Equazioni Maxwell nella materia

$$\vec{\nabla} \cdot \vec{D} = \rho \qquad \vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\vec{\nabla} \cdot \vec{B} = 0 \qquad \vec{\nabla} \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

$$\vec{D} = \varepsilon \vec{E} \qquad \vec{H} = \frac{\vec{B}}{\mu}$$

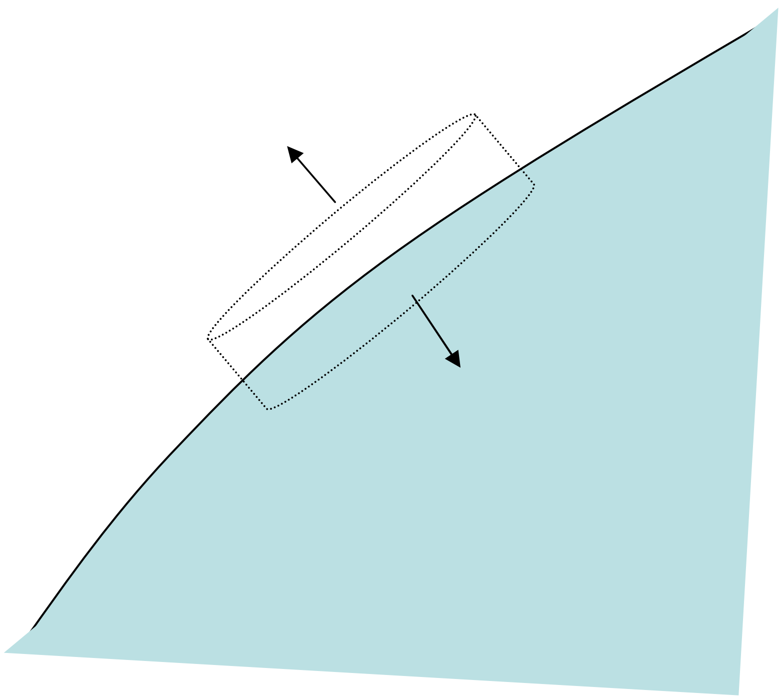
Boundary Conditions

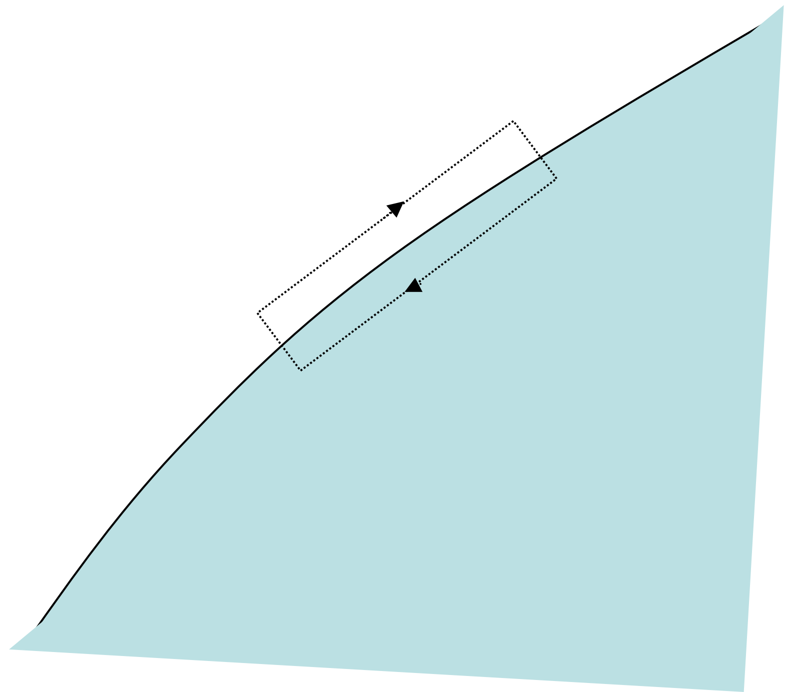
$$E_{1,t} - E_{2,t} = 0$$

$$D_{1,n} - D_{2,n} = \sigma$$

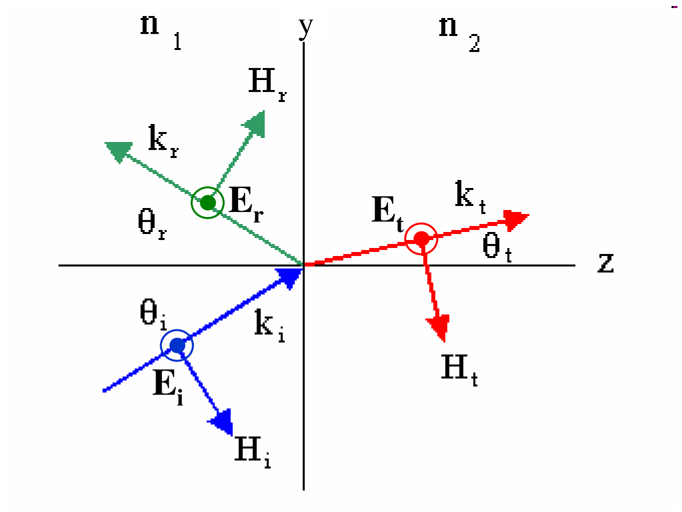
$$H_{1,t} - H_{2,t} = J$$

$$B_{1,n} - B_{2,n} = 0$$

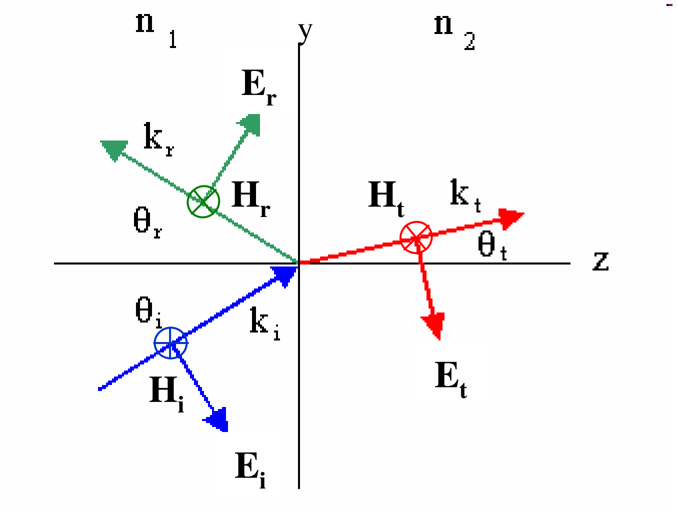




Riflessione e rifrazione

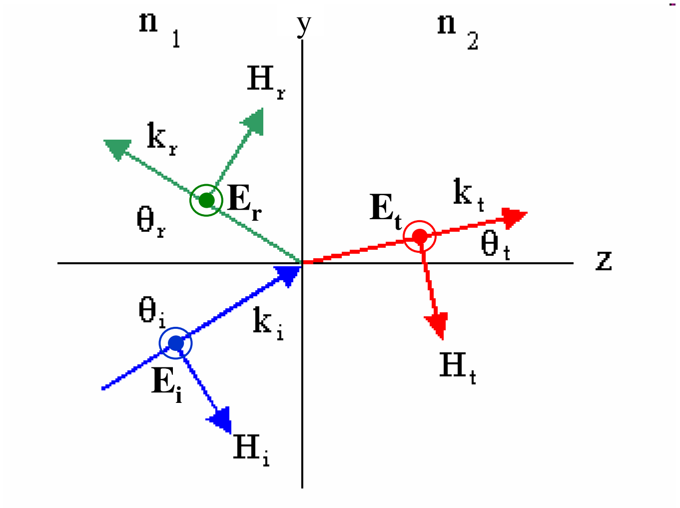


Onda s (senkrecht=perpendicolare)
Polarizzazione TE



Onda s (parallel)
Polarizzazione TM

Onda TE



