Eletromagnetismo

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

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

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

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

19 de julho de 2021

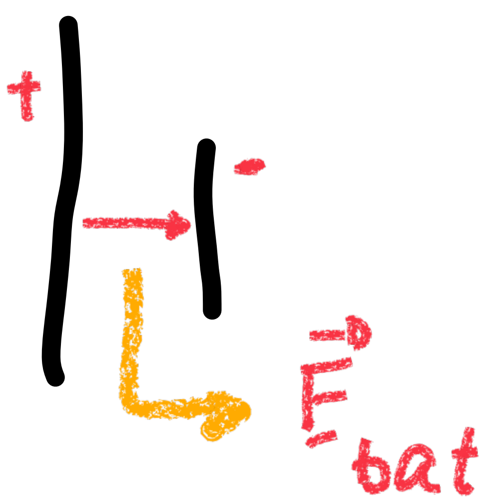
Eletrodinâmica

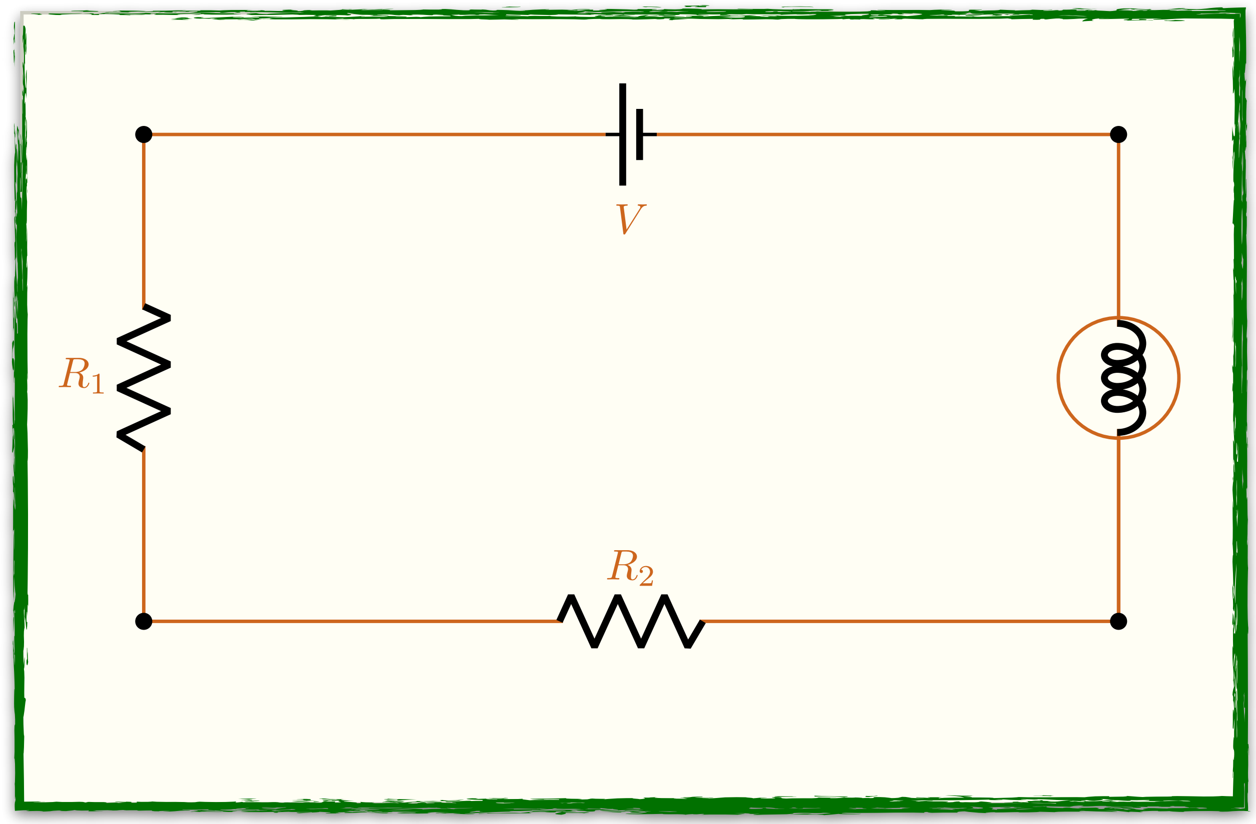
Eletrodinâmica
Força eletromotriz

$$\mathcal{E} = -\oint \vec{E}_{\text{bat}} \cdot d\vec{\ell}$$

$\Downarrow$

DENTRO DA BATERIA

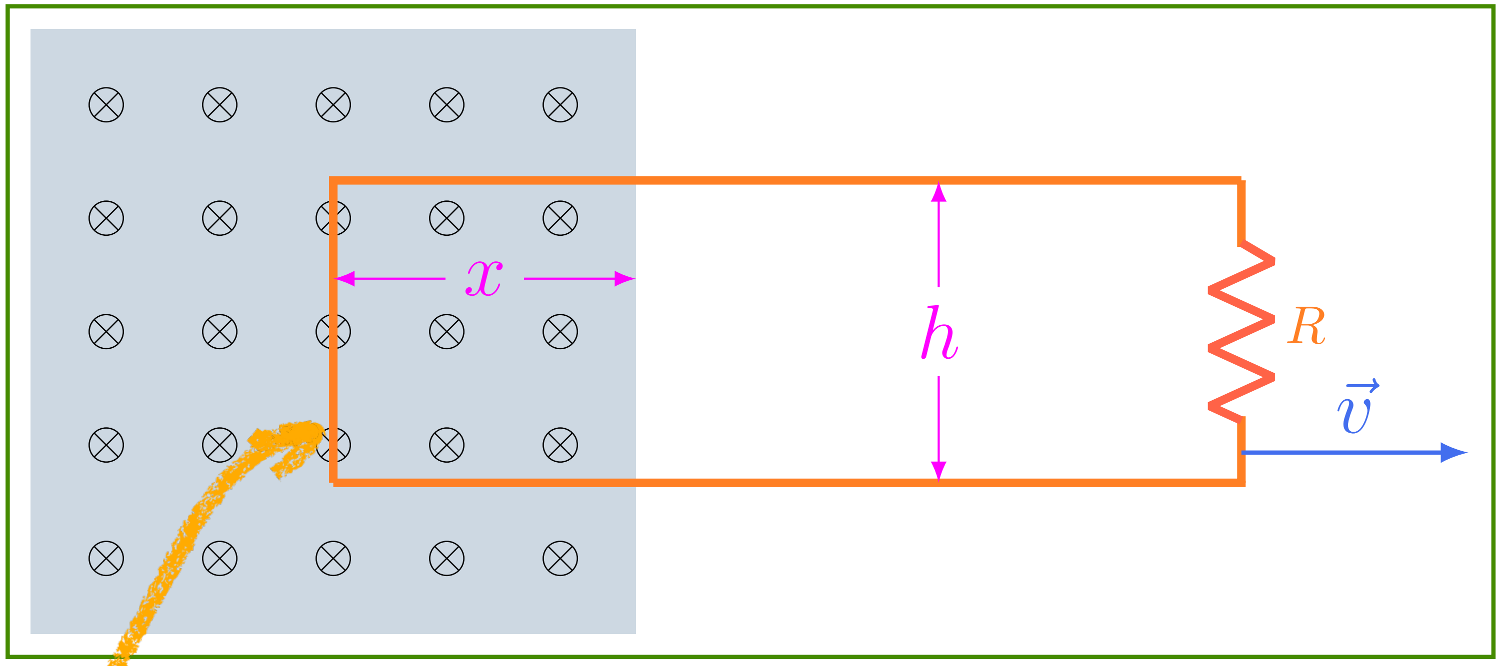




- POTENCIAL CRESCE DO POLO NEGATIVO PARA O POSITIVO
- DIFERENÇA DE POTENCIAL = FORÇA ELETROMOTRIZ

Eletrodinâmica
Força eletromotriz

$$\mathcal{E} = \int_{\text{vert}} \vec{v} \times \vec{B} \cdot d\vec{\ell}$$

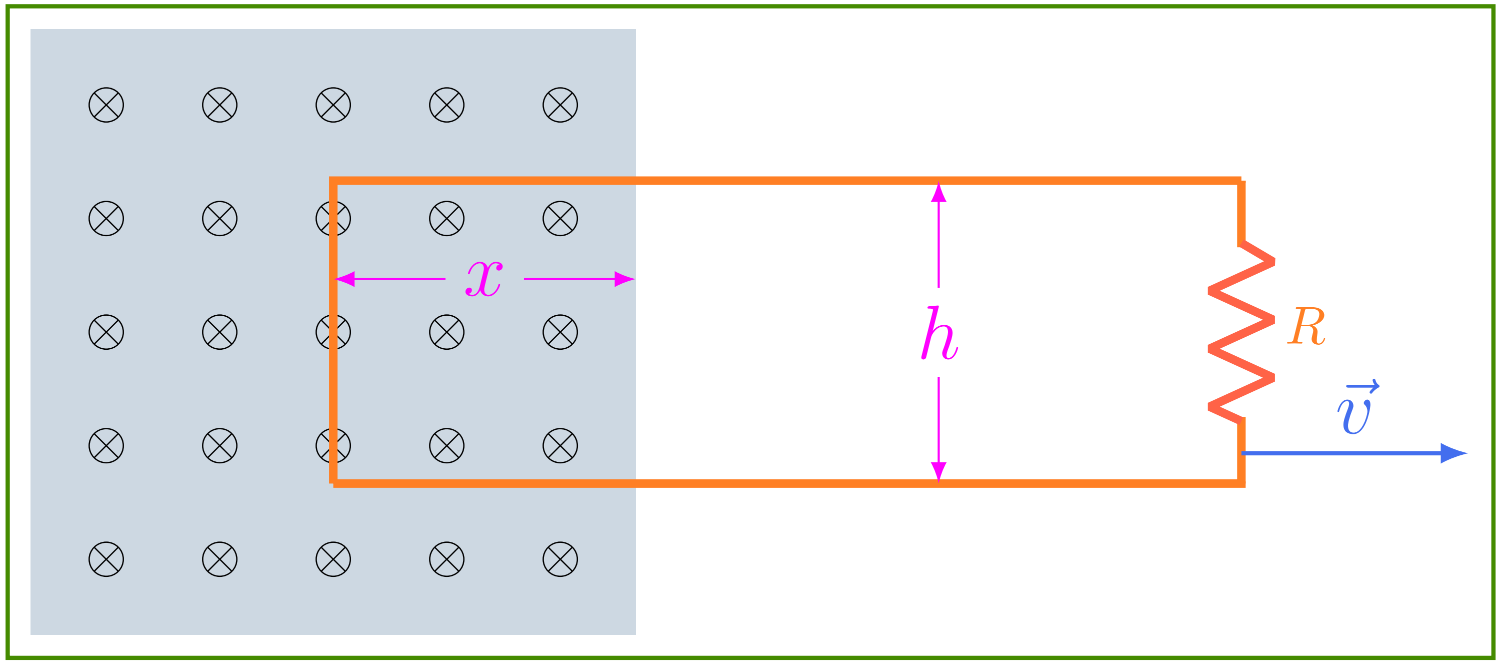


- VEM DA FORÇA DE LORENTZ, QUE EMPURRA CARGAS NO TRECHO VERTICAL DO CIRCUITO
- TUDO SE PASSA COMO SE HOUVESSE CAMPO ELÉTRICO NO TRECHO VERTICAL → APARECE f.e.m., COMO NA BATERIA

Eletrodinâmica
Força eletromotriz

$$\mathcal{E} = \int_{\text{vert}} \vec{v} \times \vec{B} \cdot \mathrm{d}\vec{\ell}$$

$$\mathcal{E} = vBh \Leftarrow (\vec{v} \perp \vec{B})$$



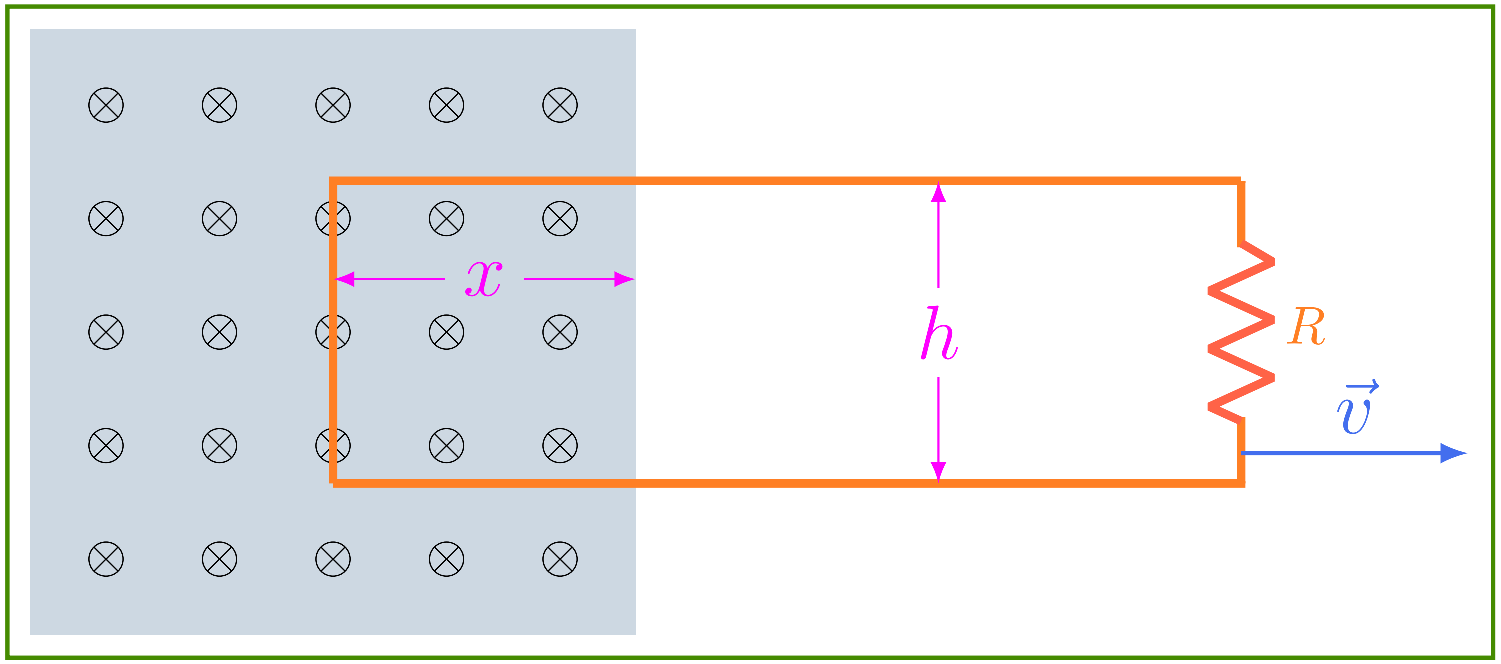
Eletrodinâmica
Força eletromotriz

$$\mathcal{E} = \int_{\text{vert}} \vec{v} \times \vec{B} \cdot \mathrm{d}\vec{\ell}$$

