December 2nd

Diffraction

Chapters 37

Schedule

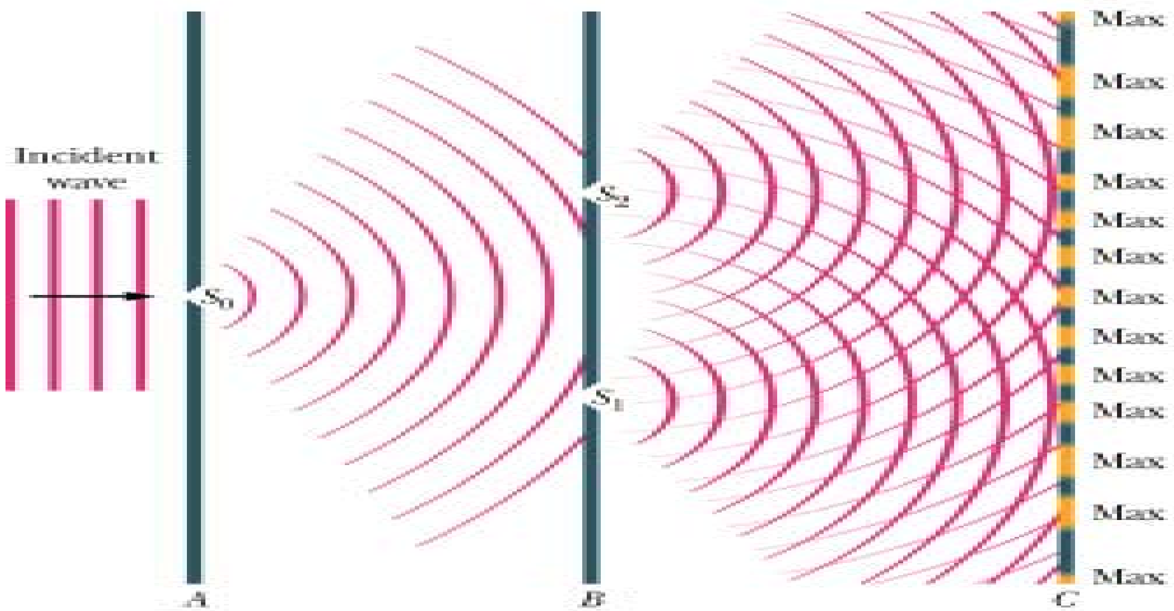
- Dec. 3-5 (Wed-Fri) – Review for final
- Dec. 3 (Wed) – HW set #12 due
- Dec. 8 (Mon) – Corrections #3 due
- Dec. 8 (Mon) – Final Exam 5:45-7:45pm

Final Exam

- Monday December 8th - 5:45 to 7:45 pm
  - Section 1 – N130 BCC (Business College)
  - Section 2 – 158 NR (Natural Resources)
- If >2 finals on Mon. may take make-up final exam on Tues. from 8-10am
  - Email Prof. Tollefson if need make-up
- Allowed 3 sheets of notes (both sides) and calculator
- Covers Chapters 22-37, HW sets 1-12
- Need photo ID

