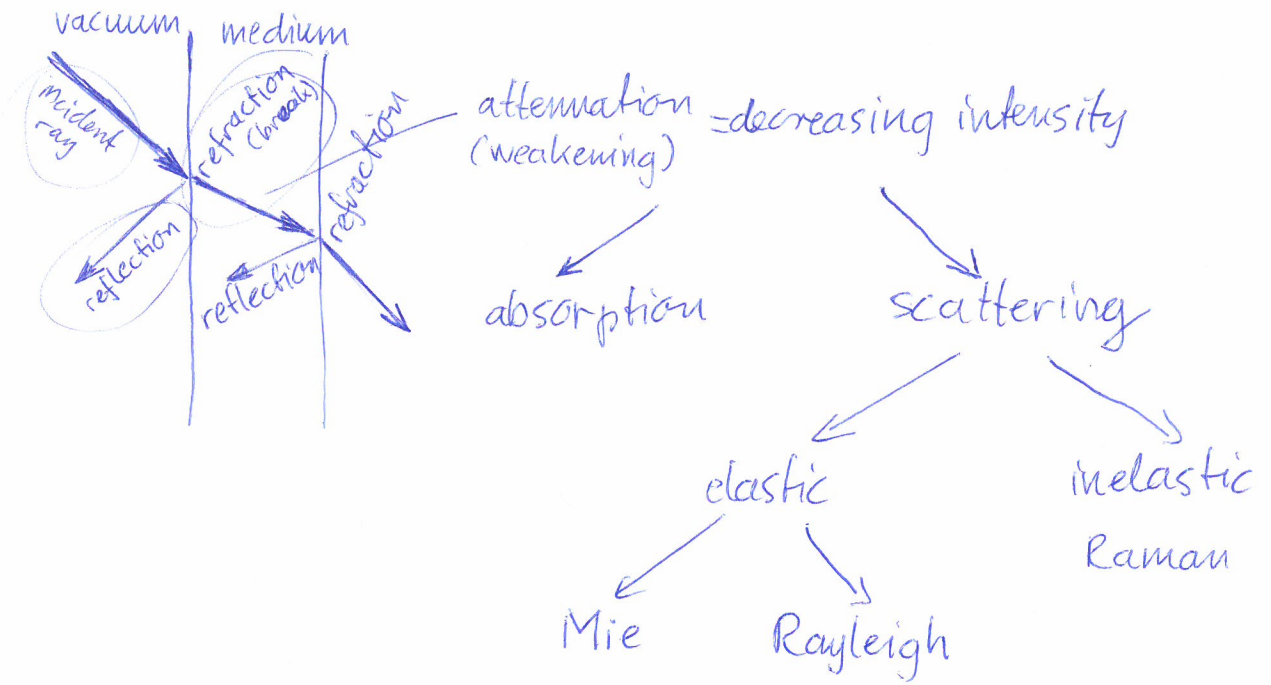
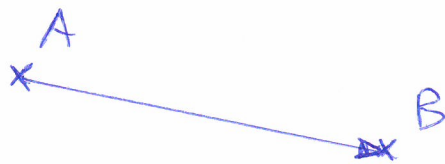


Interaction of light with medium

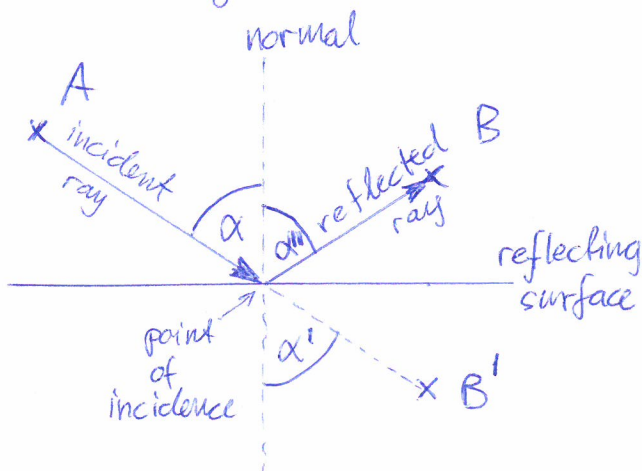


Fermat's principle: light will take between two points of space the path, which requires the least time → not necessarily the shortest path!

