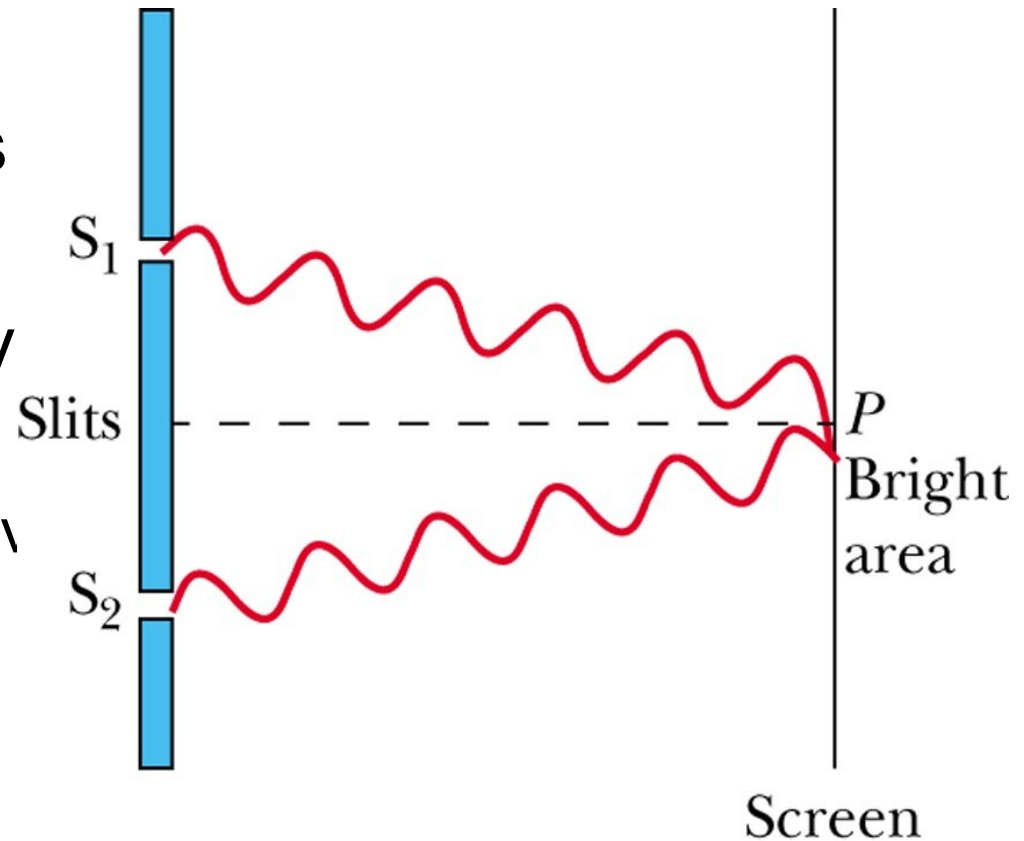


Interference in Thin Films

B.Tech -I

Interference Patterns

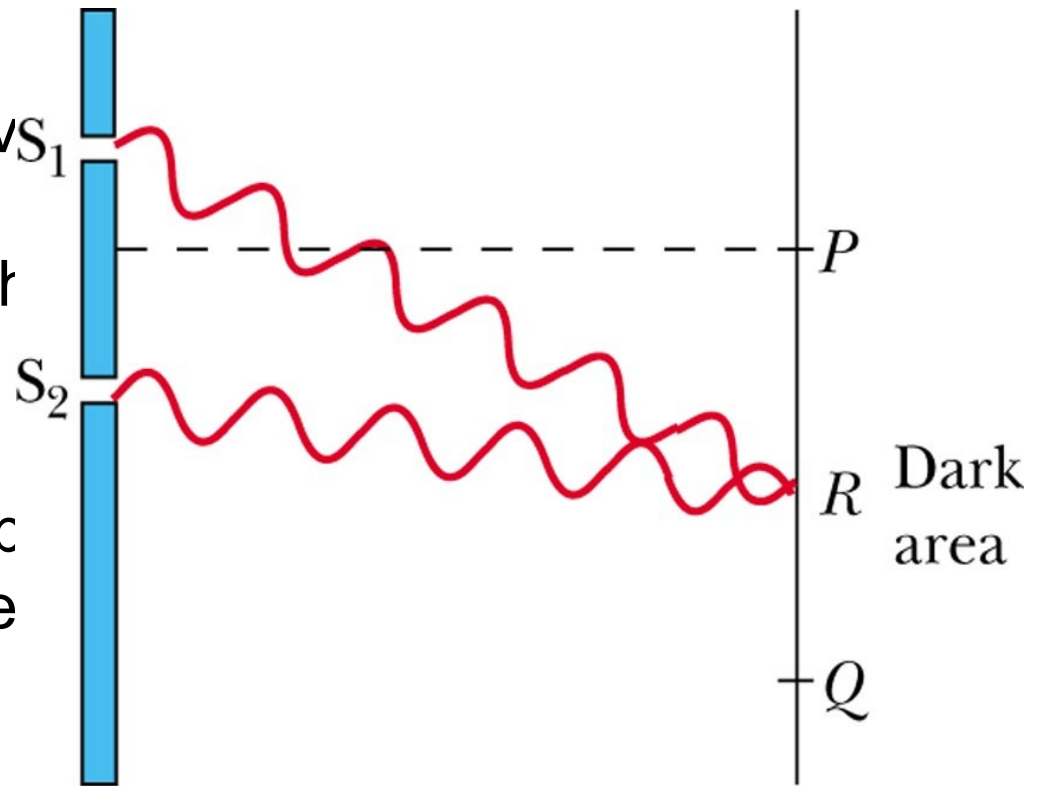
- Constructive interference occurs at the center point
- The two waves travel the same distance
 - Therefore, they arrive in phase



