Velocity of sound in air and in metal rods with PC-interface

Related topics

Linear relationship between the propagation time of sound and its respective path, longitudinal waves, longitudinal and transversal velocity of sound in solids.

Principle and task

It should be shown that a linear relationship exists between the propagation time of sound and its respective path in air.

To determine the propagation time of the sound in a metal rod of stainless steel and brass, the capability of a COBRA interface, to measure extremely small time periods (resolution 10^{-6} s), should be used. The respective velocities of sound are calculated with the help of software for measurement and analysis.

Equipment

Measuring microphone	03542.00	1
Support rod -PASS-, square, l 250 mm	02025.55	1
Support rod, stainl. steel, 250 mm	02031.00	1
Support rod, stainl. steel, 600 mm	02037.00	1
COBRA-interface 2	12100.93	1
PC COBRA data cable RS 232, 2 m	12100.01	1
Softw. COBRA Rate, time, freque.	14273.51	1
Bench clamp -PASS-	02010.00	1
Barrel base -PASS-	02006.55	2
Support rod w. hole, 100 mm	02036.00	2
Meter scale, demo, l = 1000 mm	03001.00	1
Stand tube	02060.00	2
Right angle clamp -PASS-	02040.55	1
Support	09906.00	1
Crocodile clips, bare, 10 pcs	07274.03	1
Adapter, BNC-socket/4 mm plug pair	07542.27	1
Connecting cord, 750 mm, red	07362.01	1
Connecting cord, 750 mm, blue	07362.04	1

Problems

1. Determination of the velocity of sound in air.
2. Determination of the velocity of sound in stainless steel.
3. Determination of the velocity of sound in brass.

Velocity of sound in air

Set-up and procedure

Fig. 1 shows the complete experimental set-up whereby, the following instructions are to be kept in mind:

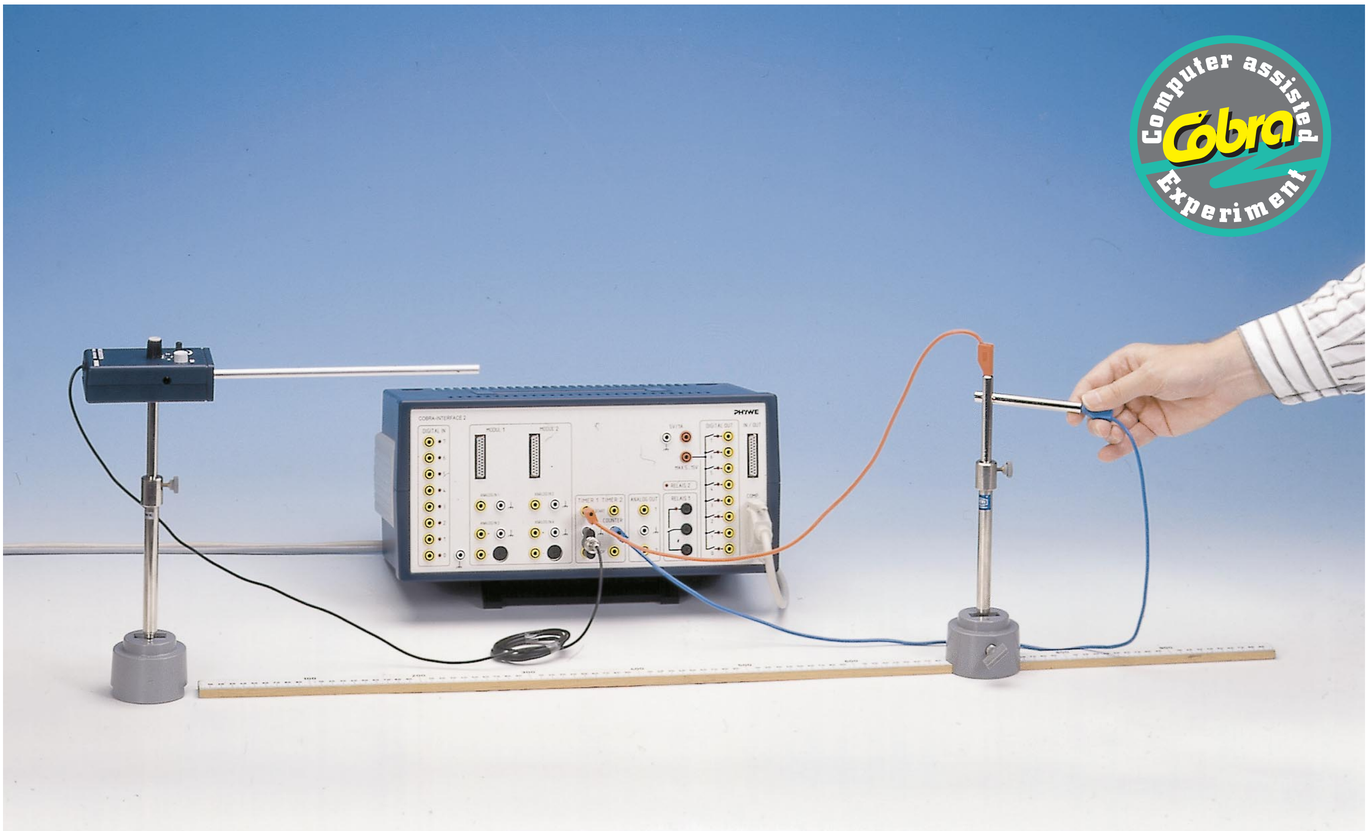
— Fix the meter scale as the static rail for the barrel base with the stand tube and the support rod fixed to the table with the help of a bench clamp.

