ZOOMING 295 "MONDAY'S CLASS"

- LAST TIME (FRIDAY APRIL 12):

$$\boxed{\begin{aligned} E &= \gamma m c^2 \\ \vec{P} &= \gamma m \vec{v} \end{aligned}}$$

$$E = \gamma(E' + v p')$$

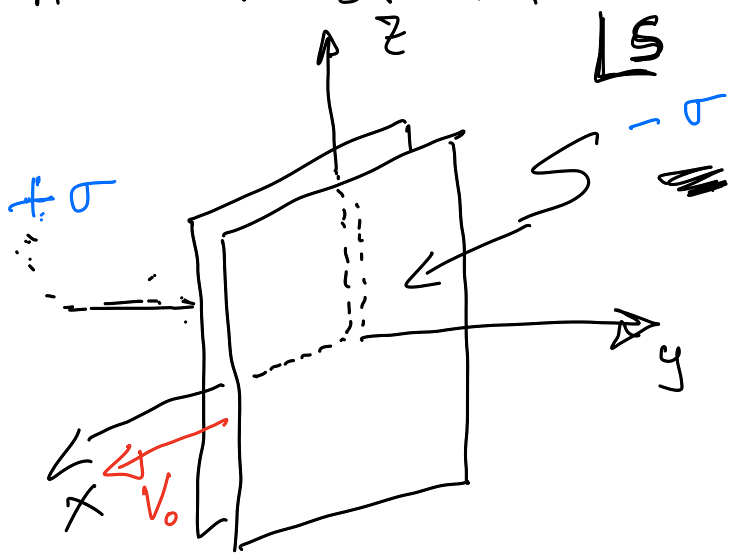
$$P = \gamma\left(p' + \frac{vE'}{c^2}\right)$$

IF E - P ARE CONSERVED IN ONE REF. FRAME, THEY ARE CONSERVED IN ALL INERTIAL FRAME.

- TODAY:
  - $\vec{E}$ AND $\vec{B}$ FIELD TRANSFORMATIONS
  - $\vec{F} = q\vec{v} \times \vec{B} \longrightarrow \underline{\underline{I\vec{l} \times \vec{B}}}$
  - TORQUE ON A LOOP OF CURRENT

IN THE S FRAME

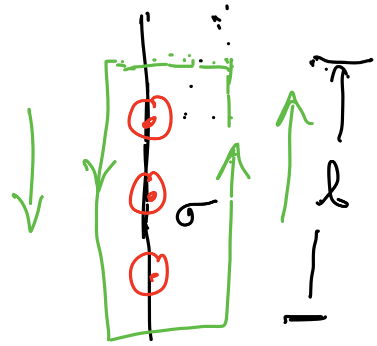
- $\vec{E} = \frac{\sigma}{\epsilon_0}\hat{j}$
- σ CHARGE DENSITY IN S



