FISICA 1 (PALEONTOLOGÍA)

2DO CUATRIMESTRE 2020

CLASE 23

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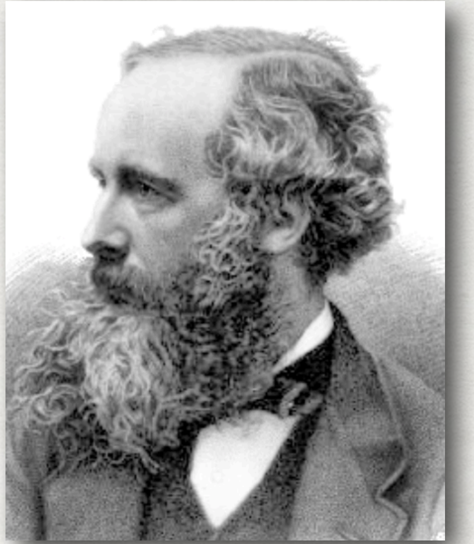
CLASE 23: Ondas electromagnéticas

Temas: Ecuaciones de Maxwell, ondas planas, espectro



James Clerck Maxwell 1831-1879

ecuaciones de Maxwell:

$$\oint \mathbf{E} \cdot d\mathbf{A} = \frac{q_{int}}{\epsilon_0}$$ Ley de Gauss para $\mathbf{E}$

$$\oint \mathbf{B} \cdot d\mathbf{A} = 0$$ Ley de Gauss para $\mathbf{B}$

$$\oint \mathbf{B} \cdot d\mathbf{l} = \mu_0 \left(i_c + \epsilon_0 \frac{d\Phi_E}{dt} \right)$$ Ley de Ampère

$$\oint \mathbf{E} \cdot d\mathbf{l} = -\frac{d\Phi_B}{dt}$$ Ley de Faraday

usando $\Phi_E \equiv \oint \mathbf{E} \cdot d\mathbf{A}$ $\quad \mu_0 \epsilon_0 \equiv \frac{1}{c^2}$

$\Phi_B \equiv \oint \mathbf{B} \cdot d\mathbf{A}$

para $q_{int} = 0 \quad i_c = 0$

$$\oint \mathbf{B} \cdot d\mathbf{l} = \frac{1}{c^2} \frac{d}{dt} \oint \mathbf{E} \cdot d\mathbf{A}$$

$$\oint \mathbf{E} \cdot d\mathbf{l} = -\frac{d}{dt} \oint \mathbf{B} \cdot d\mathbf{A}$$

ecuaciones de Maxwell en el vacío 1864

$$\mathbf{E} = \mathbf{E}(\mathbf{x}, t) \qquad \mathbf{B} = \mathbf{B}(\mathbf{x}, t)$$

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ondas planas: la solución más simple

