Nishant Jindal

Mutual Induction

I_1 & I_2 given

$[a >> b]$

$\Downarrow$

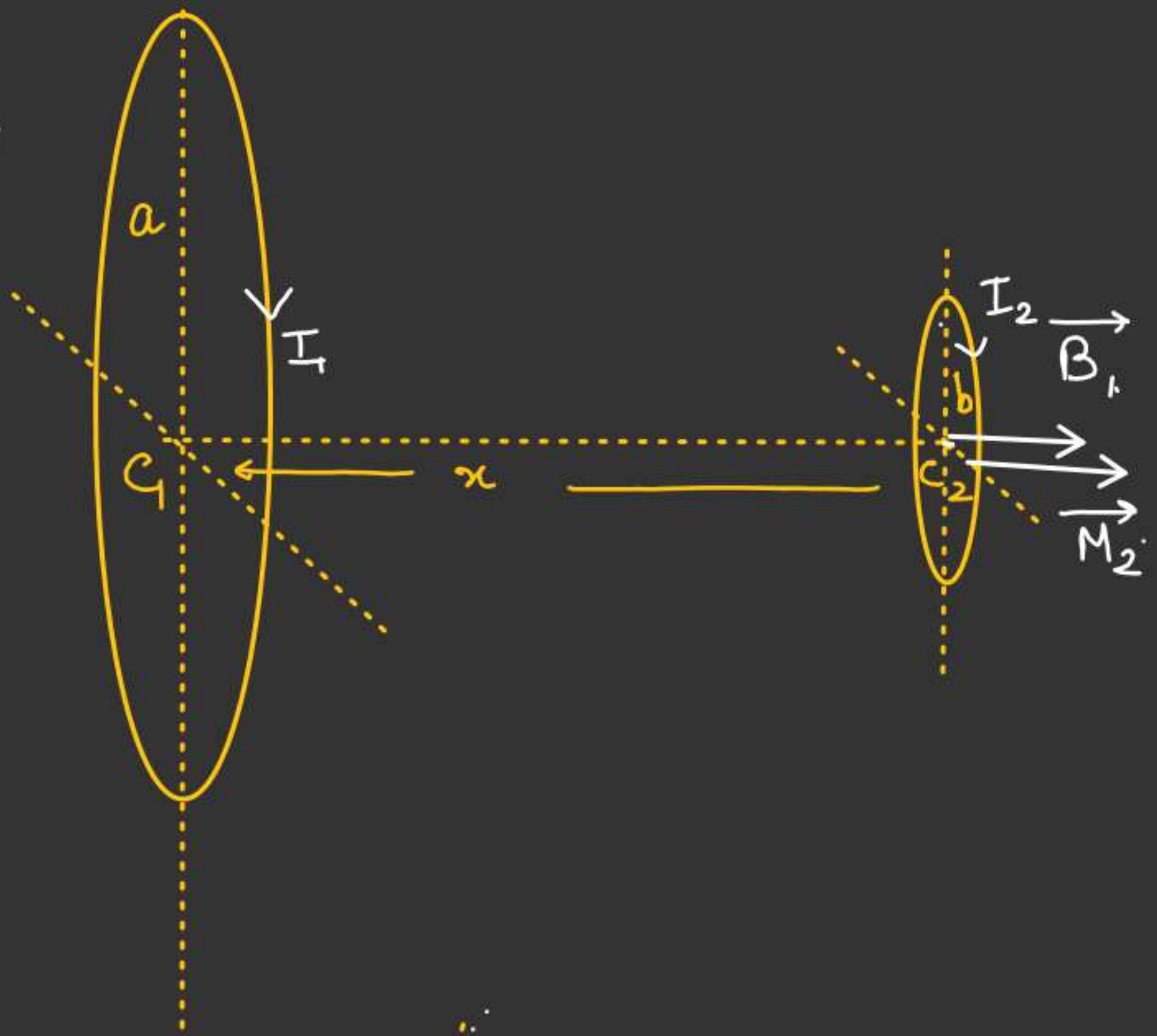
B uniform on smaller ring

$$\phi_2 = B_1 A_2$$

$$\phi_2 = \frac{\mu_0 I_1 a^2}{2(x^2+a^2)^{3/2}} \times \pi b^2$$

$$\phi_2 = \left[\frac{\mu_0 \pi a^2 b^2}{2(x^2+a^2)^{3/2}}\right] I_1$$

$$\phi_2 = M I_1 \qquad M = \frac{\mu_0 \pi a^2 b^2}{2(x^2+a^2)^{3/2}} \quad \text{Ans.}$$



