L-26 / 10.05.2023 /

Magnetic Field ($\vec{B}$)

$-q$ /

$$\vec{F}_B = -q\vec{v} \times \vec{B}$$

$$|\vec{F}_B| = qvB\sin\theta$$

$$\vec{A} = \hat{i}A_x + \hat{j}A_y + \hat{k}A_z$$

$$\vec{B} = \hat{i}B_x + \hat{j}B_y + \hat{k}B_z$$

$$\vec{A} \times \vec{B} = \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ A_x & A_y & A_z \\ B_x & B_y & B_z \end{vmatrix} = \hat{i}(A_yB_z - A_zB_y) - \hat{j}(A_xB_z - A_zB_x) + \hat{k}(A_xB_y - A_yB_x)$$

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

$$\vec{v} = \hat{i}V_x + \hat{j}V_y + \hat{k}V_z$$

$$\vec{B} = \hat{i}B_x + \hat{j}B_y + \hat{k}B_z$$

$$\therefore \vec{F}_B = q\vec{v} \times \vec{B} = q \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ v_x & v_y & v_z \\ B_x & B_y & B_z \end{vmatrix}$$

$$= q\left[\hat{i}\left(v_y B_z - v_z B_y\right) - \hat{j}\left(v_x B_z - v_z B_x\right) + \hat{k}\left(v_x B_y - v_y B_x\right)\right]$$

Example:

(i) Charge $= +1.6 \times 10^{-19}$ C is moving with a velocity 4×10^{8} m/s in $+x$ direction in a magnetic field of 2T Directed towards $+z$.

Find the magnetic force on this charge?

$\vec{F}_B = q\vec{v} \times \vec{B}$	$\vec{v} = \hat{i}\ 4 \times 10^{8}$ m/s
$q = +1.6 \times 10^{-19}$ C	$\vec{B} = \hat{k}\ 2T$

$$\vec{F}_B = q(\vec{v} \times \vec{B}) = 1.6 \times 10^{-19} \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 4\times10^8 & 0 & 0 \\ 0 & 0 & 2 \end{vmatrix}$$

$$= 1.6\times10^{-19} \left[\hat{i}\,(0-0) - \hat{j}\,(4\times10^8 \times 2 - 0) + \hat{k}\,(0-0) \right]$$

$$= 1.6 \times 10^{-19} (-\hat{j}) (8\times10^8)$$

$$= -\hat{j}\ 1.28 \times 10^{-10}$$

Ans

(ii) Charge $= -1.6\times10^{-19}\,C$

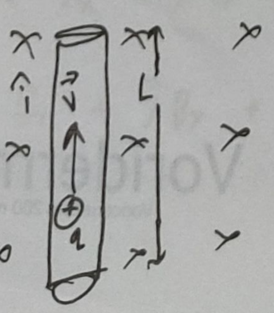
$\left\{ \text{Same as (i)} \right\}$

$$\vec{F}_B = -1.6\times10^{-19} [\hat{i} \ldots \ldots]$$

$$= +\hat{j}\ 1.28 \times 10^{-10}$$

⊛ Magnetic Force on a current carrying conductor:

(i)



$\vec{l} = \vec{10}\ m/2\,s$

$$\vec{v} = \frac{10}{2} = \vec{5}$$

$$v = \frac{L}{t}$$

$$\vec{v} = \frac{\vec{L}}{t}$$

$$\vec{F}_B = q\vec{v} \times \vec{B}$$

$$= q\,\frac{\vec{L}}{t} \times \vec{B}$$

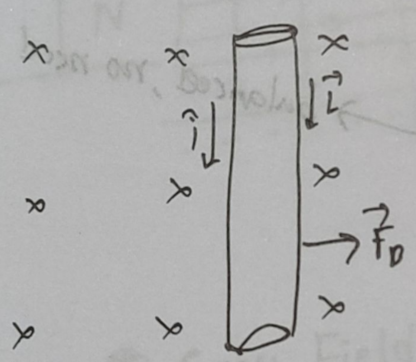
$$= \frac{q}{t}\,\vec{L} \times \vec{B}$$

$$\vec{F}_B = i\vec{L} \times \vec{B}$$

Conductor

$$\boxed{\vec{F}_L = i\vec{L} \times \vec{B}} = iLB\sin 90^\circ$$

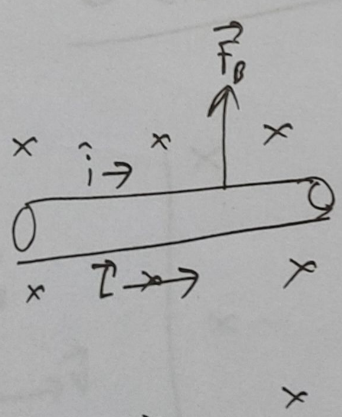
(ii)



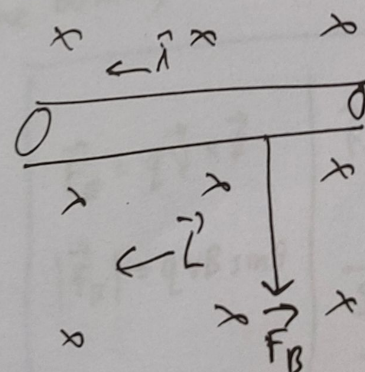
$$\vec{F}_B = i\vec{L} \times \vec{B}$$

$$= iLB\sin 90^\circ$$

(iii)



(iv)



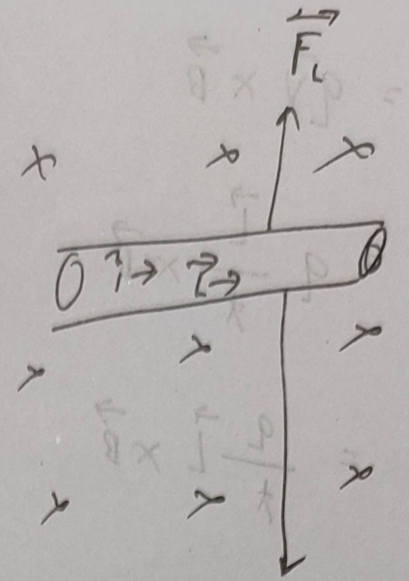
mass = m

length = L

$\vec{F}_L = i\vec{L} \times \vec{B}$

$F_L = iLB \sin 90^\circ$

$= iLB$ (up)



$m\vec{g} = \vec{F}_g$

Gravity force on ~~wire~~ conductor

$iLB = mg$

$\boxed{i = \frac{mg}{LB}}$ → balanced, no need to hold.

