## 5.3 Interference and Diffraction

Coherence
Two-Slit Interference
Multiple-slit Interference

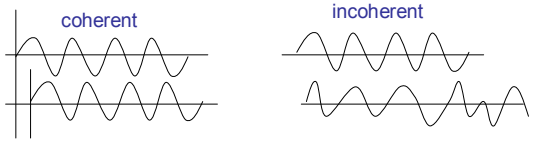
## Interference

- Interference effects are a characteristic feature of waves.
- Interference of light shows that light has wave properties.
- The interference of light waves is shown most clearly when light interacts small objects.
- Interference effects have many applications, CDs, x-ray crystallography-

## Coherence

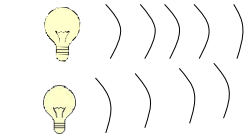
For two waves to show interference they must have coherence.

Two waves are coherent if one wave has a constant phase relation to the other

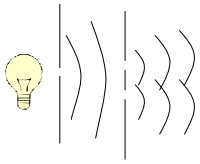



$\phi = 2\pi\frac{\Delta x}{\lambda}$ phase shift

## Coherence



Light from two separate light bulbs is Incoherent

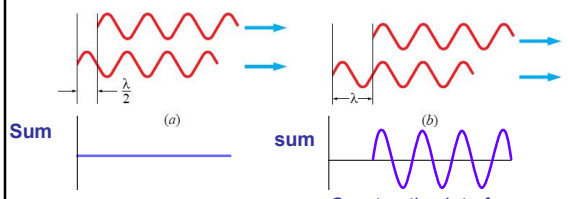


Light from a single small source passing through two slits is coherent

Laser light is coherent

## Interference

Interference results from superposition of waves



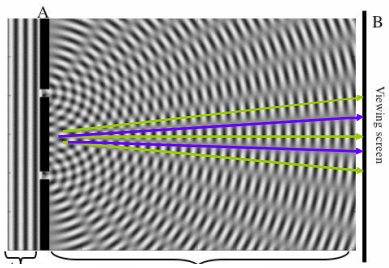

Destructive Interference

out of phase
phase shift of π, 180°

Constructive Interference

in phase
zero phase shift

## Interference in two dimensions




black maxima
white minima
gray zero

Coherent waves

Interference pattern

constructive interference

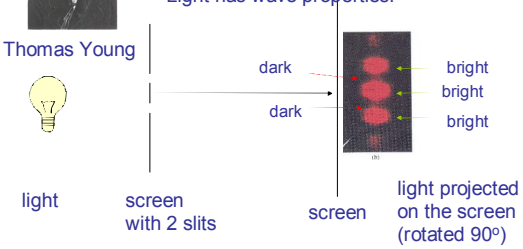
destructive interference

# Young's two slit experiment

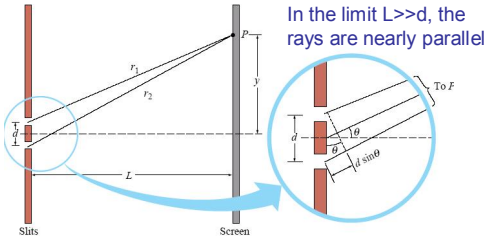
Thomas Young

Shows that light shows interference effects.

Light has wave properties.

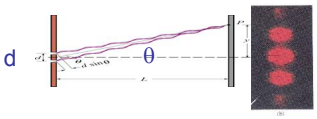



# Interference of light waves from the two slits.




Pathlength difference = $d\sin\theta$

# Pathlength differences lead to constructive and destructive interference




Maxima
constructive interference

$d\sin\theta = m\lambda$

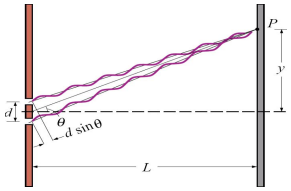
Dark
destructive interference

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

m is the order of the peak , i.e $m^{th}$ order peak

m=0, ± 1, ± 2, .....

# Wavelength of light




for small angles θ

$d\sin\theta \simeq d\tan\theta = d\frac{y}{L}$

Maxima $y = mL\frac{\lambda}{d}$

Dark $y = (m+\frac{1}{2})L\frac{\lambda}{d}$

# Question

Light from a laser is passed through two slits a distance of 0.10 mm apart and is hits a screen 5 m away. The separation between the central maximum and the first bright interference fringe is 2.6 cm. Find the wavelength If the light.

# Question

In a two slit interference experiment how does the distance between the peaks on the screen change if the distance between the slits is increased?

a) increases
b) decreases
c) stays the same
d) indeterminate

## Question

In a two slit interference experiment how does the distance between the peaks on the screen change if the wavelength of the light is increased?

