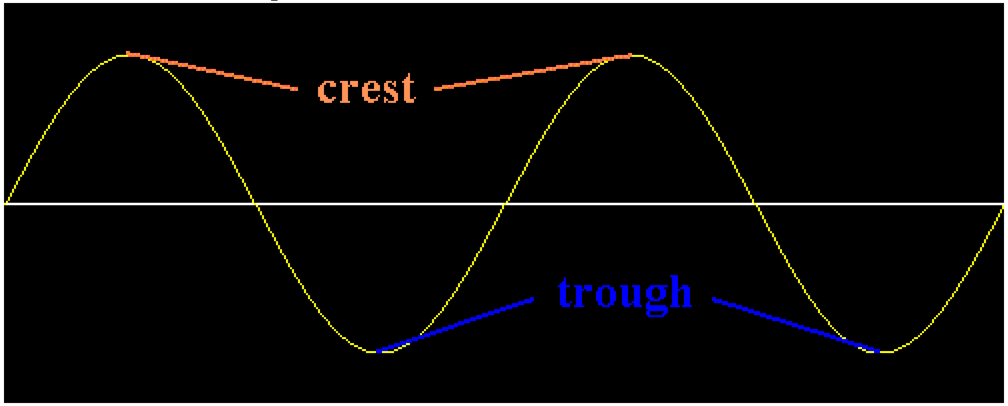
Ruben's Tube: Soundwaves in Fire

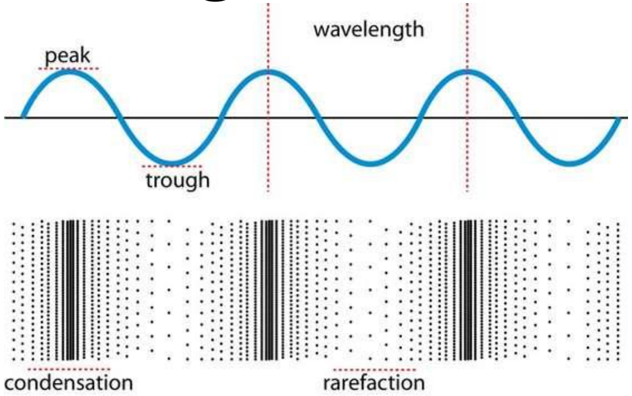
What is a Rubens' tube?

- Named after German physicist Heinrich Rubens
- A Rubens' tube, also known as a flame tube, is a metal tube with small holes drilled down its length. One end is capped off with a solid cap and the other end is covered in a sound permeable membrane. This tube, when fed propane (or any other type of flammable gas) can demonstrate standing waves in sound with fire.

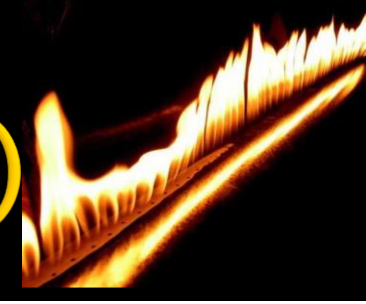
What is a sound wave?

- A sound wave is a wave through a medium that transmits sound.
- Sound waves are longitudinal comprised of compressions and rarefactions.
- Sound waves can be represented as a sin curve; areas of compression are represented as peaks and rarefactions as trough





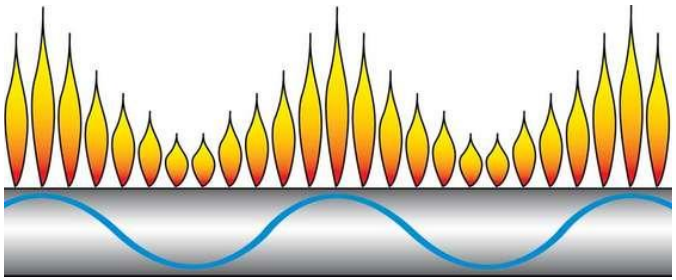
What is a sound wave? (cont.)



- Compressions occur where particles are close together (under crests on a graph)
- Rarefactions occur where particles are spread out (under troughs on a graph)
- Amplitude of waves determines their volume, or loudness
- Wavelength is distance between crests or troughs
- $v = \lambda f$

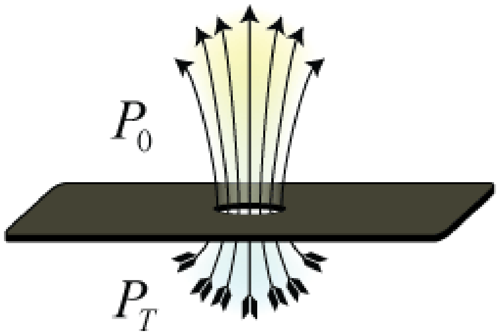
Why does it work?

- The Rubens’ tube acts like a tube with one end closed. It has a certain resonant frequency. When this frequency is played through one end of the tube, the sound wave bounces off the endcap on the other side and reflects back into the incident wave, both interfering constructively and deconstructively, creating the nodes and antinodes seen in the flame.
- This is a standing wave.



