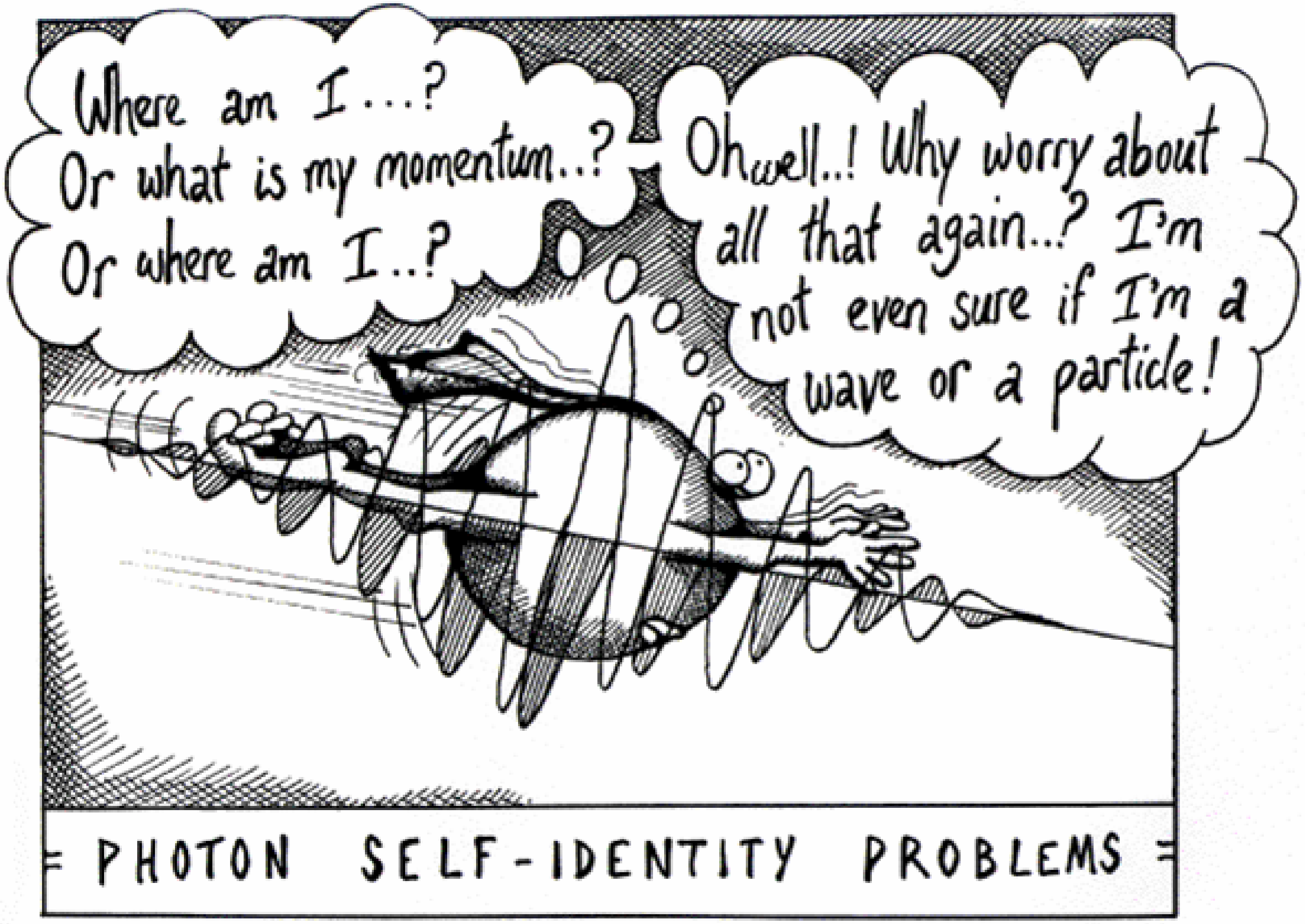


November 20th/21st

Interference

Chapter 36

Schedule for rest of term

- Nov. 24 (Mon) – Review for Midterm-3
- Nov. 25 (Tues) - no class - Midterm-3 at 6pm
- Nov. 26 (Wed) – 8am midterm-3 make-ups
- 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

