

Física IV

22 setembro 2020

Equações de Maxwell

Radiação eletromagnética

Equações de Maxwell

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

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

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

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

$$\vec{D} = \kappa \vec{E}$$

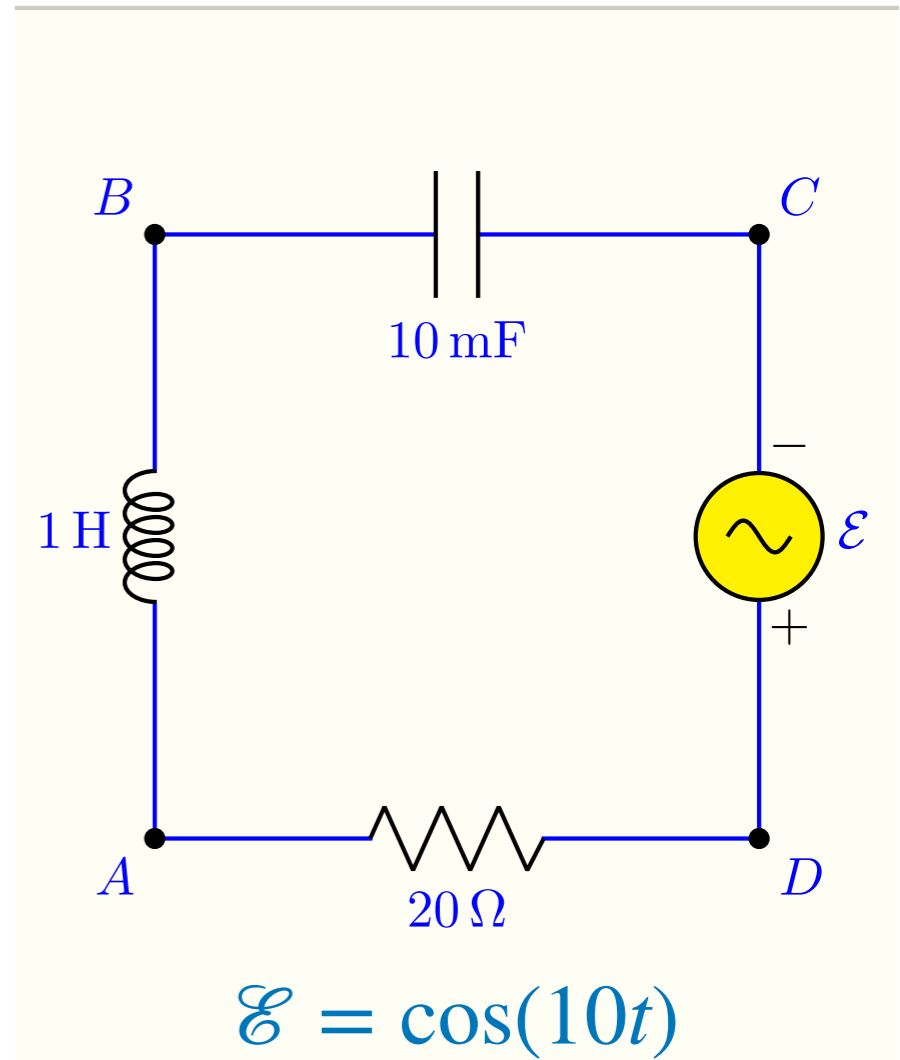
$$\vec{B} = \mu \vec{H}$$



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

Pratique o que aprendeu

$$-i\omega Lu - \frac{u}{i\omega C} + \mathcal{E}_0 \exp(i\omega t) - Ru = 0$$

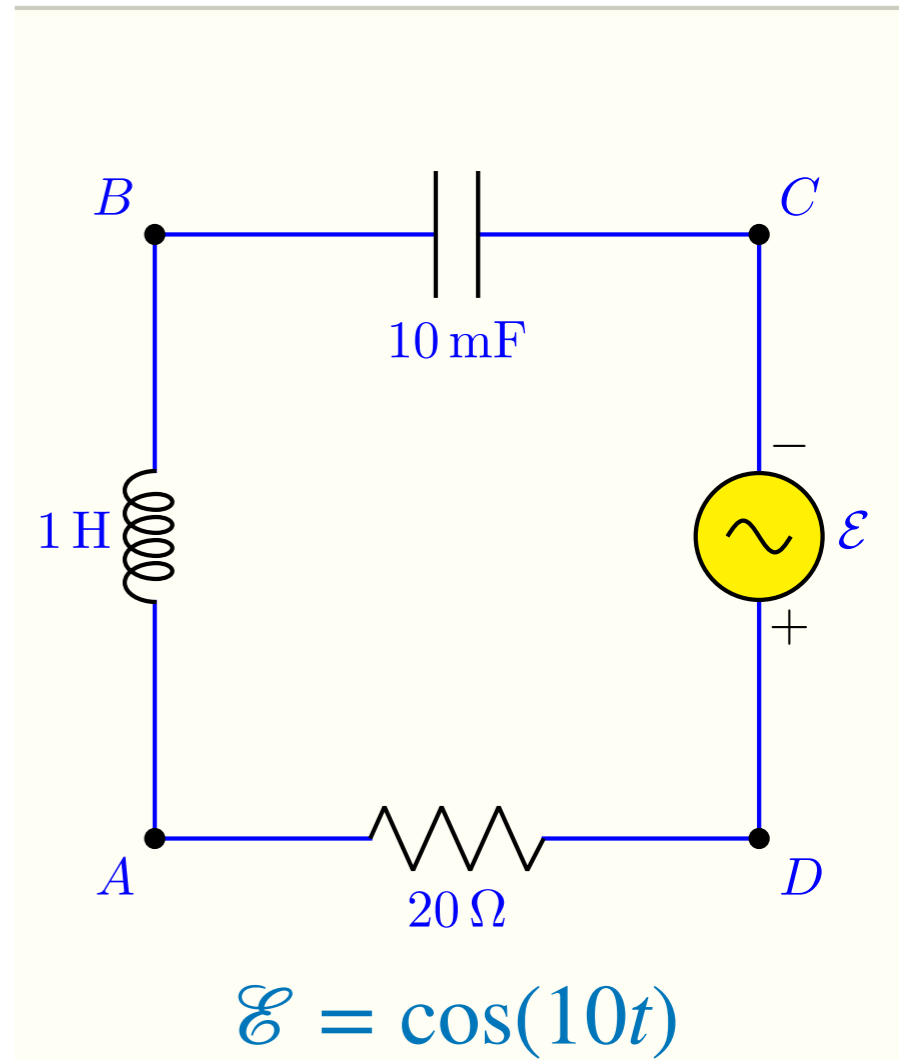


$$\vec{\nabla} \times \vec{H} = \vec{j} + \epsilon_0 \frac{\partial \vec{D}}{\partial t}$$

Pratique o que aprendeu

$$-i\omega Lu - \frac{u}{i\omega C} + \mathcal{E}_0 \exp(i\omega t) - Ru = 0$$

$$i10u + \frac{10u}{i} + 20u = \exp(i10t)$$

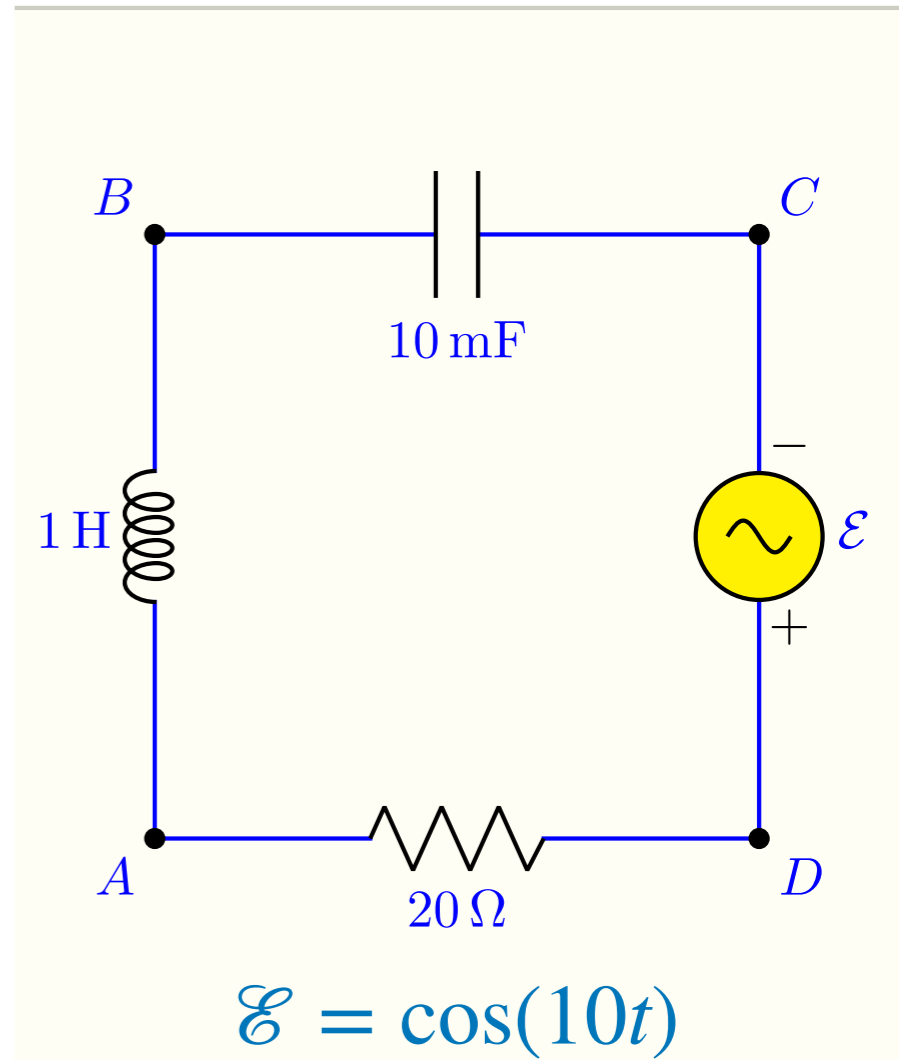


$$\vec{\nabla} \times \vec{H} = \vec{j} + \epsilon_0 \frac{\partial \vec{D}}{\partial t}$$

