CBSE Class 12 Physics Notes Chapter 7: Chapter 7 of CBSE Class 12 Physics explores Alternating Current (AC) and Electromagnetic Waves. It covers the characteristics of AC, including peak value, frequency, RMS value, and phasors. The chapter discusses AC circuit analysis with resistors, inductors, and capacitors (R, L, C), focusing on concepts like reactance, impedance, resonance, and power factor.

The section on Electromagnetic Waves introduces their generation, properties, and the electromagnetic spectrum, along with Maxwell's equations that describe their behavior. This chapter emphasizes the role of electromagnetic waves in communication technologies.

CBSE Class 12 Physics Notes Chapter 7 Overview

Chapter 7 of CBSE Class 12 Physics covers Alternating Current (AC) and Electromagnetic Waves. The chapter begins with the concept of alternating current, which is an electric current that reverses direction periodically. The key parameters of AC are the peak value, frequency, and phase. The chapter explains the mathematical representation of AC using sinusoidal functions and discusses important concepts like root mean square (RMS) value, average value, and phasors.

The analysis of AC circuits is a major focus, covering circuits containing resistors, inductors, and capacitors (R, L, C) both in series and parallel configurations. The chapter introduces reactance and impedance and discusses the concept of resonance in AC circuits. The power in AC circuits is analyzed with special attention to the power factor and its importance.

CBSE Class 12 Physics Notes Chapter 7 Alternating Current and Electromagnetic Waves

Alternating current undergoes frequent reversals in direction and varies in magnitude over time. It is embodied by

$$\mathrm{I} = \mathrm{I}_0 \sin \omega \mathrm{t} \text{ or } \mathrm{I} = \mathrm{I}_0 \cos \omega \mathrm{t}$$
$$\omega = \frac{2\pi}{\mathrm{T}} = 2\pi \mathrm{v}$$

Average Value of Alternating Current

The amount of steady current that would transport the same amount of charge through a circuit in the period of a half cycle (i.e., T/2) as is sent by the alternating current through the same circuit, in the same length of time, is known as the mean or average value of alternating current over any half cycle.

Let's say that an alternating current is represented by I=I0sinωt in order to get the mean or average value.First of all

A tiny quantity of charge is transmitted in a short period of time, dt, if the strength of the current is expected to stay constant.

$\mathrm{dq} = \mathrm{Idt}$ ...(2)

Let q be the total charge sent by alternating current in the first half cycle (i.e. $0 \rightarrow \mathrm{T}/2$).

$q = \int_0^{T/2} I dt$

$\mathrm{U\,sing}(1)$, we get, $\mathrm{q} = \int_0^{\mathrm{T}/2} \mathrm{I}_0 \sin \omega \mathrm{t} \cdot \mathrm{dt} = \mathrm{I}_0 \left[-\frac{\cos \omega \mathrm{t}}{\omega} \right]_0^{\mathrm{T}/2}$

$= -\frac{\mathrm{I}_0}{\omega} \left[\cos \omega \frac{\mathrm{T}}{2} - \cos 0^o \right]$

$= -\frac{1_0}{\omega} [\cos \pi - \cos 0^o] \quad (\because \omega \mathrm{T} = 2\pi)$

$\mathrm{q} = -\frac{\mathrm{I}_0}{\omega} [-1 - 1] = \frac{2\mathrm{I}_0}{\omega}$ ...(3)

If I_m represents the mean or average value of alternating current over the 1 st half cycle, then

$\mathrm{q} = \mathrm{I_m} \times \frac{\mathrm{T}}{2}$ ...(4)

From (3) and (4), we get $\mathrm{I_m} \times \frac{\mathrm{T}}{2} = 2 \frac{\mathrm{I}_0}{\omega} = \frac{2\mathrm{I}_0 \cdot \mathrm{T}}{2\pi}$ ...(5)

or $I_m = \frac{2}{\pi} I_0 = 0.637 \mathrm{I}_0$

Hence, mean or average value of alternating current over positive half cycle is 0.637 times the peak value of alternating current, i.e., 63.7% of the peak value.

A.C. Circuit Containing Resistance Only

Let a source of alternating e.m.f. be connected to a pure resistance R, Figure. Suppose the alternating e.m.f. supplied is represented by

$E = E_0 \sin \omega t$ ...(1)

Let I be the current in the circuit at any instant t. The potential difference developed across R will be IR. This must be equal to e.m.f. applied at that instant, i.e., $\mathrm{IR} = E = E_0 \sin \omega t$

This is the matured form of alternating current.