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Force of interaction b/w two rings

$$U = -\vec{M_2} \cdot \vec{B_1}$$

$$U = -M_2 B_1 \cos 0^\circ$$

$$U = -(I_2 \pi b^2)\frac{\mu_0 I_1 a^2}{2(x^2+a^2)^{3/2}}$$

$$U = -\frac{\mu_0 I_1 I_2 \pi a^2 b^2}{2(x^2+a^2)^{3/2}}$$

$$F = -\left(\frac{dU}{dx}\right)$$

$$F = \frac{\mu_0 I_1 I_2 \pi a^2 b^2}{2}\frac{d}{dx}\left[(x^2+a^2)^{-3/2}\right]$$

$$F = \left(\frac{\mu_0 I_1 I_2 \pi a^2 b^2}{\cancel{2}}\right)\frac{\left(-\frac{3}{2}\right)}{(x^2+a^2)^{5/2}} \times \cancel{2}x$$

$$F = -\frac{3}{2}\frac{(\mu_0 I_1 I_2 \pi a^2 b^2)\,x}{(x^2+a^2)^{5/2}}$$

Force is attractive

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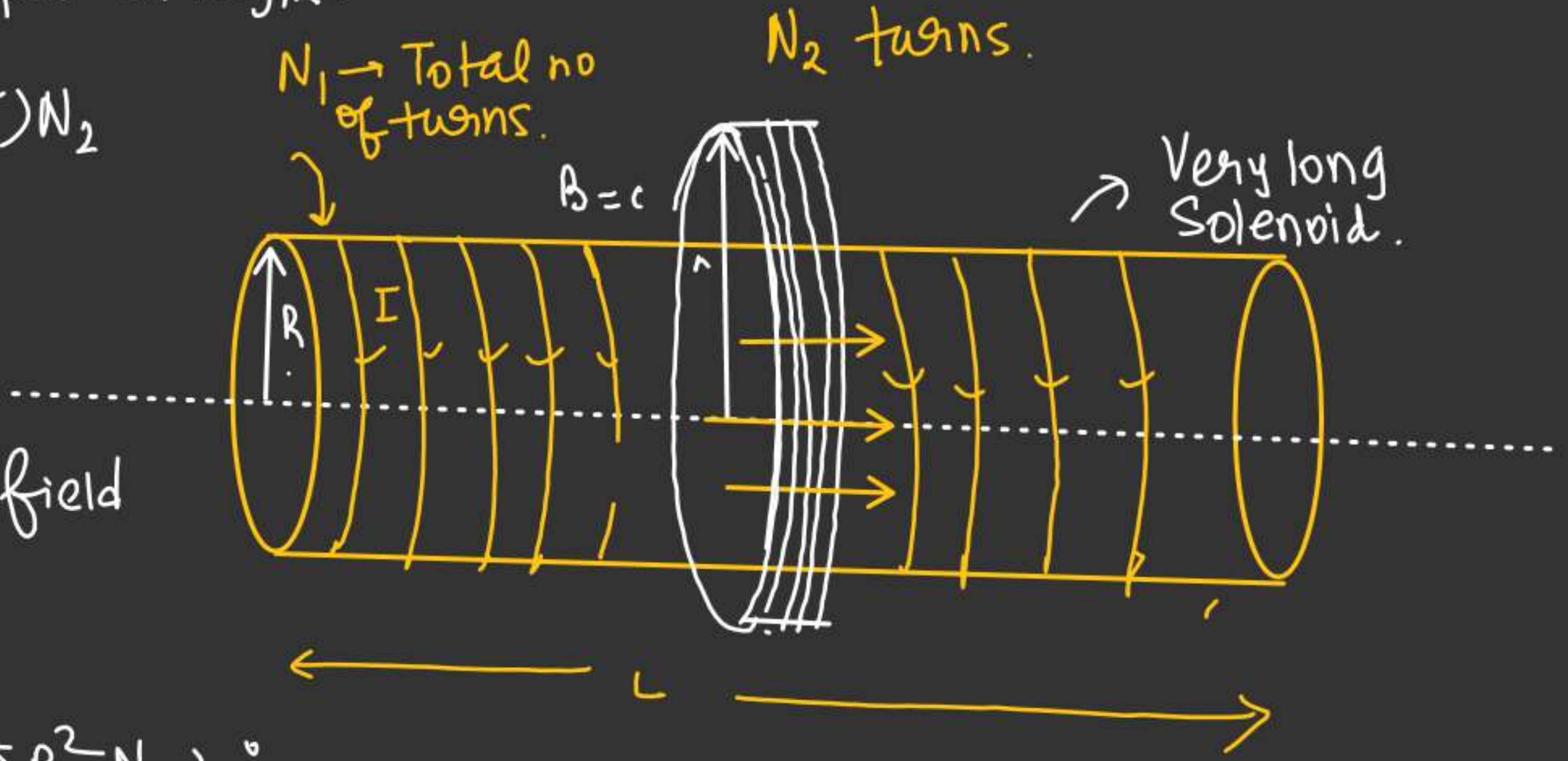
No of turns per Unit length

