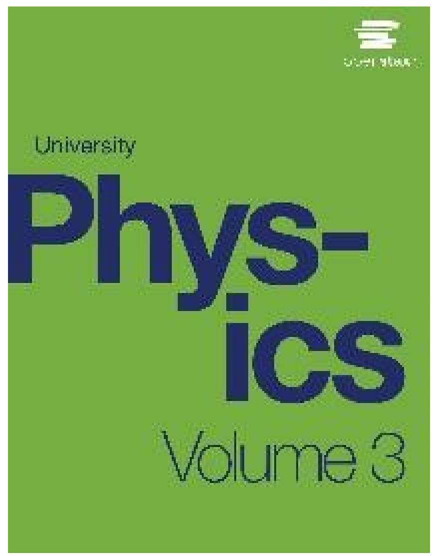
UNIVERSITY PHYSICS

Chapter 4 DIFFRACTION

PowerPoint Image Slideshow



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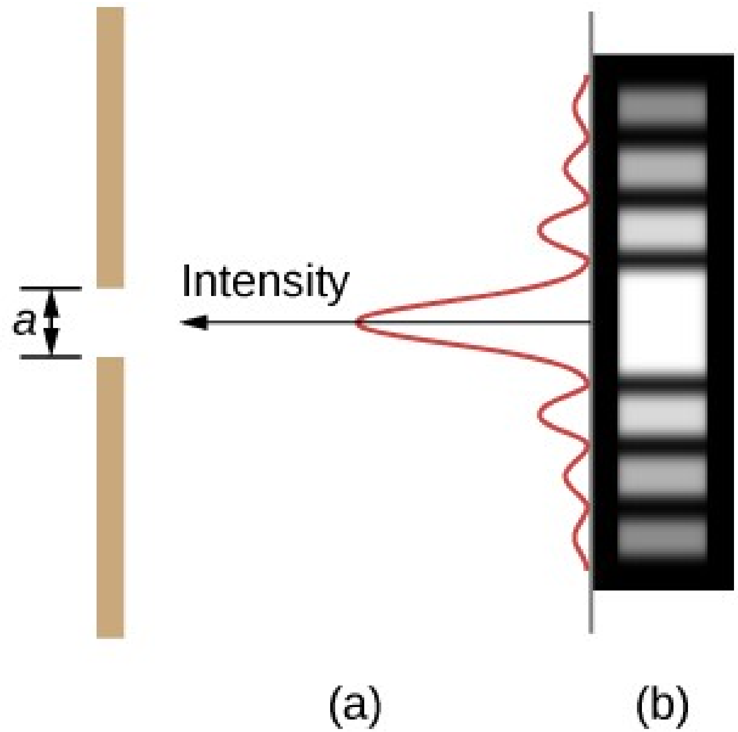
Single slit diffraction

FIGURE 4.3

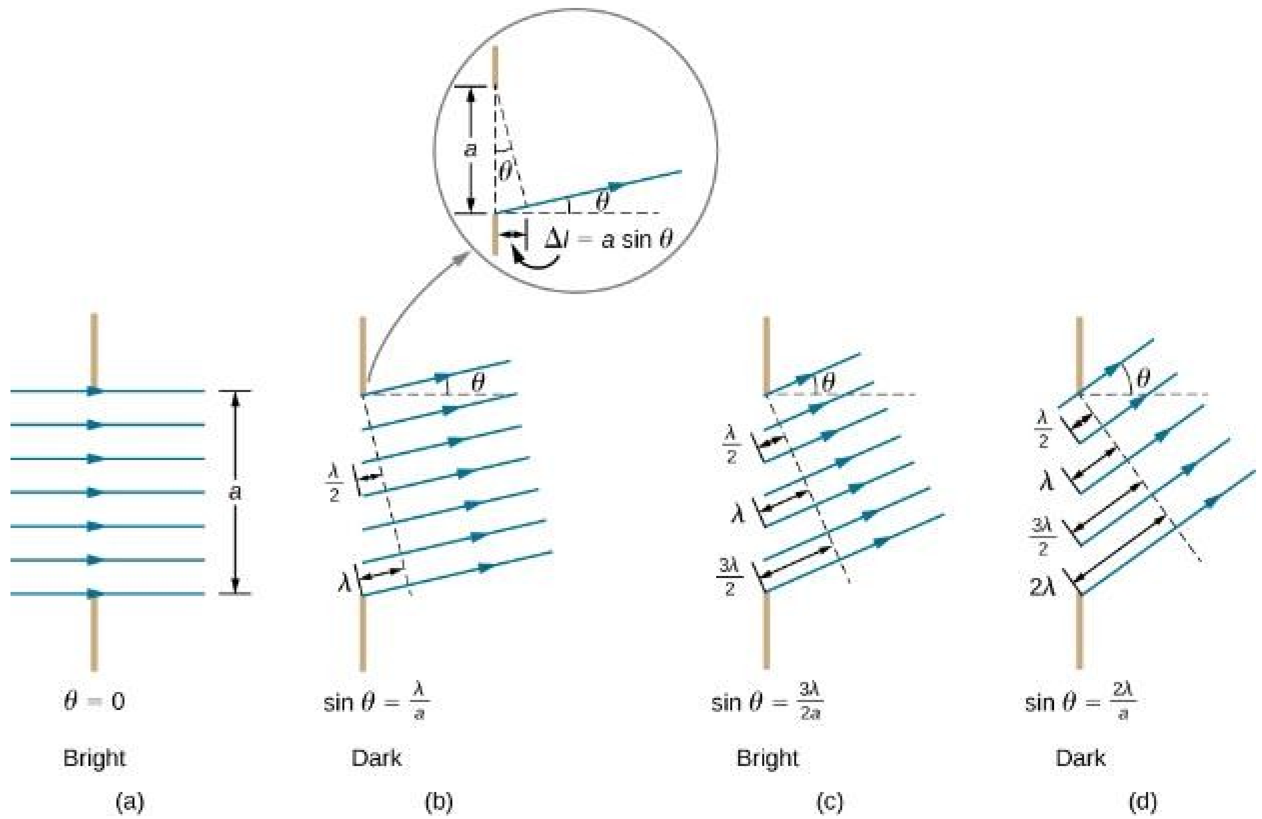


Single-slit diffraction pattern.

a) Monochromatic light passing through a single slit has a central maximum and many smaller and dimmer maxima on either side. The central maximum is six times higher than shown.