1) Propagation in one medium between two points
 least time \Leftrightarrow shortest path
rectilinear propagation
 straight line



2) Mirroring = Reflection

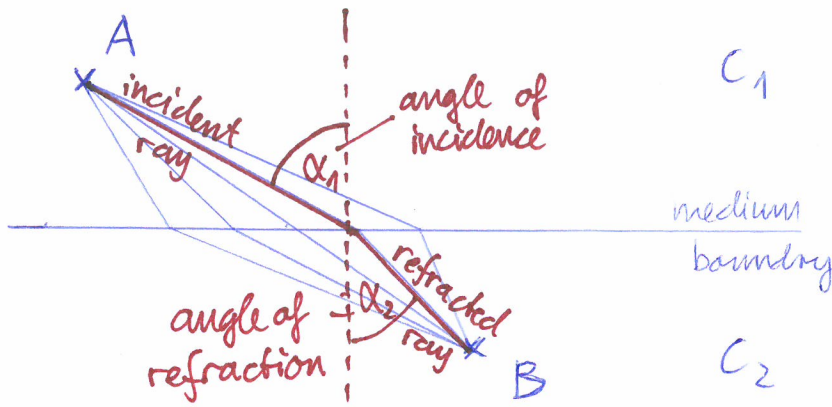


$$\left. \begin{array}{l} \alpha = \alpha' \\ \alpha' = \alpha'' \end{array} \right\} \alpha = \alpha''$$

angle of incidence

angle of reflection

3.) Refraction: propagation through an interface between two media



- speed of light is maximal in vacuum ($3 \times 10^8 \frac{m}{s}$)
- if light penetrates a medium, it will slow down somewhat

Snell's law:

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

refractive index of the second medium relative to the first

$$c_1 > c_2$$

$$\alpha_1 > \alpha_2$$

$$f_1 = f_2$$

$$\lambda_1 > \lambda_2$$

$$n_1 < n_2$$

speed of light angles

using vacuum as reference, we can introduce the concept of absolute refractive index:

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

$$\frac{c_v}{c_1} = n_1 \quad c_1 = \frac{c_v}{n_1}$$

$$n_{2,1} = \frac{\sin \alpha_1}{\sin \alpha_2} = \frac{c_1}{c_2} = \frac{\left(\frac{c_v}{n_1}\right)}{\left(\frac{c_v}{n_2}\right)} = \frac{c_v}{n_1} \cdot \frac{n_2}{c_v} = \frac{n_2}{n_1} = \frac{f \cdot \lambda_1}{f \cdot \lambda_2} = \frac{\lambda_1}{\lambda_2}$$

frequency \rightarrow

$c = f \cdot \lambda$

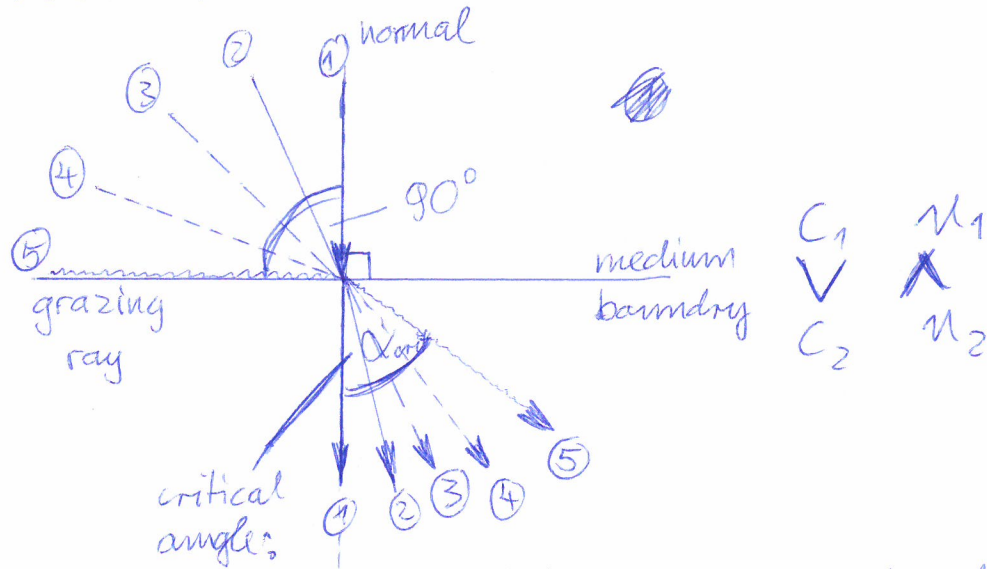
speed of light \rightarrow wavelength \rightarrow

