

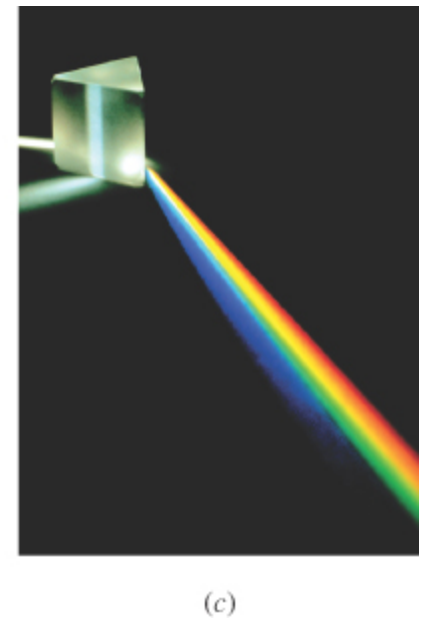
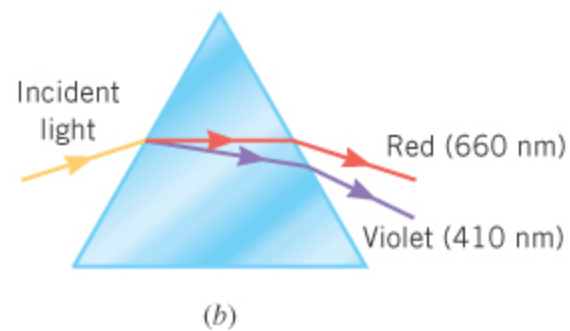
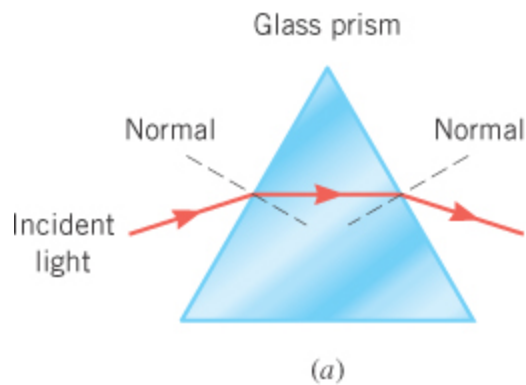
Chapter 24

Interference and the Wave Nature of Light

The Dispersion of Light: Prisms and Rainbows

The net effect of a prism is to change the direction of a light ray.

Light rays corresponding to different colors bend by different amounts.



The Dispersion of Light: Prisms and Rainbows

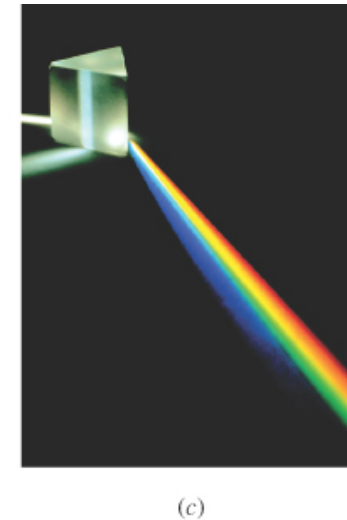
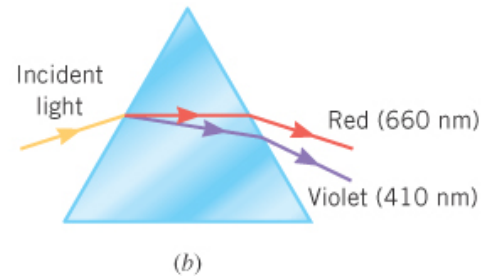
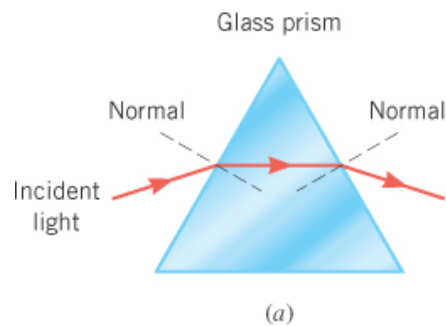
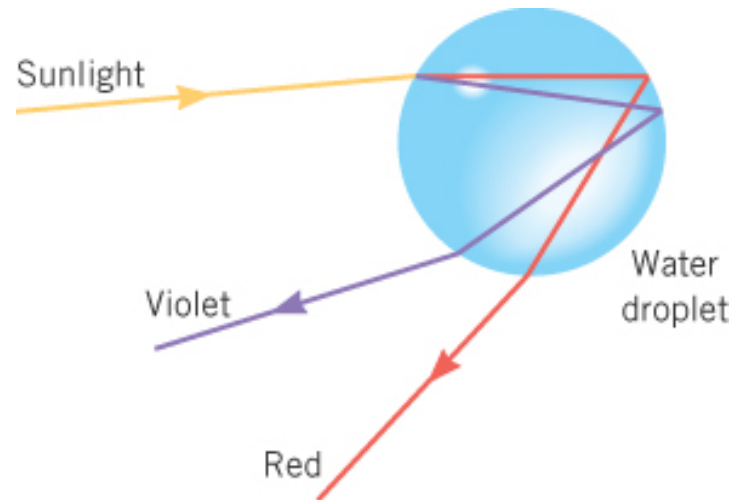


