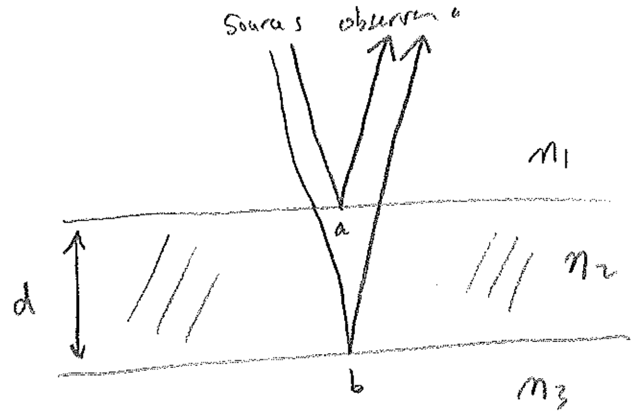
Thin film interference

→ e.g. oil on water, soap bubbles

Consider a thin layer of material w/ different index of refraction (e.g. soap bubble, layer of oil)



Light reflects off front + back surfaces, causing interference

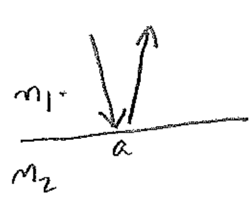
Two paths from source to observer

sao w/ path length x_a

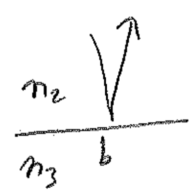
sbo w/ path length $x_b = x_a + \Delta X$ where $\Delta X = 2d$

$$E_{tot} = E_{sao} + E_{sbo} = A\sin(\omega t - kx_a + \delta_a) + A\sin(\omega t - kx_b + \delta_b)$$

δ_a, δ_b = possible phase shift upon reflection



$\delta_a = \pi$ if $n_1 < n_2$
$\delta_a = 0$ if $n_1 > n_2$



$\delta_b = \pi$ if $n_2 < n_3$
$\delta_b = 0$ if $n_2 > n_3$

Phase difference between 2 waves

$$\Delta\phi = (-kx_a + \delta_a) - (-kx_b + \delta_b) = k\,\Delta X + \delta_a - \delta_b$$

$$= \frac{2\pi}{\lambda_{n_2}}(2d) + \delta_a - \delta_b$$

where λ_{n_2} is the wavelength of light in medium w/ index of refraction n_2

Example: soap bubble

$n_1 = 1$ (air)
$n_2 = n = 1.33$ (water) $\Rightarrow \delta_a = \pi$
$n_3 = 1$ (air) $\Rightarrow \delta_b = 0$

$$\Rightarrow \Delta\phi = 2\pi\left(\frac{2d}{\lambda_n}\right) + \pi$$

If $2d = m\lambda_n$ for some integer m, then

$$\Delta\phi = 2\pi m + \pi = 2\pi(m + \tfrac{1}{2})$$ destructive

reflection from front + back surfaces cancels out.

If $2d = (m + \frac{1}{2})\lambda_n$ for some integer m then

$$\Delta\phi = 2\pi(m + \tfrac{1}{2}) + \pi = 2\pi(m+1)$$ constructive

Light of wavelength λ_n in medium is strongly reflected when film has thickness $d = (m + \frac{1}{2})\frac{\lambda_n}{2}$

ie $\frac{\lambda_n}{4}$, $\frac{3\lambda_n}{4}$, $\frac{5\lambda_n}{4}$, etc.

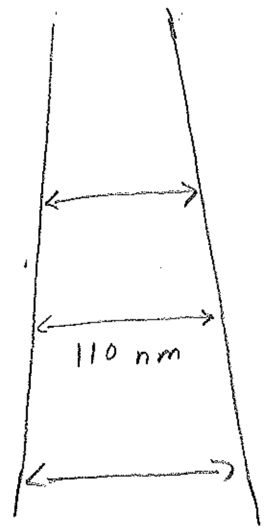
Because light travels through medium w/ speed $v = \frac{c}{n}$, the wavelength λ_n of a given color is different from its wavelength λ in vacuum. In vacuum $\lambda = \frac{c}{f}$

In medium $\lambda_n = \frac{v}{f} = \frac{c}{nf} = \frac{\lambda}{n}$.

