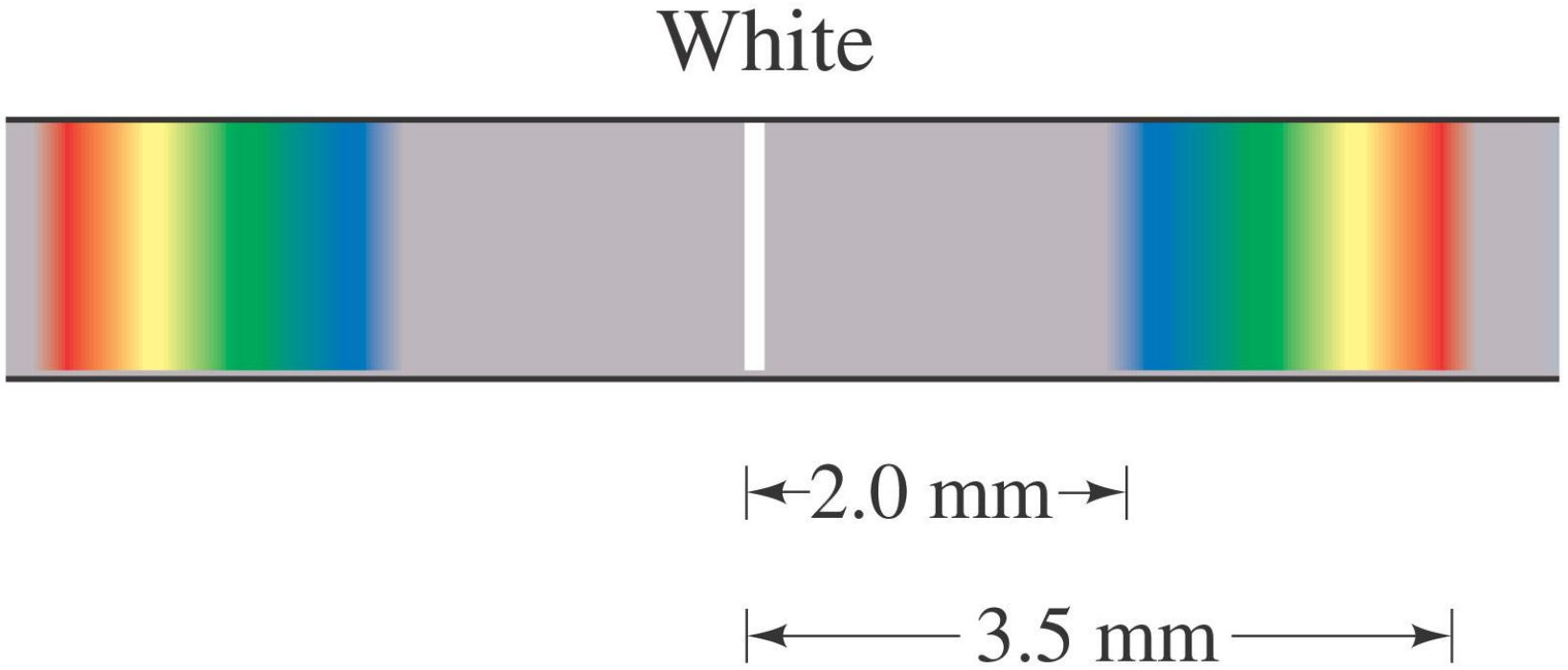
Chapter 24

The Wave Nature of Light

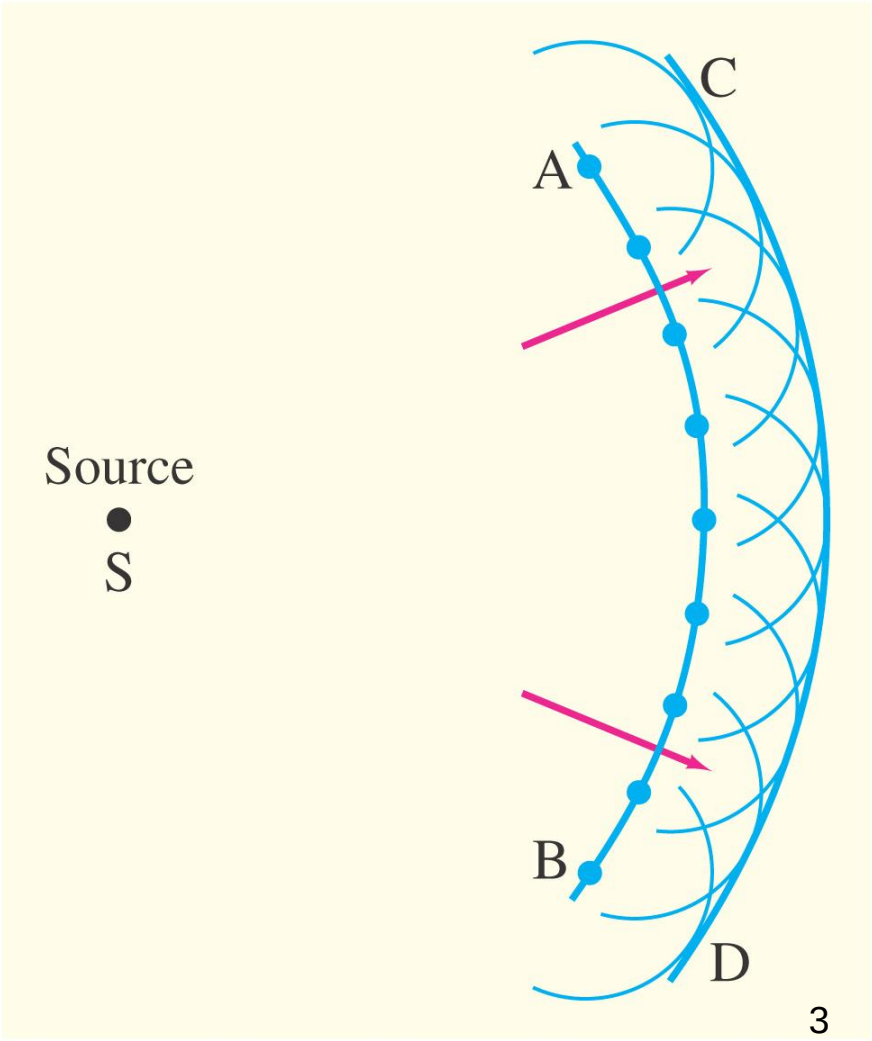


Examples of light's wave nature

- Light can exhibit behavior specific to both waves and particles (later in course)
- Need to know examples of each
- Interference – Young's Double Slit Experiment
- The Visible Spectrum and Dispersion
- Diffraction by a Single Slit
- Diffraction by a Grating of slits
- Interference by Thin Films (next unit)
- Refraction (next unit)

24.1 Waves Versus Particles; Huygens' Principle and Diffraction

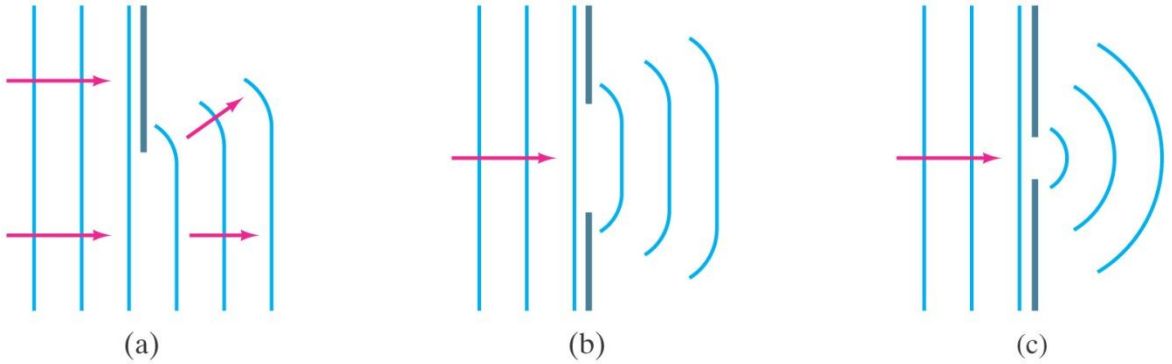
Huygens' principle: Every point on a wave front acts as a point source; the wavefront as it develops is tangent to their envelope



