Sononerds
in the classroom

ARDMS Topic: Ultrasound Physical Principles

Unit 2: Sound Waves

Sononerds Ultrasound Physics Workbook & Lectures

Unit 2: Sound Waves

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Section 2.1 Sound Waves

Before we can understand what ultrasound is, we need to look at what sound is. We will take a look at some basic physical principles behind the concept of sound and be sure to define some very key characteristics.

There are 5 things you need to know about sound:

- ➔ Sound is a type of wave that **carries energy**
- ➔ Sound is a **mechanical wave**
- ➔ Sound is a **longitudinal wave**
- ➔ Sound can only travel in a **straight line**
- ➔ Sound cannot travel through a **vacuum**

Section 2.1.1 Wave Energy

Waves are one way in which energy can be transferred from one location to another. In the case of ultrasound, the machine sends out a high frequency wave. The acoustic energy in the wave is transferred into the patient and some of that energy is transferred back to the machine.

When we are studying ultrasound, we will spend a lot of time on how the body affects the wave and energy transfer. This is known as **acoustic propagation properties.**

But, because we are using ultrasound on humans, we also need to be aware of how the energy coming from the machine affects the biological tissue. This is done through the study of **biological effects.**

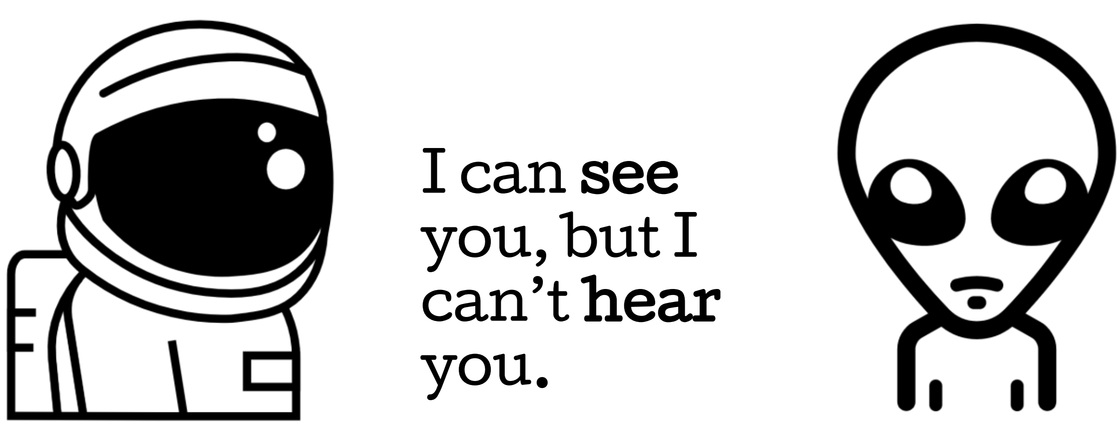
2.1.2 Classification of waves

Waves carry energy. There are many types of waves, but the big two are electromagnetic waves and mechanical waves. Some examples of these waves include:

Mechanical Waves	**Electromagnetic Waves**
Sound	Light
Ropes	Microwaves
Springs	X-rays
Seismic	Infrared & Ultraviolet
Water	Radio Waves

The big difference between the two is that electromagnetic waves DO NOT need a medium to travel in. They can carry energy through space or a vacuum.

Mechanical waves require a medium to propagate energy. The mechanical wave carries energy through particles found in a medium. In ultrasound, the medium is the body.

