Eletromagnetismo Avançado

1º ciclo
Aula de 20 de agosto

Leis de conservação

1. Carga elétrica

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

Leis de conservação

1. Carga elétrica

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

2. Energia

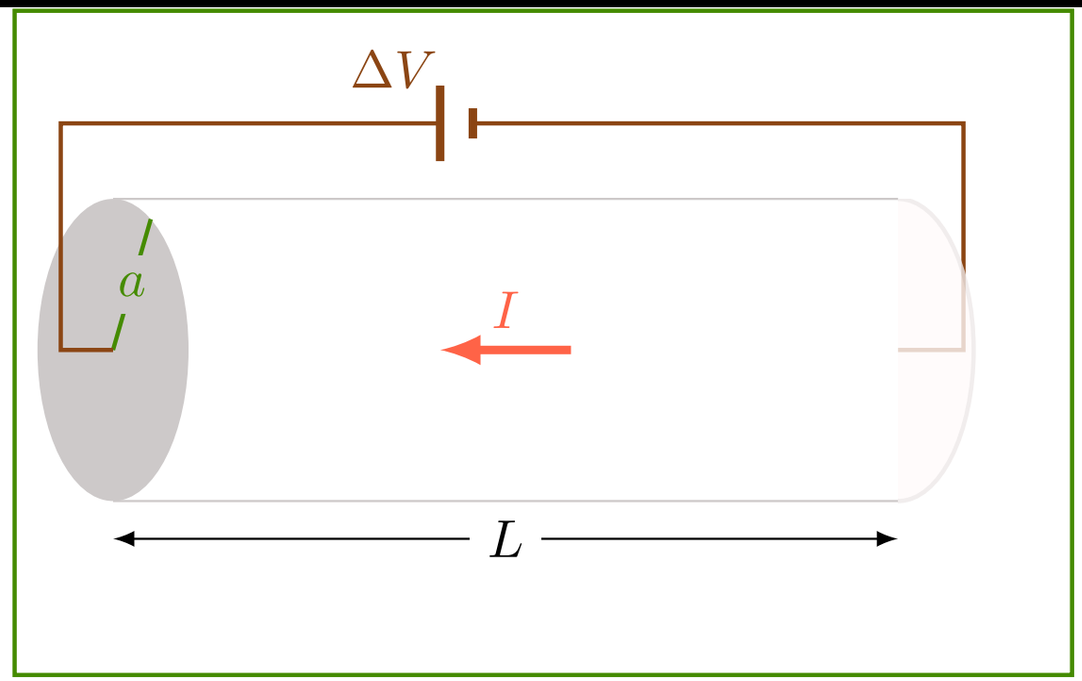
$$\frac{\partial}{\partial t}\left(u_{mec} + u_{em}\right) = -\vec{\nabla} \cdot \vec{S}$$

