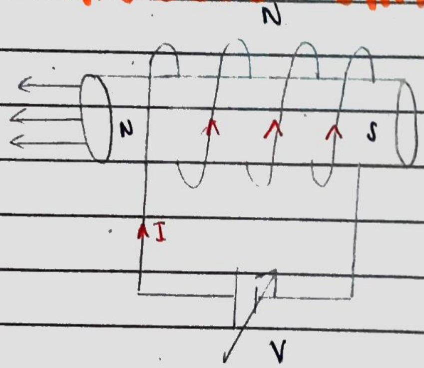
Statically Induced Emf

(i) Self-Induced

(ii) Mutually-Induced

30th NOV (a) **Self induced emf**



↳ The emf induced by ↑/↓ the value of current in a coil is known as self induced emf.

↳ & as per the Lenz's law. The dir^n of induced emf is such that it opposes the cause producing it.

Self inductance (L)

↳ property of the coil due to which it opposes the change of current in coil.

↳ coeff of self inductance

↳ (L)

↓

can be defⁿ in three ways

ⓐ In terms of weber-turn per Amp

weber turns

↳ product of flux & no. of turns w. which the flux is linking.

consider a solenoid having 'N' turns through which current 'I' is flowing. If flux 'ϕ' is produced then,

$$\text{weber turn} = N * \phi$$

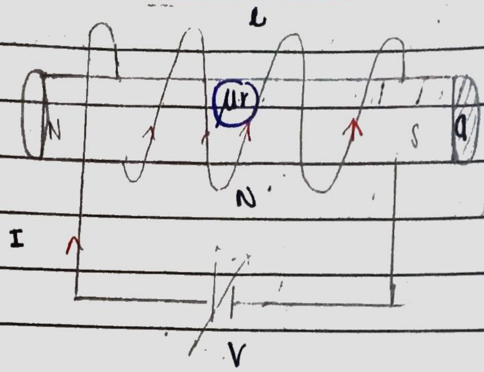
& By defⁿ

$$L = \frac{N\phi}{I} \quad \text{Henry}$$

↓

Wb /A

(b) In terms of dimensions of solenoid



Consider a solenoid having length 'l', cross sectional area 'a' & having relative permeability 'μ_r', having 'N' no. of turns

Acc. to ohm's law for mag ckt

$$\phi = \frac{\overbrace{mmf}^{NI}}{\underbrace{S}_{l/\mu_0 \mu_r a}}$$

Thus,

$$\phi = \frac{NI \mu_0 \mu_r a}{l}$$

$$\Rightarrow \underbrace{\frac{\phi}{I}}_{L/N} = \frac{N \mu_0 \mu_r a}{l}$$

$\frac{L}{N}$ (from 1st defn)

or, $\frac{L}{N} = \frac{N \mu_0 \mu_r a}{l}$

$$L = \frac{N^2 \mu_0 \mu_r a}{l} \quad ....[N^2/S]$$

© In terms of induced emf

From 1st defn

$$L = \frac{N\phi}{I}$$

or, $LI = N\phi$

Diff on both sides

or, $\frac{dLI}{dt} = \frac{d(N\phi)}{dt}$

or, $L\frac{di}{dt} = N\frac{d\phi}{dt}$

considering lenz's law, multiply both sides by (-)

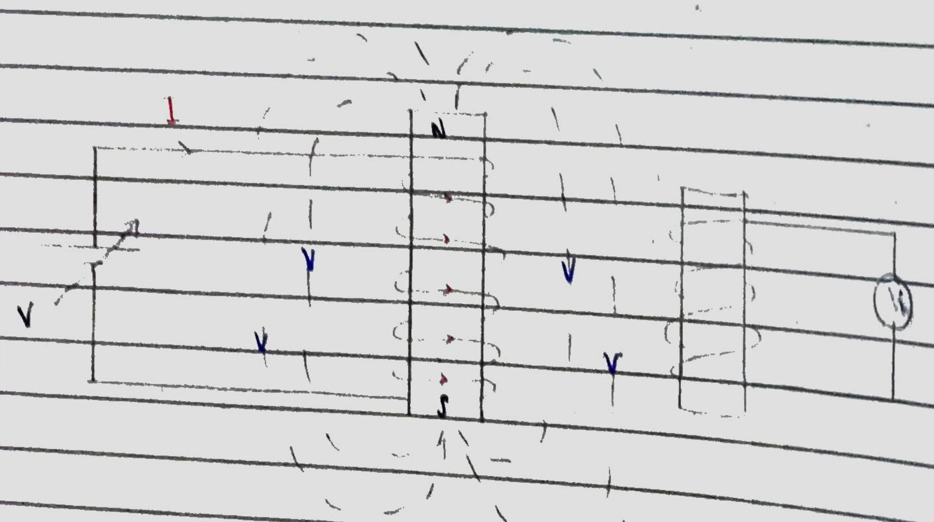
$$= -L\frac{di}{dt} = \underbrace{-N\frac{d\phi}{dt}}_{emf}$$

