Chapter 19
Optical Instruments

Topics:

- The thin-lens equation
- The camera
- The human eye
- The magnifier
- The microscope
- The telescope
- Resolution of optical instruments

Sample question:

This *anablepsis* is called the "four-eyed fish." How must the top half of its eye differ from the lower half so that it has clear vision both above and below the waterline at the same time?

Reading Quiz

1. The units of refractive power are
   A. watts.
   B. m^2.
   C. m^{-1}.
   D. joules.

Answer

1. The units of refractive power are

   C. m^{-1}.

Reading Quiz

2. *Accommodation* of the eye refers to its ability to
   A. focus on both nearby and distant objects.
   B. move in the eye socket to look in different directions.
   C. see on both the brightest days and in the dimmest light.
   D. see both in air and while under water

Answer

2. *Accommodation* of the eye refers to its ability to
   A. focus on both nearby and distant objects.

Reading Quiz

3. The magnification of a microscope is increased when
   A. the focal length of the objective lens is increased.
   B. the focal length of the objective lens is decreased.
   C. the focal length of the eyepiece is increased.
   D. the distance between the objective lens and eyepiece is decreased.

Answer

3. The magnification of a microscope is increased when

   C. the focal length of the eyepiece is increased.

Reading Quiz

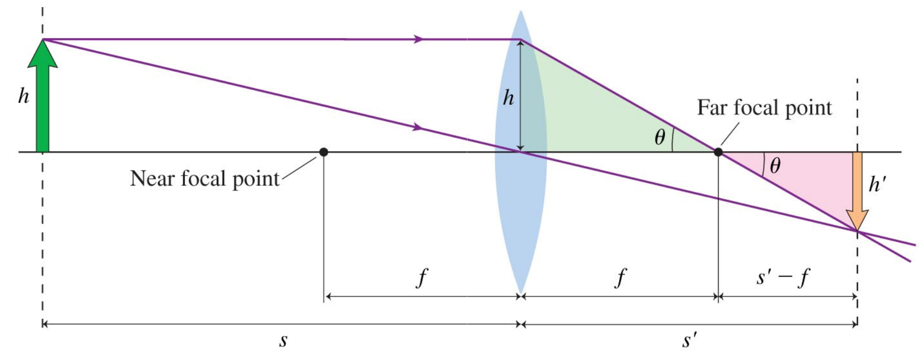
4. The fundamental resolution of an optical instrument is set by
   A. the accuracy to which lenses can be polished.
   B. the fact that white light is composed of all visible colors.
   C. the fact that all types of glass have nearly the same index of refraction.
   D. the wave nature of light.

Answer

4. The fundamental resolution of an optical instrument is set by

   D. the wave nature of light.

The Thin-Lens Equation



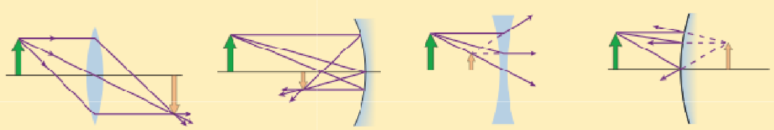
$$\frac{1}{s}+\frac{1}{s'}=\frac{1}{f}$$

Thin-lens equation (also works for mirrors) relating object and image distance to focal length