(a)

Interference Patterns, 3

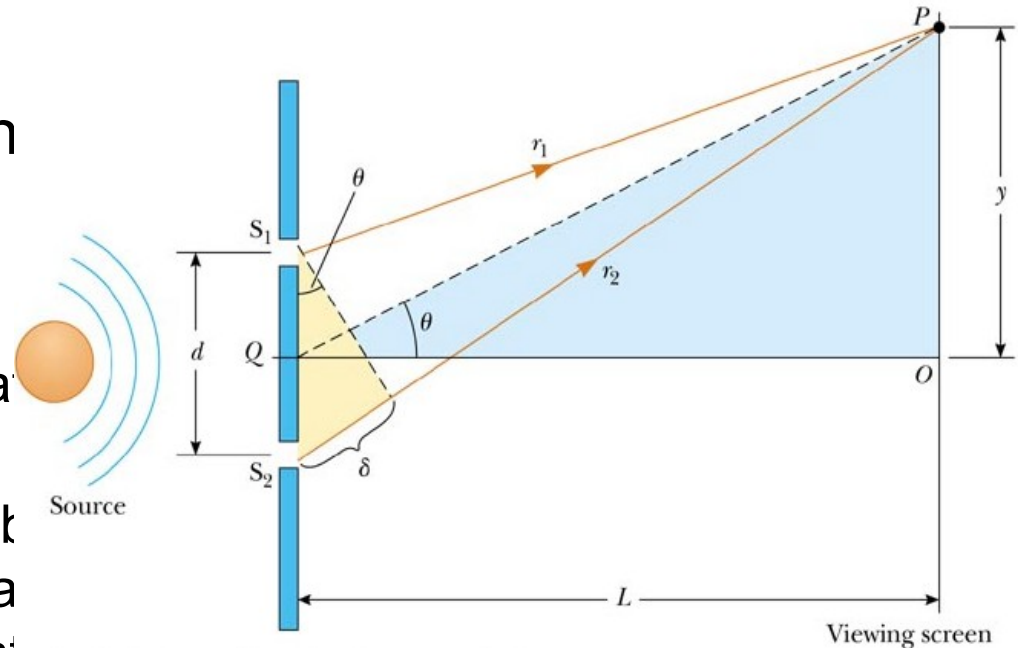
- The upper wave travels one-half of a wavelength farther than the lower wave
- The trough of the bottom wave overlaps the crest of the upper wave
- This is destructive interference
 - A dark fringe occurs



(c)

Interference Equations

- The path difference, δ , is found from the tan triangle
- $\delta = r_2 - r_1 = d \sin \theta$
 - This assumes the paths are parallel
 - Not exactly parallel, but a very good approximation since L is much greater than d



Interference Equations, 2

- For a bright fringe, produced by constructive interference, the path difference must be either zero or some integral multiple of the wavelength
- $\delta = d \sin \theta_{\text{bright}} = m \lambda$
 - $m = 0, \pm 1, \pm 2, \dots$
 - m is called the *order number*
 - When $m = 0$, it is the zeroth order maximum
 - When $m = \pm 1$, it is called the first order maximum

Interference Equations, 3

- The positions of the fringes can be measured vertically from the zeroth order maximum
- $y = L \tan \theta \approx L \sin \theta$
- Assumptions
 - $L \gg d$
 - $d \gg \lambda$
- Approximation
 - θ is small and therefore the approximation $\tan \theta \approx \sin \theta$ can be used

Interference Equations, 4

- When destructive interference occurs, a dark fringe is observed
- This needs a path difference of an odd half wavelength
- $\delta = d \sin \theta_{\text{dark}} = (m + \frac{1}{2}) \lambda$
 - $m = 0, \pm 1, \pm 2, \dots$

