The 5th International Young Naturalists' Tournament

Municipal Autonomous Institution of General Education of the city of Novosibirsk
«Gymnasium №12»

Problem №10
Rijke’s tube

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Statement of the problem

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

Hypothesis

If the vessel is filled with elastic air and communicates with the atmosphere, then it is capable of making sounds

The aim of the study

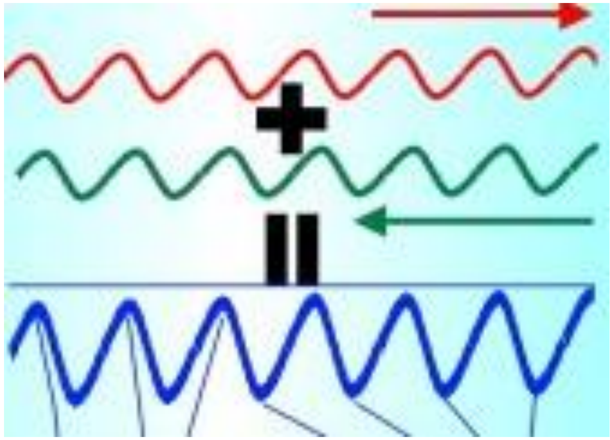
Investigate the formation's principles of the thermoacoustic oscillations in gases on the example of standing oscillations in Rijke's tubes

The tasks

1. Study the theoretical material;
2. Make a Rijke's tube;
3. Identify the significant parameters that affect the frequency of sound oscillations occurring in Rijke's tube;
4. Define the parameters that affect the speed of occurrence and the duration of the sound oscillations in the installation.

Theoretical part of the study

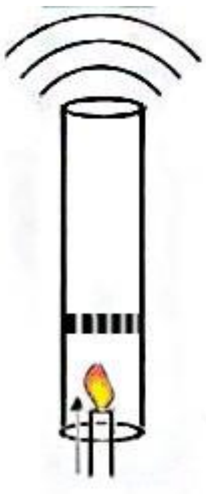
In physics, a standing wave – also known as a stationary wave – is a wave in a medium in which each point on the axis of the wave has an associated constant amplitude. The locations at which the amplitude is minimum are called nodes, and the locations where the amplitude is maximum are called antinodes.



Self-oscillation is the generation and maintenance of a periodic motion by a source of power that lacks any corresponding periodicity.

John William Strutt (3rd Baron Rayleigh)
(12.11.1842 — 30.06.1919)
British physicist

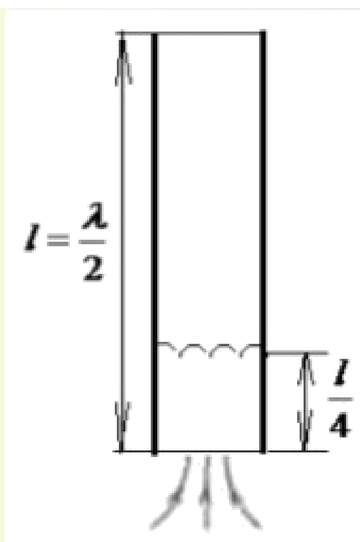
Theoretical part of the study



The Rijke's tube is a thermoacoustic resonator in which heat is converted into sound.

Any hollow vessel filled with air that is resilient in its properties and communicating with the atmosphere through openings becomes an acoustic resonator and is capable of producing sounds.

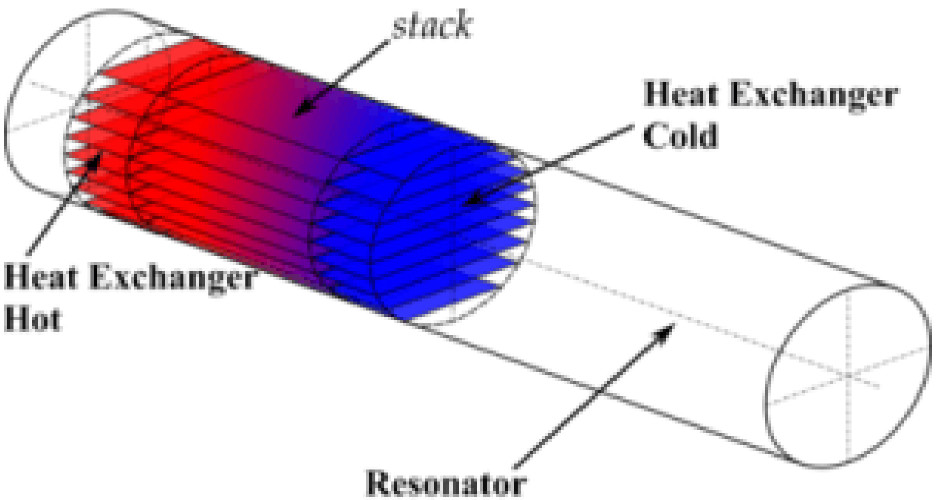
The most intense sound was observed when the heated mesh was located a quarter of the length of the pipe from the lower end. If the grid is shifted to the top of the tube, the oscillations are weakened and extinguished.



