Sound waves combining result in constructive and destructive interference, and

Light waves (electromagnetic waves) do, too!

The waves emitted by source 1 and source 2 start out in phase and arrive at point P in phase, leading to constructive interference at that point.

Constructive interference: waves are in phase at certain point
The waves emitted by the two sources have the same phase to begin with, but they arrive at point P out of phase.

As a result, destructive interference occurs at point P.

Destructive Interference: waves are $\frac{1}{2}\lambda$ out of phase from reference source.

Coherent light: when light waves maintain a constant phase relationship (same frequency). Ex: Lasers.
Young’s Double-Slit Experiment

- In 1801, Thomas Young performed an experiment that demonstrated the wave nature of light.
- His experiment showed that light waves can interfere with each other.
- He could also determine the wavelength of the coherent light from his measurements.
In Young’s double-slit experiment, the first slit ensures that light from only one direction falls on the double slits.

- $S_1$ and $S_2$ act as coherent sources of light.
- Light waves from these slits interfere constructively and destructively on the screen to produce the bright and dark fringes.

- Bright = constructive interference
- Dark = destructive interference
The waves from slits $S_1$ and $S_2$ interfere constructively and destructively depending on the difference in distances between the slits and the screen.

- **(a)** The length to the point on the screen is the same from $S_1$ and $S_2$ so there would be the same number of wavelengths in this distance: \( \therefore \) constructive interference = bright spot.

- **(b)** Another bright spot (constructive interference) occurs because the lengths $l_1$ and $l_2$ vary by $1\lambda$ and bright spots will occur everywhere lengths differ in whole number ratios of $\lambda$.

- **(c)** Dark spots will occur when lengths $l_1$ and $l_2$ differ by $\frac{1}{2} \lambda$ ratios. Destructive interference occurs whenever the difference between $l_1$ and $l_2$ equals an odd number of half-wavelengths: $1(\lambda/2)$, $3(\lambda/2)$, $5(\lambda/2)$, etc.

- The even number of half-wavelengths would result in constructive interference.
The above figure shows the intensity of light at those places. The brightness of fringes decreases as they are farther from the zeroth fringe. This decrease depends on the slit widths and the wavelength of the light.
The position of the fringes can be calculated:

- (a) Assume the screen is a large distance from the slits compared with their distance, \( d \), apart from each other. When this is the case, the rays are for the most part parallel to each other and have the same angle \( \theta \) from the normal.

- (b) The lengths of \( l_1 \) and \( l_2 \) differ by \( \Delta l \) which can be found using \( \sin \theta = \frac{\text{opp}}{\text{hyp}} \) or \( \text{opp} = \text{hyp}(\sin \theta) \), or \( \Delta l = d(\sin \theta) \) b/c the shaded triangle is a right triangle.
Constructive interference (bright fringes) occurs when $\Delta l$ is equal to a whole number wavelength of the wave in question, so...

- $\Delta l = m\lambda$ and $\Delta l = d(\sin \theta)$
- $\sin \theta = \Delta l / d = (m\lambda)/d$
- $\sin \theta d = m\lambda$

Since the angle is usually less than $1^\circ \sin \theta = \theta$ in radians and the above equation is $\theta = m\lambda/d$ when in radians

- $m =$ number of wavelengths (m also specifies the order of the fringe)
- $\lambda =$ wavelength of wave
- $d =$ distance between slits
According to image c: \( \tan \theta = \frac{o}{a} = \frac{Y}{L} \)

Since \( \theta \) is almost always less than \( 1^\circ \), \( \sin \theta = \tan \theta \), set equal to:

\[
\sin \theta \cdot d = m \cdot \lambda
\]

\[
\frac{Y}{L} = \frac{(m \cdot \lambda)}{d} \quad \text{or} \quad Y = \frac{(m \cdot \lambda \cdot L)}{d}
\]

The same reasoning can be used for dark fringes... where destructive interference occurs when wavelengths are \( \frac{1}{2} \) wave out of phase. \( \sin \theta = \frac{(m + \frac{1}{2}) \cdot \lambda}{d} \)
Evidence that light is a wave...

- When you use different colors of light (different wavelengths), the angle will be different as well...
- And, if you know the angle, the wavelength can be found.
- If light behaved as a particle, then only 2 slits of light would show up on the screen, not many.
Red light ($\lambda = 664$ nm in vacuum) is used in Young’s experiment. Find the distance $y$. 

\[ d = 1.20 \times 10^{-4} \text{ m} \]

\[ L = 2.75 \text{ m} \]

\[ m = 3 \text{ (Bright fringe)} \]

\[ m = 0 \text{ (Bright fringe)} \]

\[ m = 3 \text{ (Bright fringe)} \]
And the answer is…

- Did you get…?
- $y = 0.0456 \text{ m}$
Diffraction Grating

- An arrangement of closely spaced slits or scratches.
- Light rays travel $1\lambda$ farther than the previous to interfere constructively.
Diffraction Grating is a material that has many slits per mm instead of just 2 used by Young in his experiment. Use the same equation solving for d between slits and then divide this value into $1 \times 10^{-3}$ m to get the # of slits/mm. $\sin \theta d = m \lambda$. 
Solving for Maxima for Diffraction Grating

\[ \sin \theta = \frac{m \lambda}{d} \] just like diffraction equation!

- \(d = \) distance between slits

When using diffraction grating the central fringe is white because all colors of light overlap there.
White Light Through Diffraction Grating.

- Note that different colors (λ’s) diffract at different angles.
Double slit pattern compared with diffraction grating for a fixed $\lambda$. 

Diffraction Patterns