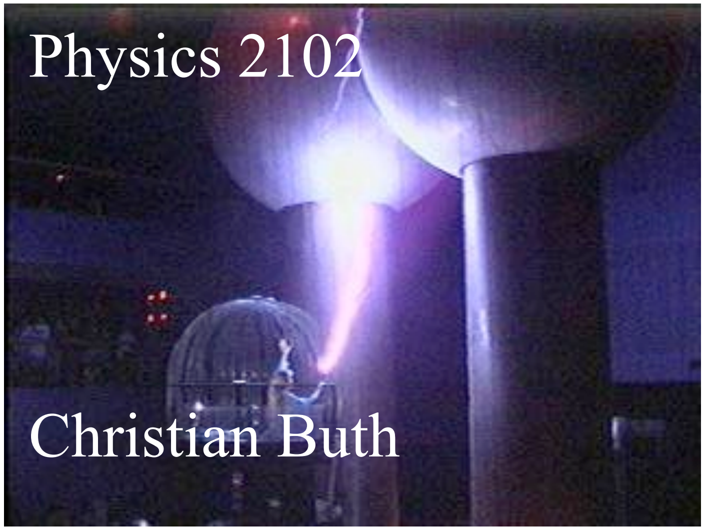
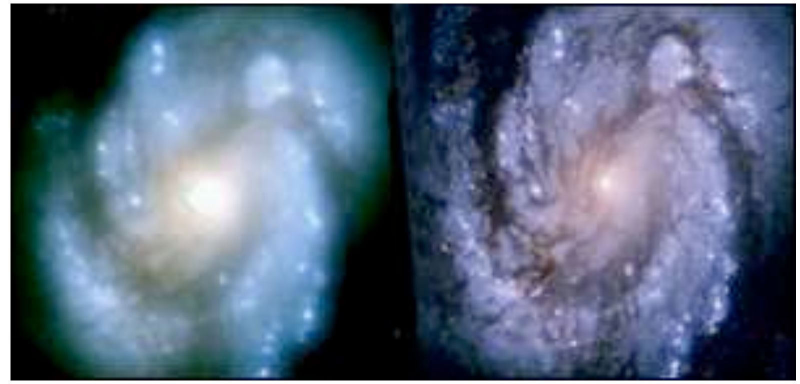
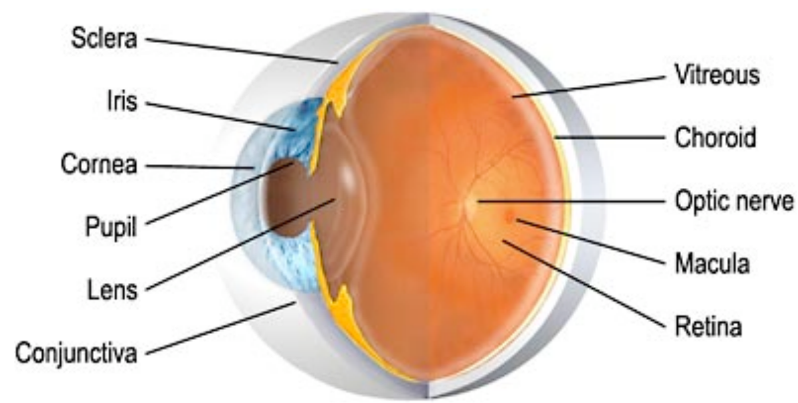




Lecture 38

Optics: Images 2

04/22/2009



Review

- Extended objects from spherical mirrors and lenses are located by **drawing rays**

