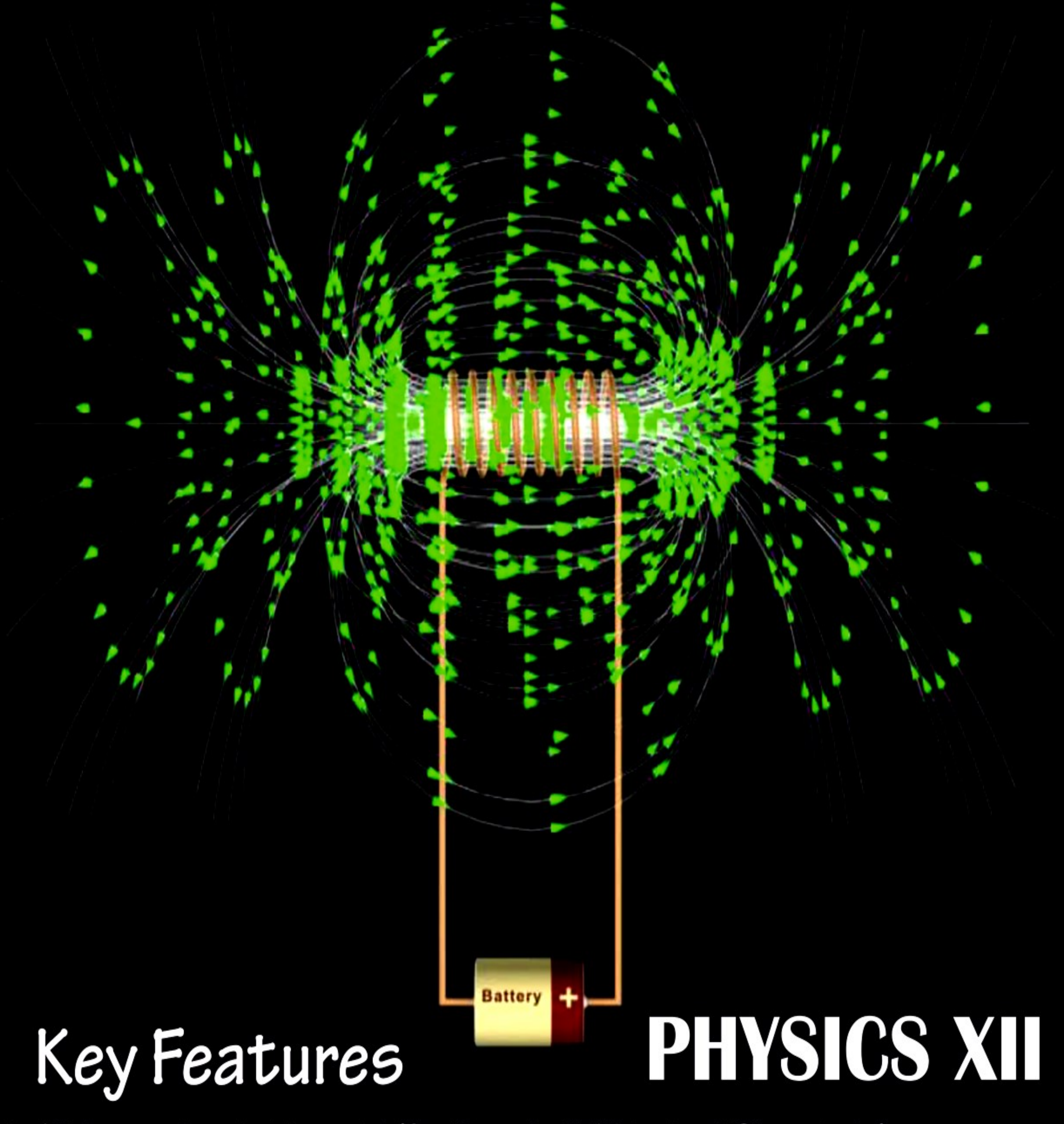
ELECTROMAGNETIC INDUCTION AND ALTERNATING CURRENTS



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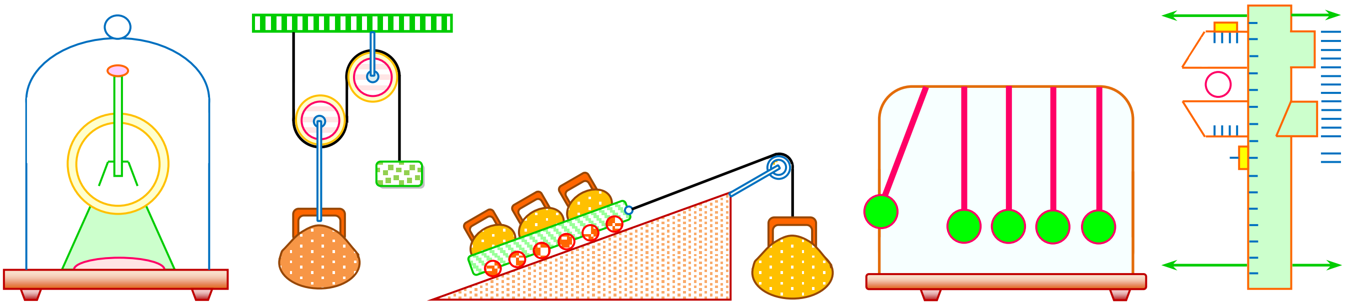

PHYSICS BOOKLET FOR JEE NEET & BOARDS

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TRANSIENT AND ALTERNATING CURRENT CIRCUIT

1 INTRODUCTION

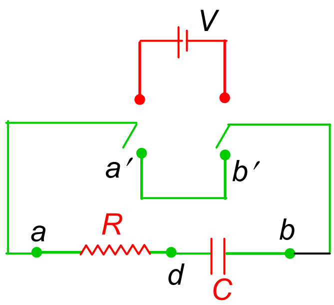
In case of circuit having pure resistance only with direct current source, the current reaches its steady state value almost instantaneously. But when capacitor and inductor are part of the circuit, it takes some time. As capacitor is charged, it oppose the flow of current and similarly any change in current is opposed by the inductor.

2 R – C CIRCUIT

2.1 CHARGING OF A CAPACITOR

The circuit diagram for charging and discharging a capacitor is given here. A resistor *R* and a capacitor *C* are connected with a double throw switch, by which the battery *V* can be connected in the circuit.

Initially, the capacitor is uncharged. When the switch is thrown to include the battery in the circuit, charge flows to the capacitor through the resistance *R*. This is called the charging current. The current continues till the voltage V_{db} across the capacitor is equal to the voltage *V* of the battery. If during the charging process the instantaneous current is *I* at an instant as shown, and the potential difference between *a* and *d*, and that between *d* and *b* are V_{ad} and V_{db} respectively, then



$$V_{ad} = iR \text{ and } V_{db} = \frac{q}{C} \quad \text{... (i)}$$

where *q* is the charge on the capacitor at that instant

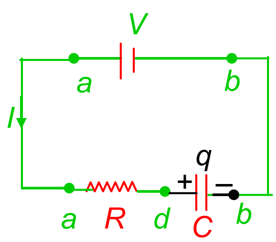
$$V_{ab} = V = V_{ad} + V_{db} = iR + \frac{q}{C} \quad \text{... (ii)}$$

where *V* is the constant voltage of the battery.

$$i = \frac{V}{R} - \frac{q}{RC} \quad \text{... (ii)}$$

Initially, as soon as the connection is made there is a current

$I_0 = \frac{V}{R}$, since the charge on the capacitance is zero



As the charging continues, *q* increases and *i* decreases and finally becomes zero. At that time,

$$\frac{V}{R} - \frac{q}{RC} = 0$$

$q = CV = Q_0$, where Q_0 is the final charge on the capacitor.

In equation (iii), i may be written as $\frac{dq}{dt}$, so

$$\frac{dq}{dt}=\frac{V}{R}-\frac{q}{RC}$$

$$\frac{dq}{VC-q}=\frac{dt}{RC}$$

Integrating both sides,
we have

$$\int_0^q \frac{dq}{VC-q}=\int_0^t \frac{dt}{RC}$$

$$-\left[\ln(VC-q)\right]_0^q=\frac{1}{RC}[t]_0^t$$

or, $$-\ln\left(\frac{VC-q}{VC}\right)=\frac{t}{RC}$$

or, $$\left(1-\frac{q}{VC}\right)=e^{\frac{-t}{RC}}$$

or, $$\frac{q}{CV}=\left(1-e^{\frac{-t}{RC}}\right)$$

or, $$q=CV\left(1-e^{-\frac{t}{RC}}\right)$$

or, $$q=Q_0\left(1-e^{\frac{-t}{RC}}\right) \qquad \text{... (1)}$$

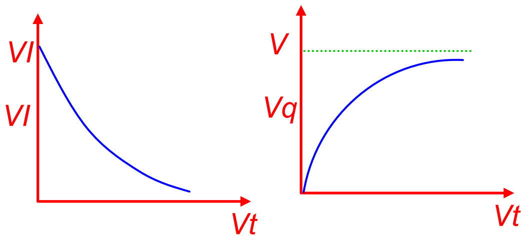
Differentiating with respect to time.

$$i=\frac{dq}{dt}=\frac{d}{dt}[VC(1-e^{-t/RC})]=\frac{V}{R}e^{-t/RC}=I_0e^{-t/RC}$$

We see that the charge and current both follow the exponential law.

When time $t=RC, q=Q_0\left(1-\frac{1}{e}\right)$ and $i=\frac{I_0}{e}$

This means that at $t = RC$, the charge has increased to $1-\frac{1}{e}$ = 63% of its final value. The current has decreased to $\frac{1}{e}$ = 37% of its initial value. The time $t = RC$ is called the **time constant** of the circuit.



The half-life of the circuit t_h is the time at which the current is half its initial value and the charge on the capacitor is half its final value $t_h=RCln2=0.693RC$

2.2 DISCHARGING OF A CAPACITOR

If in the circuit, the switch is thrown to the down position, the battery is removed from the circuit and the capacitor is discharged through resistance R.

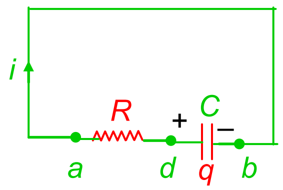
When the switch is thrown, the charge on the capacitor is Q_0 and the potential difference V_{ab} is zero.

Thus $V_{ad}+V_{db}=0$

$$V_{ad}=-V_{db}=I_0R$$

$$I_0=\frac{Q_0}{RC}=\frac{V_0}{R}$$

when $t=0, q=Q_0$ and $I_0=\frac{Q_0}{RC}=\frac{V_0}{R}$, where V_0 is the initial potential difference across the capacitor.



When the capacitor is discharging both the charge and the current decrease. Let i be the current and q be the charge on the capacitor at any instant. Then

$$\frac{q}{C}-iR=0$$

$$\Rightarrow \quad \frac{q}{C}-\left(-\frac{dq}{dt}\right)R=0$$

$$\Rightarrow \quad \frac{dq}{q}=-\frac{dt}{RC}$$

$$\ln q=-\frac{t}{RC}+\text{Constant}$$

At $t=0, q=Q_0$

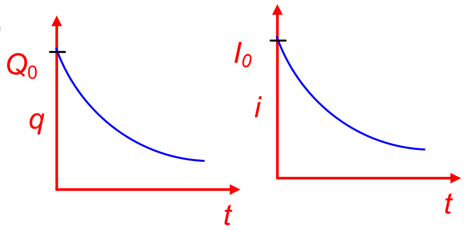
Constant $= lnQ_0$

$$lnq=-\frac{t}{RC}+lnQ_0;\ ln\frac{q}{Q_0}=-\frac{t}{RC}$$

$$q=Q_0e^{-t/RC} \quad \ldots (2)$$

Current $i=-\frac{dq}{dt}=\frac{Q_0}{RC}e^{-t/RC}$

$$=I_0e^{-t/RC}$$



$$i=I_0e^{-t/RC} \quad \ldots (3)$$

At time $t=CR, q=\frac{Q_0}{e}$ $\quad i=\frac{I_0}{e}$

Illustration 1

Question: **A capacitor of a capacity 0.1 pF is first charged and then discharged through a resistance of 10 megaohm. The time in which the potential will fall to half its original value is x log$_e$2 sec. Find x**

Solution: The charge at any instant

$$q=q_0e^{-t/RC},\ t=RC\log_e\left(\frac{q_0}{q}\right)$$

If V is the potential of the capacitor after time t and V_0 is the initial potential, then

$$\frac{q_0}{q}=\frac{CV_0}{CV}=\frac{V_0}{V}$$

$$t=RC\quad \log_e\left(\frac{V_0}{V}\right)=10^7\times0.1\times10^{-6}\log_e 2=1\times\log_e 2$$

$x = \mathbf{1}$

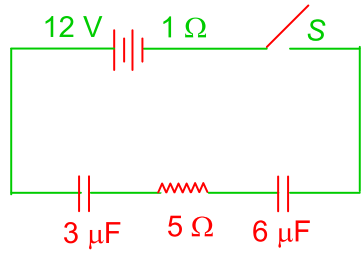
Illustration 2

Question: **Two capacitors are charged in series by a 12 V battery.**
What is the time constant of the circuit?

Solution: Effective capacitance $= \frac{6\times 3}{6+3} = 2\mu F$

Total resistance $= 1 + 5 = 6\Omega$

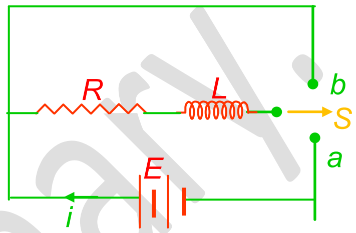
Time constant $= CR = 2\times 10^{-6}\times 6 = \mathbf{12\mu s}$



3 GROWTH AND DECAY OF CURRENT IN L – R CIRCUIT

3.1 GROWTH OF CURRENT

Consider a circuit containing a resistance *R*, an inductance *L*, a two way key and a battery of e.m.f. *E* connected in series as shown in figure. When the switch *S* is connected to *a*, the current in the circuit grows from zero value. The inductor opposes the growth of the current. This is due to the fact that when the current grows through inductor, a back e.m.f. is developed which opposes the growth of current in the circuit. So the rate of growth of current is reduced. During the growth of current in the circuit, let *i* be the current in the circuit at any instant *t*. Using Kirchoffs voltage law in the circuit we obtain



$$E - L\frac{di}{dt} = Ri$$

or $$E - Ri = \frac{Ldi}{dt}$$

or $$\frac{di}{E - Ri} = \frac{dt}{L}$$

Multiplying by – *R* on both the sides, we get $\frac{-R\,di}{E - Ri} = \frac{-Rdt}{L}$

Integrating the above equation, we have

$$\log_e(E - Ri) = -\frac{R}{L}t + A \quad \ldots \text{(i)}$$

Where *A* is integration constant. The value of this constant can be obtained by applying the condition that current *i* is zero just at start i.e. at $t = 0$. Hence

$$\log_e E = 0 + A$$

or $$A = \log_e E \quad \ldots \text{(ii)}$$

Substituting the value of *A* from equation (ii) in equation (i) we get

$$\log_e(E - Ri) = -\frac{R}{L}t + \log_e E$$

or $$\log_e\left(\frac{E - Ri}{E}\right) = -\frac{R}{L}t$$

or $$\left(\frac{E - Ri}{E}\right) = \exp\left(-\frac{R}{L}t\right)$$

or $$1 - \frac{Ri}{E} = \exp\left(-\frac{R}{L}t\right)$$

or $$\frac{Ri}{E} = \left\{1 - \exp\left(-\frac{R}{L}t\right)\right\}$$

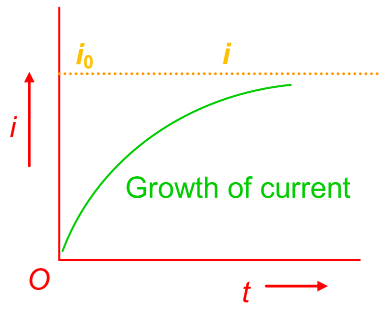
∴ $$i = \frac{E}{R}\left\{1 - \exp\left(-\frac{R}{L}t\right)\right\}$$

The maximum current in the circuit $i_0 = E/R$. So $i = i_0\left\{1 - \exp\left(-\frac{R}{L}t\right)\right\}$ *… (4)*

Equation (4) gives the current in the circuit at any instant t. It is obvious from equation (4) that $i = i_0$, when

$$\exp.\left(-\frac{R}{L}t\right) = 0 \text{ i.e., at } t = \infty$$

Hence the current never attains the value i_0 but it approaches it asymptotically. A graph between current and time is shown in figure.



☞ We observe the following points

(i) When $t = (L/R)$ then

$$i = i_0\left\{1 - \exp.\left(-\frac{R}{L}\times\frac{L}{R}\right)\right\}$$

$$= i_0\{1 - \exp.(-1)\} = i_0\left(1 - \frac{1}{e}\right)$$

$$= 0.63\, i_0$$

Thus after an interval of (L/R) second, the current reaches to a value which is 63% of the maximum current. The value of (L/R) is known as **time constant** of the circuit and is represented by τ. Thus the time constant of a circuit may be defined as the time in which the current rises from zero to 63% of its final value. In terms of τ,

$$i = i_0\,(1 - e^{-t/\tau})$$

(ii) The rate of growth of current (di/dt) is given by

$$\frac{di}{dt} = \frac{d}{dt}\left[i_0\left\{1 - \exp\left(-\frac{R}{L}t\right)\right\}\right]$$

$$\Rightarrow \frac{di}{dt} = i_0\left(\frac{R}{L}\right)\exp\left(-\frac{R}{L}t\right) \qquad \textit{... (5)}$$

From equation (4), $\exp.\left(-\frac{R}{L}t\right) = \frac{i_0 - i}{i_0}$

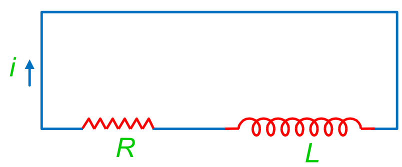
$$\therefore \quad \frac{di}{dt} = i_0\left(\frac{R}{L}\right)\left(\frac{i_0 - i}{i_0}\right) = \frac{R}{L}(i_0 - i) \qquad \textit{... (6)}$$

This shows that the rate of growth of the current decreases as i tends to i_0. For any other value of current, it depends upon the value of R/L. Thus greater is the value of time constant, smaller will be the rate of growth of current.

3.2 DECAY OF CURRENT

Let the circuit be disconnected from battery and switch S is thrown to point b in the figure. The current now begins to fall. In the absence of inductance, the current would have fallen from maximum i_0 to zero almost instantaneously. But due to the presence of inductance, which opposes the decay of current, the rate of decay of current is reduced.

Suppose during the decay of current, i be the value of current at any instant t. Using Kirchhoff's voltage law in the circuit we get



$$-L\frac{di}{dt} = Ri$$

or $$\frac{di}{dt} = -\frac{R}{L}i$$

Integrating this expression, we get

$$\log_e i = -\frac{R}{L}t + B$$

Where B is constant of integration. The value of B can be obtained by applying the condition that when $t = 0$, $i = i_0$

$\therefore \quad \log_e i_0 = B$

Substituting the value of B, we get

$$\log_e i = -\frac{R}{L}t + \log_e i_0$$

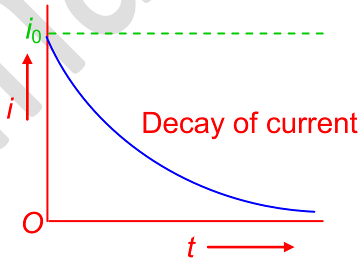
or $$\log_e \frac{i}{i_0} = -\frac{R}{L}t$$

or $$(i/i_0) = \exp\left(-\frac{R}{L}t\right)$$

or $$i = i_0 \exp\left(-\frac{R}{L}t\right) = i_0 \exp(-t/\tau) \quad \text{... (7)}$$

where $\tau = L/R$ = inductive time constant of the circuit.

It is obvious from equation that the current in the circuit decays exponentially as shown in figure.



☞ We observe the following points

(i) After $t = L/R$, the current in the circuit is given by

$$i = i_0 \exp\left(-\frac{R}{L}\times\frac{L}{R}\right) = i_0 \exp.(-1)$$

$= (i_0/e) = i_0/2.718 = 0.37\, i_0$

So after a time (L/R) second, the current reduces to 37% of the maximum current i_0. (L/R) is known as time constant τ . This is defined as the time during which the current decays to 37% of the maximum current during decay.

(ii) The rate of decay of current is given by

$$\frac{di}{dt} = \frac{d}{dt}\left\{i_0 \exp\left(-\frac{R}{L}t\right)\right\}$$

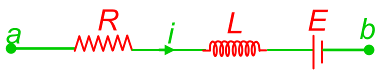
$\Rightarrow$ $$\frac{di}{dt} = \frac{R}{L} i_0 \exp\left(-\frac{R}{L}t\right) = -\frac{R}{L}i \quad \text{... (8)}$$

or $$-\frac{di}{dt} = \frac{R}{L}i$$

This equation shows that when L is small, the rate of decay of current will be large i.e., the current will decay out more rapidly.

Illustration 3

Question: **In the circuit diagram shown in figure. R = 10 Ω. L = 5 H, E = 20 V and i = 2A. This current is decreasing at a rate of –1.0 A/s. Find V_{ab} at this instant.**



Solution: P.D. across inductor,

$$V_L = L\frac{di}{dt} = (5)(-1.0) = -5 \text{ volt}$$

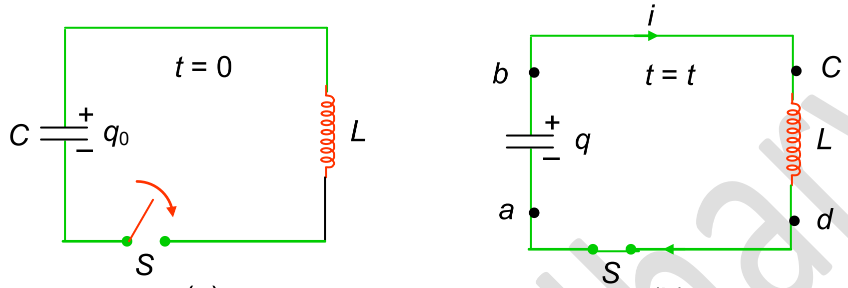
Now, $V_a - iR - V_L - E = V_b$

$\therefore \quad V_{ab} = V_a - V_b = E + iR + V_L$

$= 20 + (2)(10) - 5 = \mathbf{35\ volt}$

4 OSCILLATION IN L – C CIRCUIT

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



(a) (b)

Let us now derive an equation for the oscillations of charge and current in an L-C circuit.

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

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

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

The potential difference across capacitor = potential difference across inductor, or

$$V_b - V_a = V_c - V_d$$

$$\therefore \quad \frac{q}{C} = L\left(\frac{di}{dt}\right) \qquad \ldots \text{(i)}$$

Now, as the charge is decreasing, $i = \left(\frac{-dq}{dt}\right)$ or $\frac{di}{dt} = -\frac{d^2q}{dt^2}$

Substituting in equation (i), we get $\frac{q}{C} = -L\left(\frac{d^2q}{dt^2}\right)$

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

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

$$\text{Here } \omega = \frac{1}{\sqrt{LC}} \qquad \ldots \text{(iii)}$$

The general solution of equation (ii), is

$$q = q_0 \cos(\omega t \pm \phi) \qquad \ldots (9)$$

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

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

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

$$q = q_0 \cos \omega t, \text{ then} \quad \dots (10)$$

$$i = \frac{dq}{dt} = -q_0\omega \sin\omega t \quad \dots (11)$$

and $$\frac{di}{dt} = -q_0\omega^2 \cos\omega t \quad \dots (12)$$

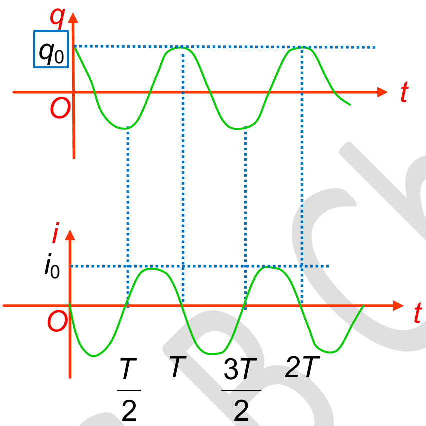
Potential energy in the capacitor

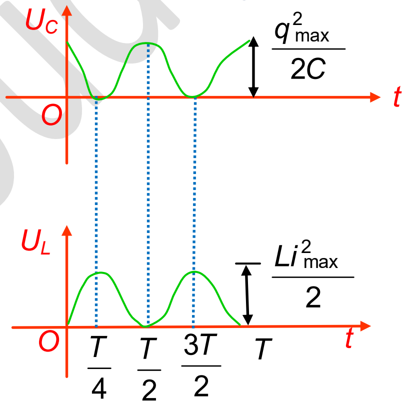
$$U_C = \frac{1}{2}\frac{q^2}{C} = \frac{1}{2}\frac{q_0^2}{C}\cos^2 \omega t = \frac{q_0^2}{4C}(1+\cos 2\omega t) \quad \dots (13)$$

Potential energy in the inductor

$$U_L = \frac{1}{2}LI^2 = \frac{1}{2}\frac{q_0^2}{C}\sin^2 \omega t = \frac{q_0^2}{4C}(1-\cos 2\omega t) \quad \dots (14)$$

Thus potential energy stored in the capacitor and that in the inductor also oscillates between maximum value and zero with double the frequency. All these quantities are shown in the figures that follows

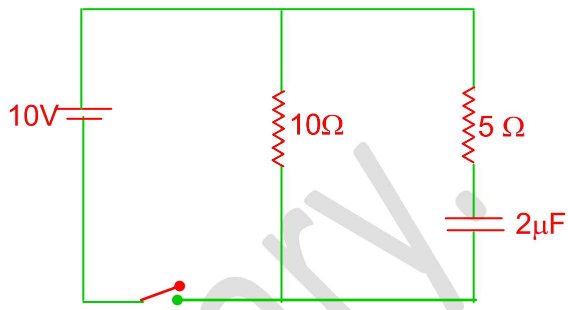




PROFICIENCY TEST - I

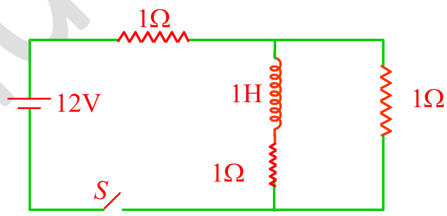
The following questions deal with the basic concepts of this section. Answer the following briefly. Go to the next section only if your score is at least 80%. Do not consult the Study Material while attempting these questions.

1. For the circuit shown above the switch is closed at $t = 0$, find
(a) the initial current through each resistor.
(b) steady state current through each resistor.
(c) final energy stored in the capacitor.



2. A solenoid has an inductance of 10 henry and *a* resistance of 2 ohms. It is connected to a 10 volt battery. The time taken for the magnetic energy to reach $\frac{1}{4}^{th}$ of its maximum value is $x \log_e 2$ sec. Find the value of x?

3. For the circuit shown, the switch S is closed at $t = 0$, find
(a) the initial current through each resistor.
(b) steady state current through each resistor
(c) final energy stored in the inductor.



4. (a) In a R-L series circuit, the value of resistance is doubled. What is the change in the time constant?
(b) In a R-C series circuit, the value of resistance is doubled, what is the change in time constant?

5. A charged capacitor has energy $E = 10$ μJ stored in it. It is connected to an inductor. What is the maximum energy stored in the inductor?

ANSWERS TO PROFICIENCY TEST - I

1. (a) 1A, 2A
   (b) 1 A, 0
   (c) 100 μJ

2. 5

3. (a) 6 A, 0, 6A
   (b) 8A, 4A, 4A
   (c) 8 J

4. (a) becomes half
   (b) becomes double

5. 10 μJ

5 INTRODUCTION: ON ALTERNATING CURRENT

Until now, we have studied only circuits with direct current (dc)- which flows only in one direction. The primary source of emf in such circuit is a battery. When a resistance is connected across the terminals of the battery, a current is established in the circuit, which flows in a unique direction from the positive terminal to the negative terminal via the external resistance.

But most of the electric power generated and used in the world is in the form of **alternating current (ac)**, the magnitude of which changes continuously with time and direction is reversed periodically as shown in figure and it is given by

$$i = \frac{e}{R} = \frac{e_0}{R}\, Sin\, wt = i_0\, Sin\, wt \qquad \dots (15)$$

Here i is instantaneous value of current i.e. magnitude of current at any instant of time and i_0 is the maximum value of current which is called **peak current** or the **current amplitude** and the current repeats its value after each time interval

$T = \frac{2\pi}{\omega}$ as shown in figure. This time interval is called the **time period.**

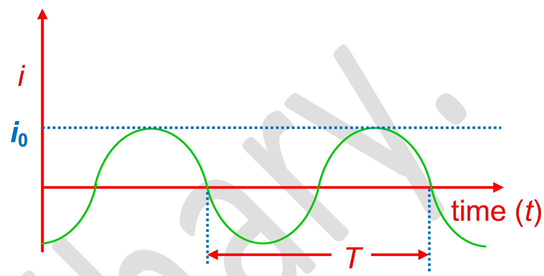


Fig. (a)

The current is positive for half the time period and negative for remaining half period. It means direction of current is reversed after each half time period. The frequency of ac in India is 50 Hz.

