Eletromagnetismo

$$\vec{\nabla} \cdot \vec{D} = \rho$$

$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

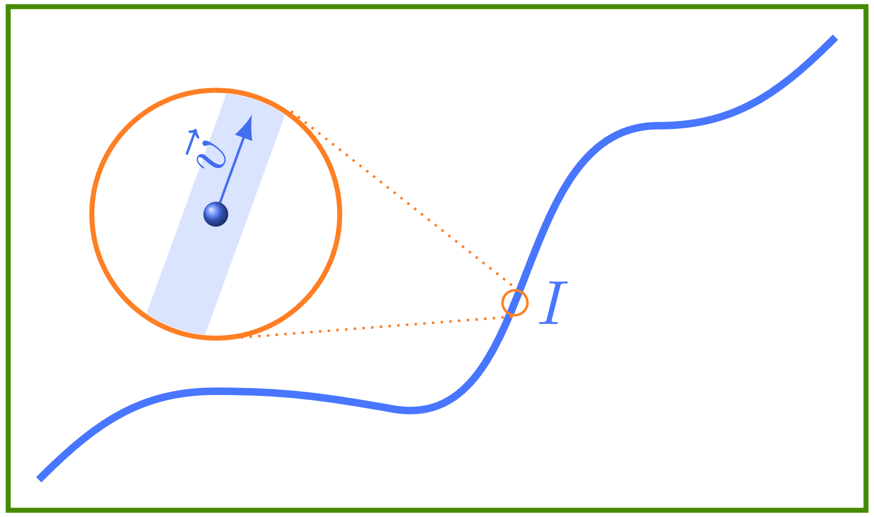
$$\vec{\nabla} \cdot \vec{B} = 0$$

$$\vec{\nabla} \times \vec{H} = \vec{j} + \epsilon_0 \frac{\partial \vec{D}}{\partial t}$$

23 de junho de 2021
Magnetostática

Corrente elétrica

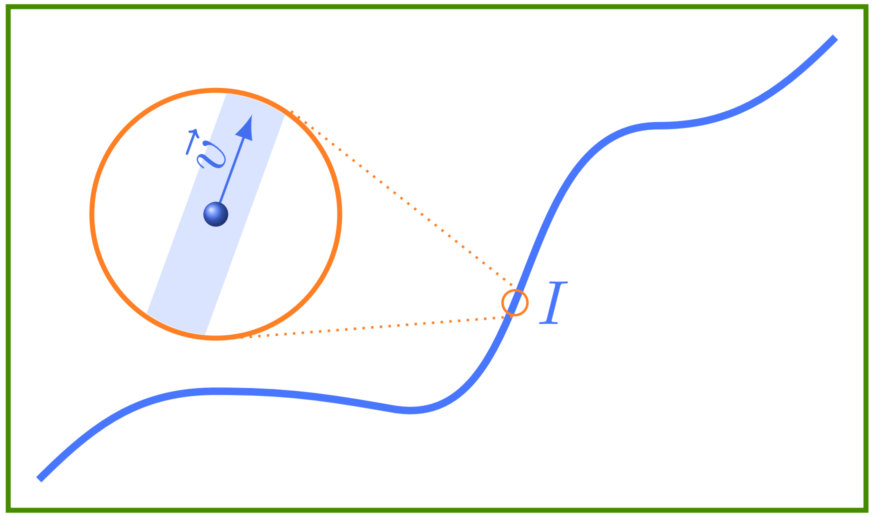
$$\vec{I} = \lambda \overrightarrow{v}$$



Corrente elétrica

$$\vec{I} = \lambda \overrightarrow{v}$$

$$\vec{F} = \int \vec{I} \times \vec{B} \, \mathrm{d}\ell$$



Corrente elétrica

$$\vec{I} = \lambda \vec{v}$$

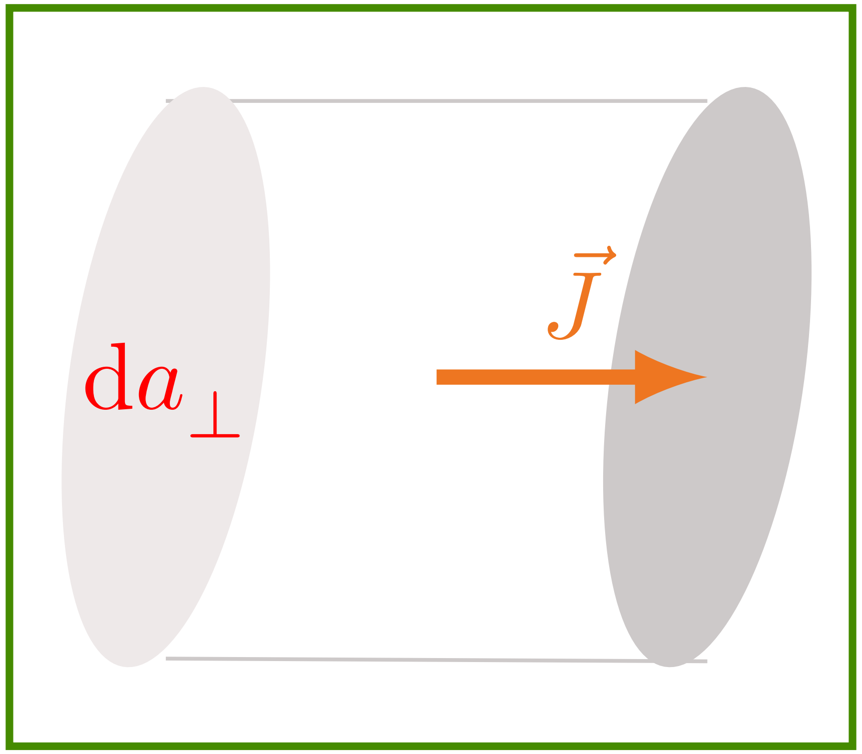
$$\vec{F} = \int \vec{I} \times \vec{B}\, d\ell$$

CONVENIENTE QUANDO CORRENTE É TRANSPORTADA EM FIOS

$$\vec{J} = \rho \vec{v}$$

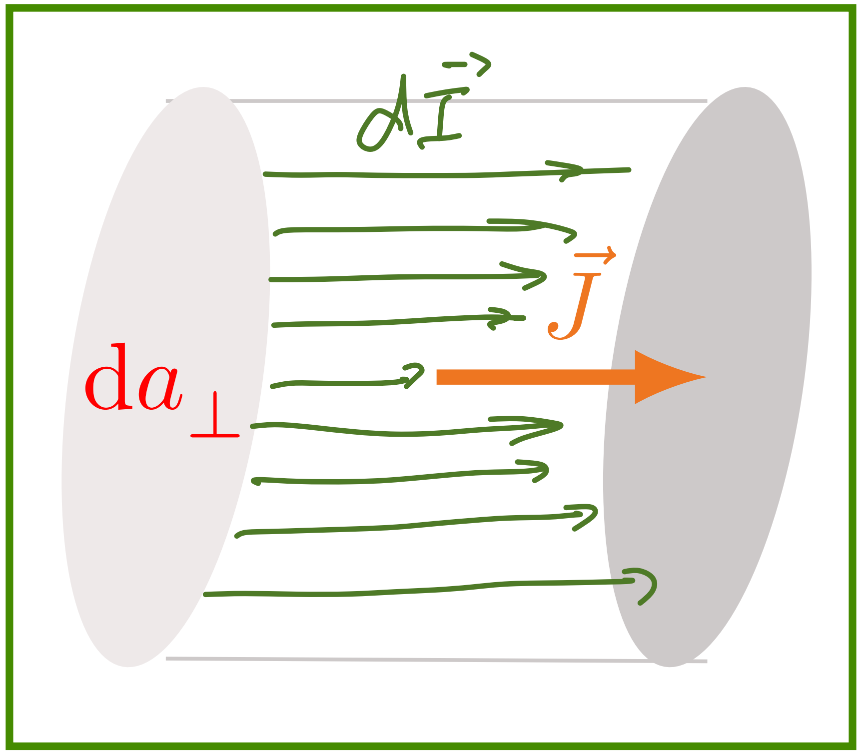
$$\vec{F} = \int \vec{J} \times \vec{B}\, d\tau$$

CONVENIENTE QUANDO A CORRENTE SE ESPALHA POR UMA REGIÃO VOLUMÉTRICA



Densidade de corrente

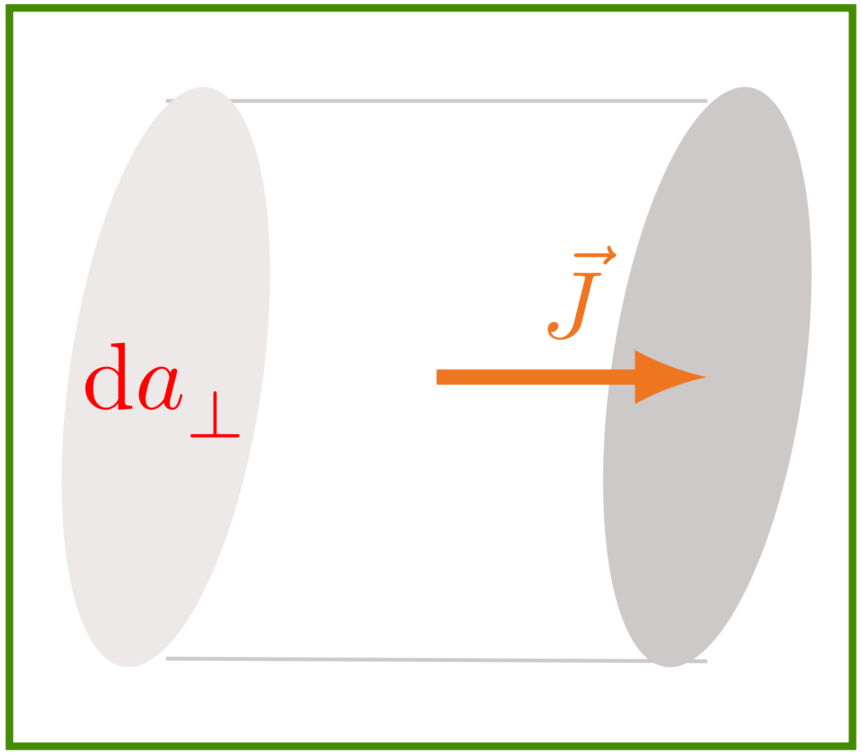
$$\vec{J} = \frac{\mathrm{d}\vec{I}}{\mathrm{d}a_{\perp}}$$



