



Magnetic field at the center of a spiral →

Total no of turns = N .

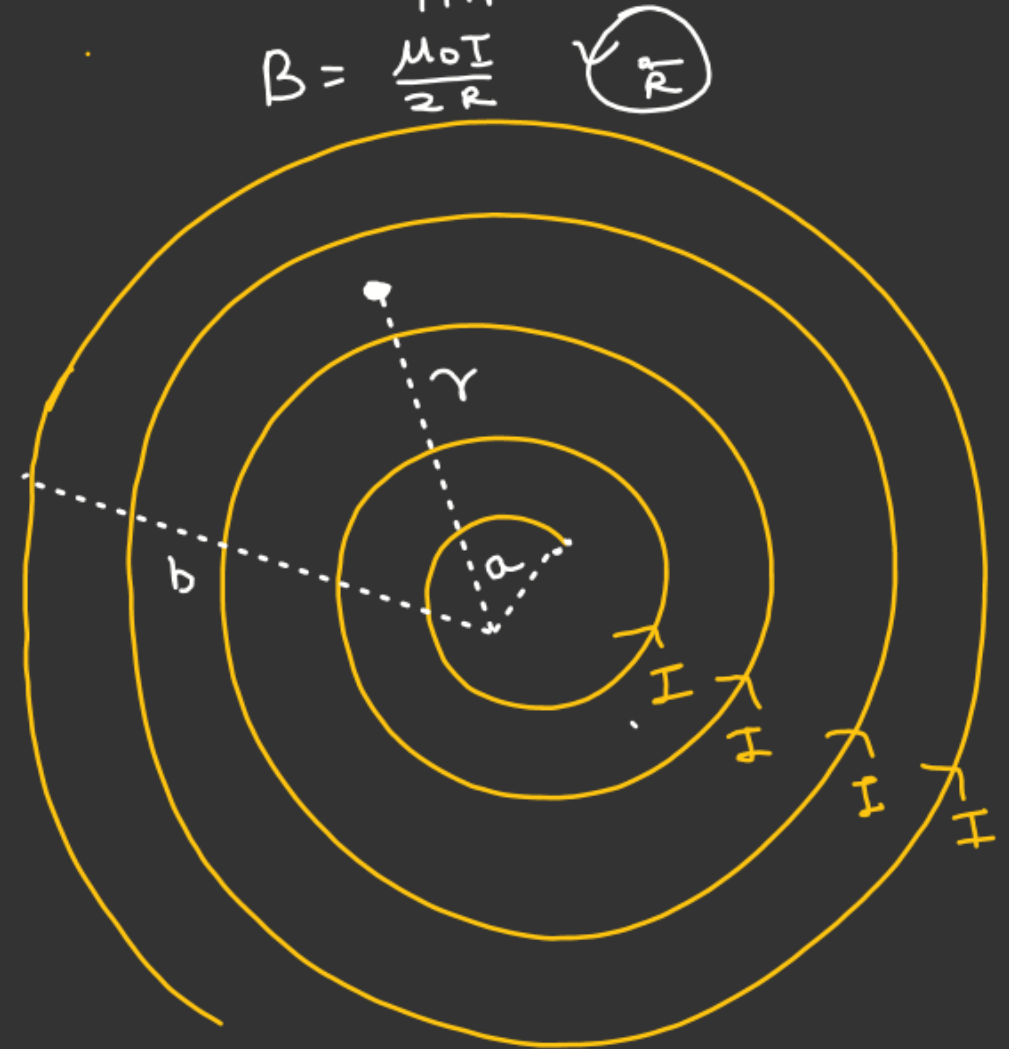
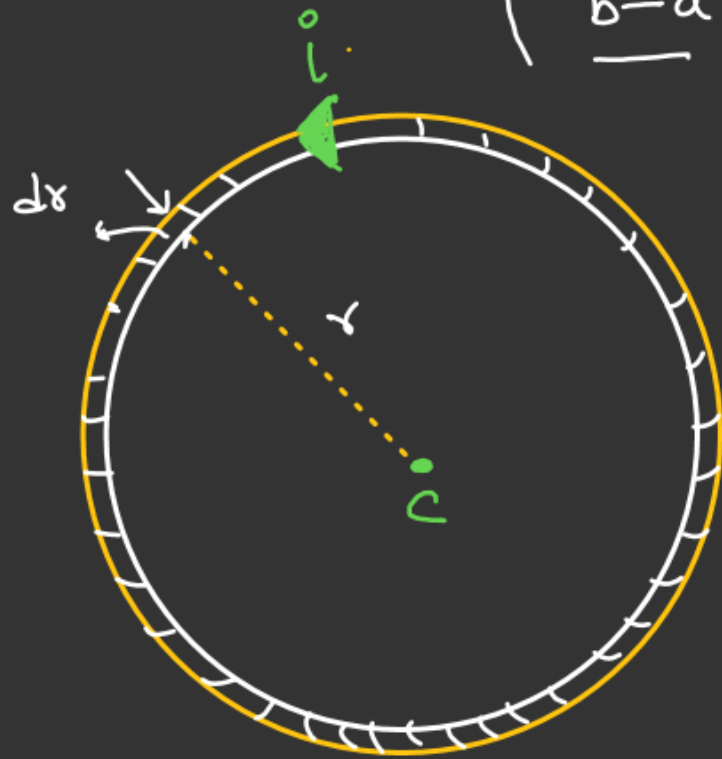
No of turns per unit width = $\left(\frac{N}{b-a}\right)$ ✓