Table 26.2 Indices of Refraction n of Crown Glass at Various Wavelengths

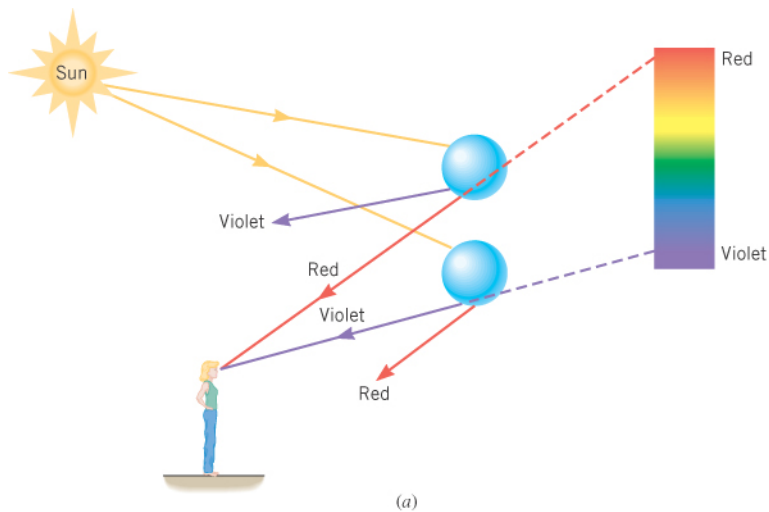
Approximate Color	Wavelength in Vacuum (nm)	Index of Refraction, n
Red	660	1.520
Orange	610	1.522
Yellow	580	1.523
Green	550	1.526
Blue	470	1.531
Violet	410	1.538

The Dispersion of Light: Prisms and Rainbows

When sunlight emerges from a water droplet, the light is dispersed into its constituent colors.



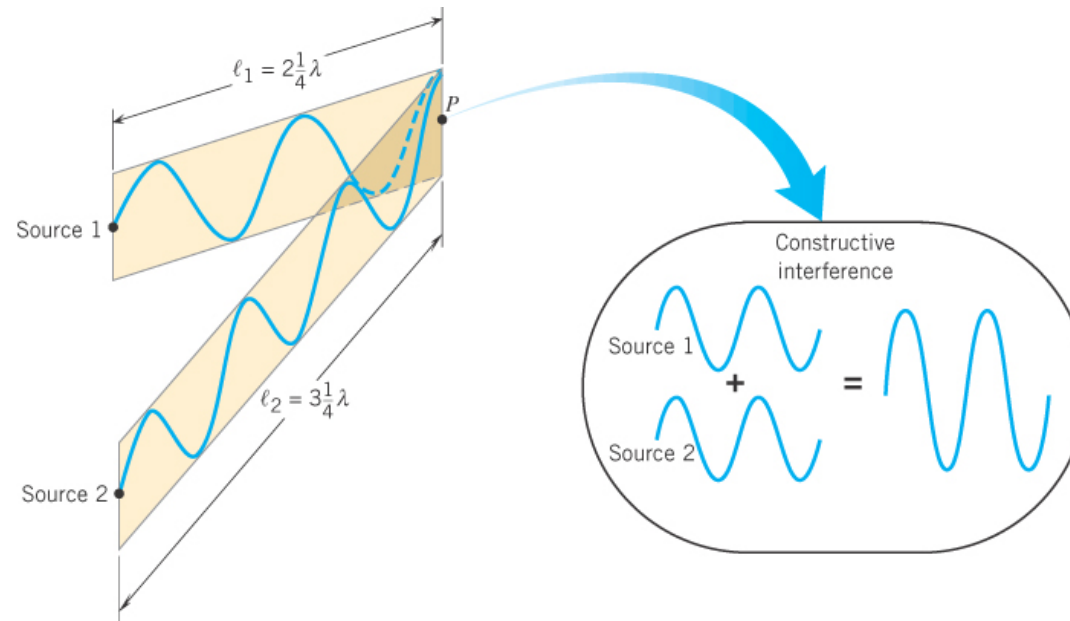
The different colors seen in a rainbow originate from water droplets at different angles of elevation.



(b)

The Principle of Linear Superposition

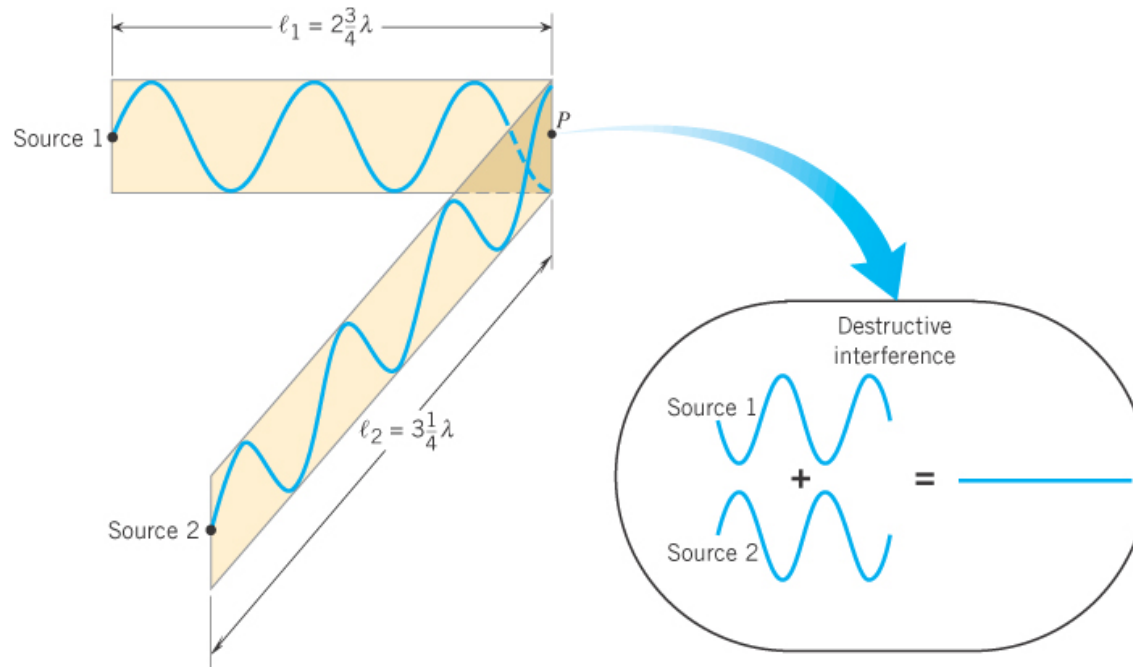
When two or more light waves pass through a given point, their electric fields combine according to the principle of superposition.



