SYNOPSIS

Introduction : When a resistor is connected across the terminals of a battery, a current is established in the circuit. The current has a unique direction, it goes from the positive terminal to the negative terminal via the external resistor. The magnitude of the current also remains almost constant. This is called direct current (dc).

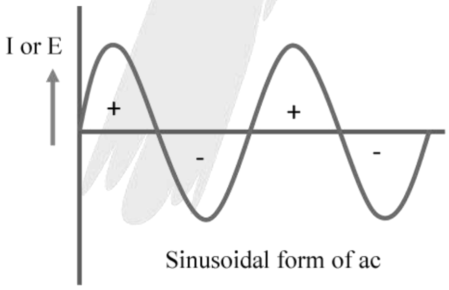
If the direction of the current in a resistor or in any other element changes alternatively, the current is called an alternating current (ac). In this chapter, we shall study the alternating current that varies sinusoidally with time.

ALTERNATING CURRENT (A.C.)

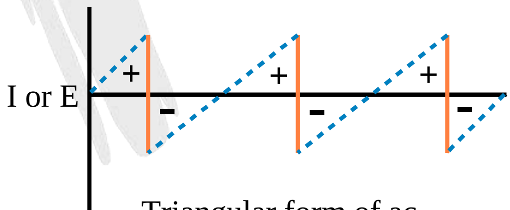
- Electric current, which keeps on changing in magnitude and direction periodically is defined as alternating current.
- It obeys Ohm's law and Joule's heating law. It is produced using the principle of electromagnetic induction.
- Graphical representations for alternating quantities can be represented in the form of the following graphs.

ALTERNATING VOLTAGE (A.V)

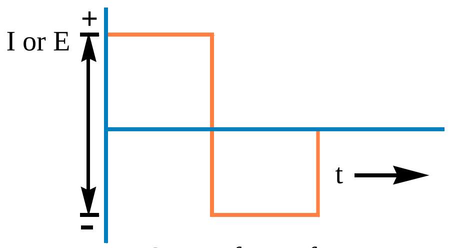
- The voltage, which changes in magnitude and direction with respect to time is defined as alternating voltage.
- The alternating voltage in general use is sinusoidal voltage. It is produced by rotating a coil in a uniform magnetic field with uniform angular velocity.



Sinusoidal form of ac



Triangular form of ac



Square form of ac

ADVANTAGES OF ALTERNATING CURRENT OVER DIRECT CURRENT

- The cost of generation of ac is less than that of dc.
- ac can be conveniently converted into dc with the help of rectifiers.
- By supplying ac at high voltages, we can minimize transmission losses or line losses.
- ac is available in a wide range of voltages. These voltages can be easily stepped up or stepped down with the help of transformers.

DISADVANTAGES OF ALTERNATING CURRENT OVER DIRECT CURRENT

- ac is more dangerous than dc.
- ac is transmitted more by the surface of the conductor. This is called skin effect. Due to this reason that several strands of thin insulated wire, instead of a single thick wire, need be used.
- For electrorefining, electro – typing electroplating, only dc can be used but not ac.

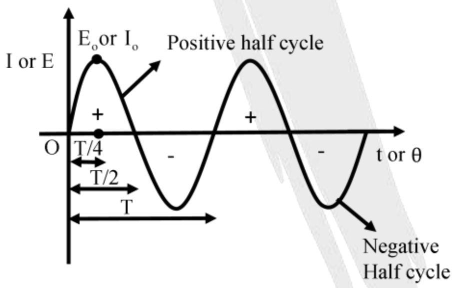
INSTANTANEOUS VALUE OF CURRENT OR VOLTAGE (I or E)

- The value of current or voltage in an ac circuit at any instant of time is called its instantaneous value.
- Instantaneous current,

  $I = I_0 \sin \omega t$ or $I = I_0 \sin(\omega t + \phi)$
- Instantaneous voltage,

  $E = E_0 \sin \omega t$ or $E = E_0 \sin(\omega t + \phi)$

  Where $(\omega t + \phi)$ is called phase



AMPLITUDE OF A.C. (PEAK VALUE) (I_0) or (I_m) :

It is the maximum value of A.C.

The value of A.C. becomes maximum twice in one cycle

.Note : Average value of a function $F(t)$ over a period of T is given by

$$< F(T) >= F_{avg} = \frac{\int_0^T F(t)\,dt}{\int_0^T dt} = \frac{1}{T}\int_0^T F(t)\,dt$$

Eg :- $< \sin^2 \omega t >= \frac{1}{2} : < \cos^2 \omega t >= \frac{1}{2} < \sin 2\omega t >= 0; < \cos 2\omega t >= 0$

AVERAGE VALUE OF A.C. < I >

- The value of current at any instant 't' is given by $I = I_0 \sin \omega t$.
- The average value of a sinusoidal wave over one complete cycle is given by

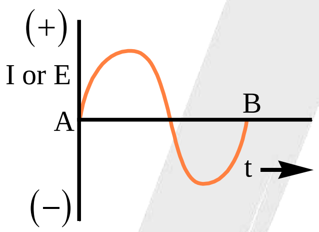
$$I_{avg} = \frac{\int_0^T I \cdot dt}{\int_0^T dt} = \frac{\int_0^T I_0 \sin \omega t \cdot dt}{\int_0^T dt} = 0$$

For half cycle :

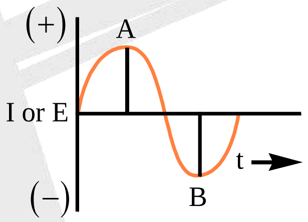
$$< I > = \frac{\int_0^{T/2} dt}{\int_0^{T/2} dt} = \frac{\int_0^{T/2} I_0 \sin \omega t\, dt}{\int_0^{T/2} dt} = \frac{2I_0}{\pi} = 0.636\, I_0 = I_{avg} = 63.7\% \text{ of } I_0$$

- Similarly $E_{avg} = \dfrac{2E_0}{\pi} = 0.637\, E_0 = 63.7\%\, E_0$

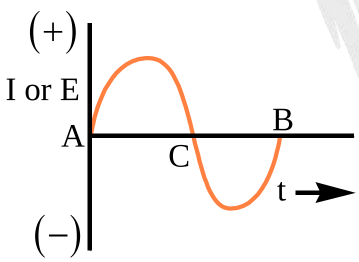
Note :

a) 

Between A and B,
$I_{avg} = 0$
$E_{avg} = 0$

b) 

Between A and B,
$I_{avg} = 0$
$E_{avg} = 0$

c) 

Between A and C
or
C and B
$I_{avg} \neq 0$
$E_{avg} \neq 0$

FREQUENCY OF A.C. (f)

- It is the number of cycles completed by A.C. in one second.

TIME PERIOD OF A.C. (T)

- It is the time taken by A.C. to complete one cycle. $f = \dfrac{1}{T}$

MEAN SQUARE VALUE OF A.C. $< I^2 >$

- $< I^2 > = \dfrac{I_0^2}{2}$

R.M.S. VALUE (I_{rms}) or EFFECTIVE VALUE (I) or VIRTUAL VALUE OF A.C.

It is the square root of the average of squares of all the instantaneous values of current over one complete cycle.

$$I_{rms}^2 = \frac{\int_0^T I^2 \cdot dt}{\int_0^T dt} = \frac{\int_0^T I_0^2 \cdot \sin^2 \omega t \cdot dt}{T} = \frac{I_0^2}{T}\int_0^T \left[\frac{1-\cos 2\omega t}{2}\right] dt = \frac{I_0^2}{2T}\left[t - \frac{\sin 2\omega t}{2\omega}\right]_0^T$$

$$= \frac{I_0^2}{2} \; ; \; \therefore \; I_{rms} = \frac{I_0}{\sqrt{2}} = 0.707\, I_0$$

- It is equal to that direct current which produces same heating in a resistance as is produced by the A.C. in same resistance during same time.

MEAN SQUARE VALUE OF A.C. $< I^2 >$

- $< I^2 > = \dfrac{I_0^2}{2}$

FORM FACTOR

$$\text{Form factor} = \frac{\text{rms value}}{\text{average value over half cycle}}$$

$$\text{Form factor} = \frac{I_{rms}}{I_{avg}} = \frac{E_{rms}}{E_{avg}}$$

We know that $I_{rms} = \dfrac{I_0}{\sqrt{2}}$ and $I_{ave} = \dfrac{2I_0}{\pi}$

$$\therefore \text{Form factor} = \frac{I_0}{\sqrt{2}} \times \frac{\pi}{2I_0} = \frac{\pi}{2\sqrt{2}} = 1.11$$

Note :

- ac ammeter and voltmeter read the r.m.s value i.e., effective value of alternating current and voltage respectively.
- ac can be measured by using hot wire ammeters or hot wire voltmeters because the heat generated is independent of the direction of current.
- ac produces the same heating effects as that of dc of magnitude $i = i_{rms}$
- ac is more dangerous than dc of same voltage. 100V ac means $E_{rms} = 100\,V$, $E_0 = 100\sqrt{2}\,V$

  100V dc is equivalent to E_{rms}
- ac can be produced by the principle of electromagnetic induction.

POWER IN AC CIRCUITS :

In dc circuits power is given by P = VI. But in ac circuits, since there is some phase angle between voltage and current, therefore power is defined as the product of voltage and that component of the current which is in phase with the voltage.

Thus $P = EI\cos\phi$, where E and I are r.m.s. values of voltage and current.

Power factor : The quantity $\cos\phi$ is called power factor.

(a) Instantaneous power : Suppose in a circuit $E = E_0 \sin\omega t$ and $I = I_0 \sin(\omega t + \phi)$ then

$$P_{\text{instantaneous}} = EI = E_0 I_0 \sin\omega t \sin(\omega t + \phi)$$

(b) Average power (True power) : The average of instantaneous power in an ac circuit over a full cycle is called average power.

Its unit is watt i.e.

$$P_{avg} = \frac{W}{t} = \frac{\int_0^T P \cdot dt}{\int_0^T dt} = \frac{\int_0^T P \cdot dt}{T} \ ; \ W = \int_0^T P \cdot dt$$

$$W = E_0 I_0 \cos\phi \int_0^T \sin^2 \omega t\, dt + \frac{E_0 I_0}{2} \sin\phi \int_0^T \sin 2\omega t\, dt$$

$$W = E_0 I_0 \cos\phi \times \frac{T}{2}$$

Average power over complete cycle, $P_{avg} = \frac{W}{T} = \frac{E_0 I_0}{2} \cos\phi$

$$= \frac{E_0}{\sqrt{2}} \frac{I_0}{\sqrt{2}} \cos\phi = E_{rms} I_{rms} \cos\phi$$

(c) Apparent or virtual power: The product of apparent voltage and apparent current in an electric circuit is called apparent power. This is always positive.

$$P_{app} = E_{rms} I_{rms} = \frac{E_0 I_0}{2}$$

- **RESISTANCE (R)** It is the opposition offered by a conductor to the flow of direct current.
- **IMPEDANCE (Z)** It is the opposition offered by a conductor to the flow of alternating current.

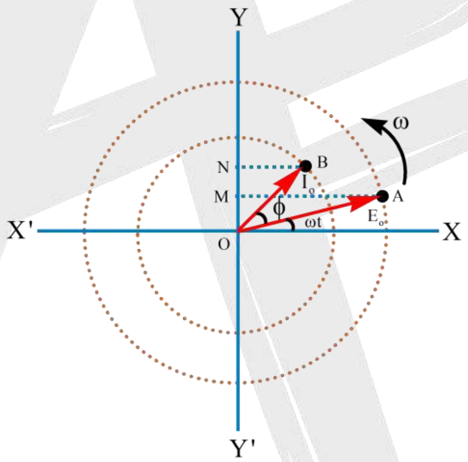
$$Z = \frac{|\text{alternating emf}|}{|\text{alternating current}|} = \frac{\text{peak value of alternating voltage}}{\text{peak value of alternating current}}$$

$$= \frac{\text{RMS value of alternating voltage}}{\text{RMS value of alternating current}}$$

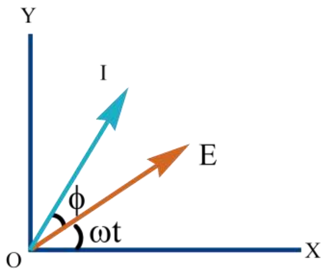
- ADMITTANCE (Y): Reciprocal of impedance of a circuit is called admittance of the circuit.

  Admittance (Y) $= \frac{1}{Z}$

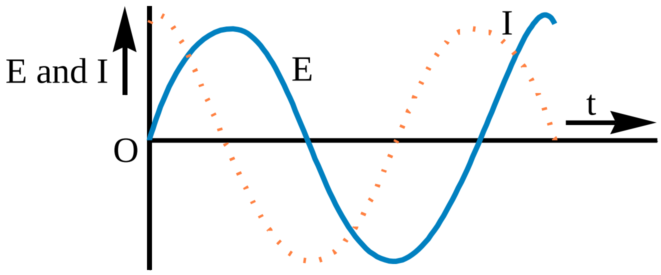
  S.I. Unit : ohm $^{-1}$ i.e. mho or siemen.
- PHASE : The physical quantity which represents both the instantaneous value and direction of A.C. at any instant is called its phase.
- It is dimensionless quantity and its unit is Radian
- Phase Difference : The diffrence between the phases of current and voltage is called Phase difference.
- If alternating emf and current are $E = E_0 \sin(\omega t + \phi_1)$ and $i = i_0 \sin(\omega t + \phi_2)$ then phase difference is $\phi = \phi_1 - \phi_2$
- The quantity that varies sinusoidally with time and can be represented as projection of a rotating vector, is called as phasor.
- A diagram, representing alternating emf and current (of same frequency) as rotating vectors (Phasors) with phase angle between them is called as phasor diagram.



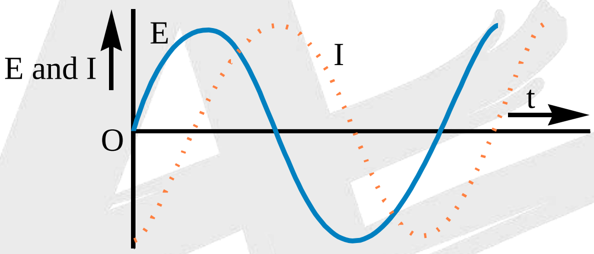
- In the above figure, $\overline{OA}$ and $\overline{OB}$ represent two rotating vectors having magnitudes E_0 and I_0 in anti - clockwise direction with same angular velocity $'\omega'$.
- OM and ON are the projections of $\overline{OA}$ and $\overline{OB}$ on Y-axis respectively.
- OM = E and ON = I, represent the instantaneous values of alternating emf and current.
- $\boxed{BOA} = \varphi$ represents the phase angle by which current I_0 leads the alternating emf E_0.
- The phasor diagram, in a simple representation is



Note: If e.m.f (or voltage) in A.C. is $E = E_0 \sin\omega t$ and the current $I = I_0 \sin(\omega t + \varphi)$ where phase difference φ is positive if current leads, negative if current lags and zero if current is inphase with the emf (or voltage).



- instantaneous emf is $E = E_0 \sin\omega t$
- instantaneous current $I = I_0 \sin(\omega t + \phi)$ where $\left[\phi = \frac{\pi}{2}\right]$; Current leads emf by $\frac{\pi}{2}$

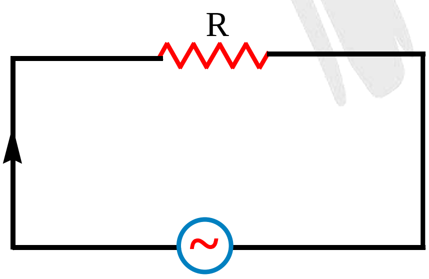


$E = E_0 \sin\omega t$; $I = I_0 \sin(\omega t - \phi)$ where $\phi = \frac{\pi}{2}$

- Current lags emf by $\frac{\pi}{2}$ or emf leads current by $\frac{\pi}{2}$

A.C THROUGH A RESISTOR

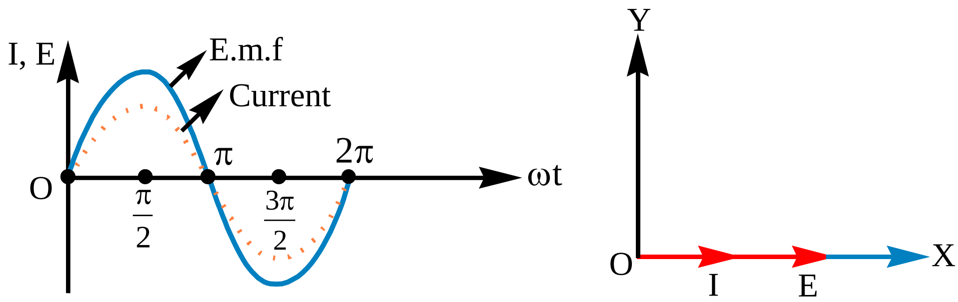
- A pure resistor of resistance R is connected across an alternating source of emf E



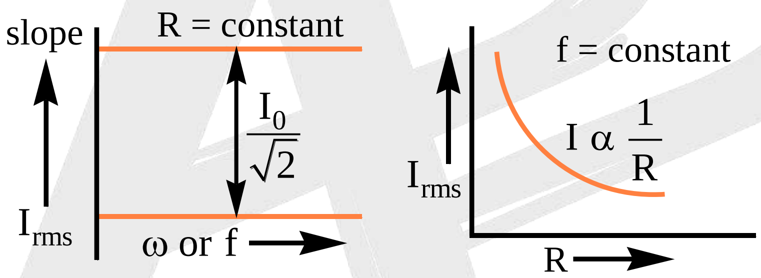
$E = E_0 \sin\omega t$

- The instantaneous value of alternating emf is $E = E_0 \sin\omega t$
- The instantaneous value of alternating current is $I = \frac{E}{R} = \frac{E_0}{R}(\sin\omega t) = I_0 \sin\omega t$
- Peak value of current, $I_0 = \frac{E_0}{R}$

- **Phasor diagrams :**



- emf and current will be in phase $(\Delta\phi = 0°)$
- emf and current have same frequency
- Peak emf is more than peak current
- The value of impedance (Z) is equal to R and reactance (X) is zero
- Apart from instantaneous value, current in the circuit is independent of frequency and decreases with increase in R (similar to that in dc circuits).

