Lenses & Refraction
Why light bends & Snell's Law

Traditional: 13-01

Themed: 04-01

Why light bends

- Refraction is the bending of light
- Diffraction: Spreading out of light (why **distant** shadows aren't crisp)
- Light bends when two things take place
  - Light ray changes speed (going from one medium to another)
  - Light ray strikes new medium at an angle
- We'll take a look at WHY it changes speed and model why the light bends because of it

Why light changes speed

- The speed of light in a vacuum is “c”
- When light interacts with a material, like water, glass, even air, it takes time to pass through each atom it encounters
- It’s like a series of stoplights: go fast, wait, go fast, wait….
- The average speed of light in the medium is slowed down by these “stoplights”….Hewitt explained it below:

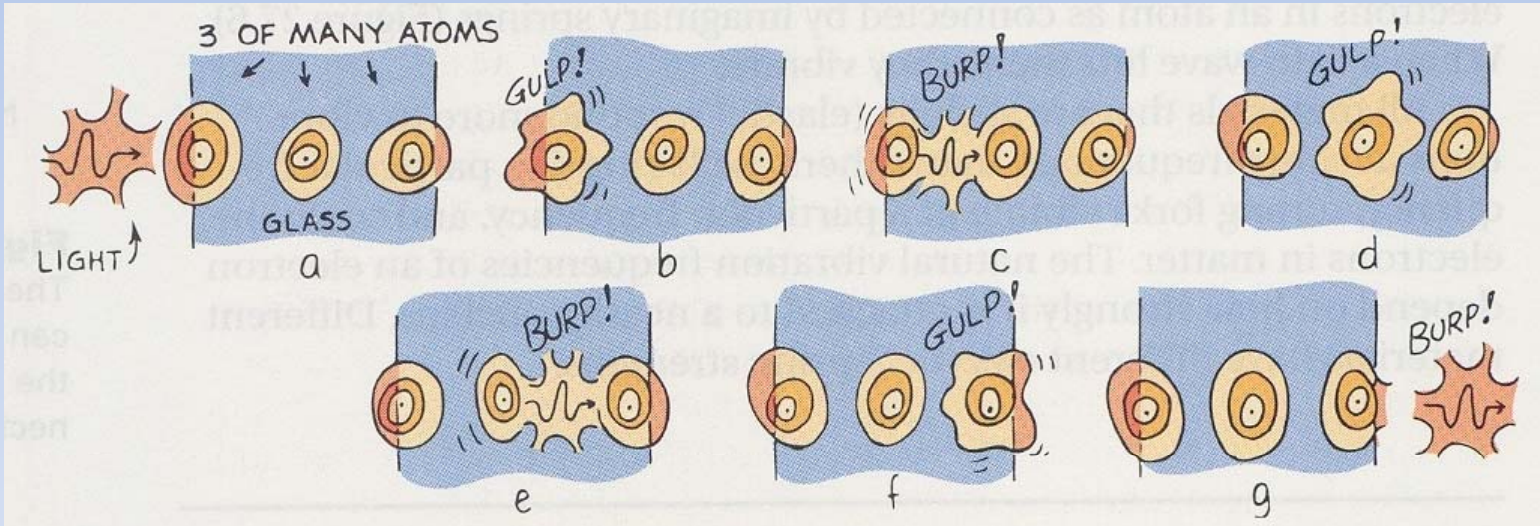
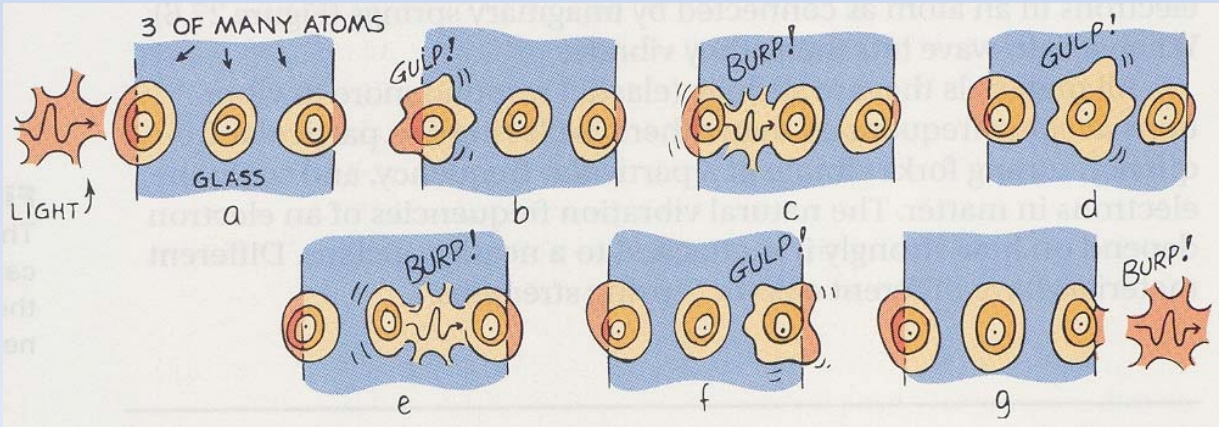