$$\mathcal{E} = vBh$$

$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$ ← $\phi = Bhx$

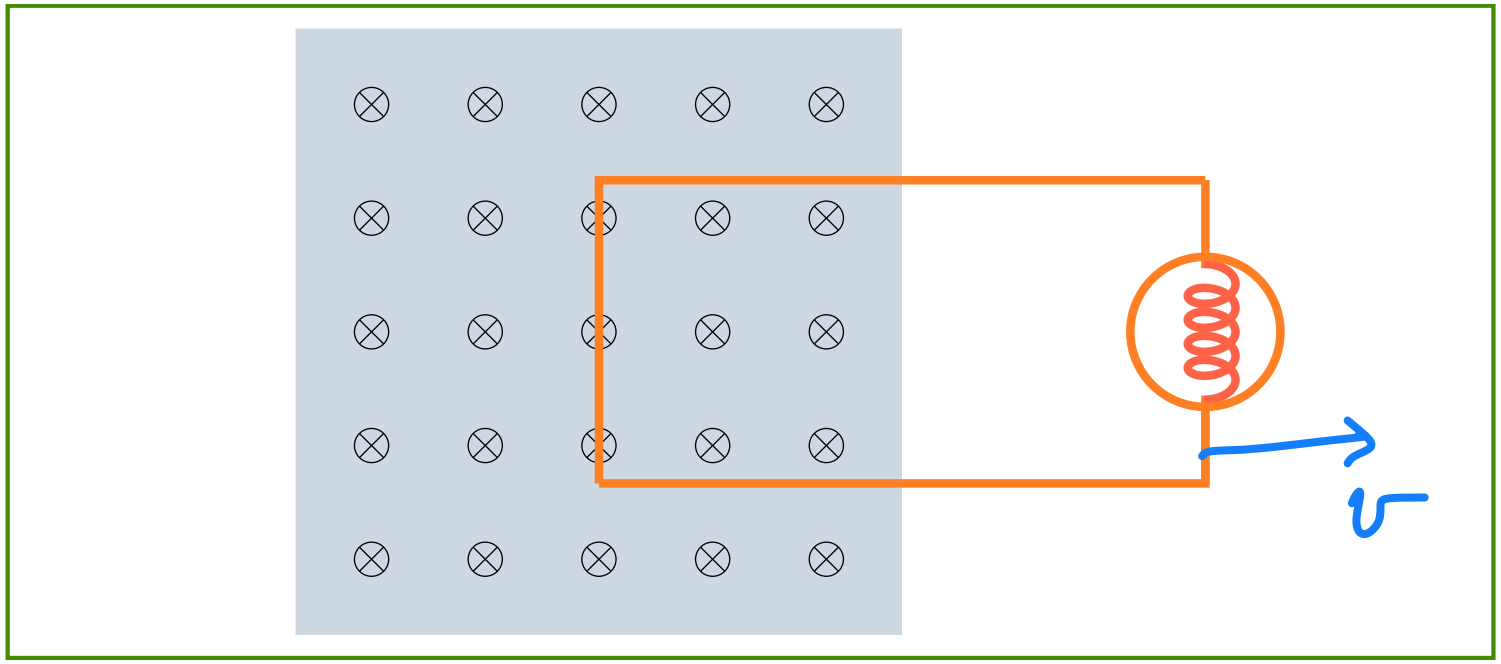
→ x ESTÁ DIMINUINDO



Eletrodinâmica
Lei de Faraday

QUATRO MODOS DE GERAR FORÇA ELETROMOTRIZ

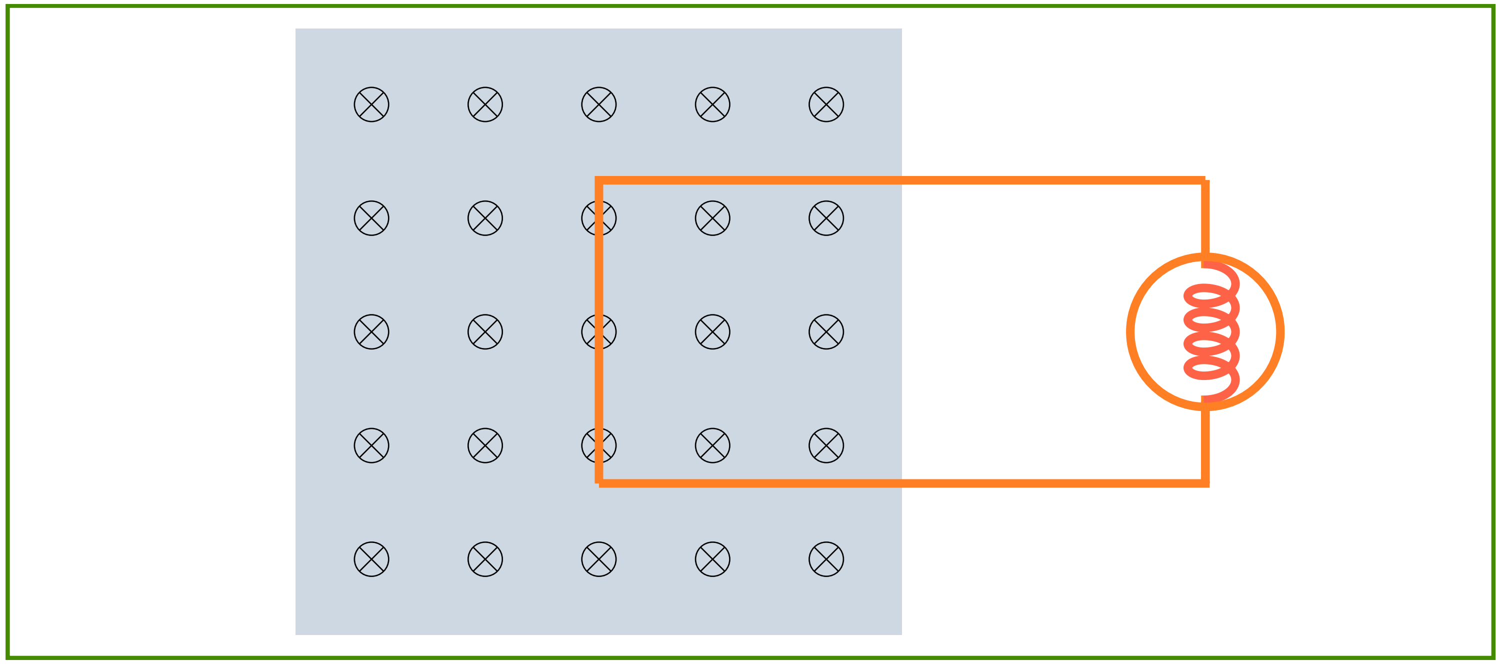
① Transladar



Eletrodinâmica
Lei de Faraday

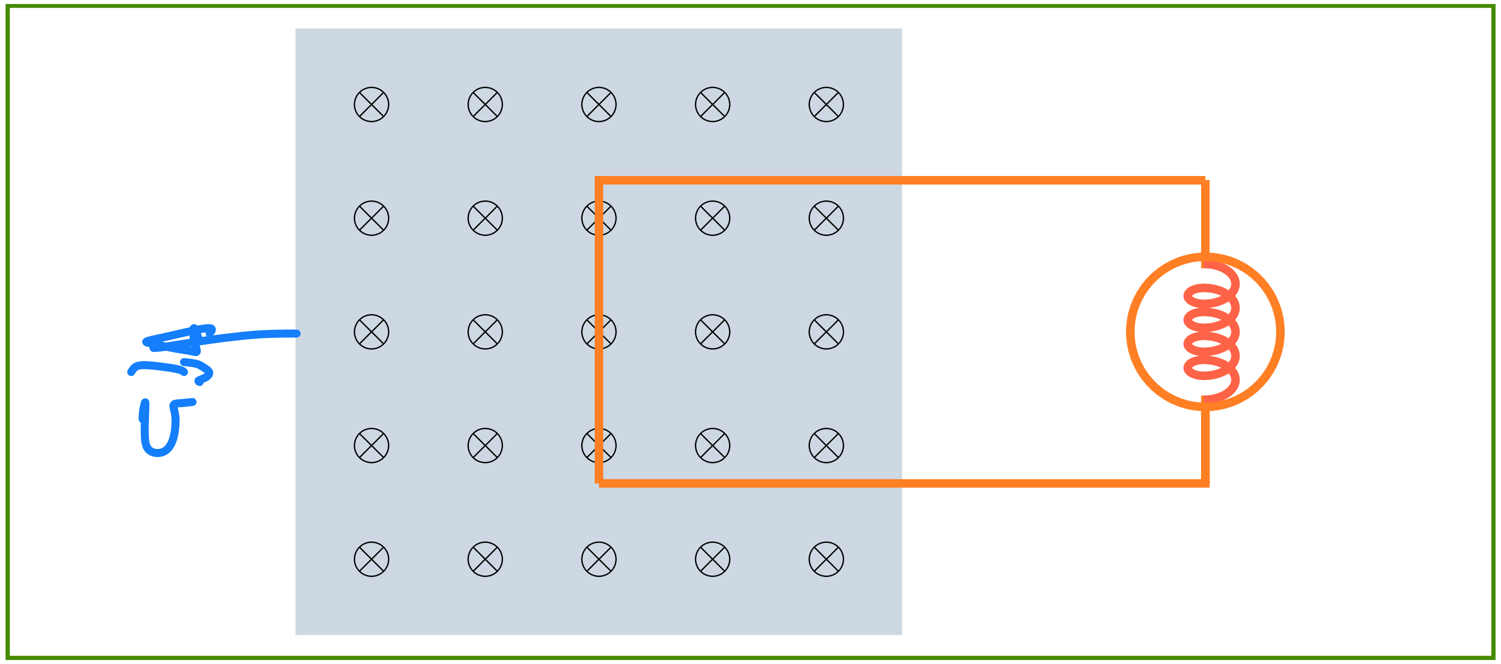
Transladar

$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$



Eletrodinâmica
Lei de Faraday

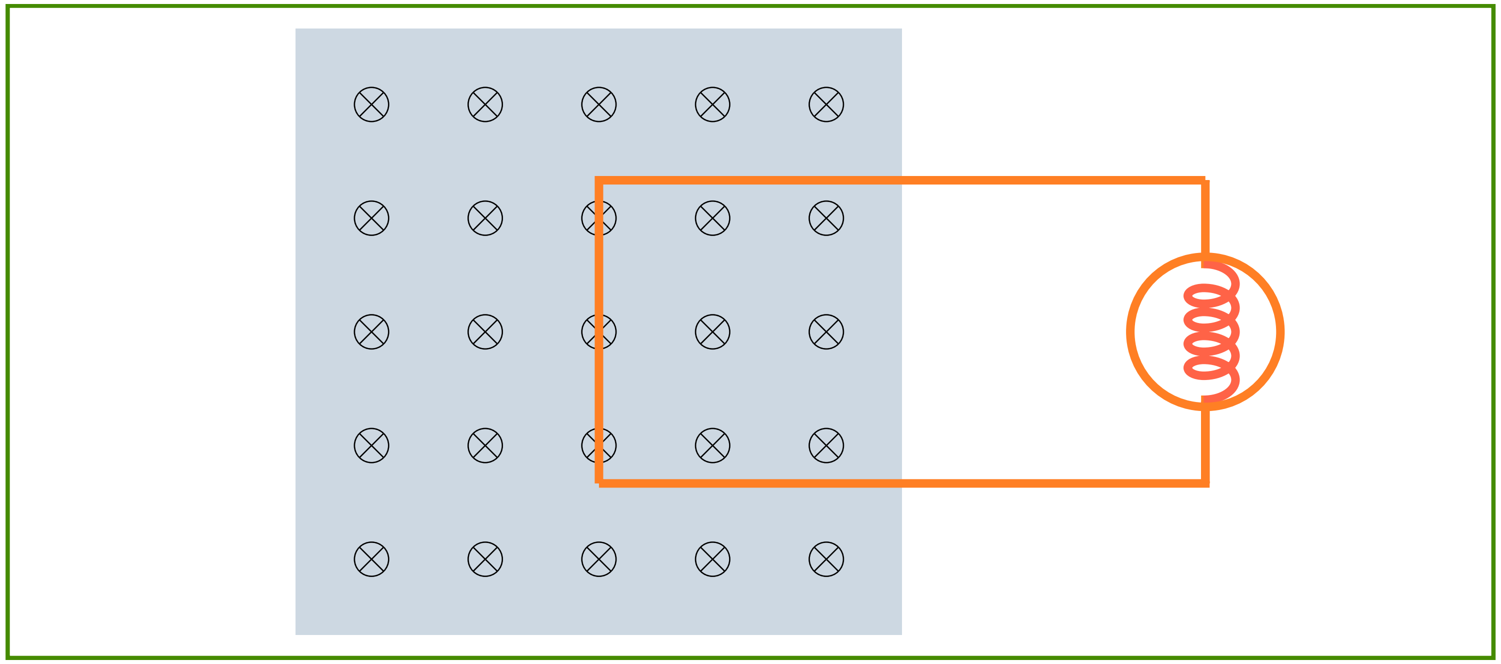
② Transladar II



Eletrodinâmica
Lei de Faraday

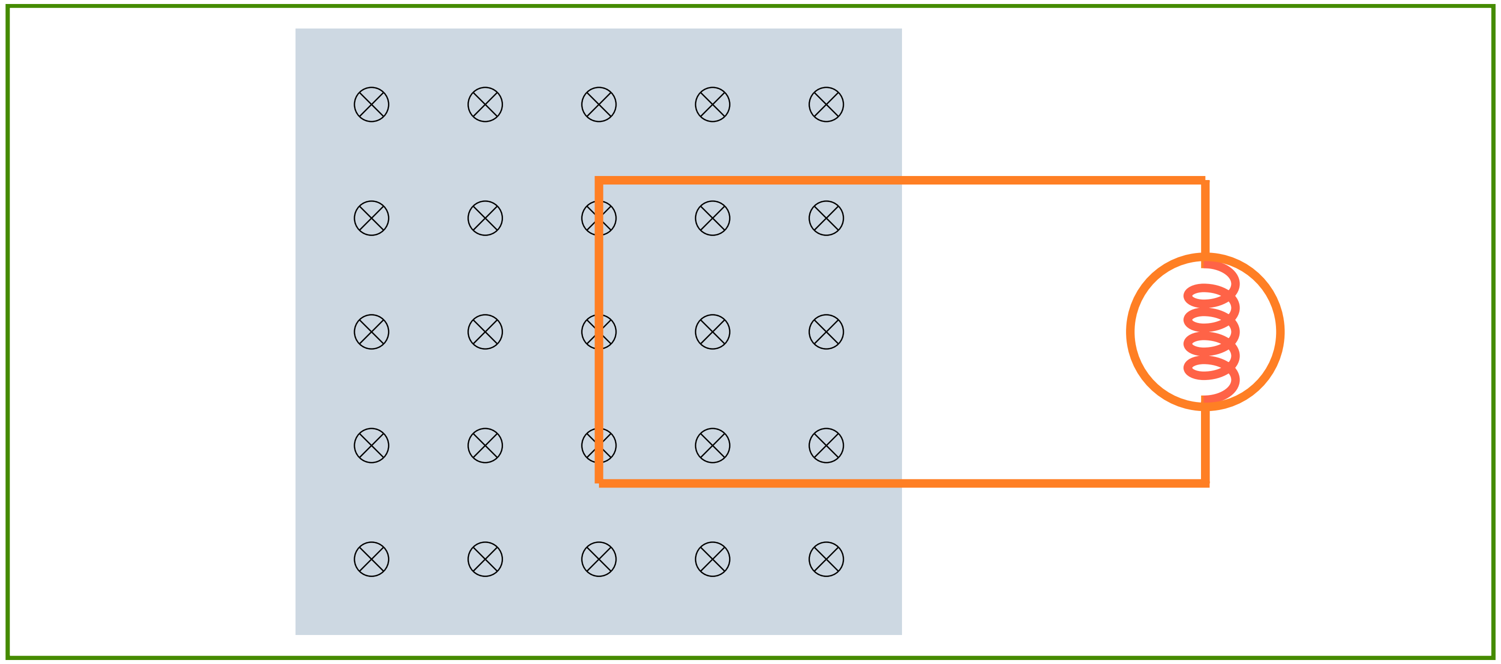
Transladar II

$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$



Eletrodinâmica
Lei de Faraday

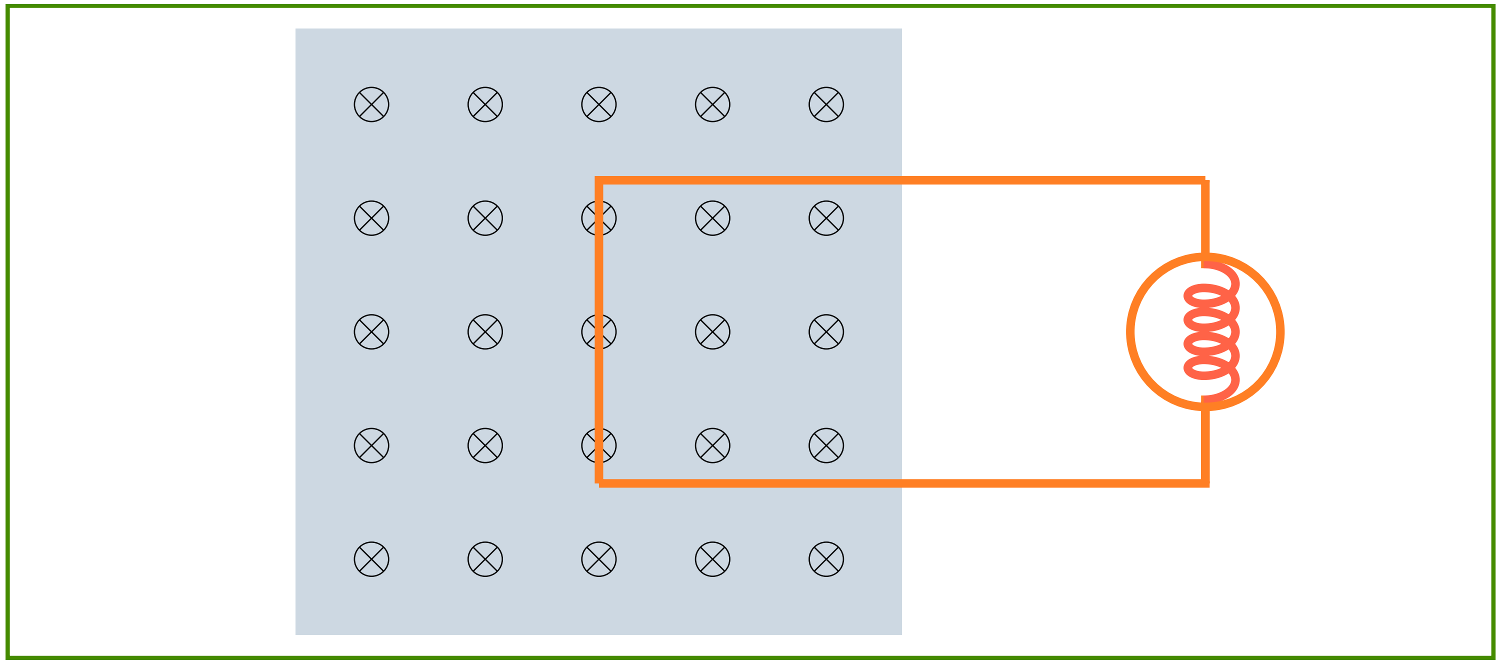
③ Aumentar/diminuir B



