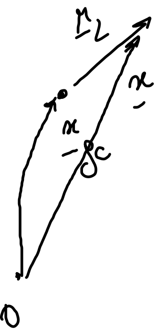


$$\underline{x} = \underline{x}_{gc} + \underline{r}_L$$

$$\parallel \quad m \frac{dv_{\parallel gc}}{dt} = q\left[E_{\parallel}(\underline{x}_{gc}) + \langle \underline{v}_L \times (\underline{r}_L \cdot \underline{\nabla}) \underline{B}(\underline{x}_{gc}) \rangle_{\parallel} \right]$$

$$\perp \quad m \frac{d\underline{v}_{\perp gc}}{dt} = q \underline{v}_{gc} \times \underline{B} + \underline{F}_{\perp}$$

$$\underline{F}_{\perp} = q\underline{E}_{\perp} + q \langle \underline{v}_L \times (\underline{r}_L \cdot \underline{\nabla}) \underline{B} \rangle_{\perp} - m v_{gc}^2 (\hat{\underline{b}} \cdot \underline{\nabla}) \hat{\underline{b}}$$

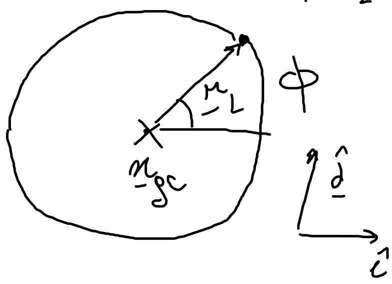
$$\underline{v}_D^{(0)} = \frac{\underline{F}_{\perp} \times \underline{B}}{qB^2}$$

$$\underline{v}_D^{(1)} = -\frac{m}{qB^2} \frac{d}{dt} \underline{v}^{(0)} \times \underline{B} = \frac{m}{qB^2} \frac{d\underline{E}_{\perp}}{dt}$$

se $\underline{F}_{\perp} = q\underline{E}_{\perp}$

Significato di

$$q\langle \underline{v}_L \times (\underline{r}_L\cdot\underline{\nabla})\underline{B}\rangle$$



$$\underline{B} = B_z\hat{\underline{k}} \qquad \phi = \omega_L t$$

$$\underline{r}_L = r_L\left(\cos\phi\,\hat{\underline{i}} + \operatorname{sen}\phi\,\hat{\underline{j}}\right) = \left(\cos(\omega_L t)\,\hat{\underline{i}} + \operatorname{sen}(\omega_L t)\,\hat{\underline{j}}\right) r_L$$

$$\underline{v}_L = \underbrace{r_L\omega_L}_{v_L}\left[-\operatorname{sen}(\omega_L t)\,\hat{\underline{i}} + \cos(\omega_L t)\,\hat{\underline{j}}\right]$$

$$q r_L v_L \left\langle\left(-\operatorname{sen}(\omega_L t)\,\hat{\underline{i}} + \cos(\omega_L t)\,\hat{\underline{j}}\right) \times \left[\underbrace{\left(\cos(\omega_L t)\frac{\partial}{\partial x} + \operatorname{sen}(\omega_L t)\frac{\partial}{\partial y}\right)}_{\underline{r}_L\cdot\underline{\nabla}}\left(B_x\hat{\underline{i}} + B_y\hat{\underline{j}} + B_z\hat{\underline{k}}\right)\right]\right\rangle$$

$$= q r_L v_L \left\langle\left(-\operatorname{sen}(\omega_L t)\,\hat{\underline{i}} + \cos(\omega_L t)\,\hat{\underline{j}}\right) \times \left[\cos(\omega_L t)\left(\frac{\partial B_x}{\partial x}\hat{\underline{i}} + \frac{\partial B_y}{\partial x}\hat{\underline{j}} + \frac{\partial B_z}{\partial x}\hat{\underline{k}}\right) + \operatorname{sen}(\omega_L t)\cdot \frac{\partial B_x}{\partial y}\hat{\underline{i}} + \frac{\partial B_y}{\partial y}\hat{\underline{j}} + \frac{\partial B_z}{\partial y}\hat{\underline{k}}\right]\right\rangle$$

$$= \frac{q r_L v_L}{2} \left(-\frac{\partial B_y}{\partial y}\hat{\underline{k}} + \frac{\partial B_z}{\partial y}\hat{\underline{j}} - \frac{\partial B_x}{\partial x}\hat{\underline{k}} + \frac{\partial B_z}{\partial x}\hat{\underline{i}} \right)$$

