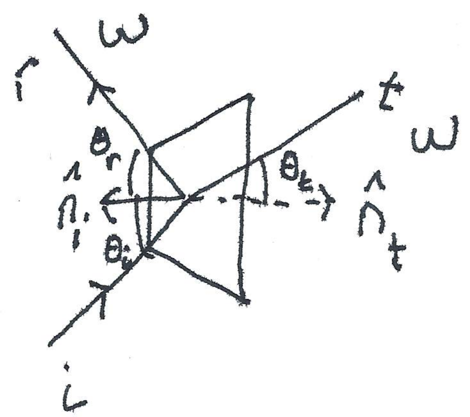
Phys 110B 12Oct20

HW due Tuesday

Planar Boundaries between LHI media (insulators)

$n_i = n_r$ n_t



$$\vec{E}_i = \hat{e}_i E_i e^{i(\vec{k}_i \cdot \vec{r} - \omega_i t)} \qquad \vec{E}_t = \hat{e}_t E_t e^{i(\vec{k}_t \cdot \vec{r} - i\omega_t t)}$$

$$\vec{E}_r = \hat{e}_r E_r e^{i(\vec{k}_r \cdot \vec{r} - \omega_r t)}$$

$$\omega_i^2 = \frac{c^2 \vec{k}_i \cdot \vec{k}_i}{n_i^2} \qquad \omega_t^2 = \frac{c^2 \vec{k}_t \cdot \vec{k}_t}{n_t^2}$$

$$\omega_r^2 = \frac{c^2 \vec{k}_r \cdot \vec{k}_r}{n_r^2}$$

B.C. parallel to boundary

$$\hat{n} \times (\vec{E}_i + \vec{E}_r) = \hat{n} \times \vec{E}_t$$ along boundary plane

boundary includes $\vec{r} = \vec{0}$

phases must be equal

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

$$\vec{k}_i \cdot \vec{r} = \vec{k}_r \cdot \vec{r} = \vec{k}_t \cdot \vec{r}$$ at the boundary

$(\vec{k}_i - \vec{k}_r) \cdot \vec{r} \,\big|_{\text{boundary}} = 0$

tangent to boundary

$(\vec{k}_t - \vec{k}_i) \cdot \vec{r} \,\big| = 0$ at boundary

$\vec{k}_i - \vec{k}_r \propto \hat{n}_i$

$\vec{k}_t - \vec{k}_i \propto \hat{n}_t \propto \hat{n}_i$

$\vec{k}_i, \vec{k}_r, \hat{n}$ all lie in one plane

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"Plane of Incidence"

1st Law of Geometric optics

$\hat{e}_i \perp \vec{k}_i$ $\quad$ $\hat{e}_t \perp \vec{k}_t$

$\hat{e}_r \perp \vec{k}_r$

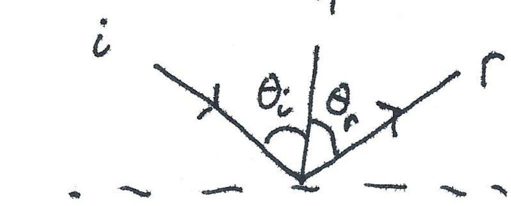
"Senkrecht"

$\perp$ to plane of incidence $\quad$ s-polarization

$\parallel$ to plane of incidence $\quad$ p-polarization

"parallel"

"2nd Law" specular reflection



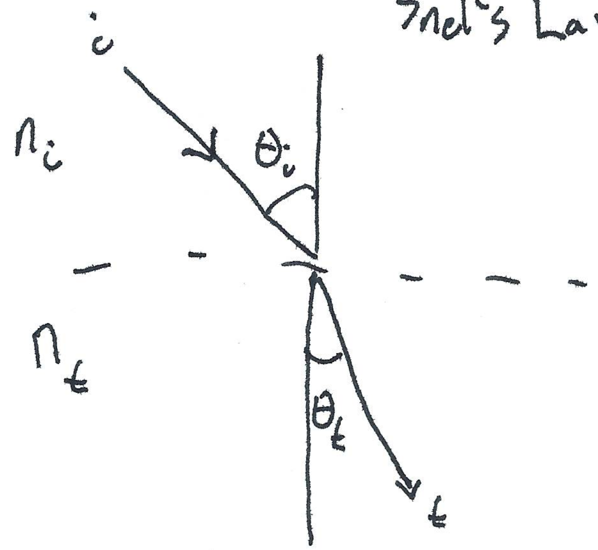
$n_i = n_r \qquad \vec{k}_i \cdot \vec{k}_i = \vec{k}_r \cdot \vec{k}_r$

