Reflection and echo (Item No.: P6011200)

Curricular Relevance

Area of Expertise:	Education Level:	Topic:	Subtopic:	Experiment:
Physik	Klasse 10-13	Akustik	Schwingungen und Wellen	Reflexion und Echo

Difficulty	Preparation Time	Execution Time	Recommended Group Size
Easy	10 Minutes	10 Minutes	1 Student

Additional Requirements:

- Microphone
- Earphones
- Piece of adhesive tape, approx. 5 cm
- PC

Experiment Variations:

Keywords:

Task and equipment

Information for teachers

Additional information

In this experiment, the students observe the reflection of sound pulses in a glass tube – with a sealed and also with an open end. They record the signal and echo with a microphone and analyse the differences in the propagation time with the "measure Acoustics" software in order to determine the difference in distance between the signal and echo.
Prior to the execution of the experiment, the students should know that sound propagates in air with a velocity of 340 metres per second. For a deeper understanding of the evaluation in terms of the reflection at the open tube end, previous knowledge in the field of oscillations and waves, e.g. based on rope waves or wave machines, would be useful.

Notes concerning the execution of the experiment

- A close look at the echoes reveals that there is a phase shift of the pulse signal in the case of the open-ended tube. This becomes obvious by the fact that the first oscillation in the time course of the echo starts in the opposite direction compared to the first oscillation of the original signal.
- Alternatively, the student can also determine the distances to a wall. In this case, loudspeakers must be used instead of earphones. Position the loudspeakers and microphone next to each other in front of a wall, emit the pulse sequence, and record the echo.
- Additional information concerning the reflection at the open tube end (results, 6.):
- At the open tube end (of low acoustic impedance), a reflection takes place just like at any other abrupt change in cross-section. The smaller the ratio between the tube diameter and the wavelength is, the more complete this reflection will be. For the sound pressure, the open end is an obstacle that can be compared to a hard wall for the sound particle velocity. The rigid tube walls maintain the sound pressure inside the tube. At the open end, however, it adapts to the constant external pressure and breaks down. Compared to the sealed tube end, this results in a shift of all of the pressure nodes and antinodes by a quarter of the wavelength. This also applies to the sound particle velocity. At the open end, the sound particle velocity is at a maximum unlike at the sealed end where it is zero. In the open tube end, an air layer oscillates to and fro like a piston.
- Notes concerning the quality of the played and displayed pulse as well as on the determination of the difference in propagation time can be found in the description of experiment P6011100 "Measurement of sound velocity".

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Task and equipment

Task

How can sound be used for determining distances?

Bats can determine the distance between themselves and other objects in their environment with the aid of ultrasound signals and, thereby, find their way. On ships, sonar is used to determine distances. In both cases, the effect of the echo is used, something that we are familiar with from our everyday lives.
Simulate an echolocation process by measuring the distance that sound travels in a glass tube. Examine also whether the tube must be sealed for this purpose.

Equipment

Position No.	Material	Order No.	Quantity
1	Metal angle bracket for glass tube o.d. = 44 mm	13289-16	2
2	Beaker, low form, plastic, 100 ml	36011-01	1
3	Software "Measure Acoustics", single user license	14441-61	1
4	Glass tube, d(outside) = 44 mm, l = 340 mm	13289-20	1
5	CD case as a reflection shield		1
Additional material			
	Microphone		1
	Pair of earphones		1
	PC		1
	piece of adhesive tape, approximately 5 cm		

Set-up and procedure

- Connect the earphones and microphone correctly to the computer.
- Place the glass tube on the two metal brackets (see Fig. 3).
- Place the beaker upside down on the table and fasten one of the earphones to the beaker with the aid of some adhesive tape (see Fig. 1).
- Open the audio settings of the PC. Set the output volume to maximum and adjust the balance so that only the earphone that is attached to the beaker emits sound.

Part 1: The sound signal that is used

- Position the microphone in front of this earphone (Fig. 1).
- Start the software "measure Acoustics" .

Fig. 1: Microphone in front of the earphone

- Open the experiment "2.5 Reflection and echo".

Help 1:
Open the experiment overview (Menu "File" → "Open experiment" or select "Open experiment" on the menu bar).
Open the folder "2 Physical properties: Oscillations and waves" and select the experiment "2.5 Reflection and echo".

- Start the sound playback in the diagram "Spectrum of the signal at the audio output (loudspeaker or headphones)". After 2 seconds, a sequence of eight sounds will be played.

Help 2:
Select "Play tones" in the diagram window "Spectrum ... (loudspeaker or headphones)".

- Start the playback again (see Help 2) but this time freeze the time course of the sound recording so that one of the eight sound pulses is clearly visible in the diagram window "Time function ... (microphone)".

Help 3:
Select "Activate/freeze diagram" in the diagram window "Time function of the signal at the audio input (microphone)".

- Adapt the frozen diagram section so that you can clearly see the recorded sound signal. If necessary, repeat the process until you have successfully recorded a sound signal.

Help 4:
Select "Fit in curve". Use also the magnifying glass "Zoom" and click in order to drag a rectangle around the area that you would like to zoom.

- Read the duration value of this signal and note it down in the report (under "Result - Observations 1").