Midterm-3

- Tuesday November 25 at 6pm
  - Section 1 – N100 BCC (Business College)
  - Section 2 – 158 NR (Natural Resources)
- Allowed one sheet of notes (both sides) and calculator
- Covers Chapters 32-35 (HW sets 9,10, and 11)
- Need photo ID
- Send me an email if you have another class on Tuesday night - tell me which class it is - makeup will be on Wednesday morning.
- Use the help-room to prepare

Review

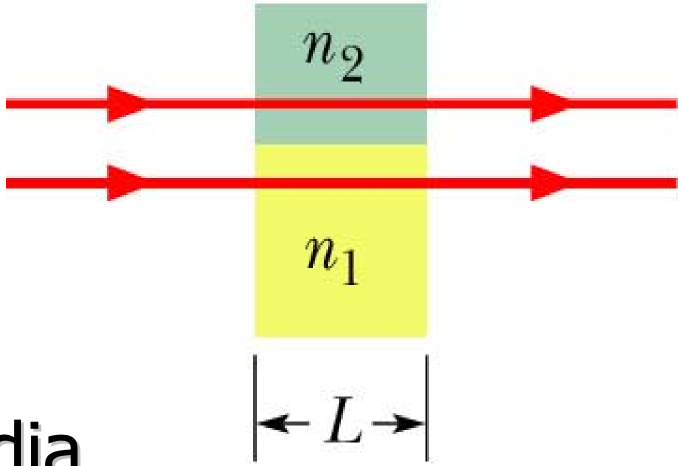
- Light is an electromagnetic wave
- Light waves interact with each other and produce constructive or destructive interference
- Frequency, *f*, of light in medium same as vacuum
- Wavelength and velocity depend on index of refraction, *n*

$$\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2} = \frac{n_2}{n_1}$$

- Wavelength of light in medium, λ_n smaller than in vacuum, λ

$$\lambda_n = \frac{\lambda}{n}$$

Index of refraction (Fig. 36-3)



- Phase difference between 2 light waves can change if waves travel through different media with different *n*
- Number of wavelengths in media

$$N_1 = \frac{L}{\lambda_{n1}} = \frac{Ln_1}{\lambda} \qquad N_2 = \frac{L}{\lambda_{n2}} = \frac{Ln_2}{\lambda}$$

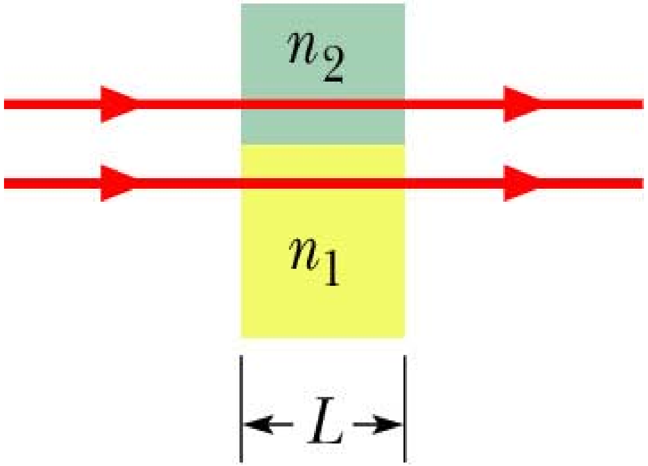
- Phase difference in terms of λ

$$\boxed{N_2 - N_1 = \frac{Ln_2}{\lambda} - \frac{Ln_1}{\lambda} = \frac{L}{\lambda}(n_2 - n_1)}$$

Checkpoint #2

- Rays have same wavelength and initially in phase. A) If 7.6 wavelengths fit within top material and 5.5 fit within bottom, which has greater index of refraction, *n* ?
- Larger *n* produce smaller λ_n

$$\boxed{\lambda_n = \frac{\lambda}{n}}$$

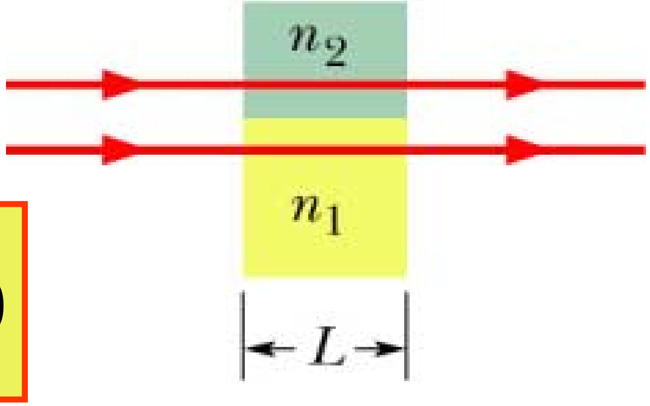


- Which material has smaller λ_n?
- Smaller λ_n means more wave-lengths in same distance

Top material has greater index of refraction

Checkpoint #2

- Rays have same wavelength and initially in phase. B) After material will interference of waves give brightest, bright intermediate, dark intermediate illumination or darkness?