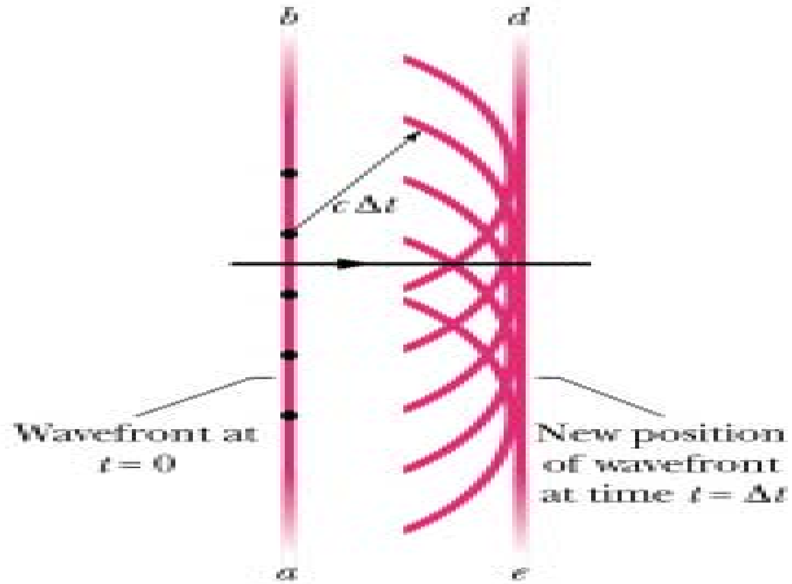
Diffraction

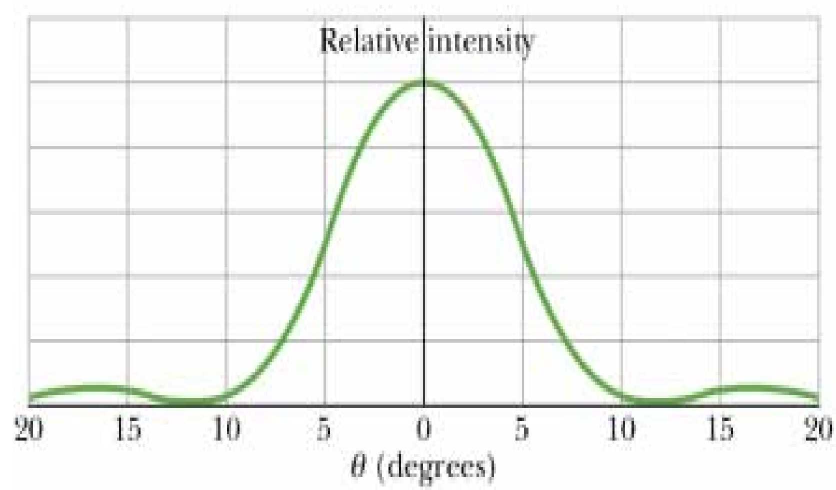
- Waves diffract (bend) if pass through an opening whose size is comparable to its wavelength
- The narrower the slit, the greater the diffraction
- Previous example of double-slit interference assumed slit width *a* much smaller than λ of incident light and we talked about 2 light rays



