Lecture-14

CSO202: Atoms, Photons & Molecules

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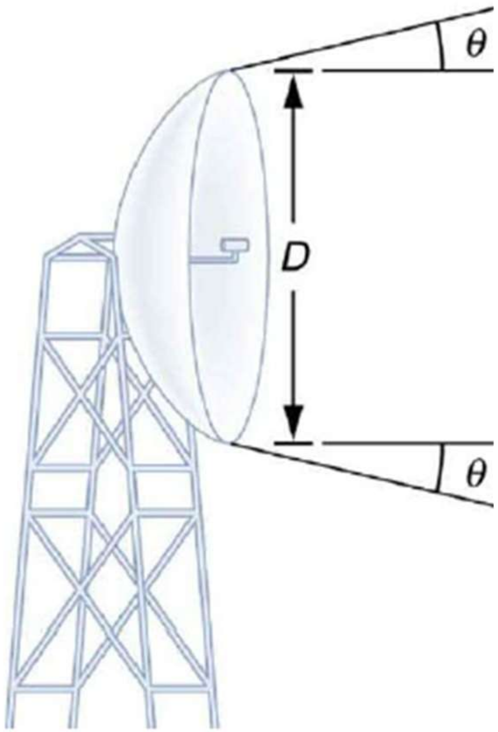
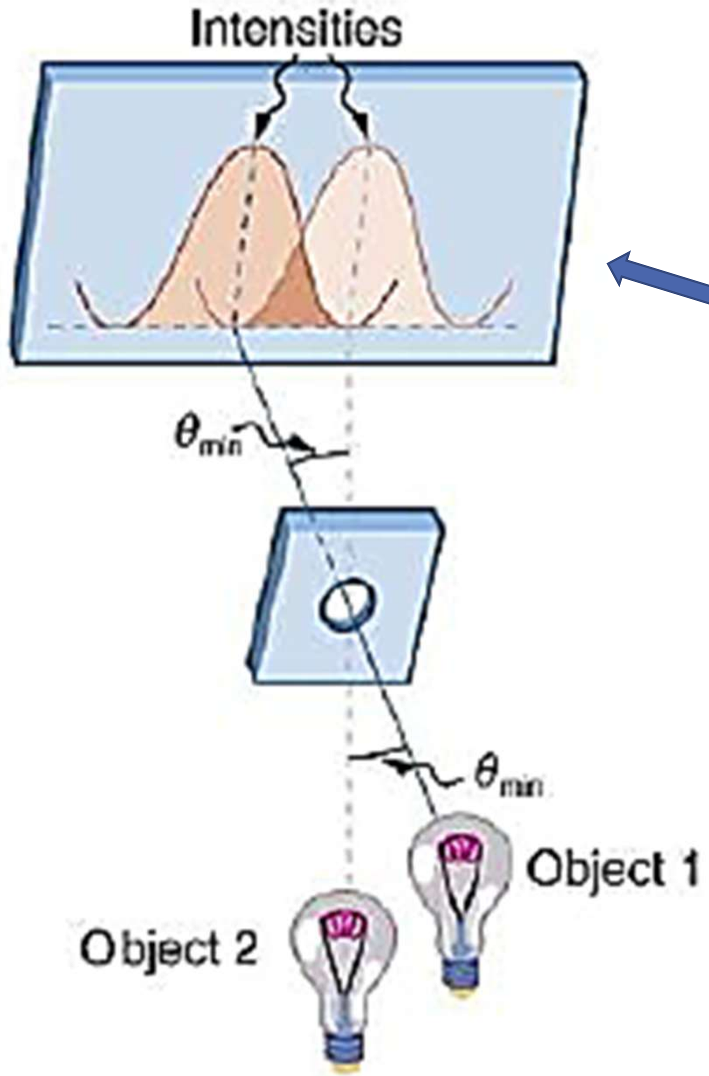
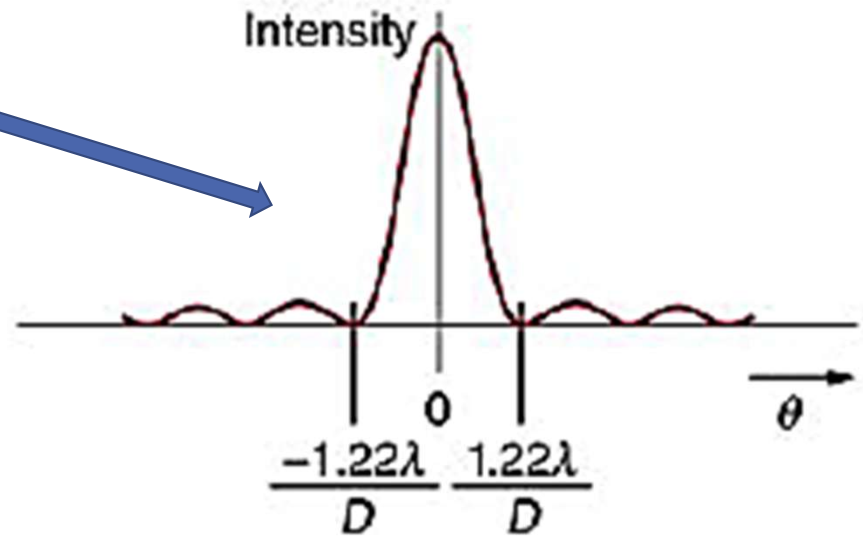


