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DETERMINATION OF SOUND VELOCITY IN DIFFERENT GASES USING INNOVATIVE DEVICES

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Abstract
In this experiment, the speed of propagation of a sound pulse in carbon dioxide and helium and neon gases is determined. Knowing the above gases' adiabatic parameters and their densities under normal atmospheric pressure, the sound speeds in them were calculated with high accuracy on the CASSY Lab device.

Key words: speed of sound, gas, pressure, impulse, adiabatic exponent, density, heat capacity.

The speed of sound is the speed of propagation of a given phase of a sound wave. The speed of sound is constant for this substance under certain external conditions and does not depend on the frequency and amplitude of the wave. Sound in gases and mixtures depends on the concentration of the components in it. In isotropic solids, Sound is approached by the density and modulus of elasticity of the substance. Sound is louder in solids than in liquids, and in liquids in gases.
The sound pulse is generated by a steep voltage edge which causes the diaphragm of a tweeter to perform a jerky motion. This motion of the diaphragm leads to a pressure variation in the gas, which can be detected by means of a microphone.
For determining the velocity of sound c in a gaseous medium, the travel time t between the pulse generation at the tweeter and the detection at the microphone is measured. As the sound pulse cannot be located exactly at the tweeter, the effective measuring distance is first determined by determining the velocity c_{air} of sound in air. To do this, two travel time measurements are carried out with the microphone being located at the location s_{A1} in one measurement and at the location s_{A2} in the other measurement. The velocity of sound in air is then obtained from the path difference

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$\Delta s = s_{A1} - s_{A2}$ and the associated travel time difference $\Delta t = t_1 - t_2$: $c_{air} = \Delta s/\Delta t$. This enables the effective measuring distance $s_{eff} = c_{air} \cdot t_1$ to be calculated for the location s_{A1}, which eventually enables a direct measurement of the velocity of sound in a gas.

The following devices were used to determine the speed of sound in different gases: Sensor-CASSY, CASSY Lab 2, Timer box, Apparatus for sound velocity, Stand for tubes and coils, Tweeter, Multi-purpose microphone, Scaled metal rail, 0.5 m, Saddle bases, Minican gas can, carbon dioxide, Minican gas can, helium, Minican gas can, neon, Fine regulating valve for Minican gas cans, Silicone tubing, 7 x 1.5 mm, 1 m, Rubber tubing, d = 4 mm, Tubing connector, Pair of cables, 25 cm, red and blue, Pair of cables, 100 cm, red and blue, PC with Windows XP/Vista/7/8.

The device was assembled in the following order:

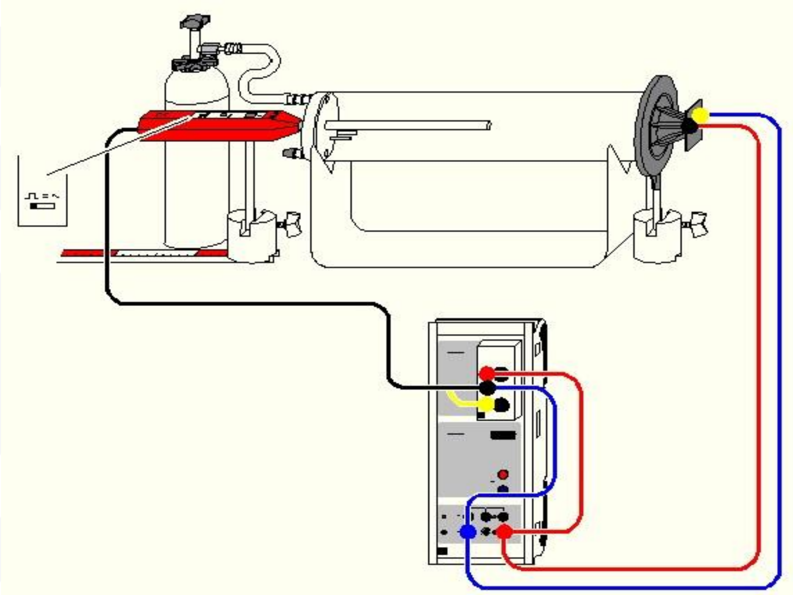
*The plastic tube was placed on the tube and coil stand and rotated so that the two hose nipples overlapped.

*The tweeter was brought close to the plastic tube so that the plastic tube was closed as tightly as possible.

*A multi-purpose microphone was inserted into the central hole of the lid approximately 1 cm deep, and aligned so that it moved parallel to the plastic tube when moved. The function switch of the multipurpose microphone is set to "Trigger" mode, which turns on the microphone.

*A measuring metal rail is placed immediately under the base of the saddle.

*A timer box was connected to input A of Sensor-CASSY and the circuit was established as shown in the first drawing; The maximum output voltage at the voltage source S is set.



(Pic.1)

To avoid unintended loss of gas, turn the handwheel of the fine regulating valve to the right stop before screwing the fine regulating valve on the gas can.

Any leakage of the measuring apparatus leads to an escape of gas and thus to a distortion of the measuring result; therefore the tweeter has to be placed as close to the plastic tube as possible.

In order to fill the plastic tube with carbon dioxide, put the silicone tubing on the lower hose nipple of the plastic tube. In this way, the gas is almost completely exchanged because the lighter air is pressed out through the upper hose nipple when carbon dioxide enters. Correspondingly, proceed the other way round when filling the plastic tube with the noble gases helium and neon: when helium or neon, respectively, enters through the upper hose nipple, the air, which is heavier, is pressed out through the lower hose nipple.

Concerning the measurements on helium and neon, keep in mind that the measuring apparatus cannot be perfectly sealed so that part of the highly-volatile gas in the plastic tube escapes. This results in a relatively high proportion of air, which distorts the measurements – therefore the measurements should be carried out quickly.

