Class Twelve Academic Program-2020

PHYSICS 2ND PAPER

Lecture : P-10

Chapter 4 : Magnetic effects of current and magnetism

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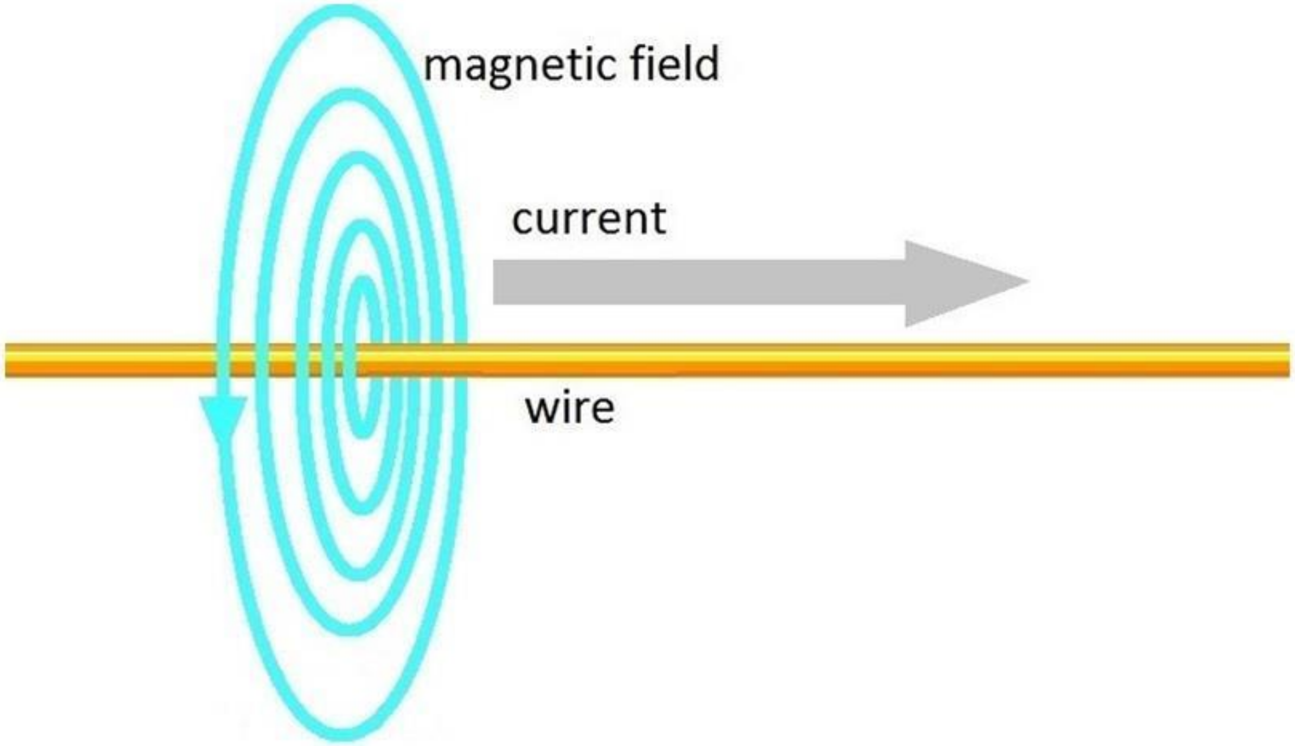
Today’s Topics:

- ✓Oersted’s concept about magnetic field
- ✓Value and direction of magnetic filed
- ✓Magnetic flux
- ✓Biot-Savart law or Laplace’s law
- ✓Ampere Law
- ✓Force on a moving charge due to magnetic field

Oersted's concept about magnetic field and his experiment

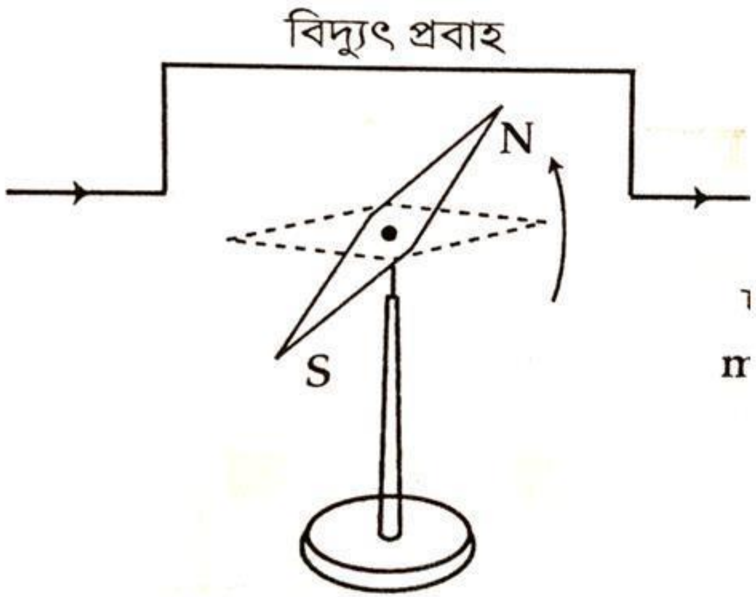
In 1820, a Danish physicist, Hans Christian Oersted, discovered that there was a relationship between electricity and magnetism. The magnetic field created by the current goes in circles around the wire.

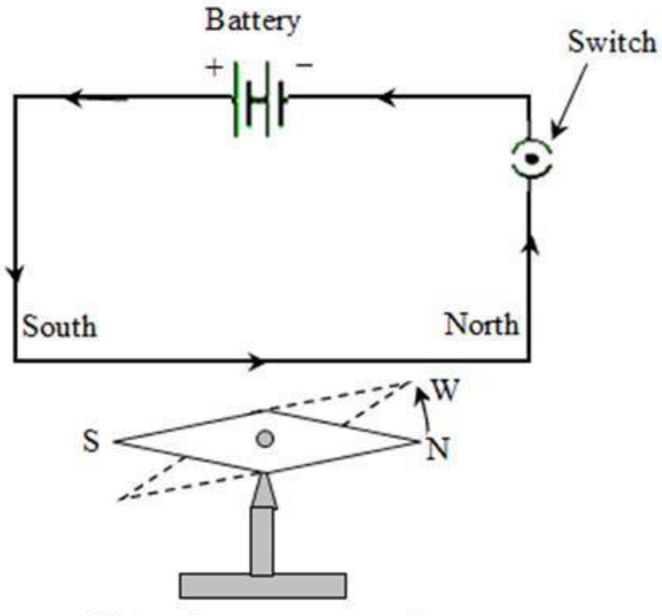


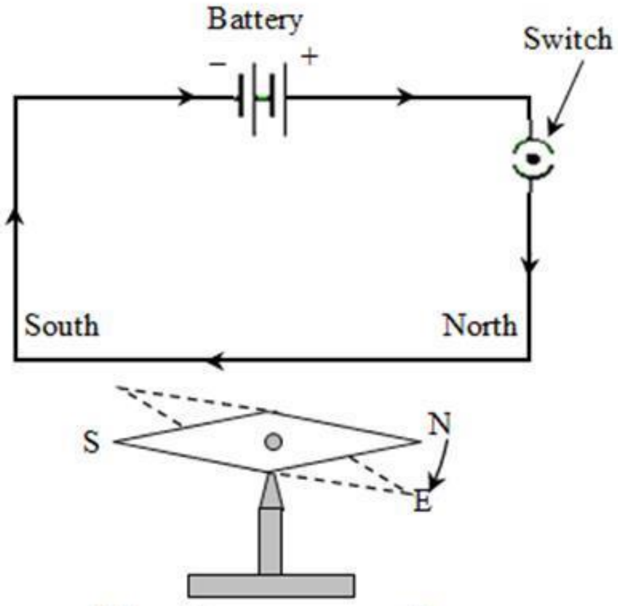
Oersted's concept about magnetic field and his experiment