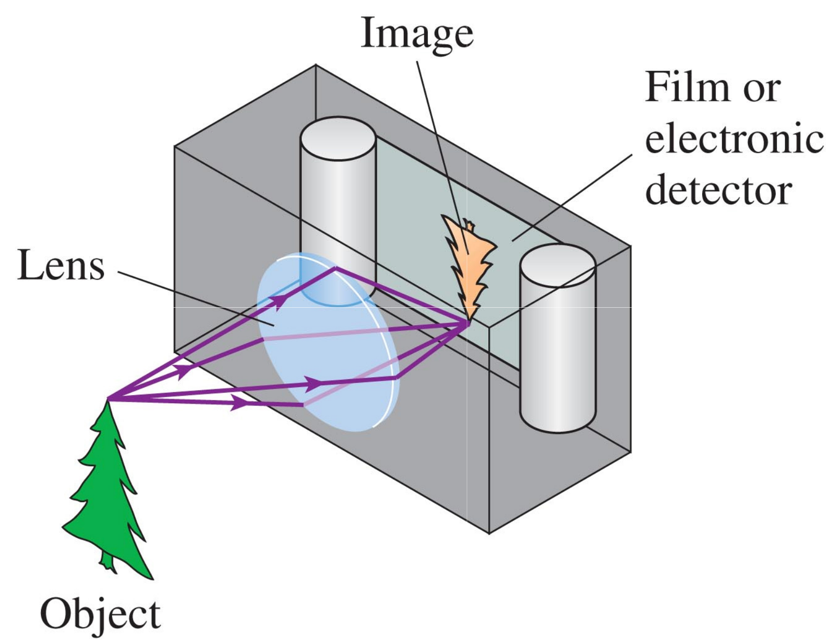
Sign Conventions for Lenses and Mirrors

TACTICS BOX 19.1 Using sign conventions for lenses and mirrors — Exercise 1

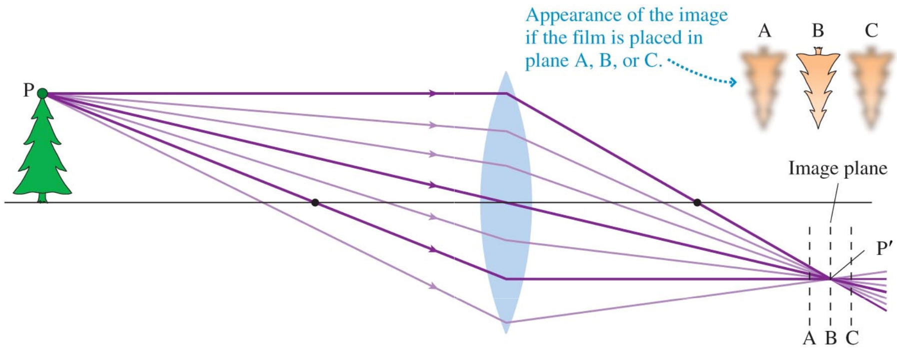
Quantity	Positive when		Negative when	
Object distance s	Always		We won't treat this case in this book.	
Image distance s'	**Real image**		**Virtual image**	
	Image is on the opposite side of the lens from the object.	Image is in front of the mirror.	Image is on the same side of the lens as the object.	Image is behind the mirror.
Focal length f	Converging lens or concave mirror		Diverging lens or convex mirror	
Image height h', Magnification M	Image is upright		Image is inverted	



