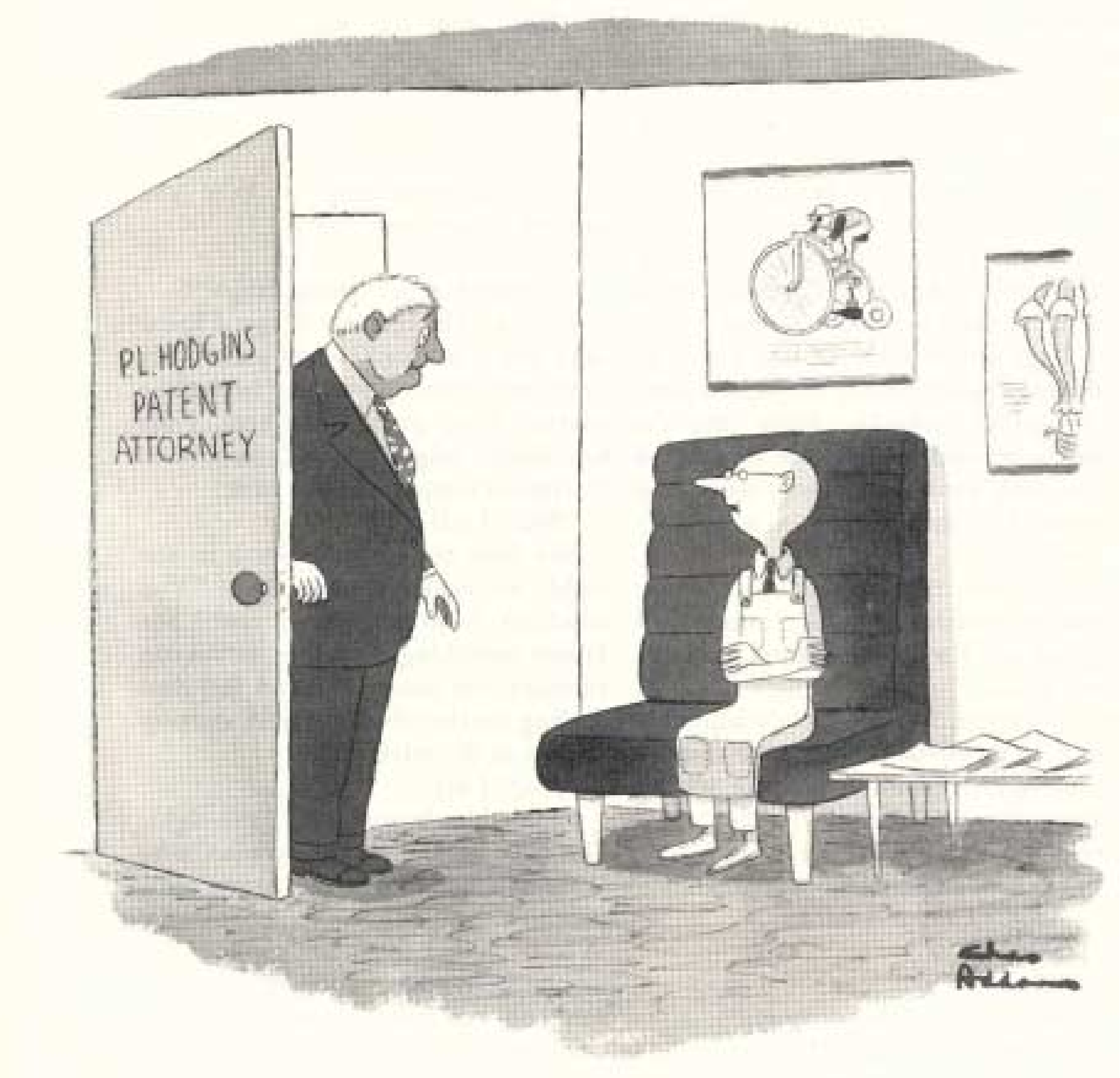
December 1st

Diffraction
Chapter 37



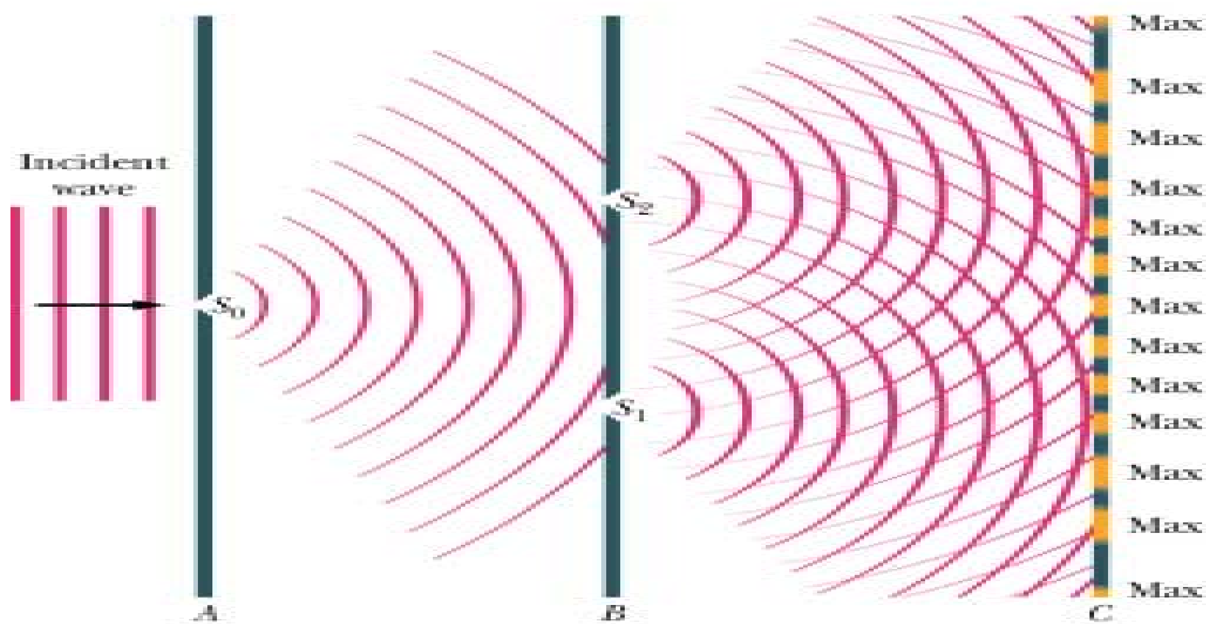
"I'm the invention. The inventor should be along any moment now."

Schedule for rest of term

- 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) – Final Exam 5:45-7:45pm
  - N130 BCC (Business College) for section 1
  - 158 NR (Natural Resources) for section 2

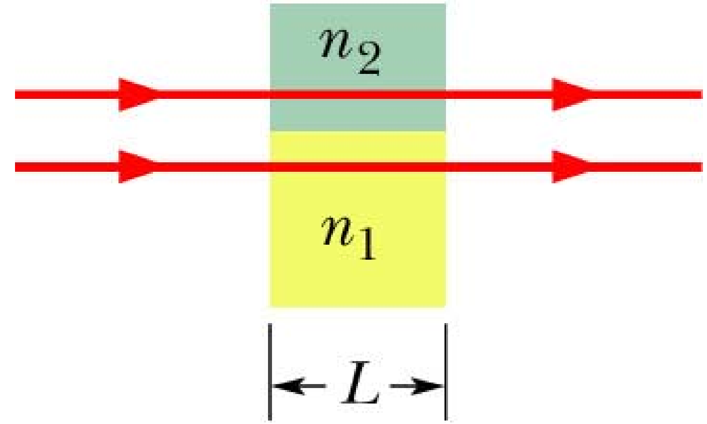
Review

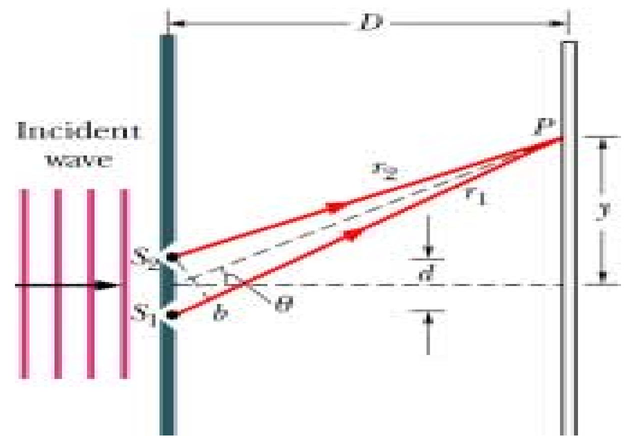
- When 2 waves interact get interference
  - If phase difference is 0 or integer # of wavelengths (1λ,2λ,…) waves are in-phase and constructively interfere giving a bright spot or maxima
  - If phase difference is half a wavelength (0.5λ,1.5λ,…) waves are out-of-phase and destructively interfere giving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