We may determine that resistance to a.c. is represented by R, which is the value of resistance to d.c., by comparing I0=E0/R with Ohm's law equation, which states that current = voltage/resistance. R can therefore diminish both a.c. and d.c. with equal effectiveness because his behaviour in both d.c. and a.c. circuits is the same.

We may determine that E and I are in phase by comparing (2) and (1). Consequently, as illustrated in figure, the voltage and current in an a.c. circuit with only R are in the same phase.

Phasor Diagram

In the a.c. circuit containing R only, current and voltage are in the same phase. Therefore, in figure, both phasors $\overrightarrow{\mathrm{I}}_0$ and $\overrightarrow{\mathrm{E}}_0$ are in the same direction making an angle $(\omega \mathrm{t})$ with OX. This is so for all times. It means that the phase angle between alternating voltage and alternating current through R is zero.
$\mathrm{I}=\mathrm{I}_0 \sin \omega \mathrm{t}$ and $\mathrm{E}=\mathrm{E}_0 \sin \omega \mathrm{t}$

A.C. Circuit Containing Inductance Only

Only the alternating current I in an a.c. circuit with L lags one-fourth of a period—that is, a phase angle of 90 degrees—behind the alternating voltage E. On the other hand, there is a 90o phase angle where the voltage across L leads the current. Figure illustrates this.

The vector diagram, also known as the phasor diagram, for the a.c. circuit with only L is shown in Figure (b). With respect to OX, the vector denoting $\vec{E}$ 0 forms an angle (ωt). Since current lags the e.m.f. by 90 degrees, the phasor for $\vec{I}$ 0 is rotated clockwise via 90 degrees from the direction of

$\overrightarrow{\mathrm{E}}_0 . \mathrm{I}=\mathrm{I}_0 \sin \left(\omega \mathrm{t}-\frac{\pi}{2}\right), \mathrm{I}_0=\frac{\mathrm{v}_0}{\mathrm{x}_{\mathrm{L}}}, \mathrm{X}_{\mathrm{L}}=\omega \mathrm{L}$

A pure inductance offers zero resistance to dc. It means a pure inductor cannot reduce dc. The units of inductive reactance

$\mathrm{X}_{\mathrm{L}}=\omega L \Rightarrow \frac{1}{\sec }(\text { henry })=\frac{1}{\sec } \frac{1}{\mathrm{amp} / \mathrm{sec}}=\mathrm{ohm}$

The dimensions of inductive reactance are the same as those of resistance.

A.C. Circuit Containing Capacitance Only

Let a capacitor with capacitance C only be linked to an alternating e.m.f. source (figure). Assume that the given alternating e.m.f.

E is equal to E0sinωt}.... (1)

The capacitor's plates receive charge from the circuit's current flow. A possible variation between the plates results from this. With each half-cycle, the current reverses and the capacitor is alternately charged and discharged. Assume q is the capacitor's charge at any given time t. Consequently, V=q/C is the potential difference across the capacitor's plates.

The potential difference V needs to always equal the applied e.m.f., that is,

$$V = \frac{q}{C} = E = E_0 \sin \omega t$$

Or $q = C\varepsilon_0 \sin \omega t$

If I is instantaneous value of current in the circuit at instant t, then

$$I = \frac{dq}{dt} = \frac{d}{dt}(C\varepsilon_0 \sin \omega t)$$

$$I = CE_0(\cos \omega t)\omega$$

$$I = \frac{E_0}{1/\omega C}\sin(\omega t + \pi/2) \qquad \ldots(2)$$

The current will be maximum i.e.,

$I = I_0$, when $\sin(\omega t + \pi/2) = \text{maximum} = 1$

$\therefore$ From $(2), I_0 = \frac{E_0}{1/\omega C} \times 1$ ...(3)

Put in (2), $I = I_0 \sin(\omega t + \pi/2)$ ...(4)

Similar to how resistance controls current in a purely resistive circuit, capacitative reactance does the same in a purely capacitative circuit. It is evident that capacitate reactance varies inversely with both the condenser's capacitance and the frequency of the alternating current.

