1/9/23

CHAPTER - 7
ALTERNATING CURRENT

☆ ALTERNATING CURRENT

The magnitude of alternating current changes continuously but its direction or polarity changes periodically.

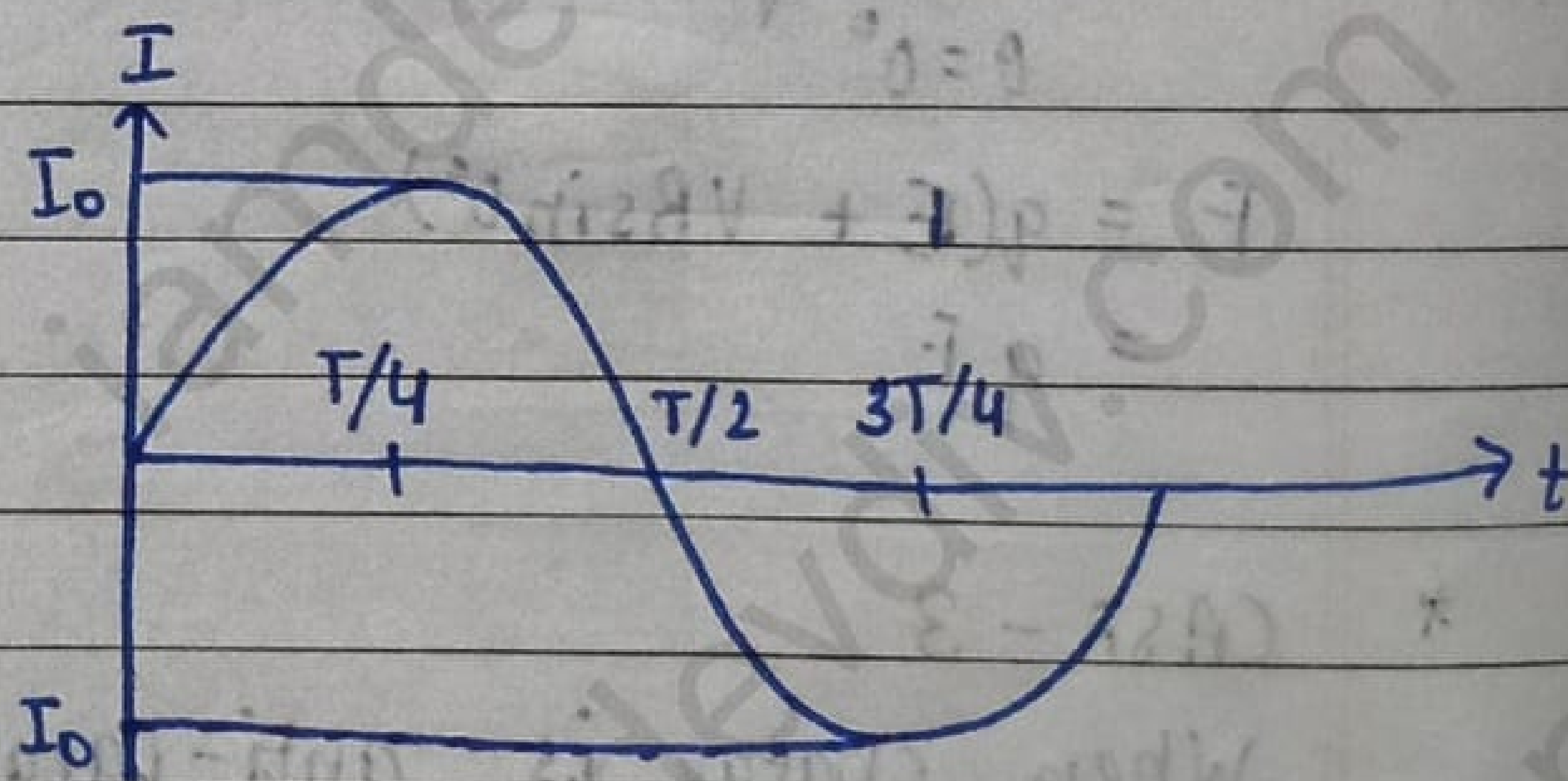
AC
- Instantaneous value
- Average value
- RMS value

• INSTANTANEOUS VALUE

$I = I_0 \sin \omega t$

$I = I_0 \sin \frac{2\pi}{T} \times \frac{T}{2} = 0$

$I = I_0 \sin \frac{2\pi}{T} \times \frac{T}{4} = I_0$



• AVERAGE VALUE

It is equal to the value of DC current when it pass through the circuit for the half-cycle.