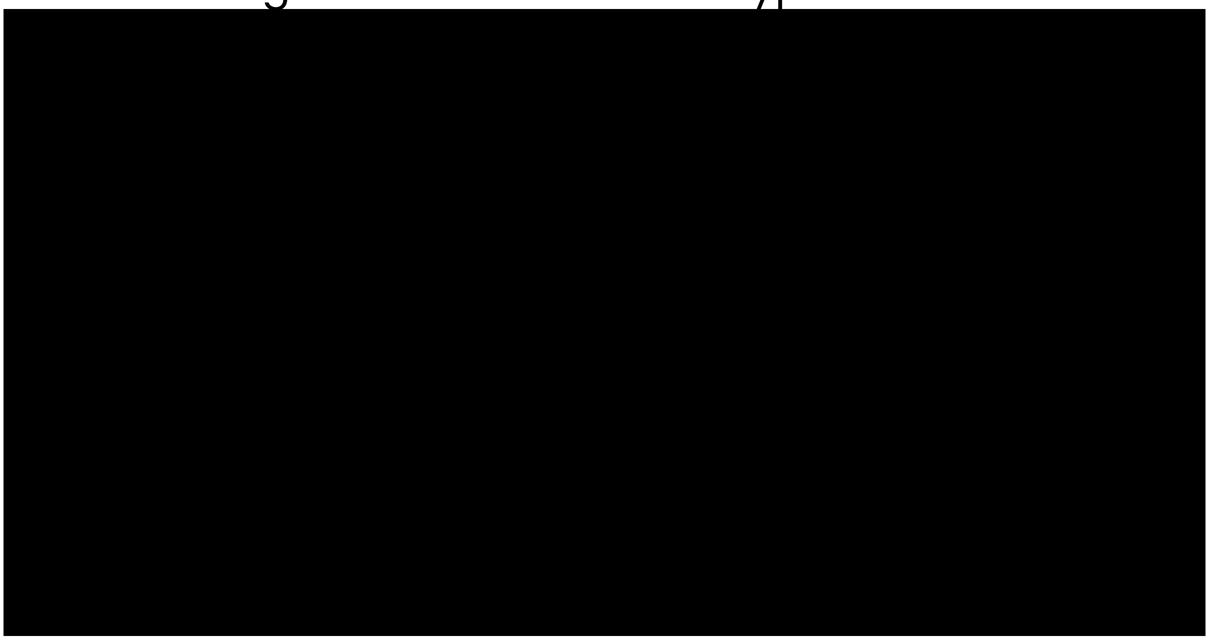


2.1.3 Mechanical Waves

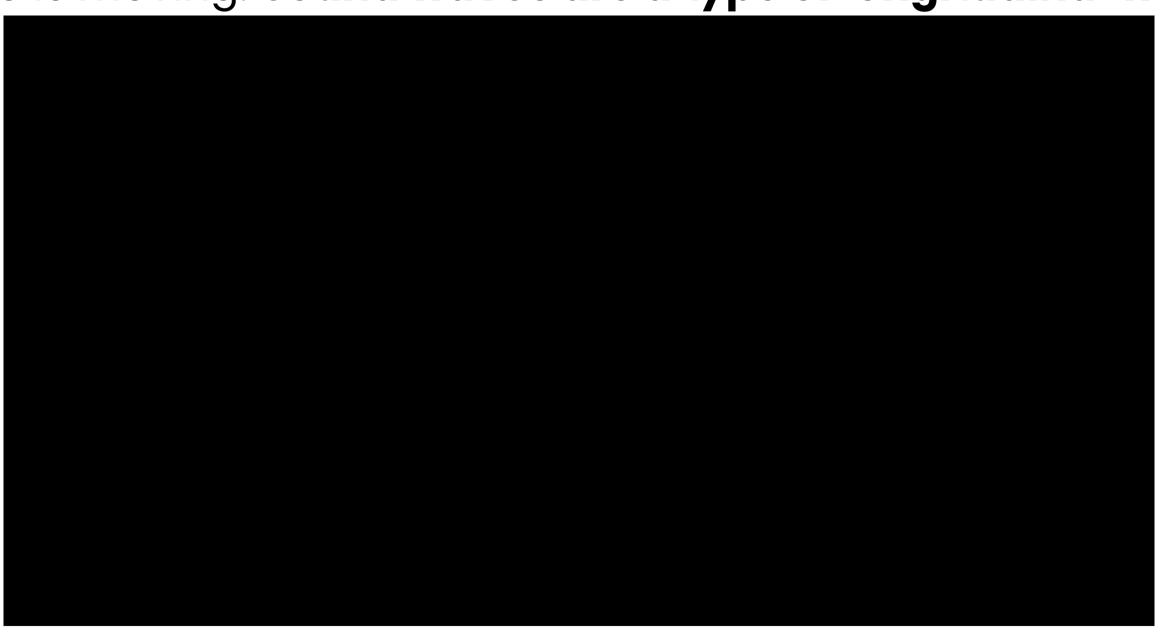
Mechanical waves require a medium to propagate or transfer energy through. The particles within the medium move as the energy interacts with them.

There are two types of mechanical waves:

- ➔ **Transverse** - particles move **perpendicular** to the direction the wave is moving. Ocean waves are a type of transverse wave.



- ➔ **Longitudinal** - the particles move **parallel** to the direction the wave is moving. **Sound waves are a type of longitudinal wave.**