Densidade de corrente

$$\vec{J} = \frac{\mathrm{d}\vec{I}}{\mathrm{d}a_{\perp}}$$

$$I = \int J \; \mathrm{d}a_{\perp}$$

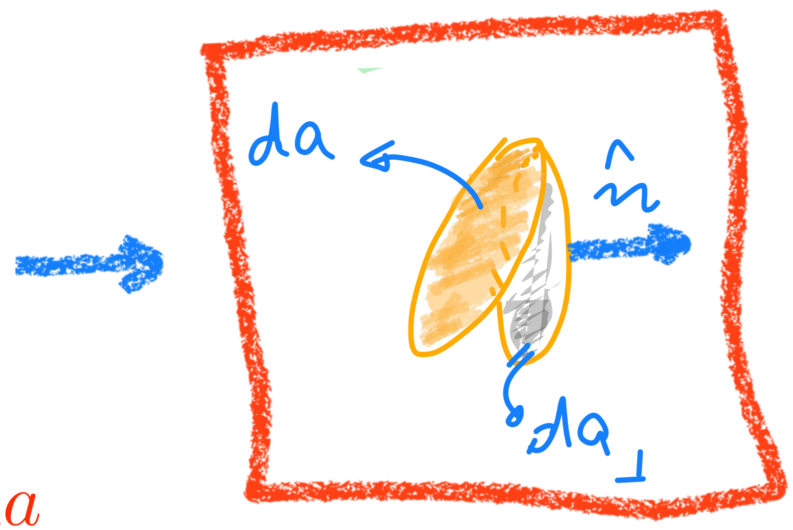


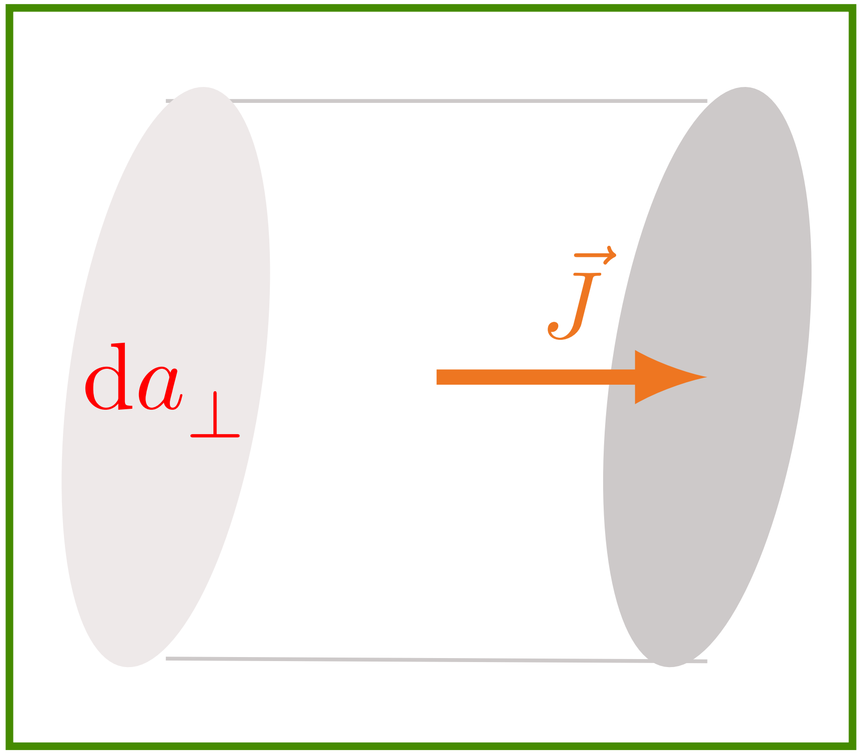
Densidade de corrente

$$\vec{J} = \frac{d\vec{I}}{da_\perp}$$

$$I = \int J \, da_\perp$$

$$I = \int_{\mathcal{A}} \vec{J} \cdot \hat{n} \, da$$





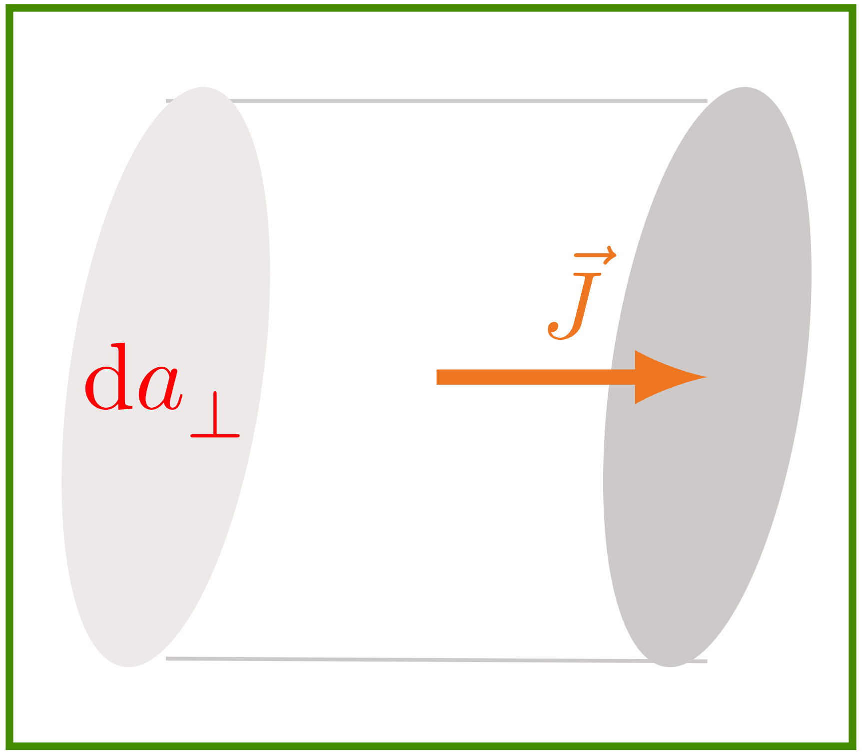
Densidade de corrente

$$\vec{J} = \frac{\mathrm{d}\vec{I}}{\mathrm{d}a_{\perp}}$$

$$I = \int J \,\mathrm{d}a_{\perp}$$

$$I = \int_{\mathcal{A}} \vec{J} \cdot \hat{n} \,\mathrm{d}a$$

Superfície fechada



Densidade de corrente

$$\vec{J} = \frac{\mathrm{d}\vec{I}}{\mathrm{d}a_{\perp}}$$

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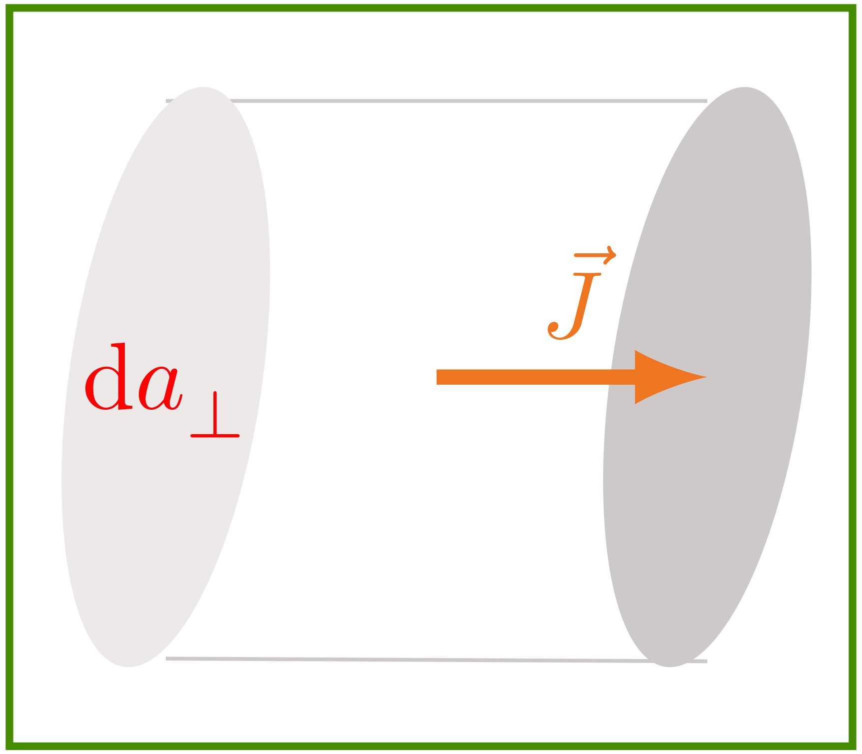
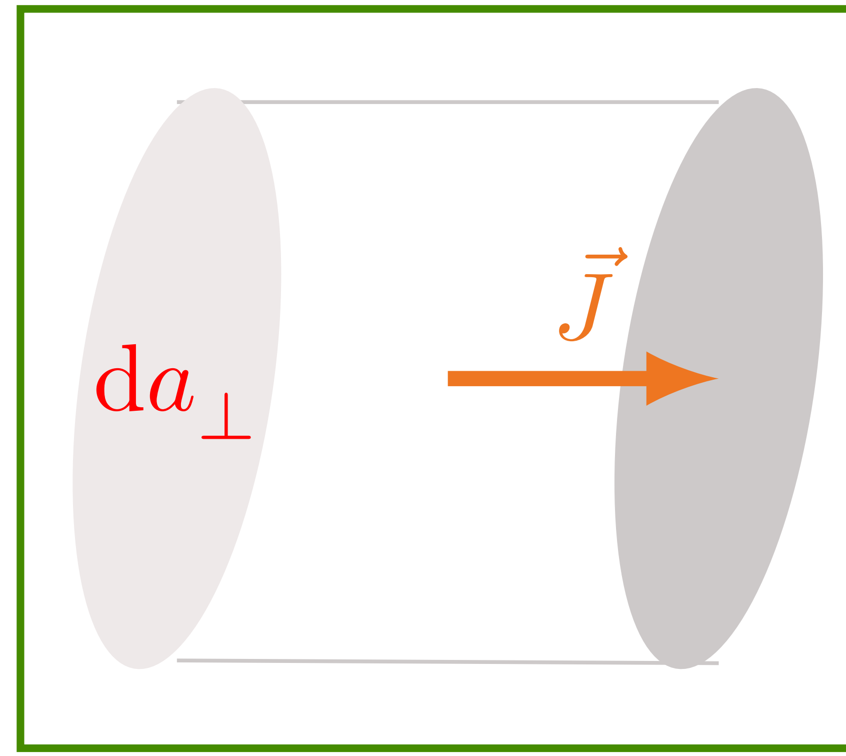
Superfície fechada

$$I = \oint_{\mathcal{A}} \vec{J} \cdot \hat{n} \, \mathrm{d}a$$



Densidade de corrente

$$\vec{J} = \frac{\mathrm{d}\vec{I}}{\mathrm{d}a_{\perp}}$$



$$I = \int J \; \mathrm{d}a_{\perp}$$

$$I = \int_{\mathcal{A}} \vec{J} \cdot \hat{n} \; \mathrm{d}a$$

Superfície fechada

TEOREMA DE GAUSS

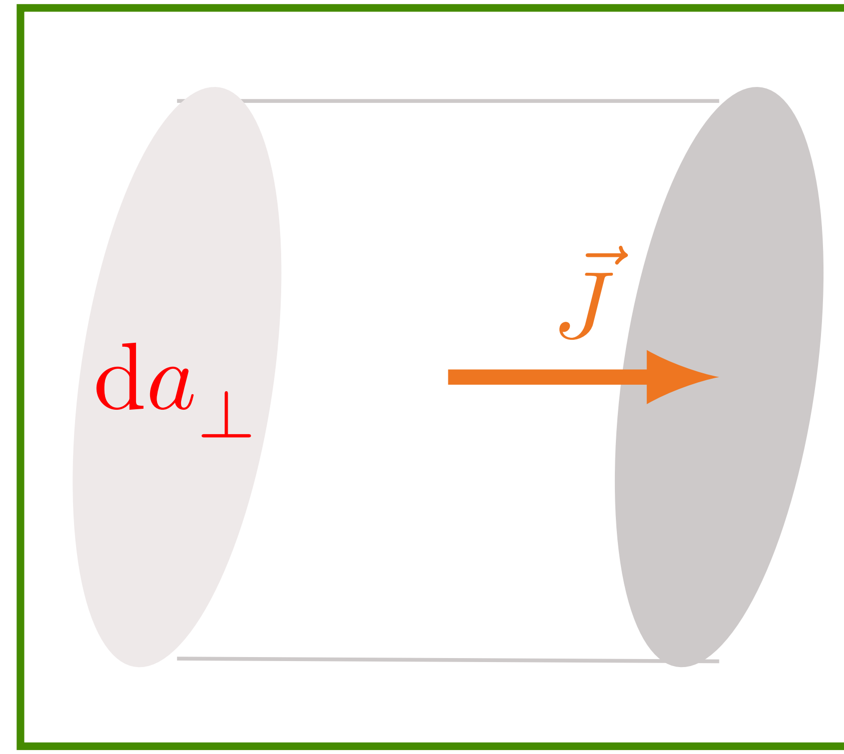
$$I = \oint_{\mathcal{A}} \vec{J} \cdot \hat{n} \; \mathrm{d}a = \int \vec{\nabla} \cdot \vec{J} \; \mathrm{d}\tau$$

