Resolution

- circular aperture

$$s_{min} \simeq 1.22 \frac{\lambda L}{a}$$

λ : wavelength

L : distance to object

a : width of aperture (diameter)

s_{min} : minimum separation you can distinguish

- eyes, telescopes, cameras, ...

angular resolution

$$\sin \theta_R = 1.22 \frac{\lambda}{a}$$

θ_R : minimum angular separation

"R" : resolution
Rayleigh criterion

small s_{min} or θ_R = see finer details

big aperture, → more resolution

Wave Equation for Light

$$c = \lambda f \quad \text{in vacuum}$$

$$c = 3 \times 10^8 \text{ m/s}$$

Light slows down in materials

$$v = \frac{c}{n}$$

index of refraction

$$n \geq 1$$

bigger n, slower light

$$n = \frac{c}{v}$$

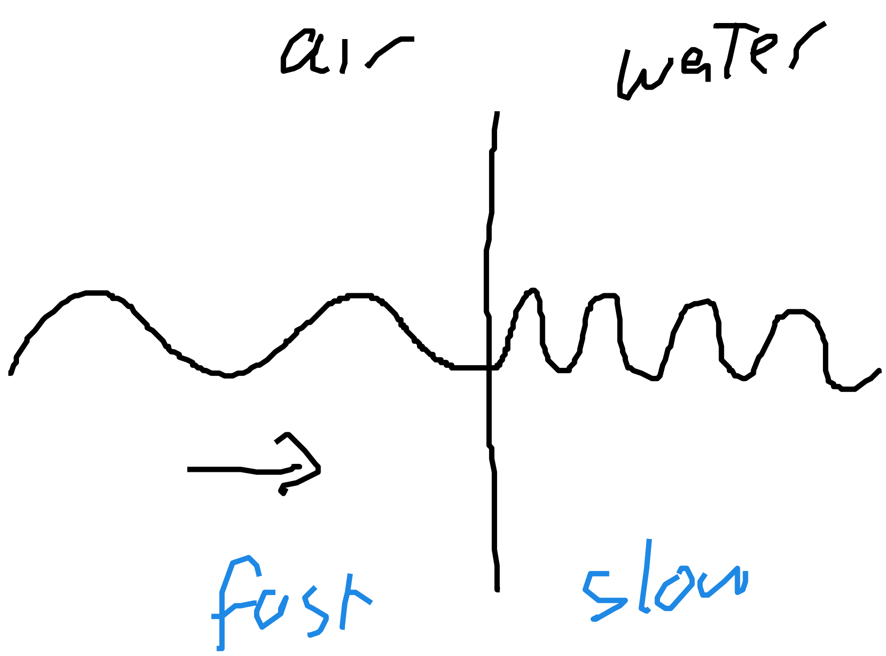
water $n = 1.33 = \frac{4}{3}$

diamond $n = 2.4$

glass $n \approx 1.5 = \frac{3}{2}$

In water

$$V = \frac{3\times10^8}{1.33} = 2.25\times10^8\ m/s$$



wavelength gets smaller as light slows down

$$V_{water} = \lambda_{water} f \Rightarrow f = \frac{V_{water}}{\lambda_{water}}$$

frequency stays the same

$$f = \frac{c}{\lambda_{air}} \longrightarrow \frac{V_{water}}{\lambda_{water}} = \frac{c}{\lambda_{air}}$$