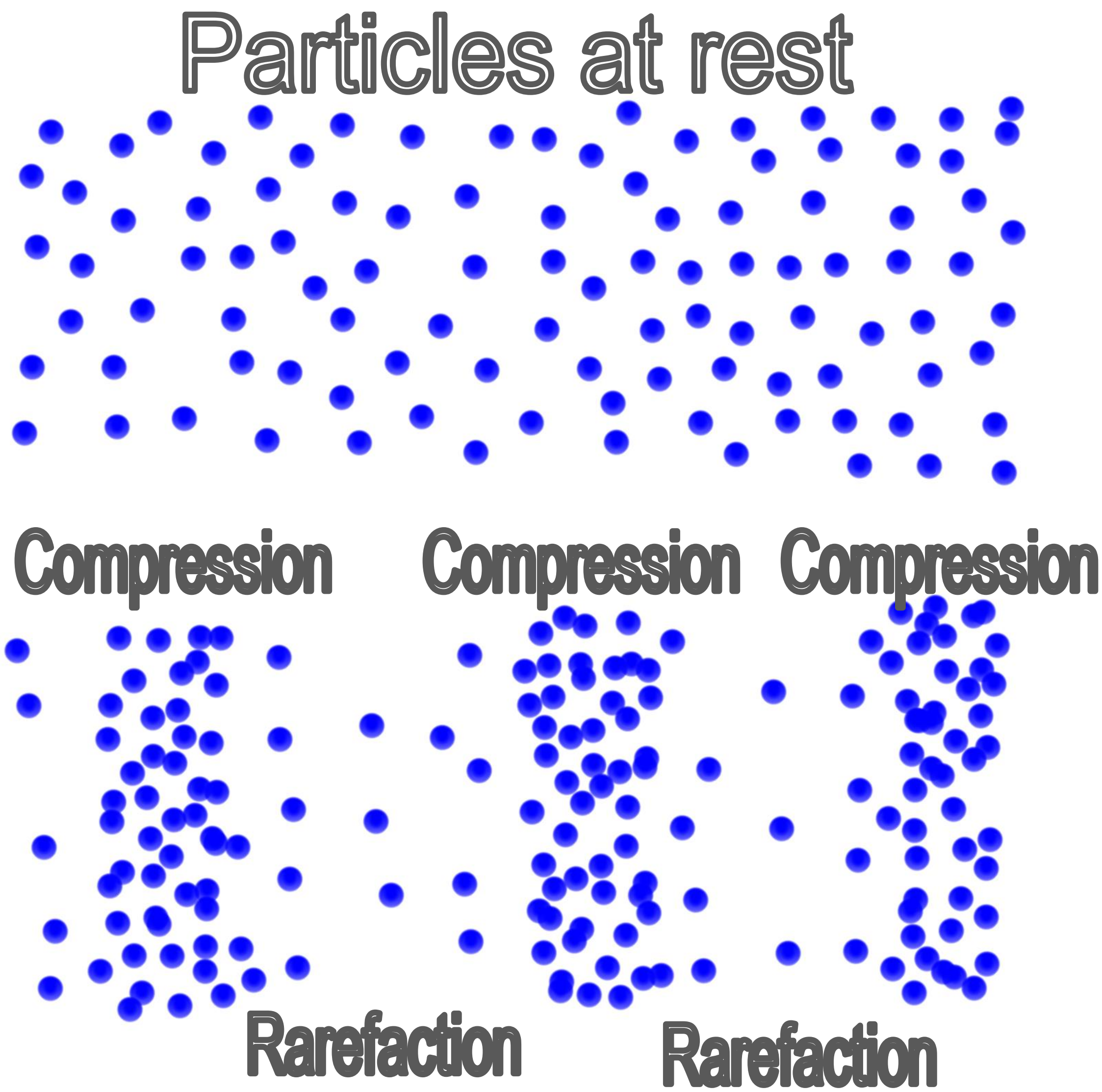


- ➔ **Note how the waves are traveling in a straight line.**

Sound waves are mechanical, longitudinal waves. The way they carry energy through a medium can be seen through cyclical **compressions and rarefactions.**

- ➔ **Compressions** occur when the particles in the medium are squeezed together. At the point of compression the particles are undergoing the most **pressure** and are at the highest **density.** They have also traveled a **distance** from their resting place.

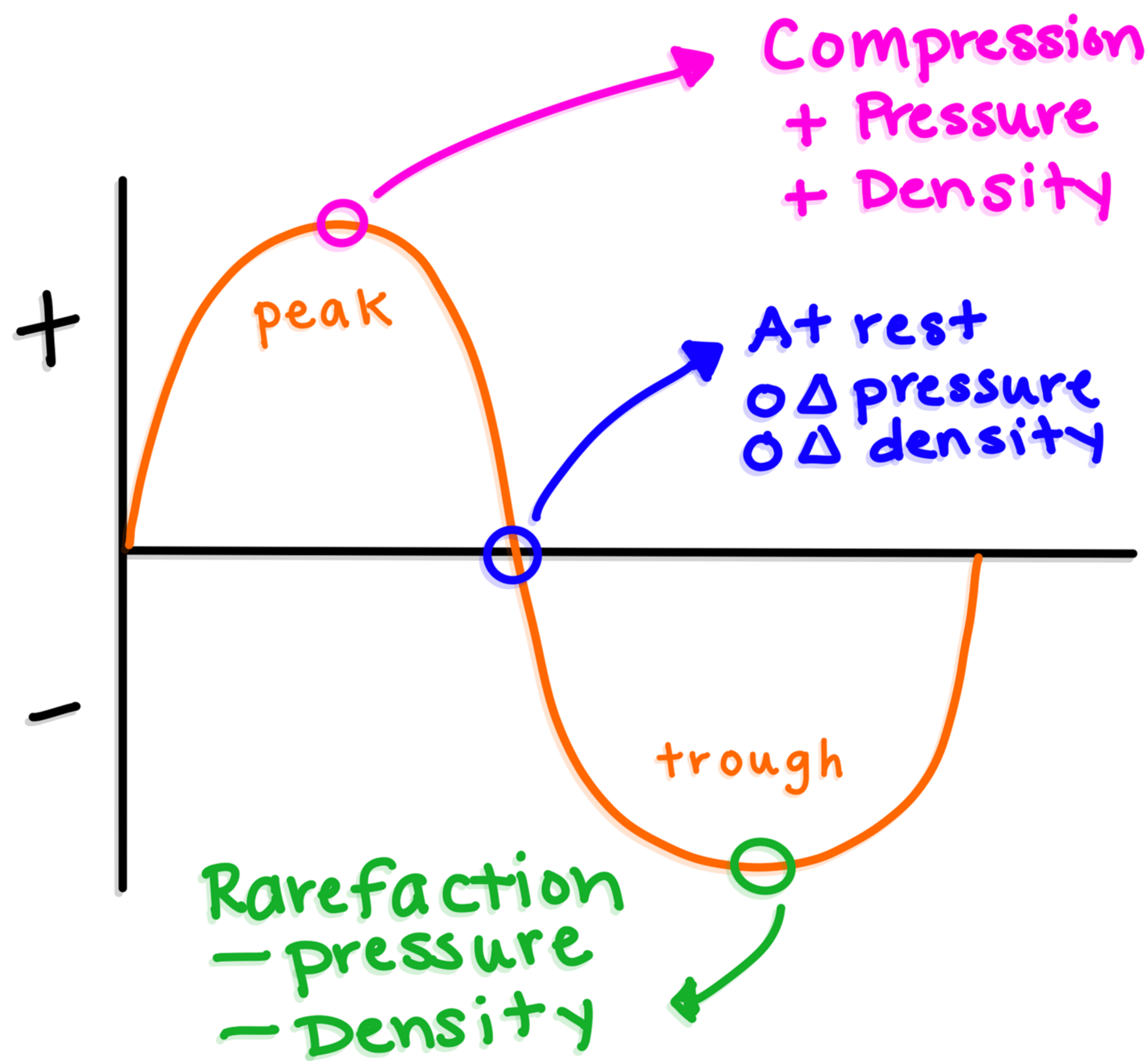
- ➔ **Rarefactions** occur when the particles in the medium are stretched apart. During rarefaction, the particles are at their least amount of **pressure** and have the lowest **density.** During rarefaction, some particles have also traveled a **distance** from their resting place.



