Instituto de Física
Universidade Federal Fluminense

Eletromagnetismo

Newton Mansur

Lei de Faraday – Neumann - Lenz

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

$$\Phi_B = \int \vec{B} \cdot d\vec{A}$$

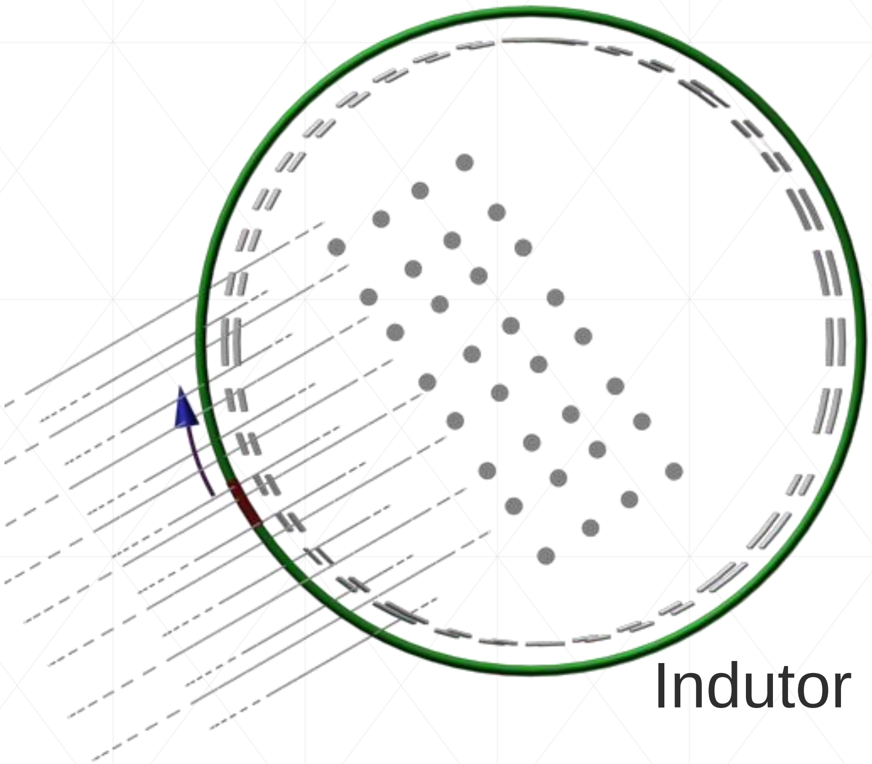
$$\mathcal{E} = -\frac{d}{dt}\Phi_B$$

$$\Phi_B = Li$$

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

$$\mathcal{E} = -L\frac{di}{dt}$$

L - Indutância



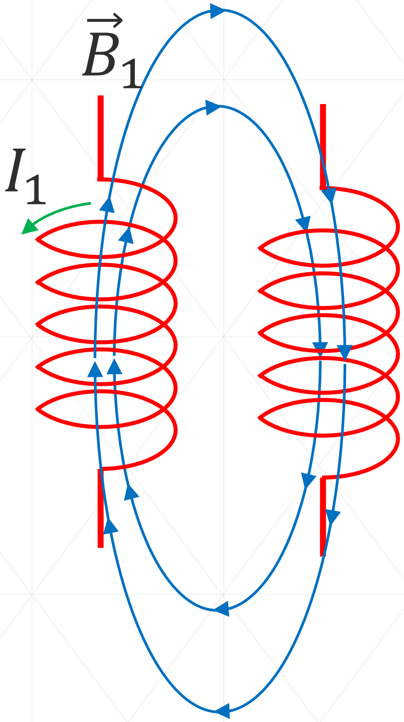
$$L = \frac{\Phi_B}{i}$$

$$U = \frac{1}{2}Li^2$$

$$L = \frac{2U}{i^2}$$

$$U = \frac{1}{2}\int BH dv$$

$$U = \mu\frac{1}{2}\int H^2 dv$$



$$\Phi_{21} = \int \vec{B}_1 \cdot d\vec{S}_2 \qquad M_{21} = \frac{\Phi_{21}}{I_1} \qquad \mathcal{E}_{21} = -N_2 M_{21} \frac{dI_1}{dt}$$