Figure 27.7 ▲
A light wave incident upon a pane of glass sets up vibrations in the atoms that produce a chain of absorptions and reemissions that pass the light energy through the material and out the other side. Because of the time delay between absorptions and reemissions, the average speed of light in glass is less than *c*.

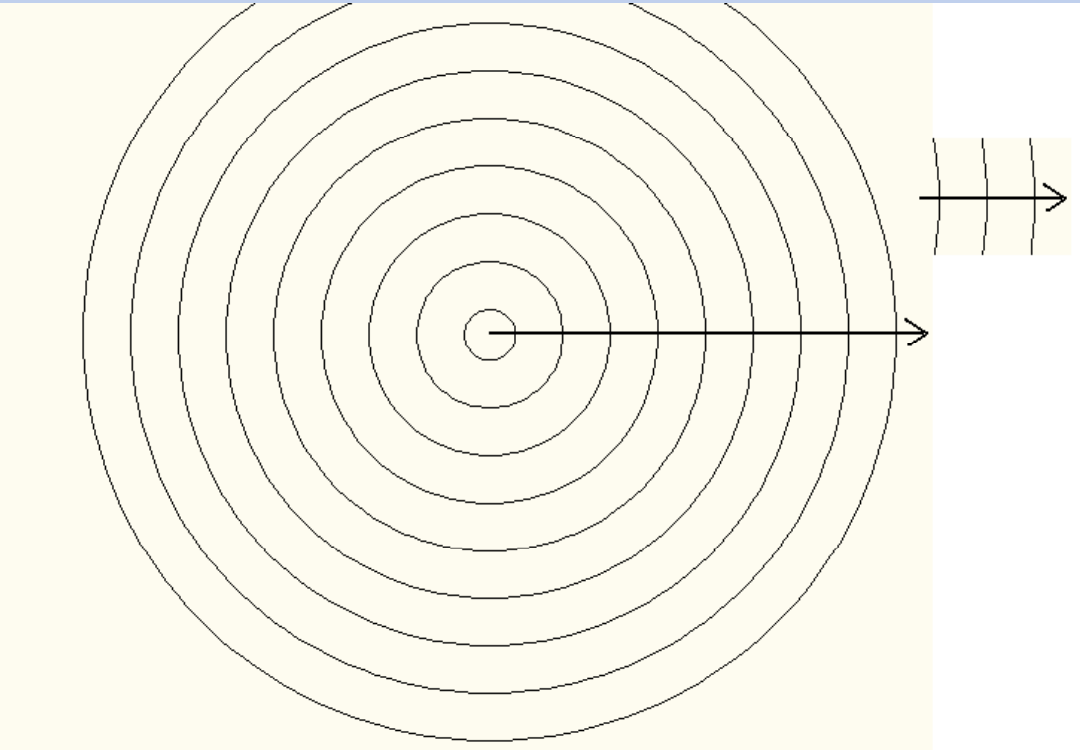
Dealing with the changing speed of light

- Different materials slow down light by different amount
- Diamond slows light down the most (60%), air slows it down a fraction of a percent
- Different transparent materials classified by how much they slow light down – Index of refraction (“n”)
- $n = c/v$, $c = 3 \times 10^8$ m/s, v is the speed of light in the transparent material of interest
- n for water is 1.33, for air 1.00, for vacuum it’s 1.00