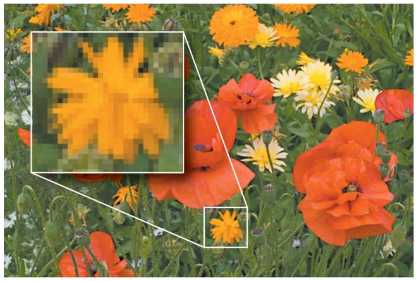
The Camera



Focusing a Camera

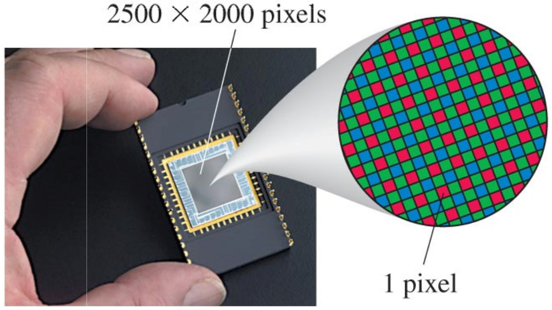


Digital Cameras

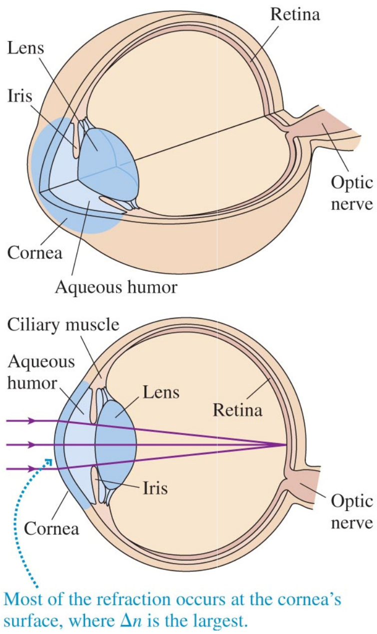


A digital image is made up of millions of *pixels*.

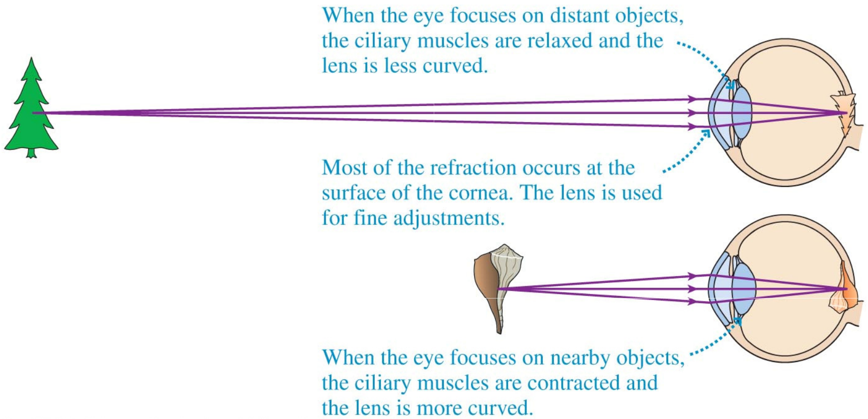
A CCD chip records the digital image.



