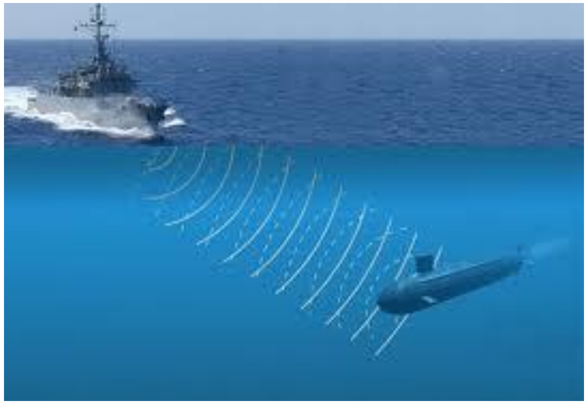
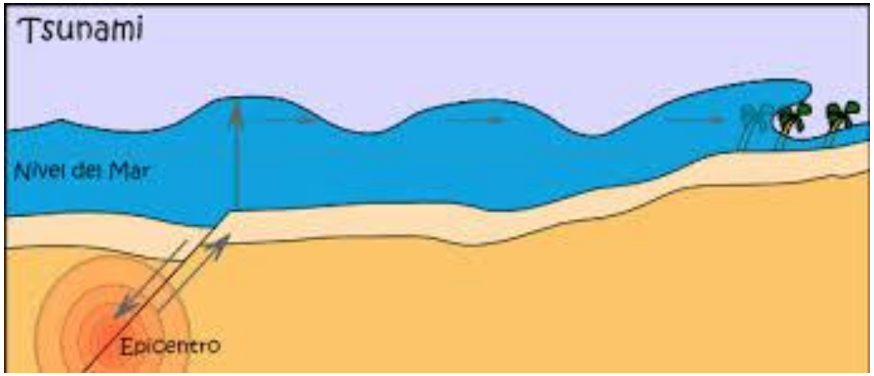
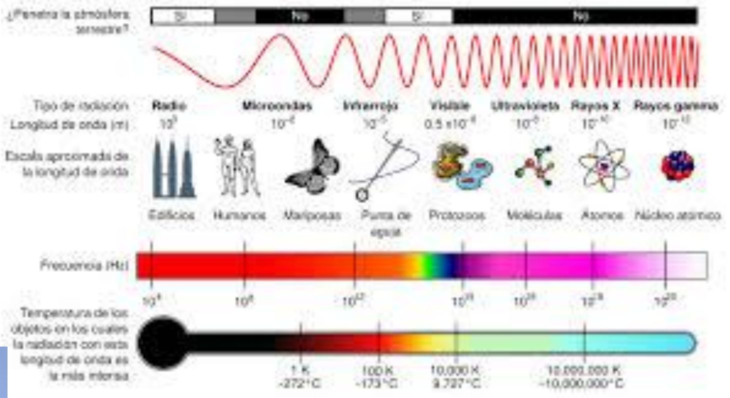
Ondas



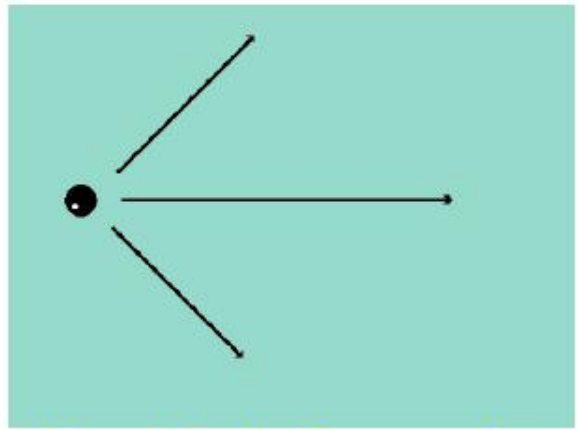

Tsunami
Nivel del Mar
Epicentro


Tipo de radiación
Longitud de onda (m)
Radio
Microondas
Infrarrojo
Visible
Ultravioleta
Rayos X
Rayos gamma
Escala aproximada de la longitud de onda
Edificios
Humanos
Mariposas
Punta de aguja
Protozoos
Moléculas
Átomos
Núcleo atómico
Frecuencia (Hz)
1 K -272°C
100 K -173°C
10,000 K 9,727°C
10,000,000 K ~10,000,000°C

