SPH3U

Unit 1.1

Characteristics of Waves

- wave
- oscillate
- vibrate
- medium
- pulse
- mechanical wave
- electromagnetic wave
- transverse wave
- crest
- trough
- cycle
- periodic
- comrpesssions
- rarefractions

Wave on a string Simulation

1. Describe the Simulation

A string suspended at two points. The left side of the string moves up and down while the right side is clamped in place.

2. What caused the wave?

Moving the wrench up or down forms a wave that propogates along the string.

3. Tension: Increasing the tention of the string increases the speed of the wave through the spring. Decreasing the tention of the string slows the speed of the wave through the string.

Damping: Increasing damping makes the wave fade away faster.

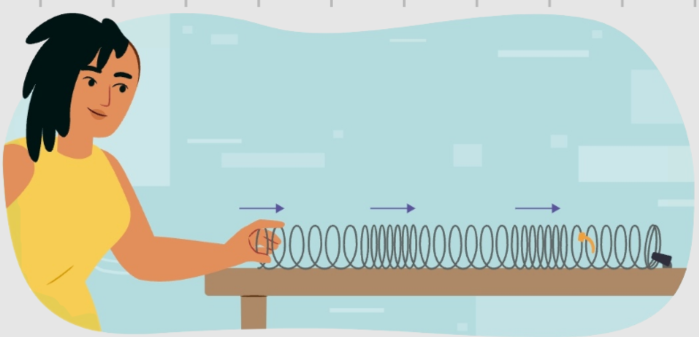
Fixed and Loose end: The wave behaves the same with these however the loose end itself shifts with the approaching wave.

No End: The wave does not reflect back, it just goes out the window forever?

Classifying Waves

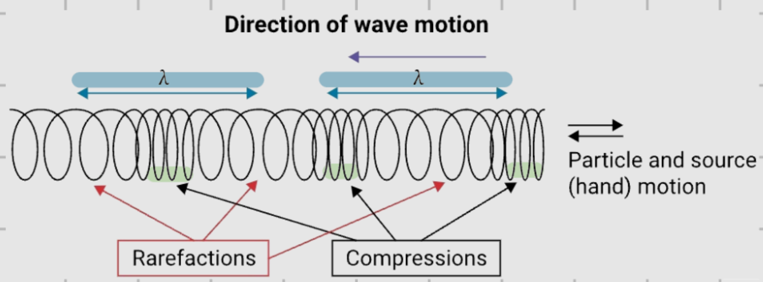
- **All waves**
  - Mechanical waves (need a medium)
    - Longitudinal (for example, sound waves)
    - Transverse (for example, water waves)
  - Electromagnetic waves (can travel without a medium)

Longitudinal waves occur when medium particles vibrate parallel to the wave's direction



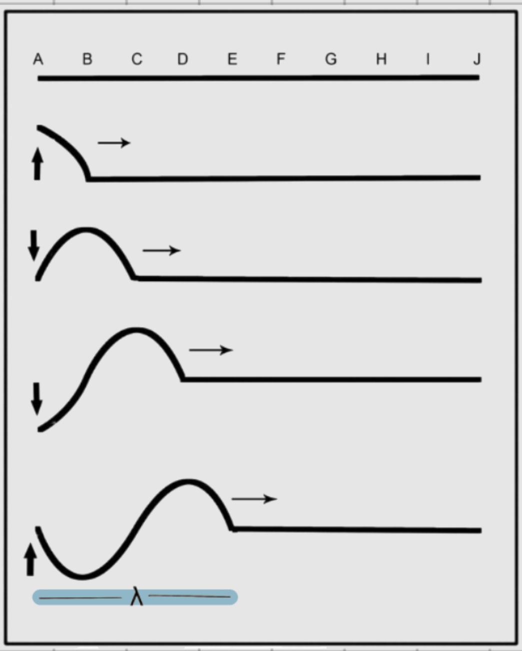
These waves can be visualized using a slinky: pushing it creates compressions (bunched coils), and pulling it creates rarefactions (spread coils)

These compresssions are rarefractions travel along the slinky, parallel to the direction of wave motion



In a transverse wave, particle motion and energy travel are perpendicular

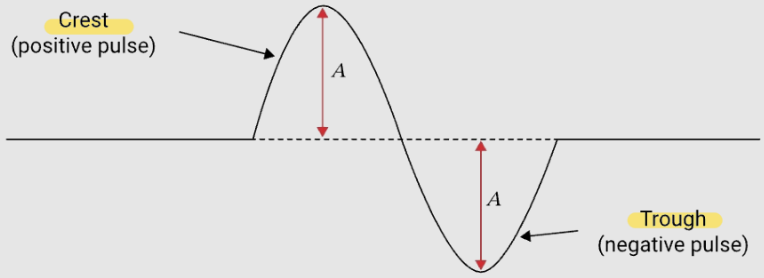
Energy moves across while particles stay in place, transferring energy sequentially



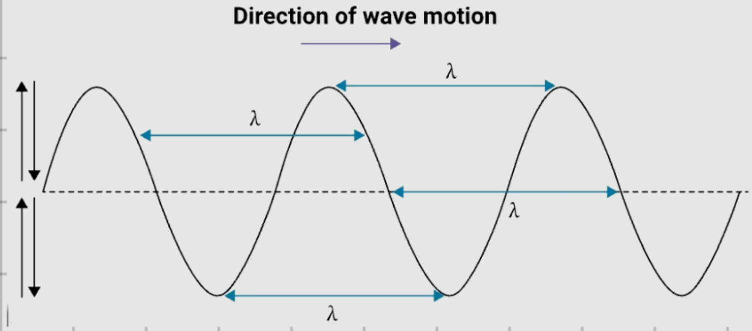
The distance the wave travels after one vibration is called the Wavelength λ

A wavelength is the distance between successive compressions or rarefactions, and amplitude is the maximum displacement from the rest position *(closeness of coils in compressions)*

Sound waves are a common example of a longitudinal wave....*now that I think about it, so is highway traffic lol*



The highest section of the wave is called the crest, the lowest section is called the trough



There are multiple ways to measure the wavelength λ

Properties of Waves Simulation

1. How is a longitudinal wave different from a transverse wave?

Particle vibration is parallel to the wave's direction in a longitudinal wave but perpendicular to the wave's direction in a transverse wave.

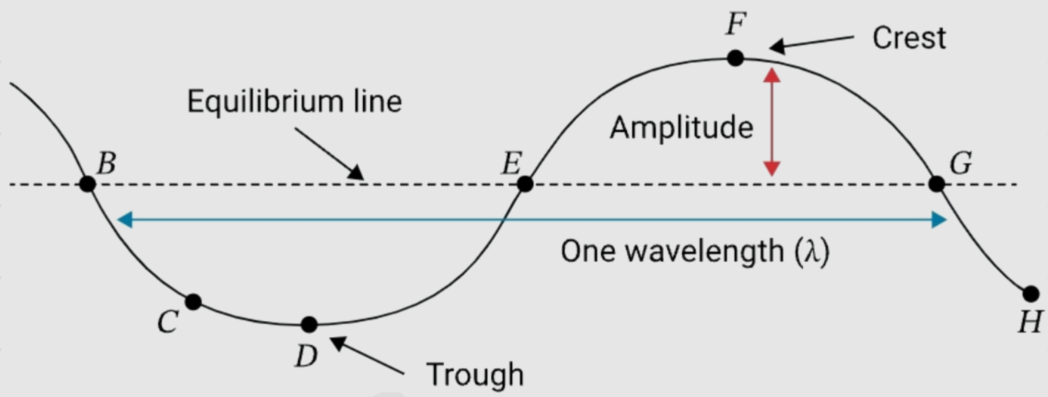
2. How would you describe a compression in a longitudinal wave?

When particles in the medium bunch up together

3. What is the highest point in the transverse wave called?

The highest point in the transverse wave is called the crest.

4. In the diagram, what is the distance from E to G in terms of wavlelenghts?



One wavelength λ is point B to point G, and since point E is halfway between point B and point G, that means the distance between point E to point G is $\frac{1}{2}\lambda$ or half a wavelength.

Scientific Notation

Scientific notation is used regularly in physics to help us communicate very large or very small numbers where standard notation would involve too many zeros which can be confusing and difficult to read.

For example, the mass of earth in kg:

6×10^{24} kg or 6000000000000000000000000 kg

Another example, the mass of an electron in kg:

9×10^{-31} kg or 0.0000000000000000000000000000009 kg

$M \times 10^{n}$ → n is the number of decimal places to be moved

→ M is a number 1 or larger but below 10

a positive n indicates a large number
a negative n indicates a small number

Examples:

299,792,458 m/s → 2.99×10^8 m/s
1 2 3 4 5 6 7 8

0.000007 m → 7.0×10^{-6} m
1 2 3 4 5 6

93.476 g → 9.3476×10^4 g
1 2 3 4

0.00391 s → 3.91×10^{-3} s
1 2 3

Significant Figures

Rule applied	Examples
All digits 1-9 (non-zeros) are significant.	193 has 3 significant figures.
Zeros between significant digits are significant.	6003 has 4 significant figures.
Leading zeros (those with no significant digits to the left) are not significant.	0.00345 has only 3 significant figures.
Trailing zeros (those to the right of all other significant digits) are significant only if a decimal point is present.	0.000000980 has 3 significant figures. 0.14000 has 5 significant figures.

In general, your final answer should have the same number of *sigfigs* as the smallest number of sigfigs used in our caluclations

Quantifying Wave Motion

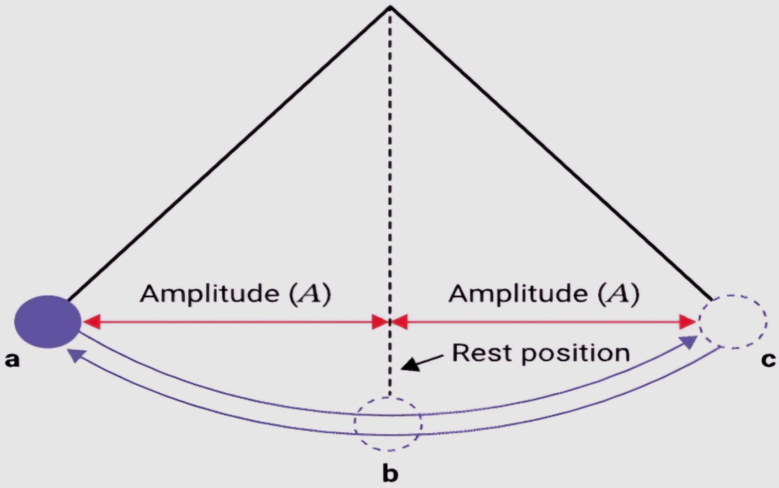
Simple pendulum, example of periodic motion

A complete cycle of the pendulum involves moving from a starting point (a), through the lowest point (b), to the opposite extreme (c), and back to the start.