Result: a) magnetic field changes with change in value and direction of current

b) magnetic field stays as long as current flows

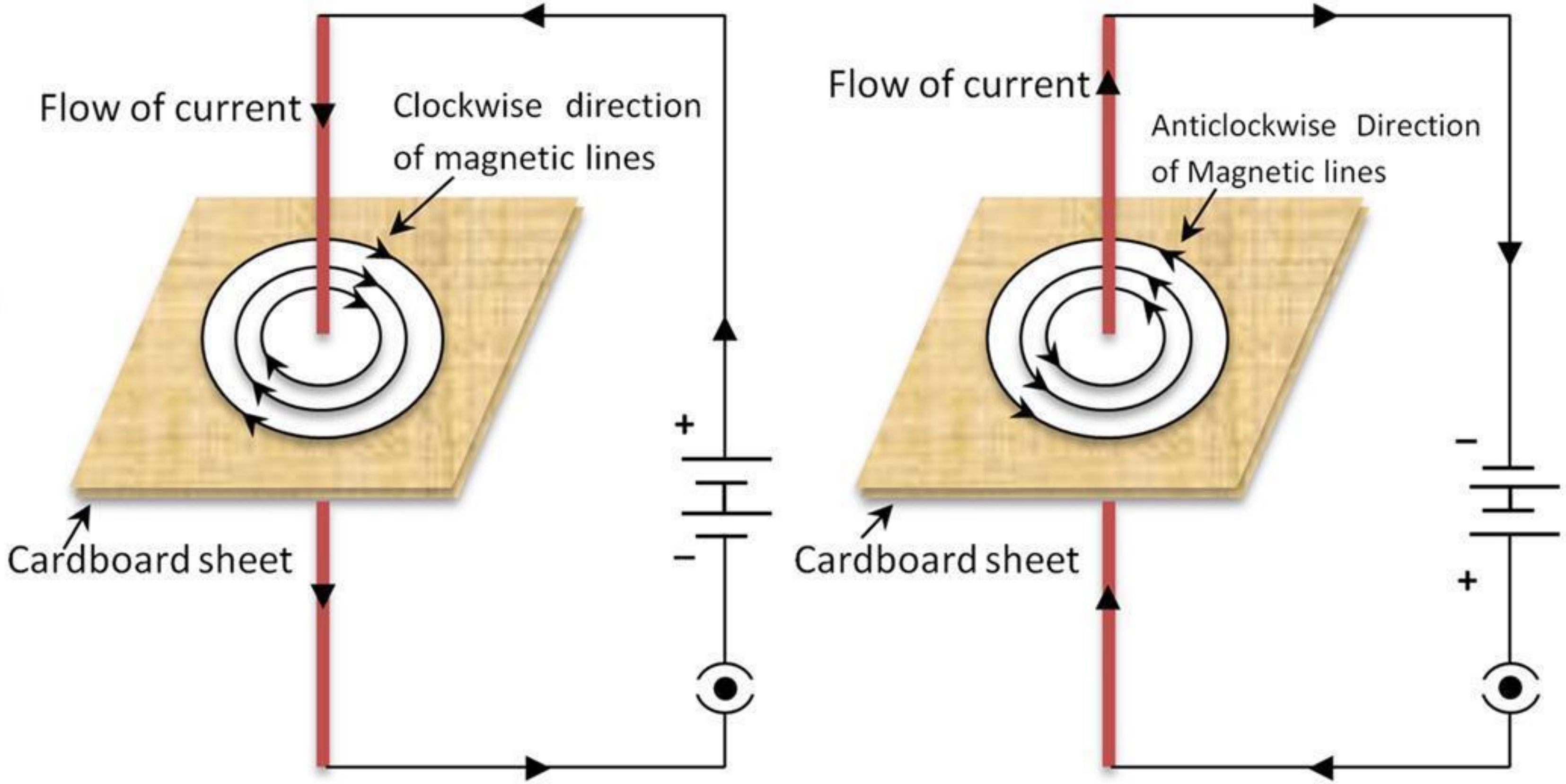






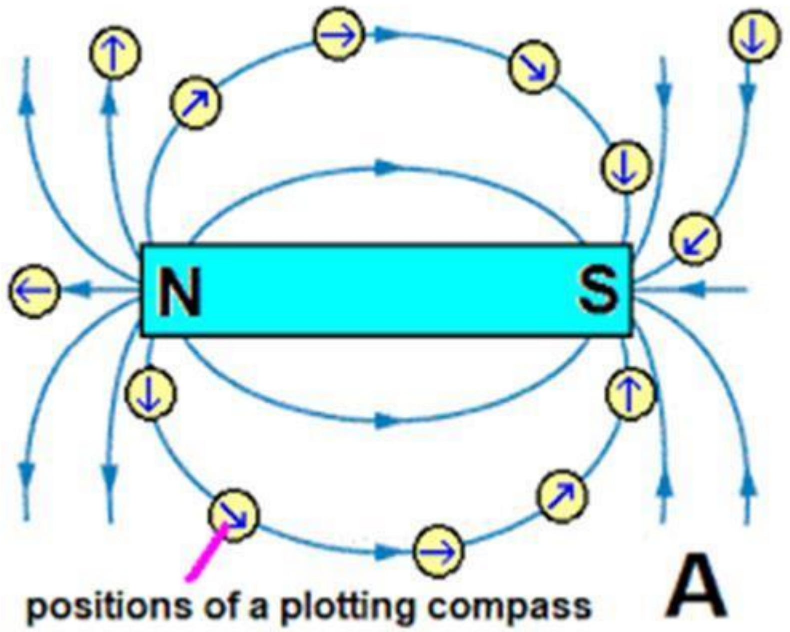
Oersted's concept about magnetic field and his experiment

Link: https://www.youtube.com/watch?v=zv4t_4fHvn4



Magnetic Field

Unit of magnetic field intensity is **Tesla (T) Wb/m^2**

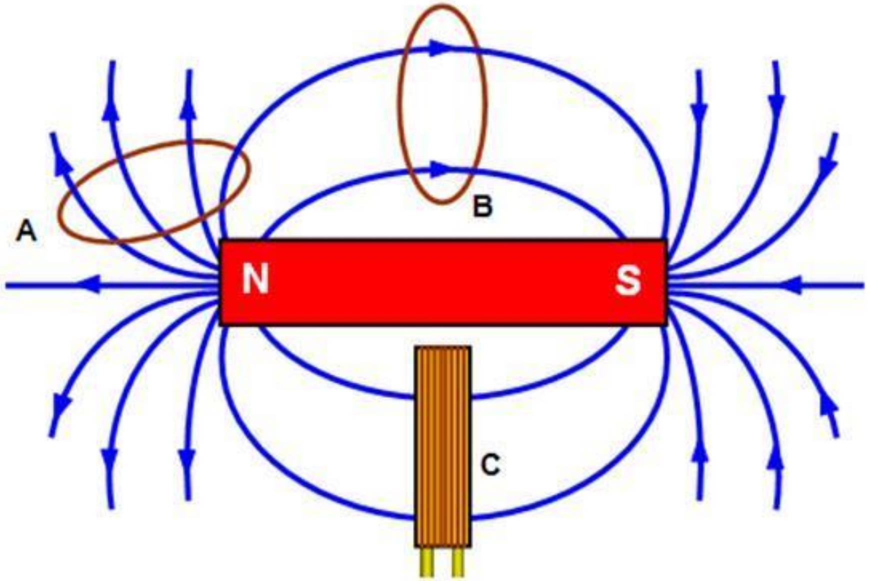


Magnetic Flux(ϕ)

Magnetic flux = line passing through the surface

$\Phi = AB\cos\theta = \mathbf{A.B}$

B= magnetic filed intensity = magnetic flux density

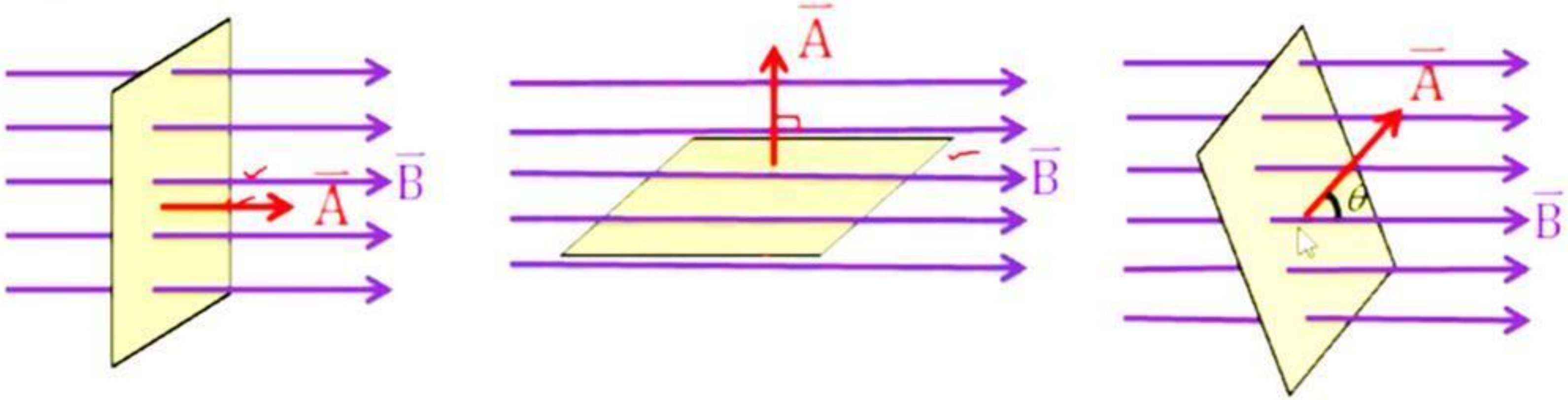


Magnetic Flux

"Magnetic flux Φ_B is the number of magnetic field lines passing through a certain area"

