DIFÚZE $\vec{\Gamma} = \pm \mu n \vec{E} - D \nabla n$

$\mu = \dfrac{|q|}{m\nu}$, $D = \dfrac{KT}{m\nu}$

$$\vec{u}_\perp = \pm \mu_\perp \vec{E} - D_\perp \frac{\nabla_\perp n}{n} + \frac{\vec{v}_E + \vec{v}_D}{1 + 1/\omega_c^2 \tau^2}$$

$$D_\perp = \frac{D}{1+\omega_c^2\tau^2} \qquad \omega_c = \frac{|q|B}{m}$$

$$\mu_\perp = \frac{\mu}{1+\omega_c^2\tau^2} \qquad \tau = 1/\nu$$

$\omega_c \tau \ll 1$

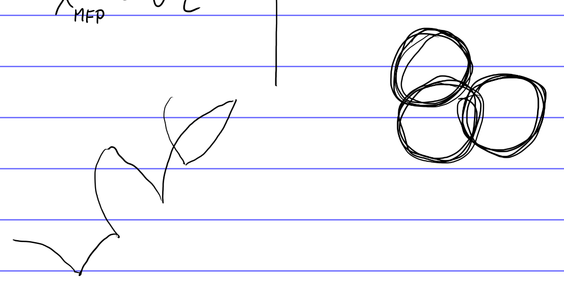
$$D_\perp \cong D = \frac{KT}{m\nu} = v^2 \cdot \tau \simeq \frac{\lambda_{MFP}^2}{\tau}$$

$\lambda_{MFP} \sim v\tau$

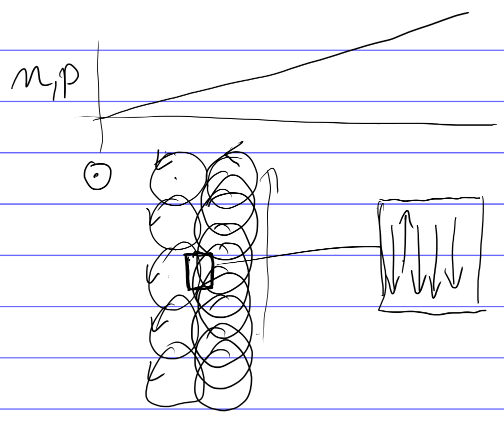
$\omega_c \tau \gg 1$

$$D_\perp \simeq \frac{D}{\omega_c^2 \tau^2} = \frac{KT\nu^2}{m\nu\omega_c^2} \sim \frac{v^2}{v^2/r_L^2} \cdot \nu = \frac{r_L^2}{\tau}$$

ŘÁDOVĚ



$$\vec{v}_E = \frac{\vec{E}\times\vec{B}}{B^2} \qquad \vec{v}_D = \frac{\nabla p \times \vec{B}}{n q B^2}$$



ZÁKLADY MHD

- plně ionizované plazma
- kvazineutrální $n_i = n_e = n$

e- a i-tekutina → 1 neutrální vodivá tekutina

- jednotekutinové proměnné

$$\rho \equiv n_i m_i + n_e m_e \simeq n(m_i + m_e)$$

$$\vec{v} = \frac{1}{\rho}(n_i m_i \vec{u}_i + n_e m_e \vec{u}_e) \simeq \frac{m_i \vec{u}_i + m_e \vec{u}_e}{m_i + m_e}$$

$$\vec{j} = q(n_i \vec{u}_i - n_e \vec{u}_e) \simeq qn(\vec{u}_i - \vec{u}_e)$$

$$\rho_q = q(n_i - n_e) \simeq 0$$

dvoutekutinové rovnice

(RI) $m_i n \dfrac{\partial \vec{u}_i}{\partial t} = qn(\vec{E} + \vec{u}_i \times \vec{B}) - \nabla p_i - m_i n \nu_{ie}(\vec{u}_i - \vec{u}_e)$

$((\vec{u}\cdot\nabla)\vec{u}$ – zanedbáváme 2. řád v rychlosti)

$\vec{P}_{ie} = -\vec{P}_{ei} = m_e n(\vec{u}_e - \vec{u}_i)\nu_{ei}$

definujeme $\eta = \dfrac{m_e}{n q^2}\nu_{ei}$ specif. odpor plazmatu

$\vec{P}_{ei} = m_e n(\vec{u}_i - \vec{u}_e)\nu_{ei} = \dfrac{m_e}{q}\vec{j}\nu_{ei} = qn\eta\vec{j}$

