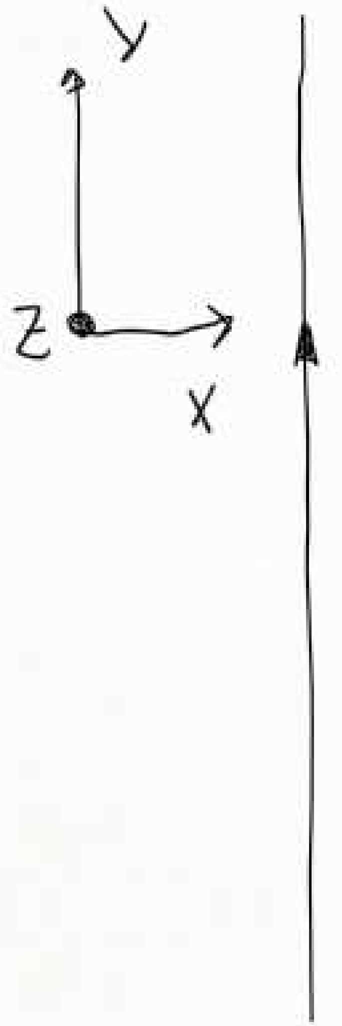
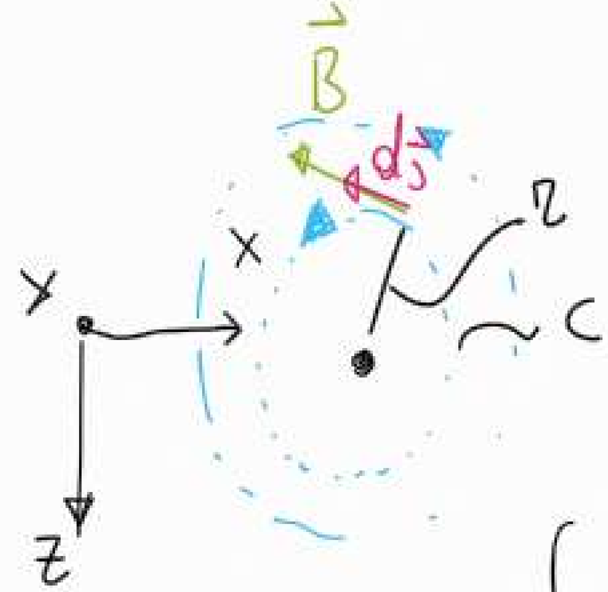
$$\oint_C \vec{B} \cdot d\vec{l} = \mu_0 \sum_k i_k = \mu_0 i$$

$$\oint_C \vec{B} \cdot d\vec{l} = \int_{\Sigma(C)} \vec{\nabla} \times \vec{B} \cdot \hat{n} \, d\Sigma = \mu_0 i = \mu_0 \int_{\Sigma(C)} \vec{J} \cdot \hat{n} \, d\Sigma \implies$$