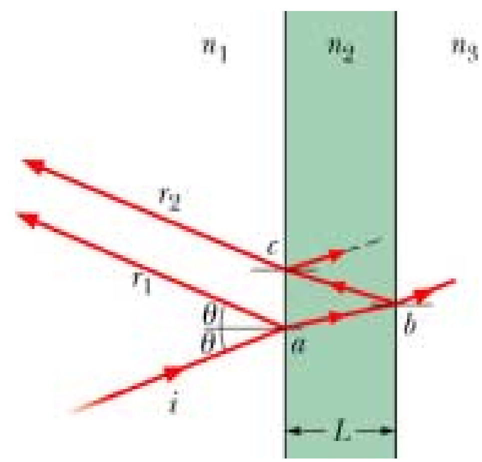


Review

- 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

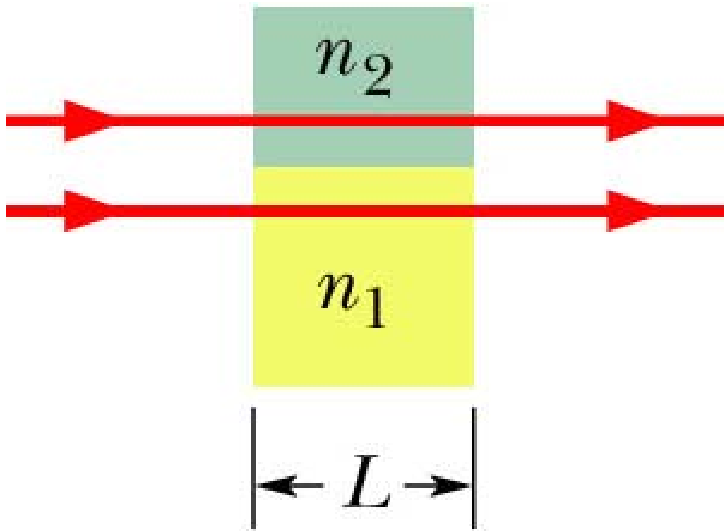
- Materials of different n
  - Different #'s of wavelengths occur in different n's

$$N_1 = \frac{L}{\lambda_{n1}} = \frac{Ln_1}{\lambda}$$

  - Phase shift given by

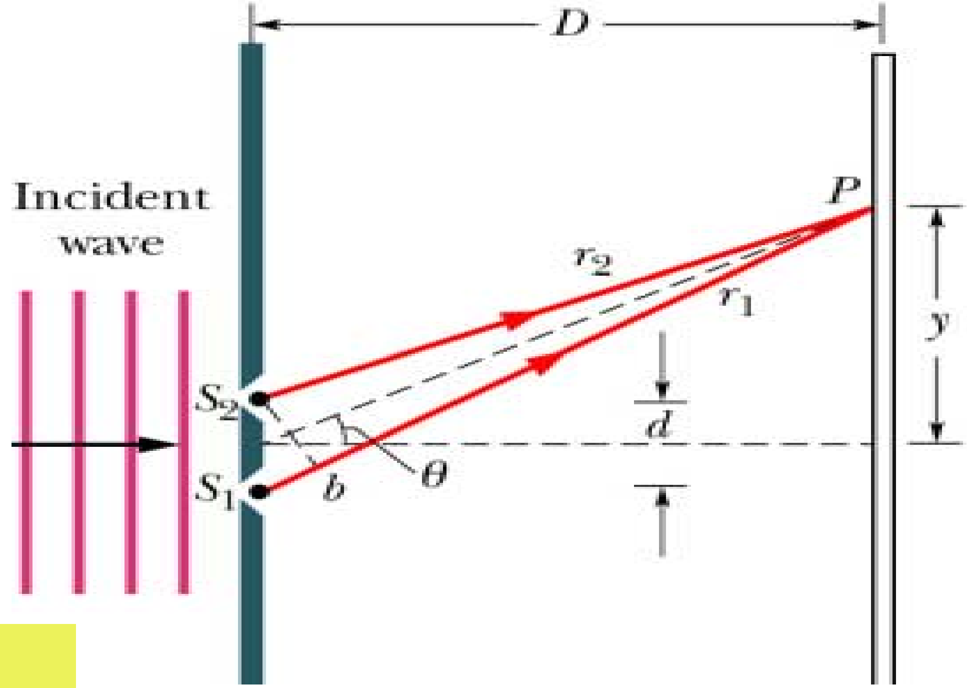
$$N_2 - N_1 = \frac{L}{\lambda}(n_2 - n_1)$$

