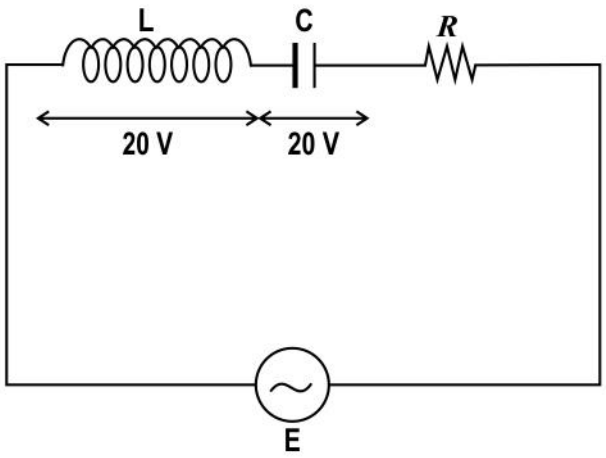
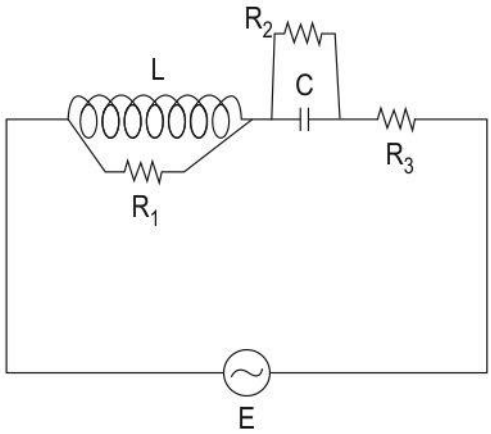
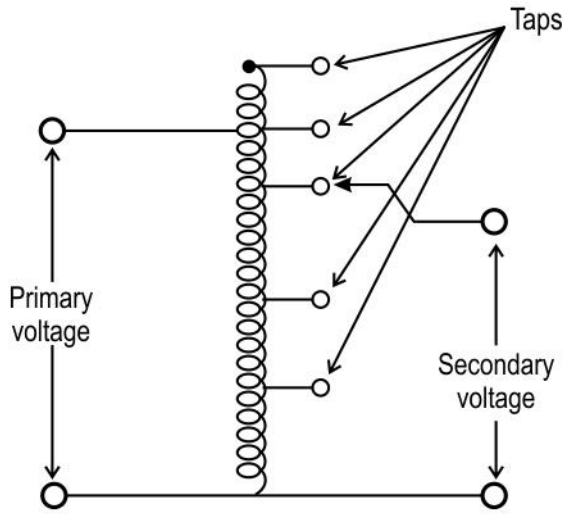
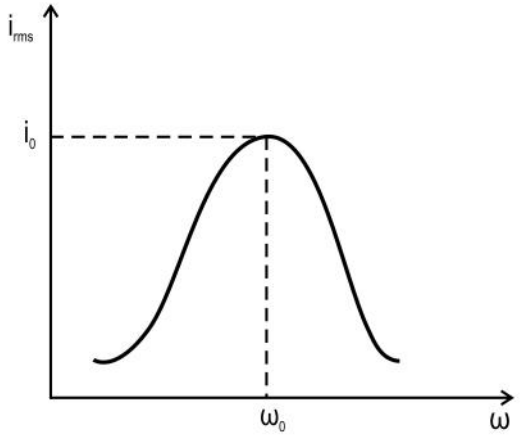
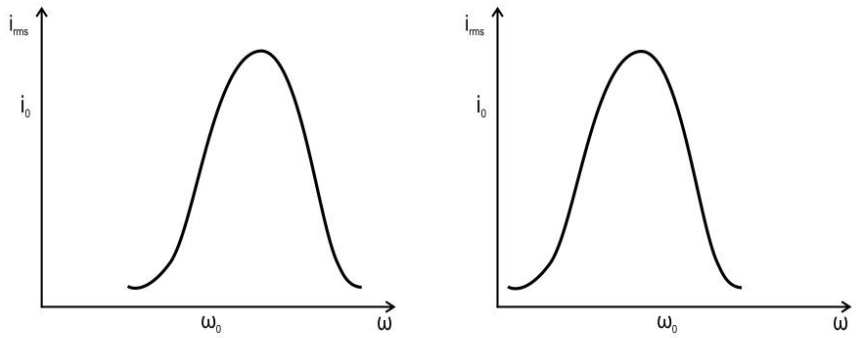
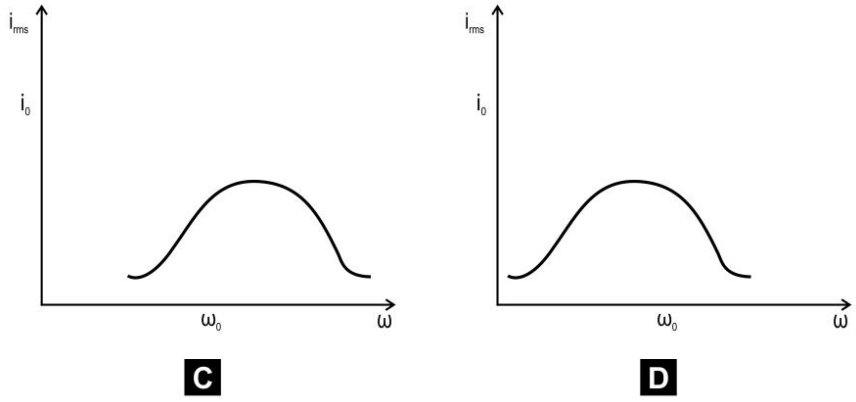
Alternating Current

