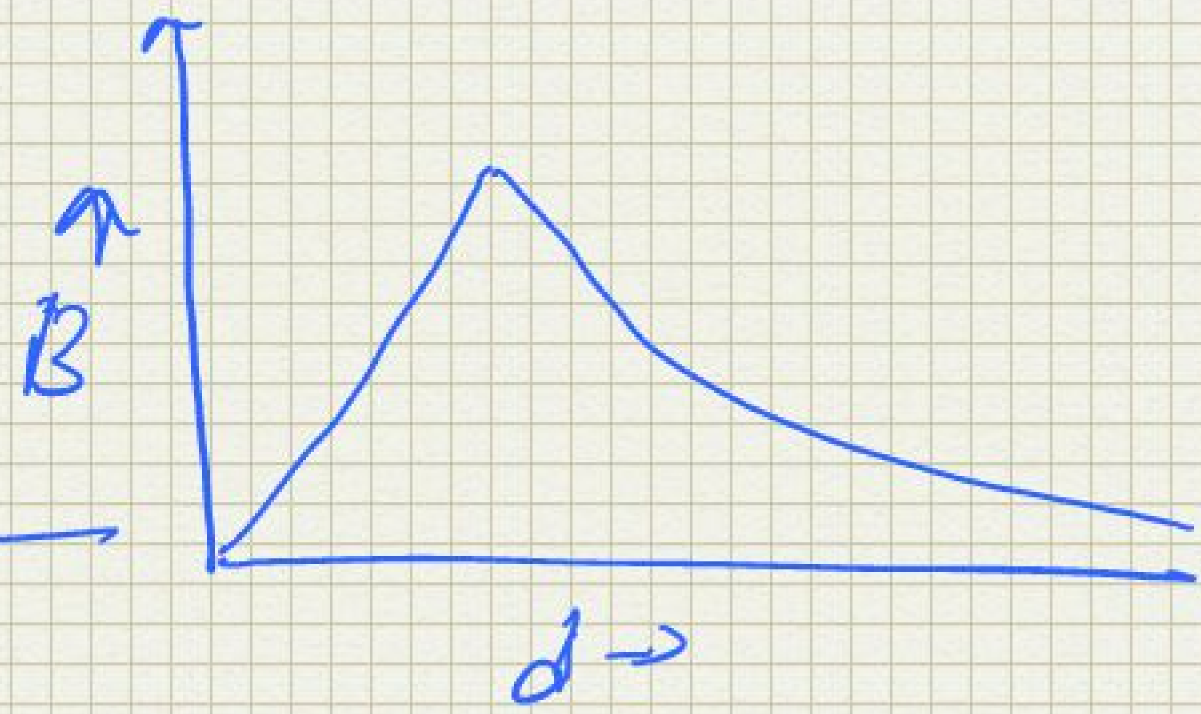
What is a Current Sheet and why are they interesting?

This satisfies $\vec{j} \times \vec{B}$.



→ Current Sheets → $\nabla \cdot \vec{B} = 0$ no source or no end!

→ But fields can be broken.
→ null points

→ It is important & interesting because it is one of the few ways you can get rid of energy.

Standard Induction equation —

$$\partial_t \vec{B} = \vec{\nabla} \times \vec{V} \times \vec{B} + \eta \Delta \cdot \vec{B}$$

magnitudes $\Rightarrow$ $\dfrac{VB}{L}$ $\qquad\qquad$ $\dfrac{\eta B}{l^2}$

Ratio of the two $= R_m = \dfrac{VB}{L} \Big/ \dfrac{\eta B}{L^2}$

$$\Rightarrow R_m = \frac{Vl}{\eta} \simeq 10^{14}$$

So that's why second term can be ignored most of the times. But if l is very very small, then the second term becomes important.

