

CHAPTER 15 WAVES

Waves are all around Us

- light from the spotlight
- ripples in a puddle of
- electricity flowing in wires
- radio and television and cell phone transmissions

The electricity flowing in the wires attached to the traffic lights is a wave.

The light you see from the traffic light is a wave.

Waves carry radio, TV and cell phone transmissions through the air around you.

The ripples in a puddle are waves.

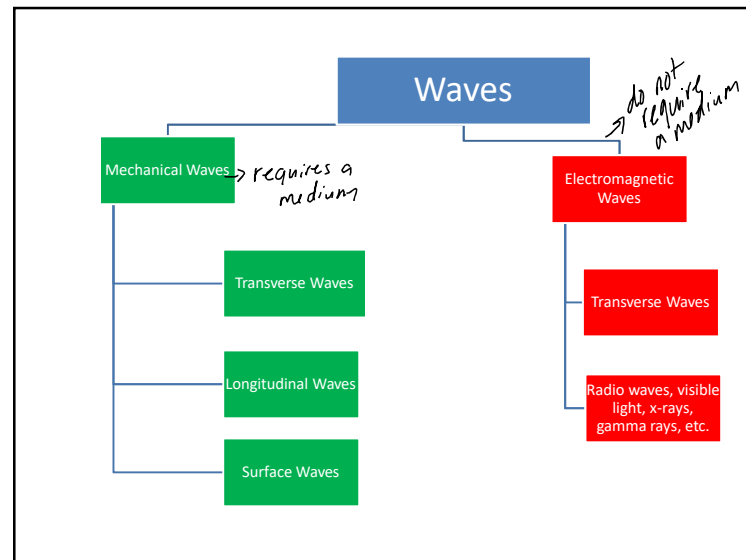
What is a wave?

- Wave- a disturbance that transmits energy through matter or space
 - Energy may spread out as a wave travels.
 - Kinetic theory explains differences in wave speed
- The speed of a wave depends on the medium
- Medium-matter through which a wave travels
 - Water, Air, Earth
 - Greatest in solids and least in gases

2 Types of Waves:

1. Mechanical
2. Electromagnetic

Intro to Waves Clip

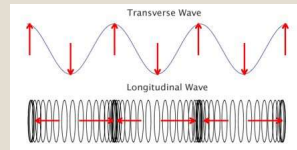


Mechanical Waves



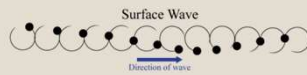
A wave that requires a medium through which to travel

- They are caused by the vibration of particles within the medium.



3 Types of Mechanical Waves:

1. Transverse
2. Longitudinal
3. Surface Waves

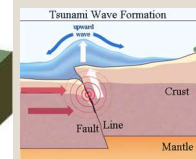
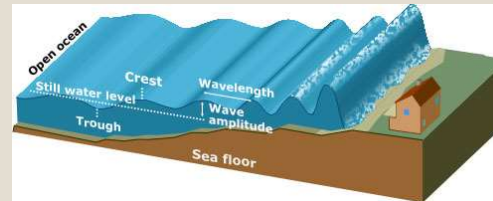


- sound waves (air)
- water waves
- waves in a spring

Mechanical Energy

A tsunami is a huge ocean wave caused by earthquakes.

- A tsunami can carry enough energy to damage coastal dwellings.



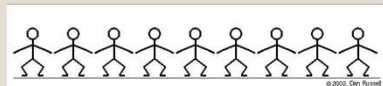
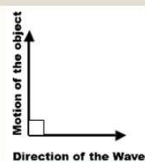
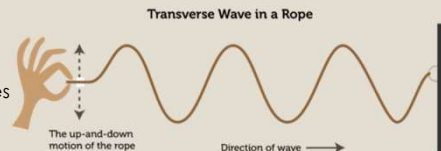
Animation

