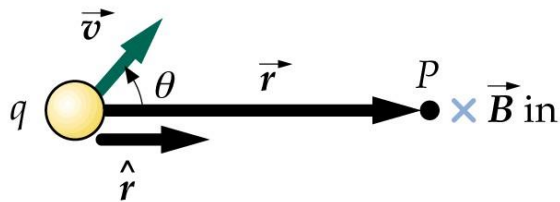




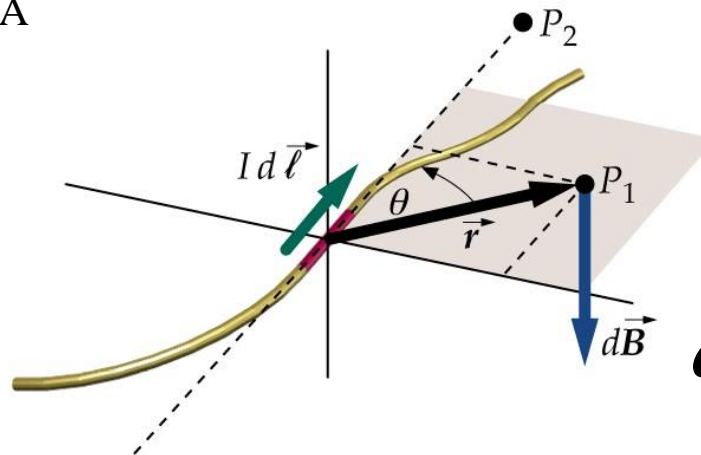
Campo Magnético

Lei de Biot-Savart

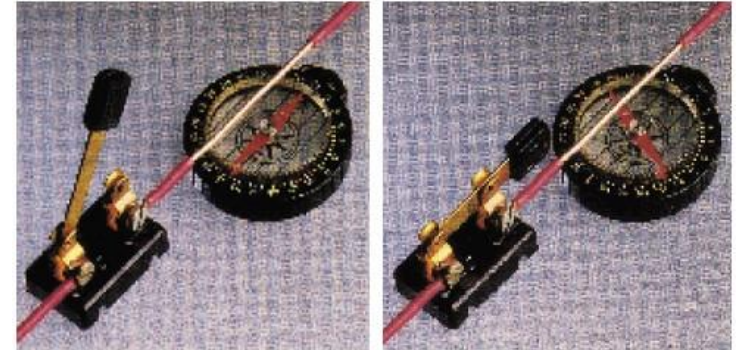


$$\vec{F} = q\vec{v} \times \vec{B} \quad \longrightarrow \quad \vec{B} = \frac{\mu_o}{4\pi} \frac{q\vec{v} \times \hat{r}}{r^2}$$