— Move the barrel base to the beginning of the meter scale and concisely lock it at the zero mark.

— Install the microphone in the axis of the length of the scale such that the end of the sound probe touches the clamped support rod. Subsequently, the microphone is not to be moved.

— Connect the microphone with the help of an adapter to Timer 1 “Stop/Ground” with the correct polarity.

Fig. 1: Experimental set-up for the measurement of the propagation time of sound.



— Connect the clamped support rod with Timer 1 “Start” and connect the second support rod to a free ground socket (for e.g. Timer 2).
— Switch the microphone on for a short while and select the mode of operation “⎍ ”; next, bring the adjustment knob for the amplification to the extreme left (smallest amplification).
— Start the program “Pulse rate, Time- and Frequency measurement”.
— Activate the program function <Setup> <Cobra> and “Timer- Mode: Low/High”.
— Open the window <Setup> <Representation> and enter the maximum scale reading for X-Axis “1” and for the Y-Axis “0.003”.
— Select the program function <Measure> <Parameter>.
— Select in the window <Mode of measurement> “Time”; select in the window <Repetition> “Manual measurement series”.
— Prepare the measurement with <F10> <o.k.> and enter the following entries in the input window:
  — Name of the X-Axis: s
  — Unit of the X-Axis: m
  — Initial value: 0.1
  — Step size: 0.1
— Activate the readiness for measurement with <Start>.
— Push the barrel base with the clamped support rod upto the 100 mm mark away from the microphone (distance 0.1 m) and strike the side of the support rod facing away from the microphone with the second support rod; holding the barrel base with one hand so that it does not slip.
— If the timer has stopped after approx. 0.0003 s accept the value of measurement with <Accept>.

Possibilities of error:

— If the timer operates continuously, the amplification of the microphone is set too low; in this case, turn the adjustment knob of the amplification gently towards the right until a light knock on the clamped support rod, stops the timer.
— If the value of measurement is too low, then the microphone is set with too high a sensitivity and the timer stops due to the surrounding noise or to the directly passing sound through the table surface; reduce the amplification. Finally, place both the barrel bases on separate tables or place a sound absorbing material under one barrel base.
— If the timer does not operate, probably a wrong mode of timer has been set with <Setup> <Cobra>, or the surrounding noise level is too high (microphone output constantly “high”).
— Carry out further measurements, whereby the barrel base with the clamped support rod is to be pushed to the various respective marks on the scale.