24.1 Waves Versus Particles; Huygens' Principle and Diffraction

Huygens' principle is consistent with diffraction:

- **Diffraction occurs with water waves but not with streams of particles.**

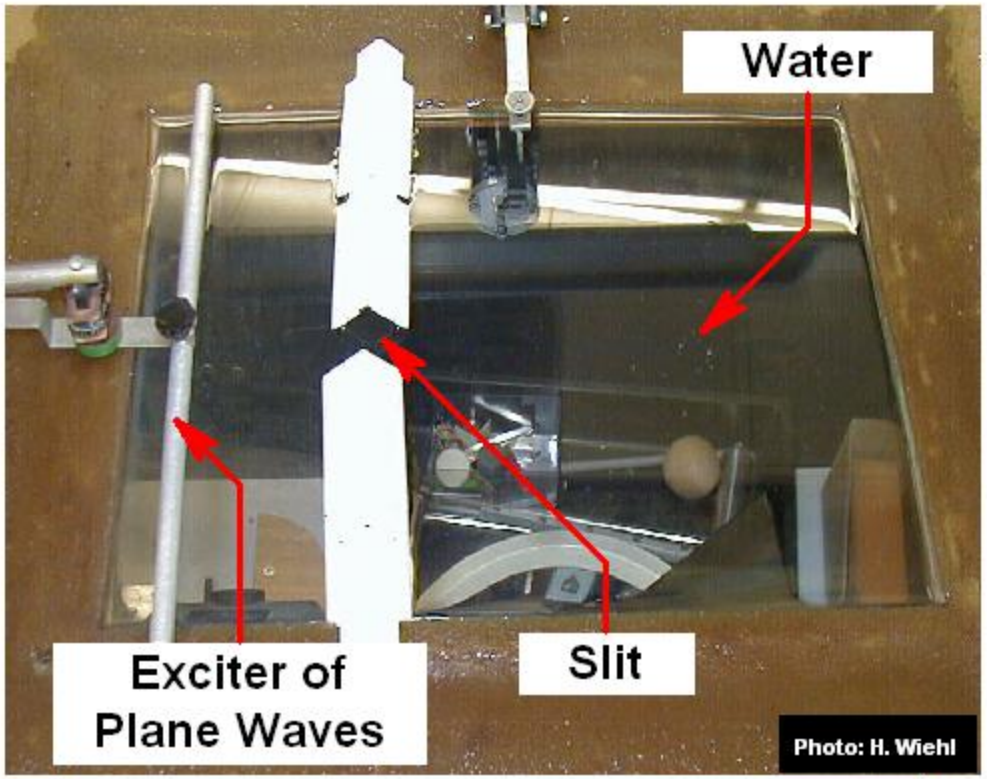


We will examine 3 types of diffraction through

- **double slit**
- **single slit**
- **diffraction grating**

Diffraction on a Slit in Wave Tank

Wave / Diffraction



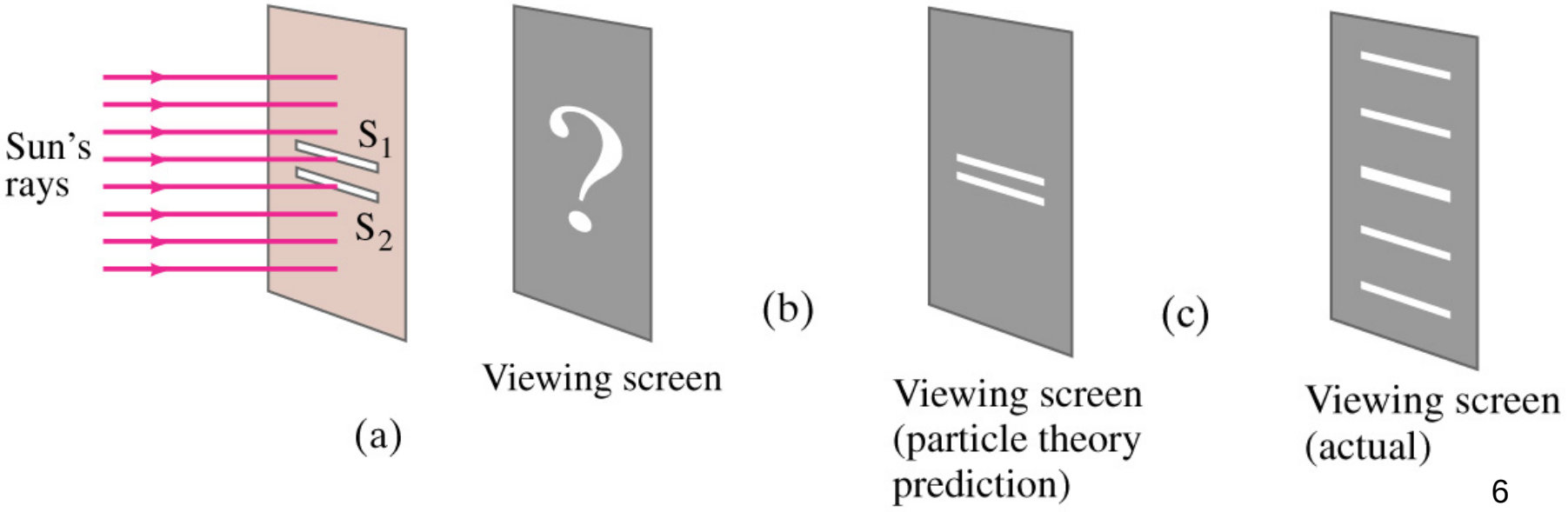
Diffraction: Single Slit

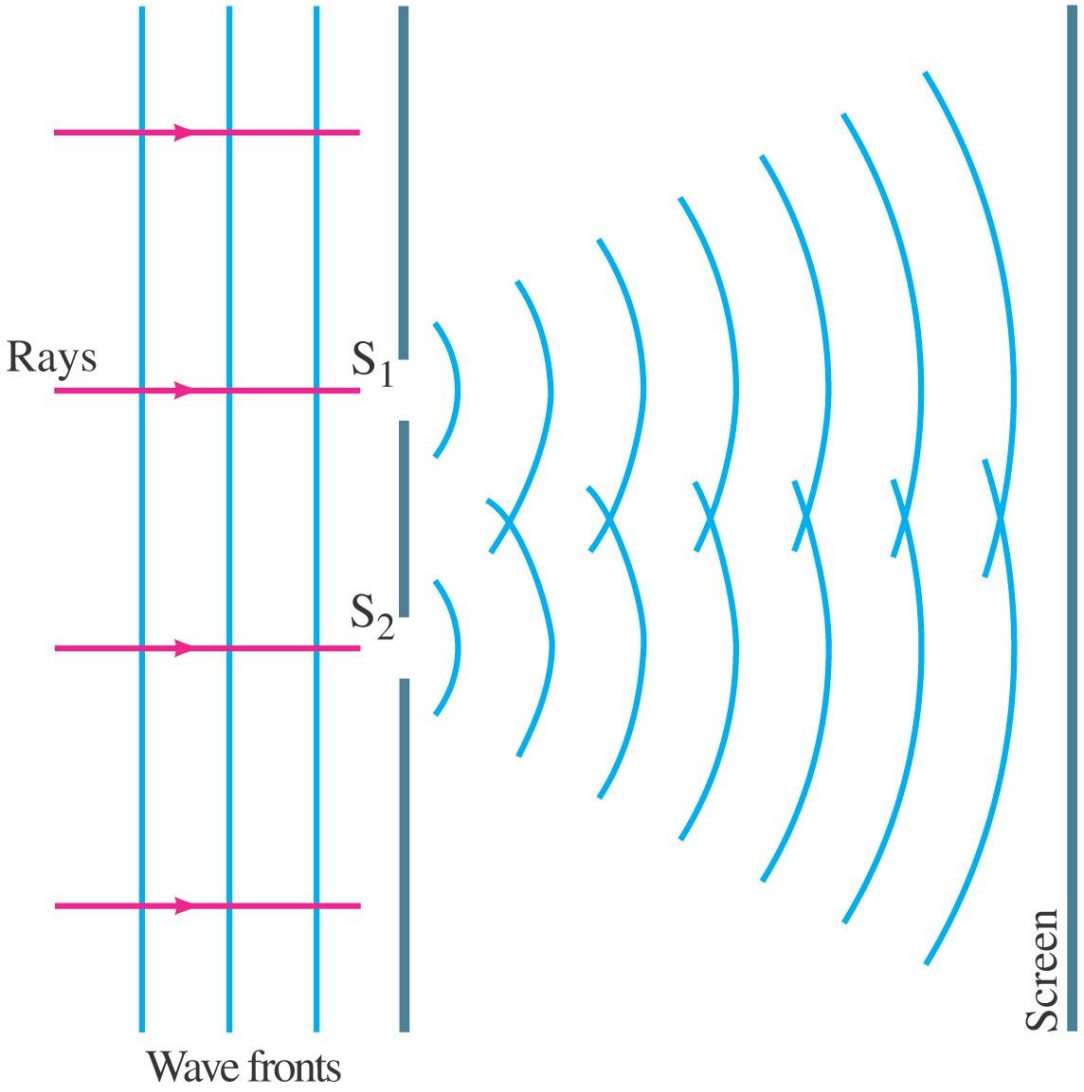
[single slit diffraction]

24.3 Interference – Young's Double-Slit Experiment

