

Related topics

Propagation of sound waves, velocity of sound, Doppler shift of frequency.

Principle and task

It should be verified, how the frequency measured from the stationary microphone changes, when a constant frequency fed loudspeaker is moved slowly towards or away from the microphone. Here, the frequency should be represented as a function of the speed of the sound source.

For the quantitative examination of the result, the speed of sound is measured from the slope of the line and compared to the theoretical value.

Equipment

Track, l 900 mm	11606.00	1
Car, motor driven	11061.00	1
Attachment for car	11061.02	1
Light barrier	11207.02	1
Sound head	03524.00	1
Plug with socket and crosshole, 2	07206.01	1
Screen with plug, l 100 mm	11202.03	1
Measuring microphone	03542.00	1
Function generator	13652.93	1
Tripod base -PASS-	02002.55	1
Barrel base -PASS-	02006.55	1
Support rod -PASS-, square, l 400 mm	02026.55	1
Right angle clamp -PASS-	02040.55	1

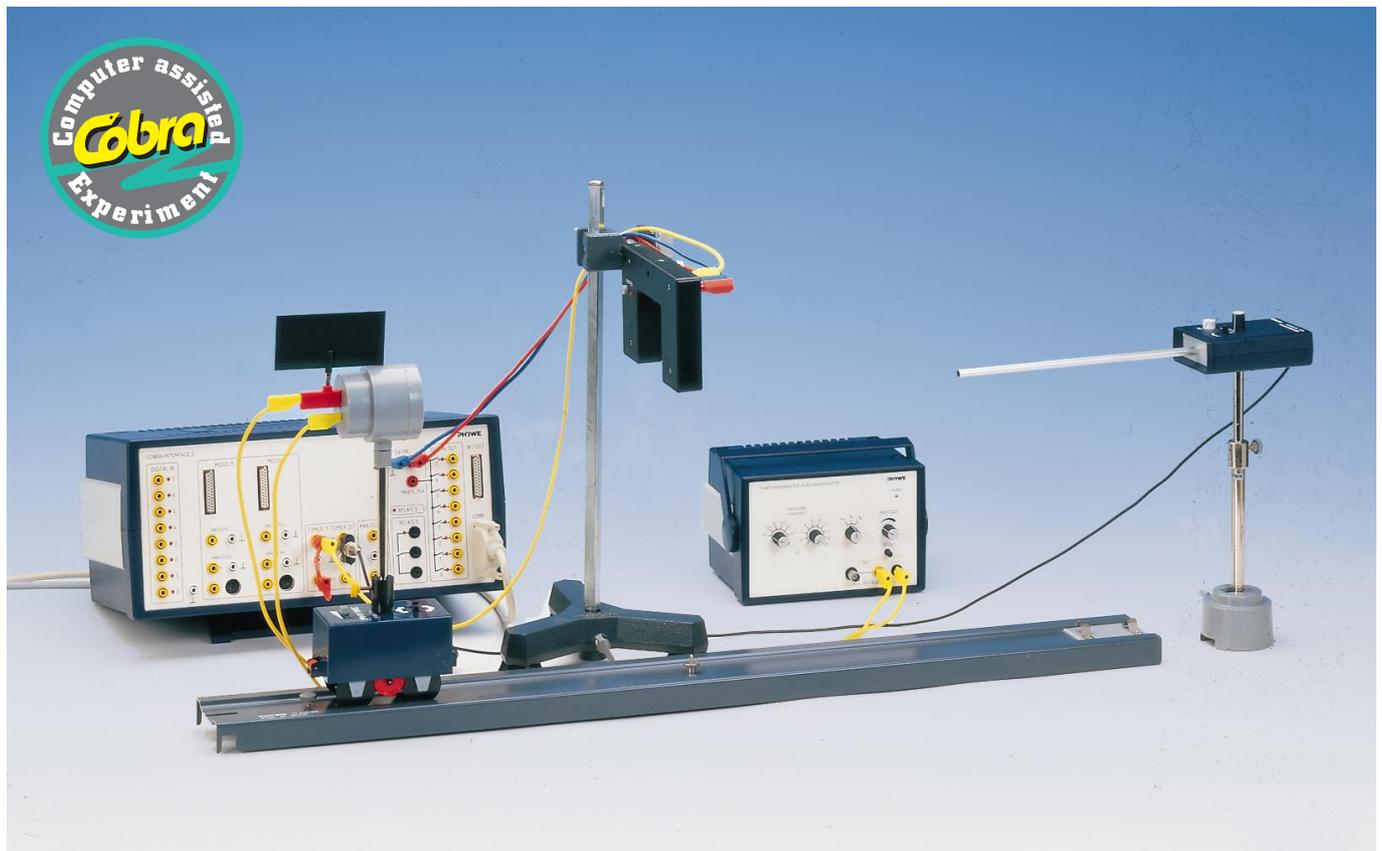
Stand tube	02060.00	1
Connecting cord, 100 mm, red	07359.01	1
Connecting cord, 750 mm, red	07362.01	1
Connecting cord, 750 mm, blue	07362.04	1
Connecting cord, 1000 mm, yellow	07363.02	2
Round cell, 1.5 V	07922.01	2
Adapter, BNC-socket/4 mm plug pair	07542.27	1
COBRA-interface 2	12100.93	1
PC COBRA data cable RS232, 2 m	12100.01	1
Softw. COBRA Rate, time, freque.	14273.51	1