Transverse Waves

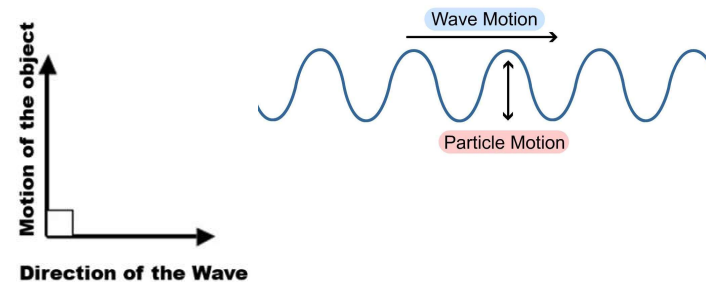
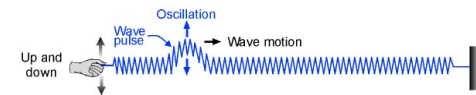
- Particles oscillate up and down about their equilibrium positions, perpendicular to the direction of wave propagation
- Its oscillations perpendicular to the direction the wave moves

Examples:

- light waves
- electromagnetic waves



Transverse Waves



Transverse Wave

Transverse Wave

← Wavelength →

isvr

Longitudinal Waves

Compressions

- Particles oscillate back and forth about their equilibrium positions, parallel to the direction of wave motion
- Oscillations in the same direction as the wave moves

Ex: Sound waves, seismic waves

Longitudinal Wave in a Spring

The back-and-forth motion of the coils of the spring is in the same direction that the wave travels.

Longitudinal Wave

Longitudinal Wave

↑ wave ↑ particle

Compression Compression
Rarefaction Rarefaction

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Surface Waves

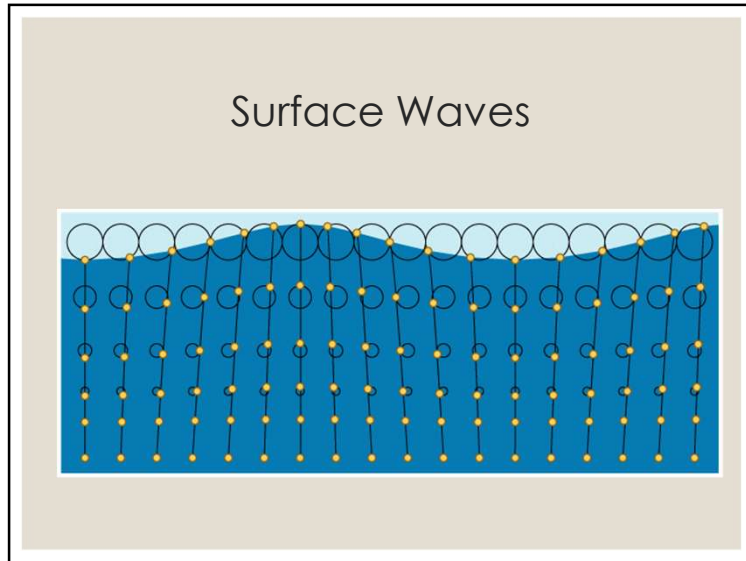
- In a surface wave, particles move in circles.
- Combination of transverse and longitudinal
 - Ex: water waves

Direction of wave

Crest

Trough

Figure 9 Ocean waves are surface waves at the boundary between air and water.



longitudinal wave

transverse wave

Surface Wave

Clip

Wave motion

Particle motion

(a) P-wave

High density

Low density

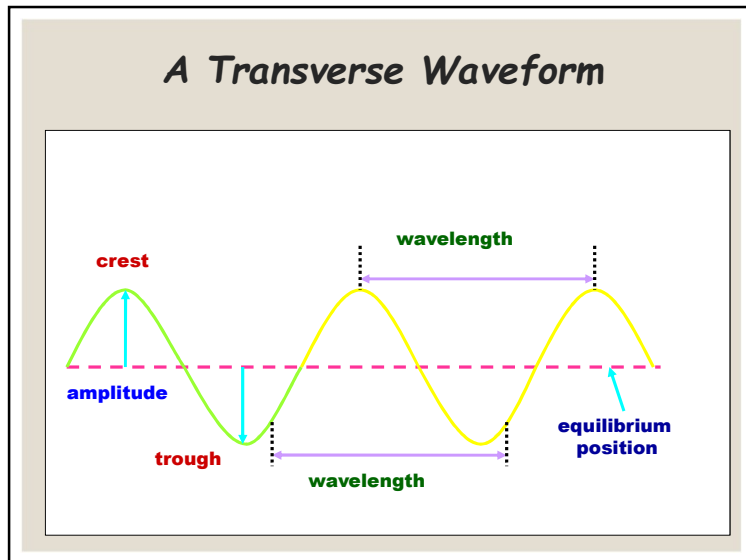
(b) S-wave

Particle motion

How Particles Move in a Surface Wave

Direction of Wave

Individual particles of the medium move in a circle as the energy of a surface wave passes through.



