Electromagnetic spectrum

- All electromagnetic waves travel through vacuum with a speed c (3 X 10^8 m/s)
- For all EM waves, $c=\lambda f$ (true for any type of wave)
- $\lambda = c/f$
- The visible portion of the spectrum forms a tiny portion of the total EM spectrum

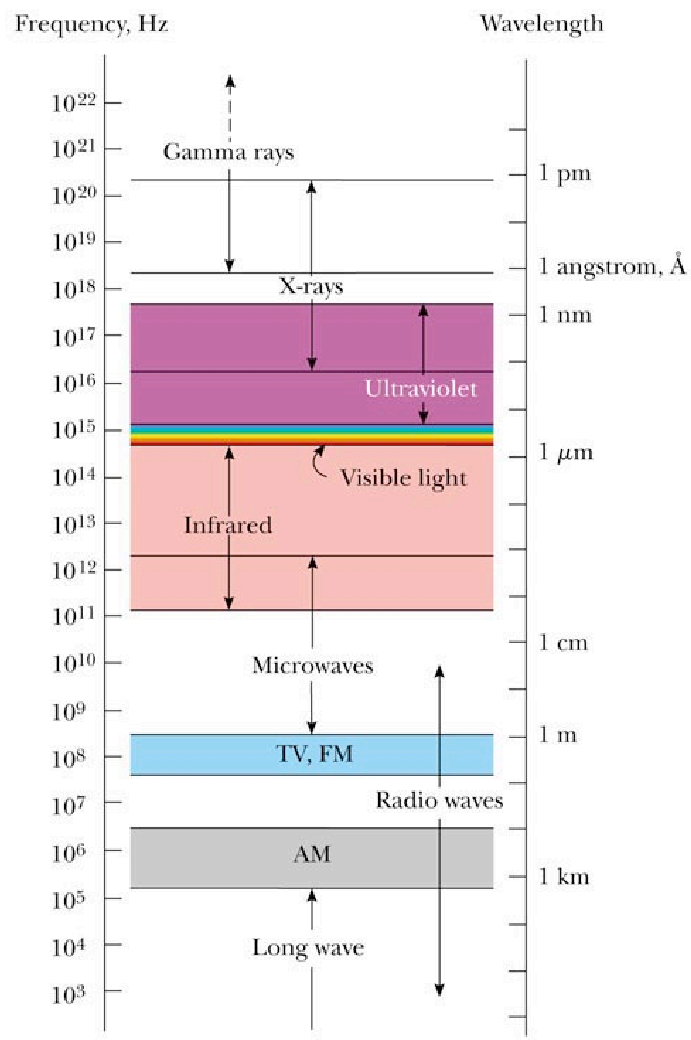
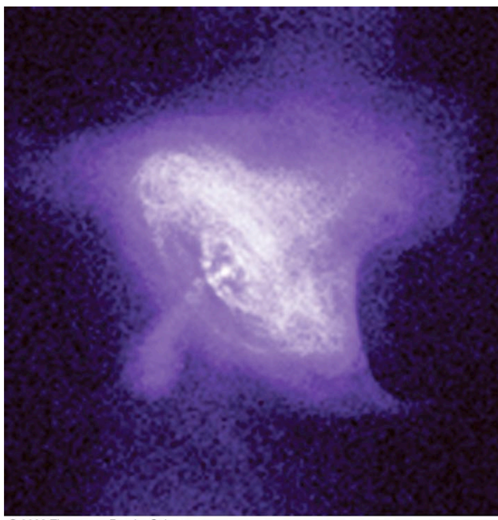


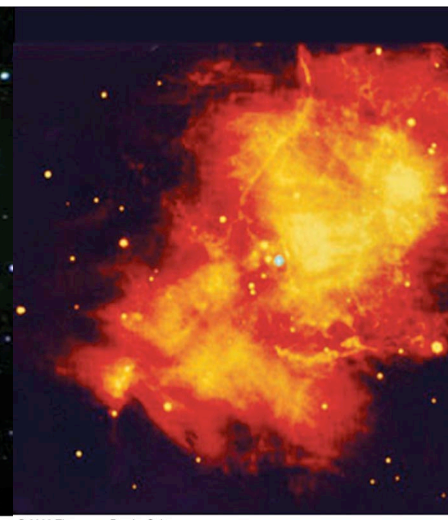
Fig. 21.22, p.675

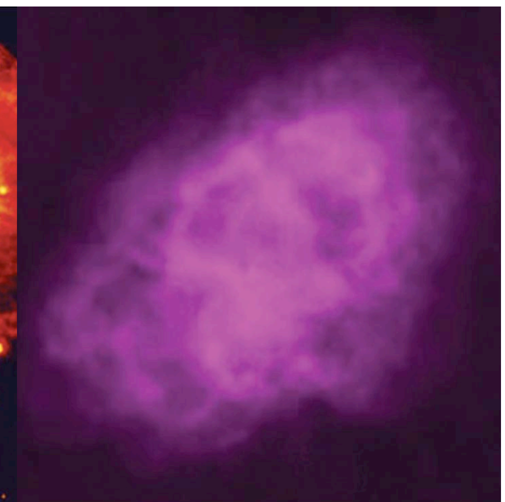
Views of Crab Nebula

increasing energy ($E = hc/\lambda = hf$)