Pratique o que aprendeu

$$-i\omega Lu - \frac{u}{i\omega C} + \mathcal{E}_0 \exp(i\omega t) - Ru = 0$$

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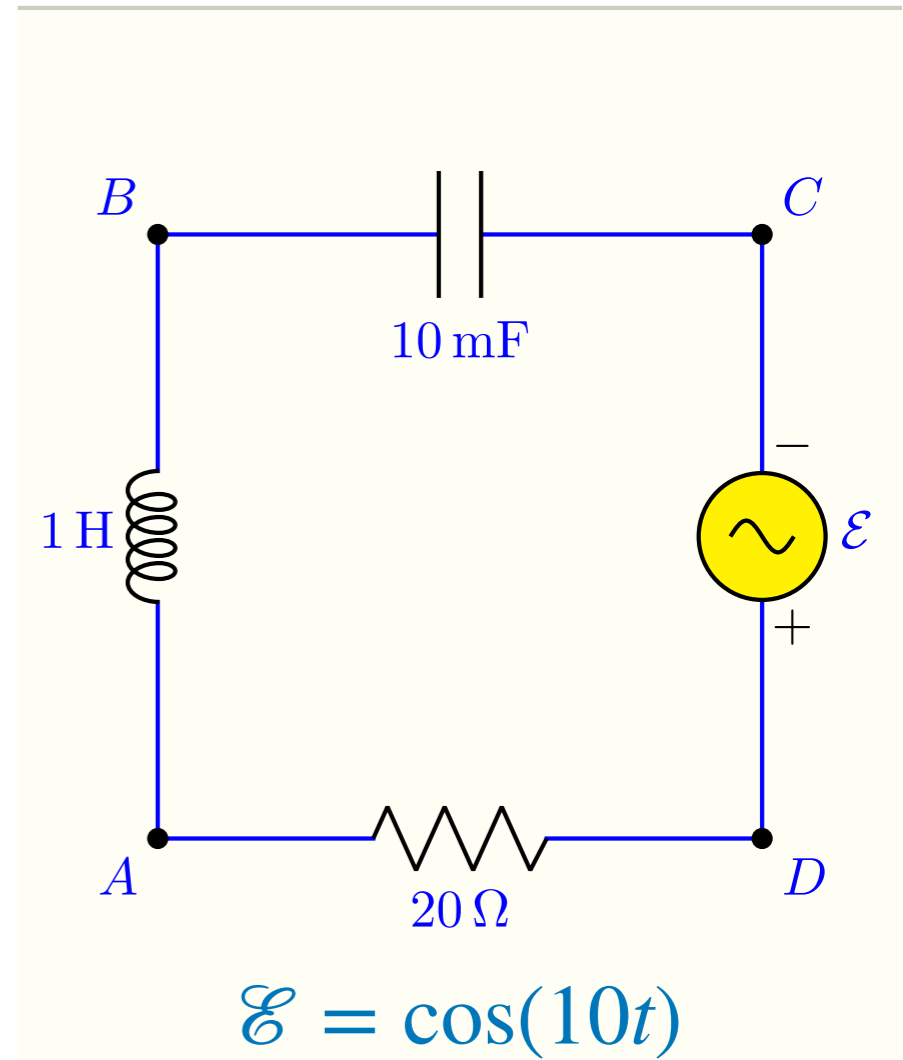
$$\vec{\nabla} \times \vec{H} = \vec{j} + \epsilon_0 \frac{\partial \vec{D}}{\partial t}$$

Pratique o que aprendeu

$$-i\omega Lu - \frac{u}{i\omega C} + \mathcal{E}_0 \exp(i\omega t) - Ru = 0$$

$$i10u + \frac{10u}{i} + 20u = \exp(i10t)$$

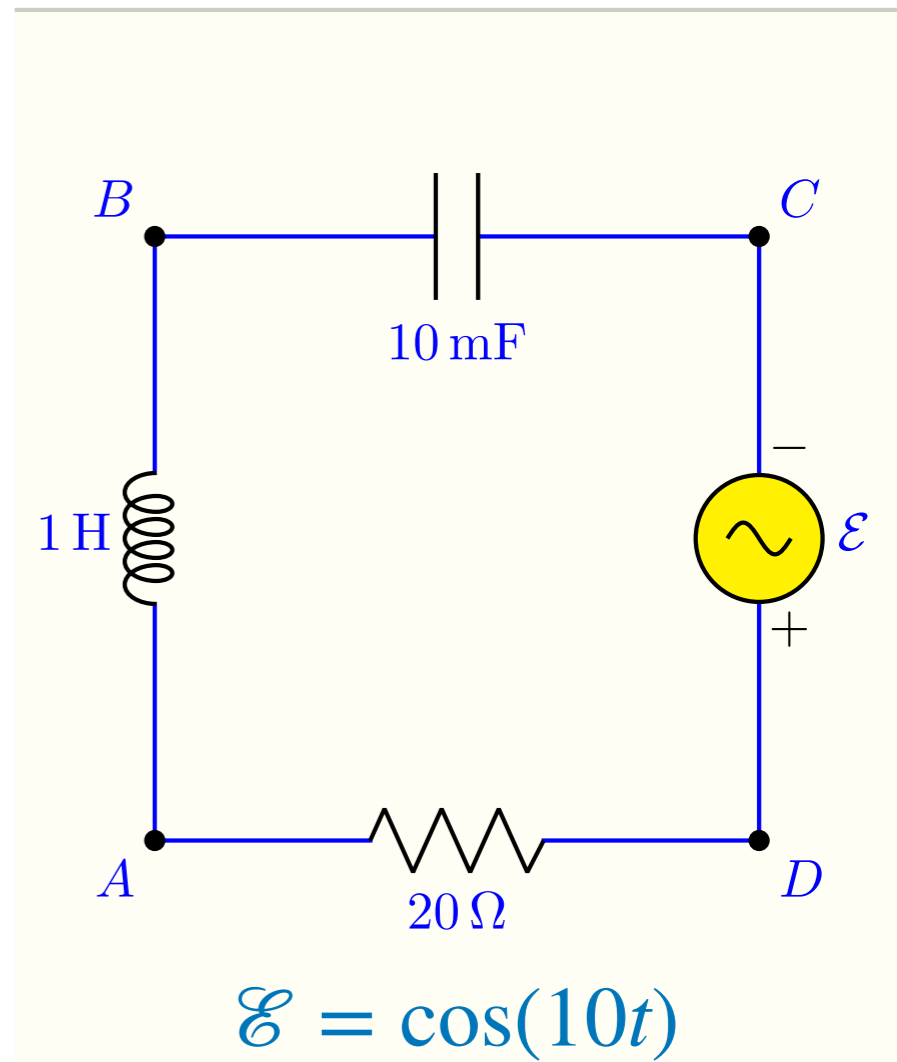
$$u = \frac{1}{20} \exp(i10t)$$



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

Pratique o que aprendeu

$$u = \frac{1}{20} \exp(i10t)$$

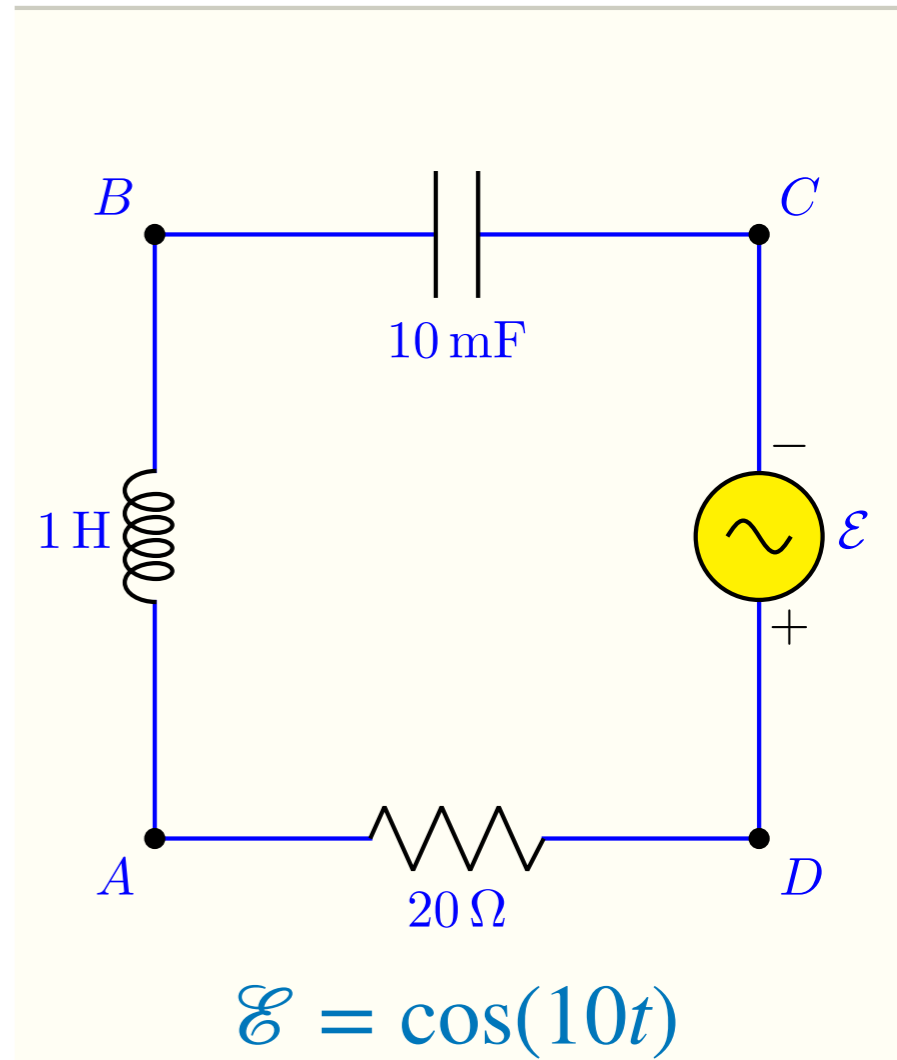


$$\vec{\nabla} \times \vec{H} = \vec{j} + \epsilon_0 \frac{\partial \vec{D}}{\partial t}$$

