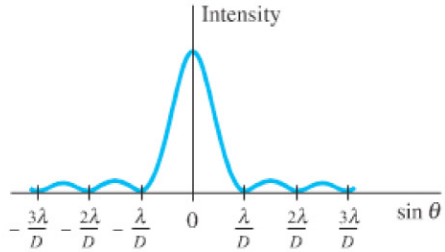


FIGURE 24–21 Intensity in the diffraction pattern of a single slit as a function of $\sin\theta$. Note that the central maximum is not only much higher than the maxima to each side, but it is also twice as wide ($2\lambda/D$ wide) as any of the others (only λ/D wide each).

pattern. A plot of the intensity as a function of angle is shown in Fig. 24–21. This corresponds well with the photo of Fig. 24–19c. Notice that minima (zero intensity) occur at

$$D\sin\theta = m\lambda, \qquad m = 1, 2, 3, \cdots, \qquad \text{[minima]} \quad \textbf{(24–3b)}$$

Single-slit diffraction minima

but *not* at $m = 0$ where there is the strongest maximum. Between the minima, smaller intensity maxima occur at approximately (not exactly) $m \approx \frac{3}{2}, \frac{5}{2}, \cdots$.

Note that the *minima* for a diffraction pattern, Eq. 24–3b, satisfy a criterion that looks very similar to that for the *maxima* (bright spots) for double-slit interference, Eq. 24–2a. Also note that D is a single slit width, whereas d in Eq. 24–2 is the distance between two slits.

CAUTION

Don't confuse Eqs. 24–2 for interference with Eqs. 24–3 for diffraction; note the differences

EXAMPLE 24–4 Single-slit diffraction maximum. Light of wavelength 750 nm passes through a slit 1.0×10^{-3} mm wide. How wide is the central maximum (*a*) in degrees, and (*b*) in centimeters, on a screen 20 cm away?

APPROACH The width of the central maximum goes from the first minimum on one side to the first minimum on the other side. We use Eq. 24–3a to find the angular position of the first single-slit diffraction minimum.

SOLUTION (*a*) The first minimum occurs at

$$\sin\theta = \frac{\lambda}{D} = \frac{7.5 \times 10^{-7}\,\text{m}}{1 \times 10^{-6}\,\text{m}} = 0.75.$$

So $\theta = 49°$. This is the angle between the center and the first minimum, Fig. 24–22. The angle subtended by the whole central maximum, between the minima above and below the center, is twice this, or 98°.
(*b*) The width of the central maximum is $2x$, where $\tan\theta = x/20\,\text{cm}$. So $2x = 2(20\,\text{cm})(\tan 49°) = 46\,\text{cm}$.

NOTE A large width of the screen will be illuminated, but it will not normally be very bright since the amount of light that passes through such a small slit will be small and it is spread over a large area. Note also that we *cannot* use the small-angle approximation here ($\theta \approx \sin\theta \approx \tan\theta$) because θ is large.

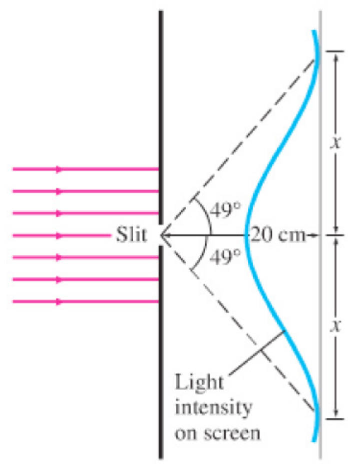
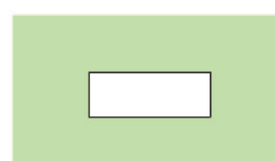


FIGURE 24–22 Example 24–4.

EXERCISE B In Example 24–4, red light ($\lambda = 750$ nm) was used. If instead yellow light ($\lambda = 550$ nm) had been used, would the central maximum be wider or narrower?

CONCEPTUAL EXAMPLE 24–5 Diffraction spreads. Light shines through a rectangular hole that is narrower in the vertical direction than the horizontal, Fig. 24–23. (*a*) Would you expect the diffraction pattern to be more spread out in the vertical direction or in the horizontal direction? (*b*) Should a rectangular loudspeaker horn at a stadium be high and narrow, or wide and flat?

FIGURE 24–23 Example 24–5.



RESPONSE (*a*) From Eq. 24–3a we can see that if we make the slit (width D) narrower, the pattern spreads out more. This is consistent with our study of waves in Chapter 11. The diffraction through the rectangular hole will be wider vertically, since the opening is smaller in that direction.
(*b*) For a loudspeaker, the sound pattern desired is one spread out horizontally, so the horn should be tall and narrow (rotate Fig. 24–23 by 90°).