Diffraction patterns and polarization

- Introduction to diffraction patterns
- Diffraction patterns from narrow slits
- Resolution of single-slit and circular apertures
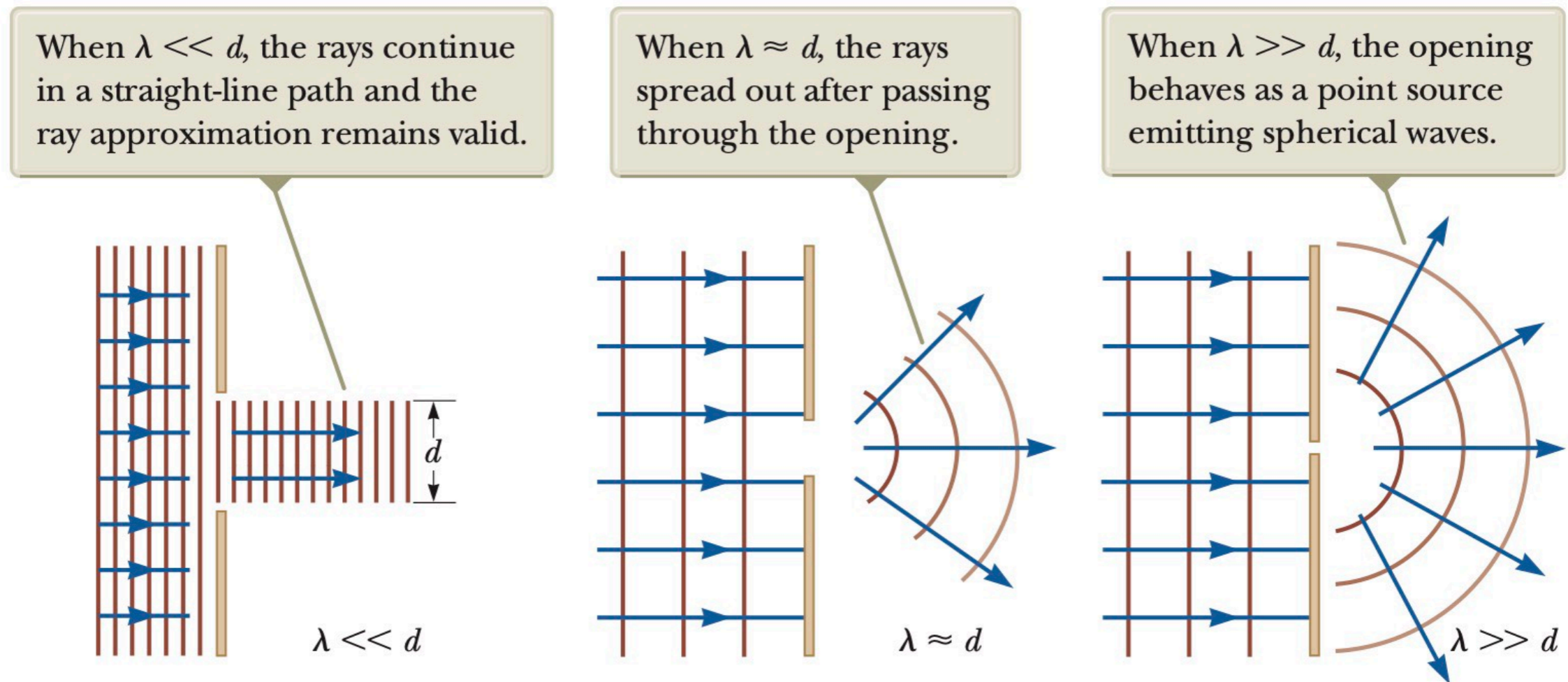- The diffraction grating
- Polarization of light waves

