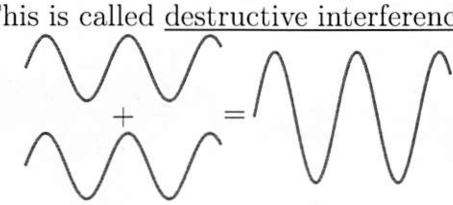
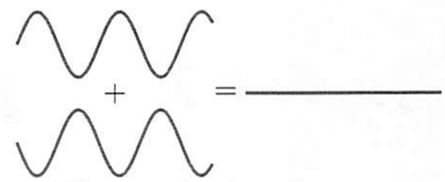
Light is a wave, and when light interacts with objects that are comparable in size to its wavelength this wave nature becomes readily apparent. We'll start by considering what happens when two waves with identical amplitudes, speeds, and wavelengths are added together. When these two waves are in-phase they line up peak-to-peak and trough-to-trough. They add to give a wave with a big amplitude. This is called constructive interference. When these two waves are out of phase they line up peak-to-trough. They cancel each other and give a wave with zero amplitude. This is called destructive interference.

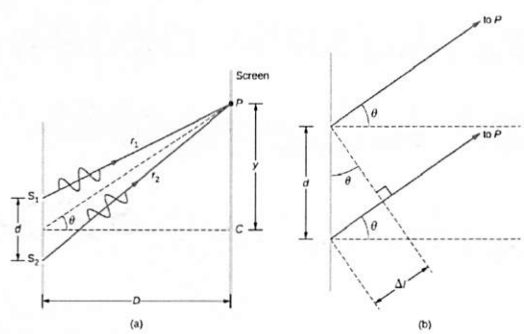


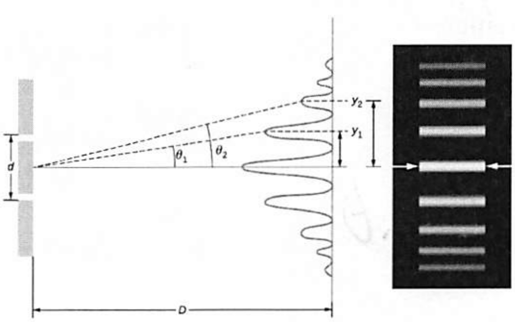
Constructive interference



Destructive interference

Arguably the most famous example of the wave nature of light comes from the Young's double slit experiment. Monochromatic light (a single color or wavelength) passes through two narrow slits that are separated by distance d. Each slit now acts as source of light. Light passing through each of these two slits then makes it to a screen or wall that is a distance L (the figures below call this D) away. Suppose we look at one position on the screen that is a distance y from the point that would be straight through or at an angle θ away from traveling straight through: $y = L \tan\theta$. One of the slits is a little closer to this point on the screen than the other, so light from that slit travels a slightly smaller distance to get there. The path length difference - the extra distance traveled by light coming from the farther slit - is equal to $d \sin\theta$.





Figures 3.7 and 3.8 from *OpenStax University Physics Volume 3.* Read for free at openstax.org.

Whenever $d \sin\theta_m = m\lambda$ where m is an integer we will have constructive interference, which leads to a *bright fringe* or an *intensity maximum.* The $m = 0$ bright spot (straight through) is sometimes called the central maximum.

Whenever $d\sin\theta_m = \left(m - \frac{1}{2}\right)\lambda$ we will have destructive interference, which leads to a *dark fringe* or an *intensity minimum.*

A diffraction grating consists of very many evenly spaced slits (or lines). As with double slit interference, there will be an intensity maximum whenever $d\sin\theta = m\lambda$ for integer m. However, in a diffraction grating these maximum become very, very narrow: sharp lines or dot rather than fringes.

Light with a wavelength of 580 nm passes through two slits separated by 1.0×10^{-5} m.

(a) At what angles will you find the first two bright fringes on either side?

$d\sin\theta = m\lambda$ $\quad$ 1st bright: $\sin^{-1}\left(\frac{1 \times 580\times10^{-9}\text{m}}{1\times10^{-5}\text{m}}\right) = 3.33°$

2nd bright $\sin^{-1}\left(\frac{2\times 580\times10^{-9}\text{m}}{1\times10^{-5}\text{m}}\right) = 6.66°$

(b) At what angles will you find the first two dark fringes on either side?

$d\sin\theta = (m-\frac{1}{2})\lambda$ $\quad$ 1st dark: $\sin^{-1}\left(\frac{0.5\cdot 580\times10^{-9}\text{m}}{1\times10^{-5}\text{m}}\right) = 1.66°$

2nd dark: $\sin^{-1}\left(\frac{1.5\cdot 580\times10^{-9}\text{m}}{1\times10^{-5}\text{m}}\right) = 4.99°$

(c) Suppose the light is incident on a screen that is 80 cm away from the slits. What is the distance from the center of the pattern to the first two dark and bright fringes on each side?

1st bright: $(.8\text{m})\tan(3.33°) = 0.0465\text{m}$

2nd bright: $(.8\text{m})\tan(6.66°) = 0.0934\text{m}$

$y = L\tan\theta$ $\quad$ 1st dark $(.8\text{m})\tan(1.66°) = 0.0232\text{m}$

2nd dark $(0.8\text{m})\tan(4.99°) = 0.0699\text{m}$

Suppose you pass 600 nm light through a diffraction grating with 500 lines per mm. At what angles would you find the first two bright spots?

$d = \frac{1\text{m}}{500{,}000} = 2.0\times10^{-6}\text{m}$ $\quad$ $d\sin\theta = m\lambda$

1st $\sin^{-1}\left(\frac{1\times 600\times10^{-9}\text{m}}{2\times10^{-6}\text{m}}\right) = 17.5°$

2nd $\sin^{-1}\left(\frac{2\times 600\times10^{-9}\text{m}}{2\times10^{-6}\text{m}}\right) = 36.9°$