$$\phi_{\text{circular coil}} = (\mu_0 n i)(\pi R^2) N_2$$

A_2 = effective area of Coil from Which magnetic field passes. $= \pi R^2$



$$\phi_{\text{circular coil}} = \left(\mu_0 \frac{N_1}{L} \pi R^2 N_2\right) i$$

$$\phi = M i$$

$$M = \left(\frac{\mu_0 N_1 N_2 \pi R^2}{L}\right)$$

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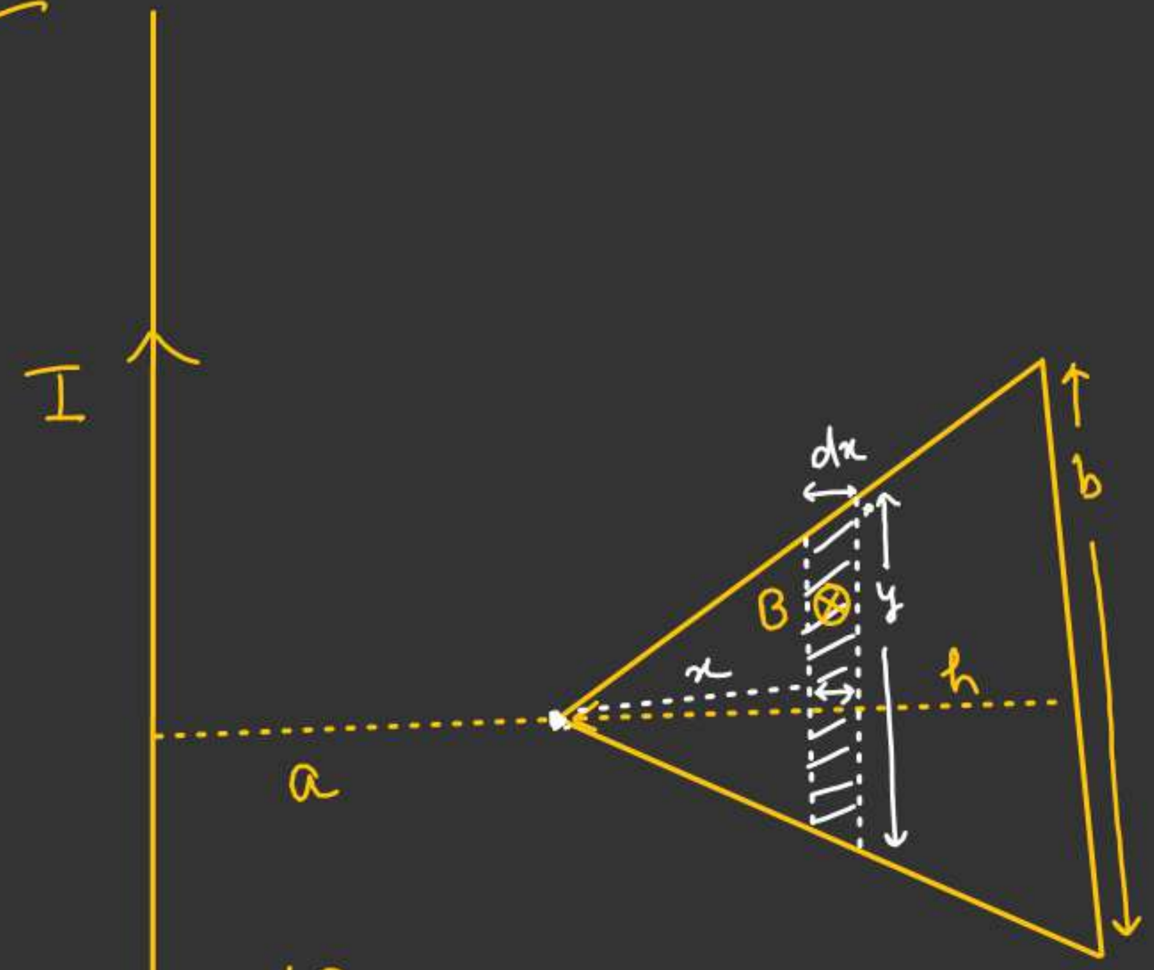


