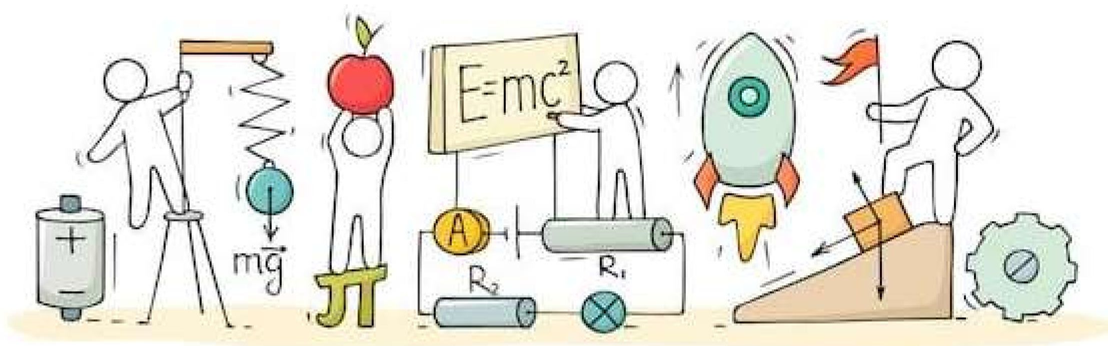
PHYSICS



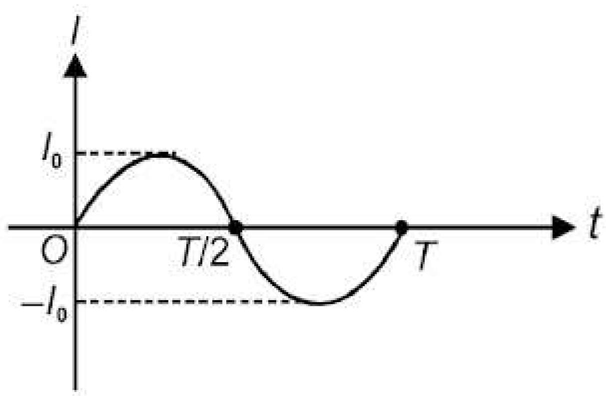
ALTERNATING CURRENT

Alternating Current:

The magnitude of alternating current changes continuously with time and its direction is reversed periodically. It is represented by

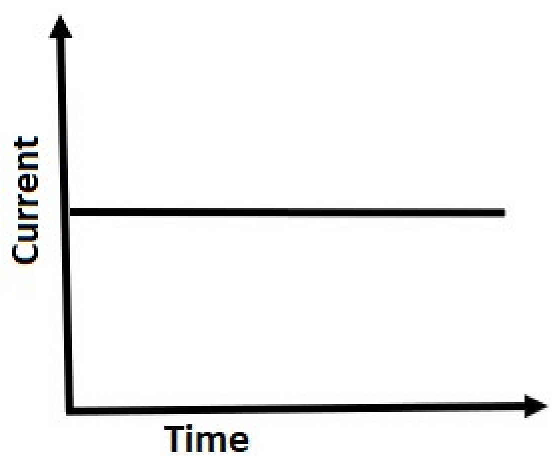
$$I = I_0 \sin \omega t \text{ or } I = I_0 \cos \omega t$$

$$\omega = \frac{2\pi}{T} = 2\pi v$$



Direct current (DC):

Direct current (DC) is electrical current which flows consistently in one direction. The current that flows in a flashlight or another appliance running on batteries is direct current.



Mean value for half cycle of AC:

Mean value of AC is the total charge that flows through a circuit element in a given time interval divided by the time interval. emf.

$$I_{mean} = \frac{\int_0^T Idt}{T}$$

For half cycle

$$I_{mean} = \frac{\int_0^{\frac{T}{2}} Idt}{\frac{T}{2}}$$

$$I_{mean} = \frac{2}{T}\int_0^{\frac{T}{2}} I_0 \sin \omega dt$$

$$I_{mean} = \frac{2I_0}{T}\left[\frac{-\cos \omega t}{\omega}\right]_0^{\frac{T}{2}}$$

$$I_{mean} = \frac{2I_0}{2\pi}\,[-\cos \pi - \cos 0] \ldots (\because \omega = \frac{2\pi}{T})$$

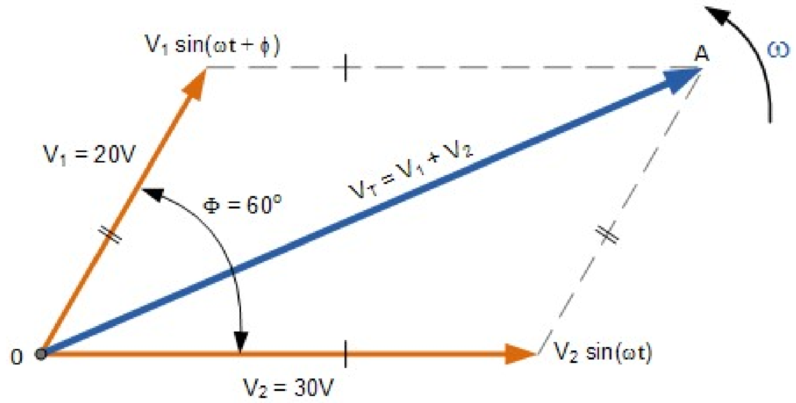
$$I_{mean} = \frac{2I_0}{\pi}$$

Note: For complete cycle, mean value = 0

Phasor Diagram:

In the a.c. circuit containing R only, current and voltage are in the same phase. Therefore, in figure, both phasors $\overrightarrow{I_0}$ and $\overrightarrow{E_0}$ are in the same direction making an angle (ωt) with OX. This is so for all times. It means that the phase angle between alternating voltage and current through R is Zero.

$$I = I_0 \sin \omega t \text{ and } E = E_0 \sin \omega t$$



Capacitive Reactance (XC):

The opposing nature of capacitor to the flow of alternating current is called capacitive reactance.

