## CBSE Test Paper-01

## Class - 12 Physics (Alternating current)

1. A 200 ohm resistor is connected in series with a $5 \mu F$ capacitor. The voltage across the resistor is $\mathrm{V}_{\mathrm{R}}=(1.20 \mathrm{~V}) \cos (2500 \mathrm{rad} / \mathrm{s}) \mathrm{t}$.Capacitive reactance is
a. $70 \Omega$
b. $80 \Omega$
c. $60 \Omega$
d. $90 \Omega$
2. The current in a series LCR circuit will be maximum, then $\omega$ is:
a. as large as possible
b. $\sqrt{L C}$
c. $\sqrt{L C R}$
d. equal to natural frequency of LCR system
3. A series circuit consists of an ac source of variable frequency, a $115.0 \Omega$ resistor, a $1.25 \mu \mathrm{~F}$ capacitor, and a 4.50-mH inductor. Impedance of this circuit when the angular frequency of the ac source is adjusted to twice the resonant angular frequency is
a. $146.0 \Omega$
b. $176.0 \Omega$
c. $166.0 \Omega$
d. $156.0 \Omega$
4. For high frequency capacitor offers:
a. Less resistance
b. More resistance
c. None of these
d. Zero resistance
5. Effective voltage $\mathrm{V}_{\mathrm{rms}}$ is related to peak voltage $\mathrm{V}_{\mathrm{O}}$ by
a. $\mathrm{V}_{\mathrm{rms}}=0.707 \mathrm{~V}_{\mathrm{o}}$
b. $\mathrm{V}_{\mathrm{rms}}=0.787 \mathrm{~V}_{\mathrm{o}}$
c. $\mathrm{V}_{\mathrm{rms}}=0.9 \mathrm{~V}_{\mathrm{o}}$
d. $\mathrm{V}_{\mathrm{rms}}=0.5 \mathrm{~V}_{\mathrm{O}}$
6. An AC current, $\mathrm{I}=\mathrm{I}_{0} \sin \omega t$ produces certain heat H in a resistor R over a time $T=2 \pi / \omega$. Write the value of the DC current that would produce the same heat in the same resistor in the same time.
7. Define the term rms value of the current. How is it related to the peak value?
8. Define the term wattless current.
9. The figure shows a series L-C-R circuit connected to a variable frequency 250 V source with $\mathrm{L}=50 \mathrm{mH}, \mathrm{C}=80 \mu \mathrm{~F}$ and $\mathrm{R}=40 \Omega$.

i. the source frequency which drives the circuit in resonance.
ii. the quality factor $(Q)$ of the circuit.
10. The number of turns in secondary coil of a transformer is 100 times the number of turns in the primary coil. What is the transformation ratio?
11. In the following circuit, calculate,
i. the capacitance ' $c$ ' of the capacitor if the power factor of the circuit is unity, and
ii. also calculate the Q -factor of the circuit.

12. A source of AC voltage $\mathrm{V}=\mathrm{V}_{0}$ sin $\omega t$ is connected to a series combination of a resistor ' R ' and a capacitor ' C '. Draw the phasor diagram and use it to obtain the expression for
i. impedance of the circuit and
ii. phase angle.
13. i. For a given $\mathrm{AC}, \mathrm{i}=\mathrm{i}_{\mathrm{m}} \sin \omega t$, show that the average power dissipated in a resistor R over a complete cycle is $\frac{1}{2} i_{m}^{2} R$.
ii. A light bulb is rated at 100 W for a 220 V AC supply. Calculate the resistance of the bulb.
14. An LC circuit contains a 20 mH inductor and a $50 \mu F$ capacitor with an initial charge of 10 mC . The resistance 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 what 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 times is the total energy 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?
15. A series of LCR circuit connected to a variable frequency 230 V source, $\mathrm{L}=5.0 \mathrm{H}$, $C=80 \mu F, R=40 \Omega$


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a. Determine the source frequency which drives the circuit in resonance.
b. Obtain the impedance of the circuit and the amplitude of current at the resonating frequency.
c. Determine the rms potential drops across the three elements of the circuit. Show that the potential drop across the LC combination is zero at the resonating frequency.