$$\boxed{\vec{\nabla} \times \vec{B} = \mu_0 \vec{J}}$$

FORMA LOCALE
LEGGE DI AMPÈRE



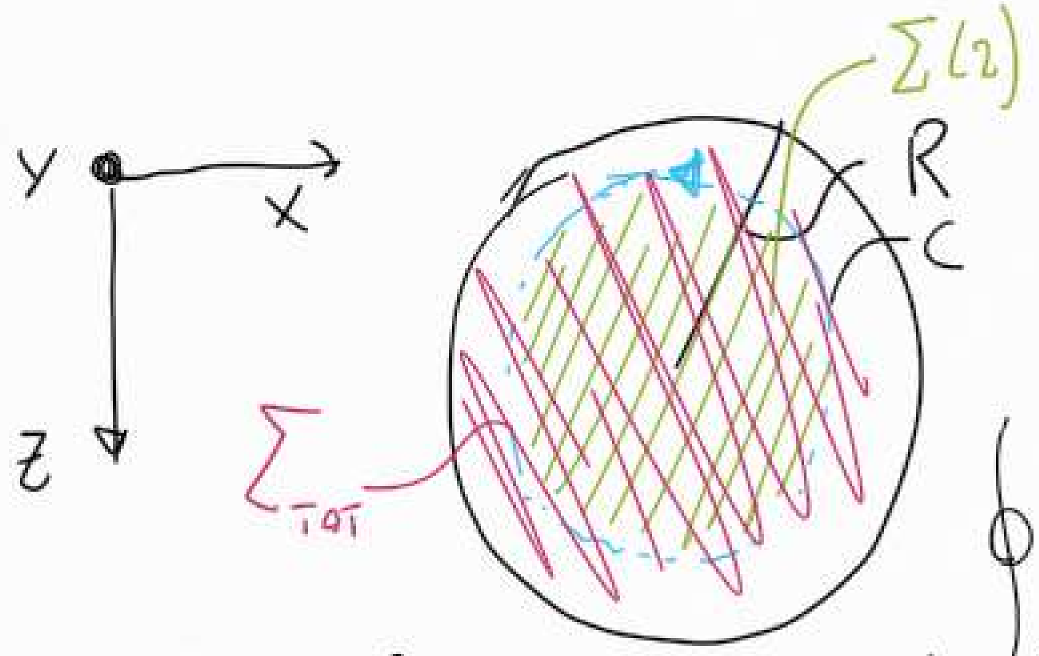


$$\oint_C \vec{B}\cdot d\vec{s} = \oint_C B\,ds = B\oint_C ds = B\,2\pi r$$

$$\oint_C \vec{B}\cdot d\vec{s} = \mu_0 i = B\,2\pi r \Rightarrow$$

$$\boxed{B = \frac{\mu_0 i}{2\pi r}}$$

Legge di Biot-Savart



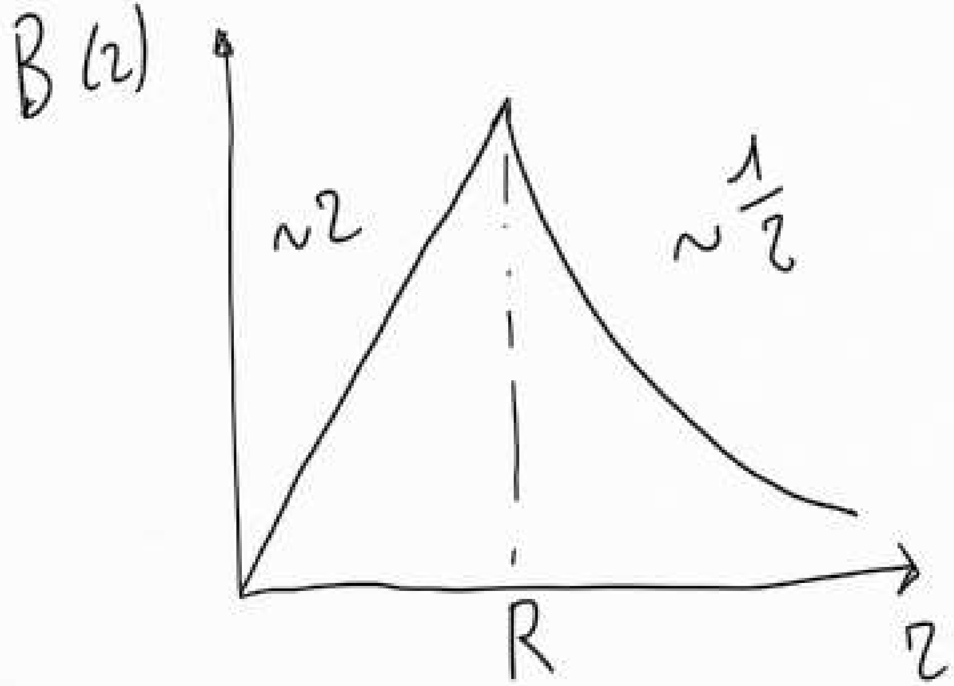
$$\oint_C \vec{B}\cdot d\vec{s} = \mu_0\, i(r) \leftarrow$$