In a d.c. circuit, $v = 0, \therefore XC = \infty$

$$X_c = \frac{1}{\omega C} = \sec \frac{1}{\text{farad}} = \frac{\sec}{\text{coulomb/ volt}}$$

$$X_c = \frac{\text{voltsec.}}{\text{amp.sec}} = \text{olm}$$

A.C. Circuit Containing Resistance, Inductance and Capacitance and Series

Phasor Treatment

Let a source of alternating e.m.f. figure be connected in series with a pure resistance R, a pure inductance L, and an ideal capacitance C capacitor. Since R, L, and C are connected in series, the amplitude and phase of the current flowing through the three elements are always the same. Let's use I=I0sinωt to express it.

However, voltage across each element bears a different phase relationship with the current. Now,

(i) The maximum voltage across R is

$\overrightarrow{\mathrm{V}}_{\mathrm{R}}=\overrightarrow{\mathrm{I}}_{0}\mathrm{R}$

In figure, current phasor $\vec{I}_0$ is represented along OX.

(Image will be uploaded soon)

As $\vec{V}_R$ is in phase with current, it is represented by the vector $\overrightarrow{\mathrm{OA}}$, along OX.

(ii) The maximum voltage across L is $\overrightarrow{\mathrm{V}}_{\mathrm{L}}=\overrightarrow{\mathrm{I}}_{0}\mathrm{X}_{\mathrm{L}}$

As voltage across the inductor leads the current by 90^o, it is represented by $\overrightarrow{\mathrm{OB}}$ along $\mathrm{OY}, 90^o$ ahead of $\overrightarrow{\mathrm{I}}_{0}$.

(iii) The maximum voltage across C is $\overrightarrow{\mathrm{V}}_{\mathrm{C}}=\overrightarrow{\mathrm{I}}_{0}\mathrm{X}_{\mathrm{C}}$

As voltage across the capacitor lags behind the alternating current by 90^o, it is represented by $\overrightarrow{\mathrm{OC}}$ rotated clockwise through 90^o from the direction of $\vec{I}_0 \cdot \overrightarrow{OC}$ is along $O\mathrm{Y}'$

Analytical Treatment of RLC Series Circuit

Let a pure resistance R, a pure inductance L and an ideal condenser of capacity C be connected in ser to a source of alternating e.m.f. Suppose the alternating e.m.f. supplied is

$\mathrm{E}=\mathrm{E}_0\sin\omega\mathrm{t}$ ...(1)

At any instant of time t, suppose

$q =$ charge on capacitor

$\mathrm{I} =$ current in the circuit

$\frac{\mathrm{dI}}{\mathrm{dt}} =$ rate of change of current in the circuit

potential difference across the condenser $= \frac{q}{C}$

potential difference across inductor $= \mathrm{L}\frac{\mathrm{dI}}{\mathrm{d}t}$

potential difference across resistance $= \mathrm{RI}$

∴ The voltage equation of the circuit is

$$\mathrm{L}\frac{\mathrm{dI}}{\mathrm{dt}}+\mathrm{RI}+\frac{\mathrm{q}}{\mathrm{C}}=\mathrm{E}=\mathrm{E}_0\sin\omega\mathrm{t} \quad \ldots(2)$$

As $I=\frac{dq}{dt}$, therefore, $\frac{dI}{dt}=\frac{d^2q}{dt^2}$

∴ The voltage equation becomes

$$\mathrm{L}\frac{\mathrm{d}^2\mathrm{q}}{\mathrm{dt}^2}+\mathrm{R}\frac{\mathrm{dq}}{\mathrm{dt}}+\frac{\mathrm{q}}{\mathrm{C}}=\mathrm{E}_0\sin\omega\mathrm{t} \quad \ldots(3)$$

This is like the equation of a forced, damped oscillator. Let the solution of equation (3) be

$$q = q_0 \sin(\omega t + \theta)$$

$$\therefore \quad \frac{dq}{dt} = q_0 \omega \cos(\omega t + \theta)$$

$$\frac{d^2 q}{dt^2} = -q_0 \omega^2 \sin(\omega t + \theta)$$

Substituting these values in equation (3), we get

$$L\left[-q_0 \omega^2 \sin(\omega t + \theta)\right] + R q_0 \omega \cos(\omega t + \theta)$$

$$\frac{q_0}{C} \sin(\omega t + \theta) = E_0 \sin \omega t$$

$$q_0 \omega \left[R \cos(\omega t + \theta) - \omega L \sin(\omega t + \theta) + \frac{1}{\omega C} \sin(\omega t + \theta)\right] = E_0 \sin \omega t$$

