Optics

What is light? Visible electromagnetic radiation

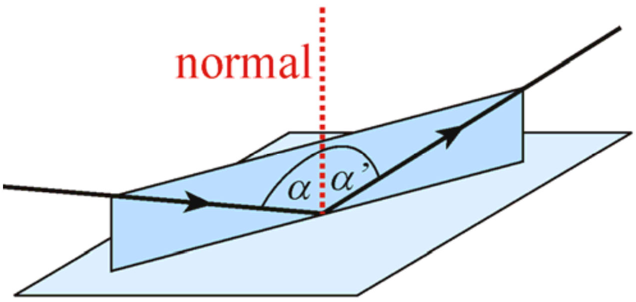
Geometrical optics (model)

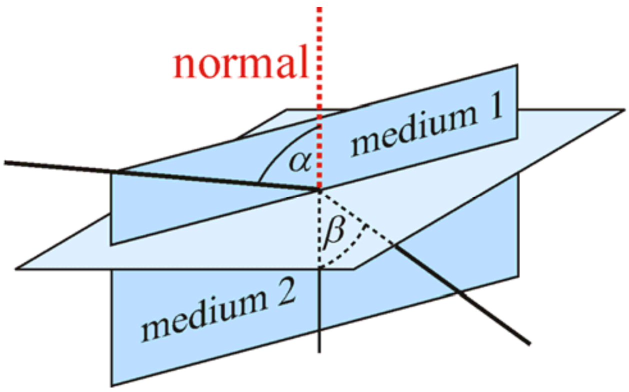
Light-ray: extremely thin parallel light beam

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





2b) $\alpha = \alpha'$

3b) $$\frac{\sin\alpha}{\sin\beta} = \frac{c_1}{c_2} = n_{21} = \frac{n_2}{n_1}$$

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

All the angles are measured from the normal!

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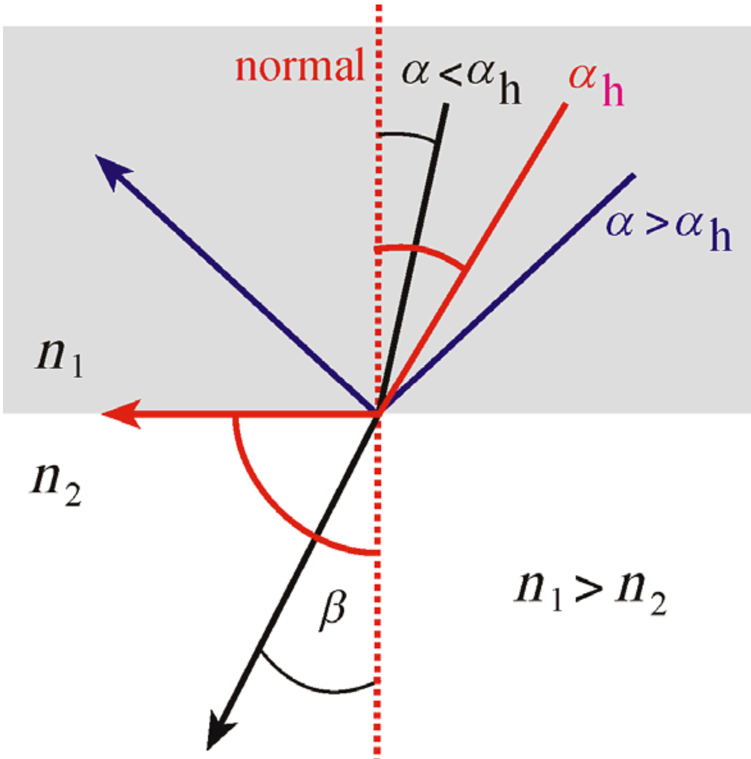
All these laws can be deduced from a single common principle!

Fermat-priciple

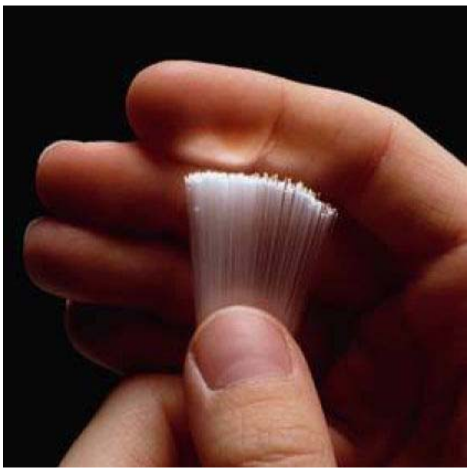
The **‘principle of shortest time’**: out of the geometrically possible paths, light will travel along the one that requires the shortest time to pass.

