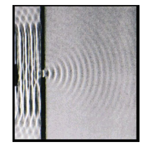
Young's Interference Experiment

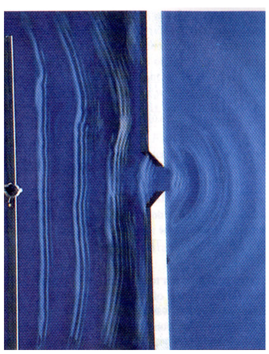
- In 1801, Thomas Young demonstrated the wave nature of light by showing that it produced interference effects
- he measured the average λ of sunlight to be 570 nm
- a single slit causes diffraction of sunlight to illuminate two slits S_1 and S_2
- each of these sends out circular waves which overlap and interfere

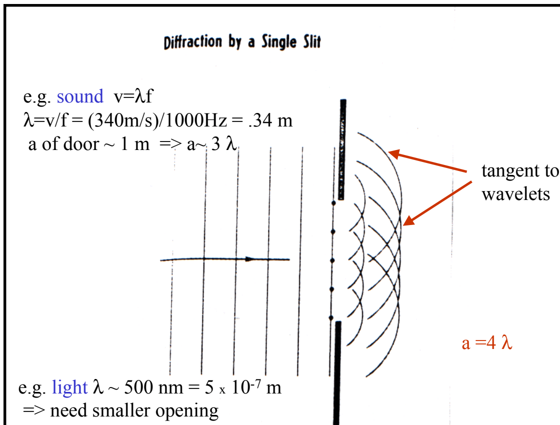
Diffraction

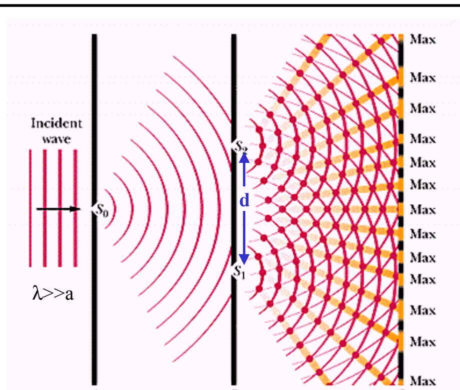
- How do we know light is a wave?
- Waves undergo diffraction
- if a wave encounters an object that has an opening of dimensions similar to its λ, part of the wave will flare out through the opening
- can be understood using Huygen's argument
- true for all waves e.g ripple tank



Water waves flare out when passing through opening of width a







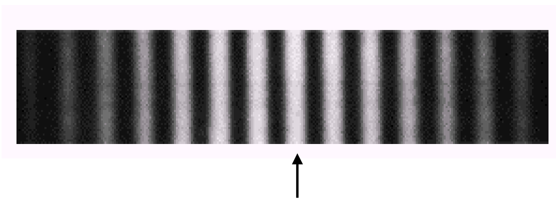
Points of same phase add constructively **Vertical screen**

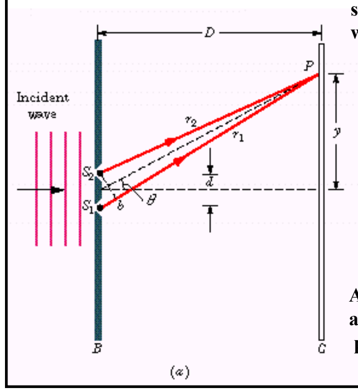
Coherence

- For interference to occur, the phase difference between the two waves arriving at any point P must <u>not depend</u> on time.
- The waves passing through slits 1 and 2 are parts of the same wave and are said to be coherent
- light from different parts of the sun is not coherent
- the first slit in Young's expt produces a coherent source of waves for the slits S_1 and S_2

Young's Double Slit

- Interference pattern depends on λ of incident light and the separation 'd' of the two slits S_1 and S_2
- bright vertical rows or bands (fringes) appear on the screen separated by dark regions





Choose any point P on the screen located at an angle θ with respect to central axis

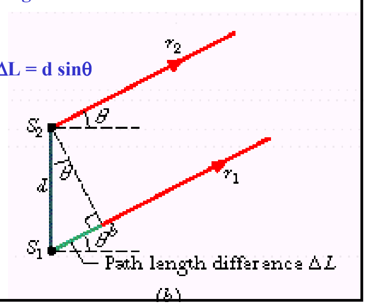
Wavelets from S_1 and S_2 interfere at P. They are in phase when they enter the slits but travel different distances to P.

Assume D>>d so that rays r_1 and r_2 are approximately parallel

If $\Delta L = 0, \lambda, 2\lambda, 3\lambda,\ldots$ then waves are in phase at P.
==> bright fringe

If $\Delta L = \lambda/2, 3\lambda/2, 5\lambda/2,\ldots$ then waves are out of phase at P.
==> dark fringe

Triangle S_1bS_2 : $S_1b = \Delta L = d\sin\theta$

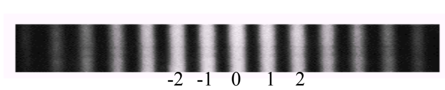


Double Slit

- Bright fringe: $\Delta L = m\lambda$
  $d\sin\theta = m\lambda$, m=0,1,2,…
- Dark fringe: $\Delta L = (m+1/2)\lambda$
  $d\sin\theta = (m+1/2)\lambda$, m=0,1,2,…
- use 'm' to label the bright fringes
- m=0 is the bright fringe at θ=0
  "central maximum"

Bright Fringes

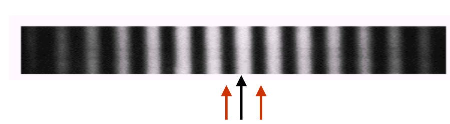
- m=1 $d\sin\theta = \lambda$
  $\theta = \sin^{-1}(\lambda/d)$
- bright fringe above or below(left or right) of central maximum has waves with $\Delta L = \lambda$
- "first" order maxima



- m=2 $\theta = \sin^{-1}(2\lambda/d)$
- "second" order maxima

Dark Fringes

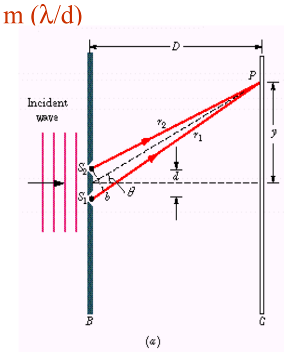
- For m=0, $\theta = \sin^{-1}(\lambda/2d)$
- "first order" minima



Position of Fringes

- Bright fringes at $d \sin\theta = m \lambda$, $m=0,1,2,\ldots$
- $\sin\theta = m (\lambda/d)$

$y/D = \tan \theta$



e.g. λ=546 nm, D=55cm, d=.12mm
hence $\lambda/d \sim 4.6 \times 10^{-3}$

Bright fringes for
$\sin\theta = m (\lambda/d) \ll 1$

Separation of Bright Fringes

- Using the fact that $\sin\theta \sim \theta$ for $\theta \ll 1$
- $\sin \theta_m \sim \theta_m = m (\lambda/d)$ $m=0,1,2, \ldots$
- $\tan \theta = \sin\theta/\cos\theta \sim \theta$ if $\theta \ll 1$
- $y_m = D \tan \theta_m \sim D \theta_m \sim m \lambda D/d$
- distance between maxima is $\Delta y = \lambda D/d$

- to increase distance between fringes (magnify) either increase D or decrease d or increase λ

Light gun