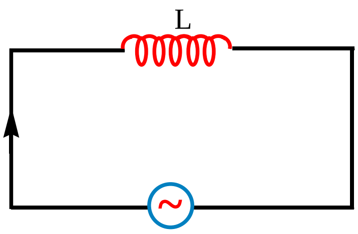


POWER

- power factor $\cos\phi = \cos 0° = 1$
- Instantaneous power $P_i = E_0 I_0 \sin^2 \omega t$
- Average power over time 'T' sec $= P_{avg} = E_{rms} I_{rms} \cos\phi = E_{rms} \cdot I_{rms} = \frac{E_{rms}^2}{R}$

A.C THROUGH AN INDUCTOR

- A pure inductor of inductance L is connected across an alternating source of emf E



$E = E_0 \sin \omega t$

- The instantaneous value of alternating emf is $E = E_0 \sin \omega t$ (A)

- The induced emf across the inductor $=-L\cdot\frac{dI}{dt}$ which opposes the growth of current in the circuit. As there is no potential drop across the circuit, so $E+\left(-L\cdot\frac{dI}{dt}\right)=0$ or $L\cdot\frac{dI}{dt}=E$

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

$$I=-\frac{E_0}{L_0}\cos\omega t=I_0\sin\left(\omega t-\frac{\pi}{2}\right) \quad (B)$$

- The instantaneous value of alternating current is

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

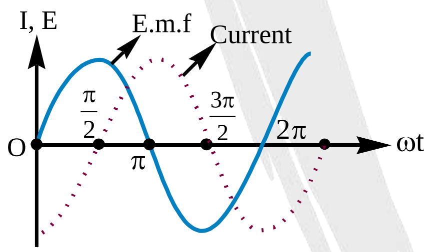
Where Peak value of current,

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

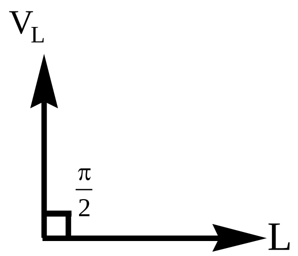
- From equation 1 & 2

Phase difference between alternating voltage and current is $\frac{\pi}{2}$

- The alternating current lags behind the emf by a phase angle of $\frac{\pi}{2}$



- Phasor diagram

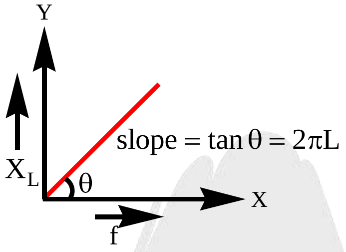


INDUCTIVE REACTANCE (X_L)

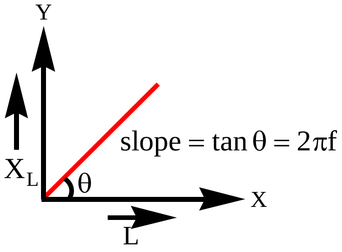
- The opposition offered by an inductor to the flow of ac is called an inductive reactance.
- The quantity ωL is analogous to resistance and is called reactance of inductor represented by X_L.

- It allows D.C. but offers finite impedance to the flow of A.C.
- Its value depends on L and f.
- Inductance not only causes the current to lag behind emf but it also limits the magnitude of current in the circuit.
- $I_0 = \frac{E_0}{\omega L} \Rightarrow \omega L = \frac{E_0}{I_0} = X_L$

  $\therefore\ X_L = \omega L = 2\pi f L \Rightarrow X_L \alpha f;$



$X_L - f$ curve



$X_L - L$ curve

- For dc, $f = 0 \quad \therefore X_L = 0$

  For ac, high frequencies, $X_L = \infty$

  $\therefore$ dc can flow easily through inductor.
- Inductive reactance in terms of RMS value is $X_L = \omega L = \frac{E_{rms}}{I_{rms}}$

Power supplied to inductor

- The instantaneous power supplied to the inductor is $P_L = iv = i_0 \sin\left(\omega t - \frac{\pi}{2}\right) \times v_0 \sin(\omega t)$

  $= -i_0 v_0 \cos(\omega t)\sin(\omega t) = -\frac{i_0 v_0}{2}\sin(2\omega t)$

  So, the average power over a complete cycle is $P_{avg} = E_{rms}.I_{rms}\cos\phi = 0 \quad (\because\ \Delta\phi = 90°)$

  $= -\frac{i_0 v_0}{2}\langle \sin(2\omega t)\rangle = 0$

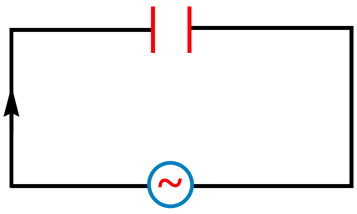
  Since the average of $\sin(2\omega t)$ over a complete cycle is zero.

  Thus, the average power supplied to an inductor over one complete cycle is zero.

A.C THROUGH A CAPACITOR

- When an alternating emf is applied to a capacitor, then alternating current is constituted in the circuit. Due to this, charge on the plates and electric field between the plates of capacitor vary sinusoidally with time.

- At any instant the potential difference between the plates of a capacitor is equal to applied emf at that time.



- A capacitor of capacity C is connected across an alternating source of emf E.
- The instantaneous value of alternating emf is $E = E_0 \sin \omega t$ (A)
- Let q be the charge on the capacitor at any instant.

  According to kirchhoff's loop rule

$$E - \frac{q}{C} = 0 \Rightarrow q = CE_0 \sin \omega t = q = CE = CE_0 \sin \omega t =$$

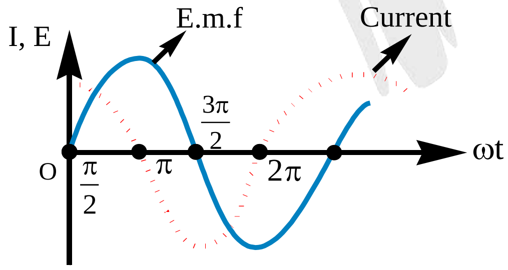
$$I = \frac{dq}{dt} = C\omega E_0 \cos \omega t = I_0 \sin\left(\omega t + \frac{\pi}{2}\right) \quad \text{(B)}$$

- The instantaneous value of alternating current is $I = I_0 \sin\left(\omega t + \frac{\pi}{2}\right)$ (B)

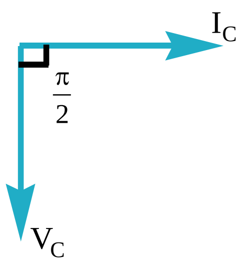
  Where peak value of current, $I_0 = \frac{E_0}{\left(\frac{1}{\omega C}\right)}$

- From equation 1 & 2

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



PHASOR DIAGRAM

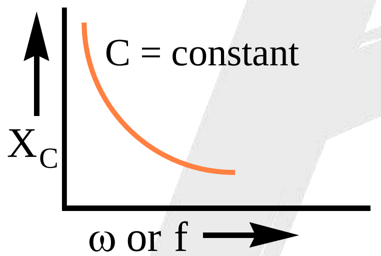


CAPACITIVE REACTANCE (X_C)

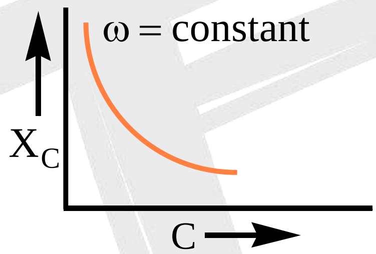
- The resistance offered by a capacitor to the flow of ac is called capacitive reactance.
- The quantity $\frac{1}{\omega C}$ is analogous to resistance and is called reactance of capacitor represented by X_C

$$I_0 = \frac{E_0}{\left(\frac{1}{\omega C}\right)} \Rightarrow X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C} = \frac{E_0}{I_0} = \frac{E_{rms}}{I_{rms}}$$

- It is the part of impedance in which A.C. leads the A.V. by a phase angle of $\frac{\pi}{2}$.
- Its value is $X_C = \frac{1}{\omega C} = \frac{1}{2\pi f C}$.
- Its value depends on C and f.
- It bypasses A.C. but blocks D.C.
- It is produced due to pure capacitor or induced charge.



$X_C - f$ curve



$X_C - C$ curve

Note : Resistance, Impedance and Reactance have the same units and Dimensional Formulae.

i.e. SI unit is ohm; Dimensional Formula is $\left(ML^2T^{-3}A^{-2}\right)$

Power supplied to capacitor :

- The instantaneous power supplied to the capacitor is $P_c = iv = i_0 \cos(\omega t) v_0 \sin(\omega t)$

$$= i_0 v_0 \cos(\omega t)\sin(\omega t); \; = \frac{i_0 v_0}{2}\sin(2\omega t)$$

So, the average power over a complete cycle is zero

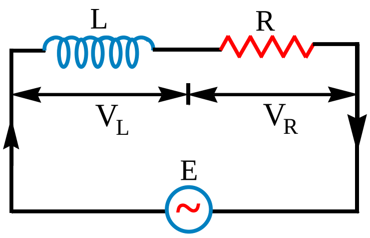
Since $< \sin(2\omega t) > = 0$ over a complete cycle.

$$P_{avg} = V_{rms} \cdot I_{rms} \cos\phi = V_{rms} \cdot I_{rms} \cos 90^\circ = 0$$

$\therefore$ no power is consumed in a purely capacitive circuit.

A.C THROUGH LR SERIES CIRCUIT

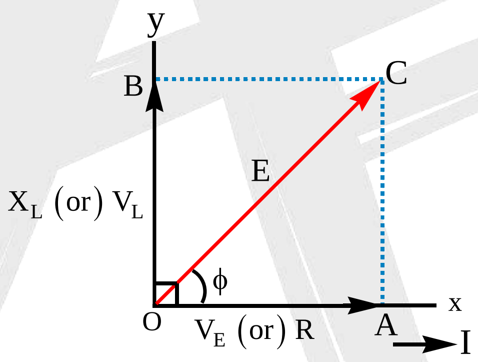
- LR circuit consists of a resistor of resistance R and an inductor of inductance L in series with a source of alternating emf
- The instantaneous value of alternating emf is $E = E_0 \sin \omega t$



- The potential difference across the inductor is given by $V_L = IX_L$ (A)
- The potential difference across the resistor, $V_R = IR$ (B)

Current I lags the voltage V_L by an angle of $\frac{\pi}{2}$,

Therefore, the resultant of V_L and V_R is $OC = \sqrt{OA^2 + OB^2}$ or $E = \sqrt{V_R^2 + V_L^2}$



Using equations (A) and (B), we get $E = \sqrt{I^2R^2 + I^2X_L^2} = I\sqrt{R^2 + X_L^2}$ where $X_L = \omega L$ is the inductive reactance.

or $I = \dfrac{E}{\sqrt{R^2 + X_L^2}}$ (C)

$I = \dfrac{E}{Z_{LR}}$; $Z_{lR} = \sqrt{R^2 + X_L^2} = \sqrt{R^2 + L^2\omega^2}$

The effective opposition offered by LR circuit to ac is called the impedance of LR circuit.

Let ϕ be the angle made by the resultant of V_L and V_R with the X-axis, then from figure, we get $\tan \phi = \dfrac{AC}{OA} = \dfrac{OB}{OA} = \dfrac{V_L}{V_R} = \dfrac{IX_L}{IR}$ or $\tan \phi = \dfrac{X_L}{R} = \dfrac{\omega L}{R}$

Note : In series LR circuit, emf leads the current or the current is said to lag behind the emf by an angle ϕ

$\therefore$ Current in L-R series circuit is given by $I = \dfrac{E}{Z_{LR}} = \dfrac{E_o}{Z_{LR}}\sin(\omega t - \phi)$ or $I = I_0 \sin(\omega t - \phi)$

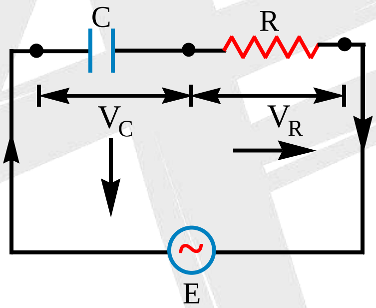
Note :

- $Z_{LR} = \sqrt{R^2 + L^2\omega^2} = \sqrt{R^2 + L^2 \times 4\pi^2 f^2}$.

  Thus Z_{LR} increases with the frequency of ac, so Z_{LR} is low for lower frequency of ac and high for higher frequency of ac
- The phase angle between voltage and current increases with the increase in the frequency of ac

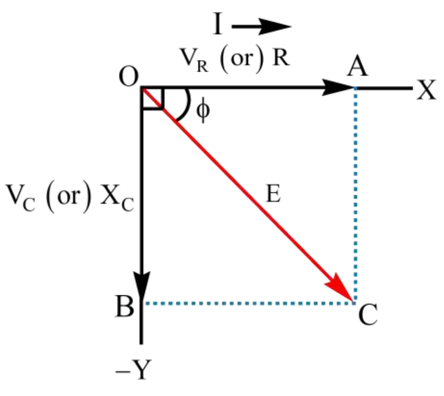
C-R SERIES CIRCUIT WITH ALTERNATING VOLTAGE

- Let an alternating source of emf $E = E_0 \sin\omega t$ be connected to a series combination of a pure capacitor of capacitance (C) and a resistor of resistance (R) as shown in figure.



- Let I be the r.m.s value of current flowing through the circuit. The potential difference across the capacitor, $V_C = IX_C$ (i)
- The current leads emf by an angle $\dfrac{\pi}{2}$ when ac flows through the capacitor.
- The potential difference across the resistor, $V_R = IR$ (ii)
- The emf and current are in phase when ac flows through resistor.

Phasor diagram.



- In figure V_C is represented by OB along negative Y-axis and the current I is represented along X-axis.
- V_R is represnted by OA along X-axis.
- The resultant potential difference of V_C and V_R is represented by OC.
- Also, the emf and current are in phase when ac flows through the resistor. So, V_R is represented by OA along X-axis.
- Therefore, the resultant potential difference of V_C and V_R is represented by OC and is given by $OC = \sqrt{OA^2 + OB^2}$ or $E = \sqrt{V_R^2 + V_C^2}$

Using equation (i) and (ii),

we get $E = \sqrt{I^2R^2 + I^2X_C^2} = I\sqrt{R^2 + X_C^2}$ or $I = \dfrac{E}{\sqrt{R^2 + X_C^2}} = \dfrac{E}{Z_{CR}}$

From the above equations of I and E, we have $Z_{CR} = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \left(\dfrac{1}{C\omega}\right)^2}$

Where Z_{CR} is the effective opposition offered by the CR circuit to ac, which is the impedance of CR circuit.

Let ϕ be the angle made by E with X-axis $\tan\phi = \dfrac{AC}{OA} = \dfrac{V_C}{V_R} = \dfrac{IX_C}{IR}$ or $\tan\phi = \dfrac{X_C}{R} = \dfrac{I}{C\omega R}$

In series CR circuit, emf lags behind the current or in other words, the current is said to lead the emf by an angle ϕ given by the above equation.

$\therefore$ Current in C-R series circuit is given by $I = \dfrac{E}{Z_{CR}} = \dfrac{E_0}{Z_{CR}}\sin(\omega t + \phi)$ or $I = I_0 \cdot \sin(\omega t + \phi)$

Note :

- The resultant potential difference of V_C and V_R is represented by OC.
- Impedance of CR circuit.

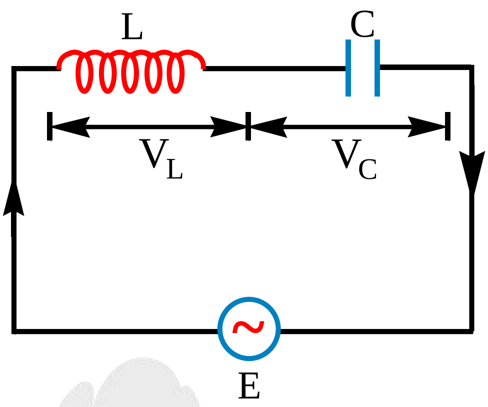
$$Z_{CR} = \sqrt{R^2 + X_C^2} = \sqrt{R^2 + \frac{1}{C^2\omega^2}} = \sqrt{R^2 + \frac{1}{4\pi^2 f^2 C^2}}$$

- For very high frequency (f) of ac. $Z \to R$ and for very low frequency of ac, $Z \to \infty$
- Phase angle between voltage and current is given by $\tan\phi = \dfrac{1}{C\omega R} = \dfrac{1}{2\pi f CR}$

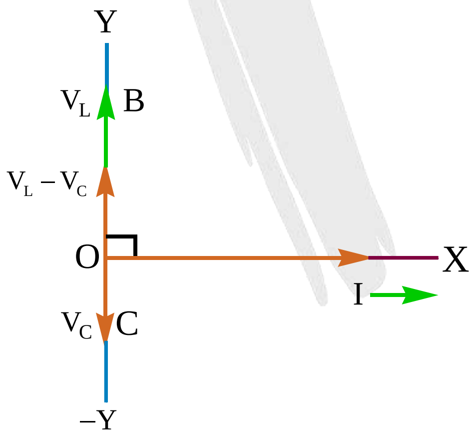
As f increases, phase angle ϕ decreases.

L – C SERIES CIRCUIT WITH ALTERNATING VOLTAGE

- Let an alternating source of emf $E = E_0 \sin \omega t$ be connected to the series combiation of a pure capacitor of capacitance (C) and an inductor of inductance (L) as shown in figure.



- Let I be the rms value of current flowing in the circuit
- The P.D across 'L' is $V_L = I \cdot X_L$
- The current I lags V_L by an angle $\frac{\pi}{2}$.
- The P.D across capacitance is $V_C = I \cdot X_C$.
- The current I leads V_C by an angle $\frac{\pi}{2}$.
- The voltage V_L and V_C are represented by OB and OC respectively.



The resultant P.D of V_L and V_C is $V = V_L - V_C = I(X_L - X_C) = I\left[\omega L - \frac{1}{\omega C}\right] = IZ_{LC}$

- From the above equation, Impedance of L-C circuit is $Z_{LC} = \left[(\omega L) - \frac{1}{\omega C}\right]$
- If $\omega L > \frac{1}{\omega C}$ i.e, $X_L > X_C$ then $V_L > V_C$ potential difference $V = V_L - V_C$.

- Now current lags behind voltage by $\frac{\pi}{2}$.
- If $\omega L < \frac{1}{\omega C}$ then $V_L < V_C$ resultant potential difference $V = V_C - V_L$

  Now current leads emf by $\frac{\pi}{2}$.

  If $\omega L = \frac{1}{\omega C}$ then $Z = \omega L - \frac{1}{\omega C} = 0$

  Current $I = \frac{E}{Z} = \infty$

  In L-C, circuit, the phase difference between voltage and current is always $\frac{\pi}{2}$.

  Power factor $\cos\phi = \cos\frac{\pi}{2} = 0$.

  So, power consumed in L-C circuit is $P = V_{rms} \times I_{rms} \times \cos\phi = 0$

  $\therefore$ In L-C circuit no power is consumed.

Note :

- In L-C, circuit, the impedence $Z = \left|\omega L - \frac{1}{\omega C}\right|$ and current $I = \frac{E}{Z}$.

  So, the impedance and current varies with frequency.
- At a particular angular frequency, $\omega L = \frac{1}{\omega C}$ and current $I = \frac{E}{Z}$ becomes maximum (I_0) and resonance occurs.

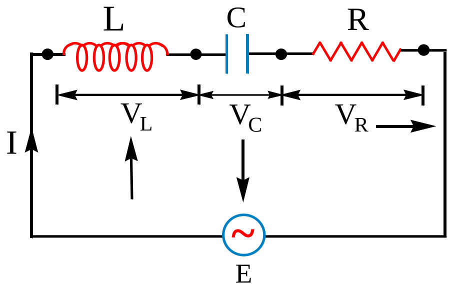
  At resonance $Z = 0$ and $I_0 = \frac{E_0}{Z} = \infty$.