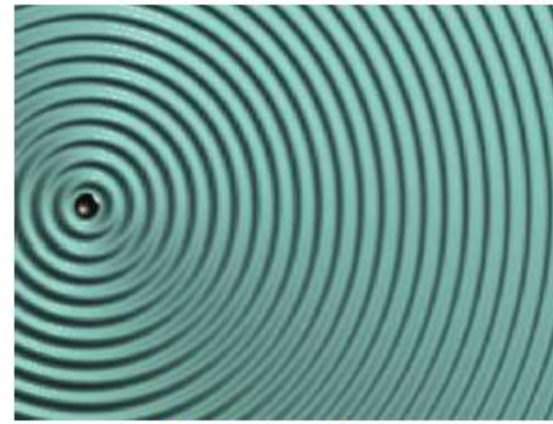
Ondas

Perturbaciones en un medio y su propagación

Medio en Equilibrio



Dirección de Propagación



Deformaciones

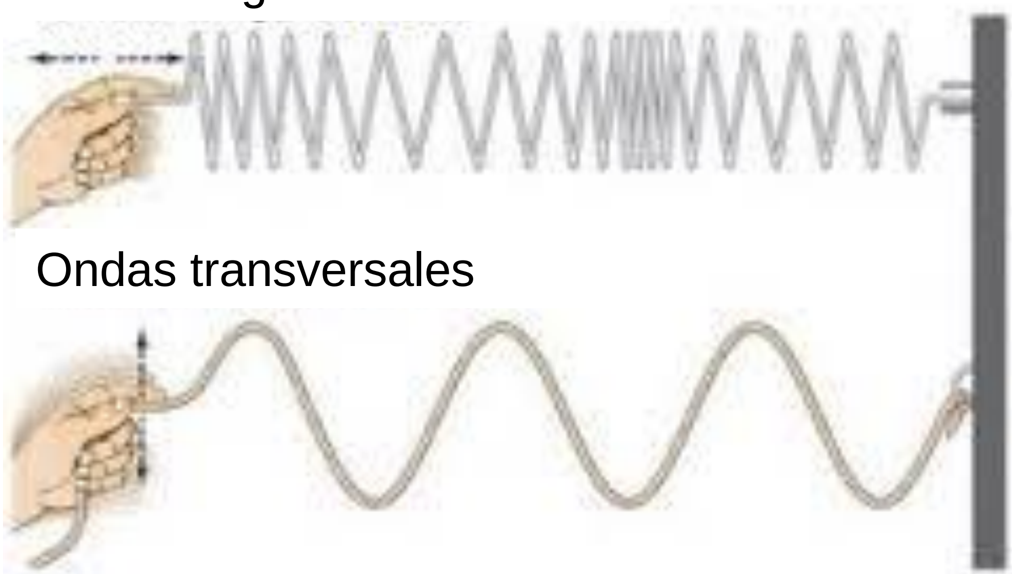
$$\vec{\varepsilon} = \vec{\varepsilon}(\vec{r}, t)$$

$$\vec{\varepsilon}(\vec{r}, t) = \varepsilon_x(xyz, t)\vec{i} + \varepsilon_y(xyz, t)\vec{j} + \varepsilon_z(xyz, t)\vec{k}$$