$$\mathbf{E} = E_{max}\, cos(kx - \omega t)\,\hat{\mathbf{j}}$$

$$\mathbf{B} = B_{max}\, cos(kx - \omega t)\,\hat{\mathbf{k}}$$

$t = 0$

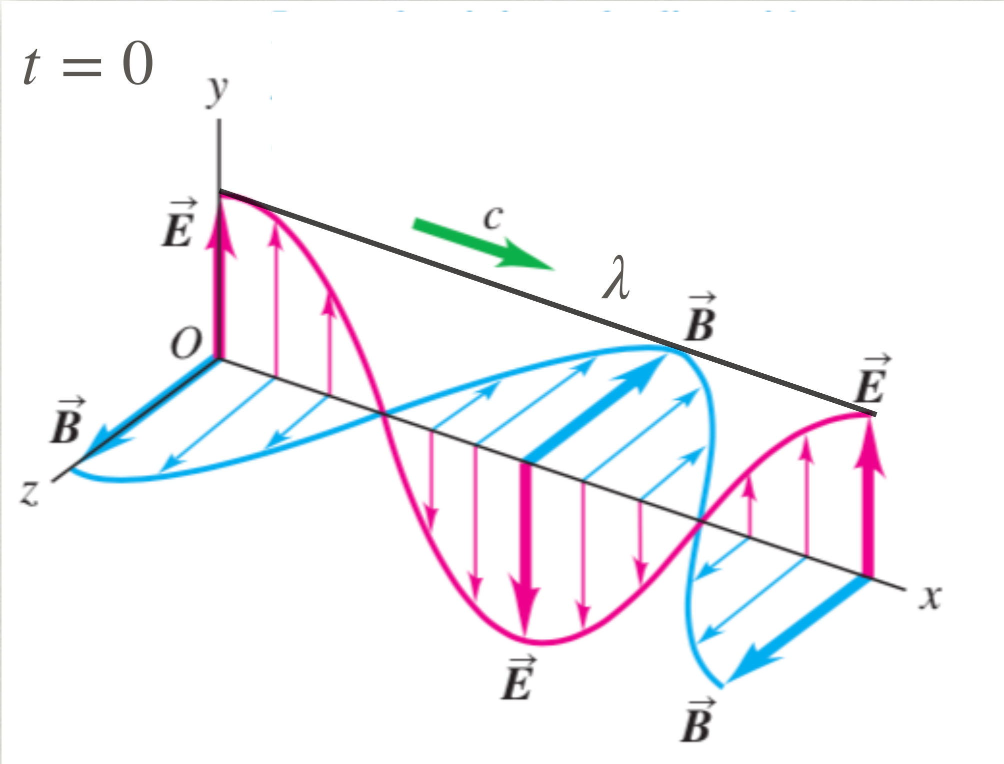
λ longitud de onda $\quad k\lambda = 2\pi \quad k = \dfrac{2\pi}{\lambda}$

$x = 0$

T período $\quad \omega T = 2\pi \quad \omega = \dfrac{2\pi}{T}$

$\dfrac{1}{T} = f$ frecuencia $\quad \omega = 2\pi f$

$$\frac{\omega}{k} = \frac{2\pi f}{2\pi/\lambda} = \lambda f = \frac{1}{\sqrt{\mu_0 \epsilon_0}} = c$$



$t = t_1$

$cos(kx - \omega t_1) = 1 \quad x = \dfrac{\omega}{k} t_1 > 0$

$$\frac{\Delta x}{\Delta t} = \frac{\omega}{k} = c$$

λ, f "espectro"

