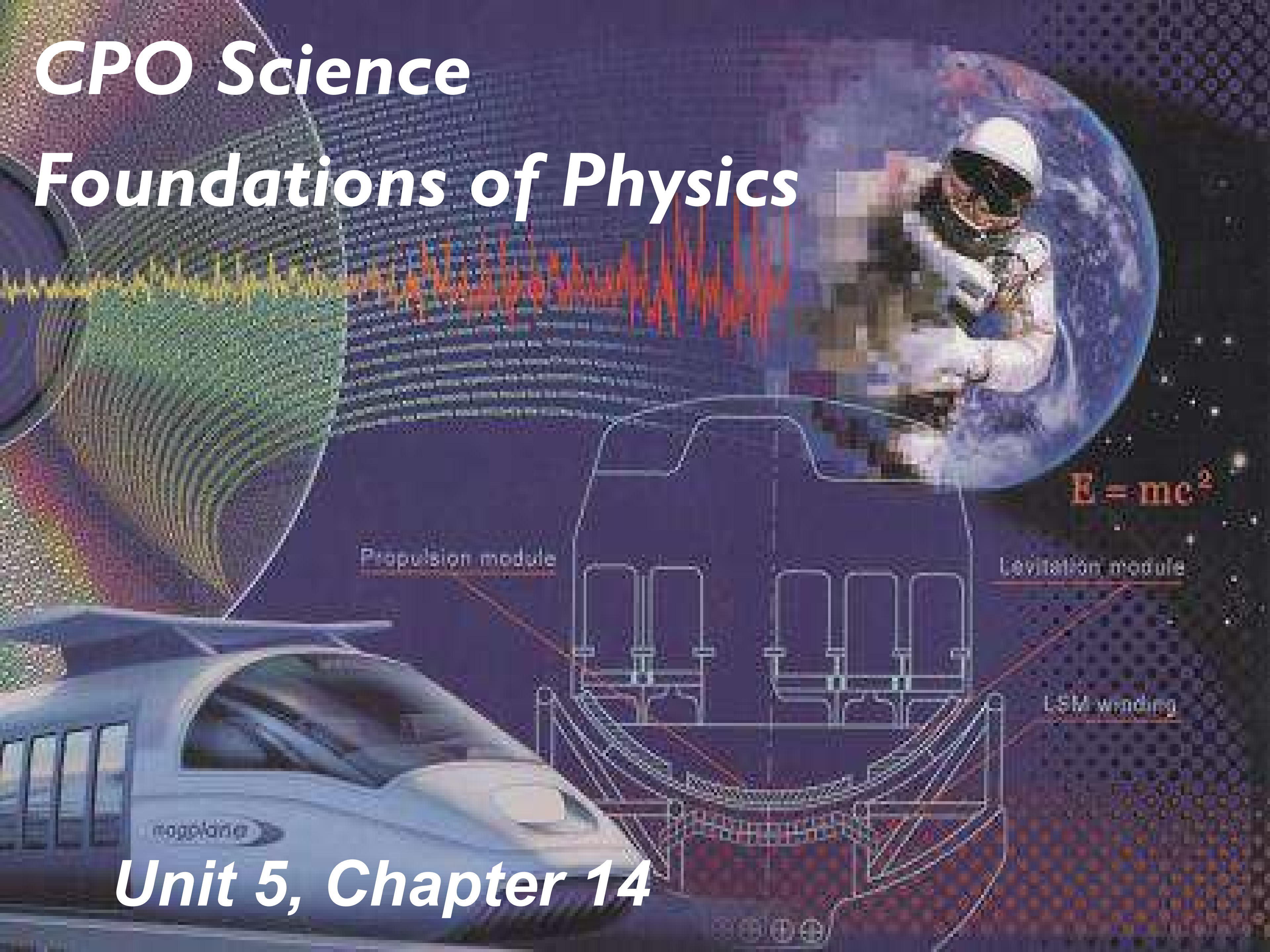
CPO Science
Foundations of Physics



Unit 5, Chapter 14

Unit 5: Waves and Sound

Chapter 14 Waves

- 14.1 Waves and Wave Pulses
- 14.2 Motion and Interaction of Waves
- 14.3 Natural Frequency and Resonance

Chapter 14 Objectives

- Recognize a wave in nature or technology.
- Measure or calculate the wavelength, frequency, amplitude, and speed of a wave.
- Give examples of transverse and longitudinal waves.
- Sketch and describe how to create plane waves and circular waves.
- Give at least one example of reflection, refraction, absorption, interference, and diffraction.
- Describe how boundaries create resonance in waves.
- Describe the relationship between the natural frequency, fundamental mode, and harmonics.

Chapter 14 Vocabulary Terms

wave
propagation
amplitude
frequency
wavelength
hertz (Hz)
wave pulse
transverse wave
longitudinal wave
oscillation
crest
trough
wave front
circular wave
plane wave

continuous
fixed boundary
open boundary
reflection
refraction
absorption
boundary condition
incident wave
reflected wave
refracted wave
standing wave
superposition principle
natural frequency

resonance
mode
node
constructive interference
fundamental
harmonic
boundary interference
destructive interference
diffraction
absorption
antinode

14.1 Waves and Wave Pulses

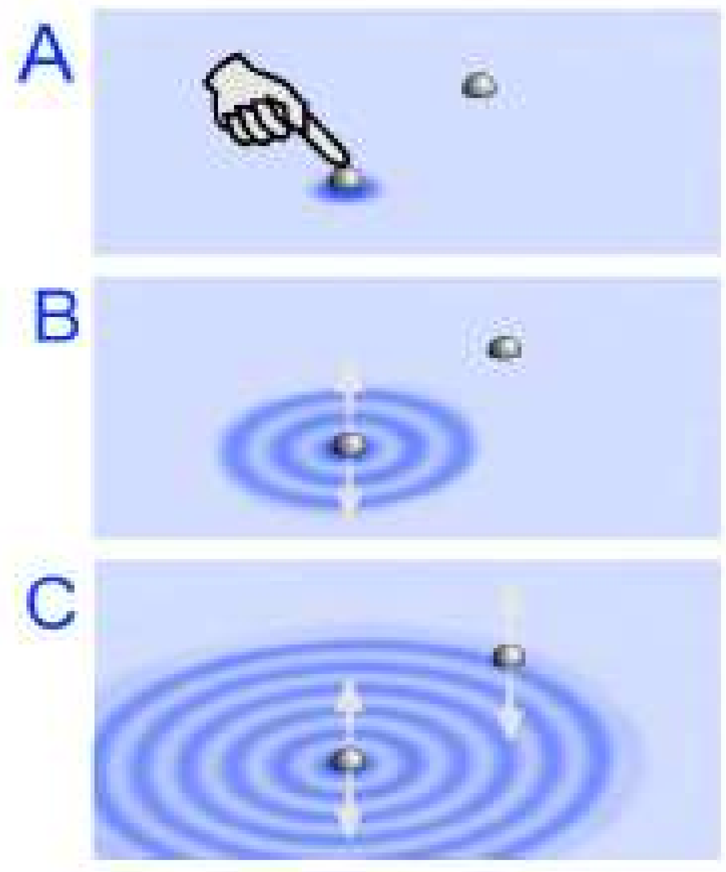
Key Question:

What is the speed of a wave?