$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi fc}$$

Where, C = capacitance

Choke Coil:

A choke coil is an inductor having a small resistance. It is a device used in ac circuits to control current without wasting too much power. As it has low resistance, its power factor $\cos\phi$ is low.

Wattless Current:

The current in an AC circuit when average power consumption in AC circuit is zero, is referred as wattless current or idle current.

A.C. Generator or A.C. Dynamo:

An a.c. generator/ dynamo is a machine that produces alternating current energy from mechanical energy. It is one of the most important applications of the phenomenon of electromagnetic induction. The generator was designed originally by a Yugoslav scientist, Nikola Tesla. The word generator is a misnomer because nothing is generated by the machine. In fact, it is an alternator converting one form of energy into another.

Transformer:

A transformer which increases the a.c. voltage is called a step-up transformer. A transformer which decreases the a.c. voltages are called a step-down transformer.

Electromagnetic Spectrum:

After the experimental discovery of electromagnetic waves by Hertz, many other electromagnetic waves were discovered by different ways of excitation.

The orderly distribution of electromagnetic radiations according to their wavelength or frequency is called the electromagnetic spectrum.

The electromagnetic spectrum has much wider range with wavelength variation 10^{-14}m to 6×10^2m.

The whole electromagnetic spectrum has been classified into different parts and subparts in order of increasing wavelength, according to their type of excitation. There is overlapping in certain parts of the spectrum, showing that the corresponding radiations can be produced by two methods. It may be noted that the physical properties of electromagnetic waves are decided by their wavelengths and not by the method of their excitation.

Main Parts of Electromagnetic Spectrum:

The electromagnetic spectrum has been broadly classified into following main parts; mentioned below in the order of increasing frequency.

- **Radio waves:** These are the electromagnetic wave of frequency range from 5×10^5Hz to 10^9Hz. These waves are produced by oscillating electric circuits having an inductor and capacitor.

  Uses:

  1. The electromagnetic waves of frequency range from 530 kHz to 1710kH form amplitude modulated (AM) band. It is used in ground wave propagation.
  2. The electromagnetic waves of frequency range 1710kHz to 54Mhz are used for short wave bands. It is used in sky wave propagation.

- **Microwaves:** Microwaves are the electromagnetic waves of frequency range 1GHz to 300GHz. They are produced by special vacuum tubes. namely, klystrons, magnetrons and Gunn diodes etc.

  Uses:

  1. Microwaves are used in Radar systems for aircraft navigation.
  2. A radar using microwave can help in detecting the speed of tennis ball, cricket ball, automobile while in motion.

- **Infrared waves:** Infrared waves were discovered by Herschel. These are the electromagnetic waves of frequency range 3×10^{11}Hz to 4×10^{14}Hz. Infrared waves sometimes are called as heat waves. Infrared waves are produced by hot bodies and molecules. These wave are not detected by human eye but snake can detect them.

  Uses:

  1. In physical therapy, i.e., to treat muscular strain.
  2. To provide electrical energy to satellite by using solar cells.
  3. For producing dehydrated fruits.

- **Visible Light:** It is the narrow region of electromagnetic spectrum, which is detected by the human eye. Its frequency is ranging from 4×10^{14}Hz to 8×10^{14}Hz. It is produced due to atomic excitation.

The visible light emitted or reflected from objects around us provides the information about the world surrounding us.

- **Ultraviolet Rays:** The ultraviolet rays were discovered by Ritter in 1801. The frequency range of ultraviolet rays is 8×10^{14}Hz to 5×10^{16} Hz. The ultraviolet rays are produced by sun, special lamps, and very hot bodies.

  Uses: Ultraviolet rays are used:

  1. For checking the mineral samples through the property of ultraviolet rays causing fluorescence. electrons in the external shell through ultraviolet absorption spectra.
  2. To destroy the bacteria and for sterilizing the surgical instruments.
  3. In burglar alarm.

- **X-rays:** The X-rays were discovered by German Physicist W. Roentgen. Their frequency range is 10^{16}Hz to 3×10^{21}Hz. These are produced when high energy electrons are stopped suddenly on a metal of high atomic number. X-rays have high penetrating power.

  Uses: X-rays are used:

  1. In surgery for the detection of fractures, foreign bodies like bullets, diseased organs and stones in the human body.
  2. In Engineering (i) for detecting faults, cracks, flaws and holes in final metal products (ii) for the testing of welding, casting and moulds.
  3. In Radio therapy, to cure untraceable skin diseases and malignant growth.

- **γ -Rays:** γ -rays are the electromagnetic waves of frequency range 3 × 1018Hz to 5 × 1022Hz. γ-rays have nuclear origin. These rays are highly energetic and are produced by the nucleus of the radioactive substances.

  Uses: γ -rays are used:

  1. In the treatment of cancer and tumours.
  2. To preserve the food stuffs for a long time as the soft. γ-rays can kill microorganisms easily.
  3. To produce nuclear reactions.

