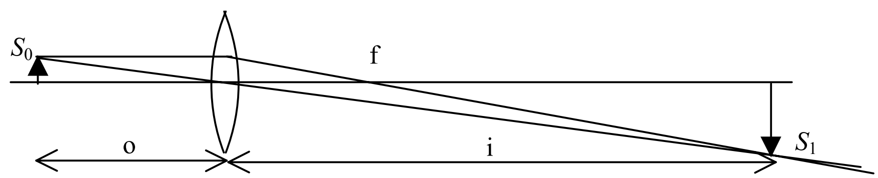
PHYS 210
Spring 2003
Optics and Biophysics

In this lecture we will briefly discuss optics, as used in a microscope, for example, and biophysics.

Geometric optics



Simple equations for the effects of thin lenses can be obtained following the rules of geometrical optics:

1) Rays going parallel to the axis on one side of the lens pass through the focal point on the other side
2) Rays going through the center of the lens are not deflected.

From these rules it follows from simple geometry that

$$\frac{1}{o}+\frac{1}{i}=\frac{1}{f}$$

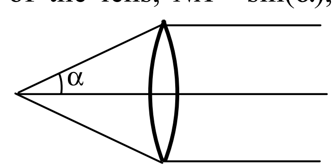
where o is the distance from the object to a convergent lens, i is the distance from the lens to the image and f is the focal length of the lens. Similarly, one can show that the magnification is $S_1/S_0 = i/o$. For example, to obtain large magnification one needs $i \gg o$ and therefore $o \sim f$.

Wave optics

On length scales comparable to the wavelength of light its propagation is no longer governed by geometric optics. Light diffraction begins to play a large role, for example, allowing the light to pass around small obstruction. Diffraction also limits the minimum size of an object that can be seen with light to approximately the wavelength of light.
More precise calculations show that the spatial resolution of a microscope is given by

$$d_{\min} = 1.22\lambda / NA,$$

where the numerical aperture NA defines the light collection ability of the lens, NA= sin(α), where α is the opening angle, see picture to the right. Numerical aperture is larger for shorter focal length lenses, but is generally smaller than 1. Thus the maximum spatial resolution that can be obtained with visible light is on the order of 0.5 µm.



Magnetic Bacteria

Among many possible biological samples we will look at Magnetospirillum magnetotacticum, a bacterium that grows in ponds. The interesting thing about this type of bacteria is that they navigate by following the magnetic field lines. If exposed to a magnetic field they will orient themselves parallel to the magnetic field and swim along the field lines from north to south pole. The bacteria are about 5 µm long and 0.5 µm thick.