Phat Srimanobhas (phat.s@cern.ch)
https://twiki.cern.ch/twiki/bin/view/Main/PhatSrimanobhasTeaching
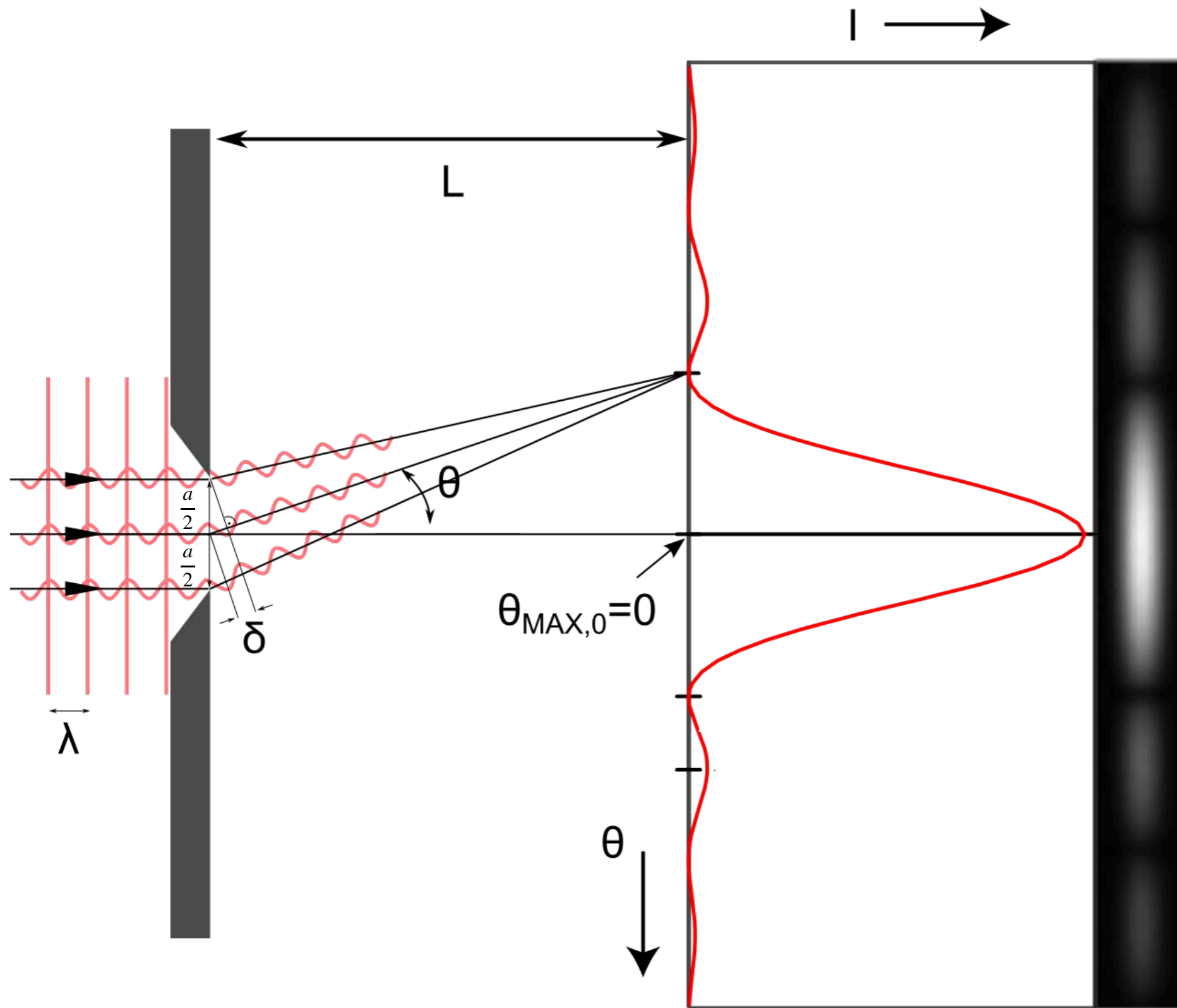
Diffraction

When light passes through a narrow slit, it spreads beyond the narrow path defined by the slit into regions that would be in shadow if light traveled in straight lines. This phenomenon is called **diffraction**.

When $\lambda \ll d$, the rays continue in a straight-line path and the ray approximation remains valid.

When $\lambda \approx d$, the rays spread out after passing through the opening.

When $\lambda \gg d$, the opening behaves as a point source emitting spherical waves.

