# Ruben’s Tube

Demonstration

*Make a flaming tube to explore the physics of acoustics and waves.*

**Number of Participants:** 2 - 20

**Audience:** Elementary and up

**Duration:** 10 - 20 mins

**Difficulty:** Level 3

**Materials Required:**

- 3” diameter metal duct pipe 5’ long
- Metal end cap (3” in diameter)
- Metal or plastic T-joint
- 3 male adapters with nuts
- Latex hose or comparable (~10 ft)
- Caulk
- Matches/lighter
- Black spray paint optional
- Speaker – 4 Ω, 50W, 4 in.
- Optional – audio amplifier
- Tape measure
- Drill
- Propane tank with high flow rate limiter

## Setup:

1. Cut latex hose into 3 parts: 2 are 2” long, plus rest for the 3$^{rd}$ part.
2. Join long end of latex hose at confluence of T joint, as in Figure 1.
3. Leaving 6 inches on each end alone, draw a straight line with the tape measure for where gas holes will go.
4. Drill 1/16” holes along the line, spacing each out by ½ - ¾”. There should be about 64 holes total if ¾’’ is used. *Note: if holes are places closer together, more gas is used but flames will light neighboring flames.*
5. 90 º around the tube, drill two ¼” holes to be used as gas inputs. Attach male adapter and secure down with nuts.

*Figure 1 Joining the latex hose. The dual holes allow propane to get into the pipe quickly and evenly.*

6. On one end of the pipe, secure cap down. On other end, secure speaker (can caulk it) to pipe, as in Figure 2.
7. If desired, solder speaker wire to speaker. Hook speaker up to phone through an amplifier.
8. Open the propane valve to low or medium. Light up the holes with a lighter or match.
9. Once there's a steady stream of flames, turn on the jams! Play discreet frequencies (using a frequency generator app) to create visible standing waves.

*Figure 2 Speaker attached to end of tube. In this case, we kept the speaker attached to the tube with caulk.*

*Figure 3 Ruben Tube in action. There is a slight delay between turning on the gas and getting full flames.*

**Vocabulary:**

- Longitudinal waves - waves with excitations parallel to their direction of propagation, e.g. sound waves.
- Transverse waves – waves with excitations perpendicular to their direction of propagation.
- Node – the point in a wave where there is no motion.
- Anti-node – The point of a wave with highest amplitude. For the tube, the highest flames are in the anti-nodes
- Standing waves – Where the nodes and anti-nodes positions don't change.
- Constructive interference – when two peaks or two troughs of a wave meet, they create higher amplitude waves.
- Destructive interference – when a peak and a trough of a wave meet, the wave amplitude drops to zero.

## Physics & Explanation:

### Elementary (ages 5-10):

When we hear music, or our own voices, or any other sound, it is our ears picking up on differences in air pressure from

> To illustrate waves, play distinct frequencies through the speakers until you can get a standing wave. To visualize more “normal” sounds and for long entertainment purposes, music works great. Explore the relationship between volume and flame height, or flow rate of propane and flame height.

By igniting the propane gas in the tube and allowing it to escape out of holes cut into the top, we can visualize where the pressure is high or low.

Sounds are waves, and different pitches create different looking standing waves.

### Middle (ages 11-13) and general public:

The speaker works by moving larger amounts of air and creating places high and low-pressure air, which is what our ears pick up as sound. By turning on the speaker and directing sound into the tube, the air inside has high pressure areas and low-pressure areas. The sound travels down the tube, and bounces back off the other end, which creates sound wave interference. In places where two high-pressure regions overlap, we get constructive interference for the flames. Where low and high-pressure regions overlap, we get destructive interference and low amplitude flames. We not only hear this sound, but can visualize it by lighting the air on fire. Since air doesn’t burn consistently by itself, a propane tank is hooked up to fill the tube with propane gas.

> Try playing higher and lower frequencies. Does the standing wave pattern change? How so? Do all frequencies work to create a standing wave pattern?

Not all input frequencies will create an obvious standing wave pattern.

In the same way that you can only play a few different notes on a trumpet or trombone when in one particular position, only certain frequencies will create standing waves because flaming tube is a fixed length. If you had a whole range of different length flaming tubes, you could create more and more standing waves with a whole spectrum of frequencies!

Which particular frequencies that create standing wave patterns depend on the dimensions of the tube.

**Highschool and up (ages 14+):**

By turning on the speaker and directing that noise into the tube, the air inside compresses and rarefacts, which is what our ears hear. We can visualize the pressure differences by lighting it on fire!

The sound bounces back off the other end of the tube, which creates sound wave interference. In places where two high-pressure regions overlap, we get constructive interference for the flames, and anti-nodes. Where low and high-pressure regions overlap, we get destructive interference and low amplitude flames, and look like nodes on the tube. The flames themselves move up and down, creating a transverse standing wave pattern.

🔑 The Ruben tube's standing waves come in discrete values and depend on the frequency of the sound played.

> What could you change to alter the flame's amplitudes, or fit more standing waves into the tube?

The amplitude of the waves can be increased by turning up the volume or increasing the flow rate coming from the propane tank.

**Additional Resources:**


- Rossing Moore & Wheeler, *The Science of Sound* 2002.
- http://hyperphysics.phy-astr.gsu.edu/hbase/Waves/clocol.html