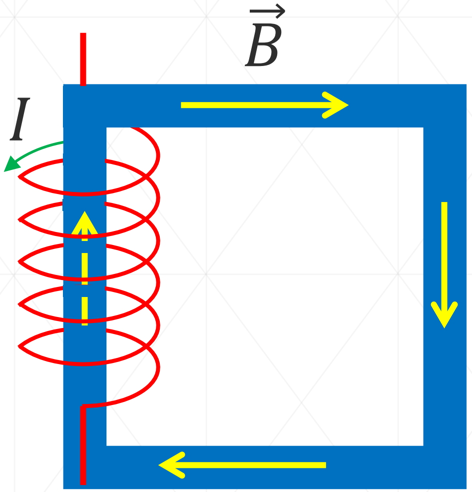
$$\Phi_{12} = \int \vec{B}_2 \cdot d\vec{S}_1 \qquad M_{12} = \frac{\Phi_{12}}{I_2} \qquad \mathcal{E}_{12} = -N_1 M_{12} \frac{dI_2}{dt}$$

$$\vec{B}_1 = \vec{\nabla} \times \vec{A}_1 \qquad \Phi_{21} = \int \vec{\nabla} \times \vec{A}_1 \cdot d\vec{S}_2 = \oint \vec{A}_1 . d\vec{l}_2$$

$$\vec{A} = \frac{\mu_1}{4\pi} \int \frac{\vec{J}}{r} dv = N \frac{\mu_1 I}{4\pi} \oint \frac{d\vec{l}}{r}$$

$$\Phi_{21} = N_1 N_2 \frac{\mu_1 I_1}{4\pi} \oint \oint \frac{d\vec{l}_1}{r} . d\vec{l}_2 \qquad M_{21} = N_1 N_2 \frac{\mu_1}{4\pi} \oint \oint \frac{d\vec{l}_1}{r} . d\vec{l}_2 = M_{12}$$

$$M_{21} = N_1 N_2 \frac{\mu_1}{4\pi} \oint \oint \frac{d\vec{l}_1}{r} . d\vec{l}_2 = M_{12}$$



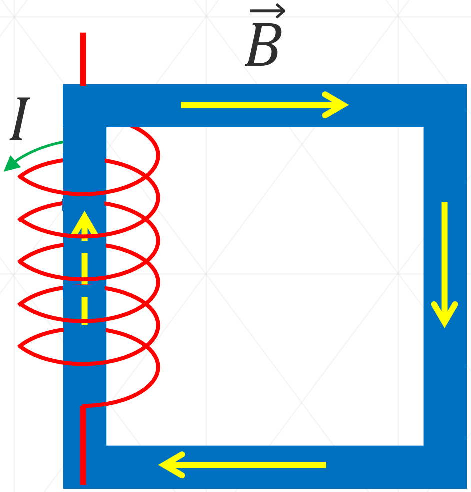
$$NI = \oint \vec{H}.d\vec{l} = Hl = \frac{B}{\mu}l = BS\frac{l}{\mu S} = \Psi\frac{l}{\mu S}$$

$$\varepsilon = IR = I\frac{l}{\sigma S} \quad I = \int \vec{j}.d\vec{S} \qquad \mathcal{F} = \Psi\frac{l}{\mu S} \quad \Psi = \int \vec{j}.d\vec{S}$$

