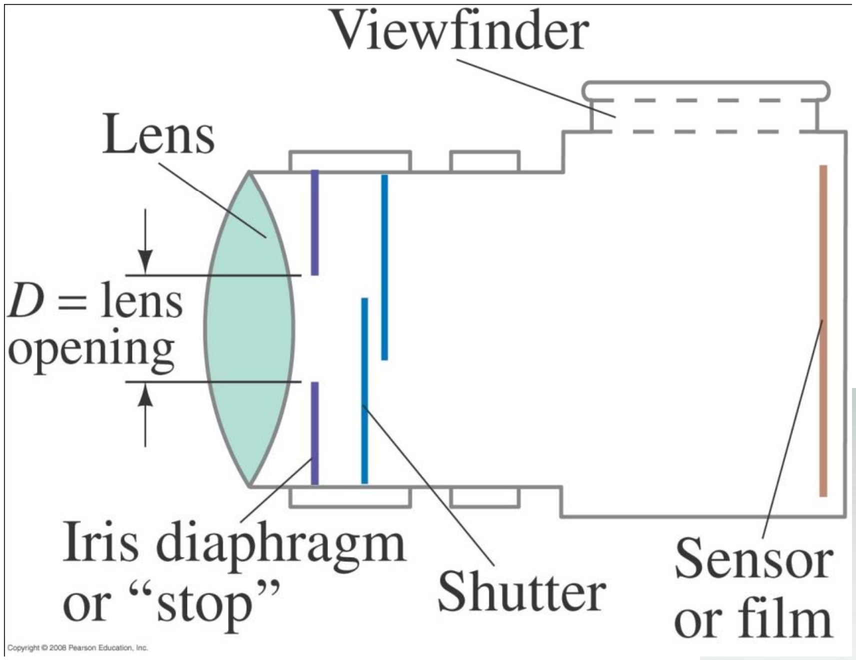
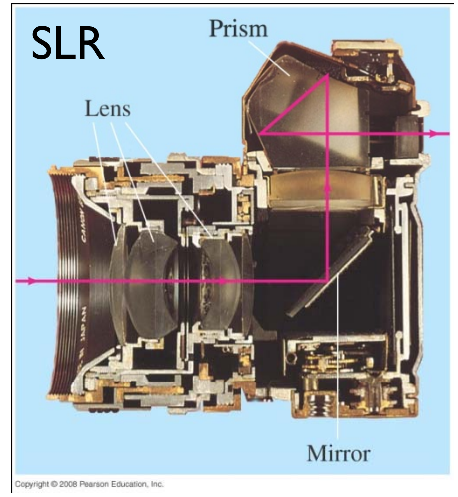
Physics 5B

Lecture 19, February 29, 2012

Chapter 33, Eye and Optical Instruments

Cameras





$$f\text{-stop} = \frac{f}{D}$$

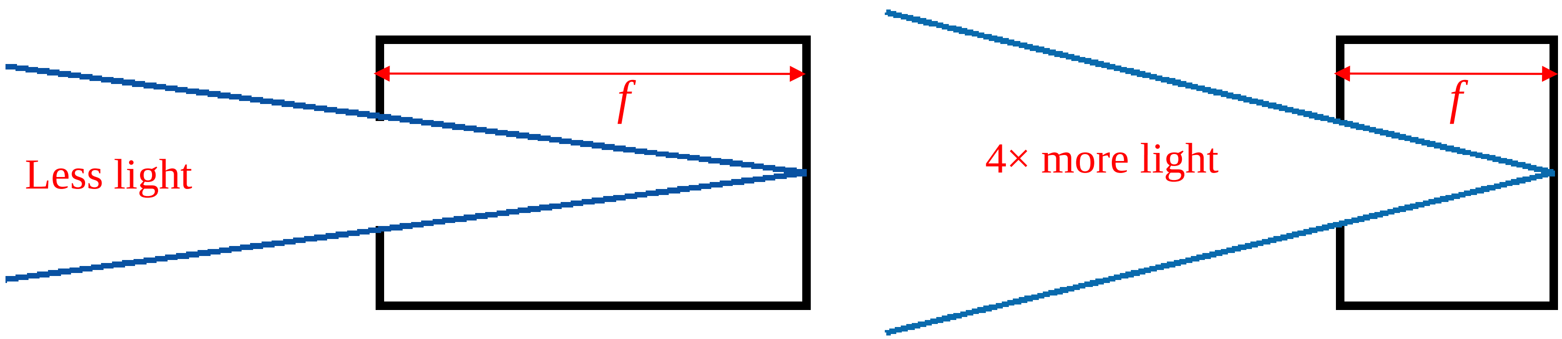
For this OM-1 camera lens the maximum aperture is

$$D_{\max} = 50\text{mm}/1.8 = 28\text{mm}$$

Exposure

- Standard *f*-stop choices
  - 1.0, 1.4, 2.0, 2.8, 4.0, 5.6, 8, 11, 16, 22, 32
- Standard shutter speeds (in 1/second)
  - 1, 2, 4, 8, 15, 30, 60, 125, 250, 500, 1000

- Increasing the *f*-stop by 1 click decreases the light exposure by a factor of 2
- Increasing the shutter speed by one click also decreases the light exposure by a factor of 2



A photograph is taken at f/2.8 with an exposure time of 1/250 seconds. The f-stop is changed to f/5.6 in order to increase the depth of field. What should be the new exposure time in order to obtain an approximately equivalent exposure?

