Resonance frequencies of Helmholtz resonators with PC interface

LEP 1.5.08

Related topics
Cavity resonator. resonance frequency, acoustic feedback, undamped oscillation.

Principle and Problems
The aim of the experiment is to show that the acoustic cavity resonators posses a characteristic frequency which is determined through their geometrical form. A round bottom glass flask is used as a resonator, which corresponds in its form and function to a Helmholtz resonator as described in the literature. The resonator is excited to vibrations in its resonance frequency through acoustic feed back; the volume of air in the resonator is decreased gradually by filling up water and the dependence of the characteristic frequency of the resonator on the volume is studied.

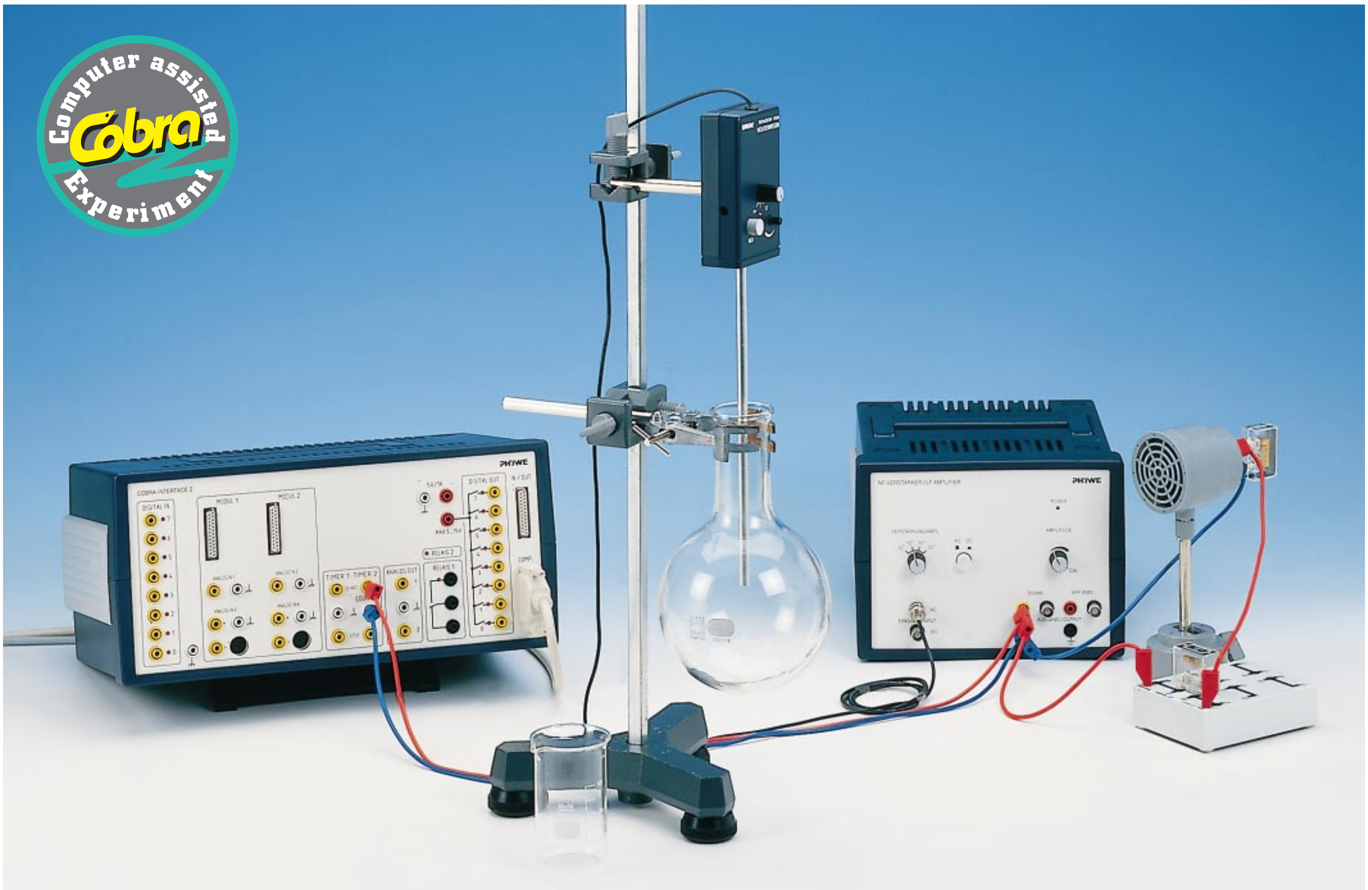
Equipment

Measuring microphone	03542.00	1
LF amplifier, 220 V	13625.93	1
Long-neck round-bott.flask 1000 ml	36050.00	1
Connection box	06030.23	1
PEK carbon resistor 2 W 5 % 100 Ohm	39104.63	1
Electr.capaci. 47 microF/63 V bip	39105.45	1
PEK electrol. capacitor 100mmF/35V	39105.25	1
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	1
Support rod -PASS-, square, l 630 mm	02027.55	1
Right angle clamp -PASS-	02040.55	2
Universal clamp	37715.00	1
Sound head	03524.00	1
Glass beaker,tall, 150 ml	36003.00	1
Connecting cord, 250 mm, red	07360.01	1
Connecting cord, 500 mm, red	07361.01	2
Connecting cord, 500 mm, blue	07361.04	2
COBRA-interface 2	12100.93	1
PC COBRA data cable RS232, 2 m	12100.01	1
Softw. COBRA Rate, time, freque.	14273.51	1

Set-up and procedure
Fig. 1 shows the complete experimental set-up; where the following points should be taken care of:

– The end of the microphone probe should be approx. 2 cm above the middle of the spherical part of the flask.
– Connect the microphone to the input “AC” of the LF-Amplifier.
– It is mandatory to connect the sound head according to Fig. 2 over the protective resistor 120 Ω to the signal output of the LF-Amplifier as the direct operation of the sound head destroys the loud speaker.