* AVERAGE VALUE OF AC FOR HALF CYCLE

$$I_{av} = \frac{\int dq}{T/2} = \frac{\int_0^{T/2} I\,dt}{T/2} = \frac{\int_0^{T/2} I_0 \sin \omega t\,dt}{T/2}$$

$$= 2 \times \frac{I_0}{T}\left[\frac{-\cos \omega t}{\omega}\right]_0^{T/2} = \frac{2 I_0}{T \times \frac{2\pi}{T}}\left[-\cos\left(\frac{2\pi}{T} \times \frac{T}{2}\right) + \cos\left(\frac{2\pi}{T} \cdot 0\right)\right]$$

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

- RMS VALUE

$$I_{rms}^2 = \frac{\int I^2 dt}{\int dt}$$

$$= \frac{\int_0^T I_0^2 \sin^2\omega t \, dt}{T}$$

$$= I_0^2 \frac{\int_0^T \sin^2\omega t \, dt}{T}$$

$$= I_0^2 \frac{\int_0^T \frac{1-\cos 2\omega t}{2}}{T}$$

$$= I_0^2 \frac{\int_0^T \frac{1}{2} - \frac{\cos 2\omega t}{2}}{T}$$

$$= \frac{\frac{I_0^2}{2}\int_0^T 1-\cos 2\omega t}{T}$$

$$= \frac{I_0^2}{2T}\left(T - \sin 2\omega t\right)_0^T$$

$$= \frac{I_0^2}{2T}\left(T - \sin 2 \times \frac{2\pi}{T} \times T\right) \qquad \left[\because \omega = \frac{2\pi}{T}\right]$$

$$= \frac{I_0^2}{2T} \times T$$

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

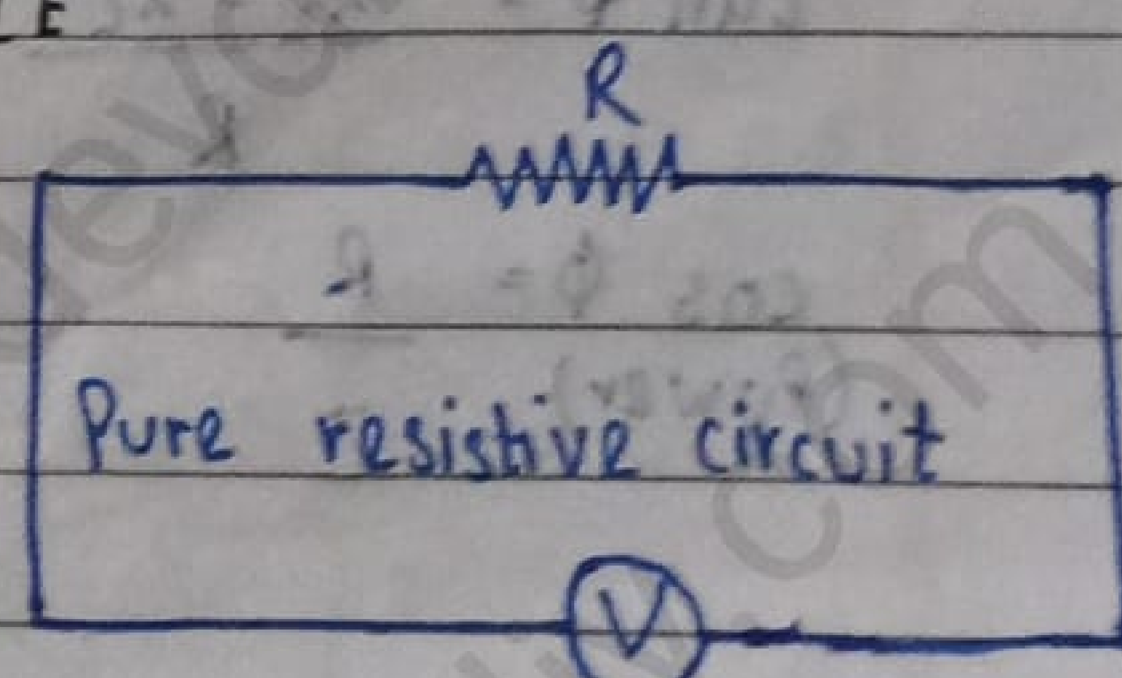
$$\boxed{I_{rms} = 70\% \text{ of } I_0}$$

