Acoustic Doppler-effect

Physics | Acoustics | Wave Motion

Difficulty level	Group size	Preparation time	Execution time
easy	1	10 minutes	10 minutes

This content can also be found online at:

http://localhost:1337/c/5f0ed987b6127b0003044a8e

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Teacher information

Application

Doppler radar

The Doppler effect, for example, is used in:

- medical applications: to determine the blood stream velocity by way of ultrasound externally through the tissue of the patients.
- radar: to measure car velocities.
- astronomy: to measure the rotational speed of stars and galaxies.

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Other teacher information (1/3)

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Prior knowledge

This method is particularly elegant since it is a contactless velocity determination procedure that does not require any knowledge concerning the frequency of the emitted signal.

Scientific principle

In the preliminary experiment, the Doppler effect as it is known from everyday life is recalled to the students' mind in a qualitative manner based on an audible frequency, while the main experiment focuses on the case of a harmonically oscillating sound source.First, the frequency of the emitted signal is measured at rest. Then, the frequency shift that is caused by the oscillating Doppler transmitter is proved with the aid of the software. This is followed by the calculation of the velocity of movement of the sound source based on the experimental values. This calculated value is then compared to the theoretical value.

Other teacher information (2/3)

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Learning objective

Understanding the principle of Doppler effect through the change in observed frequency as the source is moved and the observer is at rest.

Tasks

1. Frequency shift in the audible range via a quick movement of the Doppler transmitter. (The effect can be observed better if the experiment is performed by two persons.)

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Other teacher information (3/3)

Tasks

2. Determination of the frequency shift of the signal with the aid of the software.

The high frequency of the Doppler transmitter of 19 kHz has been selected because

- it ensures that the maximum frequency resolution can be achieved,
- this pitch is not audible and, therefore, not irritating for humans, and
- it can still be processed reliably by standard sound adapters.

The frequency of the Doppler source is electronically stabilized to be constant. If you observe a noticeable descent of the frequency (more than 10 Hz in 3 minutes), this is due to a low voltage level (less than 6 V). Please change the battery of the Doppler source.
The frequency of the Doppler source lies in a range of 19 kHz ±10 % (deviation occurs because of tolerances in the electronic components). The indicated values in the measurement table are therefore to be regarded as examples.

Safety instructions

For this experiment the general instructions for safe experimentation in science lessons apply.

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Student information

Motivation

Ambulance

When an ambulance passes by, the perceived (measured) signal of the siren becomes deeper. This means that the frequencies of the perceived sound become lower. This change in the perceived frequency of waves of all kinds, while the source and observer move relative to each other, is called the Doppler effect. The Doppler effect is used in numerous technical applications, such as in traffic radar traps or for determining the speed at which the universe is expanding.

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Tasks

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1. When the Doppler transmitter emits a sound of 4.6 kHz, move it very quickly to and fro and describe what you hear.

2. Determine the velocity of an oscillating spring pendulum with the aid of the Doppler effect:

   - Let the Doppler transmitter with the 19 kHz signal oscillate harmonically above a microphone with the aid of a spring.

   - Analyse the signal that was recorded by a microphone with the aid of a computer. Observe the Doppler effect and determine the maximum velocity of the pendulum.

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Equipment

Position	Material	Item No.	Quantity
1	Software "Measure Acoustics", single user license	14441-61	1
2	Doppler source for TESS Acoustics	13289-30	1
3	Helical spring, 3 N/m	02220-00	1
4	Measuring tape, l = 2 m	09936-00	1

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Additional equipment

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Position	Material	Quantity
1	Microphone	1
2	PC	1

Procedure (1/7)

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Part 1: Frequency shift in the audible range via a quick movement of the Doppler transmitter

Select a frequency of 4.6 kHz. Move the Doppler transmitter repeatedly and quickly towards and away from your ear or face (or the ear or face of your classmate). Note down how you perceive the frequency of the signal in the report.