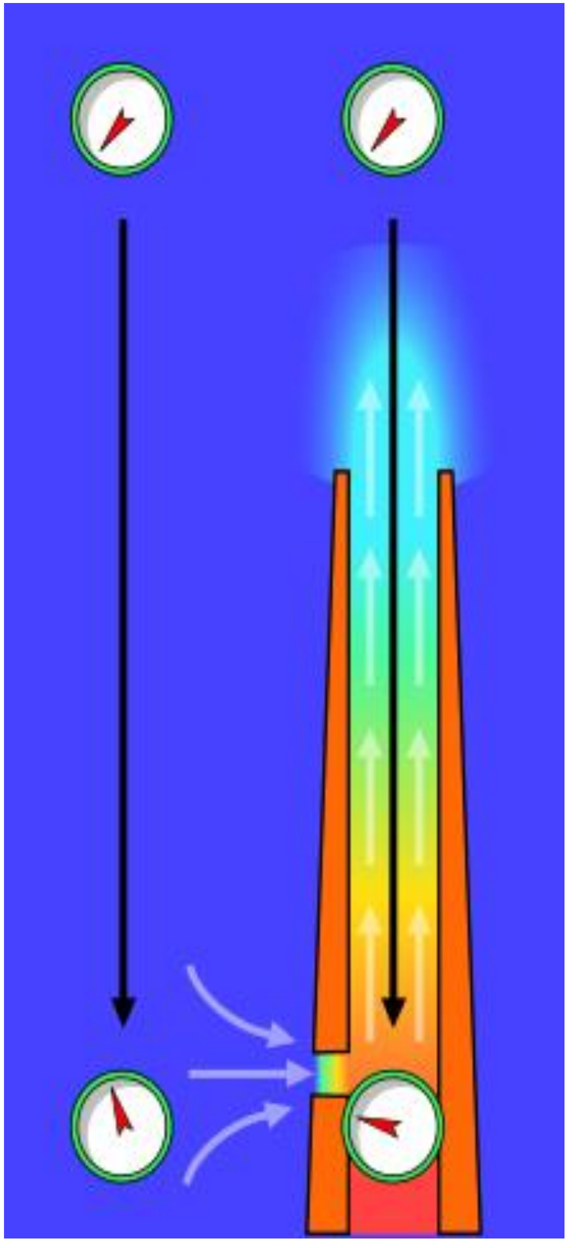
$$\nu = v/(2l)$$

***ν* - oscillation frequency in tube;**
***v* – sound's speed in air;**
***l* – tube's length**

How does Rijke’s tube sing?



The simplest thermoacoustic transducer



If you drive the air flow through the tube, it will sound in any of its positions. It is completely indifferent how the flow of air in the tube is created – by a natural convection or a pumped stream.

The grid in the tube can be heated by fire or by passing an electric current through it.

Experimental part of the study

Purpose is to simulate the phenomenon in the laboratory.

