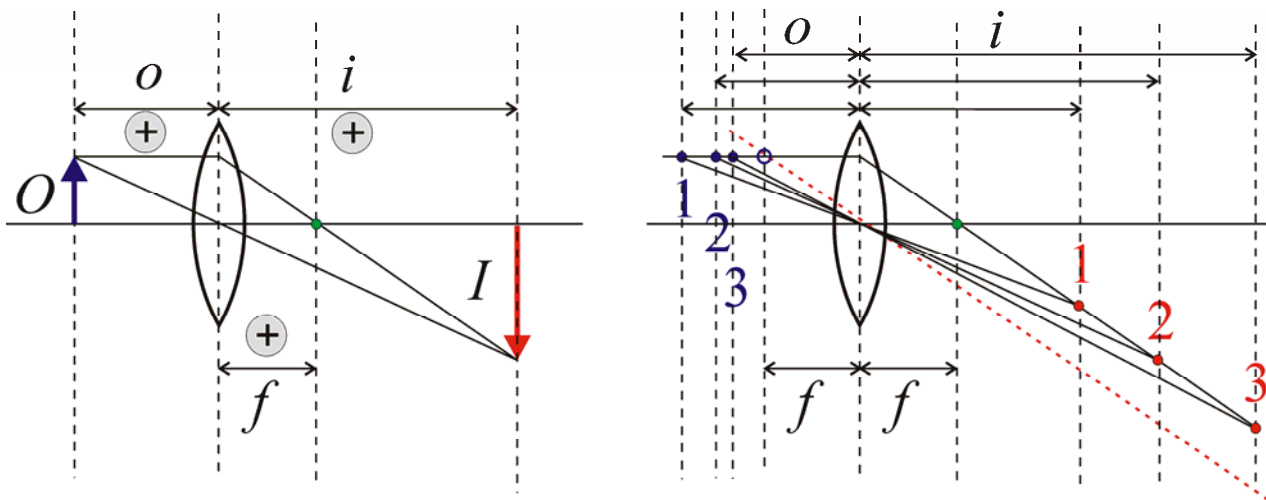


Image formation by lenses (thin lens approximation)



Lens equation and lens-makers' equation:

$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f} = (n-1) \left(\frac{1}{r_1} + \frac{1}{r_2} \right)$$

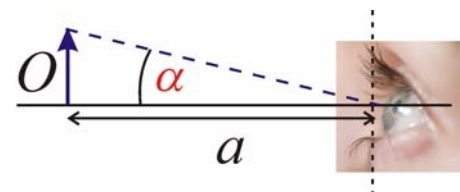
r_1, r_2 : radii of curvature of the lens surface,

n : refractive index of the medium of the lens.

Simple magnifier

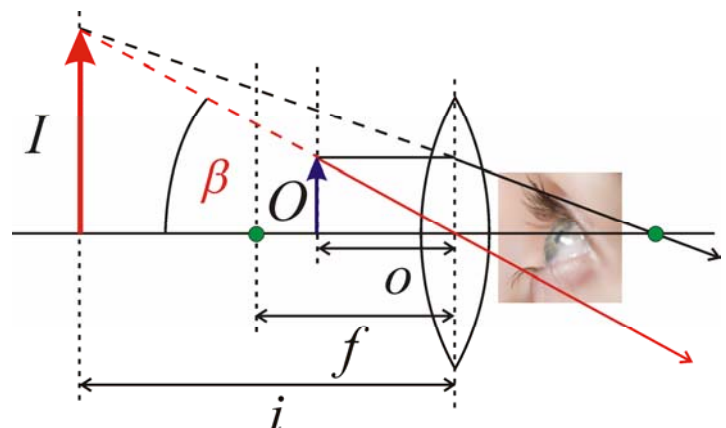
We have to compare two cases: eye looks at the **O object**

1. **without lens** from the conventional **near point** ($a \approx 25$ cm), under the angle of α



2. **with lens** from the distance o , under the angle of β

I virtual image



Angular magnification (definition):

$$N = \frac{\tan \beta}{\tan \alpha} \quad \text{and we use} \quad \frac{1}{\textcircled{o}} = \frac{1}{f} - \frac{1}{i}$$

In our case (simple magnifier):

