

Physics 1161: Lecture 21

Diffraction, Gratings, Resolving Power

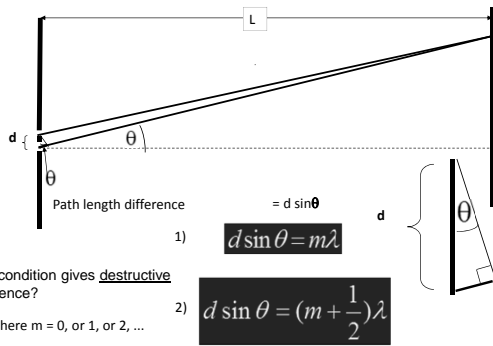
- Textbook sections 28-4 – 28-6



Recall

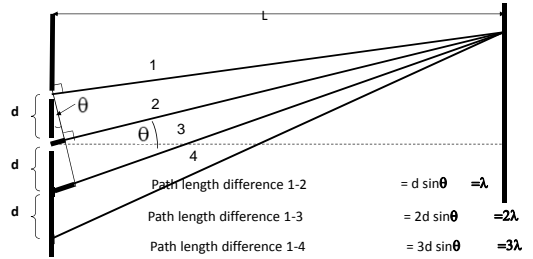
- Interference (at least 2 coherent waves)
 - Constructive (full wavelength difference)
 - Destructive (½ wavelength difference)
- Light (1 source, but different paths)
 - Thin Films
 - Double/multiple slit
 - Diffraction/single slit (today)

Young's Double Slit Review



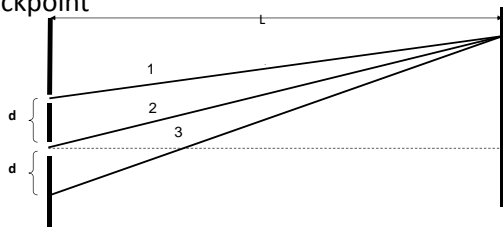
Multiple Slits

(Diffraction Grating – N slits with spacing d)



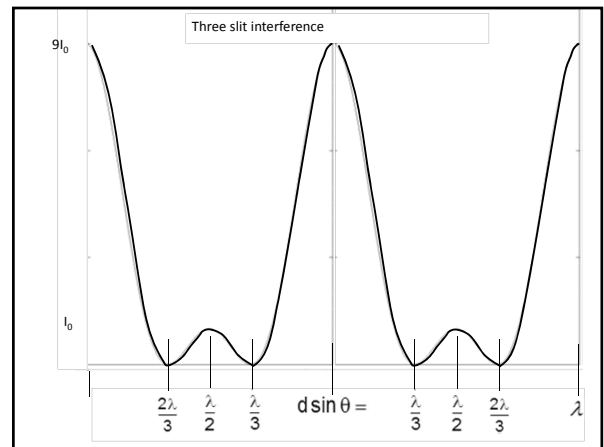
Constructive interference for all paths when...

Three Rays Checkpoint



All 3 rays are interfering constructively at the point shown. If the intensity from ray 1 is I_0 , what is the combined intensity of all 3 rays?
 1) I_0 2) $3 I_0$ 3) $9 I_0$

When rays 1 and 2 are interfering destructively, is the intensity from the **three** rays a minimum?
 1) Yes 2) No



Multiple Slit Interference (Diffraction Grating)

For many slits, maxima are still at $\sin \theta = m \frac{\lambda}{d}$ Peak location depends on wavelength!

As no. of slits increases – bright fringes become narrower and brighter.

2 slits (N=2)

10 slits (N=10)

Diffraction Grating

N slits with spacing d

* screen VERY far away

Constructive Interference Maxima are at:

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

Same as for Young's Double Slit!

Diffraction/ Huygens

Every point on a wave front acts as a source of tiny wavelets that move forward.

Light waves originating at different points within opening travel different distances to wall, and can interfere!

We will see maxima and minima on the wall.

(a) Without diffraction (b) With diffraction

Single Slit Diffraction

When $\frac{w}{2} \sin \theta = \frac{\lambda}{2}$ rays 1 and 1' interfere destructively.

Rays 2 and 2' also start $W/2$ apart and have the same path length difference.

Under this condition, every ray originating in top half of slit interferes destructively with the corresponding ray originating in bottom half.

