Eletromagnetismo Avançado

18 de agosto

Leis de conservação

Equações de Maxwell

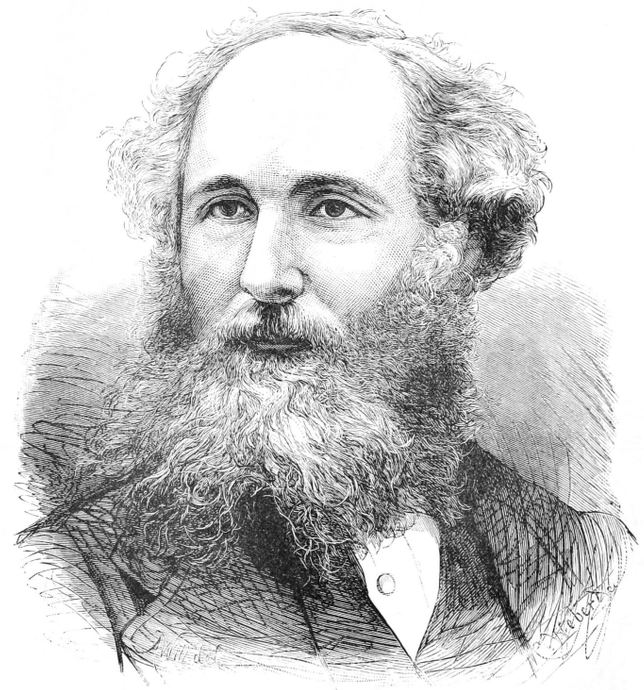
Vácuo

$$\vec{\nabla} \cdot \vec{\mathrm{E}} =$$

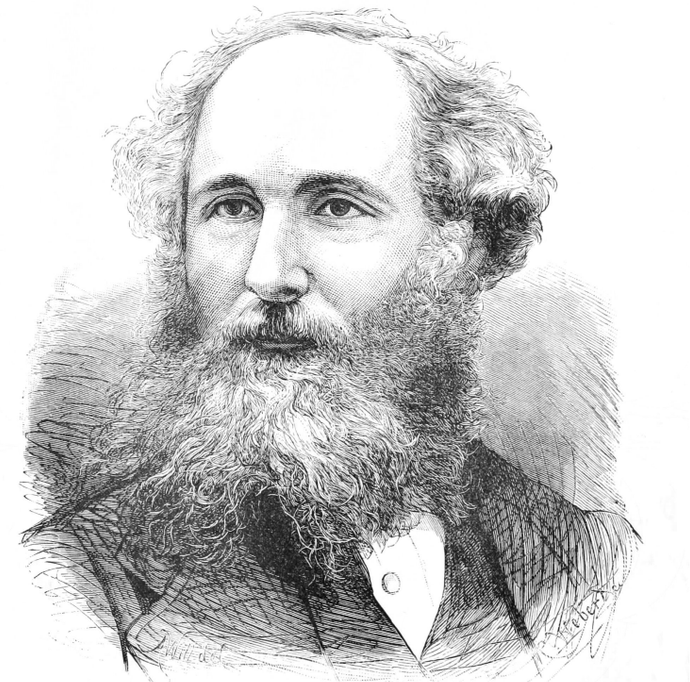
$$\vec{\nabla} \times \vec{\mathrm{E}} =$$

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

$$\vec{\nabla} \times \vec{\mathrm{B}} =$$



Equações de Maxwell



Vácuo

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

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

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

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

Leis de conservação

Emmy Noether

(1882-1935)