– Connect the capacitor directly with the connection cable in the sound head (Hint: the capacitor blocks the higher frequencies; hence ensuring that the system oscillates in the basic frequency)
– The sound head should be at a distance of 50 cm from the resonator (Round bottom flask).

Fig. 1: Experimental set-up to verify the Doppler effect.



In the first step, it should be taken care that the cavity resonator emits non-damped oscillations in its characteristic frequency: the amplification at the LF-amplifier is initially set to the minimum value:

- Press the switch of the microphone, select the operational mode "~" and bring the adjustment knob for the amplification in the microphone to the middle position.
- Set the amplification level 10^1 at the LF-amplifier and the adjustment knob such that a stable and a low tone is emitted; do not select higher amplification in order to avoid distortions (harmonic frequencies)
- If a high pitched whistle tone is heard instead of a low tone, the sound head is placed too close to the opening of the resonator: increase the distance (loosen the coupling between the resonator and the loudspeaker) and correct the amplification adjustment.

Now the frequency of the oscillation should be measured with the COBRA:

- Start the program "Pulse rate, Time- and Frequency measurement".
- Select the program function <Measure> <Parameter>.
- Select the "Mode of measurement: Frequency in Hz", "Repetition: Individual measurement" and "Gate time: 1 5".
- Start the measurement with <F10> <o.k.> and by pressing any key.

For the round bottom flask recommended by us, the range of measured values should be in the range of 160 and 180 Hz. Because of the tolerances of the glass flask, a certain margin of error is produced. Repeated measurements should lie, however, within +1 Hz for the same flask. Noise should be avoided during the measurements as it can be responsible for the larger error in the measurement.

