

Chapter 22: Wave Optics

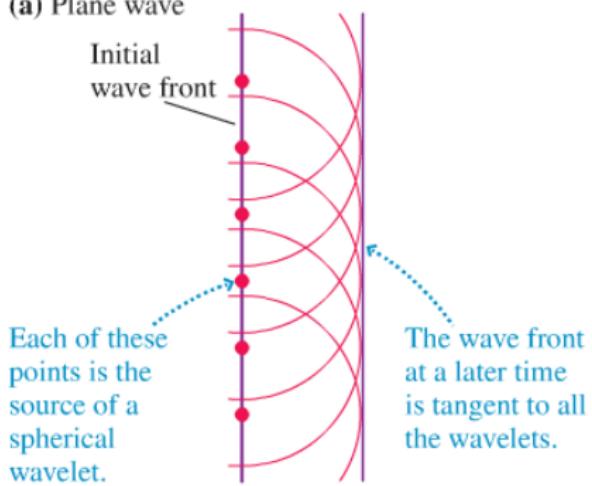
Now we go from general properties of waves to specifically studying the properties of light: optics. This chapter begins with an historical introduction to the particle and wave models of light (which we have covered already). Then we get to do all of the neat wave-like properties of light.

Diffraction - Huygen's Principle

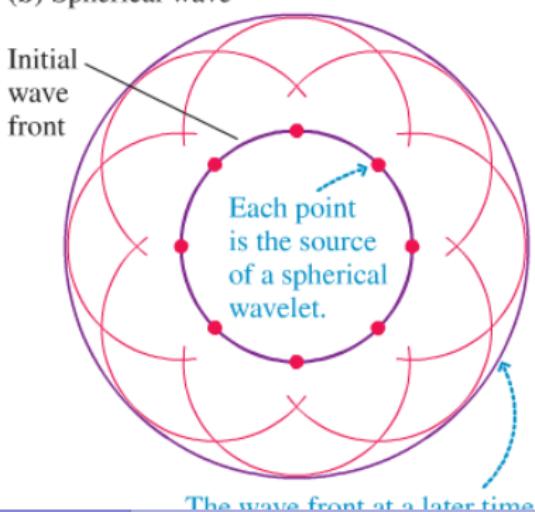
Huygen's Principle

- 1 Each point on a wave front is the source of a spherical wavelet that spreads out at the wave speed.
- 2 At a later time, the shape of the wavefront is the tangent line to all of the wavelets.

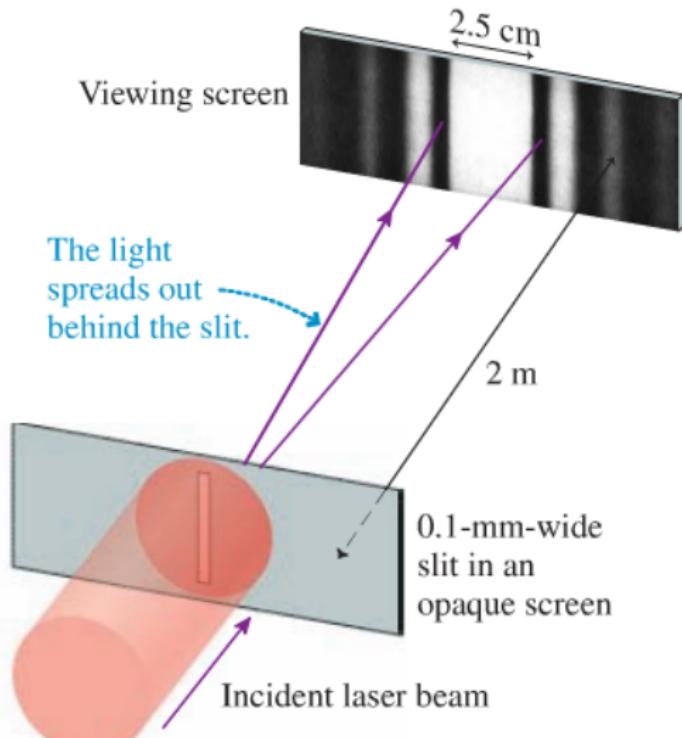
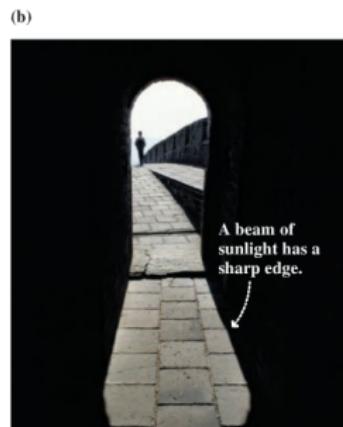
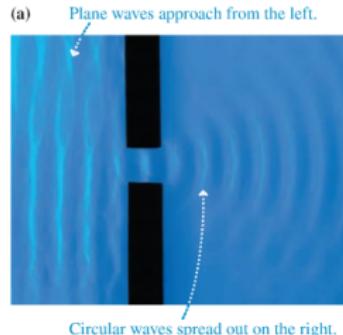
(a) Plane wave



