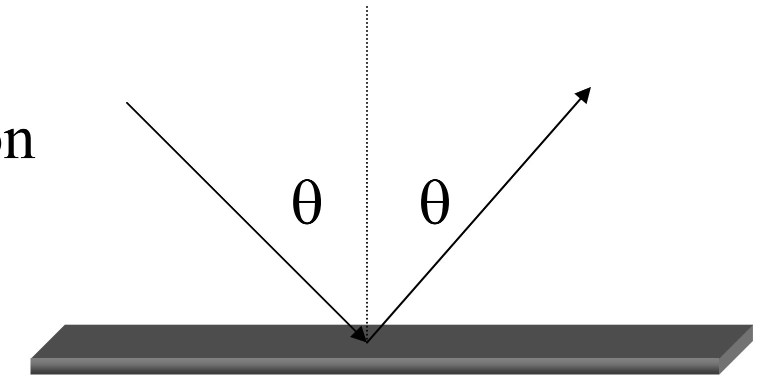
Announcements

1. Reminder – problem solving session this evening (Wednesday, Mar. 30, 2005) at 6 PM in Olin 101 (??)
2. Exam 3 will be returned at the end of class. May turn in reworked exam ≤ Monday, Apr. 4th for up to 10 extra-credit points.
3. Physics colloquium tomorrow -- Professor Lentz from UNC will speak about biophysics of membranes
4. Topics for today:
   - Geometric optics – mirrors and lenses
   - Real and virtual images
   - The mirror and lens equation

Physics of mirrors –

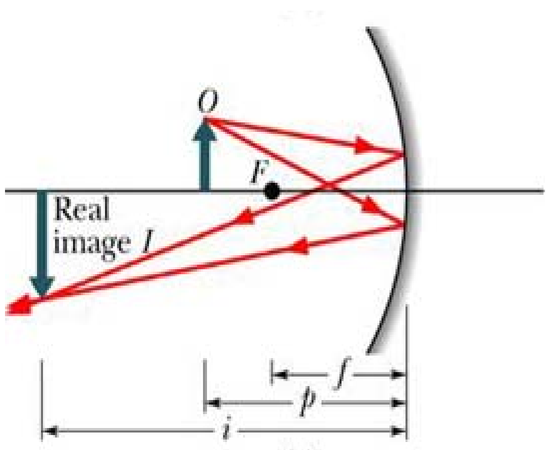
Basic idea:

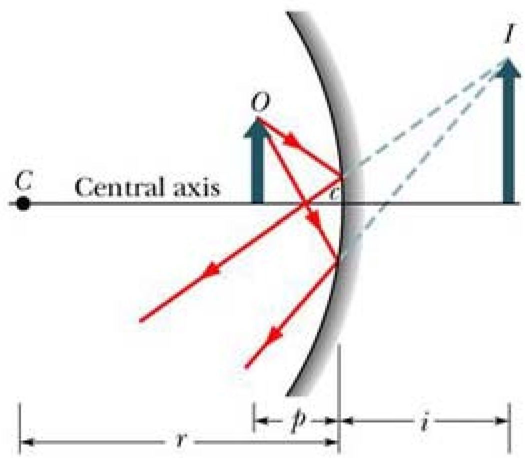
Angle of incidence=Angle of reflection



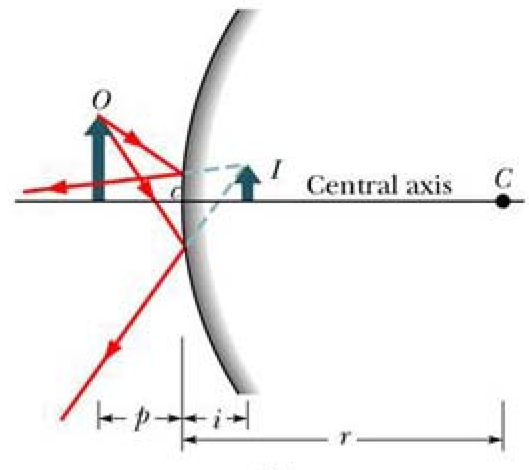
Spherical mirrors:

Concave:





Convex:

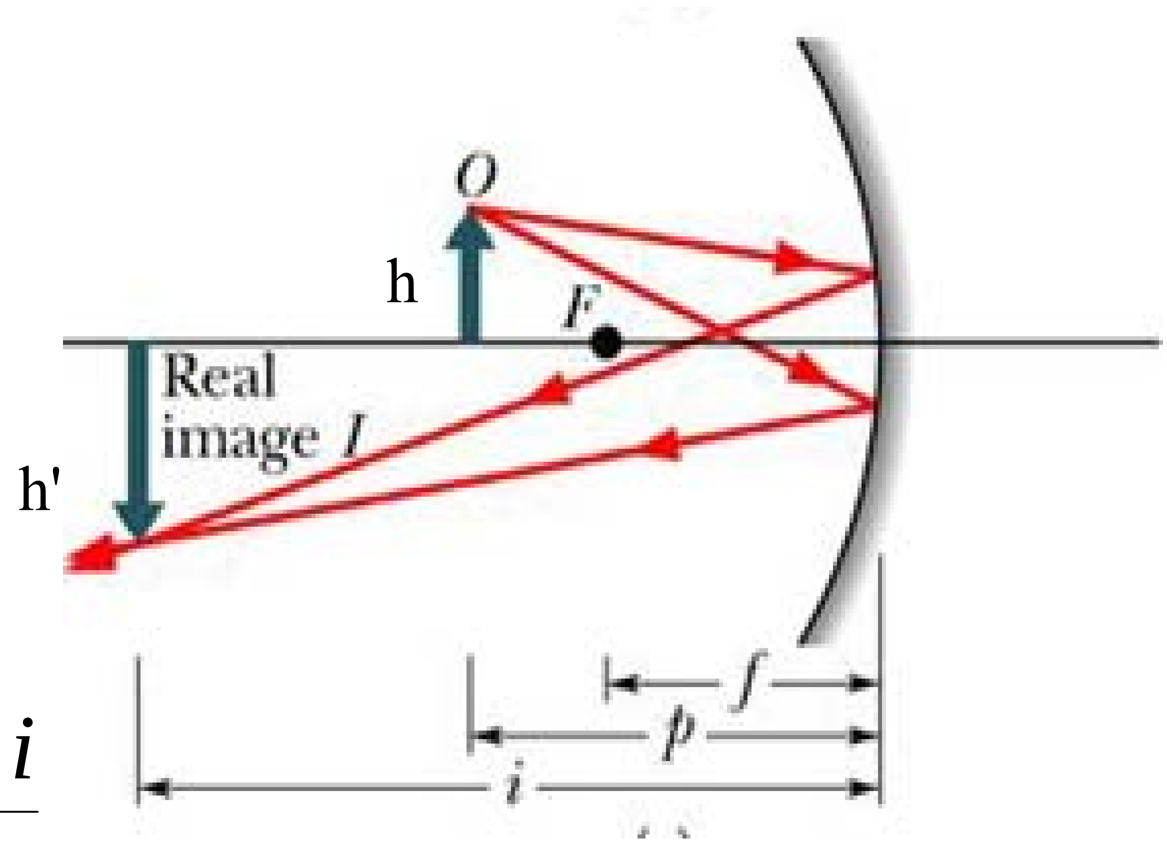


Real image

Virtual images

The mirror equation:

$$\frac{1}{p}+\frac{1}{i}=\frac{1}{f}$$



$$\text{Magnification}:$$

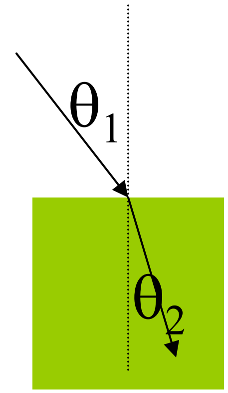
$$m=\frac{(\text{sign})h'}{h}=\frac{-i}{p}$$

+ signs for: p, f (concave mirror), i (real image), m (upright image)

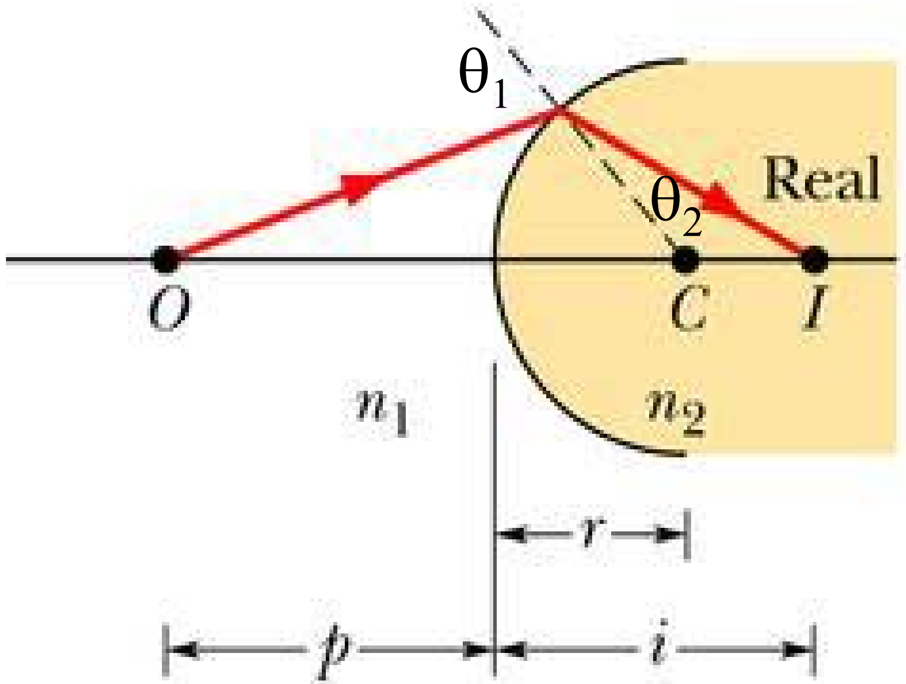
– signs for: f (convex mirror), i (virtual image), m (inverted image)

Basic physics of lenses:

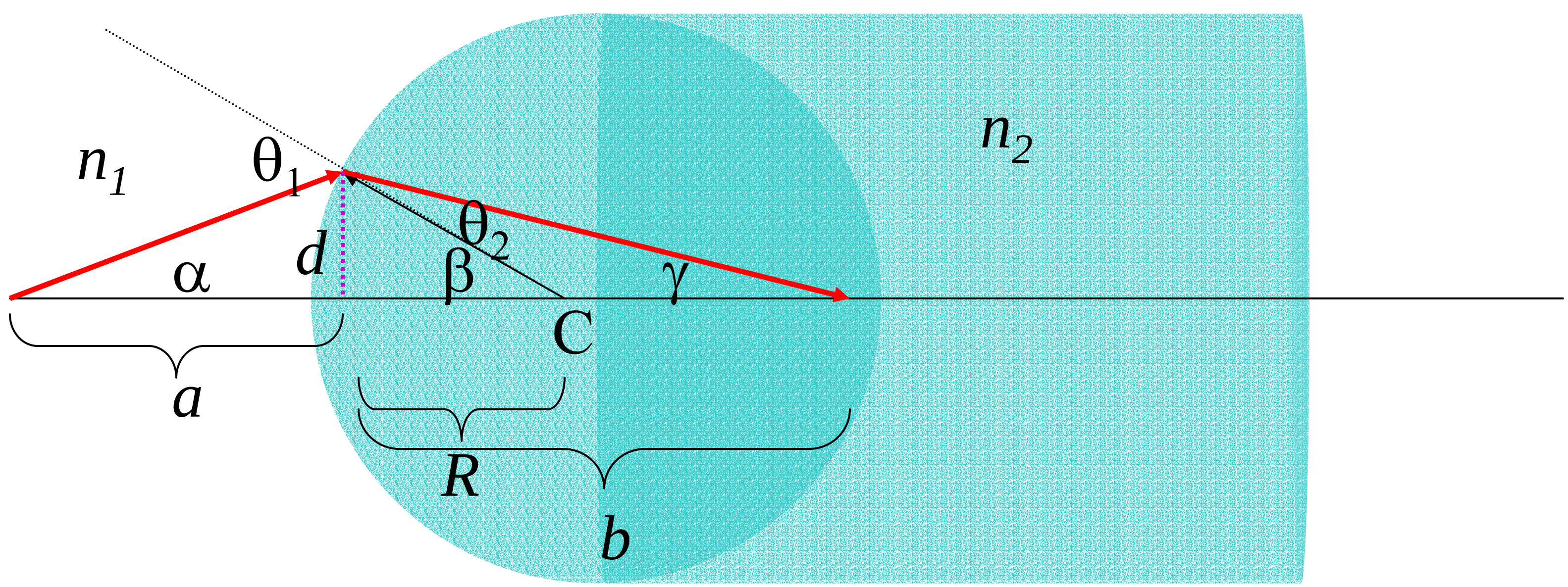
Snell's law: $n_1 \sin \theta_1 = n_2 \sin \theta_2$



Refraction at a spherical surface:



Refraction at a spherical surface



$$\theta_1 = \alpha + \beta$$

$$\tan\alpha = \frac{d}{a} \approx \alpha \qquad \tan\beta = \frac{d}{R} \approx \beta \qquad \tan\gamma = \frac{d}{b} \approx \gamma$$

$$\theta_2 = \beta - \gamma$$

$$n_1 \sin\theta_1 = n_2 \sin\theta_2 \quad \Rightarrow n_1\theta_1 \approx n_2\theta_2$$

$$\boxed{\frac{n_1}{a} + \frac{n_2}{b} = \frac{n_2 - n_2}{R}}$$

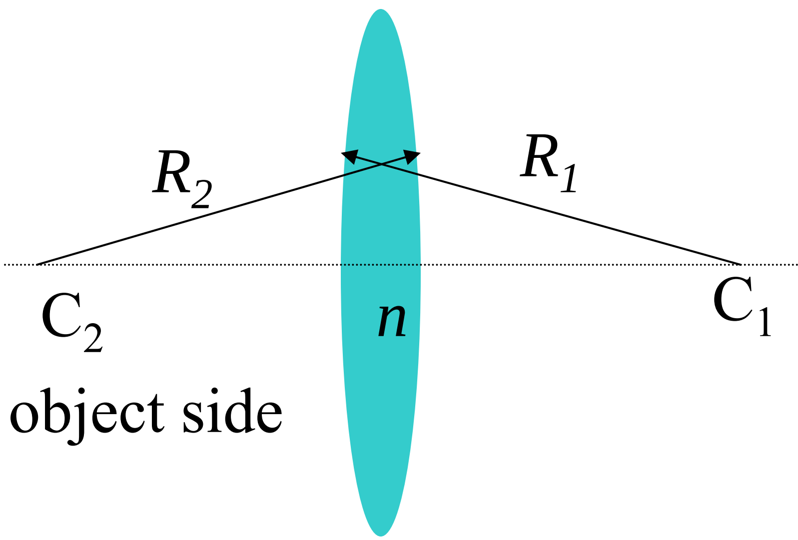
Refraction at a spherical surface – continued

$$\frac{n_1}{a}+\frac{n_2}{b}=\frac{n_2-n_2}{R}$$

➔ In the small angle approximation, result is *independent* of angle.

Leap of faith → "lens makers' equation" for thin lens in air

$$\frac{1}{f}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$

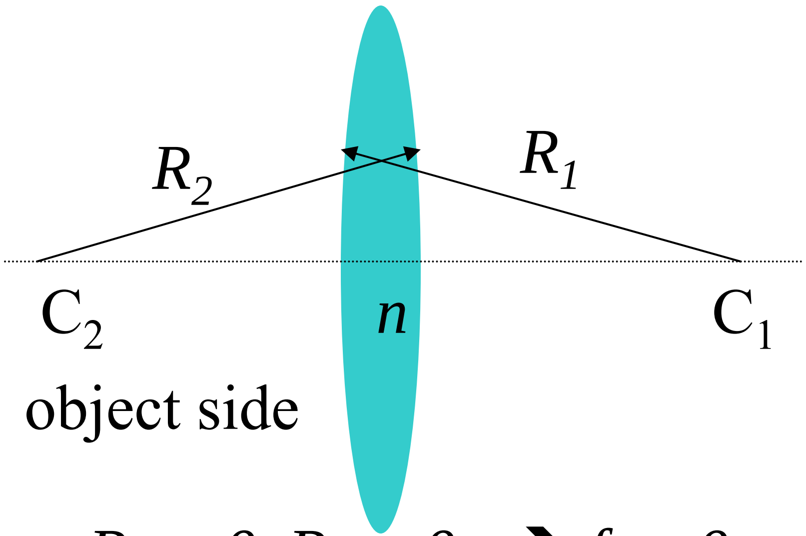


Sign convention:

R_i is positive if it is convex relative to object and negative if it is concave relative to object.

