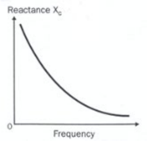
Reactance and Impedance

Definitions

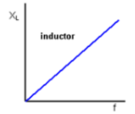
Reactance

The current and voltage for a resistor in an AC circuit are in phase (resistors are passive in nature).

The reactance of a capacitor, X_c, is frequency dependent. Capacitors block LOW frequency. Current **leads** voltage by 90 ° in a capacitor in an RC circuit



The reactance of an inductor, X_L, is also frequency dependent. Inductors block HIGH frequency. Current **lags** voltage by 90 ° in an inductor in an LR circuit



Impedance

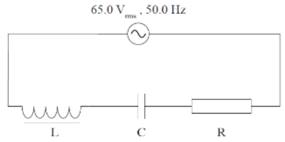
In a circuit containing resistive and reactive components, the impedance calculation is a little complex.

Equations

$X_c = \frac{1}{\omega C}$	Reactance of a capacitor	X_c	Ω
	Angular frequency	ω	s^{-1}
	Capacitance	C	F
$X_L = \omega L$	Reactance of an inductor	X_L	Ω
	Angular frequency	ω	s^{-1}
	Inductance	L	H
$V = IZ$	Voltage	V	V
	Current	I	A
	Impedance	Z	Ω
$\omega = 2\pi f$	Angular frequency	ω	s^{-1}
	Frequency	f	Hz
$f = \frac{1}{T}$	Frequency	f	Hz
	Time period	T	s

Questions

QUESTION ONE (2020;1)



Tui is investigating LCR circuits. She sets up the circuit shown using a signal generator, and sets the supply voltage to 65.0 V_{rms}, 50.0 Hz.

(a) Calculate the peak voltage of the supply.

(b) The supply voltage in the circuit above leads the circuit current by 35.0°. The resistor has a resistance of 1.50 x 10^2 Ω. Calculate the total impedance of the circuit. *A phasor diagram may be useful.*

(c) The inductor has an inductance of 0.380 H. By calculating the total reactance of the circuit, determine the capacitance of the capacitor.

(d) Explain what change needs to be made to the frequency of the signal generator to bring the circuit to resonance.

Terms

Impedance: Combination of resistance and reactance in an AC circuit
Phasor: Anti- clockwise rotating vector used to help draw sine graphs
Reactance: Ability of a capacitor/inductor to limit current in an A.C. circuit
Resistance: Ability to resist current
Resonant frequency: Frequency which produces maximum current in a RCL circuit (because $X_L = X_C$)

Tips

Z is the impedance and is calculated by:

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

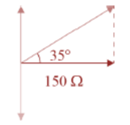
(Note: This equation is not given to you at Level 3)

If the a.c. circuit only has a resistor, $Z = \sqrt{R^2} = R$
If the a.c. circuit has resistor and a capacitor, $Z = \sqrt{(R^2 + X_c^2)}$
If the a.c. circuit has a resistor and an inductor, $Z = \sqrt{(R^2 + X_L^2)}$
If the a.c. circuit has a resistor, a capacitor and an inductor, see above.

Answers

(a) $V_{peak} = \sqrt{2} \times 65.0 = 91.9$ V

(b)



$Z = \frac{150}{\cos 35°} = 183\,\Omega$

(c)

$X_T = 150 \tan 35 = 105\,\Omega$
$X_L = 2\pi f L = 119.4\,\Omega$
$X_c = 119.4 - 105 = 14.4\,\Omega$
$C = \frac{1}{2\pi f X_c} = \frac{1}{2\pi \times 50 \times 14.4}$
$= 2.21 \times 10^{-4}$ F

(d) At resonance, $X_C = X_L$. Since the reactance of the inductor is greater than the reactance of the capacitor, the frequency of the supply will have to be reduced so as to reduce inductor reactance and increase capacitor reactance. This is because the reactance of the capacitor is inversely proportional to frequency, whereas the reactance of the inductor is directly proportional to frequency.