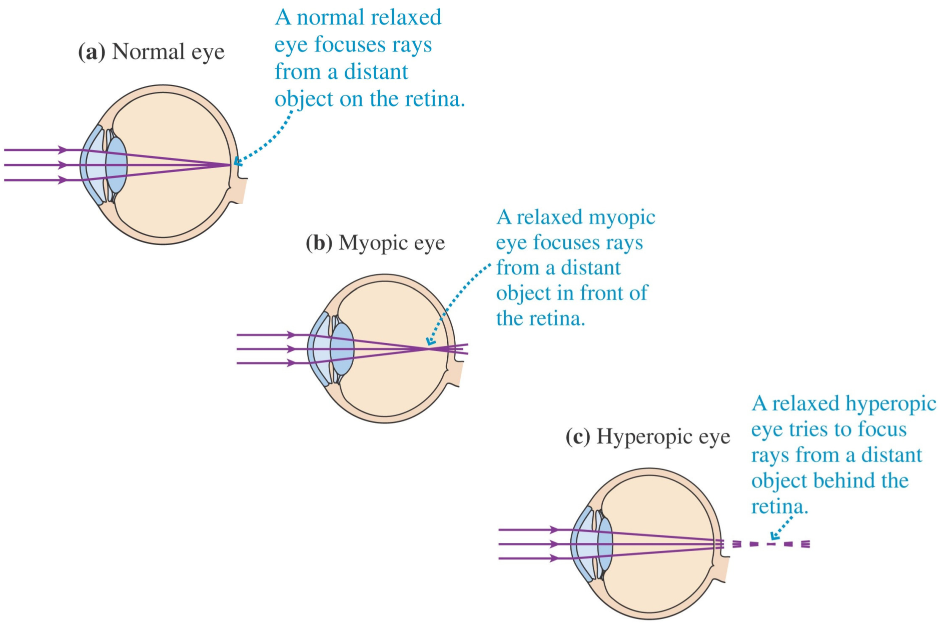
The Human Eye



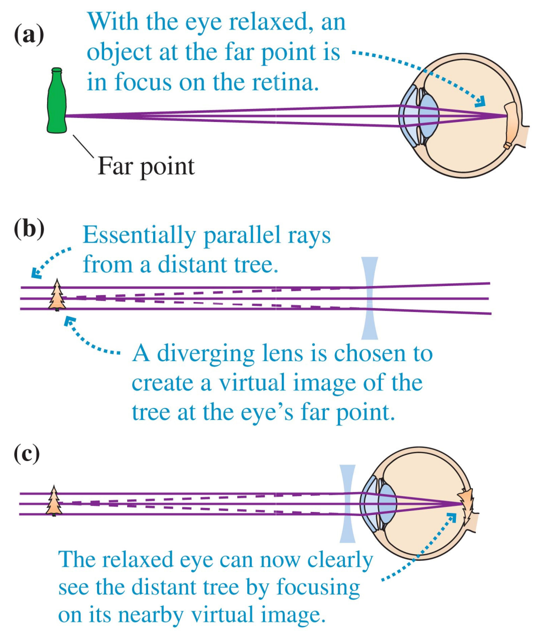
Focusing and Accommodation



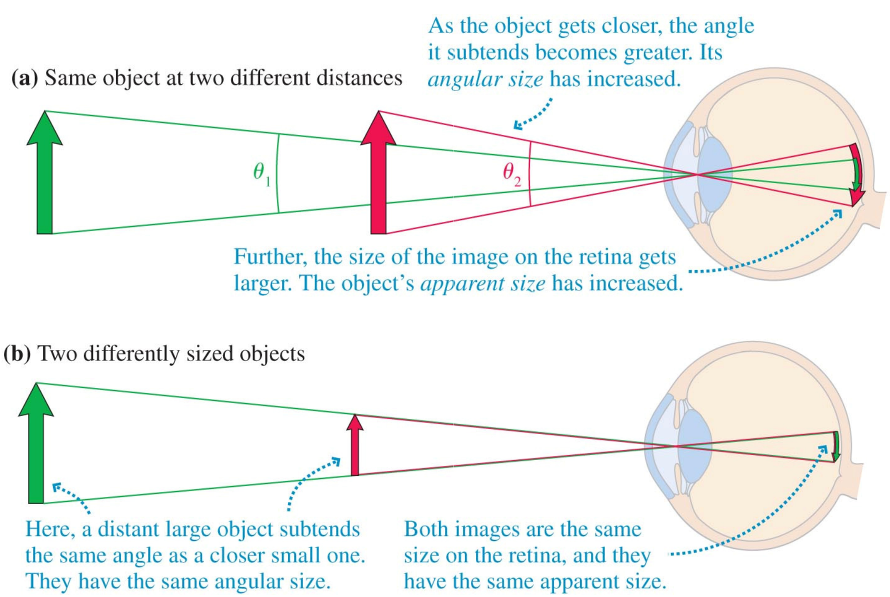
Myopia and Hyperopia



Correcting Myopia



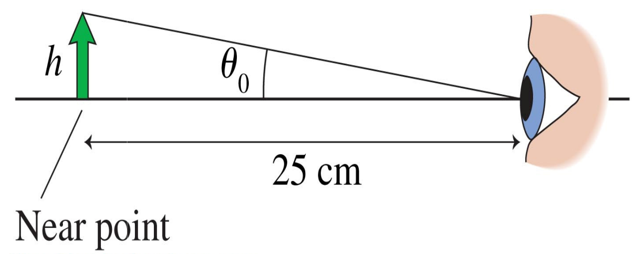
Apparent Size

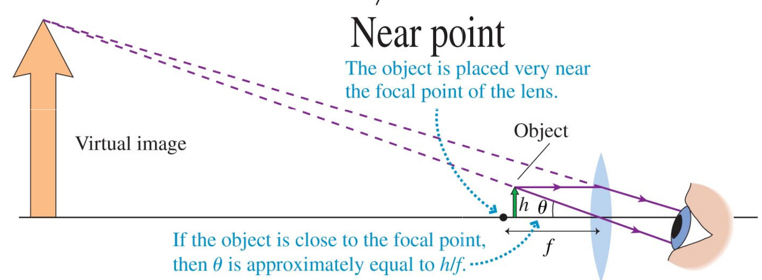


The Magnifier

Largest angular size without a magnifier is

