Lecture 27

35-2

Diffraction - If a wave encounters a barrier w/ an opening of dimensions similar to wavelength, the part of the wave that passes through opening will flare out (diffract) into region beyond barrier.

- flaring is consistent w/ spreading of wavelets from Huygens' principle,

- occurs for all kind of waves including water waves
(show slides + video)

- consider when a plane wave of light, of wavelength λ, is incident, encountering a slit w/ width $a = 6.0\lambda$ & extends into & out of page

- part of wave passing through slit flares out on far side.

(show slides)

- narrower the slit, greater the diffraction

- this diffraction shows that geometrical optics has limitations. Does not apply when a "ray" goes through a narrow slit.

Young's interference experiment

- proved that light is a wave, since it undergoes interference.
- also was able to measure wavelength of light.

- light from monochromatic source illuminates slit S_0 in screen A.
- Emerging light spreads via diffraction to illuminate two slits S_1 & S_2, in screen B.
- Diffraction of light by 2 slits sends overlapping circular waves

into region beyond screen B, where waves from one slit interfere w/ waves from another slit.

- can only see evidence for interference on a viewing screen.

- points of interference form visible bright rows AKA bright bands, bright fringes, etc.
- dark regions result from fully destructive interference (called dark bands, dark fringes)
- pattern formed is called "interference pattern"

(show slides)

How to determine location of fringes

It's all about the difference in path lengths traveled by waves

- phase difference between two waves can change if they travel paths of different lengths.

(show slides)

path length difference ΔL determines phase difference.

If ΔL is equal to zero or an integer number of wavelengths, waves arrive @ a common point in phase

If instead ΔL is half-integer # of wavelengths (odd multiple of $\frac{1}{2}\lambda$),

then waves arrive @ common point exactly out of phase & there is destructive interference.

(show slides)

Doing this calculation exactly is complicated, but we can simplify it by making an approximation:

$$D \gg d$$

& approximate rays as being parallel to each other.

Then triangle formed by S_1, S_2, + b is ≈ right triangle, & $\sin\theta = \frac{\Delta L}{d}$

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

For bright fringes (constructive interference)

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

for $m = 0, 1, 2, \ldots$

For dark fringes

$$\Delta L = d\sin\theta = (m+\tfrac{1}{2})\lambda$$

$m = 0, 1, 2, \ldots$

can figure out ~~bright fring~~ angle from bright fringes:

$$\theta = \sin^{-1}\left(\frac{m\lambda}{d}\right)$$ fringes here are called "mth order bright" or "mth side maxima"

dark fringes are @ angle:

$$\theta = \sin^{-1}\left(\frac{(m+1/2)\lambda}{d}\right)$$

dark fringes here are called

"mth order dark fringes"

or "mth minima"

Problem: What is distance on screen C (in figure) between adjacent maxima near center of interference pattern?

9

Suppose wavelength of light is 546 nm, slit separation d is 0.12 mm, & slit - screen separation D is 55 cm.

Suppose θ is small enough so that $\theta \approx \sin\theta \approx \tan\theta$.

Pick maximum w/ low enough value of m to be near center

y_m - maximum's vertical distance from center

geometry $\Rightarrow$ $\tan\theta = \frac{y_m}{D}$

$\Rightarrow \theta \approx \frac{y_m}{D}$

we know that $\sin\theta = \frac{m\lambda}{d}$

$$\Rightarrow \quad \theta \approx \frac{m\lambda}{d}$$

$$\Rightarrow \quad y_m = \frac{m\lambda D}{d}$$

next maximum is located @

$$y_{m+1} = \frac{(m+1)\lambda D}{d}$$

$$\Rightarrow \Delta y = y_{m+1} - y_m = \frac{\lambda D}{d}$$

$$= \frac{(546 \cdot 10^{-9} m)(55 \times 10^{-2} m)}{.12 \times 10^{-3} m}$$

$$= 2.5 \text{ mm}$$