- Diffraction is not only a problem for optical instruments but also for the electromagnetic radiation itself. Any beam of light having a finite diameter D and a wavelength λ exhibits diffraction spreading. The beam spreads out with an angle given by $\theta = 1.22\, \lambda/D$
- Take, for example, a laser beam made of rays as parallel as possible (angles between rays as close to $\theta = 0^0$ as possible) instead spreads out at an angle $\theta = 1.22\, \lambda/D$, where D is the diameter of the beam and λ is its wavelength.
- This spreading is impossible to observe for a flashlight, because its beam is not very parallel to start with.
- However, for long-distance transmission of laser beams or microwave signals, diffraction spreading can be significant
- To avoid this, we can increase D. This is done for laser light sent to the Moon to measure its distance from the Earth. The laser beam is expanded through a telescope to make much larger D and smaller θ.

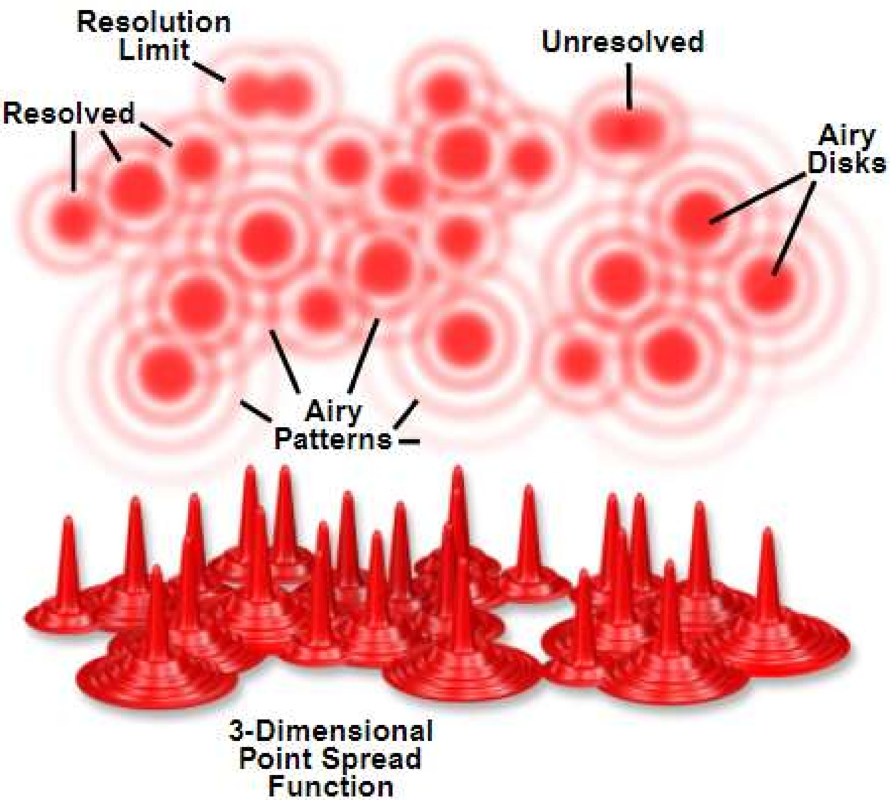


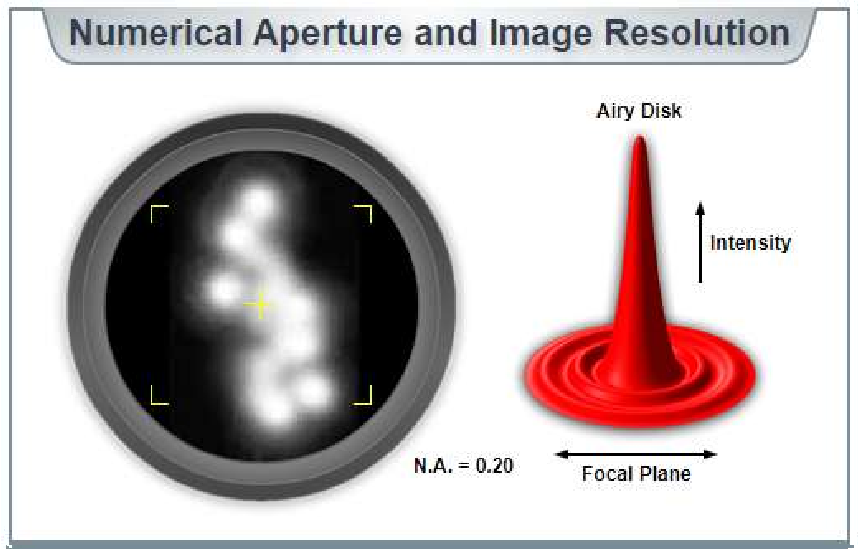
Rayleigh criterion for the diffraction limit to resolution states that *two images are just resolvable when the center of the diffraction pattern of one is directly over the first minimum of the diffraction pattern of the other.*



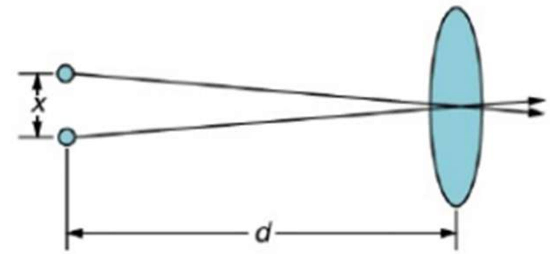
The first minimum is at an angle of $\vartheta_{min} = 1.22\lambda/D$, so that two point-objects are just resolvable if they are separated by that minimum angle. Here, λ is the wavelength of light, D is the diameter of the aperture, lens, mirror, etc., with which the two objects are observed, and ϑ_{min} has units of radians.

RESOLVING AN IMAGE

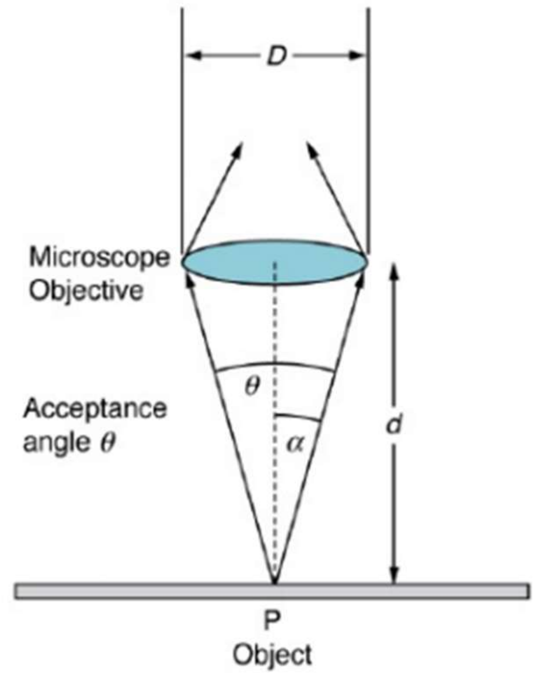



Numerical Aperture and Image Resolution
Airy Disk
Intensity
N.A. = 0.20
Focal Plane

Movie



(a)

