Chapter

22 Alternating Current

ALTERNATING AND DIRECT CURRENT

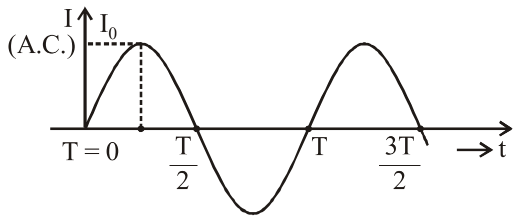
An ***alternating current*** *(A.C.) is one which periodically changes in magnitude and direction.* It increases from zero to a maximum value, then decreases to zero and reverses in direction, increases to a maximum in this direction and then decreases to zero.

The source of alternating emf may be a dynamo or an electronic oscillator.

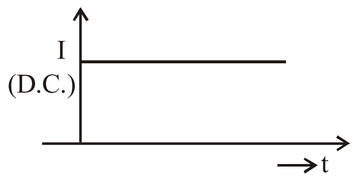
The alternating emf E at any instant may be expressed as

$$E = E_0 \sin\omega t$$

where ω is the angular frequency of alternating emf and E_0 is the peak value of emf.



Direct current *(D.C.) is that current which may or may not change in magnitude but it does not change its direction.*



Advantages of A.C. over D.C.

(i) The generation of A.C. is cheaper than that of D.C.

(ii) Alternating voltage can be easily stepped up or stepped down by using a transformer.

(iii) A.C. can be easily converted into D.C. by rectifier. D.C. is converted to A.C. by an inverter.

(iv) A.C. can be transmitted to a long distance without appreciable loss.

AVERAGE AND RMS VALUE OF ALTERNATING CURRENT

The average value of AC over one full cycle is zero since there are equal positive and negative half cycles.

The average current for half cycle is $2I_0/\pi$ where I_0 is the peak value of current.

The root mean square (rms) value of AC is

$$I_{rms} = \frac{I_0}{\sqrt{2}}$$

where I_0 is the peak or maximum value of alternating current.

The ***rms value*** *of alternating current can also be defined as the direct current which produces the same heating effect in a given resistor in a given time as is produced by the given A.C. flowing through same resistor for the same time.* Due to this reason the rms value of current is also known as **effective** or **virtual value of current**.

$$\therefore \quad I_{effective} = I_{virtual} = I_{rms} = \frac{I_0}{\sqrt{2}}$$

Similarly the rms value of alternating voltgae is called the effective or virtual value of alternating voltage (or emf).

$$\therefore \quad E_{effective} = E_{virtual} = E_{rms} = \frac{E_0}{\sqrt{2}}$$

Keep in Memory

(1) **Time period :** The time taken by A.C. to go through one cycle of changes is called its period. It is given as $T = \frac{2\pi}{\omega}$

(2) **Phase :** It is that property of wave motion which tells us the position of the particle at any instant as well as its direction of motion. It is measured either by the angle which the particle makes with the mean position or by fraction of time period.

(3) **Phase angle :** Angle associated with the wave motion (sine or cosine) is called phase angle.

(4) **Lead :** Out of the current and emf the one having greater phase angle will lead the other e.g., in equation

$i = i_0 \sin\left(\omega t + \frac{\pi}{2}\right)$ and $e = e_0 \sin \omega t$,

the current leads the emf by an angle $\frac{\pi}{2}$.

(5) **Lag :** Out of current and emf the one having smaller phase angle will lag the other. In the above equations, the emf lags the current by $\frac{\pi}{2}$.

RESISTANCE OFFERED BY VARIOUS ELEMENTS (INDUCTOR, RESISTOR AND CAPACITOR) TO A.C.

Alternating current in a circuit may be controlled by resistance, inductance and capacitance, while the direct current is controlled only by resistance.

(i) **Impedance (Z) :** *In alternating current circuit, the ratio of emf applied and consequent current produced is called the impedance* and is denoted by Z,

i.e., $Z = \frac{E}{I} = \frac{E_0}{I_0} = \frac{E_{rms}}{I_{rms}}$

Physically impedance of ac circuit is the hindrance offered by resistance along with either inductance or capacitance or both in the circuit to the flow of ac through it. Its unit is ohm.

(ii) **Reactance (X) :** *The hindrance offered by inductance or capacitance or both to the flow of ac in an ac circuit is called reactance* and is denoted by X. Thus when there is no ohmic resitance in the ciruict, the reactance is equal to impedance. The reactance due to inductance alone is called inductive reactance and is denoted by X_L, while the reactance due to capacitance alone is called the capacitive reactance and is denoted by X_C. Its unit is also ohm.

(iii) **Admittance (Y) :** *The inverse of impedance is called the admittance* and is denoted by Y, i.e., $Y = \frac{1}{Z}$

Its SI unit is ohm^{-1}.

IMPEDANCES AND PHASES OF AC CIRCUIT CONTAINING DIFFERENT ELEMENTS

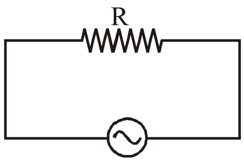
As already pointed out that in an ac circuit the current and applied emfs are not necessarily in same phase. The applied emf (E) and current produced (I) may be expresed as

$E = E_0 \sin \omega t$ and $I = I_0 \sin (\omega t + \phi)$ with $I_0 = E_0 / Z$

where E_0 and I_0 are peak values of alternating emf and current.

Circuit Containing only Resistor (R)

Consider a pure ohmic resistor (zero inductance) of resistance R connected to an alternating source of emf $E = E_0 \sin\omega t$.



$E = E_0 \sin \omega t$

Then current I in the circuit is

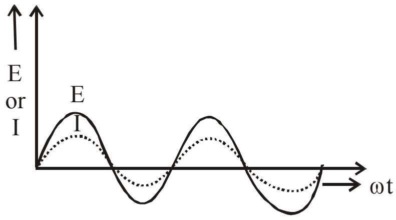
$$I = \frac{E}{R} = \frac{E_0 \sin \omega t}{R} = I_0 \sin \omega t\text{, where } I_0 = E_0 / R$$

Comparing this with standard equation, we get that **impedance of circuit, Z = R** and **phase difference between current & emf = 0.**

Hence we conclude that *in a purely resistive ac circuit the current and voltage are in same phase and impedance of circuit is equal to the ohmic resistance.*

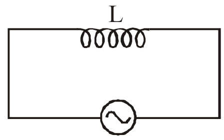
Phasor diagram :

Graph of emf or current versus ωt :



Circuit Contianing only Inductor (L)

Consider a pure inductor (zero ohmic resistance) of inductance L connected to an alternating source of emf $E = E_0 \sin \omega t$.



$E = E_0 \sin \omega t$

Then current I in the circuit is

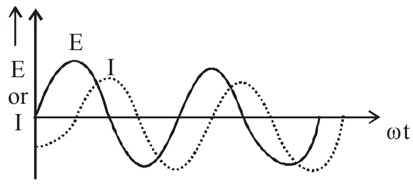
$$I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right) \quad \text{where } I_0 = \frac{E_0}{\omega L}$$

Comparing this with standard equation, we get

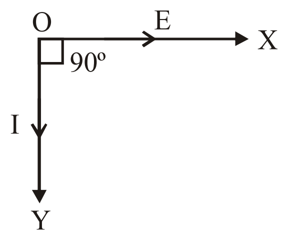
$Z = \omega L$ and phase difference $\phi = \pi/2$.

Hence we conclude that *in a purely inductive circuit the current lags behind the applied voltage by an angle π/2 and the impedance to the circuit is ωL and this is called as* ***inductive reactance.***

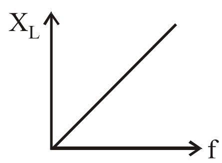
Graph of emf or current versus ωt



Phasor diagram

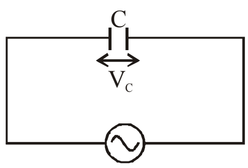


Graph between X_L and f



Circuit Containing only Capacitor

Consider a capacitor of capacitance C connected to an alternating source of emf, $E = E_0 \sin \omega t$.



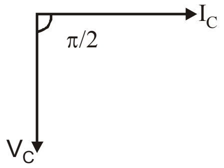
$E = E_0 \sin \omega t$

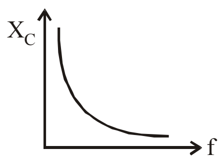
Then the current through capacitor is given by,

$$I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$$

Comparing this with standard equation, we find that **capacitive reactance $X_C = 1/\omega C$** and **phase difference $\phi = +\pi/2$**

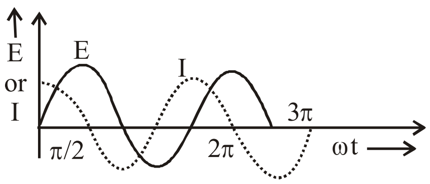
Phasor diagram **Graph between X_C and f**





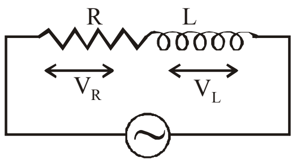
Hence we conclude that *in a purely capacitive circuit the current leads the applied emf by an angle π/2 and the impedance of the circuit is 1/ωC and this is known as capacitive reactance* $Z = X_C = \dfrac{1}{\omega C}$.

Graph of emf or current versus ωt



Circuit Containing Resistance and Inductance in Series (LR Series Circuit)

Consider a circuit containing resistance R and inductance L in series having an alternating emf $E = E_0 \sin \omega t$.

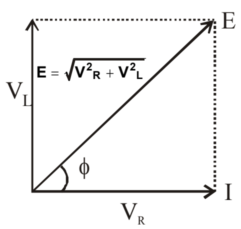


$E = E_0 \sin \omega t$

Let I be the current flowing in the circuit and V_R (= **I**R) the potential difference across resistance and V_L (= ωL.**I**) the potential difference across inductance.

The current **I** and the potential difference V_R are always in phase but the potential difference V_L across inductance leads the current **I** by an anlgle π/2.

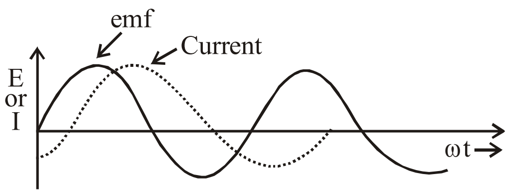
Phasor diagram



From phasor diagrom, resultant voltage is given by,

$$E = \sqrt{(V_R^2 + V_L^2)} = \sqrt{(RI)^2 + (\omega L.I)^2}$$

Graph of emf or current versus ωt



$$\therefore \quad \frac{E}{I} = \sqrt{\left[R^2 + (\omega L)^2\right]}$$

∴ Impedance of R – L circuit,

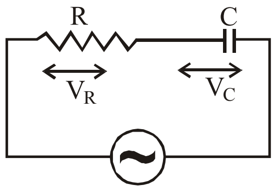
$$Z = \frac{E}{I} = \sqrt{(R^2 + X_L^2)} \quad \text{where } X_L = \omega L$$

It is obvious that *the current lags behind the emf by angle φ given by,*

$$\phi = \tan^{-1}\left(\frac{V_L}{V_R}\right) = \tan^{-1}\left(\frac{X_L}{R}\right) = \tan^{-1}\left(\frac{\omega L}{R}\right)$$

Circuit Containing Resistance and Capacitance in Series (C–R Series Circuit)

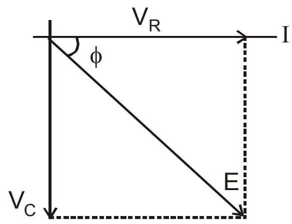
Consider a circuit containing resistance R and capacitance C in series having an alternating emf $E = E_0 \sin \omega t$.



$E = E_0 \sin \omega t$

Let I be the current flowing in the circuit, V_R the potential difference across resistance and V_C the potential difference across capacitance.

Phasor diagram



From phasor diagram the resultant emf is given by

$$E = \sqrt{(V_R^2 + V_C^2)} = \sqrt{(R\mathbf{I})^2 + (X_C\mathbf{I})^2]}$$

∴ Impedance, $Z = E/\mathbf{I} = \sqrt{(R^2 + X_C^2)}$, where

$$X_C = \left(\frac{1}{\omega C}\right)$$

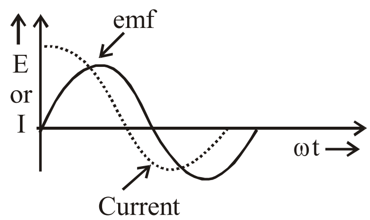
The potential difference V_R and current **I** are in same phase and the potential difference V_C lags behind the current **I** (and hence V_R) by angle π/2

The current leads the applied emf by an angle φ given by

$$\tan \varphi = \frac{V_C}{V_R} = \frac{X_C\mathbf{I}}{R\mathbf{I}} = \frac{X_C}{R}$$

or $$\tan \phi = \left(\frac{X_C}{R}\right) \Rightarrow \phi = \tan^{-1}\left(\frac{1/\omega C}{R}\right) = \tan^{-1}\left(\frac{1}{\omega CR}\right)$$

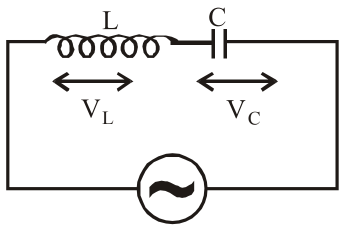
Graph of emf or current versus ωt



Circuit Containing Inductance and Capacitance in Series (Series LC Circuit)

Consider a circuit containing inductance L and capacitance C in series having an alternating emf

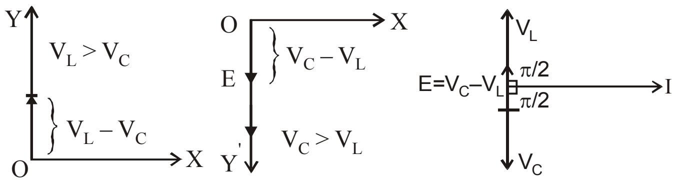
$$E = E_0 \sin \omega t.$$



$E = E_0 \sin \omega t$

Let I be the current flowing in circuit, V_L the potential difference across inductance L and V_C the p.d. across capacitance C.

