Lecture 26

Wavelength & index of refraction

- wavelength changes when speed of light changes (what we just discussed)
- occurs when light crosses interface from one medium to another.

- since speed of light depends on index of refraction, wavelength does too.

Suppose a beam of monochromatic light has wavelength λ & speed c in vacuum & wavelength λ_n & speed v in a medium w/ index of refraction n

Then using $\frac{\lambda_1}{\lambda_2} = \frac{v_1}{v_2}$

$$\Rightarrow \quad \frac{\lambda_n}{\lambda} = \frac{v}{c}$$

$$\Rightarrow \quad \lambda_n = \lambda \frac{v}{c}$$

↖ how to write in terms of index of refraction?

$$\Rightarrow \quad \lambda_n = \frac{\lambda}{n}$$

- relates wavelength of light in any medium to its wavelength in vacuum.
- greater IoR n $\Rightarrow$ lower wavelength λ

can consider frequency of light also.

we know that $f_n \cdot \lambda_n = v$

↑ freq. ↑ wavelength ↖ wave speed

$$\Rightarrow f_n = \frac{v}{\lambda_n}$$

$$\Rightarrow f_n = \frac{c/n}{\lambda/n} = \frac{c}{\lambda} = f$$

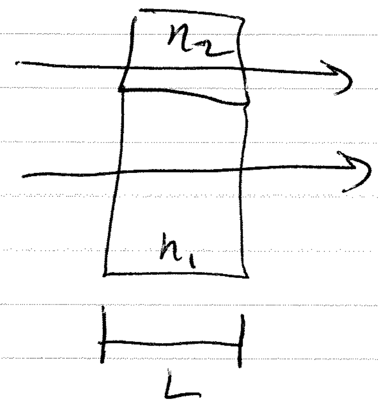
frequency of light does not change!

stays the same for vacuum or any medium

Phase differences

Since wavelength is different for different indexes of refraction, this can lead to interference of light waves.

Consider this situation:



light traveling through materials w/ different indexes of refraction

- Suppose initially wavelengths are the same & waves are in phase.

- After emerging from media, wavelengths are the same, but there is a phase shift & waves may no longer be in phase.

To find the new phase difference, count the number of wavelengths N_1 there are in the length L of medium 1:

$$N_1 = \frac{L}{\lambda_{n_1}} = \frac{L}{\lambda/n_1} = \frac{L n_1}{\lambda}$$

for medium 2:

$$N_2 = \frac{L}{\lambda_{n_2}} = \frac{L n_2}{\lambda}$$

To get phase difference between waves:

$$N_2 - N_1 = \frac{L n_2}{\lambda} - \frac{L n_1}{\lambda}$$

$$= \frac{L}{\lambda}(n_2 - n_1)$$

phase difference is really the fractional part of this number b/c wave looks the same under integer shifts. So if 45.6 then 0.6

So phase differences can lead to interference

If there are differences in the path length traveled, there can also be interference

Suppose path length difference of two light waves w/ same wavelength is ΔL.

Then fully constructive interference occurs when

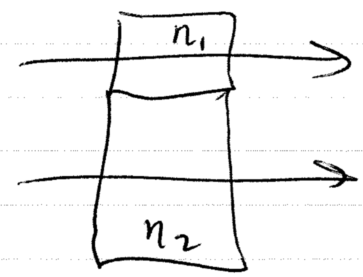
$$\frac{\Delta L}{\lambda} = 0, 1, 2, \ldots$$

fully destructive occurs when

$$\frac{\Delta L}{\lambda} = 1/2, 3/2, 5/2, \ldots$$

so path length differences can lead to interference just as w/ sound waves.

<u>Question:</u> light wave in figure



have same wavelength & amplitude & are initially in phase.

a) If 7.6 wavelengths fit w/in length of top material & 5.5 wavelengths fit in length of bottom material, which one has greater index of refraction?

top

b) If rays are angled slightly so that they meet @ the same point on a distant screen, will the interference result in brightest possible illumination, bright intermediate " , dark " " , or darkness?

bright intermediate – phase diff. is 2.1 which has fractional part 0.1, which is close to zero.