Bernoulli's Equation

$$\frac{1}{2}\rho v^2 + \rho g z + p = \text{constant}$$

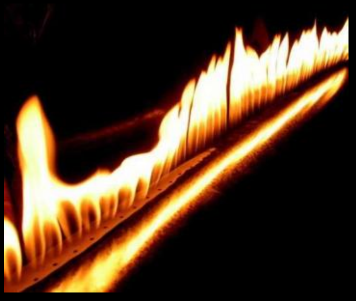


$$\frac{\rho V^2}{2} = P_T - P_0$$

$$V \propto \sqrt{(P_T - P_0)}$$

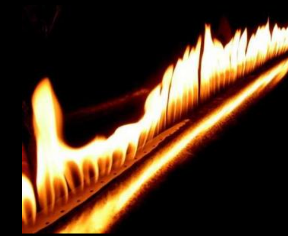
- We can apply this to the rubens tube to find out the velocity of the gas exiting the tube at that hole.
- From the original equation, $P_o + pgh + 1/2pv^2 = P_t$, where P_t is the pressure immediately inside the tube at the location of the hole, and P_o is the pressure outside.

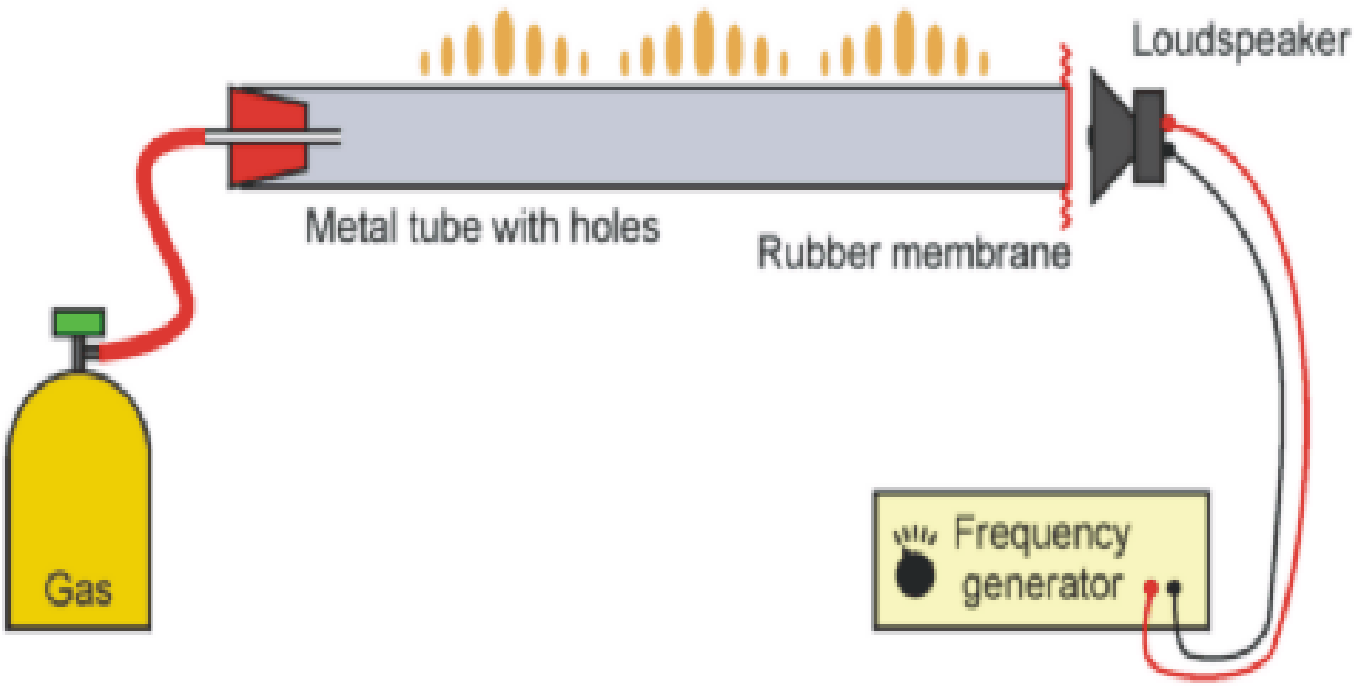
Bernoulli's Equation (cont.)



- From this we can derive $1/2pv^2 = P_t - P_o$, since the difference in height is negligible.
- So, the velocity of the gas with density p is roughly proportional to the square root of $P_t - P_o$.
- Therefore, if we had P_O and P_T, we could find out the velocity of the gas leaving the holes, which would be proportional to the height of the flame seen.

Construction of a Rubens' Tube





Construction of a Rubens' Tube (cont.)

- Materials:
  - Metal tube (preferably aluminum)
  - Drill
  - Multiple 1/16 inch drill bits
  - PVC fittings
  - Brass fittings
  - Small propane tank (or other fuel source)
  - Gas regulator
  - Vinyl tubing
  - Balloon (we later found out that a thin latex glove may work better)
  - Rubber bands
  - Silicon tape/ glue
  - Masking tape
  - Pencils
  - Speakers with amplifier
  - Sound source (frequency generator)
  - * Marshmallows *

Testing

Results

- Although it was difficult to maintain a sin wave long enough to gather data, we were able to get some.
- At 327 Hz, the wavelength was approximately .508 m.
- At 754 Hz, the wavelength was aproximately
- .1905 m
- By substituting these values in $v=\lambda f$, we got the speed of sound in propane to be 166.116 m/s and 143.637.

Problems/ Limitations with our model and possible soulutins

- Not a constant supply of propane, could only have short good runs
- Our speaker was weak and did not have a good connection to the balloon
- Solution:
- Connect the speaker better, use a stronger amp, have a better fuel source.
- We cannot calculate the exact speed of sound in propane because the holes act like Helmholtz Resonators, as well as residual interference.

Works cited

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