Diffraction

- 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

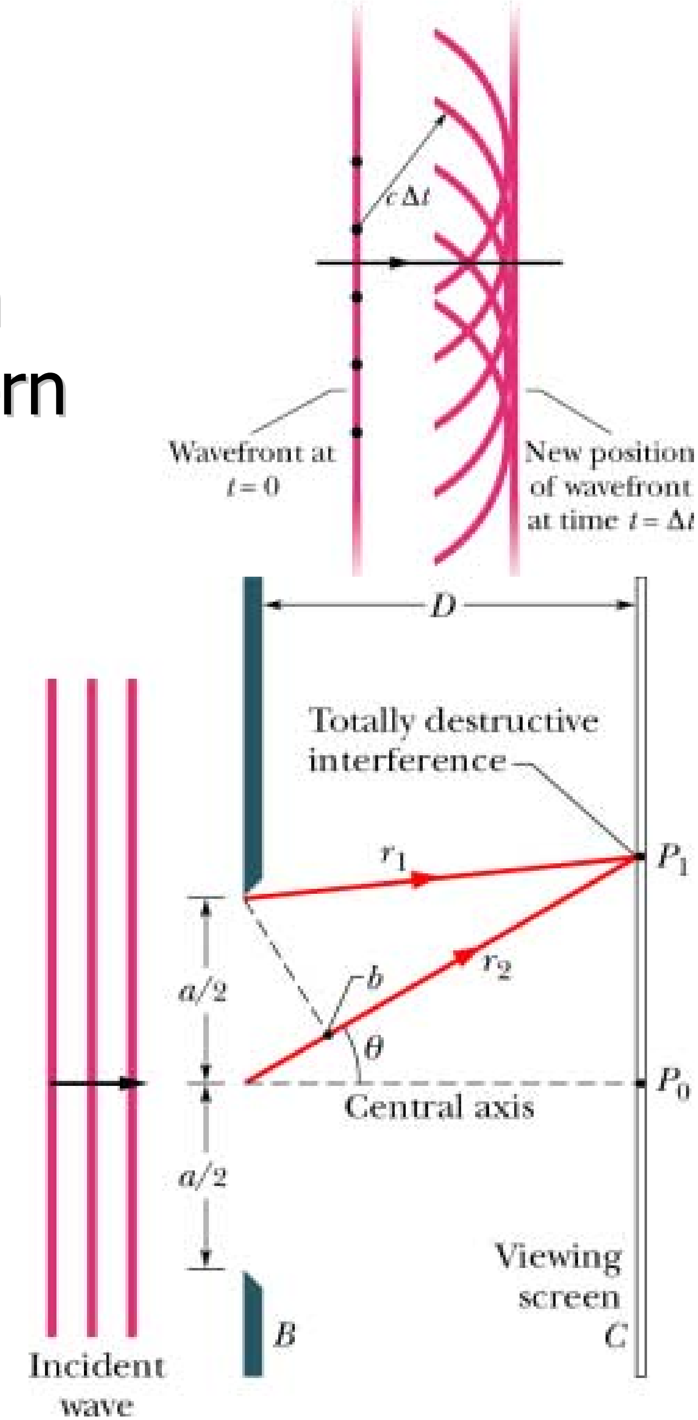




Diffraction

- Location of the first minimum for single slit diffraction pattern
- Divide slit width in half
- Wavelet from bottom half travels further distance to point P_1 than from top half
- Wavelets will destructively interfere if

