Problem 10: Rijke's Tube

Team Switzerland

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The Problem

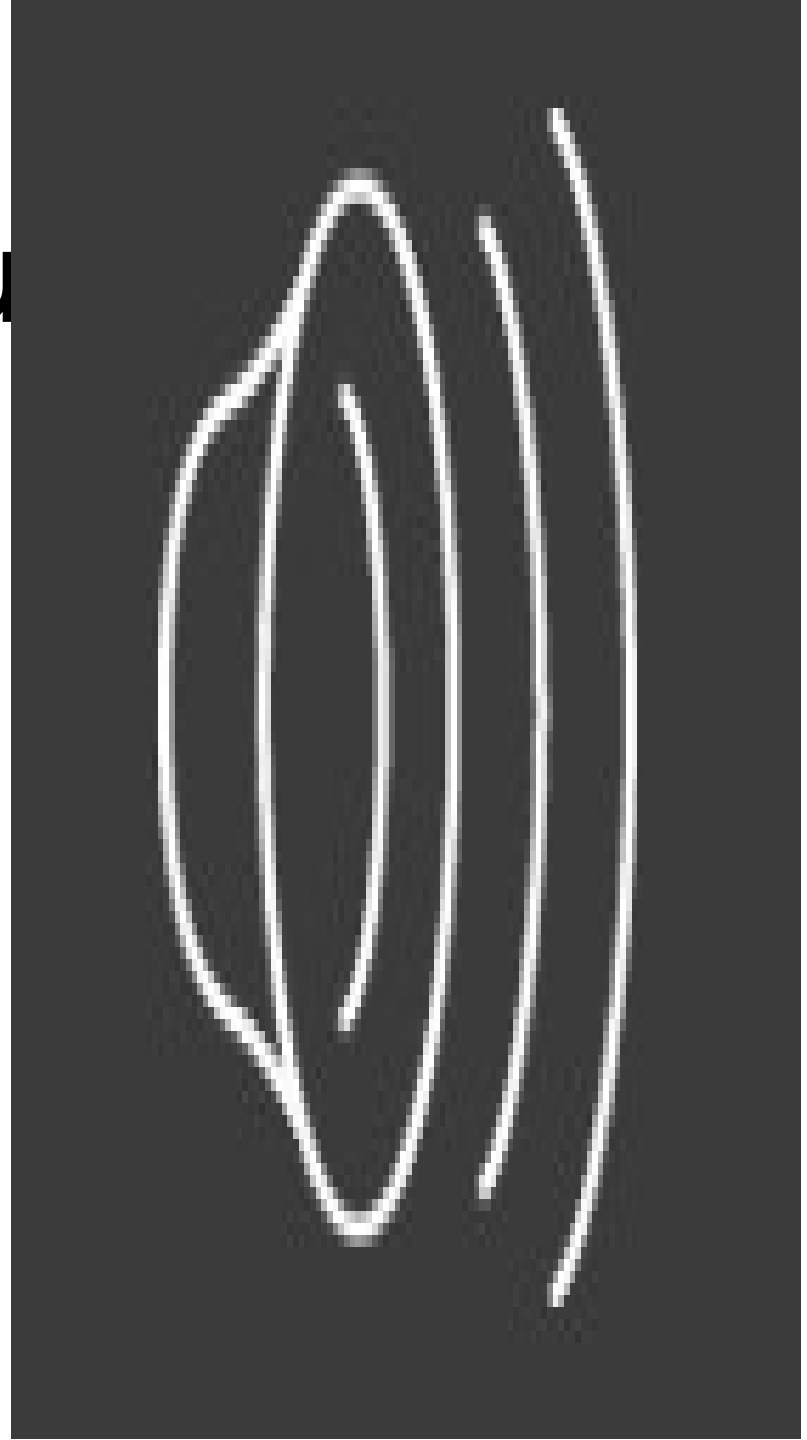
Rijke's tube

If air inside a vertical cylindrical tube open at both ends is heated, the tube produces sound. Study this effect.

Build a Rijke's tube $\longrightarrow$ Find out why it makes a sound and what relevant parameters affect it.

