Lecture 38

Chapter 36 & 37

Interference & Diffraction

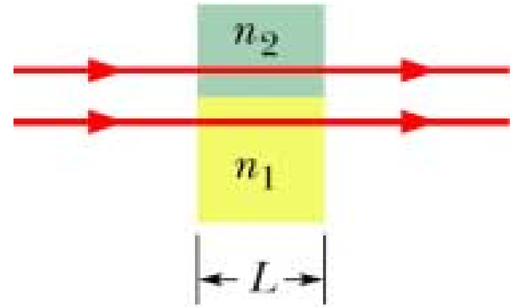
Review

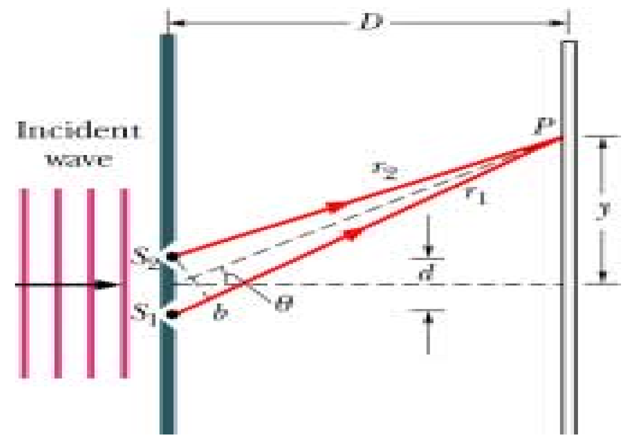
- 3 ways for phase difference between 2 light waves to change

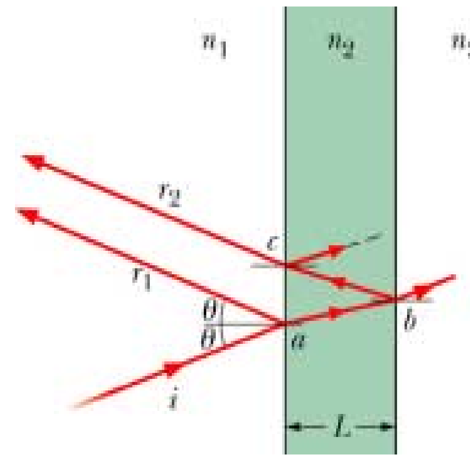
  – Waves travel through media of different indexes of refraction, *n*