Phasor diagram :



The p.d. V_C lags behind the current by angle π/2 and the p.d. V_L leads the current by angle π/2.

∴ Resultant applied emf, $E = V_C - V_L = X_C\mathbf{I} - X_L\mathbf{I}$

∴ Reactance of circuit,

$$X = E/\mathbf{I} = X_C - X_L = \left(\frac{1}{\omega C} - \omega L\right)$$

The current leads applied emf by $\phi = \pi/2$.

In case of $X_C = X_L$, Z = 0, then $\frac{1}{\omega C} = \omega L$ or $\omega = \frac{1}{\sqrt{(LC)}}$

∴ Frequency $f = \omega/2\pi == \frac{1}{2\pi\sqrt{(LC)}}$

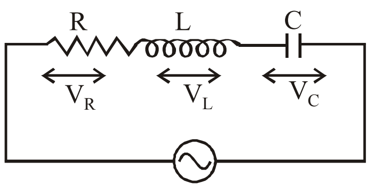
At certain frequency the impedance of the circuit is minimum and the current is maximum.

This frequency is called the **resonant frequency**.

Circuit Containing Resistance, Inductance and Capacitance in Series (Series LCR Circuit)

Consider a circuit containing a resistance R, inductance L and capacitance C in series having an alternating emf

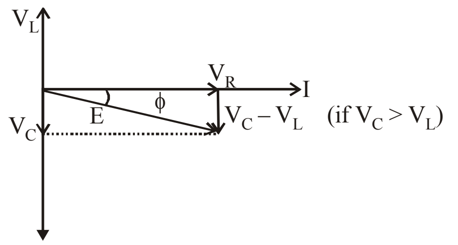
$$E = E_0 \sin \omega t.$$



$E = E_0 \sin \omega t$

Let **I** be the current flowing in circuit. V_R, V_L and V_C are respective potential differences across resistance R, inductance L and capacitance C.

Phasor diagram :



The p.d. V_R is in phase with current **I**. The p.d. V_C lags behind the current by angle π/2. The p.d. V_L leads the current by angle π/2.

∴ Resultant applied emf, $E = \sqrt{[V_R^2 + (V_C - V_L)^2]}$

i.e., $E = \sqrt{\{(R\mathbf{I})^2 + (\mathbf{I}X_C - \mathbf{I}X_L)^2\}}$

∴ Impedance, $Z = \frac{E}{\mathbf{I}} = \sqrt{\{R^2 + (X_C - X_L)^2\}}$

The phase leads of current over applied emf is given by

$$\tan\varphi = \frac{V_C - V_L}{V_R} = \frac{IX_C - IX_L}{RI} = \frac{X_C - X_L}{R}$$

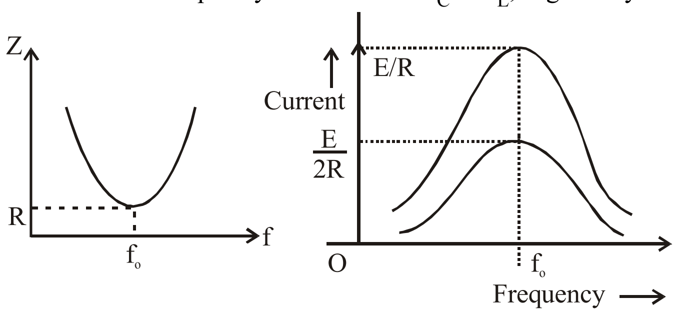
i.e., $\varphi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$

It is concluded that :

(a) If $X_C > X_L$, the value of ϕ is positive, i.e., current leads the applied emf.

(b) If $X_C < X_L$, the value of ϕ is negative, i.e., current lags behind the applied emf.

(c) If $X_C = X_L$, the value of ϕ is zero, i.e., current and emf are in same phase. This is called the case of **resonance** and resonant frequency for condition $X_C = X_L$, is given by :

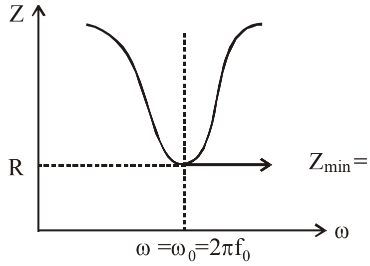


$$\frac{1}{\omega C} = \omega L \quad \text{i.e.,} \quad \omega = \frac{1}{\sqrt{LC}}$$

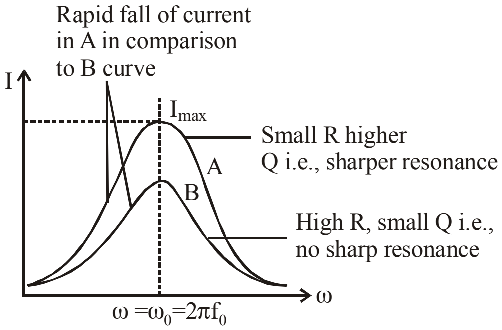
$$\therefore \quad f_o = \omega/2\pi = \frac{1}{2\pi\sqrt{(LC)}}.$$

Thus the resonant frequency depends on the product of L and C and is independent of R.

At resonance, impedance is minimum, $Z_{min} = R$ and current is maximum $\mathbf{I}_{max} = \frac{E}{Z_{min}} = \frac{E}{R}$



Resonance frequency
Circuit impedence in series RLC circuit



Resonance frequency
Current amplitude in series RLC circuit

It is interesting to note that before resonance the current leads the applied emf, at resonance it is in phase, and after resonance it lags behind the emf. LCR series circuit is also called as **acceptor circuit** and parallel LCR circuit is called **rejector circuit**.

COMMON DEFAULT

✗ ***Incorrect.*** Adding impedances / reactances /resistors algebrically.

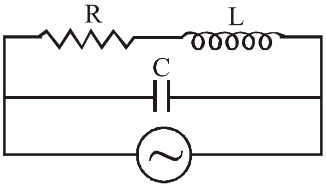
✓ ***Correct.*** For these physical quantities, vector additon must be done

✗ ***Incorrect.*** Kirchoff's laws are applicable in D.C. circuit only

✓ ***Correct.*** Kirchoff's laws are applicable in A.C. circuit also (which may include inductor and capacitor).

PARALLEL RESONANT CIRCUIT

A parallel resonant circuit consists of an inductance L and a capacitance C in parallel as shown in fig.



$E = E_0 \sin \omega t$

The condition of resonance is again that the current and applied emf must be in same phase. The condition gives angular resonant frequency.

$$\omega_r = \sqrt{\frac{1}{LC} - \frac{R^2}{L^2}}$$

$\therefore$ Resonant frequency $f_r = \dfrac{\omega_r}{2\pi} = \dfrac{1}{2\pi}\sqrt{\dfrac{1}{LC} - \dfrac{R^2}{L^2}}$

The impedance at resonance, $Z = \dfrac{R^2 + \omega^2 L^2}{R} = \dfrac{L}{RC}$

In parallel resonant circuit the impedance is maximum and the current is minimum.

If $R \to 0$, then $f_r = \dfrac{1}{2\pi\sqrt{(LC)}}$ and $Z \to \infty$.

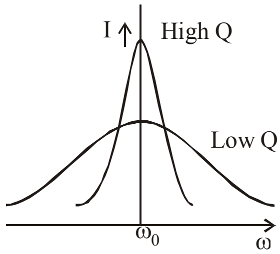
Q - FACTOR

The sharpness of tuning at resonance is measured by **Q-factor** or **quality factor** of the circuit and is given by

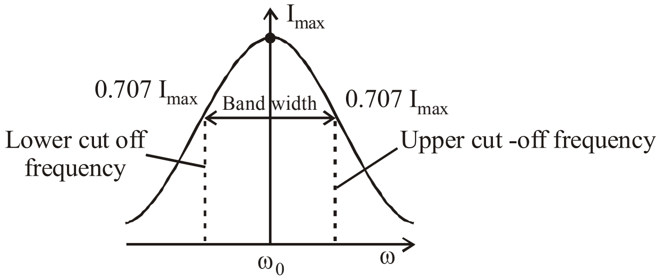
$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Higher the value of Q-factor, sharper is the resonance i.e. more rapid is the fall of current from maximum value ($\mathbf{I_0}$) with slight change in frequency from the resonance value.

It is clear from the figure that at low value of θ, the resonance is poor. However the bandwidth increases



The figure given below explains the concept of bandwidth and cut-off frequency.



when $\omega < \omega_0$	$X_C < X_L$
when $\omega > \omega_0$	$X_L > X_C$
when $\omega = \omega_0$	$X_C = X_L$

Bandwidth : *It is the band of allowed frequencies and is defined as the difference between upper and lower cut-off frequencies, the frequency at which power becomes half of maximum value and current becomes* $I_{max}/\sqrt{2}$.

POWER IN AN A.C. CIRCUIT

The power is defined as the rate at which work is being done in the circuit. In ac circuit, the current and emf are not necessarily in the same phase, therefore we write

$E = E_0 \sin \omega t$ & $\mathbf{I} = I_0 \sin(\omega t + \phi)$.

The instaneous power, $P = E\mathbf{I}$

$= E_0 \sin \omega t\, \mathbf{I_0} \sin(\omega t + \phi)$,

The *average power* $P_{av} = E_{rms} I_{rms} \cos\phi$

$$\therefore \qquad P_{av} = \frac{E_0}{\sqrt{2}}\frac{I_0}{\sqrt{2}}\cos\phi$$

In this expression $\cos\phi$ is known as **power factor.** The value of $\cos\phi$ depends on the nature of the circuit. For L, C and L-C circuit, the power factor is zero ($\because \phi = 90°$); for R-circuit $\cos\phi = 1$ ($\because \phi = 0$) and for all other circuit $\cos\phi = R/Z$, where Z = impedance.

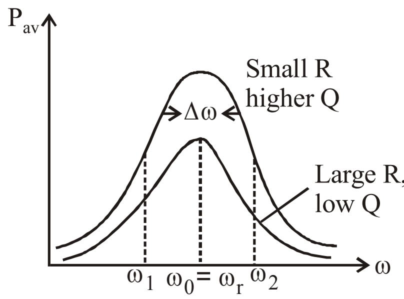
If R = 0, $\cos\phi = 0$ and $P_{av} = 0$ i.e., in a circuit with no resistance, the power loss is zero. Such a circuit is called the **wattless circuit** and the current flowing is called the **wattless current**.

Power is of two types

(i) Reactive power	$P_{reactive} = V_{rms}I_{rms}\sin\phi$ This is also called wattless power. It is not read by energy meter
(ii) Active power	$P_{active} = V_{rms}I_{rms}\cos\phi$ It is read by energy meter

Half Power Points

The values of ω at which the average power is half of its maximum value (at resonant frequency) are called half power points.



Plot of average power versus frequency for a series RLC circuit. The upper curve is for a small R & lower broad curve is for large value of R.

It is clear from the figure that for smaller R, value of Q_0 is high (Q_0 is Quality factor of circuit) & hence sharper resonance i.e. greater rate of fall of average power maximum average power P_{av} changes with slight change in frequency from resonant frequency.

The Quality factor, Q_0 is defined as, $Q_0 = \dfrac{\omega_0}{\Delta\omega}$

Where $\Delta\omega = \omega_2 - \omega_1$ and ω_2 & ω_1 are **half power points.**

Now, since $\Delta\omega \approx \dfrac{R}{L}$; so $Q_0 \approx \dfrac{\omega_0 L}{R}$

Whereas $\omega_1 = \omega_0 - \dfrac{\omega_0}{Q_0}$; $\omega_2 = \omega_0 + \dfrac{\omega_0}{Q_0}$

In concise term, we can write as, $\omega = \omega_r\left(1 \pm \dfrac{1}{Q_0}\right)$

Keep in Memory

1. Unless mentioned otherwise, all a.c. currents and voltages are r.m.s. values.
2. For resonance to occur, the presence of both L and C elements in the circuit is a must.
3. In series resonant circuit, current is maximum at resonance. In a parallel resonant circuit, current is minimum (or zero) at resonance but p.d across the combination is maximum.
4. To depict oscillatory motion mathematically we may use sines, cosines or their linear combination. This is because changing the zero position transforms one into another.
5. While adding voltage across different elements in an a.c. circuit we should take care of their phases.
6. The average current over a complete cycle in an a.c circuit is zero but the average power is not zero.
7. An inductor offers negligibly low resistance path to d.c. and a resistive path for a.c.
8. A capacitor acts as a block for d.c and a low resistance path to a.c.
9.

