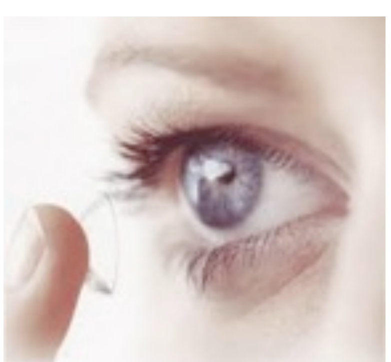
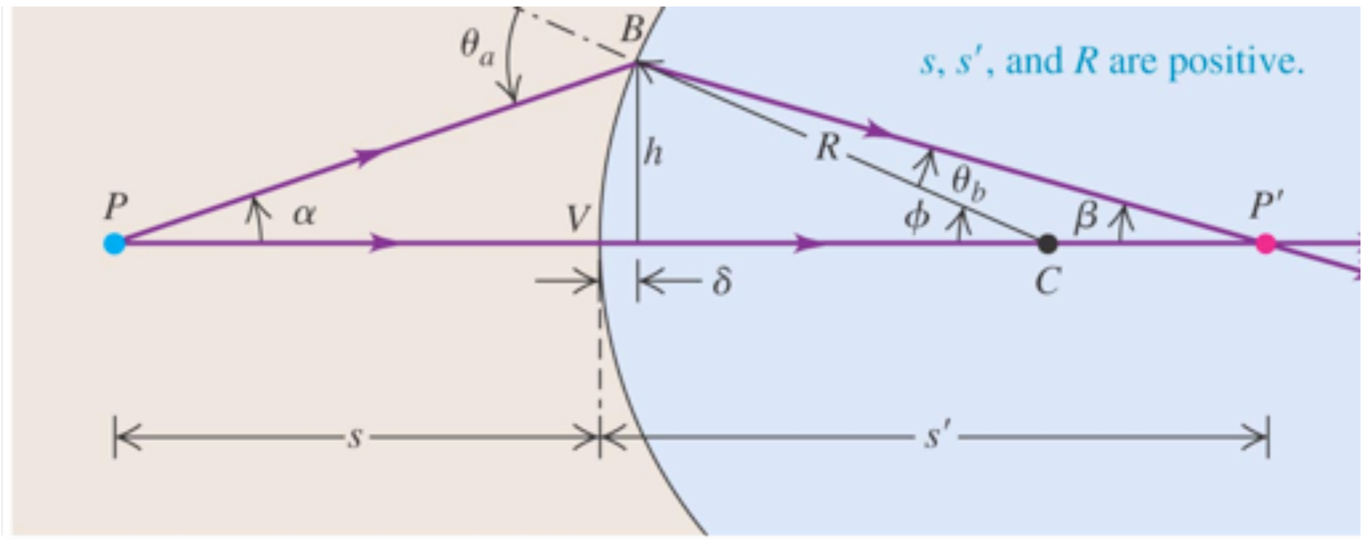
Optics overview, pt. 2

Ken Intriligator's week 9 lectures, Dec. 1, 2014



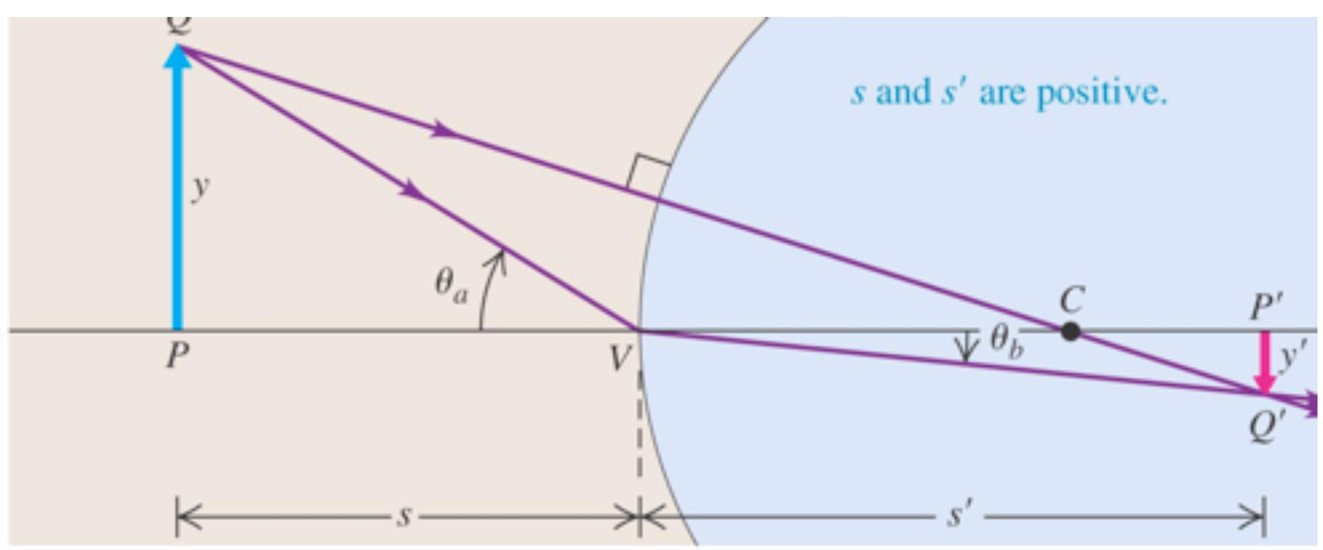
spherical refracting lens



$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R} \equiv \frac{1}{f}$$

Again follows from Fermat principle:
all rays from object to image take same time.

Here R>0 means convex surface. General rule: R>0 if center on same sign as outgoing rays.