$$dB = \left(\frac{\mu_0 i}{2r}\right)$$

No of turns in dr thickness = $\left(\frac{N}{b-a}\right) dr$

$$di = \left(\frac{N}{b-a}\right) dr \cdot (I)$$

(Current in dr thickness) $\left[\begin{array}{l} \text{No of turns in } dr \text{ thickness} \\ \text{Current in each turn} \end{array} \right]$



$$B = \frac{\mu_0 I}{4\pi R} (\phi) \quad \phi = 2\pi$$

$$B = \frac{\mu_0 I}{2R} \quad \left(\bigcirc \frac{I}{R} \right)$$

$$\int_0^B dB = \int_a^b \frac{\mu_0}{2\pi} \left(\frac{NI}{b-a} \right) dr$$

$$B = \frac{\mu_0 NI}{2(b-a)} \int_a^b \frac{dr}{r}$$

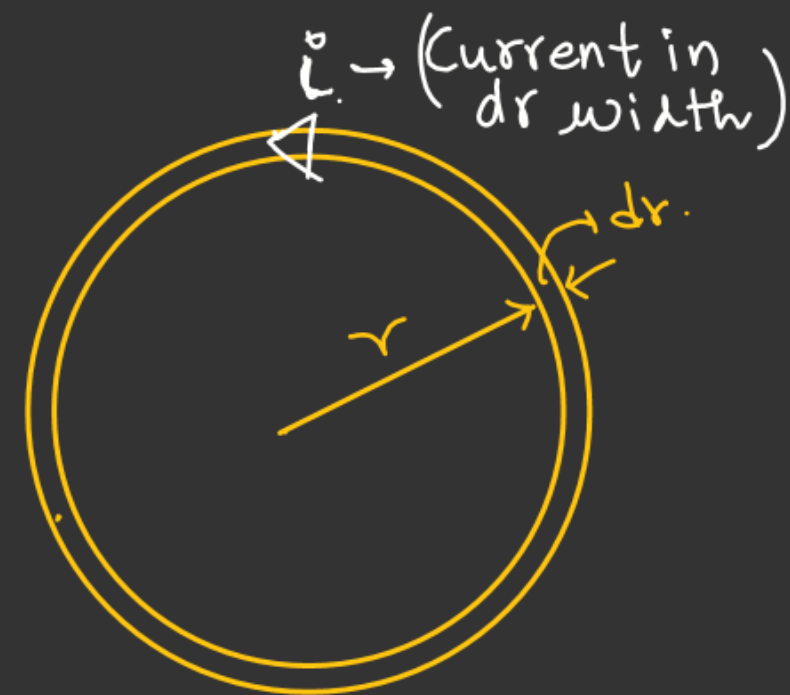
$$B = \frac{\mu_0 NI}{2(b-a)} \ln\left(\frac{b}{a}\right) \underline{\underline{\text{Ans.}}}$$