As $\omega_{\mathrm{L}} = \mathrm{X_L}$ and $\frac{1}{\mathrm{OC}} = \mathrm{X_C}$, therefore $q_0 \omega \left[R \cos(\omega t + \theta) + (X_C - X_L) \sin(\omega t + \theta)\right] = E_0 \sin \omega t$

Multiplying and dividing by,

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

$$q_0 \omega Z \left[\frac{R}{Z} \cos(\omega t + \theta) + \frac{X_C - X_L}{Z} \sin(\omega t + \theta)\right] = E_0 \sin \omega t \qquad \ldots(4)$$

Let $\frac{\mathrm{R}}{Z} = \cos \phi$ and $\frac{\mathrm{X_C - X_L}}{\mathrm{Z}} = \sin \phi$ ...(5)

So that $\tan \phi = \frac{X_c - X_L}{Z}$ ...(6)

$$\therefore q_0 \omega Z \left[\cos(\omega t + \theta) \cos \phi + \sin(\omega t + \theta) \sin \phi\right] = E_0 \sin \omega t$$

or $\quad q_0 \omega Z \cos(\omega t + \theta - \phi) = E_0 \sin \omega t = E_0 \cos(\omega t - \pi/2) \quad \ldots(7)$

Comparing the two sides of this equation, we find that $E_0 = q_0 \omega Z = I_0 Z$, where $I_0 q_0 \omega$ ...(8)

and $\omega t + \theta - \phi = \omega t - \pi/2$

and $\omega t+\theta-\phi=\omega t-\pi/2$

$\therefore\ \theta-\phi=\frac{-\pi}{2}$

or $\theta=\frac{-\pi}{2}+\phi$ ...(9)

Current in the circuit is

$$I=\frac{dq}{dt}=\frac{d}{dt}[q_0\sin(\omega t+\theta)]=q_0\omega\cos(\omega t+\theta)$$

$$I=I_0\cos(\omega t+\theta)\quad\{\text{using }(8)\}$$

Using (9), we get, $\mathrm{I}=\mathrm{I}_0\cos(\omega t+\phi-\pi/2)$

$$\mathrm{I}=\mathrm{I}_0\sin(\omega t+\phi)\qquad ...(10)$$

$$\text{From }(6),\phi=\tan^{-1}\frac{(\mathrm{X_C}-\mathrm{X_L})}{\mathrm{R}}\qquad ...(11)$$

As $\cos^2\phi+\sin^2\phi=1$

$$\therefore\ \left(\frac{R}{Z}\right)^2+\left(\frac{X_C-X_L}{Z}\right)^2=1$$

$$R_2+(X_C-X_L)^2=Z^2$$

$$Z=\sqrt{R^2+(X_C-X_L)^2}\qquad ...(12)$$

A.C. Circuit Containing Resistance & Inductance

Let a source of alternating e m f be connected to an ohmic resistance R and a coil of inductance L, in series as shown in figure.

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

We find that in RL circuit, voltage leads the current by a phase angle ϕ, where

$$\tan\phi=\frac{\mathrm{AK}}{\mathrm{OA}}=\frac{\mathrm{OL}}{\mathrm{OA}}=\frac{\mathrm{V_L}}{\mathrm{V_R}}=\frac{\mathrm{I_0X_L}}{\mathrm{I_0R}}$$

$$\tan\phi=\frac{\mathrm{X_L}}{\mathrm{R}}$$

A.C. Circuit Containing Resistance and Capacitance

Let a source of alternating e.m.f. be connected to an ohmic resistance R and a condenser of capacity C, series as shown in figure.

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

Figure represents phasor diagram of RC circuit. We find that in RC circuit, voltage lags behind the curre by a phase angle ϕ, where

$$\tan\phi = \frac{AK}{OA} = \frac{OC}{OA} = \frac{V_C}{V_R} = \frac{I_0 X_C}{I_0 R}$$

$$\tan\phi = \frac{X_C}{R}$$

Energy Stored in an Inductor

When a.c. is applied to an inductor of inductance L, the current in it grows from zero to maximum steady value $\mathrm{I_0}$ If I is the current at any instant t, then the magnitude of induced e m.f. developed in the inductor at that instant is,

$$\mathrm{E} = \mathrm{L}\frac{\mathrm{dI}}{\mathrm{dt}} \qquad \ldots(1)$$

The self induced e.m.f. is also called the back e.m.f., as it opposes any change in the current in the circuit. Physically, the self inductance plays the role of inertia. It is the electromagnetic analogue of mass in mechanics. Therefore, work needs to be done against the back e.m.f. E. in establishing the current. This work done is stored in the inductor as magnetic potential energy.