$$\phi_B = \vec{B}.\vec{A}$$
$$\phi_B = BA\cos\theta$$

θ = angle between vectors $\vec{B}$ and $\vec{A}$



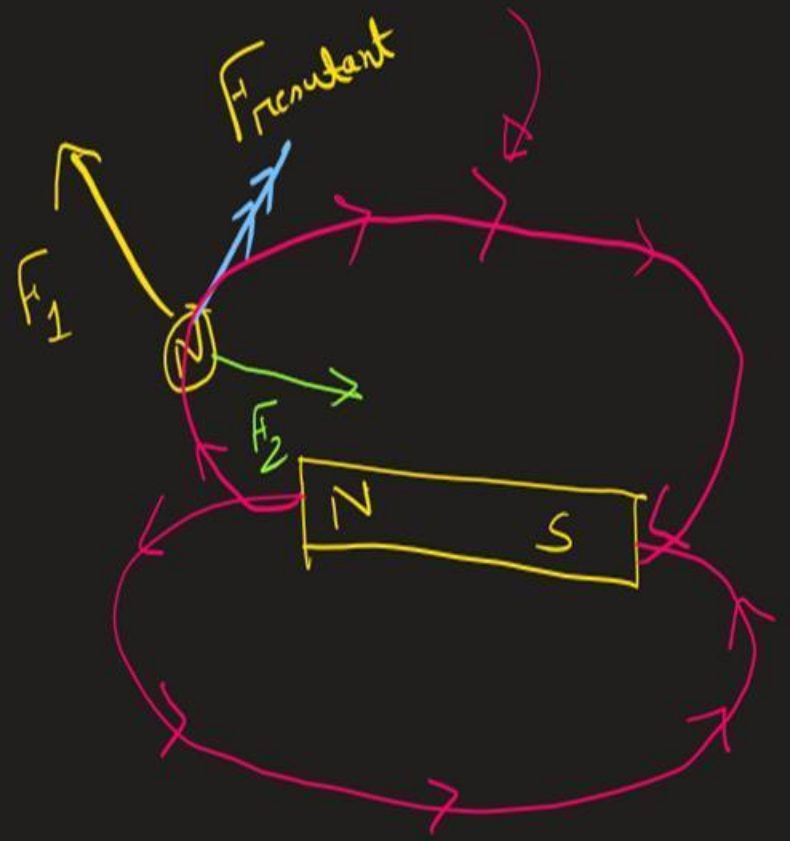
$$\phi_B = BA\cos 0^{\circ}$$
$$\phi_B = BA$$

Maximum flux

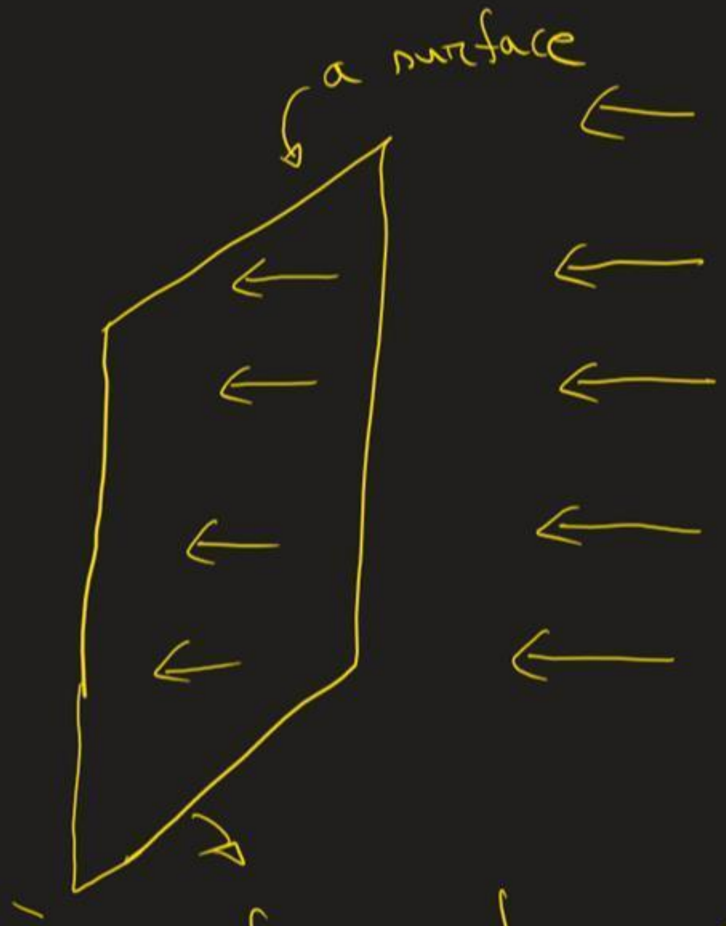
$$\phi_B = BA\cos 90^{\circ}$$
$$\phi_B = 0$$

Minimum flux

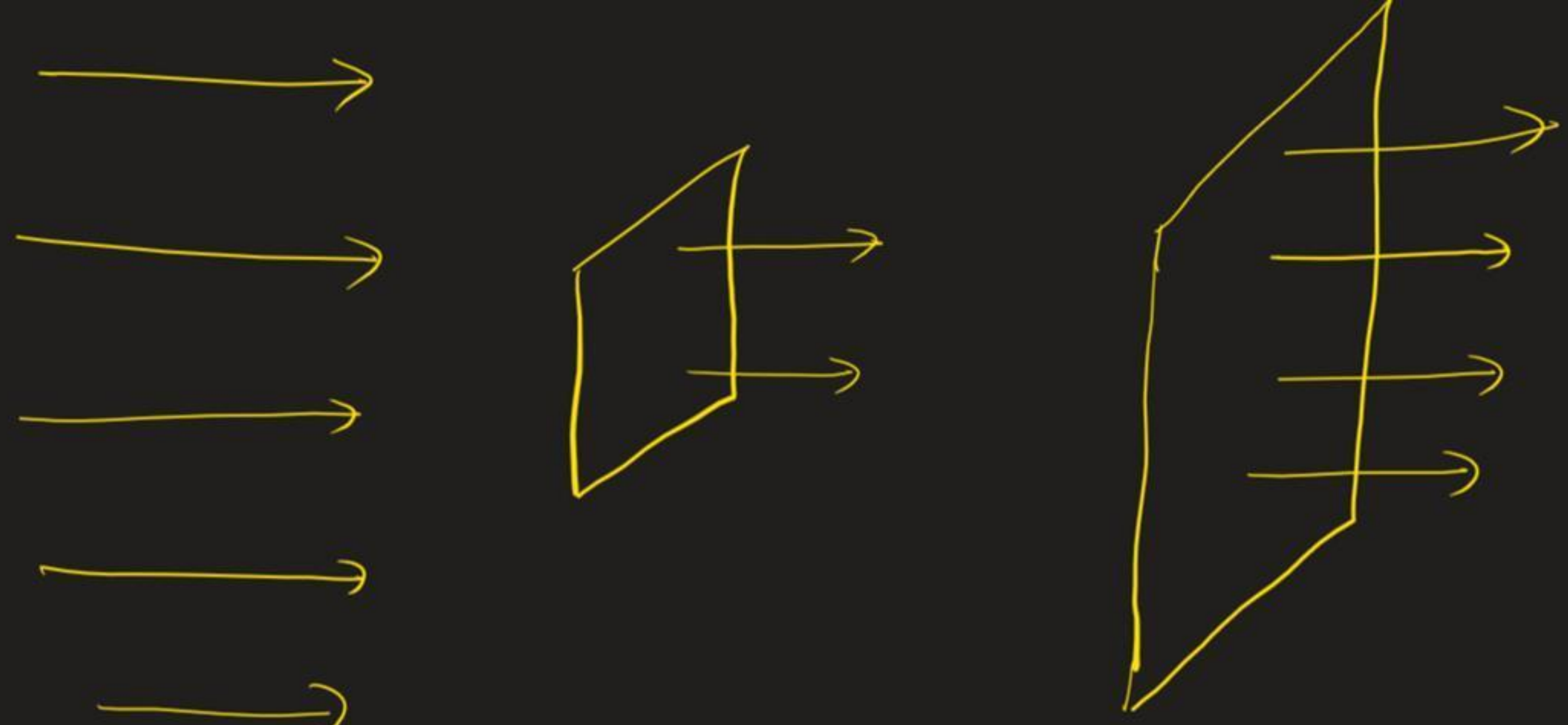
Magnetic Force Line: The path through which a magnetic north pole moves.