Magnetic Moment of the Spiral →

dM = Magnetic moment of ring of radius ' r ' having current i

$\left(\frac{N}{b-a}\right)$ = current per unit width.

$$i = \left[\left(\frac{N}{b-a}\right) \pm dr \right]$$



$$dM = i \pi r^2$$

$$\int_0^M dM = \left(\frac{\pi NI}{b-a} \right) \int_a^b r^2 dr = \frac{\pi NI}{b-a} \left[\frac{r^3}{3} \right]_a^b$$

$$M = \frac{\pi NI}{3(b-a)} [b^3 - a^3]$$

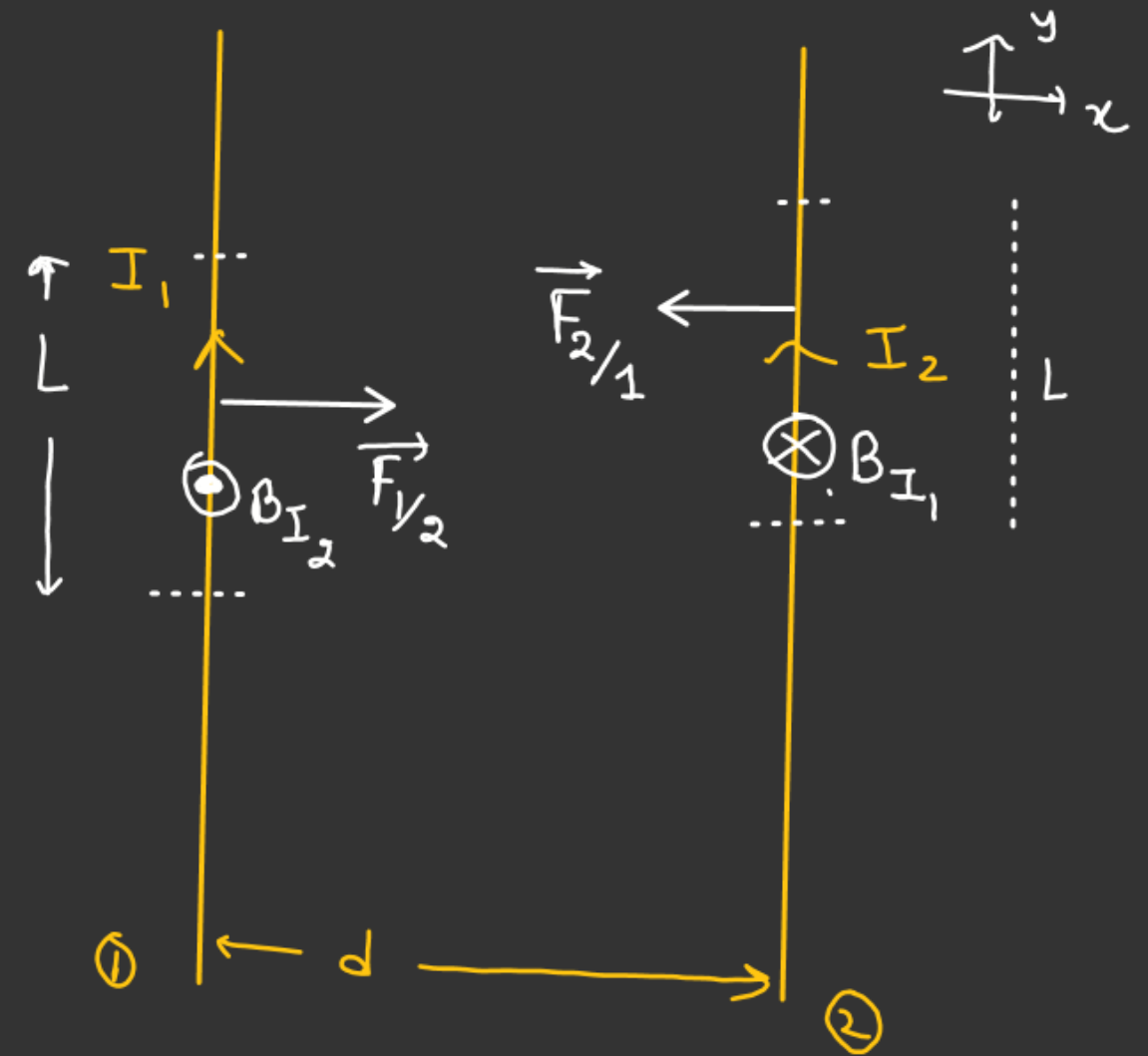
Force b/w two infinitely long parallel current carrying wire