Densidade de corrente

$$\vec{J} = \frac{\mathrm{d}\vec{I}}{\mathrm{d}a_\perp}$$

$$I = \int J \, \mathrm{d}a_\perp$$

$$I = \int_{\mathcal{A}} \vec{J} \cdot \hat{n} \, \mathrm{d}a$$



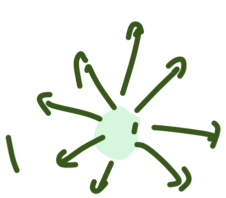
Superfície fechada

$$I = \oint_{\mathcal{A}} \vec{J} \cdot \hat{n} \, \mathrm{d}a = \int \vec{\nabla} \cdot \vec{J} \, \mathrm{d}\tau$$

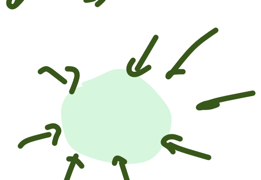
$$I = -\frac{\mathrm{d}q}{\mathrm{d}t}$$

CONVENÇÃO:

$I > 0$ => CORRENTE SAI

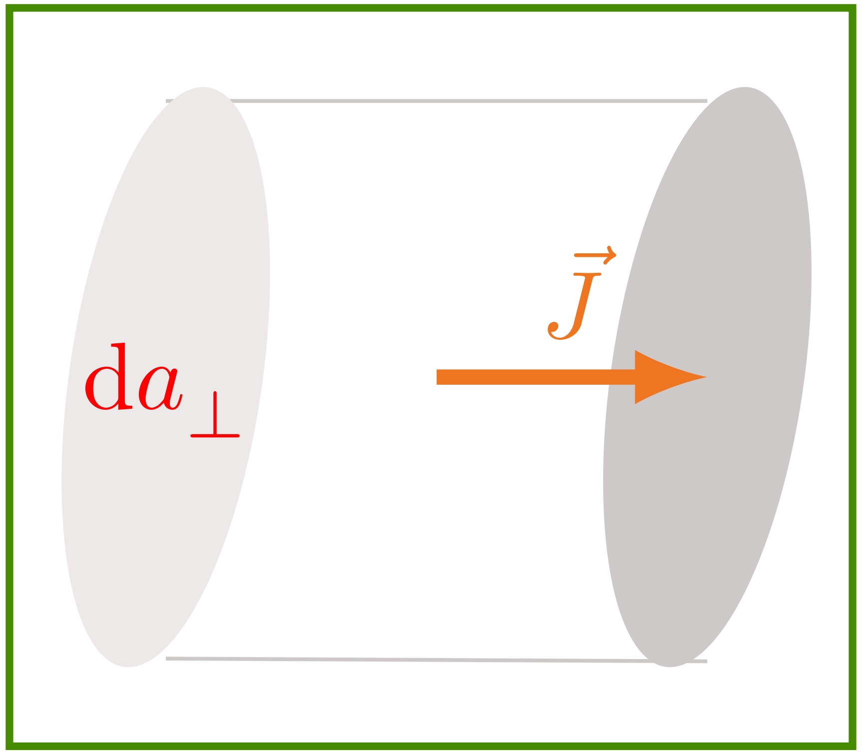


$I < 0$ => CORRENTE ENTRA



Densidade de corrente

$$\vec{J} = \frac{\mathrm{d}\vec{I}}{\mathrm{d}a_\perp}$$



$$I = \int J \, \mathrm{d}a_\perp$$

$$I = \int_{\mathcal{A}} \vec{J} \cdot \hat{n} \, \mathrm{d}a$$

Superfície fechada

$$I = \oint_{\mathcal{A}} \vec{J} \cdot \hat{n} \, \mathrm{d}a = \int \vec{\nabla} \cdot \vec{J} \, \mathrm{d}\tau$$

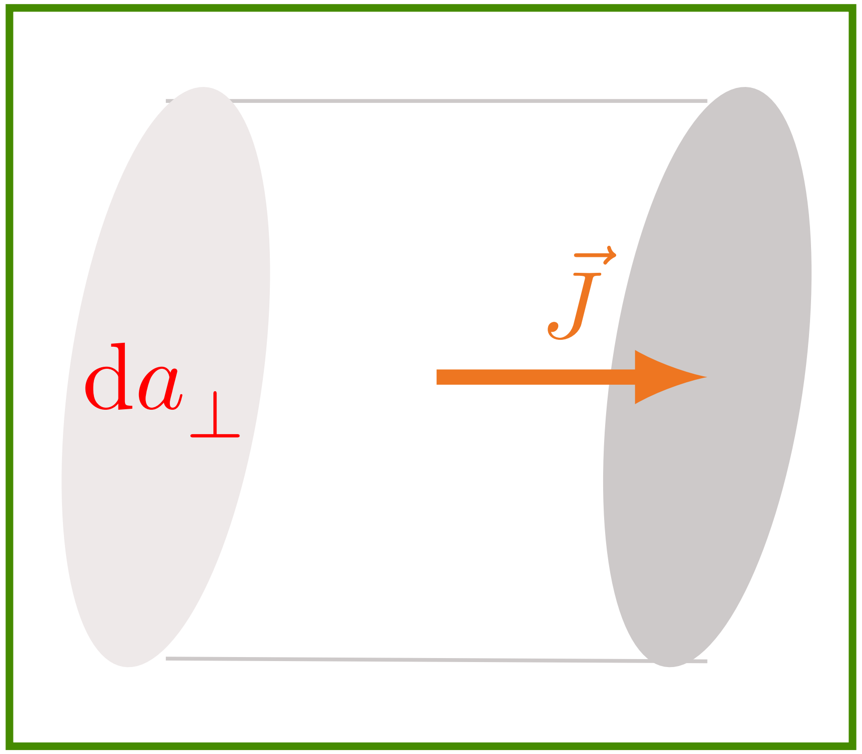
$$I = -\frac{\mathrm{d}q}{\mathrm{d}t} = -\int \frac{\partial \rho}{\partial t} \, \mathrm{d}\tau$$

Densidade de corrente

$$\vec{J} = \frac{d\vec{I}}{da_\perp}$$

$$I = \int J \, da_\perp$$

$$I = \int_{\mathcal{A}} \vec{J} \cdot \hat{n} \, da$$



Superfície fechada

$$I = \oint_{\mathcal{A}} \vec{J} \cdot \hat{n} \, da = \int \vec{\nabla} \cdot \vec{J} \, d\tau$$

$$I = -\frac{dq}{dt} = -\int \frac{\partial \rho}{\partial t} \, d\tau$$

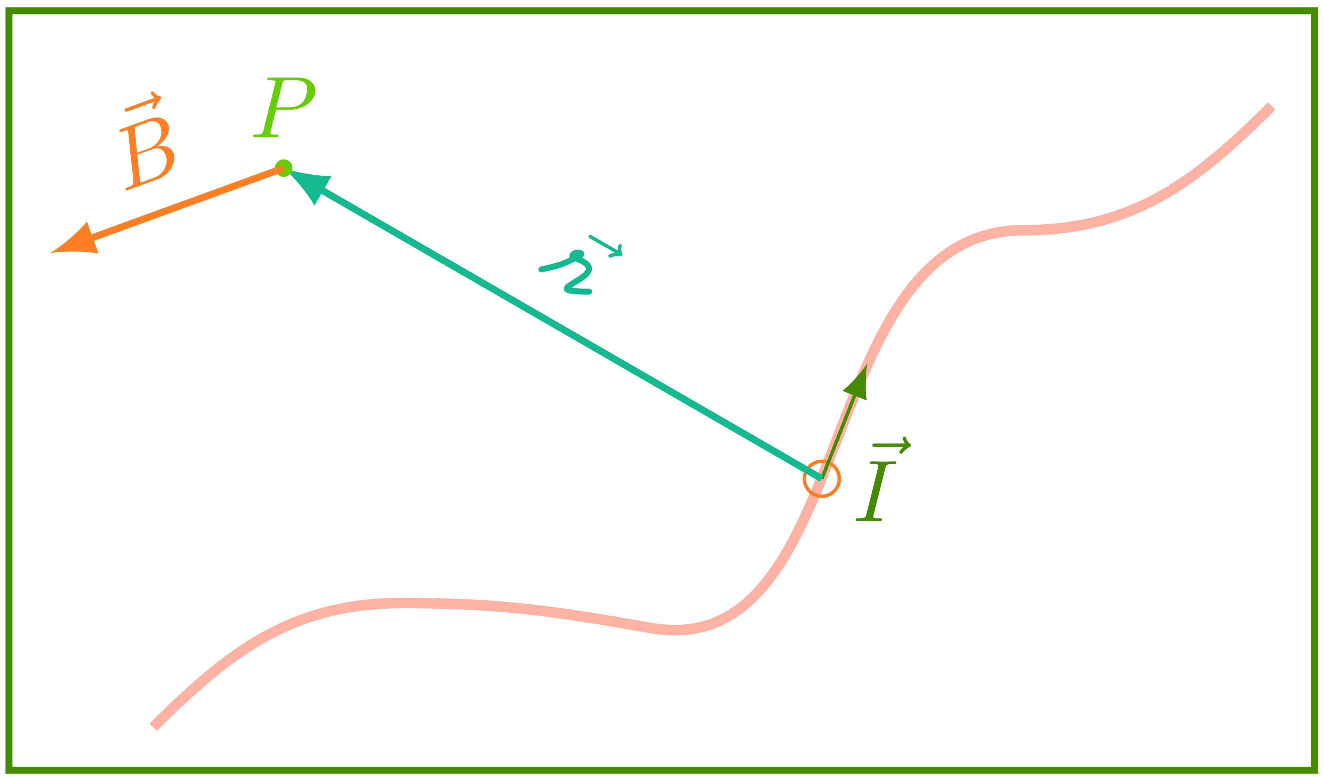
EQ. CONTINUIDADE

$$\vec{\nabla} \cdot \vec{J} = -\frac{\partial \rho}{\partial t}$$

Lei de Biot e Savart

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{\vec{I} \times \hat{\mathscr{r}}}{\mathscr{r}^2}\, \mathrm{d}\ell'$$