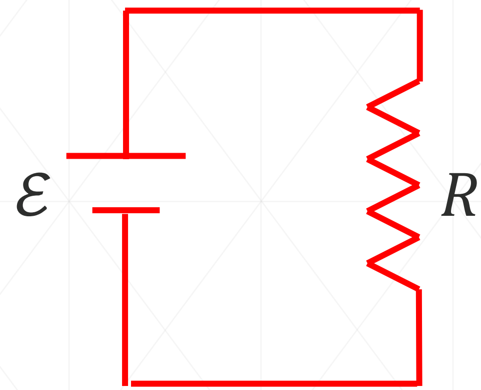
$$\mathcal{F} = NI \quad \rightarrow \quad Força\ Magnetomotriz$$

$$\Psi = \int \vec{j}.d\vec{S} \rightarrow \quad Fluxo\ Magnético$$

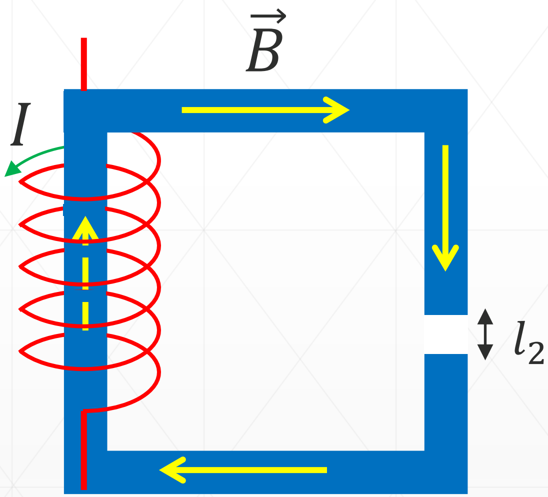
$$\mathcal{R} = \frac{l}{\mu S} \rightarrow \quad Relutância \qquad \mathcal{R} = \frac{\mathcal{F}}{\Psi}$$