  - 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*

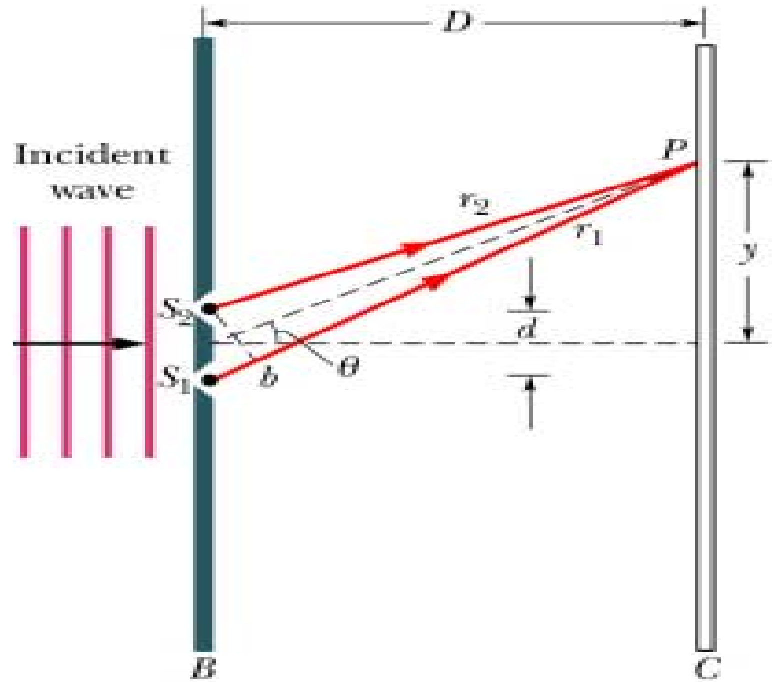
$$\Delta L = d\sin\theta$$

- Maxima, bright spots at

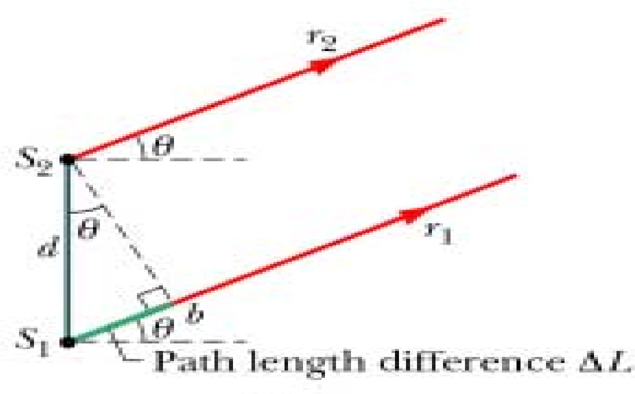
$$d\sin\theta = m\lambda, m = 0,1,2,...$$

- Minima, dark spots at

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



(a)

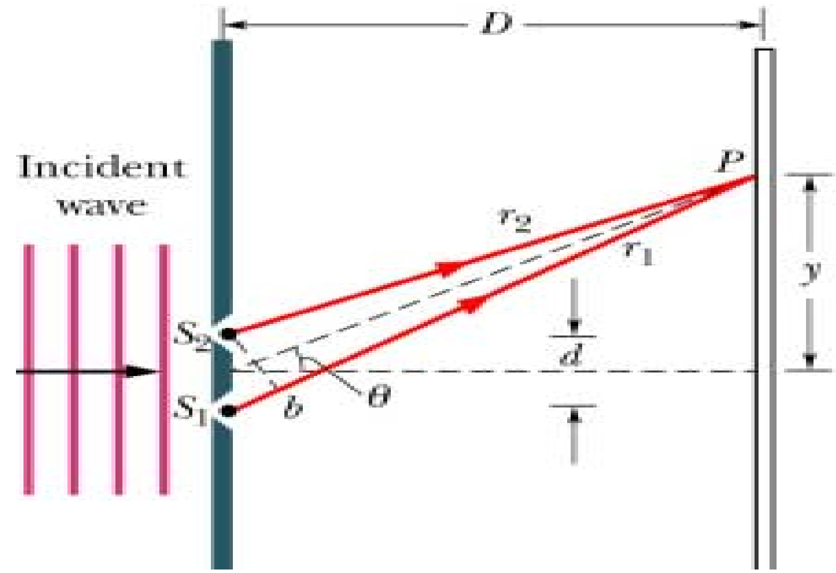


Review

- Different path lengths
- Use small angle relation

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

$$\tan\theta = {}^{y}\!/_{D}$$

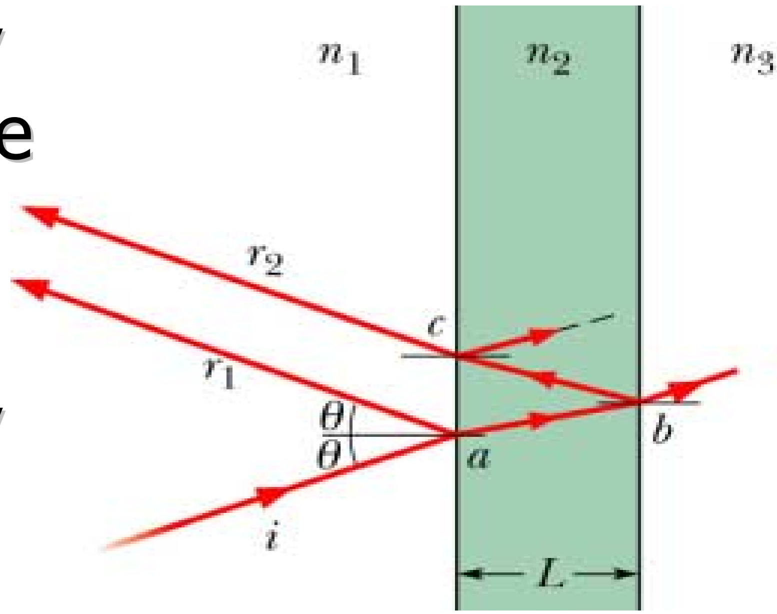


- Distance *y* on screen from central maxima to maxima of order m is
  - *D* is distance between screen and slits, *d* is distance between slits

