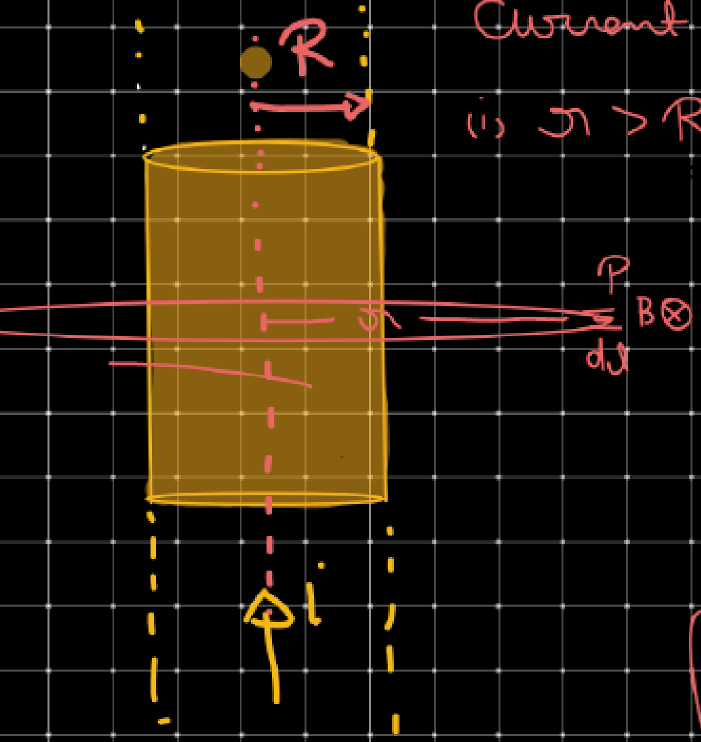
Application of Ampere Law



Current density $j = \frac{i}{\pi R^2}$

(i) $r > R$ [outside point]

$$\oint \vec{B}\cdot d\vec{l} = \mu_0 i_{in}$$

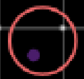
$$\oint B\,dl\cos 0 = \mu_0 i$$

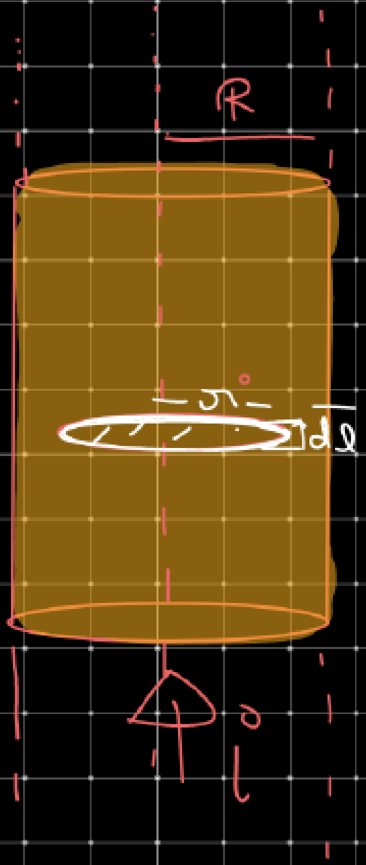
$$B\oint dl = \mu_0 i$$

$$B\times 2\pi r = \mu_0 i$$

$$B = \frac{\mu_0 i}{2\pi r}$$

$$\boxed{B \propto \frac{1}{r}}$$





$r < R$ [inside of wire]

