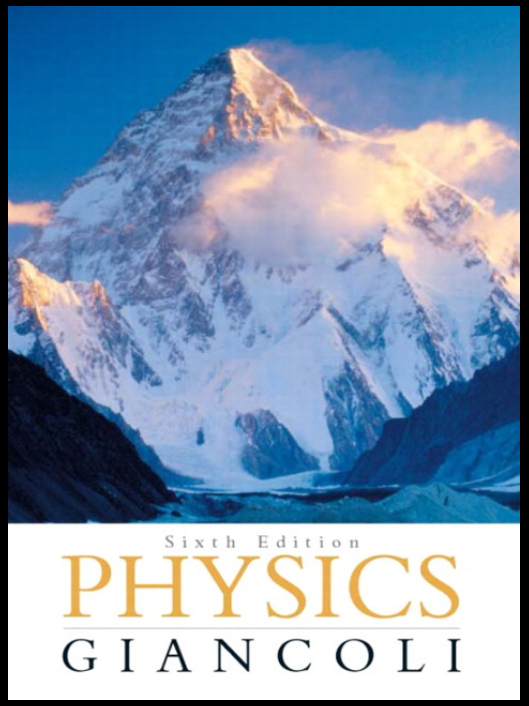


Lecture PowerPoint

Chapter 25

Physics: Principles with Applications, 6th edition

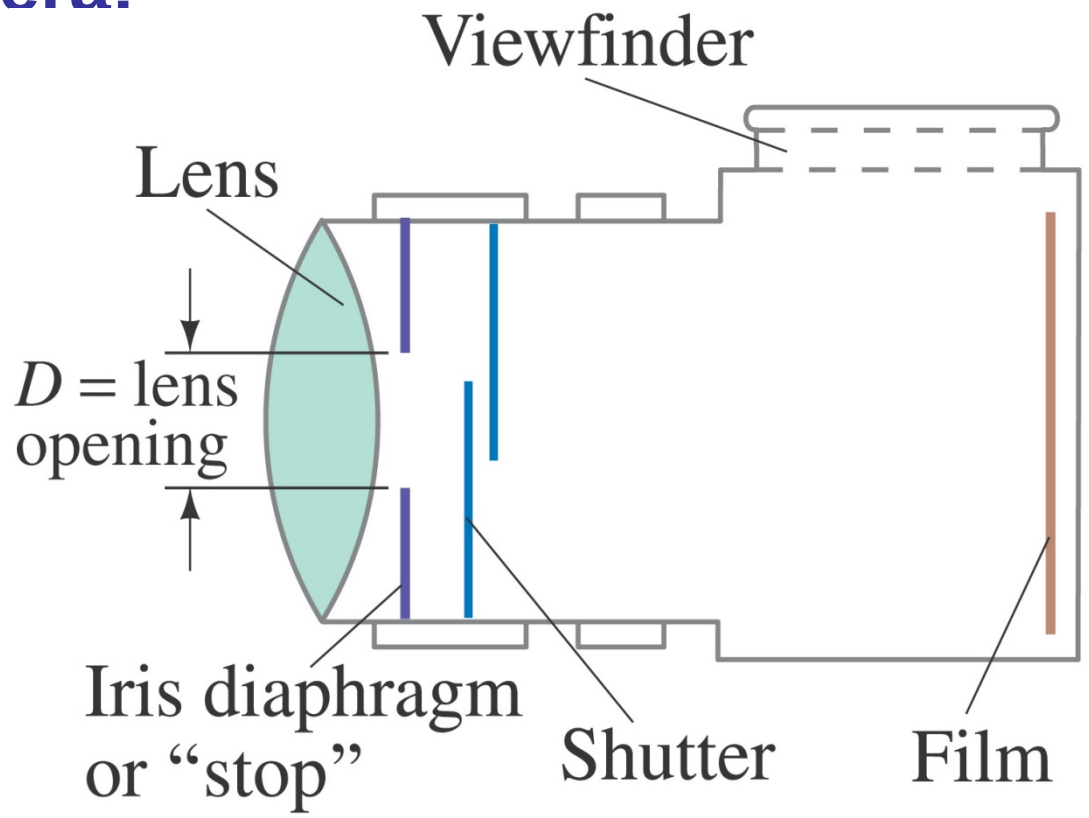
Giancoli

Ch. 25 Optical Instruments
Applications in Optics

25.1 Cameras, Film, and Digital

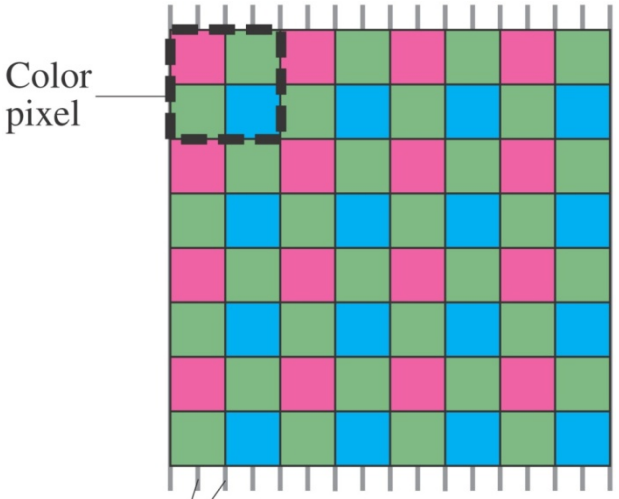
Basic parts of a camera:

- **Lens**
- **Light-tight box**
- **Shutter**
- **Film or electronic sensor**



25.1 Cameras, Film, and Digital

- A digital camera uses CCD sensors instead of film.
- CCD – made up of millions for tiny pixels
- Light reaching any pixel liberates electrons. Conducting electrodes carry these electrons (charge).
- The digitized image is sent to a processor for storage and later retrieval.