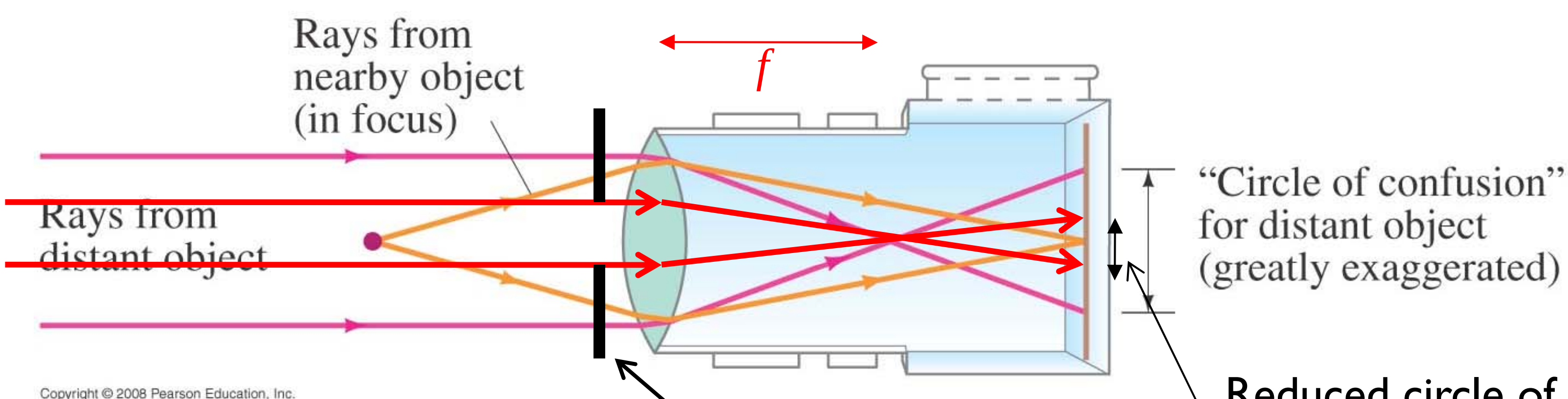
A. 1/1000 s

B. 1/500 s

C. 1/125 s

D. 1/60 s

Focal Depth of Field

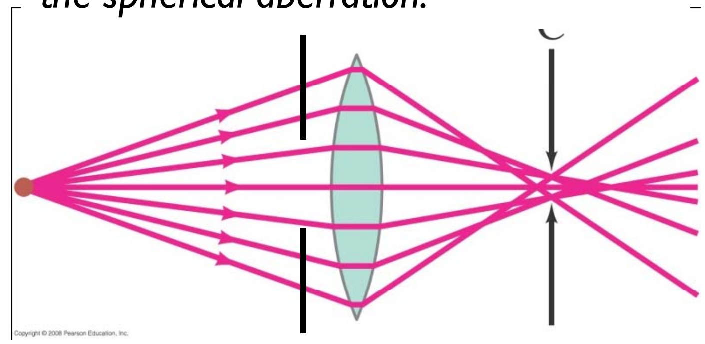


Reduced circle of confusion

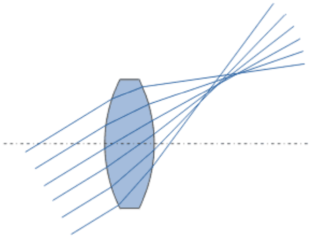
Increase the *f*-stop to decrease the lens aperture.

More Aberration

Decreasing the aperture will decrease the spherical aberration.

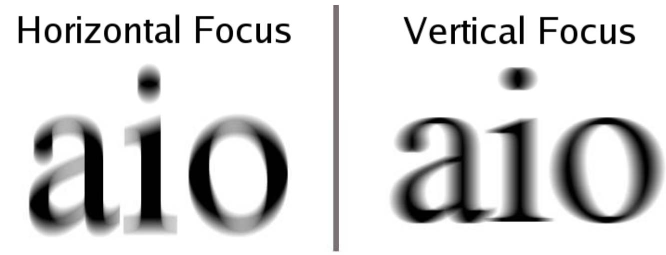


- Spherical aberration
  - Applies to spherical mirror or spherical lens surfaces.
  - Absent in parabolic mirrors, *but only on-axis!*
  - Usually corrected by using multiple spherical lenses, or mirrors plus lenses, because non-spherical lenses are expensive.
- Coma
  - Imperfect focus of off-axis rays.
  - Disease of parabolic mirrors as well as spherical surfaces.
  - Sophisticated optical systems correct this and spherical aberration together with multiple elements.

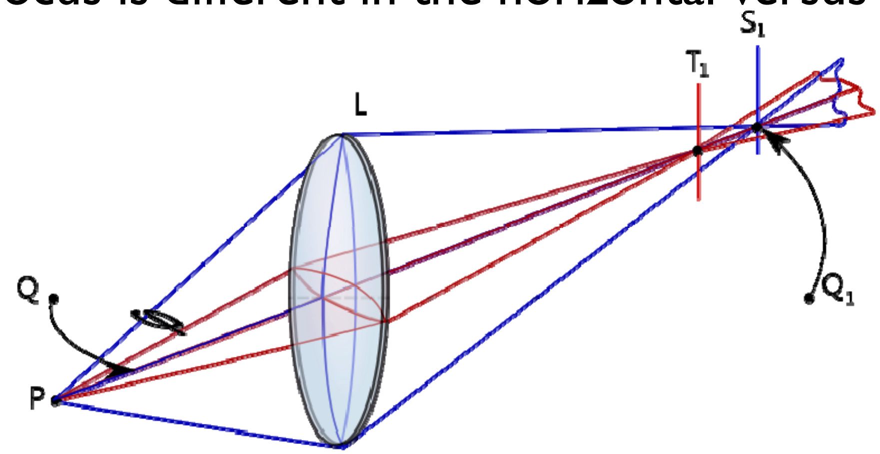


Star images that should look like circular points instead look a bit like comets.

