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ALTERNATING CURRENT

Contents

Syllabus

RC, LR and LC circuits with d.c. and a.c. sources.

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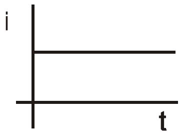
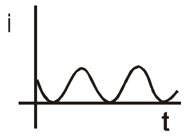
ALTERNATING CURRENT

AC AND DC CURRENT :

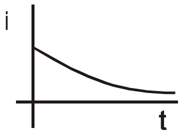
A current that changes its direction periodically is called alternating current (AC). If a current maintains its direction constant it is called direct current (DC).



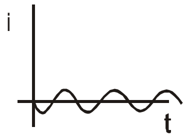
constant dc



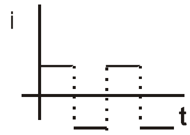
periodic dc



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.

AVERAGE VALUE :

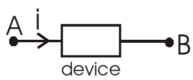
Average value of a function, from t_1 to t_2, is defined as $\langle f \rangle = \dfrac{\int_{t_1}^{t_2} f.dt}{t_2 - t_1}$. We can find the value of $\int_{t_1}^{t_2} f.dt$ graphically if the graph is simple. It is the area of f-t graph from t_1 to t_2.

ROOT MEAN SQUARE VALUE:

Root Mean Square Value of a function, from t_1 to t_2, is defined as $f_{rms} = \sqrt{\dfrac{\int_{t_1}^{t_2} f^2 dt}{t_2 - t_1}}$.

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 $= V\,i = (V_m \sin \omega t)\,(I_m \sin(\omega t + \phi))$



Average power consumed in a cycle $= \dfrac{\int_{0}^{\frac{2\pi}{\omega}} P dt}{\frac{2\pi}{\omega}} = \dfrac{1}{2} V_m I_m \cos\phi$

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

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

SOME DEFINITIONS:

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

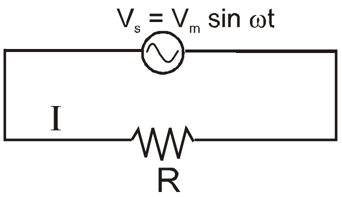
I_m sin ϕ is called **wattless current**.

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.

PURELY RESISTIVE CIRCUIT:

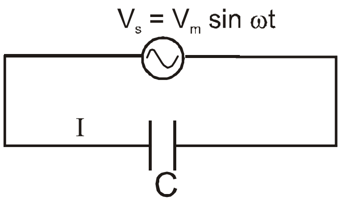


$$I = \frac{V_s}{R} = \frac{V_m \sin \omega t}{R} = I_m \sin \omega t$$

$$I_m = \frac{V_m}{R} \quad \Rightarrow \quad I_{rms} = \frac{V_{rms}}{R}$$

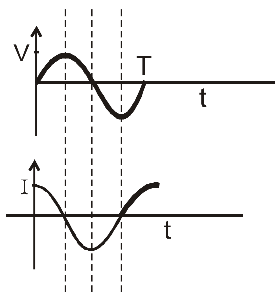
$$\langle P \rangle = V_{rms} I_{rms} \cos \phi = \frac{V_{rms}^2}{R}$$

PURELY CAPACITIVE CIRCUIT:

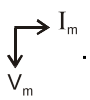


$$I = \frac{dq}{dt} = \frac{d(CV)}{dt} = \frac{d(CV_m \sin \omega t)}{dt} = CV_m \omega \cos \omega t = \frac{V_m}{1/\omega C} \cos \omega t = \frac{V_m}{X_C} \cos \omega t = I_m \cos \omega t.$$

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



I_C leads V_C by $\pi/2$ Diagrammatically (phasor diagram) it is represented as



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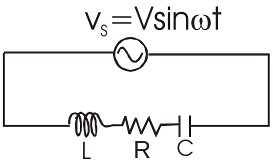
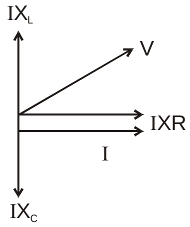
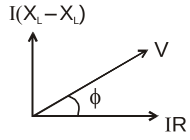
Since $\phi = 90°$, $\langle P \rangle = V_{rms} I_{rms} \cos \phi = 0$

☞ RLC SERIES CIRCUIT WITH AN AC SOURCE :







From the phasor diagram

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

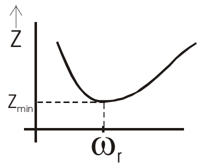
$$\tan\phi = \frac{I(X_L - X_C)}{IR} = \frac{(X_L - X_C)}{R}$$

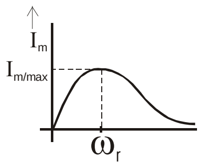
☞ RESONANCE :

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**.

So at resonance: X_L-X_C =0.

or $\omega L = \dfrac{1}{\omega C}$ or $\omega = \dfrac{1}{\sqrt{LC}}$. Let us denote this ω as ω_r.





Quality factor : $Q = \dfrac{X_L}{R} = \dfrac{X_C}{R}$

$$Q = \frac{\text{Resonance freq.}}{\text{Band width}} = \frac{\omega_R}{\Delta\omega} = \frac{f_R}{f_2 - f_1}$$

where f_1 & f_2 are half power frequencies.

☞ TRANSFORMER

A transformer changes an alternating potential difference from one value to another of greater or smaller value using the principle of mutual induction . For an ideal tranformer $\dfrac{E_s}{E_p} = \dfrac{N_s}{N_p} = \dfrac{I_p}{I_s}$, where denotations have their usual meanings.

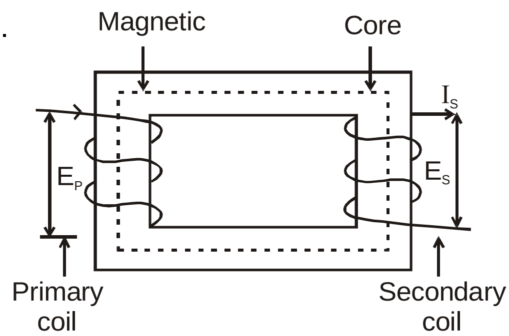
E_S N and I are the emf, number of turns and current in the coils.

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

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

Energy Losses In Transformer are due to

1. Resistance of the windings.
2. Eddy Current.
3. Hysteresis.
4. Flux Leakage.



EXERCISE # 1

PART - I : OBJECTIVE QUESTIONS

*** Marked Questions are having more than one correct option.***

SECTION (A) : AVERAGE, PEAK AND RMS VALUE

A-1. A. C. measuring instrument measures its
(A) rms value (B) Peak value (C) Average value (D) Square of current

A-2. The electric current in a circuit is given by $i = i_0 t/\tau$ for some time. What is the the rms current for the period $t = 0$ to $t = \tau$?
(A) i_0 (B) $i_0/\sqrt{3}$ (C) $i_0/\sqrt{2}$ (D) $i_0/4$

A-3. The ratio of mean value over half cycle to rms value of AC is :
(A) $2 : \pi$ (B) $2\sqrt{2} : \pi$ (C) $\sqrt{2} : \pi$ (D) $\sqrt{2} : 1$.

A-4. In an A.C. circuit, maximum value of voltage is 423 volt. Its effective voltage is :
(A) 323 V (B) 340 V (C) 400 V (D) 300 V.

A-5. 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-6. An alternating voltage E (in volt) = 200 $\sqrt{2}$ sin (100 t) is connected to a 1 μF capacitor through an ac ammeter. The reading of the ammeter shall be :
(A) 10 mA (B) 20 mA (C) 40 mA (D) 80 mA.