An alternating voltage is given by

$$V = V_0/\sqrt{2} \qquad \dots (16)$$

It also varies alternatively as shown in the figure (b), where V is instantaneous voltage and V_0 is peak voltage. It is produced by ac generator also called as ac dynamo.

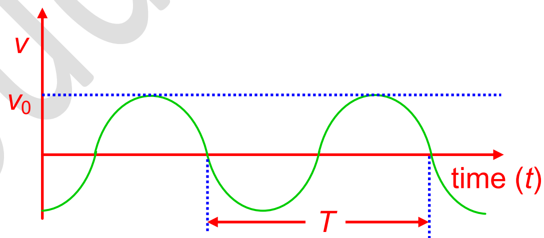
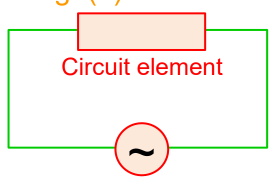


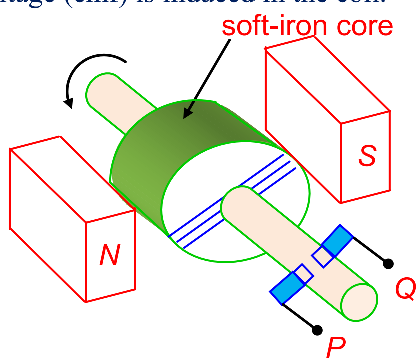
Fig. (b)

AC Circuit: An ac circuit consists of circuit element i.e., resistor, capacitor, inductor or any combination of these and a generator that provides the alternating current as shown in figure. The ac source is represented by symbol —(~)— in the circuit.



6 AC GENERATOR

The basic principle of the ac generator is a direct consequence of **Faraday's laws of electro magnetic induction**. When a coil of N turns and area of cross section A is rotated in a uniform magnetic field B with constant angular velocity as shown in figure, a sinusoidal voltage (emf) is induced in the coil.



The armature rotates about its axis between the pole – pieces of a magnet, known as field magnet (N, S).
Generally, this is an electromagnet. When a permanent magnet is used, the machine is called magneto. However a higher peak e.m.f. needs larger magnetic field and hence necessitates the use of electromagnet. The current necessary for the field magnet (when it is electromagnet) is supplied by the generator itself through a feedbac system.

7 AVERAGE AND RMS VALUE OF ALTERNATING CURRENT

7.1 AVERAGE CURRENT (MEAN CURRENT)

As we know an alternating current is given by

$i = i_0 \sin(\omega t + \phi)$ ... (i)

The mean or average value of ac over any time t is given by

$$i_{avg} = \frac{\int_0^t i\,dt}{\int_0^t dt}$$

Using equation (i)

$$i_{avg} = \frac{\int_0^t i_0 \sin(\omega t + \phi)}{\int_0^t dt}$$

In one complete cycle average current

$$i_{avg} = -\frac{i_0}{T}\left[\frac{\cos(\omega t + \phi)}{\omega}\right]_0^T$$

$$= -\frac{i_0}{T}\left[\frac{\cos(\omega T + \phi) - \cos\phi}{\omega}\right]$$

$$= -\frac{i_0}{T}\left[\frac{\cos(2\pi + \phi) - \cos\phi}{\omega}\right] = 0 \quad \text{(as } \omega T = 2\pi\text{)}$$

Since ac is positive during the first half cycle and negative during the other half cycle so i_{avg} will be zero for long time also. Hence the dc instrument will indicate zero deflection when connected to a branch carrying ac current. So it is defined for either positive half cycle or negative half cycle. Now to find mean value of current $i = i_0 \sin\omega t$ for positive half cycle. i.e. from $t = 0$ to $t = T/2$

$$i_{avg} = \frac{\int_0^{T/2} i_0 \sin\omega t}{\int_0^{T/2} dt} = \frac{2i_0}{\pi} \approx 0.637\, i_0 \quad \text{... (19)}$$

Similarly $v_{avg} = \frac{2v_0}{\pi} \approx 0.637\, v_0$ ... (20)

7.2 R.M.S. VALUE OF ALTERNATING CURRENT

The notation rms refers to root mean square, which is given by square root of mean of square current.

i.e., $i_{rms} = \sqrt{i^2_{avg}}$

$$i^2_{avg} = \frac{\int_0^T i^2 dt}{\int_0^T dt} = \frac{1}{T}\int_0^T i_0^2 \sin^2(\omega t + \phi)dt = \frac{i_0^2}{2T}\int_0^T [1 - \cos 2(\omega t + \phi)]\,dt$$

$$= \frac{i_0^2}{2T}\left[t - \frac{\sin 2(\omega t + \phi)}{2\omega}\right]_0^T$$

$$= \frac{i_0^2}{2T}\left[T - \frac{\sin(4\pi + 2\phi) - \sin 2\phi}{2\omega}\right] = \frac{i_0^2}{2}$$

$i_{rms} = \frac{i_0}{\sqrt{2}} \approx 0.707\, i_0$ ... (21)

Similarly the rms voltage is given by $V_{rms} = \frac{V_0}{\sqrt{2}} \approx 0.707\, v_0$ ... (22)

The significance of rms current and rms voltage may be shown by considering a resistance R carrying a current $i = i_0 \sin(\omega t + \phi)$

The voltage across the resistor will be

$$V = Ri = (i_0 R)\sin(\omega t + \phi)$$

The thermal energy developed in the resistor during the time t to $t + dt$ is

$$i^2 R\, dt = i_0^2 R \sin^2(\omega t + \phi)\, dt$$

The thermal energy developed in one time period is

$$U = \int_0^T i^2 R dt = R\int_0^T i_0^2 \sin^2(\omega t + \phi)\, dt$$

$$= RT\left[\frac{1}{T}\int_0^T i_0^2 \sin^2(\omega t + \phi) dt\right] = i_{rms}^2 RT \quad \text{... (23)}$$

It means the root mean square value of ac is that value of steady current, which would generate the same amount of heat in a given resistance in a given time.

So in ac circuits, current and ac voltage are measured in terms of their rms values. Like when we say that the house hold supply is 220 V ac it means the rms value is 220 V and peak value is $220\sqrt{2} = 311$ V.

Illustration 4

Question: **If the voltage (in volts) in an ac circuit is represented by the equation,**

$V = 220\sqrt{2}\sin(314t - \phi)$, (where t is in seconds)

Calculate (a) peak and rms value of the voltage (b) frequency of ac.

Solution: (a) For *ac* voltage,

$$V = V_0 \sin(\omega t - \phi)$$

The peak value

$$V_0 = 220\sqrt{2} = 311 \text{ V},$$

The rms value of voltage

$$V_{rms} = \frac{V_0}{\sqrt{2}}; \; V_{rms} = \mathbf{220\ V}$$

(b) As $\omega = 2\pi f$, $2\pi f = 314$

i.e., $f = \frac{314}{2\times\pi}$ = **50 Hz**

Illustration 5

Question: **The electric current in a circuit is given by $i = i_0 (t/T)$ for some time. Calculate the rms current for the period $t = 0$ to $t = T$ for $i_0 = 20\sqrt{3}$ A.**

Solution: The mean square current is

$$\left(i^2\right)_{avg} = \frac{1}{T}\int_0^T i_0^2 (t/T)^2\, dt = \frac{i_0^2}{T^3}\int_0^T t^2 dt = \frac{i_0^2}{3}$$

Thus, the rms current is

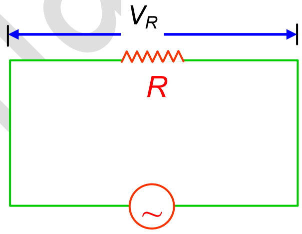
$$i_{rms} = \sqrt{i_{avg.}^2} = \frac{i_0}{\sqrt{3}} = 20 \text{ A}$$

8 SERIES AC CIRCUIT

8.1 WHEN ONLY RESISTANCE IS IN AC CIRCUIT

Consider a simple ac circuit consisting of a resistor of resistance R and an ac generator, as shown in the figure.

According to Kirchhoff's loop law at any instant, the algebraic sum of the potential difference around a closed loop in a circuit must be zero.



$$\varepsilon - V_R = 0$$

$$\varepsilon - i_R R = 0$$

$$\varepsilon_0 \sin\omega t - i_R R = 0$$

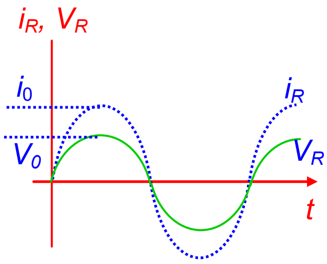
$$i_R = \frac{\varepsilon_0}{R}\sin\omega t = i_0 \sin\omega t \quad \text{.... (i)}$$

where i_0 is the maximum current. $i_0 = \frac{\varepsilon_0}{R}$

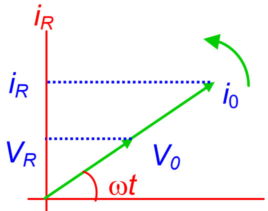
From above equations, we see that the instantaneous voltage drop across the resistor is

$$V_R = i_0 R \sin\omega t \quad \text{... (ii)}$$

We see in equation (i) & (ii), i_R and V_R both vary as sin ωt and reach their maximum values at the same time as shown in figure (a), they are said to be in phase. A phasor diagram is used to represent phase relationships. The length of the arrows correspond to V_0 and i_0. The projections of the arrows onto the vertical axis give V_R and i_R. In case of the single-loop resistive circuit, the current and voltage phasors lie along the same line, as shown in figure (b), because **i_R and V_R are in phase**.



Wave diagram
Fig. (a)

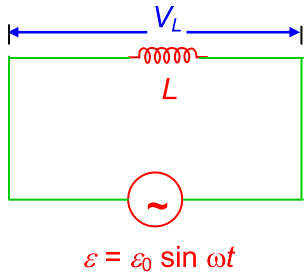


Phasor diagram
Fig. (b)

8.2 WHEN ONLY INDUCTOR IS IN AN AC CIRCUIT

Now consider an ac circuit consisting only of an inductor of inductance L connected to the terminals of an ac generator, as shown in the figure. The induced emf across the inductor is given by Ldi/dt. On applying Kirchhoff's loop rule to the circuit

$$\varepsilon - V_L = 0 \Rightarrow \varepsilon - L\frac{di}{dt} = 0$$



When we rearrange this equation and substitute $\varepsilon = \varepsilon_0 \sin \omega t$, we get

$$L\frac{di}{dt} = \varepsilon_0 \sin \omega t \qquad \text{... (iii)}$$

Integration of this expression gives the current as a function of time

$$i_L = \frac{\varepsilon_0}{L}\int \sin\omega t\, dt = -\frac{\varepsilon_0}{\omega L}\cos\omega t + C$$

For average value of current over one time period to be zero, $C = 0$

$$\therefore \qquad i_L = -\frac{\varepsilon_0}{\omega L}\cos \omega t$$

When we use the trigonometric identity $\cos \omega t = -\sin(\omega t - \pi/2)$, we can express equation as

$$i_L = \frac{\varepsilon_0}{\omega L}\sin\left(\omega t - \frac{\pi}{2}\right) \qquad \text{... (iv)}$$

From equation (iv) , we see that the current reaches its maximum values when $\cos \omega t = 1$.

$$i_0 = \frac{\varepsilon_0}{\omega L} = \frac{\varepsilon_0}{X_L} \qquad \text{... (v)}$$

where the quantity X_L, called the inductive reactance, is

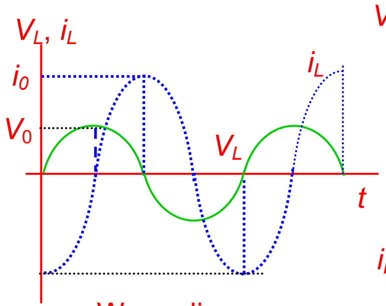
$$X_L = \omega L \qquad \text{... (24)}$$

The expression for the rms current is similar to equation (v), with ε_0 replaced by ε_{rms}.
Inductive reactance, like resistance, has unit of ohm.

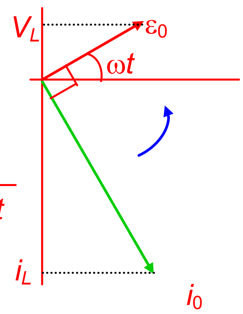
$$V_L = L\frac{di}{dt} = \varepsilon_0 \sin \omega t = I_0 X_L \sin \omega t \qquad \text{... (25)}$$

We can think of equation (v) as Ohm's law for an inductive circuit.

On comparing result of equation (iv) with equation (iii), we can see that **the current and voltage are out of phase with each other by $\pi/2$ rad, or 90°**. A plot of voltage and current versus time is given in figure (a). The voltage reaches its maximum value one quarter of an oscillation period before the current reaches its maximum value. The corresponding phasor diagram for this circuit is shown in figure (b). Thus, we see that for a sinusoidal applied voltage, the current in an inductor always lags behind the voltage across the inductor by 90°.



Wave diagram
Fig. (a)



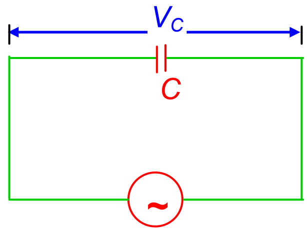
Phasor diagram
Fig. (b)

8.3 WHEN ONLY CAPACITOR IS IN AN AC CIRCUIT

Figure shows an ac circuit consisting of a capacitor of capacitance C connected across the terminals of an ac generator. On applying Kirchhoff's loop rule to this circuit we get

$$\varepsilon - V_C = 0$$

$$V_C = \varepsilon = \varepsilon_0 \sin \omega t \qquad \text{...(vi)}$$



where V_C is the instantaneous voltage drop across the capacitor. From the definition of capacitance, $V_C = Q/C$, and this value for V_C substituted into equation gives

$$Q = C\varepsilon_0 \sin \omega t$$

Since $i = dQ/dt$, on differentiating above equation gives the instantaneous current in the circuit.

$$i_C = \frac{dQ}{dt} = C\varepsilon_0\omega \cos\omega t$$

Here again we see that the current is not in phase with the voltage drop across the capacitor, given by equation (vi). Using the trigonometric identity cos ωt = sin ($\omega t + \pi/2$), we can express this equation in the alternative from

$$i_C = \omega C\varepsilon_0 \sin\left(\omega t + \frac{\pi}{2}\right) \quad \text{... (vii)}$$

From equation (vii), we see that the current in the circuit reaches its maximum value when cos ωt = 1.

$$i_0 = \omega C\varepsilon_0 = \frac{\varepsilon_0}{X_C}$$

where X_C is called the capacitive reactance.

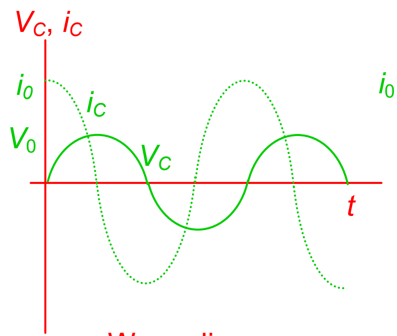
$$X_C = \frac{1}{\omega C} \quad \text{... (26)}$$

The SI unit of X_C is also ohm. The rms current is given by an expression similar to equation with V_0 replaced by V_{rms}.

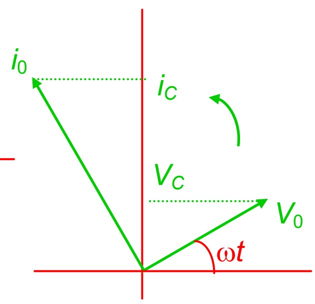
Combining equation (vi) & (vii), we can express the instantaneous voltage drop across the capacitor as

$$V_C = V_0 \sin \omega t = I_0 X_C \sin \omega t \quad \text{... (27)}$$

Comparing the result of equation (vii) with equation (vi), we see that the **current is $\pi/2$ rad = 90° out of phase with the voltage** across the capacitor. A plot of current and voltage versus time, shows that the current reaches its maximum value one quarter of a cycle sooner than the voltage reaches its maximum value. The corresponding phasor diagram is shown in the figure (b).Thus we see that for a sinusoidally applied emf, the current always leads the voltage across a capacitor by 90°.



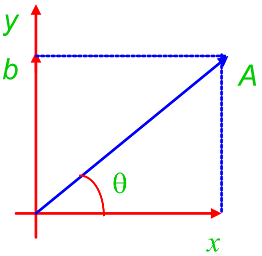
Wave diagram
Fig. (a)



Phasor diagram
Fig. (b)

8.4 VECTOR ANALYSIS (PHASOR ALGEBRA)

The complex quantities normally employed in ac circuit analysis, can be added and subtracted like coplanar vectors. Such coplanar vectors, which represent sinusoidally time varying quantities, are known as phasors.



In cartesian form, a phasor A can be written as,

$$A = a + jb$$

where a is the x-component and b is the y component of phasor A.

The magnitude of A is, $|A| = \sqrt{a^2 + b^2}$

and the angle between the direction of phasor A and the positive x-axis is,

$$\theta = \tan^{-1}\left(\frac{b}{a}\right)$$

When a given phasor A, the direction of which is along the x-axis is multiplied by the operator j, a new phasor $j\,A$ is obtained which will be 90° anticlockwise from A, i.e., along y-axis. If the operator j is multiplied now to the phasor jA, a new phasor j^2A is obtained which is along x-axis and having same magnitude as of A. Thus,

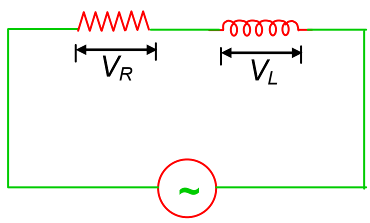
$$j^2 A = -A$$

$$j^2 = -1 \quad \text{or } j = \sqrt{-1}$$

Now using the j operator, let us discuss different circuits of an ac.

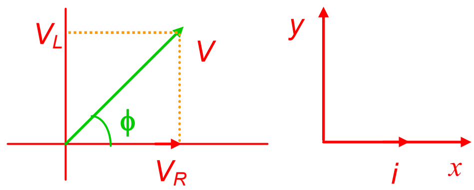
8.5 SERIES L-R CIRCUIT

Now consider an ac circuit consisting of a resistor of resistance R and an inductor of inductance L in series with an ac source generator.



Suppose in phasor diagram, current is taken along positive x-direction. The V_R is also along positive x-direction and V_L along positive y-direction as we know potential difference across a resistance in ac is in phase with current and it leads in phase by 90° with current across the inductor, so we can write

$$V = V_R + jV_L = iR + j(iX_L)$$
$$= iR + j(i\omega L)$$
$$= iZ$$



Here, $Z = R + jX_L = R + j\,(\omega L)$ is called as impedance of the circuit. Impedance plays the same role in ac circuits as the ohmic resistance does in dc circuits. The modulus of impedance is,

$$|Z| = \sqrt{R^2 + (\omega L)^2} \qquad \text{... (28)}$$

The potential difference leads the current by an angle,

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

$$\phi = \tan^{-1}\left(\frac{\omega L}{R}\right) \qquad \text{... (29)}$$

Illustration 6

Question: **An alternating voltage of 100 volt r.m.s. at a frequency of 400/π cycles/second is supplied to a circuit containing a pure inductance of 0.01 H and a pure resistance of 6 ohms in series. Calculate (i) the current, (ii) potential difference across the resistance, (iii) potential difference across the inductance.**

Solution: The impedance of *L-R* series circuit is given by

$$Z = [R^2 + (\omega L)^2]^{1/2} = [(R)^2 + (2\pi f L)^2]^{1/2} = \mathbf{10\ \Omega}$$

(i) R.M.S. value of current

$$I_{rms} = \frac{\varepsilon_{rms}}{Z} = \mathbf{10\ amp}$$

(ii) The potential difference across the resistance is given by

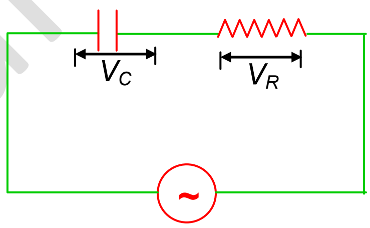
$$V_R = I_{rms} \times R = \mathbf{60\ V}$$

(iii) Potential difference across inductance is given by

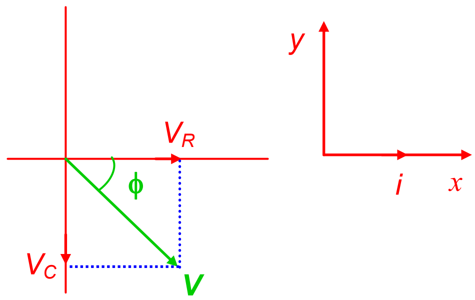
$$V_L = I_{rms} \times (\omega L) = \mathbf{80\ V}$$

8.6 SERIES C-R CIRCUIT

Now consider an ac circuit consisting of a resistor of resistance *R* and a capacitor of capacitance *C* in series with an ac source generator.



Suppose in phasor diagram current is taken along positive x-direction. Then V_R is also along positive x-direction but V_C is along negative *y*-direction as potential difference across a capacitor in ac lags in phase by 90° with the current in the circuit. So we can write.



$$V = V_R - jV_C = iR - j\,(iX_C)$$

$$= iR - j\left(\frac{i}{\omega C}\right) = iZ$$

Here, impedance is, $Z = R - j\left(\frac{1}{\omega C}\right)$

The modulus of impedance is,

$$|Z| = \sqrt{R^2 + \left(\frac{1}{\omega C}\right)^2} \quad \text{... (30)}$$

and the potential difference lags the current by an angle,

$$\phi = \tan^{-1}\left|\frac{V_C}{V_R}\right| = \tan^{-1}\frac{X_C}{R} = \tan^{-1}\left(\frac{1/\omega C}{R}\right) = \tan^{-1}\left(\frac{1}{\omega RC}\right) \quad \text{... (31)}$$

Illustration 7

Question: **An A.C. source of angular frequency ω is fed across a resistor *R* and a capacitor *C* in series. The current registered is *i*. If now the frequency of the source is changed to ω/3 (but maintaining the same voltage), the current in the circuit is found to be halved. The ratio of reactance of resistance at the original frequency is $\sqrt{x \times 10^{-1}}$. Find the value of *x*?**

Solution: At angular frequency ω, the current in *R-C* circuit is given by

$$i_{rms} = \frac{\varepsilon_{rms}}{\sqrt{\{R^2 + (1/\omega^2 C^2)\}}} \quad \text{... (i)}$$

When frequency is changed to $\omega/3$, the current is halved. Thus

$$\frac{i_{rms}}{2} = \frac{\varepsilon_{rms}}{\sqrt{\left\{R^2 + 1/(\omega/3)^2C^2\right\}}} = \frac{\varepsilon_{rms}}{\sqrt{\{R^2 + (9/\omega^2C^2)\}}} \quad \text{... (ii)}$$

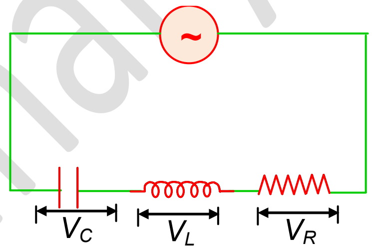
From equation (i) and (ii), we have $\dfrac{1}{\sqrt{\{R^2 + (1/\omega^2C^2)\}}} = \dfrac{2}{\sqrt{\{R^2 + (9/\omega^2C^2.)\}}}$

Solving this equation, we get $3R^2 = \dfrac{5}{\omega^2C^2}$

Hence, the ratio of reactance to resistance is $\dfrac{(1/\omega C)}{R} = \sqrt{\left(\dfrac{3}{5}\right)}$ $\Rightarrow$ x = **6**

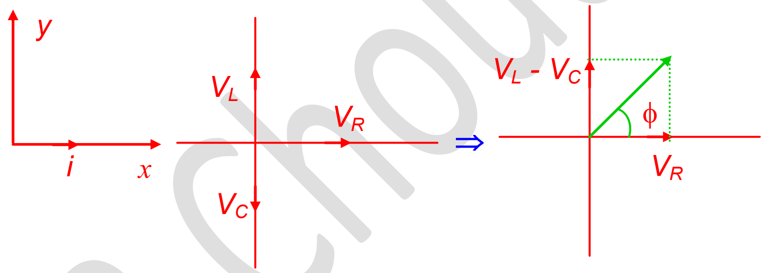
8.7 SERIES L-C-R CIRCUIT

Now consider an ac circuit consisting of a resistor of resistance *R*, a capacitor of capacitance *C* and an inductor of inductance *L* in series with an ac source generator.



Suppose in a phasor diagram current is taken along positive *x*-direction. Then V_R is along positive *x*-direction, V_L along positive *y*-direction and V_C along negative *y*-direction, as potential difference across an inductor leads the current by 90° in phase while that across a capacitor, lags by 90°.

$$V = \sqrt{V_R^2 + (V_L - V_C)^2}$$



So, we can write, $V = V_R + jV_L - jV_C = iR + j(iX_L) - j(iX_C)$

$iR + j\,[i\,(X_L - X_C)] = iZ$

Here impedance is,

$$Z = R + j\,(X_L - X_C) = R + j\left(\omega L - \frac{1}{\omega C}\right)$$

The modulus of impedance is, $|Z| = \sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2}$ ***... (32)***

and the potential difference leads the current by an angle,.

$$\phi = \tan^{-1}\left|\frac{V_L - V_C}{V_R}\right| = \tan^{-1}\left(\frac{X_L - X_C}{R}\right)$$

$$\phi = \tan^{-1}\left(\frac{\omega L - \dfrac{1}{\omega C}}{R}\right) \quad \text{... (33)}$$

The steady current in the circuit is given by $i = \dfrac{V_0}{\sqrt{R^2 + \left(\omega L - \dfrac{1}{\omega C}\right)^2}} \sin(\omega t + \phi)$

where ϕ is given from equation (19)

The peak current is $i_0 = \dfrac{V_0}{\sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}}$

It depends on angular frequency ω of ac source and it will be maximum when

$$\omega L = \frac{1}{\omega C} \Rightarrow \omega = \sqrt{\frac{1}{LC}}$$

and corresponding frequency is

$$\nu = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{1}{LC}} \qquad \text{... (34)}$$

This frequency is known as **resonant frequency** of the given circuit. At this frequency peak current will be $i_0 = \dfrac{V_0}{R}$

If the resistance R in the LCR circuit is zero, the peak current at resonance is $i_0 = \dfrac{V_0}{0}$

It means, there can be a finite current in pure LC circuit even without any applied emf, when a charged capacitor is connected to pure inductor.

This current in the circuit is at frequency, $\nu = \dfrac{1}{2\pi}\sqrt{\dfrac{1}{LC}}$

Illustration 8

Question: **A resistor of resistance R, an inductor of inductance L and a capacitor of capacitance C all are connected in series with an a.c. supply. The resistance of R is 16 ohm and for a given frequency, the inductive reactance of L is 24 ohm and capacitive reactance of C is 12 ohm. If the current in the circuit is 5 amp., find**

(a) the potential difference across R, L and C

(b) the impedance of the circuit

(c) the voltage of a.c. supply

Solution:

(a) Potential difference across resistance

$V_R = iR = 5 \times 16 =$ **80 volt**

Potential difference across inductance

$V_L = i \times (\omega L) = 5 \times 24 =$ **120 volt**

Potential difference across condenser

$V_C = i \times (1/\omega C) = 5 \times 12 =$ **60 volt**

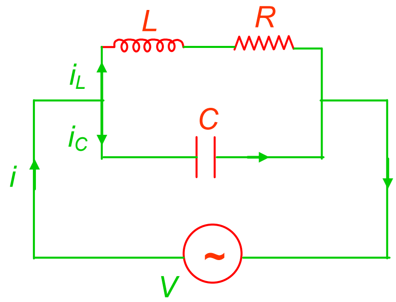
(b) $$Z = \sqrt{\left[R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2\right]}$$

$$= \sqrt{[(16)^2 + (24-12)^2]} = \textbf{20 ohm}$$

(c) The voltage of a.c. supply is given by

$v = iZ = 5 \times 20 =$ **100 volt**

9 PARALLEL AC CIRCUIT



Let us consider an alternating source connected across an inductance L in parallel with a capacitor C.

The resistance in series with the inductance is R.

Let the instantaneous value of emf applied be V and the corresponding current is i, i_L and i_C. Then,

$$i = i_L + i_C$$

or, $$\frac{V}{Z} = \frac{V}{R + j\omega L} - \frac{V}{j/\omega C}$$

$$= \frac{V}{R + j\omega L} + j(\omega C)V \quad (\text{as } j^2 = -1)$$

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

$\frac{1}{Z}$ is known as ***admittance (Y)***. Therefore,

$$Y = \frac{1}{Z} = \frac{R - j\omega L}{R^2 + \omega^2 L^2} + j\omega C = \frac{R + j(\omega CR^2 + \omega^3 L^2 C - \omega L)}{R^2 + \omega^2 L^2}$$

∴ The magnitude of the admittance,

$$Y = |Y| = \frac{\sqrt{R^2 + (\omega CR^2 + \omega^3 L^2 C - \omega L)^2}}{R^2 + \omega^2 L^2} \quad \text{... (35)}$$

The admittance will be minimum, when

$$\omega CR^2 + \omega^3 L^2 C - \omega L = 0$$

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

It gives the condition of resonance and the corresponding frequency,

$$f = \frac{\omega}{2\pi} = \frac{1}{2\pi}\sqrt{\frac{1}{LC} - \frac{R^2}{L^2}} \quad \text{... (36)}$$

is known as **resonance frequency**. At resonance frequency, admittance is minimum or the impedance is maximum. Thus, the parallel circuit does not allow this frequency from the source to pass in the circuit. Due to this reason the circuit with such a frequency is known as **rejector circuit**.