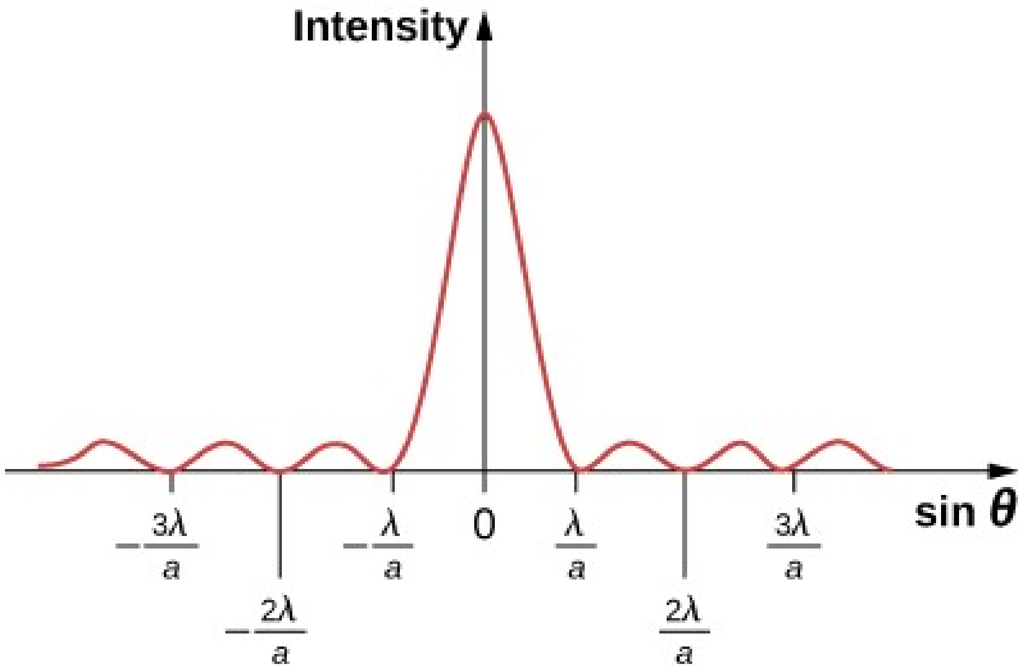
b) The diagram shows the bright central maximum, and the dimmer and thinner maxima on either side.

FIGURE 4.4



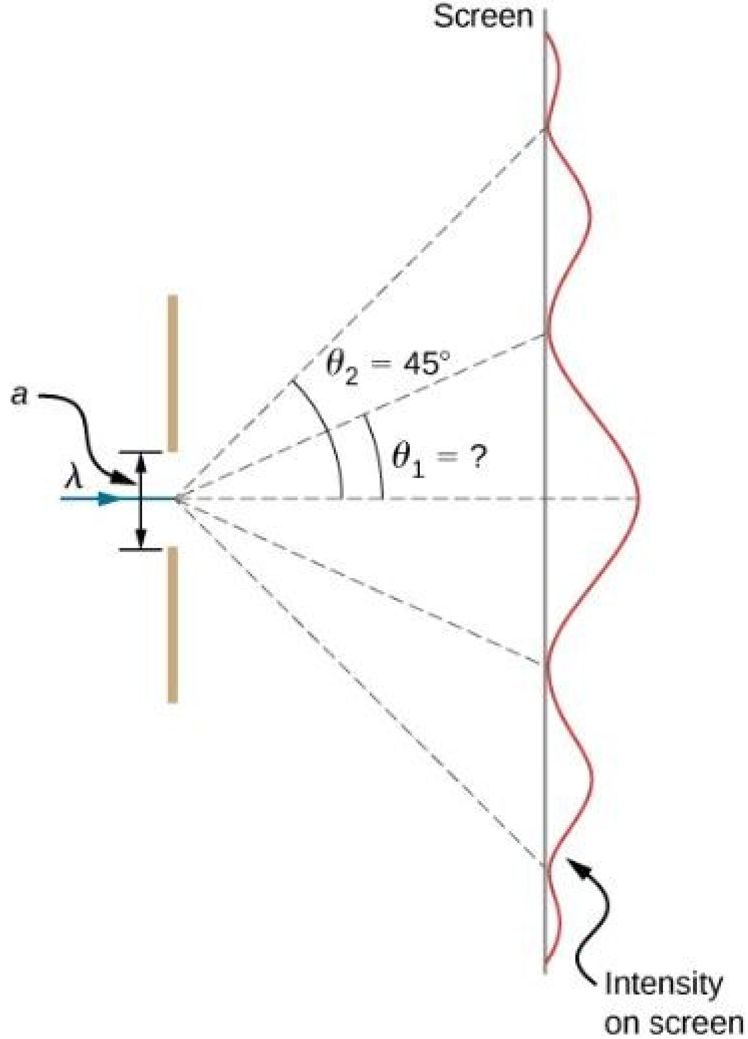
Light passing through a single slit is diffracted in all directions and may interfere constructively or destructively, depending on the angle. The difference in path length for rays from either side of the slit is seen to be $D \sin \theta$.

FIGURE 4.5



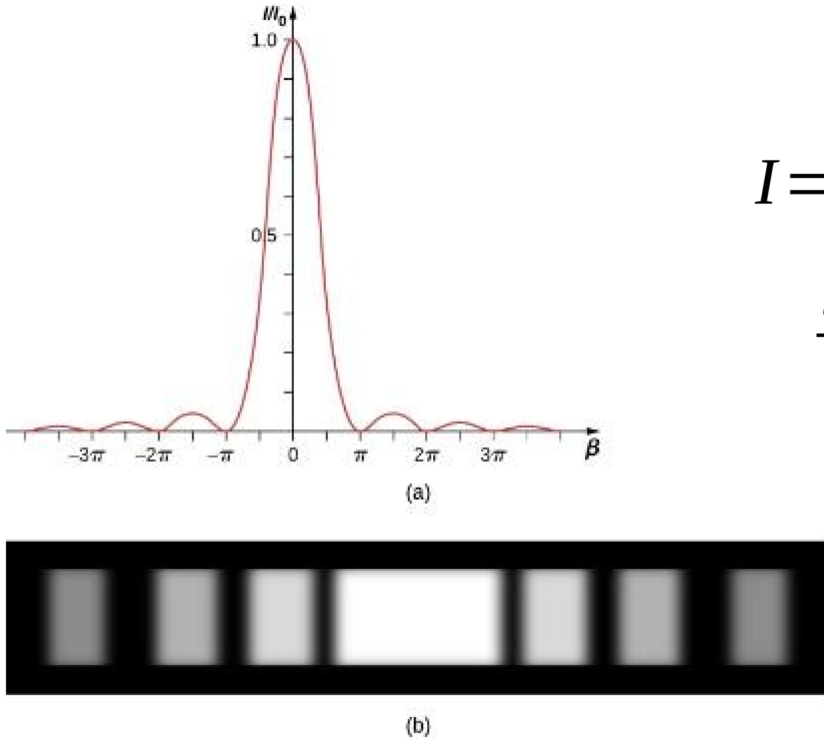
A graph of single-slit diffraction intensity showing the central maximum to be wider and much more intense than those to the sides. In fact, the central maximum is six times higher than shown here.

FIGURE 4.6



In this example, we analyze a graph of the single-slit diffraction pattern.

