Announcements

- Homework
  - Last video homework due on Monday
  - Old Webwork assignments have all been opened up for late credit until the day of the "final"
- On Monday we shall review and talk about what the Final will look like / require
- You probably want a grade report that is as up-to-date as possible. I get that. All I can promise is I'll do my best.
- Polling: `rembold-class.ddns.net`

Review Question

What is the total phase difference between the below two waves

$$A = \cos(10t - 5x_1)$$
$$B = \cos(10t - 5x_2 + 2)$$

if $x_1 = 8\,\mathrm{m}$ and $x_2 = 4\,\mathrm{m}$?

A. 18 rad

B. 20 rad

C. 22 rad

D. 40 rad

Solution: 18 rad – Being more careful with the positives and negatives here, this should really be -18, which we could then take an abs value of.
I'll give credit for either answer on the polling. My bad, sorry for confusion.

Waves in Materials

- In many cases, waves move from one material to another
- Depending on materials, waves can speed up or slow down in the process
  - Frequency stays the same
    - Property of the wave source
  - Wavelength will change
    - Property of the medium
- Can describe the speed of light in a material (v) via the index of refraction n:

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

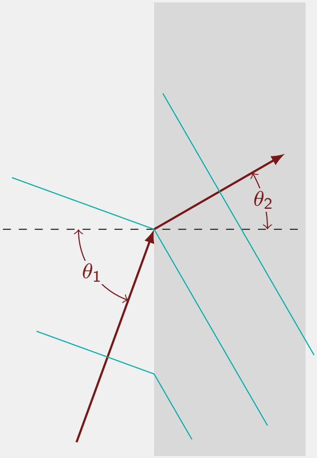
Material	n
Vacuum	1.00000
Air	1.00029
Water	1.33
Quartz	1.46
Plexiglass	1.51
Diamond	2.417

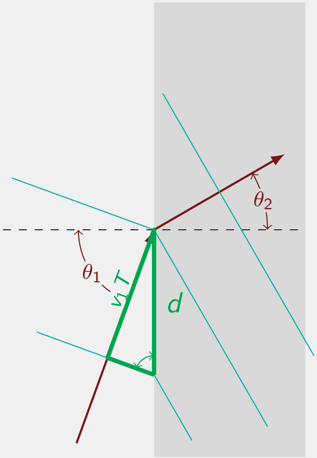
Changing Wavelengths

Suppose orange light at 600 nm passes from a vacuum into Plexiglass. What is the wavelength of the radiation in the plexiglass?

Solution: 397 nm, Purple!

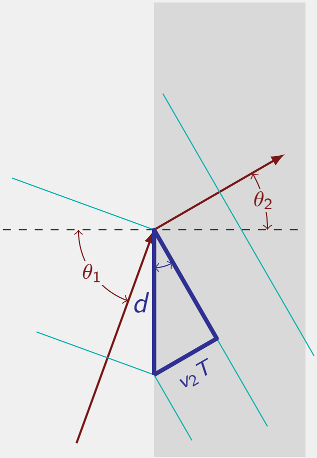
Bending Waves





- Outside of material:

$$\sin\theta_1 = \frac{v_1 T}{d}$$



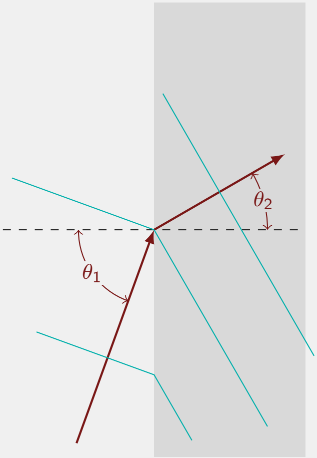
- Outside of material:

$$\sin\theta_1 = \frac{v_1 T}{d}$$

- Inside of material:

$$\sin\theta_2 = \frac{v_2 T}{d}$$

Bending Waves



- Outside of material:

$$\sin\theta_1 = \frac{v_1 T}{d}$$

- Inside of material:

$$\sin\theta_2 = \frac{v_2 T}{d}$$

- Since d and T don't change:

$$\frac{\sin\theta_1}{v_1} = \frac{\sin\theta_2}{v_2}$$

Behold the Law of Snell

- Rewriting the velocities in terms of n, we get Snell's Law.

Snell's Law

Upon transitioning materials, light is bent according to:

$$n_1 \sin \theta_1 = n_2 \sin \theta_2$$

where θ_1 and θ_2 are measured with respect to the surface normal and n_1 and n_2 are the indices of refraction in the two materials.

- This bending of light is called refraction
- Responsible for much of the warping and distortion of light we see on an everyday basis
- In some materials, n might depend on the wavelength of light!

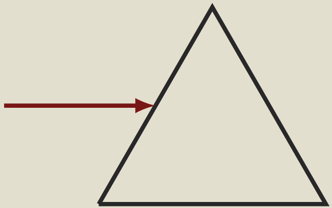
Tricksy Light Rays

Suppose you shine light onto a diamond at an angle with the normal of 20°. Diamond has an index of refraction of 2.4602 for violet light and 2.4065 for red light. If the diamond is 10 cm thick (clearly you are rich), how separated is the red and violet light upon exiting the diamond?

Solution: 0.32 mm

Prism Example

An equilateral triangle composed of quartz ($n = 1.42$) has light shown in as seen below. In what direction is the light traveling when it leaves the quartz?



Solution: 34.29° below horizontal

Review Question

Suppose a piece of special glass had an index of refraction that varied with wavelength, such that

$$n(\lambda) = \frac{900\,\text{nm}}{\lambda}$$

White light contains light at all wavelengths of the visible spectrum. Suppose white light was shone onto this piece of glass at angle of 60° with the normal. Given that red light has a wavelength around $700\,\text{nm}$ and violet light a wavelength around $400\,\text{nm}$, determine the angular separation between the resulting violet and red light inside the glass.

A. 17.65°

B. 19.71°

C. 22.63°

D. 37.36°

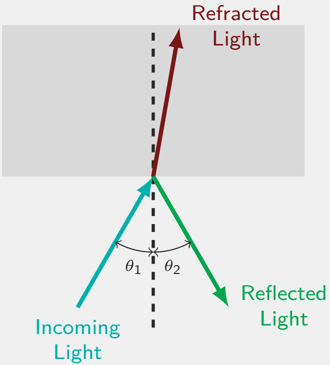
Solution: 19.71°

Reflection

- At any boundary, some reflection can occur
- Light reflects at the same angle in arrived

$$\theta_1 = \theta_2$$

- Will always have some combination of reflection and refraction at a boundary
- Reflecting off a higher index of refraction material results in a phase shift of π



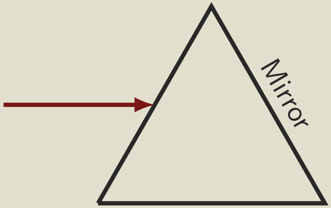
Bubbles!

Suppose you have a thin slick of oil (n=1.47) floating atop a puddle of water (n=1.33). If the oil slick is 0.1 microns thick and you are standing directly above looking straight down, what wavelengths would you see constructively adding?

Solution: Only visible would be $\lambda = 400\,\text{nm}$, rest smaller wavelengths

Prism Example

An equilateral triangle composed of quartz ($n = 1.42$) has light shown in as seen below. The right side of the triangle is a perfect mirrored surface. In what direction is the light traveling when it leaves the quartz?



Solution: 30° left of vertical