If light is a wave, interference effects will be seen, where one part of wavefront can interact with another part.

The interference pattern that resulted was proof of wave not particle nature of light

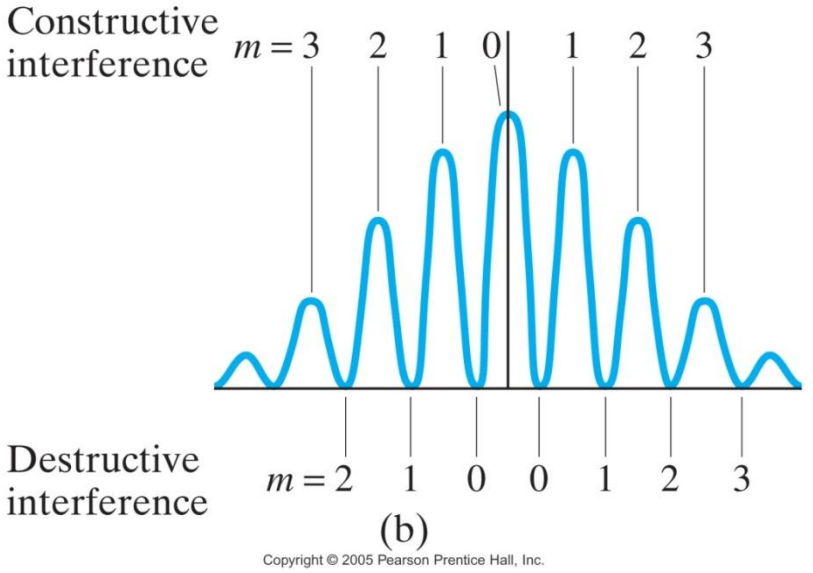


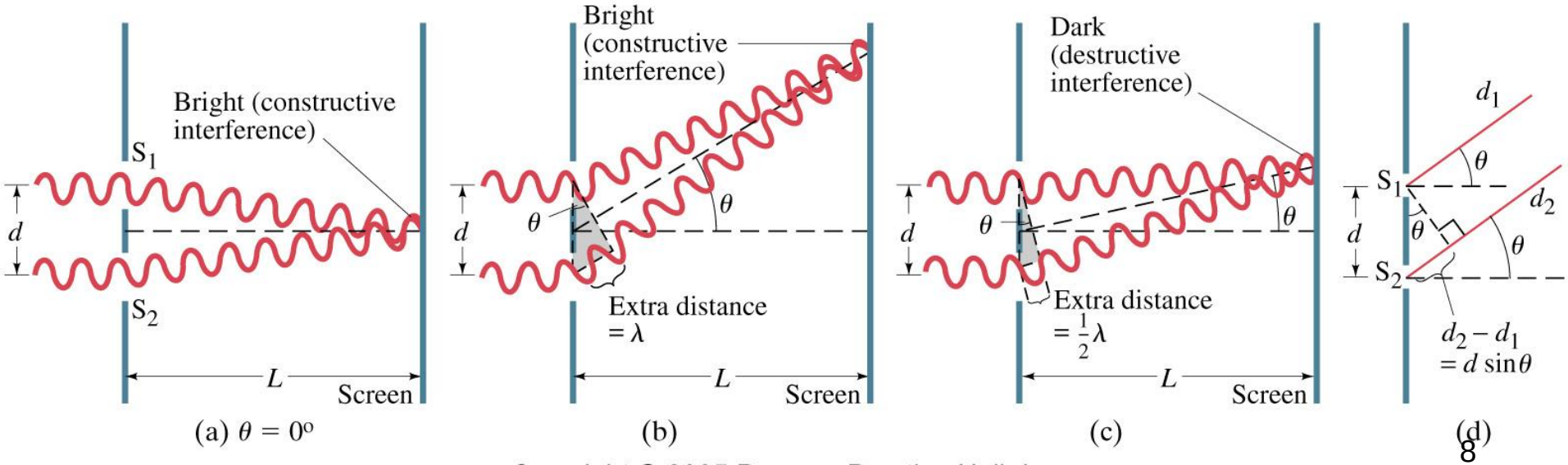


If light is a wave, there should be an interference pattern which is a set of alternating bright and dark lines on the screen.

Formation of an interference pattern

The interference occurs because each point on the screen is not the same distance from both slits. Depending on the path length difference, the wave can interfere constructively (bright spot) or destructively (dark spot).