- Look at phase difference in terms of λ

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

- Given # of wavelengths for each material

$$N_2 - N_1 = 7.6 - 5.5 = 2.1$$

- Waves are 2.1 wavelengths out of phase after passing through materials

Interference

- If phase difference is an integer # of wavelengths (0,1,2,…) then waves are in phase and have full constructive interference (brightest spot)
- If phase difference is 0.5 wavelengths (half a wavelength) then waves are completely out of phase and fully destructive interference (dark spot)

- Effective phase difference is decimal fraction

Checkpoint #2

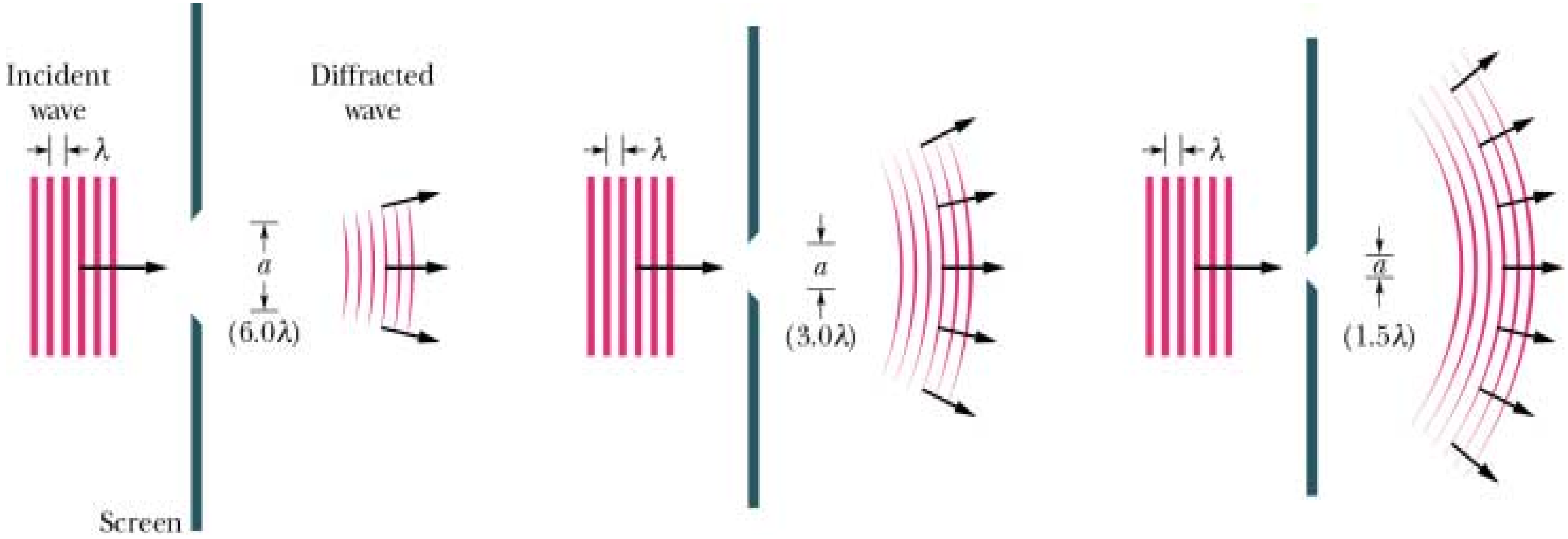
- B) After material will interference of waves give brightest, bright intermediate, dark intermediate illumination or darkness?

- Total phase difference = 2.1
- Effective phase difference = 0.1
- Our effective phase difference is closer to 0 than 0.5 so intermediate bright spot but not the brightest.

