5.2 Interference

Coherence

Two-Slit Interference

Thin film Interference

Interference Effects

Interference is a general property of waves.

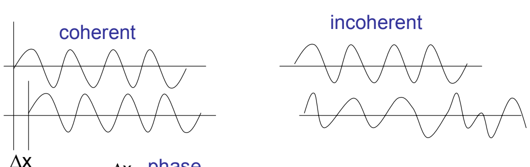
A condition for interference is that the wave source is coherent.

Interference between two waves gives characteristic interference patterns due to constructive and destructive interference.

Coherence

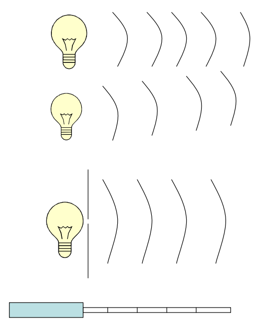
For two waves to show interference they must have coherence.

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

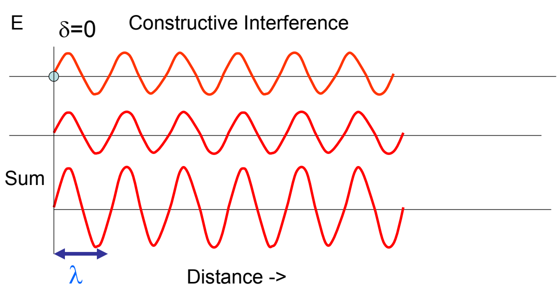


Light from two separate light bulbs is Incoherent

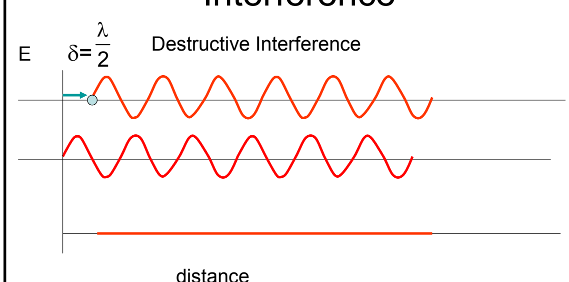
Light from a single light bulb passing through a small slit is coherent

Laser light is coherent

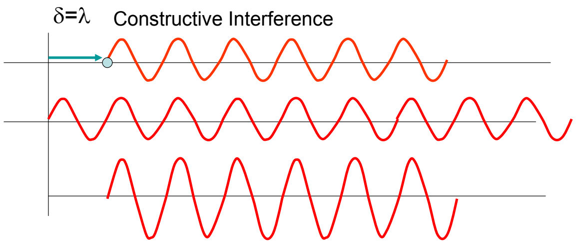
Interference



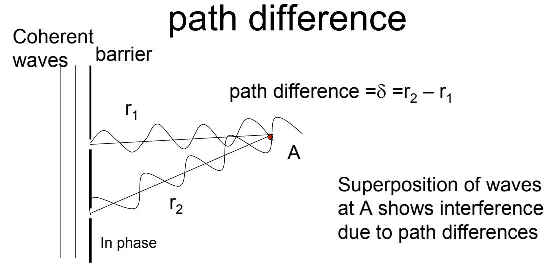
Interference



Interference



path difference

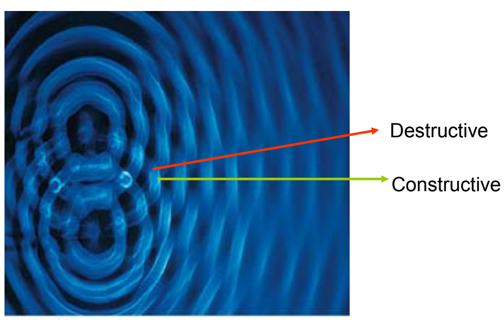


Condition for constructive interference $\delta = m\lambda$

Condition for destructive interference $\delta = (m + \frac{1}{2})\lambda$

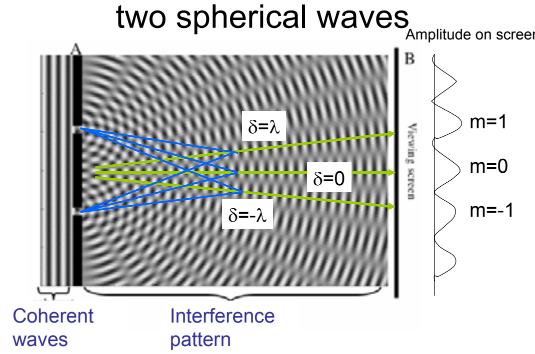
Order number m $\quad$ m = 0 $\pm$ 1, $\pm$ 2,….

