Bright (constructive interference)

Bright (constructive interference)

Dark (destructive interference)

Extra distance $= \lambda$

Extra distance $= \frac{1}{2}\lambda$

$d_2 - d_1 = d \sin\theta$

(a) $\theta = 0°$  (b)  (c)  (d)

**FIGURE 24–7** How the wave theory explains the pattern of lines seen in the double-slit experiment. (a) At the center of the screen the waves from each slit travel the same distance and are in phase. (b) At this angle $\theta$, the lower wave travels an extra distance of one whole wavelength, and the waves are in phase; note from the shaded triangle that the path difference equals $d \sin\theta$. (c) For this angle $\theta$, the lower wave travels an extra distance equal to one-half wavelength, so the two waves arrive at the screen fully out of phase. (d) A more detailed diagram showing the geometry for parts (b) and (c).

To determine exactly where the bright lines fall, first note that Fig. 24–7 is somewhat exaggerated; in real situations, the distance $d$ between the slits is very small compared to the distance $L$ to the screen. The rays from each slit for each case will therefore be essentially parallel, and $\theta$ is the angle they make with the horizontal as shown in Fig. 24–7d. From the shaded right triangles shown in Figs. 24–7b and c, we can see that the extra distance traveled by the lower ray is $d \sin\theta$ (seen more clearly in Fig. 24–7d). **Constructive interference** will occur, and a bright fringe will appear on the screen, when the *path difference, $d \sin\theta$,* equals a whole number of wavelengths:

$$d \sin\theta = m\lambda, \qquad m = 0, 1, 2, \cdots. \qquad \begin{bmatrix} \text{constructive} \\ \text{interference} \\ \text{(bright)} \end{bmatrix} \quad \textbf{(24–2a)}$$

The value of $m$ is called the **order** of the interference fringe. The first order $(m = 1)$, for example, is the first fringe on each side of the central fringe (which is at $\theta = 0$, $m = 0$). Destructive interference occurs when the path difference $d \sin\theta$ is $\frac{1}{2}\lambda$, $\frac{3}{2}\lambda$, and so on:

$$d \sin\theta = \left(m + \tfrac{1}{2}\right)\lambda, \qquad m = 0, 1, 2, \cdots. \quad \begin{bmatrix} \text{destructive} \\ \text{interference} \\ \text{(dark)} \end{bmatrix} \quad \textbf{(24–2b)}$$

The bright fringes are peaks or maxima of light intensity, the dark fringes are minima. The intensity of the bright fringes is greatest for the central fringe $(m = 0)$ and decreases for higher orders, as shown in Fig. 24–9. How much the intensity decreases with increasing order depends on the width of the two slits.

**FIGURE 24–8** Two traveling waves are waves shown undergoing (a) constructive interference, (b) destructive interference. (See also Section 11–12.)



+

=

(a)

+

=

(b)



Constructive interference

$m = 3$  2  1  0  1  2  3

Destructive interference

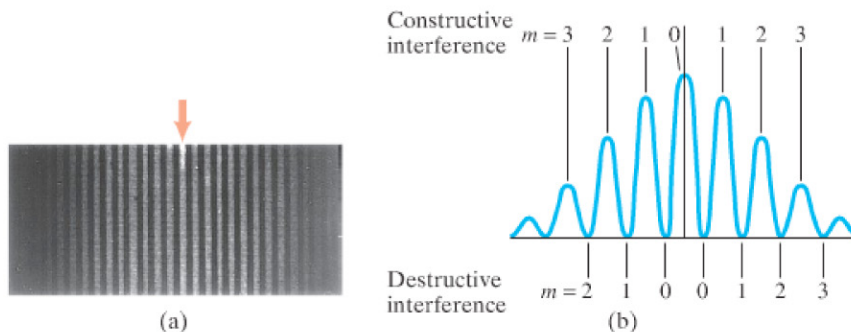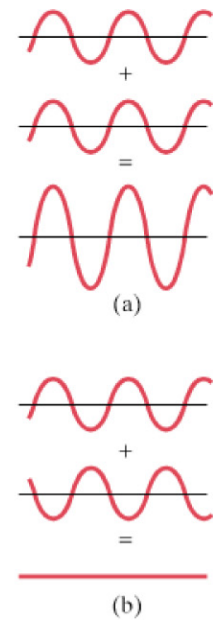$m = 2$  1  0  0  1  2  3

(a)

(b)

**FIGURE 24–9** (a) Interference fringes produced by a double-slit experiment and detected by photographic film placed on the viewing screen. The arrow marks the central fringe. (b) Graph of the intensity of light in the interference pattern. Also shown are values of $m$ for Eq. 24–2a (constructive interference) and Eq. 24–2b (destructive interference).