Ondas

Perturbaciones en un medio y su propagación

Ondas longitudinales

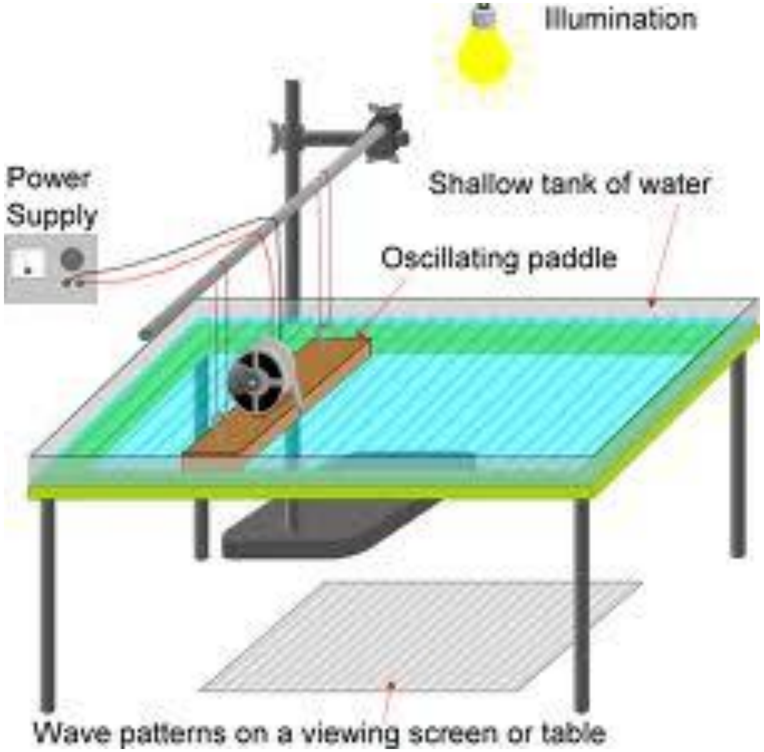


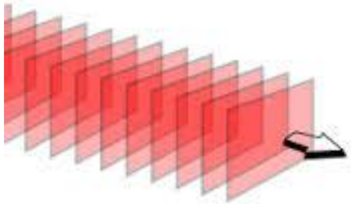
Ondas

Frentes de ondas: Plano

$$\vec{\varepsilon} = \vec{\varepsilon}(x, t)$$

$$\vec{\varepsilon}(\vec{r}, t) = \varepsilon_x(x, t)\vec{i} + \varepsilon_y(x, t)\vec{j} + \varepsilon_z(x, t)\vec{k}$$