Fig. 2 shows an example of measurement, in which a regression line is drawn with <Graphic> <Linear regression>.

Theory and evaluation

It is obvious from Fig. 2 that the distance of the source from the microphone and the propagation time are proportional. The sound propogates with constant velocity.

The sound velocity can be measured accurately, with the help of the gradient of lines. In Fig. 3 before the calculation of the sound velocity, the point $s = 0/t = 0$ is added.

In the literature, the sound velocity is found to be

$$c_0 = 331.8 \text{ m/s}$$

at 0° C, with dependence on the temperature.

$$c\,(T) = c_0 \sqrt{\frac{T}{273}}$$

The temperature was 22°C. during the duration of the measurements. For this temperature, the sound velocity is calculated to be

$$c(295 \text{ K}) = 344.9 \text{ m/s}.$$

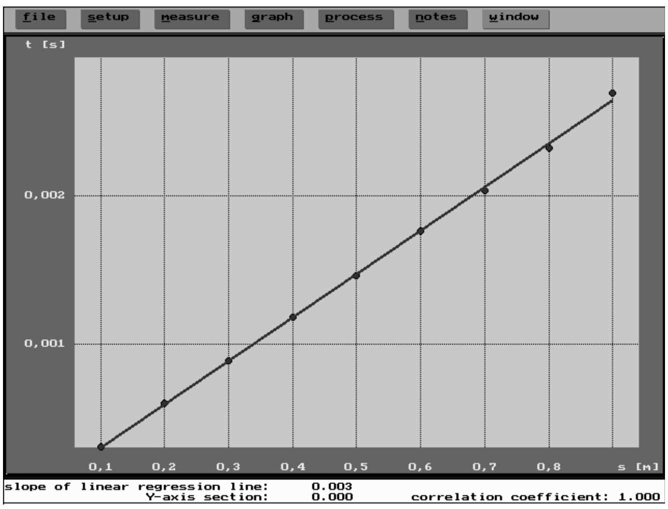


Fig. 2: Measurement of the propagation time of sound as the function of the path *s*.

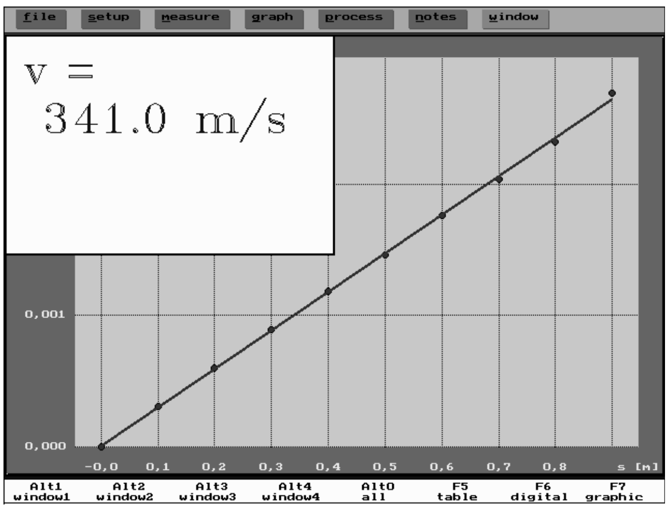


Fig. 3: as in Fig. 2, with the added point $s = 0/t = 0$ and the calculation of the velocity sound.

Velocity of sound in metals

Set-up and procedure

Fig. 4 shows the complete experimental set-up, where the following instructions are to be taken care of:

— Clamp the support rod of stainless steal with the help of the support, the stand tube and the bench clamp at the table.

— Push the sound probe of the microphone close to the front of the clamped support rod.

— Connect the microphone with the help of the adapter to Timer 1 “Stop/Ground” with the correct polarity.

