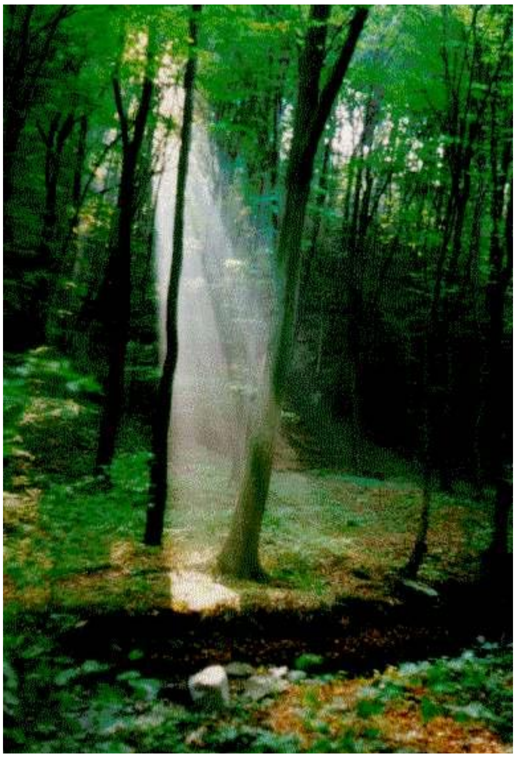
Optics

What is light? Visible electromagnetic radiation



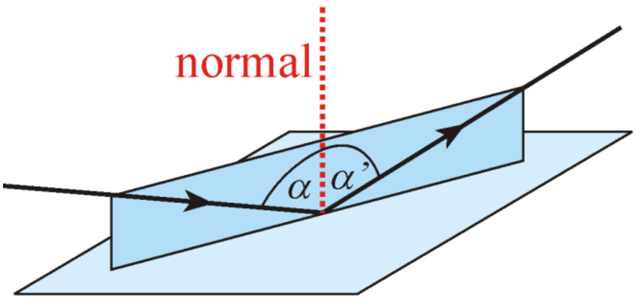
Geometrical optics (model)

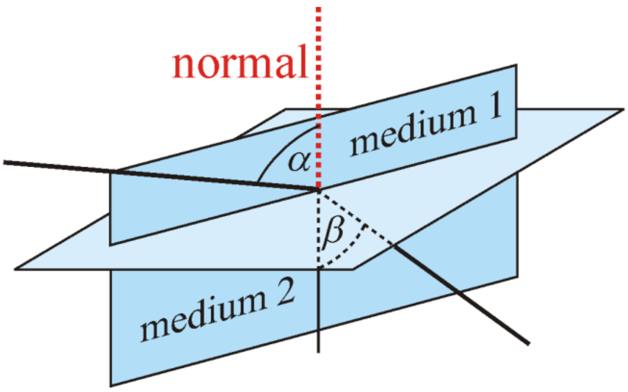
Light-ray: extremely thin parallel light beam

