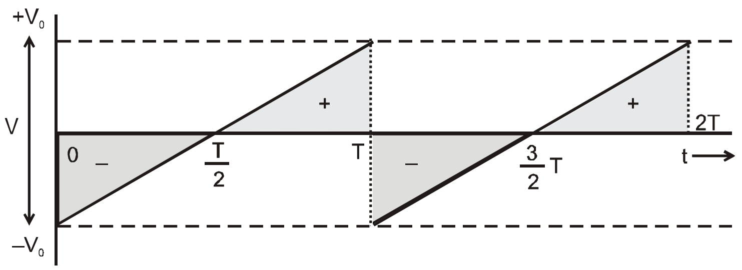
(i) RMS Value (ii) Peak Value (iii) Frequency (iv) Initial phase (v) Current at t = 0

A-2. The household supply of electricity is at 220 V rms value and 50 Hz .Calculate the peak voltage and the minimum possible time in which the voltage can change from the rms value to zero.

A-3. If a direct current of value 'a' ampere is superimposed on an alternating current $I = b \sin \omega t$ flowing through a wire, what is the effective(rms) value of the resulting current in the circuit?



A-4. Find the average for the saw-tooth voltage of peak value V_0 from t=0 to t=2T as shown in figure.



A-5. In a LR circuit discharging current is given by $I = I_0 e^{-t/\tau}$ where τ is the time constant of the circuit find the rms current for the period t = 0 to t = τ.

Section (B) : Power consumed in an ac circuit

B-1. A resistor of resistance 100 Ω is connected to an AC source ε = (12V) sin (250 π s^{-1})t. Find the power consumed by the bulb.

B 2. In an ac circuit the instantaneous values of current and applied voltage are respectively i = 2(Amp) sin (250 π s^{-1})t and ε = (10V) sin [(250 π s^{-1})t + $\frac{\pi}{3}$]. Find the instantaneous power drawn from the source at t = $\frac{2}{3}$ ms and its average value.

B-3. A bulb is designed to operate at 12 volts constant direct current. If this bulb is connected to an alternating current source and gives same brightness. What would be the peak voltage of the source ?

Section (C) : AC source with R, L, C connected in series

C-1. 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 12V, 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 capacitor is connected in series with the coil.

C-2. An electric bulb is designed to consume 55 W when operated at 110 volts. It is connected to a 220 V, 50 Hz line through a choke coil in series. What should be the inductance of the coil for which the bulb gets correct voltage ?

C 3. A resistor, a capacitor and an inductor (R = 300 Ω, C = 20 μF, L = 1.0 henry) are connected in series with an AC source of, E_{rms} = 50 V and $\nu = \frac{50}{\pi}$ Hz. Find (a) the rms current in the circuit and (b) the rms potential differences across the capacitor, the resistor and the inductor.

C-4. An LCR series circuit with 100Ω resistance is connected to an ac source of 200 V and angular frequency 300 rad/s. When only the capacitance is removed, the current lags behind the voltage by 60°. When only the inductance is removed, the current leads the voltage by 60°. Calculate the current and the power dissipated in the LCR circuit.

C-5. A 20 volts 5 watt lamp (lamp to be treated as a resistor) is used on AC mains of 200 volts and $\frac{50}{\pi}\sqrt{11}$ c.p.s. Calculate the (i) capacitance of the capacitor, or inductance of the inductor, to be put in series to run the lamp. (ii) How much pure resistance should be included in place of the above device so that the lamp can run on its rated voltage. (iii) which is more economical (the capacitor, the inductor or the resistor).

C-6. A circuit has a resistance of 50 ohms and an inductance of $\frac{3}{\pi}$ henry. It is connected in series with a condenser of $\frac{40}{\pi}$ μF and AC supply voltage of 200 V and 50 cycles/sec. Calculate

(i) the impedance of the circuit,

(ii) the p.d. across inductor coil and condenser.

(iii) Power factor

C-7. In an L-R series A.C circuit the potential difference across an inductance and resistance joined in series are respectively 12 V and 16V. Find the total potential difference across the circuit.

C-8. An inductor 2/π Henry, a capacitor 100/π μF and a resistor 75 Ω are connected in series across a source of emf $V = 10 \sin 100\pi t$. Here t is in second. (a) find the impedance of the circuit.(b) find the energy dissipated in the circuit in 20 minutes.

SECTION (D) : RESONANCE

D-1. A series LCR circuit containing a resistance of 120Ω 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. Find the values of L and C. At what frequency the current in the circuit lags the voltage by 45°?

D-2. A series circuit consists of a resistance, inductance and capacitance. The applied voltage and the current at any instant are given by

$$E = 141.4 \cos (5000\, t - 10^\circ)$$

and $$I = 5 \cos (5000\, t - 370^\circ)$$

The inductance is 0.01 henry. Calculate the value of capacitance and resistance.

D-3. An electro magnetic wave of wavelength 300 metre can be transmitted by a transmission centre. A condenser of capacity 2.5 μF is available. Calculate the inductance of the required coil for a resonant circuit. Use $\pi^2 = 10$.

D-4. An inductance of 2.0 H, a capacitance of 18 μF and a resistance of 10 kΩ are connected to an AC source of 20 V with adjustable frequency (a) What frequency should be chosen to maximise the current(RMS) in the circuit? (b) What is the value of this maximum current (RMS) ?

Section (E) : Transformer

E-1. In a transformer ratio of secondary turns (N_2) and primary turns (N_1) i.e. $\frac{N_2}{N_1} = 4$. If the voltage applied in primary is 200 V, 50 Hz, find (a) voltage induced in secondary (b) If current in primary is 1A, find the current in secondary if the transformer is (i) ideal and (ii) 80% efficient and there is no flux leakage.

E-2. A transformer has 50 turns in the primary and 100 turns in the secondary. If the primary is connected to a 220 V DC supply, what will be the voltage across the secondary ?

PART - II : OBJECTIVE QUESTIONS

*** Marked Questions may have more than one correct option.**

Section (A) : Average, peak and RMS values and RMS values

A-1. In an ac circuit, the instantaneous voltage e(t) and current I(t) are given by $e(t) = 5[\cos \omega t + \sqrt{3} \sin \omega t]$ volt

$i(t) = 5\left[\sin\left(\omega t + \frac{\pi}{4}\right)\right]$ amp then:

(A) Current leads voltage by $\frac{\pi}{4}$

(B) Voltage leads current by $\frac{\pi}{3}$

(C) Voltage leads current by $\frac{\pi}{6}$

(D) Current leads voltage by $\frac{\pi}{12}$

A-2. The voltage of an AC source varies with time according to the equation, $V = 100 \sin 100\pi t \cos 100\pi t$. Where t is in second and V is in volt. Then :

(A) the peak voltage of the source is 100 volt

(B) the peak voltage of the source is $(100/\sqrt{2})$ volt

(C) the peak voltage of the source is 50 volt

(D) the frequency of the source is 50 Hz

A-3. An alternating voltage is given by : $e = e_1 \sin \omega t + e_2 \cos \omega t$. Then the root mean square value of voltage is given by :

(A) $\sqrt{e_1^2 + e_2^2}$

(B) $\sqrt{e_1 e_2}$

(C) $\sqrt{\frac{e_1 e_2}{2}}$

(D) $\sqrt{\frac{e_1^2 + e_2^2}{2}}$

A-4. The RMS value of current i = 2 sin 100 π t + 2 sin(100 π t + 30°) is :

(A) $\sqrt{2}$ A (B) $2\sqrt{2+\sqrt{3}}$ (C) 4 (D) None

A-5. An AC voltage of V = $220\sqrt{2}$ sin $\left(100\pi t + \frac{\pi}{2}\right)$ is applied across a DC voltmeter, its reading will be:

(A) $220\sqrt{2}$ V (B) $\sqrt{2}$ V (C) 220 V (D) zero

Section (B) : Power consumed in an AC circuit

B-1. Energy dissipates in LCR circuit in :

(A) L only (B) C only (C) R only (D) all of these

B-2. The potential difference V across and the current I flowing through an instrument in an AC circuit are given by :

V = 5 cos ωt volt

I = 2 sin ωt Amp.

The power dissipated in the instrument is :

(A) zero (B) 5 watt (C) 10 watt (D) 2.5 watt

B-3. A direct current of 2 A and an alternating current having a maximum value of 2 A flow through two identical resistances. The ratio of heat produced in the two resistances in the same time interval will be:

(A) 1 : 1 (B) 1 : 2 (C) 2 : 1 (D) 4 : 1

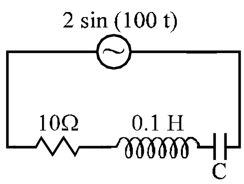
B-4. What is the rms value of an alternating current which when passed through a resistor produces heat, which is thrice that produced by a D.C. current of 2 ampere in the same resistor in the same time interval?