24.3 Interference – Young's Double-Slit Experiment

We can use geometry to find the conditions for constructive and destructive interference:

$$d \sin\theta = m\lambda, \qquad m = 0, 1, 2, \cdots. \qquad \text{(24-2a)}$$

[constructive interference (bright)]

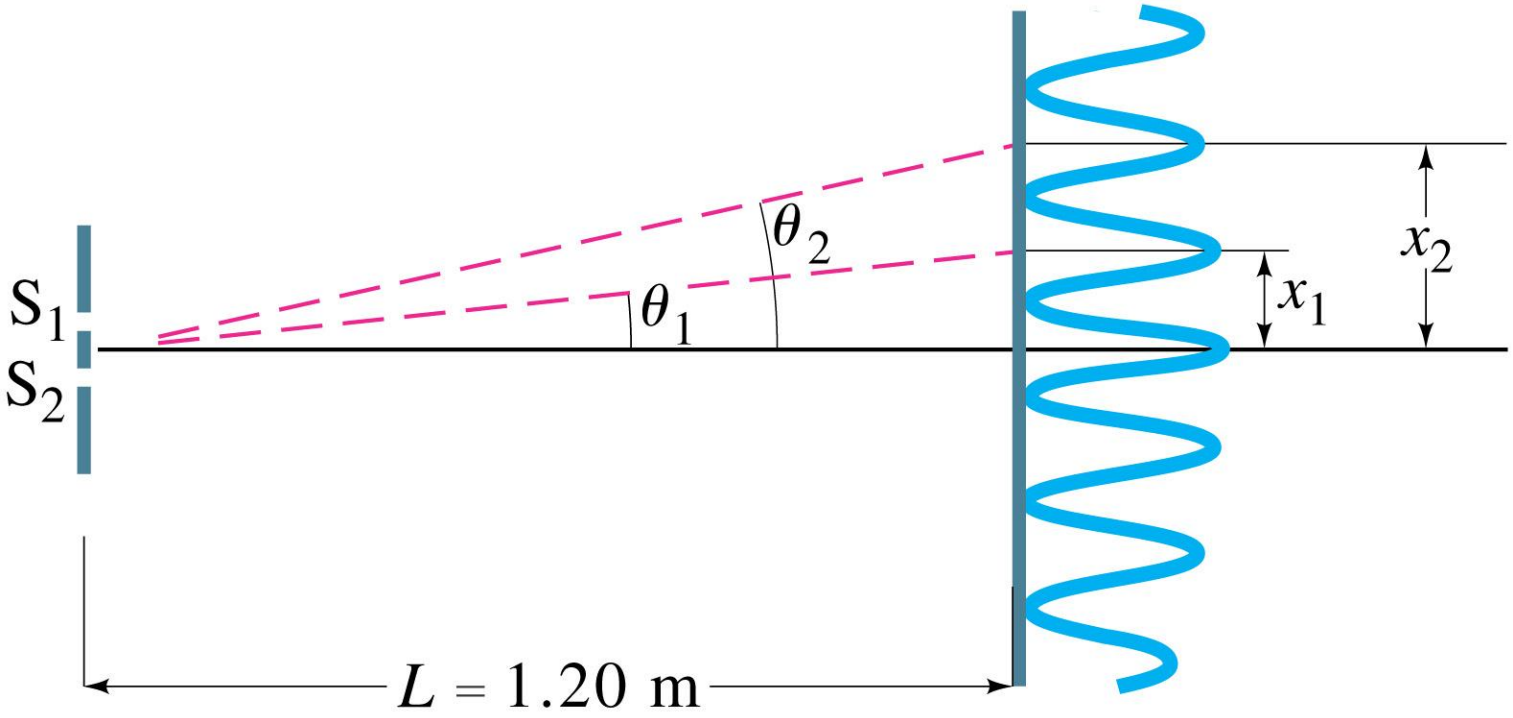
$$d \sin\theta = \left(m + \tfrac{1}{2}\right)\lambda, \qquad m = 0, 1, 2, \cdots. \qquad \text{(24-2b)}$$

[destructive interference (dark)]

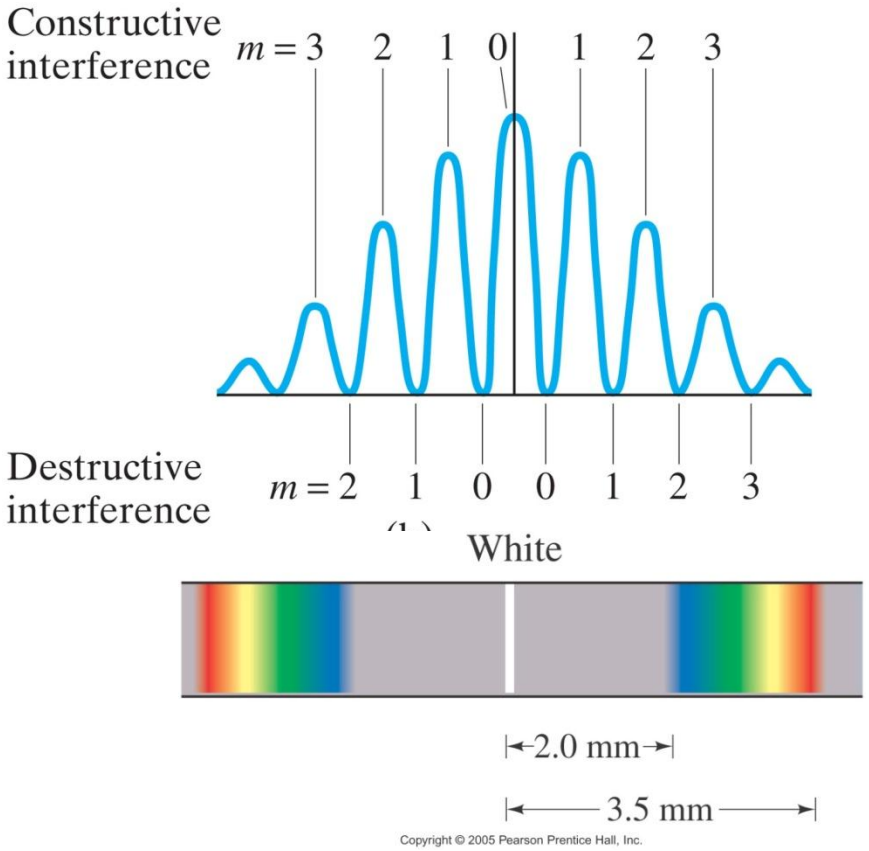
Angle θ is a very small angle so:

$$\sin\theta \approx \tan\theta = \frac{x}{L}$$

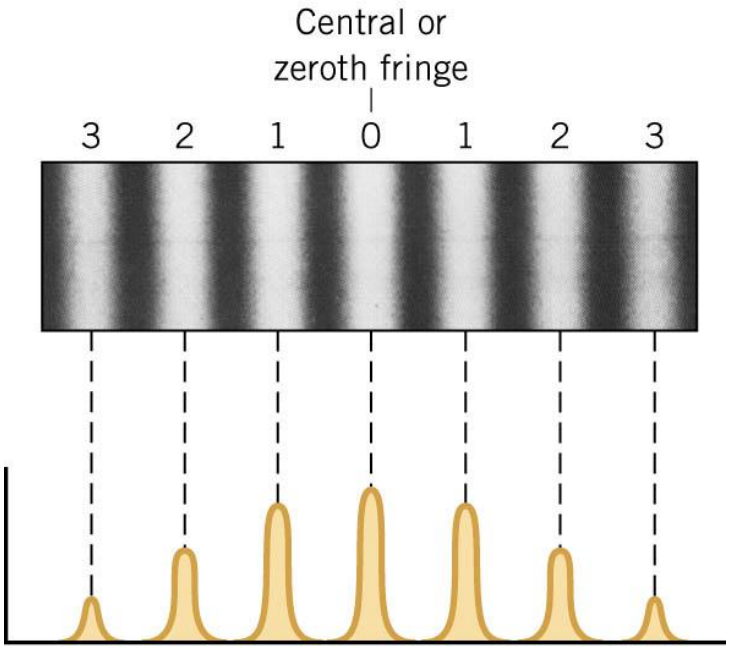
$$d\sin\theta = d\left(\frac{x}{L}\right) = m\lambda$$



