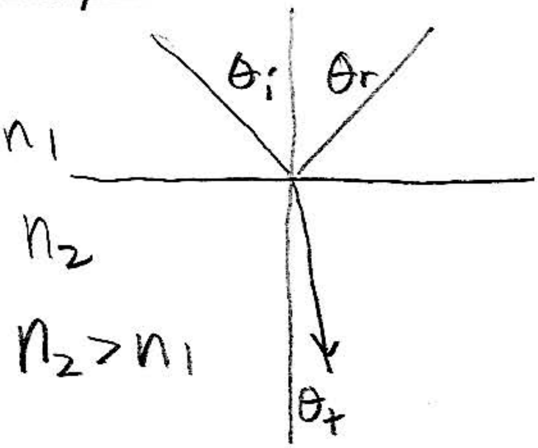
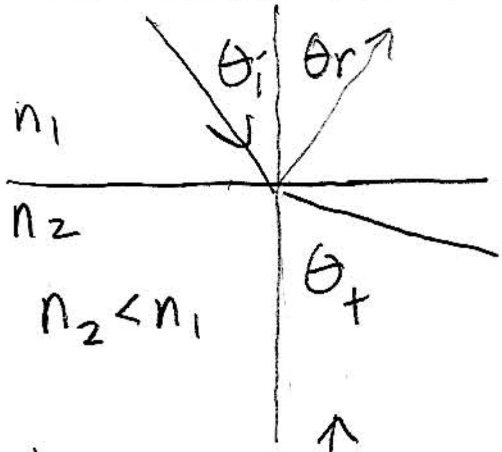




when $\theta_t = 90° = \frac{\pi}{2}$

$$n_1 \sin\theta_i = n_2$$

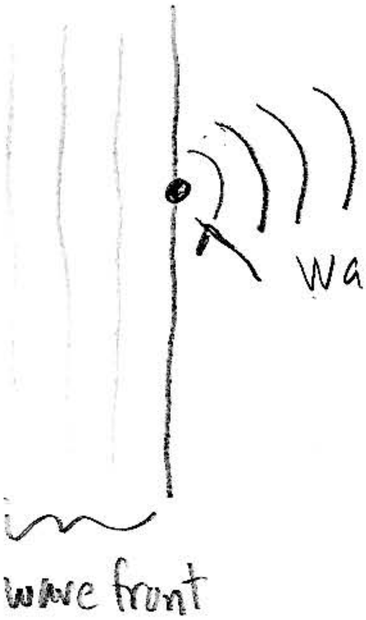
$$\sin\theta_i = \frac{n_2}{n_1} < 1$$

when $\theta_i > \sin^{-1}\left(\frac{n_2}{n_1}\right)$,

"total internal reflection"

next time you swim, look up from underwater.