Charging and Discharging of a Capacitor:

The instantaneous charge on a capacitor on charging at any instant of time t is given by

$$q = q_0\left(1 - e - \frac{t}{Rc}\right)$$

where RC = τ, is called time constant of a R – C circuit.

The instantaneous charge on a capacitor in discharging at any instant of time t is given by

$$q = q_0 e - \frac{t}{Rc}$$

Time constant of a R – C circuit is the time in which charge in the capacitor grows to 63.8% or decay to 36.8% of the maximum charge on capacitor.

Transient Current: An electric current which very for a small finite time, while growing from zero to maximum or decaying from maximum to zero, is called a transient current.

Differences between Alternating Current and Direct Current:

Alternating Current	Direct Current
AC is safe to transfer longer distance even between two cities and maintain the electric power.	DC cannot travel for a very long distance. It loses electric power.
The rotating magnets cause the change in direction of electric flow.	The steady magnetism makes DC flow in a single direction.
The frequency of AC is dependent upon the country. But generally, the frequency is 50 Hz or 60 Hz.	DC has no frequency of zero frequency.
In AC the flow of current changes its direction backwards periodically.	It flows in a single direction steadily.
Electrons in AC keep changing its directions – backward and forward	Electrons only move in one direction – that is forward.

Use of Transformers in Transmission:

- **In electric power** transmission, transformers allow transmission of electric power at high voltages, which reduces the loss due to heating of the wires.
- In many **electronic devices,** a transformer is used to convert voltage from the distribution wiring to convenient values for the circuit requirements.
- **Signal and audio** transformers are used to couple stages of amplifiers and to match devices such as microphones and record players to the input of amplifiers.

- **Audio transformers** allowed telephone circuits to carry on a two-way conversation over a single pair of wires.
- **Resonant transformers** are used for coupling between stages of radio receivers, or in high-voltage Tesla coils.

MIND MAP : LEARNING MADE SIMPLE CHAPTER - 7

Alternating Current

AC Current
Direction of current changes alternatively
$i = i_0 \sin\omega t$
$v = v_0 \sin\omega t$

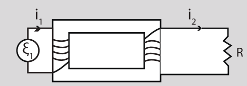
- **RMS value or root mean square value**: $i_{rms} = i_0/\sqrt{2}$, $v_{rms} = v_0/\sqrt{2}$
- **Mean value or Average value**: $i_{mean} = 2i_0/\pi$, $v_{rms} = 2v_0/\pi$
- **Peak value or Max^m value**: $i_0 = \sqrt{2}\, i_{rms}$, $v_0 = \sqrt{2}\, v_{rms}$

Contribution
In 1883 Nikola Tesla constructed the first induction motor at the age of 27 years only.

A C Generator
A device generating alternating current having elements magnet, Armature and graphite Brushes emf induced through coil

$E = NBA\,\omega \sin\omega t$

$i = E/R = NBA\,\omega \sin \omega t/R$



$E_2 = -N_2E_1/N_1$

$i_2 = -N_1E_1/N_2$

If $N_2 > N_1$ it is called step–up Transfomer

If $N_1 > N_2$, it is called step–down Transfomer

Transformer
It is used to obtain a high AC voltage from a Low–voltage AC source or vice–versa

Efficiency of a transformer
- η = output power/Input power
- 99% efficiency can easily achieved

Power in AC Circuit
$P = E_{rms}\, i_{rms} \cos\phi = \frac{E_0}{\sqrt{2}} \times \frac{i_0}{\sqrt{2}} \cos\phi = \frac{1}{2} E_0 i_0 \cos\phi$

Impedance
The ratio of emf applied and the current produced in an AC circuit $Z = E_0/i_0$ Ohm

Reactance
The hindrance offered by inductance or capacitance or both to the flow of AC in AC denoted by (X) Ohm

A C Circuits

Inductive (L) circuit

$i = i_0 \sin\left(\omega t - \frac{\pi}{2}\right)$

Phase difference b/w V& I, $\phi = \pi/2$

Power factor $\cos(\phi) = 0$

Voltage leads current by $\pi/2$

$P = 0$

Capacitive (C) circuit

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

$\phi = \pi/2$ or $-\pi/2$

$\cos\phi = 0$

Power(P) = 0

Current leads the voltage by $\pi/2$

Resistive (R) circuit

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

$\phi = 0°$

$\cos\phi = 1$

$P = V_0 I_0/2$

Current & voltage both are in same phase

R–C circuit

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

$Z = \sqrt{R^2 + X_c^2}$

$X_c = 1/\omega C$

$\tan\phi = 1/\omega CR$

$i_0 = E_0/Z$

- Power factor $\cos\phi = \frac{R^2}{\sqrt{R^2 + X_c^2}}$
- current leading.