Onde $\mu_o = 4\pi \times 10^{-7} \text{ Tm/A}$



Experimento de Oersted



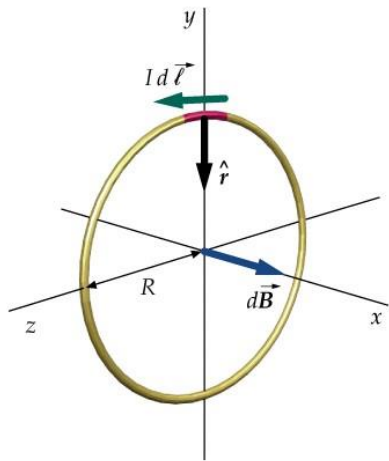
$$\vec{F} = (I\vec{l} \times \vec{B})$$

$$d\vec{F} = (Id\vec{l} \times \vec{B})$$

$$d\vec{B} = \frac{\mu_o}{4\pi} \frac{Id\vec{l} \times \hat{r}}{r^2}$$



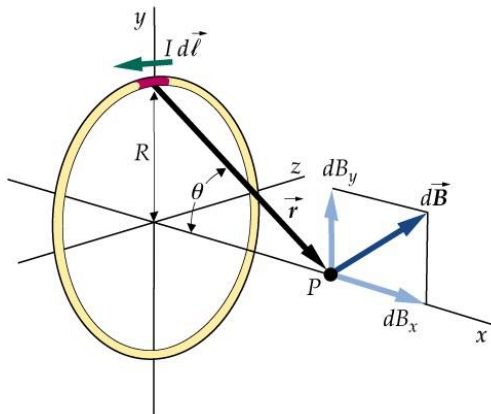
Campo Magnético em espiras



$$d\vec{B} = \frac{\mu_o}{4\pi} \frac{Id\vec{l} \times \hat{r}}{r^2} \quad \Rightarrow \quad dB = \frac{\mu_o}{4\pi} \frac{Idl \sin \theta}{r^2} \quad \text{Com } \theta = 90^\circ$$

$$B = \int dB = \frac{\mu_o}{4\pi} \frac{I}{R^2} \oint dl \quad \Rightarrow \quad B = \frac{\mu_o I}{2R}$$

para qualquer ponto do eixo:
$$dB = \frac{\mu_o}{4\pi} \frac{Idl}{(x^2 + R^2)}$$



$$dB_x = dB \sin \theta = \frac{\mu_o}{4\pi} \frac{Idl}{(x^2 + R^2)} \frac{R}{\sqrt{x^2 + R^2}}$$

$$B_x = \oint dB_x = \frac{\mu_o}{4\pi} \frac{IR}{(x^2 + R^2)^{3/2}} \oint dl$$

$$B_x = \frac{\mu_o}{4\pi} \frac{2\pi R^2 I}{(x^2 + R^2)^{3/2}}$$

$$B_y = 0$$

$$B_z = 0$$



Campo Magnético em um solenóide

Densidade de espiras $n=N/L$

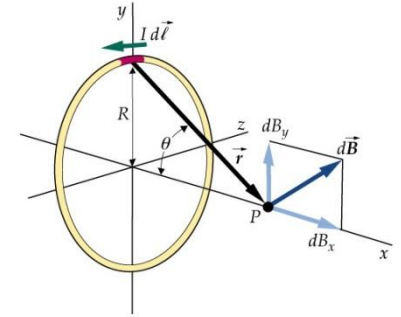
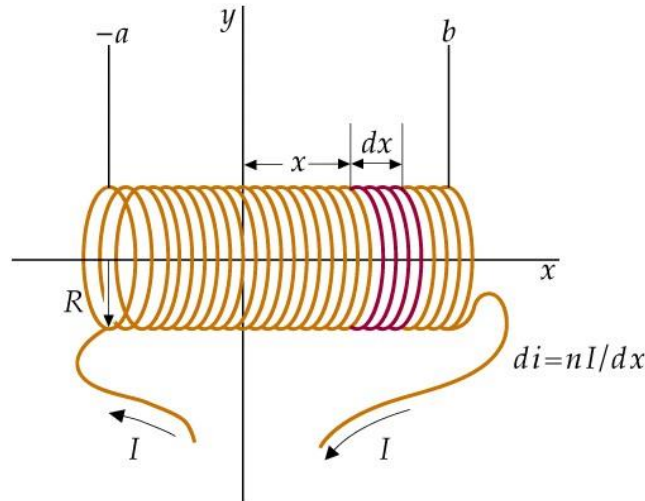
Em um pedaço dx do solenóide existem ndx espiras e portanto a corrente total por este trecho do solenóide é $nI dx$