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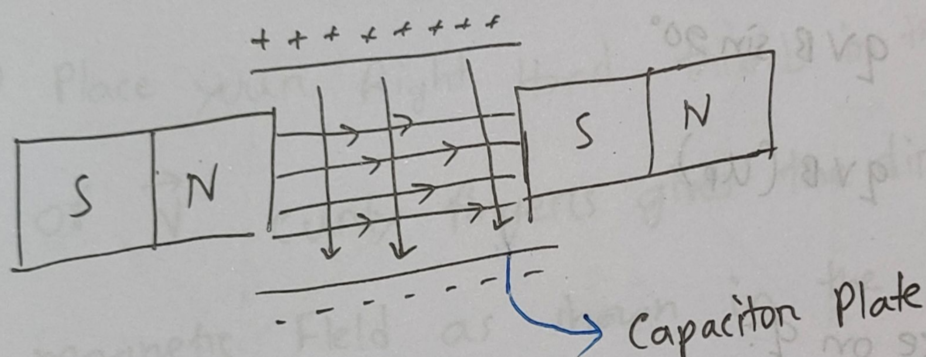
Magnetic Field:

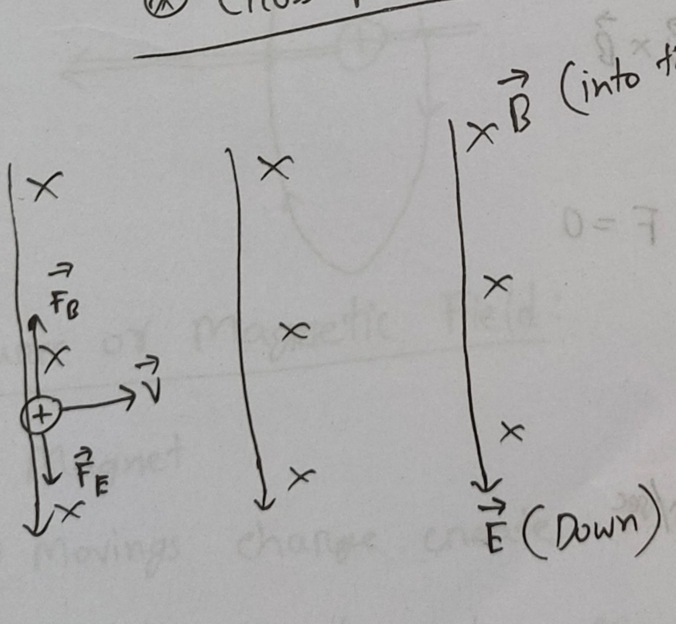
Magnetic Force on change : $\vec{F}_B = q\vec{V} \times \vec{B}$

Magnetic Force on current changing conductor

$$\vec{F}_L = i\vec{L} \times \vec{B}$$



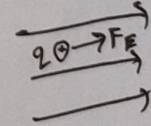
⊛ Cross Field



$\vec{F}_B = q\vec{V} \times \vec{B}$

$|\vec{F}_B| = qVB\sin\theta$

$\vec{F}_E = q\vec{E}$



Electric Force on q:

$$\vec{F}_E = q\vec{E} \quad (\text{Down})$$

$$|F_E| = qE \quad (\text{Down})$$

magnetic Force on q:

$$\vec{F}_B = q\vec{V} \times \vec{B}$$

$$|F_B| = qVB \sin 90^\circ$$

$$= qVB \ (\text{Up})$$

⊛ Total Force on q:

$$\vec{F} = \vec{F}_E + \vec{F}_B$$

$$= q\vec{E} + q\vec{V} \times \vec{B}$$

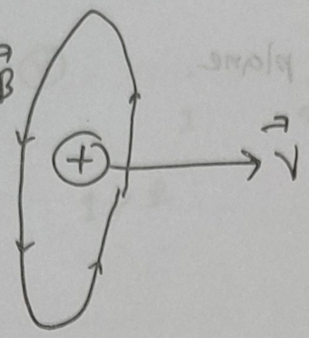
if,

$$|F_E| = |F_B| \ ; \quad F = 0$$

$$qE = qVB$$

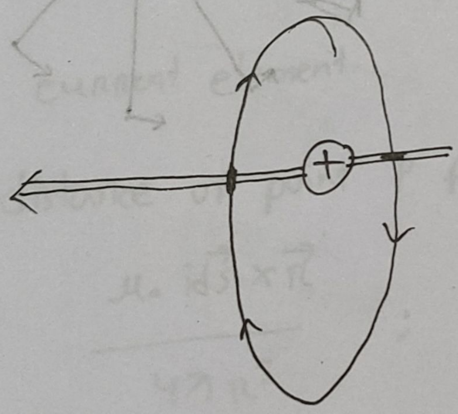
$$\boxed{V = \frac{E}{B}} \ \text{m/sec}$$

* Moving change create a circular magnetic Field.



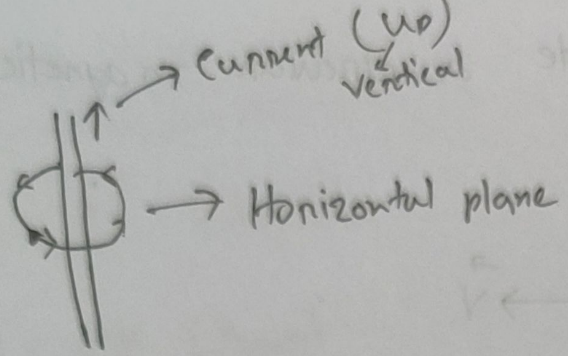
* Right Hand Rule (Direction of magnetic Field due to a moving change).

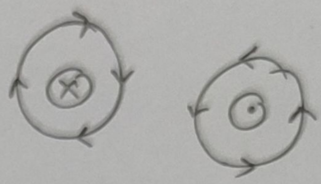
⇒ Place your Right Hand thumb in the direction of $\vec{v}$. curly fingers gives the direction of the magnetic Field as shown in the figure.

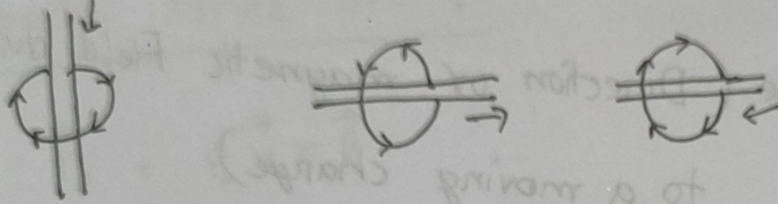


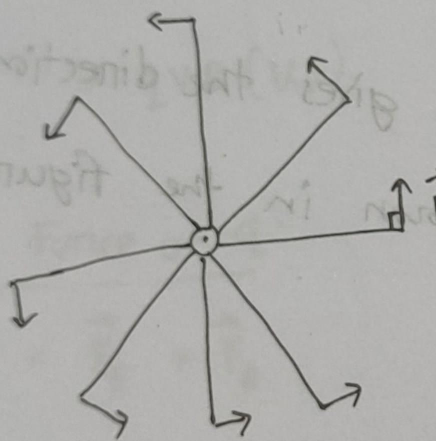
* <u>Source of Magnetic Field:</u>

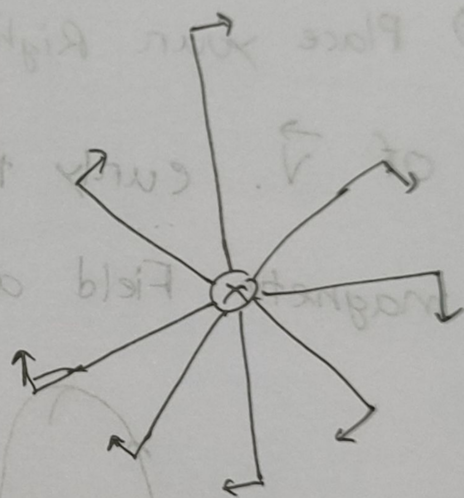
(i) Magnet
(ii) Movings change creates Magnetic Field.
(iii) Electric current produce Magnetic Field.