— Connect the crocodile clip to the clamp screw of the support and connect it with a free ground socket of the COBRA Interface (e.g. Timer 2).

— Connect the support rod with hole (this serves as a hammer to strike the clamped metal rod). to Timer 1 “Start” with the help of the connecting cable

— Switch the microphone on and select the mode of operation “⎍”;next bring the adjustment knob for the amplification to the extreme left (smallest amplification).

— Start the program “Pulse rate, Time- and Frequency measurement”.

— Activate the program function <Setup> <Cobra> and “Timer- Mode: Low/High”.

— Open the window <Setup> <Representation> and enter the maximum scale reading for X-Axis “1” and for the Y-Axis “0.001”.

— Select the program function <Measure> <Parameter>.

— Select in the window <Mode of operation > “Time”; select in the window <Repetition> “Manual measurement series”.

— Prepare the measurement with <F10> <o.k.> and enter the following entries in the input window:

  — Name of the X-Axis: s

  — Unit of the X-Axis: m

  — Initial value: 0.6

  — Step size: 0

— Activate the readiness for measurement with <Start>.

— Lightly strike the front area of the clamped support rod, lying opposite to the microphone by the support rod connected to input „Start“ of the Timer.

— If the watch stops after approx. 0.00013 s accept the measurement values with <Accept>.

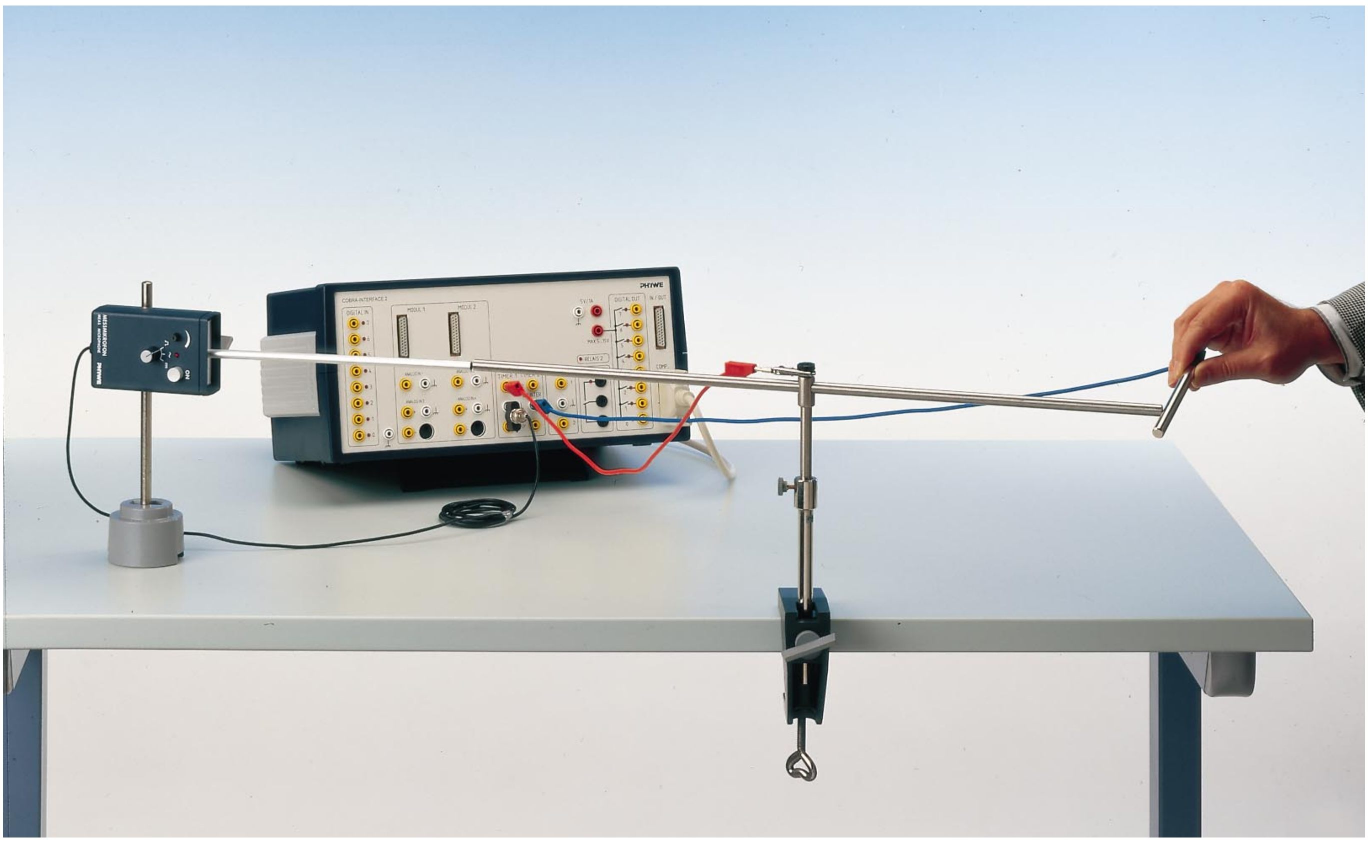
— Carry out at least 5 such measurements; Reject the erroneous results with <Cancel>, for e.g. the incorrect striking of the rod, and repeat the measurement.