$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$$

Pratique o que aprendeu

$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$$

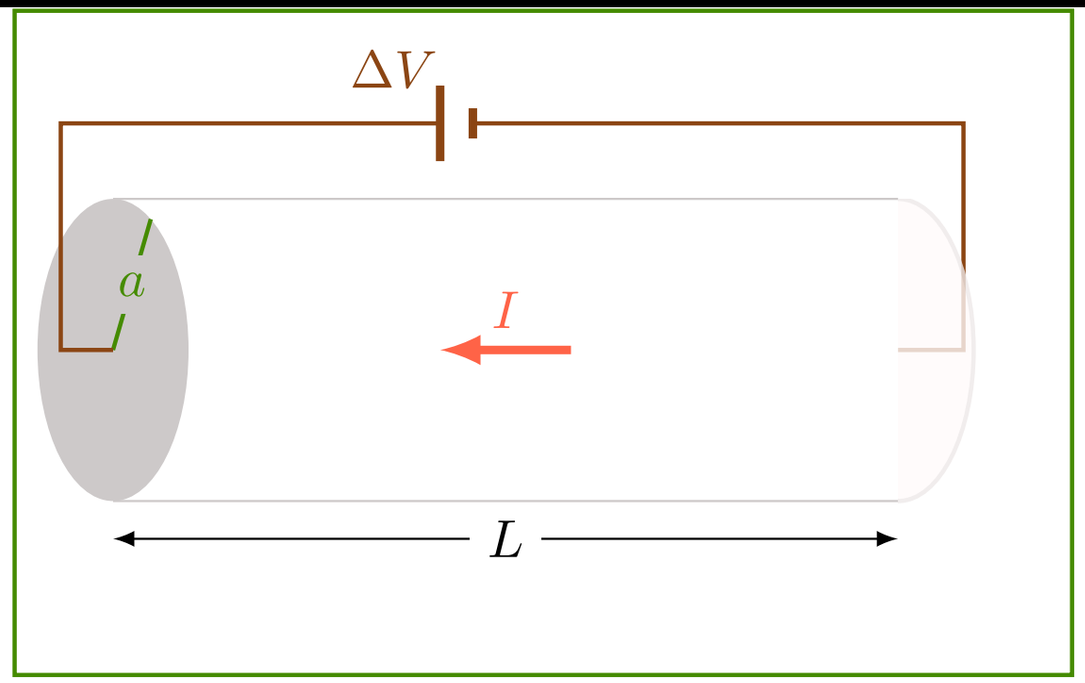
$\vec{S} = ?$



Pratique o que aprendeu

$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$$

$$E = \frac{V}{L}$$



Pratique o que aprendeu

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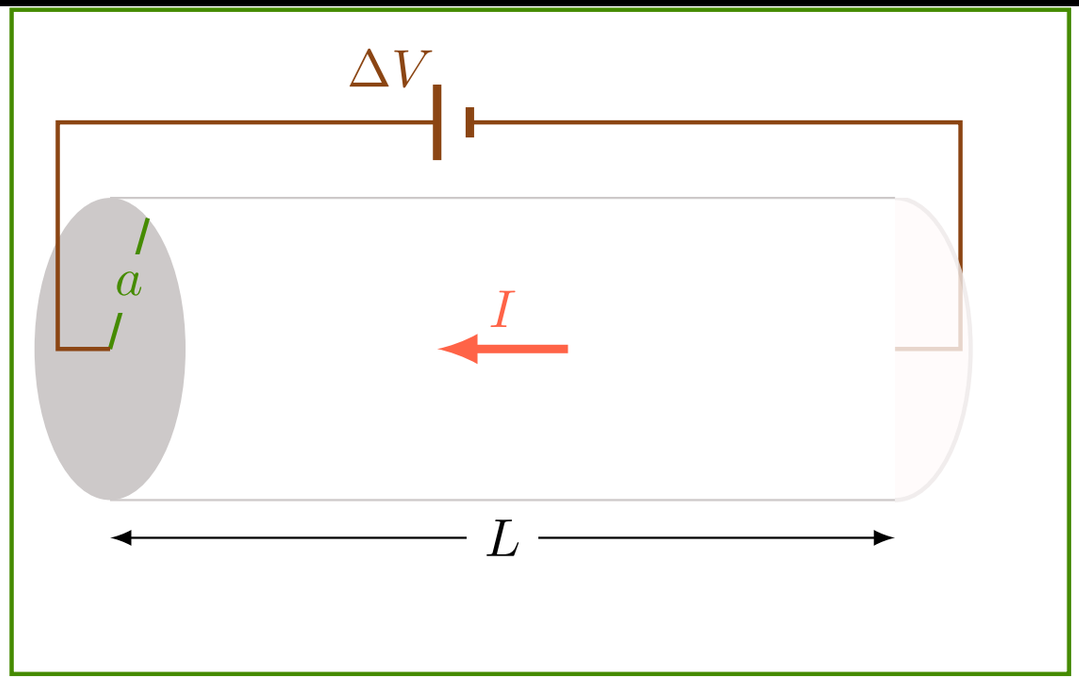
$$E = \frac{V}{L}$$

$$\vec{E} = \frac{V}{L}\hat{z}$$



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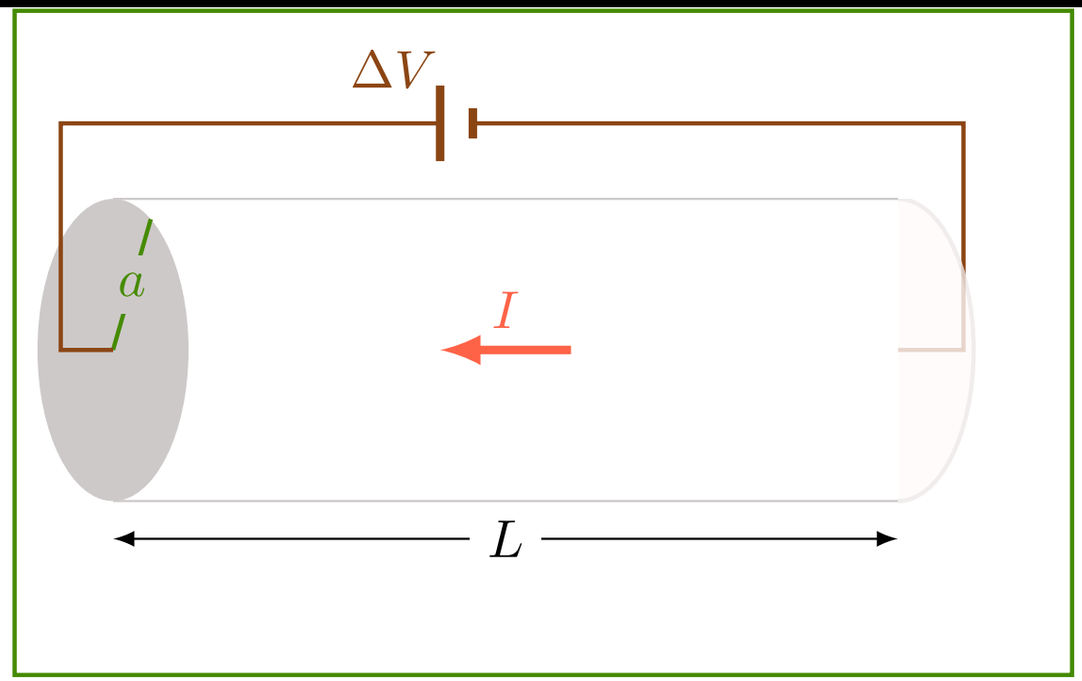
$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$$

$$E = \frac{V}{L}$$

$$\vec{E} = \frac{V}{L}\hat{z}$$

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



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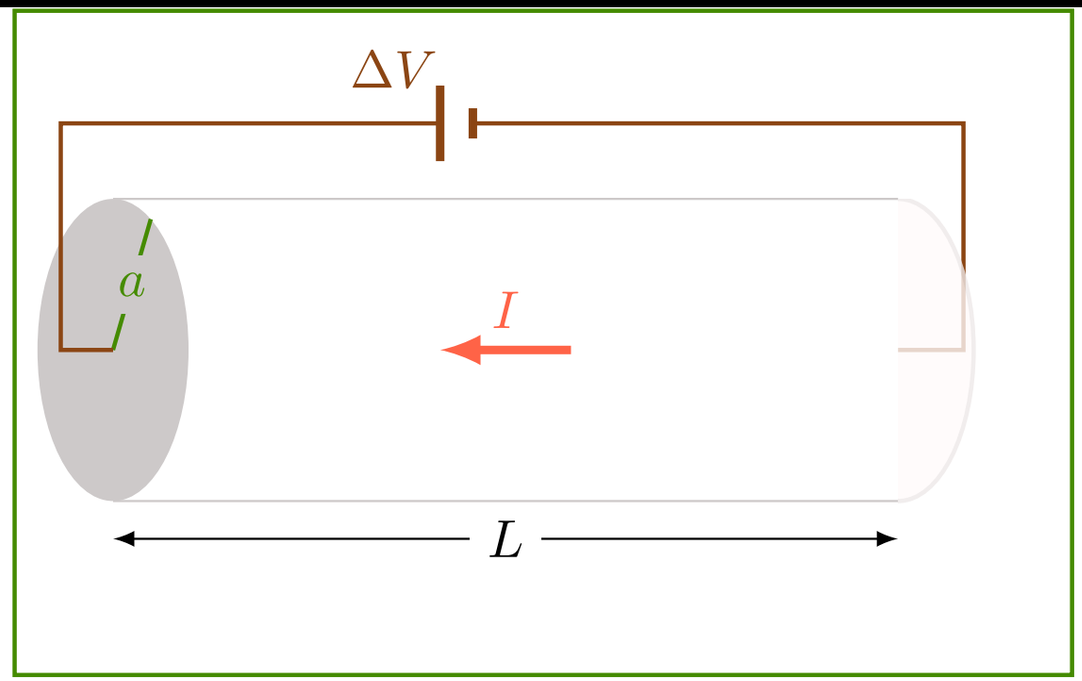