***Students read Section 14.1 AFTER Investigation 14.1**

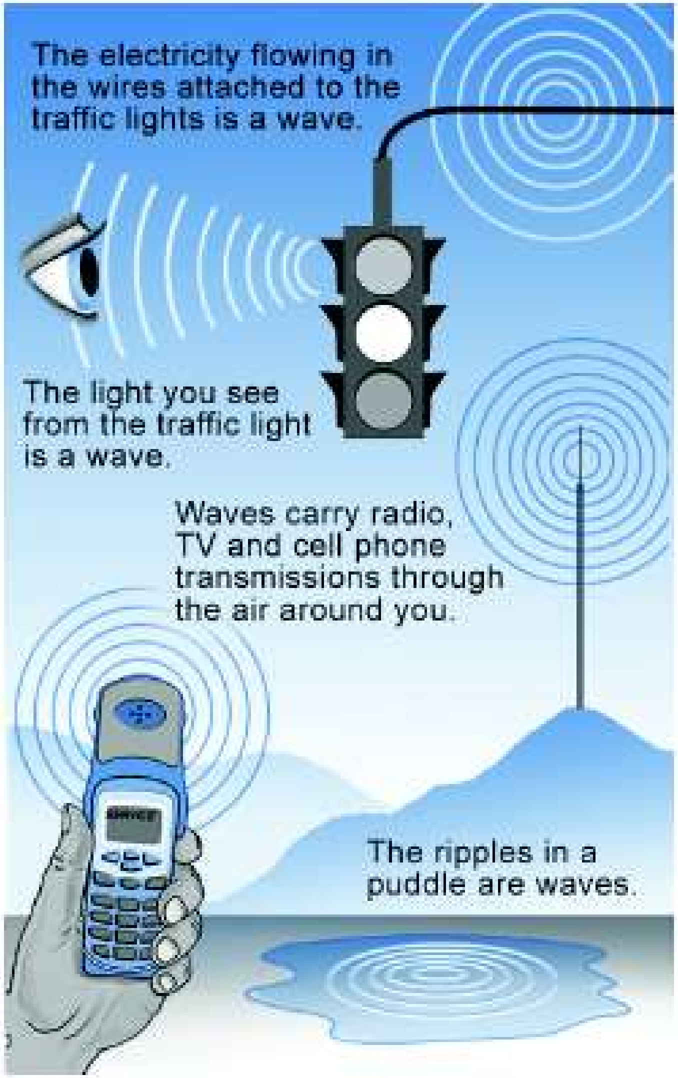
14.1 Waves

- A wave is an oscillation that travels.
- A ball floating on water can oscillate up and down in harmonic motion.
- The surface of the water oscillates in response and the oscillation spreads outward from where it started.



14.1 Why learn about waves?

- **Waves carry useful information and energy.**
- **Waves are all around us:**
  - light from the stoplight
  - ripples in a puddle of
  - electricity flowing in wires
  - radio and television and cell phone transmissions



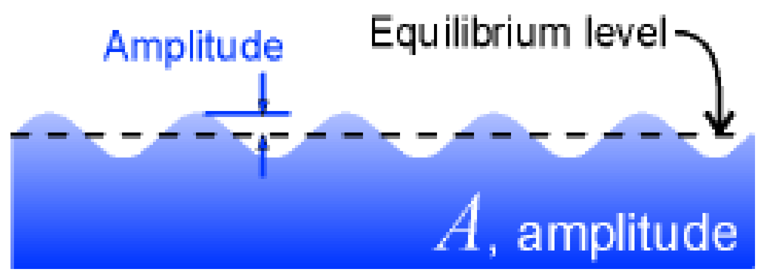
14.1 Recognize waves

- **Anytime you see a vibration that moves...**
- **Anything that makes or responds to sound...**
- **Anything that makes or responds to light ...**
- **Anything that transmits information through the air (or space) without wires...**
  - cell phones, radio, and television.
- **Anything that allows you to "see through" objects...**
  - ultrasound, CAT scans, MRI scans, and X rays

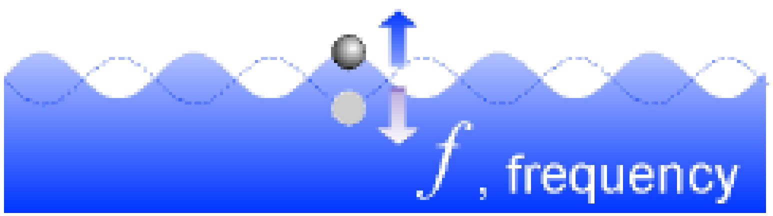
14.1 Characteristics of waves

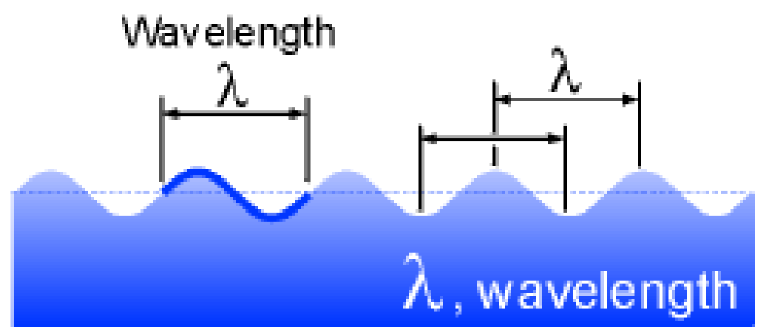
- Waves have cycles, frequency, and amplitude, just like oscillations.

The amplitude of a wave is the maximum movement from equilibrium.



The frequency of a wave tells how often each point oscillates.

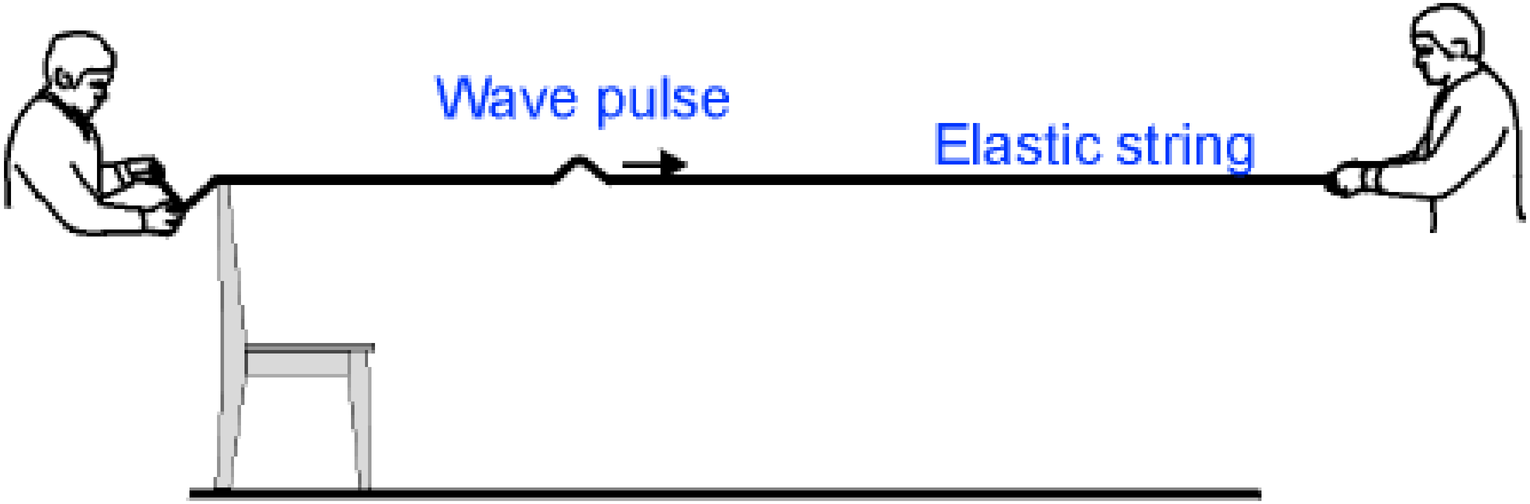




The wavelength of a wave is the length of one complete cycle.

14.1 Wave pulses

A wave **pulse** is a short length of wave, often just a single oscillation.



14.1 Relationship between speed, frequency, and wavelength

- The speed of a wave equals the frequency times the wavelength.

