ELL-101 (Introduction to Electrical Engineering)

Module-4

- Magnetic circuit
  - → Reluctance
  - → Inductance (Self & mutual)
  - → Energy
- Electrical Machines
  - → Transformer
  - → DC Generators/Motors
  - → AC Generators/Motors

→ Reference Books :

- "Electric Machinery" by A.E. Fitzgerald, C. Kingsly, S.D. Umans ✓

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  McGraw Hill Publication

- "Engineering Electromagnetics" by W.H. Hayt, J. A. Buck ✓

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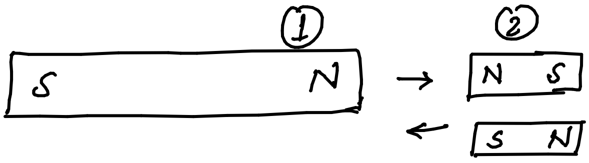
  McGraw Hill Publication



• Magnets produce force

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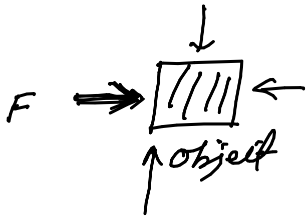
Magnetic force



1 N.

↓

Force is a vector quantity

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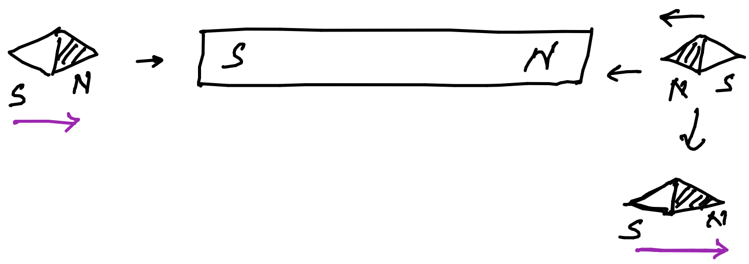
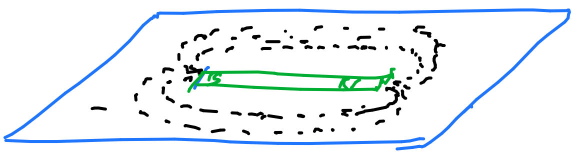
Magnitude + Direction

Magnetic force is also a vector quantity.



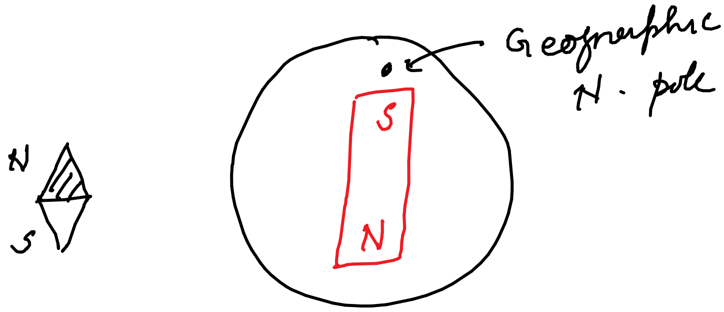


Magnetic lines of force

Magnetic field →

Field lines

→ Magnetite (Lodestone)



→ 1820 (C. Oersted)

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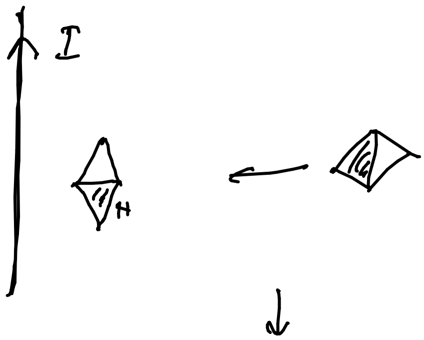

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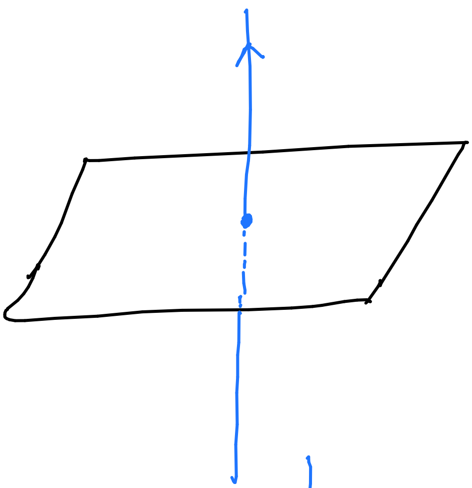
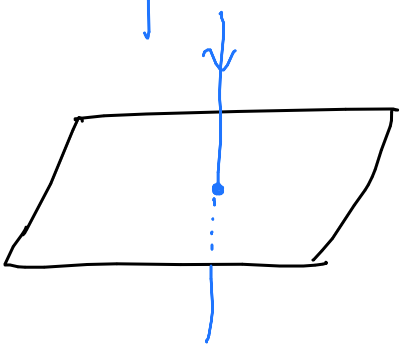
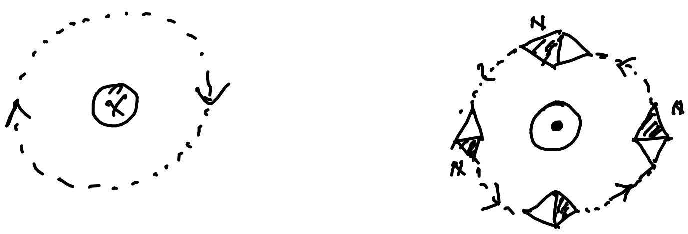


⊙ ← current coming out from the plane



⊗ ← current going into the plane.