Assim, a contribuição deste trecho para o campo magnético na origem é

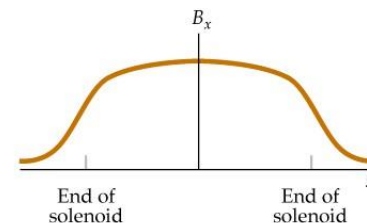
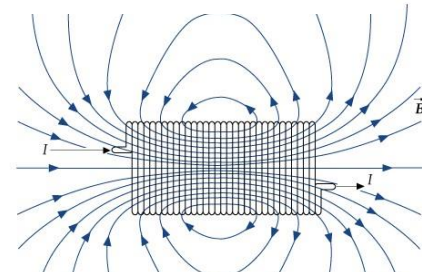
$$dB_x = \frac{\mu_0}{4\pi} \frac{2\pi R^2 n I dx}{(x^2 + R^2)^{3/2}}$$

$$\Rightarrow B_x = \frac{\mu_0}{4\pi} 2\pi R^2 n I \int_{-a}^b \frac{dx}{(x^2 + R^2)^{3/2}}$$

$$B_x = \frac{1}{2} \mu_0 n I \left(\frac{b}{(b^2 + R^2)^{1/2}} + \frac{a}{(a^2 + R^2)^{1/2}} \right)$$



$$B_x = \frac{\mu_0}{4\pi} \frac{2\pi R^2 I}{(x^2 + R^2)^{3/2}}$$

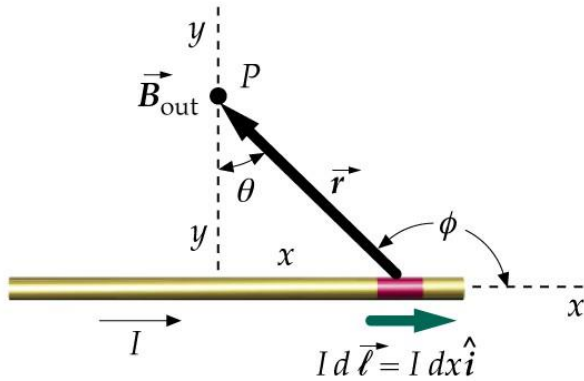


Para $a, b \gg R$

$$B_x = \mu_0 n I$$



Campo Magnético produzido por um fio reto



$$d\vec{B} = \frac{\mu_0}{4\pi} \frac{I d\vec{l} \times \hat{r}}{r^2}$$

Mas, como a contribuição de todos os elementos $d\vec{l}$ têm a mesma direção e sentido, podemos usar a forma escalar

$$dB = \frac{\mu_0}{4\pi} \frac{I dx}{r^2} \sin \phi = \frac{\mu_0}{4\pi} \frac{I dx}{r^2} \cos \theta$$

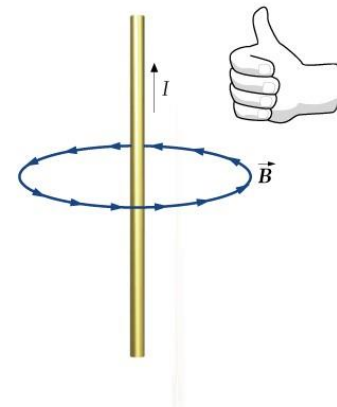
Usando-se

$$\begin{cases} x = y \tan \theta \\ dx = \frac{r^2}{y} d\theta \end{cases}$$

$$dB = \frac{\mu_0}{4\pi} \frac{I}{y} \cos \theta d\theta$$

$$B = \int_{-\theta_1}^{\theta_2} \frac{\mu_0}{4\pi} \frac{I}{y} \cos \theta d\theta$$