Fermat's Principle

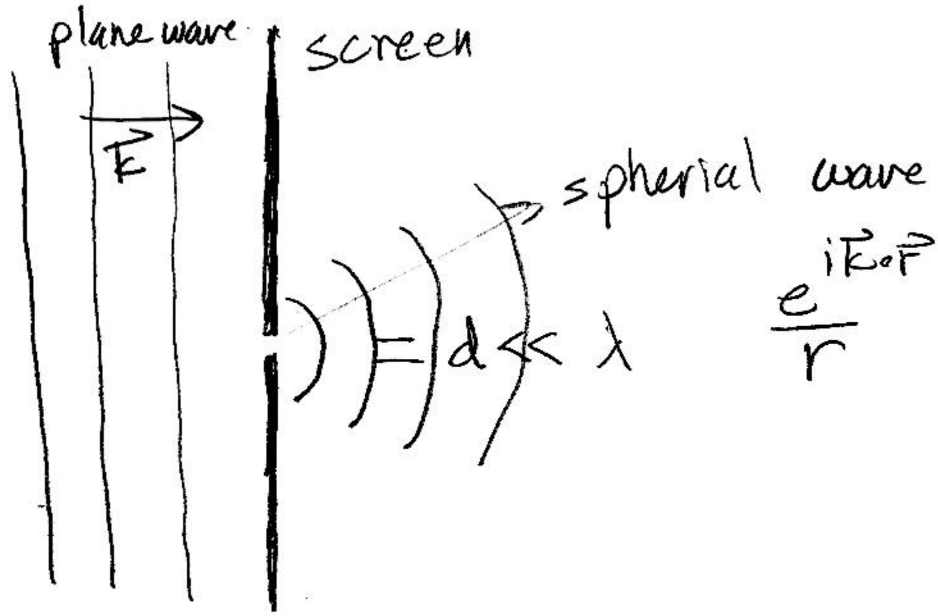


wave front: like a source of a new spherical wave

$$\frac{e^{i\vec{k}\cdot\vec{r}}}{r} \qquad |\vec{k}| = \frac{2\pi}{\lambda}$$

$\frac{1}{r^2}$ power $\propto \frac{1}{r^2}$

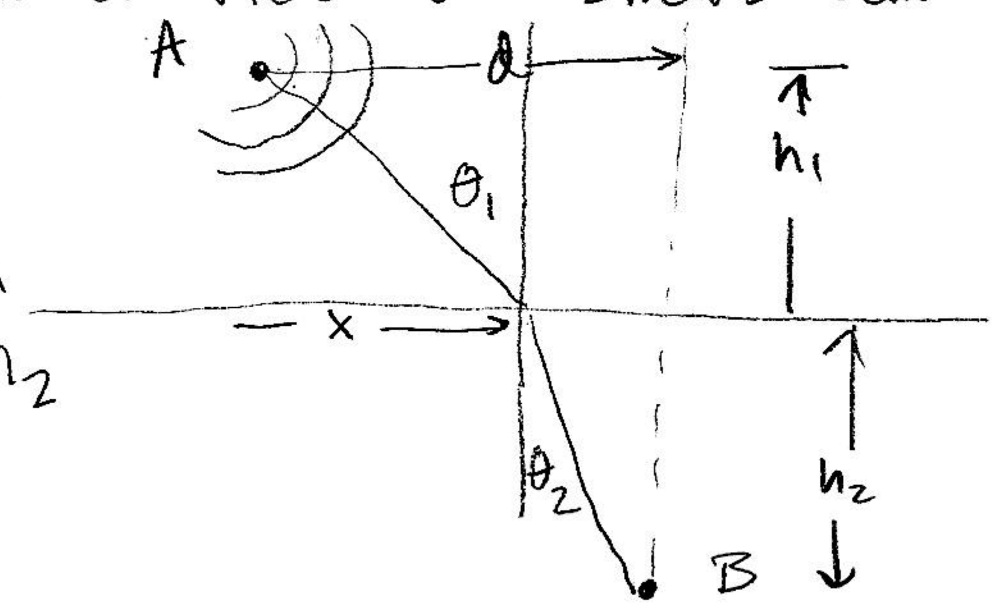
meaning



integrate over wavefront to propagate.

---

another view of Snell's Law.



Snell's law: $n_1 \sin\theta_1 = n_2 \sin\theta_2$
is the path that <u>minimizes</u> the time it takes to go from point A to point B

$$T_{BA} = \frac{\sqrt{h_1^2 + x^2}}{(c/n_1)} + \frac{\sqrt{h_2^2 + (d-x)^2}}{(c/n_2)}$$