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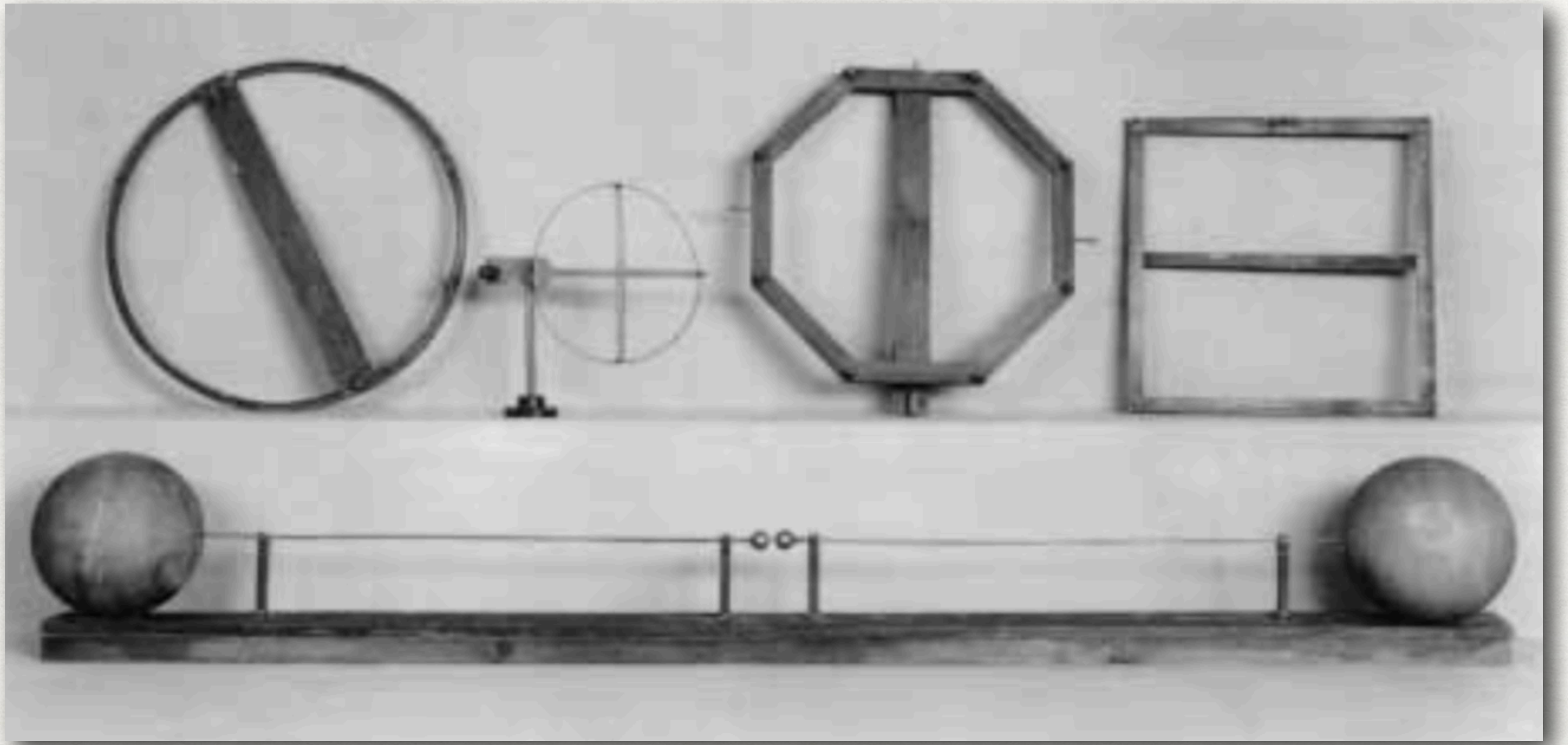
Heinrich Hertz 1857-1894

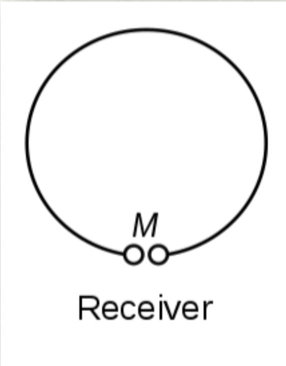
experimento de Hertz 1886: existen las ondas electromagnéticas?