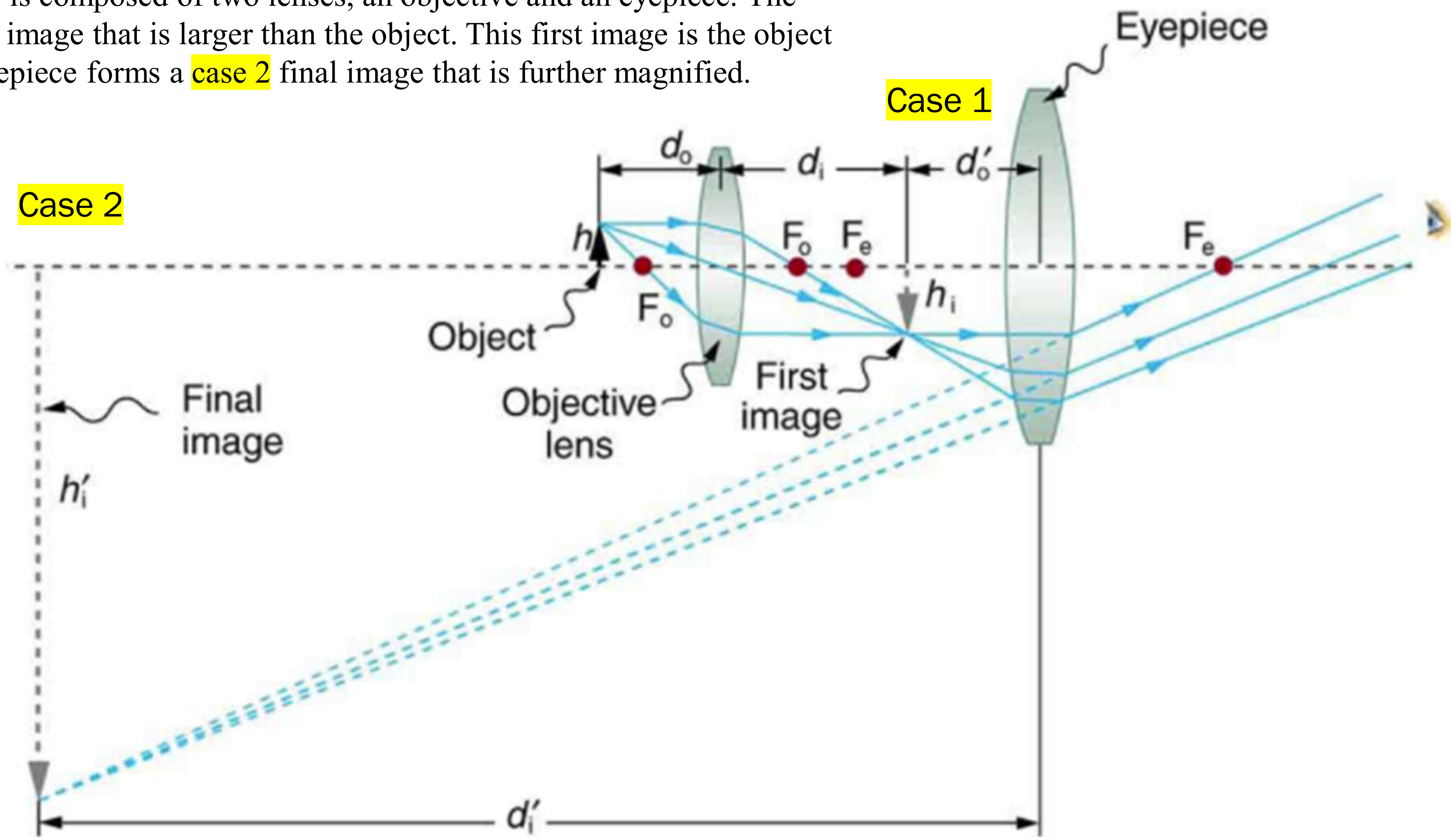


- In most biology laboratories, resolution is presented when the use of the microscope is introduced.
- The ability of a lens to produce sharp images of two closely spaced point objects is called resolution.
- The smaller the distance by which two objects can be separated and still be seen as distinct, the greater the resolution. The resolving power of a lens is defined as that distance x.
- An expression for resolving power is obtained from the Rayleigh criterion.

- Microscopes were first developed in the early 1600s by eyeglass makers in The Netherlands and Denmark
- The simplest compound microscope is constructed from two convex lenses. The first lens is called the objective lens, and has typical magnification values from 5x to 100x
- In standard microscopes, the objectives are mounted such that when you switch between objectives, the sample remains in focus. Objectives arranged in this way are described as parfocal
- The second convex lens, the eyepiece, also referred to as the ocular or tube lens, has several lenses which slide inside a cylindrical barrel. The focusing ability is provided by the movement of both the objective lens and the eyepiece
- The purpose of a microscope is to magnify small objects, and both lenses contribute to the final magnification.
- Additionally, the final enlarged image is produced in a location far enough from the observer to be easily viewed, since the eye cannot focus on objects or images that are too close

SCHEMATICALLY...

a compound microscope is composed of two lenses, an objective and an eyepiece. The objective forms a case 1 image that is larger than the object. This first image is the object for the eyepiece. The eyepiece forms a case 2 final image that is further magnified.



Since each lens produces a magnification that multiplies the height of the image, it is apparent that the overall magnification 'm' is the product of the individual magnifications: $m = m_o m_e$, where m_o is the magnification of the objective and m_e is the magnification of the eyepiece. This equation can be generalized for any combination of thin lenses and mirrors that obey the thin lens equations.