For the current I at an instant t, the rate of doing work is,

$$\frac{\mathrm{dW}}{\mathrm{dt}} = \mathrm{EI}$$

If we ignore the resistive losses, and consider only inductive effect, then

Using $(1), \frac{\mathrm{dW}}{\mathrm{dt}} = \mathrm{EI} = \mathrm{L}\frac{\mathrm{dI}}{\mathrm{dt}} \times \mathrm{I}$ or $\mathrm{dW} = \mathrm{LIdI}$

Total amount of work done in establishing the current I is,

$$\mathrm{W} = \int \mathrm{dW} = \int_0^1 \mathrm{L}I\,\mathrm{dI} = \frac{1}{2}\mathrm{LI}^2$$

Thus energy required to build up current in an inductor = energy stored in inductor,

$$\mathrm{U_B} = \mathrm{W} = \frac{1}{2}\mathrm{LI}^2$$

Electric Resonance

Series Resonance Circuit

A circuit in which inductance L, capacitance C and resistance R are connected in series, and the circuit admits maximum current corresponding to a given frequency of a.c., is called series resonance circuit.
The impedance (Z) of an RLC circuit is given by

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

At very low frequencies, inductive reactance $\mathrm{X_L}=\omega \mathrm{L}$ is negligible, but capacitive reactance $(\mathrm{X_C}=1/\omega \mathrm{C})$ is very high.
As frequency of alternating e.m.f. applied to the circuit is increased, X_1 goes on increasing and X_c goes on decreasing. For a particular value of $\omega\,(=\omega_t$, say)

$$\mathrm{X_L}=\mathrm{X_c}$$

i.e., $\omega_r\,\mathrm{L}=\dfrac{1}{\omega_\mathrm{r}\mathrm{C}}$ or $\omega_\mathrm{r}=\dfrac{1}{\sqrt{\mathrm{LC}}}$

$$2\pi \mathrm{v_r}=\frac{1}{\sqrt{\mathrm{LC}}} \text{ or } \mathrm{v_r}=\frac{1}{2\pi\sqrt{\mathrm{LC}}}$$

At this particular frequency v_f as $\mathrm{X_L}=\mathrm{X_c}$, therefore, from (1)

$$Z=\sqrt{R^2+0}=R=\text{minimum}$$

i.e. impedance of RLC circuit is minimum and hence the current $I_0=\dfrac{E_0}{Z}=\dfrac{E_0}{R}$ becomes maximum. This frequency is called series resonance frequency.

The Q factor of series resonant circuit is defined as the ratio of the voltage developed across the inductance or capacitance at resonance to the impressed voltage, which is the voltage applied across R.
i.e.,

$$\text{i.e.}\quad Q=\frac{\text{voltage across } L \text{ or } C}{\text{applied voltage (= voltage across R)}}$$

$$Q=\frac{(\omega_r\,\mathrm{L})\,I}{\mathrm{RI}}=\frac{\omega_\mathrm{r}\mathrm{L}}{\mathrm{R}}$$

$$\text{or}\quad \mathrm{Q}=\frac{(1/\omega_\mathrm{r}\mathrm{C})\,\mathrm{I}}{\mathrm{RI}}=\frac{\mathrm{I}}{\mathrm{RC}\omega_\mathrm{r}}$$

Using $\omega_r=\dfrac{1}{\sqrt{\mathrm{LC}}}$, we get

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

$$\text{or}\quad Q=\frac{1\sqrt{LC}}{RC}=\frac{1}{R}\sqrt{\frac{L}{C}}$$

Thus $Q=\dfrac{1}{R}\sqrt{\dfrac{L}{C}}$ ...(1)

The quantity $\left(\dfrac{\omega_r}{2\Delta\omega}\right)$ is regarded as a measure of the sharpness of resonance, i.e., Q factor of the resonance circuit is the ratio of resonance angular frequency to bandwidth of the circuit (which is a difference in angular frequencies at which power is half the maximum power or current is $\mathrm{I_0}/\sqrt{2}$.