The waves emitted by the sources start out in phase and arrive at point P in phase, leading to **constructive interference**.

$$\ell_2 - \ell_1 = m\lambda \quad m = 0, 1, 2, 3, \dots$$

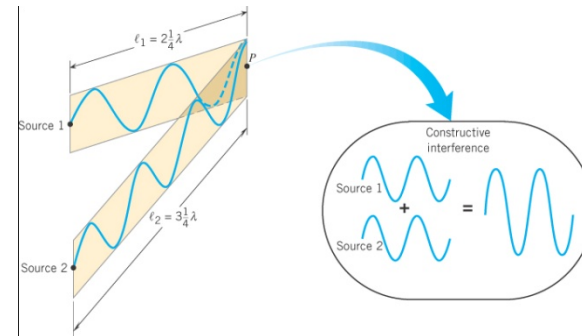
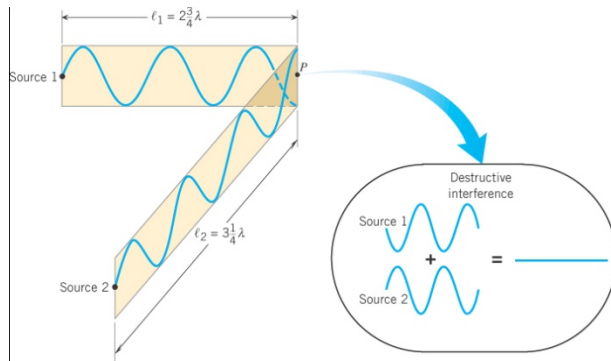
The Principle of Linear Superposition



The waves emitted by the sources start out in phase and arrive at point P out of phase, leading to **destructive interference**.

$$\ell_2 - \ell_1 = \left(m + \frac{1}{2}\right)\lambda \quad m = 0, 1, 2, 3, \dots$$

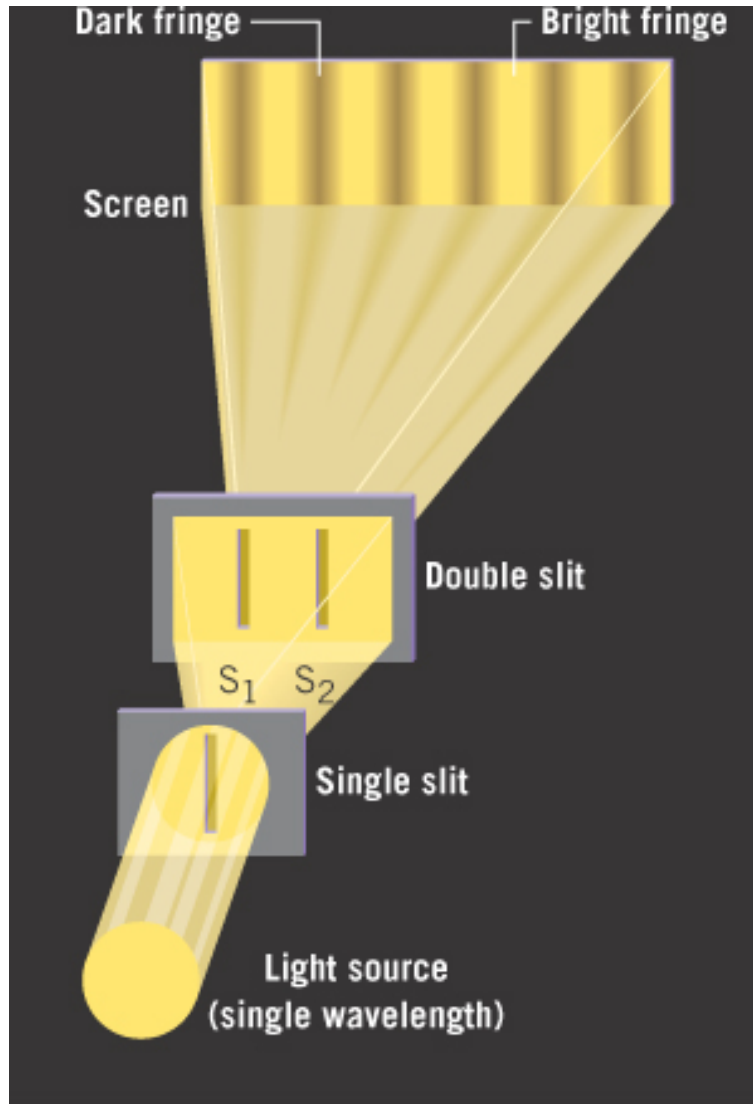
The Principle of Linear Superposition



If constructive or destructive interference is to continue occurring at a point, the sources of the waves must be **coherent sources**.

Two sources are coherent if the waves they emit maintain a constant phase relation.