$$\theta_0 \approx \frac{h}{25\text{ cm}}$$





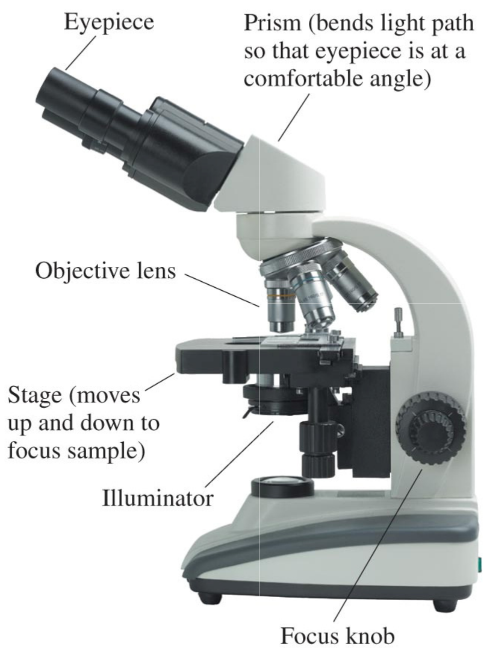
With a magnifier, the angular size is

$$\theta_0 \approx \frac{h}{f}$$

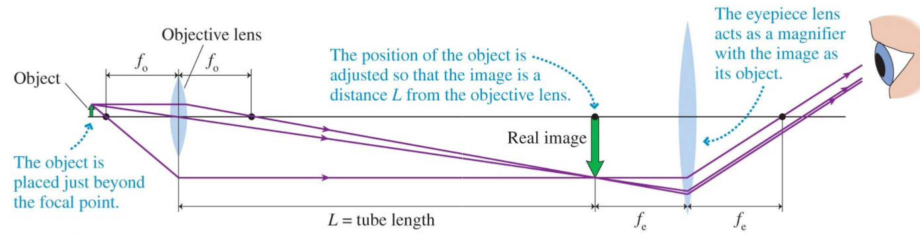
The magnification is thus

$$M = \frac{\theta}{\theta_0} = \frac{25\text{ cm}}{f}$$

The Microscope

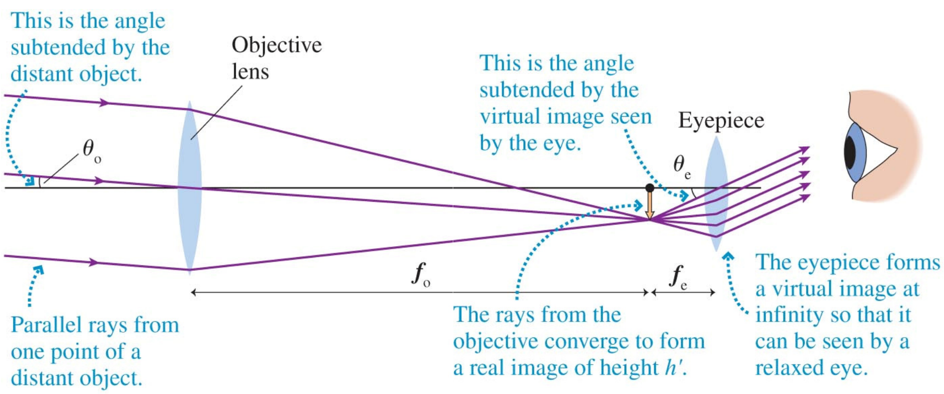