(b) Spherical wave

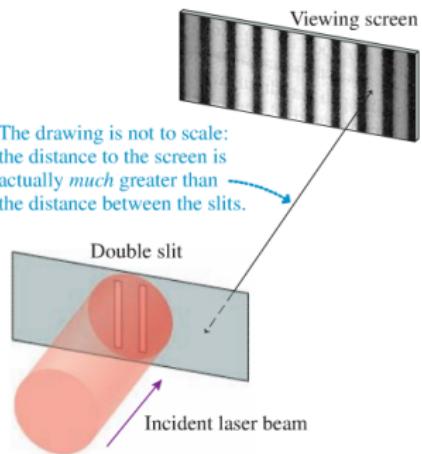


Diffraction - Single Slit



Young's Double-Slit Experiment

(a)



(b)

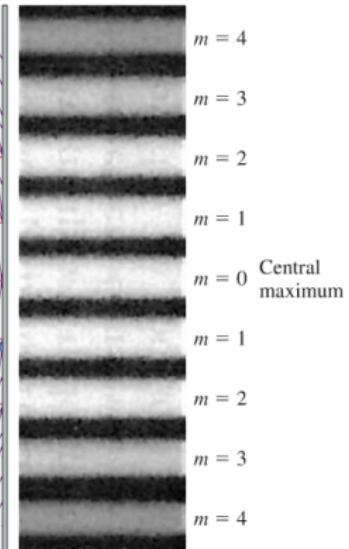
1. A plane wave is incident on the double slit.