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

Review

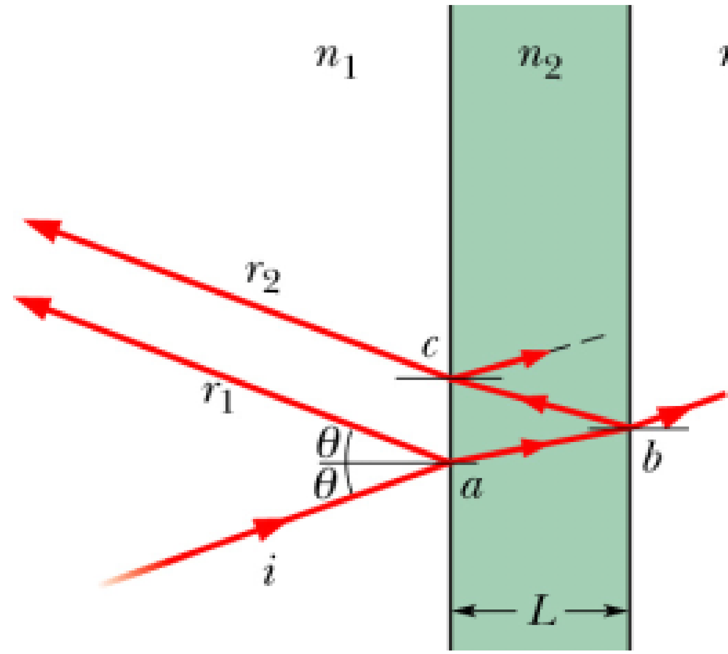
- Reflection
- If incident light reflected by surface with higher *n* phase shifted by ½λ
  - n1 < n2, phase shift = 0.5λ
- If incident light reflected by surface with lower *n* no phase shift
  - n1 > n2, phase shift = 0
- Refracted light is not phase shifted