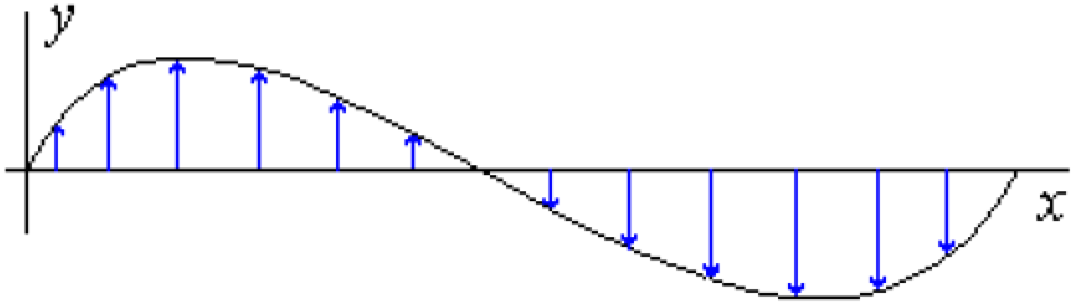


Ondas

Frentes de ondas: Plano

Polarización lineal

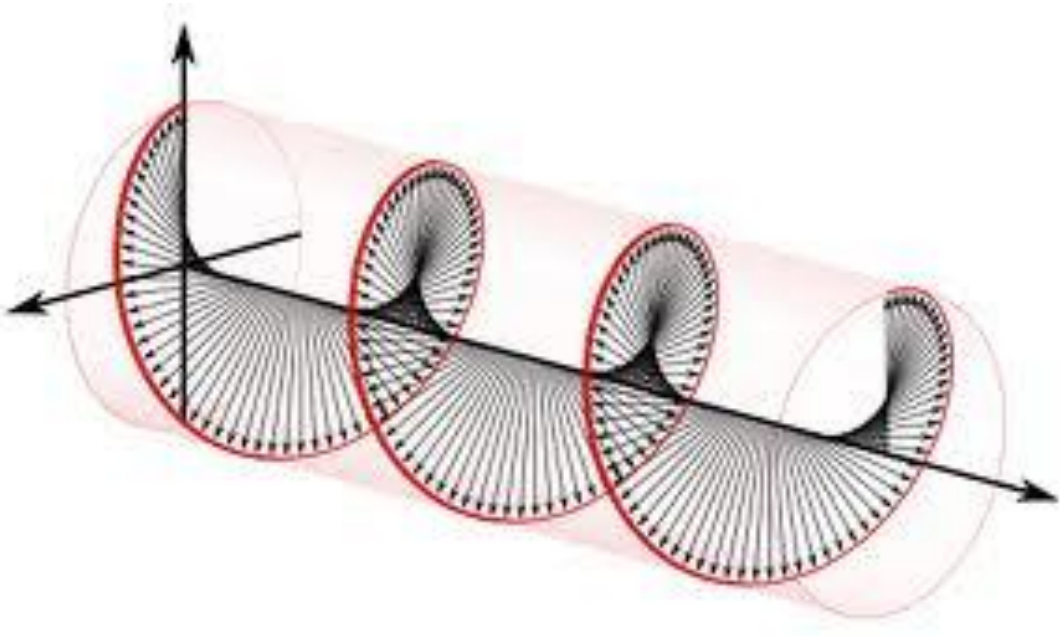
$$\vec{\varepsilon} = \varepsilon(x,t)\vec{j}$$