Pratique o que aprendeu
Corrente de deslocamento

$$u = \frac{1}{20} \exp(i10t)$$

Capacitor $\Rightarrow D = \frac{1}{\epsilon_0} \frac{Q}{A}$

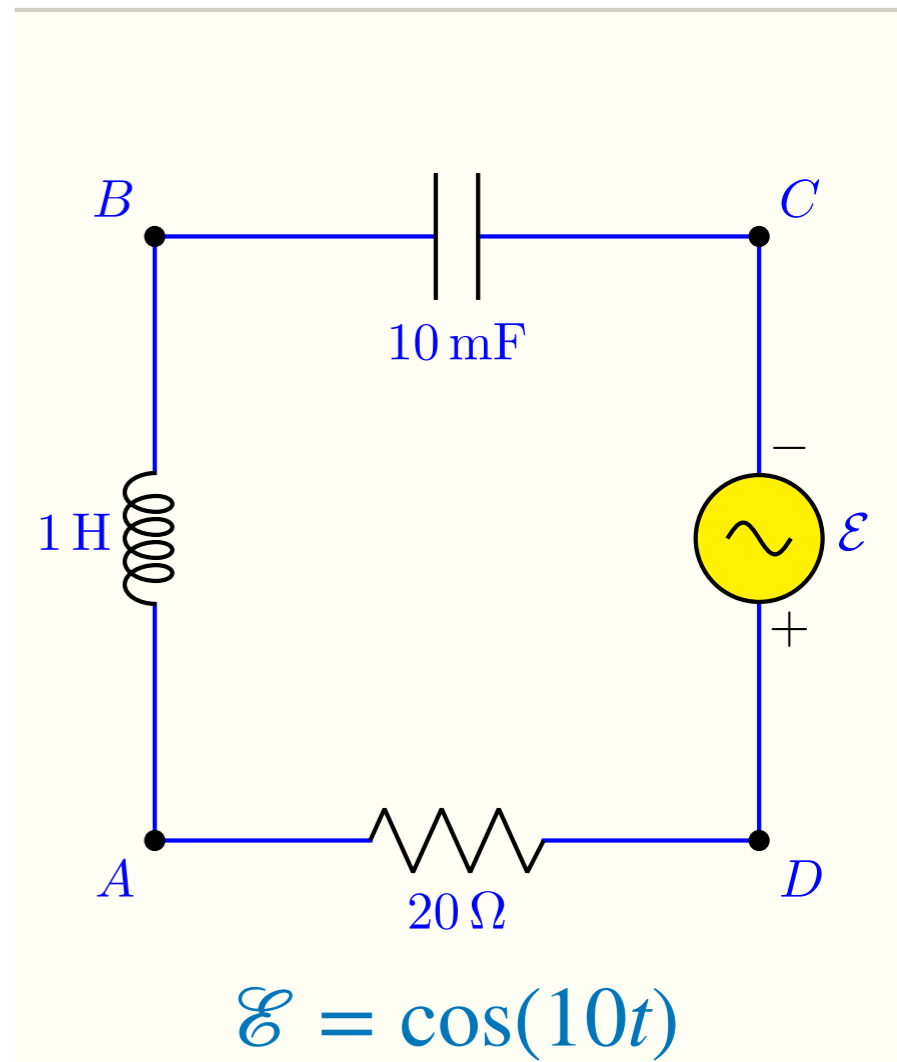


$$\vec{\nabla} \times \vec{H} = \vec{j} + \epsilon_0 \frac{\partial \vec{D}}{\partial t}$$

Pratique o que aprendeu
Corrente de deslocamento

$$u = \frac{1}{20} \exp(i10t)$$

$$D = \frac{1}{\epsilon_0} \frac{Q}{A}$$



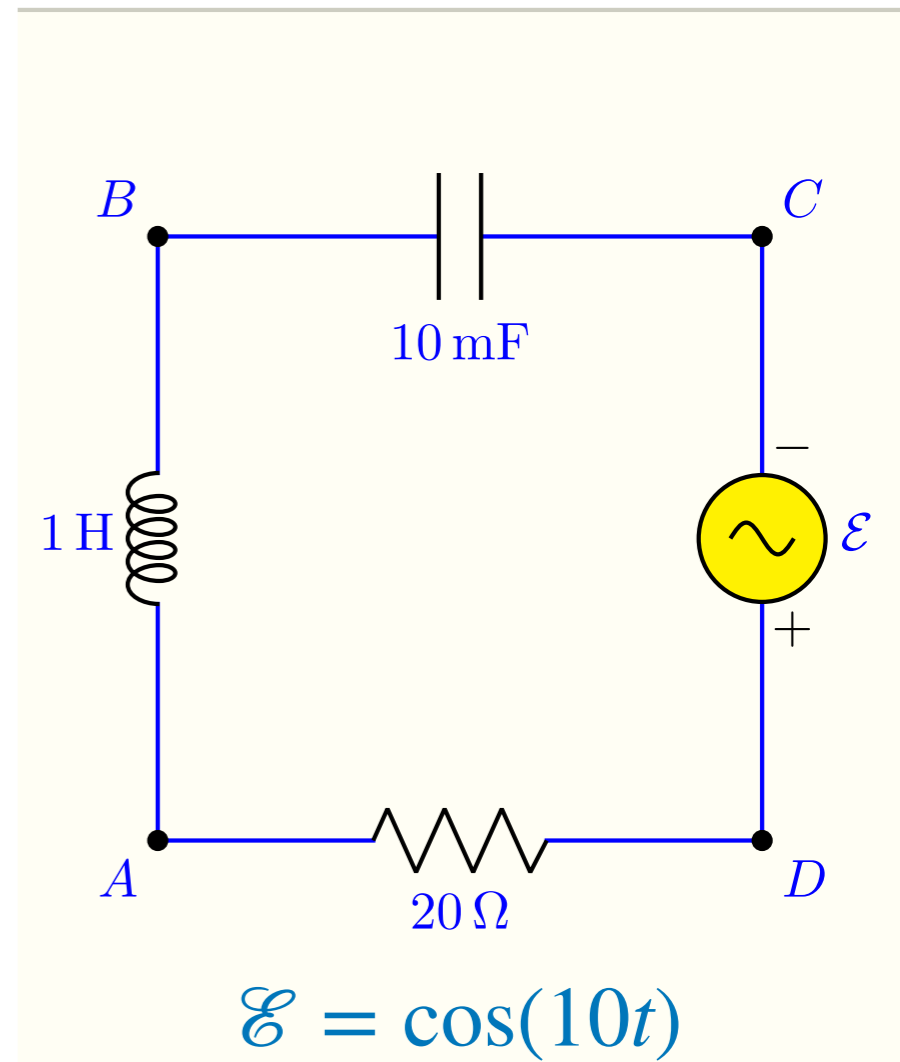
$$\vec{\nabla} \times \vec{H} = \vec{j} + \epsilon_0 \frac{\partial \vec{D}}{\partial t}$$

Pratique o que aprendeu
Corrente de deslocamento

$$u = \frac{1}{20} \exp(i10t)$$

$$D = \frac{1}{\epsilon_0} \frac{Q}{A}$$

$$I = \frac{dQ}{dt}$$



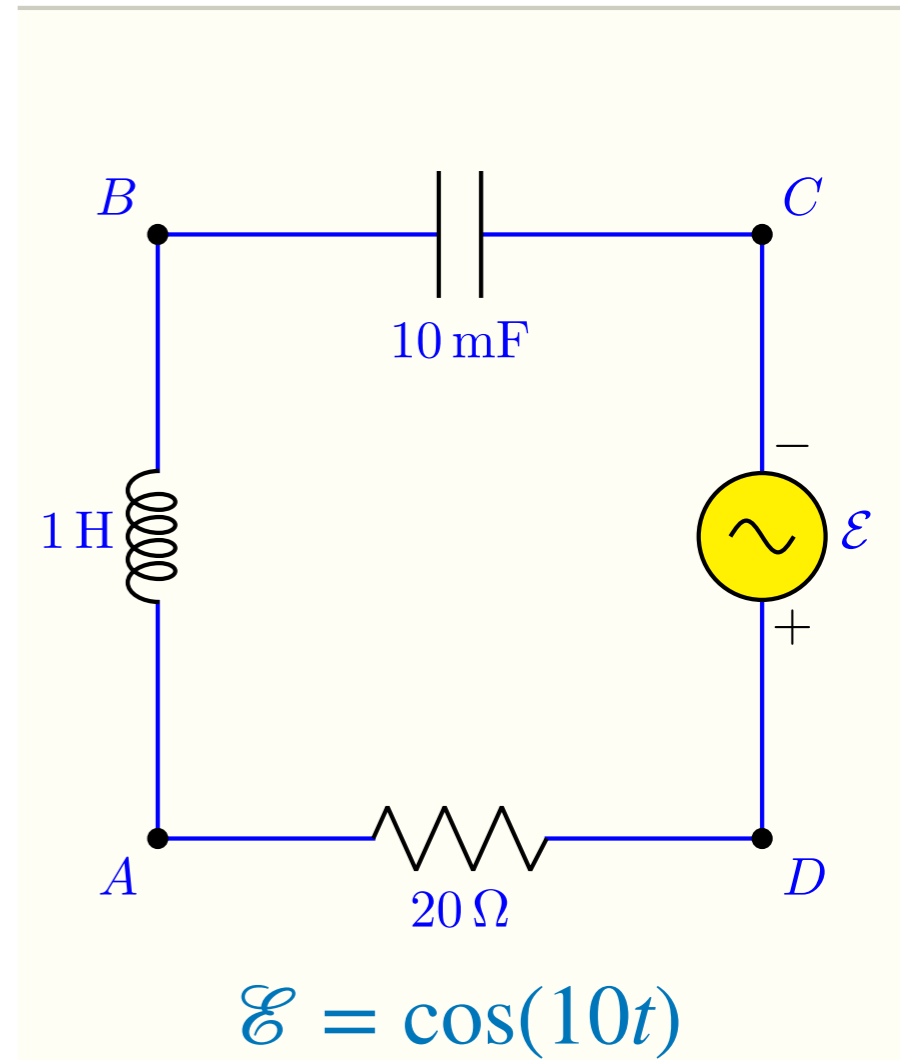
$$\vec{\nabla} \times \vec{H} = \vec{j} + \epsilon_0 \frac{\partial \vec{D}}{\partial t}$$