Interference Equations, final

- For bright fringes

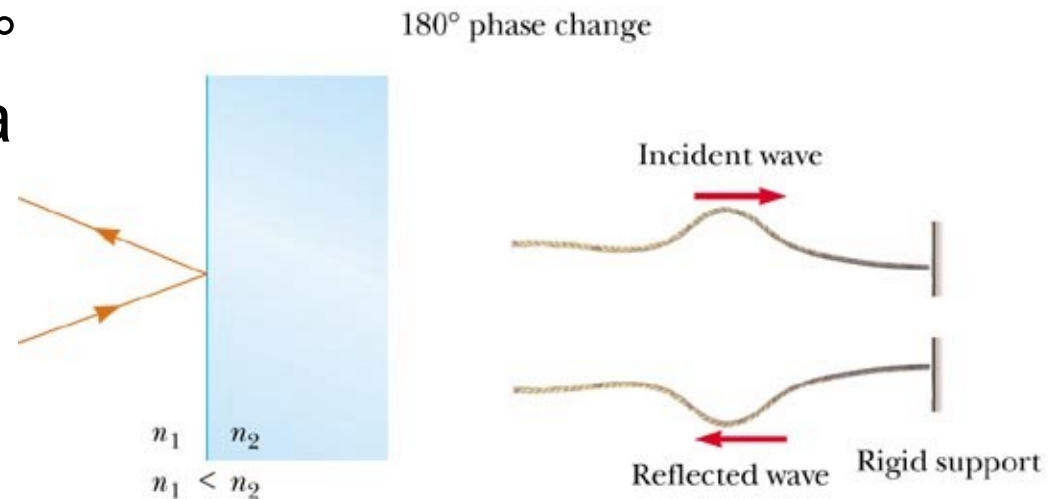
$$y_{\text{bright}} = \frac{\lambda L}{d} m \quad m = 0, \pm 1, \pm 2 \dots$$

- For dark fringes

$$y_{\text{dark}} = \frac{\lambda L}{d} \left(m + \frac{1}{2} \right) \quad m = 0, \pm 1, \pm 2 \dots$$

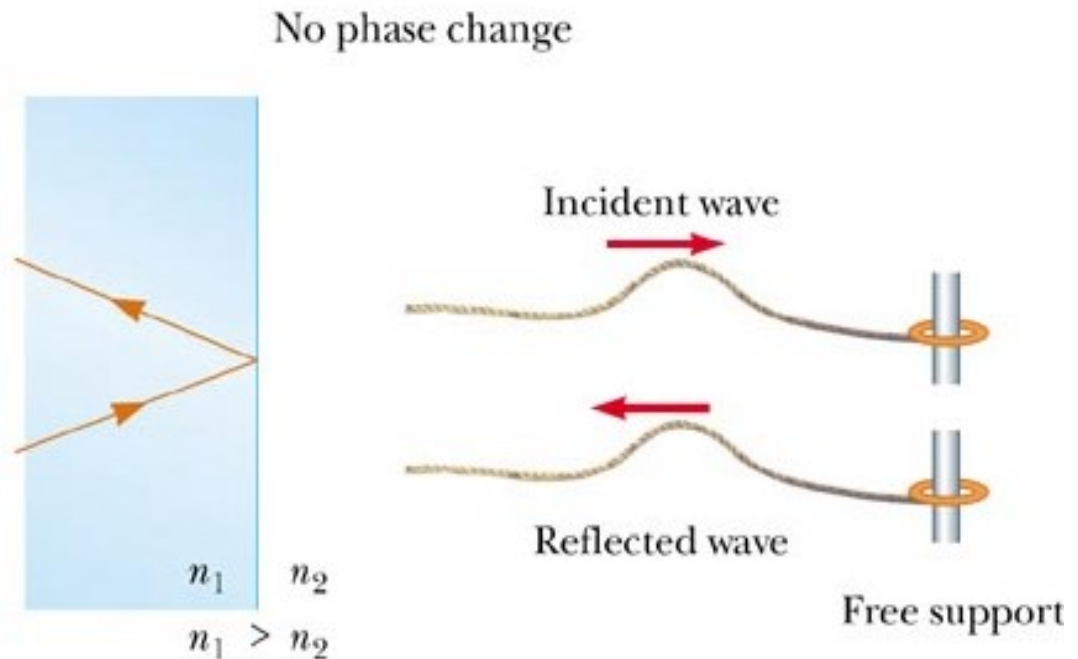
Phase Changes Due To Reflection

- An electromagnetic wave undergoes a phase change of 180° upon reflection from a medium of higher index of refraction than the one in which it was traveling
 - Analogous to a reflected pulse on a string



Phase Changes Due To Reflection, cont

- There is no phase change when the wave is reflected from a boundary leading to medium of lower index of refraction
 - Analogous to a pulse string reflecting from free support