A-7. An AC voltage is given by :

$$E = E_0 \sin \frac{2\pi t}{T}$$

Then the mean value of voltage calculated over time interval of T/2 seconds :
(A) is always zero (B) is never zero (C) is $(2e_0/\pi)$ always (D) may be zero

A-8. An AC voltage of V = $220\sqrt{2} \sin\left(2\pi 50\ t + \frac{\pi}{2}\right)$ is applied across a DC voltmeter, its reading will be:
(A) $220\sqrt{2}$ V (B) $\sqrt{2}$ V (C) 220 V (D) zero

A-9. r.m.s. value of current i = 3 + 4 sin ($\omega t + \pi/3$) is:
(A) 5 A (B) $\sqrt{17}$ A (C) $\frac{5}{\sqrt{2}}$ A (D) $\frac{7}{\sqrt{2}}$ A

A-10. A coil of inductance 5.0 mH and negligible resistance is connected to an alternating voltage V = 10 sin (100 t). The peak current in the circuit will be :
(A) 2 amp (B) 1 amp (C) 10 amp (D) 20 amp

A-11. The peak value of an alternating e.m.f given by $E = E_0 \cos \omega t$, is 10 volt and frequency is 50 Hz. At time t = (1/600) sec, the instantaneous value of e.m.f is :

(A) 10 volt (B) $5\sqrt{3}$ volt (C) 5 volt (D) 1 volt

A-12. 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

SECTION (B) : POWER CONSUMED IN AN AC CIRCUIT

B-1. 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) $\frac{E_0^2 R}{2(|z|)^2}$ (D) $\frac{I_0^2 |z| \cos\phi}{2}$

B-2. In an a.c. circuit, V & I are given by
V = 100 sin (100 t) volt.
I = 100 sin (100 t + π/3) mA.

(A) 10^4 watt (B) 10 watt (C) 2.5 watt (D) 5 watt.

B-3. The current flowing in a coil is 3 A and the power consumed is 108 W. If the a.c. source is of 120 V, 50 Hz, the resistance of the circuit is :

(A) 24Ω (B) 10Ω (C) 12Ω (D) 6Ω.

B-4. If the frequency of the source e.m.f. in an AC circuit is n, the power varies with a frequency :

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

B-5. An AC of frequency f is flowing in a circuit containing only a choke coil L. If E_0 and i_0 represent peak value of the voltage and the current respectively, the average power given by the source to the choke is equal to :

(A) $\frac{1}{2} i_0 E_0$ (B) $\frac{1}{2} i_0^2 (2\pi f L)$ (C) zero (D) $\frac{1}{2} E_0 (2\pi f L)$.

B-6. 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-7. An alternating potential $V = V_0 \sin \omega t$ 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

(A) zero (B) 0.5 $V_0 I_0$ (C) 0.707 $V_0 I_0$ (D) 1.414 $V_0 I_0$

SECTION (C) : AC SOURCE WITH R, L, C CONNECTED IN SERIES

C-1. In an AC circuit the potential differences across an inductance and resistance 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

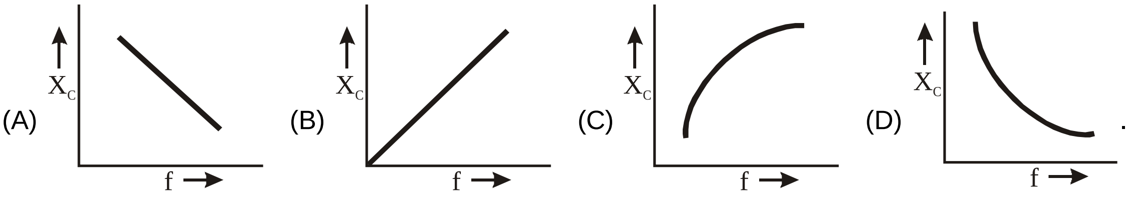
C-2. When 100 volt DC is applied across a solenoid, a current of 1.0 amp flows in it. When 100 volt AC is applied across the same coil, the current drops to 0.5 amp. If the frequency of the AC source is 50 Hz, the impedance and inductance of the solenoid are

(A) 200 ohm and 0.55 henry (B) 100 ohm and 0.86 henry
(C) 100 ohm and 1.0 henry (D) 100 ohm and 0.93 henry.

C-3. In an L-R circuit, the value of L is $(0.4/\pi)$ henry and the value of R is 30 ohm. If in the circuit, an alternating emf of 200 volt at 50 cycles per second is connected, the impedance of the circuit and current will be :

(A) 11.4 ohm, 17.5 ampere (B) 30.7 ohm, 6.5 ampere
(C) 40.4 ohm, 5 ampere (D) 50 ohm, 4 ampere.

C-4. The reactance of a capacitor X_C in an ac circuit varies with frequency f of the source voltage. Which one of the following represents this variation correctly ?



C-5. A sinusoidal voltage $V_0 \sin \omega t$ is applied across a series combination of resistance R and capacitance C. The amplitude of the current in this circuit is :

(A) $\dfrac{V_0}{\sqrt{R^2+\omega^2C^2}}$ (B) $\dfrac{V_0}{\sqrt{R^2-C^2\omega^2}}$ (C) $\dfrac{V_0}{(R+C\omega)}$ (D) $\dfrac{V_0}{\sqrt{R^2+\dfrac{1}{\omega^2C^2}}}$

C-6. In a L R circuit the A.C. source has voltage 220 V and the potential difference across the inductance is 176 V. The potential difference across the resistance will be :

(A) 44 V (B) 396 V (C) 132 V (D) $\sqrt{[(250\times176)]}V$.

C-7. An inductive circuit contains a resistance of 10 Ω and an inductance of 2 H. If an ac voltage of 120 V and frequency 60 Hz is applied to this circuit, the current would be nearly:

(A) 0.72 A (B) 0.16 A (C) 0.48 A (D) 0.80 A.

C-8. A coil of resistance R and inductance L is connected to a battery of E volt emf. The final current flowing in the coil is :

(A) E/R (B) E/L (C) $E/(R^2+\omega^2L^2)^{1/2}$ (D) $EL(R^2+L^2)^{1/2}$.

C-9. The impedance of a series circuit consists of 3 ohm resistance and 4 ohm reactance. The power factor of the circuit is :

(A) 0.4 (B) 0.6 (C) 0.8 (D) 1.0

C-10. By what percentage the impedance in an AC series circuit should be increased so that the power factor changes from (1/2) to (1/4) (when R is constant) ?

(A) 200% (B) 100% (C) 50% (D) 400%

C-11. If in a series L-C-R circuit, the voltage across R, L and C are V_R, V_L and V_C respectively, then the voltage of applied across AC source must be :

(A) $V_R+V_L+V_C$ (B) $\sqrt{[(V_R)^2+(V_L-V_C)^2]}$

(C) $V_R+V_C-V_L$ (D) $[(V_R+V_L)^2+V_C^2]^{1/2}$.

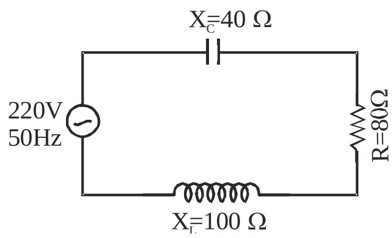
C-12. The power factor of the circuit shown in figure is :

(A) 0.2

(B) 0.4

(C) 0.8

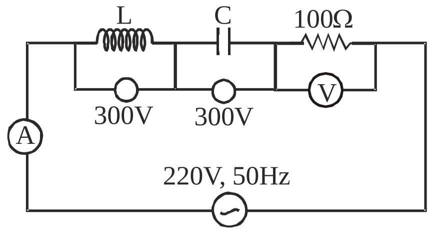
(D) 0.6.



C-13. A coil having an inductance of $\frac{1}{\pi}$ henry is connected in series with a resistance of 300 Ω. If 20 volt from a 200 cycle source are impressed across the combination, the value of the phase angle between the voltage and the current is :

(A) $\tan^{-1}\frac{5}{4}$ (B) $\tan^{-1}\frac{4}{5}$ (C) $\tan^{-1}\frac{3}{4}$ (D) $\tan^{-1}\frac{4}{3}$

C-14. In the circuit shown in figure, what will be the readings of voltmeter and ammeter ?