$$d\phi = B\cdot(\text{Area of strip})$$

$$d\phi = \frac{\mu_0 I}{2\pi(a+x)} \times y\,dx$$

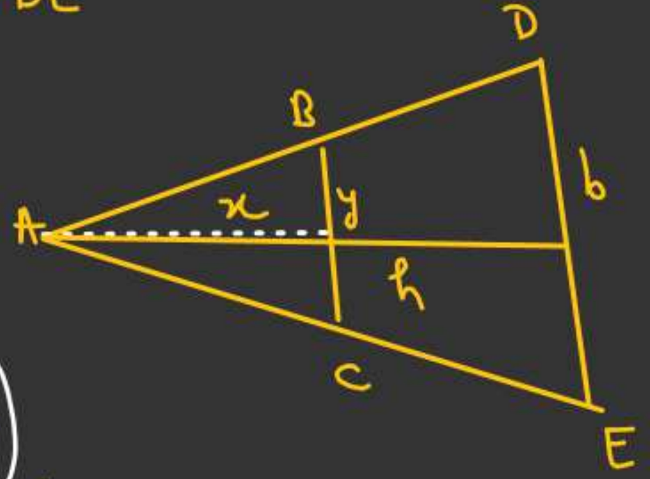
$$d\phi = \frac{\mu_0 I}{2\pi(a+x)} \times \frac{b}{h}x\,dx$$

$$\int_0^{\phi} d\phi = \frac{\mu_0 I b}{2\pi h}\int_0^{h} \frac{x\,dx}{(a+x)}$$

$$= \frac{\mu_0 I b}{2\pi h}\int_0^{h} \left[\frac{(a+x)}{(a+x)} - \frac{a}{(a+x)}\right]dx$$

$$= \frac{\mu_0 I b}{2\pi h}\left[\int_0^{h} dx - \int_0^{h} \frac{a}{a+x}dx\right]$$