Average Power in RLC circuit or Inductive Circuit

Let the alternating e.m.f. applied to an RLC circuit be,

$E = E_0 \sin \omega t$ ...(1)

If alternating current developed lags behind the applied e.m.f. by a phase angle ϕ, then

$\mathrm{I} = \mathrm{I}_0 \sin(\omega \mathrm{t} - \phi)$ ...(2)

Power at instant t, $\frac{\mathrm{dW}}{\mathrm{dt}} = \mathrm{EI}$

$$\frac{\mathrm{dW}}{\mathrm{dt}} = \mathrm{E}_0 \sin \omega \mathrm{t} \times \mathrm{I}_0 \sin(\omega \mathrm{t} - \phi)$$
$$= \mathrm{E}_0 \mathrm{I}_0 \sin \omega \mathrm{t}(\sin \omega \cos \phi - \cos \omega \sin \phi)$$
$$= \mathrm{E}_0 \mathrm{I}_0 \sin^2 \omega \cos \phi - \mathrm{E}_0 \mathrm{I}_0 \sin \omega \cos \omega \sin \phi$$
$$= \mathrm{E}_0 \mathrm{I}_0 \sin^2 \omega t \cos \phi - \frac{\mathrm{E}_0 \mathrm{I}_0}{2} \sin 2\omega \sin \phi$$

If this instantaneous power is assumed to remain constant for a small time dt, then small amount of work done in this time is.

$$\mathrm{dW} = \left(\mathrm{E}_0 \mathrm{I}_0 \sin^2 \omega \mathrm{t} \cos \phi - \frac{\mathrm{E}_0 \mathrm{I}_0}{2} \sin 2\omega \sin \phi\right) \mathrm{dt}$$

Total work done over a complete cycle is

$$\mathrm{W} = \int_0^{\mathrm{T}} \mathrm{E}_0 \mathrm{I}_0 \sin^2 \omega t \cos \phi \mathrm{dt} - \int_0^{T} \frac{\mathrm{E}_0 \mathrm{I}_0}{2} \sin 2\omega \sin \phi \mathrm{dt}$$
$$\mathrm{W} = \mathrm{E}_0 \mathrm{I}_0 \cos \phi \int_0^{\mathrm{T}} \sin^2 \omega \mathrm{dt} - \frac{\mathrm{E}_0 \mathrm{I}_0}{2} \sin \phi \int_0^{\mathrm{T}} \sin 2\omega \mathrm{tdt}$$

As $\int_0^{\mathrm{T}} \sin^2 \omega \mathrm{td} = \frac{\mathrm{T}}{2}$ and $\int_0^{\mathrm{T}} \sin \omega \mathrm{tdt} = 0$

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

$\therefore$ Average power in the inductive circuit over a complete cycle.

$$P = \frac{W}{T} = \frac{E_0 I_0 \cos \phi}{T} \cdot \frac{T}{2} = \frac{E_0}{\sqrt{2}} \frac{I_0}{\sqrt{2}} \cos \phi$$

$P = E_v I_v \cos \phi$ ...(3)

> Hence average power over a complete cycle in an inductive circuit is the product of virtual e.m.f., virtual current and cosine of the phase angle between the voltage and current.
>
> **Note:**
>
> The relation (3) is applicable to all a.c. circuits. $\cos \phi$ and Z will have appropriate values for different circuits.
>
> For example:
>
> (i) In PL circuit, $Z = \sqrt{R^2 + X_L^2}$ and $\cos \phi = \frac{R}{Z}$
>
> (ii) $\mathrm{In\,RC}$ circuit, $Z = \sqrt{\mathrm{R}^2 + \mathrm{X}_\mathrm{C}^2}$ and $\cos \phi = \frac{\mathrm{R}}{\mathrm{Z}}$
>
> (iii) In LC circuit, $\mathrm{Z} = \mathrm{X_L} - \mathrm{X_c}$ and $\phi = 90^o$
>
> (iv) In RLC circuit, $\mathrm{Z} = \sqrt{\mathrm{R}^2 + (\mathrm{X_L} - \mathrm{X_C})^2}$ and $\cos \phi = \frac{\mathrm{R}}{\mathrm{Z}}$
>
> In all a.c. circuits, $I_v = \frac{E_v}{Z}$

Power Factor of an A.C. Circuit

We have proved that average power/cycle in an inductive circuit is

$P = E_v I_v \cos\phi$ ...(1)

Here, P is called true power, (E_V, I_V) is called apparent power or virtual power and $\cos\phi$ is called power factor of the circuit.