(A) 800 V, 2 A

(B) 220 V, 2.2 A

(C) 300 V, 2 A

(D) 100 V, 2 A

C-15. 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.

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

C-16.* If a resistance of 30Ω, a capacitor reactance 20 Ω, and an inductor of inductive reactance 60Ω are connected in series to a 100 V, 50 Hz power source, then -
(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

C-17. 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
(A) π (B) 2π (C) $\pi/4$ (D) 0

C-18.* 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?
(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.

SECTION (D) : RESONANCE

D-1. The power factor of a series LCR circuit when at resonance is :
(A) zero (B) 0.5
(C) depends on the values of L, C and R (D) one

D-2. 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-3. A 10 Ω resistance, 5 mH coil and 10 μF capacitor are joined in series. When a variable frequency alternating current source is joined to this combination, the circuit resonates. If the resistance is halved, the resonance frequency :
(A) is halved (B) is doubled (C) remains unchanged (D) is quadrupled.

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 n. If the resonant frequency is n_r, then the current lags behind voltage, when :
(A) n = 0 (B) $n < n_r$ (C) $n = r_r$ (D) $n > n_r$

D-6.* 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

SECTION (E) : TRANSFORMER

E-1. The core of a transformer is laminated to reduce
(A) eddy current loss (B) hysteresis loss (C) copper loss (D) magnetic loss

E-2. A power transmission line feeds input power at 2300 V to a step-down transformer, with its primary windings having 4000 turns. The number of turns in the secondary windings in order to get output power at 230 V is :
(A) 300 (B) 400 (C) 500 (D) 600

E-3. A step up transformer of turns ratio 2 : 1 has 50 Hz. AC voltage applied to primary. The frequency of AC output voltage across secondary is :
(A) zero (B) 25 Hz (C) 50 Hz (D) 100 Hz.

E-4. A power (step up) transformer with an 1 : 8 turn ratio has 60 Hz, 120 V across the primary; the load in the secondary is $10^4\ \Omega$. The current in the secondary is
(A) 96 A (B) 0.96 A (C) 9.6 A (D) 96 mA

E-5. 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-6. 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

PART - II : MISLLANEOUS QUESTIONS

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1. COMPREHENSION TYPE

COMPREHENSIONS # 1 :

Choke coil is an instrument which is the combination of resistance and inductance. In the resistance power is lost and no power is lost in inductor

1. Power loss in AC circuit of A.C. source of voltage V ; will be minimum when
(A) Inductance is high, resistance is high
(B) Inductance is low, resistance is high
(C) Inductance is low, resistance is low
(D) Inductance is high, resistance is low

2. The average power dissipation in pure inductance is

(A) $\frac{1}{2}Li^2$ (B) $2Li^2$ (C) zero (D) $\frac{Li^2}{4}$

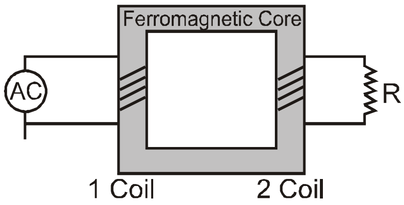
3.* The potential difference V across and current I flowing through an instrument in an AC circuit is given by V = 5sinωt (volts), I = 2cosωt (amp)
(A) Maximum power dissipated is 10 W
(B) Maximum power dissipated is 5W
(C) Average power dissipated is 5 W
(D) Average power dissipated is zero

4. An alternating current of frequency f is flowing in a circuit containing only choke coil of resistance R and inductance L, V_0 and I_0 represent peak value of the voltage and the current respectively, the average power given by source is equal to

(A) $\frac{V_0 I_0}{2}$ (B) $\frac{V_0^2}{(2\pi f)L}$ (C) $\frac{I_0^2 R}{2}$ (D) zero

COMPREHENSION # 2

A freshman physics lab is designed to study the transfer of electrical energy from one circuit to another by means of a magnetic field using simple transformer. Each transformer has two coils of wire electrically insulated from each other but wound around a common core of ferromagnetic material. The two wires are close together but do not touch each other.



The primary (1) coil is connected to a source of alternating (AC) current. The secondary (2) coil is connected to a resistor such as a light bulb. The AC source produces an oscillating voltage and current in the primary voltage and AC current in the secondary coil.
Students collected the following data comparing the number of turns per coil (N), the voltage (V) and the current (I) in the coil of three transformers.

	Primary coil			**Secondary coil**		
	N_1	V_1	I_1	N_2	V_2	I_2
Transformer 1	100	10 V	10A	200	20V	5A
Transformer 2	100	10 V	10A	50	5V	20A
Transformer 3	200	10 V	10A	100	5V	20A

5. The primary coil of a transformer has 100 turns and is connected to a 120 Volt AC source. How many turns are in the secondary coil if there's a 2400 V across it.

(A) 5 (B) 50 (C) 200 (D) 2000

6. A transformer with 40 turns in its primary coil is connected to a 120 Volt AC source. If 20 watts of power is supplied to the primary coil, how much power is developed in the secondary coil.

(A) 10 W (B) 20 W (C) 80W (D) 160 W

7. Which of the following is a correct expression for R, the resistance of the load connected to the secondary coil :

(A) $(V_1 / I_1)(N_2 / N_1)$ (B) $(V_1 / I_1)(N_2 / N_1)^2$
(C) $(V_1 / I_1)(N_1 / N_2)$ (D) $(V_1 / I_1)(N_1 / N_2)^2$

8. A 12 V battery is used to supply 2.0 mA of current to the 300 turns in the primary coil of a given transformer. What is the current in the secondary coil if N_2 = 150 turns –

(A) 0 A (B) 1.0 mA (C) 2.0 mA (D) 4.0 A

2. MATCH THE COLUMN

9. Match the following

Column I	Column II
(A) In case of series L-C-R circuit, at resonance	(i) Current in the circuit has same frequency as of applied voltage
(B) Only resistor in an a.c. circuit	(ii) Voltage lags the current by $\pi/2$
(C) Only inductor in an a.c. circuit	(iii) Current lags the voltage by $\pi/2$
(D) Only capacitor in an a.c. circuit	(iv) Reactance of the circuit is zero
	(v) Current is in phase with applied voltage

10. Match the following

Column I	Column II
(A) For square wave having peak value v_0	(i) $v_0 > v_{rms} > v_{av}$
(B) For sinusoidal wave having peak value v_0	(ii) In a pure inductance
(C) Current leads the voltage by $\pi/2$	(iii) $v_{av} = v_{rms} = v_0$
(D) Wattless current = Total current	(iv) In a pure capacitance

3. ASSERTION / REASON

A statement of **Statement-1** is given and a Corresponding statement of **Statement-2** is given just below it of the statements, mark the correct answer as –

(A) If both Statement-1 and Statement-2 are true and Statement-2 is the correct explanation of Statement-1.

(B) If both Statement-1 and Statement-2 are true and Statement-2 is NOT correct explanation of Statement-1.

(C) If Statement-1 is true but Statement-2 is false.

(D) If Statement-1 is false but Statement-2 is true.

(E) If both Statement-1 and Statement-2 are false.

11. **Statement-1 :** An alternating current does not show any magnetic effect.
Statement-2 : Alternating current varies with time.

12. **Statement-1 :** An inductor is connected to an ac source. When the magnitude of current decreases in the circuit, energy is absorbed by the ac source.
Statement-2 : When current through an inductor decreases, the energy stored in inductor decreases.

13. **Statement-1 :** Average power consumed in an ac circuit is equal to average power consumed by resistors in the circuit.
Statement-2 : Average power consumed by capacitor and inductor is zero.

14. **Statement-1 :** The D. C. and A. C. both can be measured by a hot wire instrument.
Statement-2 : The hot wire instrument is based on the principle of magnetic effect of current.