Amplitude (A) is the maximum displacement from the rest position.

1 cycle = 1 vibration = 1 oscillation

A Simple Pendulum



One vibration or one cycle

Period

The period (T) is the time for one complete cycle, typically measured in seconds.

Period Formula: $T = \frac{\text{total time}}{\text{number of cycles}}$

Example: Period of a pendulum

The pendulum makes 20 cycles in 5.0 seconds. What is the time needed to complete one cycle?

Step	Example
Given	$\text{Total time} = 5.0\ \text{s}$ $\text{Number of cycles} = 20$
Unknown	$\text{Period } (T) = ?$
Equation	$T = \frac{\text{total time}}{\text{number of cycles}}$
Solve	$T = \frac{5.0\ \text{s}}{20} = 0.25\ \text{s}$
Statement	The time to complete one cycle is **0.25 s.**

The total time had 2 significant digits, and the number of cycles can be considered exact. Therefore, our final statement had 2 significant digits.

The period is usually measured in seconds, but larger units of time can be used for convenience if the period is very long. For example, the period of the moon orbiting the Earth is 27.3 days.

1. A pendulum swings through 4 cycles in 20 s. What is the period of the pendulum?

$T = \frac{20\ s}{4} = 5$ seconds

2. A pendulum swings from one side to the other in 10 s. What is the period?

$T = \frac{10\ s}{0.5} = 20$ seconds

3. A pendulum swings through 30 cycles in 1 minute. What is its period?

$T = \frac{60s}{30} = 2$ seconds

Frequency

The number of cycles per second is called frequency (f). The unit of frequency is the hertz (Hz). Note: 1 Hz = 1/s.

Frequency Formula : $f = \frac{\text{number of cycles}}{\text{total time}}$

A pendulum swings through 12 cycles in 24 seconds. What is the frequency of the pendulum?

Step	Example
Given	$\text{Number of cycles} = 12$ $\text{Total time} = 24\text{ s}$
Unknown	$\text{Frequency } (f) = ?$
Equation	$f = \frac{N}{t}$
Solve	$f = \frac{12}{24\text{ s}} = 0.50\text{ Hz}$
Statement	The frequency of the pendulum is **0.50 Hz.** (The pendulum completes 0.5 of a cycle in 1 s.)

Time had 2 significant digits, and number of cycles is exact, so our final answer was recorded with 2 significant digits.

Relationship Between Period and Frequency

$T = \frac{1}{f}$ \& $f = \frac{1}{T}$ They're inverse!

If you know the period you can find the frequency and if you know the frequency you can find the period!

Example: A pendulum vibrates 22 times in 11 s. Find the period and the frequency.

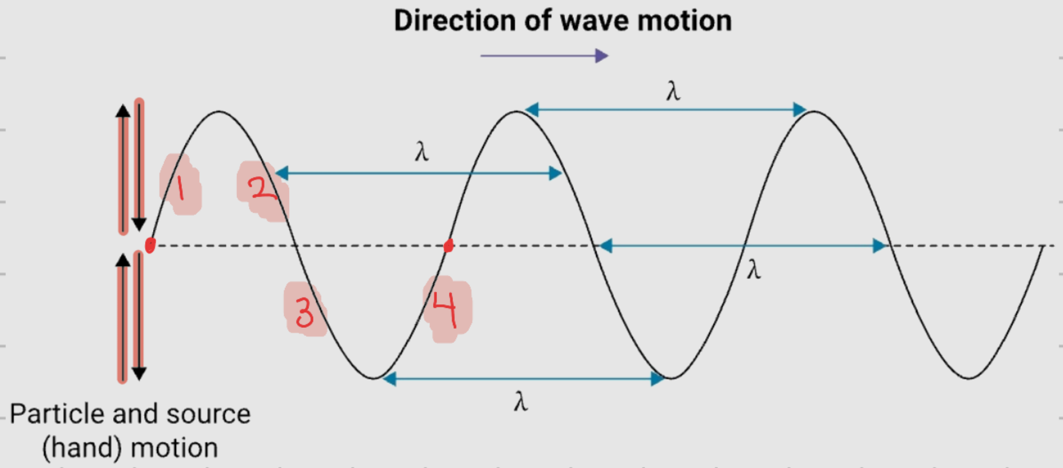
$$T = \frac{\text{total time}}{\text{number of cycles}} = \frac{11\,s}{22} = 0.5\,s$$

$$f = \frac{1}{T} = \frac{1}{0.5\,s} = 2.0\,Hz$$

∴ The period of the Pendulum is 0.5 s and the frequency of the pendulum is 2.0 Hz.

Amplitude

Ampltiude is the distance a particle moves from its rest position.



In one full cycle, the pendulum will travel four amplitudes.

Example:
A student is sitting on a swing, going back and forth with a constant amplitude of 1.4 m. Find the total horizontal distance that the student moves through in five cycles.

Number of amplitudes = 4 x 5 cycles = 20
Total horizontal distance = 20 x 1.4 = 28 m

∴ The student moves 28 m horizontally.

Speed of a Wave

Formula

$$v = \frac{d}{t}$$

- *v* represents the speed of the wave, in metres per second (m/s)
- *d* represents the distance the wave travels, in metres (m)
- *t* represents the time it takes for the wave to travel, in seconds (s)

The length of the wave has a special name, the wavelength (λ), so instead of using *d*, use λ.

The time for a wave to complete on cycle also has a special name, the period (T), so instead of t, use T.

This gives us a new formula for speed of a wave:

Formula

$$v = \frac{\lambda}{T}$$

- *v* represents the speed of the wave, in metres per second (m/s)
- λ represents the length of one cycle of the wave, in metres (m)
- *T* represents the time for one cycle of the wave to pass by, in seconds (s)

Since there is an inverse relationship between frequency and period, we can multiply by frequency instead of dividing by period, this is the universal wave equation:

Formula

Universal wave equation

↳ works for any wave

$$v = f\lambda$$

- *v* represents the speed of the wave, in metres per second (m/s)
- λ represents the length of one cycle of the wave, in metres (m)
- *f* represents the frequency of the wave, in Hertz (Hz)

Example 1: Universal wave equation

A sound wave has a frequency of 256 Hz and is travelling at 335 m/s. What is the wavelength of the sound wave?

$$V = f\lambda \rightarrow \lambda = \frac{V}{f} = \frac{335 \text{ m/s}}{256 \text{ Hz}}$$

$$\lambda = 1.31 \text{ m}$$

∴ the wavelength of the sound wave is 1.31 m

Example 2: Water Wave

The wavelength of a water wave in a swimming pool is 4.0 m. The wave travels 6.0 m in 2.7 s. Find the frequency of the wave.

$$V = f\lambda \rightarrow f = \frac{V}{\lambda}$$

$$V = \frac{\text{distance}}{\text{time}} = \frac{6.0\ m}{2.7 s} = 2.22\ m/s$$

$$f = \frac{2.22\ m/s}{4.0 m} = 0.555\ Hz$$

$\therefore$ The frequency of the wave is 0.56 Hz

"Wave on a string" Simulation

Conclusion: The speed of a wave pulse (no matter the amplitude or width) remains constant as long as it is in the same medium.

Practice 1:

A sound wave has a frequency of 1200 Hz and a wavelength of 0.4 m. Determine its speed.

$$v = f\lambda = 1200 \times 0.4\ m$$

$$v = 480\ m/s$$

Practice 2:

A boat bobs up and down 12 times in 24 s. The speed of the waves is 3 m/s. What is the wavelength of the waves.

$$f = \frac{\#\text{ of cycles}}{\text{time}} = \frac{12}{24} = 0.5\ Hz$$

$$v = f\lambda \rightarrow \lambda = \frac{v}{f} = \frac{3\ m/s}{0.5 Hz}$$

$$\lambda = 6\ m$$

Practice 3:

A wave in a rope travels 8.0 m in 0.25 s. If the wavelength is 2.0 m, find the frequency.

$$v = \frac{\text{distance}}{\text{time}} = \frac{8\text{ m}}{0.25\text{ s}} = 32\text{ m/s}$$

$$v = f\lambda \rightarrow f = \frac{v}{\lambda} = \frac{32\text{ m/s}}{2.0\text{ m}}$$

$$f = 16\text{ Hz}$$

Reflection of Waves

Fixed end

When a wave reaches a fixed end, the wave flips upside down (inverts), everything else (amplitude, speed, wavelength) remain the same.

Free end

When a wave reaches a free end, the wave ***does not*** flip upside down, nothing changes, amplitude, speed and wavelength remains the same.

end of 1.1

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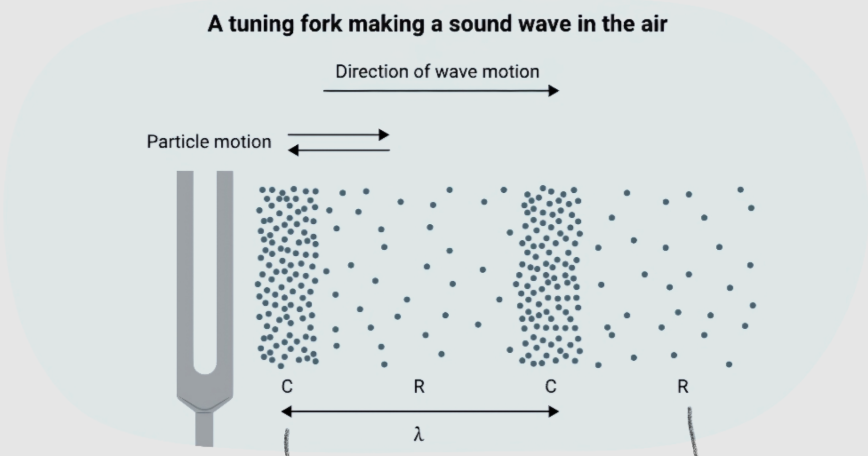
Unit 1.2

Transmission of Waves

- noise
- frequency
- hertz
- decibel (dB)
- logarithmic scale
- Doppler effect
- density
- ultrasonic



Longitudinal Wave

compressions

rarefractions

Speed of Sound in Air

Sound travels at 332 m/s at normal air pressure and 0°C and the speed of sound increases with higher air temperatures.

For each 1°C increase in temperature, the speed of sound increases by 0.59 m/s.

Formula

$$v = 332\ \mathrm{m/s} + (0.59\ \mathrm{m/s} \bullet {}^{\circ}\mathrm{C})T$$

Where *T* is the temperature in degrees Celsius.

Note: This equation can only be used when the sound is travelling through air. If it is travelling in a different medium, for example water, you cannot use this equation.

Example 1:

Calculate the speed of sound in air when the temperature is 18°C.