$$\sigma = \sigma_{REST}\,\gamma_{v_0}$$

$$\vec{K} = \sigma \vec{V}_0 = \sigma v_0 \hat{\imath}$$

$$\vec{B} = \mu_0 K \hat{k} = \mu_0 \sigma v_0 \hat{k}$$



$$\oint \vec{B}\cdot d\vec{l} = \mu_0 I_{enc}$$

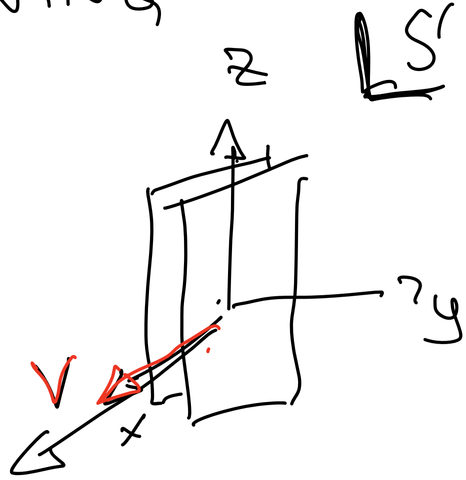
$$2Bl = \mu_0 K l$$

For 1 sheet

$$|\vec{B}| = \frac{\mu_0 K}{2}$$

SWITCH FRAME TO S' MOVING

$$\vec{V} = V\hat{\imath}$$



$$V_0' = \frac{V_0 - V}{1 - \frac{V_0 V}{c^2}}$$

$$\sigma \rightarrow \sigma' = \gamma_{v_0'}\,\sigma = \underbrace{\sigma_{REST}\,\gamma_{v_0}}_{\sigma}\,\gamma_V\left(1 - \frac{V_0 V}{c^2}\right)$$

$$\sigma' = \sigma\,\gamma_V\,(1 - V_0 V)$$

$$K \rightarrow K' = \sigma' \frac{V_0 - V}{1 - V_0 V}$$

$$= \sigma \gamma_v \cancel{\left(1 - V_0 V\right)} \frac{(V_0 - V)}{\cancel{1 - V_0 V}}$$

$$\bullet \; |E'| = \frac{\sigma'}{\epsilon_0} = \frac{\sigma \gamma_v \left(1 - \frac{V_0 V}{c^2}\right)}{\epsilon_0}$$

But $\mu_0 = \frac{1}{\epsilon_0 c^2}$

$$= \gamma_v \left(\frac{\sigma}{\epsilon_0} - V \frac{\sigma V_0}{\epsilon_0 c^2} \right)$$

$$\boxed{E'_y = \gamma \left(E_y - V B_z \right)}$$

$$\bullet \; B' = \mu_0 k'$$

$$= \mu_0 \sigma \gamma (V_0 - V)$$

$$= \gamma \left(\underline{\mu_0 \sigma V_0} - \mu_0 \sigma V \right)$$

$$= \gamma \left(B - \frac{\sigma}{\epsilon_0 c^2} V \right)$$

$$\Rightarrow \boxed{B'_z = \gamma \left(B_z - V E_y \right)}$$

IN GENERAL, IF COMPONENT OF FIELD IS ∥ (PARALLEL) TO $\vec{v}$ WE'LL CALL THIS $E_{\parallel}$ OR $B_{\parallel}$

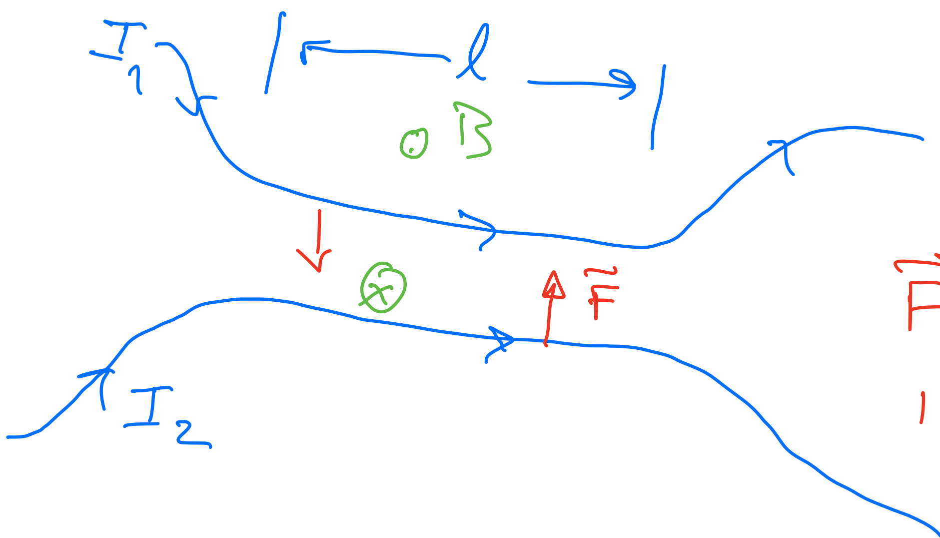
IF PERP. THEN WE'LL USE $\perp$

$$\boxed{\begin{cases} E'_{\parallel} = E_{\parallel} \\ \vec{E}'_{\perp} = \gamma\left(\vec{E}_{\perp} + \vec{v} \times \vec{B}_{\perp}\right) \end{cases} \quad \begin{cases} B'_{\parallel} = B_{\parallel} \\ \vec{B}'_{\perp} = \gamma\left(\vec{B}_{\perp} - \frac{\vec{v}}{c^2} \times \vec{E}_{\perp}\right) \end{cases}}$$