15. **Statement-1 :** The electrostatic energy stored in capacitor plus magnetic energy stored in inductor will always be zero in a series LCR circuit driven by ac voltage source under condition of resonance.
Statement-2 : The complete voltage of ac source appears across the resistor and voltages across C and L are zero in a series LCR circuit driven by ac voltage source under condition of resonance.

16. **Statement-1 :** Peak voltage across the resistance can be greater than the peak voltage of the source in an series LCR circuit.
Statement-2 : Peak voltage across the inductor can be greater than the peak voltage of the source in an series LCR circuit.

4. TRUE OR FALSE

17. **(i)** Wattless current is I_0 sin ϕ (where ϕ is phase difference between V and I and I_0 is maximum current.)
(ii) Pure capacitive reactance dissipates zero power in a.c. circuit.
(iii) The voltage in pure capacitatives circuit always leads the current by $\pi/2$.
(iv) When a coil of inductance L and resistance R is attached to two terminals at which an emf $v = V_0 \sin(\omega t)$ is maintained, the average rate of consumption of energy is $\frac{1}{2}V_0^2R/\left(R^2+\omega^2L^2\right)$.
(v) A certain RLC combination, R_1, L_1, C_1, has a resonant frequency that is the same as that of a different combination, R_2, L_2, C_2. You now connect the two combinations in series. This new circuit has the same resonant frequency as the separate individual circuits.

EXERCISE # 2

PART - I : MIXED OBJECTIVE

* ***Marked Questions are having more than one correct option.***

SINGLE CORRECT ANSWER TYPE

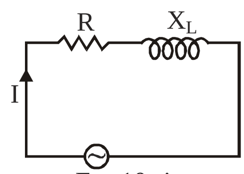
1. A coil of resistance 200 ohms and self inductance 1.0 henry has been connected to an a.c. source of frequency $200/\pi$ Hz. The phase difference between voltage and current is :
(A) 30º (B) 63º (C) 45º (D) 75º

2. Resonance frequency of a circuit is f. If the capacitance is made 4 times the initial value, then the resonance frequency will become :
(A) f/2 (B) 2f (C) f (D) f/4

3. The p.d. across an instrument in an a.c. circuit of frequency f is V and the current flowing through it is I such that V = 5 cos $(2\pi ft)$ volt and I = 2 sin $(2\pi ft)$ amp. The power dissipate in the instrument is :
(A) zero (B) 10 watt (C) 5 watt (D) 2.5 watt.

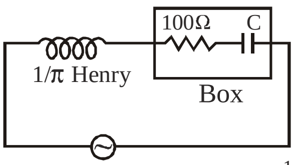
4. The phase difference between current and voltage in an AC circuit is $\pi/4$ radian. If the frequency of AC is 50 Hz, then the phase difference is equivalent to the time difference :
(A) 0.78 s (B) 15.7 ms (C) 0.25 s (D) 2.5 ms

5. An ac-circuit having supply voltage E consists of a resistor of resistance 3Ω and an inductor of reactance 4Ω as shown in the figure. The voltage across the inductor at t = π/ω is :



(A) 2 volts (B) 10 volts
(C) zero (D) 4.8 volts

6. 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

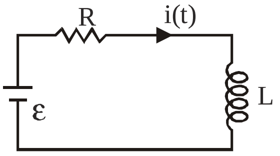


(A) $\frac{1}{\sqrt{2}}$ (B) 1
(C) $\frac{\sqrt{3}}{2}$ (D) $\frac{1}{2}$

7. In a transformer $n_P = 500,\ n_S = 5000$ Input voltage is 20 V and frequency is 50 Hz. Then in the output, we have

(A) 200 V, 500 Hz (B) 200 V, 50 Hz (C) 20 V, 50 Hz (D) 2 C, 5 Hz.

8. Suppose the emf of the battery, the circuit shown varies with time **t** so the current is given by i(t) = 3 + 5t, where **i** is in amperes and **t** is in seconds. Taking R = 4Ω, L = 6H, the expression for the battery emf as function of time is :



(A) 21 + 10 t (B) 42 + 20 t (C) 21 – 20 t (D) 42 – 20 t

9. An a.c. 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 the source is changed to ω/3 (but maintaining the same voltage), the current in the circuit is found to be halved. The ratio of reactance and resistance at the original frequency will be :

(A) $\sqrt{\frac{2}{3}}$ (B) $\sqrt{2}$ (C) $\sqrt{\frac{3}{5}}$ (D) $\sqrt{\frac{1}{3}}$

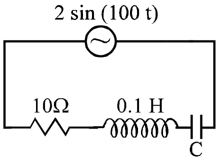
10. A box P and a coil Q are connected in series with an ac source of variable frequency. The emf of source at 10 V. Box P contains a capacitance of 1μF in series with a resistance of 32Ω coil. Q has a self-inductance 4.9 mH and a resistance of 68Ω series. The frequency is adjusted so that the maximum current flows in P and Q. The voltage across P will be (Approximately) :

(A) 2.2 V (B) 5.3 V (C) 7.7 V (D) 9.2 V

11. An LCR series circuit with 100Ω resistance is connected to an AC source of 200V and angular frequency 300 rad/s. When only capacitance is removed, the current lags behind the voltage by 60º. When only the inductance is removed the current leads the voltage by 60º. The power dissipated in the LCR circuit will be:

(A) 200 W (B) 400 W (C) 600 W (D) 800 W

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



(A) 400 μF (B) 300 μF

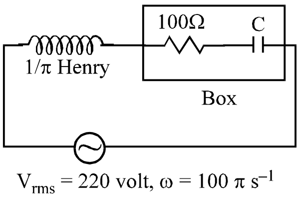
(C) 500 μF (D) 200 μF

13. When a resistance R is connected in series with an element A, the electric current is found to be lagging behind the voltage by angle θ_1. When the same resistance is connected in series with element B, current leads voltage by θ_2. When R, A, B are connected in series, the current now leads voltage by θ. Assume same AC source is used in all cases, then :

(A) $\theta = \theta_2 - \theta_1$ (B) $\tan\theta = \tan\theta_2 - \tan\theta_1$

(C) $\theta = \frac{\theta_1 + \theta_2}{2}$ (D) None of these

14. 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) $\frac{1}{2}$

15. When 100 V DC is applied across a solenoid a current of 1 A flows in it. When 100 V AC is applied across the same coil, the current drops to 0.5 A. If the frequency of the AC source is 50 Hz, the impedance and inductance of the solenoid are:
(A) 100Ω, 0.93 H (B) 200Ω, 1.0 H (C) 10Ω, 0.86H (D) 200Ω, 0.55 H

16. The power in ac circuit is given by $P = E_{rms}I_{rms}\cos\phi$.The vale of $\cos\phi$ in series LCR circuit at resonance is:
(A) zero (B) 1 (C) $\frac{1}{2}$ (D) $\frac{1}{\sqrt{2}}$

17. 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

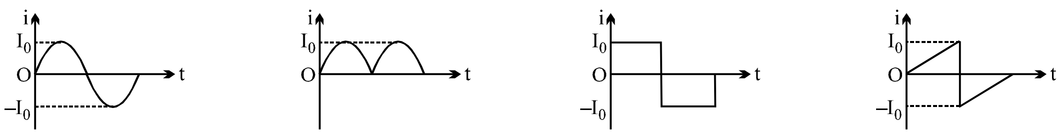
18. An AC current is given by $I = I_0 + I_1 \sin wt$ then its rms value will be
(A) $\sqrt{I_0^2 + 0.5 I_1^2}$ (B) $\sqrt{I_0^2 + 0.5 I_0^2}$ (C) 0 (D) $I_0/\sqrt{2}$

19. The phase difference between current and voltage in an AC circuit is $\pi/4$ radian. If the frequency of AC is 50 Hz, then the phase difference is equivalent to the time difference :
(A) 0.78 s (B) 15.7 ms (C) 0.25 s (D) 2.5 ms

20. Power factor of an L-R series circuit is 0.6 and that of a C–R series circuit is 0.5. If the element (L, C, and R) of the two circuits are joined in series the power factor of this circuit is found to be 1. The ratio of the resistance in the L-R circuit to the resistance in the C–R circuit is
(A) 6/5 (B) 5/6 (C) $\frac{4}{3\sqrt{3}}$ (D) $\frac{3\sqrt{3}}{4}$

21. The effective value of current $i = 2 \sin 100\pi t + 2 \sin(100\pi t + 30°)$ is :
(A) $\sqrt{2}$ A (B) $2\sqrt{2+\sqrt{3}}$ (C) 4 (D) None

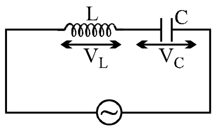
22. If I_1, I_2, I_3 and I_4 are the respective r.m.s. values of the time varying currents as shown in the four cases I, II, III and IV. Then identify the correct relations.

