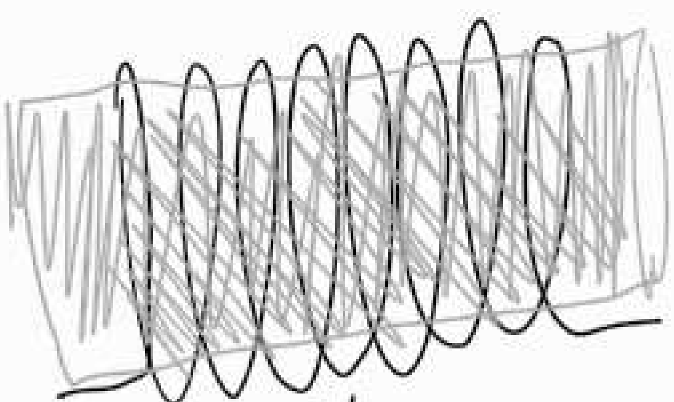
DIAMAGNETI	PARAMAGNETI	FERROMAGNETI
$\chi_m < 0$	$\chi_m > 0$	$\chi_m > 0$
$\chi_m \sim -10^{-5}$	$\chi_m \sim 10^{5}$	$\chi_m \sim 10^{3} \div 10^{4}$

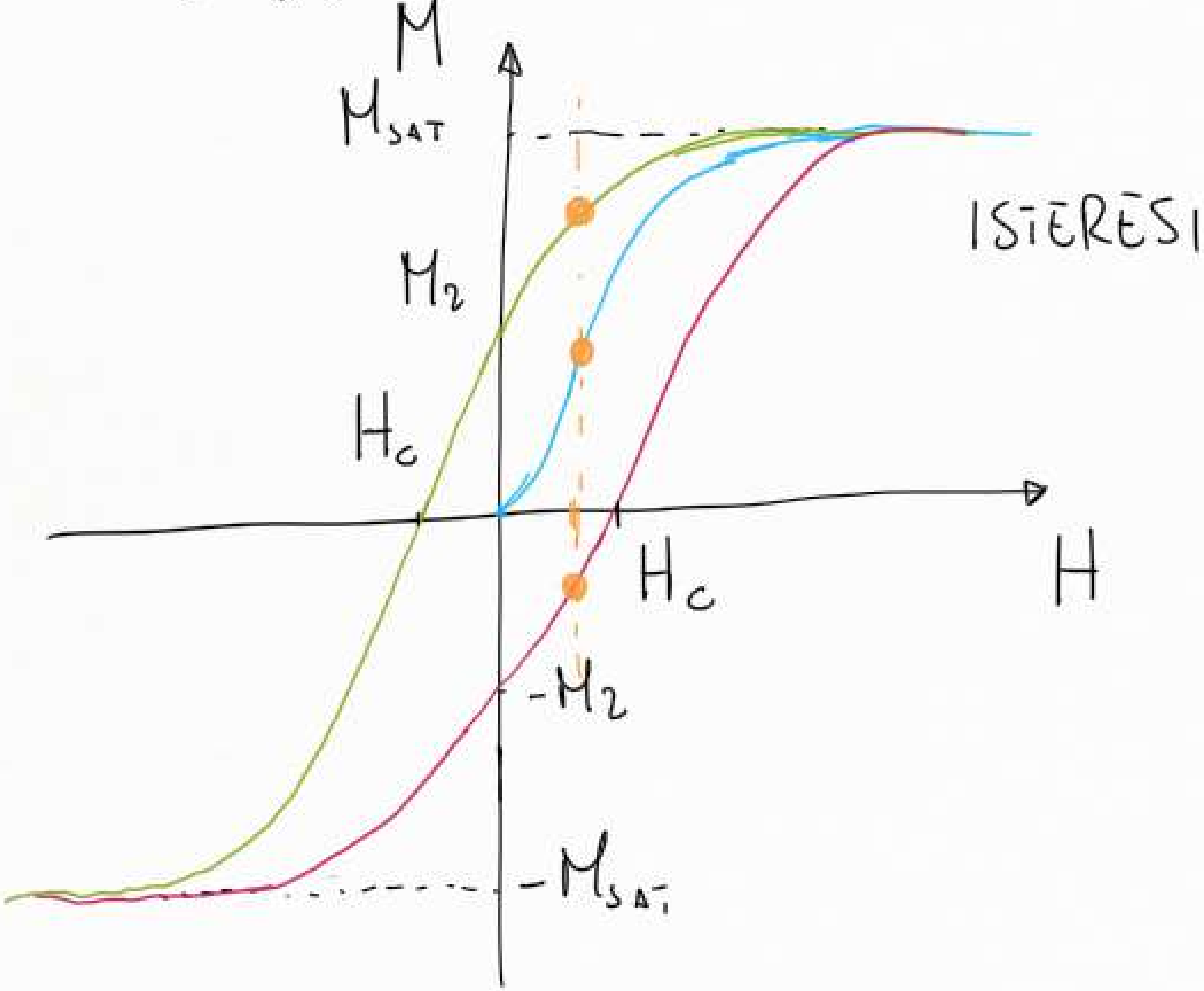
$$\begin{cases} \vec{M} = \chi_m \vec{H} \\ \vec{B} = \mu_0 (\vec{H} + \vec{M}) \end{cases}$$

