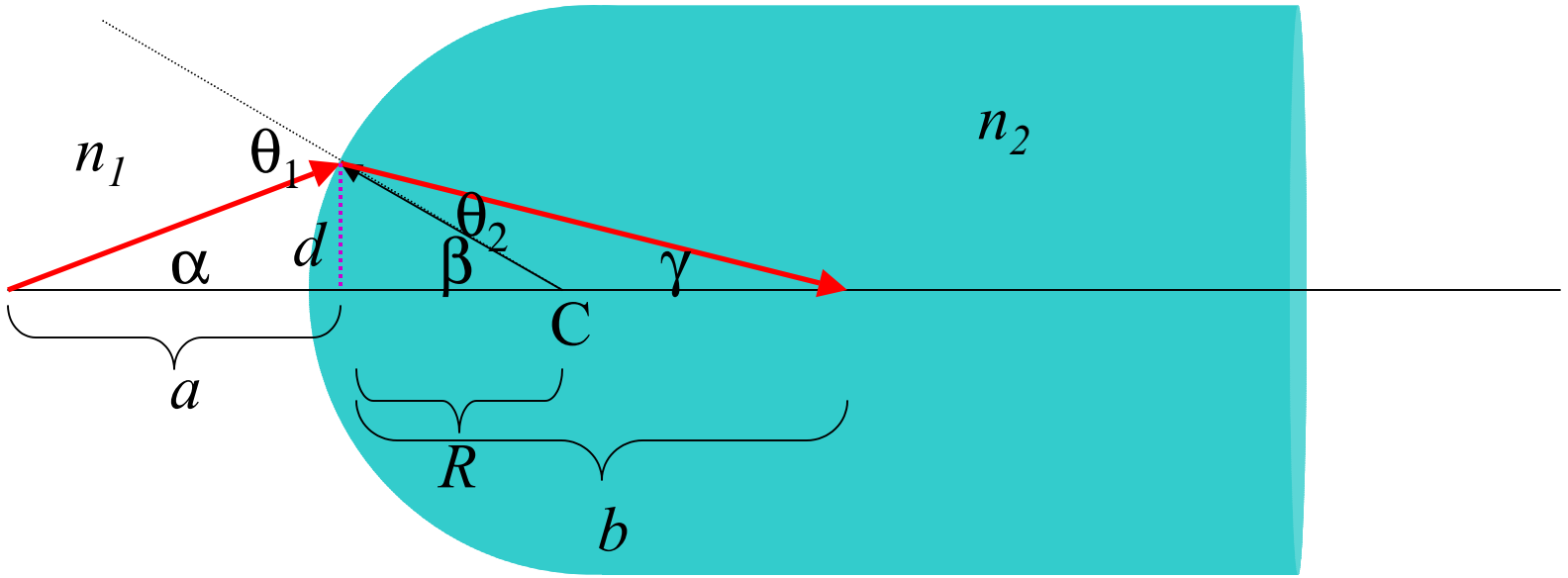
Announcements

1. Please pick up reworked exam papers
2. Today's topic –

   Images formed with lenses (Chap. 36)

   - Refraction in the spherical geometry
   - Thin lens equation
   - Converging and diverging lenses
   - Microscopes & telescopes

Refraction at a spherical surface



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

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

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

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

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

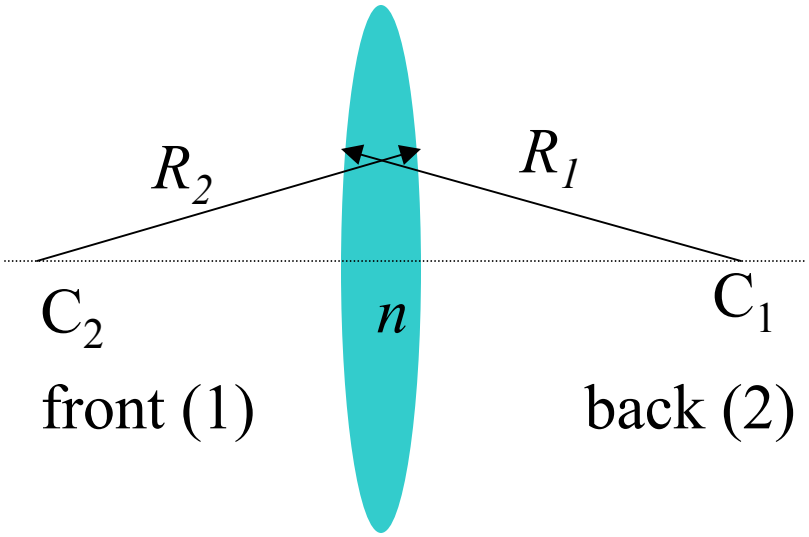
Refraction at a spherical surface – continued