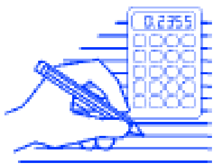
$$v = f\lambda$$

Speed (m/sec) → v

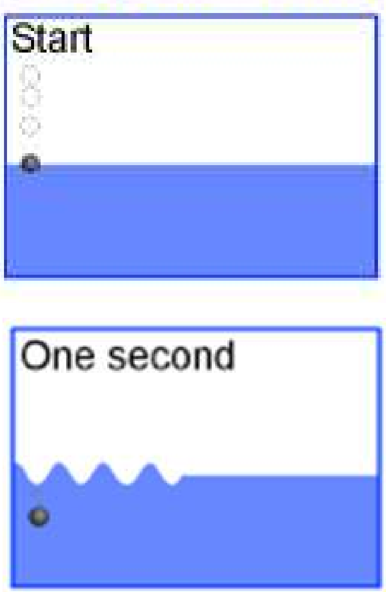
Frequency (cycles/sec) → f

Wavelength (m) → λ

14.1 Calculate wave speed



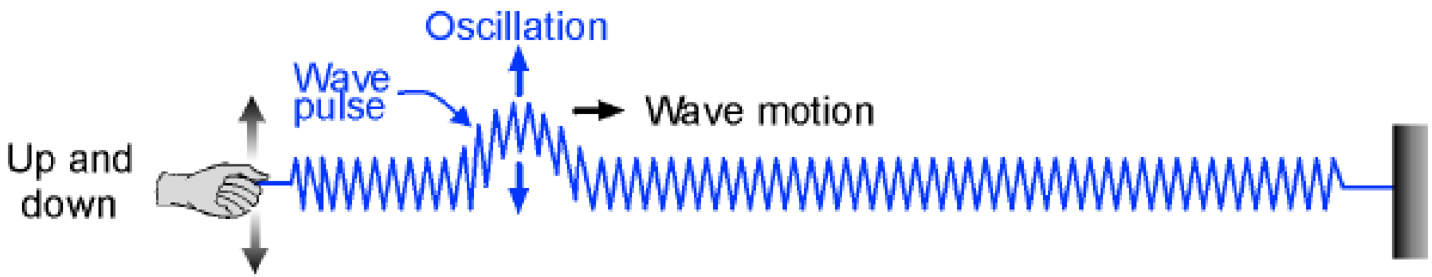
Calculate how long it takes a wave to move from one place to another



- A student does an experiment with waves in water.
- The student measures the wavelength of a wave to be 5 centimeters.
- By using a stopwatch and observing the oscillations of a floating ball, the student measures a frequency of 4 Hz.
- If the student starts a wave in one part of a tank of water, how long will it take the wave to reach the opposite side of the tank 2 meters away?

14.1 Transverse and longitudinal waves

- **A transverse wave has its oscillations perpendicular to the direction the wave moves.**

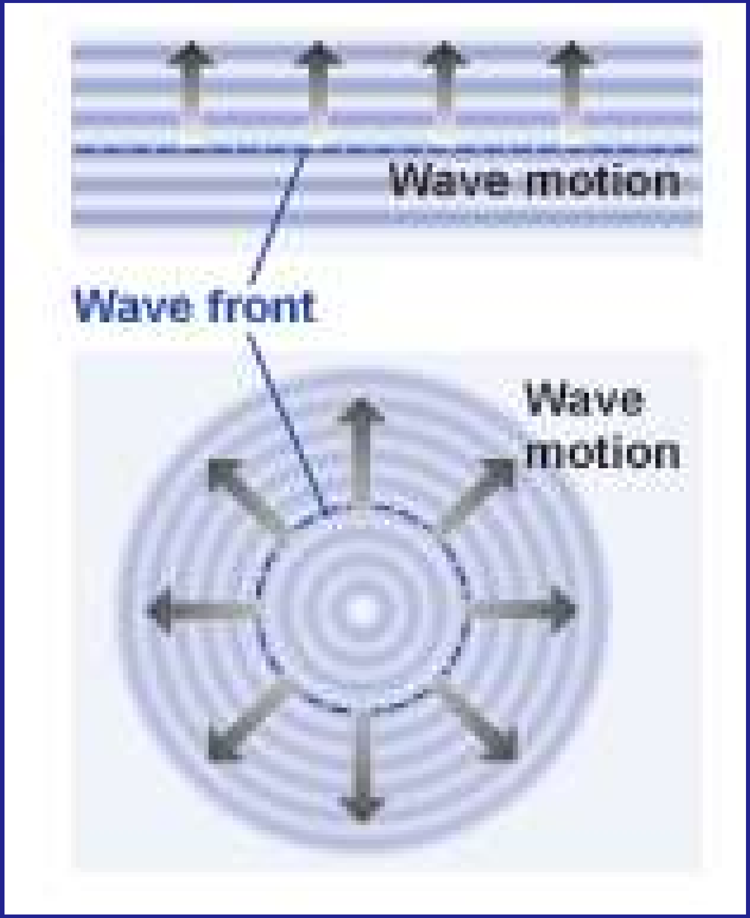


A longitudinal wave has oscillations in the same direction as the wave moves.

14.2 Motion and Interaction of Waves

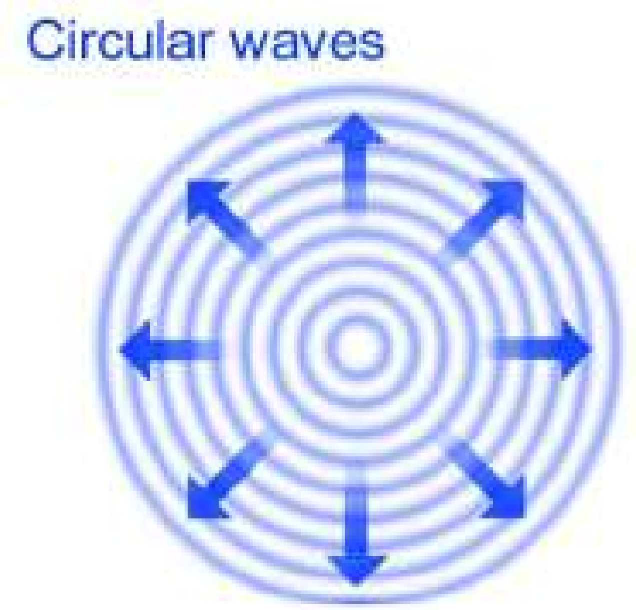
Key Question:

How do waves move and interact with things?

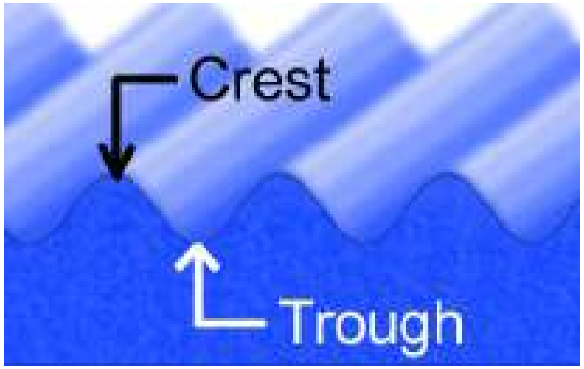


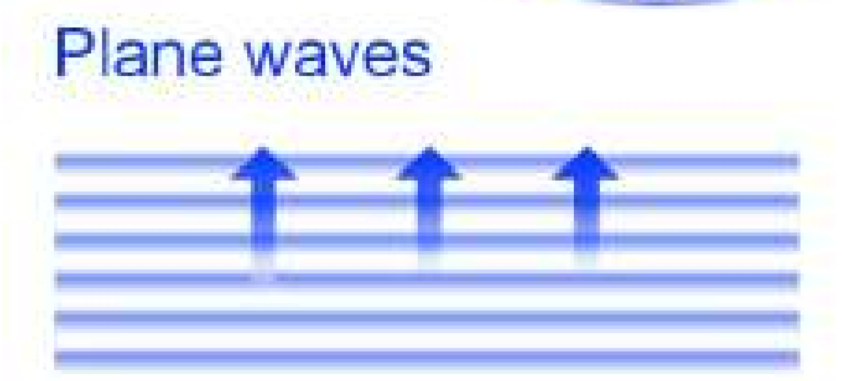
*Students read Section 14.2 AFTER Investigation 14.2