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)



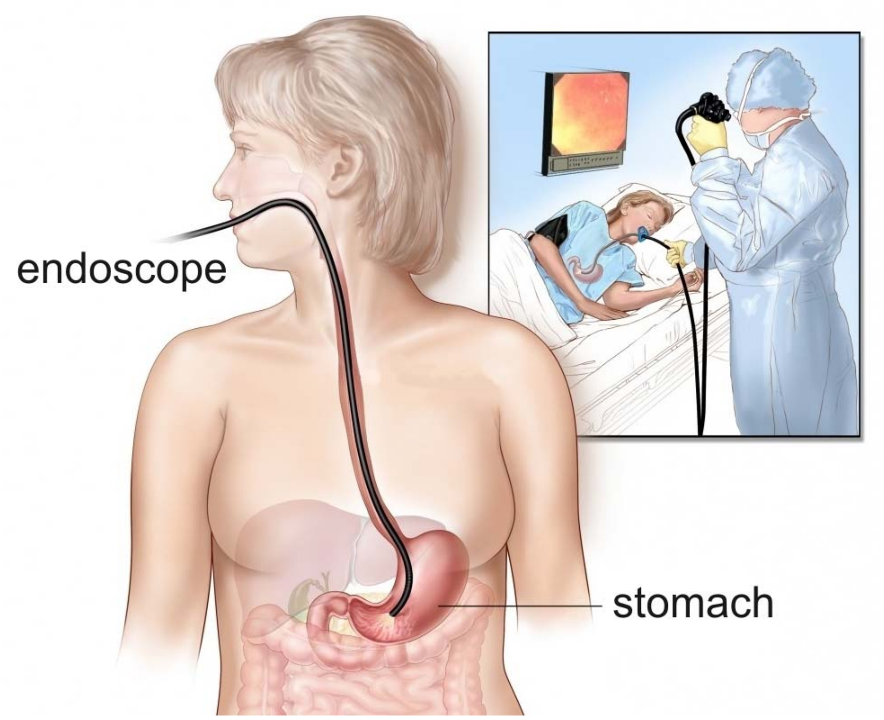


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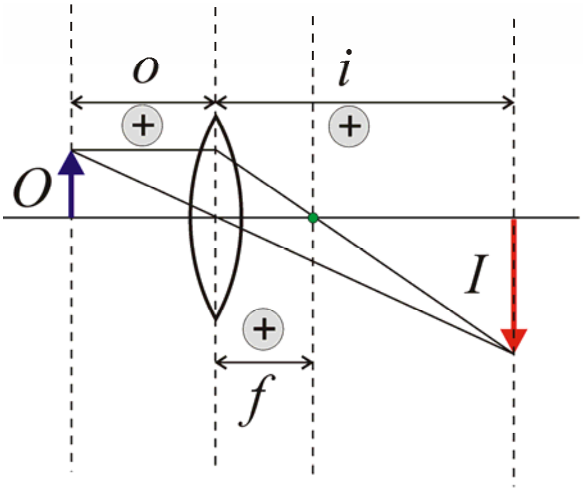
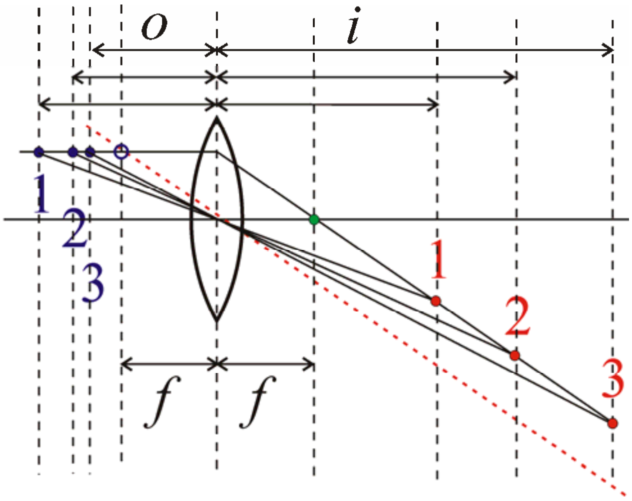
Image formation by lenses (thin lens approximation)