X-ray | optical | infra-red | radio







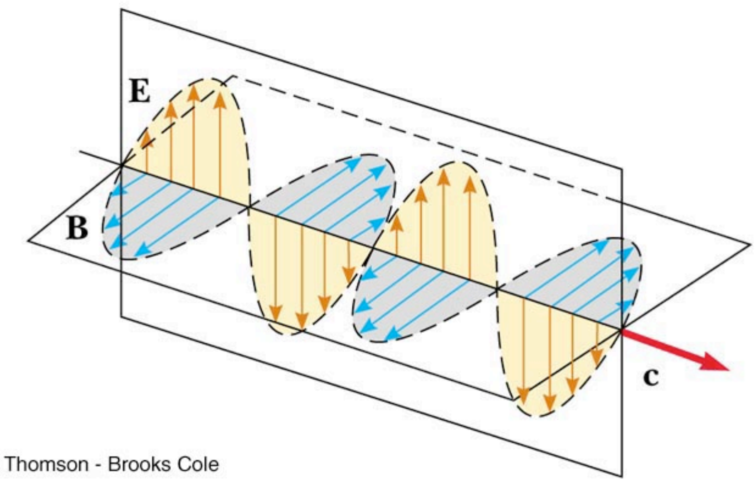
increasing wavelength

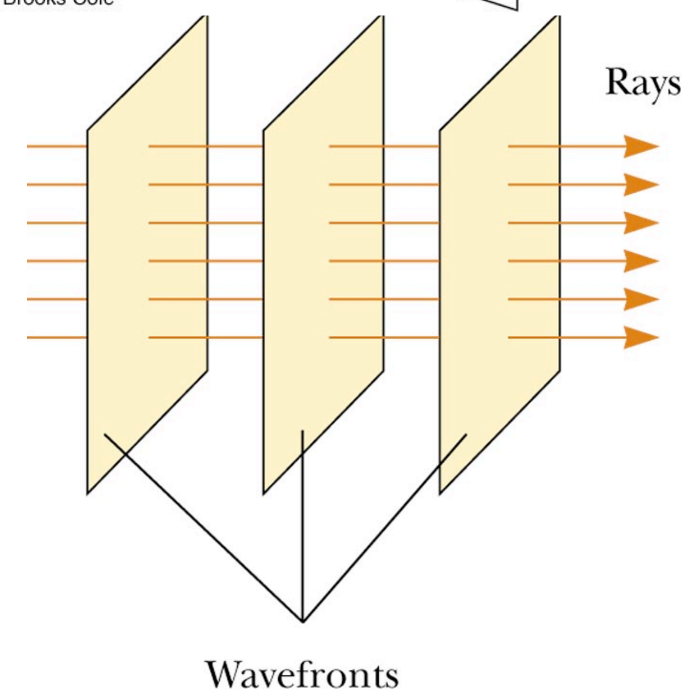
And now for something not so completely different

- Now that we've discovered that light is an electromagnetic wave moving at a speed of 3 X 10^8 m/s, we're ready to begin the study of optics, i.e. the behavior of light
- First, there's the question of the nature of light
  - Is light a stream of particles, or is it a wave?
- Some people (Isaac Newton, for example) were fond of the particle theory of light
- Others, such as Christian Huygens thought that light had to be a wave (and we saw how Maxwell explained light as an EM wave)
- Who's right? Both. Light can behave both as a wave and as a stream of particles depending on what phenomenon you're looking at.
  - It's our problem that we insist on trying to classify it as one thing or another.
- In fact, we can divide optics into two branches
  - geometric optics: stream of particles idea works just fine
  - physical optics: definite wave-like properties, stream of particles concept doesn't work at all

Let's start with geometric optics (it's easier)

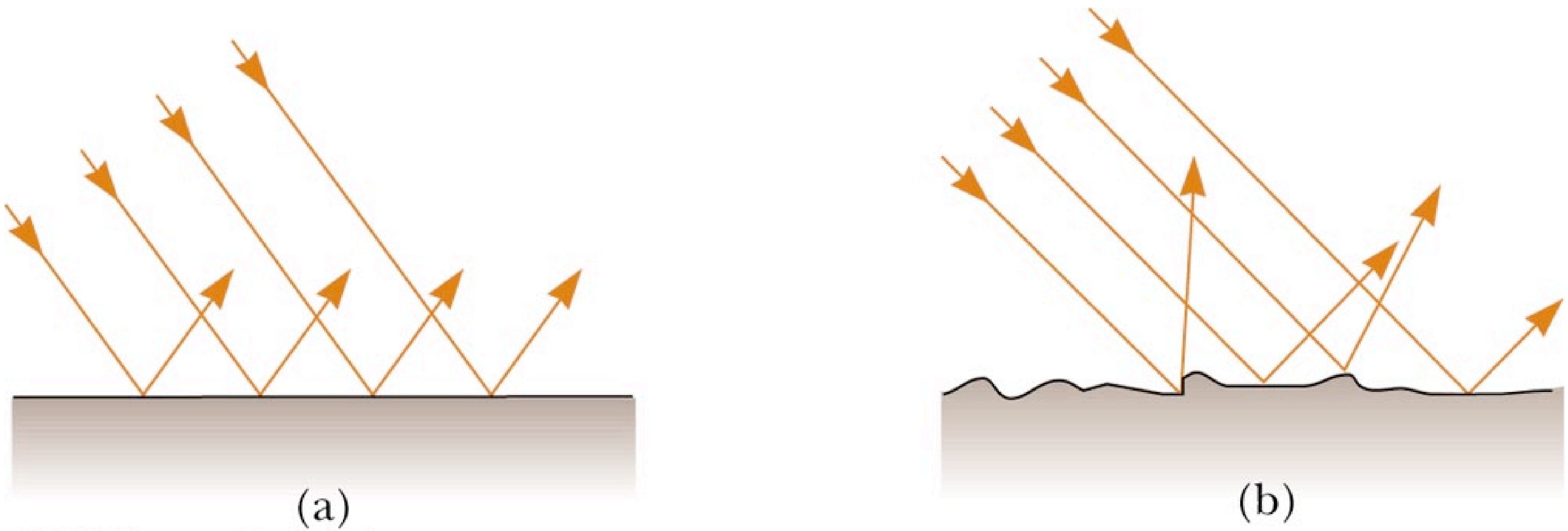
- Light travels in a straight line (as long as it's travelling through a homogenous medium)
- I can represent a light wave by
  - (1) drawing the wavefronts (surfaces where the electric field has the same phase)
  - (2) drawing ray(s) perpendicular to the wavefronts that indicate the direction that the wave is travelling