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) $\alpha = \alpha'$

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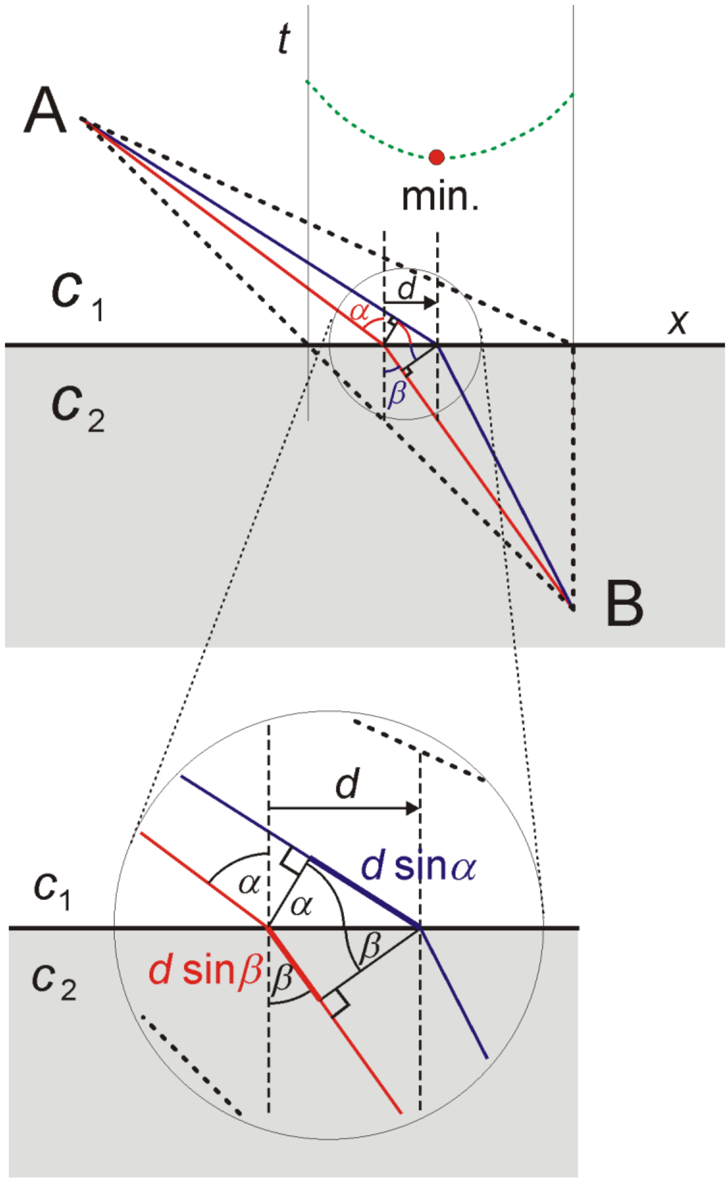
All these laws can be deduced from a single common principle!

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.