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

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

Leap of faith → "lens makers' equation"

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



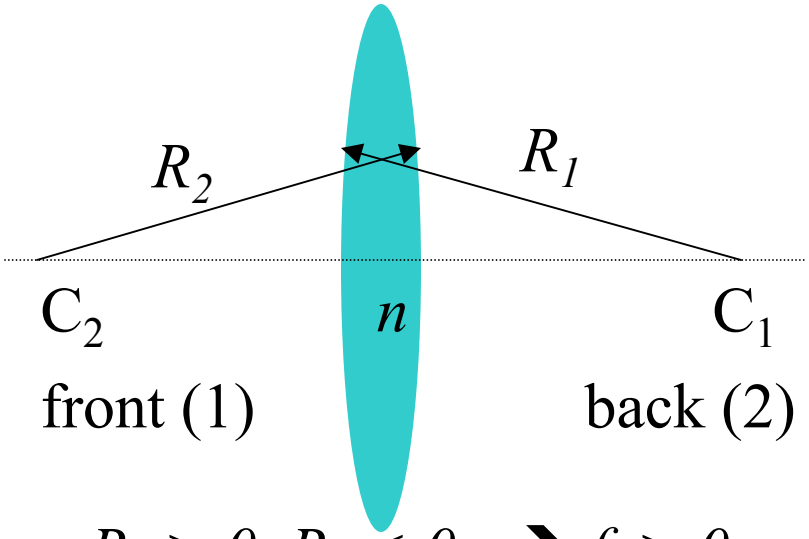
Sign convention:

R_i is positive if C_i is in "back" of lens

R_i is negative if C_i is in "front" of lens

Lens makers' equation – continued:

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

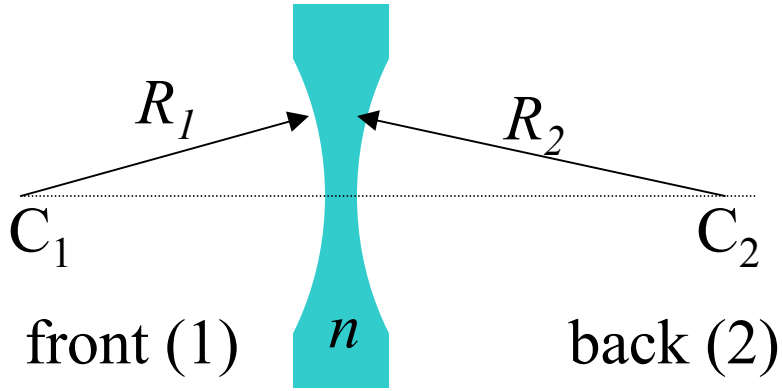


Sign convention:

R_i is positive if C_i is in "back" of lens

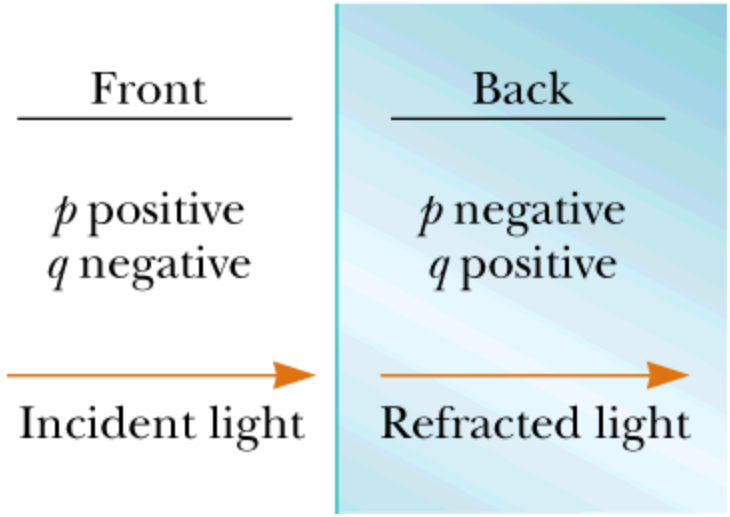
R_i is negative if C_i is in "front" of lens

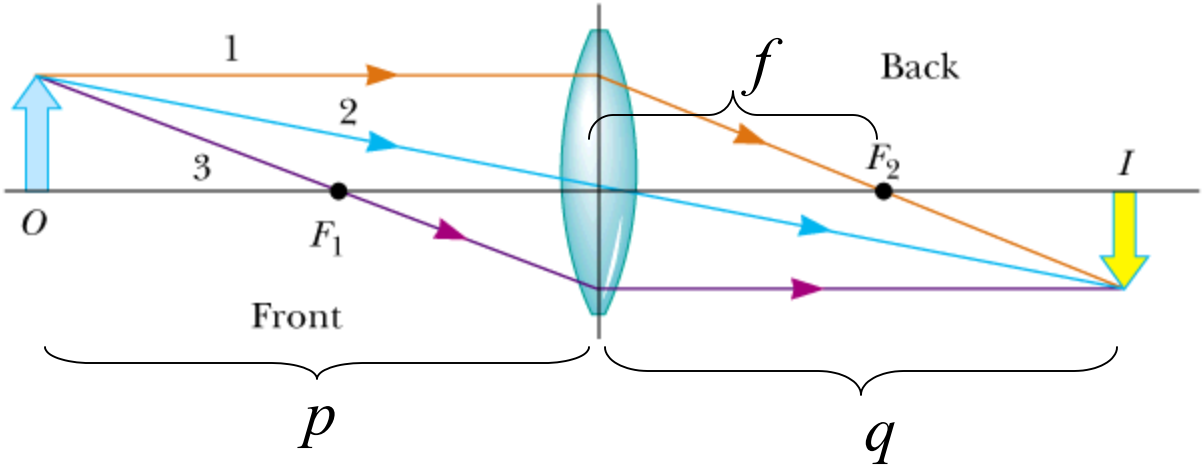
$R_1 > 0, R_2 < 0$ ➔ $f > 0$ ➔ converging lens



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

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





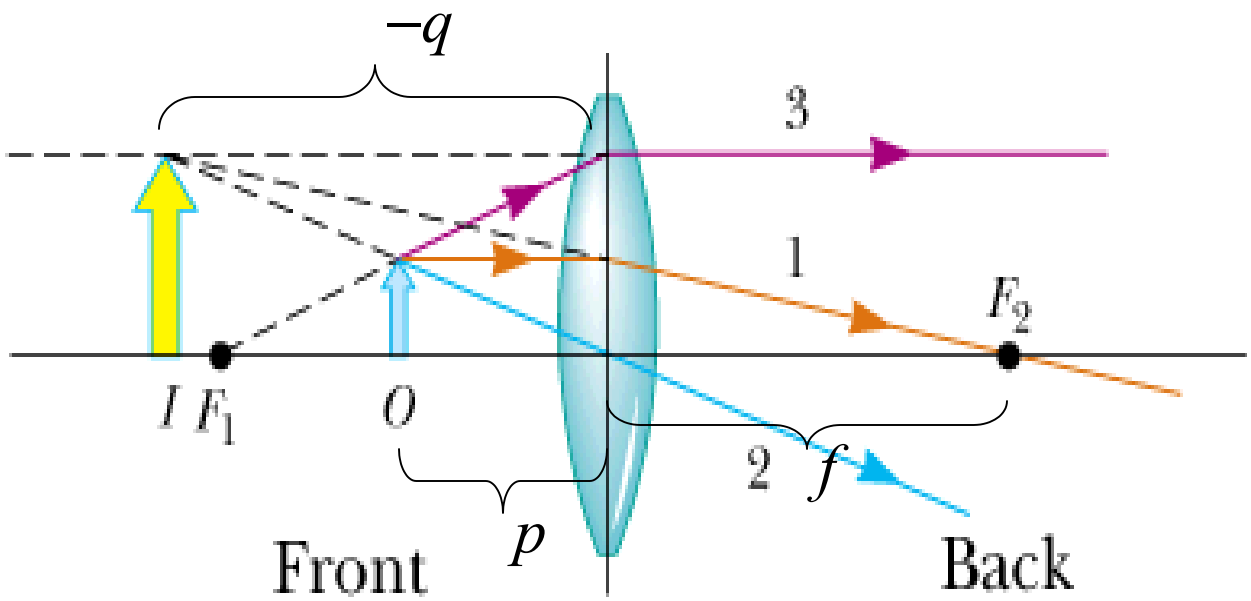
Example:

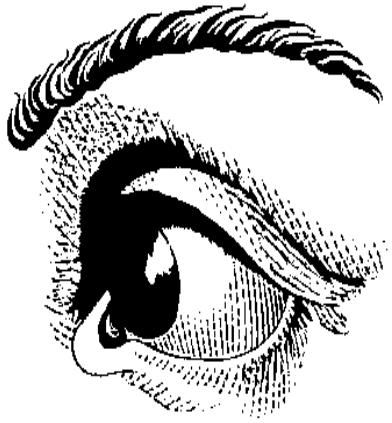
$f = 2$ cm, $p = 5$ cm

➔ $q = 3.33$ cm

(real image)

Thin lens refraction -- continued





Example:

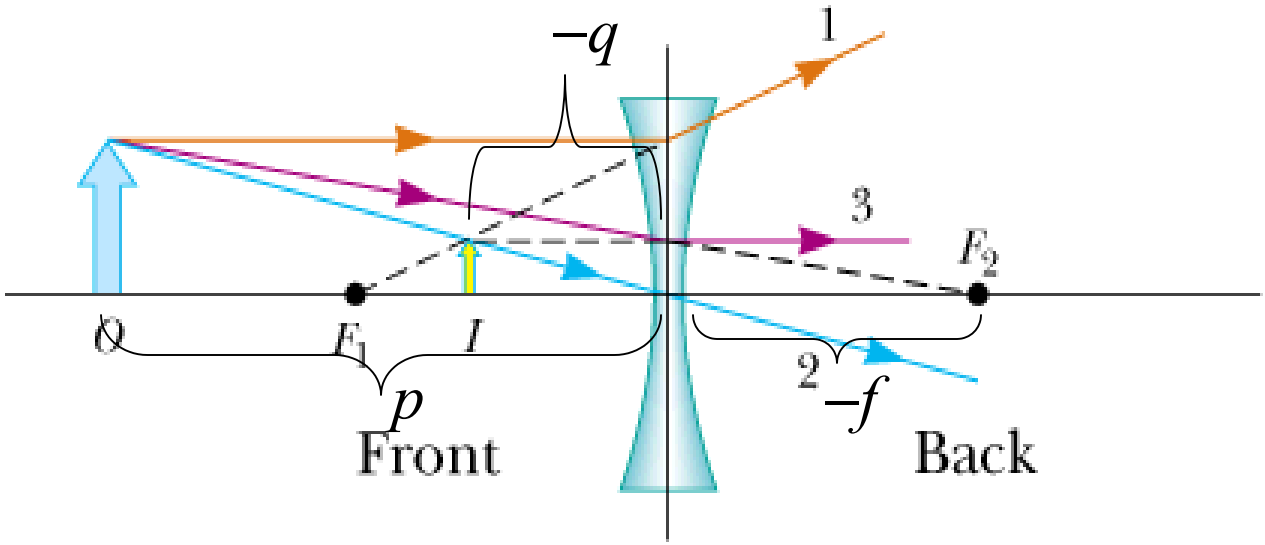
$f = 2$ cm, $p = 1.2$ cm

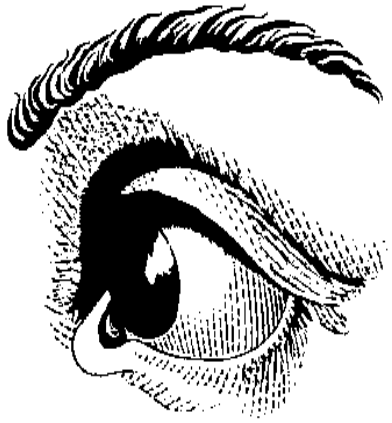
➔ $q = -3$ cm

(virtual image)

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

Thin lens refraction -- continued





Example:

f = -2 cm, p = 4 cm

➔ q = -1.333 cm

(virtual image)

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