25.1 Cameras, Film, and Digital

Camera adjustments:

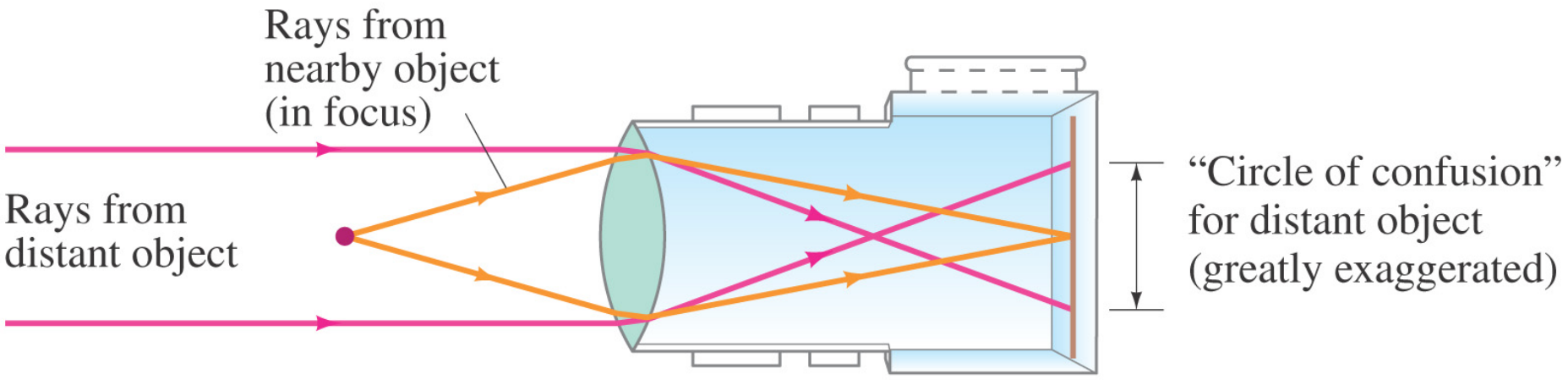
- **Shutter speed: controls the amount of time light enters the camera. A faster shutter speed makes a sharper picture. Ex: 1/30 s, 1/60 s etc.**

- **f-stop: controls the maximum opening of the shutter. This allows right amount of light to enter to properly expose film, and must be adjusted for external light conditions. Ex: f/2.8, f/4, f/8 etc.**

- **Focusing: this adjusts the position of the lens so that the image is positioned on the film.**

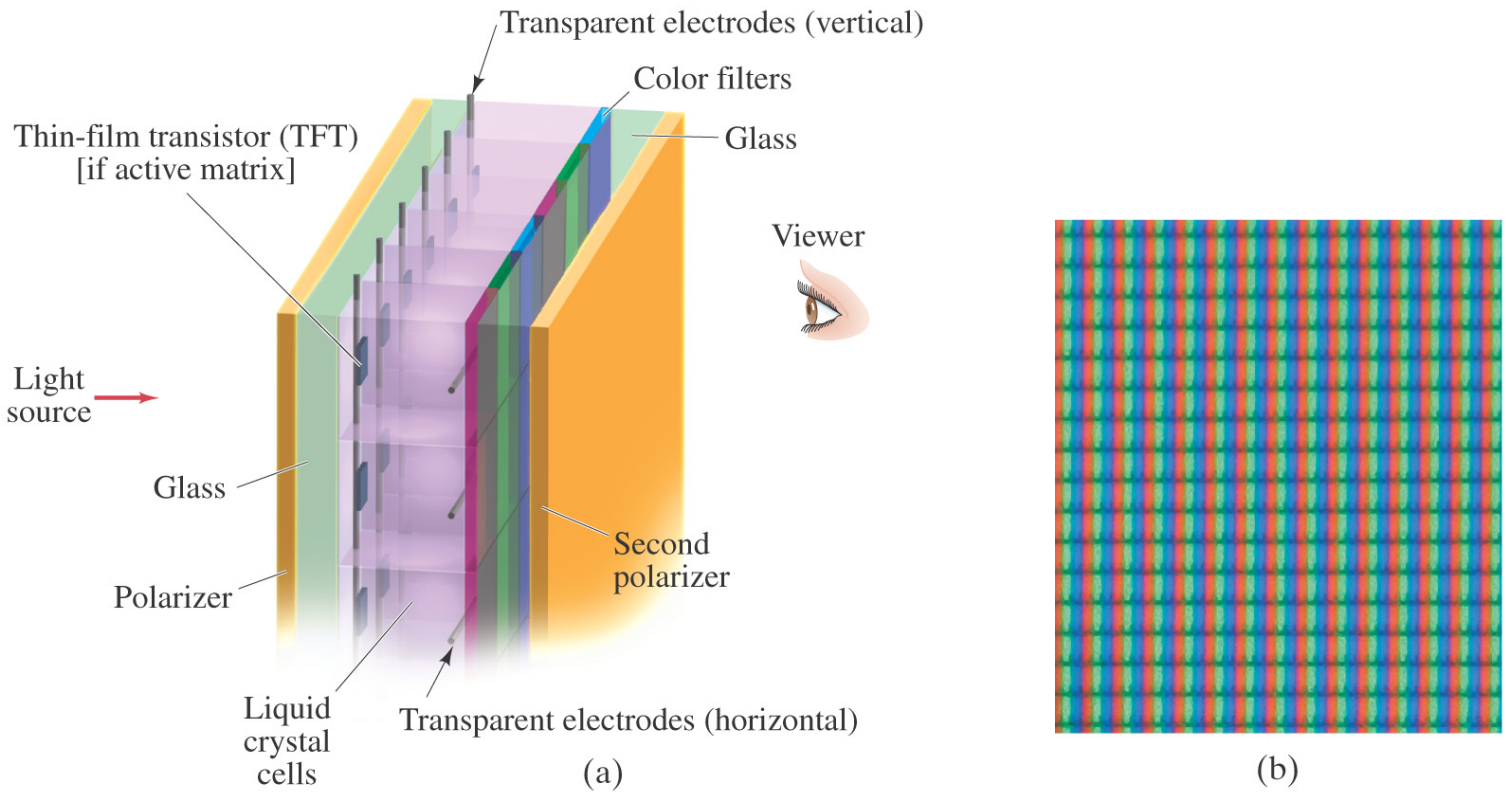
Cameras, Film, and Digital

There is a certain range of distances over which objects will be in focus; this is called the depth of field of the lens. Objects closer or farther will be blurred.