$V = 332 \text{ m/s} + (0.59 \text{ m/s} \cdot {}^\circ C)T$

insert T and solve for V

$V = 332 \text{ m/s} + (0.59 \text{ m/s} \cdot {}^\circ C) \times (18^\circ C)$
$= 332 \text{ m/s} + 10.62$
$= 342.62 \rightarrow$ round for 2 sigfigs $= 340$

$\therefore$ the speed of sound is 340 m/s in 18 °C air

Example 2: Finding the wavelength of sound

A 350 Hz tuning fork is sounded outside where the temperature is -20.0 °C. What is the wavelength of the sound?

Plan: $V = f\lambda \rightarrow \lambda = \frac{V}{f}$ I have f, I need V

$V = 332 \text{ m/s} + (0.59 \text{ m/s} \cdot {}^\circ C)T$

$V = 332 \text{ m/s} + (0.59 \text{ m/s} \cdot {}^\circ C) \times (-20^\circ C)$
$= 332 \text{ m/s} - 11.8$
$= 320.2 \text{ m/s}$

$$\lambda = \frac{V}{f} = \frac{320.2 \text{ m/s}}{350 \text{ Hz}}$$

$= 0.9148 \text{ m} \rightarrow 0.91 \text{ m}$ 2 sigfigs

$\therefore$ the wavelength of the sound is 0.91 m.

Example 3: Finding air temperature

What is the temperature if the speed of sound is 360 m/s?

$$V = 332\ m/s + (0.59\ m/s \cdot {}^\circ C)T$$

$$360\ m/s = 332\ m/s + (0.59\ m/s \cdot {}^\circ C)T$$

Plug in V

isolate and solve for T

$$360\ m/s - 332\ m/s = (0.59\ m/s \cdot {}^\circ C)T$$

$$28\ m/s = (0.59\ m/s \cdot {}^\circ C)\ T$$

$$\frac{28\ m/s}{0.59\ m/s \cdot {}^\circ C} = T$$

$$T = 47.45^\circ C \rightarrow 47^\circ C \quad \text{2 sig figs}$$

∴ the temperature of the air is 47°C.

Speed of Sound in various materials

Sound waves travel at different speeds through solids, liquids, and gases due to the arrangement and interaction of their particles.

State	Material	Speed of sound (m/s)
Gas	Carbon dioxide	258
	Oxygen	317
	Nitrogen	338
	Helium	970
	Hydrogen	1270

In gases, particles are spread out with almost no attraction, meaning they must physically collide to transmit sound, making it the slowest medium for sound travel.

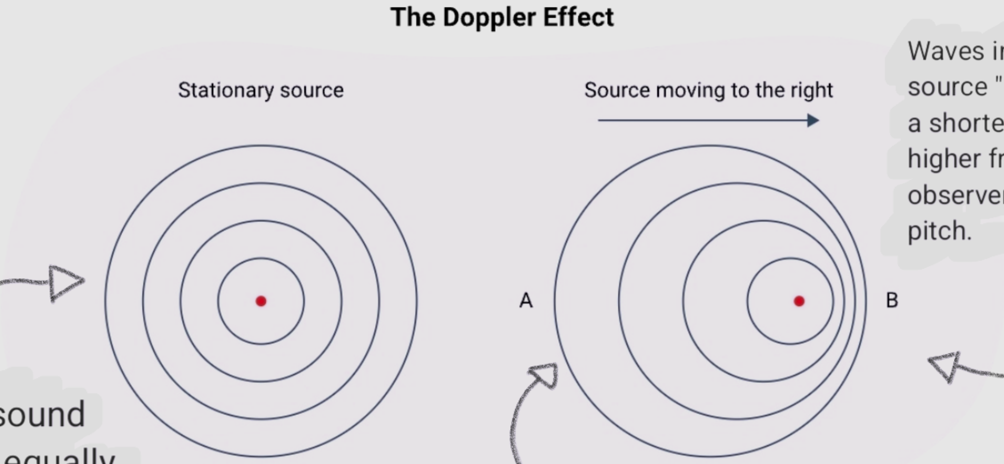
State	Material	Speed of sound (m/s)
Liquid	Alcohol	1241
	Sea water	1470
	Fresh water	1493
	Mercury	1452
State	**Material**	**Speed of sound (m/s)**
Solid	Pine wood	3320
	Maple wood	4110
	Steel	5050
	Glass	5050
	Aluminum	5104

In liquids, particles are less attracted and further apart, requiring more movement to disturb neighbors, which slows sound down.

In solids, particles are strongly attracted and close together, allowing disturbed particles to immediately push or pull neighbors, resulting in fast sound transmission.

The doppler effect

The Doppler effect describes the change in perceived sound frequency from a moving source, such as a siren, appearing higher-pitched when approaching and lower-pitched when receding.



Waves in front of the moving source "bunch up," resulting in a shorter wavelength and higher frequency, which an observer perceives as a higher pitch.

A stationary sound source emits equally spaced sound waves in all directions. When the sound source moves, the waves are no longer concentric.

Waves behind the moving source stretch out, leading to a longer wavelength and lower frequency, perceived as a lower pitch.

Formula

$$f_{observed} = f_{source}\left(\frac{v_{sound}}{v_{sound} \pm v_{source}}\right)$$

$$f_2 = f_1\left(\frac{v_{sound}}{v_{sound} \pm v_{source}}\right)$$

Example 1: Calculating sound frequency

A car is travelling down a highway at 27 m/s when the temperature of the air is 12° C. The driver sounds a 420 Hz horn when passing a stationary person at the side of the road. What frequency can the person hear when the car is approaching and when it is moving away?

$$f_2 = f_1\left(\frac{v_{sound}}{v_{sound} \pm v_{source}}\right)$$

$$f_2 = 420\,Hz\left(\frac{v_{sound}}{v_{sound} \pm 27\,m/s}\right) \rightarrow \text{need } v_{sound}$$

$$v = 332\,m/s + (0.59\,m/s \cdot {}^\circ C)T$$

Plug in temperature

$$v = 332\,m/s + (0.59\,m/s \cdot {}^\circ C) \times 12^\circ C$$

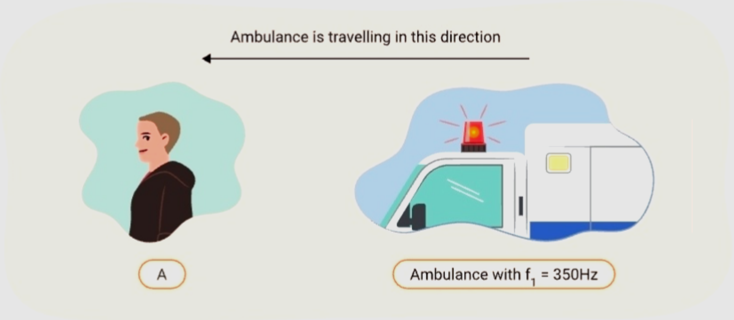
$$v = 339.08\,m/s$$

Moving Away	Moving Towards
$f_2 = 420\,Hz\left(\frac{339.08\,m/s}{339.08\,m/s + 27\,m/s}\right)$	$f_2 = 420\,Hz\left(\frac{339.08\,m/s}{339.08\,m/s - 27\,m/s}\right)$
$f_2 = 420\,Hz(0.92625)$	$f_2 = 420(1.0865)$
$f_2 = 389.023\,Hz$	$f_2 = 456.3368\,Hz$

∴ The person hears a frequency of 460 Hz when the car is approaching and 390 Hz when it is moving away.

Example 1:

In the following diagram, will a person at point "A" hear a higher or lower frequency than 350 Hz? Why?



The person at "A" will hear a frequency lower than 350 Hz. This is because the source of the sound is moving towards the person. The movement of the source causes the waves to bunch up together making the perceived frequency lower than the actual frequency of the source.

Example 2:

What would the ambulance have to be doing so the person wll hear a frequency equal to 350 Hz?

The ambulance would have to be stationary.

Example 3:

A car horn has a frequency of 480 Hz and the car is moving at 25 m/s. The speed of sound in air is 334 m/s. Find the apparent frequency detected by an observer when the car is moving away from them.

$$f_2 = f_1 \left(\frac{V_{sound}}{V_{sound} \pm V_{source}} \right)$$

$$f_2 = 480\ Hz \left(\frac{334\ m/s}{334\ m/s + 25\ m/s} \right)$$

$$f_2 = 480\ Hz\ (0.9304)$$

$\Rightarrow f_2 = 446.57$

$\therefore$ The apparent frequency of the sound by the observer would be 450 Hz.

Example 4:

A racing car on a straight track sounds a 510 Hz horn during a promotion. The car is moving at 42 m/s and the temperature is 28°C. Find the apparent frequency of the horn for a stationary observer when the car is moving toward the observer.

need V_{sound} for the doppler formula

$$V = 332 + (0.59)(28°C)$$
$$v = 332 + 16.52$$
$$v = 348.52 \text{ m/s}$$

Plug in values

$$f_2 = 510\,Hz\left(\frac{348.52 \text{ m/s}}{348.52 \text{ m/s} - 42 \text{ m/s}}\right)$$
$$f_2 = 510\,Hz\,(1.137)$$
$$f_2 = 579.88$$

- The apparent frequency of the horn for the stationary observer is 580 Hz.

Example 5:

A truck sounds its 450 Hz horn while moving towards a stationary person. The person hears a frequency of 465 Hz. The speed of sound is 340 m/s. How fast is the truck moving?

$$f_2 = f_1\left(\frac{V_{sound}}{V_{sound} \pm V_{source}}\right)$$ Plug in values

$$465\,Hz = 450\,Hz\left(\frac{340 \text{ m/s}}{340 \text{ m/s} - V_{source}}\right)$$ isolate V_{source}

$$\frac{465\,Hz}{450\,Hz} = \frac{340 \text{ m/s}}{340 \text{ m/s} - V_{source}}$$

$$1.0333\ Hz(340\ m/s - V_{source}) = 340\ m/s$$

$$351.333 - 1.0333V_{source} = 340\ m/s$$

$$-1.0333V_{source} = 340\ m/s - 351.333$$

$$-1.0333V_{source} = -11.333$$

$$V_{source} = \frac{-11.333}{-1.0333}$$

$$V_{source} = 10.967\ m/s$$

$\therefore$ The truck is moving at 11 m/s

Example: Echoes

A person yells and hears the echo off a cliff 2.5 s later. The speed of sound in air is 344 m/s. Find the distance from the person to the cliff.

distance = speed x time

$$d = 344\ m/s \times 2.5\ s$$
$$d = 860\ m$$

the echo travels 860 m both ways so the distance to the cliff is half of 860 m.

$\therefore$ The cliff is 430 m from the person.