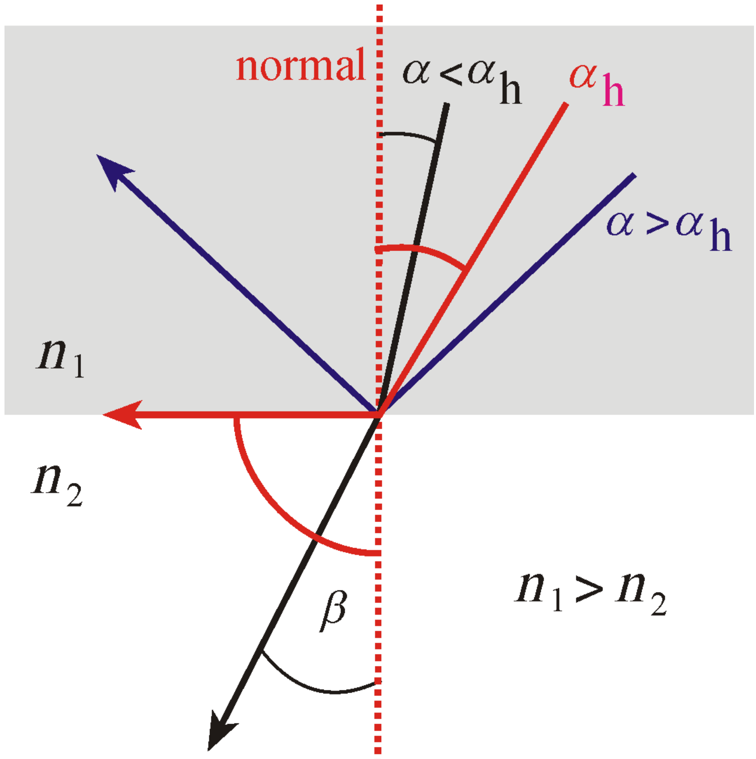


$$t_{\min} = \frac{d \sin\alpha}{c_1} = \frac{d \sin\beta}{c_2}$$

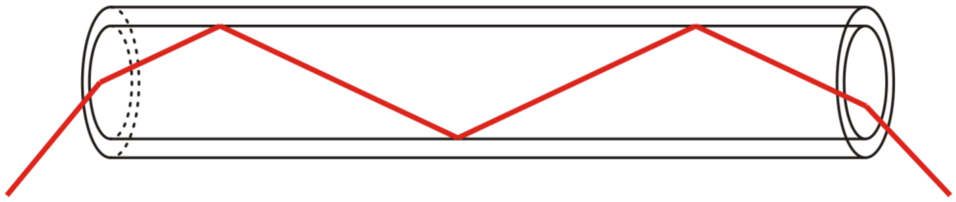
$$\frac{\sin\alpha}{\sin\beta} = \frac{c_1}{c_2}$$

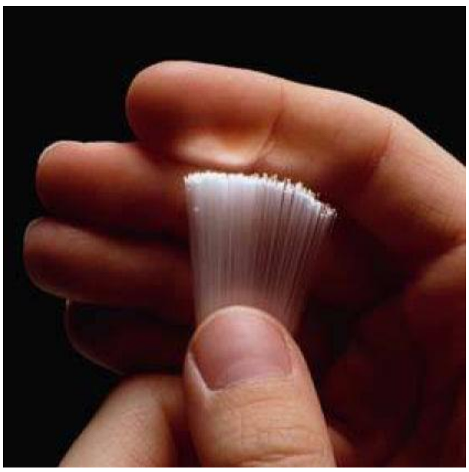
Total reflection
(If $n_1 > n_2$)

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



Application e.g.: Optical fiber (endoscopy)