Magnetic field represents the density of magnetic force lines.



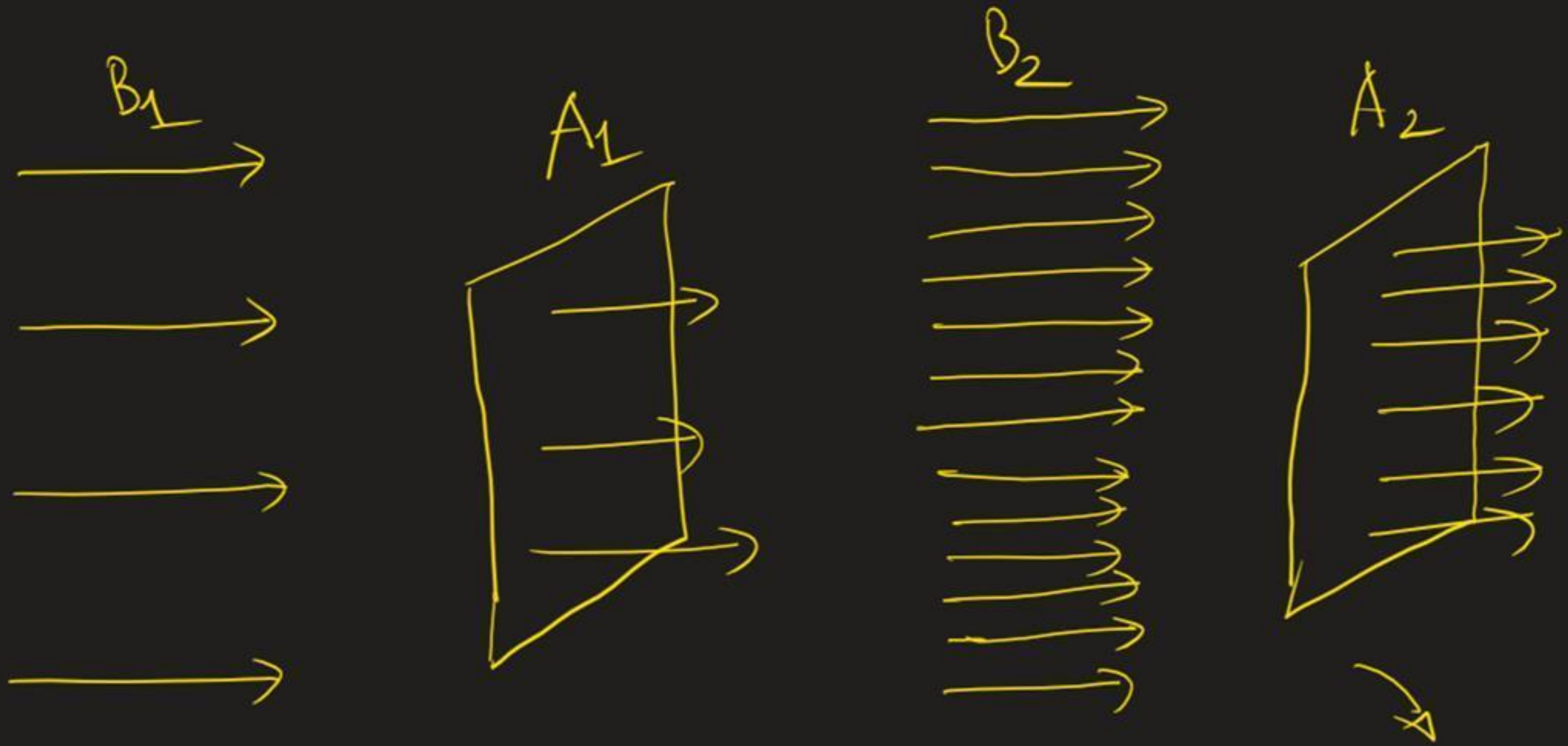
Magnetic flux of a surface represents the total no. of magnetic force lines passing that surface.



* The larger the are, the more force lines passes through it

So, the more magnetic flux it gets.

So, $\boxed{\phi \propto A}$ [A is area of the surface]



here, $A_1 = A_2$

but, $B_2 > B_1$ as

force line density is

greater in 2nd case

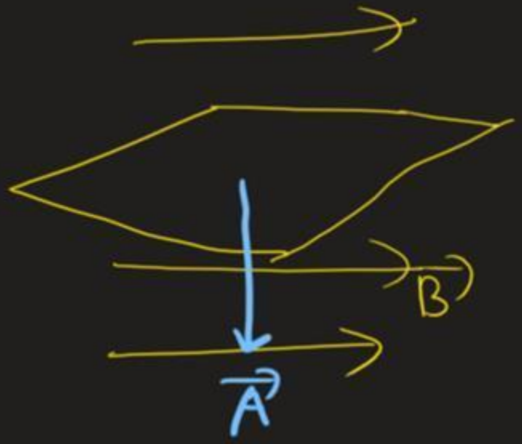
more force line and so more flux

$$\therefore \boxed{\varphi \propto B}$$

$\theta = \vec{A} \wedge \vec{B} = 0^\circ$

ϕ = maximum

→ No force line passing through the surface



$\theta = \vec{A} \wedge \vec{B} = 90^\circ$

$\phi = 0$

$0^\circ \longrightarrow$ max

$90^\circ \longrightarrow 0$

→ property of $\cos\theta$

So, $\boxed{\phi \propto \cos\theta}$

$\phi \propto A B \cos\theta$

$\Rightarrow \boxed{\phi = A B \cos\theta}$ (constant = 1 (in SI unit))

SI unit → $1\ wb = 10^8\ Mx$

(weber) (maxwell)

1 Tesla = $1\ wb/m^2$

$A \longrightarrow \phi$

$\therefore 1 \longrightarrow \boxed{\frac{\phi}{A} = B}$ → unit $= \frac{wb}{m^2} = T$ (Tesla) $= 10^4\ G$ (Gauss)

MATH 01

A circular surface having radius of 0.5m is at 30° with a magnetic filed. Magnetic flux density is 5 Wb/m2. Calculate magnetic flux.

π θ B

$\phi = AB\cos\theta$

$= \pi r^2 \times B \times \cos\theta$

$= 3.1416 \times 0.5^2 \times 5 \times \cos 30^\circ$

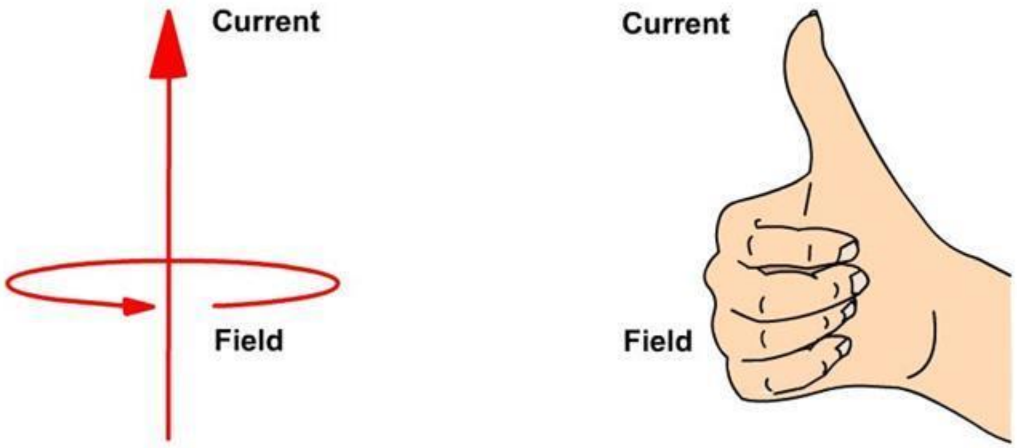
$= 1.9635$ wb

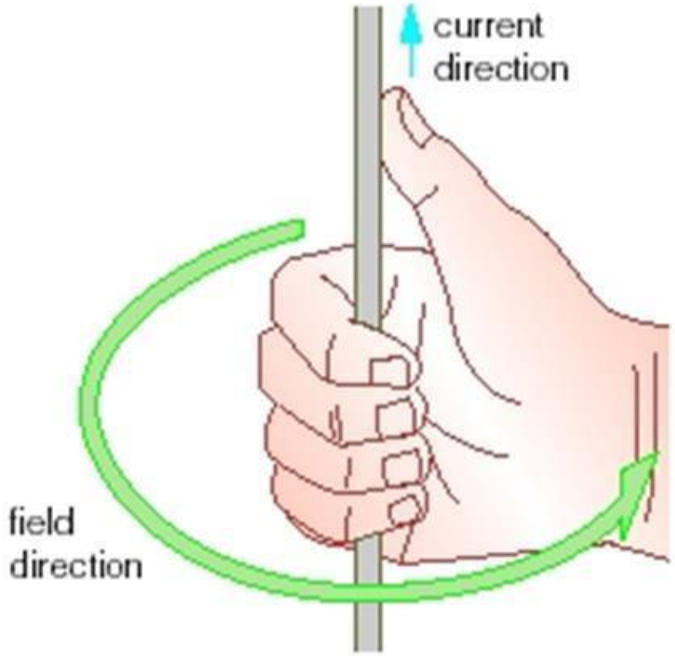
Direction of magnetic filed

How?