$\Rightarrow -L \dfrac{di}{dt} = emf$

$L = - \dfrac{emf}{di/dt}$

indicates opposion.

b) mutually induced emf



Emf induced in one coil due to the change in current in neighbouring coil is known as mutually induced emf.

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Page ____

• Mutual induction (M)

Phenomenon of generation of induced emf in one coil by changing the current in neighbouring coil.

↳ Co-efficient of mutual induction is M

can also be defined in 3 ways.

(a) In terms of weber-turn per ampere

↳ consider there are two magnetically coupled coils having N_1 & N_2 turns resp.

Then, coeff. of mutual inductance betn the two coil is defined as the weber-turns in one coil due to current in the other coil.

Let a current of 'I_1' amp. is flowing through first coil which sets up a flux of 'ϕ_1' Wb in first coil

& if $K\%$ of this flux links w. the second coil.

Then, acc. to defn weber turn for 2nd coil due to the current in 1st coil is given by

$$\phi_2 = \frac{K}{100} * \phi_1$$

↳ ($K\%$ of ϕ_1)

so,

$$m = \frac{N_2 \phi_2}{I_1}$$

Thus,

$$m = \frac{N_2 K \phi_1}{100 I_1}$$

(b) In terms of dimension of solenoid

↓

1st has N_1, a, I_1
2nd has only N_2
] length & area same

& ↓ μ_r is same for both

consider two solenoids having no. of turns 'N_1' & 'N_2' of equal length 'l' & area of cross section 'a' & relative permeability 'μ_r'.

Acc. to Ohm's law for mag. ckt

$$\phi_1 = \frac{mmf}{S}$$ → NI

→ $l / \mu_0 \mu_r a$

or, $\phi_1 = \dfrac{N_1 I_1}{\dfrac{l}{\mu_0 \mu_r a}}$

or, $\phi_1 = \dfrac{N_1 I_1 \times \mu_0 \mu_r a}{l}$

Assume 100% linkage

$\phi_1 = \phi_2$

x harxa

$\left[m = \dfrac{N_2 \phi_1}{I_1} \right]$

so,

$\dfrac{m}{N_2} = \dfrac{\phi_1}{I_1}$ (i)

$\Rightarrow \dfrac{\phi_1}{I_1} = \dfrac{N_1 \mu_0 \mu_r a}{l}$

from eqn (i)

or, $\dfrac{m}{N_2} = \dfrac{N_1 \mu_0 \mu_r a}{l}$

$m = \dfrac{N_1 N_2 \mu_0 \mu_r a}{l}$ $\left[m = \dfrac{N_1 N_2}{S} \right]$

or, $\phi_1 = \dfrac{N_1 I_1}{\dfrac{l}{\mu_0 \mu_r a}}$

or, $\phi_1 = \dfrac{N_1 I_1 * \mu_0 \mu_r a}{l}$

Assume 100% linkage

$\phi_1 = \phi_2$

$\left[m = \dfrac{N_2 \phi_1}{I_1} \right]$ x harxa

so,

$\dfrac{m}{N_2} = \dfrac{\phi_1}{I_1}$ (i)

$\Rightarrow \dfrac{\phi_1}{I_1} = \dfrac{N_1 \mu_0 \mu_r a}{l}$ m / N2

From eqn (i)

or, $\dfrac{m}{N_2} = \dfrac{N_1 \mu_0 \mu_r a}{l}$

$m = \dfrac{N_1 N_2 \mu_0 \mu_r a}{l}$ $\left[m = \dfrac{N_1 N_2}{S} \right]$

© In terms of induced emf

Assume 100% linkage.