Lens makers' equation – continued:

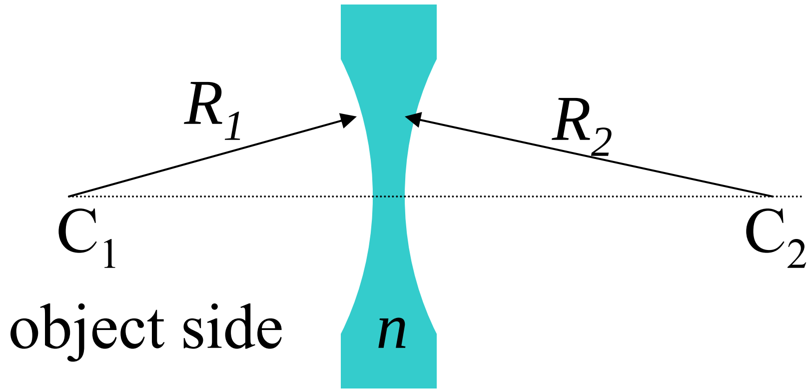
$$\frac{1}{f}=(n-1)\left(\frac{1}{R_1}-\frac{1}{R_2}\right)$$



Sign convention:

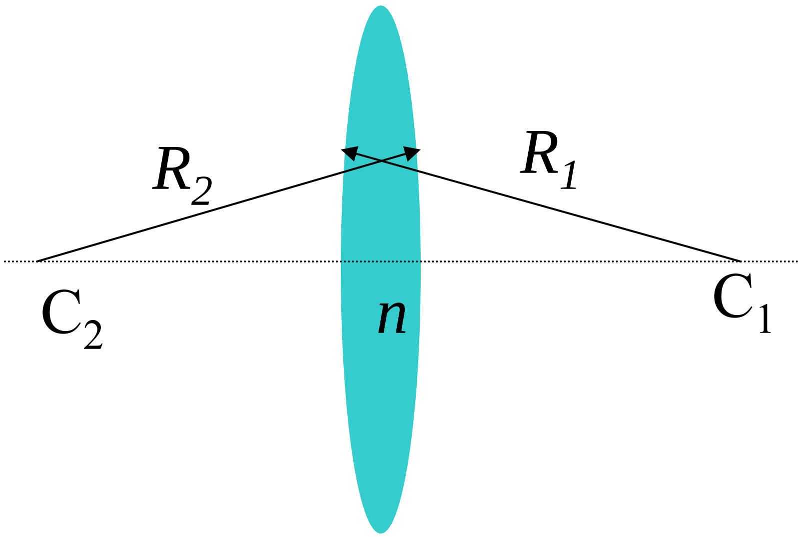
R_i is positive if it is convex relative to object and negative if it is concave relative to object.

$R_1 > 0$, $R_2 < 0$ ➔ $f > 0$ ➔ converging lens



$R_1 < 0$, $R_2 > 0$ ➔ $f < 0$ ➔ diverging lens

Lens makers' equation:



$$\frac{1}{f} = (n-1)\left(\frac{1}{R_1} - \frac{1}{R_2}\right)$$

Sign convention:

R_i is positive if it is convex relative to object and negative if it is concave relative to object.

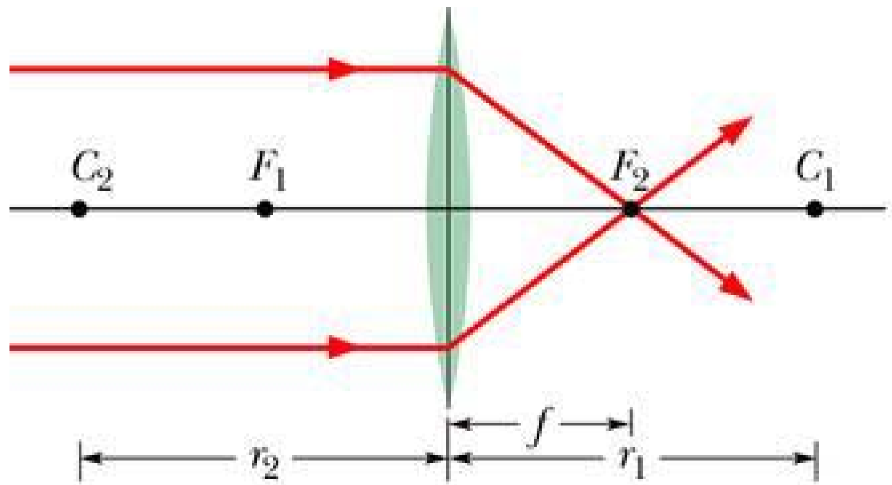
Lens makers' equation can be proven using

- Snell's law: $n_1 \sin \theta_1 = n_2 \sin \theta_2$
- small angle approximation: $\sin \theta_1 \approx \tan \theta_1 \approx \theta_1$
- thin lens approximation: thickness << f,p,i