Ondas

Frentes de ondas: Plano

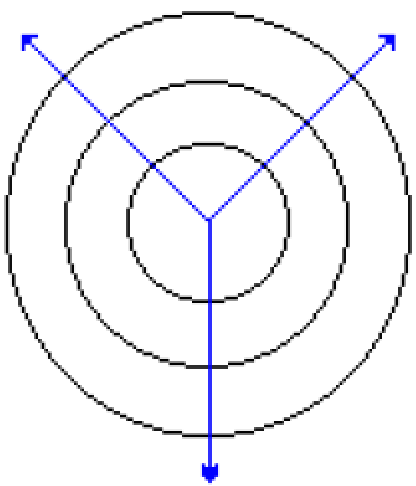
Polarización circular



Ondas

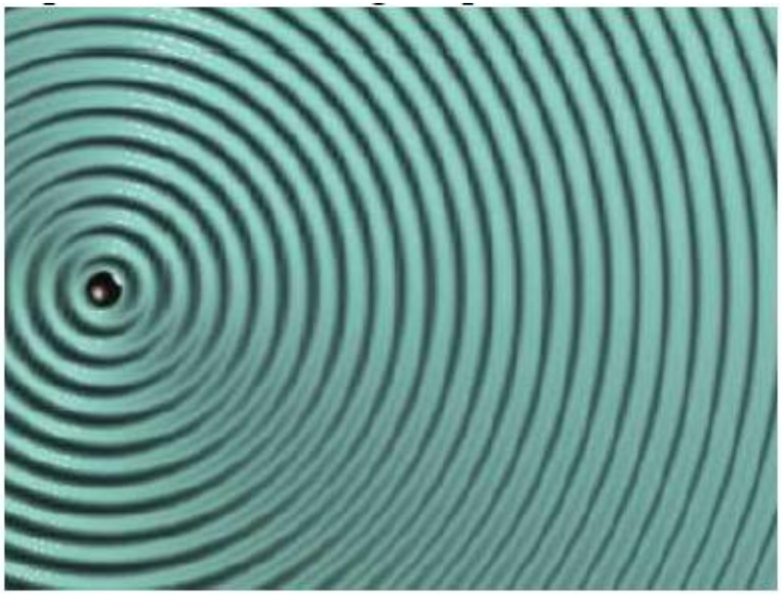
Frentes de ondas: Esférico

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



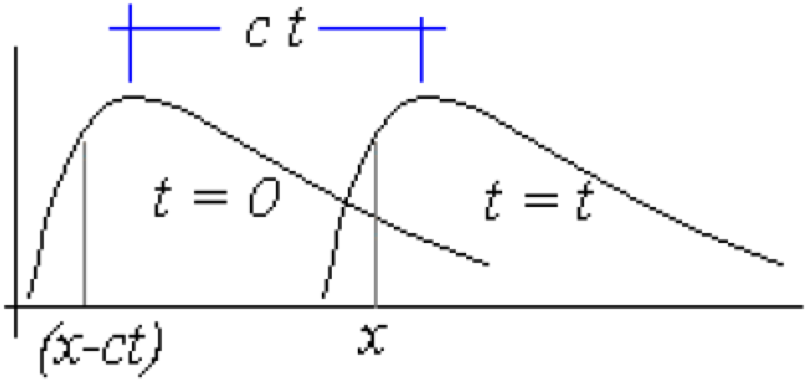
Ondas

Frentes de ondas: Circular



Ondas

Ecuación de las ondas



$$\varepsilon = \varepsilon(x - ct) \quad \rightarrow$$

$$\varepsilon = \varepsilon(x + ct) \quad \leftarrow$$

Definiendo la variable:

$$\xi = x \pm ct$$

Podemos escribir la perturbación de manera general como

$$\varepsilon = \varepsilon(\xi)$$

Ondas

Ecuación de las ondas

Derivando respecto de x

$$\frac{\partial \varepsilon}{\partial x} = \frac{\partial \varepsilon}{\partial \xi}\frac{\partial \xi}{\partial x} = \frac{\partial \varepsilon}{\partial \xi}$$

$$\frac{\partial^2 \varepsilon}{\partial x^2} = \frac{\partial}{\partial \xi}\left(\frac{\partial \varepsilon}{\partial x}\right)\frac{\partial \xi}{\partial x} = \frac{\partial}{\partial \xi}\left(\frac{\partial \varepsilon}{\partial \xi}\right) = \boxed{\frac{\partial^2 \varepsilon}{\partial \xi^2}}$$

Derivando respecto de t

$$\frac{\partial \varepsilon}{\partial t} = \frac{\partial \varepsilon}{\partial \xi}\frac{\partial \xi}{\partial t} = \pm c\,\frac{\partial \varepsilon}{\partial \xi}$$

$$\frac{\partial^2 \varepsilon}{\partial t^2} = \frac{\partial}{\partial \xi}\left(\frac{\partial \varepsilon}{\partial t}\right)\frac{\partial \xi}{\partial t}$$

$$= \frac{\partial}{\partial \xi}\left(\pm c\,\frac{\partial \varepsilon}{\partial \xi}\right)(\pm c) = c^2\boxed{\frac{\partial^2 \varepsilon}{\partial \xi^2}}$$

$$\boxed{\frac{\partial^2 \varepsilon}{\partial x^2} - \frac{1}{c^2}\frac{\partial^2 \varepsilon}{\partial t^2} = 0}$$

Ondas

Ecuación de las ondas

$$\frac{\partial^2 \varepsilon}{\partial x^2} - \frac{1}{c^2}\frac{\partial^2 \varepsilon}{\partial t^2} = 0$$

$$\nabla^2 \vec{\varepsilon} - \frac{1}{c^2}\frac{\partial^2 \vec{\varepsilon}}{\partial t^2} = 0$$

$$\nabla^2 \varepsilon_x - \frac{1}{c^2}\frac{\partial^2 \varepsilon_x}{\partial t^2} = 0$$

$$\nabla^2 \varepsilon_y - \frac{1}{c^2}\frac{\partial^2 \varepsilon_y}{\partial t^2} = 0$$

$$\nabla^2 \varepsilon_z - \frac{1}{c^2}\frac{\partial^2 \varepsilon_z}{\partial t^2} = 0$$