Help 5:
In the diagram window "Time function ... (microphone)", use the crosshair "Mark" in order to determine the x-value (here: time in ms) at the location of the crosshair by reading the value off the status bar at the bottom of the screen.

Note: Determination of the pulse duration

Figure 2 shows one of the eight pulses. Due to the limitation of the displayed time interval to 100 ms, usually only one or two pulses will be displayed in the diagram

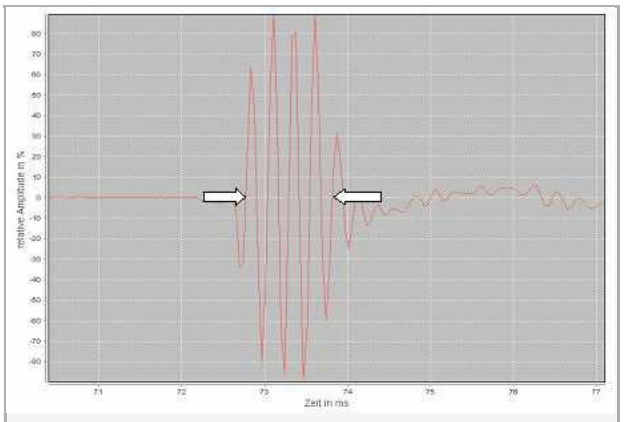

Fig. 2: Determination of the duration of a single pulse

The transient and settling processes that are normal for sinusoidal oscillations and also caused by the hardware must be neglected for the determination of the pulse duration. The pulse starts with the first oscillation with a clearly stronger deflection, i.e. when the curve crosses the x-axis prior to this deflection. Correspondingly, the pulse ends after the last oscillation with a clearly stronger deflection. Both points are marked by arrows in the diagram. Usually, a pulse covers four periods. The question as to how clearly the pulse is displayed depends on the experiment set-up, ambient noises, and also on the quality of the loudspeakers that are used.

Part 2: Sealed tube

- Now, place the earphone and microphone in front of the same opening of the glass tube. Both components should be positioned as exactly as possible next to each other at the tube end (Fig. 3).
- Seal the other end of the tube by pushing the back of a CD case against the opening (Fig. 3). If necessary, prop the case up with another object so that it cannot fall over.

Fig. 3: The earphone and microphone in front of the sealed glass tube

- Readjust the standard section for further measurements.

Help 6:
Select ✥ "Standard diagram section".

- Restart the output of the eight sound pulses (see Help 2) and freeze the time course (see Help 3). Adapt the diagram section (see Help 4). Observe the pulses that will be displayed.
- Use the crosshair in order to determine the duration of each pulse as well as the time interval between the pulses (see Help 5). To do so, read the values of the starting points of the pulses. Note down your results (under "Result - Observations 2/3").

Part 3: Open tube

- Now, remove the CD case so that the tube end is open (Fig. 4).
- Repeat the measurement of the second part of the experiment.
- In the frozen diagram, read the number of identifiable pulses and measure their durations and intervals with the aid of the crosshair (see Help 5). Note down your results (under "Result - Observations 4/5").

Fig. 4: The earphone and microphone in front of the open glass tube

Report: Reflection and echo

Result - Observations 1

Part 1: The sound signal that is used

Duration of one of the eight emitted pulses:

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Result - Observations 2

Part 2: Sealed tube

Duration of the individual pulses that were recorded with the microphone:

a) First pulse

b) Second pulse

c) Third pulse

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Robert-Bosch-Breite 10
D - 37079 Göttingen

Tel: +49 551 604 - 0
Fax: +49 551 604 - 107

info@phywe.de
www.phywe.com

Result - Observations 3

Part 2: Sealed tube

Time interval between the pulses that were recorded with the microphone:

a) Between the first and second pulse:

b) Between the second and third pulse:

Result - Observations 4

Part 3: Open tube

Durations of the individual pulses that were recorded with the microphone:

a) First pulse

b) Second pulse

c) Third pulse

Result - Observations 5

Part 3: Open tube

Time intervals between the pulses that were recorded with the microphone:

Between the first and second pulse:

Between the second and third pulse:

Evaluation - Question 1

How are the three pulses generated that can be observed during the measurement in the tube?

Evaluation - Question 2

How does it become clear that the second and third pulses do not come from a sound source and that they are, instead, echoes of the first pulse?

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Evaluation - Question 3

Use the time intervals between the pulses to calculate the additional distance that they have travelled.

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Evaluation - Question 4

How are the results connected to the tube length of 34 cm?

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Evaluation - Question 5

Sound waves are reflected at points where the propagation medium changes. What is it that changes for the sound at the tube end if it is not sealed?

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Robert-Bosch-Breite 10
D - 37079 Göttingen

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info@phywe.de
www.phywe.com

Evaluation - Question 6

Based on the calculated distances, what can you say as to where exactly the sound is reflected in the case of the open tube end?

Evaluation - Question 7

Why would it have been impossible with this set-up to perform this experiment with longer sounds?

Evaluation - Question 8

If you produce a brief sound with your voice (e.g. coughing), then this sound is usually at least 100 ms long. How far away from a wall must you stand so that your brain can register an echo, i.e. so that it can separate your sound and the echo from each other?

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D - 37079 Göttingen

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Fax: +49 551 604 - 107

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