Liquid Crystal Displays (LCD)

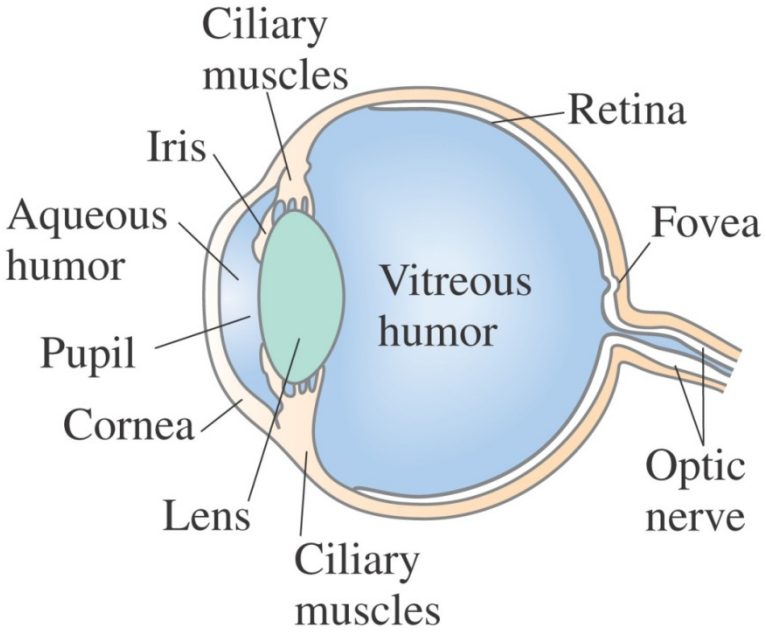
Color LCD displays are more complicated; each pixel has three subpixels to provide the different colors. A source of light is behind the display (unlike calculators and watches, which use ambient light). The pixels must be able to make finer adjustments than just on and off to provide a clear image.

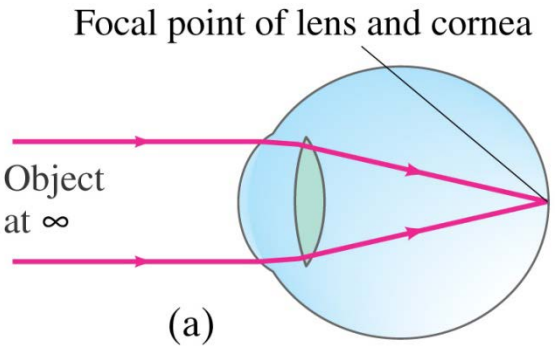


25.2 The Human Eye

The human eye resembles a (vastly more complex and sophisticated) camera in its basic functioning, with its adjustable lens, iris (aperture), and retina (detector).

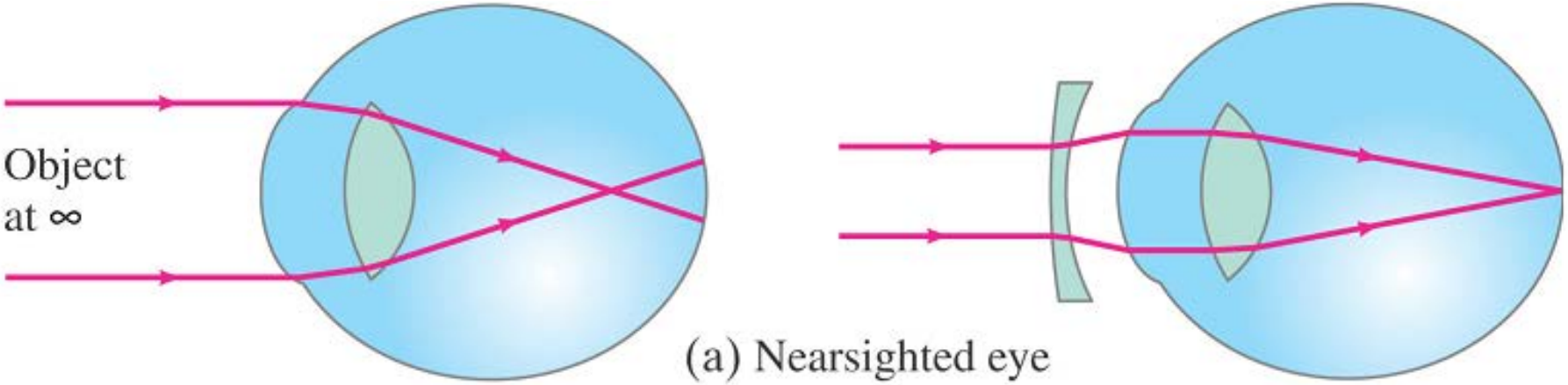
Near point: closest distance at which eye can focus clearly. Normal is about 25 cm.





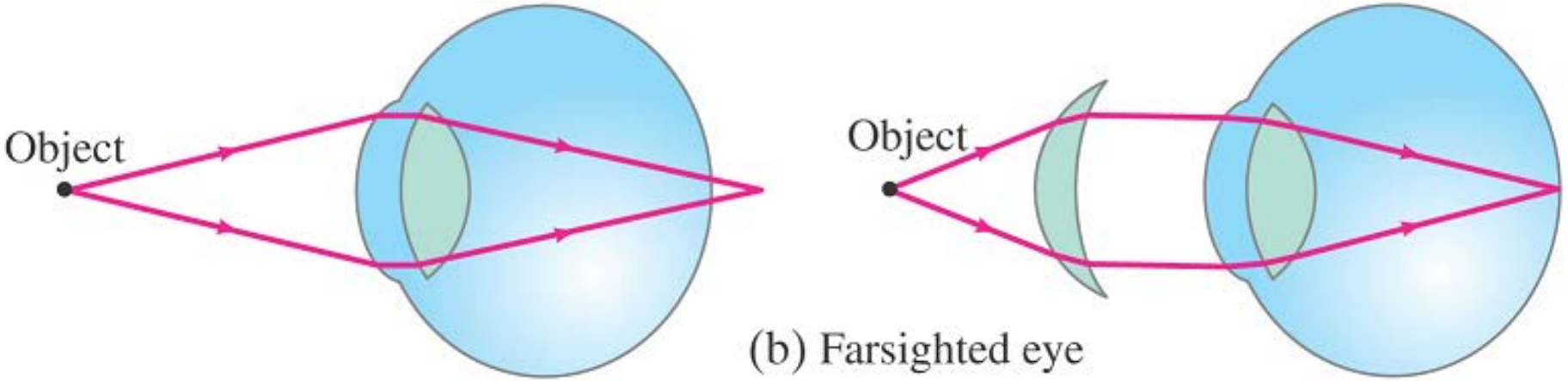
The Human Eye; Corrective Lenses

Nearsightedness can be corrected with a diverging lens.