Current (up)
vertical
Horizontal plane






$\vec{B}$



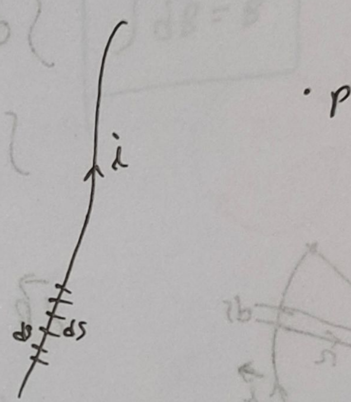
L-28/ 17.05.2023/

⊗

1 2

1 > 2

⊛ Biot - Savart Law:



s = length

i = current

$$\int ds = s$$

ds = line element

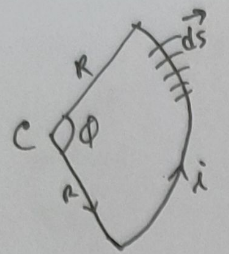
$i\vec{ds}$ = current element

$\vec{r}$ = distance of point P from ds.

$$\vec{dB} = \frac{\mu_0 \, i\vec{ds} \times \vec{r}}{4\pi r^3} \; ; \; \mu_0 = 4\pi \times 10^{-7} \text{ H/m}$$

$$|\vec{dB}| = \frac{\mu_0 \, i ds r \sin\theta}{4\pi r^3} = \frac{\mu_0 \, i ds \sin\theta}{4\pi r^2}$$

$$\vec{B} = \int_{l=0}^{l} \vec{dB}$$



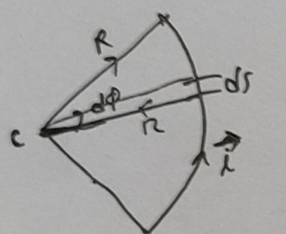
i = current

R = Radius

$$d\vec{B} = \frac{\mu_0 \, i\vec{ds} \times \vec{r}}{4\pi r^3}$$

$$\int ds = s$$

$$\int d\phi = \phi$$



$$d\vec{B} = \frac{\mu_0 \, i\vec{ds} \times \vec{r}}{4\pi r^3}$$

$$|d\vec{B}| = \frac{\mu_0 \, i ds r \sin 90^\circ}{4\pi r^3}$$

$$= \frac{\mu_0 \, i ds}{4\pi r^2}$$

$$s = R\theta$$

$$ds = Rd\theta = Rd\phi$$

$$|R| = |r|$$

$$= \frac{\mu_0 \, i R d\phi}{4\pi R^2}$$

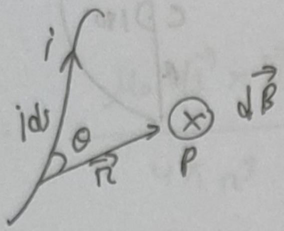
$$dB = \frac{\mu_0 \, i d\phi}{4\pi R}$$

$$B = \int dB = \int_{\phi=0}^{\phi} \frac{\mu_0 \, i d\phi}{4\pi R} = \frac{\mu_0 i}{4\pi R} \int_0^{\phi} d\phi = \frac{\mu_0 i \phi}{4\pi R}$$

$$\therefore \boxed{B = \frac{\mu_0 i \phi}{4\pi R}}$$

L-27/22.05.2023/

ids



$$i\vec{ds} = d\vec{B} = \frac{\mu_0 i \vec{ds} \times \vec{r}}{4\pi r^3}$$

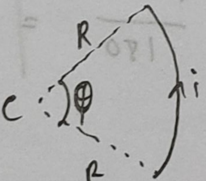
$$|d\vec{B}| = \frac{\mu_0 i ds\, r \sin\theta}{4\pi r^3}$$

$$\boxed{\begin{aligned} \Sigma dB &= B \\ \int dB &= B \end{aligned}}$$

⊛ Source of Magnetic Field:

⇒ Magnetic Field due to currents:

⊛ ARC



$$B = \int dB = \int_0^{\varphi} \frac{\mu_0 i d\varphi}{4\pi R} = \frac{\mu_0 i \varphi}{4\pi R}$$

Example:

current, $i = 2A$

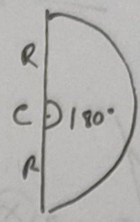
length, $s = 2m$

$\phi = \frac{\pi}{2}$

$$B = \frac{\mu_0 i\varphi}{4\pi R} = \frac{4\pi \times 10^{-7} \times 2 \times \frac{\pi}{2}}{4\pi \times 2}$$

$$= \frac{\pi}{2} \times 10^{-7}$$

⊛ $\frac{1}{2}$ Circle

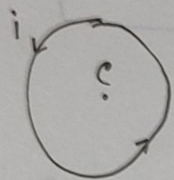


$\phi = \pi$

$$B = \frac{\mu_0 i \phi}{4\pi R} = \frac{\mu_0 i \pi}{4\pi R}$$

$$= \frac{\mu_0 i}{4R}$$

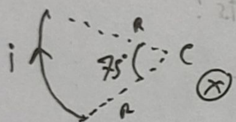
⊛



$$B = \frac{\mu_0 i \phi}{4\pi R} = \frac{\mu_0 i 2\pi}{4\pi R} = \frac{\mu_0 i}{2R}$$

⊛ 75°

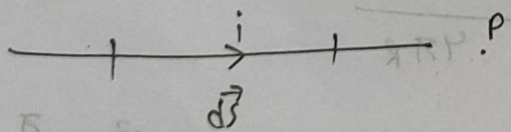
$$\phi = 75° = 75 \cdot \frac{\pi}{180}$$



$$B = \frac{\mu_0 i \phi}{4\pi R} = \frac{\mu_0 i}{4\pi R} \cdot \frac{\pi 75}{180} = \frac{\mu_0 i 75}{4R \cdot 180}$$

⊛

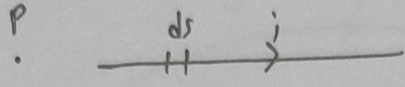
$\theta = 0$



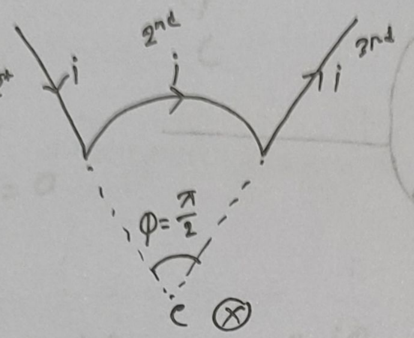
$\sin 0° = 0$

$$\vec{dB} = \frac{\mu_0 i d\vec{s} \times \vec{r}}{4\pi r^3} = \frac{\mu_0 i ds r \sin\theta}{4\pi r^3} = 0$$