Example: Sonar

A fishing vessel sends out a signal towards the bottom of the ocean. It receives one echo back after 0.30 s and another after 0.80 s. One echo is from a school of fish and the other is from the ocean floor. If the speed of sound in this sea water is 1470 m/s, how far above the ocean floor are the fish?

$$d = vt$$

$$d_{fish} = \frac{vt}{2} = \frac{1470 \text{ m/s} \times 0.30 \text{ s}}{2} = 220.5 \text{ m}$$

$$d_{ocean} = \frac{vt}{2} = \frac{1470 \text{ m/s} \times 0.80 \text{ s}}{2} = 588 \text{ m}$$

$$588 - 220.5 = 367.5 \text{ m}$$

$\therefore$ The fish are 370 m above the ocean floor

End of 1.2 :)

Unit 1.3

Reflecting on Waves

Task 1: Multiply choice - Terms you need to know

1. The energy of the wave travels perpendicular to the motion of the particles.
    - transverse wave
    - Longitudinal wave
    - Transverse and Longitudinal wave

2. The lowest point of a transverse wave.
    - Crest
    - Trough
    - None

3. The area of a longitudinal wave where the particles are far apart (lower pressure area)
    - Compression
    - Rarefaction
    - Echo

4. Used to view internal body structures.
    - Echo
    - Ultrasound
    - Sonar
    - Echolocation

5. Animals use this to locate prey.
    - Echo
    - Ultrasound
    - Sonar
    - Echolocation

6. Reflection of a sound wave from a surface.
    - Echo
    - Ultrasound
    - Sonar
    - Echolocation

7. Used to locate objects underwater
    - Echo
    - Ultrasound
    - Sonar
    - Echolocation

Task 2: True/False - How much do you know about waves?

1. A sound wave is a longitudinal wave.
   - True
   - False

2. When a wave comes to a fixed end, it will not invert when it reflects.
   - True
   - False

3. Sound travels slowest in a gas.
   - True
   - False

4. If a sound is made in a vacuum (ex. outer space), the sound cannot be heard.
   - True
   - False

5. Humans cannot hear sounds with a frequency above 20 Hz.
   - True
   - False

Task 3: What do you know?

1. A 280.0 Hz buzzer produces sound waves that are 1.21 m long. What is the temperature of the air in which the sound is produced?

Calculate speed of sound

$V = f\lambda = 280 \text{ Hz} \times 1.21 \text{ m}$

$V = 338.8 \text{ m/s}$

Plug speed of sound into formula

$V = 332 \text{ m/s} + (0.59 \cdot {}^\circ C)T$

$338.8 \text{ m/s} = 332 \text{ m/s} + (0.59 \cdot {}^\circ C)T$

$338.8 \text{ m/s} - 332 \text{ m/s} = 0.59T$

$6.8 = 0.59T$

$T = \frac{6.8}{0.59}$

$T = 11.52^\circ C$ ∴ The temperature of the air is $11.5^\circ C$.

2. A tuning fork with a frequency of 420 Hz emits sound with a wavelength of 0.82 m in air. If the temperature of the air increases, what will happen to the wavelength: increase, decrease, or stay the same?

When the air temperature increases, the Speed of Sound in that air also increases.

$\lambda = \frac{v}{f}$ tells us that the wavelength is the result of the speed of the wave divided by it's frequency.

Therefore a larger "V" or speed of the wave due to a higher air temperature would result in an increased wavelength.

3. Find the frequency and the period for each of the following:

- A light bulb turns on and off 60 times in 1 s.
- A hummingbird flaps its wings 120 times in 6 s.

$T = \frac{\text{total time}}{\text{number of cycles}}$ and $f = \frac{\text{number of cycles}}{\text{total time}}$

200

200

Light Bulb:

$T = \frac{1s}{60} = 1.6 \times 10^{-2}\,s$

$f = \frac{60}{1s} = 60\,Hz$

$\therefore 2.0 \times 10^{-2}\,s$ at $60\,Hz$

Hummingbird:

$T = \frac{6s}{120} = 5.0 \times 10^{-2}\,s$

$f = \frac{120}{6s} = 20\,Hz$

$\therefore 5.0 \times 10^{-2}\,s$ at $20\,Hz$

4. A train on a straight track sounds a 400.0 Hz horn as it passes a parked car on the road. The train is moving at 20.0 m/s and the temperature is 10.0°C. Find the apparent frequency of the horn for a person sitting inside the car when the train is approaching.

$f_2 - f_1 \left(\frac{V_{sound}}{V_{sound} - V_{source}} \right)$ first calculate V_{sound}

$V = 332\,m/s + (0.59 \cdot °c)\,T$

$V = 332\,m/s + (0.59 \cdot °c) \times 10°c$

$V = 332\,m/s + 5.9$

$V = 337.9\,m/s$

plug in values

$f_2 = 400\,Hz \left(\frac{337.9\,m/s}{337.9\,m/s - 20\,m/s} \right)$

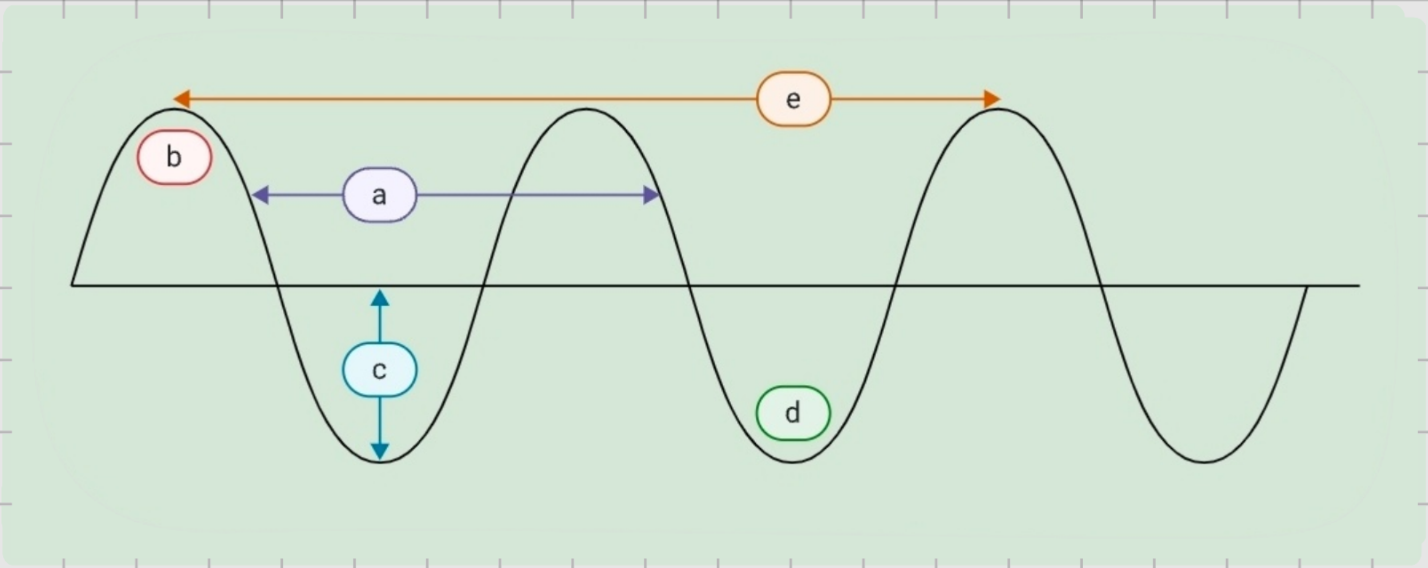
$f_2 = 400\,Hz \times 1.06291$

$f_2 = 425.165\,Hz$

∴ The perceived frequency of the horn by the person in the car is 425 Hz.

Task 4: Label the wave

For the different letters labelling the wave, select and match the appropriate name or numerical description.



a) 1λ

b) crest

c) amplitude

d) trough

e) 2λ

Task 5: Reflection

- What concepts do you need to improve on?

I understand the concepts well enough, maybe I can be faster at deciphering Scientific notation.

- What are your strengths as an independent learner?

My natural intuition and knowledge

- What have you done to help you focus?

Pomodoro technique, stimulating music and caffeine.

- What resources, if any, have you turned to for help?

Claude (ai) when I was stuck on a question I thought didn't make sense. I use it sparingly because I know if it's abused it can take away from my knowledge and understanding. I value my learning process so it's a tool I'm careful with.

- What areas do you need improvement on?

Focus, avoiding distractions. I think I can improve over time with consistency. Like how I worked my way up to a 7 km run.

End of 1.3

:)

Unit 1.4

Interference of Waves

- constructive interference
- destructive intereference
- superposition
- nodes
- antinodes
- loops

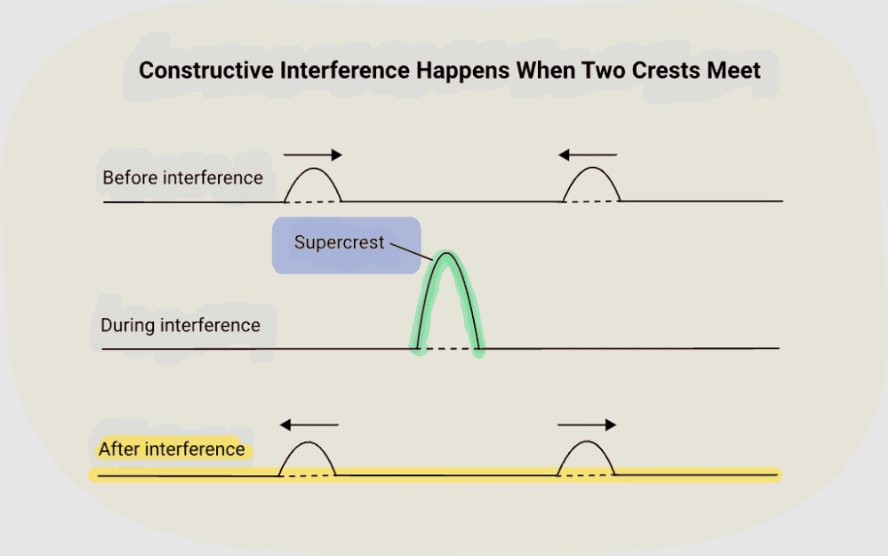
Constructive Interference

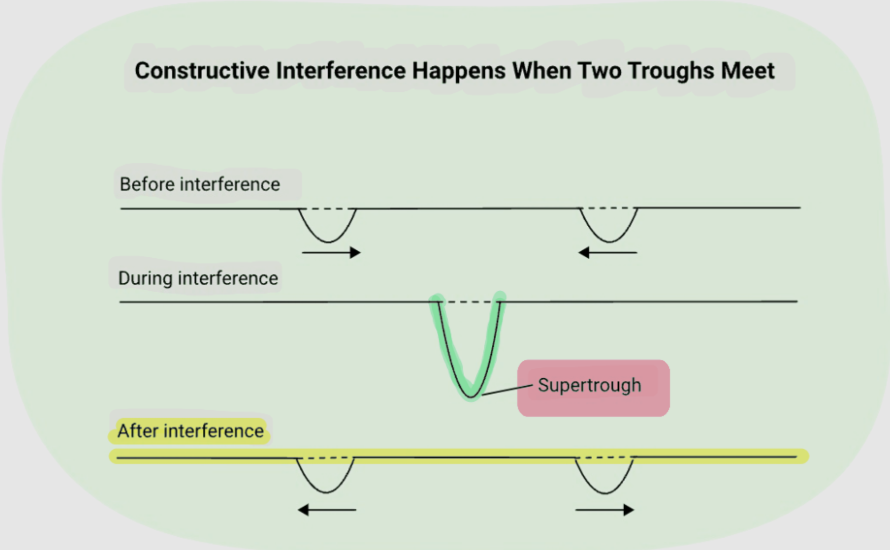
Constructive interference happens when a crest meets a crest or a trough meets a trough.