(A) 6 ampere (B) 2 ampere (C) $2\sqrt{3}$ ampere (D) 0.65 ampere

B-5. A resistor and a capacitor are connected to an AC supply of 200 volt, 50 Hz in series. The current in the circuit is 2 ampere. If the power consumed in the circuit is 100 watt, then the resistance in the circuit is:

(A) 100 Ω (B) 25 Ω (C) $\sqrt{125 \times 75}$ Ω (D) 400 Ω

B-6. The power factor of the circuit is $1/\sqrt{2}$. The capacitance of the circuit is equal to



(A) 400 μF (B) 300 μF

(C) 500 μF (D) 200 μF

B-7. An electric bulb and a capacitor are connected in series with an AC source. On increasing the frequency of the source, the brightness of the bulb :

(A) increase (B) decreases

(C) remains unchanged (D) sometimes increases and sometimes decreases

B-8.* Average power consumed in an A.C. series circuit is given by (symbols have their usual meaning) :

(A) $E_{rms} I_{rms} \cos\phi$ (B) $(I_{rms})^2 R$ (C) $\frac{E_{max}{}^2 R}{2(|z|)^2}$ (D) $\frac{I_{max}{}^2 |z| \cos\phi}{2}$

B-9. If the frequency of the source e.m.f. in an AC circuit is n, the power varies with a frequency :

(A) n (B) 2n (C) n/2 (D) zero

Section (C) : AC source with R, L, C connected in series

C-1. A 0.21-H inductor and a 88-Ω resistor are connected in series to a 220-V, 50-Hz AC source. The current in the circuit and the phase angle between the current and the source voltage are respectively.
(Use $\pi = 22/7$)

(A) 2 A, $\tan^{-1} 3/4$ (B) 14.4 A, $\tan^{-1} 7/8$ (C) 14.4 A, $\tan^{-1} 8/7$ (D) 3.28 A, $\tan^{-1} 2/11$

C-2. An LCR series circuit with 100 Ω resistance is connected to an AC source of 200 V and angular frequency 300 radians per second. When only the capacitance is removed, the current lags the voltage by 60°. When only the inductance is removed, the current leads the voltage by 60°. Then the current and power dissipated in LCR circuit are respectively

(A) 1A, 200 watt. (B) 1A, 400 watt. (C) 2A, 200 watt. (D) 2A, 400 watt.

C-3.* In an AC series circuit when the instantaneous source voltage is maximum, the instantaneous current is zero. Connected to the source may be a

(A) pure capacitor

(B) pure inductor

(C) combination of pure an inductor and pure capacitor

(D) pure resistor

C-4. In an L-R series circuit ($L = \frac{175}{11}$ mH and R = 12Ω), a variable emf source ($V = V_0 \sin \omega t$) of $V_{rms} = 130\sqrt{2}$ V and frequency 50 Hz is applied. The current amplitude in the circuit and phase of current with respect to voltage are respectively(Use $\pi = 22/7$)

(A) 14.14A, 30° (B) $10\sqrt{2}$ A, $\tan^{-1}\frac{5}{12}$ (C) 10 A, $\tan^{-1}\frac{5}{12}$ (D) 20 A, $\tan^{-1}\frac{5}{12}$

C-5. In an AC circuit, a resistance of R ohm is connected in series with an inductance L. If phase angle between voltage and current be 45°, the value of inductive reactance will be.

(A) R/4 (B) R/2

(C) R (D) cannot be found with the given data

C-6. In an AC circuit the potential differences across an inductor and resistor joined in series are respectively 16 V and 20 V. The total potential difference across the circuit is

(A) 20 V (B) 25.6 V (C) 31.9 V (D) 53.5 V

C-7. An AC voltage source $V = 200\sqrt{2} \sin 100\, t$ is connected across a circuit containing an AC ammeter(it reads rms value) and capacitor of capacity 1 μF. The reading of ammeter is :

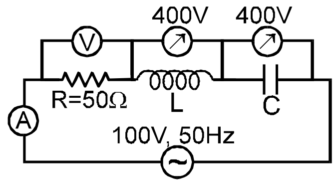
(A) 10 mA (B) 20 mA (C) 40 mA (D) 80 mA

C-8. If in a series LCR AC circuit, the rms voltage across L, C and R are V_1, V_2 and V_3 respectively, then the voltage of the source is always :

(A) equal to $V_1 + V_2 + V_3$ (B) equal to $V_1 - V_2 + V_3$

(C) more than $V_1 + V_2 + V_3$ (D) none of these is true

C-9. In the series LCR circuit as shown in figure, the voltmeter and ammeter readings are :



(A) V = 100 volt, I = 2 amp (B) V = 100 volt, I = 5 amp

(C) V = 1000 volt, I = 2 amp (D) V = 300 volt, I = 1 amp

Section (D) : Resonance

D-1*. Power factor may be equal to 1 for :

(A) pure inductor (B) pure capacitor (C) pure resistor (D) An LCR circuit

D-2. In a series R-L-C circuit, the frequency of the source is half of the resonance frequency. The nature of the circuit will be

(A) capacitive (B) inductive (C) purely resistive (D) data insufficient

D-3. A series LCR circuit containing a resistance of 120 ohm has angular resonance frequency 4×10^3 rad s^{-1}. At resonance, the voltage across resistance and inductance are 60V and 40 V respectively. The values of L and C are respectively :

(A) 20 mH, 25/8 μF (B) 2mH, 1/35 μF (C) 20 mH, 1/40 μF (D) 2mH, 25/8 nF

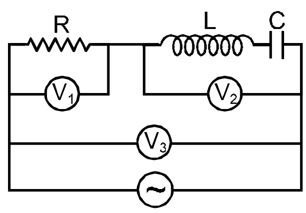
D-4. In an LCR circuit, the capacitance is made one-fourth, when in resonance. Then what should be the change in inductance, so that the circuit remains in resonance ?

(A) 4 times (B) 1/4 times (C) 8 times (D) 2 times

D-5. A resistor R, an inductor L and a capacitor C are connected in series to an oscillator of frequency υ. If the resonant frequency is υ_r, then the current lags behind voltage, when :

(A) $\upsilon = 0$ (B) $\upsilon < \upsilon_r$ (C) $\upsilon = \upsilon_r$ (D) $\upsilon > \upsilon_r$

D-6. A resistor R, an inductor L, a capacitor C and voltmeters V_1, V_2 and V_3 are connected to an oscillator in the circuit as shown in the adjoining diagram. When the frequency of the oscillator is increased, upto resonance frequency, the voltmeter reading (at resonance frequency) is zero in the case of :



(A) voltmeter V_1 (B) voltmeter V_2

(C) voltmeter V_3 (D) all the three voltmeters

Section (E) : Transformer

E-1. An ideal efficient transformer has a primary power input of 10kW. The secondary current when the transformer is on load is 25A. If the primary : secondary turns ratio is 8 : 1, then the potential difference applied to the primary coil is

(A) $\frac{10^4 \times 8^2}{25}$V (B) $\frac{10^4 \times 8}{25}$V (C) $\frac{10^4}{25 \times 8}$V (D) $\frac{10^4}{25 \times 8^2}$V

E-2. A transformer is used to light a 140 watt, 24 volt lamp from 240 V AC mains. The current in the main cable is 0.7 amp. The efficiency of the transformer is :

(A) 48% (B) 63.8% (C) 83.3% (D) 90%

E-3. In a step-up transformer the voltage in the primary is 220 V and the current is 5A. The secondary voltage is found to be 22000 V. The current in the secondary (neglect losses) is

(A) 5 A (B) 50 A (C) 500 A (D) 0.05 A

E-4. 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 current

Section (F) : Miscellaneous

F 1. A capacitor is a perfect insulator for :

(A) constant direct current (B) alternating current

(C) direct as well as alternating current (D) variable direct current

F 2. A choke coil sould have :

(A) high inductance and high resistance (B) low inductance and low resistance

(C) high inductance and low resistance (D) low inductance and high resistance

F 3. A choke coil is preferred to a rheostat in AC circuit as :

(A) it consumes almost zero power (B) it increases current

(C) it increases power (D) it increases voltage

F-4. In ac circuit when ac ammeter is connected it reads i current. If a student uses dc ammeter in place of ac ammeter the reading in the dc ammeter will be:

(A) $\frac{i}{\sqrt{2}}$ (B) $\sqrt{2}$ i (C) 0.637 i (D) zero

F-5. An AC ammeter is used to measure current in a circuit. When a given direct constant current passes through the circuit, the AC ammeter reads 3 ampere. When an alternating current passes through the circuit, the AC ammeter reads 4 ampere. Then the reading of this ammeter if DC and AC flow through the circuit simultaneously, is :

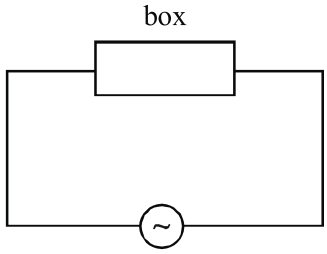
(A) 3 A (B) 4 A (C) 7 A (D) 5 A

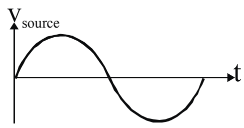
F 6. In an a.c. circuit consisting of resistance R and inductance L, the voltage across R is 60 volt and that across L is 80 volt. The total voltage across the combination is

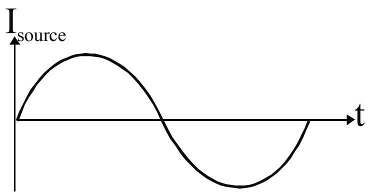
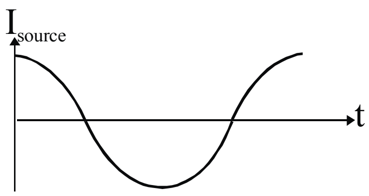
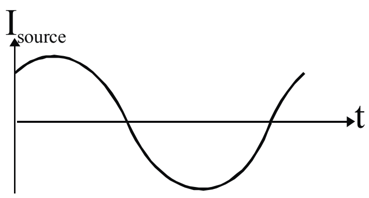
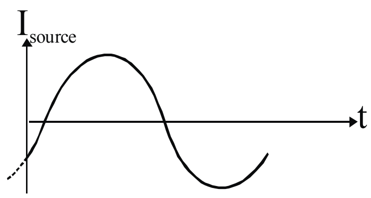
(A) 140 V (B) 20 V (C) 100 V (D) 70 V

PART - III : MATCH THE COLUMN

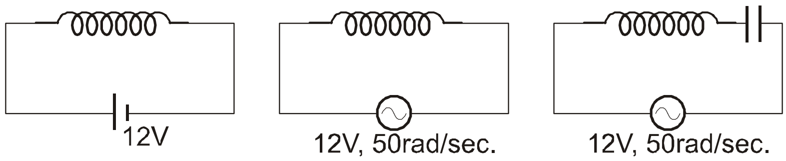
1. Box may have any series combination of L, C and R. Column-I represents source current and column-II represents possible statements.





Column I		**Column II**	
(A)		(P)	Box may contain LCR.
(B)		(Q)	Box may contain only LR.
(C)		(R)	Power factor of box is zero.
(D)		(S)	Box may contain only CR.
		(T)	State of resonance.

2. A steady current 4 A flows in an inductor coil when connected to a 12 V dc source as shown in figure 1. If the same coil is connected to an ac source of 12 V, 50 rad/s, a current of 2.4 A flows in the circuit as shown in figure 2. Now after these observations, a capacitor of capacitance $\frac{1}{50}$F is connected in series with the coil as shown in figure 3 with the same AC source :



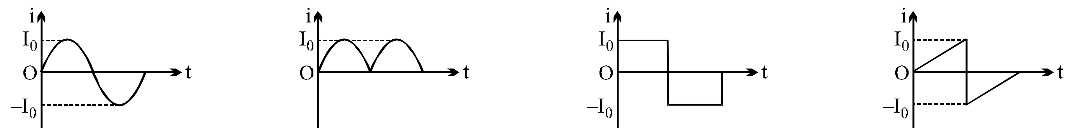
(Figure 1) (Figure 2) (Figure 3)

	Column-I	**Column-II (in S.I units)**
(A)	The inductance of the coil (nearly)	(p) 24
(B)	The resistance of the coil	(q) 3
(C)	Average power (nearly)	(r) 0.08
(D)	Total reactance	

Exercise # 2

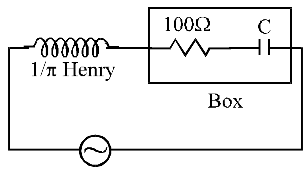
PART - I : ONLY ONE OPTION CORRECT TYPE

1. If I_1, I_2, I_3 and I_4 are the respective r.m.s. values of the time varying currents as shown in the four cases I, II, III and IV. Then identify the correct relations.



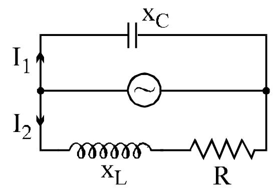
(A) $I_1 = I_2 = I_3 = I_4$ (B) $I_3 > I_1 = I_2 > I_4$ (C) $I_3 > I_4 > I_2 = I_1$ (D) $I_3 > I_2 > I_1 > I_4$

2. In the circuit, as shown in the figure, if the value of R.M.S current is 2.2 ampere, the power factor of the box is



(A) $\frac{1}{\sqrt{2}}$ (B) 1 (C) $\frac{\sqrt{3}}{2}$ (D) $\frac{1}{2}$

3. In the shown AC circuit phase difference between currents I_1 and I_2 is



(A) $\frac{\pi}{2} - \tan^{-1}\frac{x_L}{R}$ (B) $\tan^{-1}\frac{x_L - x_C}{R}$

(C) $\frac{\pi}{2} + \tan^{-1}\frac{x_L}{R}$ (D) $\tan^{-1}\frac{x_L - x_C}{R} + \frac{\pi}{2}$

4. The current in a circuit containing a capacitance C and a resistance R in series leads over the applied voltage of frequency $\frac{\omega}{2\pi}$ by. **[REE - 1991]**

(A) $\tan^{-1}\left(\frac{1}{\omega CR}\right)$ (B) $\tan^{-1}(\omega CR)$ (C) $\tan^{-1}\left(\omega\frac{1}{R}\right)$ (D) $\cos^{-1}(\omega CR)$

5. In a circuit, an inductance of 0.1 Henry and a resistance of 1Ω are connected in series with an AC source of voltage V = 5 sin 10 t. The phase difference between the current and applied voltage will be **[REE - 1996]**

(A) π (B) 2π (C) $\pi/4$ (D) 0

6. An alternating EMF of angular frequency ω is applied across an inductance. The instantaneous power developed in the circuit has an angular frequency. **[REE - 1999]**

(A) $\frac{\omega}{4}$ (B) $\frac{\omega}{2}$ (C) ω (D) 2ω

7. A bulb and a capacitor are connected in series to a source of alternating current. If its frequency is increased, while keeping the voltage of the source constant, then. **[REE - 1999]**

(A) bulb will give more intense light

(B) bulb will give less intense light

(C) bulb will give light of same intensity as before

(D) bulb will stop radiating light

8. A coil has an inductance of $\frac{2.2}{\pi}$ H and is joined in series with a resistance of 220 Ω. When an alternating e.m.f. of 220 V at 50 c.p.s. is applied to it, then the wattless component of the rms current in the circuit is

(A) 5 ampere (B) 0.5 ampere (C) 0.7 ampere (D) 7 ampere

9. The overall efficiency of a transformer is 90%. The transformer is rated for an output of 9000 watt. The primary voltage is 1000 volt. The ratio of turns in the primary to the secondary coil is 5 : 1. The iron losses at full load are 700 watt. The primary coil has a resistance of 1 ohm.

(i) The voltage in secondary coil is :

(A) 1000 volt (B) 5000 volt (C) 200 volt (D) zero volt

(ii) In the above, the current in the primary coil is :

(A) 9 amp (B) 10 amp (C) 1 amp (D) 4.5 amp

(iii) In the above, the copper loss in the primary coil is :

(A) 100 watt (B) 700 watt (C) 200 watt (D) 1000 watt

(iv) In the above, the copper loss in the secondary coil is :

(A) 100 watt (B) 700 watt (C) 200 watt (D) 1000 watt

(v) In the above, the current in the secondary coil is :

(A) 45 amp (B) 46 amp (C) 10 amp (D) 50 amp

(vi) In the above, the resistance of the secondary coil is approximately :

(A) 0.01 Ω (B) 0.1 Ω (C) 0.2 Ω (D) 0.4 Ω

PART - II : INTEGER TYPE QUESTION

1. A circuit containing a 0.1 H inductor and a 500 μF capacitor in series is connected to a 230 volt, 100/π Hz supply. The resistance of the circuit is negligible. (a) Obtain the rms value of current (in A). (b) Obtain the rms values of potential (in V) drops across each element. (c) What is the average power transferred to the inductor? (d) What is the average power transferred to the capacitor? (e) What is the total average power absorbed by the circuit? ['Average' implies average over one cycle.]