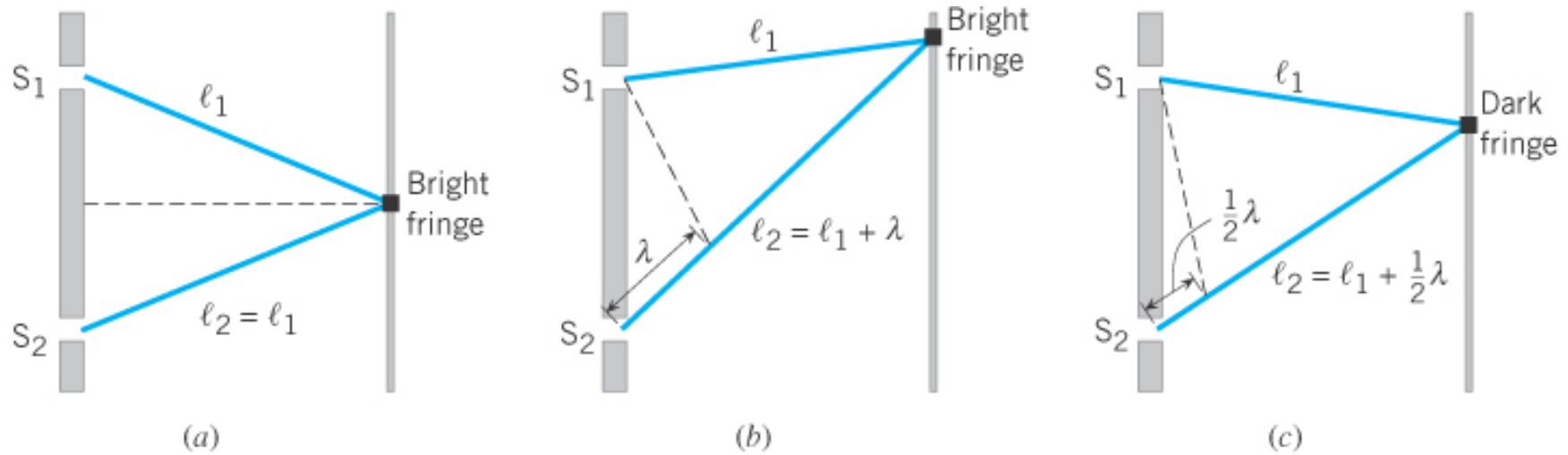
Young's Double Slit Experiment



In Young's experiment, two slits act as coherent sources of light.

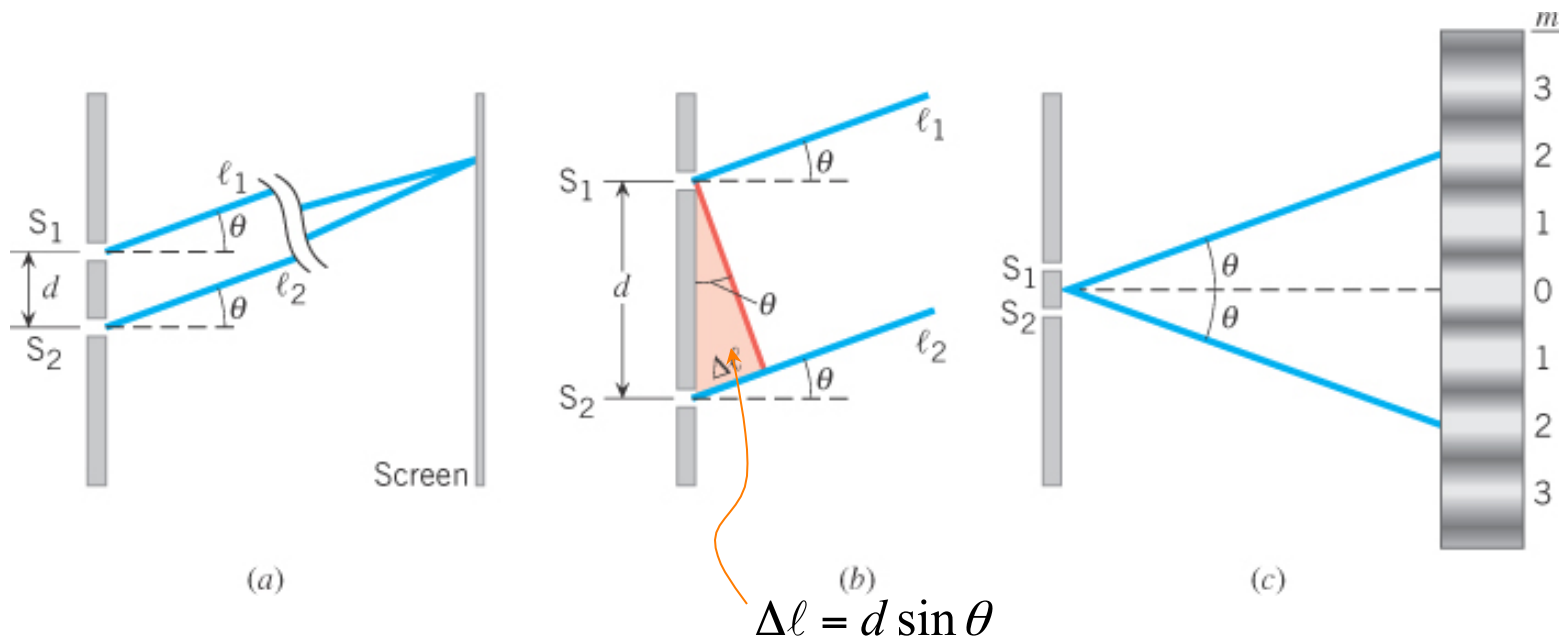
Light waves from these slits interfere constructively and destructively on the screen.

Young's Double Slit Experiment



The waves coming from the slits interfere constructively or destructively, depending on the difference in distances between the slits and the screen.