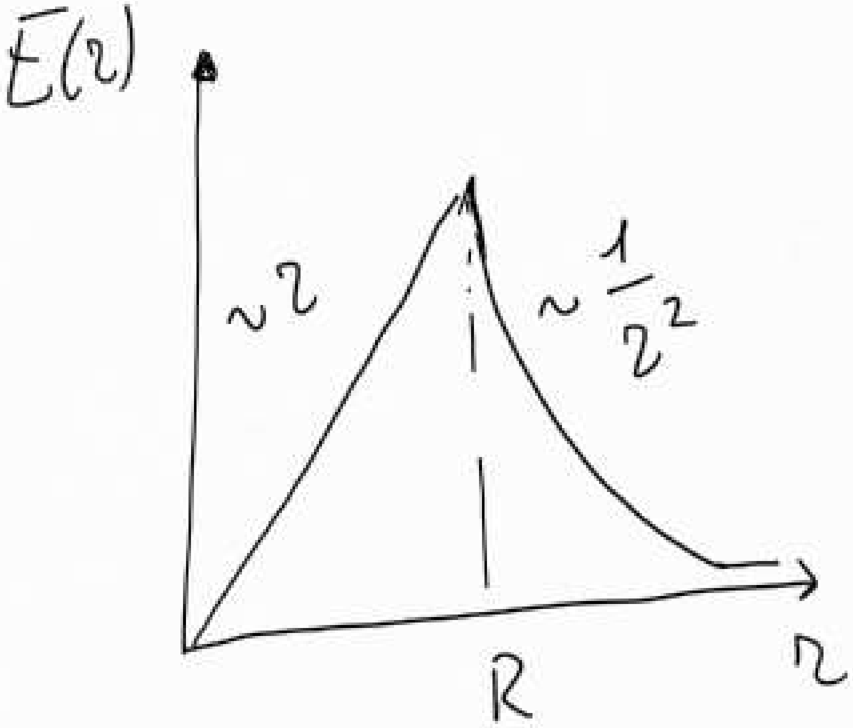
$$\oint_C \vec{B}\cdot d\vec{s} = B\, 2\pi r \leftarrow$$

$$i(r) = \int_{\Sigma(r)} J\, d\Sigma = J \int_{\Sigma(r)} d\Sigma = J\pi r^2, \quad J\pi R^2 = i \equiv J\,\Sigma_{TOT} \mapsto$$

$$i(r) = J\pi r^2 = \frac{\cancel{\pi} r^2 i}{\cancel{\pi} R^2} = \frac{r^2 i}{R^2} \mapsto$$

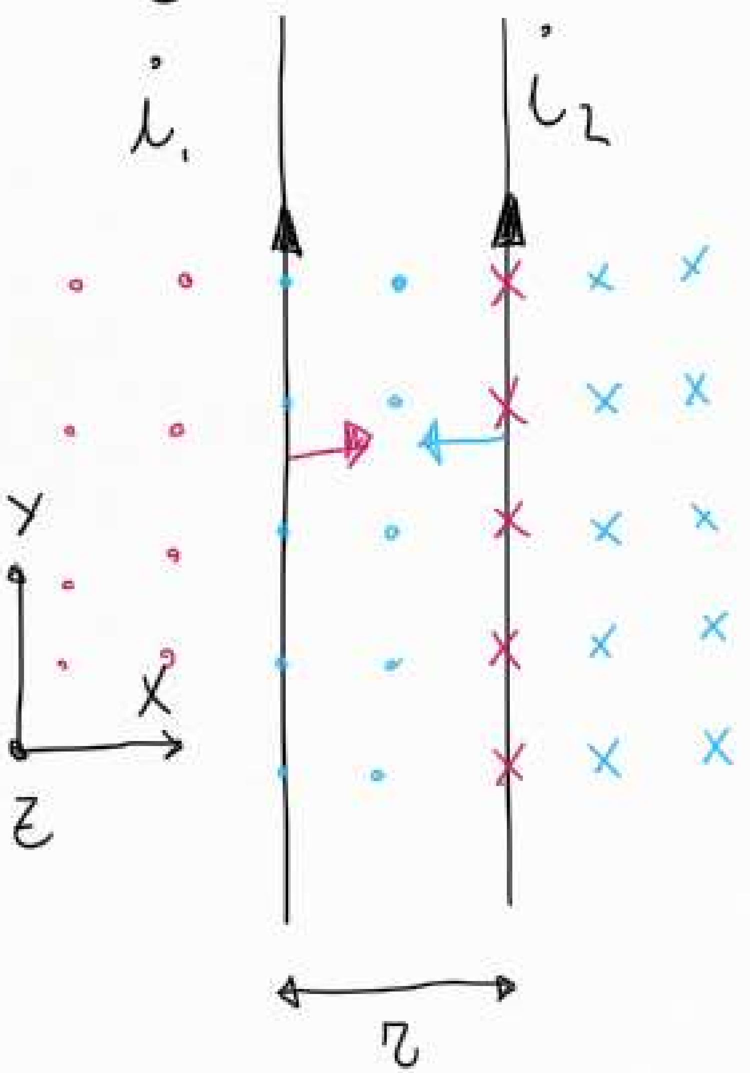
$$B\, 2\pi r = \mu_0 \frac{r^2 i}{R^2} \mapsto \quad B = \frac{\mu_0 r i}{2\pi R^2}$$