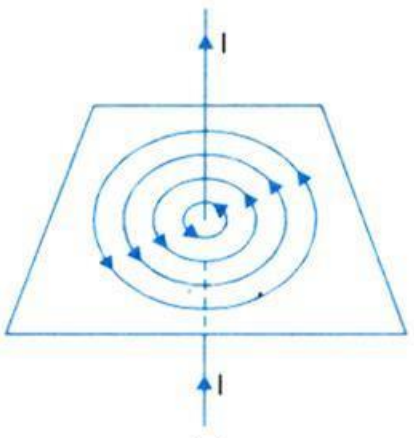
a) Maxwell’s cork screw rule
b) Fleming’s right hand rule

The Right Hand Grip Rule

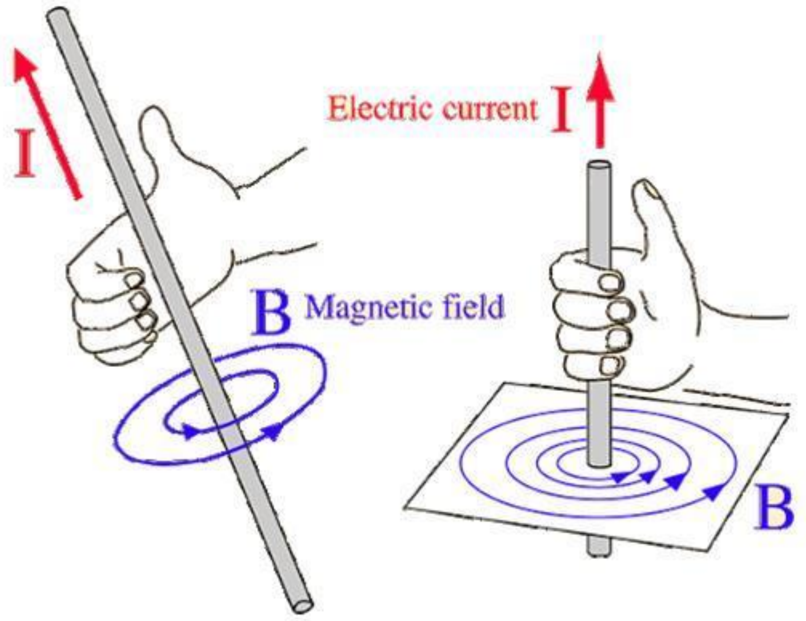


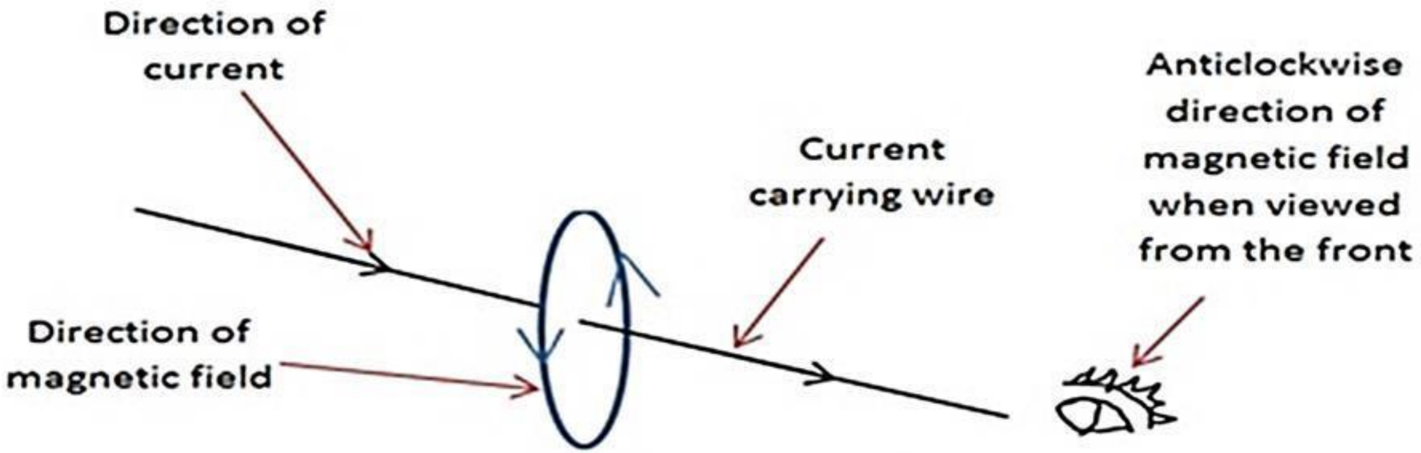


Fleming's right hand rule

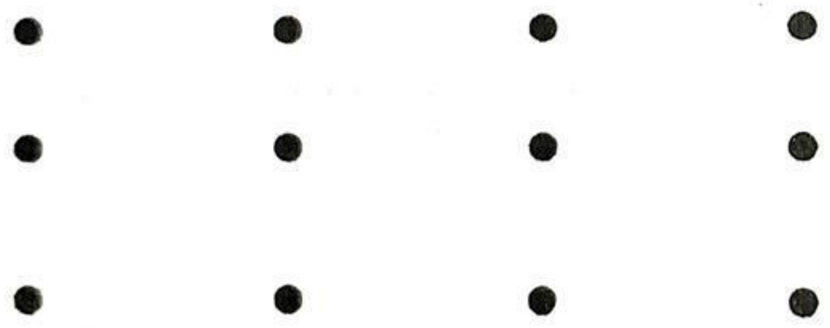


(a) (b)





Direction of magnetic field on a surface

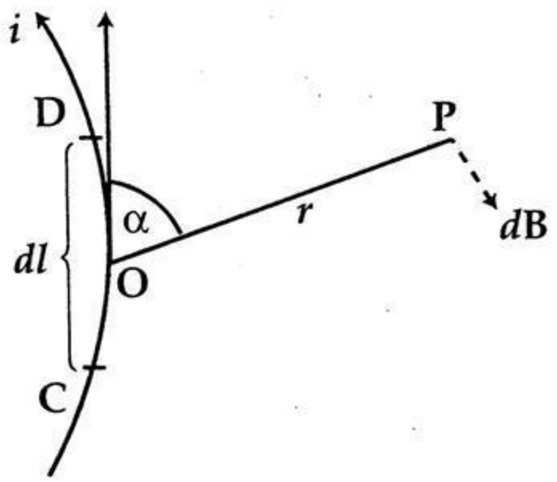


(ক) কাগজ তলের বাইরের দিকে

(খ) কাগজ তলের ভেতরের দিকে

Biot-Savart law or Laplace's law

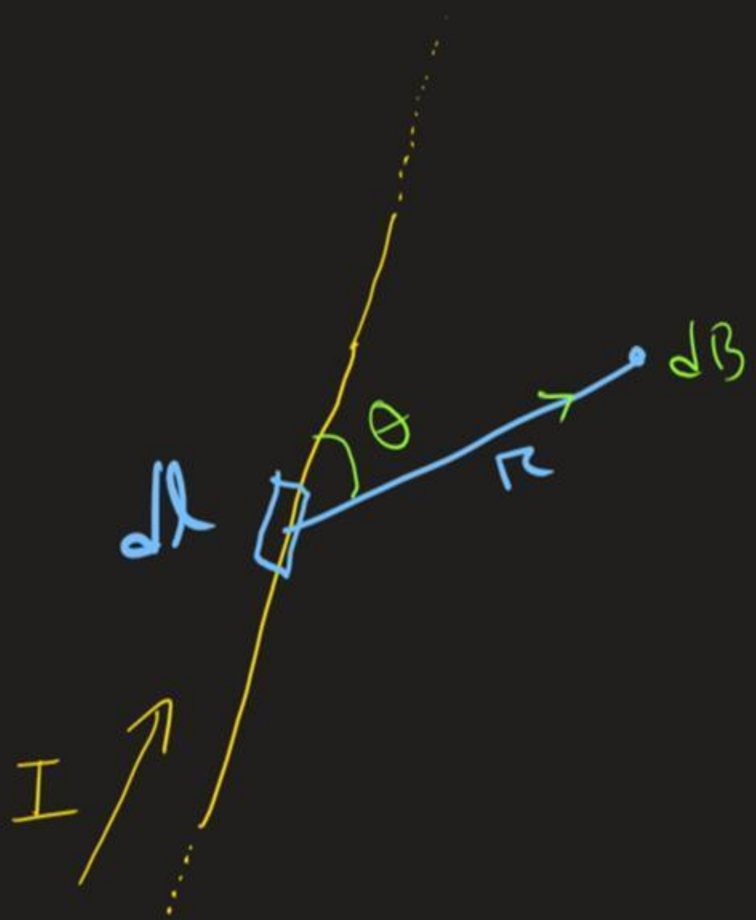
Magnetic filed occurs surrounding a current carrying conductor. Scientist Oersted stated this phenomenon and mathematician Laplace gave formula for this. Scientist Biot and Savart first proved this formula experimentally.



