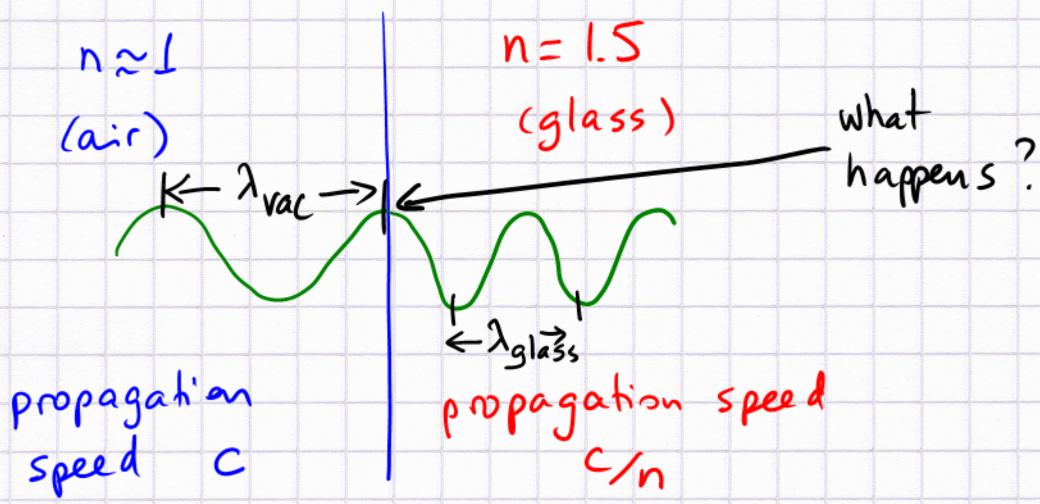
Two-beam interference (thin films)

Compared to the Michelson interferometer two complications (may) arise:

1) light travelling in an optically dense medium

2) phase change when reflection occurs at an interface n_1/n_2 when $n_1 < n_2$

Problem 1: consider light (EM single-frequency wave) passing from $n=1$ (vacuum or air) into an $n>1$ material ($n=1.33$ for water, 1.50 for glass, fiber)



$$\lambda f = c$$

$$\downarrow$$

$$\lambda_{glass} f = c_{glass}$$

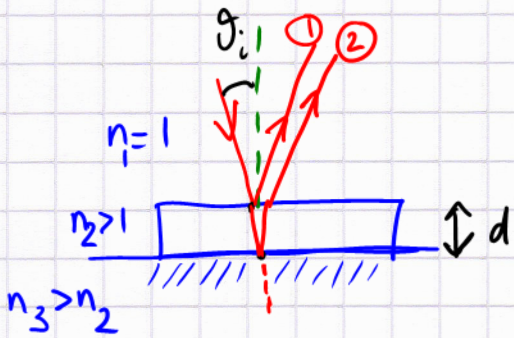
$$\frac{\lambda}{n} f = \frac{c}{n}$$

Q: Why does the frequency remain unaffected?

A: if f was different, the EM wave couldn't propagate consistently, but would either be torn apart or pile up.

Why? in the medium neighboring layers of atoms have outer electrons moving due to $\vec{E}(t)$ pushing. The accelerating electrons radiate EM waves. Locally the electrons oscillate with frequency $f = f_{vac}$.

How does this affect interference conditions?



The path length difference between ① and ② ≈ 2d ($2d \cos\vartheta_{refraction}$) — small angle

The wavelengths $\lambda = \lambda_{vac} \approx \lambda_{air}$, λ_2 (in medium with n_2), and (not needed here): λ_3 in $n_3 > n_2$ medium

Constructive interference ($m = 0, \pm 1, \pm 2, \ldots$) vs. destructive

$$2d = m\lambda_2 = m\frac{\lambda}{n} \qquad\qquad 2d = \left(m + \tfrac{1}{2}\right)\frac{\lambda}{n}$$