Inductive reactance	**Capacitive reactance**
$X_L = \omega L = 2\pi fL$ $\Rightarrow X_L \propto f$	$X_C = \dfrac{1}{\omega C} = \dfrac{1}{2\pi fC}$ $\Rightarrow X_C \propto \dfrac{1}{f}$
Current through pure inductor lags behind emf by 90°	Current through pure capacitor leads emf by 90°
For d.c $f = 0 \therefore X_L = 0$	For d.c $f = 0 \Rightarrow X_C = \infty$
For a.c as f increases X_L increases	For a.c as f increases X_C decreases

10.

Series Resonant circuit	**Parallel resosant circuit**
$X_L = X_C$	$\dfrac{1}{X_L} = \dfrac{1}{X_C}$
$\nu_r = \dfrac{1}{2\pi\sqrt{LC}}$	$\nu_r = \dfrac{1}{2\pi}\sqrt{\dfrac{1}{LC} - \dfrac{R^2}{L^2}}$
$Z = \sqrt{R^2 + (X_L - X_C)^2}$	$\dfrac{1}{Z} = \sqrt{\dfrac{1}{R^2} + \left(C\omega - \dfrac{1}{L\omega}\right)^2}$

11. The principle of electric meter is heating effect of current. These meters give the reading of I_{rms}. It is important to note that these meters can measure D.C. as well as A.C.
12. D.C. flows through the cross-section of the conductor whereas A.C. flows mainly along the surface of the conductor. This is also known as **Skin Effect**. The skin effect is directly proportional to the frequency.

Example 1.

Calculate the r.m.s. value of e.m.f. given by
$E = 8 \sin \omega t + 6 \sin 2 \omega t$ volts.

Solution :

The mean square value is given by $E = \overline{E^2}$

$$\therefore \quad \overline{E^2} = \overline{(8\sin \omega t + 6\sin 2\omega t)^2}$$

$$= 64\overline{\sin^2 \omega t} + 96\overline{\sin \omega t}.\overline{\sin 2\omega t} + 36\overline{\sin^2 2\omega t}$$

We know that $\overline{\sin^2 \omega t} = \frac{1}{2}$, $\overline{\sin^2 2\omega t} = \frac{1}{2}$, and

$\overline{\sin \omega t}.\overline{\sin 2\omega t} = 0$

$$\therefore \quad \overline{E^2} = 64 \times \frac{1}{2} + 96 \times 0 + 36 \times \frac{1}{2} = 32 + 18 = 50$$

or $\quad E_{r.m.s.} = \sqrt{(\overline{E^2})} = \sqrt{50} = 7.07$ volt

Example 2.

When 100 volt D.C. is applied across a solenoid a current of 1.0 amp flows in it. When 100 volt A.C. is applied across the same coil, the current drops to 0.5 amp. If the frequency of the A.C. source is 50 Hz, then determine the impedance and inductance of the solenoid.

Solution :

In case of D.C., $\omega = 0$ and hence $Z = R$

$$\therefore \quad Z = R = \frac{E}{I} = \frac{100}{1} = \mathbf{100\,\Omega}$$

For A.C., $Z = \left[R^2 + (2\pi n L)^2\right]^{1/2}$

$$= [(100)^2 + (100\pi L)^2]^{1/2}$$

(where $\omega = 2\pi n$ & n is frequency of AC source)

$$\therefore \quad 200 = [(100)^2 + (100\pi L)^2]^{1/2}$$

$\left\{\because Z = \frac{100}{0.5} = 200\,\Omega\right\}$ Solving we get L = **0.55 henry**

Example 3.

A coil has an inductance of 0.7 henry and is joined in series with a resistance of 220 Ω. When an alternating e.m.f. of 220 V at 50 cycles per second, is applied to it, then what will be the wattless component of current in the circuit?

Solution :

Here, $X_L = \omega L = 2\pi n L = 2\pi \times 50 \times 0.7 \times = 220\,\Omega$

$R = 220\,\Omega$

$$Z = \sqrt{R^2 + X_L^2} = \sqrt{220^2 + 220^2} = 220\sqrt{2} \text{ ohm.}$$

$\therefore$ wattless component of current is

$$\mathbf{I} = \frac{E_O}{Z} = \frac{220}{220\sqrt{2}} = \frac{1}{\sqrt{2}} = 0.707\text{A}$$

Example 4.

A 60 volt-10 watt bulb is operated at 100 volt-60 Hz a.c. The inductance required is

(a) 2.56 H (b) 0.32 H
(c) 0.64 H (d) 1.28 H

Solution : (d)

$$\mathbf{I} = \frac{P}{V} = \frac{10}{60} = \frac{1}{6}\text{A}; \qquad R = \frac{V^2}{P} = \frac{60 \times 60}{10} = 360\,\Omega;$$

$$Z = \frac{V}{\mathbf{I}} = \frac{100}{1/6} = 600\,\Omega$$

$$X_L^2 = Z^2 - R^2 = 600^2 - 360^2 = (600 + 360)(600 - 360)$$

$$X_L = \sqrt{960 \times 240} = 240 \times 2 = 480\,\Omega$$

$$\omega L = 2\pi n L = X_L = 480$$

$$L = \frac{X_L}{2\pi n} = \frac{480}{120\pi} = 1.28\text{ H}$$

Example 5.

An a.c. circuit consists of only an inductor of inductance 2H. If the current is represented by a sine wave of amplitude 0.25 amp. and frequency 60 Hz, calculate the effective potential difference across the inductor.

Solution :

The effective potential difference across the inductor is given by

$$V_{eff} = I_{eff}.\, X_L = \frac{I_0}{\sqrt{2}}.2\pi f L; \quad V_{eff} = V_{rms}$$

Given that $I_0 = 0.25$ amp, f = 60 Hz, L = 2H

$$\therefore \quad V_{eff} = \frac{0.25}{\sqrt{2}} \times 2 \times 3.14 \times 60 \times 2 = 133.2 \text{ Volt}$$

Example 6.

If a domestic appliance draws 2.5 A from a 220-V, 60- Hz A.C. power supply, then find

(a) the average current
(b) the average of the square of the current
(c) the current amplitude
(d) the supply voltage amplitude.

Solution :

(a) The average of sinusoidal AC values over any whole number of cycles is zero.

(b) RMS value of current = I_{rms} = 2.5 A

$$\therefore \quad (I^2)_{av} = (I_{rms})^2 = 6.25\text{ A}^2$$

(c) $I_{rms} = \frac{I_m}{\sqrt{2}}$

$\therefore$ Current amplitude $= \sqrt{2} I_{rms} = \sqrt{2}(2.5\text{A}) = 3.5\text{ A}$

(d) $V_{rms} = 220\text{V} = \frac{V_m}{\sqrt{2}}$

$\therefore$ Supply voltage amplitude

$$V_m = \sqrt{2}(V_{rms}) = \sqrt{2}(220V) = 311\text{ V.}$$

Example 7.

A 100 μF capacitor in series with a 40 Ω resistance is connected to a 110 V, 60 Hz supply.

(a) What is the maximum current in the circuit?
(b) What is the time lag between current maximum and voltage maximum?

Solution :

(a) Here, $C = 100\ \mu F = 100 \times 10^{-6}$ F, $R = 40\ \Omega$,
$V_{rms} = 110$ V, $f = 60$ Hz

Peak voltage, $V_0 = \sqrt{2}\ .\ V_{rms} = 100\sqrt{2} = 155.54$ V

Circuit impedance, $Z = \sqrt{R^2 + \frac{1}{\omega^2 C^2}}$

$$= \sqrt{40^2 + \frac{1}{(2 \times \pi \times 60 \times 100 \times 10^{-6})^2}}$$

$$= \sqrt{1600 + 703.60} = \sqrt{2303.60} = 48\ \Omega$$

Hence, maximum current in coil,

$$I_0 = \frac{V_0}{Z} = \frac{155.54}{48} = 3.24\ A$$

(b) Phase lead angle (for current),

$$\theta = \tan^{-1}\frac{1}{\omega C R} = \tan^{-1}\frac{1}{2 \times 3.14 \times 60 \times 100 \times 10^{-6} \times 40}$$

$= \tan^{-1} 0.66315 = 33°\ 33'$ (taken 33.5°)

$$\text{Time lead, } t = \frac{\theta}{\omega} = \frac{\theta}{2\pi\nu} = \frac{33.5}{360 \times 60} = 0.001551 \text{ sec}$$

$= 1.551 \times 10^{-3}$ sec

Voltage will lag current by = 1.551 ms.

Example 8.

30.0 μF capacitor is connected to a 220 V, 50 Hz source. Find the capacitive reactance and the current (rms and peak) in the circuit. If the frequency is doubled, what happens to the capacitive reactance and the current?

Solution :

The capacitive reactance is $X_C = \frac{1}{2\pi f C} = 106\Omega$

The rms current is $I_{rms} = \frac{V_{rms}}{X_C} = 2.08A$

The peak current is $I_m = \sqrt{2} I_{rms} = 2.96A$

This current oscillates between 2.96A and – 2.96A and is ahead of the voltage by 90º.

If the frequency is doubled, the capacitive reactance is halved and consequently, the current is doubled.

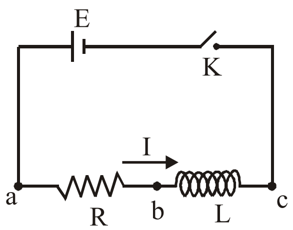
VARYING CURRENT

When the key in a D.C. circuit (containing a D.C. source of emf, inductance coil, resistance and capacitor) is closed or opened, the current in the circuit varies. This is known as varying current as it varies w.r.t. time and takes a final value after a short while.

Growth of Current

If K is closed at $t = 0$ so at $t = 0$, current in the circuit $I = 0$

After closing the key K at time t let current in the circuit = I and for small time in the circuit, current varies with time,



so if rate of change of current with time = $\frac{dI}{dt}$ then due to phenomenon of self induction, induced emf across inductance $= -L\frac{dI}{dt}$

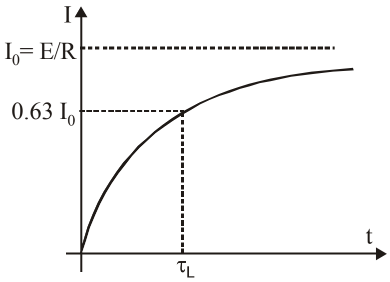
Potential difference across the resistance = IR

During growth of current in L-R circuit, if we applying Kirchhoff's loop rule then

$$E + \left(-L\frac{dI}{dt}\right) = IR$$

On solving it we get the value of current at any time t during growth of current in LR-circuit. $I = I_0\left(1 - e^{-\frac{R}{L}t}\right)$

Graph showing how current varies with time



Time Constant

$\frac{L}{R}$ has dimensions of time. It is called **inductive time constant** of LR-circuit.

$$\text{At } t = \frac{L}{R};\quad I = I_0(1 - e^{-\frac{R}{L}\cdot\frac{L}{R}}) = I_0(1 - e^{-1}) = I_0\left(\frac{e-1}{e}\right)$$

$$= I_0\left(\frac{2.71 - 1}{2.71}\right) = 0.632\ I_0$$

The ***inductive time constant*** *of an LR-circuit is the time in which the current grows from zero to 0.632 (or 63.2%) of its maximum value.* When $t \to \infty$.

$$I = I_0\left(1 - e^{-\frac{R}{L}.\infty}\right) = I_0\left(1 - e^{-\infty}\right) = I_0(1 - 0)$$

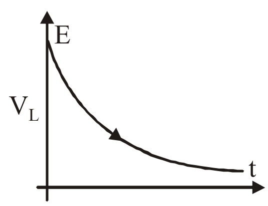
Potential difference across resistance :

$$V_R = E\left(1 - e^{-\frac{R}{L}t}\right);\ V_L = L\frac{dI}{dt}$$

$$I = I_0 - I_0 e^{-\frac{R}{L}t};$$

$$\frac{dI}{dt} = 0 - I_0\, e^{-\frac{R}{L}t}\left(-\frac{R}{L}\right)$$

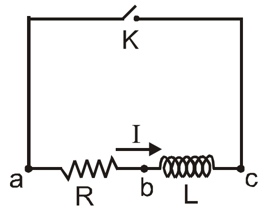
$$V_L = E\, e^{-\frac{R}{L}t}$$



Initially, an inductor acts to oppose changes in the current through it. A long time later, it acts like ordinary connecting wire.

DECAY OF CURRENT

Let the current has reached its steady state value I_0 through inductor. Now switch K in the circuit shown in fig. has been closed.



Let this time is $t = 0$.

Let at $t = 0$ current in the circuit (which is maximum) $= I_0$

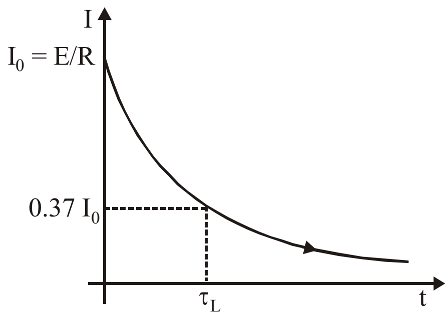
After time t current in the circuit = I

Applying Kirchhoff's loop rule to this circuit

$$0 + \left(-L\frac{dI}{dt}\right) = IR \quad \text{(since there is no source of e.m.f.)}$$

or $L\frac{dI}{dt} = -IR$ or $\frac{dI}{I} = -\frac{R}{L}dt$

The eq^n. gives the value of current at any time t during decay of current in LR-circuit.



