Grade 11 Notes June 1-5, 2020

Over the next coming weeks we will be finishing the unit on Sound and skimming the unit on Electromagnetism. It is important that you download the notes for Grade 12 as we will be expecting you to be familiar with the information.

This week we are going to continue our investigation of sound energy looking at

1. **The Principle of Superposition**
2. **Resonance**
3. **Resonance in Pipes and Strings**
4. **Beats**

Remember there is assignment due this week on Wednesday June 3, 2020. I will be sending out a new assignment Thursday this week. Questions email me.

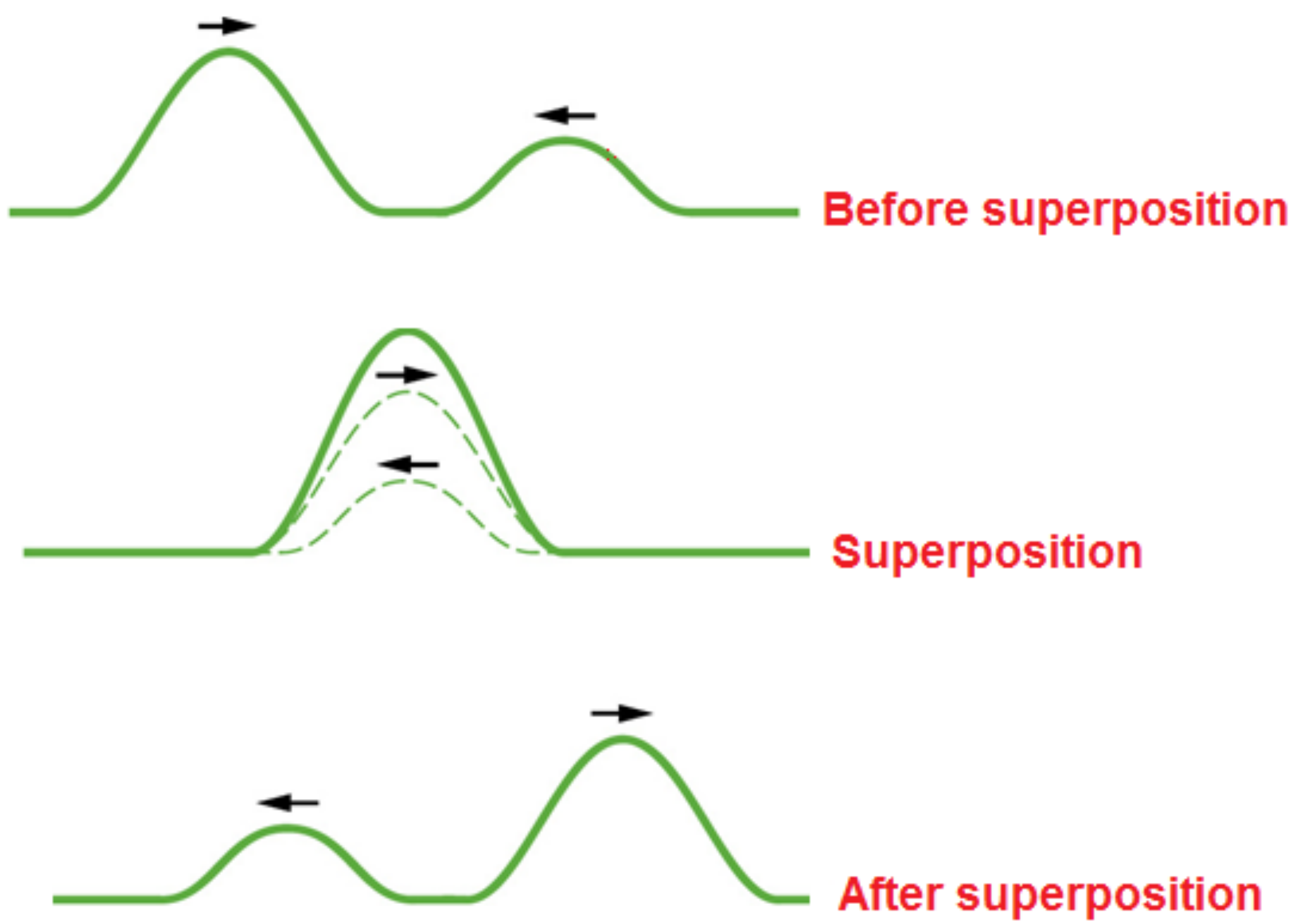
Have a good week.