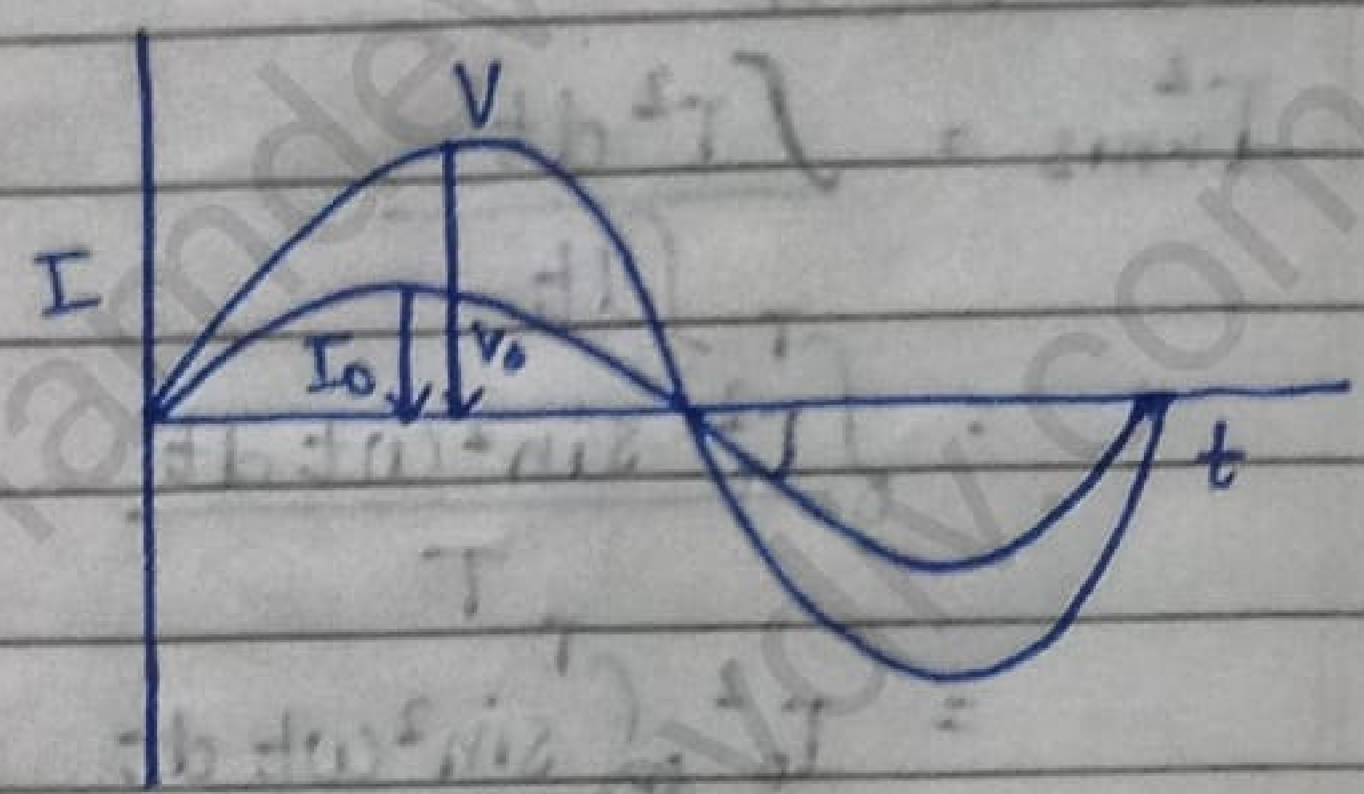
☆ LCR CIRCUIT OR IMPEDANCE TRIANGLE

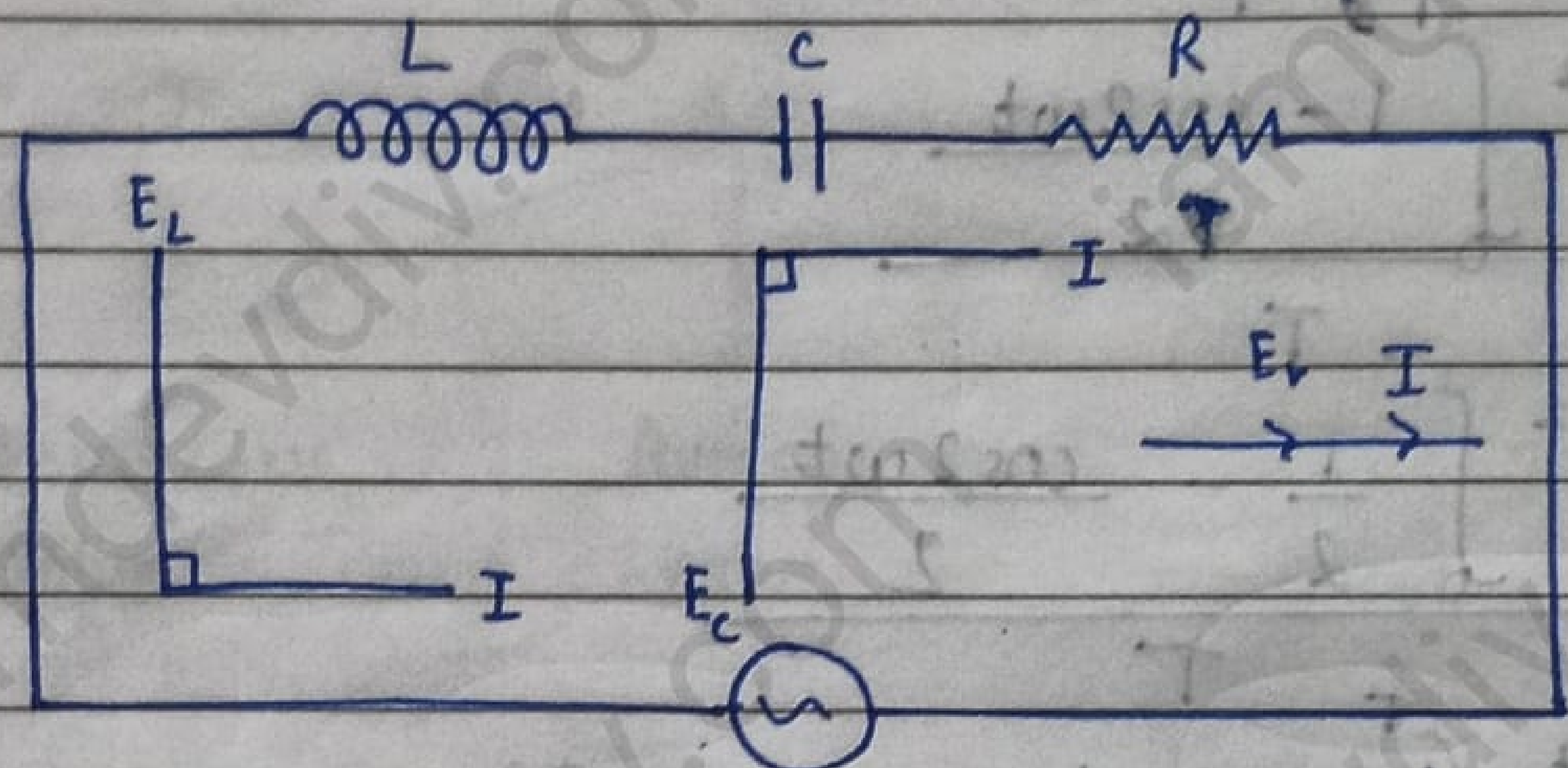
$V = V_0 \sin\omega t$

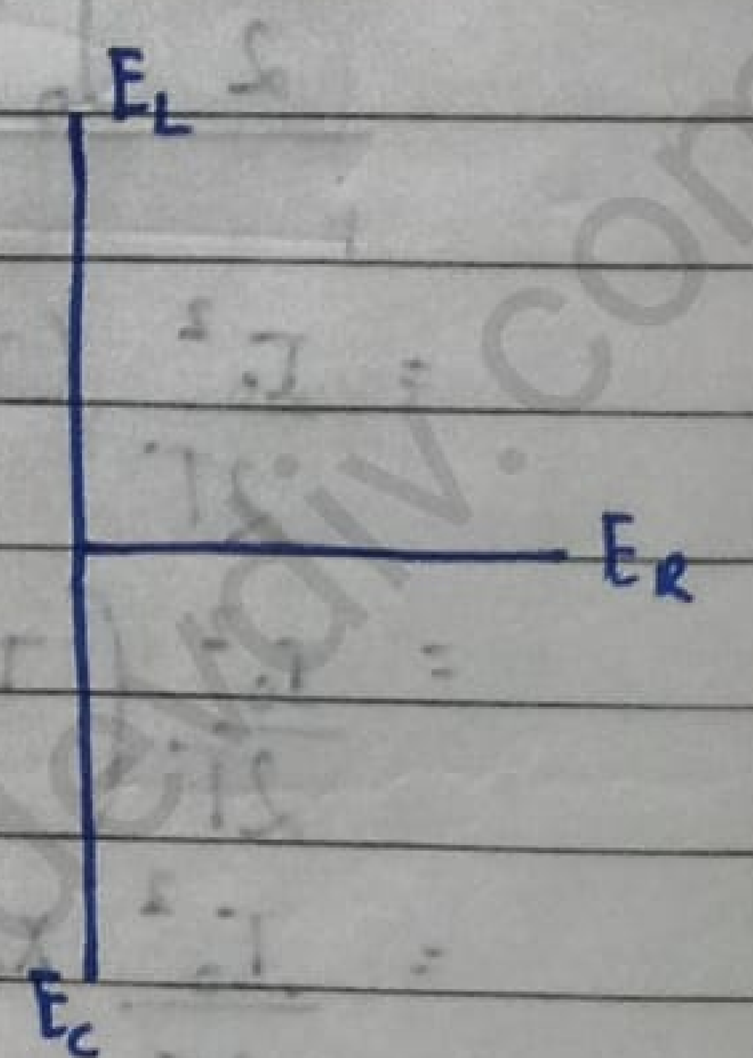
$I = \frac{V}{R}$

$I = \frac{V_0}{R}\sin\omega t = I_0 \sin\omega t$









$$E_0 = \sqrt{(E_L - E_C)^2 + E_R^2}$$

$$E_R = I_0 R$$

$$E_L = I_0 X_L$$

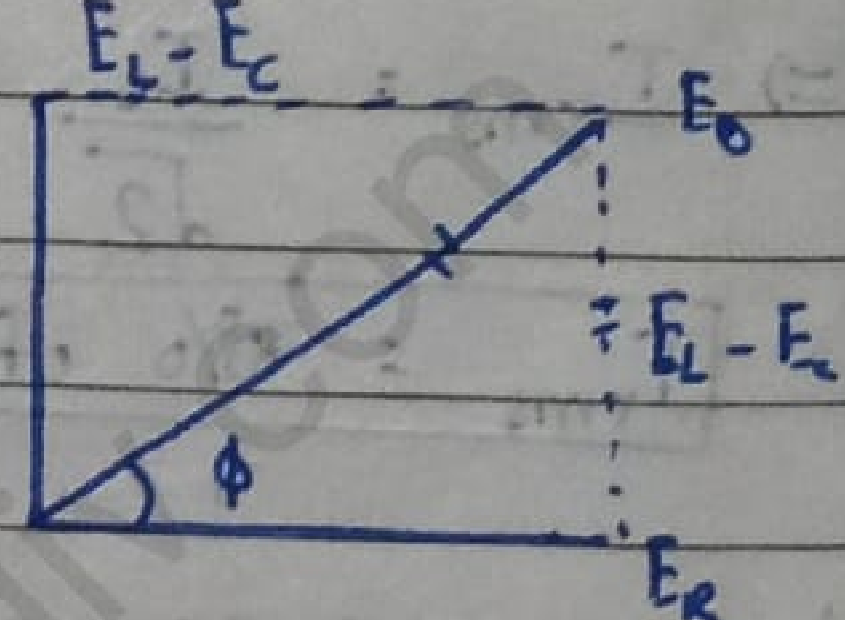
$$E_C = I_0 X_C$$

$$E_0 = \sqrt{(I_0 X_L - I_0 X_C)^2 + (I_0 R)^2}$$

$$\Rightarrow E_0 = I_0 \sqrt{(X_L - X_C)^2 + R^2}$$

$$\Rightarrow \frac{E_0}{I_0} = \sqrt{(X_L - X_C)^2 + R^2}$$

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



