Exercise 3
Acoustic Resonance

Aim

Observation of acoustic resonance in a Quincke`s tube, determination of the sound speed in different gases, determination of the ratio of specific heats of gases c_p/c_v *and degrees of freedom.*

Required theoretical knowledge

Waves. Amplitude, phase, wavelength, velocity, frequency of a wave. Longitudinal and transverse waves. Sound and its velocity. Acoustic waves in gases. Interference of waves, standing waves. Speed of sound in gases. Degrees of freedom. Ratio of specific heats of gases

$$\kappa = \frac{c_p}{c_v}$$

Equipment

Vertical Quincke`s tube connected with the parallel tube of a smaller diameter. The loudspeaker located above the Quinck`s tube and activated by the acoustic generator. The Quincke`s tube is connected to the water supply. A measurement setup is shown in Fig. 1.

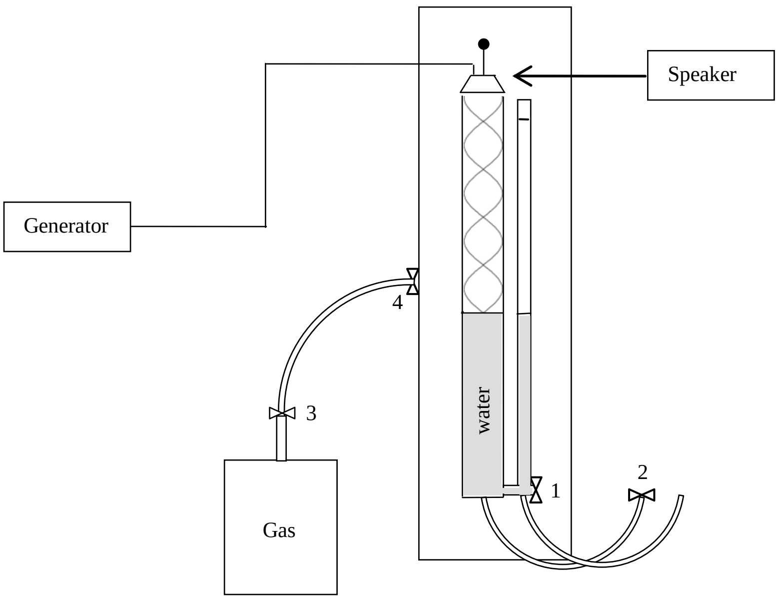

Fig. 1. Acoustic resonance measurement setup.

Quincke's tube is a one-side closed tube with the movable bottom. This movable bottom is realized by filling the tube with water. A loudspeaker is placed in front of the open end of the tube. The loudspeaker, excited by the frequency generator, activates the sound waves inside the tube. The acoustic waves travel towards the closed end of the tube, reflect there and on the way back interfere with the succeeding incident waves. As a result, the standing waves are formed there. When the tube length is changing by filling the tube with water, we can hear at certain positions of the water level - in places where the antinodes are located - the intense high sound. The first node is located always at the surface of water and the last anti-node is located always at the open end of the tube. The number of nodes and antinodes along the tube depends on the frequency of the sound source.

Problems for discussion:

Acoustic waves
Standing waves
How to calculate the standing wave wavelength knowing the waves nodes?

Measurement plan:

1. Turn on the PC. Start Exercise_3 software.

Option A – Air

2. Lower the loudspeaker to the open end of the Quincke`s tube,
3. Switch on the acoustic generator and set up a certain frequency according to the instructor’s advice.
4. Close the valve 1 at the bottom of the Quinck`s tube. Open valve 2 **gently** turn on the running water supply tap and **slowly** fill in the tube with water.
5. While water is filling the Quinck`s tube, you can hear the intense sound at a certain tube length. Mark these lengths with a piece of chalk (or marker) on the milimmeter scale on the right side of the tube. The marks indicate the antinodes of the standing waves. While filling in the tube with water , please don`t exceed the blue line marked in the upper part of the tube.
6. Turn on the valve at the bottom of the Quinck`s tube and remove **slowly** water from the tube by opening valve 1, checking again the location of the standing wave antinodes on the scale next to the tube.
7. Repeat measurements for the different frequencies given by the instructor in ranges 400 – 1600 Hz.
8. Write down the result in the Table 1.

Option B – CO_2

1. Turn off the valve at the bottom of the Quinck`s tube (turn it towards a wall).
2. **Gently** turn on a water tap above a washbasin and fill in the glass tube with running water. When the level of water reaches the blue line at the glass tube, turn off a water tap.
3. Lift the soundspeaker above the tube and plug the tube with a cork.
4. Open the valve of the CO_2 bottle and fill in with gas a gas tank next to the bottle. A small valve on top of the tank must be in horizontal position.
5. Turn this small valve on top of the tank into vertical position and simultaneously turn on the valve at the bottom of the Quinck`s tube (turn it towards you) and slowly lower the level of water in a glass tube. In this way you can fill in the Quinck`s tube with CO_2.
6. Remove the cork and put on the loudspeaker slightly above the top of the Quinck`s tube.
7. Turn off both gas valves and set the generator to the frequency given by teaching assistant.
8. Turn off (turn towards the wall) the valve at the bottom of the Quinck`s tube. Turn on a water tap above a washbasin and slowly fill in the glass tube with running water.

While the level of water is going up, draw marks at places where you can hear the maximal sounds.

9. Repeat 1-8 for the different frequencies.
10. After finishing the measurement leave valve 1 open.

Data processing:

1. Calculate of the mean value of the wavelength λ_{mean} for all given frequencies.
2. Open *Calc* software.
3. Draw a graph of $\lambda = v \cdot \frac{1}{f}$ – fit a straight line to the experimental points – use one-parameter linear regression.
4. Calculate the speed of sound v and its uncertainty.
5. The sound velocity in gases is given by the formula:

$$v = \sqrt{\frac{\kappa RT}{\mu}} \qquad (1)$$

6. where T is the gas temperature, μ is the molecular mass (assume that air consist of: 78% N_2, 21% O_2, 1 % Ar), R is the universal gas constant R=8.313 J/K and $\kappa = \frac{c_p}{c_v}$ is the ratio of the molar specific heats for gas at constant pressure and volume, respectively.
7. Calculate κ and its uncertainty.
8. The coefficient κ depends on degrees of freedom *i:*

$$\kappa = \frac{i+2}{i} \qquad (2)$$

9. Calculate degress of freedom for measured gas. Compare with theoretical value: for air κ = 5, for CO_2 κ = 6.

Literature

1. Halliday, Resnick "Fundamentals of Physics - 8th edition", John Wiley 2007,