Thus, Power factor $= \frac{\text{true power (P)}}{\text{apparent power } (\mathrm{E_v I_v})} = \cos\phi$ ...(2)

$= \frac{\mathrm{R}}{\sqrt{\mathrm{R}^2 + (\mathrm{X_L} - \mathrm{X_C})^2}}$ [from impedance triangle]

Power factor $= \cos\phi = \frac{\text{Resistance}}{\text{Impedance}}$

In a non-inductance circuit, $\mathrm{X_L} = \mathrm{X_C}$

$\therefore$ Power factor $= \cos\phi = \frac{\mathrm{R}}{\sqrt{\mathrm{R}^2}} = \frac{\mathrm{R}}{\mathrm{R}} = 1, \phi = 0^o$

This is the maximum value of power factor. In a pure inductor or an ideal capacitor, $\phi = 90^o$.

Power factor $= \cos\phi = \cos 90^o = 0$.

Average power consumed in a pure inductor or ideal a capacitor, $\mathrm{P} = \mathrm{E}_v I_\mathrm{y} \cos 90^o =$ Zero. Therefore, current through pure L or pure C, which consumes no power for its maintenance in the circuit is called Idle current or Watt less current.

In actual practice, we do not have ideal inductor or ideal capacitor. Therefore, there does occur some dissipation of energy. However, inductance and capacitance continue to be most suitable for controlling current in a.c. circuits with minimum loss of power.

A.C. Generator or A.C. Dynamo

A device that converts mechanical energy into alternating current energy is called an a.c. generator/dynamo. It is among the most significant uses of the electromagnetic induction phenomena. Scientist Nikola Tesla, who was originally from Yugoslavia, created the generator. Since the machine doesn't produce anything, the term "generator" is misleading. It is actually an alternator that transforms one type of energy into another.

Principle

The basis of an alternating current generator/dynamo is the electromagnetic induction phenomenon, which states that an e.m.f. is induced in a coil anytime the amount of magnetic flux associated with the coil varies. It lasts for however long there is a shift in the magnetic flux passing through the coil. The Fleming right-hand rule indicates the direction of the induced current.

Construction

The essential parts of an a.c. dynamo is shown in the figure.

1. Armature: ABCD is a rectangular armature coil. It consists of a large number of turns of insulated copper wire wound over a laminated soft iron core, I. The coil can be rotated about the central axis.

2. Field Magnets: N and S are the pole pieces of a strong electromagnet in which the armature coil is rotated. Axis of rotation is perpendicular to the magnetic field lines. The magnetic field is of the order of 1 to 2 tesla.

3. Slip Rings: R_1 and R_2 are two hollow metallic rings, to which two ends of armature coil are connected. These rings rotate with the rotation of the coil.

4. Brushes: B_1 and B_2 are two flexible metal plates or carbon rods. They are fixed and are kept in light contact with R_1 and R_2 respectively. The purpose of brushes is to pass on current from the armature coil to the external load in resistance R.

Theory and Working:

As the armature coil is rotated in the magnetic field, angle θ between the field and normal to the coil changes continuously. Therefore, magnetic flux linked with the coil changes. An e.m.f. is induced in the coil.

To start with, suppose the plane of the coil is perpendicular to the plane of the paper in which magnetic field is applied, with AB at front and CD at the back, figure (a). The amount of magnetic flux linked with the coil in this position is maximum. As the coil is rotated anticlockwise (or clockwise), AB moves inwards and CD moves outwards. The amount of magnetic flux linked with the coil changes. According to Fleming's right hand rule, current induced in AB is from A to B and in CD, it is from C to D. In the external circuit, current flows from B_2 to B_1, figure (a).

After half the rotation of the coil, AB is at the back and CD is at the front, figure. Therefore, on rotating further, AB moves outwards and CD moves outwards and CD moves inwards. The current induced in AB is from B to A and in CD, it is from D to C. Through external circuit, current flows from B_1 to B_2; figure (b). This is repeated. Induced current in the external circuit changes direction after every half rotation of the coil. Hence the current induced is alternating in nature.

