Blue Print (As per PU Board)

Topic	1 mark questions	2 marks questions	3 marks questions	5 marks questions	Total Marks
Alternating Current	–	–	1	–	3

One mark questions

1. **Write an expression for (i) alternating voltage (ii) alternating current**
Answer:
(i) $E = E_0 \sin \omega t$
$E =$ Voltage at any instant of time t.
$E_0 =$ Peak value of the voltage
$\omega =$ Angular frequency with which the coil is rotated.
(ii) $i = i_0 \sin \omega t$
$i =$ Current at any instant of time t.
$i_0 =$ Peak value of the current

2. **Write expression for (i) Inductive reactance and (ii) Capacitive reactance.**
Answer: Inductive reactance $= X_L = \omega L = 2\pi fL$
Capacitive reactance $= X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi fC}$
Where f is the frequency of the source. L is the inductance of the coil. C is the capacitance of the capacitor. ω is the angular frequency of rotation of the coil.

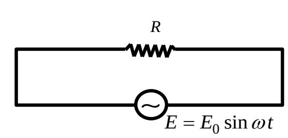
3. **Define phase angle in an ac circuit.**
Answer: Phase angle is the angle between effective voltage and current in the phase diagram.
$\tan \phi = \left(\dfrac{X_L - X_C}{R} \right)$

Two marks questions

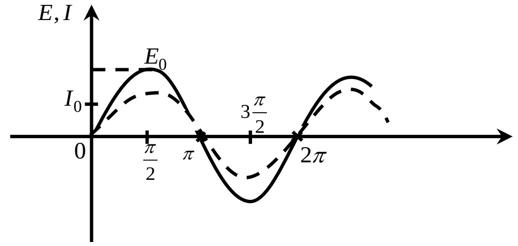
4. **Explain the mechanism of tuning in a radio or TV set.** (2 marks)
Answer: The tuning mechanism in a radio or TV set makes use of the principle of resonant circuits. The antenna of a radio accepts signals from many broadcasting stations. The signals picked up in the antenna act as a source in the tuning circuit of the radio. The circuit can be driven at many frequencies. But to hear one particular radio station, we tune the radio. (1 mark)
In tuning, we vary the capacitance of the capacitor in the tuning circuit such that the resonant frequency of the circuit becomes nearly equal to the frequency of the radio signal received. (1 mark)

5. **A bulb is rated $100\,\text{W}$ for a $220\,\text{V}$ ac supply. Find the resistance of the bulb.**
Answer: $P = \dfrac{V^2}{R}$ (1 mark)
$R = \dfrac{V^2}{P} = \dfrac{(200)^2}{100} = 484\,\Omega$ (1 mark)

6. **Derive an expression for current in an AC circuit having a pure resistance. Explain the phase relation between them using a graph.**
Answer: Consider a pure resistance R the ends of which are connected to an ac source of emf given by $E = E_0 \sin \omega t$.



The current in the circuit is given by $I = \dfrac{E}{R} = \dfrac{E_0 \sin \omega t}{R}$



$= \left(\frac{E_0}{R}\right)\sin\omega t$

$\frac{E_0}{R} = \frac{\text{Peak value of voltage}}{\text{Resistance}} = $ Peak value of current $= I_0$

$\therefore I = I_0 \sin\omega t$ (1 mark)

From the graphs we observe that voltage and current attain their respective maximum values simultaneously at $\omega t = \frac{\pi}{2}$ and become zero at $\omega t = \pi$. Hence we say that voltage and current are in phase in an *ac* circuit containing a resistance. (1 mark)

Three marks questions

7. Define resonant frequency. Derive an expression for resonant frequency.

Answer: An *ac* circuit is said to have resonance when the current in the circuit is maximum. The frequency of the *ac* circuit when resonance is achieved is called resonant frequency. (1 mark)

At resonance $X_L = X_C$ (Inductive reactance=capacitance reactance) (1 mark)

