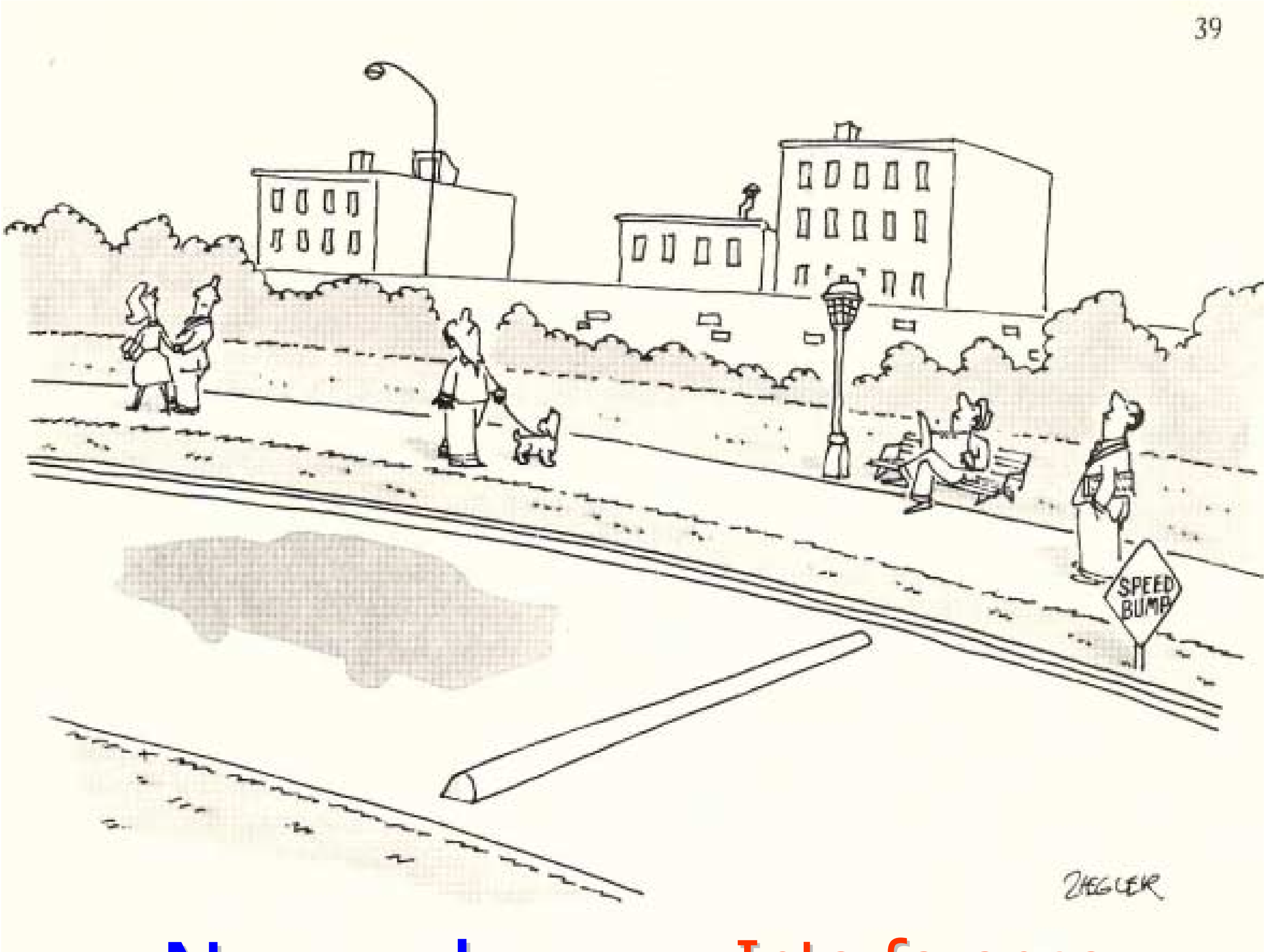


November 26th

Interference
Chapter 36

Schedule for rest of term

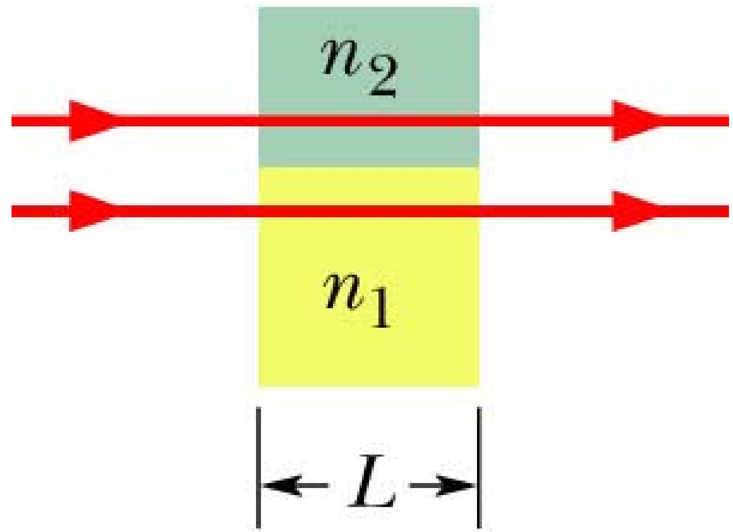
- Nov. 26 (Wed) – class – finish Chpt. 36
- Dec. 1-2 (Mon-Tues) – cover Chpt. 37
- Dec. 3-5 (Wed-Fri) – Review for final
- Dec. 3 (Wed) – HW set #12 due
- Dec. 8 (Mon) – Corrections #3 due
- Dec. 8 (Mon) – 5:45-7:45 pm Final Exam
  - N130 BCC (Business College) for section 1
  - 158 NR (Natural Resources) for section 2