2. An LCR circuit has L = 10 mH, R = 150 Ω and C = 1 μF connected in series to a source of 150 $\sqrt{2}$ cos ωt volt. At a frequency that is 50% of the resonant frequency, calculate

(a) the net reactance of the circuit (in Ω).

(b) the current amplitude (in A).

(c) the average power dissipated per cycle (in watt)

3. A 2000 Hz, 20 volt source is connected to a resistance of 20 ohm, an inductance of 0.125/π H and a capacitance of 500/π nF all in series. Calculate the time (in sec.) in which the resistance (thermal capacity = 100 joule/ºC) will get heated by 10º C. (Assume no loss of heat)

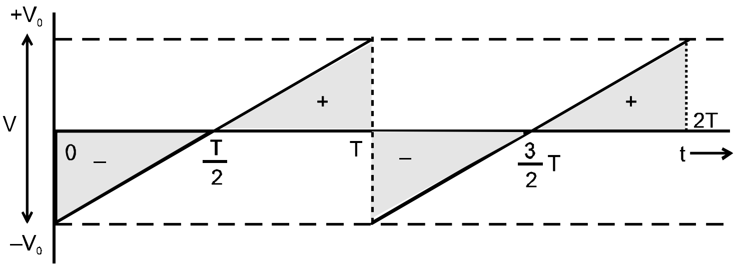
4._ In a series LCR circuit with an ac source of 50 V, R = 300Ω, frequency $\nu = \frac{50}{\pi}$ Hz. The average electric field energy, stored in the capacitor and average magnetic energy stored in the coil are 25 mJ and 5 mJ respectively. The RMS current in the circuit is 0.10 A. Then find:

(a) Capacitance (c) of capacitor

(b) Inductance (L) of inductor.

(c) The sum of rms potential difference across the three elements.

5. Find the rms value for the saw-tooth voltage of peak value V_0 from t=0 to t=2T as shown in figure is $\frac{V_0}{\sqrt{x}}$. Find value of x?



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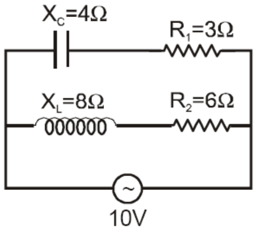
6. In the figure shown an ideal alternative current (A.C.) source of 10 Volt is connected. Find half of the total average power (in watts) given by the cell to the circuit.



PART - III : ONE OR MORE THAN ONE CORRECT OPTIONS

1.* An AC source supplies a current of 10 A (rms) to a circuit, rms voltage of source is 100 V. The average power delivered by the source :

(A) must be 1000 W
(B) may be less than 1000 W
(C) may be greater than 1000 W
(D) may be 1000 W

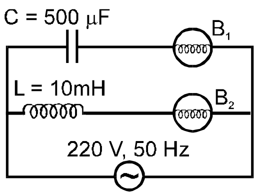
2.* Which of the following quantities have zero average value over a cycle. If an inductor coil having some resistance is connected to a sinusoidal AC source.

(A) induced emf in the inductor
(B) current
(C) joule heat
(D) magnetic energy stored in the inductor

3.* In a series LCR circuit with an AC source (E_{rms} = 50 V and $\nu = 50/\pi$ Hz), R = 300 Ω, C = 0.02 mF, L = 1.0 H, Which of the following is correct

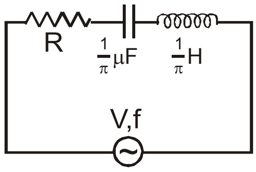
(A) the rms current in the circuit is 0.1 A
(B) the rms potential difference across the capacitor is 50 V
(C) the rms potential difference across the capacitor is 14.1 V
(D) the rms current in the circuit is 0.14 A

4.* In the circuit shown in 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 the brightness of bulb B_1 will increase and that of B_2 will decrease.
(D) only B_2 will glow because the capacitor has infinite impedance

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



(A) has a current I given by $I = \frac{V}{R}$
(B) has a resonance frequency 500 Hz
(C) has a voltage across the capacitor which is 180^0 out of phase with that across the inductor
(D) has a current given by $I = \frac{V}{\sqrt{R^2 + \left(\frac{1}{\pi} + \frac{1}{\pi}\right)^2}}$

6.* A circuit is set up by connecting L = 100 mH, C = 5 μF and R =100 Ω in series. An alternating emf of $(150\sqrt{2})$ volt, $\frac{500}{\pi}$ Hz is applied across this series combination. Which of the following is correct

(A) the impedance of the circuit is 141.4 Ω

(B) the average power dissipated across resistance 225 W

(C) the average power dissipated across inductor is zero.

(D) the average power dissipated across capacitor is zero.

7.* A coil of inductance 5.0 mH and negligible resistance is connected to an oscillator giving an output voltage E = (10V) sin ωt. Which of the following is correct

(A) for ω = 100 s^{-1} peak current is 20 A (B) for ω = 500 s^{-1} peak current is 4 A

(C) for ω = 1000 s^{-1} peak current is 2 A (D) for ω = 1000 s^{-1} peak current is 4 A

8.* In a series RC circuit with an AC source(peak voltage E_0 = 50 V and f = 50 /π Hz), R = 300 Ω, C = 25 μF. Then :

(A) the peak current is 0.1 A (B) the peak current is 0.7 A

(C) the average power dissipated is 1.5 W (D) the average power dissipated is 3 W

9.* 11 kW of electric power can be transmitted to a distant station at (i) 220 V or (ii) 22000 V. Which of the following is correct

(A) first mode of transmission consumes less power

(B) second mode of transmission consumes less power

(C) first mode of transmission draws less current

(D) second mode of transmission draws less current.

10.* A town situated 20 km away from a power house at 440 V, requires 600 KW of electric power at 220 V. The resistance of transmission line carrying power is 0.4 Ω per km. The town gets power from the line through a 3000 V–220 V step-down transformer at a substation in the town. Which of the following is/are correct

(A) The loss in the form of heat is 640 kW (B) The loss in the form of heat is 1240 kW

(C) Plant should supply 1240 kW (D) Plant should supply 640 kW

11.* In an AC circuit, the power factor - **[REE - 2000]**

(A) is zero when the circuit contains an ideal resistance only

(B) is unity when the circuit contains an ideal resistance only

(C) is zero when the circuit contains an ideal inductance only

(D) is unity when the circuit contains an ideal inductance only

12.* An inductive reactance, X_L = 100 Ω, a capacitive reactance, X_C = 100 Ω, and a resistance R = 100 Ω, are connected in series with a source of 100 sin (50 t) volts. Which of the following statements are correct? **[REE - 1996]**

(A) The maximum voltage across the capacitor is 100 V.

(B) The net impedance of the circuit is 100 Ω.

(C) The maximum voltage across the inductance is 100 V.

(D) The maximum voltage across the series is 100 V.

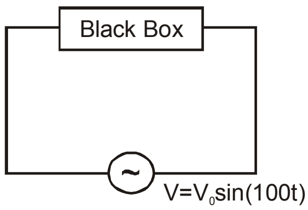
13. In a series R-C circuit the supply voltage (Vs) is kept constant at 2V and the frequency f of the sinusoidal voltage is varied from 500 Hz to 2000 Hz. The voltage across the resistance R = 1000 ohm is measured each time as V_R. For the determination of the C a student wants to draw a linear graph and try to get C from the slope. Then she may draw a graph of **[Olympiad (Stage-1) 2017]**

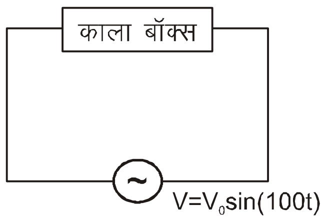
(A) f^2 against V_R^2 (B) $\frac{1}{f^2}$ against $\frac{V_S^2}{V_R^2}$ (C) $\frac{1}{f^2}$ against $\frac{1}{V_R^2}$ (D) f against $\frac{V_R}{\sqrt{V_S^2 - V_R^2}}$

PART - IV : COMPREHENSION

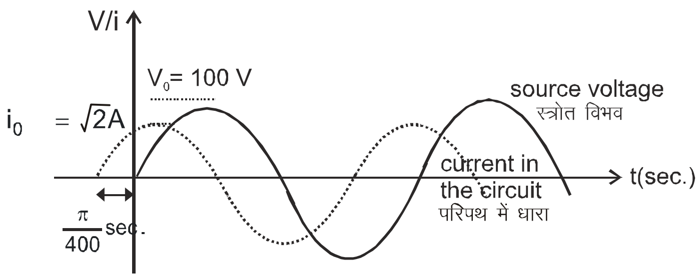
COMPREHENSION - 1

A voltage source V = V_0 sin (100 t) is connected to a black box in which there can be either one element out of L, C, R or any two of them connected in series.