$\lambda \ll d$

$\lambda \approx d$

$\lambda \gg d$

Fraunhofer diffraction: all light rays are approximately parallel to each other. We consider situation with long distance from the diffracting object.
Fresnel diffraction: the diffraction pattern created near the object.
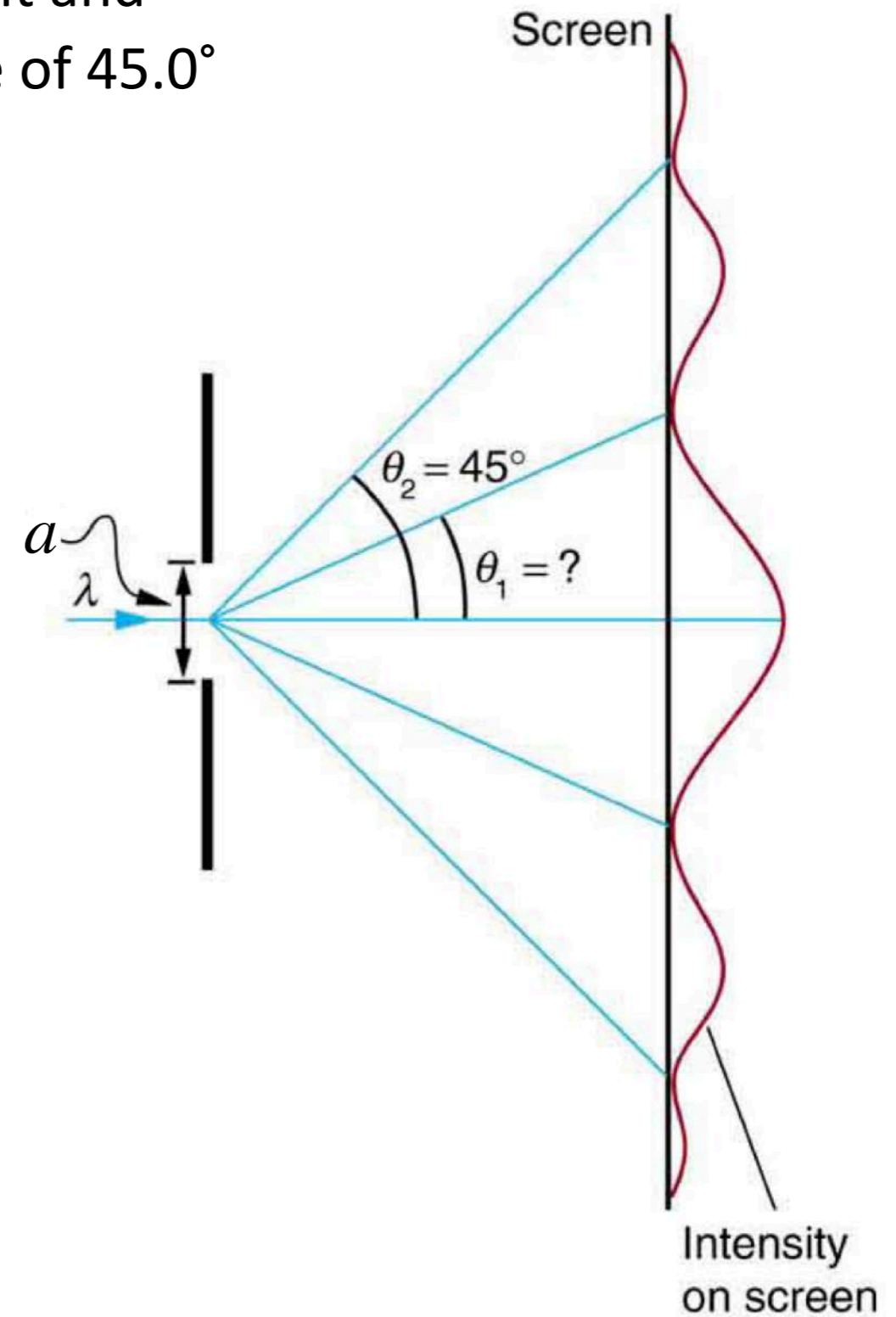
A single-slit diffraction