☞ ***If R = 0, resonance frequency is*** $\frac{1}{2\pi\sqrt{LC}}$ ***same as resonance frequency in series circuit.***

At resonance, the reactive component of Y is real. The reciprocal of the admittance is called the **parallel resistor** or the **dynamic resistance**. The dynamic resistance is thus, reciprocal of the real part of the admittance.

$$\text{Dynamic resistance} = \frac{R^2 + \omega^2 L^2}{R}$$

$$\text{Substituting } \omega^2 = \frac{1}{LC} - \frac{R^2}{L^2}$$

we have, dynamic resistance = $\frac{L}{CR}$

$\therefore$ peak current through the supply = $\frac{V_0}{L/CR} = \frac{V_0 CR}{L}$

The peak current through capacitor = $\frac{V_0}{1/\omega C} = \omega C V_0$. The ratio of the peak current through capacitor and through the supply is known as **Q-factor**.

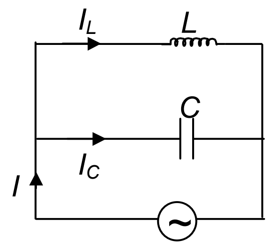
Thus, Q-factor = $\frac{V_0 \omega C}{V_0 CR/L} = \frac{\omega L}{R}$ ... (37)

This is basically the measure of current magnification. The rejector circuit at resonance exhibits current magnification of $\frac{\omega L}{R}$, similar to the voltage magnification of the same ratio exhibited by the series acceptor circuit at resonance.

☞ ***At resonance the current through the supply and voltage are in phase, while the current through the capacitor leads the voltage by 90°.***

Illustration 9

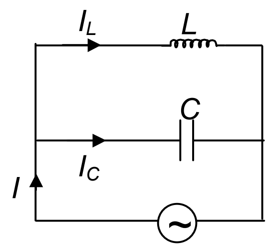
Question: **For the circuit shown in figure. Current in inductance is 0.8 *A* while in capacitance is 0.6 A. The current drawn from the source is $x \times 10^{-1}$. Find the value of x?**



Solution: In this ac circuit $\varepsilon = \varepsilon_0 \sin \omega t$ is applied across an inductance and capacitance in parallel, current in inductance will lag the applied voltage while across the capacitor will lead,

and so, $I_L = \frac{V}{X_L} \sin\left(\omega t - \frac{\pi}{2}\right) = -0.8 \cos \omega t$

$I_C = \frac{V}{X_C} \sin\left(\omega t + \frac{\pi}{2}\right) = +0.6 \cos \omega t$



So the current drawn from the source,

$I = I_L + I_C = -0.2 \cos \omega t$ i.e., $|I| = 0.2$ A $\Rightarrow$ x = **2**

Illustration 10

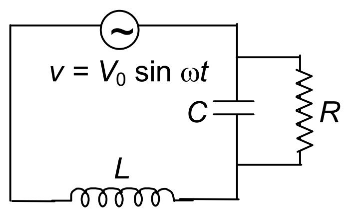
Question: **An emf $V_0 \sin \omega t$ is applied to a circuit which consists of a self inductance *L* of negligible resistance in series with a variable capacitor *C*. The capacitor is shunted by a variable resistance *R*. Find the value of *C* for which the amplitude of the current is independent of *R* (L = ½ H, $\omega = 10^3$ rad/sec)**

Solution: To make the problem easy, let us make use of phasor algebra. The complex impedance, of the circuit as shown in the figure.

$Z = j\omega L + Z'$.

where Z' is complex impedence due to *C* and *R* in parallel and is given by

$$\frac{1}{Z'} = \frac{1}{R} + j\omega C = \frac{1 + j\omega CR}{R}$$



or $Z' = \dfrac{R}{1 + j\omega CR} = \dfrac{R(1 - j\omega CR)}{1 + \omega^2 C^2 R^2}$

$\therefore$ $Z = j\omega L + \dfrac{R(1 - j\omega CR)}{1 + \omega^2 C^2 R^2}$

$= \dfrac{R}{1 + \omega^2 C^2 R^2} + j\left(\omega L - \dfrac{\omega CR^2}{1 + \omega^2 C^2 R^2}\right)$

The magnitude of Z is thus given by

$$Z = \sqrt{\left[\dfrac{R^2}{(1 + \omega^2 C^2 R^2)^2} + \left(\omega L - \dfrac{\omega CR^2}{1 + \omega^2 C^2 R^2}\right)^2\right]}$$

or $Z^2 = \dfrac{R^2}{(1 + \omega^2 C^2 R^2)^2} + \omega^2 L^2 + \dfrac{\omega^2 C^2 R^4}{(1 + \omega^2 C^2 R^2)^2} - \dfrac{2\omega^2 LCR^2}{1 + \omega^2 C^2 R^2}$

$= \dfrac{R^2 - 2\omega^2 LCR^2}{1 + \omega^2 C^2 R^2} + \omega^2 L^2$

The peak value of current will be independent of R, if Z or Z^2 is also independent of R. It is possible when

$R^2 - 2\omega^2 LCR^2 = 0$,

or $C = 1/2\omega^2 L$ $=$ **1 μF**

10 POWER IN AN AC CIRCUIT

In case of a steady current the rate of doing work is given by,

$P = Vi$

In an alternating circuit, current and voltage both vary with time, so the work done by the soruce in time interval dt is given by

$dW = Vidt$

Suppose in an ac, the current is leading the voltage by an angle ϕ. Then we can write,

$V = V_0 \sin \omega t$

and $i = i_0 \sin(\omega t + \phi)$

$dW = V_0 i_0 \sin \omega t \sin(\omega t + \phi)\, dt$

$= V_0 i_0 (\sin^2 \omega t \cos\phi + \sin \omega t \cos \omega t \sin\phi)\, dt.$

The total work done in a complete cycle is

$$W = V_0 i_0 \cos\phi \int_0^T \sin^2 \omega t\, dt + V_0 i_0 \sin\phi \int_0^T \sin \omega t \cos \omega t\, dt$$

$$= \frac{1}{2} V_0 i_0 \cos\phi \int_0^T (1 - \cos 2\omega t)\, dt + \frac{1}{2} V_0 i_0 \sin\phi \int_0^T \sin 2\omega t\, dt = \frac{1}{2} V_0 i_0 T \cos\phi$$

The average power delivered by the soruce is, therefore,

$$P = \frac{W}{T} = \frac{1}{2} V_0 i_0 \cos\phi = \left(\frac{V_0}{\sqrt{2}}\right)\left(\frac{i_0}{\sqrt{2}}\right)(\cos\phi) = V_{rms}\, i_{rms} \cos\phi$$

or $\langle P \rangle_{one\ cycle} = V_{rms}\, i_{rms} \cos\phi$ ... (38)

Here, the term $\cos\phi$ is known as **power factor**.

It is said to be leading if current leads voltage, lagging if current lags voltage. Thus, a power factor of 0.5 lagging means current lags the voltage by 60° (as $\cos^{-1} 0.5 = 60°$). The product of V_{rms} and i_{rms} gives the apparent power. While the true power is obtained by multiplying the apparent power by the power factor $\cos\phi$. Thus,

and apparent power = $V_{rms} \times i_{rms}$

True power = apparent power × power factor

For $\phi = 0°$, the current and voltage are in phase. The power is thus, maximum ($V_{rms} \times i_{rms}$). For $\phi = 90°$, the power is zero. The current is then stated **wattless**. Such a case will arise when resistance in the circuit is zero. The circuit is purely inductive or capacitive.

***Illustration* 11**

Question: **A series *LCR* with *R* = 20 Ω, *L* = 1.5 H and *C* = 35 μF is connected to a variable frequency 200 V a.c. supply. When the frequency of the supply equals the natural frequency of the circuit. What is the average power transferred to the circuit in one complete cycle?**

Solution: When the frequency of the supply equals the natural frequency of the circuit, resonance occurs.

∴ $Z = R = 20$ ohm.

$$i_{rms} = \frac{E_{rms}}{Z} = \frac{200}{20} = 10\,A$$

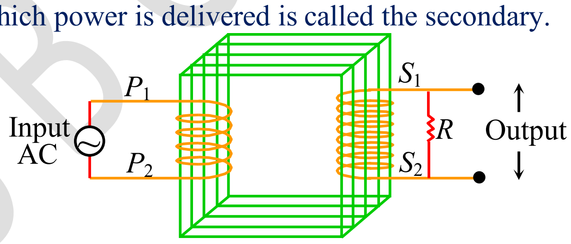
Average power transferred/cycle

$P = E_{rms} i_{rms} \cos 0° = 200 \times 10 \times 1 =$ **2000 watt**

11 TRANSFORMERS

One of the great advantage of *ac* over *dc* for electric-power distribution is that it is much easier to step voltage level up and down with ac than with dc. The necessary conversion is accomplished by a static device called transformer using the principle of mutual induction.

The figure shows an idealised transformer which consists of two coils or windings, electrically insulated from each other but wound on the same core. The winding to which power is supplied is called primary, the winding from which power is delivered is called the secondary.



Laminated core

The *ac* source causes an alternating current in the primary which sets up an alternating flux in the core and this induces an emf in each winding of secondary in accordance with Faraday's law. For ideal transformer we assume that primary has negligible resistance and all the flux in core links both primary and secondary. The primary winding has N_1 turns and secondary has N_2 turns. When the magnetic flux changes because of changing currents in the two coils, the resulting induced emf are

$$e_1 = -N_1 \frac{d\phi_B}{dt} \text{ and } e_2 = -N_2 \frac{d\phi_B}{dt}$$

The flux per turn ϕ_B is same in both primary and the secondary so that the emf per turn is same in each. The ratio of secondary emf Σ_2 to the primary emf Σ_1 is therefore equal at any instant to the ratio of secondary to primary turns.

$$\frac{e_2}{e_1} = \frac{N_2}{N_1}$$

If the windings have zero resistance, the induced emf e_1 and e_2 are equal to the terminal voltage across the primary and the secondary respectively, hence

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

If $N_2 > N_1$ then $V_2 > V_1$ and we have **step up** transformer, if $N_2 < N_1$ then $V_2 < V_1$ and we have a **step down** transformer.

If the transformer is assumed to be 100% efficient (no energy losses) the power input is equal to the power output i.e.

$$I_2V_2 = I_1V_1 \qquad \therefore \qquad \frac{I_2}{I_1} = \frac{N_1}{N_2}$$

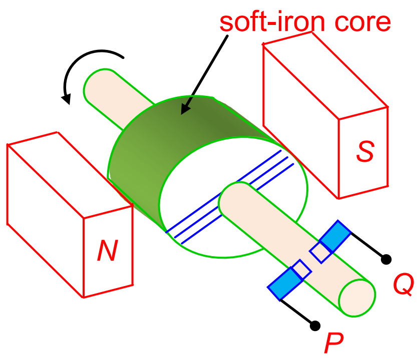
All the currents and voltages derived above have same frequency as that of source. The equations obtained above apply to ideal transformers, although some energy is lost but well designed transformers have efficiency more than 95%, this is a good approximation. The causes of energy losses and their rectification is given below:

Cause	Rectification
1. Due to poor design and air gaps in the core, all the flux due to primary does not pass through the secondary.	*1. By winding the primary and secondary coil one over the other.*
2. Resistance of windings causes I^2R loss.	*2. In high current, low voltage, these are minimised by using thick wire.*
3. The alternating magnetic flux induces eddy currents in the core and causes heating.	*3. By using laminated core it can be reduced.*
4. Alternating magnetisation of core causes hystersis loss.	*4. It is kept minimum by using a magnetic material having low hystersis loss. (e.g. soft iron)*

AC GENERATOR

A device which converts mechanical energy into electrical energy using principle of electromagnetic induction is called ac generator. A schematic design and simplified diagram is shown in figure.

It consists of three main parts, a magnet, an armature with slip rings and brushes. The armature contains coil of *N* loops which rotates in the magnetic field generated by the magnets.



Suppose the plane of coil having area *A* is perpendicular to the magnetic field and rotating with constant angular velocity ω, at $t = 0$. The flux through each turn of coil at time *t* is $\phi = BA\cos\theta$, where $\theta = \omega t$ is the angle by which coil rotates in time *t*. The total emf induced in the coil is,

$$e = -\frac{Nd\phi}{dt}$$
$$= NBA\omega \sin \omega t$$
$$= e_0 \sin \omega t$$

Here, $e_0 = NBA\omega$ is the maximum generated emf is known as peak emf. This emf is delivered to external circuits from two graphite brushes B_1 and B_2 which touches permanently the slip rings C_1 and C_2. As the armature rotates the slip rings C_1 and C_2 slip against the brushes so that the contact is maintained all the time.

The mechanical energy which gets converted into electrical energy required for rotation is provided by falling water from height in hydro-electric generator. The frequency of rotation is 50Hz in India.

PROFICIENCY TEST - II

The following questions deal with the basic concepts of this section. Answer the following briefly. Go to the next section only if your score is at least 80%. Do not consult the Study Material while attempting these questions.

1. State whether the following statements are true or false giving reason in brief
(a) dc is more dangerous than ac of same rms value.
(b) the average value of ac may be zero over half cycle.

2. Define reactance X and impedance Z. Can these be negative? If yes, when and what does it imply?

3. Can an ac source be connected to a circuit and yet not delivering any power to it? If so under what circumstances?

4. The potential difference V across and the current I flowing through an ac circuit is given by, $V = 5\cos\omega t$; $I = 2\sin\omega t$
What is the power dissipated?

5. A 10 ohm electric iron is connected to 120 volt, 60 Hz wall outlet. What is the rms potential difference on the electric iron?

6. What is the inductive reactance of a coil if the current through it is 20 mA and voltage across it is 100 V?

7. The electric current in an ac circuit is given by $i = i_0 \sin\omega t$. What is the minimum time taken by the current to change from its maximum value to the rms value for $\omega = \frac{\pi}{4}$ rad/s.

8. Find the value of an inductance, which should be connected in series with a capacitor of capacitance 5 μF, a resistance of 10 Ω and an ac source of 50 Hz so that the power factor (PF) of the circuit is unity. (take $\pi^2 = 10$)

9. The voltage and current in a series AC circuit are given by
$V = V_0 \cos\omega t$ and $i = i_0\ (\cos\omega t + \frac{\pi}{3})$, where $V_0 = 16$ V, $i_0 = 4$ A
What is the power dissipated in the circuit?

ANSWERS TO PROFICIENCY TEST - II

1. (a) False
(b) True

2. $X_L = \omega L,\ X_C = \frac{1}{\omega C}$

Reactance can be negative when $X_C > X_L$. It implies current leads the applied voltage in the circuit.

3. Yes, when the phase difference between voltage and current is 90°

4. Zero, as $\phi = 90°$

5. 120 V

6. 5 kΩ

7. 1 sec

8. 2 H

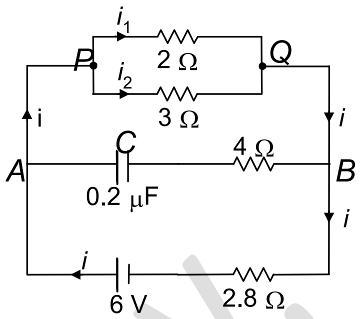
9. 16 W

SOLVED OBJECTIVE EXAMPLES

Example 1:

In the adjoining figure, the current in the steady state, in the 2 Ω resistor is (Internal resistance of battery can be neglected.)

(a) 0.3 A
(b) 0.5 A
(c) 0.7 A
(d) 0.9 A



Solution:

In the steady state, the condenser, *C*, does not allow any *d.c.* to pass through it. Hence, current in the *AB* branch (i.e. 4 Ω resistor) = 0. Hence current, i ($i_1 + i_2$) in the remaining circuit

$$= \frac{6V}{2.8\Omega + (6/5)\Omega}$$

$$= \frac{6V}{4\Omega}$$

= 1.5 A.

This current is divided between the resistors 2 Ω and 3 Ω. Hence, current through the 2 Ω resistor

$$= 1.5 \times \frac{3}{5} = \mathbf{0.9\ A.}$$

∴ **(d)**

Example 2:

A uniformly wound solenoidal coil of self-inductance 1.8 × 10^{-4} H and resistance 6Ω is broken into two identical coils. These induction coils are then connected in parallel across a 12 V battery of negligible resistance. The time constant of the circuit is (neglect mutual induction between the coils)

(a) $\frac{3}{2} \times 10^{-5}\,s$ **(b)** 2×10^{-5} s **(c)** $\frac{20}{3} \times 10^{-4}\,s$ **(d)** 3×10^{-5} s

Solution:

The inductance of the circuit (*L*) is given by

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}, \text{ where } L_1 = L_2 = \frac{1.8}{2} \times 10^{-4} H$$

$$\Rightarrow \quad L = \frac{L_1}{2} = \frac{1.8}{4} \times 10^{-4} H$$

Similarly, resistance of the circuit : $R = \frac{6}{4}\Omega = 1.5\Omega$

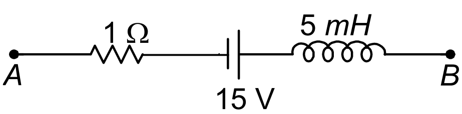
∴ time constant : $\tau = \frac{L}{R} = \frac{0.45 \times 10^{-4}}{1.5} = \mathbf{3 \times 10^{-5}\,sec}$

∴ **(d)**

Example 3:

The network shown in figure is part of a complete circuit. If at a certain instant, the current is 5 A and is decreasing at the rate 10^3 A/s, the $V_B - V_A$ is

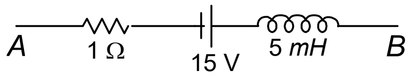
(a) 20 V **(b) 15 V**
(c) 10 V **(d) 5 V**



Solution:

Moving from *A* to *B*

$V_A - V_B = (1 \times 5) - (15) - (5 \times 10^{-3} \times 10^3)$
$= -15$ V



$V_B - V_A = \mathbf{15}\ V$; $\frac{di}{dt}$ is negative as i decreases with time.

∴ **(b)**

Example 4:

If resistance of 100 Ω and inductance of 0.5 henry and capacitance of 10 × 10^{-6} F are connected in series through 50 Hertz a.c. supply. The impedance is

(a) 1.8765 Ω **(b) 18.76 Ω** **(c) 189.5 Ω** **(d) 101.3Ω**

Solution:

Here $R = 100\ \Omega$, $L = 0.5$ H, $C = 10^{-5}$ F

$X_L = \omega L = 2\pi\nu L = 100\pi \times 0.5 = 50\pi$

$$X_c = \frac{1}{\omega C} = \frac{1}{2\pi\nu C} = \frac{1}{2\pi \times 50 \times 10 \times 10^{-6}} = \frac{10^3}{\pi}$$

$$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{(100)^2 + \left(50\pi - \frac{10^3}{\pi}\right)^2}$$

$$= \sqrt{35934.1} = \mathbf{189.5\ \Omega}$$

∴ **(c)**

Example 5:

In an L-R circuit, the value of L is $\left[\frac{0.4}{\pi}\right]$ henry and the value R is 30 ohm. If in the circuit, an alternating emf of 200 V rms value at 50 cycles per second is connected, the impedance of the circuit and current will be

(a) 11.4 ohm, 17.5 amphere **(b) 30 ohm, 6.5 ampere**

(c) 40 ohm, 5 amphere **(d) 50 ohm, 4 ampere**

Solution:

Here $X_L = \omega_L = 2\pi\ \nu L = 40\ \Omega$

$R = 30\ \Omega$

$$Z = \sqrt{R^2 + X_L^2} = \sqrt{30^2 + 40^2} = \mathbf{50\ \Omega}$$

$$I_{rms} = \frac{V_{rms}}{Z} = \frac{200}{50} = \mathbf{4\ A}$$

∴ **(d)**

Example 6:

A series *LCR* circuit is tuned to resonance. The impedance of the circuit now is

(a) $\left[R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2\right]^{1/2}$ **(b)** $\left[R^2 + (\omega L)^2 + \left(\frac{1}{\omega C}\right)^2\right]^{1/2}$

(c) $\left[R^2 + \left(\frac{1}{\omega C} - \omega L\right)^2\right]^{1/2}$ **(d)** R

Solution:

At resonance

$(\omega L - \frac{1}{\omega C}) = 0$

So impedance $(Z) = \boldsymbol{R}$

∴ **(d)**

Example 7:

An inductor of inductance 100 mH is connected in series with a resistance, a variable capacitance and an AC source of frequency 2.0 kHz. The value of the capacitance so that maximum current may be drawn into the circuit is

(a) 60 nF **(b) 63 nF** **(c) 65 nF** **(d) 89 nF**

Solution:

This is an LCR series circuit; the current will be maximum when the net reactance is zero. For this,

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

or, $$C = \frac{1}{\omega^2 L} = \frac{1}{4\pi^2 \times (2.0\times 10^3 s^{-1})^2\ (0.1H)} = \mathbf{63\ nF}$$

∴ **(b)**

Example 8:

In an A.C. circuit, a resistance of *R* Ω is connected in series with an inductance *L*. If phase angle between voltage and current be 45°, the value of inductive reactance will be

(a) *R*/4 **(b) *R*/2**

(c) *R* **(d) cannot be found with given data**

Solution:

$\tan\phi = \tan 45°$

$= \frac{X_L}{R}$

∴ $X_L = R$

∴ **(c)**

Example 9:

An inductor coil joined to a 6 V battery draws a steady current of 12 A. This coil is connected to a capacitor and an AC source of rms voltage 6 V in series. If the current in the circuit is in phase with the emf, the rms current is

(a) 12 A **(b) 20 A** **(c) 8 A** **(d) 24 A**

Solution:

The resistance of the coil is $R = \frac{6V}{12\,A} = 0.5\ \Omega$

In this AC circuit, the current is in phase with the emf, this means that the net reactance of the circuit is zero. The impedance is equal to the resistance. i.e.,

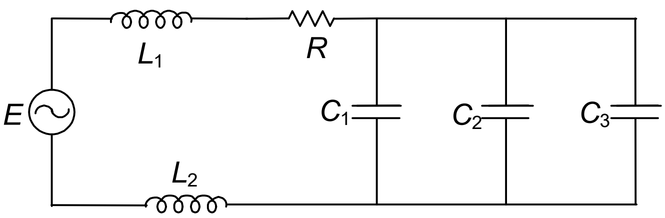
$Z = 0.5\ \Omega.$

The rms current = $\frac{\text{rms voltage}}{Z} = \frac{6\,V}{0.5\,\Omega} = \mathbf{12\ A.}$

∴ **(a)**

Example 10:

A generator with an adjustable frequency of oscillation is connected to resistance, $R = 100$ Ω, inductances, $L_1 = 1.7$ mH and $L_2 = 2.3$ mH and capacitances, $C_1 = 4$ μF, $C_2 = 2.5$ μF and $C_3 = 3.5$ μF. The resonant angular frequency of the circuit is



(a) 0.5 rad/s

(b) 0.5×10^4 rad/s

(c) 2 rad/s

(d) 2×10^{-4} rad/s

Solution:

$C_{eff} = C_1 + C_2 + C_3$

$= 4\ \mu F + 2.5\ \mu F + 3.5\ \mu F$

$= 10\ \mu F$

$L_{eff} = L_1 + L_2$

$= 1.7 \text{ mH} + 2.3 \text{ mH} = 4 \text{ mH}$

Resonance frequency,

$$\omega = \frac{1}{\sqrt{L_{eff} C_{eff}}} = \frac{1}{\sqrt{4\times10^{-3}\times10\times10^{-6}}} = \frac{10^4}{2} = \mathbf{0.5 \times 10^4 \text{ rad/s.}}$$

$\therefore$ **(b)**

***Example* 11:**

Figure shows an ac generator connected to a "black box" through a pair of terminals. The box contains an *RLC* circuit whose elements and connections we do not know. Measurements outside the box reveal that $v(t)$ = (75 V) sin $\omega_d t$, and

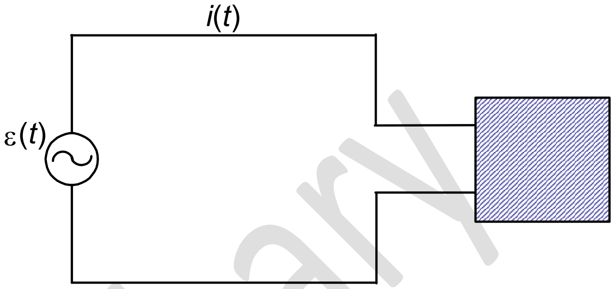
$i(t)$ = (1.2 A) sin ($\omega_d t$ + 42°). Which one of the following statements is correct?

(a) The power factor is sin 42° and the circuit in the box is largely capacitive.

(b) The power factor is cos 42° and the circuit consists of inductors and resistors.

(c) The rate at which the energy delivered to the box by the generator is 66.88 W.

(d) The circuit consists of capacitors and resistors and the rate at which the energy delivered to the box by the generator is 33.4 W.



$X_c > X_L$
CosØ = +Ve

***Solution*:**

$V(t)$ = (75 V) sin $\omega_d t$

$i(t)$ = (1.2 A) sin ($\omega_d t + 42^\circ$)

Since the current leads the voltage by 42°, the circuit consists of resistors and capacitors. The power factor is cos 42°.

The rate at which the energy is delivered to the box by the generator,

$$P = V_{rms}\ i_{rms} \cos\phi$$

$$= \left(\frac{75V}{\sqrt{2}}\right)\frac{(1.2A)}{\sqrt{2}} \cos 42^\circ = \mathbf{33.4\ W}$$

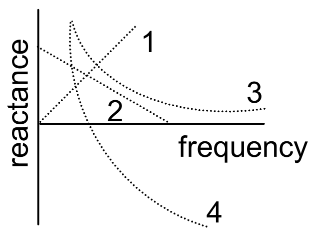
$\therefore$ **(d)**

***Example* 12:**

Which of the following plots may represent the reactance of the series LC combination?

(a) 1 **(b) 3**

(c) 2 **(d) 4**



***Solution*:**

Since $X_{LC} = \omega L - \dfrac{1}{\omega C}$

$\therefore$ **(d)**

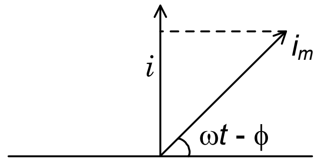
***Example* 13:**

In *RLC* circuit, at a frequency ν, the potential difference across each device are $(\Delta V_R)_{max}$ = 8.8 V, $(\Delta V_L)_{max}$ = 2.6 V and $(\Delta V_C)_{max}$ = 7.4 V. The combined potential difference $(\Delta V_L + \Delta V_C)_{max}$ across the inductor and capacitor is

(a) 10 V **(b) 7.8 V** **(c) 7.4 V** **(d) 4.8 V**

Solution:

A phasor representing the alternating current and potential differences across the resistor, capacitor and inductor in the *RLC* circuit.

