Resolution

Resolution:

The ability to **resolve** two sources of light depends on . . .

(a) "Well resolved" (b) "Just resolved" (c) "Not resolved"

Resolution of two sources through a single slit

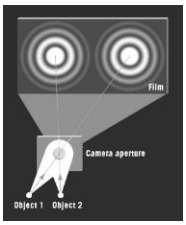
Well resolved

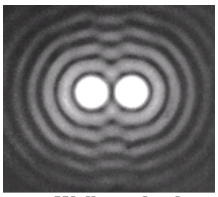
Just resolved

Not resolved

Resolution of two sources through a circular aperture

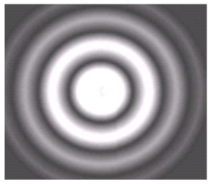
Examples:





Well resolved

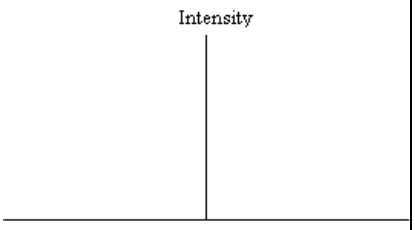
Just resolved



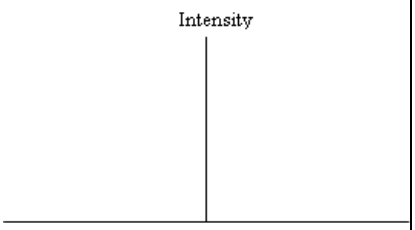
Not resolved

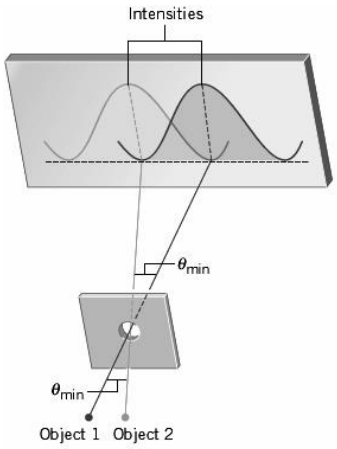
Intensity Patterns

Well resolved

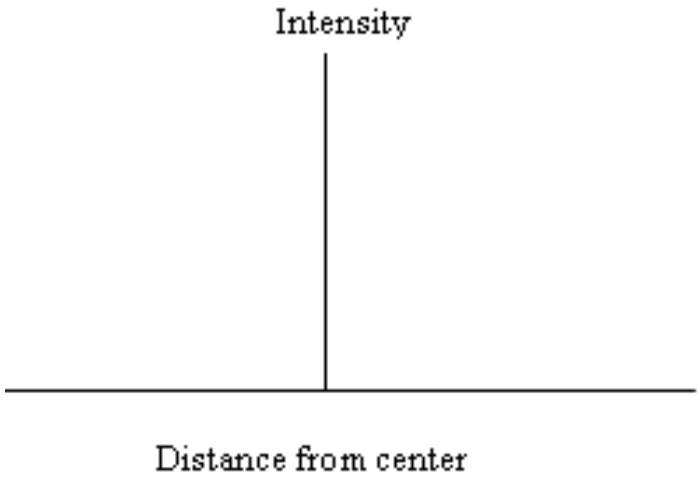


Not resolved





Just resolved



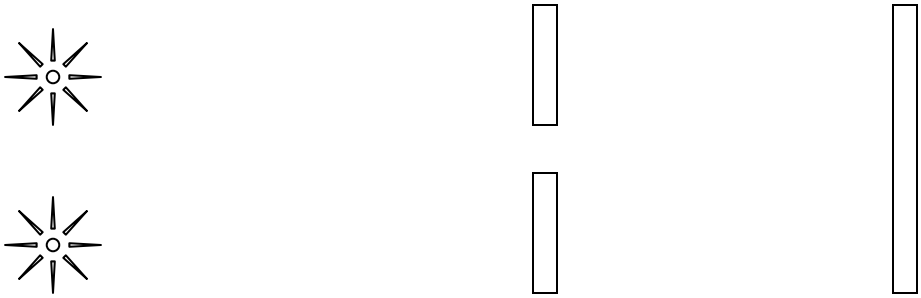
Resolving Power:

Single Slit

Circular Aperture

Rayleigh Criterion:

Distance Relationship



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1. The brightest star in the winter sky in the Northern Hemisphere is Sirius. In reality, Sirius is a system of two stars that orbit each other. The Hubble Space Telescope (diameter 2.4 m) is pointed at the Sirius system, which is 7.98×10^{16} meters from Earth.

   a) What is the minimum separation needed between the stars in order for the telescope to just resolve them?

   Assumption:

   b) What is the resolving power of the telescope?

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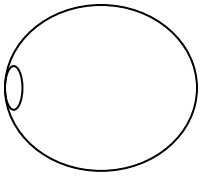
2. a) What is the resolving power of your eye?

   Assumptions:



   b) How far away can a car be for you to just distinguish between the two headlights at night?

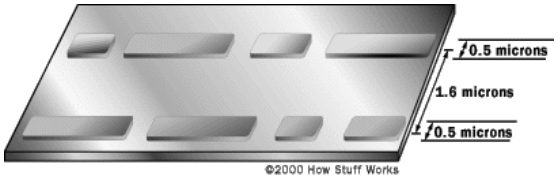
   Assumptions:

Significance of Resolution

Due to diffraction effects, all devices have a limit on their ability to perceive and to resolve between sources of light. For instance, our eyes can never see atoms since atoms are smaller than the wavelength of visible light so light waves will just diffract around them. Here are some cases where diffraction and resolution are important.

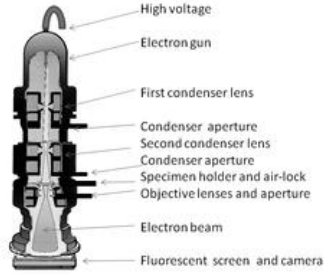
1. CDs and DVDs

CDs and DVDs store digital information as "bumps" and "pits" etched into a plastic surface. Music CDs have data tracks approximately 5×10^{-7} m wide with the bumps and pits just over 1×10^{-7} m high. The bumps and pits on a DVD are much smaller so that more data can be stored. The data is read by reflecting a laser beam off the surface. The wavelength of laser light used to read the data and the size of the aperture of the lens used to receive the laser light places a limit on how close together the bumps and pits can be placed, that is, places a limit on the resolution of the data.



2. Electron Microscopes

In order to resolve objects beyond the limits imposed by the wavelength of visible light, the wave properties of electrons are used in electron microscopes. The de Broglie wavelength of an electron is much smaller than the wavelength of a photon of visible light so a microscope using an electron beam can resolve objects that are much smaller than those of a light microscope.



Transmission Electron Microscope

3. Radio Telescopes

Astronomers often wish to detect the radio waves emitted by very distant objects like quasars and galaxies. However, since the wavelength of radio waves is much larger than visible light, the ability of a radio telescope to resolve sources is more limited than that of light telescopes. To get around this limitation, astronomers use two or more radio telescopes separated by a large distance, called a Very Large Array (VLA). For instance, in New Mexico, there is a VLA consisting of 27 parabolic dishes each of diameter 25 m arranged in a Y-shape that covers an area of 570 km^2.

EXAMPLE: The Galaxy Cygnus A can be resolved optically as an elliptically shaped galaxy. However, it is also a strong emitter of radio waves of wavelength 0.15 m. The Galaxy is estimated to be 5.0×10^{24} m from Earth. Use of a radio telescope shows that the radio emission is from two sources separated by a distance of 3.0×10^{21} m. Estimate the diameter of the dish required to just resolve the sources.