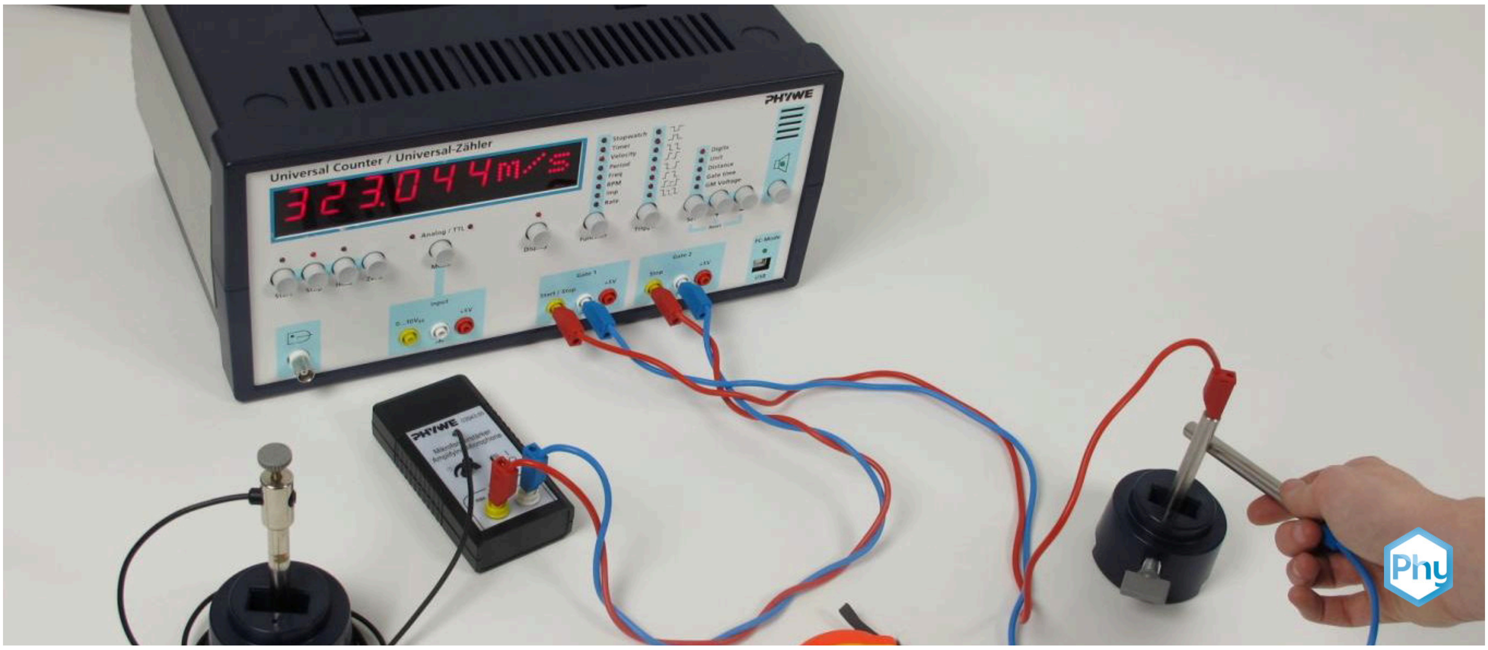
Velocity of sound in air with Universal Counter



Physics | Acoustics | Sound generation & propagation

Applied Science | Engineering | Applied Mechanics | Fluiddynamics & Aerodynamics

Difficulty level	Group size	Preparation time	Execution time
medium	2	45+ minutes	45+ minutes

This content can also be found online at:

http://localhost:1337/c/60112bb28b903a00038a5734

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General information

Application

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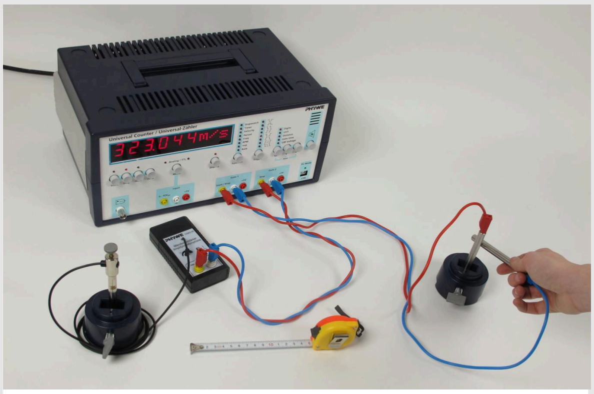

Fig.1: Experimental set-up

The speed of sound in air is very important for distance measurements and fields as the understanding of the behaviour of vibrations in gases. As such this experiment can be used to measure the speed of sound in air.

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Other information (1/2)

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Prior knowledge

There is no required prior knowlege for this experiment.

Scientific principle

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

Other information (2/2)

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Learning objective

The goal of this experiment is to determine the velocity of sound in air.

Tasks

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

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Equipment

Position	Material	Item No.	Quantity
1	PHYWE Universal Counter	13601-99	1
2	PHYWE Measuring microphone with amplifier	03543-00	1
3	Battery 9 V	07405-00	1
4	Support rod with hole, stainless steel, 10 cm	02036-01	2
5	Support	09906-00	1
6	Barrel base expert	02004-00	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	Capacitor 1 microF/ 100V, G2	39113-01	1

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Setup and Procedure

Setup

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.

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.

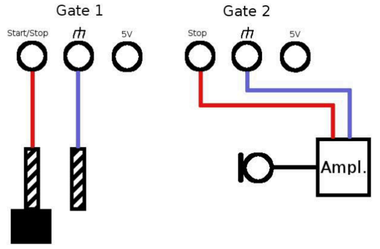

Fig. 2: Schematic circuit: blue cables are grounding connections.

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Procedure

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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.

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Evaluation

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Results (1/3)

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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.

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

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

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

Results (2/3)

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is equivalent to the time $t = \frac{1}{v} \cdot s$ (2)

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

1/v = (2.9$\pm$0.013)$cdot10^{-3}$ s/m (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) m/s (4)

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

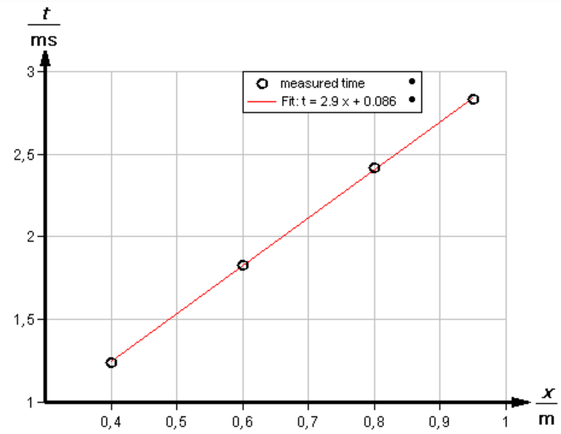

Fig. 3: Propagation time as function of distance: measurements and fitted function.

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Results (3/3)

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The literature value is given as c_a =331 m/s for the temperature T_a = 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 $c(23^\circ C) = 344.7$ So the measurements are in perfect agreement with the literature.

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.

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