$c_1 = f \cdot \lambda_1$

$c_2 = f \cdot \lambda_2$

Refraction based phenomena and some applications

Phenomenon #1 → critical angle



it is the maximum possible angle of refraction when light goes from lower to higher refractive index medium. (angle of incidence is 90°)

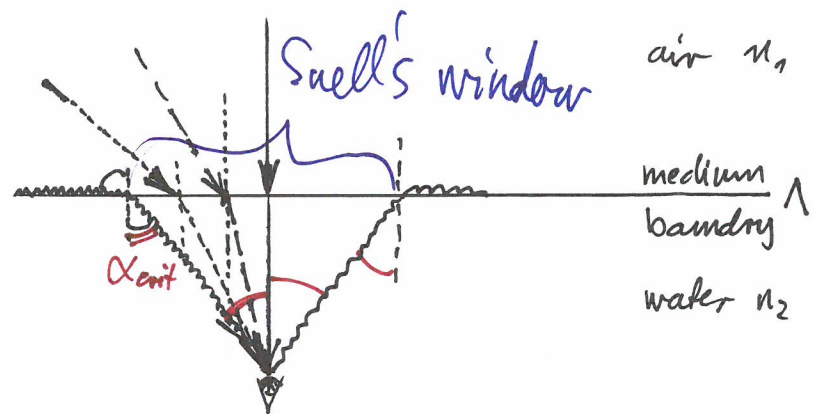
$$\frac{\sin \alpha_1}{\sin \alpha_2} = \frac{n_2}{n_1}$$

Formation of Snell's window

$$\frac{\sin 90^\circ}{\sin \alpha_{crit}} = \frac{n_2}{n_1}$$

$$\frac{1}{\sin \alpha_{crit}} = \frac{n_2}{n_1}$$

$$\sin \alpha_{crit} = \frac{n_1}{n_2}$$

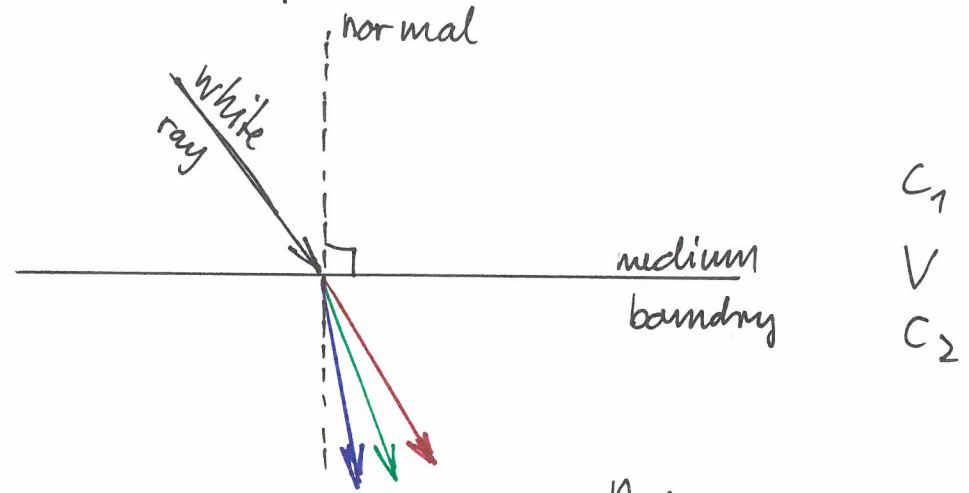


Snell's window is always seen under $2 \cdot \alpha_{crit}$.

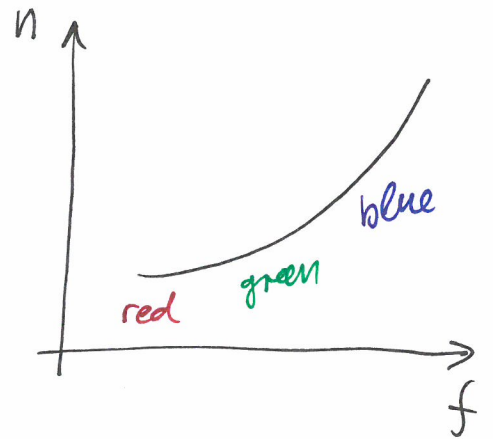
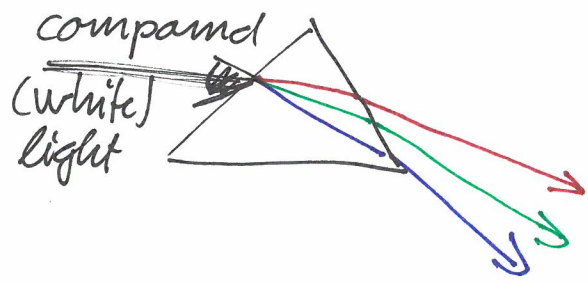
Application: Refractometry