Reflection

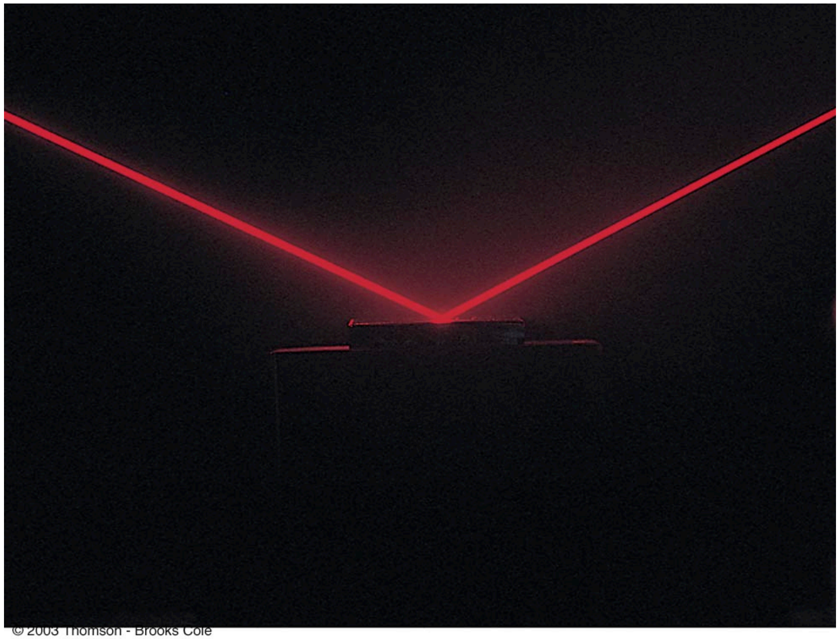
When a light ray hits a surface of a medium with a different index of refraction, part of the light will be reflected.