$$\oint \bar{B}\cdot d\bar{l} = \mu_0 i_{in}$$

$$\oint B\,dl\cos 0 = \mu_0 i_{in}$$

$$B\oint dl = \mu_0 i_{in}$$

$$B\oint dl = \mu_0 \frac{i r^2}{R^2}$$

$$B\times 2\pi \cancel{r} = \frac{\mu_0 i r^2}{R^2}$$

$$\boxed{B = \frac{\mu_0 i r}{2\pi R^2}}$$

$$\boxed{B \propto r}$$

$$\pi R^2 = i$$

$$1 = \frac{i}{\pi R^2}$$

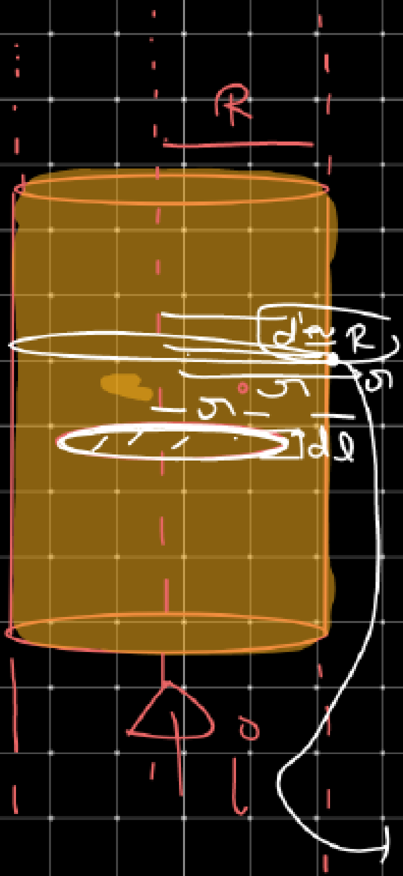
$$i' = \frac{i}{\cancel{\pi} R^2}\times \cancel{\pi} r^2$$

$$i' = \frac{i\times r^2}{R^2}$$

$$J = \frac{i}{\pi R^2}$$

$$\pi r^2 \to J\times A$$

$$i = J\times \pi r^2$$



(I) $r < R$ [inside) Imp

$$B = \frac{\mu_0 I r}{2\pi R^2} \qquad \underbrace{B \propto r}_{\text{st-line}}$$

(II) $r > R$ [outside point]

$$B = \frac{\mu_0 I}{2\pi r} \qquad B \propto \frac{1}{r}$$

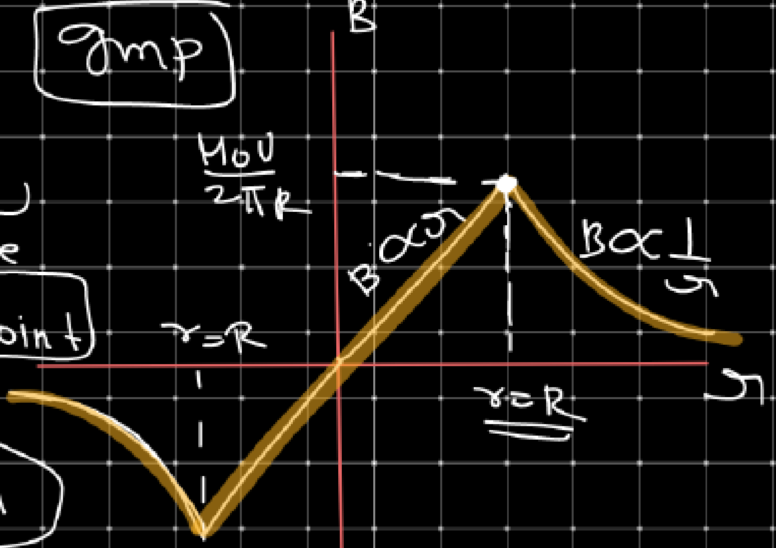
(III) $r = R$ [Just surface]