Finally, the dependence of the characteristic frequency upon the volume *V* of the spherical part of the round bottom flask should be verified. We will assume that this volume corresponds to the indication of the glass manufacturers as "1000 ml". Through the gradual filling up of water in respective portions of 100 ml, the volume *V* of air is lowered to 900, 800, … 400 ml. The corresponding frequencies fare measured as follows:

- Select <Measure> <Parameter> and effect the following
- changes: "Repetition: Measurement series manual", "Gate time: 10 s".
- Open the window <Setup> <Representation> and enter as the maximum scale readings for the X-Axis "1000" and for the Y-Axis "260".
- Process the measurement with <F10> <o.k.>and enter the following entries in the input window:
- Name of the X-Axis: V
- Unit of the X-Axis: ml
- Initial value: 1000
- Step size: – 100
- Produce the sound described above and start the measurement with <Start>.
- If the process of measurement runs well, accept the measurement value with <Accept>.
- Measure 100 ml water in the beaker and pour into the round bottom flask; for that the round bottom flask is temporarily taken off the holder so that the microphone is protected from splashing water.
- Carry out the measurement series, as described, till the air volume is reduced to 400 ml.
- Save the measurement series as readable text data with <File> <Save> "Format: ASCII".

Theory and evaluation

The frequency of oscillation of the resonator increases with the decrease in the volume of air. Fig. 3 shows the relationship for the typical example of measurement. The measurement value table is obtained with <Window> <F5> (Fig. 4).
According to the formula, characteristic frequency of our acoustic resonator is calculated:

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

Here C is the velocity of sound, *l* the length of the flask neck, *r* the radius of the neck and *V* the volume of the sphere. It is seen that, *f* is proportional to $1/\sqrt{V}$ For the verification of its conformity with the theory for e.g., the ratio

$$\frac{f(500\ ml)}{f(1000\ ml)} = \frac{225.5}{169.1} = 1.33$$

can be calculated; the value varies by less than 6 % from the desired value $\sqrt{2}$ = 1.41.

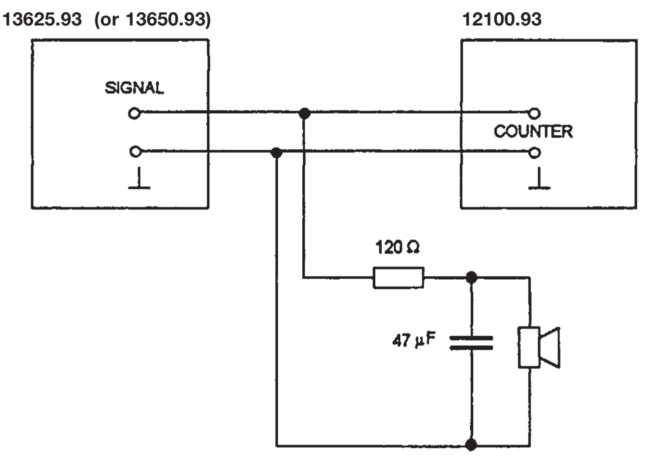


Fig. 2: Connection between Amplifier output, COBRA and the sound head.

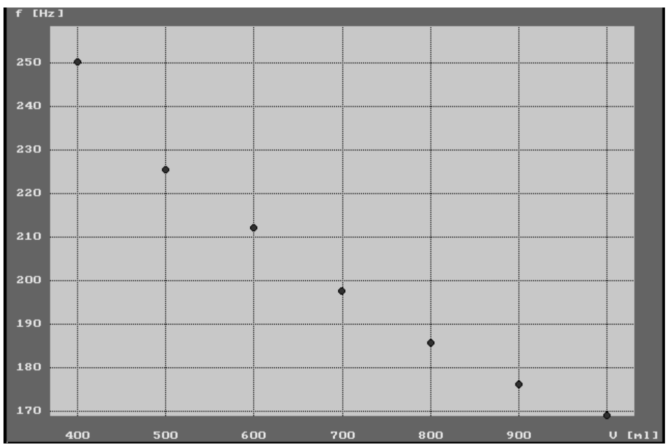


Fig. 3: Frequency of the resonator as a function of the air volume in the spherical part of the round bottom flask.

Fig. 4: Measurement value table for Fig. 3.