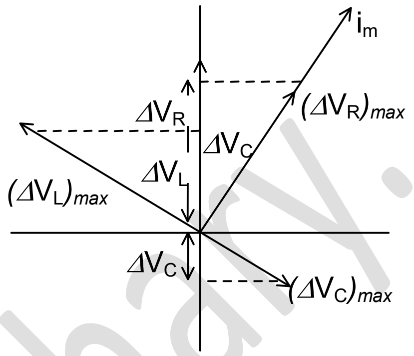


$$\varepsilon_m \sin \omega t = i_m R \sin(\omega t - \phi) + i_m X_L \sin\left(\omega t - \phi + \frac{\pi}{2}\right)$$

$$+ i_m X_C \sin\left(\omega t - \phi - \frac{\pi}{2}\right)$$

$$= (V_R)_{max} \sin(\omega t - \phi) + (V_L)_{max} \sin\left(\omega t - \phi + \frac{\pi}{2}\right)$$

$$+ (V_C)_{max} \sin\left(\omega t - \phi - \frac{\pi}{2}\right)$$

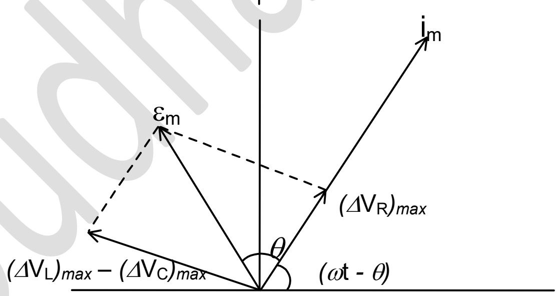


$V_L + V_C$ =

$$(V_L)_{max} \sin\left(\omega t - \phi + \frac{\pi}{2}\right) + (V_C)_{max} \sin\left(\omega t - \phi - \frac{\pi}{2}\right)$$

$$V_L + V_C = (V_L)_{max}\left[\sin(\omega t - \phi)\cos\frac{\pi}{2} + \cos(\omega t - \phi)\sin\frac{\pi}{2}\right]$$

$$+ (V_C)_{max}\left[\sin(\omega t - \phi)\cos\frac{\pi}{2} - \cos(\omega t - \phi)\sin\frac{\pi}{2}\right]$$



$$= \left[(V_L)_{max} - (V_C)_{max}\right] \cos(\omega t - \phi)$$

$(V_L + V_C)_{max} = (V_L)_{max} - (V_C)_{max} = 2.6 \text{ V} - 7.4 \text{ V}$

$= -4.8$ V

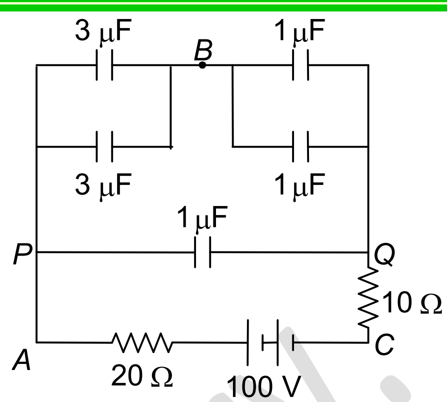
$\left|(V_L + V_C)_{max}\right|$ = **4.8 V**

∴ **(d)**

SOLVED SUBJECTIVE EXAMPLES

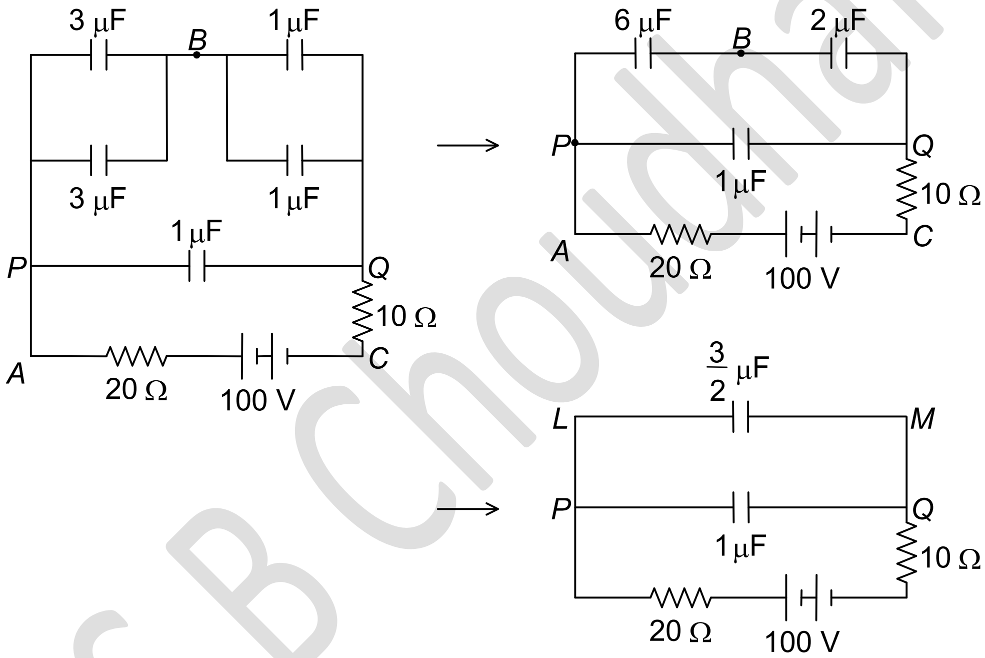
***Example* 1:**

In the diagram shown, find the potential difference between the points *A* and *B*.



***Solution*:**

The given circuit is equivalent to the following, which are self-explanatory.



In the steady state, there is no current in the circuit. Hence the points *P* and *Q* are at the same potential as points *A* and *C*. Similarly the potential between *L* and *M* is the same as that between points *P* and *Q*. The capacitance across LM is $\frac{3}{2}\mu F$. Hence the charge

$$Q = CV = \frac{3}{2}\times10^{-6}\times100 = 150 \times 10^{-6}\text{ C}$$

The charge on each of the 6 μF and 2 μF is also 150×10^{-6} C since they are connected in series. Thus the potential difference between *A* and *B* is equal to that between the plates of 6 μF capacitance carrying the charge *Q*.

Hence the potential difference $V_{AB} = \frac{Q}{6\mu F} = \frac{150\times10^{-6}}{6\times10^{-6}}$ = **25 V**

Example **2:**

In an oscillating LC circuit, the energy is shared equally between the electric and magnetic fields. If L = 12 mH and C = 1.7 μF, how much time (in μs) is needed for this condition to arise, assuming an initially fully charged capacitor.

Solution:

Total energy $U_E = \frac{1}{2}U_{E,max}$

$$\Rightarrow \quad \frac{q^2}{2C} = \frac{1}{2}\frac{Q^2}{2C} \Rightarrow q = \frac{Q}{\sqrt{2}}$$

Since, at $t = 0$, it is given that C has maximum charge, we have the solution to be

$$q = Q\cos\omega t \Rightarrow \frac{Q}{\sqrt{2}} = Q\cos\omega t$$

$$\Rightarrow \quad \omega t = 45° = \frac{\pi}{4} \text{ rad}$$

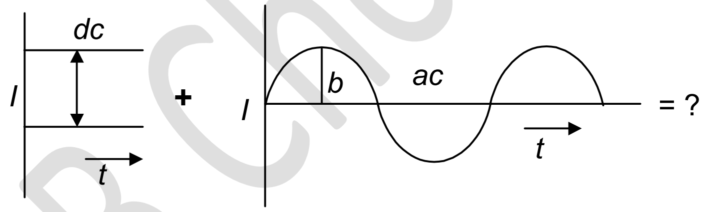
$$\omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{(12\times10^{-3})(1.7\times10^{-6})}} = 7\times10^3 \text{ rad/s}$$

$$\therefore \quad \text{required } t = \frac{\omega t}{\omega} = \frac{(\pi/4)}{(7\times10^3)} = 1.12\times10^{-4} \text{ s}$$

$$\Rightarrow \quad t = \mathbf{112\ \mu s}$$

Example **3:**

If a direct current of value a = 1 ampere is superimposed on an alternating current $I = b\sin\omega t$, when b = 4A, flowing through a wire, what is the effective value of the resulting current in the circuit?



***Solution*:**

As current at any instant in the circuit will be, $I = I_{dc} + I_{ac} = a + b\sin\omega t$

$$\text{So,} \quad I_{eff} = \left[\frac{\int_0^T I^2 dt}{\int_0^T dt}\right]^{1/2} = \left[\frac{1}{T}\int_0^T (a + b\sin\omega t)^2\, dt\right]^{1/2}$$

$$\text{i.e.,} \quad I_{eff} = \left[\frac{1}{T}\int_0^T (a^2 + 2ab\sin\omega t + b^2\sin^2\omega t)\,dt\right]^{1/2}$$

but as

$$\frac{1}{T}\int_0^T \sin\omega t\, dt = 0 \text{ and } \frac{1}{T}\int_0^T \sin^2\omega t\, dt = \frac{1}{2}$$

$$\text{So,} \quad I_{eff} = \left[a^2 + \frac{1}{2}b^2\right]^{1/2} = \mathbf{3A}$$

Example 4:

A 12 ohm resistance and an inductance of 0.05/π henry with negligible resistance are connected in series. Across the end of this circuit is connected a 130 volt alternating voltage of frequency 50 cycles/second. Calculate the potential difference across the inductance.

Solution:

The impedance of the circuit is given by

$$Z = \sqrt{(R^2 + \omega^2 L^2)} = \sqrt{[R^2 + (2\pi f L)^2]}$$

$$= \sqrt{[(12)^2 + \{2 \times 3.14 \times 50 \times (0.05/3.14)\}^2]} = \sqrt{(144 + 25)} = 13 \text{ ohm}$$

Current in the circuit $i = E/Z = \frac{130}{13} = 10$ amp.

Inductive reactance of coil $X_L = \omega L = 2\pi fL$

∴ $X_L = 2\pi \times 50 \times \left(\frac{0.05}{\pi}\right) = 5$ ohm.

Potential difference across inductance

$V_L = i \times X_L = 10 \times 5 =$ **50 volt.**

Example 5:

A resistance of 10 ohm is joined in series with an inductance of 0.5 henry and a capacitor to obtain maximum current. What will be the potential difference across the inductance. The current is being supplied by 200 volts and 50 rad/s per second mains.

Solution:

The current in the circuit would be maximum when

$$\omega L = \frac{1}{\omega C} \quad \text{or} \quad C = \frac{1}{\omega^2 L}$$

Here $\omega L = 1/\omega C$. So the impedance Z of the circuit

$$Z = \sqrt{\left[R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2\right]} = R = 10 \text{ ohm}$$

$$I = \frac{E}{R} = \frac{200}{10} = 20 \text{ amp.}$$

Potential difference across inductance

$V_L = \omega L \times I =$ **500 V**

Example 6:

A 100 volt a.c. source of frequency 500 hertz is connected to *LCR* circuit with *L* = 8.1 milli-henry, *C* = 12.5 microfarad and *R* = 10 ohm, all connected in series. Find the potential difference across the resistance.

Solution:

The impedance of LCR circuit is given by

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

where $X_L = \omega L = 2\pi fL$

$= 2 \times 3.14 \times 500 \times (8.1 \times 10^{-3}) = 25.4$ ohm

and $X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC} = \frac{1}{2.3.14 \times 400 \times (12.5 \times 10^{-6})} = 25.4$ ohm

∴ $Z = \sqrt{[(10)^2 + (25.4 - 25.4)^2]} = 10$ ohm

∴ $I_{rms} = \frac{E_{rms}}{Z} = \frac{100 \text{ volt}}{10 \text{ ohm}} = 10$ amp.

Potential difference across resistance

$V_R = I_{rms} \times R = 10$ amp $\times$ 10 ohm

$= $ **100 volt.**

Example 7:

An LCR series circuit with 100 Ω resistance is connected to an AC source of 200 V and angular frequency 300 radians per second. When only the capacitance is removed, the current lags behind the voltage by 60°. When only the inductance is removed, the current leads the voltage by 60°. Calculate power dissipated in LCR circuit.

Solution:

$$\tan 60° = \frac{\omega L}{R} \text{ or } \tan 60° = \frac{1/\omega C}{R}$$

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

Impendance of circuit $Z = \sqrt{\left[R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2\right]} = R$

Current in the circuit

$$I_0 = \frac{V_0}{Z} = \frac{V_0}{R} = \frac{200}{100}$$

$= 2$ Amp.

Average power $\overline{P} = \frac{1}{2} V_0 I_0 \cos\phi$

But, $\tan\phi = \frac{\omega L - (1/\omega C)}{R} = 0$ $\quad (\cos\phi = 1)$

Now, $\overline{P} = \frac{1}{2} \times 200 \times 2 \times 1 =$ **200 watt.**

Example 8:

A current of 4 A flows in a coil when connected to a 12 V d.c. source. If the same coil is connected to a 12 V, 50 rad/s, a.c. source, a current of 2.4 A flows in the circuit. The inductance of the coil is $x \times 10^{-2}$ H. Find x.

Solution:

When the coil is connected to a d.c. source, its resistance R is given by

$$R = \frac{V}{I} = \frac{12}{4} = 3\,\Omega$$

When it is connected to a.c. source, the impedance Z of the coil is given by

$$Z = \frac{V_{rms}}{I_{rms}} = \frac{12}{2.4} = 5\Omega$$

For a coil, $Z = \sqrt{[R^2 + (\omega L)^2]}$

$\therefore$ $$5 = \sqrt{[(3)^2 + (50L)^2]}$$

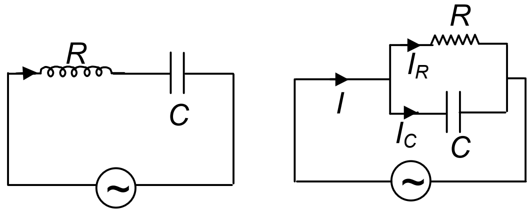
or $25 = [(3)^2 + (50\,L)^2]$

Solving we get $L = 0.08$ henry $\Rightarrow$ **x = 8**

Example 9:

For a resistance $R = 100\ \Omega$ and capacitance $C = 100\ \mu F$ in series, the impedence is twice that of a parallel combination of the same elements. What is the angular frequency of applied emf?

Solution:



(A) (B)

As shown in figure (a), in case of series combination,

$$Z_s = \sqrt{R^2 + X_C^2} = [R^2 + (1/\omega C)^2]^{1/2}$$

In case of parallel combination,

$$I_R = \frac{V}{R}\sin\omega t \text{ and } I_C = \frac{V}{X_C}\sin\left(\omega t + \frac{\pi}{2}\right)$$

So, $I = I_R + I_C = \frac{V}{R}\sin\omega t + \frac{V}{X_C}\cos\omega t$

i.e., $I = I_0 \sin(\omega t + \phi)$

with $I_0 \cos\phi = \frac{V}{R}$ and $I_0 \sin\phi = \frac{V}{X_C}$

So, $I_0 = \left[\left(\frac{V}{R}\right)^2 + \left(\frac{V}{X_C}\right)^2\right]^{1/2} = \frac{V}{Z_P}$

i.e., $\frac{1}{Z_P} = \left[\frac{1}{R^2} + \left(\frac{1}{X_C}\right)^2\right]^{1/2}$

i.e., $Z_P = \frac{R}{\sqrt{1+\omega^2C^2R^2}}$

and as according to given problem,

$Z_s = 2Z_P$, i.e., $Z_s^2 = 4Z_P^2$

i.e., $\frac{(R^2\omega^2C^2+1)}{\omega^2C^2} = 4\frac{R^2}{(1+R^2\omega^2C^2)}$

i.e., $(1 + R^2\omega^2C^2)^2 = 4R^2\omega^2C^2$

or, $1 + R^2\omega^2C^2 = 2R\omega C$

or, $(R\omega C - 1)^2 = 0$

or, $\omega = \frac{1}{RC}$,

$\omega =$ **100 rad/s**

MIND MAP

1. *RC* circuit

(i) Charging of capacitor

$q = q_0\left(1 - e^{\frac{-t}{RC}}\right)$, $i = \frac{E}{R} e^{\frac{-t}{RC}}$

(ii) Discharging of capacitor

$q = q_0 e^{\frac{-t}{RC}}$, $i = \frac{q_0}{RC} e^{\frac{-t}{RC}}$

2. *L-R* circuit

(i) Growth of current

$i_R = \frac{E}{R}(1 - e^{\frac{-Rt}{L}})$

(ii) Decay of current

$i_R = \frac{I_0}{R} e^{\frac{-Rt}{L}}$

TRANSIENT CURRENT CIRCUIT

3. *L-C* oscillation

When a capcitor is charged up to Q_0 and then connected to an inductor

(i) $\frac{Ldi}{dt} + \frac{Q}{C} = 0$

(ii) $Q = Q_0 \cos \omega t$

(iii) $i = -Q_0 \omega \sin \omega t$

(iv) $\omega = \frac{1}{\sqrt{LC}}$

MIND MAP

ALTERNATING CURRENT CIRCUITS

1. (a) Instantaneous current

$i = i_0 \sin(\omega t + \phi)$

Instantaneous voltage

$v = v_0 \sin(\omega t + \phi)$

(b) Average current for positive half cycle

$i_{avg} = \frac{2i_0}{\pi} \cong 0.637\, i_0$

Average voltage for positive half cycle

$v_{avg} = \frac{2v_0}{\pi} \approx 0.637\, v_0$

(c) RMS current

$i_{rms} = \frac{i_0}{\sqrt{2}} = 0.707\, i_0$

RMS voltage

$v_{rms} = \frac{v_0}{\sqrt{2}} = 0.707\, v_0$

2. Series AC circuit

(i) When only resistance is in ac circuit

(a) $V_0 = i_0 R$

(b) Voltage is in phase with current

(ii) When only capacitor is in ac circuit

(a) $V_0 = i_0 X_C$, where, $X_c = \frac{1}{\omega C}$

(b) Voltage is lagging with current by $\frac{\pi}{2}$

(iii) When only inductor is in ac circuit

(a) $V_0 = i_0 X_L$ where $X_L = \omega L$

(b) Voltage is leading with current by $\pi/2$

(iv) Series LR circuit

Impedance $(Z) = \sqrt{R^2 + \omega L^2}$

Phase angle, $\phi = \tan^{-1}\left(\frac{\omega L}{R}\right)$

(v) Series CR circuit

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

Phase angle, $\phi = \tan^{-1}\left(\frac{1}{\omega RC}\right)$

(vi) Series LCR – circuit

Impedance $Z = \sqrt{R^2 + (\omega L - \frac{1}{\omega C})^2}$

Phase angle $\phi = \tan^{-1}\left(\frac{\omega L - \frac{1}{\omega C}}{R}\right)$

(vii) Resonance frequency when L, C, R are in series is, $\omega = \frac{1}{\sqrt{LC}}$

3. Parallel AC circuit

(a) When L and R are in series with C in parallel

Admittance $(Y) = \frac{1}{Z} = \frac{1}{R + j\omega L} + j\omega C$

(b) Resonance frequency (ω)

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

(c) Dynamic resistance $= \frac{1}{Y}$

4. Power $= I_{rms} V_{rms} \cos\phi$

where $\cos\phi$ is power factor

EXERCISE – I

CBSE PROBLEMS

1. What is iron loss in a transformer?

2. Sketch a graph to show how the reactance of (i) a capacitor (ii) an inductor varies as a function of frequency?

3. A capacitor blocks d.c. and allows a.c. Why?

4. A bulb connected in series with a solenoid is lit by a.c. source. If a soft iron core is introduced in the solenoid, will the bulb glow brighter?

5. Derive an expression for the average power over a complete cycle of a.c. in a non-inductive circuit.

6. What is meant by r.m.s. value of a.c.? Derive an expression for r.m.s. value of alternating current and emf.

7. Give the principle, construction, theory and working of an a.c. generator.

8. The core of a transformer is laminated, why?

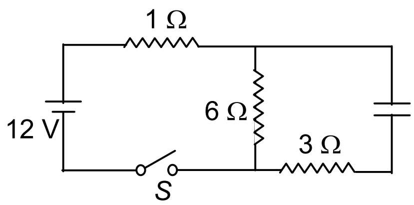
9. When a current flows in the coil of a transformer, then why does its core become hot?

10. What is the maximum value of power factor? When does it occur?

EXERCISE – II

NEET-SINGLE CHOICE CORRECT

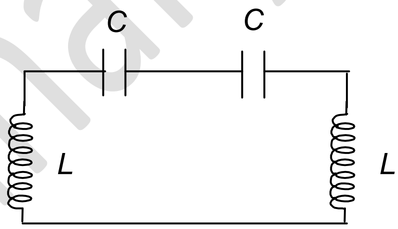
1. When the switch is closed, the initial current through the 1 Ω resistor is



(a) 12 A (b) 4 A
(c) 3 A (d) $\frac{10}{7}$ V

2. A coil of inductance 1.0 H and resistance 100 Ω is connected to a battery of emf 12 V. The energy stored in the magnetic field associated with the coil at an instant 10 ms after the circuit is switched on
(a) 1.4 mJ (b) 2.8 mJ (c) 4.2 mJ (d) 5.6 mJ

3. The natural frequency of the circuit shown in the figure is



(a) $\frac{1}{2\pi\sqrt{LC}}$ (b) $\frac{1}{\pi\sqrt{LC}}$
(c) $\frac{2}{\pi\sqrt{LC}}$ (d) none of these

4. In a circuit containing an inductance of zero resistance, the current leads the applied a.c. voltage by a phase angle of
(a) 90° (b) – 90° (c) 0° (d) 180°

5. The resonant frequency of a circuit of negligible resistance containing one inductance of 50 mH and a capacitance of 500 pF connected in series is
(a) $\frac{10^5}{\pi}$ Hz (b) $\frac{1}{\pi}$ Hz (c) $\frac{100}{\pi}$ Hz (d) $\frac{1000}{\pi}$ Hz

6. In an a.c. circuit V & I are given by $V = 100 \sin (100\, t)$ volts. $I = 100 \sin (100\, t + \pi/3)\ mA$
The power dissipated in the circuit is
(a) 10^4 watt (b) 10 watt (c) 2.5 watt (d) 5 watt

7. A 20 volt a.c. is applied to a circuit consisting of a resistance and a coil with a negligible resistance. If the voltage across the resistance is 12 volts, the voltage across the coil is
(a) 16 volt (b) 10 volt (c) 8 volt (d) 6 volt

8. A series combination of R, L, C is connected to an a.c. source. If the resistance is 3 Ω and the reactance is 4 Ω, the power factor of the circuit is
(a) 0.4 (b) 0.6 (c) 0.8 (d) 1.0

9. In an LCR circuit, the capacitance is made one-fourth of its value when it is in resonance. Then what should be the corresponding change in inductance, so that the circuit remains in resonance?
(a) 4 times (b) 1/4 times (c) 8 times (d) 2 times

10. An alternating current having peak value 14 A is used to heat a metal wire. To produce the same heating effect, a constant i can be used where i is
(a) 14 A (b) about 20 A (c) 7 A (d) about 10 A

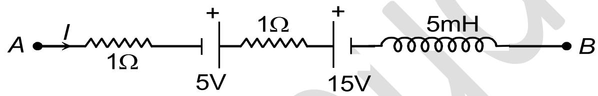
11. A step –down transformer transforms a supply line voltage of 2200 volt into 220 volt. The primary coil has 5000 turns. The efficiency and power transmitted by the transformer are 90% and 8 kilowatt respectively. Then the number of turns in the secondary is
(a) 5000 (b) 50 (c) 500 (d) 5

12. In an AC circuit, a resistance of *R* ohm is connected in series with an inductance *L*. If phase difference between voltage and current be 45^0, the value of inductive reactance will be
(a) $R/4$ (b) $R/2$
(c) R (d) cannot be found with the given data

13. A coil has an inductance of 0.7 H and is joined in series with a resistance of 220Ω. An alternating emf of 220V at 50 Hz is applied to it. Then the wattless component of the current in the circuit is
(a) 5 amp (b) 0.5 amp (c) 0.7 amp (d) 7 amp

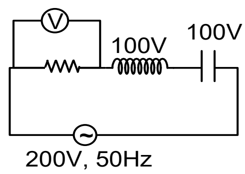
14. The voltage and current in a series *AC* circuit are given by $V = V_0 \cos \omega t$ and $I = I_0 \left(\cos \omega t + \frac{\pi}{3}\right)$. What is the power dissipated in the circuit?
(a) $\frac{V_0 I_0}{2}$ (b) 0 (c) $\frac{V_0 I_0}{4}$ (d) $\frac{\sqrt{3}}{2} V_0 I_0$

15. The network shown in the figure is part of a complete circuit. If at a certain instant, the current *I* is 10 *A*, and is decreasing at a rate 10^3 A/s then $V_A - V_B$ is

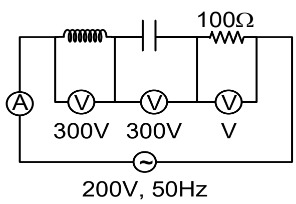


(a) 20 V (b) 15 V (c) 10 V (d) 5 V

16. In the circuit of figure, what will be the reading of the voltmeter?
(a) 300 V (b) 900 V
(c) 200 V (d) 400 V



17. In a circuit shown in figure, what will be the readings of the voltmeter and ammeter if a.c. source of 200 V and 50 Hz is connected
(a) 800 V, 2 A (b) 300 V, 2 A
(c) 200 V, 2 A (d) 100 V, 2 A



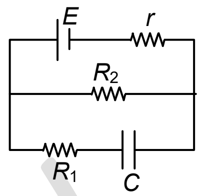
18. The root-mean-square value of an alternating current of 50 Hz frequency is 10 A. The time taken by the alternating current in reaching from zero to maximum value and peak value will be
(a) 2×10^{-2} s and 14.14 A (b) 1×10^{-2} s and 7.07 A
(c) 5×10^{-3} s and 7.07 A (d) 5×10^{-3} s and 14.14 A

19. A 120 volt AC source is connected across a pure inductor of inductance 0.70 Henry. If the frequency of the source is 60 Hz, the current passing through the inductor is
(a) 4.55 A (b) 0.325 A
(c) 0.455 A (d) 3.25 A

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

21. An alternating current flows through a circuit consisting of inductance L and resistance R. Periodicity of the supply is $\omega/2\pi$. Which of the following is true?
(a) the limiting value of impedance is L for low frequency
(b) the limiting value of impedance for low frequency is R
(c) limiting value of impedance for high frequency is R
(d) the limiting value of impendence for low frequency is $L\omega$

22. The charge on either plate of the capacitor C as shown in the figure is



(a) CE
(b) $\frac{CER_1}{R_2+r}$
(c) $\frac{CER_2}{R_2+r}$
(d) $\frac{CER_1}{R_1+r}$

23. Alternating current cannot be measured by D.C. ammeter because
(a) A.C. can not pas through D.C. Ammeter
(b) A. C. changes direction
(c) Average value of current for complete cycle is zero
(d) D.C. Ammeter will get damaged

24. In a series R-L-C AC circuit, for a particular value of R, L and C, power supplied by the source is P at resonance. If the value of inductance is halved, then the power from the source again at resonance is P'. Then
(a) $P = \frac{P'}{2}$
(b) $P = 2P'$
(c) $P = 4P'$
(d) $P = P'$

25. In a circuit, capacitor ($C = 4\ \mu$F) is connected in series with a resistor ($R = 2.5$ M Ω) with a battery of 12 V having negligible internal resistance. Find the time after which potential difference across capacitor becomes three times of potential difference across resistor (ln2 = 0.693).
(a) 13.86 s
(b) 1.386 s
(c) 6.93 s
(d) 20 s

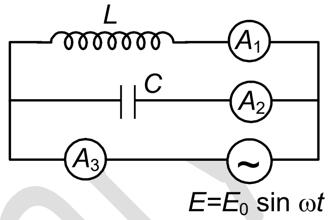
EXERCISE – III

IIT-JEE- SINGLE CHOICE CORRECT

1. A capacitor of capacitance 10μF is charged to a potential of 1V. It is connected in parallel to an inductor of inductance 10^{-3} H. The maximum current that will flow in the circuit has the value

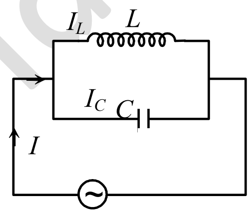
(a) 1 μA (b) 1mA (c) $\sqrt{1000}$ mA (d) 100 mA

2. An inductor L and a capacitor C are connected in the circuit as shown in the figure. The frequency of the power supply is equal to the resonant frequency of the circuit. Which ammeter will read zero ampere?



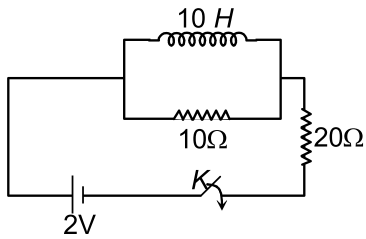
(a) A_1 (b) A_2
(c) A_3 (a) none of these

3. The magnitude of currents in different branches are shown in the circuit. Then



(a) $I = I_L + I_C$ if inductor and capacitor are pure
(b) $I = I_L - I_C$ if inductor and capacitor are pure
(c) $I = I_L + I_C$ if inductor and capacitor are not pure
(d) $I = I_L - I_C$ if inductor and capacitor are not pure

4. Two resistors of 10 Ω and 20 Ω and an ideal inductor of 10 H are connected to a 2 V battery as shown in figure. At time $t = 0$, key K is closed. Then the initial and final currents through the battery are



(a) $\frac{1}{15}A, \frac{1}{10}A$ (b) $\frac{1}{10}A, \frac{1}{15}A$

(c) $\frac{2}{15}A, \frac{1}{10}A$ (d) $\frac{1}{15}A, \frac{2}{25}A$

5. Match List I (expression for current) with List II (rms value of current) and select the correct answer.

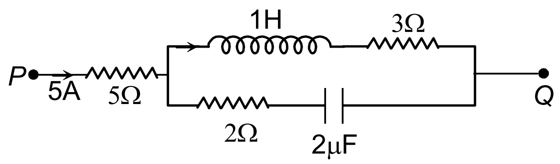
List –I	List-II
A. $I = I_0 \sin\omega t \cos\omega t$	1. I_0
B. $I = I_0 \sin\left(\omega t + \frac{\pi}{3}\right)$	2. $I_0/\sqrt{2}$
C. $I = I_0(\sin\omega t + \cos\omega t)$	3. $I_0\, e$
D. $I = I_0(e)$	4. $I_0/\left(2\sqrt{2}\right)$

	A	B	C	D
(a)	4	2	1	3
(b)	4	2	3	1
(c)	2	4	3	1
(d)	2	4	1	3

6. In a region of uniform magnetic induction $B = 10^{-2}$ T, a circular coil of radius 30cm and resistance π^2 ohm is rotated about an axis which is diameter of the coil. If the coil rotates at 200 rpm, the amplitude of the alternating current induced in the coil is

(a) $4\pi^2$ mA (b) 30 mA (c) 6 mA (d) 200 mA

7. In the given circuit, the potential difference between point P and Q in steady state is

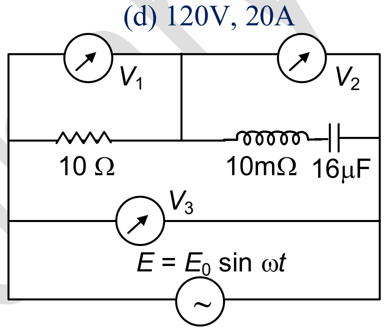


(a) 40 V (b) 21 V
(c) 18 V (d) 18 V

8. A circular coil of radius 0.1 m has 80 turns of wire. If the magnetic field through the coil increases from 0 to 2 tesla in 0.4 sec and the coil is connected to a 11 ohm resistor, what is the current (in A) through the resistor during the 0.4 sec?
(a) (8/7)A (b) (7/8)A (c) 8A (d) 7A

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

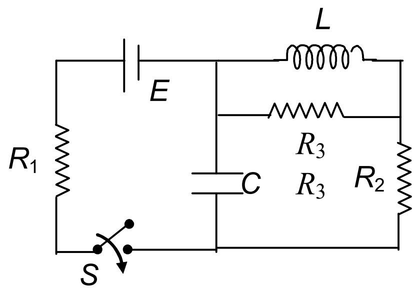
10. In the figure, which voltmeter reads zero, when ω is equal to the resonant frequency of series LCR circuit?