➔ Lens equation: $$\frac{1}{p} + \frac{1}{i} = \frac{1}{f}$$

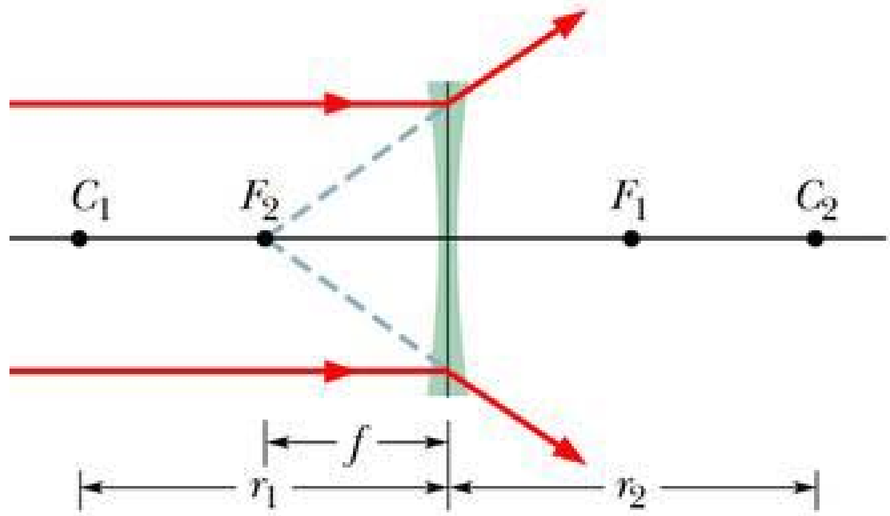
Example of thin lenses:

Converging lens: $f > 0$



(a)

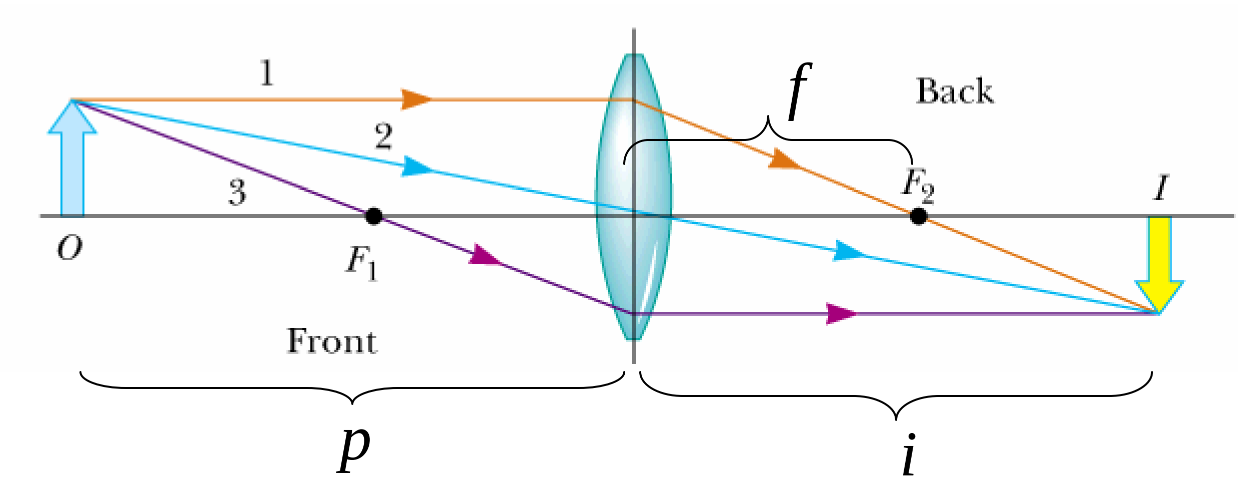
Diverging lens: $f > 0$



(c)

Example: $\frac{1}{p}+\frac{1}{i}=\frac{1}{f}$

Forming a real image using a converging lens



Example:

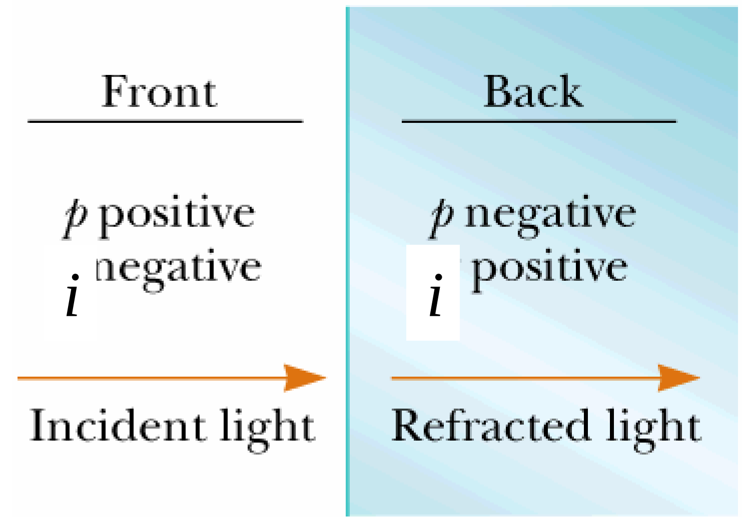
$f = 2$ cm, $p = 5$ cm

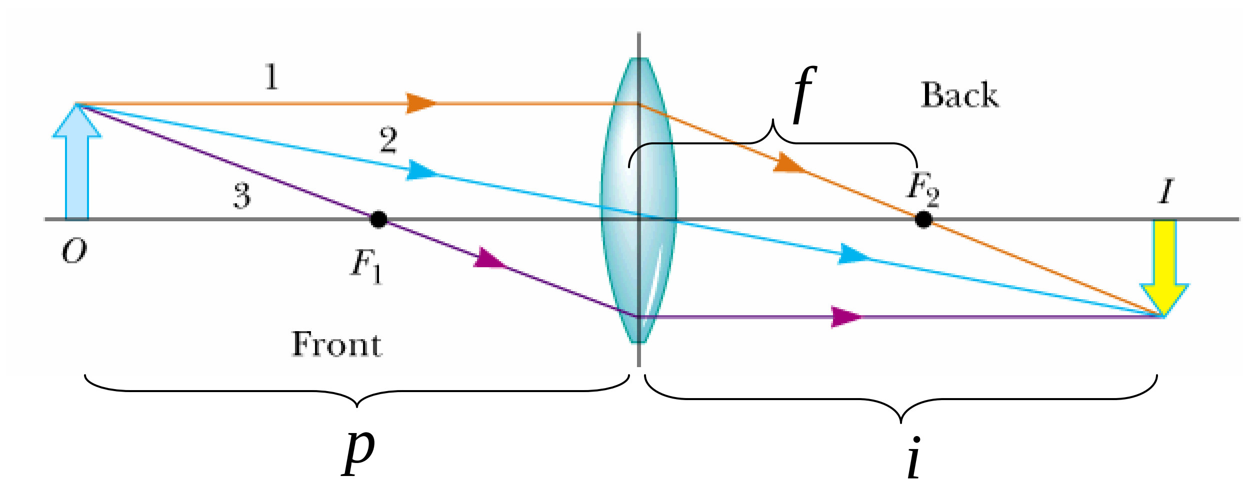
➔ $i = 3.33$ cm

(real image)

This could represent, for example the lens system of a camera.