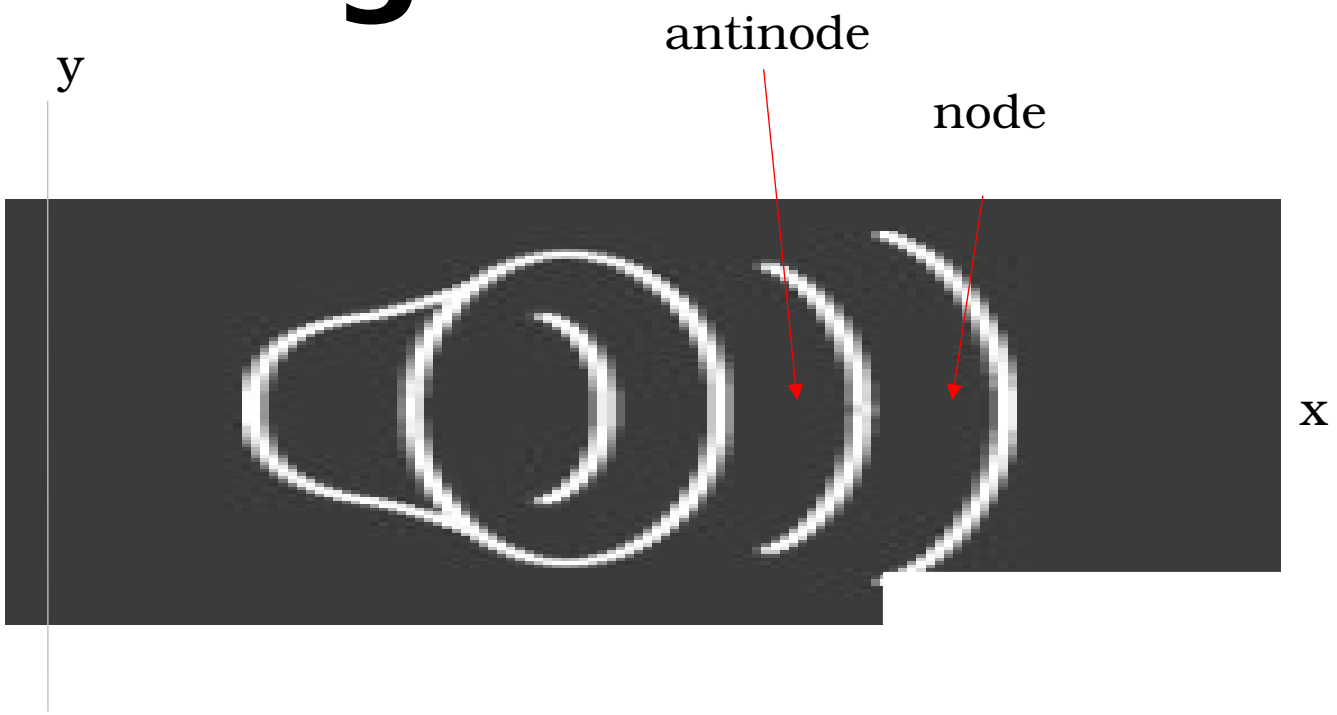
What is a Rijke's Tu

1. Bunsen burner heats up mesh
2. Bunsen burner is removed
3. Sound is produced



Theory: Standing Waves on Strings

Different Modes



x = location y = displacement n = mode L = length of the string

Theory: Standing Waves in Tubes

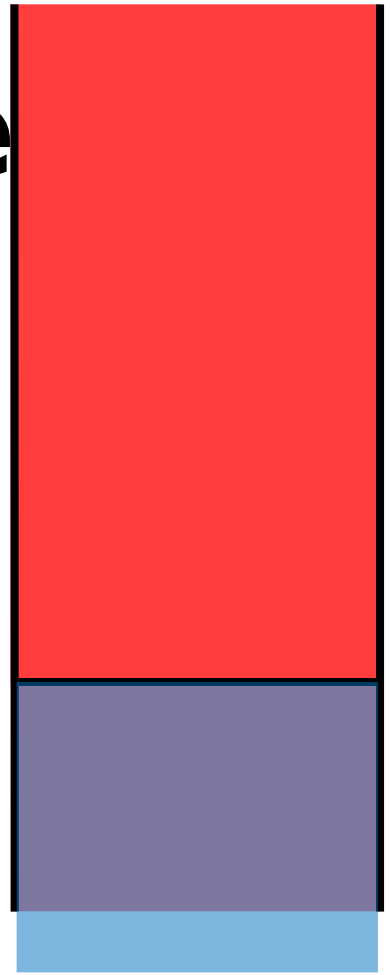
The standing wave causes a continual tone:

Fundamental Harmonic Tone

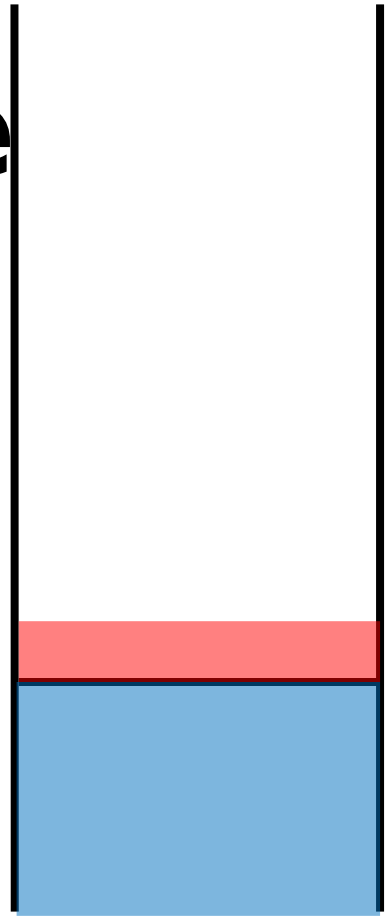
First Harmonic

Second Harmonic

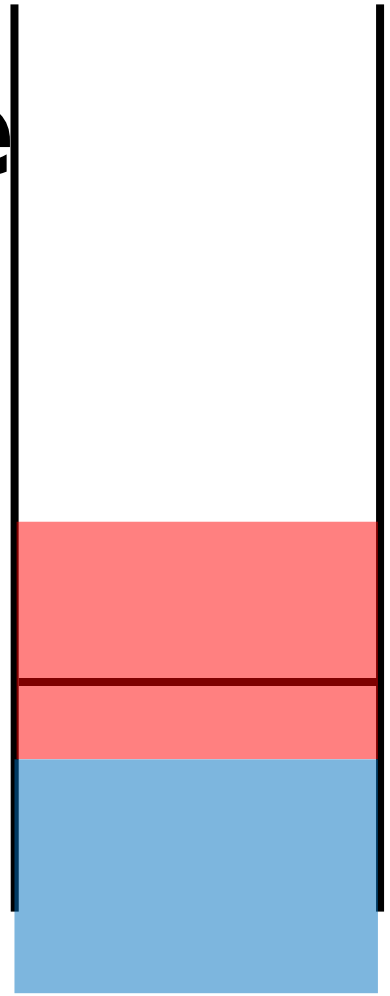
Theory: Rijke’s Tube



Theory: Rijke's Tube



Theory: Rijke's Tube



Theory: Frequency

Tube length $2\frac{L}{n} = \lambda$

Frequency $f = \frac{c}{\lambda} = \frac{nc}{2L}$

Wave Parameters:
f = frequency
λ = wavelength
c = propagation speed
n = mode

Tube Parameters:
L = length of the tube
d = diameter of tube

Correction due to wave reflection outside of the tube

$$f = \frac{nv}{2L + 0.8d}$$

The theory suggests that the frequency (pitch of sound) is inversely proportional to the length of the tube.