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## Answers

1. b. $80 \Omega$

Explanation: $\mathrm{V}_{\mathrm{R}}=(1.20 \mathrm{~V}) \cos (2500 \mathrm{rad} / \mathrm{s}) \mathrm{t}$
$\omega=2500 \mathrm{rad} / \mathrm{s}$
$C=5 \mu F=5 \times 10^{-6} F$
Capacitive reactance
$X_{C}=\frac{1}{\omega C}=\frac{1}{2500 \times 5 \times 10^{-6}}=80 \Omega$
2. d. equal to natural frequency of LCR system

Explanation: for maximum current in LCR series circuit impedance Z will be minimum
$i=\frac{E}{Z}$
$Z=\sqrt{R^{2}+\left(X_{L}-X_{C}\right)^{2}}$
impedance Z will be minimum when $X_{L}=X_{C}$
hence
$\omega L=\frac{1}{\omega C}$
$\omega=\frac{1}{\sqrt{L C}}$
this is equal to natural frequency of LCR system
3. a. 146.0

Explanation: $R=115 \Omega$
$C=1.25 \mu F=1.25 \times 10^{-6} F$
$L=4.5 \mathrm{mH}=4.5 \times 10^{-3} H$
resonant angular frequency
$\omega_{0}=\frac{1}{\sqrt{L C}}=\frac{1}{\sqrt{4.5 \times 10^{-3} \times 1.25 \times 10^{-6}}}=\frac{1}{7.5 \times 10^{-5}}$
given that the angular frequency of the ac source
$\omega=2 \omega_{0}=\frac{2}{7.5 \times 10^{-5}}=26666.6 \mathrm{rad} / \mathrm{s}$
impedance
$Z=\sqrt{R^{2}+\left(\omega L-\frac{1}{\omega C}\right)^{2}}$

$$
=\sqrt{115^{2}+\left[\left(26666.6 \times 4.5 \times 10^{-3}\right)-\left(\frac{1}{26666.6 \times 1.25 \times 10^{-6}}\right)\right]^{2}}
$$

$Z=146 \Omega$
4. a. Less resistance

Explanation: capacitive reactance
$X_{C}=\frac{1}{\omega C}=\frac{1}{2 \pi f C}$
$X_{C} \propto \frac{1}{C}$
hence, for high frequency capacitor offers less resistance.
5. a. $\mathrm{V}_{\mathrm{rms}}=0.707 \mathrm{~V}_{\mathrm{O}}$

Explanation: Average value of $\mathrm{V}^{2}$ over a complete cycle is given by
$\bar{V}^{2}=\frac{1}{T} \int_{0}^{T} V^{2} d t$
$V=V_{o} \sin \omega t$
$T=\frac{2 \pi}{\omega}$
$\bar{V}^{2}=\frac{\omega}{2 \pi} \int_{0}^{2 \pi / \omega} V_{o}^{2} \sin ^{2} \omega t d t=\frac{\omega}{2 \pi} V_{o}^{2} \int_{0}^{2 \pi / \omega} \frac{(1-\cos 2 \omega t)}{2} d t$
$\bar{V}^{2}=\frac{\omega}{2 \pi} \frac{V_{o}^{2}}{2}\left[t-\frac{\sin 2 \omega t}{2 \omega}\right]_{0}^{2 \pi / \omega}=\frac{\omega}{2 \pi} \frac{V_{o}^{2}}{2}\left(\frac{2 \pi}{\omega}\right)$
$\bar{V}^{2}=\frac{V_{0}^{2}}{2}$
The root-mean-square value of the alternating voltage is given by

$$
\begin{aligned}
& V_{r m s}=\sqrt{\bar{V}^{2}}=\frac{V_{o}}{\sqrt{2}} \\
& \mathrm{~V}_{\mathrm{rms}}=0.707 \mathrm{~V}_{0}
\end{aligned}
$$