  Resonant angular frequency $\omega_0 = \frac{1}{\sqrt{LC}}$

  Resonant frequency $f_0 = \frac{1}{2\pi\sqrt{LC}}$.

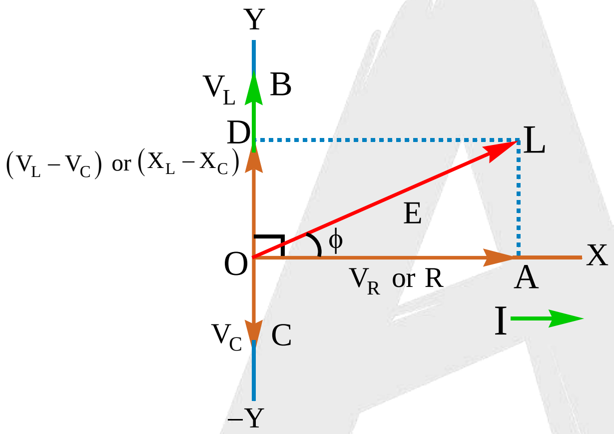
A.C Through LCR series circuit:

- A circuit containing pure inductor of inductance (L), pure capacitor of capacitance (C) and resistor of resistance (R), all joined in series, as shown in figure.
- Let E be the r.m.s value of the applied alternating emf to the LCR circuit.



- The potential difference across L, $V_L = IX_L$ ... (i)
- The potential difference across C, $V_C = IX_C$ ... (ii)
- The potential difference across R, $V_R = IR$ ... (iii)

Phasor Diagram:



- Since V_L and V_C are in opposite phase, so their resultant $(V_L - V_C)$ is represented by OD

  (Here $V_L > V_C$)
- The resultant of V_R and $(V_L - V_C)$ is given by OL.

  The magnitude of OL is given by

$$OL = \sqrt{(OA)^2 + (OD)^2} = \sqrt{V_R^2 + (V_L - V_C)^2}$$

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

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

$\therefore$ Impedance (Z) of LCR circuit is given by

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

$$\therefore I = \frac{E}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{E}{\sqrt{R^2 + \left(L\omega - \frac{1}{C\omega}\right)^2}}$$

- Let ϕ be the phase angle between E and I, then from Phasor diagram

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

$$\tan\phi = \frac{\left(L\omega - \frac{1}{C\omega}\right)}{R}$$ $\therefore$ Current L-C-R series circuit is given by

$$I = \frac{E}{Z} = \frac{E_0}{Z}\sin(\omega t \pm \phi) \text{ or } I = I_0.\sin(\omega t \pm \phi)$$

- If X_L and X_C are equal then $Z = R$ i.e., expression for pure resistance circuit.

  If $X_L = 0$ then $Z = \sqrt{R^2 + X_C^2}$ i.e., expression for series RC circuit

  Similarly, if $X_C = 0$ then $Z = \sqrt{R^2 + X_L^2}$ i.e., expression for series RL circuit.

  Also, $\cos\phi = \frac{R}{Z}$

Case (i):

If $X_L > X_C$ then ϕ is positive. In this case the current lags behind the emf by a phase angle $\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$

Case (ii):

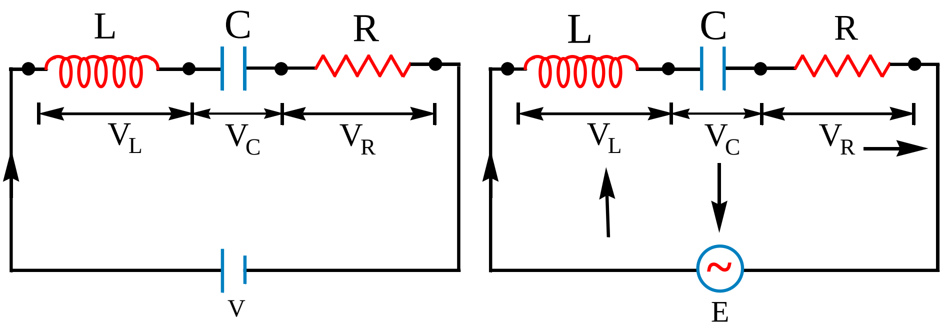
If $X_L < X_C$ then ϕ is negative. In this case the current lags behind the emf by a phase angle $\phi = \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$

Case (iii):

If $X_L = X_C$ then ϕ is 0. In this case the current and emf are in phase.

- If $X_L > X_C$, then the circuit will be inductive
- If $X_L < X_C$, then the circuit will be capacitive
- If $X_L = X_C$, then the circuit will be purely resistive
- The LCR circuit can be inductive or capacitive or purely resistive depending on the value of frequency of alternating source of emf.
- At some frequency of alternating source, $X_L > X_C$ and for some other frequency, $X_L < X_C$. There exists a particular value of frequency where $X_L = X_C$ (This situation is explained under resonance of LCR series circuit)

Note: Relation between applied pd & pd's across the components in L-C-R circuit



For 'dc'

$V = V_R + V_L + V_C$

(Only before steady state)

For 'ac'

$V = IZ$

$= I\sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(IR)^2 + (IX_L - IX_C)^2}$

$V^2 = V_R^2 + (V_L - V_C)^2$

Where $V_L = IX_L = I\omega L$

$V_C = IX_C = \dfrac{1}{\omega C}$

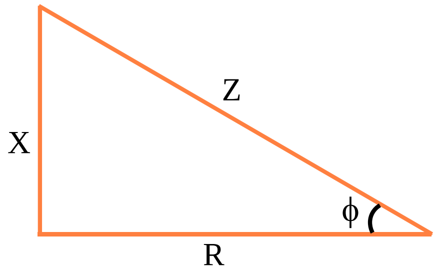
$V_R = IR$

Note: Rules to be followed for various combinations of ac circuits

- Compute effective resistance of the circuit as R
- Calculate the net reactance of the circuit as $X = X_L - X_C$

  where $X_L = \omega L,\ X_C = \dfrac{1}{\omega C}$
- Resistance offered by all the circuit elements to the flow of ac is impedance (Z)

  $\therefore Z = \sqrt{R^2 + X^2} = \sqrt{R^2 + (X_L - X_C)^2}$
- Calculate the peak value of current as $I_0 = \dfrac{E_0}{Z}$
- The phase difference between emf & current can be known by constructing an ac triangle as



$\tan\phi = \dfrac{X}{R}$

$\sin\phi = \dfrac{X}{Z}$

$\cos\phi = \dfrac{R}{Z}$

Resonant frequency:

Electrical Resonance Series L-C-R Circuit:

Electrical resonance is said to take place in a series LCR circuit, when the circuit allows maximum current for a given frequency of alternating supply, at which capacitive reactance becomes equal to the inductive reactance.

The current (I) in a series LCR circuit is given by

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

From the above equation (i), it is clear that current I will be maximum if the impedance (Z) of the circuit is minimum.

At low frequencies, $L\omega = L \times 2\pi f$ is very small and $\frac{1}{C\omega} = \frac{1}{C \times 2\pi f}$ is very large.

At high frequencies, $L\omega$ is very large and $\frac{1}{C\omega}$ is very small.

For a particular frequency (f_0),

$L\omega = \frac{1}{C\omega}$ i.e., $X_L = X_C$ and the impedance (Z) of LCR circuit is minimum and is given by $Z = R$.

Therefore, at the particular frequency (f_0), the current in LCR circuit becomes maximum.

The frequency (f_0) is known as the **resonant frequency** and the phenomenon is called electrical resonance.

Again, for electrical resonance

$(X_L - X_C) = 0$. i.e., $X_L = X_C$

Or $L\omega = \frac{1}{C\omega} \Rightarrow \omega^2 = \frac{1}{LC}$

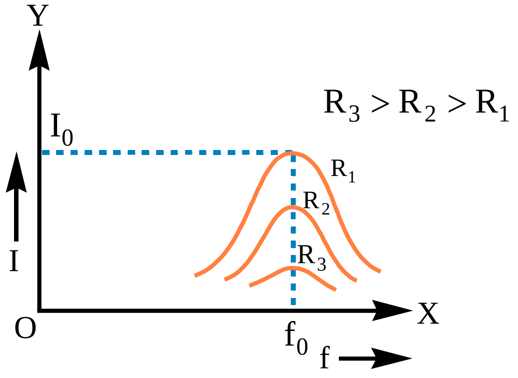
Or $\omega = \frac{1}{\sqrt{LC}} \Rightarrow (2\pi f_0) = \frac{1}{\sqrt{LC}}$

Or $f_0 = \frac{1}{2\pi\sqrt{LC}}$ .....(ii)

This is the value of resonant frequency.

The resonant frequency is independent of the resistance R in the circuit. However, the sharpness of resonance decreases with the increase in R.

Series LCR circuit is more selective when resistance of this circuit is small.



Note: Series LCR circuit at resonance admit maximum current at particular frequencies, so they can be used to tune the desired frequency or filter unwanted frequencies. They are used in transmitters and receivers of radio, television and telephone carrier equipment etc.

Resonance in L-C circuit:

At resonance,

(a) Net reactance $X = 0$

(b) $X_L = X_C$

(c) Impedance $Z = 0$

(d) peak value of current $I_0 = \frac{E_0}{Z} = \infty$

(e) Resonant frequency $f_0 = \frac{1}{2\pi\sqrt{LC}}$

(f) Voltage and current differ in phase by $\frac{\pi}{2}$

(g) power factor $\cos\phi = 0$

Resonance in L-C-R Circuit:

At resonance,

(a) Net reactance $X = 0$

(b) $X_L = X_C$

(c) Impedance $Z = R$ (minimum)

(d) Peak value of current $I_0 = \frac{E_0}{Z} = \frac{E_0}{R}$ (maximum but not infinity)

(e) Resonant frequency $f_0 = \frac{1}{2\pi\sqrt{LC}}$

(f) Voltage and current will be in phase

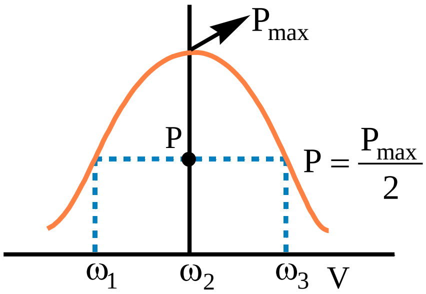
(g) power factor $\cos\phi = 1$

(h) Resonant frequency is independent of value of R

(i) A series L-C-R circuit behaves like a pure resistive circuit at resonance

Half power Frequencies and Band Width:

- The frequencies at which the power in the circuit is half of the maximum power (the power at resonance) are called half power frequencies.



Parameter	R-L circuit	R-C circuit	L-C circuit	L-C-R circuit
(A) Input emf	$E = E_0 \sin \omega t$	$E = E_0 \sin \omega t$	$E = E_0 \sin \omega t$	$E = E_0 \sin \omega t$
(B) Resulting current	$I = I_0 \sin(\omega t - \phi)$	$I = I_0 \sin(\omega t + \phi)$	$I = I_0 \sin\left(\omega t \pm \frac{\pi}{2}\right)$	$I = I_0 \sin(\omega t \pm \phi)$
(C) Resistance	R	R	0	R
(D) Net reactance	$X = X_L = \omega L$	$X = X_C = \frac{-1}{\omega C}$	$X = \omega L - \frac{1}{\omega C}$	$X = \omega L - \frac{1}{\omega C}$
(5) Impedance	$Z = \sqrt{R^2 + (\omega L)^2}$	$Z = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2}$	$Z = \sqrt{\left(\omega L - \frac{1}{\omega C}\right)^2}$	$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$
(6) Peak value of current	$I_0 = \frac{E_0}{Z}$	$I_0 = \frac{E_0}{Z}$	$I_0 = \frac{E_0}{Z}$	$I_0 = \frac{E_0}{Z}$
(7) Phase difference between E & I	$\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$	$\phi = \tan^{-1}\left(\frac{-1}{\omega RC}\right)$	$\phi = 90°$	$\phi = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$
(8) Lead/ lag	I lags E by ϕ	I lags E by ϕ	If $X_L > X_C$, I lags E by 90° If $X_L < X_C$, I leads E by 90° If $X_L = X_C$, E and I are in phase	If $X_L > X_C$, I lags E by ϕ If $X_L < X_C$, I leads E by ϕ If $X_L = X_C$, E and I are in phase

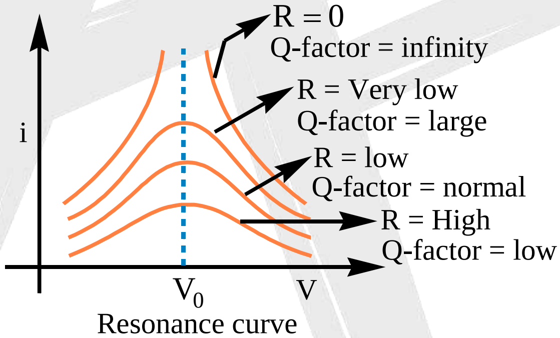
- The current in the circuit at half power frequencies (HPF) is $1/\sqrt{2}$ or 0.707 or 70.7% of maximum current (current at resonance).
- There are two half power frequencies

  $\omega_1 \rightarrow$ called lower half power frequency. At this frequency the circuit is capacitive.

  $\omega_3 \rightarrow$ called upper half power frequency. It is greater than ω_2. At this frequency the circuit is inductive.
- Band width $(\Delta\omega)$: The difference of half power frequencies ω_1 and ω_3 is called band width $(\Delta\omega)$ and $\Delta\omega = \omega_3 - \omega_1$
- For series resonant circuit it can be proved $(\Delta\omega = R/L)$

Quality Factor (Q – factor) of series Resonant circuit:

- The characteristic of a series resonant circuit is determined by the quality factor (Q – factor) of the circuit.
- It defines sharpness of i – v curve at resonance when Q – factor is large, the sharpness of resonance curve is more and vice-versa.



Resonance curve

- Q – factor is also defined as follows

$$Q - \text{factor} = 2\pi \times \frac{\text{Maximum energy stored}}{\text{Energy dissipation}} = \frac{2\pi}{T} \times \frac{\text{Maximum energy stored}}{\text{Mean Power dissipated}}$$

$$= \frac{\text{Resonant frequency}}{\text{Band width}} = \frac{\omega_0}{\Delta\omega} = Q - \text{factor} = \frac{V_L}{V_R} \text{ or } \frac{V_C}{V_R} = \frac{\omega_0 L}{R} \text{ or } \frac{1}{\omega_0 CR} \Rightarrow Q - \text{factor} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Wattless Current:

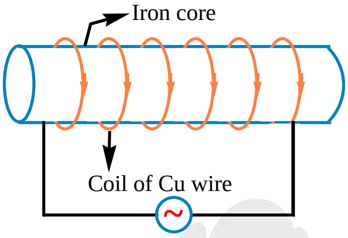
In an ac circuit, $R = 0 \Rightarrow \cos\phi = 0$ so $P_{av} = 0$, i.e., in resistanceless circuit the power consumed is zero, such a circuit is called the wattless circuit and the current flowing is called the wattless current.

Or

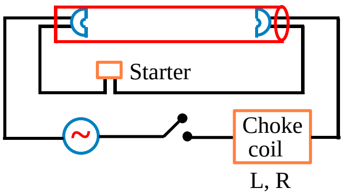
The component of current which does not contribute to the average power dissipation is called wattless current. Wattless current $= I_{rms} \sin\phi$

Choke Coil:

- Choke coil (or ballast) is a device having high inductance and negligible resistance
- It is used to control current in ac circuits and is used in fluorescent tubes
- The power loss in a circuit containing choke coil is least
- In a dc circuit current is reduced by means of a rheostat. This results in a loss of electrical energy I^2R per sec.



Choke coil

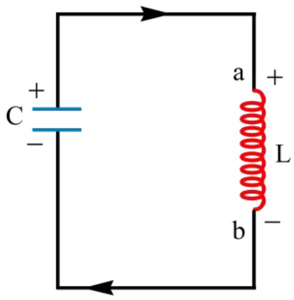


Application of choke coil

- It consists of a copper coil wound over a soft iron laminated core. This coil is put in series with the circuit in which current is to be reduced.
- Soft iron is used to improve inductance (L) of the circuit
- The inductive reactance or effective opposition of the choke coil is given by $X_L = \omega L = 2\pi \nu L$
- For an ideal choke coil $r = 0$, no electric energy is wasted, i.e., average power $P = 0$
- In actual practice choke coil is equivalent to a R – L circuit
- Choke coil for different frequencies are made by using different substances in their core
- For low frequency L should be large thus iron core choke coil is used. For high frequency ac circuit, L should be small, so air cored choke coil is used
- The choke coil can be only in ac circuits not in dc circuits, because for dc frequency $\nu = 0$. Hence $X_L = 2\pi \nu L = 0$
- Choke coil is based on the principle of wattless current
- The current in the circuit $I = \frac{E}{Z}$ with $Z = \sqrt{(R+r)^2 + (\omega L)^2}$
- The power loss in the choke $p_{av} = V_{rms} I_{rms} \cos\varphi \to 0$ as $\cos\varphi = \frac{r}{Z} = \frac{r}{\sqrt{r^2+\omega^2 L^2}} = \frac{r}{\omega L} \to 0$

LC Oscillations:

A capacitor (C) and an inductor (L) are connected as shown in the figure. Initially the charge on the capacitor is Q

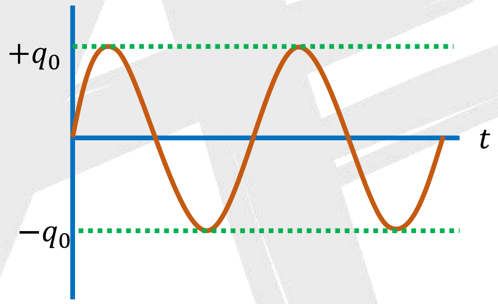


$\therefore$ Energy stored in the capacitor $U_E = \frac{Q^2}{2C}$

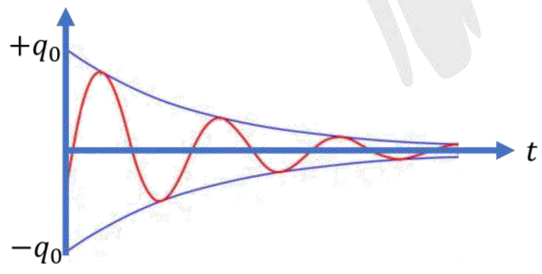
The energy stored in the inductor, $U_B = 0$

The capacitor now begins to discharge through the inductor and current begins to flow in the circuit. As the charge on the capacitor decreases, U_E decreases but the energy $U_B = \frac{1}{2}LI^2$ in the magnetic field of the inductor increases. Energy is thus transferred from capacitor to inductor. When the whole of the charge on the capacitor disappears, the total energy stored in the electric field in the capacitor gets converted into magnetic field energy in the inductor. At this stage, there is maximum current in the inductor. Energy now flows from inductor to the capacitor except that the capacitor is charged oppositely. This process of energy transfer continues at a definite frequency (ν). Energy is continuously shuttled back and forth between the electric field in the capacitor and the magnetic field in the inductor.

If no resistance is present in the LC circuit, the LC oscillation will continue infinitely as shown.