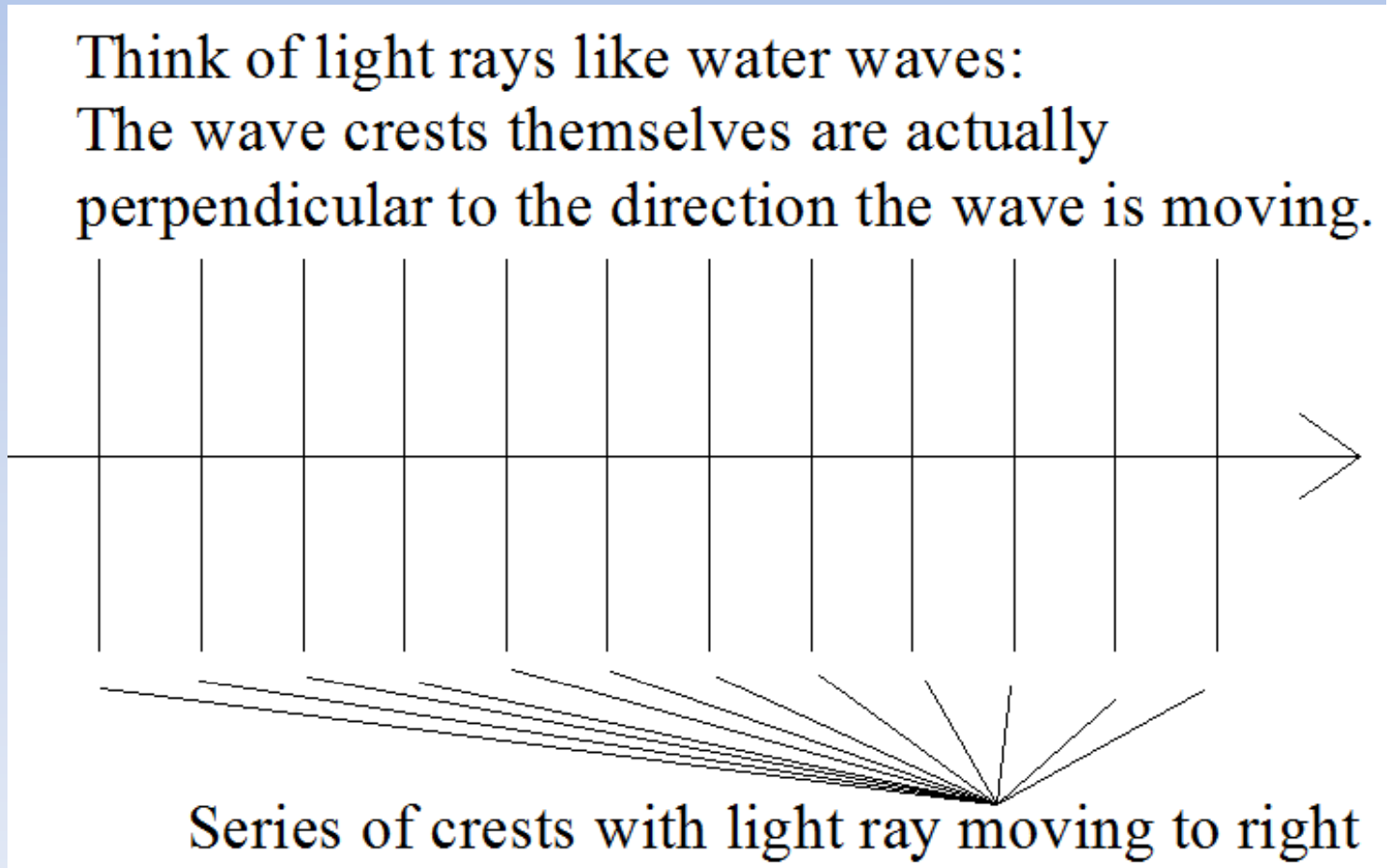
Why light bends – light rays/wave fronts

- Light behaves like a wave and spreads out in all directions
- Unless you're extremely close to the source, wave fronts don't seem curved, but flat



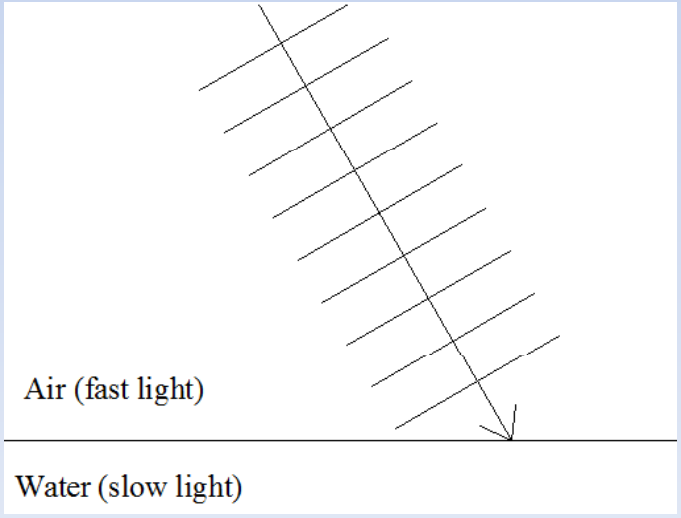
Why light bends – light rays/wave fronts