$$\boxed{B = \frac{\mu_0 I}{2\pi R}}$$

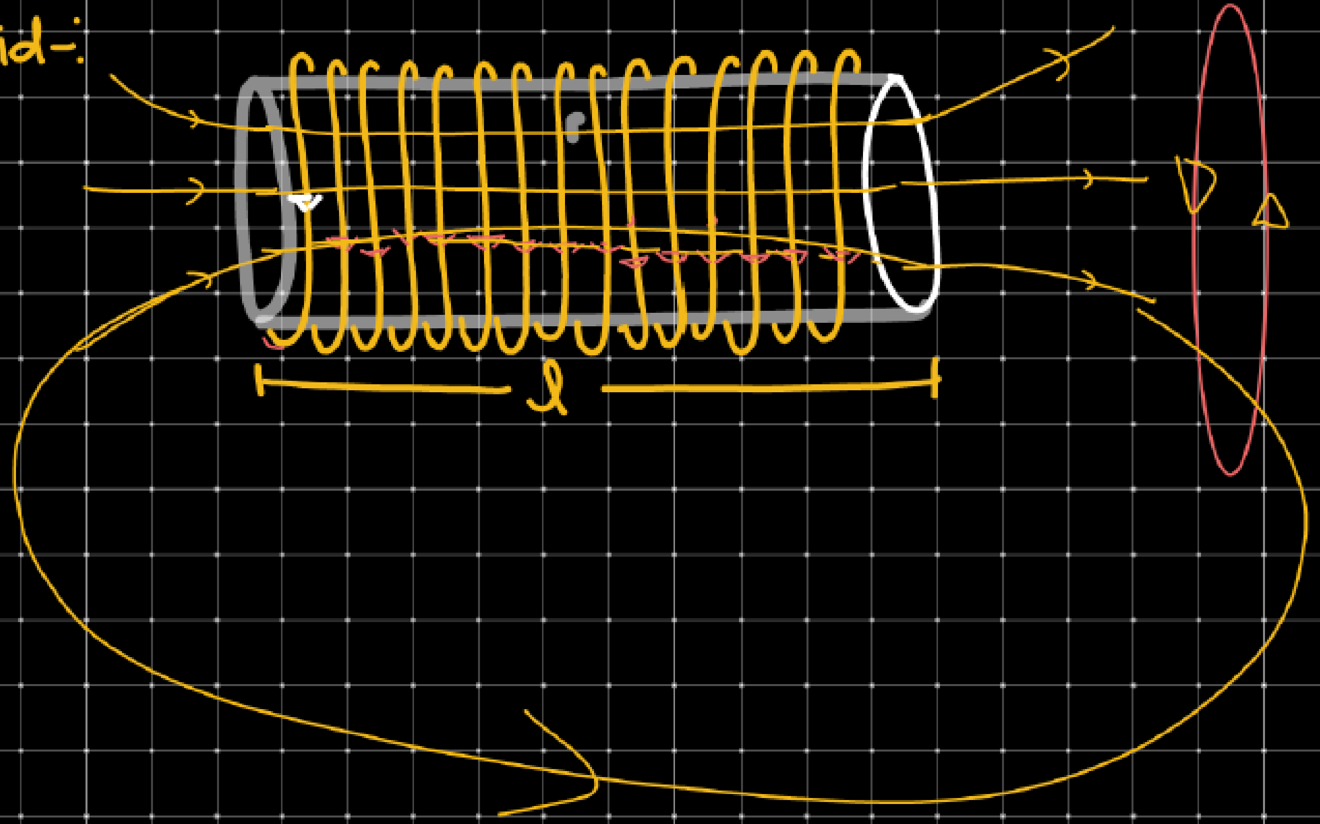
$$\oint B \cdot dl = \mu_0 I$$