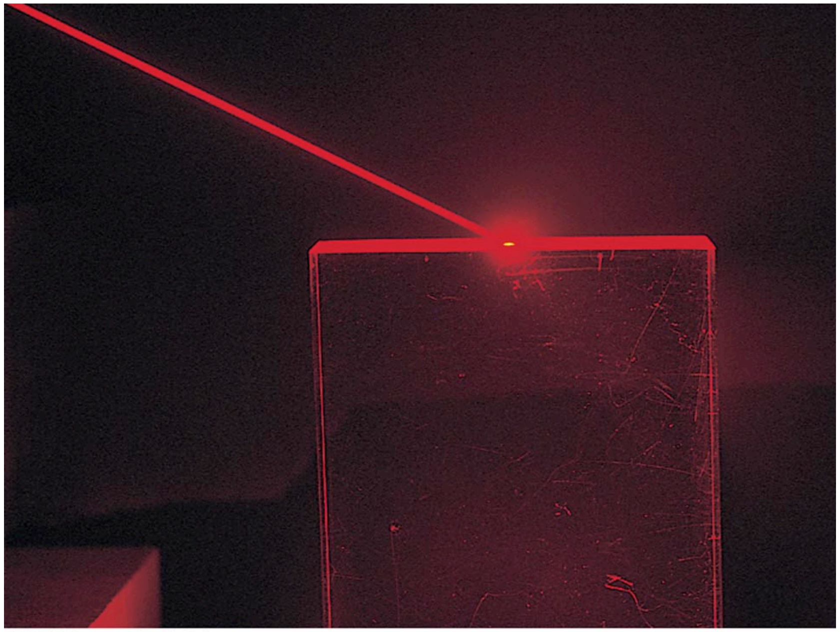


Specular reflection, from a smooth surface

Diffuse reflection, from an irregular surface

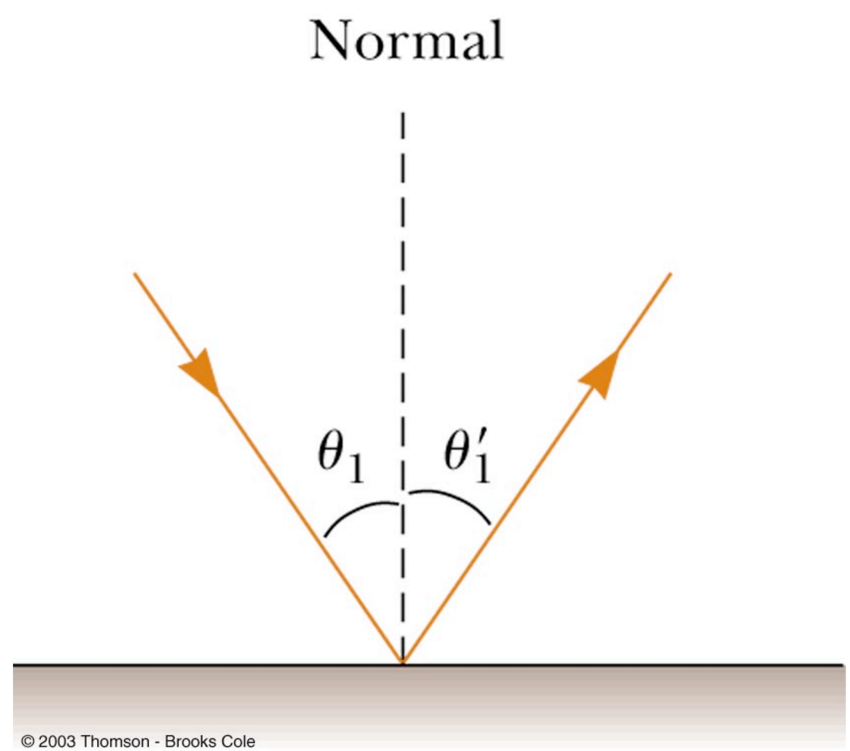
Specular and diffuse reflection





Reflection

- Draw a line normal (perpendicular) to the surface
- Consider the angle between the incident ray and the reflected ray
- $\theta_1 = \theta_1'$
- The angle of reflection is equal to the angle of incidence
  - just what you'd expect if light were a stream of particles



True, no matter what angle of surface

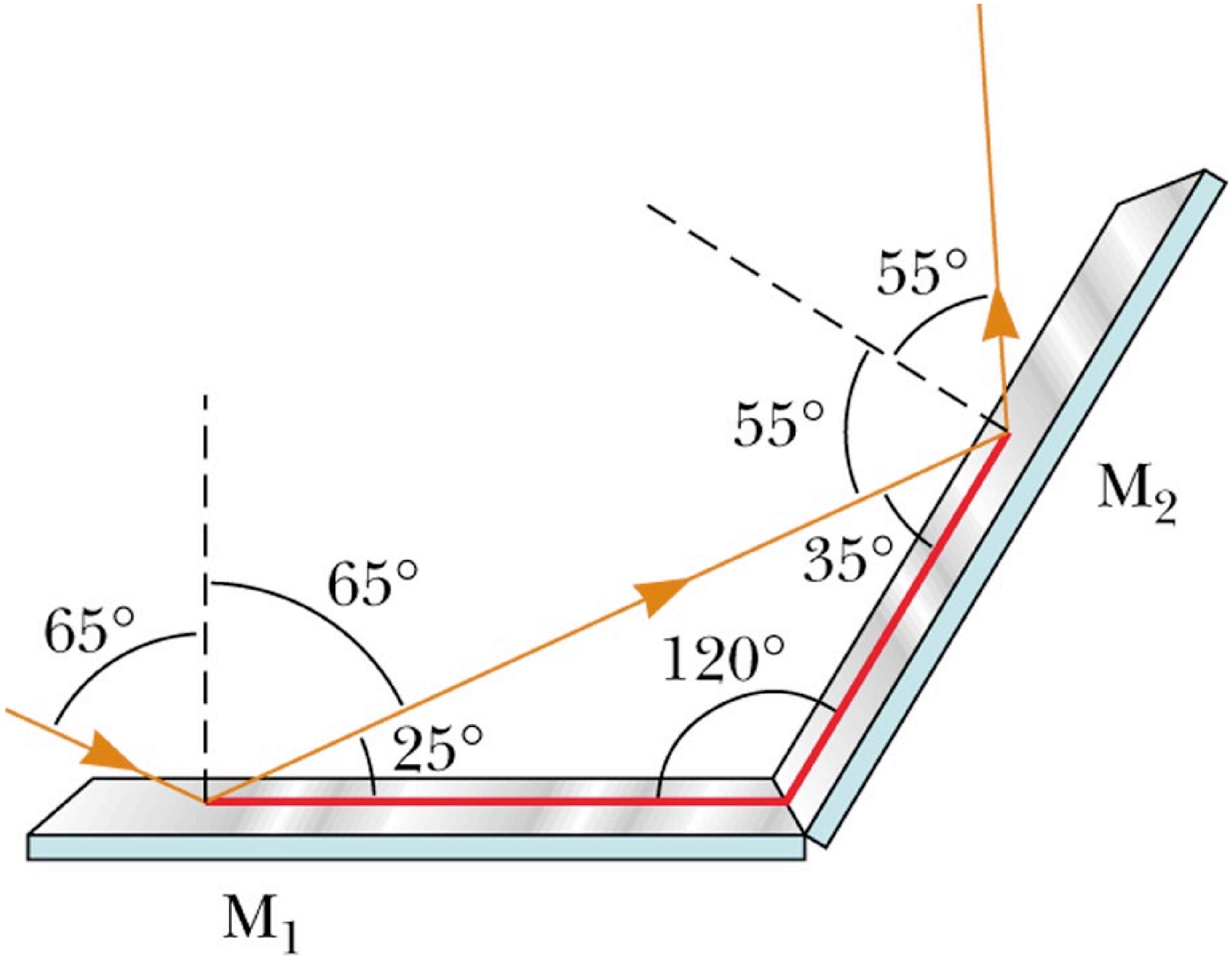


Fig. 22.5, p.690

Reflection and refraction

- Not all of the light is reflected at the surface
- Some of it is transmitted (refracted) into the 2nd medium
- Note that the refracted angle is not equal to the incident angle
- In fact, the angles are related to the velocities of light in the two media
    - $\sin \theta_1/\sin \theta_2 = v_2/v_1$