  – Waves travel along paths of different lengths

  – Waves are reflected

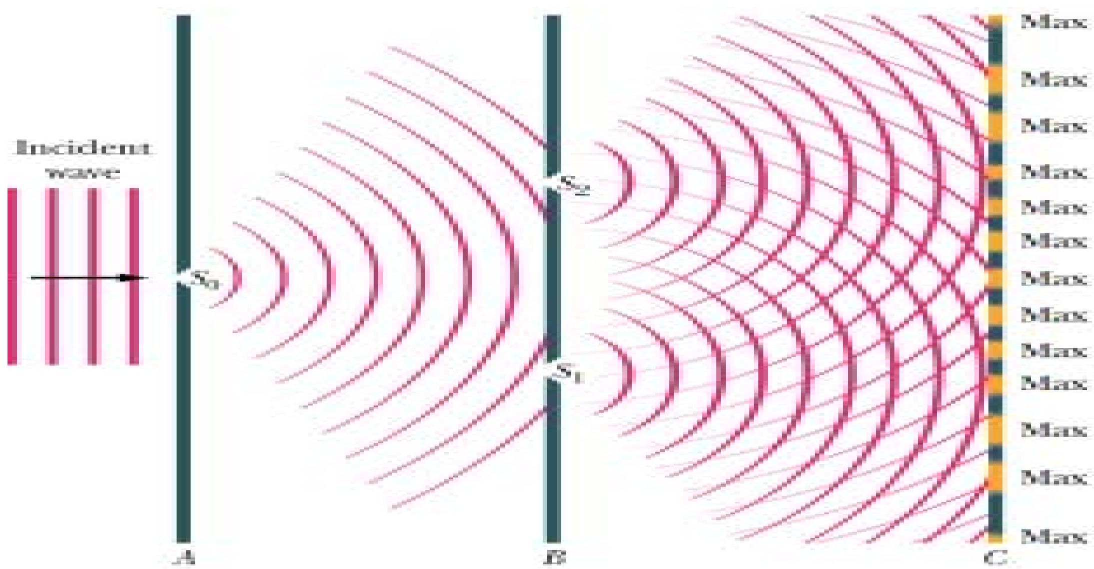






Review

- 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

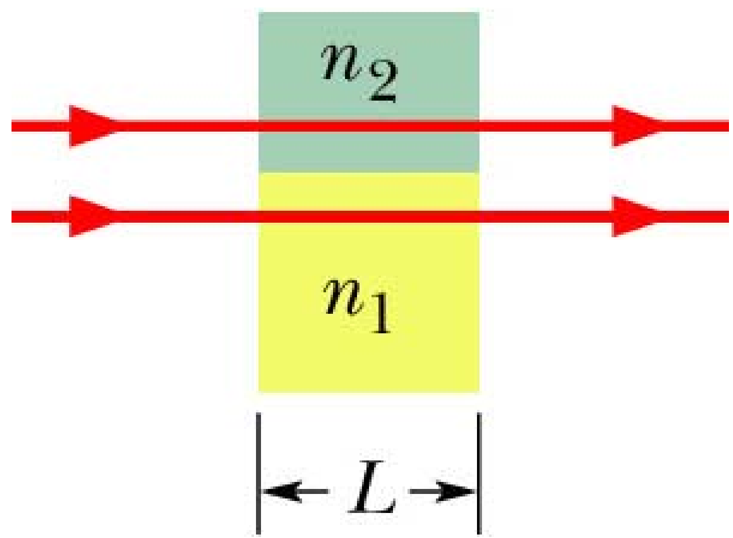


Review

- Materials of different n
  - Different #'s of wavelengths occur in different n's
  - Phase shift given by

$$N_2 - N_1 = \frac{L}{\lambda}(n_2 - n_1)$$

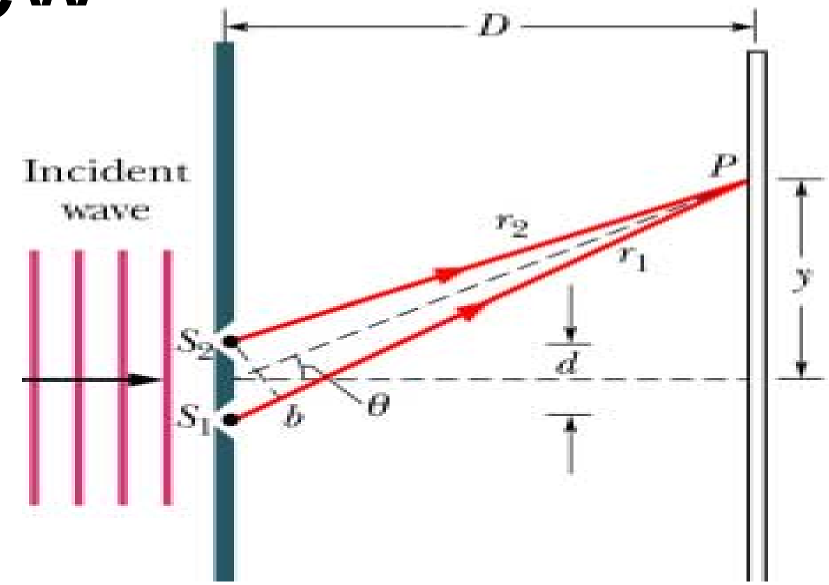
  - Effective phase difference is decimal fraction
  - 1 λ = 2π radians = 360°



Review

- Different path lengths
  - Ray 1 travels distance ΔL 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 ΔL to angle with central axis θ and distance between slits *d*