From 1st defⁿ

$$m = \frac{N_2 \phi_2}{I_1} \quad (=\phi_1)$$

or, $m I_1 = N_2 \phi_1$

Diff on BS w.r.t time

or, $\frac{d(m I_1)}{dt} = \frac{d(N_2 \phi_1)}{dt}$

or, $m \frac{di_1}{dt} = N_2 \frac{d\phi_1}{dt}$

Acc. to lenz's law, for opposion multiply bs by (-)

or, $-m \frac{di_1}{dt} = -N_2 \frac{d\phi_1}{dt}$

yesma no. of turns (N_2) is 2nd

&

$\frac{d\phi_1}{dt}$ is 1st coil

so, mutually induced emf (e_m)

• $\to$ self induced emf

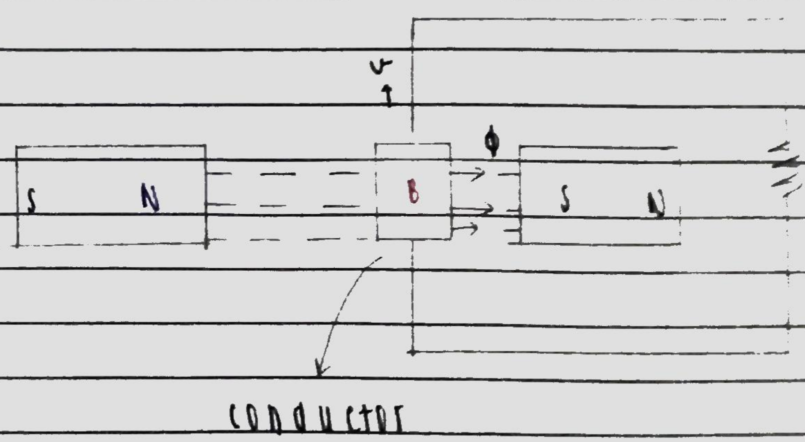
Thus,

$$-M \frac{di_1}{dt} = e_m$$

$$M = -\frac{e_m}{\frac{di_1}{dt}}$$

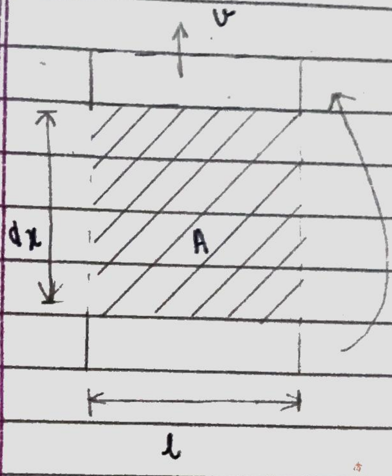
iii) Dynamically Induced emf

The emf induced when there is relative motion betn the coil & the magnetic field then it is known as dynamically induced emf.



Consider a conductor of length 'l' is moved with velocity 'v' in the magnetic field of flux density 'B'

let 'dx' is the distance travelled by the conductor in small time 'dt' sec.



eta more hunxa in dt time

let 'A' be the area swept by the conductor in time 'dt' sec then,

we know that,

$$v = \frac{dx}{dt}$$

velocity

$$dx = v\,dt$$

Area swept is:

$$A = l * b$$
$$= l * dx$$

we know that,

$$B = \frac{d\phi}{A}$$

Then,

$$d\phi = B * A$$
$$= B * l * dx$$

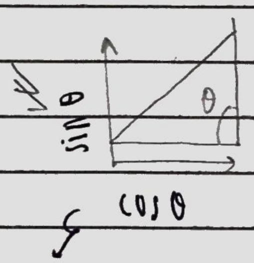
$$d\phi = B * l * v\,dt$$

or, $\frac{d\phi}{dt} = B\,l\,v$

$\therefore\ e = B\,l\,v$

If conductor is lying at some angle θ w. magnetic field.

$$e = B\,l\,v \sin\theta$$



yesari move huda no $d\phi$