L–C circuit

$i = i_0 \sin\left(\omega t \pm \frac{\pi}{2}\right)$

$X = X_L - X_C$

$\phi = \pi/2$

- Power factor = 0, Either voltage or current leading

L–R circuit

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

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

$X_L = \omega L$

$\tan\phi = \omega L/R$

$i_0 = E_0/Z$

- power factor = R/Z
- voltage is leading

L–C–R circuit

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

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

$X = X_c - X_L$

$= \left(\frac{1}{\omega c} - \omega L\right)$

$\tan\phi = \left(\frac{1}{\omega c} - \omega L\right)/R$, $i_0 = \frac{E_0}{Z}$

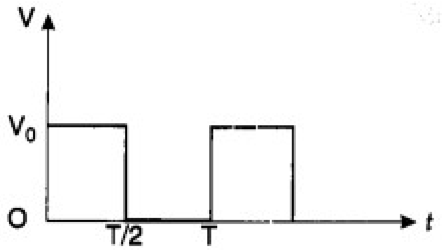
Important Questions

Multiple Choice questions-

1. Alternating voltage (V) is represented by the equation

(a) $V(t) = V_m e^{\omega t}$
(b) $V(t) = V_m \sin \omega t$
(c) $V(t) = V_m \cot \omega t$
(d) $V(t) = V_m \tan \omega t$

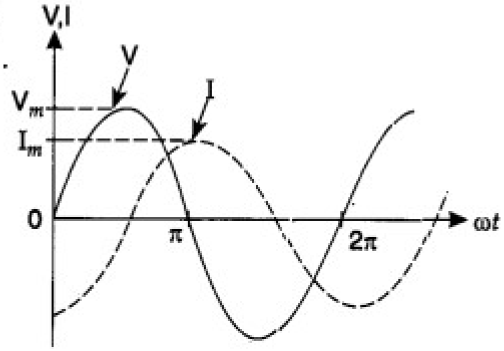
2. The rms value of potential difference V shown in the figure is



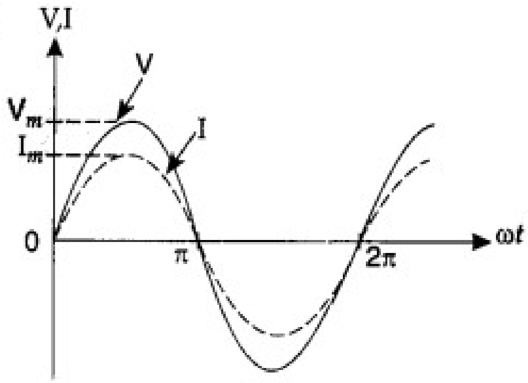
(a) $\frac{V_0}{\sqrt{3}}$ (b) V_0 (c) $\frac{V_0}{\sqrt{2}}$ (d) $\frac{V_0}{2}$

3. The phase relationship between current and voltage in a pure resistive circuit is best represented by

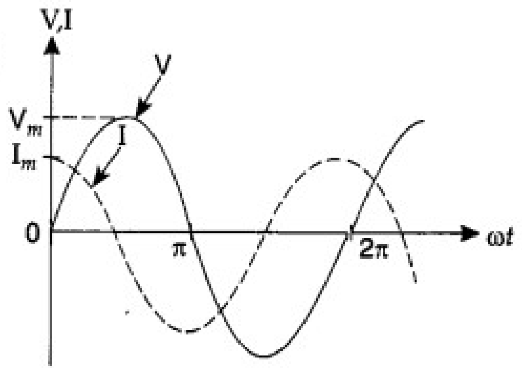
(a)



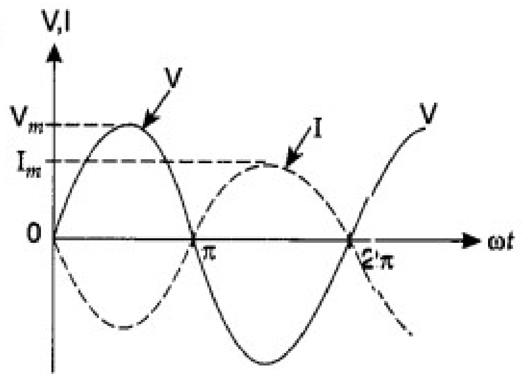
(b)



(c)



(d)



4. In the case of an inductor

(a) voltage lags the current by $\frac{\pi}{2}$

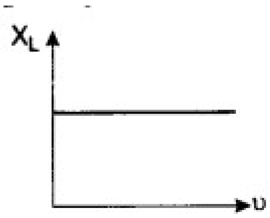
(b) voltage leads the current by $\frac{\pi}{2}$

(c) voltage leads the current by $\frac{\pi}{3}$

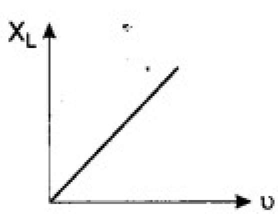
(d) voltage leads the current by $\frac{\pi}{4}$

5. Which of the following graphs represents the correct variation of inductive reactance X_L with frequency u?

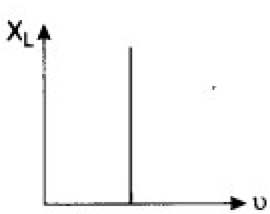
(a)



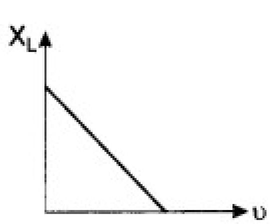
(b)



(c)



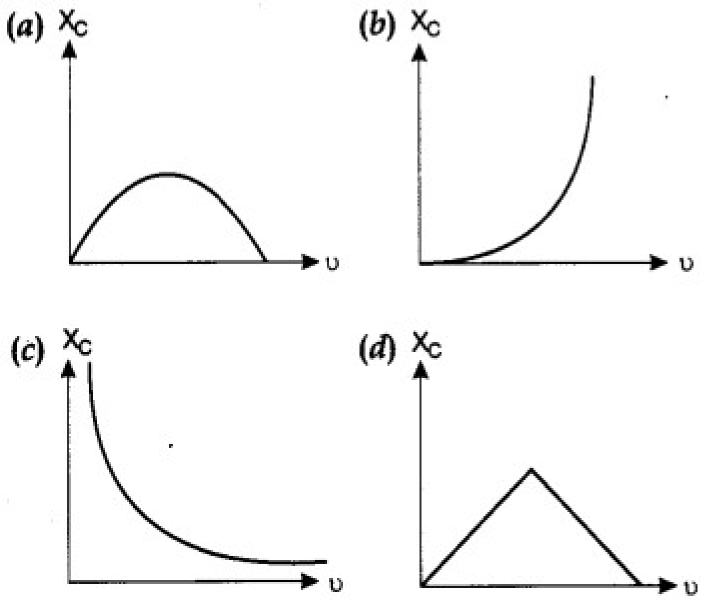
(d)



