Lecture 16

Wednesday, October 6, 2021 11:33 AM

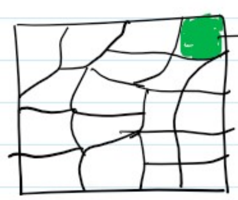
mutual & self inductance
voltage induced → Faraday's law $E = \frac{d\lambda}{dt}$

Coupling factor
leakage flux (leakage inductance comes into picture)

ferromagnetic material

when we energize a coil → energization / magnetizing / inrush current
Ac excitation (transformers → losses in the transformer
no load/open circuit operation

physics → dimagnetic
paramagnetic
ferromagnetic → material which are iron based → alloys nickel, cobalt.
ferrimagnetic



→ domain → magnetic moment associated with them
↓
Randomly oriented & thus net magnetic moment is zero.

↑
they no longer become completely random

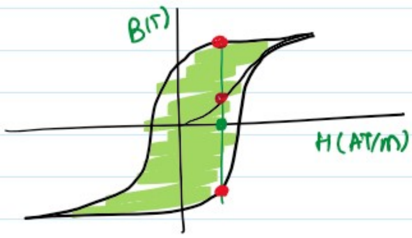
External magnetic field is applied → magnet moments align in the direction of field (applied)

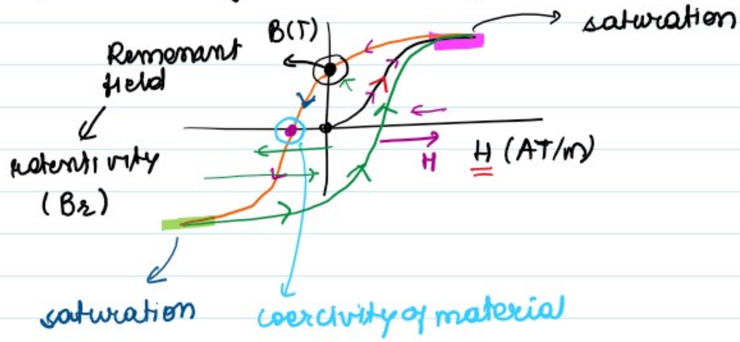
alignment leads to enhancement of field inside magnetic material
Even with small amount of magnetic field applied the resultant / enhancement ~~is~~ inside the material is high.

But there is a limit to this increase in field inside the material
↓
saturation
this observation is also seen from material characteristics curve
↓
B–H (magnetic field density vs. intensity)

B(T) → saturation

B–H (magnetic field density vs. intensity)





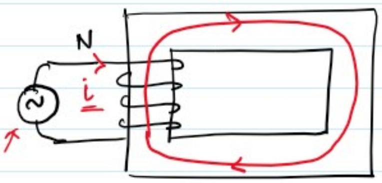
multivalued function, non linear
Hysteresis curve of material
Area under the curve changes applied voltage & frequency

AC excitation of coil wound on a magnetic material
↓
has hysteresis characteristics

$V = \frac{d\lambda}{dt}$

$V \rightarrow \lambda \rightarrow B \rightarrow H \rightarrow i$

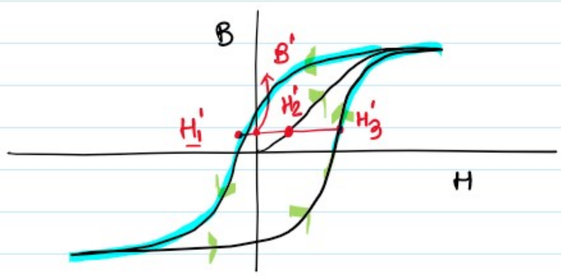
$\rightarrow B = \frac{\phi}{A} = \frac{N\phi}{A} \cdot \frac{1}{N} = \boxed{\frac{\lambda}{AN}}$