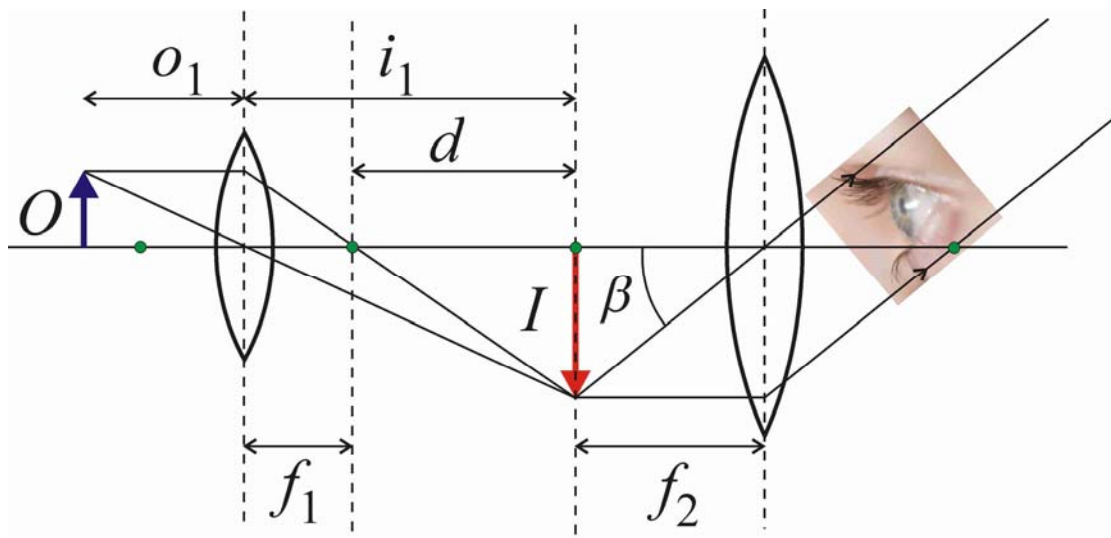
$$N = \frac{\tan \beta}{\tan \alpha} = \frac{\frac{I}{i}}{\frac{O}{a}} = \frac{\frac{O}{o}}{\frac{O}{a}} = \frac{a}{\textcircled{o}} = a \left(\frac{1}{f} - \frac{1}{i} \right).$$

Two possible answers:

- I. if $i = -a$ than $N = \frac{a}{f} + 1,$
- II. if $i = -\infty$ than $N = \frac{a}{f}$

In the I. case eye looks at the virtual image **with accommodation**,
in the II. case **without accommodation**, eye is focused at infinity,
thus $o = f$.

Lens systems (1) **microscope**



Without accommodation, eye is focused at infinity.

Angular magnification of microscope:

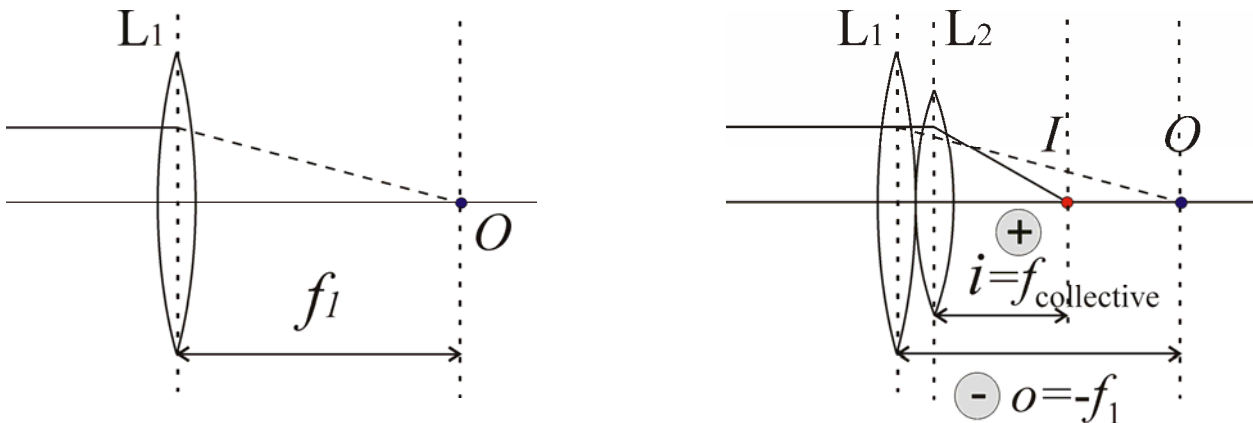
$$N = \frac{\text{tg}\beta}{\text{tg}\alpha} = \frac{\frac{I}{f_2}}{\frac{O}{a}} = \frac{I}{f_2} \frac{a}{O} = \frac{I}{O} \frac{a}{f_2} = \frac{i_1}{o_1} \frac{a}{f_2};$$