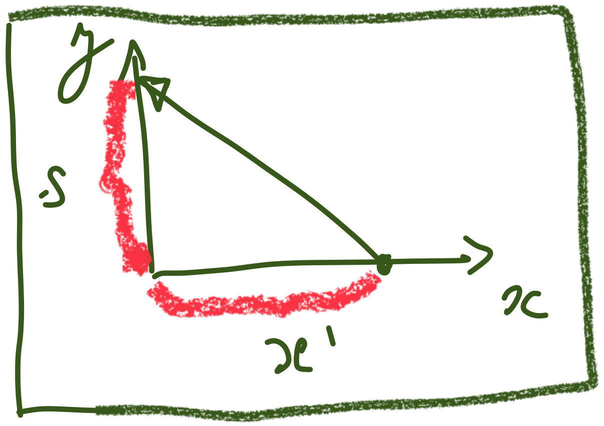
$$\mu_0 = 4\pi \times 10^{-7}\,\mathrm{N/A^2}$$

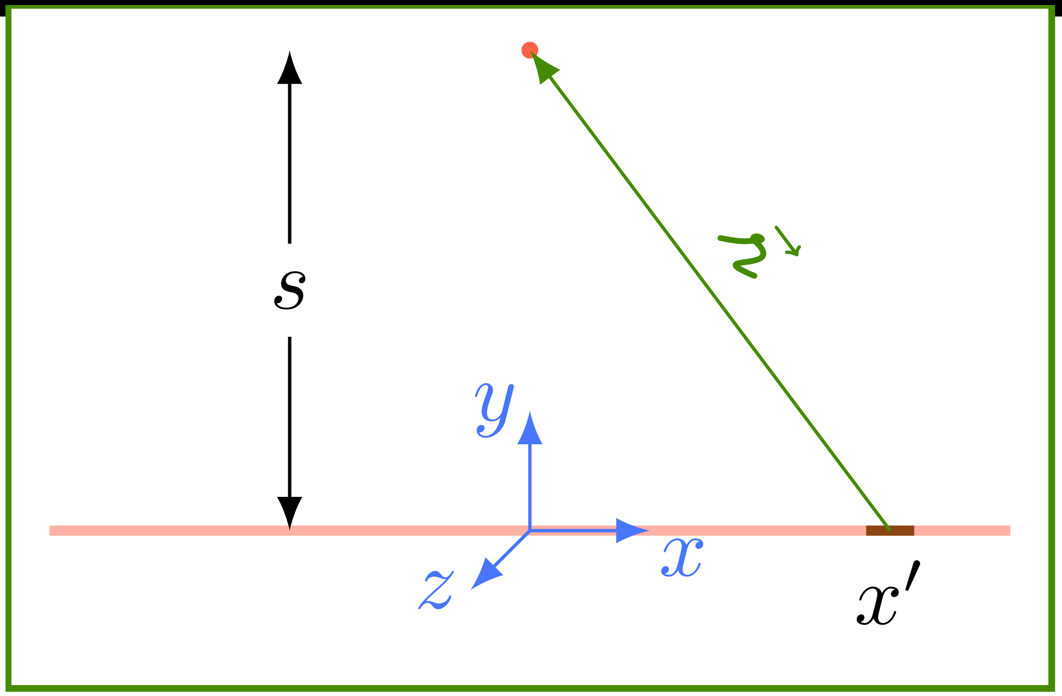


$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{\vec{I} \times \hat{\mathscr{r}}}{\mathscr{r}^2} \, \mathrm{d}\ell'$$

Pratique o que aprendeu

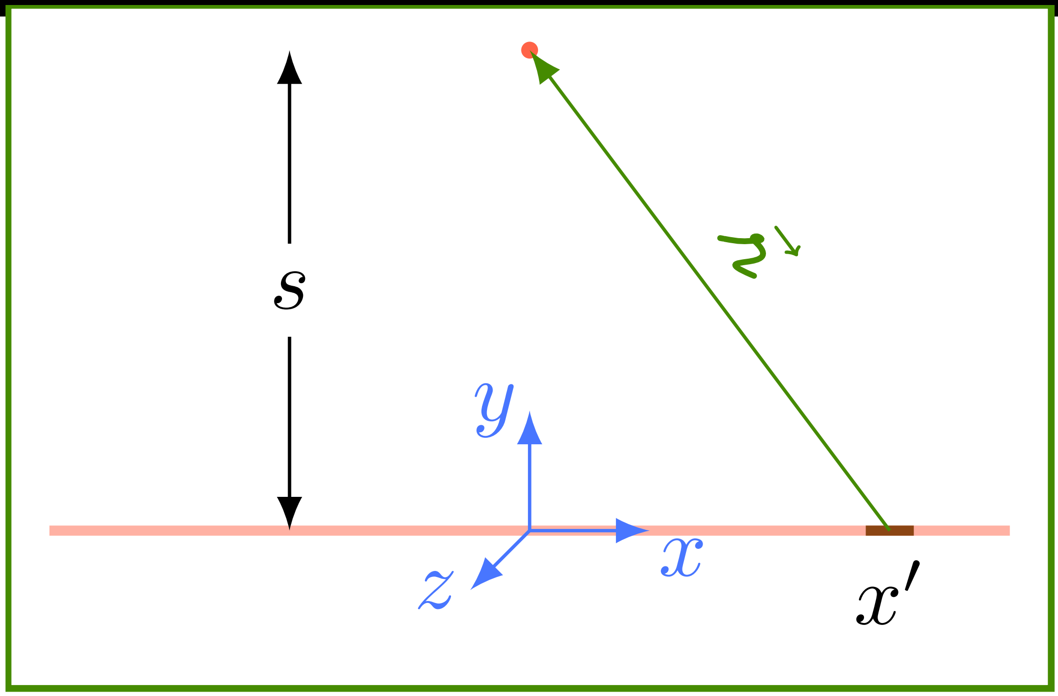
$$\vec{\mathscr{r}} = -x'\hat{x} + s\hat{y}$$





$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{\vec{I} \times \hat{\mathscr{r}}}{\mathscr{r}^2} \, \mathrm{d}\ell'$$

Pratique o que aprendeu

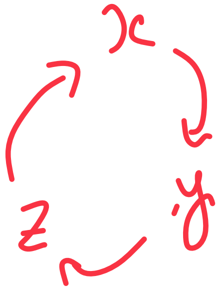


$$\vec{\mathscr{r}} = -x'\hat{x} + s\hat{y}$$

$$\vec{I} = I\hat{x}$$

Pratique o que aprendeu

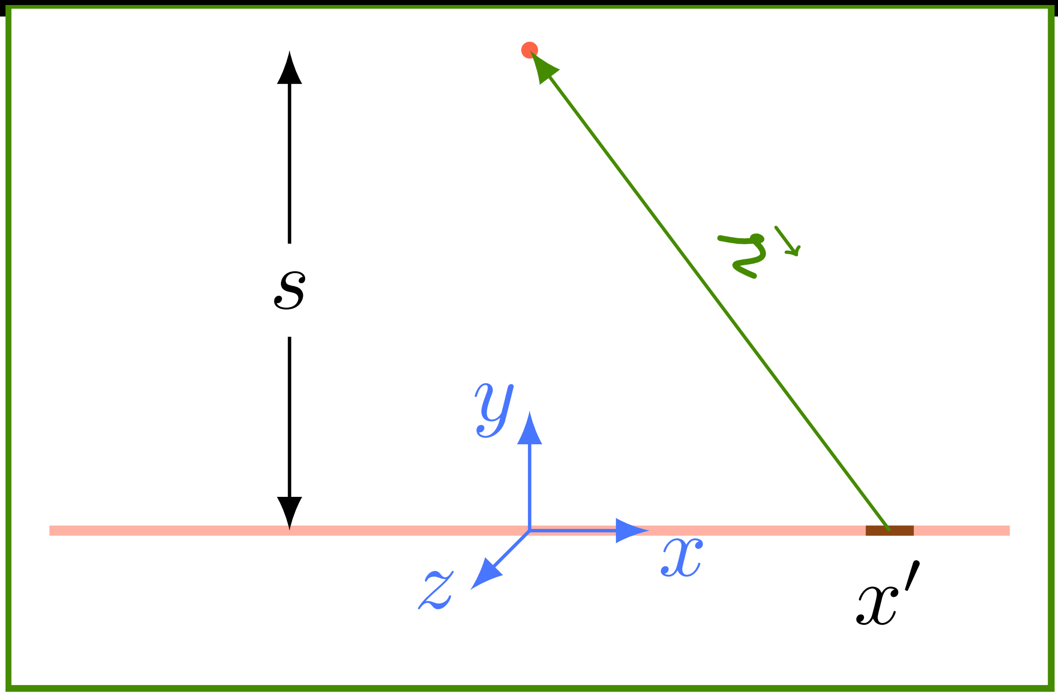
$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{\vec{I} \times \hat{\mathscr{r}}}{\mathscr{r}^2}\, \mathrm{d}\ell'$$



$$\vec{\mathscr{r}} = -x'\hat{x} + s\hat{y}$$

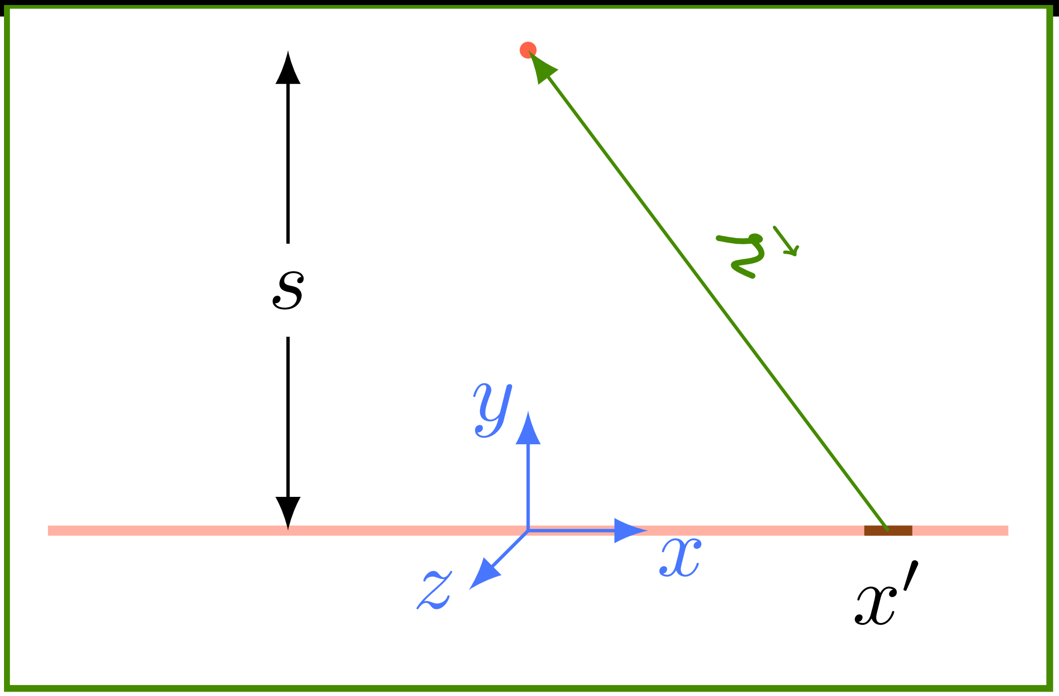
$$\vec{I} = I\hat{x}$$

$$\vec{I} \times \vec{\mathscr{r}} = Is\hat{z}$$



Pratique o que aprendeu

$$\vec{B} = \frac{\mu_0}{4\pi}\int \frac{\vec{I}\times\hat{\mathscr{r}}}{\mathscr{r}^2}\,\mathrm{d}\ell'$$