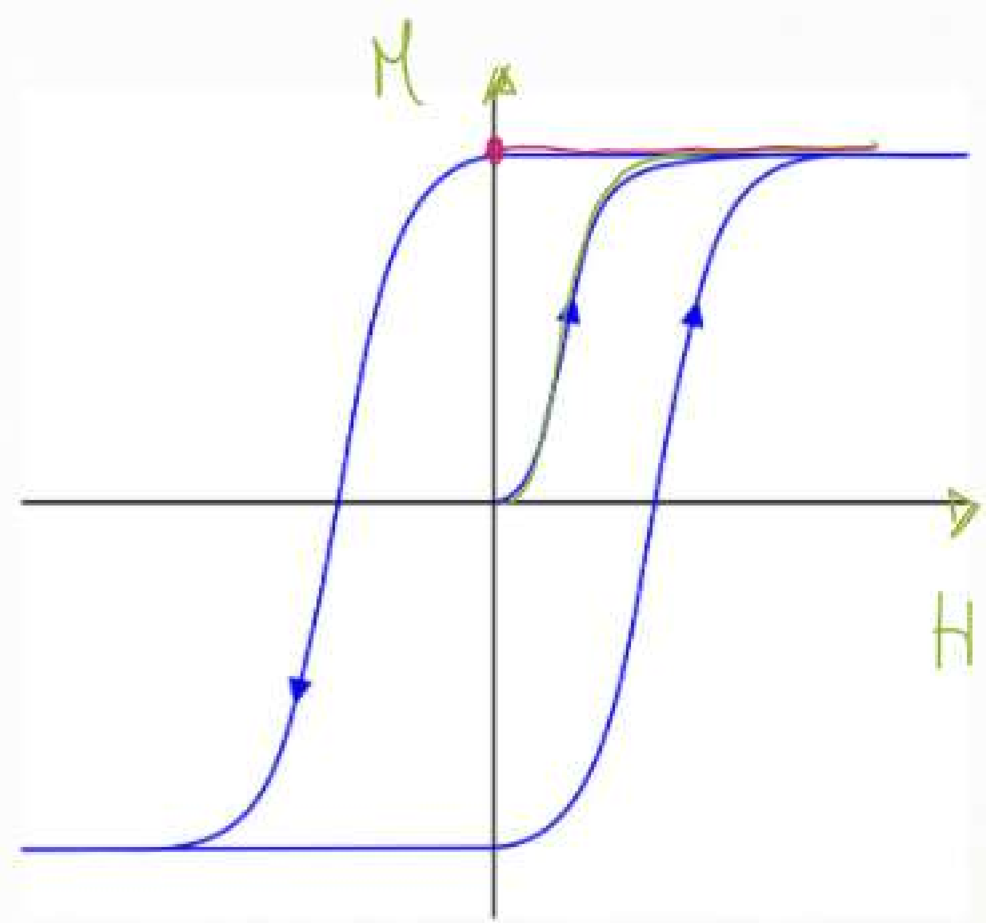
vero sl per diamagneti e paramagneti



n, i

$$H = \frac{B_0}{\mu_0} = n\, i$$

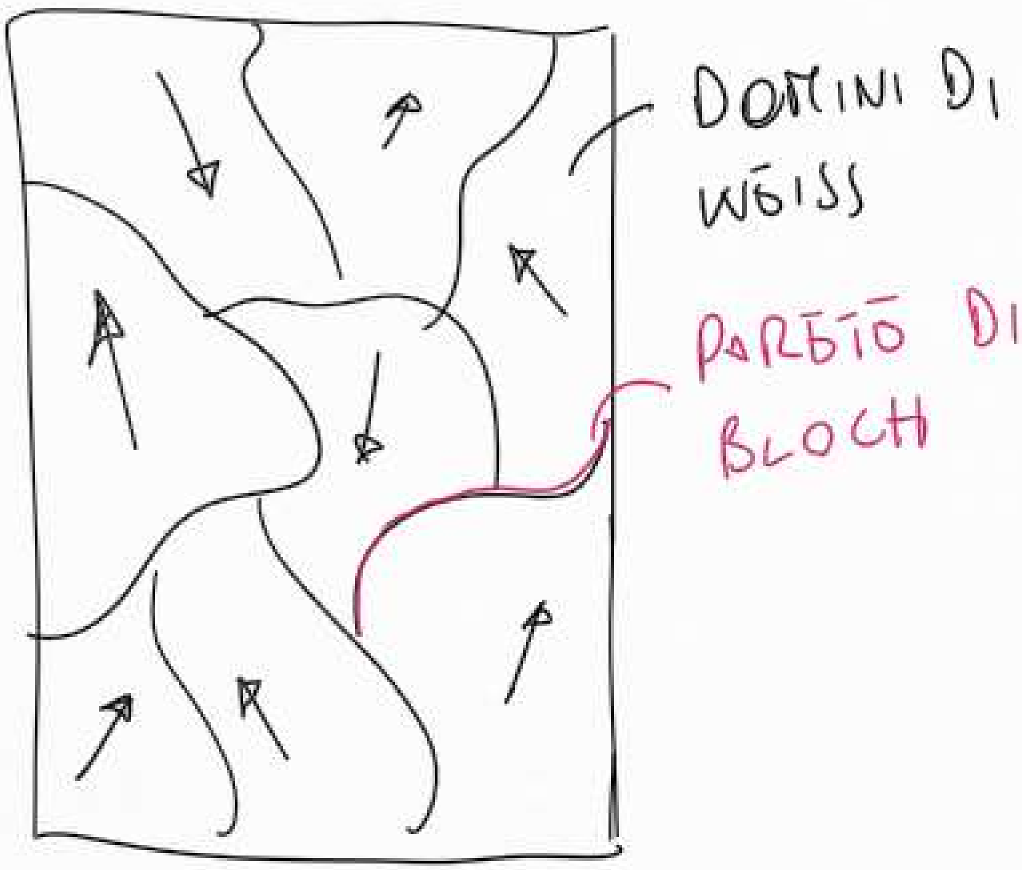




$T < T_c$ di Curie

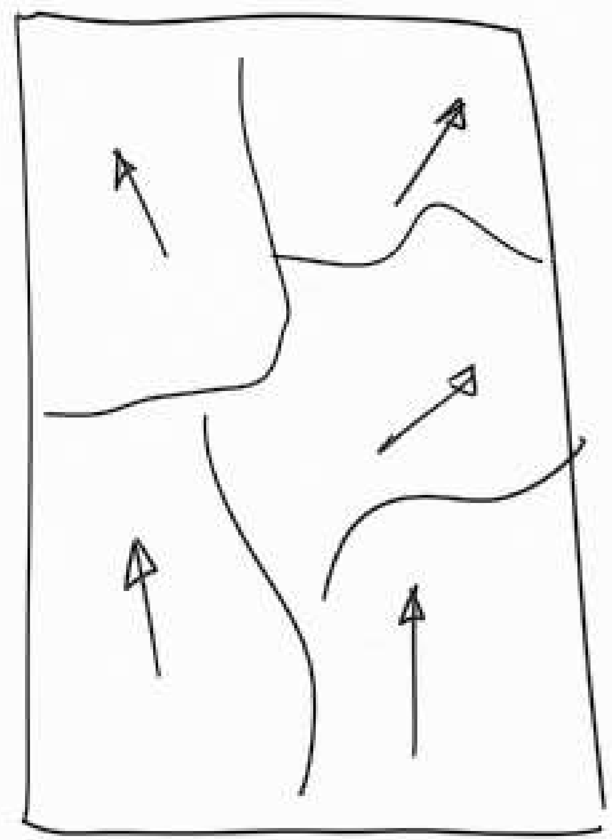
se $T > T_c$ questi materiali sono dei paramagneti