$$\mathcal{R} = \frac{\mathcal{F}}{\Psi}$$



$$R = \frac{\mathcal{E}}{I}$$

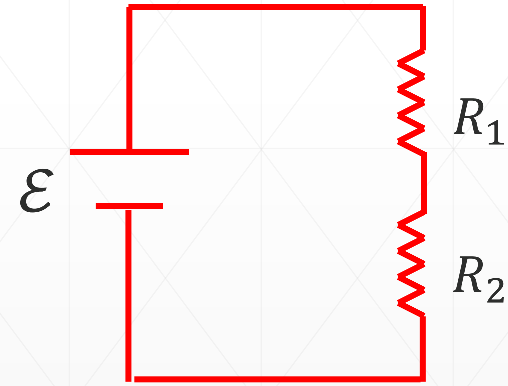


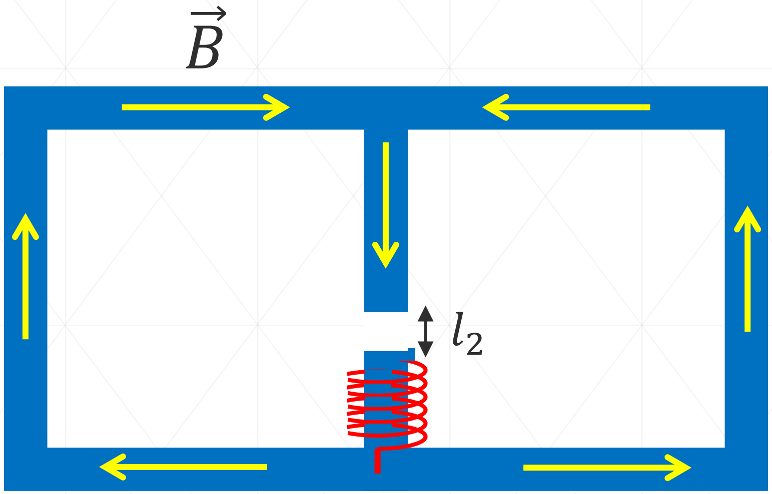
$$\mathcal{R}_1 = \frac{l_1}{\mu_1 S}$$

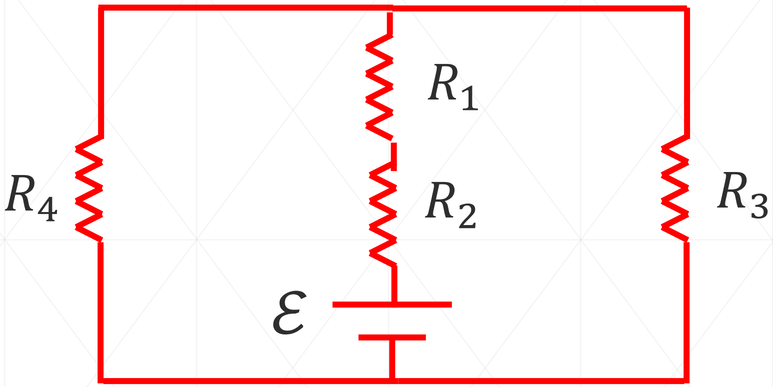
$$\mathcal{R}_2 = \frac{l_2}{\mu_0 S}$$

$$\mathcal{R}_T = \mathcal{R}_1 + \mathcal{R}_2$$

$$\Psi = \frac{\mathcal{F}}{\mathcal{R}_T}$$

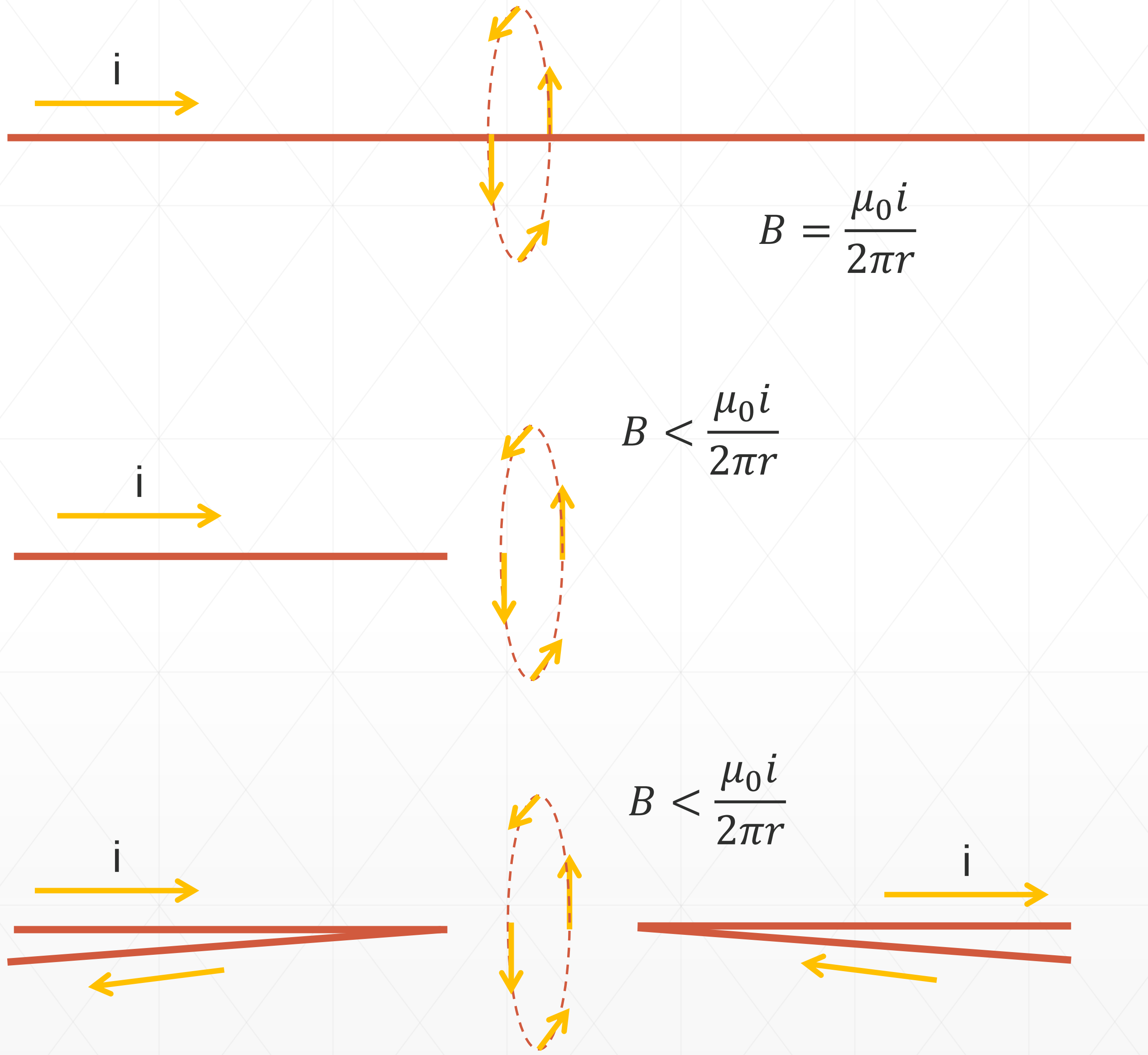