However in an actual LC circuit, some resistance is always present due to which energy is dissipated in the form of heat. So LC oscillation will not continue infinitely with same amplitude as shown.



Let q be the charge on the capacitor at any time t and $\frac{di}{dt}$ be the rate of change of current. Since no battery is connected in the circuit, $\frac{q}{c} - L.\frac{di}{dt} = 0$ but $i = -\frac{dq}{dt}$

From the above equations, we get $\frac{q}{C} + L\frac{d^2q}{dt^2} = 0 \Rightarrow \frac{d^2q}{dt^2} + \frac{1}{LC}q = 0$

The above equation is analogues to $\frac{d^2x}{dt^2}+\omega^2 x=0$ (differential equation of S.H.M)

Hence on comparing $\omega^2=\frac{1}{LC}\Rightarrow \omega=\frac{1}{\sqrt{LC}}=2\pi f=\frac{1}{\sqrt{LC}}\Rightarrow f=\frac{1}{2\pi\sqrt{LC}}$

The charge therefore oscillates with a frequency $f=\frac{1}{2\pi\sqrt{LC}}$ and varies sinusoidally with time.

Comparison of L-C oscillations with SHM:

The L-C oscillations can be compared to S.H.M of a block attached to spring

- In L-C oscillation $\omega_0=\frac{1}{\sqrt{LC}}$
- In mechanical oscillations $\omega_0=\sqrt{\frac{K}{m}}$ where K is the spring constant
- In L-C oscillations $\frac{1}{C}=\left(\frac{V}{q}\right)$ tells us the potential difference required to store a unit charge
- In a mechanical oscillation $K\left(=\frac{F}{x}\right)$ tells us the external force required to produce a unit displacement of mass
- In L-C oscillations current is the analogous quantity for velocity of the mass in mechanical oscillations
- In L-C oscillations energy stored in capacitor is analogous to potential energy in mechanical oscillations
- In L-C oscillations energy stored in inductor is analogous to kinetic energy of the mass in mechanical oscillations
- In L-C oscillations maximum charge on capacitor q_0 is analogous to amplitude in mechanical oscillations
- $\therefore$ As $V_{max}=A\omega$ is mechanical oscillations, $I_0=q_0\omega_0$ in L-C oscillations

Analogies between Mechanical and Electrical Quantities	
Mechanical system	Electrical system
Mass m	Inductance L
Force constant k	Reciprocal capacitance 1/C
Displacement x	Charge q
Velocity $v=dx/dt$	Current $I=dq/dt$
Mechanical energy	Electromagnetic energy

Energy of LC Oscillations:

Let q_0 be the initial charge on a capacitor. Let the charged capacitor be connected to an inductor of inductance L. LC circuit will sustain an oscillation with frequency $\left(\omega = 2\pi f = \frac{1}{\sqrt{LC}}\right)$

At an instant t, charge q on the capacitor and the current i are given by:

$q(t) = q_0 \cos \omega t$; $i = -q_0 \omega \sin \omega t$

Energy stored in the capacitor at time t is

$$U_E = \frac{1}{2}CV^2 = \frac{1}{2}\frac{q^2}{C} = \frac{q_0^2}{2C}\cos^2(\omega t)$$

Energy stored in the inductor at time t is $U_M = \frac{1}{2}Li^2$

$$= \frac{1}{2}Lq_0^2\omega^2 \sin^2(\omega t) = \frac{q_0^2}{2C}\sin^2(\omega t) \qquad \left(\because \omega^2 = \frac{1}{\sqrt{LC}}\right)$$

Sum of energies $U_E + U_M = \frac{q_0^2}{2C}\left(\cos^2 \omega t + \sin^2 \omega t\right) = \frac{q_0^2}{2C}$

As q_0 and C, both are time independent, this sum of energies stored in capacitor and inductor is constant in time. Note that it is equal to the initial energy of the capacitor.

Transformer:

- A transformer works on the principle of mutual induction
- It is a static device that is used to increase or decrease the voltage in an AC circuit
- On a laminated iron core two insulated copper coils called primary and secondary are wound
- Primary is connected to an alternating source of emf, by mutual induction, an emf is induced in the secondary.

Voltage ratio:

- If V_1 and V_2 are the primary and secondary voltages in a transformer, N_1 and N_2 are the number of turns in the primary and secondary coils of the transformer,

  then $\frac{V_1}{V_2} = \frac{N_1}{N_2}$
- In a transformer the voltage per turn is the same in primary and secondary coils
- The ratio N_2 / N_1 is called transformation ratio
- The voltage ratio is the same as the ratio of the number of turns on the two coils

Current Ratio:

- If the primary and secondary currents are I_1 and I_2 respectively, then for ideal transformer

$$\frac{V_2}{V_1}=\frac{I_1}{I_2}=\frac{N_2}{N_1}$$

- In an ideal transformer the ampere turns are the same in primary and secondary coils
- If $N_s > N_P$ voltage is stepped up, then the transformer is called step-up transformer.
- If $N_s < N_P$ voltage is stepped down, then the transformer is called step-down transformer.
- In step – up transformer, $V_S > V_P$ and $I_S < I_P$
- In step-down transformer, $V_S < V_P$ and $I_S > I_P$
- Frequency of input a.c is equal to frequency of output a.c
- Transformation of voltage, is not possible with d.c

Efficiency of Transformer (η)

Efficiency is defined as the ratio of output power and input power

$$\text{Efficiency} = \frac{\text{output power}}{\text{input power}}$$

i.e., $\eta\% = \frac{P_{out}}{P_{in}}\times 100 = \frac{V_s i_s}{V_P i_P}\times 100$

- For an ideal transformer $P_{out} = P_{in}$ so $\eta = 100\%$ (But efficiency of practical transformer lies between 70% - 90%)

  For practical transformer $P_{in} = P_{out} + P_{losses}$

  So, $\eta = \frac{P_{out}}{P_{in}}\times 100 = \frac{P_{out}}{(P_{out}+P_L)}\times 100 = \frac{(P_{in}-P_L)}{P_{in}}\times 100$

- In an ideal transformer the input power is equal to the output power.

  $V_1 I_1 = V_2 I_2$

  The efficiency of an ideal transformer is 100%

Losses in a Transformer:

- The losses in a transformer are divided in to two types. They are copper losses and iron losses
- The loss of energy that occurs in the copper coils of the transformer (i.e. primary and secondary coils) is called 'copper losses'. These are nothing but joule heating losses where electrical energy is converted in to heat energy

  The loss of energy that occurs in the iron core of the transformer (i.e. hysteresis loss and eddy current loss) is called 'iron losses'

Minimizing the losses in a Transformer:

- The core of a transformer is laminated and each lamination is coated with a paint of insulation to reduce the 'eddy current' losses.
- By choosing a material with narrow 'hysteresis loop' for the core, the hystersis losses are minimized.

Uses of Transformer:

- A transformer is used in almost all ac operations, e.g
- In voltage regulators for TV, refrigerator, computer, air conditioner etc.
- In the induction furnaces.
- Step down transformer is used for welding purposes
- In the transmission of ac over long distance
- Step down and step up transformers are used in electrical power distribution
- Audio frequency transformers are used in radiography, television, radio, telephone etc.
- Radio frequency transfomers are used in radio communication

EXERCISE – 1

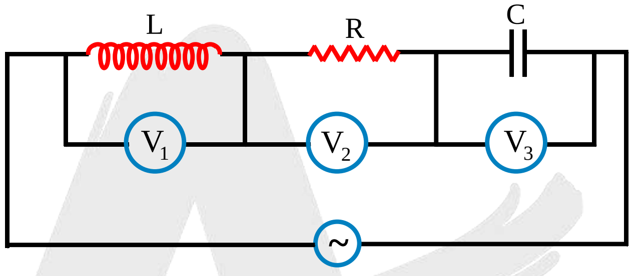
1. The effective value of current $i = 2\sin 10\pi t + 2\cos(100\pi t + 30°)$ is $\sqrt{\alpha}$ A. Find α ?

2. In the above quation the average value of voltage (V) in one time period will be :

(A) $\frac{V_0}{\sqrt{3}}$ (B) $\frac{V_0}{2}$ (C) $\frac{V_0}{\sqrt{2}}$ (D) Zero

3. A square wave AC of current 2 A is passed through on AC ammeter. Reading shown by it (in A) is :

4. If the readings of V_1 and V_3 are 100 volt each then reading of V_2 (in volt) is :



5. The value of current in two series LCR circuits at resonance is same when connected across a sinusoidal voltage source. Then :

(A) both circuits must be having same value of capacitance and inductor

(B) in both circuits ratio of L and C will be same

(C) for both the circuits $\frac{X_L}{X_C}$ must be same at that frequency

(D) both circuits must have same impedance at all frequencies

6. A power transformer is used to step up an alternating emf of 220 volt to 11 kV to transmit 4.4 kW of power. If the primary coil has 1000 turns, what is the current in the secondary?

(A) 4 A (B) 0.4 A (C) 0.04 A (D) 0.2 A

7. A transformer with 8 : 1 turns ratio has 60 Hz, 120 volt input. The frequency (in Hz) of output is :

8 A power line is used to transmit 100 MW power. Power factor of load is 0.866 and resistance of line is $8\ \Omega$. The power loss in the wire is 2%. What is the current (in A) in the wires. Find $\frac{I}{100}$.

9. In an A.C circuit the instantaneous values of current and voltage are $I = 120\sin\omega t$ ampere and $E = 300\sin(\omega t + \pi/3)$ volt respectively. What will be the inductive reactance of series LCR circuit if the resistance and capacitive reactance are 2 ohm and 1 ohm respectively?

(A) 4.5 ohms (B) 2 ohms (C) 2.5 ohms (D) 3 ohms

10. A 120V, 60Hz a.c. power is connected 800Ω non-inductive resistance and unknown capacitance in series. The voltage drop across the resistance is found to be 102V, then the voltage drop across the capacitor is

(A) 8V (B) 102V (C) 63V (D) 55V

11. A coil has an inductance of 0.7H and is joined in series with a resistance of 220Ω. When an alternating e.m.f. of 220V at 50 c.p.s. is applied to it, then the wattless component of the current in the circuit is

(A) 5 ampere (B) 0.5 ampere (C) 0.7 ampere (D) 7 ampere

12. Two alternating voltage generators produce emfs of the same amplitude E_0 but with a phase difference of $\frac{\pi}{3}$. The resultant e.m.f.is

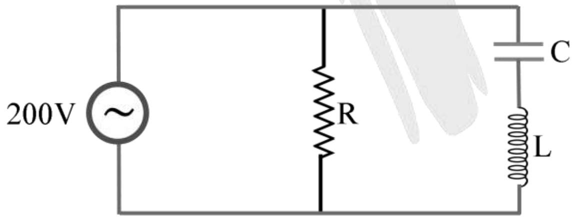
(A) $E_0 \sin\left(\omega t + \frac{\pi}{3}\right)$ (B) $E_0 \sin\left(\omega t + \frac{\pi}{6}\right)$

(C) $\sqrt{3}E_0 \sin\left(\omega t + \frac{\pi}{6}\right)$ (D) $\sqrt{3}E_0 \sin\left(\omega t + \frac{\pi}{2}\right)$

13. A bulb is rated at 100 V, 100 W, it can be treated as a resistor. Find out the inductance of an inductor (called choke coil) that should be connected in series with the bulb to operate the bulb at its rated power with the help of an ac source of 200 V and 50 Hz

(A) $\frac{\pi}{\sqrt{3}}$H (B) 100 H (C) $\frac{\sqrt{2}}{\pi}$H (D) $\frac{\sqrt{3}}{\pi}$H

14. In the circuit diagram shown, $X_C = 100\Omega$, $X_L = 200\Omega$ & $R = 100\Omega$. The effective current through the source is



(A) 2A (B) $2\sqrt{2}$A (C) 0.5 A (D) $\sqrt{0.4}$A

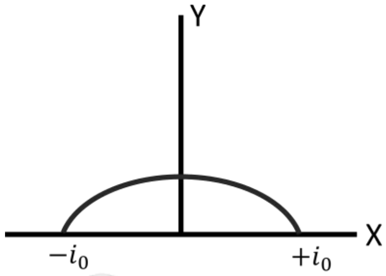
15. The instantaneous value of current and emf in an AC circuit are $I = \frac{1}{\sqrt{2}} \sin 314t$ amp and $E = \sqrt{2} \sin\left(314t - \frac{\pi}{6}\right)$ V, respectively. The phase difference between E and I (with respect to I) will be

(A) $-\frac{\pi}{6}$rad (B) $-\frac{\pi}{3}$rad (C) $\frac{\pi}{6}$rad (D) $\frac{\pi}{3}$rad

16. If $i = t^2, 0 < t < T$ then rms value of current is

(A) $\frac{T^2}{\sqrt{2}}$ (B) $\frac{T^2}{2}$ (C) $\frac{T^2}{\sqrt{5}}$ (D) $\frac{T^2}{5}$

17. The rms current value of a semi-circular wave which has a maximum value i_0 is



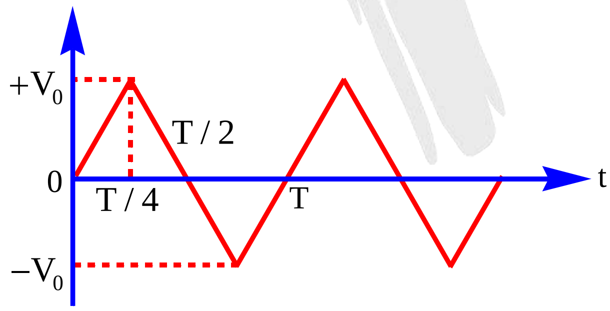
(A) $\frac{i_0}{\sqrt{3}}$ (B) $\sqrt{\frac{2}{3}}i_0$ (C) $\frac{i_0}{\sqrt{2}}$ (D) $2i_0$

18. RMS value of current $i = 3 + 4\sin\left(\omega t + \frac{\pi}{3}\right)$ is $\sqrt{\alpha}$ A. Find α ?

19. Current in an AC circuit is given by $i = 2\sqrt{2}\sin\left(\pi t + \frac{\pi}{4}\right)$, then the average value of current during time t = 0 to t= 1 sec is :

(A) 0 (B) $\frac{4}{\pi}$A (C) $\frac{4\sqrt{2}}{\pi}$A (D) $2\sqrt{2}$ A

20. The voltage time (V-t) graph for trianggular wave having peak value. V_0 is as shown in figure. The average value of voltage V in time interval from t = 0 to T is :



(A) 0 (B) $\frac{V_0}{2}$ (C) $\frac{V_0}{\sqrt{2}}$ (D) None of these

21. In a series LR circuit, the voltage drop across inductor is 8 volt and across resistor is 6 volt. Then voltage applied and power factor of circuit respectively are :

(A) 14 V, 0.8 (B) 10 V, 0.8 (C) 10 V, 0.6 (D) 14 V, 0.6

EXERCISE – 2

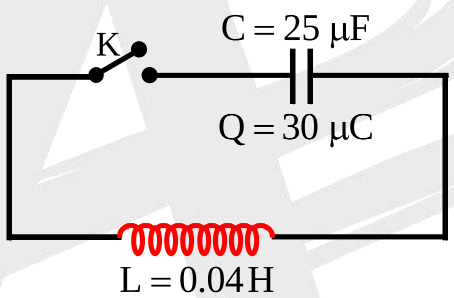
1. The output of an AC generator is given by : $E = E_m \sin\left(\omega t - \frac{\pi}{4}\right)$ and current is given by $i = i_m \sin\left(\omega t - \frac{3\pi}{4}\right)$. The circuit contains a single element other than the generator. It is :

(A) a capacitor (B) a resistor (C) an inductor (D) data insufficient

2. A capacitor of $50\ \mu F$, a resistor $10\ \Omega$, an ideal inductor L, are in series with an ideal AC source of frequency 50 Hz. The value of L, for which the phase angle between current and voltage is zero will be : (Take $\pi^2 = 10$)

(A) 0.2 H (B) 0.4 H (C) 2 H (D) 4 H

3. In the ideal oscillating circuit, the capacitance of the capacitor is $25\ \mu F$ and has initial charge of $30\ \mu C$. The inductance of coil is 0.04 H. The maximum magnitude of current (in mA) in the circuit, after closing the switch K is :



4. The series RLC circuit in resostance condition is called :

(A) selector circuit (B) rejector circuit (C) amplifier circuit (D) oscillator circuit

5. In a series RLC circuit, the frequency of the source is half of the resonance frequency. The nature of the circuit will be :

(A) capacitive (B) inductive (C) purely resistive 0(D) selective

6. In an LRC series circuit at resonance current in the circuit is $10\sqrt{2}\ A$. If now frequency of the source is changed such that now current lags by $45°$ than applied voltage in the circuit. Which of the following is correct?

