Maxwell's equations in matter

$$\vec{\nabla} \cdot \vec{E} = \frac{1}{\varepsilon_0} \rho \qquad \nabla \cdot B = 0$$

$$\vec{\nabla} \times \vec{E} = - \frac{\partial \vec{B}}{\partial t} \qquad \vec{\nabla} \times \vec{B} = \frac{1}{c^2} \dot{\vec{E}} + \mu_0 \vec{J}$$

$$\frac{1}{c^2} = \varepsilon_0 \mu_0$$

$$\rho = \rho_{ext} + \rho_{pol}$$

$$\rho_{pol} = - \frac{\partial \vec{P}}{\partial t}$$

$$\vec{J} = \vec{J}_{ext} + \vec{J}_{pol} + \vec{J}_{mag}$$

$$\vec{J}_{pol} = \frac{\partial \vec{P}}{\partial t}$$

$$\dot{\rho}_{pol} + \underbrace{\frac{\partial}{\partial \vec{r}} \cdot \vec{J}_{pol}}_{\nabla \cdot J_{pol}} = 0$$

$$\vec{J}_{mag} = \vec{\nabla} \times \vec{M}$$

$$\vec{\nabla} \cdot \vec{E} = \frac{1}{\varepsilon_0} \left(\rho_{ext} - \vec{\nabla} \cdot \vec{P} \right)$$

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

$$\vec{\nabla} \times \vec{B} = \mu_0 \left[\frac{\partial}{\partial t} \left(\varepsilon_0 \vec{E} \right) + \right.$$

$$\left. + \vec{J}_{ext} + \frac{\partial \vec{P}}{\partial t} + \vec{\nabla} \times \vec{M} \right]$$

$$\vec{\nabla} \times \left(\frac{1}{\mu_0} \vec{B} - \vec{M} \right) = \frac{\partial}{\partial t} \left(\varepsilon \vec{E} + \vec{P} \right)$$

$$+ \vec{J}$$

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

$$\begin{cases} \vec{D} = \varepsilon_0 \vec{E} + \vec{P} \\ \vec{B} = \mu_0 \vec{H} + \mu_0 \vec{M} \end{cases}$$

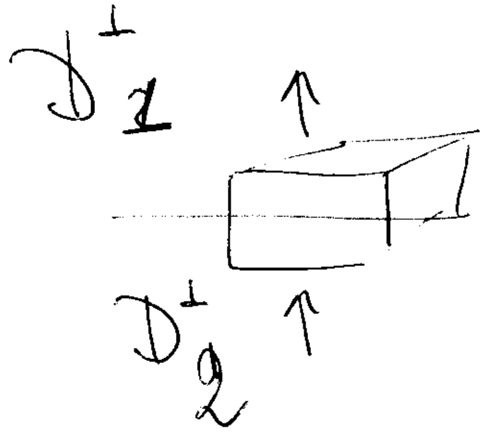
$$\boxed{\begin{array}{ll} \vec{\nabla} \cdot \vec{D} = \rho & \vec{\nabla} \cdot \vec{B} = 0 \\ \vec{\nabla} \times \vec{E} = -\dot{\vec{B}} & \vec{\nabla} \times \vec{H} = \dot{\vec{D}} + \vec{J} \end{array}}$$

$$\begin{cases} \vec{D} = \varepsilon_0 \vec{E} + \vec{P} \\ \vec{B} = \mu_0 \vec{H} + \mu_0 \vec{M} \end{cases}$$

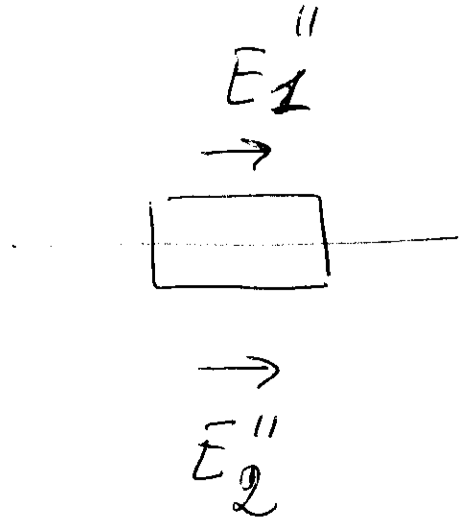
$$\begin{cases} \vec{P} = \varepsilon_0 \chi_e \vec{E} \\ \vec{M} = \chi_m \vec{H} \end{cases} \qquad \begin{array}{l} \varepsilon = 1 + \chi_e \\ \mu = 1 + \chi_m \end{array}$$

$$\begin{cases} \vec{D} = \varepsilon \varepsilon_0 \vec{E} \\ \vec{B} = \mu \mu_0 \vec{H} \end{cases}$$

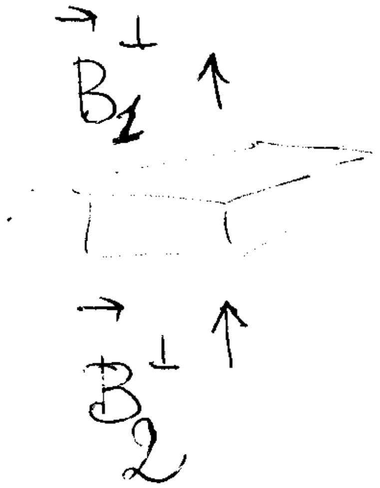
Boundary conditions



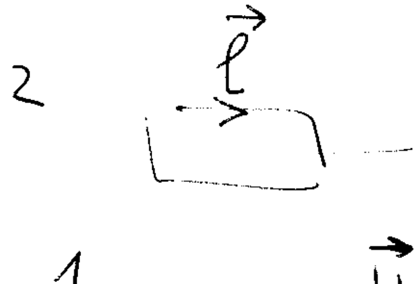
$$D_1^\perp = D_2^\perp$$



$$\vec{E}_1^{\parallel} = \vec{E}_2^{\parallel}$$



$$B_1^\perp = B_2^\perp$$



$$\vec{H}_1^{\parallel} - \vec{H}_2^{\parallel} = \vec{K}_{ext} \times \vec{n}$$

$$\vec{H}_1 \cdot \vec{\ell} - \vec{H}_2 \cdot \vec{\ell} = \vec{K}_{ext} \, (\vec{u} \times \vec{\ell})$$