2.1.4 Acoustic Variables

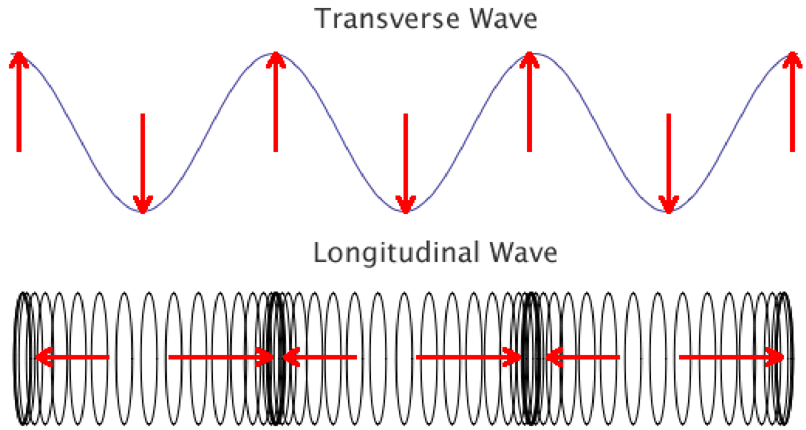
To identify a sound wave, there must be a cyclical change in at least one of the acoustic variables. The acoustic variable include:

- ➔ **Pressure** - Measured in Pascals (Pa), this is the force in an area.
- ➔ **Density** - Mass per unit of volume, density is usually expressed in kilograms per centimeters cubed (km/ cm^3)
- ➔ **Particle Motion (distance)** - distance a particle moves, measured in a length unit (cm, mm, ft, miles)

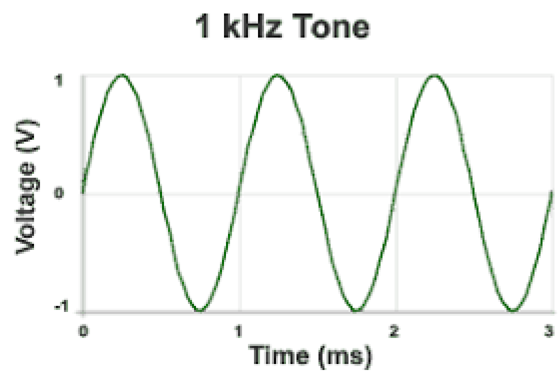


- ➔ **Know the multiple names for the parts of a sound wave.**

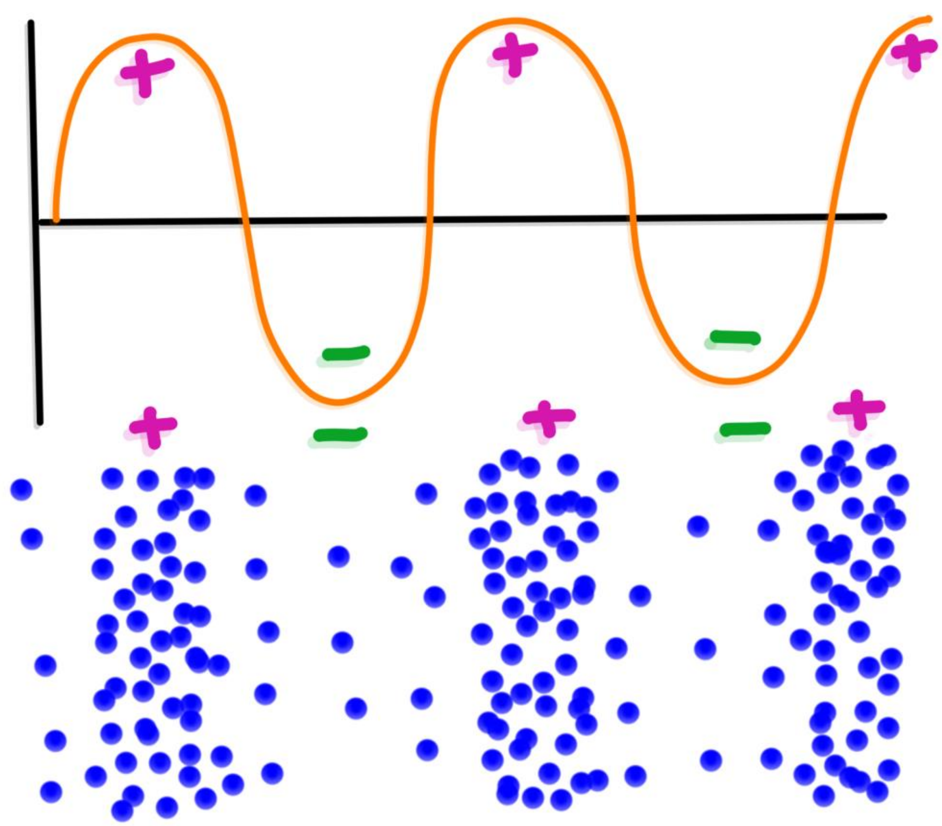
It's not uncommon for transverse and longitudinal waves to be diagrammed like this:



Which is why I think it is confusing when we diagram sound waves to also look like this:

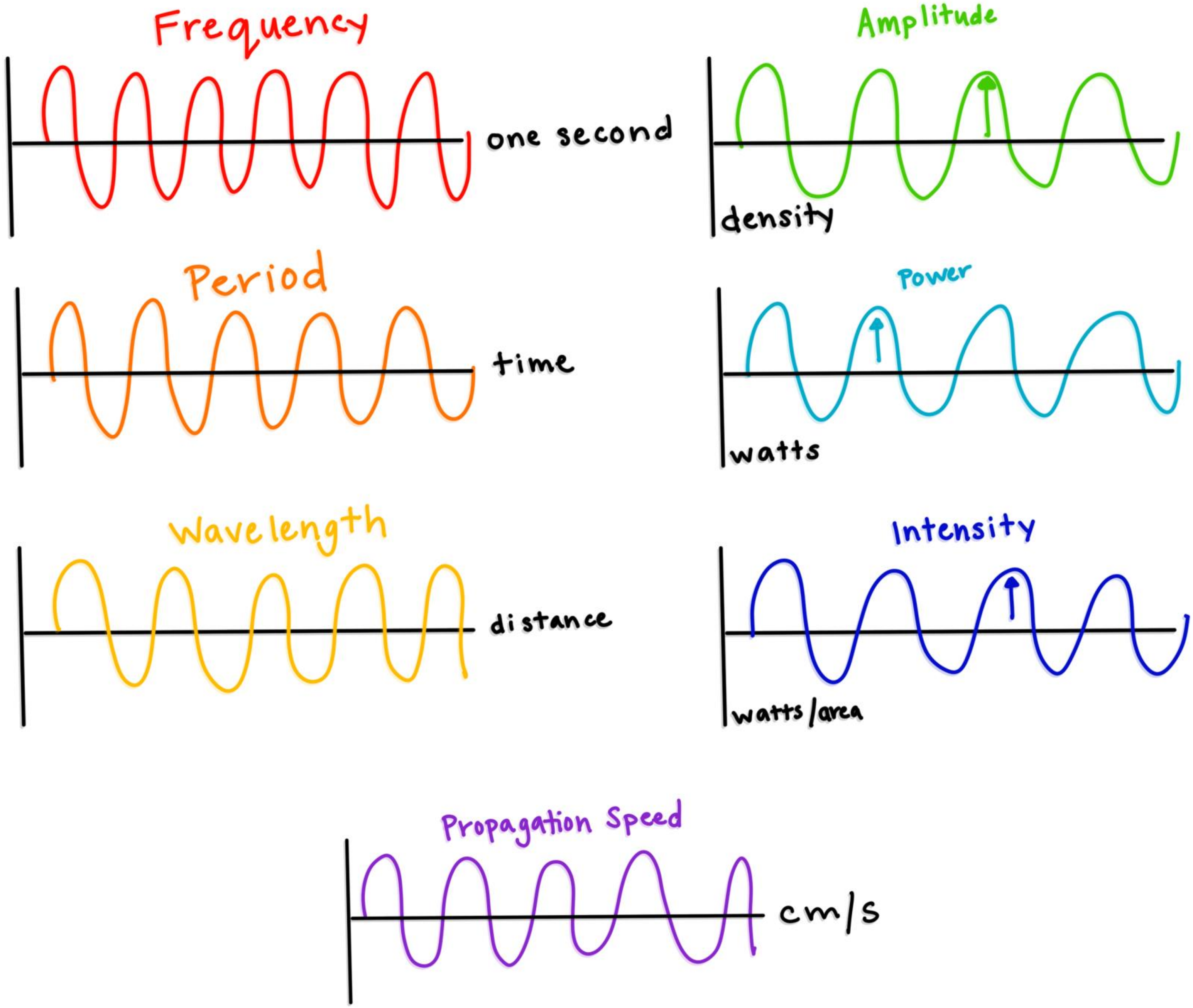


Remember that when we use the sinusoidal waveform to represent a sound wave, we are showing the positive and negative change of the acoustic variables.



2.1.5 Acoustic Parameters

Sinusoidal graphs can also help us to visualize the 7 acoustic parameters or descriptors of sound waves by changing the X or Y axis labels. We will discuss these 7 descriptors in detail in the next unit.



