MM 5

(1) Electrodynamic principle

Lorenz force

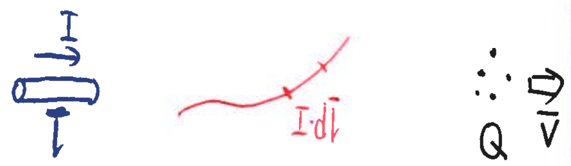
Current in a conducting wire

speed

$$\bar{I}\cdot\bar{l} = Q\cdot\bar{V} \quad [A\cdot m]$$

$$\begin{bmatrix} A\cdot m & A\cdot s\cdot\frac{m}{s} \\ A\cdot m & A\cdot m \end{bmatrix}$$

» Current moment «



[A·m] [A·m] [A·m]

Forces on a charge

Charges are affected by magnetic and electric field:

Magnetic field

Laplace's law: $\bar{F}_M = I\,\bar{l}\times\bar{B} = Q\cdot\bar{V}\times\bar{B}$ [N]

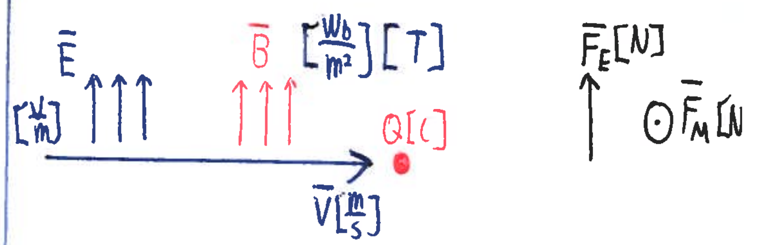
Electric field

$$\bar{E} = \frac{\bar{F}}{Q} \Rightarrow \bar{F}_E = Q\bar{E} \quad [N]$$

The sum of forces

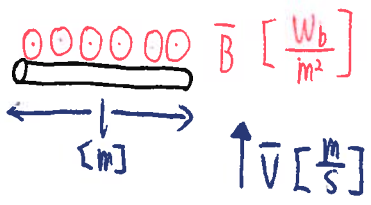
$$\bar{F} = \bar{F}_E + \bar{F}_M = Q\,(\bar{E} + \bar{V}\times\bar{B}) \quad [N]$$

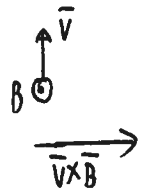
Lorenz force

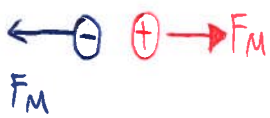


(2) Electrodynamic principle

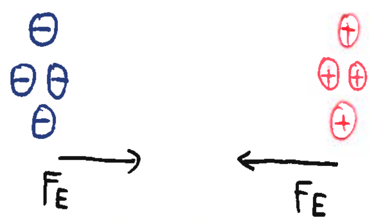
A metal rod moves through a magnetic field







This will create an electric field.



Therefore, it will create a equal weight.

So we have

$$\bar{F}_{ToT} = \bar{F}_M + \bar{F}_E = \bar{0}$$

$$\bar{F}_M = -\bar{F}_E$$

$$|\bar{F}_M| = |\bar{F}_E|$$

$$Q \cdot V \cdot B = QE$$

$$VB = E$$

$$VB = \frac{V}{l}$$

$$V = B \cdot l \cdot v \ [V]$$

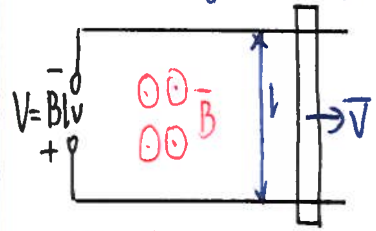
↑ voltage ↑ speed

$$\bar{v} \times \bar{B} = |\bar{v}| \cdot |\bar{B}| \cdot \sin\theta \cdot \hat{n}$$

(θ is the angle between $\bar{v}$ and $\bar{B}$)

Electrodynamic generator:

(Voltage generator)



$\bar{v} \times \bar{B}$

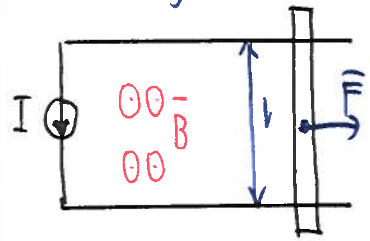
↓

voltage.

Move the rod to generate voltage.

Electrodynamic motor:

(force generator)



Laplace's law

$\bar{F} = I\bar{l} \times \bar{B}$

$F = BlI$

Add currents to move the rod.

Electrodynamic basic formula:

$$\begin{cases} V = Blv \ [V] & \text{Voltage} \\ F = BlI \ [N] & \text{Force} \end{cases}$$

(3) Exercise 1

a) Power delivered to R

Current in R

$$I_1 = \frac{V}{R} = \frac{Blv}{R} \ [A]$$

or

$$I_2 = \frac{F}{Bl} \ [A]$$

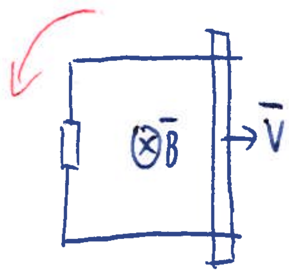
$$\Rightarrow I_1 \cdot I_2 = \frac{Blv}{R} \cdot \frac{F}{Bl} = \frac{F \cdot v}{R}$$

$$= I^2$$

$$P_R = I^2 R$$

b) $P_{MEK} = F_{app} \cdot V$

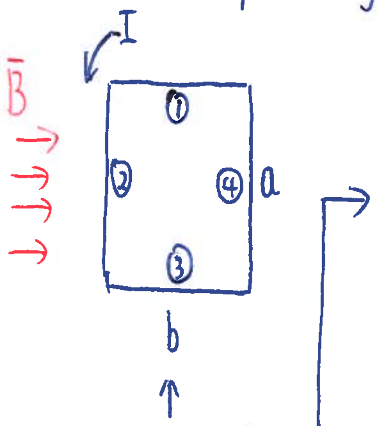
c) Current ~~[illegible]~~ flow direction

