Physics 202, Lecture 28
Today’s Topics
- Michelson Interferometer
- Diffraction
  - Single Slit Diffraction
  - Multi-Slit Interference
  - Diffraction on Circular Apertures
  - The Rayleigh Criterion
- Wave Superposition Using Phasors

Michelson Interferometer
Very sensitive method for measuring small changes in path length differences and/or small change in speed of light propagation

Single-Slit Diffraction
- If lights were just rays

Single-Slit Diffraction Pattern Explained
- The slit is not a point source → Interference

\[ E_p = \sum E_i \]
\[ = \sum \left( \frac{\Delta y}{D} E_0 \right) \sin(\omega t + \frac{2\pi}{\lambda} y \sin \theta) \]
\[ = \frac{D}{D/2} \int_{-D/2}^{D/2} E_0 \sin(\omega t + \frac{2\pi}{\lambda} y \sin \theta) dy \]
\[ = \frac{2E_0}{D} \frac{2\pi D}{\lambda} \sin \theta \sin(\omega t) \]
\[ I = I_0 \left[ \frac{\sin(\beta/2)}{\beta/2} \right]^2 \]
\[ \beta = \frac{2\pi D}{\lambda} \sin \theta \]

The text also offers a derivation using phasors. Not on exam, but please read.
**Single Slit Diffraction: Where Are the Dark Fringes?**

The dark fringes occur at:

$$I = 0 \rightarrow \sin(\beta/2) = 0 \rightarrow \sin \theta_{\text{dark}} = m\lambda/D, \quad m = \pm 1, \pm 2, \pm 3,...$$

**Summary: Single-slit Diffraction**

Separation between minima = \( \frac{\lambda}{D} \)

$$I = I_0 \left[ \frac{\sin(\beta/2)^2}{\beta/2} \right]$$

$$\beta = \frac{2\pi}{\lambda} D \sin \theta$$

**Reminder: Two-slit Interference**

Separation between minima = \( \frac{\lambda}{d} \)

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

**Two-slit Diffraction**

- Diffraction factor, \((\sin(\beta/2)/2)^2\) vs. \(\theta\)
- Interference factor, \(\cos^2 \left( \frac{\delta}{2} \right)\) vs. \(\theta\)
- Intensity, \(I_0\) vs. \(\theta\)
Multi-Slit Interference

- # secondary maxima = N - 2
- Higher N → more suppression of secondary minima
  (Grating: N > 1000, highly sensitive to λ, good for measuring λ.)

Diffraction on Circular Apertures

- Light through apertures will produce diffractive patterns depending on their shape. For circular apertures, the diffractive patterns is made of concentric rings

Resolution of Single-slit and Circular Apparatus

- Using phasors to calculate diffraction patterns
  - http://people.clarkson.edu/~jsvoboda/eta/phasors/Phasor10.html
  - First: Add two waves
  - From geometry of figure, A = 2A₀⁺cos(δ/2)
  - same result as we obtained using trig identities last lecture.

- Rayleigh’s Criterion

Using phasors to calculate diffraction patterns

- http://people.clarkson.edu/~jsvoboda/eta/phasors/Phasor10.html

- First: Add two waves

Resolution of Single-slit and Circular Apparatus

- Single slit: θ_min = λ/D
- Circular opening: θ_min = 1.22 λ/D

Separation between minima = 1.22 \( \frac{\lambda}{D} \)
Using phasors to add three waves

\[ A_0 \sin(\alpha) + A \sin(\alpha + \delta) + A \sin(\alpha + 2\delta) \]

destructive interference when \( \delta = 120^\circ \)

In the figure, a beam of light from an underwater source is incident on a layer of carbon disulfide and the glass bottom of the container. The container is surrounded by air. Some of the refracted and reflected rays are shown in the diagram. For the rays shown, the interface at which the reflected light changes phase is

A. 1 only
B. 2 only
C. 3 only
D. 1 and 2
E. 2 and 3

The distance between the slits in a double-slit experiment is increased by a factor of 4. If the distance between the fringes is small compared with the distance from the slits to the screen, the distance between adjacent fringes near the center of the interference pattern

A. increases by a factor of 2.
B. increases by a factor of 4.
C. depends on the width of the slits.
D. decreases by a factor of 2.
E. decreases by a factor of 4.
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Which of the phasor diagrams shows the first minimum for five equally spaced in-phase sources?

The size of the smallest things that can be seen with an optical microscope is limited by diffraction. Which of the following could help a microscopist see smaller things?

A. A more powerful microscope could be used.
B. The microscope could have a lens with a shorter focal length.
C. The microscope could have a lens with a longer focal length.
D. The diameter of the lens could be smaller.
E. Light with a shorter wavelength could be used.
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