$$B = \frac{\mu_0}{4\pi} \frac{I}{R} (\sin \theta_1 + \sin \theta_2)$$

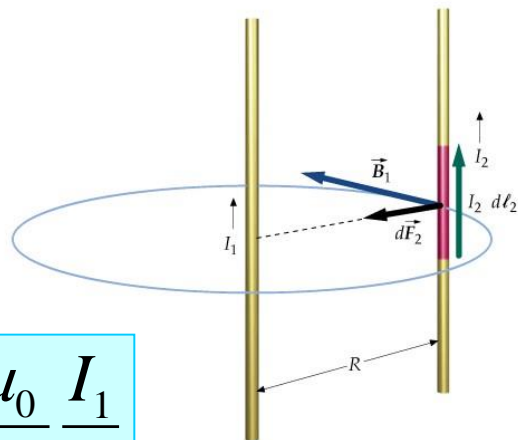


Para fio infinito

$$B = \frac{\mu_0}{2\pi} \frac{I}{R}$$



Força magnética entre fios paralelos



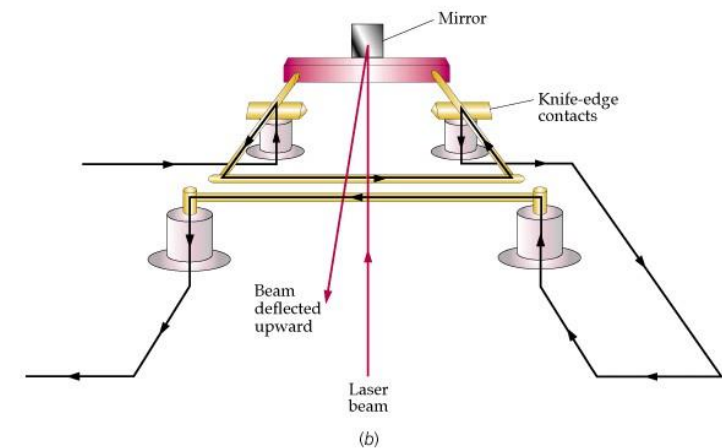
$$d\vec{F}_2 = \left| I dl_2 \times \vec{B}_1 \right|$$

$$B_1 = \frac{\mu_0 I_1}{2\pi R}$$

$$dF_2 = I_2 dl_2 \frac{\mu_0 I_1}{2\pi R}$$

$$\frac{dF_2}{dl_2} = \frac{\mu_0 I_1 I_2}{2\pi R}$$

Balança de Corrente



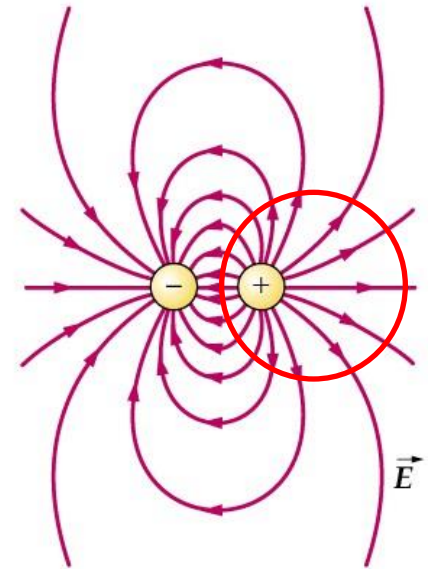
Definição de Ampère (A)

Um ampère é a corrente que, quando mantida em dois condutores retos e paralelos, de comprimento infinito e seção reta desprezível, colocados a uma distância de um metro no vácuo, produz uma força de 2×10^{-7} N/m entre os dois condutores.



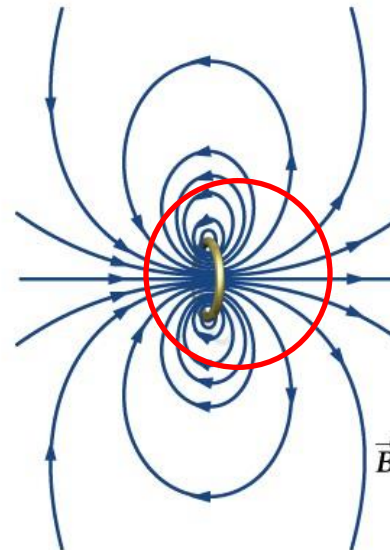
Lei de Gauss para o campo elétrico

$$\Phi_E = \oint_S \vec{E} \cdot d\vec{S} = \frac{Q}{\epsilon_0}$$



Lei de Gauss para o campo magnético

$$\Phi_B = \oint_S \vec{B} \cdot d\vec{S} = 0$$



Não existe monopólos magnéticos.
As linhas de campo magnético são fechadas.