$H = 0$



$M = 0$

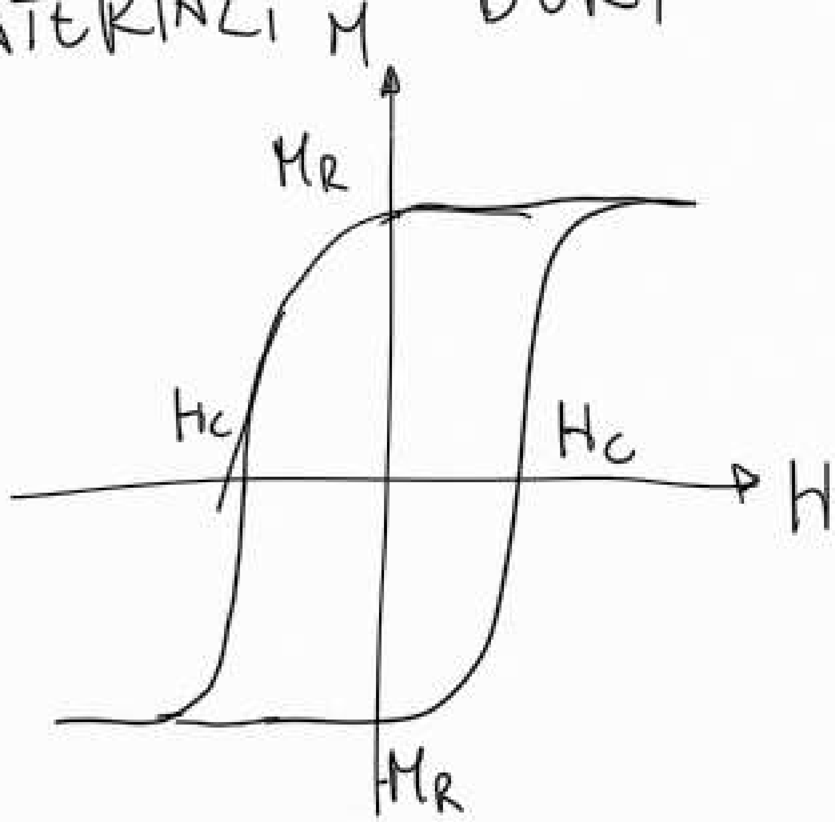
$H \neq 0 \uparrow$



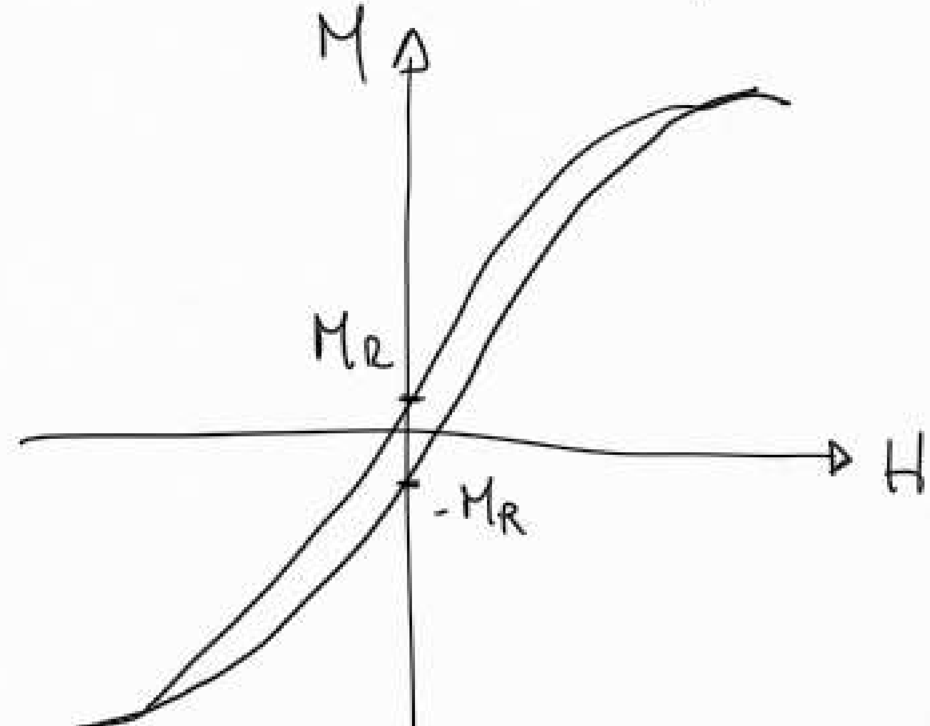
$M \neq 0$

$\vec{M} \parallel \vec{H}$

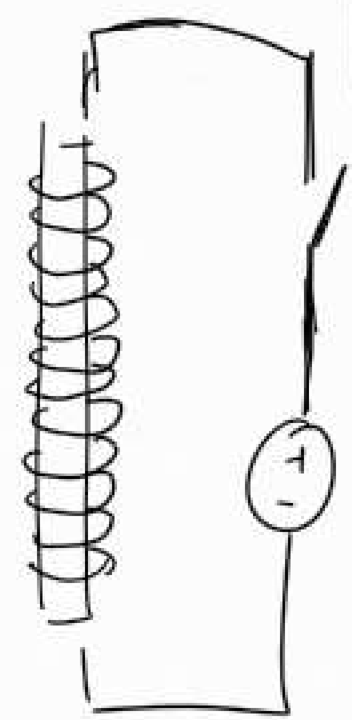
MATERIALI DURI



MATERIALI DOLCI

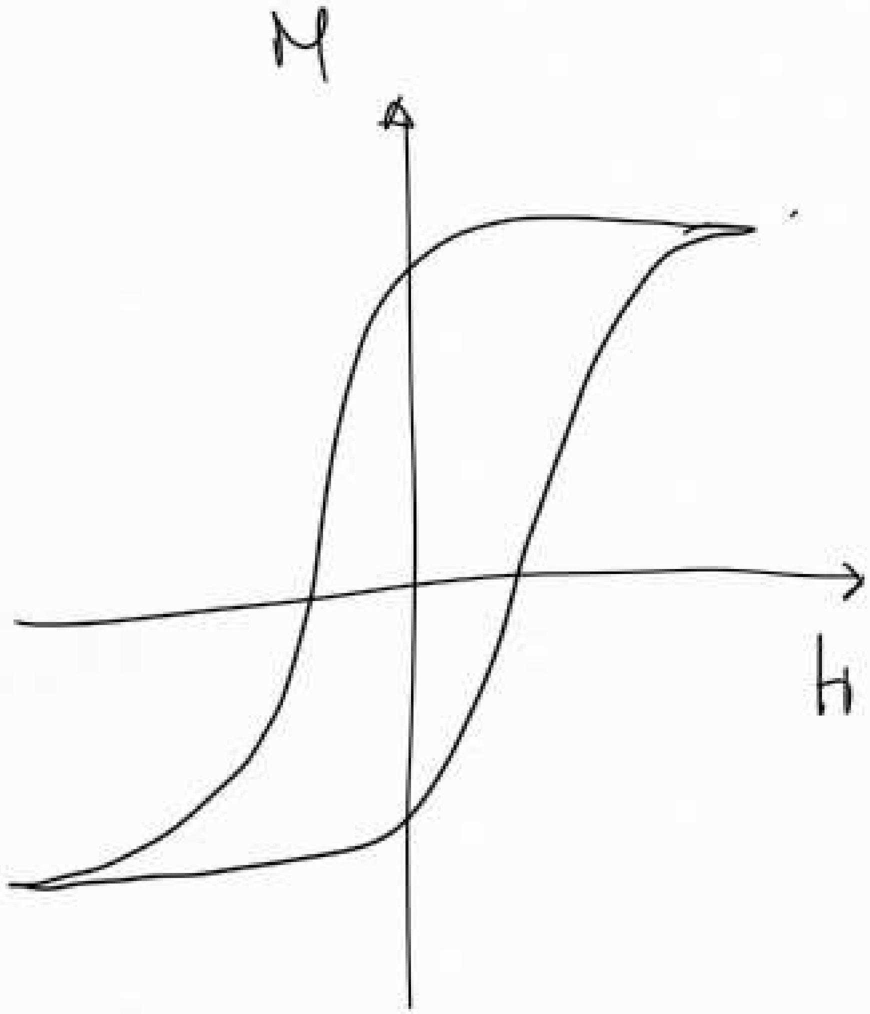


$$\vec{B} = \mu_0 (\cancel{\vec{H}} + \vec{M})$$



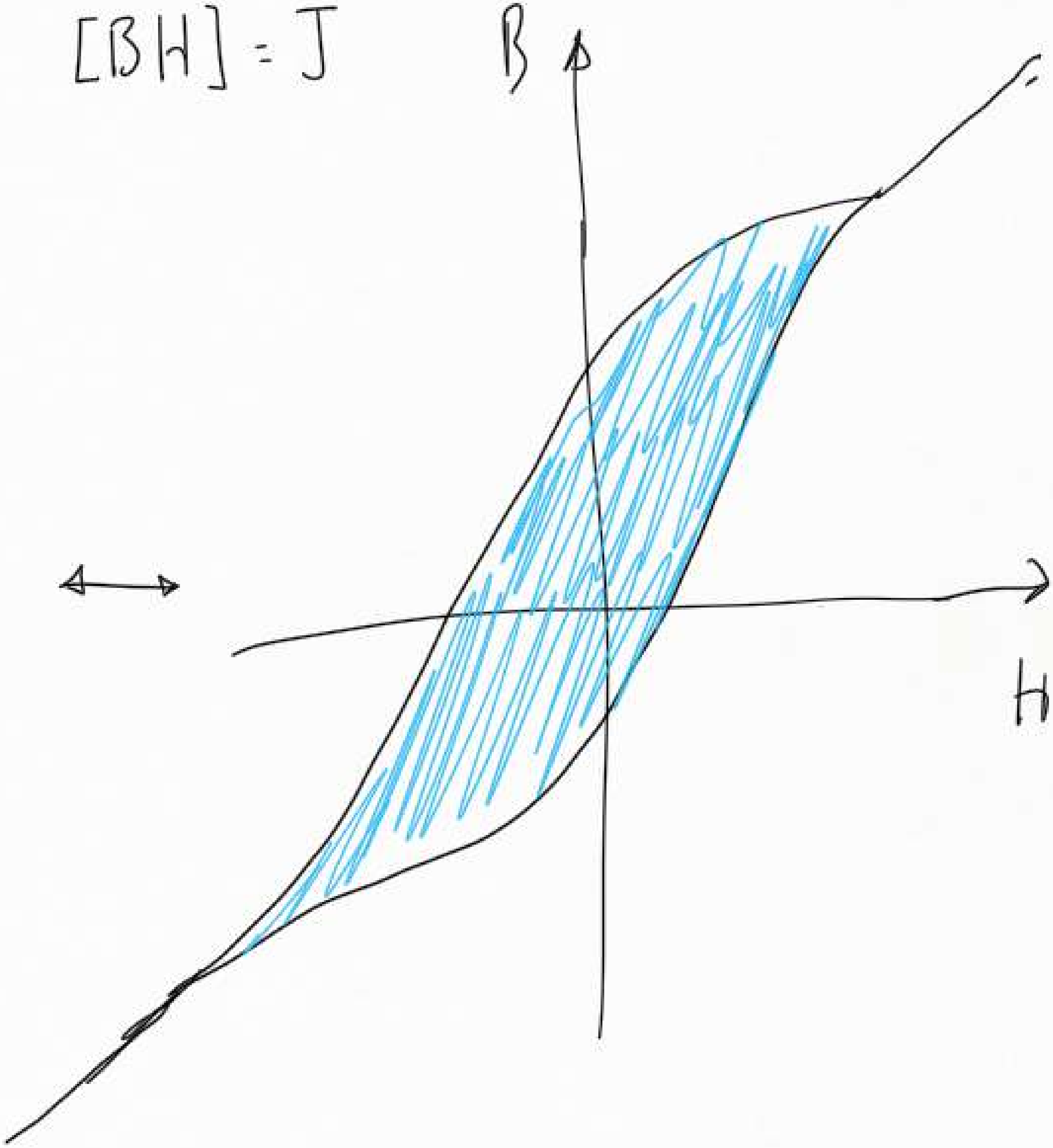
ELETTROMAGNETE

$$\vec{B} = \mu_0 (\vec{H} + \vec{M})$$

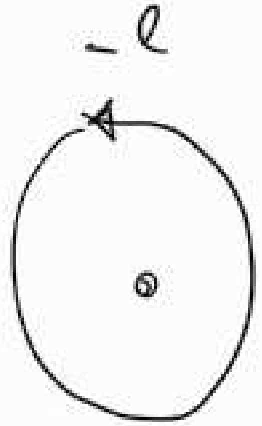