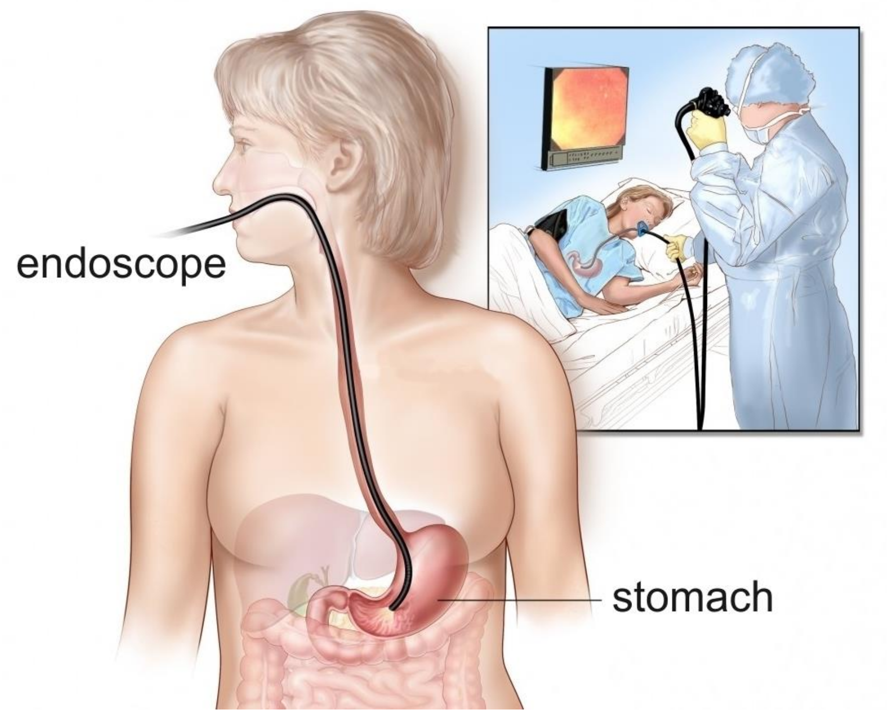


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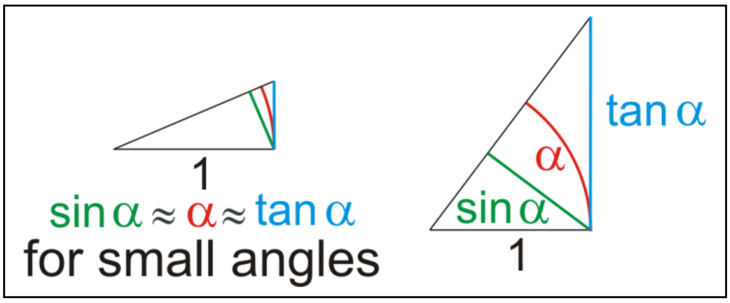
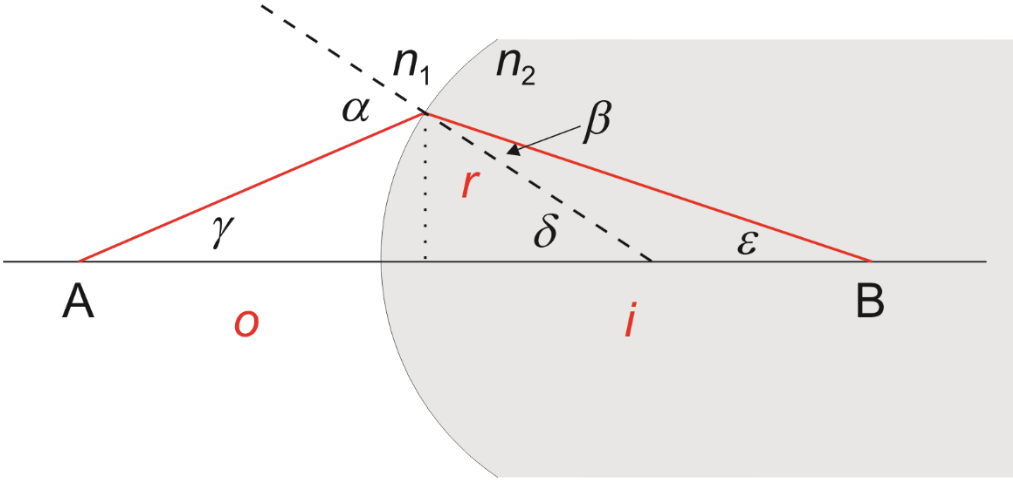
Image formation by simple curved surface (sphere with radius r):

For small angles:

$$\frac{\sin\alpha}{\sin\beta} = \boxed{\frac{n_2}{n_1} \approx \frac{\alpha}{\beta}}$$



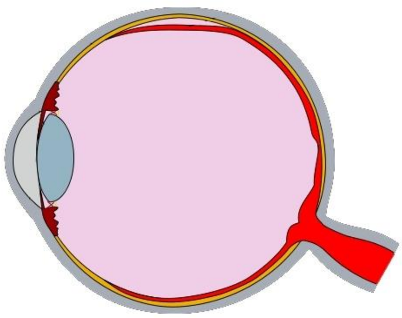


$$\alpha = \gamma + \delta; \qquad \beta = \delta - \varepsilon$$

The power in this case:

$$\frac{n_1}{o} + \frac{n_2}{i} = \frac{(n_2 - n_1)}{r} = D$$

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



medium	***r*** [mm]	***n***	***n_2-n_1***	***D*** [dpt]
air		1		
			0,37	48
cornea	7,7	1,37		