Biot-Savart law or Laplace's law

a) for finite length wire **b)for infinite length wire** **c)for circular loop**

Biot - Savart law:



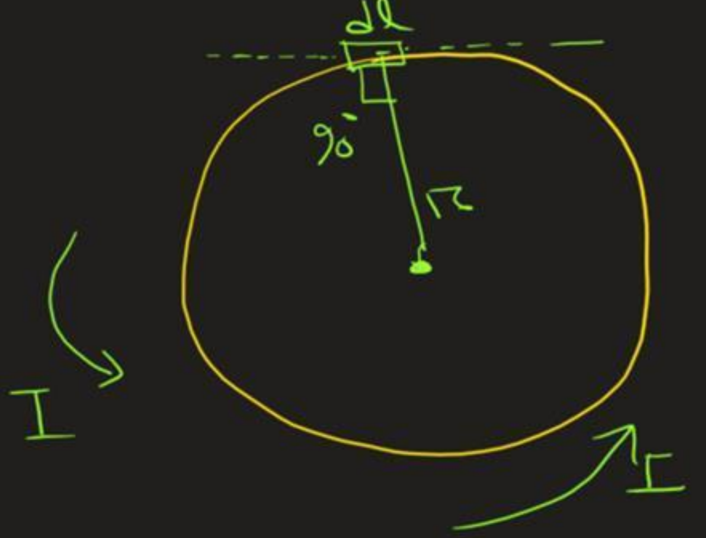
$$dB = \frac{\mu_0}{4\pi} \frac{I\,dl \sin\theta}{r^2}$$

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

direction of dl in direction of I

$$\theta = \vec{dl} \wedge \vec{r}$$

Magnetic field at the center of a current carrying circular wire:



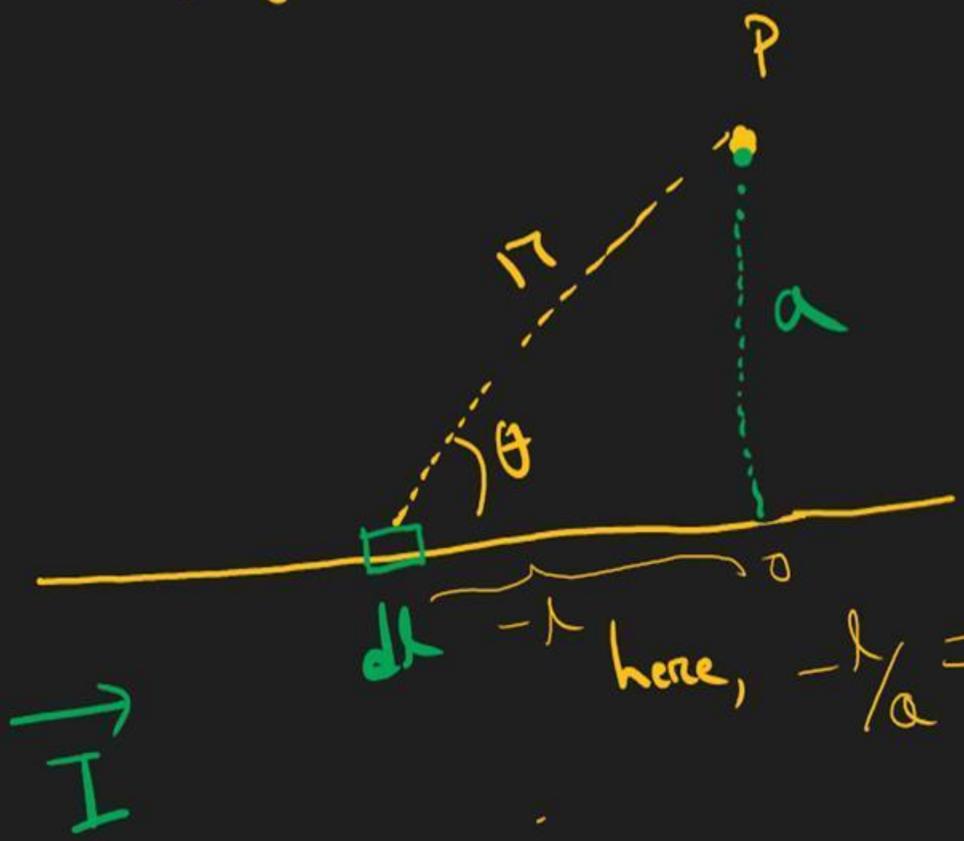
$$B = \int dB = \frac{\mu_0 I}{4\pi} \int \frac{dl \sin\theta}{r^2}$$

$$= \frac{\mu_0 I}{4\pi r^2} \times \int dl \qquad [\because \sin\theta = \sin 90° = 1]$$

$$= \frac{\mu_0 I}{4\pi r^2} \times 2\pi r \qquad [\int dl = 2\pi r]$$

$$\Rightarrow \boxed{B = \frac{\mu_0 I}{2r}}$$

Magnetic field at "a" distance from a finite length wire carrying I current.



$$dB = \frac{\mu_0}{4\pi} \frac{I\,dl\sin\theta}{r^2}$$

$$B = \int dB = \frac{\mu_0 I}{4\pi} \int \frac{dl\,\sin\theta}{r^2}$$

here, $-l/a = \cot\theta$ and, $r/a = \operatorname{cosec}\theta$

$\Rightarrow$ $\boxed{dl = a\operatorname{cosec}^2\theta\, d\theta}$ $\Rightarrow$ $\boxed{r = a\operatorname{cosec}\theta}$

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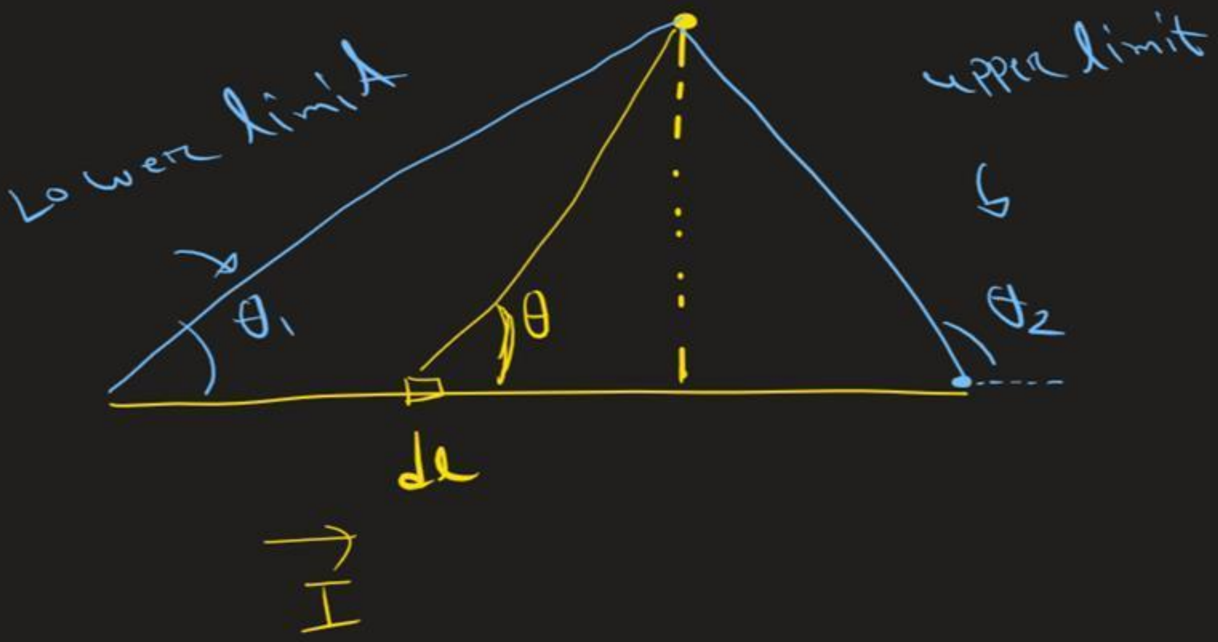


$$dl = a\,\mathrm{cosec}^2\theta\, d\theta\ ;\quad r = a\,\mathrm{cosec}\,\theta$$

$$B = \frac{\mu_0 I}{4\pi}\int \frac{dl\,\sin\theta}{r^2}$$

$$= \frac{\mu_0 I}{4\pi}\int_{\theta_1}^{\theta_2} \frac{a\,\mathrm{cosec}^2\theta \cdot d\theta \cdot \sin\theta}{a^2\,\mathrm{cosec}^2\theta}$$

$$= \frac{\mu_0 I}{4\pi a}\int_{\theta_1}^{\theta_2} \sin d\theta = \boxed{\frac{\mu_0 I}{4\pi a}\left(\cos\theta_1 - \cos\theta_2\right)}$$

(for infinite wire)

So, $B = \frac{\mu_0 I}{4\pi a}\left(\cos 0^\circ - \cos 180^\circ\right)$

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

MATH 05

A wire is carrying 2 amp current. How much magnetic field will be produced at 5 cm distance perpendicularly from the wire ?

