Mechanics

Acoustics

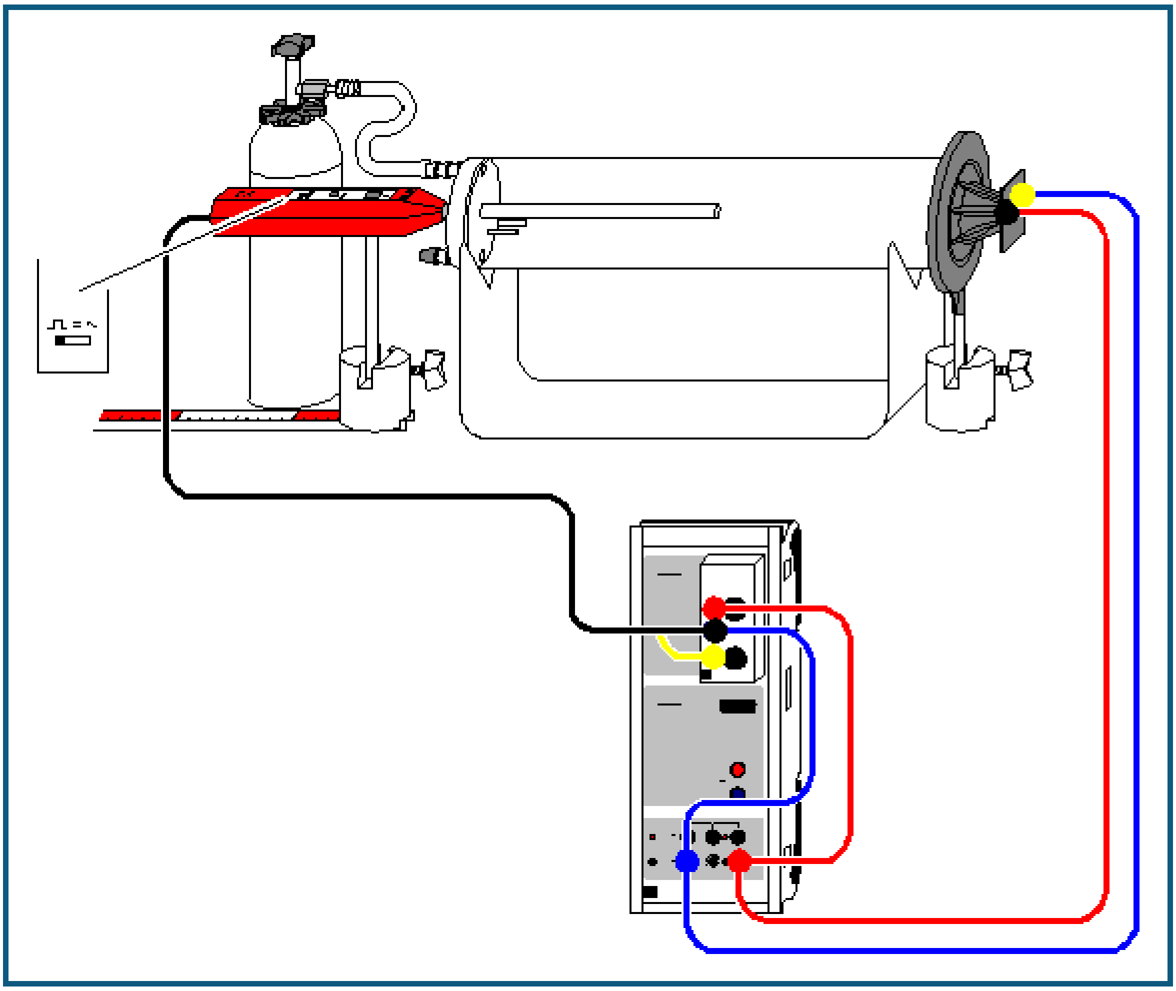
Wavelength and velocity of sound

Determining the velocity of sound in gases

Description from CASSY Lab 2

For loading examples and settings, please use the CASSY Lab 2 help.

Velocity of sound in gases



Be careful when handling Minican gas cans

- The cans are pressurized; use only the fine regulating valve (660 980) to discharge gas.
- Protect the cans against sun light or warming over 50 °C.
- Do not use force to open the cans.
- Only dispose of completely emptied cans.
- Never refill the cans.

Experiment description

In this experiment, the velocity of propagation of a sound pulse in carbon dioxide and in the noble gases helium and neon is determined. 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

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

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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 $\Delta s = s_{A1}\text{-}s_{A2}$ and the associated travel time difference $\Delta t = t_1\text{-}t_2$: $c_{air} = \Delta s/\Delta t$. 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.

Equipment list

1	Sensor-CASSY	524 010 or 524 013
1	CASSY Lab 2	524 220
1	Timer box	524 034
1	Apparatus for sound velocity	413 60
1	Stand for tubes and coils	516 249
1	Tweeter	587 07
1	Multi-purpose microphone	586 26
1	Scaled metal rail, 0.5 m	460 97
2	Saddle bases	300 11
1	Minican gas can, carbon dioxide	660 999
1	Minican gas can, helium	660 984
1	Minican gas can, neon	660 985
1	Fine regulating valve for Minican gas cans	660 980
1	Silicone tubing, 7 x 1.5 mm, 1 m	667 194
1	Rubber tubing, d = 4 mm	604 481
1	Tubing connector	604 510
1	Pair of cables, 25 cm, red and blue	501 44
1	Pair of cables, 100 cm, red and blue	501 46
1	PC with Windows XP/Vista/7/8	

Experiment setup (see drawing)

- Lay the plastic tube (without heating coil) on the stand for tubes and coils, and turn it so that the two hose nipples are one above the other.
- Move the tweeter close to the plastic tube so that the plastic tube is closed as tight as possible.
- Insert the multipurpose microphone in the central bore of the cap to a depth of approx. 1 cm, and align it so that it moves parallel to the plastic tube when it is displaced. Set the function switch of the multipurpose microphone to the "Trigger" mode. Do not forget to switch the microphone on.
- Lay the scaled metal rail immediately under the saddle base.
- Plug the timer box on the input A of the Sensor-CASSY, and set up the circuit as shown in the drawing; set the maximum output voltage at the voltage source S.

Experiment notes

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

Load settings

First determine the effective measuring distance 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:

- 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:

Gas	Density ρ	Adiabatic exponent $\kappa = C_p/C_V$
Carbon dioxide	1.98 kg/m^3	1.29
Nitrogen (air)	1.25 kg/m^3	1.40
Neon	0.90 kg/m^3	1.64
Helium	0.18 kg/m^3	1.63

Evaluation

In the prepared display **Evaluation**, the relation between c^2 and $1/\rho$ is shown. There you can, e.g. by entering the formula 101300*1.4*x in Free fit, draw the straight line which corresponds to the mean adiabatic coefficient κ=1.4 at normal air pressure.

Deviations of the measured values from this straight line are normal, particularly in the case of helium, which is highly volatile, because then the actual density of the gas is higher.

The great differences in the velocity of sound are essentially due to the different densities ρ of the gases as the differences in the adiabatic exponents C_p/C_V are relatively small.