$$\Delta L = \frac{\lambda}{2}$$



Diffraction

- Assume screen far away from slit so rays are ||
- Use trig to find ΔL

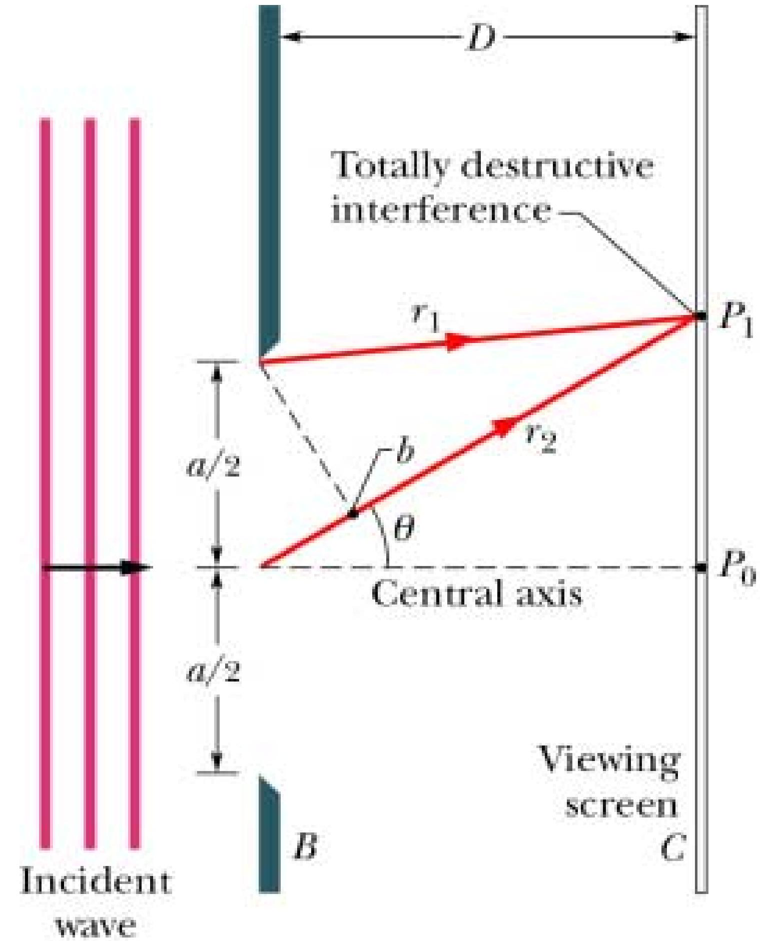
$$\sin\theta = \frac{\Delta L}{a/2}$$

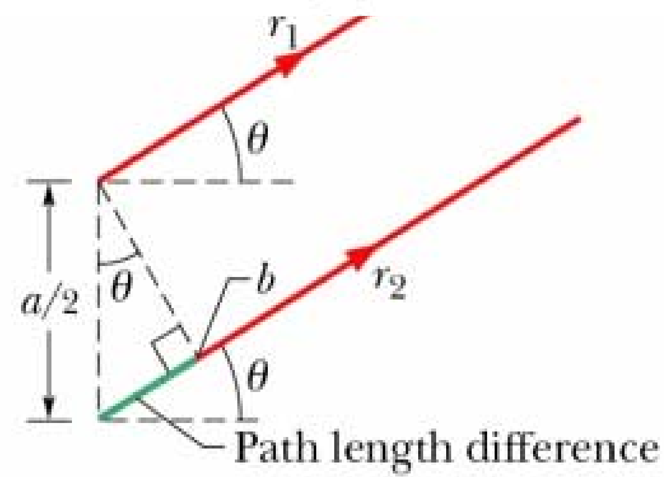
- For first minimum on screen

$$\Delta L = \frac{\lambda}{2} = \frac{a}{2}\sin\theta$$

- Rearrange to find

$$a\sin\theta = \lambda$$

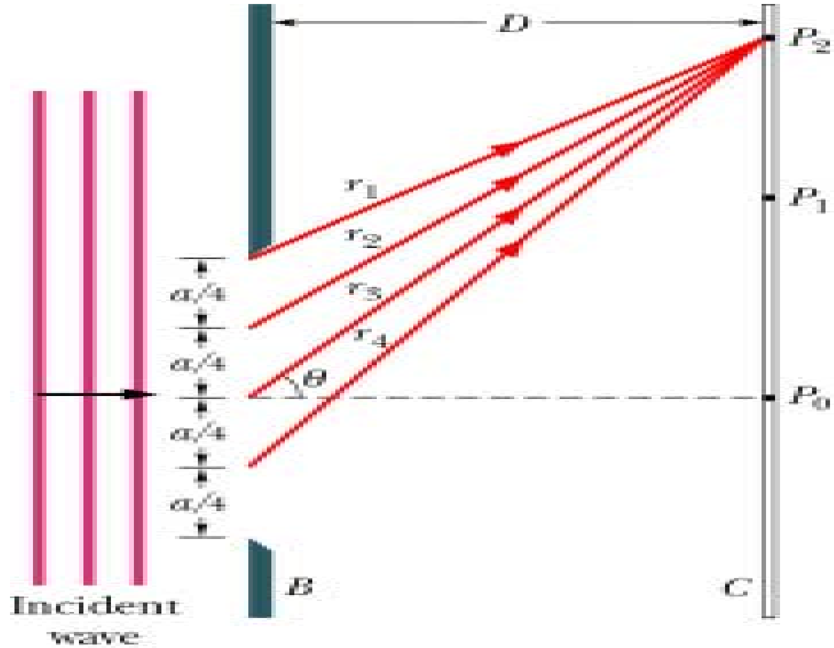




Diffraction - Single Slit

- Minima (dark fringes) from single-slit diffraction

$$a \sin\theta = m\lambda, \ \ m = 1,2,3..$$



- *a* is the width of slit
- *m* =0 is missing
  - where the bright central maximum is located
- Location on the screen is:

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

- Maxima are half-way between minima

Checkpoint #1

- Diffraction pattern from single narrow slit illuminated by blue light (450 nm). Do the minima shift away from or toward the bright central maximum if we switch to yellow light (575 nm)?

$$a \sin\theta = m\lambda$$

- If wavelength λ increases then $\sin\theta$ and θ increase so fringes move further away from center
- Location of minima from diffraction changes for different wavelengths λ

Checkpoint #1

- Diffraction pattern from single narrow slit illuminated by blue light (450 nm). Do the minima shift away from or toward the bright central maximum if we decrease the slit width?