(a) Nearsighted eye

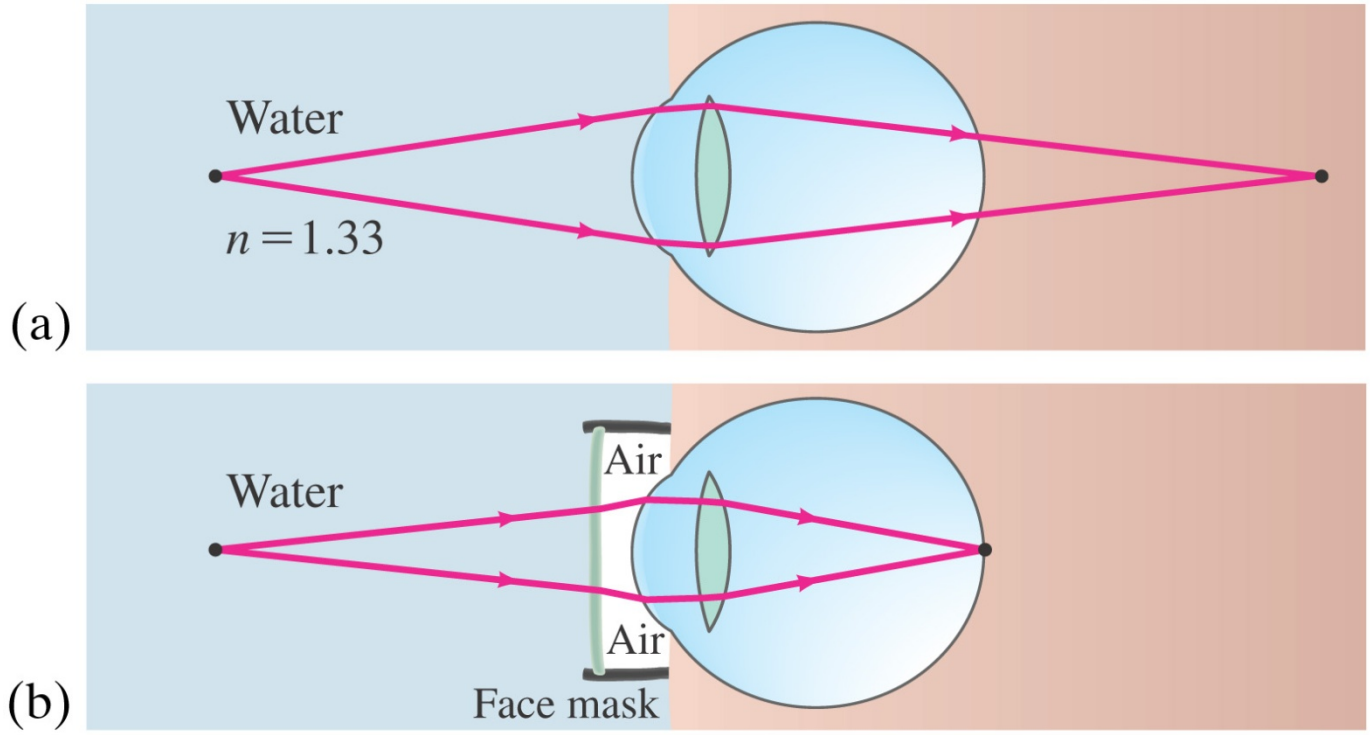
And farsightedness with a converging lens.



(b) Farsighted eye

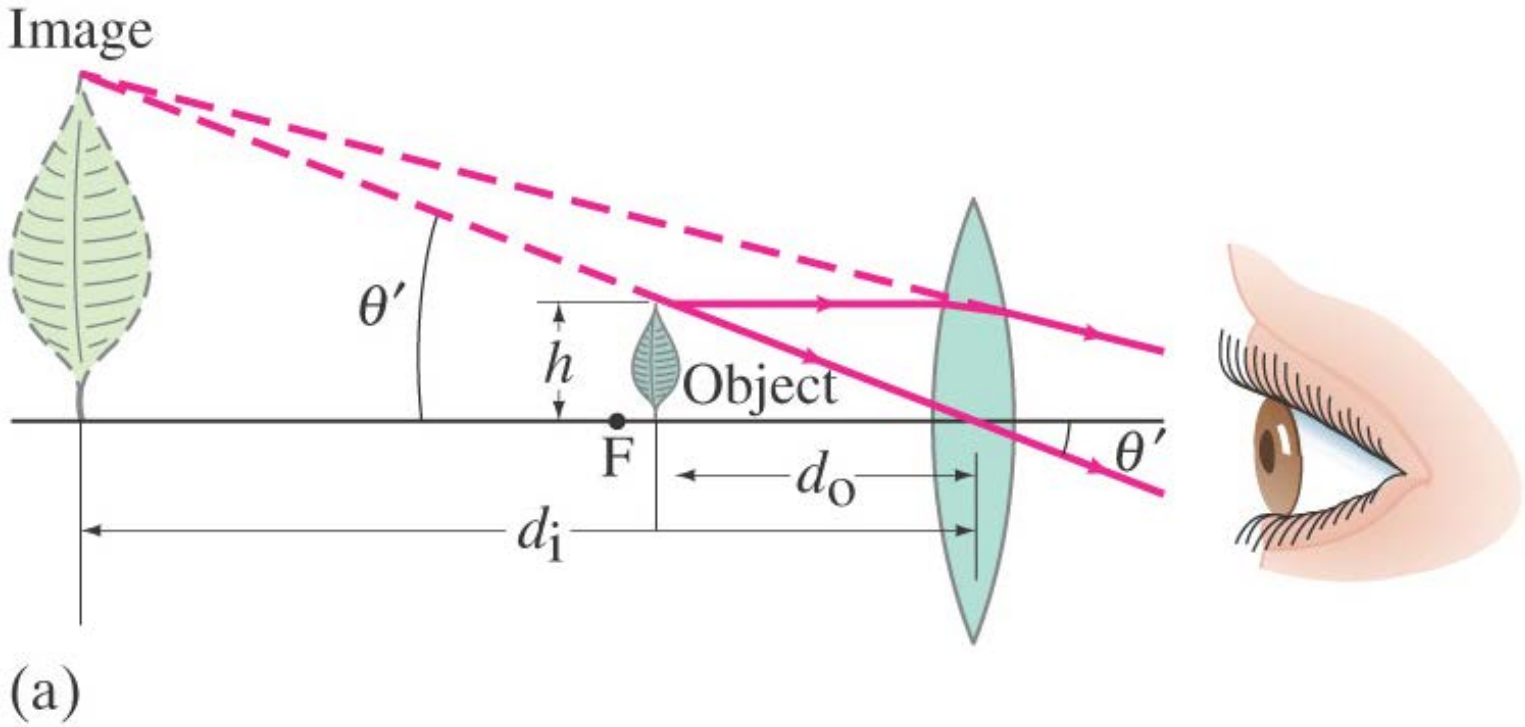
Underwater vision and goggles

Vision is blurry underwater because light rays are bent much less than they would be if entering the eye from air. This can be avoided by wearing goggles.