Review

- Materials of different n
  - Different #'s of wavelengths occur for different index of refractions, *n*
  - Phase shift given by

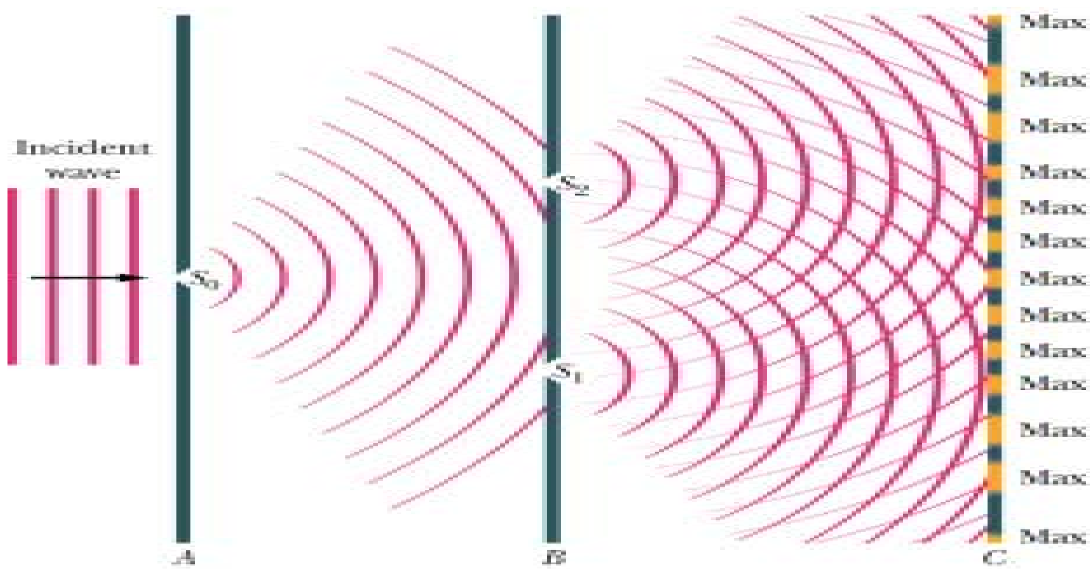
$$N_2 - N_1 = \frac{L}{\lambda}(n_2 - n_1)$$

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



Review

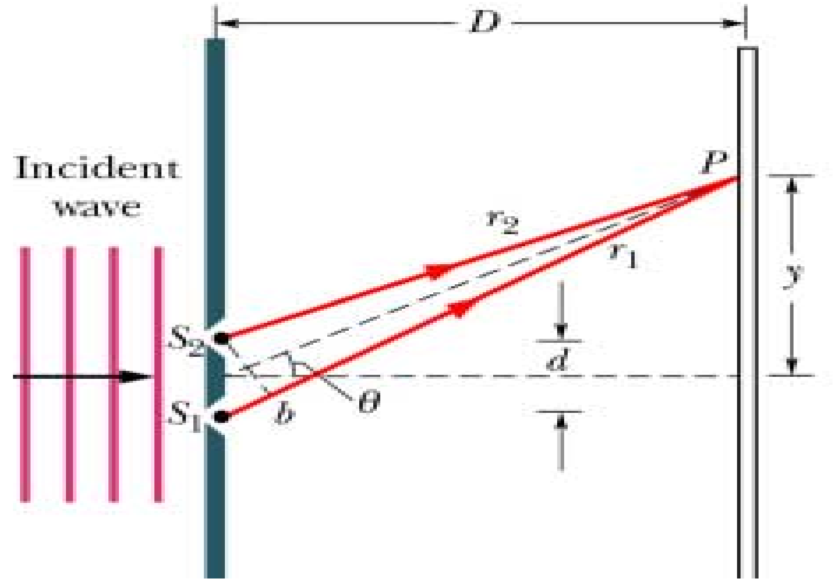
- When 2 waves interact get interference
  - If phase difference is 0 or integer # of wavelengths (1λ,2λ,…) waves are in-phase and constructively interfere giving a bright spot or maxima
  - If phase difference is half a wavelength (0.5λ,1.5λ,…) waves are out-of-phase and destructively interfere giving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