$$a \sin\theta = m\lambda$$

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

- Decrease slit width a, increases sinθ and θ so fringes more further away from center
- If $a = \lambda$ then $\theta = 90°$ for first dark fringe, only see interference pattern since bright maxima from diffraction covers entire viewing area

Diffraction from Single Slit

- Intensity of light as function of angle θ from central axis

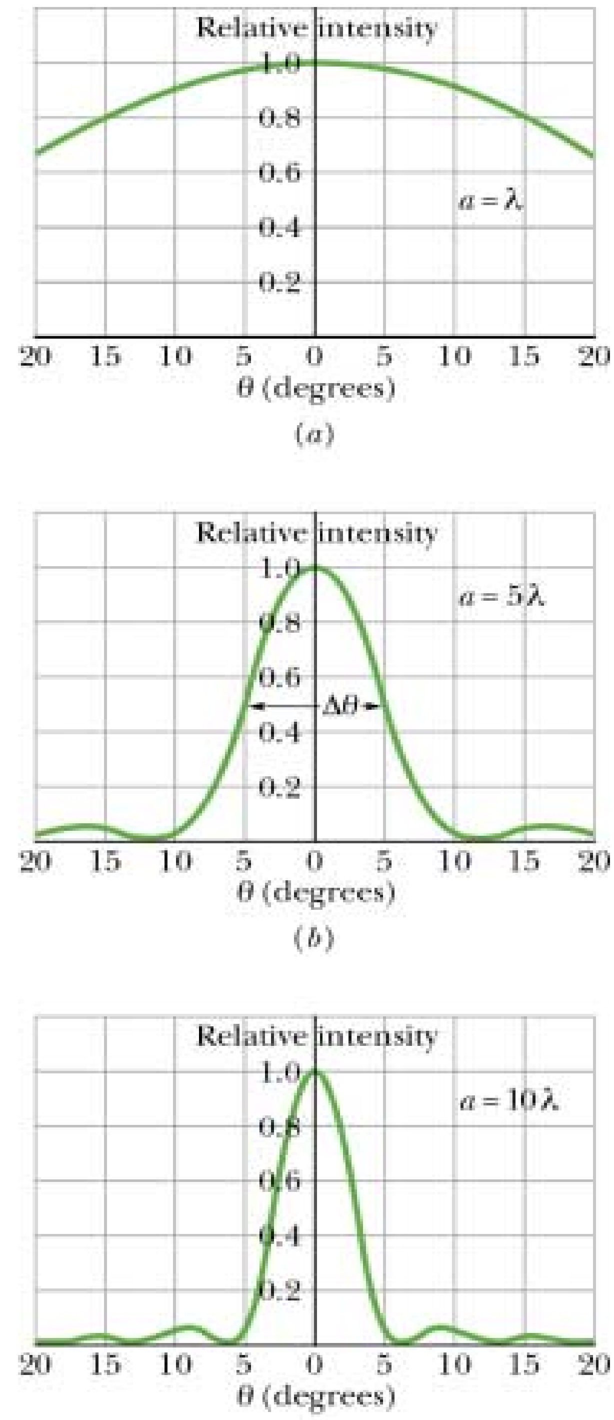
$$I(\theta) = I_m \left(\frac{\sin \alpha}{\alpha} \right)^2$$

- I_m is intensity at central maximum
- α is ½ the phase difference ϕ between top and bottom rays from slit with width *a*

$$\alpha = \tfrac{1}{2}\phi = \frac{\pi a}{\lambda} \sin \theta$$

Diffraction Single Slit

- Width of central diffraction maximum decreases as slit gets bigger (*a* increases)
  - Light undergoes less bending as slit gets bigger
- Secondary maxima much dimmer than central
- If slit is much wider than wavelength of light ($a >> \lambda$) the secondary maxima disappear, no longer have diffraction from single slit



