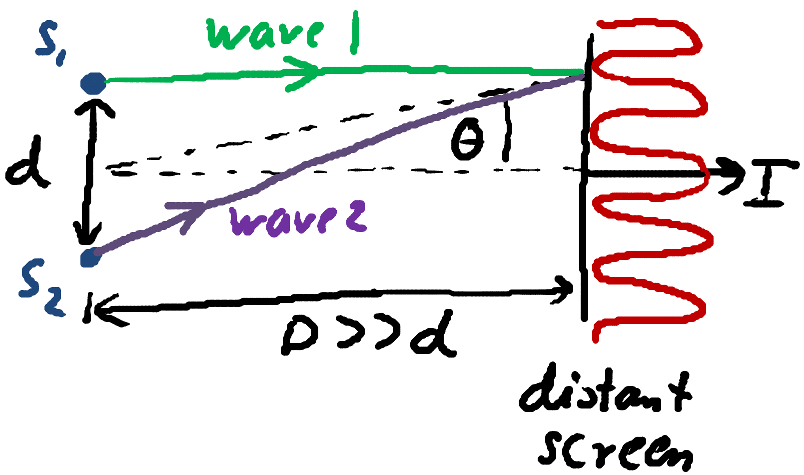
Recap

Lecture 32

- **Interference:**

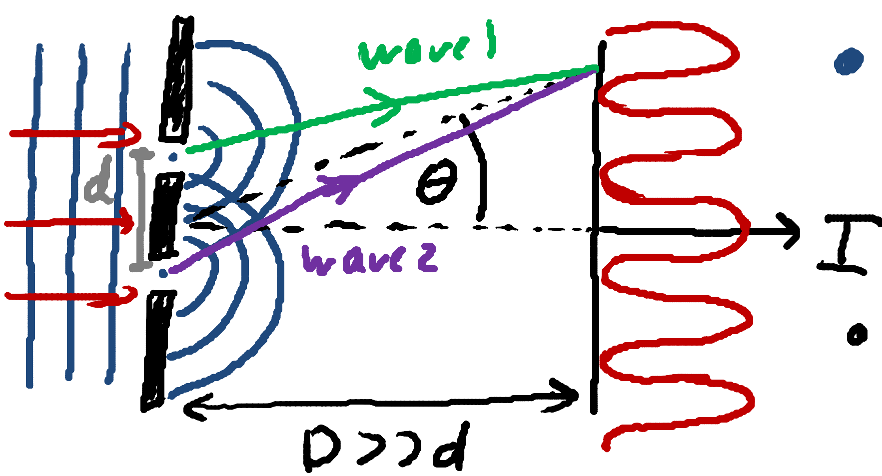
- for two waves from two sources or for double slit:



- path length difference for the two waves:

$$\Delta path = d \cdot \sin\theta$$

- Maxima (constructive interference) at: $d \sin\theta = m\lambda$ $m = 0, \pm1, \pm2 \ldots$