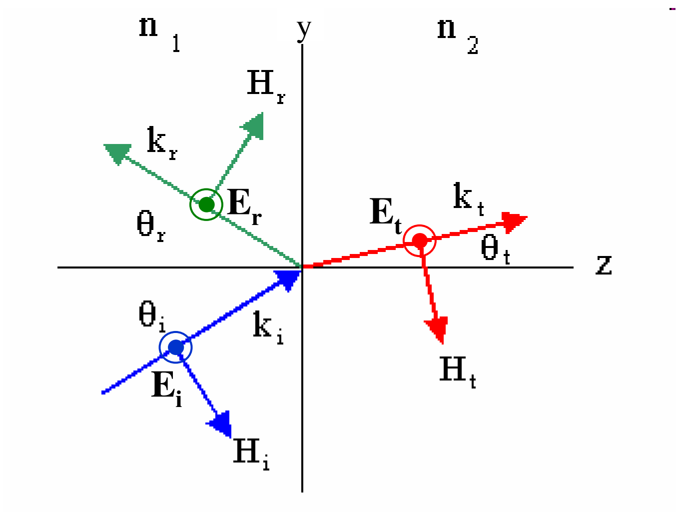
$$\vec{E}_i(\vec{r},t) = E_i e^{j(\vec{k}_i\cdot\vec{r}-\omega_i t)}\hat{e}_x \quad \vec{H}_i(\vec{r},t) = H_i e^{j(\vec{k}_i\cdot\vec{r}-\omega_i t)}(\hat{e}_z \cos\theta_i - \hat{e}_y \sin\theta_i)$$

$$\vec{E}_r(\vec{r},t) = E_r e^{j(\vec{k}_r\cdot\vec{r}-\omega_r t+\varphi_r)}\hat{e}_x \quad \vec{H}_r(\vec{r},t) = H_r e^{j(\vec{k}_r\cdot\vec{r}-\omega_r t+\varphi_r)}(\hat{e}_z \cos\theta_r + \hat{e}_y \sin\theta_r)$$

$$\vec{E}_t(\vec{r},t) = E_t e^{j(\vec{k}_t\cdot\vec{r}-\omega_t t+\varphi_t)}\hat{e}_x \quad \vec{H}_t(\vec{r},t) = H_t e^{j(\vec{k}_t\cdot\vec{r}-\omega_t t+\varphi_t)}(\hat{e}_z \cos\theta_t - \hat{e}_y \sin\theta_t)$$

$$H_i = \frac{n_1}{\mu_1 c}E_i \quad H_r = \frac{n_1}{\mu_1 c}E_r \quad H_t = \frac{n_2}{\mu_2 c}E_t$$