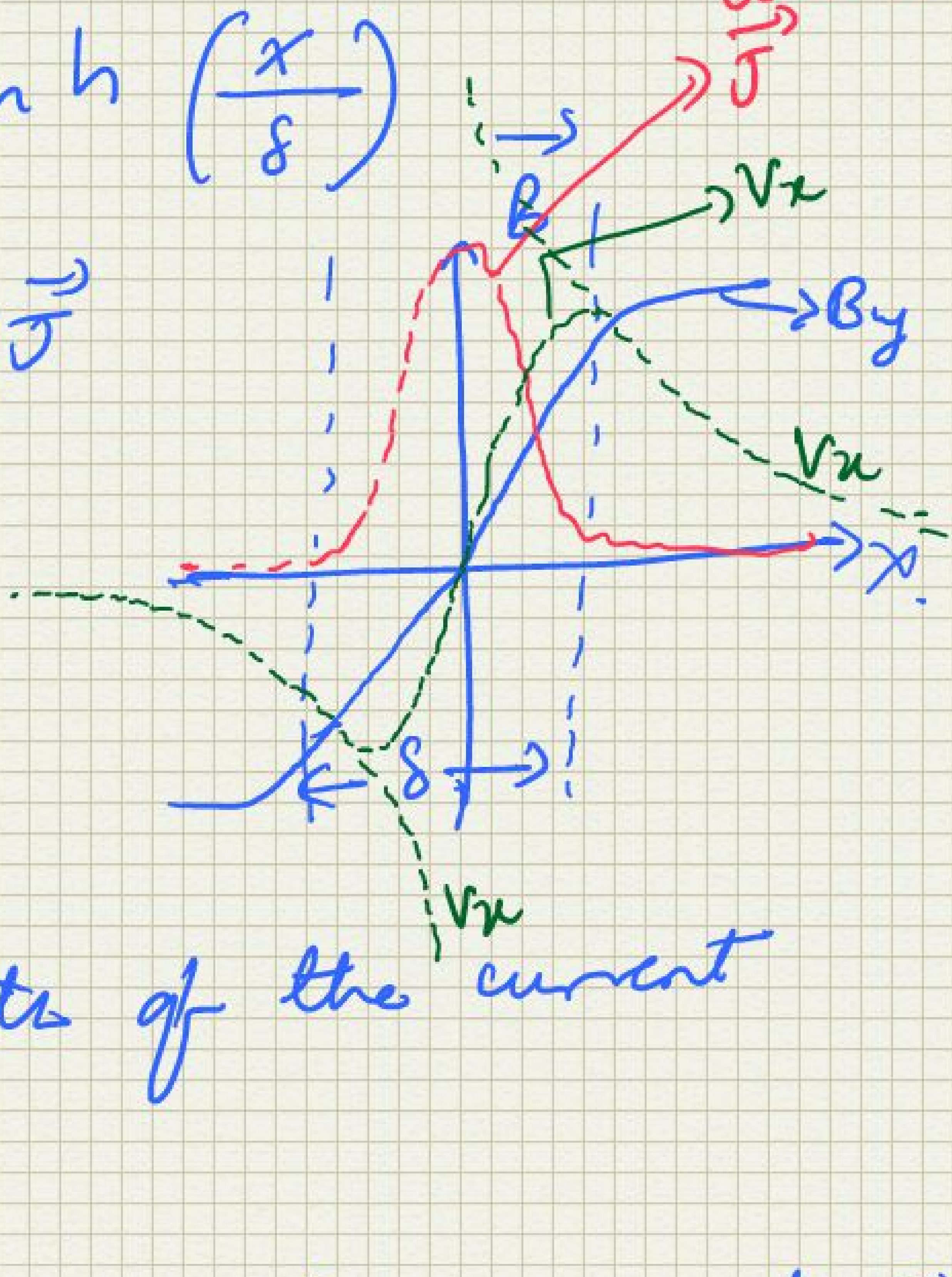
$\left|\dfrac{B}{l}\right| = |J| \Rightarrow$ if $l\downarrow \Rightarrow J\uparrow \Rightarrow$ current is high (in current sheets).

Its imp when VB/L & $\eta B/L^2$ is comparable.

$$\frac{VB}{L} = \frac{\eta B}{L^2} \Rightarrow V = \frac{\eta}{L} \Rightarrow \eta = VL \qquad \eta = \frac{1}{\mu\sigma}$$

Harris Sheet (1D & Stationary)

$$B_y = B_0 \tanh\left(\frac{x}{\delta}\right)$$



$$E = -\vec{V} \times \vec{B} + \eta \vec{J}$$

$$\vec{J} = \nabla \times \vec{B}$$

$$\nabla \times E = 0$$

$$\nabla E = \text{const.}$$

$\delta \rightarrow$ breadth of the current sheets.