$$B \times 2\pi R = \mu_0 I$$

$$\boxed{B = \frac{\mu_0 I}{2\pi R}}$$

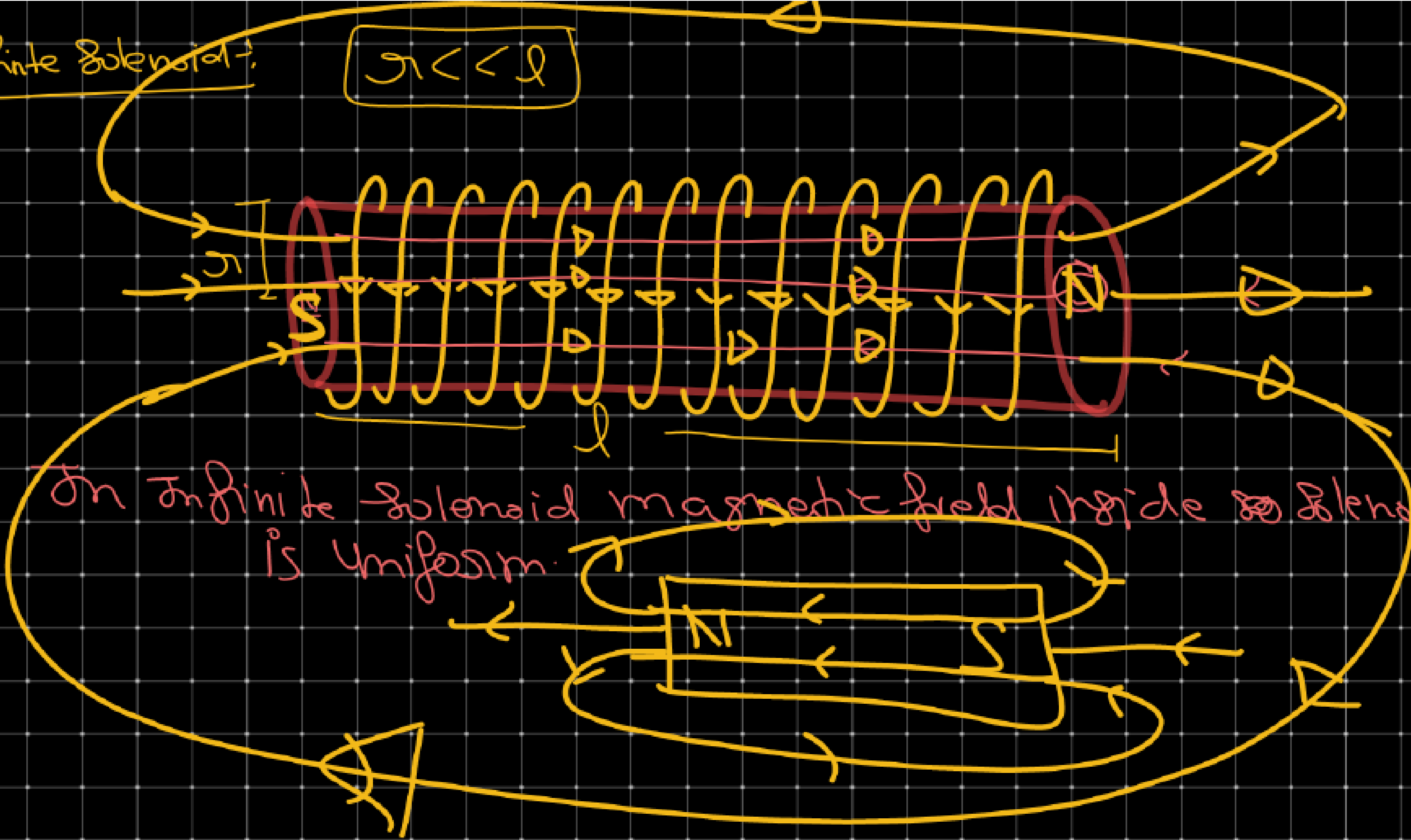


⇒ Solenoid-:



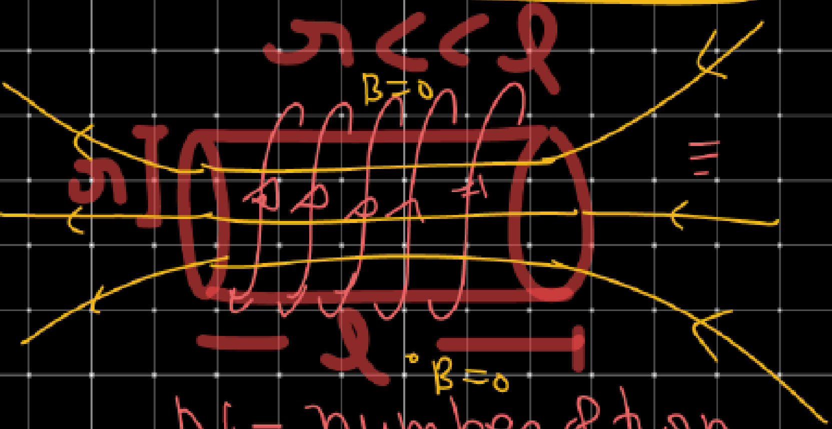
Infinite Solenoid :-

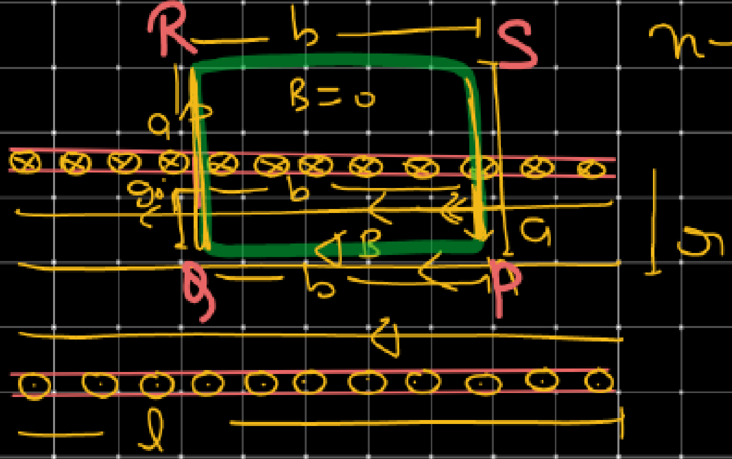
$\boxed{r << l}$



In Infinite Solenoid magnetic field inside solenoid is uniform.

Infinite Solenoid





n → number of turn per unit length

N = number of turn

$n = \frac{N}{l}$

↳ turn density

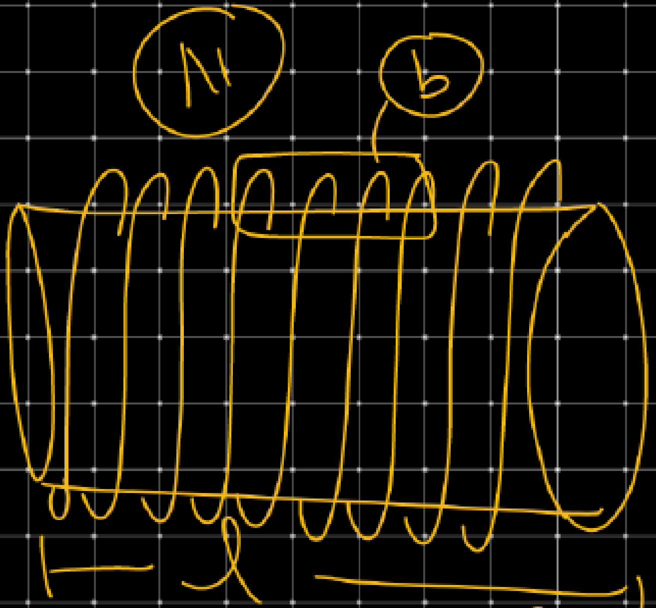
$$\oint \bar{B}\cdot d\bar{l} = \mu_0 i_{in}$$

$$\oint_{PQ} \bar{B}\cdot d\bar{l} + \oint_{QR} \bar{B}\cdot d\bar{l} + \oint_{RS} \bar{B}\cdot d\bar{l} + \oint_{SP} \bar{B}\cdot d\bar{l} = \mu_0 i_{in}$$