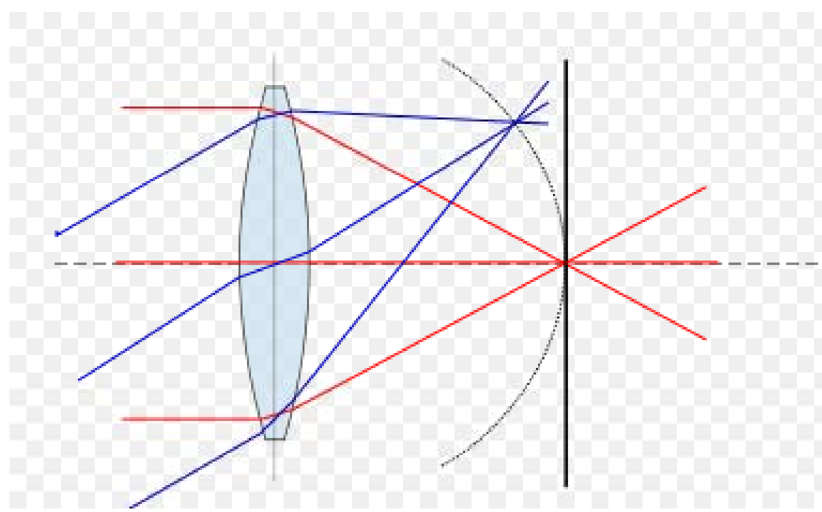
More Aberration



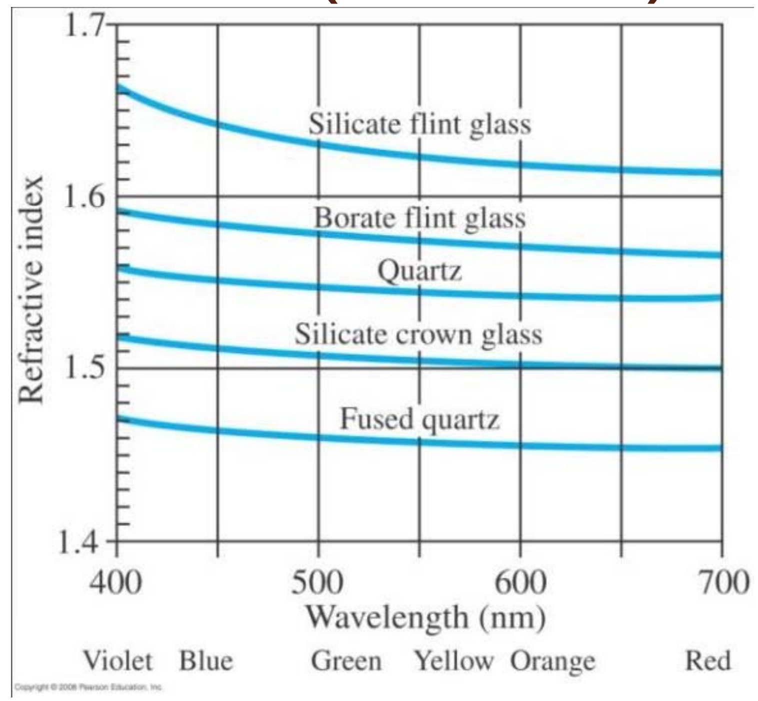
- Off-axis astigmatism
  - Example: the focus is different in the horizontal versus vertical planes

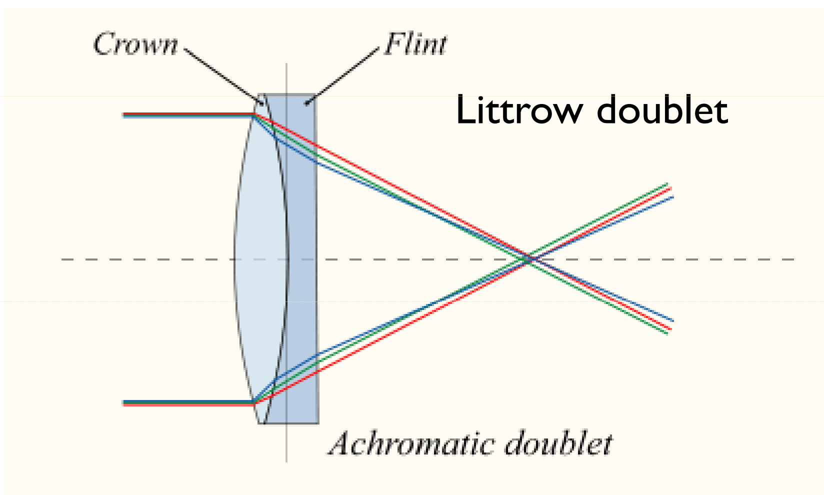


- Curvature of field
  - Make the film or CCD curved
  - Or flatten the field with additional optical elements



Chromatic Aberration (review)