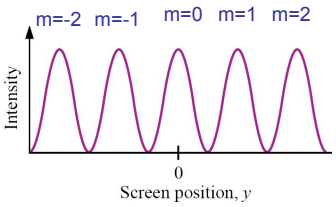
a) increases
b) decreases
c) stays the same
d) indeterminate

## Intensity

- When two waves are superimposed the amplitude is equal to the sum of the amplitudes of the two waves.
- The intensity of the wave is proportional to the square of the amplitude.

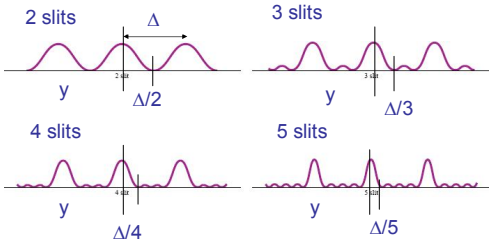
## Intensity profile

The superposition of light from 2 slits gives a sinusoidal intensity profile (for the case where the slit width is much smaller than d)

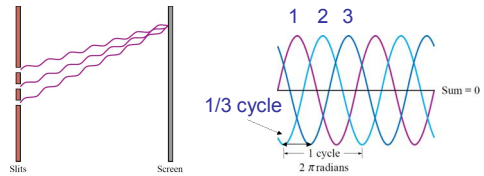



## Multiple slits

As the number of slits having the same separation increases the position of the maxima remains the same but the width of the peak decreases.



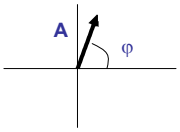

## For multiple slits, destructive interference requires a smaller phase shift (smaller angle)



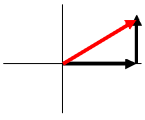

For 3 slits destructive interference is observed when the phase shift is $2\pi/3$ instead of $2\pi/2$ (for 2 slits)

## Phasor Addition

The phasor is a useful tool to describe the superposition of sine waves with different phases.

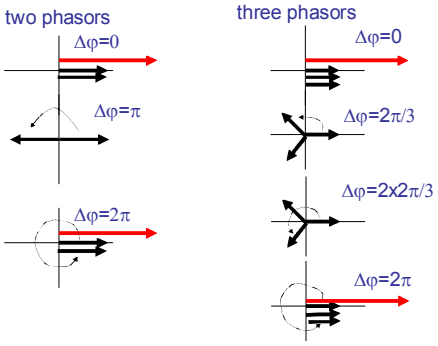



Phasor is specified by an Amplitude and Phase



Phasors add like vectors

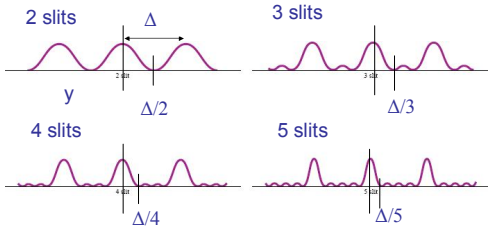
# Interference




# Intensities due to multiple slits

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

Destructive interference when m' is an integer not a multiple of N = no. of slits.
Constructive interference when m' is an integer multiple of N (m=m'/N)

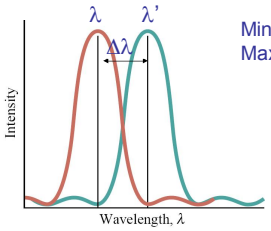



# Diffraction grating

- A diffraction grating has a large number of slits N.
- As N gets large the width of the peak gets narrow, Δ/N
- The amplitude of the peak increases with N.
- The diffraction grating is useful for resolving closely spaced wavelengths of light

# Resolution

Two different wavelengths of light can be resolved if the peak of one is at the first minimum of the second.




Minimum for mth order λ peak = Maxima for mth order λ' peak

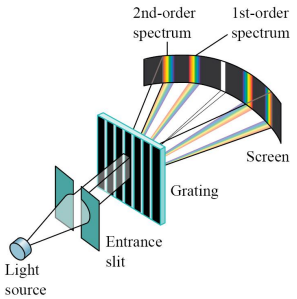
$$d \sin\theta_{min} = (m + \frac{1}{N})\lambda =$$

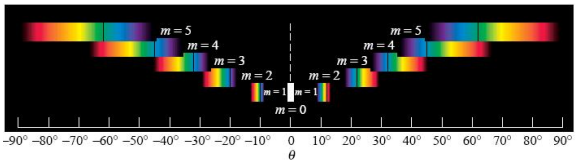
$$d \sin\theta'_{max} = m\lambda' = m(\lambda + \Delta\lambda)$$

Resolving Power $\frac{\lambda}{\Delta\lambda} = mN$

m order of the diffraction
N = no. of slits

# Spectrometer



## Question 65

A 400 line/mm diffraction grating is 3.5 cm wide. Two spectral lines whose wavelengths average to 560 nm are just barely resolved in the $4^{th}$ order spectrum of this grating. What is the difference between their wavelengths?