Thin lenses and optical instruments

Physics 114
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References and photo sources:


http://cvs.anu.edu.au (D. Denning and M. Kirk)

http://www.ebiomedia.com
converging lens

rays from 30

focal length

focal length

Converging lens
(a) Converging lenses

(c) Ray 3 passes straight through the center of the lens (assumed very thin).
(b) Diverging lenses
Power of lens measured in diopters

\[ P = \frac{1}{f} \]

where \( f \) 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:

\[ m = \frac{h_i}{h_o} = -\frac{d_i}{d_o} \]
Real image: rays actually pass thru image
Virtual image: rays do not actually pass thru image

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 +.
Aberrations

Spherical aberration

Chromatic aberration
The electromagnetic spectrum
from "The Joy of Visual Perception: A Web Book"
http://www.yorku.ca/cyc/
©1994 Encyclopaedia Britannica, Inc.
Types of eyes in the animal kingdom

A. Ocellus
B. Pinhole Eye
C. Compound Eye

D. Lens and Retina (Vertebrate)
The Compound Eye of a Mosquito

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) chaffinch; (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
Virtual Magnifying glass

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

(b) \[ N = 25 \text{ cm for normal eye} \]
Refracting telescope

Parallel rays from object at \( \infty \)

\( \theta \)

\( |\theta| \)

\( F_e' \)

\( F_o \)

\( F_e \)

\( I_1 \)

\( I_2 \)

Objective

Eyepiece

40 inch refractor – Yerkes Observatory
Reflecting telescope

Concave mirror (objective)

Eyepiece (lens)

Eyepiece (mirror)
Keck Observatory
Hubble Space Telescope
Compound microscope
Camera
Light vs. depth of field

Shutter speed

f-stop = \( f/D \), each f-stop = 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
Slow exposure time
(Note hand motion)
Small opening
Large depth of field
of focus

Fast Time
Large opening
Narrow Field of focus