Physics 202, Lecture 26

Today's Topics

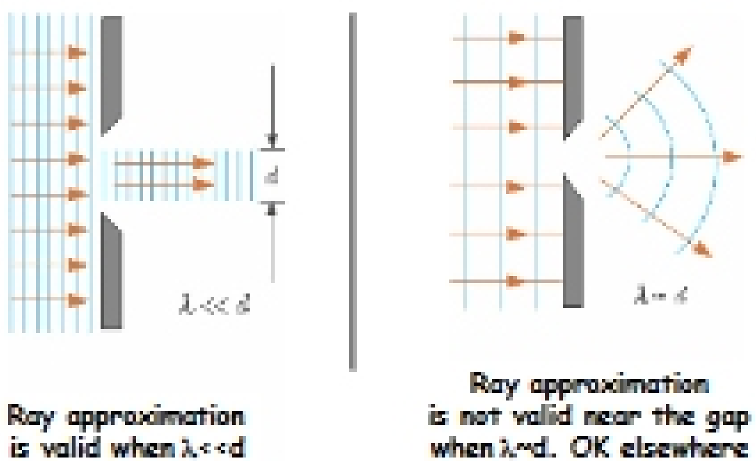
- Wave Nature of Waves: Interference
  - Breakdown of ray approximation
  - Huygen's principle
  - Light as Waves
  - Double-Slit Interference
  - Multi-Slit Interference

Reminder: Light and Optics

- Nature of Lights
  - Lights as rays
  - Lights as EM waves: f, λ, ϕ, v, A, interference …
  - Lights as group of photons
- Optics: Physics of lights
  - Geometric Optics: Treat light as rays (Ch. 35,36)
    → Ray approximation.
  - Wave Optics: Wave properties becomes important
    Interferences, diffraction…(Ch. 37,38)

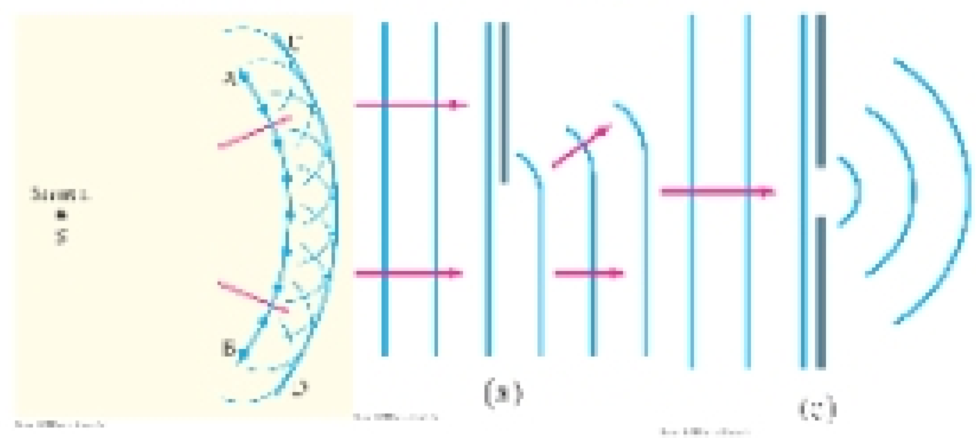
Ray Approximation

- When the wavelength of the light is much smaller than the size of the optical objects it encounters, it can be treated as (colored) rays.



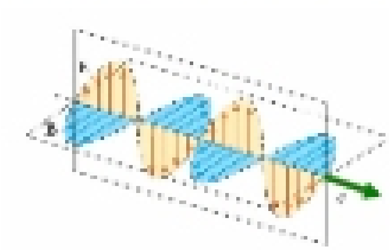
The Huygens' Principle

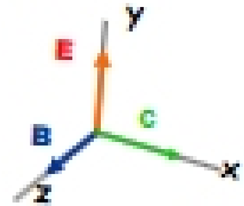
- Every point on a wave front can be considered as a secondary source of waves that spread out in the forward direction. The new wave is the result of the superposition of these secondary waves



Reminder: Light Waves

- Nature of Lights:
  Rays (classical), ➔EM waves🡸, ➔Photons🡸.
- Review: Electromagnetic plane waves
  $E= E_{max}\sin(\omega t-kx+\phi)$, $B= B_{max}\sin(\omega t-kx+\phi)$, $E/B=c$
  - As the E component and B component of an EM wave are 100% correlated, we can use just one of them to represent an EM wave.