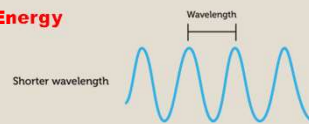
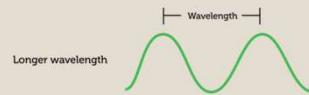
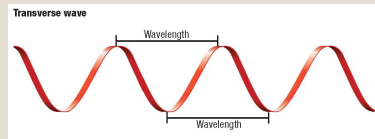
Wave Properties of a Transverse Wave

- **Crest**-the highest point of a transverse wave
- **Trough**-the lowest point of a transverse wave
- A cycle consists of one crest and one trough.
- **Amplitude**-the greatest distance that particles in a medium move from their normal position when a wave passes

The diagram shows a blue transverse wave moving to the right. A horizontal dashed line is labeled 'Rest position' and 'Undisturbed state'. The distance between two crests is 'Wavelength'. The distance from the rest position to a crest is 'Amplitude'. The highest point is 'Crest' and the lowest point is 'Trough'. An arrow at the bottom indicates the 'Direction of wave motion'.

Wavelength of a Transverse Wave

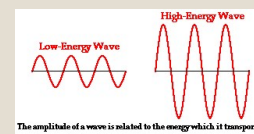
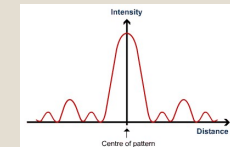
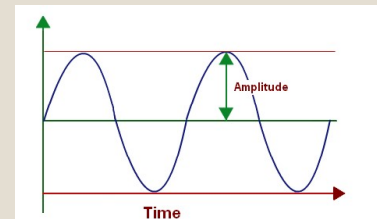
- **Wavelength**-the distance between any two successive identical parts of a wave
- Ex. Crest to Crest
- Ex. Trough to Trough



Shorter the Wavelength = More Energy

Amplitude of Transverse Wave

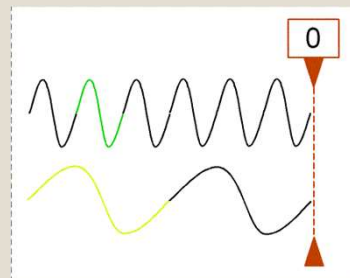
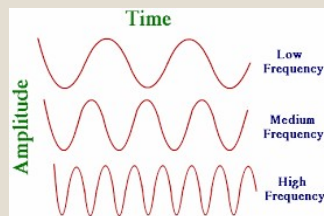
- The amount of energy carried by a wave.
- Larger the amplitude = more energy



Frequency

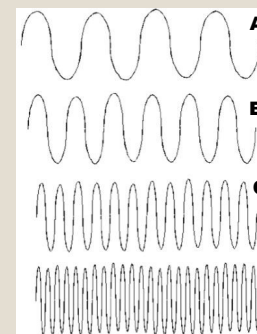
The number of cycles or vibrations per unit of time.
 The number of waves produced in a given amount of time.

- unit hertz (Hz)



Frequency in Waves

Describe the relationship between frequency and energy for each example?



A Longitudinal Waveform

◦ A cycle consists of **one compression** and **one expansion** of the particles of the medium.

The diagram shows a longitudinal wave moving to the right, indicated by an arrow labeled "Velocity of propagation". The particles of the medium oscillate horizontally, perpendicular to the direction of wave travel, as shown by a double-headed arrow labeled "Displacement". A cycle is defined as one full compression (crowded area) followed by one full expansion (stretched-out area).

Wavelength of a Longitudinal Wave

- **Compressions:** the crowded areas of a longitudinal wave
- **Rarefactions:** the stretched-out areas of a longitudinal wave

The diagram shows a blue longitudinal wave. Two horizontal brackets labeled "Wavelength" indicate the distance between two consecutive compressions (crowded areas) and between two consecutive rarefactions (stretched-out areas).