$\theta = 180°$



$$d\vec{B} = \frac{\mu_0\, i\, d\vec{s} \times \vec{r}}{4\pi r^3} = \frac{\mu_0\, i\, ds\, r \sin\theta}{4\pi r^3} = 0$$



1st

$\theta = 0°$

$$B = \frac{\mu_0\, i\, ds\, r \sin\theta}{4\pi r} = 0$$

3rd

$\theta = 180°$

$$B = \frac{\mu_0\, i\, ds\, r \sin\theta}{4\pi r} = 0$$

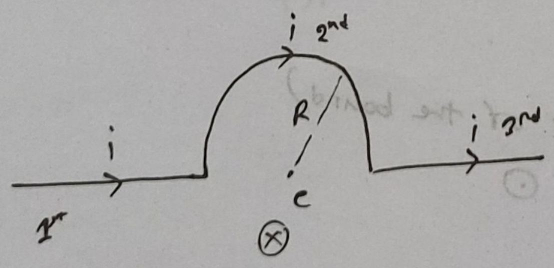
2nd

$\phi = \frac{\pi}{2}$

$$B = \frac{\mu_0 i \phi}{4\pi R}$$

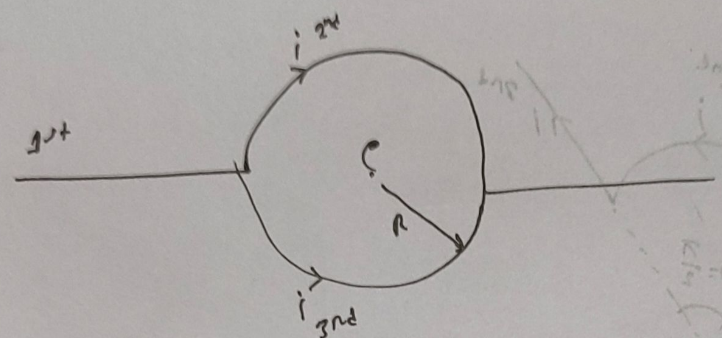
$$= \frac{\mu_0 i \pi/2}{4\pi R}$$

Find the magnetic Field at the center of the arc.



$\underline{1^{st}}$	$\underline{3^{rd}}$	$\underline{2^{nd}}$
$\theta = 0$	$\theta = 180^\circ$	$\theta = \pi$
$dB = 0$	$dB = 0$	$B = \frac{\mu_0 i \theta}{4\pi R} = \frac{\mu_0 i \pi}{4\pi R}$

⊛



$\underline{2^{nd}}$

$\phi = \pi$

$$B = \frac{\mu_0 i \phi}{4\pi R}$$

$$B_{upper} = \frac{\mu_0 \frac{i}{2} \pi}{4\pi R} \quad \text{(Into the board)} \ \otimes$$

$\underline{3^{rd}}$

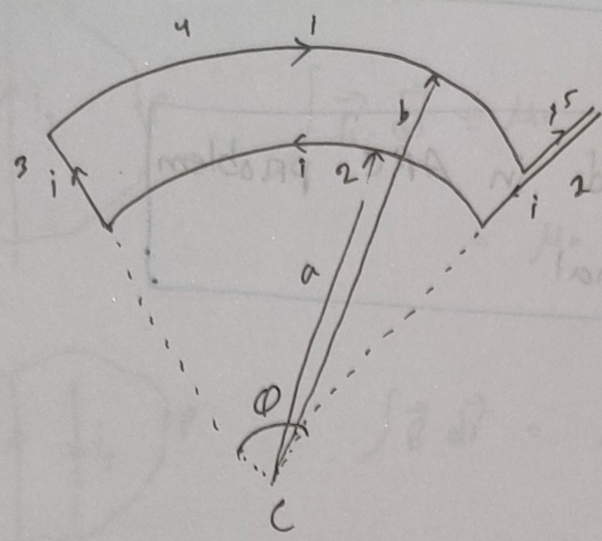
$\phi = \pi$

$$B = \frac{\mu_0 i \phi}{4\pi R}$$

$$B_{lower} = \frac{\mu_0 \frac{i}{2} \pi}{4\pi R} \quad \text{(Out of the bound)} \ \odot$$

$\therefore B = B_{upper} + B_{lower} = 0$ (cancel each other).

⊛



$$1 = 3 = 5 = B = 0$$

2nd

$$B_{inner} = \frac{\mu_0 i \phi}{4\pi R} = \frac{\mu_0 i \phi}{4\pi a} \text{ (OOB)}$$

4th

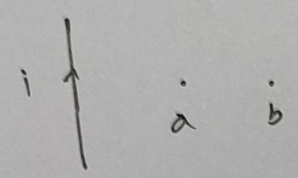
$$B_{upper} = \frac{\mu_0 i \phi}{4\pi b} \text{ (into the bound)}$$

$$B_{net} = (B_{inner} - B_{upper}) \text{ (OOB)}$$

$$= \frac{\mu_0 i \phi}{4\pi}\left(\frac{1}{a} - \frac{1}{b}\right)$$

L-30/24.05.2023/

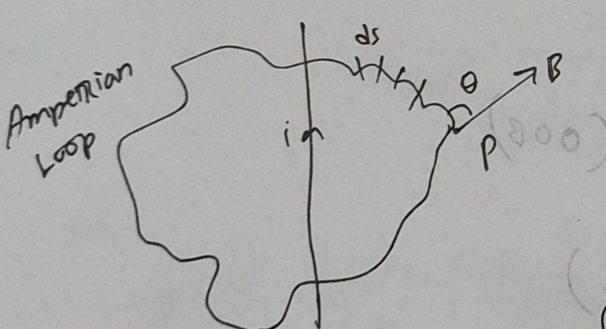
✱ Magnetic Field in ARC problem must in Final



✱ Closer distance → stronger magnetic Field.

$$\left.\begin{aligned} B &\propto i \\ B &\propto \frac{1}{r} \end{aligned}\right\} B \propto \frac{i}{r} \Rightarrow B = k\frac{i}{r} \; ; \; k = \frac{\mu_0}{2\pi}$$

✱ Ampere's Law:

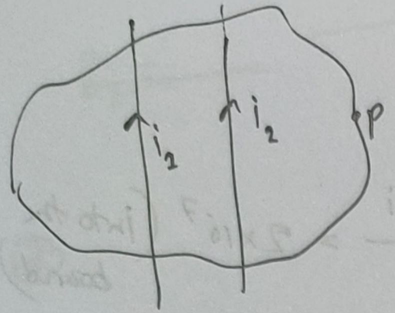


$$S = \int ds$$

$$\oint \vec{B} \cdot \vec{ds} = \mu_0 \, i_{enclosed}$$

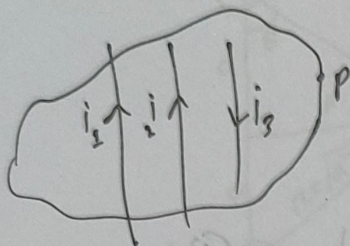
Current inclosed in Amperian loop

$$\int B \, ds \cos\theta = \mu_0 i$$

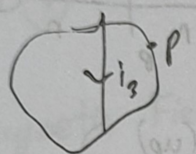


$$\int \vec{B} \cdot \vec{ds} = \mu_0 \, i_{enclosed}$$

$$= \mu_0 (i_1 + i_2)$$

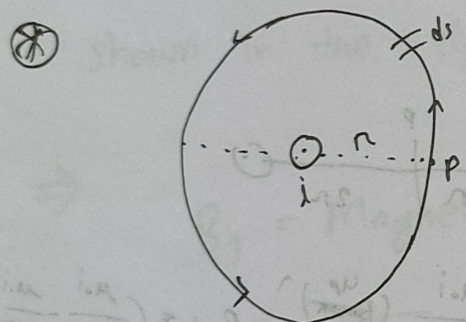


$$\int \vec{B} \, \vec{ds} = \mu_0 (i_1 + i_2 - i_3)$$



$$\oint \vec{B} \, \vec{ds} = \mu_0 \, i_{enclosed}$$

$$= -\mu_0 i_3$$



$$\int ds = s = 2\pi r$$

θ = between ds and B

$= 0°$

$$\oint \vec{B} \, \vec{ds} = \mu_0 \, i_{enclosed}$$

$$= \mu_0 i$$

$$\oint B \, ds \cos 0° = \mu_0 i$$

$$\int B \, ds = \mu_0 i$$

$$B \int ds = \mu_0 i$$

$$Bs = \mu_0 i$$

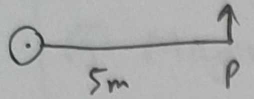
$$B \, 2\pi r = \mu_0 i$$

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

$$= \frac{4\pi \times 10^{-7} \cdot i}{2\pi r}$$

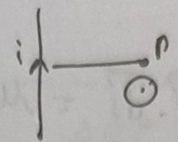
$$= \boxed{\frac{2 \times 10^{-7} \cdot i}{r}}$$

2A



$$B = \frac{\mu_0 i}{2\pi r} = \frac{4\pi\times10^{-7}\times2}{2\pi 5}$$

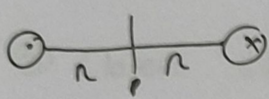
$$= \frac{4\times10^{-7}}{5}\ T$$



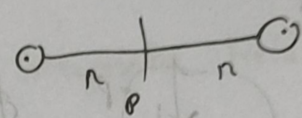
$i = 2A$

$r = 2m$

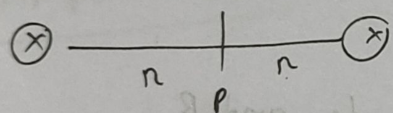
$$B = \frac{\mu_0 i}{2\pi r} = 2\times10^{-7}\ \text{(into the board)}$$



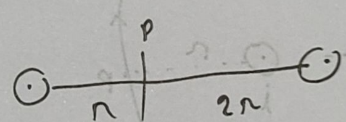
$$\left.\begin{aligned} B_1 &= \frac{\mu_0 i}{2\pi r}\ (\text{up}) \\ B_2 &= \frac{\mu_0 i}{2\pi r}\ (\text{up}) \end{aligned}\right\} B_{net} = 2\frac{\mu_0 i}{2\pi r}$$



$$\left.\begin{aligned} B_1 &= \frac{\mu_0 i}{2\pi r}\ (\text{up}) \\ B_2 &= \frac{\mu_0 i}{2\pi r}\ (\text{Down}) \end{aligned}\right\} B_{net} = 0$$



$$\left.\begin{aligned} B_1 &= \frac{\mu_0 i}{2\pi r}\ (\text{Down}) \\ B_2 &= \frac{\mu_0 i}{2\pi r}\ (\text{up}) \end{aligned}\right\} B_{net} = 0$$



$$\left.\begin{aligned} B_1 &= \frac{\mu_0 i}{2\pi r}\ (\text{up}) \\ B_2 &= \frac{\mu_0 i}{2\pi 2r}\ (\text{Down}) \end{aligned}\right\} B_{net} = \left(\frac{\mu_0 i}{2\pi r} - \frac{\mu_0 i}{4\pi r}\right)\ (\text{up})$$

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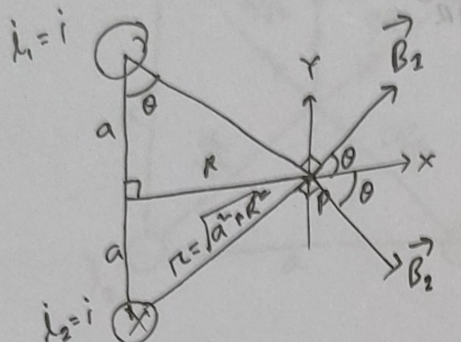
~~$B_2 =$~~



Final Must

Find Magnetic Field at Point P along the perpendicular bisector of the line joining the currents i_1 & i_2 as shown in the figure.

⇒ B_1 = Magnetic Field at P due to $i_1 = i$

$r = \sqrt{a^2+R^2}$

$$B_1 = \frac{\mu_0 i_1}{2\pi r} = \frac{\mu_0 i}{2\pi\sqrt{a^2+R^2}} \; ;$$

B_{1x} = x component of $\vec{B}_1$ = $B_1 \cos\theta$ (Right)

B_{1y} = y component of $\vec{B}_1$ = $B_1 \sin\theta$ (Up)

B_2 = magnetic field at P due to $i_2 = i$

$r = \sqrt{a^2 + R^2}$

$$B_2 = \frac{\mu_0 i_2}{2\pi r} = \frac{\mu_0 i}{2\pi\sqrt{a^2+R^2}}$$

$B_{2x} = B_2 \cos\theta$ (Right)

$B_{2y} = B_2 \sin\theta$ (Down)

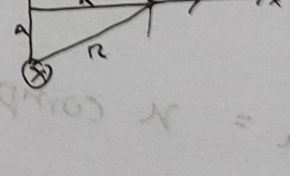
$$\vec{B}_{net} = \vec{B_1} + \vec{B_2}$$

$$= B_1 \cos\theta\ \hat{i} + B_1 \sin\theta\ \hat{j} + B_2 \cos\theta\ \hat{i} - B_2 \sin\theta\ \hat{j} \quad [B_1 = B_2]$$

$$= 2 B_1 \cos\theta\ \hat{i} \text{ (Right)}$$

$$= 2 B_2 \cos\theta\ \hat{i} \text{ (Right)}$$

B_{1y} and B_{2y} cancel each other, because same magnitude & opposite direction.