Ondas

Ecuación de las ondas

Ecuación de Navier–Stokes (fluido incompresible)

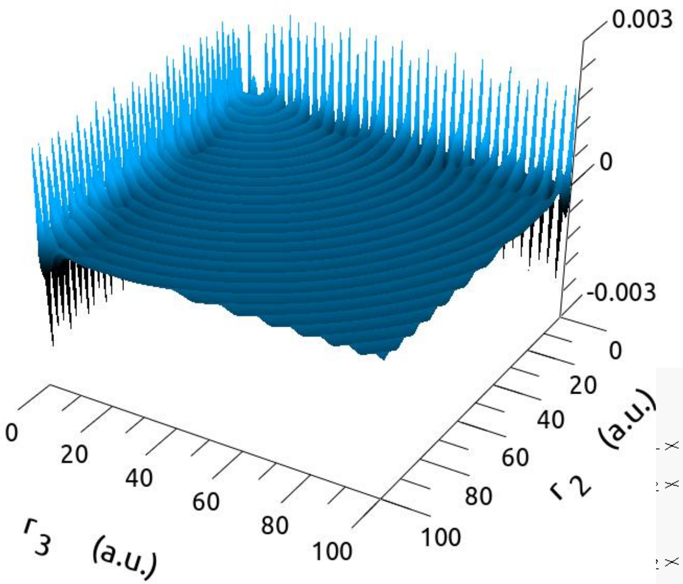
$$\rho\left(\frac{\partial \mathbf{v}}{\partial t} + \mathbf{v}\cdot\nabla\mathbf{v}\right) = -\nabla p + \mu\nabla^2\mathbf{v} + \mathbf{f}.$$