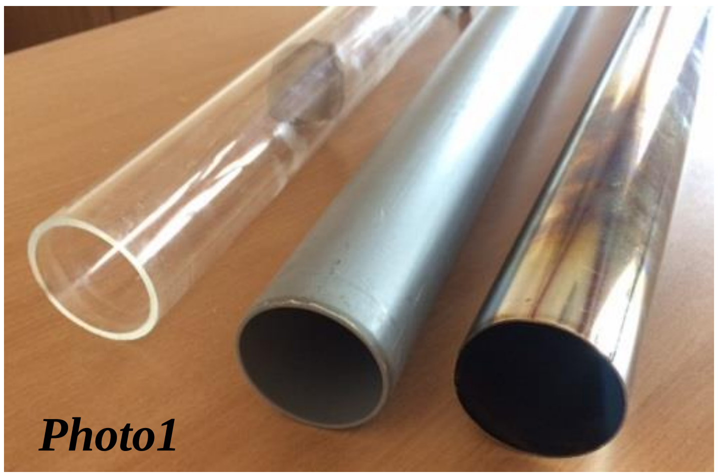


Photo1

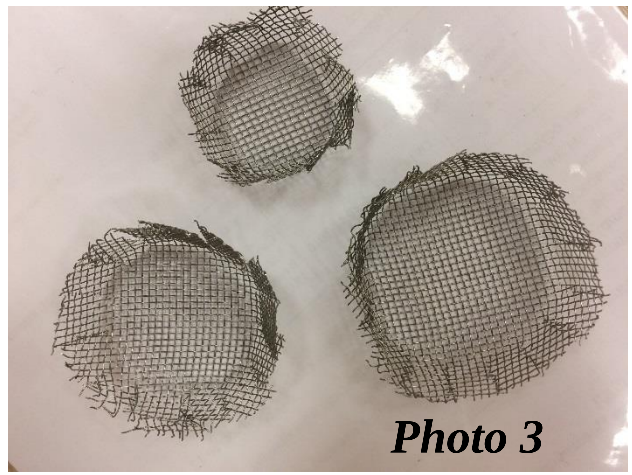


Photo 3

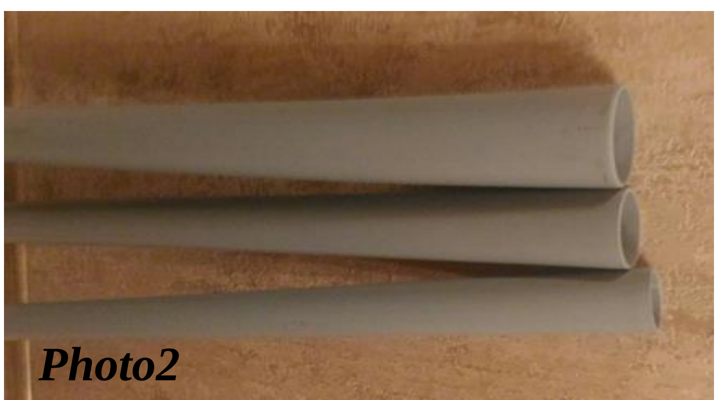


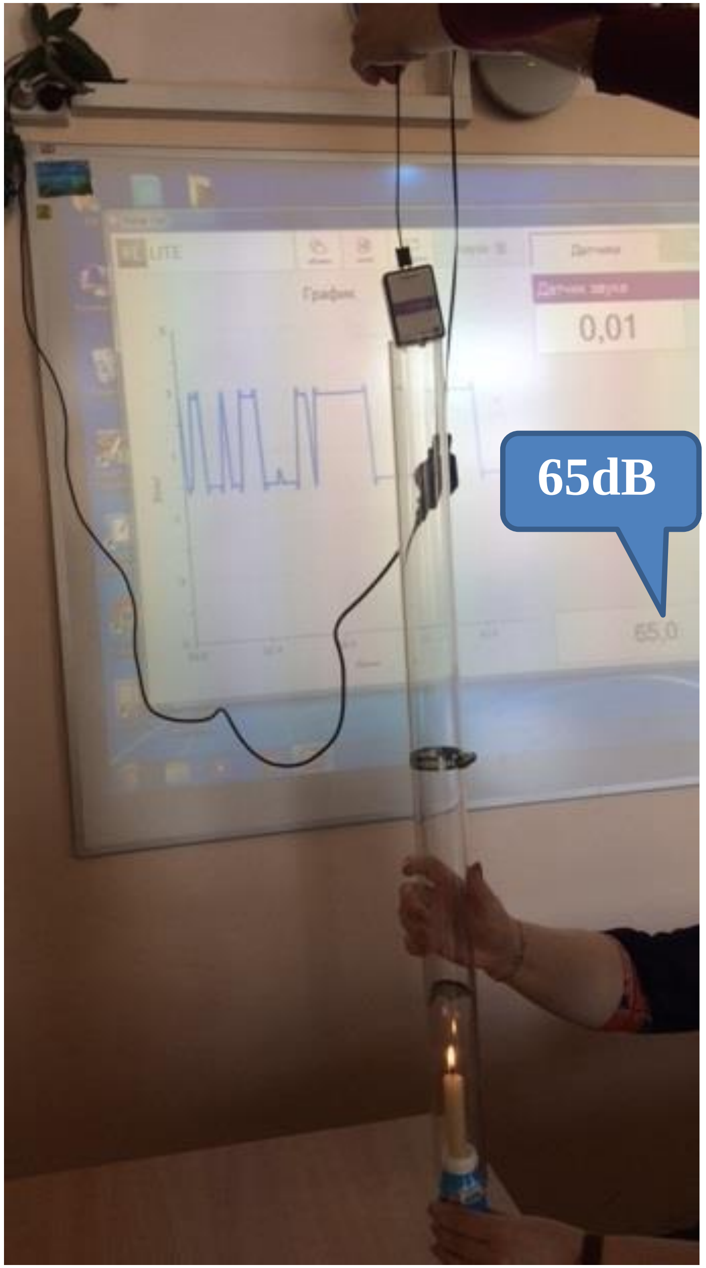
Photo2

Photo 4

Equipment:

1 – tubes made of metal, glass and plastic with the diameter of 50 mm;
2 – plastic tubes with the diameter of 25, 50, 70 мм;
3 – steel flat mesh;
4 – steel sponges of different rigidity.

Experimental part of the study



The purpose is to define the dependence of the formed sounds' loudness in tubes made of plastic, glass and metal, having the same length and diameter.

Table 1. Volume of sound

Metal	Glass	Plastic
62,5 dB	65 dB	63 dB

Thus, we made the conclusion that the volume of sound oscillations doesn't depend on the substance of the resonator. Since the tube's size is the same, the volume of air enclosed in them is also the same.

<u>Experimental part of the study</u>

<u>The purpose</u> is to define the dependence of the sound's loudness from the location of the heated mesh.

Table 2. Dependence of the received sound's loudness on the hot grid's location.

0 cm	5 cm	10 cm	15 cm	20 cm
0 dB	0 dB	7 dB	12 dB	48 dB
25 cm	30 cm	35 cm	40 cm	45 cm
63 dB	42 dB	8 dB	0 dB	0 dB

As you can see, the perceived sound is created when the heated mesh is located from 10 up to 35 cm. The maximum loudness of the sound vibrations is got when the mesh is located on the one-fourth of the tube's length.

Experimental part of the study

The purpose is to define the dependence of the sound vibrations on the radius of the tube.

$$L + 0{,}63\,R = n\lambda/4$$

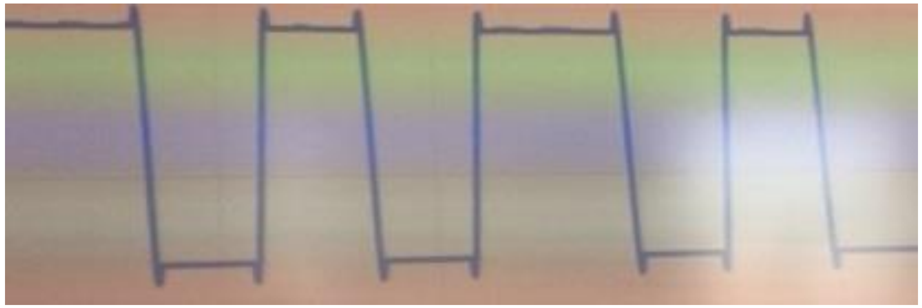
L – tube's length, R – its radius, λ – wavelength, n – any odd number (1,3,5..)

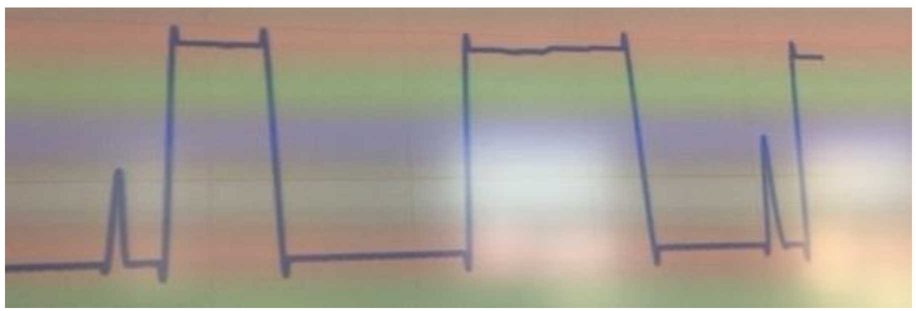
Having made the necessary calculations, we made sure that, for a tube with a diameter of 35 mm, the optimum length for excitation of sound vibrations is 80-100 cm. But this effect disappeared in a tube less than 48 cm. For a tube of 25 mm in diameter, the maximum length at which stable sound is still observed, is approximately 200 cm. For a tube with a diameter of 35 mm at such a length, the oscillations couldn't be recorded.