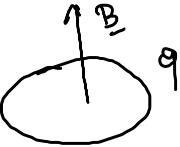
$$\underline{\nabla}\cdot\underline{B} = 0 \Rightarrow \frac{\partial B_x}{\partial x} + \frac{\partial B_y}{\partial y} + \frac{\partial B_z}{\partial z} = 0$$

$$\Rightarrow \frac{\partial B_x}{\partial x} + \frac{\partial B_y}{\partial z} = -\frac{\partial B_z}{\partial z}$$

$$= \frac{q r_L v_L}{2}\underbrace{\left[\frac{\partial B_z}{\partial x}\hat{\underline{i}} + \frac{\partial B_z}{\partial y}\hat{\underline{j}} + \frac{\partial B_z}{\partial z}\hat{\underline{k}} \right]}_{-\underline{\nabla}|\underline{B}(\underline{x}_{gc})|} = -\mu\, \underline{\nabla}|\underline{B}(\underline{x}_{gc})|$$

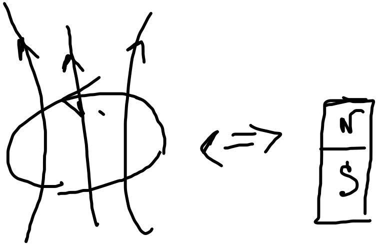
mom. magnetico

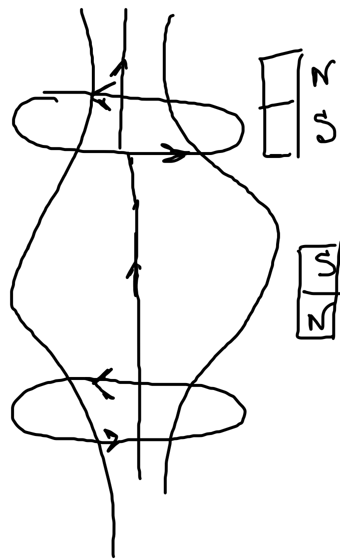
$$\frac{q r_L v_L}{2} = \mu = \cancel{q}\frac{m v_L}{2\cancel{q}B} v_L = \frac{m v_L^2}{2B}$$



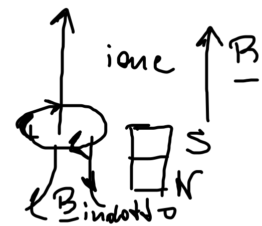
$$i = \frac{q}{T_L} \qquad A = \pi r_L^2 \qquad \omega_L = qB/m$$

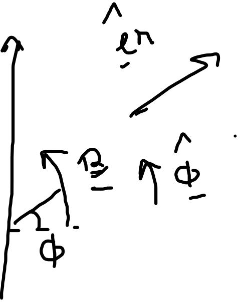
$$m_{spira} = A \cdot i = \pi \frac{m^{\cancel{2}} v_L^2}{\cancel{q^2} B^{\cancel{2}}} \cdot \frac{\cancel{q}}{2\cancel{\pi}} \frac{\cancel{q}B}{\cancel{m}} = \frac{m v_L^2}{2B} = \mu$$





Bottiglia magnetica





$$\hat{\underline{b}} = \hat{\underline{\phi}}$$

$$\underline{F} = -m v^2_{\parallel gc} \, (\hat{\underline{b}} \cdot \underline{\nabla}) \hat{\underline{b}}$$

