Velocity of sound using Kundt's tube and digital function generator (Item No.: P2150605)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physics	University	Oscillations and Mechanical Waves, Acoustics	Sound Waves	Velocity of sound using Kundt's tube and digital function generator

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Intermediate	1 Hour	1 Hour	2 Students

Additional Requirements:

Experiment Variations:

Keywords:

longitudinal waves, sound velocity in gases, frequency, wavelength, stationary waves, natural frequency

Overview

Short description

Principle

Cork dust in a glass tube is set into tiniest motion by a sound wave. If the frequency of the sound wave matches the natural frequency of the volume in the glass tube, a standing wave will form. The corc dust then assembles in visible patterns that show the nodes of pressure and motion of the standing wave. From the length of the volume and the number of the nodes, the velocity of sound in the tube can be calculated for each natural frequency.

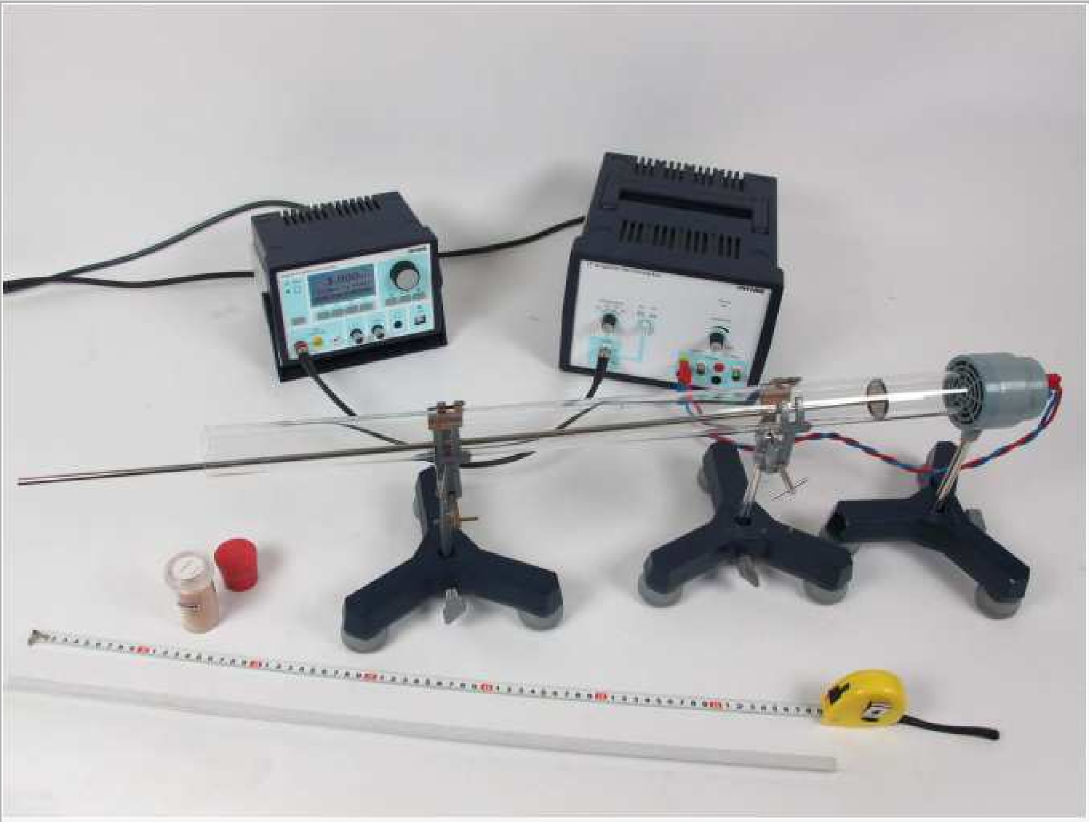

Fig. 1: Experimental set-up

Equipment

Position	Material	Bestellnr.	Menge
1	PHYWE Digital Function Generator, USB	13654-99	1
2	Loudspeaker / Sound head, 8 ohms	03524-01	1
3	Tripod base PHYWE	02002-55	3
4	Universal clamp	37715-00	2
5	Kundt's apparatus	03475-88	1
6	Cork dust, 3 g	03477-00	1
7	Measuring tape, l = 2 m	09936-00	1
8	Thermometer -10...+50 °C	38034-00	1
9	Connecting cord, 32 A, 500 mm, red	07361-01	1
10	Connecting cord, 32 A, 500 mm, blue	07361-04	1

Tasks

Determine the velocity of sound in air using Kundt’s tube at different lengths of volume.

Set-up and procedure

Set-up

Perform the experimental set-up according to Fig. 1. Use the charging strip to distribute the cork dust over the glass tube. Use the piston to close one end of the glass tube. At the other end, set up the sound head in such manner, that the center of the sound head is in line with the center of the tube’s cross sectional area. This way most of the sound will enter the tube and the amplification will stay bearable.

Connect the output of the digital function generator directly to the sound head via the connecting cords. Set the digital frequency generator to an amplitude of 3 V to 5 V and choose a sinusoidal signal and signal-type "out".