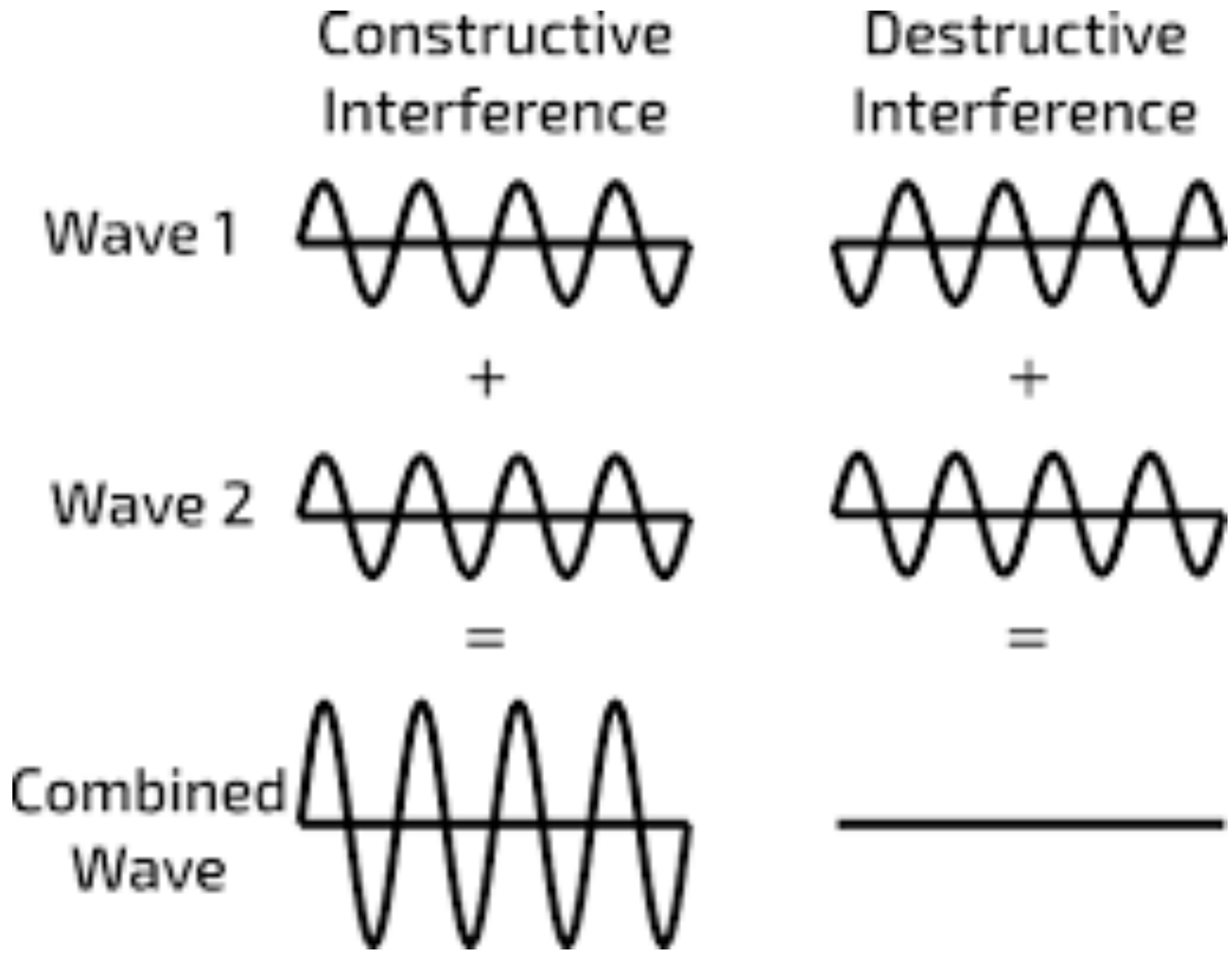
Miss Takken

1. The Principle of Superposition

What happens when two sound waves interfere? Do the sounds bounce off each? Pass through each other with no effect? Or pass through each other with effect? The answer is the last one. While the sounds are together the sound waves interfere but then pass through as if nothing happened.