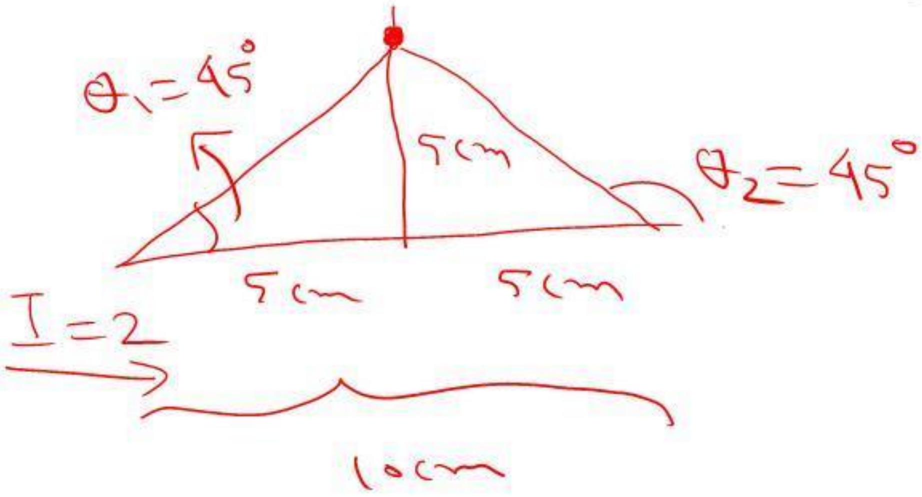
$$B = \frac{\mu_0 I}{2\pi a} = \frac{4\pi \times 10^{-7} \times 2}{2\pi \times 5 \times 10^{-2}} = 8 \times 10^{-6}\ T$$

(Ans)

assume, 0.1m = 10cm

MATH 06

A wire of 5m length is carrying 2 amp current. How much magnetic field will produce at 5 cm distance perpendicularly from the wire ?



$$B = \frac{\mu_0 I}{4\pi a}(\cos\theta_1 - \cos\theta_2)$$

$$= \frac{4\pi \times 10^{-7} \times 2}{4\pi \times 5 \times 10^{-2}} \times (\cos 45^\circ - \cos 135^\circ)$$

$$= 5.65 \times 10^{-6}\ T$$

Poll Question 02

A wire of 5m length is carrying 2 amp current. It is bent and shaped as a circular loop. How much magnetic field will produce at the center of the circle?

(a) $15.8 \times 10^{-7}\ T$

(b) $15.8 \times 10^{-6} T$

(c) Zero

(d) No answer

$l = 2\pi r = 5$

$r = \frac{5}{2\pi}$

$$B = \frac{\mu_0 I}{2r} = \frac{4\pi \times 10^{-7} \times 2}{2 \times \frac{5}{2\pi}}$$

$$= 1.58 \times 10^{-6}\ T$$

$$= 15.8 \times 10^{-7}\ T$$

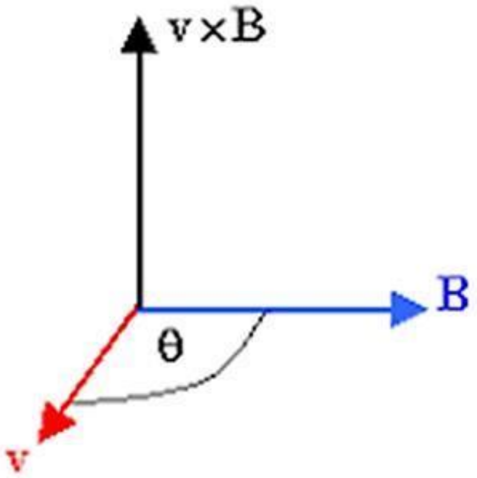
Force on a moving charge due to magnetic field

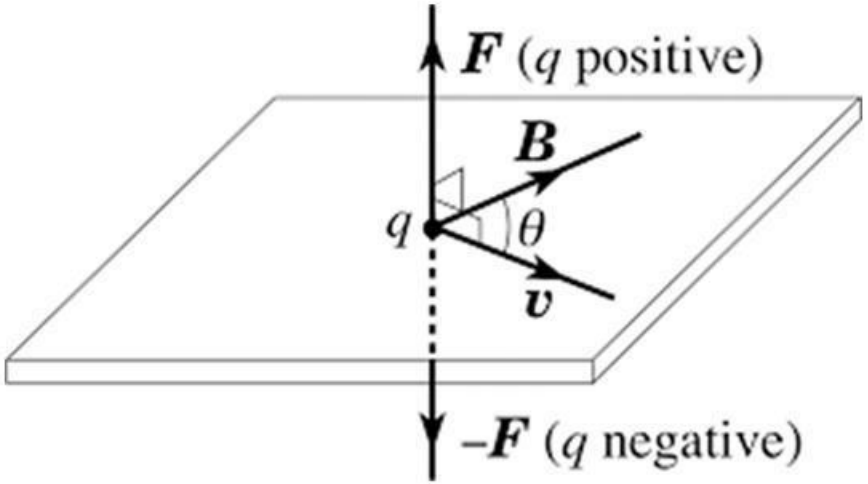
If a charge (**positive, negative**) moves in a magnetic filed it'll feel magnetic force on it.

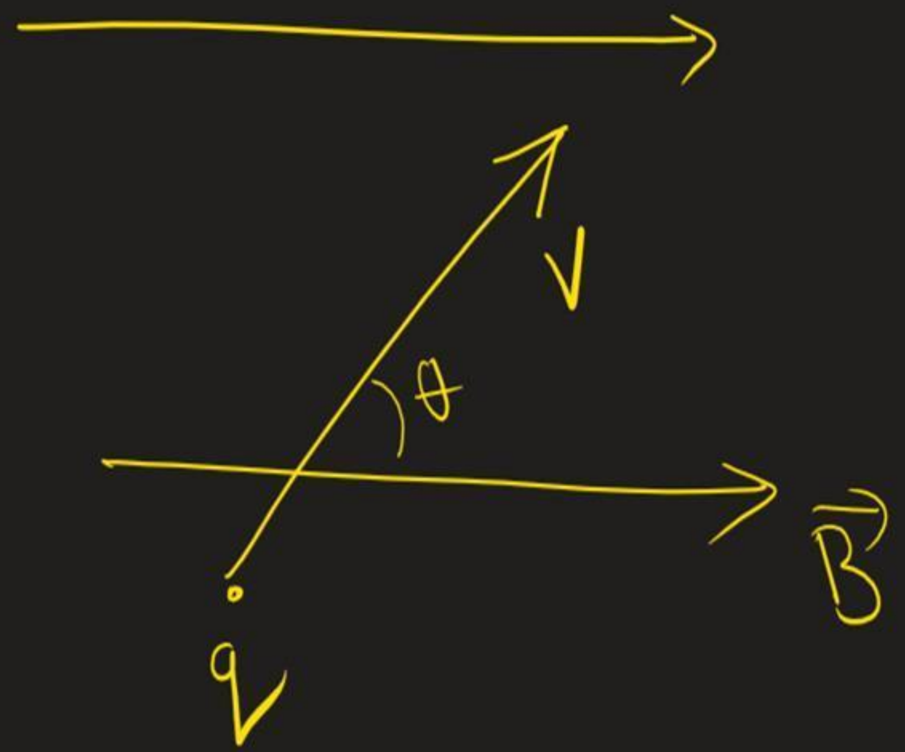
F = qVBSinθ

→ **F** = q (***V*** X **B**)