Again, dimensions of $\frac{L}{R}$ are same as that of time

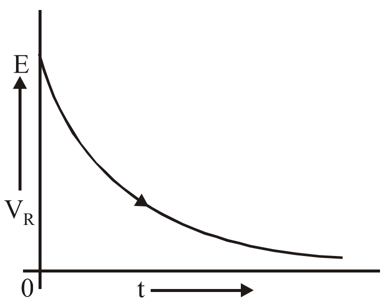
The inductive time constant of the LR-circuit can also be defined by using equation

Setting $t = \frac{L}{R}$ in equation., we get

$$I = I_0\, e^{-\frac{R}{L}\cdot\frac{L}{R}} = I_0\, e^{-1} = \frac{1}{e}I_0 \qquad \text{or } I \cong 0.37\, I_0.$$

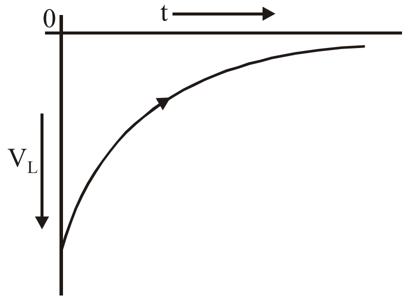
As $t \to \infty$, $I \to 0$

$V_R = IR$



or $V_R = e^{-\frac{R}{L}t}$ $\quad V_L = L\frac{dI}{dt}$ $\quad I = I_0\, e^{-\frac{R}{L}t}$

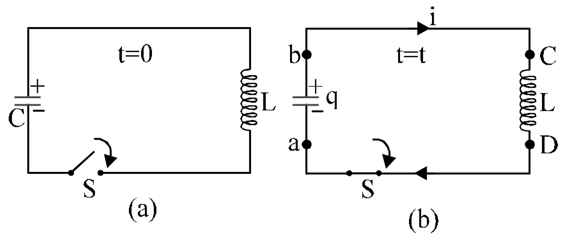
$\frac{dI}{dt} = I_0\, e^{-\frac{R}{L}t}\left(-\frac{R}{L}\right)$ $\quad$ or $V_L = -E\, e^{-\frac{R}{L}t}$



LC OSCILLATIONS

If a charged capacitor C is short-circuited though an inductor L, the charge and current in the circuit start oscillating simple harmonically. If the resistance of the circuit is zero, no energy is dissipated as heat. Assume an idealized situation in which energy is not radiated away from the circuit. With these idealizations-zero resistance and no radiation, the oscillations in the circuit persist indefinitely and the energy is transferred from the capacitor's electric field to the inductor's magnetic field back and forth. The total energy associated with the circuit is constant. This is analogous to the transfer of energy in an oscillating mechanical system from potential energy to kinetic energy and back, with constant total energy.

Let us now derive an equation for the oscillations in an L-C circuit.



Refer figure (a) : The capacitor is charged to a potential difference V such that charge on capacitor $q_0 = CV$

Here q_0 is the maximum charge on the capacitor. At time $t = 0$, it is connected to an inductor through a switch S. At time $t = 0$, switch S is closed.

Refer figure (b) : When the switch is closed, the capacitor starts discharging. Let at time t charge on the capacitor is q ($< q_0$) and since, it is further decreasing there is a current i in the circuit in the direction shown in figure.

The potential difference across capacitor = potential difference across inductor,

or $V_b - V_a = V_c - V_d$ $\quad \therefore \quad \frac{q}{C} = L\left(\frac{di}{dt}\right)$ ...(i)

Now, as the charge is decreasing,

$i = \left(\frac{-dq}{dt}\right)$ $\quad$ or $\quad \frac{di}{dt} = -\frac{d^2q}{dt^2}$

Substituting this value of $\frac{di}{dt}$ in equation (i), we get

$$\frac{q}{C} = -L\left(\frac{d^2q}{dt^2}\right) \quad \text{or} \quad \frac{d^2q}{dt^2} = -\left(\frac{1}{LC}\right)q \qquad \text{...(ii)}$$

This is the standard equation of simple harmonic motion $\left(\frac{d^2x}{dt^2} = -\omega^2 x\right)$

Here $\omega = \frac{1}{\sqrt{LC}}$ or $f = \frac{1}{2\pi\sqrt{LC}}$ ...(iii)

The general solution of equation (ii),

is $q = q_0 \cos(\omega t \pm \phi)$

In case $\phi = 0$ as $q = q_0$ at $t = 0$.

Thus, we can say that charge in the circuit oscillates with angular frequency given by equation (iii). Thus,

In L-C oscillations, q, i and $\frac{di}{dt}$ all oscillate harmonically with same angular frequency ω. But the phase difference between q and i or between i and $\frac{di}{dt}$ is π/2. Their amplitudes are q_0, $q_0\omega$ and $\omega_2 q_0$ respectively. So

$q = q_0 \cos\omega t$, then

$$i = \frac{dq}{dt} = -q_0\omega \sin\omega t \quad ; \quad \frac{di}{dt} = -q_0\omega^2 \cos\omega t$$

Similarly potential energy across capacitor (U_C) and across inductor (U_L) also oscillate with double the frequency 2ω.

TRANSFORMER

*A **transformer** is a device for converting high voltage into low voltage and vice versa, without change in power.*

There are two types of transformers.

(a) **Step up transformer :** *It converts low voltage into high voltage.*

(b) **Step down transformer :** *It converts high voltage into low voltage.*

The **principle of a transformer** is based on mutual induction and a transformer always works on AC. The input is appleid across primary terminals and output is obtained across secondary terminals.

The ratio of number of turns in secondary and primary is called the turn ratio

i.e., $\frac{n_S}{n_P}$ = *turn ratio* K.

If E_P and E_S are alternating voltages, $\mathbf{I_P}$ and $\mathbf{I_S}$ the alternating currents across primary and secondary terminals respectively then, $\frac{E_S}{E_P} = \frac{n_S}{n_P} = K = \frac{I_P}{I_S}$.

Efficiency of transformer,

$$\eta = \frac{Output\ power}{Input\ power} = \frac{P_{out}}{P_{in}} = \frac{E_S I_S}{E_P I_P}$$

Comparative study of step-up transformer and step-down transformer.

Step - up transformer	Step - down transformer
1. $E_s > E_P$	1. $E_s < E_p$
2. $N_s > N_p$	2. $N_s < N_p$
3. $I_S < I_p$	3. $I_s > I_p$
4. $Z_s < Z_p$	4. $Z_s < Z_p$
5. k > 1	5. k < 1

Power losses in a transformer :

(a) **Copper loss.** This is due to resistance of the winding of primary and secondary coil (I^2 R)

(b) **Iron loss or Eddy current loss.**

(c) **Loss due to leakage of magnetic flux.**

(d) **Hysteresis :** Due to repeated magnetisation and demagnetisation of iron core.

(e) **Humming loss :** Due to vibration.

Inspite of all these losses, we have transformers with efficiency of 70% – 90%.

Example 9.

An ideal choke takes a current of 10 ampere when connected to an A.C. supply of 125 volt and 50 Hz. A pure resistor under the same conditions takes a current of 12.5 ampere.

If the two are connected to an A.C. supply of $100\sqrt{2}$ volt and 40 hertz, then find the current in a series combination of the above resistor and inductor.

Solution :

For series combination, $Z = \sqrt{[R^2 + (X_L)^2]}$

$R = \frac{125}{12.5} = 10\,\Omega$, $\omega L = 2\pi f L = V/I$

$\therefore\ 2\pi \times 50 \times L = 125/10 = 12.5$ or $2\pi L = 0.25$

For 40 Hz frequency, $X_L = 2\pi L \times f = 0.25 \times 40 = 10\,\Omega$

Now $Z = \sqrt{[(10)^2 + (10)^2]} = 10\sqrt{2}$;

Current $= \frac{I_0}{Z} = \frac{100\sqrt{2}}{10\sqrt{2}} = 10\,A$

Example10.

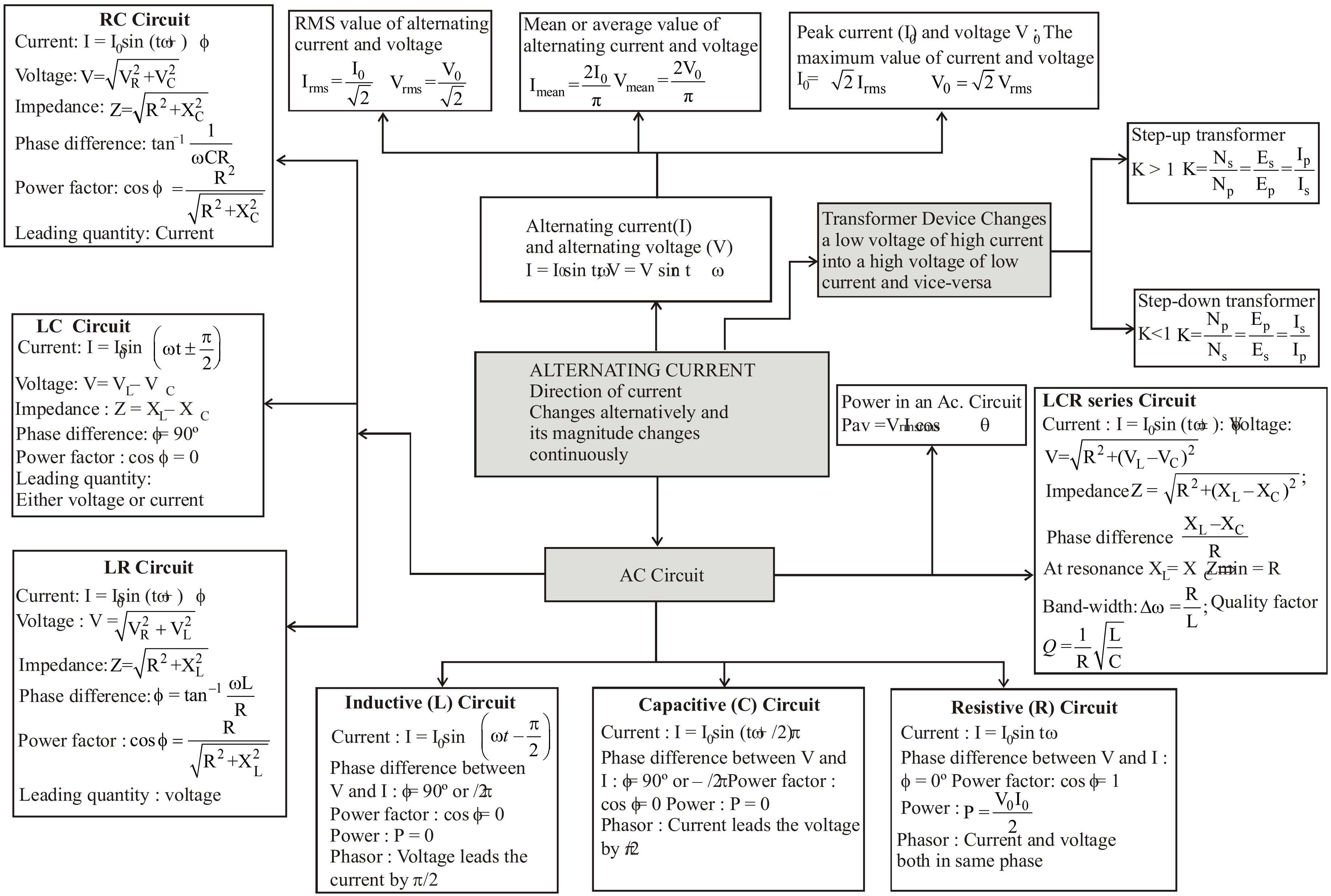
A low loss transformer has 230 V applied to primary and gives 4.6 V in secondary. The secondary is connected to a load which draws 5 A current. Find the current in primary.