Onda TE



$$\vec{k}_i \cdot \vec{r} - \omega_i t = \vec{k}_r \cdot \vec{r} - \omega_r t + \varphi_r = k_t \cdot \vec{r} - \omega_t t + \varphi_t$$

$$\begin{cases} E_i + E_r = E_t \\ H_i \cos\theta_i - H_r \cos\theta_r = H_t \cos\theta_t \end{cases}$$

$$\begin{cases} E_i + E_r = E_t \\ \dfrac{n_1}{\mu_1 c} E_i \cos\theta_i - \dfrac{n_1}{\mu_1 c} E_r \cos\theta_r = \dfrac{n_2}{\mu_2 c} E_t \cos\theta_t \end{cases}$$

Onda TE e TM, conservazione fase all'interfaccia

$$\vec{k}_i \cdot \vec{r} - \omega_i t = \vec{k}_r \cdot \vec{r} - \omega_r t + \varphi_r = \vec{k}_t \cdot \vec{r} - \omega_t t + \varphi_t$$

$$\varphi_r = \varphi_t = 0$$

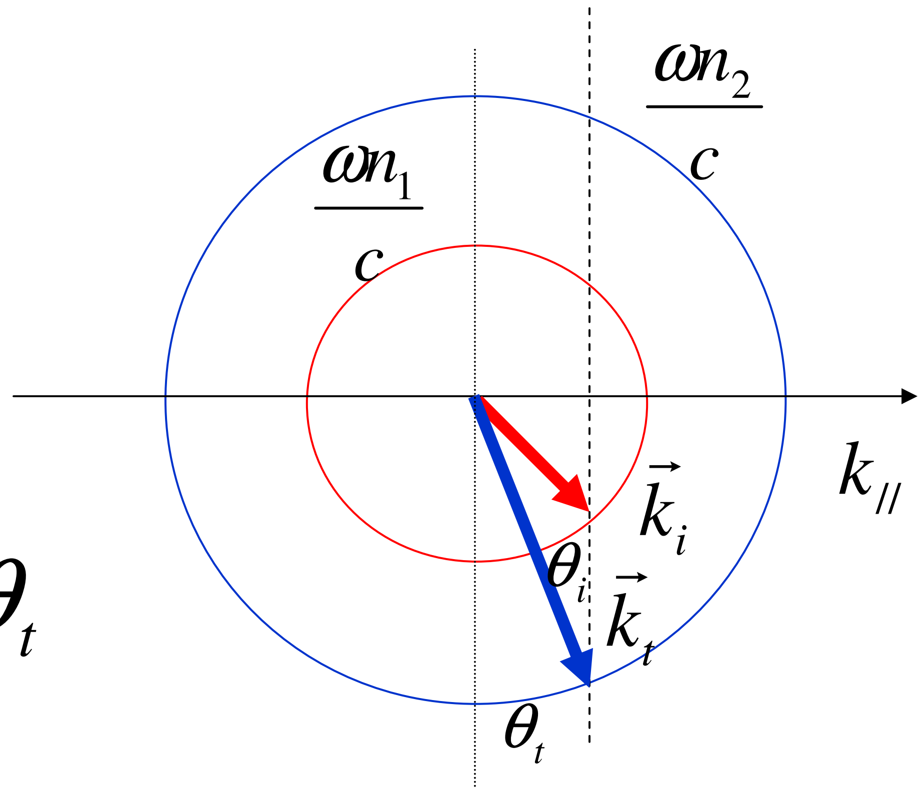
$$\omega_i = \omega_r = \omega_t \equiv \omega$$

$$\vec{k}_{i,//} = \vec{k}_{r,//} = \vec{k}_{t,//} \qquad \begin{cases} \theta_i = \theta_r \\ n_1 \sin\theta_i = n_2 \sin\theta_t \end{cases}$$

Metodo grafico per rifrazione

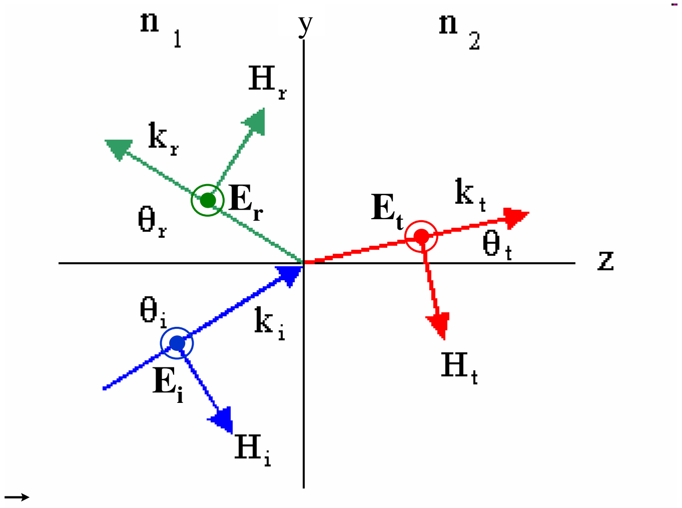
$$\omega_i = \omega_r = \omega_t \equiv \omega$$