Interference of Light Waves

- When two light waves meet at certain location, the resulting effect is determined by the superposition (i.e. sum) of the two individual waves
- e.g. Two light waves with same color and amplitude.
  $E_1= E_0\sin(\omega t-kx+\phi_{10}) = E_0\sin(\omega t+\phi_1)$
  $E_2= E_0\sin(\omega t-kx+\phi_{20}) = E_0\sin(\omega t+\phi_2)$

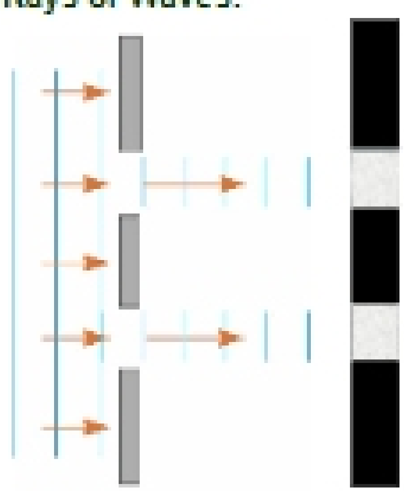
$\Delta\phi=\phi_1-\phi_2$
$\phi=(\phi_1+\phi_2)/2$

→ $E=E_1+E_2 = 2E_0 \cos(\Delta\phi/2) \sin(\omega t+ \phi/2)$
→ Resulting amplitude: $E_{max}= 2E_0\cos(\Delta\phi/2)$
  - Constructive interference: $\Delta\phi=0, 2\pi, 4\pi,\ldots$ $E_{max}=2E_0$
  - Destructive interference: $\Delta\phi=\pi, 3\pi, 5\pi,\ldots$ $E_{max}=0$

Quiz: If the intensity of each incoming light is I, what is the resulting intensity when (1):constructive, (2):destructive?

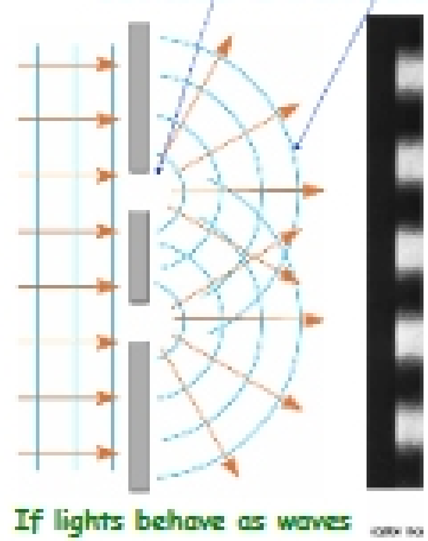
Test of the Wave Nature of Light: Double-Slit Experiment

- Rays or Waves:



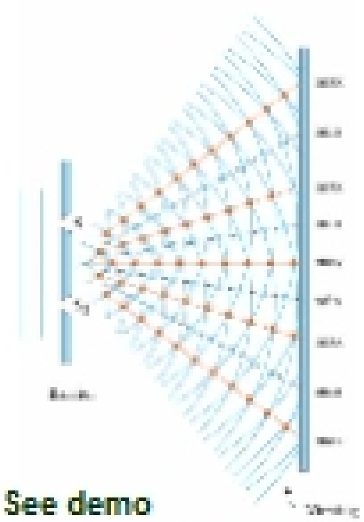
If lights behave as rays

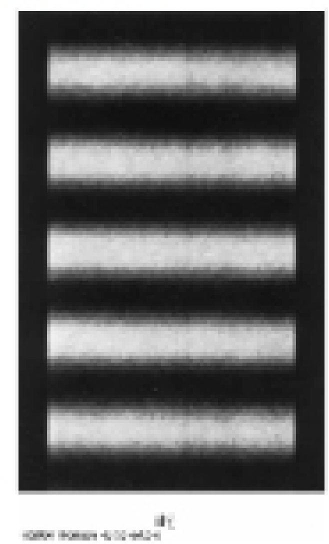
Diffraction & interference



If lights behave as waves

Young's Famous Double-Slit Experiment Thomas Young (1803)