Carrying out the experiment

First, the effective measuring distance is determined s_{eff}:

*Insert the multipurpose microphone in the plastic tube by approx. 1 cm, read the position s_{A1}, and write it in the first line of the table. Write the travel time Δt_{A1} in the table with . Repeat the measurement of the travel time several times to improve the accuracy of measurement.

*Insert the multipurpose microphone entirely in the plastic tube, read the position s_{A2}, and write it in the next line of the table. Write the travel time Δt_{A1} in the table with . Repeat the measurement of the travel time several times to improve the accuracy of measurement.

*In order to determine the average travel times t_1 and t_2, select Draw Mean, and determine the velocity of sound in air $c_{air} = \Delta s/\Delta t = (s_{A1}-s_{A2})/(t_1-t_2)$.

*Determine the effective measuring distance $s_{eff} = c_{air} \cdot t_1$; for this enter the determined travel times t_1 and t_2 in the Settings seff (right mouse button on s_{eff}) in the formula $(s_{A1}-s_{A2})/(t_1-t_2)*t_1$.

Now the velocity of sound in carbon dioxide, helium and neon can be measured directly:

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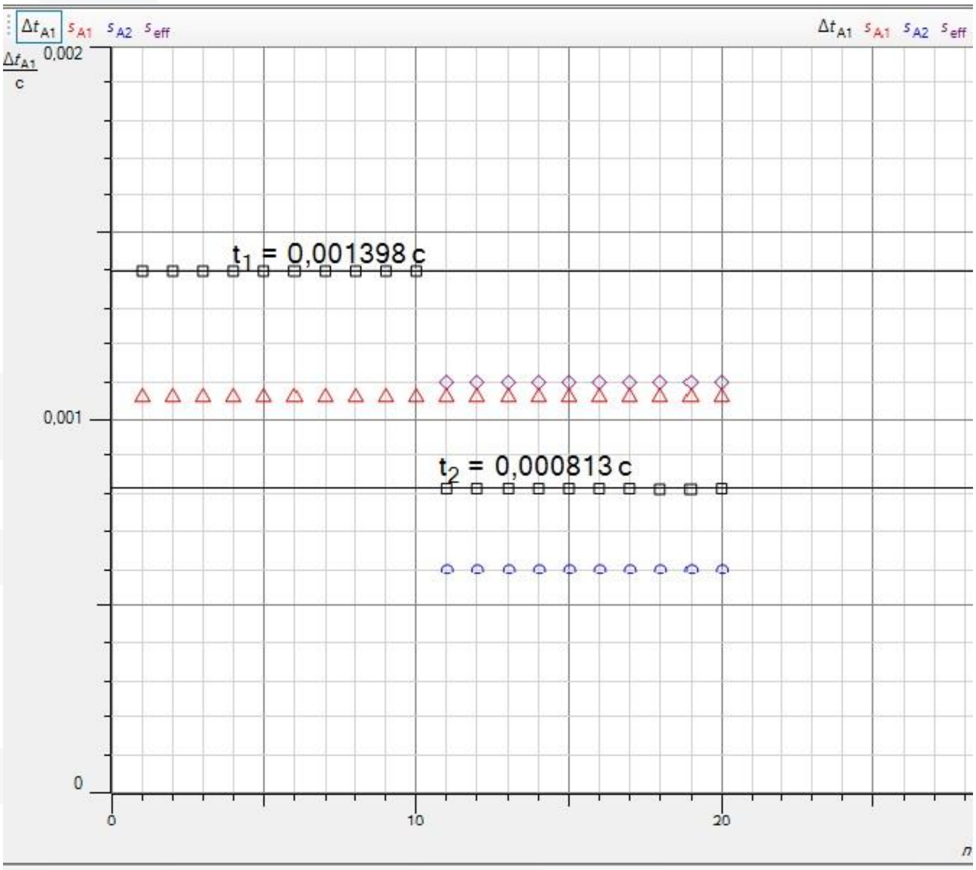
Shift the multipurpose microphone back to the position s_{A1}.
Let gas in through the hose nipple. Open the fine regulating valve very cautiously until the gas flowing out of the gas can is heard.
Read the velocity of sound, and write it in the prepared display **Input** in the table or enter it there using drag & drop. In addition, write the density ρ in the table:
As sound waves in gases exhibit only little dispersion, – i.e., the group and phase velocity are equal to a good approximation when sound propagates in gases – the velocity of sound c can simply be determined experimentally from the velocity of propagation of a sound pulse: $c^2 = p\,\kappa/\rho$ with $\kappa = C_p/C_V$
κ- adiabatic exponent, ρ- density, p- pressure, C_p, C_V- specific heat capacity.

Gas	Density ρ	Adiabatic exponent $\kappa = C_p/C_V$	speed of sound c
Carbon dioxide	1.98 kg/m³	1.29	256.9 m/s
Nitrogen (air)	1.25 kg/m³	1.40	336.8 m/s
Neon	0.90 kg/m³	1.64	429.6 m/s
Helium	0.18 kg/m³	1.63	957.7 m/s



(Pic.2)

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Summary

The relationship between c^2 and 1/r was shown in the Prepared Evaluation display. By entering the formula 101300*1.4*x in free fitting, a straight line corresponding to the average adiabatic coefficient k=1.4 at normal air pressure was drawn.

It is normal for the measured values to deviate from this straight line, especially if the helium is very volatile, because then the actual density of the gas will be higher.

The large differences in the speed of sound are mainly due to the different densities ρ of the gases, since the differences in the adiabatic exponents C_p/C_V are relatively small.

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