$\triangle ABC$ & ADE



$$\frac{y}{x} = \frac{b}{h}$$

$$y = \left(\frac{b}{h}x\right)$$

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Concept of Self Induction

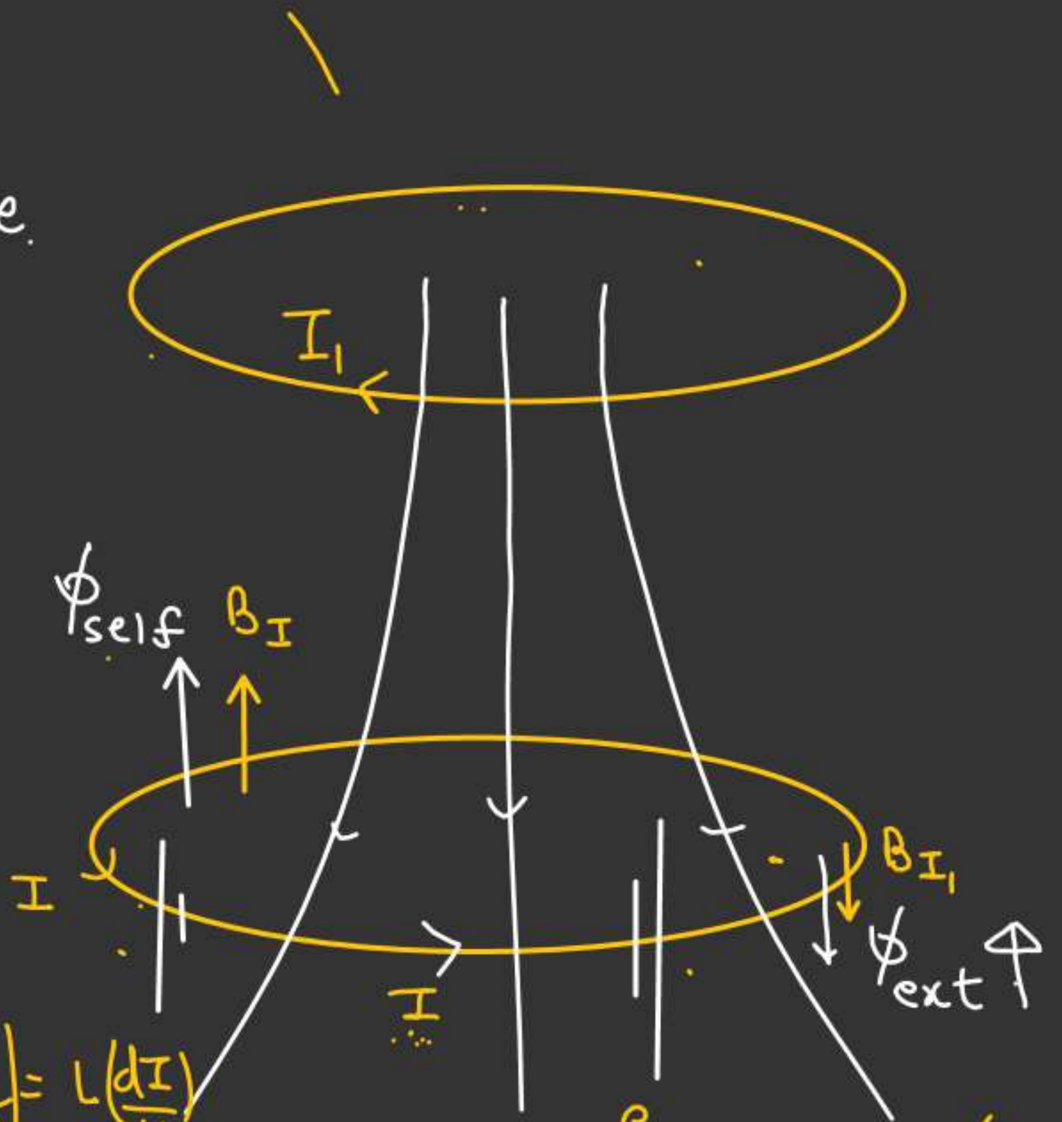
$\phi_{self} \propto I$. $L =$ Self Inductance.

$\phi_{self} = L I$

$\mathcal{E}_{self} = \dfrac{-d\phi_{self}}{dt} = \ominus L\left(\dfrac{dI}{dt}\right)$

$\mathcal{E}_{self}$ opposes the rate of change of (dI/dt)

S.I Unit → "Henry"



$|\mathcal{E}_{self}| = L\left(\dfrac{dI}{dt}\right)$

$\mathcal{E}_{mutual} = M\left(\dfrac{dI_1}{dt}\right)$

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Inductor

- Work on the principal of Self Induction.
- For Ideal Inductor we neglect the resistance of the inductor.
- Solenoid behave as a inductor.

Self Inductance of a Solenoid :-

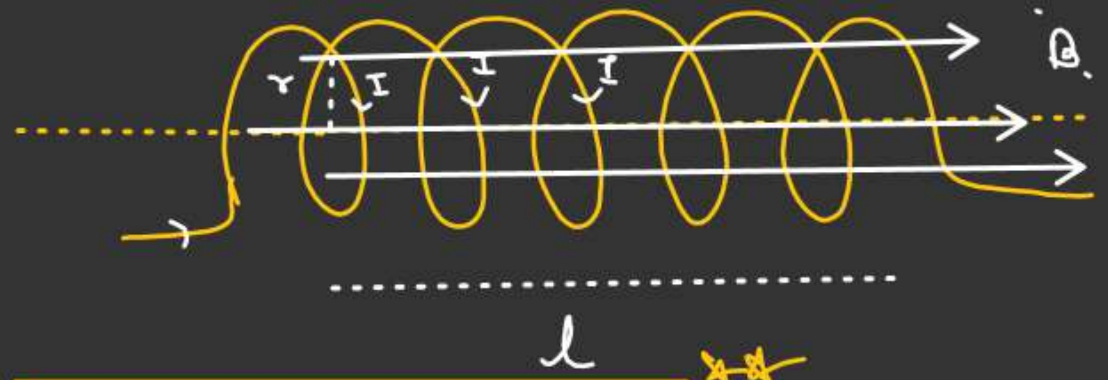
$\ell >> r$ (Infinite or Very long Solenoid)