6. In a pure capacitive circuit if the frequency of ac source is doubled, then its capacitive reactance will be

(a) remains same
(b) doubled
(c) halved
(d) zero

7. Which of the following graphs represents the correct variation of capacitive reactance Xc with frequency v u?



8. In an alternating current circuit consisting of elements in series, the current increases on increasing the frequency of supply. Which of the following elements are likely to constitute the circuit?

(a) Only resistor
(b) Resistor and inductor
(c) Resistor and capacitor
(d) Only inductor

9. In which of the following circuits the maximum power dissipation is observed?

(a) Pure capacitive circuit
(b) Pure inductive circuit
(c) Pure resistive circuit
(d) None of these

10. In series LCR circuit, the phase angle between supply voltage and current is

(a) $\tan\phi = \frac{X_L - X_C}{R}$ (b) $\tan\phi = \frac{R}{X_L - X_C}$

(c) $\tan\phi = \frac{R}{X_L + X_C}$ (d) $\tan\phi = \frac{X_L + X_C}{R}$

Very Short:

1. The instantaneous current flowing from an ac source is I = 5 sin 314 t. What is the rms value of current?
2. The instantaneous emf of an ac source is given by E = 300 sin 314 t. What is the rms value of emf?
3. Give the phase difference between the applied ac voltage and the current in an LCR circuit at resonance.
4. What is the phase difference between the voltage across the inductor and the capacitor in an LCR circuit?
5. What is the power factor of an LCR series circuit at resonance?
6. In India, the domestic power supply is at 220 V, 50 Hz, while in the USA it is 110 V, 50 Hz. Give one advantage and one disadvantage of 220 V supply over 110 V supply.
7. Define the term ‘wattles current’. (CBSE Delhi 2011)
8. In a series LCR circuit, $V_L = V_C \neq V_R$. What is the value of the power factor? (CBSE AI 2015)
9. Define capacitor reactance. Write its SI units. (CBSE Delhi 2015)
10. Define quality factor in series LCR circuit. What is its SI unit? (CBSE Delhi 2016)

Short Questions:

1. State the phase relationship between the current flowing and the voltage applied in an ac circuit for (i) a pure resistor (ii) a pure inductor.
2. A light bulb is in turn connected in a series (a) across an LR circuit, (b) across an RC circuit, with an ac source. Explain, giving the necessary mathematical formula, the effect on the brightness of the bulb in case (a) and (b), when the frequency of the ac source is increased. (CBSE 2019C)
3. An air-core solenoid is connected to an ac source and a bulb. If an iron core is inserted in the solenoid, how does the brightness of the bulb change? Give reasons for your answer.
4. A bulb and a capacitor are connected in series to an ac source of variable frequency. How will the brightness of the bulb change on increasing the frequency of the ac source? Give reason.
5. An ideal inductor is in turn put across 220 V, 50 Hz, and 220 V, 100 Hz supplies. Will the current flowing through it in the two cases be the same or different?
6. State the condition under which the phenomenon of resonance occurs in a series LCR circuit, plot a graph showing the variation of current with a frequency of ac source in a series LCR circuit.
7. Give two advantages and two disadvantages of ac over dc.
8. In a series, LCR circuit connected to an ac source of variable frequency and voltage v = vm sin ωt, draw a plot showing the variation of current (I) with angular frequency (ω) for two

different values of resistance R1 and R2 ($R_1 > R_2$). Write the condition under which the phenomenon of resonance occurs. For which value of the resistance out of the two curves, a sharper resonance is produced? Define the Q-factor of the circuit and give its significance. (CBSE Delhi 2013C)

Long Questions:

1. Prove mathematically that the average power over a complete cycle of alternating current through an Ideal inductor is zero.
2. Draw the phasor diagram of a series LCR connected across an ac source $V = V_o \sin \omega t$. Hence, derive the expression for the impedance of the circuit. Obtain the conditions for the phase angle under which the current is
   (i) maximum and
   (ii) minimum. (CBSE AI 2019)

Assertion and Reason Question:

1. For two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false and R is also false.

Assertion: A bulb connected in series with a solenoid is connected to A.C. source. If a soft iron core is introduced in the solenoid, the bulb will glow brighter.

Reason: On introducing soft iron core in the solenoid, the inductance decreases.

2. For two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

a) Both A and R are true and R is the correct explanation of A.
b) Both A and R are true but R is not the correct explanation of A.
c) A is true but R is false.
d) A is false and R is also false.