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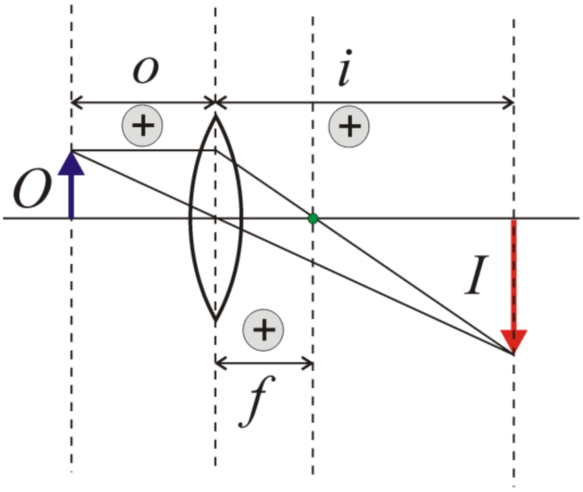
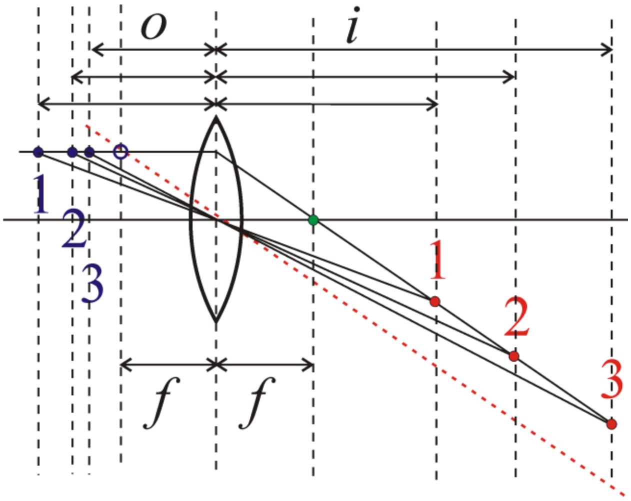
Image formation by lenses (thin lens approximation)





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

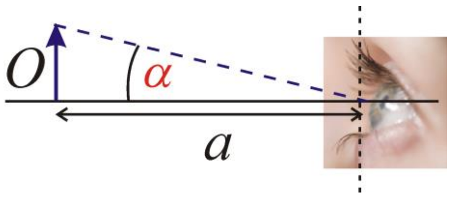
$$\frac{1}{o}+\frac{1}{i}=\frac{1}{f}=(n-1)\left(\frac{1}{r_1}+\frac{1}{r_2}\right)$$

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

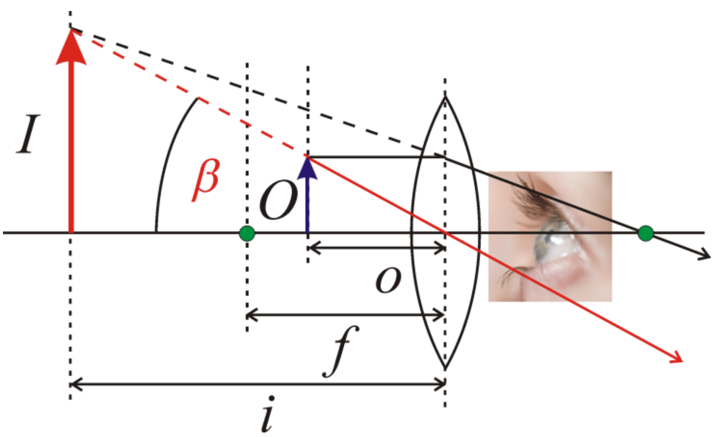
n: refractive index of the medium of the lens.

