Phase Difference

Consider a light wave traveling in the z-direction.

$$\vec{E}_1 = E_{10}\sin(kz - \omega t + \delta_1)\,\hat{\imath}$$
$$\vec{B}_1 = B_{10}\sin(kz - \omega t + \delta_1)\,\hat{\jmath}$$

Consider a second light wave of the same wavelength also traveling in the z-direction.

$$\vec{E}_2 = E_{20}\sin(kz - \omega t + \delta_2)\,\hat{\imath}$$
$$\vec{B}_2 = B_{20}\sin(kz - \omega t + \delta_2)\,\hat{\jmath}$$

Any interference is determined by the phase difference $\boldsymbol{\phi = \delta_2 - \delta_1}$ and the relative intensities.

Phase Difference

$$\phi = \delta_2 - \delta_1$$

For waves completely in phase $\phi = (2m)\pi$
I will refer to this as a phase difference of 0

For waves completely out of phase $\phi = (2m+1)\pi$
I will refer to this as a phase difference of π

Phase Changes

For waves originally in phase, consider effects that may change phase.

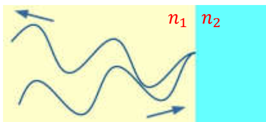
Path length difference

- $\Delta L = m\lambda$ ⇒ phase change of 0
- $\Delta L = \left(m + \frac{1}{2}\right)\lambda$ ⇒ phase change of π

Phase Changes due to Reflection

Waves traveling in a medium with index of refraction n_1 reflect off a surface of a medium with index of refraction n_2.

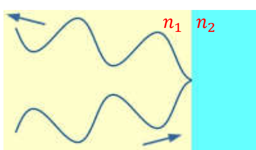
If $n_1 > n_2$ there will be no change of phase



Phase Changes due to Reflection

Waves traveling in a medium with index of refraction n_1 reflect off a surface of a medium with index of refraction n_2.

If $n_1 < n_2$ there will be a change of phase of π



Phase Difference

For waves originally in phase, consider effects that may change phase.

Path length difference
- $\Delta L = m\lambda$ $\Rightarrow$ phase change of 0
- $\Delta L = \left(m + \frac{1}{2}\right)\lambda$ $\Rightarrow$ phase change of π

Reflection
- $n_1 > n_2$ $\Rightarrow$ phase change of 0
- $n_1 < n_2$ $\Rightarrow$ phase change of π

Phase Difference

For waves originally in phase, consider effects that may change phase.

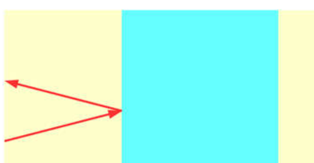
Path length difference
- $\Delta L = m\lambda$ $\Rightarrow$ phase change of 0
- $\Delta L = \left(m + \frac{1}{2}\right)\lambda$ $\Rightarrow$ phase change of π

Reflection
- $n_1 > n_2$ $\Rightarrow$ phase change of 0
- $n_1 < n_2$ $\Rightarrow$ phase change of π

"Low to high, change is π." (D.M. Sparlin)
"High to low, change is NO." (Anonymous S&T Student)

Thin Film Interference

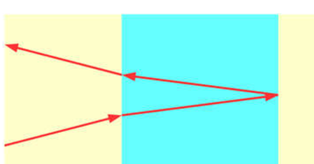
Consider light reflecting off a thin film.



Some light will reflect off the first surface.

Thin Film Interference

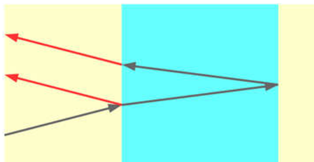
Consider light reflecting off a thin film.



Some light will reflect off the second surface.

Thin Film Interference

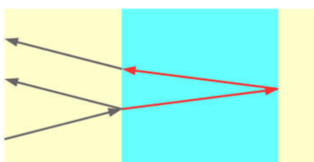
Consider light reflecting off a thin film.