n1 < n2 > n3
Example: soap bubble in air

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

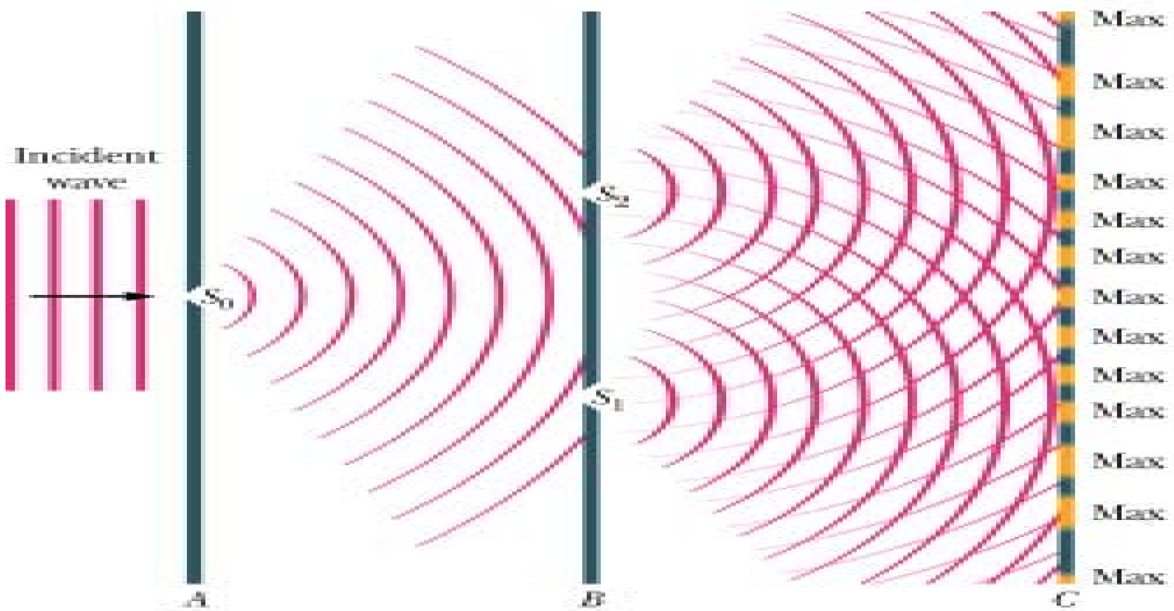


$$2L = (m + \tfrac{1}{2})\frac{\lambda}{n_2}, \ \mathrm{m} = 0,1,2,\ldots$$

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

Diffraction

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

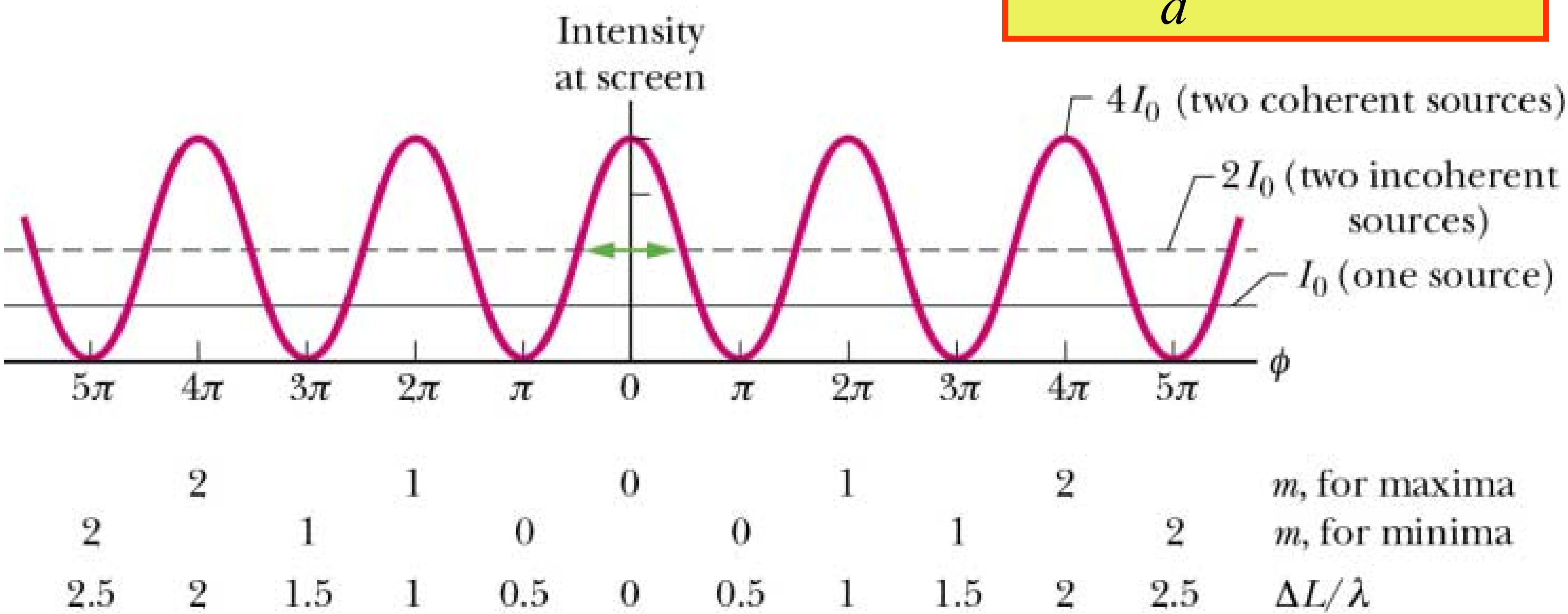


Two slit interference (Fig. 36-9)

- Intensity of 2 coherent sources $I = 4I_0 \cos^2(\tfrac{1}{2}\phi)$
- Maxima when $\phi = 2\pi\, m$
- Minima when $\phi = 2\pi\,(m + 1/2)$
- *m* is called the "order"