14.2 Waves in Motion



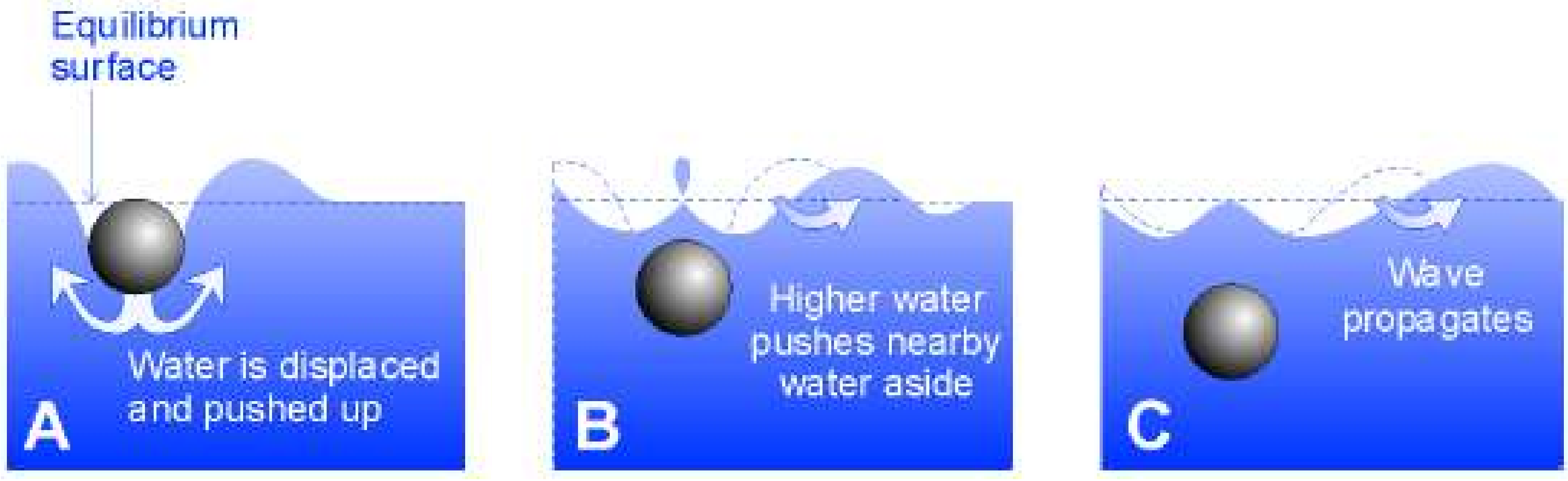
- Waves have crests and troughs.
- The crest of a wave is sometimes called a wave front.
- The shape of a wave is determined by its wave front.





14.2 Propagation of waves

The word propagation means "to spread out and grow."



14.2 Propagation of waves

- **Water waves propagate along surfaces that are continuous.**

A water wave can not spread across a discontinuous surface.

14.2 Waves and boundaries

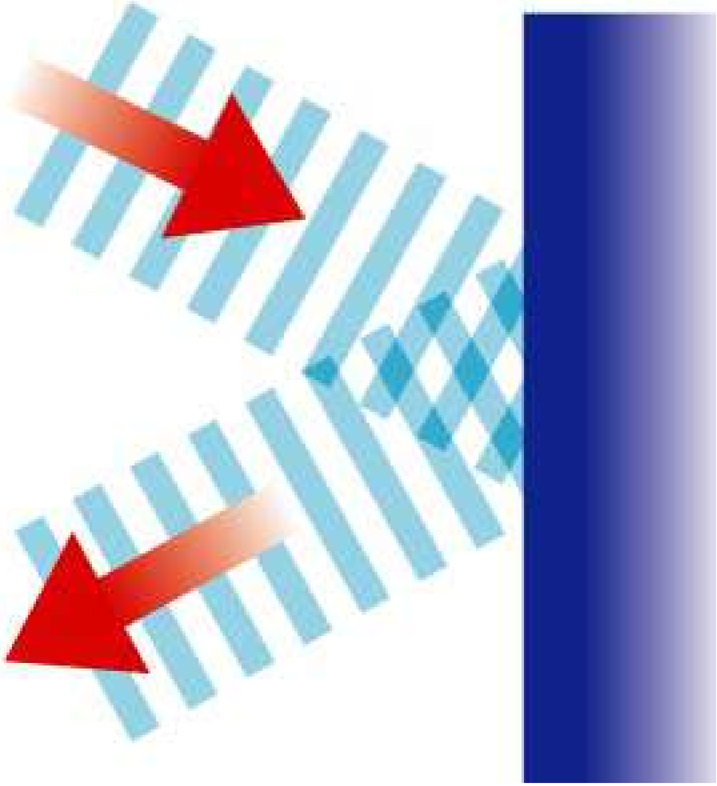
- **A boundary is a place where conditions change.**

What a wave does at a boundary depends on the boundary conditions.
Waves can interact with boundaries in four different ways...

Wave Interactions

Reflection

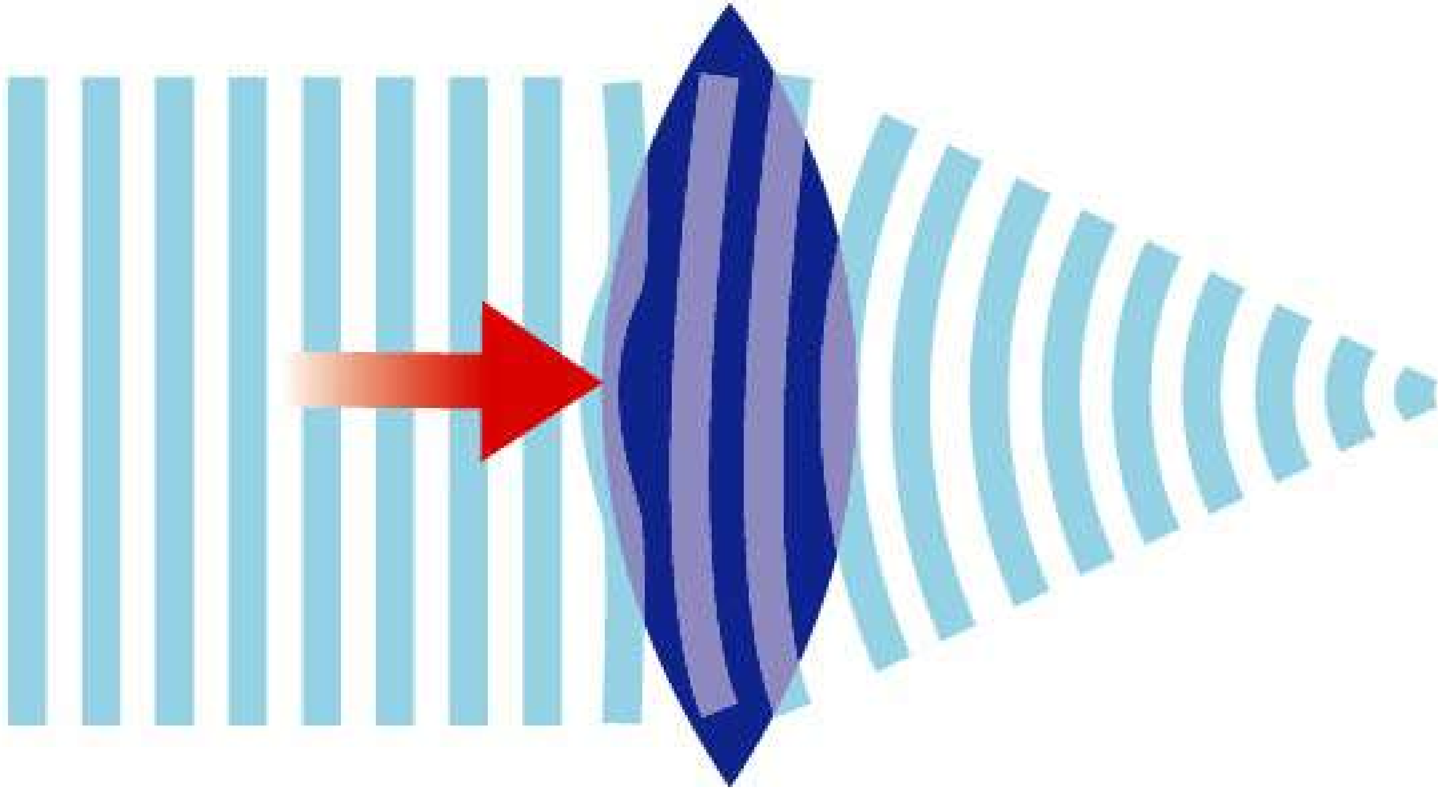
Wave bounces off a material and goes in a new direction.