$$[BH] = J$$

$\longleftrightarrow$



MECCANISMI DI MAGNETIZZAZIONE



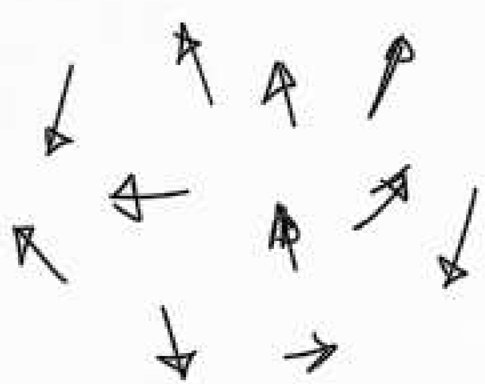
precessione di Larmor

$\downarrow$

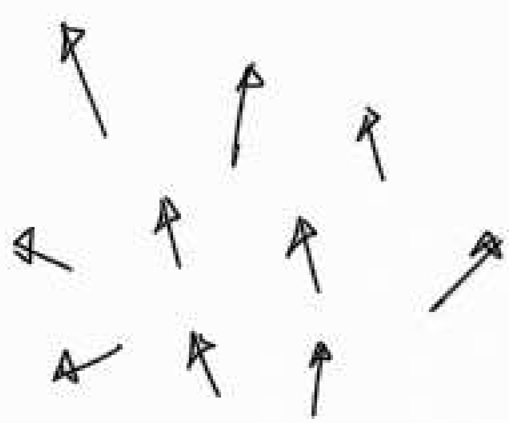
diamagnetismo

PERTURBAZIONE DEL MOTO ORBITALE ELETTRONICO

$H = 0$



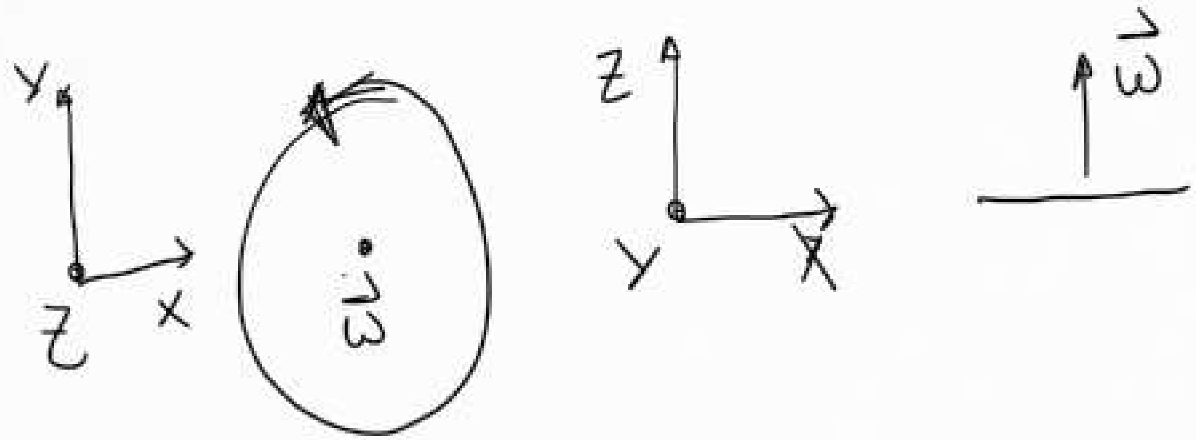
$H \neq 0 \uparrow$



MAGNETIZZAZIONE PER ORIENTAMENTO

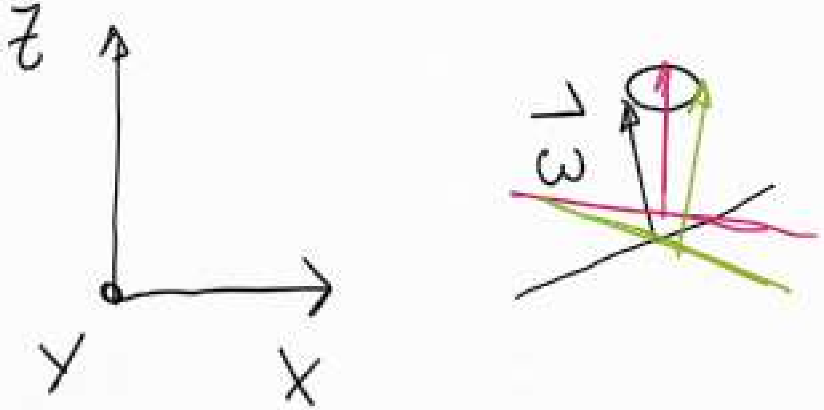