- Notice the light ray moves in the same direction as its wave fronts move



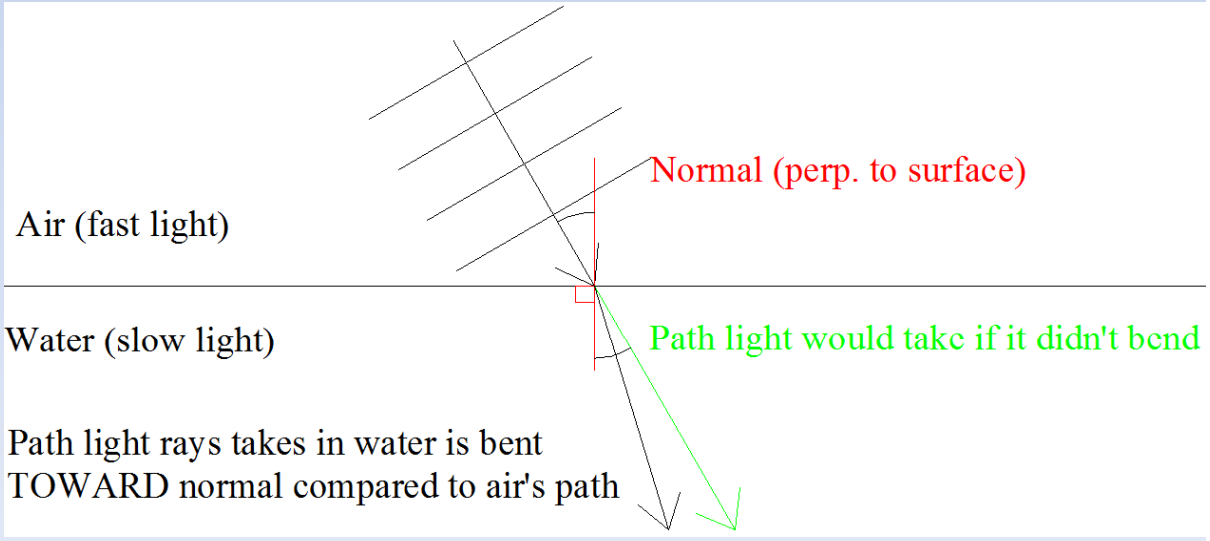
How/why light bends when slowing down

- When the light ray enters a more optically dense medium it slows down
- If the light ray strikes at an angle, the wave front won't slow down uniformly
- Notice the right end slows down first
- Just like if your car's right tire slowed while the left tire kept going, the ray takes a right turn….see?



