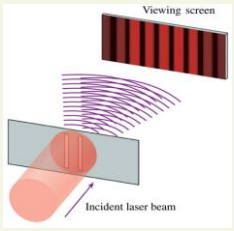
11 Light – Wave Optics

Wave Model of Light

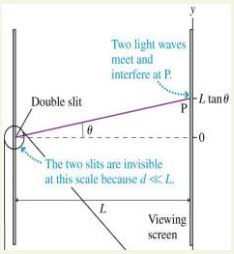
Light travels as a *wave* through space. It displays:

- *diffraction:* spreading of the wave after emerging from an aperture.
- *interference:* due to overlap of waves. Constructive interference occurs when crest meets crest, while destructive interference occurs when crest meets trough.
- The wave model for light is valid when the aperture < 1 mm in size.

Young's Double Slit Experiment



Light illuminates the double slits of separation d and the waves from each slit spread out behind the slit and interfere. A screen placed a distance L from the slits shows the interference pattern.

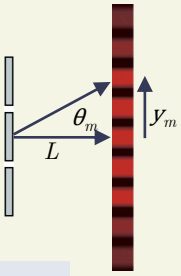


Constructive interference (resulting in a bright fringe) occurs when both waves arrive in phase at P.

The order m denotes the m^{th} bright fringe starting with $m = 0$ at the center.

Bright fringes are equally spaced and located at

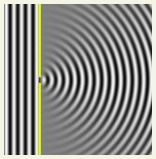
$$\theta_m = m\frac{\lambda}{d}, \quad y_m = \frac{m\lambda L}{d}, \quad m = 0, 1, 2, \ldots$$



Descructive interference (resulting in a dark fringe) occurs when both waves arrive out of phase at P. They are located exactly halfway between the bright fringes:

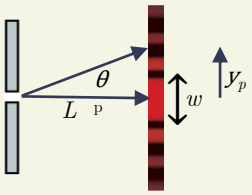
$$\theta_m = \left(m + \tfrac{1}{2}\right)\frac{\lambda}{d}, \quad y_m = \frac{\left(m + \frac{1}{2}\right)\lambda L}{d}, \quad m = 0, 1, 2, \ldots$$

Huygens Principle



Each point on a wave front (surface of constant phase) is the source of a spherical wavelet. The interference of these wavelets forms the wave front at any later time.

Single Slit



When light of wavelength λ passes through a single slit of width a the diffraction pattern displayed on a screen shows a bright central maximum of width

$$w = \frac{2\lambda L}{a}$$

surrounded by weaker fringes.

Dark fringes are located at angles and positions at

$$\theta_p = p\frac{\lambda}{a}, \quad y_p = \frac{p\lambda L}{a}, p = 1, 2, 3, \ldots$$

If the aperture is **circular** instead of a slit, the width of the central maximum is

$$w = \frac{2.44\lambda L}{D}$$

Diffraction Grating

A diffraction grating is a periodic array of closely packed slits. It is the basis of spectroscopy.

When light passes through a diffraction grating with adjacent slits spacing d, the *interference pattern* shows very bright and narrow fringes at

$$d\sin\theta_m = m\lambda, \quad y_m = L\tan\theta_m, \quad m = 0, 1, 2, \ldots$$

We can't use the small angle approximation here.

The Michelson Interferometer

is used to make very precise measurements with light waves.

Constructive interference: $L_2 - L_1 = m\,\lambda/2 \quad m = 0, 1, 2 \ldots$
Destructive interference: $L_2 - L_1 = (m + 1/2)\,\lambda/2$