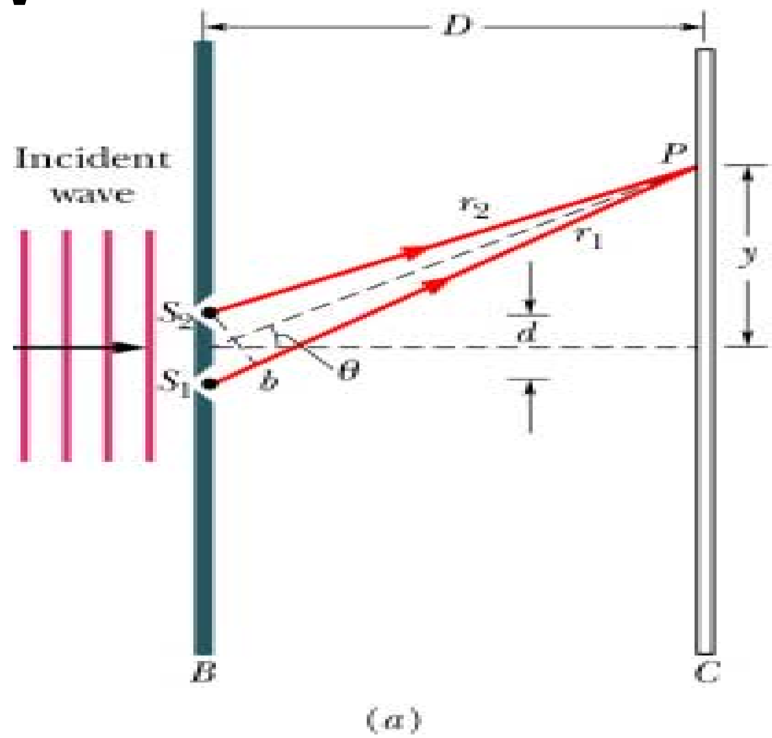
$$\Delta L = d\sin\theta$$

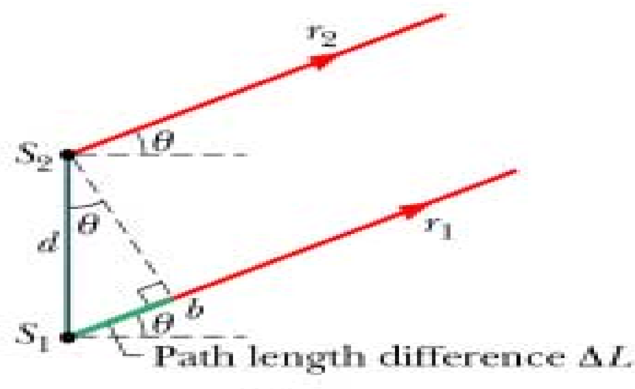
- Maxima, bright spots at

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

- Minima, dark spots at

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



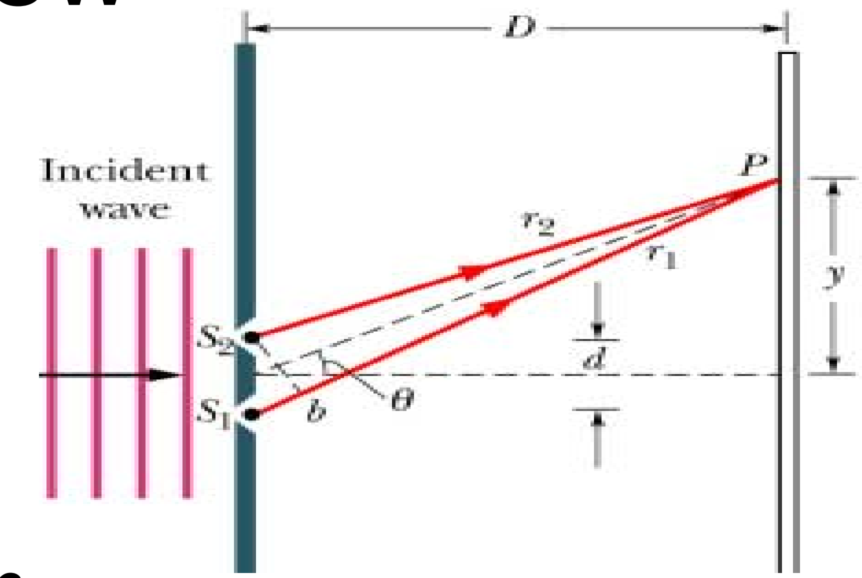


Review

- Different path lengths
- Use small angle relation

$$\tan\theta = \sin\theta = \theta$$

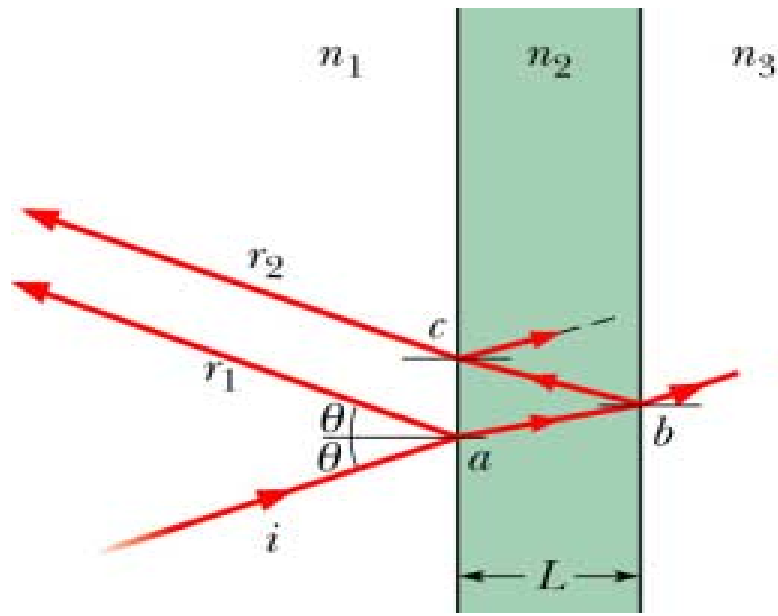