una distribución de cargas estáticas generan $\mathbf{E}$ constante

una distribución de cargas a v=cte generan $\mathbf{B}$ constante

→ cargas aceleradas





$$\lambda f = c \sim 3 \times 10^8 \, m/s$$

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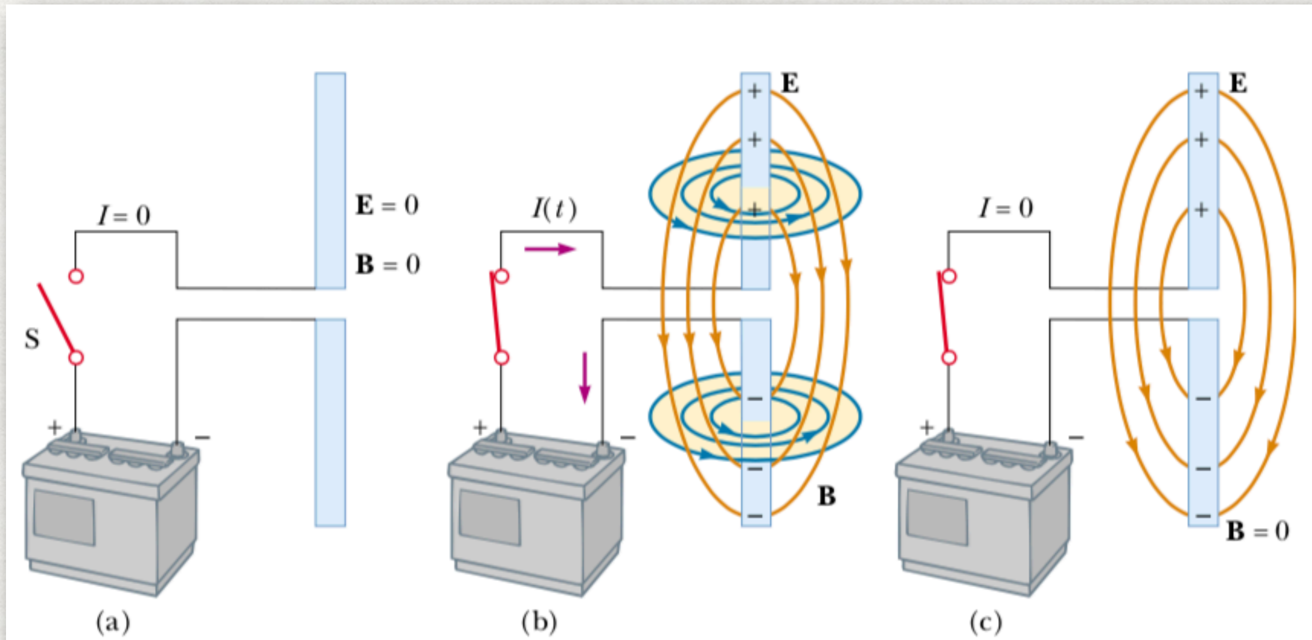
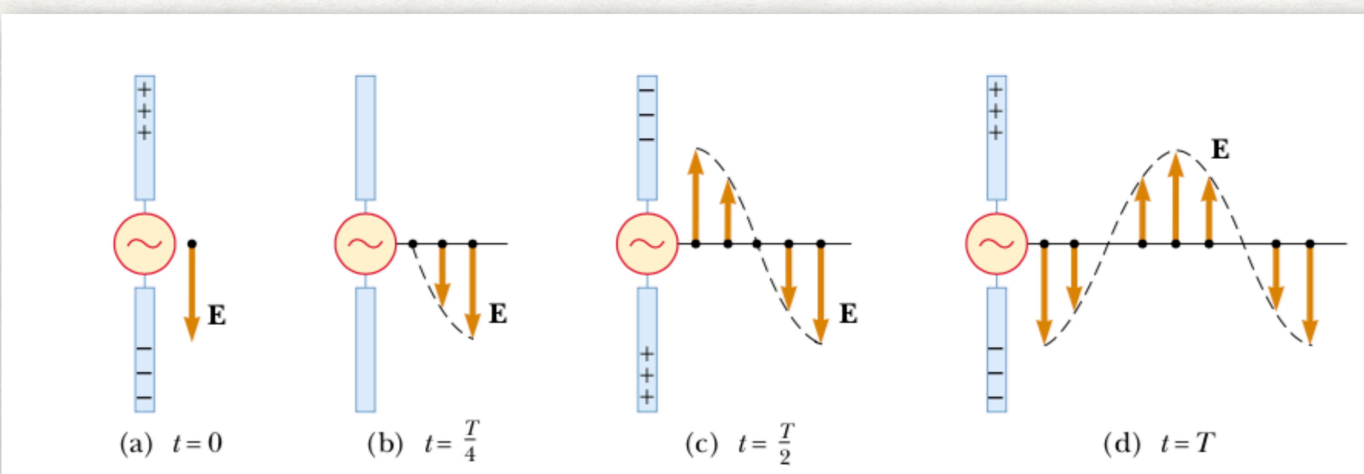
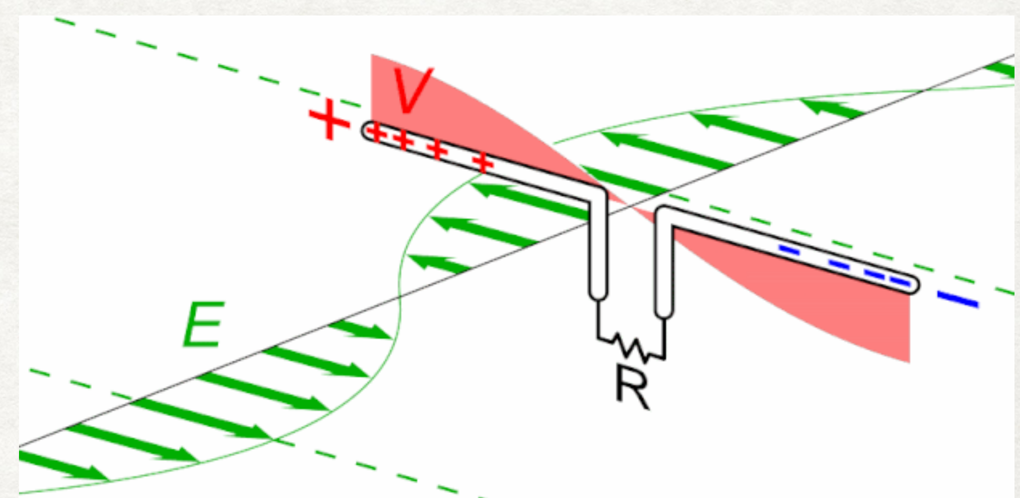
experimento de Hertz: existen las ondas electromagnéticas?