Phenomenon #2

→ dispersion

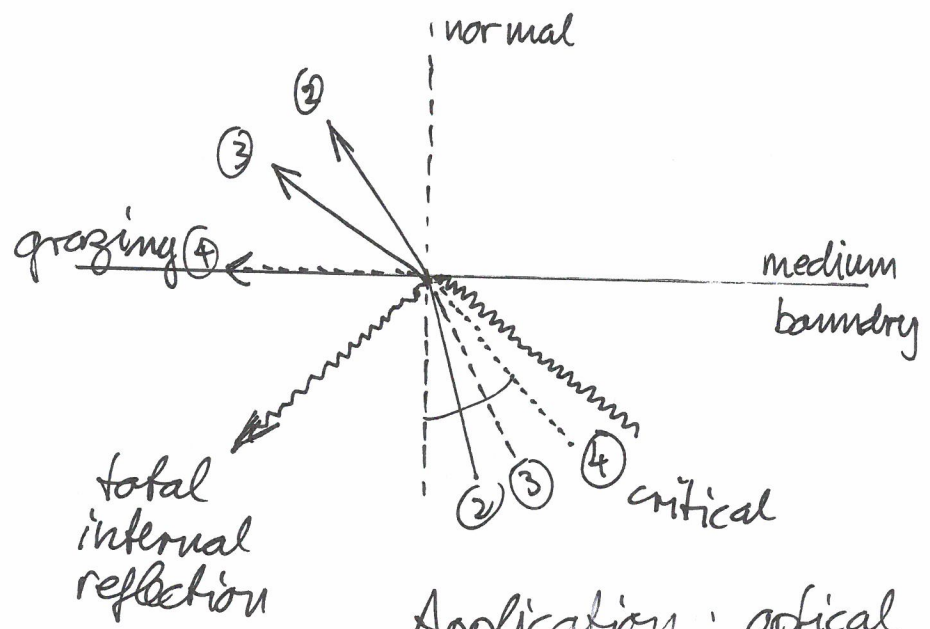


application: prism monochromator
one color



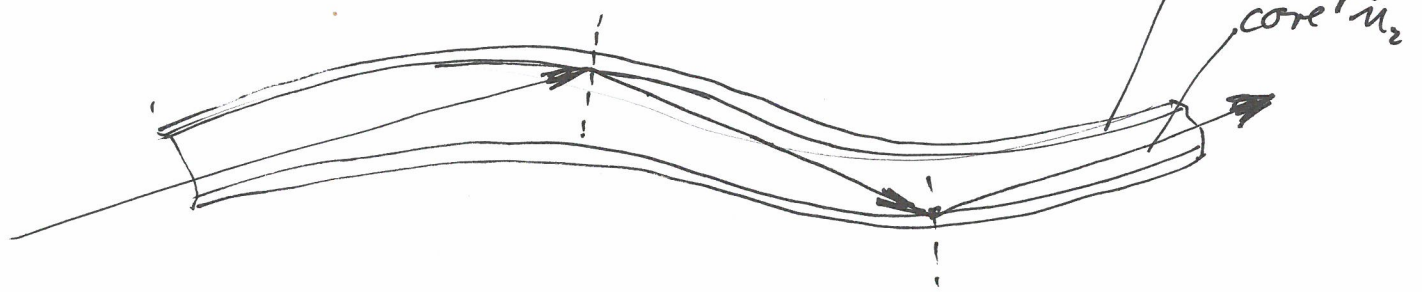
Phenomenon #3

→ total internal reflection



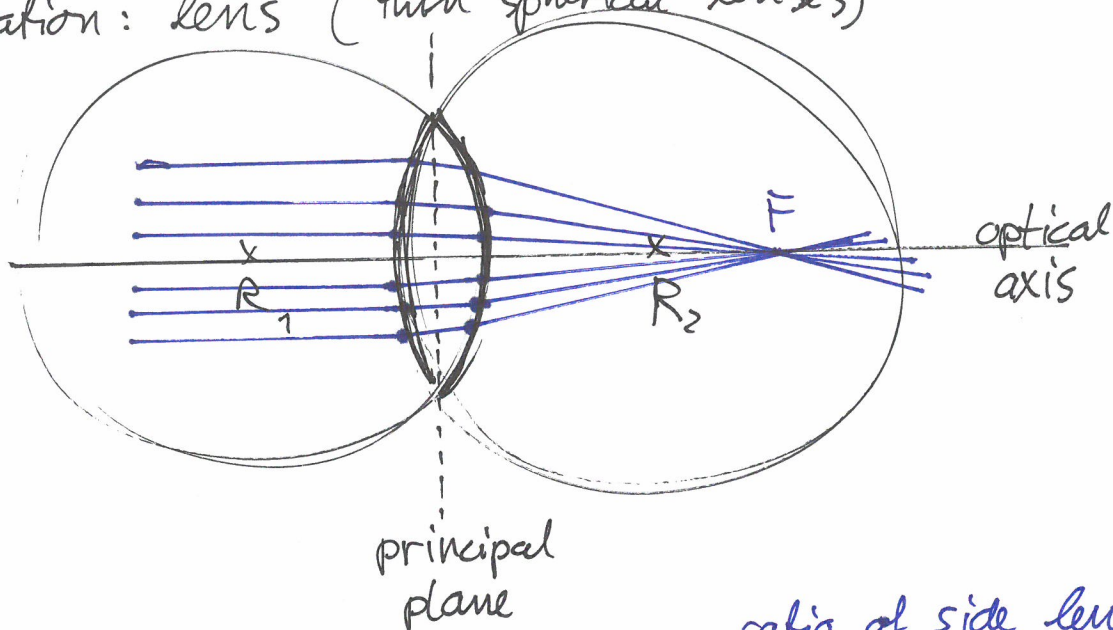