Interference

- For interference pattern to appear waves must have a constant phase difference
- If phase difference does not vary with time waves are coherent
- Light is produced by emission from individual atoms
- Atoms in conventional light (light bulbs, sunlight) are in random phases so light is incoherent
- Lasers are designed so atoms emit coherent and monochromatic light

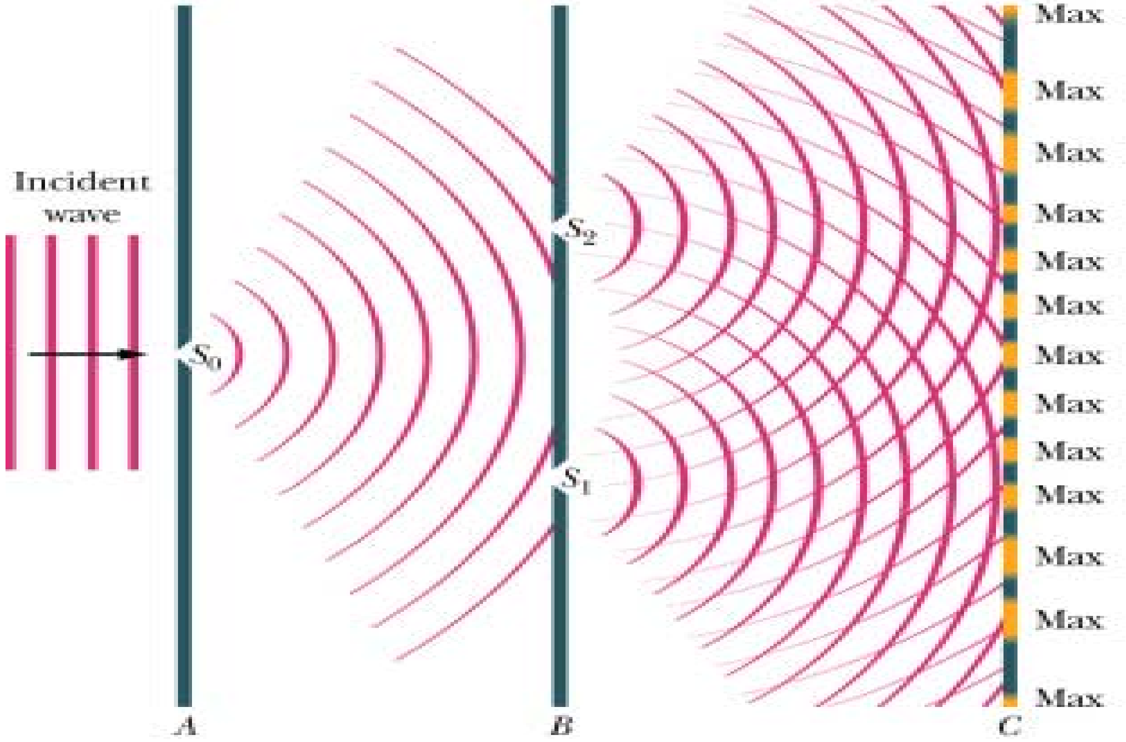
Diffraction (Fig. 36-5)



- Waves diffract if pass through opening whose size is comparable to its wavelength
- Narrower the slit, greater the diffraction
- Geometric optics doesn’t work in this case

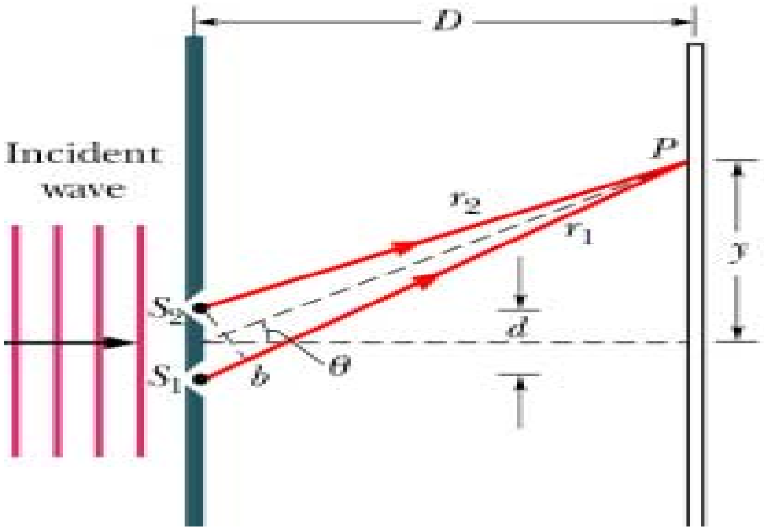
Young’s experiment (Fig. 36-6)

