Velocity of sound in air (Item No.: P2150305)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physics	University	Oscillations and Mechanical Waves, Acoustics	Sound Waves	Velocity of sound in air

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

Additional Requirements:

Experiment Variations:

Keywords:

Wave propagation, longitudinal wave, air pressure variation, sound wave, sound pulses

Introduction

Overview

The velocity of sound in air is determined by measurement of sound propagation times across various known distances.

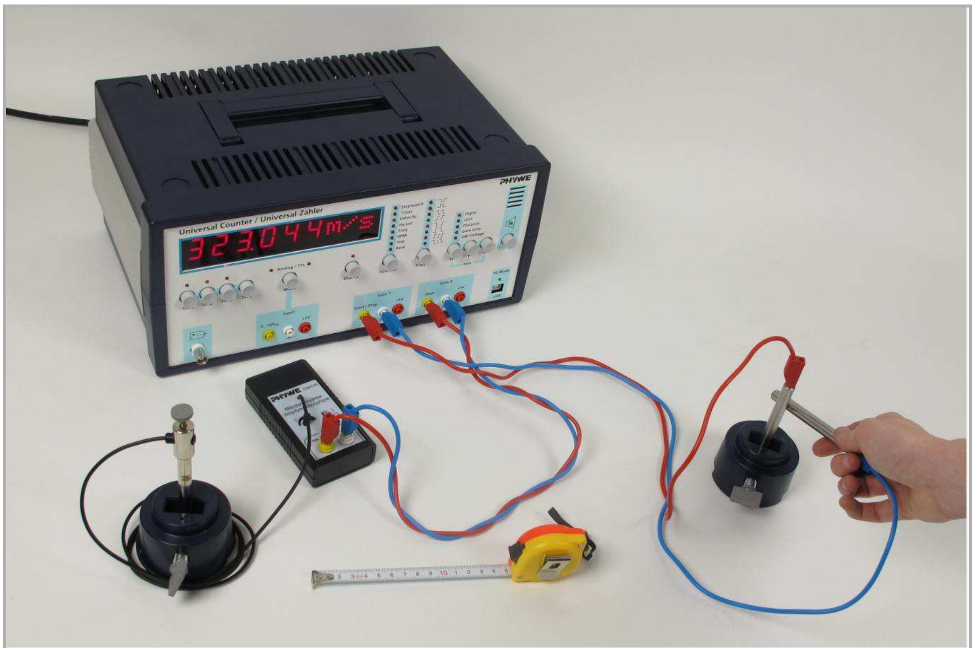

Fig. 1: Experimental set-up

Equipment

Position No.	Material	Order No.	Quantity
1	Universal Counter	13601-99	1
2	Measuring microphone with amplifier	03543-00	1
3	Barrel base PHYWE	02006-55	2
4	Capacitor 1 microF/ 100V, G2	39113-01	1
5	Support	09906-00	1
6	Support rod with hole, stainless steel, 10 cm	02036-01	2
7	Measuring tape, l = 2 m	09936-00	1
8	Connecting cord, 32 A, 500 mm, red	07361-01	2
9	Connecting cord, 32 A, 500 mm, blue	07361-04	2
10	Flat cell battery, 9 V	07496-10	1

Tasks

Determine the sound velocity in air for different distances between sound source and microphone by measuring the sound propagation times.

Set-up and procedure

Set-up

Install the experiment according to Figs. 1 and 2. The barrel base that serves as sound source should either stand on foamed material or be set up on a different table top to avoid measuring the sound velocities in solids, which would be much higher than the sound velocity in air.

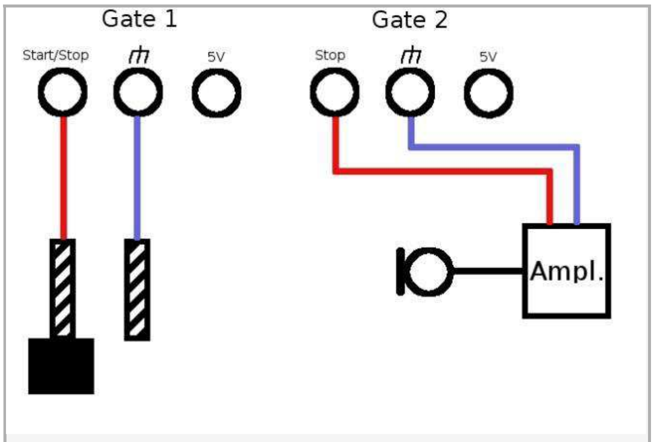

Fig. 2: Schematic circuit: blue cables are grounding connections.

The rod on the barrel base is connected to the Start/Stop jack of Gate 1 at the universal counter. The loose rod with the hole is connected to the Ground jack. Parallel to the input jacks, the capacitor is put on top of both plugs. Thereby, it is ensured that a contact bounce of the rods will not trigger multiple start signals.

The microphone amplifier is connected to the Stop and Ground jacks of Gate 2. Use the function Timer in order to measure the time, the sound wave needs to propagate through the distance between sound source and microphone. Set the Trigger to two incoming pulses.

Procedure

The velocity of sound will be investigated for a minimum of three different distances between 30 cm and 100 cm. To obtain good statistics, the measurement for each rod should be recorded at least five times.