Wave Interactions

Refraction

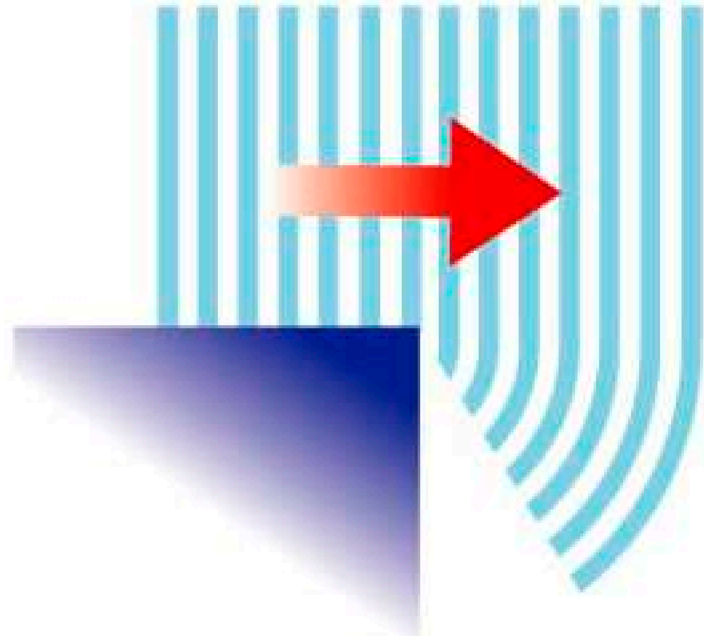
Wave passes through a material and bends.

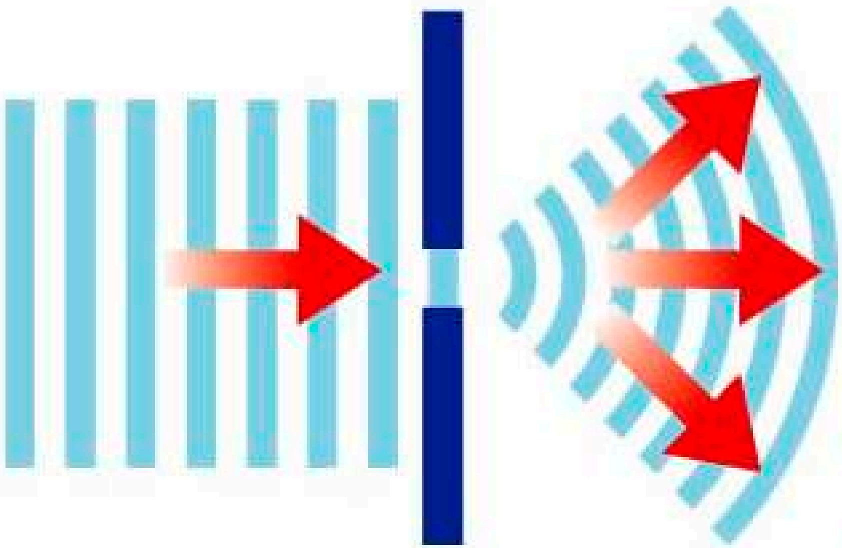


Wave Interactions

Diffraction

Wave bends around or goes through a hole in a material.



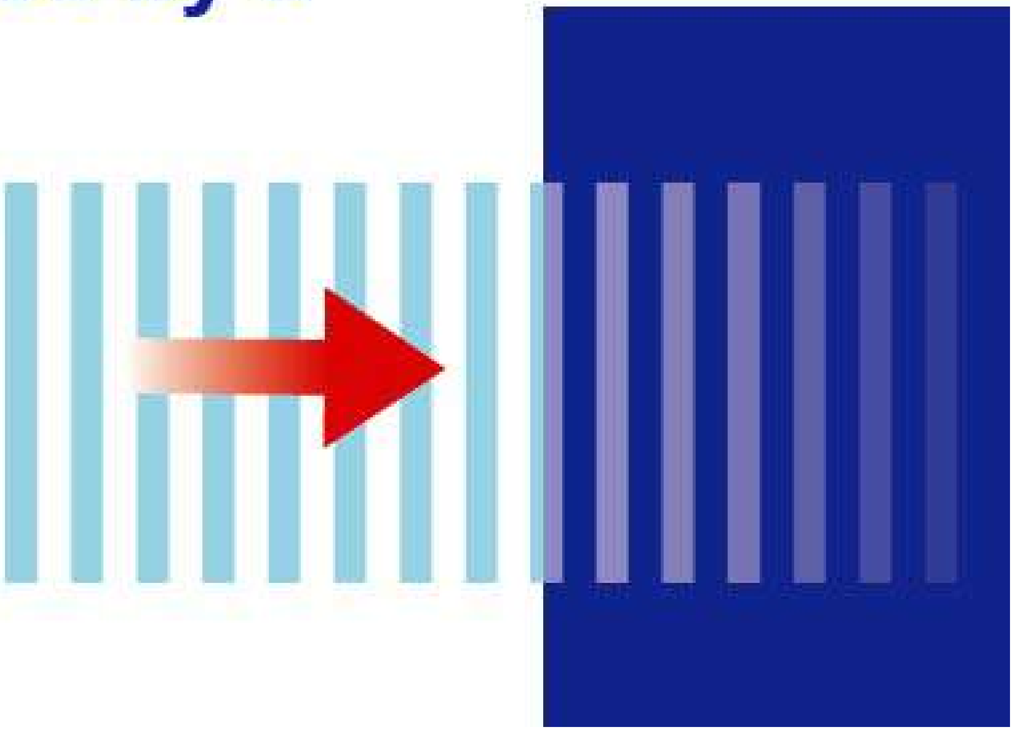


When plane waves go through a small hole, they become circular waves.

Wave Interactions

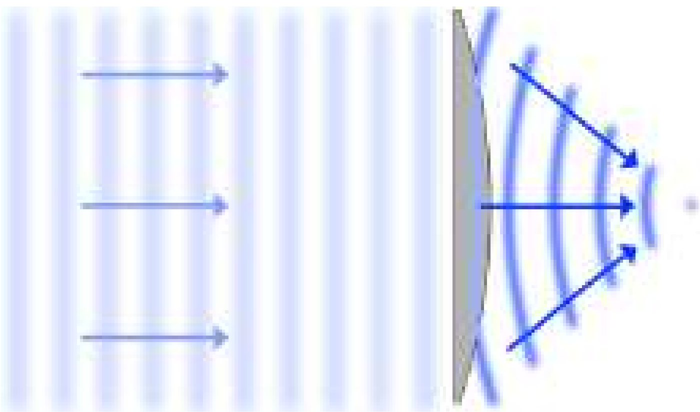
Absorption

Wave is absorbed by a material and may disappear.



14.2 Waves and boundaries

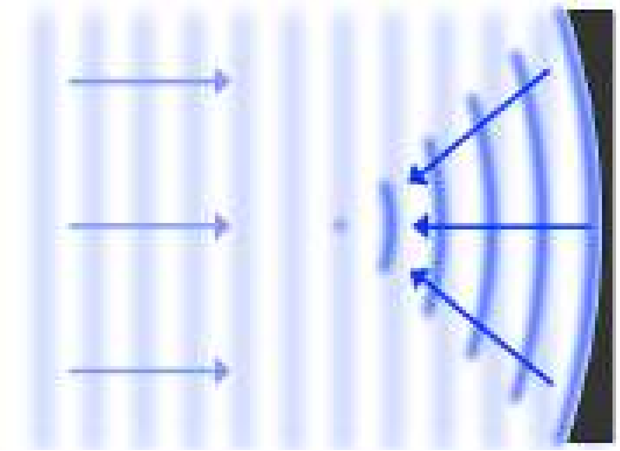
- **The wave approaching a boundary is called the incident wave.**
- **The wave sent from a boundary is the reflected wave.**
- **A wave that is bent passing through a boundary is called a**

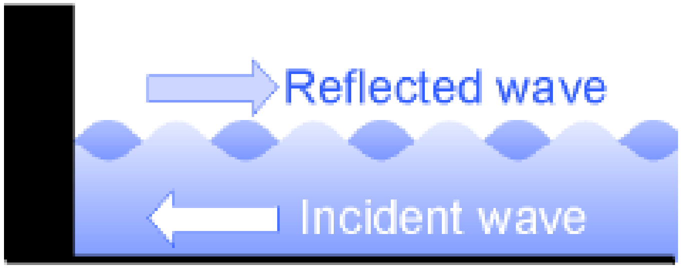


This incident plane wave refracts a circular wave after passing through a convex barrier.

