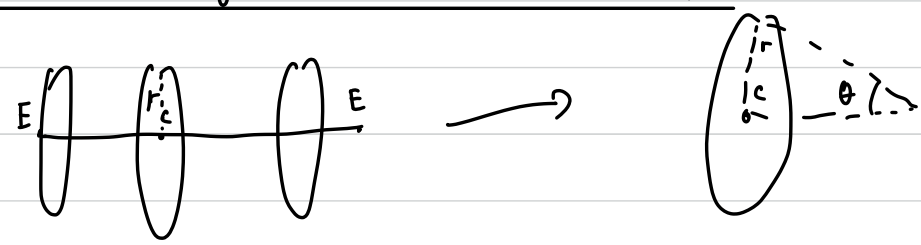
HW 1 Fisika Listrik dan Magnet.

Qornain Aji
21/481767/TK/53170

Problem ~~#~~ 1 Magnetic Field Produced by



$\boxed{A}$ Determine the magnetic field $B_{1,c}$ produced at center of this loop!

Using Biot Savart : $\dfrac{\mu_0}{4\pi} \dfrac{q\,|v|\,|\vec{r}|\sin\theta}{|\vec{r}|}$ ....(i)

we know that $I = \dfrac{\Delta Q}{\Delta t} = \dfrac{q}{\Delta s / v}$

$I\,\Delta s = q\,v$ substitute into (i)

$$B_{1c} = \frac{\mu_0}{4\pi} \frac{I\,\Delta s \cdot \cancel{|\vec{r}|} \sin\theta}{|\vec{r}|^{\cancel{3}\,2}} = \frac{\mu_0}{4\pi} \frac{I\,\Delta s \sin\theta}{|\vec{r}|^2}$$

We know that $\sum \Delta s = 2\pi R$ with $\theta = 90°$

Sigma notation is used because of the sum of all Δs = circumferences

$$B_{1c} = \frac{\mu_0}{\cancel{4\pi}_{\,2}} \frac{I\,\cancel{2\pi R}\,\sin 90°}{|\vec{r}|^{\cancel{2}}} = \frac{\mu_0 I}{2|\vec{r}|} = \frac{\mu_0 I}{2|\vec{r}|}$$

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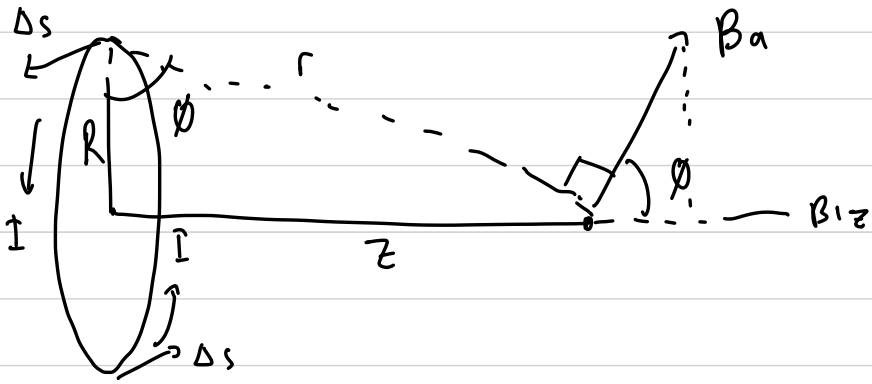
B.



We know that : $B_a = \dfrac{\mu_0 I (\Delta s \times r)}{4\pi |\vec{r}|^3} = \dfrac{\mu_0 I |\Delta s| |\vec{r}| \sin 90^\circ}{4\pi |\vec{r}|^3}$

$$= \frac{\mu_0 I \, 2\pi R}{4\pi |\vec{r}|^2} = \frac{\mu_0 I R}{2|\vec{r}|^2}.$$

Becaux $(\Delta s \times r)$ have the result of B_a that going slightly upwards. we can find B_{1z} by using $B_a \cos \emptyset$.

$$B_{1z} = B_a \cos\theta = \frac{\mu_0 I R}{2|\vec{r}|^2} \cdot \frac{R}{|\vec{r}|} = \frac{\mu_0 I R^2}{2|\vec{r}|^3} \;//$$