Thin lens equation: $\frac{1}{p}+\frac{1}{i}=\frac{1}{f}$ assuming sign convention:





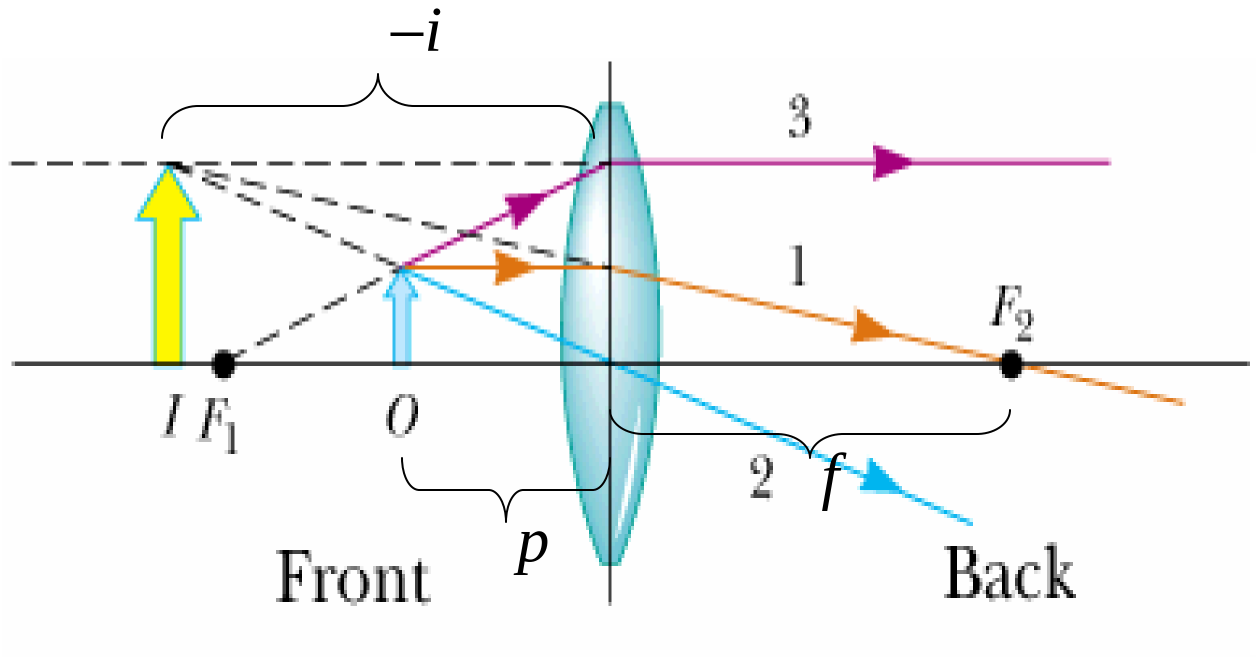
Example:

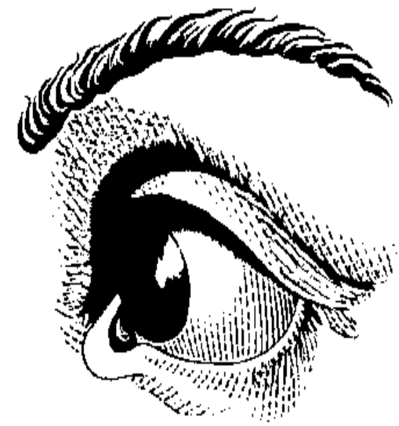
$f = 2$ cm, $p = 5$ cm

➔ $i = 3.33$ cm

(real image)

Thin lens refraction -- continued





Example:

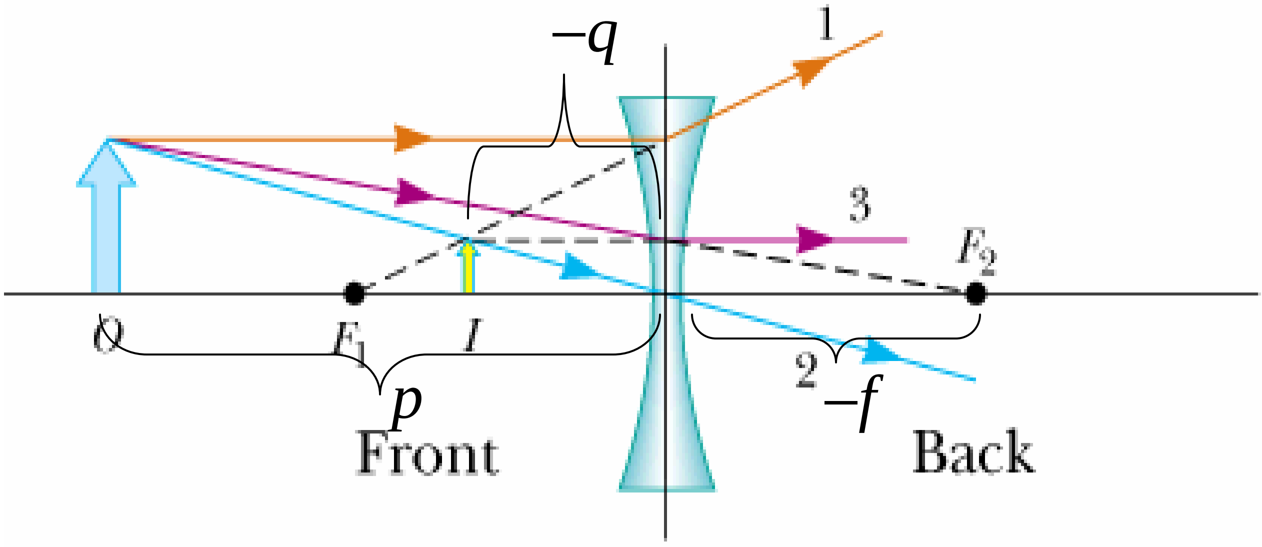
$f = 2$ cm, $p = 1.2$ cm

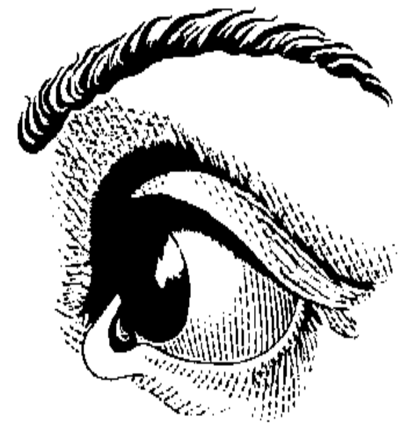
➔ $i = -3$ cm

(virtual image)

$$M = \frac{-i}{p} = 2.5$$

Thin lens refraction -- continued





Example:

f = -2 cm, p = 4 cm

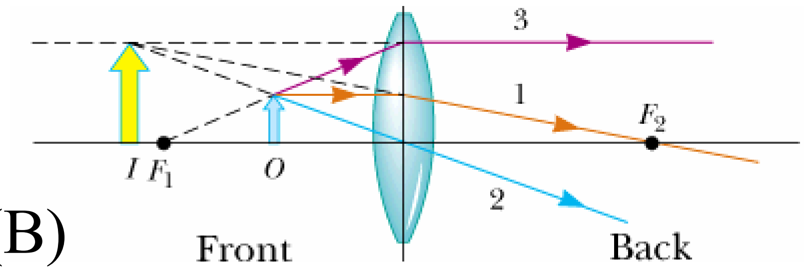
$$M = \frac{-i}{p} = 0.333$$

➔ i = -1.333 cm

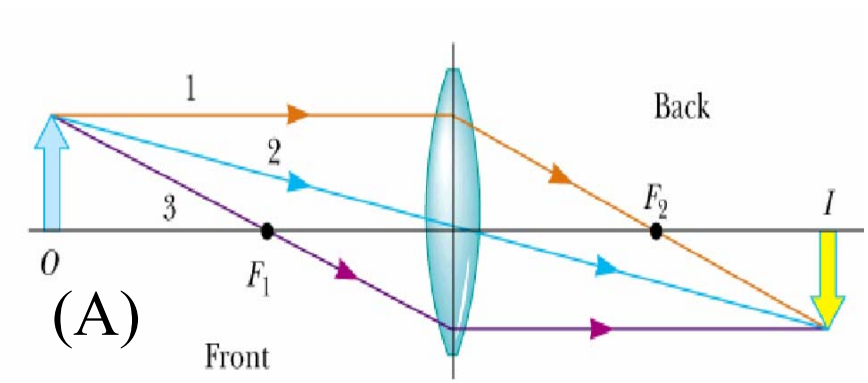
(virtual image)

Sherlock Holmes is apparently examining some evidence.

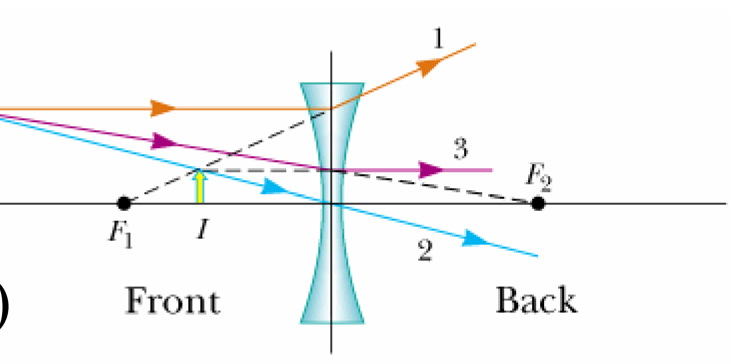
Which ray diagram most closely describes this situation:



(B)



(A)