$$\vec{k}_{i,//} = \vec{k}_{r,//} = \vec{k}_{t,//}$$



$$n_1 \sin\theta_i = n_2 \sin\theta_t$$

Onda TE

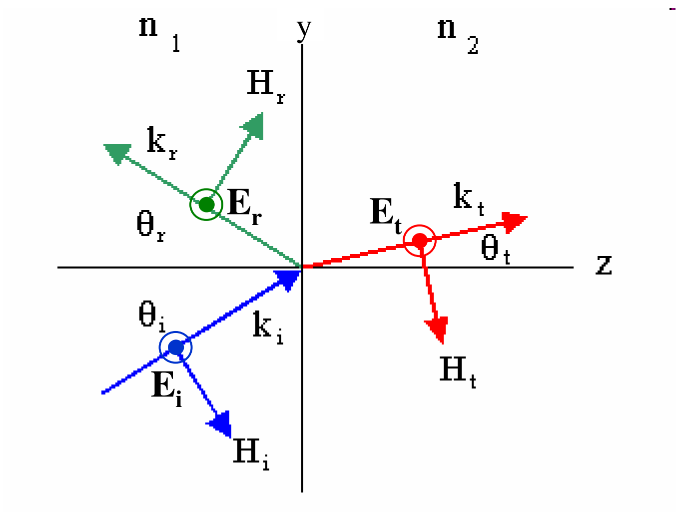


$$\vec{k}_i \cdot \vec{r} - \omega_i t = \vec{k}_r \cdot \vec{r} - \omega_r t + \varphi_r = \vec{k}_t \cdot \vec{r} - \omega_t t + \varphi_t$$

$$\begin{cases} E_i + E_r = E_t \\ H_i \cos\theta_i - H_r \cos\theta_r = H_t \cos\theta_t \end{cases}$$

$$\begin{cases} E_i + E_r = E_t \\ \dfrac{n_1}{\mu_1 c} E_i \cos\theta_i - \dfrac{n_1}{\mu_1 c} E_r \cos\theta_r = \dfrac{n_2}{\mu_2 c} E_t \cos\theta_t \end{cases}$$

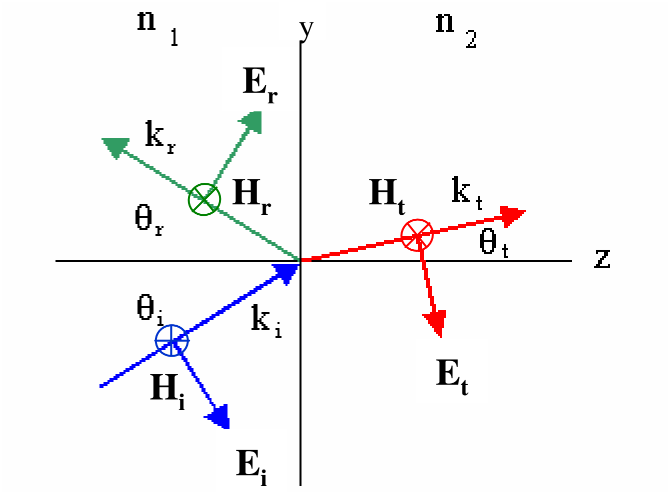
Onda TE



$$
\begin{cases}
E_i + E_r = E_t \\
\dfrac{n_1}{\mu_1 c} E_i \cos\theta_i - \dfrac{n_1}{\mu_1 c} E_r \cos\theta_r = \dfrac{n_2}{\mu_2 c} E_t \cos\theta_t
\end{cases}
$$

$$
\begin{cases}
E_r = \dfrac{n_1 \cos\theta_i - n_2 \cos\theta_t}{n_1 \cos\theta_i + n_2 \cos\theta_t} E_i \\
E_t = \dfrac{2 n_1 \cos\theta_i}{n_1 \cos\theta_i + n_2 \cos\theta_t} E_i
\end{cases}
\Longrightarrow
\begin{cases}
E_r = \dfrac{\sin(\theta_i - \theta_t)}{\sin(\theta_i + \theta_t)} E_i \\
E_t = \dfrac{2 \cos\theta_i \sin\theta_t}{\sin(\theta_i + \theta_t)} E_i
\end{cases}
$$

Onda TM

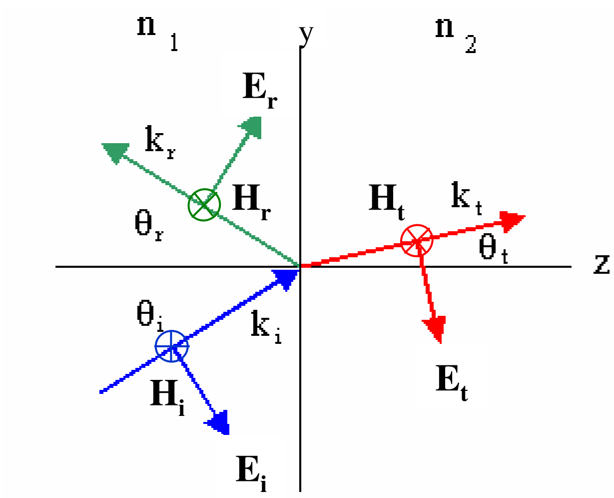


$$\vec{k}_i \cdot \vec{r} - \omega_i t = \vec{k}_r \cdot \vec{r} - \omega_r t + \varphi_r = \vec{k}_t \cdot \vec{r} - \omega_t t + \varphi_t$$

$$\begin{cases} H_i + H_r = H_t \\ E_i \cos\theta_i - E_r \cos\theta_r = E_t \cos\theta_t \end{cases}$$

$$\begin{cases} \dfrac{n_1}{\mu_1 c} E_i + \dfrac{n_1}{\mu_1 c} E_r = \dfrac{n_2}{\mu_2 c} E_t \\ E_i \cos\theta_i - E_r \cos\theta_r = E_t \cos\theta_t \end{cases}$$