$$\tan\phi = \frac{X_L - X_C}{R} = \frac{E_L - E_C}{E_R}$$

$$\cos\phi = \frac{R}{Z}$$
(Power)

- RESONANCE

It is a condition ~~where~~ when impedance of the circuit becomes minimum and current becomes maximum.

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

At resonance, $X_L = X_C$

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

$\Rightarrow Z = R$ (Minimum impedance)

★ AVERAGE POWER IN AC

$P_{in} = I_{in} V_{in}$

↳ instantaneous

$V_{in} = V_0 \sin \omega t$

$I_{in} = I_0 \sin (\omega t - \phi)$

$P_{in} = I_0 \sin (\omega t - \phi) V_0 \sin (\omega t)$

$= \frac{1}{2} V_0 I_0 [2 \sin(\omega t) . \sin (\omega t - \phi)]$

$= \frac{1}{2} V_0 I_0 [\cos \phi - \cos (2\omega t - \phi)]$

For average value of $\cos (2\omega t - \phi)$ of complete cycle is zero

$P_{av} = \frac{1}{2} V_0 I_0 \cos \phi$

$\Rightarrow P_{av} = \frac{V_0}{\sqrt{2}} \times \frac{I_0}{\sqrt{2}} \cos \phi$

$\Rightarrow P_{av} = i_{rms} V_{rms} \cos \phi$

★ WATTLESS CURRENT

In purely inductive or purely capacitive circuit, power loss is zero. In such a circuit, current flowing is called wattless current.

$$I_{wattless} = I \sin \phi = I \left(\frac{X_C}{Z}\right) = I \left(\frac{X_L}{Z}\right)$$