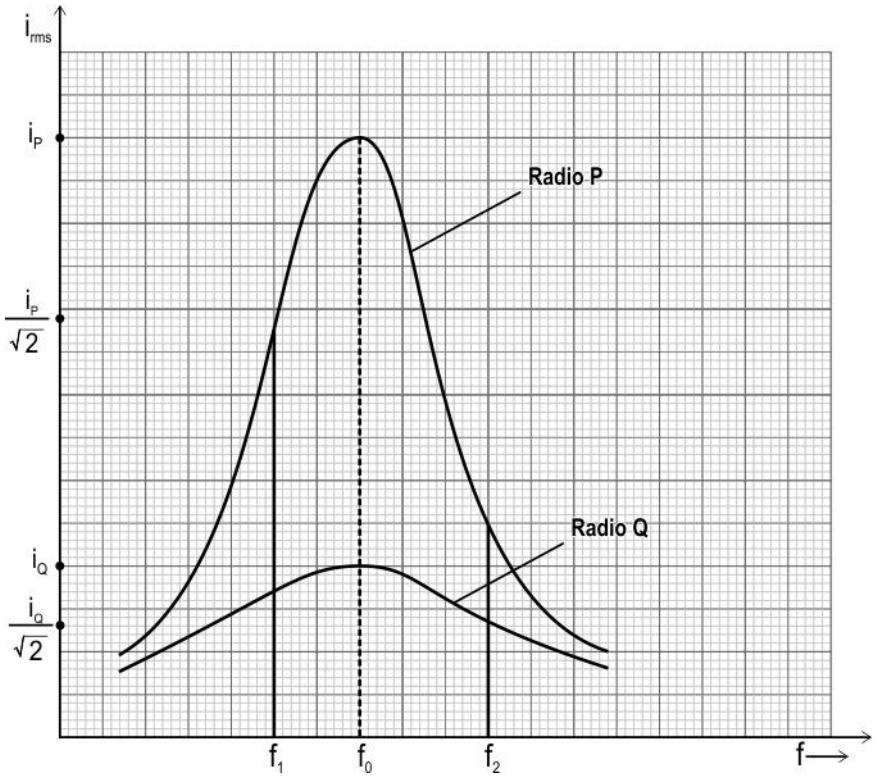
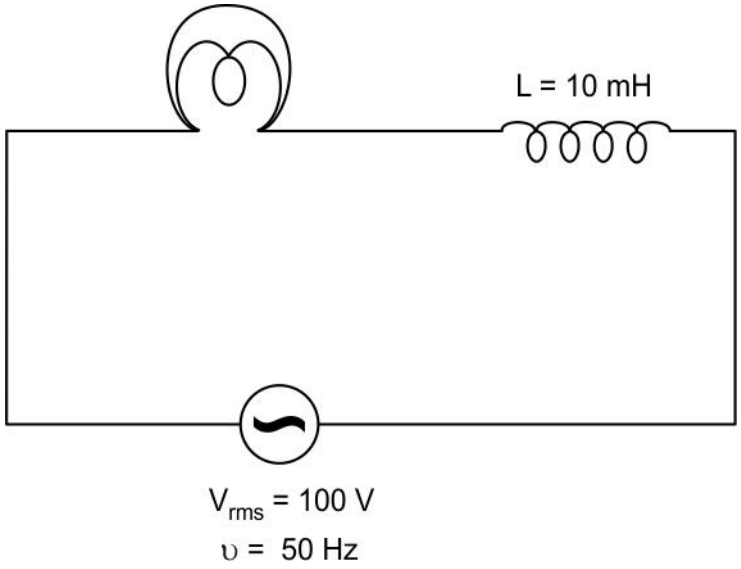
Q.No	Question	Marks
	Multiple Choice Question	
Q.96	Shown below is a series LCR circuit connected to an ac source of emf E. The voltage drop across the inductor and the capacitor is 20 V.  Which of the following will happen if the value of R is doubled? A. The voltage across L will be doubled. B. The voltage across C will remain the same. C. The voltage across the LC combination will be halved. D. The voltage across the LC combination will remain the same.	1
Q.97	A very high frequency AC source of peak EMF 200 V is connected across a circuit as shown in the figure. The components of the circuit are L = 1 mH, C = 1 μF, R_1=10 ohm, R_2 = 40 ohm, R_3 = 30 ohm. What is the approximate value of the peak current flowing through this circuit?  A. 0 A	1