Conservação da energia

Capacitor carregado

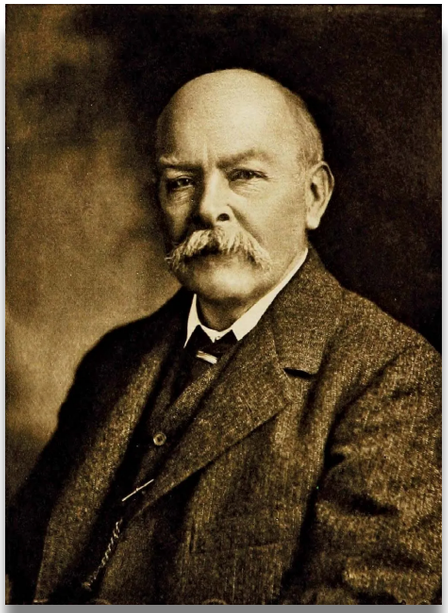
$$W = \frac{q^2}{2C}$$

Meio condutor

- Carga decai
- Energia decai

$$\frac{\mathrm{d}W}{\mathrm{d}t} = -\frac{\mathrm{d}}{\mathrm{d}t}\int_{\mathcal{V}} \frac{1}{2}\left(\epsilon_0 E^2 + \frac{1}{\mu_0}B^2\right)\mathrm{d}\tau - \frac{1}{\mu_0}\int_{\mathcal{S}} \vec{\mathbf{E}} \times \vec{\mathbf{B}} \cdot \hat{\mathbf{n}}\,\mathrm{d}a$$

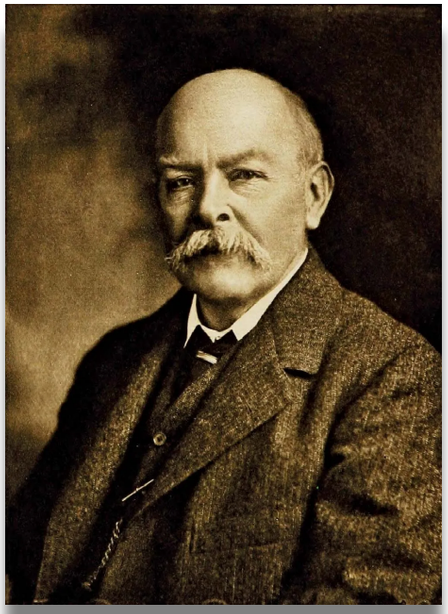
Conservação da energia



Vetor de Poynting

$$\vec{\mathbf{S}} \equiv \frac{1}{\mu_0}\left(\vec{\mathbf{E}} \times \vec{\mathbf{B}}\right)$$

Conservação da energia



Vetor de Poynting

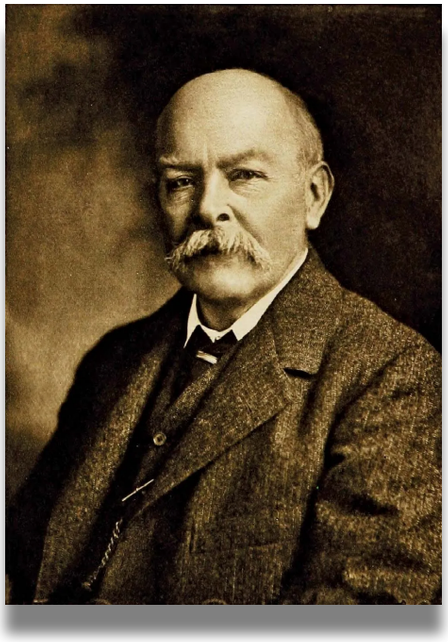
$$\vec{\mathbf{S}} \equiv \frac{1}{\mu_0}\left(\vec{\mathbf{E}} \times \vec{\mathbf{B}}\right)$$

$$\frac{\mathrm{d}W}{\mathrm{d}t} = -\frac{\mathrm{d}}{\mathrm{d}t}\int_{\mathcal{V}} \frac{1}{2}\left(\epsilon_0 E^2 + \frac{1}{\mu_0}B^2\right)\mathrm{d}\tau - \int_{\mathcal{S}} \vec{\mathbf{S}}\cdot\hat{\mathbf{n}}\mathrm{d}a$$

$$\frac{\mathrm{d}W}{\mathrm{d}t} = \frac{\mathrm{d}}{\mathrm{d}t}\int_{\mathcal{V}} u_{mec}(\vec{\mathbf{r}})\mathrm{d}\tau$$

$$\Rightarrow \quad \frac{\mathrm{d}}{\mathrm{d}t}\int_{\mathcal{V}} \left(u_{mec} + u_{EM}\right)\mathrm{d}\tau = -\int_{\mathcal{S}} \vec{\mathbf{S}}\cdot\hat{\mathbf{n}}\mathrm{d}a$$

