6.2 Interference

Coherence

Two-Slit Interference

Thin film Interference

Interference Effects

Interference is a general property of waves.

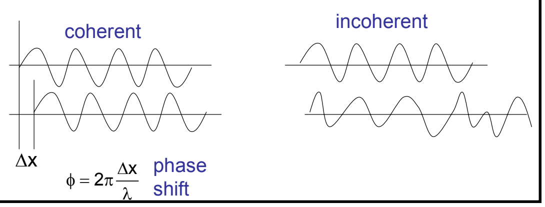
A condition for interference is that the wave source is coherent.

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

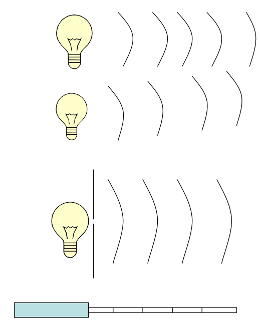
Coherence

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



Coherence

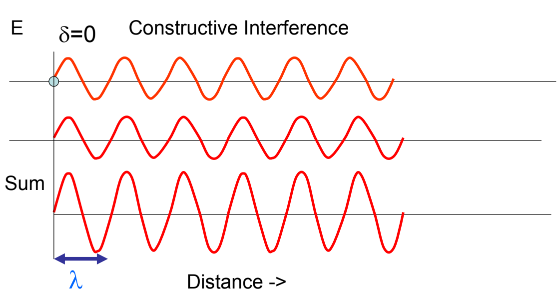


Light from two separate light bulbs is Incoherent

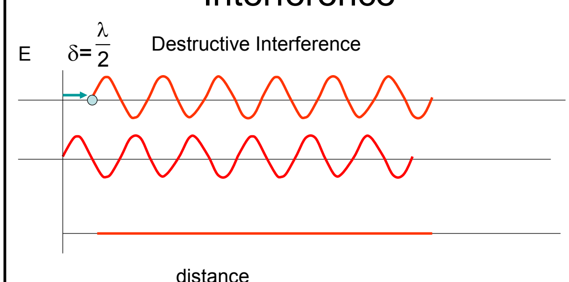
Light from a single light bulb passing through a small slit is coherent

Laser light is coherent

Interference

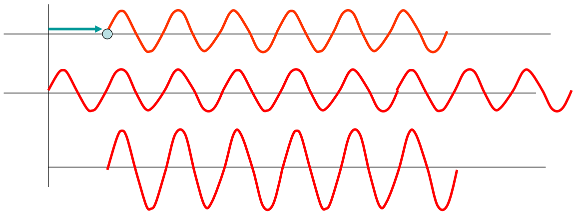


Interference

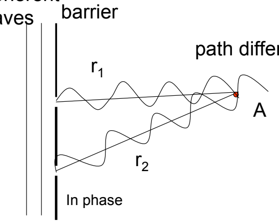


Interference

$\delta=\lambda$ Constructive Interference



path difference

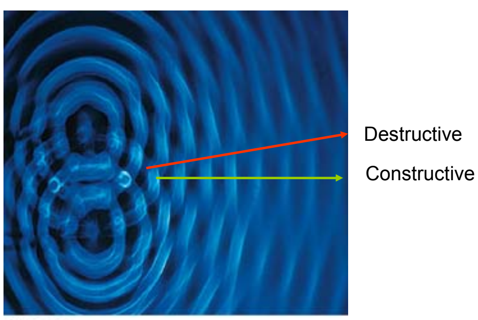


Superposition of waves at A shows interference due to path differences

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

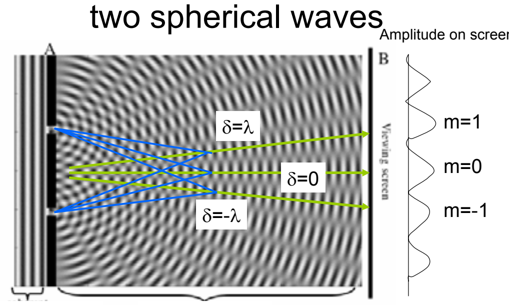
Condition for destructive interference $\delta = (m+\frac{1}{2})\lambda$

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



Interference pattern of water waves

Interference pattern due to two spherical waves

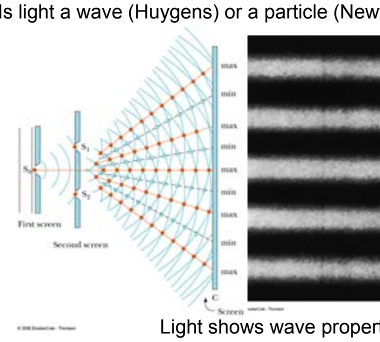


Coherent waves $\quad$ Interference pattern

Young's two slit experiment

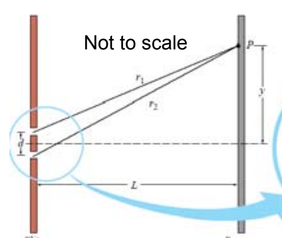
Thomas Young

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

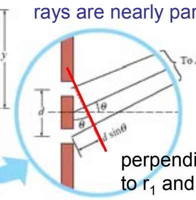


Light shows wave properties

Path difference from the two slits



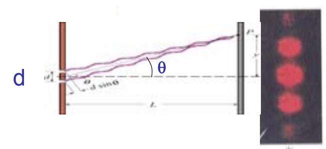
In the limit L>>d, the rays are nearly parallel