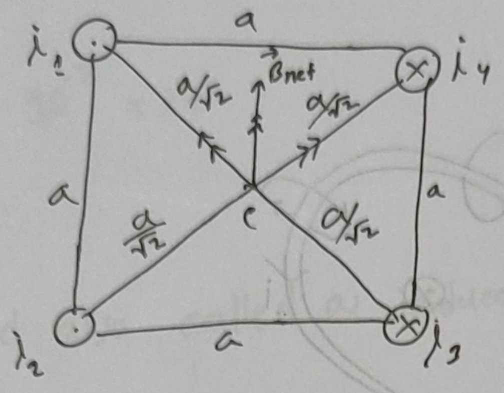
$$\therefore B_{net} = 2 B_1 \cos\theta$$

$$= 2 \times \frac{\mu_0 i}{2\pi r} \cos\theta$$

$$= 2 \cdot \frac{\mu_0 i}{2\pi\sqrt{a^2+R^2}} \cdot \frac{a}{r}$$

$$\boxed{B_{net} = \frac{\mu_0 i a}{\pi\sqrt{a^2+R^2}} \text{ (Right)}} \to \hat{i}$$

⊗ Example:



Find magnetic field at the center of the square.

$$B_1 = \frac{\mu_0 i_1}{2\pi r} = \frac{\mu_0 i}{2\pi \frac{a}{\sqrt{2}}} \text{ (towards } i_4)$$

$$B_2 = \frac{\mu_0 i}{2\pi \frac{a}{\sqrt{2}}} \text{ (towards } i_1)$$

$$B_3 = \frac{\mu_0 i}{2\pi \frac{a}{\sqrt{2}}} \text{ (towards } i_4)$$

$$B_4 = \frac{\mu_0 i}{2\pi \frac{a}{\sqrt{2}}} \text{ (towards } i_1)$$

$$B_{net} = B_1 \sin 45° + B_3 \sin 45° + B_2 \sin 45° + B_4 \sin 45°$$

$$= 4 B_1 \sin 45° \quad [\because B_1 = B_2 = B_3 = B_4]$$

$$B_{net} = \sqrt{(B_1 + B_3)^2 + (B_2 + B_4)^2} \; \hat{j}$$

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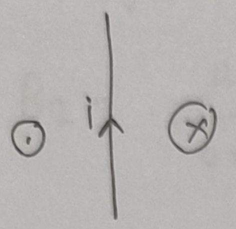
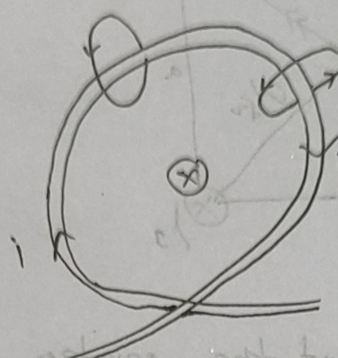
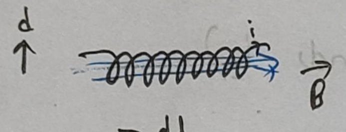




~~Solemoi~~

Solenoid:



i = current

l = length = 2m

$l >> r$

r = radius $= \frac{a}{2}$

$\therefore n = \frac{N}{l}$ = No of turn per unit length

N = total number of turn

$= 8$

$n = \frac{8}{2} = 4$

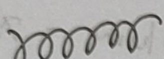
B = magnetic Field inside the solinoid.

$B = \mu_0 i_n$

$B = 4 \cdot \pi \cdot 10^{-7} \times 14$

$= T$

(*) Solenoid also called as induced

(*) 

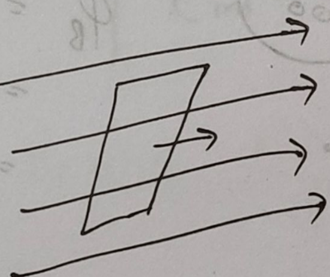
$B = \mu_0 i n$

$= 40 i \frac{N}{L} s$

(i) $\Phi_E = \vec{E} \cdot \vec{A}$

$= EA \cos\theta$

$= EA$

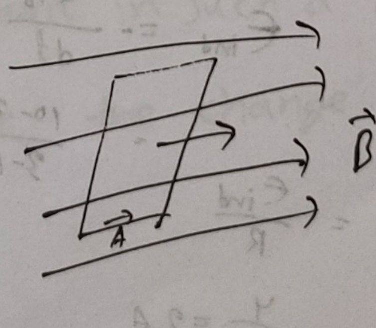


$\theta = 0°$

(ii) $30°$

$\Phi_E = EA \cos 30°$

(*) Magnetic Flux (Φ_B)



$\Phi_B = \vec{B} \cdot \vec{A} = BA \cos\theta$

$= BA \cos 0°$

$\Phi_B = BA$

①

$\phi_B \uparrow\downarrow \Rightarrow B \uparrow\downarrow$

$\phi_B \uparrow\downarrow \Rightarrow A \uparrow\downarrow$

$\Rightarrow \cos\theta \uparrow\downarrow$

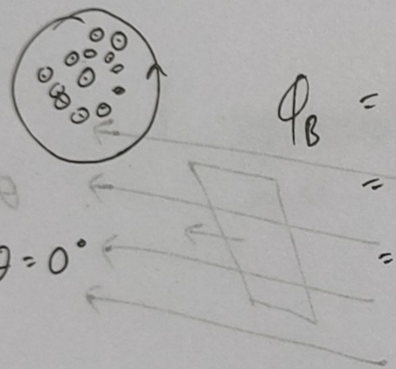
(*) X-sectional area = A

$A = \pi r^2$

$r = 0.01\,m$

Volume $= \pi r^2 l$

(*)



$\theta = 0°$

$\phi_B = \vec{B} \cdot \vec{A}$

$= BA\cos 0°$

$= BA$

$BA = (\mu_0 i n)(\pi r^2)$

$= 3.94 \times 10^{-10}\, i$

(*) Faradays Law or induction:

$\epsilon_{ind} = -\frac{d\phi_B}{dt}$

$= \frac{10-2}{3-1} = 4$ Volt

$i_{ind} = \frac{\epsilon_{ind}}{R}$

$= \frac{4}{2} = 2A$

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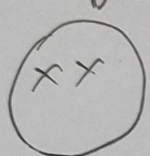
Faraday's Law of Induction

$$\epsilon_{ind} = \frac{d\phi_B}{dt}$$

$$i = \frac{\epsilon_{ind}}{R}$$

$t = 1\ sec$ $\quad B = 2$



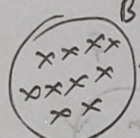
$A = 2m^2$

$\phi_B = 4$

$t = 3\ sec$

$B = 10$

$A = 2m^2$



$\phi_B = 20$

$$d\phi_B = \phi_{Bf} - \phi_{Bi}$$

$$= 20 - 4$$

$$= 16$$

$$dt = \cancel{}\ t_f - t_i = 3 - 1 = 2\ sec$$

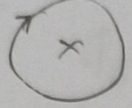
$$\epsilon_{ind} = \frac{d\phi_B}{dt} = \frac{16}{2} = 8\ Volt$$

$$i = \frac{e_{ind}}{R} = \frac{8}{2} = 4A$$

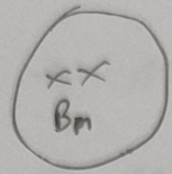
$$\epsilon_{ind} = N \frac{d\phi_B}{dt}$$

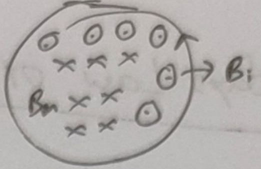
Lenz's Laws

Induced current (i) will appear in such a ~~direction~~ direction that it (i) will oppose the change that produced.



