Optics

What is light?   Visible electromagnetic radiation
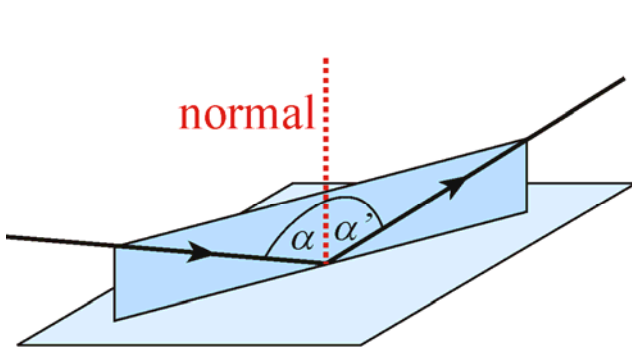
Geometrical optics (model)

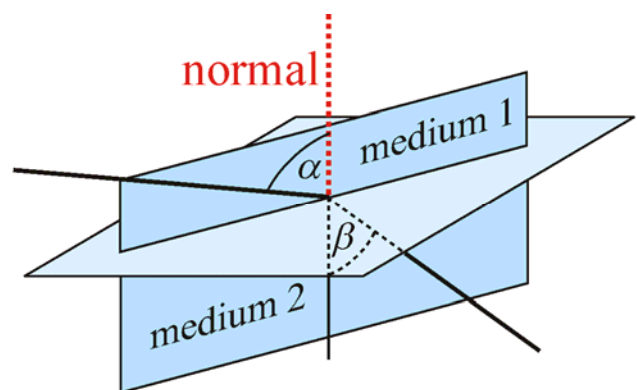**Light-ray:** extremely thin parallel light beam

Using this model, the explanation of several optical phenomena can be given as the solution of simple **geometric problems**.

1. law of rectilinear propagation
2. law of reflection
3. law of refraction

2a, **3**a) The incident ray, the normal and the reflected ray, or refracted ray lie in the same plane.

2b) $\alpha = \alpha'$ **3**b) $\dfrac{\sin \alpha}{\sin \beta} = \dfrac{c_1}{c_2} = n_{21} = \dfrac{n_2}{n_1}$

($c_1 > c_2$ thus $n_1 < n_2$)

All the angles are measured from the normal!

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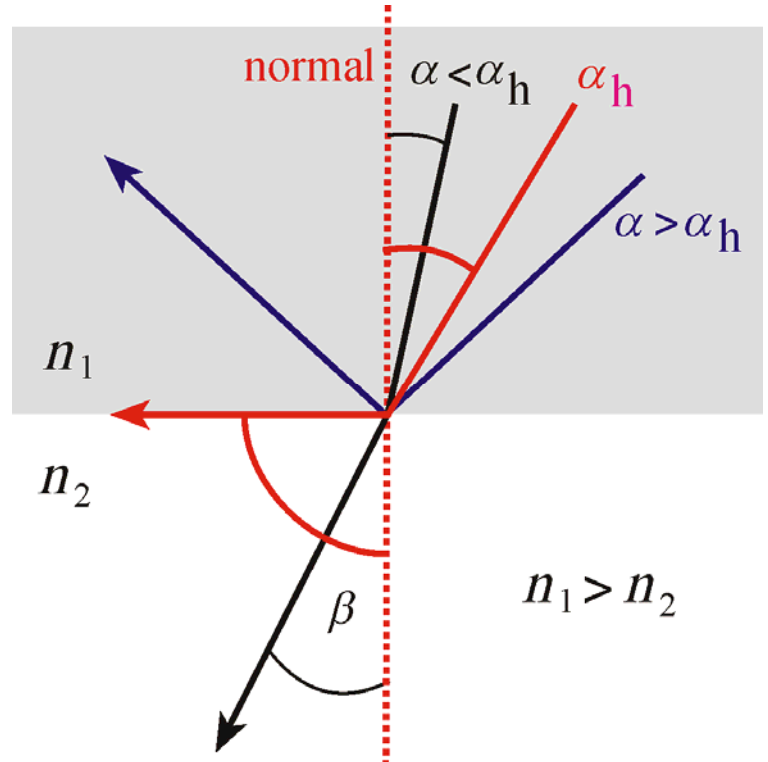All these laws can be deduced from a single common principle!

Fermat-priciple

The **'principle of shortest time'**: out of the geometrically possible paths, light will travel along the one that requires the shortest time to pass.