$$B = \mu_0 n i$$

$$B = \left(\mu_0 \frac{N}{\ell} i\right)$$

$$\phi_{self} = \left[\left(\mu_0 \frac{N}{\ell}\right)\underbrace{(\pi r^2)}_{\text{Area}} N\right] i$$

$$\phi_{self} = L i$$



$$\boxed{L = \frac{\mu_0 N^2 \pi r^2}{\ell}}$$

Inductance of an inductor or Solenoid

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Inductor:

* Working of Inductor based on the principal of Self Induction.

$$\phi_{self} = LI.$$

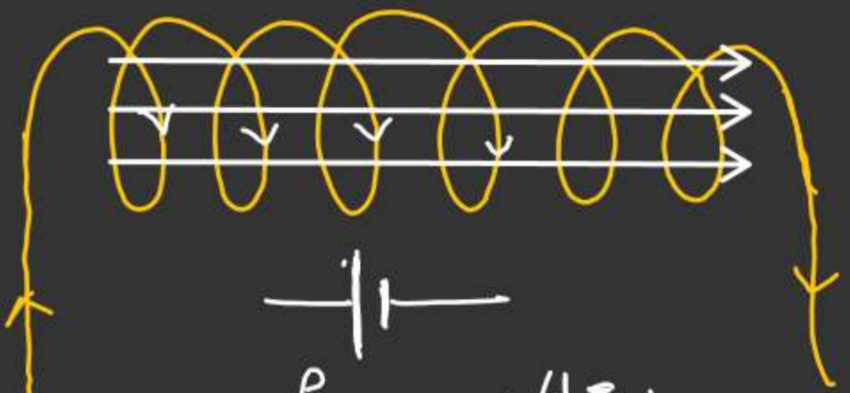
$$\mathcal{E}_{self} = -\frac{d\phi_{self}}{dt} = -L\left(\frac{dI}{dt}\right)$$

$\Downarrow$

$$\boxed{\mathcal{E}_{ind} = -L\left(\frac{dI}{dt}\right)}$$

Lenz's Law

Induced emf always in such a way so that it opposes the rate of change of dI/dt.



$I.$

$\left(\frac{dI}{dt}\right) \rightarrow$ increasing

$\Downarrow$

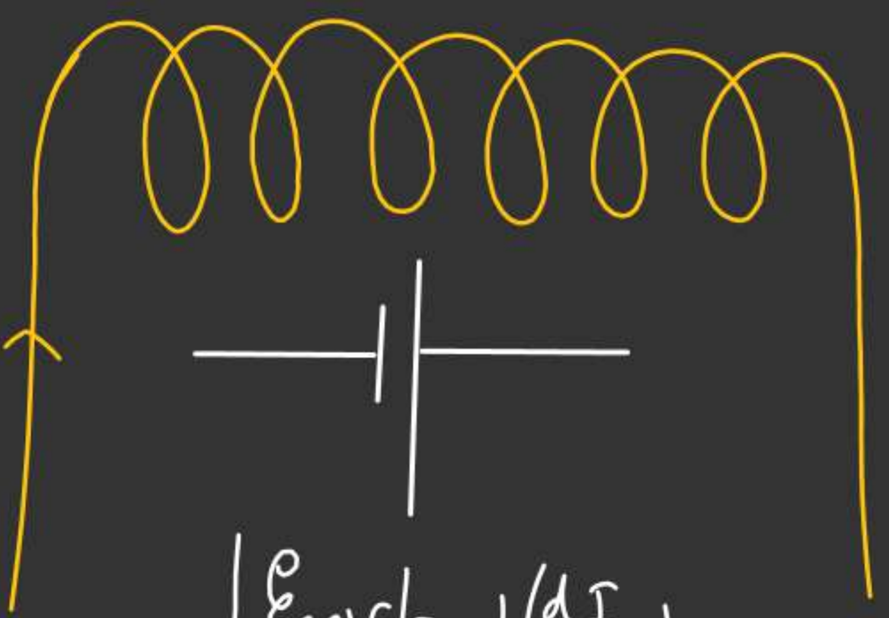
In the interval when magnetic field build-up in the solenoid from 0 to B