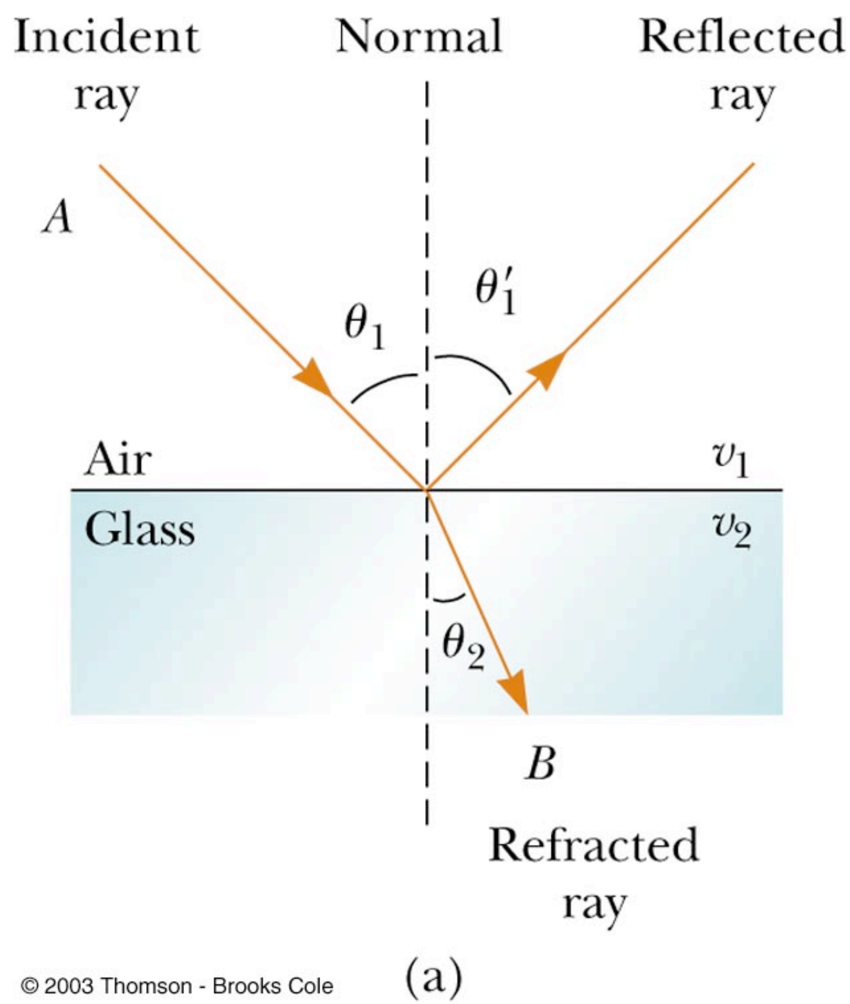
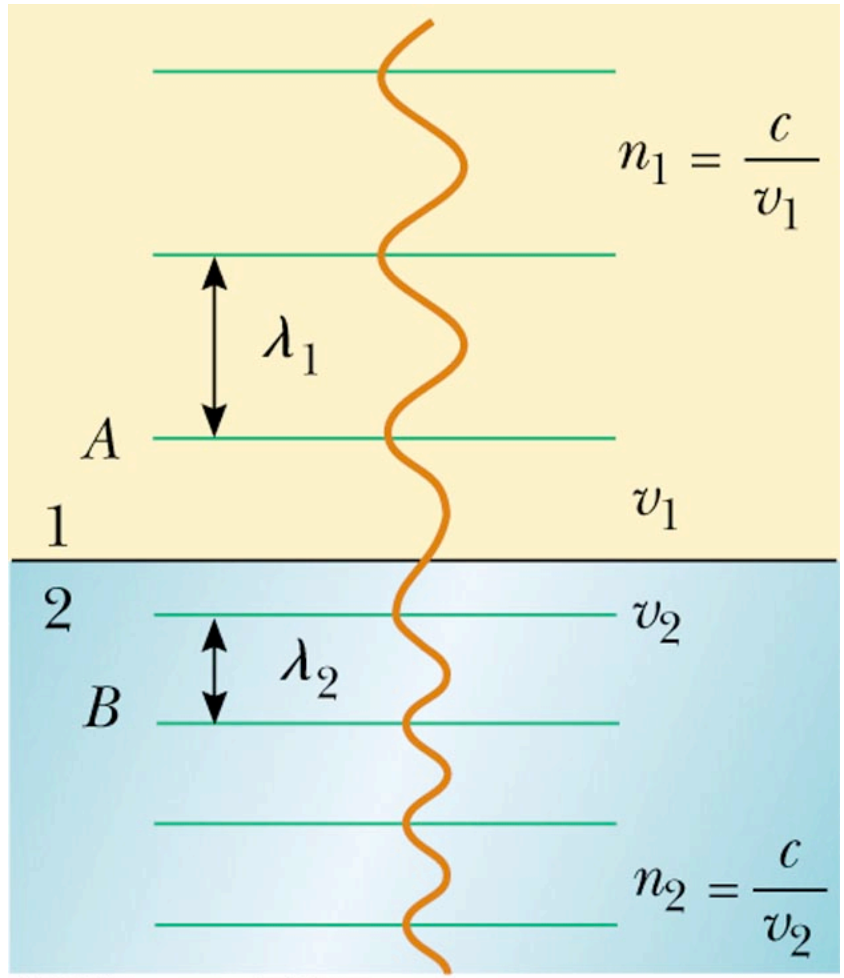


Fig. 22.6a, p.691

Snell's law

- Light travels at a speed c in vacuum, but slower in other media
- Define n = c/v, where v is the speed that light travels in a given medium (glass, water, etc)
- So, as light travels from air to glass, its speed changes; its frequency does not, so its wavelength must
  - $\lambda_1 = \lambda_o/n$