Conservação da energia

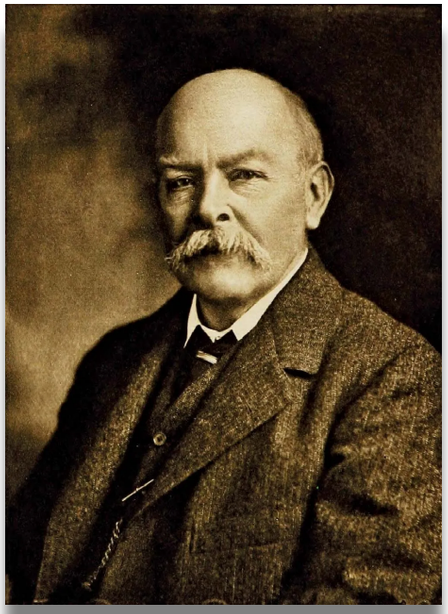


Vetor de Poynting

$$\vec{\mathbf{S}} \equiv \frac{1}{\mu_0}\left(\vec{\mathbf{E}} \times \vec{\mathbf{B}}\right)$$

$$\frac{\mathrm{d}W}{\mathrm{d}t} = -\frac{\mathrm{d}}{\mathrm{d}t}\int_{\mathcal{V}} \underbrace{\frac{1}{2}\left(\epsilon_0 E^2 + \frac{1}{\mu_0}B^2\right)}_{u_{EM}} \mathrm{d}\tau - \int_{\mathcal{S}} \vec{\mathbf{S}} \cdot \hat{\mathbf{n}}\mathrm{d}a$$

Conservação da energia



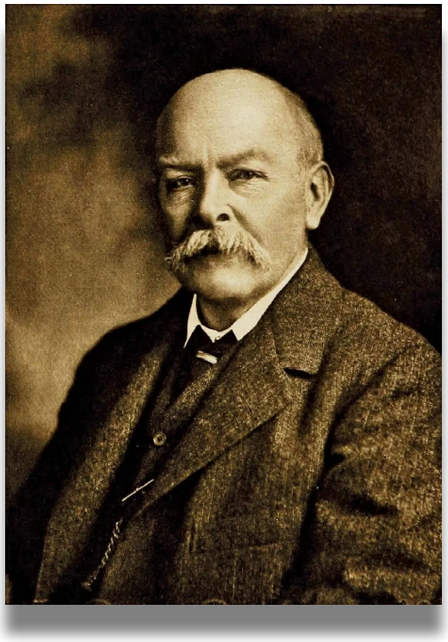
Vetor de Poynting

$$\vec{\mathbf{S}} \equiv \frac{1}{\mu_0}\left(\vec{\mathbf{E}} \times \vec{\mathbf{B}}\right)$$

$$\frac{\mathrm{d}W}{\mathrm{d}t} = -\frac{\mathrm{d}}{\mathrm{d}t}\int_{\mathcal{V}} \underbrace{\frac{1}{2}\left(\epsilon_0 E^2 + \frac{1}{\mu_0}B^2\right)}_{u_{EM}} \mathrm{d}\tau - \int_{\mathcal{S}} \vec{\mathbf{S}} \cdot \hat{\mathbf{n}}\mathrm{d}a$$

$$\frac{\mathrm{d}W}{\mathrm{d}t} = \frac{\mathrm{d}}{\mathrm{d}t}\int_{\mathcal{V}} u_{mec}(\vec{\mathbf{r}})\mathrm{d}\tau$$