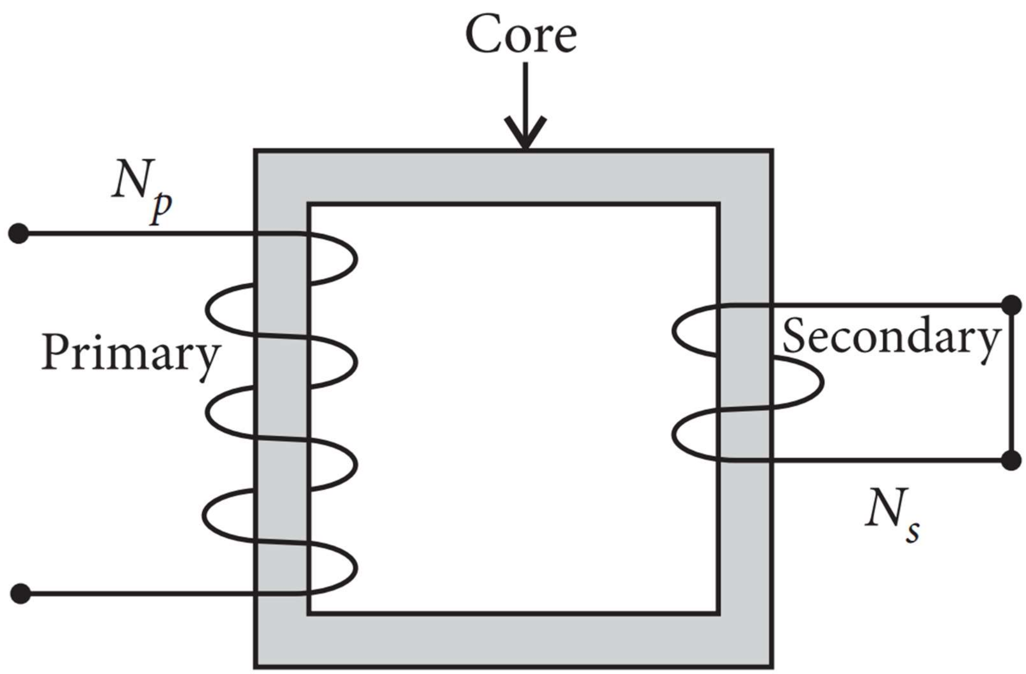
Assertion: An alternating current shows magnetic effect.

Reason: Magnitude of alternating current varies with time.

Case Study Questions:

1. Step-down transformers are used to decrease or step-down voltages. These are used when voltages need to be lowered for use in homes and factories. A small town with a demand of

800kW of electric power at 220V is situated 15km away from an electric plant generating power at 440V. The resistance of the two wire line carrying power is 0.5Q per km. The town gets power from the line through a 4000 - 220V step-down transformer at a sub-station in the town.



(i) The value of total resistance of the wires is:

a) 25Ω
b) 30Ω
c) 35Ω
d) 15Ω

(ii) The line power loss in the form of heat is:

a) 550kW
b) 650kW
c) 600kW
d) 700kW

(iii) How much power must the plant supply, assuming there is negligible power loss due to leakage?

a) 600kW
b) 1600kW
c) 500W
d) 1400kW

(iv) The voltage drop in the power line is:

a) 1700V
b) 3000V

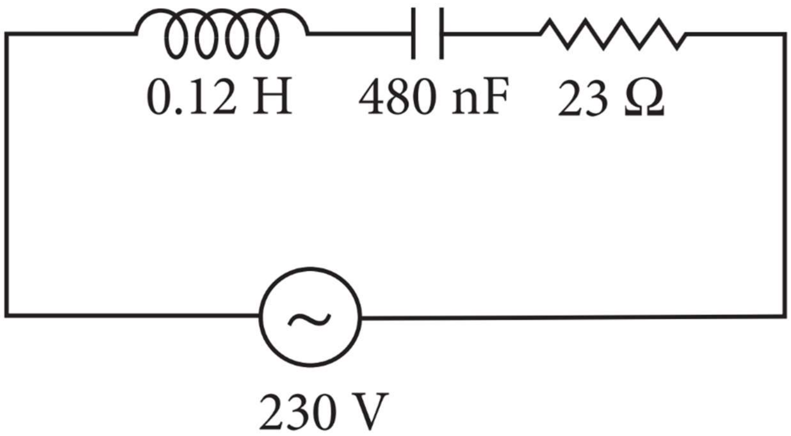
c) 2000V
d) 2800V

(v) The total value of voltage transmitted from the plant is:

a) 500V
b) 4000V
c) 3000V
d) 7000V

2. When the frequency of ac supply is such that the inductive reactance and capacitive reactance become equal, the impedance of the series LCR circuit is equal to the ohmic resistance in the circuit. Such a series LCR circuit is known as resonant series LCR circuit and the frequency of the ac supply is known as resonant frequency. Resonance phenomenon is exhibited by a circuit only if both Land Care present in the circuit. We cannot have resonance in a RL or RC circuit.

A series LCR circuit with L = 0.12H, C = 480nF, R=23Ω is connected to a 230V variable frequency supply.



(i) Find the value of source frequency for which current amplitude is maximum.

a) 222.32Hz
b) 550.52Hz
c) 663.48Hz
d) 770Hz

(ii) The value of maximum current is:

a) 14.14A
b) 22.52A
c) 50.25A
d) 47.41A

(iii) The value of maximum power is:

a) 2200W
b) 2299.3W

c) 5500W
d) 4700W

(iv) What is the Q-factor of the given circuit?

a) 25
b) 42.21
c) 35.42
d) 21.74

(v) At resonance which of the following physical quantity is maximum?

a) Impedance
b) Current
c) Both (a) and (b)
d) Neither (a) nor (b)

✓ Answer Key:

Multiple Choice Answers-

1. Answer: b
2. Answer: c
3. Answer: b
4. Answer: b
5. Answer: b
6. Answer: c
7. Answer: c
8. Answer: c
9. Answer: c
10. Answer: a

Very Short Answers:

1. Answer:

   The rms value of current is $\frac{5}{\sqrt{2}}$.