$$\vec{\mathscr{r}} = -x'\hat{x} + s\hat{y}$$

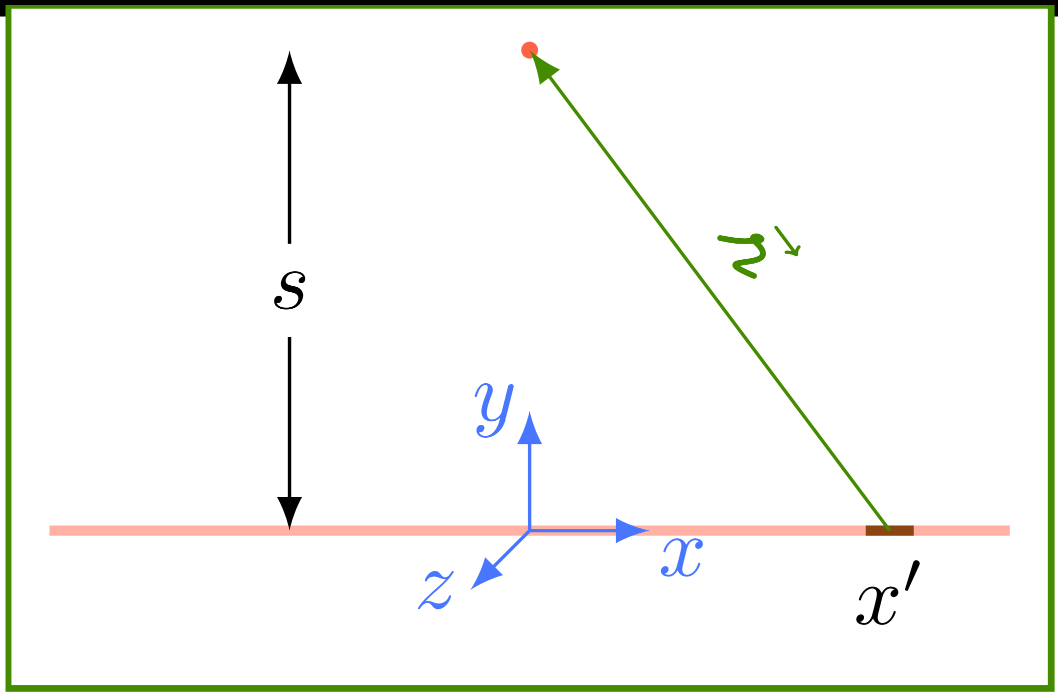
$$\vec{I} = I\hat{x}$$

$$\vec{I}\times\vec{\mathscr{r}} = Is\hat{z}$$

$$\vec{B} = \frac{\mu_0}{4\pi}\int \frac{Is}{(x'^2+s^2)^{3/2}}\,\mathrm{d}x'\,\hat{z}$$

Pratique o que aprendeu

$$\vec{B} = \frac{\mu_0}{4\pi}\int \frac{\vec{I}\times\hat{\boldsymbol{\mathscr{r}}}}{\mathscr{r}^2}\,\mathrm{d}\ell'$$



$$\vec{\mathscr{r}} = -x'\hat{x} + s\hat{y}$$

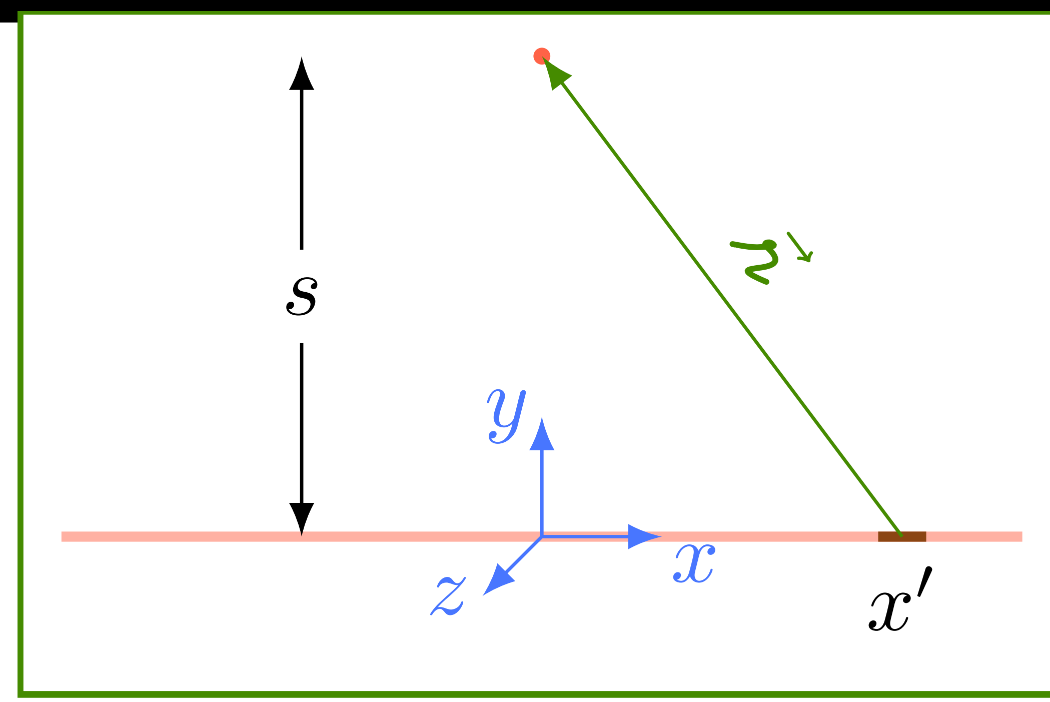
$$\vec{I} = I\hat{x}$$

$$\vec{I}\times\vec{\mathscr{r}} = Is\hat{z}$$

$$\vec{B} = \frac{\mu_0}{4\pi}\int \frac{Is}{(x'^2+s^2)^{3/2}}\,\mathrm{d}x'\,\hat{z} \qquad x' = s\tan\theta$$

Pratique o que aprendeu

$$\vec{B} = \frac{\mu_0}{4\pi}\int \frac{\vec{I}\times\hat{\mathscr{r}}}{\mathscr{r}^2}\,\mathrm{d}\ell'$$



$$\vec{\mathscr{r}} = -x'\hat{x} + s\hat{y}$$

$$\vec{I} = I\hat{x}$$

$$\vec{I}\times\vec{\mathscr{r}} = Is\hat{z}$$

DIFERENCIAL → $\mathrm{d}x' = s\sec^2\theta\,\mathrm{d}\theta$

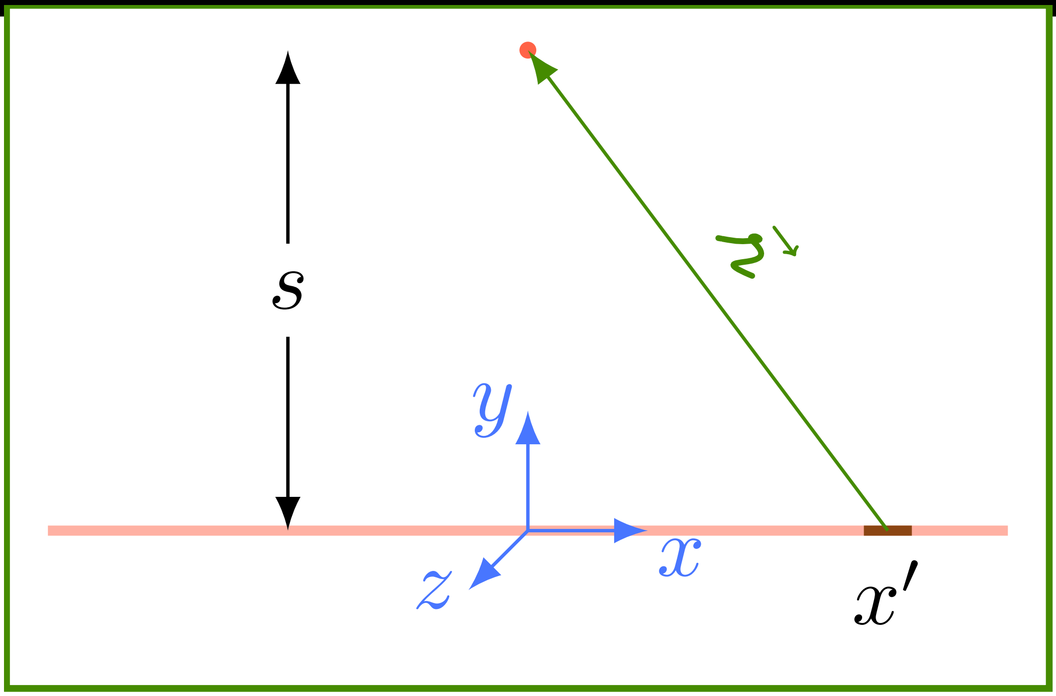
$$\vec{B} = \frac{\mu_0}{4\pi}\int \frac{Is}{(x'^2+s^2)^{3/2}}\,\mathrm{d}x'\,\hat{z} \qquad x' = s\tan\theta$$

$$\int_{-\pi/2}^{\pi/2} \frac{s\sec^2\theta}{s^2\sec^3\theta}\,d\theta = \frac{1}{s}\int_{-\pi/2}^{\pi/2}\cos\theta\,d\theta$$

LIMITES → $x' = \pm\infty \Rightarrow \theta = \pm\frac{\pi}{2}$

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{\vec{I} \times \hat{\mathscr{r}}}{\mathscr{r}^2} \, \mathrm{d}\ell'$$

Pratique o que aprendeu



$$\vec{\mathscr{r}} = -x'\hat{x} + s\hat{y}$$

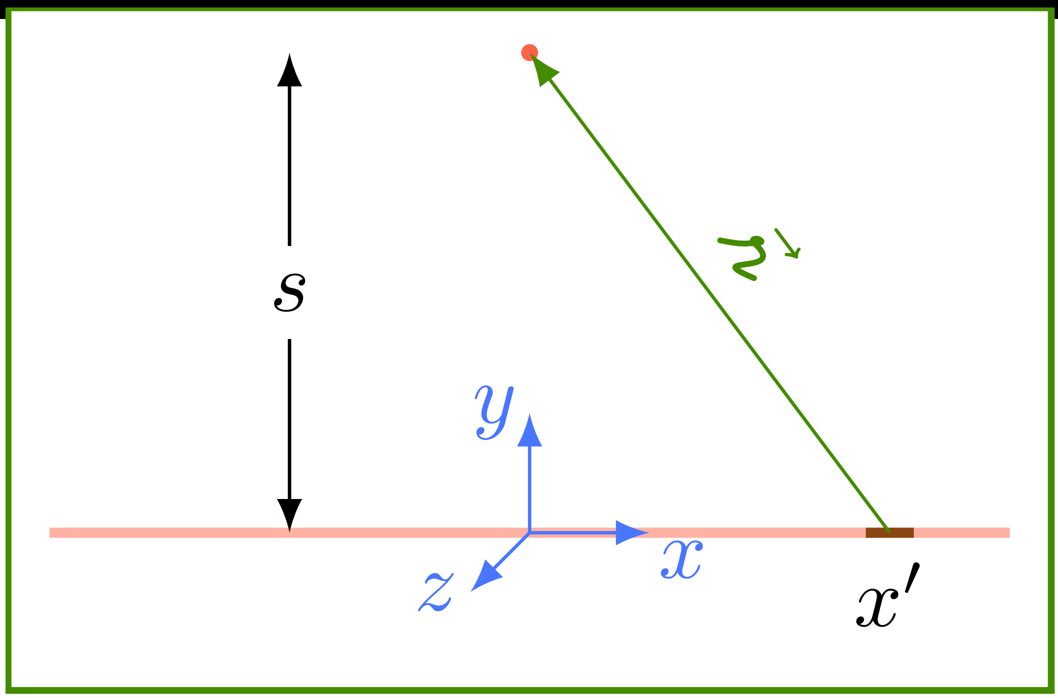
$$\vec{I} = I\hat{x}$$

$$\vec{I} \times \vec{\mathscr{r}} = Is\hat{z}$$

$$\vec{B} = \frac{\mu_0 I}{4\pi s}(\sin\frac{\pi}{2} - \sin\frac{-\pi}{2})\hat{z}$$