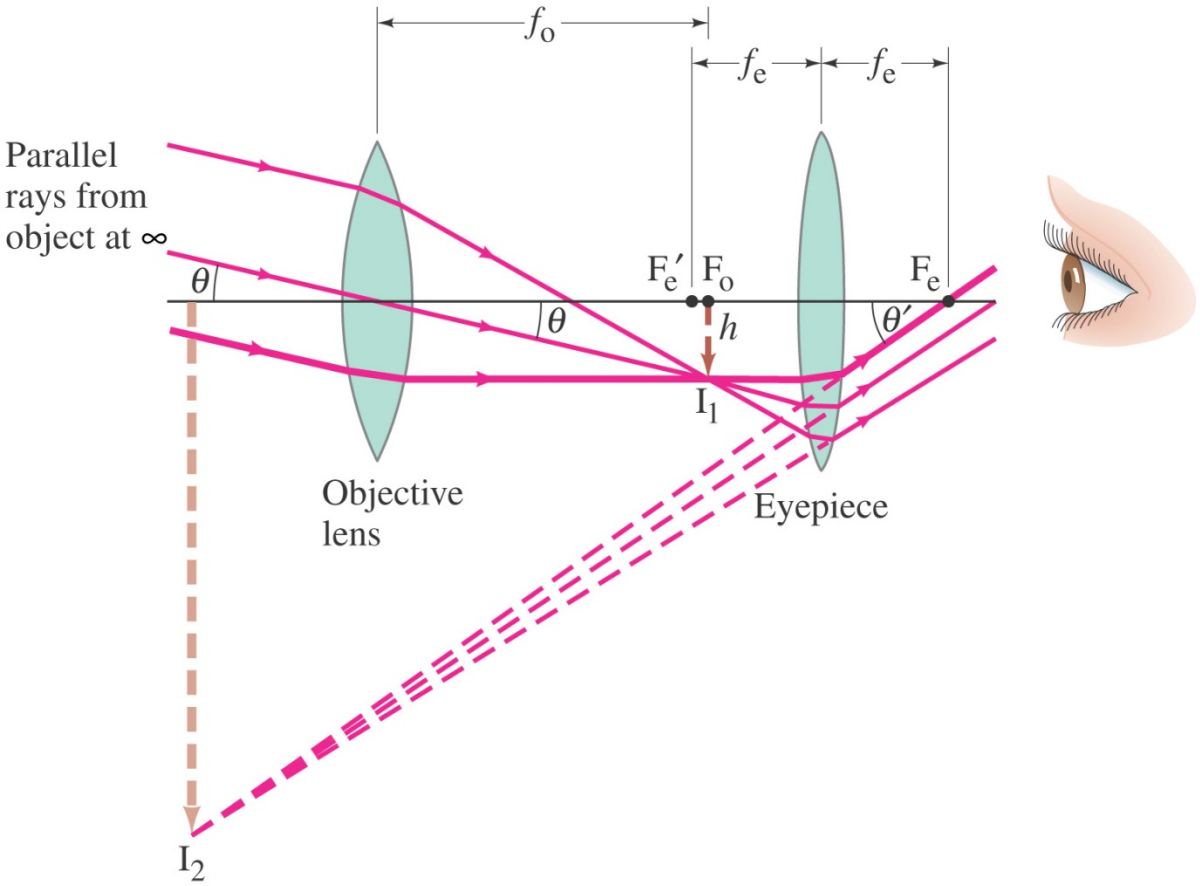
25.3 Magnifying Glass

A magnifying glass (simple magnifier) is a converging lens. It allows us to focus on objects closer than the near point, so that they make a larger, and therefore clearer, image on the retina.



25.4 Telescopes

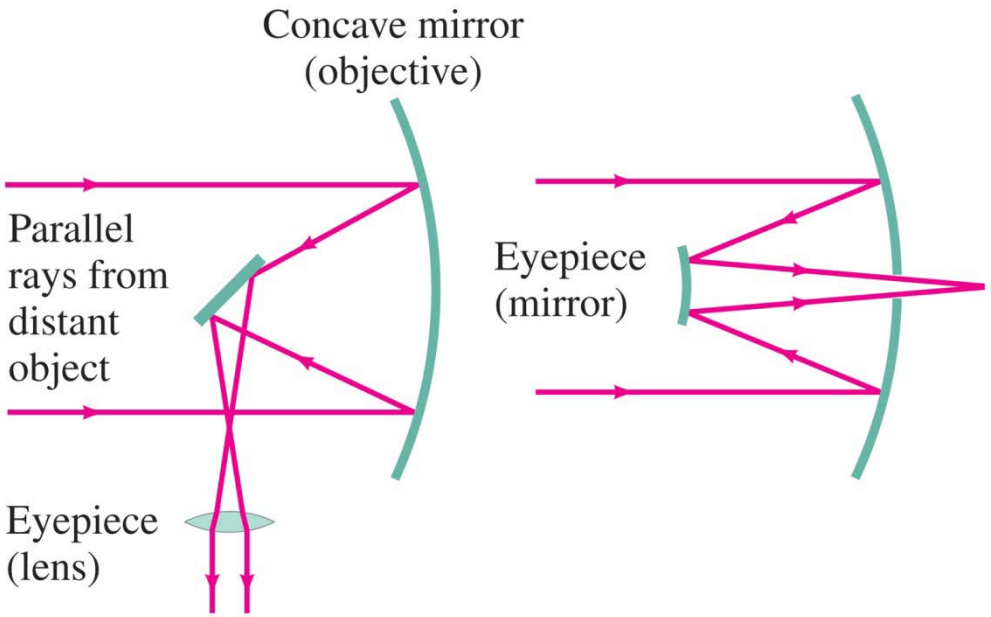
A refracting telescope consists of two lenses at opposite ends of a long tube. The objective lens is closest to the object, and the eyepiece is closest to the eye.



$$M = \frac{\theta'}{\theta} = \frac{(h/f_e)}{(h/f_o)} = -\frac{f_o}{f_e} \quad \textbf{(25-3)}$$

Reflecting Telescopes

- Astronomical telescopes need to gather as much light as possible.
- And obtain the sharpest view possible.
- The objective must be as large as possible.
- Mirrors are now used instead of lenses, as they can be made much larger.
- Mirrors focus all wavelengths of light equally (no chromatic aberration)