This interaction causes the pulses to combine, forming larger crests called supercrests or larger troughs called supertroughs.

Diagrams show pulses before and during interference, where they superimpose momentarily.

The amplitude of the supercrest or supertrough is the sum of the amplitudes of the original pulses.



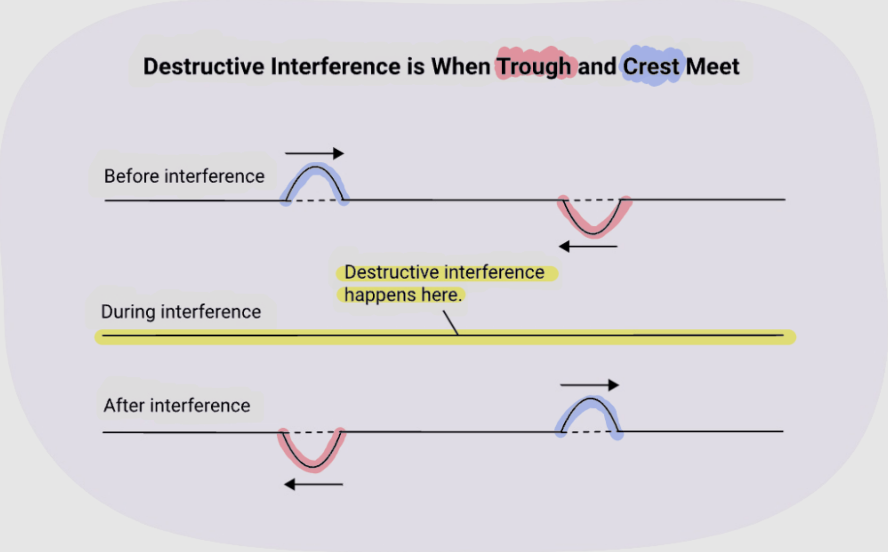


After interfering, the pulses pass through each other and remain unchanged.

Destructive Interference

When a crest and a trough meet during interference, their opposing actions on the medium's particles cancel each other out.

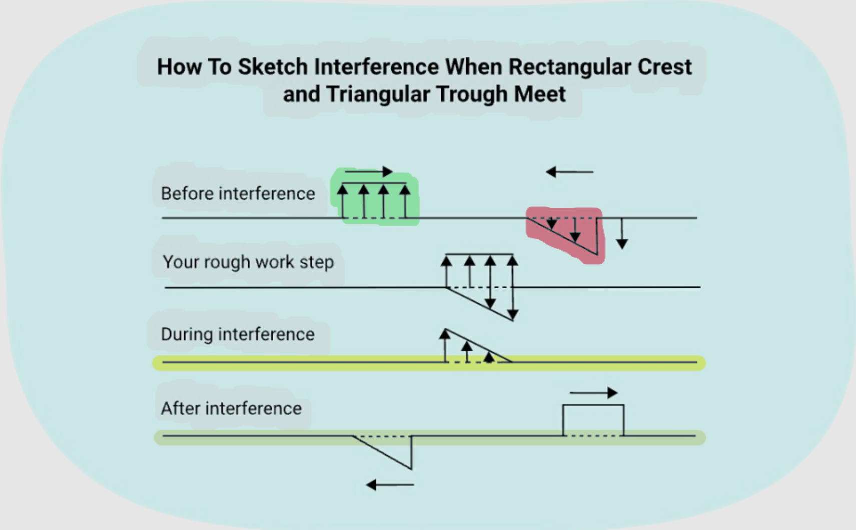
This results in a resultant wave with a lower amplitude than either original pulse.



This scenario demonstrates that pulses pass through each other rather than bouncing off, and during interference, the amplitude can become zero if the positive and negative amplitudes are equal and cancel each other.

Principle of Superposition

The resulting amplitude of two interfering waves at any point is the algebraic sum of their individual displacements.



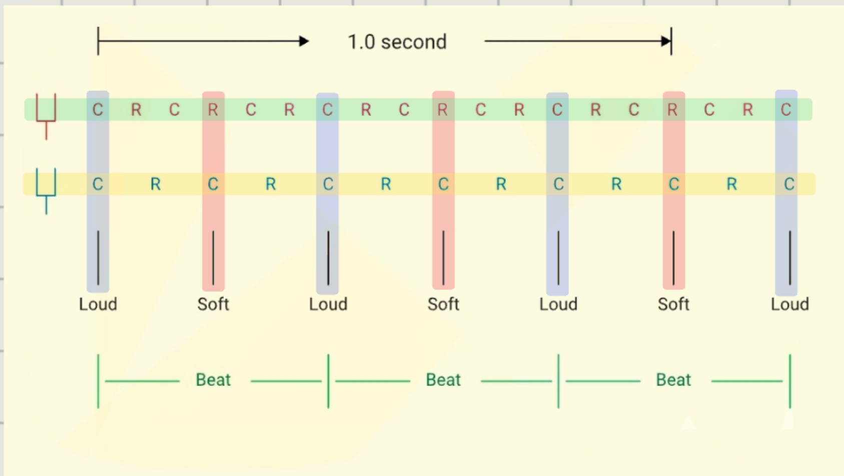
Positive displacements are from crests

Negative displacements are from troughs

Opposite displacements can cancel each other out during superposition but the pulses pass through each other unchanged afterwards.

Beats

When two nearly identical frequencies are sounded together, a person hears dramatic changes in the loudness of the sound at regular time intervals, typically a loud-soft-loud pattern. This pattern is known as beats, it is the constructive and destructive interference of the two sounds with slightly different frequencies.



Beats occur when the crests and troughs of the two sound waves shift in and out of phase.

When they are in phase, the sounds get louder due to constructive interference, and when they are out of phase, the sound is very faint due to destructive interference.

The top fork emits eight compressions and rarefactions per second, resulting in a frequency of 8.0 Hz.

The bottom fork has a frequency of 5.5 Hz

The difference between the two frequencies is called the beat frequency.

Formula Beat Frequency

$$f_b = |f_2 - f_1|$$

Where:

f_b is the beat frequency

f_1 and f_2 are the frequencies of the two tuning forks (or any other sources of sound).

$f_b = 8\text{ Hz} - 5.5\text{ Hz}$

$f = 2.5\text{ Hz}$

The waves interfere constructively and destructively, producing 2.5 beats within a one-second interval.

Example: Frequency of tuning forks

Two tuning forks with slightly different frequencies are sounded together. One has a frequency of 256 Hz and the other has a frequency of 253 Hz. They are sounded together.

a) What is the beat frequency?

$f_b = 256\text{ Hz} - 253\text{ Hz}$

$f_b = 3\text{ Hz}$

$\therefore$ The beat frequency is 3 Hz

b) The 256 Hz fork is removed and replaced with a new fork. Now when the two tuning forks are sounded together, you hear 10 beats in 5.0 s. What is the new frequency of the weighted fork?

Beat Frequency is beats per second, so:

$$f_b = \frac{10 \text{ beats}}{5.0 \text{ s}} = 2 \text{ beats per second}$$

$$f_b = f_2 - f_1$$

$$2 \text{ Hz} = f_2 - 253 \text{ Hz}$$

$$2 \text{ Hz} + 253 \text{ Hz} = f_2$$

$$f_2 = 255 \text{ Hz}$$

Example 1:

Tuning fork 1 (420.0 Hz) is sounded along with tuning fork 2 and exactly 20 beats are counted in 10.00 s. Tuning fork 2 is sounded along with tuning fork 3 (426.0 Hz) and exactly 12 beats are detected in 3.00 s. What is the frequency of tuning fork 2? Explain your reasoning.

$$f_b = \frac{20 \text{ beats}}{10 \text{ s}} = 2 \text{ Hz}$$

$$f_b = |f_2 - f_1|$$

$$2 \text{ Hz} = |f_2 - 420 \text{ Hz}|$$

$$f_2 = 2 \text{ Hz} + 420 \text{ Hz}$$

$$f_2 = 422 \text{ Hz}$$

or

$$2 \text{ Hz} = |420 \text{ Hz} - f_2|$$

$$f_2 = 420 \text{ Hz} - 2 \text{ Hz}$$

$$f_2 = 418 \text{ Hz}$$

$$f_b = \frac{12 \text{ beats}}{3 \text{ s}} = 4 \text{ Hz}$$

$$4 \text{ Hz} = |f_2 - 426 \text{ Hz}|$$

$$f_2 = 4 \text{ Hz} + 426 \text{ Hz}$$

$$f_2 = 430 \text{ Hz}$$

or

$$4 \text{ Hz} = |426 \text{ Hz} - f_2|$$

$$f_2 = 426 \text{ Hz} - 4 \text{ Hz}$$

$$f_2 = 422 \text{ Hz}$$

- Tuning fork 2 has a frequency of 422 Hz. I know this because 422 Hz is the only common possibility in both scenarios.

Example 2:

Tuning fork 1 (256 Hz) is sounded along with tuning fork 2 (255 Hz). What is the beat frequency?

$$f_b = |f_2 - f_1|$$

$$f_b = |256\text{ Hz} - 255\text{ Hz}|$$

$$f_b = 1\text{ Hz}$$

∴ The beat frequency is 1.00 Hz

Example 3:

Elastic bands are attached to tuning fork 1 (which was 256 Hz) to reduce its frequency. It is sounded again with tuning fork 2 (255 Hz), making exactly 12 beats in 6.00 s. What is the new frequency of tuning fork 1? Explain your reasoning.

$$f_b = \frac{12\text{ beats}}{6\text{ s}} = 2\text{ Hz}$$

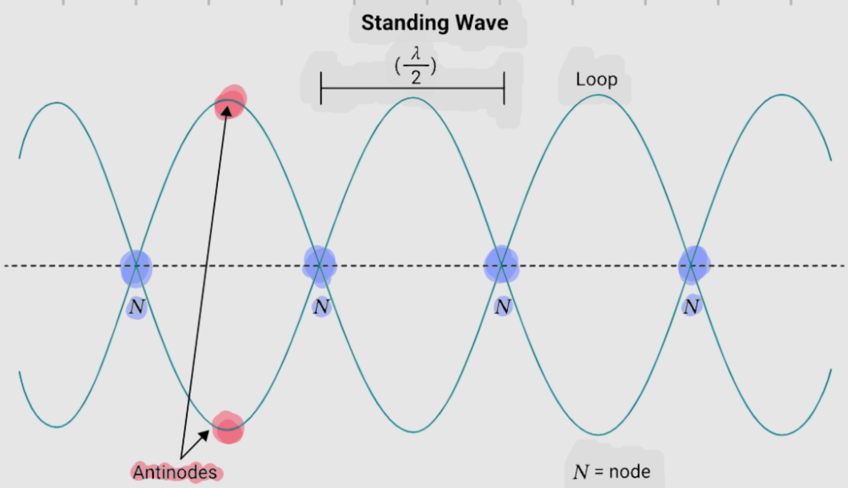
$f_b = |f_2 - f_1|$ isolate f_1

$2\text{ Hz} = \|255\text{ Hz} - f_1\|$	$2\text{ Hz} = \|f_1 - 255\text{ Hz}\|$
$f_1 = 255\text{ Hz} - 2\text{ Hz}$	$f_1 = 2\text{ Hz} + 255\text{ Hz}$
$f_1 = 253\text{ Hz}$	$f_1 = 257\text{ Hz}$

∴ We know tuning fork 1 was 256 Hz and the elastic bands lowered the frequency so it cant be 257 Hz, meaning it must be 253 Hz.