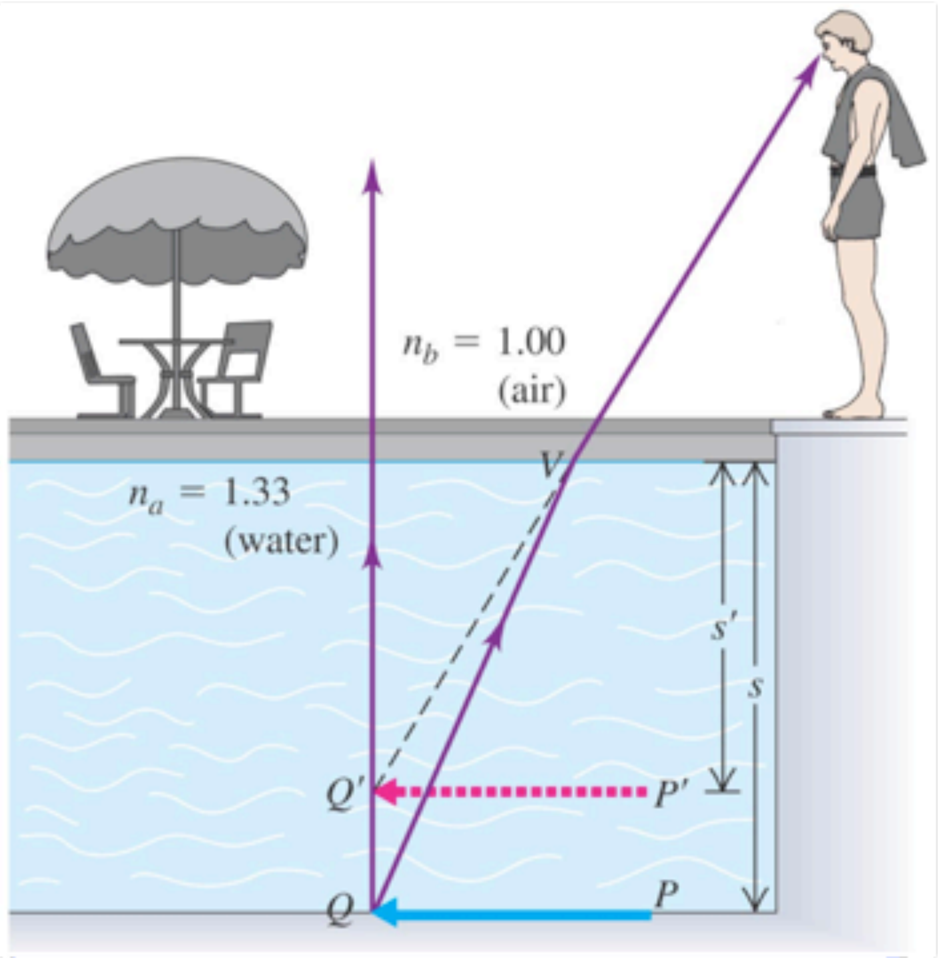
$$n_1 \sin\theta_a = n_2 \sin\theta_b$$

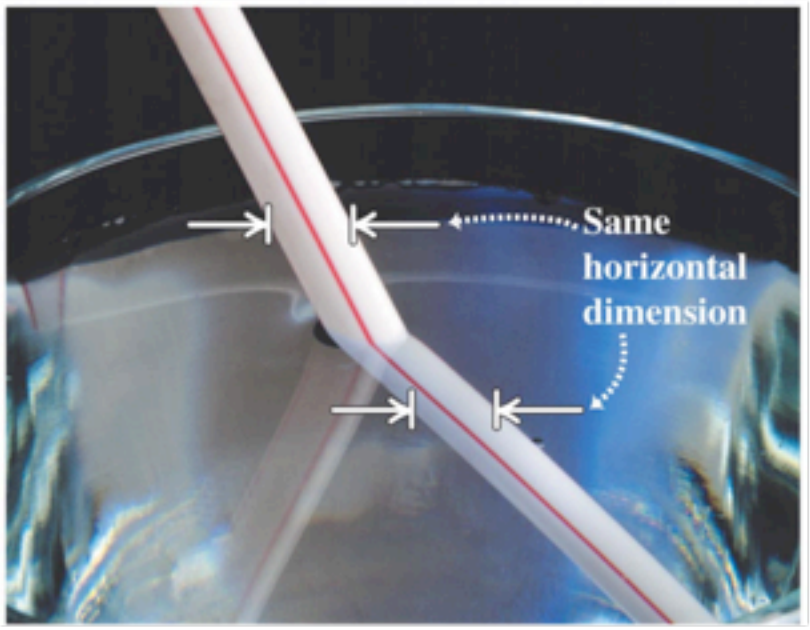
$$(n_1 \equiv n_a, \;\; n_2 \equiv n_b)$$

$$m = \frac{y'}{y} = \frac{-s' \tan\theta_b}{s \tan\theta_a} \approx -\frac{s' \sin\theta_b}{s \sin\theta_a} = -\frac{n_1 s'}{n_2 s}$$

Apparent depth of a swimming pool

- Follow Example 34.7 using Figure 34.26 at the left.
- Figure 34.27 (right) shows that the submerged portion of the straw appears to be at a shallower depth than it actually is.





$$\frac{n_1}{s} + \frac{n_2}{s'} = \frac{n_2 - n_1}{R} \equiv \frac{1}{f}$$

$$R \rightarrow \infty$$

$$\frac{n_1}{s} + \frac{n_2}{s'} = 0.$$

s'<0, virtual image
m=1.

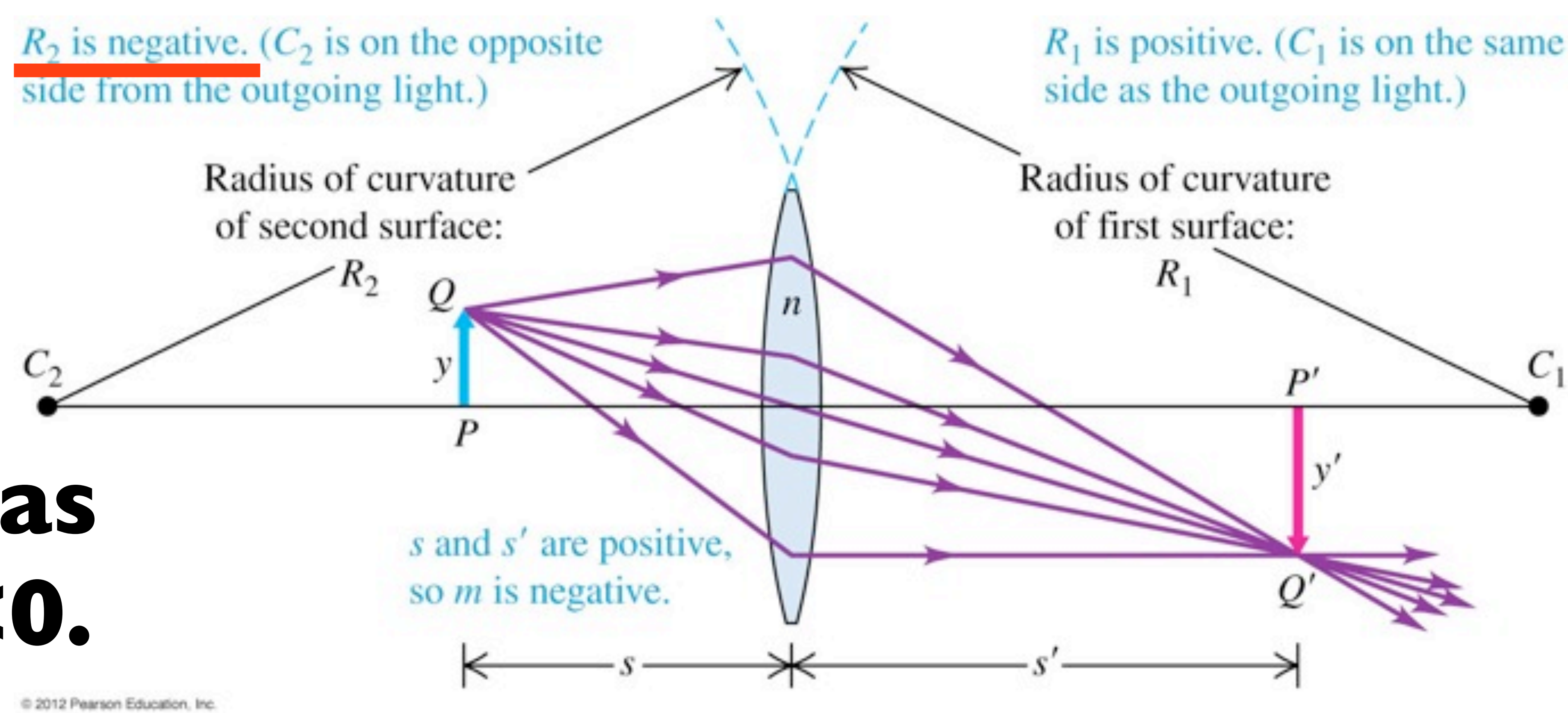
Thin lenses

Use equation for two spherical surfaces, almost on top of each other (thin). Get a nice, simple eqn.:

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

$$m = -\frac{s'}{s}$$

!signs: this lens has R1>0, R2<0.