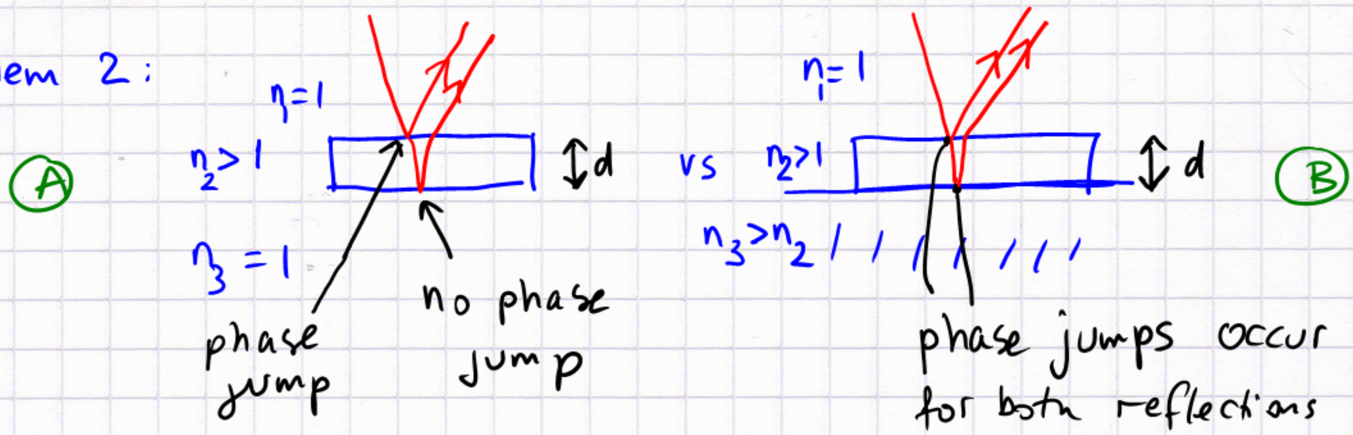
Define "optical" path length:

$$2dn = m\lambda_{vac} \qquad\qquad 2dn = \left(m + \tfrac{1}{2}\right)\lambda_{vac}$$

Note that both reflections involve phase jumps. Since these jumps (sign reversals) happen in both beams, we ignore them.

However, be careful → Problem 2

Problem 2:

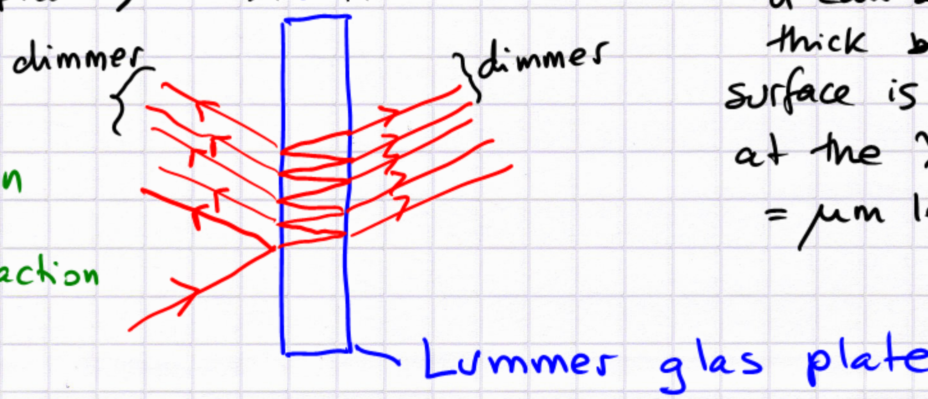


For a thin plate (film) in air the reflections from the front and bottom surfaces are different.

The interference results obtained above for case (B) are reversed for case (A), since a phase jump by π = sign reversal $\hat{=}$ change by $\lambda/2$.

Note: do not memorize the possible cases, but always derive the conditions! There are too many cases, e.g., we do get interference on both sides!

In an Optics course (and lab) one also generalizes the result to multiple-beam interference (Fabry-Perot IF, and Lummer plate) →| d |←



A sharper interference pattern emerges.
→ multi-slit diffraction gratings

d can be mm thick but surface is plane at the λ-level = μm level