Eletrodinâmica
Lei de Faraday

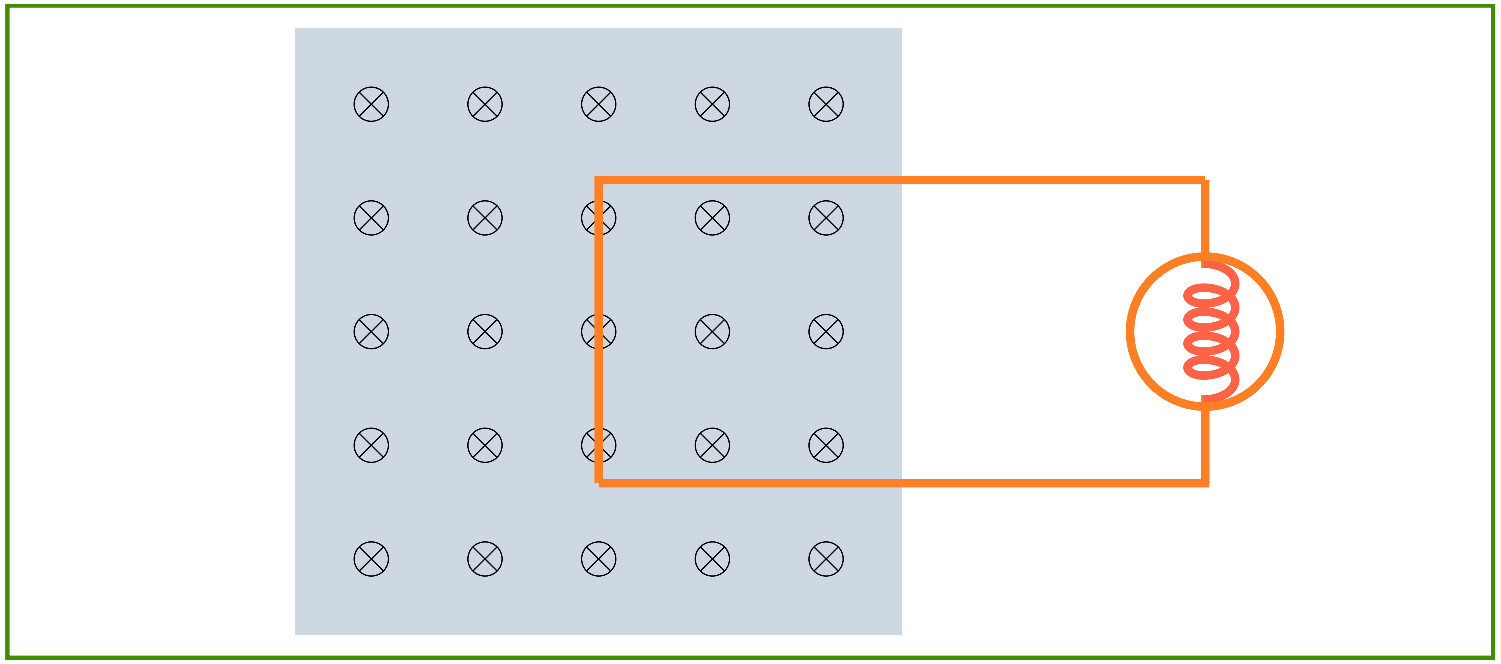
Aumentar/diminuir B

$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$



Eletrodinâmica
Lei de Faraday

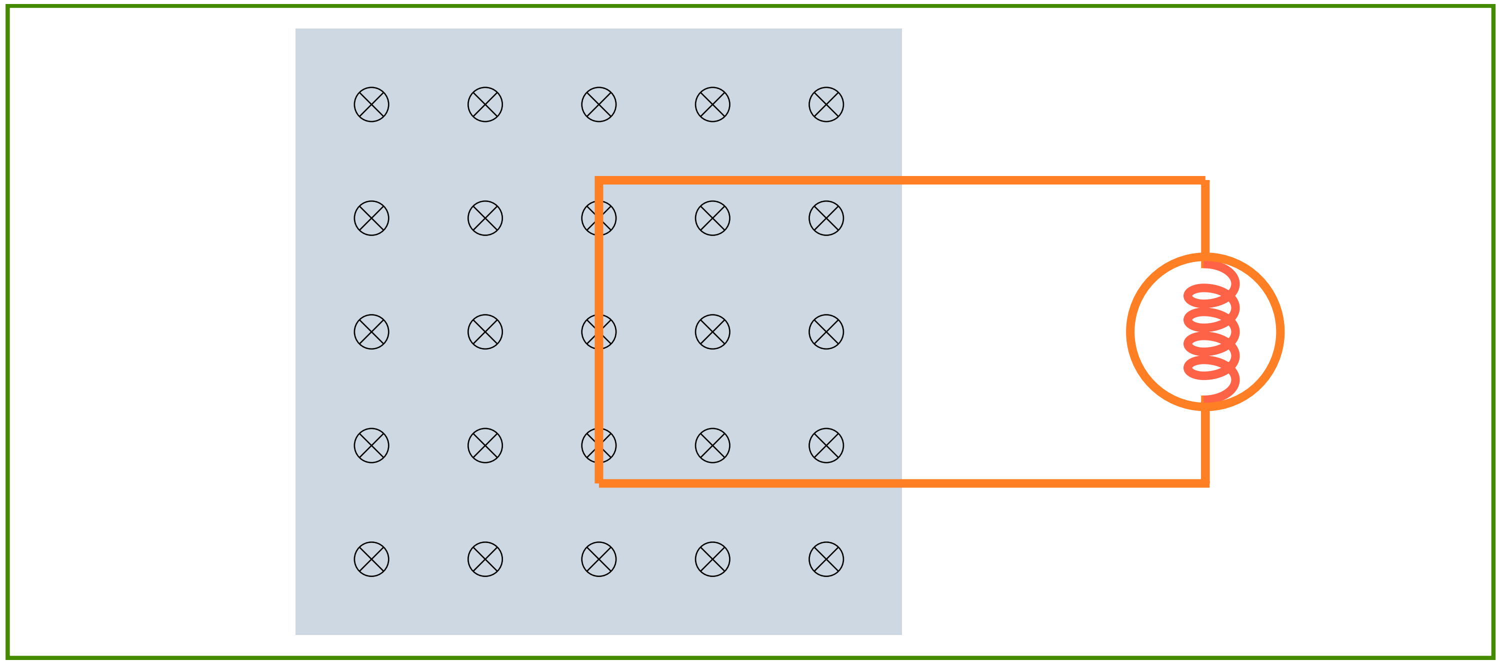
(4) Rodar { CIRCUITO OU CAMPO $\vec{B}$



Eletrodinâmica
Lei de Faraday

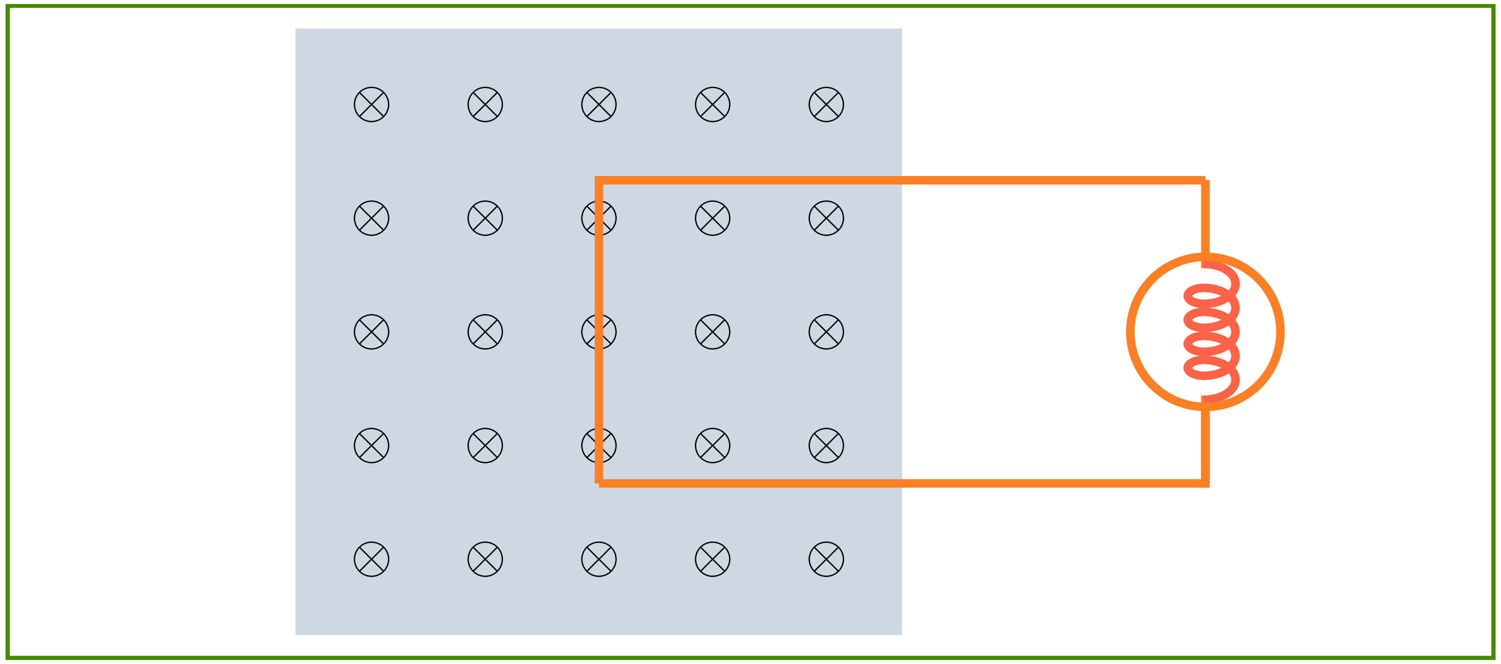
Rodar

$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$



Eletrodinâmica
Lei de Faraday

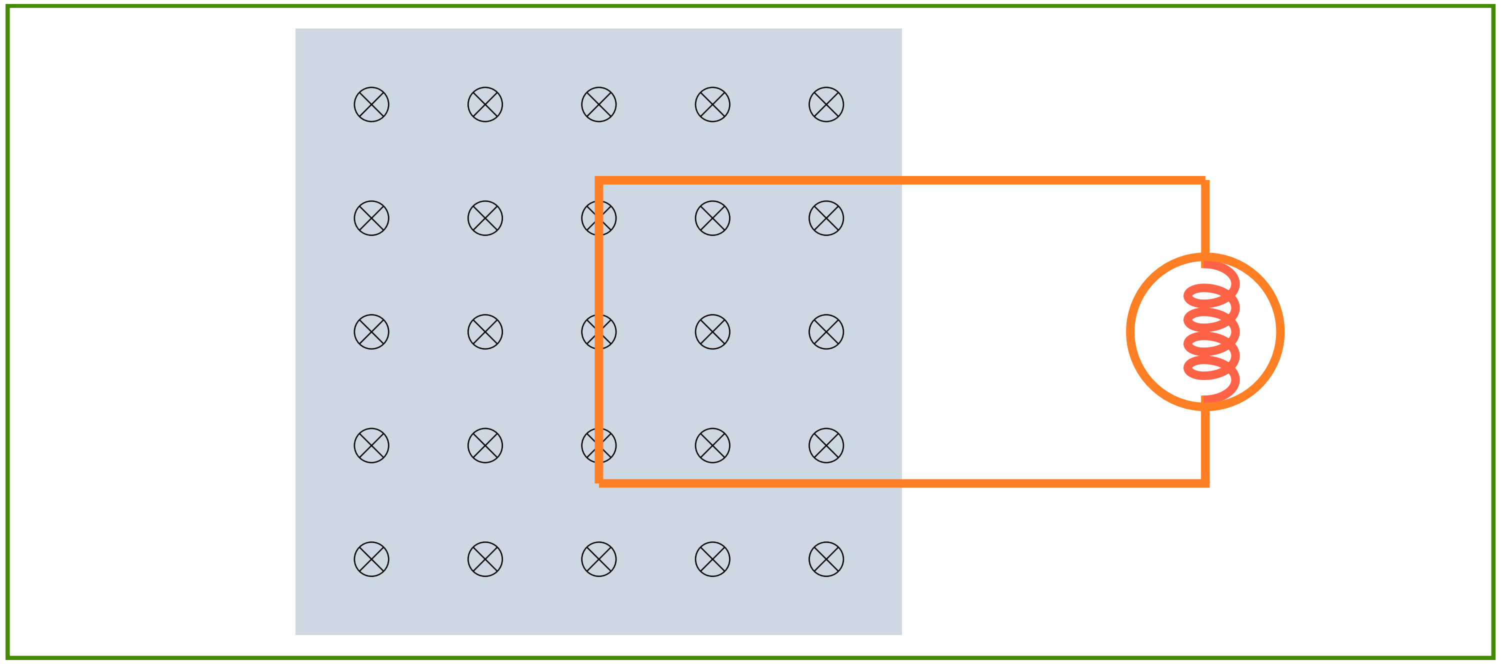
$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$



Eletrodinâmica
Lei de Faraday

$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$

$$\mathcal{E} = -\frac{\mathrm{d}}{\mathrm{d}t}\left(\int_A \vec{B}\cdot\hat{n}\,\mathrm{d}a\right)$$

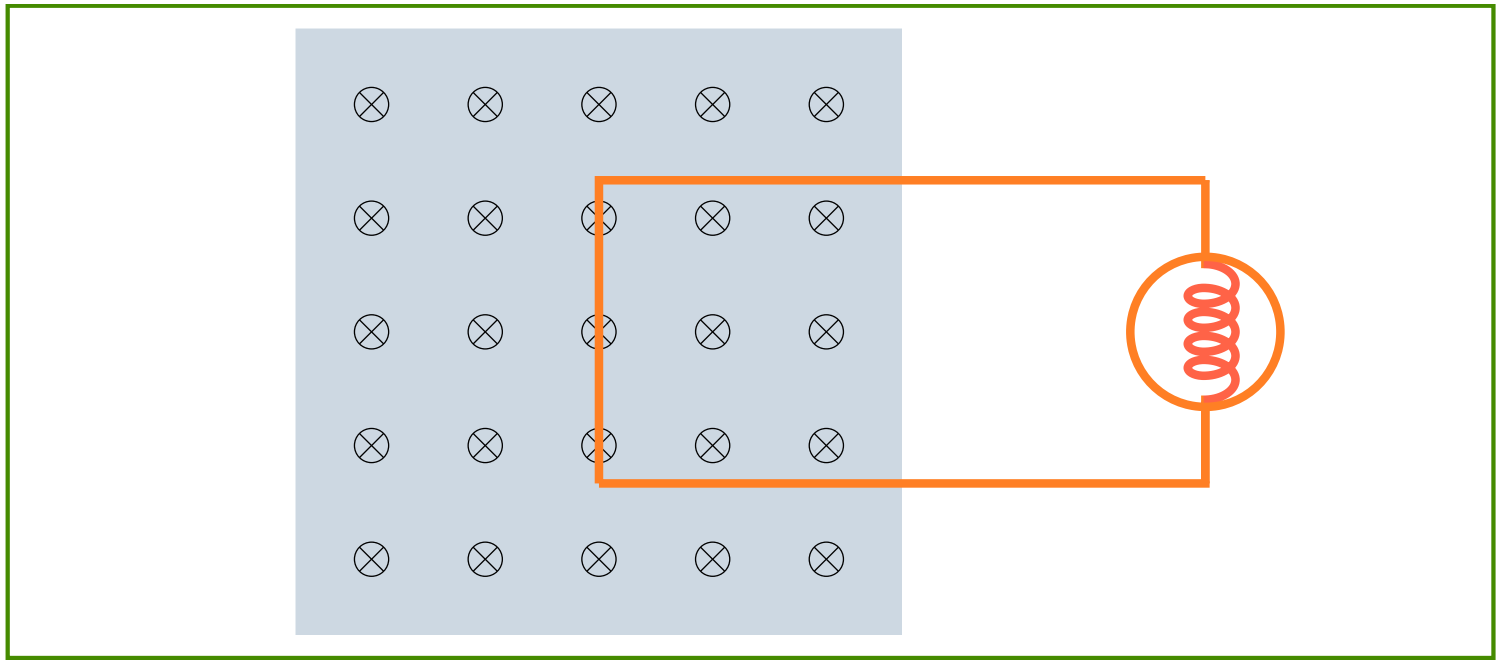