$$\vec{F}_{2/1} = I_2 (\vec{L} \times \vec{B}_{I_1})$$

$$\begin{aligned} \vec{F}_{2/1} &= I_2 L B_{I_1} (\hat{j} \times -\hat{k}) \\ &= I_2 L B_{I_1} (-\hat{i}) \end{aligned}$$

$$\left(\frac{F_{2/1}}{L} \right) = I_2 \frac{\mu_0 I_1}{2\pi d} = \left(\frac{\mu_0 I_1 I_2}{2\pi d} \right)$$

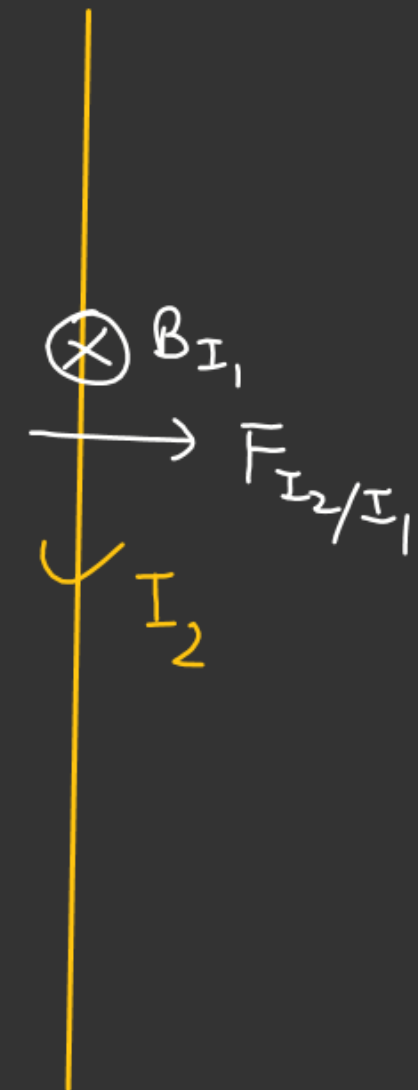
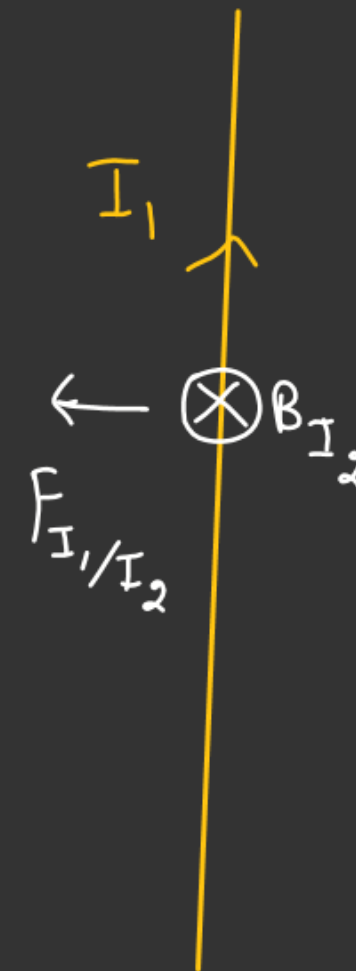
$$\left(\frac{F_{1/2}}{L} \right) = I_1 L B_{I_2} = \left(\frac{\mu_0 I_1 I_2}{2\pi d} \right)$$