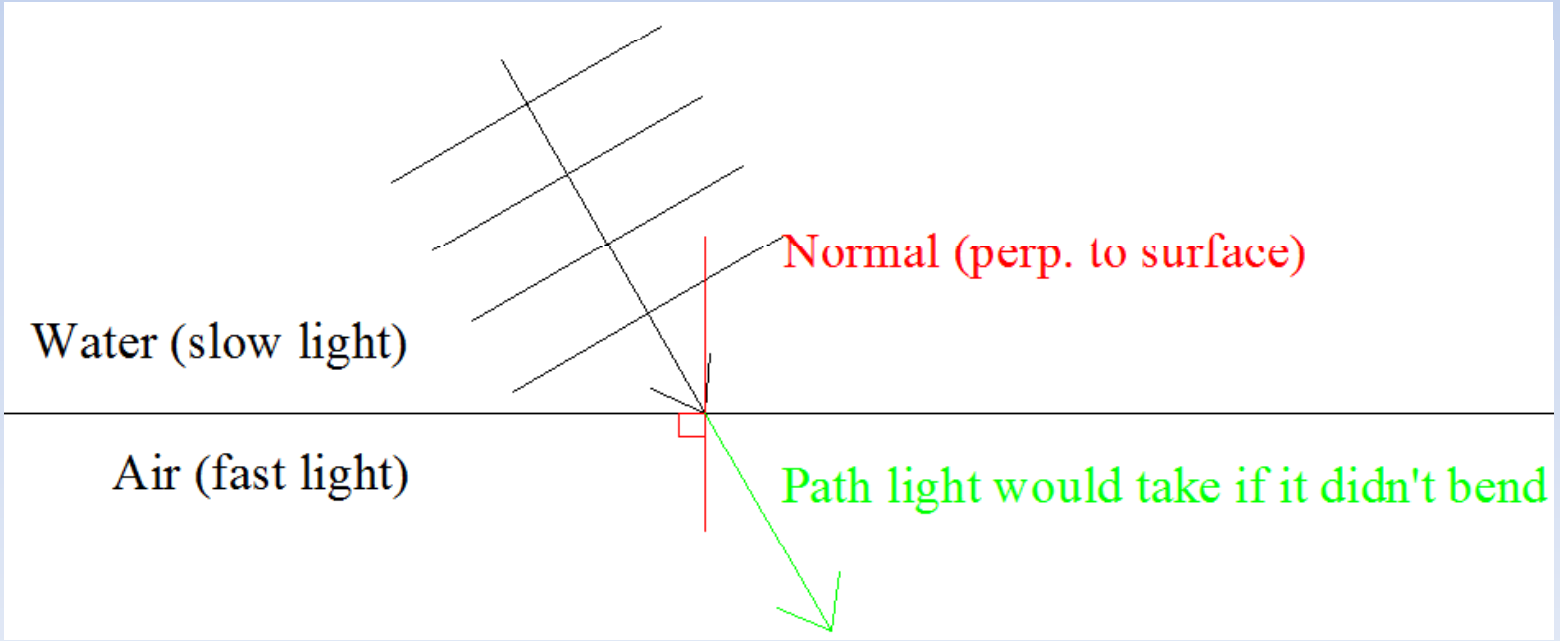
How/why light bends when slowing down

- Do you see the incident angle? Refracted angle? Notice they're measured relative to normal?
- The refracted angle is going to be less than the incident angle
- We say that light "bends toward the normal" when slowing down
- Look for yourself, do you see what "toward" means?