Eletrodinâmica
Lei de Faraday

$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$

$$\mathcal{E} = -\frac{\mathrm{d}}{\mathrm{d}t}\left(\int_A \vec{B}\cdot\hat{n}\,\mathrm{d}a\right)$$

$$\mathcal{E} = -\int_A \frac{\partial \vec{B}}{\partial t}\cdot\hat{n}\,\mathrm{d}a$$



↳ SE CIRCUITO NÃO SE DEFORMAR

Eletrodinâmica
Lei de Faraday

$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$

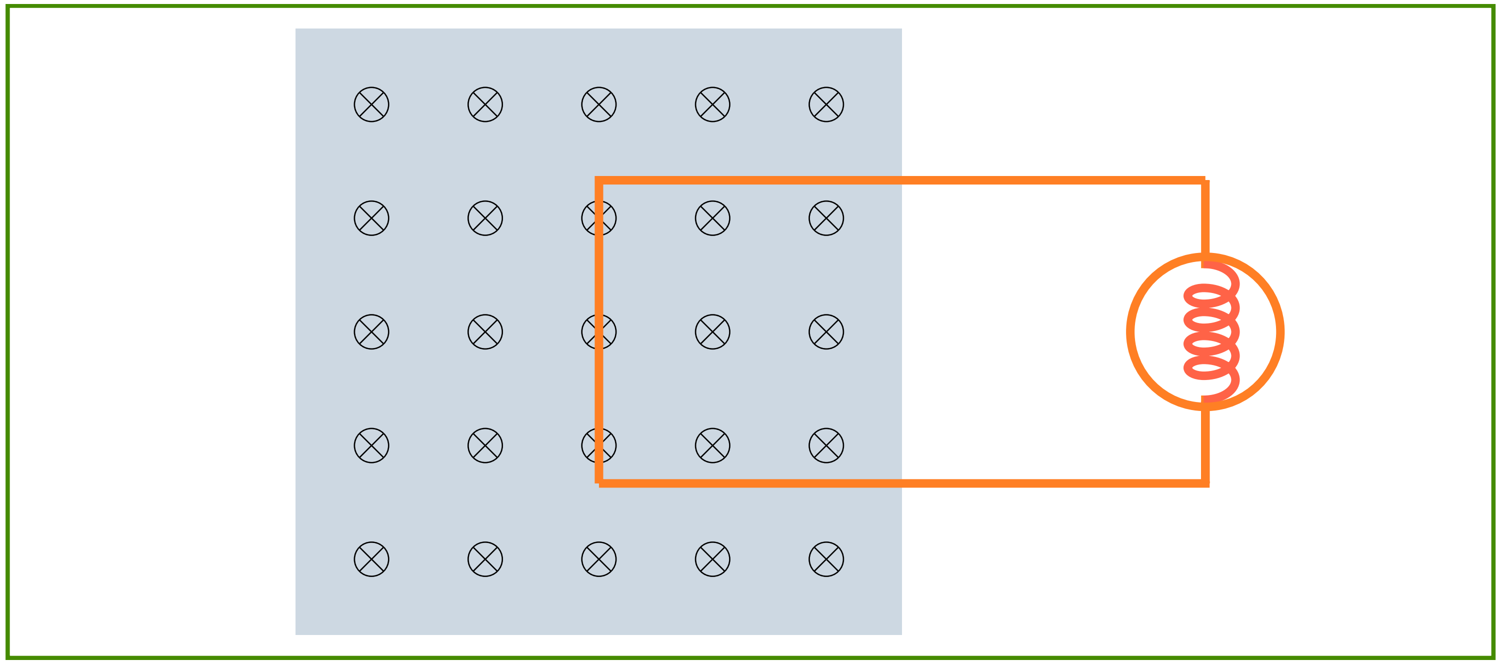
$$\mathcal{E} = -\frac{\mathrm{d}}{\mathrm{d}t}\left(\int_A \vec{B}\cdot\hat{n}\,\mathrm{d}a\right)$$

$$\mathcal{E} = -\int_A \frac{\partial \vec{B}}{\partial t}\cdot\hat{n}\,\mathrm{d}a$$

$$\int \vec{E}\cdot\mathrm{d}\vec{\ell} = -\int_A \frac{\partial \vec{B}}{\partial t}\cdot\hat{n}\,\mathrm{d}a$$