Onda TM

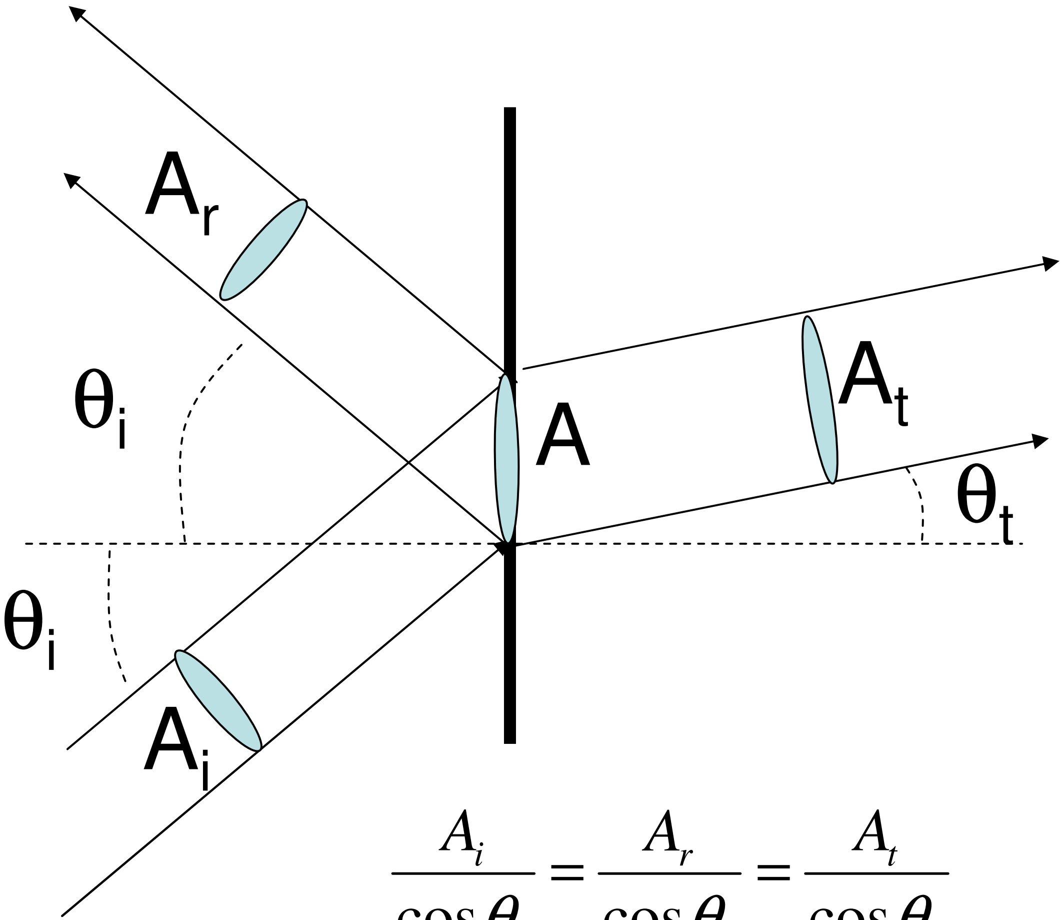


$$\begin{cases} \dfrac{n_1}{\mu_1 c} E_i + \dfrac{n_1}{\mu_1 c} E_r = \dfrac{n_2}{\mu_2 c} E_t \\ E_i \cos\theta_i - E_r \cos\theta_i = E_t \cos\theta_t \end{cases}$$

$$\begin{cases} E_r = \dfrac{n_2 \cos\theta_i - n_1 \cos\theta_t}{n_2 \cos\theta_i + n_1 \cos\theta_t} E_i \\ E_t = \dfrac{2 n_1 \cos\theta_i}{n_2 \cos\theta_i + n_1 \cos\theta_t} E_i \end{cases} \Longrightarrow \begin{cases} E_r = \dfrac{\tan(\theta_i - \theta_t)}{\tan(\theta_i + \theta_t)} E_i \\ E_t = \dfrac{2 \cos\theta_i \sin\theta_t}{\sin(\theta_i + \theta_t)\cos(\theta_i - \theta_t)} E_i \end{cases}$$

$$\left|\vec{S}\right| = \left|\vec{E}\times\vec{H}^*\right| = \left|\vec{E}\times\left(\frac{\vec{k}\times\vec{E}^*}{\mu\omega}\right)\right|$$

$$= \frac{n}{\mu c}\left|\vec{E}\right|^2 = \frac{\varepsilon c}{n}\left|\vec{E}\right|^2 = nc\left|\vec{E}\right|^2$$