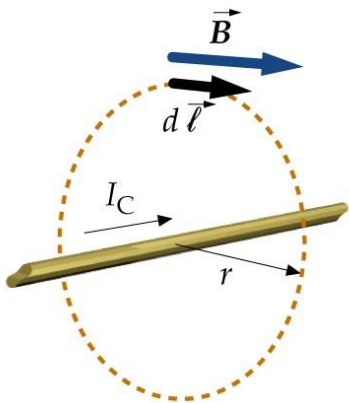


Lei de Ampère (Lei da Circuitação de Ampère)

$$\oint_C \vec{B} \cdot d\vec{l} = \mu_0 I_C$$

Onde C é qualquer caminho fechado.

Campo Magnético produzido por um fio reto



$$\oint_C \vec{B} \cdot d\vec{l} = B \oint_C dl = \mu_0 I_C$$

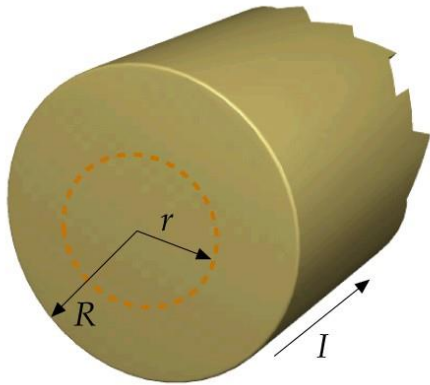
$$B(2\pi r) = \mu_0 I_C$$



$$B = \frac{\mu_0 I}{2\pi r}$$

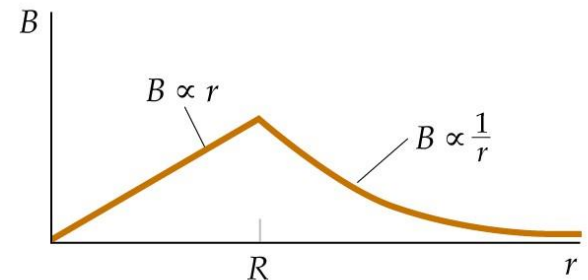


Campo Magnético produzido no interior de um fio reto



$$\oint_C \vec{B} \cdot d\vec{l} = \mu_0 I_C$$

$$\oint_C \vec{B} \cdot d\vec{l} = B \oint_C dl = B 2\pi r = \mu_0 I_C$$



$$B = \frac{\mu_0}{2\pi} \frac{I_C}{r}$$

Para $r < R$

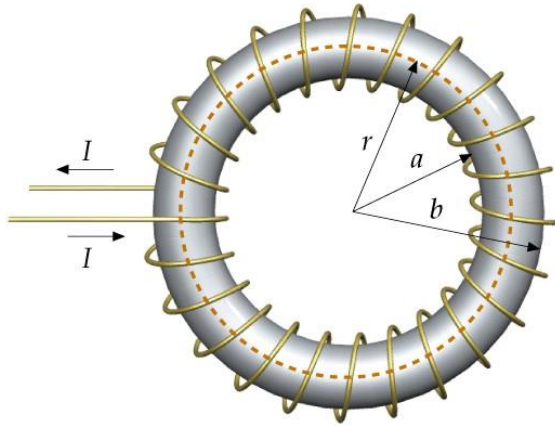


$$I_C = \frac{\pi r^2}{\pi R^2} I$$

$$B = \frac{\mu_0}{2\pi} \frac{(r^2 / R^2) I}{r} = \frac{\mu_0}{2\pi} \frac{r I}{R^2}$$



Campo Magnético produzido por um toróide



$$\oint_C \vec{B} \cdot d\vec{l} = \mu_0 I_C$$

$$\oint_C \vec{B} \cdot d\vec{l} = B \oint_C dl = B 2\pi r = \mu_0 I_C = \mu_0 NI$$