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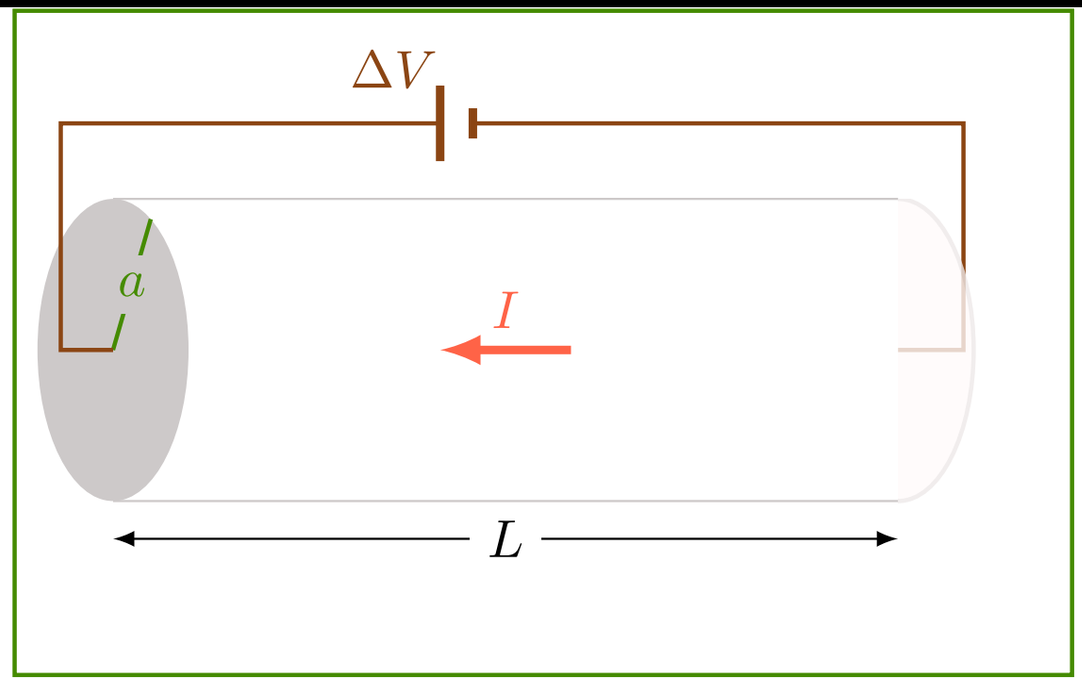

$$\vec{S} = -\frac{VI}{\text{Área}}\hat{s}$$

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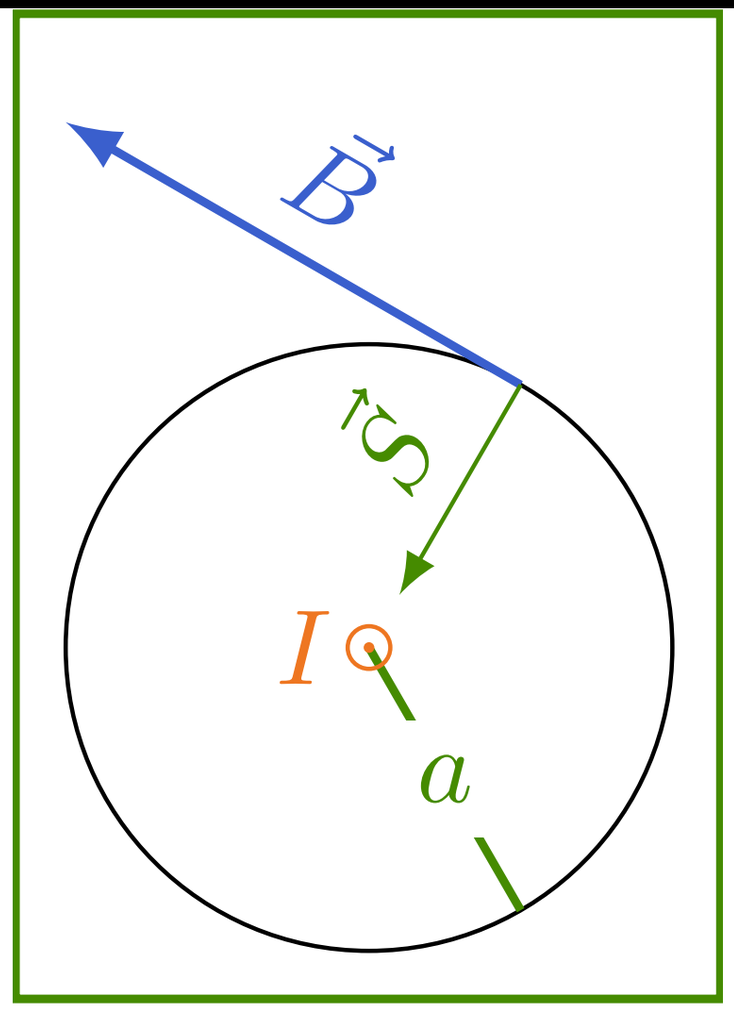