Conservazione energia

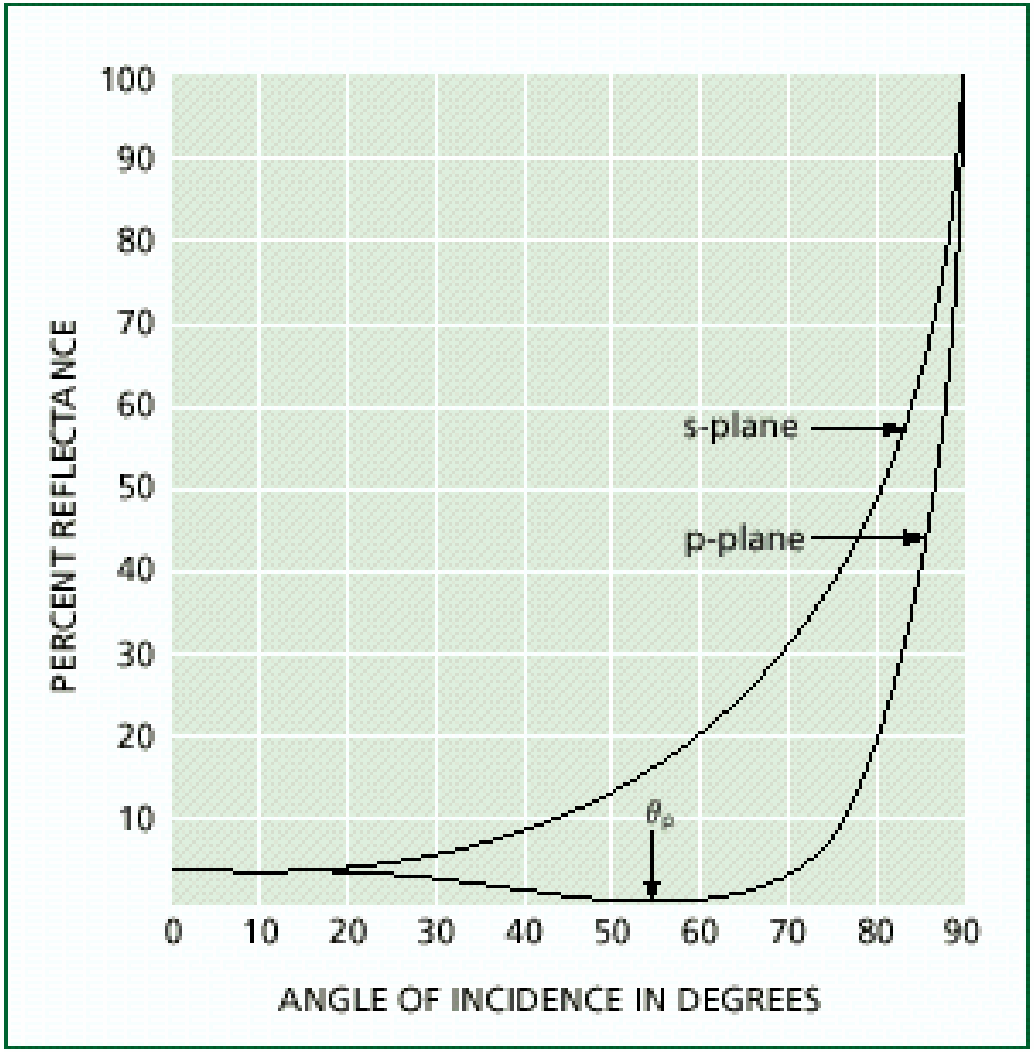
$$\frac{A_i}{\cos\theta_i} = \frac{A_r}{\cos\theta_i} = \frac{A_t}{\cos\theta_t}$$

$$\left|\vec{S}_i\right|A_i = \left|\vec{S}_r\right|A_r + \left|\vec{S}_t\right|A_t$$

$$n_1\left|\vec{E}_i\right|^2 A_i = n_1\left|\vec{E}_r\right|^2 A_r + n_2\left|\vec{E}_t\right|^2 A_t$$