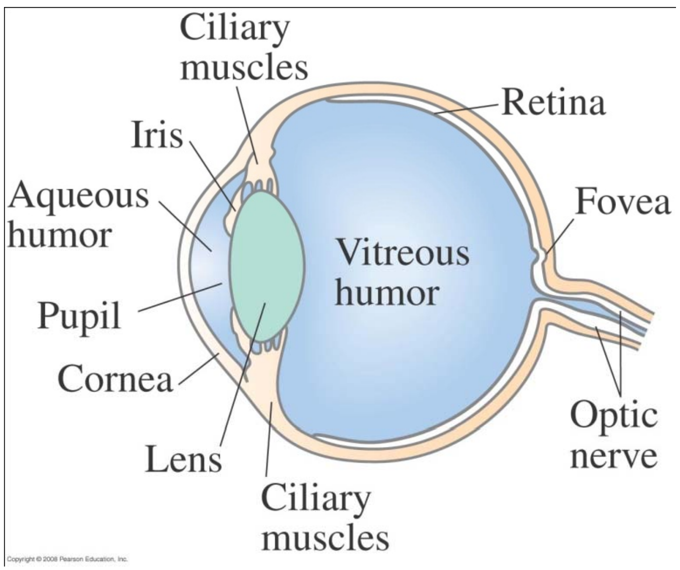


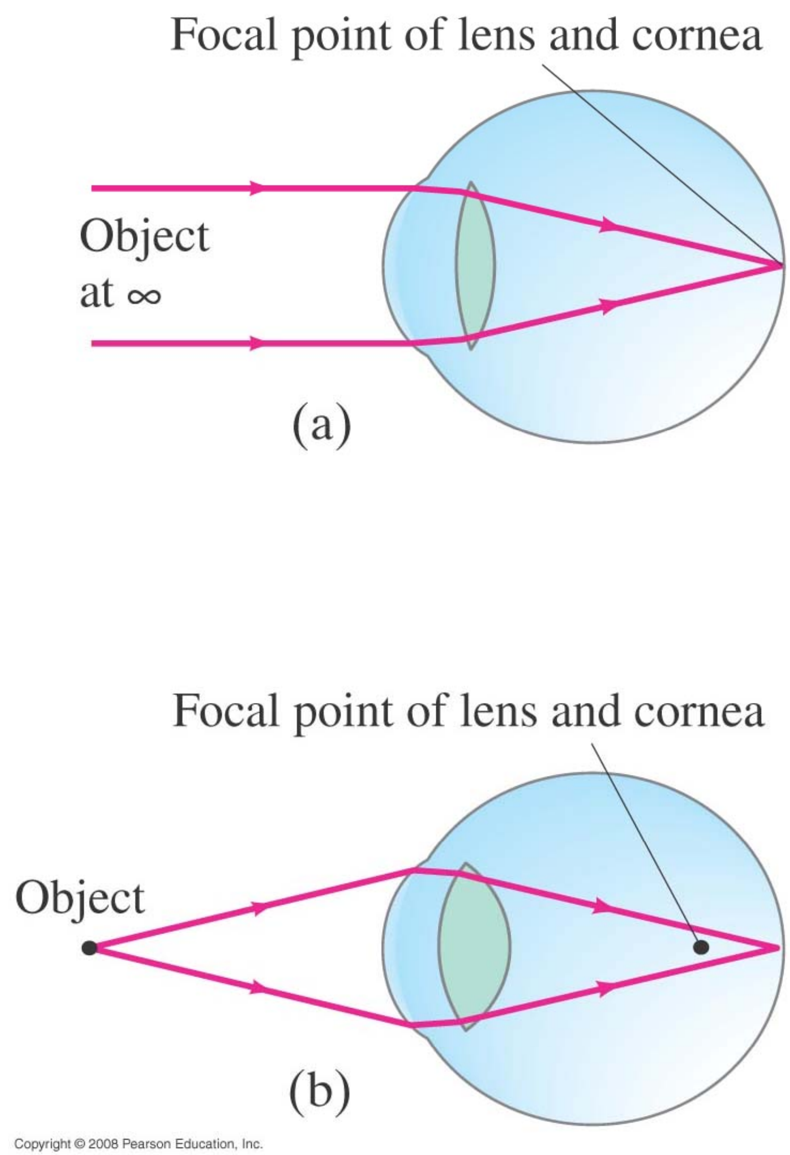
$$\frac{1}{f} = (2n_1 - n_2 - 1)\cdot\frac{1}{R}$$

$$\text{Blue}: \left(2\times 1.51 - 1.64 - 1\right)\cdot\frac{1}{R} = 0.38\cdot\frac{1}{R}$$

$$\text{Red}: \left(2\times 1.50 - 1.62 - 1\right)\cdot\frac{1}{R} = 0.38\cdot\frac{1}{R}$$