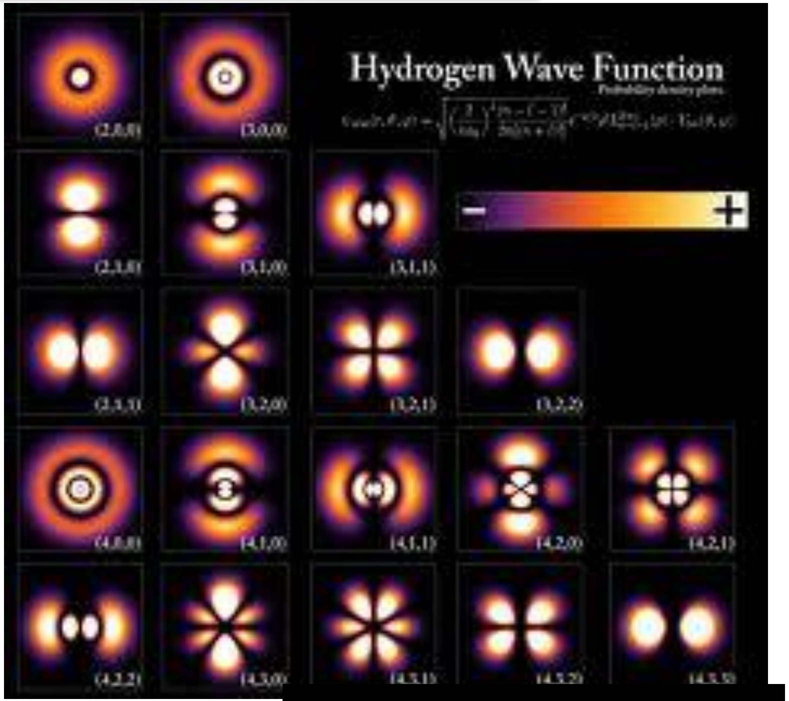
Ondas

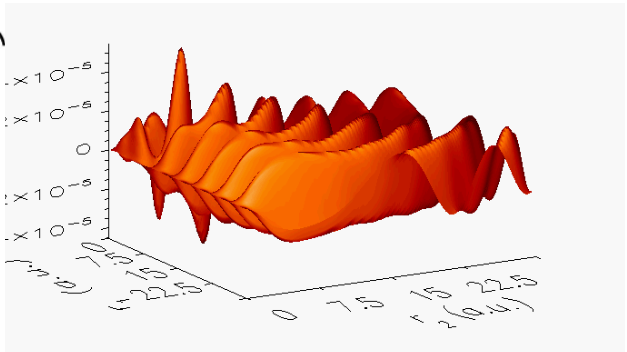
Ecuación de las ondas

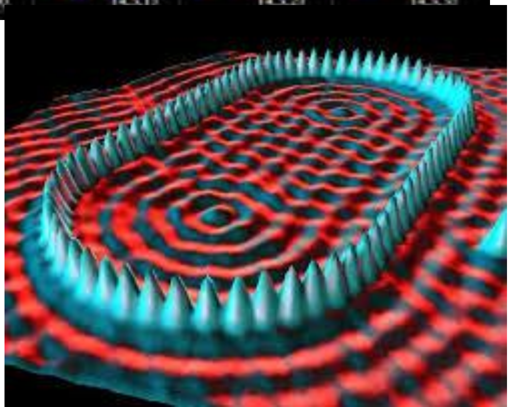
Ecuación de Schrödinger

$$[\frac{-\hbar^2}{2m}\nabla^2+V]\Psi=i\hbar\frac{\partial}{\partial t}\Psi$$







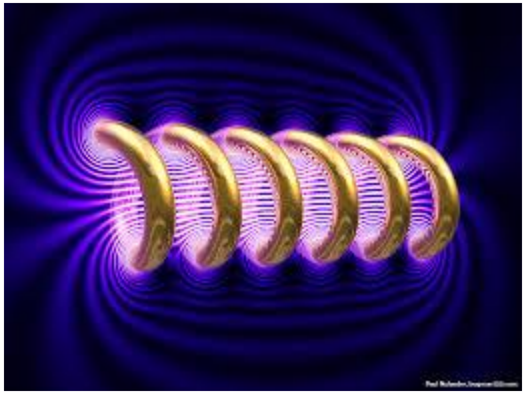


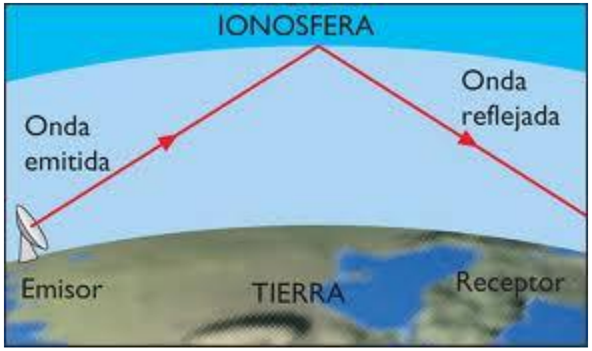
Ondas

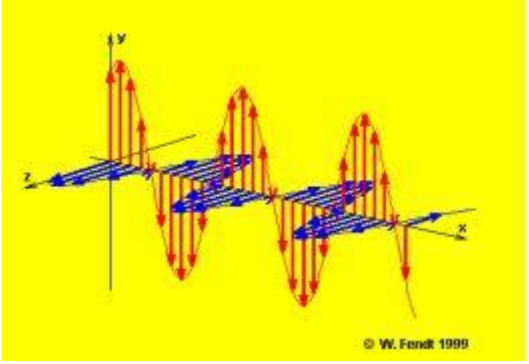
Ecuación de las ondas

Ecuaciones de Maxwell

$$\nabla \cdot \mathbf{D} = \rho$$
$$\nabla \cdot \mathbf{B} = 0$$
$$\nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$
$$\nabla \times \mathbf{H} = \mathbf{J} + \frac{\partial \mathbf{D}}{\partial t}$$