Experiments: Parameters

Tube

Orientation

Length

Diameter

Material

Gauze

Temperature

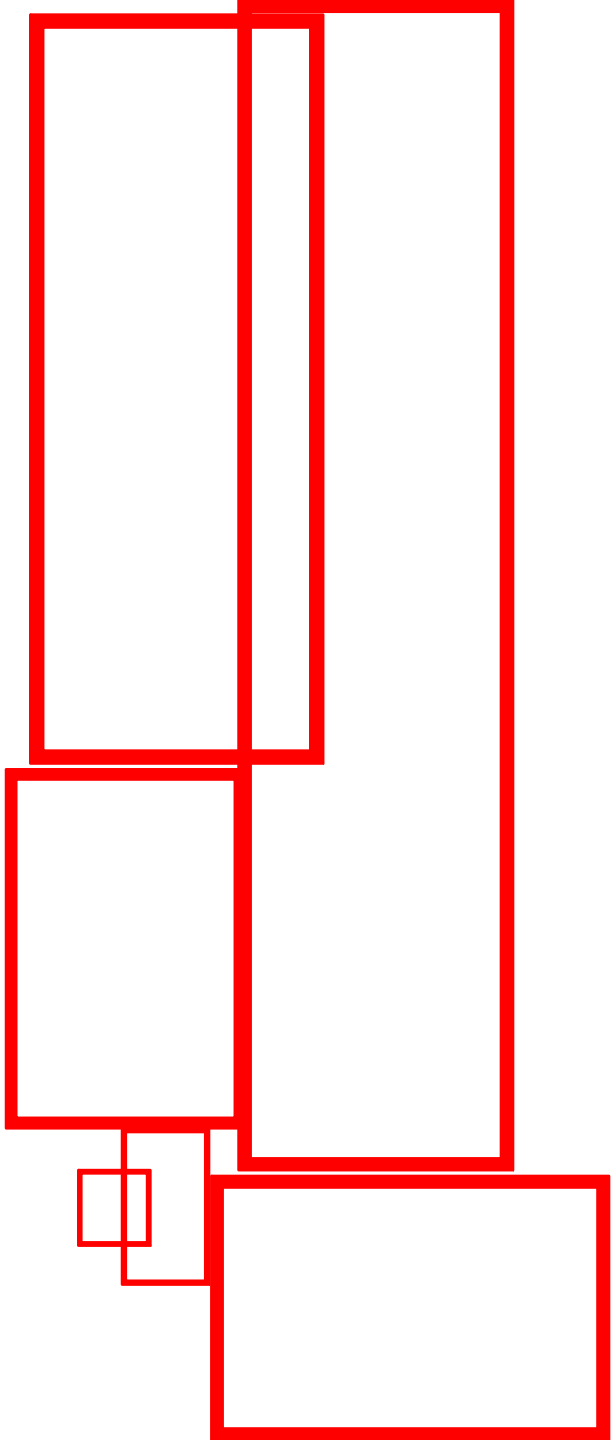
Position

Material

investigated

Set Up

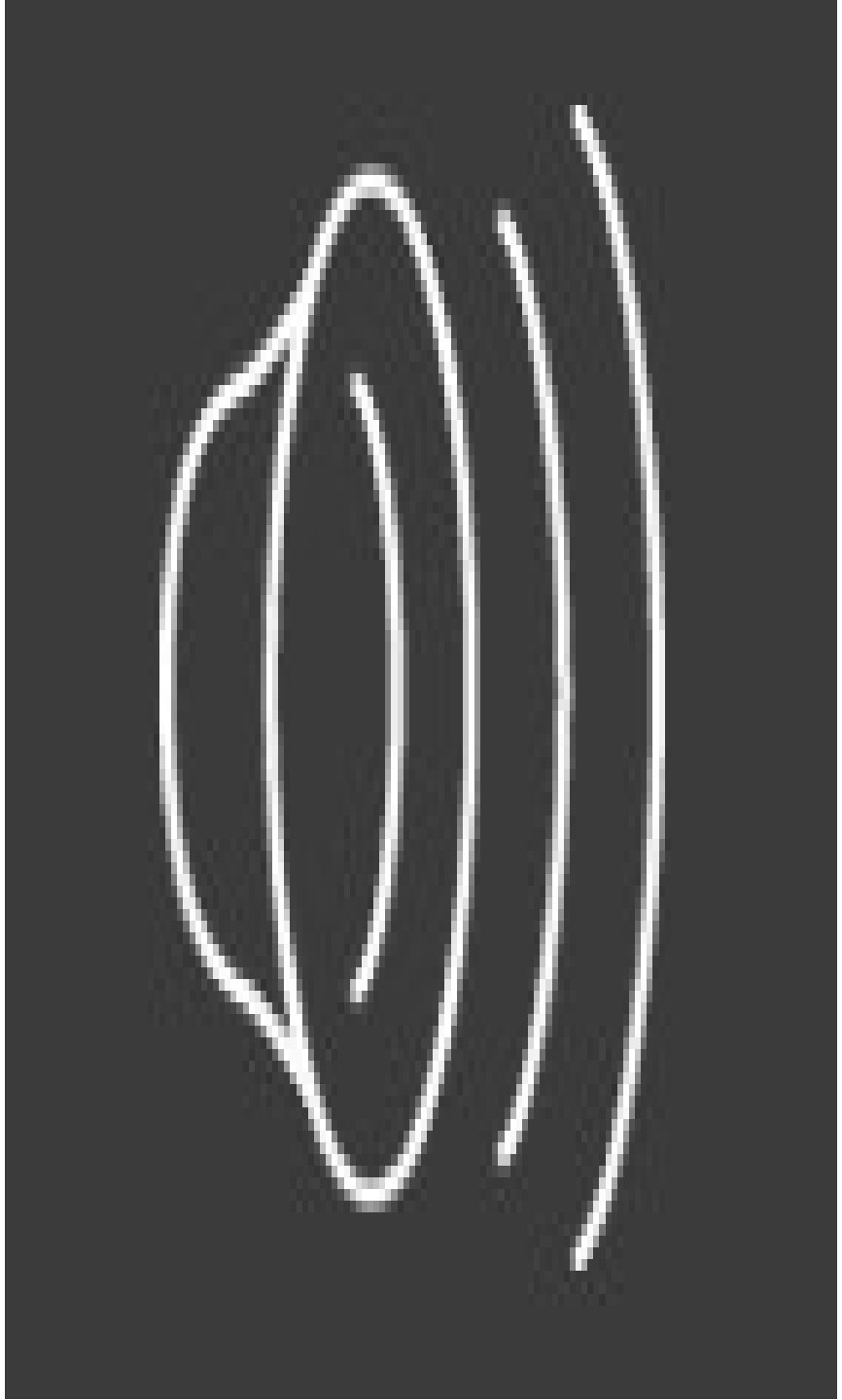
- 3 tubes made of steel
- Clamps
- Stand
- Bunsen burner
- Lighter
- Aluminum gauze