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Procedure (2/7)

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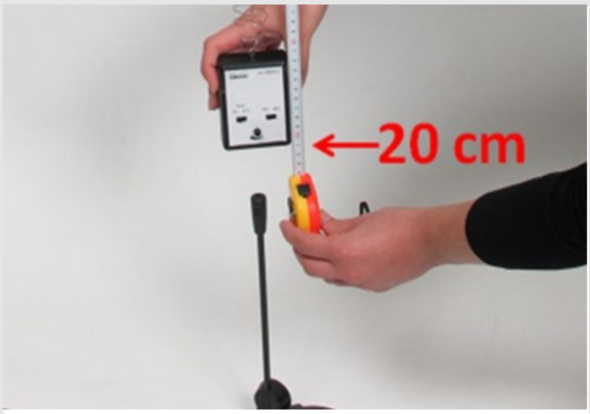
Part 2: Determination of the frequency shift of the 19 kHz signal with the aid of the software

Connect the microphone correctly to the computer.

Open the audio settings of the PC. Set the recording sound volume of the microphone to maximum. Start the software "measure Acoustics"

Open the experiment "3.7a Doppler effect".



Doppler source and microphone

Procedure (3/7)

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Help 1:
Open the experiment overview (Menu "File" → "Open experiment" or select "Open experiment" on the menu bar. Open the folder "3 Applications in the field of medicine, music and everyday life" and select the experiment "3.7a Doppler effect, alternative 1".

- Select a frequency of 19 kHz at the Doppler transmitter and switch it on.
- Note down the approximate values of the maximum of the frequency of the transmitted signal in the report under "Result - Observations 2".

Help 2:
Select the magnifying glass "Zoom" in the corresponding diagram window. Press and hold the mouse button and drag a rectangle from the upper left-hand corner to the lower right-hand corner.

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Procedure (4/7)

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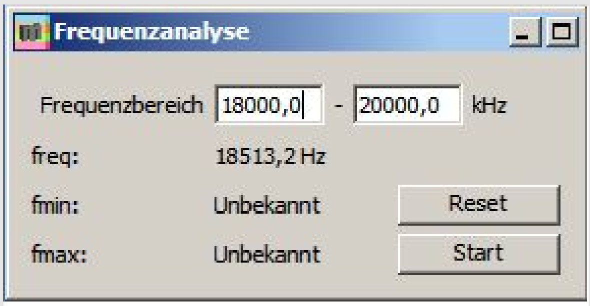
Help 3:
Use the crosshair "Mark" on the grey bar in the diagram window in order to determine the x-value (here: frequency in Hz) and the y-value (here: relative amplitude of the sound pressure in %) at the location of the crosshair. Read the two values off the status bar at the bottom of the screen.



Frequency analysis

Procedure (5/7)

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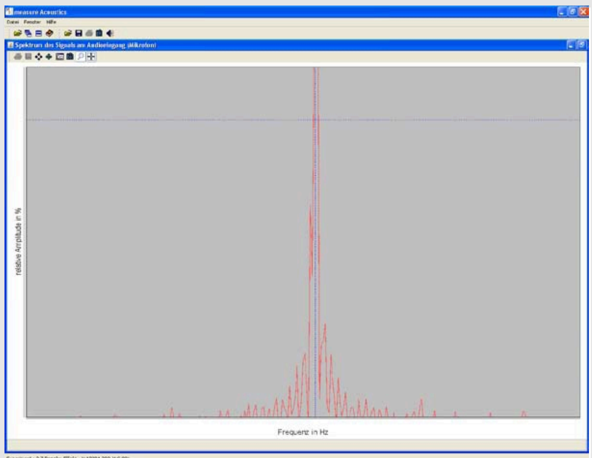
The frequency of the transmitted signal can also be read off the "Frequency analysis" window (freq = … Hz)

- Now set the frequency range for the measurement in the "Frequency analysis" window. The interval should cover a range of about 1000 - 2000 Hz around the maximum of the frequency of the transmitted signal. (Example: The measurement of the maximum of the frequency of the signal resulted in app. 18 500 Hz. Set the minimum frequency value to 18 000 Hz and the maximum frequency value to 19 000 Hz).
- Perform the experiment.