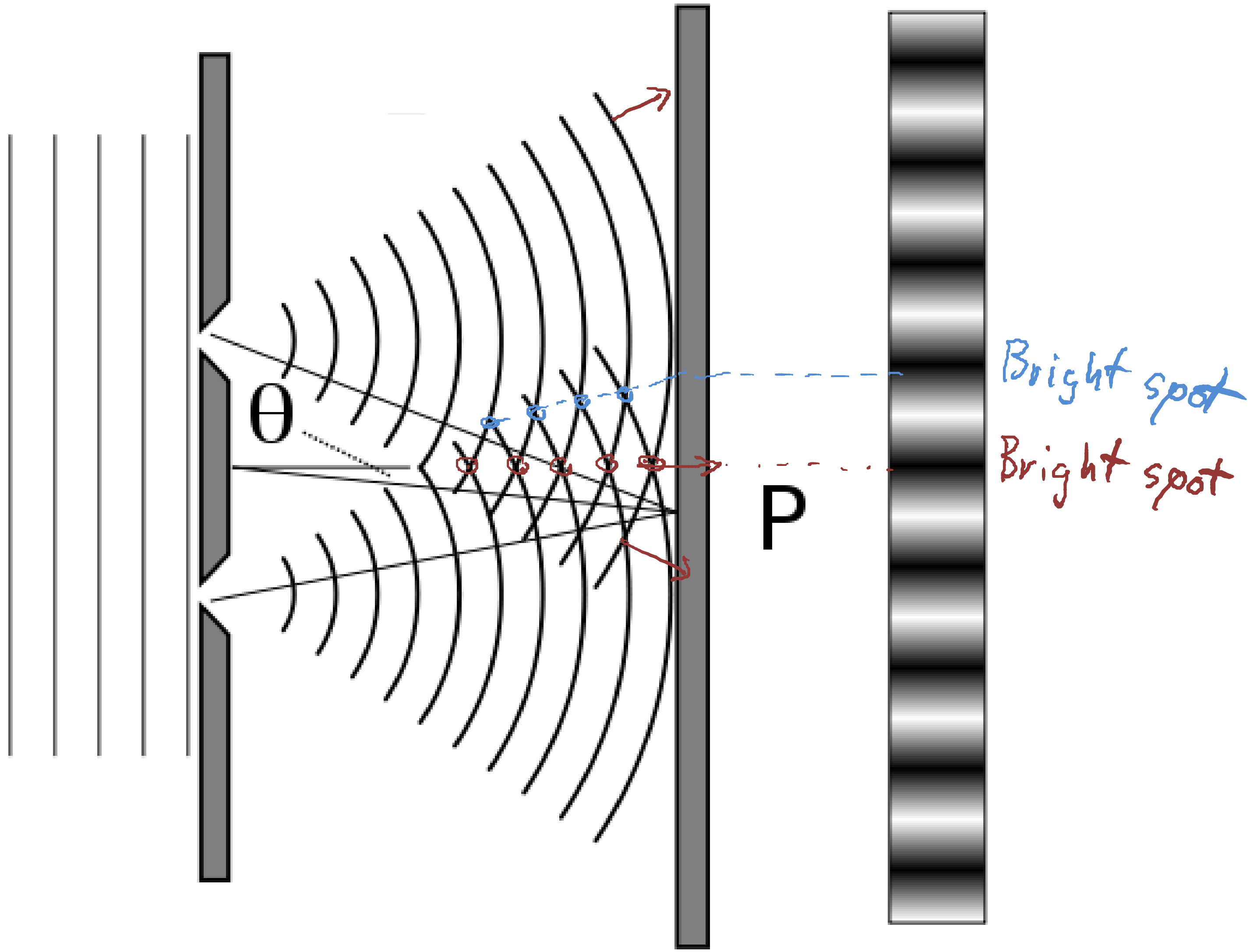
- Minima (destructive interference) at: $d \sin\theta = (m + \frac{1}{2})\lambda$ $m = 0, \pm1, \pm2 \ldots$

- Very narrow slits (width $\lesssim \lambda$) behave like a point source.

Today:

- **Thin-film Interference**
- **Diffraction**
  - Single slit

Interference between waves from two narrow slits



Sources phase difference between two waves

① (Last time) path length difference $\Delta\phi = \frac{2\pi}{\lambda}\Delta path$

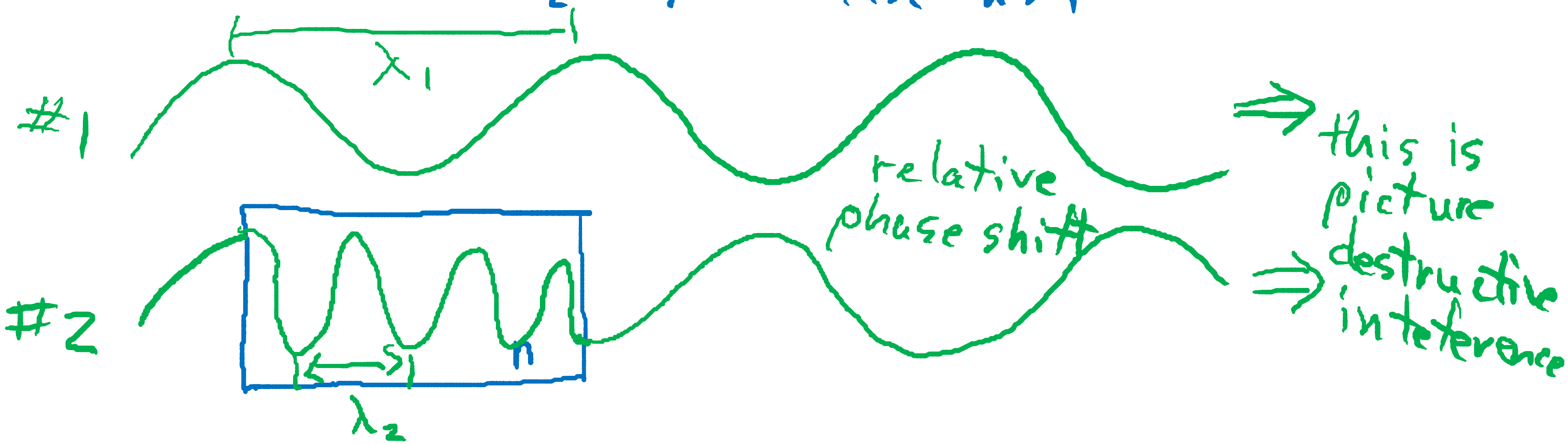
② Waves travel at different speeds through different mediums (characterized by index of refraction, n)