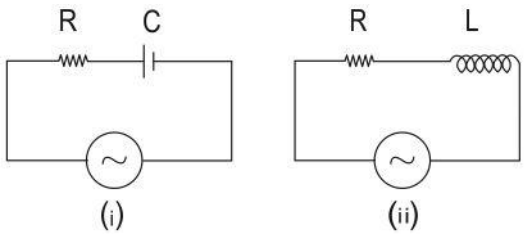
	B. 2.5 A C. 5 A D. 6.67 A	
Q.98	A capacitor has a dielectric of dielectric constant 6, that completely occupies the space between its plates. If a current I flows through this capacitor when connected to an AC source, what will be the current in the circuit when this dielectric is removed? A. I/6 B. I - 6 C. I D. 6I	1
	An autotransformer is a special transformer that has a single winding with an iron core. In an autotransformer, portions of the same winding act as both the primary and secondary. It has two end terminals and one or more terminals at intermediate tap points. The input voltage is applied across two of the terminals. The output voltage is taken across two terminals, one terminal of which is usually in common with the input voltage terminal. They are generally used in home applications with small voltage conversions. The figure below shows an autotransformer with several 'taps'.  	
Q.99	Which of the following is an advantage of an autotransformer compared to an ordinary two-winding transformer? A. Lower cost B. No hysteresis loss C. Copper loss is negligible D. Better isolation of primary and secondary	1
Q.100	In the transformer shown in the image above, if the number of turns between the points where the input voltage is connected is 800 and the maximum output	1

	voltage that can be obtained is 115% of the input voltage, what is the total number of turns in the coil? *(The turns ratio of an autotransformer is calculated with the same formula as two-winding transformers.)* A. 685 B. 695 C. 915 D. 920	
Q.101	In the autotransformer shown in the image above, the output terminal shown by the arrow can be connected to any of the taps. For a given input voltage, how many different stepped-down voltages can be obtained? *(Consider the transformer to be ideal.)* A. 2 B. 3 C. 4 D. 5	1
Q.102	The graph below shows the frequency response of an LCR circuit when connected to an AC source.  Which of the following graphs CORRECTLY represents the change in the frequency response of the LCR circuit if the capacitance and the inductance of the circuit are increased and resistance is decreased?	1

	  A. A B. B C. C D. D	
Q.103	Assertion (A): Current drawn through a long wire of finite resistance connected across an ac generator decreases when that wire is wound into a coil of many loops. Reason (R): Inductor offers back emf to the time varying ac current whereas a resistor doesn't. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Q.104	Assertion (A): Resonant frequencies of two different LCR series circuits with different L, C and R values may be same. Reason (R): Resonant frequency of an LCR series circuit is independent of R, L and C values of a circuit.	1

	Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	
Q.105	Assertion (A): Greater average power is consumed by the resistor-only ac circuit than by the resistor–inductor (RL) series combination in the same ac circuit. Reason (R): For the same ac circuit, the R-L reactance is less than resistance offered to the current flow. Select the correct option. A. Both A and R are true and R is the correct explanation of A B. Both A and R are true but R is NOT the correct explanation of A C. A is true but R is false D. A is false and R is also false	1
Free Response Questions/Subjective Questions		
Q.106	For designing a high-quality sound delivery system, Anne includes two speakers in the sound system that is connected to an input ac supply. The speakers are connected separately. She connects an inductor in series to both of the speakers individually, so that speaker 1 delivers low-frequency signals and speaker 2 delivers high-frequency signals. (a) Will speaker 1 deliver low-frequency signals? (b) Will speaker 2 deliver high-frequency signals as desired? (c) Give a reason for your answer in (a) and (b). If need be, suggest correction(s) with appropriate reason.	3
Q.107	The graph below shows the variation in current flowing through two LCR circuits used in radios P and Q, with the change in frequency. To prevent adjacent-channel interference while tuning the radio to a particular frequency it is desirable that the frequency of adjacent channels does not lie in the bandwidth region of the selected frequency.	3

	 (a) Which radio will allow a person to hear a radio channel of frequency f_o, without the interference of other frequencies? Give reason. (*Assume f_1, f_o and f_2 are the only radio frequencies available and to prevent adjacent-channel interference on the band*) (b) Compare the resistance and capacitance of LCR circuit used in radios P and Q, if both the circuits have the same inductance. Give reason.	
Q.108	Consider a small bulb with negligible resistance connected to an inductor L = 10 mH in an ac circuit with an input rms voltage of 100 V.  If the frequency of input ac voltage is increased from 50 Hz to 50 kHz,	3

	a. What is the percentage change in the rms current in the ac circuit? b. Will the bulb glow brighter or dimmer? Explain your answer.	
Q.109	The output emf of an ac generator is 10sin100πt. The ac generator is connected to the following circuit elements individually: a. 100-ohm Resistor b. 10μF Capacitor c. 10mH Inductor. Determine the instantaneous voltage and current through each one of them.	4
Q.110	Given are two ac circuits, each connected to identical power supplies.  The ac source is of angular frequency ω in both the circuits (i) and (ii) initially. If the frequency is changed to ω/3, maintaining the same voltage, the current in the circuit (i) is halved whereas the current in the circuit (ii) is doubled. Determine the initial ratio of capacitive reactance in a circuit (i) to the inductive reactance in the circuit (ii), that is, when the angular frequency in both the circuits was ω.	3

Answer key and Marking Scheme

Q.No	Answers	Marks
Q.96	D. The voltage across the LC combination will remain the same.	1
Q.97	C. 5 A	1
Q.98	A. I/6	1
Q.99	A. Lower cost	1
Q.100	D. 920	1
Q.101	B. 3	1
Q.102	B. B	1
Q.103	A. Both A and R are true and R is the correct explanation of A	1
Q.104	C. A is true but R is false	1
Q.105	C. A is true but R is false	1
Q.106	(a) Yes. (0.5 marks) (b) No. (0.5 marks) (c) Since both the speakers are connected to an inductor, the current in an inductive circuit decreases with increasing frequency. Thus, an inductor connected in series with a speaker blocks high-frequency signals and allows low-frequency signals. So both speaker 1 and 2 will deliver low-frequency signals. (1 mark) Correction: If speaker 2 is connected to a capacitor instead of an inductor, the capacitor blocks low-frequency signals and passes high-frequency signals. This is because the current in a capacitive circuit increases with increasing frequency. So speaker 2 connected to a capacitor in series will deliver high-frequency signals, as desired. (1 mark)	3
Q.107	(a) Radio P will allow the person to hear the radio channel of frequency f_o, without the interference of other frequencies. (0.5 marks)	3