C_1 n_1
 V \wedge
 C_2 n_2

Application: optical fibre, endoscopy
mantle n_1
core n_2

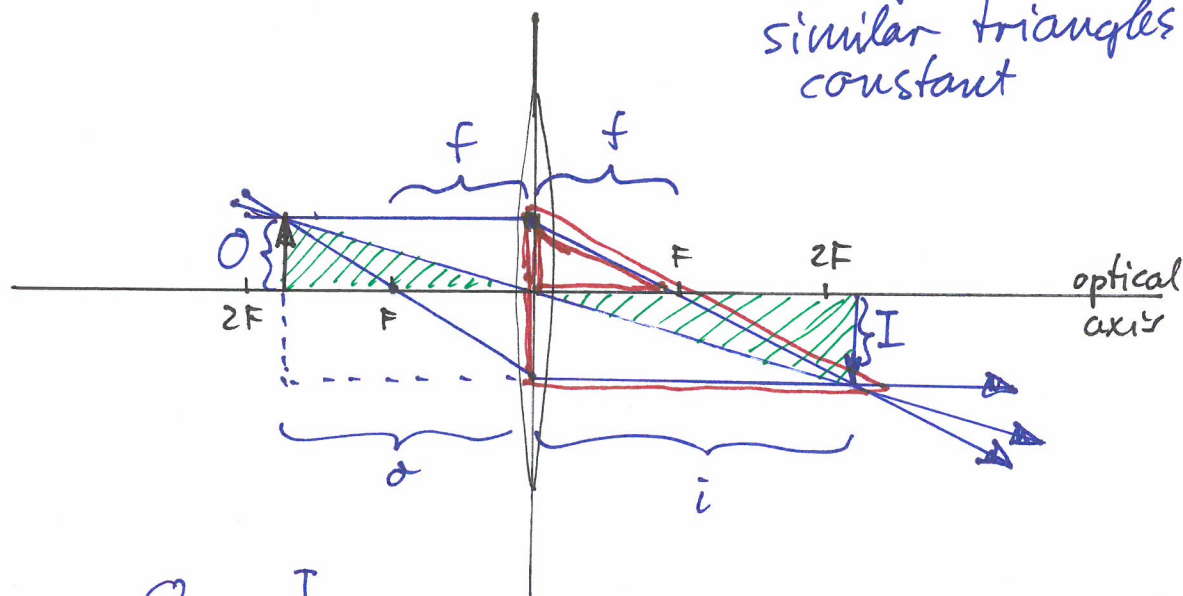


Phenomenon#4: Refraction on a curved surface

Application: lens (thin spherical lenses)