Ondas

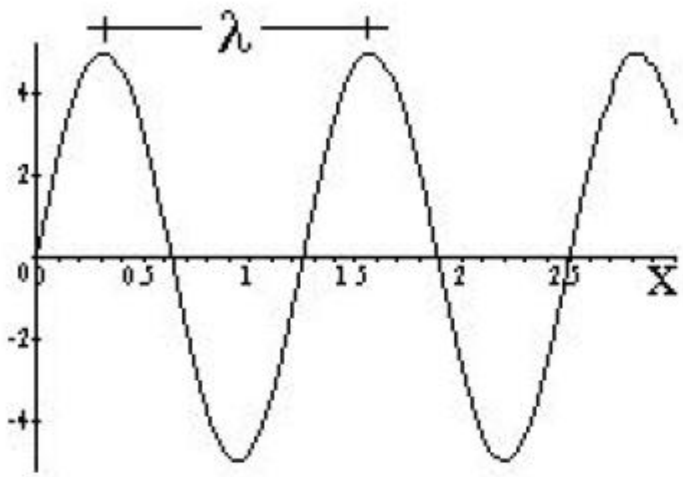
Ondas Sinusoidales

$$\varepsilon = \varepsilon_o \operatorname{sen}(kx - wt)$$

$$\frac{w}{k} = c$$

$$\varepsilon = \varepsilon_o \operatorname{sen} k(x - ct)$$

Para un momento particular del tiempo (que podemos elegir sin inconvenientes que sea t=0)



$$\lambda = \frac{2\pi}{k} \Rightarrow k = \frac{2\pi}{\lambda}$$

número de onda

Ondas

Ondas Sinusoidales

$$\varepsilon = \varepsilon_{\circ}\,\mathrm{sen}(-wt) = -\varepsilon_{\circ}\,\mathrm{sen}(wt)$$

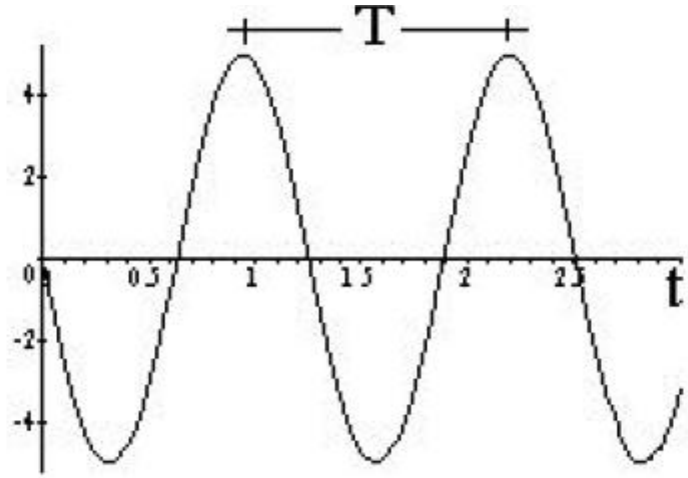
$$\varepsilon_{\circ}\,\mathrm{sen}(wt) = \varepsilon_{\circ}\,\mathrm{sen}\,w(t+T)$$

$$T = \frac{2\pi}{w}$$

frecuencia angular

$$w = \frac{2\pi}{T}$$

Para un punto espacial particular (que podemos elegir sin inconvenientes que sea x=0)



Ondas

Ondas Sinusoidales

frecuencia

$$\lambda\nu = c$$

$$\lambda = \frac{c}{\nu}$$

$$\varepsilon = \varepsilon_{\circ}\,\mathrm{sen}\,\frac{2\pi}{\lambda}(x - ct) \qquad \varepsilon = \varepsilon_{\circ}\,\mathrm{sen}\,\frac{2\pi}{T}\left(\frac{x}{c} - t\right) \qquad \varepsilon = \varepsilon_{\circ}\,\mathrm{sen}\,2\pi\nu\left(\frac{x}{c} - t\right)$$