FIGURE 4.9



$$I = I_0\left(\frac{\sin\beta}{\beta}\right)^2$$

$$\frac{\pi a \sin\theta}{\lambda}$$

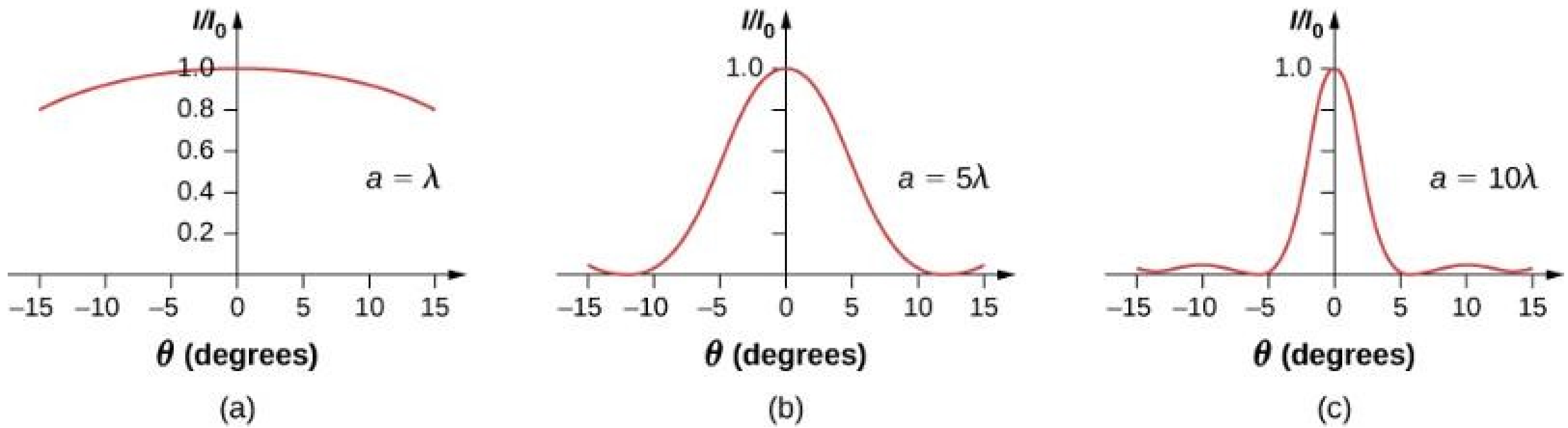
a) The calculated intensity distribution of a single-slit diffraction pattern.

b) The actual diffraction pattern.

FIGURE 4.10

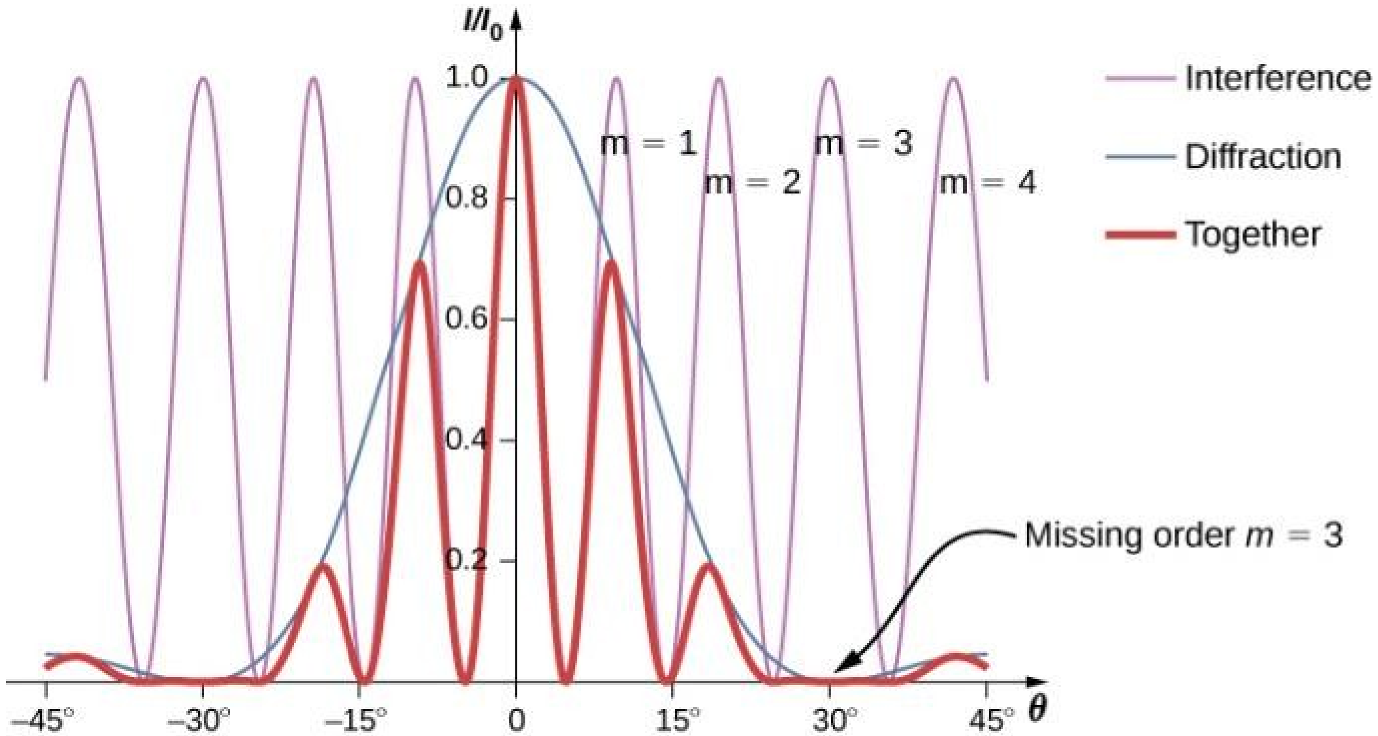
$$I = I_0\left(\frac{\sin\beta}{\beta}\right)^2$$

$$\frac{\pi a \sin\theta}{\lambda}$$



Single-slit diffraction patterns for various slit widths. As the slit width *D* increases from $D = \lambda$ to 5λ and then to 10λ , the width of the central peak decreases as the angles for the first minima decrease as predicted by **Equation 4.1**.