$$\vec{F} = q\vec{v}\ x\ \vec{B}$$

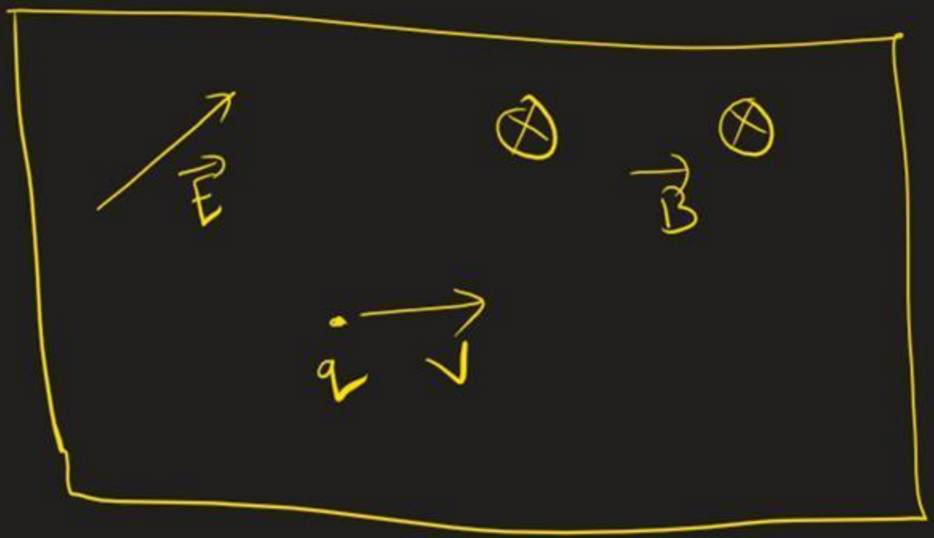






$$\vec{F} = q(\vec{V} \times \vec{B})$$

$$F = qVB\sin\theta$$



$$\vec{F} = \vec{F}_e + \vec{F}_m$$

$$= q\vec{E} + q\left(\vec{v} \times \vec{B}\right)$$

$$= \vec{F}_{Lorentz}$$

MATH 02

A proton with 1.5X10^7 m/s speed enters at 30° angle with a magnetic filed of 2.5 Wb/m2 intensity. How much force will work on proton?

v θ B

$F = qvB\sin\theta$

$= 1.6\times10^{-19} \times 1.5\times10^{7} \times 2.5 \times \sin 30^{\circ}$

$= 3\times10^{-12}$ N

MATH 03

একটি ইলেকট্রন $\vec{E} = (\hat{i} + 2\hat{j} - 8\hat{k})$ Vm^{-1} তড়িৎক্ষেত্রে ও $\vec{B} = (2\hat{i} + 3\hat{k})$ T চৌম্বকক্ষেত্রে $(2\hat{i} + 2\hat{j})$ ms^{-1} বেগে প্রবেশ করল। ইলেকট্রনের উপর বলের মান বের কর।

$$F = q\{(\vec{v} \times \vec{B}) + \vec{E}\}$$

$$\vec{v} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 2 & 2 & 0 \\ 2 & 0 & 3 \end{vmatrix} = 6\hat{i} - 6\hat{j} - 4\hat{k}$$

$$= -1.6 \times 10^{-19} \times \{(6\hat{i} - 6\hat{j} - 4\hat{k}) + \hat{i} + 2\hat{j} - 8\hat{k}\}$$

$$= -1.6 \times 10^{-19} (7\hat{i} - 4\hat{j} - 12\hat{k})$$

(Ans)

Poll Question 01

A proton with 200 m/s speed enters parallelly with a magnetic filed of 5T intensity. How much force will work on proton?

(a) $1.6 \times 10^{-16} N$

(b) $1.6 \times 10^{-19} N$

(c) Zero

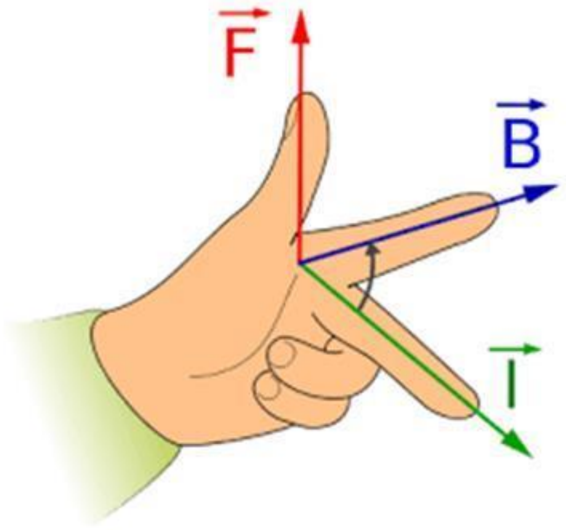
(d) No answer

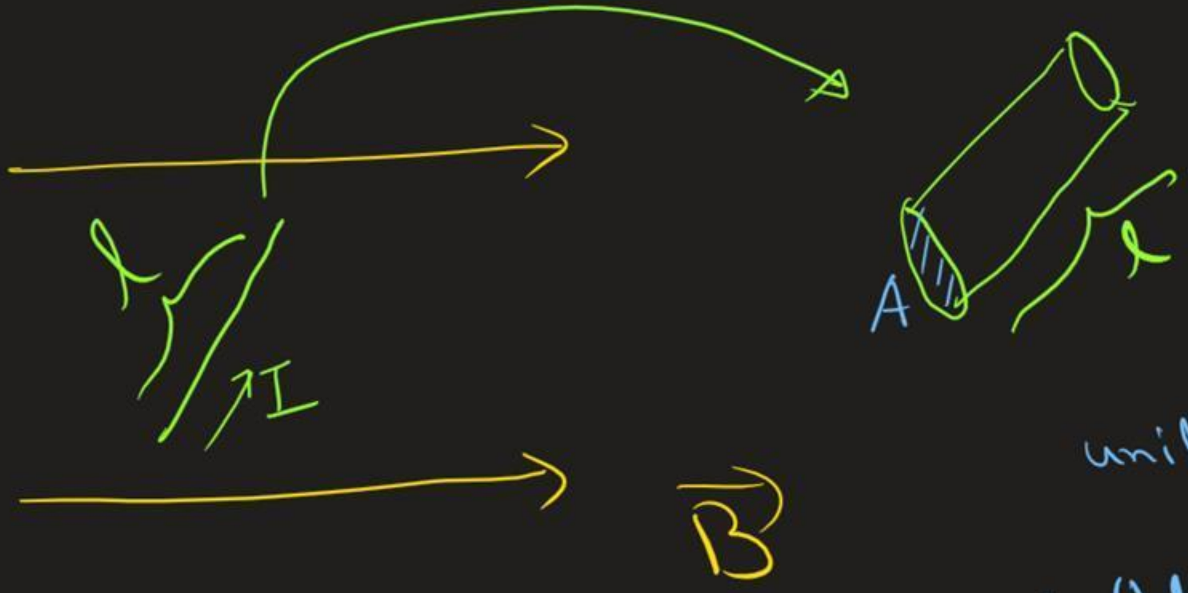
$\theta = 0^\circ / 180^\circ \rightarrow \sin\theta = 0$

$F = qvB\sin\theta = 0$

Magnetic force on conductor

$F = ILB \sin\theta$





Volume = $A\ell$

unit volume $\longrightarrow$ n (no. of charge)

$\therefore A\ell$ " $\longrightarrow$ $nA\ell$

$\therefore Q = nA\ell e$

$F = q\,V\,B\sin\theta$ [$I = nAve$]

$= (nA\ell e)\,V\,B\sin\theta$

$F = I\ell B\sin\theta$ So, $\vec{F} = I(\vec{\ell} \times \vec{B})$

MATH 04

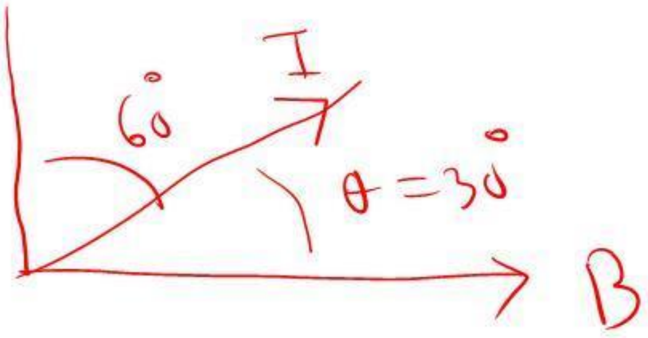
Wire of 1.5m length carrying 5A current is at 60° angle in perpendicular direction with a magnetic field with intensity of 5T. Calculate force per length of the conductor.

$$F = I l B \sin\theta$$

$$\frac{F}{l} = I B \sin\theta$$

$$= 5 \times 5 \times \sin(90^\circ - 60^\circ)$$

$$= 12.5 \, N/m$$



না বুঝে মুখস্থ করার অভ্যাস
প্রতিভাকে ধ্বংস করে।