B(r)
~r
~1/r
R
r


E(r)
~r
~1/r²
R
r

$d\vec{F} = i\,d\vec{l} \times \vec{B}$, ma $d\vec{l} = \hat{t}\,dl \Rightarrow$

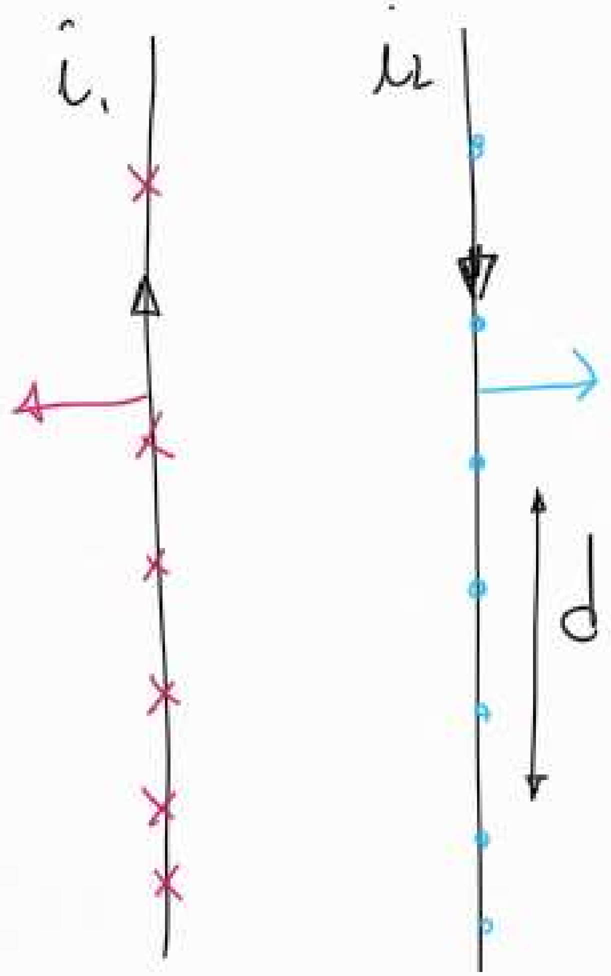
$\frac{d\vec{F}}{dl} = i\,\hat{t} \times \vec{B}$ forza per unità di lunghezza