Lens equation and **lens-makers' equation**:

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

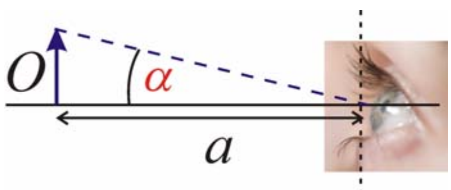
r_1, r_2: radii of curvature of the lens surface,

n: refractive index of the medium of the lens.

Simple magnifier

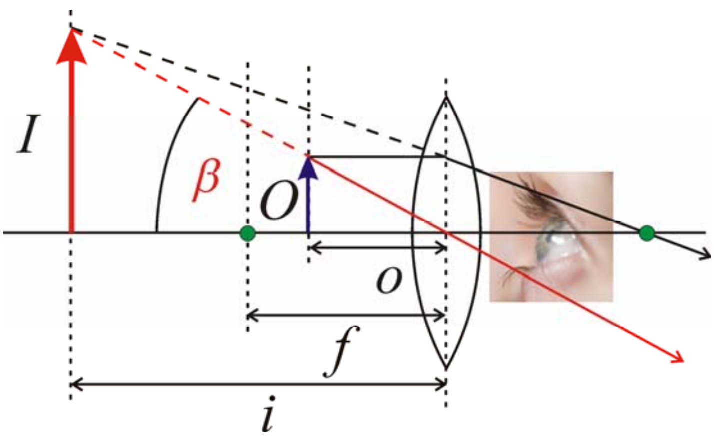
We have to compare two cases: eye looks at the *O* object

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):

$$N = \frac{tg\beta}{tg\alpha} \qquad \text{and we use} \qquad \frac{1}{o} = \frac{1}{f} - \frac{1}{i}$$

In our case (simple magnifier):

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

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 $o = f$.

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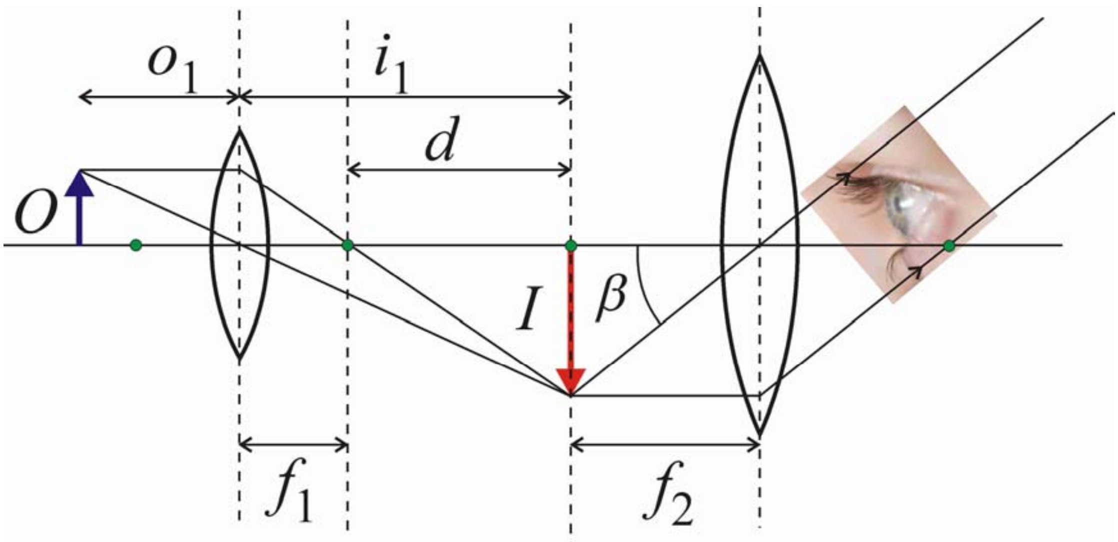
Lens systems (1) microscope



Without accommodation, eye is focused at infinity.