The Microscope



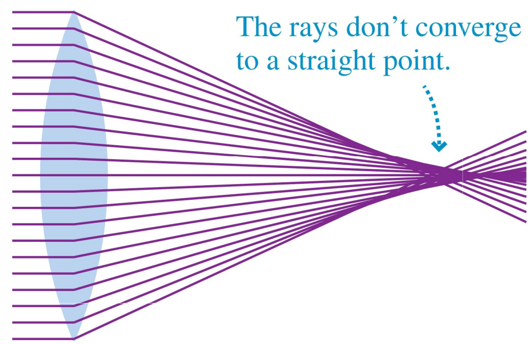
$$M = M_o M_e = -\frac{L}{f_0}\frac{25\text{ cm}}{f_e}$$

The Telescope



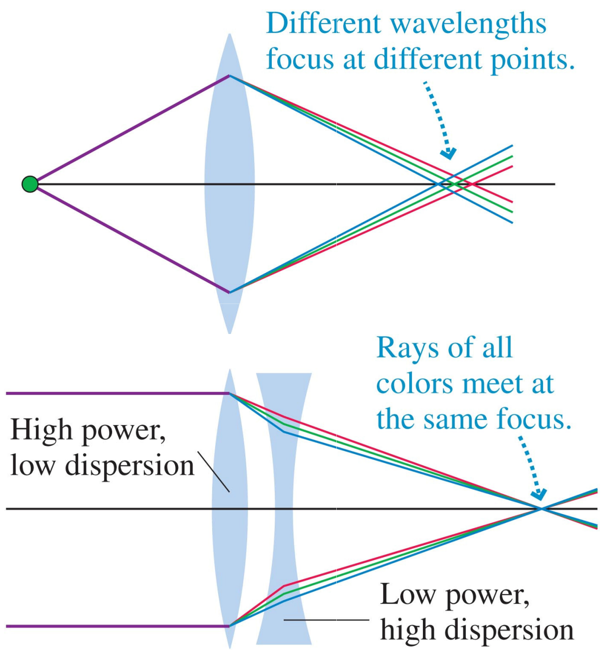
$$M = -\frac{f_0}{f_e}$$

Lens Aberrations: Spherical Aberration

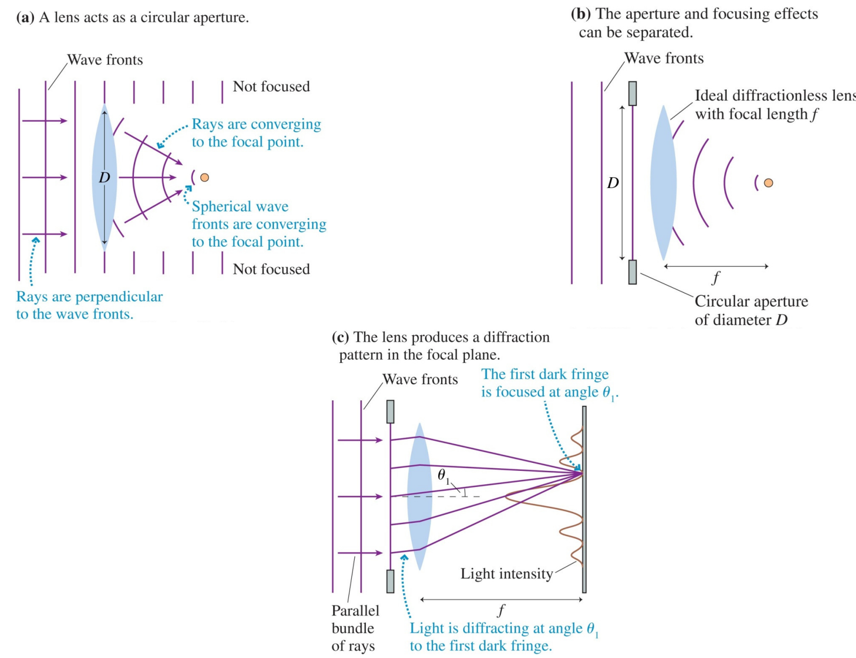


The Hubble space telescope originally suffered from spherical aberration.