$\parallel$ ALIGNS WITH $\vec{v}$

$I\vec{\ell} \times \vec{B}$ FORCE FROM $q\vec{v} \times \vec{B}$

$B_1 = \frac{\mu_0 I_1}{2\pi r}$



$\vec{F} = q\vec{v} \times \vec{B}$ IS UPWARDS ON I_2 WIRE

"SUM UP ALL $q\vec{v}\times\vec{B}$ FORCE THE CURRENT

$$I = q v n$$ ← # OF q'S PER UNIT LENGTH

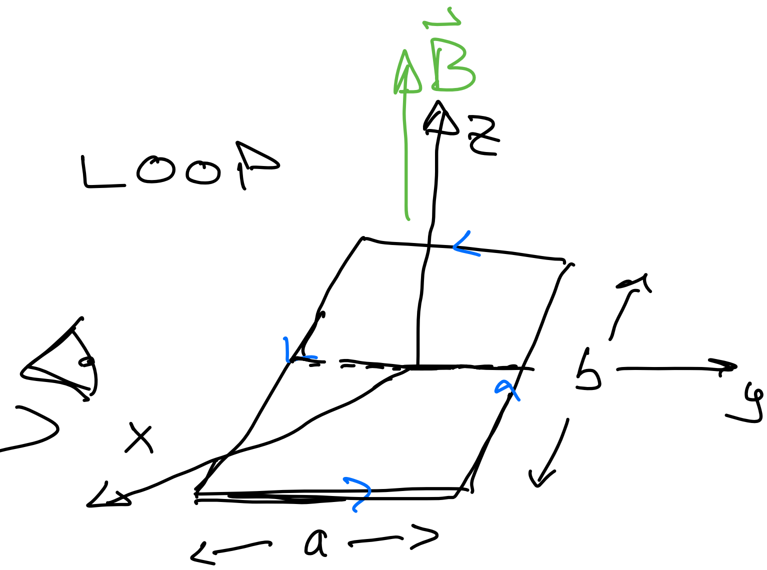
$$\overset{\text{TOTAL}}{F} = \text{"}\sum F\text{"} = \underbrace{q_2 v_2 n_2}\, B_1\, l = I_2\, l\, B_1$$

$$= I_2\, \vec{l} \times B_1$$

$$\boxed{\vec{F} = I\vec{l}\times\vec{B}}$$ FOR CURRENT CARRY WIRES

EXTERNAL

• TORQUE ON LOOP



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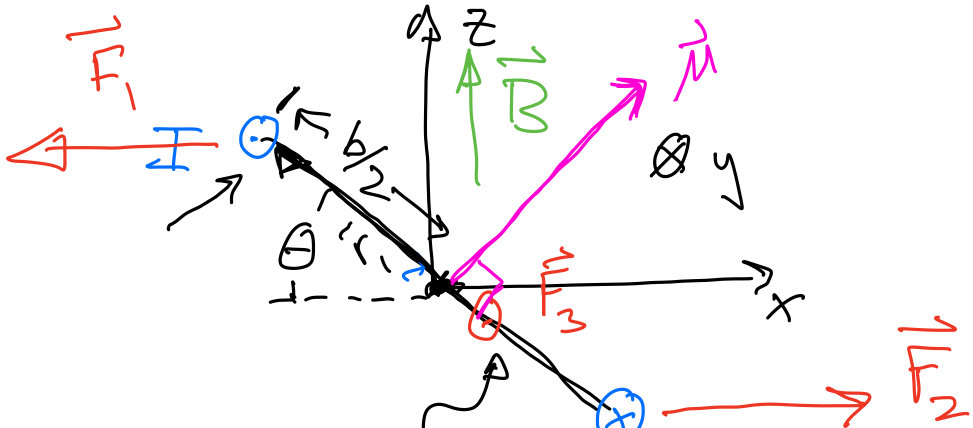


