① Ampere's circuital law states that line integral of magnetic field around any closed loop is equal to μ_0 times the electric current flowing through the cross-section area enclosed by that loop

Mathematically, $\oint B.dl = \mu I$

Let the current flowing in the solenoid having number of turns per unit length n be I. Magnitude of magnetic field inside the solenoid is B while outside is zero.

Now $\oint_{loop} B.dl = \int B_{ab}.L + \int B_{bc}.L + \int B_{cd}.L + \int B_{da}$

The value of first term $\int B_{ab}.L = BL$.

The second and fourth term are zero because angle between magnetic field and the length loop is $90°$

The third term is also zero as the value of magnetic field outside the solenoid is zero.

Total current flowing through the loop

$I_{total} = (nL)I$

From Ampere's circuital law, we get $BL = \mu_0 nLI$

$\Rightarrow B = \mu_0 nI$

2a) Derivation:- consider a symmetrical long solenoid having number of turns per unit length equal to n. Let I be the current flowing in the solenoid then by right hand rule, the magnetic field is parallel to the axis of the solenoid.

Field outside the solenoid: consider a closed path abcd. Applying Ampere's law to this path.

$\oint \vec{B} \cdot \vec{dl} = \mu \times 0$.

(since net current enclosed by path is zero.)

As $dl \neq 0$ $\therefore B = 0$.

$\therefore$ Outside the solenoid the magnetic field is zero.

Field inside the solenoid: consider a closed path pqrs. The line integral of magnetic field vector B along path pqrs is.

$$\oint_{pqrs} \vec{B} \cdot \vec{dl} = \int_{pq} \vec{B} \cdot \vec{dl} + \int_{qr} \vec{B} \cdot \vec{dl} + \int_{rs} \vec{B} \cdot \vec{dl} + \int_{sp} \vec{B} \cdot \vec{dl} \quad \text{--- (i)}$$

For path pq. $\vec{B}$ and $\vec{dl}$ are along the same direction

$\therefore \int_{pq} \vec{B} \cdot \vec{dl} = \int B\, dl = Bl$

For paths qr and sp. $\vec{B}$ and $\vec{dl}$ are mutually perpendicular

$\therefore \int_{qr} \vec{B} \cdot \vec{dl} = \int_{s} \vec{B} \cdot \vec{dl} = \int B \cdot dl \cos 90^\circ = 0$

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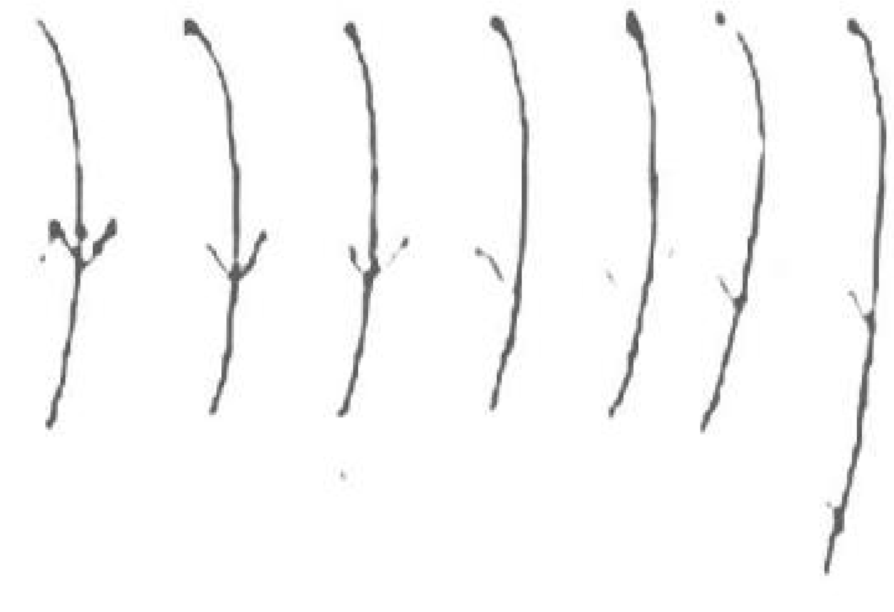
For path HS : B = 0 (since field is zero outside solenoid)

$\therefore \int_{HS} \vec{B} \cdot d\vec{l} = 0$.