y position of maxima

$$y = \frac{m\lambda D}{d}, \quad m = 0,1,2\ldots$$



3-slit interference

- The distance between each is *d*.
- The most intense maxima are still given by

$$y = \frac{m\lambda D}{d}$$

- But now there are also secondary maxima related to the larger spacing 2*d*

$$y = \frac{m\lambda D}{2d}$$

4-slit interference

- The distance between each is *d*.
- The most intense maxima are still given by

$$y = \frac{m\lambda D}{d}$$

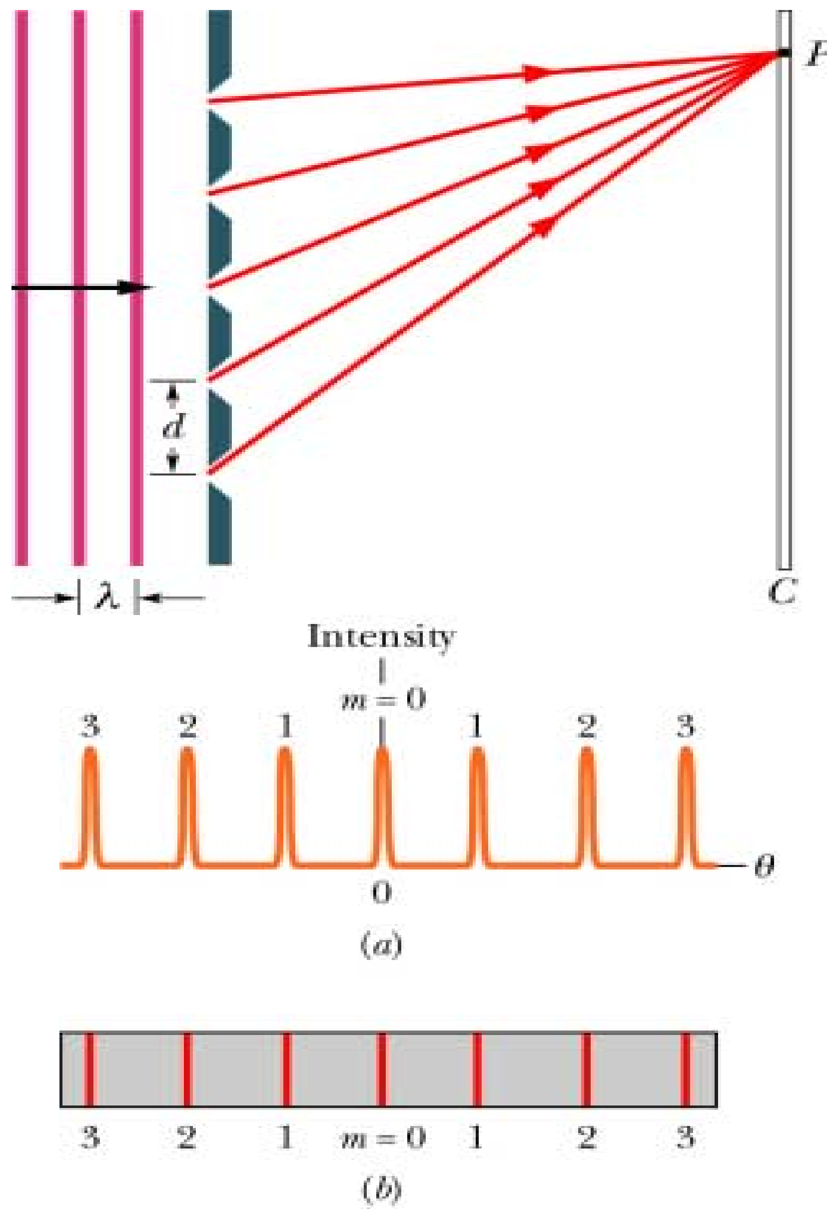
- But now there are also secondary maxima related to the larger spacing 3*d*