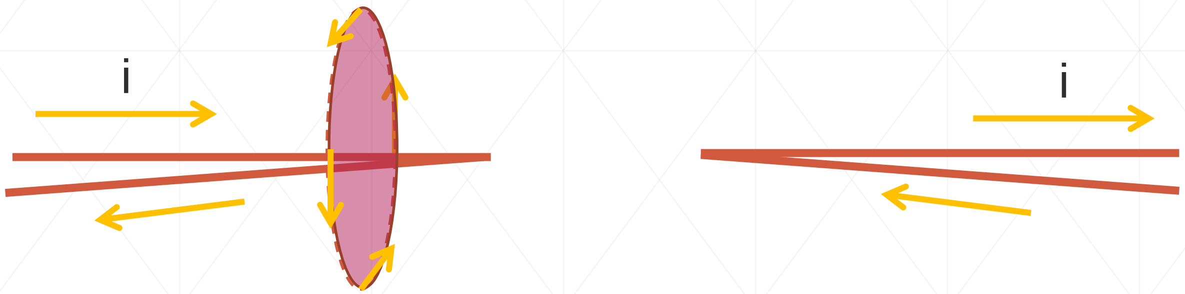


$$\mathcal{R}_1 = \frac{l_1}{\mu_1 S} \qquad \mathcal{R}_2 = \frac{l_2}{\mu_0 S} \qquad \mathcal{R}_3 = \frac{l_3}{\mu_1 S} \qquad \mathcal{R}_4 = \frac{l_4}{\mu_0 S}$$

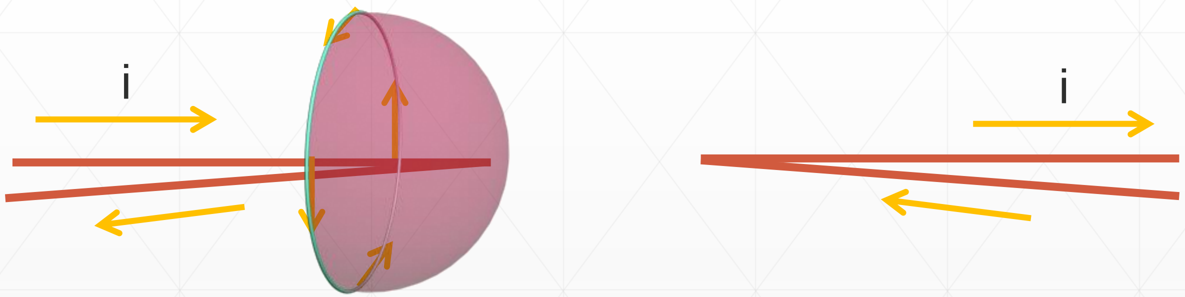
$$\mathcal{R}_T = \frac{\mathcal{R}_3 \mathcal{R}_4}{\mathcal{R}_3 + \mathcal{R}_4} + \mathcal{R}_1 + \mathcal{R}_2 \qquad \Psi = \frac{\mathcal{F}}{\mathcal{R}_T}$$