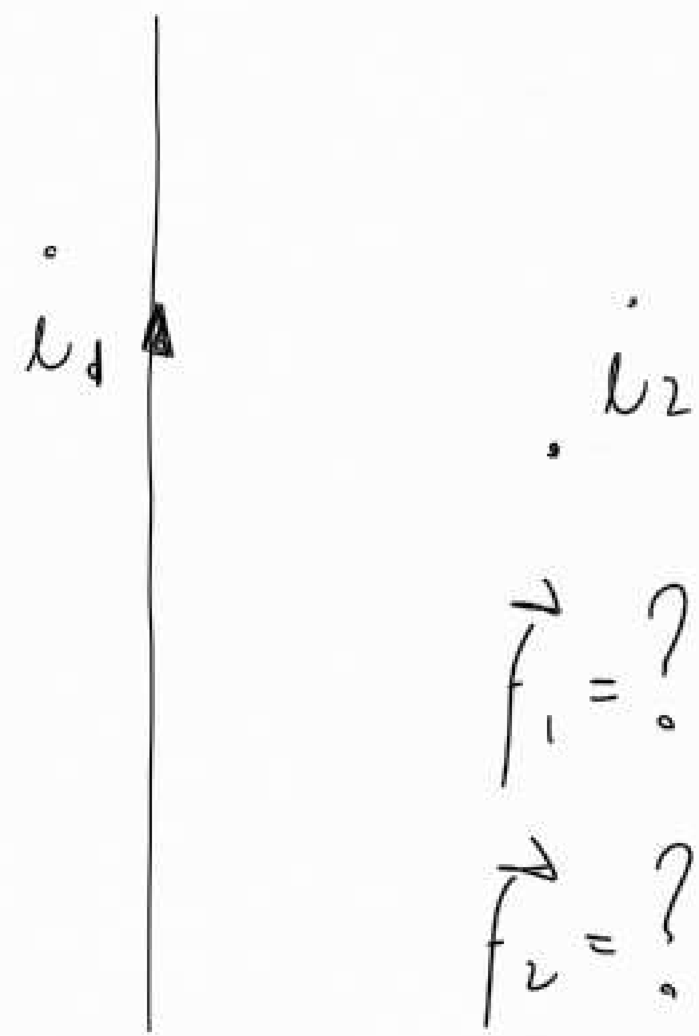
$$\vec{f}_1 = \frac{d\vec{F}_1}{dl} = i_1 \hat{t} \times \vec{B}_2 = i_1 \hat{y} \times \hat{z} B_2 = i_1 B_2 \hat{x}$$

$$\vec{f}_2 = \frac{d\vec{F}_2}{dl} = i_2 \hat{t} \times \vec{B}_1 = i_2 \hat{y} \times (-\hat{z}) B_1 = -i_2 B_1 \hat{x}$$

$$\left.\begin{aligned} f_1 &= i_1 B_2 = \frac{i_1 \mu_0 i_2}{2\pi r} \\ f_2 &= i_2 B_1 = \frac{i_2 \mu_0 i_1}{2\pi r} \end{aligned}\right\} f_1 = f_2, \quad \vec{f}_1 = -\vec{f}_2$$