(A) Frequency must be increased and current after the change is 10 A

(B) Frequency must be decreased and current after the change is 10 A

(C) Frequency must be decreased and current is same as that of initial value

(D) The given information is insufficient to conclude anything

7. A high impedance AC voltmeter is connected in turn across the inductor, capacitor and the resistor in a series circuit having an AC source of 100 V (rms) and gives the same reading in volts in each case. This reading (in volt) is :

8. In above question the resonance frequency of the circuit (in hertz) is $\frac{25n}{\pi}$. Find n?

9. In a step-up transformer the turns ratio is 10. If the frequency of the current in the primary coil is 50 Hz then the frequency of the current in the secondary coil will be :

(A) 500 Hz (B) 5 Hz (C) 60 Hz (D) 50 Hz

10. A pure resistive circuit element *'x'* when connected to an A.C. supply of peak voltage 100 V gives a peak current of 4 A which is in phase with the voltage. A second circuit element *'y'* when connected to the same AC supply also gives the same value of peak current but the current lags behind by 90°. If the series combination of 'x' and 'y' is connected to the same supply. R.M.S. value of current is

(A) $\frac{5}{\sqrt{2}}$ A (B) 2A

(C) 1/2 A (D) $\frac{\sqrt{2}}{5}$ A

11. An ideal inductor takes a current of 10 A when connected to a 125 V, 50 Hz AC supply. A pure resistor across the same source takes 12.5 A. if the two are connected in series across a $100\sqrt{2}$V , 40 Hz supply, the current through the circuit will be

(A) 10 A (B) 12.5 A

(C) 20 A (D) 25 A

12. An AC source of variable frequency is applied across a series L-C-R circuit. At a frequency double the resonance frequency. The impedance is $\sqrt{10}$ times the minimum impedance. The inductive reactance is

(A) R (B) 2R (C) 3R (D) 4R

13. An LCR circuit has L = 10 mH, R = 3Ω , and C = $1\mu F$ connected in series to a source of 15 $\cos\omega t$ volt. The current amplitude at a frequency that is 10% lower than the resonant frequency is

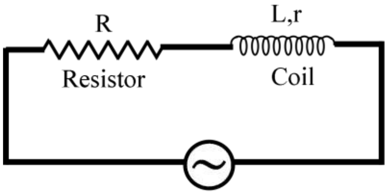
(A) 0.5 A (B) 0.7 A (C) 0.9 A (D) 1.1 A

14. A capacitor has a resistance of 1200 $M\Omega$ and capacitance of $22\mu F$. When connected to an a.c. supply of frequency 80 hertz, then the alternating voltage supply required to drive a current of 10 virtual ampere is

(A) 904 2V (B) 904V

(C) 904 / 2V (D) 452V

15. For the circuit shown in the figure the rms value of voltages across R and coil are E_1 and E_2, respectively.



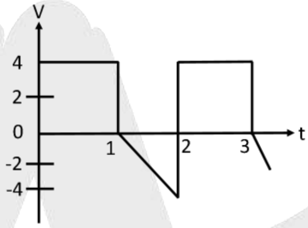
$e = E_0 \sin\omega t$

$e_{rms} = E$

The power (thermal) developed across the coil is

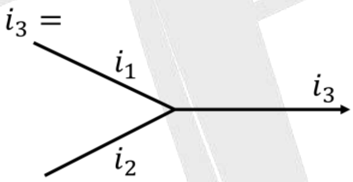
(A) $\frac{E - E_1^2}{2R}$ (B) $\frac{E - E_1^2 - E_2^2}{2R}$ (C) $\frac{E^2}{2R}$ (D) $\frac{(E - E_1)^2}{2R}$

16. The rms and the average value of the voltage wave shown in figure are



(A) $\frac{32}{3}$V; 1V (B) $\frac{11}{3}$V;1V (C) $\frac{11}{3}$V;3V (D) $\frac{32}{3}$V;3V

17. If $i_1 = i_{0_1}\sin(\omega t), i_2 = i_{0_2}\sin(\omega t + \phi)$, then



(A) $\sqrt{i_{0_1}^2 + i_{0_2}^2}\ \sin\{\phi + \omega t\}$

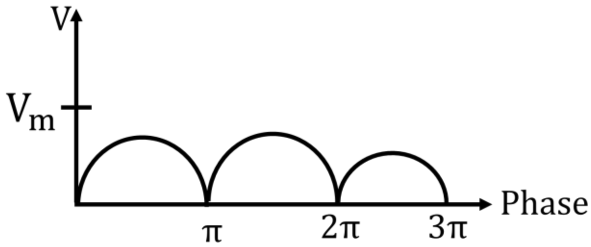
(B) $(i_{0_1} + i_{0_2})\sin\left(\frac{\phi}{2} + \omega t\right)$

(C) $\left(\sqrt{i_{0_1}^2 + i_{0_2}^2 + 2i_{0_1}i_{0_2}\cos\phi}\right)\sin[\phi + \omega t]$

(D) $\left(\sqrt{i_{0_1}^2 + i_{0_2}^2 + 2i_{0_1}i_{0_2}\cos\phi}\right)\sin[\alpha + \omega t]$

where $\alpha = \text{Tan}^{-1}\left[\frac{i_{0_2}\sin\phi}{i_{0_1} + i_{0_2}\cos\phi}\right]$

18. The average and effective values for the waveshape shown in the figure are:



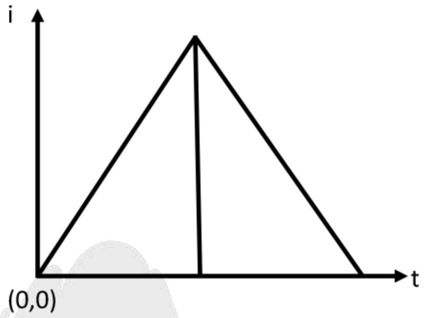
(A) $\frac{2}{\pi}V_m$ and $\frac{V_m}{2}$ (B) $\frac{V_m}{\pi}$ and $\frac{V_m}{\sqrt{2}}$ (C) $\frac{2}{\pi}V_m$ and $\frac{V_m}{\sqrt{2}}$ (D) $\frac{V_m}{\pi\sqrt{2}}$ and $\frac{V_m}{\sqrt{2}}$

19. Calculate the reading which will be given by a hot-wire voltmeter if it is connected across the terminals of a generator whose voltage waveform is represented by

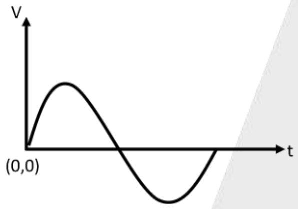
$v = 200\sin\omega t + 100\sin 3\omega t + 50\sin 5\omega t$

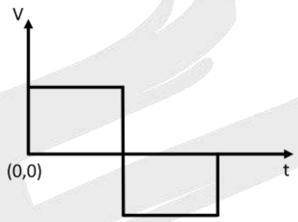
(A) 110V (B) 162V (C) 200V (D) 220V

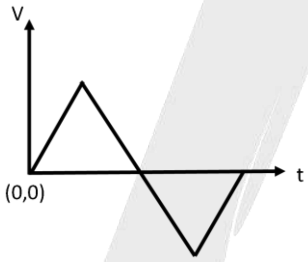
20. The current 'i' in an inductance coil varies with time 't' according to following graph

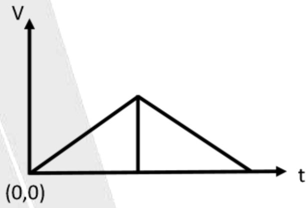


Which one of the following figures shows the variations of voltage in the coil

(A)


(B)


(C)


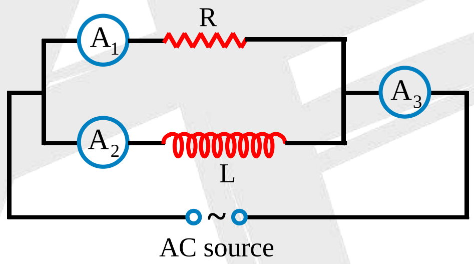
(D)


EXERCISE – 3

1. When a voltage $v_s = 200\sqrt{2}\sin(\omega t + 15°)$ is applied to and AC circuit the current in the circuit is found to be $i = 2\sin\left(\omega t + \frac{\pi}{4}\right)$ then average power consumed in the circuit is $100\sqrt{\alpha}$ watt. Find α ?

2. A 300 Ω resistor is connected in series with a parallel-plate capacitor across the terminals of a 50.0 Hz AC generator. When the gap between the plates is empty, its capacitance is $\frac{70}{22}\mu F$. The ratio of the rms current in the circuit when the capacitor is empty to that when ruby mica of dielectric constant k = 5.0 is insertd between the plates, is equal to $\frac{3}{n}$. Find n ?

3. In the circuit shown, assuming all ammeters to be ideal, if readings of the ammeters A_1 and A_2 are i_1 and i_2 respectively then reading of the ammeter A_3 is :

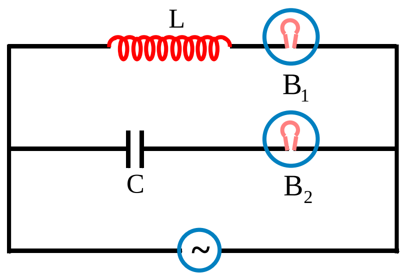


(A) equal to $(i_1 + i_2)$ (B) greater than $(i_1 + i_2)$

(C) less than $(i_1 + i_2)$ (D) equal to $2|(i_1 - i_2)|$

4. A $2\mu F$ capacitor is initially charged to 20 volt and then shorted across a $8\mu H$ inductor. The maximum value of the current (in A) in the circuit is :

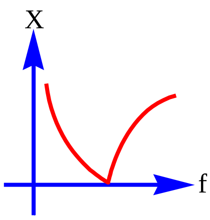
5. Two identical bulbs are connected to an AC source by using an inductor and a capacitor in series, with the bulbs as shown then the brightness fo B_1 and B_2 will be :

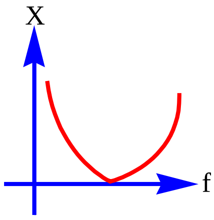


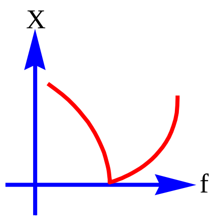
(A) Same for both cases (B) More for B_1 than B_2

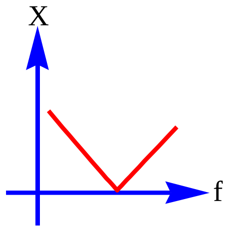
(C) Depends on the frequency of source (D) More for B_2 than B_1

6. In a series LC circuit, which of the following represents variation of magnitude of reactance (X) with frequency (f)?

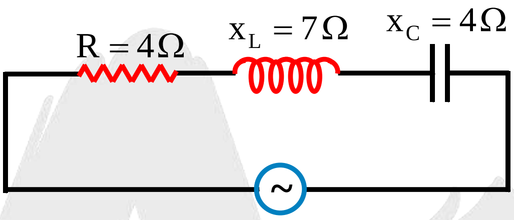
(A) 

(B) 

(C) 

(D) 

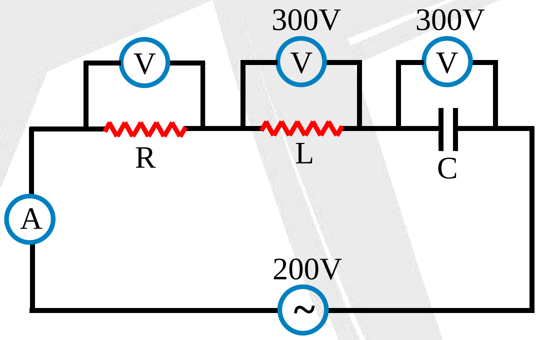
7. In the series LCR circuit as shwon in figure, the heat developed in 80 seconds and amplitude of wattless current is :



$E = 25\sin(100\pi t + \pi/2)$

(A) 4000 J, 3 A (B) 8000 J, 3 A (C) 4000 J, 4 A (D) 8000 J, 5 A

8. In the series circuit shown in the figure, the voltmeter reading (in V) will be (all the meters are ideal) :



9. The impedance of a series RL circuit is same as the series RC circuit when connected to the same AC source separately keeping the same resistance. The frequency of the source is :

(A) $\frac{1}{\sqrt{LC}}$ (B) $\frac{1}{2\pi\sqrt{LC}}$ (C) $\frac{R}{L}$ (D) $\frac{1}{RC}$

10. A current source sends a current $i = i_0\cos(\omega t)$. When connected across an unknown load gives a voltage output of $v = v_0\sin\left(\omega t + \frac{\pi}{4}\right)$ across that load. Then voltage across the current source may be brought in phase with the current through it by :

(A) connecting an inductor in series with the load

(B) connecting a capacitor in series with the load

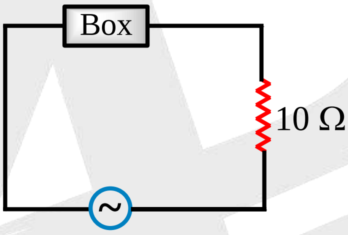
(C) connecting an inductor in parallel with the load

(D) connecting a capacitor in parallel with the load

11. A combination of elements is enclosed in a black box and the voltage and currents are measured across this balck box, the expression for applied voltage; $V_s = 200\sqrt{2}\sin\omega t$ and the current flowing in is $i = 2\sqrt{2}\sin\left(\omega t + \frac{\pi}{4}\right)$ where $\omega = 100\pi$ rad / sec. Then the wrong statement is :

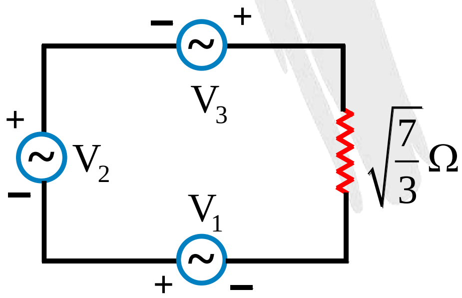
(A) There must be a capacitor is the black box
(B) Power factor of circuit = 0.707
(C) There must be a resistor in the box
(D) There must be an inductor in the box

12. In the circuit shown power factor of box is given by 0.5 and power factor of circuit is given power factor of circuit is given by $\frac{\sqrt{3}}{2}$. Current leading the voltage. Find the effectie resistance of the box is



(A) 2Ω (B) 3Ω (C) 4Ω (D) 5Ω

13. Three alternating voltage sources $V_1 = 3\sin\omega t$ volt, $V_2 = 5\sin(\omega t + \phi_1)$ volt and $V_3 = 5\sin(\omega t - \phi_2)$ volt connected across a resistance $R = \sqrt{\frac{7}{3}}\Omega$ as shown in the figure (where ϕ_1 and ϕ_2 corresponds to 30° and 127° respectively). Find the peak current through the resistor.



(A) 1 A (B) 2 A (C) 3 A (D) 4 A

14. Find the effective value or rms value of an alternating current that changes according to the law. (All quantities are in S.I. unit and symbols have their usual meanings.)

$I = 10$, when $0 < t < \frac{T}{8}$; $I = 0$, when $\frac{T}{8} < t < \frac{T}{2}$

$I = -10$, when $\frac{T}{2} < t < \frac{5}{8}T$;

$I = 0$, when $\frac{5}{8}T < t < T$; $I = 10$, when $T < t < \frac{9}{8}T$

(A) 5A (B) 3A (C) 6A (D) 8A

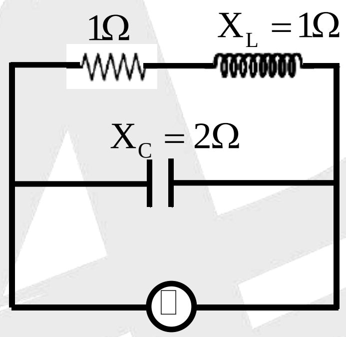
15. An LCR series circuit with 100 Ω resistance and $\frac{1}{\sqrt{3}}$H inductance is connected to an AC source of 200 V and angular freuency 300 rad/s. When the inductor is removed, the current leads the voltage by $60°$. Calculate the power dissipated in the LCR circuit

(A) 50 watt (B) 100 watt (C) 200 watt (D) 400 watt

16. A current of 4 A flows in a coil when connected to a 12 V DC source. If the same coil is connected to a 12 V, 50 rad/s, AC source, a current of 2.4 A flows in the circuit. Determine the reactance of coil.

(A) 2Ω (B) 4Ω (C) 6Ω (D) 8Ω

17. In the given A.C. circuit, choose the **CORRECT** statement(s).



$V = 100 \sin \omega t$

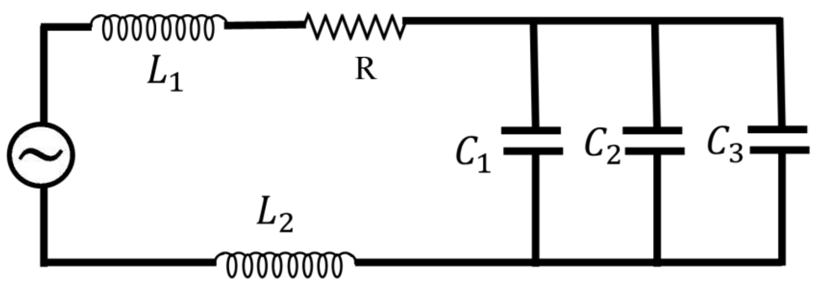
(A) Impedance of circuit is 2Ω

(B) Power factor of circuit is $\frac{1}{\sqrt{2}}$

(C) Peak value of current through resistance is $50\sqrt{2}$ A

(D) Average power supplied by source is 2500W.

18. A generator with an adjustable frequency of oscillation is connected to resistance, $R = 100\Omega$ inductances, $L_1 = 1.7\text{mH}$ and $L_2 = 2.3\text{mH}$ and capacitances, $C_1 = 4\mu F, C_2 = 2.5\mu F$ and $C_3 = 3.5\mu F$ The resonant angular frequency of the circuit is



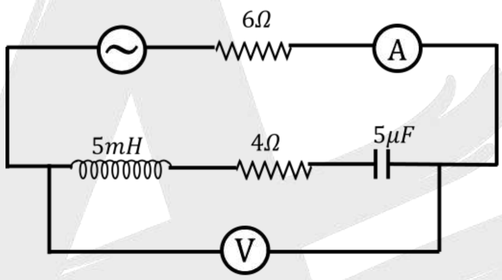
(A) 0.5rad/s (B) $0.5\times10^4\text{rad/s}$

(C) 2 rad/s (D) $2\times10^{-4}\text{rad/s}$

19. An A.C. circuit contains a resistor 'R', an inductor 'L' and a capacitor 'C' connected in series. When it is connected to an A.C. generator of fixed output voltage and variable frequency, the current in the circuit is found to be leading the applied voltage $\frac{\pi}{4}$ rad, when the frequency is f_1 When the frequency of the generator increased to f_2 the current is found to be lagging behind the applied voltage by $\frac{\pi}{4}$ rad. The resonant frequency of the circuit is

(A) $\frac{f_1 f_2}{f_1 + f_2}$ (B) $\frac{f_1 + f_2}{2}$ (C) $\frac{2f_1 f_2}{f_1 + f_2}$ (D) $\sqrt{f_1 f_2}$

20. In the circuit shown in the figure, the ac source gives a voltage $V = 20\cos(2000t)$. Neglecting source resistance, the voltmeter and ammeter reading will be



(A) 0V, 0.47A (B) 1.68V, 0.47A (C) 0V, 1.4A (D) 5.6V, 1.4A

EXERCISE – 4

1. Current in an AC circuit is given by $i = 3\sin\omega t + 4\cos\omega t$ then :

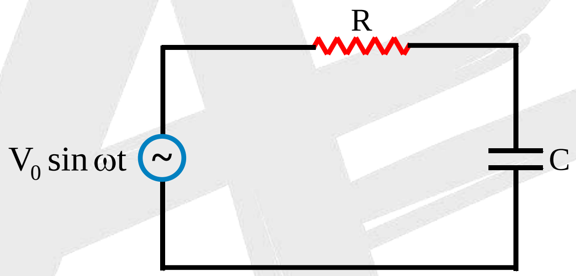
(A) rms value of current is 5 A

(B) mean value of this current in one half period will be $\frac{6}{\pi}$

(C) if voltage applied is $V = V_m \sin\omega t$ then the circuit must contain resistance and capacitance

(D) if voltage applied is $V = V_m \sin\omega t$, the circuit may contain only resistance and inductance

2. An AC voltage source $V = V_0 \sin\omega t$ is connected across resistance R and capacitance C as shown in figure. It is given that $R = \frac{1}{\omega C}$. The peak current is I_0. If the angular frequency of the voltage source is changed to $\frac{\omega}{\sqrt{3}}$ then the new peak current in the circuit is :



(A) $\frac{I_0}{2}$ (B) $\frac{I_0}{\sqrt{2}}$ (C) $\frac{I_0}{\sqrt{3}}$ (D) $\frac{I_0}{3}$

3. The secondary coil of an ideal step-down transformer is delivering 500-watt power at 12.5 A current. If the ratio of turns in the primary to the secondary is 5 : 1, then the current flowing in the primary coil will be :

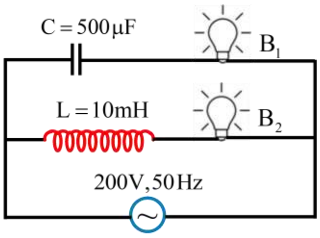
(A) 62.5 A (B) 2.5 A (C) 6 A (D) 0.4 A

4. A transformer may be used to provide maximum power transfer between two AC circuits that have different impedances Z_1 and Z_2. The ratio of turns $\frac{N_1}{N_2}$ needed to meet this condition is given by :

(A) $\frac{N_1}{N_2} = \frac{Z_1}{Z_2}$ (B) $\frac{N_1}{N_2} = \frac{Z_2}{Z_1}$

(C) $\frac{N_1}{N_2} = \sqrt{\frac{Z_2}{Z_1}}$ (D) $\frac{N_1}{N_2} = \sqrt{\frac{Z_1}{Z_2}}$

5. In the circuit shown in the figure, if both the bulbs B_1 and B_2 are identical



(A) Their brightness will be the same

(B) B_2 will be brighter than B_1

(C) As frequency of supply voltage is increased, brightness of B_1 will increase and that of B_2 will decrease

(D) Only B_2 will glow because the capacitor has infinite impedance.