- Young’s double-slit interference experiment proved light was a wave
- Produce interference pattern with
  - Bright bands, bright fringes, or maxima
  - Dark bands, dark fringes, or minima



Young’s experiment (Fig. 36-8)

- What causes the fringes?
- Waves from each slit travel different distances which causes a phase difference



- If path length difference, ΔL, is 0 or integer # of wavelengths, waves interfere fully constructively

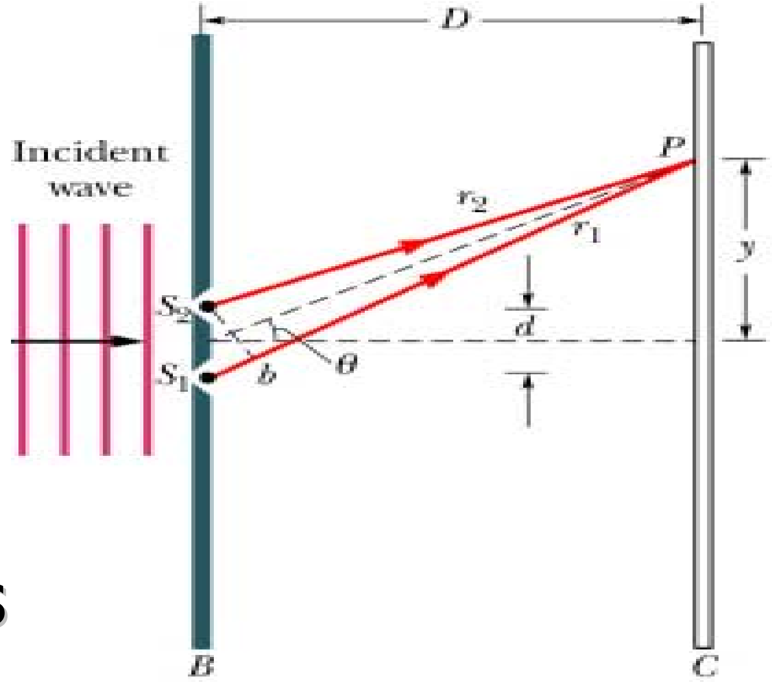
$$\Delta L = m\lambda, \quad \mathrm{m}=0,1,2,...$$

- If ΔL is odd multiple of 1/2 wavelength, waves interfere fully destructively

$$\Delta L = (m+1/2)\lambda, \quad \mathrm{m}=0,1,2,...$$

Young’s experiment (Fig. 36-8)

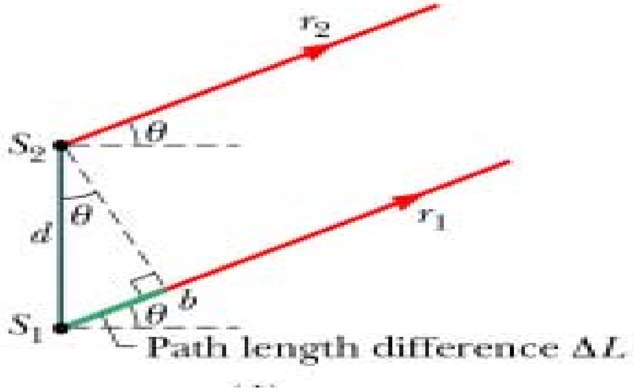
- Find the path length difference ΔL for rays from 2 slits a distance *d* apart
- If distance to screen, *D*, is much greater than distance between slits, *d*, rays are || and at angle θ to central axis and the right triangle, S_1S_2b, relates ΔL to *d*



(a)

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

$$\boxed{\Delta L = d\sin\theta}$$



Young's experiment

- Bright fringes or maxima –

$$\boxed{\Delta L = d\sin\theta = m\lambda,\ \mathrm{m}=0,1,2,\ldots}$$

  - Central maximum when m=0, $\Delta L = 0$
  - First order fringe or first maxima at m=1, $\Delta L = 1\lambda$
  - Second maxima or second order fringe at m=2
- Dark fringes or minima –