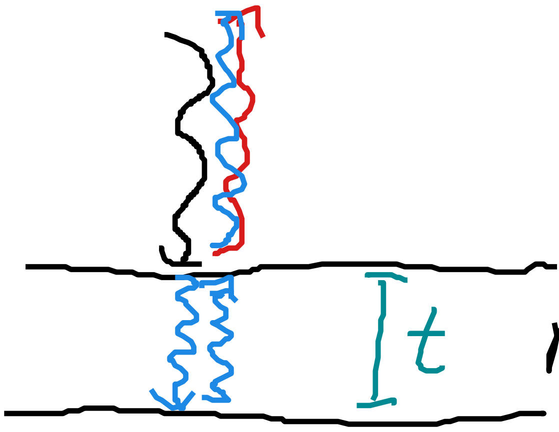
$$n = \frac{c}{V_{water}} = \frac{\lambda_{air}}{\lambda_{water}} \rightarrow \boxed{\lambda_{water} = \frac{\lambda_{air}}{n}}$$

Thin Film Interference

air — $n = 1$

oil — $n = 1.4$

water — $n = 1.33$



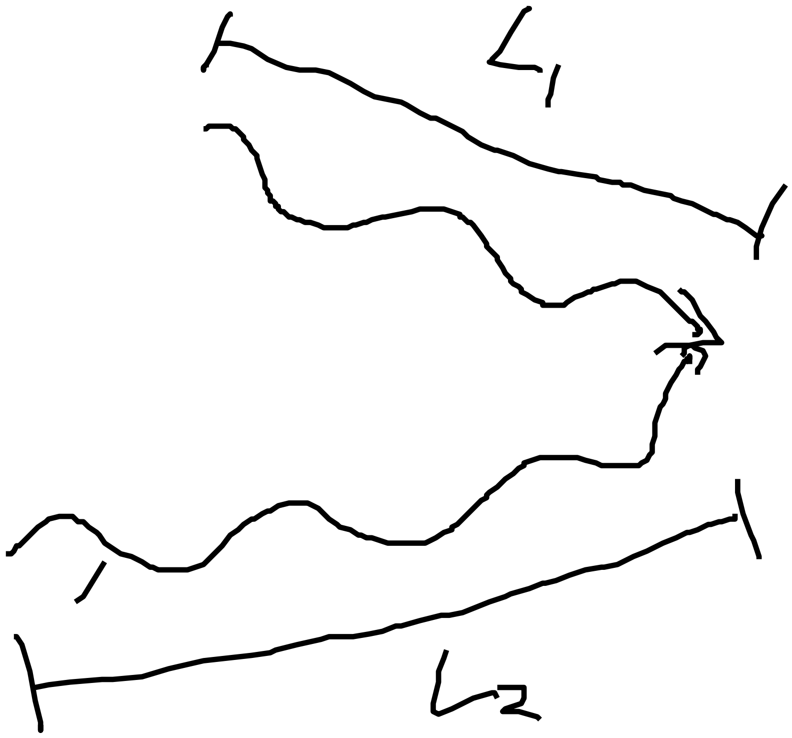
t: thickness of oil

Light hits an interface,
some is reflected and
some (usually) is transmitted

Some light reflects directly
off top surface
Some reflects off bottom surface.
These two rays can interfere

Path Length Difference Δl

- two waves with same λ in sync with each other initially



If $\underbrace{|L_2 - L_1|}_{\Delta l} = (\text{integer})\lambda$

then constructive interference

If $|L_2 - L_1| = (\text{integer} + \frac{1}{2})\lambda$

destructive interference

$$2t = \Delta l$$ ← path length difference

except . . .

when light reflects off of a slower medium (higher index) its phase flips by $180°$.