Total reflection
(If $n_1 > n_2$)

$$\frac{\sin \alpha_h}{\sin \frac{\pi}{2}} = \sin \alpha_h = \frac{n_2}{n_1}$$

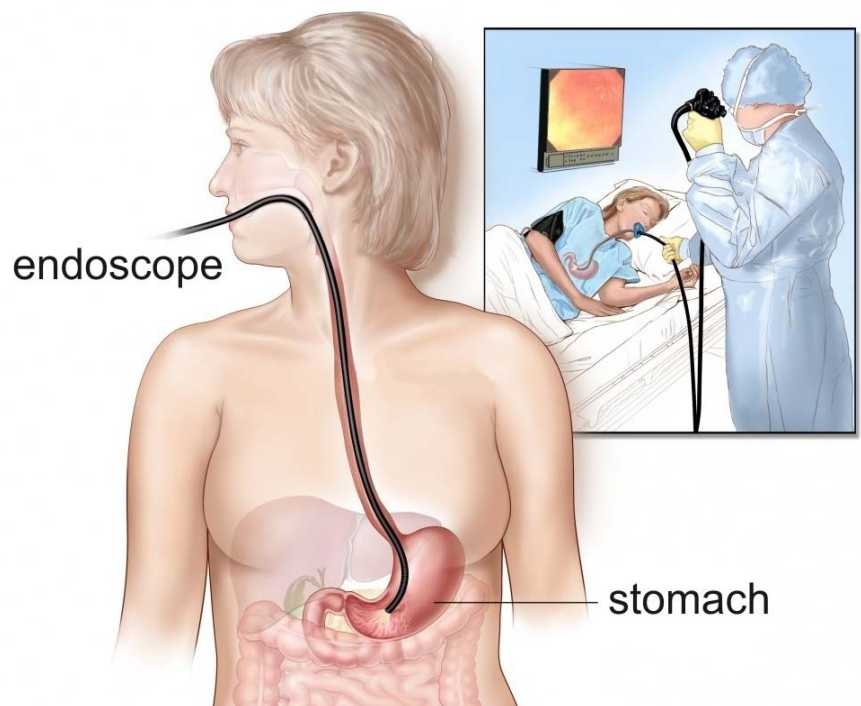
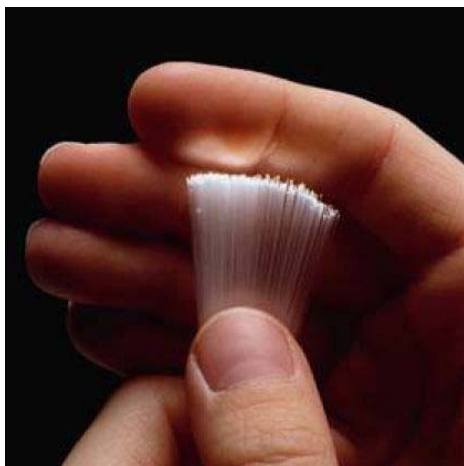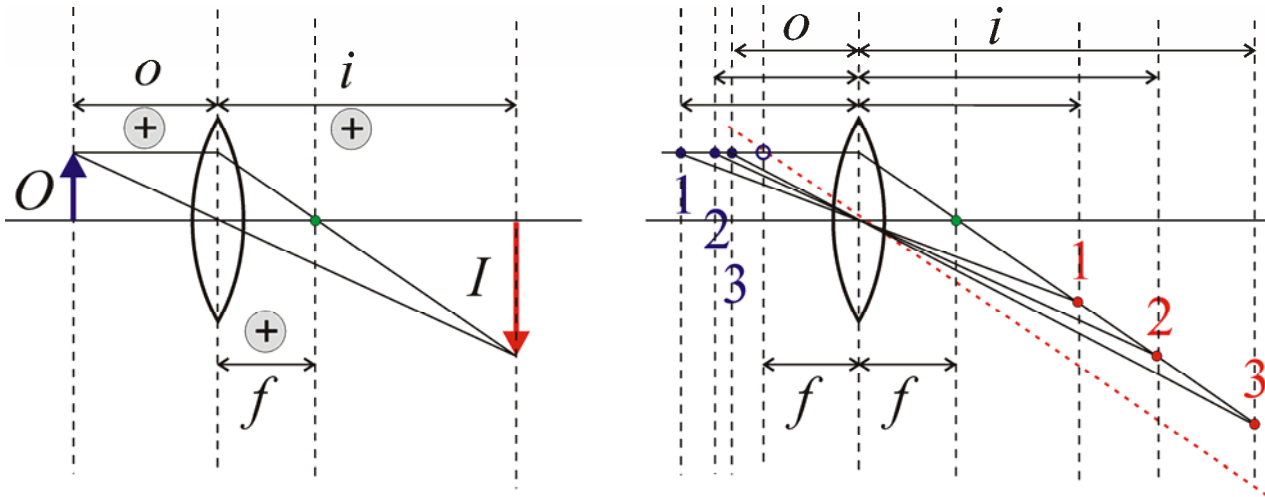Application e.g.:   Optical fiber (endoscopy)