Peer instruction question:

In a camera, the image formed on the film must be

(A) real (B) virtual (first vote)

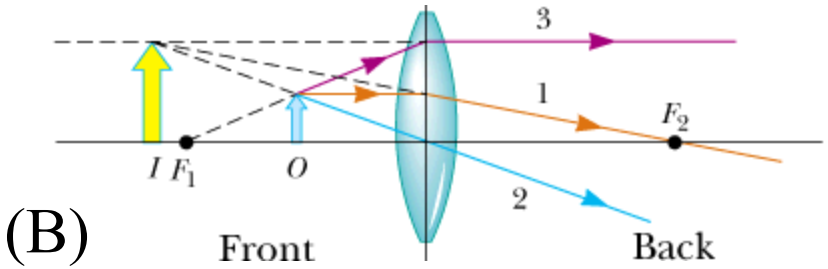
(B) upright (B) inverted (second vote)

The image formed by the view finder would be

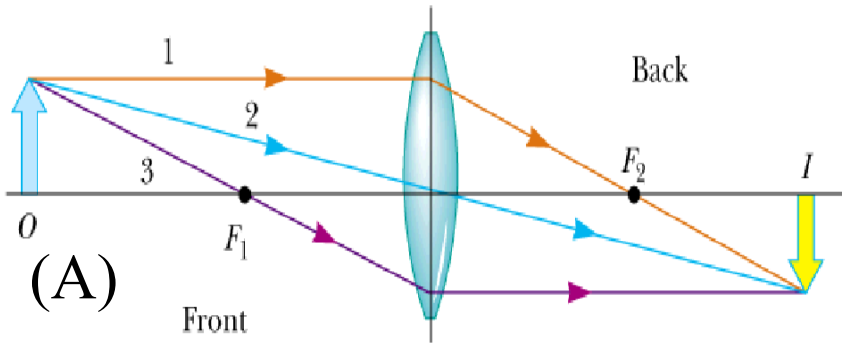
(A) real (B) virtual (third vote)

Sherlock Holmes is apparently examining some evidence.

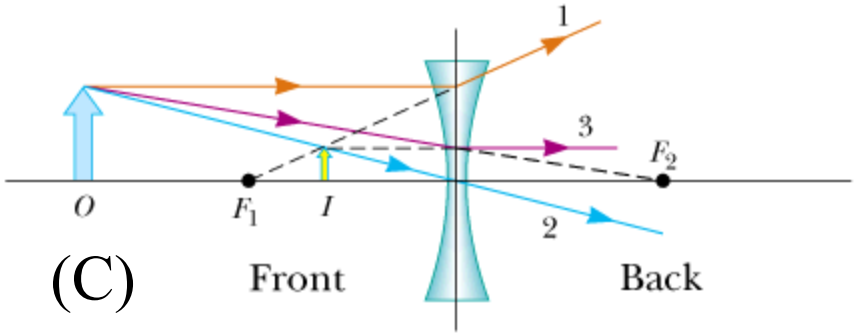
Which array diagram most closely describes this situation:



(B)



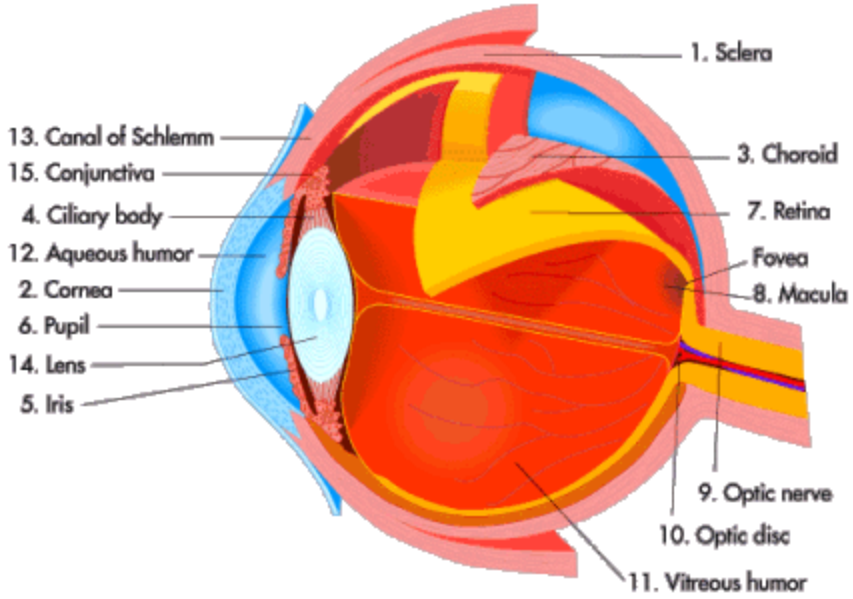
(A)

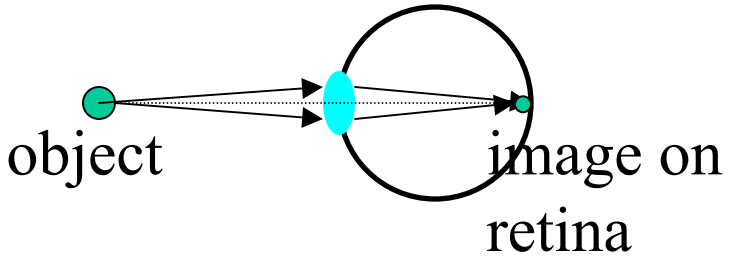


(C)

View of the eye from

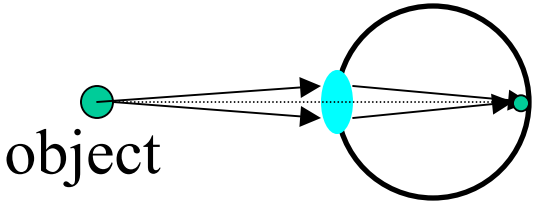
http://science.howstuffworks.com/eye1.htm





Vision problems and corrective lenses

Ideal vision:



Near sighted vision – problem with "Far point"

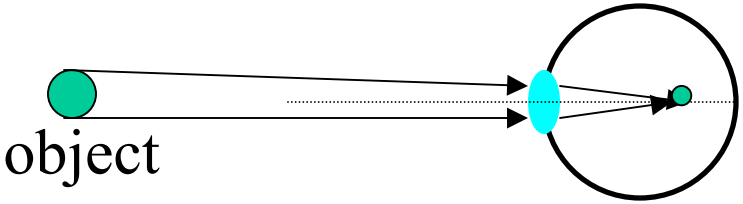


image in front of retina ➔ need diverging corrective lens

Far sighted vision – problem with "Near point"