The measurement is initiated by striking the metal rods against each other which produces a sound. Due to the contact of the rods, the electrical circuit is closed which starts the timer. After the sound has reached the microphone at distance , the microphone generates a second electrical pulse which stops the measurement.

Take care to generate the sound at approximately the same height in which the microphone is located to ensure that the detected sound wave has propagated horizontally and actually travelled the distance that had been measured before. That measured distance should correspond to the distance from the front side of the microphone capsule to the side of the clamped-in metal rod facing the microphone.

During the recordings, no background noises should occur. These would influence the measurement and may lead to much shorter sound propagation times. For a correct comparison with literature values, you need to measure the ambient temperature during the experiment.

Notes

If the measurement does not stop despite clearly audible tone, it may be necessary to adapt the output voltage of the microphone amplifier.

Results and evaluation

Below, the evaluation of the obtained values is described with the help of example values. Your results may vary from those presented here.
The velocity of sound in air is determined by regarding the slope of the function between propagation time and distance. Calculate the mean values of the measured propagation times for each distance separately. Table 1 shows example measurements for varying distances as well as the mean value for each distance.

Distance t/ms	40 cm	60 cm	80 cm	95 cm
#1	1.25	1.82	2.38	2.84
#2	1.25	1.84	2.51	2.83
#3	1.23	1.85	2.41	2.84
#4	1.24	1.83	2.41	2.83
#5	1.24	1.82	2.40	2.84
mean	1.24	1.83	2.42	2.83

The calculated values are plotted in Fig. 3, so that a function that fits the measured values can be found. The slope of this function is the inverse velocity, as the velocity

$$v = \frac{s}{t} \quad (1)$$

is equivalent to the time

$$t = \frac{1}{v} \cdot s \quad (2)$$

which corresponds to the form of the fitted function. From Fig. 3 we obtain the slope in units of seconds per meter:

$$\frac{1}{v} = (2.9 \pm 0.013) \cdot 10^{-3} \text{ s/m} \quad (3)$$

Here, the units have been converted from milliseconds (see Tab. 1) to seconds. This results in the velocity of sound in air as

$$v_{air} = (345 \pm 2) \text{ m/s} \quad (4)$$

at room temperature of $T = 23\ ^{\circ}\mathrm{C} = 296$ K.

The literature value is given as c_0 =331 m/s for the temperature T_0 = 0°C = 273 K. The relation between velocity of sound and ambient temperature in Kelvin (K)

$$c(T) = c_0 \cdot \sqrt{\frac{T}{T_0}}$$

yields the reference value

$$c(23^{\circ}C) = 344.7 \text{ m/s}$$

So the measurements are in perfect agreement with the literature.

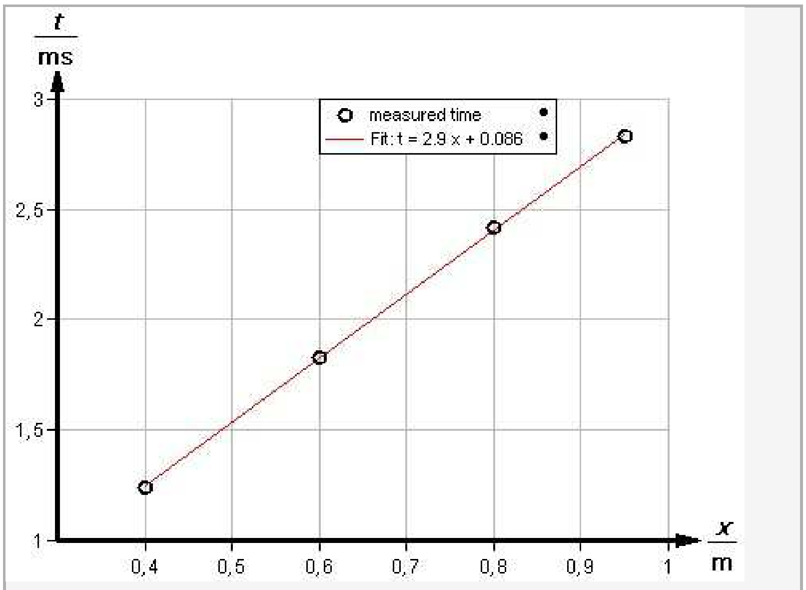

Fig. 3: Propagation time as function of distance: measurements and fitted function.

Notes:
As can be seen in the fitting function, there is a slight offset of the function of 86 µs. If you would measure the propagation time for a distance of 0 cm, the counter would still measure a time of 86 µs. This effect is caused by the experimental setup. The strike of the rods, as well as the arrival of the sound wave at the microphone, send a pulse to the counter. Both signals take time to be processed by the connected devices. The offset of the function equals the difference of those processing times. In case of the example measurement, the stop signal takes 86 µs longer to reach the counter than the start signal does.
Because of the offset of the function, it is required to measure the sound propagation time for at least two different distances. The velocity can only be determined by the slope of the function.

Robert-Bosch-Breite 10
D - 37079 Göttingen
Tel: +49 551 604 - 0
Fax: +49 551 604 - 107
info@phywe.de
www.phywe.com