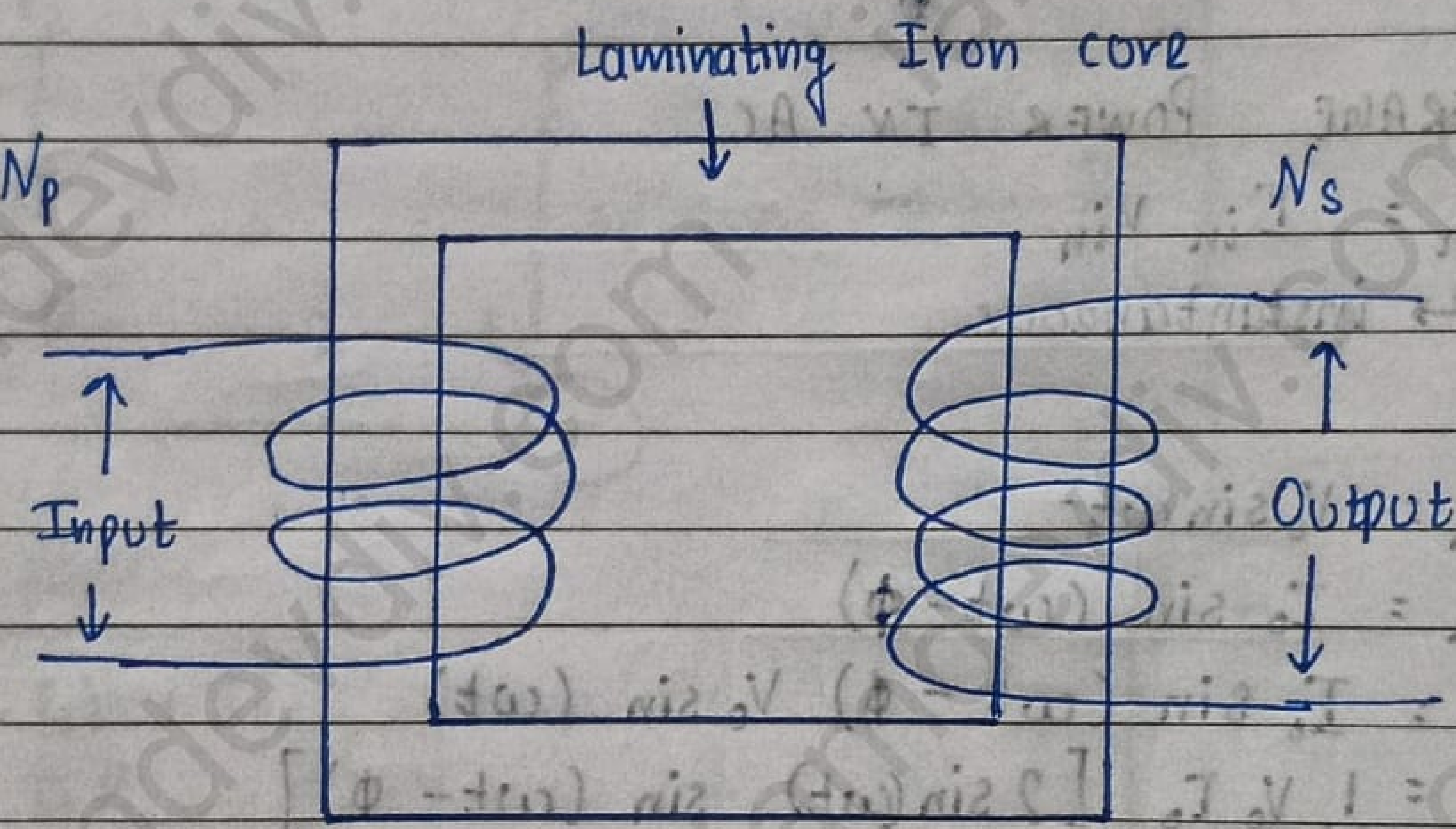
★ TRANSFORMER

It is a device which is used to step up or step down the input voltage.

- **PRINCIPLE**

It is based on the principle of Faraday's law of mutual induction

- **CONSTRUCTION**



It consists of large number of laminating cores. There are two types of winding : one is called primary winding and other is called secondary winding. AC Input is given to primary winding and output is taken from secondary winding.

- **WORKING**

When AC input is given to primary winding, current in primary changes due to which flux link with the coil changes and due to change in flux, EMF will induce which is called primary EMF. Due to mutual induction, the same flux will link to the secondary and hence, due to change in flux, the EMF will induce in secondary called secondary EMF.

$$E = -N \frac{d\phi}{dt}$$

$$E_p = -N_p \frac{d\phi}{dt} \quad \text{--- (1)}$$

$$E_s = -N_s \frac{d\phi}{dt} \quad \text{--- (2)}$$

Divide eq^n (2) by (1)

$$\boxed{\frac{E_s}{E_p} = \frac{N_s}{N_p}}$$

$$\frac{E_s}{E_p} = K$$

↳ Transformation ratio

Also,

$$P = IV$$

$$E_p I_p = E_s I_s$$

$$\Rightarrow \boxed{\frac{E_p}{E_s} = \frac{I_s}{I_p}}$$

↳ K ⇒ Transformation ratio

* CASE - 1

When $K > 1$

$E_s > E_p$

OR $N_s > N_p$

Then transformer will be step up

* CASE - 2

When $K < 1$

$E_p > E_s$

OR $N_p > N_s$

Then transformer will be step down

* CASE - 3

When $K = 1$

$E_s = E_p$

OR $N_s = N_p$

then transformer will be ideal transformer.

- EFFICIENCY OF TRANSFORMER

$$\eta = \frac{\text{Output power}}{\text{Input power}}$$

$$\eta \% = \frac{E_s I_s}{E_p I_p} \times 100$$

- USES OF TRANSFORMER

1. It is used to step down the voltage in various small project like welding purpose.
2. It is used to regulate the voltage which are used in costly appliances like AC, Refrigerator, etc.
3. In long distance transmission.