Pratique o que aprendeu

$$\vec{B} = \frac{\mu_0}{4\pi}\int \frac{\vec{I}\times\hat{\mathscr{r}}}{\mathscr{r}^2}\,\mathrm{d}\ell'$$



$$\vec{\mathscr{r}} = -x'\hat{x} + s\hat{y}$$

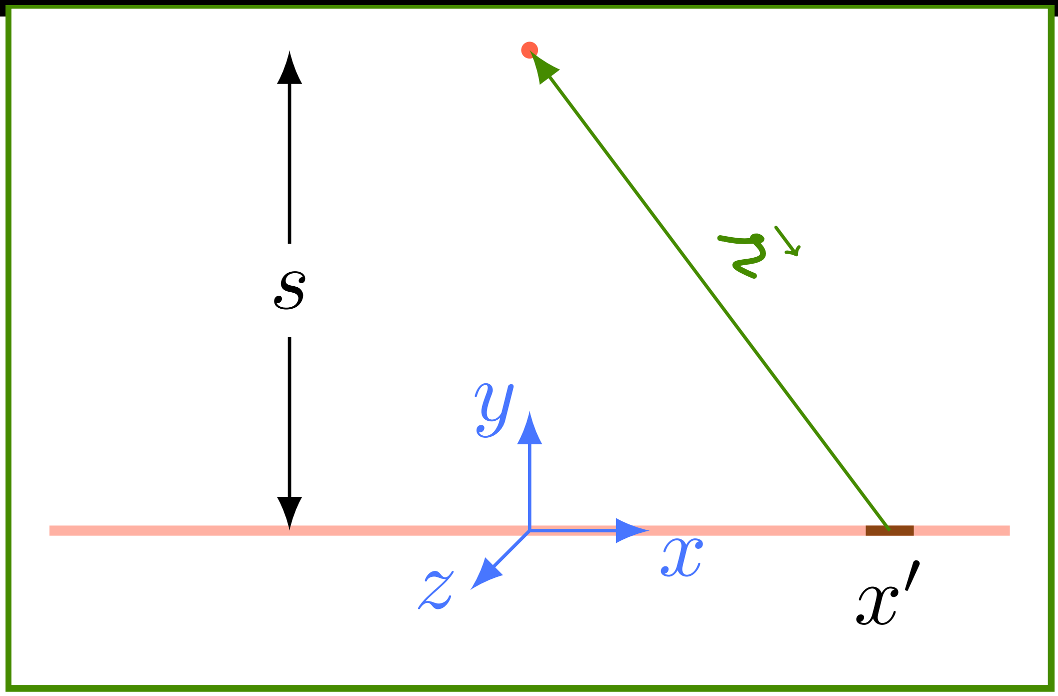
$$\vec{I} = I\hat{x}$$

$$\vec{I}\times\vec{\mathscr{r}} = Is\hat{z}$$

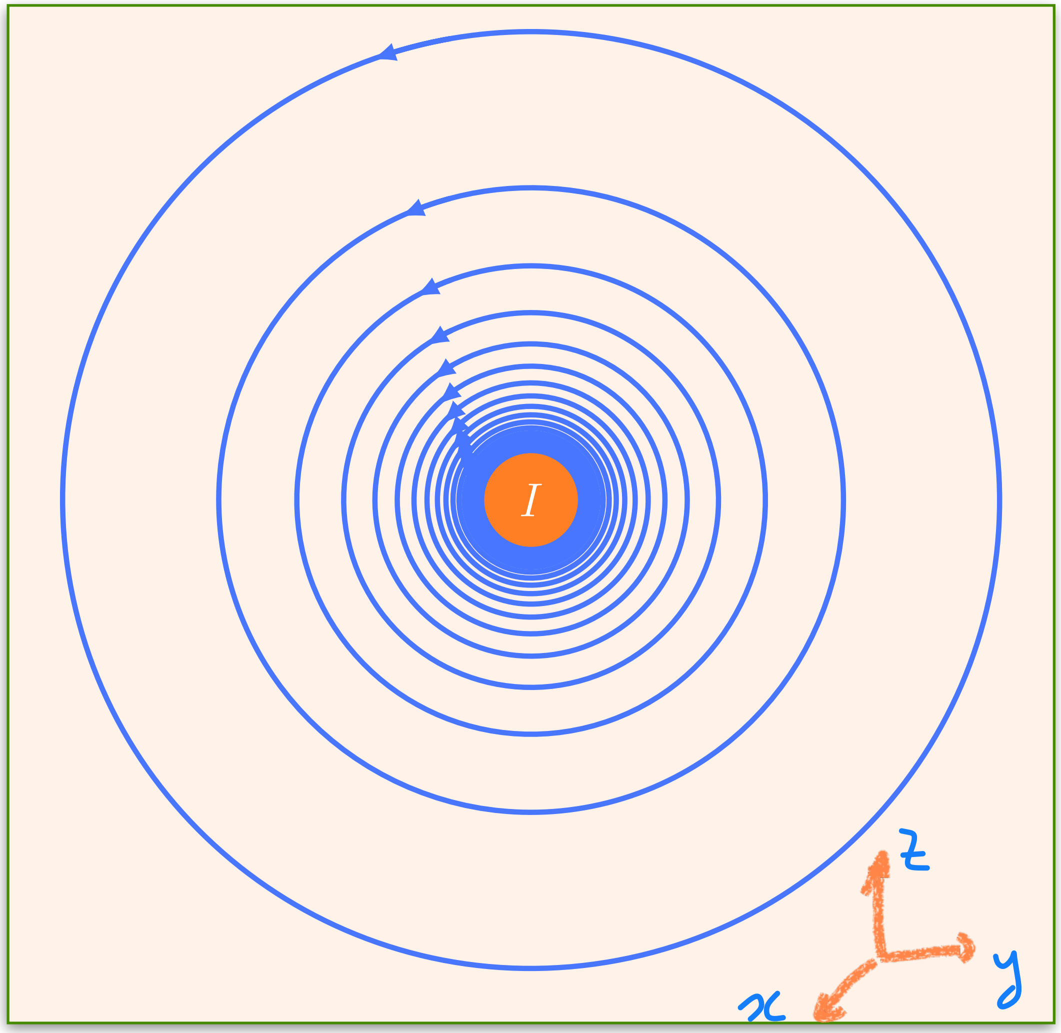
$$\vec{B} = \frac{\mu_0 I}{2\pi s}\hat{z}$$

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{\vec{I} \times \hat{\mathscr{r}}}{\mathscr{r}^2} \, \mathrm{d}\ell'$$