Example: wave #1 – through vacuum $c = \lambda_1 f \Rightarrow \lambda_1 = \frac{c}{f}$

wave #2 – through some material

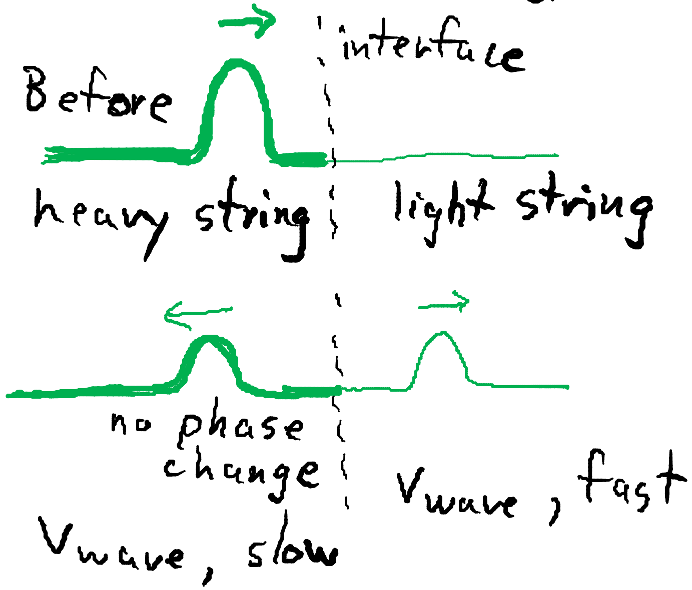
$V_{wave} = \frac{c}{n} = \lambda_2 f \Rightarrow \lambda_2 = \frac{c}{nf} = \lambda_1/n$