V [ml]	f [Hz]
400.0	250.300
500.0	225.500
600.0	212.300
700.0	197.600
800.0	185.800
900.0	176.200

An elegant examination of the tallying of the measurement results, the theory is contained here-in and fits the measurement points of Fig. 3, a theoretical curve formed on the basis of the proportionality between fand $1/\sqrt{V}$. The formation of such a curve is possible with a commercial program of table calculation. We should briefly indicate the process in the example by Excel® of Microsoft®. Fig. 5 shows a possible representation which is executed by the following steps:

- Start the table calculation and read in COBRA-Measurement value data (ASCII-Format).
- It is enough, to accept the core data in lines 110, columns a,b of Fig. 5, the rest can be deleted.
- Produce in the free part of column A by fast process, a group of numbers 350, 355, 360, …1050.
- Copy the frequency values measured with 400 ml, 500 ml, …1000 ml from the lines 410 into the relevant field of column B.
- Enter the formula 12/Columns C the formula "=$B$10*Root (1000)/Root (A12)". (This formula multiplies the frequency value measured with the 1000 ml by the root of 1000 and then divides it with root of the value of the volume in ml.
- Copy the formula in the complete column below the field till the end of the table. The frequencies of the theoretical curve are calculated at once, which arbitrarily takes the measurement point with 1000 ml.
- Mark the table from line 12 to the end and call the function "XY-Point diagram".
- With some graphical supplements, the reproduced figures of the diagram in Fig. 5 are obtained.

It is seen that the measurement values are in approximately good conformity with the calculated course of the curve. The small systematic variation indicates that the effective volume for the measurement example was a little higher than 1000 ml.

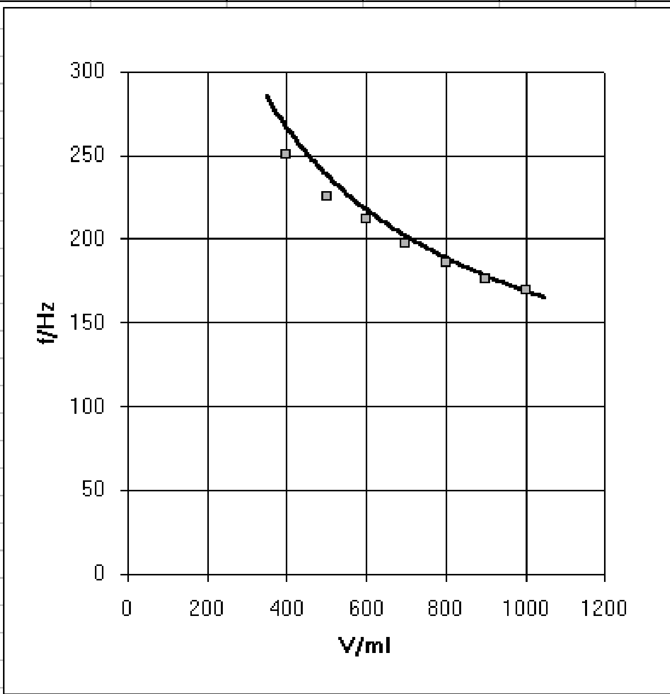
Fig. 5: Compares the measurement values with the theoretical cuve by table calculation.

Microsoft Excel - CBT2-3.XLS

Datei Bearbeiten Formel Format Daten Optionen Makro Fenster ?

C12 =$B$10*WURZEL(1000)/WURZEL(A12)

	A	B	C	D
1	V	f	f(calc)	
2	ml	Hz	Hz	
3				
4	400	250,3		
5	500	225,5		
6	600	212,3		
7	700	197,6		
8	800	185,8		
9	900	176,2		
10	1000	169,1		
11				
12	350		285,831169	
13	355		283,811135	
14	360		281,833333	
15	365		279,896312	
16	370		277,998688	
17	375		276,139144	
18	380		274,316423	
19	385		272,529326	
20	390		270,776708	
21	395		269,057474	
22	400	250,3	267,370576	
23	405		265,715015	
24	410		264,089831	
25	415		262,494108	
26	420		260,926965	



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