This is the Principle of Superposition. The Principle of Superposition states that the resulting amplitude of two interfering pulses is the algebraic "sum" of the amplitudes of the "individual" pulses.





The wave sum can be constructive or destructive. If two sound destructively interfere they cancel each other out and we call the result a node. If you have two speakers 180^{o} out of phase with each other you can create a dead spot in the room. Anti-nodes are places of constructive interference where the wave is the highest.

If two waves constantly interfere we get what is called a **standing wave**.

Standing Wave Pattern

These points remains stationary and are called **nodes** or nodal points.

Midway between the nodes are areas where double crests and double troughs occur. These are called **anti-nodes**.

What is the distance between nodes?

This is called the internodal distance

$$d_n = ½\lambda$$

The number of internodal distances is always one less than the number of nodes. In the picture above there are 5 nodes so 4 internodal distances.

Mediums such as a guitar string are considered to be fixed as they are attached at both ends. The standing wave terminates with nodes.

Mediums such as car antennas have "free ends" and the waves terminate with an anti-node.

Example: A standing wave has distance of 45 cm between four consecutive nodes. What is the wavelength of the wave? What is the speed of the wave in the medium if the frequency of the source is 30 Hz?

Since there is four nodes that means we have 3 internodal distances or $3/2\lambda$.

$3/2\lambda = 45$
$\lambda = 2(45)/3$
$\lambda = 30$ cm = 0.3 m

$v = f\lambda$
$v = 30 \times 0.3$
$v = 9$ m/s

2. Resonance

Resonance is the response of an object that is free to vibrate to a periodic force with the same frequency as the natural frequency of the object.

Examples: wine glass breaking when opera singer sings, swings in park, windows shaking, soldiers breaking step while crossing a bridge, Tacoma Narrows Bridge

Sympathetic Vibration ~ same as resonance but another vibrating object supplies the periodic force (i.e. tuning forks)

https://www.youtube.com/watch?v=sxRkOQmzLgo

https://www.youtube.com/watch?v=dihQuwrf9yQ

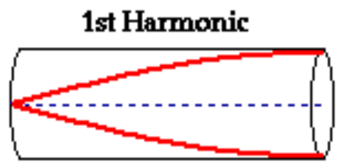
https://www.youtube.com/watch?v=C-V1uXeyGmg

Check out these videos on resonance and sympathetic vibrations. The second one is a super cool BBQ!

3. Resonance in Pipes and Strings

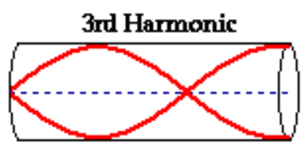
Pipes: Many instruments are basically columns of air that we resonate. Examples include flutes, clarinets, saxophones, trombones, pipe organ etc. But how does the instrument work.

Situation # 1 1 end open = closed air column (think playing a jug)



The red lines represent the resonant pattern set up in the column of air. Notice is has one end as a node and the other end as an antinode.

$\frac{1}{4}\lambda$ = 1st Resonant Length



$\frac{3}{4}\lambda$ = 2nd Resonant Length

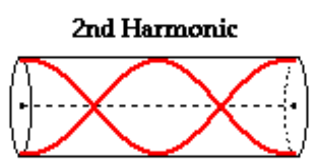
$5/4\lambda$ = 3rd Resonant Length

etc. the pattern continues.

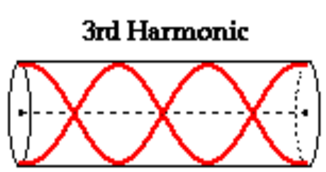
Situation # 2 Both ends open = open air columns

Notice that both ends of the red pattern are antinodes.