6. Heat produced by DC is $\mathrm{H}=\mathrm{I}^{2} \mathrm{RT}$....(i)

Heat produced by AC is
$H=I_{V}^{2} R T \quad$ or $\quad H=\left(\frac{I_{0}}{\sqrt{2}}\right)^{2} R T$
Where $\mathrm{I}_{\mathrm{V}}=\mathrm{I}_{0} / \sqrt{2}=$ rms value of the AC current
From Eqs. (i) and (ii), we get
$I^{2} R T=\frac{I_{0}^{2} R T}{2}$ or $I=I_{0} / \sqrt{2}$
where I stands for DC and $\mathrm{I}_{0}$ is the peak value of AC current.
7. It is defined as the value of Alternating Current (AC) over a complete cycle which
would generate same amount of heat in a given resistor that is generated by steady current in the same resistor and in the same time during a complete cycle. It is also called virtual value or effective value of AC.
Let the peak value of the current be $\mathrm{I}_{0}$
$\therefore \quad I_{r m s}=\frac{I_{0}}{\sqrt{2}} \Rightarrow I_{r m s}=\frac{I_{0}}{\sqrt{2}}$
Where, $\mathrm{I}_{0}$ peak value of AC.
8. The current in an AC circuit is said to be Wattless Current when the average power consumed in such circuit corresponds to Zero.Such current is also called as Idle Current.
9. Given, $\mathrm{L}=50 \mathrm{mH}=50 \times 10^{-3} \mathrm{H}$
$C=80 \mu F=80 \times 10^{-6} F$
$R=40 \Omega, V=200 \mathrm{~V}$
i. In the L-C-R, the resonant angular frequency when $\mathrm{X}_{\mathrm{L}}=\mathrm{X}_{\mathrm{C}}$

$$
\begin{aligned}
& \omega_{0}=\frac{1}{\sqrt{L C}}=\frac{1}{\sqrt{50 \times 10^{-3} \times 80 \times 10^{-6}}}=500 \mathrm{rad} / \mathrm{s} \\
& \omega=2 \pi v \Rightarrow v=\frac{\omega}{2 \pi} \\
& \Rightarrow \quad v=\frac{500}{2 \pi}=\frac{250}{\pi}=79.61 \approx 80 \mathrm{~Hz}
\end{aligned}
$$

ii. Quality factor, $Q=\frac{\omega_{0} L}{R}=\frac{500 \times 50 \times 10^{-3}}{40}=0.625$
10. Transformation ratio
$\Rightarrow k=\frac{N_{s}}{N_{p}}$
Since $N_{s}=100 \times N_{p}$
Thus $k=\frac{100 N_{p}}{N_{p}}=100$
11. i. Power factor, $\cos \phi=\frac{R}{Z}$ or $\mathrm{Z}=\mathrm{R}$ [For power factor unity $\cos \theta=1$ ]

$$
\begin{aligned}
& \therefore X_{C}=X_{L} \text { or } \frac{1}{2 \pi f C}=2 \pi f L \\
& \text { or } C=\frac{1}{4 \pi^{2} f^{2} L}=\frac{1}{4 \times 9.87 \times(50)^{2} \times 200 \times 10^{-3}} \\
& =5 \times 10^{-5} F \\
& \text { or } C=50 \mu F
\end{aligned}
$$

ii. Q -factor $=\frac{1}{R} \sqrt{\frac{L}{C}}$

$$
Q=\frac{1}{10} \sqrt{\frac{200 \times 10^{-3}}{5 \times 10^{-5}}}=6.32
$$

12. i. $V=V_{0} \sin \omega t$

From diagram, by parallelogram law of vector addition, $\mathrm{V}_{\mathrm{R}}+\mathrm{V}_{\mathrm{C}}=\mathrm{V}$
Using pythagorean theorem,


We get
$V^{2}=V_{R}^{2}+V_{C}^{2}=(I R)^{2}+\left(I X_{C}\right)^{2} \Rightarrow V^{2}=I^{2}\left(R^{2}+X_{C}^{2}\right), \mathrm{X}_{C}$ and R being the capacitive reactance and resistance of the resistor respectively.
$\therefore I=V / \sqrt{R^{2}+X_{C}^{2}}=V / Z$ (say) where, $\mathrm{Z}=\sqrt{R^{2}+X_{C}^{2}}=\sqrt{R^{2}+1 / \omega^{2} C^{2}}$ $\mathrm{Z}=$ impedance of the circuit.
ii. The phase angle $\phi$ between resultant voltage and current is given by $\tan \phi=\frac{V_{C}}{V_{R}}=\frac{I X_{C}}{I R}=\frac{X_{C}}{R}=\frac{1 / \omega C}{R}=\frac{1}{\omega R C} \Rightarrow \phi=\tan ^{-1}\left(\frac{1}{\omega R C}\right)$
13. i. The average power dissipated,

$$
\bar{P}=\left(i^{2} R\right)=\left(i_{m}^{2} R \sin ^{2} \omega t\right)=i_{m}^{2} R\left(\sin ^{2} \omega t\right)
$$