In a comoving system, $V = 0$, $E = \eta \vec{J}$

only $\vec{E}$ $\parallel^{el}$ to $\vec{J}$

But also $E \perp^r$ to $\vec{J}$.

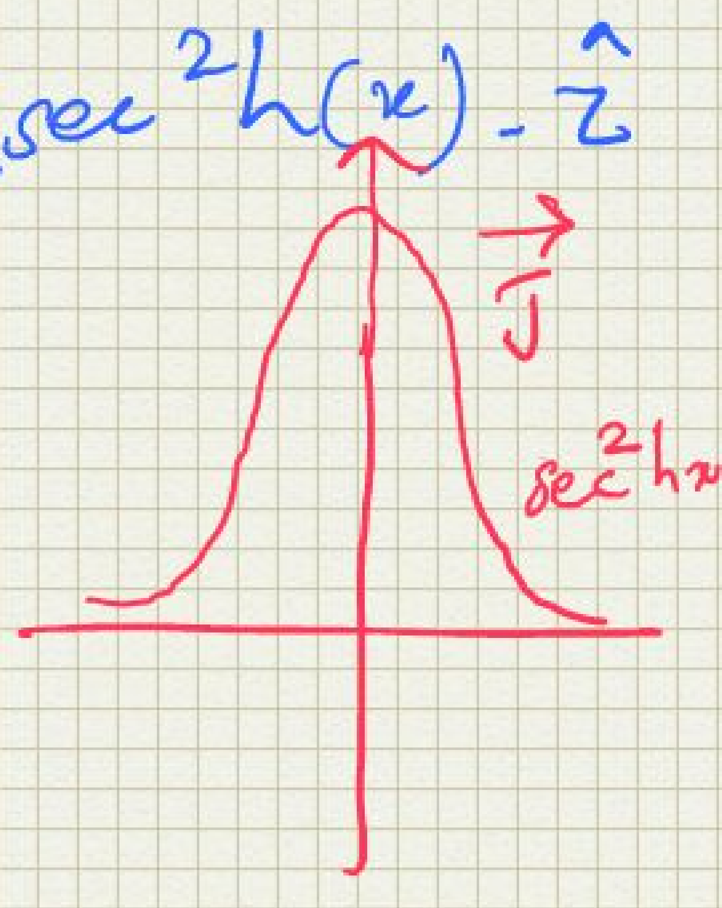
But there will be $\vec{B}$. If the plasma has only $\bar{e}$'s then if you comove with the plasma at drift velocity J can be 0. But plasma also has protons so $J \neq 0$.

Current density, $J = ?$ in Harris Sheet

$$J = \nabla \times \vec{B} \qquad \vec{E} = \text{const.}$$

$$= \nabla \times \left(B_0 \tanh\left(\frac{x}{\delta}\right) \right)$$

$$= \frac{\delta}{\delta x} \times \left(\tanh\left(\frac{x}{\delta}\right) \right) = \frac{B_0}{\delta} \sec^2 h(x) \cdot \hat{z}$$



E is also in $\hat{z}$.

Now Calculating E.

$$E_z = V_x B_y + \eta J_z$$

$$E_z = -\underbrace{V_x B_y}_{=0} + \eta J_z \qquad \vec{J}\cdot\hat{z} = |J|$$

$$= V_x B_0 \tanh\left(\frac{x}{\delta}\right) + \frac{\eta B_0}{\delta} \operatorname{sech}^2\left(\frac{x}{\delta}\right)$$

$$\therefore V_x = \frac{\eta \frac{B_0}{\delta} \operatorname{sech}^2\left(\frac{x}{\delta}\right) - E_z}{B_0 \tanh\left(\frac{x}{\delta}\right)}$$

$$V_x = \frac{\eta}{\delta} \frac{1}{\cosh^2\left(\frac{x}{\delta}\right)} \cdot \frac{1}{\frac{\sinh\left(\frac{x}{\delta}\right)}{\cancel{\cosh(x/\delta)}}}$$

$$- \frac{E_z}{B_0} \coth\left(\frac{x}{\delta}\right)$$

$$V_x = -\frac{E_z}{B_0} \coth\left(\frac{x}{\delta}\right) + \frac{\eta B_0}{\delta} \operatorname{sech}\left(\frac{x}{\delta}\right) \operatorname{cosech}\left(\frac{x}{\delta}\right)$$

Z..