Review

- 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*

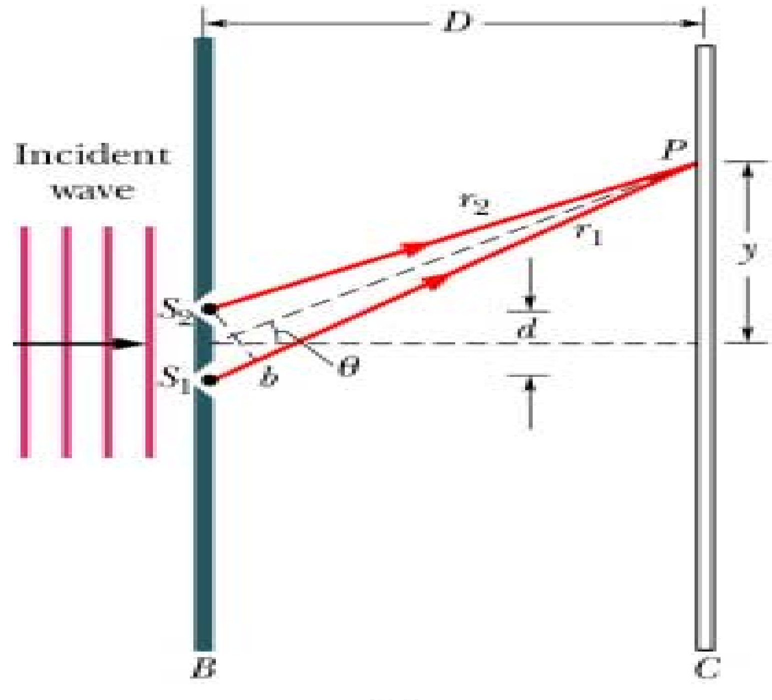
$$\Delta L = d\sin\theta$$

- Maxima, bright spots at

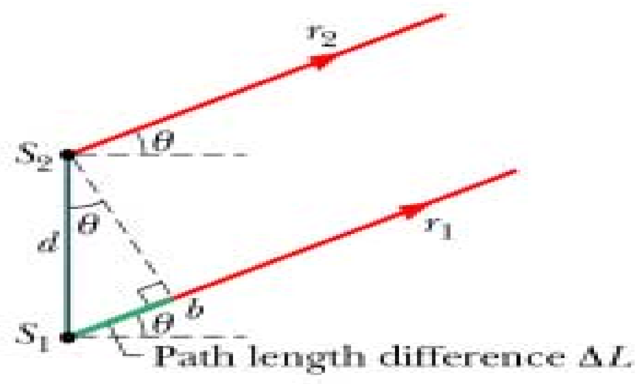
$$d\sin\theta = m\lambda, m = 0,1,2,...$$

- Minima, dark spots at

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



(a)

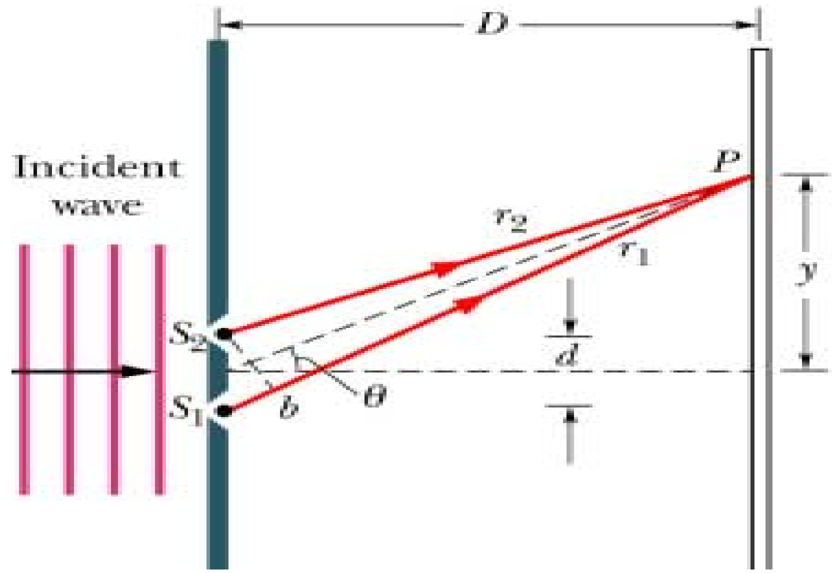


Review

- Different path lengths

- Use small angle relation

$$\tan\theta \approx \sin\theta \approx \theta$$

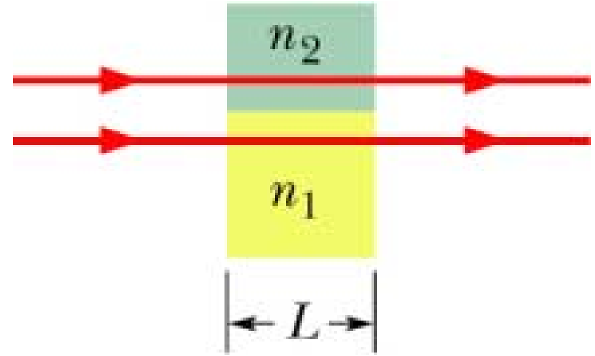


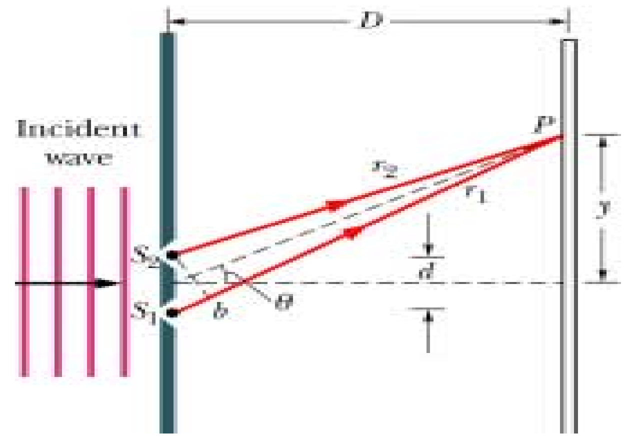
- Distance y on screen from central maxima to maxima of order m is
  - D the is distance from slits to the screen and d is the distance between the slits

