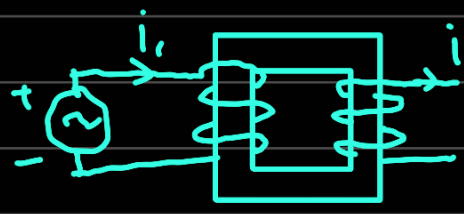
Day-17

→ Transformer : no-load operation



No load : $i_2 = 0$

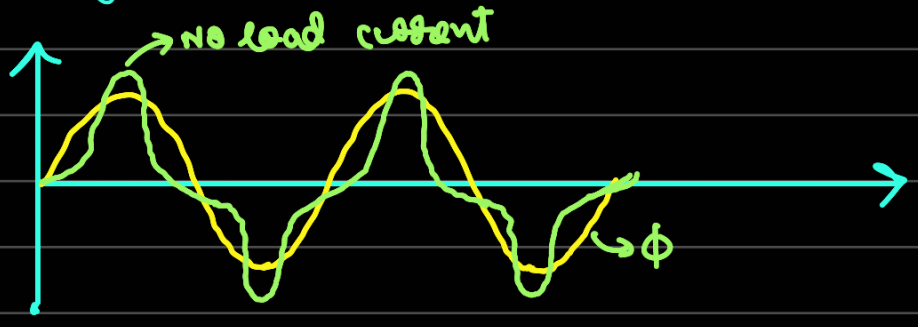
$$v_1 = i_1 R_1 + \frac{d\psi}{dt}$$

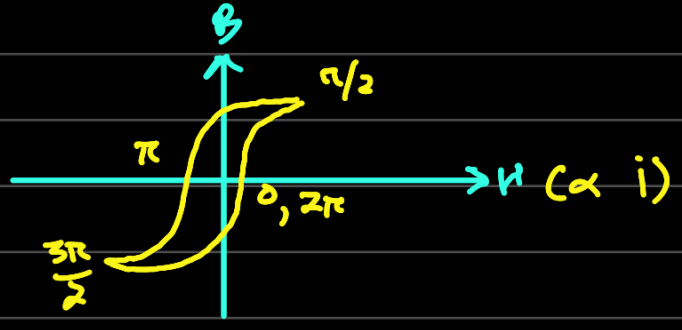
Neglecting resistance drop,

$$v_1 \approx \frac{d\psi}{dt} = N\frac{d\phi}{dt}$$

$$v_1 = V_m \sin \omega t \Rightarrow \phi = -\frac{V_m}{N\omega}\cos \omega t$$

⇒ No load current of a Transformer is not sinusoidal, because of non-linear and multi-valued nature of B-H curve of core.





→ $i_1(t)$ has half-wave symmetry (HWS)

$$i_1(t) = -i_1(t \pm T/2)$$

$T \rightarrow$ time period of $i_1(t)$

HWS $\Rightarrow$ No even harmonics in Fourier series expansion

$$\Rightarrow i_1(t) = \sum_{n \rightarrow odd} I_{an} \cos \omega t + \sum_{n \rightarrow odd} I_{bn} \sin \omega t$$

$(\omega = 2\pi/T)$

$$i_1(t) = I_{a_1} \cos \omega t + I_{b_1} \sin \omega t + I_{a_3} \cos 3\omega t + I_{b_3} \sin 3\omega t + \ldots$$

$$i_{eq}(t) = I_a \cos \omega t + I_b \sin \omega t$$

$$V_1 = V_m \sin \omega t$$

$$\frac{1}{2\pi} \int v_1 i_1 \, d\omega t = \frac{1}{2\pi} \int v_1 i_{eq} \, d\omega t \rightarrow \text{Same core loss}$$