Direction is determined by Cork's Right-hand Screw rule

→ 1820/21 J. B. Biot & F. Savart

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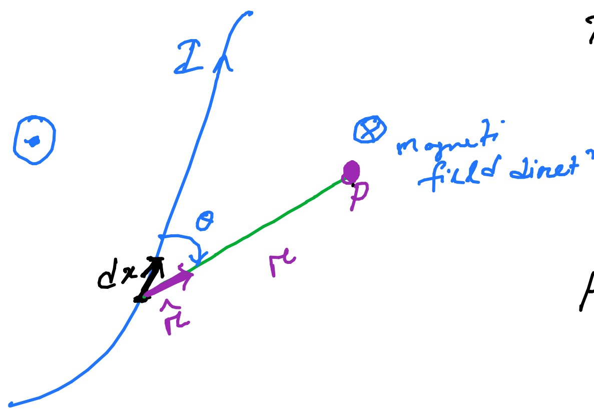
How to compute magnetic field intensity for a current carrying conductor.



The objective: Compute magnetic field at point P

H : Magnetic field intensity (A/m)

$\vec{dx}$: Small wire segment in the direction of I

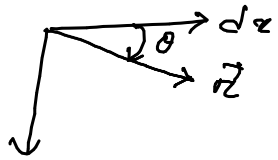
$\hat{r}$: unit vector that points from $\vec{dx}$ to P.

r : the distance between dx & P.

$$\boxed{\vec{dH} = \frac{1}{4\pi}\left[\frac{I\,\vec{dx}\times\hat{r}}{r^2}\right]}$$

$\vec{dx} \times \hat{r}$

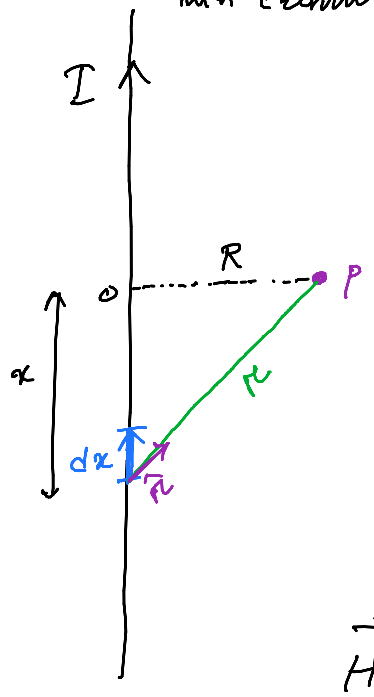
$$= \frac{I}{4\pi}\left[\frac{dx\,\sin\theta}{r^2}\right]$$



The magnetic field intensity at point P due to the entire wire

$$\boxed{\vec{H} = \int_{wire} \vec{dH} = \frac{I}{4\pi}\int_{wire}\frac{\vec{dx}\times\hat{r}}{r^2}}$$

Thin current carrying conductor



$$d\vec{H} = \frac{1}{4\pi}\frac{I\, d\vec{x} \times \vec{r}}{r^2}$$

$$r = x^2 + R^2 \qquad \sin\theta = \frac{R}{r} = \frac{R}{\sqrt{x^2+R^2}}$$

$$d\vec{H} = \frac{I}{4\pi}\left[\frac{1}{x^2+R^2}\,\frac{R}{\sqrt{x^2+R^2}}\,dx\right]$$

$$\vec{H} = \int_{-\infty}^{\infty} d\vec{H} = \frac{I}{4\pi}\int_{-\infty}^{\infty}\frac{R}{(x^2+R^2)^{3/2}}\,dx$$

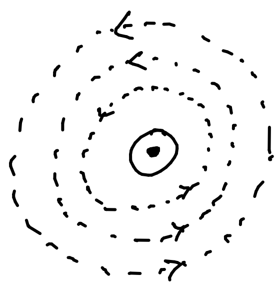
$$\vec{H} = \frac{2I}{4\pi}\int_{0}^{\infty}\frac{R}{(x^2+R^2)^{3/2}}\,dx$$

$$\vdots$$

$$= \frac{I}{2\pi}\left[\frac{x}{R\sqrt{x^2+R^2}}\right]_0^{\infty}$$

$$= \frac{I}{2\pi}\left[\frac{x}{R\,x\sqrt{1+R^2/x^2}}\right]_0^{\infty}$$

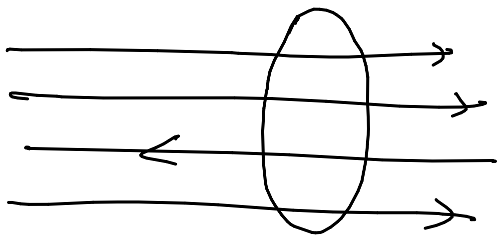
$$\boxed{H = \frac{I}{2\pi R}} \checkmark$$