Pratique o que aprendeu

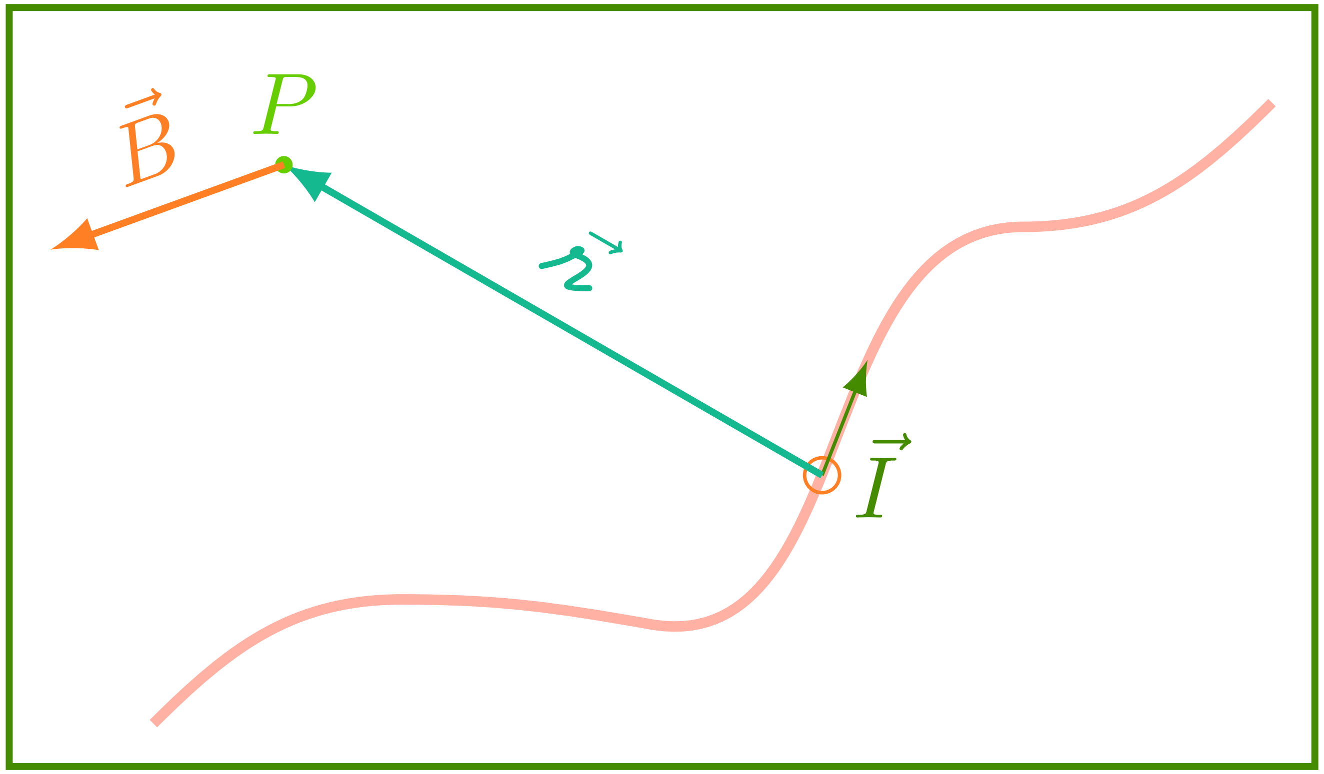


$$\vec{B} = \frac{\mu_0 I}{2\pi s} \hat{z}$$



Lei de Biot e Savart

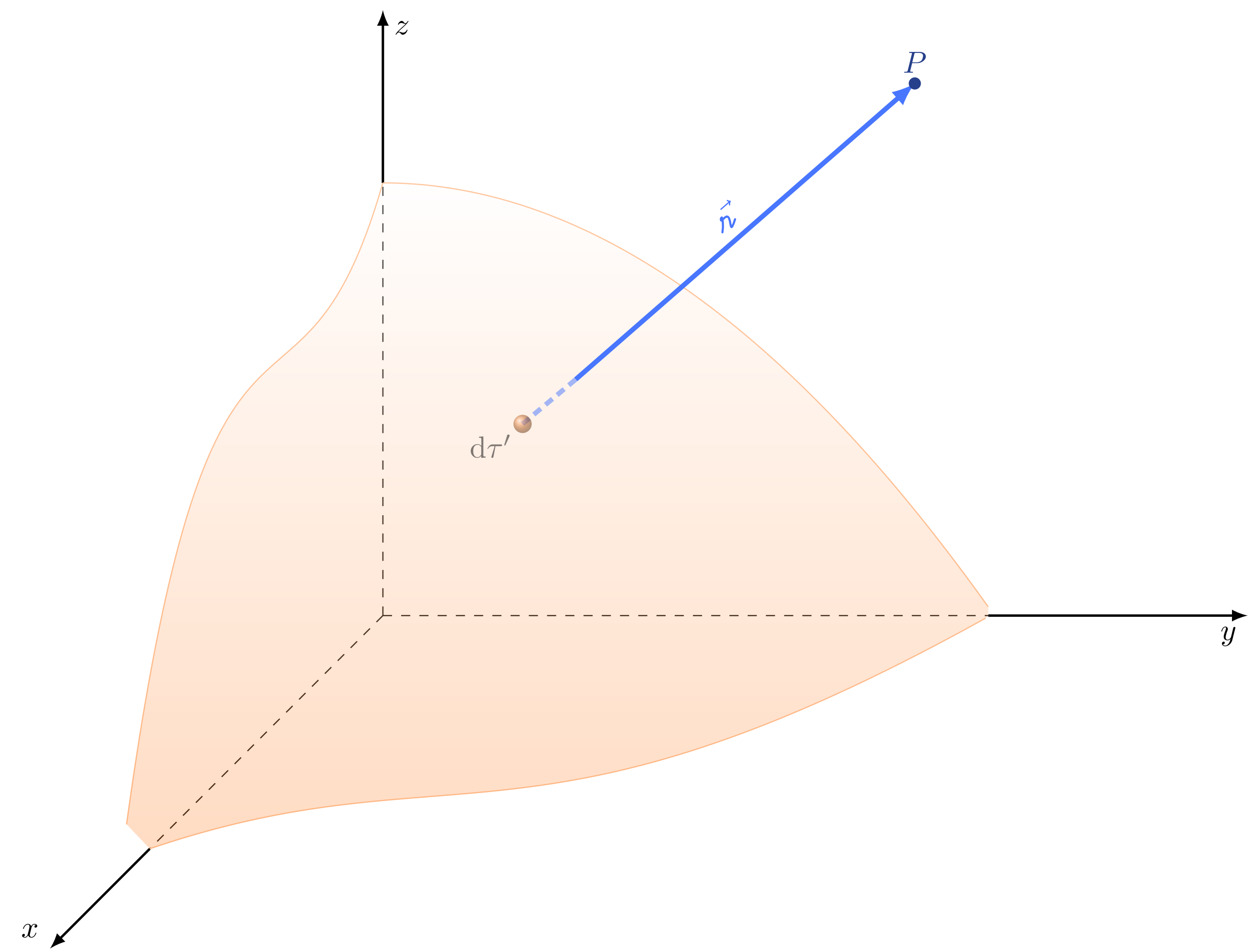
$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{\vec{I} \times \hat{\mathscr{r}}}{\mathscr{r}^2} \, \mathrm{d}\ell'$$ → FIO



Lei de Biot e Savart

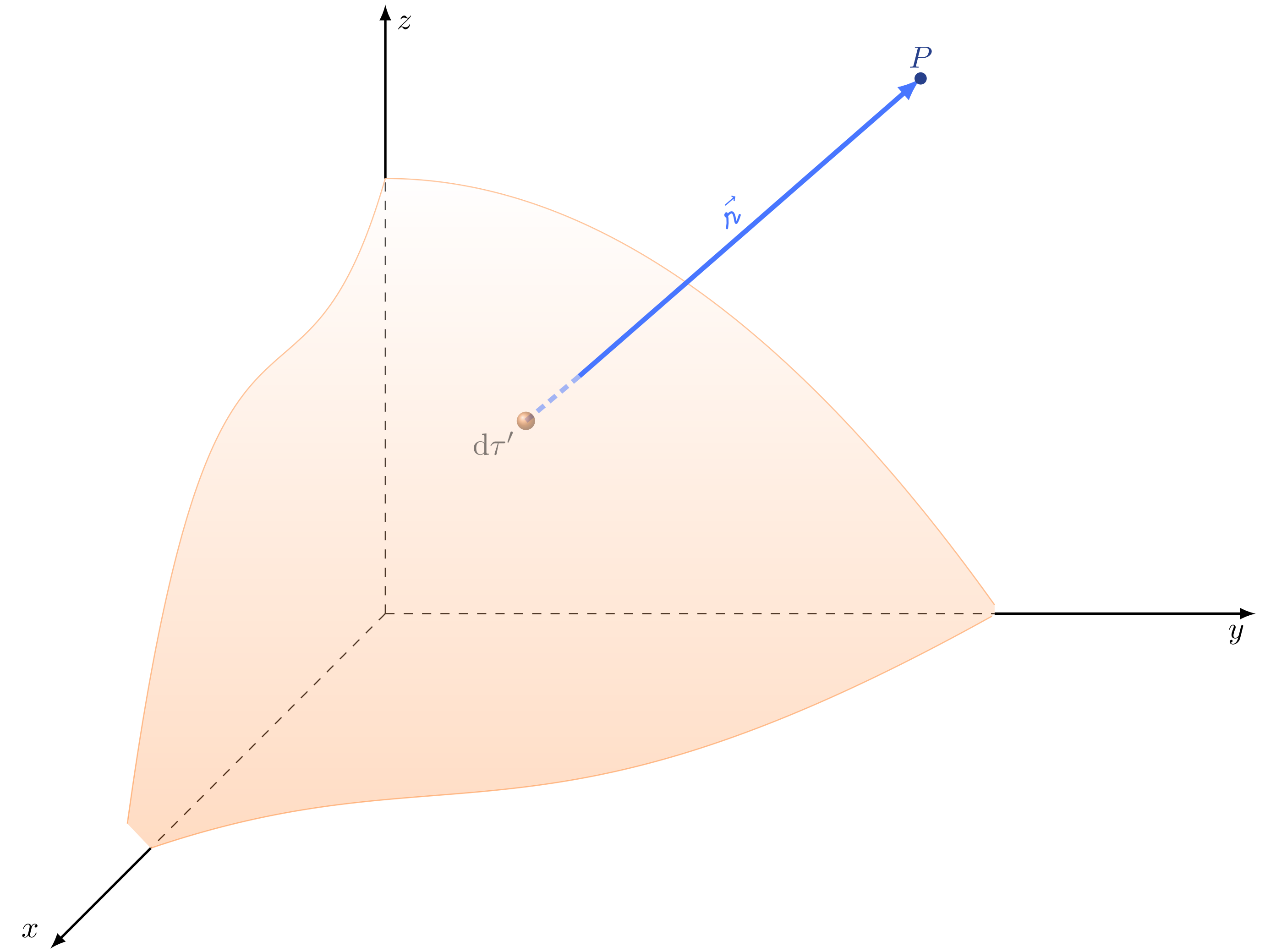
$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{\vec{I} \times \hat{\boldsymbol{\mathscr{r}}}}{\mathscr{r}^2} \, \mathrm{d}\ell' \longrightarrow \text{1D}$$

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{\vec{J} \times \hat{\boldsymbol{\mathscr{r}}}}{\mathscr{r}^2} \, \mathrm{d}\tau' \longrightarrow \text{3D}$$



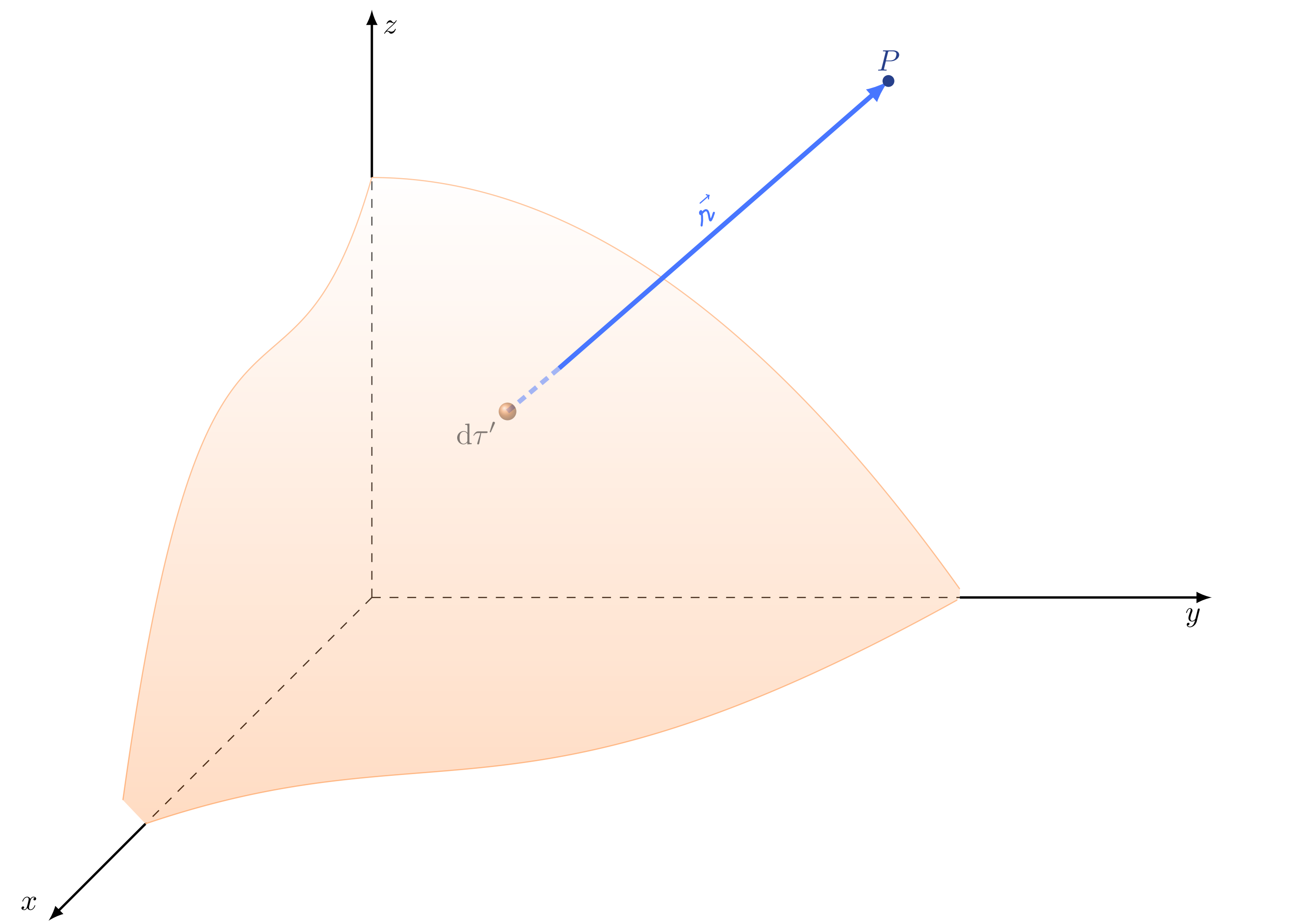
Lei de Biot e Savart

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{\vec{J} \times \hat{\boldsymbol{\mathscr{r}}}}{\boldsymbol{\mathscr{r}}^2}\, \mathrm{d}\tau'$$