6. An inductor 4H and a resistance 5Ω are connected in series with an AC source. At a particular instant, voltage across inductor is 3 volt and across resistor is 4 volt. For that particular instant, choose correct options

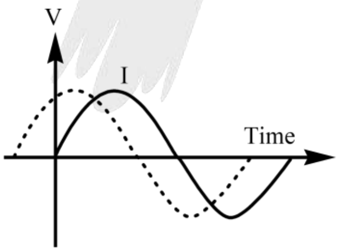
(A) Voltage across source is 5 volt

(B) Voltage across source may be 7 volt

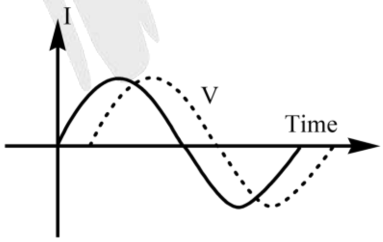
(C) Voltage across source may be 1 volt

(D) Current in circuit is 1.6 amp

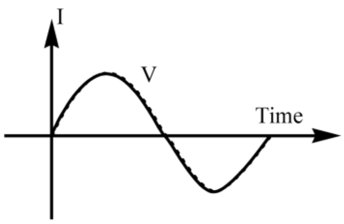
7. The diagram shows the variation of V and I in an AC circuit. The circuit only be a series RC or series RL or series LC or series RLC. Consider the four different combinations of V and I graphs. Pick the correct combination/combinations for each graph. Solid curves represent I and broken curves represent V

(A)


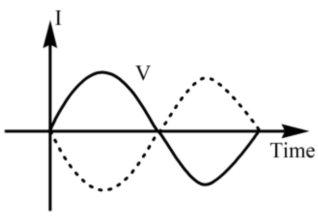
Phase difference between V and I is $\pi/4$

(B)


Phase difference between V and I is $\pi/4$

(C)


V and I are in the same phase

(D)


V and I have a phase difference of π

Take the angular frequency of the AC voltage source to be 100rad/s(This is ω)

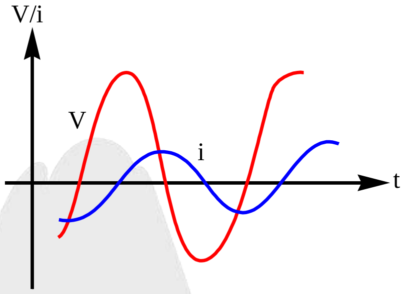
(I): $R = 1k\Omega$, $L = 1H$ and $C = 100\mu F$ (II): $R = 1\Omega$ and $L = 10^{-2}H$

(III): $R = 100\Omega$ and $C = 10^{+2}\mu F$ (IV) $L = 1H$, $C = 100\mu F$ and $R = 1\Omega$

(A) $A \to II; D \to I, IV$ (B) $C \to I; D \to$ none

(C) $V \to III; C \to IV$ (D) $A \to II, III; B \to II, III$

8. Graph shows variation of source emf V and current i in a series RLC circuit, with time.



(A) The current leads the emf in the circuit

(B) The circuit is more inductive than capacitive

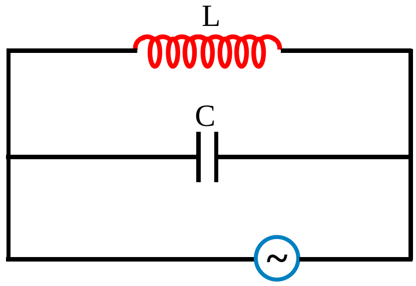
(C) To increase the rate at which energy is transferred to the resistive load, L should be decreased.

(D) To increase the rate at which energy is transferred to the resistive load, C should be increased.

9. A coil is connected to an alternating emf of voltage 24 V and of frequency 50 Hz. The reading on the ammeter connected to the coil in series is 10 mA. If a 1 μF capacitor is connected to the coil in series the ammeter shows 10 mA again. What would be the approximate reading on a DC ammeter if the coil was connected to a 180 V DC voltage supply? (Take $\pi^2 = 10$)

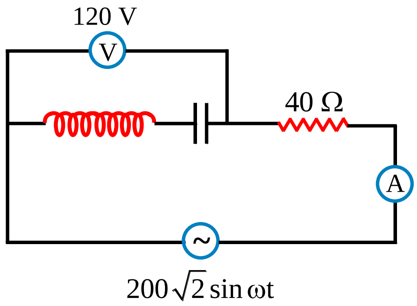
(A) 1 A (B) 2 A (C) 3 A (D) 4 A

10. An alternating voltage $V_0 = 100\,V$ with angular frequency ω is connected across the capacitor and inductor having $X_L = 5\Omega$ and $X_C = 10\ \Omega$. Find the ratio of current through inductor to AC source.



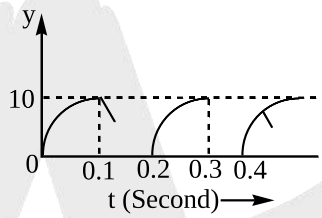
(A) 1 : 1 (B) 2 : 2 (C) 2 : 1 (D) 4 : 3

11. In the given LCR series circuit find the reading of the hot wire ammeter.



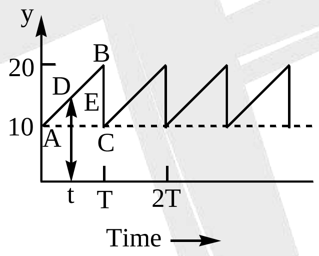
(A) 2 A (B) 3 A (C) 4 A (D) 1 A

12. Calculate the rms value of the function shown in figure if it is given that for $0 < t < 0.1,\ y = 10\left(1-e^{-100t}\right)$ and for $0.1 < t < 0.2,\ y = 10e^{-50(t-0.1)}$



(A) 4.9 (B) 5.9 (C) 6.9 (D) 7.9

13. What is the significance of the rms and average values of a wave?



(A) rms value of wave is 13.6
(B) rms value of wave is 15.2
(C) average value of waveform is 13
(D) average value of waveform is 15

14. A full-wave rectified sinusoidal voltage is clipped at $\frac{1}{\sqrt{2}}$ of its maximum value.

(A) The average of a voltage is $0.54\ V_M$
(B) The average of a voltage is $0.34\ V_M$
(C) The rms value of voltage $0.584\ V_M$
(D) The rms value of voltage $0.484\ V_M$

15. A current of 4 A flows in a coil when connected to a 12V DC source. If the same coil is connected to 1 12V, 50 rad/s AC source a current of 2.4 A flows in the circuit.

(A) The inductance of the coil is 0.04Ω

(B) The inductance of the coil is 0.08Ω

(C) The power developed in the circuit if a 2500 μF capacitor is connected in series with the coil is 17.28 ω

(D) The power developed in the circuit if a 2500 μF capacitor is connected in series with the coil is 15.28 ω

16. The quality factor of an oscillating circuit connected in series to a source of alternating emf is $Q=\sqrt{\alpha n^2-\frac{1}{\beta}}$. Find $\alpha+\beta$? If at resonance the voltage across the capacitor is n times that of the source.

17. An oscillating circuit consisting of a coil and a capacitor connected in series is fed an alternating emf, with coil inductance being chosen to provide the maximum current in the circuit. The quality factor of the system, provided an n-fold increase of inductance results in an η-fold decreases of the current in the circuit is $Q=\sqrt{\frac{n^2-\alpha}{(n-\beta)^2}-\frac{1}{\gamma}}$. Find $\alpha+\beta+\gamma$?

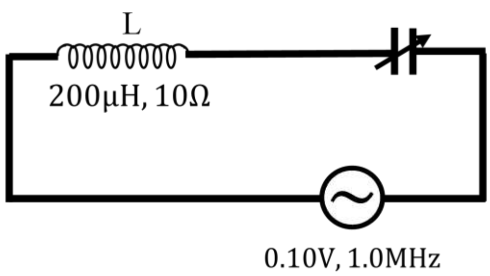
18. A circuit consisting of a capacitor and a coil connected in series is fed two alternating voltages of equal amplitudes but different frequencies. The frequency of one voltage is equal to the natural oscillation frequency (ω_0) of the circuit, the frequency of the other voltage is η times higher. The ratio of the current amplitudes is $\sqrt{\alpha+\frac{Q^2}{n^2}(n^2-\beta)^2}$

19. A box P and a coil Q are connected in series with an ac source of variable frequency. The emf of source at 10 V. Box P contains a capacitance of $1\mu F$ in series with a resistance of 32Ω coil Q has a self-inductance 4.7 mH and a resistance of 68Ω series. The frequency is adjusted so that the maximum current flows in P and Q. Find the voltage across P.

(A) $V_P=5.5V$ (B) $V_P=6.6V$ (C) $V_P=7.7V$ (D) $V_P=8.8V$

20. An LCR series circuit with 100Ω resistance is connected to an AC source of 200V and angular frequency 300 rad/s. When only capacitance is removed, the current lagas behind the voltage by $60°$. When only the inductance is removed the current leads the voltage by $60°$. The power dissipated in the LCR circuit $(\text{in } \omega)$.

21. At resonance, V_L and V_C are both very much greater than the applied potential, V itself. The quality factor for an LCR circuit in resonance is given by $Q=\frac{X_L}{R}$. In practice, $Q=200$ has been achieved



(I) At resonance, the capacitor has been adjusted for

(A) $200\times10^{-6}\mu F$ (B) $0.00013\mu F$ (C) $0.0013\mu F$ (D) 0.0013F

(II)At resonance, the potential difference across the inductance is

(A) 1.3V (B)13V (C)0.3V (D) none of these

(III) The potential across the capacitance at resonance is

(A) 13V (B) >13 V (C) <13V (D) none of these

(IV) The Q factor is

(A) $\frac{V_L}{V_C}$ (B) $\frac{V_C}{V_L}$ (C) $\frac{V_C}{V}$ (D) $\frac{V_L}{V}$

(V) choose the right statement.

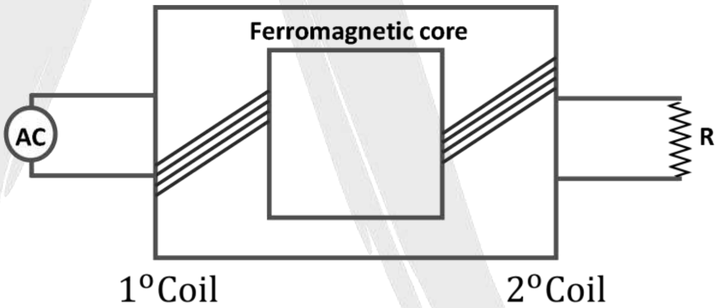
(A) $V_L + V_C$ can be greater than $V_{applied}$

(B) $V_L + V_C = V_{applied}$

(C) $V_L + V_C < V_{applied}$

(D) none of these

22. A physics lab is designed to study the transfer of electrical energy from one circuit to another by means of a magnetic field using simple transformers. Each transformer has two coils of wire electrically insulated from each other but wound around a common core of ferromagnetic material. The two wires are close together but do not touch each other.



The primary coil is connected to a source of alternating (AC) current. The secondary coil is connected to a resistor such as a light bulb. The AC source produces an oscillating voltage and current in the primary coil that produces an oscillating magnetic field in the core material. This in turn induces an oscillating voltage and AC current in the secondary coil. Student collected the following data comparing the number of turns per coil (N), the voltage (V) and the current (I) in the coils of three transformers

	Primary Coil			**Secondary coil**		
	N_1	V_1	I_1	N_2	V_2	I_2
Transformer 1	100	10V	10 A	20	20V	5A
Transformer 2	100	10V	10 A	50	5V	20A
Transformer 3	200	10V	10 A	100	5V	20A

(I) The primary coil of a transformer has 100 turns and is connected to a 120V AC source. How many turns are in the secondary coil if there is a 2400 V across it

(A) 5 (B) 50 (C) 200 (D) 2000

(II) A transformer with 40 turns in its primary coil is connected to a 120 V AC source. If 20 W of power is supplied to the primary coil, the power developed in the secondary coil is

(A) 10 W (B) 20 W (C) 80 W (D) 160 W

(III) One of the following is a correct expression for R, the resistance of the load connected to the secondary coil (pick the correct one)

(A) $\left(\frac{V_{1^0}}{I_{1^0}}\right)\left(\frac{N_{2^0}}{N_{1^0}}\right)$ (B) $\left(\frac{V_{1^0}}{I_{1^0}}\right)\left(\frac{N_{1^0}}{N_{2^0}}\right)^2$ (C) $\left(\frac{V_{1^0}}{I_{1^0}}\right)\left(\frac{N_{1^0}}{N_{2^0}}\right)$ (D) $\left(\frac{V_{1^0}}{I_{1^0}}\right)\left(\frac{N_{1^0}}{N_{2^0}}\right)^2$

(IV) A 12 V battery is used to supply 2.0 mA of current to the 300 turns in the primary coil of a given transformer. What is the current in the secondary coil if $N_2 = 150$ turns

(A) zero (B) 1.0 mA (C) 2.0 mA (D) 4.0 mA

EXERCISE – 5

1. For a LCR series circuit with an AC source of angular frequency ω :

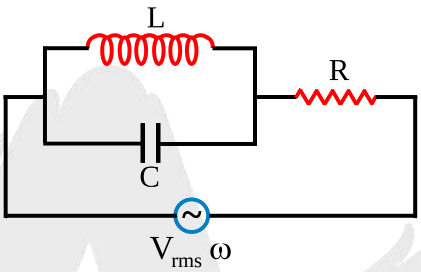
(A) circuit will be capacitive if $\omega > \frac{1}{\sqrt{LC}}$

(B) circuit will be inductive if $\omega = \frac{1}{\sqrt{LC}}$

(C) power factor of circuit will be unity if capacitive reactance equals inductive reactance

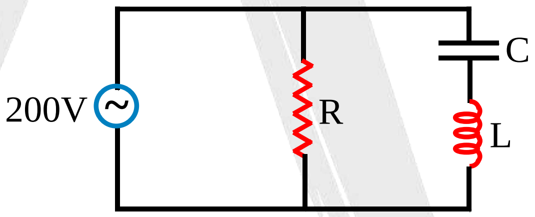
(D) current will be leading voltage if $\omega > \frac{1}{\sqrt{LC}}$

2. In the given LCR circuit the value of rms current through the AC source is:

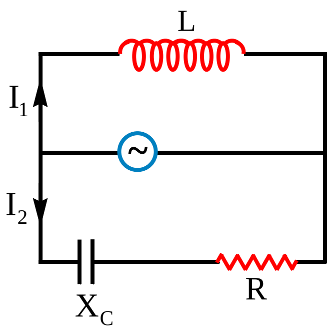


(A) $\frac{V_{rms}}{\sqrt{R^2+\left(\omega L-\frac{1}{\omega C}\right)^2}}$ (B) $\frac{V_{rms}}{\sqrt{R^2+\left(\frac{\omega L}{1-\omega^2 LC}\right)^2}}$ (C) $\frac{V_{rms}}{\sqrt{R^2+(\omega^2 LC-\omega L)^2}}$ (D) $\frac{V_{rms}}{\sqrt{(R+\omega L)^2+\frac{1}{\omega^2 C^2}}}$

3. In the circuit diagram shown, $X_C = 100\ \Omega$, $X_L = 200\ \Omega$ and $R = 100\ \Omega$. The effective current through the source is $\alpha\sqrt{2}$ amp. Find α ?



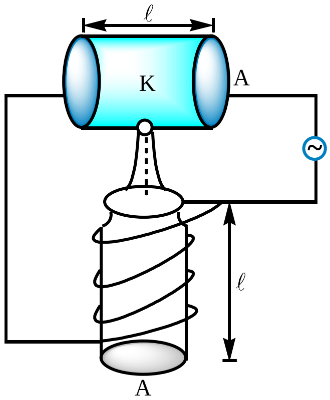
4. In the given circuit assuming inductor and source to be ideal, the phase difference between current I_1 and I_2 :



(A) $\tan^{-1}\left(\frac{X_C}{R}\right) - \frac{\pi}{2}$ (B) $\tan^{-1}\left(\frac{X_C}{R}\right)$

(C) $\tan^{-1}\left(\frac{X_C}{R}\right) + \frac{\pi}{2}$ (D) $\frac{\pi}{2}$

5. Figure shows a system of inductor and parallel plate capacitor made of 2 parallel circular plates of area A and filled with dielectric liquid of dielectric constant K as shown.



A small leak develops in capacitor and liquid starts to fill the inductor of same dimensions having n turns/unit length. Find the ratio of magnitude of initial to final reactance of circuit after liquid fills the inductor completely.

Given : $\omega^2 A^2 n^2 = c^2$

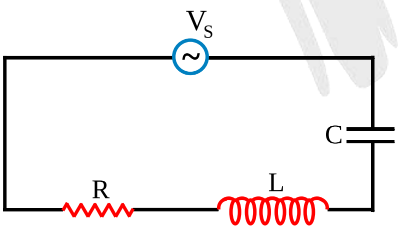
$\omega \to$ angular frequency of AC

$c \to$ speed of light

and $\mu_r \to$ relative permeability of liquid

(A) $K\dfrac{(K-1)}{(\mu_r+1)}$ (B) $\dfrac{1}{K}\dfrac{(1-K)}{(1-\mu_r)}$ (C) $\dfrac{(1-\mu_r)K}{(1+K)}$ (D) $\dfrac{1}{K}\left(\dfrac{K+1}{(1-\mu_r)}\right)$

6. A series RLC circuit is activated by an AC source of voltage V_S volt and variable angular frequency (ω) as shown in the circuit. V_{RL} and V_C are the potential drops across RL and C respectively. Select the correct statement:



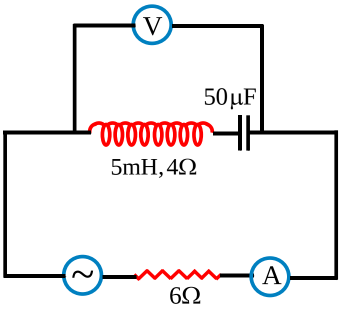
(A) At low frequency limit, both V_{RL} and V_C are proportional to ω

(B) At high frequency limit, V_{RL} approaches V_S but V_C is proportional to $\dfrac{1}{\omega^2}$

(C) At high frequency limit, both V_{RL} and V_C are proportional to $\dfrac{1}{\omega^2}$

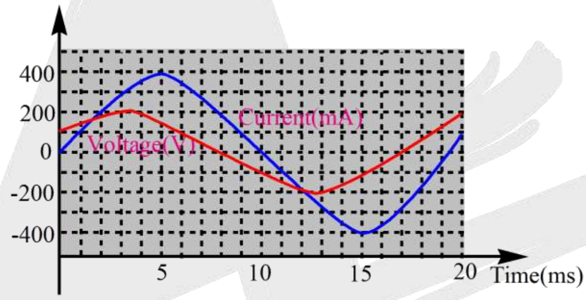
(D) At low frequency limit, V_{RL} is proportional to $\dfrac{1}{\omega}$, whereas V_C approaches V_S

7. In the circuit shown in the figure, the AC source gives a voltage $V = 20\cos(2000t)$ volt. Neglecting source resistance, the voltmeter and ammeter readings will be



(A) 0V, 2A (B) 0V, 1.4A (C) 5.6V, 0.47A (D) 1.68V, 0.47A

8. The given graph shows variation with time in the source voltage and steady state current drawn by a series RLC circuit. Which of the following statement(s) is/are correct?