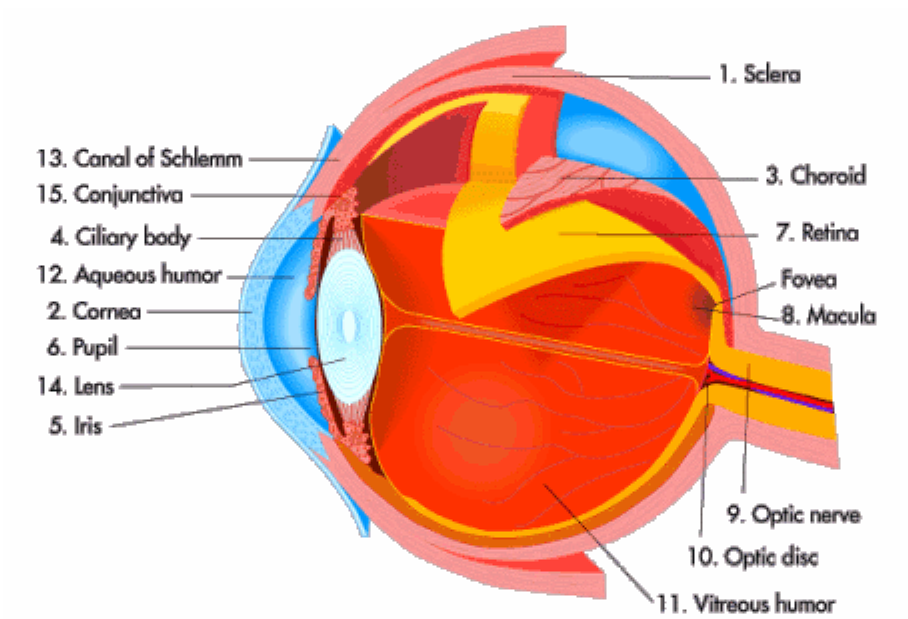
(C)

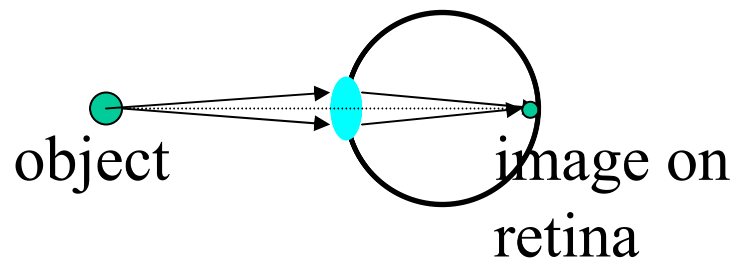
The above photo was taken from the website: http://www.allaboutvision.com/slides/slidephotos-frames-men.htm. It shows Kevin Rahm modeling some eyeglasses. (Note: the idea for this question was developed by Professor Steven Beichner at NCSU.)

1. Are the lenses
   A. Converging
   B. Diverging
2. Is Kevin Rahm
   A. Nearsighted
   B. Farsighted

View of the eye from

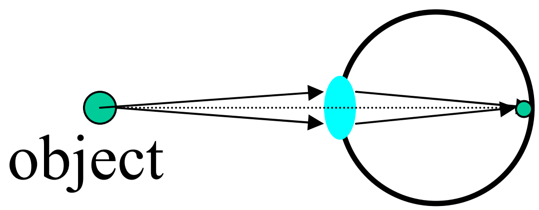
http://science.howstuffworks.com/eye1.htm





Vision problems and corrective lenses

Ideal vision:



Near sighted vision – problem with “Far point”

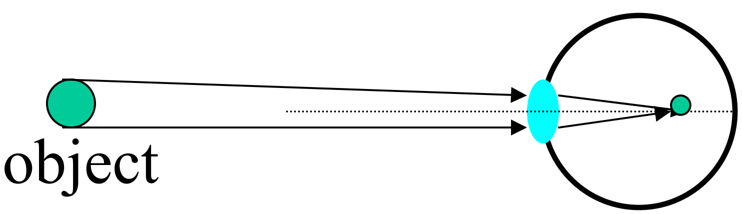


image in front of retina ➔ need diverging corrective lens

Far sighted vision – problem with “Near point”

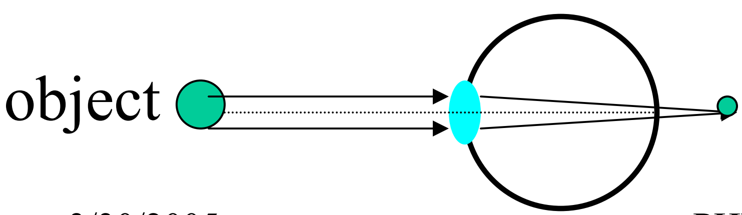
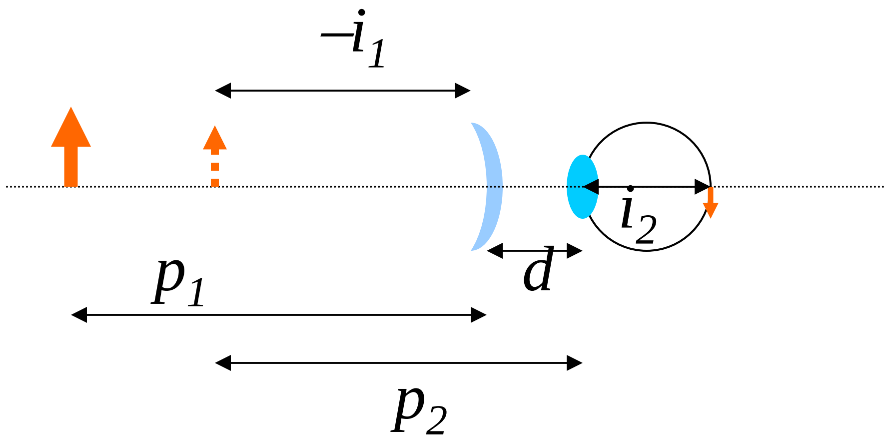


image in back of retina ➔ need converging corrective lens

Refraction from two or more lenses

→ Successive use of lens equation



$$\frac{1}{p_1} + \frac{1}{i_1} = \frac{1}{f_1}$$

$$p_2 = -i_1 + d$$

$$\frac{1}{p_2} + \frac{1}{i_2} = \frac{1}{f_2}$$

Example:

$p_1 = 50$ cm; $f_1 = -25$ cm; $f_2 = 1.4$ cm; $d = 1.0$ cm

We find:

$i_1 = -16.667$ cm; $i_2 = 1.52$ cm

Without the diverging lens:

$i_2 = 1.44$ cm (short of retina)