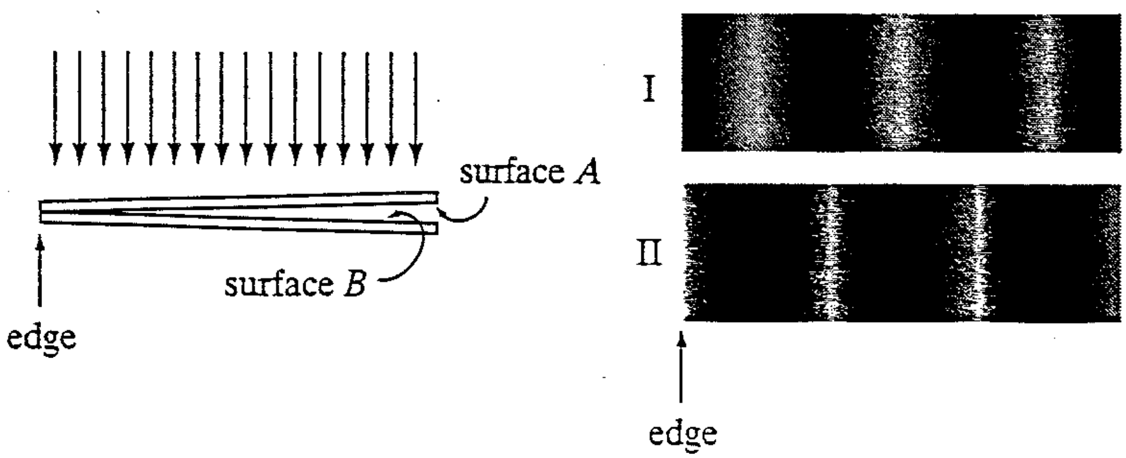
For example: yellow in vacuum has $\lambda = 580$ nm
in water has $\lambda = 440$ nm

Q: Why different colors in soap films & oil slicks?

Because thickness varies vertically

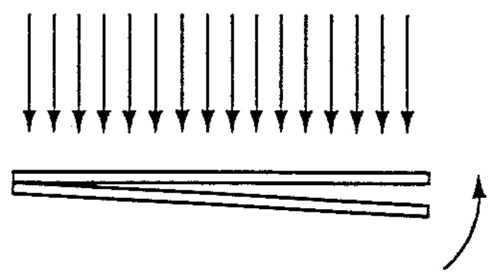


Monochromatic light shines on a pair of identical glass microscope slides that form a very narrow wedge. The top surface of the upper slide and the bottom surface of the lower slide have special coatings on them so that they reflect no light. The inner two surfaces (A and B) have nonzero reflectivities. A top view of the slides looks like



1. I.
2. II.

Consider two identical microscope slides in air illuminated with monochromatic light. The bottom slide is rotated (counterclockwise about the point of contact in the side view) so that the wedge angle gets a bit smaller. What happens to the fringes?