i
$B = \frac{\mu_0 i}{2\pi r}$
i
$B < \frac{\mu_0 i}{2\pi r}$
i
$B < \frac{\mu_0 i}{2\pi r}$
i



$$\oint \overrightarrow{B} \cdot \overrightarrow{ds} = \mu_0 i$$



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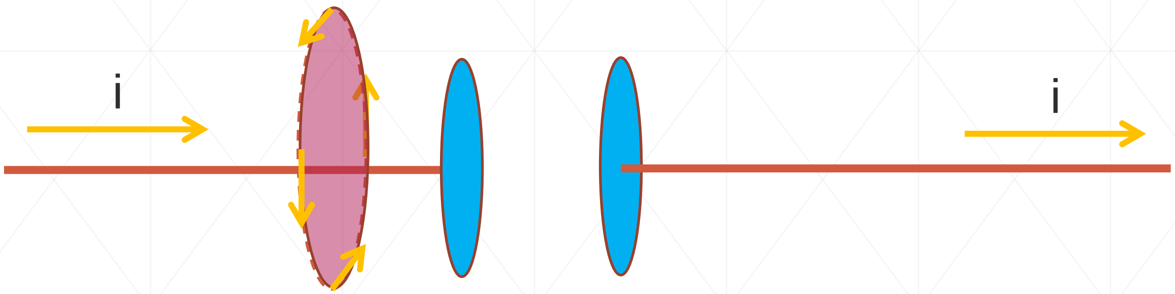
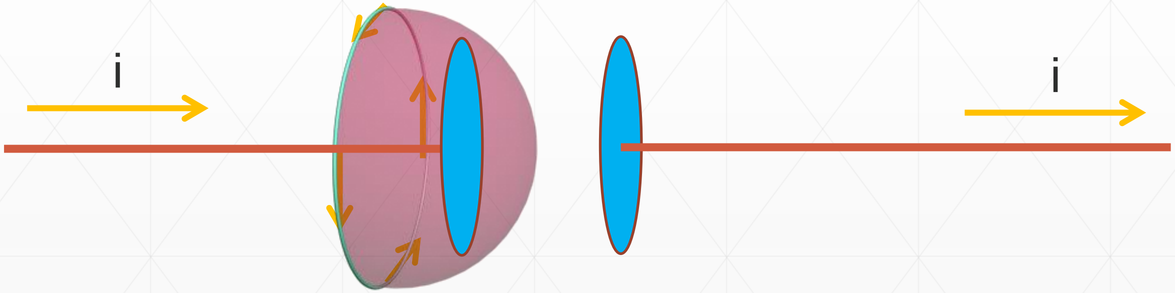
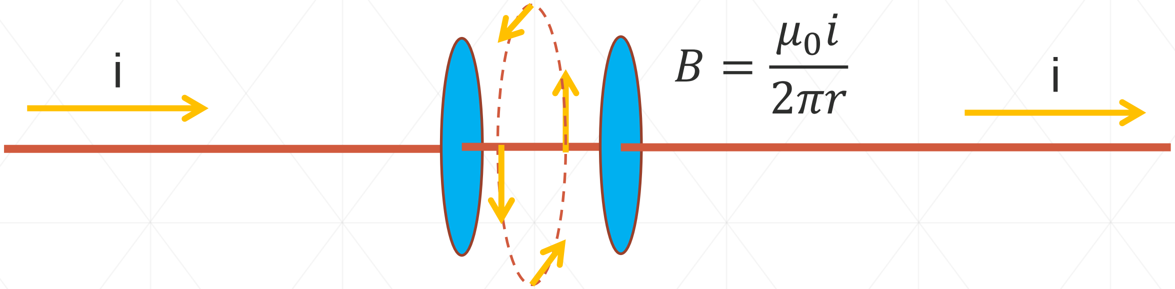
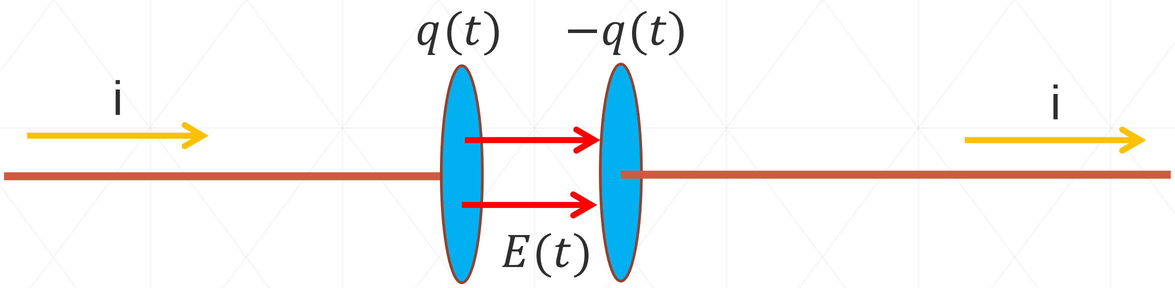