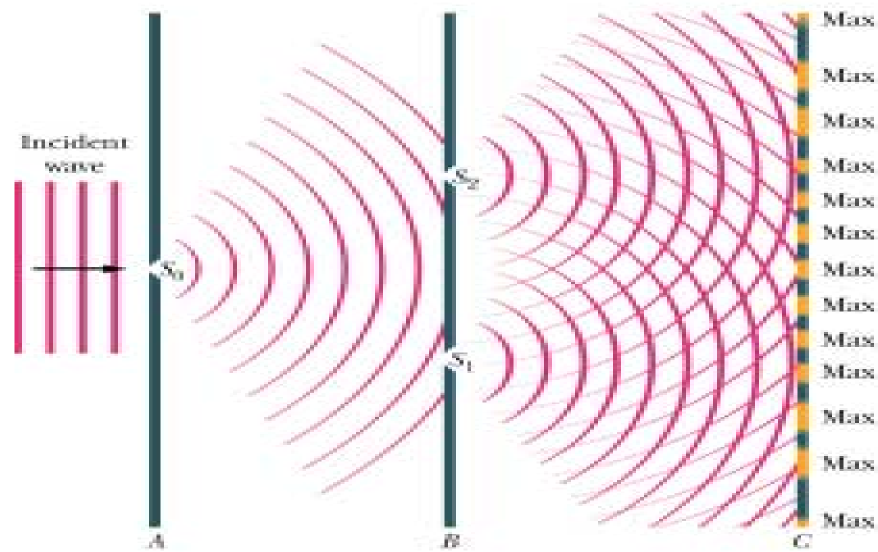
Diffraction

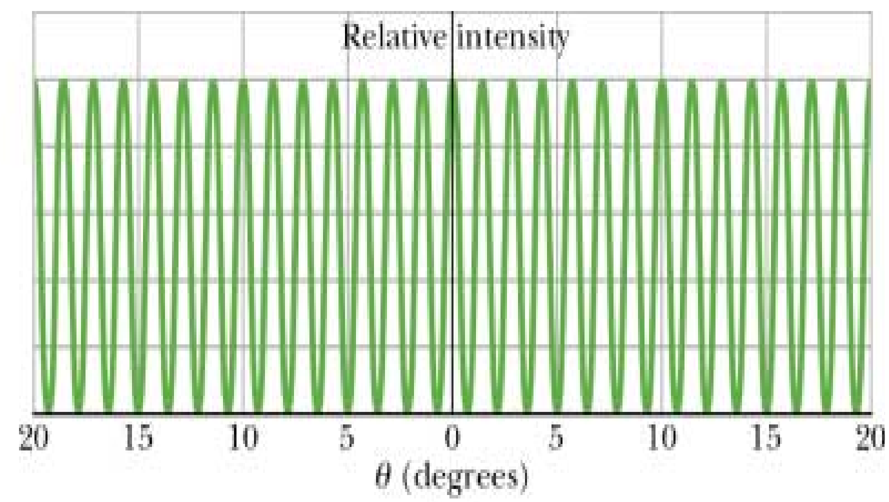
- Interference –
  - Combining waves from small number of coherent sources – double-slit experiment with a<<λ
- Diffraction –
  - Combining of large number of wavelets from single wavefront – as in single slit experiment
- Diffraction and interference are both
  - the result of combining waves with different phases at a given point
  - Usually present simultaneously