Derivation:

Step 1: refraction from surface 1: $$\frac{n_0}{s} + \frac{n_L}{\tilde{s}} = \frac{n_L - n_0}{R_1}$$

Step 2: refraction from surface 2: $$-\frac{n_L}{\tilde{s}} + \frac{n_0}{s'} = \frac{n_0 - n_L}{R_2}$$

add: $$\frac{n_0}{s} + \frac{n_0}{s'} = (n_L - n_0)(\frac{1}{R_1} - \frac{1}{R_2})$$

$n_0 =$ index of refraction outside lens, =1 for air.

signs

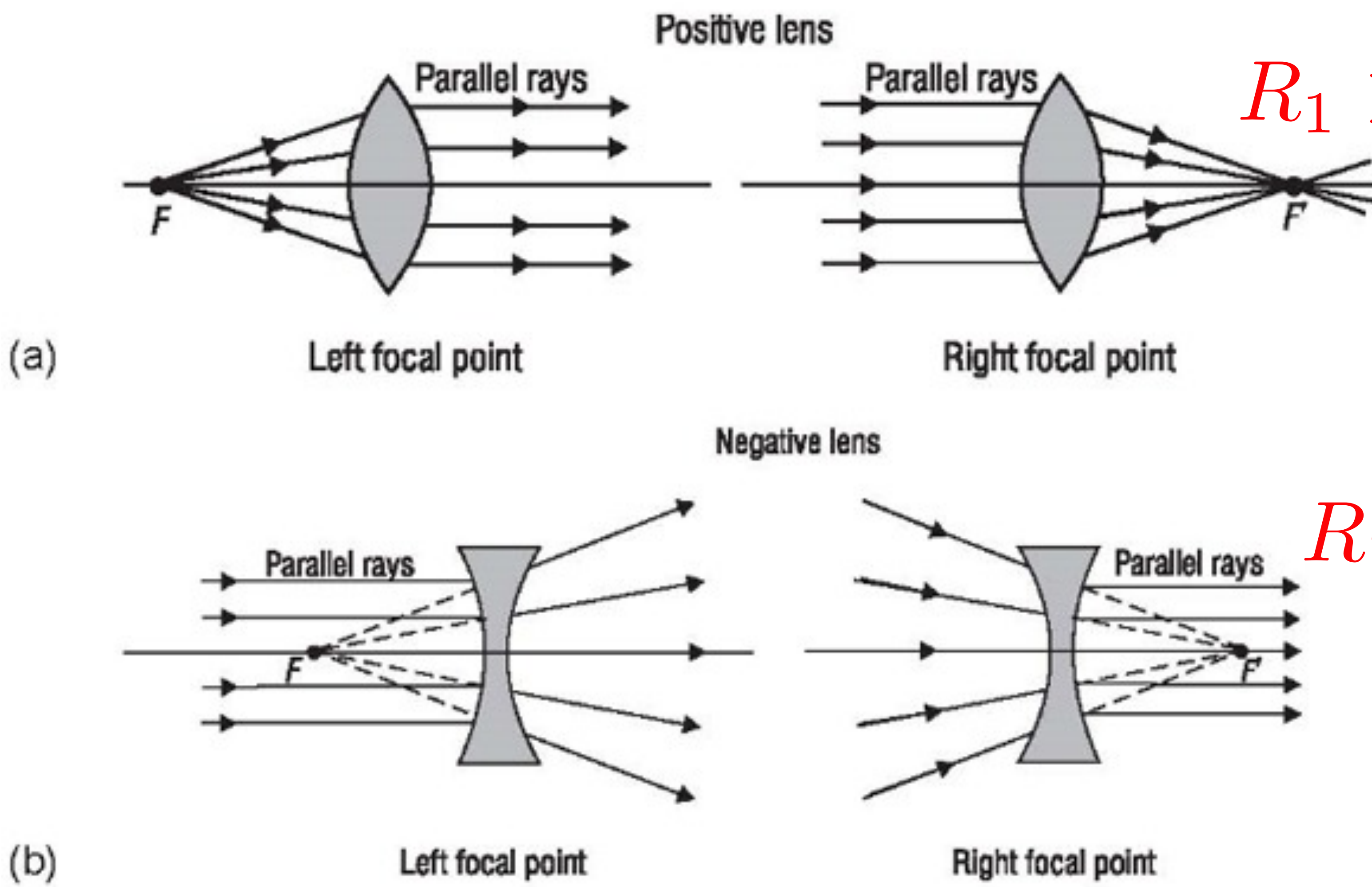


Figure 3-23 *Relationship of light rays to right and left focal points in thin lenses*

$R_1 > 0,\ R_2 < 0,\ f > 0$

converging lens

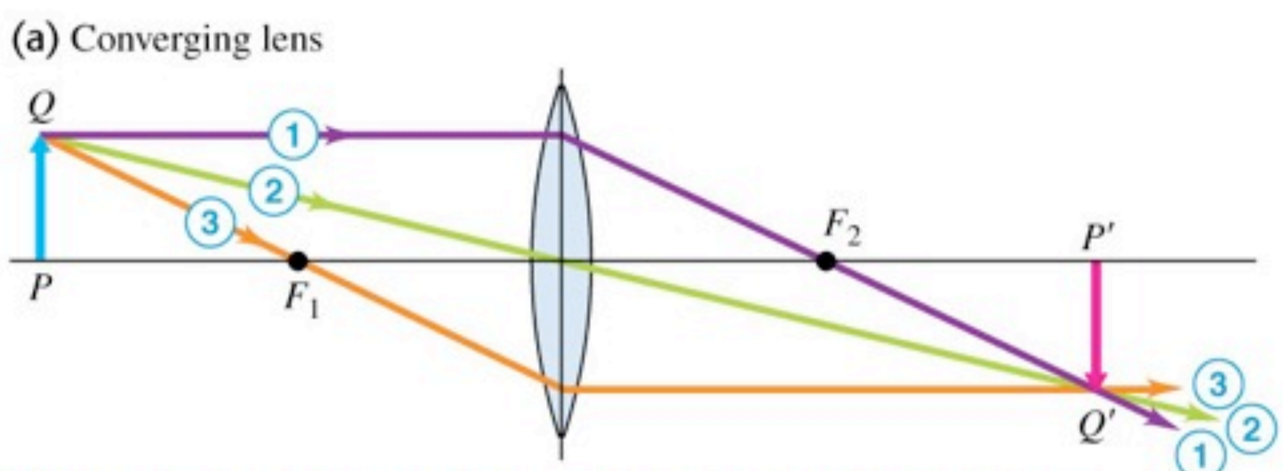
$R_1 < 0,\ R_2 > 0,\ f < 0$

diverging lens

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

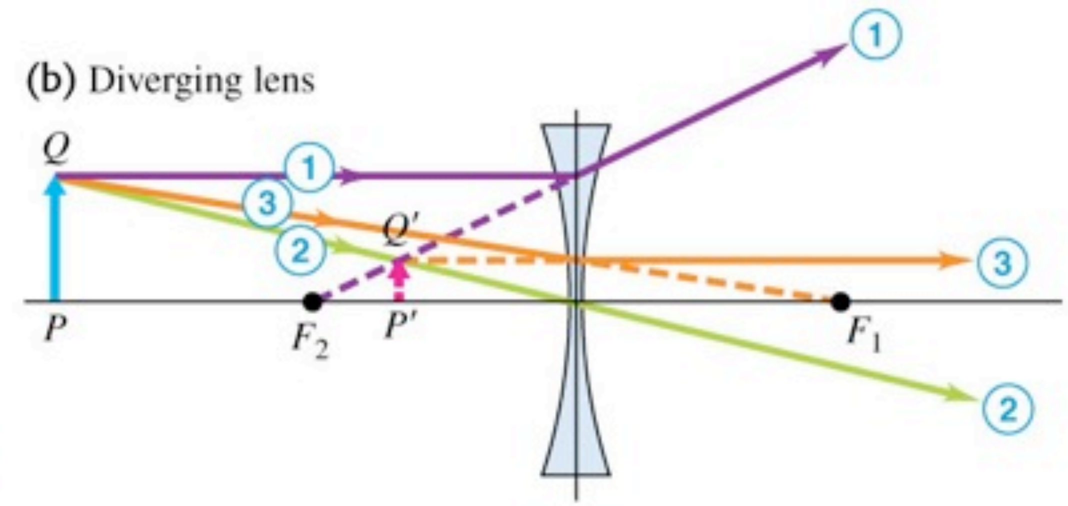
Graphical methods

$f > 0$



1 Parallel incident ray refracts to pass through second focal point F_2.
2 Ray through center of lens does not deviate appreciably.
3 Ray through the first focal point F_1 emerges parallel to the axis.