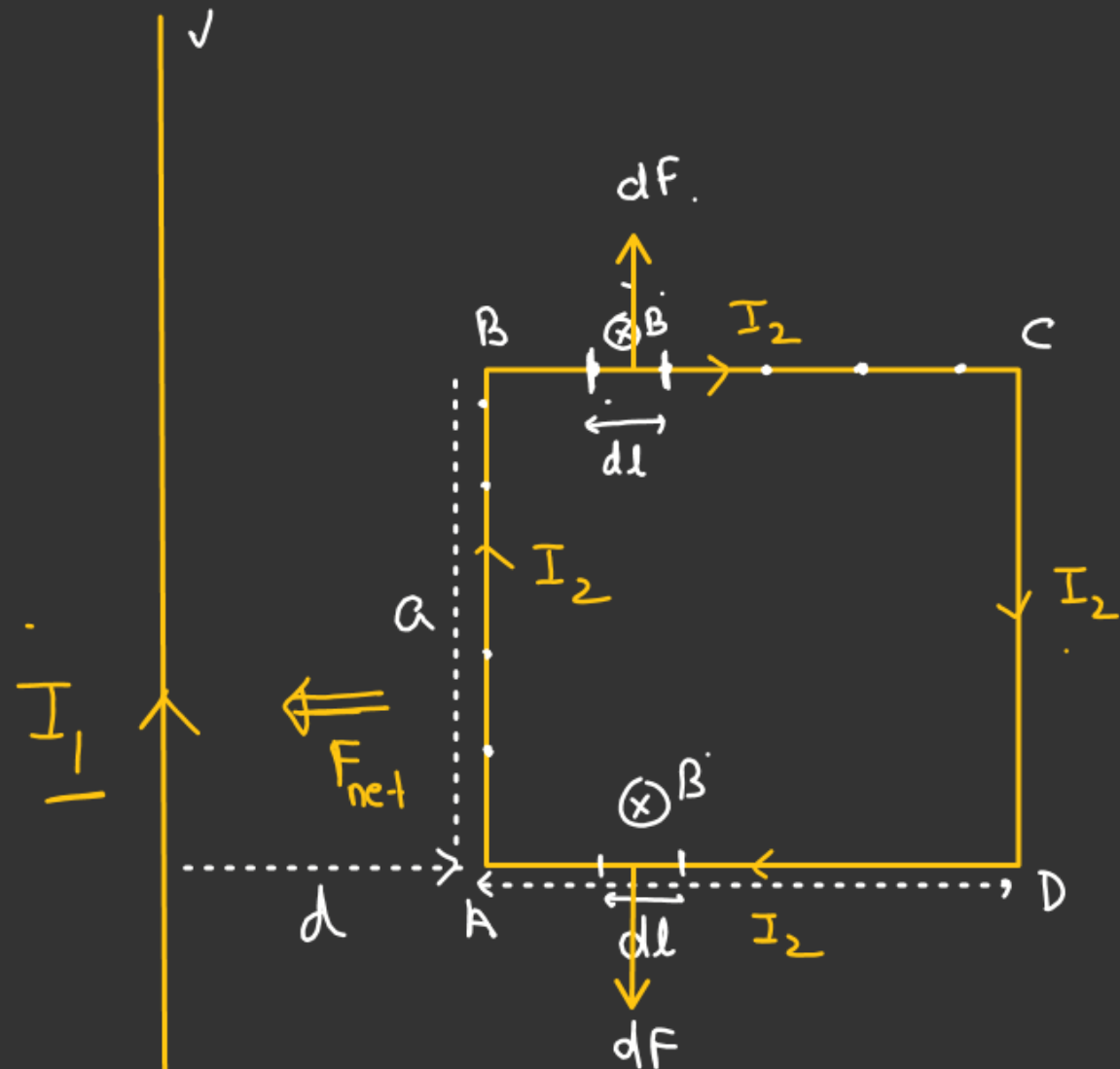


$$\text{Magnetic Force per unit length} = \left(\frac{\mu_0 I_1 I_2}{2\pi d} \right)$$

⇓

If current flow in same direction
then attractive in nature
and if current flow in opposite
direction then repulsive in
nature





① Find Magnetic force of interaction b/w infinitely long wire and Square frame.