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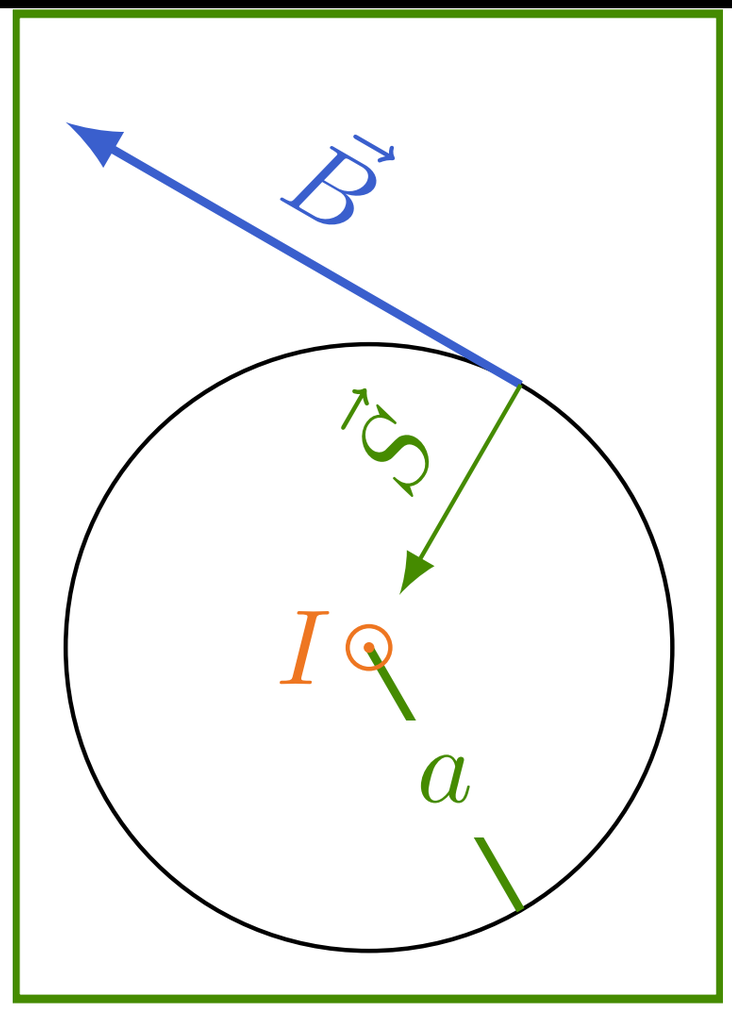
Pratique o que aprendeu

$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$$

$$\int_{\mathcal{A}} \vec{S} \cdot \hat{n} = VI$$

Um pouco de física



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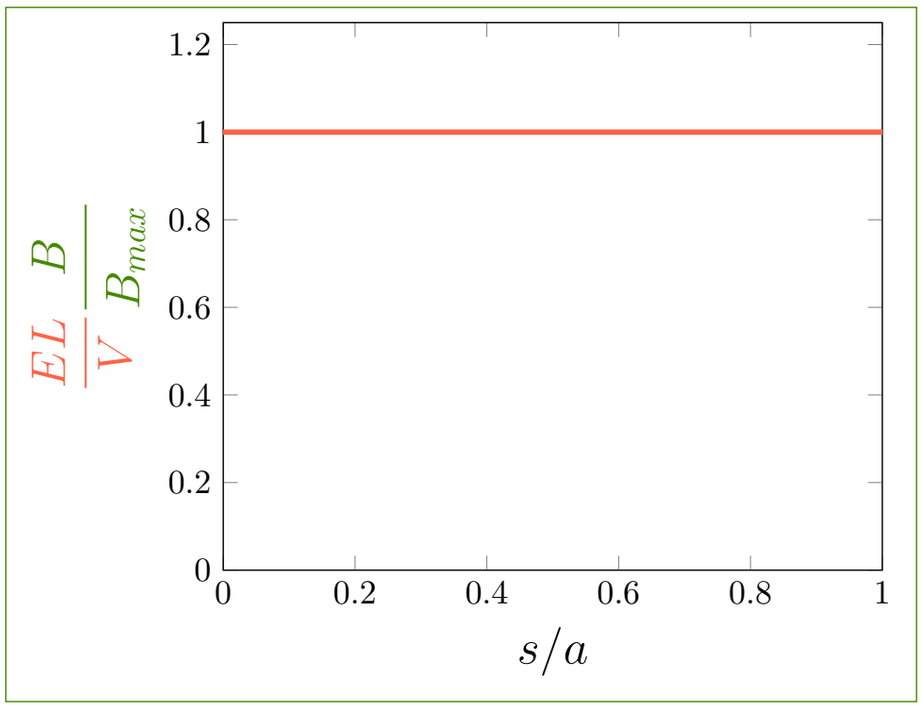