Interference in Thin Films, final

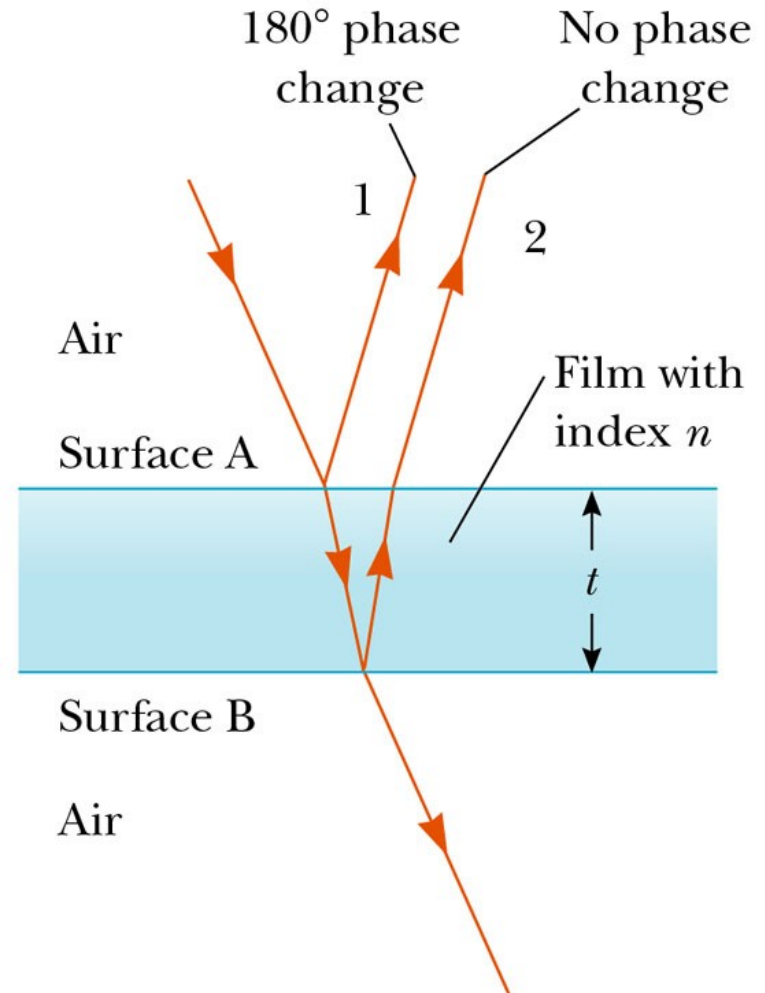
- Be sure to include two effects when analyzing the interference pattern from a thin film
 - Path length
 - Phase change

Interference in Thin Films, 2

- Facts to remember
 - An electromagnetic wave traveling from a medium of index of refraction n_1 toward a medium of index of refraction n_2 undergoes a 180° phase change on reflection when $n_2 > n_1$
 - There is no phase change in the reflected wave if $n_2 < n_1$
 - The wavelength of light λ_n in a medium with index of refraction n is $\lambda_n = \lambda/n$ where λ is the wavelength of light in vacuum

Interference in Thin Films, 3

- Ray 1 undergoes a phase change of 180° with respect to the incident ray
- Ray 2, which is reflected from the lower surface, undergoes no phase change with respect to the incident wave



Interference in Thin Films, 4

- Ray 2 also travels an additional distance of $2t$ before the waves recombine
- For constructive interference
 - $2nt = (m + \frac{1}{2}) \lambda \quad m = 0, 1, 2 \dots$
 - This takes into account both the difference in optical path length for the two rays and the 180° phase change
- For destruction interference
 - $2 n t = m \lambda \quad m = 0, 1, 2 \dots$

Interference in Thin Films, 5

- Two factors influence interference
 - Possible phase reversals on reflection
 - Differences in travel distance
- The conditions are valid if the medium above the top surface is the same as the medium below the bottom surface
- If the thin film is between two different media, one of lower index than the film and one of higher index, the conditions for constructive and destructive interference are *reversed*

Thin Films, 1

- Identify the thin film causing the interference
- Determine the indices of refraction in the film and the media on either side of it
- Determine the number of phase reversals: zero, one or two

Thin Films, 2

- The interference is constructive if the path difference is an integral multiple of λ and destructive if the path difference is an odd half multiple of λ
 - The conditions are reversed if one of the waves undergoes a phase change on reflection

Problem Solving with Thin Films, 3

Equation	1 phase reversal	0 or 2 phase reversals
$2nt = (m + \frac{1}{2}) \lambda$	constructive	destructive
$2nt = m \lambda$	destructive	constructive

Interference in Thin Films, Example

- An example of different indices of refraction
- A coating on a solar cell
- There are two phase changes