2. Answer:

   The rms value of voltage is $\frac{300}{\sqrt{2}}$

3. Answer:

   The applied ac voltage and the current in an LCR circuit at resonance are in phase.

Hence phase difference = 0.

4. Answer: The phase difference is 180°.
5. Answer: The power factor is one.
6. Answer:

   Advantage: less power loses

   Disadvantage: more fatal.
7. Answer: It is the current at which no power is consumed.
8. Answer: One.
9. Answer: It is the opposition offered to the flow of current by a capacitor. It is measured in ohm.
10. Answer: The quality factor is defined as the ratio of the voltage developed across the capacitor or inductor to the applied voltage. It does not have any unit.

Short Questions Answers:

1. Answer:

   (i) Electric current and voltage applied in a pure resistor are in same phase, i.e. Φ = 0°

   (ii) Applied voltage leads electric current flowing through pure-inductor in an ac circuit by phase angle of π/2.
2. Answer:

   a) The current in LR circuit is given by

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

   When the frequency of ac source ω increases, I decreases, and hence brightness decreases.

   (b) The current in RC circuit is given by

   $$I = \frac{V}{\sqrt{R^2+\frac{1}{\omega^2C^2}}}$$

   When the frequency of ac source ω increases, I increases, and hence brightness increases.
3. Answer: Insertion of an iron core in the solenoid increases its inductance. This in turn increases the value of inductive reactance. This decreases the current and hence the brightness of the bulb.
4. Answer:

   When the frequency of the ac is increased, it will decrease the impedance of the circuit as Z = $\sqrt{R^2+(1/2\pi fC)^2}$. As a result, the current and hence the brightness of the bulb will increase.

5. Answer:

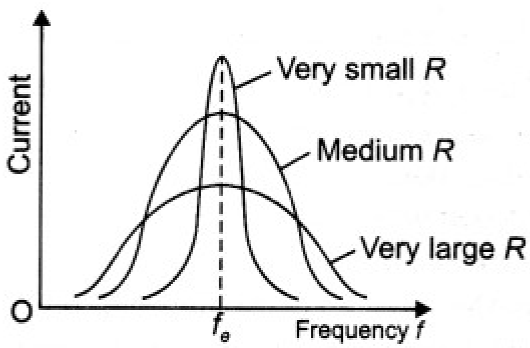
The current through the inductor is given by I = $\frac{V}{X_L} = \frac{V}{2\pi f L}$. The current is inversely proportional to the frequency of applied ac.

6. Answer: The phenomenon occurs when the inductive reactance becomes equal to the capacitive reactance., i.e., X_L - X_C

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

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

The graph is as shown below.



7. Answer:

Advantages of ac:

(a) The generation and transmission of ac are more economical than dc.

(b) The alternating voltage may be easily stepped up or down as per need by using suitable transformers.

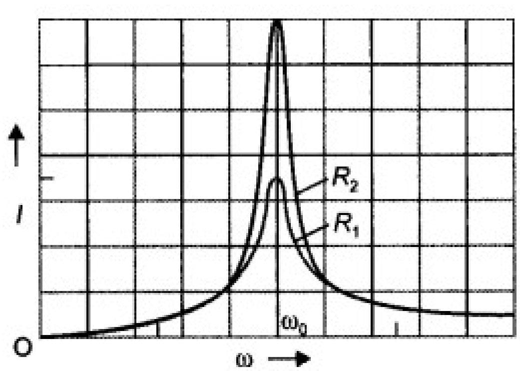
Disadvantages of ac:

(a) It is more fatal than dc.

(b) It cannot be used for electrolysis.

8. Answer:

The plot is as shown.



Resonance occurs in an LCR circuit when

$X_L = X_C$.

The smaller the value of R sharper is the resonance. Therefore, the curve will be sharper for R_2. It determines the sharpness of the resonance. The larger the value of Q sharper is the resonance.

Long Questions Answers:

1. Answer:

Let the instantaneous value of voltage and current in the ac circuit containing a pure inductor are

$V = V_m \sin \omega t$ and

$I = I_m \sin(\omega t - \pi/2) = -I_m \cos \omega t$

where $\pi/2$ is the phase angle by which voltage Leads currently when ac flows through an inductor. Suppose the voltage and current remain constant for a small-time dt. Therefore, the electrical energy consumed in the small-time dt is

$dW = V\,I\,dt$

The total electrical energy consumed in one time period of ac is given by

$$W = \int_0^T VI\,dt = -\int_0^T V_m \sin\omega t .\, I_m \cos\omega t dt$$

$$= -V_m I_m \int_0^T \sin\omega t \cos\omega t dt$$

$$\text{or } W = -\frac{I_m V_m}{2} \int_0^T 2 \sin \omega t \cos \omega t\, dt$$

$$\text{or } W = -\frac{I_m V_m}{2} \int_0^T \sin 2\omega t\, dt$$

$$\text{or } W = -\frac{I_m V_m}{2} \left[-\frac{\cos(2\omega t)}{2\omega} \right]_0^T = 0$$

Therefore, the total electrical energy consumed in an ac circuit by a pure inductor is W = 0

Now average power is defined as the ratio of the total electrical energy consumed over the entire cycle to the time period of the cycle, therefore