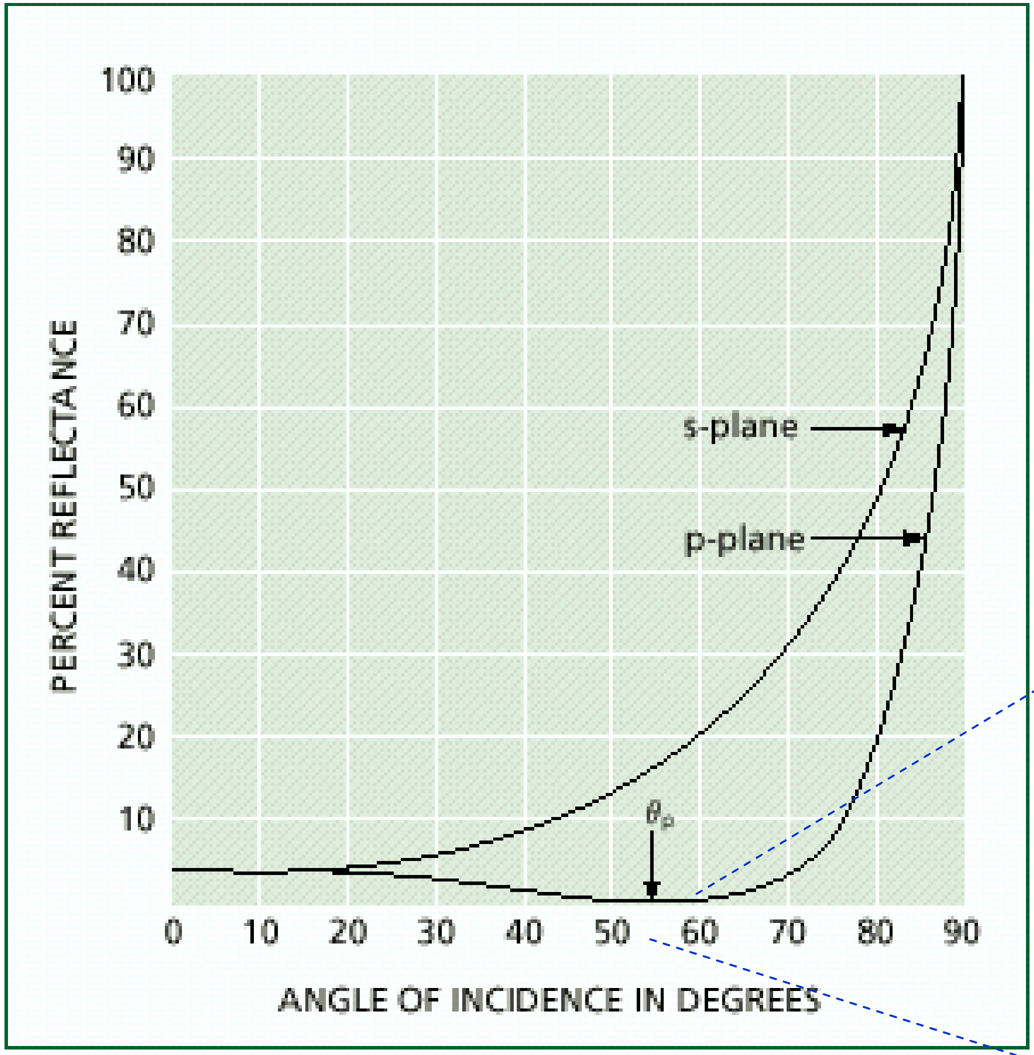
$$1 = \left|r\right|^2 + \left|t\right|^2 \frac{n_2}{n_2}\frac{\cos\theta_i}{\cos\theta_t}$$

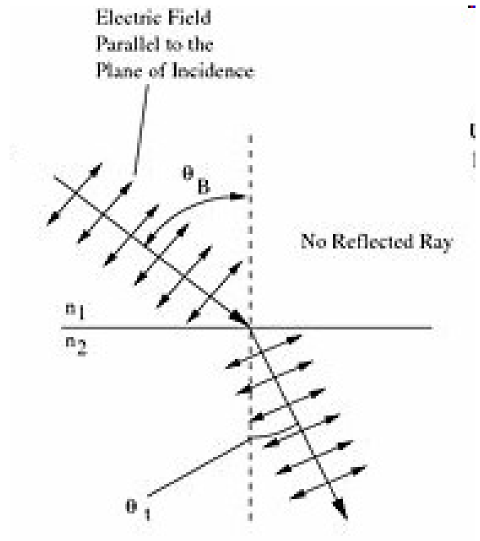
Aria-Vetro



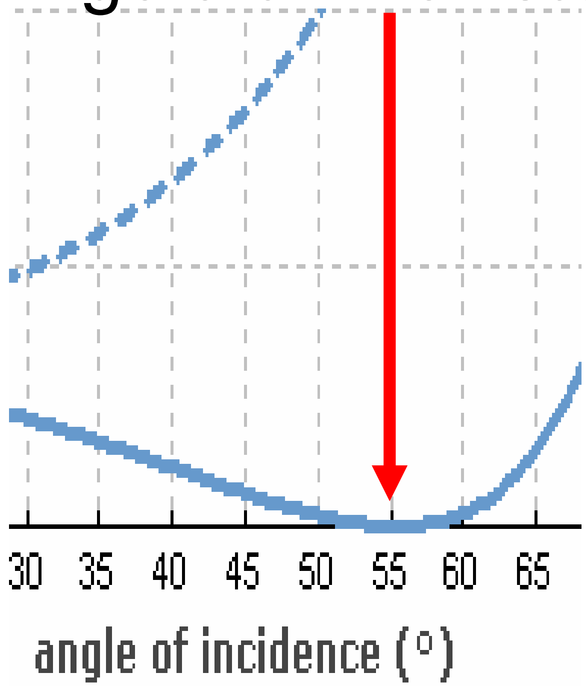
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
70
80
90
PERCENT REFLECTANCE
ANGLE OF INCIDENCE IN DEGREES
s-plane
p-plane
θ_p