Heinrich Hertz 1857-1894





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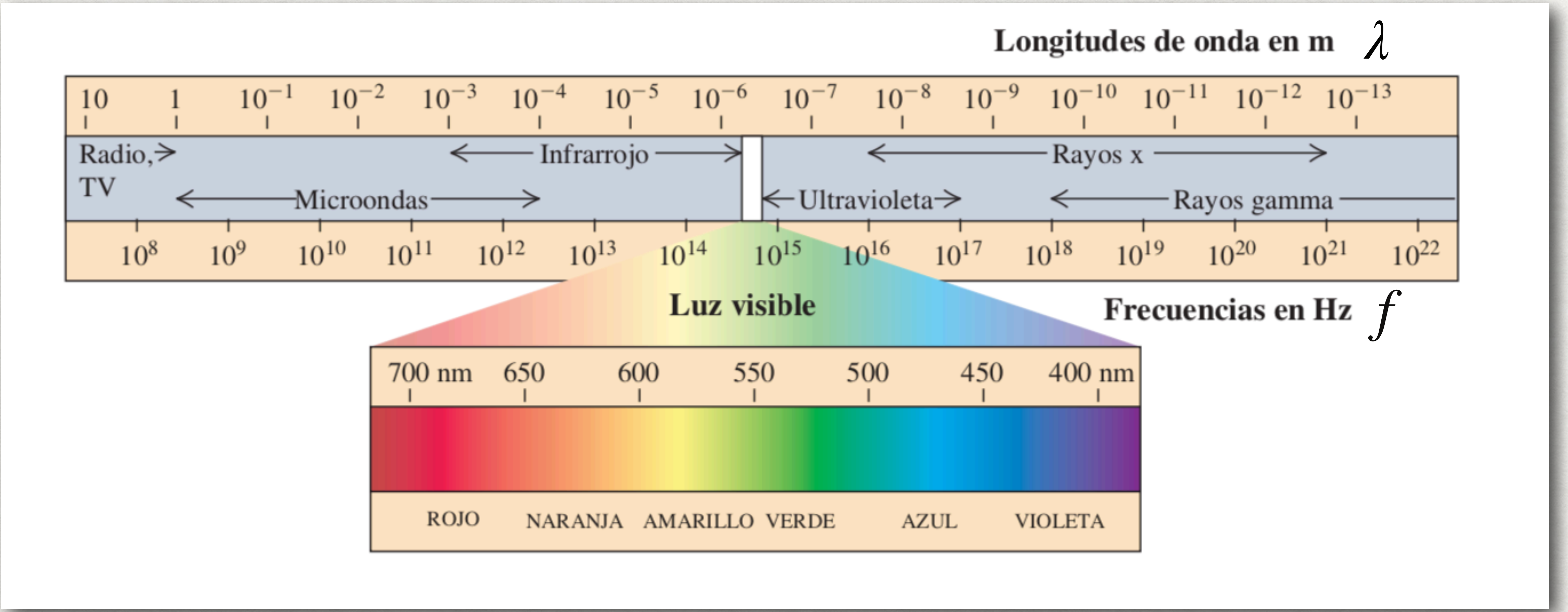
espectro electromagnético