Coord. cilindriche

$\hat{\underline{b}} \cdot \underline{\nabla}$: comp. lungo ϕ del gradiente $= \frac{1}{r} \frac{\partial}{\partial \phi}$

$$\hat{\underline{b}} = -\text{sen}\phi \, \hat{\underline{i}} + \cos\phi \, \hat{\underline{j}}$$

$$\frac{1}{r} \frac{\partial}{\partial \phi} \hat{\underline{b}} = \frac{1}{r} \underbrace{-\cos\phi \, \hat{\underline{i}} - \sin\phi \, \hat{\underline{j}}} = -\frac{\hat{\underline{e}}_r}{r}$$

$$\underline{F} = \frac{m v^2_{\parallel gc}}{r} \hat{\underline{e}}_r$$

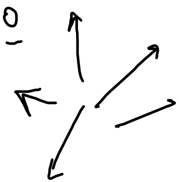
Riassunto

$$\underline{v}_D = \underline{v}_E + \underline{v}_{\nabla|\underline{B}|} + \underline{v}_{centr.} \qquad \underline{v}_E^{(0)} = \frac{\underline{E}\times\underline{B}}{B^2}$$

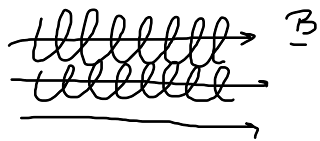
$$\underline{v}_D^{(0)} = \frac{\underline{F}\times\underline{B}}{qB^2} \qquad \underline{F} = \underline{F}_E + \underline{F}_{\nabla|\underline{B}|} + \underline{F}_{centr.} \qquad \underline{v}^{(0)}_{\nabla|\underline{B}|} = -\frac{mv_L^2}{2qB^3}\left(\underline{\nabla}|\underline{B}|\times\underline{B}\right)$$

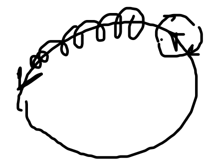
$$\underline{v}_D^{(1)} = -\frac{m}{qB^2}\left[\frac{d}{dt}\underline{v}_D^{(0)}\times\underline{B}\right] \qquad \underline{v}_{centr} = \frac{1}{qB^2}\frac{mv_\parallel^2}{r}\hat{\underline{r}}\times\underline{B}$$

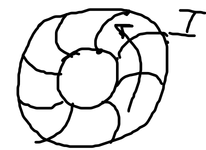
$\underline{B} = \underline{0}$



$\underline{B} \neq 0$







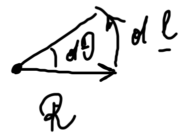
Legge Ampere

$$\oint_C \underline{B}\cdot d\underline{l} = \mu_0 I_{conc}$$

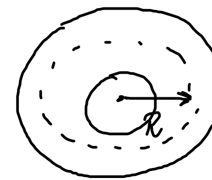
C: circonferenza lungo la linea di campo

$|\underline{B}|$ è cost. lungo la circonf.

$\underline{B} \parallel d\underline{l}$ $\quad d\underline{l}$

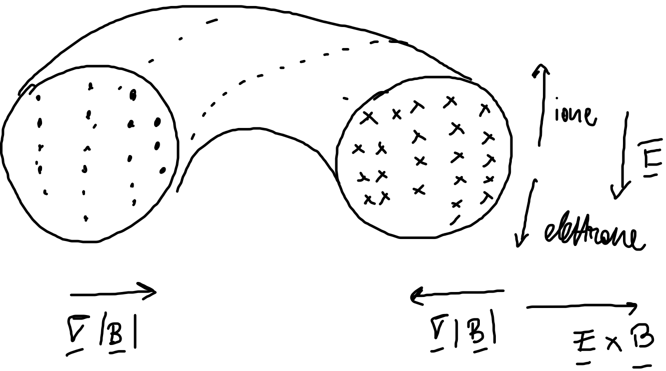


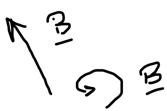
$$d\underline{l} = R\,d\theta\,\hat{\underline{e}}_\theta$$



$$\int B(R)\,\hat{\underline{e}}_\theta \cdot R\,d\theta\,\hat{\underline{e}}_\theta = \mu_0 \cdot N I$$

$$BR\int_0^{2\pi} d\theta = \mu_0 N I; \qquad B(R) = \frac{\mu_0 N I}{R} \qquad B \propto \frac{1}{R}$$





$$\underline{F}_{\nabla|B|} \propto - \frac{\underline{\nabla}|\underline{B}| \times \underline{B}}{q}$$

$$\underline{v}_{E\times B} = \frac{\underline{E} \times \underline{B}}{B^2} \qquad f_{em} \propto \frac{d\Phi}{dt}$$

1) Bobine storte: stellarator

2) Corrente toroidale: Tokamak