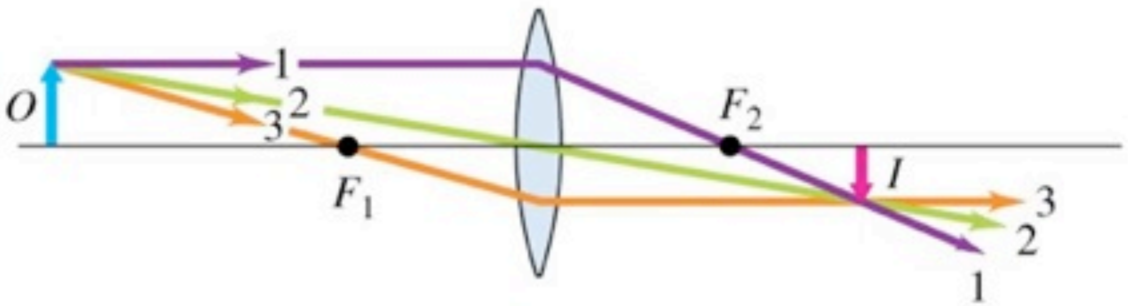
$f < 0$



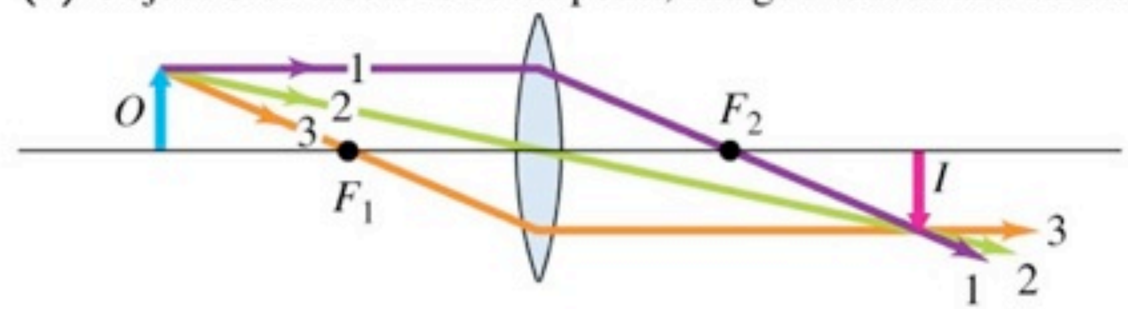
1 Parallel incident ray appears after refraction to have come from the second focal point F_2.
2 Ray through center of lens does not deviate appreciably.
3 Ray aimed at the first focal point F_1 emerges parallel to the axis.

More examples

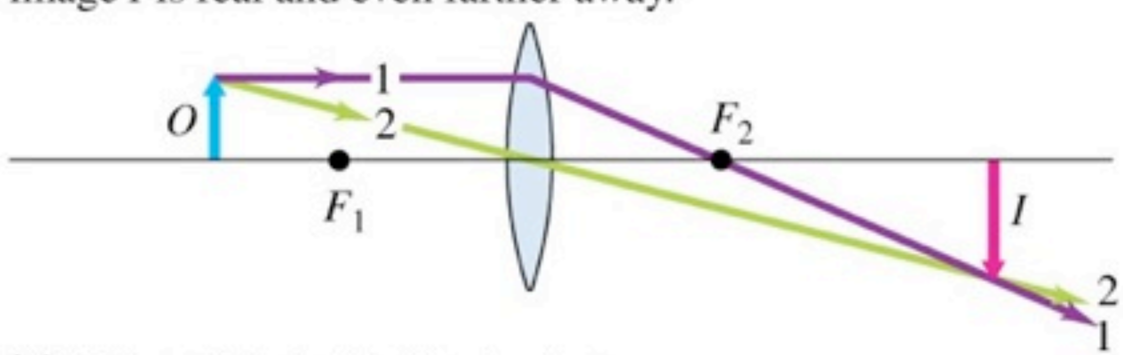
(a) Object O is outside focal point; image I is real.



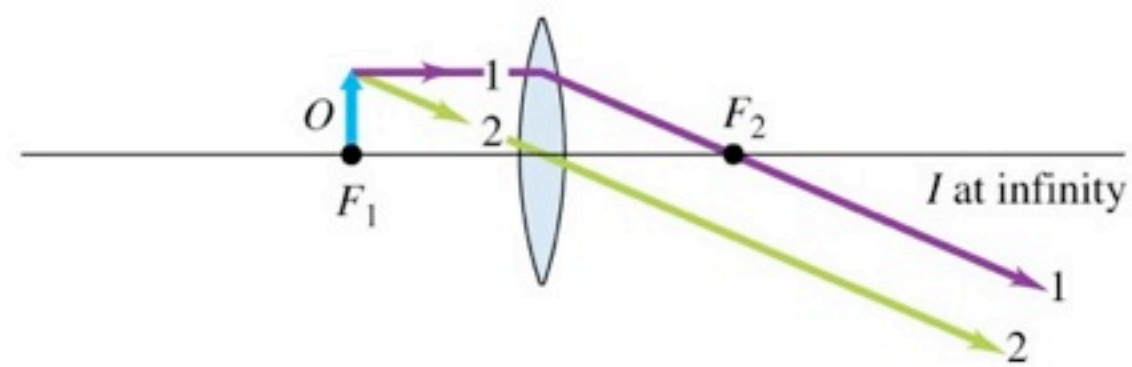
(b) Object O is closer to focal point; image I is real and farther away.



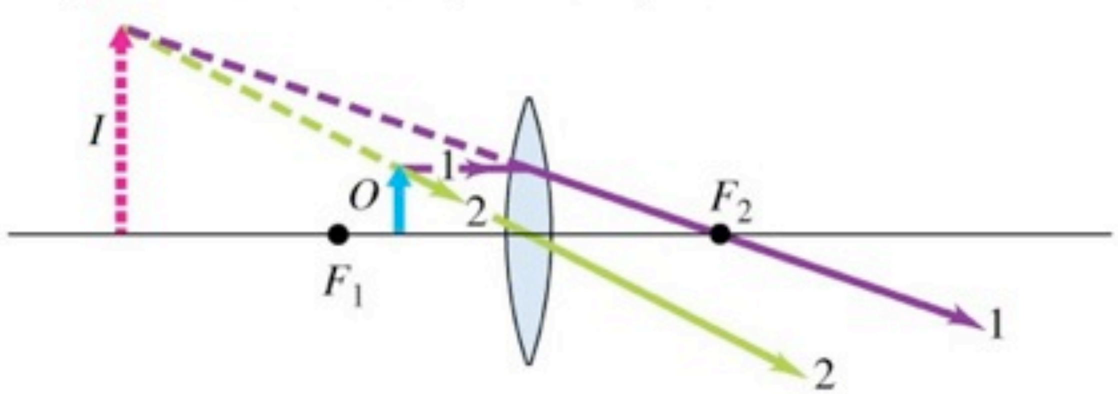
(c) Object O is even closer to focal point; image I is real and even farther away.



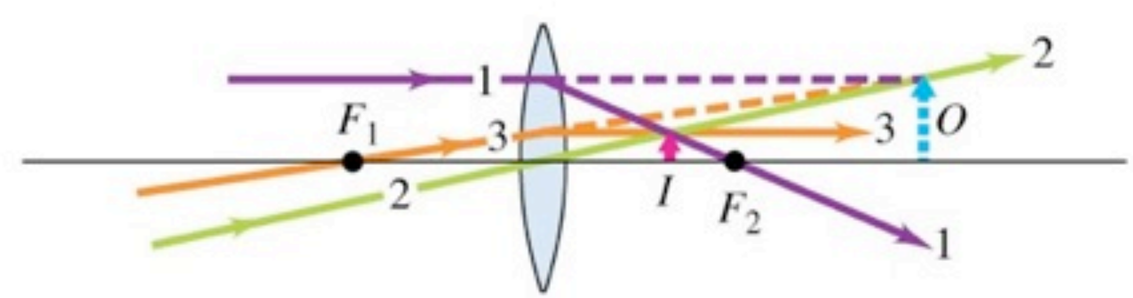
(d) Object O is at focal point; image I is at infinity.