Conservação da energia



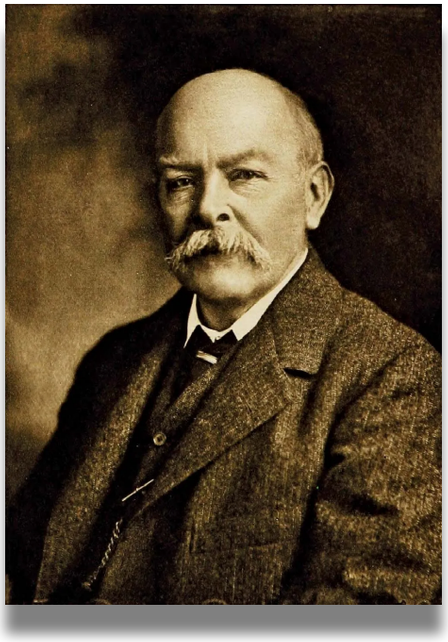
Vetor de Poynting

$$\vec{\mathbf{S}} \equiv \frac{1}{\mu_0}\left(\vec{\mathbf{E}} \times \vec{\mathbf{B}}\right)$$

$$\frac{\mathrm{d}W}{\mathrm{d}t} = -\frac{\mathrm{d}}{\mathrm{d}t}\int_{\mathcal{V}} \frac{1}{2}\left(\epsilon_0 E^2 + \frac{1}{\mu_0}B^2\right)\mathrm{d}\tau - \int_{\mathcal{S}} \vec{\mathbf{S}} \cdot \hat{\mathbf{n}}\,\mathrm{d}a$$

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

Conservação da energia



Vetor de Poynting

$$\vec{\mathbf{S}} \equiv \frac{1}{\mu_0}\left(\vec{\mathbf{E}} \times \vec{\mathbf{B}}\right)$$

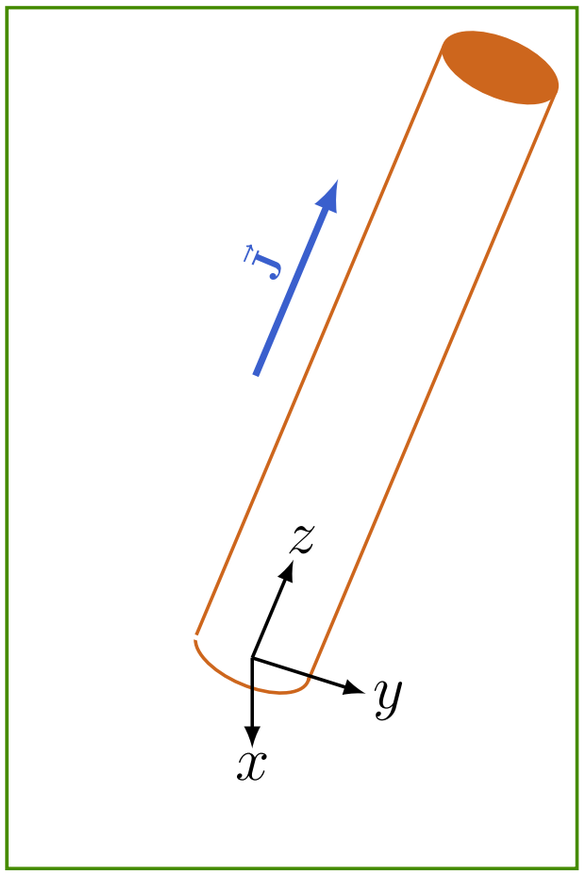
$$\frac{\partial u}{\partial t} + \vec{\boldsymbol{\nabla}} \cdot \vec{\mathbf{S}} = 0$$