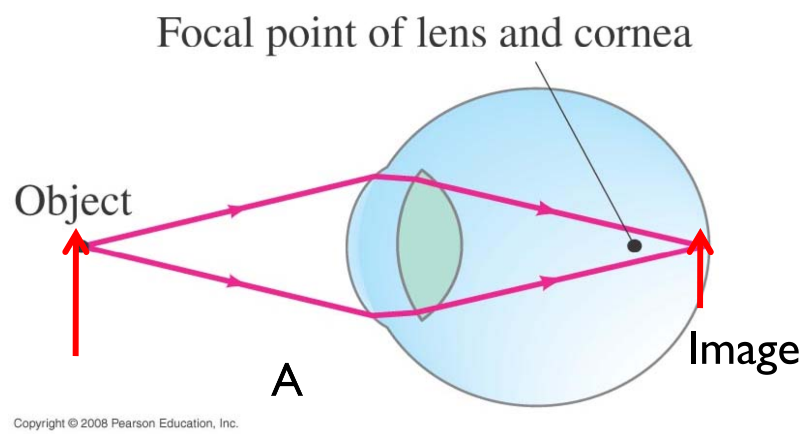
The Eye

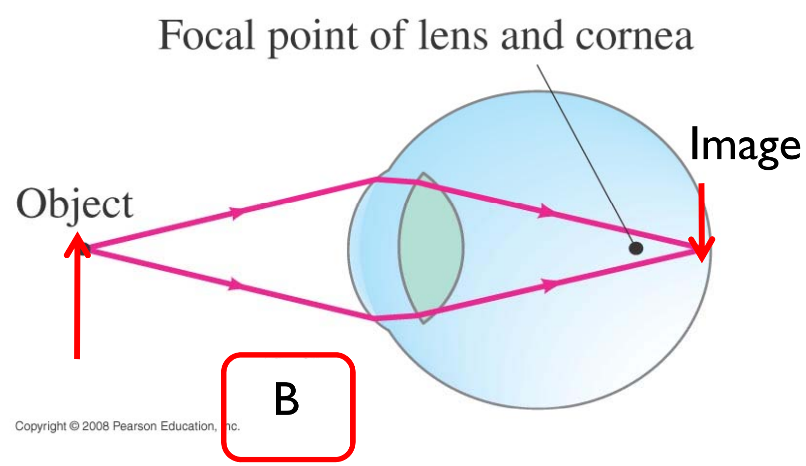




Typically the object can be no closer than about 25 cm (the "near point") to be focused on the retina.

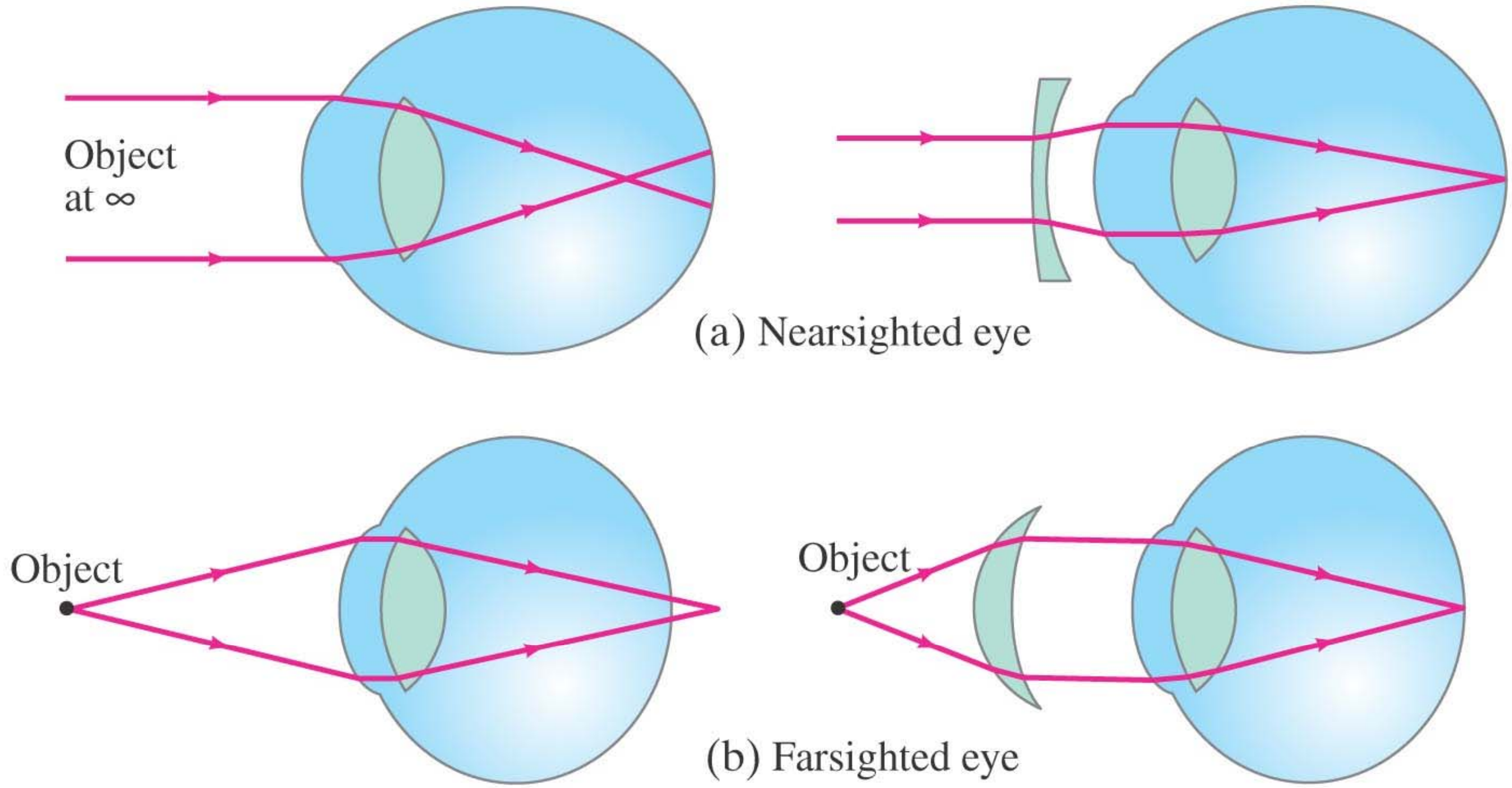
Which figure best represents the image formed on the retina by the object?