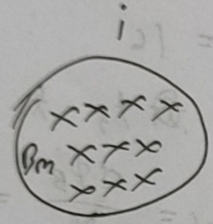
increasing B

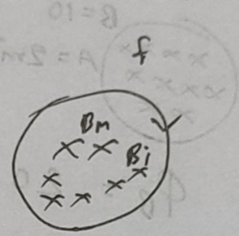




Anti Clock-Wise

decreasing B





current

Clock Wise

$$|\epsilon| = N \frac{d\phi_B}{dt} \quad ; N = 1$$

$$\epsilon = \frac{d\phi_B}{dt}$$

$$\phi_B = \vec{B}\cdot\vec{A}$$

$$= BA\cos\theta$$

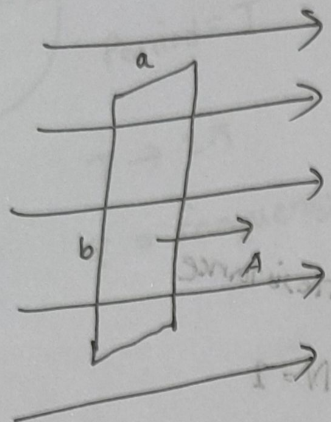
$$i \leftarrow \epsilon \leftarrow \frac{d\phi_B}{dt} \Rightarrow$$

(i) $B \uparrow\downarrow \Rightarrow \frac{dB}{dt}$

(ii) $A \uparrow\downarrow \Rightarrow \frac{dA}{dt}$

(iii) $\cos\theta \uparrow\downarrow \Rightarrow \frac{d\cos\theta}{dt}$

Example:



$$\theta(t) = \theta = \omega t$$

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

$$= BA\cos\theta$$

$$\mathcal{E}_{ind} = N\frac{d\Phi_B}{dt}$$

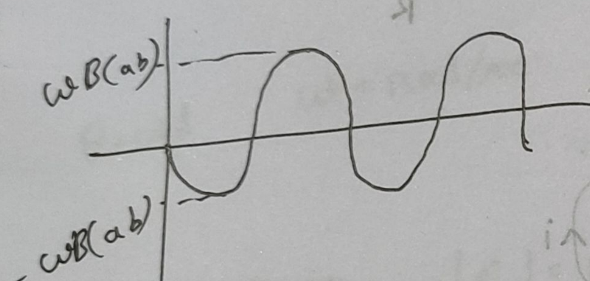
$$= N\frac{d}{dt}(BA\cos\theta)$$

$$= N\,BA\left(\frac{d}{dt}\cos\theta\right)$$

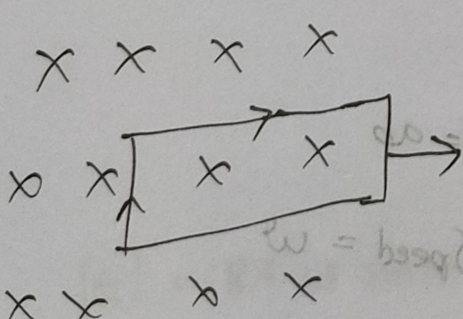
$$= N\,BA\left(\frac{d}{dt}\cos\omega t\right)$$

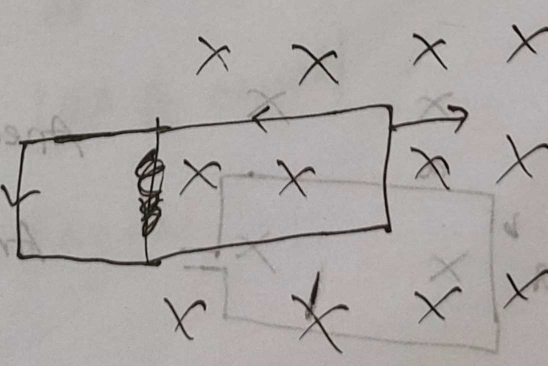
$$= -NBA\sin\omega t\,(\omega)$$

$$= -N\omega B(ab)\sin\omega t$$



Example:





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Faraday's Law

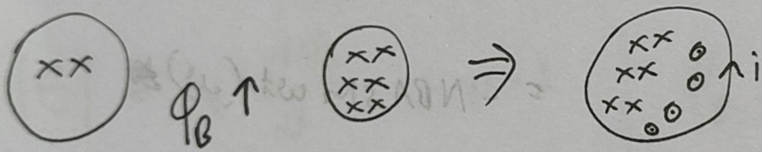
ϵ = Induced EMF = $V\epsilon_{ind}$

R = resistance

$$\epsilon = -N\frac{d\phi_B}{dt} \quad ;$$

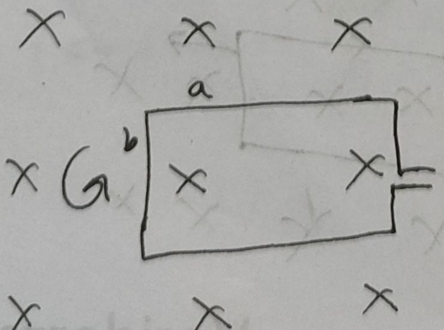
$$|\epsilon| = N\frac{d\phi_B}{dt}$$

$$\text{induced current} = i = \frac{\epsilon}{R} = \frac{N\frac{d\phi_B}{dt}}{R}$$



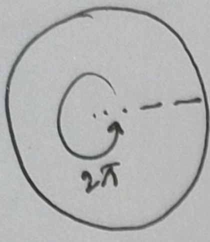
$$\frac{d\phi_B}{dt} = \epsilon \quad ; \quad i = \frac{\epsilon}{R}$$

⊛



Area, $A = ab$

Angle Speed = ω

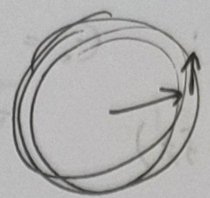


$\theta = 2\pi$

Period $= T$

$T \to 2\pi$

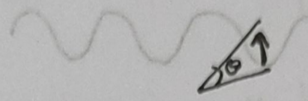
f = frequency



$f = 3$ cycle/sec

$= 3$ Hz

$T = \frac{1}{3} = \frac{1}{f}$



$\theta \Rightarrow t$

$\omega = \frac{\theta}{t}$

$T = \frac{1}{f}$

$f \to \omega$

$t = T, \quad \theta = 2\pi$

$\omega = \frac{\theta}{t} = \frac{2\pi}{T} = 2\pi f$

$\theta = \omega t \qquad \omega =$ red/sec $\qquad \omega = 2\pi f$

induced EMF $= |\epsilon| = \epsilon_{ind} = \frac{d\phi_B}{dt}$; $\phi_B = BA\cos\theta$