14.2 Waves and boundaries

- Boundaries that are not straight can be used to change the shape of the wave fronts and therefore change the direction of a wave.
- A sharp boundary creates strong reflections.
- A soft boundary absorbs wave energy and produces little reflection.

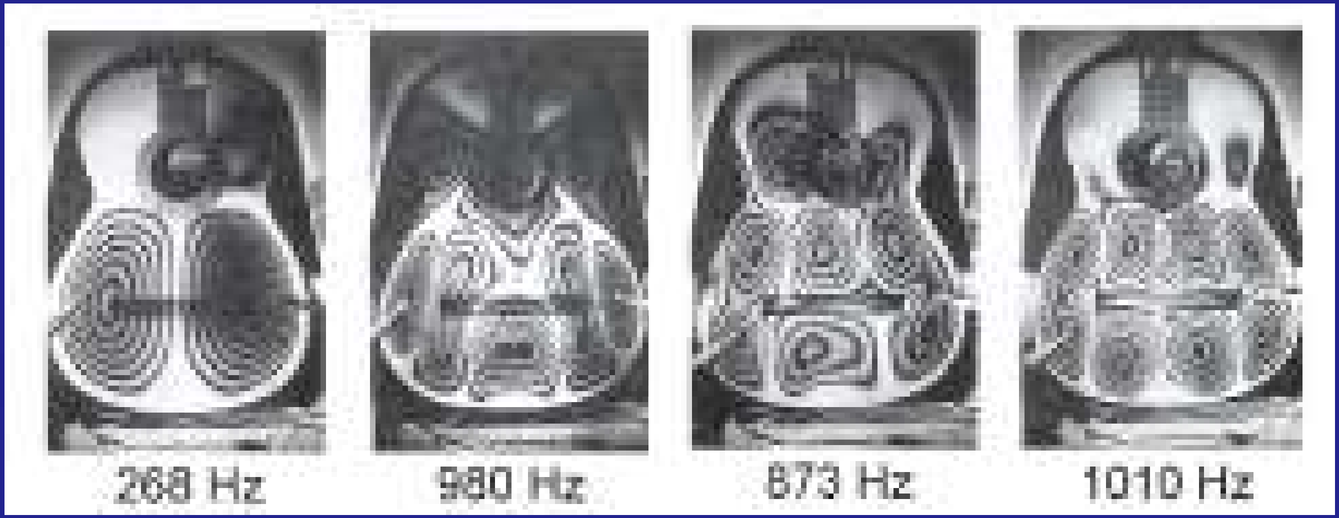




14.3 Natural Frequency and Resonance

Key Question:

How do we make and control waves?

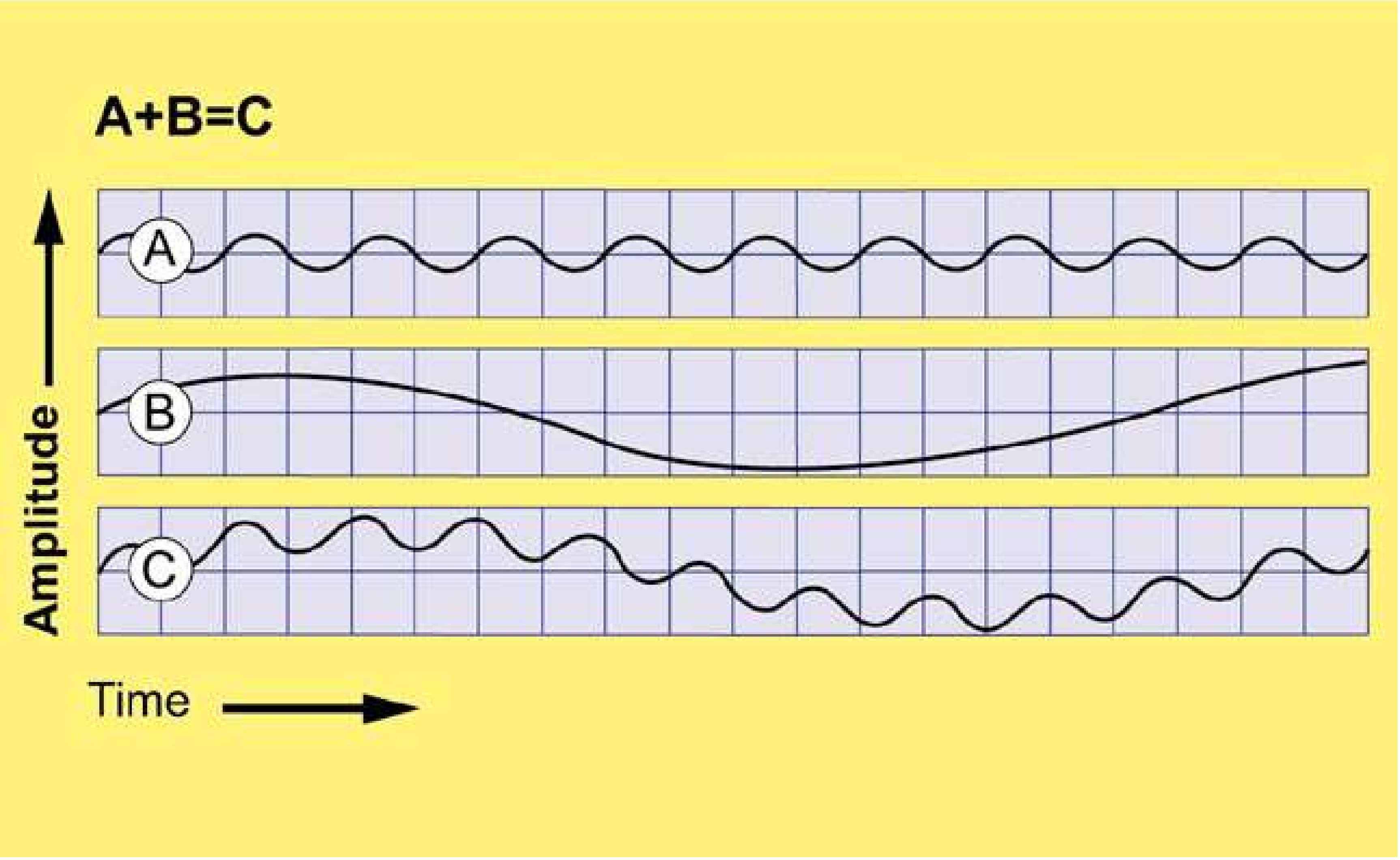


***Students read Section 14.3 AFTER Investigation 14.3**

14.2 Superposition principle

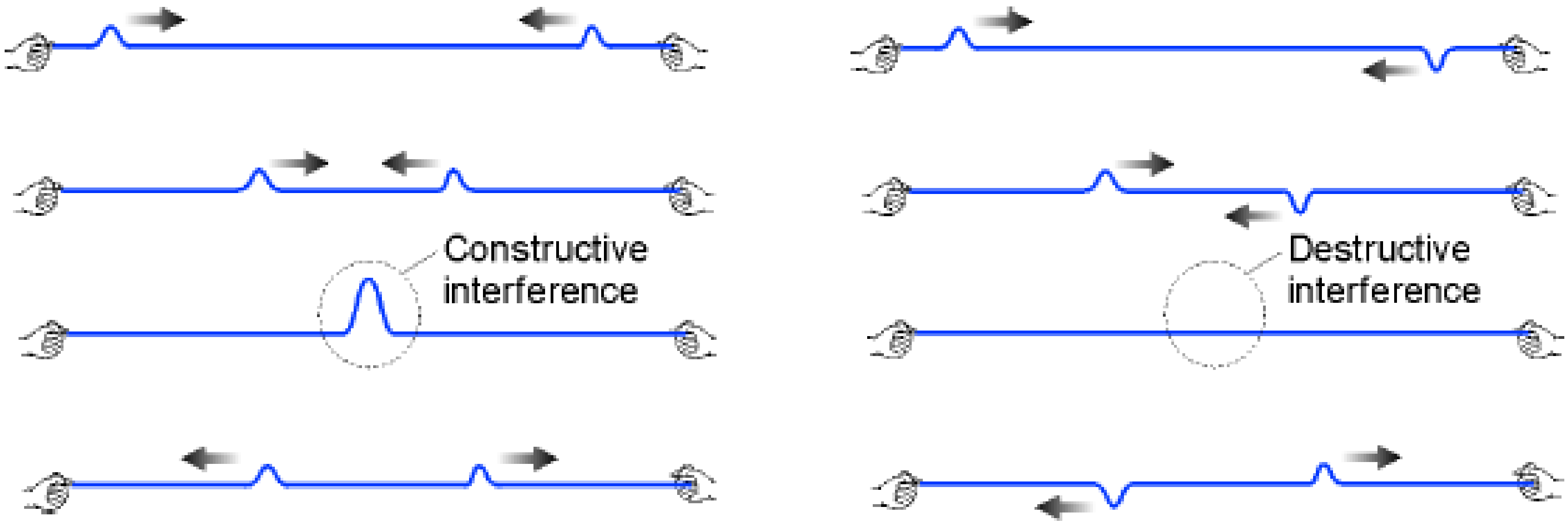
- It is common for there to be many waves in the same system at the same time.
- When more than one wave is present, the total oscillation of any point is the <u>sum</u> of the oscillations from each individual wave.
- The sound waves and light waves you experience are the superposition of thousands of waves with different frequencies and amplitudes.
- Your eyes, ears, and brain separate the waves in order to recognize individual sounds and colors.