1st minimum at: $\sin \theta = \lambda/w$

Single Slit Diffraction

When $\frac{w}{4} \sin(\theta) = \frac{\lambda}{2}$ rays 1 and 1' will interfere destructively.

Rays 2 and 2' also start $w/4$ apart and have the same path length difference.

Under this condition, every ray originating in top quarter of slit interferes destructively with the corresponding ray originating in second quarter.

2nd minimum at $\sin \theta = 2\lambda/w$

Single Slit Diffraction Summary

Condition for halves of slit to destructively interfere $\sin(\theta) = \frac{\lambda}{w}$

Condition for quarters of slit to destructively interfere $\sin(\theta) = 2 \frac{\lambda}{w}$

Condition for sixths of slit to destructively interfere $\sin(\theta) = 3 \frac{\lambda}{w}$

All together... $\sin \theta = m \frac{\lambda}{w}$ (m=1, 2, 3, ...)

THIS FORMULA LOCATES MINIMA!!

Narrower slit => broader pattern

Note: interference only occurs when $w > \lambda$.

Light on a Screen Checkpoint

A laser is shone at a screen through a very small hole. If you make the hole even smaller, the spot on the screen will get:

(1) Larger (2) Smaller

Which drawing correctly depicts the pattern of light on the screen?

Diffraction from Circular Aperture

1st diffraction minimum

Central maximum

Diameter D

light

Maxima and minima will be a series of bright and dark rings on screen

First diffraction minimum is at:

Intensity from Circular Aperture

Intensity I

1.22 $\frac{\lambda}{D}$

First diffraction minimum

$\sin \theta \approx \theta$

Intensities

These objects are *just* resolved

Two objects are just resolved when the maximum of one is at the minimum of the other.

Resolving Power

To see two objects distinctly, need $\theta_{\text{objects}} \gg \theta_{\text{min}}$

θ_{objects} is angle between objects and aperture:

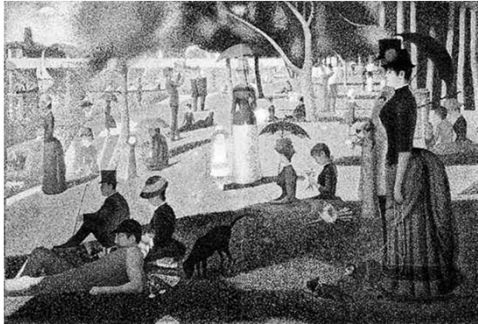
$\tan \theta_{\text{objects}} \approx d/y$

θ_{min} is minimum angular separation that aperture can resolve:

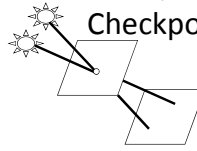
$\sin \theta_{\text{min}} \approx \theta_{\text{min}} = 1.22 \lambda / D$

Improve resolution by increasing θ_{objects} or decreasing θ_{min}

Pointillism – Georges Seurat



Binary Suns
Checkpoint



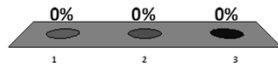
Astronaut Joe is standing on a distant planet with binary suns. He wants to see them but knows it's dangerous to look straight at them. So he decides to build a pinhole camera by poking a hole in a card. Light from both suns shines through the hole onto a second card.

But when the camera is built, Astronaut Joe can only see one spot on the second card! To see the two suns clearly, should he make the pinhole larger or smaller?

To see the two suns clearly, should he make the pinhole larger or smaller?
larger smaller

How does the maximum resolving power of your eye change when the brightness of the room is decreased.

1. Increases
2. Remains constant
3. Decreases



Recap.

- Interference: Coherent waves
 - Full wavelength difference = Constructive
 - ½ wavelength difference = Destructive
- Multiple Slits
 - Constructive $d \sin(\theta) = m \lambda$ (m=1,2,3...)
 - Destructive $d \sin(\theta) = (m + 1/2) \lambda$ 2 slit only
 - More slits = brighter max, darker mins
- Huygens' Principle: Each point on wave front acts as coherent source and can interfere.
- Single Slit:
 - Destructive: $w \sin(\theta) = m \lambda$ (m=1,2,3...)
 - Resolution: Max from 1 at Min from 2

opposite!