Pratique o que aprendeu
Corrente de deslocamento

$$u = \frac{1}{20} \exp(i10t)$$

$$D = \frac{1}{\epsilon_0} \frac{Q}{A}$$

$$I = \frac{dQ}{dt} \Rightarrow u = i\omega t$$



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

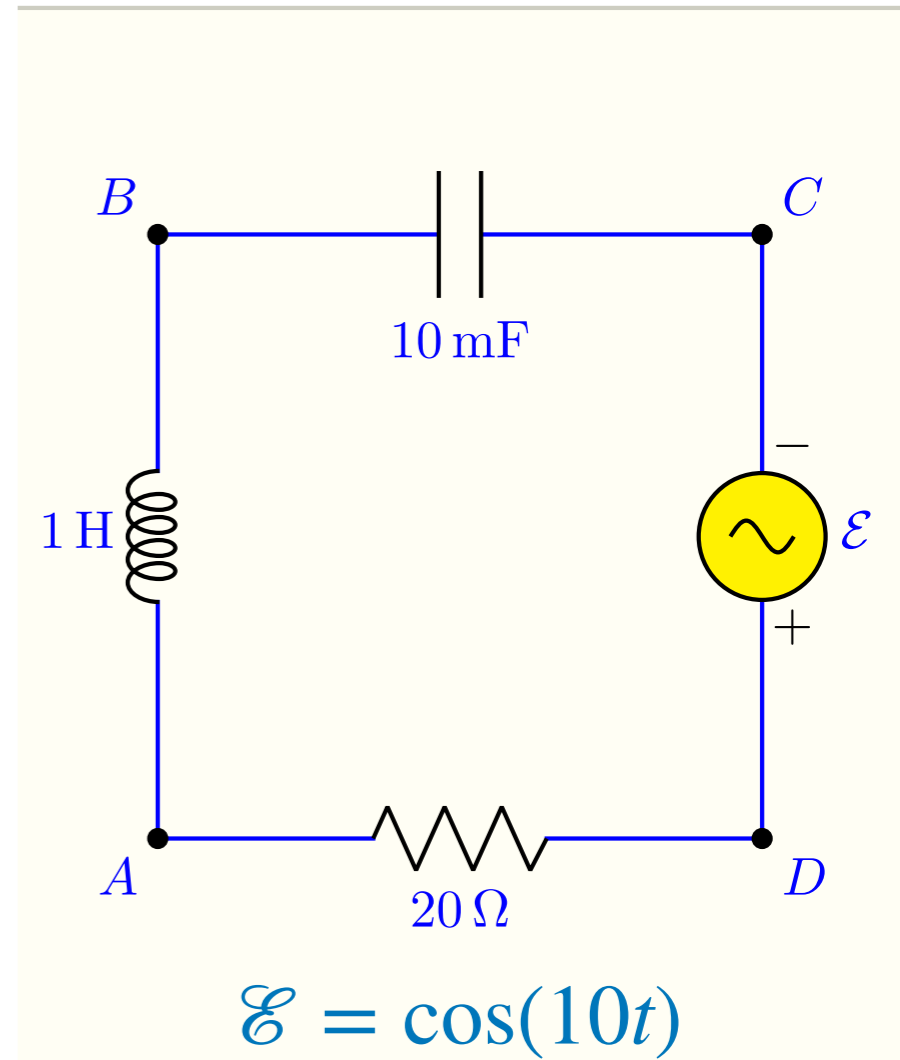
Pratique o que aprendeu
Corrente de deslocamento

$$u = \frac{1}{20} \exp(i10t)$$

$$D = \frac{1}{\epsilon_0} \frac{Q}{A}$$

$$I = \frac{dQ}{dt} \Rightarrow u = i\omega z$$

$$z = \frac{u}{10i}$$



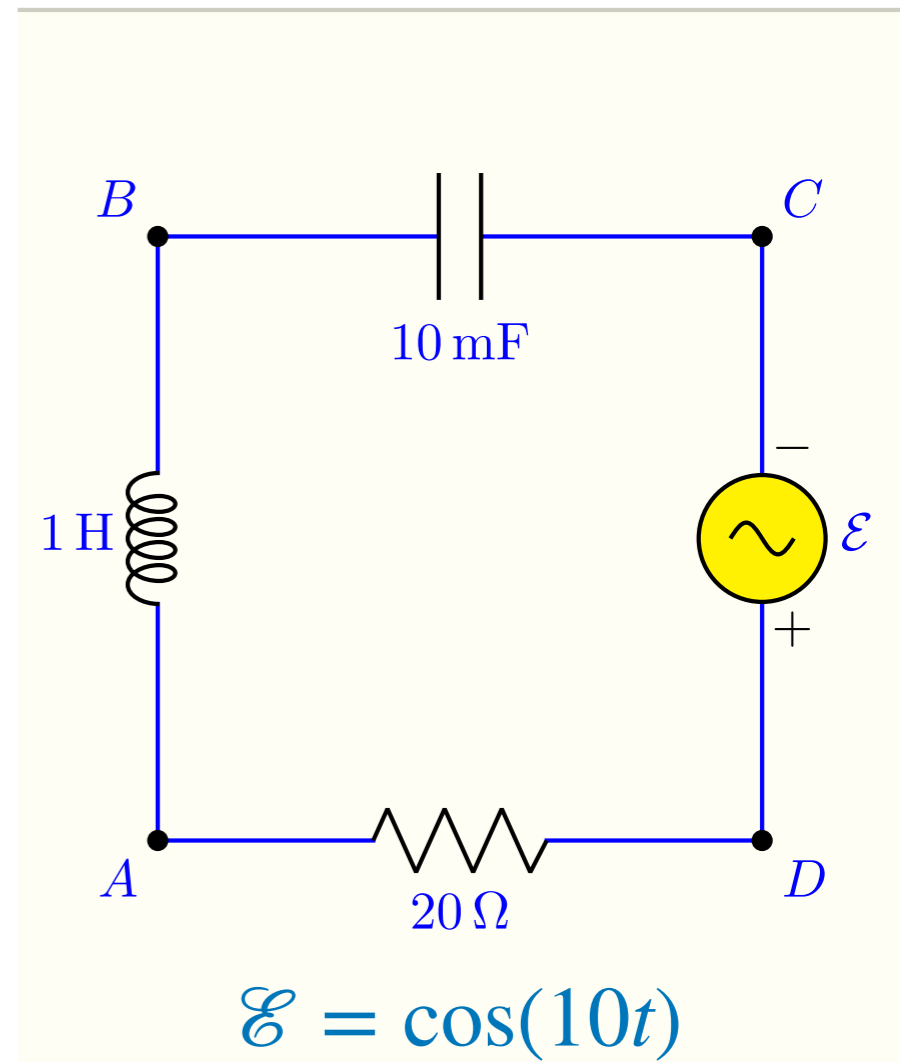
$$\vec{\nabla} \times \vec{H} = \vec{j} + \epsilon_0 \frac{\partial \vec{D}}{\partial t}$$