Solⁿ

For AB

$$\vec{F}_{AB} = \left(\frac{\mu_0 I_1 I_2}{2\pi d} \right) a (-\hat{i})$$

$$B = \frac{\mu_0 I_1}{2\pi d}$$

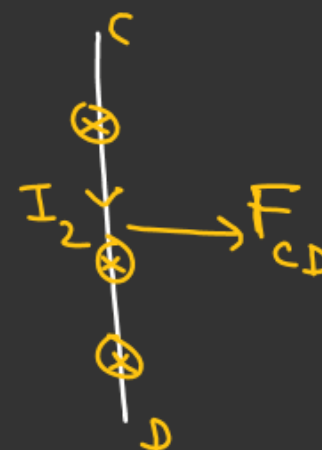
[due to infinitely long wire]



F_{AB}

For CD:-

$$\vec{F}_{BD} = \left(\frac{\mu_0 I_1 I_2}{2\pi(d+a)} \right) a (\hat{i})$$

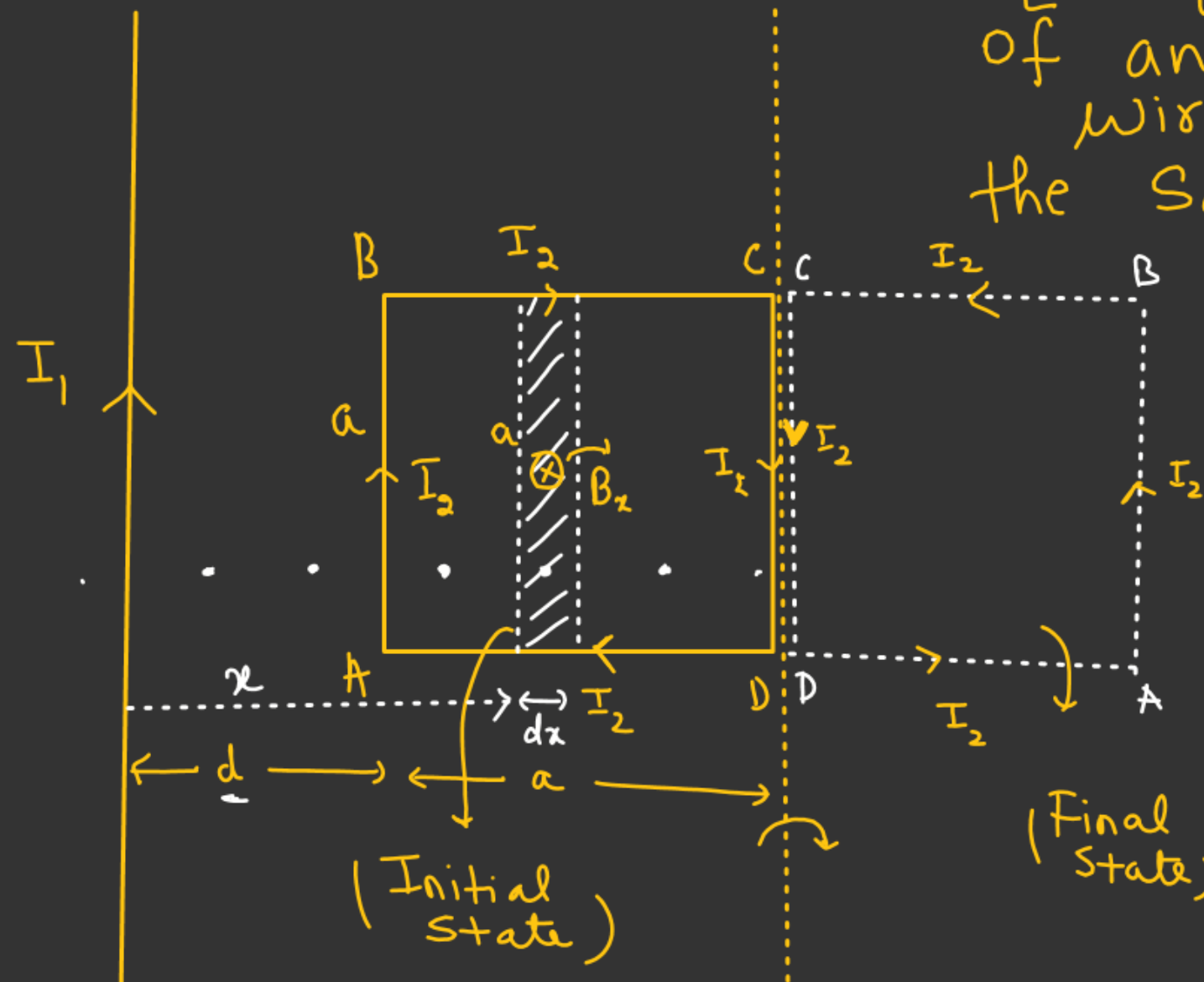


F_{CD}

$$F_{net} = \left[\frac{\mu_0 I_1 I_2 a}{2\pi d} \right] \left[\frac{1}{(d+a)} - \frac{1}{d} \right]$$

