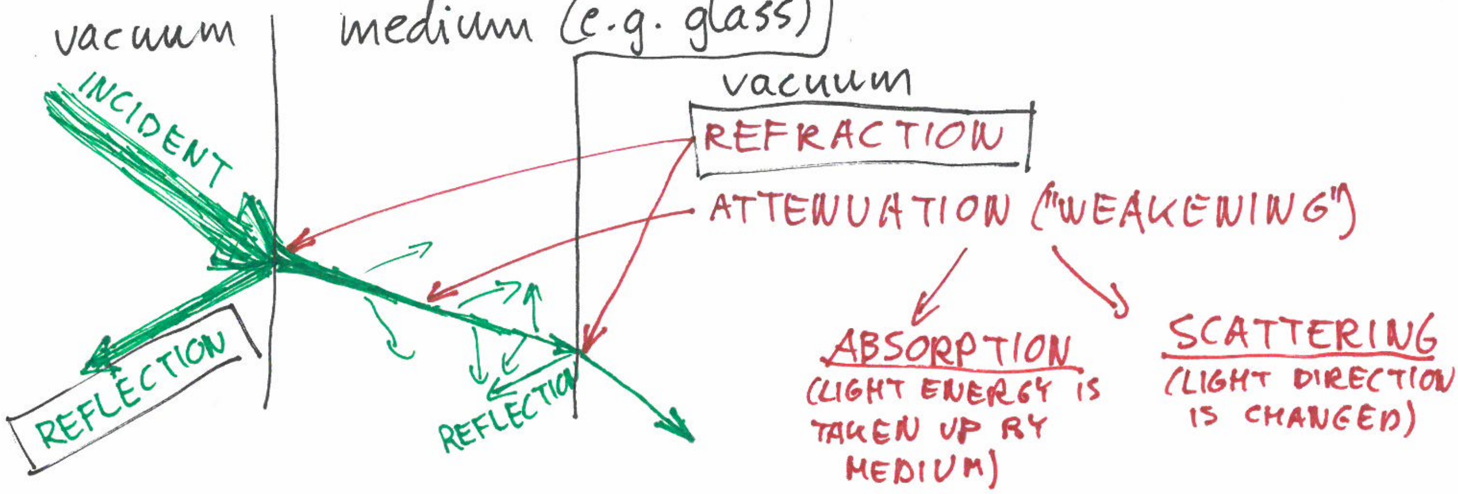
Optics ⇒ light and image formation

- **Geometric ~**
- Wave ~
- Quantum ~

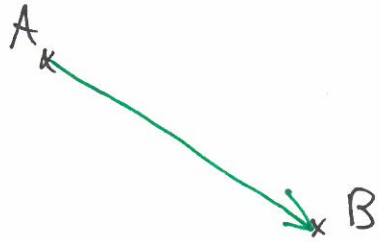
Light Ray:
- thin beam of light
- how does it interact with matter?
- how does it travel through media?



① FERMAT'S PRINCIPLE [ferma:] : between two point light takes the pathway which requires the least time

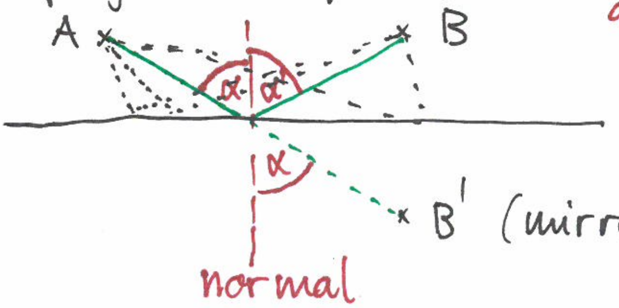
② Propagation of light in a homogenious medium:

light travels in a straight line

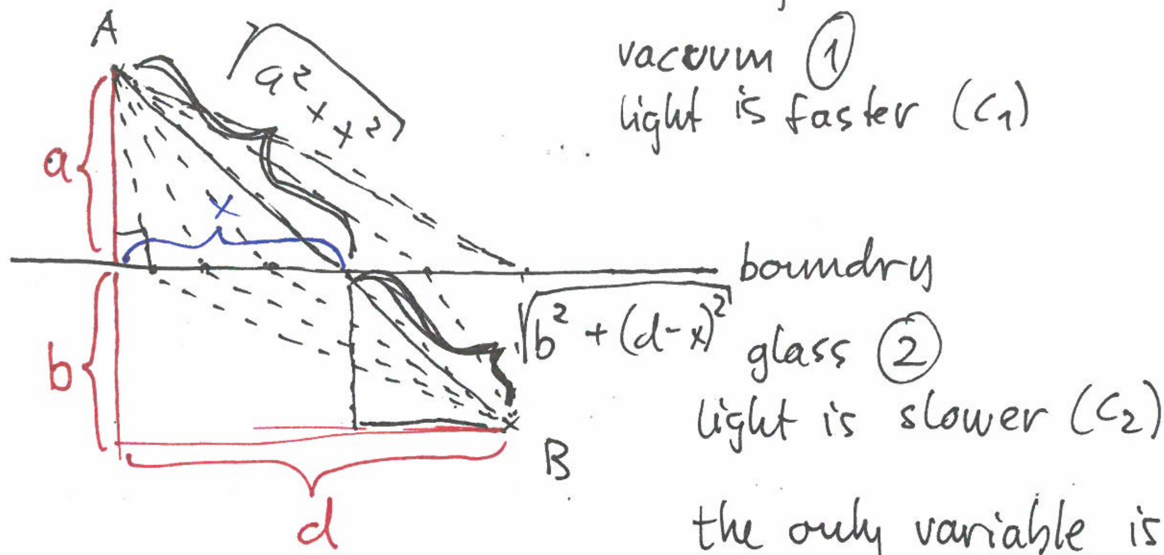


③ Propagation of light including a reflective surface:

angle of incidence (α) = angle of reflection (α')



④ Refraction: propagation of light through an
"breaking" ~~~~ ~~~~ boundry of two media



the only variable is the point x of entry into the 2nd medium

speed = $\frac{\text{track}}{\text{time}}$
time = $\frac{\text{track}}{\text{speed}}$

