



CHAPTER 15 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



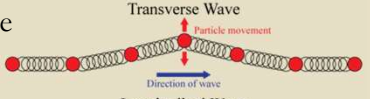
Intro to Waves Clip

Mechanical Waves

A wave that requires a medium through which to travel

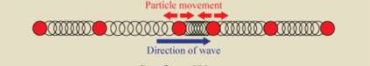
- They are caused by the vibration of particles within the medium.



Transverse Wave

Particle movement

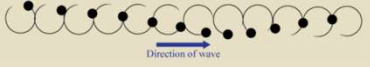
Direction of wave



Longitudinal Wave

Particle movement

Direction of wave



Surface Wave

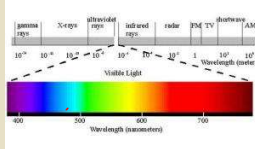
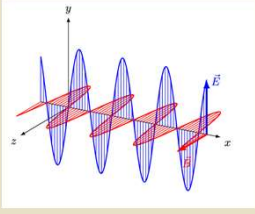
Direction of wave

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

Electromagnetic Waves

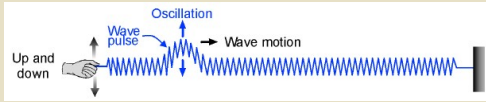
- Wave caused by a disturbance in electric and magnetic fields by vibrating charged particles.
- Does not require a medium
- Also called a light wave
- can transfer energy through a **vacuum**
- can also transfer energy through a **material medium**

Example: light waves through space, through air, through glass

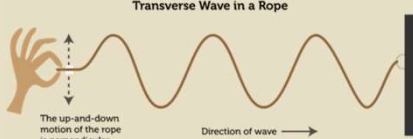
Transverse Waves

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



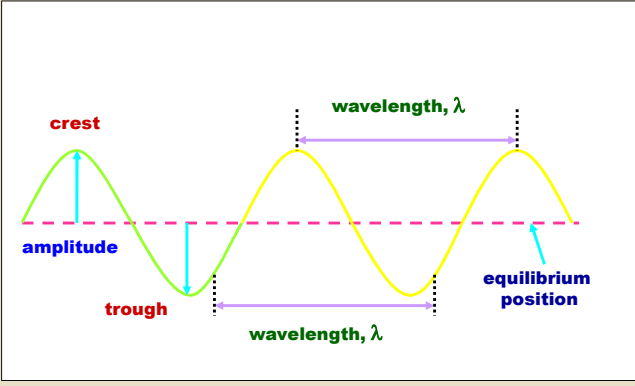
- Its oscillations perpendicular to the direction the wave moves

Examples: light waves, electromagnetic waves



The up-and-down motion of the rope is perpendicular to the direction of the wave.

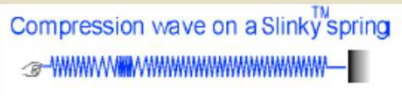
A Transverse Waveform



Longitudinal Waves

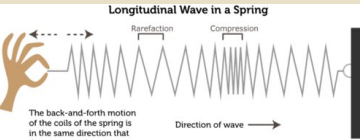
Compression

- Particles oscillate back and forth about their equilibrium positions, parallel to the direction of wave motion



Ex: Sound waves

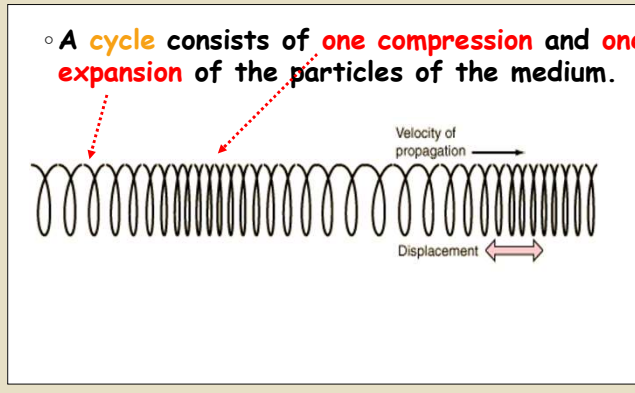
- Oscillations in the same direction as the wave moves



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

A Longitudinal Waveform

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



Wave Properties

- 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 transverse wave on a grid. A horizontal dashed line represents the 'Undisturbed state'. The wave oscillates above and below this line. The distance between two consecutive crests is labeled 'Wavelength'. The vertical distance from the undisturbed state to a crest is labeled 'Amplitude'. The highest point is labeled 'Crest' and the lowest point is labeled 'Trough'. An arrow at the bottom indicates the 'Direction of wave motion' to the right.

Wavelength

- Wavelength-the distance between any two successive identical parts of a wave
- Compressions: the crowded areas of a longitudinal wave
- Rarefactions: the stretched-out areas of a longitudinal wave

The top diagram shows a transverse wave with two 'Wavelength' labels indicating the distance between two consecutive crests. The bottom diagram shows a longitudinal wave with two 'Wavelength' labels indicating the distance between two consecutive compressions.