Young's Double Slit Experiment



**Bright fringes
of a double-slit**

$$\sin \theta = m \frac{\lambda}{d} \quad m = 0, 1, 2, 3, \dots$$

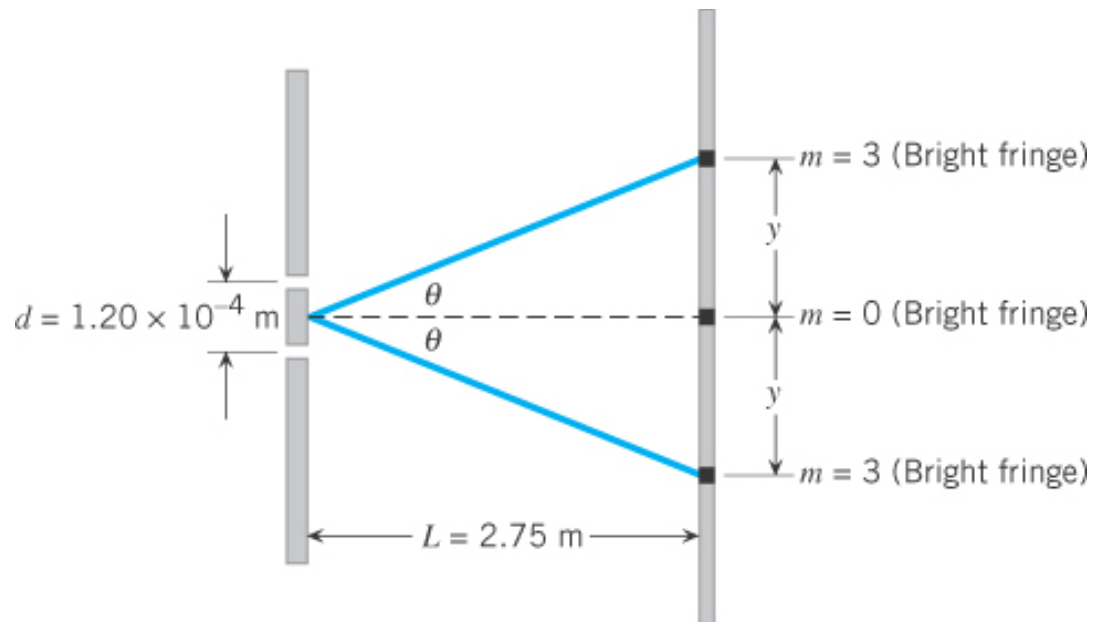
**Dark fringes
of a double-slit**

$$\sin \theta = \left(m + \frac{1}{2}\right) \frac{\lambda}{d} \quad m = 0, 1, 2, 3, \dots$$

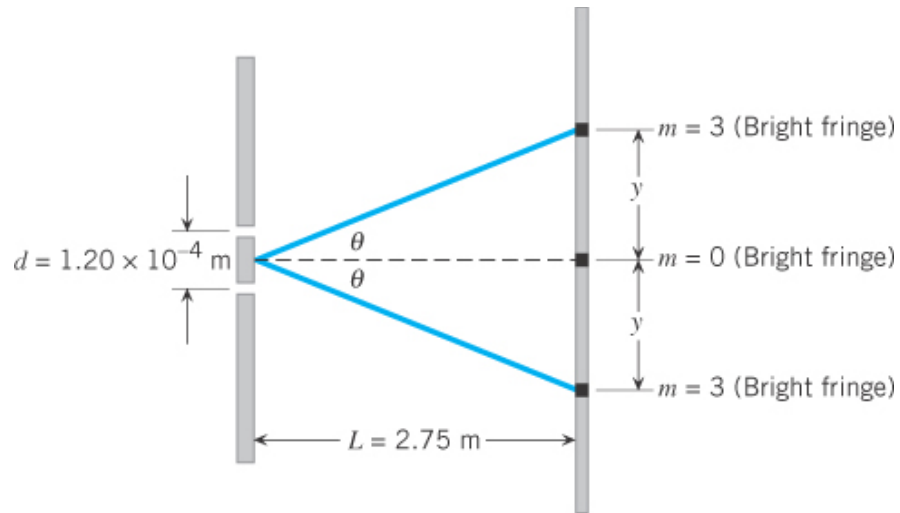
Young's Double Slit Experiment

Example: Young's Double-Slit Experiment

Red light (664 nm) is used in Young's experiment with slits separated by 0.000120 m. The screen is located a distance 2.75 m from the slits. Find the distance on the screen between the central bright fringe and the third-order bright fringe.



Young's Double Slit Experiment



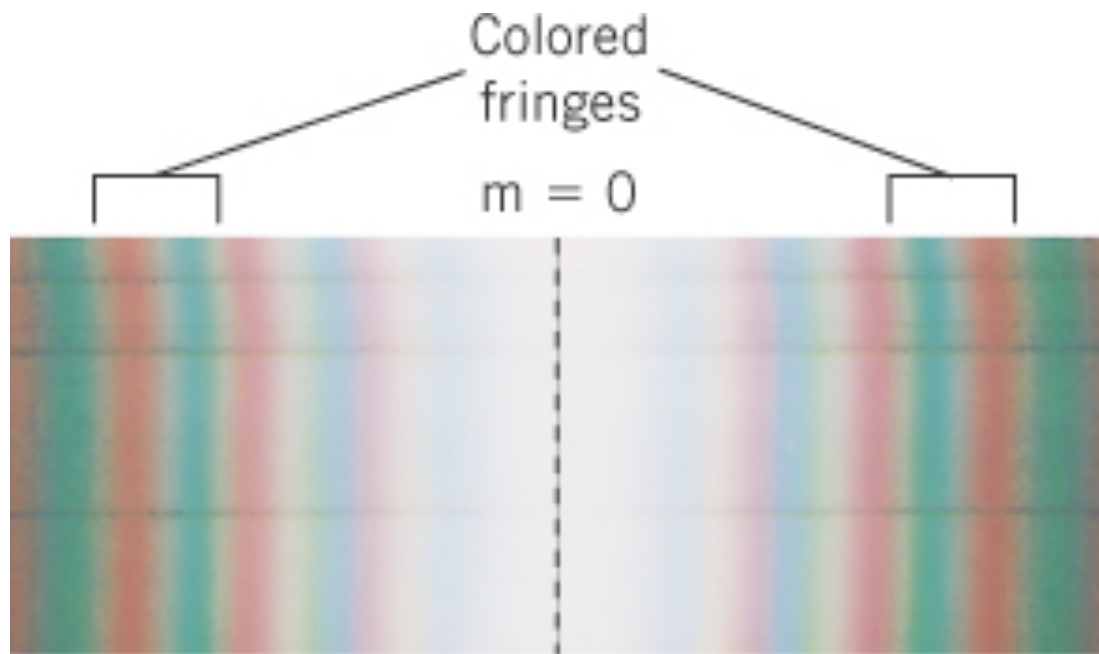
$$\theta = \sin^{-1}\left(m \frac{\lambda}{d}\right) = \sin^{-1}\left(3 \frac{664 \times 10^{-9} \text{ m}}{1.20 \times 10^{-4} \text{ m}}\right) = 0.951^\circ$$