Solution :

Assuming no loss of power $E_p \mathbf{I}_p = E_s \mathbf{I}_s$

$$\therefore\ \mathbf{I}_p = \frac{E_s \mathbf{I}_s}{E_p} = 4.6 \times \frac{5}{230} = 0.1\,A$$

CONCEPT MAP



RC Circuit
Current: $I = I_0 \sin(\omega t + \phi)$
Voltage: $V = \sqrt{V_R^2 + V_C^2}$
Impedance: $Z = \sqrt{R^2 + X_C^2}$
Phase difference: $\tan^{-1}\frac{1}{\omega CR}$
Power factor: $\cos\phi = \frac{R}{\sqrt{R^2 + X_C^2}}$
Leading quantity: Current
RMS value of alternating current and voltage
$I_{rms} = \frac{I_0}{\sqrt{2}}$ $V_{rms} = \frac{V_0}{\sqrt{2}}$
Mean or average value of alternating current and voltage
$I_{mean} = \frac{2I_0}{\pi}$ $V_{mean} = \frac{2V_0}{\pi}$
Peak current (I_0) and voltage V_0: The maximum value of current and voltage
$I_0 = \sqrt{2}\, I_{rms}$ $V_0 = \sqrt{2}\, V_{rms}$
Step-up transformer
$K > 1$ $K = \frac{N_s}{N_p} = \frac{E_s}{E_p} = \frac{I_p}{I_s}$
Alternating current(I) and alternating voltage (V)
$I = I_0 \sin \omega t$, $V = V_0 \sin \omega t$
Transformer Device Changes a low voltage of high current into a high voltage of low current and vice-versa
Step-down transformer
$K < 1$ $K = \frac{N_p}{N_s} = \frac{E_p}{E_s} = \frac{I_s}{I_p}$
LC Circuit
Current: $I = I_0 \sin\left(\omega t \pm \frac{\pi}{2}\right)$
Voltage: $V = V_L - V_C$
Impedance : $Z = X_L - X_C$
Phase difference: $\phi = 90^\circ$
Power factor : $\cos\phi = 0$
Leading quantity:
Either voltage or current
ALTERNATING CURRENT
Direction of current
Changes alternatively and its magnitude changes continuously
Power in an Ac. Circuit
$P_{av} = V_{rms} I_{rms} \cos\theta$
LCR series Circuit
Current : $I = I_0 \sin(\omega t + \phi)$; Voltage:
$V = \sqrt{R^2 + (V_L - V_C)^2}$
Impedance $Z = \sqrt{R^2 + (X_L - X_C)^2}$;
Phase difference $\frac{X_L - X_C}{R}$
At resonance $X_L = X_C$, $Z_{min} = R$
Band-width: $\Delta\omega = \frac{R}{L}$; Quality factor
$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$
LR Circuit
Current: $I = I_0 \sin(\omega t + \phi)$
Voltage : $V = \sqrt{V_R^2 + V_L^2}$
Impedance: $Z = \sqrt{R^2 + X_L^2}$
Phase difference: $\phi = \tan^{-1}\frac{\omega L}{R}$
Power factor : $\cos\phi = \frac{R}{\sqrt{R^2 + X_L^2}}$
Leading quantity : voltage
AC Circuit
Inductive (L) Circuit
Current : $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$
Phase difference between V and I : $\phi = 90^\circ$ or $\pi/2$
Power factor : $\cos\phi = 0$
Power : P = 0
Phasor : Voltage leads the current by $\pi/2$
Capacitive (C) Circuit
Current : $I = I_0 \sin(\omega t + \pi/2)$
Phase difference between V and I : $\phi = 90^\circ$ or $-\pi/2$ Power factor : $\cos\phi = 0$ Power : P = 0
Phasor : Current leads the voltage by $\pi/2$
Resistive (R) Circuit
Current : $I = I_0 \sin \omega t$
Phase difference between V and I : $\phi = 0^\circ$ Power factor: $\cos\phi = 1$
Power : $P = \frac{V_0 I_0}{2}$
Phasor : Current and voltage both in same phase

EXERCISE - 1
Conceptual Questions

1. The resistance of a coil for dc is in ohms. In ac, the resistance will
(a) be zero (b) decrease
(c) increase (d) remain same

2. In an a.c. circuit, the r.m.s. value of current, I_{rms} is related to the peak current, I_0 by the relation
(a) $I_{rms} = \sqrt{2}\, I_0$ (b) $I_{rms} = \pi I_0$
(c) $I_{rms} = \frac{1}{\pi} I_0$ (d) $I_{rms} = \frac{1}{\sqrt{2}} I_0$

3. In a RLC circuit capacitance is changed from C to 2 C. For the resonant frequency to remain unchanged, the inductance should be changed from L to
(a) 4L (b) 2L (c) L/2 (d) L/4

4. An LCR series circuit, connected to a source E, is at resonance. Then the voltage across
(a) R is zero
(b) R equals applied voltage
(c) C is zero
(d) L equals applied voltage

5. In a LCR circuit at resonance which of these will effect the current in circuit
(a) R only (b) L and R only
(c) R and C only (d) all L, C and R

6. Fleming's left and right hand rules are used in
(a) DC motor and AC generator
(b) DC generator and AC motor
(c) DC motor and DC generator
(d) Both rules are same, any one can be used

7. The time taken by the current to rise to 0.63 of its maximum value in a d.c. circuit containing inductance (L) and resistance (R) depends on
(a) L only (b) R only (c) $\frac{L}{R}$ (d) LR

8. A bulb and a capacitor are connected in series to a source of alternating current. If its frequency is increased, while keeping the voltage of the source constant, then bulb will
(a) give more intense light
(b) give less intense light
(c) give light of same intensity before
(d) stop radiating light

9. In LCR circuit if resistance increases quality factor
(a) increases finitely (b) decreases finitely
(c) remains constant (d) None of these

10. In an A.C. circuit with phase voltage V and current I, the power dissipated is
(a) VI (b) V^2I (c) VI^2 (d) V^2I^2

11. Which of the following will have the dimensions of time
(a) LC (b) R/L (c) L/R (d) C/L

12. In an oscillating LC circuit the max. charge on the capacitor is Q. The charge on capacitor when the energy is stored equally between electric and magnetic field is
(a) Q/2 (b) $Q/\sqrt{3}$ (c) $Q/\sqrt{2}$ (d) Q

13. The power factor of an AC circuit having resistance (R) and inductance (L) connected in series and an angular velocity ω is
(a) R/ωL (b) $R/(R^2+\omega^2L^2)^{1/2}$
(c) ωL/R (d) $R/(R^2-\omega^2L^2)^{1/2}$

14. A.C. power is transmitted from a power house at a high voltage as
(a) the rate of transmission is faster at high voltages
(b) it is more economical due to less power loss
(c) power cannot be transmitted at low voltages
(d) a precaution against theft of transmission lines

15. In a pure capacitive A.C. circuit current and voltage differ in phase by
(a) 0° (b) 45° (c) 90° (d) 180°

16. Which of the following statement is incorrect ?
(a) In LCR series ac circuit, as the frequency of the source increases, the impedence of the circuit first decreases and then increases.
(b) If the net reactance of an LCR series ac circuit is same as its resistance, then the current lags behind the voltage by 45°.
(c) At resonance, the impedence of an ac circuit becomes purely resistive.
(d) Below resonance, voltage leads the current while above it, current leads the voltage.

17. Resonance frequency of LCR series a.c. circuit is f_0. Now the capacitance is made 4 times, then the new resonance frequency will become
(a) $f_0/4$ (b) $2f_0$ (c) f_0 (d) $f_0/2$.

18. A capacitor has capacitance C and reactance X, if capacitance and frequency become double, then reactance will be
(a) 4X (b) X/2 (c) X/4 (d) 2X

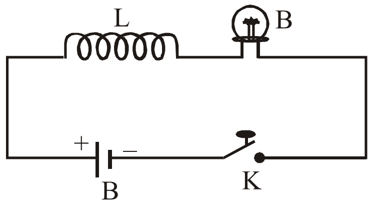
19. In a series resonant circuit, having L,C and R as its elements, the resonant current is i. The power dissipated in circuit at resonance is
(a) $\frac{i^2R}{(\omega L - 1/\omega C)}$ (b) zero
(c) $i^2\omega L$ (d) i^2R.
Whereas ω is angular resonant frequency

20. An inductance L having a resistance R is connected to an alternating source of angular frequency ω. The Quality factor Q of inductance is
(a) R/ωL (b) $(\omega L/R)^2$ (c) $(R/\omega L)^{1/2}$ (d) ωL/R

21. The core of any transformer is laminated so as to
(a) reduce the energy loss due to eddy currents
(b) make it light weight
(c) make it robust and sturdy
(d) increase secondary voltage

22. The time constant of C–R circuit is
(a) 1/CR (b) C/R
(c) CR (d) R/C

23. In the circuit of Fig, the bulb will become suddenly bright if



(a) contact is made or broken
(b) contact is made
(c) contact is broken
(d) won't become bright at all

24. Energy in a current carrying coil is stored in the form of
(a) electric field (b) magnetic field
(c) dielectric strength (d) heat

25. In a circuit L, C and R are connected in series with an alternating voltage source of frequency f. The current leads the voltage by 45°. The value of C is

(a) $\frac{1}{\pi f(2\pi fL - R)}$ (b) $\frac{1}{2\pi f(2\pi fL - R)}$

(c) $\frac{1}{\pi f(2\pi fL + R)}$ (d) $\frac{1}{2\pi f(2\pi fL + R)}$

EXERCISE - 2
Applied Questions

1. In an A.C. circuit, the current flowing in inductance is $I = 5 \sin(100t - \pi/2)$ amperes and the potential difference is $V = 200 \sin(100t)$ volts. The power consumption is equal to
(a) 1000 watt (b) 40 watt
(c) 20 watt (d) Zero

2. If resistance of 100Ω, and inductance of 0.5 henry and capacitance of 10×10^6 farad are connected in series through 50 Hz A.C. supply, then impedance is
(a) 1.8765 Ω (b) 18.76 Ω
(c) 187.6 Ω (d) 101.3 Ω

3. Using an A.C. voltmeter the potential difference in the electrical line in a house is read to be 234 volt. If the line frequency is known to be 50 cycles/second, the equation for the line voltage is
(a) $V = 165 \sin(100\pi t)$ (b) $V = 331 \sin(100\pi t)$
(c) $V = 220 \sin(100\pi t)$ (d) $V = 440 \sin(100\pi t)$

4. An inductance of negligible resistance whose reactance is 22 Ω at 200 Hz is connected to 200 volts, 50 Hz power line. The value of inductance is
(a) 0.0175 henry (b) 0.175 henry
(c) 1.75 henry (d) 17.5 henry

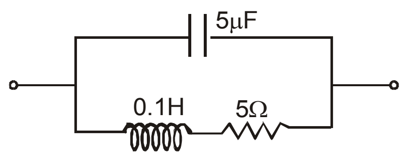
5. An inductive circuit contains resistance of 10 ohms and an inductance of 2 henry. If an A.C. voltage of 120 Volts and frequency 60 Hz is applied to this circuit, the current would be nearly
(a) 0.32 Amp (b) 0.16 Amp
(c) 0.48 Amp (d) 0.80 Amp

6. In an a.c. circuit V and **I** are given by
$V = 100 \sin(100t)$ volts
$\mathbf{I} = 100 \sin(100t + \pi/3)$ mA
the power dissipated in the circuit is
(a) 10^4 watt (b) 10 watt (c) 2.5 watt (d) 5.0 watt

7. The primary winding of a transformer has 100 turns and its secondary winding has 200 turns. The primary is connected to an A.C. supply of 120 V and the current flowing in it is 10 A. The voltage and the current in the secondary are
(a) 240 V, 5 A (b) 240 V, 10 A
(c) 60 V, 20 A (d) 120 V, 20 A

8. A step down transformer is connected to 2400 volts line and 80 amperes of current is found to flow in output load. The ratio of the turns in primary and secondary coil is 20 : 1. If transformer efficiency is 100%, then the current flowing in the primary coil will be
(a) 1600 amp (b) 20 amp
(c) 4 amp (d) 1.5 amp

9. In the circuit shown in fig, the resonant frequency is
(a) 75 kc/s
(b) 750 kc/s
(c) 7.5 kc/s
(d) 75 mc/s



10. An alternating voltage E (in volts) = $200\sqrt{2} \sin 100t$ is connected to one micro farad capacitor through an a.c. ammeter. The reading of the ammeter shall be
(a) 100 mA (b) 20 mA (c) 40 mA (d) 80 mA

11. The r.m.s value of an a.c. of 50 Hz is 10 amp. The time taken by the alternating current in reaching from zero to maximum value and the peak value of current will be
(a) 2×10^{-2} sec and 14.14 amp
(b) 1×10^{-2} sec and 7.07 amp
(c) 5×10^{-3} sec and 7.07 amp
(d) 5×10^{-3} sec and 14.14 amp

12. The frequency of A.C. mains in India is
(a) 30 c/s (b) 50 c/s
(c) 60 c/s (d) 120 c/s

13. A 12 Ω resistor and a 0.21 henry inductor are connected in series to an a.c. source operating at 20 volt, 50 cycle. The phase angle between the current and source voltage is
(a) 30º (b) 40º (c) 80º (d) 90º

14. A step down transformer reduces 220 V to 110 V. The primary draws 5 ampere of current and secondary supplies 9 ampere. The efficiency of transformer is
(a) 20% (b) 44% (c) 90% (d) 100%

15. An alternating current is given by
$i = i_1 \cos\omega t + i_2 \sin\omega t$
The rms current is given by
(a) $\frac{i_1 + i_2}{\sqrt{2}}$ (b) $\frac{|i_1 + i_2|}{\sqrt{2}}$
(c) $\sqrt{\frac{i_1^2 + i_2^2}{2}}$ (d) $\sqrt{\frac{i_1^2 + i_2^2}{\sqrt{2}}}$

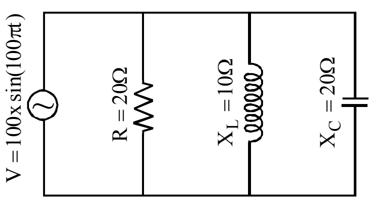
16. The impedance in a circuit containing a resistance of 1 Ω and an inductance of 0.1 H in series, for AC of 50 Hz, is
(a) $100\sqrt{10}\Omega$ (b) $10\sqrt{10}\Omega$
(c) 100Ω (d) $\sqrt{10}\Omega$