(RE) $m_e n \dfrac{\partial \vec{u}_e}{\partial t} = -qn(\vec{E} + \vec{u}_e \times \vec{B}) - \nabla p_e + \vec{P}_{ei}$

1) sečteme (RI) + (RE)

$$n\frac{\partial}{\partial t}(m_i\vec{u}_i + m_e\vec{u}_e) = qn\vec{E} - qn\vec{E} + qn(\vec{u}_i - \vec{u}_e)\times\vec{B} - \nabla(p_e + p_i) + \vec{P}_{ie} + \vec{P}_{ei}$$

$(m_i\vec{u}_i + m_e\vec{u}_e) = \vec{v}\cdot(m_i + m_e)$, $qn(\vec{u}_i - \vec{u}_e) = \vec{j}$, $p = p_e + p_i$

$$\rho\frac{\partial \vec{v}}{\partial t} = \vec{j}\times\vec{B} - \nabla p$$

2) $m_e (RI) - m_i (RE)$

$$m_i m_e n \frac{\partial}{\partial t}(\vec{u}_i - \vec{u}_e) = qn(m_i + m_e)\vec{E} + qn(m_e\vec{u}_i + m_i\vec{u}_e)\times\vec{B} - m_e\nabla p_i + m_i \nabla p_e - (m_e + m_i)\vec{P}_{ei}$$

$(\vec{u}_i - \vec{u}_e) = \vec{j}/qn$, $n(m_i + m_e) = \rho$, $(m_e + m_i)\vec{P}_{ei} = (m_e + m_i)qn\eta\vec{j} = \rho q \eta \vec{j}$

$$m_e\vec{u}_i + m_i\vec{u}_e = +m_i\vec{u}_i + m_e\vec{u}_e + m_i(\vec{u}_e - \vec{u}_i) + m_e(u_i - u_e) = \frac{\rho}{n}\vec{v} - \frac{\vec{j}}{qn}(m_i - m_e)$$

$(\vec{u}_e - \vec{u}_i) = -\vec{j}/qn$, $(u_i - u_e) = \vec{j}/qn$

$$\frac{m_i m_e n}{q}\frac{\partial}{\partial t}\left(\frac{\vec{j}}{n}\right) = q\rho\vec{E} + q\rho\vec{v}\times\vec{B} - (m_i - m_e)\vec{j}\times\vec{B} - m_e\nabla p_i + m_i\nabla p_e - \rho q\eta\vec{j}$$

$: q\rho$

$$\vec{E} + \vec{v}\times\vec{B} = \eta\vec{j} + \frac{1}{q\rho}\left(\frac{m_i m_e}{q}\frac{\partial}{\partial t}\left(\frac{\vec{j}}{n}\right) + (m_i - m_e)\vec{j}\times\vec{B} + m_e\nabla p_i - m_i\nabla p_e\right)$$

$\lim m_e/m_i \to 0$: $\dfrac{1}{q\rho} \to \dfrac{1}{qnm_i}$

$$\vec{E} + \vec{v}\times\vec{B} = \eta\vec{j} + \frac{1}{qn}(\vec{j}\times\vec{B} - \nabla p_e)$$

$\eta\vec{j}$ – ODPOR; $\vec{j}\times\vec{B}$ – Hallův proud

ZOBECNĚNÝ OHMŮV ZÁKON

$\vec{E} + \vec{v}\times\vec{B}$ – el. pole ve souřadné soustavě spoj. s plazmatem

často stačí

$$\vec{E} + \vec{v}\times\vec{B} = \eta\vec{j}$$

+ kontinuita hmoty a náboje

$$\frac{\partial \rho}{\partial t} + \nabla\cdot(\rho\vec{v}) = 0 \qquad \frac{\partial \rho_q}{\partial t} + \nabla\cdot\vec{j} = 0 \to \nabla\cdot\vec{j} = 0$$

$$\rho\frac{\partial \vec{v}}{\partial t} = \vec{j}\times\vec{B} - \nabla p$$

$$\vec{E} + \vec{v}\times\vec{B} = \eta\vec{j} + \dots$$

+ MXW

horké plazma, astro plazma, slun. vítr