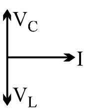


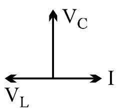
(A) $I_1 = I_2 = I_3 = I_4$ (B) $I_3 > I_1 = I_2 > I_4$ (C) $I_3 > I_4 > I_2 = I_1$ (D) $I_3 > I_2 > I_1 > I_4$

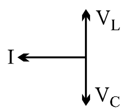
23. In series LR circuit $X_L = 3R$. Now a capacitor with $X_C = R$ is added in series. Ratio of new to old power factor is
(A) 1 (B) 2 (C) $\frac{1}{\sqrt{2}}$ (D) $\sqrt{2}$

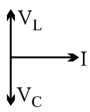
24. The current I, potential difference V_L across the inductor and potential difference V_C across the capacitor in circuit as shown in the figure are best represented vectorially as



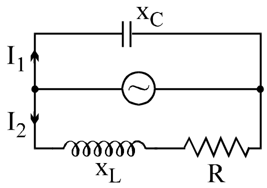
(A) 

(B) 

(C) 

(D) 

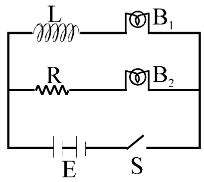
25. In the shown AC circuit phase different between currents I_1 and I_2 is



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

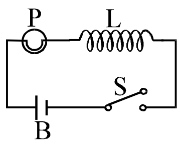
26. In a series R-L-C circuit, the frequency of the source is half of the resonance frequency. The nature of the circuit will be
(A) capacitive (B) inductive (C) purely resistive (D) data insufficient

27. An inductor L, a resistance R and two identical bulbs B_1 and B_2 are connected to a battery through a switch S as shown in the figure. The resistance of coil having inductance L is also R. Which of the following statement gives the correct description of the happenings when the switch S is closed?



(A) The bulb B_2 lights up earlier than B_1 and finally both the bulbs shine equally bright.
(B) B_1 light up earlier and finally both the bulbs acquire equal brightness.
(C) B_2 lights up earlier and finally B_1 shines brighter than B_2.
(D) B_1 and B_2 light up together with equal brightness all the time.

28. In figure, a lamp P is in series with an iron-core inductor L. When the switch S is closed, the brightness of the lamp rises relatively slowly to its full brightness than it would do without the inductor. This is due to



(A) the low resistance of P (B) the induced-emf in L
(C) the low resistance of L (D) the high voltage of the battery B

MULTIPLE CORRECT ANSWER(S) QUESTIONS

29. Average value of A.C. current in a half time period may be :
(A) positive (B) negative (C) zero (D) none

30. An AC source rated 100 V (rms) supplies a current of 10 A (rms) to a circuit. The average power delivered by the source :
(A) must be 1000 W (B) may be 1000 W
(C) may be greater than 1000 W (D) may be less than 1000 W

31. A constant current i is maintained in a solenoid. Which of the following quantities will increase if an iron rod is inserted in the solenoid along its axis ?
(A) magnetic field at the centre (B) magnetic flux linked with the solenoid
(C) self-inductance of the solenoid (D) rate of Joule heating

32. 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 line source 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 substitution 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

33. 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

34. 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.

35. A pure inductance of 1 henry is connected across a 110 V, 70Hz source. Then correct option are (Use π = 22/7):
(A) reactance of the circuit is 440 Ω
(B) current of the circuit is 0.25 A
(C) reactance of the circuit is 880 Ω
(D) current of the circuit is 0.5 A

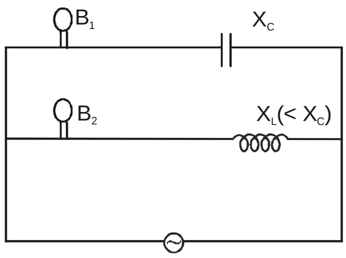
36. In a series LCR circuit with an AC source(E_{rms} = 50 V and ν = 50/π Hz), R = 300 Ω, C = 0.02 mF, L = 1.0 H, Which of the following is correct
(A) the rms current in the circuit is 0.1 A
(B) the rms potential difference across the capacitor is 50 V
(C) the rms potential difference across the capacitor is 14.1 V
(D) the rms current in the circuit is 0.14 A

37. In the AC circuit shown below, the supply voltage has a constant rms value V but variable frequency f. At resonance, the circuit
(A) has a current i given by i = V/R
(B) has a resonance frequency 500 Hz
(C) has a voltage across the capacitor which is 180° out of phase with that across the inductor
(D) has a current given by $I = \dfrac{V}{\sqrt{R^2 + \left(\dfrac{1}{\pi} + \dfrac{1}{\pi}\right)^2}}$

38. 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

39. A coil of inductance 5.0 mH and negligible resistance is connected to an oscillator giving an output voltage E = $(10\sqrt{2}$ V) sin ωt. Which of the following is correct
(A) for ω = 100 s^{-1} current is 20 A
(B) for ω = 500 s^{-1} current is 4 A
(C) for ω = 1000 s^{-1} current is 2 A
(D) for ω = 1000 s^{-1} current is 4 A

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



(A) their brightness will be the same
(B) B_2 will be brighter than B_1
(C) as frequency of supply voltage is increased, brightness of B_1 will increase and that of B_2 will decrease
(D) only B_2 will glow because the capacitor has infinite impedance

41. A metal sheet is placed in front of a strong magnetic pole. A force is needed to -
(A) hold the sheet there if the metal is magnetic
(B) hold the sheet there if the metal is nonmagnetic
(C) move the sheet away from the pole with uniform velocity if the metal is magnetic
(D) move the sheet away from the pole with uniform velocity if the metal is nonmagnetic Neglect any effect of paramagnetism, diamagnetism and gravity.

42. The symbols L, C, R represent inductance, capacitance and resistance respectively. Dimension of frequency are given by the combination
(A) 1/RC
(B) R/L
(C) $\frac{1}{\sqrt{LC}}$
(D) C/L

PART - II : SUBJECTIVE QUESTIONS

* ***Marked Questions are having more than one correct option.***

1. An inductor of reactance 10 Ω and a resistance of 10 Ω are connected in series and the combination is connected to a 220-V, 50-Hz a.c. supply. Calculate the peak current (in A) through the circuit.

2. The current in a coil of inductance L = 2.0 H is increasing according to the law i = 2 sin t^2. Find the amount of change in stored energy (in J) during the period when the current changes from 0 to 2 A.

3. A circuit contains a resistance of 40 ohm and inductance of $\frac{0.3}{\pi}$ henry and an alternating effective emf of 500 volt at a frequency of 50 cycles per second applied across it in series. If the value of power factor in the circuit is (0.1) y then find the value of y.

4. A high-impedance AC voltmeter is connected in turn across the inductor, the capacitor, and the resistor in a series circuit having an AC source of 100 V (rms) and gives the same reading in volts in each case. If this reading is 20y then find value of y.