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

Lateral Magnification: $|m|=\frac{h'}{h}$

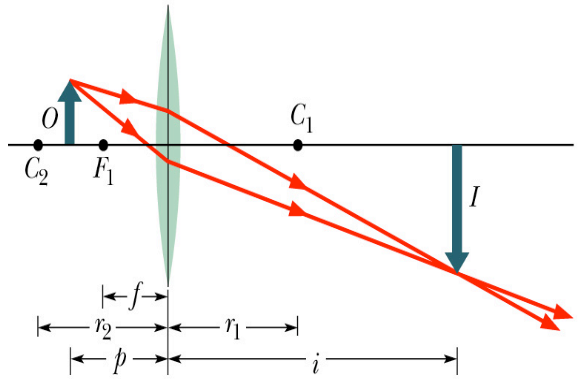
Lateral Magnification: $m=-\frac{i}{p}$

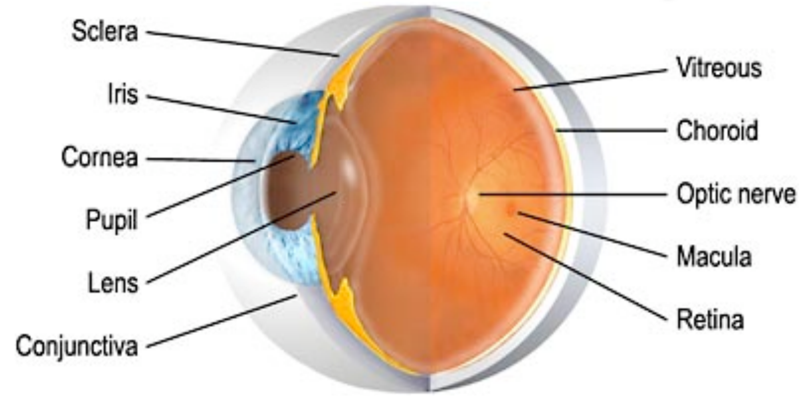
Spherical Refracting Surface: $\frac{n_1}{p}+\frac{n_2}{i}=\frac{n_2-n_1}{r}$

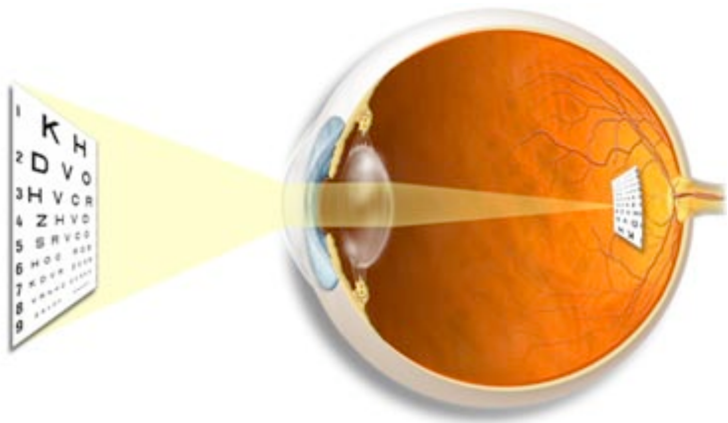
Thin Lens: $\frac{1}{f}=\frac{1}{p}+\frac{1}{i}$

Thin Lens in Air: $\frac{1}{f}=(n-1)\left(\frac{1}{r_1}-\frac{1}{r_2}\right)$

Optical Instruments: the Human Eye





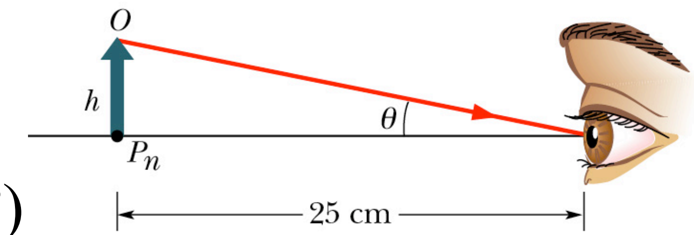


The human eye consists of a variable-geometry lens (crystalline) which produces a real image on a "screen" (retina) which is transmitted to the brain via the optical nerve.

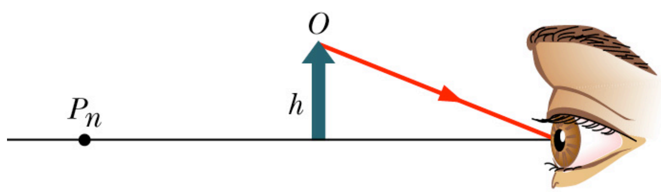
The cristalline automatically adjusts itself so we see well any object placed between infinity and a distance called "near point" (about 25cm for a typical 20 year old). The "image distance" is the eye diameter~2cm.