$$\frac{1}{o_1} = \frac{1}{f_1} - \frac{1}{i_1} = \frac{i_1 - f_1}{f_1 i_1} = \frac{d}{f_1 i_1}$$

$$N = \frac{d}{f_1 i_1} \frac{i_1 a}{f_2} = \frac{da}{f_1 f_2}$$

Lens systems (2) **power** (refractive strength)

How high the collective focal length of two close juxtaposed lenses is $\{L_1(f_1), L_2(f_2)\}$?



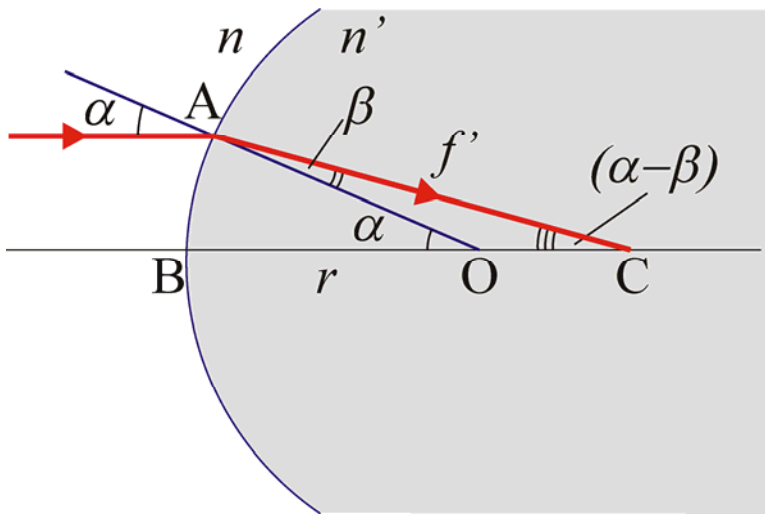
Let's apply the lens equation for O as a virtual object.

$$-\frac{1}{f_1} + \frac{1}{f_{\text{collective}}} = \frac{1}{f_2} \quad \frac{1}{f_{\text{coll.}}} = \frac{1}{f_1} + \frac{1}{f_2} = D_{\text{coll.}} = D_1 + D_2$$

In such cases **powers are added**. Units $[1/\text{m}]$, **dioptre**, $[\text{dpt}]$.

Application e.g.: glasses, contact lenses.

Image formation by simple curved surface (sphere with radius r):



For small angles:

$$1. \quad \frac{\sin \beta}{\sin \alpha} = \frac{n}{n'} \approx \frac{\beta}{\alpha}$$

For the arc AB:

$$2. \quad f'(\alpha - \beta) \approx r \alpha$$

$$\frac{\alpha - \beta}{\alpha} = \frac{r}{f'} \quad 1 - \frac{\beta}{\alpha} = \frac{r}{f'}$$

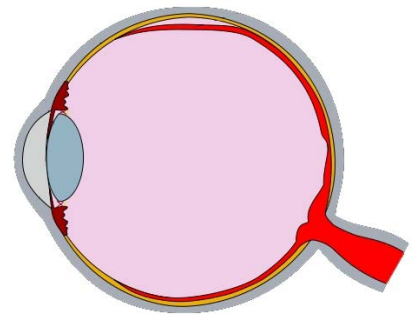
Substitution according to equation 1.:

$$1 - \frac{n}{n'} = \frac{r}{f'}, \quad \frac{n' - n}{n'} = \frac{r}{f'}$$

The **power** in this case:

$$D = \frac{n'}{f'} = \frac{n' - n}{r}$$

Application: for the human eye
e.g. the power of cornea



<i>medium</i>	<i>r [mm]</i>	<i>n</i>	<i>n'-n</i>	<i>D [dpt]</i>
air		1		
			0,37	48
cornea	7,7	1,37		

There are phenomena that cannot be explained by this model.