$\langle \vec{m} \rangle$ momento di dipolo magnetico medio (per atomo/molecola)

$\vec{M} = n \langle \vec{m} \rangle \leftrightarrow \vec{P} = n \langle \vec{p} \rangle$



$$H = 0$$

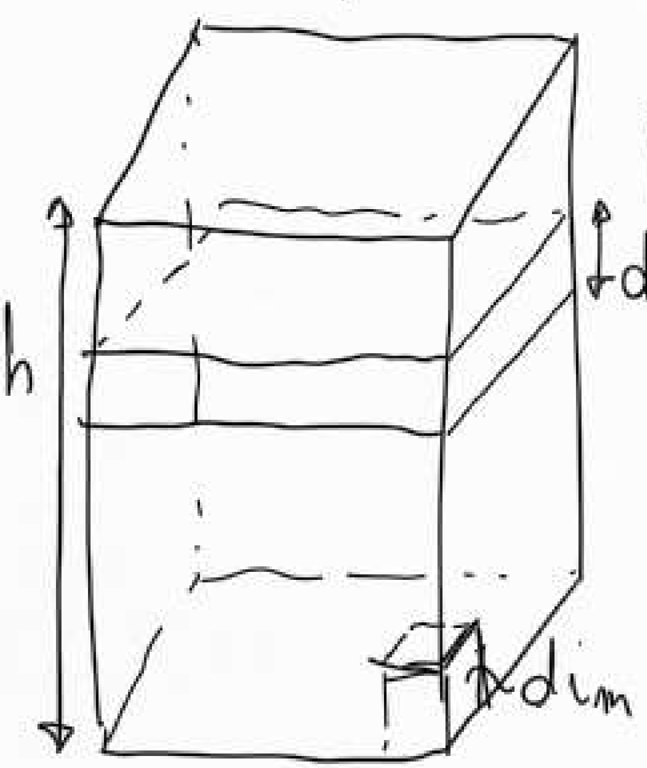
$$\langle \vec{m}_i \rangle$$



$$H \neq 0$$

$$\langle \vec{m}_{\parallel} \rangle \neq \langle \vec{m}_{\perp} \rangle$$

$$\vec{M} \equiv n\langle \vec{m} \rangle \longleftrightarrow \vec{P} = n\langle \vec{p} \rangle \ , \quad \vec{m} = i\,\Sigma\,\hat{n}$$