At steady state. the variation of current in the circuit and the source voltage are plotted together with time, using an oscilloscope, as shown



1. The element(s) present in black box is/are :

(A) only C (B) L and C (C) L and R (D) R and C

2. Values of the parameters of the elements, present in the black box are -

(A) $R = 50\Omega$, $C = 200\ \mu f$ (B) $R = 50\Omega$, $L = 2m\mu$

(C) $R = 400\ \Omega$, $C = 50\ \mu\ f$ (D) None of these

3. If AC source is removed, the circuit is shorted for some time so that capacitor is fully discharged and then a battery of constant EMF is connected across the black box, at $t = 0$. The current in the circuit will -

(A) increase exponentially with time constant = 0.02 sec.

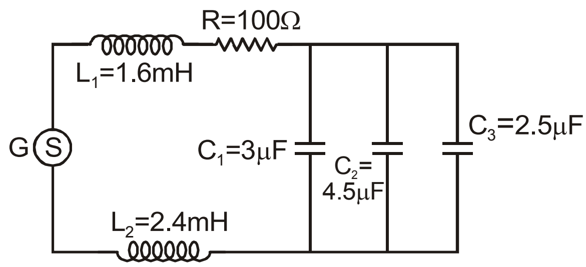
(B) decrease exponentially with time constant = 0.01 sec.

(C) oscillate with angular frequency 20 rad/sec

(D) first increase and then decrease

Comprehension-2

An ac generator G with an adjustable frequency of oscillation is used in the circuit, as shown.



4. Current drawn from the ac source will be maximum if its angular frequency is -

(A) 10^5 rad/s (B) 10^4 rad/s (C) 5000 rad/s (D) 500 rad/s

5. To increase resonant frequency of the circuit, some of the changes in the circuit are carried out. Which change(s) would certainly result in the increase in resonant frequency ?

(A) R is increased.

(B) L_1 is increased and C_1 is decreased.

(C) L_2 is decreased and C_2 is increased.

(D) C_3 is removed from the circuit.

6. If the ac source G is of 100 V rating at resonant frequency of the circuit, then average power supplied by the source is -

(A) 50 W (B) 100 W (C) 500 W (D) 1000 W

7. Average energy stored by the inductor L_2 (Source is at resonance frequency) is equal to

(A) zero (B) 1.2 mJ (C) 2.4 mJ (D) 4 mJ

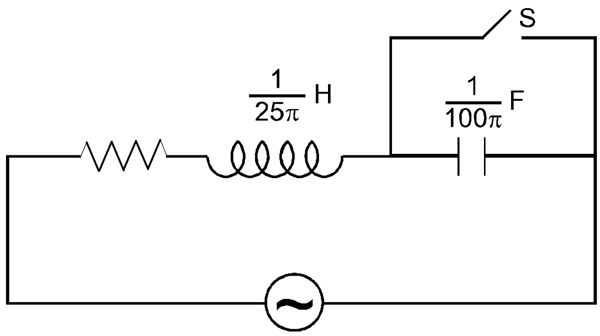
8. Thermal energy produced by the resistance R in time duration 1 μs, using the source at resonant condition, is

(A) 0 J (B) 1 μJ

(C) 100 μJ (D) not possible to calculate from the given information

Comprehension-3

In the LCR circuit shown in figure unknown resistance and alternating voltage source are connected. When switch 'S' is closed then there is a phase difference of $\frac{\pi}{4}$ between current and applied voltage and voltage accross resister is $\frac{100}{\sqrt{2}}$ V. When switch is open current and applied voltage are in same phase. Neglecting resistance of connecting wire answer the following questions :



9. Peak voltage of applied voltage sources is :

(A) $200\sqrt{2}$ V

(B) 100 V

(C) $100\sqrt{2}$ V

(D) $\frac{100}{\sqrt{2}}$ V

10. Resonance frequency of circuit is :

(A) 50 Hz

(B) 25 Hz

(C) 75 Hz

(D) Data insufficient for caculation

11. Average power consumption in the circuit when 'S' is open :

(A) 2500 W

(B) 3000 W

(C) 5000 W

(D) 1250 W

Exercise # 3

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

*** Marked Questions may have more than one correct option.**

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

[JEE 2010; 3/163, –1]

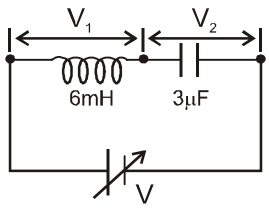
(A) the bulb glows dimmer (B) the bulb glows brighter

(C) total impedence of the circuit is unchanged (D) total impedence of the circuit increases

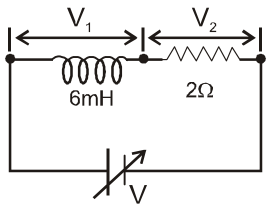
2. You are given many resistances, capacitors and inductors. These are connected to a variable DC voltage source (the first two circuits) or an AC voltage source of 50 Hz frequency (the next three circuits) in different ways as shown in **Column II.** When a current I (steady state for DC or rms for AC) flows through the circuit, the corresponding voltage V_1 and V_2. (indicated in circuits) are related as shown in **Column I.** Match the two column. **[JEE 2010; 8/163]**

Column I **Column II**

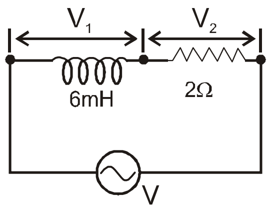
(A) $I \neq 0, V_1$ is proportional to I

(p) 

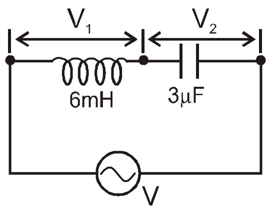
(B) $I \neq 0, V_2 > V_1$

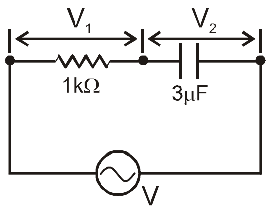
(q) 

(C) $V_1 = 0$, $V_2 = V$

(r) 

(D) $I \neq 0, V_2$ is proportional to I

(s) 

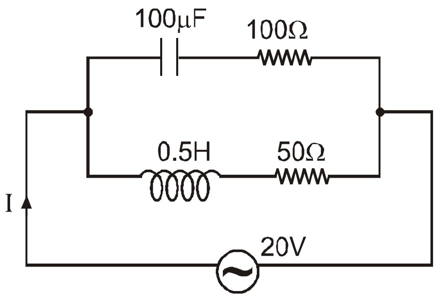
(t) 

3. 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 $\mathbf{I_R}$ through the resistor and voltage V_C across the capacitor are compared in the two cases. Which of the following is/are true? **[JEE 2011; 4/160]**

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

4. 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 **[JEE 2011; 4/160]**

5. 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) **[IIT-JEE-2012, Paper-2; 4/66]**



(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 100Ω resistor = $10\sqrt{2}$ V (D) The voltage across 50Ω resistor = 10V

Paragraph for Questions 6 and 7

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 transformers 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. **[JEE (Advanced)-2013]**

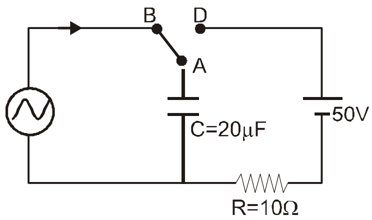
6. If the direct transmission method with a cable of resistance 0.4 Ω km^{-1} is used, the power dissipation (in %) during transmission is :

(A) 20 (B) 30 (C) 40 (D) 50

7. 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 200V, 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

8. At time t = 0, terminal A in the circuit shown in the figure is connected to B by a key and alternating current $I(t) = I_0\cos(\omega t,)$, with I_0 = 1A and ω = 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 on ly A and D are connected. A total charge Q flows from the battery to charge the capacitor fully. If C = 20μ, R = 10Ω and the battery is ideal with emf of 50V, identify the correct statement (s) **[JEE (Advanced)-2014,P-1, 3/60]**



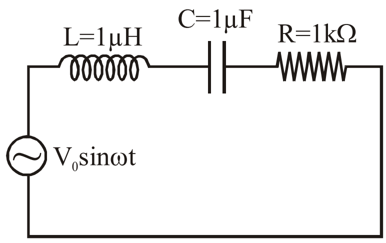
(A) Magnitude of the maximum charge on the capacitor before $t = \frac{7\pi}{6\omega}$ is 1×10^{-3} C.