$k_i \sin\theta_i = k_r \sin\theta_r$

$\Rightarrow \theta_i = \theta_r$

"3rd Law" Snell's Law Law of refraction

Snel's Law



$$k_i \sin\theta_i = k_t \sin\theta_t$$

$$\frac{c k_i}{n_i} = \omega = \frac{c k_t}{n_t}$$

$$n_i \sin\theta_i = n_t \sin\theta_t$$

Linearity Symmetry Translational symmetry along boundary

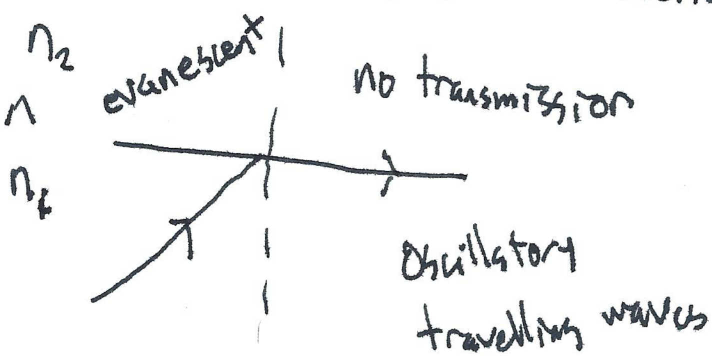
time-translation symmetry

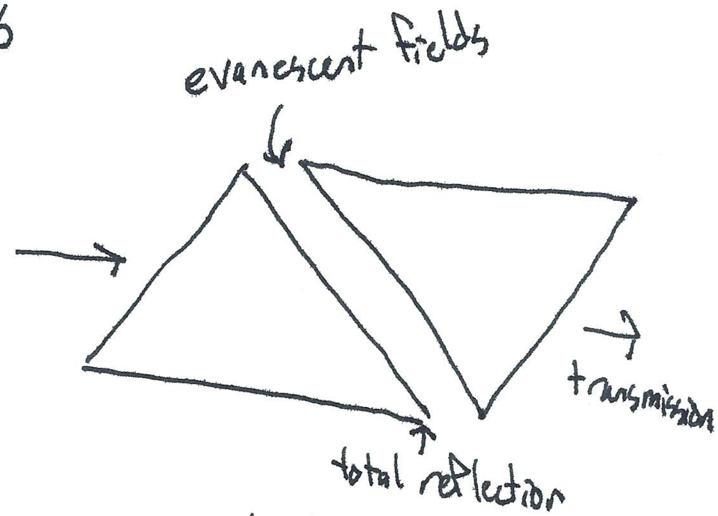
$\vec{k}$ parallel to the boundary is conserved

ω must be conserved

"Kinematic" Laws of optics

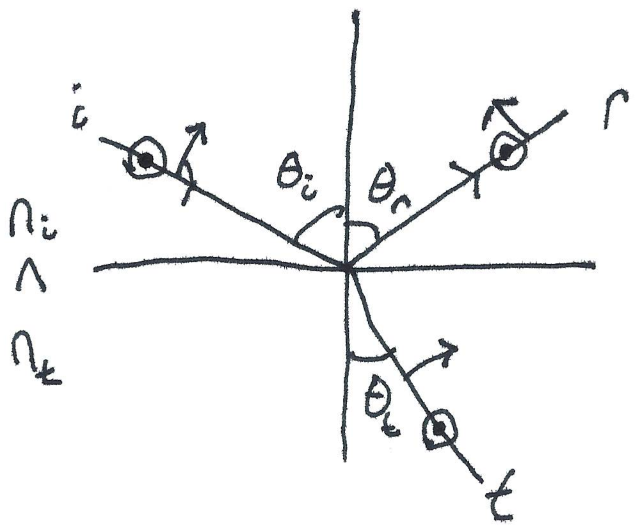
total internal reflection





Optical tunneling

Brewster Angle / Polarizing Angle



no p-polarized reflected wave

"dynamic" rules of reflection and refraction

R, T

"Fresnel" Laws

Assuming phase factors cancel

$$\hat{n}\cdot(\epsilon_i \hat{e}_i E_i + \epsilon_r \hat{e}_r E_r) = \hat{n}\cdot \epsilon_t \hat{e}_t E_t$$