$$B\times b + \oint B\,dl\cos 90^\circ + 0 + \oint B\,dl\cos 90^\circ = \mu_0 i_{in}$$

$$B\times b = \mu_0 n i b$$

$$\boxed{B = \mu_0 n i}$$



number of turn
per unit length

$$n = \frac{N}{l}$$

$$\boxed{N = nl}$$

Number of turn = $n \times b$

Current = $nb \times i$

N-turn → each turn → i

$N \longrightarrow l$ 1 unit = $\frac{N}{l}$

b-length = $\frac{N}{l} b = nb$ total = nbi

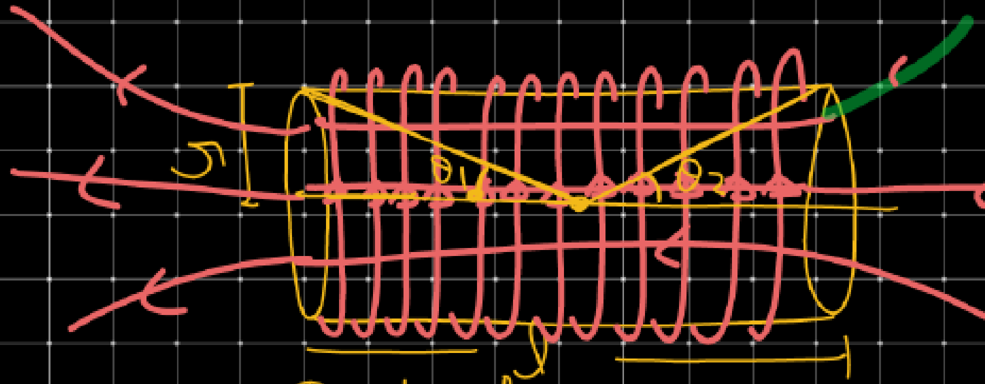
B inside the solenoid is equal to $\mu_0 n i$

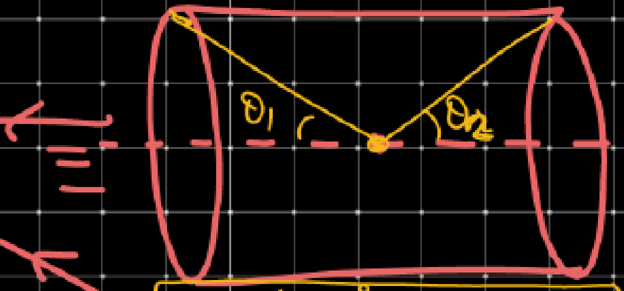
$$B = \mu_0 n i \quad [\text{Uniform}]$$

$$B = \mu_0 \left[\frac{N}{l}\right] i$$

$$\boxed{B = \frac{\mu_0 N i}{l}}$$

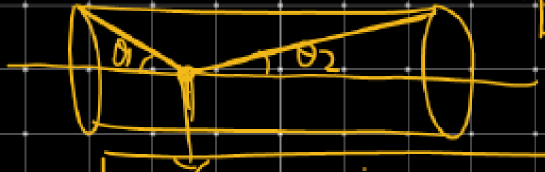
⇒ Magnetic field due to finite solenoid





$$B = \frac{\mu_0 n i}{2}\left[\cos\theta_1 + \cos\theta_2\right]$$

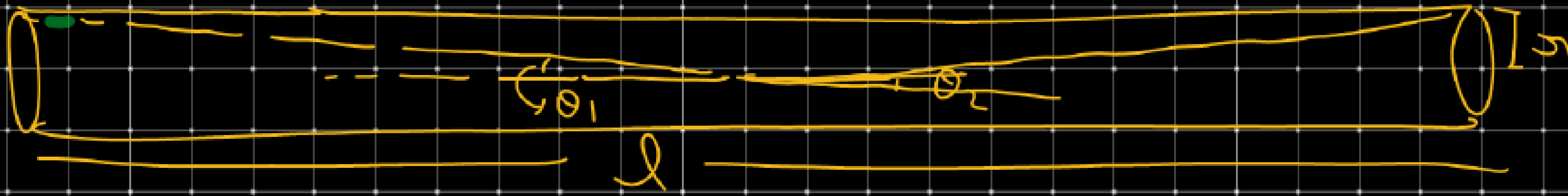
$$\boxed{B = \frac{\mu_0 n i}{2}\left[\cos\theta_1 + \cos\theta_2\right]}$$