$\frac{1}{2}\lambda$ = 1st Resonant Length



1λ = 2nd Resonant Length



$3/2\lambda$ = 3rd Resonant Length
etc. The pattern continues.

Example:

Let's test the theory by working out the length of pipe needed to build a musical instrument that resonants with a 512 Hz tuning fork.

What is the formula to find λ? $v = f\lambda$

Let us choose a tuning fork of a set frequency i.e. 512 Hz

Today the temperature is 25^{o} so v must be

$v = 332 + 0.6(25) = 347$ m/s

Calculate the λ and about 3 resonant lengths for each type of air column.

$\lambda = v/f = 347/512 = 0.68$ m

Closed: The pattern is $1/4\lambda$, $3/4\lambda$, $5/4\lambda$ etc.

$1/4\lambda = 1/4(0.68) = 0.17$ m
$3/4\lambda = 3/4(0.68) = 0.51$ m
$5/4\lambda = 5/4(0.68) = 0.85$ m

Open: The pattern is $1/2\lambda$, λ, $3/2\lambda$ etc.

$1/2\lambda = 1/2(0.68) = 0.34$ m
$\lambda = 0.68$ m
$3/2\lambda = 3/2(0.68) = 1.02$ m

Resonance on Strings: Stringed instruments like guitars, pianos, violins etc. also deal with resonance, but each end is attached so has to end on a node.

The resonance on strings depend on four factors; tension, material, length and thickness (diameter) of the string. If any factor is changed the frequency changes.

The formula that relates these factors together is

$$\frac{f_2}{f_1} = \frac{\sqrt{T_2} \times L_1 \times d_1 \times \sqrt{\rho_1}}{\sqrt{T_1} \times L_2 \times d_2 \times \sqrt{\rho_2}}$$

where f stands for frequency, T stands for tension in Newtons (N), L stands for length in meters (m), d stands for diameter in meters (m) and ρ stands for density in kg/m^3.

Example: The frequency of one string of 50 cm length and with a diameter of 0.50 mm is 320 Hz. A second string under the same tension and made of the same material is 1.0 m long and 0.25 mm in diameter. What is the frequency of the second string? Note: Here tension and density are not changed or given so I am going put them in as a value of 1.

$$\frac{f_2}{f_1} = \frac{\sqrt{T_2} \times L_1 \times d_1 \times \sqrt{\rho_1}}{\sqrt{T_1} \times L_2 \times d_2 \times \sqrt{\rho_2}}$$

$$\frac{f_2}{f_1} = \frac{\sqrt{1} \times 0.5 \times 0.5 \times \sqrt{1}}{\sqrt{1} \times 1.0 \times 0.25 \times \sqrt{1}}$$

$$\frac{f_2}{f_1} = \frac{0.25}{0.25}$$

$$\frac{f_2}{f_1} = 1$$

$f_2 = 1 \times f_1 = 1 \times 320 = 320$ Hz. This is a case where two changes cancelled each other out and didn't change the sound.

Now you try pg 512 # 20, 21, 27, 28

4. Beats

When two tuning forks (or notes) of slightly different frequency are struck at the same time the longitudinal waves produced create an interference pattern and we hear **beats.**

Beats are periodic changes in sound intensity (loudness). Check out this video for a demonstration. https://www.youtube.com/watch?v=yia8spG8OmA

Beat Frequency = $|f_2 - f_1|$ (an absolute value, so beat frequency is always positive)

Example ~ Tuning pianos. A piano tuner strikes a 256 Hz tuning fork (middle C) and plays middle C on a piano. She hears 15 beats in 5.0 s. What are the possible frequencies of the out-of-tune note?

BF = 15/5.0
BF = 3 Hz

So the out of tune note is either 256 +/- 3 Hz or 253 Hz or 256 Hz. When the piano tuner hears the beats she doesn't know if she is too high or too low. She tightens the string and if the beat frequency goes up she know she should have loosened the string. If it goes down she was going the right way.