(e) Object O is inside focal point; image I is virtual and larger than object.

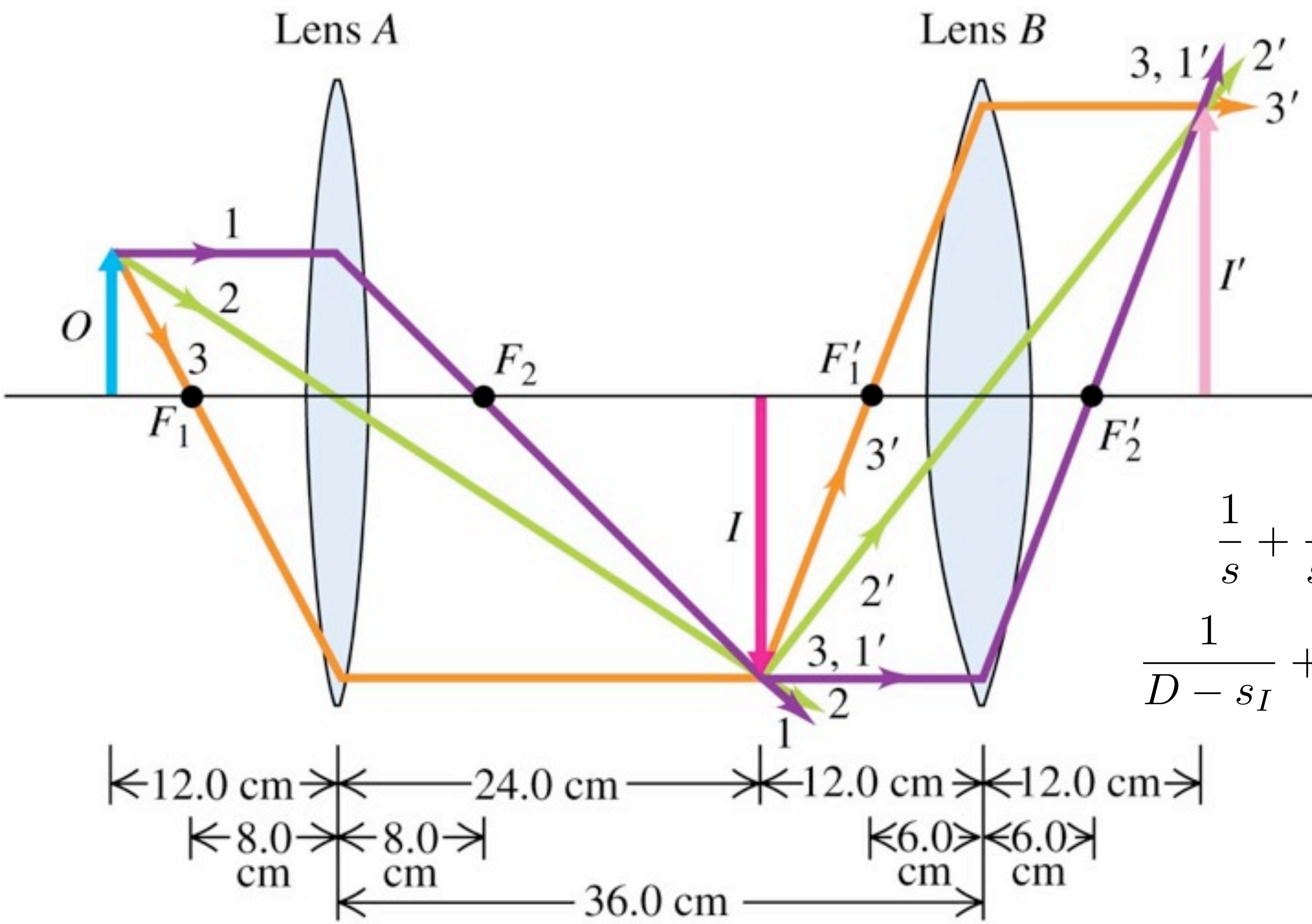


(f) A virtual object O (light rays are *converging* on lens)



Combining lenses

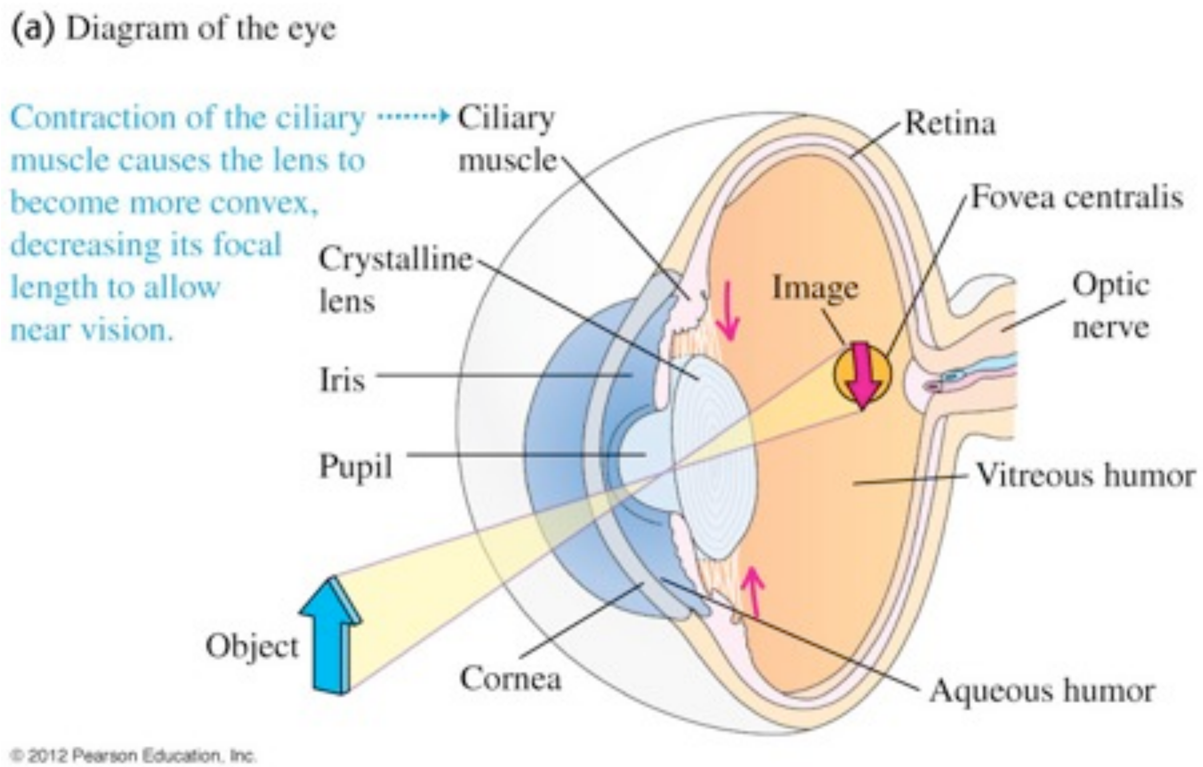
Image from first lens = "object" for next lens:

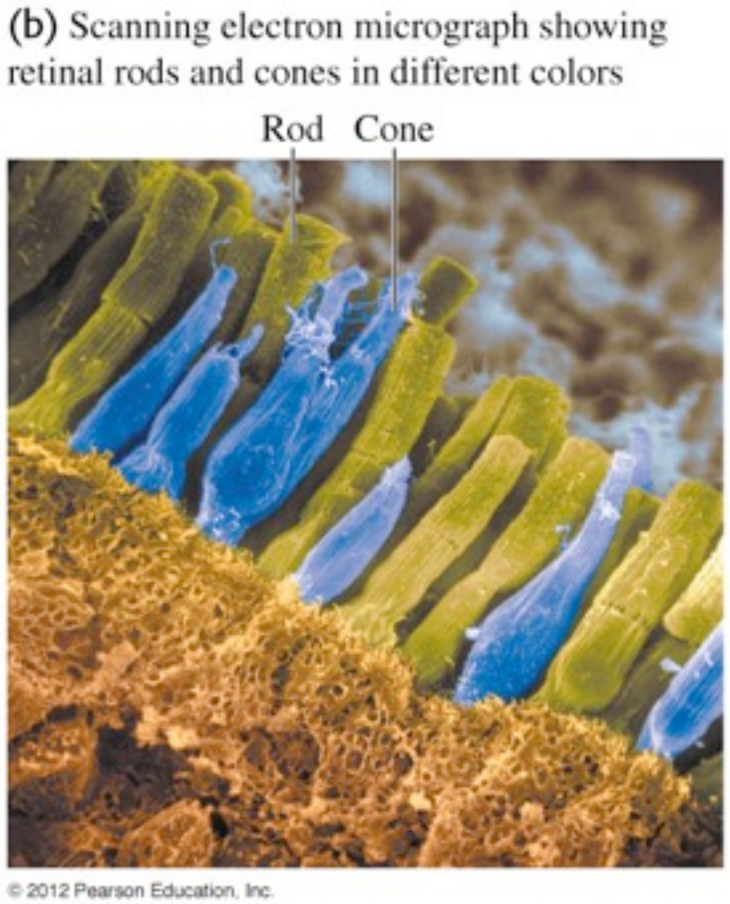


$$\frac{1}{s} + \frac{1}{s_I} = \frac{1}{f_1}$$

$$\frac{1}{D - s_I} + \frac{1}{s'} = \frac{1}{f_2}$$

Eyes





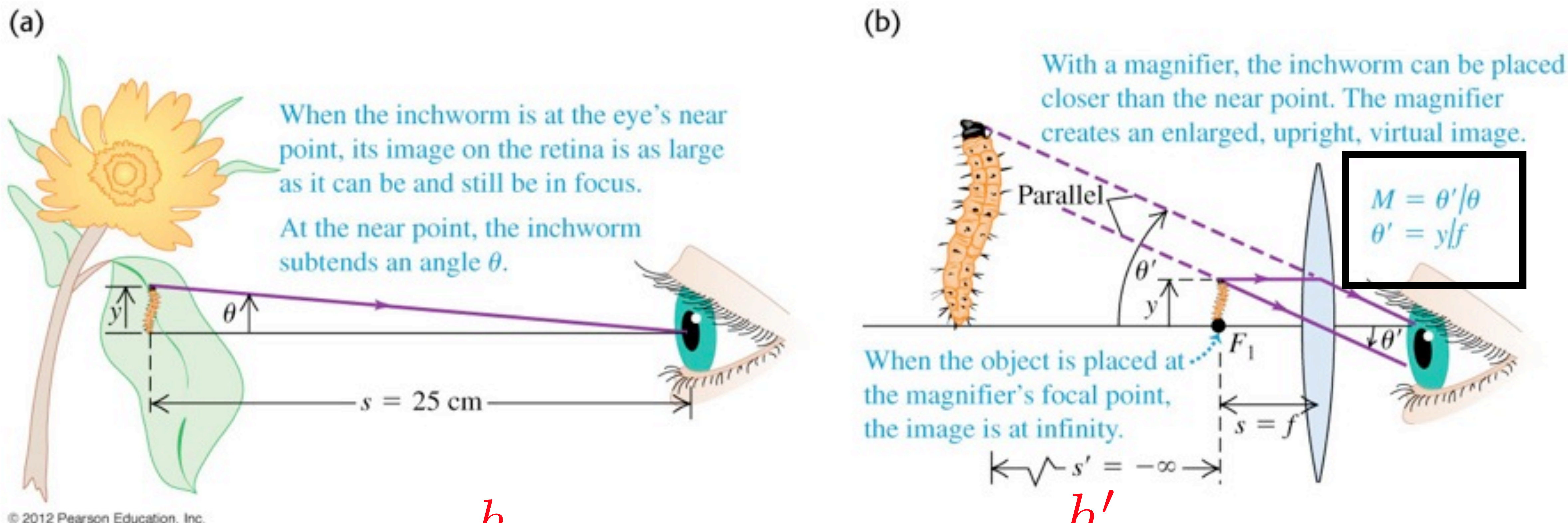
Curious fact: we have a blind spot from where the "wiring" goes in front of the detectors. All other animals have the same issue, except the octopus. Their wiring has the better seeming design of going out the back side, behind the detectors. Discussed in Feynman Lectures, see

http://www.feynmanlectures.caltech.edu/I_36.html

eye’s near point

Look at some text and slowly bring it closer to your eye. At some point, you can’t focus anymore. That is your eye’s near point. If you’re in your 20s, it’s probably around 10cm. If you’re in your 40s, it’s probably more like 20cm. As you age, it goes farther out, why people need reading or bifocal glasses. If you’re looking at something small, you want to bring it as close to your eye as possible, so bring it to your near point. The book often takes it to be 25cm.

Magnifier



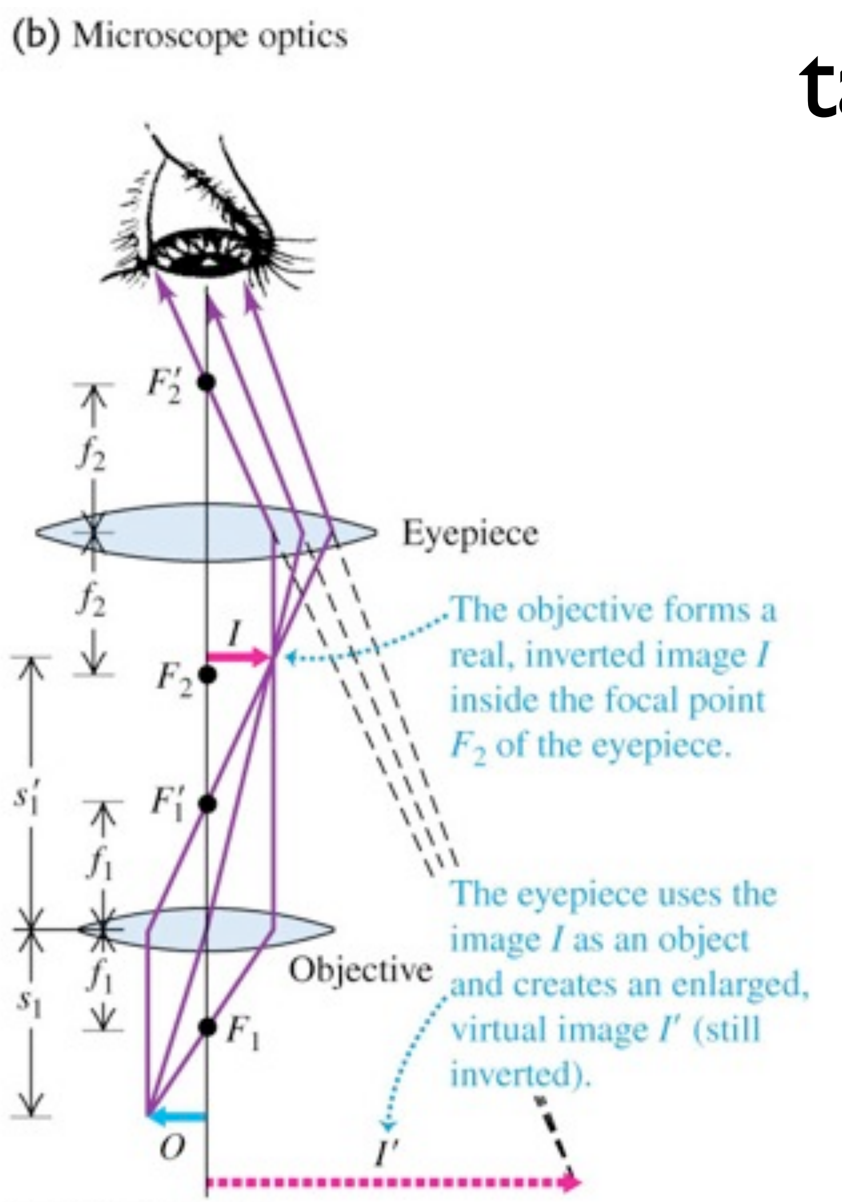
$$\tan\theta = \frac{h}{s} \approx \theta \qquad \tan\theta' = \frac{h'}{s'} \approx \theta'$$

$$m = \frac{\theta'}{\theta} \qquad \theta \approx h/L_{min} \qquad \theta' \approx h/f$$ similar triangles

