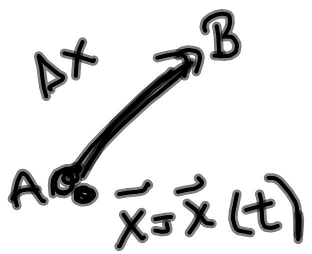


"smooth function"

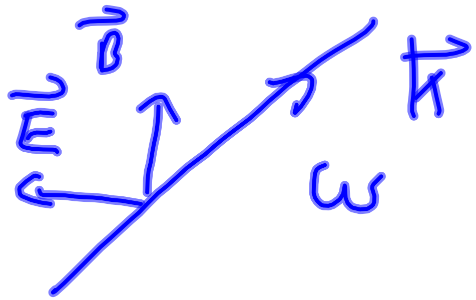
$$\Delta W = F\,\Delta x$$

ion

$$\frac{\Delta W}{\Delta t} = F\,\underbrace{\frac{\Delta x}{\Delta t}}_{v(t)} = \underbrace{q E v}_{J}$$

$$\frac{dW}{dt} = F\,v(t)$$

$$\vec{E}(\vec{x},t)\,,\ \vec{B}(\vec{x},t)$$

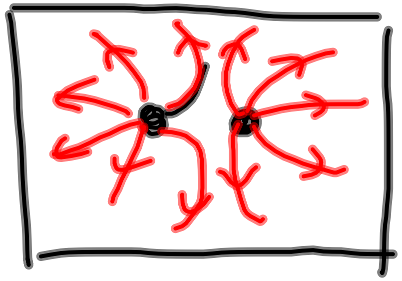


$$\frac{dW}{dt} = \int d^3x \, \vec{E}(\vec{x},t) \cdot \vec{J}(\vec{x},t)$$

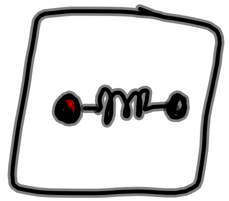
$q \longrightarrow \rho$

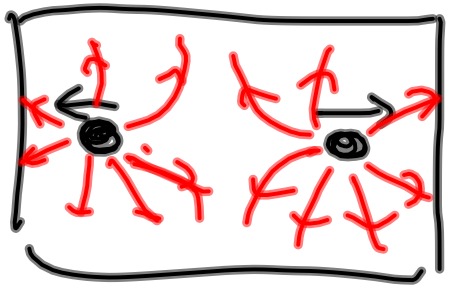
$q\vec{v} \longrightarrow \vec{J}$

Convertion of E&M energy into mechanical energy.

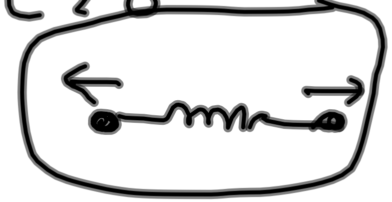


$t=0$





$t>0$



$$\underbrace{\vec{E}\cdot\left[\nabla\times\vec{H}\right.}\left.-\frac{\partial\vec{D}}{\partial t}\right] = \vec{J}\cdot\vec{E}$$

$$\vec{E}\cdot\nabla\times\vec{H} = \vec{H}\cdot\underbrace{(\nabla\times\vec{E})}_{-\frac{\partial\vec{B}}{\partial t}} - \nabla\cdot(\vec{E}\times\vec{H})$$

$$\vec{E}\cdot\frac{\partial\vec{D}}{\partial t} + \vec{H}\cdot\frac{\partial\vec{B}}{\partial t} = \epsilon\,\vec{E}\cdot\frac{\partial\vec{E}}{\partial t} + \frac{1}{\mu}\vec{B}\cdot\frac{\partial\vec{B}}{\partial t}$$

$$\vec{D} = \epsilon\vec{E}$$
$$\vec{B} = \mu\vec{H}$$

$$\boxed{E = \frac{\epsilon}{2}\int \vec{E}^2\, d^3x}$$

$$\frac{\partial(\vec{E}\cdot\vec{E})}{\partial t} = 2\vec{E}\cdot\frac{\partial\vec{E}}{\partial t} \quad , \quad \frac{\partial(\vec{B}\cdot\vec{B})}{\partial t} = 2\vec{B}\cdot\frac{\partial\vec{B}}{\partial t}$$