5. A circuit has a coil of resistance 400 ohm and inductance 1 henry. It is connected in series with a capacitor of 25 μF and A.C. supply voltage of 200 V and 50/π cycles/sec. If the p.d. across inductor coil and capacitor are x and y volts respectively, then find the value of x, y.

6. A current of 4A flows in a coil when connected to a 12 V d.c. source. If the same coil is connected to 12 V, 50 rad/s.a.c. source a current of 2.4 A flows in the circuit. If the inductance of the coil is 20y mH, then find the value of y.

7. Find the value of an inductance which should be connected in series with a capacitor of 5 μF, a resistance of 10Ω and an ac source of 50 Hz so that the power factor of the circuit is unity.

8. 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.

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

10. 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.

11. 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.

12. A box P and a coil Q are connected in series with an ac source of variable frequency. The emf of source at 10 V. Box P contains a capacitance of 1μF in series with a resistance of 32Ω coil Q has a self-inductance 4.9 mH and a resistance of 68Ω series. 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.

13. 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°?

EXERCISE # 3

PART-I IIT-JEE (PREVIOUS YEARS PROBLEMS)

***Marked Questions are having more than one correct option.**

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

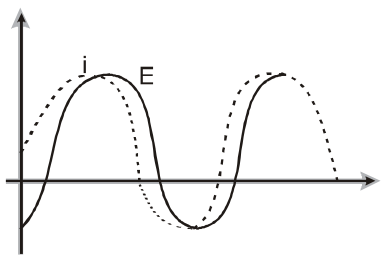
(A) is zero when the circuit contains an ideal resistance only

(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

2. When an AC source of emf $E = E_0 \sin(100\, t)$ is connected across a circuit, the phase difference between the E and the current i in the circuit is observed to be $\frac{\pi}{4}$, as shown in the diagram. If the circuit consists possibly only of R-C or R-L or L-C series, find the relationship between the two elements.

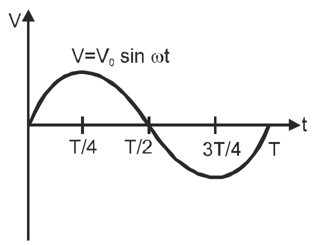


[JEE 2003 (Screening) 3/90 Each]

(A) $R = 1k\Omega$, $C = 10\ \mu F$ (B) $R = 1k\Omega$, $C = 1\ \mu F$

(C) $R = 1k\Omega$, $L = 10$ H (D) $R = 1k\Omega$, $L = 1H$

3. In an L–R series circuit, a sinusoidal voltage $V = V_0 \sin\omega t$ is applied. It is given that L = 35 mH, $R = 11\Omega$, $V_{rms} = 220$ V, $\omega/2\pi = 50$ Hz and $\pi = 22/7$. Find the amplitude of current in the steady state and obtain the phase difference between the current and the voltage. Also plot the variation of current for one cycle on the given graph. **[JEE 2004 (Mains) 4/60]**

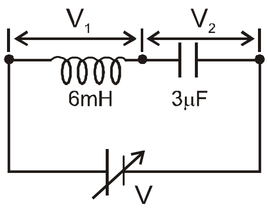
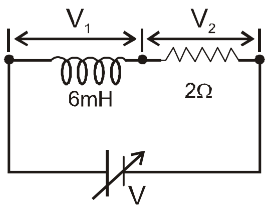
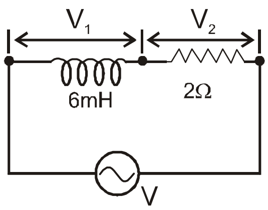
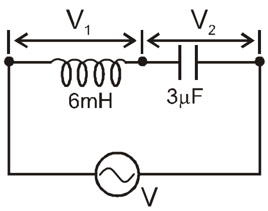
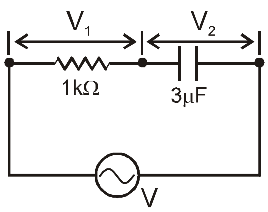


4. An AC voltage source of variable angular frequency ω and fixed amplitude V connected in series with a capacitance C and an electric bulb of resistance R (inductance zero). When ω is increased :

(A) the bulb glows dimmer (B) the bulb glows brighter **[JEE 2010; 3/163, –1]**

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

5. 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 : **[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) 

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

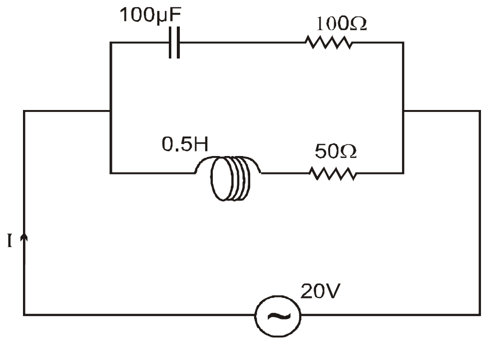
[IIT-JEE 2011; 4/160 conducted by IIT Kanpur]

7.* 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 c urrent 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 ?

[IIT-JEE 2011; 4/160 conducted by IIT Kanpur]

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

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



(A) The current through the circuit, I is 0.3A.

(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 = 10 V. **[A.C, PARALLEL CIRCUIT, MODERATE]**

[IIT-JEE 2012 ; 4/136 conducted by IIT Delhi]

PART-II AIEEE (PREVIOUS YEARS PROBLEMS)

*** Marked Questions are having more than one correct option.**

1. The power factor of an A.C. circuit having resistance R and inductance L (connected in series) and an angular velocity ω is – **[AIEEE 2002; 4/300]**

(1) $\frac{R}{\omega L}$ (2) $\frac{R}{(R^2 + \omega^2 L^2)^{1/2}}$ (3) $\frac{\omega L}{R}$ (4) $\frac{R}{(R^2 - \omega^2 L^2)^{1/2}}$

2. In a transformer, number of turns in the primary are 140 and that in the secondary are 280. If current in primary is 4 A, then that in the secondary is : **[AIEEE 2002; 4/300]**

(1) 4 A (2) 2 A (3) 6 A (4) 10 A

3. In an oscillating LC circuit the maximum charge on the capacitor is Q. The charge on the capacitor when the energy is stored equally between the electric and magnetic field is : **[AIEEE 2003; 4/300]**

(1) Q/2 (2) $Q/\sqrt{3}$ (3) $Q/\sqrt{2}$ (4) Q

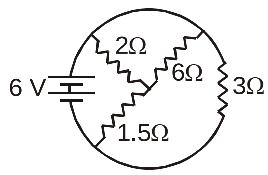
4. Alternating current can not be measured by D.C. ammeter because : **[AIEEE 2004; 4/300]**

(1) A.C. current pass through d.C. ammeter

(2) A.C. change direction

(3) average value of current for complete cycle is zero

(4) D.C. ammeter will get damaged



5. In an LCR circuit, capacitance is changed from C to 2C. For the resonant frequency to remain unchanged, the inductance should be changed from L to : **[AIEEE 2004; 4/300]**

(1) 4L (2) 2L (3) L/2 (4) L/4

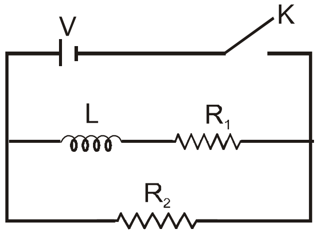
6. A circuit has a resistance of 12 ohm and an impedance of 15 ohm. The power factor of the circuit will be : **[AIEEE 2005; 4/300]**

(1) 0.8 (2) 0.4 (3) 1.25 (4) 0.125

7. The phase difference between the alternating current and emf is $\pi/2$. Which of the following cannot be the constituent of the circuit? **[IIT-JEE 2011; 4/160 conducted by IIT Kanpur]**

(1) C alone (2) R, L (3) L, C (4) L alone

8. In the circuit shown below, the key K is closed at t = 0. The current through the battery is :



[AIEEE 2010; 4/144, –1]

