Lecture 38

Chapter 36 & 37
Interference & Diffraction
Review

• 3 ways for phase difference between 2 light waves to change
  – Waves travel through media of different indexes of refraction, \( n \)
  – Waves travel along paths of different lengths
  – Waves are reflected
Review

- When 2 waves interact get interference
  - If phase difference is 0 or integer # of wavelengths (1λ, 2λ, …) waves are in-phase and constructively interfere giving a bright spot or maxima
  - If phase difference is half a wavelength (0.5λ, 1.5λ, …) waves are out-of-phase and destructively interfere giving a dark spot or minima
Review

- Materials of different $n$
  - Different #’s of wavelengths occur in different $n$’s
  - Phase shift given by
    \[ N_2 - N_1 = \frac{L}{\lambda}(n_2 - n_1) \]
  - Effective phase difference is decimal fraction
  - $1 \lambda = 2\pi$ radians = 360°
Review

- Different path lengths
  - Ray 1 travels distance $\Delta L$ farther than ray 2
  - Waves interfere fully constructively when
    \[ \Delta L = m\lambda, \; m = 0,1,2,... \]
    - Central maximum at $m=0$, first order maxima $m=1$, second order maxima $m=2$
    - Waves interfere fully destructively when
      \[ \Delta L = (m+1/2)\lambda, \; m = 0,1,2,... \]
      - First order minima $m=0$, second order minima $m=1$, third order minima $m=2$
Review

- Different path lengths
- Relate path length difference $\Delta L$ to angle with central axis $\theta$ and distance between slits $d$

$$\Delta L = d \sin \theta$$

- Maxima, bright spots at

$$d \sin \theta = m\lambda, \ m = 0,1,2,...$$

- Minima, dark spots at

$$d \sin \theta = (m + 1/2)\lambda, \ m = 0,1,2,...$$
Review

• Different path lengths

• Use small angle relation

\[ \tan \theta = \sin \theta = \theta \]

• Distance \( y \) on screen from central maxima to maxima of order \( m \) is
  
  – \( D \) is distance between screen and slits, \( d \) is distance between slits

\[ y = \frac{mD\lambda}{d} \]
Review

- **Reflection**
- If incident light reflected by surface with lower \( n \) no phase shift
  - \( n_1 > n_2 \), phase shift = 0
- If incident light reflected by surface with higher \( n \) phase shifted by \( \frac{1}{2} \lambda \)
  - \( n_1 < n_2 \), phase shift = 0.5\( \lambda \)
- Refracted light is not phase shifted
Review

- Phase shift from thin films
- Combine reflection and path length difference
- First find phase shift (if any) between 2 rays from reflection at top and bottom of film
- Which path length equation to use depends on the reflection phase shift and what type of interference you want, maxima or minima

\[ 2L = (m + \frac{1}{2}) \frac{\lambda}{n_2}, \quad m = 0, 1, 2, \ldots \]

\[ 2L = m \frac{\lambda}{n_2}, \quad m = 0, 1, 2, \ldots \]
Review

• Checkpoint #5 – Light reflects ⊥ from film of thickness L between 2 other media. For given index of refractions, which situations will A) give zero phase difference from reflection at film interfaces

1. If \( n_1 > n_2 \), no phase change
2. If \( n_1 < n_2 \), \( \frac{1}{2} \lambda \) phase change
• (1) \( n_1 > n_2 > n_3 \) – no phase shift either surface, phase diff = 0, in phase
• (2) \( n_1 > n_2 < n_3 \) – top surface no phase shift, bottom surface shifted \( \frac{1}{2}\lambda \), phase diff = \( \frac{1}{2}\lambda \)
• (3) \( n_1 > n_2 < n_3 \) – same as (2) phase diff = \( \frac{1}{2}\lambda \)
• (4) \( n_1 < n_2 < n_3 \) – top and bottom surface both have \( \frac{1}{2}\lambda \) phase shift, phase diff = 0, in phase
Review

• Checkpoint #5 – B) for which situations will the film be dark if $2L=0.5\lambda$ phase difference

• Reflection causes 2&3 to be out-of-phase by $\frac{1}{2}\lambda$ so additional $\frac{1}{2}\lambda$ from path length makes waves in phase so constructive and bright

• 1 & 4 are in phase by reflection so $\frac{1}{2}\lambda$ from path length makes waves out-of-phase and dark
Diffraction (1)

- Waves **diffract** (bend) if pass through an opening whose size is comparable to its wavelength.
- The narrower the slit, the greater the diffraction.
- Previous example of double-slit interference assumed slit width $a$ much smaller than $\lambda$ of incident light and we talked about 2 light rays.
Diffraction (2)

• Do we still get an interference pattern if we have only one slit?
  • Yes, see a bright central maximum and then other less bright spots on the sides (side maxima) separated by dark minima
    – Caused by interference of wavelets from same wavefront going through slit
Diffraction (3)

• **Interference** –
  – Combining waves from small number of coherent sources – double-slit experiment with slit width much smaller than wavelength of the light

• **Diffraction** –
  – Combining of large number of wavelets from single wavefront – as in single slit experiment

• **Diffraction and interference are both**
  – the result of combining waves with different phases at a given point
  – Usually present simultaneously

• Example see photo 37-14 p.902