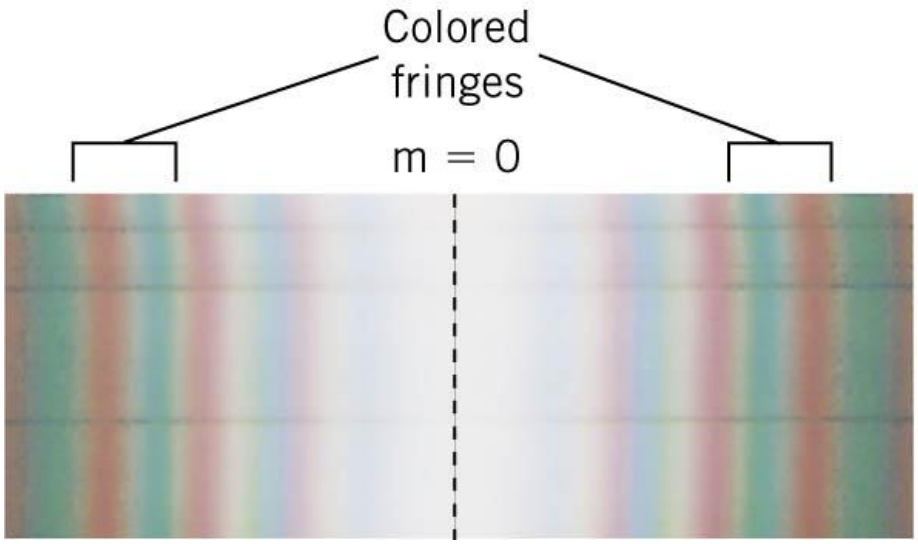
m is the number of the order of the higher fringes from the bright central maximum



Since the position of the maxima (except the central one) depends on wavelength, the first- and higher-order fringes contain a spectrum of colors.



monochromatic light

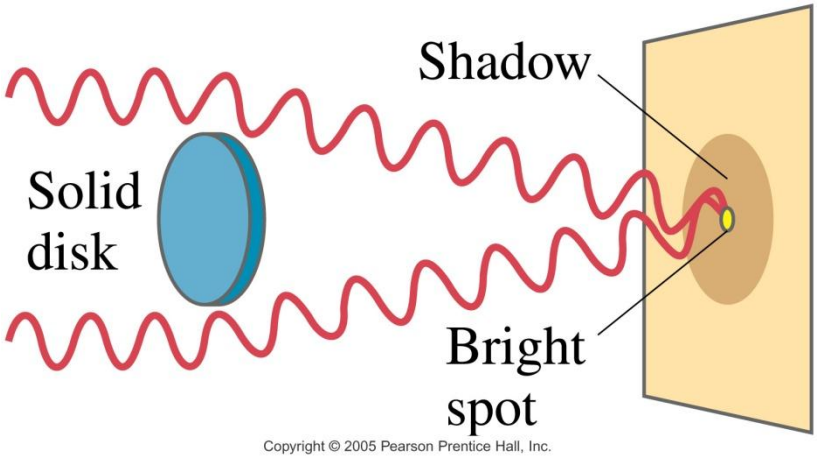


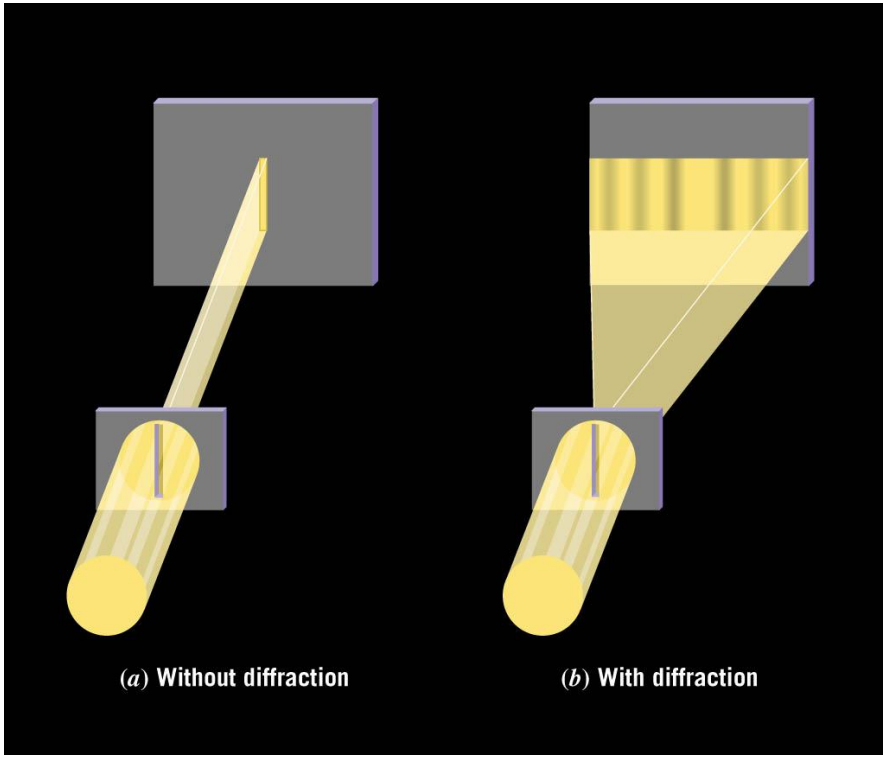
white light

Young's experiment

24.5 Diffraction by a Single Slit or Disk

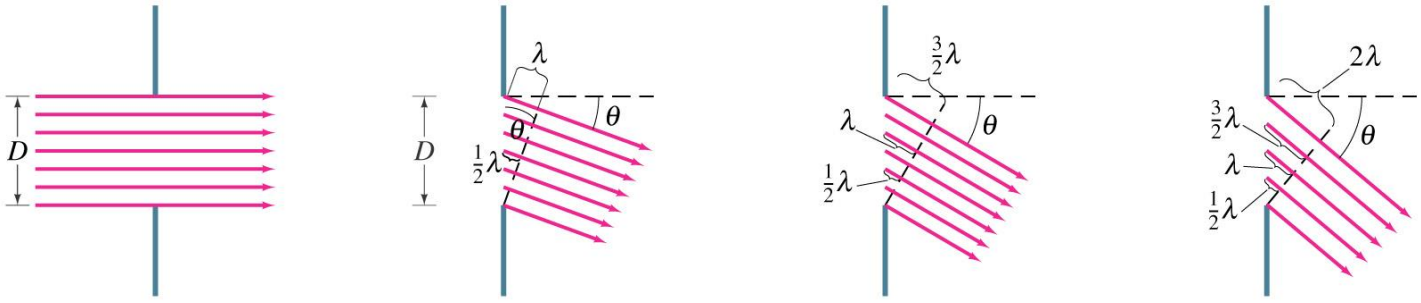
Light will also diffract through a single slit or around an obstacle.

