

Physics 202, Lecture 27

Today's Topics

- Wave Nature of Waves: Interference
 - Breakdown of ray approximation
 - Huygen's principle
 - Light as Waves
 - Two-Slit Interference
- Thin Film Interference
 - Change of Phase at Boundaries
 - Exercise on Thin Film Interference
 - Exercise on Non Reflective Coating

1

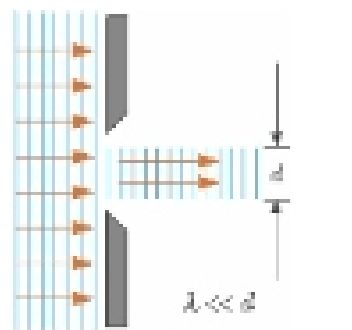
Reminder: Light and Optics

- 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. 31,32)
→ Ray approximation.
 - Wave Optics: **Wave properties becomes important**
Interference, diffraction...(Ch. 33,34)

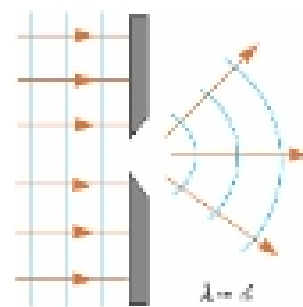
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Ray Approximation

- 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.



Ray approximation is valid when $\lambda \ll d$

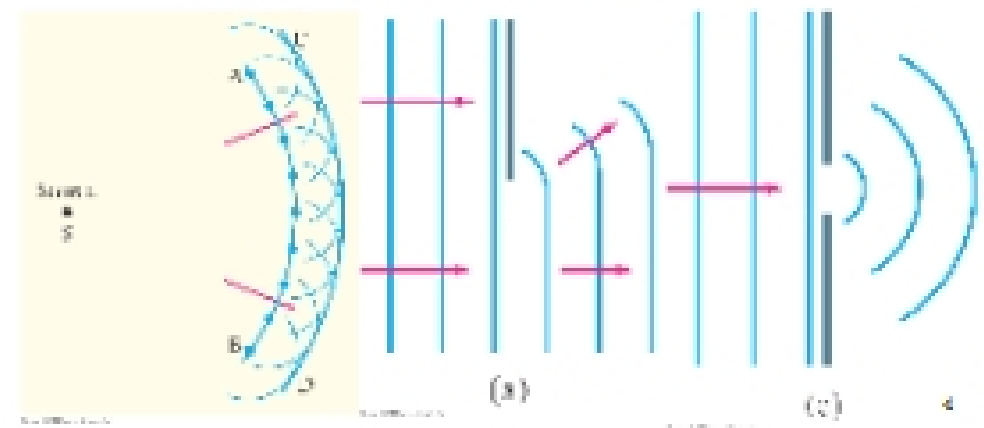


Ray approximation is not valid near the gap when $\lambda \sim d$. OK elsewhere

3

Huygens' Principle

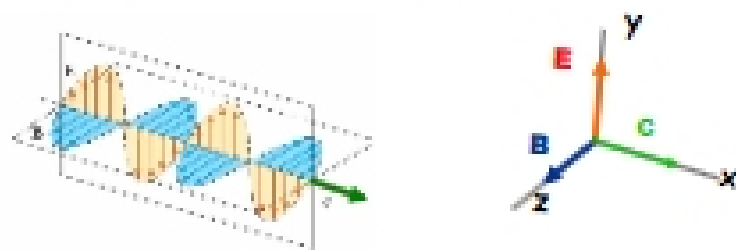
- Every point on a wave front can be considered as a secondary source of waves that spread out in the forward direction. The new wave is the result of the superposition of these secondary waves



4

Reminder: Light Waves

- Nature of Lights:
 - Rays (classical), →EM waves←, →Photons←.
- Review: Electromagnetic plane waves
 - $E = E_{max} \sin(\omega t - kx + \phi)$, $B = B_{max} \sin(\omega t - kx + \phi)$, $E/B = c$
 - The E component and B component of an EM wave are 100% correlated, so 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.
 - $E_1 = E_0 \sin(\omega t - kx + \phi_{10}) = E_0 \sin(\omega t + \phi_1)$
 - $E_2 = E_0 \sin(\omega t - kx + \phi_{20}) = E_0 \sin(\omega t + \phi_2)$
- $E = E_1 + E_2 = 2E_0 \cos(\Delta\phi/2) \sin(\omega t + \phi/2)$
 - $\Delta\phi = \phi_1 - \phi_2$
 - $\phi = \phi_1 + \phi_2$
- Resulting amplitude: $E_{max} = 2E_0 \cos(\Delta\phi/2)$
 - Constructive interference: $\Delta\phi = 0, 2\pi, 4\pi, \dots$ $E_{max} = 2E_0$
 - Destructive interference: $\Delta\phi = \pi, 3\pi, 5\pi, \dots$ $E_{max} = 0$
- Q: 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

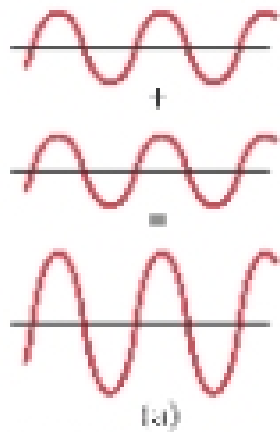
- Rays or Waves:
 - If lights behave as rays
 - Diagram showing parallel rays passing through two slits, resulting in two distinct bright spots on a screen.
 - If lights behave as waves
 - Diagram showing waves diffracting through two slits and interfering, resulting in a pattern of alternating bright and dark fringes on a screen.