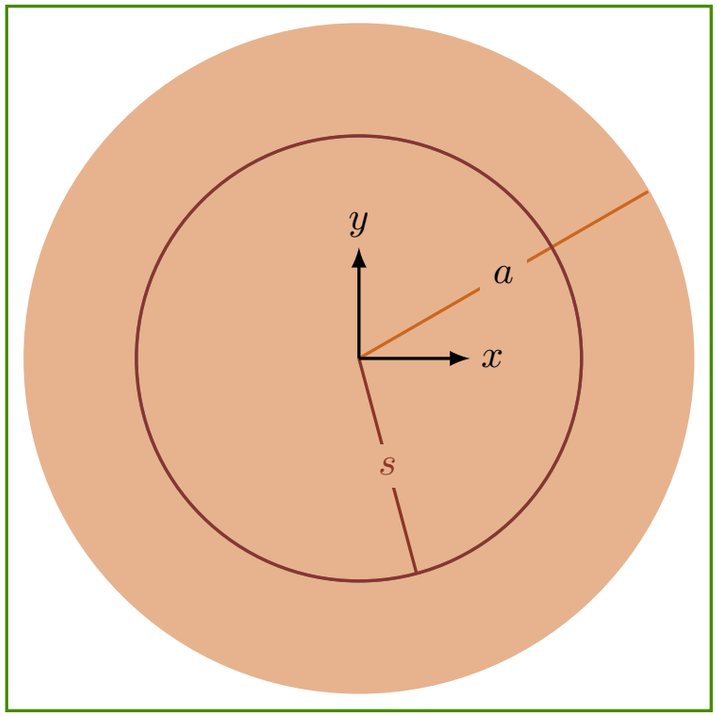
$$\vec{\mathbf{S}} = ?$$

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

Pratique o que aprendeu

$\vec{\mathbf{S}} = ?$

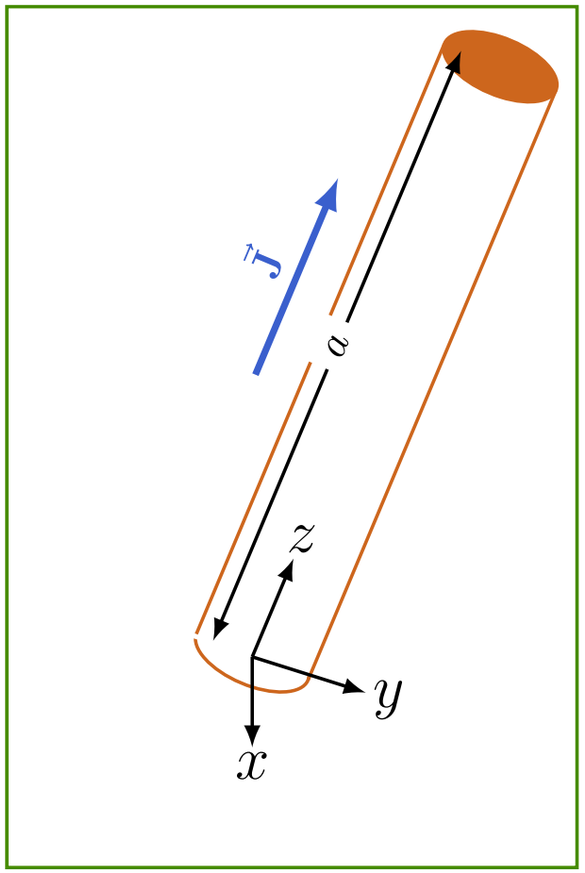