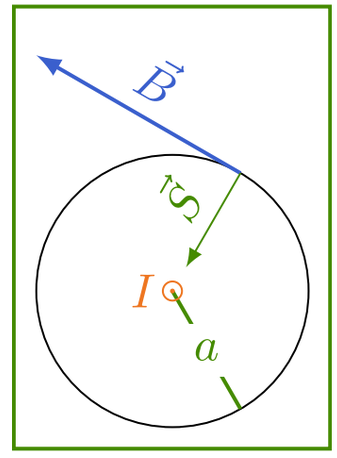

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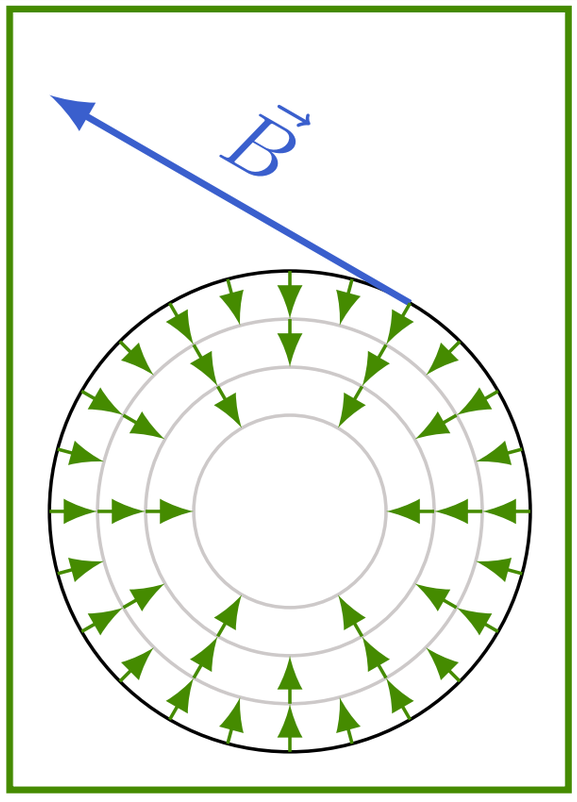
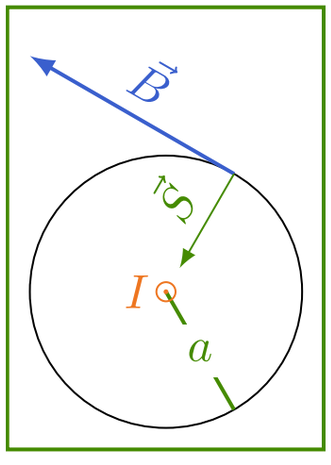
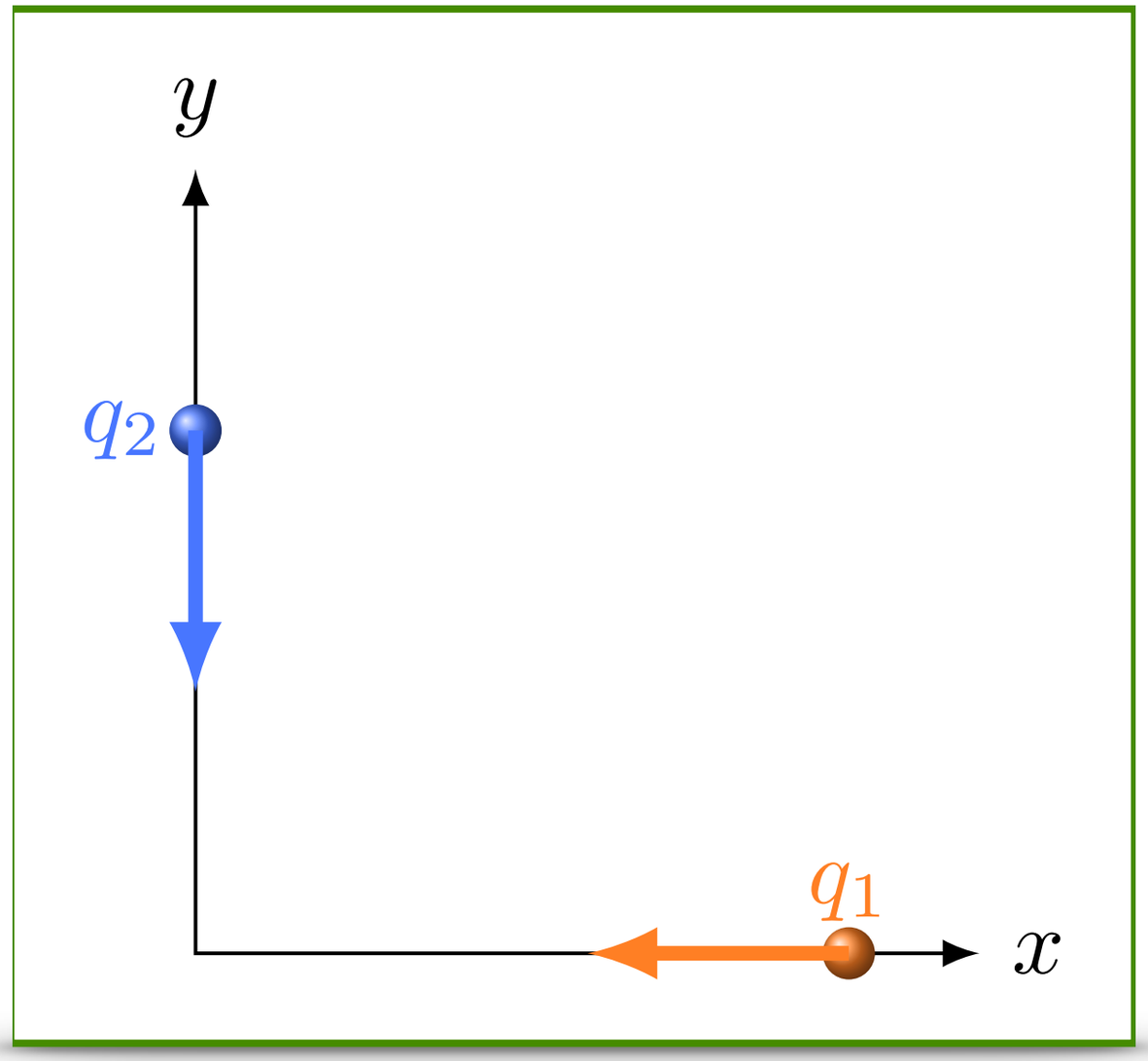