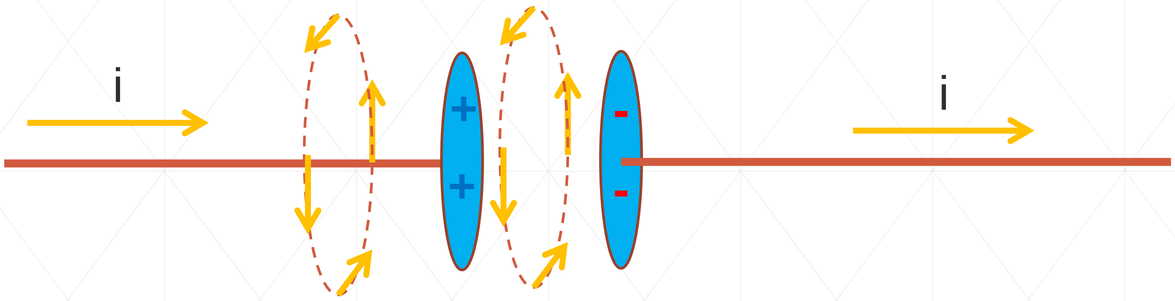




$$E(t) = \frac{\sigma(t)}{\epsilon_0} = \frac{q(t)}{A\epsilon_0} \qquad q(t) = A\epsilon_0 E(t) \qquad i = \frac{dq}{dt} = A\epsilon_0 \frac{dE(t)}{dt}$$

$$i = \epsilon_0 \frac{dE(t)A}{dt} \qquad i = \epsilon_0 \frac{d\Phi_E}{dt} \qquad i_D = \epsilon_0 \frac{d\Phi_E}{dt}$$

Corrente de deslocamento



$$\oint \overrightarrow{B} \cdot \overrightarrow{ds} = \mu_0(i + i_D)$$

$$\oint \overrightarrow{B} \cdot \overrightarrow{ds} = \mu_0(i + \epsilon_0 \frac{d\Phi_E}{dt})$$

$$\oint \overrightarrow{B} \cdot \overrightarrow{ds} = \mu_0 i \qquad \oint \overrightarrow{B} \cdot \overrightarrow{ds} = \mu_0 i_D$$

Equações de Maxwell

Lei de Gauss $$\oint \vec{E} \cdot d\vec{A} = \frac{q_{int}}{\epsilon_0}$$ $$\oint \vec{B} \cdot d\vec{A} = 0$$

Lei de Ampère $$\oint \vec{B} \cdot d\vec{s} = \mu_0 (i + \epsilon_0 \frac{d\Phi_E}{dt}) = \mu_0 \left(i + \epsilon_0 \frac{d}{dt} \int \vec{E} \cdot d\vec{A}\right)$$

Lei de Faraday $$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt} = -\frac{d}{dt} \int \vec{B} \cdot d\vec{A}$$