Pratique o que aprendeu
Corrente de deslocamento

$$u = \frac{1}{20} \exp(i10t)$$

$$D = \frac{1}{\epsilon_0} \frac{Q}{A}$$

$$z = \frac{u}{10i}$$



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

Pratique o que aprendeu
Corrente de deslocamento

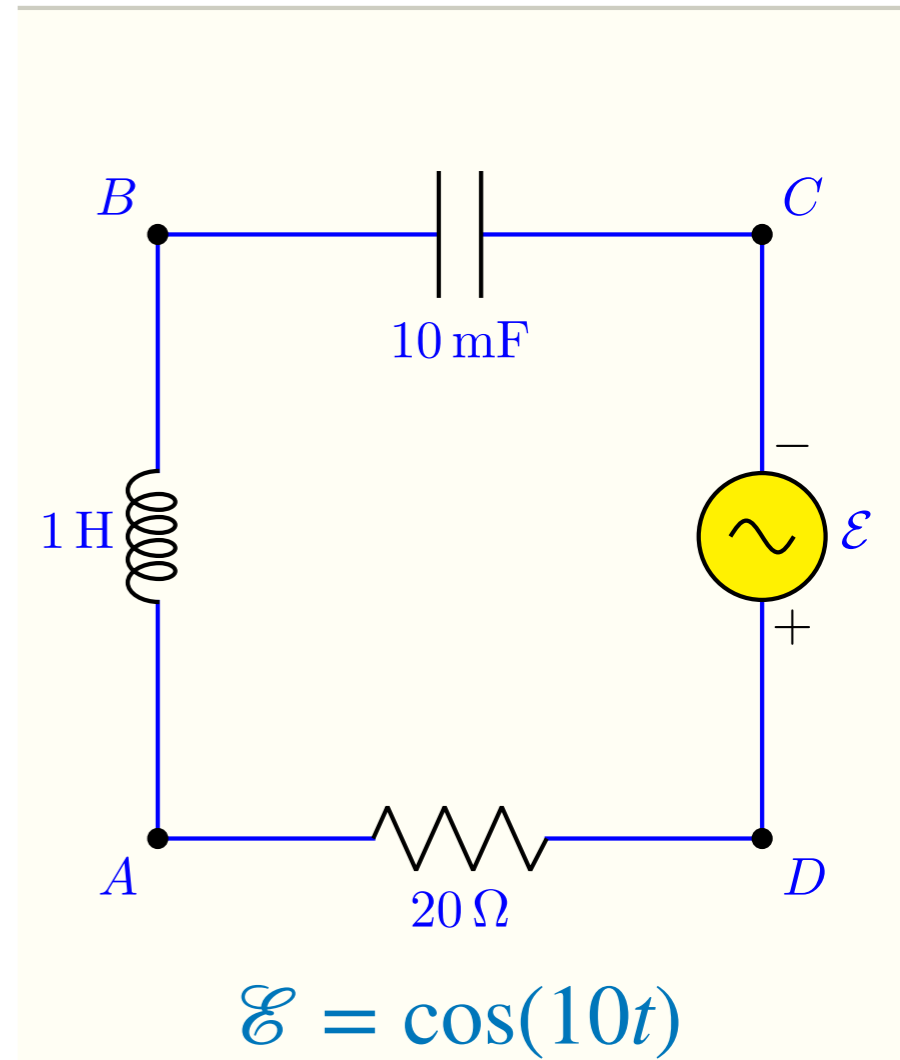
$$u = \frac{1}{20} \exp(i10t)$$

$$D = \frac{1}{\epsilon_0} \frac{Q}{A}$$

$$z = \frac{u}{10i}$$

$$z = \frac{\exp(10it)}{200i}$$

$$Q = \frac{\sin(10t)}{200}$$



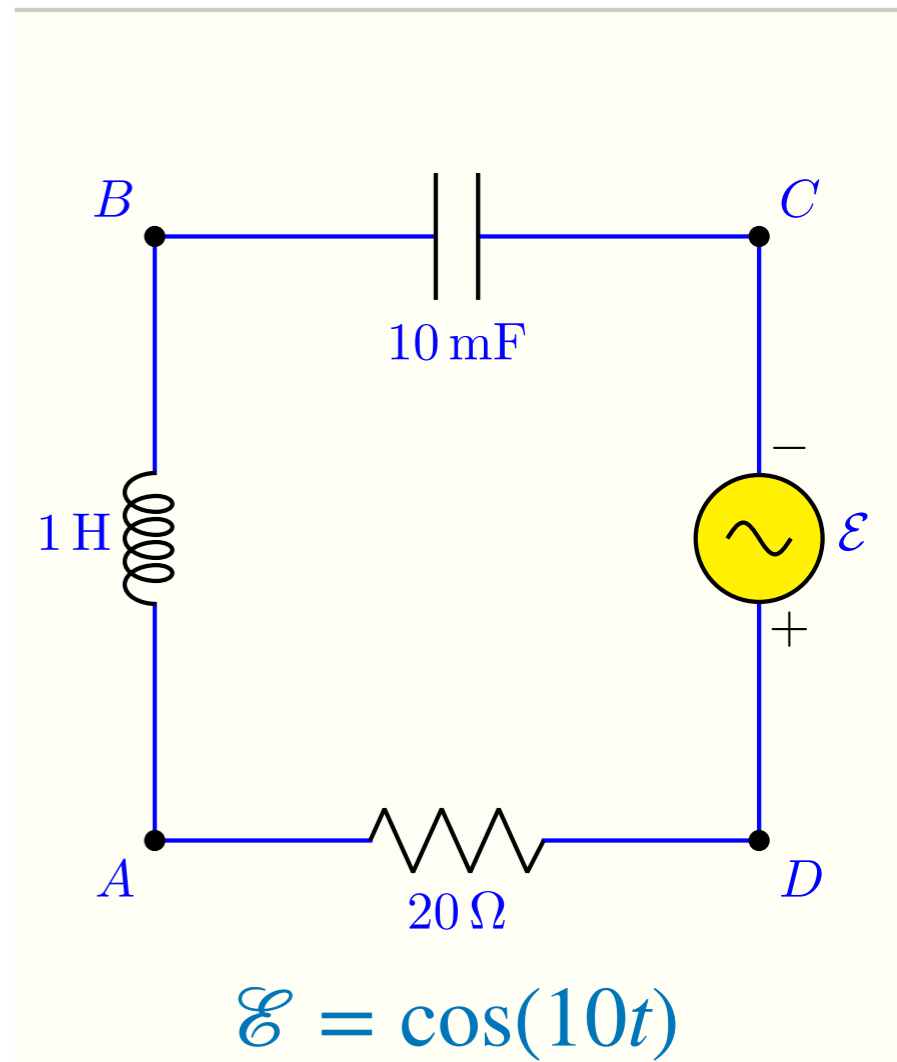
$$\vec{\nabla} \times \vec{H} = \vec{j} + \epsilon_0 \frac{\partial \vec{D}}{\partial t}$$

Pratique o que aprendeu
Corrente de deslocamento

$$u = \frac{1}{20} \exp(i10t)$$

$$D = \frac{1}{\epsilon_0} Q$$

$$Q = \frac{\sin(10t)}{200}$$



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

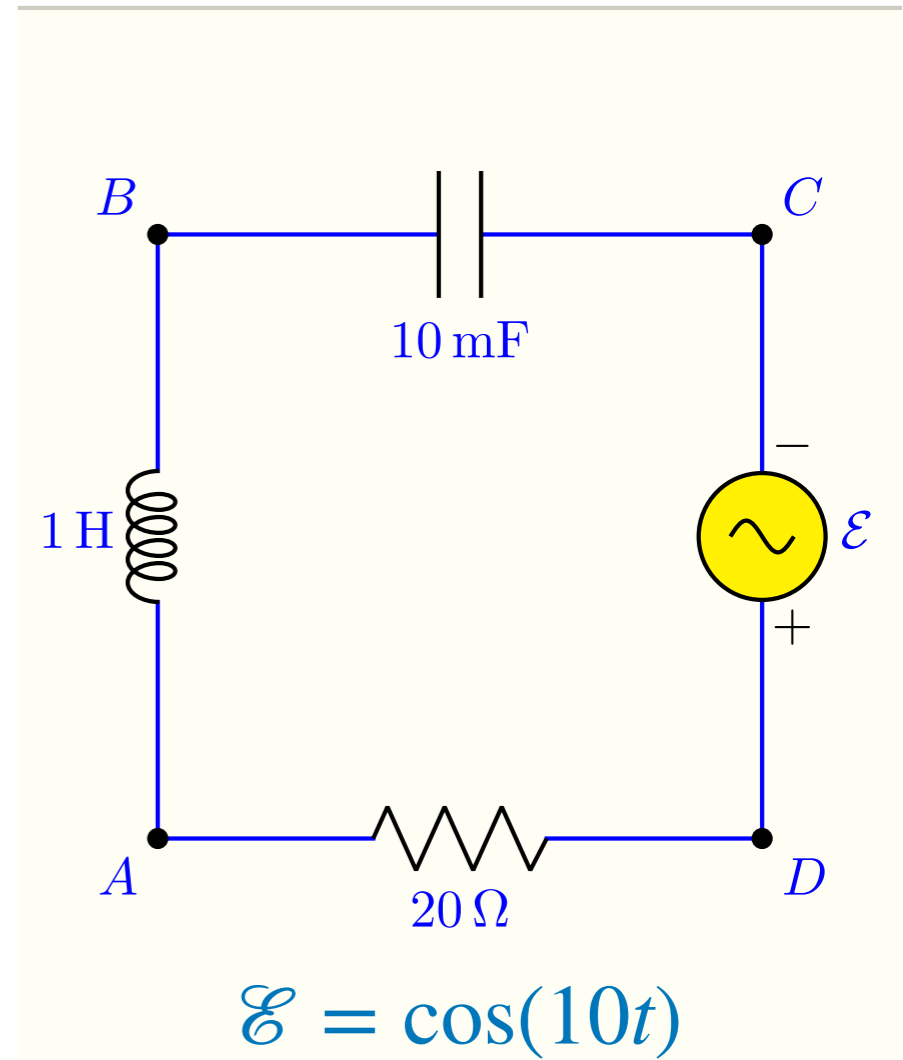
Pratique o que aprendeu
Corrente de deslocamento

$$u = \frac{1}{20} \exp(i10t)$$

$$D = \frac{1}{\epsilon_0} \frac{Q}{A}$$

$$Q = \frac{\sin(10t)}{200}$$

$$D = \frac{1}{A\epsilon_0} \frac{\sin(10t)}{200}$$



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

Pratique o que aprendeu
Corrente de deslocamento

$$u = \frac{1}{20} \exp(i10t)$$

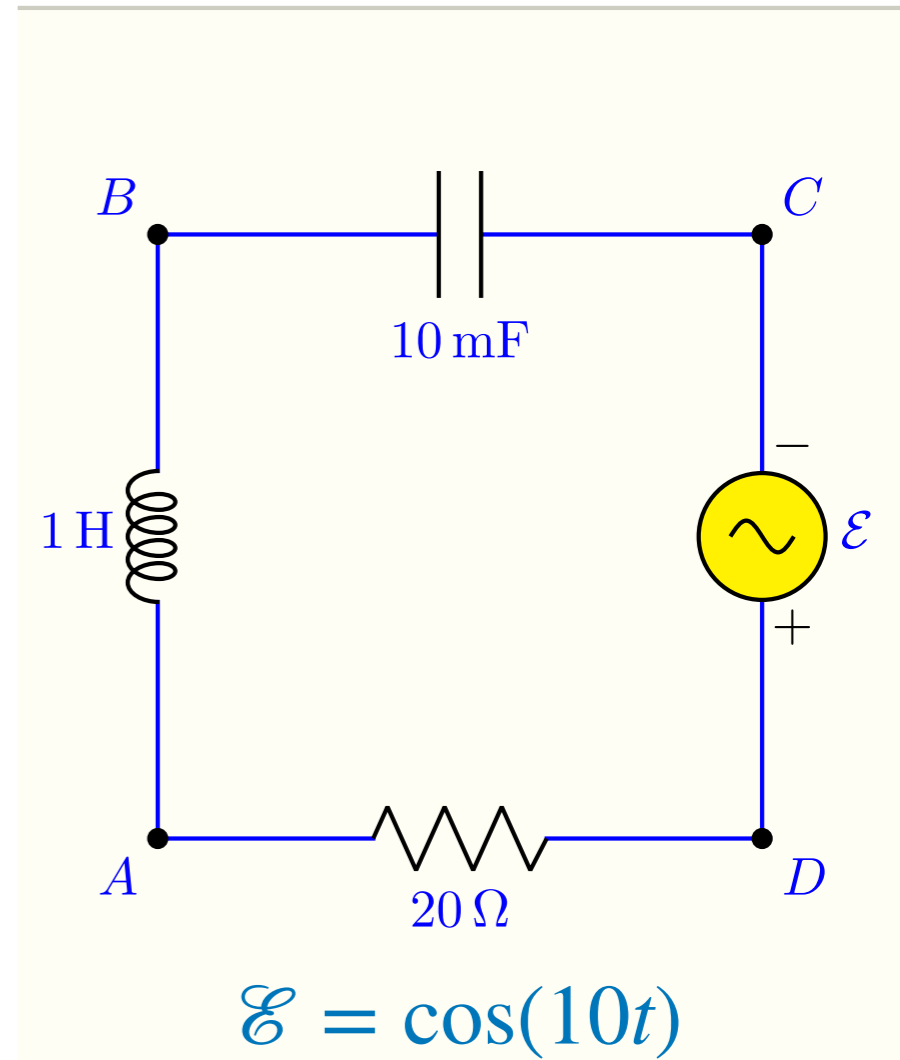
$$D = \frac{1}{\epsilon_0} \frac{Q}{A}$$