$$F_d = f\,d = \frac{\mu_0\, i_1 i_2\, d}{2\pi r}$$



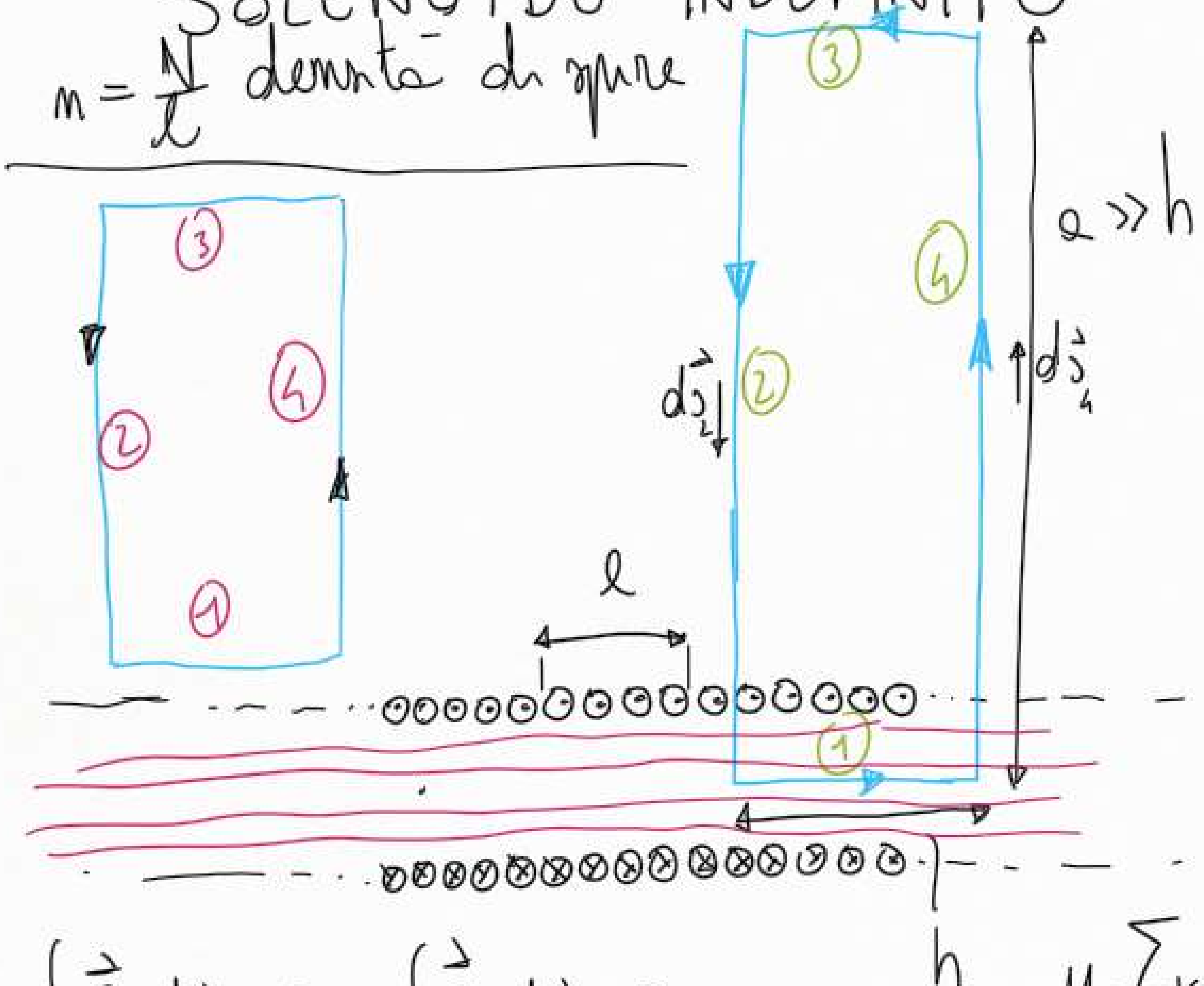
esercizio per casa

$\vec{f}_1 = ?$

$\vec{f}_2 = ?$

SOLENOIDE INDEFINITO

$n = \frac{N}{l}$ densità di spire



$$\oint_c \vec{B}\cdot d\vec{s} = \int_{(1)} \vec{B}\cdot d\vec{s} + \dots + \int_{(4)} \vec{B}\cdot d\vec{s}$$

$$\int_{(3)} \vec{B}\cdot d\vec{s} = 0 \quad \text{perché } \vec{B} = 0$$

$$\int_{(2)} \vec{B}\cdot d\vec{s} = \int_{(4)} \vec{B}\cdot d\vec{s} = 0 \quad \text{perché } \vec{B} \perp d\vec{s}$$

$$\oint_c \vec{B}\cdot d\vec{s} = \int_{(1)} \vec{B}\cdot d\vec{s} = B\int_{(1)} ds = Bh$$