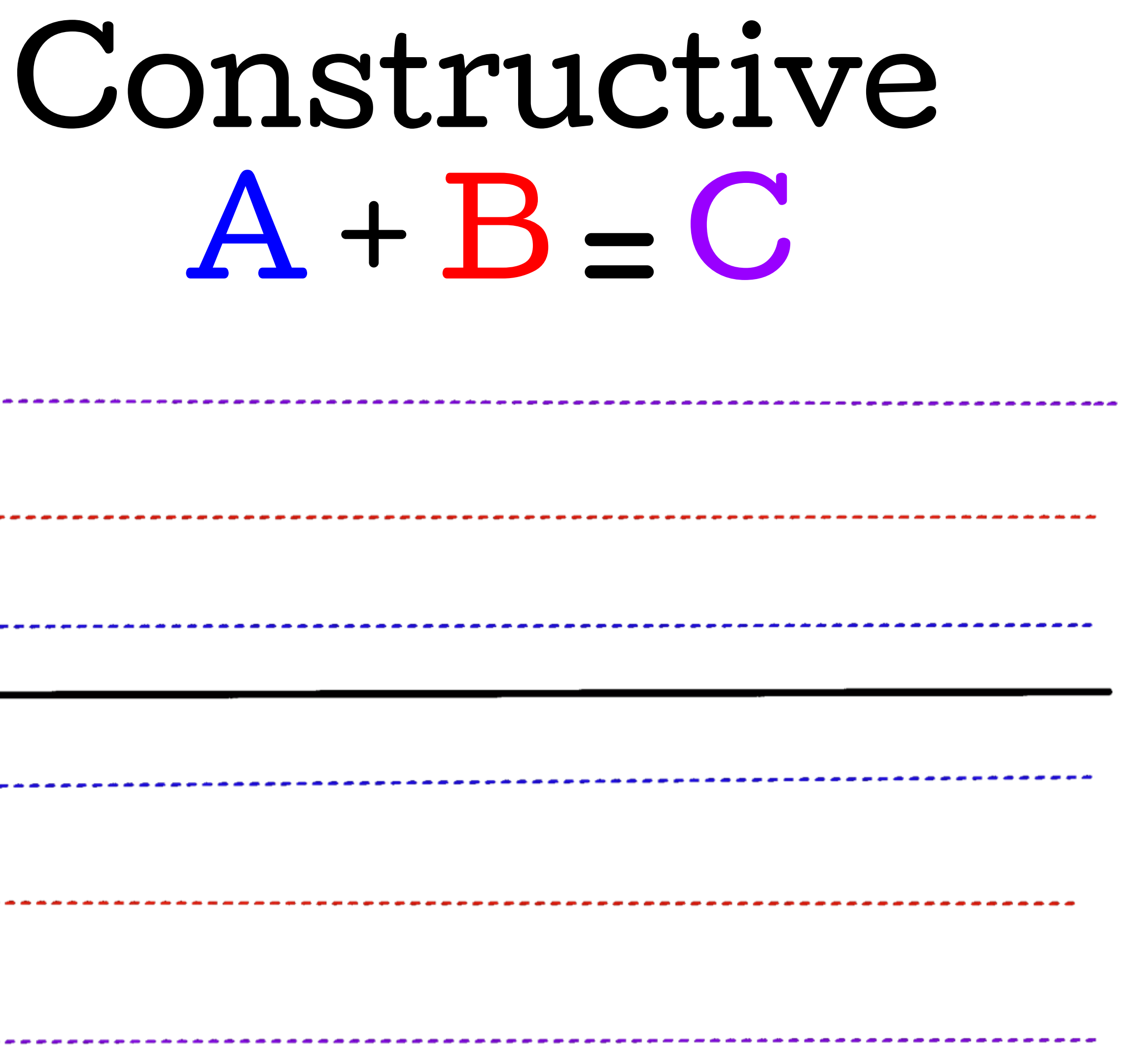
- ➔ **The 7 acoustic parameters are Frequency, Period, Wavelength, Amplitude, Power, Intensity & Propagation Speed**

2.1.6 Sound Wave Interaction

When a sound wave is produced is it rarely the only sound wave in the area. When sound wave come in "contact" with one another, they will interact. Their interaction causes each original sound wave to lose its properties as the two sound waves combine into a new wave. This is called **interference.**

Constructive Interference

Two wave that are in-phase (meaning their peaks and troughs line up) they will add to one another, making a bigger wave than either of the two original waves.

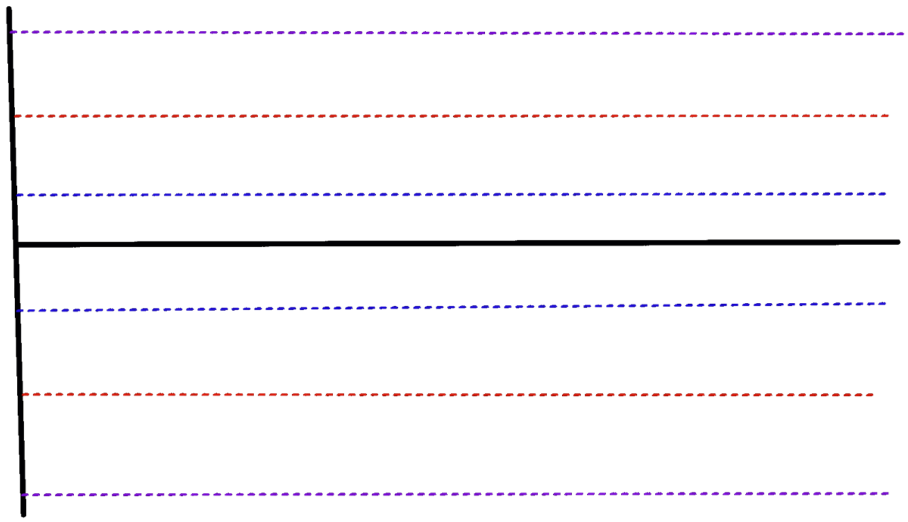


Destructive Interference

Two waves that are out-of-phase (meaning their peaks and troughs do not line up) will subtract from one another, making the new wave smaller than at least one of the original waves. Depending on the strength and the degree to which they are out of phase, the wave may look very different or only slightly different.