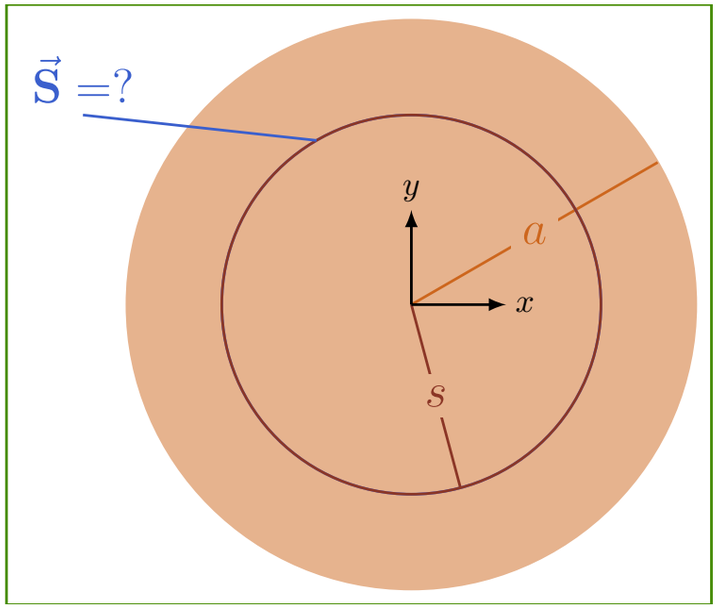


$$\vec{\mathbf{S}} = \frac{1}{\mu_0}\vec{\mathbf{E}} \times \vec{\mathbf{B}}$$

Pratique o que aprendeu

$\vec{\mathbf{S}} = ?$

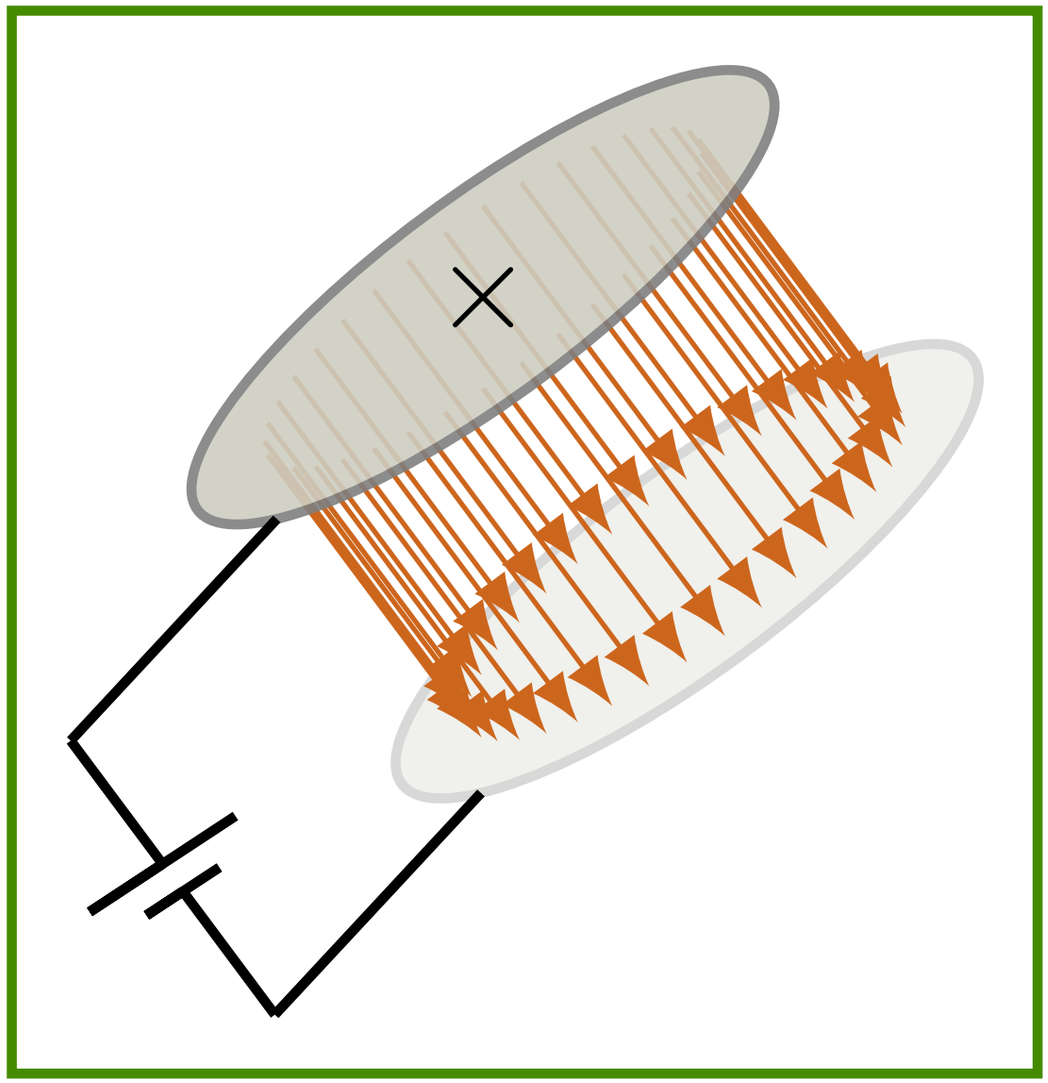