(a) V_1 (b) V_2
(c) V_3 (d) None of these

11. An ideal choke takes a current of 8 ampere when connected to an AC supply of 100 volt and 50Hz. A pure resistor under the same conditions takes a current of 10 ampere. If the two are connected to an AC supply of 150 volt and 40 Hz, then the current in a series combination of the above resistor and inductor is
(a) 10 amp (b) 8 amp (c) 18 amp (d) $\left(15/\sqrt{2}\right)$amp

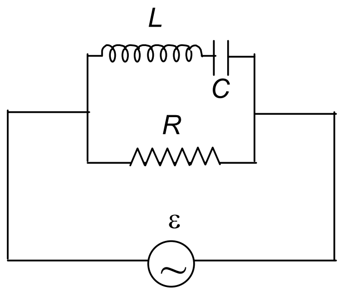
12. Current in R_3 just after closing the switch and in steady state respectively, will be



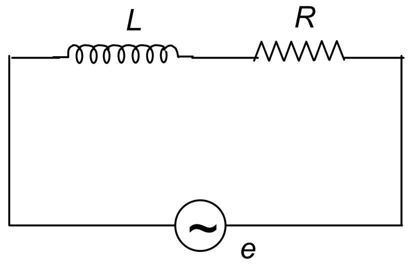
(a) 0,0 (b) $\frac{E}{R_3}$,0

(c) 0, $\frac{E}{R_3}$ (d) indeterminate

13. In the circuit shown in the figure at resonance.
(a) The power factor is zero
(b) The current through the a.c. source is minimum
(c) The current through the a.c. source is maximum
(d) Currents through L and R are equal.

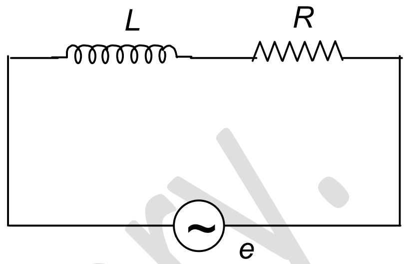


14. In the circuit shown in figure, the r.m.s. value of e is 5 V and r.m.s. value of voltage drop across L is 3 V. The r.m.s. value of voltage across R will be



(a) 2 V (b) 3 V
(c) 4 V (d) 0 V

14. In the circuit shown in figure, the r.m.s. value of e is 5 V and r.m.s. value of voltage drop across L is 3 V. The r.m.s. value of voltage across R will be

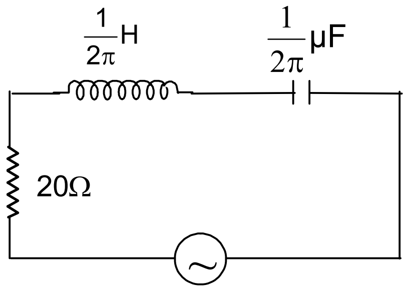


(a) 2 V (b) 3 V
(c) 4 V (d) 0 V

15. An AC source producing emf $\varepsilon = \varepsilon_0$ [cos $(100\,\pi\ s^{-1})t$ + cos $(500\,\pi\ s^{-1})t$] is connected in series with a capacitor and a resistor. The steady-state current in the circuit is found to be $i = i_1 \cos[(100\,\pi\ s^{-1})\,t + \phi_1] + i_2 \cos[(500\,\pi\ s^{-1})t - \phi_2]$, Then

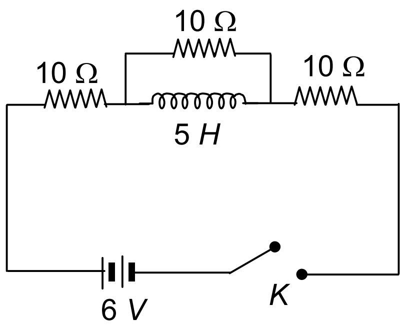
(a) $i_1 > i_2$
(b) $i_1 = i_2$
(c) $i_1 < i_2$
(d) the information is insufficient to find the relation between i_1 and i_2.

16. In the a.c. circuit shown in figure, the supply voltage has a constant r.m.s. value ε but variable frequency f. Resonance frequency in Hertz is



(a) 10 (b) 100
(c) 1000 (d) 200

17. In the circuit shown in figure, the initial value of current through the battery after closing the circuit (i.e., K pressed) is

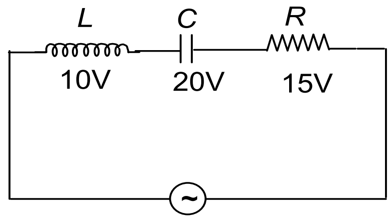


(a) 0.2 A (b) 0.24 A
(c) 0.3 A (d) none of these

18. The plates of a capacitor are charged to a potential difference of 320 volt and are then connected to a resistor. The potential difference across the capacitor decays exponentially with time. After 1sec, the potential difference between the plates of the capacitor is 240 V, then after 2 and 3 seconds potential difference between the plates will be, respectively

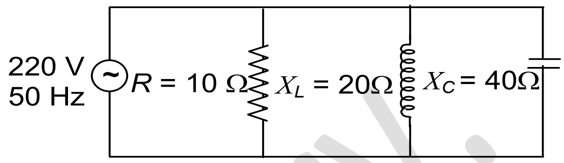
(a) 200 V and 180 V (b) 180 V and 135 V (c) 160 V and 80 V (d) 140 V and 20V

19. In the circuit shown in the figure, if value of $R = 60\ \Omega$, then the current flowing through the capacitor will be



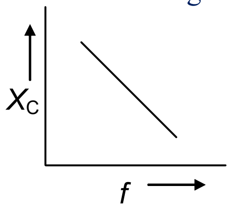
(a) 0.5 A (b) 0.25 A
(c) 0.75 A (d) 1.0 A

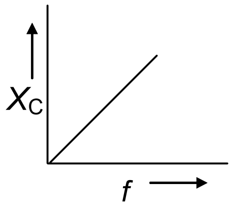
20. The value of admittance in the adjoining circuit shown in figure is

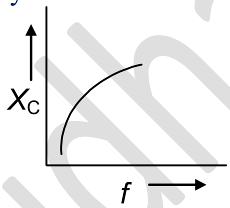


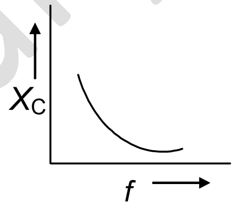
(a) 0.1 mho (b) 0.25 mho
(c) 0.35 mho (d) 9.7 mho

21. The reactance of a capacitor X_C in an ac circuit varies with frequency of the source voltage. Which one of the following represents this variation correctly?

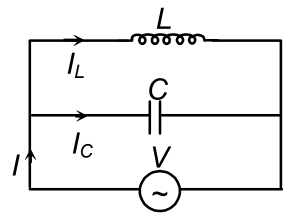
(a) 

(b) 

(c) 

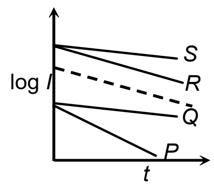
(d) 

22. For the circuit shown in figure current in inductance is 0.8 A while in capacitance is 0.6 A. What is the current drawn from the source?



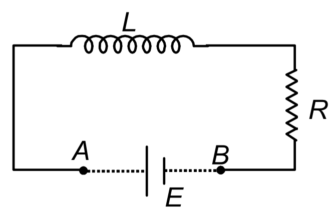
(a) 0.2 A (b) 0.4 A (c) 0.6 A (d) 1 A

23. A capacitor is charged through a resistor of resistance X. If the resistance is made $2X$ then the graph between log I and t is (the dotted line represents the initial graph)



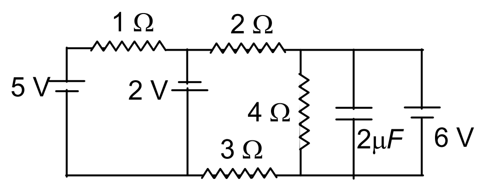
(a) P (b) Q (c) R (d) S

24. An inductor (L = 100 mH), a resistor (R = 100 Ω) and a battery (E = 100 V) are initially connected in series as shown in the figure. After a long time the battery is disconnected after short circuiting the points A and B. The current in the circuit 1 ms after the short circuit is



(a) 1 A (b) 1/e A (c) e A (d) 0.1 A

25. The current in 1 Ω resistance and the charge stored in the capacitor are



(a) 5 A, 10 μC (b) 7 A, 12 μC
(c) 4 A, 12μC (d) 6 A, 6 μC

EXERCISE – IV

ONE OR MORE THAN ONE CHOICE CORRECT

1. Power factor may be one for

(a) pure inductor (b) pure capacitor (c) pure resistor (d) series LCR circuit

2. Current in circuit may be wattless if

(a) inductance in the circuit is zero

(b) resistance in the circuit is zero

(c) current is alternating

(d) reactance in the circuit is zero but inductance not zero.

3. Average power in an A.C. circuit is given by

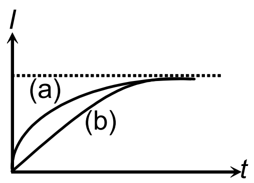
(a) $E_{rms} I_{rms} \cos \phi$ (b) $(I_{rms})^2 R$ (c) $\frac{E_0^2 R}{2(|Z|)^2}$ (d) $\frac{I_0^2 |Z| \cos \phi}{2}$

4. In an AC series circuit, the instantaneous current is zero when the instantaneous voltage is maximum. Connected to the source may be

(a) pure inductor (b) pure capacitor

(c) pure resistor (d) combination of inductor and capacitor

5. A coil of inductance L and resistance R is connected across a d.c. source of emf E (of negligible internal resistance). The current in the circuit varies with time t as shown by curve (a). When one or more of parameters E, R and L are changed, the curve (b) is obtained. Steady state current is same in both the cases. Then possible changes is/are



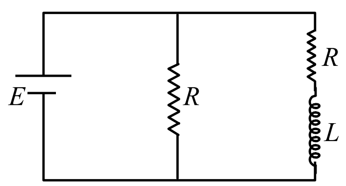
(a) E and R are kept constant and L is increased

(b) E and R are kept constant and L is decreased

(c) E and R are both halved and L is kept constant

(d) E and L are kept constant and R is decreased

6. In the circuit shown



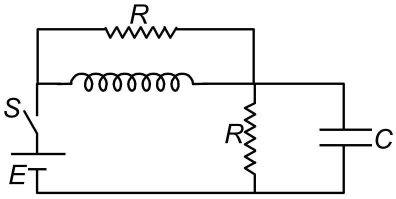
(a) time constant is L/R

(b) time constant is $2L/R$

(c) steady state current in inductor is $2E/R$

(d) steady state current in inductor is E/R

7. In the circuit shown switch S is closed at time $t = 0$, initially capacitor is uncharged and initially current through the inductor is zero. Then



(a) initial current through capacitor is $E/2R$

(b) initial rate of rise of current through inductor is E/L

(c) initial current through capacitor is E/R

(d) initial rate of rise of current through inductor is $2E/L$

8. The S.I. unit of inductance Henry can be written as

(a) weber/ampere (b) volt-sec/ampere

(c) Joule/ampere^2 (d) ohm-second

9. If an alternating voltage is given by $e = e_1 \sin \omega t + e_2 \cos \omega t$ the

(a) root mean square value of voltage is $\frac{\sqrt{e_1^2 + e_2^2}}{2}$

(b) average value of voltage over one time period $\frac{e_1 + e_2}{2}$

(c) root mean square value of voltage is $\sqrt{\frac{e_1^2 + e_2^2}{2}}$

(d) average value of voltage over one time period is zero

10. A capacitor of capacitance 1 μF is charged to potential difference of 2V and is connected across an inductor of 1 mH. At an instant when potential difference across capacitor is 1V, the current in the circuit is i_1. The maximum current through inductor is i_0, then

(a) $i_0 = \sqrt{4000}$ mA (b) $i_0 = \sqrt{2000}$ mA

(c) $i_1 = \sqrt{3000}$ mA (d) $i_1 = \sqrt{1000}$ mA

11. An inductive reactance $X_L = 100\Omega$, a capacitive reactance $X_C = 100\ \Omega$ and resistance $R = 100\ \Omega$ are connected in series to an a.c. source of $e = 100 \sin (50\ t)$ volts. Which of the following statements is/are correct.

(a) the maximum voltage across capacitor is 100 volts

(b) the impedance of the circuit is 100 Ω

(c) the maximum voltage across inductor is 100 volts

(d) the maximum voltage across the combination is 100 volts

12. A circuit consists of a resistance and capacitance in series. An alternating emf of 180 volts and 100 cycle/sec frequency is applied to it. If rms value of current is 6 amp and power consumed in the resistance is 360 watts then

(a) circuit impendence is 30 ohms

(b) capacitive reactance is 100 ohms

(c) circuit resistance is 10 ohm

(d) circuit resistance is 20 ohms

13. A circuit has resistance $R = 10\ \Omega$ and coil of inductance $L = 15$H in series. At any instant current flowing through the circuit is $i = 2t^2 - 4$, then which of the following is/are correct

(a) voltage across the coil at $t = 1$ sec is 60V

(b) energy stored in the inductor at $t = 1$ sec is 30 J

(c) voltage at $t = 2/3$ sec is 60 V

(d) energy store in the inductor at $t = 2/3$ sec is 30 J

14. An L-C-R series circuit with 100 Ω resistance is connected to an *ac* source. When only the capacitance is removed, the current lags behind voltage by $\frac{\pi}{4}$. When only the inductance is removed, the current leads voltage by $\frac{\pi}{4}$. Then

(a) Inductive reactance is 100 Ω

(b) Capacitive reactance is 100 Ω

(c) Impedance of L-C-R circuit is 100 Ω

(d) maximum potential difference across inductor is equal to maximum potential difference across capacitor when all are connected in circuit.

15. A leaky parallel plate capacitor is filled completely with a material having dielectric constant $K = 5$ and electrical conductivity σ. If initial charge on the capacitor is q_0, positive plate and negative plate of capacitor are connected to each other by conducting wire at $t = 0$, then

(a) time constant of the circuit is $\frac{5\varepsilon_0}{\sigma}$

(b) current in the circuit at any time t is $\frac{q_0\sigma}{5\varepsilon_0}e^{-\frac{t\sigma}{5\varepsilon_0}}$

(c) current in the circuit at any time t is $\frac{q_0\sigma}{5\varepsilon_0}\left(1-e^{-\frac{\sigma t}{5\varepsilon_0}t}\right)$

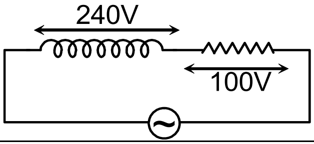
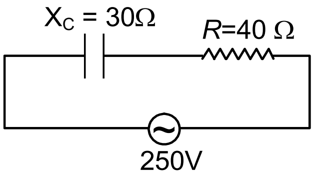
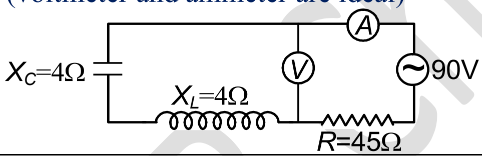
(d) none of these

EXERCISE – V

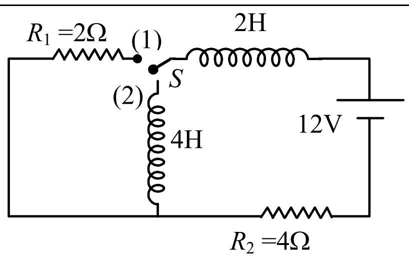
MATCH THE FOLLOWING

Note: Each statement in column – I has only one match in column –II

1. Questions asked in column –I and answers are given in column-II, match the following

Column – I	Column - II
I. A current of 2A is flowing in given L-R circuit, voltage across inductor and resistor are given. The voltage in volt across a.c. source will be 	**A.** zero
II. If the given R-C circuit is connected to a 250 V ac source. Capacitive reactance is X_C = 30 Ω and resistance is R = 40 Ω, the voltage in volt across capacitor will be 	**B.** 2
III. What will be the voltmeter reading in volt in the given circuit (voltmeter and ammeter are ideal) 	**C.** 260
IV. In the above question reading of ammeter in ampere is	**D.** 150

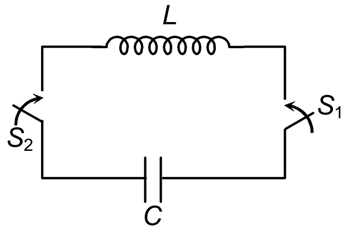
2. In the given circuit diagram switch S is closed with position (1) at t = 0, and steady state reached after long time $t = t_0$ and switch is shifted from position (1) to position (2) at $t = t_0$



Column – I	Column - II
I. The current in 4 Ω just after t = 0	**A.** 3A
II. The current in 4 Ω just before $t = t_0$	**B.** 2/3 A
III. The current in 4 Ω just after $t = t_0$	**C.** 2 A
IV. The current in 4 Ω after a very long time from the instant when switch is shifted from (1) to (2)	**D.** zero

Note: Each statement in column – I has one or more than one match in column –II.

3. A capacitor of capacity C is fully charged with a battery of emf V_0 and connected through an inductor of inductance L through two switches S_1 and S_2 respectively as shown in the figure. At $t = 0$, both switches S_1 and S_2 are closed. Given below are two columns. In column I, some conditions related to system and in column II, their corresponding times are given, match the column I with column II.



Column -I	Column -II
I. Charge on the capacitor is maximum	**A.** $\frac{\pi}{2}\sqrt{LC}$
II. Current in the inductor is maximum	**B.** $\pi\sqrt{LC}$
III. Electrostatic energy stored in the system is maximum	**C.** $\frac{3\pi}{2}\sqrt{LC}$
IV. Magnetic energy stored in the system is maximum	**D.** $2\pi\sqrt{LC}$

REASONING TYPE

Directions: Read the following questions and choose

(A) If both the statements are true and statement-2 is the correct explanation of **statement-1**.
(B) If both the statements are true but statement-2 is not the correct explanation of **statement-1**.
(C) If statement-1 is True and **statement-2** is False.
(D) If statement-1 is False **and statement-2** is True.

1. **Statement-1**: A resistance is connected to an ac source. Now a capacitor is included in the circuit. The average power absorbed by the resistance will not be same.
Statement-2: By including a capacitor or an inductor in the circuit root mean square current and power factor will be changed.
(a) (A) (b) (B) (c) (C) (d) (D)

2. **Statement-1**: In LCR series circuit, power factor can be improved by introducing a capacitor of appropriate capacitance in the circuit.
Statement-2: By adjusting C, the value of Z can be made to approach R in ac circuit.
(a) (A) (b) (B) (c) (C) (d) (D)

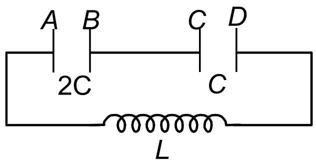
3. **Statement-1**: Reactances of inductor and capacitor respectively vary linearly and inversely with frequency.
Statement-2: Reactance of inductor and capacitor does not depend on the frequency.
(a) (A) (b) (B) (c) (C) (d) (D)

4. **Statement-1**: In any a.c. series circuit, the applied instantaneous voltage is not equal to the algebraic sum of the instantaneous voltage across the different elements of the circuit.
Statement-2: The voltage across different elements are not in phase only their phasor sum is equal to the applied voltage.
(a) (A) (b) (B) (c) (C) (d) (D)

5. **Statement-1**: The average power over one complete cycle in a.c circuit cannot be negative.
Statement-2: A pure inductance or a pure capacitance does not consume average power.
(a) (A) (b) (B) (c) (C) (d) (D)

LINKED COMPREHENSION TYPE

Two capacitors P and Q of capacitance $2C$ and C are connected in series with an inductor of inductance L. Initially capacitors are charged such that $V_B - V_A = 4V_0$ and $V_C - V_D = V_0$ (see figure). Maximum current in the circuit is I_{max} at $t = t_0$



1. Maximum current that will flow in the circuit is

(a) $V_0\sqrt{\frac{6C}{L}}$ (b) $V_0\sqrt{\frac{C}{L}}$ (c) $\frac{V_0}{2}\sqrt{\frac{L}{6C}}$ (d) $\frac{V_0}{2}\sqrt{\frac{L}{6C}}$

2. Find the potential difference across capacitor P at $t = t_0$

(a) $\frac{V_0}{2}$ (b) $3V_0$ (c) $2V_0$ (d) $\frac{5}{2}V_0$

3. Maximum energy stored in inductor is

(a) $\frac{1}{2}CV_0^2$ (b) $\frac{1}{6}CV_0$ (c) $3CV_0^2$ (d) $\frac{17}{2}CV_0^2$

4. Charge on capacitor Q at $t = t_0$ is

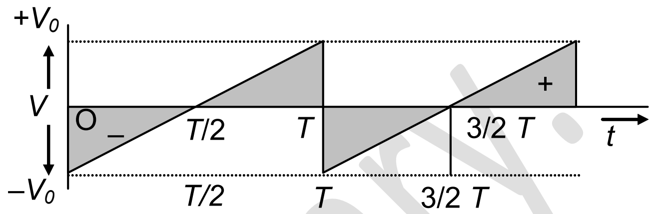
(a) $3CV_0$ (b) $6CV_0$ (c) CV_0 (d) zero

EXERCISE – VI

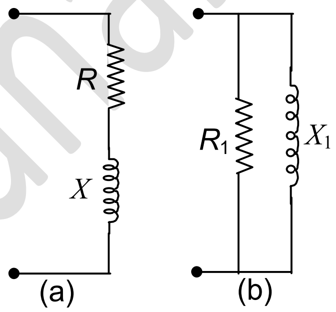
SUBJECTIVE PROBLEMS

1. A coil has a resistance of 10 Ω and an inductance of 0.4 henry. It is connected to an AC source of 6.5 V, $\frac{30}{\pi}$ Hz. The average power consumed in the circuit is x × 10^{-3} W. Find the value of *x*.

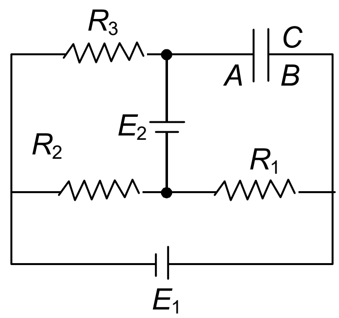
2. Find the rms value for the saw-tooth voltage of peak value $V_0 = 10\sqrt{3}$ volts as shown in figure.



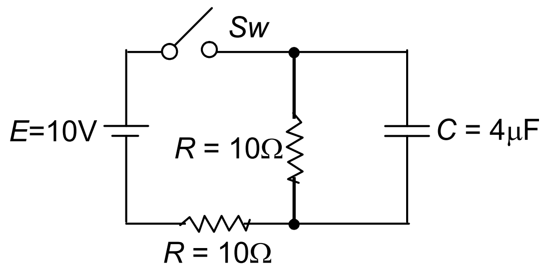
3. The series and parallel circuits shown in figure have the same impedance and the same power factor. If $R = 3\Omega$ and $X = 4\Omega$. The value of X_1 is $a \times 10^{-2}$ Ω. Find the value of *a*.



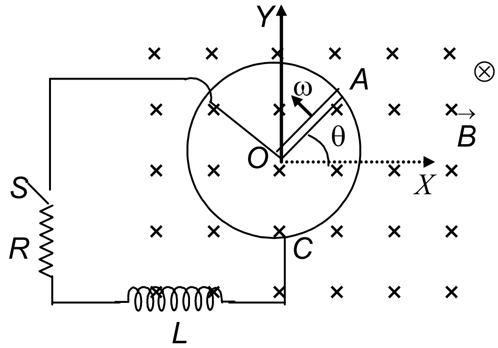
4. Find the potential difference $\phi_B - \phi_A$ between the plates of a capacitor *C* in the circuit shown in figure. If the sources have emf's $E_1 = 4.0$ V and $E_2 = 1.0$ V and the resistances are equal to $R_1 = 10\ \Omega$, $R_2 = 20\ \Omega$, and $R_3 = 30\ \Omega$. The internal resistance of the sources are negligible.



5. The voltage across the capacitor C varies with time *t* as $V = a(1-e^{-bt})$ volts as shown in the figure after the shorting of the switch *Sw* at the moment *t* = 0. Calculate the value of $\frac{a}{b}$ in volts – ohm-μF.

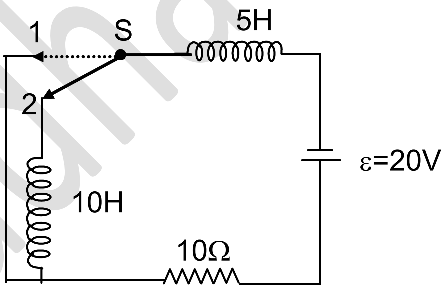


6. A metal rod *OA* of mass m = 1 kg and length r = $\sqrt{2}$ m is rotating with a constant angular speed ω = $\frac{\pi}{2}$ rad/s in a vertical plane about a horizontal axis at the end *O*. The free end A is arranged to slide without friction along a fixed conducting circular ring in the same plane as that of rotation. A uniform and constant magnetic induction $\vec{B}$ = 2T is applied perpendicular and into the plane of rotation as shown in the Figure. An inductor *L* = 2H and an external resistance *R* = πΩ are connected through a switch *S* between the point *O* and a point *C* on the ring to form an electrical circuit. Neglect the resistance of the ring and the rod. Initially, the switch is open. Switch is closed at time $t = 0$.

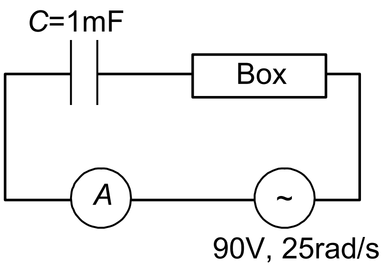


Calculate the torque required to maintain the constant angular speed at $t = \frac{1}{2}$ s (given that the rod OA was along the positive X-axis at $t = 0$).

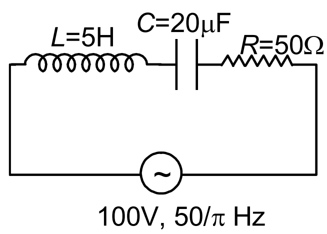
7. In the circuit shown the switch S is shifted to position 2 from position 1 at $t = 0$, having been in position 1 for a long time. The current in the circuit as a function of time is $I = a–b\ e^{-ct}$, where a, b and c are constants. Find the value of $\frac{a \times c}{b}$ in M.K.S.Units



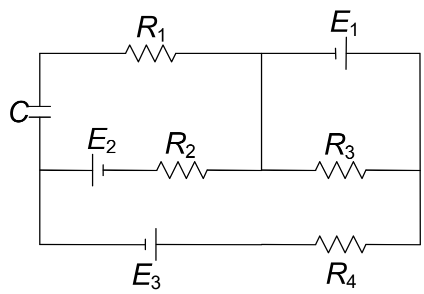
8. In the circuit shown, if the power factor of the circuit is 1 and power factor of box is $\frac{3}{5}$. Calculate the reading of ammeter



9. For the given LCR circuit. Calculate the Q factor (voltage gain) of the circuit



10. In the given circuit,
$E_1 = 3E_2 = 2E_3 = 6$ V
$R_1 = 2R_4 = 6\ \Omega$
$R_3 = 2R_2 = 4\ \Omega$
$C = 5\ \mu F$
Find the charge on the capacitor in steady state.