LOOP
SEEN EDGE ON

IDEA:

COMPUTE $I\vec{\ell} \times \vec{B}$ ON 4 SIDES

$$F_1 = I\vec{\ell}_1 \times B = IaB(-\hat{i})$$

OPPOSITE SIDE

$$\vec{F}_2 = IaB(\hat{i})$$

THESE TWO FORCES GIVE A TORQUE

$$\vec{\tau}_1 = \vec{r}_1 \times \vec{F}_1 = \frac{b}{2} F_1 \sin\theta(-\hat{j})$$

$$= -Ia\frac{b}{2} B \sin\theta\, \hat{j}$$

AND

$$\vec{\tau}_2 = \vec{r}_2 \times \vec{F}_2 = -Ia\frac{b}{2} B \sin\theta\, \hat{j}$$

TOTAL IS

AREA

$$\vec{\tau} = \vec{\tau}_1 + \vec{\tau}_2 = -\underbrace{I\,\boxed{ab}}_{}\,B \sin\theta\, \hat{j}$$

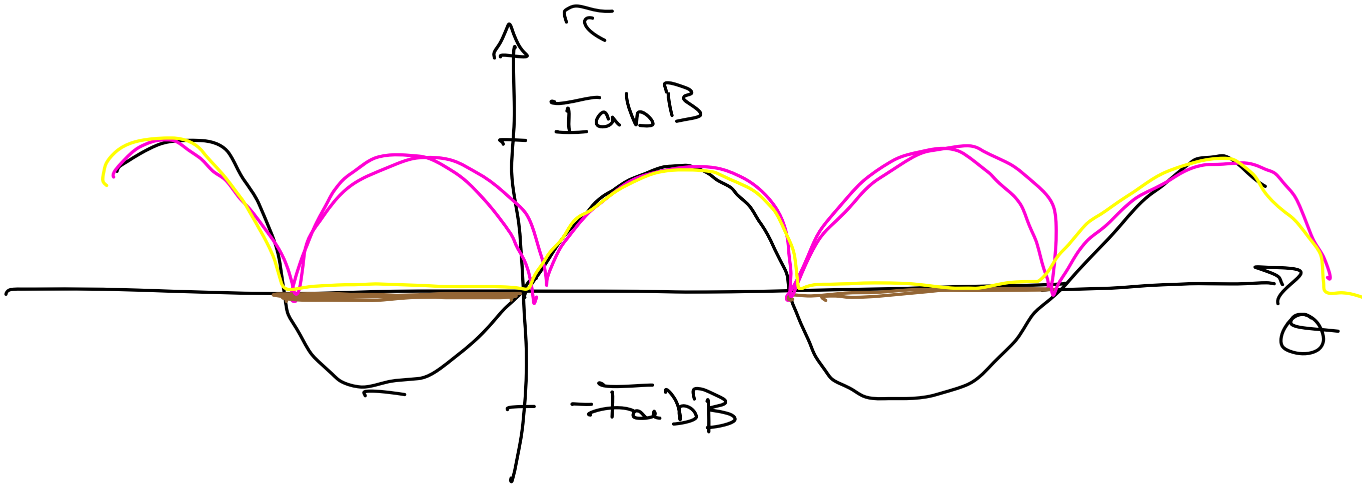
MAGNETIC MOMENT

$$\vec{\mu} = I\vec{A}$$

TORQUE ON A LOOP OF CURRENT

$$\boxed{\vec{\tau} = \vec{\mu} \times \vec{B}}$$

$\vec{\mu}$ LIKES TO ALIGN WITH $\vec{B}$



WAYS TO BUILD A MOTOR