Destructive

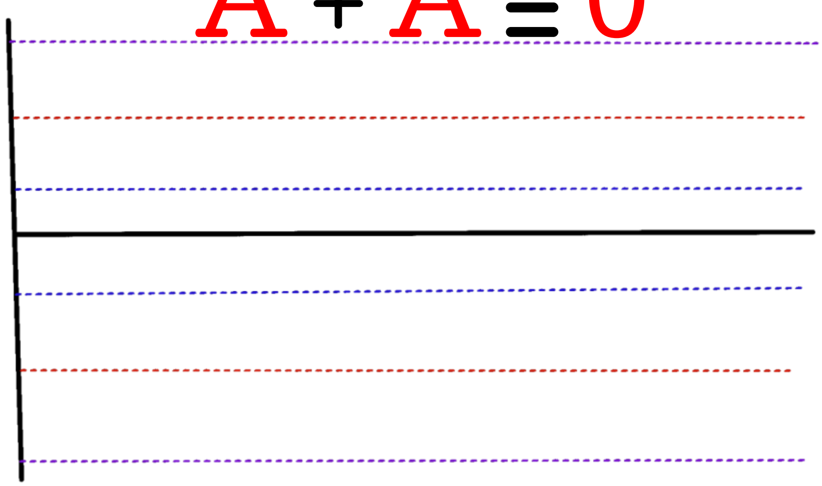
A + B = C



If two waves are the same strength and frequency and are are 180 degrees out of phase, then complete destruction will occur and they will cancel each other out.