General condition for destructive interference:

Exercise

Visible light of wavelength 550 nm falls on a single slit and produces its second diffraction minimum at an angle of 45.0° relative to the incident direction of the light.
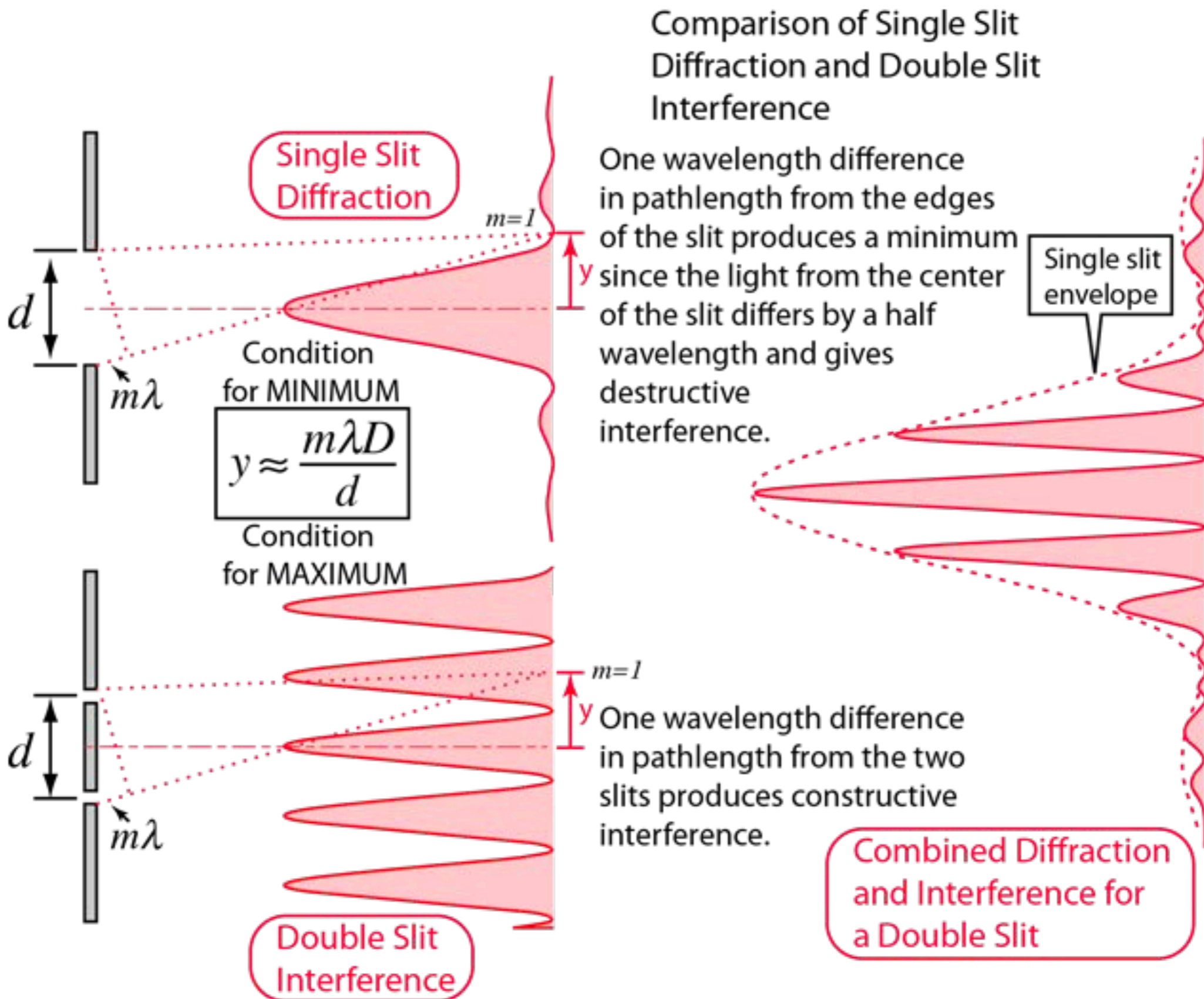
(A) What is the width of the slit?
(B) At what angle is the first minimum produced?