$$\oint \vec{B}\cdot d\vec{s} = 0 = \int_{(1)} \vec{B}\cdot d\vec{s} = 0$$

$$\Downarrow$$

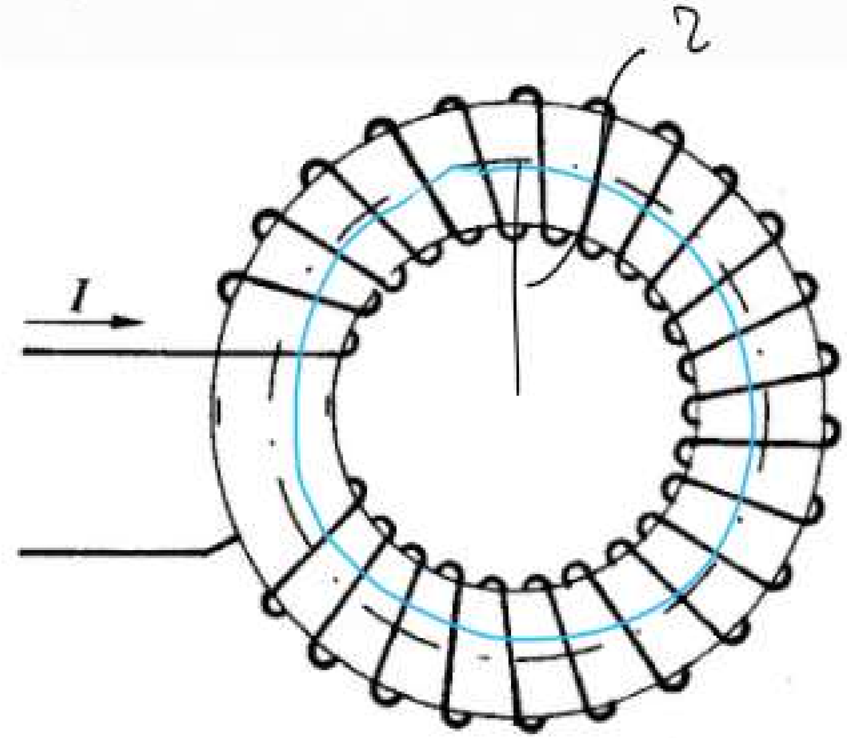
$$\vec{B} = 0$$

$$\mu_0 \sum_k i_k = \mu_0 n h i \Rightarrow$$

$$\boxed{B = \mu_0 n i}$$

campo generato da un solenoide indefinito

SOLENOIDI TOROIDALI



$A = NI$

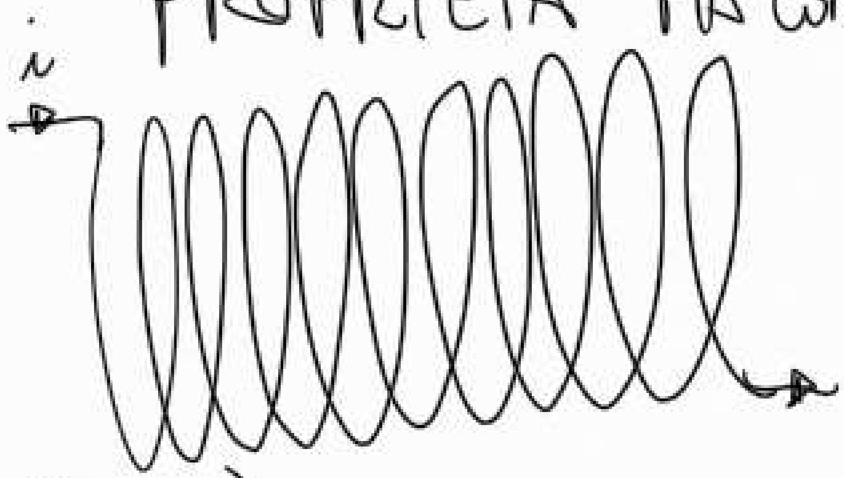
$B = \mu_0 \frac{NI}{l}$

N = numero di spire

$$\oint_c \vec{B}\cdot d\vec{s} = B\oint_c ds = B\,2\pi r \quad , \mu_0 \sum_k i_k = \mu_0 N i \Rightarrow$$

$$\boxed{B = \frac{\mu_0 N i}{2\pi r}}$$

PROPRIETÀ MAGNETICHE DELLA MATERIA



$n \mapsto B_0 = \mu_0 n i$

$\vec{B}_0$ // parallelo all'asse del solenoide

$\vec{H} \equiv \frac{\vec{B}_0}{\mu_0}$, se riempiamo il solenoide, $\frac{B}{B_0} = K_m$ $\quad (K_m = \mu_r)$