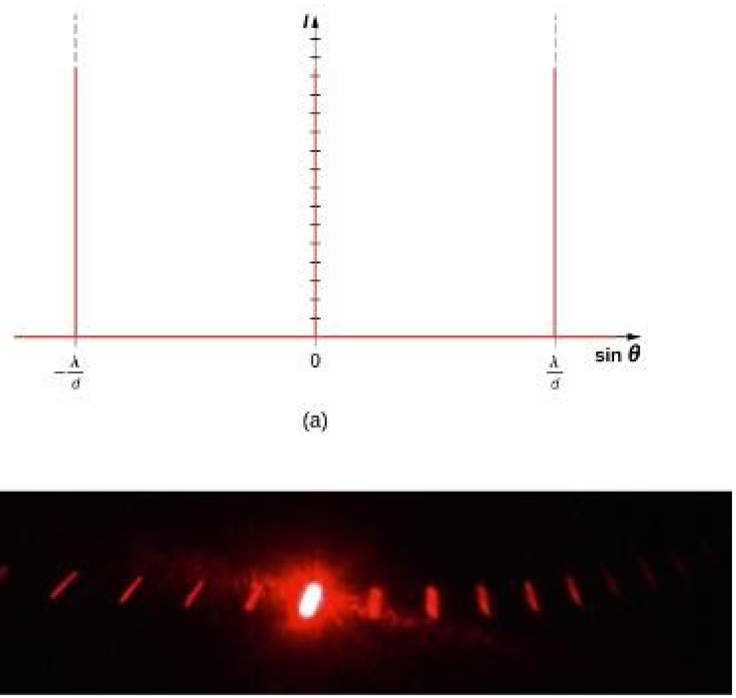
FIGURE 4.11



Diffraction from a double slit. The purple line with peaks of the same height are from the interference of the waves from two slits; the blue line with one big hump in the middle is the diffraction of waves from within one slit; and the thick red line is the product of the two, which is the pattern observed on the screen. The plot shows the expected result for a slit width $D = 2\lambda$ and slit separation $d = 6\lambda$. The maximum of $m = \pm 3$ order for the interference is missing because the minimum of the diffraction occurs in the same direction.

Diffraction gratings

FIGURE 4.12



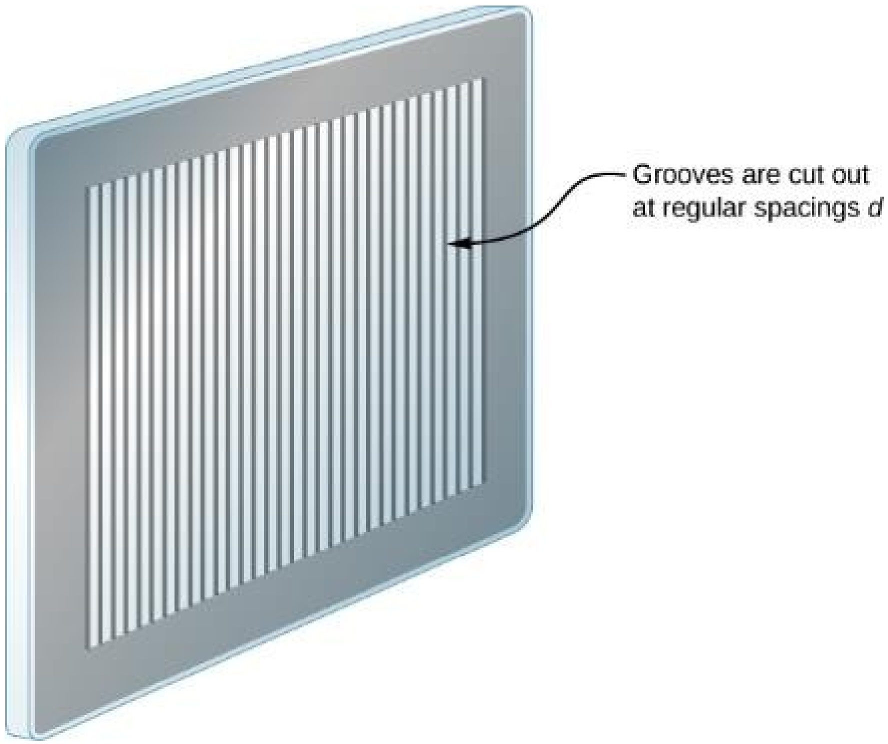
(a)

(b)

a) Intensity of light transmitted through a large number of slits. When *N* approaches infinity, only the principal maxima remain as very bright and very narrow lines.

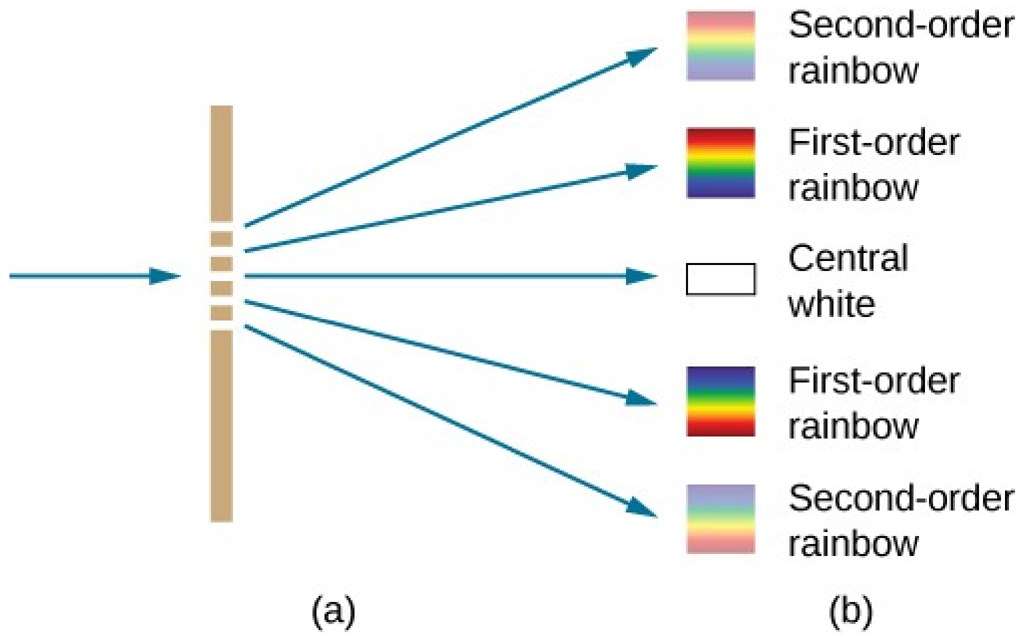
b) A laser beam passed through a diffraction grating. (credit b: modification of work by Sebastian Stapelberg)

FIGURE 4.13



A diffraction grating can be manufactured by carving glass with a sharp tool in a large number of precisely positioned parallel lines.