$$\Rightarrow \frac{V_m I_{b_1}}{2} = \frac{V_m I_b}{2}$$

$$\Rightarrow I_{b_1} = I_b$$

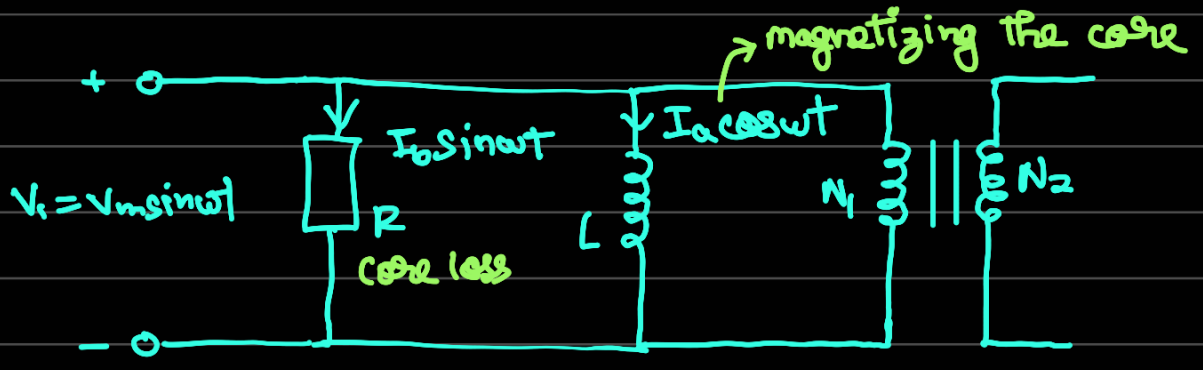
I_{RMS} is same (Same wire loss)

$$\sqrt{I_{a_1}^2 + I_{b_1}^2 + I_{a_3}^2 + I_{b_3}^2 + \ldots} = \sqrt{I_a^2 + I_b^2}$$

$$\Rightarrow I_a = \sqrt{I_{a_1}^2 + I_{a_3}^2 + I_{b_3}^2}$$

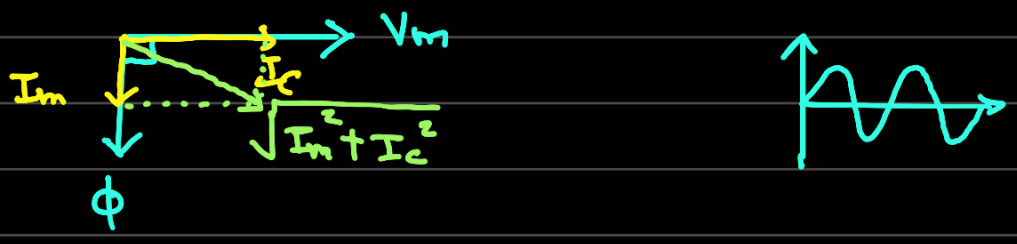
Now, $v_1 = V_m \sin \omega t$

$i_{eq} = I_a \cos \omega t + I_b \sin \omega t$



→ Phasor diagram

(Assume anticlockwise rotation)

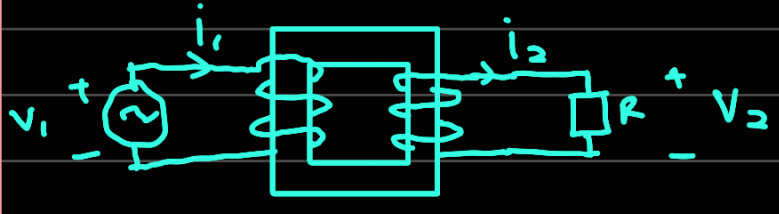


$$v_1(t) = V_m \sin\omega t$$
$$i_1(t) = I_a \cos\omega t + I_b \sin\omega t$$

$$P_{in}(t) = \underbrace{V_m I_a \cos\omega t \sin\omega t}_{\text{Reactive}} + \underbrace{V_m I_b \sin^2\omega t}_{\text{Active}}$$

→ Transformer : with load

(load means current)



$$V_1 = \frac{d\psi_1}{dt} = N\frac{d\phi}{dt}$$ (ϕ won't change)

☆ Ideal transformer

• No core loss ⇒ loop area of hysteresis

core is zero

- Leakage effects of flux are neglected
- Resistance of wires is zero
- Core permeability is infity

$$\left.\begin{aligned} v_1 &= N_1 \frac{d\phi}{dt} \\ v_2 &= N_2 \frac{d\phi}{dt} \end{aligned}\right\} \quad \frac{v_1(t)}{v_2(t)} = \frac{N_1}{N_2}$$