Lei de Biot e Savart

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{\vec{J} \times \hat{\mathscr{r}}}{\mathscr{r}^2}\, \mathrm{d}\tau'$$



$$\vec{\nabla} \cdot \vec{B} = \frac{\mu_0}{4\pi} \int \vec{\nabla} \cdot \frac{\vec{J} \times \hat{\mathscr{r}}}{\mathscr{r}^2}\, \mathrm{d}\tau'$$

$$\vec{A} \cdot (\vec{B} \times \vec{C}) = \vec{B} \cdot (\vec{C} \times \vec{A})$$
$$= -\vec{B} \cdot (\vec{A} \times \vec{C})$$

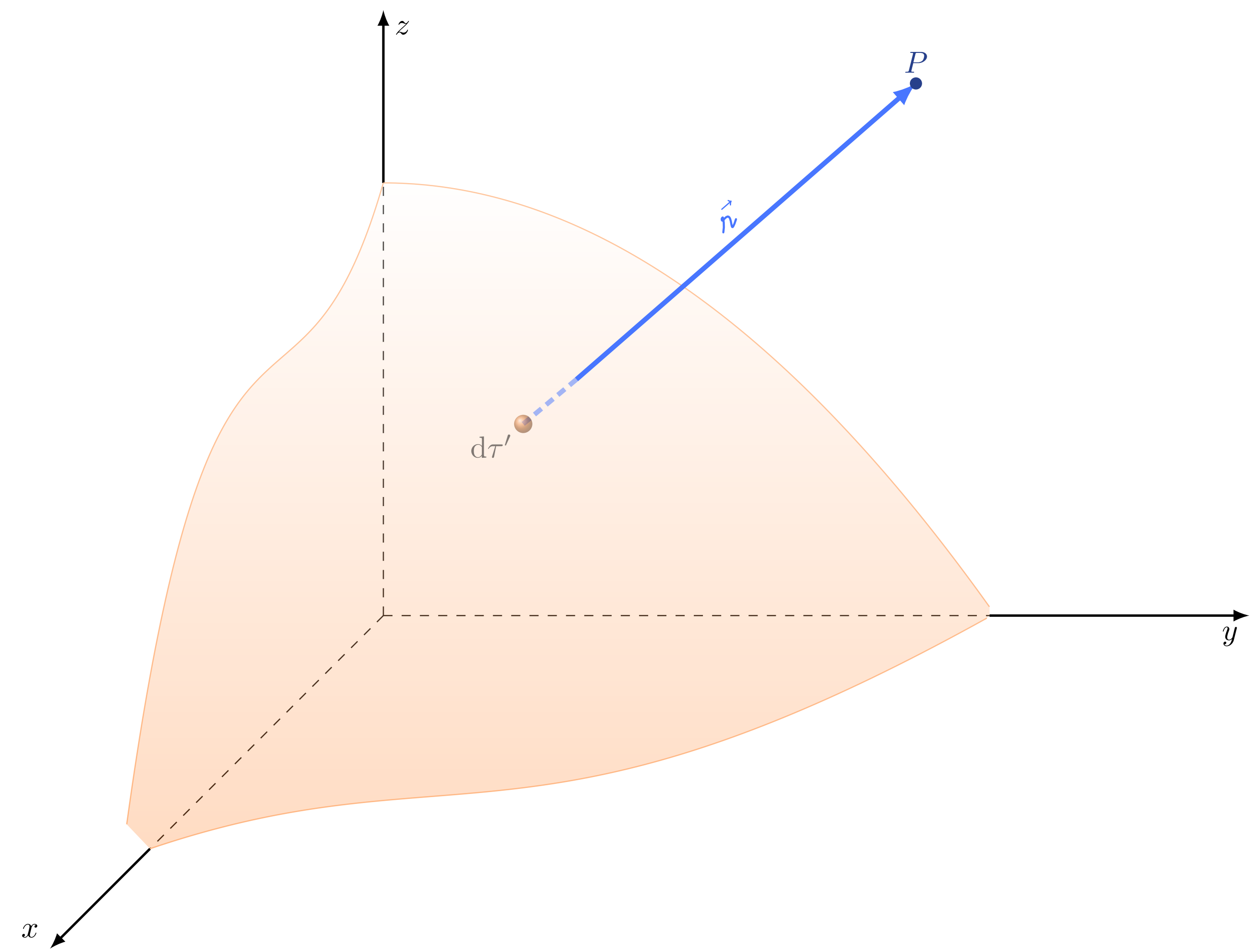
$$\vec{\nabla} \cdot \frac{\vec{J} \times \vec{\mathscr{r}}}{\mathscr{r}^2} = -\vec{J} \cdot \left(\vec{\nabla} \times \frac{\vec{\mathscr{r}}}{\mathscr{r}^2} \right)$$

Lei de Biot e Savart

$$\vec{B} = \frac{\mu_0}{4\pi} \int \frac{\vec{J} \times \hat{\mathscr{r}}}{\mathscr{r}^2} \, \mathrm{d}\tau'$$

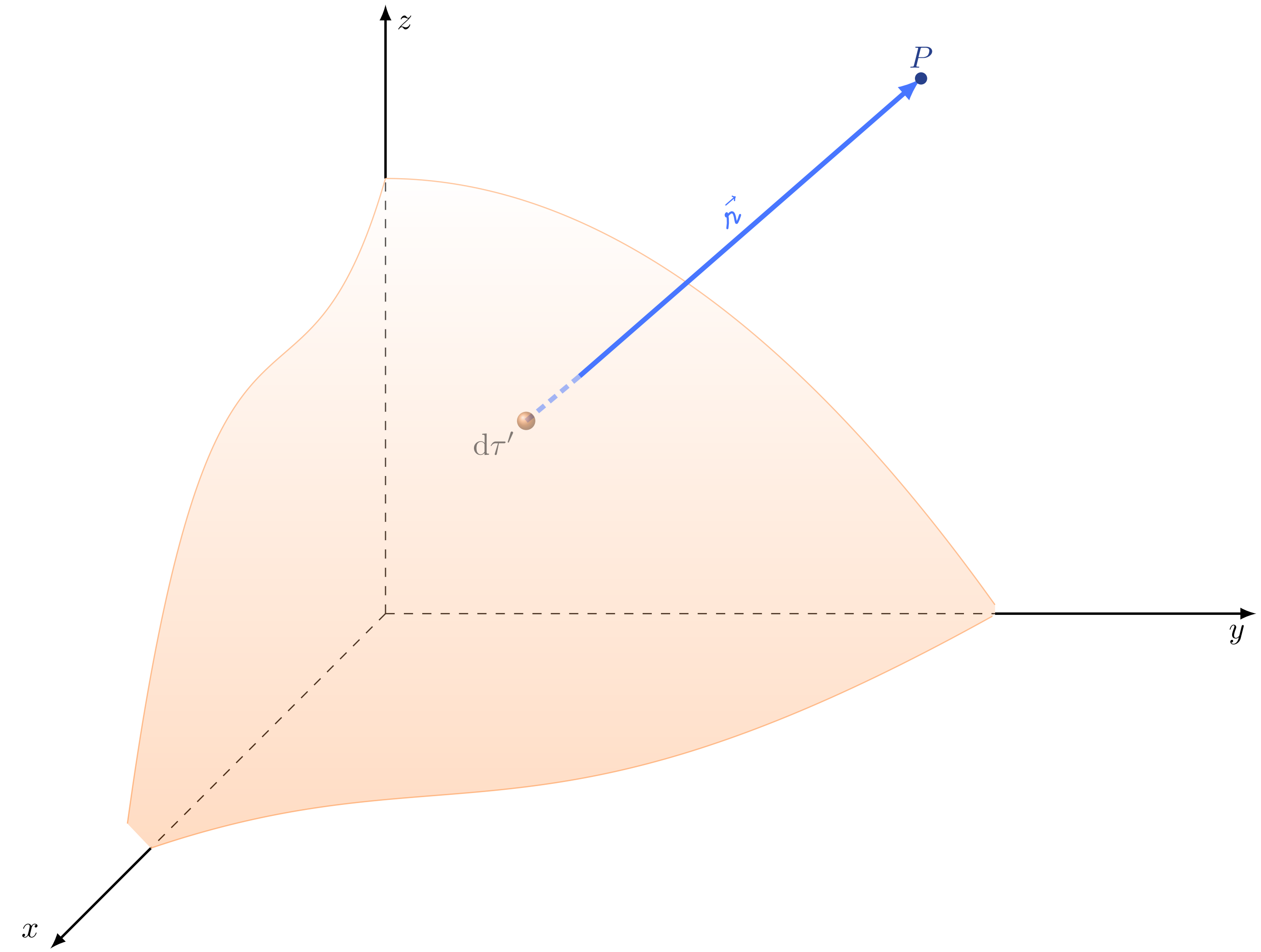
$$\vec{\nabla} \cdot \vec{B} = \frac{\mu_0}{4\pi} \int \vec{\nabla} \cdot \frac{\vec{J} \times \hat{\mathscr{r}}}{\mathscr{r}^2} \, \mathrm{d}\tau'$$

$$\vec{\nabla} \cdot \frac{\vec{J} \times \hat{\mathscr{r}}}{\mathscr{r}^2} = -\vec{J} \cdot \vec{\nabla} \times \frac{\hat{\mathscr{r}}}{\mathscr{r}^2}$$



Lei de Biot e Savart

$$\vec{B} = \frac{\mu_0}{4\pi}\int \frac{\vec{J}\times\hat{\mathscr{r}}}{\mathscr{r}^2}\,\mathrm{d}\tau'$$



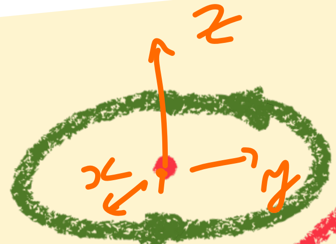
$$\vec{\nabla}\cdot\vec{B} = \frac{\mu_0}{4\pi}\int \vec{\nabla}\cdot\frac{\vec{J}\times\hat{\mathscr{r}}}{\mathscr{r}^2}\,\mathrm{d}\tau'$$

$$\vec{\nabla}\cdot\frac{\vec{J}\times\hat{\mathscr{r}}}{\mathscr{r}^2} = -\vec{J}\cdot\vec{\nabla}\times\frac{\hat{\mathscr{r}}}{\mathscr{r}^2}$$

$\frac{\hat{\mathscr{r}}}{\mathscr{r}^2} \sim \vec{E}$ DE CARGA PONTUAL $\Rightarrow \vec{\nabla}\times\vec{E} = \vec{\nabla}\times\frac{\hat{\mathscr{r}}}{\mathscr{r}^2} = 0$

$$\vec{\nabla}\cdot\vec{B} = 0$$

STOKES



$$\int \vec{\nabla}\times\frac{\hat{\mathscr{r}}}{\mathscr{r}^2}\cdot d\vec{a} = \oint \frac{\hat{\mathscr{r}}}{\mathscr{r}^2}\cdot d\vec{\ell}$$

$0 \quad (\hat{\mathscr{r}} \perp d\vec{\ell})$

$= 0 \Rightarrow \vec{\nabla}\times\frac{\hat{\mathscr{r}}}{\mathscr{r}^2} = 0$