$$\mathcal{E}_{self} = L\left(\frac{dI}{dt}\right)$$

I

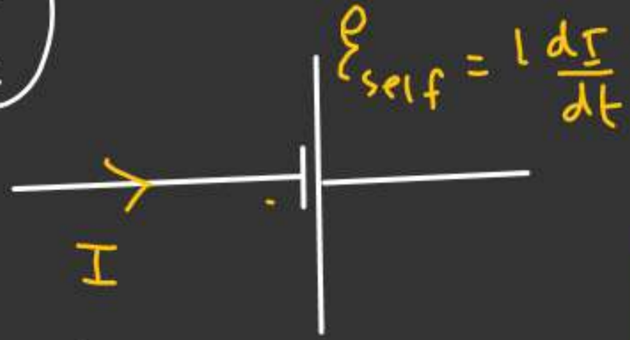
$$|\mathcal{E}_{self}| = L\frac{dI}{dt}$$

$\left(\frac{dI}{dt}\right)_{decreasing}$ I

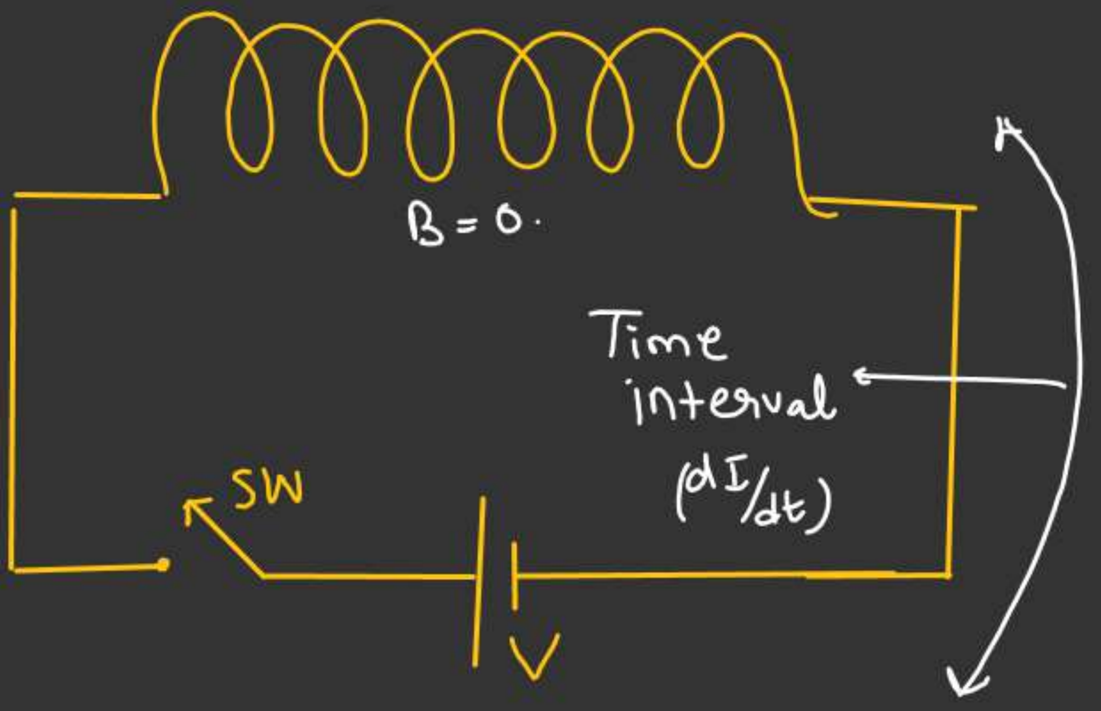


$|\mathcal{E}_{self}| = L\left(\frac{dI}{dt}\right)$

$\frac{dI}{dt} \to -ve$



$\mathcal{E}_{self} = +ve \Rightarrow$ Support I



Time interval (dI/dt)