— Save the measurement series with <File> <Save> on the hard disk.

Possibility of errors:

— In case the Timer starts and operates continuously, the amplification of the microphone is set too low; in this case turn the adjustment knob of the amplification gently towards the right until a light knock on the clamped support rod stops the timer.

Fig. 4: Experimental set-up for the measurement of the sound velocity in a metal rod.



— If the value of the measurement is very low, the microphone is set to high sensitivity and the timer stops due to the surrounding/background noise; reduce the amplification.

— If the timer does not operate, probably a wrong mode of timer has been set through <Setup> <Cobra> or the surroundings noise level of the is too high (microphone output is constantly “high”).

Fig. 5 shows an example of measurement. The respective table of measurements is reproduced in Fig. 6. It is observed, that the time measurement differs only by a few micro seconds. If the individual time values lie clearly above this accumulated range, it is certain that an error is caused due to incorrect striking of the rod; such measurement values should be removed before the calculation of the sound velocity with the help of <Process> <Delete>.

A corresponding measurement series is carried out with a brass rod (in Window 2).

Theory and evaluation

The following steps are essential to measure the velocity sound as represented in Fig. 7:

— Select <Process> <Zero point> <o.k.>, to add the point of measurement $s = 0/t = 0$.

— Draw the regression line with <Graphic> <Equilibrium line>.

— Compute the sound velocity with <Process> <Calculate> “Calculation of: Velocity”, “Window: 4”.

A representation according to Fig. 8 is obtained for the measurement series taken in Window 2 for the brass rod, after switching over to the simultaneous representation of all the windows with <Window> <Alt 0>, and after copying all the measurement values into the Window 4 with <Process> <New Table>.

Often, the following values are found in the literature as longitudinal sound velocity:

Iron, Steel:	5,1 km/s,
Brass:	3,4 km/s.

Fig. 6: Table of values for Fig. 5.

s [m]	t [s]
0.6	0.000134
0.6	0.000137
0.6	0.000135
0.6	0.000134
0.6	0.000134

Basically, the elastic characterestics of solid bodies and their resultant velocities of sound depend on the pre-heat treatment and minor impurities. They are therefore, no material constants, like for example density. It is expected from the selected measurement process, that the propagation time measured is a little too high, due to the transitional path of the end of the rod towards the microphone sensor,which has not been taken into account. For elimination of this error value, the measurement series should be carried out with different rods of same material but of different lengths. The accurate value of the sound velocity is obtained from the reciprocal of the slope of the measured line $t(s)$, which does not pass through the origin in this case. Fig. 9 shows an example of measurement with both the support rods of stainless steel with $l = 250$ mm and $l = 60$ cm. The sound velocity calculated from that agrees with the theoretical value.