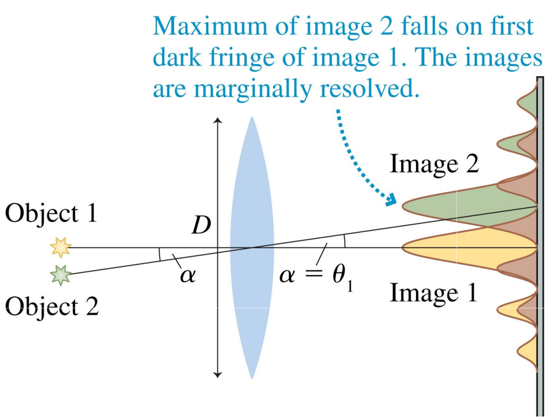
Chromatic Aberration

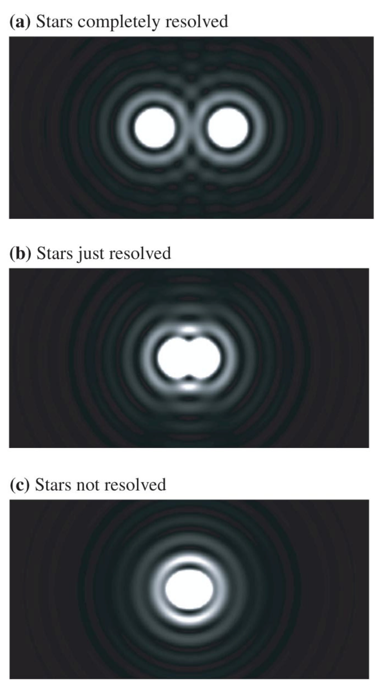


Resolution and the Wave Nature of Light



Rayleigh's Criterion

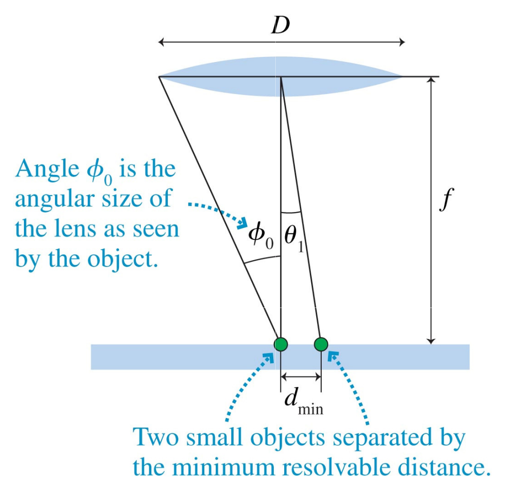




Two objects are resolvable if their angular separation is greater than

$$\theta_1 = \frac{1.22\lambda}{D}$$

The Resolution of a Microscope

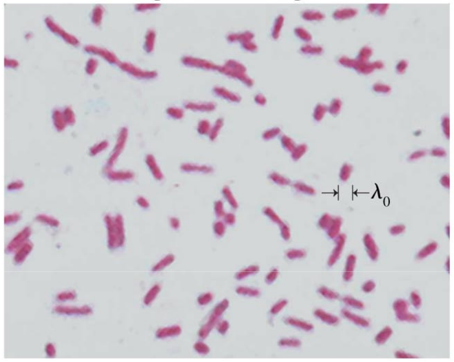


$$\text{Numerical aperture NA} = n \sin\phi_0$$

$$\text{Resolving power RP} = d_{\text{min}} = \frac{0.61\lambda_0}{\text{NA}}$$

Optical and Electron Micrographs of *e. coli*

Optical microscope



Electron microscope