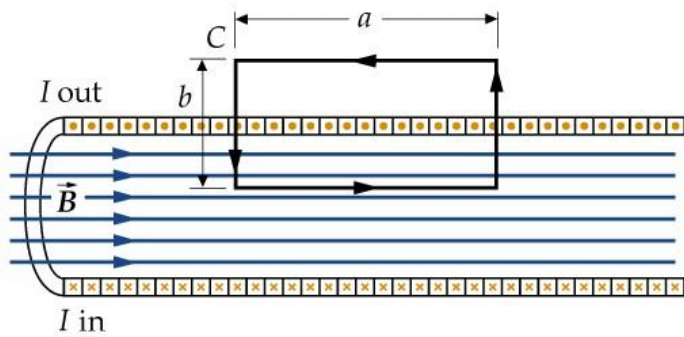
$$B = \frac{\mu_0}{2\pi} \frac{NI}{r}$$

E para $r < a$ ou $r > b$

$$B = 0$$



Campo Magnético produzido por um solenóide



$$\oint_C \vec{B} \cdot d\vec{l} = \mu_0 I_C$$

Onde, $n = N/L$

$$\oint_C \vec{B} \cdot d\vec{l} = B \oint_C dl = Ba = \mu_0 I_C = \mu_0 naI$$



Para $L \gg R$

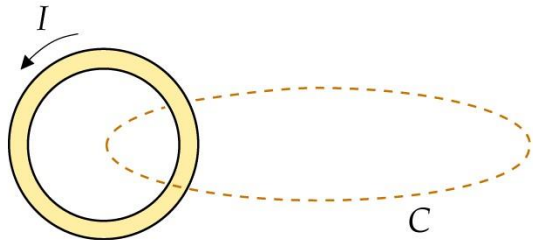
$$B = \mu_0 nI$$

Campo magnético uniforme dentro do solenóide (exceto nas extremidades)

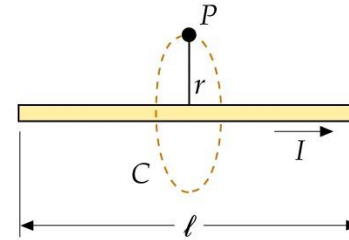


Limitações da Lei de Ampère

$$\oint_C \vec{B} \cdot d\vec{l} = \mu_0 I_C$$

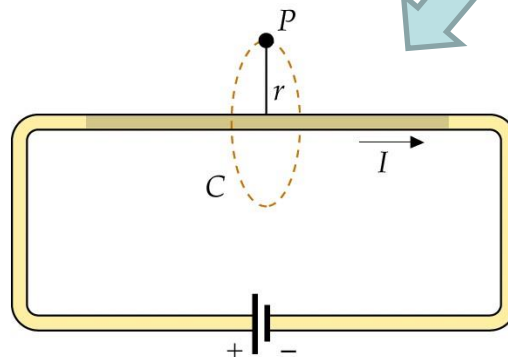


B não é constante



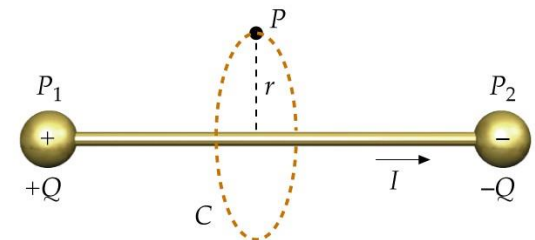
B é constante, mas . . .

Outros ramos perturbam os cálculos



Ou

A corrente não forma um circuito fechado





Lei de Ampère

$$\oint_C \vec{B} \cdot d\vec{l} = \mu_0 I_C$$

Equivalente à Lei de Ampère para o Campo Elétrico

$$\oint_C \vec{E} \cdot d\vec{l} = \Delta V_C = 0 \quad (\text{Regra das malhas de Kirchoff})$$