Fundamental, overtone and tone colour (Item No.: P6011800)

Curricular Relevance

Area of Expertise: Physik
Education Level: Klasse 7-10
Topic: Akustik
Subtopic: Grundlagen: Schwingungen und Wellen
Experiment: Grundton, Oberton und Klangfarbe

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

Additional Requirements:

- Microphone
- Pair of loudspeakers
- Recommended instruments: keyboard, string instrument or monochord

Experiment Variations:

Keywords:

Task and equipment

Information for teachers

Additional information

In this experiment, the students examine the frequency spectra of their voices and of two instruments. They learn that the various overtone spectra are responsible for the different tone colours (timbres) while the fundamental tones determine the pitch. In addition, they try to simulate the sound of an instrument with a sequence of pure tones.
Prior to the execution of the experiment, the students should be familiar with the operation of the "measure Acoustics" software. They should know what a frequency spectrum is and why bodies have natural frequencies.
The monochord (03430-00) that is stated as an option in the material list enables the string length in millimetres or the sound pitch to be specified by placing a wooden block (i.e. a bridge) under the string.

Notes concerning the execution of the experiment

- In part 2, the students have to play the concert pitch tone A (440 Hz) on two different instruments. If no instruments are available, the students can also use the saved audio files. It is also possible to use other audio files provided that they were saved in WAV format (44 kHz, 8 bits, mono). These settings can be checked or modified by opening the WAV file in the Windows audio recorder and saving it once more.
- In part 3, the students have to simulate the sound of an instrument based on their observations in part 2. A potential configuration for a piano could be:

Tone	Frequency in Hz	Amplitude in %	Decay time in ms	Playback time in ms
1	436	40	3000	3000
2	880	15	2500	2500
3	1321	18	2000	2000
4	1766	10	1500	1500
5	2215	8	1000	1000
6	2661	3	1000	1000
7	3123	4	1000	1000

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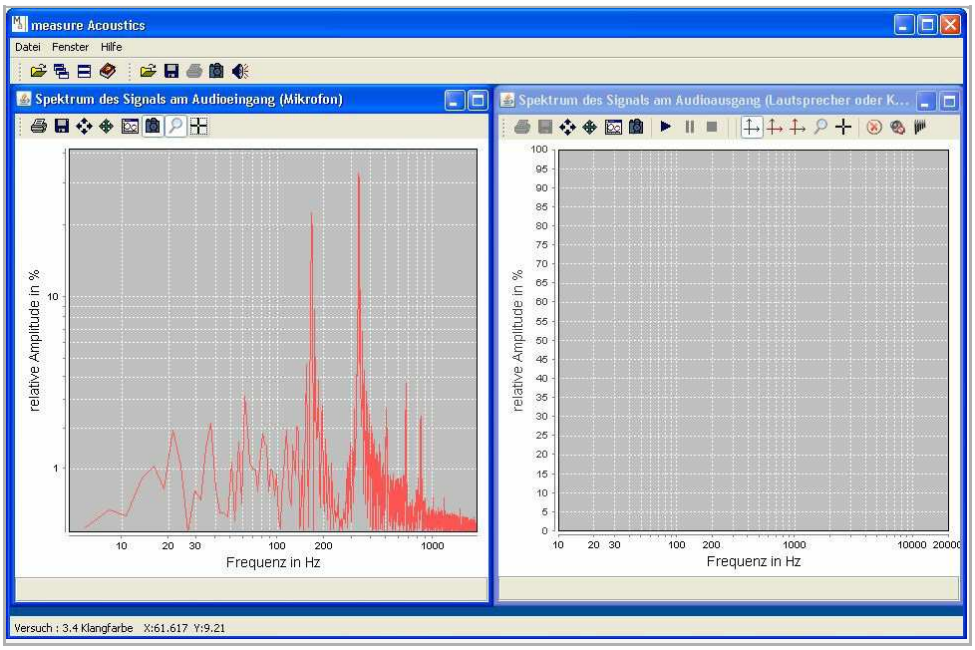
Task and equipment

Task

What is the tone colour?

