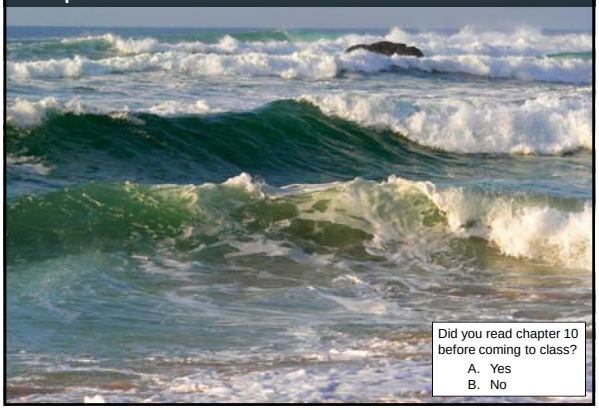
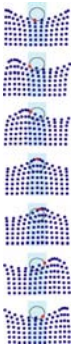
Chapter 10: Waves



Wave concepts

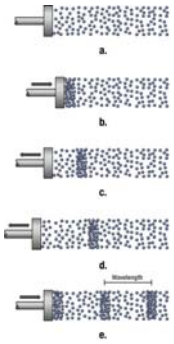
- Waves are a "disturbance" that travels (usually through a medium).
- They carry energy away from a source.
- The disturbance and associated energy move along, the material does not.

Types of Waves: Surface Waves



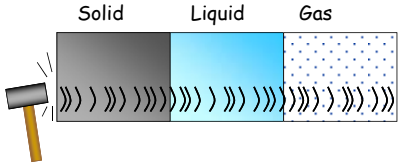
Types of Waves: Compression Waves

- Come from compressing atoms (or molecules) close together and then pulling them apart
- The oscillations are parallel/antiparallel to the direction of travel



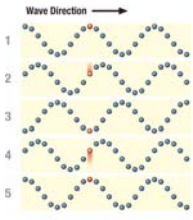
Types of Waves: Compression Waves

- Compression waves can travel through solids and fluids



Types of Waves: Transverse waves

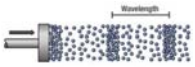
- The oscillations in a transverse wave are perpendicular to the direction of travel
- Mechanical transverse waves (shear waves) require rigid bonds, so they only travel through solids



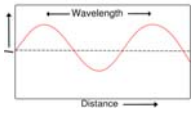
Wave Properties: Wavelength

- Wavelength is the distance between two similar parts of the wave

Compression Wave

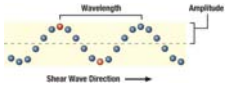


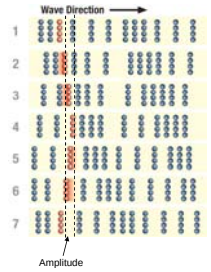
Transverse Wave



Wave Properties: Amplitude

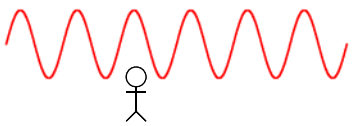
- Amplitude is the amount of displacement from the rest position
- A measure of the wave energy
- Related to loudness (sound) or brightness (light)





Wave Properties: Frequency

- Frequency is the number of wave crests which pass a point per second.
  - sound: pitch, 20 to 20,000 Hz
  - light: color, 10^{15} Hz
  - earthquake: 10 to 1,000 Hz
  - radio: kHz (AM) to MHz (FM)



Wave Properties: Speed

- Speed = frequency × wavelength
- Speed usually depends almost exclusively on the medium.
- However, frequency/wavelength can play an extremely minor role in special cases.
  - This is how we get rainbows

Wave Properties: Speed

- The speed of sound is 340 m/s (about 1/5 mile/sec)
- The speed of light is 3×10^8 m/s

You hear the thunder five seconds after seeing the lightning.

How far away is the lightening?

If you double the frequency of a wave, the speed will

a) Double
b) Be cut in half
c) Remain essentially unchanged

Speed = frequency × wavelength.

Sound

- A compression wave in a fluid (air, water, etc).
- Long wavelength, low frequency → low pitch
- Short wavelength, high frequency → high pitch

"Talking"
Outboard
Propeller whine


Visible Light

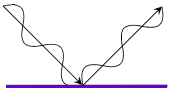
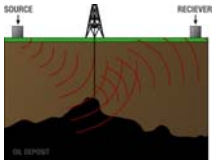
- A transverse wave (but what is waving?)
- Long wavelength, low frequency → red light
- Short wavelength, high frequency → blue light
- Speed is the same for all colors (in our model)

Wave Behavior

- All waves will
  - Reflect
  - Refract
  - Diffract
  - Interfere

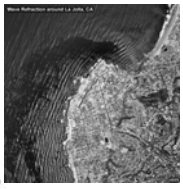
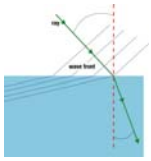
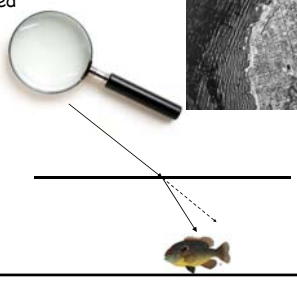
Reflection



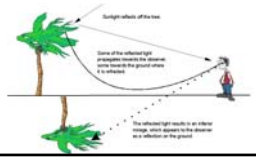



Refraction

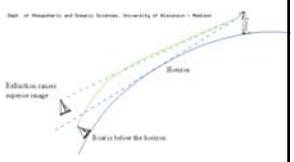
The bending of a wave as it enters a medium with different properties so that the wave speed changes.

Bonus Material: Mirages are due to refraction


Bonus Material:
Mirages are due to refraction

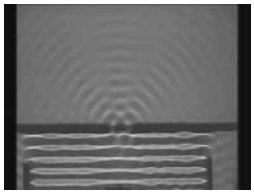



Diffraction

- The wave fans out when it encounters an obstacle or opening.
- The amount of diffraction depends on relationship between wavelength and size of opening:
  - most when wavelength is similar to opening
  - small when wavelength is much smaller than opening.

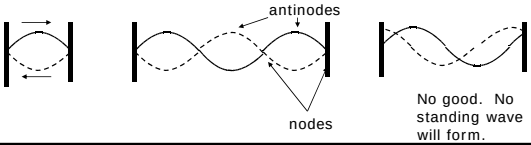
Interference

- When two or more waves meet.
  - constructive interference: two crests add together
  - destructive interference: crest and trough cancel

Standing waves

- Points of the medium that are permanently at rest are called Nodes
- Points of the medium that have maximum oscillation are called Anti-Nodes
- Only certain frequencies produce standing waves in a given system. These are called resonance frequencies.
- The energy of a wave is associated with its frequency.
- We can create one dimensional standing waves using a rope:

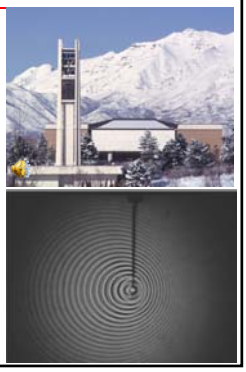


Higher Dimensions

- Standing waves are possible in two dimensions as well

The Doppler Effect

- When the source and the observer are in motion relative to one another, the observed frequency can change.
- If they are moving together, frequency increases
- If they are moving apart, frequency decreases



Bonus material: Shock waves

- If a source is moving faster than the speed of the wave, shock waves form.