$$y = L \tan \theta = (2.75 \text{ m}) \tan(0.951^\circ) = 0.0456 \text{ m}$$

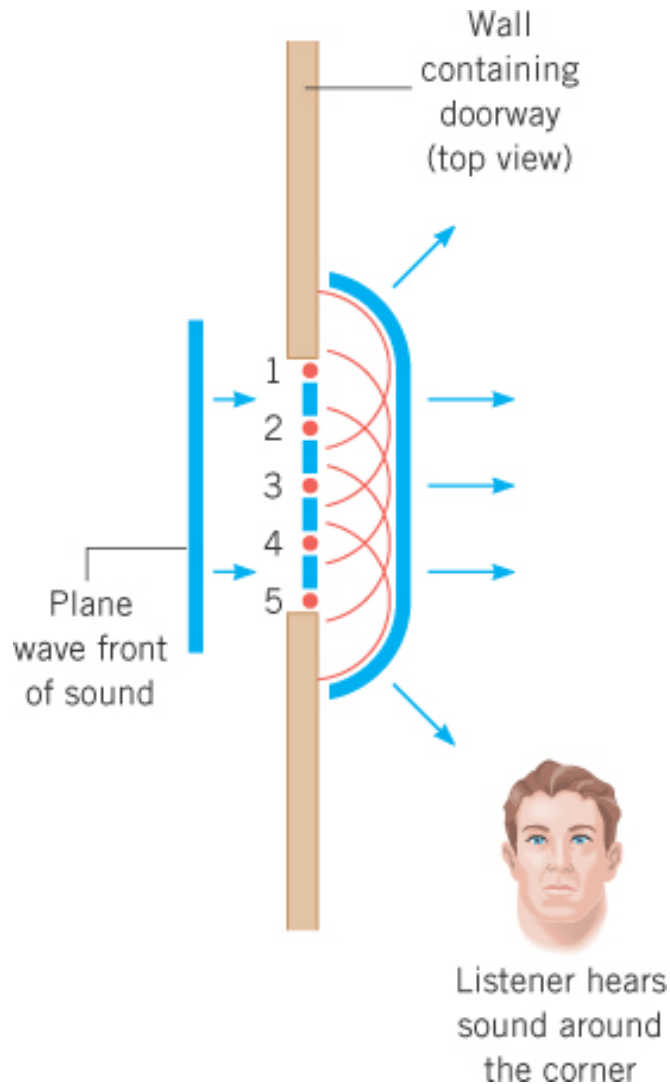
Young's Double Slit Experiment

Conceptual Example: White Light and Young's Experiment

The figure shows a photograph that illustrates the kind of interference fringes that can result when white light is used in Young's experiment. Why does Young's experiment separate white light into its constituent colors? In any group of colored fringes, such as the two singled out, why is red farther out from the central fringe than green is? Why is the central fringe white?



Diffraction

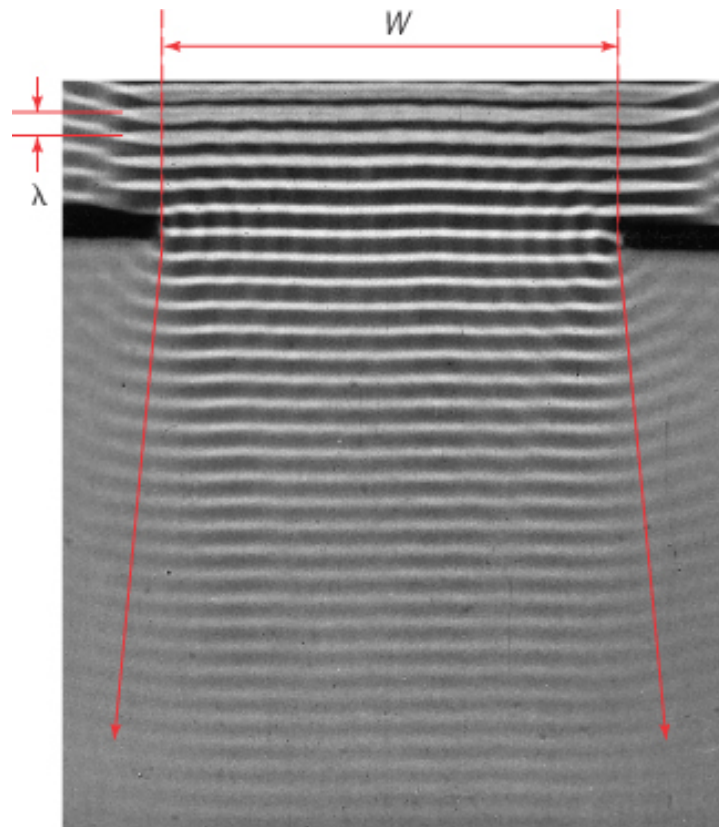


Diffraction is the bending of waves around obstacles or the edges of an opening.

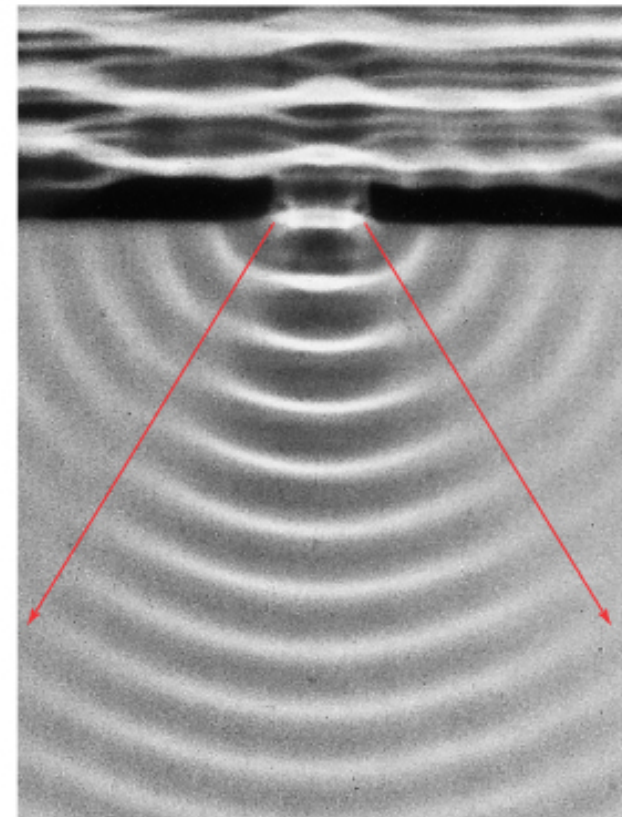
Huygens' principle

Every point on a wave front acts as a source of tiny wavelets that move forward with the same speed as the wave; the wave front at a latter instant is the surface that is tangent to the wavelets.