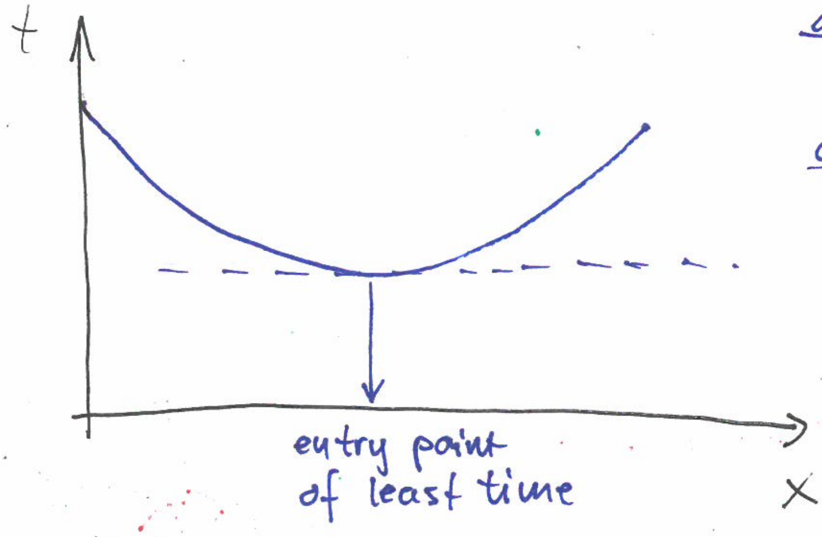
Pythagoras $a^2+b^2=c^2$

path in medium ① is $\sqrt{a^2+x^2}$

path in medium ② is $\sqrt{b^2+(d-x)^2}$

total time: $t = \frac{\sqrt{a^2+x^2}}{c_1} + \frac{\sqrt{b^2+(d-x)^2}}{c_2}$

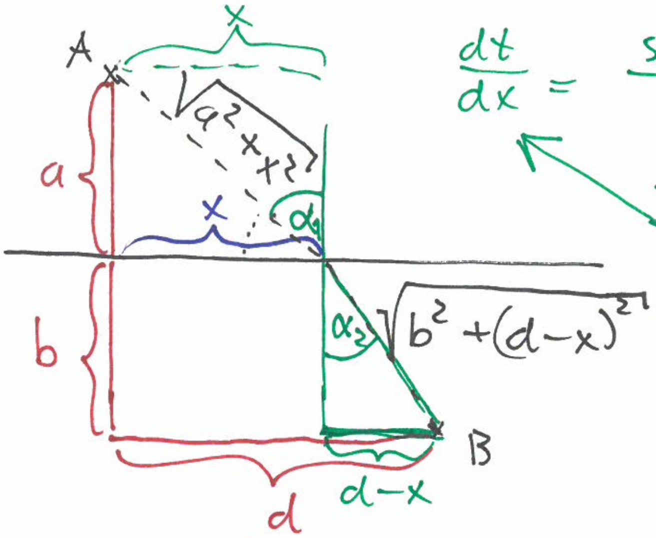
we need to find the x for which t is minimal



derivative: slope of tangent line

derivative at minimum is zero!

derivative: $\frac{dt}{dx} = \frac{2x}{c_1\sqrt{a^2+x^2}} - \frac{2(d-x)}{c_2\cdot\sqrt{b^2+(d-x)^2}}$



$$\frac{dt}{dx} = \frac{\sin\alpha_1}{c_1} - \frac{\sin\alpha_2}{c_2}$$

tangent (= derivative) is zero for fastest path

$$0 = \frac{\sin\alpha_1}{c_1} - \frac{\sin\alpha_2}{c_2}$$

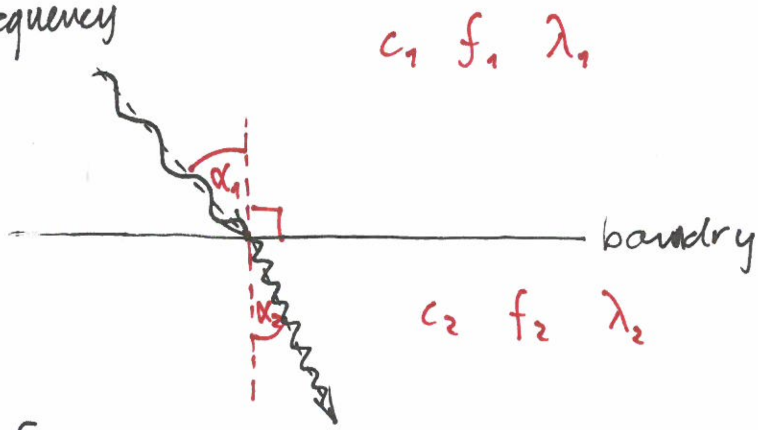
$$\frac{\sin\alpha_1}{c_1} = \frac{\sin\alpha_2}{c_2}$$

Snell's law

$$\boxed{\frac{c_1}{c_2} = \frac{\sin\alpha_1}{\sin\alpha_2}}$$

$$\boxed{c = \lambda \cdot f}$$

c – speed of light, λ – wavelength, f – frequency



if $c_1 > c_2$ then:

$f_1 = f_2$

$\varepsilon_1 = \varepsilon_2$

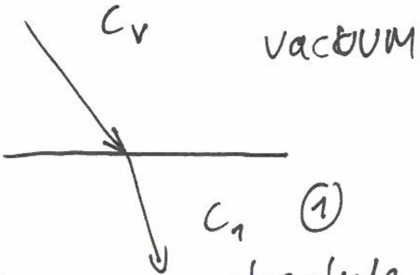
$\lambda_1 > \lambda_2$

$$\boxed{\varepsilon = h \cdot f}$$

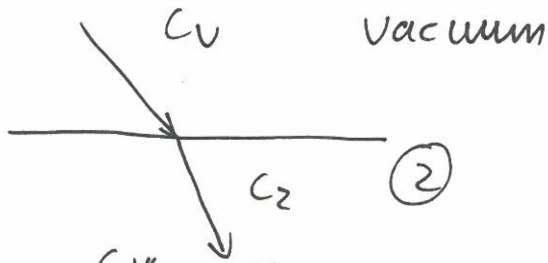
ε – photon energy, h – Planck's constant, f – frequency

$$\boxed{\frac{\sin\alpha_1}{\sin\alpha_2} = \frac{c_1}{c_2} = \frac{\lambda_1}{\lambda_2} = n_{2,1}}$$

"n" is the refractive index (index of refraction) of the second medium relative to the first