$$Q = \frac{\sin(10t)}{200}$$

$$D = \frac{1}{A\epsilon_0} \frac{\sin(10t)}{200}$$

⇒

$$\epsilon_0 \frac{\partial D}{\partial t} = \frac{1}{A} \frac{\cos(10t)}{20}$$



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

Pratique o que aprendeu
Corrente de deslocamento

$$u = \frac{1}{20} \exp(i10t)$$

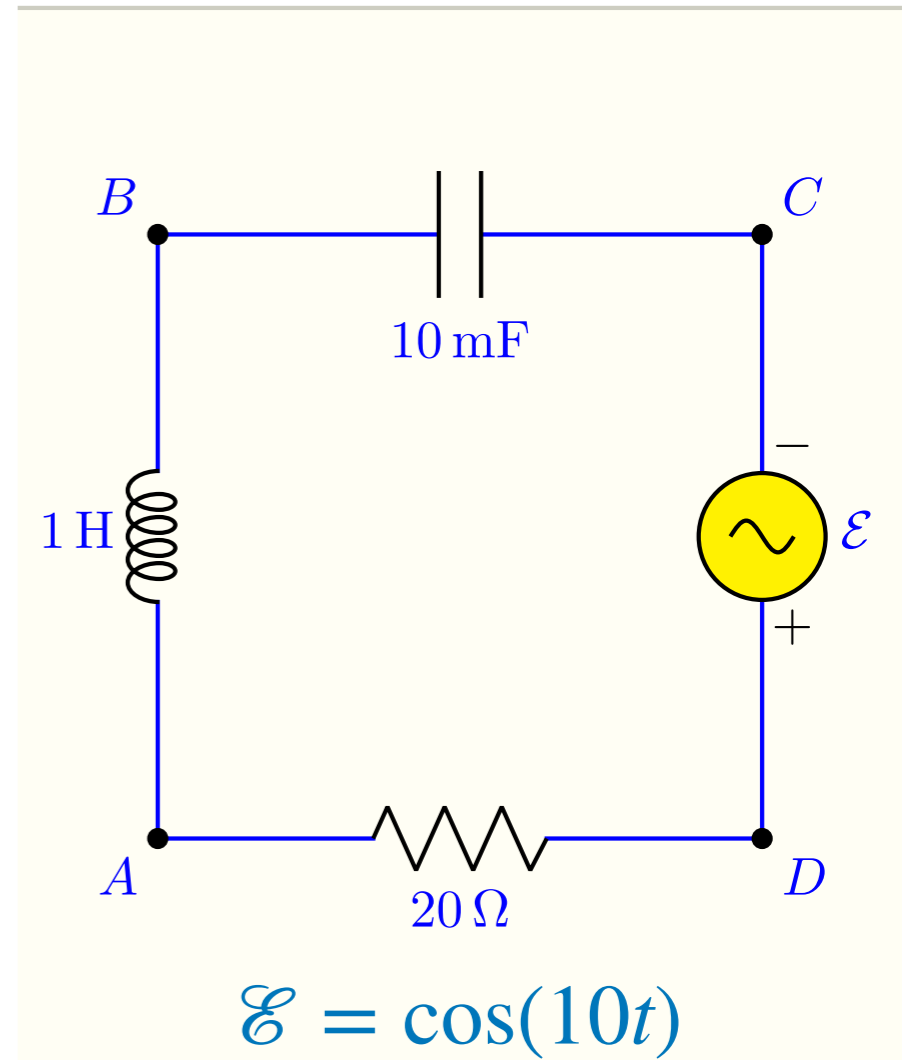
$$D = \frac{1}{\epsilon_0} \frac{Q}{A}$$

$$Q = \frac{\sin(10t)}{200}$$

$$D = \frac{1}{A\epsilon_0} \frac{\sin(10t)}{200}$$

⇒

$$A\epsilon_0 \frac{\partial D}{\partial t} = \frac{\cos(10t)}{20}$$



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

Pratique o que aprendeu
Corrente de deslocamento

$$I = \frac{1}{20} \cos(10t)$$

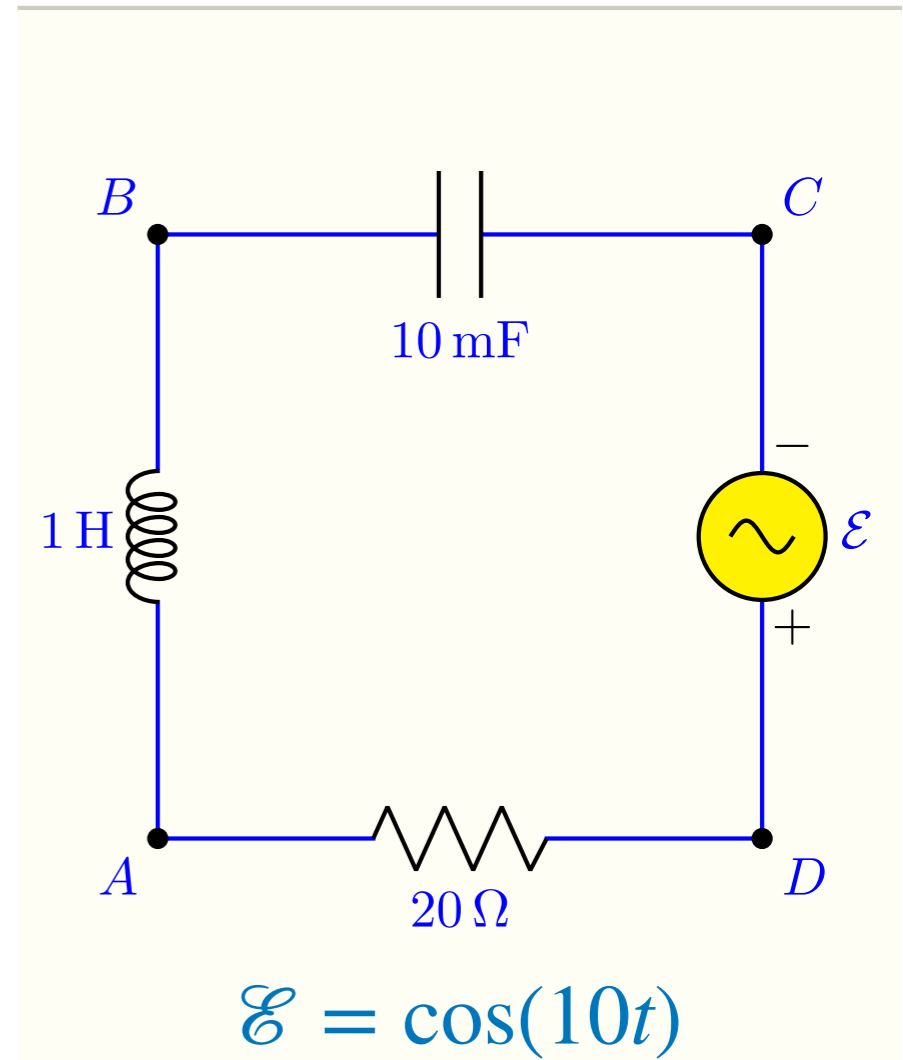
$$D = \frac{1}{\epsilon_0} \frac{Q}{A}$$