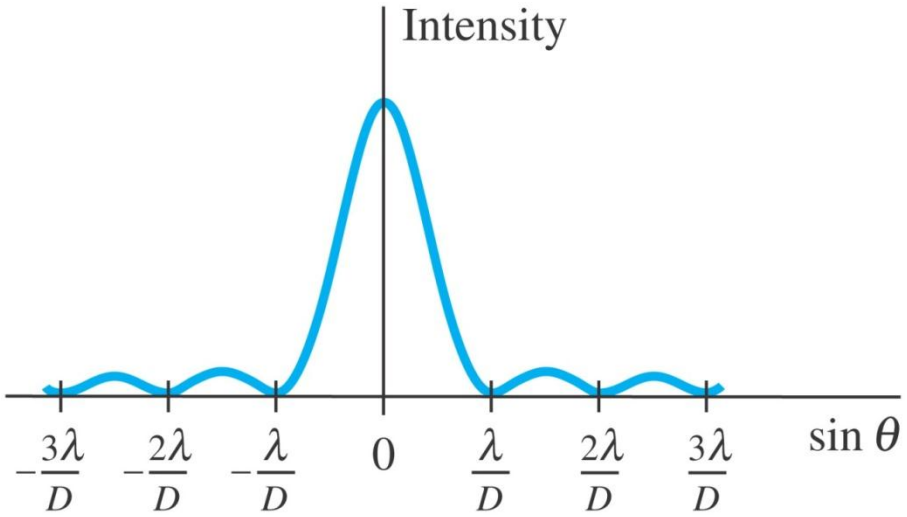




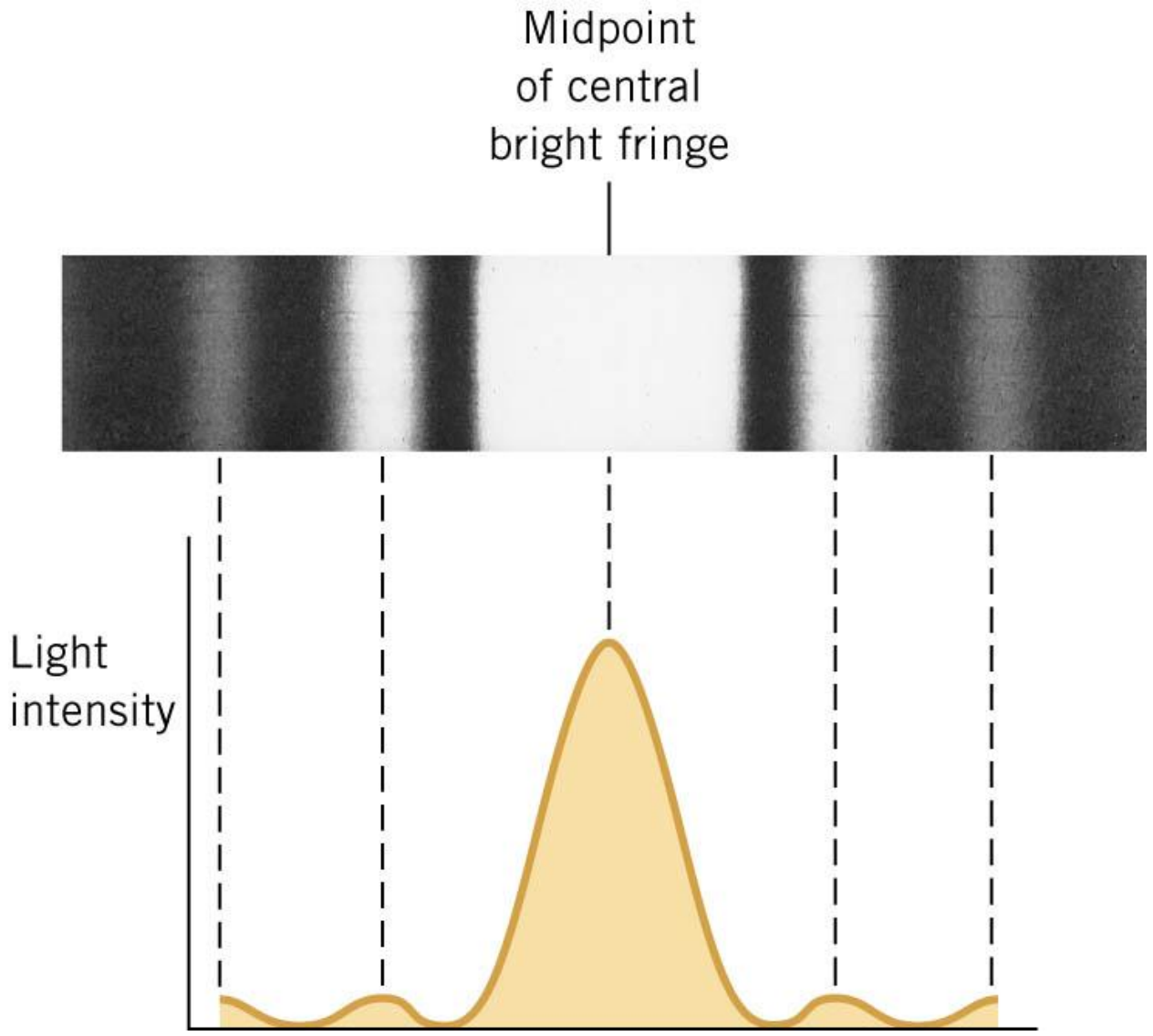
24.5 Diffraction by a Single Slit or Disk

The resulting pattern of light and dark stripes is called a diffraction pattern.





Pattern has a wide, very bright central maximum with weak higher order fringes.



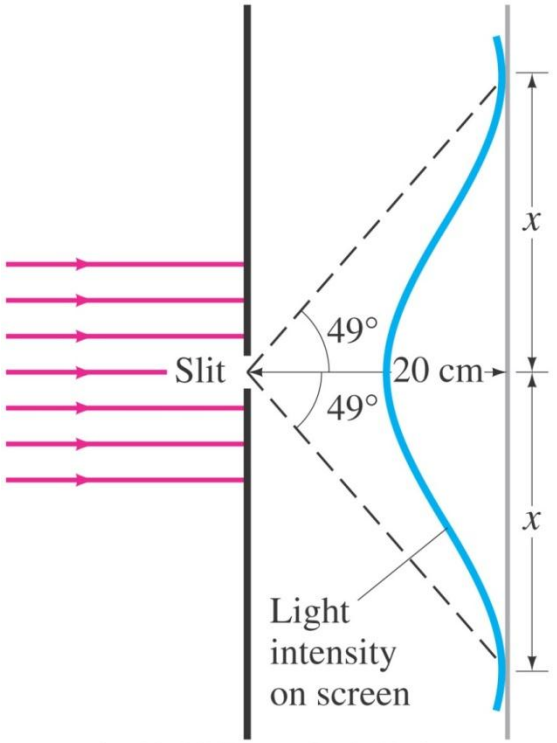
single slit diffraction

The minima of the single-slit diffraction pattern occur when

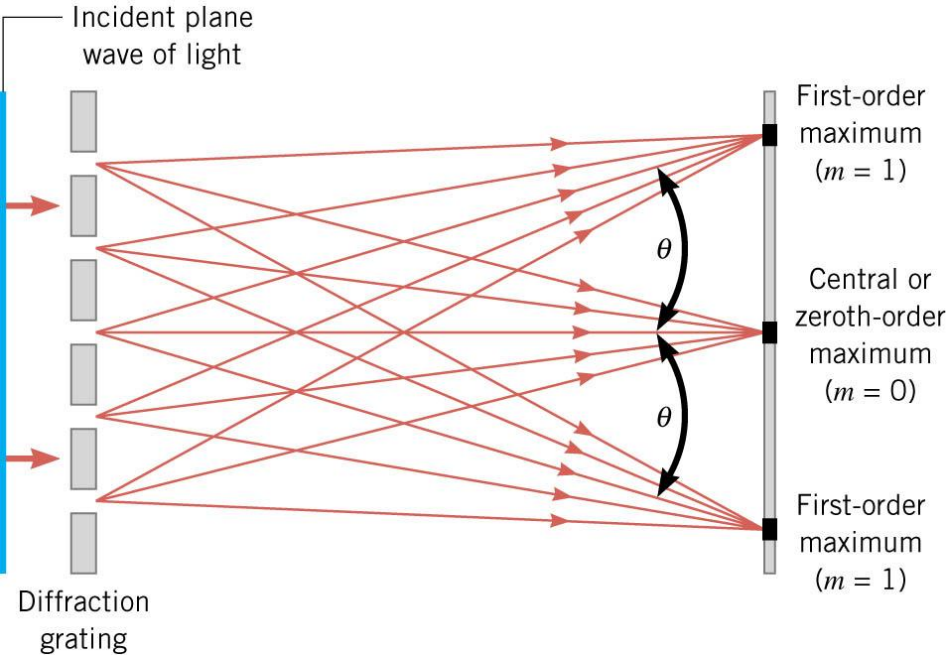
$$D \sin\theta = m\lambda, \qquad m = 1, 2, 3, \cdots$$