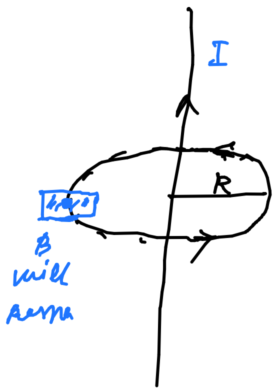
- Magnetic Flux : φ_B (Weber) (Wb)
- Magnetic flux density : B (Weber/m^2)

$$\varphi_B \leftrightarrow B \quad \rightarrow \quad \varphi_B := BA \text{ (Not always true)}$$

- Flux is the net amount of magnetic field lines passing through a surface.



- The B is constant in a region.



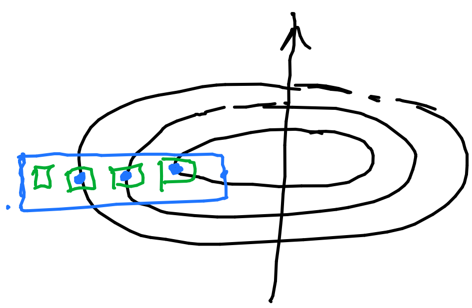
$$H = \frac{I}{2\pi R}$$

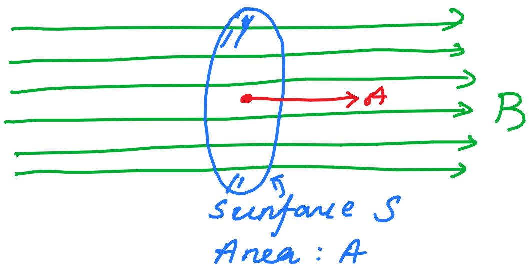
$$\boxed{B = \mu_0 H}$$

μ_0 : Permeability of free space

$R \pm \delta R$

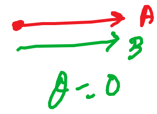
- B is variable over a region (surface)

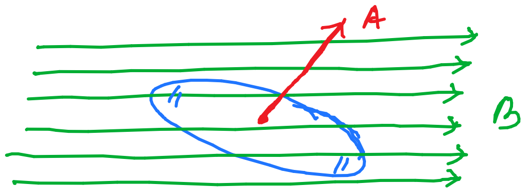




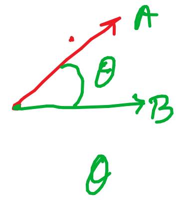
S is the surface where I am interested to compute the flux.

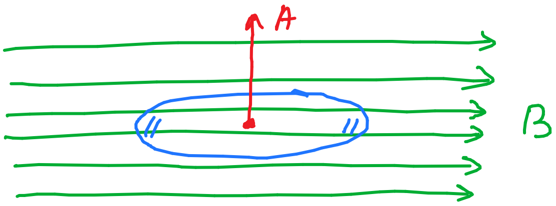
- Maximum number of magnetic field lines are passing through S



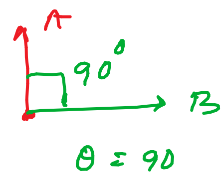


- Reduced number of field lines

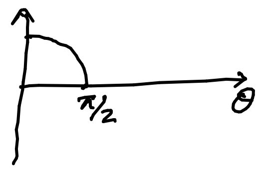




- No field lines passing through S

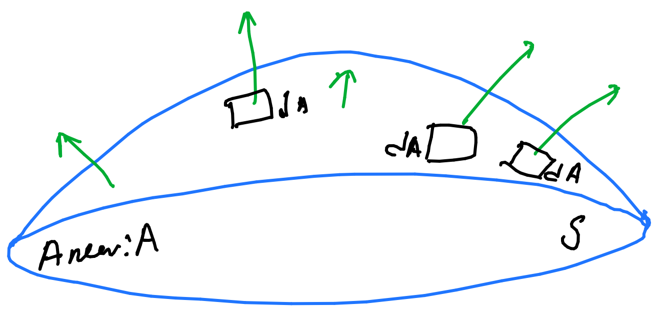


$$\Phi_B = BA\cos\theta$$



$$\boxed{\Phi_B := \vec{B}\cdot\vec{A}}$$

$\Phi_B = BA$ ✓ when $\theta = 0^\circ$



B is not constant / not uniform over the entire surface S.

- Partition the entire surface with tiny areas & denote them as $\vec{dA}$ such that over $\vec{dA}$ the B is constant/uniform.

- Since B is constant in dA, so

$$d\varphi_B := \vec{B}\cdot\vec{dA}$$

- Total flux over the entire region is

$$\boxed{\Phi_B := \iint_{\text{surface}} d\varphi_B = \iint_{\text{surface}} \vec{B}\cdot\vec{dA}} \quad (Wb)$$