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 $\boldsymbol{\alpha}$



2. with lens from the distance o, under the angle of $\boldsymbol{\beta}$

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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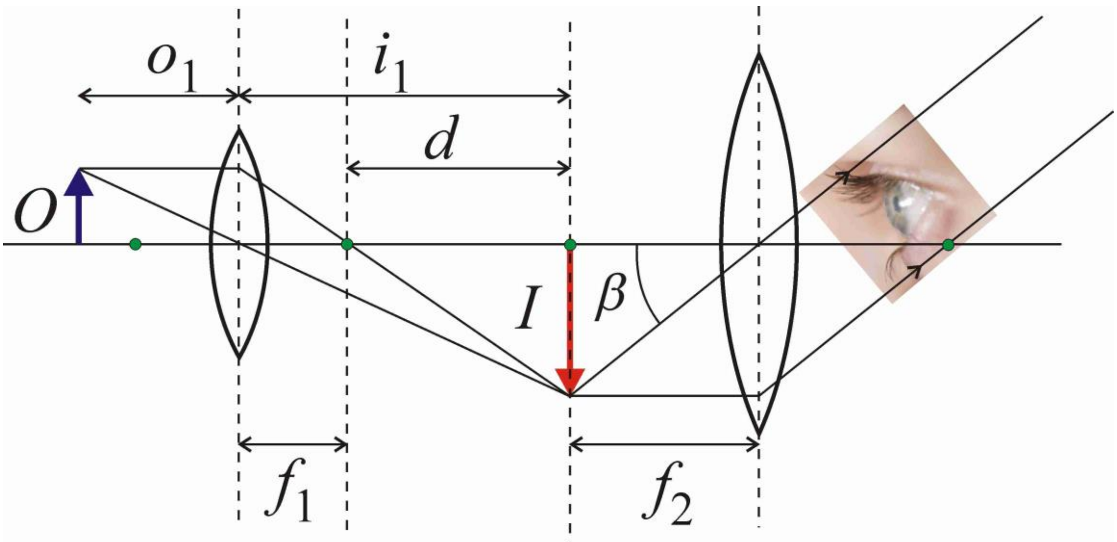
Lens systems (1) microscope



Without accommodation, eye is focused at infinity.

Angular magnification of microscope:

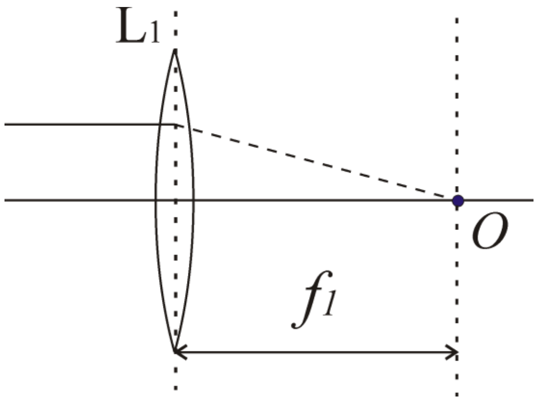
$$N=\frac{tg\beta}{tg\alpha}=\frac{\dfrac{I}{f_2}}{\dfrac{O}{a}}=\frac{I}{f_2}\frac{a}{O}=\frac{I}{O}\frac{a}{f_2}=\frac{i_1}{o_1}\frac{a}{f_2}\ ;$$

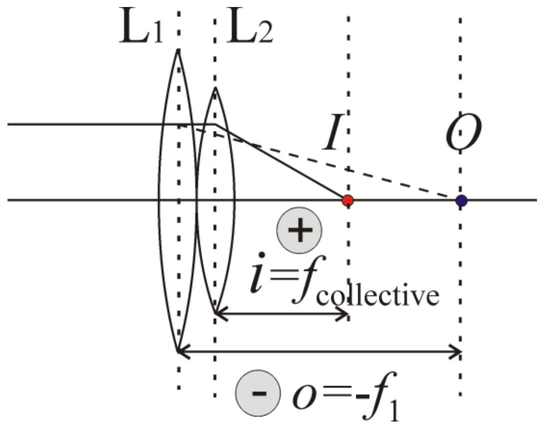
$$\frac{1}{o_1}=\frac{1}{f_1}-\frac{1}{i_1}=\frac{i_1-f_1}{f_1 i_1}=\frac{d}{f_1 i_1}$$

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

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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There are phenomena that cannot be explained by this model.