Resonance frequencies of Helmholtz resonators with Cobra4 Xpert-Link (Item No.: P2150864)

Curricular Relevance

Area of Expertise: Physics

Education Level: University

Topic: Oscillations and Mechanical Waves, Acoustics

Subtopic: Sound Waves

Experiment: Resonance frequencies of Helmholtz resonators with Cobra4 Xpert-Link

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Intermediate	10 Minutes	10 Minutes	2 Students

Additional Requirements:

Experiment Variations:

Keywords:

Cavity resonator, resonance frequency, acoustic resonant circuit

Introduction

Overview

Acoustic cavity resonators possess a characteristic frequency which is determined by their geometrical form. In this case the resonator is excited to vibrations in its resonance frequency by background noise.

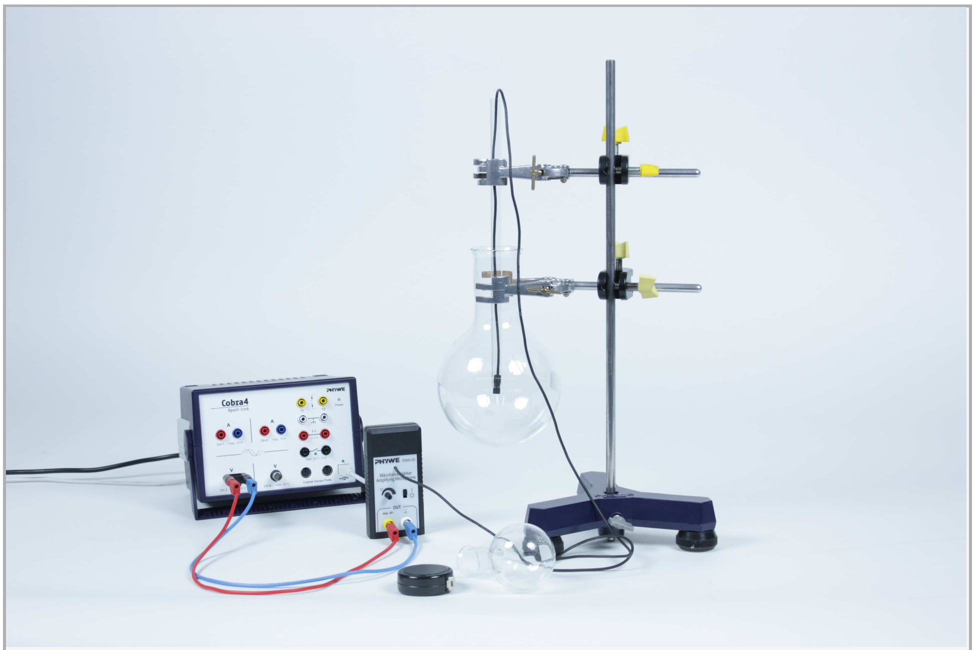

Fig. 1: Set-up for the investigation of the characteristic oscillations in a cavity resonator.

Equipment

Position No.	Material	Order No.	Quantity
1	Cobra4 Xpert-Link	12625-99	1
2	Software measureLAB	14580-61	1
3	Measuring microphone with amplifier	03543-00	1
4	Tripod base PHYWE	02002-55	1
5	Long-neck round-bott.flask 1000ml	36050-00	1
6	Glass tube,diam 12mm l 300 mm	45126-01	1
7	Universal clamp	37715-00	2
8	Boss head	02043-00	2
9	Support rod, stainless steel, 500 mm	02032-00	1
10	Long-neck round-bott.flask 100ml	36046-00	1
11	Measuring tape, l = 2 m	09936-00	1
12	Connecting cord, 32 A, 500 mm, red	07361-01	1
13	Connecting cord, 32 A, 500 mm, blue	07361-04	1
14	Flat cell battery, 9 V	07496-10	1

Task

Determination of different resonance frequencies of a resonator depending on the volume.

Set-up and procedure

Set up the equipment in accordance with Fig. 1. The sound probe is extended through the glass tube and should be located in the upper third of the round part of the flask.