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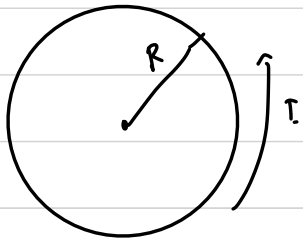
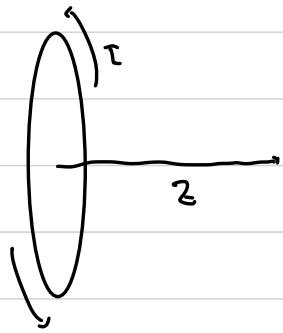
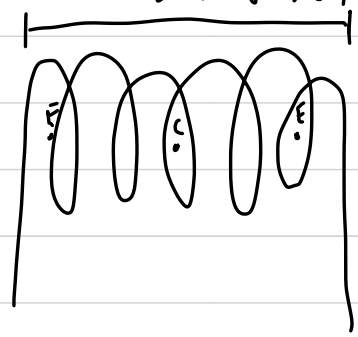
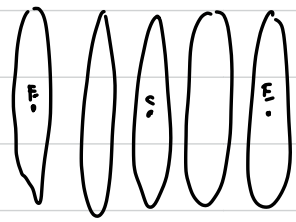






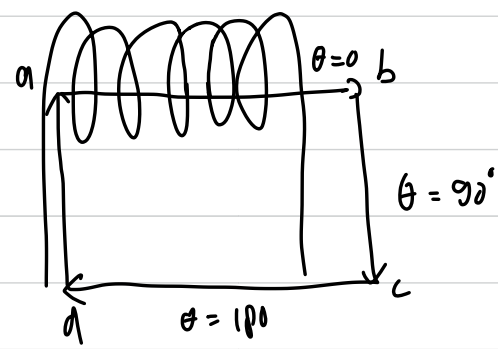
$dN = n\,dx$



c Using Ampere's Law

$$\oint B \cdot dx = \oint B\, dx \cos\theta = I_{enc}\, \mu_0$$

Consider there is an close empiran loop as follows :



$$\oint_{abcd} B\, dx \cos\theta = \int_a^b B\, dx \cos(0) + \int_b^c B\, dx \cos(90^\circ) + \int_c^d B\, dx \cos(180^\circ) + \int_d^a B\, dx \cos(90)$$

for $\int_c^d B\, dx \cos(180^\circ) = -1$; but the direction is canceled out by another B feild as shown as bellow :

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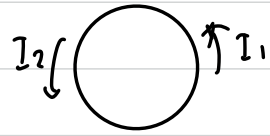


$\otimes B_{I_1}$
$\odot B_{I_2}$ } canceled each other.

So, $\int_c^d B\,dx \cos(180) \approx 0$

$$\oint_{abcd} B\,dx \cos\theta = \int_a^b B\,dx = Bx = I_{enc}\,\mu_0$$

We know that $dN = n\,dx$

$$\int dN = \int n\,dx$$

$$\boxed{N = nx} \quad \text{..... (i)}$$

We know also :

$$I_{enc} = I\,N \quad \text{substitute with (i)}$$

$$= I\,n\,x$$

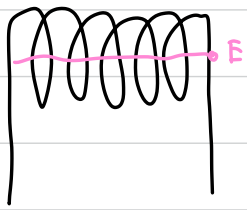
Thus

$$Bx = I\,n\,x\,\mu_0$$

$$B = I\,n\,\mu_0 = B_{sc}$$

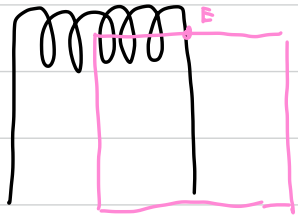
The magnetic field of B_{sc} is $\Rightarrow I\,n\,\mu_0$

D



Determine B_{se} produced at edege of this solenoid (point E)

Considered amperian :



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We can see that the length of the impertars loop has reduced by half.

$$\oint_{abcd} B\,dx = \int_a^b B\,dx = \mu_0 I_{enc}$$

$$= Bx = \mu_0 I_{enc}$$

We know that the total loop has reduced by half so:

$$d\frac{N}{2} = n\,dx$$

$$\boxed{N/2 = nx}$$

then : $I_{enc} = IN = I\frac{nx}{2}$; substitute back into the main equation

$$Bx = \mu_0 \left(I\frac{n}{2}x\right)$$

$$B = \mu_0 \frac{In}{2} = B_{se}$$

The magnetic field of B_{se} is $\Rightarrow I\frac{n}{2}\mu_0$

E Determine the value of B_{sc} and B_{se} for the case when $R \ll L$!

The value of B_{sc} and B_{se} for $R \ll L$ has no changes.