l = length
A : area of crossection

$\underline{l}\,\underline{H} = \underline{N}\,i$

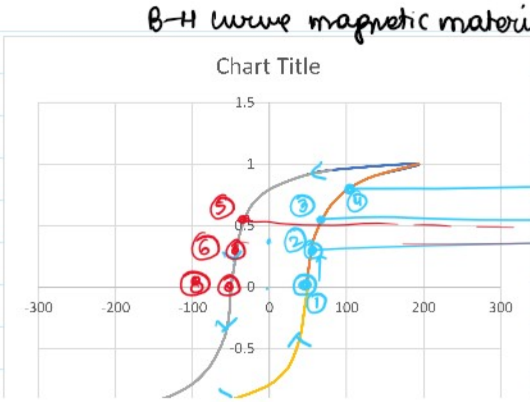
$l\frac{H}{N} = i$

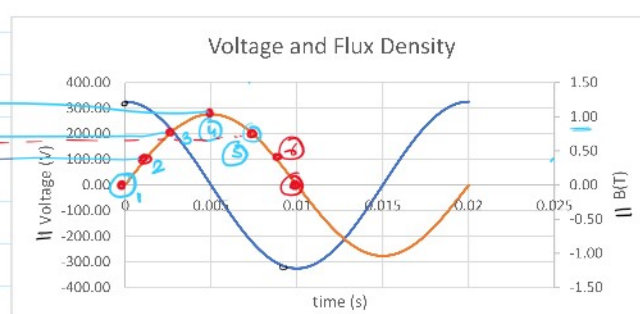


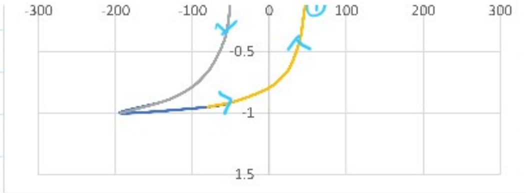
point by point → time variation

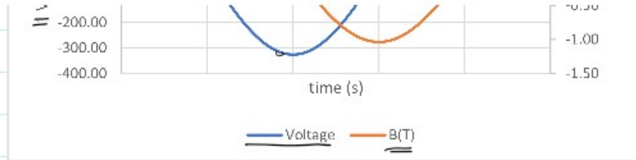
$v(t) \rightarrow \lambda(t) \rightarrow B(t) \rightarrow H(t) \rightarrow i(t)$
↓
$V_m \cos(\omega t)$

B-H curve magnetic material









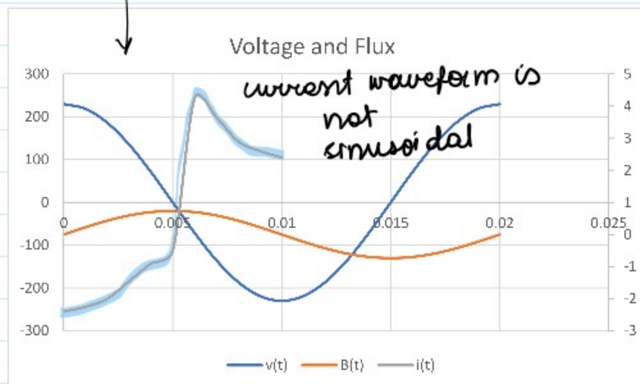
V	230.00	V					
F	50 Hz//	N	1	A	1	L	1.00

$V = \frac{d\lambda}{dt}$ λ phase shifted by $90°$

H AT/m	B,T //
48	0
52	0.2
58	0.4
73	0.6
85	0.7
103	0.8
135	0.9
193	1
80	0.95
42	0.9
2	0.8
-18	0.7
-29	0.6
-40	0.4
-45	0.2
-50	0
-52	-0.2
-58	-0.4
-73	-0.6
-85	-0.7
-103	-0.8
-135	-0.9
-193	-1
-80	-0.95
-42	-0.9
-2	-0.8
18	-0.7
29	-0.6
40	-0.4
45	-0.2
50	0

t	V	B(t)	H(t)
0	325.27	0.00	48.00
5.00E-04	321.26	0.16	51.24
0.001	309.35	0.32	55.60
1.50E-03	289.82	0.47	63.25
0.002	263.15	0.61	74.03
2.50E-03	230.00	0.73	90.78
0.003	191.19	0.84	115.04
0.004	100.51	0.98	158.40
4.50E-03	50.88	1.02	206.12