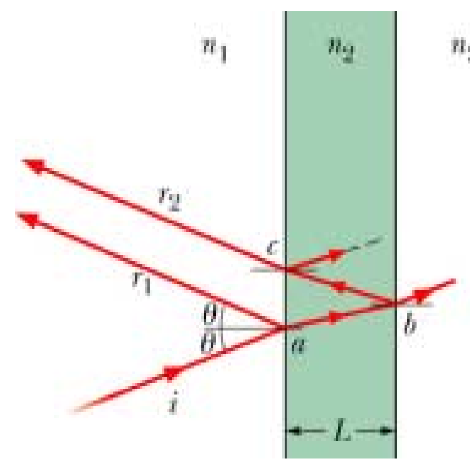
$$y = \frac{mD\lambda}{d}$$

Interference

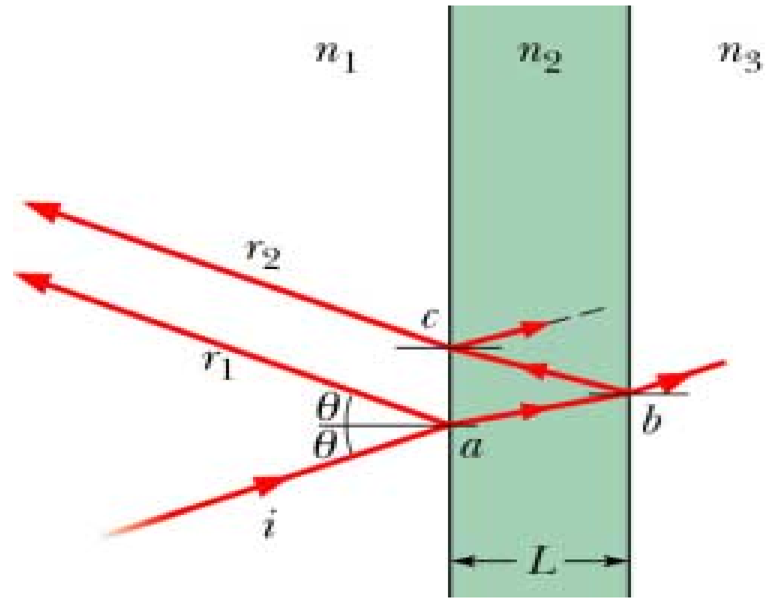
- 3 ways for the phase difference between 2 light waves to change
  - Waves travel through media of different indexes of refraction, *n*
  - Waves travel along paths of different lengths
  - Waves are reflected – discuss today







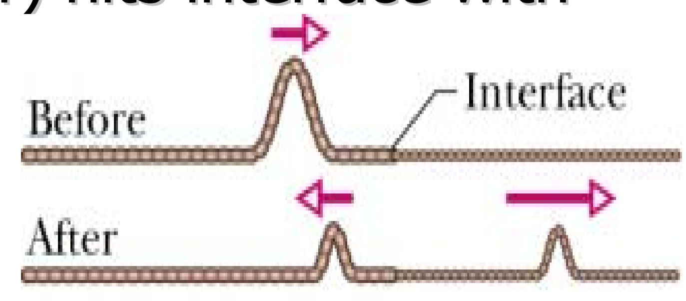
Interference (Fig. 36-12)



- Interference of light occurs in thin films when light waves are reflected from front and back surfaces
- Both reflection and refraction occur at the surfaces
- Region *ac* is bright if waves are in phase; and dark if waves are out of phase
- Assume light almost ⊥ to film ($\theta \approx 0$) so path length difference ΔL between ray 1 and 2 is 2L

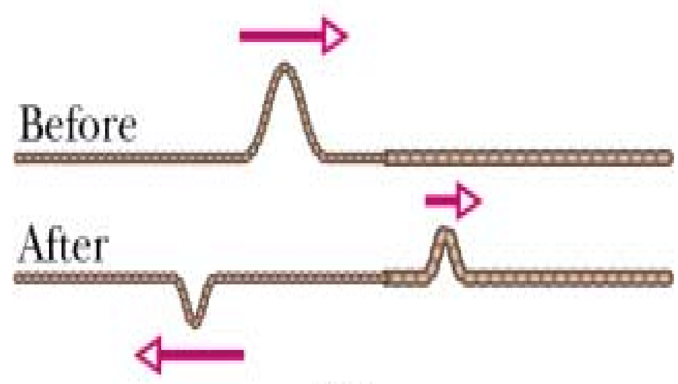
Interference (Fig. 36-13)

- Refraction at interface (the transmitted wave) never changes the phase
- Reflection of wave can give a phase difference - Analogous to waves on a string
- Wave in denser string (moving slower) hits interface with lighter string
  - Transmitted wave has same phase
  - Reflected wave has same phase



(a)

- Wave in lighter string (moving faster) hits interface with denser string
  - Transmitted wave has same phase
  - Reflected wave phase shifts by ½λ