(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 = 2×10^{-3} C.

9. In the circuit shown, L = 1 μH, C = 1 μF and R = 1 kΩ. They are connected in series with an a.c. source $V = V_0 \sin \omega t$ as shown. Which of the following options is/are correct ? **[JEE Advance-2017]**



(A) The frequency at which the current will be in phase with the voltage is independent of R.

(B) At $\omega \sim 0$ the current flowing through the circuit becomes nearly zero

(C) At $\omega >> 10^6$ rad.s^{-1}, the circuit behaves like a capacitor.

(D) The current will be in phase with the voltage if $\omega = 10^4$ rad.s^{-1}.

10. The instantaneous voltages at three terminals marked X, Y and Z are given by

$$V_X = V_0 \sin \omega t$$

$$V_Y = V_0 \sin\left(\omega t + \frac{2\pi}{3}\right) \text{ and}$$

$$V_Z = V_0 \sin\left(\omega t + \frac{4\pi}{3}\right)$$

An ideal voltmeter is configured to read rms value of the potential difference between its terminals. It is connected between points X and Y and then between Y and Z. The reading(s) of the voltmeter will be:- **[JEE(Advanced) 2017]**

(A) $V_{XY}^{rms} = V_0$

(B) $V_{YZ}^{rms} = V_0\sqrt{\frac{1}{2}}$

(C) Independent of the choice of the two terminals

(D) $V_{XY}^{rms} = V_0\sqrt{\frac{3}{2}}$

PART - II : JEE(MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

1. In a series LCR circuit R = 200 Ω 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 30º. On taking out the inductor from the circuit the current leads the voltage by 30º. The power dissipated in the LCR circuit is **[AIEEE 2010; 4/144, –1]**

(1) 305 W (2) 210 W (3) 0 W (4) 242 W

2. An arc lamp requires a direct current of 10A at 80V to function. If it is connected to a 220V (rms), 50Hz AC supply, the series inductor needed for it to work is close to :- **[JEE(Main) 2016; 4/120, –1]**

(1) 0.065 H (2) 80 H (3) 0.08 H (4) 0.044 H

3. For an RLC circuit driven with voltage of amplitude v_m and frequency $w_0 = \frac{1}{\sqrt{LC}}$ the current exhibits resonance. The quality factor, Q is given by : **[JEE(Main) 2018; 4/120, –1]**

(1) $\frac{\omega_0 R}{L}$ (2) $\frac{R}{(\omega_0 C)}$ (3) $\frac{CR}{\omega_0}$ (4) $\frac{\omega_0 L}{R}$

4. In an a. c. circuit, the instantaneous e.m.f. and current are given by **[JEE(Main) 2018; 4/120, –1]**

e = 100 sin 30 t

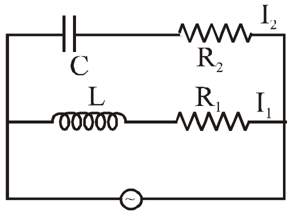
$$i = 20 \sin\left(30t - \frac{\pi}{4}\right)$$

In one cycle of a.c., the average power consumed by the circuit and the wattless current are, respectively.

(1) $\frac{1000}{\sqrt{2}}$, 10 (2) $\frac{50}{\sqrt{2}}$, 0 (3) 50, 0 (4) 50, 10

5. A power transmission line feeds input power at 2300 V to a step down transformer with its primary windings having 4000 turns. The output power is delivered at 230 V bv the transformer. If the current in the primary of the transformer is 5A and its efficiency is 90%, the output current would be :**[JEE(Main) 2019 Jan.; 4/120, –1]**

(1) 25 A (2) 50 A (3) 35 A (4) 45 A

6. 

In the above circuit, $C = \frac{\sqrt{3}}{2}\mu F$, $R_2 = 20\Omega$, $L = \frac{\sqrt{3}}{10}$ H and $R_1 = 10\Omega$. Current in L-R_1 path is I_1 and in C-R_2 path it is I_2. The voltage of A.C source is given by V= $200\sqrt{2}\sin(100t)$ volts. The phase difference between I_1 and I_2 is : **[JEE-Main 2019 Jan.; 4/120, –1]**

(1) 30° (2) 0° (3) 90° (4) 60°

7. A circuit connected to an ac source of emf $e = e_0\sin(100t)$ with t in seconds, gives a phase difference of $\frac{\pi}{4}$ between the emf e and current i. Which of the following circuits will exhibit this ?

[JEE(Main) 2019 April; 4/120, –1]

(1) RC circuit with R = 1 kΩ and C = 1μF

(2) RL circuit with R = 1kΩ and L = 1mH

(3) RL circuit with R = 1 kΩ and L = 10 mH

(4) RC circuit with R = 1kΩ and C = 10 μF

8. A LCR circuit behaves like a damped harmonic oscillator. Comparing it with a physical spring-mass damped oscillator having damping constant 'b', the correct equivalence would be:

[JEE(Main) 2020 Jan; 4/100, –1]

(1) $L \leftrightarrow m, C \leftrightarrow \frac{1}{k}, R \leftrightarrow b$ (2) $L \leftrightarrow \frac{1}{b}, C \leftrightarrow \frac{1}{m}, R \leftrightarrow \frac{1}{k}$

(3) $L \leftrightarrow m, C \leftrightarrow k, R \leftrightarrow b$ (4) $L \leftrightarrow k, C \leftrightarrow b, R \leftrightarrow m$

9. In LC circuit the inductance L = 40 mH and capacitance C = 100 μF. If a voltage V(t) = 10sin(314 t) is applied to the circuit, the current in the circuit is given as :

[JEE(Main) 2020 Jan; 4/100, –1]

(1) 0.52 cos 314 t (2) 0.52 sin 314 t (3) 10 cos 314 t (4) 5.2 cos 314 t

10. A 750 Hz, 20 V (rms) source is connected to a resistance of 100 Ω, an inductance of 0.1803 H and a capacitance of 10 μF all in series. The time in which the resistance (heat capacity 2J/°C) will get heated by 10°C. (assume no loss of heat to the surroundings) is close to : **[JEE(Main) 2020 Sept.; 4/100, –1]**

(1) 418 s (2) 245 s (3) 348 s (4) 365 s

11. An AC circuit has R = 100 Ω, C = 2 μF and L = 80 mH, connected in series. The quality factor of the circuit is : **[JEE(Main) 2020 Sept.; 4/100, –1]**

(1) 0.5 (2) 2 (3) 20 (4) 400

Answers

Exercise # 1

PART - I

Section (A) :

A-1. (i) $2\sqrt{2}$ A, (ii) 4A, (iii) 50 Hz, (iv) $\frac{\pi}{3}$, (v) $2\sqrt{3}$ A

A-2. $220\sqrt{2}$ V, 2.5 ms

A-3. $I_{eff} = \left[a^2 + \frac{1}{2}b^2\right]^{1/2}$ **A-4.** 0

A-5. $\frac{I_o}{e}\sqrt{(e^2-1)/2}$

Section (B) :

B-1. 0.72 W **B 2.** 10 W, 5 W

B-3. $12\sqrt{2}$ volts

Section (C) :

C-1. 0.08 H, 17.28 W

C-2. $\frac{2.2\sqrt{3}}{\pi}$ = 1.2 H = $\frac{7\sqrt{3}}{10}$ H

C 3. (a) 0.1 A
(b) 50 V, 30 V, 10 V (Note that the sum of the rms potential differences across the three elements is greater than the rms voltage of the source.)

C-4. 2A, 400W

C-5. (i) $\frac{125}{33}$ µF or 2.4 H (ii) 720 Ω
(iii) It will be more economical to use inductance or capacitance in series with the lamp to run it as it.It consumes no power while there would be dissipation of power when resistance is inserted in series with the lamp.

C-6. Z = $50\sqrt{2}$ ohm, V_C = $500\sqrt{2}$ volt and V_L = $600\sqrt{2}$ volt, $\frac{1}{\sqrt{2}}$

C-7. 20 V **C-8.** 125 Ω, 288 J

Section (D) :

D-1. 0.2 mH, $\frac{1}{32}$ µF, 8×10^5 rad/s

D-2. 4 µF, R = $\frac{141.4}{5}$ Ω

D-3. 1×10^{-8} henry

D-4. (a) $\frac{250}{3\pi}$ Hz (b) 2 mA

Section (E) :

E-1. (a) 800 V; (b) (i) 0.25 A (ii) 0.2 A.