- Example see photo 37-14 p.902

Diffraction

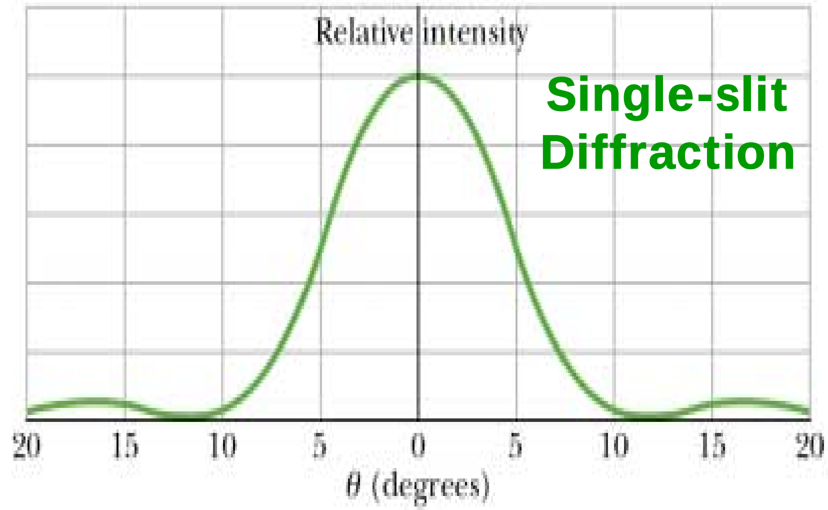
- Previous discussion of double-slit experiment assumed width of slit a<< λ
- Central maxima of diffraction pattern from each single slit covered entire screen so only saw interference pattern
- Bright fringes had same intensity and equal size

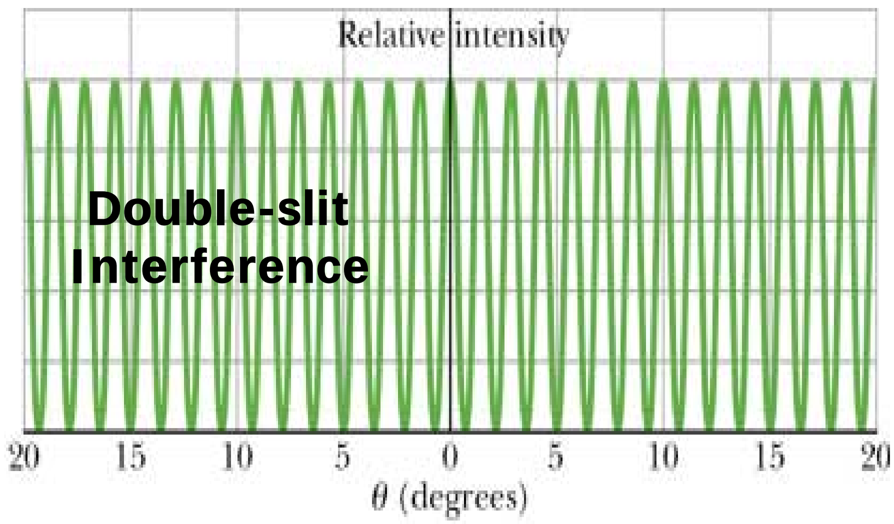


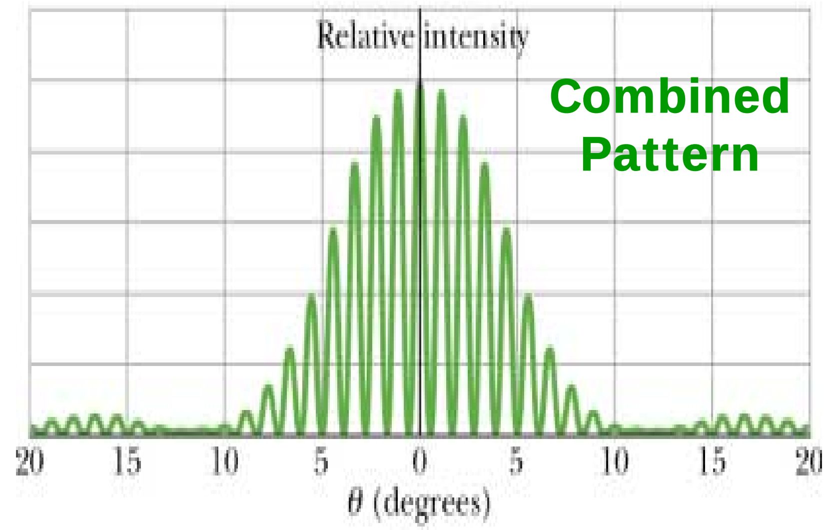


Diffraction

- Double slit interference pattern is modified by diffraction pattern of light passing through each slit
- Position of fringes doesn't change but intensity is affected