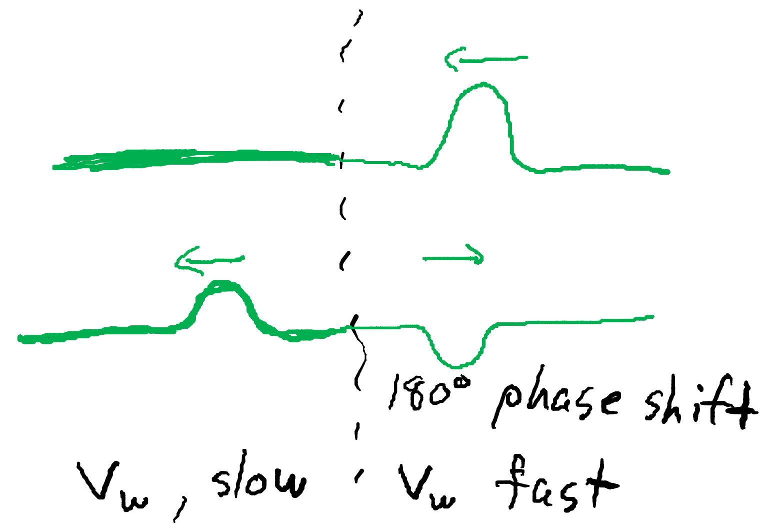
$\lambda_2 < \lambda_1$ because $n > 1$



(3) Phase shift due to reflection from some interface

- Mechanical analogy



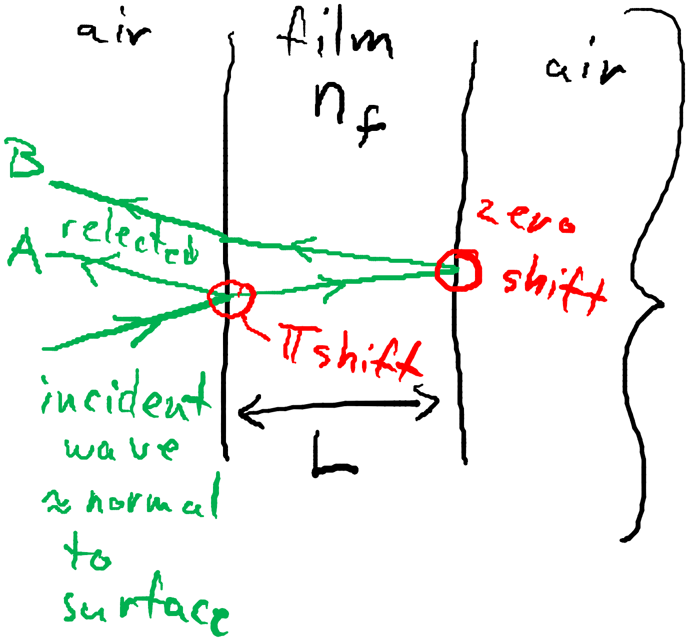


- E-M waves

Reflection type	Phase shift in reflection
slow → fast $n_{incident} > n_{transmitted}$	0
fast → slow $n_{incident} < n_{transmitted}$	π

Thin-Film Interference

- Consider a thin film of thickness L in air



Factors contributing to $\Delta\phi_{B,A}$

(1) Path length difference $= 2L$

(2) Wavelength in film

$$\lambda_f = \frac{\lambda_{vacuum}}{n_f} \quad \text{while in the film}$$

(3) Phase shifts due to reflection

Total phase shift between B and A:

$$\Delta\phi_{B,A} = \phi_B - \phi_A = \left(\frac{2\pi}{\lambda_f} 2L + 0\right) - \pi = \frac{2\pi}{\lambda_{vac.}} n_f (2L) - \pi$$

⇒ Constructive intereference condition

$$\underline{\Delta\phi_{B,A}} = m(2\pi) \Rightarrow \boxed{2L_m = \left(m + \frac{1}{2}\right)\frac{\lambda_{vacuum}}{n_f} \quad m = 0, 1, 2 \ldots}$$

⇒ Destructie interfence condition

$$\Delta\phi_{B,A} = \left[\text{integer} + \frac{1}{2}\right](2\pi) \Rightarrow \boxed{2L_m = m\,\frac{\lambda_{vacuum}}{n_f} \quad m = 0, 1, 2 \ldots}$$