Experiments

Tube Orientation

According to the theory, the tube only works when upright.



Experiments: Tube Length

Model for frequency:

$$f = \frac{nv}{2L+0.8d}$$

Investigated lengths:

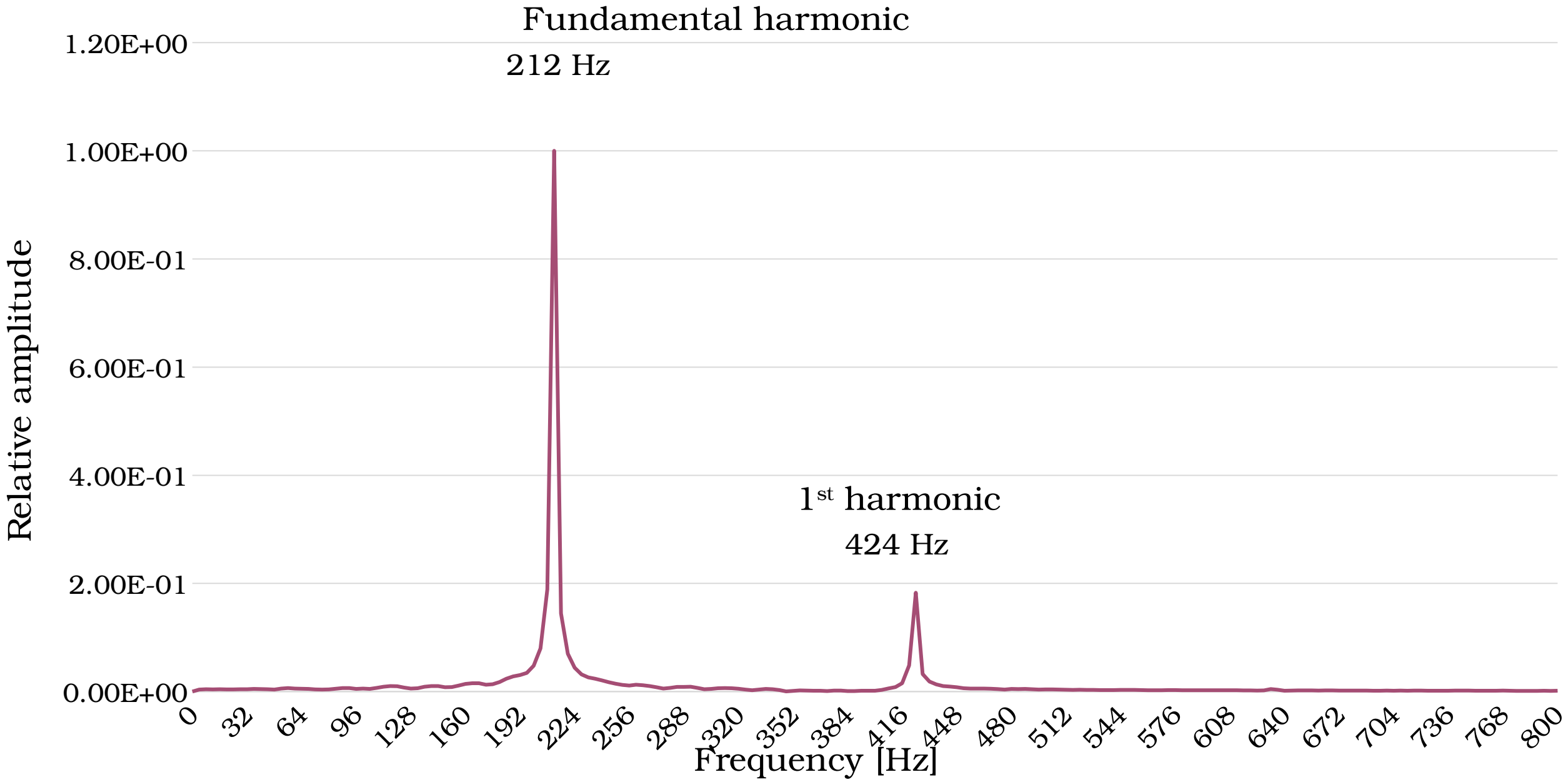
0.83m

1.16m

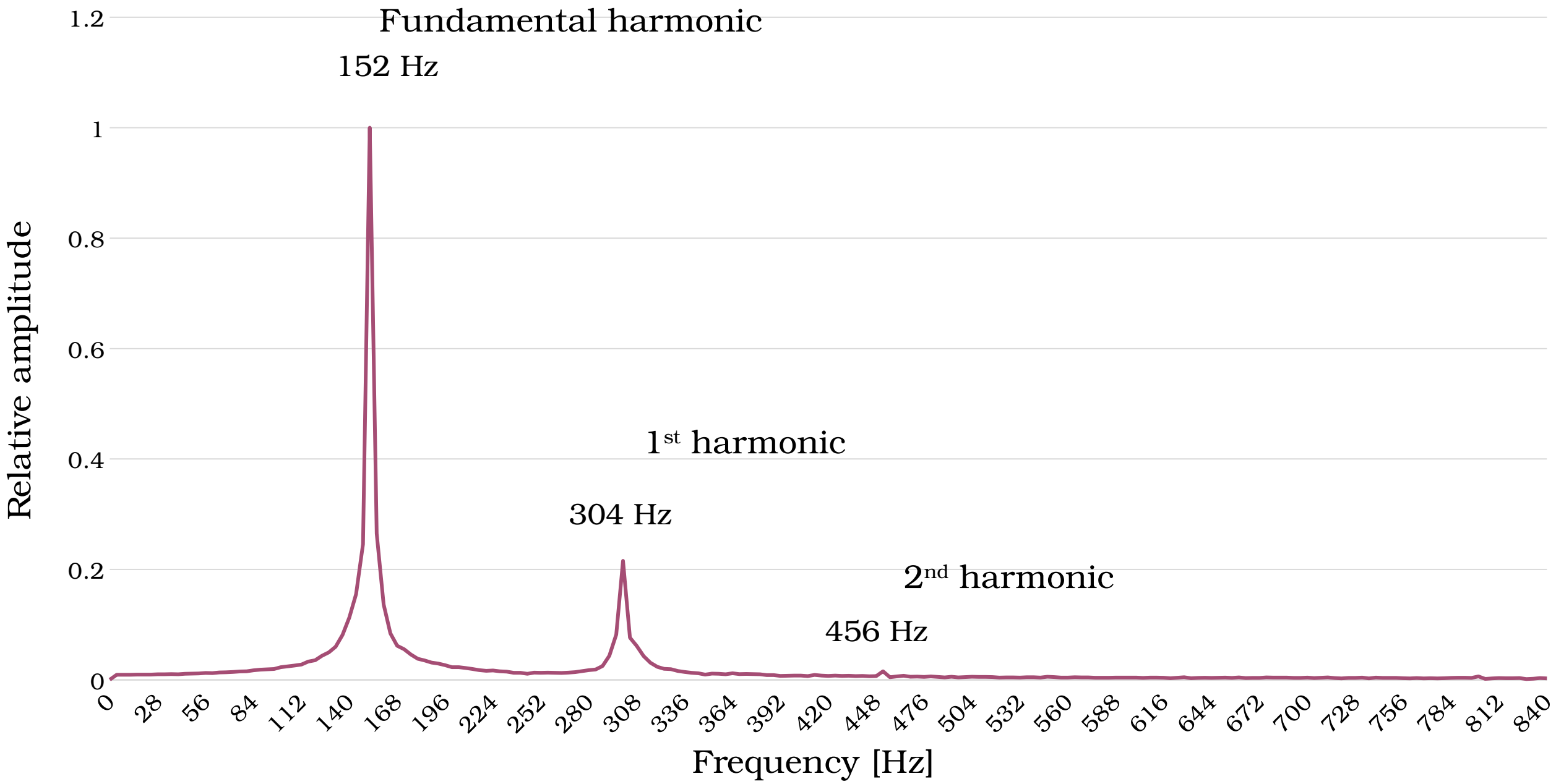
1.46m

Decreasing frequency

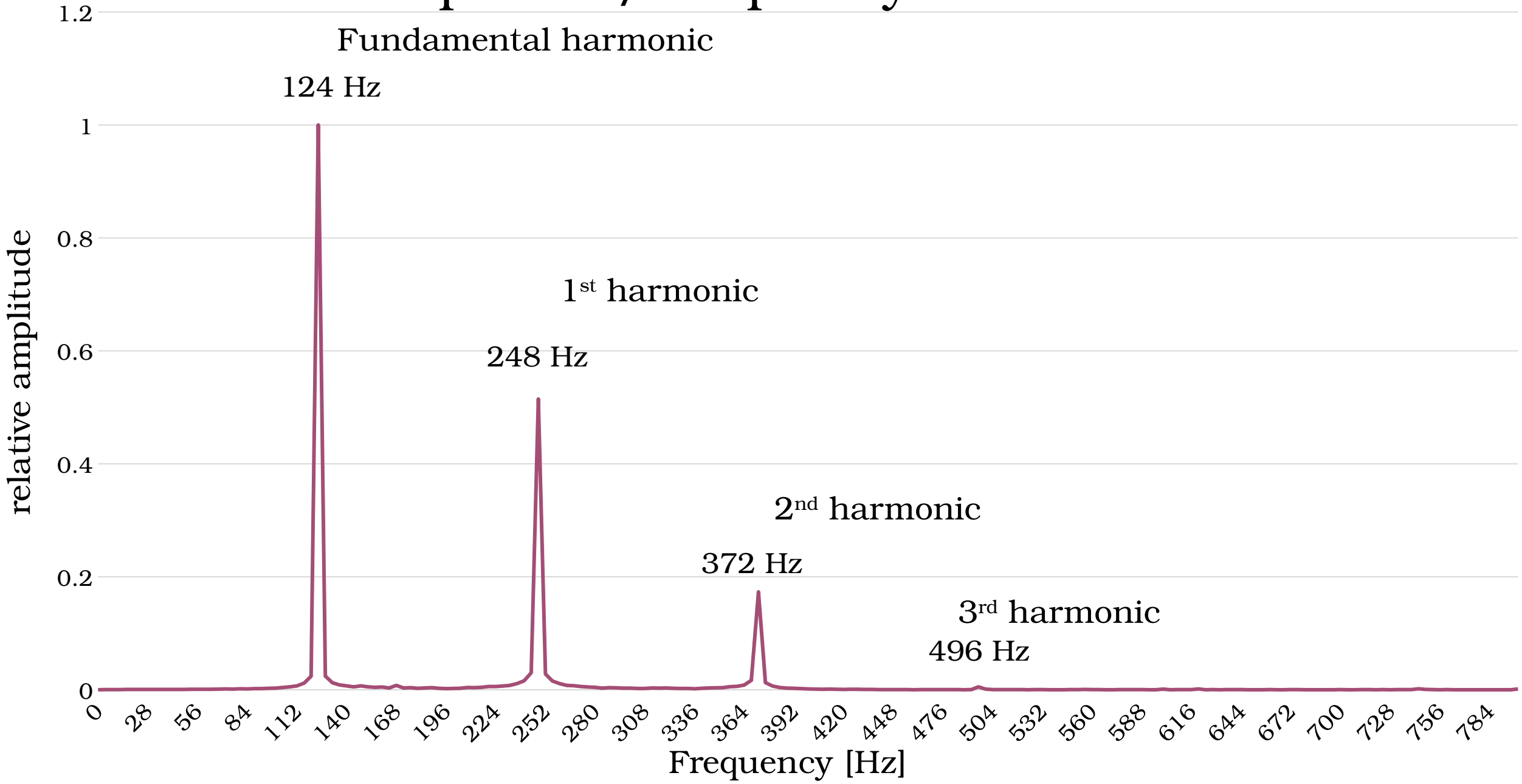
Amplitude/Frequency for 0.83m



Amplitude/Frequency for 1.16m