E-2. zero

PART - II

Section (A) :

A-1. (D) **A-2.** (C) **A-3.** (D)
A-4. (D) **A-5.** (D)

Section (B) :

B-1. (C) **B-2.** (A) **B-3.** (C)
B-4. (C) **B-5.** (B) **B-6.** (C)
B-7. (A) **B-8.** (A,C) **B-9.** (B)

Section (C) :

C-1. (A) **C-2.** (D) **C-3.** (A)(B)(C)
C-4. (D) **C-5.** (C) **C-6.** (B)
C-7. (B) **C-8.** (D) **C-9.** (A)

Section (D) :

D-1. (C)(D) **D-2.** (A) **D-3.** (A)
D-4. (A) **D-5.** (D) **D-6.** (B)

Section (E) :

E-1. (B) **E-2.** (C) **E-3.** (D)
E-4. (D)

Section (F) :

F 1. (A) **F 2.** (C) **F 3.** (A)
F-4. (D) **F-5.** (D) **F 6.** (C)

PART - III

1. (A) → P,T; (B) → R; (C) → P,S; (D) → P,Q

2. (A) → (r), (B) → (q), (C) → (p), (D) → (q)

Exercise # 2

PART - I

1. (B) **2.** (A) **3.** (C)
4. (A) **5.** (C) **6.** (D)
7. (A) **8.** (B)
9. **(i)** (C) **(ii)** (B) **(iii)** (A) **(iv)** (C) **(v)** (B) **(vi)** (B)

PART - II

1. (a) 23; (b) 460, 230 ; (c) 0 ; (d) 0 ; (e) 0
2. (a) 150, (b) 1, (c) 75
3. 50 sec.
4. (a) C = 20 μF (b) 1 H (c) 35.36 V
5. 3 **6.** 9

PART - III

1. (B,D) **2.** (A,B) **3.** (A,B)
4. (B,C) **5.** (A,B,C) **6.** (A,B,C,D)
7. (A,B,C) **8.** (A,C) **9.** (B,D)
10. (A,C) **11.** (B,C) **12.** (A,B,C,D)
13. (B)

PART - IV

1. (D) **2.** (A) **3.** (B)
4. (C) **5.** (D) **6.** (B)
7. (B) **8.** (D) **9.** (C)
10. (B) **11.** (C)

Exercise # 3

PART - I

1. (B)
2. (A) $\rightarrow$ r,s,t ; (B) $\rightarrow$ q,r,s,t ; (C) $\rightarrow$ p,q ; (D) $\rightarrow$ q,r,s,t
As per given conditions, there will be no steady state in circuit 'p', so it should not be considered in options of 'c'.
3. (B,C)
4. 4
5. (A,C or C) Since $I_{rms} = \frac{1}{\sqrt{10}} \approx 0.3$ A so A may or may not be correct.
6. (B) **7.** (A) **8.** (C,D)
9. (A,B) **10.** (C,D)

PART - II

1. (4) **2.** (1) **3.** (4)
4. (1) **5.** (4) **7.** (3)
8. (4) **9.** (1) **10.** (1)
11. (3) **12.** (2)

RANKER PROBLEMS

SUBJECTIVE QUESTIONS

1. The current in a coil of self inductance 2.0 Henry is changing according to $i = 2 \sin t^2$ ampere. Find the amount of energy spend during the period when the current changes from zero to 2 ampere.

[REE- 1991]

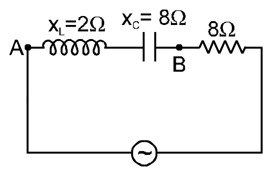
2. A current of 4 A flows in a coil when connected to a 12 V d.c. source. If the same coil is connected to a 12 V, 50 rad/s, AC source, a current of 2.4 A flows in the circuit. Determine the inductance of the coil. Also, find the power developed in the circuit if a 2500 μF condenser is connected in series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

[REE - 1993]

3. A series LCR circuit containing a resistance of 120 ohm has angular resonance frequency 4×10^5 rad s^{-1}. At resonance, the voltage across resistance and inductance are 60V and 40 V respectively. Find the values of L and C. At what frequency the current in the circuit lags the voltage by 45º? **[REE - 1995]**

4. A box P and a coil Q are connected in series with an AC source of variable frequency. The EMF. of source is constant at 10 V. Box P contains a capacitance of 1 μF 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. **[REE - 1998]**

5._ An inductor (x_L = 2Ω) a capacitor (x_C = 8Ω) and a resistance (8Ω) is connected in series with an ac source. The voltage output of A.C source is given by $v = 10 \cos 100\pi t$.



(a) Find the impedance of the circuit.

(b) Find the instantaneous p.d. between A and B, when it is half of the voltage output from source at that instant.

6. An inductor 20×10^{-3} Henry, a capacitor 100 μF and a resistor 50Ω are connected in series across a source of EMF $V = 10 \sin 314\, t$. Find the energy dissipated in the circuit in 20 minutes. If resistance is removed from the circuit and the value of inductance is doubled, then find the variation of current with time (t in second) in the new circuit. **[REE - 1999]**

7. The electric current in an AC circuit is given by $i = i_0 \sin \omega t$. What is the time taken by the current to change from its maximum value to the rms value? **[REE - 1999]**

8. A series LCR circuit with $L = 0.125/\pi$ H, $C = 500/\pi$ nF, $R = 23\ \Omega$ is connected to a 230 V variable frequency supply.

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

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

(c) For what reactance of the circuit , the power transferred to the circuit is half the power at resonance? What is the current amplitude at this reactance?

(d) If ω is the angular frequency at which the power consumed in the circuit is half the power at resonance,write an expression for ω

(e) What is the Q-factor (Quality factor) of the given circuit?

9. An RLC circuit includes a 1.6 H inductor and a 250 μF capacitor rated at 400 V. The circuit is connected across a sine-wave generator whose peak voltage is 32V. What minimum resistance must the circuit have to ensure that the capacitor voltage does not exceed its rated value when the generator is at the resonant frequency.

Answers

1. 4 joule

2. 08 H; 17.28 watt

3. 2×10^{-4} H; $\frac{1}{32}$ μF; 8×10^5 rad/s

4. P=76.96 Ω ,Q=97.59 Ω, P = 7.6 V; Q = 9.8 V, net impedance = 100 Ω

5._ (a) 10Ω (b) $\frac{24}{5}$ volts

6. 951.52 J; 0.52 cos 314 t

7. T/8 or $\frac{\pi}{4\omega}$

8. (a) 2000 Hz, $10\sqrt{2}$ A (b) 2000 Hz, 2300 watt (c) 23 Ω, 10 A.

(d) $\frac{0.125}{\pi}\omega - \frac{1\times10^9}{\omega\frac{500}{\pi}} = \pm 23$ (e) 500/23

9. 6.4Ω

SELF ASSESSMENT PAPER

JEE (ADVANCED) PAPER

SECTION-1 : ONE OPTION CORRECT TYPE (Maximum Marks - 12)

1. In a purely resistive AC circuit, the current

(A) Lags behind the EMF in phase

(B) Is in phase with the EMF

(C) Leads the EMF in phase

(D) Leads the EMF in half the cycle and lags behind it in the other half.