Set-up and procedure

Fig. 1 shows the complete experimental set-up where the following instructions are to be taken care of:

- Fix the plug with 3 sockets into the upper socket of the sound head before the connecting cable of the function generator is connected to the sound head. The cross socket of the plug serves the purpose of holding the diaphragm.
- Connect the fork type light barrier to the output 5 V/1 A of the COBRA-Interface with the right polarity.
- Connect the sockets Start and Stop of the Timer 1 with one another and connect the light barrier to the signal output (yellow socket).
- Connect the microphone to the sockets "counter" and "-ground" of the input Timer 2 with the help of the adapter in the right polarity. (If you still work with the predecessor of COBRA interface, you require the adapter 07542.20 connected with the collar adapter with connecting cable 07542.05 because of the different socket system)

Fig. 1: Experimental set-up to verify the Doppler effect.



- Keep the microphone in such a way, that the tube moves on the level of the axis of the sound head.
- Switch on the Function generator for warming up (optimum frequency stability is reached after approx. 10 minutes); select frequency level 10^3 and keep the fine adjustment to the maximum, and the amplitude adjustment to the minimum.

First of all, the speed of the car is measured for various speed adjustments and directions. The charging position of the batteries should be maintained so that the measured speeds are guaranteed even for the subsequent measurement of the frequencies. The speed of the car moving towards the microphone, we note as positive and in the reverse direction as negative.

- Start the program “Pulse rate, time- and frequency measurement”.
- Activate program function <Setup> <Cobra> and Select “Timer-Mode: Low/High”.
- Select program function <Measure> <Parameter>.
- Select in the window <Mode of measurement> “Time”; select in the window <Repetition> “Manual measurement series”.
- Select <Measure> <Start> and activate readiness to start measurement with <o.k.>.
- Carry out the entries in the open window as per Fig. 2 and select <Start>:
- When the message “Timer 1 ready to start” appears at the lower part of the screen, start the car in the direction of the light barrier.
- If the measurement process runs correctly, accept the measurement value with <Accept>.
- Carry out at least one more measurement in the same manner.
- Stop measurement with <End of measurement series> and add the point of the curve $s = 0 / t = 0$ with <Process> <Zero point>.
- Draw the regression line (with <Graphic> <Linear regression>).
- With <Process> <Calculate> calculate the velocity and depict in window 4.

Fig. 3 shows the result for the measurement example.

Then in the similar manner, the maximum adjustable negative, as well as the smallest and the highest positive velocities are measured. In Fig. 4, shows all the results for the measurement example.

After these preparations, the frequency f_B of the received signals the microphone for the four adjustable extreme velocities of the sound head as well as for the stationary sound head are to be determined. With that the f_B is expressed as a function of v .

- Press the switch of the microphone for a while and select the mode of operation “□□”; bring the adjustment approximately to the mean position.
- Set a mean signal amplitude at the already switched on and warmed up function generator.

name of X axis:s	
unit of X axis:cm	
initial value:10.0	
step size:0.0	
cancel	start

Fig. 2: Parameter inputs for all the speed measurements.

- Activate program function <Setup> <Representation> and enter “X-Axis: 30” / “Y-Axis: 12000”.
 - Select program function <Measure> <Parameter>.
 - Select in the window <Mode of the measurement> and enter “Frequency in Hz”; “Gate time: 1 s” and select in the window <Repetition> “Manual measurement series”.
 - Select <Measure> <Start> and activate the readiness of the measurement with <o.k.>.
 - Carry out the entries in the open window according to Fig. 5 (enter the highest negative velocity measured in the previous measurement series as the “initial value”!):
 - Place the experimental car next to the microphone, place the sliding regulator to the maximum velocity and start the car towards the negative direction.
- If the car runs smoothly, start the measurement with <Start> (Fig. 5).