$\theta = \theta(t) = \omega t$

$\phi_B = BA \cos \omega t$

$= \frac{d}{dt}(BA\cos\theta)$

$= \frac{d}{dt}(BA\cos\omega t)$

$\epsilon = \left| BA \frac{d}{dt} \cos\omega t \right|$

$|\epsilon| = BA\omega \sin\omega t$; $(A = ab)$

$= B\,ab\,\omega \sin\omega t$

$\epsilon = NB\,ab\,\omega \sin\omega t \quad (N = N)$

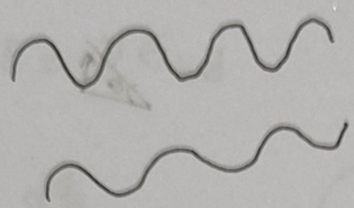
$\epsilon = \epsilon_0 \sin \omega t$; $\epsilon_0 = Bab\omega$

$= Bab2\pi f$

$\epsilon = \epsilon_0 \sin(2\pi f t)$

$\epsilon(t)$

$i(t)$



Example:

$\phi_B(t) = 6t^2 + 2t + 4$; t = time

$\phi_B = 6\cdot 0 + 2\cdot 0 + 4 = 4$

$\phi_B(1) = 6\cdot 1^2 + 2 + 4$

$= \cancel{12}\ 12$

$\epsilon = \dfrac{d\phi_B}{dt}$; $t = 2\,s$

$= \dfrac{d}{dt}(6t^2 + 2t + 4) = 12t + 2$

$t = 2$ sec ; $= 12\cdot 2 + 2$

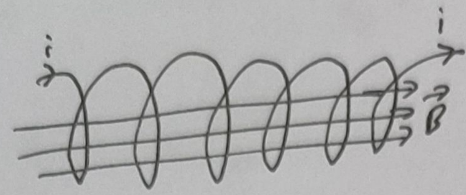
$= 24 + 2$

$= 26$ Volt

$R = 2$ Ohm

$i = \dfrac{\epsilon}{R} = \dfrac{26}{2} = 13\,A$

Example:



$i = 1.5\,A$

$n = 22000/m$

Dia = 3.2 cm

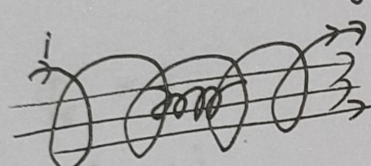
B inside solenoid = $\mu_0 i n$

$B = 4\pi \times 10^{-7} \times 1.5 \times 22000$

$= 0.041\ T$

$\Phi_B = B \cdot A = BA$

$= (\mu_0 i n)\pi r^2$



inner solenoid,

Area $= \pi r^2$

$N = 130$

dia $= 2.1$ cm

$r = \frac{2.1}{2} =$ cm

Φ_{Bi} thru inner solenoid $= \Phi_B = BA$

$= (\mu_0 i n)\pi r^2$

$= 0.041 \times \pi \times \left(\frac{2.1}{2\times 100}\right)^2$

$\Phi_{Bi} = 1.42 \times 10^{-5}$

$i = 1.5\,A \rightarrow 0A$

$\Delta t \rightarrow 25$ ms

$B_i = \mu_0 i n = 0$

$B_f = BA = 0 \cdot A = 0$

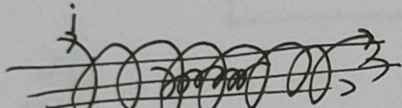
What is the induced emf in the inner coil?

$$\epsilon = N \frac{d\Phi_B}{dt} = N \frac{\Phi_{Bf} - \Phi_{Bi}}{\Delta t} = N \frac{0 - 1.42 \times 10^{-5}}{25 \times 10^{-3}}$$

$$\epsilon = 130 \left(\frac{-1.42 \times 10^{-5}}{25 \times 10^{-3}} \right)$$

$$\epsilon = 75 \times 10^{-3} \text{ Volt}$$

Example:



$i = 0, B = 0, \Phi_{Bi} = 0$

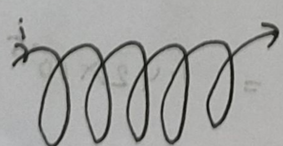
$i = 1.5, B, \Phi_{Bf} = ?$

$0 \rightarrow 1.5\,A$

$\Delta t \rightarrow 25\,ms$

$\epsilon_{ind} = ?$

㊟ Self induction:

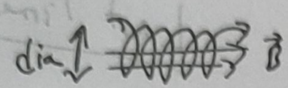


$i = 0 \rightarrow 0.4$

$\Delta t = 4$ sec

$i \to \uparrow$, $B = \mu_0 i n \uparrow$, $\varphi_B \uparrow$

$$\epsilon = -N \frac{d\varphi_B}{dt}$$



l = length

N = no of turns

n = no. of turns/length

$B = \mu_0 i n$

$r = \frac{dia}{2}$ = radius

$\varphi_B = (\mu_0 i n) A$; $i \uparrow \varphi_B \uparrow$

$i \downarrow \varphi_B \downarrow$

$\varphi_B \propto i$; $N\varphi_B$ = Flux induce

$N\varphi_B \propto i$; L = is constant

$N\varphi_B = Li$; L = inductor,

$$\epsilon = -N\frac{d\varphi_B}{dt} = -\frac{d}{dt}(N\varphi_B) = -\frac{d}{dt}(Li)$$

Self induced emf: $\boxed{\epsilon_L = -L\frac{di}{dt}}$

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Faraday's Law

Inductence

Last Time

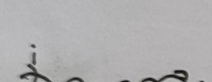
Example:

i	t
0	0 sec
0.1 A	1 sec
0.2 A	2 sec

$L = 3H$

$$\left.\begin{aligned} di &= 0.2 - 0.1 = 0.1\,A \\ dt &= 2-1 = 1\,sec \end{aligned}\right\} \frac{di}{dt} = 0.1$$

$N\phi_B = Li$



Solenoid, inductor $\quad L = 3H$

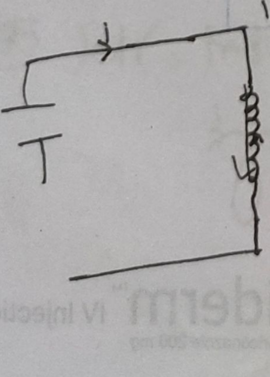
$$\epsilon_L = \left| N \frac{d\phi_B}{dt} \right| = \frac{d}{dt}(N\phi_B) = \frac{d}{dt}(Li)$$

$$|\epsilon_L| = L\frac{di}{dt} = 3 \times 0.1$$
$$= 0.3 \text{ Volt}$$
$$= \text{self induced emf}$$

Self induction:

increasing

$0 \to 0.2A$
2 sec



$$\epsilon_L = \left| L\frac{di}{dt} \right|$$