Interference

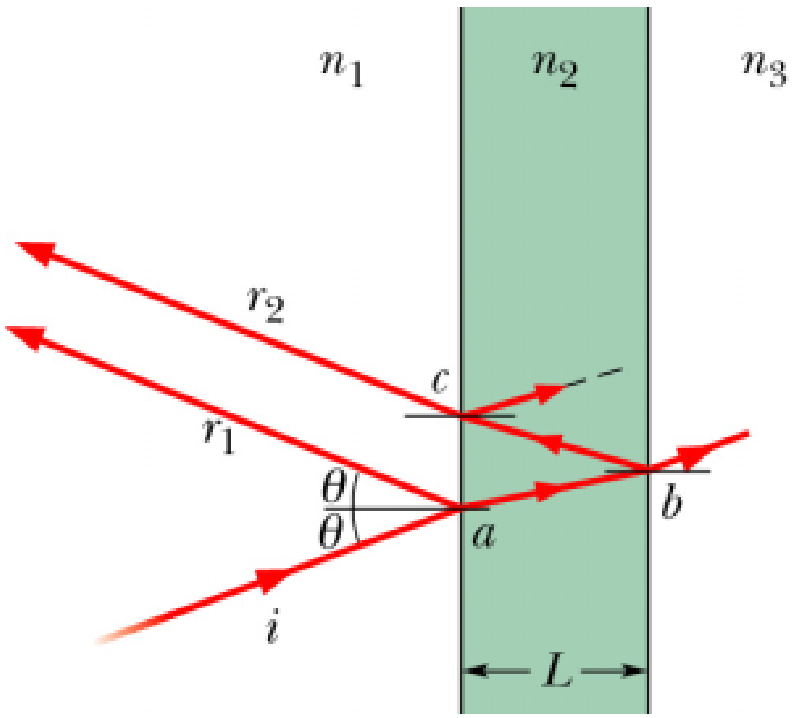
- Phase change due to reflection:
  - Incident wave in medium with larger n (slower speed) no phase shift
    - Light reflects off material with smaller n
  - Incident wave in medium with smaller n (faster speed) phase shift of ½λ
    - Light reflects off material with bigger n
- No phase shift for refracted light

Interference (Fig. 36-12)

- If n_1, n_3 = 1.0 for air, and n_2=1.5 for glass

- Reflected ray 1 (at a) is phase shifted by ½ λ since $n_1 < n_2$

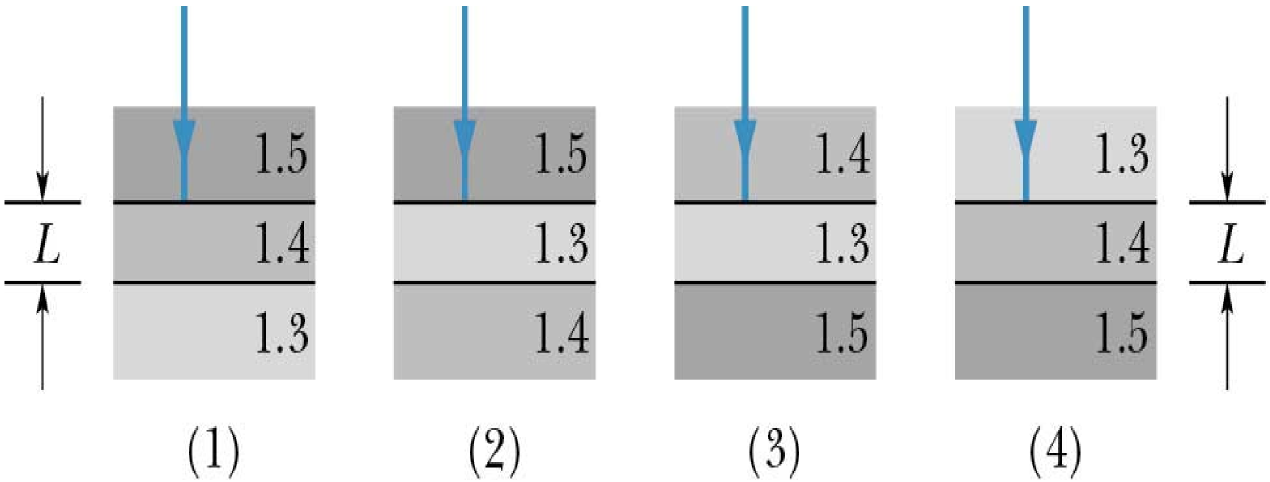
- Reflected ray 2 (at b) has no phase shift since $n_2 > n_3$



Checkpoint #5

- Light reflects ⊥ from film of thickness L between 2 other media.
- A) For given index of refractions, which situations will give zero phase difference (or a bright spot) from reflection at film interfaces