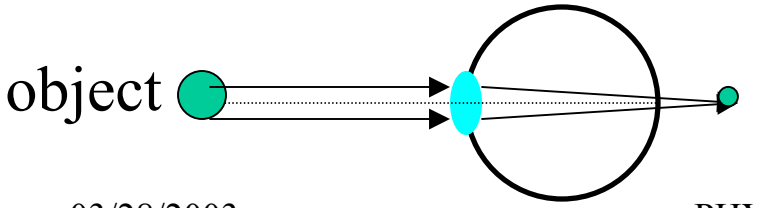
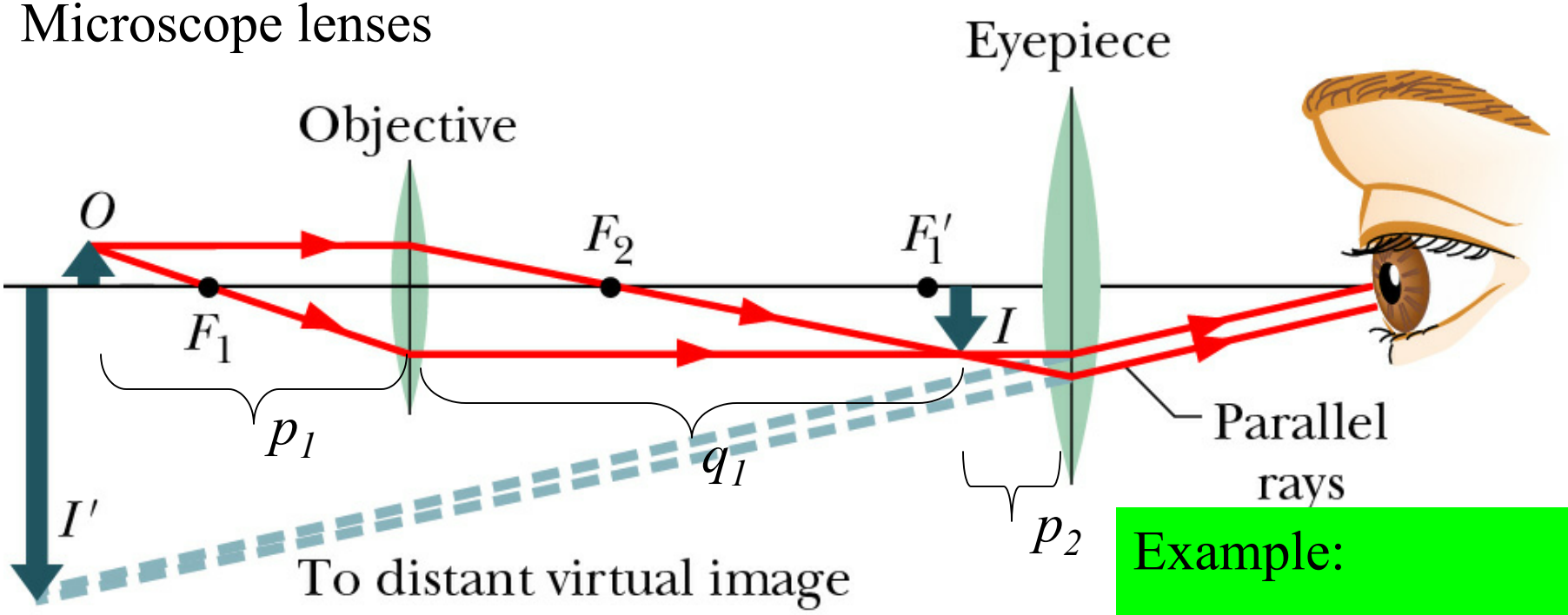


image in back of retina ➔ need converging corrective lens

Microscope lenses



Example:

$p_1 = 3\text{cm}$ $f_{ob} = 2$ cm

$p_2 = 0.9\text{cm}$ $f_{ey} = 1$ cm

M =20

$$\frac{1}{p_1}+\frac{1}{q_1}=\frac{1}{f_{ob}};\ \frac{1}{p_2}+\frac{1}{q_2}=\frac{1}{f_{ey}} \qquad M=\frac{-q_1}{p_1}\frac{-q_2}{p_2}$$

Peer instruction question –

How can you photograph a microscope image?

(A) Simply place a camera where the eye would go.

(B) It is not possible to photograph a microscope image.

(C) You would need to modify the setup.