Diffraction



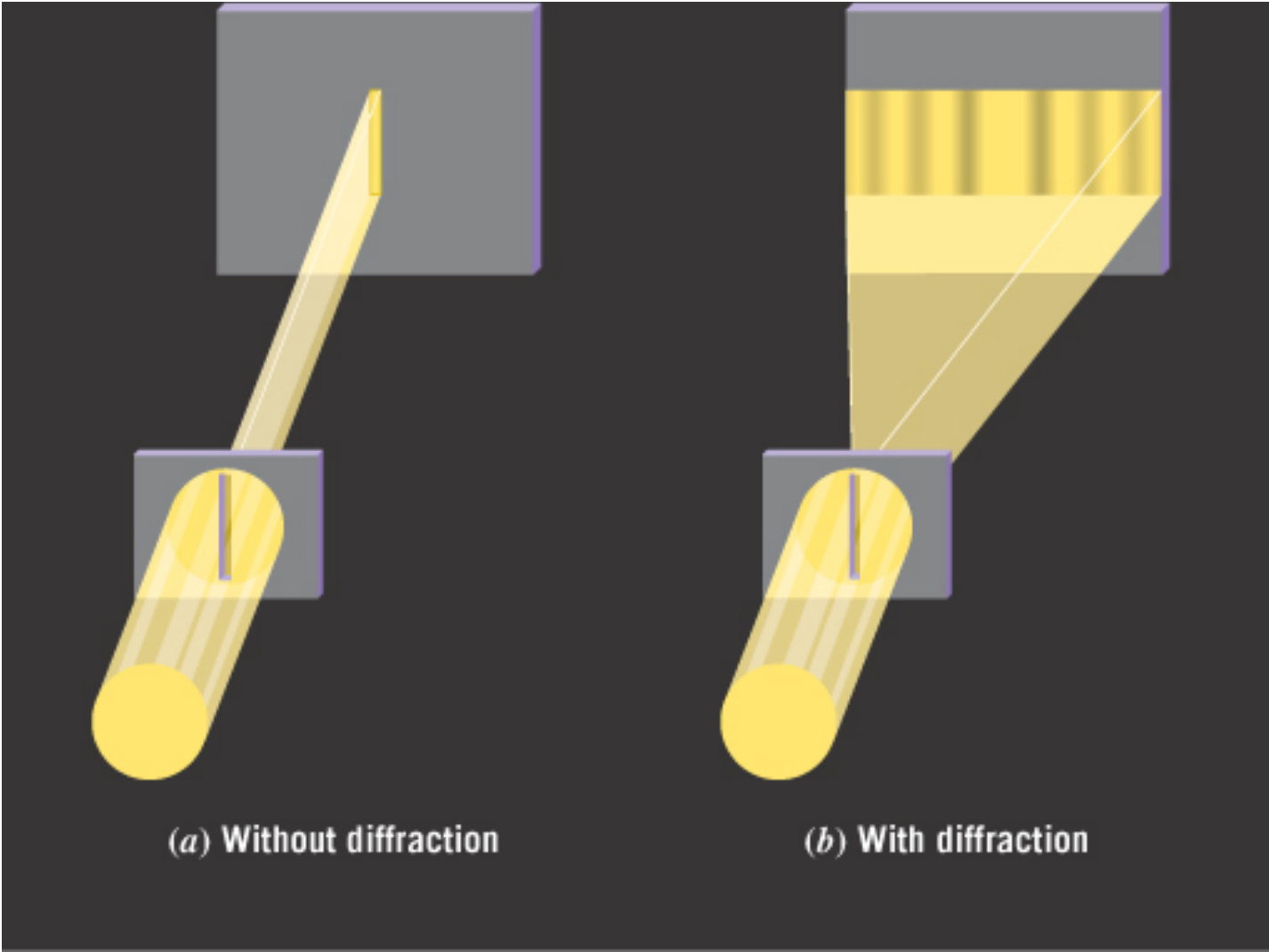
(a) Smaller value for λ/W ,
less diffraction.



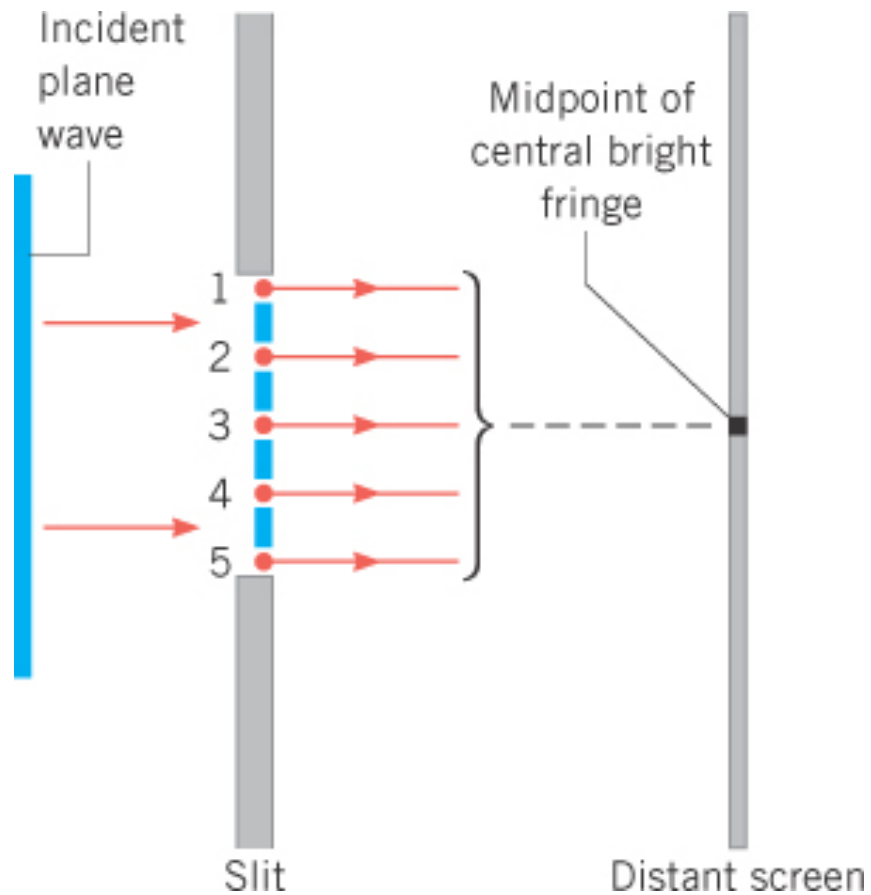
(b) Larger value for λ/W ,
more diffraction.