$$y = \frac{m\lambda D}{3d}$$

- The primary maxima gets narrower as the number of slits increases.

Diffraction Gratings (Figs. 37-16, 17)

- Increase # of slits from 2 to a large number
- Bright fringes in intensity plot are now very narrow (called lines) and separated by wide dark regions
- A mask that contains a large number of || slits at equal separation distances, *d*, is called a diffraction grating



Diffraction Gratings (Figs. 37-16, 17)

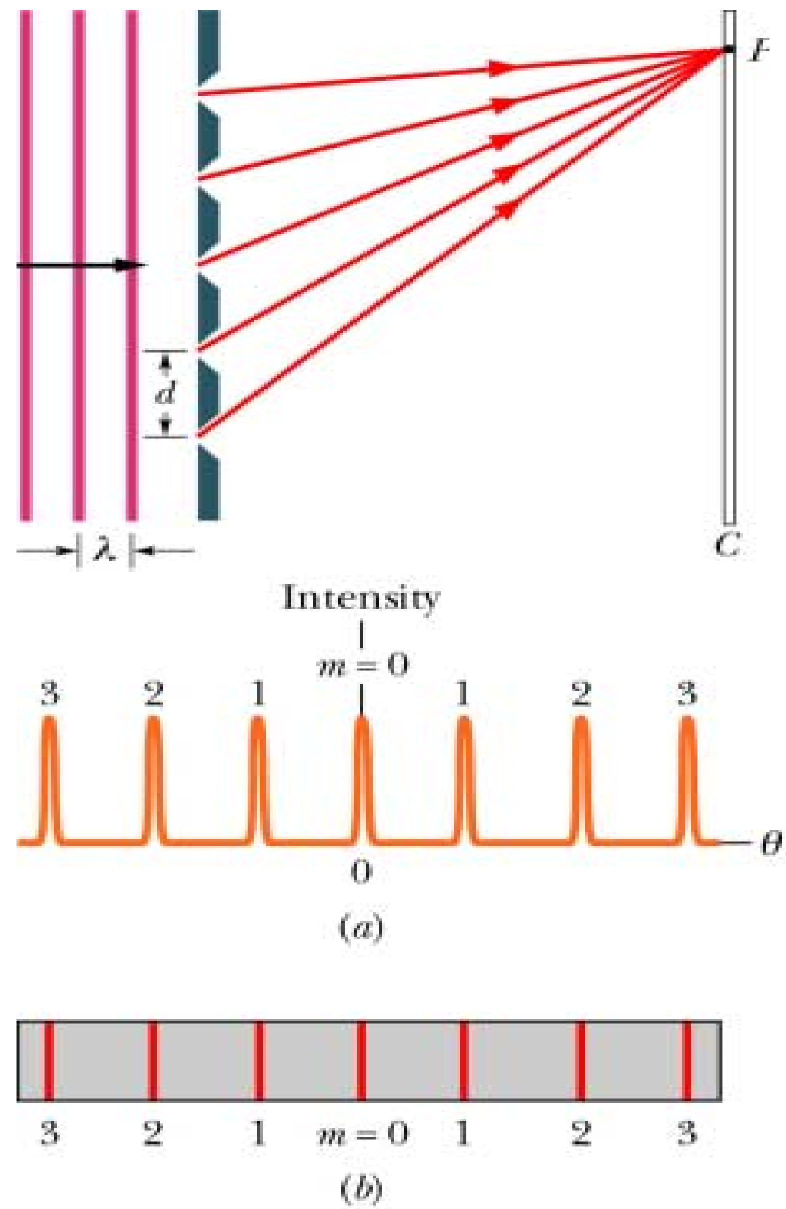
- The equation for the positions of the maxima are the same as those for two slits at distance *d*