$$F_{net} = \frac{\mu_0 I_1 I_2 a}{2\pi d} \left[\frac{-a}{d(d+a)} \right] = \ominus \frac{\mu_0 I_1 I_2 a^2}{2\pi d^2 (d+a)}$$

[A Square loop is in the plane of an infinitely long current carrying wire. Find the work done in rotating the Square loop along side CD to 180°]



$$U = -[\vec{M} \cdot \vec{B}]$$

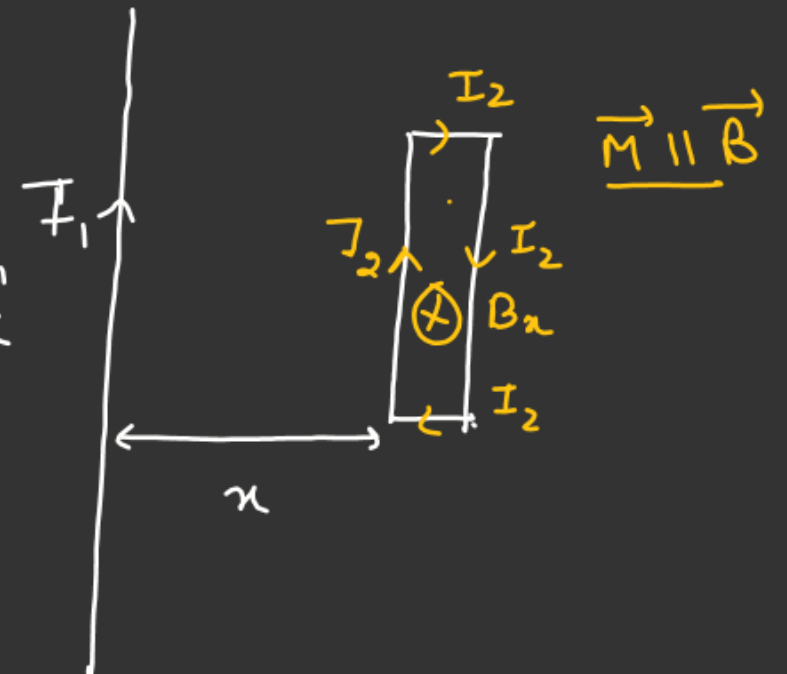
$dU =$ P.E of rectangular loop having thickness dx and length a .