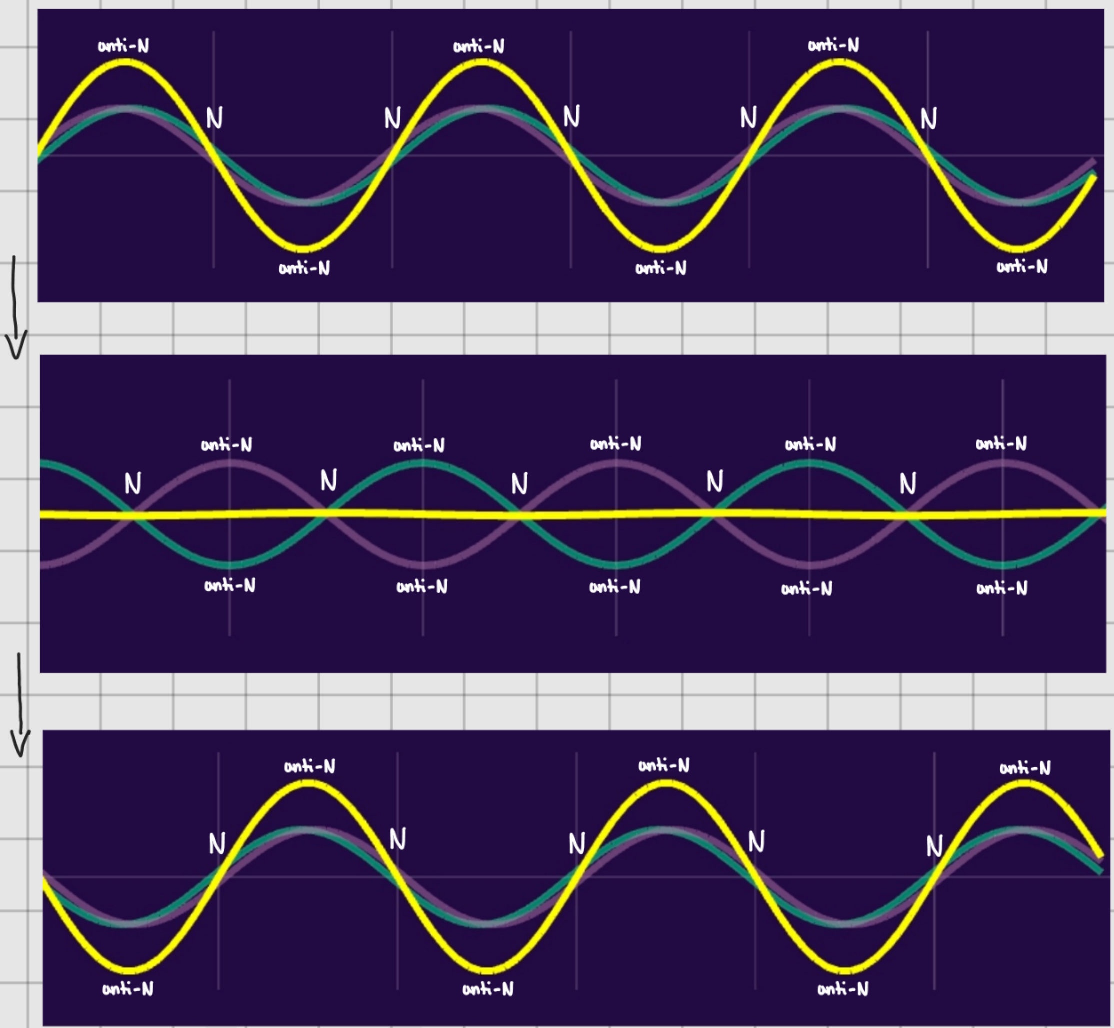
Standing Waves

When two identical waves move in the opposite direction and interefere in a medium, a standing wave is formed.



points called nodes remain stationary where crests meet troughs, resulting in no displacement.

Midway between nodes are antinodes, where crests meet crests or troughs meet troughs, producing displacements twice as large as the source waves.



In a standing wave, nodes stay at rest, while other points move back and forth. Antinodes have the largest particle displacement because they are the result of interference of the crests on crests and troughs on troughs of the interfering waves.

This makes standing waves appear to have no wave motion and only particle motion, hence the name.

$= \frac{\lambda}{2}$

The distance from one node to the next, or one loop, is half a wavelength.

Example 1:

The distance between two successive (one right after the other) nodes in a standing wave is 20.0 cm. The frequency of the source is 15 Hz. Find the speed of the waves.

$$\text{Distance of nodes} = \frac{\lambda}{2}$$

$$20\text{ cm} = \frac{\lambda}{2}$$

$$\lambda = 2 \times 20\text{ cm}$$

$$\lambda = 40\text{ cm}$$

$$v = f\lambda$$

$$v = 15\text{ Hz} \times 0.4\text{ m/s}$$

$$v = 6\text{ m/s}$$

$\therefore$ The speed of the wave is 6.0 m/s

Example 2:

A vibrating source makes a standing wave in a string as shown in the following diagram. The source moves up and down, completing 22 cycles in 5.5 s. The distance from the first node to the sixth node is 6.0 m. Find the speed of the waves.

$$\frac{6\text{ m}}{5\text{ nodes}} = \frac{\lambda}{2} \rightarrow \lambda = 2\left(\frac{6}{5}\right)$$

$$\text{Period} = \frac{\text{total time}}{\text{cycles}} = \frac{5.5\text{ s}}{22} = 0.25$$

$$f = \frac{1}{T} = \frac{1}{0.25} = 4\text{ Hz}$$

$$v = f\lambda = 4\text{ Hz} \times 2\left(\frac{6}{5}\right)$$

$$v = 9.6\text{ m}$$

$\therefore$ The speed of the waves are 9.6 m/s

Example 3:

A source with a frequency of 30.0 Hz is used to make waves in a rope 12 m long. It takes 0.20 s for the waves to travel from one fixed end of the rope to the other. What is the speed of the wave? What is the wavelength? How many loops are there in the standing wave in the rope?

$$v = \frac{d}{t} = \frac{12\ m}{0.2\ s}$$

$$v = 60\ m/s$$

$$\lambda = \frac{v}{f} = \frac{60\ m/s}{30\ Hz}$$

$$\lambda = 2\ m$$

$$1\ \text{Loop} = \frac{\lambda}{2} = \frac{2\ m}{2} = 1\ m$$

$$\text{number of loops} = \frac{\text{length of rope}}{\text{length of loop}} = \frac{12}{1} = 12$$

∴ The speed of the wave is 60 m/s. The wavelength is 2.0 m and there are 12 loops in the wave.

Example 4:

Two waves travelling in opposite directions at 6.0 m/s produce nodes that are 0.40 m apart. What is the wavelength? Find the frequency of the waves.

$$\frac{\lambda}{2} = \text{one loop}$$

$$\frac{\lambda}{2} = 0.4\ m$$

$$\lambda = 0.4\ m \times 2$$

$$\lambda = 0.8\ m$$

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

$$f = \frac{6\ m/s}{0.8\ m}$$

$$f = 7.5\ Hz$$

∴ The wavelength is 0.8 m and the frequency is 7.5 Hz

Example 5:

You tie the two opposite ends of a long rope to fixed positions. You have a source that can set up standing waves in the rope, a metre stick, and a stopwatch. Describe a procedure you could use to find the speed of the waves in the rope using the principles of standing waves.

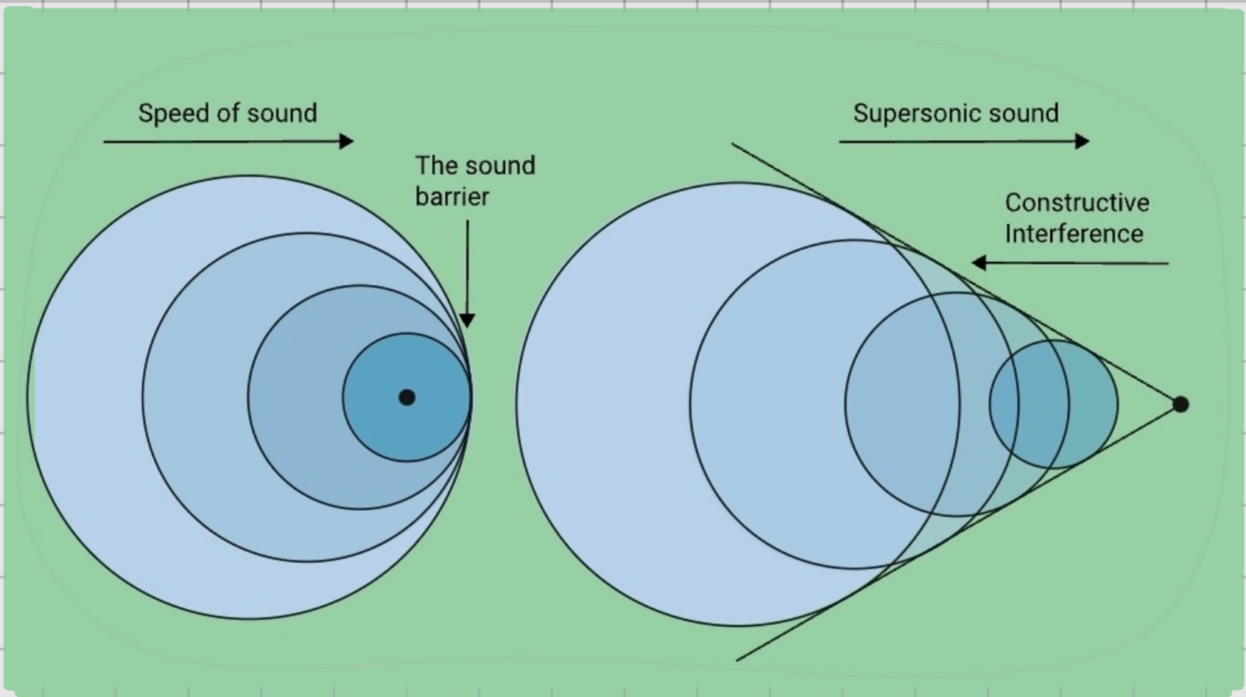
I would use the metre stick to measure the distance from any two adjacent nodes. This would give me the wavelength easily, I would simply have to multiply the distance of the two nodes by 2 to get the wavelength since 1 loop = $\lambda/2$.