Amplitude/Frequency for 1.46m



Experiments vs. Theory

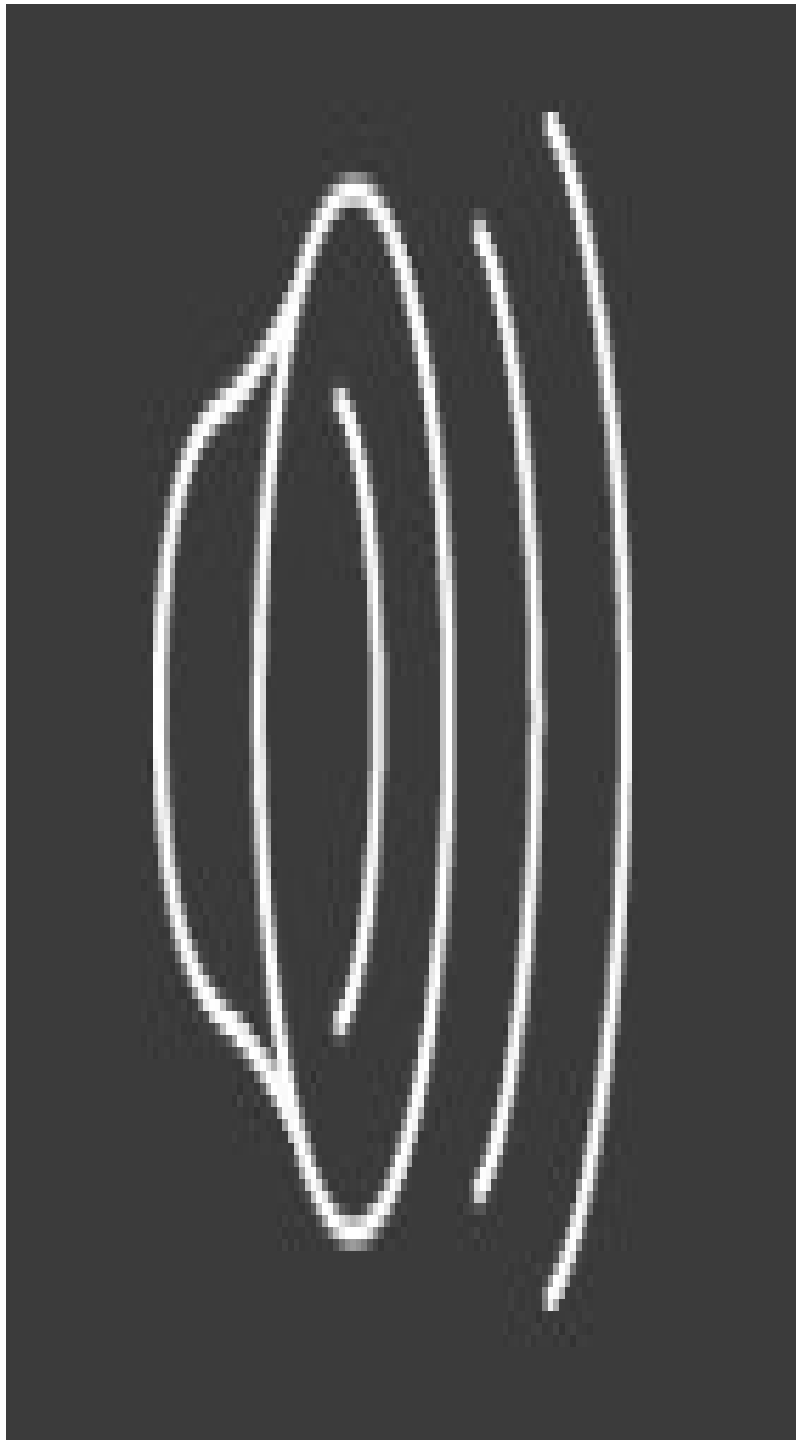
Experiments

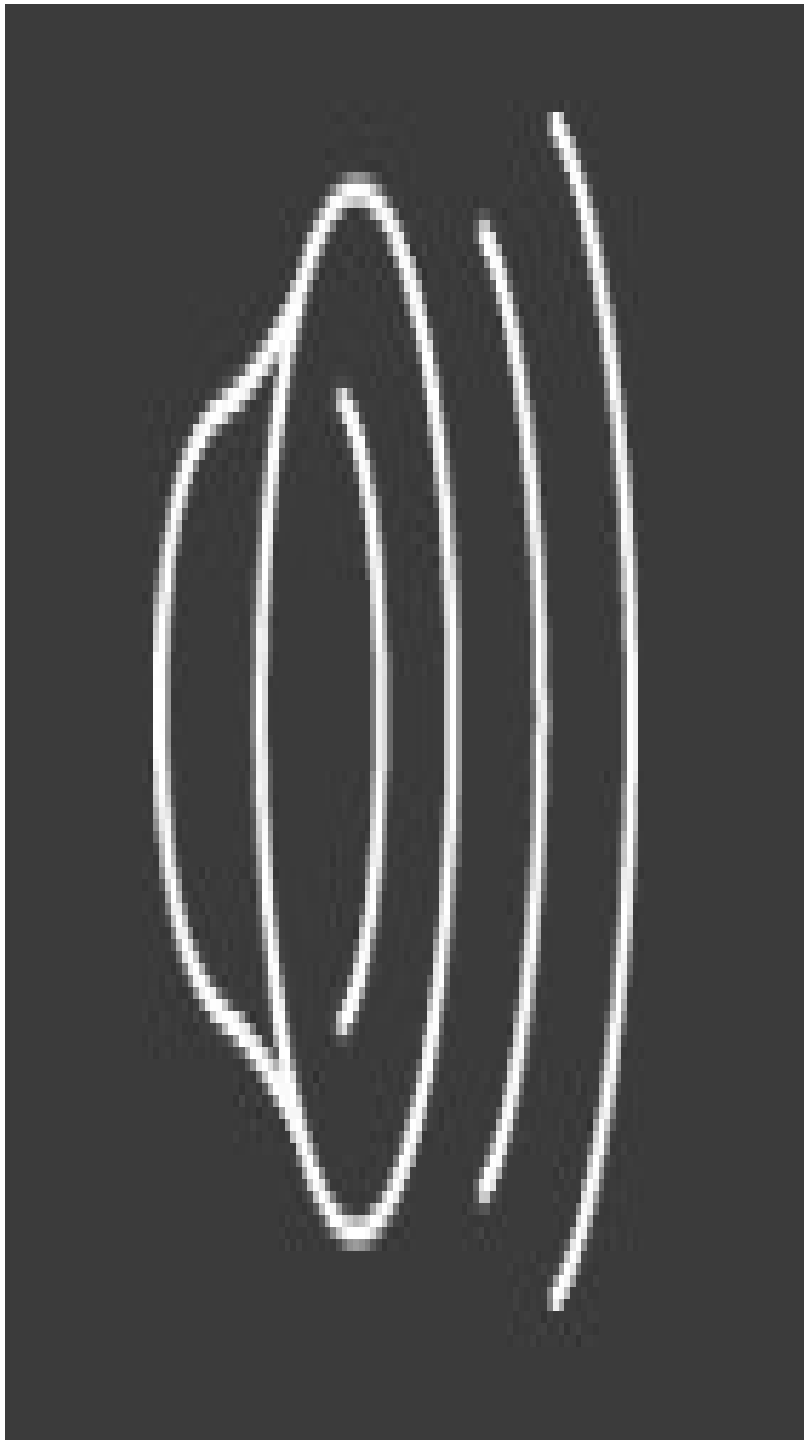
Theory

Temperature of gauze

Heating gauze vs. cooling gauze

Heating





Cooling

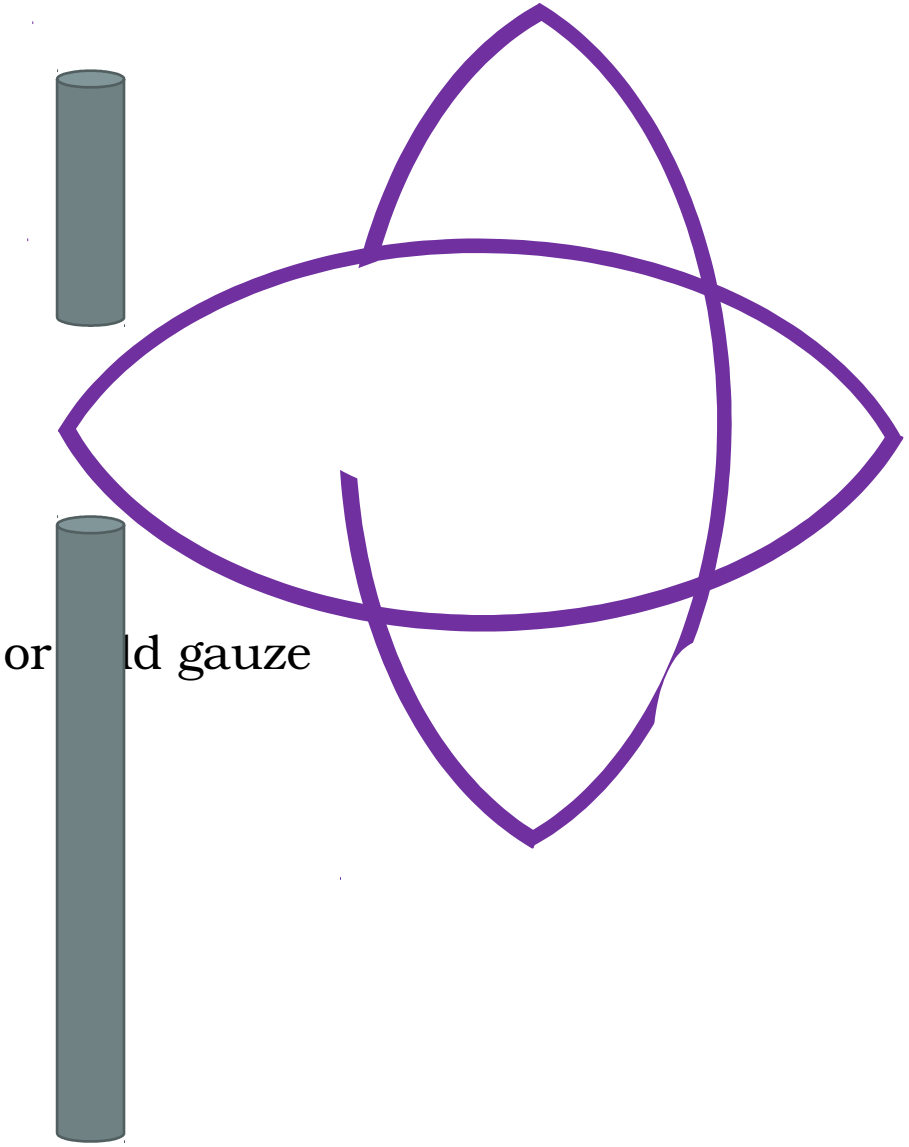
Conclusion

Sound creation:

- Produced by standing wave vertical tube, driven by temperature difference of the gauze.

Relevant Parameters:

- Tube in upright position.
- Works with positive or negative temperature difference between gauze and air.
- Frequency inversely proportional to tube length.
  (high pitch ↔ high frequency ↔ short tube)



Thank you for listening

Sources

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http://hyperphysics.phy-astr.gsu.edu/hbase/Waves/standw.html

https://www.youtube.com/watch?v=BhQUW9s-R8M

http://www.sciencedirect.com/science/article/pii/S1877705814028963

http://ilyam.org/proc2006/11_Singing_tube_Australia_Kathryn_Zealand_98-115_Proc_19th_IYPT_2006.pdf

Sine Wave or Harmonic Wave

Wave at a specific time: $y(x) = y_{max} \cdot \sin(kx)$

x = location
y = elongation
y_{max} = amplitude
λ = wavelength
$k = \frac{2\pi}{\lambda}$ = wave number
t = time
f = frequency
$\omega = 2\pi f$ = angular frequency

Family of waves at different times: $y(x, t) = y_{max} \cdot \sin(kx - \omega t)$

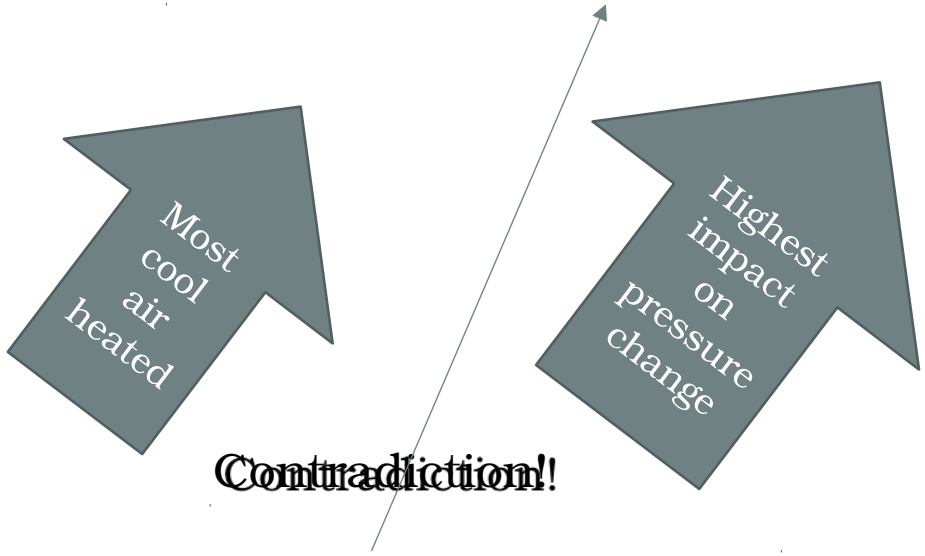
Gauze Position explained with Rayleigh index

Acoustic Wave: caused by pressure difference due to the rising heat

Velocity of particles: high Δ pressure results in low Δ velocity

Δv

Δp



Contradiction!

Rayleigh Index (= function of pressure and velocity) shows ideal placement of gauze at 25%, where Δ p and Δ v are maximized

FFT