Start the software “measureLAB”, and choose the experiment from the start screen. All necessary presetting will be loaded. If you wish to check the parameters, click on the gear wheel button, choose “Sensors/Channels” and select Channel CH3. The measurement range has to be set to “10 V”, as this range corresponds to the microphone amplifier output range.

Start the measurement by clicking the “Record” button.

Adjust the amplification of the microphone to an intermediate level. In this experiment ambient noise is desired. If the ambient noise level during measurement is too weak, you can generate an appropriate noise in a simple manner. It is, e.g., sufficient to rub two sheets of sand paper together, or gently knock on the flask. If the signal stops refreshing in the oscilloscope view the trigger threshold (slide control on the right) has to be adjusted to a lower value.

Your signal may look like this:

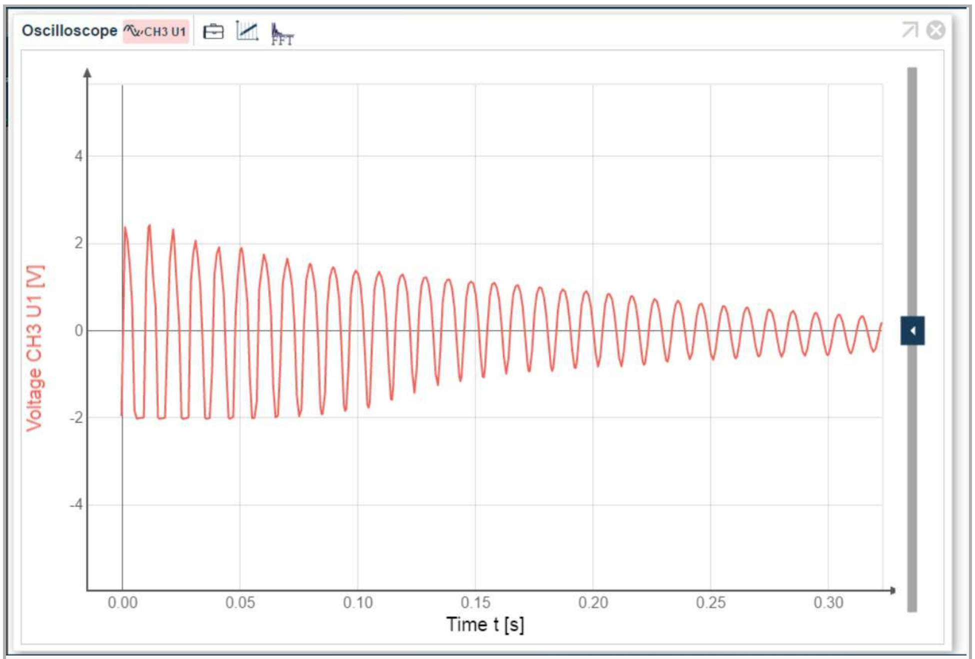

Fig. 2: Empty flask

The amplitude of the signal can be enhanced by either adding further noise or by readjusting the microphone amplification.

You can switch between oscilloscope view and fourier spectrum by clicking on the “FFT” (“Fast Fourier Transformation”) button. While the oscilloscope signal is a superposition of different signals of various frequencies, the FFT will provide you with a live analysis of the frequencies that are contributing to the signal. The number of counts is a measure for the contribution of each frequency.

Your signal may look like this:

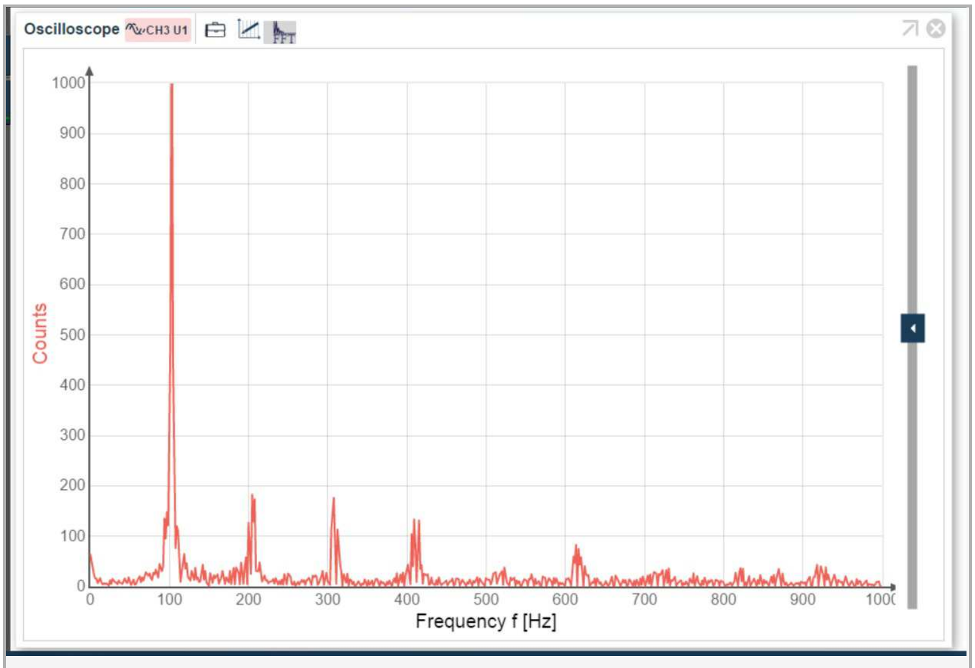

Fig. 3: Empty flask (Fourier spectrum).

Use the FFT analysis and determine the position of the resonance frequency of the 1000 ml flask, which is only filled with air, from the spectrum.

Repeat the experiment after the spherical part of the flask has been half-filled with water.
For comparison purposes, perform the above mentioned measurement steps for the 100 ml round-bottomed flask. You may wish to observe the frequency shift live while slowly filling the reservoir.

When using the 100 ml flask, the sound probe should be inserted into the flask without a glass tube, because the glass tube can influence the resonance length.

Your results may look like this:

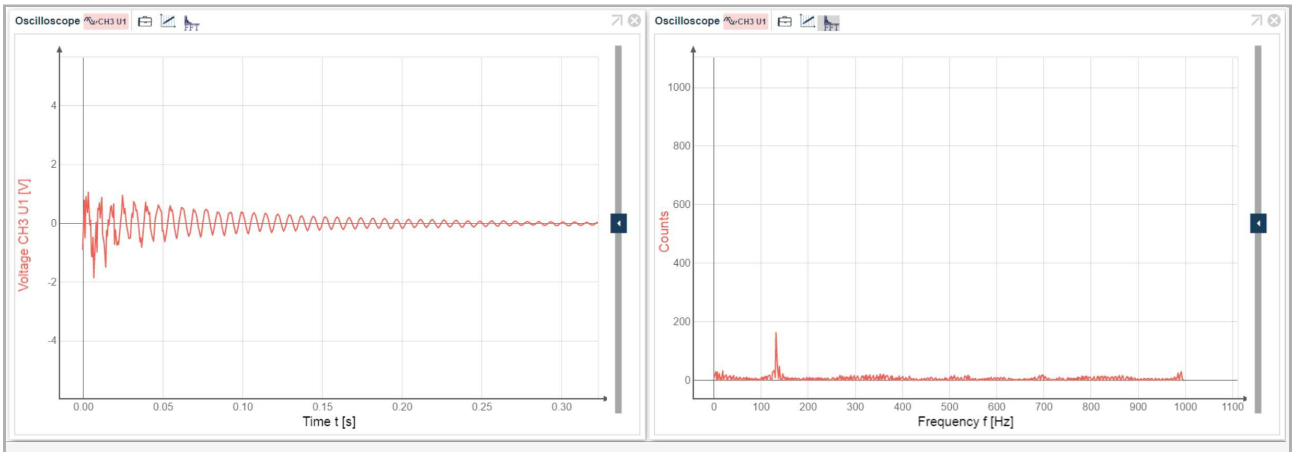

Fig. 4: Half-filled flask. Note the frequency shift in the Fourier spectrum in comparison to the empty flask measurement.