STOKES

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

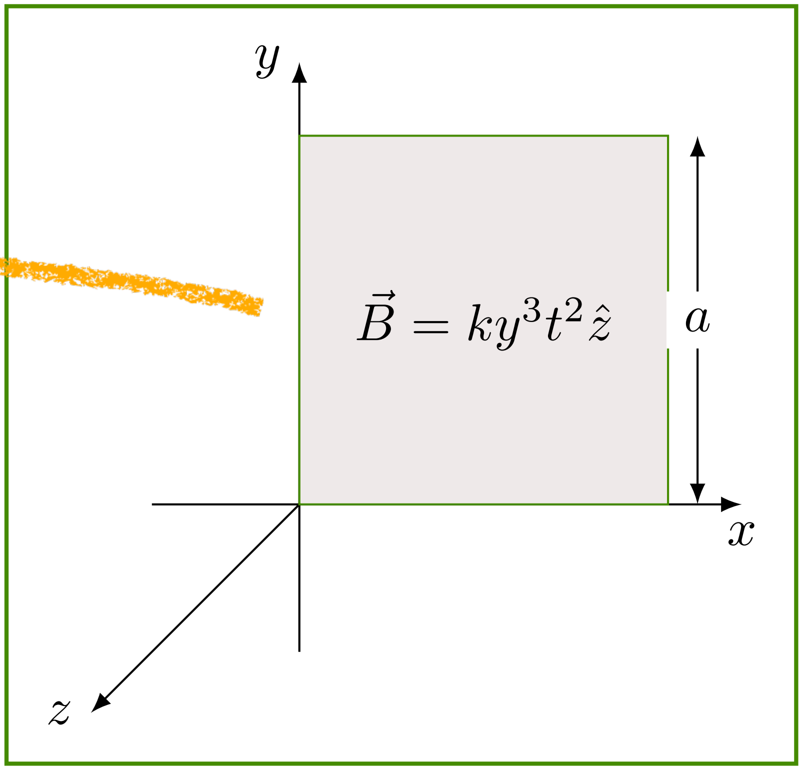


Pratique o que aprendeu

$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$

Problema 7.13

$\mathcal{E} = ?$



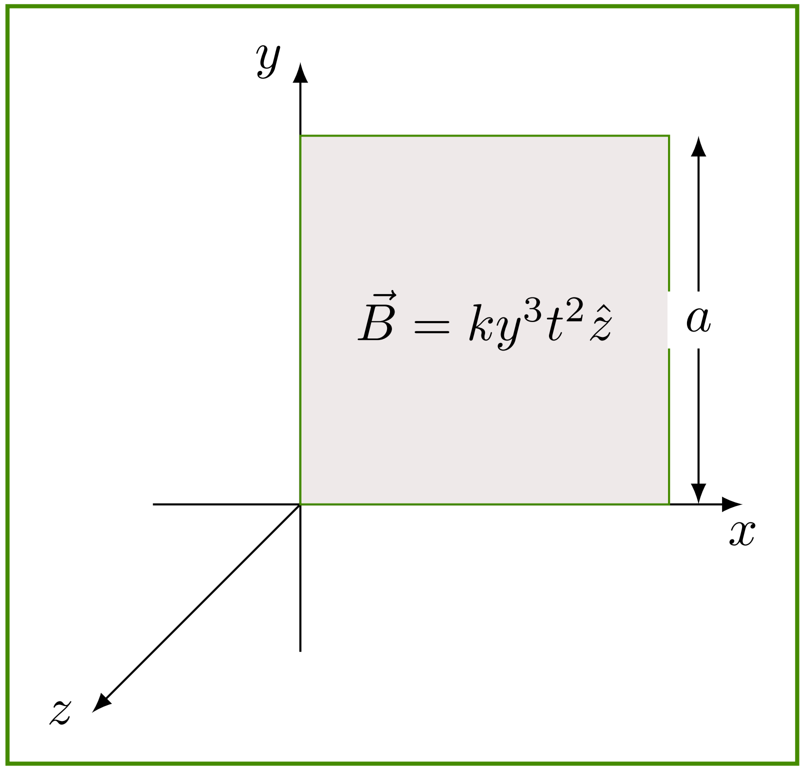
Pratique o que aprendeu

$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$

Problema 7.13

$$\mathcal{E} = ?$$

$$\phi = \int_0^a \int_0^a k y^3 t^2 \, \mathrm{d}x \, \mathrm{d}y$$



Pratique o que aprendeu

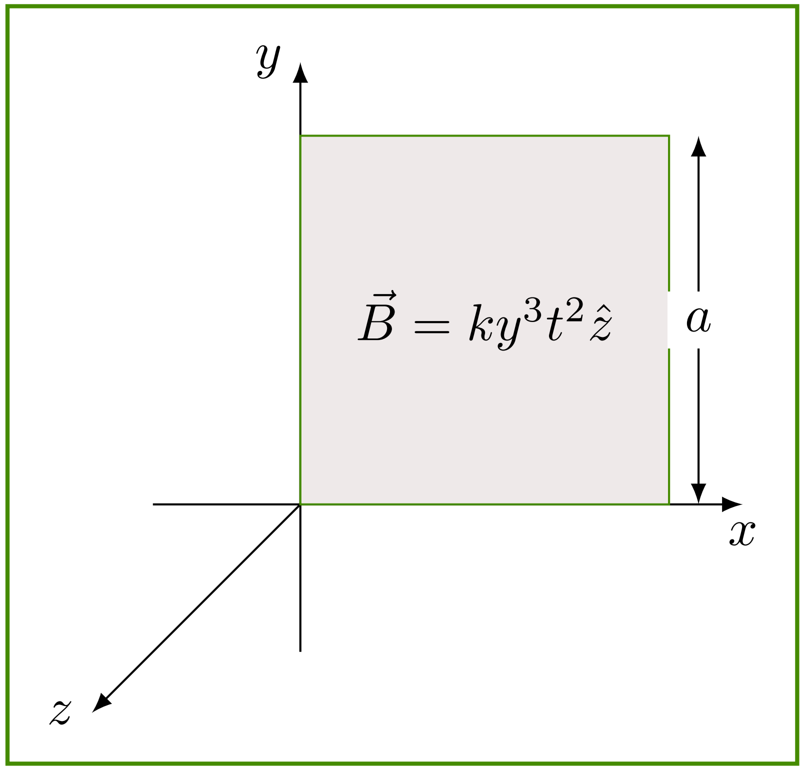
$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$

Problema 7.13

$$\mathcal{E} = ?$$

$$\phi = \int_0^a \int_0^a k y^3 t^2 \, \mathrm{d}x \, \mathrm{d}y$$

$$\phi = k t^2 a \int_0^a y^3 \, \mathrm{d}y$$



Pratique o que aprendeu

$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$

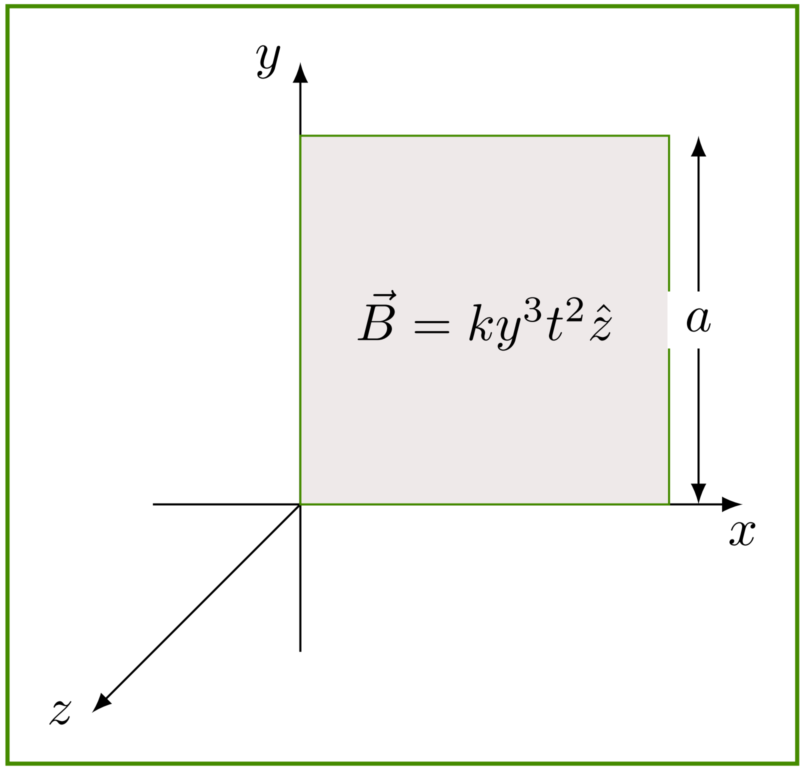
Problema 7.13

$$\mathcal{E} = ?$$

$$\phi = \int_0^a \int_0^a k y^3 t^2 \,\mathrm{d}x\,\mathrm{d}y$$

$$\phi = k t^2 a \int_0^a y^3 \,\mathrm{d}y$$

$$\phi = k t^2 \frac{a^5}{4}$$



Pratique o que aprendeu

$$\mathcal{E} = -\frac{d\phi}{dt}$$

Problema 7.13

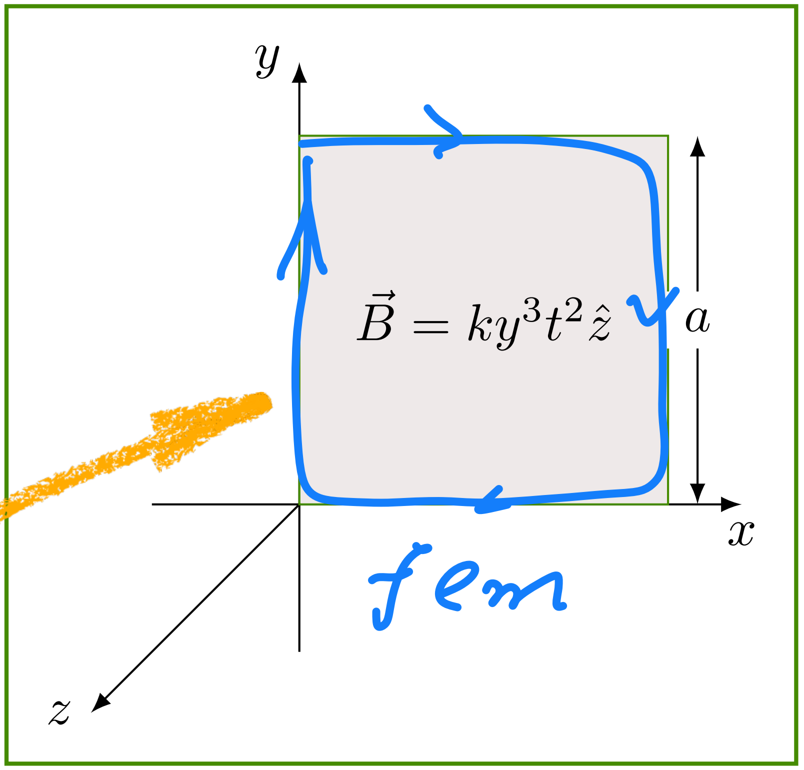
$$\mathcal{E} = ?$$

$$\phi = \int_0^a \int_0^a k y^3 t^2 \, dx \, dy$$

$$\phi = k t^2 a \int_0^a y^3 \, dy$$

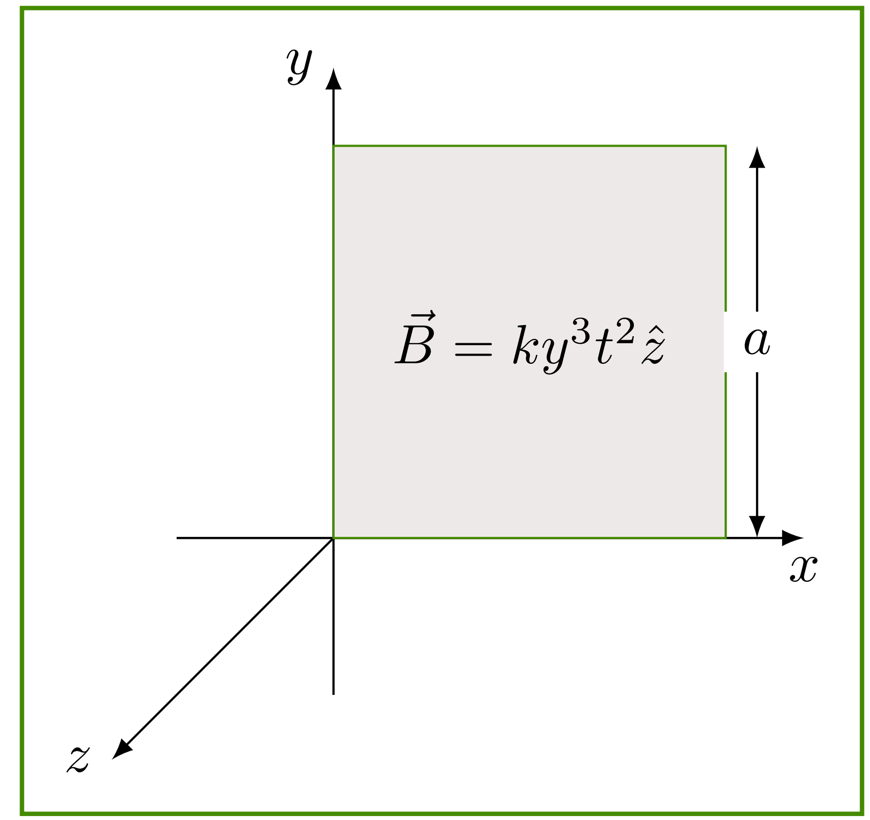
$$\phi = k t^2 \frac{a^5}{4}$$

$$\mathcal{E} = -k t \frac{a^5}{2}$$



Eletrodinâmica
Lei de Lenz

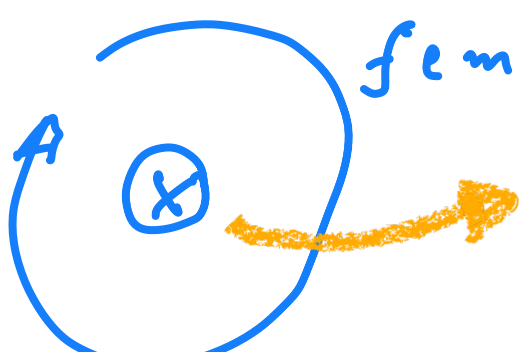
$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$



f.e.m. combate variação do fluxo

NO CASO, FLUXO CRESCE

$\Rightarrow$ fem PRODUZ CAMPO NO SENTIDO OPOSTO (SENTIDO $-\hat{z}$)