17. The primary winding of transformer has 500 turns whereas its secondary has 5000 turns. The primary is connected to an A.C. supply of 20 V, 50 Hz. The secondary will have an output of
(a) 2 V, 5 Hz (b) 200 V, 500 Hz
(c) 2V, 50 Hz (d) 200 V, 50 Hz

18. Determine the rms value of the emf given by
E (in volt) = 8 sin (ω t) + 6sin (2 ω t)
(a) $5\sqrt{2}$V (b) $7\sqrt{2}$V (c) 10V (d) $10\sqrt{2}$V

19. A transformer is used to light a 140 W, 24 V bulb from a 240 V a.c. mains. The current in the main cable is 0.7 A. The efficiency of the transformer is
(a) 63.8 % (b) 83.3 % (c) 16.7 % (d) 36.2 %

20. In the given circuit, the current drawn from the source is



(a) 20 A (b) 10 A (c) 5 A (d) $5\sqrt{2}$ A

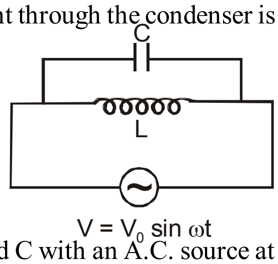
21. An AC voltage source has an output of $V = 200\sin 2\pi ft$. This source is connected to a 100 Ω resistor. RMS current in the resistance is
(a) 1.41 A (b) 2.41 A (c) 3.41 A (d) 0.71 A

22. An alternating voltage $V = V_0 \sin \omega t$ is applied across a circuit. As a result, a current $I = I_0 \sin (\omega t - \pi/2)$ flows in it. The power consumed per cycle is
(a) zero (b) $0.5\, V_0I_0$
(c) $0.707\, V_0I_0$ (d) $1.414\, V_0I_0$

23. In an A.C. circuit, a resistance of R ohm is connected in series with an inductance L. If phase angle between voltage and current be 45°, the value of inductive reactance will be
(a) R/4
(b) R/2
(c) R
(d) cannot be found with given data

24. The ratio of mean value over half cycle to r.m.s. value of A.C. is
(a) 2 : π (b) $2\sqrt{2}$: π (c) $\sqrt{2}$: π (d) $\sqrt{2}$: 1

25. For the circuit shown in the fig., the current through the inductor is 0.9 A while the current through the condenser is 0.4 A. Then



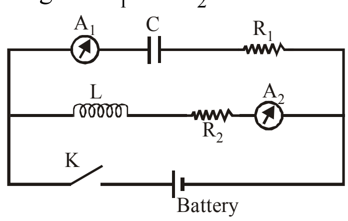
(a) current drawn from generator I = 1.13 A
(b) ω = 1/(1.5 LC)
(c) I = 0.5 A
(d) I = 0.6 A

26. In series combination of R, L and C with an A.C. source at resonance, if R = 20 ohm, then impedence Z of the combination is
(a) 20 ohm (b) zero (c) 10 ohm (d) 400 ohm

27. In an LR circuit f = 50 Hz, L=2H, E=5 volts, R=1 Ω then energy stored in inductor is
(a) 50 J (b) 25 J
(c) 100 J (d) None of these

28. A capacitor in an ideal LC circuit is fully charged by a DC source, then it is disconnected from DC source, the current in the circuit
(a) becomes zero instantaneously
(b) grows , monotonically
(c) decays monotonically
(d) oscillate infinitely

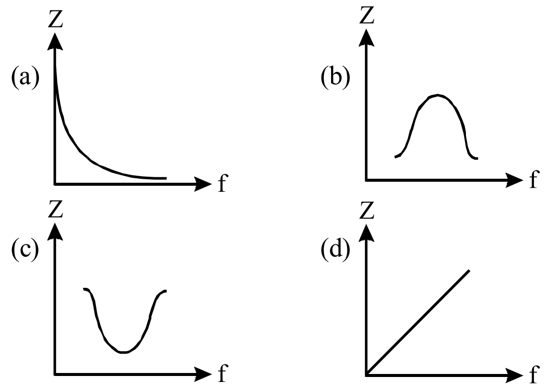
29. In a circuit inductance L and capacitance C are connected as shown in figure. A_1 and A_2 are ammeters.



When key K is pressed to complete the circuit, then just after closing key (K), the readings of A_1 and A_2 will be
(a) zero in both A_1 and A_2
(b) maximum in both A_1 and A_2
(c) zero in A_1 and maximum in A_2
(d) maximum in A_1 and zero in A_2

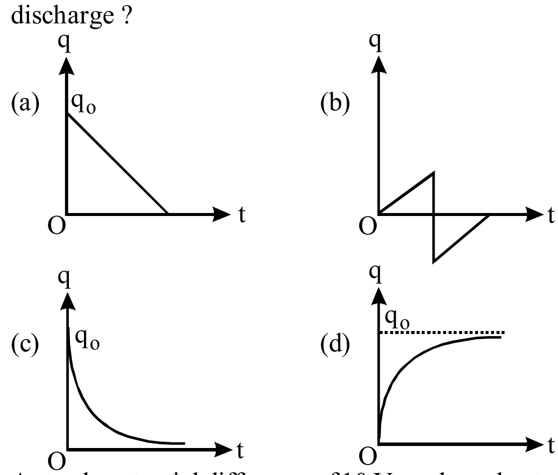
30. The tuning circuit of a radio receiver has a resistance of $50\,\Omega$, an inductor of 10 mH and a variable capacitor. A 1 MHz radio wave produces a potential difference of 0.1 mV. The values of the capacitor to produce resonance is (Take $\pi^2 = 10$)
(a) 2.5 pF (b) 5.0 pF (c) 25 pF (d) 50 pF

31. Which one of the following curves represents the variation of impedance (Z) with frequency f in series LCR circuit?



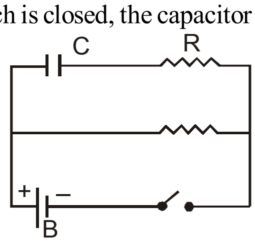
32. Two coils A and B are connected in series across a 240 V, 50 Hz supply. The resistance of A is $5\,\Omega$ and the inductance of B is 0.02 H. The power consumed is 3 kW and the power factor is 0.75. The impedance of the circuit is
(a) $0.144\,\Omega$ (b) $1.44\,\Omega$ (c) $14.4\,\Omega$ (d) $144\,\Omega$

33. In LCR series circuit fed by a DC source, how does the amplitude of charge oscillations vary with time during discharge ?



34. A steady potential difference of 10 V produces heat at a rate x in a resistor. The peak value of the alternating voltage which will produce heat at a rate $\frac{x}{2}$ in the same resistor is
(a) 5V (b) $5\sqrt{2}$ V (c) 10V (d) $10\sqrt{2}$ V

35. In the circuit shown, when the switch is closed, the capacitor charges with a time constant
(a) RC
(b) 2RC
(c) $\frac{1}{2}$RC
(d) RC ln 2



36. In the question 86, if the switch is opened after the capacitor has been charged, it will discharges with a time constant
(a) RC (b) 2RC (c) $\frac{1}{2}$RC (d) RC ln 2

37. An alternating voltage of 220 V, 50 Hz frequency is applied across a capacitor of capacitance 2 μF. The impedence of the circuit is
(a) $\frac{\pi}{5000}$ (b) $\frac{1000}{\pi}$ (c) 500π (d) $\frac{5000}{\pi}$

38. An inductive coil has a resistance of 100 Ω. When an a.c. signal of requency 1000 Hz is fed to the coil, the applied voltage leads the current by 45°. What is the inductance of the coil ?
(a) 10mH (b) 12mH (c) 16mH (d) 20mH.

39. The primary of a transformer has 400 turns while the secondary has 2000 turns. If the power output from the secondary at 1000 V is 12 kW, what is the primary voltage?
(a) 200 V (b) 300 V (c) 400 V (d) 500 V

40. An inductor of self inductance 100 mH and a resistor of resistance 50Ω, are connected to a 2 V battery. The time required for the current to half its steady value is
(a) 2 milli second (b) 2 *l*n (0.5) milli second
(c) 2 *l*n (3) milli second (d) 2 *l*n (2) milli second

41. The instantaneous voltage through a device of impedance 20 Ω is e = 80 sin 100 πt. The effective value of the current is
(a) 3 A (b) 2.828 A (c) 1.732 A (d) 4 A

42. A transformer has an efficiency of 80%. It works at 4 kW and 100 V. If secondary voltage is 240 V, the current in primary coil is
(a) 0.4 A (b) 4 A (c) 10 A (d) 40 A

43. The primary winding of transformers has 500 turns whereas its secondary has 5000 turns. The primary is connected to an A.C. supply of 20 V, 50 Hz. The secondary will have an output of
(a) 2V, 5Hz (b) 200 V, 500 Hz
(c) 2V, 50 Hz (d) 200 V, 50Hz

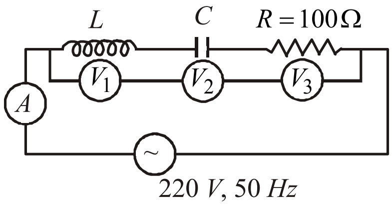
44. A step up transformer operates on a 230 V line and supplies a current of 2 ampere. The ratio of primary and secondary winding is 1:25 . The current in primary is
(a) 25 A (b) 50 A (c) 15 A (d) 12.5 A

45. A step-up transformer has transformation ratio of 3 : 2. What is the voltage in secondary, if voltage in primary is 30 V?
(a) 45 V (b) 15 V (c) 90 V (d) 300 V

46. In an experiment, 200 V A.C. is applied at the ends of an LCR circuit. The circuit consists of an inductive reactance $(X_L) = 50\,\Omega$, capacitive reactance $(X_C) = 50\,\Omega$ and ohmic resistance $(R) = 10\,\Omega$. The impedance of the circuit is
(a) 10Ω (b) 20Ω (c) 30Ω (d) 40Ω

47. In a region of uniform magnetic induction $B = 10^{-2}$ tesla, a circular coil of radius 30 cm and resistance π^2 ohm is rotated about an axis which is perpendicular to the direction of B and which forms a diameter of the coil. If the coil rotates at 200 rpm the amplitude of the alternating current induced in the coil is
(a) $4\pi^2$ mA (b) 30 mA (c) 6 mA (d) 200 mA

48. In the given circuit the reading of voltmeter V_1 and V_2 are 300 volt each. The reading of the voltmeter V_3 and ammeter A are respectively



(a) 150 V and 2.2 A (b) 220 V and 2.2 A
(c) 220 V and 2.0 A (d) 100 V and 2.0 A

Directions for Qs. (49 to 50) : Each question contains STATEMENT-1 and STATEMENT-2. Choose the correct answer (ONLY ONE option is correct) from the following-

(a) Statement -1 is false, Statement-2 is true
(b) Statement -1 is true, Statement-2 is true; Statement -2 is a correct explanation for Statement-1
(c) Statement -1 is true, Statement-2 is true; Statement -2 is not a correct explanation for Statement-1
(d) Statement -1 is true, Statement-2 is false

49. **Statement - 1 :** A capacitor blocks direct current in the steady state.
Statement - 2 : The capacitive reactance of the capacitor is inversely proportional to frequency f of the source of emf.

50. **Statement - 1 :** In the purely resistive element of a series LCR, AC circuit the maximum value of rms current increases with increase in the angular frequency of the applied emf.
Statement - 2 : $I_{max} = \frac{\varepsilon_{max}}{z}$, $z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$, where I_{max} is the peak current in a cycle.