Interference Pattern



Interference pattern of water waves

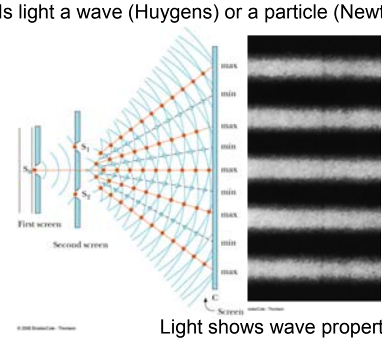
Interference pattern due to two spherical waves



Young's two slit experiment

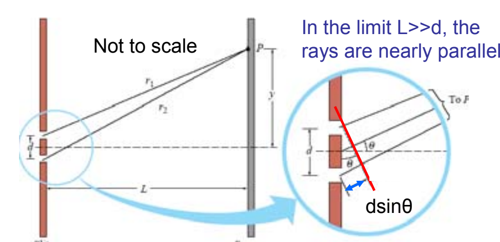
Thomas Young

Is light a wave (Huygens) or a particle (Newton)?



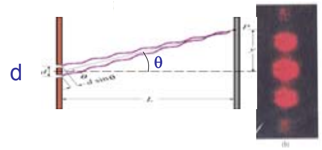
Light shows wave properties

Path difference from the two slits



path difference $\quad \delta = d\sin\theta$

Interference pattern



maxima
m=2
m=1
m=0 Central maximum
m= -1
m= -2

Bright
constructive interference

$$d\sin\theta_{bright} = m\lambda$$

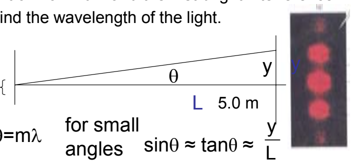
Dark
destructive interference

$$d\sin\theta_{dark} = (m + 1/2)\lambda$$

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

Wavelength of light

Light from a laser is passed through two slits a distance of 0.10 mm apart and is hits a screen 5.0 m away. The separation between the central maximum and the first bright interference fringe is 2.6 cm. Find the wavelength of the light.



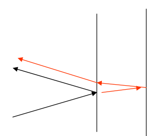
$d\sin\theta = m\lambda$ for small angles $\sin\theta \approx \tan\theta \approx \frac{y}{L}$

$\Rightarrow d\frac{y}{L} = m\lambda$ solve for λ for m= 1

$$\lambda = \frac{yd}{mL} = \frac{(2.6\text{x}10^{-2}\text{m})(0.1\text{x}10^{-3}\text{m})}{(1)(5.0\text{m})} = 5.2\text{x}10^{-7}\text{m} = 520\text{nm}$$

Thin film interference

Thin film interference

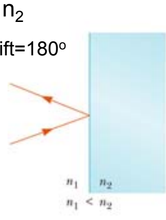


- In thin film interference is interference between light reflected from front an back surfaces of a thin film.
- The phase difference is due to two factors:
  - Path difference through the film (corrected for the change in speed of light in the material)
  - Phase shift due to reflection at the interface

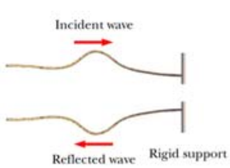
Phase shift due to reflection

$n_1 < n_2$

phase shift=180º



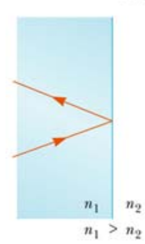
Reflection with inversion
phase shift = 180º

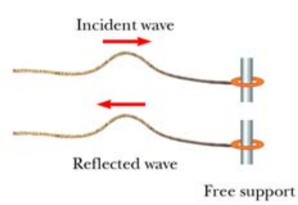


Phase shift due to reflection

$n_1 > n_2$
Phase shift = zero

Reflection without inversion
Phase shift = zero





Soap Film in Air

Destructive Interference

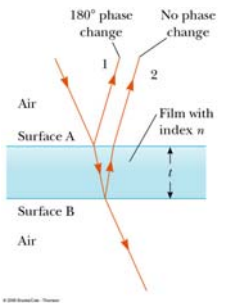
For a film in air the phase difference due to reflection is 180°.