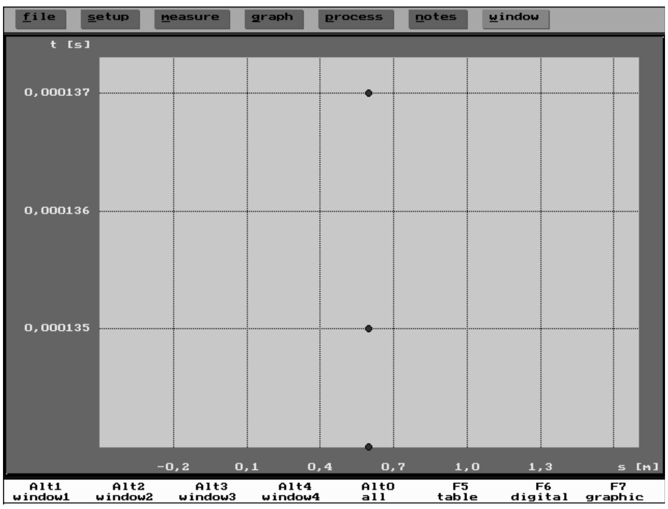


Fig. 5: Distribution of the propagation time of the sound in the support rod of stainless steel.

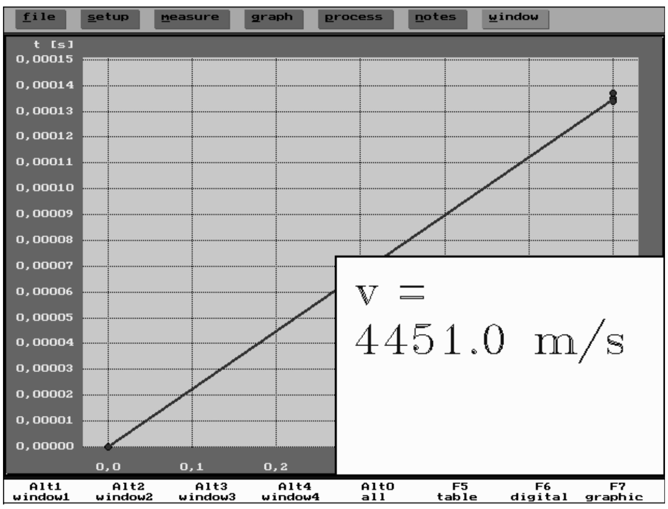


Fig. 7: Sound velocity in the support rod of stainless steel.

Fig. 8: Sound velocity in a brass rod with representation of measurement values in graphical and tabular form.

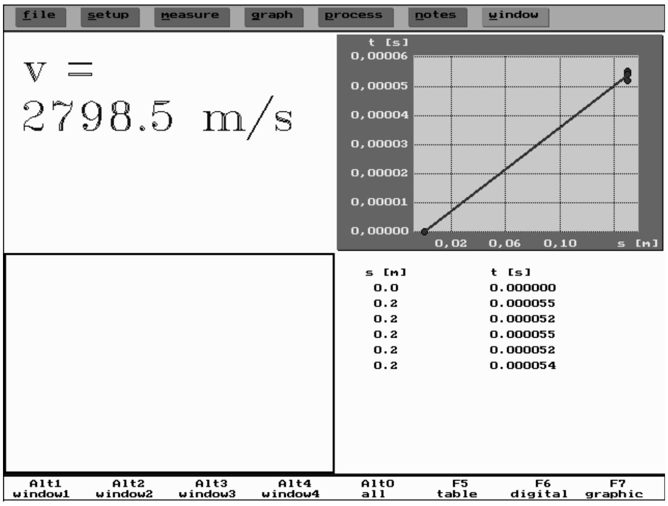


Fig. 9: Measurement of the sound velocity in stainless steel with two rods of different lengths.