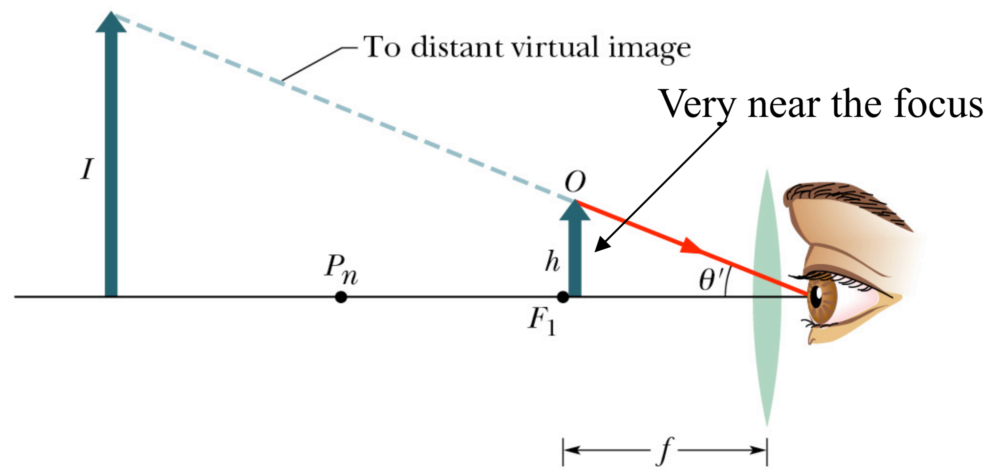
Magnifying Lens

The magnification of an object is |m|=i/p ~i θ/h, but i=eye diameter.
Maximum magnification: |m|~2cm/25cm (!?)



We'd like to make p smaller (move the object closer). We use a magnifying lens to produce a (larger) image than our eye can see:



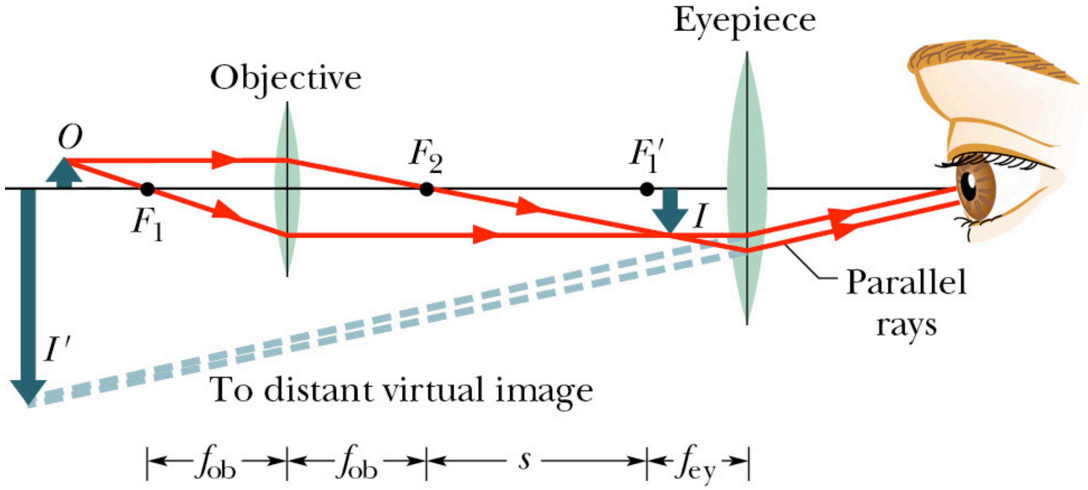


Angular magnification (different from lateral): $m_\theta=\theta'/\theta$.

$$\theta = \frac{h}{25cm} \qquad \theta' \cong \frac{h}{f} \qquad m_\theta = \frac{25cm}{f}$$

Optical Instruments, Compound Microscope

To increase the magnification of a lens, one wants to have a short focal length. That means small radii of curvature (very curved lens). This, in turn implies a lot of aberration (one is immediately out of the thin lens approximation). A solution to this is obtained by combining two lenses. The resulting device is called microscope.



Object O is magnified by the objective:

$$m = -\frac{i}{p}$$

And its image is magnified by the eyepiece:

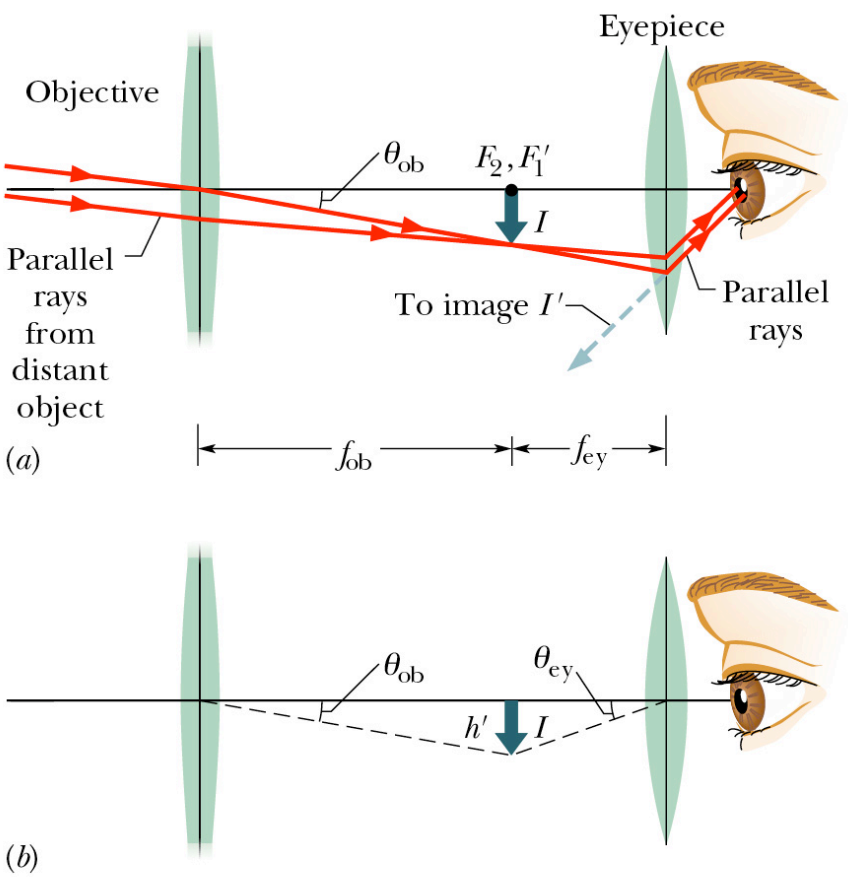
$$m_\theta = \frac{25cm}{f}$$

Total magnification:

$$\boxed{M = m m_\theta = -\frac{s}{f_{ob}}\frac{25cm}{f_{ey}}}$$

Optical Instruments, Refracting Telescope

Telescopes are arrangement of lenses that improve vision of objects very far away. They are configured like a microscope. However, the objective forms an image essentially at its focus, and therefore the eyepiece’s focus has to be placed at that same point.



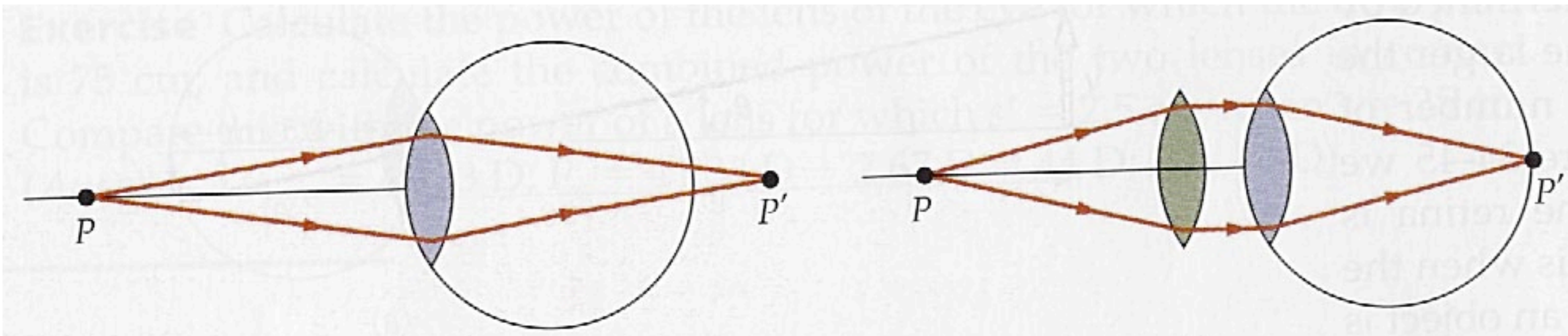
The magnification is given by the ratio θ_{ey}/θ_{ob}, and since