100 % Destructive

A + A = 0

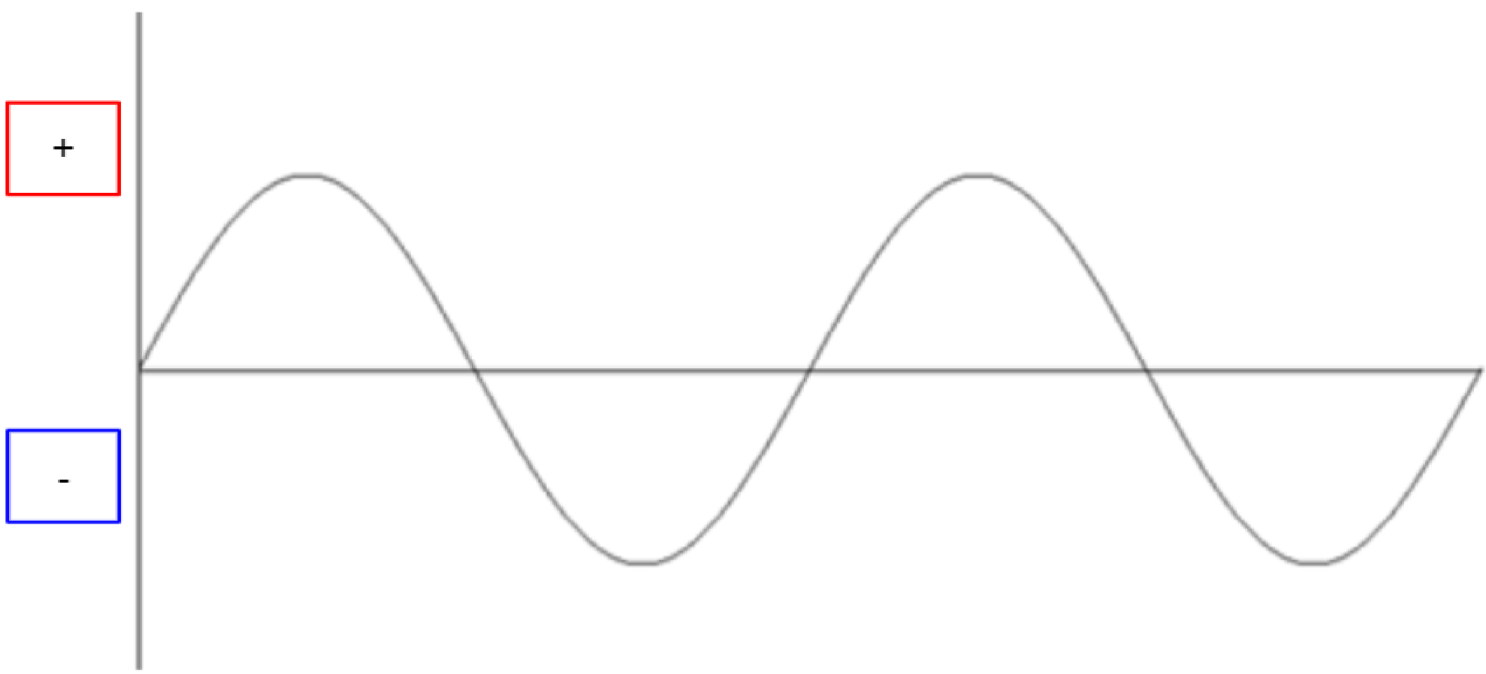


Section 2.2 Activities← Link to Answers

1. List the 5 things you need to know about sound:

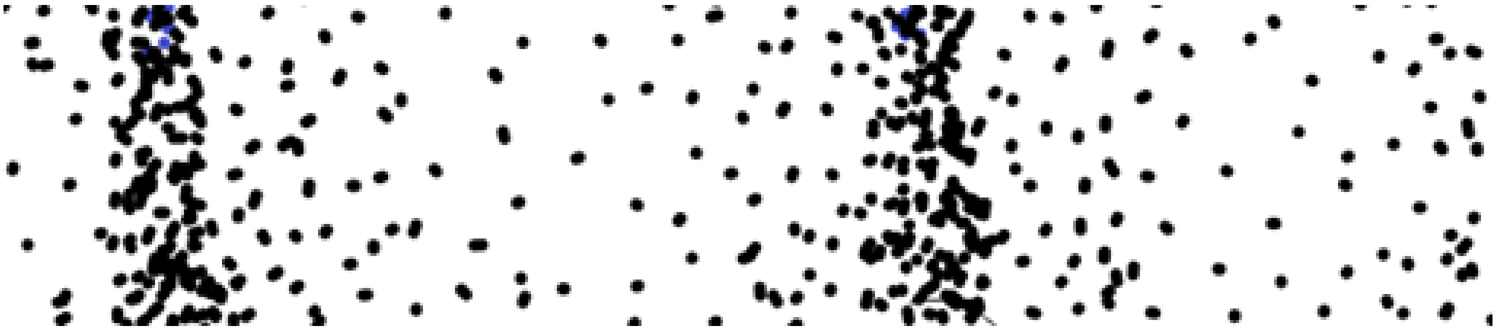
1.	
2.	
3.	
4.	
5.	

1. Drag the labels to the correct area:



Rarefaction	High Pressure	High Density	Low Density
Compression	Peak	Low Pressure	Trough

3. Drag the labels to the correct area:

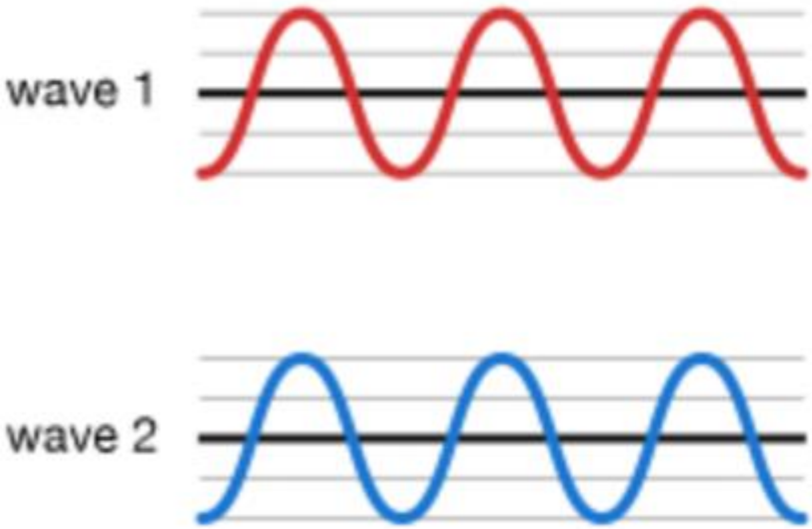


Rarefaction	High Pressure	High Density	Low Density
Compression	Peak	Low Pressure	Trough

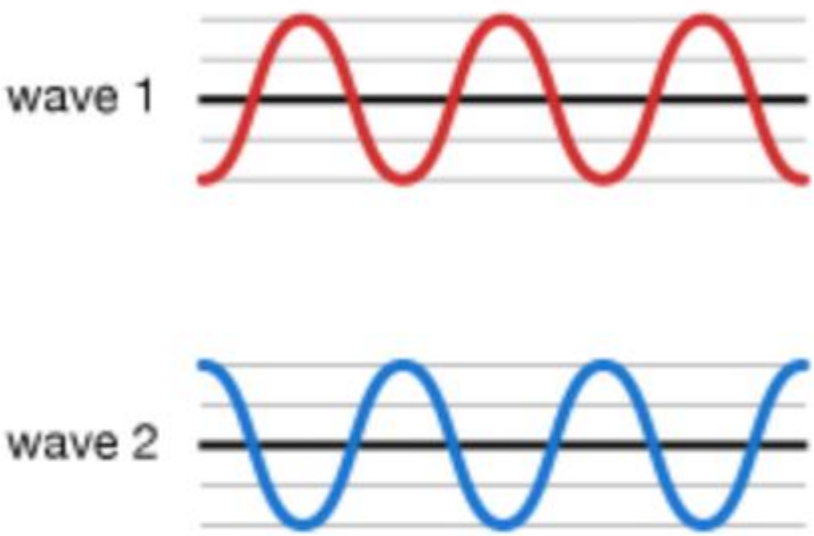
4. Complete the Acoustic Variable Chart:

Variable	Definition	Units

5. What will happen if wave 1 & wave 2 interfere with each other?



6. What will happen if wave 1 & wave 2 interfere with each other?



7. What are the 7 parameters that describe sound?

1.	
2.	
3.	
4.	
5.	
6.	
7.	

Section 2.3 Nerd Check!

1. What are the 5 things you need to know about sound?
2. What are acoustic propagation properties?
3. What are bioeffects?
4. What are the two main types of waves?
5. What are some examples of mechanical waves?
6. What are some examples of EM waves?
7. Can sound travel in space (vacuum)?
8. Can light travel in space (vacuum)?
9. What does sound require to propagate?
10. In ultrasound, what do we consider to be the medium in which sound travels?
11. What are the two types of mechanical waves?
12. Describe how a transverse wave particle moves.
13. Describe how a longitudinal wave particle moves.
14. Can sound bend?
15. Define a compression.
16. Define a rarefaction.
17. What are the 3 acoustic variables and their units?
18. What is another name for the area of compression?
19. What is another name for the area of rarefaction?
20. Where are high pressure/densities found?
21. Where are neutral pressure / densities found?
22. Where are negative pressure/ densities found?
23. What are the 7 acoustic parameters?
24. What is interference?
25. What is constructive interference?
26. What does it mean to be in-phase?
27. What is destructive interference?
28. What does it mean to be out-of-phase?
29. How does 100% destructive interference occur?