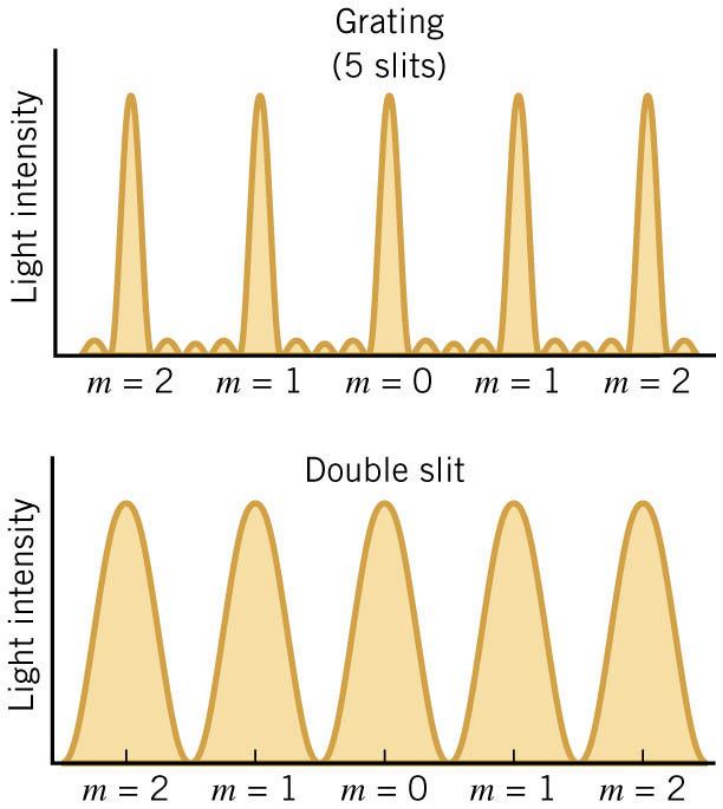
can't use sin θ = tan θ because θ is large

