* Drift Motions (guiding center)

- $\vec{E}$: $\vec{v}_E = \dfrac{\vec{E}\times\vec{B}}{B^2}$

$$A+B : \vec{v}_{c+\nabla B} = \frac{m\left(v_\parallel^2 + \frac{v_\perp^2}{2}\right)}{qB^2R_c^2}\left(\vec{R}_c \times \vec{B}\right)$$

- $\vec{F}_\perp$: $\vec{v}_F = \dfrac{\vec{F}\times\vec{B}}{qB^2}$

- $\vec{g}$: $\vec{v}_g = \dfrac{m\vec{g}\times\vec{B}}{qB^2}$

$$\frac{\nabla B}{B} = -\frac{\vec{R}_c}{R_c^2}$$

- ∇B : $\vec{v}_{\nabla B} = \pm\frac{1}{2}v_\perp r_L \dfrac{\vec{B}\times\nabla B}{B^2} = \pm\frac{1}{2}v_\perp \dfrac{mv_\perp}{B|q|}\dfrac{\vec{B}\times\nabla B}{B^2} = \dfrac{-\frac{1}{2}mv_\perp^2}{qB^2}\dfrac{\vec{B}\times\vec{R}_c}{R_c^2} = \boxed{\dfrac{\frac{1}{2}mv_\perp^2}{qB^2}\dfrac{\vec{R}_c\times\vec{B}}{R_c^2}}$ A

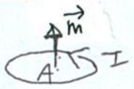
$\pm|q| = q$

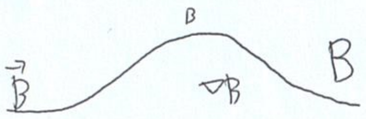
- curvature : $\vec{v}_c = \boxed{\dfrac{mv_\parallel^2\vec{R}_c\times\vec{B}}{qB^2R_c^2}}$ B

$$\vec{v}_{\nabla B} = \pm\frac{1}{2}v_\perp r_L\frac{\vec{B}\times\nabla B}{B^2} = \frac{\vec{F}\times\vec{B}}{qB^2} \rightarrow -\frac{1}{2}v_\perp\frac{mv_\perp}{Bq}\frac{\nabla B\times\vec{B}}{B^2} = \frac{\vec{F}\times\vec{B}}{qB^2} \rightarrow \vec{F}_\perp = -\frac{\frac{1}{2}mv_\perp^2}{B}\nabla B = -\mu\nabla B_\perp$$

magnetic moment

$$\boxed{|\vec{m}|} = IA = \frac{|q|}{\tau}\pi r_L^2 = \frac{|q|}{2\pi}\omega_c\pi r_L^2 = \frac{|q|}{2}\frac{B|q|}{m}\frac{m^2v_\perp^2}{B^2|q|^2} = \boxed{\frac{\frac{1}{2}mv_\perp^2}{B}}$$ 증명완료





$\vec{F} = -\mu\nabla_\parallel B$

$\vec{F}_\parallel = m\dfrac{d\vec{v}_\parallel}{dt} = -\mu\nabla_\parallel B$

$$v_\parallel m\frac{dv_\parallel}{dt} = \boxed{\frac{d}{dt}\left(\frac{1}{2}mv_\parallel^2\right)} = -\mu\frac{\partial B}{\partial s}\frac{\partial s}{\partial t} \simeq \boxed{-\mu\frac{dB}{dt}}$$

($\nabla_\parallel B$, $v_\parallel$)

Energy conservation

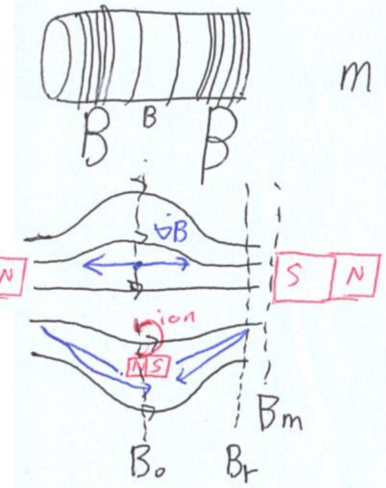
$$\frac{d}{dt}\left(\frac{1}{2}mv_\parallel^2 + \frac{1}{2}mv_\perp^2\right) = 0$$

$$\frac{d}{dt}\left(\frac{1}{2}mv_\parallel^2\right) + \frac{d}{dt}\left(\frac{1}{2}mv_\perp^2\right) = 0$$

$$\rightarrow -\mu\frac{dB}{dt} + \frac{d}{dt}(\mu B) = 0$$

$$-\mu\frac{dB}{dt} + \mu\frac{dB}{dt} + B\frac{d\mu}{dt} = 0$$

$$\boxed{\therefore \frac{d\mu}{dt} = 0}$$ μ: adiabatic invariant



(E. Fermi)

guiding center

magnetic mirror (Hannes Alfvén)

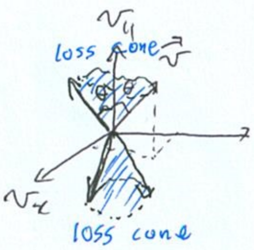
$\left(\begin{array}{l}\frac{1}{2}mv_\parallel^2 : \text{kinetic energy} \\ \frac{1}{2}mv_\perp^2 : \text{potential energy}\end{array}\right)$

trapping condition : $B_r \le B_m$

① $\frac{1}{2}mv_{\parallel 0}^2 + \frac{1}{2}mv_{\perp 0}^2 = \cancel{\frac{1}{2}mv_{\parallel r}^2} + \frac{1}{2}mv_{\perp r}^2$ (0)

② μ : $\dfrac{\frac{1}{2}mv_{\perp 0}^2}{B_0} = \dfrac{\frac{1}{2}mv_{\perp r}^2}{B_r}$

$$\Rightarrow \frac{v_{\perp 0}^2}{v_{\perp r}^2} = \frac{B_0}{B_r} = \frac{v_{\perp 0}^2}{v_{\parallel 0}^2 + v_{\perp 0}^2} = \sin^2\theta$$



$v\sin\theta = v_\perp$

$v\cos\theta = v_\parallel$

$$\therefore \sin^2\theta = \frac{B_0}{B_r} \ge \frac{B_0}{B_m} = \frac{1}{R_m}$$

(R_m : mirror ratio)