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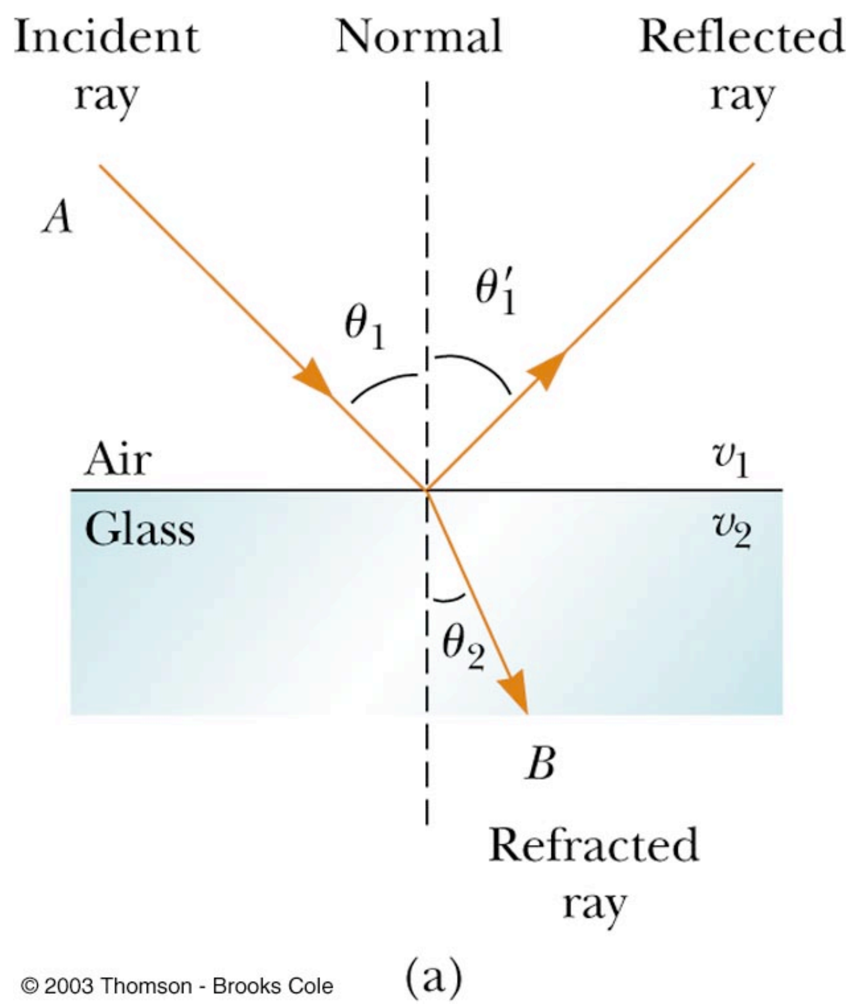
- So, as light travels from air to glass, its speed changes; its frequency does not, so its wavelength must
  - $\lambda_1 = \lambda_o/n$
- I can re-write the proportionality that we had before
  - $\sin\theta_1/\sin\theta_2 = v_2/v_1$
- as
  - $\sin\theta_1/\sin\theta_2 = n_2/n_1$
  - $n_1 \sin\theta_1 = n_2 \sin\theta_2$