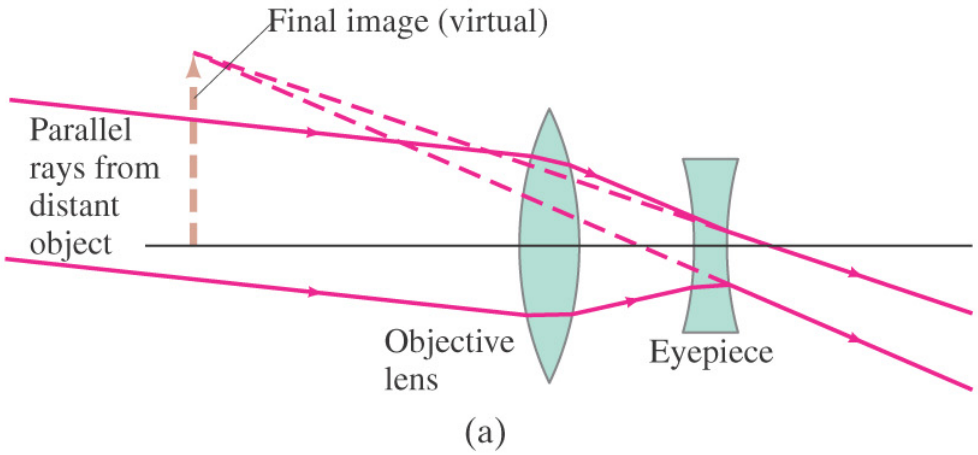
$$M = \frac{\theta'}{\theta} = \frac{(h/f_e)}{(h/f_o)} = -\frac{f_o}{f_e}$$

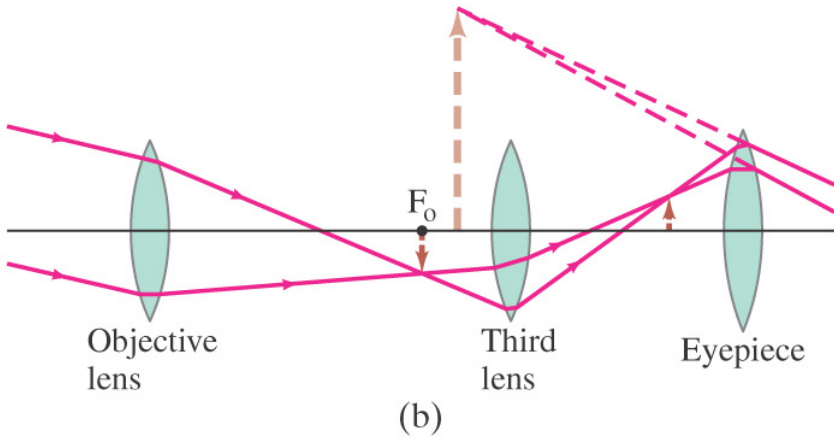
Newtonian **Cassegrain**

25.4 Telescopes

Refracting Telescopes:

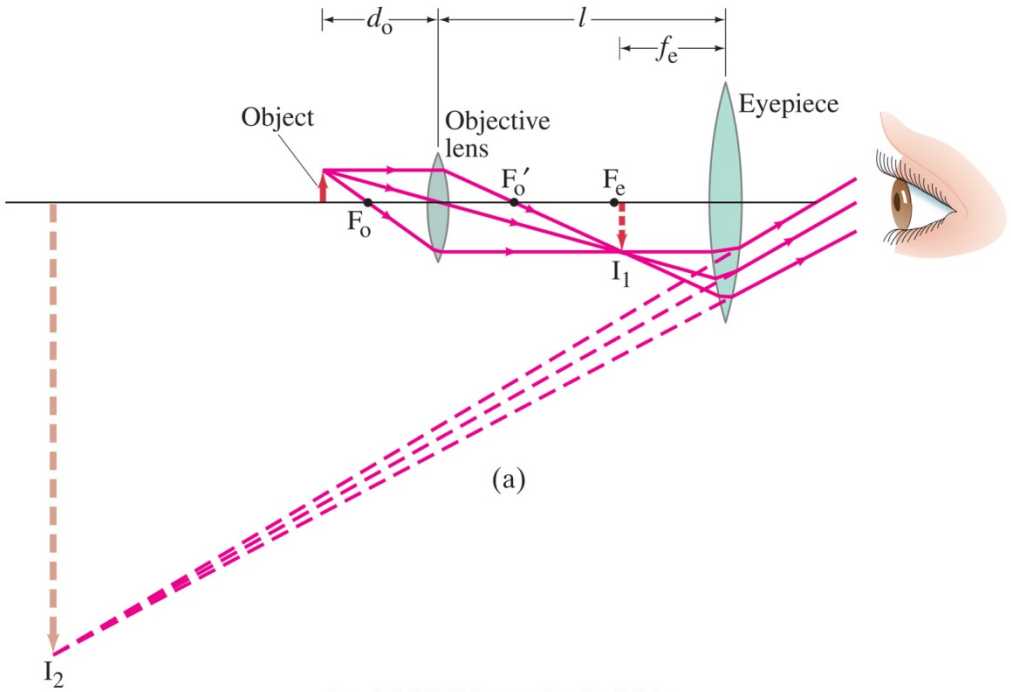
- Refractors consist of an objective lens and an eyepiece lens.
- Naturally produce upside down images
- A terrestrial telescope, used for viewing objects on Earth, should produce an upright image.
- Here are two models, a Galilean type and a spyglass:





25.5 Compound Microscope

A compound microscope also has an objective and an eyepiece; it is different from a telescope in that the object is placed very close to the eyepiece.