ANSWERS

EXERCISE – II

NEET-SINGLE CHOICE CORRECT

1. (b)	2. (b)	3. (a)	4. (b)	5. (a)
6. (c)	7. (a)	8. (b)	9. (a)	10. (d)
11. (c)	12. (c)	13. (b)	14. (c)	15. (d)
16. (c)	17. (c)	18. (d)	19. (c)	20. (c)
21. (b)	22. (c)	23. (c)	24. (d)	25. (a)

EXERCISE – III

IIT-JEE-SINGLE CHOICE CORRECT

1. (d)	2. (c)	3. (b)	4. (a)	5. (a)
6. (c)	7. (a)	8. (a)	9. (a)	10. (b)
11. (d)	12. (a)	13. (c)	14. (c)	15. (c)
16. (c)	17. (a)	18. (b)	19. (b)	20. (a)
21. (d)	22. (a)	23. (b)	24. (b)	25. (b)

EXERCISE – IV

MORE THAN ONE CHOICE CORRECT

1. (c,d)	2. (a,b,c)	3. (a,b,c,d)	4. (a,b,d)	5. (a,c)
6. (a,d)	7. (b,c)	8. (a,b,c,d)	9. (c,d)	10. (a, c)
11. (a,b,c,d)	12. (a,c)	13. (a, b)	14. (a,b,c,d)	15. (a,b)

EXERCISE – V

MATCH THE FOLLOWING

1. I – C, II – D, III – A, IV – B
2. I – D, II – C, III – B, IV – A
3. I – B, D, II – A, C, III – B,D, IV – A, C

REASONING TYPE

1. (a)	2. (a)	3. (c)	4. (a)	5. (b)

LINKED COMPREHENSION TYPE

1. (a)	2. (b)	3. (c)	4. (a)	

EXERCISE – VI

SUBJECTIVE PROBLEMS

1. 625

2. 10 V

3. 625

4. 1 V

5. 100

6. 6 N-m

7. 1

8. 3 A

9. 10

10. 12 μC

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 1

Q.1 An alternating current changes from a complete cycle in 1μs, then the frequency in Hz will be -
(1) 10^{-6} (2) 50
(3) 100 (4) 10^6

Q.2 An alternating voltage source is connected, in an A.C. circuit whose maximum value is 170 volt. The value of potential at a phase angle of 45º will be -
(1) 120.56 Volt (2) 110.12 Volt
(3) 240 Volt (4) Zero

Q.3 In an ac circuit, the current is given by i = 4 sin (100πt + 30º) ampere. The current becomes maximum first time (after t = 0) at t equal to -
(1) (1/200) sec (2) (1/300) sec
(3) (1/50) sec (4) None of the above

Q.4 The instantaneous value of current in an ac circuit is I = 2 sin (100πt + π/3) A. The current at the beginning (t = 0) will be -
(1) $2\sqrt{3}$ A (2) $\sqrt{3}$ A
(3) $\frac{\sqrt{3}}{2}$ A (4) Zero

Q.5 In A.C. circuit the average value per cycle of e.m.f. or current is -
(1) peak value / $\sqrt{2}$ (2) 0
(3) peak value (4) None of the above

Q.6 The form factor for sinusoidal potential is -
(1) $\pi\sqrt{2}$ (2) $2\sqrt{2}\,\pi$
(3) $\frac{\pi}{2\sqrt{2}}$ (4) $\frac{\pi}{2}$

Q.7 The r.m.s. value of potential due to superposition of given two alternating potentials $E_1 = E_0 \sin \omega t$ and $E_2 = E_0 \cos \omega t$ will be -
(1) E_0 (2) $2E_0$
(3) $E_0\sqrt{2}$ (4) 0

Q.8 If the value of E_{rms} is 5 volt, then the tolerance of the component in volt is -
(1) 1 (2) $\frac{1}{\sqrt{5}}$
(3) $\sqrt{5}$ (4) $5\sqrt{2}$

Q.9 A mixer of 1000Ω resistance is connected to an A.C. source of 200V and 50 cycle per sec. The value of average potential difference across the mixer will be -
(1) 308 V (2) 264 V
(3) 220 V (4) 0

Q.10 If instantaneous value of current is I = 10 sin (314 t) A, then the average current for the half cycle will be -
(1) 10 A (2) 7.07 A
(3) 6.37 A (4) 3.53 A

Q.11 The r.m.s. value of alternating current is 10 amp having frequency of 50 Hz. The time taken by the current to increase from zero to maximum and the maximum value of current will be -
(1) 2×10^{-2} sec. and 14.14 amp
(2) 1×10^{-2} sec. and 7.07 amp
(3) 5×10^{-3} sec. and 7.07 amp
(4) 5×10^{-3} sec. and 14.14 amp

Q.12 In a circuit an a.c. current and a d, c. current are supplied together. The expression of the instantaneous current is given as i = 3 + 6 sin ωt. Then the rms value of the current is -
(1) 3 (2) 6
(3) $3\sqrt{2}$ (4) $3\sqrt{3}$

Q.13 The emf and the current in a circuit are
E = 12 sin (100πt) ;
I = 4 sin (100πt + π / 3) then -
(1) The current leads the emf by 60º
(2) The current lags the emf by 60º
(3) The emf leads the current by 60º
(4) The phase difference between the current and the emf is zero

Q.14 The direction of alternating current get changed in one cycle -
(1) two times (2) one time
(3) 50 times (4) 60 times

Q.15 If the frequency of alternating potential is 50Hz then the direction of potential, changes in one second by -
(1) 50 times (2) 100 times
(3) 200 times (4) 500 times

Q.16 The time period of of alternating current with frequency of one KHz one second will be -
(1) 0.10 (2) 0.01
(3) 1×10^{-3} (4) 1×10^{-2}

Q.17 The value of alternating e.m.f. is e = 500 sin 100πt , then the frequency of this potential in Hz is -
(1) 25 (2) 50
(3) 75 (4) 100

Q.18 The frequency of an alternating current is 50Hz, then the time to complete one cycle for current vector will be-
(1) 20 ms (2) 50 ms
(3) 100 ms (4) 1 s

Q.19 In the above question, time taken by current to rise from zero to maximum is -
(1) $\frac{1}{200}$ sec (2) $\frac{1}{100}$ sec
(3) $\frac{1}{50}$ sec (4) $\frac{1}{400}$ sec

Q.20 In the equation for A.C. $I = I_0 \sin \omega t$, the current amplitude and frequency will respectively be -

(1) $I_0, \frac{\omega}{2\pi}$ (2) $\frac{I_0}{2}, \frac{\omega}{2\pi}$

(3) $I_{rms}, \frac{\omega}{2\pi}$ (4) I_0, ω

Q.21 The sinusoidal voltage wave changes from 0 to maximum value of 100 volt. The voltage when the phase angle is 30º will be -

(1) 70.7 volt (2) 50 volt

(3) 109 volt (4) – 100 volt

Q.22 If the frequency of ac is 60 Hz the time difference corresponding to a phase difference of 60º is -

(1) 60 s (2) 1 s

(3) 1/60 s (4) 1/360 s

Q.23 The domestic power supply is at 220 volt. The amplitude of emf will be -

(1) 220 V (2) 110 V

(3) 311 V (4) None of this

Q.24 The phase difference between the current and the electromotive force in an ac circuit is $\pi/4$ radian. If the frequency is 50 Hz, then the time difference corresponding to this phase difference, will be -

(1) 0.25 s (2) 0.02 s

(3) 2.5 ms (4) 25 ms

Q.25 In A.C. circuit the ratio of virtual current and the r.m.s. current is –

(1) 0 (2) 0.5

(3) 1 (4) $\sqrt{2}$

Q.26 If the r.m.s. value of A.C. is I_{rms} then peak to peak value is -

(1) $\sqrt{2}\, I_{rms}/2$ (2) $I_{rms}/\sqrt{2}$

(3) $2\sqrt{2}\, I_{rms}$ (4) $2\, I_{rms}$

Q.27 The average value or alternating current for half cycle in terms of I_0 is -

(1) $\frac{2I_0}{\pi}$ (2) $\frac{I_0}{\pi}$

(3) $\frac{I_0}{\sqrt{2}}$ (4) 0

Q.28 Sinusoidal peak potential is 200 volt with frequency 50Hz. It is represented by the equation -

(1) E = 200 sin 50t

(2) E = 200 sin 314t

(3) $E = 200\sqrt{2} \sin 50t$

(4) $E = 200\sqrt{2} \sin 314t$

Q.29 If the instantaneous value of currents is I = 100 sin 314t Amp. then the average of current in Ampere for half cycle is -

(1) 100 (2) 70.7

(3) 63.7 (4) 35.3

Q.30 The equation of current in an ac circuit is $I = 4 \sin (100\pi t + \pi/6)$ ampere. The current at the beginning (t = 0) will be -
(1) 1 A (2) 2 A
(3) 3 A (4) 4 A

Q.31 RMS value of ac $i = i_1 \cos \omega t + i_2 \sin \omega t$ will be-
(1) $\frac{1}{\sqrt{2}}(i_1 + i_2)$ (2) $\frac{1}{\sqrt{2}}(i_1 + i_2)^2$
(3) $\frac{1}{\sqrt{2}}(i_1^2 + i_2^2)^{1/2}$ (4) $\frac{1}{\sqrt{2}}(i_1^2 + i_2^2)^{1/2}$

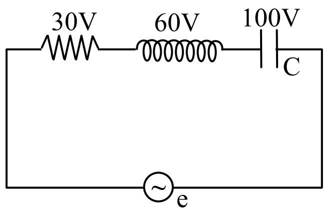
Q.32 The phase difference between the alternating current and voltage represented by the following equation $I = I_0 \sin \omega t$, $E = E_0 \cos (\omega t + \pi / 3)$, will be -
(1) $\frac{\pi}{3}$ (2) $\frac{4\pi}{3}$
(3) $\frac{\pi}{2}$ (4) $\frac{5\pi}{6}$

Q.33 The inductance of a resistance less coil is 0.5 Henry. In the coil the value of A.C. is 0.2 Amp whose frequency is 50Hz. The reactance of circuit is -
(1) 15.7 Ω (2) 157Ω
(3) 1.57Ω (4) 757Ω

Q.34 The inductive reactance of a coil is 1000Ω. If its self inductance and frequency both are increased two times then inductive reactance will be -
(1) 1000 Ω (2) 2000 Ω
(3) 4000 Ω (4) 16000 Ω

Q.35 In an L-C-R series circuit R = 10Ω, X_L = 8Ω and X_C = 6Ω the total impedance of the circuit is -
(1) 10.2Ω (2) 17.2Ω
(3) 10Ω (4) None of the above

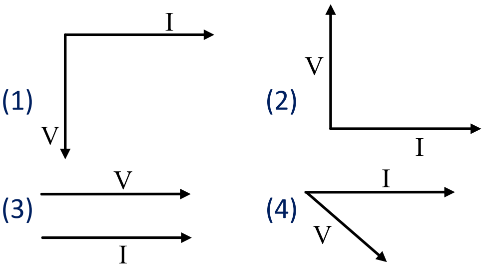
Q.36 In the given figure, the potential difference is shown on R, L and C. The e.m.f. of source in volt is -



(1) 190 (2) 70 (3) 50 (4) 40

Q.37 In an L.C.R series circuit R = 1Ω, X_L = 1000Ω and X_C = 1000Ω. A source of 100 m.volt is connected in the circuit the current in the circuit is -
(1) 100 mAmp (2) 1 μAmp
(3) 0.1 μAmp (4) 10 μAmp

Q.38 Which of the following figure showing the phase relationship is correct phase diagram for an R–C circuit-



Q.39 A coil of inductance 0.1 H is connected to an alternating voltage generator of voltage E = 100 sin (100t) volt. The current flowing through the coil will be -

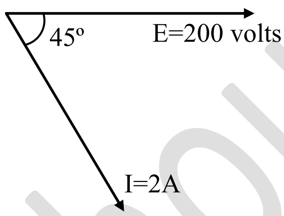
(1) $I = 10\sqrt{2}$ sin (100t) A

(2) $I = 10\sqrt{2}$ cos (100t) A

(3) I = – 10 sin (100t) A

(4) I = – 10 cos (100t) A

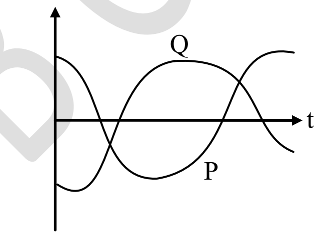
Q.40 The vector diagram of the current and voltage in a given circuit is shown in the figure. The components of the circuit will be -



(1) L–C–R (2) L–R

(3) L–C–R or L–R (4) C–R

Q.41 Figure shows the variation of voltage with time for an ac $I = I_0 \sin \omega t$ flowing through a circuit -



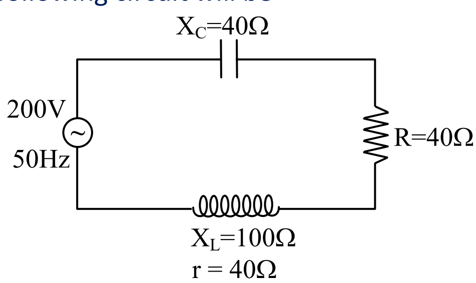
(1) Curve P is for R–L and Q for R–C circuit

(2) Curve P is for R–C and Q for R–L circuit

(3) Both are for R–C circuit

(4) Both are for R–L circuit

Q.42 The power factor of the following circuit will be-



(1) 0.2 (2) 0.4 (3) 0.6 (4) 0.8

Q.43 In a circuit, the reactance of a coil is 20Ω. If the inductance of the coil is 50 mH then angular frequency of the current will be -

(1) 400 rad/sec (2) 1 rad/sec
(3) 2.5 rad/sec (4) 0.2 rad/sec

Q.44 If a capacitor is connected to two different A.C. generators then the value of capacitive reactance is -

(1) directly proportional to frequency
(2) inversely proportional to frequency
(3) independent of frequency
(4) inversely proportional to the square of frequency

Q.45 Alternating current lead the applied e.m.f. by $\pi/2$ when the circuit consists of -

(1) only resistance
(2) only capacitor
(3) only an inductance coil
(4) capacitor and resistance both

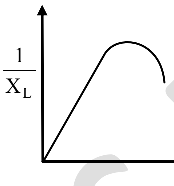
Q.46 The reactance of a capacitor is X_1 for frequency n_1 and X_2 for frequency n_2 then $X_1 : X_2$ is -

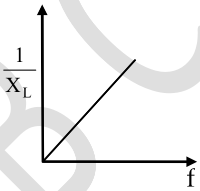
(1) 1 : 1 (2) $n_1 : n_2$
(3) $n_2 : n_1$ (4) $n_1^2 : n_2^2$

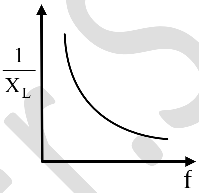
Q.47 A coil has reactance of 100Ω when frequency is 50Hz. If the frequency becomes 150Hz, then the reactance will be -

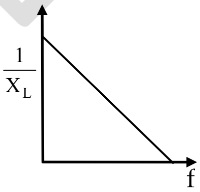
(1) 100Ω (2) 300Ω
(3) 450Ω (4) 600Ω

Q.48 In pure inductive circuit, the curves between frequency f and inductive reactance $1/X_L$ is -

(1) 

(2) 

(3) 

(4) 

Q.49 In pure capacitive circuit if the frequency of A.C. is doubled, then the value of capacitive reactance will become -

(1) Two times (2) 1/2 times
(3) No change (4) 1/4 times

Q.50 In an A.C. circuit, a capacitor of $1\mu F$ value is connected to a source of frequency 1000 rad/sec. The value of capacitive reactance will be -

(1) 10Ω (2) 100Ω
(3) 1000Ω (4) $10,000\Omega$

Q.51 In an A.C. circuit capacitance of 5μF has a reactance as $\frac{1}{1000}$ Ω. The frequency of A.C. in MHz will be -
(1) 1000/π (2) 100/π
(3) 200 (4) 5000

Q.52 In an A.C. circuit X_L = 300Ω, X_C = 200Ω and R = 100Ω the impedance of circuit is -
(1) 600Ω (2) 200Ω
(3) 141Ω (4) None of the above

Q.53 A resistance of 50Ω, an inductance of 20/π Henry and a capacitor of 5/π μF are connected in series with an A.C. source of 230 volt and 50 Hz. The impedance of circuit is-
(1) 5Ω (2) 50Ω
(3) 5KΩ (4) 500Ω

Q.54 In an L–C–R series circuit R = $\sqrt{5}$ Ω,X_L = 9Ω and X_C = 7Ω. If applied voltage in the circuit is 50 volt then impedance of the circuit in ohm then impedance of the circuit in ohm will be -
(1) 2 (2) 3
(3) 2 $\sqrt{5}$ (4) 3 $\sqrt{5}$

Q.55 The potential difference between the ends of a resistance R is V_R between the ends of capacitor is $V_C = 2V_R$ and between the ends of inductance is $V_L = 3V_R$, then the alternating potential of the source in terms of V_R will be -
(1) $\sqrt{2}\,V_R$ (2) V_R
(3) $V_R/\sqrt{2}$ (4) $5V_R$

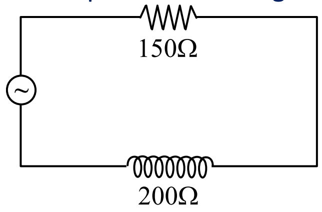
Q.56 In an A.C. circuit the impedance is Z = 100∠ 30º Ω, then the resistance of the circuit in ohm will be -
(1) 50 (2) 100
(3) 50 $\sqrt{3}$ (4) 100 $\sqrt{3}$

Q.57 In an LCR circuit, the voltages across the components are V_L, V_C and V_R respectively. The voltage of source will be -
(1) $[V_R + V_L + V_C]$
(2) $[V_R^2 + V_L^2 + V_C^2]^{1/2}$
(3) $[V_R^2 + (V_L + V_C)^2]^{1/2}$
(4) $[V_R^2 + (V_L - V_C)^2]^{1/2}$

Q.58 In an electric circuit the applied alternating emf is given by E = 100 sin (314 t) volt, and current flowing I = sin (314t + π /3). Then the impedance of the circuit is (in ohm) -
(1) $100/\sqrt{2}$ (2) 100
(3) $100\sqrt{2}$ (4) None of the above

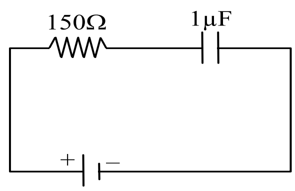
Q.59 The percentage increase in the impedance of an ac circuit, when its power factor changes form 0.866 to 0.5 is (Resistance constant) -
(1) 73.2% (2) 86.6%
(3) 90.8% (4) 66.6%

Q.60 The impedance of the given circuit will be -



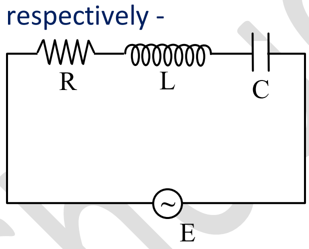
(1) 50 ohm (2) 150 ohm
(3) 200 ohm (4) 250 ohm

Q.61 The impedance of the given circuit will be -



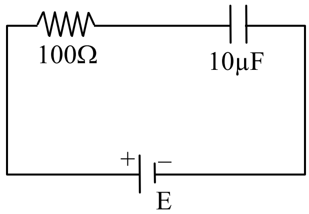
(1) Zero (2) Infinite
(3) 55 ohm (4) 2500 ohm

Q.62 If E_0 = 200 volt, R = 25 ohm. L = 0.1 H and C = 10^{-5} F and the frequency is variable, then the current at f = 0 and f = ∞ will be respectively -



(1) 0 A, 8 A (2) 8 A, 0 A
(3) 8 A, 8 A (4) 0 A, 0 A

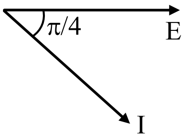
Q.63 The impedance of the circuit given will be -

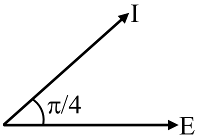


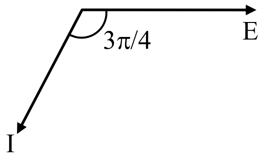
(1) Zero (2) Infinite
(3) 110 ohm (4) 90 ohm

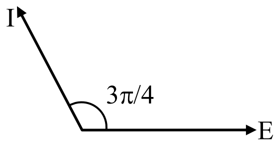
Q.64 A coil of resistance R and inductance L is connected to a cell of emf E volt. The current flowing through the coil will be -
(1) E/R (2) E/L
(3) $\frac{E}{\sqrt{L^2+R^2}}$ (4) $\frac{\sqrt{EL}}{\sqrt{L^2+R^2}}$

Q.65 In a certain circuit E = 200 cos (314t) and I = sin (314t + π/4). Their vector representation is -

(1) 

(2) 

(3) 

(4) 

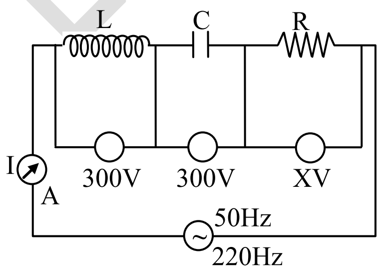
Q.66 In question (65) reactance X will be -
(1) 70.7 ohm (2) 0.707 ohm
(3) 100 ohm (4) 141 ohm

Q.67 In question (65) the power factor is -
(1) 0.5 (2) 0.707
(3) 0.85 (4) 1.0

Q.68 The electric resonance is sharp in L-C-R circuit if in the circuit -
(1) R is greater (2) R is smaller
(3) R = X_L or X_C (4) Does not depend on R

Q.69 In a series resonant L–C–R circuit, if L is increased by 25% and C is decreased by 20%, then the resonant frequency will -
(1) Increase by 10%
(2) Decrease by 10%
(3) Remain unchanged
(4) Increase by 2.5%

Q.70 If R = 100 Ω then the value of X and I in the given circuit will be -



(1) 800 V, 2A (2) 300 V, 2A
(3) 220 V, 2.2A (4) 100 V, 2A

Q.71 In question (70) the value of inductance will be-

(1) 0.12 H (2) 0.24 H
(3) 0.31 H (4) 0.43 H

Q.72 In an LCR. series circuit the resonating frequency can be decreased by -
(1) Decreasing the value of C
(2) Decreasing the value of L
(3) Decreasing both the values of L and C
(4) Increasing the value of C

Q.73 Which of the following statements is correct for L–C–R series combination in the condition of resonance -
(1) Resistance is zero
(2) Impedance is zero
(3) Reactance is zero
(4) Resistance, impedance and reactance all are zero

Q.74 In an LCR circuit, the resonating frequency is 500 kHz. If the value of L is increased two times and value of C is decreased $\frac{1}{8}$ times, then the new resonating frequency in kHz will be -
(1) 250 (2) 500 (3) 1000 (4) 2000

Q.75 In resonating circuit value of inductance and capacitance is 0.1H and 200 μF. For same resonating frequency if value of inductance is 100H then necessary value of capacitance in μF will be -
(1) 4 (2) 0.2 (3) 2 (4) 0.3

Q.76 The inductance of the motor of a fan is 1.0 H. To run the fan at 50 Hz the capacitance of the capacitor that will cancel its inductive reactance, will be -
(1) 10 μF (2) 40 μF
(3) 0.4 μF (4) 0.04 μF

Q.77 In ac circuit at resonance -
(1) Impedance = R
(2) Impedance = $\left(\omega L - \frac{1}{\omega C}\right)$
(3) The voltages across L and C are in the same phase
(4) The phase difference of current in C relative to source voltage is π

Q.78 An ac circuit resonates at a frequency of 10 kHz. If its frequency is increased to 11 kHz, then -
(1) Impedance will increase by 1.1 times
(2) Impedance will remain unchanged
(3) Impedance will increase and become inductive
(4) Impedance will increase and become capacitive

Q.79 In an ac circuit 6 ohm resistor, an inductor of 4 ohm and a capacitor of 12 ohm are connected n series with an ac source of 100 volt (rms). The average power dissipated in the circuit will be -
(1) 600 W (2) 500 W
(3) 400 W (4) 200 W

Q.80 In an ac circuit emf and current are $E = 5 \cos \omega t$ volt and $I = 2 \sin \omega t$ ampere respectively. The average power dissipated in this circuit will be -
(1) 10 W (2) 2.5 W
(3) 5 W (4) Zero

Q.81 The equations of alternating e.m.f. and current in an A.C. circuit are $E = 5 \cos \omega t$ volt and $I = 2 \sin \omega t$ ampere respectively. The average power loss in this circuit will be -
(1) 1 watt (2) 2.5 watt
(3) 3 watt (4) Zero

Q.82 The series combination of resistance R and inductance L is connected to an alternating source of e.m.f. $e = 311 \sin (100 \pi t)$. If the value of wattless current is 0.5A and the impedance of the circuit is 311Ω, the power factor will be -
(1) $\frac{1}{2}$ (2) $\frac{1}{\sqrt{2}}$
(3) $\frac{1}{\sqrt{3}}$ (4) $\frac{1}{\sqrt{5}}$

Q.83 In an L–C–R series circuit the loss of power is in -
(1) Only R (2) Only L
(3) Only C (4) both L and C

Q.84 In an ac circuit the readings of an ammeter and a voltmeter are 10 A and 25 volt respectively, the power in the circuit will be -
(1) More than 250 W
(2) Always less than 250 W
(3) 250 W
(4) Less than 250 W or 250 W

Q.85 A choke coil of 100 ohm and 1 H is connected to a generator of $E = 200 \sin (100t)$ volt. The average power dissipated will be -
(1) Zero (2) 200 W
(3) 141 W (4) 100 W

Q.86 A choke coil of negligible resistance carries 5 mA current when it is operated at 220 V. The loss of power in the choke coil is -
(1) Zero (2) 11 W
(3) 44×10^3 W (4) 1.1 W

Q.87 The ratio of apparent power and average power in an A.C. circuit is equal to -
(1) Reciprocal of power factor
(2) Efficiency
(3) Power factor
(4) Form factor

Q.88 In an A.C. circuit, a resistance of 3Ω, an inductance coil of 4Ω and a condenser of 8Ω are connected in series with an A.C. source of 50 volt (R.M.S.). The average power loss in the circuit will be -
(1) 600 watt (2) 500 watt
(3) 400 watt (4) 300 watt

Q.89 In an A.C. circuit, i = 5 sin $(100t-\frac{\pi}{2})$ ampere an A,V, V = 200 sin (100 t) volt. The power loss in the circuit will be -

(1) 20 volt (2) 40 volt
(3) 1000 watt (4) 0 watt

Q.90 When N identical bulbs are connected in parallel, total power consumption is P, what would be the power consumption when they connected in series-

(1) P (2) PN (3) P/N (4) P/N^2

Q.91 Two bulbs of 500 watt and 300 watt work on 200 volt r.m.s. the ratio of their resistances will be-

(1) 25 : 9 (2) 3 : 5 (3) 9 : 25 (4) 5 : 9

Q.92 An air core coil and an electric bulb are connected in series with an A.C. source. If an iron rod is put in the coil, then the intensity of bulb's will-

(1) Be same (2) Increase
(3) Decrease (4) Decrease, increase

Q.93 If a bulb and a coil are connected in series with D.C. source and a iron core put in the coil then the glowing of bulb -

(1) Decreases (2) Increases
(3) No change (4) Zero

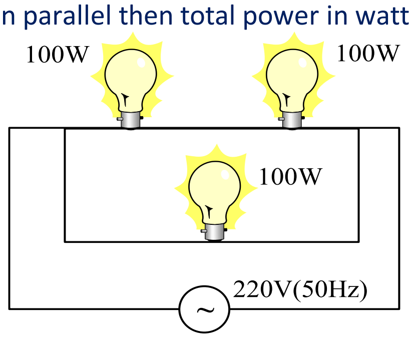
Q.94 Three bulbs of 40, 60 and 100 watt are connected in series with the source of 200 volt. Then which of the bulb will be glowing the most -

(1) 100 watt
(2) 60 watt
(3) 40 watt
(4) All are glowing equally

Q.95 If two bulbs each of 220V, 30 watt are connected in series, then we get electric power as -

(1) 60 watt (2) 15 watt
(3) 6 watt (4) 30 watt

Q.96 Two electric bulbs of 100 watt (220 volt) are connected in series and these are connected with other bulb of 100W (220V) in parallel then total power in watt will be -

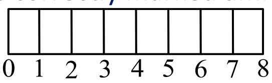


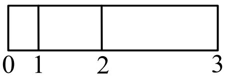
(1) 300 watt (2) 50 watt
(3) 150 watt (4) 25 watt

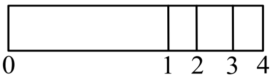
Q.97 The A.C. meters are based on the principle of -

(1) Heating effect
(2) magnetic effect
(3) Chemical effect
(4) Electromagnetic effect

Q.98 The correctly marked ammeter for A.C. current is shown in -

(1) 

(2) 

(3) 

(4) None of these

Q.99 Alternating current can not be measured by direct current meters, because -
(1) alternating current can not pass through an ammeter
(2) the average value of current for complete cycle is zero
(3) some amount of alternating current is destroyed in the ammeter
(4) None of these

Q.100 The A.C. meters measure its -
(1) root mean square value
(2) peak value
(3) square mean value
(4) None of the above

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 2

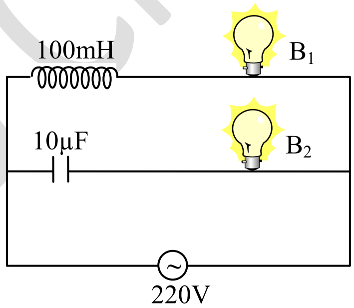
Q.1 The self inductance of a choke coil is 10mH. When it is connected with a 10V D.C. source, then the loss of power is 20 watt. When it is connected with 10 volt A.C. source loss of power is 10 watt. The frequency of A.C. source will be -
(1) 50Hz (2) 60Hz
(3) 80Hz (4) 100Hz

Q.2 We have two cables of copper of same length. In one, only one wire of cross–section area A and in second ten wires each of cross–section area A/10 are present. When A.C. and D.C. flow in it. Choose the correct cable for better efficiency -
(1) Only one wire for D.C. and the other for A.C
(2) Only one wire for A.C. and the other for D.C.
(3) Any wire for D.C. but only multy–wire cable for A.C.
(4) Only one wire for D.C. and only multy–wire packet for A.C.