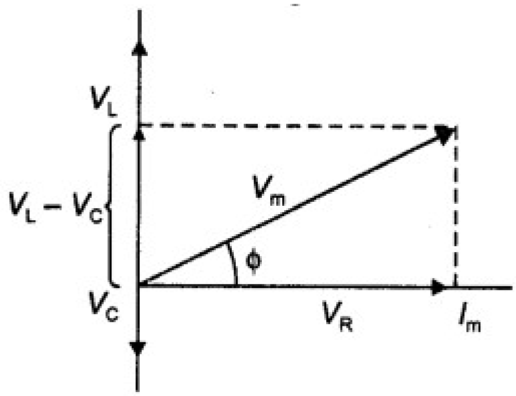
$$P_{av} = \frac{W}{T} = 0$$

Hence, the average power consumed in an ac circuit by a pure inductor is $P_{av} = 0$

Thus, a pure inductor does not consume any power when ac flows through it. Whatever energy is used in building up current is returned during the decay of current.

2. Answer:

The voltages across the various elements are drawn as shown in the figure below.



From the diagram, we observe that the vector sum of the voltage amplitudes V_R, V_L, and V_C equals a phasor whose length is the maximum applied voltage V_m, where the phasor Vm makes an angle ϕ with the current phasor Im. Since the voltage phasors, V_L and V_C are in opposite direction, therefore, a difference phasor (V_L - V_C) is drawn which is perpendicular to the phasor V_R. Adding vectorially we have

$$V_m = \sqrt{V_R^2 + (V_L - V_C)^2}$$
$$= \sqrt{(I_m R)^2 + (I_m X_L - I_m X_C)^2}$$

$$\text{or } V_m = I_m \sqrt{R^2 + (X_L - X_C)^2}$$

where X_L = ω L and X_C = 1 / ω C, therefore, we can express the maximum current as

$$I_m = \frac{V_m}{\sqrt{R^2 + (X_L - X_C)^2}}$$

The impedance Z of the circuit is defined as $Z = \sqrt{R^2 + (X_L - X_C)^2}$

For maximum Im, Z should be minimum (Z = R) or $X_C = X_L = 0$ and Φ = 0

For (I_m)min Φ → 90° ($|X_C - X_L| >> R$) Z → ∞

Assertion and Reason Answers:

1. (d) A is false and R is also false.

Explanation:

On introducing soft iron core, the bulb will glow dimmer. This is because on introducing soft iron core in the solenoid, its inductance L increases, the inductive reactance, $X_L = W_L$ increases and hence the current through the bulb decreases.

2. (b) Both A and R are true but R is not the correct explanation of A.

Explanation:

Like direct current, an alternating current also produces magnetic field. But the magnitude and direction of the field goes on changing continuously with lime.

Case Study Answers:

1. Answer :

(i) (d) 15Ω

Explanation:

Resistance of the two wire lines carrying power $= 0.5\frac{\Omega}{\text{Km}}$

Total resistance = $(15 + 15)0.5 = 15\Omega$

(ii) (c) 600kW

Explanation:

Line power loss = I^2R

RMS current in the coil,

$$I = \frac{P}{V_1} = \frac{800 \times 10^3}{4000} = 200\text{A}$$

∴ Power loss = $(200)^2 \times 15 = 600\text{kW}$

(iii) (d) 1400kW

Explanation:

Assuming that the power loss is negligible due to the leakage of the current.

The total power supplied by the plant,

= 800kW + 600kW = 1400kW

(iv) (b) 3000V

Explanation:

Voltage drop in the power line = IR

= 200 × 15 = 3000V

(v) (d) 7000V

Explanation:

Total voltage transmitted from the plant,

= 3000V + 4000V = 7000V

2. Answer :

i. (c) 663.48Hz

Explanation:

Here, L = 0.12H, e = 480nF = 480 × 10^{-9}F

$\mathrm{R} = 23\Omega$, V = 230V

$$\mathrm{V_0} = \sqrt{2} \times 230 = 325.22\mathrm{V}$$

$$\mathrm{I_0} = \frac{\mathrm{V_0}}{\sqrt{\mathrm{R}^2 + \left(\omega\mathrm{L} - \frac{1}{\omega\mathrm{C}}\right)^2}}$$

At resonance, $\omega\mathrm{L} - \frac{1}{\omega\mathrm{C}} = 0$

$$\omega = \frac{1}{\sqrt{\mathrm{LC}}} = \frac{1}{\sqrt{0.12 \times 480 \times 10^9}} = 4166.67\,\mathrm{rad\ s^{-1}}$$

$$\upsilon_\mathrm{R} = \frac{4166.67}{2 \times 3.14} = 663.48\mathrm{H_z}$$

ii. (a) 14.14A

Explanation:

Current, $\mathrm{I_0} = \frac{\mathrm{V_0}}{\mathrm{R}} = \frac{325.22}{23} = 14.14\mathrm{A}$

iii. (b) 2299.3W

Explanation:

Maximum power, $\mathrm{P_{max}} = \frac{1}{2}(\mathrm{I_0})^2\mathrm{R}$

$$= \frac{1}{2} \times (14.14)^2 \times 23 = 2299.3\mathrm{W}$$

iv. (d) 21.74

Explanation:

Quality factor, $\mathrm{Q} = \frac{\mathrm{X_R}}{\mathrm{R}} = \frac{\omega_\mathrm{r}\mathrm{L}}{\mathrm{R}}$

$$= \frac{4166.67 \times 0.12}{23} = 21.74$$

v. (b) Current