The value of B is depent on I, n, and μ_0. There is no R on the equations. Thus the value of $B_{sc} = In\mu_0$ and $B_{se} = \mu_0 \frac{In}{2}$

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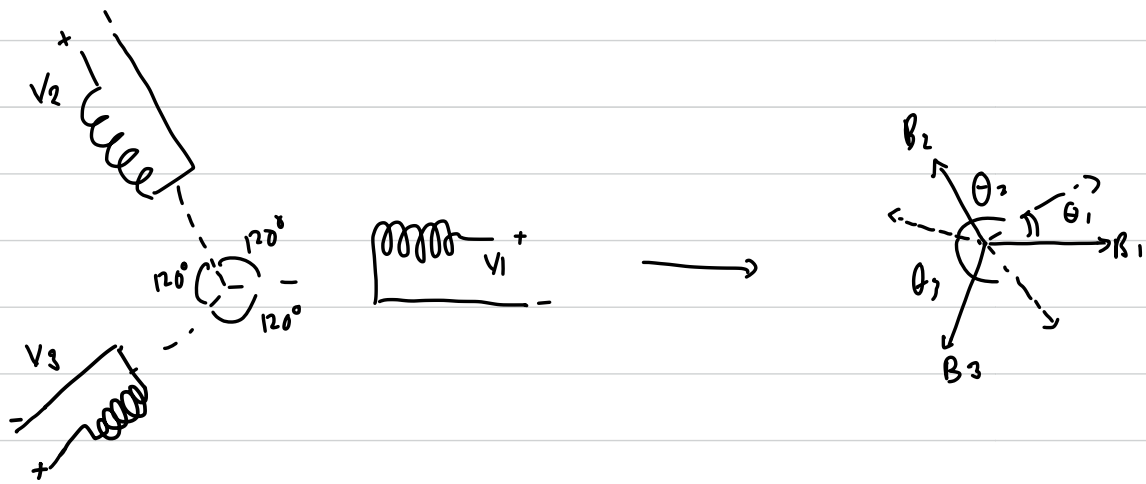
Problem #2 : Polyphase Motor



Known Variables:

$\theta_1 = 0°$

$\theta_2 = 120°$

$\theta_3 = 240°$

$B_1 = B_0 \sin(\omega_1 t + \alpha_1)$

$B_2 = B_0 \sin(\omega_2 t + \alpha_2)$

$B_3 = B_0 \sin(\omega_3 t + \alpha_3)$

A Determine value $\omega_1, \omega_2, \omega_3, \alpha_1, \alpha_2, \alpha_3$ so that counter clock wise rotation magnetic with angular velocity ω_0!

We know that the equation using sinusoidal signal wave to make smooth rotations. We can now assume that B_1 at $t=0$ has the minimum B_0 so:

$$B_1 = \cancel{B_0} \sin(\omega_1 t + \alpha_1) = 0$$

$$\sin(\omega_1 t + \alpha_1) = 0 \quad ; t=0$$

$$\sin \alpha_1 = 0$$

$$\alpha_1 = 0°$$

if B_1 has no magnetic field, than the arrow of B_0 would be the resultan of B_2 and B_3.

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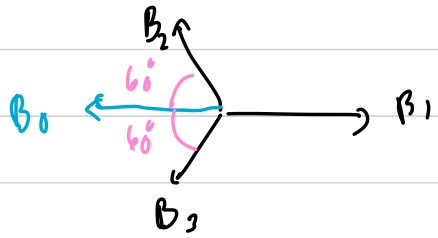
The image can be represent with this picture :



We know that in order to get B_0 maximum, we can add the $B_2 = B_0 \sin(\omega_2 t + \alpha_2)$ and $B_3 = B_0 \sin(\omega_3 t + \alpha_3)$. So the relationship between angle $60°$ with B_2 and B_3 is

- $B_2 = B_0 \sin(\omega_2 t + \alpha_2)$; with $t \Rightarrow 0 \longrightarrow B_0 \sin(\alpha_2)$

  $B_{2x} = B_0 \cos 60° = B_0 \frac{1}{2}$

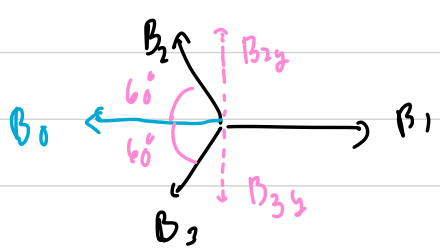
  $B_2 = B_0 \sin(\alpha_2)$ with α_2 must be $n\frac{\pi}{3}$; with $n \in R$

- $B_3 = B_0 \sin(\omega_3 t + \alpha_3)$; $t = 0 \longrightarrow B_0 \sin(\alpha_3)$

  $B_{3x} = B_0 \cos 120° = B_0\left(-\frac{1}{2}\right)$

  $B_3 = B_0 \sin(\alpha_3)$ with α_3 must be $n\frac{\pi}{3}$; with $n \in R$

We dont know the difference phase between the magnetic field, so we can inspect using the $t = 0$ picture



We can see that B_{2y} is positive while B_{3y} is negative.