Aria-Vetro

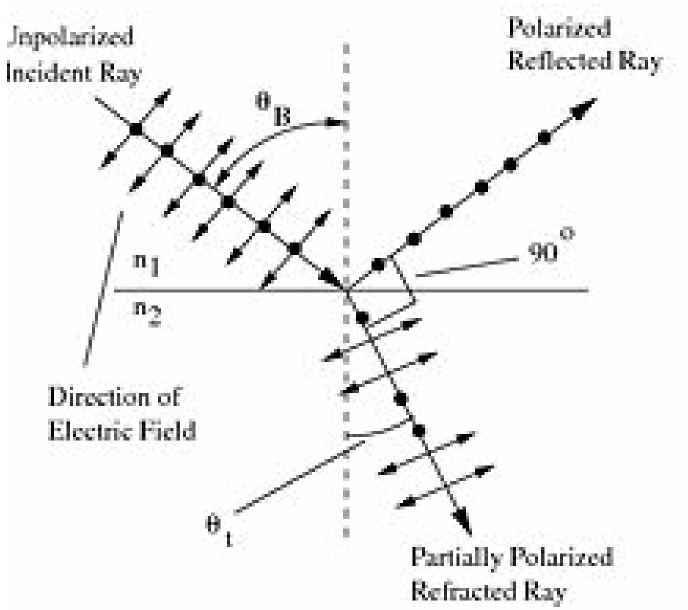




Angolo di Brewster



Angolo di Brewster



$$E_r = \frac{\tan(\theta_i - \theta_t)}{\tan(\theta_i + \theta_t)} E_i$$

$$\theta_i + \theta_t = \frac{\pi}{2}$$

Luce riflessa è polarizzata

Luce riflessa è polarizzata

Foto senza filtro polarizzatore

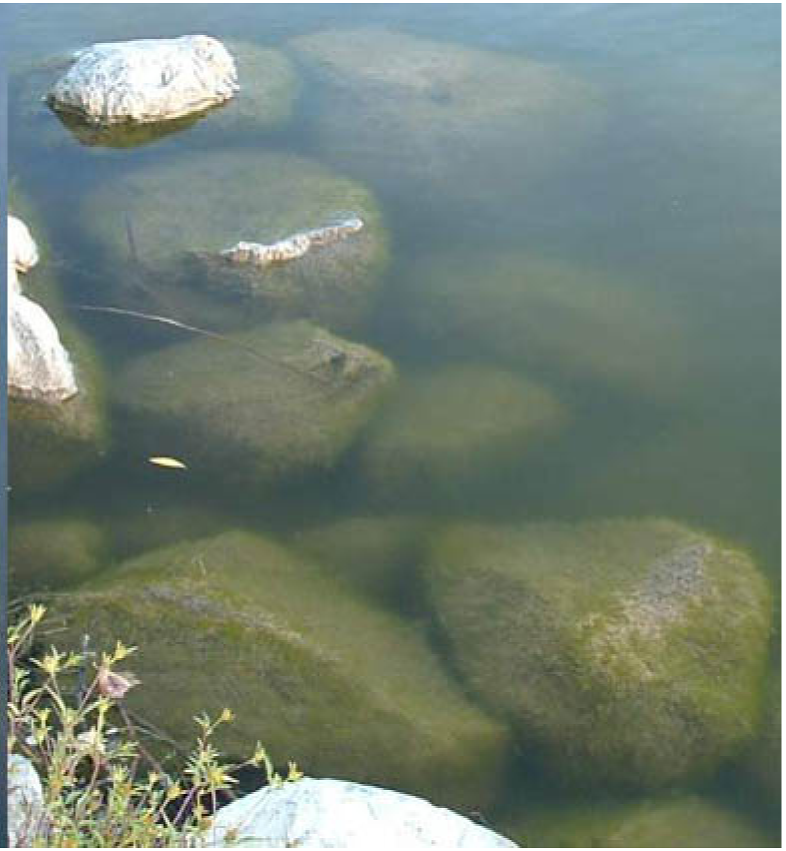
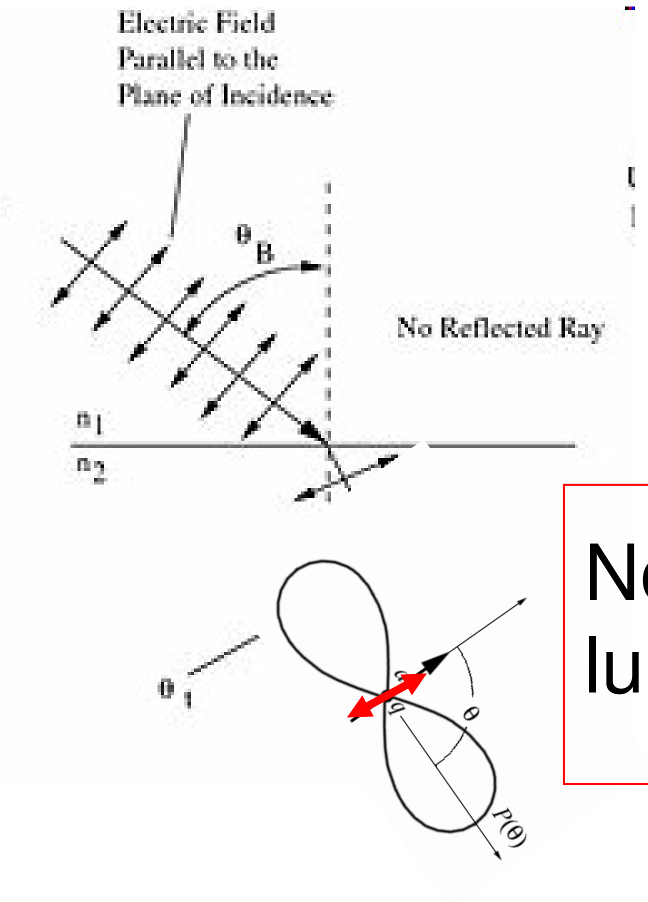


Foto senza filtro polarizzatore
che taglia la luce riflessa

Angolo Brewster e teorema estinzione



$$\vec{S} = \frac{p^2 \omega^4 \sin^2 \theta}{32\pi^2 \varepsilon_o c^3 r^2}\hat{r}$$

Non c'è emissione
lungo l'asse del dipolo