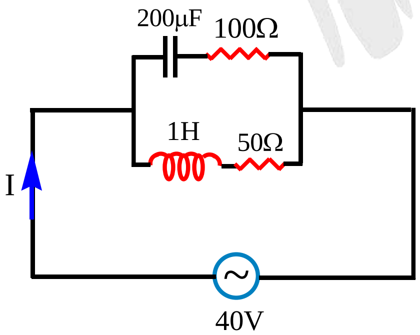
(A) Current lags the voltage

(B) Resistance in the circuit is $250\sqrt{3}\Omega$

(C) Reactance in the circuit is 500Ω

(D) Average power dissipation in the circuit is $20\sqrt{3}$watt

9. In the given circuit, the AC source has $\omega = 50$rad/s. Considering the inductor and capacitor to be ideal, the correct choice(s) is(are)



(A) The voltage across 100Ω resistor $= 20\sqrt{2}$V

(B) The voltage across 50Ω resistor $= 20\sqrt{2}$V

(C) The current through the circuit, I is $\frac{3}{\sqrt{10}}$A

(D) The current through the circuit, I is 1.2A

10. A series circuit has an impedance of Z (in Ω) and a power factor of $\cos\phi$, at $f = 50\,\text{Hz}$. The source voltage lags the current. Then, [Where X_C is capacitive reactance and X_L is inductive reactance]

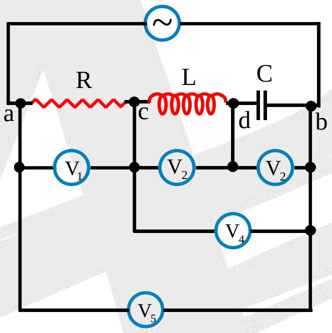
(A) A capacitor is added in series with the circuit in order to increase power factor

(B) An inductor is added in series with the circuit in order to increase power factor

(C) The power factor can never be raised to unity

(D) The value of $(X_L - X_C) = -\sqrt{\frac{Z^2\tan^2\phi}{1+\tan^2\phi}}$

11. Five infinite – impedance voltmeters, calibrated to read rms values, are connected as shown in figure. Let $R = 400\,\Omega$, $L = 3.5\,\text{H}$, $C = 5\,\mu\text{F}$, $\omega = 200\,\text{rad/s}$ and $V = 30.0\,\text{V}$. The reading of voltmeters will be



(A) $V_2 = 42\,\text{V}, V_3 = 64\,\text{V}, V_4 = 22\,\text{V}$

(B) $V_1 = 24\,\text{V}, V_2 = 42\,\text{V}, V_4 = 18\,\text{V}$

(C) $V_1 = 24\,\text{V}, V_4 = 6\,\text{V}, V_5 = 30\,\text{V}$

(D) $V_2 = 42\,\text{V}, V_3 = 60\,\text{V}, V_5 = 30\,\text{V}$

12. In an LCR series AC circuit, voltage across resistance is 2volt. The inductive and capacitive reactances are $10\,\Omega$ and $5\,\Omega$ respectively. The phase difference between voltage across the circuit and current is $30°$, then pick up the correct statement(s)

(A) The resistance of resistor is $5\sqrt{3}\,\Omega$

(B) The current in the circuit is $\frac{2}{5\sqrt{3}}\,\text{A}$

(C) The voltage of AC source is $\frac{2}{\sqrt{3}}$ volt

(D) The voltage of AC source is $4\sqrt{3}$ volt

13. Two alike discharge lamps are operated from the mains, 230V and 50Hz, and they are both connected to inductors in series. The inductors are alike. A condenser is connected in series to one of the discharge tubes. With this arrangement it is ensured that when the current through one of the lamps is maximum, then the current through the other one is minimum and vice – versa. (anti-stroboscopic navigation). The average value of the power is 8W. Then which of the following is/are correct? (Assume discharge lamps as resistors)

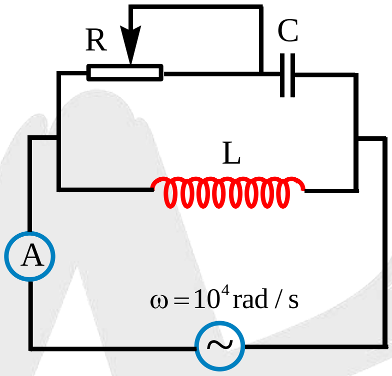
(A) The value of resistance of discharge tube is $3.3 k\Omega$

(B) The capacitance of condenser is $6.6 \mu F$

(C) The total ohmic resistance of the discharge tube and the inductor together is $4.67 k\Omega$

(D) The capacitive reactance is double of inductive reactance.

14. In the circuit shown, angular frequency of source is $\omega = 10^4 rad/s$. Value of inductance is 10 mH. If value of current measured by AC ammeter does not depend on resistance of resistor, then



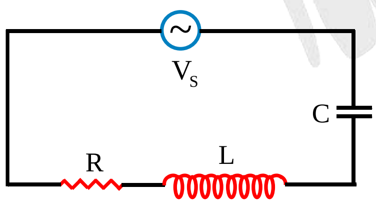
(A) Value of capacitance of capacitor is $1 \mu F$

(B) Value of capacitance of capacitor is $2 \mu F$

(C) Impedence of circuit is 100Ω

(D) Impedence of circuit is 1000Ω

15. A series RLC circuit is activated by a frequency (ω) variable AC source of voltage V_S volt as shown in the circuit. V_{RL} and V_C are the potential drops across RL and C respectively. Select the incorrect statement(s)



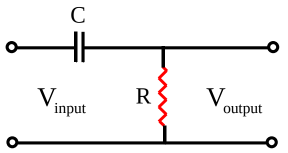
(A) At low frequency limit, both V_{RL} and V_C are proportional to ω

(B) At high frequency limit, V_{RL} approaches V_S but V_C is proportional to $\frac{1}{\omega^2}$

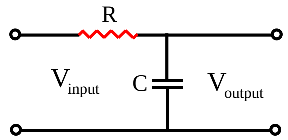
(C) At high frequency limit, both V_{RL} and V_C are proportional to $\frac{1}{\omega^2}$

(D) At low frequency limit, V_{RL} is proportional to ω, whereas V_C approaches V_S

16. Figure shows two circuits in each case V_0 denotes peak value of input voltage. Input voltage is given by $V = V_0 \sin \omega t$ and output by $V = V_M \sin(\omega t + \delta)$



Circuit -1



Circuit - 2

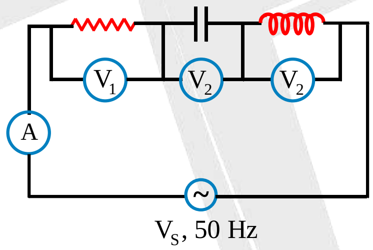
(A) In circuit -1 maximum output voltage is $V_M = \frac{V_0}{\sqrt{1+(\omega RC)^{-2}}}$

(B) In circuit – 2 maximum output voltage is $V_M = \frac{V_0}{\sqrt{1+(\omega RC)^2}}$

(C) In circuit – 1 average power dissipated is given by $P_{av} = \frac{V_0^2}{2R\sqrt{[1+(\omega RC)^{-2}]}}$

(D) Phase angle δ for circuit – 2 is given by $\tan \delta = \omega RC$

17. In the figure shown v_1, v_2, v_3 are AC voltmeters and A and AC ammeter. The readings of v_1, v_2, v_3 and A are 10 V, 20 V, 20 V, 2 A respectively. Find the values of R, C, L and the source voltage V_S. If the inductor is short circuited then what will be the readings of V_1, V_2 and A?



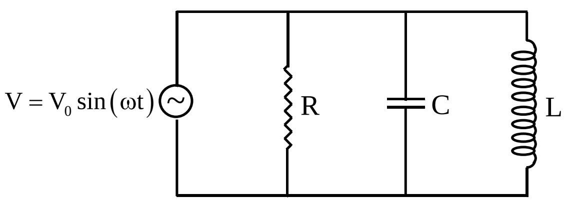
(A) The reading of V_1 is $2\sqrt{5}$volt

(B) The reading of V_2 is $4\sqrt{5}$volt

(C) The current in ammeter is $\frac{2}{\sqrt{5}}$A

(D) The current in ammeter is $\frac{5}{\sqrt{2}}$A

18. For the circuit shown in figure, Which of the following are correct?



(A) The instantaneous current through the inductance $I_L = -\frac{V_0}{\omega L}\cos(\omega t)$

(B) The total instantaneous current through the source is $V_0\sqrt{\frac{1}{R^2} + \left[\frac{1}{L\omega} - C\omega\right]^2}$

(C) The expression for phase angle is $\phi = \tan^{-1}\left[R\left(C\omega - \frac{1}{L\omega}\right)\right]$

(D) The impedance of the circuit is $Z = \frac{1}{\sqrt{\frac{1}{R^2}+\left(\frac{1}{\omega L}-\omega C\right)^2}}$

19. A solenoid with inductance L = 7 mH and active resistance $R = 44\Omega$ is first connected to a source of direct voltage V_0 and then to a source of sinusoidal voltage with effective value $V = V_0$. At what frequency of the oscillator will the power consumed by the solenoid be $\eta = 5.0$ times less than in the former case?

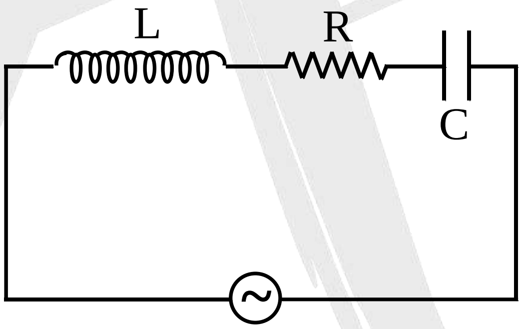
(A) $\sqrt{15}$ kHr
(B) $\sqrt{19}$ kHr
(C) $\sqrt{24}$ kHr
(D) $\sqrt{29}$ kHr

20. A circuit consisting of a capacitor and a coil in series in connected to the mains. Varying the capacitance of the capacitor, the heat power generated in the coil is increased n = 1.7 times. How much (in percent) was the value of $\cos\phi$ changed in the process ?

(A) 20%
(B) 30%
(C) 40%
(D) 50%

21. In the circuit shown in figure. L, C, R are connected with an AC source of rms value V. The value of frequency bandwidth when current in the circuit is $\frac{V}{\sqrt{2}R}$ is

$$\Delta\omega = \frac{\omega_0}{r}\left[\sqrt{R^2C^2\omega_0^2 + \alpha} - \sqrt{R^2C^2\omega_0^2 - \beta}\right].$$ Find $\alpha + \beta + \gamma$



22. A capacitor with capacitance $C = 1.0\ \mu F$ and a coil with active resistance $R = 10\Omega$ and inductance $L = 1.0\,mH$ are connected in parallel to a source of sinusoidal voltage $V = 3V$. Then

(A) The frequency ω at which the resonance sets in is 3×10^4 rad/s

(B) The frequency ω at which the resonance sets in is 2×10^4 rad/s

(C) the effective value of the fed current in resonance, as well as the corresponding currents flowing through the coil and through the capacitor are 3mA, 1A and 1A respectively

(D) the effective value of the fed current in resonance, as well as the corresponding currents flowing through the coil and through the capacitor are 4mA, 2A and 1A respectively

23. A capacitor with capacitance C and a coil with active resistance R and inductance L are connected in parallel to a source of sinusoidal voltage of frequency ω.

(A) The phase difference between the current fed to the circuit and the source voltage is

$$\phi = \tan^{-1}\left[\frac{\omega C\left(R^2+\omega^2L^2\right)-\omega L}{R}\right]$$

(B) The phase difference between the current fed to the circuit and the source voltage is

$$\phi = \tan^{-1}\left[\frac{2\omega C\left(R^2+\omega^2L^2\right)-\omega L}{R}\right]$$

(C) A circuit consists of a capacitor with capacitance C and a coil with active resistance R and inductance L connected in parallel. The impedance of the circuit at frequency ω of alternating voltage is $z=\sqrt{\dfrac{R^2+\omega^2L^2}{\omega^2R^2C^2+\left(1-\omega^2LC\right)^2}}$

(D) A circuit consists of a capacitor with capacitance C and a coil with active resistance R and inductance L connected in parallel. The impedance of the circuit at frequency ω of alternating voltage is $z=\sqrt{\dfrac{2R^2+\omega^2L^2}{\omega^2R^2C^2+\left(1-\omega^2LC\right)^2}}$

24. A black-box contains an inductor L, resistor R and a capacitor of capacitance C. It is observed that when black-box is connected through a DC source then current through this resistance is zero (at t = 0). Again when the box is connected through an AC source of rms value V_{rms} the current through the source is equal to the current through the resistor at resonance. The equivalent impedance is $z=\dfrac{1}{\sqrt{\dfrac{1}{R^2}+\left[\alpha\omega C-\dfrac{\beta}{\omega L}\right]^2}}$. Find $\alpha+\beta$?

25. In the circuit, switch S_1 was closed for a long time. At time t = 0 the switch is opened again.

(A) The maximum potential difference across the plates of the capacitor after the switch is opened is 200 V

(B) The angular frequency of oscillation of the charge on the capacitor is 200 rad/s

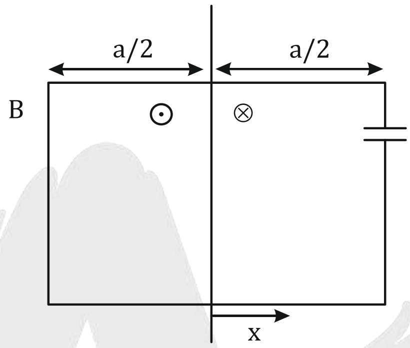
(C) Now the battery and the resistance $(100\,\Omega)$ are removed and an AC source with a peak emf of 200 V and angular frequency 100 rad/s is applied between A and B. The peak value of the current drawn from the source is 3A

(D) The phase difference between the current and the source emf is $\dfrac{\pi}{2}$

26. A square rigid loop of dimension 'a' meter is placed in a region of uniform magnetic field B, as shown. Half of the loop is inside & the other half is outside the field. Self-inductance of the loop is L = 100 Henry & the resistance of loop is R = 50Ω. A capacitor is also connected in loop in one of the sides of loop having capacitance

C = 1μF. At t = 0 external force (agent) starts moving loop according to equation $x = \frac{a}{2}\sin(\omega_0 t)$,

where ω_0 = 100 rad/s.



(A) Current starts with anticlock wise direction, after some time its direction may change.

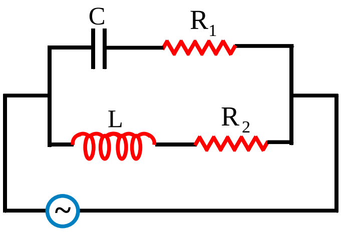
(B) Peak value of current in loop is $\left(\frac{B\omega_0 a^2}{2R}\right)$

(C) Average power delivered by external agent in one cycle is $\left(\frac{B^2\omega_0^2 a^4}{8R}\right)$

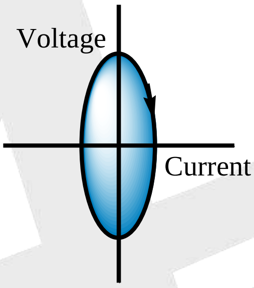
(D) If angular frequency of oscillation is more than ω_0 then average power delivered by external agent will decrease.

Proficiency Test-1

1. In the circuit the rms value of voltage across the capacitor C, inductor L and resister R_1 are respectively $5\sqrt{5}$, 10 V and 5 V. Then the peak voltage (in volt) across R_2 is :



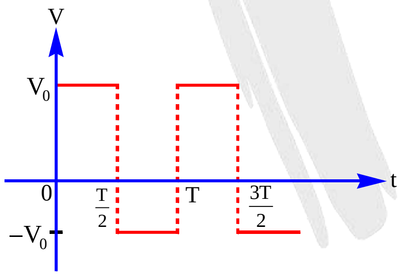
2. The graph shows current vs. Voltage in a series RLC AC circuit. The arrow indicates the direction that this curve is drawn as time progresses. In this plot, the :



(A) current lags the voltage by about $90°$ (B) current leads the voltage by about $90°$

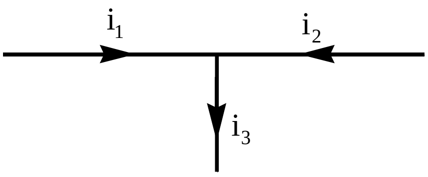
(C) current and voltage are in phase (D) current and voltage are $180°$ out of phase

3. The mean and rms value of an alternating voltage for half cycle as shown in figure are respectively :



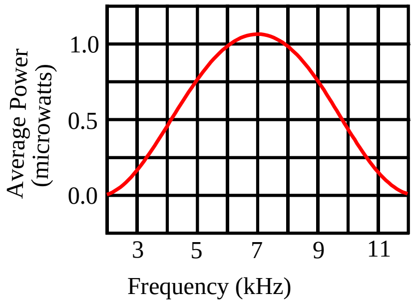
(A) V_0, V_0 (B) $\frac{V_0}{2}, V_0$ (C) $\frac{3V_0}{2}, \frac{V_0}{2}$ (D) $\frac{V_0}{4}, \frac{V_0}{2}$

4. In the given figure if $i_1 = 3\sin\omega t$ and $i_2 = 4\cos\omega t$, then i_3 is :



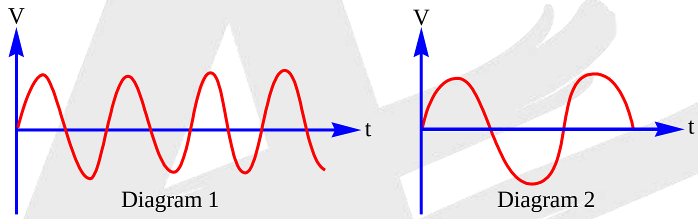
(A) $5\sin(\omega t + 53°)$ (B) $5\sin(\omega t + 37°)$ (C) $5\sin(\omega t + 45°)$ (D) $5\cos(\omega t + 53°)$

5. The plot given below is of the average power delivered to an LRC circuit versus frequency. The quality factor of the circuit is :



(A) 5
(B) 2.4
(C) 2.8
(D) 1.4

6. An series LCR circuit is resonating with a source whose emf varies with time as described in diagram-1. If we replace source by another source whose emf varies with time according to diagram-2, then :



(A) for getting resonance again, decrease R
(B) current will remain in phase with source voltage
(C) for getting resonance again, decrease C
(D) current will lead source voltage after replacing the source

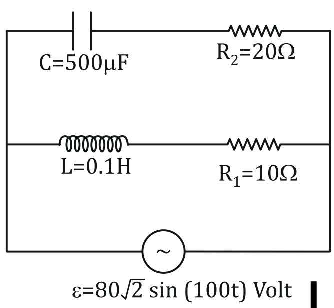
7. A source of voltage 50 V, 25 Hz is connected in series to a resistance of 400Ω, and inductance of $\pi\,H$, and a capacitor of $10\pi\ \mu F$. What is the average power dissipated in the circuit ?