FIGURE 4.14



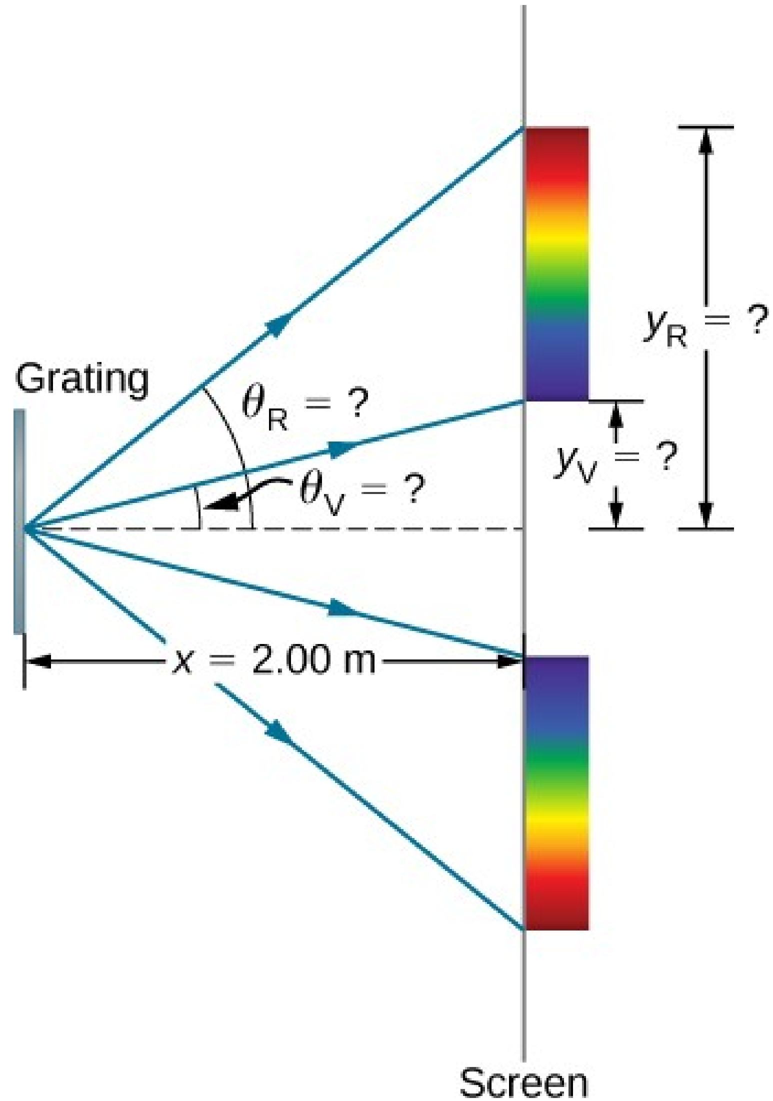
a) Light passing through a diffraction grating is diffracted in a pattern similar to a double slit, with bright regions at various angles.

b) The pattern obtained for white light incident on a grating. The central maximum is white, and the higher-order maxima disperse white light into a rainbow of colors.

FIGURE 4.16

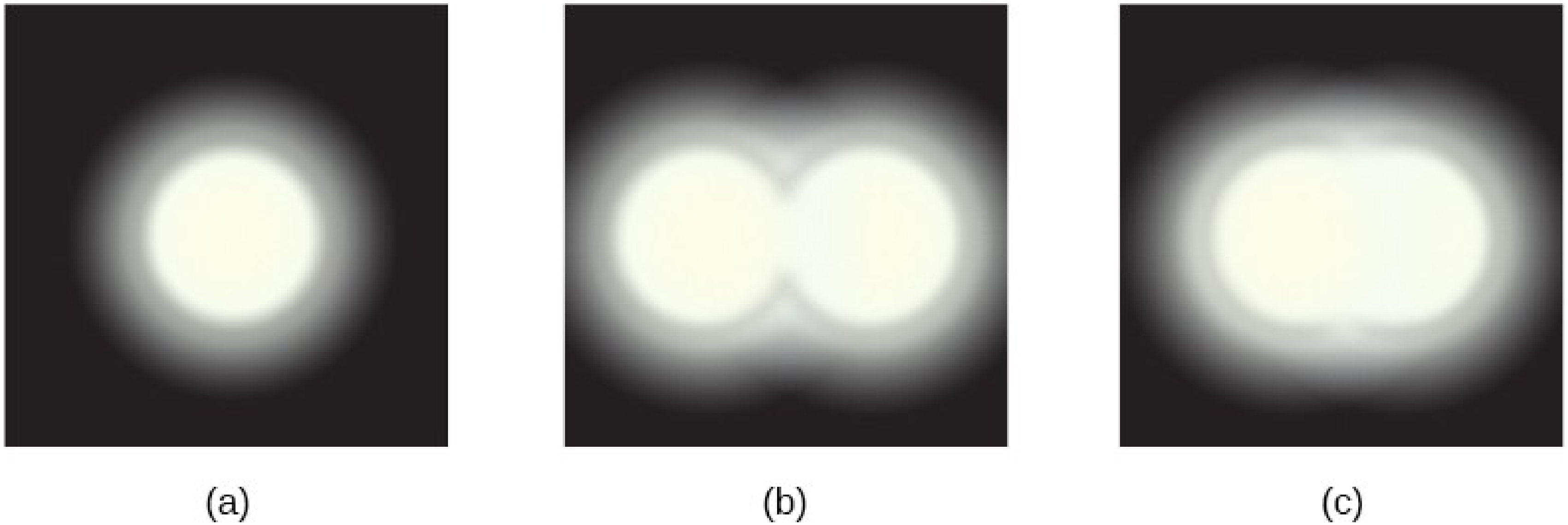
a) The diffraction grating considered in this example produces a rainbow of colors on a screen a distance $x = 2.00$ m from the grating. The distances along the screen are measured perpendicular to the *x*-direction. In other words, the rainbow pattern extends out of the page.

b) In a bird's-eye view, the rainbow pattern can be seen on a table where the equipment is placed.



Circular aperture

FIGURE 4.17

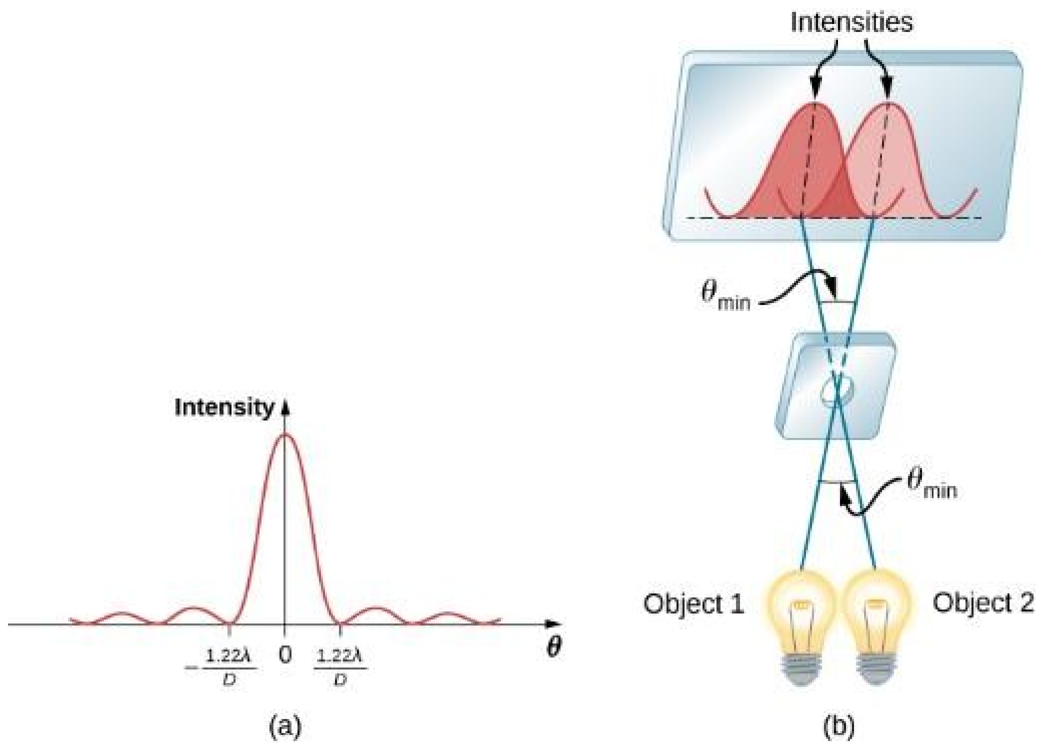


a) Monochromatic light passed through a small circular aperture produces this diffraction pattern.

b) Two point-light sources that are close to one another produce overlapping images because of diffraction.

c) If the sources are closer together, they cannot be distinguished or resolved.