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Image formation by lenses (thin lens approximation)

Lens equation and lens-makers' equation:

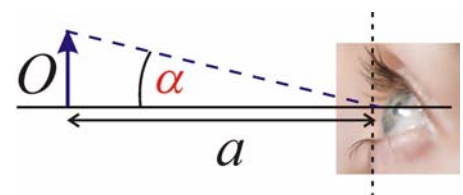$$\frac{1}{o} + \frac{1}{i} = \frac{1}{f} = (n-1)\left(\frac{1}{r_1} + \frac{1}{r_2}\right)$$

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

n: refractive index of the medium of the lens.

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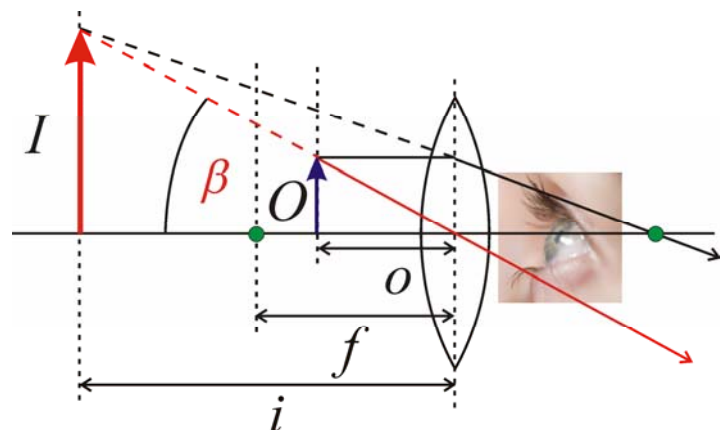
We have to compare two cases: eye looks at the O object

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):

$$N = \frac{tg\beta}{tg\alpha} \qquad \text{and we use} \qquad \frac{1}{\textcircled{o}} = \frac{1}{f} - \frac{1}{i}$$
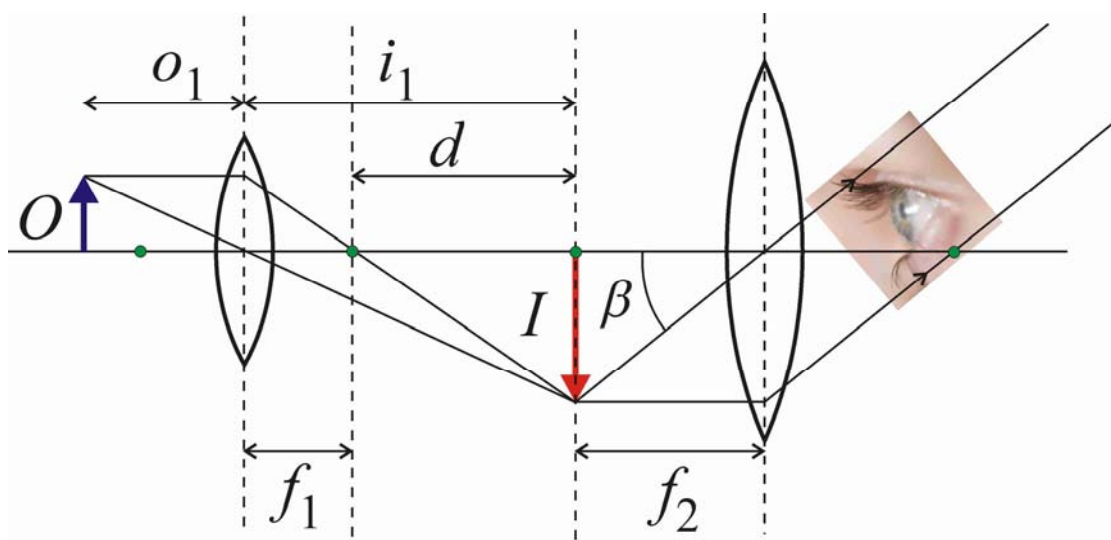
In our case (simple magnifier):

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

Two possible answers:

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

II. if $i = -\infty$ than $N = \dfrac{a}{f}$

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

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Lens systems (1) microscope

Without accommodation, eye is focused at infinity.
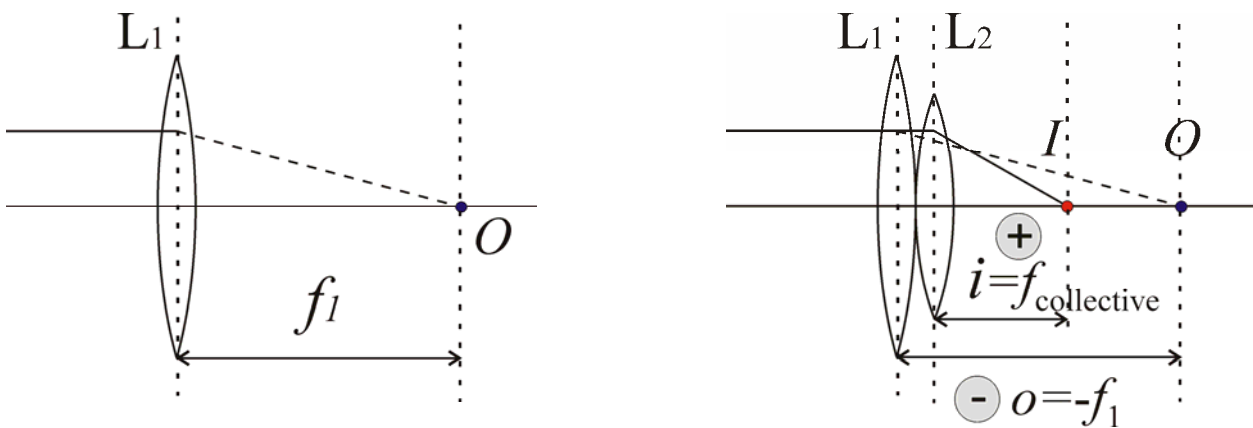
Angular magnification of microscope:

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

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

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

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

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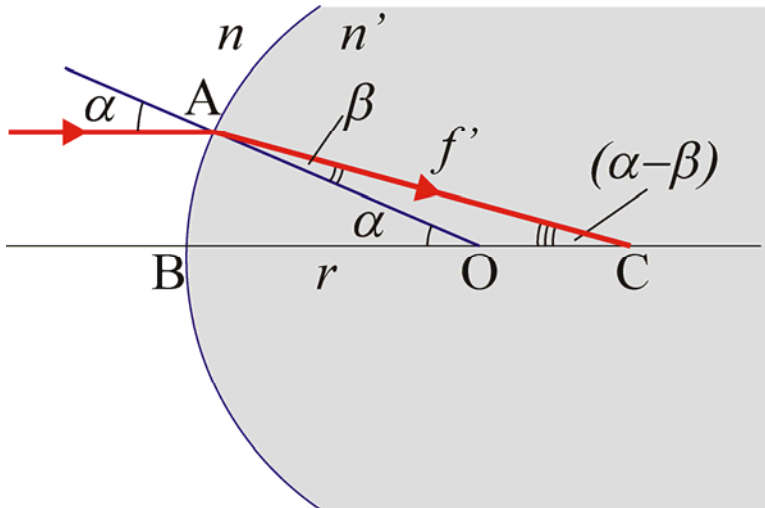

Let's apply the lens equation for O as a virtual object.

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

In such cases powers are added. Units [1/m], dioptre, [dpt].
Application e.g.: glasses, contact lenses.

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

For small angles:

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

For the arc AB:

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

$$\dfrac{\alpha - \beta}{\alpha} = \dfrac{r}{f'} \qquad\qquad 1 - \dfrac{\beta}{\alpha} = \dfrac{r}{f'}$$
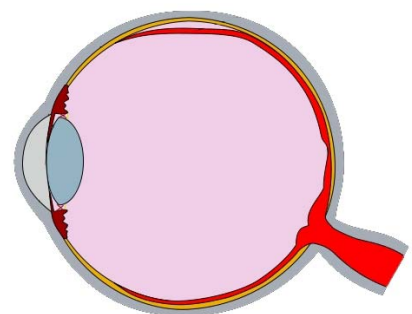
Substitution according to equation 1.:

$$1 - \dfrac{n}{n'} = \dfrac{r}{f'}, \qquad\qquad \dfrac{n'-n}{n'} = \dfrac{r}{f'}$$

The power in this case:

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

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

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

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There are phenomena that cannot be explained by this model.