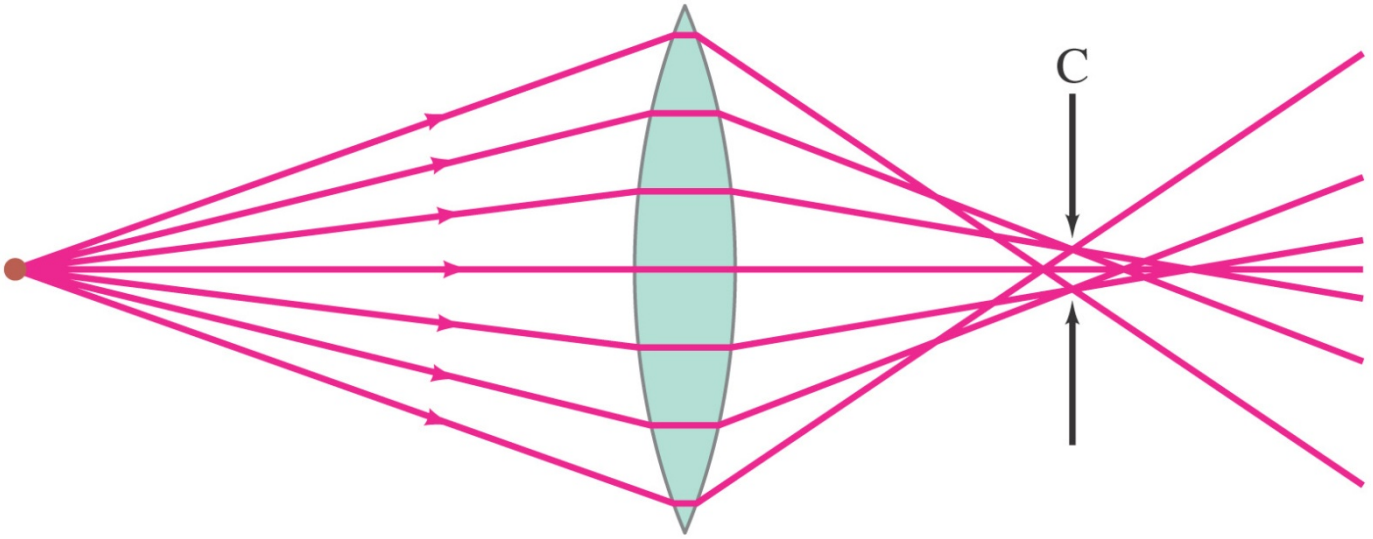


$$M = M_e m_o = \left(\frac{N}{f_e}\right)\left(\frac{l - f_e}{d_o}\right) \quad \textbf{(25-6a)}$$

$$\approx \frac{Nl}{f_e f_o}. \quad \textbf{(25-6b)}$$

25.6 Spherical Aberrations of Lenses

Spherical aberration: rays far from the lens axis do not focus at the focal point.



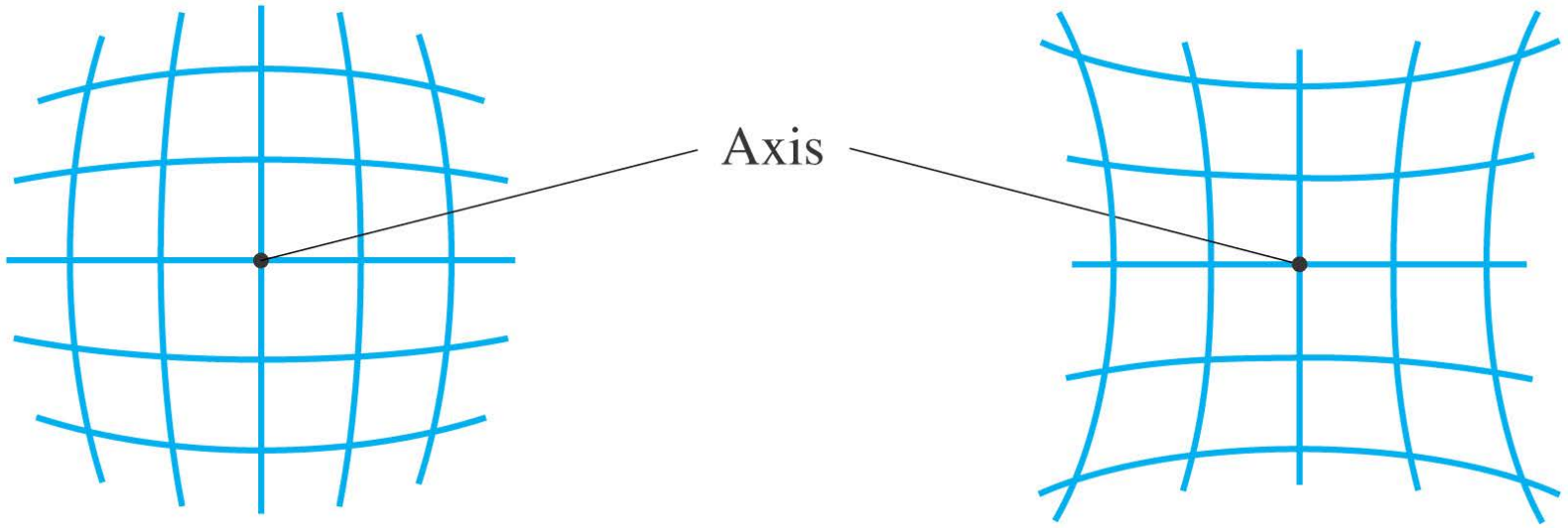
Solutions: compound-lens systems (camera lenses can have > 15 elements!)

use only central part of lens (e.g. by stopping it down)

Aspherical lens surfaces (expensive to produce)

Aberrations of Lenses and Mirrors

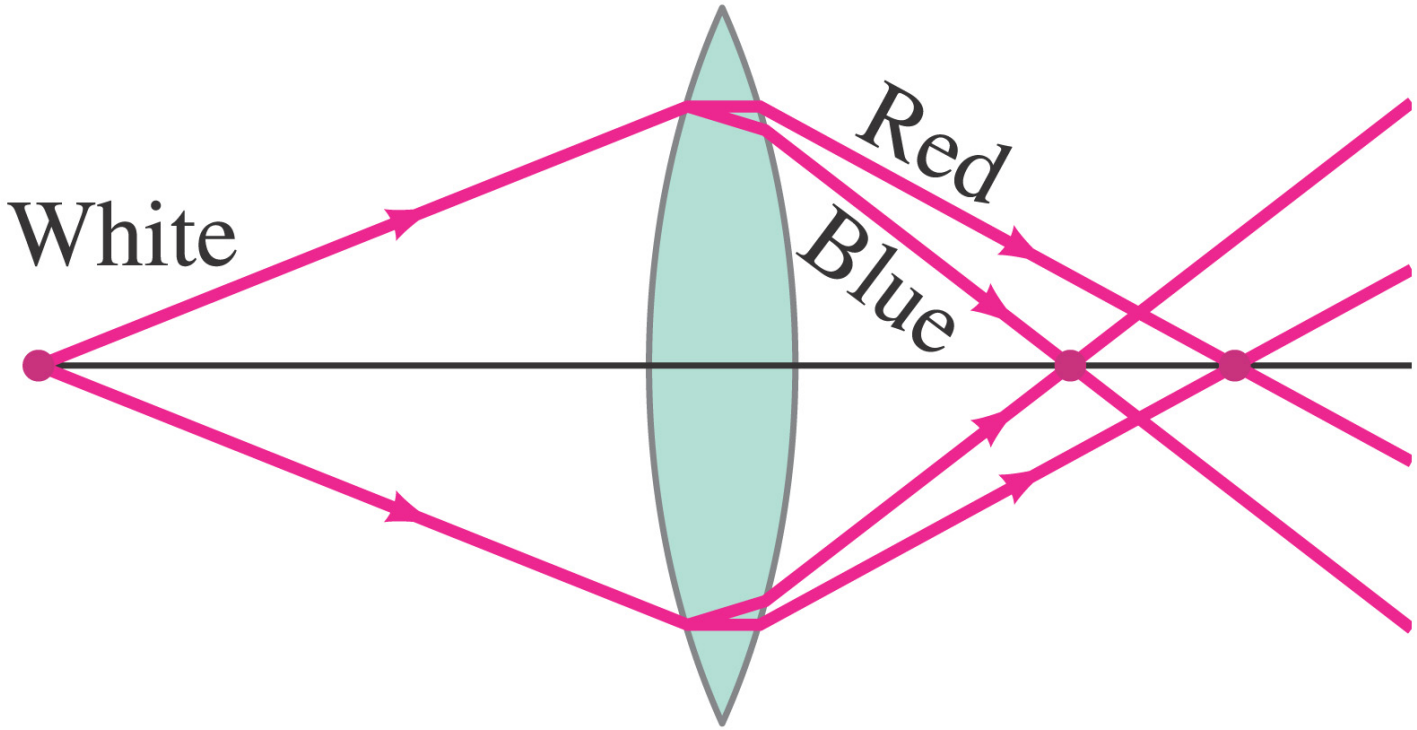
Geometric Distortion: caused by variation in magnification with distance from the lens. Barrel and pincushion distortion:



Solutions: multiple elements, aspheric curves, stopping down, image processing

Chromatic Aberration

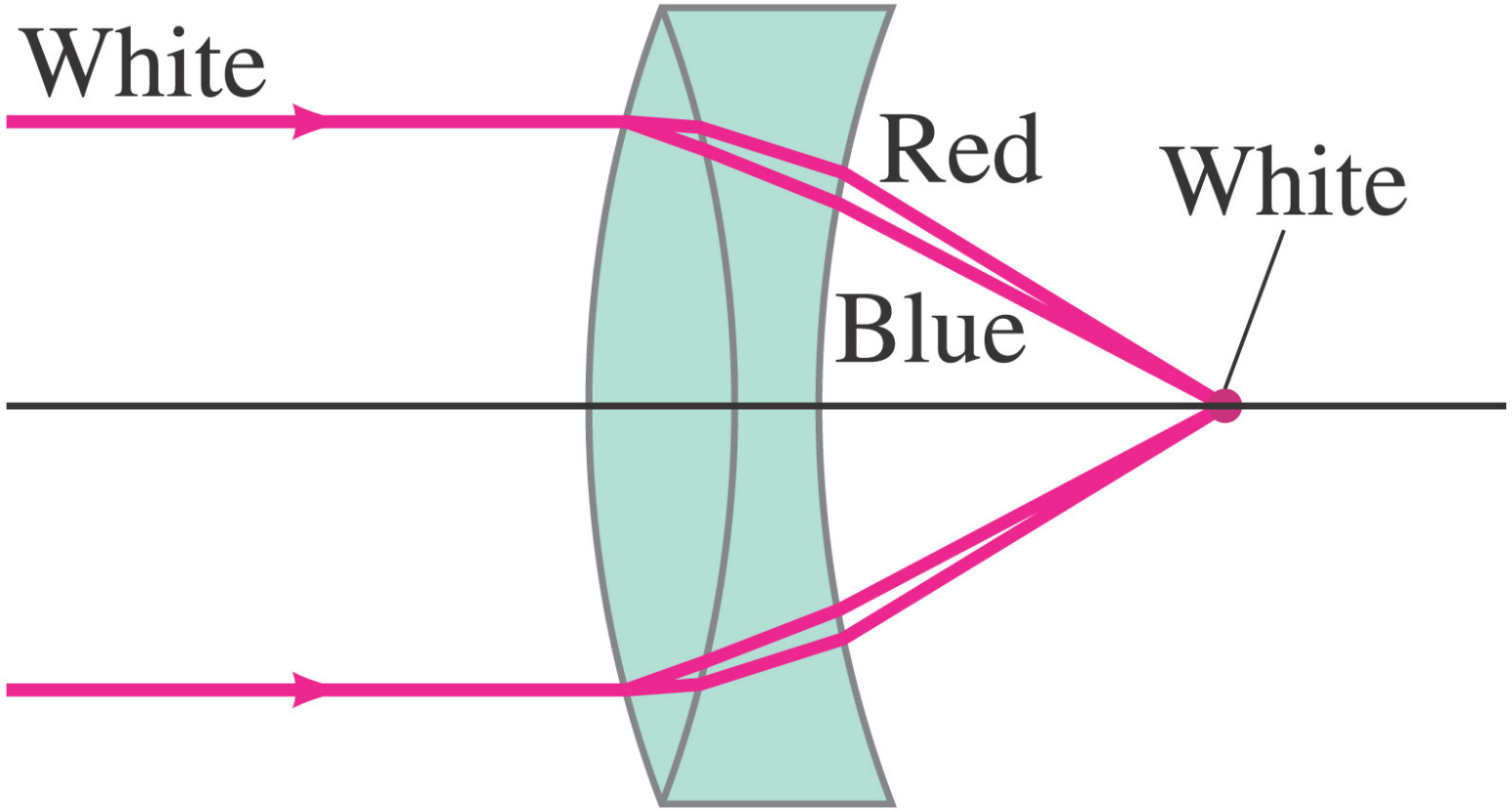
Light of different wavelengths has different indices of refraction and focuses at different points



Solutions: Use only the center, stop down, use very long focal length, use colored filters, use multiple lenses

The Achromatic Doublet

- Achromatic doublet is a lens made of two lenses of different glass types that have different amounts of dispersion.
- Usually a Strong Converging lens made from a low dispersion glass, is glued to a Weaker Diverging lens (made from a higher dispersion glass)
- The space between can be filled with glue, or oil.



- Anti-reflection coatings are required to prevent “ghost” images forming

25.7 Limit of Resolution: Diffraction

- **Resolution is the smallest separation (or angle) at which a lens can barely distinguish two separate objects.**
- **Resolution is limited by aberrations and by diffraction.**
- **Aberrations can be minimized.**
- **Diffraction is unavoidable; it is due to the size of the lens compared to the wavelength of the light.**

Summary of Chapter 25

- Camera: uses a lens to form an image.
- Human eye: forms image by letting light through pupil; adjusts to different light levels using iris and focuses by changing thickness of lens.
- Nearsighted vision is corrected by diverging lens, farsighted by converging lens.
- Simple magnifier: object closer to focal point.
- Astronomical telescope: objective and eyepiece; object infinitely far away.
- Compound microscope: objective and eyepiece; object close to eyepiece.
- Spherical aberration: rays far from axis do not go through focal point.
- Chromatic aberration: different wavelengths have different focal points.
- Resolution of optical devices is limited by diffraction.