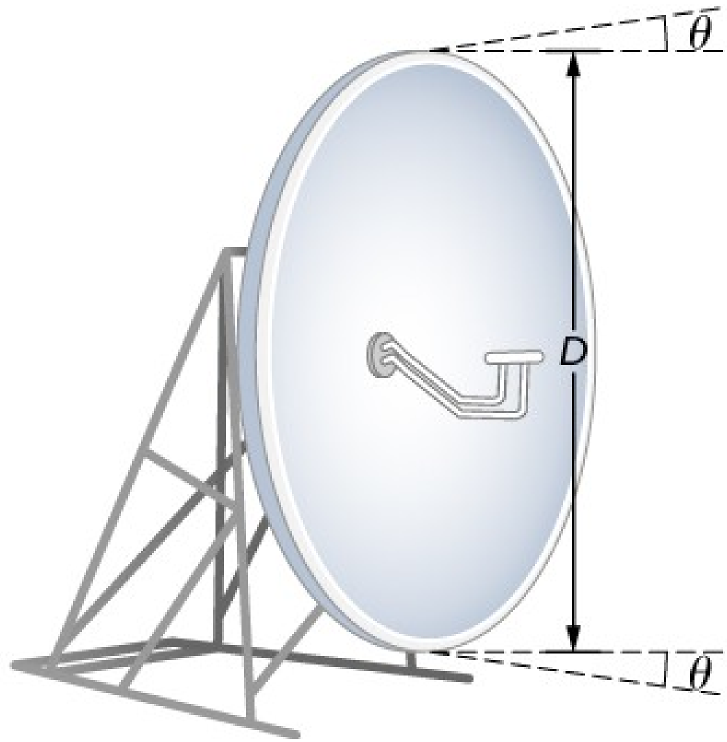
FIGURE 4.18



a) Graph of intensity of the diffraction pattern for a circular aperture. Note that, similar to a single slit, the central maximum is wider and brighter than those to the sides.

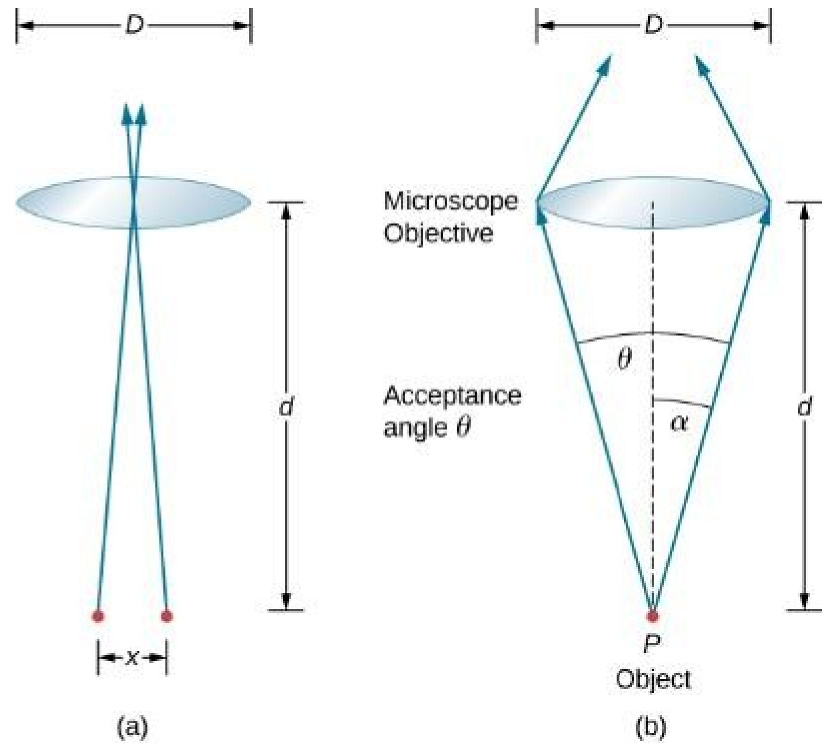
b) Two point objects produce overlapping diffraction patterns. Shown here is the Rayleigh criterion for being just resolvable. The central maximum of one pattern lies on the first minimum of the other.

FIGURE 4.21



The beam produced by this microwave transmission antenna spreads out at a minimum angle $\theta = 1.22\lambda/D$ due to diffraction. It is impossible to produce a near-parallel beam because the beam has a limited diameter.

FIGURE 4.22

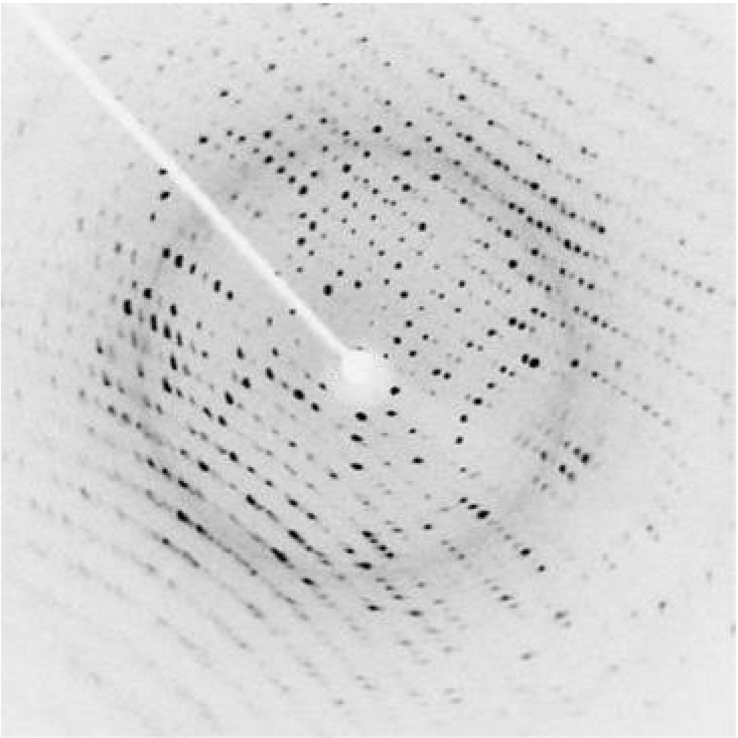


a) Two points separated by a distance *x* and positioned a distance *d* away from the objective.

b) Terms and symbols used in discussion of resolving power for a lens and an object at point *P* (credit a: modification of work by “Infopro”/Wikimedia Commons).