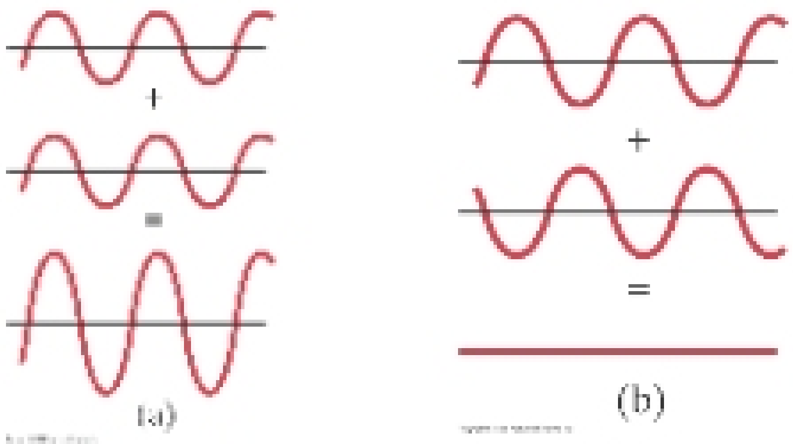




- See demo

Double-Slit Experiment Explained

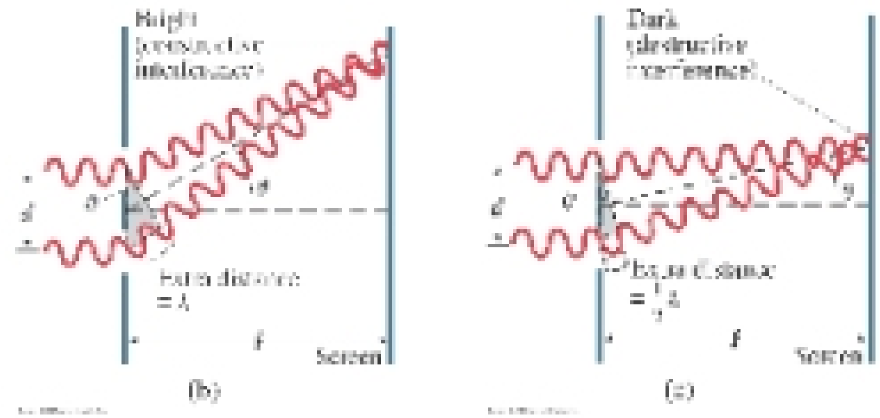
❑ The experiment can be easily explained by interference



Constructive, $\Delta\phi=0\pi, 2\pi, 4\pi,..$ Destructive, $\Delta\phi=\pi, 3\pi, 5\pi,..$

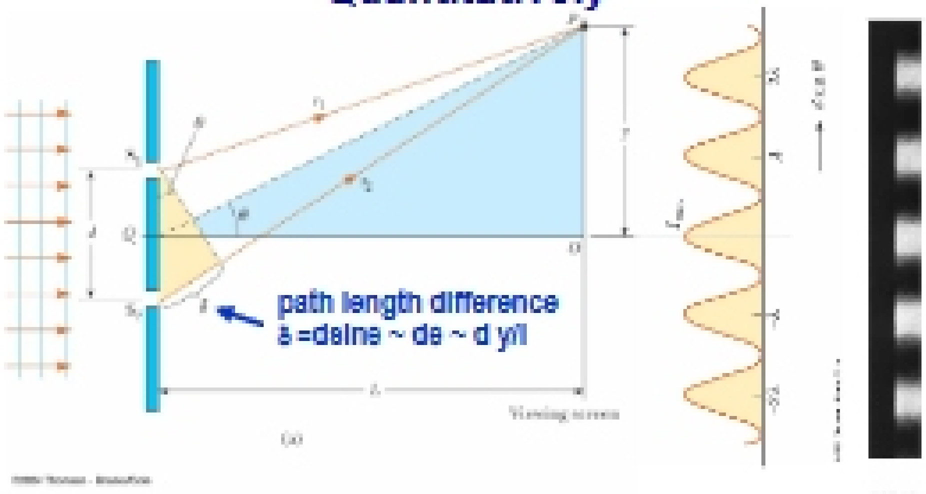
Double-Slit Experiment Explained

❑ The experiment can be easily explained by interference



Constructive, $\Delta\phi=0\pi, 2\pi, 4\pi,..$ Destructive, $\Delta\phi=\pi, 3\pi, 5\pi,..$

Quantitatively



$$\Delta\phi = k(r_2 - r_1) = kd\sin\theta = \frac{2\pi d}{\lambda}\sin\theta$$

$$I = I_o\cos^2\left(\frac{\pi d\sin\theta}{\lambda}\right)$$

Double-Slit Experiment Explained

- Constructive: $\Delta\phi=0\pi, 2\pi, 4\pi, \ldots$, or $2m\pi$, $m=0,1,2\ldots$

$$\frac{2\pi d}{\lambda}\sin\theta = 2m\pi \Longrightarrow d\sin\theta = m\lambda$$

Bright spots

- Destructive: $\Delta\phi=\pi, 3\pi, 5\pi, \ldots$, or $(2m+1)\pi$, $m=0,1,2\ldots$

$$\frac{2\pi d}{\lambda}\sin\theta = 2(m+1)\pi \Longrightarrow d\sin\theta = (m+\frac{1}{2})\lambda$$

Dark spots