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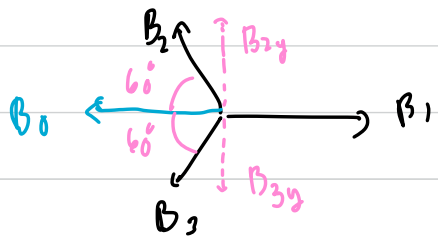


In order B_{2y} to have positive value, in quadran II, $\sin \alpha_2$ will be $120°$. For B_{3y} in quadran III, $\sin \alpha_3$ will be $240°$. all of these were in condition of $t = 0$

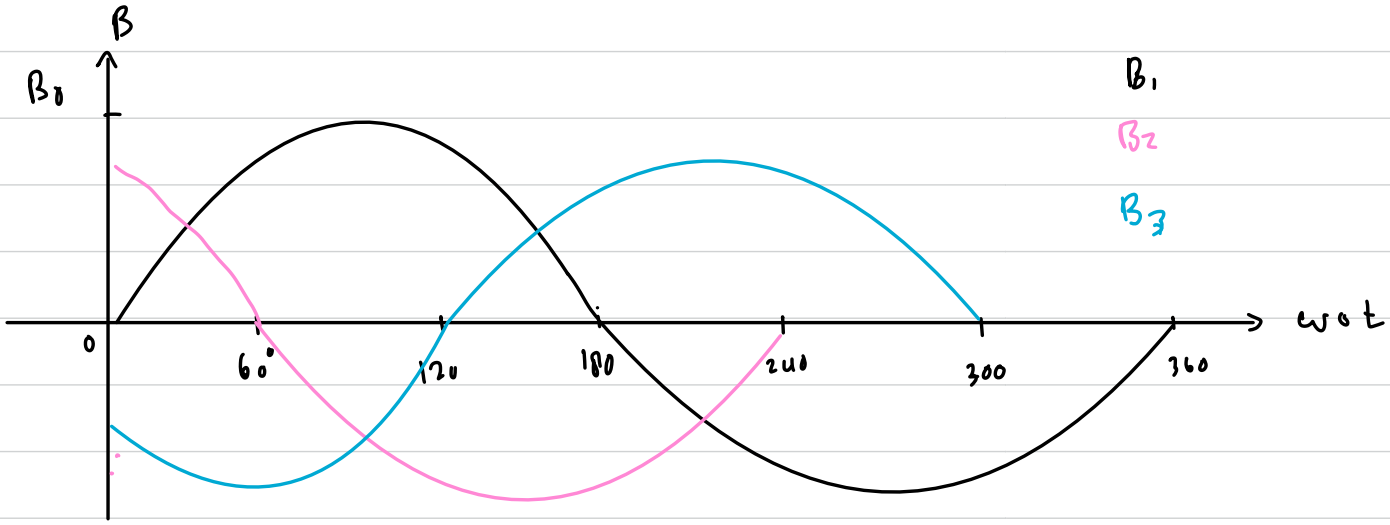
So, the wrap from B_1, B_2, B_3 is:

$$B_1 = B_0 \sin(\omega_1 t + 0°)$$
$$B_2 = B_0 \sin(\omega_2 t + 120°)$$
$$B_3 = B_0 \sin(\omega_3 t + 240°)$$

If the angular velocity is constant ω_0, then:

$$B_1 = B_0 \sin(\omega_0 t + 0°)$$
$$B_2 = B_0 \sin(\omega_0 t + 120°)$$
$$B_3 = B_0 \sin(\omega_0 t + 240°)$$

To know that if B_1, B_2 and B_3 is moving counter clock wise, we can draw the graph coordinates as below.