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

$$\omega^2 = \frac{1}{LC}$$

$$\omega = \frac{1}{\sqrt{LC}}$$

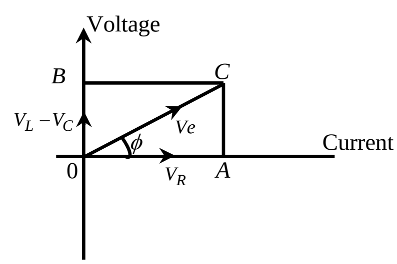
$$2\pi f_R = \frac{1}{\sqrt{LC}}$$

$$f_R = \frac{1}{2\pi\sqrt{LC}}$$ (1 mark)

8. Define power factor of an *ac* circuit. Derive an expression for power factor using phase diagram. (3 marks)

Answer: The power in *ac* circuits is given by

$P = VI\cos\phi$ …(1) (1 mark)



$\cos\phi$ is called the power factor of the circuit

In the phase diagram voltage is plotted on the $y-$axis and current on the x-axis. We find that the combined voltage $(V_L - V_C)$ and the voltage across R act perpendicular to each other. Let ϕ be the phase angle of the circuit i.e., the angle between effective voltage and current. (1 mark)

The voltage across R acts along the $X-$axis since voltage and current are in phase.

$$\cos\phi = \frac{V_R}{V_e}$$

But $V_e = IZ$ where $Z =$ impedance of the circuit

$V_R = IR$

$$\therefore \cos\phi = \frac{IR}{IZ}$$

$$\therefore \cos\phi = \frac{R}{z}$$ (1 mark)

9. Calculate the resonant frequency of a series circuit with $L = 2.0\,\text{H}$, $C = 32\mu\text{F}$ and $R = 10\Omega$, what is the Q value of this circuit? (3 marks)

Answer: $\omega_0 = \dfrac{1}{\sqrt{LC}} = \dfrac{1}{\sqrt{2\times 32\times 10^{-6}}} = \dfrac{1}{8\times 10^{-3}} = \dfrac{1000}{8} = 125\,\text{s}^{-1}$

Resonant frequency $= \dfrac{\omega_0}{2\pi} = \dfrac{125}{2\times 3.14} = 19.9$

$Q = \dfrac{\omega_0 L}{R} = \dfrac{125\times 2}{10} = 25$

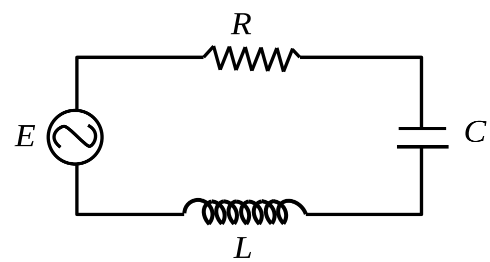
Five marks questions

10. Figure shows a series LCR circuit connected to a variable frequency $230\,\text{V}$ source. $L = 5.0\,\text{H}$, $C = 80\mu\text{F}$, $R = 40\Omega$

(a) Determine the source frequency which drives the current 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 combination is zero at the resonating frequency.



Answer:

(a) $\omega = \dfrac{1}{\sqrt{LC}} = \dfrac{1}{\sqrt{5\times 80\times 10^{-6}}} = \dfrac{1000}{20} = 50\,\text{rad}\,\text{s}^{-1}$, Resonant frequency $= f = \dfrac{50}{2\pi} = 8\text{Hz}$ (1 mark)

(b) $X_L = \omega L = 50\times 5 = 250\Omega$ (1 mark)

$X_C = \dfrac{1}{\omega C} = \dfrac{1}{50\times 80\times 10^{-6}} = \dfrac{10^{-6}}{4000} = 250\Omega$ (1 mark)

$Z = \sqrt{(X_L - X_C)^2 + R^2}$ (1 mark)

$= \sqrt{(250-250)^2 + 40^2}$

$Z = 40\Omega$

(c) $I_0 = \dfrac{V}{R} = \dfrac{230}{40} = 5.6\,\text{A}$

$V_L = IX_L = 5.6\times 250 = 1400\,\text{V}$

$V_C = IX_C = 5.6\times 250 = 1400\,\text{V}$

$\therefore V_L = V_C$ (1 mark)

