Problem 10: Rijke’s Tube

Team Switzerland

Reporter: Michael Klein
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 → Find out why it makes a sound and what relevant parameters affect it.
What is a Rijke’s Tube?

1. Bunsen burner heats up mesh

2. Bunsen burner is removed

3. Sound is produced
Theory: Standing Waves on Strings

\[ x = \text{location} \quad y = \text{displacement} \quad n = \text{mode} \quad L = \text{length of the string} \]
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
- \( \lambda \): 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
Amplitude/Frequency for 0.83m

Fundamental harmonic
212 Hz

1st harmonic
424 Hz
Amplitude/Frequency for 1.16m

Fundamental harmonic
152 Hz

1st harmonic
304 Hz

2nd harmonic
456 Hz
Amplitude/Frequency for 1.46m

Fundamental harmonic
124 Hz

1st harmonic
248 Hz

2nd harmonic
372 Hz

3rd harmonic
496 Hz
Experiments vs. Theory
Temperature of gauze

Heating gauze vs. cooling gauze
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)

Hot or cold gauze
Thank you for listening
Sources

http://www.physicsclassroom.com/class/waves/Lesson-4/Formation-of-Standing-Waves
http://hyperphysics.phy-astr.gsu.edu/hbase/Waves/standw.html
https://www.youtube.com/watch?v=BhQUW9s-R8M
Sine Wave or Harmonic Wave

Wave at a specific time:

\[ y(x) = y_{\text{max}} \cdot \sin(kx) \]

Family of waves at different times:

\[ y(x, t) = y_{\text{max}} \cdot \sin(kx - \omega t) \]
Gauze Position explained with Rayleigh index

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

Velocity of particles: high pressure results in low velocity

Contradiction!

Rayleigh Index (function of pressure and velocity) shows ideal placement of gauze at 25%, where $\Delta p$ and $\Delta v$ are maximized.
FFT