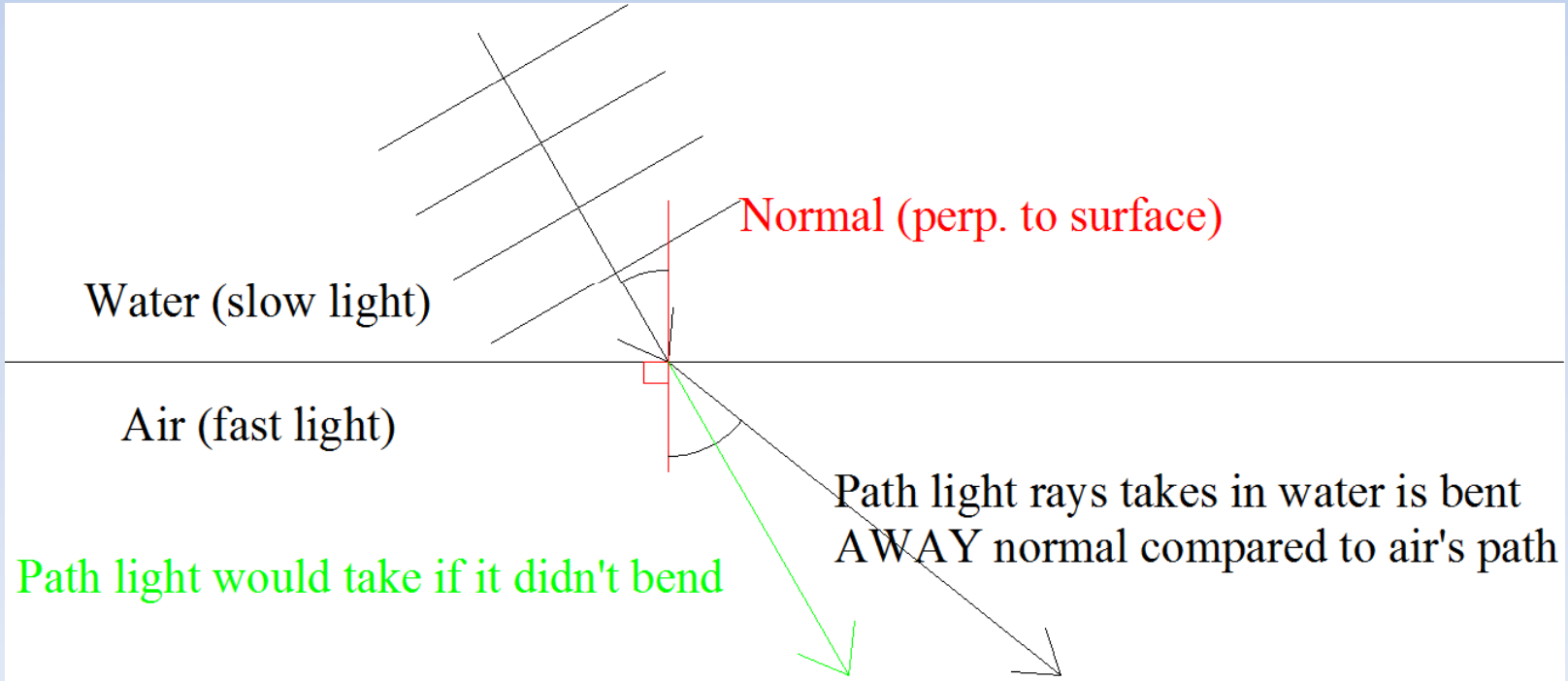
How/why light bends when speeding up

- When the light ray speeds up, which "tire" will speed up first: The left or right?
- Will that make it take a right or left turn?
- Which way will the light ray bend: toward or away from the normal?



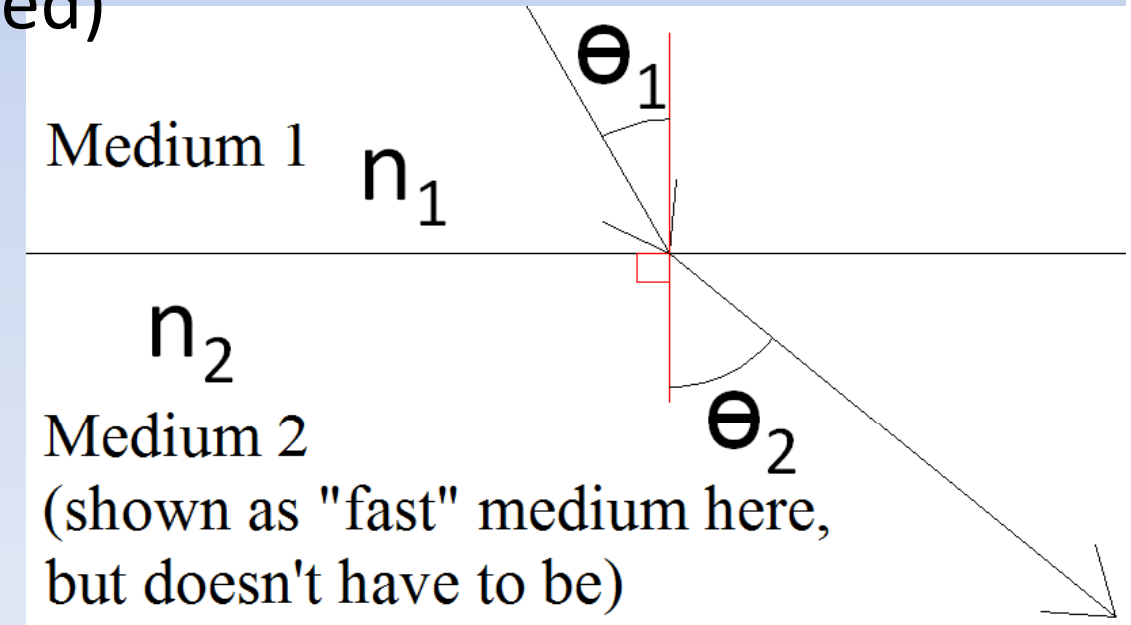
How/why light bends when speeding up

- Upon entering a less optically dense medium (speeding up), light bends away from normal
- Can you pick out the incident and refracted angles shown below? Do you see for yourself the refracted angle is bigger?



Snell's law

- Obviously since light bends in refraction, angle of incidence is NOT equal to angle of refraction
- Snell's law relates the incident and refracted angles with how much the speed of light is in each medium (index of refraction):
- $n_1 \sin \theta_1 = n_2 \sin \theta_2$
- n is the index of refraction; θ is the angle (incident or refracted)



Practice math

- How fast is the speed of light in water? (n=1.33)

2.25 E8 m/s

- Light enters water from air. The incident angle is 55 degrees. What is the refracted angle?

38 degrees

- Light exits water into air at 90 degrees (skims the surface). What is the incident angle going from water into air?

48.7 degrees