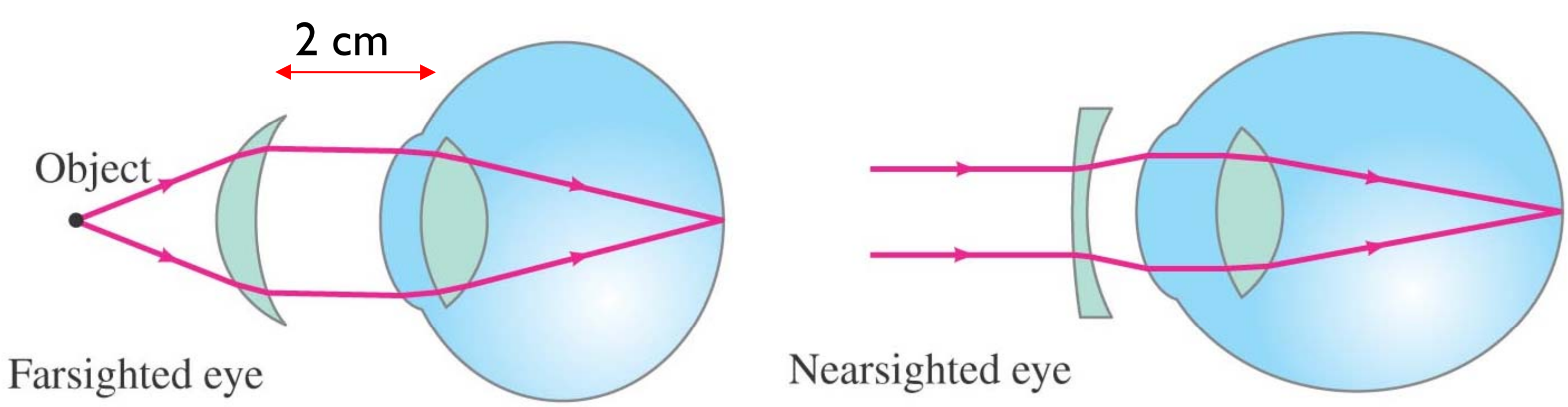
See the following paper from 1890:
SOME PRELIMINARY EXPERIMENTS ON VISION WITHOUT
INVERSION OF THE RETINAL IMAGE
DR. GEORGE M.STRATTON
University of California

Eye Corrections



Problem 33-98

A woman can see clearly with her right eye only when objects are between 45 cm and 155 cm away. Prescription bifocals should have what powers so that she can see distant objects clearly (upper part) and be able to read a book 25 cm away (lower part) with her right eye? Assume that the glasses will be 2.0 cm from her eye.



2.0 D

–0.65 D

The student in this photo is

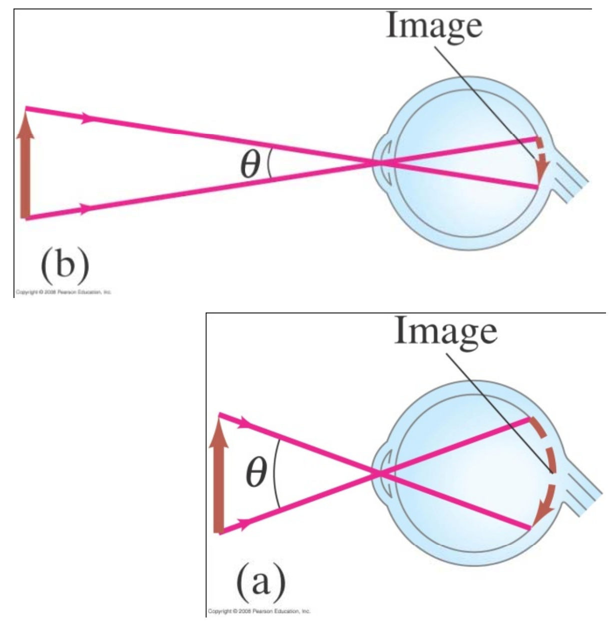
A. Nearsighted.

B. Farsighted.

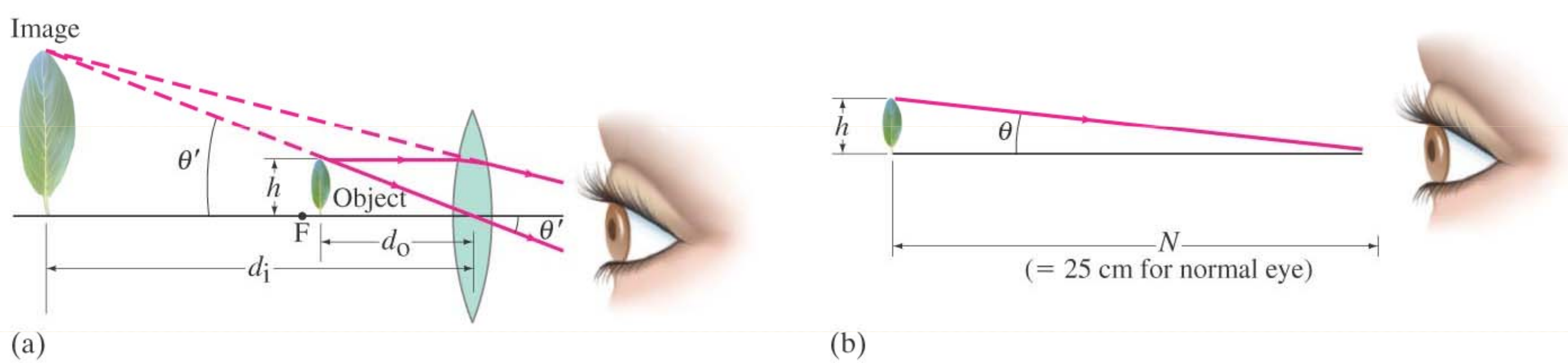
Magnifying Glass

An object close to the eye will subtend a large angle and produce a large image on the retina. But if it is closer than about 25 cm the eye won't be able to focus on it.

A converging lens will produce a virtual image further away (or at infinity), allowing the eye to focus comfortably.