$$\boxed{B_P = \frac{\mu_0 n i}{2}\left[\cos\theta_1 + \cos\theta_2\right]}$$

Infinite Solenoid

$$\boxed{r << l}$$

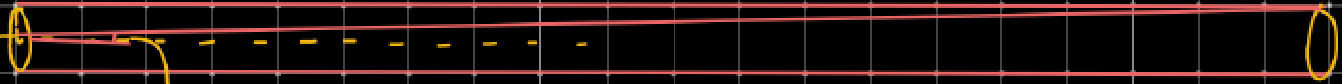


$$\underline{\theta_1 = \theta_2 = 0^\circ}$$

$$B = \frac{\mu_0 n i}{2}\left[\cos 0 + \cos 0\right] = \frac{\mu_0 n i}{2}(1+1)$$

$$= \underline{\mu_0 n i}$$

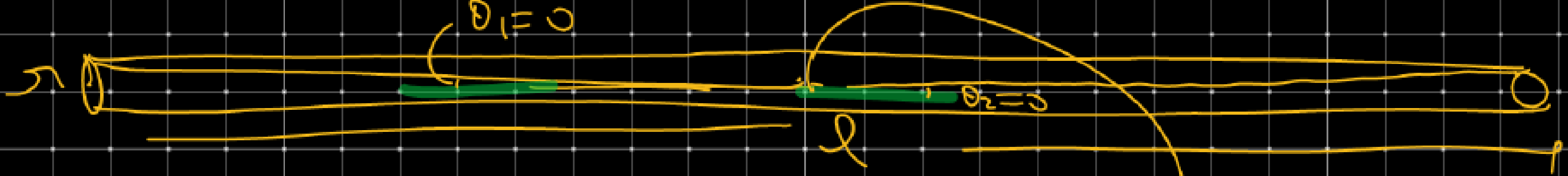
For semi infinite solenoid at outside point (Just outside)

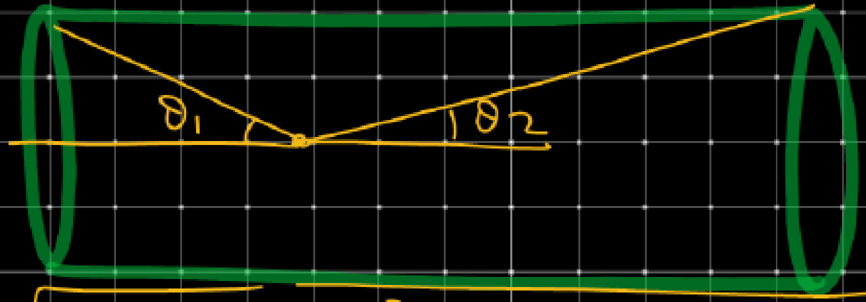


$\theta_1 = 90^\circ$ $\quad \theta_2 = 0$

$$\frac{\mu_0 n i}{2}\left(\cos 90 + \cos 0^\circ\right)$$

$$= \boxed{\frac{\mu_0 n i}{2}}$$





$$\boxed{B = \frac{\mu_0 n i}{2}\left[\cos\theta_1 + \cos\theta_2\right]}$$

$$B = \frac{\mu_0 n i}{2}\left[\cos 0 + \cos 0\right]$$

$$ = \frac{\mu_0 n i}{\cancel{2}} \times \cancel{2}$$

$$ = \underline{\underline{\mu_0 n i}}$$

⟹ <u>Graph of Solenoid</u>