(1) $\frac{VR_1R_2}{\sqrt{R_1^2+R_2^2}}$ at t = 0 and $\frac{V}{R_2}$ at t = ∞

(2) $\frac{V}{R_2}$ at t = 0 and $\frac{V(R_1+R_2)}{R_1R_2}$ at t = ∞

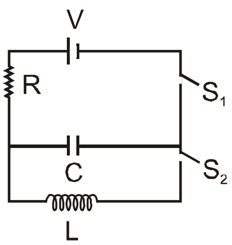
(3) $\frac{V}{R_2}$ at t = 0 and $\frac{VR_1R_2}{\sqrt{R_1^2+R_2^2}}$ at t = ∞

(4) $\frac{V(R_1+R_2)}{R_1R_2}$ at t = 0 and $\frac{V}{R_2}$ at t = ∞

9. 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 30°. On taking out the inductor from the circuit the current leads the voltage by 30°. The power dissipated in the LCR circuit is : **[AIEEE 2010; 4/144, –1]**

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

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



[JEE Mains 2013]

(1) Work down by the battery is half of the energy dissipated in the resistor

(2) At t = τ, q = (CV/2)

(3) At t = 2τ, q = CV $(1 - e^{-2})$

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

NCERT QUESTIONS

1. A 100 Ω resistor is connected to a 220 V, 50 Hz ac supply.
(a) What is the rms value of current in the circuit?
(b) What is the net power consumed over a full cycle?

2. A 44 mH inductor is connected to 220V, 60 Hz ac supply. Determine the rms value of the current in the circuit?

3. Obtain the resonat frequency ω_r of a series LCR circuit with L = 2.OH, C = 32 μF and R = 10 Ω . What is the Q -value of this circuit.

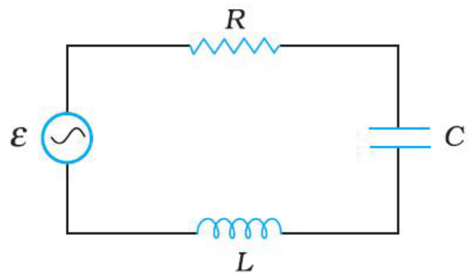
4. Whay is a choke coil needed in the use of fluorescent tubes with ac mains? Why can we not use an ordinary instead of the choke coil?

5. A charged 30 μF capacitor is connected to a 27 mH inductor. What is the angular frequency of free oscillations of the circuit?

6. Suppose the initial charge on the capacitor in Exercise 8.11 is 6 mC. What is the total energy stred in the circuit initially? What is the total energy at later time?

7. A radio can tune over the frequency range of a portion of **MW** broadcast band; (800 kHz to 1200 kHz). If its LC circuit has an effective inducatance of 200 μH , what must be the range of its variable capacitor? [**Hint:** For tuning, the natural frequency i.e., the frequency of oscillations of the LC circuit should be equal to the frequency of the radiowave.]

8. Figure shows a series LCR circuit connected to avriable frequency 230 V source. L =5.0 H, C= 80 μF R = 40 Ω .
(a) Determine the source frequency which drives the circuit in resonance.
(b) Obtain the inpedance of the circuit and the amplitude of current at the resonating frequency.
(c) Determine the rms potential drops across the tharee elements of the circuit. Show that the potential drop across the LC combination is zero at the resonating frequency.



9. An LC circuit contains a 20 mH inductor and a 50 μF capacitor with an initial charge of 10 mC. The resistnce of the circuit is negligible. Let the instant the circuit is closed be t = 0.
(a) What is the total energy stored initially? Is it conserved during LC oscillations?
(b) What is the natural frequency of the circuit?
(c) At wht time is the energy stored
(i) completely electrical (i.e., stored in the capacitor)?
(ii) completely magnetic (i.e., stored in the inductor)?
(d) At what time is the total enetgy shared equally between the inductor and the capacitor?
(e) If a resistor is inserted in the circuit, how much energy is eventually dissipated as heat?

10. A coil of inducatnce 0.50 H and resistance 10 Ω is connected to 240 V, 50 Hz ac supply.
(a) What is the maximum current in the coil?
(b) What is the time lag between the voltage maximum and the current maximum?

11. Obtain the answers (a) to (b) above if the circuit is connected to a high frequency supply (240 V, 10 kHz). Hence, explain the statement that at very high frequency, an inductor in a circuit nearly amounts to an open circuit. How does an inductor behave in a dc circuit after the steady astate ?
(a) I_0 = 1.1 x 10^{-2} A
(b) tan ϕ = 100 π , ϕ is close to 33.5° π /2.
I_0 is much smaller than the low frequency case (Exercise 8.17) showing thereby that at high frequencise, L nearly amounts to an open circuit. In a dc circuit (after steady state) ω = 0, so here L acts like a pure conductor.

12. A circuit containing a 80 mH inductor and a 60 μF capacitor in series is connected to a 230 V, 50 Hz supply . The resistance of the circuit is negligible.
(a) Obtain the current amplitude and rms values.
(b) Obtain the rms values of potential drops across each element.
(c) What is the average power transferred to the capacitor?
(d) What is the average power transferred to the capacitor?
(e) What is the total average power absorbed by the circuit? ['Average implies 'averaged over one cycle',]

13. A series LCR circuit with L = 0.12 H, C = 480 nF, R = 23 Ω is connected to a 230 V variable frequency supply.
(a) What is the source frequency for which currnet 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 which frequencies of the source is the power transferred to the circuit half the power at resonant frequency? What is the current emplitude at these frequencies?
(d) What is the Q -factor of the given circuit?

14. Answer the following questions:
(a) In any ac circuit, is the applied instantaaneous voltage tqual to the algebrabic sum of the instantaneous voltages across the series elements of the circuit? Is the same true for rms voltage?
(b) For circuits used for transporting electric power, a low power factor implies large power loss in transmission.
(c) Power factor can often be inproved by the use of a capacitor of appropriate capacitance in the circuit.
(d) A capacitor is used in the primary circuit of an induction coil.
(e) An applied voltage signal consists of a superposition of a dc voltage and an ac voltage of high frequency. The circuit consists of an inductor and a capacitor in series. Show that the dc signal will appear across C and the ac singal across L.
(f) A choke coil in series with a lamp is connected to a dc line.The lamp is seen to shine brightly. Insertion of an iron core in the choke causes no change in the lamp's brightness. Predict the corresponding observations if the cinnection is to an ac line.
(g) A lamp is connected in series with a capacitor. Predict your observations for dc and ac connections. what happens in each if the capacity is reduced?

ANSWERS

Exercise # 1

PART-I

A-1.	(A)	**A-2.**	(B)	**A-3.**	(B)	**A-4.**	(D)	**A-5.**	(D)	**A-6.**	(B)	**A-7.**	(D)
A-8.	(D)	**A-9.**	(B)	**A-10.**	(D)	**A-11.**	(B)	**A-12.**	(C)	**B-1.***	(ABCD)	**B-2.**	(C)
B-3.	(C)	**B-4.**	(B)	**B-5.**	(C)	**B-6.**	(A)	**B-7.**	(A)	**C-1.**	(B)	**C-2.**	(A)
C-3.	(D)	**C-4.**	(D)	**C-5.**	(D)	**C-6.**	(C)	**C-7.**	(B)0	**C-8.**	(A)	**C-9.**	(B)
C-10.	(B)	**C-11.**	(B)	**C-12.**	(C)	**C-13.**	(D)	**C-14.**	(B)	**C-15.**	(A)	**C-16.***	(AD)
C-17.	(C)	**C-18.***	(ABCD)	**D-1.**	(D)	**D-2.**	(A)	**D-3.**	(C)	**D-4.**	(A)	**D-5.**	(D)
D-6.*	(BC)	**E-1.**	(A)	**E-2.**	(B)	**E-3.**	(C)	**E-4.**	(D)	**E-5.**	(C)	**E-6.**	(D)