Wave Properties of a Longitudinal Wave

Label the parts of the following wave.

The diagram shows a longitudinal wave with several arrows pointing to different parts of the wave cycle, intended for a labeling exercise.

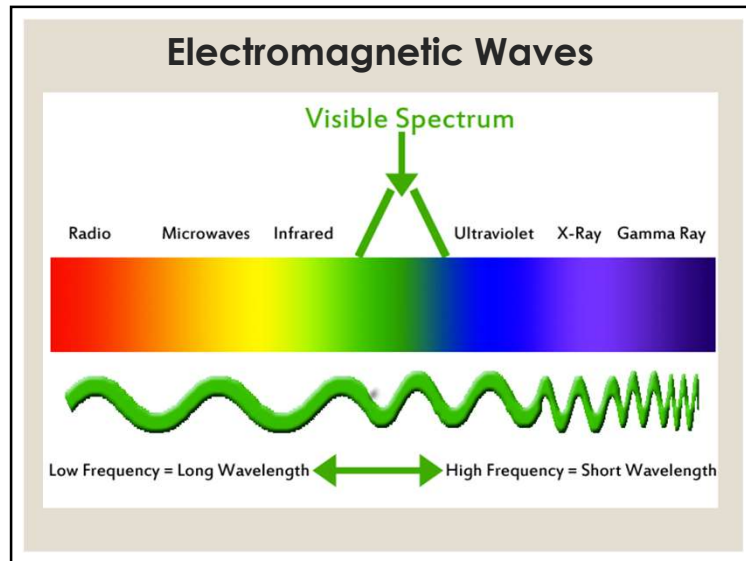
What type of wave is shown above?

Electromagnetic Waves

- Wave caused by a disturbance in electric and magnetic fields by vibrating charged particles.
- Does not require a medium
- Also called a light wave
- Can transfer energy through a **vacuum**
- **Can also transfer** energy through a **material medium**
- Considered **transverse waves** because they have similar characteristics; therefore, they have the same parts.

Example: radio wave, gamma rays, x- rays, visible light

The top right diagram shows a prism dispersing white light into a spectrum of colors, labeled with "Visible Light" and "Other Parts of the Spectrum". The bottom left diagram shows "The Electromagnetic Spectrum" with various types of waves and their uses: Radio (communication), Microwaves (cooking), Infrared (remote control), Visible Light (vision), Ultraviolet (tanning beds), X-rays (medical imaging), and Gamma Rays (cancer treatment). The bottom right diagram shows a transverse electromagnetic wave with electric field (E) and magnetic field (B) vectors oscillating perpendicular to each other and to the direction of propagation.



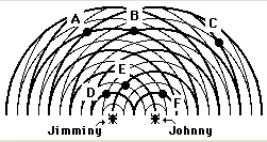
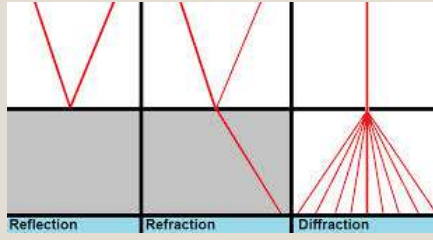
Lets Practice Wave Properties

Label the parts of the following wave.

What type of wave is shown above?

Wave Interactions

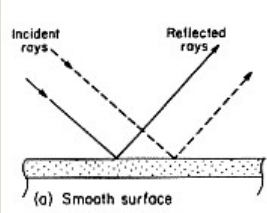
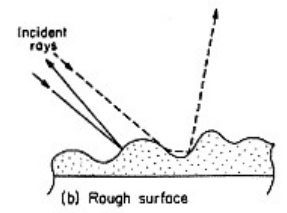
- Waves bend when they pass from one medium to another at an angle.
- Waves will experience :
 - Reflection
 - Diffraction
 - Refraction
 - Interference

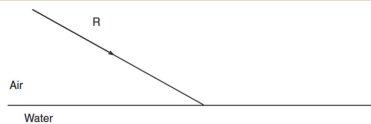
1. Reflection

The bouncing back of a wave as it meets a surface or boundary

- Examples:
 - The reflection of light waves in a lake can create a mirror image of a landscape.
 - Water waves are reflected when they hit the side of a boat.