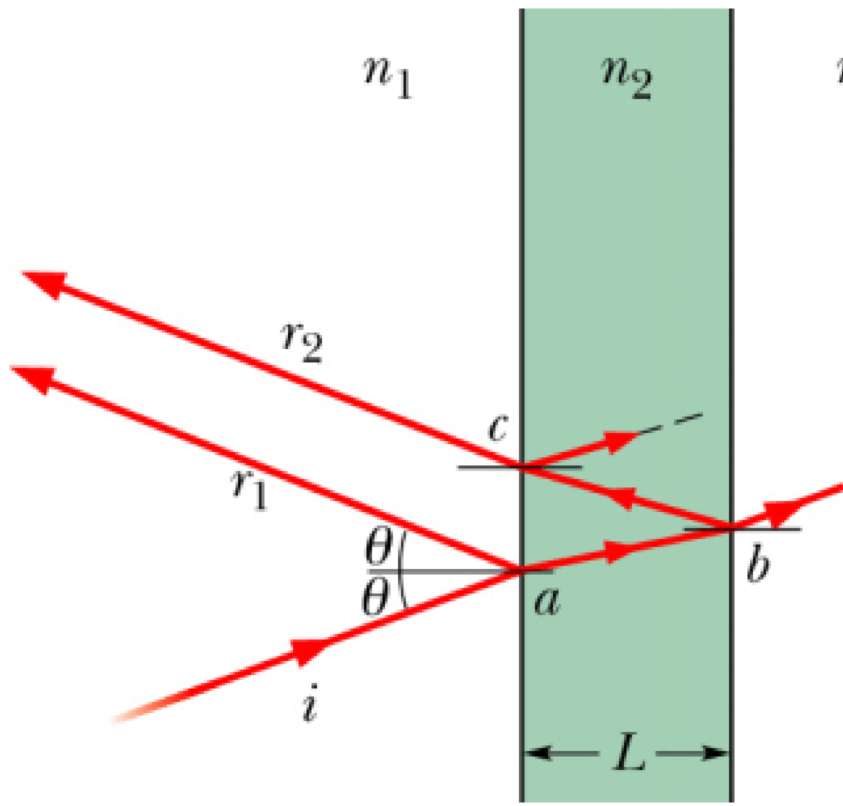
- $n_1 > n_2$, no phase change
- $n_1 < n_2$, ½λ phase change



A) 1 & 4

Interference (Fig. 36-12)

- For thin films 3 ways to get a phase difference between waves
  - By reflection
  - By waves traveling along different path lengths
  - By waves traveling through different media of different n



Interference (Fig. 36-12)

- Phase change due to transmission in material n_2 from *a* to *b* to *c* over a total length 2L
- 1 and 2 are in phase if

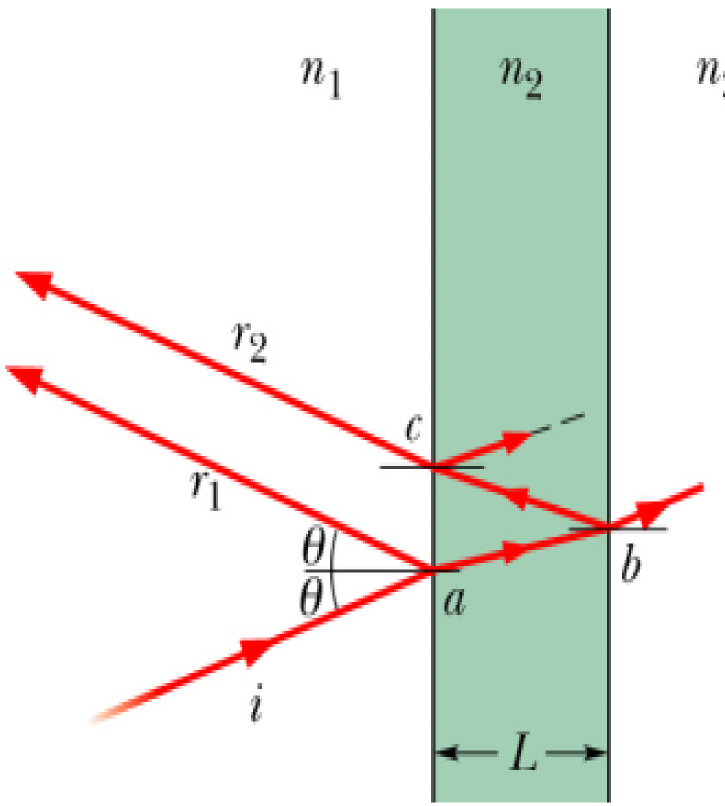
$$2L = 0, \lambda_{n2}, 2\lambda_{n2}...$$

$$2L = m\lambda_{n2}, \quad m = 0,1,2...$$

- 1 and 2 are out of phase if

$$2L = \tfrac{1}{2}\lambda_{n2}, \tfrac{3}{2}\lambda_{n2}...$$

$$2L = (m + \tfrac{1}{2})\lambda_{n2}, \quad m = 0,1,2...$$



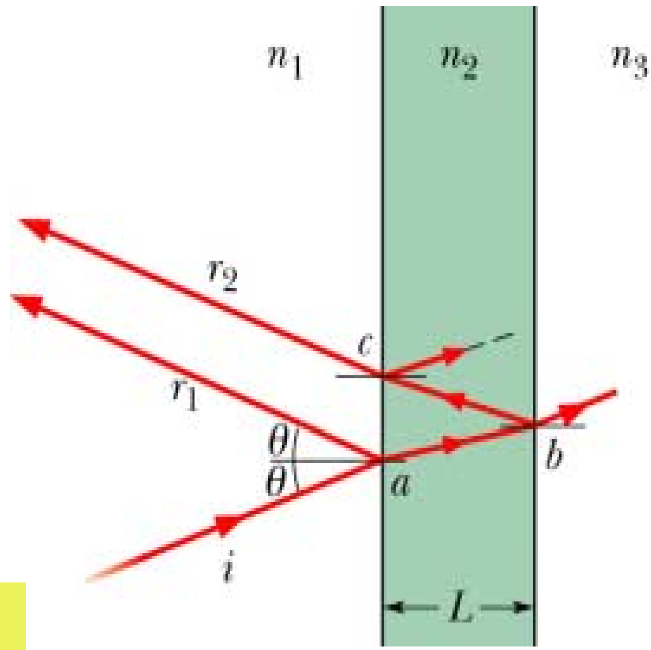
$$\lambda_{n2} = \frac{\lambda}{n_2}$$

Interference (Fig. 36-12)