2. An alternating potential V = V_0 sin ωt is applied across a circuit. As a result the current $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$ flows in it. The power consumed in the circuit per cycle is **[REE - 1992]**

(A) zero (B) 0.5 V_0I_0 (C) 0.707 V_0I_0 (D) 1.414 V_0I_0

3. A power transformer (step up) with an 1 : 8 turn ratio has 60 Hz, 120 V across the primary; the load in the secondary is 10^4 Ω. The current in the secondary is

(A) 96 A (B) 0.96 A (C) 9.6 A (D) 96 mA

4. When 100 V DC is applied across a solenoid, a steady current of 1 A flows in it. When 100 V AC is applied across the same solenoid, the current drops to 0.5 A. If the frequency of the AC source is $150\sqrt{3}/\pi$ Hz, the impedance and inductance of the solenoid are :

(A) 200 Ω and 1/3 H (B) 100 Ω and 1/16 H

(C) 200 Ω and 1.0 H (D) 1100 Ω and 3/117 H

SECTION-2 : ONE OR MORE THAN ONE CORRECT TYPE (Maximum Marks - 32)

5. A series LCR circuit is operated at resonance. Then

(A) Voltage across R is minimum (B) Impedance is minimum

(C) Power transferred is maximum (D) Current amplitude is minimum

6. An alternating EMF of frequency $\frac{1}{2\pi\sqrt{LC}}$ is applied to a series LCR circuit. For this frequency of the applied EMF,

(A) The circuit is at 'resonance' and its impedance is made up only of a reactive part

(B) The current in the circuit is in phase with the applied EMF and the voltage across R equals this applied EMF potential differences

(C) The sum of the potential differences across the inductance and capacitance equals the applied EMF which is 180° ahead of phase of the current in the circuit

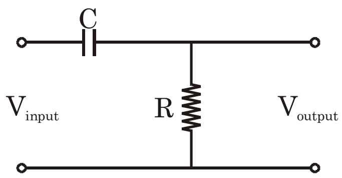
(D) The quality factor of the circuit is ωL/R or 1/ωCR and this is a measure of the voltage magnification (produced by the circuit at resonance) as well as the sharpness of resonance of the circuit

7. If a resistance of 30Ω, a capacitor of reactance 20 Ω, and an inductor of inductive reactance 60Ω are connected in series to a 100 V, 50 Hz power source, then - **[REE - 1994]**

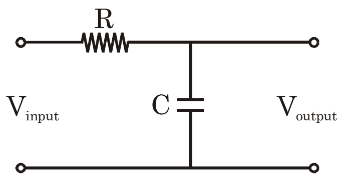
(A) A current of 2.0 A flows (B) A current of 3.33 A flows

(C) Power factor of the circuit is zero (D) Power factor of the circuit is 3/5

8. Figure shows two circuits in each case V_0 denotes peak value of input voltage. Input voltage is given by $V = V_0 \sin\omega t$ and output voltage by $V = V_M \sin(\omega t + \delta)$:



Circuit-1



Circuit-2

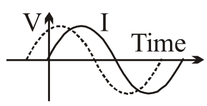
(A) In circuit-1 maximum output voltage is $V_M = \dfrac{V_0}{\sqrt{1+(\omega RC)^{-2}}}$

(B) In circuit-2 maximum output voltage is $V_M = \dfrac{V_0}{\sqrt{1+(\omega RC)^{2}}}$

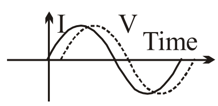
(C) In circuit-1 average power dissipated is given by $P_{av} = \dfrac{V_0^2}{2R\sqrt{\left[1+(\omega RC)^{-2}\right]}}$

(D) Phase angle δ for circuit-2 is given by $\tan\delta = \omega RC$

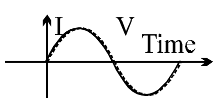
9. The diagram shows the variation of V and I in an AC circuit. The circuit only be a series RC or series RL or series LC or series RLC. Consider the four different combinations of V and I graphs. Pick the correct combination/ combinations for each graph. Solid curves represent I and broken curves represent V.

(a) 

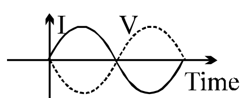
Phase difference between V & I is π/4

(b) 

Phase difference between V & I is π/4.

(c) 

V and I are in the same phase

(d) 

V and I have a phase difference of π

Take the angular frequency of the AC voltage source to be 100 rad/s (This is ω)

(I) R = 1kΩ, L = 1H and C = 100μF

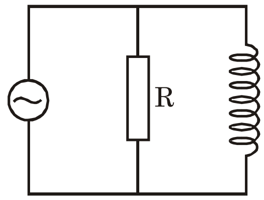
(II) R = 1Ω and L = 10^{-2}H

(III) R = 100Ω and C = 10^{+2}μF

(IV) L = 1H, C = 100μF and R = 1Ω

(A) a → II ; d → I, IV (B) c → I ; d → none (C) b → III ; c → IV (D) a → II,III ; b → II,III

10. In a circuit, alternating voltage with amplitude U_0 = 100 V. is applied. The phase difference between current and voltage through the source is equal $\varphi = \pi/4$. R = 100 Ohm and the inductance is resistance free. Take ω = 100 rad/s



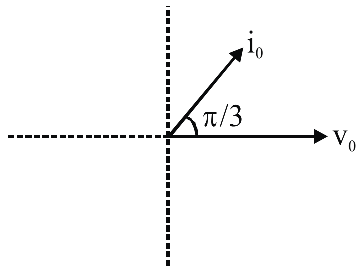
(A) The amplitude of current is $\sqrt{2}$ amp.

(B) The average power dissipated is 50 W

(C) The inductance is 1H

(D) The amplitude of current through the inductance is 0.5 A

11. For an LCR series circuit, phasors of current i and applied voltage $v = v_0 \sin\omega t$ are shown in diagram at t =0. Which of the following is/are **CORRECT**?



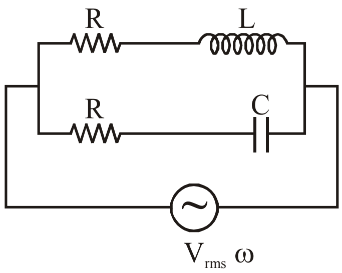
(A) At $t = \frac{\pi}{2\omega}$, instantaneous power supplied by source is negative.

(B) From $0 < t < \frac{2\pi}{3\omega}$, average power supplied by source is positive.

(C) At $t = \frac{5\pi}{6\omega}$, instantaneous power supplied by source is negative.

(D) If ω is increased slightly, angle between the two phasors decreases.

12. In this circuit given, the value of $R = \sqrt{\frac{L}{C}}$. Consider the following statements and choose the correct option



(i) RMS value of current through a.c. source is $\frac{V_{rms}}{2R}$

(ii) Impedance of circuit is independent of ω

(iii) Impedance of circuit depends upon ω

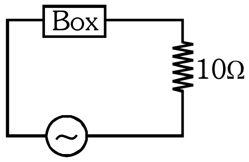
(iv) Current through the source is $\frac{V_{rms}}{\sqrt{R^2 + \omega^2 L^2}}$

(A) only (iii) and (iv) are correct
(B) only (ii) is correct
(C) only (i) and (ii) are correct
(D) only (iv) is correct

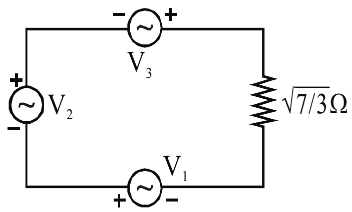
SECTION-3 : NUMERICAL VALUE TYPE (Maximum Marks - 18)

13. A 100 volt AC source of angular frequency 500 rad/s is connected to a LCR circuit with L = 0.8 H, C = 5 μF and R = 10 Ω, all connected in series. The potential difference (in volt) across the resistance is

14. In the circuit shown power factor of box is given by 0.5 and power factor of circuit is given by $\frac{\sqrt{3}}{2}$. Current leading the voltage. The effective resistance of the box is made by using 5 resistance of equal value. Find the value of each resistance (Assume all the combination are in series)



15. Three alternating voltage sources V_1 = 3sinωt volt, V_2=5sin(ωt +ϕ_1) volt and V_3 = 5 sin(ωt – ϕ_2) volt connected across a resistance $R=\sqrt{\frac{7}{3}}\Omega$ as shown in the figure (where ϕ_1 and ϕ_2 corresponds to 30° and 127° respectively). Find the peak current (in Amp) through the resistor.



16. A choke coil is connected to an AC source. Some power is dissipated in coil. Now a capacitor is connected in series with the coil and source is same, then average power dissipated in the circuit does not change. If ratio of inductive reactance of coil and capacitive reactance of capacitor is $\frac{1}{x}$ then find x

17. A power line is used to transmit 100 MW power. Power factor of load is 0.866 and resistance of line is 8Ω. the power loss in the wire is 2 %. What is the current (in A) in the wires. fill $\frac{i}{100}$ in OMR sheet.

18. The primary of a 1 : 3 step - up transformer is connected to a source and the secondary is connected to a resistor R. The power dissipated by R in this situation is P. If R is connected directly to the source it will dissipate a power P/x. Then x is–

Answers

1.	(B)	**2.**	(A)	**3.**	(D)	**4.**	(A)	**5.**	(B)(C)
6.	(B)(D)	**7.**	(A)(D)	**8.**	(A,B)	**9.**	(B,C)	**10.**	(A,B,C)
11.	(B,C,D)	**12.**	**(B)**	**13.**	100.00	**14.**	1.00	**15.**	3.00
16.	2.00	**17.**	5.00	**18.**	9.00				