if one ray flips its phase and the other doesn't then criteria reverse

$$\Delta l = m\lambda$$ destructive interference

$$\Delta l = \left(m + \tfrac{1}{2}\right)\lambda$$ constructive interference

m is an integer

Visible light $\lambda_{air} = 500nm$ green

thickness of oil is $t = 125nm$

$$2t = \Delta l$$

$$2t = 2(125nm) = 250nm$$

$$250nm \stackrel{?}{=} m\lambda$$

solve for m and see if it

is an integer or half-integer

$$m = \frac{250nm}{\lambda_{oil}} = \frac{250nm}{\lambda_{air}/n_{oil}}$$

$$m = \frac{250nm}{500nm/1.4} = 1.4\left(\frac{1}{2}\right) = 0.7$$

$m \approx 0.7$ is a little closer to 0.5 than 1

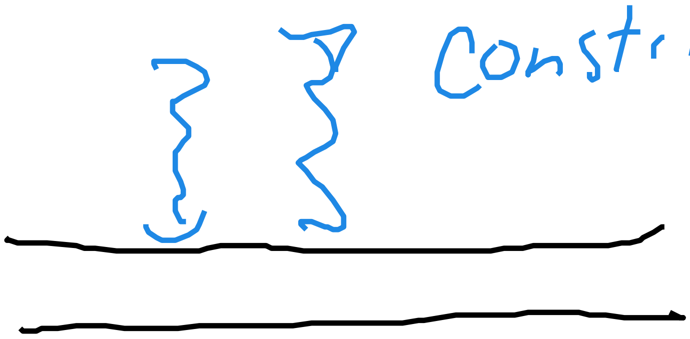
constructive interference

$$2t = \left(m + \frac{1}{2}\right)\frac{\lambda_{air}}{n}$$: constructive

"perfect" reflection

$$2t = m\frac{\lambda_{air}}{n}$$: destructive

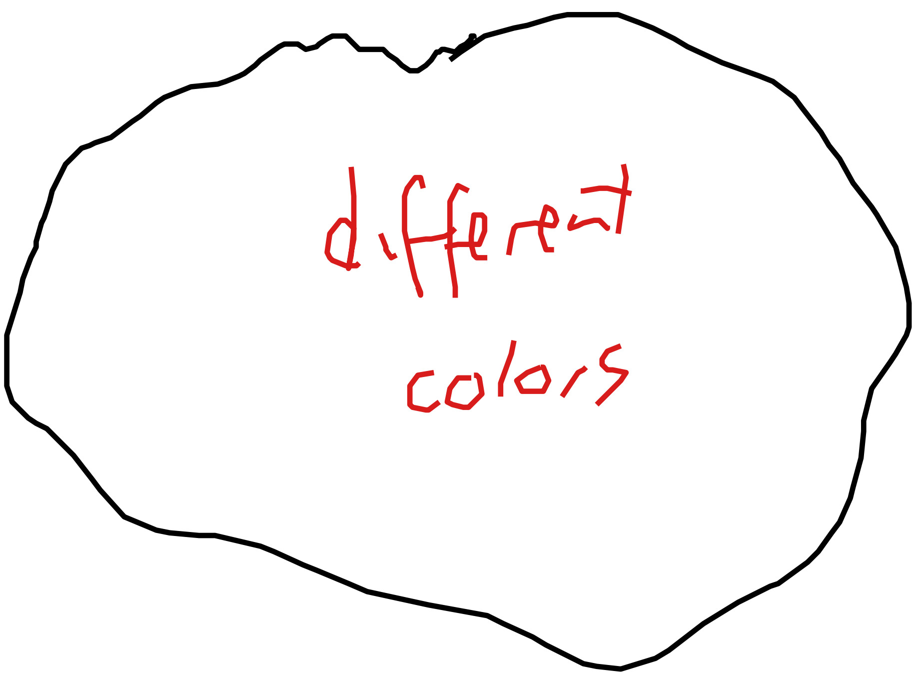
"perfect" transmission



constructive interference

no blue light
makes it through

puddle of oil or a thin
soap film



blue-blocking glasses

$\lambda = 400\text{nm}$

$n = 1.5$ for film

minimum thickness where we get reflection

minimize: $m=0$

$$2t = \left(m + \frac{1}{2}\right)\frac{\lambda_{air}}{n}$$

$$2t = \frac{1}{2}\frac{\lambda_{air}}{n}$$

$$t = \frac{1}{4}\frac{400\text{nm}}{1.5}$$

$$= 66.7\text{ nm}$$