- Distance *y* on screen from central maxima to maxima of order m is
  - *D* is distance between screen and slits, *d* is distance between slits



$$y = \frac{mD\lambda}{d}$$

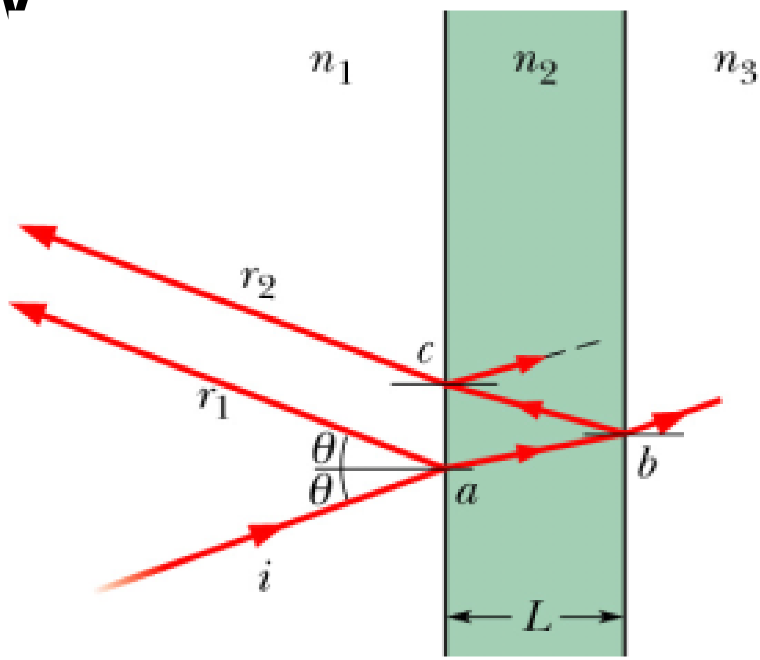
Review

- Reflection
- If incident light reflected by surface with lower *n* no phase shift
  - n1 > n2, phase shift = 0
- If incident light reflected by surface with higher *n* phase shifted by ½λ
  - n1 < n2, phase shift = 0.5λ
- 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