Leis de conservação

$$\vec{S} = \frac{1}{\mu_0}\vec{E} \times \vec{B}$$

3. Momento



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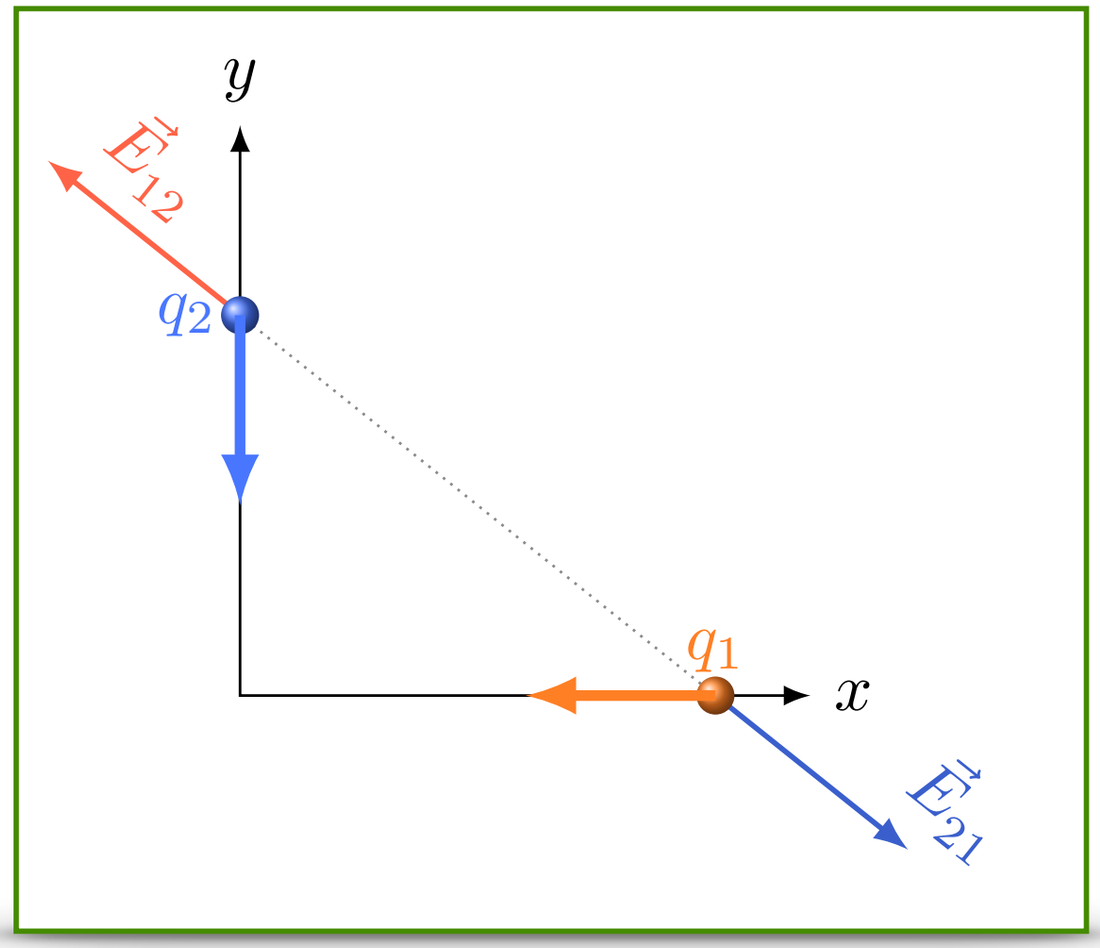

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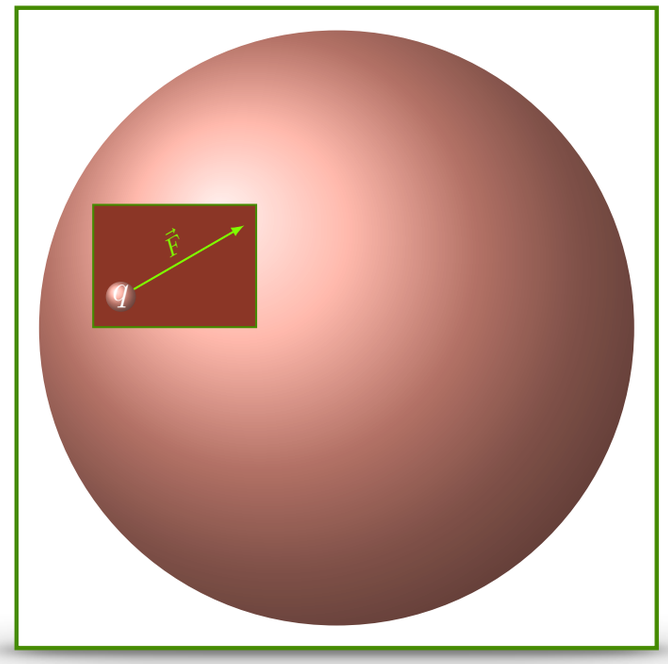

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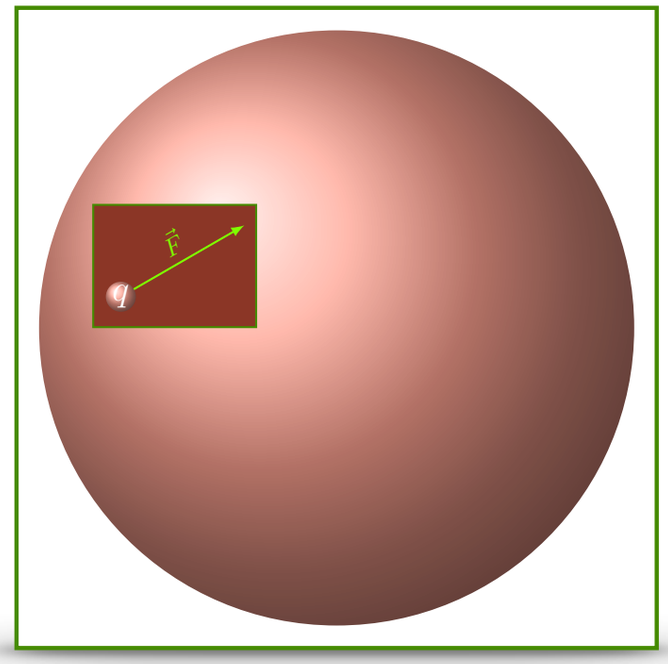

