25-3 Thin Films

Important Ideas

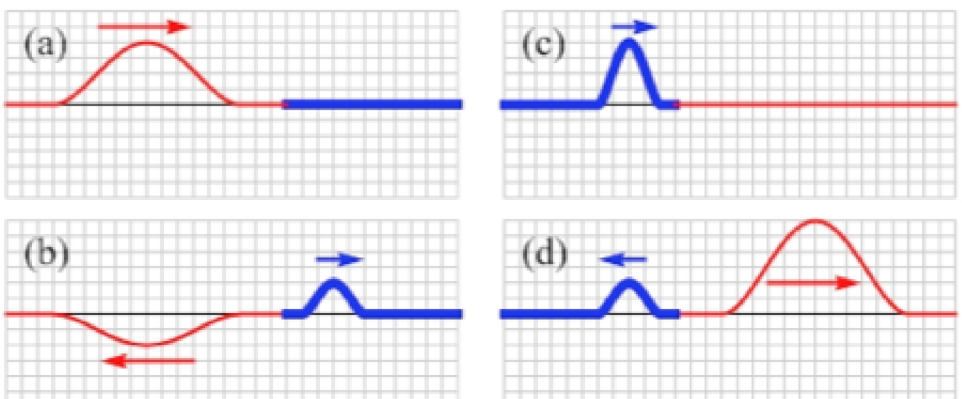
- For two sources that are 180° out of phase, when one source emits a peak, the other source emits a trough.

- For two sources that are 180° out of phase:

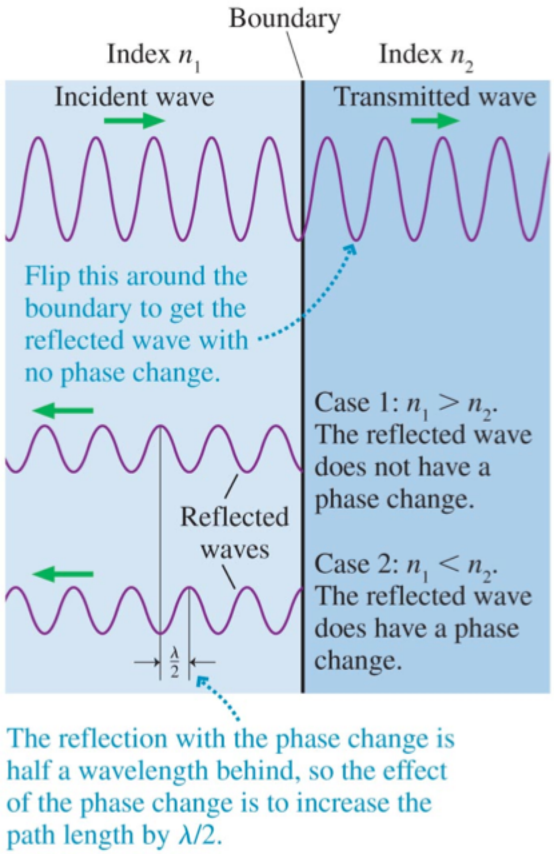
$$\begin{aligned}
\text{Destructive Interference:} \qquad \text{path-length difference} = |L_1 - L_2| = \Delta L &= m\lambda \\
\text{Constructive Interference:} \qquad \text{path-length difference} = |L_1 - L_2| = \Delta L &= \left(m + \frac{1}{2}\right)\lambda
\end{aligned}$$

  Mathematically, two sources that are 180° out of phase have the same effect as two sources that are in phase and have a path-length difference of $\Delta L = (1/2)\lambda$.

- Suppose that a string of density μ_1 is connected to a *larger density* string of density $\mu_2 > \mu_1$. When a sinusoidal wave traveling on string 1 reaches string 2, a wave will be transmitted and a wave will be reflected. The reflected wave will be inverted, which is the equivalent of a 180° phase change. If string 1 is instead connected to a *lower density* string of density $\mu_2 < \mu_1$, then the reflected wave will NOT be inverted.



- When light travels through a material of index n_1 and is incident on a material of index n_2, some of the light is transmitted and some of it is reflected. If the light reflects off a material of *greater* index ($n_2 > n_1$), the reflected wave is inverted (the equivalent of a 180° phase change). When light travels through a material of index n_1 and reflects off a material of *less* index ($n_2 < n_1$), the reflected wave is NOT inverted (and thus has the same phase as the incident wave).