EXERCISE - 3
Exemplar & Past Years NEET/AIPMT Questions

Exemplar Questions

1. If the rms current in a 50 Hz AC circuit is 5 A, the value of the current 1/300 s after its value becomes zero is
(a) $5\sqrt{2}$A (b) $5\sqrt{3/2}$ A
(c) 5/6 A (d) $5/\sqrt{2}$A

2. An alternating current generator has an internal reactance R_g and an internal reactance X_g. It is used to supply power to a passive load consisting of a resistance R_g and a reactance X_L. For maximum power to be delivered from the generator to the load, the value of X_L is equal to
(a) zero (b) X_g
(c) $-X_g$ (d) R_g

3. When a voltage measuring device is connected to AC mains, the meter shows the steady input voltage of 220 V. This means
(a) input voltage cannot be AC voltage, but a DC voltage
(b) maximum input voltage is 220 V
(c) the meter reads not v but $< v^2 >$ and is calibrated to read $\sqrt{< v^2 >}$
(d) The pointer of the meter is stuck by some mechanical defect

4. To reduce the resonant frequency in an L-C-R series circuit with a generator
(a) the generator frequency should be reduced
(b) another capacitor should be added in parallel to the first
(c) the iron core of the inductor should be removed
(d) dielectric in the capacitor should be removed

5. Which of the following combinations should be selected for better tuning of an L-C-R circuit used for communication?
(a) R = 20 Ω, L = 1.5 H, C = 35 μF
(b) R = 25 Ω, L = 2.5 H, C = 45 μF
(c) R = 15 Ω, L = 3.5 H, C = 30 μF
(d) R = 25 Ω, L = 1.5 H, C = 45 μF

6. An inductor of reactance 1Ω and a resistor of 2Ω are connected in series to the terminals of a 6V (rms) AC source. The power dissipated in the circuit is
(a) 8 W (b) 12 W
(c) 14.4 W (d) 18 W

7. The output of a step-down transformer is measured to be 24 V when connected to a 12 W light bulb. The value of the peak current is
(a) $1/\sqrt{2}$ A (b) $\sqrt{2}$ A
(c) 2 A (d) $2\sqrt{2}$ A

NEET/AIPMT (2013-2017) Questions

8. A coil of self-inductance L is connected in series with a bulb B and an AC source. Brightness of the bulb decreases when ***[2013]***
(a) number of turns in the coil is reduced
(b) a capacitance of reactance $X_C = X_L$ is included in the same circuit
(c) an iron rod is inserted in the coil
(d) frequency of the AC source is decreased

9. The primary of a transformer when connected to a dc battery of 10 volt draws a current of 1 mA. The number of turns of the primary and secondary windings are 50 and 100 respectively. The voltage in the secondary and the current drawn by the circuit in the secondary are respectively ***[NEET Kar. 2013]***
(a) 20 V and 0.5 mA
(b) 20 V and 2.0 mA
(c) 10 V and 0.5 mA
(d) Zero and therefore no current

10. A transformer having efficiency of 90% is working on 200V and 3kW power supply. If the current in the secondary coil is 6A, the voltage across the secondary coil and the current in the primary coil respectively are : ***[2014]***

(a) 300 V, 15A (b) 450 V, 15A
(c) 450V, 13.5A (d) 600V, 15A

11. A resistance 'R' draws power 'P' when connected to an AC source. If an inductance is now placed in series with the resistance, such that the impedance of the circuit becomes 'Z', the power drawn will be ***[2015]***

(a) $P\sqrt{\frac{R}{Z}}$ (b) $P\left(\frac{R}{Z}\right)$
(c) P (d) $P\left(\frac{R}{Z}\right)^2$

12. A series R-C circuit is connected to an alternating voltage source. Consider two situations: ***[2015 RS]***

(A) When capacitor is air filled.
(B) When capacitor is mica filled.

Current through resistor is i and voltage across capacitor is V then :

(a) $V_a > V_b$ (b) $i_a > i_b$
(c) $V_a = V_b$ (d) $V_a < V_b$

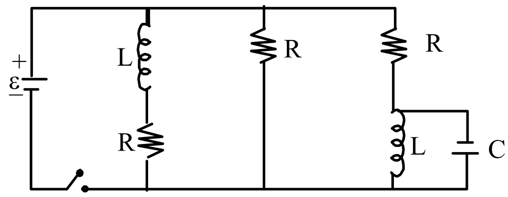
13. An inductor 20 mH, a capacitor 50 μF and a resistor 40Ω are connected in series across a source of emf V = 10 sin 340 t. The power loss in A.C. circuit is : ***[2016]***

(a) 0.51 W (b) 0.67 W
(c) 0.76 W (d) 0.89 W

14. A small signal voltage $V(t) = V_0 \sin \omega t$ is applied across an ideal capacitor C : ***[2016]***

(a) Current I (t), lags voltage V(t) by 90°.
(b) Over a full cycle the capacitor C does not consume any energy from the voltage source.
(c) Current I (t) is in phase with voltage V(t).
(d) Current I (t) leads voltage V(t) by 180°.

15. Figure shows a circuit that contains three identical resistors with resistance R = 9.0 Ω each, two identical inductors with inductance L = 2.0 mH each, and an ideal battery with emf ε = 18 V. The current 'i' through the battery just after the switch closed is ***[2017]***



(a) 0.2 A (b) 2 A
(c) 0 (d) 2 mA

Hints & Solutions

EXERCISE - 1

1. (c) The coil has inductance L besides the resistance R. Hence for ac its effective resistance $\sqrt{R^2 + X_L^2}$ will be larger than its resistance R for dc.

2. (d)

3. (c) We know that $f = \frac{1}{2\pi\sqrt{(LC)}}$,
when C is doubled, L should be halved so that resonant frequency remains unchanged.

4. (b)

5. (a) At resonance, $\omega L = \frac{1}{\omega C}$
Hence the impedance of the circuit would be just equal to R (minimum). In other words, the LCR-series circuit will behave as a purely resistive circuit. Due to this the current is maximum. This condition is known as resonance

$\therefore \quad Z = R, \quad \text{Current} = \frac{V}{R}$

6. (c) 7. (c) 8. (a) 9. (b) 10. (a)

11. (c)

12. (c) In the case of maximum charge on capacitor, the whole energy is, stored in capacitor in the form of electric field which is

$$U = \frac{1}{2}\frac{Q^2}{C}$$

When energy in distributed equally between electric and magnetic field , then energy stored in electric field

i.e. in capacitor is $U_1 = \frac{U}{2} = \left(\frac{1}{2}\frac{Q^2}{C}\right)\frac{1}{2}$

At that time if charge on capacitor is Q_1, then

$$U_1 = \frac{1}{2}\frac{Q_1^2}{C} = \frac{U}{2} = \frac{1}{4}\frac{Q^2}{C} \Rightarrow Q_1 = Q/\sqrt{2}$$

13. (b) 14. (b) 15. (c)

16. (d) Option (d) is false because the reason why the voltage leads the current is because $\frac{1}{C\omega} > L\omega$ and if the voltage lags, the inductive reactance is greater than the capacitive reactance.

17. (d) In LCR series circuit, resonance frequency f_0 is given by

$$L\omega = \frac{1}{C\omega} \Rightarrow \omega^2 = \frac{1}{LC} \quad \therefore \quad \omega = \sqrt{\frac{1}{LC}} = 2\pi f_0$$

$$\therefore \quad f_0 = \frac{1}{2\pi\sqrt{LC}} \quad \text{or} \quad f_0 \alpha \frac{1}{\sqrt{C}}$$

When the capacitance of the circuit is made 4 times, its resonant frequency become f_0'

$$\therefore \quad \frac{f_0'}{f_0} = \frac{\sqrt{C}}{\sqrt{4C}} \quad \text{or} \quad f_0' = \frac{f_0}{2}$$

18. (c) The reactance of capacitor $X = \frac{1}{\omega C}$ where w is frequency and C is the capacitance of capacitor.

19. (d) At resonance wL= 1/wC
and i = E/R , So power dissipated in circuit is P = i^2R.

20. (d) $Q = \frac{\text{Potential drop across capacitor or inductor}}{\text{Potential drop across R.}}$

$$= \frac{\omega L}{R}$$

21. (a)

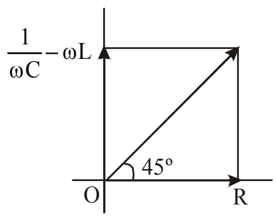
22. (c) The time constant for resonance circuit,
=CR
Growth of charge in a circuit containing capacitance and resistance is given by the formula,
$q = q_0(1 - e^{-t/CR})$
CR is known as time constant in this formula.

23. (c) When a circuit is broken, the induced e.m.f. is largest. So the answer is (c).

24. (b) Energy stored in a coil = $\frac{1}{2}Li^2$
where, L is the self-inductance and *i* the current flowing through the inductor. Thus, energy is stored in the magnetic field of the coil.

25. (d) From figure,

$$\tan 45^\circ = \frac{\frac{1}{\omega C} - \omega L}{R}$$



$$\Rightarrow \frac{1}{\omega C} - \omega L = R$$

$$\Rightarrow \frac{1}{\omega C} = R + \omega L$$

$$\Rightarrow C = \frac{1}{\omega(R + \omega L)} = \frac{1}{2\pi f(R + 2\pi f L)}$$

EXERCISE - 2

1. (d) Power, $P = \mathbf{I}_{r.m.s} \times V_{r.m.s} \times \cos\phi$

In the given problem, the phase difference between voltage and current is p/2. Hence

$P = \mathbf{I}_{r.m.s} \times V_{r.m.s} \times \cos(\pi/2) = 0.$

2. (c) $Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$

Here R = 100 W, L = 0.5 henry, C = 10 × 10^6 farad

$\omega = 2\, p\, \pi = 100\, \pi.$

3. (b) $V = V_0 \sin \omega t$

Voltage in r.m.s. value

$V_0 = \sqrt{2} \times 234\text{ V} = 331\text{ volt}$

and $\omega t = 2\pi n t = 2\pi \times 50 \times t = 100\pi t$

Thus, the equation of line voltage is given by

V = 331 sin (100 π t)

4. (a) $X_L = \omega L = 2\pi n L$

$\therefore\ L = \frac{X_L}{2\pi n} = \frac{22 \times 7}{2 \times 22 \times 200} H = 0.0175 H$

5. (b)

6. (c) $P = V_{r.m.s} \times I_{r.m.s} \times \cos\phi = \frac{1}{2} V_0 I_0 \cos\phi$

$= \frac{1}{2} \times 100 \times (100 \times 10^{-3}) \cos \pi/3 = 2.5\text{ W}$

7. (a) $\frac{E_s}{E_p} = \frac{n_s}{n_p}$ or $E_s = E_p \times \left(\frac{n_s}{n_p}\right)$

$\therefore\ E_s = 120 \times \left(\frac{200}{100}\right) = 240 V$

$\frac{\mathbf{I}_p}{\mathbf{I}_s} = \frac{n_s}{n_p}$ or $\mathbf{I}_s = \mathbf{I}_p\left(\frac{n_p}{n_s}\right)$ $\therefore\ \mathbf{I}_s = 10\left(\frac{100}{200}\right) = 5$ amp

8. (c) $\frac{\mathbf{I}_s}{\mathbf{I}_p} = \frac{n_p}{n_s}$; $\frac{80}{\mathbf{I}_p} = \frac{20}{1}$ or $\mathbf{I}_p = 4$ amp.

9. (a)

10. (b) $\mathbf{I} = \frac{E}{X_C} = E\omega C = \left(\frac{E_0}{\sqrt{2}} \times \omega C\right)$

$\therefore\ I = 120 \times \left(\frac{200}{100}\right) = 240V = 20 \times 10^{-3}$ amp.

11. (d) 12. (b)

13. (c) The phase angle is given by

$\tan\phi = \frac{\omega L}{R} = \frac{2\pi \times 50 \times 0.21}{12} = 5.5$

$\phi = \tan^{-1} 5.5 = 80°$

14. (c) $\eta = \frac{E_S I_S}{E_P I_P}$ $\therefore\ \eta = \frac{110 \times 9}{220 \times 5} = 0.9 \times 100\% = 90\%$

15. (c) 16. (b)

17. (d) The transformer converts A.C. high voltage into A.C. low voltage, but it does not cause any change in frequency.

$\frac{E_s}{E_p} = \frac{N_s}{N_p} \Rightarrow E_s = \frac{N_s}{N_p} E_p = \frac{5000}{500} \times 20 = 200V$

Thus output has voltage 200 V and frequency 50 Hz.

18. (a) $E = 8 \sin \omega t + 6 \sin 2\omega t$

$\Rightarrow E_{peak} = \sqrt{8^2 + 6^2} = 10\text{ V}$

$E_{rms} = \frac{10}{\sqrt{2}} = 5\sqrt{2}\text{ V}$

19. (b) Power of source = EI = 240 × 0.7 = 166

$\Rightarrow$ Efficiency $= \frac{140}{166} \Rightarrow \eta = 83.3\%$

20. (d) 21. (a)

22. (a) The phase angle between voltage V and current I is π/2. Therefore, power factor cos ϕ = cos (π/2) = 0. Hence the power consumed is zero.

23. (c) $\tan\phi = \frac{\omega L}{R} = \frac{X_L}{R}$

Given ϕ = 45°. Hence $X_L = R$.

24. (b) We know that $\mathbf{I}_{rms} = \mathbf{I}_0/\sqrt{2}$ and $\mathbf{I}_m = 2\mathbf{I}_0/\pi$

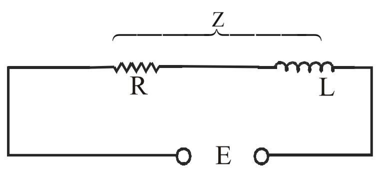
$\therefore\ \frac{\mathbf{I}_m}{\mathbf{I}_{rms}} = \frac{2\sqrt{2}}{\pi}$

25. (c) The current drawn by inductor and capacitor will be in opposite phase. Hence net current drawn from generator

$= I_L - I_C = 0.9 - 0.4 = 0.5$ amp.

26. (a)

27. (d) $L = 2H, E = 5$ volts, $R = 1\Omega$



Energy in inductor $= \frac{1}{2}LI^2 \quad I = \frac{E}{Z}$

$$I = \frac{5}{\sqrt{R^2 + (\omega L)^2}} = \frac{5}{\sqrt{1 + 4\pi^2 \times 50^2 \times 4}}$$

$$= \frac{5}{\sqrt{1 + (200\pi)^2}} = \frac{5}{200\pi}$$

$$\text{Energy} = \frac{1}{2} \times 2 \times \frac{5 \times 5}{200 \times 200\pi^2} = 6.33 \times 10^{-5} \text{ joules}$$

28. (a) In ideal condition of LC circuit $R = 0$ and LC oscillation continue indefinitely. Energy being shunted back and forth between electric field of capacitor and magnetic field of inductor. As capacitor is fully charged current in L is zero and $\frac{1}{2}\frac{q_0{}^2}{C}$ energy is stored in electric field. Then capacitor begins to discharge through L causing a current to flow and build up a magnetic field, around L. Therefore, energy stored.