2. Waves spread out behind each slit.

Top view of the double slit

3. The waves interfere in the region where they overlap.

4. Bright fringes occur where the antinodal lines intersect the viewing screen.

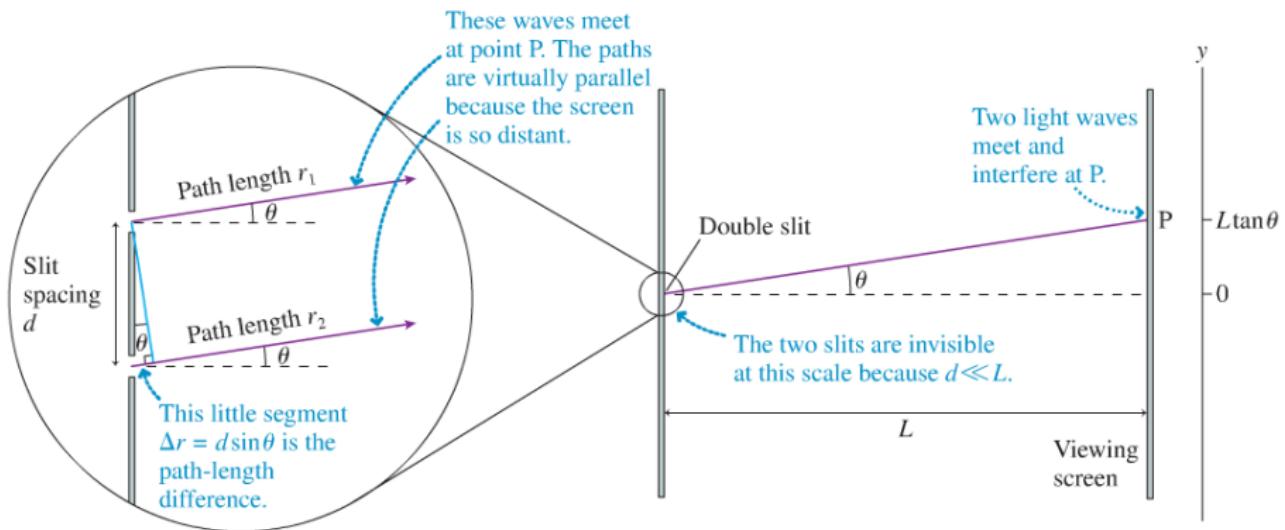


Young's Double-Slit Experiment

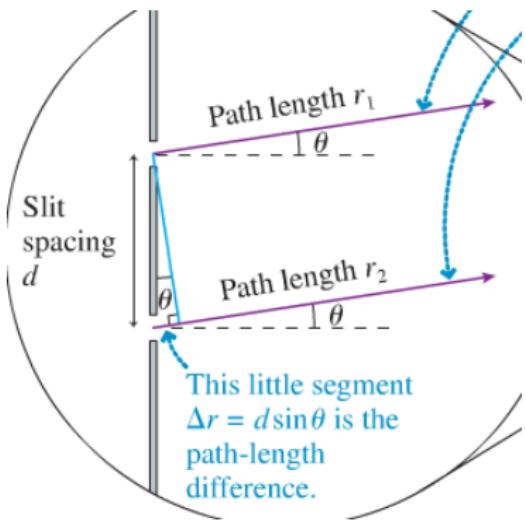
Notes

- The slit-width (a) and slit-separation (d) are similar in size to the wavelength of light (λ)
- The wave fronts arrive at the two slits from the same source in about the same time - they are in phase ($\Delta\phi = 0$).
- Each slit acts like a point-source by Huygen's principle.

Analyzing Young's Double-Slit Experiment



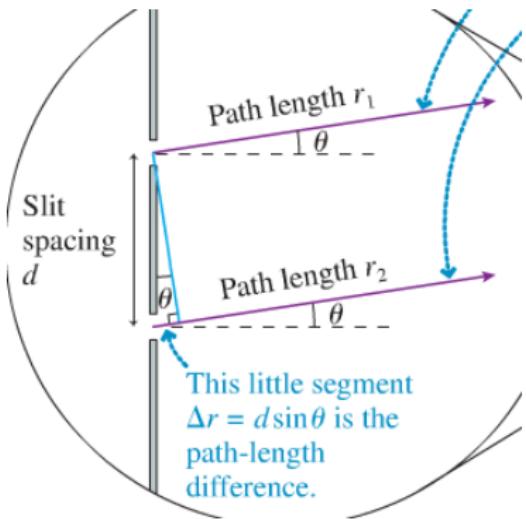
Analyzing Young's Double-Slit Experiment



- Constructive interference occurs when

$$\Delta r = d \sin \theta_m = m\lambda, m = 0, 1, 2, 3, \dots$$

Analyzing Young's Double-Slit Experiment



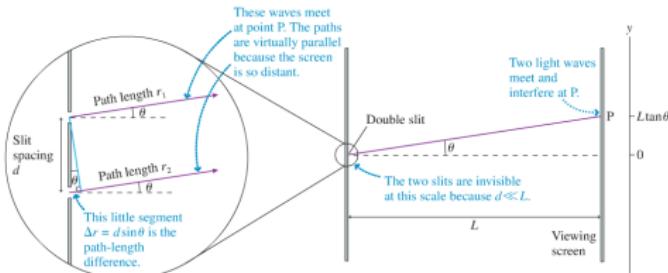
- Constructive interference occurs when

$$\Delta r = d \sin \theta_m = m\lambda, m = 0, 1, 2, 3, \dots$$

- In practice, the angle is small and $\sin \theta \approx \theta$

$$\theta_m = m \frac{\lambda}{d}$$

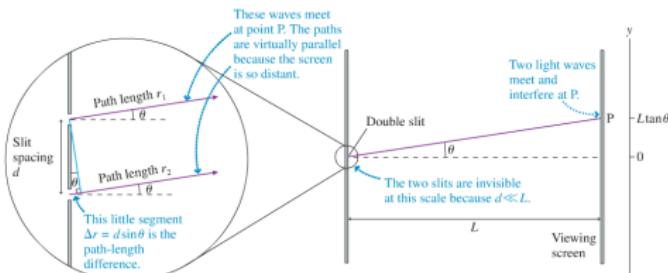
Analyzing Young's Double-Slit Experiment