Note what happens with extremely thin film $\lambda \gg L$

⇒ always have destructive interfence of reflection

Examples of Thin-Film Interference

Soap bubble

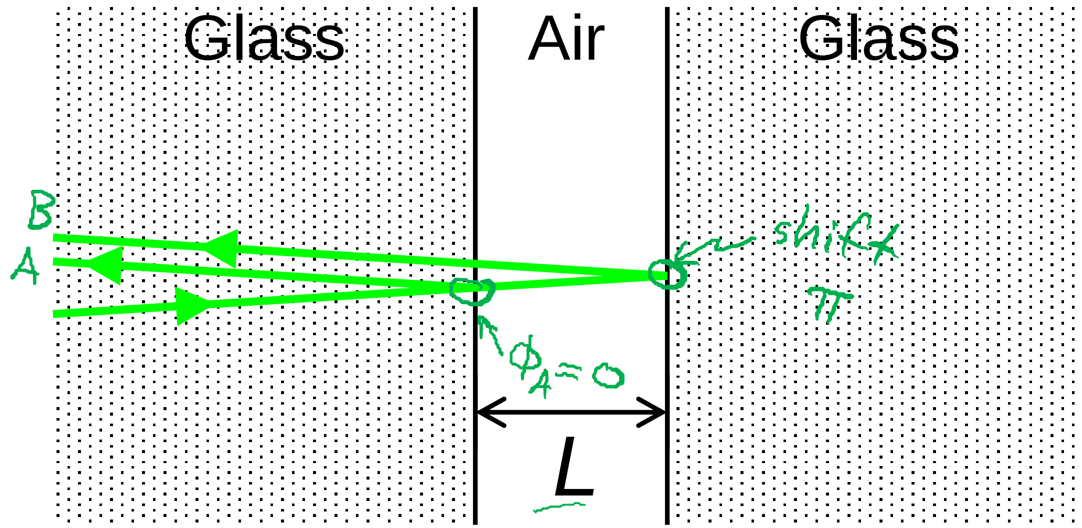
Thin oil film

Example: Thin film of air:

$$\Delta\phi_{B,A} = \phi_B - \phi_A$$

$$\left(\frac{2\pi}{\lambda}2L + \pi\right) - (0)$$

$$\Delta\phi_{B,A} = m(2\pi)$$



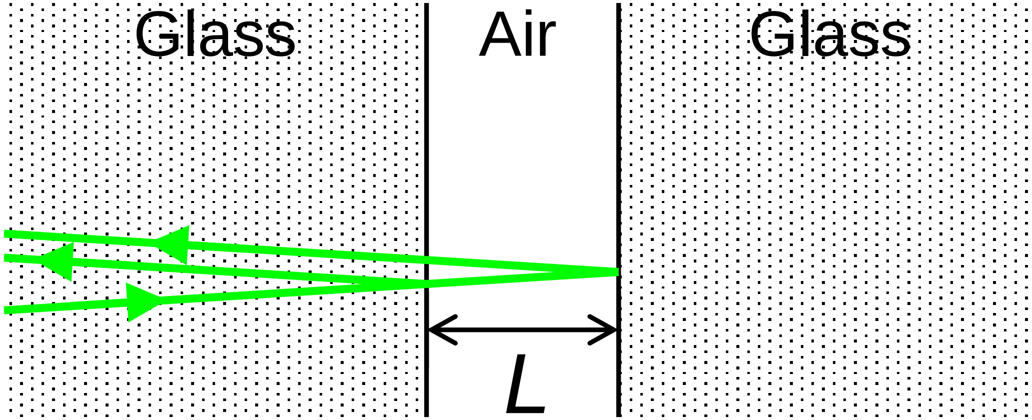
For a given (vacuum) wavelength λ of normally incident light, which equation gives the film thicknesses for constructive interference of reflected light?

A. $2L_m = m\lambda,\ m = 0, 1, 2, \ldots.$

B. $2L_m = (m - \frac{1}{2})\lambda,\ m = 1, 2, \ldots.$

C. Neither of the above equations.

Example: Thin film of air:



• Constructive interference

$2L_m = (m - \frac{1}{2})\lambda \quad m = 1, 2, 3 \ldots$

$L_1 = \frac{\lambda}{4} \quad L_2 = \frac{3\lambda}{4}$

Destructive interence will occur midway between L_1 + L_2

$\Rightarrow \Delta L$ for light → dark $\frac{\lambda}{4}$

For (vacuum) wavelength $\lambda = 550$ nm of normally incident light, what is the film thickness difference between the center of a dark fringe and the center of one of its adjacent bright fringes?