To calculate the magnitude of e.m.f. induced, suppose

$\mathrm{N}=$ number of turns in the coil,

$\mathrm{A}=$ area enclosed by each turn of the coil

$\overrightarrow{\mathrm{B}}=$ strength of magnetic field

$\theta=$ angle which normal to the coil makes with $\vec{B}$ at any instant t, figure.

Magnetic flux linked with the coil in this position

$\phi = \mathrm{N}(\vec{\mathrm{B}} \cdot \vec{\mathrm{A}}) = \mathrm{NBA}\cos\theta = \mathrm{NBA}\cos\omega\mathrm{t}$ ...(1)

where ω is angular velocity of the coil.

As the coil is rotated, θ changes; therefore, magnetic flux ϕ linked with the coil changes and hence an e.m is induced in the coil.

At the instant t, if e is the e.m.f. induced in the coil, then

$$e = \frac{-d\phi}{dt} = -\frac{d}{dt}(NAB\cos\omega t)$$

$$e = -NAB\frac{d}{dt}(\cos\omega t) = -NAB(-\sin\omega t)\omega$$

$$E = NAB\omega\sin\omega t \quad ...(2)$$

The induced e.m.f. will be maximum, when

$\sin\omega\mathrm{t} = \text{maximum} = 1$

emax $= e_0 = NAB\omega \times 1$ ...(3)

Put in $(2), \mathrm{e} = \mathrm{e}_0 \sin\omega\mathrm{t}$ ...(4)

The variation of induced e.m.f. with time (i.e. with position of the coil) is shown in figure.

Electromagnetic Spectrum

Numerous other electromagnetic waves were found by various means of stimulation following Hertz's experimental discovery of electromagnetic waves.

The electromagnetic spectrum is the ordered arrangement of electromagnetic radiations based on their wavelength or frequency.

Based on the type of excitation, the entire electromagnetic spectrum has been divided into several portions and subparts that are arranged in increasing wavelength order. Certain regions of the spectrum exhibit overlap, indicating that the corresponding radiations can be generated using two different techniques. It should be remembered that wavelengths, not methods of excitation, determine the physical characteristics of electromagnetic waves.

Main Parts of Electromagnetic Spectrum

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

Radiowaves

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

Uses: The various frequency ranges are used for different types of wireless communication systems as mentioned below

(i) The electromagnetic waves of frequency range from 530 kHz to $1710\mathrm{kH}$ form amplitude modulated (AM) band. It is used in ground wave propagation.

(ii) The electromagnetic waves of frequency range $1710\mathrm{kHz}$ to $54\mathrm{Mhz}$ are used for short wave bands. It is used in sky wave propagation.

(iii) The electromagnetic waves of frequency range $54\mathrm{Mhz}$ to $890\mathrm{MHz}$ are used in television waves.

(iv) The electromagnetic waves of frequency range $88\mathrm{MHz}$ to $108\mathrm{MHz}$ from frequency modulated (FM) radio band. It is used for commercial FM radio.

(v) The electromagnetic waves of frequency range $300\mathrm{MHz}$ to $3000\mathrm{MHz}$ form ultra high frequency (UHF) band. It is used in cellular phones communication.

Benefits of CBSE Class 12 Physics Notes Chapter 7

The CBSE Class 12 Physics notes for Chapter 7 on Alternating Current and Electromagnetic Waves offer several benefits:

Conceptual Clarity: The notes help students understand complex concepts like AC circuits, reactance, impedance, resonance, and electromagnetic waves, making it easier to grasp the subject matter.

Exam Preparation: Well-structured notes focus on key points and formulas, aiding in efficient revision and preparation for board exams and competitive exams like JEE and NEET.

Problem-Solving Skills: The notes include explanations of how to solve problems related to AC circuits and electromagnetic waves, enhancing students' analytical and problem-solving abilities.

Quick Revision: Summarized content allows for quick revision before exams, helping students recall essential concepts and formulas.

Application-Oriented Learning: The notes highlight the real-world applications of alternating current and electromagnetic waves, linking theoretical concepts to practical uses, especially in communication technologies.

Time Management: Concise notes save time by presenting information in a clear and organized manner, allowing students to cover more topics in less time.