The next thing I would need to do is to use the stopwatch to measure how long it takes for the wave to cycle a certain amount of times, maybe 5 or 10, something easy. Once I have the time, I can use the formula frequency = number of cycles / total time to calculate the frequency.

Now that I have the wavelength and the frequency, I just plug them into $v = f * \lambda$ and easily solve for the speed of the wave.

Sonic Booms

When an airplane travels at the speed of sound, sound waves in front of the jet pile up and superimpose on each other. The waves interfere constructively to produce a sound of wave incredible amplitude and energy.



There are severe restrictions on supersonic air travel across the world for this reason.

End of 1.4 :)

Unit 1.5

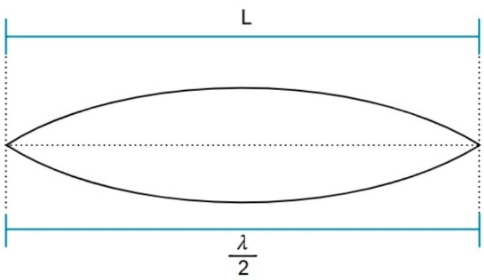
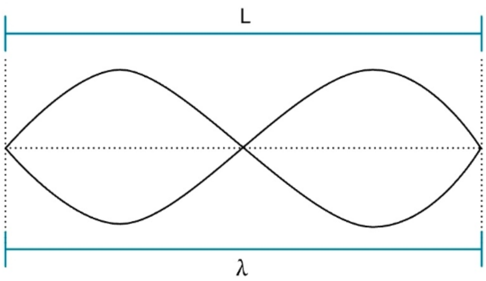
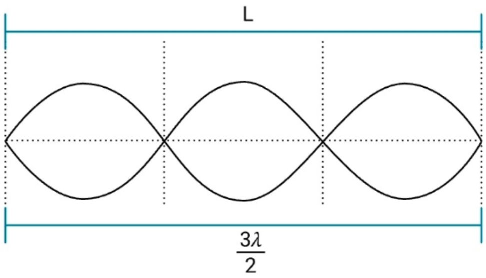
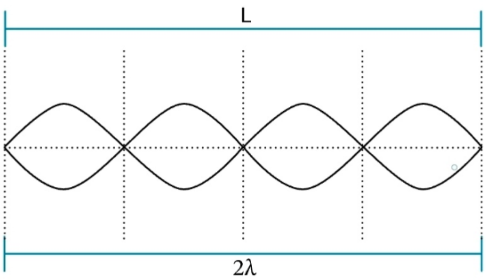
Resonance

- amplify
- resonance

Fundamental Frequency

- The lowest frequency that will produce a standing wave f_1

$$f_1 = \frac{v}{2L}$$

Frequency	Number of loops in standing wave	Diagram of standing wave
f_1 (fundamental frequency) $L = \frac{\lambda}{2}$ or $\lambda = 2L$	1	
$f_2 = 2f_1$	2	
$f_3 = 3f_1$	3	
$f_4 = 4f_1$	4	
$f_n = nf_1$	n	

Example

A 4.0 m long string is fixed at both ends. A pulse in the string takes 0.10 s to start from one end and reach the other.

1. What is the speed of the waves in the string?

$$v = \frac{d}{t} = \frac{4m}{0.1s}$$
$$v = 40 \ m/s$$

$\therefore$ Speed of the wave is 40 m/s

2. What is the wavelength of the fundamental frequency?

$$\lambda = 2L$$
$$\lambda = 2 \times 4m$$
$$\lambda = 8m$$

$\therefore$ the wavelength of f_1 is 8.0 m

3. What is the fundamental frequency of the string?

$$f_1 = \frac{v}{2L}$$
$$f_1 = \frac{40 m/s}{2 \times 4m}$$
$$f_1 = 5 \ Hz$$

$\therefore$ The f_1 of the string is 5.0 Hz

4. Find the frequency that will produce a standing wave with 3 loops.

$f_3 = 3f_1$

$f_3 = 3 \times 5\ Hz$

$f_3 = 15\ Hz$

- A frequency of 15 Hz will produce a standing wave with 3 loops.

5. Identify another frequency that will produce a standing wave in the string. How many loops will it have?

$f_4 = 4f_1$

$f_4 = 4 \times 5\ Hz$

$f_4 = 20\ Hz$

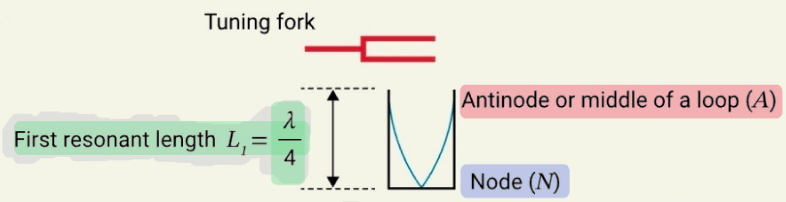
- A 20 Hz frequency would produce a standing wave with four loops

6. Will a frequency of 23 Hz produce a standing wave in the string? Explain.

No, 23 Hz will not produce a standing wave in the string because 23 Hz is not a multiple of the 5 Hz f_1 and it needs to be to satisfy the equation $f_n = nf_1$

Closed Air Columns

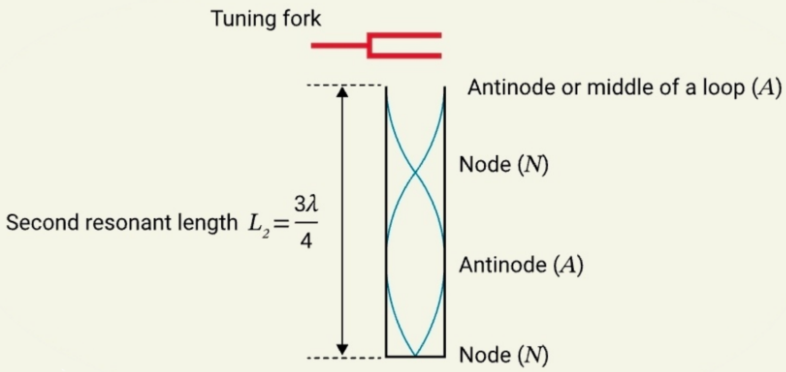
When a tuning fork is placed at the top of a closed air column, sound travels down, reflects off the water, and moves back up, creating a standing wave.



The shortest air column for resonance has a length of $L_1 = \frac{\lambda}{4}$

Unlike standing waves in strings where both ends are nodes, this air column has one node and one antinode.

Resonance occurs, producing a louder sound, when an antinode is at the top of the air column.



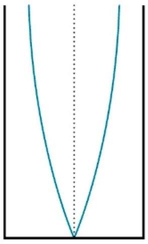
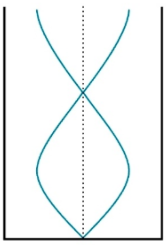
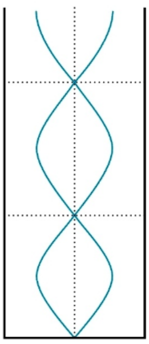
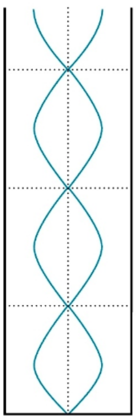
If the air column is raised, there will no longer be a sound until eventually another antinode is positioned at the top of the air column, allowing resonance to take place.

To achieve second resonant length, an additional loop was required. We know one loop of a standing wave is L = λ/2.

$$L_2 = \frac{\lambda}{4} + \frac{\lambda}{2} = \frac{3\lambda}{4}$$

Each loop would result in the next resonant length, coming in additions of λ/2 loops

This means the third resonant length is: $L_3 = \frac{3\lambda}{4} + \frac{\lambda}{2} = \frac{5\lambda}{4}$

Length	Number of loops in standing wave	Diagram of standing wave
L_1	0.5	L_1  $\frac{\lambda}{4}$
$L_2 = 3L_1$	1.5	L_2  $\frac{3\lambda}{4}$
$L_3 = 5L_1$	2.5	L_3  $\frac{5\lambda}{4}$
$L_4 = 7L_1$	3.5	L_4  $\frac{7\lambda}{4}$
$L_n = (2n-1)L_1$	$n - 0.5$	

Example 1:

The first resonant length of a closed air column is 20 cm. Find the second and third resonant lengths.

$L_1 = \frac{\lambda}{4} \rightarrow \lambda = L_1 \times 4$

$\lambda = 20\text{ cm} \times 4$

$\lambda = 80\text{ cm}$

$L_2 = \frac{3\lambda}{4}$

$L_2 = \frac{3(80\text{ cm})}{4}$

$L_2 = 60\text{ cm}$

or

$L_2 = 3L_1$

$L_2 = 3 \times 20\text{ cm}$

$L_2 = 60\text{ cm}$

$L_3 = \frac{5\lambda}{4}$

$L_3 = \frac{5(80\text{ cm})}{4}$

$L_3 = 100\text{ cm}$

or

$L_3 = 5L_1$

$L_3 = 5 \times 20\text{ cm}$

$L_3 = 100\text{ cm}$

Example 2:

What is the shortest air column that will resonate with a tuning fork with a frequency of 460 Hz, when the speed of sound in air is 344 m/s?

$v = f\lambda \rightarrow \lambda = \frac{v}{f} = \frac{344\text{ m/s}}{460\text{ Hz}} = 0.7478\text{ m}$

$L_1 = \frac{\lambda}{4} = \frac{0.7478\text{ m}}{4} = 0.1869\text{ m}$

∴ The shortest air column is 0.19 m.

Example 3:

A tuning fork causes resonance in a pipe with one closed end. The difference between the first resonant length and the second resonant length is 0.390 m. The air temperature is 26.0 °C. Find the frequency of the turning fork and the third resonant length of the pipe.