How close your eye can focus

$$M \approx L_{min}/f$$

Microscopes



take: $s_1 \approx f_1$

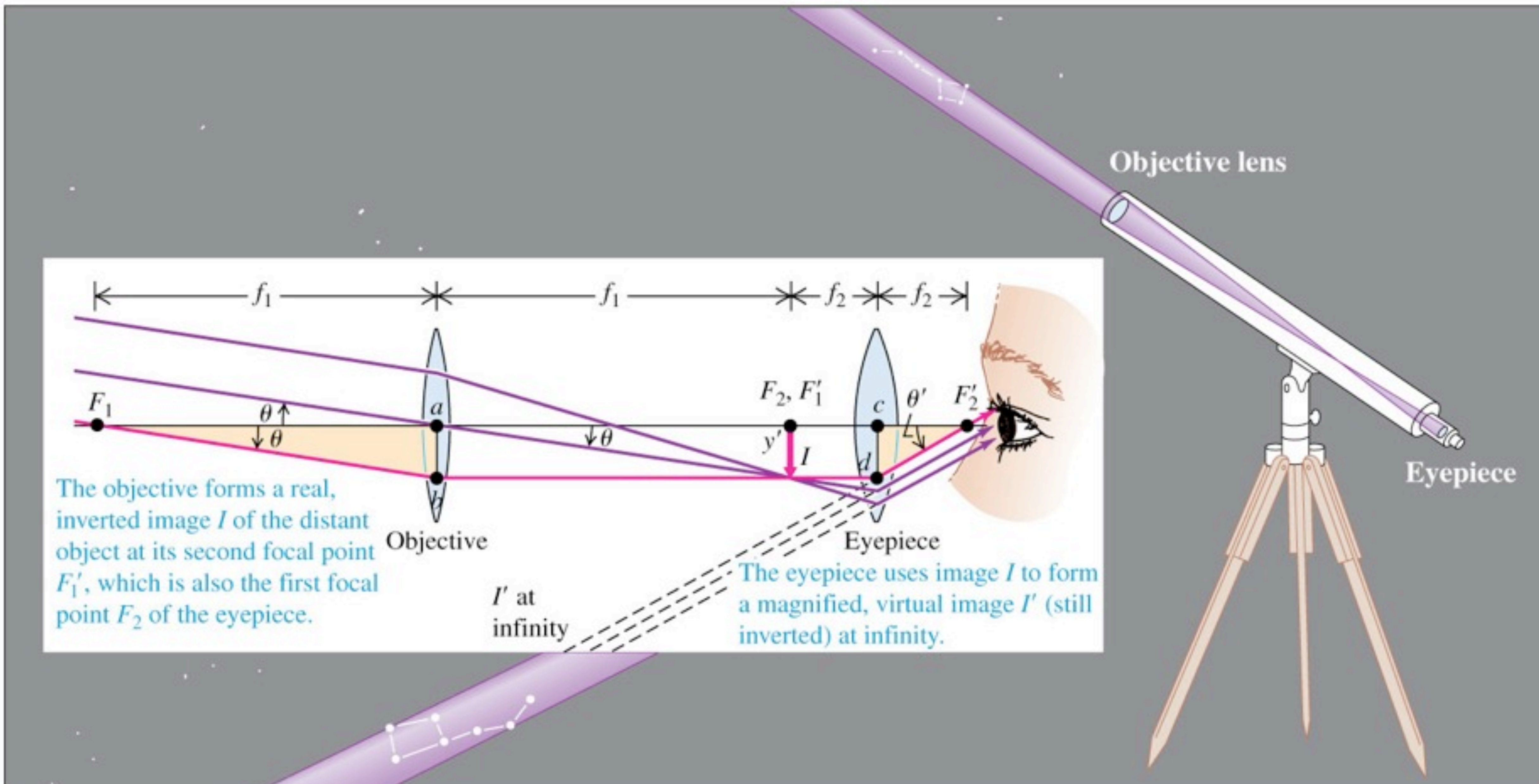
$$m_1 = -\frac{s_1'}{s_1} \approx -\frac{s_1'}{f_1}$$

$$M_2 = L_{min}/f_2$$

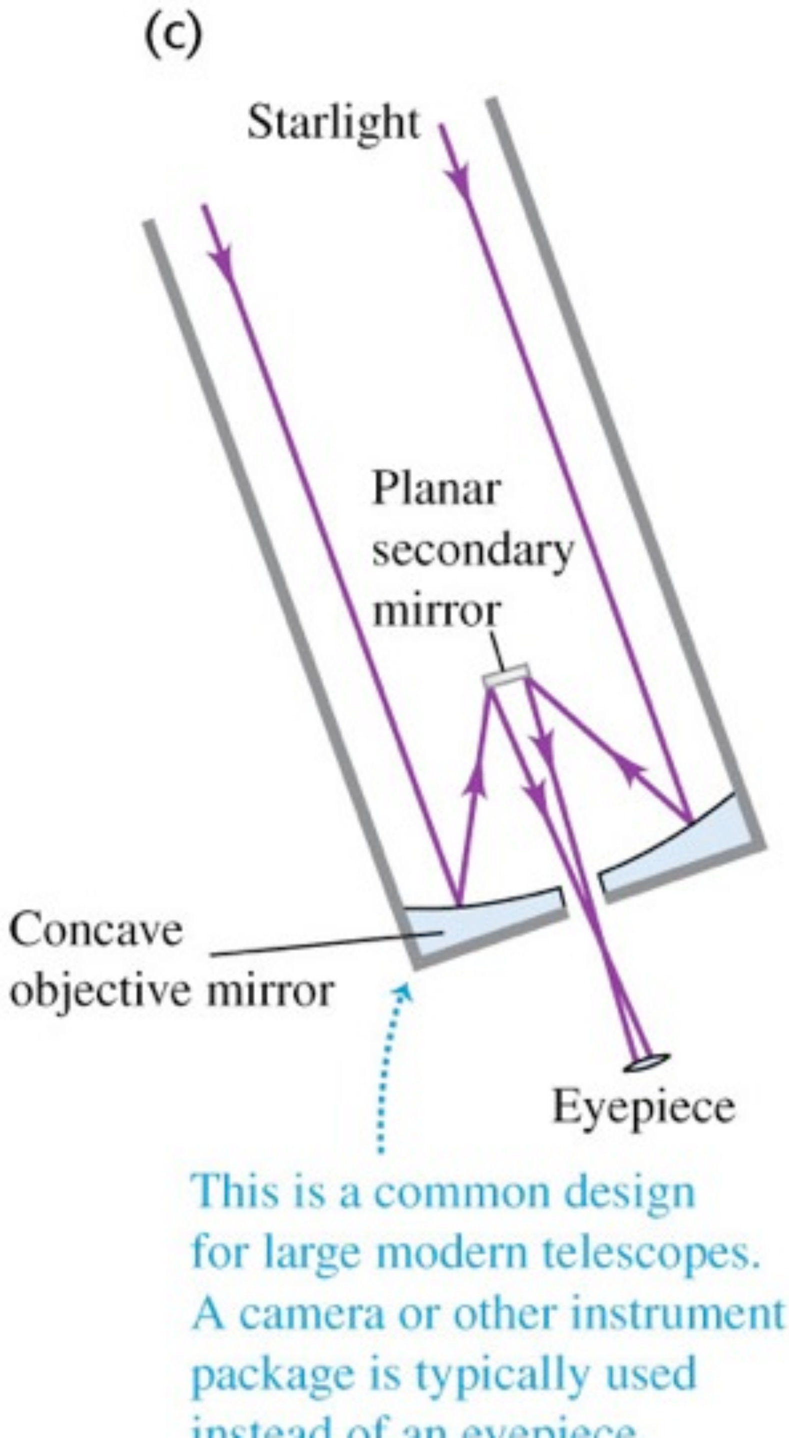
$$M = m_1 M_2 = \frac{L_{min} s_1'}{f_1 f_2}$$