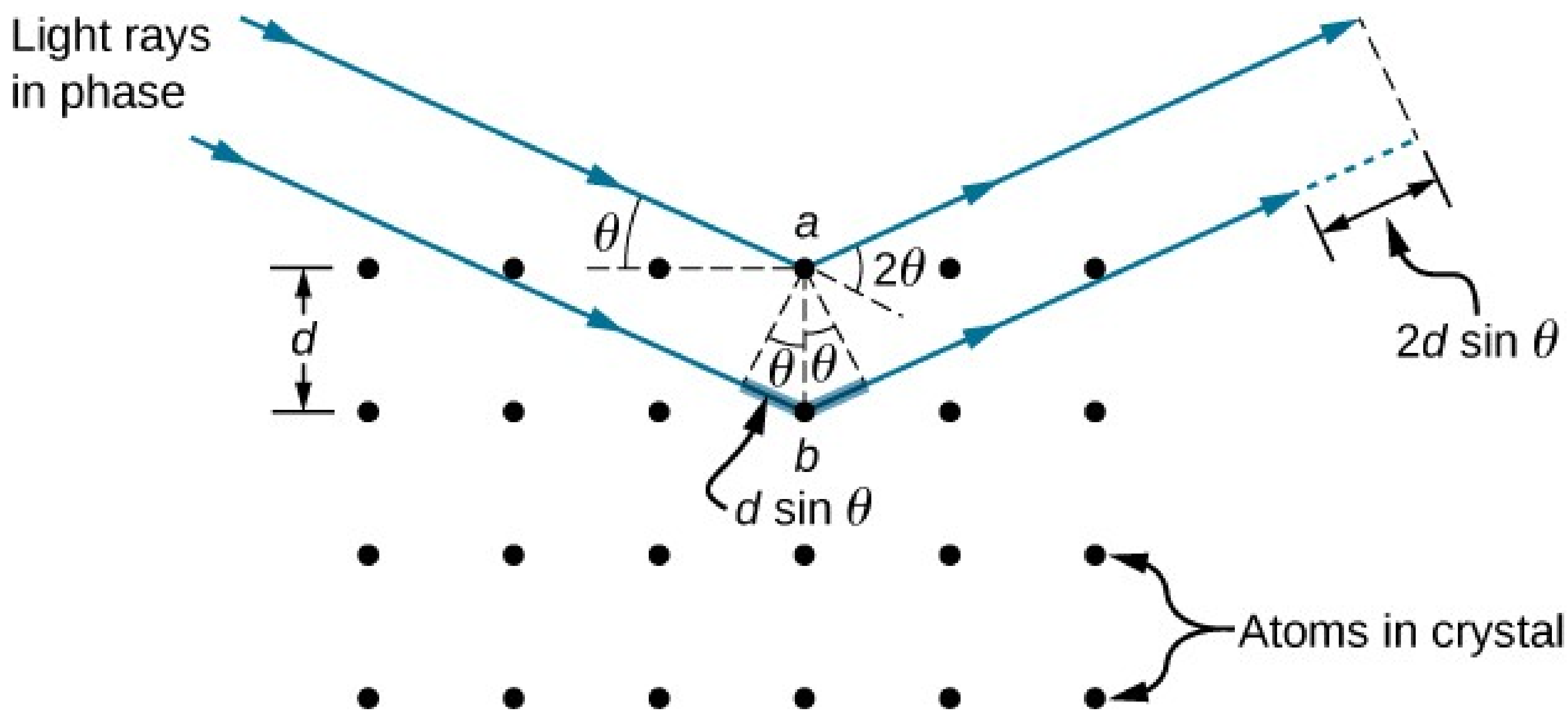
X-ray diffraction

FIGURE 4.24



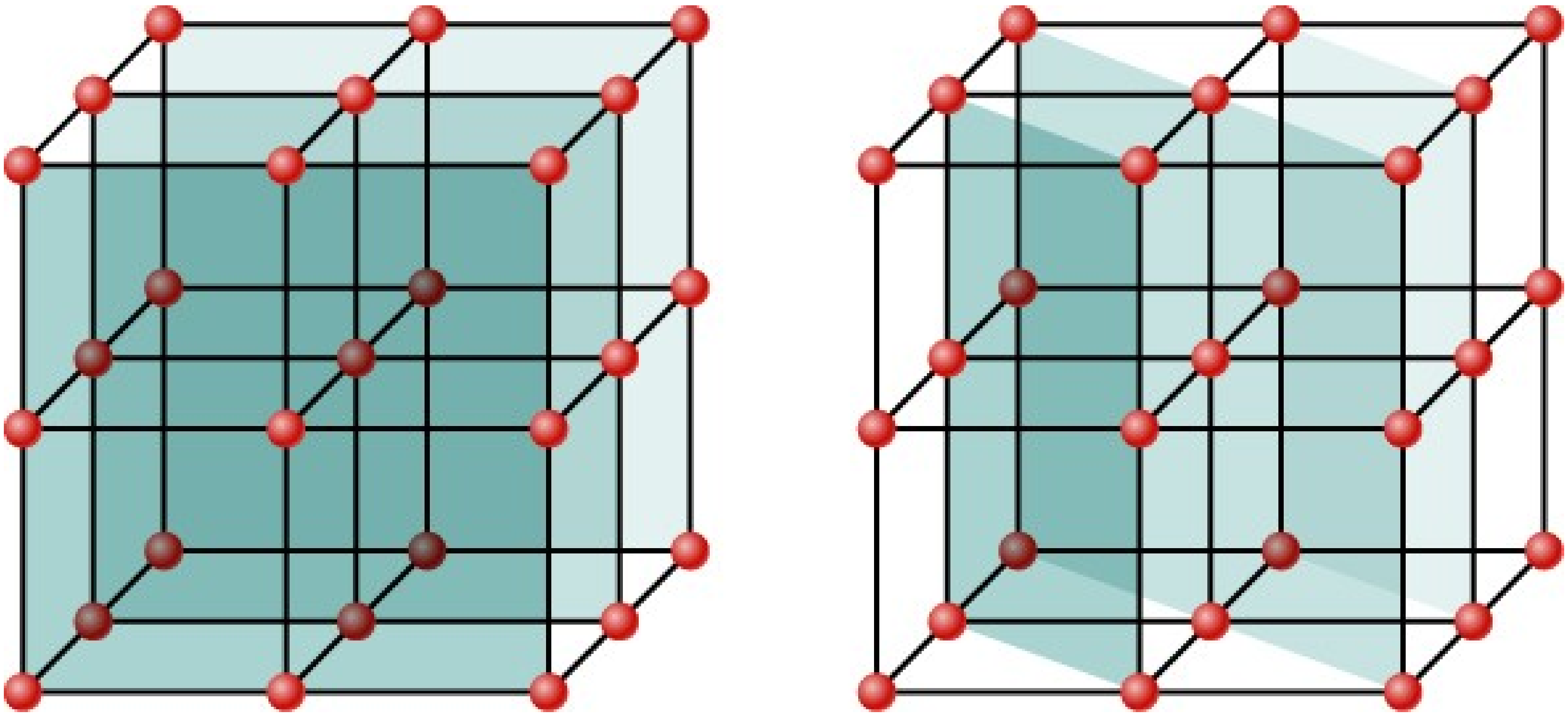
X-ray diffraction from the crystal of a protein (hen egg lysozyme) produced this interference pattern. Analysis of the pattern yields information about the structure of the protein. (credit: “Del45”/Wikimedia Commons)