$$d\sin\theta = m\lambda$$

$$y = \frac{m\lambda D}{d}$$

- Grating spacing is

$$d = \frac{\text{Total Width}}{\text{Num. Rulings}} = \frac{w}{N}$$

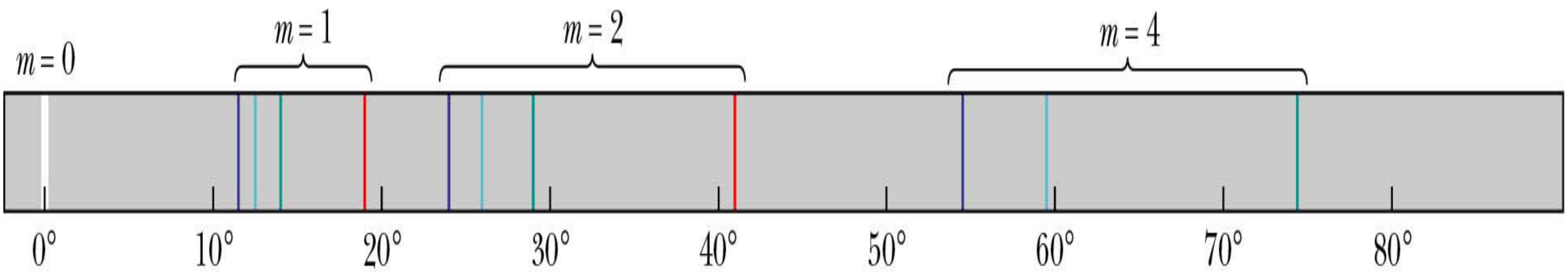


Diffraction Gratings (Fig. 37-22)

- Angle θ from central axis to any line depends on wavelength of light λ
  - Larger λ, bigger θ

$$d \sin\theta = m\lambda$$

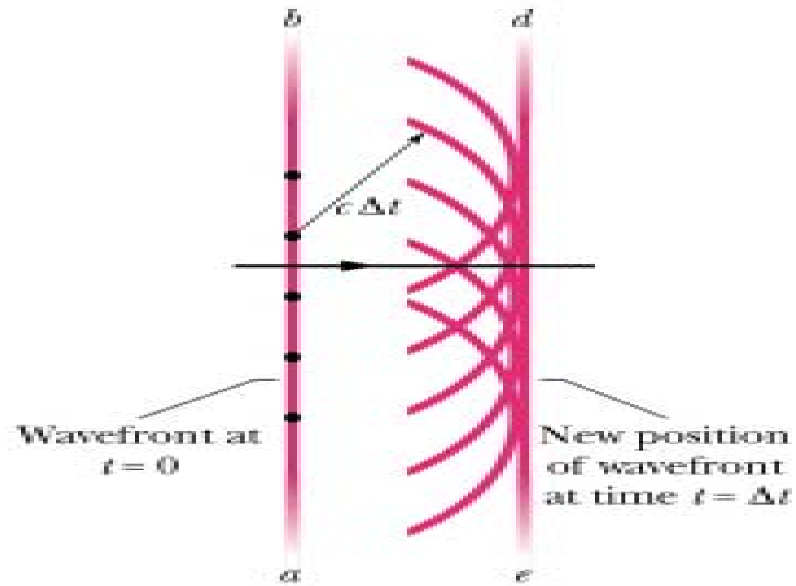
- Light from a given source can be split into its emission lines (below are lines for hydrogen)
  - Use this to determine types of gases in stars

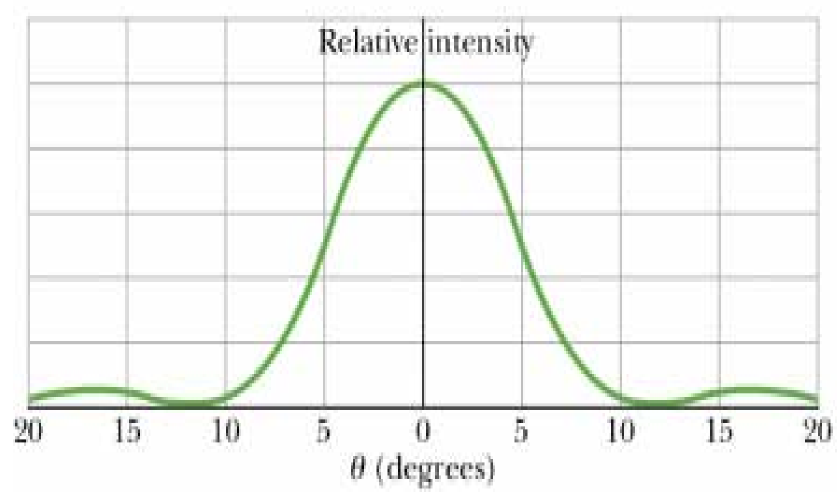


Violet=430 nm Red=690 nm

Diffraction

- 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

- 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