- Assume n1<n2>n3 (air to glass to air)

- Rays 1 and 2 are ½λ out of phase from reflections at *a* and *b*
- If we want the waves 1 and 2 to be in phase, ray 2 must change phase in the material n_2 by the amount

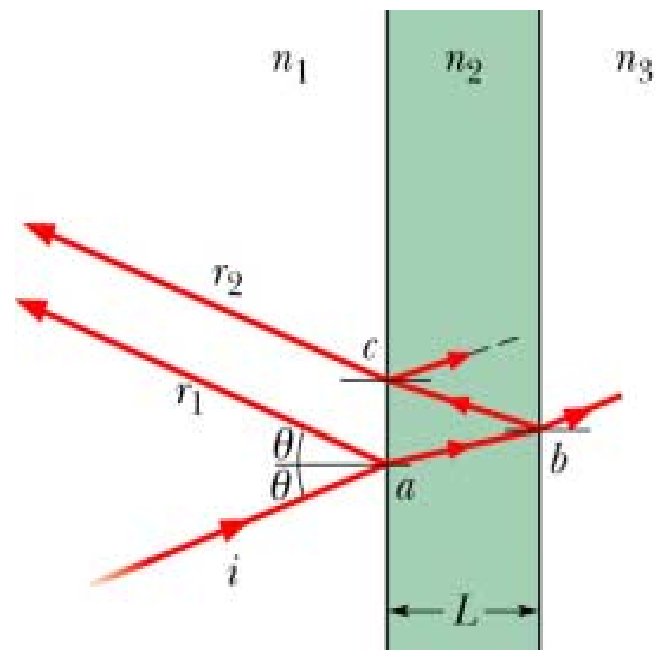
$$2L = (m + \tfrac{1}{2})\lambda_{n2}, \quad m = 0,1,2...$$



Interference (Fig. 36-12)

- And for waves 1 and 2 to be out of phase, ray 2 must change phase in the material by

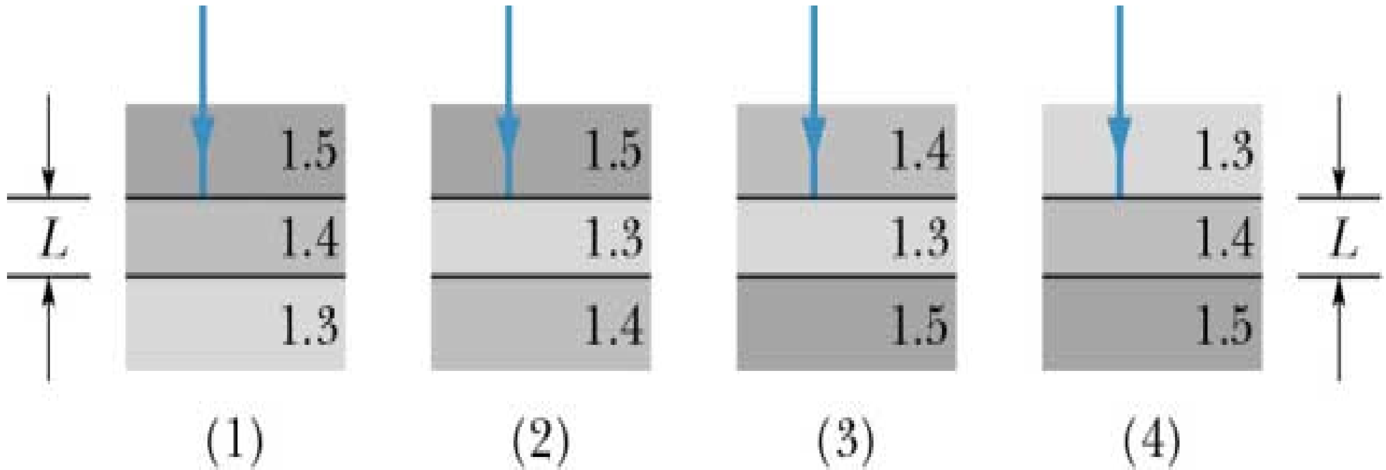
$$2L = m\lambda_{n2}, \ \ \mathrm{m} = 0,1,2,...$$



- $L << \lambda_{n2}$ is the same as m=0 - it will be out of phase (dark)
- An example is reflection from soap film – we can see varying thickness from the difference colors (very thin film looks dark)

Checkpoint #5

- B) For the given index of refractions, which situations will film be dark if $2L=0.5\lambda_n$



- For 1 and 4 there is no phase change from reflection, and the path difference of $0.5\lambda_n$ will make the total out of phase (dark)
- For 2 and 3 there is a $½\lambda_n$ phase change from reflection, and the path difference of $0.5\lambda_n$ will make the total in phase (bright)