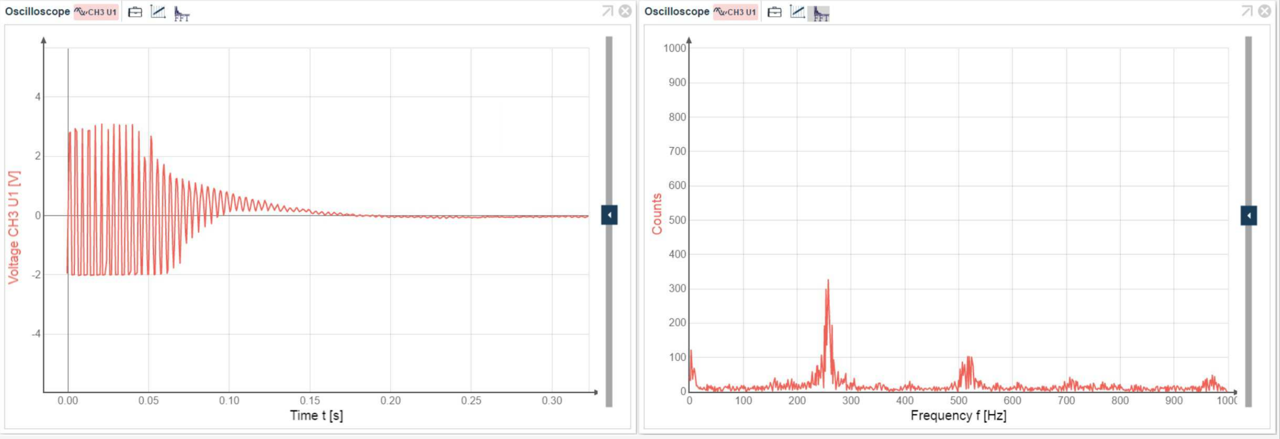

Fig. 5: Empty 100 ml flask.

You may wish to perform additional measurements for different kinds of flasks that are available in your lab. To perform a quantitative analysis the quantity of water with which the flasks are filled should be weighed or determined with a graduated cylinder.

Use the measuring tape to determine the tube length and (inner) diameter of the tube of each flask, and determine the diameter of the spherical volume of each flask. You will need these values for a calculation of the respective resonance frequencies.

Theory and evaluation

The characteristic oscillation spectrum of the round flask consists of a single resonance line with a frequency of 195 Hz. After reducing the air volume in the round-bottomed flask by 50 % by adding water, the frequency rises to 245 Hz. Additionally, secondary lines are observed and the noise of the ambient level becomes slightly more obvious, which implies a reduction in resonator quality.

A system consisting of a tube and a hollow body, like the round-bottom flask used here, represents a Helmholtz resonator in its general form. The condition for the applicability of the following formula is thus that the tube length is small compared to the sound wavelength. The sound wavelength of the resonance frequencies occurring in this case is 1.4 m, which is larger than the tube length of the round-bottom flask. The natural resonance frequency of such an acoustic resonant circuit can be derived under the assumption that the air filling in the sphere works against the movement of the “air piston” in the tube like an elastic spring. Taking the mouth correction for the tube length into consideration, the frequency f is given by the following formula:

$$f = \frac{c}{2\pi}\sqrt{\frac{\pi r^2}{(l+\frac{1}{2}\pi r)}\cdot\frac{1}{V}}$$

where c is the speed of sound, l the tube length, r the radius of the tube, and V the volume of the hollow body attached to the tube.

Using the following numerical values for the 1000 ml flask:

c = 343 m/s
r = 0.023 m
l = 0.085 m

V = $10.23\cdot 10^{-4}\,\mathrm{m}^3$

the resonance frequency of the empty round-bottomed flask is calculated to be 199 Hz, and the resonance frequency of the flask which is half filled with water is 280 Hz.

A comparison of the two resonance frequencies confirms that the frequency is inversely proportional to the square root of the volume of the hollow body.