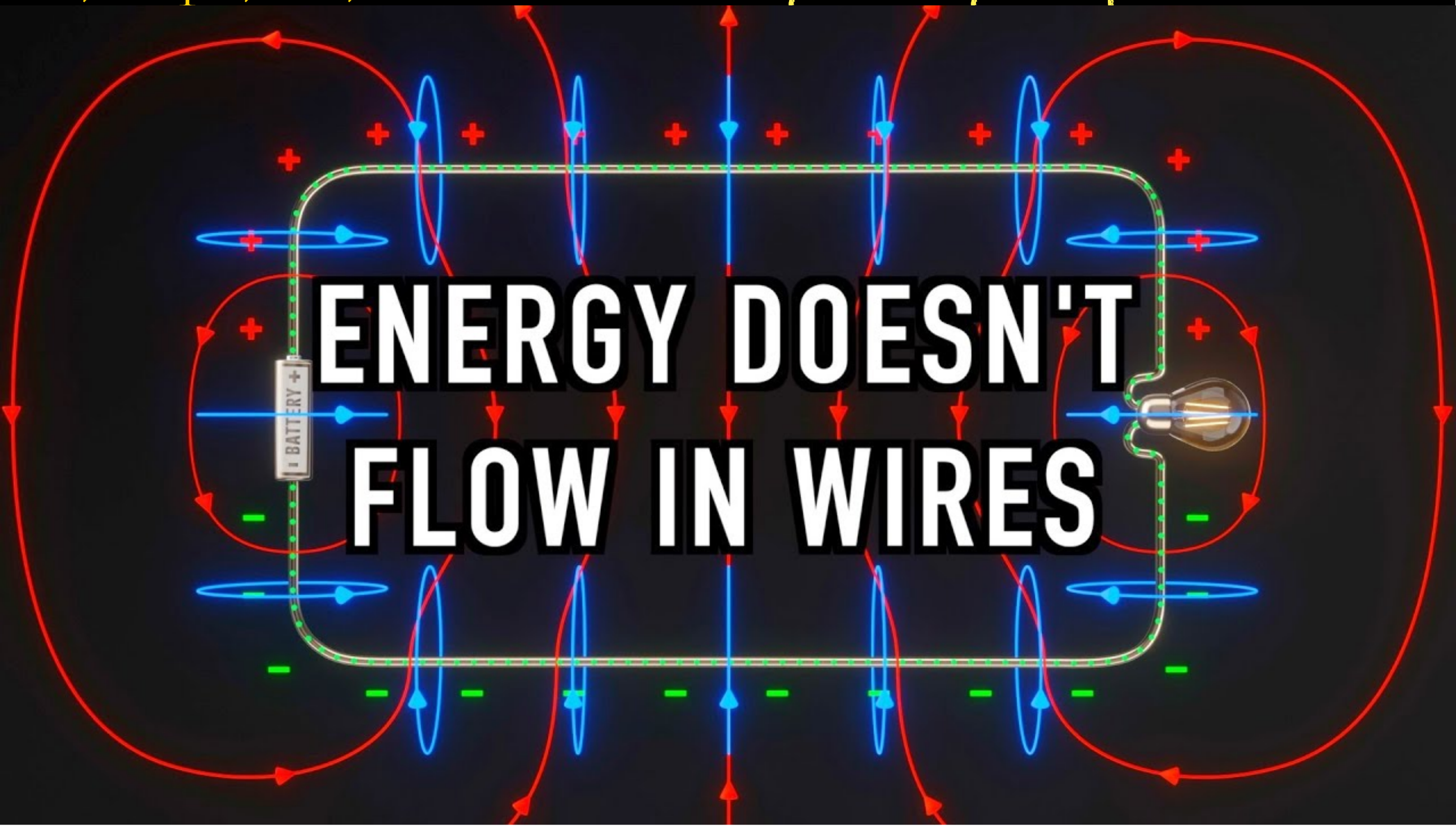


$$\vec{\mathbf{S}} = \frac{1}{\mu_0}\vec{\mathbf{E}} \times \vec{\mathbf{B}}$$

Pratique o que aprendeu

Linhas de campo de $\vec{S}$?




ENERGY DOESN'T
FLOW IN WIRES
BATTERY