$$\theta_{ob} = h'/f_{ob} \qquad \theta_{ey} = h'/f_{ey}$$

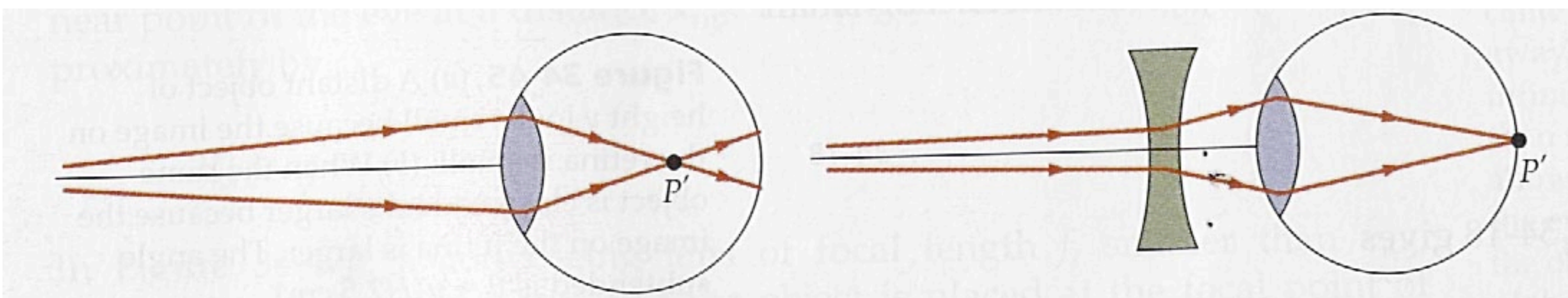
$$m = -\frac{f_{ob}}{f_{ey}}$$

Refracting telescopes are of limited use (chromatic aberration). Reflecting telescopes built with mirrors are preferred in astronomy.

Eyeglasses & Contact Lenses



A farsighted person needs a convergent lens.



A nearsighted person needs a divergent lens.

The "power" of a lens is measured in **dioptres**: $P=1/f$ with f is in m.
Glasses with -6D are divergent glasses with $f=-1/6D = -0.17m = -17cm$
The dioptres add! Two lenses have $1/f=1/f_1+1/f_2 \rightarrow D=D_1+D_2$

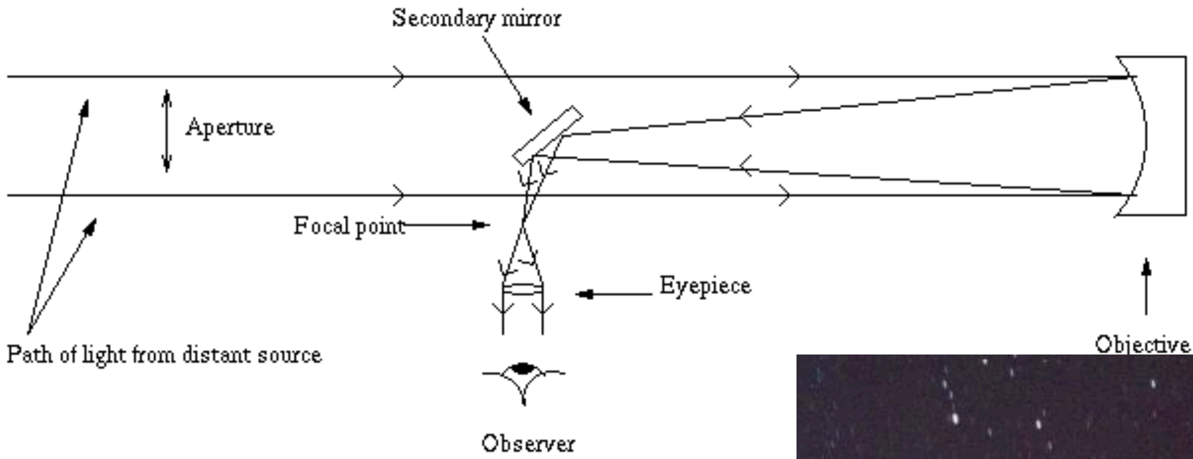
Example

The world's largest refracting lens telescope is at the Yerkes Observatory of the University of Chicago at Williams Bay, Wisconsin. (Bigger telescopes use mirrors instead of lenses.) The objective has a diameter of 102cm and a focal length of 19.5m. The focal length of the eyepiece is 10cm. What is its magnifying power?

$$m = -\frac{f_{ob}}{f_{ey}} = -\frac{19.5m}{0.1m} = -195$$

Why so large (102cm)? Because the larger the objective, the more light it gathers.

Reflective Telescopes



Keck observatory (Mauna Kea, Hawaii) and the Hale-Bopp comet.

Largest optical telescope, composed of 36 (!) hexagonal mirror segments performing as a single mirror 10m wide.

Summary

- Magnifying lens

Simple Magnifier: $m_\theta \approx \dfrac{25\text{ cm}}{f}$

- Microscope and telescope combination of an **objective** and an **eyepiece**

- Magnification of microscope and telescope

$$\boxed{M = m m_\theta = -\frac{s}{f_{ob}} \frac{25cm}{f_{ey}}}$$

$$m = -\frac{f_{ob}}{f_{ey}}$$