$\frac{c_v}{c_1} = n_1$ absolute refractive index of the ① medium

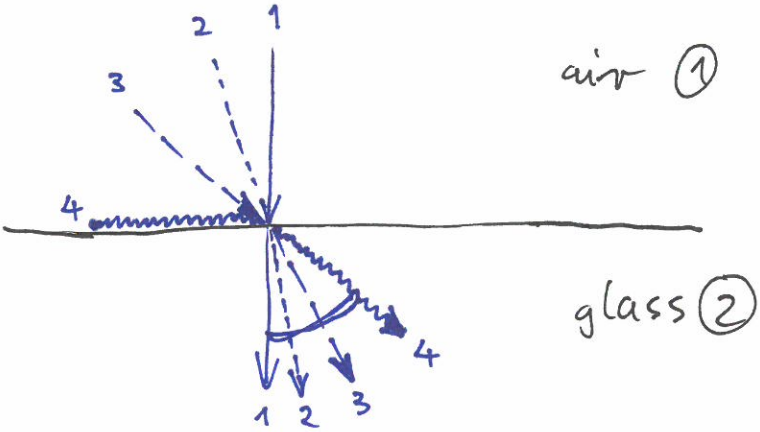


$\frac{c_v}{c_2} = n_2$

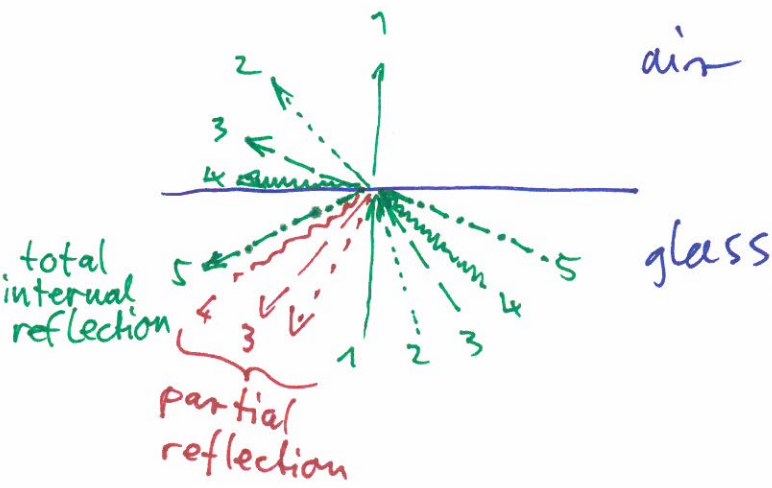
$$c_1 = \frac{c_V}{n_1} \qquad c_2 = \frac{c_V}{n_2}$$

$$n_{2,1} = \frac{c_1}{c_2} = \frac{\left(\frac{c_V}{n_1}\right)}{\left(\frac{c_V}{n_2}\right)} = \frac{c_V}{n_1} \cdot \frac{n_2}{c_V} = \frac{n_2}{n_1}$$

$$\boxed{\frac{\sin\alpha_1}{\sin\alpha_2} = \frac{c_1}{c_2} = \frac{\lambda_1}{\lambda_2} = \frac{n_2}{n_1} = n_{2,1}}$$



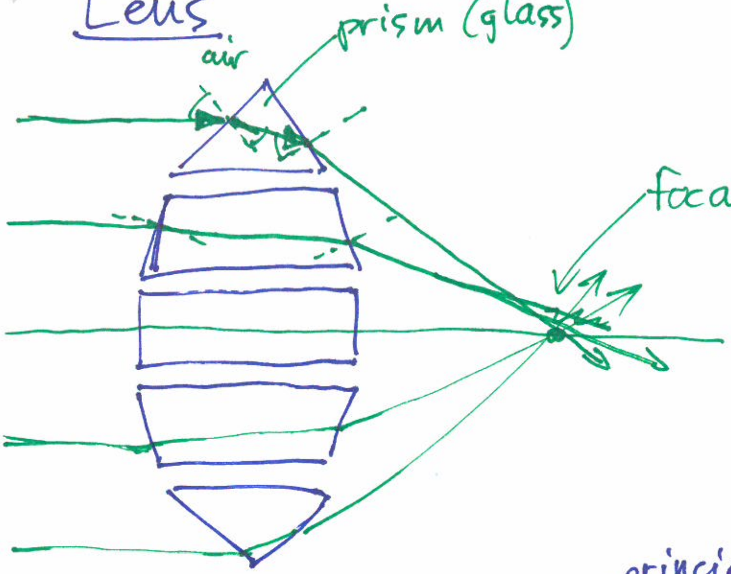
if light travels from "faster medium" to "slower medium", and the angle of incidence is $90° = \frac{\pi}{2}$ rad then the angle of refraction is the maximum, we call it <u>critical angle</u>