↳ permeabilità magnetica relativa

$B = K_m \mu_0 n i \equiv \mu n i$, $\mu \equiv K_m \mu_0$

↳ p. m. assoluta

$[\mu] = [\mu_0] = \frac{Tm}{A} = \frac{H}{m}$

$$B = K_m B_0 = K_m \mu_0 H = \mu H \Rightarrow \vec{B} = \mu \vec{H} \qquad (\vec{D} = \varepsilon \vec{E})$$

$$\mu_0 \rightarrow \mu \qquad (\vec{P} = \varepsilon_0 \chi \vec{E})$$

$$\vec{B} = \frac{\mu i}{4\pi} \oint \frac{d\vec{s} \times \hat{r}}{r^2} \, , \quad \oint \vec{B} \cdot d\vec{s} = \mu i \qquad (\vec{D} = \varepsilon_0 \vec{E} + \vec{P})$$

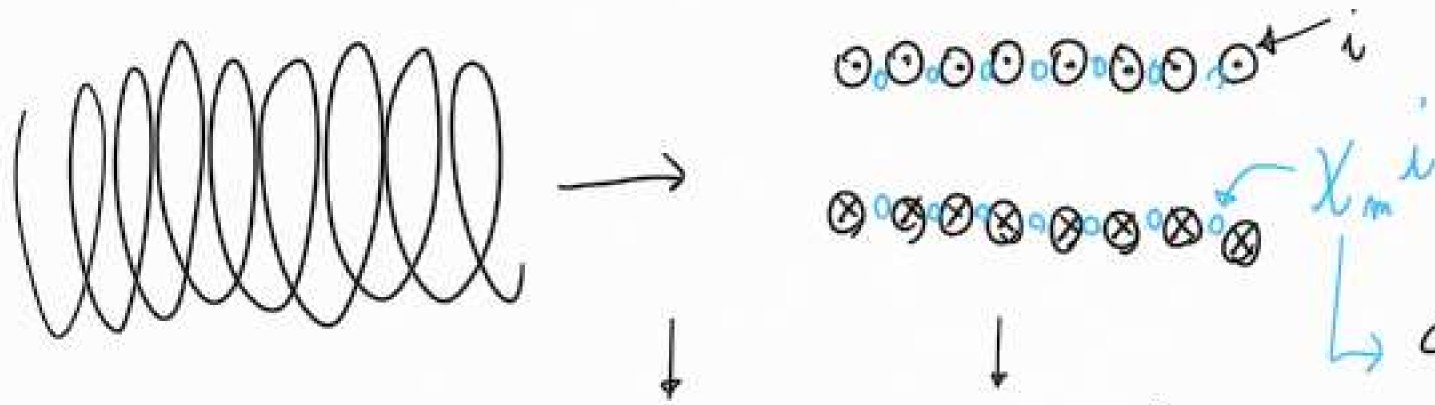
$$\vec{B} - \vec{B}_0 = K_m \vec{B}_0 - \vec{B}_0 = (K_m - 1)\vec{B}_0 \equiv \chi_m \vec{B}_0 = \chi_m \mu_0 \vec{H}$$

magnetizzazione

suscettività magnetica

$$\vec{M} \equiv \chi_m \vec{H}$$

$$\vec{B} = \vec{B} - \vec{B}_0 + \vec{B}_0 = \chi_m \mu_0 \vec{H} + \mu_0 \vec{H} = \mu_0 (\vec{H} + \vec{M})$$



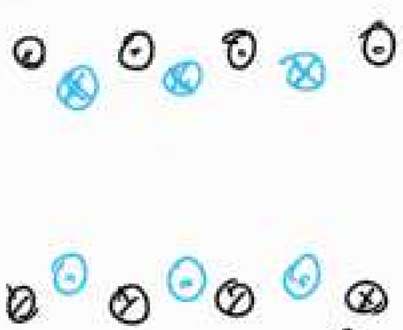
corrente amperiana o di Ampère

$$B = B_0 + \chi_m B_0 = \mu_0 n i + \mu_0 \chi_m n i$$

1 DIAMAGNETI

$K_m < 1$

$\chi_m = K_m - 1 < 0$



$\chi_m \sim 10^{-5} \div 10^{-8}$

2 PARAMAGNETI

$K_m > 1$

$\chi_m > 0$

$\chi_m \sim 10^{-5}$

3 FERROMAGNETI

$K_m > 1$, $K_m \sim 10000$

$\chi_m = K_m - 1 \approx K_m$

FERRO, COBALTO, NICHEL