use tan θ = x/L to get width of maxima



24.6 Diffraction Grating





$$m\lambda = d\sin\theta \quad m = 1, 2, 3..$$

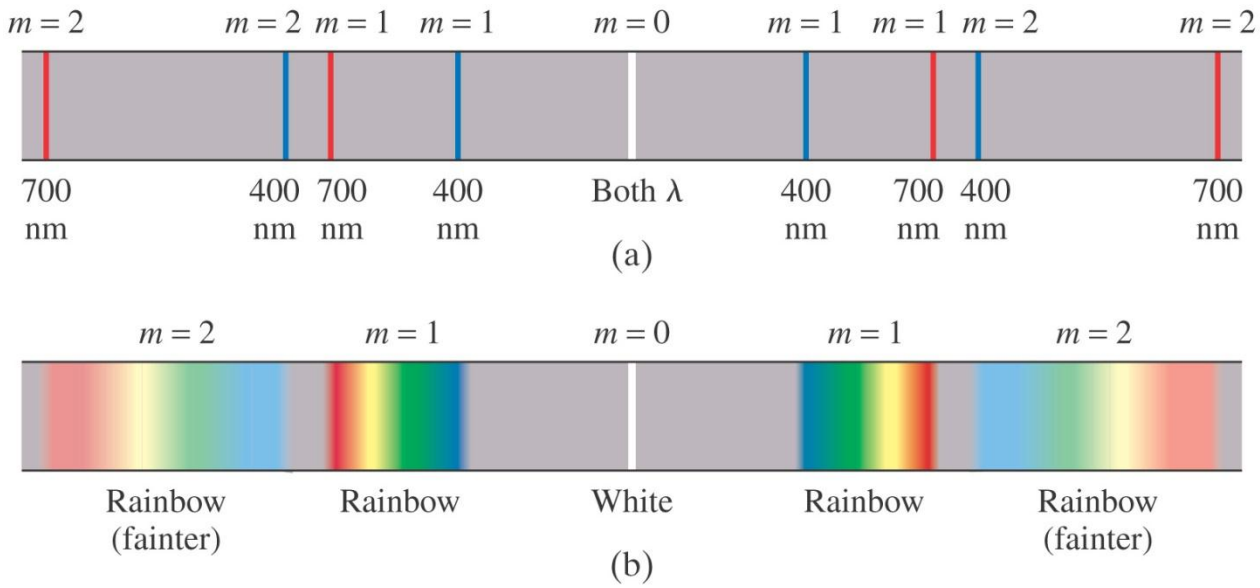
$$d = \frac{1}{N} \quad N = lines/cm$$

diffraction gratings

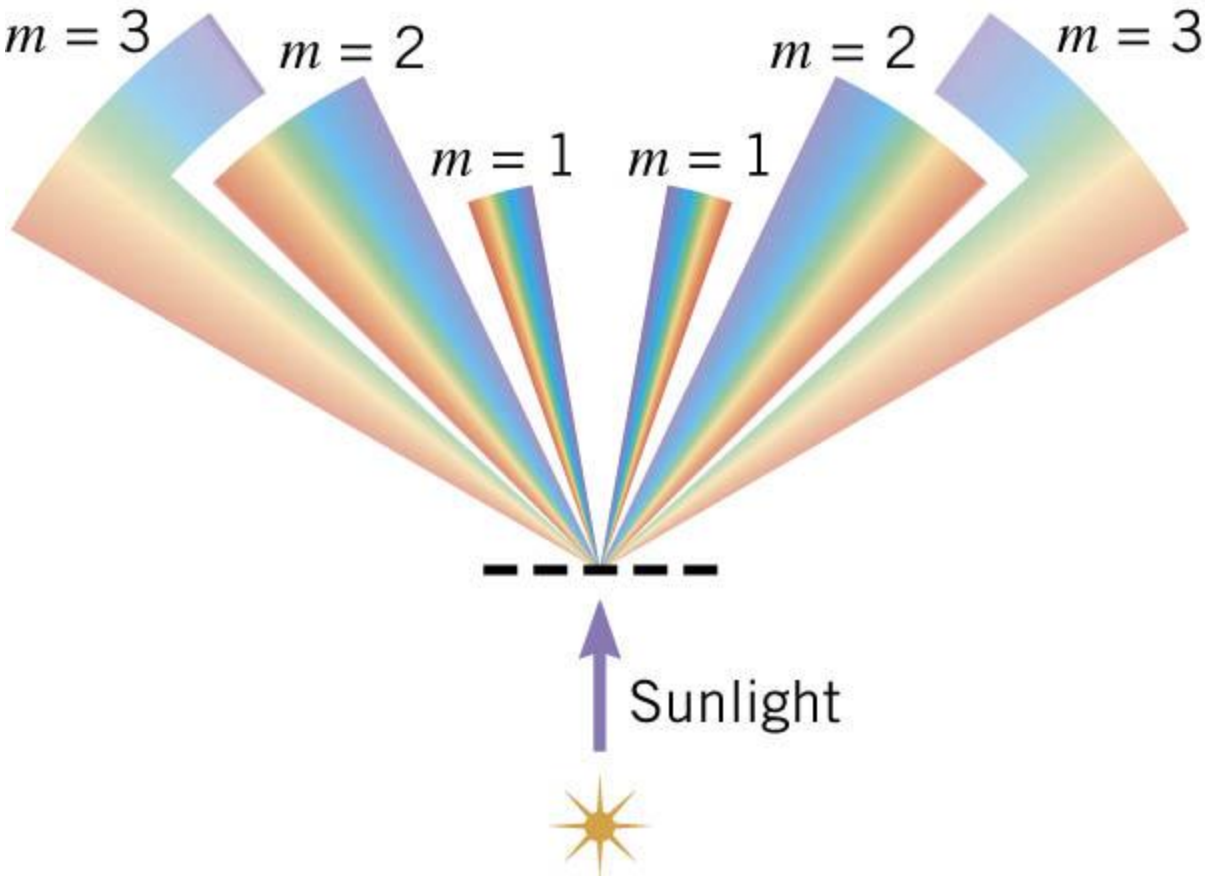
24.6 Diffraction Grating

The maxima of the diffraction pattern are defined by

$$\sin\theta = \frac{m\lambda}{d}, \qquad m = 0, 1, 2, \qquad \textbf{(24-4)}$$



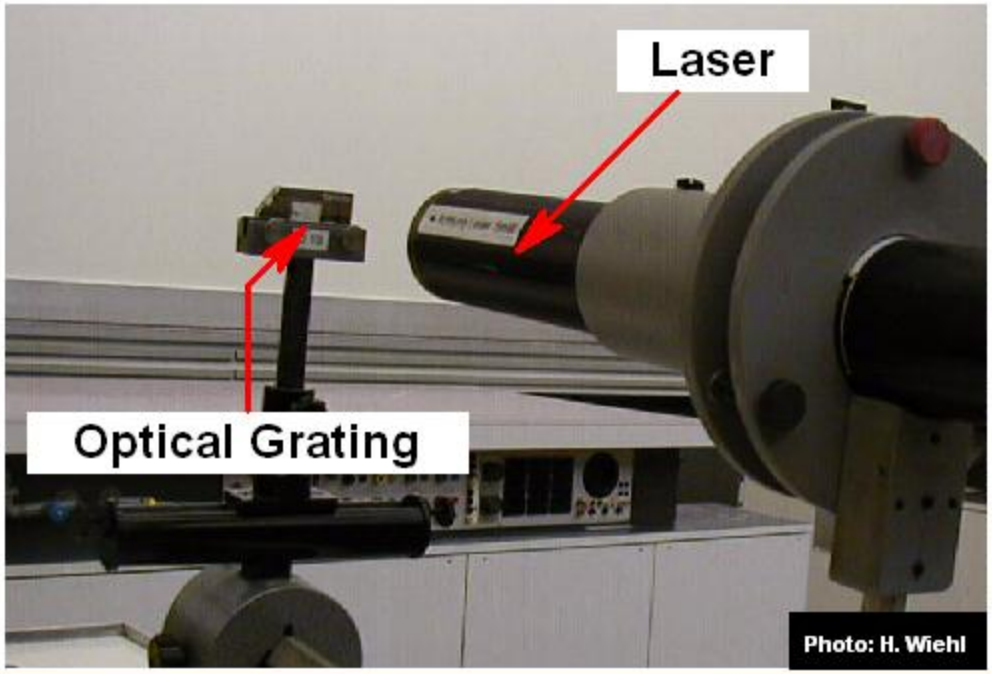
Interference pattern from diffraction gratings



Diffraction on an Optical Grating With Laser Light

Wave / Diffraction

Video: H. Wiehl



Diffraction on a Grating with Laser

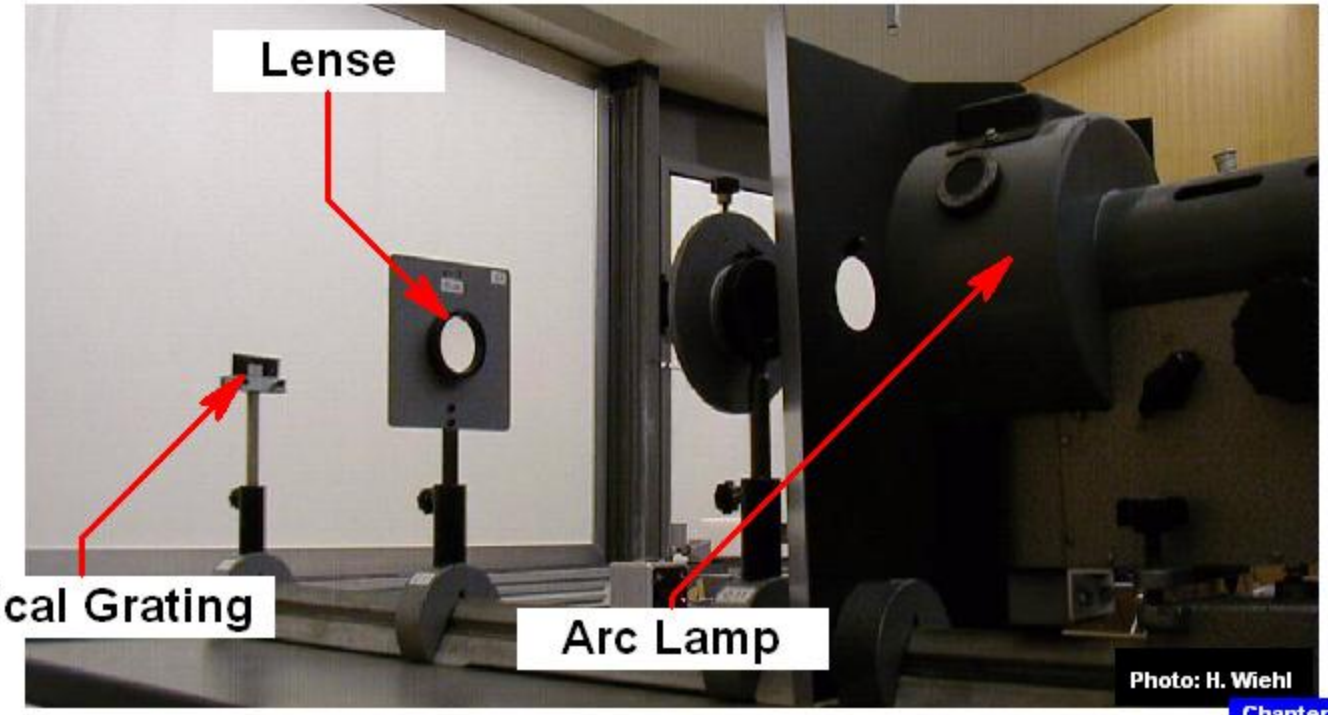
Chapter 3 Section 2

[diffraction with laser]

Diffraction of White Light on an Optical Grating

Wave / Diffraction

Video: H. Wiehl



Diffraction of White Light

Chapter 3 Section 2

[diffraction with white light]