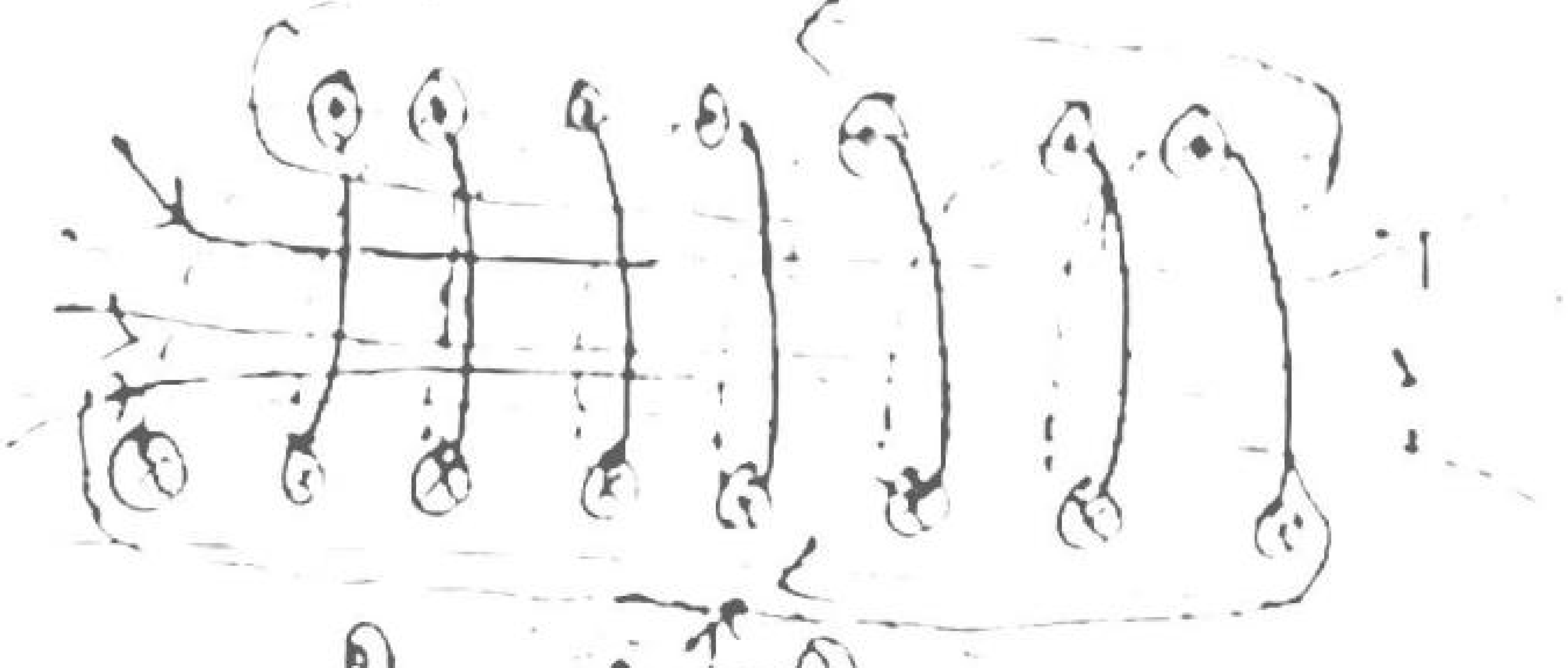
From equation (i) gives

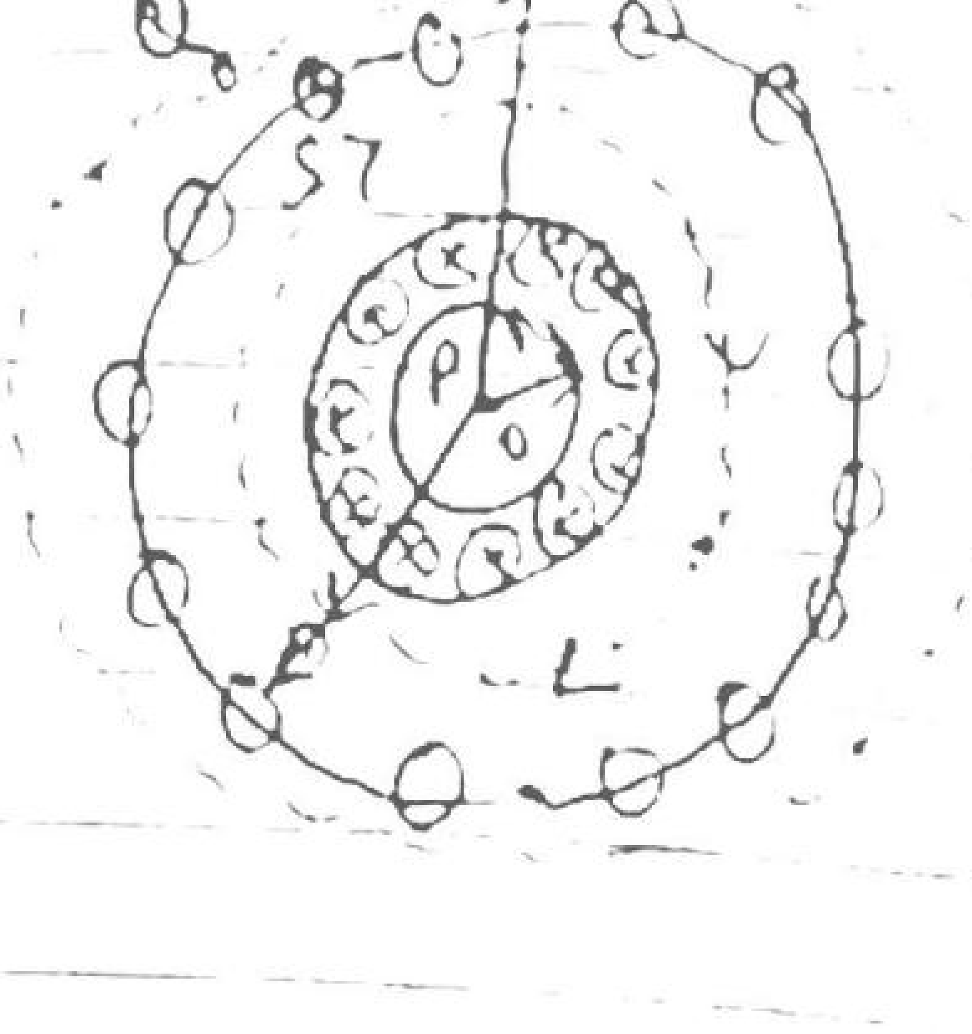
$$\oint_{PQRS} \vec{B} \cdot d\vec{l} = \int_{PQ} \vec{B} \cdot d\vec{l} = Bl \quad (ii)$$

By Ampere's law $\oint \vec{B} \cdot d\vec{l} = \mu_0 \times$ net current

$\therefore Bl = \mu_0 (nIl) \quad \therefore B = \mu_0 n I$.

b). In a toroid, magnetic lines don't exist outside the body. (Toroid is closed whereas solenoid is opened on both sides) magnetic field is uniform inside a toroid whereas for a solenoid, it is different at the two ends and centre.





c) The magnetic field lines of toroid are circular having common centre, Inside a given a solenoid the magnetic field may be made strong by

(i) passing large current and.

(ii) using laminated coil of soft iron.

(12) Given that

$n = 300$

$I = 5A$

$l = 0.5\,m$

$r_0 = 0.01\,cm.$

$\frac{l}{r} = \frac{0.5}{0.01 \times 10^{-2}} = 100 \Rightarrow l >> r$

$B = \mu_0 n I = 4\pi \times 10^{-7} \times 300 \times 5$

$= 20 \times 3000 \times \pi \times 10^{-7}$

$= 6000 \times \pi \times 10^{-7} = 6\pi \times 10^{-4}$

$= 1.88 \times 10^{-3}\,T$

(4) Here, $B = 2.52 \times 10^{-3}\,T$;

$\mu_0 = 4\pi \times 10^{-7}\,Hm^{-1}$

$l = 0.5\,m.$

$N = 500.$

Therefore, number of turns per unit length of the solenoid.

$n = \frac{N}{l} = \frac{500}{0.5} = 1000\,m^{-1}$

If I is the current through the solenoid, thin

$$B = \mu_0 n I$$

$$I = \frac{B}{\mu_0 n} = \frac{2.52 \times 10^{-3}}{4\pi \times 10^{-7} \times 1000} = 2.0A$$