Exercise

A screen is placed 50.0 cm from a single slit, which is illuminated with light of wavelength 690 nm. If the distance between the first and third minima in the diffraction pattern is 3.00 mm, what is the width of the slit?

Intensity of two-slit diffraction patterns

Single Slit Diffraction

Condition for MINIMUM

$$y \approx \frac{m\lambda D}{d}$$

Condition for MAXIMUM

Double Slit Interference

Comparison of Single Slit Diffraction and Double Slit Interference

One wavelength difference in pathlength from the edges of the slit produces a minimum since the light from the center of the slit differs by a half wavelength and gives destructive interference.

Single slit envelope

One wavelength difference in pathlength from the two slits produces constructive interference.

Combined Diffraction and Interference for a Double Slit

Intensity of two-slit diffraction patterns

The diffraction pattern acts as an "envelope" (the blue dashed curve) that controls the intensity of the regularly spaced interference maxima.

Interference fringes

Diffraction minima

The combined effects of two-slit and single-slit interference. This pattern is produced when 650-nm light waves pass through two 3.0-μm slits that are 18-μm apart.
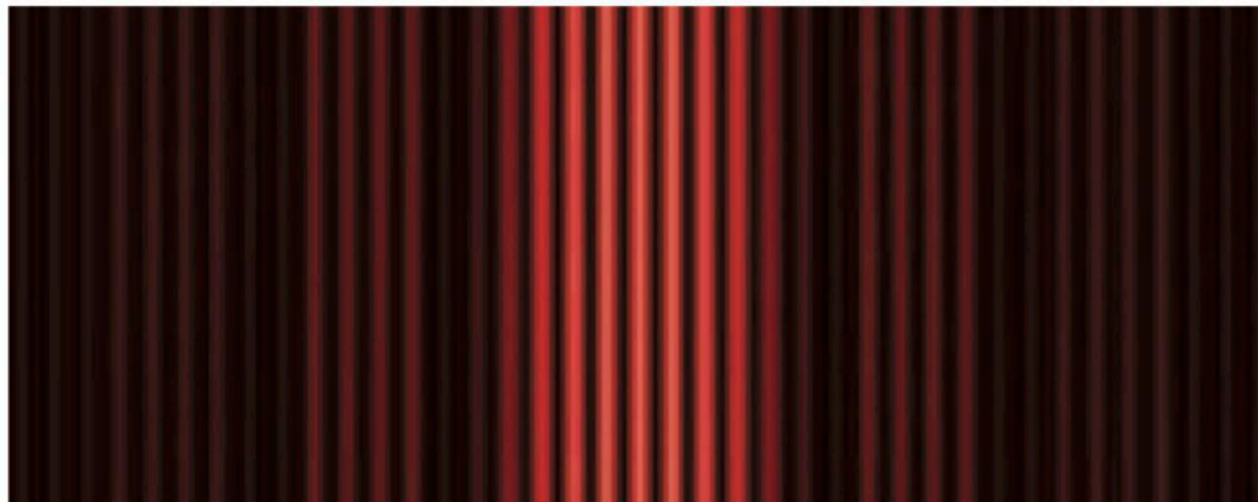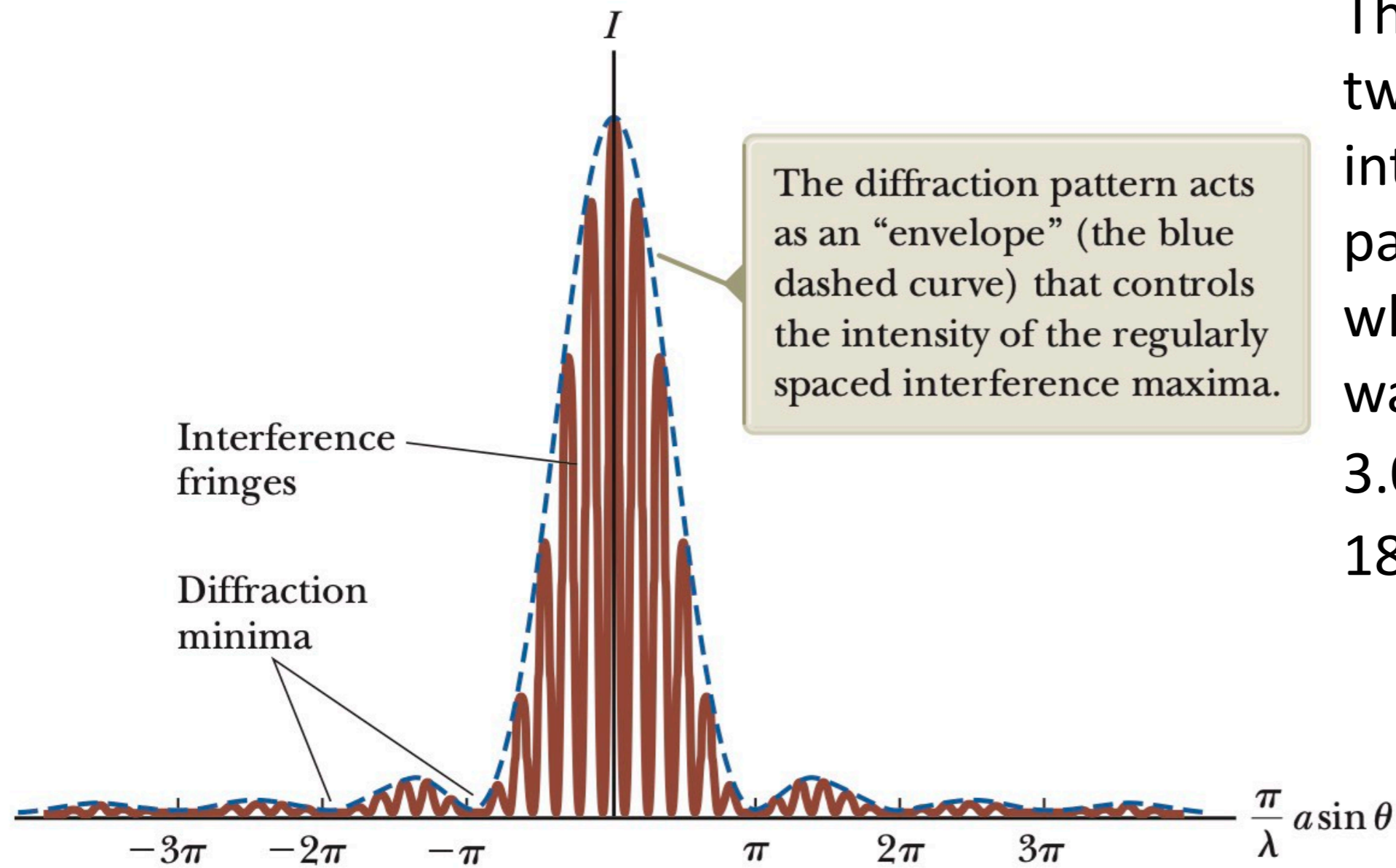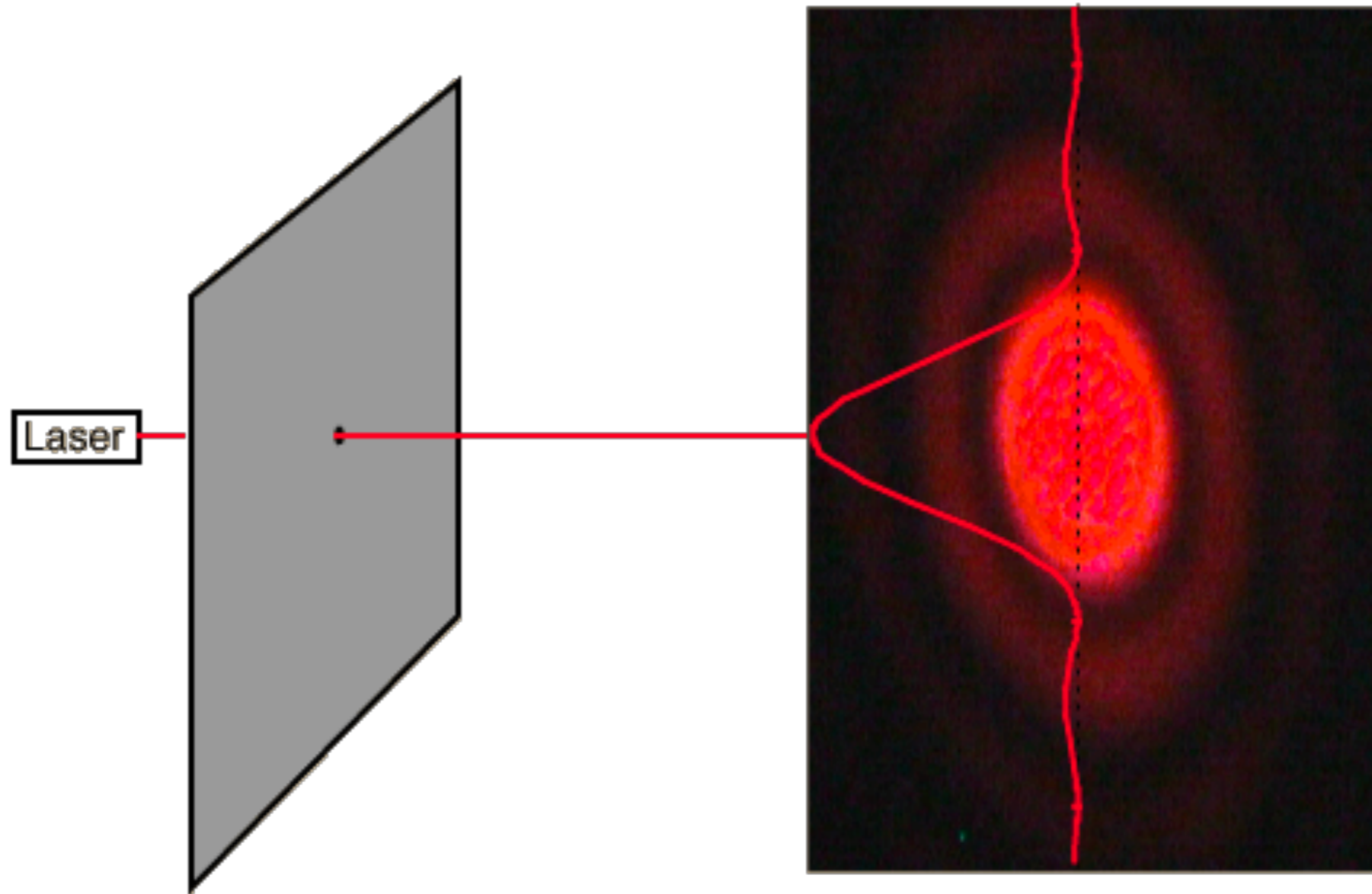
Exercise