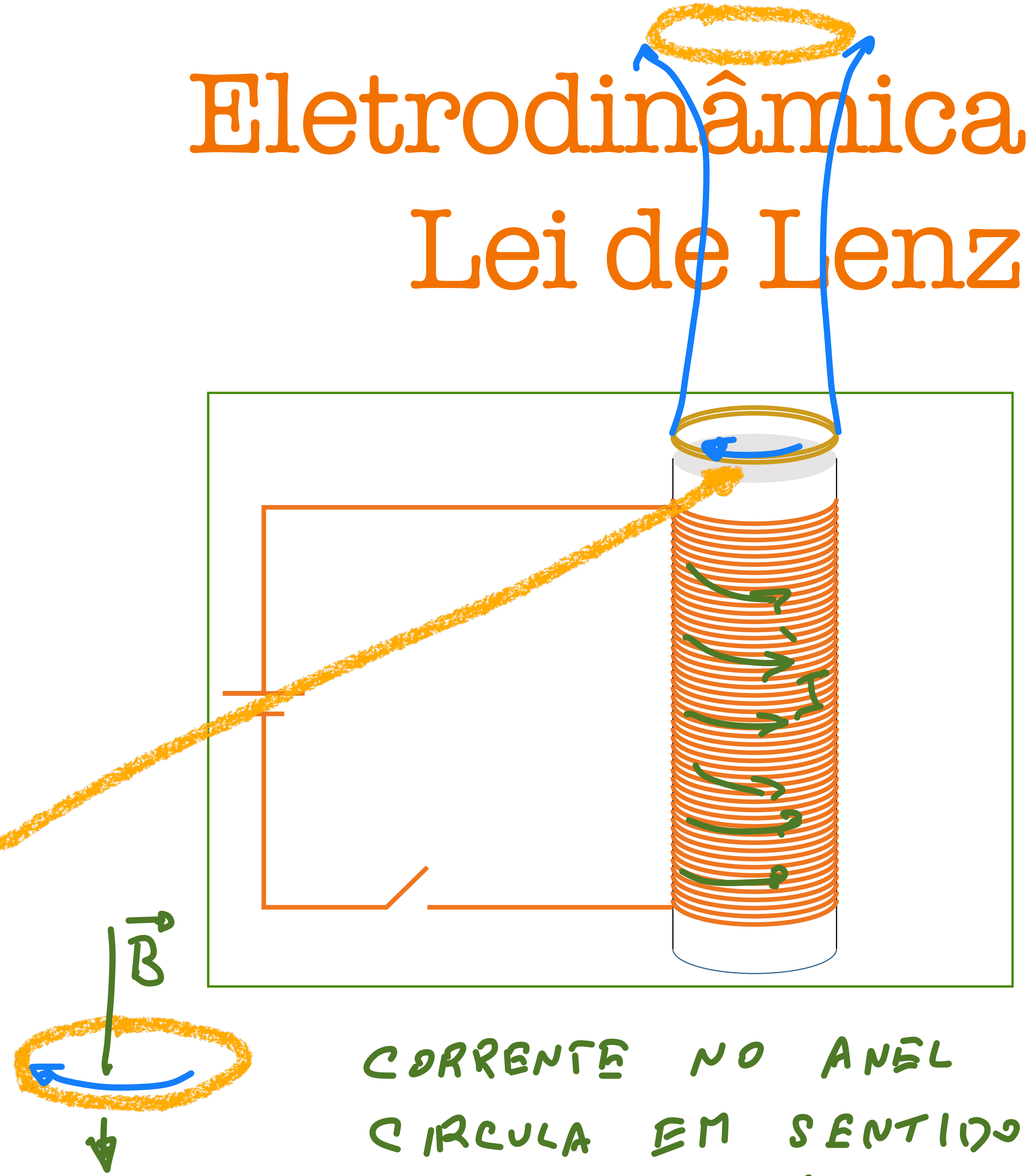


CAMPO DEVIDO A fem, PELA REGRA DA MÃO DIREITA

Eletrodinâmica
Lei de Lenz

$$\mathcal{E} = -\frac{d\phi}{dt}$$

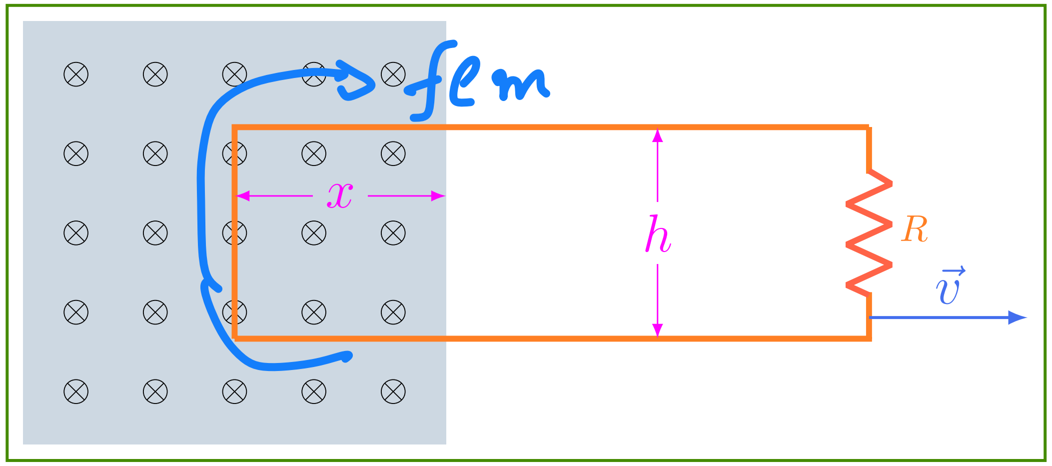
ANEL PULA PARA CIMA PORQUE fem GERA CORRENTE NO SENTIDO MOSTRADO NA FIGURA, QUE PRODUZ CAMPO $\vec{B}$ PARA BAIXO, PARA COMBATER O CRESCIMENTO DO FLUXO PROVOCADO PELO SOLENÓIDE.



CORRENTE NO ANEL CIRCULA EM SENTIDO OPOSTO AO DA CORRENTE NO SOLENÓIDE

CORRENTES EM SENTIDOS OPOSTOS SE REPELEM

Eletrodinâmica
Lei de Lenz



$$\mathcal{E} = -\frac{\mathrm{d}\phi}{\mathrm{d}t}$$

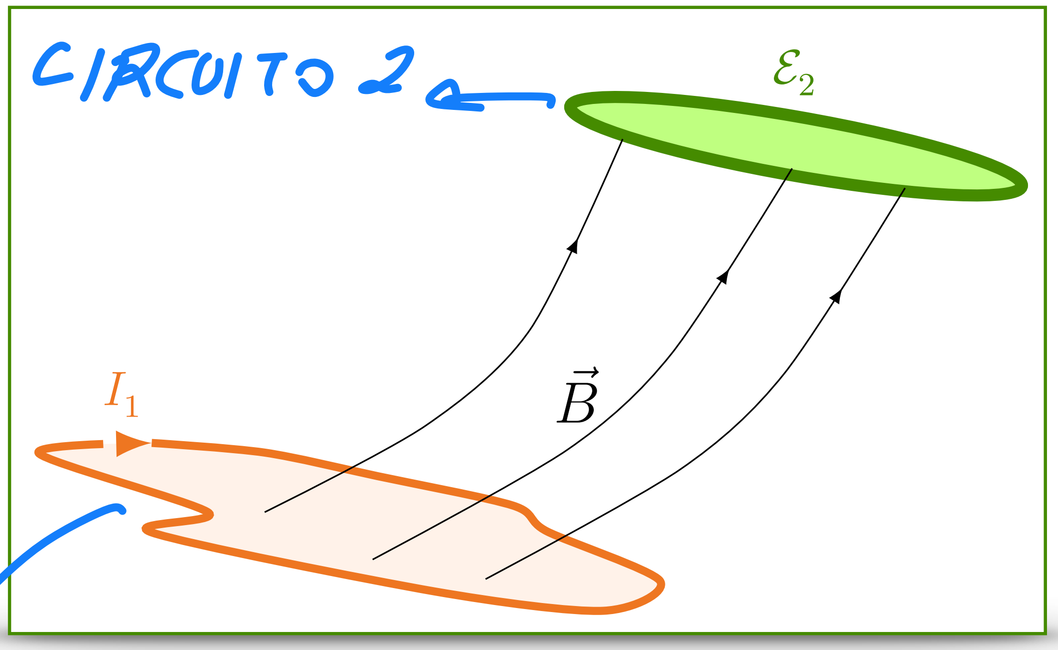
fem produz campo para dentro da tela, para combater a redução do fluxo causada pelo movimento do circuito

