* Fluid drift perpendicular to $\vec{B}$

$$nm\left[\cancel{\frac{\partial \vec{u}}{\partial t}} + \cancel{(\vec{u}\cdot\nabla)\vec{u}}\right] = nq(\vec{E}+\vec{u}\times\vec{B}) - \nabla P$$

assumption

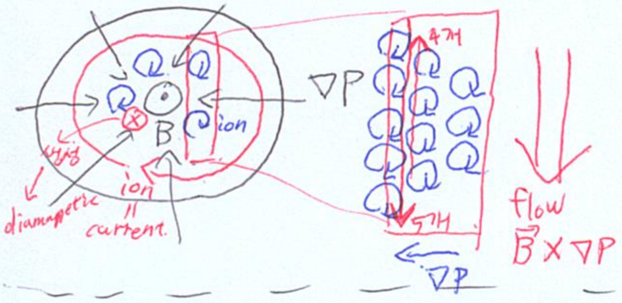
$$\vec{B}\times(\vec{B}\times\vec{u}) = \vec{B}(\vec{B}\cdot\vec{u}) - \vec{u}(\vec{B}\cdot\vec{B}) = \underline{\vec{B}(\vec{B}\cdot\vec{u})} - B^2\vec{u}$$

$\hookrightarrow \vec{u}_\perp$ 만 고려시 0

$$nq(\vec{E}+\vec{u}\times\vec{B}) - \nabla P = 0 \xrightarrow{(\times\vec{B})} nq(\vec{E}\times\vec{B}) + nq\boxed{(\vec{u}\times\vec{B})\times\vec{B}} - \nabla P\times\vec{B} = 0$$

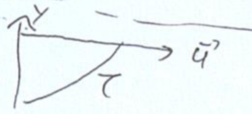
$$\rightarrow nq(\vec{E}\times\vec{B}) - nqB^2\vec{u}_\perp - \nabla P\times\vec{B} = 0 \rightarrow \vec{u}_\perp = \underbrace{\frac{\vec{E}\times\vec{B}}{B^2}}_{\vec{v}_E} + \underbrace{\frac{\vec{B}\times\nabla P}{nqB^2}}_{\vec{v}_D}$$

diamagnetic drift



Shear stress $\tau = \mu \dfrac{du}{dy}$ — μ: dynamic viscosity

$\nu = \dfrac{\mu}{\rho}$: kinetic viscosity, momentum diffusivity



$\tau = \mu \dfrac{d\vec{u}}{dy} = \mu\nabla\vec{u}$ (P와 단위 같다.)

$P = C\rho^\gamma$ — $\gamma = 1$: isothermal; $\gamma = \dfrac{2+N}{N}$: adiabatic compression

$\nabla P \longleftrightarrow \mu\nabla^2\vec{u} = \rho\nu\nabla^2\vec{u}$

* plasma approximation

$n_i \approx n_e \approx n$

$n_i q_i + n_e q_e \approx n(e) + n(-e) \neq 0$

* Complete set of fluid equations

$$\frac{\partial n_j}{\partial t} + \nabla\cdot(n_j\vec{u}_j) = 0 \quad (j : \text{ion, electron})$$

$$n_j m_j\left[\frac{\partial \vec{u}_j}{\partial t} + (\vec{u}_j\cdot\nabla)\vec{u}_j\right] = n_j q_j(\vec{E}+\vec{u}_j\times\vec{B}) - \nabla P_j + \bar{R}_{ji}$$

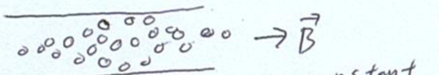
$$P_j = C_j(n_j m_j)^{\gamma_j}$$

$$\varepsilon_0\nabla\cdot\vec{E} = \cancel{\sum_j n_j q_j} \; \phi^{n_i+n_e} \qquad \nabla\cdot\vec{B} = 0$$

0 아니다! — plasma approximation

$$\nabla\times\vec{E} = -\frac{\partial\vec{B}}{\partial t} \qquad \nabla\times\vec{B} = \mu_0\sum_j n_j q_j\vec{u}_j + \mu_0\varepsilon_0\frac{\partial\vec{E}}{\partial t}$$

* Fluid drift parallel to $\vec{B}$



∇n ∇n — T = constant

$-\nabla P = F$ $\quad F = -\nabla P$

isothermal, $\vec{B} = B_0\hat{z}$ for electron

ϕ: $-$ $+$ $-$

$\vec{E}$: $\leftarrow$ $\rightarrow$

$\vec{F}_E$ (for electron): $\rightarrow$ $\leftarrow$

$$nm\left[\frac{\partial\vec{u}}{\partial t} + \cancel{(\vec{u}\cdot\nabla)\vec{u}}\right] = nq(\vec{E}+\cancel{\vec{u}\times\vec{B}}) - \nabla P + \bar{R}$$

무시, 0

$$\rightarrow nm\frac{\partial u}{\partial t} = -neE_z - kT\frac{\partial n}{\partial z}$$

$\dfrac{\partial u}{\partial t} = 0$

$$\frac{\partial u_z}{\partial t} = -\frac{e}{m}E_z - \frac{kT}{nm}\frac{\partial n}{\partial z} = 0$$

(neglect electron inertia. $\approx m$ 배로 작다)

$$+\frac{e}{m}\frac{\partial\phi}{\partial z} - \frac{kT}{nm}\frac{\partial n}{\partial z} = 0$$

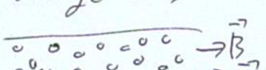
$$\frac{e}{kT}\frac{\partial\phi}{\partial z} - \frac{1}{n}\frac{\partial n}{\partial z} = 0 \rightarrow \frac{e\phi}{kT} - \ln n = \text{constant}$$

$$\rightarrow n = n_0\exp\left(\frac{e\phi}{kT}\right)$$

($n = n_0$ with $\phi = 0$)

(Boltzmann relation) response

homogeneous



$$nm\left[\frac{\partial\vec{u}}{\partial t} + \cancel{(\vec{u}\cdot\nabla)\vec{u}}\right] = nq(\vec{E}+\cancel{\vec{u}\times\vec{B}}) - \cancel{\nabla P} + \bar{R}$$

무시, 0, 저항

$$nm\frac{\partial u}{\partial t} = -neE_z + \bar{R}_{ei}$$

$$\bar{R}_{ei} = -n_e m\nu_{ei}(\vec{u}_e - \vec{u}_i)$$

$$nm\cancel{\frac{\partial\vec{u}}{\partial t}} = -neE_z - nm\nu(\vec{u}_e - \vec{u}_i) = 0$$

neglect inertia

$$E_z = -\frac{m\nu}{e}(\vec{u}_e - \vec{u}_i)$$

$$J_z = ne(\vec{u}_i - \vec{u}_e)$$

$$\rightarrow E_z = \frac{m\nu}{ne^2}J_z = \eta J_z$$

Ohm's Law (simplified)

$\boxed{\eta = \dfrac{m\nu}{ne^2}}$ resistivity

$$\therefore \bar{R}_{ei} = -nm\nu_{ei}(\vec{u}_e - \vec{u}_i) = -nm\frac{ne^2}{m}\eta(\vec{u}_e - \vec{u}_i) = ne\eta\vec{J}$$