(A) 2 W
(B) 4 W
(C) 6 W
(D) 8 W

8. A choke coil is connected to an AC source. Some power is dissipated in coil. Now a capacitor is connected in series with the coil and source is same, then average power dissipated in the circuit does not change. If rate of inductive reactance of coil and capacitive reactance of capacitor is $\frac{I}{x}$ then find x.

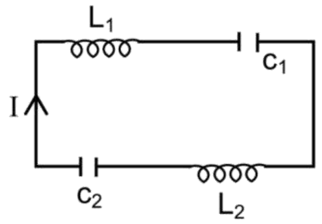
9. Consider an ac circuit as shown in the figure, then choose the correct option (s).

(A) At $t = \frac{\pi}{200}$ sec, the current through resistor R_1 is $4\sqrt{2}A$.
(B) At $t = \frac{\pi}{100}$ sec, the potential drop across the capacitor is $40\sqrt{2}$ volt.
(C) At $t = \frac{3\pi}{400}$ sec, the potential drop across the inductor is zero.
(D) At $t = \frac{\pi}{100}$ sec, the current through the capacitor is 2 A.



10. Figure shows LC circuit with two inductors and two capacitors. When the circuit was set-up (not at t = 0), the capacitors were not charged. The current in circuit is given by $I = 12\sin(2t + \pi/3)$, where 't' is time in seconds. Given $L_1 = 3H$, $L_2 = 2H$, $C_1 = 0.2F$.

Select the correct statements:



(A) $C_2 = 1/15$ F

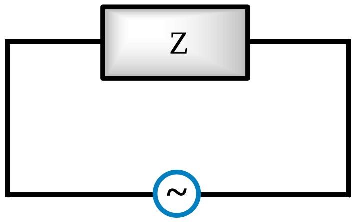
(B) $C_2 = 0.15$ F

(C) At $t = 7\pi/12$ s energy in inductor (L_1) is maximum

(D) At $t = \pi/3$ s energy in capacitor (C_2) is increasing

Proficiency Test-2

1. In a block box of unknown elements (L or C or R or any other combination of these). An AC voltage $E = E_0 \sin(\omega t + \phi)$ is applied and current in the circuit was found to be $i = i_0 \sin\left(\omega t + \phi + \frac{\pi}{4}\right)$. Then the unknown elements in the box may be:



(A) only capacitor

(B) inductor and resistor both

(C) either capacitor, resistor and inductor or only capacitor and resistor

(D) only resistor

2. An alternating voltage of 260 volt and $\omega = 100$ radian/second, is applied in an LCR series circuit where $L = 0.01\text{H}, C = 4 \times 10^{-4}\text{F}$ and $R = 10\Omega$. The power (in W) supplied by the source is :

3. A coil (which can be modelled as a series circuit) has been designed for high Q performance at a rated voltage and a specified frequency. If the frequency of operation is doubled and the coil is operated at the same rated voltage, then the Q factor and the active power P consumed by the coil will be affected as below :

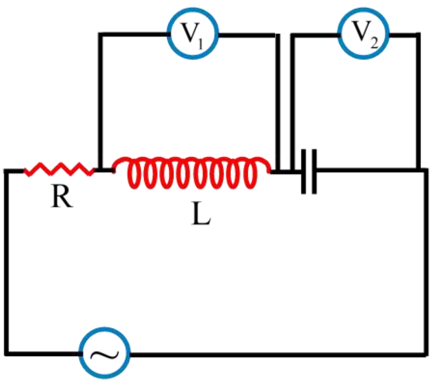
(A) P is doubled, Q is halved

(B) P is halved, Q is doubled

(C) P remains constant but Q increases 4 times

(D) P decreases 4 times but Q is doubled

4. In the circuit shown, resistance $R = 100\Omega$, inductance $L = \frac{2}{\pi}$ Hand capacitance $C = \frac{8}{\pi}$ μFare connected in series with an AC source of 200 volt and frequency 'f'. If the readings of the hot wire voltmeters V_1 and $V_2$are same then



(A) f = 125 Hz

(B) $f = 250\pi$Hz

(C) Current through R is 2A

(D) $V_1 = V_2 = 2000$volt

5. A circuit, containing an inductance and a resistance connected in series, has an AC source of 200V, 50 Hz connected across it. An AC current of 10A rms flows through the circuit and the power loss is measured to be 1 kW

(A) The inductance of the circuit is $\frac{\sqrt{3}}{10\pi}\text{H}$

(B) The frequency of the AC when the phase difference between the current and emf becomes $\frac{\pi}{4}$, with the above components is $\frac{50}{\sqrt{3}}\text{Hz}$

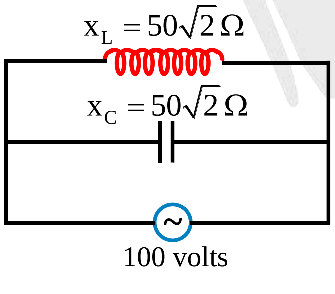
(C) The frequency of the AC when the phase difference between the current and emf becomes $\frac{\pi}{3}$, with the above components is $\frac{25}{\sqrt{3}}\text{Hz}$

(D) The frequency of the AC when the phase difference between the current and emf becomes $\frac{\pi}{4}$, with the above components is $\frac{25}{\sqrt{3}}\text{Hz}$

6. A coil, a capacitor and an AC source of voltage 24 V (rms) are connected in series. By varying the frequency of the source, a maximum rms current of 6 A is observed. If this coil is connected to a DC battery of emf 12 V and internal resistance 2Ω, then find current, through it.

(A) 2 A (B) 3 A (C) 6 A (D) 9 A

7. In an AC ciruit capacitive reactance of capacitor is $X_C = 50\sqrt{2}\,\Omega$ and inductive reactance of inductor is $X_L = 50\sqrt{2}\,\Omega$. If the source voltage is 100 volts. Then find the current passing through the source.



(A) 1 A (B) 2 A (C) 0 A (D) None of these

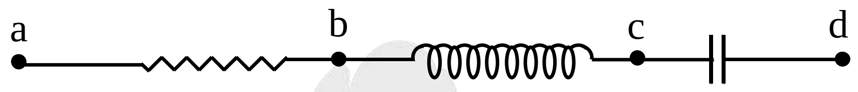
8. A DC ammeter and an AC thermal ammeter are connected to a circuit in series. When a DC is passed through the circuit, the DC ammeter shows $I_1 = 6\,A$. When an AC flows through the circuit, the AC ammeter shows $I_2 = 8\,A$. What will the difference in final readings of ammeters, if the DC and the AC flow simultaneously through the circuit ?

(A) 2 A (B) 4 A (C) 6 A (D) 8 A

9. An RLC circuit includes a 1.6 H inductor and a 250 μF capacitor rated at 400 V. The circuit is connected across a sine-wave generator whose peak voltage is 32 V. What minimum resistance must the circuit have to ensure that the capacitor voltage does not exceed its rated value when the generator is at the resonant frequency?

(A) 2.4Ω (B) 3.6Ω (C) 4.8Ω (D) 6.4Ω

10. An AC source with $V_{max} = 205\,V$ and $f = 50\,Hz$ is connected between points a and d having a resistance of $R = 40\Omega$, inductance of $L = 185\,mH$ and a capacitance of $C = 65\,\mu F$ as shown in figure. A power supply with $\Delta V_{rms} = 120\,V$ is connected between points a and d in figure.



(A) The maximum voltage between points a and b is 200V

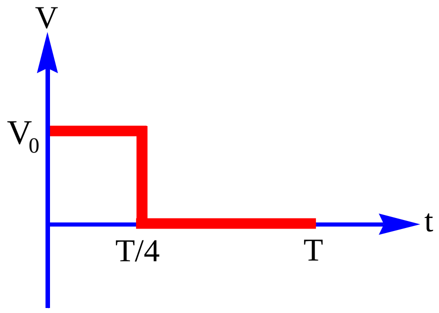
(B) The maximum voltage between points b and c is 290V

(C) The maximum voltage between points c and d is 245V

(D) The maximum voltage between points b and d is 45V

Proficiency Test-3

1 A periodic voltage V varies with time t as shown in the figure. T is the time period. The rms value of the voltage is :



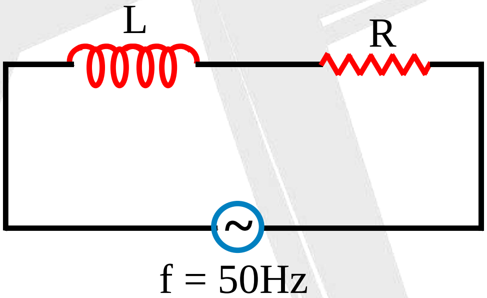
(A) $\frac{V_0}{8}$

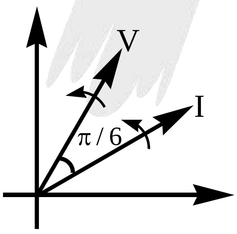
(B) $\frac{V_0}{2}$

(C) V_0

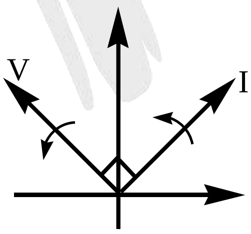
(D) $\frac{V_0}{4}$

2. Consider an ideal inductor and a resistor connected to an AC source as shown. The phasor diagram of the circuit is best represented by : $\left(L = \frac{2}{\pi}\text{mH},\ R = 0.15\ \Omega\right)$

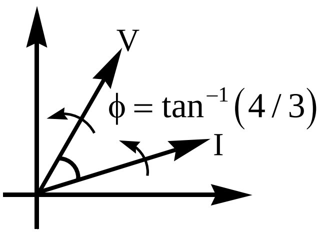




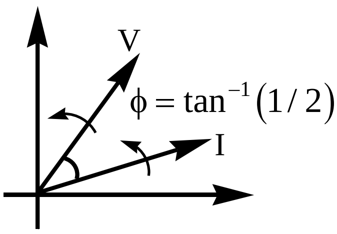
(A)



(B)

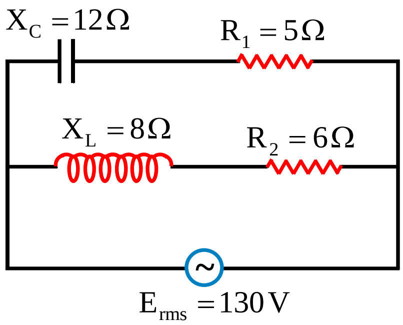


(C)

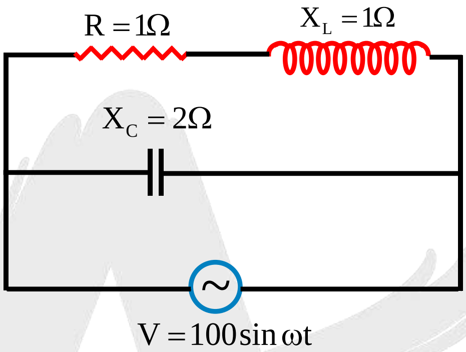


(D)

3. What is the amount of power delivered by the AC source in the circuit shown (in watt)?



4. In the given AC circuit, choose the correct statement(s)



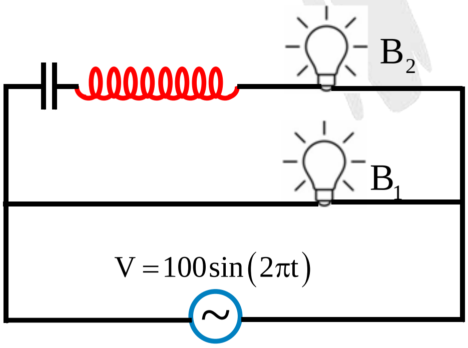
(A) Impedance of circuit is 2Ω

(B) Power factor of circuit is $\frac{1}{\sqrt{2}}$

(C) Peak value of current through resistance is $50\sqrt{2}A$

(D) Average power supplied by source is 1500 W

5. Two similar bulbs of rating (100W, $50\sqrt{2}V$) are connected in circuit as shown when frequency of source is varied, brightness of B_2 changes. It is observed that a 50 Hz frequency both the bulbs have same brightness.



Select correct alternative(s)

(A) Current in both the bulbs will be in same phase when both have same brightness

(B) Current through source will be 2A when both the bulbs have same brightness

(C) Current through source will be $2\sqrt{2}A$ when both the bulbs have same brightness

(D) B_1 will be more brighter for all frequencies except 60 Hz.

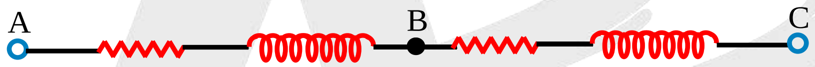
6. When a resistance R is connected in series with an element A, the electric current is found to be lagging behind the voltage by angle $30°$. When the same resistance is connected in series with element B, current leads by $60°$. When R, A, B are connected in series, the current now leads voltage by ϕ. Find ϕ? (assume same AC source is used in all cases)

(A) $\phi = \tan^{-1}\left(\frac{2}{\sqrt{3}}\right)$ (B) $\phi = \tan^{-1}\left(\frac{\sqrt{2}}{3}\right)$ (C) $\phi = \tan^{-1}\left(\frac{3}{\sqrt{2}}\right)$ (D) $\phi = \tan^{-1}\left(\frac{\sqrt{3}}{2}\right)$

7. A coil with inductance L and resistance R is connected to an alternating source. The capacity of a capacitor connected in series with the coil such that active power of circuit does not change is given by $C = \frac{1}{n\omega^2 L}$. Find value of n.

(A) 2 (B) 4 (C) 3 (D) 1

8. If an AC voltage 100 V is applied between points A and B, then current of 1 A and phase difference between current and voltage will be $\Delta\phi = 37°$. If the same voltage is applied between pionts B and C, then current of 5 A and $\Delta\phi = 53°$. What will be the impedance in the chain, if the same voltage is applied between points A and C? Round off to nearest integer.

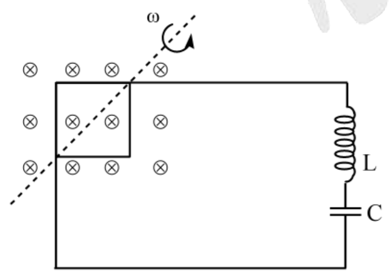


(A) 88 Ω (B) 91 Ω (C) 101 Ω (D) 119 Ω

9. In a series LCR circuit, the frequencies at which the current amplitude falls to $\frac{1}{\sqrt{2}}$ of the current at resonance are separated by an interval equal to

(A) $\frac{R}{\pi L}$ (B) $\frac{R}{2\pi L}$ (C) $\frac{2R}{\pi L}$ (D) $\frac{3R}{2\pi L}$

10. In the given arrangement the square loop of area $10 cm^2$ rotates with an angular velocity ω about its diagonal. The loop is connected to a inductance of L = 100mH. I and a capacitance of 10 mF in series. The lead wires have a net resistance of 10Ω. Given that $B = 0.1T$ and $\omega = 63 rad s^{-1}$, then



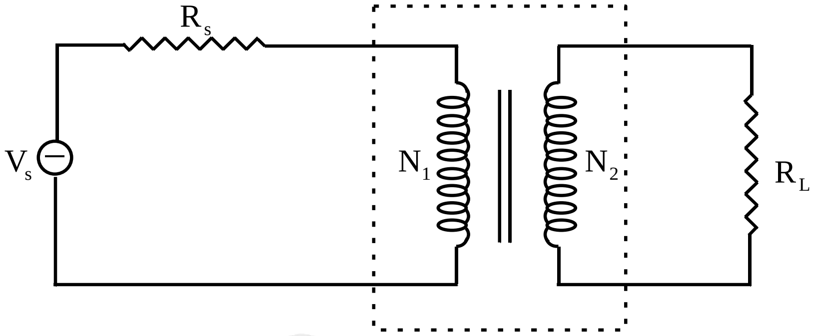
(A) The r.m.s. current is 4×10^{-4} A

(B) The Energy dissipated in 50 sec is 8.12×10^{-5} J

(C) If the current is in phase with voltage, then the frequency of rotation of the coil is 31.6 rad/s

(D) If the current is in phase with voltage, then the frequency of rotation of the coil is 15.8 rad/s

11. In the transformer shown in figure, the load resistor is 50Ω. The turns ratio $N_1 : N_2$ is 10:2 and the source voltage is 200 V (r.m.s). If a voltmeter across the load measures 25 V (r.m.s), what is the source resistance R_s in Ω



EXERCISE – 1

1	2	3	4	5	6	7	8	9	10
2	D	2	200	C	B	60	5	1	3
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
2	3	4	2	A	C	B	17	B	A
21									
C									

EXERCISE – 2

1	2	3	4	5	6	7	8	9	10
C	A	30	A	A	A	100	10	D	B
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
A	D	B	B	B	A	D	C	B	D

EXERCISE – 3

1	2	3	4	5	6	7	8	9	10
6	10	C	10	C	A	A	200	B	A
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
D	D	C	A	D	B	ACD	B	D	D

EXERCISE – 4

1	2	3	4	5	6	7	8	9	10
C	B	B	D	BC	BC	BC	BCD	A	C
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
C	C	BD	AC	BC	5	6	2	C	400
21	**(I)** – B; **(II)** – C; **(III)** – A; **(IV)** – CD; **(V)** – D								
22	**(I)** – D; **(II)** – B; **(III)** – A; **(IV)** – D								

EXERCISE – 5

1	2	3	4	5	6	7	8	9	10
C	B	2	C	B	B	BC	ABD	AB	BD
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
BD	AB	AD	BC	BD	AB	ABC	ABCD	C	B
21	**22**	**23**	**24**	**25**	**26**				
10	AC	AC	2	ABCD	ABCD				

Proficiency Test-1

1	2	3	4	5	6	7	8	9	10
10	A	A	A	D	D	B	2	ABC	AC

Proficiency Test-2

1	2	3	4	5	6	7	8	9	10
C	1000	D	AC	AB	A	C	B	D	ABCD

Proficiency Test-3

1	2	3	4	5	6	7	8	9	10	11
B	C	1514	AC	AC	A	A	D	B	ABC	750