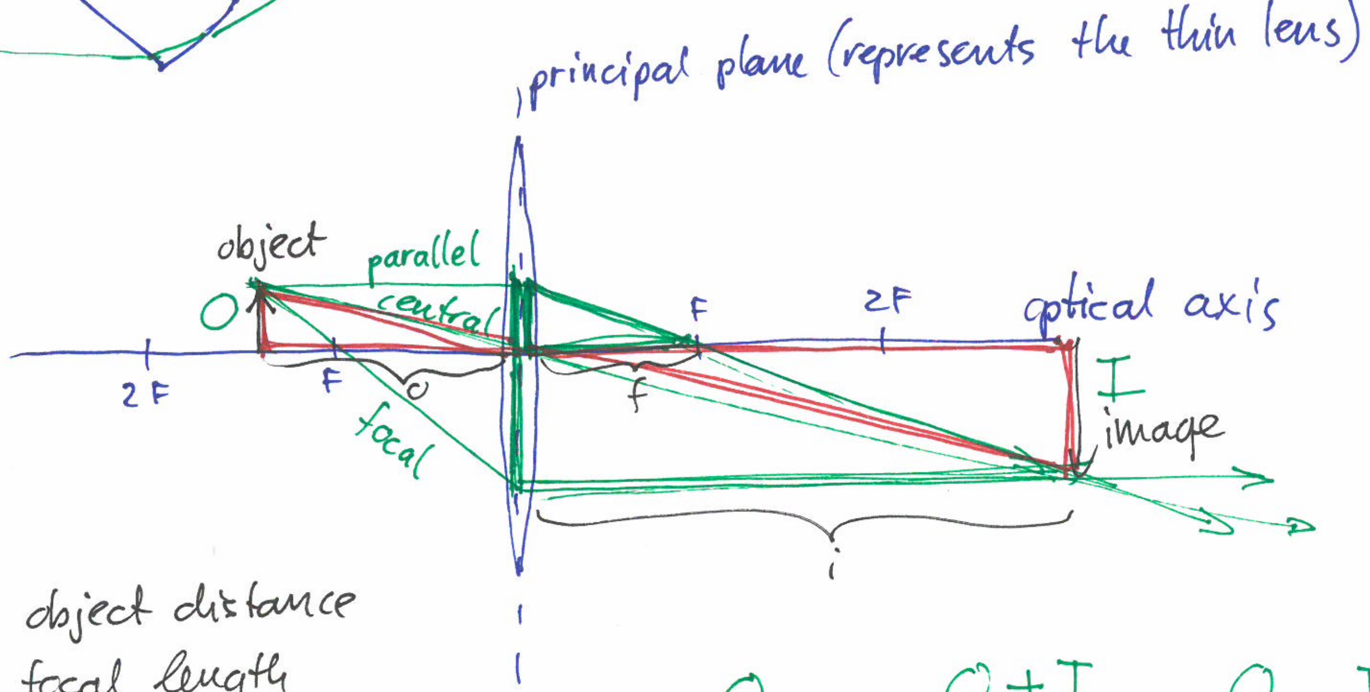
if light travels from "slower medium" to "faster medium" and the angle of incidence is greater than the critical angle it won't enter the faster medium but will be completely reflected = this is called <u>total internal reflection</u> TIR

use: optical fibre
endoscopy

Lens



focal point: light rays parallel to the optical axis (symmetry axis of the lens) are collected here



o object distance

f focal length

i image distance

O object size

I image size

$$\frac{O}{f} = \frac{O+I}{i} = \frac{O}{i} + \frac{I}{i}$$

$$\frac{O}{o} = \frac{I}{i}$$

$$\frac{O}{f} = \frac{O}{i} + \frac{O}{o} \quad / : O$$

$$\boxed{\frac{1}{f} = \frac{1}{i} + \frac{1}{o}}$$

thin lens equation