- Using some simple trigonometry:

$$y_m = \frac{m\lambda L}{d}, m = 0, 1, 2, 3, \dots$$

Analyzing Young's Double-Slit Experiment



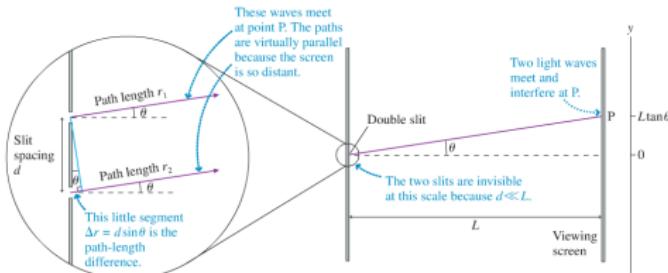
- Using some simple trigonometry:

$$y_m = \frac{m\lambda L}{d}, m = 0, 1, 2, 3, \dots$$

- Similarly, we can get the dark fringe positions:

$$y'_m = \left(m + \frac{1}{2}\right) \frac{\lambda L}{d}, m = 0, 1, 2, \dots$$

Analyzing Young's Double-Slit Experiment



- Using some simple trigonometry:

$$y_m = \frac{m\lambda L}{d}, m = 0, 1, 2, 3, \dots$$

- Similarly, we can get the dark fringe positions:

$$y'_m = \left(m + \frac{1}{2}\right) \frac{\lambda L}{d}, m = 0, 1, 2, \dots$$

- And we can get the fringe spacing

$$\Delta y = y_{m+1} - y_m = \frac{(m+1)\lambda L}{d} - \frac{m\lambda L}{d} = \frac{\lambda L}{d}$$

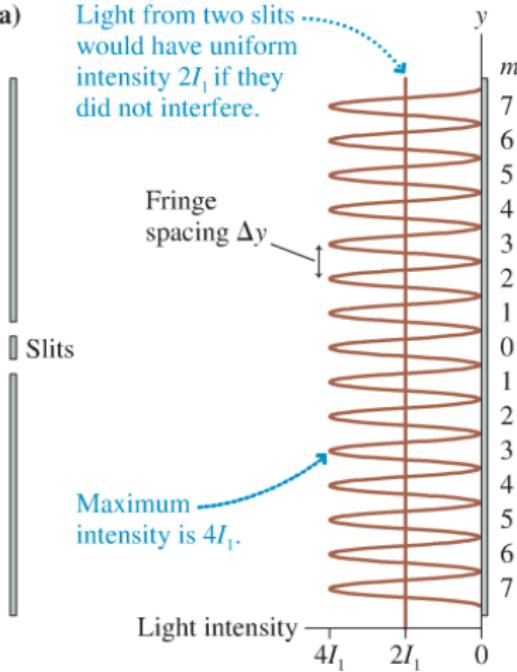
Young's Double-Slit Fringe Intensity

(a)

Light from two slits would have uniform intensity $2I_1$ if they did not interfere.

Fringe spacing Δy

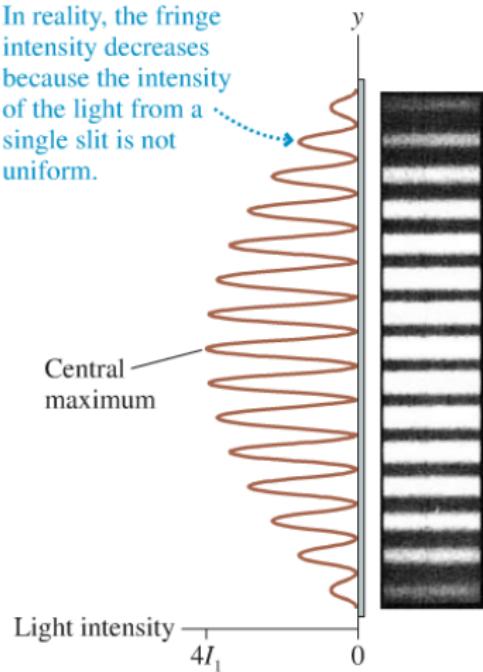
Maximum intensity is $4I_1$.



(b)

In reality, the fringe intensity decreases because the intensity of the light from a single slit is not uniform.

Central maximum



$$I_{\text{double}} = 4I_1 \cos^2\left(\frac{\pi d}{\lambda L}y\right)$$