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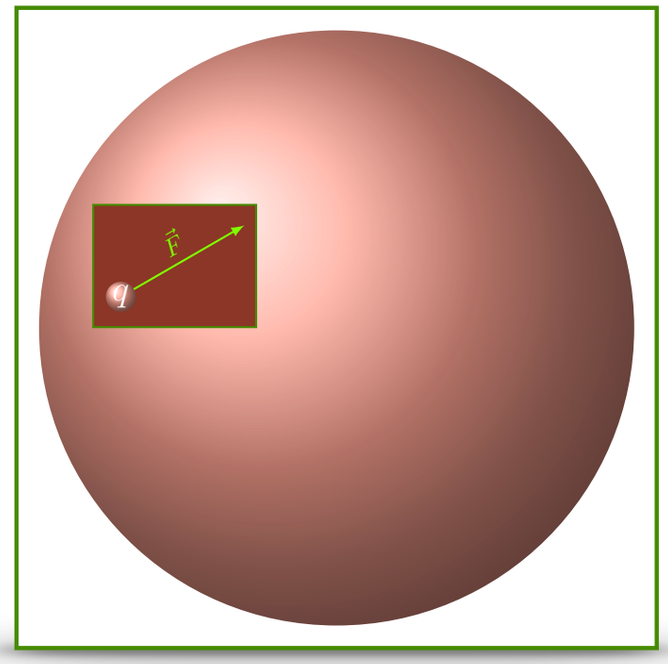

$$\rho = \epsilon_0 \vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{E}}$$

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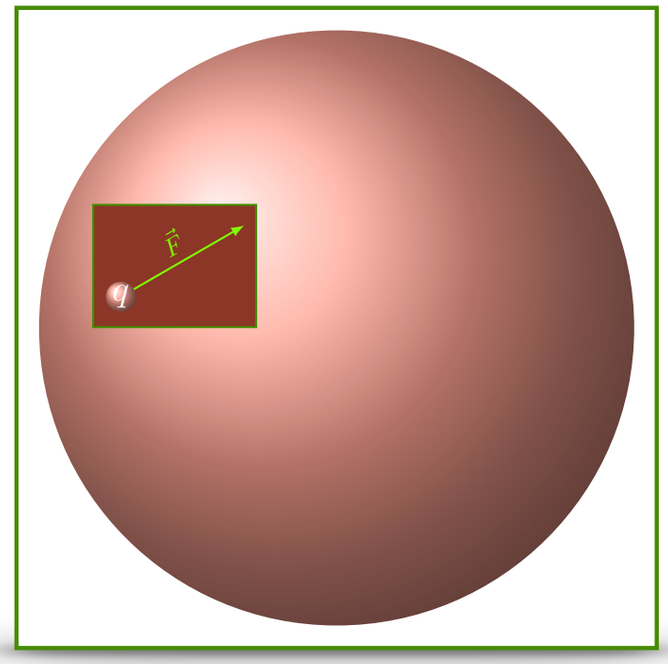

$$\rho = \epsilon_0 \vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{E}}$$

$$\vec{\mathbf{J}} = \frac{1}{\mu_0}\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{B}} - \epsilon_0 \frac{\partial \vec{\mathbf{E}}}{\partial t}$$

$$\frac{\partial \vec{\mathbf{E}}}{\partial t} \times \vec{\mathbf{B}} = ?$$

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$$\frac{\partial}{\partial t}\left(\vec{\mathbf{E}} \times \vec{\mathbf{B}}\right) = \frac{\partial \vec{\mathbf{E}}}{\partial t} \times \vec{\mathbf{B}} + \vec{\mathbf{E}} \times \frac{\partial \vec{\mathbf{B}}}{\partial t}$$

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$$\vec{\mathbf{E}} \times \vec{\boldsymbol{\nabla}} \times \vec{\mathbf{E}} = \frac{1}{2}\vec{\boldsymbol{\nabla}} E^2 - (\vec{\mathbf{E}} \cdot \vec{\boldsymbol{\nabla}})\vec{\mathbf{E}}$$

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$$\vec{\mathbf{E}} \times \vec{\boldsymbol{\nabla}} \times \vec{\mathbf{E}} = \frac{1}{2}\vec{\boldsymbol{\nabla}} E^2 - (\vec{\mathbf{E}} \cdot \vec{\boldsymbol{\nabla}})\vec{\mathbf{E}}$$

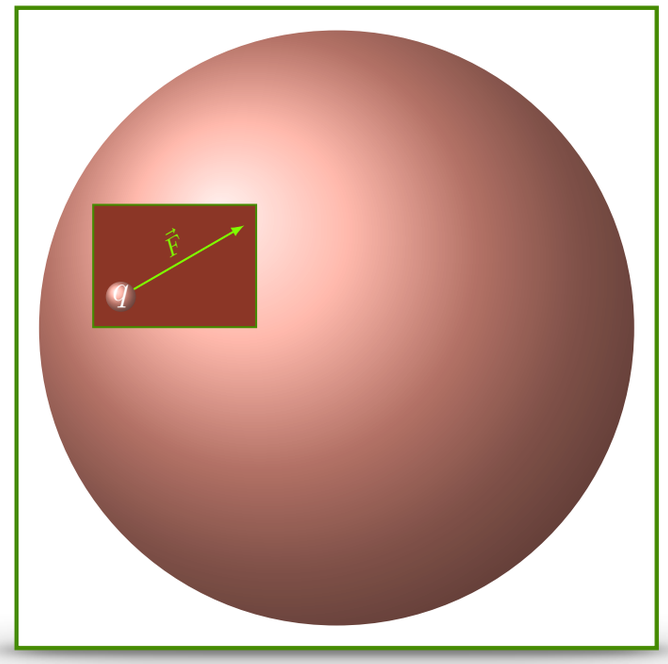
$$\vec{\mathbf{B}} \times (\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{B}}) = \frac{1}{2}\vec{\boldsymbol{\nabla}} B^2 - (\vec{\mathbf{B}} \cdot \vec{\boldsymbol{\nabla}})\vec{\mathbf{B}}$$

Leis de conservação

3. Momento

$$\vec{\mathbf{F}} = \int_{\mathcal{V}} \rho\vec{\mathbf{E}} + \vec{\mathbf{J}} \times \vec{\mathbf{B}} \, \mathrm{d}\tau$$

$$\vec{\mathbf{f}} = \rho\vec{\mathbf{E}} + \vec{\mathbf{J}} \times \vec{\mathbf{B}}$$



$$\rho = \epsilon_0 \vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{E}}$$

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$$\frac{\partial \vec{\mathbf{E}}}{\partial t} \times \vec{\mathbf{B}} = \frac{\partial}{\partial t}\left(\vec{\mathbf{E}} \times \vec{\mathbf{B}}\right) + \vec{\mathbf{E}} \times (\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{E}})$$