Snell's law

Reflection and refraction

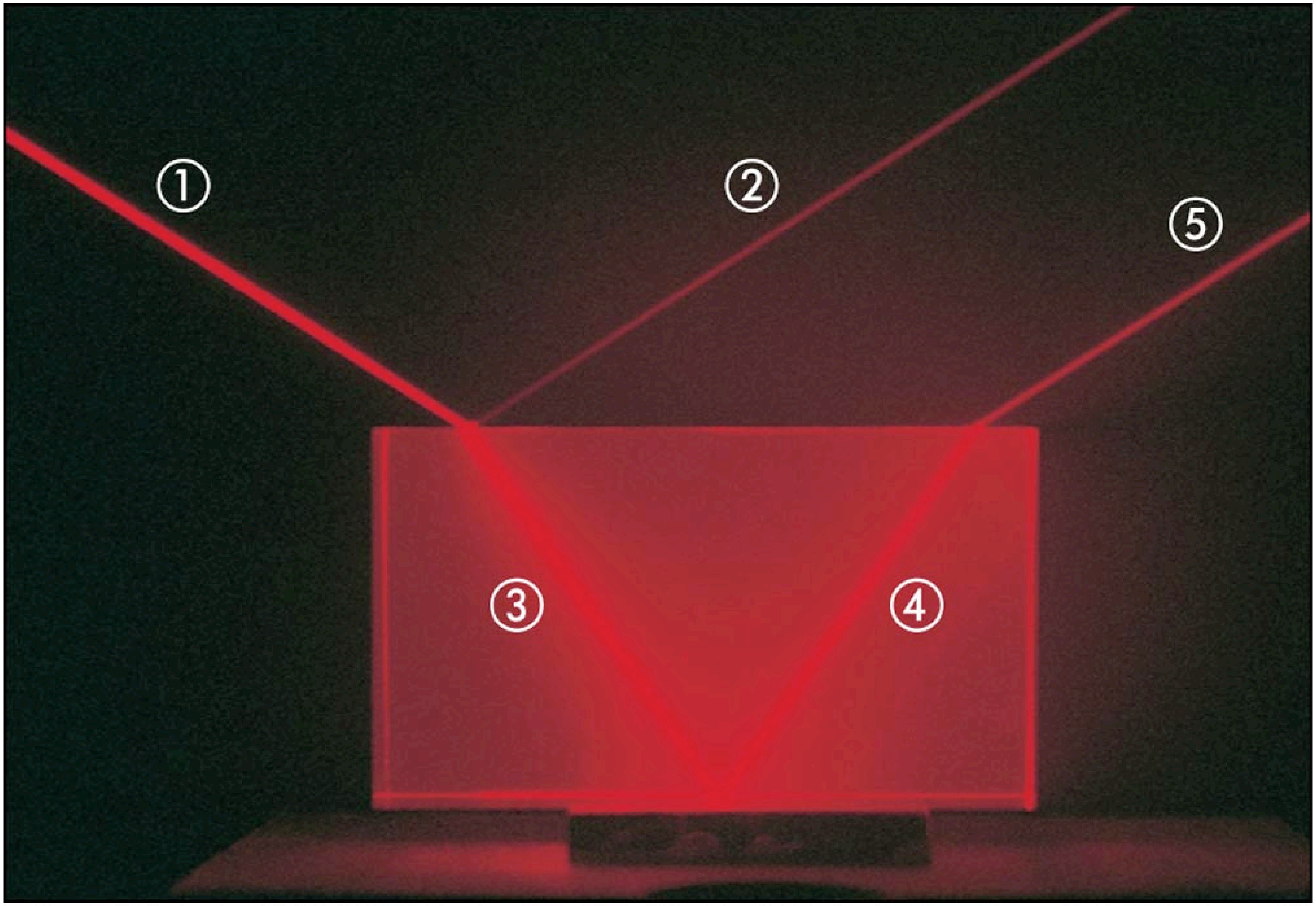
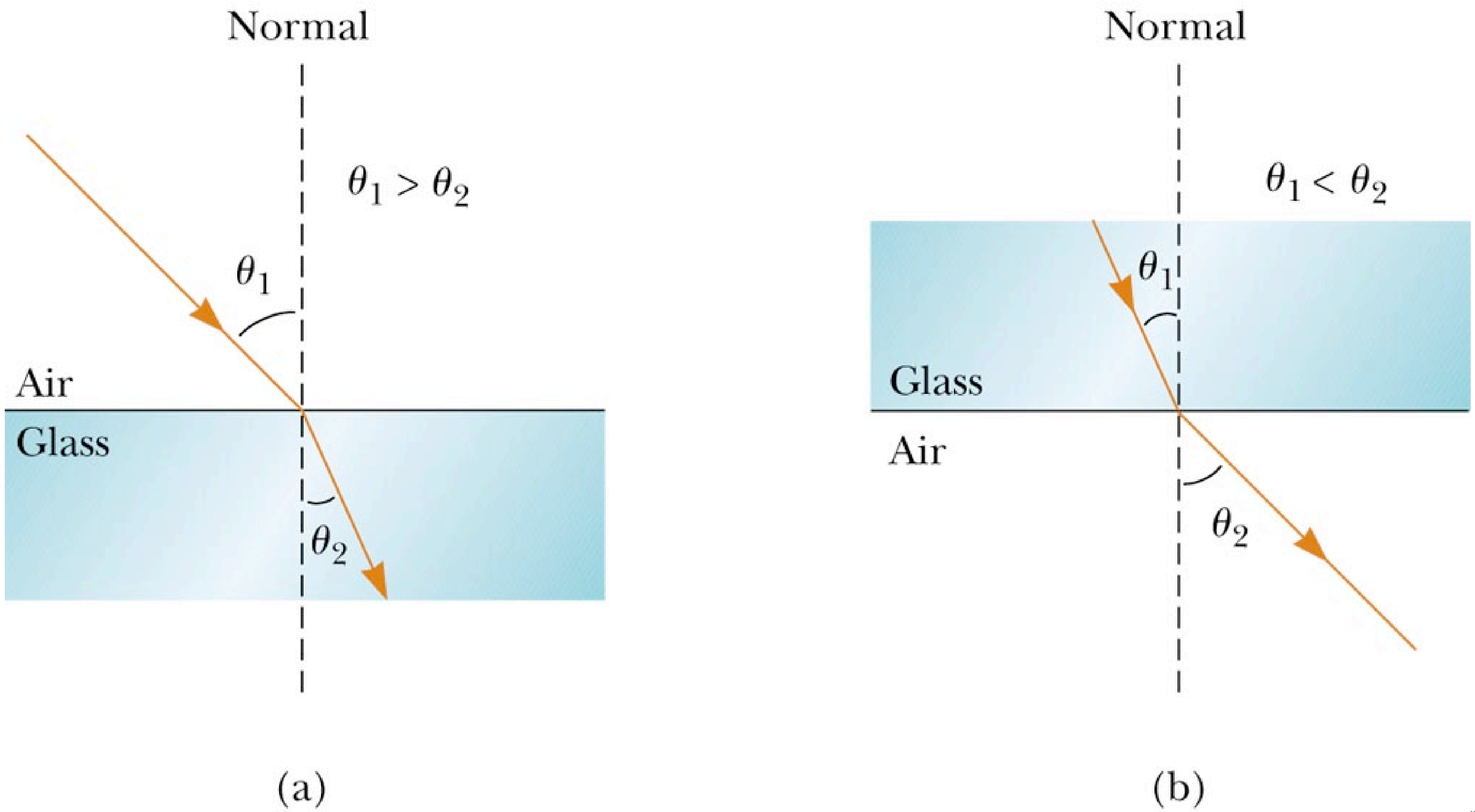


Fig. 22.6b, p.691

Refraction

…bend in

…bend out



p.691

Something for spring break

- When light goes from air to glass, it bends towards the normal
  - because it travels more slowly in glass than in air
- Why do waves in Florida (or anywhere else for that matter) come in parallel to the shore?
  - because of refraction