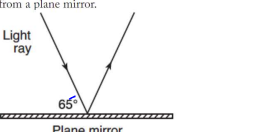



Reflection



Air
Water

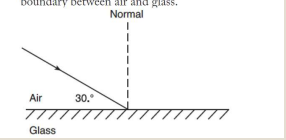
The diagram below represents a light ray reflecting from a plane mirror.



Light ray
65°
Plane mirror

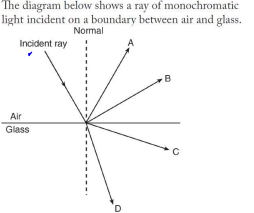
The angle of reflection for the light ray is

1. The diagram below represents a light ray striking the boundary between air and glass.



Air
30°
Glass

The diagram below shows a ray of monochromatic light incident on a boundary between air and glass.




Incident ray
Normal
A
B
C
D
Air
Glass

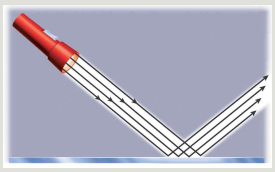
Which ray best represents the path of the reflected light ray?

Reflection

Rough surfaces reflect light rays in many directions.

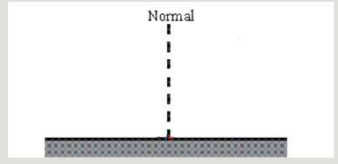


Smooth surfaces reflect light rays in one direction.




The **angle of reflection** is the light rays reflecting off the surface.


The **angle of incidence** is the light rays striking the surface



Reflection of Waves



Smooth Surface


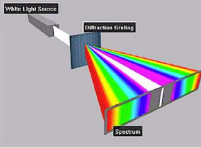
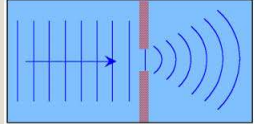
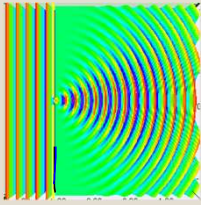


Rough Surface

2. Diffraction

The bending of a wave as it passes an edge or an opening

- Examples:
 - Water waves diffract around a block in a tank of water.
 - Sound waves passing through a door diffract.

Diffraction

How Diffraction Occurs

The obstacle is larger than the wavelength, so there is little diffraction.

The opening in the obstacle is smaller than the wavelength, so there is a lot of diffraction.

Radio reception in a hilly area

Tilt angle from x-axis: 45°

Tilt angle from x-axis: 30°

3. Refraction

- The bending of waves as they pass from one medium to another
- All waves are refracted when they pass from one medium to another at an angle.
- Molecules slow down when then move from one medium to another

Deep Water → Slow → Shallow Water

Fish is Here

Fish Appears Here

$n_1 \sin \alpha = n_2 \sin \beta$

Refraction of Waves

Conceptual Animation of Wave Refraction

Faster Air

Slower Water

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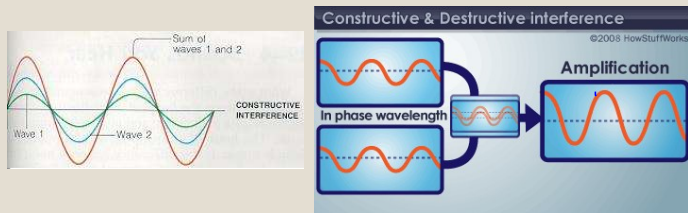
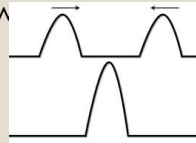
4. Interference

- The combination of two or more waves that exist in the same place at the same time
- Occurs in all waves
- Two types
 - Constructive interference
 - Destructive interference

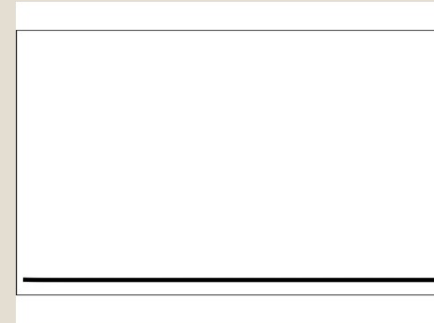
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Type 1: Constructive Interference