Now in $L = \frac{1}{2}LI_0^2$ when C is fully discharged, V across the plate reduces to zero.

$\therefore$ Electric field energy is transferred to magnetic field and vice-versa.

29. (d) Initially there is no D.C. current in inductive circuit and maximum D.C.current is in capacitive current. Hence, the current is zero in A_2 and maximum in A_1.

30. (a) $L = 10\text{ mHz} = 10^{-2}\text{ Hz}$

$f = 1\text{MHz} = 10^6\text{ Hz}$

$$f = \frac{1}{2\pi\sqrt{LC}}; \quad f^2 = \frac{1}{4\pi^2 LC}$$

$$\Rightarrow C = \frac{1}{4\pi^2 f^2 L} = \frac{1}{4 \times 10 \times 10^{-2} \times 10^{12}} = \frac{10^{-12}}{4} = 2.5 \text{ pF}$$

31. (c) Impedance at resonant frequency is minimum in series LCR circuit.

$$\text{So, } Z = \sqrt{R^2 + \left(2\pi fL - \frac{1}{2\pi fC}\right)^2}$$

When frequency is increased or decreased, Z increases.

32. (c) $P = \frac{E_v^2 \cos\phi}{Z}$

$$P = 3000 = \frac{(240)^2(0.75)}{Z} \text{d} \quad \Rightarrow Z = 14.4\Omega$$

33. (c) 34. (c)

35. (a) The resistance in the middle plays no part in the charging process of C, as it does not alter either the potential difference across the RC combination or the current through it.

36. (b) C discharges through both resistance in series.

37. (d) Impedence of a capacitor is $X_C = 1/\omega C$

$$X_C = \frac{1}{2\pi fC} = \frac{1}{2\pi \times 50 \times 2 \times 10^{-6}} = \frac{5000}{\pi}.$$

38. (c)

39. (a) $N_P = 400, N_S = 2000$ and $V_S = 1000$ V.

$$\frac{V_P}{V_S} = \frac{N_P}{N_S} \text{ of, } V_P = \frac{V_S \times N_P}{N_S} = \frac{1000 \times 400}{2000} = 200\text{V}.$$

40. (d) The time constant of the circuit is

$$\tau = \frac{L}{R} = \frac{100 \times 10^{-3}}{50} = 2 \times 10^{-3} \text{ s} = 2 \text{ milli second.}$$

Current at time t is given by $I = I_0 e^{-t/\tau}$

where I_0 is the steady current. Therefore, time for I to fall to $I_0/2$ is

$$e^{-t/\tau} = \frac{1}{2} \text{ or, } e^{t/\tau} = 2, t = \tau\ell n(2) = 2\ell n(2) \text{ milli second.}$$

41. (b) Given equation, $e = 80 \sin 100\pi t$ …(i)

Standard equation of instantaneous voltage is given by $e = e_m \sin\omega t$ …(ii)

Compare (i) and (ii), we get $e_m = 80$ V

where e_m is the voltage amplitude.

Current amplitude $I_m = \frac{e_m}{Z}$ where Z = impendence

$= 80/20 = 4$ A.

$$I_{r.m.s} = \frac{4}{\sqrt{2}} = \frac{4\sqrt{2}}{2} = 2\sqrt{2} = 2.828 \text{ A.}$$

42. (d) As $E_p \mathbf{I}_p = P_i \quad \therefore \mathbf{I}_p = \frac{P_i}{E_p} = \frac{4000}{100} = 40$ A.

43. (d)

44. (b) $\frac{n_p}{n_s} = \frac{E_p}{E_s} = \frac{1}{25}$

$\therefore E_s = 25E_p$

But $E_S I_S = E_P I_P \Rightarrow I_P = \frac{E_S \times I_S}{E_p} \Rightarrow I_P = 50\text{A}$

45. (a) Transformation ratio $k = \frac{N_S}{N_P}$

$$\text{Since } \frac{V_S}{V_P} = \frac{N_S}{N_P} \quad \therefore V_S = \frac{N_S}{N_P} \times V_P$$

$$V_S = \frac{3}{2} \times 30 = 45\text{V}$$

46. (a) Given : Supply voltage (V_{ac}) = 200 V

Inductive reactance (X_L) = 50 W

Capacitive reactance (X_C) = 50 W

Ohmic resistance (R) = 10 W.

We know that impedance of the LCR circuit

$$(Z) = \sqrt{\{(X_L - X_C)^2 + R^2\}} = \sqrt{\{(50-50)^2 + (10)^2\}} = 10\Omega$$

47. (c) $I_0 = \dfrac{E_0}{R} = \dfrac{nBA\omega}{R}$

Given, $n = 1, B = 10^{-2}$ T,

$A = \pi(0.3)^2 m^2, R = \pi^2$

$f = (200/60)$ and $\omega = 2\pi(200/60)$

Substituting these values and solving, we get

$I_0 = 6 \times 10^{-3}$ A = 6mA

48. (b) As $V_L = V_C = 300\ V$, resonance will take place

$\therefore V_R = 220\ V$

Current, $I = \dfrac{220}{100} = 2.2\ A$

$\therefore$ reading of $V_3 = 220\ V$

and reading of $A = 2.2\ A$

49. (b) 50. (c)

EXERCISE - 3

Exemplar Questions

1. (b) As given that, $v = 50$ Hz, $I_{rms} = 5$A

$t = \dfrac{1}{300}$ s

As we know that $I_{rms} = \dfrac{I_0}{\sqrt{2}}$

I_0 = Peak value = $\sqrt{2}.I_{rms} = \sqrt{2} \times 5$

$I_0 = 5\sqrt{2}$A

at, $t = \dfrac{1}{300}$ sec, $I = I_0 \sin\omega t = 5\sqrt{2}\sin 2\pi vt$

$= 5\sqrt{2}\sin 2\pi \times 50 \times \dfrac{1}{300}$

$I = 5\sqrt{2}\sin\dfrac{\pi}{3} = 5\sqrt{2} \times \dfrac{\sqrt{3}}{2} = 5\sqrt{3/2}$ Amp

$\left(\therefore \sin\dfrac{\pi}{3} = \dfrac{\sqrt{3}}{2}\right)$

$I = \left(5\sqrt{\dfrac{3}{2}}\right)$ Amp

2. (c) To deliver maximum power from the generator to the load, total internal reactance must be equal to conjugate of total external reactance.

So, $X_{int} = X_{ext}$

$X_g = (X_L) = -X_L$

Hence, $X_L = -X_g$ (Reactance in external circuit)

3. (c) As we know that,

The voltmeter in AC reads rms values of voltage

$I_{rms} = \sqrt{2}I_0$ and $V_{rms} = \sqrt{2}v_0$

The voltmeter in AC circuit connected to AC mains reads mean value ($\langle v^2 \rangle$) and is calibrated in such a way that it gives rms value of $\langle v^2 \rangle$, which is multiplied by form factor $\sqrt{2}$ to give rms value V_{rms}.

4. (b) As we know that,

The resonant frequency in an L-C-R series circuit is

$$v_0 = \frac{1}{2\pi\sqrt{LC}}$$

So, to reduce v_0 either increase L or increase C.

To increase capacitance, another capacitor must be connect in parallel with the first capacitor.

5. (c) As we know that, Quality factor (Q) of an L-C-R circuit must be higher so Q is

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$

where R is resistance, L is inductance and C is capacitance of the circuit.

So, for higher Q, L must be large, and C and R should be low.

Hence, option (c) is verify.

6. (c) As given that,

$X_L = 1\Omega, R = 2\Omega, E_{rms} = 6V, P_{av} = ?$

The average power dissipated in the L, R, series circuit with AC source

Then $P_{av} = E_{rms} I_{rms} \cos\phi$ ... (i)

$$I_{rms} = \frac{I_0}{\sqrt{2}} = \frac{E_{rms}}{Z}$$

$$Z = \sqrt{R^2 + X_L^2} = \sqrt{4+1} = \sqrt{5}$$

$$I_{rms} = \frac{6}{\sqrt{5}} A$$

$$\cos\phi = \frac{R}{Z} = \frac{2}{\sqrt{5}}$$

By putting the value of I_{rms}, E_{rms}, $\cos\phi$ in equation (i), then,

$$P_{av} = 6 \times \frac{6}{\sqrt{5}} \times \frac{2}{\sqrt{5}} = \frac{72}{\sqrt{5}\sqrt{5}}$$

$$= \frac{72}{5} = 14.4 \text{ watt}$$

7. (a) As given that,

Secondary voltage (V_S) is :

$V_S = 24$ Volt

Power associated with secondary is :

$P_S = 12$ Watt

As we know that $P_S = V_S I_S$

$$I_S = \frac{P_s}{V_s} = \frac{12}{24} = \frac{1}{2} A = 0.5 \text{ Amp}$$

Peak value of the current in the secondary

$$I_0 = I_S\sqrt{2} = 0.5\sqrt{2}$$

$$= \frac{5}{10}\sqrt{2} \Rightarrow \left[I_0 = \frac{1}{\sqrt{2}} \text{Amp}\right]$$

NEET/AIPMT (2013-2017) Questions

8. (c) By inserting iron rod in the coil,
$L\uparrow z\uparrow I\downarrow$ so brightness $\downarrow$

9. (d) A transformer is essentially an *AC* device. *DC* source so no mutual induction between coils
$\Rightarrow E_2 = 0$ and $I_2 = 0$

10. (b) Efficiency $\eta = \frac{V_s I_s}{V_p I_p} \Rightarrow 0.9 = \frac{V_s(6)}{3\times 10^3}$

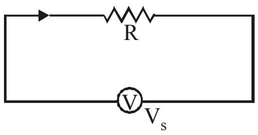
$\Rightarrow V_s = 450$ V

As $V_p I_p = 3000$ so

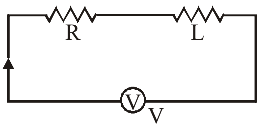
$$I_p = \frac{3000}{V_p} = \frac{3000}{200} A = 15A$$

11. (d)

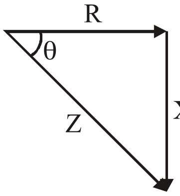
Pure resistor



L-R series circuit



Phasor diagram



$\cos\theta = \frac{R}{Z}$

Z = impedance

For pure resistor circuit, power

$$P = \frac{V^2}{R} \Rightarrow V^2 = PR$$

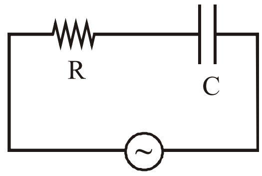
For L-R series circuit, power

$$P^1 = \frac{V^2}{Z}\cos\theta = \frac{V^2}{Z}\cdot\frac{R}{Z} = \frac{PR}{Z^2}\cdot R = P\left(\frac{R}{Z}\right)^2$$

12. (a) For series R – C circuit, capacitive reactance,

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

$X_c = 1/c\omega$



AC Source

$$\text{Current } i = \frac{V}{Z_c} = \frac{V}{\sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2}}$$

$$V_c = iX_c = \frac{V}{\sqrt{R^2 + \left(\frac{1}{C\omega}\right)^2}} \times \frac{1}{C\omega}$$

$$V_c = \frac{V}{\sqrt{(RC\omega)^2 + 1}}$$

If we fill a di-electric material like mica instead of air then capacitance $C\uparrow \Rightarrow V_c\downarrow$

So, $V_a > V_b$

13. (a) Given: L = 20 mH; C = 50 μF; R = 40 Ω

V = 10 sin 340 t

$$\therefore V_{runs} = \frac{10}{\sqrt{2}}$$

$$X_C = \frac{1}{\omega C} = \frac{1}{340\times 50\times 10^{-6}} = 58.8\,\Omega$$

$X_L = \omega L = 340 \times 20 \times 10^{-3} = 6.8\,\Omega$

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

$$= \sqrt{40^2 + (58.8 - 6.8)^2} = \sqrt{4304}\,\Omega$$

Power loss in A.C. circuit,

$$P = i_{rms}^2 R = \left(\frac{V_{rms}}{Z}\right)^2 R$$

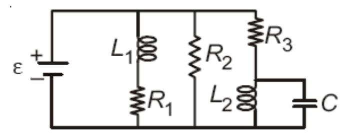
$$= \left(\frac{10/\sqrt{2}}{\sqrt{4304}}\right)^2 \times 40 = \frac{50\times 40}{4304} \simeq 0.51 \text{ W}$$

14. (b) As we know, power $P = V_{rms}\cdot I_{rms}\cos\phi$

as $\cos\phi = 0$ $(\because \phi = 90°)$

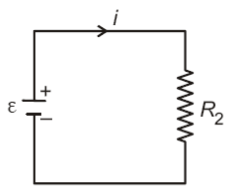
$\therefore$ Power consumed = 0 (in one complete cycle)

15. (b)



At t = 0, no current flows through R_1 and R_3

$\therefore$



Current through battery just after the switch closed is

$$i = \frac{\varepsilon}{R_2} = \frac{18}{9} = 2A$$