Biomedical Imaging - Intro

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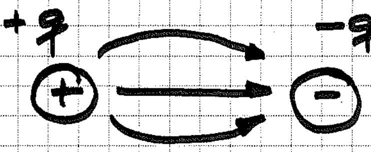
Electromagnetic radiation

- **Electric field $\vec{E}$**

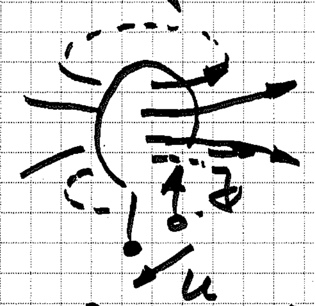


$$\vec{\nabla}\vec{E} = \frac{\rho_q}{\varepsilon_0}$$

"charge density"

"permittivity" (ability to polarize)

- **Magnetic field $\vec{B}$**

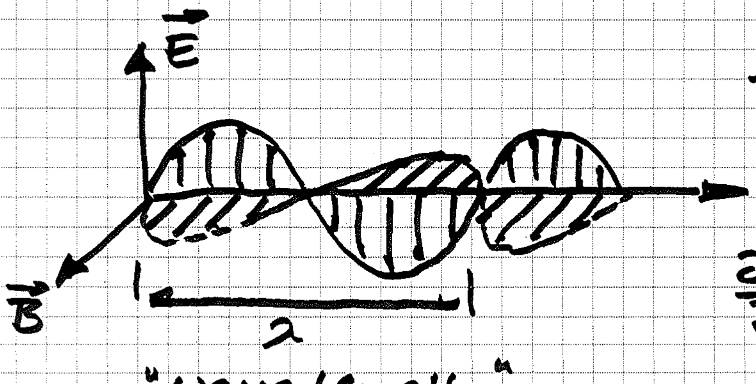


$$\vec{\nabla}\times\vec{B} = \mu_0 \vec{I}$$

"permeability" (ability to magnetize)

"current density"

$$\left[\vec{\nabla}\times\vec{B} = \mu_0 \vec{I} + \varepsilon_0\mu_0 \frac{\partial \vec{E}}{\partial t}\right]$$



"wave length"

$$\frac{\partial^2 \vec{E}}{\partial t^2} - c_0^2 \vec{\nabla}^2 \vec{E} = 0$$

$$\frac{\partial^2 \vec{B}}{\partial t^2} - c_0^2 \vec{\nabla}^2 \vec{B} = 0$$

- **Wave speed c_0**

$$c_0 = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = 3 \cdot 10^8 \frac{m}{s}$$

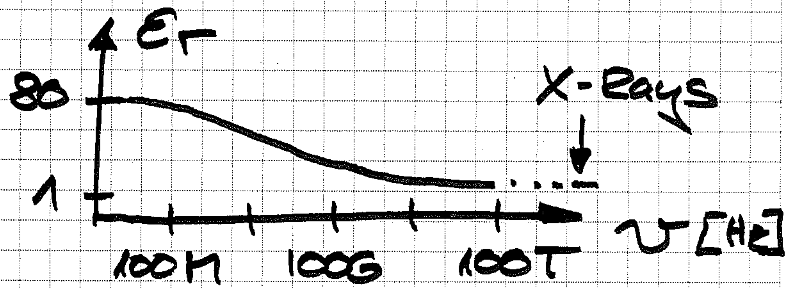
EM radiation in biological tissue

2

- **Permeability μ** $\quad \mu = \mu_r \mu_0$

  $\rightarrow \mu_r \sim 1$ in tissue

- **Permittivity ε** $\quad \varepsilon = \varepsilon_r \varepsilon_0$



MRI

"frequency"

- **Photon energy E** $\quad E = h \cdot f = h \cdot \nu$

  "Planck's constant"

  $[h = 6.6 \cdot 10^{-34}\, Js]$

  with $c = \lambda \cdot f = \lambda \cdot \nu$

  $$\boxed{E = h \cdot \frac{c}{\lambda}} \qquad \boxed{c = \frac{1}{\sqrt{\mu \varepsilon}}}$$

EM attenuation in biological tissue

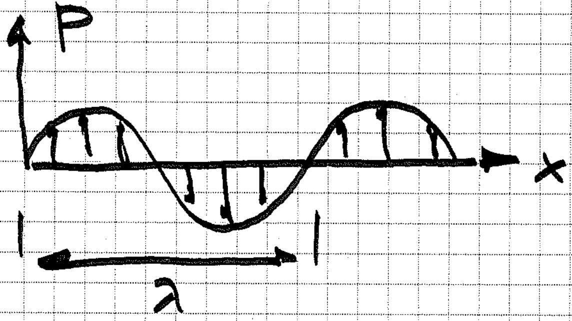
- Attenuation law $\quad |\vec{E}| = |\vec{E}_0| e^{-\mu(f) z}$

  "linear attenuation coefficient"

Acoustic or mechanical waves

- Acoustic waves require medium to propagate (EM waves do not) !
- Pressure p $p = \rho \cdot c \cdot u$ - "velocity of displacement"

"density"   "speed of sound"



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

$$c = \frac{1}{\sqrt{\kappa \rho}} \sim 1500 \frac{m}{s}$$

"tissue compressibility"

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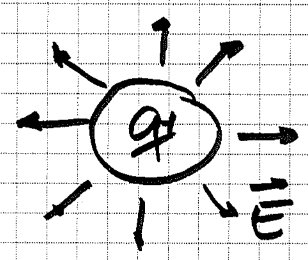
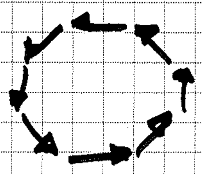
recall $\vec{\nabla} \vec{E} = \frac{\partial E_x}{\partial x} + \frac{\partial E_y}{\partial y} + \frac{\partial E_z}{\partial z}$

$\vec{\nabla} \times \vec{B} = \left(\frac{\partial B_z}{\partial y} - \frac{\partial B_y}{\partial z} \right) \vec{e}_x + (\dots$



$\vec{\nabla} \vec{E} > 0$



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