Equações de Maxwell

Lei de Gauss

$$\oint \vec{E} \cdot d\vec{A} = \int \vec{\nabla} \cdot \vec{E} dV = \frac{q_{int}}{\epsilon_0} = \frac{1}{\epsilon_0} \int \rho \, dV$$

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

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

Equações de Maxwell

Lei de Ampère

$$\oint \vec{B} \cdot d\vec{s} = \int \vec{\nabla} \times \vec{B} \cdot d\vec{A} = \mu_0 \left(i_{Int} + \epsilon_0 \frac{d}{dt} \int \vec{E} \cdot d\vec{A}\right)$$

$$\int \vec{\nabla} \times \vec{B} \cdot d\vec{A} = \mu_0 \left(\int \vec{J} \cdot d\vec{A} + \epsilon_0 \frac{d}{dt} \int \vec{E} \cdot d\vec{A}\right)$$

$$\int \vec{\nabla} \times \vec{B} \cdot d\vec{A} = \int \left(\mu_0 \vec{J} + \mu_0 \epsilon_0 \frac{d\vec{E}}{dt}\right) \cdot d\vec{A}$$

$$\vec{\nabla} \times \vec{B} = \mu_0 \vec{J} + \mu_0 \epsilon_0 \frac{d\vec{E}}{dt}$$

Equações de Maxwell

Lei de Faraday

$$\oint \vec{E} \cdot d\vec{s} = -\frac{d\Phi_B}{dt} = -\frac{d}{dt}\int \vec{B} \cdot d\vec{A}$$

$$\int \vec{\nabla} \times \vec{E} \cdot d\vec{A} = \int -\frac{d\vec{B}}{dt} \cdot d\vec{A}$$

$$\vec{\nabla} \times \vec{E} = -\frac{d\vec{B}}{dt}$$

Equações de Maxwell

Lei de Gauss $\vec{\nabla} \cdot \vec{E} = \frac{\rho}{\epsilon_0}$ $\vec{\nabla} \cdot \vec{B} = 0$

Lei de Ampère $\vec{\nabla} \times \vec{B} = \mu_0 \vec{J} + \mu_0 \epsilon_0 \frac{d\vec{E}}{dt}$

Lei de Faraday $\vec{\nabla} \times \vec{E} = -\frac{d\vec{B}}{dt}$

Equações de Maxwell

Lei de Faraday $$\vec{\nabla} \times \vec{E} = -\frac{d\vec{B}}{dt}$$

$$\vec{\nabla} \times \vec{\nabla} \times \vec{E} = \vec{\nabla} \times -\frac{d\vec{B}}{dt} = -\frac{d}{dt}\vec{\nabla} \times \vec{B}$$

$$\nabla^2\vec{E} - \vec{\nabla} \cdot (\vec{\nabla} \cdot \vec{E}) = -\frac{d}{dt}\vec{\nabla} \times \vec{B}$$

Lei de Gauss $$\vec{\nabla} \cdot \vec{E} = \frac{\rho}{\epsilon_0} \quad para\, \rho = 0 \quad \vec{\nabla} \cdot \vec{E} = 0$$

Lei de Ampère $$\vec{\nabla} \times \vec{B} = \mu_0\vec{J} + \mu_0\epsilon_0\frac{d\vec{E}}{dt}$$

$para\, \vec{J} = 0$ $$\vec{\nabla} \times \vec{B} = \mu_0\epsilon_0\frac{d\vec{E}}{dt}$$

$Equações\ de\ Maxwell$

$$\nabla^2 \vec{E} = -\mu_0 \epsilon_0 \frac{d^2 \vec{E}}{dt^2}$$

$Em\ 1\ dimensão$

$$\frac{d^2 E_x(z,t)}{dz^2} = -\mu_0 \epsilon_0 \frac{d^2 E_x(x,t)}{dt^2} = -\frac{1}{v^2} \frac{d^2 E_x(x,t)}{dt^2}$$

$$v = \sqrt{\frac{1}{\mu_0 \epsilon_0}} = 2{,}998x10^8 \frac{m}{s} = c$$