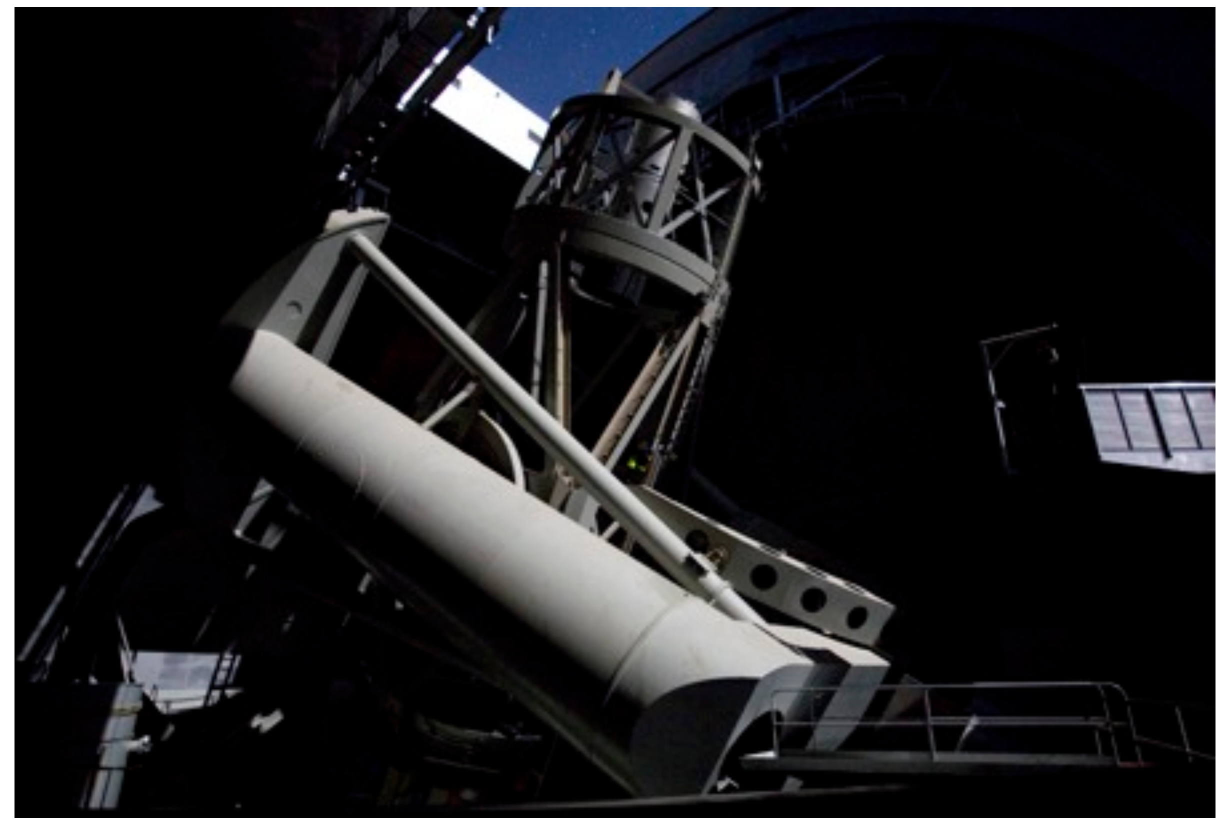
telescopes

$$M = \frac{\theta'}{\theta} = \frac{y'/f_2}{-y'/f_1} = -\frac{f_1}{f_2}$$



modern telescopes

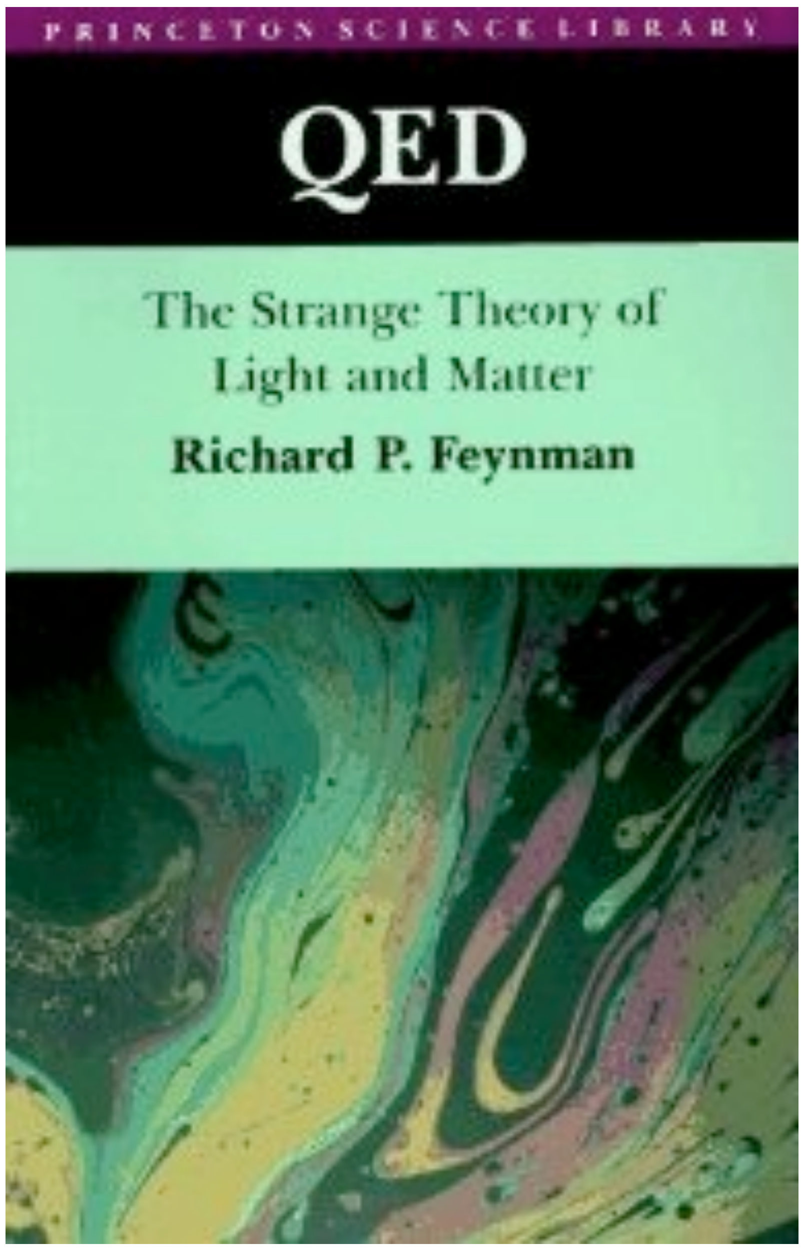




Local: Mt. Palomar, Caltech's telescope, open to public.

http://www.astro.caltech.edu/palomar/

just for fun (I think so):



Light's actual path can be understood in terms of summing over all possible paths, with arrows (complex phases). The classical path is where this sum doesn't completely cancel out. Other paths allowed, important in QM, connects description of light as a classical E & M wave with the QM description in terms of photons. There's more to optics than meets the eye! (Was inspirational for me.)