→ $i(t)$



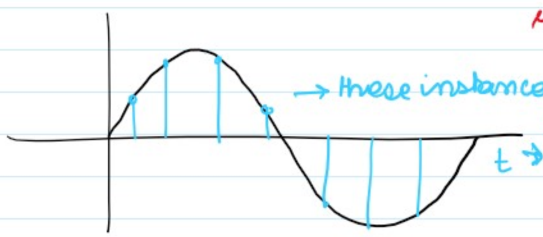
AC excitation → core flux is sinusoidal
↓
corresponding current is not sinusoidal

fourier series is required to obtain the frequency content

$$\int d\lambda = \int v\, dt$$

$$\lambda(t) = \lambda_m \sin(\omega t + \phi) - \underbrace{\lambda(0)}_{\text{remanent flux (initial value)}} + \lambda_m \sin \phi$$

ϕ → dependent on point on voltage wave at which connected to source

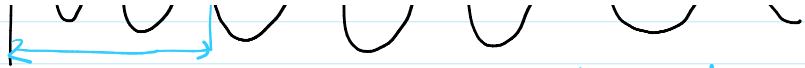


$\lambda(0) = 0$ $\phi = 90°$ $\lambda(t=0) = 2\lambda_m$

$\phi = 0°$ $\lambda(t=0) = 0$

if $\lambda(0) = 0$

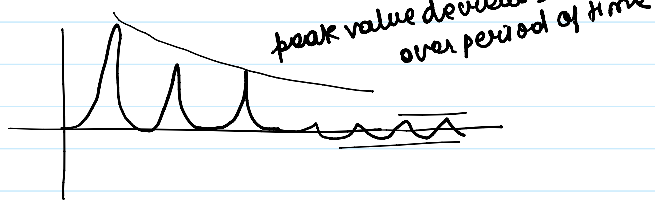
transient portion (inrush current) → large value

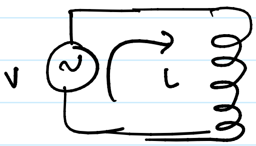


transient portion (inrush current) → large value

we analyzed and plotted steady state values of $\lambda(t), B(t), H(t)$
$i(t)$

* non linear characteristics of material leads to non sinusoidal waveform.





$V = V_m \cos\omega t = V(t)$

$i(t)$ = difficult to write an expression //

$$= \sum_{n=1}^{\infty} A_n \cos(n\omega t + \phi_n)$$

$$p(t) = \underbrace{v(t)}_{B(t)}\ \underbrace{i(t)}_{H(t)}$$

$B(t)$, $H(t)$ → property of material

$$\int p(t) = e(t)$$

$$\int v(t)\, i(t)\, dt = e(t)$$

losses that are taking place.

$$B = \frac{\lambda}{AN} \qquad \lambda = \int v\, dt \qquad \lambda_m = \frac{V_m}{\omega}$$

$$B(t) = \frac{\lambda(t)}{AN} \qquad = \int V_m \cos\omega t\, dt$$

$$H(t) = \frac{N i(t)}{l} \qquad \lambda(t) = \underbrace{\frac{V_m}{\omega}}_{\lambda_m = \frac{V_m}{\omega}} \sin(\omega t)$$

$$B(t)\, H(t) = \frac{\lambda(t)}{AN} \cdot \frac{N i(t)}{l}$$

$$= \frac{V_m}{\omega AN} \sin(\omega t) \cdot \frac{N i(t)}{l}$$

$$= \frac{V_m \cdot N}{\omega l A N} \sin(\omega t) \cdot I(t)$$

$$B(t)\,H(t) = \frac{V_m}{\omega\,(Vol)} \sin(\omega t)\; I(t)$$

$$\boxed{lA = \text{volume}}$$

$$BH = \frac{K}{Vol} \sin(\omega t)\, I(t)$$

volume $\times$ density = mass of the material

$$BH = \frac{\rho K}{\rho (Vol)} \cdot \sin(\omega t)\, I(t)$$

mass.

$$\underbrace{M \cdot BH}_{} = \rho K \sin(\omega t)\, I(t)$$

$$\frac{\text{losses}}{kg} \quad \left(\frac{\text{loss}}{\text{mass}} ,\ \frac{W}{kg} \right)$$

losses taking place can be found.