$L_1 = \frac{\lambda}{4}$

$L_2 = \frac{3\lambda}{4}$ $\rightarrow$ $\frac{3\lambda}{4} - \frac{\lambda}{4} = 0.39\text{ m}$

$V = 332 + (0.59 \cdot °C)(26°C)$

$V = 347.34\text{ m/s}$

$2\lambda = 0.39\text{ m} \times 4$

$\lambda = 0.78\text{ m}$

$V = f\lambda$

$f = \frac{V}{\lambda}$

$f = \frac{347.34\text{ m/s}}{0.78\text{ m}}$

$f = 445.31\text{ Hz}$

$$\boxed{\begin{aligned} L_3 &= \frac{5\lambda}{4} \\ L_3 &= \frac{5(0.78\text{ m})}{4} \\ L_3 &= 0.975\text{ m} \end{aligned}}$$

∴ The frequency of the tuning fork is 445 Hz and the third resonant length is 0.975 m.

Example 4:

A ship's whistle is 0.50 m long and is closed at one end. If the speed of sound is 350 m/s, calculate the first and second resonant frequencies for the ship's whistle.

$L_1 = \frac{\lambda}{4}$, Since the ship's whistle does not change length L_1 and L_2 will be 0.50 m.

$0.5\text{ m} = \frac{\lambda}{4} \rightarrow \lambda = 0.5\text{ m} \times 4 \rightarrow \lambda = 2\text{ m}$

$v = f\lambda \rightarrow f = \frac{v}{\lambda} = \frac{350\text{ m/s}}{2\text{ m}}$

$f = 175\text{ Hz}$

$L_3 = \frac{3\lambda}{4}$

$0.5\ m = \frac{3\lambda}{4}$

$3\lambda = 0.5\ m \times 4$

$3\lambda = 2\ m$

$\lambda = \frac{2m}{3}$

$\lambda = \frac{2}{3}\ m$ (or $0.667\ m$) $\rightarrow$ $v = f\lambda \rightarrow f = \frac{v}{\lambda}$

$f = \frac{350\ m/s}{(\frac{2}{3}\ m)}$

$f = 525\ Hz$

$\therefore$ The first resonant frequency is 180 Hz and the second resonant frequency is 530 Hz.

Lab Activity

Speed of sound in air using a closed air column

$f = 1024\ Hz$

$L_1 = 8.4\ cm$ or $0.084\ m$

$L_2 = 25.2\ cm$ or $0.252\ m$

1. Using the equations for the resonant lengths, calculate the wavelength (in metres). Do this for both L1 and L2.

$L_1 = \frac{\lambda}{4} \rightarrow \lambda = L_1 \times 4$

$\lambda = 0.084\ m \times 4$

$\lambda = 0.336\ m$

$L_2 = \frac{3\lambda}{4} \rightarrow \lambda = \frac{L_2 \times 4}{3}$

$\lambda = \frac{0.252\ m \times 4}{3}$

$\lambda = 0.336\ m$

$\therefore$ The wavelengths are $0.336\ m$

2. Using the universal wave equation , calculate the speed of sound in air using the frequency of the tuning fork (f = 1024 Hz) and the wavelength calculated in Question 1.

$v = f\lambda$

$v = 1024\ Hz \times 0.336\ m$

$v = 344.064\ m/s$

$\therefore$ The speed of sound in air is 344.1 m/s

3. Find the theoretical speed in air at 23.0 °C

$V_{sound} = 332\ m/s + (0.59\ m/s\,°C)T$

$V_{sound} = 332\ m/s + (0.59\ m/s°C)(23°C)$

$V_{sound} = 332\ m/s + 13.57$

$V_{sound} = 345.57\ m/s$

$\therefore$ The theoretical speed of sound in air is 345 m/S

4. Find the percent error for the experimental speed of sound calculations compared to the theoretical speed of sound in air.

$$\text{Percent Error} = \left| \frac{\text{experimental value} - \text{theoretical value}}{\text{theoretical value}} \right| \times 100\%$$

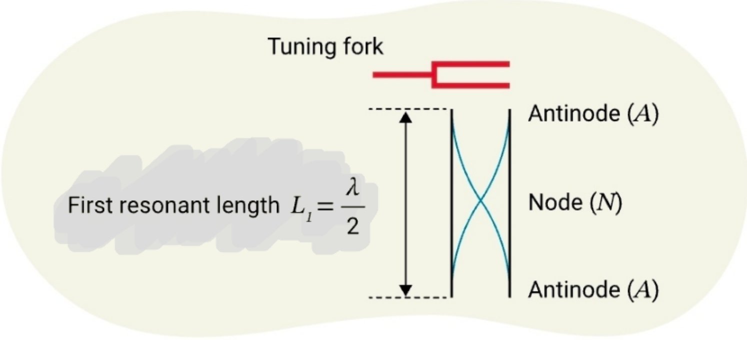
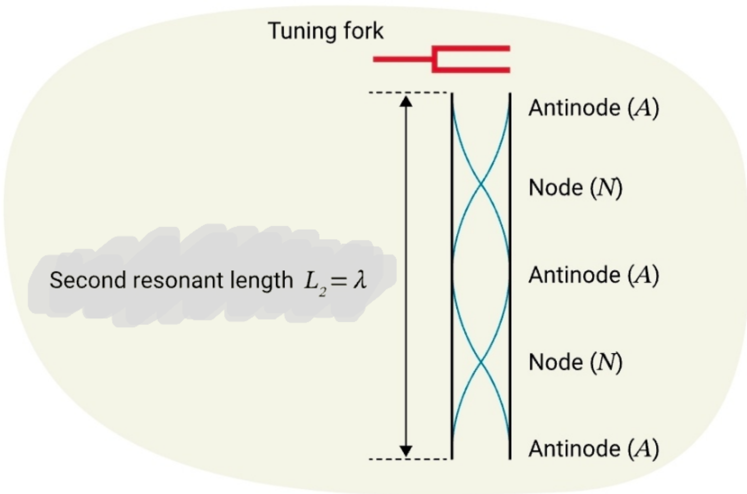
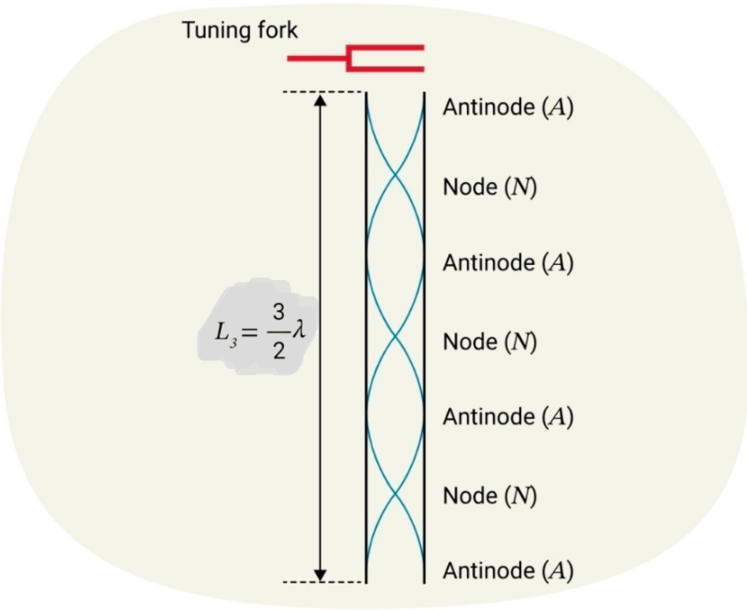
$$\text{Percent Error} = \left| \frac{344.1\ m/s - 345.6\ m/s}{345.6\ m/s} \right| \times 100\%$$

$$\text{Percent Error} = -0.434\%$$

$\therefore$ The percent error is -0.4340%

Open Air Columns

Another type of air column where neither end is fixed and both ends of the standing wave are antinodes

Length	Number of loops in standing wave	Diagram of standing wave
L_1	1	
$L_2 = 2L_1$	2	
$L_3 = 3L_1$	3	
$L_n = nL_1$	n	

Example:

An organ pipe, which is 1.2 m long and open at both ends, produces a note with the fundamental frequency. If the speed of sound in air is 345 m/s, what is the fundamental frequency?

$L_1 = \frac{\lambda}{2}$

$\lambda = L_1 \times 2$

$\lambda = 1.2\ m \times 2$

$\lambda = 2.4\ m$

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

$f = \frac{345\ m/s}{2.4\ m}$

$f = 143.75\ Hz$

or

$f_1 = \frac{v}{2L}$

$f_1 = \frac{345\ m/s}{2(1.2\ m)}$

$f_1 = 143.75\ Hz$

∴ The fundamental frequency is 144 Hz

Example 1:

A tuning fork with a frequency of 380 Hz is sounded near the top of an open air column when the speed of sound is 344 m/s. What is the wavelength of the sound? What are the first three resonant lengths?

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

$\lambda = \frac{344 \text{ m/s}}{380 \text{ Hz}}$

$\lambda = 0.91 \text{ m}$

$L_1 = \frac{\lambda}{2}$

$L_1 = \frac{0.91 \text{ m}}{2}$

$L_1 = 0.45 \text{ m}$

$L_2 = 2L_1$

$L_2 = 0.91 \text{ m}$

$L_3 = 3L_1$

$L_3 = 1.4 \text{ m}$

$\therefore$ The λ is 0.91m and L_1, L_2, L_3 are 0.45 m, 0.91 m and 1.4 m respectively.

Example 2:

A 450 Hz tuning fork is held at the top of an open air column when the temperature of the air is 18 °C. How much longer is the third resonant length than the second resonant length?

$V_{sound} = 332 + (0.59)(18°c)$

$V_{sound} = 342.62 \text{ m/s}$

$\lambda = \frac{V}{f} = \frac{342.62 \text{ m/s}}{450 \text{ hz}}$

$\lambda = 0.7614 \text{ m}$

$L_2 = 2L_1$ and $L_3 = 3L_1$

so

$3L_1 - 2L_1 = L_1$

so just find L_1

$L_1 = \frac{\lambda}{2} = \frac{0.7614 \text{ m}}{2}$

$L_1 = 0.3807 \text{ m}$

$\therefore$ The difference between L_3 and L_2 is 0.38 m

Example 3:

An open air column is set up inside a home so that it will resonate with a tuning fork, using its first resonant length. Both the air column and tuning fork are taken outside in the wintertime, but now, resonance is not observed. Explain why this happens.

The drop in temperature from indoors which is likely a temperature regulated environment to the cold outdoors of wintertime changed the speed of sound. Since wavelength = speed of wave / frequency, the wavelength was changed which changes the positions of the antinodes from where they were indoors in the warmer environment ruining the standing wave and stopping the resonance.

Example 4:

Explain whether a tuning fork with a lower or higher frequency will be required to cause resonance outside.

Since the wavelength is determined by the speed of the wave and the frequency and our goal is to preserve the old wavelength, we must lower the frequency to match the old wavelength since we're dividing a smaller speed value than before.

Using easy numbers as an example, if the speed of sound was 300 m/s before we went outside and the frequency of our tuning fork is 100 Hz the wavelength is 3 m. If the speed of sound changes to 270 m/s that would make our wavelength change to 2.7 m. To get back to 3 m wavelength we have to lower our frequency to 90 Hz. 270 m/s / 90 hz = 3 m.