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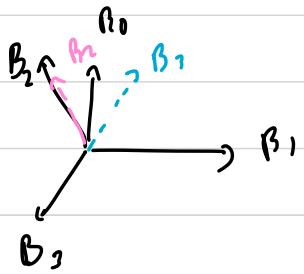
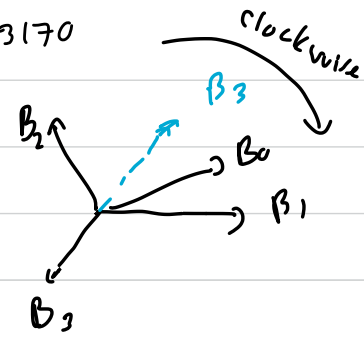
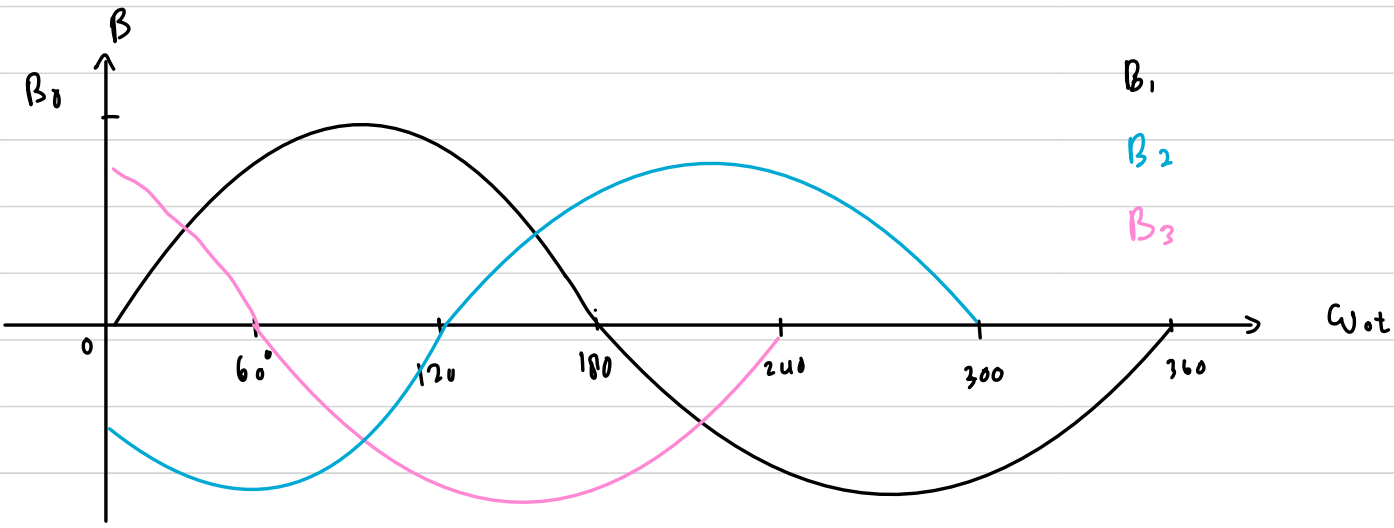
1)



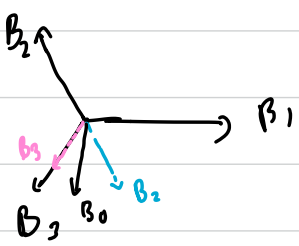
2)



As $t=0$, $B_1 = 0$, B_2 and B_3 is $\frac{\sqrt{3}}{2}$ and $-\frac{\sqrt{3}}{2}$.
thus the direction of B_0 is approximately in between B_2 and B_1.
As time goes on, B_0 will pointing towards $-B_3$ and B_1.
it shows that it is counter clock-wise. In order to fix that,
α_1, α_2 and α_3 must be 0, $-120°$, and $-240°$.



1)



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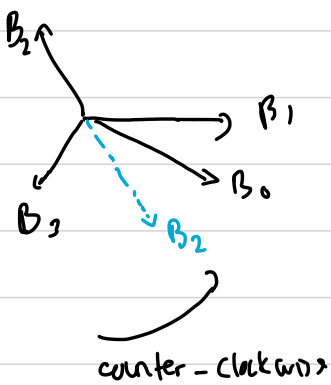

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Now, at $t=0$, $B_1 = 0$, , B_2 and B_3 is $-\frac{\sqrt{3}}{2}$ and $\frac{\sqrt{3}}{2}$.
The direction of B_0 is approximately in between B_3 and $-B_2$ As times goes on, B_0 will pointing towards $-B_2$ and B_1. It shows after the change of α_1 α_2 and α_3, the movement of B_0 is now counter clockwise.

Hence $\omega_1 = \omega_2 = \omega_3 = \omega_0$ and $\alpha_1 = 0^\circ$; $\alpha_2 = -120^\circ$; and $\alpha_3 = -240^\circ$

B Determine the value of α_1, α_2, and α_3 for clockwise rotating magnetic field.

As in explanation (A), in order to have clockwise rotating magnetic field of B_0, the value of α_1, α_2, and α_3 is 0, 120°, and 240°

C Now let us consider a general case where the coil's position are at θ_1, θ_2 and θ_3.

Determine value of α_1 α_2 and α_3 for counter-clockwise magnetic field.