$$\boxed{\int_V \vec{E}\cdot\vec{J}\, d^3x = -\int_V d^3x\, \frac{\partial}{\partial t}\left[\frac{1}{2}\left(\epsilon\vec{E}^2 + \frac{1}{\mu}\vec{B}^2\right)\right] - \int_V d^3x\, \nabla\cdot\underbrace{(\vec{E}\times\vec{H})}_{\vec{S}}}$$

$\frac{\partial}{\partial t} E_{mechanical}$

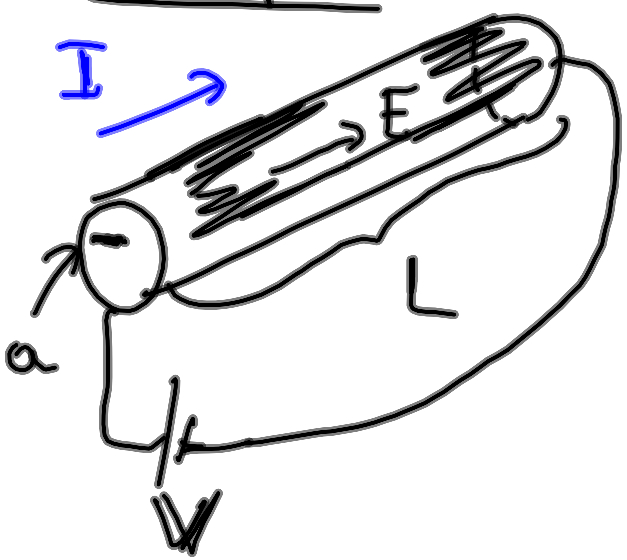
$-\frac{\partial}{\partial t} E_{electromag.\ field}$

$\vec{S}$ Pointying vector

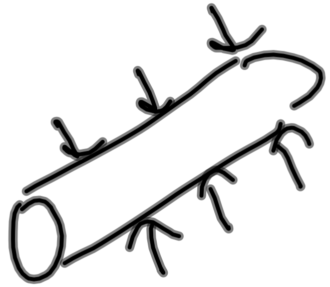
$$\int_V \nabla\cdot\vec{S} = \oint_S \vec{S}\cdot\vec{n}\, da$$

$$\frac{1}{\mu\epsilon} = c^2$$

Example

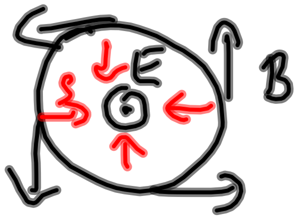


$$E = \frac{V}{L}$$



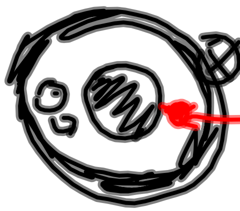
$$\oint_c \vec{B}\cdot d\vec{l} = \mu_0 I$$

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



$$S = \frac{EB}{\mu_0} = \frac{V}{L}\frac{\cancel{\mu_0} I}{\cancel{\mu_0} 2\pi a}$$

$$\oint_s \vec{S}\cdot d\vec{a} = \frac{VI}{L\,\cancel{2\pi a}}\,\cancel{2\pi a L}$$



$$P = VI$$

Conservation of momentum

$$\vec{F} = q(\vec{E} + \vec{v}\times\vec{B}) = \int_V (\rho\vec{E} + \vec{J}\times\vec{B})\, d^3x$$

$$\vec{F} = \frac{d\vec{P}_{\text{mechanical}}}{dt}$$

$q \to \rho$

$q\vec{v} \to \vec{J}$

Vacuum: $\nabla\cdot\vec{D} = \rho$, $\epsilon_0 \nabla\cdot\vec{E} = \rho$

$$\vec{J} = \nabla\times\vec{H} - \frac{\partial\vec{D}}{\partial t} \qquad \vec{H} = \frac{\vec{B}}{\mu_0}$$

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

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