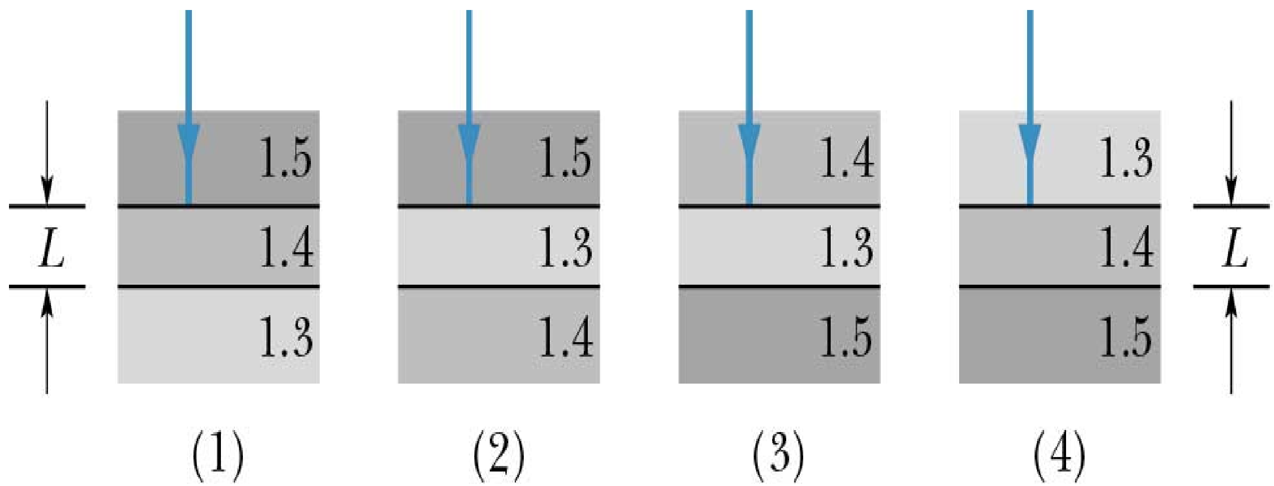


$$2L = (m + \tfrac{1}{2})\frac{\lambda}{n_2}, \ \mathrm{m} = 0,1,2,...$$

$$2L = m\frac{\lambda}{n_2}, \ \mathrm{m} = 0,1,2,...$$

Review

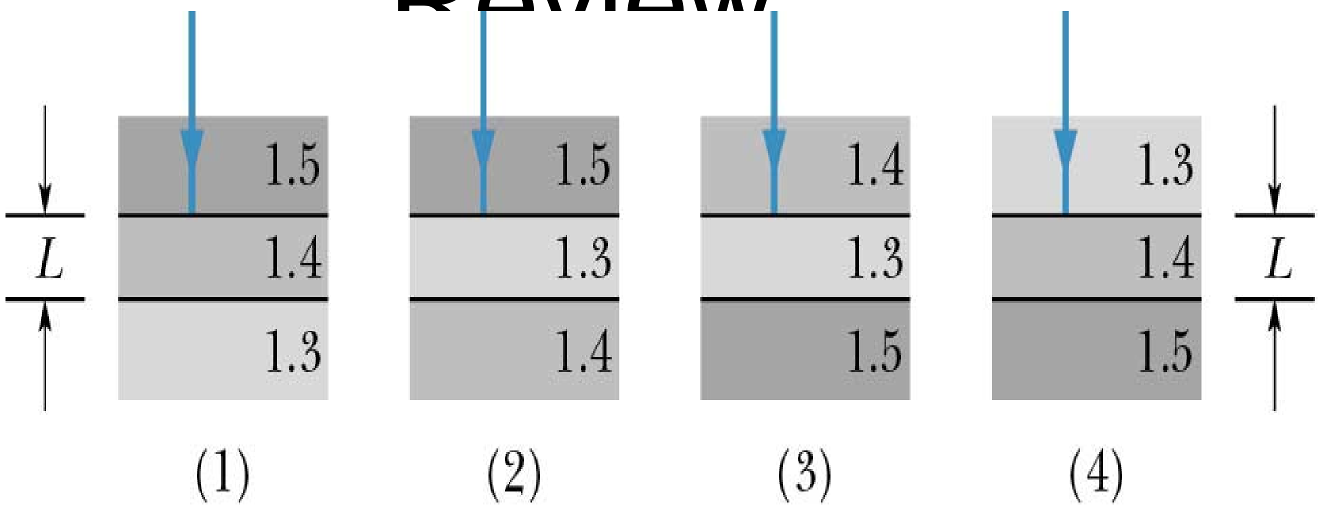
- Checkpoint #5 – Light reflects ⊥ from film of thickness L between 2 other media. For given index of refractions, which situations will A) give zero phase difference from reflection at film interfaces



