**PHYSICS**
**Mechanical Waves & Sound**
**Study Guide**

## Waves

The ***medium*** is the material a wave is travelling through. A medium can be a solid, liquid, or gas.

***Mechanical waves*** are the movement of a disturbance through a medium without net movement of the particles of the medium.

- The wave will travel through the medium, but the particles of the medium only vibrate or oscillate in place
- Waves transfer energy from one place to another without transferring matter

Waves come in two types:

- ***Transverse waves***: the particles of the medium oscillate in a direction perpendicular to the direction the wave travels
- ***Longitudinal waves***: the particles of the medium oscillate in a direction parallel to the direction the wave travels

## Wave Parts & Properties

***Equilibrium position***: the position of the medium when no wave travels through it.

***Crest***: the high points of a transverse wave.

***Trough***: the low points of a transverse wave.

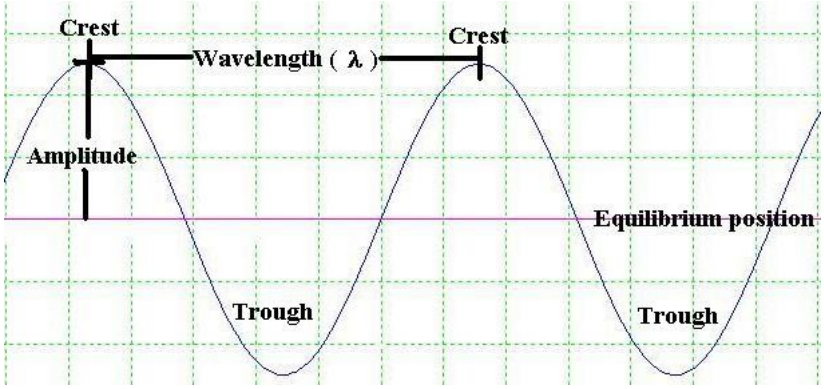
***Compression***: the areas of a longitudinal wave where the medium is squeezed together.

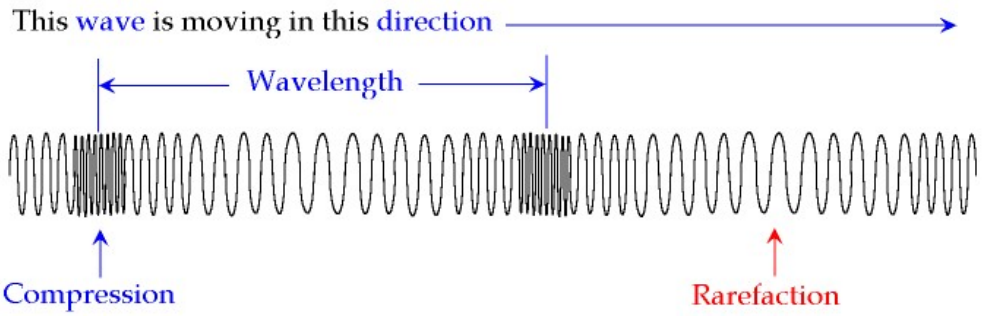
***Rarefaction***: the areas of a longitudinal wave where the medium is stretched apart.

***Amplitude*** (A): the height of the wave, the distance from the equilibrium position to a crest or a trough in a transverse wave, how tightly compressed the areas of compression are in a longitudinal wave.

- The amplitude of a wave determines how much energy is carried by the wave

***Wavelength*** ($\lambda$): the distance between two neighboring crests or troughs in a transverse wave, the distance between two neighboring compressions or rarefactions in a longitudinal wave.




## Frequency & Period

A ***cycle*** is the movement of the wave that is repeated again and again and again.

***Frequency*** (f) is the number of cycles that are completed in one second. Frequency is measured with the unit Hertz (Hz).

$$f = \frac{\text{cycles}}{\text{time}}$$

***Period*** (T) is the amount of time it takes to complete one cycle of a wave. Period is measured with the unit seconds (s).

$$T = \frac{\text{time}}{\text{cycles}}$$

Frequency and period are inverses of each other. If you know the value of one, you can always find the value of the other using these equations:

$$f = \frac{1}{T} \qquad\qquad T = \frac{1}{f}$$

## Wave Speed

***Wave speed*** is how quickly a wave moves. It is calculated using the wave speed equation:

$$v = \lambda f$$

| |
|---|
| $v$ = wave speed (m/s) |
| $\lambda$ = wavelength (m) |
| $f$ = frequency (Hz) |

Wave speed is determined **only** by properties of the medium, not by properties of the wave itself. If you want to change the speed of a wave, you must change the medium in some way.

The wave speed equation can be rearranged using algebra to solve for wavelength or frequency:

$$\lambda = \frac{v}{f} \qquad\qquad f = \frac{v}{\lambda}$$

## Superposition & Wave Interference

***Principle of Superposition***: when two waves meet, they pass through each other. Where the waves overlap, they add together.

- When the added together waves give a bigger wave, it is called ***constructive interference***
- When the added together waves give a smaller wave, it is called ***destructive interference***

***Total constructive interference***: the maximum possible constructive interference, occurs when the two waves being added together are completely aligned (crests align with crests and troughs align with troughs).

***Total destructive interference***: the maximum possible destructive interference, results in no wave at all, occurs when the two waves being added together are completely misaligned (crests align with troughs and vice versa).

## Standing Waves

***Standing waves*** are waves that look like they are locked in place and not moving.

***Nodes*** are the points of a standing wave that do not move.

***Anti-nodes*** are the points of a standing wave that have maximum movement.

Standing waves are formed by waves reflecting off the far side of the medium and interfering with new waves being sent down the medium. If waves are sent down the medium at the correct frequencies, standing waves will result as the waves interfere and add together.

The different standing wave shapes that can be formed are called ***harmonics***.

The frequencies that standing waves occur at are called ***harmonic frequencies***.

Harmonic frequencies are multiples of the ***fundamental frequency*** (the frequency of the 1$^{st}$ harmonic).

## Sound

***Sound*** is longitudinal waves that travel through solid, liquid, and gas mediums. Our ears are designed to detect these longitudinal waves and our brains interpret the detected waves as sound.

***Speed of sound***: the speed of sound depends on the medium the sound travels through.

- Fastest through solids
- Slowest through gases
- In between through liquids

***Pitch***: how high or low the sound is.

- Corresponds with the frequency of the wave
- Frequencies below the level of human hearing are called ***infrasonic***
- Frequencies above the level of human hearing are called ***ultrasonic***

***Volume***: how loud the sound is.

- Corresponds with the amplitude of the wave

## Beats

When two waves of almost identical frequency are added together, you hear the volume of the sound alternate from high to low again and again. This alternation of the volume is called ***beats***.

The ***beat frequency*** is the frequency of the alternation between high and low volume. It equals the difference in the frequency of the two waves being combined.

Beat frequency = (frequency of wave 1) – (frequency of wave 2)

Beats occur because the waves change from times of constructive interference (high volume) to times of destructive interference (low volume) and back again.

## Doppler Effect

The ***Doppler Effect*** is the apparent change in the frequency of a wave due to relative motion of the source and the observer.

- The actual sound being produced never changes in frequency, it just sounds like it has changed to the observer
- Occurs whenever the source and observer are getting closer together or farther apart, whether it is the source or the observer that is actually moving

***Blue shift***: when the source is getting closer to the observer, the observer perceives a higher frequency (higher pitch).

***Red shift***: when the source is getting farther from the observer, the observer perceives a lower frequency (lower pitch).