Destructive interference occurs when the path length difference equals zero or integral multiples of the wavelength in the film.

Condition for destructive interference

$\delta=2t= m\lambda_{film} = m\frac{\lambda}{n}$

m=0, 1, 2 , 3 …………



The wavelength in the film is shorter than in air.

Soap film in air

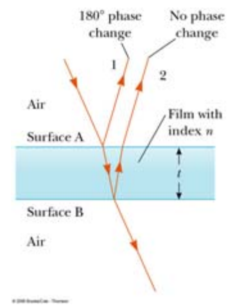
Constructive Interference

For constructive interference the path difference (2t) must be half integral multiples of the wavelength to make up for the phase shift on reflection.

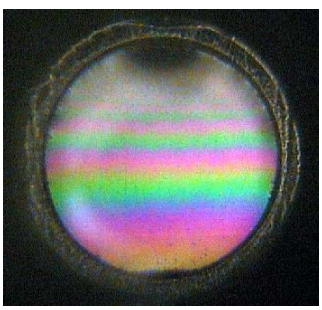
Condition for constructive interference

$\delta=2t= (m+\frac{1}{2})\lambda_{film} = (m+\frac{1}{2})\frac{\lambda}{n}$

M=0, 1, 2, 3………



Soap film

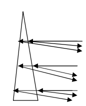


Question

A vertical soap film displays a series of colored band due to reflected light. Find the thickness of the film at the position of the 3th green band from the top (λ=550 nm, n =1.33)

Constructive Interference

$2t = (m+\frac{1}{2})\frac{\lambda}{n}$



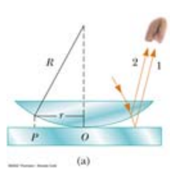
2t=1/2 (λ/n) m=0

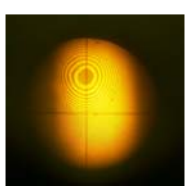
2t=3/2(λ/n) m=1

2t=5/2 (λ/n) m=2

$t = (m+\frac{1}{2})\frac{\lambda}{2n}$ $= (2+\frac{1}{2})\frac{550nm}{2(1.33)} = 517nm$

Newton's rings



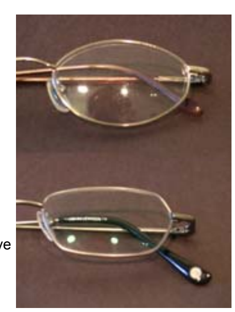


Interference due to reflected light from two surfaces of the thin film of air.

Why is it dark in the middle?

Anti-reflective Coating

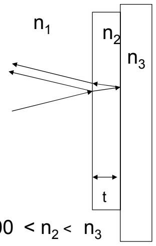
no coating



anti-reflective coating

Anti-reflective coatings are used to reduce reflections at the air-glass interface.

Anti-reflective Coating



Anti-reflective coatings consists of a thin-layer of material with a refractive index in between that of air and glass. Destructive interference between light reflected at the two surfaces reduces the intensity of reflected light.

What is the condition for destructive interference?

$n_1 = 1.00 < n_2 < n_3$

- There is a phase shift of 180° at both interfaces.
- The phase difference due to reflection is zero
- The path difference must be a half-integral number of wavelengths.

$$2t = (m + \frac{1}{2})\frac{\lambda}{n_2}$$

Question

An anti-reflective coating of MgF_2 (n=1.38) is used on a glass surface to reduce reflections. Find the minimum thickness of the coating that can be used for green light (λ=550 nm).

For destructive interference

$$2t = (m + \frac{1}{2})\frac{\lambda}{n_2}$$

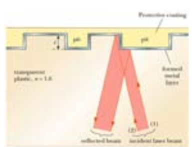
minimum at m=0 ⇨ $2t = \frac{1}{2}\frac{\lambda}{n}$

Solve for t

$$t = \frac{\lambda}{4n} = \frac{550nm}{4(1.38)} = 100nm$$

Quarter wavelength (in coating) thickness

Optical compact disc



A CD stores information in a series of pits and bumps in the plastic.
The information is read by a reflected laser beam.
The intensity of the beam is changed by destructive interference of the reflected light

$$t = \frac{\lambda}{4n}$$

destructive interference