- Waves combine without any phase difference
- Waves combine to form a bigger wave
- Increases amplitude

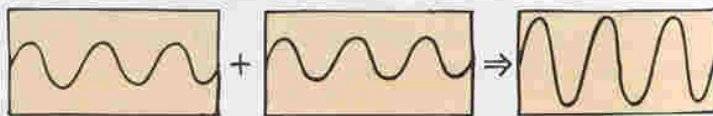


Constructive Interference



Wave Addition

Constructive Interference
Amplitude ~ Intensity



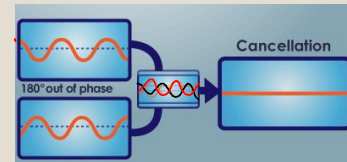
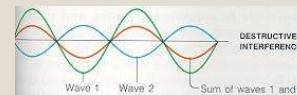
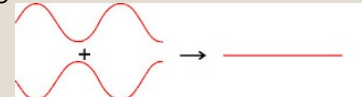
The superposition of two identical transverse waves in phase produces a wave of increased amplitude.



The superposition of two identical longitudinal waves in phase produces a wave of increased intensity.

Type 2: Destructive Interference

- Waves combine differing by multiples of 1/2 wavelength
- waves combine to form a wave smaller than the largest of the original waves
- Decreases amplitude



Destructive Interference

Wave Subtraction Destructive Interference

Two identical transverse waves that are out of phase destroy each other when they are superimposed.

Two identical longitudinal waves that are out of phase destroy each other when they are superimposed.

Interference Waves (Dead Spots)

Destructive Interferences- creates a dark area

- Both waves cancel each other out

Constructive interference-creates a bright area

- Both waves overlap and increase

Dead Spots

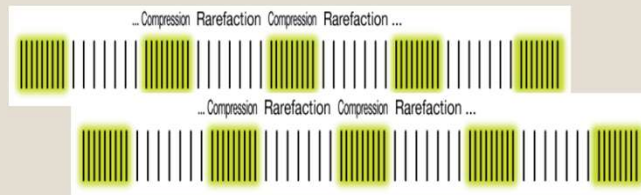
Waves can interfere so destructively with one another that they produce **dead spots**, or places where no sound at all can be heard.

Happens in both transverse waves and longitudinal waves.

Speakers Video

Warm Up!

Draw a model of two sound waves meeting to form a dead spot.



The compression of one sound wave overlaps with the rarefaction of another sound wave and cancel each other out. **No Sound is produced**

Interference

- Interference of light waves creates colorful displays
 - Ex. Rainbows, oil in water, soap bubbles

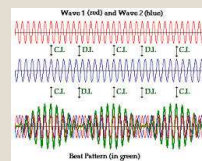
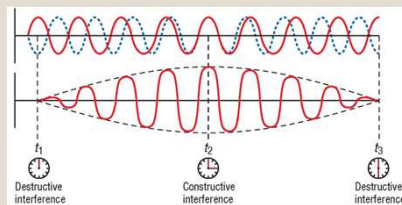


The colors seen in a soap bubble or an oil film on water are a common example of interference. Light reflecting off the front and back surfaces of the thin soap film interferes, resulting in different colors being enhanced.



Interference

- Interference of sound waves produces beats



Which statement best explains why the music is quieter in some spots?

- Sound waves reflect off the walls of the theater. Then, the compression of one sound wave meets the compression of another sound wave resulting in destructive interference.
- Sound waves reflect off the walls of the theater. Then, the compression of one sound wave meets the rarefaction of another sound wave resulting in destructive interference.
- Sound waves reflect off the walls of the theater. Then, the rarefaction of one sound wave meets the rarefaction of another sound wave resulting in constructive interference.
- Sound waves reflect off the walls of the theater. Then, the compression of one sound wave meets the rarefaction of another sound wave resulting in constructive interference.

Answer: B

When light waves interfere the result is often a pattern of light and dark areas, like those seen in the image below. The dark areas are caused by _____ interference and the light areas are caused by _____ interference.

- A. Constructive; destructive
- B. Longitudinal; transverse
- C. Destructive; constructive
- D. Transverse; longitudinal

Answer: C