A. 1100 nm B. 550 nm C. 275 nm

D. 183 nm E. 138 nm

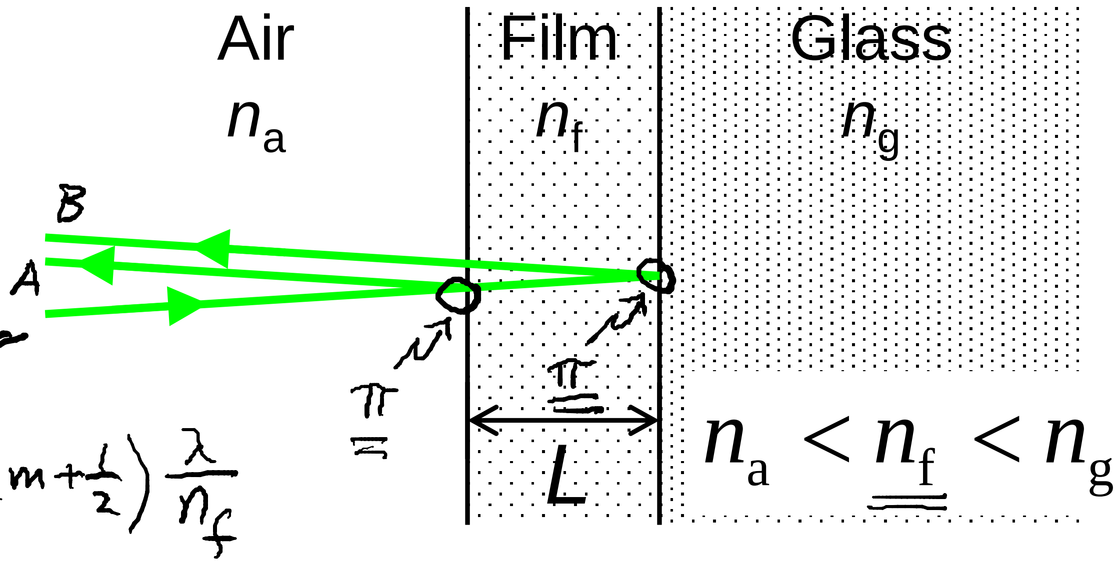
Example: Antireflection coating:

$$\Delta\phi_{B,A} = \left(\frac{2\pi}{\lambda_f}2L + \pi\right) - \pi$$

$$\Delta\phi_{B,A} = \left(m + \tfrac{1}{2}\right)2\pi$$

$$\Rightarrow \frac{2\pi}{\lambda_f}2L = \left(m+\tfrac{1}{2}\right)\cancel{2\pi}$$

$$2L = \left(m+\tfrac{1}{2}\right)\lambda_f = \left(m+\tfrac{1}{2}\right)\frac{\lambda}{n_f}$$



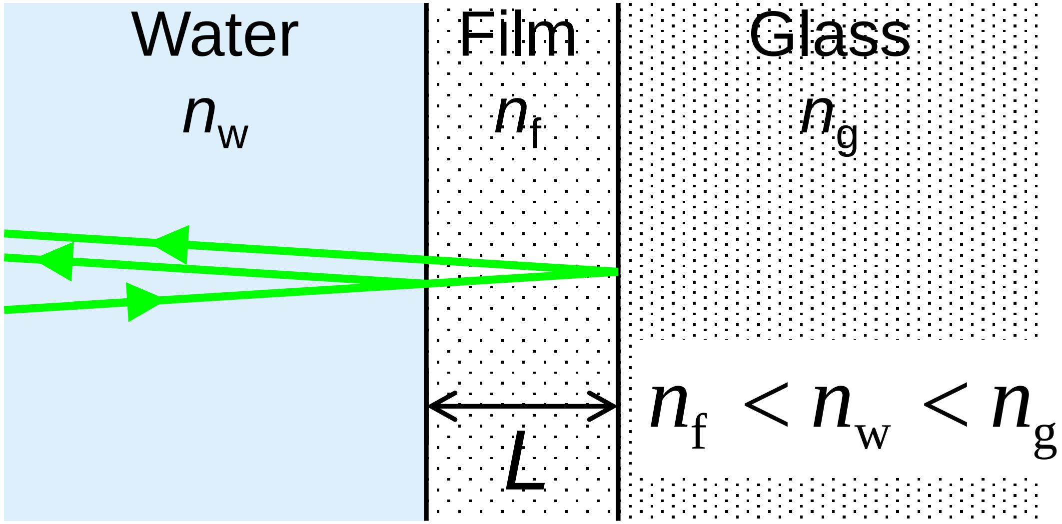
For a given (vacuum) wavelength λ of normally incident light, which equation gives the film thicknesses for destructive interference of reflected light?

A. $2L_m = m\lambda/n_f\,,\ m = 0, 1, 2, \ldots.$

B. $2L_m = (m+\frac{1}{2})\,\lambda/n_f\,,\ m = 1, 2, \ldots.$

C. Neither of the above equations.

Example: Antireflection coating:



For a given (vacuum) wavelength λ of normally incident visible light, the thin film has the minimum thickness required for it to function as an antireflection coating when the coated glass is in air.

If the coated glass is immersed in water, will the thin film function as an antireflection coating for any visible light?

A. Yes.	**B. No.**	**C. Not enough information.**