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ondas electromagnéticas en la materia

$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}} \qquad v = \frac{1}{\sqrt{\mu\, \epsilon}} = \frac{1}{\sqrt{K_m \mu_0\, K\, \epsilon_0}}$$

K_m permeabilidad relativa

K constante dieléctrica

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$$v = \frac{1}{\sqrt{\mu_0 \epsilon_0}}\, \frac{1}{\sqrt{K_m\, K}} = \frac{c}{\sqrt{K_m\, K}}$$

$K \geq 1$

$K_M \sim 1$ salvo ferromangnéticos

$$v \leq c$$

ejemplos:

lámpara de vapor de sodio $f = 5.9 \times 10^{14}\, Hz$

diamante $K = 5.84$ *y* $K_M = 1.00$

$$\lambda_{vacio} = \frac{c}{f} = \frac{3 \times 10^8\, m/s}{5.9 \times 10^{14} 1/s} = 589\, nm$$

$$v_{diamante} = \frac{c}{\sqrt{K_m\, K}} = \frac{3 \times 10^8\, m/s}{\sqrt{5.84 \times 1}} = 1.24 \times 10^8\, m/s$$

$$\lambda_{diamante} = \frac{v}{f} = \frac{1.24 \times 10^8\, m/s}{5.9 \times 10^{14} 1/s} = 244\, nm$$

radio FM $f = 90\, MHz$

ferrita $K = 10$ *y* $K_M = 1000$

$$\lambda_{vacio} = \frac{c}{f} = \frac{3 \times 10^8\, m/s}{90 \times 10^{6} 1/s} = 3.33\, m$$

$$v_{ferrita} = \frac{c}{\sqrt{K_m\, K}} = \frac{3 \times 10^8\, m/s}{\sqrt{10 \times 1000}} = 3 \times 10^6\, m/s$$