If n1>n2, no phase change

If n1<n2, ½λ phase change

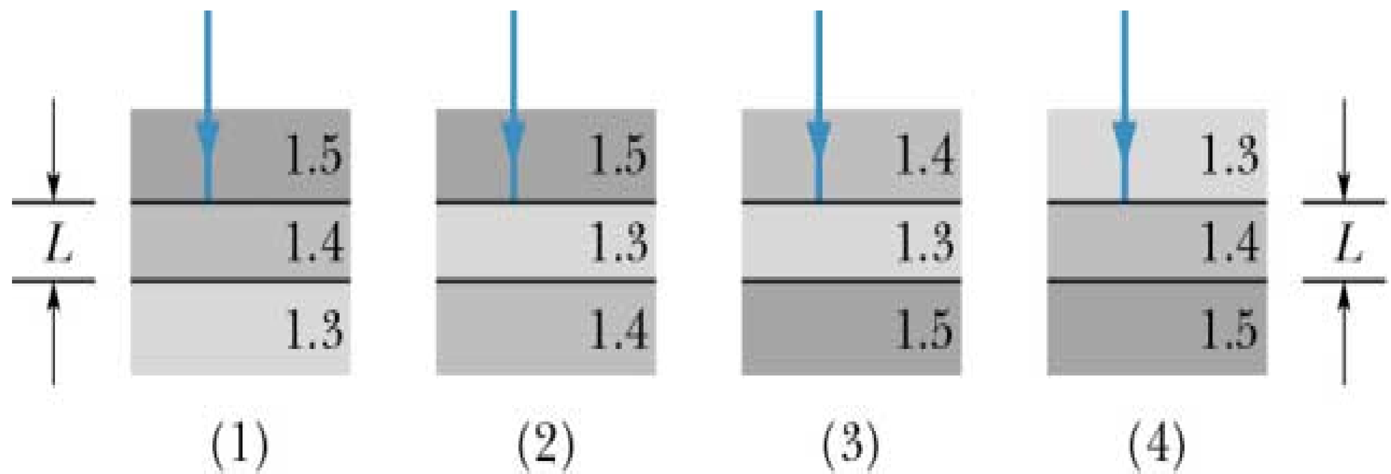
Review



- (1) n1>n2>n3 – no phase shift either surface, phase diff = 0, in phase
- (2) n1>n2<n3 – top surface no phase shift, bottom surface shifted ½λ, phase diff = ½λ
- (3) n1>n2<n3 – same as (2) phase diff = ½λ
- (4) n1<n2<n3 – top and bottom surface both have ½λ phase shift, phase diff = 0, in phase

Review

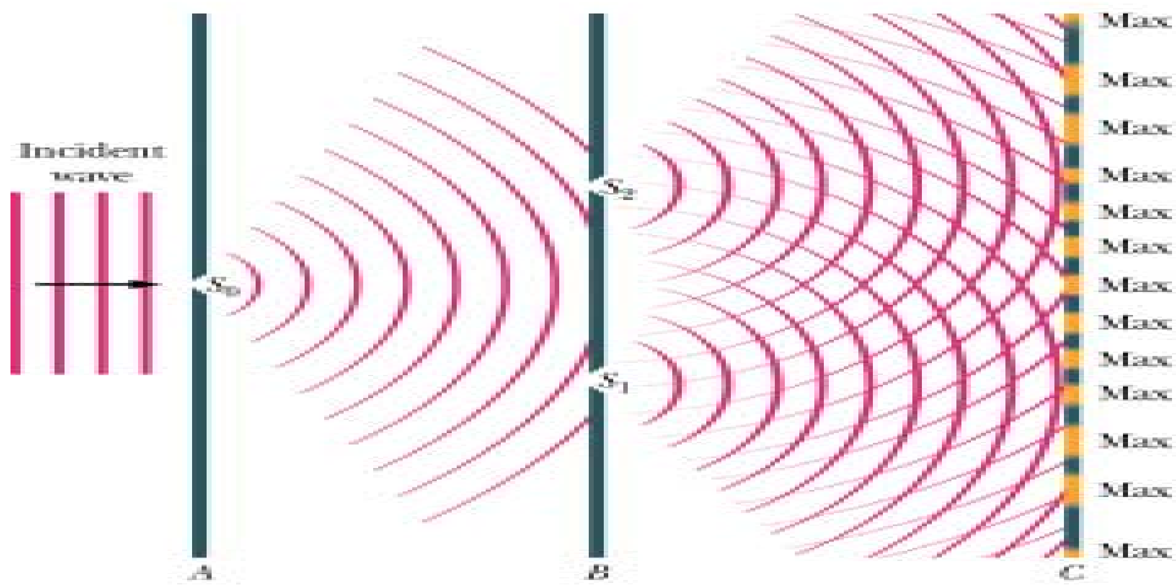
- Checkpoint #5 – B) for which situations will the film be dark if 2L=0.5λ phase difference