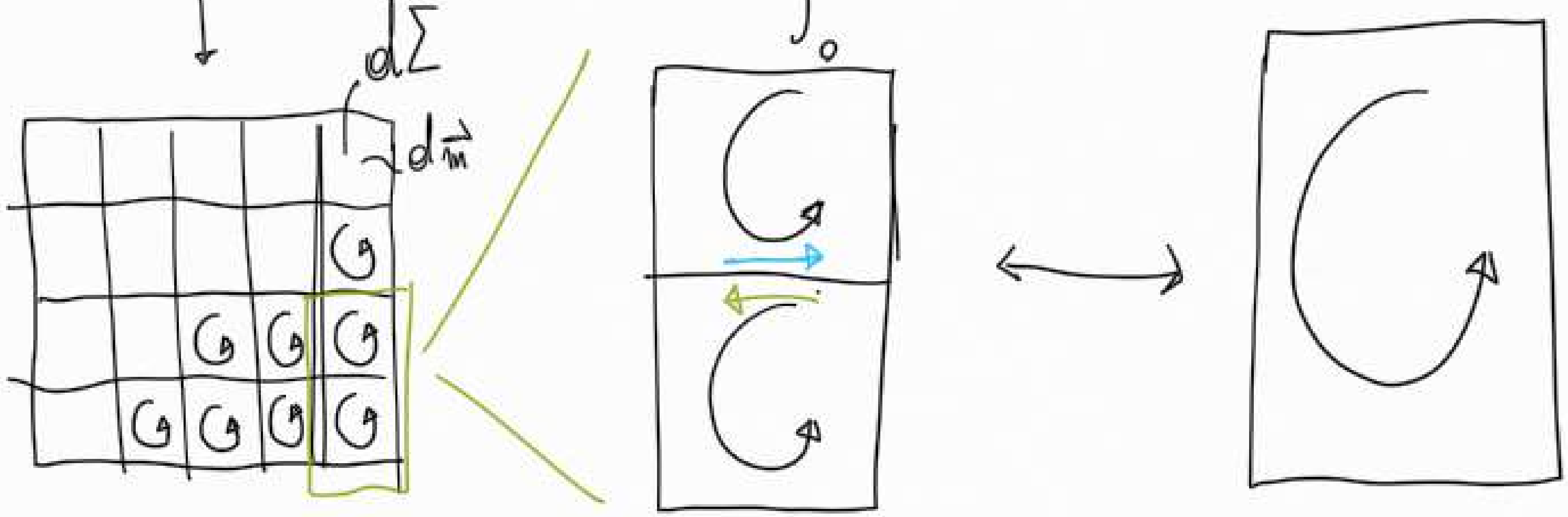
$\vec{M} \uparrow$ uniforme

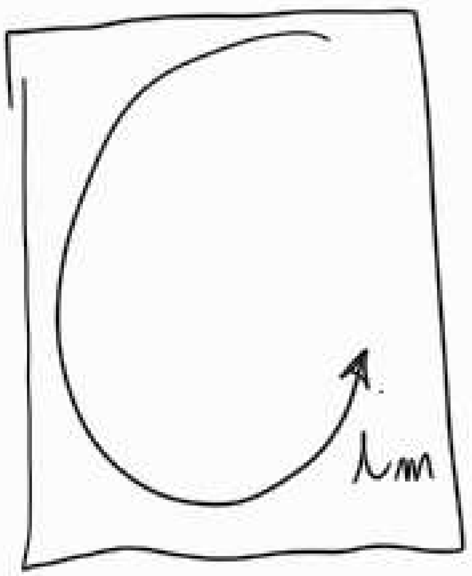
"Σ" "n̂"

$$d\vec{m} = \vec{M}\,d\tau = \vec{M}\,d\Sigma\,dh = M\,d\Sigma\,dh\,\hat{z} =$$

$$= di_m\,d\Sigma\,\hat{z} \ , \quad di_m \equiv M\,dh \Rightarrow$$

$$i_m = \int_0^h M\,dh = Mh$$

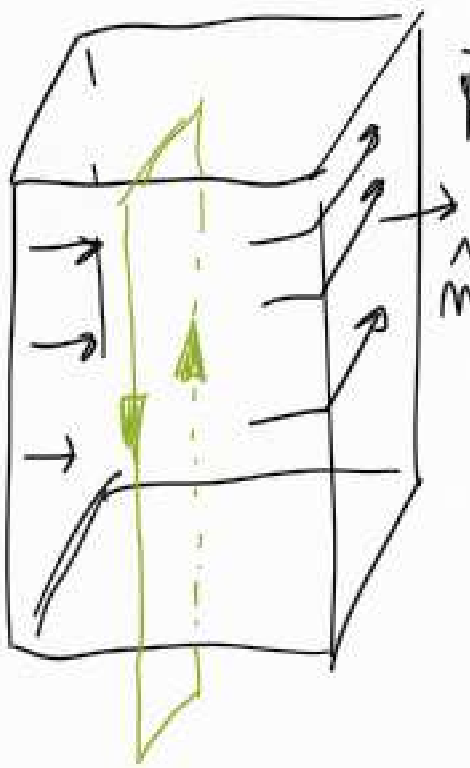




$$i_m = M h \implies M = \frac{i_m}{h} \equiv J_m \qquad [J_m] = \frac{A}{m} \neq [J]$$

correnti amperiane

densità di corrente amperiana



$$\vec{M}\uparrow \qquad \vec{J}_m = \vec{M} \times \hat{n} \longleftrightarrow \sigma_p = \vec{P}\cdot\hat{n}$$