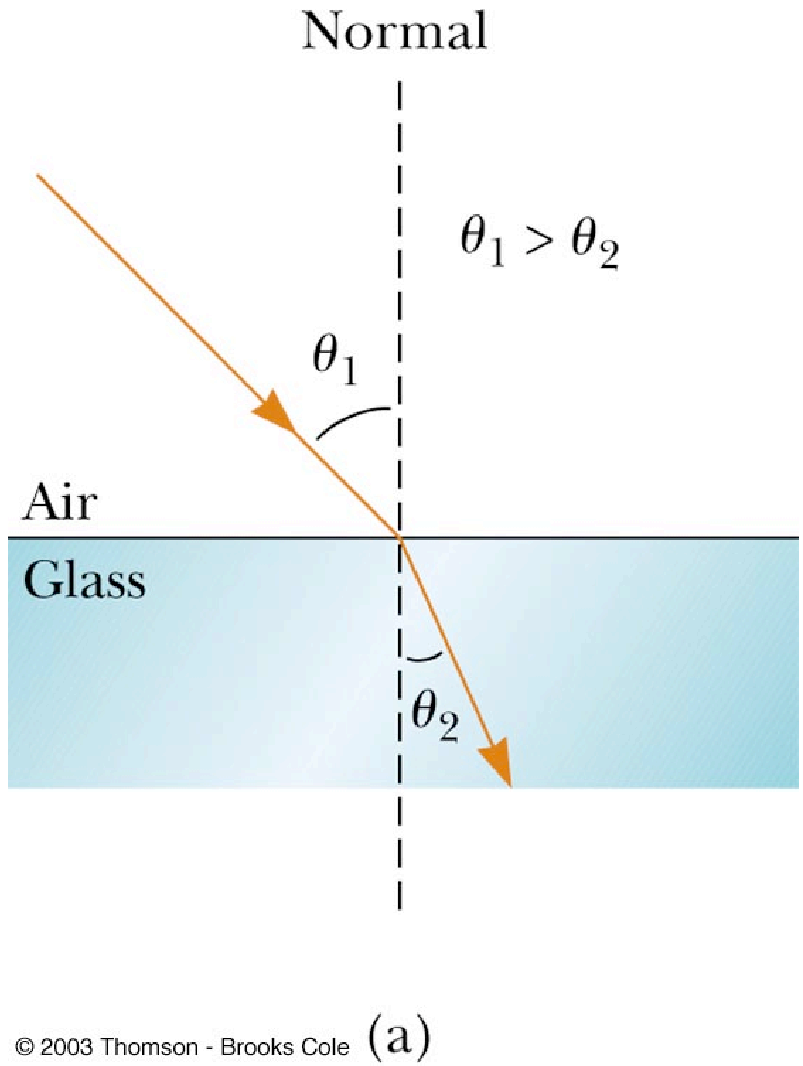
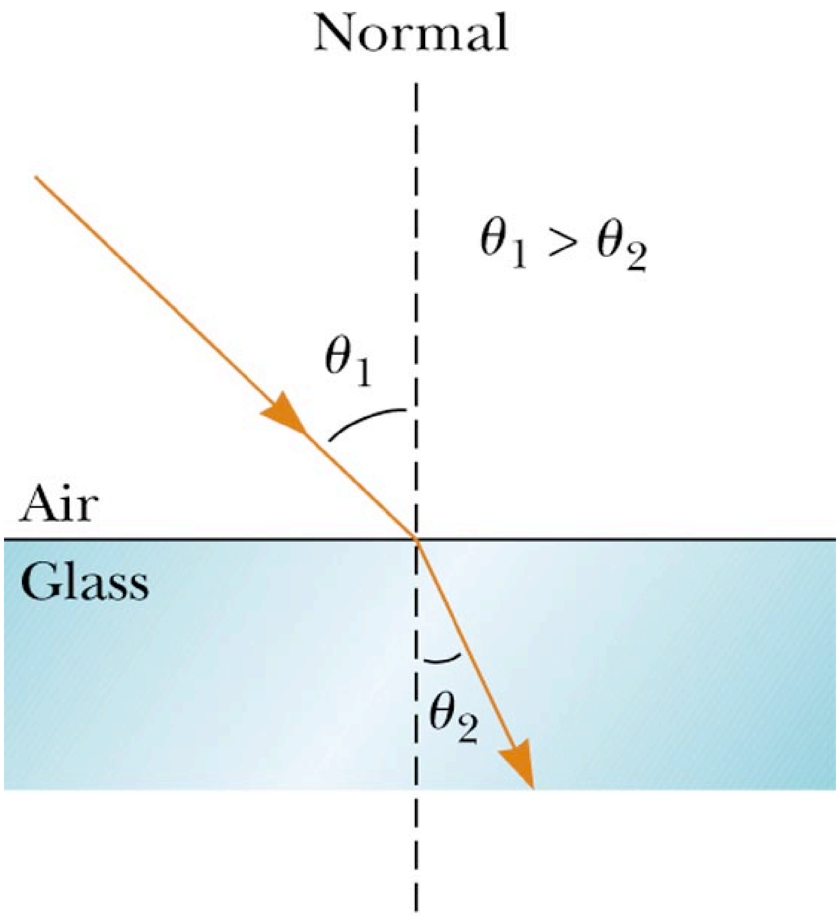


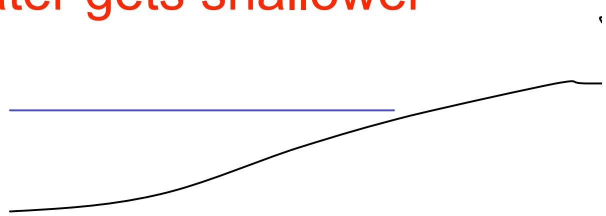
Fig. 22.7a, p.691

Something for spring break



 (a)

- What happens near the shoreline?
  - The water gets shallower



- The velocity of a wave is proportional to the depth of the water
  - v α depth
- So as the wave approaches the shore, v decreases (like n increasing) and the wave bends towards the shore, no matter what its original direction