Eletrodinâmica
Indutância

DEVIDO AO CIRCUITO 1

$$\phi_2 = \int \vec{B}_1 \cdot \hat{n}\, da_2$$

NO CIRCUITO 2

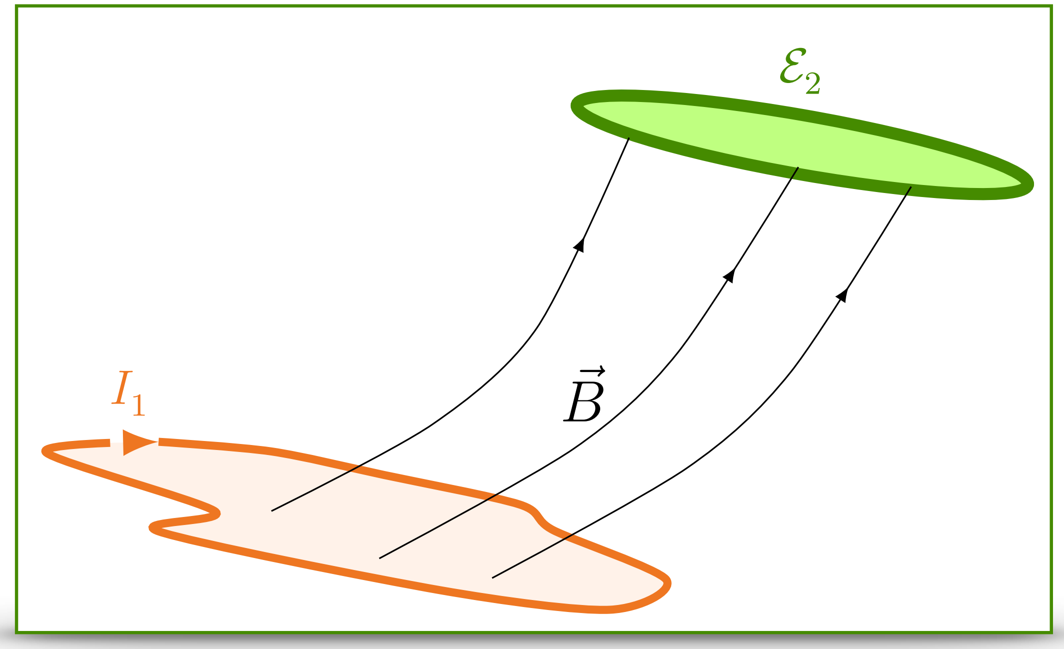


CIRCUITO 1

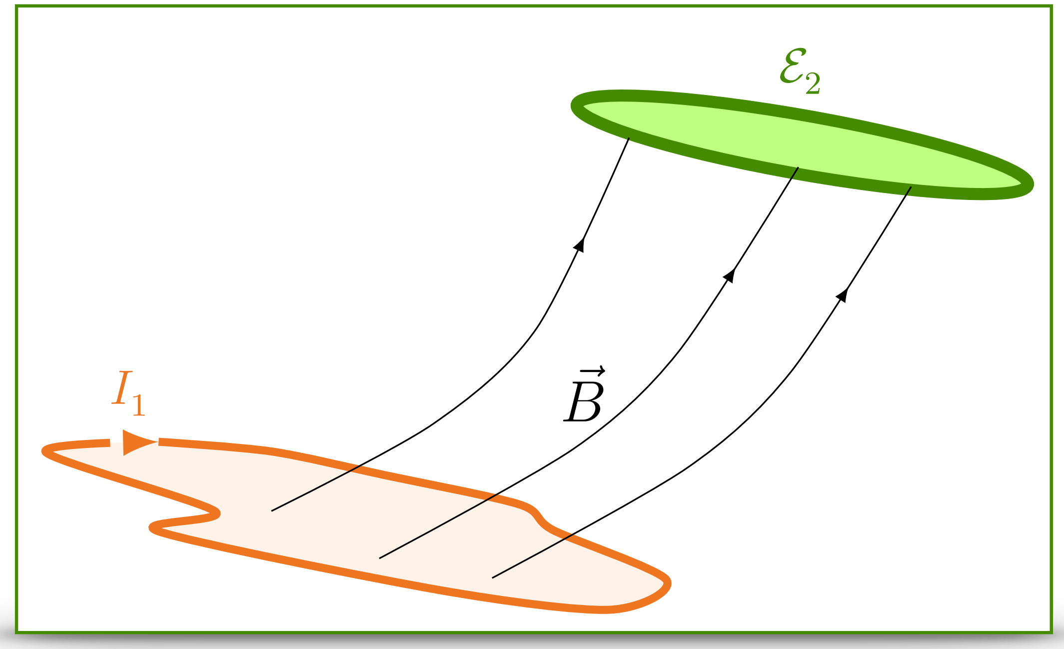
Eletrodinâmica
Indutância

$$\phi_2 = \int \vec{B}_1 \cdot \hat{n}\, \mathrm{d}a_2$$

$$\phi_2 = \int \vec{\nabla} \times \vec{A}_1 \cdot \hat{n}\, \mathrm{d}a_2$$



Eletrodinâmica
Indutância



$$\phi_2 = \int \vec{B}_1 \cdot \hat{n}\, \mathrm{d}a_2$$

$$\phi_2 = \int \vec{\nabla} \times \vec{A}_1 \cdot \hat{n}\, \mathrm{d}a_2$$

STOKES

$$\phi_2 = \oint \vec{A}_1 \cdot \mathrm{d}\vec{\ell}_2$$

$$\vec{A}_1 = \frac{\mu_0}{4\pi} I_1 \oint \frac{\mathrm{d}\vec{\ell}_1}{r}$$

⟹ EXPRESSÃO GERAL PARA O POTENCIAL VETOR PRODUZIDO POR UM CIRCUITO

Eletrodinâmica
Indutância

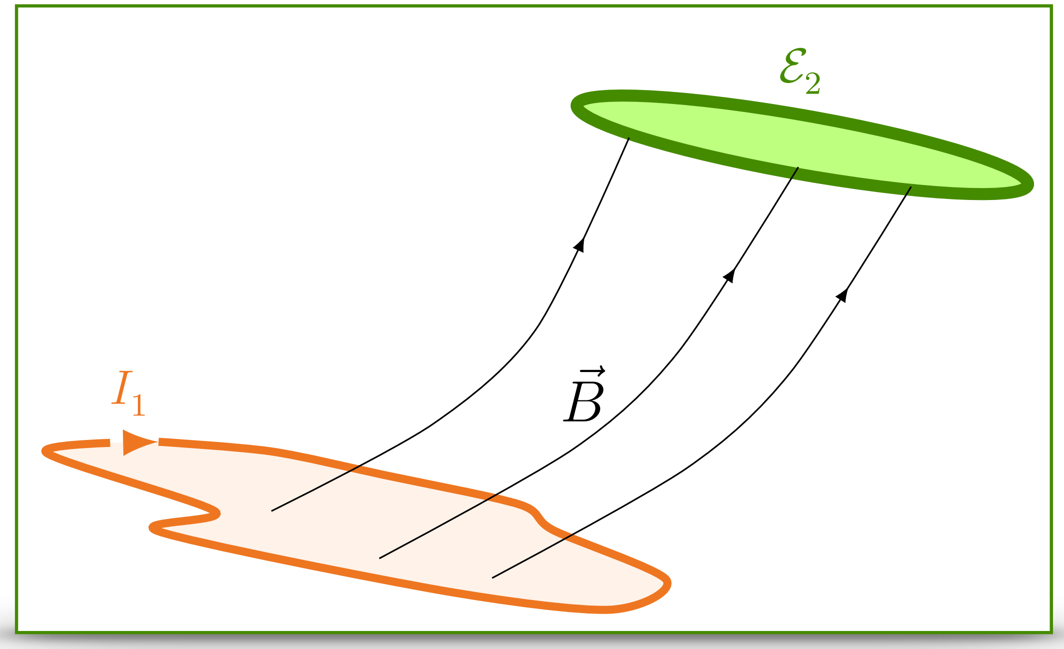
$$\phi_2 = \int \vec{B}_1 \cdot \hat{n}\, \mathrm{d}a_2$$

$$\phi_2 = \int \vec{\nabla} \times \vec{A}_1 \cdot \hat{n}\, \mathrm{d}a_2$$

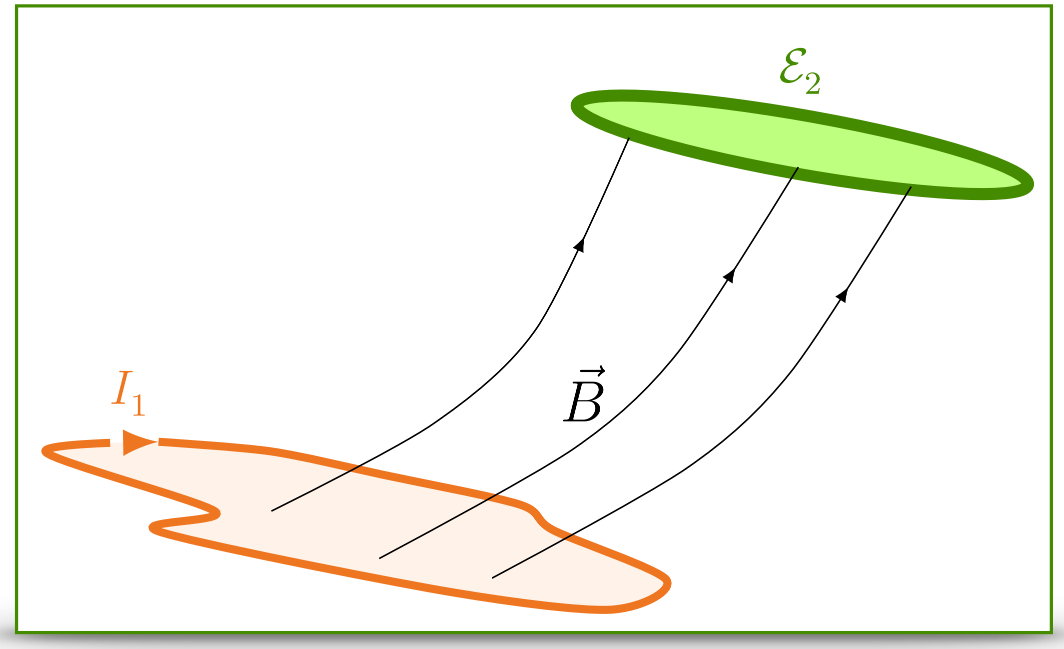
$$\phi_2 = \oint \vec{A}_1 \cdot \mathrm{d}\vec{\ell}_2$$

$$\vec{A}_1 = \frac{\mu_0}{4\pi} I_1 \oint \frac{\mathrm{d}\vec{\ell}_1}{\mathscr{r}}$$

$$\phi_2 = \frac{\mu_0}{4\pi} I_1 \oint \oint \frac{\mathrm{d}\vec{\ell}_1 \cdot \mathrm{d}\vec{\ell}_2}{\mathscr{r}}$$



Eletrodinâmica
Indutância



$$\phi_2 = \int \vec{B}_1 \cdot \hat{n}\, \mathrm{d}a_2$$

$$\phi_2 = \int \vec{\nabla} \times \vec{A}_1 \cdot \hat{n}\, \mathrm{d}a_2$$

$$\phi_2 = \oint \vec{A}_1 \cdot \mathrm{d}\vec{\ell}_2$$

$$\vec{A}_1 = \frac{\mu_0}{4\pi} I_1 \oint \frac{\mathrm{d}\vec{\ell}_1}{r}$$

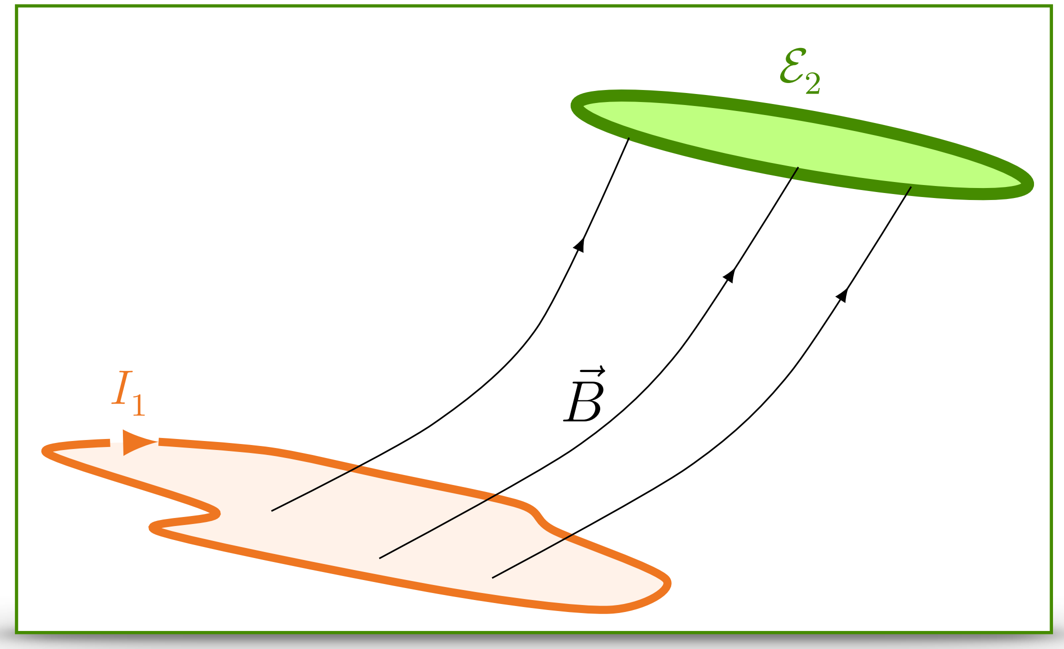
$$\phi_2 = \frac{\mu_0}{4\pi} I_1 \oint \oint \frac{\mathrm{d}\vec{\ell}_1 \cdot \mathrm{d}\vec{\ell}_2}{r} = M I_1$$

INDUTÂNCIA MÚTUA

Eletrodinâmica
Indutância

$$\frac{d}{dt}\left(\phi_2 = M I_1\right)$$

$$\mathcal{E}_2 = -M\frac{\mathrm{d}I_1}{\mathrm{d}t}$$



Eletrodinâmica
Indutância

$$\phi_2 = M I_1$$

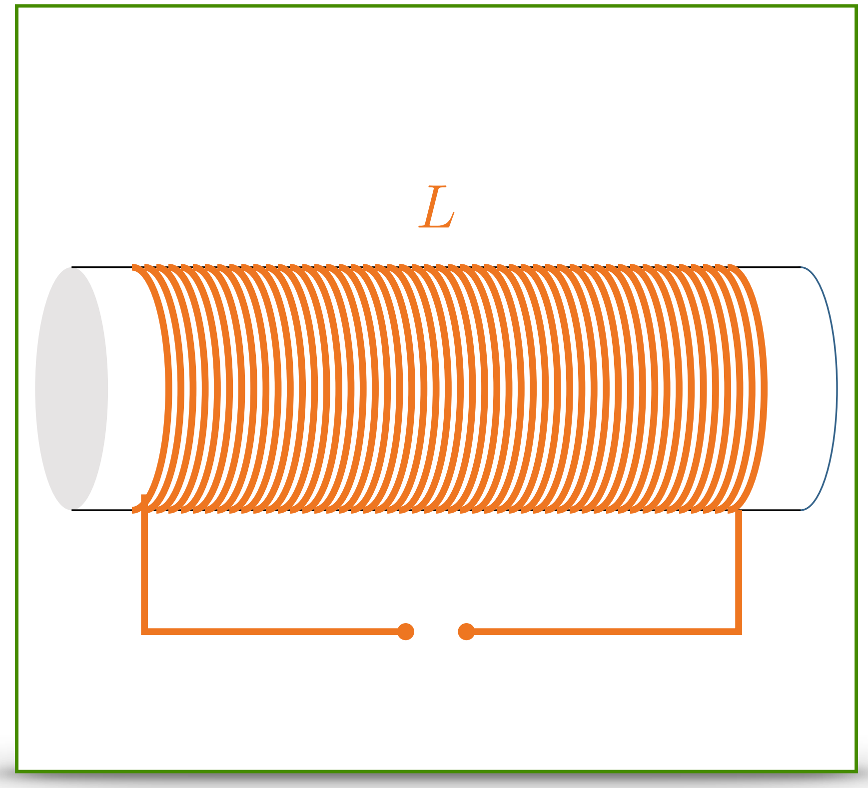
$$\mathcal{E}_2 = -M \frac{\mathrm{d}I_1}{\mathrm{d}t}$$