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$$\vec{\mathbf{B}} \times (\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{B}}) = \frac{1}{2}\vec{\boldsymbol{\nabla}} B^2 - (\vec{\mathbf{B}} \cdot \vec{\boldsymbol{\nabla}})\vec{\mathbf{B}}$$

Leis de conservação

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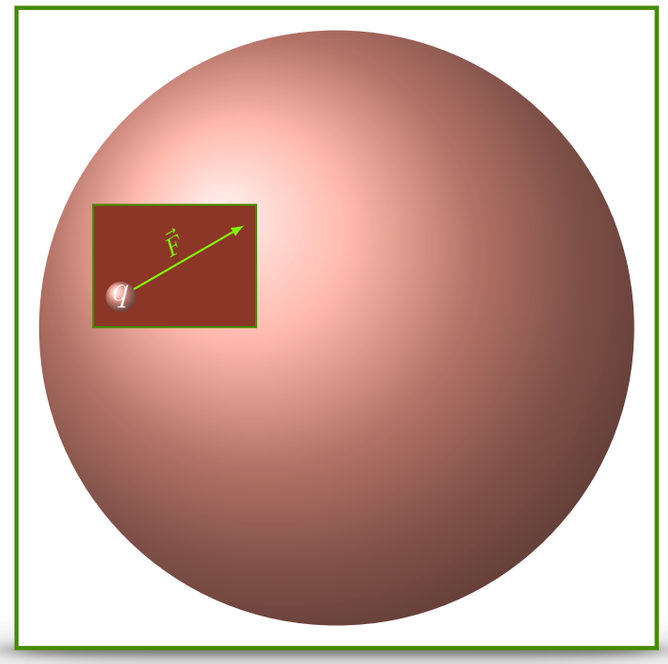

$$\rho = \epsilon_0 \vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{E}}$$

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$$\vec{\mathbf{J}} \times \vec{\mathbf{B}} = -\frac{1}{\mu_0}\vec{\mathbf{B}} \times (\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{B}}) + \epsilon_0 \vec{\mathbf{B}} \times \frac{\partial \vec{\mathbf{E}}}{\partial t}$$

$$\frac{\partial \vec{\mathbf{E}}}{\partial t} \times \vec{\mathbf{B}} = \frac{\partial}{\partial t}\left(\vec{\mathbf{E}} \times \vec{\mathbf{B}}\right) + \vec{\mathbf{E}} \times (\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{E}})$$

$$\vec{\mathbf{E}} \times (\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{E}}) = \frac{1}{2}\vec{\boldsymbol{\nabla}} E^2 - (\vec{\mathbf{E}} \cdot \vec{\boldsymbol{\nabla}})\vec{\mathbf{E}}$$

$$\vec{\mathbf{B}} \times (\vec{\boldsymbol{\nabla}} \times \vec{\mathbf{B}}) = \frac{1}{2}\vec{\boldsymbol{\nabla}} B^2 - (\vec{\mathbf{B}} \cdot \vec{\boldsymbol{\nabla}})\vec{\mathbf{B}}$$

Leis de conservação

3. Momento

$$\vec{\mathbf{f}} = \epsilon_0[(\vec{\boldsymbol{\nabla}}\cdot\vec{\mathbf{E}})\vec{\mathbf{E}} + (\vec{\mathbf{E}}\cdot\vec{\boldsymbol{\nabla}})\vec{\mathbf{E}}] + \frac{1}{\mu_0}[(\vec{\mathbf{B}}\cdot\vec{\boldsymbol{\nabla}})\vec{\mathbf{B}}]$$
$$- \frac{1}{2}\vec{\boldsymbol{\nabla}}\left(\epsilon_0 E^2 + \frac{1}{\mu_0}B^2\right) - \epsilon_0\frac{\partial}{\partial t}\left(\vec{\mathbf{E}}\times\vec{\mathbf{B}}\right)$$

Leis de conservação

3. Momento

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$$\vec{\mathbf{f}} = \epsilon_0[(\vec{\boldsymbol{\nabla}}\cdot\vec{\mathbf{E}})\vec{\mathbf{E}} + (\vec{\mathbf{E}}\cdot\vec{\boldsymbol{\nabla}})\vec{\mathbf{E}}] + \frac{1}{\mu_0}[(\vec{\boldsymbol{\nabla}}\cdot\vec{\mathbf{B}})\vec{\mathbf{B}} + (\vec{\mathbf{B}}\cdot\vec{\boldsymbol{\nabla}})\vec{\mathbf{B}}]$$
$$- \frac{1}{2}\vec{\boldsymbol{\nabla}}\left(\epsilon_0 E^2 + \frac{1}{\mu_0}B^2\right) - \epsilon_0\frac{\partial}{\partial t}\left(\vec{\mathbf{E}}\times\vec{\mathbf{B}}\right)$$

Leis de conservação

3. Momento

$$(\vec{\mathbf{\nabla}} \cdot \vec{\mathbf{E}})\vec{\mathbf{E}} + (\vec{\mathbf{E}} \cdot \vec{\mathbf{\nabla}})\vec{\mathbf{E}} = ?$$

Leis de conservação

3. Momento

$$(\vec{\nabla}\cdot\vec{\mathbf{E}})\vec{\mathbf{E}} + (\vec{\mathbf{E}}\cdot\vec{\nabla})\vec{\mathbf{E}} = ?$$

$$\begin{bmatrix}\frac{\partial}{\partial x} & \frac{\partial}{\partial y} & \frac{\partial}{\partial z}\end{bmatrix}\begin{bmatrix}E_xE_x & E_xE_y & E_xE_z\\ E_yE_x & E_yE_y & E_yE_z\\ E_zE_x & E_zE_y & E_zE_z\end{bmatrix} = \begin{bmatrix}(\vec{\nabla}\cdot\vec{\mathbf{E}})E_x + \vec{\mathbf{E}}\cdot\vec{\nabla}E_x & \{\}E_y & \{\}E_z\end{bmatrix}$$

Leis de conservação

Noether