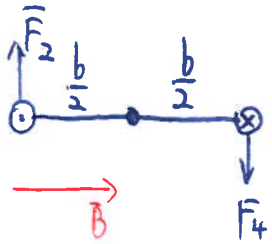


We can use lenz's law or $\bar{V} \times \bar{B}$ to find current direction. (all use right hand)

(4) Moment in magnetic field

Current loop in magnetic field





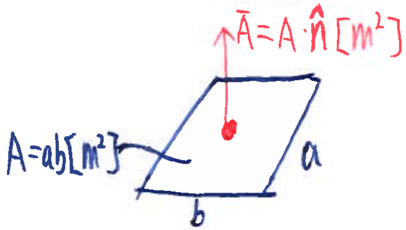
$F_2 = F_4 = B \cdot a \cdot I$

$$\begin{aligned} \tau &= \text{force} \cdot \text{arm} \\ &= \frac{b}{2} \cdot \bar{F}_2 + \frac{b}{2} \cdot \bar{F}_4 \\ &= (B \cdot a I \cdot \frac{b}{2}) \times 2 \\ &= BabI \ [N \cdot m] \end{aligned}$$

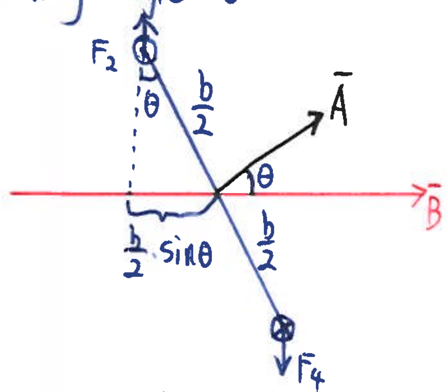
We introduce the area

$A = ab \ [m^2]$

$\tau = IAB \ [N \cdot m]$



Turning angle θ



So we have:

$\bar{\tau} = IN(\bar{A} \times \bar{B}) \quad [N \cdot m]$

N is the turns in the loop.

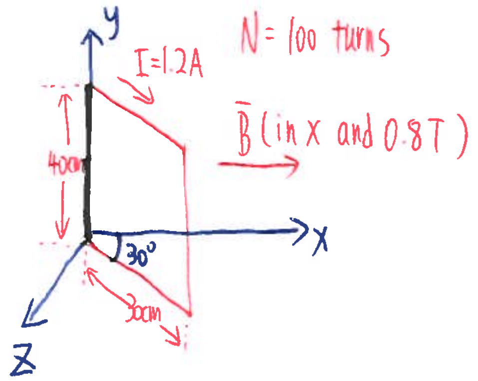
The magnetic dipole moment for loop can be defined.

$\bar{\mu} = I \cdot N \cdot \bar{A}$

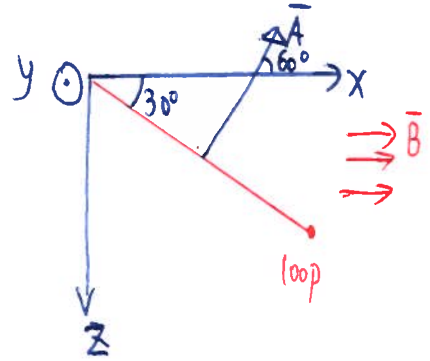
So the turning moment $\bar{\tau}$ (torque)

$\bar{\tau} = \bar{\mu} \times \bar{B} \quad [N \cdot m]$

(5) Exercise 2



We see in $-y$ direction



Magnetic dipole moment

$$\bar{\mu} = I \cdot N \cdot \bar{A}$$

$$= 1.2 \cdot 100 \cdot 0.3 \cdot 0.4 \cdot \begin{bmatrix} \cos 60^\circ \\ 0 \\ -\sin 60^\circ \end{bmatrix} \begin{matrix} \frac{1}{2} \\ \\ -\frac{\sqrt{3}}{2} \end{matrix}$$

$$\bar{B} = \begin{Bmatrix} 0.8 \\ 0 \\ 0 \end{Bmatrix}$$

Turning moment

$$\bar{T} = \bar{\mu} \times \bar{B} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \mu_x & \mu_y & \mu_z \\ B_x & B_y & B_z \end{vmatrix} = \begin{vmatrix} \hat{x} & \hat{y} & \hat{z} \\ \mu_x & 0 & \mu_z \\ B_x & 0 & 0 \end{vmatrix} = \begin{Bmatrix} 0 \\ \mu_z \cdot B_x \\ 0 \end{Bmatrix}$$

$$= 1.2 \cdot 100 \cdot 0.12 \cdot \left[-\frac{\sqrt{3}}{2}\right] \cdot 0.8 \cdot \hat{y} \approx -10\hat{y} \; [N \cdot m]$$