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

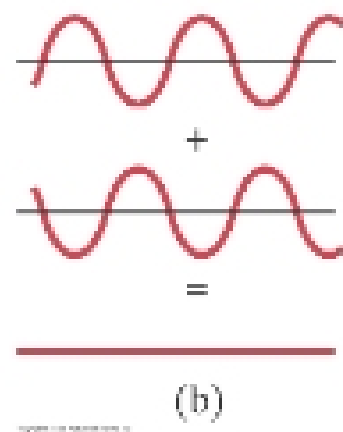
- See demo
 - Diagram illustrating the experimental setup for Young's double-slit experiment, showing a monochromatic light source, a double-slit, and a screen.
 - Image showing the resulting interference pattern of light on a screen, characterized by alternating bright and dark fringes.

Double-Slit Experiment Explained

□ The experiment can be easily explained by interference



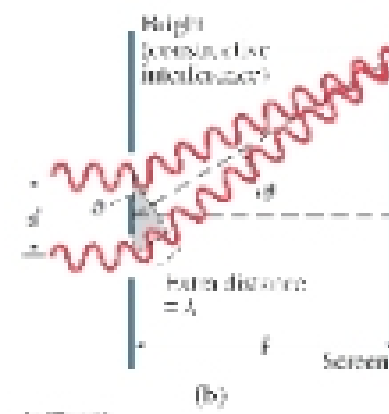
Constructive, $\Delta\phi = 0\pi, 2\pi, 4\pi, \dots$



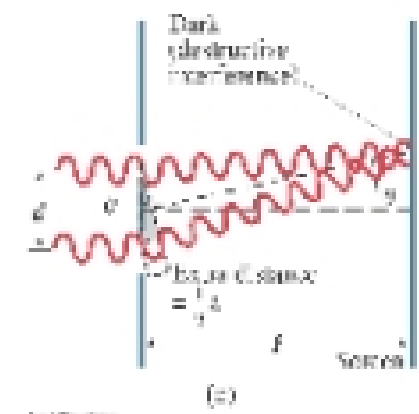
Destructive, $\Delta\phi = \pi, 3\pi, 5\pi, \dots$

Double-Slit Experiment Explained

□ The experiment can be easily explained by interference

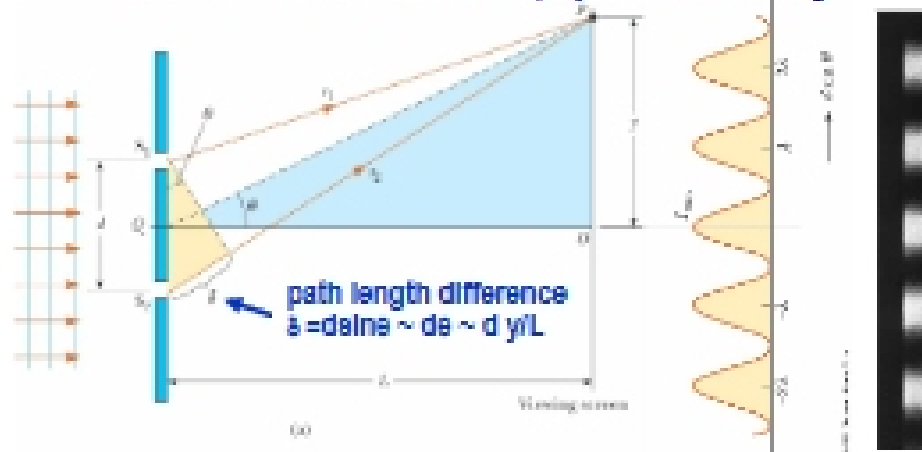


Constructive, $\Delta\phi = 0\pi, 2\pi, 4\pi, \dots$



Destructive, $\Delta\phi = \pi, 3\pi, 5\pi, \dots$

Two-slit interference, quantitatively



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

$$I = I_0 \cos^2 \left(\frac{\pi d \sin \theta}{\lambda} \right)$$

Two-Slit Experiment: Summary

➤ Constructive: $\Delta\phi = 0\pi, 2\pi, 4\pi, \dots$, or $2m\pi$, $m=0,1,2,\dots$

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

Bright spots

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

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

Dark spots