$$Q = \frac{\sin(10t)}{200}$$

$$D = \frac{1}{A\epsilon_0} \frac{\sin(10t)}{200}$$

⇒

$$A\epsilon_0 \frac{dD}{dt} = \frac{\cos(10t)}{20}$$



Equações de Maxwell Espaço livre

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

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

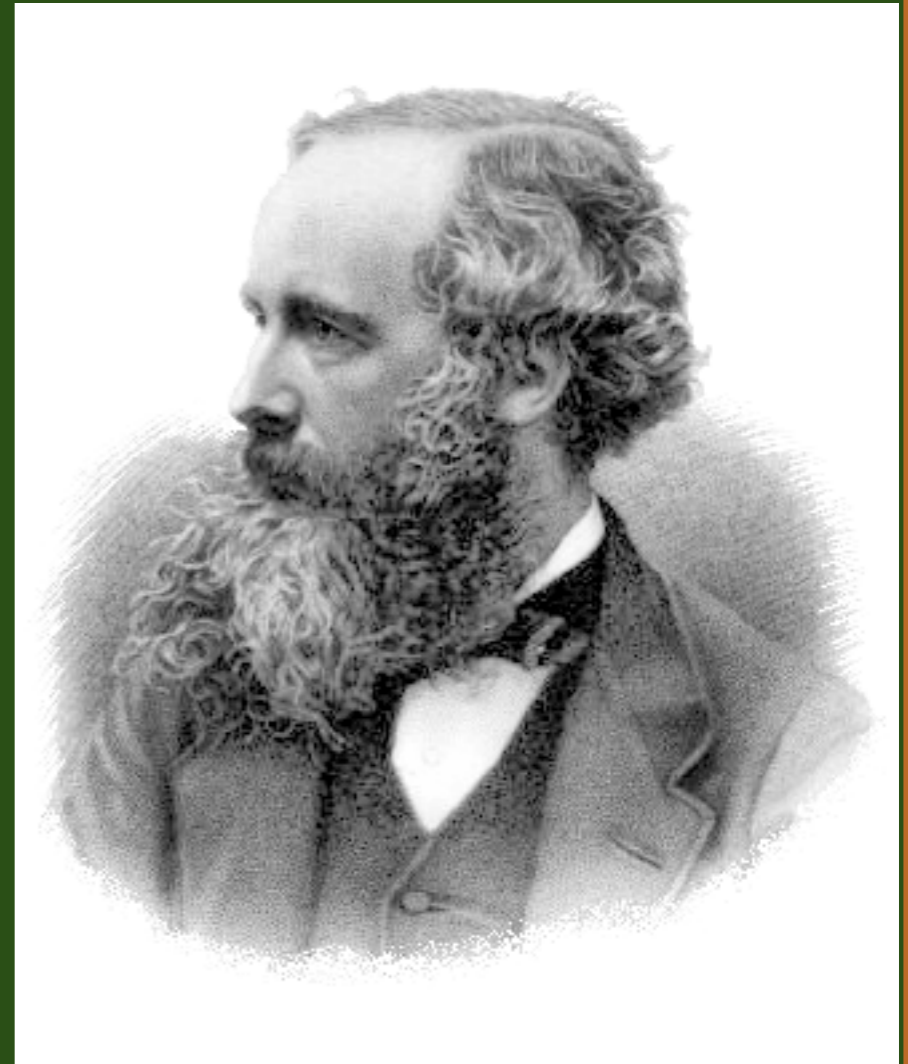
$$\vec{\nabla} \cdot \vec{B} = 0$$

$$\vec{\nabla} \times \vec{B} = \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}$$



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

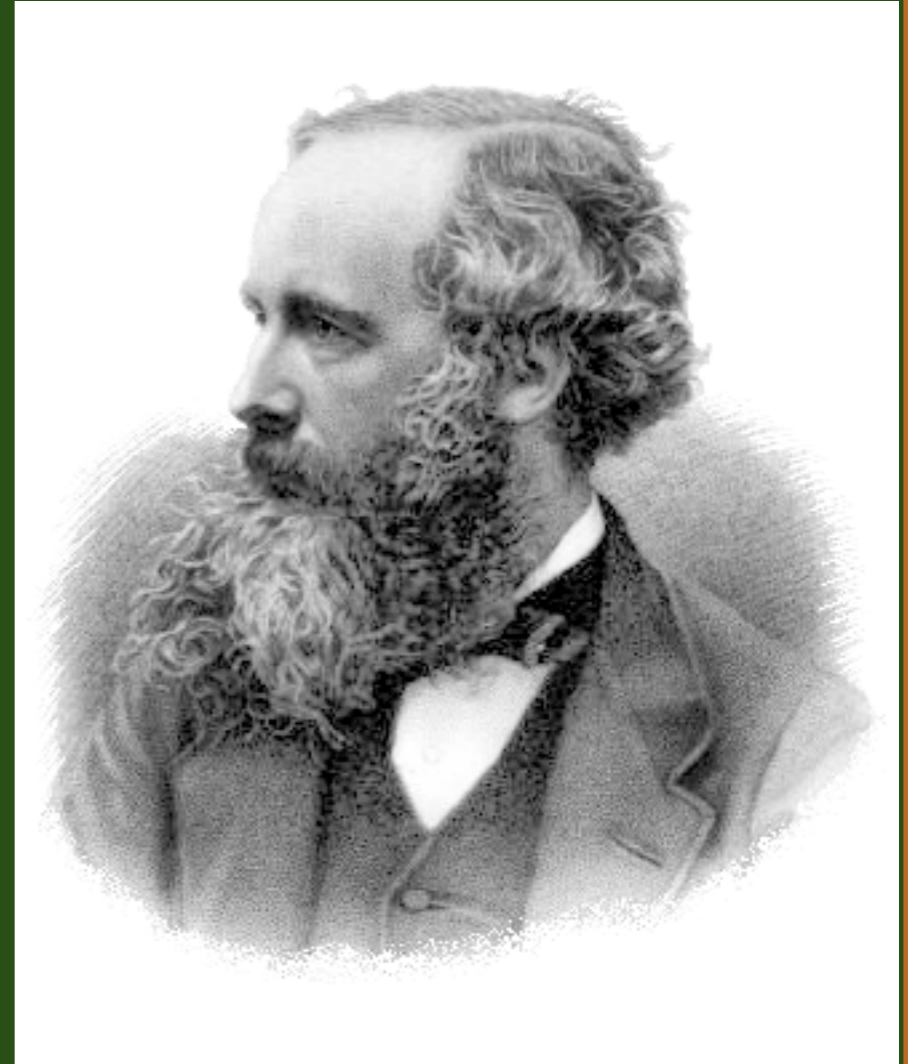
$$\vec{\nabla} \times \vec{B} = \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}$$



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

$$\vec{\nabla} \times \vec{B} = \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}$$

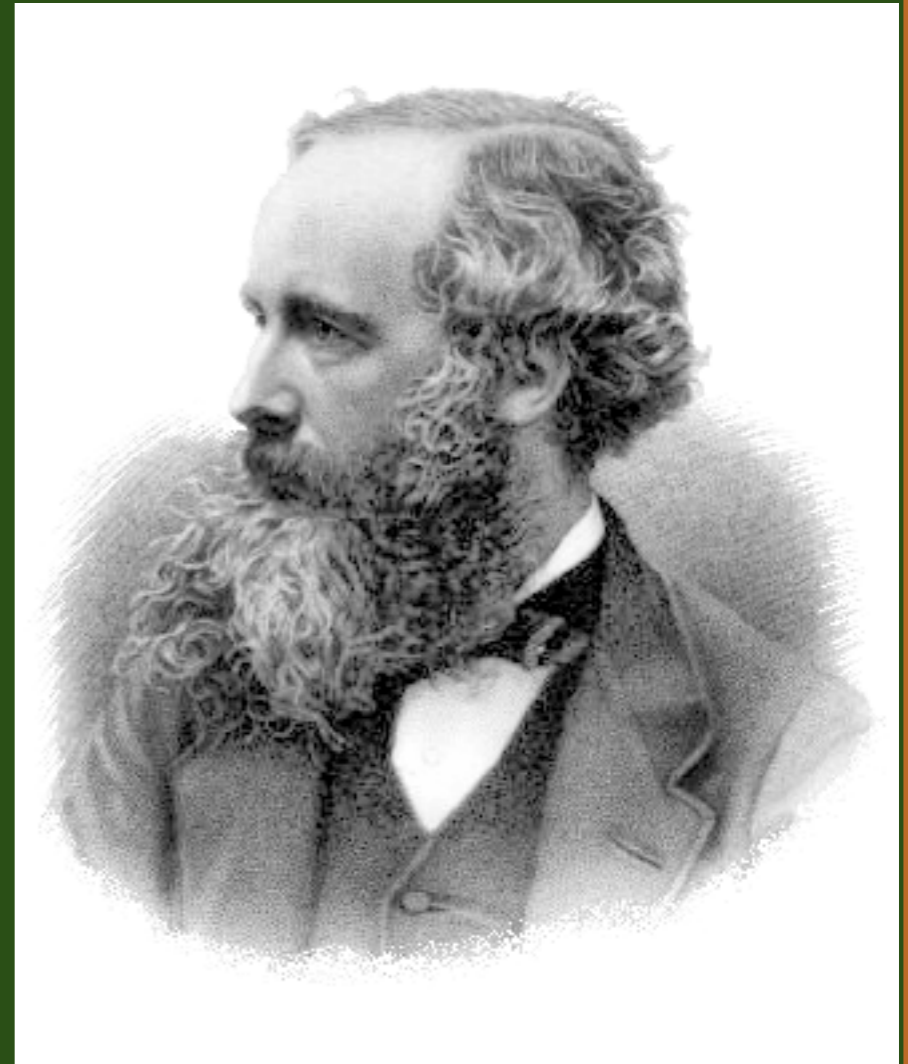
$$\vec{\nabla} \times (\vec{\nabla} \times \vec{B}) = \mu_0 \epsilon_0 \frac{\partial \vec{\nabla} \times \vec{E}}{\partial t}$$



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

$$\vec{\nabla} \times \vec{B} = \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}$$

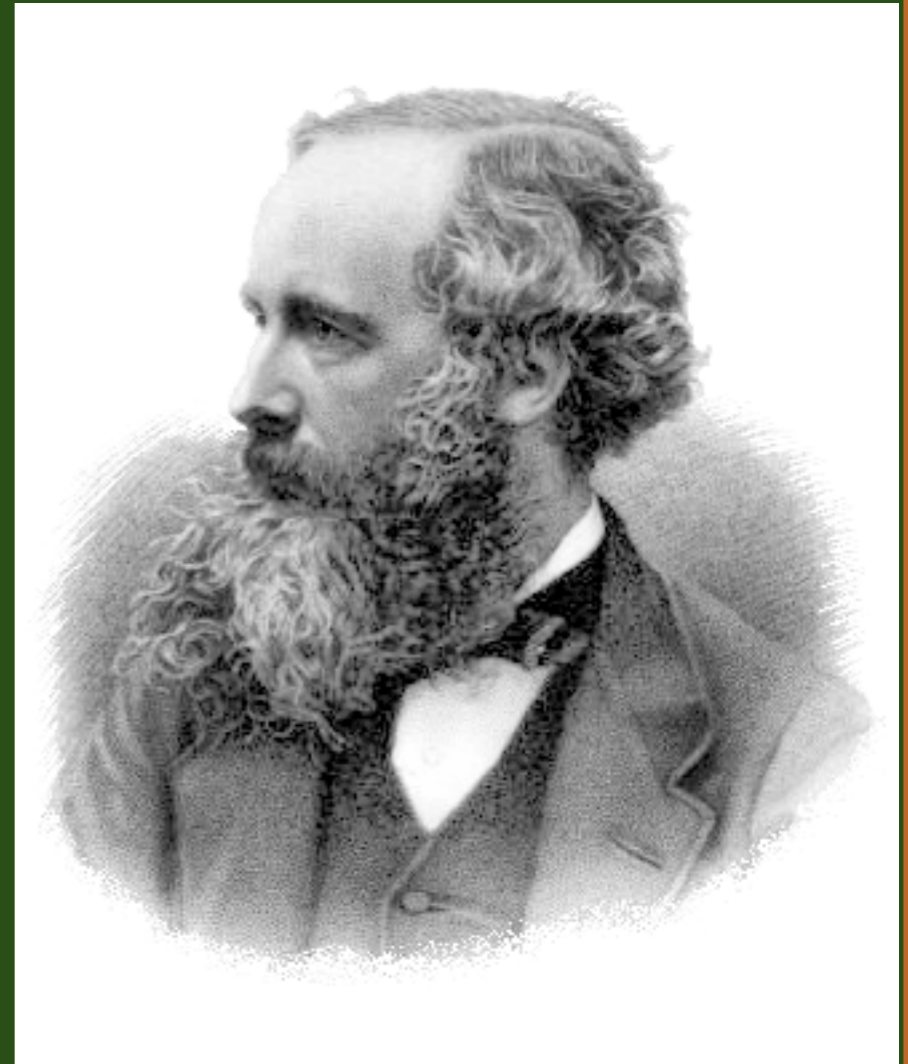
$$\vec{\nabla}(\vec{\nabla} \cdot \vec{B}) - \nabla^2 \vec{B} = -\mu_0 \epsilon_0 \frac{\partial^2 \vec{B}}{\partial t^2}$$