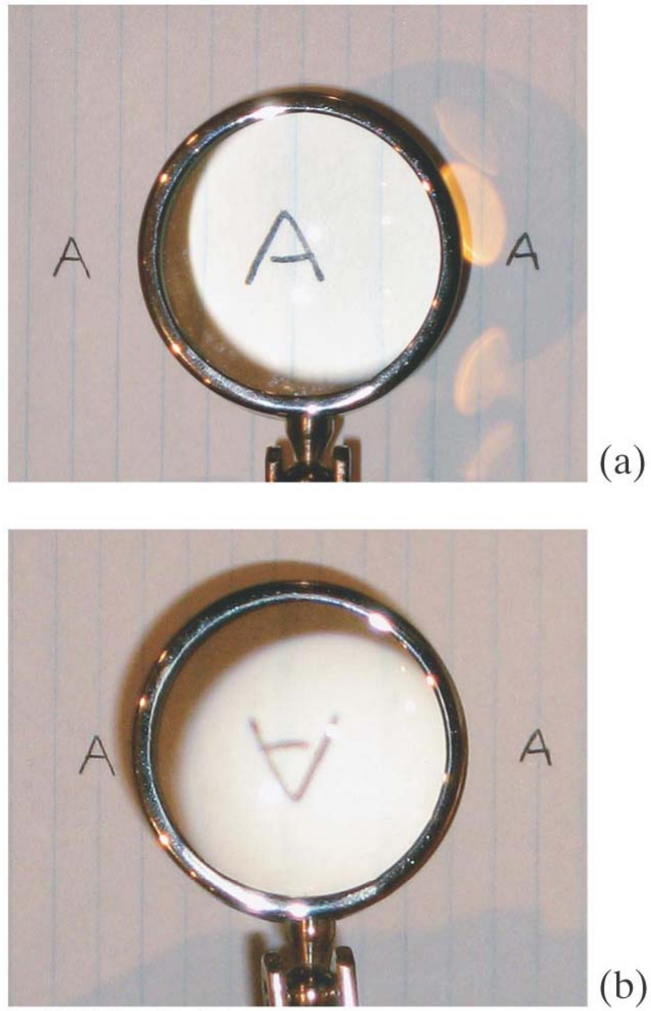


$$\text{Angular magnification } M \equiv \frac{\theta'}{\theta} = \frac{25\,\text{cm}}{f}$$

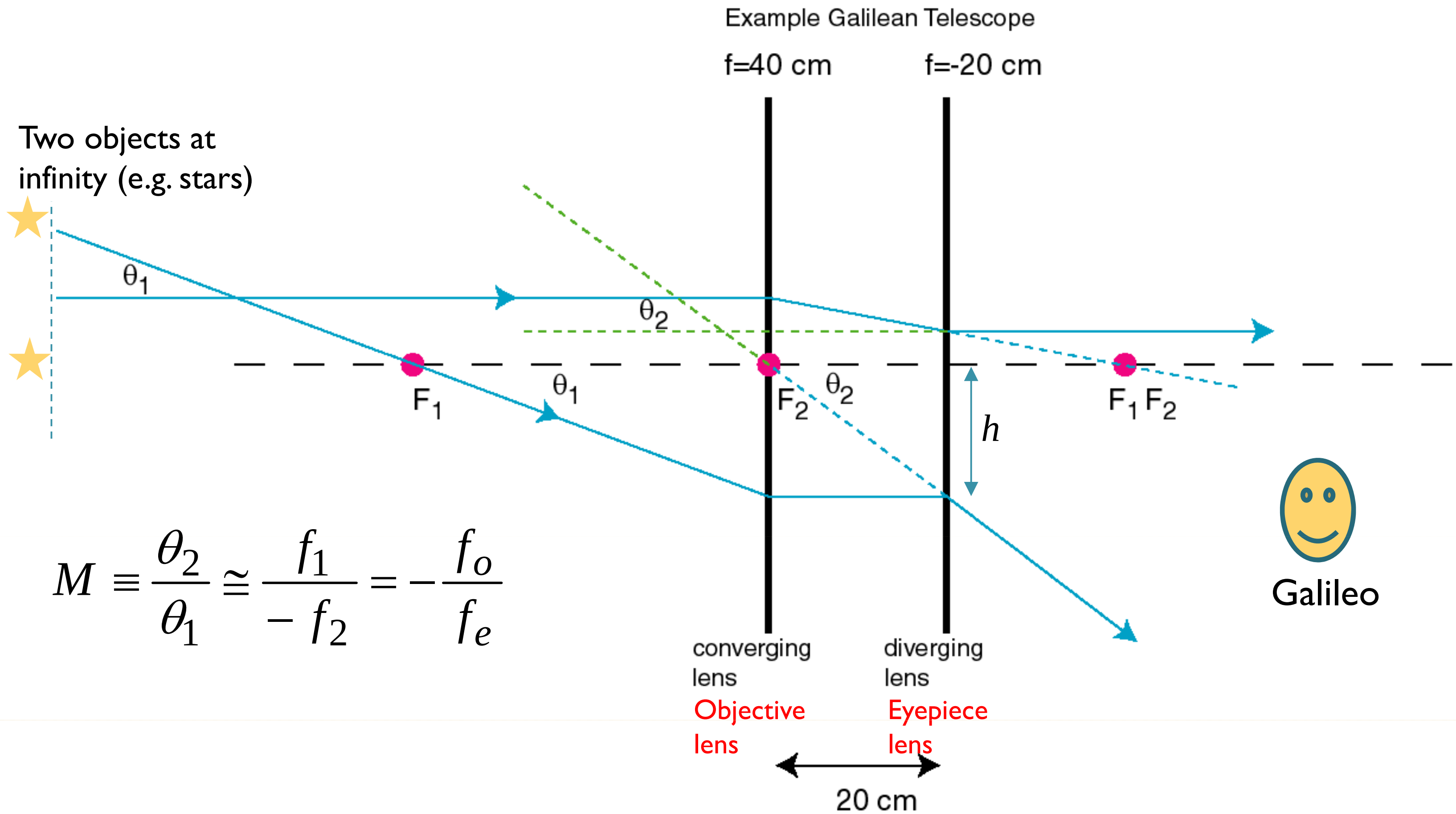


Magnifying Glass

Here the glass is held too far away from the object, and an inverted, real image is formed.