We need to have α_1 α_2 and α_3 with the value of 0°, -120°, and -240°. If B_1, B_2, and B_3 is shifted in the value of θ_1, θ_2, θ_3, then the value of α_1, α_2 and α_3 will be replaced by θ_1, θ_2, and θ_3

Hence the value of α_1, α_2 and α_3 is

$\alpha_1 = -\theta_1$

$\alpha_2 = -\theta_2$

$\alpha_3 = -\theta_3$

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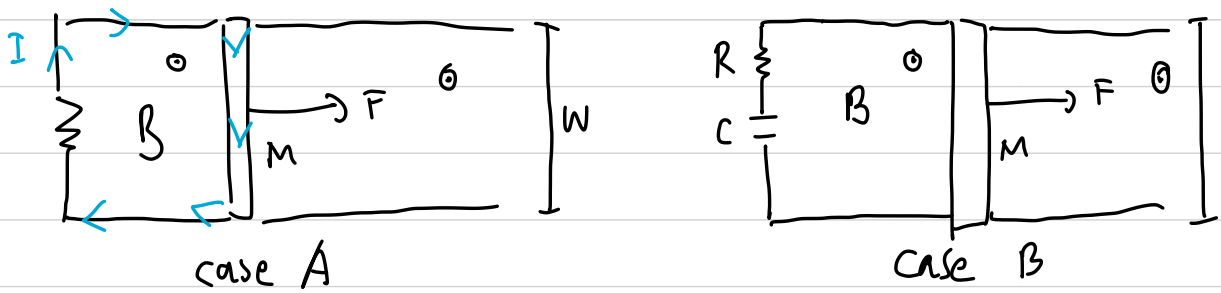
D Determine α_1, α_2 and α_3 for clockwise rotating magnetic field.
The answer is quite trivial if we look again in explanation (A).
For rotating clockwise, the value of α_1, α_2, and α_3 is $0°$, $120°$, and $240°$. If B_1, B_2 and B_3 is shifted in value of θ_1, θ_2, and θ_3; then the value of α_1 α_2 and α_3 will be.

$\alpha = \theta_1$

$\alpha_2 = \theta_2$

$\alpha_3 = \theta_3$

Problem # 3 : Moving Conductor with RC Circuit



A For Case A, determine the conductor plate velocity $v(t)$ as a function of time t! Determine also the current $I(t)$ that flows in the circuit as a function of time t!

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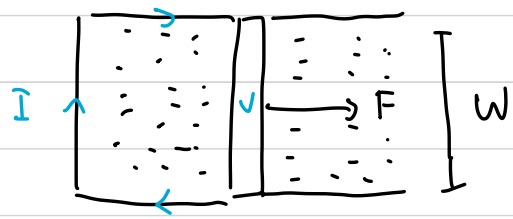
We know that the current flows counter clock wise using right hand rules.



We can use an equation of Electro magnetic force from Faraday's Law:

$$\mathcal{E} = \frac{\Delta \Phi}{\Delta t} = \frac{B \Delta A}{\Delta t} = B l \frac{\Delta s}{\Delta t} = B l v = IR$$

$$I = \frac{B l v}{R}$$

We know that Lorentz Forces principle is :

$$F_{lorenzt} = B q V$$
$$= B q \frac{W}{t} = B I W$$

After knowing the lorenzt Forces, we can calculate the net forces in the loop.

$$\Sigma F = ma$$
$$F - F_{lorenzt} = ma$$
$$F - BIW = ma$$
$$F - B\left(\frac{BWV}{R}\right)W = m \cdot a$$
$$F - \frac{B^2 W^2 V}{R} = m \frac{dv}{dt}$$

$$\left(\frac{F}{m} - \frac{(BW)^2 V}{Rm}\right) = \frac{dv}{dt}$$

$$dt = \frac{dv}{\left(\frac{F}{m} - \frac{(BW)^2 V}{m}\right)}$$

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Using

$$\frac{F}{m} - \frac{(BW)^2}{RM} v = x$$

$$-\frac{(BW)^2}{RM} dv = dx$$

$$dv = dx \frac{RM}{(BW)^2}$$

; we can substitute into the main equation.