ratio of side lengths of similar triangles is constant



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

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

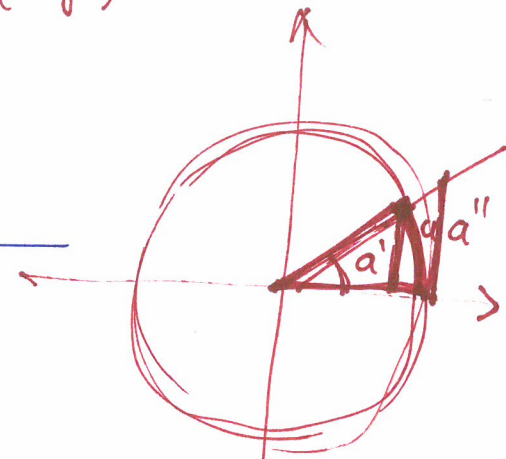
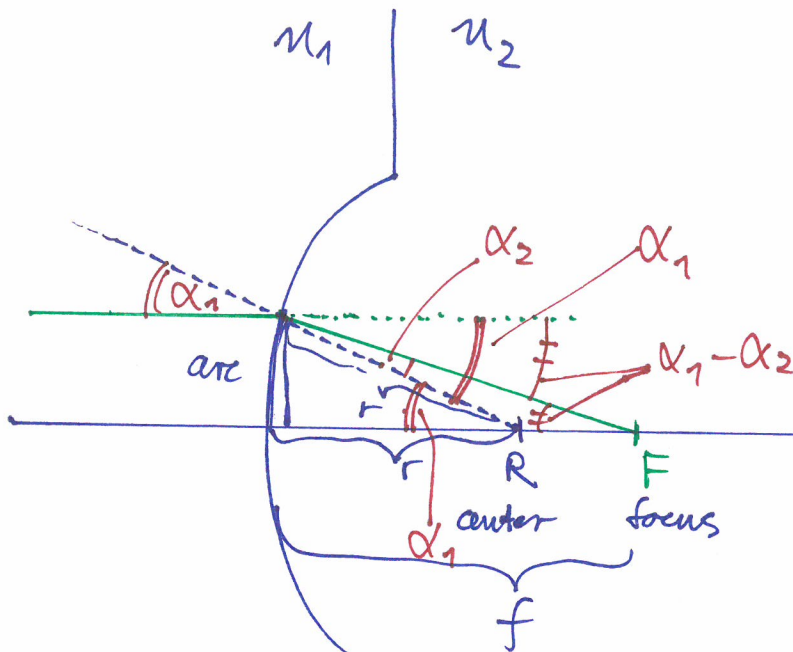
$$\frac{O}{f} = \frac{O}{i} + \frac{O}{o} \quad \text{/: } O$$

$$\boxed{\frac{1}{f} = \frac{1}{i} + \frac{1}{o}} \Rightarrow \text{lens equation}$$

How does the focal length depend on the parameters of the curved surface? $n_1; n_2; r$

$$\text{angle} = \frac{\text{arc}}{\text{radius}} \quad [\text{radian}]$$

$$\sin(\text{angle}) =$$



for small angles:

$$\alpha [\text{rad}] \approx \sin \alpha \approx \tan \alpha$$

this is valid for paraxial rays (= close to axis)

$$\frac{\sin \alpha_2}{\sin \alpha_1} = \frac{n_1}{n_2} \approx \frac{\alpha_2}{\alpha_1}$$

$$\alpha_1 = \frac{\text{arc}}{r} \quad \text{arc} = r \cdot (\alpha_1)$$

$$\tan(\alpha_1 - \alpha_2) = \frac{\text{arc}'}{f} \approx \frac{\text{arc}'}{f} \approx \alpha_1 - \alpha_2 \quad \text{arc}' = f(\alpha_1 - \alpha_2)$$

$$\text{arc} \approx \text{arc}'$$

$$r \cdot \alpha_1 \approx f \cdot (\alpha_1 - \alpha_2)$$

$$\frac{r}{f} = \frac{\alpha_1 - \alpha_2}{\alpha_1} = \left(\frac{\alpha_1}{\alpha_1} \right) - \left(\frac{\alpha_2}{\alpha_1} \right) = 1 - \frac{n_1}{n_2}$$

power
of the
curved
surface

$$D = \frac{n_2}{f} = \frac{n_2 - n_1}{r}$$

two curved surfaces = lens

the powers add up

n_1



$$D = D_1 + D_2 = \frac{n_1 - n_2}{r_1} + \frac{n_1 - n_2}{r_2}$$

lens maker's
equation

$$D = (n_1 - n_2) \left(\frac{1}{r_1} + \frac{1}{r_2} \right)$$

usually air $n_1 = 1$