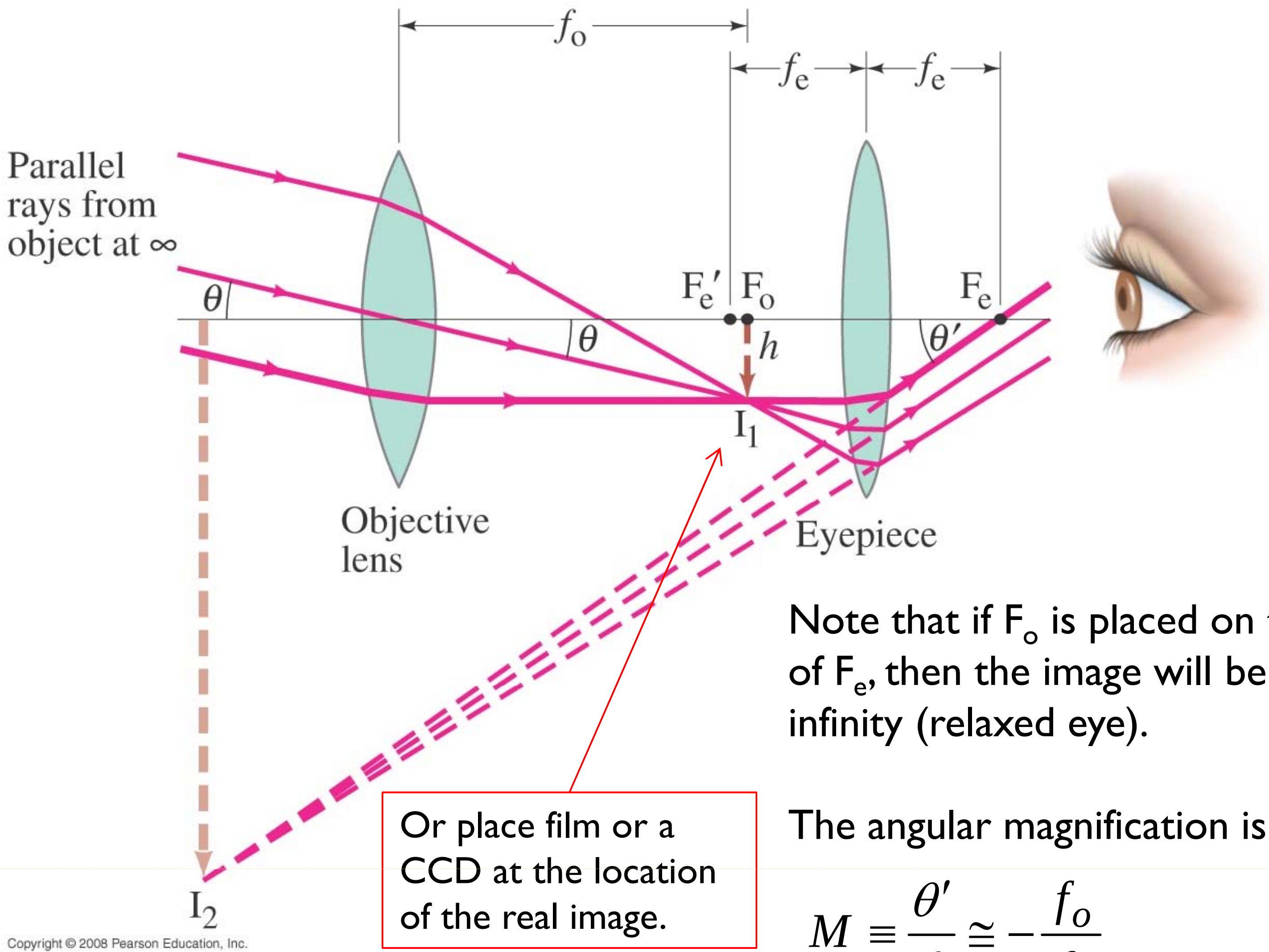
Galilean Telescope (opera glasses)



$$M \equiv \frac{\theta_2}{\theta_1} \cong \frac{f_1}{-f_2} = -\frac{f_o}{f_e}$$

The focus of the diverging lens is placed on top of the focus of the converging lens. Then incoming rays that are parallel (from an object at infinity) are parallel again after passing through the diverging lens. A significant angular magnification results, which is the ratio of the focal lengths.

Astronomical Refracting Telescope



Note that if F_o is placed on top of F_e, then the image will be at infinity (relaxed eye).

The angular magnification is

$$M \equiv \frac{\theta'}{\theta} \cong -\frac{f_o}{f_e}$$

Lick Observatory Refractor

Antique telescope built in the late 19th century on Mt. Hamilton near San Jose. At 36" diameter, it is the world's 3rd largest refracting telescope.
All modern astronomical telescopes use a primary mirror rather than a lens.