The extent of the diffraction increases as the ratio of the wavelength to the width of the opening increases.

Diffraction

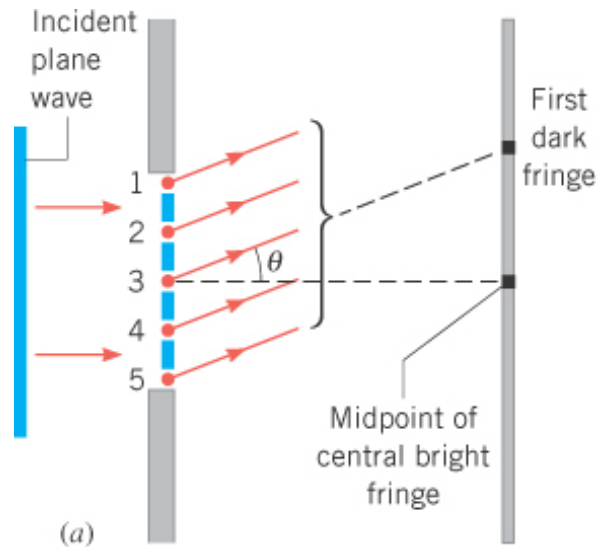


Diffraction

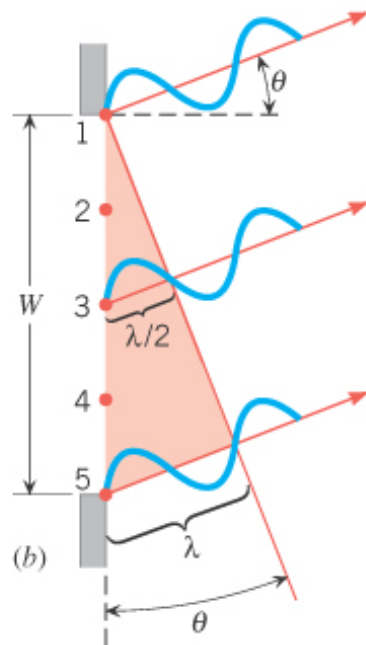


This top view shows five sources of Huygens' wavelets.

Diffraction



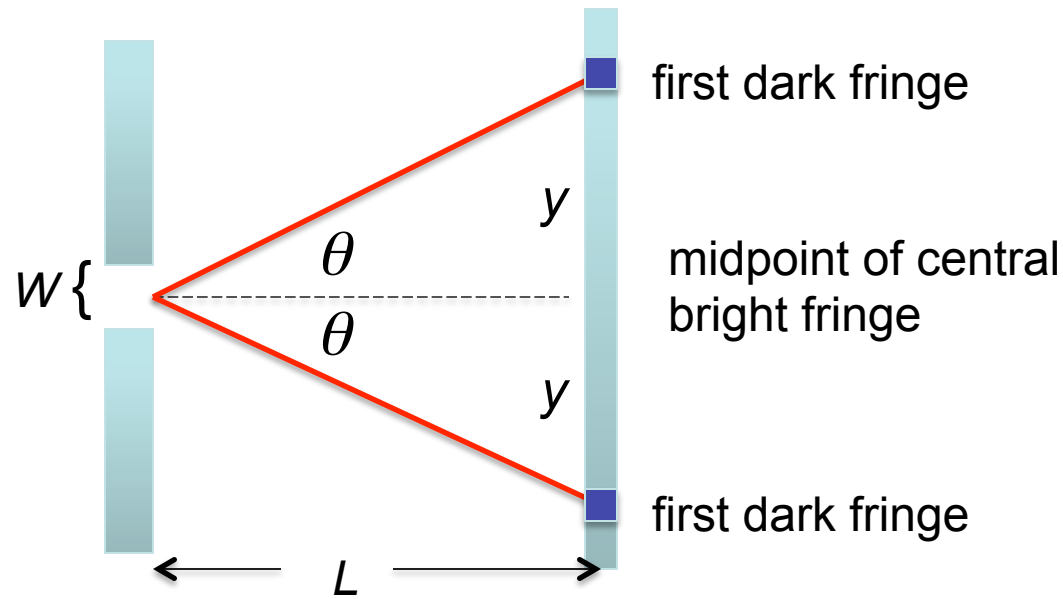
These drawings show how destructive interference leads to the first dark fringe on either side of the central bright fringe.



Dark fringes for single-slit diffraction

$$\sin \theta = m \frac{\lambda}{W} \quad m = 1, 2, 3, \dots$$

Example for single-slit diffraction. Light passes through a slit and shines on a flat screen that is located $L = 0.40$ m away. The wavelength of the light in a vacuum is $\lambda = 410$ nm. The distance between the midpoint of the central bright fringe and the first dark fringe is y . Determine the width $2y$ of the central bright fringe when the width of the slit is (a) $W = 5.0 \times 10^{-6}$ m and (b) $W = 2.5 \times 10^{-6}$ m.



$$(a) \quad \theta = \sin^{-1} \left(\frac{\lambda}{W} \right) = \sin^{-1} \left(\frac{410 \times 10^{-9}}{5.0 \times 10^{-6}} \right) = 4.7^\circ$$

$$2y = 2L \tan \theta = 2(0.40) \tan 4.7^\circ = 0.066 \text{ m}$$

$$(b) \quad 2y = 0.13 \text{ m} \rightarrow \text{The width of the central bright fringe is greater for smaller } W$$

Diffraction

**Diffraction pattern
formed by an opaque
disk.**