$\because \sin ^{2} \omega t=\frac{1}{2}(a-\cos 2 \omega t)$
$\therefore\left(\sin ^{2} \omega t\right)=\frac{1}{2}[1-(\cos 2 \omega \theta)]=\frac{1}{2}(\because \cos 2 \omega t=0)$
$\therefore \quad \bar{P}=\frac{1}{2} i_{m}^{2} R$
ii. ) Power of the bulb $\mathrm{P}=100 \mathrm{~W}$
voltage, $\mathrm{V}=220 \mathrm{~V}$
$R=\frac{V^{2}}{P}=\frac{(220)^{2}}{100}=484 \Omega$
14. a. Total initial energy
$E=\frac{Q_{0}^{2}}{2 C}=\frac{10^{-2} \times 10^{-2}}{2 \times 50 \times 10^{-6}} J=1 \mathrm{~J}$
This energy shall remain conserved in the absence of resistance.
b. Angular frequency, $\omega=\frac{1}{\sqrt{L C}}$
$=\frac{1}{\left(20 \times 10^{-3} \times 50 \times 10^{-6}\right)^{1 / 2}} H z$
$=10^{3} \mathrm{rads}^{-1}$
$v=\frac{10^{3}}{2 \pi} H z=159 H z$
c. $Q=Q_{0} \cos \omega t$

Or $Q=Q_{0} \cos \frac{2 \pi}{T} t$, where $T=\frac{1}{v}=\frac{1}{159} s=6.3 \mathrm{~ms}$
Energy stored is completely electrical at $\mathrm{t}=0, \mathrm{~T} / 2,3 \mathrm{~T} / 2 \ldots$
Electrical energy is zero i.e. energy stored is completely magnetic at $t=\frac{T}{4}, \frac{3 T}{4}, \frac{5 T}{4}, \ldots$
d. At $t=\frac{T}{8}, \frac{3 T}{8}, \frac{5 T}{8}, \ldots\left[\because Q=Q_{0} \cos \frac{\omega T}{8}=Q_{0} \cos \frac{\pi}{4}=\frac{Q_{0}}{\sqrt{2}}\right]$
$\therefore$ Electrical energy $=\frac{Q^{2}}{2 C}=\frac{1}{2} \frac{Q_{0}^{2}}{2 C}$, which is half of 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.
15. Here, $\mathrm{L}=5.0 \mathrm{H}, R=40 \Omega$
$C=80 \mu F=80 \times 10^{-6} F$
$\mathrm{E}_{\mathrm{V}}=230$ volt
$E_{0}=\sqrt{0} E_{v}=\sqrt{2} \times 230 V$
a. Resonance angular frequency,
$\omega r=\frac{1}{\sqrt{L C}}$
$=\frac{1}{\sqrt{5 \times 80 \times 10^{-6}}}=\frac{1}{2 \times 10^{-7}}=50 \mathrm{rad} / \mathrm{sec}=50 \mathrm{rad} / \mathrm{sec}$.
b. Impedance $Z=\sqrt{R^{2}+\left(\omega L-\frac{1}{\omega C}\right)^{2}}$

At resonance, $\omega L=\frac{1}{\omega C}$
$Z=\sqrt{R^{2}}=R=40 \Omega$
Amplitude of current at resonating frequency
$I_{0}=\frac{E_{0}}{z}=\frac{\sqrt{2} \times 230}{40}=8.13 \mathrm{amp}$
$I_{v}=\frac{I_{0}}{\sqrt{2}}=\frac{8.13}{\sqrt{2}}=5.75 \mathrm{amp}$
c. Potential drop across L
$V_{L r m s}=I_{v} \omega_{r} L=5.75 \times 50 \times 5.0=1437.5 \mathrm{~V}$
Potential drop across R
$V_{R r m s}=I_{v} \times R=5.75 \times 40=230$ volt
Potential drop across C
$V_{C r m s}=I_{v}\left(\frac{1}{\omega_{r} C}\right)$
$=5.75 \times \frac{1}{50 \times 80 \times 10^{-6}}$
$=\frac{5.75}{4} \times 10^{3}=1437.5 \mathrm{~V}$
Potential drop across LC circuit
$V_{L C r m s}=V_{L r m s}-V_{C r m s}=0$