FIGURE 4.25



X-ray diffraction with a crystal. Two incident waves reflect off two planes of a crystal. The difference in path lengths is indicated by the dashed line.

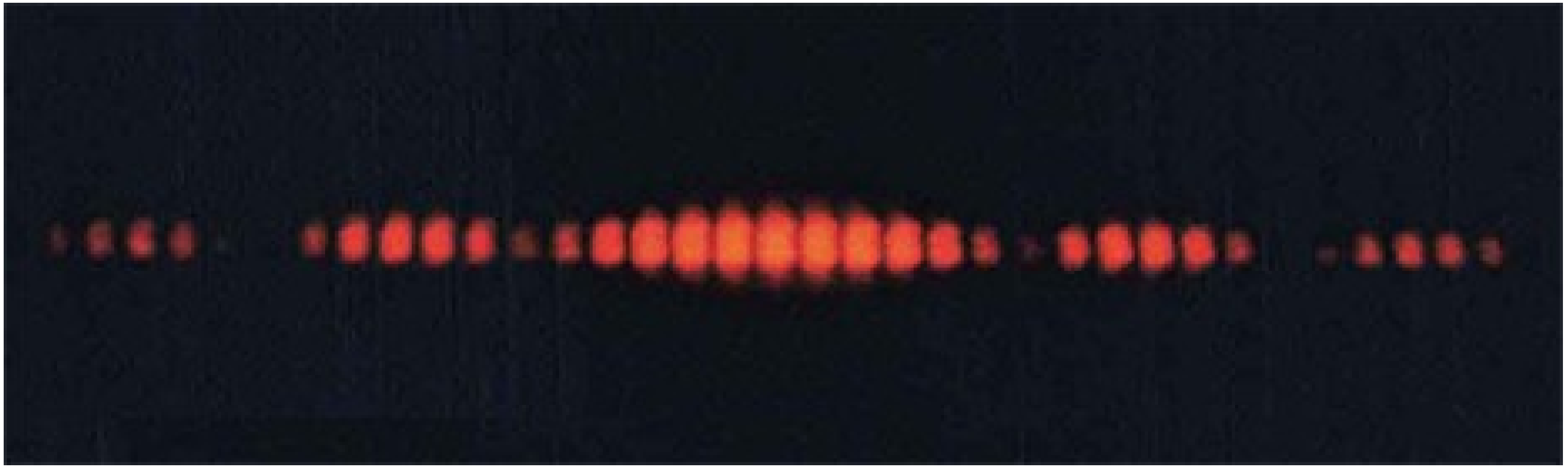
FIGURE 4.26



Because of the regularity that makes a crystal structure, one crystal can have many families of planes within its geometry, each one giving rise to X-ray diffraction.

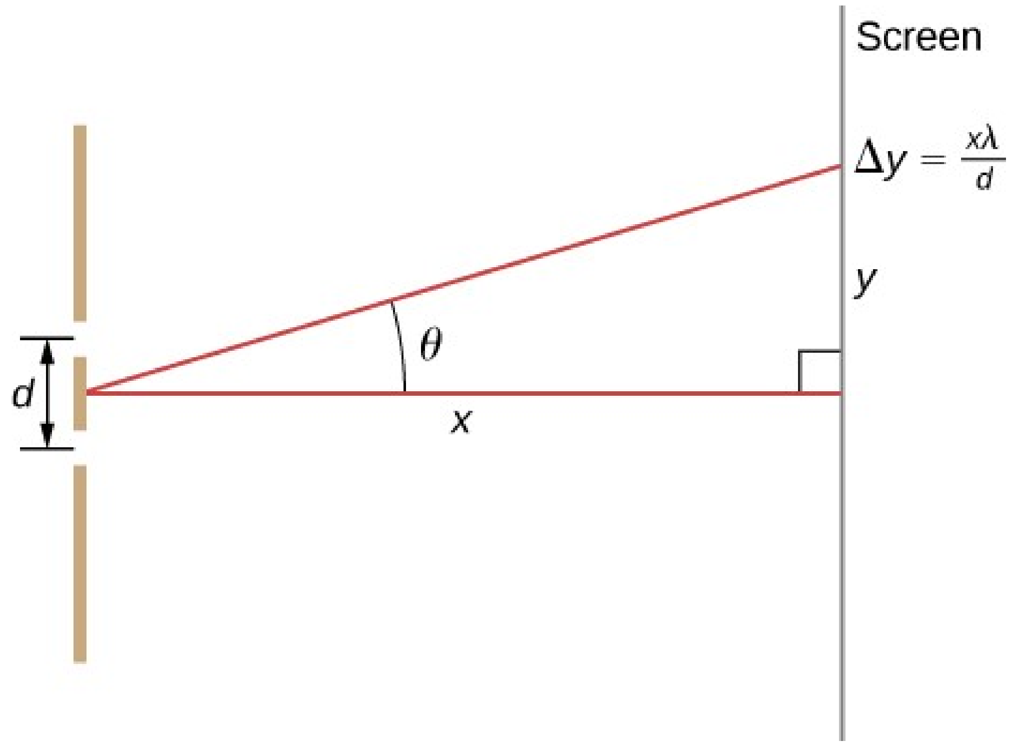
Examples

EXERCISE 8



Shown below is the central part of the interference pattern for a pure wavelength of red light projected onto a double slit. The pattern is actually a combination of single- and double-slit interference. Note that the bright spots are evenly spaced. Is this a double- or single-slit characteristic? Note that some of the bright spots are dim on either side of the center. Is this a single- or double-slit characteristic? Which is smaller, the slit width or the separation between slits? Explain your responses.

EXERCISE 53



The analysis shown below also applies to diffraction gratings with lines separated by a distance *d*. What is the distance between fringes produced by a diffraction grating having 125 lines per centimeter for 600-nm light, if the screen is 1.50 m away? (*Hint:* The distance between adjacent fringes is $\Delta y = x\lambda/d$, assuming the slit separation *d* is comparable to λ.)