- Reflection causes 2&3 to be out-of-phase by ½λ so additional ½λ from path length makes waves in phase so constructive and bright
- 1 & 4 are in phase by reflection so ½λ from path length makes waves out-of-phase and dark

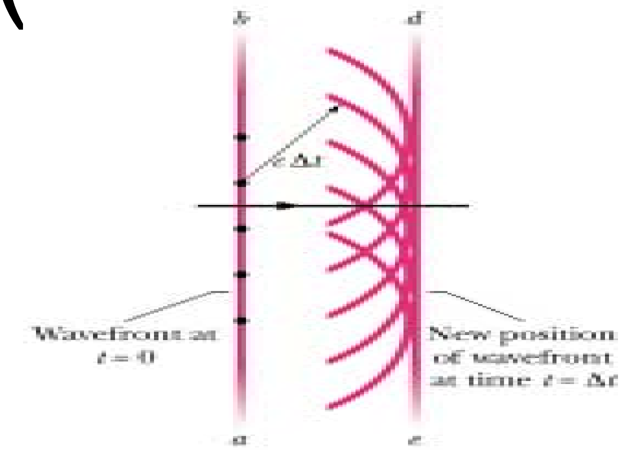
Diffraction (1)

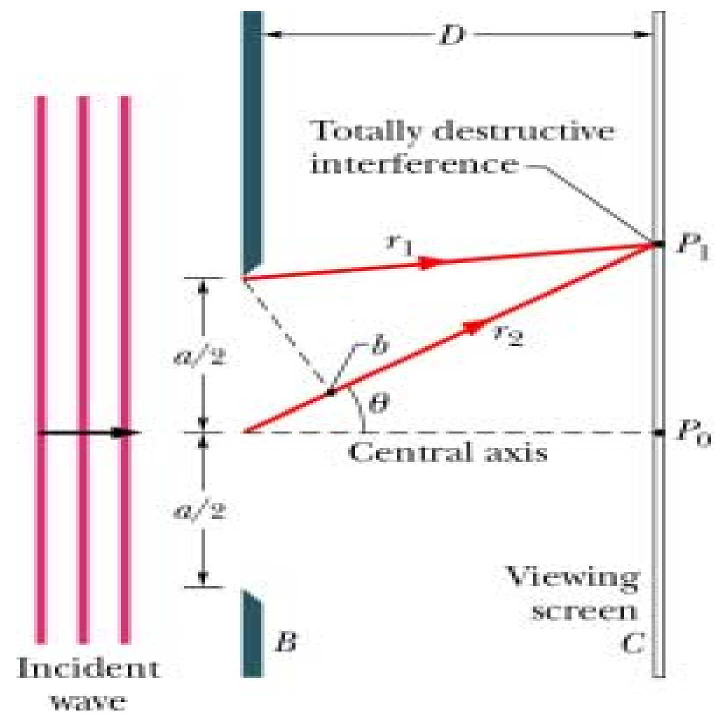
- Waves diffract (bend) if pass through an opening whose size is comparable to its wavelength
- The narrower the slit, the greater the diffraction
- Previous example of double-slit interference assumed slit width *a* much smaller than λ of incident light and we talked about 2 light rays



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