Angular magnification of microscope:

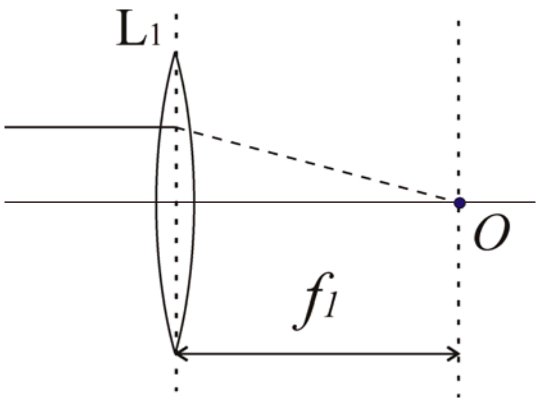
$$N = \frac{tg\beta}{tg\alpha} = \frac{\frac{I}{f_2}}{\frac{O}{a}} = \frac{I}{f_2}\frac{a}{O} = \frac{I}{O}\frac{a}{f_2} = \frac{i_1}{o_1}\frac{a}{f_2};$$

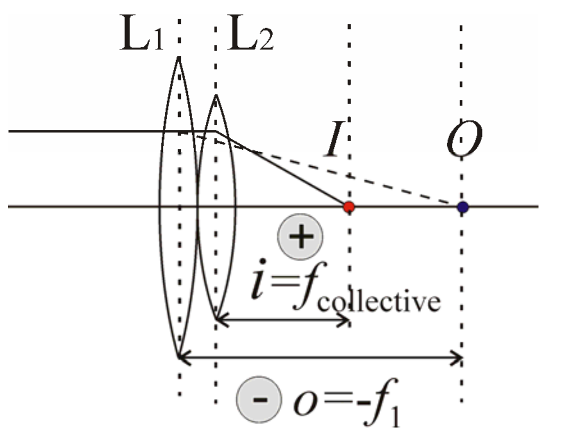
$$\frac{1}{o_1} = \frac{1}{f_1} - \frac{1}{i_1} = \frac{i_1 - f_1}{f_1 i_1} = \frac{d}{f_1 i_1}$$

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

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.

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

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

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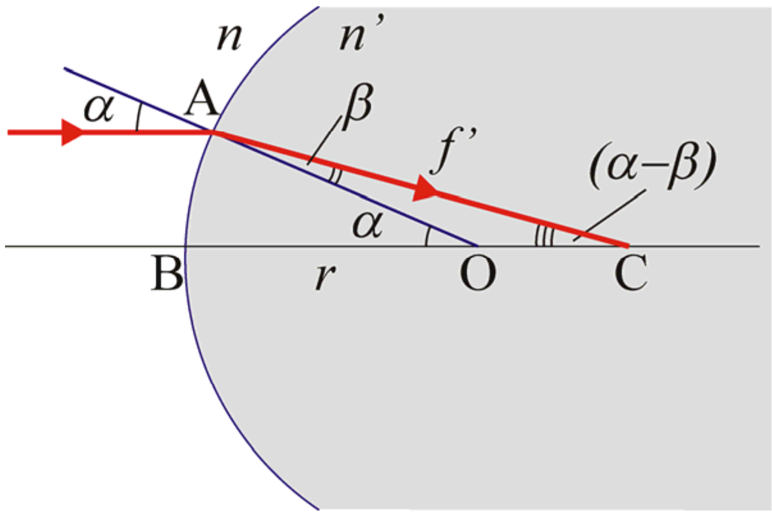
Image formation by simple curved surface (sphere with radius r):



For small angles:

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

For the arc AB:

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

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

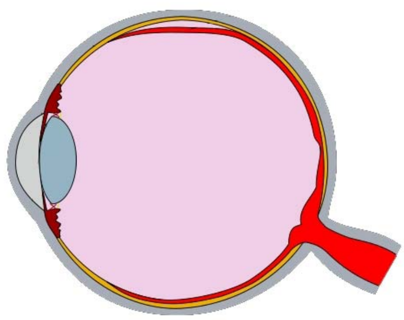
Substitution according to equation 1.:

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

The power in this case:

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

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



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.