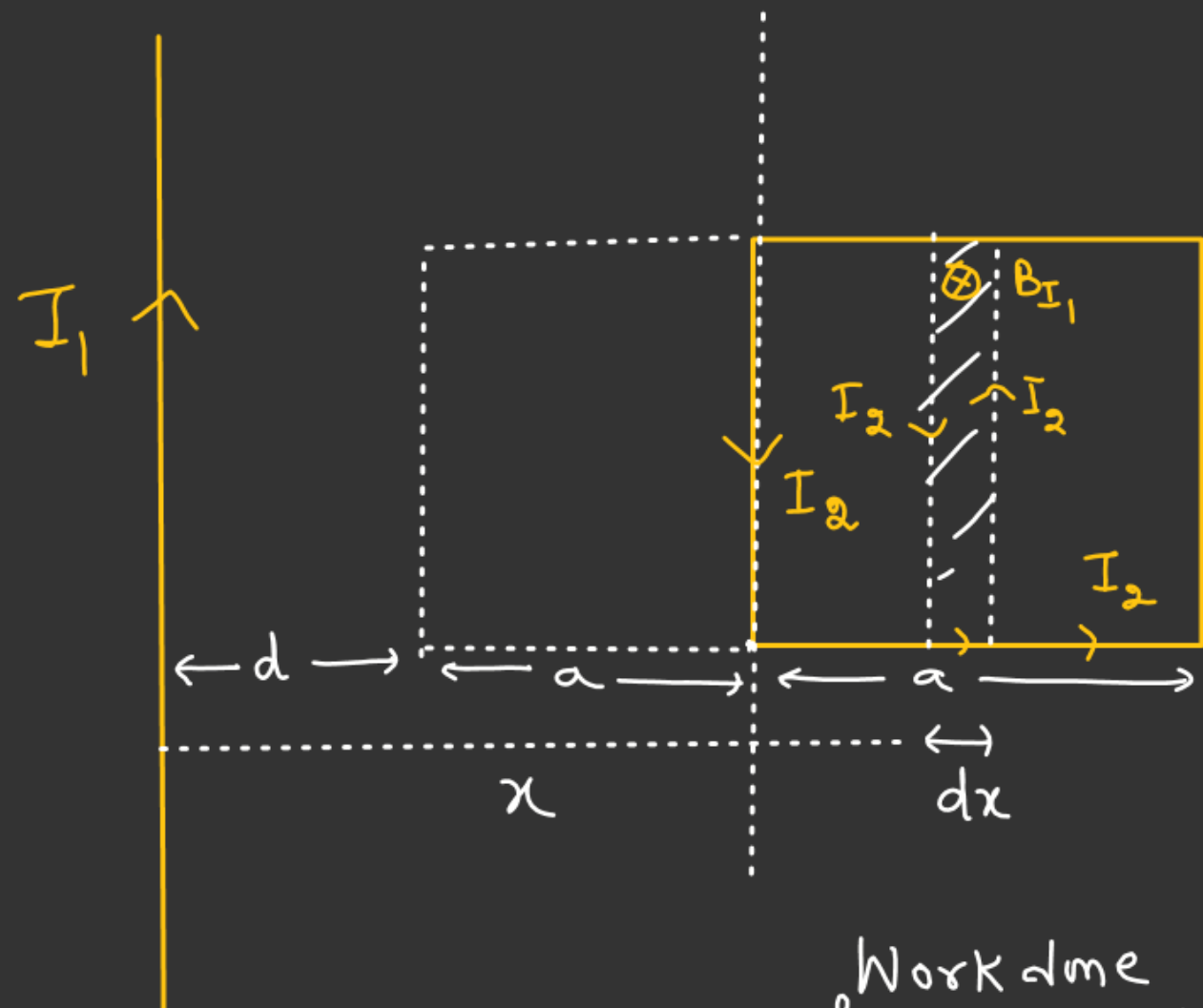
$$dU = -dm \cdot B_x$$

$$dU = -I_2 (a dx) \frac{\mu_0 I_1}{2\pi x}$$

(Final State) $\int_0^a dU = -\frac{\mu_0 I_1 I_2 a}{2\pi} \int_d^{d+a} \frac{dx}{x}$

$$U_i = -\frac{\mu_0 I_1 I_2 a}{2\pi} \ln\left(\frac{d+a}{d}\right)$$





$$dU_f = -dn(B_{I_1})_n \cos \pi$$

$$dU_f = + \frac{\mu_0 I_1 (a dx) I_2}{2\pi x}$$

$$\int_{U_i}^{U_f} dU_f = \frac{\mu_0 I_1 I_2 a}{2\pi} \int_{d+a}^{d+2a} \frac{dx}{x}$$

$$U_f = \frac{\mu_0 I_1 I_2 a}{2\pi} \ln \left[\frac{d+2a}{d+a} \right]$$

$$\begin{aligned} \text{Work done by ext agent} &= \Delta U = \\ &= U_f - U_i = \frac{\mu_0 I_1 I_2 a}{2\pi} \left[\ln \left(\frac{d+2a}{d+a} \right) + \ln \left(\frac{d+a}{a} \right) \right] \\ &= \frac{\mu_0 I_1 I_2 a}{2\pi} \ln \left[\frac{d+2a}{a} \right] \checkmark \end{aligned}$$