DIFFRACTION AND INSTRUMENT RESOLUTION

The ability of an optical system, such as a microscope or a telescope, to distinguish between closely spaced objects is limited by the wave nature of light. To understand this limitation, consider **Figure 20,** which shows two light sources far from a narrow slit. The sources can be taken as two point sources that are not coherent. For example, they could be two distant stars that appear close to each other in the night sky.

If no diffraction occurred, you would observe two distinct bright spots (or images) on the screen at the far right. However, because of diffraction, each source is shown to have a bright central region flanked by weaker bright and dark rings. What is observed on the screen is the resultant from the superposition of two diffraction patterns, one from each source.

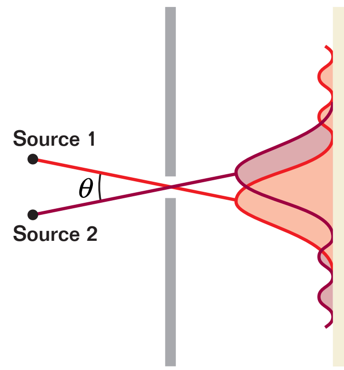

Figure 20
Each of two distant point sources produces a diffraction pattern.

Resolution depends on wavelength and aperture width

If the two sources are separated so that their central maxima do not overlap, as in **Figure 21,** their images can just be distinguished and are said to be barely *resolved.* To achieve high resolution or **resolving power,** the angle between the resolved objects, θ, should be as small as possible as shown in **Figure 20.** The shorter the wavelength of the incoming light or the wider the opening, or *aperture,* through which the light passes, the smaller the angle of resolution, θ, will be and the greater the resolving power will be. For visible-light telescopes, the aperture width, D, is approximately equal to the diameter of the mirror or lens. The equation to determine the limiting angle of resolution *in radians* for an optical instrument with a circular aperture is as follows:

resolving power

the ability of an optical instrument to form separate images of two objects that are close together

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

The constant 1.22 comes from the derivation of the equation for circular apertures and is absent for long slits. Note that one radian equals $(180/\pi)°$, as discussed in the Appendix J feature "Angular Kinematics." The equation indicates that for light with a short wavelength, such as an X ray, a small aperture is sufficient for high resolution. On the other hand, if the wavelength of the light is long, as in the case of a radio wave, the aperture must be large in order to resolve distant objects. This is one reason why radio telescopes have large dish-like antennas.

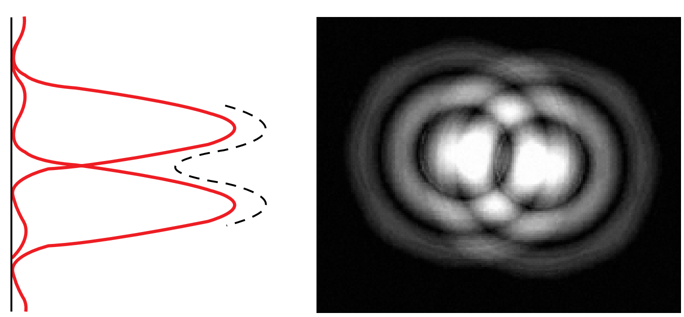

Figure 21
Two point sources are barely resolved if the central maxima of their diffraction patterns do not overlap.