The Superposition Principle



14.2 Interference

- If two waves add up to create a larger amplitude, constructive interference has occurred.
- In destructive interference, waves add up to make a smaller amplitude.

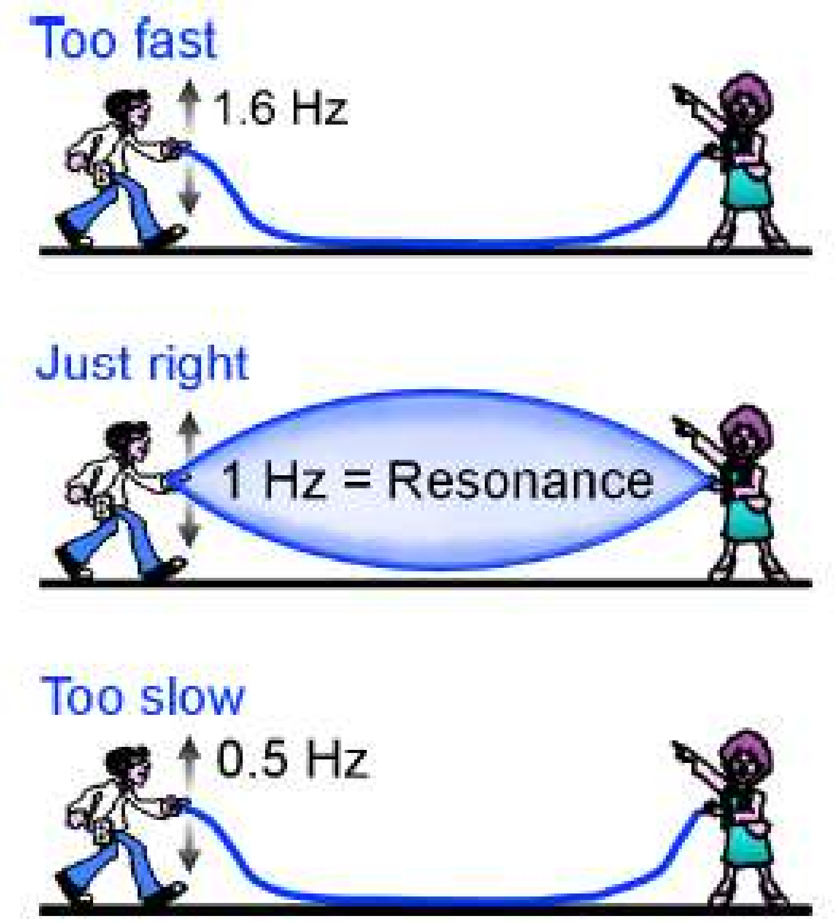


14.3 Natural Frequency and Resonance

- Waves can show natural frequency and resonance, just like oscillators.
- The natural frequency of a wave depends on the wave and also on the system that contains the wave.
- Resonance in waves is caused by reflections from the boundaries of a system.

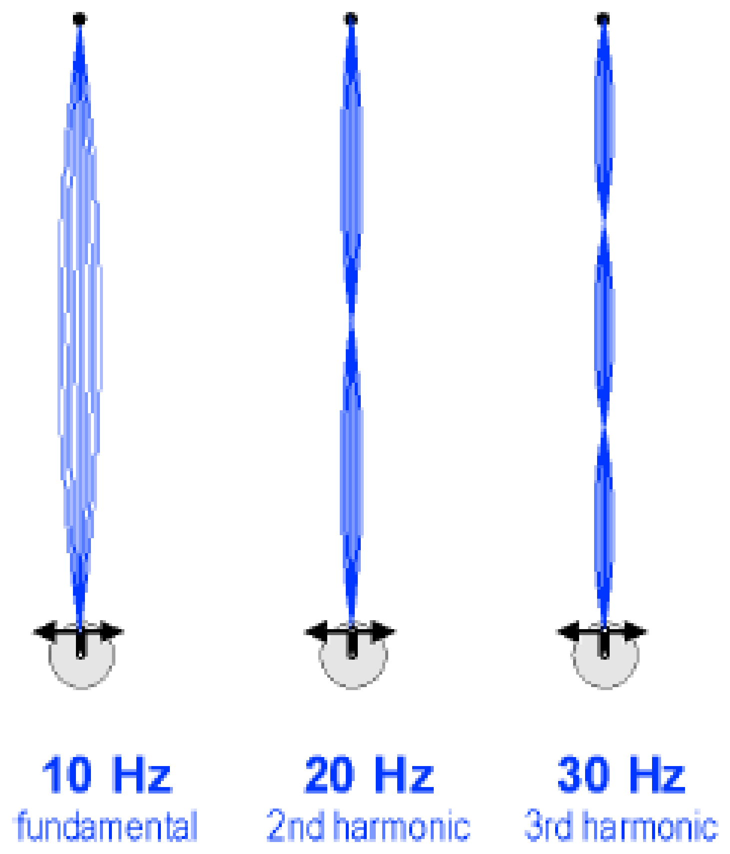
14.3 Standing waves

- A wave that is confined between boundaries is called a standing wave.
- With all waves, resonance and natural frequency are dependent on reflections from boundaries of the system containing the wave.



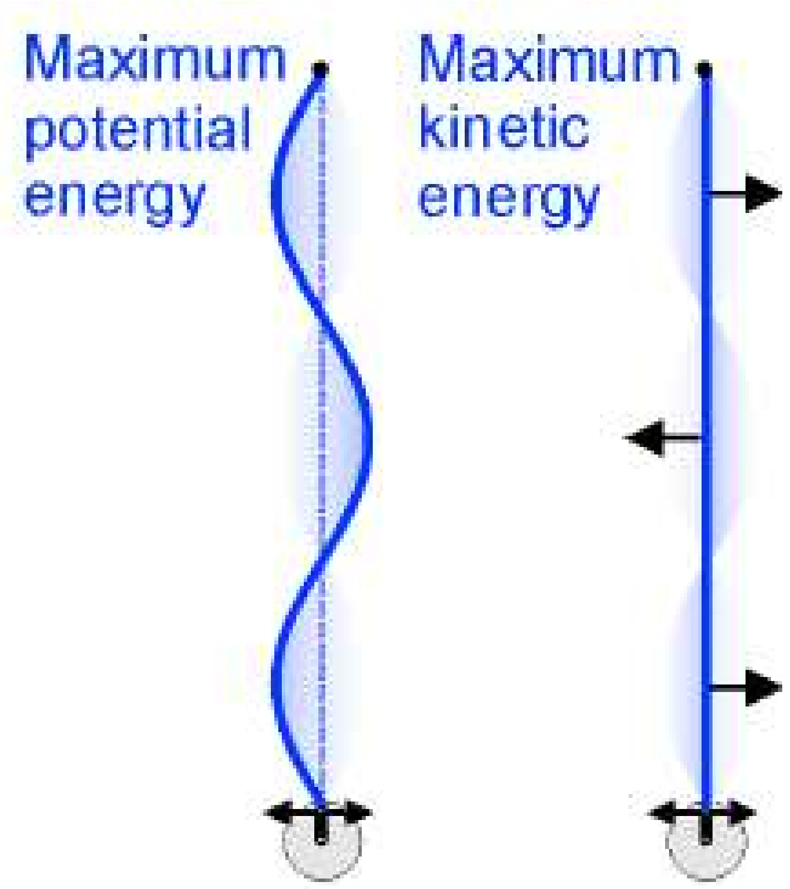
14.3 Standing Waves and Harmonics

- The standing wave with the longest wavelength is called the fundamental.
- The fundamental has the lowest frequency in a series of standing waves called harmonics.
- The first three standing wave patterns of a vibrating string shows that patterns occur at multiples of the fundamental frequency.