Q.3 In a series LCR circuit L = 1H, C = 6.25 μF and R = 1 ohm. Its quality factor is -
(1) 400 (2) 200
(3) 125 (4) 25

Q.4 A bulb of rated values 60 V and 10 W is connected in series with a source of 100 V and 50 Hz. The coefficient of self induction of a coil to be connected in series for its operation will be -
(1) 1.53 H (2) 2.15 H
(3) 3.27 H (4) 3.89 H

Q.5 Two identical bulbs B_1 and B_2 are connected to an ac source. B is connected in series with a coil of 100 mH and B_2 with a capacitor of 10 μF as shown in the figure. The brightness of B_1 and B_2 will be-



(1) Same in both
(2) More in B_1
(3) Depending on the frequency of the source
(4) More in B_2

Q.6 An L–C–R series circuit with a resistance of 100 ohm is connected to an ac source of 200 V (rms) and angular frequency 300 rad/s. When only the capacitor is removed. the current lags behind the voltage by 60º. When only the inductor is removed , the current leads with the voltage by 60º. The average power dissipated is-
(1) 50W (2) 100 W (3) 200 W (4) 400 W

Q.7 A coil when connected to a dc source of 12 V, carries a current of 4 A. If this coil is connected to an ac source of 12 V and 50 rad/s, then it carries a current of 2.4 A. The inductance of the coil is -
(1) 48 H (2) 4 H
(3) 12.5 H (4) 8×10^{-2} H

Q.8 Waves of wavelength 300 m are transmitted from a broadcasting station. If a capacitor f 2.4 μF is used in a resonant circuit for these waves, then the inductance of coil used will be-

(1) 10^{-6} H (2) 1.056×10^{-8} H
(3) 10.56×10^{-8} H (4) 105.6×10^{-8} H

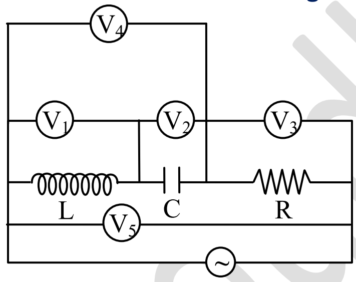
Q.9 A generator of 100 V (rms) is connected in an ac circuit and 1 A (rms) current is flowing in the circuit. If the phase difference between the voltage and the current is $\pi/3$. then the average power consumption and the power factor of the circuit will be -

(1) 50 W, 0.86 (2) 100 W, 0.86
(3) 100 W, 0.5 (4) 50 W, 0.5

Q.10 When a current of 0.5 A (rms) is passed through a coil, its reactance and power loss are found to be 25 ohm and 16 W. The impedance of the coil is -

(1) 50 ohm (2) 68.7 ohm
(3) 76.4 ohm (4) 92.3 ohm

Q.11 In the adjoining A.C. circuit the voltmeter whose reading will be zero at resonance is -



(1) V_1 (2) V_2
(3) V_3 (4) V_4

Q.12 In the above problem, the two voltmeters whose readings are equal, will be -

(1) V_4 and V_1 (2) V_1 and V_3
(3) V_4 and V_5 (4) V_1 and V_2

Q.13 In Q.11, if $\omega L/R = 10$ and $V_3 = 100$ volt then reading of V_2 will be -

(1) 10 volt (2) 100 volt
(3) 1000 volt (4) uncertain

Q.14 $2.5/\pi$ μF capacitor and a 3000–ohm resistance are joined in series to an a.c. source of 200 volt and 50 sec^{-1} frequency. The power factor of the circuit and the power dissipated in it will respectively -

(1) 0.6, 0.06W (2) 0.06, 0.6W
(3) 0.6, 4.8W (4) 4.8, 0.6W

Q.15 The current through 'a' wire changes with time according to the equation $I = \sqrt{t}$. The correct value of the rms current within the time interval t = 2 to t = 4s will be -

(1) $\sqrt{3}$ A (2) 3 A
(3) $3\sqrt{3}$ A (4) None of the above

Q.16 The time required for a 50 Hz alternating current to increase from zero to 70.7% of its peak value is -

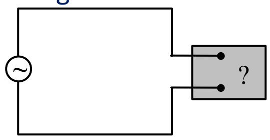
(1) 2.5 ms (2) 10 ms
(3) 20 ms (4) 14.14 ms

Q.17 Figure 92 shows an AC generator connected to a "block box" through a pair of terminals. The box contains possible R,L, C or their combination, whose elements and arrangements are not known to us. Measurements outside the box reveals that

$e = 75 \sin(\omega t)$ volt,

$i = 1.5 \sin(\omega t + 45^{\circ})$ amp

then, the wrong statement is -



(1) There must be a capacitor in the box
(2) There must be an inductor in the box
(3) There must be a resistance in the box
(4) The power factor is 0.707

Q.18 In ac circuit contains a pure capacitor, across which an ac emf e = 100 sin (1000t), volt is applied. If the peak value of the current is 200 mA, then the value of the capacitor is -
(1) 2 μF (2) 20 μF
(3) 5 μF (4) 500μF

Q.19 In a series LCR circuit C = 25 μF, L = 0.1 H and R = 25Ω. When an ac source of emf e = 311 sin (314t) then the impedance is -
(1) 99 ohm (2) 80 ohm
(3) 57 ohm (4) 25 ohm

Q.20 Consider two cables A and B. In A, a single copper wire of cross–sectional area x is used, while in B, a bunch of 15 wires each of cross–sectional area x/15 is used. Then for the flow of high frequency AC, the -
(1) Cable A is more suitable then B
(2) Cable B is more suitable then A
(3) Both cables are equally suitable
(4) Nothing specific can be predicted

Q.21 An ac circuit contains a resistance R and a reactance X. If the impedance of the circuit is given by $Z = 50 \angle \pi/6$.
Then the resistance and the reactance are, respectively (in ohms) -
(1) Zero ; 50 (2) $25\sqrt{3}$; 25
(3) 25 ; $25\sqrt{3}$ (4) 25 ; 25

Q.22 In a series LCR circuit with R = 11 ohm, the instantaneous value of the current i in the circuit and instantaneous value of the applied ac emf e, are respectively -

i = 200 mA, e = 110 volt

If the phase difference between the current and voltage is π/3, then the instantaneous ac power in the circuit is –
(1) 22W (2) 0.44W
(3) 0.22W (4) None of the above

Q.23 A d.c. voltage with appreciable riple expressed as $V = V_1 + V_2 \cos \omega t$ is applied to a resistor R. The amount of heat generated per second is given by -
(1) $\frac{V_1^2 + V_2^2}{2R}$ (2) $\frac{2V_1^2 + V_2^2}{2R}$
(3) $\frac{V_1^2 + 2V_2^2}{2R}$ (4) None of these

Q.24 The electric current in a circuit is given by $i = \frac{i_0 t}{\tau}$ for some time. The rms current for the period t = 0 to $t = \tau$ will be-

(1) $\frac{i_0}{\sqrt{2}}$ (2) $\frac{i_0}{\sqrt{3}}$

(3) $\frac{i_0}{2}$ (4) $\frac{i_0}{3}$

Q.25 A series AC circuit has a resistance of 4Ω and an inductor of reactance 3Ω. The impedance of the circuit is z_1. Now a capacitor of reactance 6Ω is connected in the series of above combination, the impedance becomes z_2, Then $\frac{z_1}{z_2}$ will be-

(1) 1 : 1 (2) 5 : 4

(3) 4 : 5 (4) 2 : 1

Q.26 An AC source is rated 220 V, 50 Hz. The average voltage is calculated in a time interval of 0.01 s, It -

(1) must be zero (2) may be zero

(3) is never zero (4) is $\frac{20}{\sqrt{2}}$ volt

Q.27 An AC ammeter is used to measure current in a circuit. When a given direct current passes through the circuit, the AC ammeter reads 3A. When another alternating current passes through the circuit the AC ammeter reads 4 A, then reading of this ammeter if DC and AC flow through the circuit simultaneously is-

(1) 3 A (2) 4 A (3) 7 A (4) 5 A

Q.28 An inductor (L) and resistance (R) are connected in series with an AC source. The phase difference between voltage (V) and current (i) is 45°. Now a capacitor (3) is connected in series with L-R, If the phase difference between V and i remain same, then capacitive reactance and impedance of L-C-R circuit will be-

(1) $R, R\sqrt{2}$ (2) $2R, R\sqrt{2}$

(3) R, R (4) $2R, R\sqrt{3}$

Q.29 In a series LCR circuit the voltage across the resistance, capacitance and inductance is 10 V each. If the capacitor is removed, the voltage across the inductance will be-

(1) 10 V (2) $10\sqrt{2}$V (3) $\frac{10}{\sqrt{2}}$V (4) 20 V

Q.30 An alternating emf 100 cos 100 t volt is connected in series to a resistance of 10 Ω and inductance 100 mH, what is the phase difference between the current in the circuit and the emf-

(1) $\frac{\pi}{4}$ (2) zero (3) π (4) $\frac{\pi}{2}$

Q.31 A coil having an inductance of $\frac{1}{\pi}$ Henry is connected in series with a resistance of 300 Ω. If 20 V from a 200 cycle/s source are impressed across the combination. The power factor of the circuit will be-

(1) $\frac{2}{5}$ (2) $\frac{3}{5}$ (3) $\frac{4}{5}$ (4) $\frac{2}{3}$

Q.32 In an AC circuit, a resistance of R ohm is connected in series with an inductance L. If phase angle between voltage and current be 45°, the value of inductive reactance will be-
(1) R/4
(2) R/2
(3) R
(4) Cannot be found with the given data

Q.33 In LCR series AC circuit, the phase angle between current and voltage is-
(1) any angle between 0 and $\pm \pi / 2$
(2) $\pi / 2$
(3) π
(4) any angle between 0 and π

Q.34 A coil has an inductance of 0.7 H and is joined in series with a resistance of 220 Ω. When an alternating e.m.f. of 220 V at 50 cps is applied to it, then the wattless component of the current in the circuit is-
(1) 5 ampere (2) 0.5 ampere
(3) 0.7 ampere (4) 7 ampere

Q.35 A direct current of 2 A and an alternating current having a maximum value of 2 A flow through two identical resistances. The ratio of heat produced in the two resistances will be-
(1) 1 : 1 (2) 1 :2 (3) 2 : 1 (4) 4 : 1

Q.36 An alternating voltage is connected in series with a resistance R and an inductance L. If the potential drop across the resistance is 200 volt and across the inductance is 150 volt, the applied voltage is-
(1) 350 volt (2) 250 volt
(3) 500 volt (4) 300 volt

Q.37 An AC circuit using an inductor and a capacitor in series has a maximum current. If L = 0.5 H and C = 8 μF, then the angular frequency of input AC voltage will be -
(1) 500 (2) 5×10^5
(3) 4000 (4) 5000

Q.38 A resistor and an inductor are connected to an AC supply of 120 volt and 50 Hz. The current in the circuit is 3 ampere. If the power consumed in the circuit is 108 watt, then the resistance in the circuit is-
(1) 12 ohm (2) 40 ohm
(3) $\sqrt{(52 \times 28)}$ ohm (4) 360 ohm

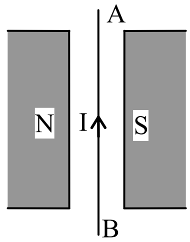
Q.39 In an AC circuit, the current lags behind the voltage by $\pi/3$. The components of the circuit are-
(1) R and L (2) L and C
(3) R and C (4) only R

Q.40 A 10 ohm resistance, 5 mH coil and 10 μF capacitor are joined in series. When a suitable frequency alternating current source is joined to the combination the circuit resonates. If the resistance is halved, the resonance frequency-
(1) is halved (2) is doubled
(3) remains unchanged (4) is quadrupled

Q.41 A conducting wire is stretched between the poles of a magnet. There is a strong uniform magnetic field in the region between the poles. If an alternating current

$$I = I_0 \sin \omega t$$

is passed through the wire AB, the wire will-



(1) remain stationary
(2) be pulled towards north pole
(3) be pulled towards south pole
(4) vibrate with a frequency $\omega/2\pi$

Q.42 In an LR circuit, the inductive reactance is equal to resistance R of the circuit. An e.m.f. $E = E_0 \cos \omega t$ is applied to the circuit. The power consumed in the circuit is-

(1) E_0^2/R (2) $E_0^2/2R$
(3) $E_0^2/4R$ (4) $E_0^2/8R$

Q.43 The voltage of an AC supply varies with time (t) as V = 120 sin 100 πt cos 100πt. The maximum voltage and frequency respectively are -
(1) 60 volt, 100 Hz
(2) $\frac{120}{\sqrt{2}}$ volt, 100 Hz
(3) 120 volt, 100 Hz
(4) 60 volt, 200 Hz

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 3

Q.1 The value of quality factor is-

(1) $\frac{\omega L}{R}$ (2) $\frac{\omega}{RC}$

(3) $\sqrt{LC}$ (4) L/R

Q.2 A capacitor of capacity C and reactance X if capacitance and frequency become double then reactance will be-

(1) 4X (2) $\frac{X}{2}$ (3) $\frac{X}{4}$ (4) 2X

Q.3 For a series LCR circuit the power loss at resonance is-

(1) $\frac{V^2}{\left[\omega L - \frac{1}{\omega C}\right]}$ (2) $I^2L\omega$

(3) I^2R (4) $\frac{V^2}{C\omega}$

Q.4 In a circuit L, C and R are connected in series with an alternating voltage source of frequency f. The current leads the voltage by 45º. The value of C is-

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

(3) $\frac{1}{\pi f(2\pi fL - R)}$ (4) $\frac{1}{\pi f(2\pi fL + R)}$

Q.5 A transistor-oscillator using a resonant circuit with an inductor L (of negligible resistance) and a capacitor C in series produce oscillations of frequency f. If L is doubled and C is changed to 4C, then frequency will be-

(1) $\frac{f}{4}$ (2) 8f (3) $\frac{f}{2\sqrt{2}}$ (4) $\frac{f}{2}$

Q.6 A coil of inductive reactance 31 Ω has a resistance of 8 Ω. It is placed in series with a condenser of capacitative reactance 25 Ω. The combination is connected to an a.c. source of 110 volt. The power factor of the circuit is-

(1) 0.56 (2) 0.64 (3) 0.80 (4) 0.33

Q.7 What is the value of inductance L for which the current is a maximum in a series LCR circuit with C = 10 μF and ω = 1000 s^{-1} ?

(1) 10 mH

(2) 100 mH

(3) 1 mH

(4) cannot be calculated unless R is known

Q.8 In an a.c. circuit the e.m.f. (e) and the current (i) at any instant are given respectively by-

$e = E_0 \sin\omega t$

$i = I_0 \sin(\omega t - \phi)$

The average power in the circuit over one cycle of a.c. is-

(1) $\frac{E_0 I_0}{2}\cos\phi$ (2) $E_0 I_0$

(3) $\frac{E_0 I_0}{2}$ (4) $\frac{E_0 I_0}{2}\sin\phi$

Q.9 The reactance of an inductance of 0.01 H for 50 Hz A.C. is-
(1) 6.28 Ω (2) 3.14 Ω
(3) 1.57 Ω (4) 0.84 Ω

Q.10 In an A.C. circuit containing only capacitance, the current-
(1) leads the voltage by 90º
(2) leads the voltage by 180º
(3) lags the voltage by 90º
(4) remains in phase with the voltage

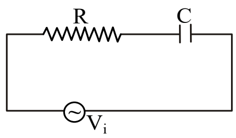
Q.11 A choke coil should have-
(1) high resistance and low inductance
(2) high resistance and high inductance
(3) low resistance and high inductance
(4) low resistance and low inductance

Q.12 The impedance of a circuit, when a resistance R and an inductor of inductance L are connected in series in an A.C. circuit of frequency (f) is-
(1) $\sqrt{R+4\pi fL^2}$ (2) $\sqrt{R+4\pi^2f^2L^2}$
(3) $\sqrt{R^2+4\pi^2f^2L^2}$ (4) $\sqrt{R^2+2\pi^2f^2L^2}$

Q.13 The coil of choke in a circuit-
(1) increases the current
(2) decreases the current
(3) has high resistance to d.c. circuit
(4) does not change the current

Q.14 A capacitor of capacitance 2μF is connected in the tank circuit of an oscillator oscillating with a frequency of 1 kHz. If the current flowing in the circuit is 2mA, the voltage across the capacitor will be-
(1) 0.16 V (2) 0.32 V (3) 79.5 V (4) 159 V

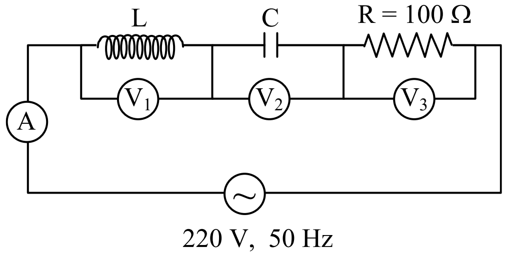
Q.15 A 50 Hz a.c. source of 20 volts is connected across R and C as shown in figure below. The voltage across R is 12 volts. The voltage across C is-



(1) 8 V
(2) 16 V
(3) 10 V
(4) Not possible to determine unless values of R and C are given

Q.16 Power dissipated in an LCR series circuit connected to an a.c. source of emf ε is-
(1) $\varepsilon^2 R \Big/ \sqrt{R^2+\left(L\omega-\frac{1}{C\omega}\right)^2}$
(2) $\varepsilon^2 R \Big/ \left[R^2+\left(L\omega-\frac{1}{C\omega}\right)^2\right]$
(3) $\varepsilon^2 \sqrt{\left[R^2+\left(L\omega-\frac{1}{C\omega}\right)^2\right]} \Big/ R$
(4) $\dfrac{\varepsilon^2\left[R^2+\left(L\omega-\frac{1}{C\omega}\right)^2\right]}{R}$

Q.17 In the given circuit the reading of voltmeter V_1 and V_2 are 300 volts each. The reading of the voltmeter V_3 and ammeter A are respectively –



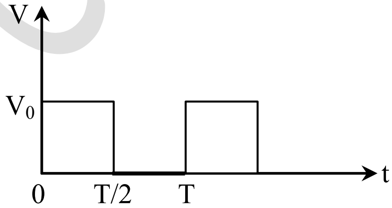
(1) 150 V, 2.2 A (2) 220 V, 2.2 A
(3) 220 V, 2.0 A (4) 100 V, 2.0 A

Q.18 A 220 volt input is supplied to a transformer. The output circuit draws a current of 2.0 ampere at 440 volts. If the efficiency of the transformer is 80%, the current drawn by the primary windings of the transformer is –
(1) 3.6 ampere (2) 2.8 ampere
(3) 2.5 ampere (4) 5.0 ampere

Q.19 In an ac circuit an alternating voltage e = $200\sqrt{2}$ sin 100 t volts is connected to a capacitor of capacity 1 μF. The r.m.s. value of the current in the circuit is :
(1) 20 mA (2) 10 mA
(3) 100 mA (4) 200 mA

Q.20 An ac voltage is applied to a resistance R and an inductor L in series. If R and the inductive reactance are both equal to 3Ω, the phase difference between the applied voltage and the current in the circuit is :
(1) zero (2) $\pi/6$ (3) $\pi/4$ (4) $\pi/2$

Q.21 The r.m.s. value of potential difference V shown in the figure is :



(1) $V_0/\sqrt{3}$ (2) V_0
(3) $V_0/\sqrt{2}$ (4) $V_0/2$

Q.22 A coil has resistance 30 ohm and inductive reactance 20 Ohm at 50 Hz frequency. If an ac source, of 200 volt, 100 Hz, is connected across the coil, the current in the coil will be
(1) 2.0 A (2) 4.0 A
(3) 8.0 A (4) $\frac{20}{\sqrt{13}}$ A

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 4

Q.1 In an L-C-R series circuit, R = 10Ω, X_L = 8Ω and X_C = 6Ω the total impedance of the circuit is-
(1) 10.2 Ω (2) 17.2 Ω
(3) 10 Ω (4) None of the above

Q.2 In the above question, the phase difference between voltage and current is-
(1) 0.2º (2) 11º (3) 30º (4) 45º

Q.3 In an LCR circuit R = 100 Ω, L = 1.0 mH and C = 1000 μF, then the resonating frequency in the circuit will be-
(1) 100 Hz (2) 2000 Hz
(3) 2000/π Hz (4) 1000/2π Hz

Q.4 A capacitor is connected to an A.C. generator. The ratio of reactance and impedance of capacitor is-
(1) 1 (2) Less than 1
(3) Greater than 1 (4) Zero

Q.5 A capacitor is connected to an A.C. circuit, then the phase difference between current and the voltage is-
(1) π (2) π/2 (3) –π/2 (4) zero

Q.6 In the condition of resonance what is the value of frequency in Hz. When C = 1 μF and L = 1μH -
(1) 10^6 (2) $10^6/2\pi$
(3) $2\pi \times 10^{-6}$ (4) $2\pi \times 10^6$

Q.7 The power factor of pure inductance or capacitance is-
(1) 1 (2) zero (3) π (4) None

Q.8 In a circuit the frequency is f = 1000/2π Hz and the inductance is 2 henry, then the reactance will be-
(1) 200 Ω (2) 200 μΩ
(3) 2000 Ω (4) 2000 μΩ

Q.9 Which is not correct for average power P at resonance-
(1) $P = I_{rms} V_{rms}$ (2) $P = \frac{V}{\sqrt{2}}\frac{I}{\sqrt{2}}$
(3) P = VI (4) $P = I^2_{rms} R$

Q.10 The r.m.s. value of alternating current is 10 amp. having frequency of 50 Hz. The time taken by the current to increase from zero to maximum and the maximum value of current will be-
(1) 2×10^{-2} s and 14.14 amp.
(2) 1×10^{-2} s and 7.07 amp.
(3) 5×10^{-3} s and 7.07 amp.
(4) 5×10^{-3} s and 14.14 amp.

Q.11 A generator produces a voltage V = 240 sin 120t volt where V is in volts and t in second. The frequency and r.m.s voltage are-
(1) 60 Hz and 240 V (2) 19 Hz and 120 V
(3) 19 Hz and 170 V (4) 754 Hz and 170 V

Q.12 In pure inductance the current is-
(1) Leading, potential by $\pi/2$
(2) Lagging, potential by $\pi/2$
(3) in same phase with potential
(4) With a phase difference of π with potential

Q.13 In an A.C. circuit capacitance of 5μF has a reactance as 1000 Ω. The frequency of A.C. will be-
(1) $\frac{1000}{\pi}$ cycle/s (2) $\frac{100}{\pi}$ cycle/s
(3) 200 cycle/s (4) 5000 cycle/s

Q.14 The impedance of L-R circuit is shown by-
(1) LR (2) L/R
(3) $\sqrt{L^2\omega^2 + R^2}$ (4) $\sqrt{R^2\omega^2 + L^2}$

Q.15 Alternating current is flowing in inductance L and resistance R. The frequency of source is $\omega/2\pi$. Which of the following statement is correct-
(1) For low frequency the limiting value of impedance is L
(2) For high frequency the limiting value of impedance is ωL
(3) For high frequency the limiting value of impedance is R
(4) For low frequency the limiting value of impedance is ωL

Q.16 In an A.C. circuit inductance, capacitance and resistance are connected. If the effective voltage across inductance is V_L, across capacitance is V_C and across resistance is V_R, then the total effective value of voltage is-
(1) $V_R + V_L + V_C$ (2) $V_R + V_L - V_C$
(3) $\sqrt{V_R^2 + (V_L - V_C)^2}$ (4) $\sqrt{V_R^2 - (V_L - V_C)^2}$

Q.17 In an L-C-R series resonating circuit the relation between X_L and X_C is-
(1) $X_L/X_C = 1$ (2) $X_L/X_C > 1$
(3) $X_L/X_C < 1$ (4) $X_L/X_C = -1$

Q.18 Two different AC circuits have same current. One is containing only inductance while the other contains only capacitance. If the frequency of applied emf is increased then the current will change as-
(1) increase in first and decrease in second
(2) decrease in both
(3) increase in both
(4) decrease in first and increase in second

Q.19 Which one of the following has not the same unit-
(1) $\sqrt{LC}$ (2) $\frac{1}{\sqrt{LC}}$
(3) RC (4) $\frac{L}{R}$

Q.20 If the output of an A.C. generator is E = 170sin377t, then the frequency will be-
(1) 50 Hz (2) 110 Hz
(3) 60 Hz (4) 230 Hz

Q.21 The r.m.s value of alternating current is-
(1) Double of peak value
(2) Half of peak value
(3) $\frac{1}{\sqrt{2}}$ times of peak value
(4) Equal to peak value

Q.22 The r.m.s. value of current for a variable current i = $i_1\cos\omega t + i_2\sin\omega t$-
(1) $\frac{1}{\sqrt{2}}(i_1+i_2)$ (2) $\frac{1}{\sqrt{2}}(i_1+i_2)^2$
(3) $\frac{1}{\sqrt{2}}(i_1^2+i_2^2)^{1/2}$ (4) $\frac{1}{2}(i_1^2+i_2^2)^{1/2}$

Q.23 The inductance of a coil is 0.70 henry. An A.C. source of 120 volt is connected parallel with it. If the frequency of A.C. is 60 Hz, then the current which is flowing in inductance, will be-
(1) 4.55 amp (2) 0.355 amp
(3) 0.455 amp (4) 3.55 amp

Q.24 A capacitor of capacity C is connected in A.C. circuit. The applied emf is $V = V_0 \sin\omega t$, then the current is-
(1) $I = \frac{V_0}{\omega L}\sin\omega t$
(2) $I = \frac{V_0}{\omega L}\sin(\omega t + \pi/2)$
(3) $I = V_0\omega C\sin\omega t$
(4) $I = V_0\omega C\sin(\omega t + \pi/2)$

Q.25 In an A.C. circuit, a capacitor of 1 μF value is connected to a source of frequency 1000 rad/s. The value of capacitive reactance will be-
(1) 10 Ω (2) 100 Ω
(3) 1000 Ω (4) 10,000 Ω

Q.26 In an A.C. circuit resistance and inductance are connected in series. The potential and current in inductance is-
(1) $V_0\sin\omega t$, $\frac{V_0}{\omega L}\sin\omega t$
(2) $V_0\sin\omega t$, $\frac{V_0}{\omega L}\sin(\omega t + \pi/2)$
(3) $V_0\sin(\omega t + \pi/2)$, $\frac{V_0}{\omega L}\sin\omega t$
(4) $V_0\sin(\omega t + \pi/2)$, $\frac{V_0}{\omega L}\sin(\omega t - \pi/2)$

Q.27 Which of the following statements is correct, for an LCR series combination having the resonating condition as-
(1) the current is minimum
(2) the phase difference between the current and e.m.f. is π/2
(3) the tempedance is equal to R
(4) the value of power factor is minimum

Q.28 The current $I = I_0\sin(\omega t - \pi/2)$ is flowing in a variable current circuit. The potential $E = E_0\sin\omega t$ is applied to the circuit. The loss of power will be-
(1) $P = E_0I_0/\sqrt{2}$ (2) $P = E_0I_0/2$
(3) $P = EI/\sqrt{2}$ (4) P = zero

Q.29 Power factor of a best choke coil is-
(1) Near about zero (2) Zero
(3) Near about one (4) One

Q.30 The peak value of alternating potential is E_0 then r.m.s. value of the same will be-
(1) $E_0/2$ (2) $\sqrt{E_0}$
(3) $E_0/\sqrt{2}$ (4) $E_0\sqrt{2}$

Q.31 In an inductive circuit the equation of A.C., is $i = i_0\sin\omega t$ then-
(1) $E = E_0\sin(\omega t + \pi/2)$ (2) $E = E_0\sin(\omega t - \pi/2)$
(3) $E = E_0\sin\omega t$ (4) None of the above

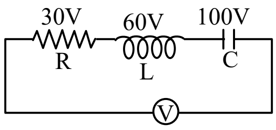
Q.32 In an A.C. circuit, the reactive reactance X_L –
(1) $2\pi fL$ (2) $1/(2\pi fL)$ (3) $\pi fL/2$ (4) $2/\pi fL$

Q.33 A coil has reactance of 100 Ω. When frequency is 50 Hz. If the frequency becomes 150 Hz, then the reactance will be-
(1) 100Ω (2) 300Ω (3) 450Ω (4) 600Ω

Q.34 If a choke of negligible resistance works on 220V source and 5mA current is flowing through it, then the loss of power in choke coil is-
(1) zero (2) 11 watt
(3) 44×10^3 watt (4) 1.1 watt

Q.35 Correct expression for A.C.
(1) $\tan\theta = \dfrac{\omega L - \dfrac{1}{\omega C}}{R}$ (2) $\sin\theta = \dfrac{\omega L - \dfrac{1}{\omega C}}{R}$
(3) $\cos\theta = \dfrac{\omega L - \dfrac{1}{\omega C}}{R}$ (4) None of these

Q.36 In the given figure, the potential difference is shown on R, L and C. The e.m.f. of source in volt is-



(1) 190 (2) 70 (3) 50 (4) 40

Q.37 In an alternating current circuit L = 0.5 H and C = 8 μF. For maximum value of current in the circuit the angular frequency will be-
(1) 500 rad/s (2) 250 rad/s
(3) 150 rad/s (4) 100 rad/s

Q.38 A circuit with e.m.f. $E = 200\sin\omega t$ and $I = \sin\omega t$, contains a capacitance and inductance, then the value of power factor will be-
(1) 0 (2) 1 (3) 0.6 (4) 0.3

Q.39 In a resistance of 25Ω A.C. is passed to produce heat of the rate of 250 watt. The value of current in the resistance will be-
(1) 0.316 A (2) 1 A
(3) 3.16 A (4) 10 A