There will be interference between the reflected rays.

Thin Film Interference

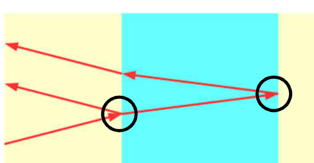
Consider light reflecting off a thin film.



There could be a phase change due to path length difference.

Thin Film Interference

Consider light reflecting off a thin film.



There could be one or two phase changes due to reflections.

Thin Film Interference

Determining interference patterns can be an exercise in counting the number of phase changes of π.

Thin Film Interference

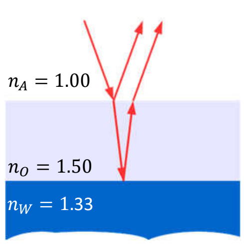
Determining interference patterns can be an exercise in counting the number of phase changes of π.

Remember: λ depends on the index of refraction.

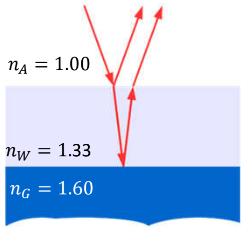
$$n = \frac{c}{v} = \frac{\lambda f}{\lambda_n f} = \frac{\lambda}{\lambda_n}$$

$$\boxed{\lambda_n = \frac{\lambda}{n}}$$

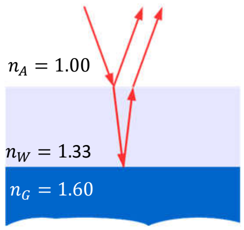
Example: A layer of oil ($n_O = 1.50$) floats on top of water ($n_W = 1.33$). It is observed that 610nm light shining normally on the oil is minimally reflected. What is smallest possible thickness of the oil film?



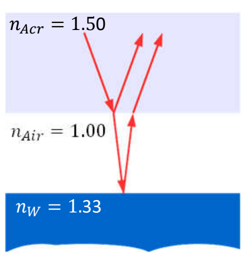
Example: How would the answer change if it were a thin film of water on a glass plate? [Looking for minimal reflection with $\lambda = 610\text{nm}$, $n_G = 1.60$]



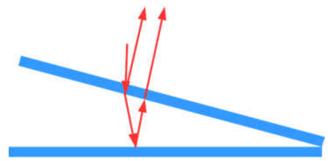
Example: How would the answer change if maximum reflection was observed? [$\lambda = 610\text{nm}$, $n_G = 1.60$]



Example: An acrylic plate is floating on water in such a way that a thin volume of air is trapped between the plate and the water at the center of the plate. Maximum reflection is observed for light with $\lambda = 560\text{nm}$. What is the smallest possible thickness of the air volume.?



Example: A wedge of air is created between glass plates resulting in an interference pattern. Where do bright fringes occur? Where do dark fringes occur?



(Angle is greatly exaggerated and thickness of glass is not to scale.)

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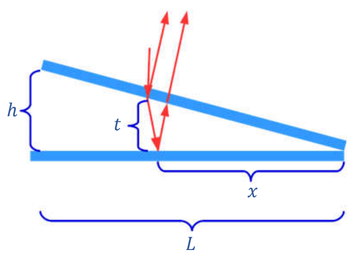
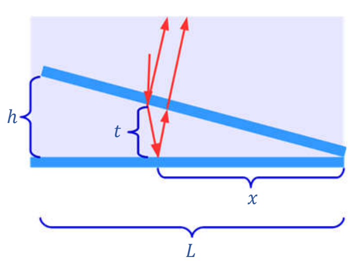


Example: How does this question change if the plates are in water so that the wedge is made of water?



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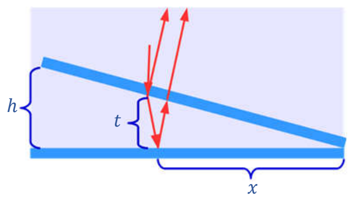

Why do we not consider reflections off the other glass surfaces?