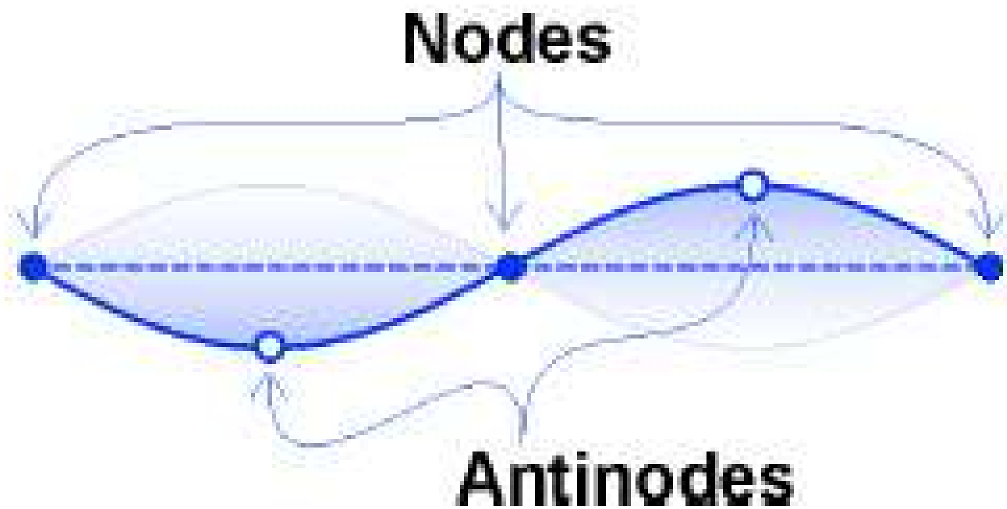
14.3 Energy and Waves

- All waves propagate by exchanging energy between two forms.
- For water and elastic strings, the exchange is between potential and kinetic energy.
- For sound waves, the energy oscillates between pressure and kinetic energy.
- In light waves, energy oscillates between electric and magnetic fields.



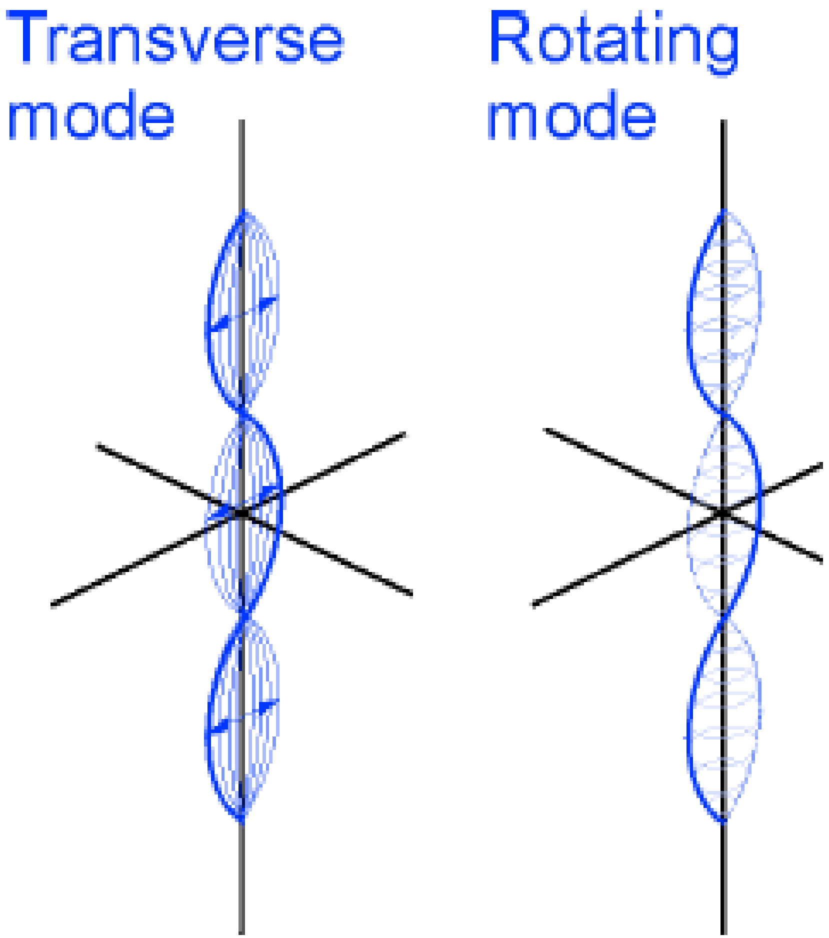
14.3 Describing Waves

- Standing waves have nodes and antinodes.
- A node is a point where the string stays at its equilibrium position.
- An antinode is a point where the wave is as far as it gets from equilibrium.



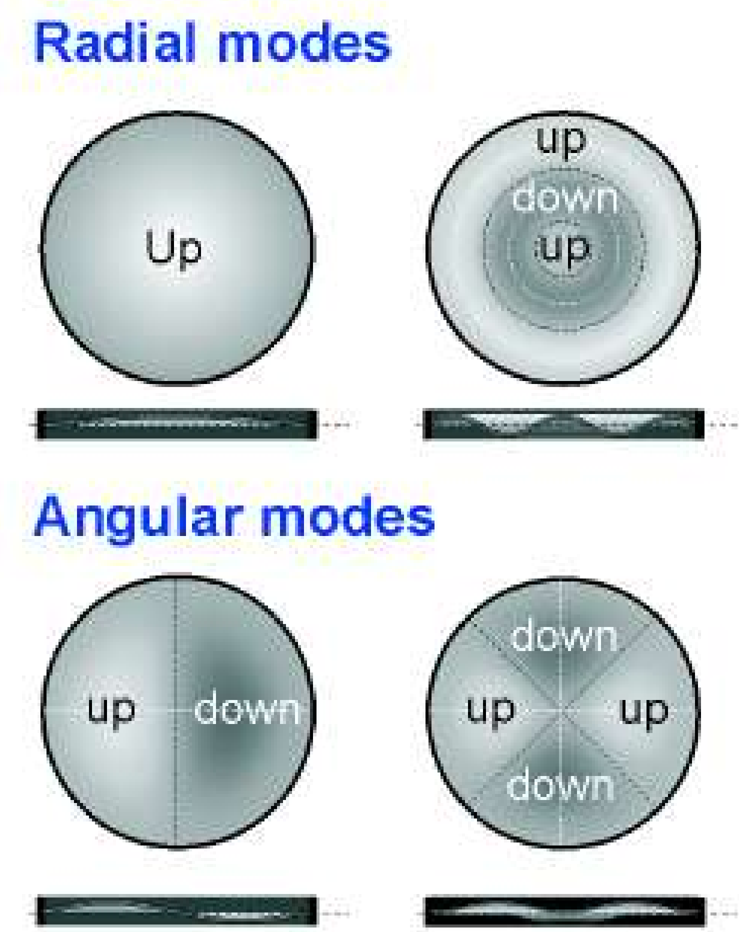
14.3 Describing Waves

- A mode is a category of types of wave behavior.
- One mode of the vibrating string is a rotating wave and the other mode is a transverse wave.
- Because a vertical vibrating string moves in circles, the wave looks the same from the front and from the side.



14.3 Standing waves in 2 and 3 dimensions

- **Most vibrating objects have more complex shapes than a string.**
- **Complex shapes create more ways an object can vibrate.**
- **Two- and three-dimensional objects tend to have two or three families of modes**



Application: Microwave Ovens