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

$$\vec{\nabla} \times \vec{B} = \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}$$

$$\vec{\nabla} (\vec{\nabla} \cdot \vec{B}) - \nabla^2 \vec{B} = -\mu_0 \epsilon_0 \frac{\partial^2 \vec{B}}{\partial t^2}$$

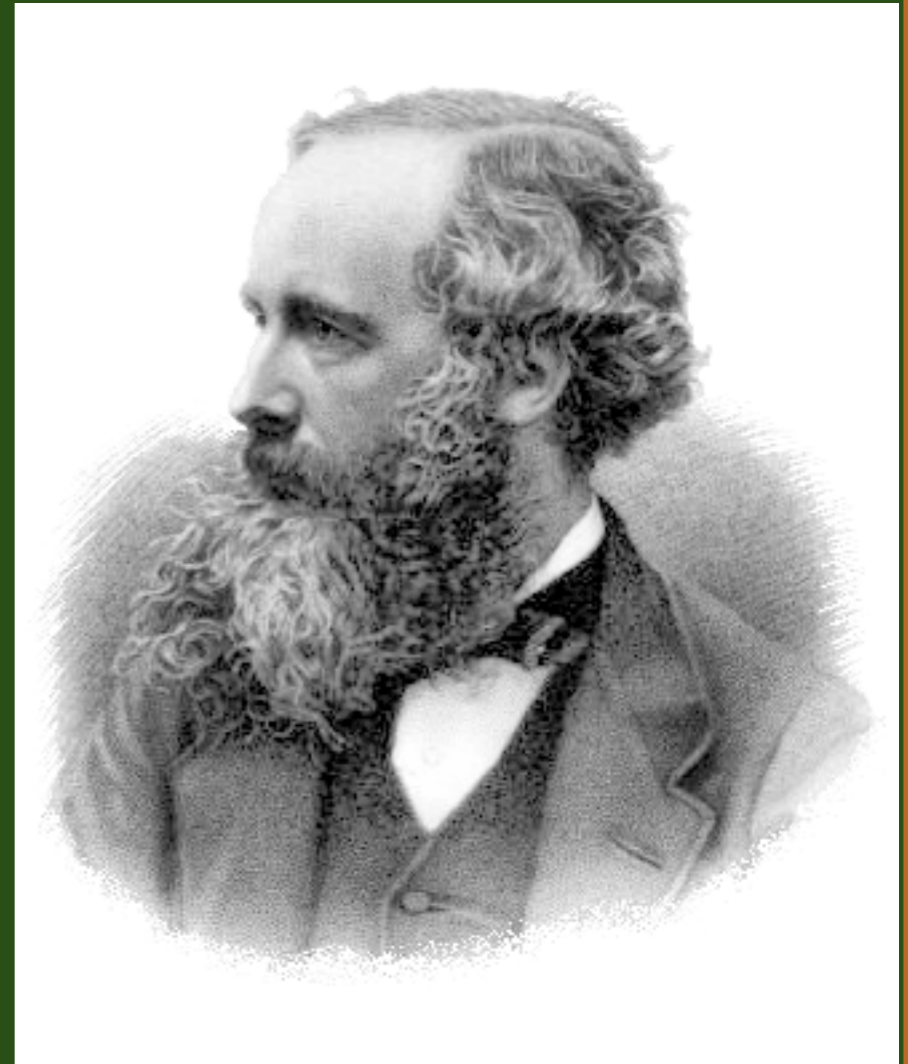


$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\vec{\nabla} \times \vec{B} = \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}$$

$$\vec{\nabla} (\vec{\nabla} \cdot \vec{B}) - \nabla^2 \vec{B} = -\mu_0 \epsilon_0 \frac{\partial^2 \vec{B}}{\partial t^2}$$

$$\nabla^2 \vec{B} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{B}}{\partial t^2}$$



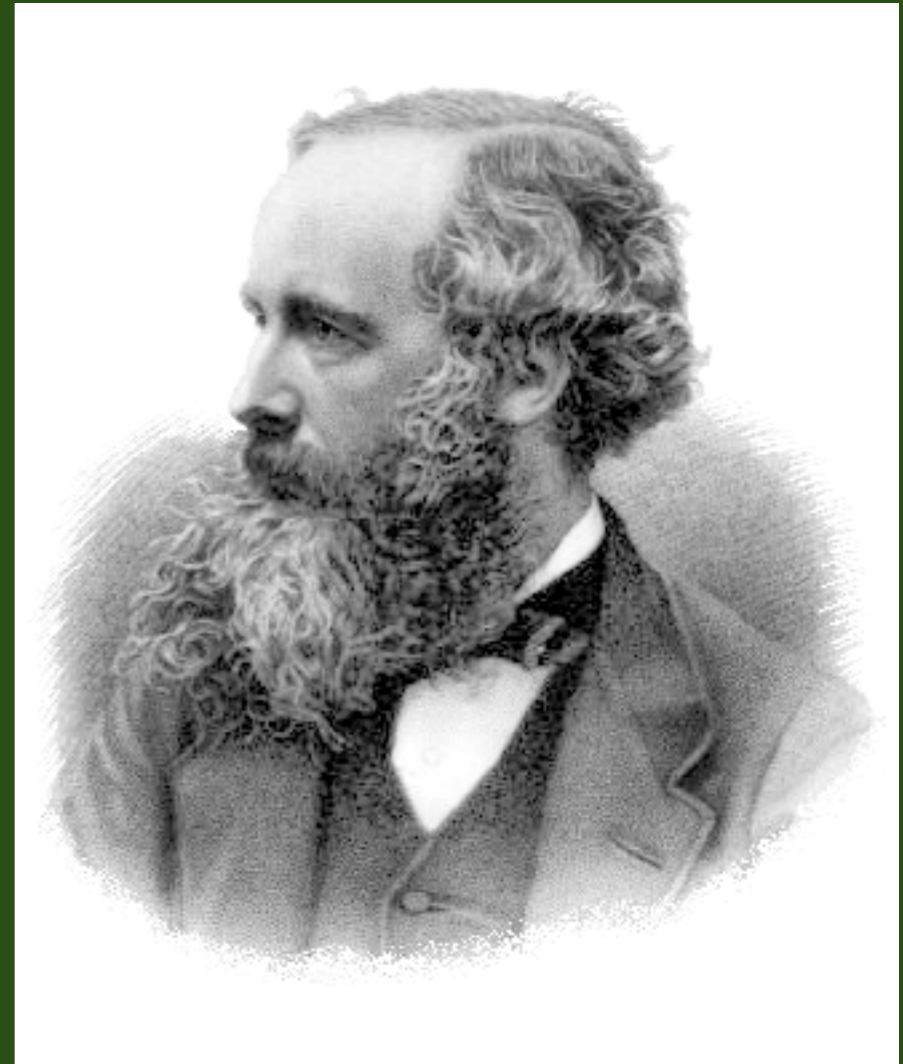
$$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\vec{\nabla} \times \vec{B} = \mu_0 \epsilon_0 \frac{\partial \vec{E}}{\partial t}$$

$$\vec{\nabla} (\vec{\nabla} \cdot \vec{B}) - \nabla^2 \vec{B} = -\mu_0 \epsilon_0 \frac{\partial^2 \vec{B}}{\partial t^2}$$

$$\nabla^2 \vec{B} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{B}}{\partial t^2}$$

$$\nabla^2 \vec{E} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{E}}{\partial t^2}$$



Equações de Maxwell Espaço livre

$$\nabla^2 \vec{E} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{E}}{\partial t^2}$$

$$\nabla^2 \vec{B} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{B}}{\partial t^2}$$



Equações de Maxwell

Espaço livre

$$\nabla^2 \vec{E} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{E}}{\partial t^2}$$

$$\nabla^2 f = \frac{1}{v^2} \frac{\partial^2 f}{\partial t^2}$$



Equações de Maxwell

Espaço livre

$$\nabla^2 \vec{E} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{E}}{\partial t^2}$$

$$\nabla^2 f = \frac{1}{v^2} \frac{\partial^2 f}{\partial t^2}$$

$$f = f(\vec{r}, t)$$



Equações de Maxwell

Espaço livre

$$\nabla^2 \vec{E} = \mu_0 \epsilon_0 \frac{\partial^2 \vec{E}}{\partial t^2}$$

$$\nabla^2 f = \frac{1}{v^2} \frac{\partial^2 f}{\partial t^2}$$

$$f = f(\vec{r}, t)$$

D'Alembert

$$f = f(\hat{k} \cdot \vec{r} - vt)$$