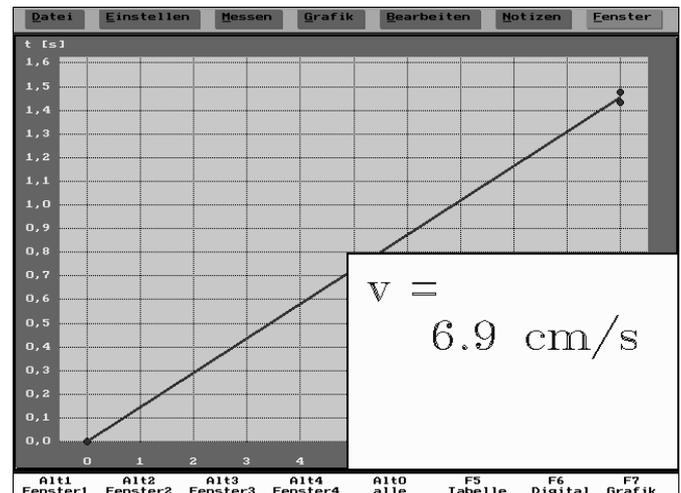


Fig. 3: Example for the measurement of the velocity (smallest adjustable negative velocity).

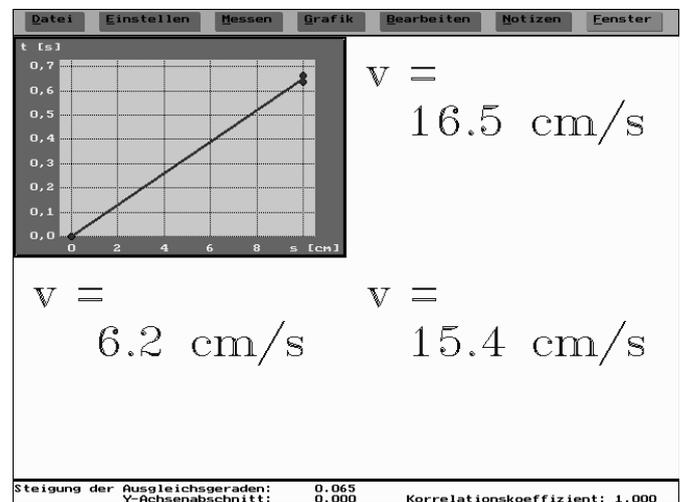


Fig. 4: Measurement of velocities by the sound head fitted on the car (above: v negative; below v positive).

Theory and evaluation

At the end of five measurements, a regression line is drawn in the represented graphic with <Graphic> <Linear regression> and a diagram is obtained on the screen which corresponds to the diagram reproduced in Fig. 6 of our measurement example. The set frequency of the generator is described as 'band the frequency measured with the microphone is described as f_B '; therefore,

$$f_B = f_0 \cdot \frac{f_0}{1 - \frac{v}{c}}$$

Here, v is the velocity of the sound head and c is the velocity of the sound. As in our case, $v \ll c$ is nearly correct (also as in the case of the stationary sound source with the moving observer):

$$f_B = f_0 \cdot \left(1 + \frac{v}{c}\right)$$

name of X axis:v

unit of X axis:cm/s

initial value:-16.5

step size:

cancel **start**

Fig. 5: Input of the parameter on the first measurement of frequency (measurement example).

The function $f(v)$ is therefore, a line with a slope $m = f_0/c$. The slope m measured, allows, for e.g., the calculation of the velocity of sound c as per:

$$c = \frac{f_0}{m} = \frac{10920 \text{ Hz}}{0.339 \text{ Hz/(cm/s)}} = 322 \frac{\text{m}}{\text{s}}$$

It is self explanatory, that this is not a precise method of determination of the velocity of sound; the inaccuracy is limited above all to only 1 Hz of the data of the relatively small frequency variations.

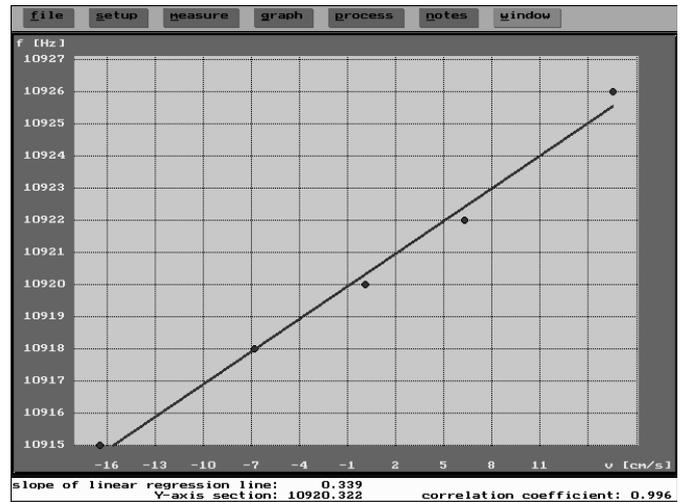


Fig. 6: Frequency measured depending on the velocity of the source of the sound.