Substitute:

$$dt = \frac{1}{x} \frac{-Rm}{(BW)^2} dx$$

Integral Both side:

$$\int dt = \frac{-Rm}{(BW)^2} \int \frac{1}{x} dx$$

$$t = \frac{-Rm}{(BW)^2} \ln x + C$$

Substitute back : $x = \frac{F}{m} - \frac{(BW)^2}{RM} v$

$$t = \frac{-Rm}{(BW)^2} \ln \left(\frac{F}{m} - \frac{(BW)^2}{RM} v \right) + c$$

We know that the initial condition at $t = 0$; $v = 0$

$$0 = \frac{-RM}{(BW)^2} \ln \left(\frac{F}{m} \right) + C$$

$$C = \frac{Rm}{(BW)^2} \ln \left(\frac{F}{m} \right)$$

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The particular solutions :

$$t = -\frac{Rm}{(BW)^2} \ln\left(\frac{F}{m} - \frac{(BW)^2}{Rm} v\right) + \frac{Rm}{(BW)^2} \ln\left(\frac{F}{m}\right)$$

$$t = \frac{Rm}{(BW)^2}\left(\ln\left(\frac{F}{m}\right) - \ln\left(\frac{F}{m} - \frac{(BW)^2}{Rm} v\right)\right)$$

$$t = \frac{Rm}{(BW)^2} \ln\left(\frac{\frac{F}{m}}{\frac{F}{m} - \frac{(BW)^2}{Rm} v}\right)$$

$$t\frac{(BW)^2}{Rm} = \ln\left(\frac{\frac{F}{m}}{\frac{F}{m} - \frac{(BW)^2}{Rm} v}\right)$$

$$e^{t\frac{(BW)^2}{Rm}} = \frac{\frac{F}{m}}{\frac{F}{m} - \frac{(BW)^2}{Rm} v}$$

$$e^{-t\frac{(BW)^2}{Rm}} = \frac{\frac{F}{m} - \frac{(BW)^2}{Rm} v}{F/m}$$

$$\frac{F}{m} e^{-t\frac{(BW)^2}{Rm}} = \frac{F}{m} - \frac{(BW)^2}{Rm} v$$

$$\frac{F}{\cancel{m}}\left(e^{-t\frac{(BW)^2}{Rm}} - 1\right) = -\frac{(BW)^2}{R\cancel{m}} v$$

$$\frac{FR}{(BW)^2}\left(1 - e^{-t\frac{(BW)^2}{Rm}}\right) = v(t)$$

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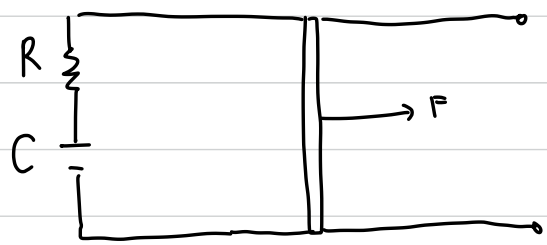
$$V(t) = \frac{FR}{(BW)^2}\left(1 - e^{-t\frac{(BW)^2}{Rm}}\right)$$

Subtitute V into

$$I = \frac{BWV}{R}$$

$$I(t) = \frac{BW}{R}\frac{FR}{(BW)^2}\left(1 - e^{-t\frac{(BW)^2}{Rm}}\right) \quad //$$

B Case B



Determine also the current I (t) and velocity V(t) for Case B!

As we know, that capasitor in the loop doesn't have any resistance. The current will by pass the loop just like Case A. After a while, the capasitor become fully charged. when the capasitor is fully charged, the current will be stopped when $t \to \infty$

$$I(\infty) = \frac{BW}{R}\frac{FR}{(BW)^2}\left(1 - e^{0}\right) = \frac{BW}{R}\frac{FR}{(BW)^2}(1-1) = 0$$

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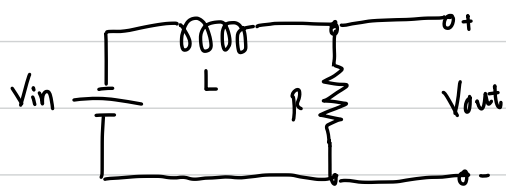
If $I(\infty)$ is 0

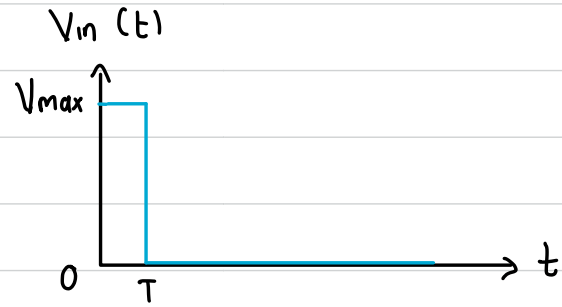
Because of $I(\infty) \approx V(\infty)$

then $V(\infty)$ also $= 0$ because :

$$I = \frac{B l v}{R} \quad //$$

Problem # 4 : Impulse Response

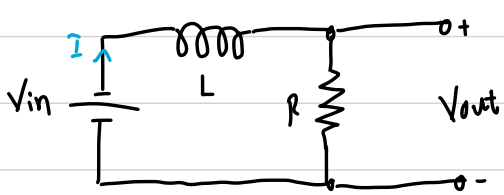




$$V_{in} \begin{cases} V_{max} & 0 \leq t \leq T \\ 0 & \text{otherwise} \end{cases}$$

assume $t = 0$; $I = 0$.

