Physics 142 - December 1, 2005

Geometric Optics

Dispersion

\[ n \text{ depends on } \lambda (\nu) \]

Typically \( n(\text{red}) < n(\text{blue}) \)
\[ n_1 \sin \theta_1 = n_2 \sin \theta_2 \]

\[ n_1 \sin \theta_c = n_2 \sin 90^\circ \]

\( \theta_c \) = critical angle

If \( \theta_e > \theta_c \) Total internal reflection
Incident

reflected

refracted

Scattering (electric dipole)
Thin lenses and optical instruments

Physics 142
Fall 2005 – S. Manly

References and photo sources:

http://cvs.anu.edu.au (D. Denning and M. Kirk)
http://www.ebiomedia.com
(a) Converging lenses

Ray 3 passes straight through the center of the lens (assumed very thin).
(b) Diverging lenses

Double concave  Planoconcave  Concave meniscus
Power of lens measured in diopters

\[ P = \frac{1}{f} \quad \text{where } f \text{ is focal length in meters} \]

Power is positive for converging lenses and negative for diverging lenses
Lens equation:

\[ \frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f} \]

Magnification:

\[ m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} \]
Sign convention is the tricky part, especially in multiple lens systems

Convention from Giancoli p. 841:

- Focal length is + for converging lens and - for diverging lens
- Object distance is + if on the side of the lens from which the light is coming (usual, unless in multi-lens system)
- Image distance is + if on the opposite side of the lens from where the light is coming, if on same side, image distance is –
- Image distance is + for real images and – for virtual images
- Height of image is + if image is upright and – if image is inverted. Height of object is always taken to be +.

Real image: rays actually pass thru image
Virtual image: rays do not actually pass thru image
Aberrations

Spherical aberration

Chromatic aberration
The electromagnetic spectrum
from "The Joy of Visual Perception: A Web Book"
http://www.yorku.ca/cyc/
Types of eyes in the animal kingdom

A. Ocellus

B. Pinhole Eye

C. Compound Eye

D. Lens and Retina (Vertebrate)
Aeschna dragonfly
28,000 facets
A bee’s eye view
Fig. 2.9. Resolution of the eyes of various animals measured physiologically and deduced from anatomical criteria compared to body height: (1) man; (2) peregrine falcon; (3) hen; (4) cat; (5) pigeon; (6) chiffinch; (7) rat; (8) bat (Myotis); (9) frog; (10) lizard; (11) minnow; (12) dragonfly (Aeshna); (13) bee (Apis); (14) Chlorophanus; (15) housefly (Musca); (16) hoverfly (Syrriina), frontal region FO; (17) jumping spider (Methaphidippus), anteromedian eye AM, postero-lateral eye PL; (18) fruit fly, Drosophila. (From Kirschfeld 1976.)
Anableps - minnow
Magnifying glass

In a virtual magnifying glass, the image is virtual and forms at a distance greater than the focal length of the lens. The magnification formula is:

\[ m = \frac{\theta'}{\theta} = \frac{N}{f} \]

where:
- \( m \) is the magnification,
- \( \theta' \) is the angle of the image,
- \( \theta \) is the angle of the object,
- \( N \) is the numerical aperture,
- \( f \) is the focal length of the lens.

The diagram illustrates the geometry of how light rays converge at the image point, forming an enlarged virtual image. The focal length \( f \) is typically estimated as 25 cm for a normal eye.
Refracting telescope

Parallel rays from object at $\infty$ are focused at $F_0$ by the objective lens. The eye (at $I_1$) views these rays through the eyepiece lens, which focuses them at $F'_e$. The image $I_2$ is observed by the observer.

40 inch refractor – Yerkes Observatory
Reflecting telescope

(a)

Concave mirror (objective)

Eyepiece (lens)

(b)

Eyepiece (mirror)
World's Largest Optical Telescopes

- Herschel 4.2m
- Palomar 5m
- Russian 6m
- Keck I 10m
- VLT 8.2m
- Keck II 10m

Central mirror holes not shown to scale
© W.M. Keck Observatory
Keck Observatory
Hubble Space Telescope
Compound microscope

(a)

(b)
Light vs. depth of field

Shutter speed

\[ f\text{-stop} = \frac{f}{D}, \text{ each f-stop} = \text{factor of 2 in light intensity} \]

Faster the object or darker the day, need slower speed and/or larger D

Larger D means narrower depth of field