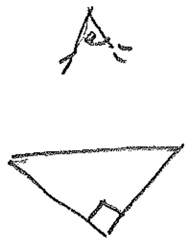


1. They are spaced farther apart.
2. They are spaced closer together.
3. They don't change.

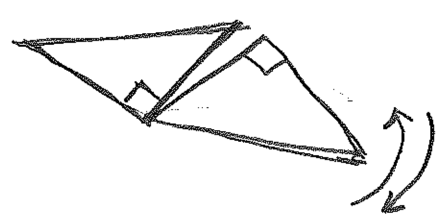
[DEMO] Hand out Porro prisms

Put screen down in front of blackboard

- Polish prisms
- Look until you see your eye

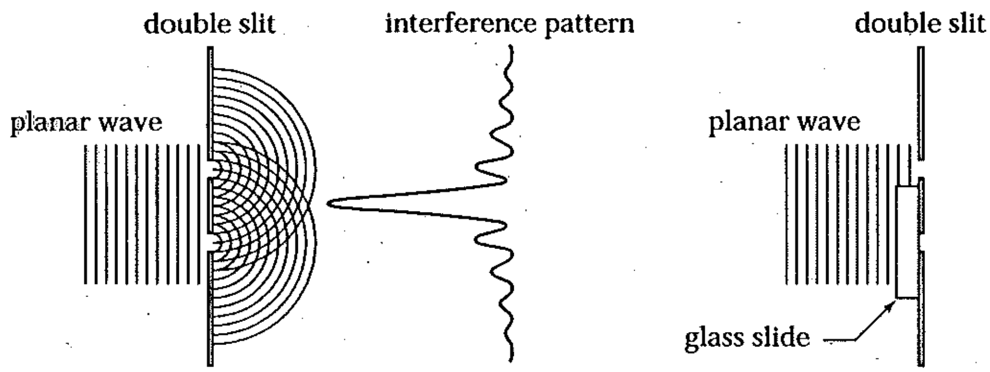


- Rotate slightly to see line
- Place 2nd prism behind to see interference fringes



rotate prism to see fringes more further apart or closer together

An interference pattern is formed on a screen by shining a planar wave on a double-slit arrangement (left). If we cover one slit with a glass plate (right), the phases of the two emerging waves will be different because the wavelength is shorter in glass than in air. If the phase difference is 180°, how is the interference pattern, shown left, altered?



1. The pattern vanishes.
2. The bright spots lie closer together.
3. The bright spots are farther apart.
4. There are no changes.
5. Bright and dark spots are interchanged.

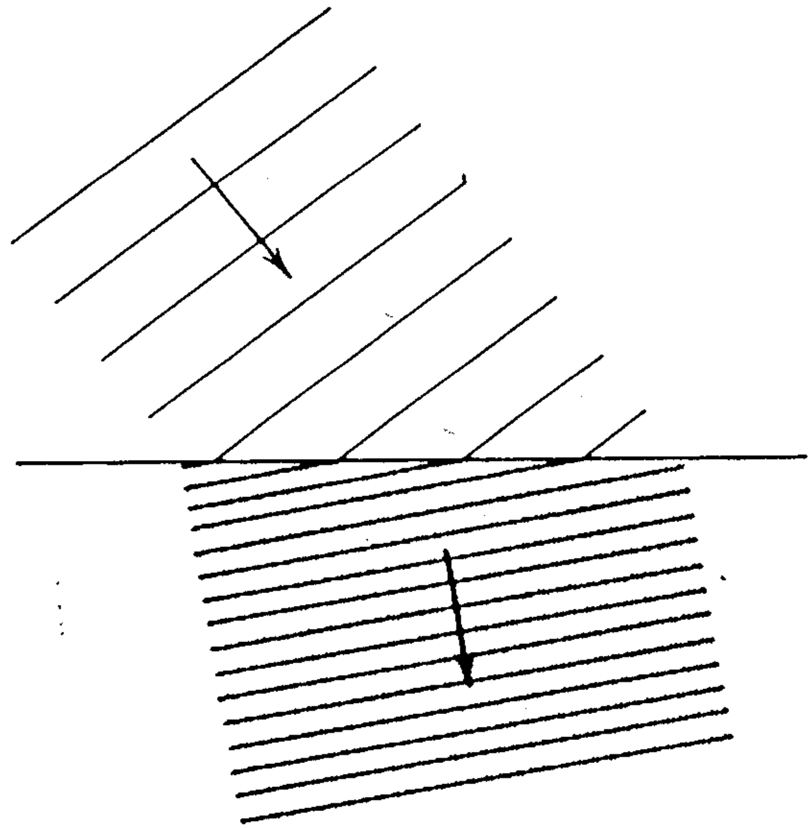


Fig. 5-3. Effect on the orientation of wavecrests and corresponding direction of travel when light passes into a medium in which it travels more slowly.