11. A radio can tune over the frequency range of a portion of MW broadcast band $(800\text{ kHz to }1200\text{kHz})$. If its LC circuit has an effective inductance of $200\mu\text{H}$, what must be the range of the variable capacitor? **(5 marks)**

Answer: For 800 kHz

$f_1 = 800\text{ kHz} = 8\times 10^5\text{ Hz}$

$L_1 = 200\mu\text{H} = 2\times 10^{-4}\text{ H}$

$C_1 = ?$

$f_1 = \frac{1}{2\pi\sqrt{L_1C_1}}$ (1 mark)

$f_1^2 = \frac{1}{4\pi^2 L_1C_1}$

$\therefore C_1 = \frac{1}{4\pi^2 f_1^2 L_1}$

$= \frac{1}{4\times(3.14)^2\times\left(8\times10^5\right)^2\times2\times10^{-4}}$ (1 mark)

$= 0.000792\times10^{-6}\,\text{F}$

$= 792\,\text{pF}$ (1 mark)

$C_2 = \frac{1}{4\times(3.14)^2\times\left(12\times10^5\right)^2\times2\times10^{-4}}$ (1 mark)

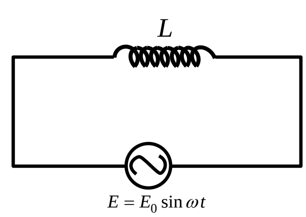
$= 0.000352\times10^{-6}\,\text{F}$

$= 352\,\text{pF}$ (1 mark)

12. Derive an expression for the current in an *ac* circuit containing a coil of pure inductance. Explain the phase relation using a graph (5 marks)

Answer: Consider a coil of pure inductance L the ends of which are connected to an *ac* source of voltage $E = E_0 \sin\omega t$. The varying current passing through the coil induces an emf V given by

$V = -L\frac{dI}{dt}$ …(1) (1 mark)



Where $\frac{dI}{dt}$ is the rate of change of current.

Now $V = -E$ (By Lenz's law) …(2)

From (1) and (2)

$E = L\frac{dI}{dt}$

(1 mark)

$E_0 \sin\omega t = L\frac{dI}{dt}$

$dI = \frac{E_0}{L}\sin\omega t\, dt$

$\int dI = \int \frac{E_0}{L}\sin\omega t\, dt$

$I = \frac{E_0}{L}\int \sin\omega t\, dt$

$= \frac{E_0}{L}\left[-\frac{\cos\omega t}{\omega}\right]$

$= -\frac{E_0}{\omega L}\left[\sin\left(\frac{\pi}{2}-\omega t\right)\right]$

$I = \frac{E_0}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right)$ (1 mark)

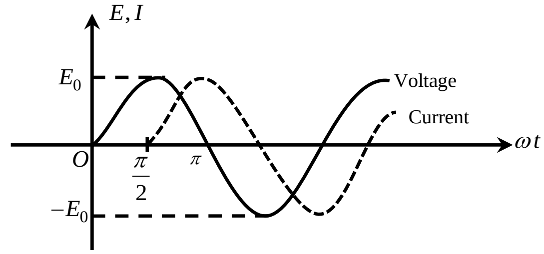
Put $\frac{E_0}{\omega L} = I_0$

Where ωL is the effective measure of opposition to the flow of current.

$\omega L = X_L$ This is called Inductive reactance of L.

$\therefore\ I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$ (1 mark)

If we draw a graph of voltage and current against ωt, we get two curves as shown in the figure,



When $\omega t = \frac{\pi}{2}, \quad E = E_0, \quad I = 0$

$\omega t = \pi, \quad E = 0, \quad I = I_0$

Thus voltage and current are not in phase. Since voltage has reached its peak value earlier than current, we say that voltage leads the current by $\frac{\pi}{2}$ in an *ac* circuit containing inductance. (1 mark)