$$\oint \vec{H} \cdot d\vec{l} = N_1 i_1 - N_2 i_2$$

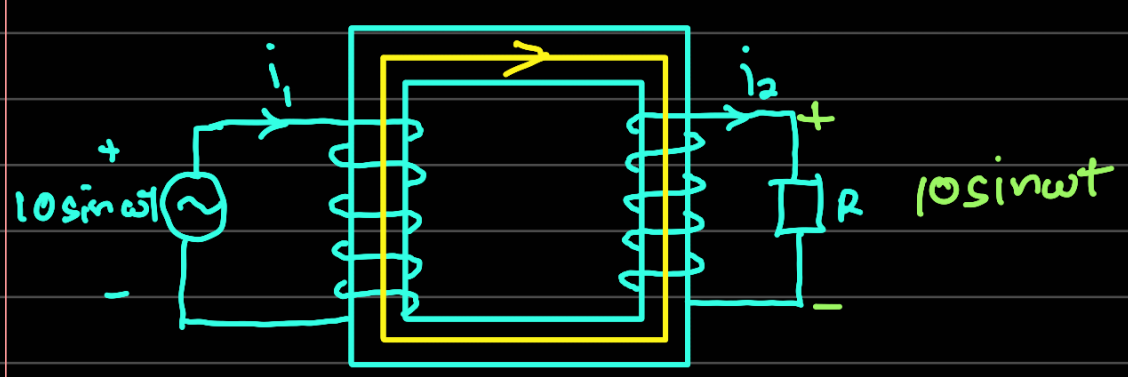
$$\Rightarrow \frac{B\,l_c}{\mu_0 \mu_r} = N_1 i_1 - N_2 i_2 \qquad \text{(No saturation effected)}$$

As $\mu_r \longrightarrow \infty$, LHS $= 0$

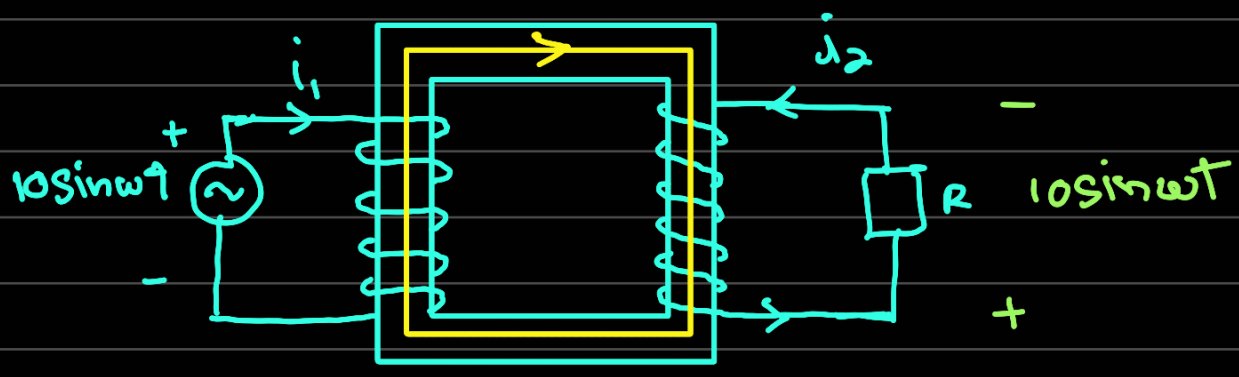
So $N_1 i_1 = N_2 i_2$

$$\Rightarrow \frac{i_1}{i_2} = \frac{N_2}{N_1}$$

So $v_1(t)\, i_1(t) = v_2(t)\, i_2(t)$



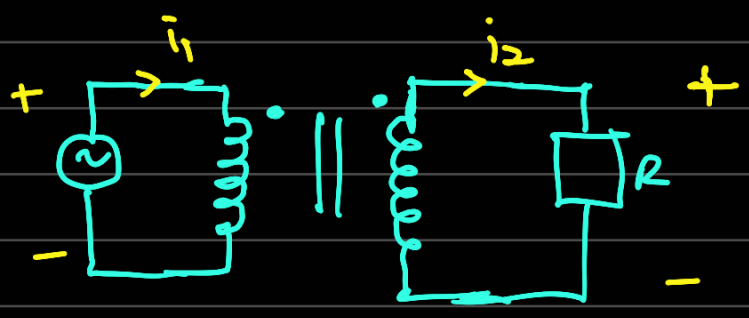
① Same sense of winding



(2) Different sense of winding

→ Dot convention

(1)



(2)