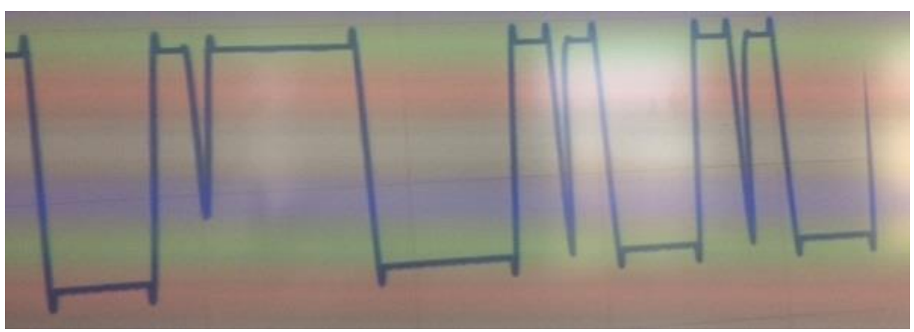
Experimental part of the study

The purpose is to study the process of stable sound oscillations' occurrence from the temperature difference in the lower and upper parts of the air column.

Experimental installation

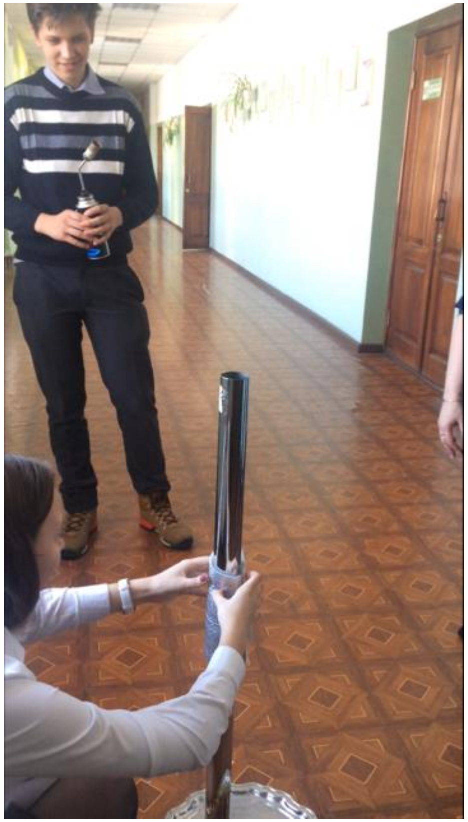






Experimental part of the study

The purpose is to study the process of stable sound vibrations' occurrence from the spatial location of the tube.



We made the conclusion that the stable sound vibrations can be observed with the vertical arrangement of the tube, the sound stops with its horizontal position or with overlapping of the bottom hole.

The concept of an installation demonstrating thermoacoustic oscillations in gases

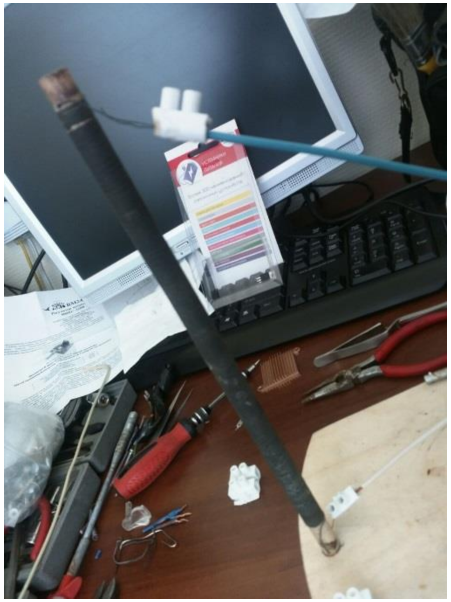


Table 1. Calculations of tube's length

Frequency, Hz		1.00	Wavelength 1 octave, m	2.00	Wavelength 2 octave, m
Note		octave		octave	
Do	C	261.63	1,2995	523.25	0,649785
Re	D	293.66	1,1578	587.32	0,578901
Mi	E	329.63	1,0314	659.26	0,51573
Fa	F	349.23	0,9735	698.46	0,486785
Sol	G	392.00	0,8673	784.00	0,433673
La	A	440.00	0,7727	880.00	0,386364
Si	H	493.88	0,6884	987.75	0,344217

Assembly of thermoacoustic organ

Conclusions

Thus, we made the following conclusions:

1. The higher the temperature difference in the air column enclosed inside the tube, the higher the frequency of sound vibrations;
2. The best sound is provided by a tube with a diameter of 40 mm;
3. Sound vibrations generated in a plastic pipe may be obtained by injecting cold air;
4. When the air is pumped into the pipe, sound is formed in any of its locations, and when the air is heated, only in the vertical one.

References

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