Thin Films

- Thin films often result in interference between the reflected wave at the front surface of the film and the reflected wave at the back surface of the film. Our approach will assume that the wave starts in medium 1, and is normally incident on a thin film (medium 2) of thickness t that is on a third medium (medium 3). The goal is to calculate the *path length difference* ΔL between the two reflected waves. Though our book describes an equivalent method, I prefer to teach the following way of thinking about it.

  1. Identify whether there is a phase change in the reflected wave at the top of the film.
  2. Identify whether there is a phase change in the reflected wave at the bottom of the film.
  3. Identify the path length difference in the two reflected waves: $\Delta L = 2t$.
  4. Count the total number of phase changes. Identify whether it is 0, 1, or 2.
  5. For 0 or 2 phase changes, use the interference equations for two sources that are in phase. For 1 phase change, use the interference equations for two sources that are out of phase.

     Two sources in phase.

$$\begin{aligned}
\text{Constructive: (0 or 2 phase changes)} \qquad \Delta L = 2t &= m\frac{\lambda}{n_{film}} \\
\text{Destructive: (0 or 2 phase changes)} \qquad \Delta L = 2t &= \left(m + \frac{1}{2}\right)\frac{\lambda}{n_{film}}
\end{aligned}$$

Two sources 180° out of phase.

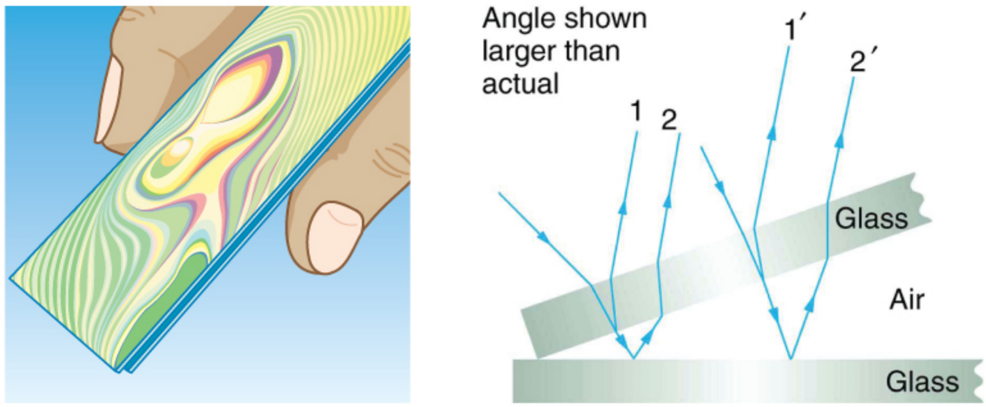
$$\text{Constructive: (1 phase change)} \qquad \Delta L = 2t = \left(m + \frac{1}{2}\right)\frac{\lambda}{n_{film}}$$

$$\text{Destructive: (1 phase change)} \qquad \Delta L = 2t = m\frac{\lambda}{n_{film}}$$

Examples

1. Suppose that you have a thin soap bubble with air on both sides of the bubble layer. Light reflecting from the front surface of the bubble will have a phase change of
   (a) 0°.
   (b) 180°.
2. For the previous question, light reflecting from the back surface of the bubble will have a phase change of
   (a) 0°.
   (b) 180°
3. Suppose that you have a thin soap bubble with air on both sides of the bubble layer. If $n = 1.35$, What is the thickness of the soap film if light of 650 nm constructively interferes?
4. Suppose that you have a thin soap film that floats on water. If $n = 1.35$, What is the thickness of the soap film if light of 650 nm constructively interferes?

5. Two microscope slides have a thin layer of air between them. A thin piece of paper is between the ends of the slides and holds one slide at an angle θ above the other slide as shown below.



(a) (b)

If light of wavelength 650 nm is incident on the slides, what is the first position x from where the slides are in contact that a bright fringe occurs?

If white light of wavelength 400 nm - 700 nm was incident on the slides, what is the first position x that a bright fringe occurs and what color would it be?