In a double-slit experiment, the wavelength of the light source is 405 nm, the slit separation is 19.44 μm, and the slit width is 4.050 μm. Consider the interference of the light from the two slits and also the diffraction of the light through each slit. How many bright interference fringes are within the central peak of the diffraction envelope?
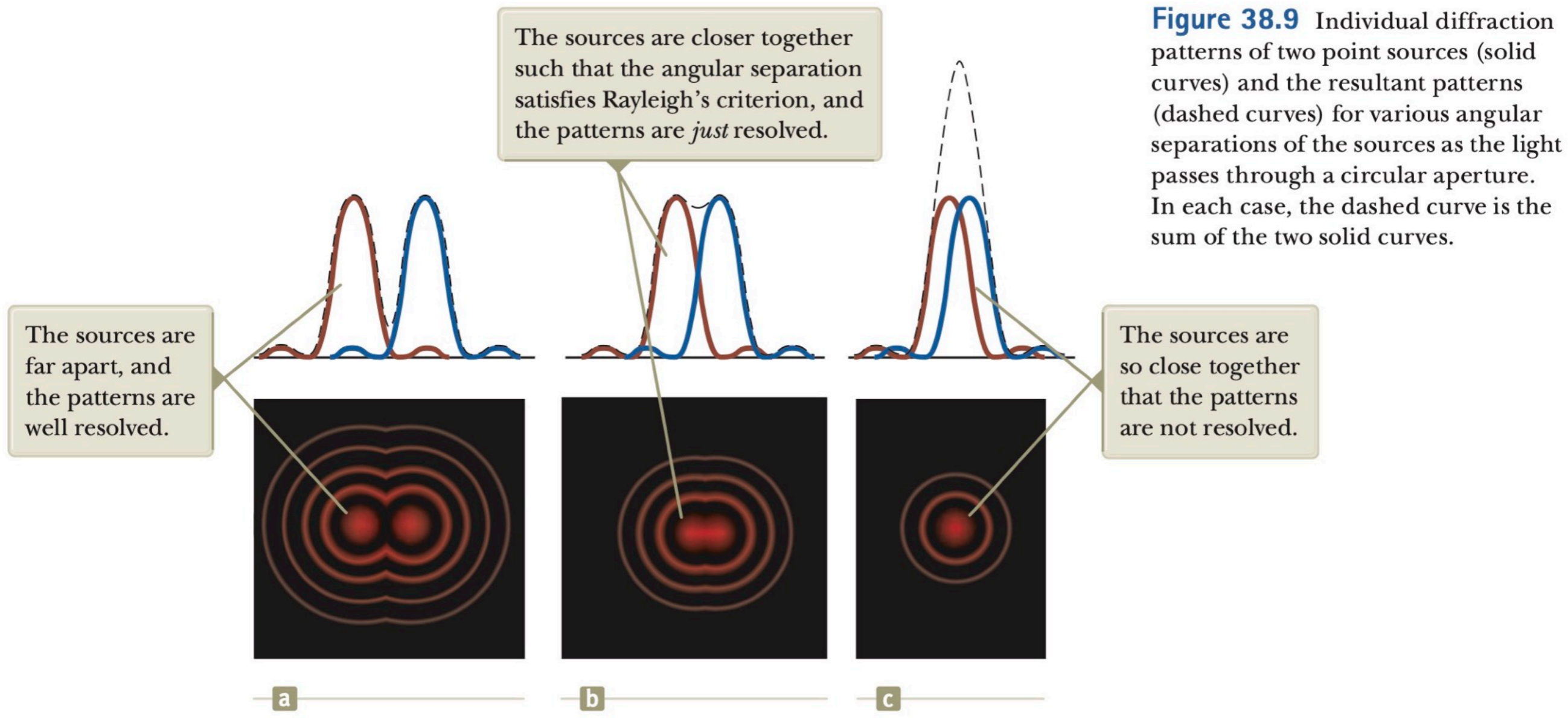
Circular apertures and resolution

When light from a point source passes through a small circular aperture, it does not produce a bright dot as an image, but rather a diffuse circular disc known as **Airy's disc** surrounded by much fainter concentric circular rings.

Circular apertures and resolution

When the central maximum of one image falls on the first minimum of another image, the images are said to be just resolved. This limiting condition of resolution is known as **Rayleigh's criterion**.

The sources are closer together such that the angular separation satisfies Rayleigh's criterion, and the patterns are *just* resolved.

Figure 38.9 Individual diffraction patterns of two point sources (solid curves) and the resultant patterns (dashed curves) for various angular separations of the sources as the light passes through a circular aperture. In each case, the dashed curve is the sum of the two solid curves.

The sources are far apart, and the patterns are well resolved.

The sources are so close together that the patterns are not resolved.

a

b

c

Exercise

The angular resolution of a radio telescope is to be 0.100° when the incident waves have a wavelength of 3.00 mm. What minimum diameter is required for the telescope's receiving dish?

Exercise

A circular radar antenna on a Coast Guard ship has a diameter of 2.10 m and radiates at a frequency of 15.0 GHz. Two small boats are located 9.00 km away from the ship. How close together could the boats be and still be detected as two objects?