Lorentz force $J \times B \rightarrow J_z \times B_y \rightarrow$ $-x$ direction. Flows inwards (in 1D towards the center & stays there). In 2D plasma flows out through the ends of the current sheets (slightly change in direction from inflow).

So the Lorentz force pushes it towards the center so it makes reconnection go faster.

So, Magnetic Pressure is the center is lowest (tension in 1D model.) because $B = 0$ in center & B is maximum at the sides $\rightarrow$ annihilates itself in the center.

So, in this way, the current sheet is fed.

→ Low Resistivity but is heated.

$\eta J^2 \rightarrow$ heating rate at the current sheet (loss term).

For stationary situation, the pressure built in the current sheet = pressure that pushes it in ⇒ eqn for thickness of the sheet.

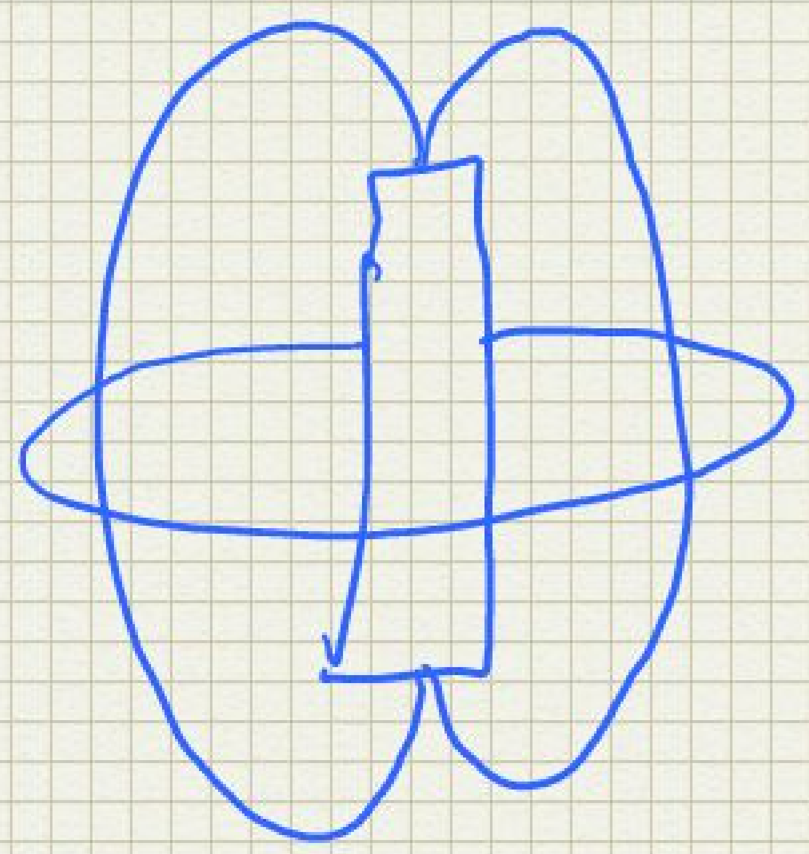
This sheet ⇒ $J^2 \uparrow$.

$\eta J^2 = Bp \Longrightarrow$ stationary sheet.

↳ efficient way of getting rid of magnetic energy.

Nuetron Stars Dynamics

$J = \vec{v} \times \vec{B}$



Charge Separation

→ protons are closer to the equator & electrons near the poles.

→ Synchrotron radiation from jets

→ Charges is built up at the surface of the nuetron star?

→ Scale height ≃ 2 cm!

→ Corona is present because X-ray emissions.

The disk is a Faraday disk

→ a hole in the middle

where a dipole can be placed.

→ It is forced to rotate. Magnet is standing still. (or opposite)

→ B is in the z-direction.

v is in the ϕ direction.

⇒ $\vec{E}$ is radial in the rotating disk. Faraday's exp.

→ This will build an $\vec{E}$ field which makes charge separation,

→ (Magnetic field moving wrt to a conductor ⇒ charge separation)

→ But in a pulsar, it is 100% conducting. 10% protons 10% $\bar{e}$,

→ The field must rotate with it.

→ So how charge separation occurs?