Note:

If either the glass tube or the cork dust are damp, this experiment cannot work properly. To dry the dust or the glass tube you can carefully heat them up in an oven to a maximum of 60 °C and bake them out.

Procedure

Determine the velocity of sound in air. In order to do that, count the number of nodes for different natural frequencies for an open ended as well as a closed volume. For better statistics use the piston to examine at least two different lengths of volume.

To find the natural frequencies, start from 0 Hz and go up to maximum 4 000 Hz in steps of 100 Hz.

When first patterns start to show, increase the frequency more slowly in steps of 10 Hz until the pattern does not wiggle anymore. When the whole pattern throughout the glass tube is absolutely static you found the natural frequency and generated a standing wave. Note down the number of nodes and the frequency before you continue to the next natural frequency. For each volume length find at least three natural frequencies for the open ended and the closed standing wave respectively.

Measure the room temperature during the experiment and note it down for later correction of the results.

Theory and evaluation

Theory

The distance between two nodes of a standing wave is half its wavelength in case of parallel propagation of the waves, which can be assumed for this experiment. Therefore the wave-length for each natural frequency can easily be determined and the frequency can be read directly from the digital function generator's display. Keeping in mind that the period T is the inverse of frequency

$$T = 1/\nu \quad (1)$$

and the wavelength is obtained from

$$\lambda = c/\nu = c \cdot T. \quad (2)$$

The speed of sound can be found as the slope of the plot of wavelength vs. period.

Alternatively, the wavelength can be calculated from the total number of nodes n and the length of the volume L. For standing waves with one open end we obtain

$$\lambda = \frac{4L}{2n+1}. \quad (3)$$

For two open ends one finds the following wavelength

$$\lambda = \frac{2L}{n}. \quad (4)$$

Sound propagates in gases with varying speed depending on the gas temperature T_{gas}. From the equation of state for ideal gases one can derive the following relation

$$c \propto \sqrt{T_{\mathrm{gas}}}.$$

Comparison of sound speeds for different temperatures T_{gas} and T'_{gas} leads to

$$c = c' \cdot \sqrt{\frac{T_{\mathrm{gas}}}{T'_{\mathrm{gas}}}}. \quad (5)$$

Evaluation

In the following, the evaluation of the obtained values is described with the help of example values. Your results may vary from those presented here.

Measurements with the plugged tube for two different volume lengths are shown in Table 1.

Tab. 1: Measured values for different tube lengths L.

$L = 615\,\mathrm{mm}$		$L = 350\,\mathrm{mm}$	
ν in Hz	n	ν in Hz	n
990	3	1150	2
1250	4	1600	3
2000	7	2250	4
2250	8	2700	5
2500	9	3200	6
3000	11	3654	7
3750	13		

From Fig. 4, Fig. 5 and equation (2), we obtain the sound speed with 336 m/s and 330 m/s, respectively. The temperature during measurements was 19 °C.

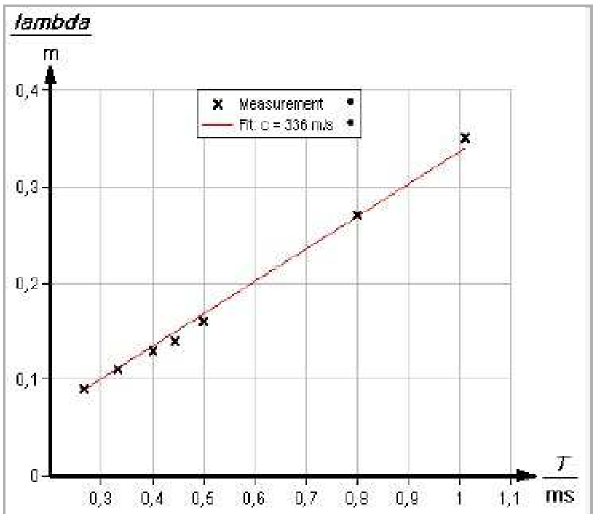

Fig. 4: Measurements for L=615 mm.

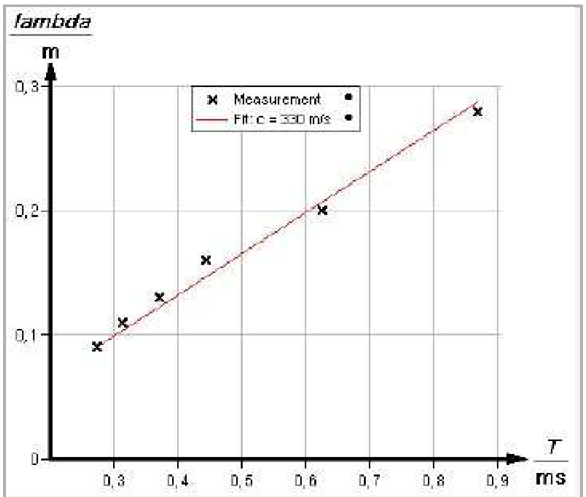

Fig. 5: Measurements for L=350 mm.

In the literature, a value of $c = 343\,\mathrm{m/s}$ is given for room temperature of 20 °C.
Utilizing equation (5) the experimental velocity of sound at 20 °C is obtained as 345 m/s and 339 m/s respectively.