	Both f_1 and f_2 do not lie in the bandwidth of the radio P while frequency f_1 lies in the bandwidth of radio Q. (0.5 marks) (b) The maximum current at resonance in an LCR circuit is given by $i_{max} = V/R$ Since $i_P > i_Q$, the resistance of circuit used in radio P is less than the resistance of the circuit used in radio Q. (*0.5 marks for correct answer and 0.5 marks for correct reason*) The resonance frequency $f_o = 1/(2\pi\sqrt{LC})$ As L and f_o is the same for both circuits the capacitance of both circuits will be the same. *(0.5 marks for correct answer and 0.5 marks for correct reason.)*	
Q.108	a. For angular frequency ν = 50 Hz Inductive reactance $X_L = \omega L = 2\pi \times 50 \times 10 \times 10^{-3} = \pi$ ohm $I_{rms} = V_{rms}/X_L = 100/\pi$ A [0.5 mark for correct value of I_{rms}] For angular frequency ν = 50 kHz Inductive reactance $X'_L = \omega L = 2\pi \times 50 \times 10^3 \times 10 \times 10^{-3} = 1000\pi$ ohm $I'_{rms} = V_{rms}/X_L = 1/10\pi$ A [0.5 mark for correct value of I'_{rms}] % decrease in I_{rms} $= |\Delta I_{rms}|/I_{rms} \times 100$ $= 999\pi/(10\pi \times 100) \times 100$ = 99.9 % [1 mark for correct calculation of % decrease of I_{rms}] b. Bulb glows dimmer. [0.5 mark for correct conclusion]	3

	Increase in angular frequency increases the inductive reactance that further results in the decrease in I_{rms} current flowing through the bulb. Hence the bulb glows dimmer. [0.5 mark for correct reason explanation]	
Q.109	a. 100 ohm Resistor: Voltage across R = 10sin100πt Current i = V/R = 10sin100πt /100 = 0.1 sin100πt [0.5 mark for voltage & 0.5 mark for correct expression of current] b. 10μF Capacitor: Voltage across C = 10sin100πt Current i = 10sin100πt /X_c Here $X_c = 1/C\omega = 1000/\pi$ ohm Current through C = i = V/X_c = 10sin(100πt + π/2) / (1000/π) $= \frac{10 \sin\left(100\pi t + \frac{\pi}{2}\right)}{\left(\frac{1000}{\pi}\right)} = \frac{\pi}{100} \sin\left(100\pi t + \frac{\pi}{2}\right)$ [0.5 mark for voltage & 1 mark for correct expression of current] c. 10mH Inductor : Voltage across L = 10sin100πt Inductive reactance, $X_L = L\omega = 10 \times 10^{-3} \times 100\pi = \pi$ ohm Current through an inductor, i = V/X_L $= \frac{10}{\pi} \sin\left(100\pi t - \frac{\pi}{2}\right)$ [0.5 mark for voltage & 1 mark for correct expression of current]	4
Q.110	In circuit (i):	3

$$I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2}}$$

$$I/2 = \frac{V}{Z'} = \frac{V}{\sqrt{R^2 + \left(\frac{3}{C\omega}\right)^2}}$$

Substituting for I,

$$\frac{V}{\sqrt{R^2 + \left(\frac{1}{c\omega}\right)^2}} = \frac{2V}{\sqrt{R^2 + \left(\frac{3}{c\omega}\right)^2}}$$

[1 mark for expression for currents]

Transposing and solving:

$3R^2 = 5\,(1/C\omega)^2 = 5X_C^2$

$X_C/R = \sqrt{3}/\sqrt{5}$

[0.5 mark for correct ratio X_C/R]

In circuit (ii):

$$I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + \left(L\omega\right)^2}}$$

$$2I = \frac{V}{Z} = \frac{V}{\sqrt{R^2 + L^2\omega^2/9}}$$

Substituting for I,

$$\frac{2V}{\sqrt{R^2 + \left(L\omega\right)^2}} = \frac{V}{\sqrt{R^2 + L^2\omega^2/9}}$$

[1 mark for expression for currents]

Transposing and solving,

$X_L/R = 3\sqrt{3}/\sqrt{5}$

So the ratio:

$X_C / X_L = 1/3$

[0.5 mark for correct final ratio]