perpendicular to r_1 and r_2

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

Interference pattern



Bright
constructive interference

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

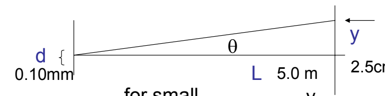
Dark
destructive interference

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

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

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.



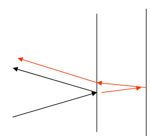
$d\sin\theta = m\lambda$ for small angles $\sin\theta \approx \theta \approx \frac{y}{L}$ $\Rightarrow$ $d\frac{y}{L} = m\lambda$

solve for λ for m= 1

$$\lambda = \frac{yd}{mL} = \frac{(2.6x10^{-2}m)(0.1x10^{-3}m)}{(1)(5.0m)} = 5.2x10^{-7}m = 520nm$$

Thin film interference

Thin film interference

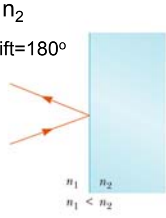


- In thin film interference is interference between light reflected from front an back surfaces of a thin film.
- The phase difference is due to two factors:
  - Path difference through the film (corrected for the change in speed of light in the material)
  - Phase shift due to reflection at the interface

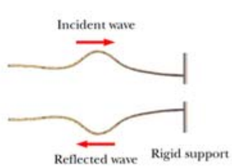
Phase shift due to reflection

$n_1 < n_2$

phase shift=180^o



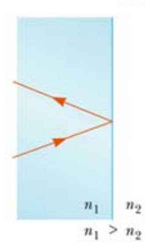
Reflection with inversion
phase shift = 180^o

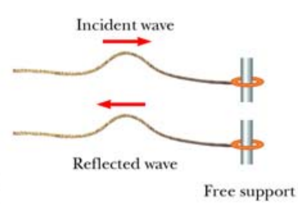


Phase shift due to reflection

$n_1 > n_2$
Phase shift = zero

Reflection without inversion
Phase shift = zero





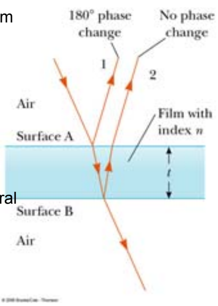
Thin film Interference

Interference between light reflected from Top and bottom surfaces.

For a film in air the phase difference due to reflection is 180^{o}.

If the path difference (2t) is negligible then there is destructive interference.

Destructive interference occurs when the path length difference equals integral multiples of the wavelength.



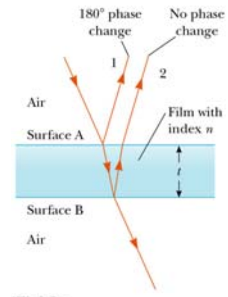
Condition for destructive interference

$\delta = 2t = m\lambda_{film} = m\frac{\lambda}{n}$ The wavelength in the film is shorter than in air.

m=0, 1, 2 , 3 …………

Thin film Interference for a soap film in air

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

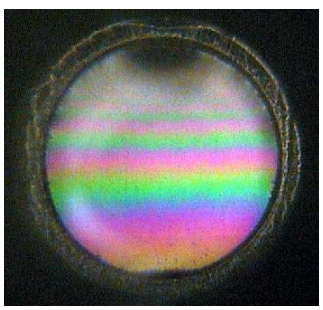


Condition for constructive interference

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

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 5th green band from the top (λ=550 nm, n =1.33)

Constructive Interference

The 5th band has m=4 (the first is m=0)

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

$$t = (m+\frac{1}{2})\frac{\lambda}{2n} \quad = (4+\frac{1}{2})\frac{550nm}{2(1.33)} = 930nm$$

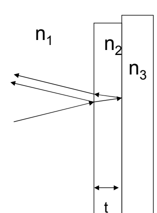
Anti-reflective Coating

no coating

anti-reflective coating

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

Anti-reflective Coating



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.

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?

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

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

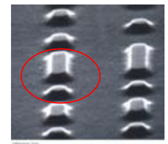
$$2t = (m + \frac{1}{2})\frac{\lambda}{n_2}$$ minimum at m=0 ⇨ $$2t = \frac{1}{2}\frac{\lambda}{n}$$

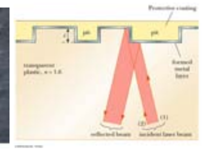
Solve for t

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

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