Amplitude and wavelength tell you about energy.

- larger amplitude = more energy
- shorter wavelength = more energy

Period (time)

- the time required for one full wavelength to pass a certain point
- complete cycle or wave oscillation to occur

The top diagram shows a transverse wave with two '1 cycle' labels. Each cycle is marked between two consecutive crests or two consecutive troughs, and is labeled with the Greek letter lambda (λ). The caption below is 'Crest, Trough and Wavelength'. The bottom diagram shows a sine wave on a coordinate system with displacement 's' on the vertical axis and distance 'd' on the horizontal axis. The time taken for one full cycle to pass a point is labeled 'Time Period'. The vertical distance from the equilibrium line to a peak is labeled 'amplitude'.

The diagram shows three snapshots of a wave passing a point at different times: $t = 0\text{ s}$, $t = 1\text{ s}$, and $t = 2\text{ s}$. The snapshots show the wave moving to the right, with a person standing at a fixed point observing the wave's oscillation.

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)

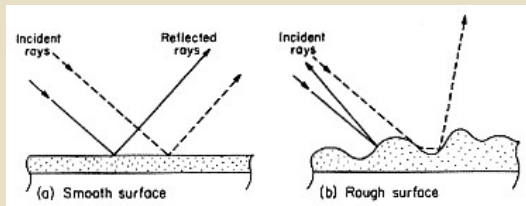
The left diagram shows three waves with different frequencies: 'Low Frequency' (few cycles), 'Media Frequency' (medium cycles), and 'High Frequency' (many cycles). The vertical axis is labeled 'Amplitude'. The right diagram shows a wave with a vertical axis labeled '0' at the top, indicating the equilibrium position.

1. Reflection

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

◦ Examples:

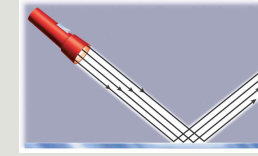
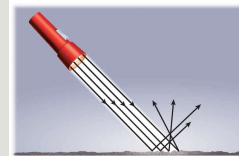
- The reflection of light waves in a lake can create a mirror image of a landscape.
- Water waves are reflected when they hit the side of a boat.



Reflection

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.

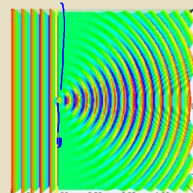
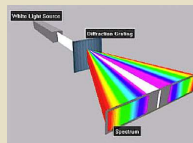
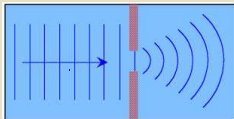
The *angle of incidence* is the light rays striking the surface

2. Diffraction

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

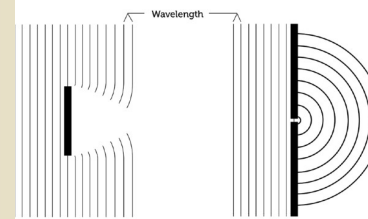
◦ Examples:

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



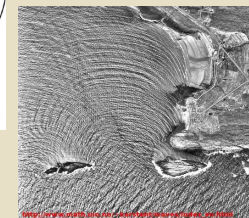
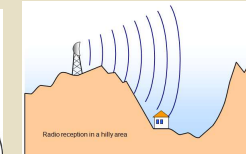
Diffraction

How Diffraction Occurs



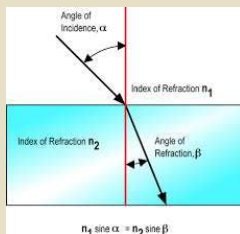
The obstacle is longer than the wavelength, so there is little diffraction.

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



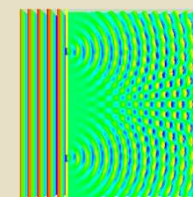
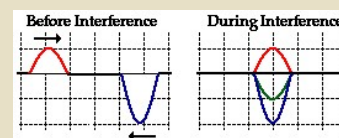
3. Refraction

- 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.



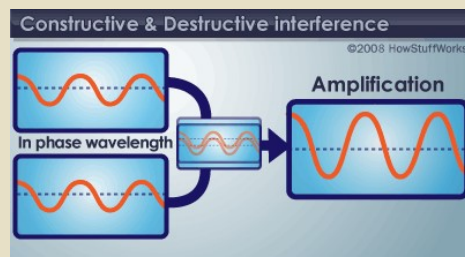
4. Interference

- 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



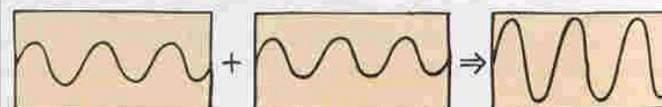
Type 1: Constructive Interference

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



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