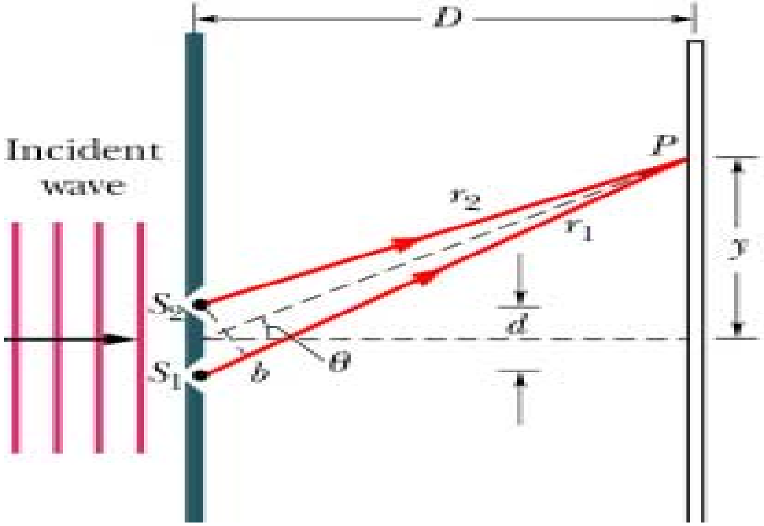
$$\boxed{\Delta L = d\sin\theta = (m+1/2)\lambda,\ \mathrm{m}=0,1,2,\ldots}$$

  - First order minima at m=0, $\Delta L = 0.5\lambda$
  - Second minima when m=1, $\Delta L = 1.5\lambda$

Checkpoint #3

- What is ΔL for two rays if point P is A) a third side maximum and B) a third minimum
- A) For maximum, third side is m=3 so

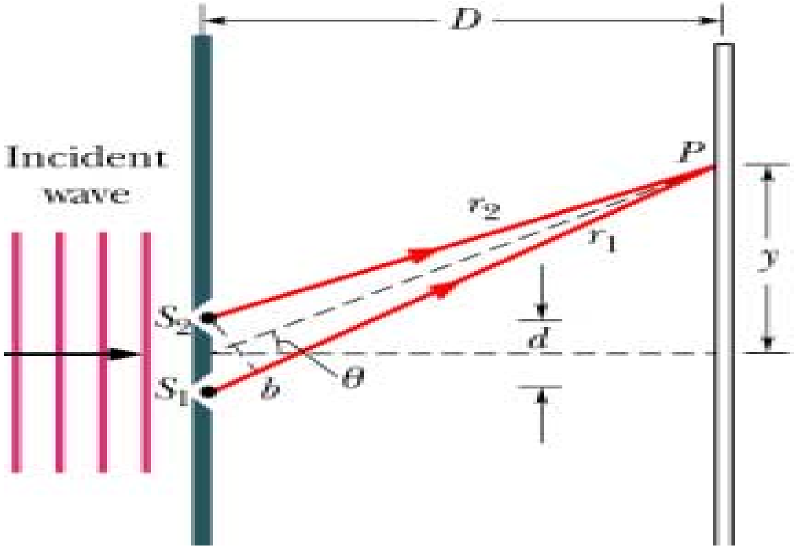
$$\Delta L = m\lambda = 3\lambda$$



- B) For minimum, third side is m=2 so

$$\Delta L = (m + 1/2)\lambda = 2.5\lambda$$

Locating the fringes (Fig. 36-5)



- What is location of maxima or minima on screen, *y* in relation to central axis?

$$\tan\theta = \frac{y}{D}$$

- For small angles (in radians)

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

- From path difference interference

$$\sin\theta = \frac{m\lambda}{d}$$

- Location of maxima or minima on the screen is

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

Intensity of fringes

- What is the intensity of the fringes?
- If waves coherent, phase difference ϕ does not change with time
- Intensity I depends on intensity of single slit I_0 and phase difference ϕ between waves

$$\boxed{I = 4I_0 \cos^2(\tfrac{1}{2}\phi)}$$

- Phase difference is related to distance between slits d and angle from central axis θ

$$\boxed{\phi = \frac{2\pi d}{\lambda}\sin\theta}$$

- Proof on p.873-874

Intensity of fringes (Fig. 36-9)

- Intensity of 2 coherent sources at bright fringe is

$$I = 4I_0\cos^2(\tfrac{1}{2}\phi) \qquad I_{\max} = 4I_0$$

- No fringe pattern if sources incoherent, intensity have uniform value of $2I_0$
- Average intensity of coherent waves is $I_{avg}=2I_0$