PART-II

1.	(D)	**2.**	(C)	**3.***	(BD)	**4.**	(C)	**5.**	(D)	**6.**	(B)	**7.**	(B)

8. (A) **9.** (A) - p, s, t ; (B) - p, s, t ; (C) - p, r; (D) - p, q **10.** (A) - r ; (B) - p ; (C) - s ; (D) - q, s

11.	(D)	**12.**	(A)	**13.**	(A)	**14.**	(C)	**15.**	(E)	**16.**	(D)

17. **(i)** False **(ii)** True **(iii)** False **(iv)** True **(v)** True

Exercise # 2

PART-I

1.	(B)	**2.**	(A)	**3.**	(A)	**4.**	(D)	**5.**	(D)	**6.**	(A)	**7.**	(B)
8.	(B)	**9.**	(C)	**10.**	(C)	**11.**	(B)	**12.**	(C)	**13.**	(B)	**14.**	(A)
15.	(D)	**16.**	(B)	**17.**	(D)	**18.**	(A)	**19.**	(D)	**20.**	(D)	**21.**	(D)
22.	(B)	**23.**	(D)	**24.**	(D)	**25.**	(C)	**26.**	(A)	**27.**	(A)	**28.**	(B)
29.	(ABC)	**30.**	(BD)	**31.**	(ABC)	**32.**	(AC)	**33.**	(BD)	**34.**	(ABCD)	**35.**	(AB)
36.	(AB)	**37.**	(ABC)	**38.**	(AC)	**39.**	(ABC)	**40.**	(BC)	**41.**	(AC)	**42.**	(ABC)

PART-II

1.	22	**2.**	4	**3.**	8	**4.**	5	**5.**	16 ; 64	**6.**	4	**7.**	$\frac{20}{\pi^2} \cong 2H$

8. 20 V **9.** C = 9.2 μF **10.** 0.08 H, 17.28 W **11.** 2A, 400W

12. 77Ω, 97.6Ω, 7.7V, 9.76V **13.** 0.2 mH, $\frac{1}{32}$ μF, 8 × 10^5 rad/s

Exercise # 3

PART-I

1. (BC) **2.** (A) **3.** 20 A, $\frac{\pi}{4}$ **4.** (B) **5. (A)–r,s,t ; (B)–q,r,s,t ; (C)–p,q ; (D)–q,r,s,t**

6. 4 **7.*** (BC) **8.*** (AC)

PART-II

1. (2) **2.** (2) **3.** (3) **4.** (3) **5.** (3) **6.** (1) **7.** (2)

8. (2) **9.** (4) **10.** (3)

Exercise # 4

1. (a) 2.20 A (b) 484 W

2. 15.9 A

3. 125 s^{-1} ; 25

4. A choke coil reduces voltage across the tube without wasting power. A resistor would waste power power as heat.

5. 1.1 x 10^{-3} s^{-1}

6. 0.6 J, same at later times.

7. $v = \frac{1}{2\pi}\sqrt{\frac{1}{LC}}$, i.e., $C = \frac{1}{4\pi^2 v^2 L}$

For L = 200 μH , v = 1200 kHz, C = 87.9 pF.

For L = 200 μH, v = 800 kHz , C = 197.8 pF.

The variable capacitor should have a range of about 88 pF to 198 pF.

8. (a) 50 rad s^{-1} (b) 40 Ω , 8.1 A

(c) $V_{L\,rms}$ = 14375.5. V, V_{Crms} = 1437.5V, V_{Rrms}= 230 V

$$V_{LCrms} = I_{rms}\left(\omega_0 L - \frac{1}{\omega_0 C}\right) = 0$$

9. (a) 1.0 J. Yes, sum of the energies stored in L and C is conserved if R = 0

(b) ω = 10^3 $rads^{-1}$, v = 159 Hz

(c) $q = q_0 \cos \omega t$

(i) energy stored is completely electrical at t = 0, $\frac{T}{2}$, T $\frac{3T}{2}$,...........

(ii) energ stored is completely magntic (i.e., electrical energy is zero)

at $t = \frac{T}{4}, \frac{3T}{4}, \frac{5T}{4}$ .... , where $T = \frac{1}{v}$ = 6.3 ms.

(d) At $t = \frac{T}{8}, \frac{3T}{8}, \frac{5T}{8}$,..........., because $q = q_0 \cos \frac{\omega T}{8} = q_0 \cos \frac{\pi}{4} = \frac{q_0}{\sqrt{2}}$.

Therefore electricl energy $= \frac{q^2}{2C} = \frac{1}{2}\left(\frac{q_0^2}{2C}\right)$ which is half the total energy.

(e) R damps out the LC oscillations eventually. The whole of the initial energy (= 1.0 J) is eventually dissipated as heat.

10. For an LR circuit, if $V = V_0 \sin \omega t$

$$I = \frac{V_0}{\sqrt{R^2+\omega^2 L^2}} \sin(\omega t - \phi), \text{ where } \tan\phi = (\omega L / R).$$

(a) I_0 1.82 A

(b) V is maximum at t = 0, I is maximum at t = (ϕ / ω).

Now $\tan\phi \frac{2\pi\nu L}{R} = 1.571$ or $\phi \approx 57.5^o$

Therefore, time lag = $\left(\frac{57.5\pi}{180}\right) \times \frac{1}{2\pi \times 50} = 3.2$ ms

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

$$I = \frac{V_0}{\left|\omega L - \frac{1}{\omega C}\right|} \sin\left(\omega t + \frac{\pi}{2}\right); \quad \text{if } R = 0$$

where - sign appears if $\omega L > 1/\omega C$, and + appears if $\omega L < 1\omega/C$.
I_0 =11.6 A, I_{rms} 8.24A
(b) V_{Lrms}= 207 V, V_{Crms} = 437 V
(Note : 437 V – 207 V =230 V is equal to the applied rms voltage as should be the case. The voltage across L and C gets subtracted because thet are 180º out of phase.)
(c) Whatever be the current I in L, actual voltage leads current by $\pi/2$. Therefore, average power consumed by L is zero.
(d) For C, voltage lags by $\pi/2$. Again, average power consumed by C is zero.
(e) Total average power absorbed is zero.

13. ω_0 = 4167 rad s^{-1} ; v_0 = 663 Hz
I_0^{max} = 14.1A

(b) $\bar{p} = (1/2)\ I_0^2 R$ which is maximum at the same frequency (663 Hz) for which I_0 is maximum P_{mas} = (1/2) $(I_{max})^2$ R = 2300 W.

(c) At $\omega = \omega_0 \pm \Delta\omega$ [Approximation good if $(R/2L) << \omega_0$].

$\Delta\omega$ = R/2L = 95.8 rad s^{-1}; $\Delta v = \Delta\omega/2\pi$ = 15.2 Hz.

Power absorbed is half the peak power at v = 648 Hz and 678 Hz.

At these frequencies, current amplitude is $(1/\sqrt{2})$times I_0^{max}, i.e., current amplitude (at half the peak power points) is 10 A .
(d) Q = 21.7

14. (a) Yes. The same is not true for rms voltage, because voltages across different elements may not be phase. See, for example, answer to Exercise 8.22
(b) To supply a given power, low power factor means a large current isneeded. This causes larger heat losses due to the factor $I^2 R$.
(c) Power factor = (R/Z). Many ac machines have inductive reactance.A capacitance of appropriate value reduces the net reactance os that Z approaches R.
(d) The high induced voltage, when the circuit is broken, is used to charge the capacitor, thus avoiding sparks, etc.
(e) For dc, impedance of L is negligible and of C very high (infinige), so the co signal appears across C. For hing frequency ac, impedance of L is high and that of C is low. So, the ac singal appears across L,
(f) For a steady state dc,L has no effect, even if is increased by an iron core. For ac, the lamp will shine dimly becaause of additional impedance to the choke. It wii shine because C'conducts' ac. Reducing C, will increase impedance impedance of Cand the lamp will shine less brightly than before.