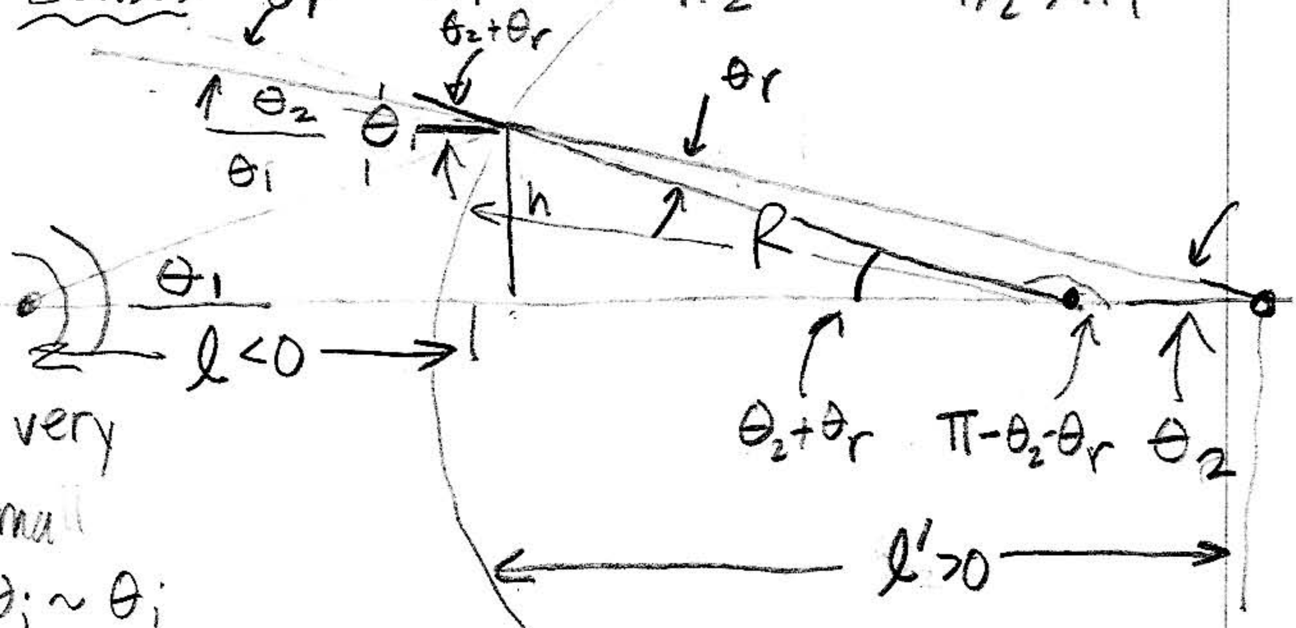
$$\frac{dT}{dx} = \frac{n_1}{c}\frac{x}{\sqrt{h_1^2+x^2}} - \frac{n_2}{c}\frac{x}{\sqrt{h_2^2+(d-x)^2}}$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

This is an illustration of "Fermat's Principle," that....

$$\int_{A,\text{path}}^{B} n(x)\,dx$$ is an extremum for actual path

Lenses



θ_i very small

$\sin\theta_i \sim \theta_i$

$\tan\theta_i \sim \theta_i$

$\cos\theta_i \simeq 1$

$$\theta_i = \theta_1 + \theta_2 + \theta_r$$

$$\theta_1 \simeq -\frac{h}{\ell} \qquad \theta_2 \simeq \frac{h}{\ell'}$$

$$n_1\theta_i = n_2\theta_r$$ (small angle snell).

$$\theta_2+\theta_r = \frac{h}{R}$$

$$\theta_r = \frac{h}{R}-\frac{h}{\ell'}$$

$$\theta_i = \left(\frac{n_2}{n_1}\right)\theta_r = \left(\frac{n_2}{n_1}\right)h\left(\frac{1}{R}-\frac{1}{\ell'}\right)$$

$$\theta_i = \theta_1+\theta_2+\theta_r$$

$$\frac{n_2}{n_1}\cancel{h}\left(\frac{1}{R}-\frac{1}{\ell'}\right) = -\frac{\cancel{h}}{\ell}+\cancel{\frac{h}{\ell'}}+\frac{\cancel{h}}{R}-\cancel{\frac{h}{\ell'}}$$

$$n_2\left(\frac{1}{R}-\frac{1}{\ell'}\right) = n_1\left(\frac{1}{R}-\frac{1}{\ell}\right)$$

$$\boxed{\frac{n_2}{\ell'}-\frac{n_1}{\ell} = \frac{(n_2-n_1)}{R}}$$ independent of θ!

for $n_2<n_1$, the light penetrating the n_2 region diverges