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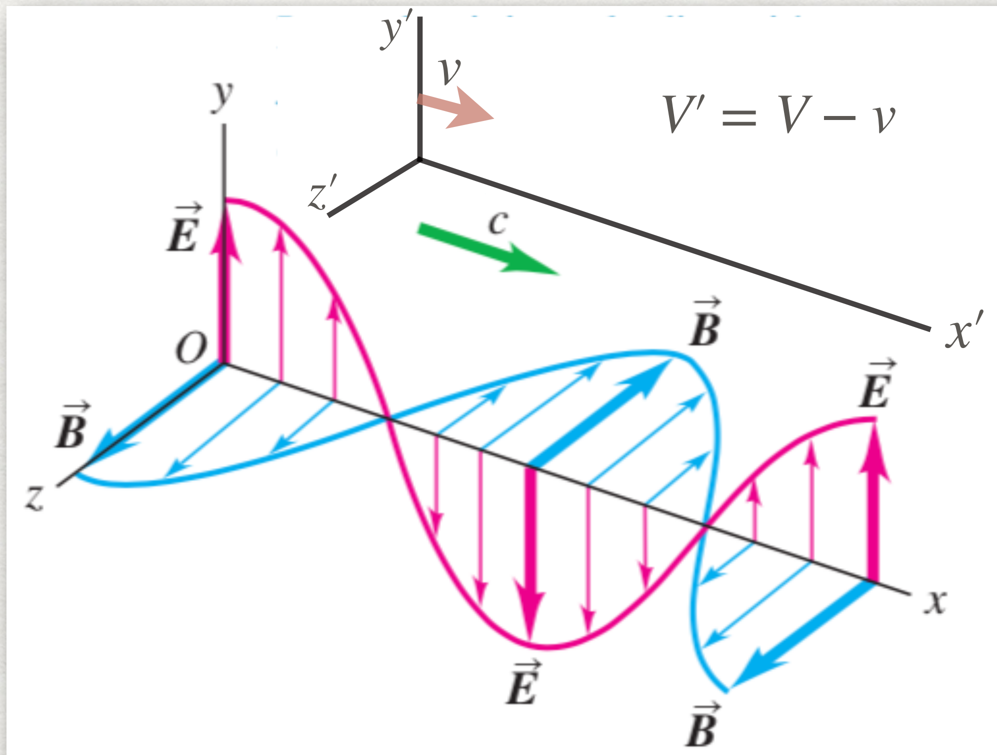
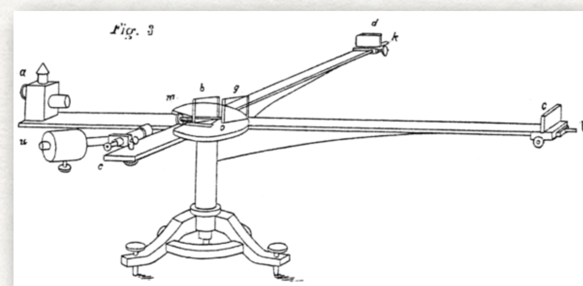
ondas electromagnéticas y relatividad especial: c con respecto a quién?

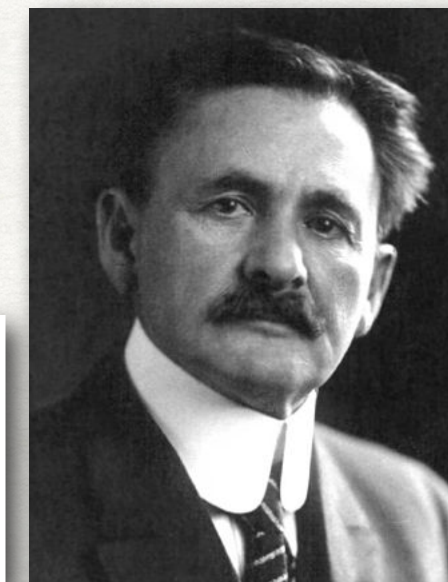


$$c = \frac{1}{\sqrt{\mu_0 \epsilon_0}}$$

respecto al aether?

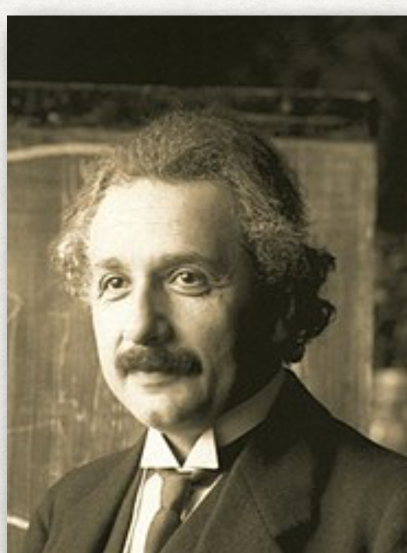
1887





Albert Michelson

Edward Morley



respecto a quien sea: teoría especial de la relatividad 1905

$$V' = \frac{V - v}{1 - \frac{vV}{c^2}}$$

Albert Einstein 1879-1955