Diffraction

- Intensity of combined pattern is given by

$$I(\theta) = I_m \left(\frac{\sin\alpha}{\alpha} \right)^2 (\cos^2 \beta)$$

- I_m is intensity of central maximum

- First term $(\sin\alpha/\alpha)^2$ is due to diffraction from slit of width *a* where

$$\alpha = \frac{\pi a}{\lambda} \sin\theta$$

- Second term of $\cos^2\beta$ is due to two-slit interference with slits separated by distance *d* where

$$\beta = \frac{\pi d}{\lambda} \sin\theta$$

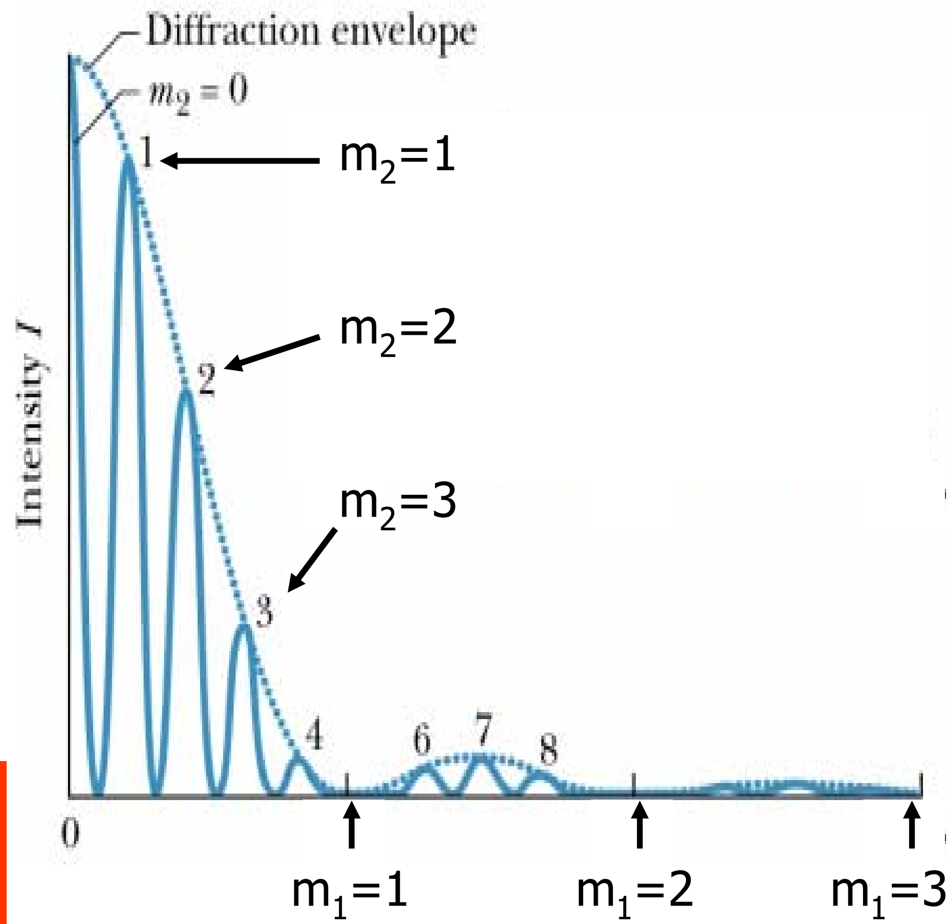
Diffraction

- Typical situation
- Location of diffraction minima given by

$$y_1 = \frac{m_1 \lambda D}{a}, \quad m_1 = 1,2\ldots$$

- Location of two-slit maxima given by

$$y_2 = \frac{m_2 \lambda D}{d}, \quad m_2 = 0,1,2\ldots$$



Diffraction – Circular Aperture

- Circular aperture of diameter *d* makes a ring pattern with the first minima at
  - Can treat your eye's pupil as a circular aperture
- Rayleigh's criterion for resolvability is angular separation between two point sources must be

$$\sin\theta = 1.22\frac{\lambda}{d}$$

$$\theta_R = 1.22\frac{\lambda}{d}$$