$$\hat{n}\cdot(\hat{b}_i B_i + \hat{b}_r B_r) = \hat{n}\cdot b_t B_t$$

$$\hat{n}\times(\hat{e}_i E_i + \hat{e}_r E_r) = \hat{n}\times(\hat{b}_t B_t)$$

$$\hat{n}\times\left(\frac{1}{\mu_i}\hat{b}_i B_i + \frac{1}{\mu_r}\hat{b}_r B_r\right) = \hat{n}\times\left(\frac{\hat{b}_t}{\mu_t} B_t\right)$$

$$\vec{B} = \frac{\hat{k}}{v}\times\vec{E}$$

s- polarization

$$\frac{E_t}{E_i} = \frac{2n_i \cos\theta_i}{n_i \cos\theta_i + \frac{\mu_i}{\mu_t}\sqrt{n_t^2 - n_i^2 \sin^2\theta_i}}$$

$$\frac{E_r}{E_i} = \frac{n_i \cos\theta_i - \frac{\mu_i}{\mu_t}\sqrt{n_t^2 - n_i^2 \sin^2\theta_i}}{n_i \cos\theta_i + \frac{\mu_i}{\mu_t}\sqrt{n_t^2 - n_i^2 \sin^2\theta_i}}$$

p - polarization

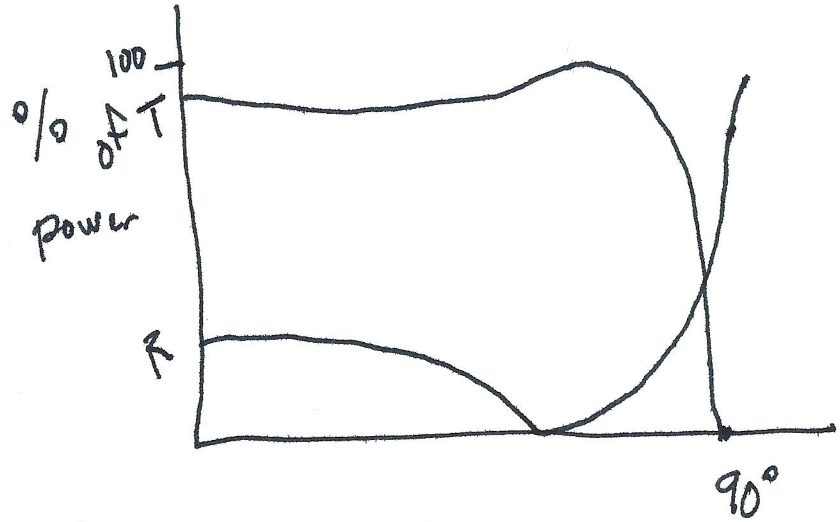
$$\frac{E_t}{E_i} = \frac{2n_i n_t \cos\theta_i}{\frac{\mu_i}{\mu_t} n_t^2 \cos\theta_i + n_i\sqrt{n_t^2 - n_i^2 \sin^2\theta_i}}$$

$$\frac{E_r}{E_i} = \frac{\frac{\mu_i}{\mu_t} n_t^2 \cos\theta_i - n_i\sqrt{n_t^2 - n_i^2 \sin^2\theta_i}}{\frac{\mu_i}{\mu_t} n_t^2 \cos\theta_i + n_i\sqrt{n_t^2 - n_i^2 \sin^2\theta_i}}$$

Normal Incidence

$$\frac{E_t}{E_i} = \frac{2n_i}{n_i + n_t} \qquad \frac{E_r}{E_i} = \frac{n_t - n_i}{n_i + n_t}$$

p-polarized



reflection is large at "grazing" incidence

X-ray optics

grazing incidence mirrors