Auto indutância

$$\mathcal{E} = -L \frac{\mathrm{d}I}{\mathrm{d}t}$$

CIRCUITO TAMBÉM PRODUZ CAMPO $\vec{B}$ SOBRE ELE MESMO

AUTO INDUTÂNCIA

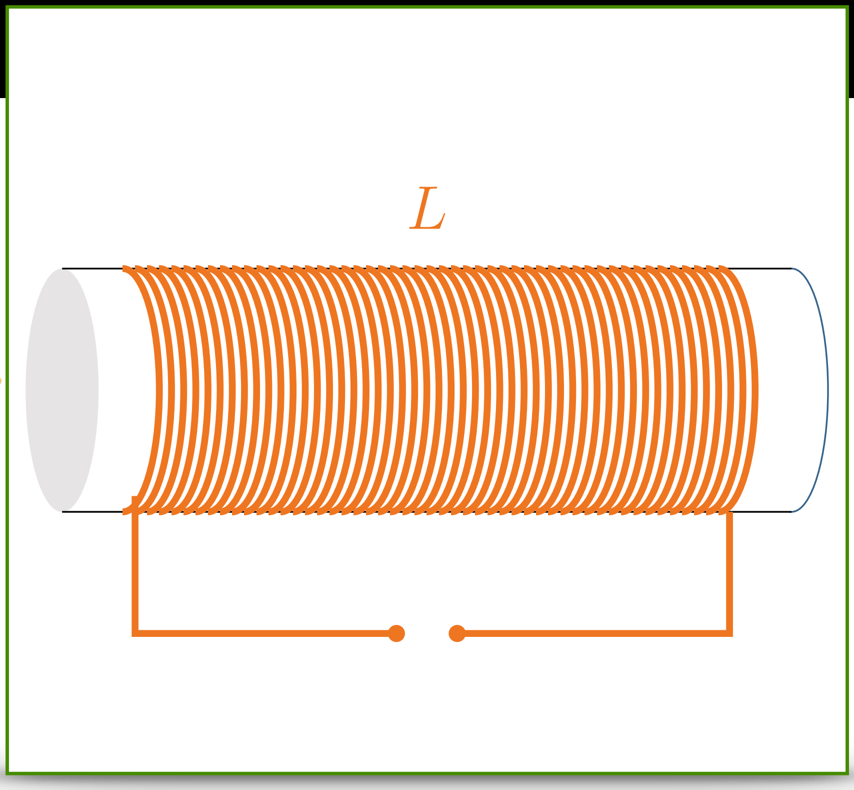


M e L EXPRESSOS EM HENRYS (H)

Pratique o que aprendeu

$$\mathcal{E} = -L\frac{\mathrm{d}I}{\mathrm{d}t}$$

$$L = ?$$

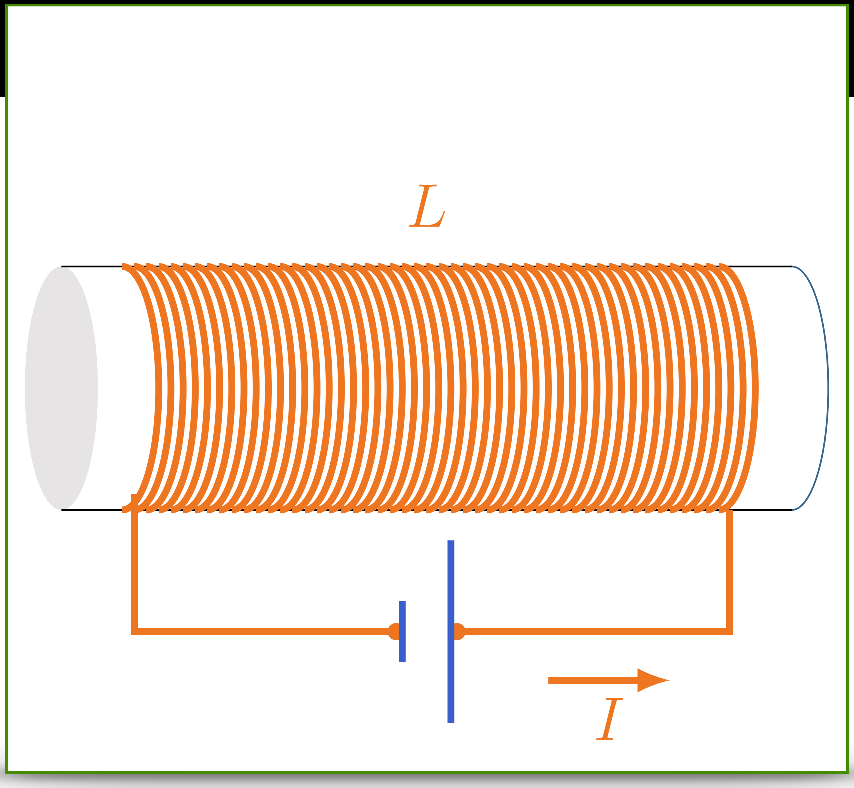


Pratique o que aprendeu

$$\mathcal{E} = -L\frac{\mathrm{d}I}{\mathrm{d}t}$$

$$B = \mu_0 \frac{N}{\ell} I$$

(PARALELO AO EIXO DO SOLENÓIDE)

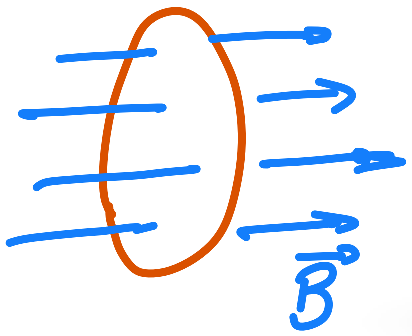


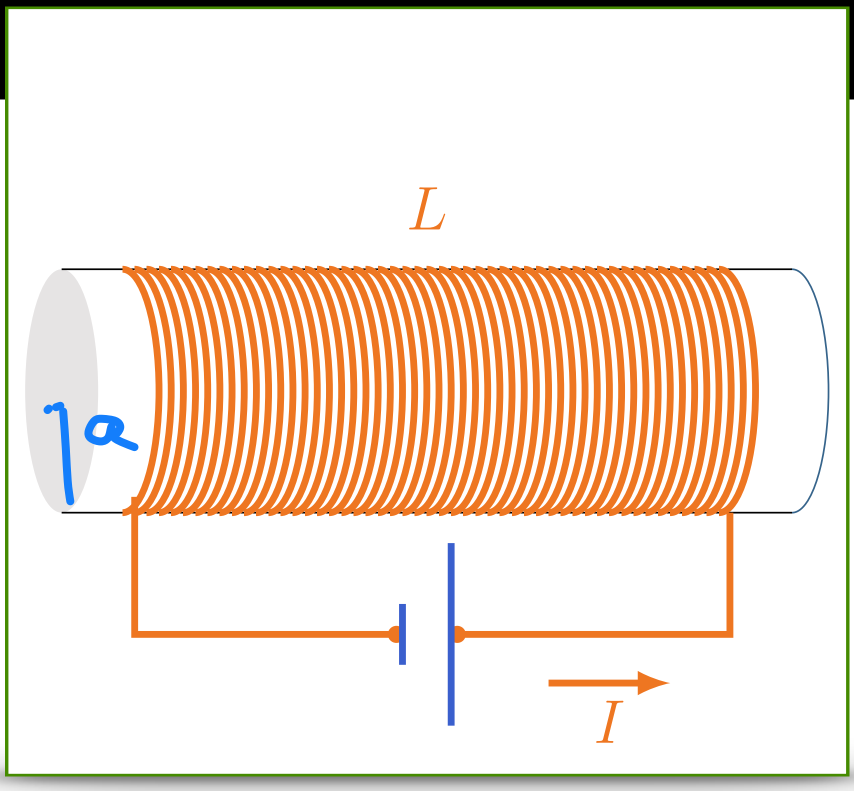
Pratique o que aprendeu

$$\mathcal{E} = -L\frac{\mathrm{d}I}{\mathrm{d}t}$$

$$B = \mu_0 \frac{N}{\ell} I$$

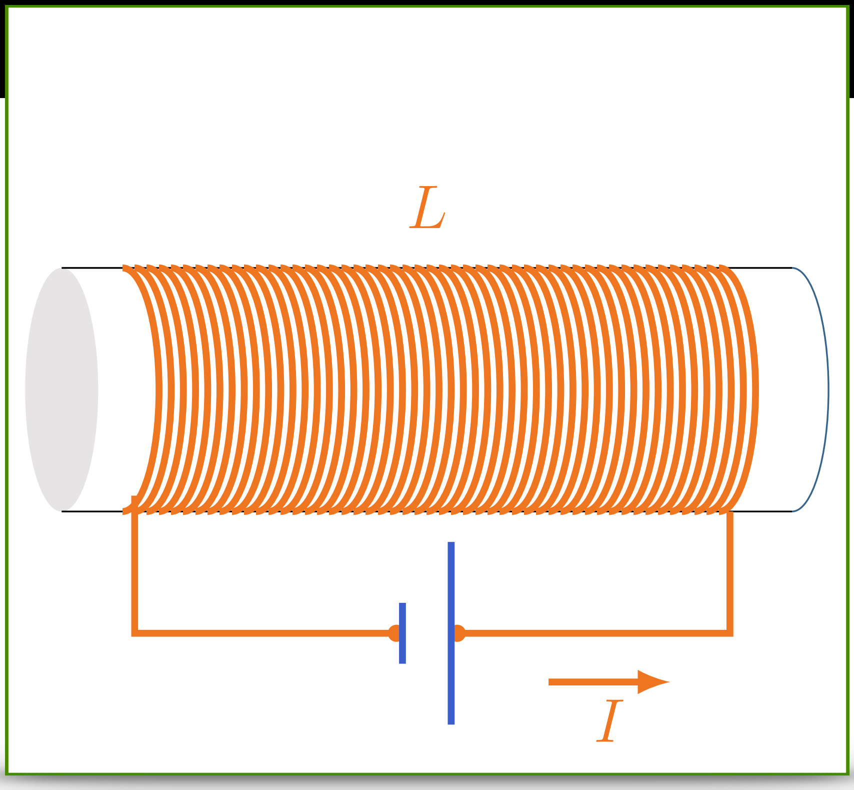
$$\phi_{1\ \mathrm{espira}} = \mu_0 \frac{N}{\ell} I \pi a^2$$





Pratique o que aprendeu

$$\mathcal{E} = -L\frac{\mathrm{d}I}{\mathrm{d}t}$$



$$B = \mu_0 \frac{N}{\ell} I$$

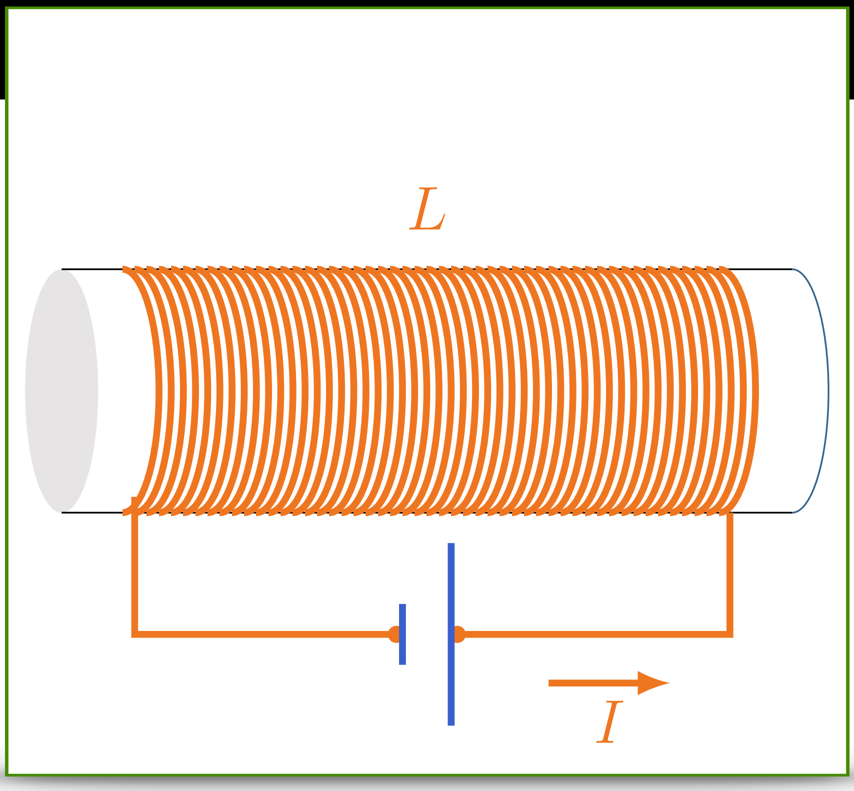
$$\phi_{1\ \text{espira}} = \mu_0 \frac{N}{\ell} I \pi a^2$$

$$\phi = \mu_0 \frac{N^2}{\ell} I \pi a^2$$

$$\mathcal{E} = -\mu_0 \frac{N^2}{\ell} \pi a^2 \frac{\mathrm{d}I}{\mathrm{d}t}$$

Pratique o que aprendeu

$$\mathcal{E} = -L\frac{\mathrm{d}I}{\mathrm{d}t}$$



$$B = \mu_0 \frac{N}{\ell} I$$

$$\phi_{1\ \text{espira}} = \mu_0 \frac{N}{\ell} I \mathcal{A}$$

$$\phi = \mu_0 \frac{N^2}{\ell} I \mathcal{A}$$

VOLUME DO SOLENÓIDE

$$\mathcal{E} = -\mu_0 \frac{N^2}{\ell} \mathcal{A} \frac{\mathrm{d}I}{\mathrm{d}t} \quad \Rightarrow \quad L = \mu_0 \left(\frac{N}{\ell}\right)^2 \mathcal{V}$$