Interference

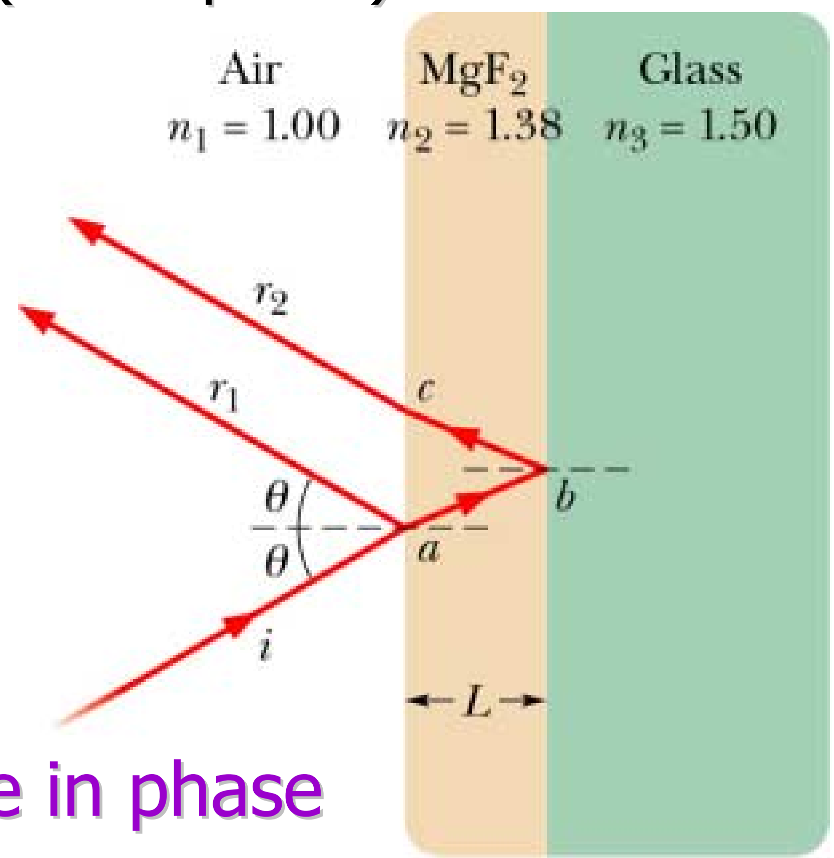
- Need combination of phase shifts from reflection and path length difference to determine what wavelengths of light will interfere destructively or constructively
- Equations for path length always hold but which equation gives in-phase and which gives out-of-phase waves depends on index of refractions of media

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

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

Sample problem 36-5

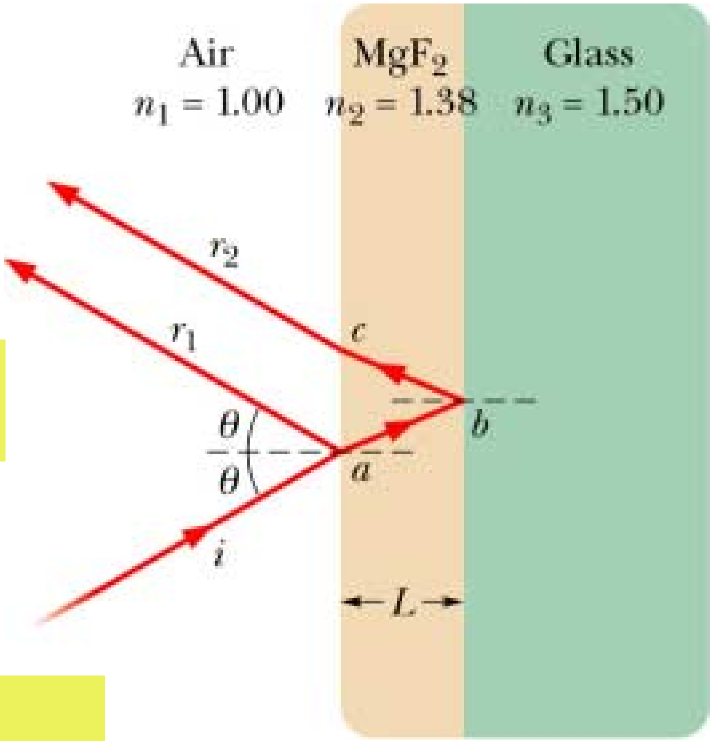
- What thickness, L, is needed to eliminate reflections at middle of visible spectrum λ=550 nm?
  - Want destructive interference (out of phase)
- Need light waves reflected from 2 surfaces to be exactly out of phase
- First look at phase due to reflection
  - Ray 1 is ½λ since $n_1<n_2$
  - Ray 2 is ½λ since $n_2<n_3$



From reflection alone, rays are in phase

Sample problem 36-5

- What thickness, L, is needed to eliminate reflections at middle of visible spectrum λ=550 nm?



  - Need path length difference to put rays out of phase

$$2L = (m + \tfrac{1}{2})\lambda_{n2}, \ \ \mathrm{m} = 0,1,2,...$$

  - Least thickness is when m=0

$$L = \frac{\lambda_{n2}}{4} = \frac{\lambda}{4n_2} = \frac{550\,\mathrm{nm}}{4(1.38)} = 99.6\,\mathrm{nm}$$

$$\lambda_{n2} = \frac{\lambda}{n_2}$$