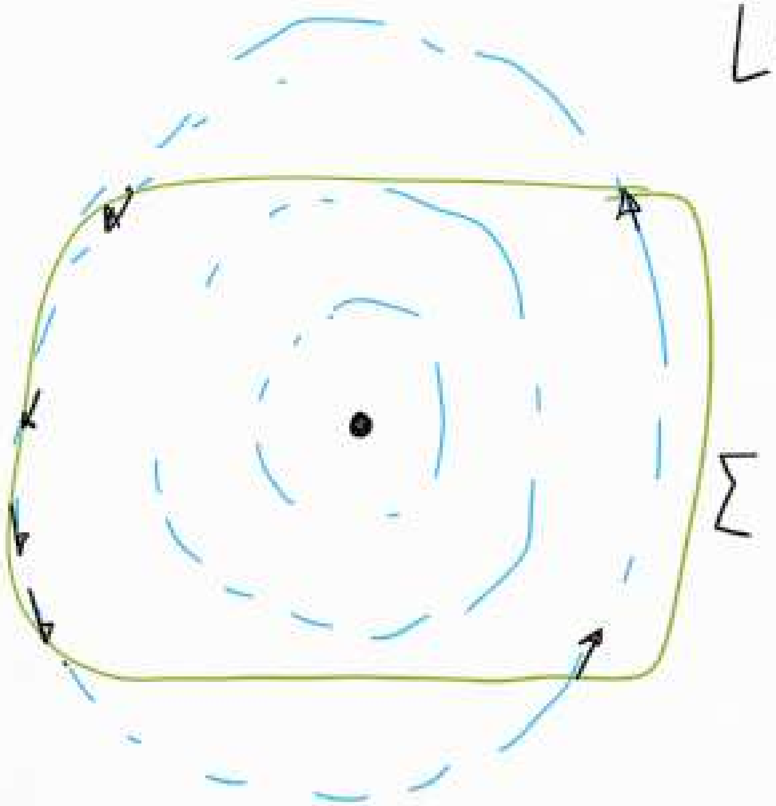
$$\boxed{H = \frac{B_0}{\mu_0}}$$

$$\oint \vec{B}\cdot d\vec{s} = \mu_0 i_m$$

$$\shortparallel$$

$$\oint \mu_0(\cancel{\vec{H}} + \vec{M})\cdot d\vec{s} = \mu_0 \oint \vec{M}\cdot d\vec{s} = \mu_0 i_m \implies \oint \vec{M}\cdot d\vec{s} = i_m$$

LA LEGGE DI GAUSS

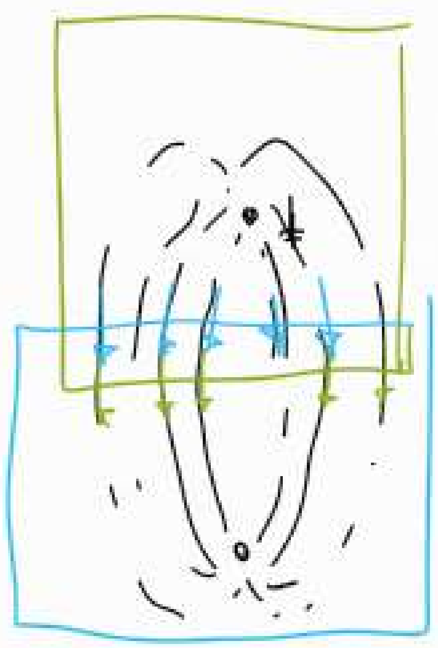


$$\boxed{\oint_{\Sigma} \vec{B} \cdot \hat{n} \, d\Sigma = 0}$$

$$[\Phi_{\Sigma}(B)] = Tm^2 = Wb$$

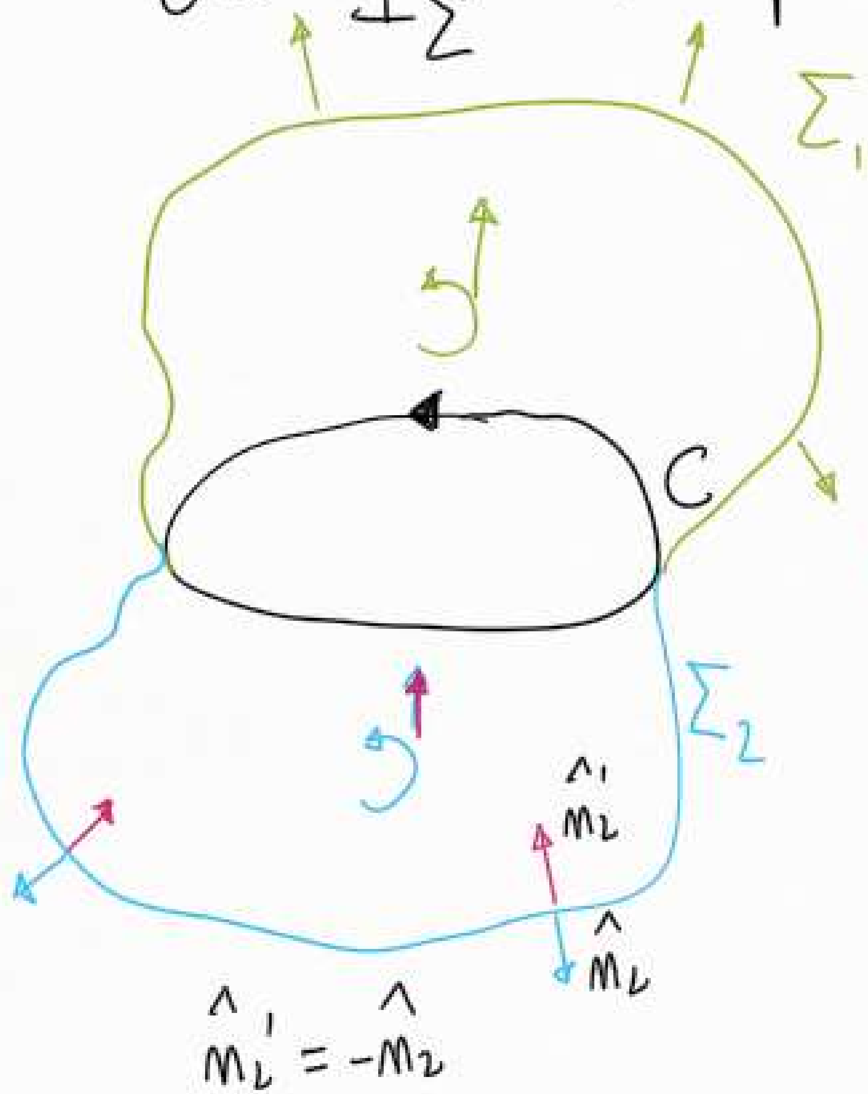
weber

$\updownarrow$



$$\oint_{\Sigma} \vec{E} \cdot \hat{n} \, d\Sigma = \frac{q_{IN.}}{\varepsilon_0}$$