Q.40 A choke coil has-
(1) Low resistance and high inductance
(2) High resistance and high inductance
(3) Low resistance and low inductance
(4) High resistance and low inductance

Q.41 In an LCR circuit C = 25 μF, L = 0.1H, R = 25Ω, if E = 310 sin 314 t volts in the generator voltage which is connected in the circuit then the value of current in the circuit is-
(1) $i = 5.4\sin(314t - \phi)$ (2) $i = 3.1 \sin(314t + \phi)$
(3) $i = 3.1\sin(314t - \phi)$ (4) $i = 3.46 \sin(314t + \phi)$

Q.42 In an LCR circuit C=25 μF, L = 0.1H, R = 25Ω, if E = 310 sin 314 t volts is the generator voltage which is connected in the circuit then, how much inductance should be connected so that impedance is minimum-
(1) 0.31 H (2) 0.41 H
(3) 1.25 H (4) 1.75 H

Q.43 5 cm long 10 Ω resistance and 5 mH inductance of a solenoid, is connected with 10 volt battery. The value of current which flows in stable condition of solenoid in ampere is-
(1) 5 (2) 1 (3) 2 (4) Zero

Q.44 The value of current at half power points is-
(1) $I_m\sqrt{2}$ (2) $I_m/\sqrt{2}$
(3) $2I_m$ (4) $I_m/2$

Q.45 The self inductance of a choke coil is 10 mH. When it is connected with a 10V D.C. source, then the loss of power is 20 watt. When it is connected with 10 volt A.C. source loss of power is 10 watt. The frequency of A.C. source will be-
(1) 50 Hz (2) 60 Hz
(3) 80 Hz (4) 100 Hz

Q.46 The inductance of a choke coil is 0.2 henry and its resistance is 0.50 ohm. If a current of 2.0 amp (rms value) and frequency 50 hertz be passed through it. What will be the potential difference across its ends-
(1) 125.6 volt (2) 250.1 volt
(3) 62.5 volt (4) none of these

Q.47 An alternating voltage $E = 200\sqrt{2}\sin(100t)$volt is connected to a 1 μF capacitor through an A.C. ammeter. The reading of ammeter is-
(1) 10 mA (2) 20 mA
(3) 40 mA (4) 80 mA

Q.48 In an A.C. circuit V and I are given by
$V = 100 \sin(100t)$ volts
$I = 100 \sin(100t + \pi/3)$ mA
The power dissipated in the circuit is-
(1) 10^4 watt (2) 10 watt
(3) 2.5 watt (4) 5.0 watt

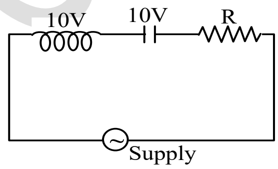
Q.49 An alternating e.m.f. of frequency $\nu\left(=\frac{1}{2\pi\sqrt{LC}}\right)$ is applied to a series LCR circuit. For this frequency of the applied e.m.f.-
(1) The circuit is at resonance and its impedance is made up only of a reactive part
(2) The current in the circuit is out of phase with the applied e.m.f. and the voltage across R equals this applied e.m.f.
(3) The sum of the p.d's across the inductance and capacitance equals the applied e.m.f. which is 180º ahead of phase of the current in the circuit
(4) The quality factor of the circuit is ωL/R or 1/ωCR and this a measure of the voltage magnification (produced by the circuit at resonance of the circuit

Q.50 A bulb and a capacitor are connected in series to a source of alternating current. If its frequency is increased, while keeping the voltage of the source constant, then-
(1) Bulb will give more intense light
(2) Bulb will give less intense light
(3) Bulb will give light of same intensity as before
(4) Bulb will stop radiating light

Q.51 The inductance of the oscillatory circuit of a radio station is 10 milli henry and its capacitance is 0.25 μF. Taking the effect of the resistance negligible, wavelength of the broadcasted waves will be (velocity of light = 3.0×10^8 m/s, π = 3.14)
(1) 9.42×10^4 m (2) 18.8×10^4 m
(3) 4.5×10^4 m (4) none of these

Q.52 A coil has an inductance of 0.7 henry and is joined in series with a resistance of 220 Ω. When the alternating emf of 220 V at 50 Hz is applied to it then the phase through which current lags behind the applied emf and the wattless component of current in the circuit will be respectively-
(1) 30º, 1 A (2) 45º, 0.5 A
(3) 60º, 1.5 A (4) none of these

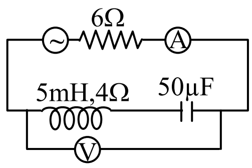
Q.53 If value of R is changed, then-



(1) Voltage across L remains same
(2) Voltage across C remains same
(3) Voltage across LC combination remains same
(4) Voltage across LC combination changes

Q.54 When 100 V D.C. is applied across a coil a current of 1A flows through it. When 100V A.C. of 50 Hz is applied to the same coil only 0.5A flows. The inductance of the coil is-
(1) 0.55 H (2) 55 mH
(3) 0.55 mH (4) 5.5 mH

Q.55 In the circuit shown in the figure, the A.C. source gives a voltage V = 20cos(2000t) volt neglecting source resistance, the voltmeter and ammeter readings will be-



(1) 0 V, 1.4 A (2) 5.6 V, 1.4 A
(3) 0 V, 0.47 A (4) 1.68 V, 0.47 A

Q.56 The inductive reactance of an inductive coil with $\frac{1}{\pi}$ henry and 50 Hz-

(1) $\frac{50}{\pi}$ ohm (2) $\frac{\pi}{50}$ ohm
(3) 100 ohm (4) 50 ohm

Q.57 In an alternating circuit applied voltage and flowing current are $E = E_0\sin\omega t$ and $I = I_0\sin(\omega t+\pi/2)$ respectively. Then the power consumed in the circuit will be-
(1) Zero (2) $E_0I_0/2$
(3) $E_0I_0/\sqrt{2}$ (4) $E_0I_0/4$

Q.58 In the L-R circuit R = 10Ω and L = 2H. If 120V, 60Hz alternating voltage is applied then that the flowing current in this circuit will be-
(1) 0.32 A (2) 0.16 A
(3) 0.48 A (4) 0.80 A

Q.59 The relation between an A.C. voltage source and time in SI units is- $V = 120\sin(100\pi t)\cos(100\pi t)$ volt value of peak voltage and frequency will be respectively-
(1) 120 volt and 100 Hz
(2) $\frac{120}{\sqrt{2}}$ volt and 100 Hz
(3) 60 volt and 200 Hz
(4) 60 volt and 100 Hz

Q.60 In which of the following case power factor will be negligible-
(1) Inductance and resistance both high
(2) Inductance and resistance both low
(3) Low resistance and high inductance
(4) High resistance and low inductance

Q.61 An inductance of 0.4 Henry and a resistance of 100 ohm are connected to a A.C. voltage source of 220 V and 50 Hz. Then find out the phase difference between the voltage and current flowing in the circuit-
(1) $\tan^{-1}(2.25\pi)$ (2) $\tan^{-1}(0.4\pi)$
(3) $\tan^{-1}(1.5\pi)$ (4) $\tan^{-1}(0.5\pi)$

Q.62 Choke coil-
(1) Decreases current in A.C.
(2) Increases current in A.C.
(3) Decreases current in D.C.
(4) Increases current in D.C.

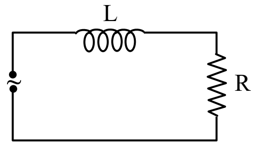
Q.63 In a circuit 20Ω resistance and 0.4 H inductance are connected with a source of 220 volt of frequency 50 Hz, then the value of ϕ will be-
(1) $\tan^{-1}(4\pi)$ (2) $\tan^{-1}(2\pi)$
(3) $\tan^{-1}(1\pi)$ (4) $\tan^{-1}(3\pi)$

Q.64 If $V = 100\sin 100t$ volt, and $I = 100\sin(100t + \frac{\pi}{6})$A, then find the watt less power in watt-

(1) 10^4 (2) 10^3
(3) 10^2 (4) 2.5×10^3

Q.65 If an A.C. main supply is given to be 220 V. What would be the average e.m.f. during a positive half cycle-
(1) 198 V (2) 386 V
(3) 256 V (4) None of these

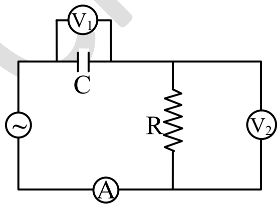
Q.66 An inductor and a resistor in series are connected to an A.C. supply of variable frequency. As the frequency of the source is increased, the phase angle between current and the potential difference across source will be-



(1) First increase and then decrease
(2) First decrease and then increase
(3) Go on decreasing
(4) Go on increasing

Q.67 An A.C. supply gives 30 V r.m.s. which passes through a 10 Ω resistance. The power dissipated in it is-
(1) $90\sqrt{2}$ W (2) 90 W
(3) $45\sqrt{2}$ W (4) 45 W

Q.68 The diagram shows a capacitor C and a resistor R connected in series to an AC source, V_1 and V_2 are voltmeters and A is an ammeter. Consider now the following statements-
(I) Readings in A and V_2 are always in phase
(II) Reading in V_1 is ahead with reading in V_2
(III) Readings in A and V_1 are always in phase
Which of these statements are is correct-



(1) I only (2) II only
(3) I and II only (4) II and III only

Q.69 In a series LCR circuit voltage across resister, inductor and capacitor are 1 V, 3 V and 2 V respectively. At the instant t when the source voltage is given by $V = V_0 \cos \omega t$, the current in the circuit will be-
(1) $I = I_0 \cos\left(\omega t + \frac{\pi}{4}\right)$ (2) $I = I_0 \cos\left(\omega t - \frac{\pi}{4}\right)$
(3) $I = I_0 \cos\left(\omega t + \frac{\pi}{3}\right)$ (4) $I = I_0 \cos\left(\omega t - \frac{\pi}{3}\right)$

Q.70 Phase difference between V and I at resonance is-
(1) 0 (2) $2\pi/3$
(3) $\pi/3$ (4) None of these

Q.71 A capacitor of capacitance 100 μF and a resistance of 100 Ω is connected in series with AC supply of 220V, 50 Hz. The current leads the voltage by ....

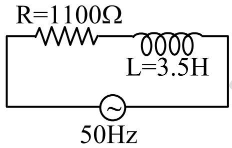
(1) $\tan^{-1}\left(\frac{1}{2\pi}\right)$ (2) $\tan^{-1}\left(\frac{1}{\pi}\right)$

(3) $\tan^{-1}\left(\frac{2}{\pi}\right)$ (4) $\tan^{-1}\left(\frac{4}{\pi}\right)$

Q.72 In an AC circuit decrease in impedance with increase in frequency is indicates that circuit has/have-

(1) only resistance
(2) resistance and inductance
(3) resistance and capacitance
(4) resistance, capacitance and inductance

Q.73 For given circuit the power factor is-

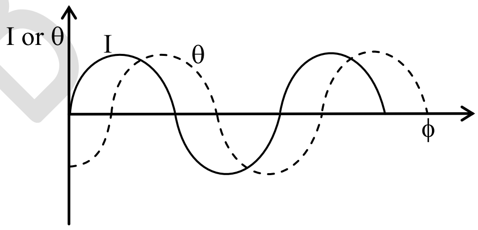


(1) 0 (2) 1/2 (3) $1/\sqrt{2}$ (4) None

Q.74 If the current through an inductor of inductance L is given by $I = I_0 \sin\omega t$, then the voltage across inductor will be-

(1) $I_0\omega L \sin(\omega t - \pi/2)$ (2) $I_0\omega L \sin(\omega t + \pi/2)$
(3) $I_0\omega L \sin(\omega t - \pi)$ (4) None of these

Q.75 When an AC source of e.m.f. $e = E_0\sin(100t)$ is connected across a circuit, the phase difference between the e.m.f. e and the current i in the circuit is observed to be $\pi/4$, as shown in the diagram. If the circuit consists possibly only of R-C or R-L or L-C is series, find the relationship between the two elements-



(1) R = 1kΩ, C = 10μF (2) R = 1kΩ, C = 1μF
(3) R = 1kΩ, C = 10H (4) R = 1kΩ, C = 1H

Q.76 A LC circuit is in the state of resonance. If C = 0.1 μF and L = 0.25 henry. Neglecting ohmic resistance of circuit what is the frequency of oscillations-

(1) 1007 Hz (2) 100 Hz
(3) 109 Hz (4) 500 Hz

Q.77 There is a 5Ω resistance in an A.C., circuit. Inductance of 0.1 H is connected with it in series. If equation of A.C. e.m.f. is 5 sin 50 t then the phase difference between current and e.m.f. is-

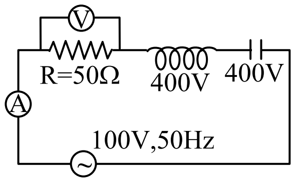
(1) $\frac{\pi}{2}$ (2) $\frac{\pi}{6}$ (3) $\frac{\pi}{4}$ (4) 0

Q.78 An inductor of inductance L and resistor of resistance R are joined in series and connected by a source of frequency ω. Power dissipated in the circuit is-

(1) $\frac{(R^2+\omega^2L^2)}{V}$ (2) $\frac{V^2R}{(R^2+\omega^2L^2)}$

(3) $\frac{V}{(R^2+\omega^2L^2)}$ (4) $\frac{\sqrt{R^2+\omega^2L^2}}{V^2}$

Q.79 In given LCR circuit, the voltage across the terminals of a resistance & current will be-



(1) 400 V, 2A (2) 800 V, 2A
(3) 100V, 2A (4) 100V, 4A

Q.80 In a purely capacitive circuit average power dissipated in the circuit is-
(1) $V_{rms} I_{rms}$
(2) Depends on capacitance
(3) Infinite
(4) Zero

Q.81 Phase of current in LCR circuit-
(1) Is in the phase potential
(2) Leading from the phase of potential
(3) Lagging from the phase of potential
(4) Before resonance frequency, leading from the phase of potential and after resonance frequency, lagging from the phase of potential

Q.82 In LCR circuit at resonance conditions impedance will be-
(1) Equal to R (2) Less than R
(3) Greater than R (4) Zero

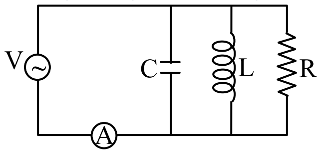
Q.83 In a circuit having a resistance of 100 Ω connected is series with a capacitive reactance of 100 Ω to an alternating voltage source, the current-
(1) Leads voltage by 90º
(2) Leads voltage by 45º
(3) Lags behind voltage by 90º
(4) Lags behind voltage by 45º

Q.84 Which is not correct for capacitive reactance-
(1) Resistance of pure capacitor is zero
(2) Inversely proportional to frequency
(3) Proportional to capacitance
(4) Phase difference between voltage and current is 90º

Q.85 The power loss in pure inductor in an A.C. circuit will be-
(1) $V_{rms} I_{rms}$ (2) More
(3) Zero (4) None of these

Q.86 The hot wire ammeter measures-
(1) D.C. current (2) A.C. current
(3) None of above (4) both (1) & (2)

Q.87 An AC source of variable frequency is connected to a capacitor C resistor R and inductor L as shown. A is an ammeter. As the frequency is steadily increased the current in A will-



(1) go on decreasing gradually
(2) go on increasing gradually
(3) first increase and then decrease
(4) first decrease and then increase

Q.88 200 Ω resistance and 1H inductance are connected in series with an A.C. circuit. The frequency of the source is $\frac{200}{2\pi}$ Hz. Then phase difference in between V and I will be-

(1) 30º (2) 60º (3) 45º (4) 90º

Q.89 In an LCR circuit 10 Ω resistance, 0.5 μF capacitor and 8 H inductor are connected in series, their angular resonance frequency will be-

(1) 800 rad/sec (2) 600 rad/sec
(3) 500 rad/sec (4) 300 rad/sec

Q.90 In LCR circuit, capacitor C is changed to 4C, then what should be the value of L to keep resonance frequency same-

(1) 2 L (2) L/2 (3) L/4 (4) 4L

Q.91 Energy loss in pure capacitance in A.C. circuit is-

(1) $\frac{1}{2}CV^2$ (2) CV
(3) $\frac{1}{4}CV^2$ (4) Zero

Q.92 Frequency of A.C. in India is-

(1) 45 Hz (2) 60 Hz
(3) 50 Hz (4) None of the above

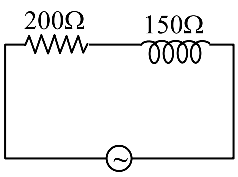
Q.93 In LCR circuit, the voltage across the terminals of a resistance, inductance & capacitance are 40V, 30V & 60V, then the voltage across the main source will be-

(1) 130 volt (2) 100 volt
(3) 70 volt (4) 50 volt

Q.94 A source of 220V is applied in an A.C. circuit. The value of resistance is 220Ω. Frequency & inductance are 50 Hz and 0.7 H, then wattless current is-

(1) 0.5 amp (2) 0.7 amp
(3) 1.0 amp (4) None

Q.95 Impedance of the following circuit will be-



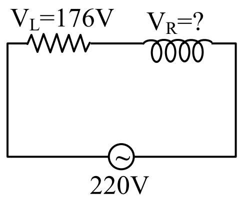
(1) 150 Ω (2) 200 Ω
(3) 250 Ω (4) 340 Ω

Q.96 Power dissipated in pure inductance will be-

(1) $\frac{LI^2}{2}$ (2) $2LI^2$

(3) $\frac{LI^2}{4}$ (4) Zero

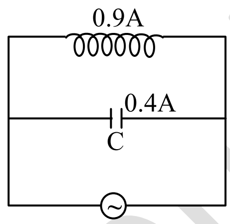
Q.97 In showing figure find V_R –



(1) 132 V (2) 396 V

(3) 185 V (4) $\sqrt{220 \times 176}$ V

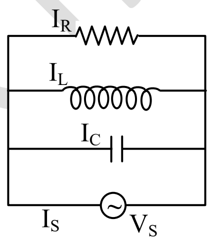
Q.98 For given LCR circuit, total current is-



(1) 0.5 A (2) 0.13 A

(3) $\sqrt{(0.9)^2 + (0.4)^2}$ (4) Zero

Q.99 For given parallel circuit correct statement is-



(1) $V = V_R + V_L + V_C$
(2) $I_S = I_R + I_L + I_C$
(3) $I_S < I_R$
(4) value of I_L and I_C may be greater than I_S

Q.100 The power factor of L-R circuit is-

(1) $\frac{\omega L}{R}$ (2) $\frac{R}{\sqrt{(\omega L)^2 + R^2}}$

(3) ωLR (4) $\sqrt{\omega LR}$

Q.101 If alternating current of rms value 'a' flows through resistance R then power loss in resistance is-

(1) zero (2) a^2R

(3) $\frac{a^2R}{2}$ (4) $2a^2R$

Q.102 For an alternating current of frequency $\frac{500}{\pi}$ Hz in L-C-R series circuit with L = 1H, C = 1μF, R = 100Ω, impedance is-

(1) 100 Ω (2) $100\sqrt{\pi}\ \Omega$

(3) $100\sqrt{2\pi}\ \Omega$ (4) 100 πΩ

Q.103 Which of the following device in alternating circuit provides maximum power-

(1) Only capacitor
(2) Capacitor and resistor
(3) Only inductor
(4) Only resistor

Q.104 If an alternating current i = i_m sinωt is flowing through a capacitor then voltage drop ΔV_C across capacitor C will be ?

(1) $-\frac{i_m}{\omega C}$ sinωt

(2) $-\frac{i_m}{\omega C}$ cosωt

(3) $-\frac{i_m}{\omega C}\left(\sin\omega t+\frac{\pi}{4}\right)$

(4) $\frac{i_m}{\omega C}\left(\sin\omega t-\frac{\pi}{4}\right)$

Q.105 If alternating current of 60 Hz frequency is flowing through inductance of L = 1 mH and drop in ΔV_L is 0.6 V then alternating current-

(1) $\frac{1}{\pi}$A (2) $\frac{5}{\pi}$A (3) $\frac{50}{\pi}$A (4) $\frac{20}{\pi}$A

Q.106 For an alternating current I = I_0cosωt, what is the rms value and peak value of current-

(1) I_0, $\frac{I_0}{\sqrt{2}}$ (2) $\frac{I_0}{\sqrt{2}}$, I_0

(3) I_0, $\frac{I_0}{\sqrt{2}}$ (4) $2I_0$, $\frac{I_0}{\sqrt{2}}$

Q.107 If an alternating current i = $i_m$sinωt is flowing through an inductor then voltage drop ΔV_L across inductor L will be-

(1) $i_m\omega L$ sinωt (2) $i_m\omega L$cosωt

(3) $i_m\omega L\sin\left(\omega t+\frac{\pi}{4}\right)$ (4) $i_m\omega L\cos\left(\omega t-\frac{\pi}{4}\right)$

Q.108 If frequency of alternating source is made zero then which of the following statement is true-

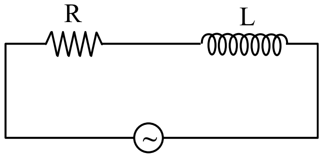
(1) current through capacitor will be zero
(2) current through resistance will be zero
(3) current through inductance will be zero
(4) all

Q.109 The power factor of an A.C. circuit having resistance (R) and inductance (L) connected in series and an angular velocity ω is -

(1) $\frac{R}{\omega L}$ (2) $\frac{R}{(R^2+\omega^2L^2)^{1/2}}$

(3) $\frac{\omega L}{R}$ (4) $\frac{R}{(R^2-\omega^2L^2)^{1/2}}$

Q.110 Power factor of the circuit is –



(1) $\frac{R}{\omega L}$ (2) $\frac{R}{\sqrt{R^2+\omega^2L^2}}$

(3) $\frac{R}{R^2+\omega^2L^2}$ (4) none of these

Q.111 Alternating current can not be measured by D.C. ammeter because -
(1) A.C. can not pass through D.C. Ammeter
(2) A.C. changes direction
(3) Average value of current for complete cycle is zero
(4) D.C. Ammeter will get damaged

Q.112 In an LCR series a.c. circuit, the voltage across each of the components, L, C and R is 50 V. The voltage across the LC combination will be -
(1) 50 V (2) $50\sqrt{2}$
(3) 100 V (4) 0 V (zero)

Q.113 In a LCR circuit capacitance is changed from C to 2C. For the resonant frequency to remain unchanged, the inductance should be changed from L to -
(1) 4 L (2) 2 L
(3) L/2 (4) L/4

Q.114 The self inductance of the motor of an electric fan is 10 H. In order to impart maximum power at 50 Hz, it should be connected to a capacitance of – \
(1) 4μF (2) 8μF (3) 1μF (4) 2μF

Q.115 A circuit has a resistance of 12 ohm and an impedance of 15 ohm. The power factor of the circuit will be -
(1) 0.8 (2) 0.4 (3) 1.25 (4) 0.125

Q.116 The phase difference between the alternating current and emf is $\pi/2$. Which of the following cannot be the constituent of the circuit ?
(1) C alone (2) R L
(3) L C (4) L alone

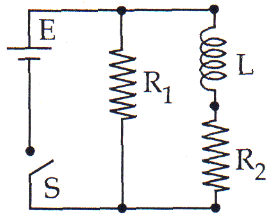
Q.117 In a series resonant LCR circuit, the voltage across R is 100 volts and R = 1 kΩ with C = 2 μF. The resonant frequency ω is 200 rad/s. At resonance the voltage across L is -
(1) 250 V (2) 4×10^{-3} V
(3) 2.5×10^{-2} V (4) 40 V

Q.118 In an a.c. circuit the voltage applied is $E = E_0 \sin\omega t$. The resulting current in the circuit is $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$. The power consumption in the circuit is given by -

(1) $P = \frac{E_0I_0}{\sqrt{2}}$ (2) P = zero

(3) $P = \frac{E_0I_0}{2}$ (4) $P = \sqrt{2}\, E_0I_0$

Q.119 An inductor of inductance L = 400 mH and resistors of resistances R_1 = 2Ω and R_2 = 2Ω are connected to a battery of emf 12V as shown in the figure. The internal resistance of the battery is negligible. The switch S is closed at t = 0. The potential drop across L as a function of time is –



(1) $6\,e^{-5t}$ V (2) $\frac{12}{t}e^{-3t}$ V

(3) $6\left(1-e^{-t/0.2}\right)$V (4) $12\,e^{-5t}$ V

Q.120 In a series LCR circuit R = 200 Ω and the voltage and the frequency of the main supply is 220 V and 50 Hz respectively. On taking out the capacitance from the circuit the current lags behind the voltage by 30°. On taking out the inductor from the circuit the current leads the voltage by 30°. The power dissipated in the LCR circuit is –

(1) 242 W (2) 305 W

(3) 210 W (4) Zero W

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 5

These questions consists of two statements each, printed as Assertion and Reason. While answering these questions you are required to choose any one of the following four responses.
(A) If both Assertion & Reason are true & the Reason is a correct explanation of the Assertion.
(B) If both Assertion and Reason are true but Reason is not a correct explanation of the Assertion.
(C) If Assertion is true but the Reason is false.
(D) If Assertion & Reason both are false.

Q.1 **Assertion :** Power loss in ideal choke coil is zero.
Reason : Ideal choke coil has zero resistance.
(1) A (2) B (3) C (4) D

Q.2 **Assertion :** Average power loss in series LC circuit or in parallel LC circuit is always zero.
Reason : Average values of voltage and current in A.C. is zero.
(1) A (2) B (3) C (4) D

Q.3 **Assertion :** Average of sinusoidal A.C. can never be zero for half cycle.
Reason : Impedance given by inductance does not depends on frequency.
(1) A (2) B (3) C (4) D

Q.4 **Assertion :** The division are equally marked on the scale of A.C. ammeter.
Reason : Heat produced is directly proportional to the current.
(1) A (2) B (3) C (4) D

Q.5 **Assertion :** The alternating current lags behind the e.m.f. by a phase angle of $\pi/2$, when A.C. flows through an inductor.
Reason : The inductive reactance increases as the frequency of A.C. source decreases.
(1) A (2) B (3) C (4) D

Q.6 **Assertion :** Capacitor serves as a block for D.C. and offers an easy path to A.C.
Reason : Capacitive reactance is inversely proportional to frequency.
(1) A (2) B (3) C (4) D

Q.7 **Assertion :** At resonance, LCR circuit have a minimum current.
Reason : At resonance, in LCR circuit, the current and e.m.f. are in phase with each other.
(1) A (2) B (3) C (4) D

Q.8 **Assertion :** When A.C. circuit contain resistor only, its power is minimum.
Reason : Power of a circuit is independent of phase angle.
(1) A (2) B (3) C (4) D

Q.9 **Assertion :** Choke coil is preferred over a resistor to adjust current in an A.C. circuit.
Reason : Power factor for inductance is zero, so power loss is also zero.
(1) A (2) B (3) C (4) D

Q.10 **Assertion :** If the frequency of alternating current in an A.C. circuit consisting of an inductance coil is increased than current get decreased.
Reason : The current is inversely proportional to frequency of alternating current.
(1) A (2) B (3) C (4) D

Q.11 **Assertion :** The resistance of a coil for direct current is 5 ohm. An alternating current is sent through it. The resistance will remain same.
Reason : The resistance of a coil does not depend upon nature of current.
(1) A (2) B (3) C (4) D

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 1 (ANSWERS)

Q. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	4	1	2	2	2	3	1	4	4	3	4	4	1	1	2	3	2	1	1	1
Q. No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ans.	2	4	3	3	3	3	1	2	3	2	3	4	2	3	1	3	1	4	4	3
Q. No.	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Ans.	1	4	1	2	2	3	2	3	2	3	2	3	2	2	1	3	4	2	1	4
Q. No.	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Ans.	2	4	2	1	1	4	2	2	3	3	4	4	3	3	2	1	1	3	1	4
Q. No.	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Ans.	4	2	1	4	4	1	1	4	4	4	2	3	3	3	2	3	1	2	2	1

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 2 (ANSWERS)

Q. No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	3	3	1	1	3	4	4	2	4	2	4	4	3	3	1	1	2	1	1	2
Q. No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ans.	2	1	2	2	1	2	4	2	3	1	2	3	1	2	3	2	1	1	1	3
Q. No.	41	42	43																	
Ans.	4	3	1																	

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 3 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Ans.	1	3	3	2	3	3	2	1	2	1	3	3	2	1	2	2	2	4	1	3	3	2

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 4 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Ans.	1	2	4	1	3	2	2	3	3	4	3	2	2	3	2	3	1	4	2	3
Q.No.	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
Ans.	3	3	3	4	3	3	3	4	1	3	1	1	2	1	1	3	1	2	3	1
Q.No.	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
Ans.	2	1	2	2	3	1	2	3	4	1	1	2	3	1	2	3	1	2	4	3
Q.No.	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
Ans.	2	1	2	4	1	4	2	1	2	1	2	3	3	2	1	1	3	2	3	4
Q.No.	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
Ans.	4	1	2	3	3	4	4	3	3	3	4	3	4	1	3	4	1	1	4	2
Q.No.	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
Ans.	2	1	4	2	2	2	2	1	2	2	3	4	3	3	1	2	1	2	4	1

IMPORTANT PRACTICE QUESTION SERIES FOR IIT-JEE EXAM – 5 (ANSWERS)

Q.No.	1	2	3	4	5	6	7	8	9	10	11
Ans.	1	2	4	4	3	1	4	4	1	1	1