Frequency spectrum of the received signal

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Procedure (6/7)

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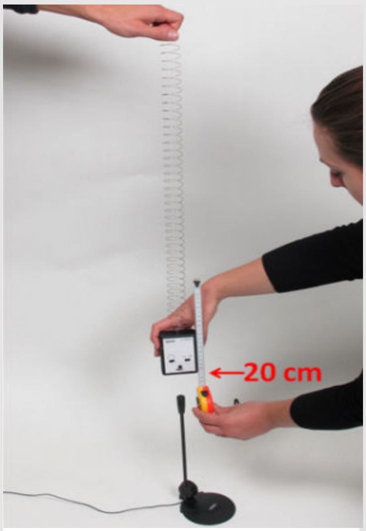

Experimental setup

- Student 1: Hold the spring on one end and attach the Doppler transmitter to the other end. The spring extends to a rest position.
- Place the microphone on the floor directly below the Doppler transmitter. Align the microphone upwards towards the transmitter.
- Student 2: Hold the measuring tape so that it approximately forms an extension of the spring. The zero of the scale must be located at the lower end of the Doppler transmitter. The measuring tape and the spring are slightly offset so that the Doppler transmitter can be deflected without touching the measuring tape.

Procedure (7/7)

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- Activate the frequency analysis by selecting "start".
- Student 2: Pull the Doppler transmitter 20 cm down towards the floor or microphone and release it.
- Describe what the curve in the diagram window "Spectrum of the signal at the audio input (microphone)" looks like and how it has changed after several oscillations in the report.
- Stop the measurement of the frequency after some oscillations by selecting "stop". Note down the highest (f_{max}) and the lowest (f_{min}) frequency value towards which the maximum of the curve shifts in the report.
- Observe and note down how the maximum and minimum are connected to the deflection of the spring.
- Repeat these measurements several times.

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Protocol

Task 1

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Filll in the blank:

In comparison to the frequency of the source, the pitch heard when the Doppler transmitter approaches the listener ______, and the pitch is ______ during the recession.

higher
lower

Check

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Task 2

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Note down the greatest/smallest value of the frequency towards which the maximum of the curve shifts after only a few oscillations.

	$f_{min}\,[Hz]$	$f_{max}\,[Hz]$	$f_{min}-f_{max}\,[Hz]$	$f_{min}+f_{max}\,[Hz]$
Measurement 1				
Measurement 2				
Measurement 3				
Measurement 4				
Mean value				

Task 3

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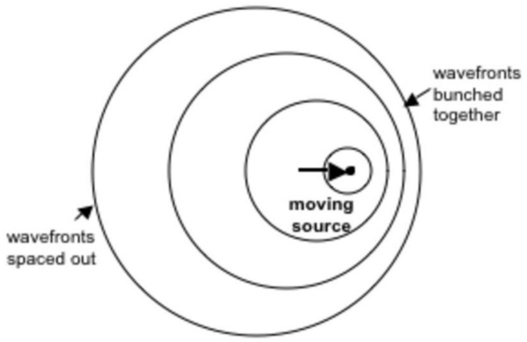
Fill in the blank:

Based on the formula $f' = f_0 \frac{c}{c-v}$, if the source is moving at the speed of sound, the Doppler equation predicts a perceived momentary ______ frequency by an observer in front of the source. Hence, the wavelength is ______.

Check



Doppler effect

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Slide	Score / Total
Slide 20: Doppler transmitter	0/2
Slide 22: Doppler equation	0/2

Total Score 0 / 4

Show solutions   Retry

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