Se Φ_Σ è sempre 0 $\rightarrow$ il campo è detto <u>solenoidale</u>

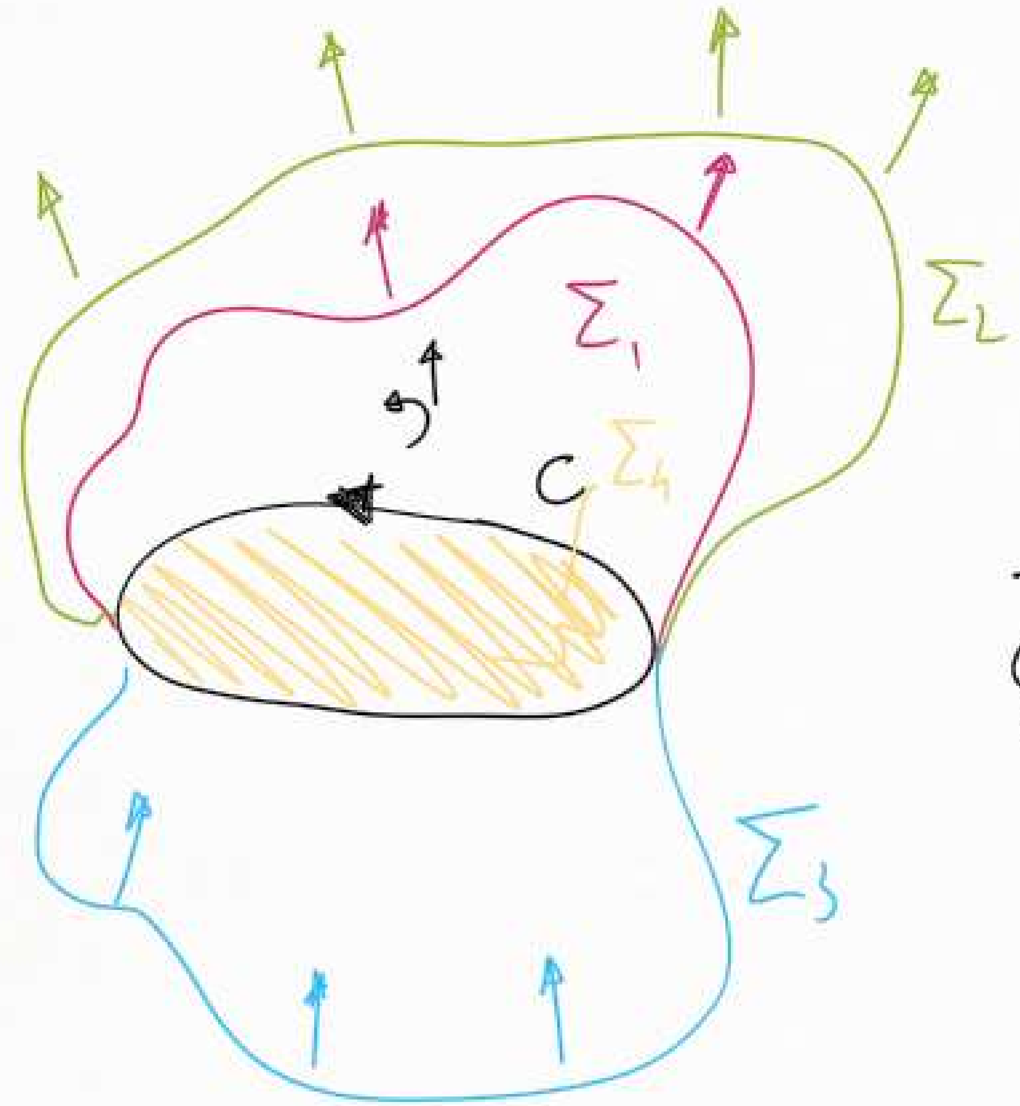


$$\oint_{\Sigma_1+\Sigma_2} \vec{B}\cdot\hat{n}\,d\Sigma = \oint_{\Sigma_1}\vec{B}\cdot\hat{n}_1\,d\Sigma + \oint_{\Sigma_2}\vec{B}\cdot\hat{n}_2\,d\Sigma =$$

$$= \Phi_{\Sigma_1}(\vec{B}) + \Phi_{\Sigma_2}(\vec{B}) = 0 \Rightarrow \Phi_{\Sigma_2}(\vec{B}) = -\Phi_{\Sigma_1}(\vec{B})$$

$$\boxed{\oint_{\Sigma_2}\vec{B}\cdot\hat{n}_2'\,d\Sigma} = -\oint_{\Sigma_2}\vec{B}\cdot\hat{n}_2\,d\Sigma = -\Phi_{\Sigma_2}(\vec{B}) =$$

$$= \boxed{\Phi_{\Sigma_1}(\vec{B})}$$



$$\Phi_{\Sigma_1} = \Phi_{\Sigma_2} = \Phi_{\Sigma_3} = \Phi_C$$

solo se il campo è solenoidale

Φ_C è il flusso concatenato a C

Equazioni generali della magnetostatica

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 (i + i_m), \quad \oint \vec{M} \cdot d\vec{s} = i_m \Rightarrow$$

$$\oint \vec{B} \cdot d\vec{s} = \mu_0 i + \mu_0 \oint \vec{M} \cdot d\vec{s} \Rightarrow \oint (\vec{B} - \mu_0 \vec{M}) \cdot d\vec{s} = \mu_0 i$$

$$\vec{B} = \mu_0 (\vec{H} + \vec{M}) \Rightarrow \vec{B} - \mu_0 \vec{M} = \mu_0 \vec{H} \Rightarrow$$

$$\oint (\vec{B} - \mu_0 \vec{M}) \cdot d\vec{s} = \oint \mu_0 \vec{H} \cdot d\vec{s} = \mu_0 i \Rightarrow$$

campo di induzione dielettrica $\vec{D} = \varepsilon \vec{E}$

$$\oint \vec{H} \cdot d\vec{s} = i \longleftrightarrow \oint_\Sigma \vec{D} \cdot \hat{n} \, d\Sigma = q$$

$$\oint_{\Sigma} \vec{B} \cdot \hat{n}\, d\Sigma = \int_{\tau(\Sigma)} \vec{\nabla} \cdot \vec{B}\, d\tau = 0$$ teorema di divergenza

$$\Downarrow$$

$$\vec{\nabla} \cdot \vec{B} = 0 \qquad \vec{\nabla} \cdot \vec{E} = \frac{\rho}{\varepsilon_0}$$

$$\vec{\nabla} \times \vec{B} = \mu_0 \vec{J} \qquad \vec{\nabla} \times \vec{E} = 0$$

magnetostatica   elettrostatica

$$\left\{ \begin{array}{ll} \vec{\nabla} \cdot \vec{H} = 0 & \vec{\nabla} \cdot \vec{D} = \rho \\ \vec{\nabla} \times \vec{H} = \vec{J} & \vec{\nabla} \times \vec{D} = 0 \end{array} \right\}$$