A Determine the output voltage Vout as a function of time t!



We know that $V_{in} = V_{max}$. The total of all Voltage is

$V_{max} = V_L + V_R$ .... (1)

$V_L = L \frac{dI}{dt}$ ... (2)

$V_R = I R$ .... (3)

Substitute (2) and (3) into (1)

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$$V_{max} = L\frac{dI}{dt} + IR$$

∴ isolate dt

$$V_{max} - IR = L\frac{dI}{dt}$$

$$dt = \frac{L\,dI}{V_{max} - IR}$$

Integral both side :

$$\int_0^T dt = L\int_0^I \frac{dI}{V_{max} - IR}$$

$$T = L\int_0^I \frac{dI}{V_{max} - IR}$$

assume that :

$V_{max} - IR = x$

$-R\,dI = dx$ .... (1) subtitute into dI

$$T = \frac{-L}{R}\int \frac{dx}{x}$$

$$T = \frac{-L}{R}\ln x\,\Big] \rightarrow T = \frac{-L}{R}\ln(V_{max} - IR)\Big]_0^I$$

$$T = -\frac{L}{R}\left(\ln(V_{max} - IR) - \ln(V_{max})\right)$$

$$\frac{-TR}{L} = \ln\left(\frac{V_{max} - IR}{V_{max}}\right)$$

$$e^{-\frac{TR}{L}} = 1 - \frac{IR}{V_{max}}$$

$$e^{-\frac{R}{L}T} - 1 = -\frac{IR}{V_{max}}$$

$$I = \frac{V_{max}}{R}\left(1 - e^{-\frac{R}{L}T}\right) \;//$$

We want to find V_{out}. We can see in the picture that $V_{out} = V_R = IR$

Thus:

$$V_{out} = IR = \frac{V_{max}}{\cancel{R}}\left(1 - e^{-\frac{R}{L}T}\right)\cancel{R}$$

$$\boxed{V_{out} = V_{max}\left(1 - e^{-\frac{R}{L}T}\right)} \;//$$

B Assume that the time interval T is very short so that $T \rightarrow 0$, and $V_{max}\,T \approx \Phi_{imp}$. Show that the output voltage V_{out} can be approximated by the following equation :

$$V_{out}(t) \approx \left(\frac{\Phi_{imp}}{T}\right)e^{-t/\tau} \quad \text{where } \tau = \frac{L}{R}$$

We know that:

$$V_{out} = V_{max}\left(1 - e^{-\frac{R}{L}T}\right) \quad ; \text{ substitute } T = \frac{L}{R}$$

$$= V_{max}\left(1 - e^{-\frac{T}{T}}\right)$$

(Continue in next page) *

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Another technique for a verry short interval is to examine taylor series on $e^{-\frac{T}{\tau}}$

$$e^{\frac{T}{\tau}} = 1 + \frac{T}{\tau} + \left(\frac{T}{\tau}\right)^2 \frac{1}{2!} + \left(\frac{T}{\tau}\right)^3 \frac{1}{3!} + \ldots\ldots$$ substitute into V_{out}

$$V_{out} = V_{max}\left(1 - e^{-\frac{T}{\tau}}\right) = V_{max}\left(\frac{e^{\frac{T}{\tau}} - 1}{e^{\frac{T}{\tau}}}\right) = V_{max}\left(e^{\frac{T}{\tau}} - 1\right)e^{-\frac{T}{\tau}}$$

$$V_{out} = V_{max}\left(\left(1 + \frac{T}{\tau} + \left(\frac{T}{\tau}\right)^2 \frac{1}{2!} + \ldots\right) - 1\right)e^{-\frac{T}{\tau}}$$

See that if $T \to 0$, than all of higher order except order 0 will be perish. But for this question, we will take until order 1 to prove the problem.

$$V_{out} = V_{max}\left(\left(1 + \frac{T}{\tau}\right) - 1\right)e^{-\frac{T}{\tau}}$$

$$V_{out} = V_{max}\frac{T}{\tau} \cdot e^{-\frac{T}{\tau}}$$; We know that $V_{max}\,T = \Phi_{imp}$; then substitute it.

$$\boxed{V_{out} = \frac{\Phi_{imp}}{\tau} e^{-\frac{T}{\tau}}}$$ //