If one plays a note, e.g. the concert pitch A, on different instruments, it will sound different from instrument to instrument. This is called the tone colour or timbre. Since every instrument has a typical tone colour, this particular tone colour can be recreated with electronic tone generators, e.g. synthesizers or keyboards.
Examine the tone colour of different tones in this experiment.

1. Analyse the frequency spectrum of your voice.
2. Compare the tone colours of various different instruments.
3. Simulate the sound of an instrument with the PC.



Equipment

Position No.	Material	Order No.	Quantity
1	Software "Measure Acoustics", single user license	14441-61	1
Additional material			
	Microphone		1
	Pair of loudspeakers		1
	PC		1
	instruments (recommendation:)		
	Keyboard instrument		1
	String instrument		1
	Or		
	Monochord	03430-00	1

Set-up and procedure

- Connect the loudspeakers and the microphone correctly to the computer.
- Open the audio settings of the PC. Set the sound output volume to a pleasant value. The sound volume for recording should be at maximum.

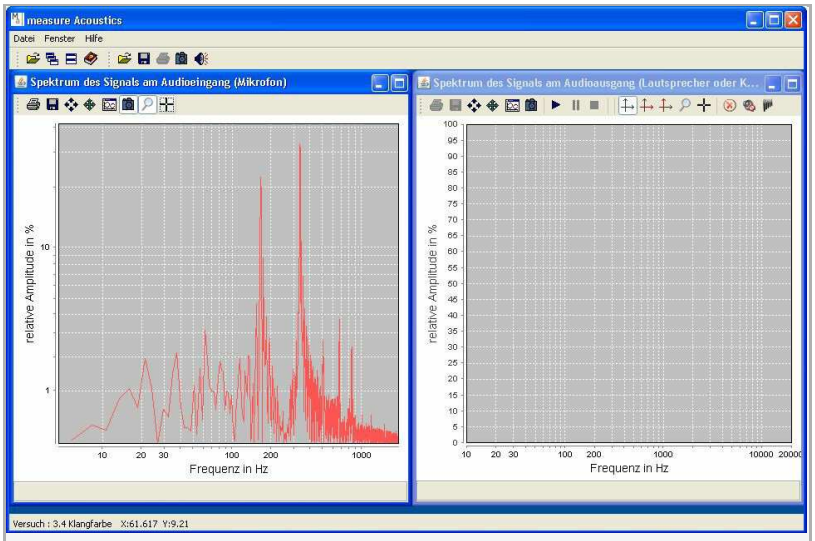


Fig. 1: Adapted diagram section of the frequency spectrum

Part 1: Frequency spectrum of your voice

- Start the software "measure Acoustics".
- Open the experiment "3.4 Fundamental, overtone, and tone colour".

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 "3.4 Fundamental, overtone, and tone colour".

- Position the microphone directly in front of you and sing the sound "oo" (like in "too") with any pitch you like.
- Hold the tone for a few seconds while freezing the diagram.

Help 2:
Select "Activate/freeze diagram" in the diagram "Spectrum of the signal at the audio input (microphone)".

- If necessary, adapt the diagram section so that you can clearly see the frequency spectrum of your voice (Fig. 1).

Help 3:
Select "Zoom" in the diagram window. Then, keep the mouse button pressed and drag a rectangle from the upper left-hand corner to the lower right-hand corner.

- Note down the frequencies that you can see in the frequency spectrum along with their respective relative amplitudes in the report

(under "Result - Observations 1").

Part 2: Tone colour of instruments
Now, record the spectrum of two instruments instead of the spectrum of your voice. Completely different types of instruments, e.g. a string instrument and a keyboard instrument, will provide the best results.
Repeat the process of part 1 for both instruments:

- Position the microphone close to the instrument and play the concert pitch A (440 Hz).
- While doing so, freeze the frequency spectrum (see Help 2).
- Look at the diagram and note down the frequencies with the associated relative amplitudes in the report under "Result - Observations 2".

If you do not have an instrument, you can also play the audio recording of the note A (440 Hz) of a piano or violin. Proceed as follows:

- Position the microphone in front of the loudspeakers.

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- Open the audio player in the "measure Acoustics" program.

Help 4:
Select "Open player" from the toolbar.

- Load an audio file.

Help 5:
You will find audio files of violins and pianos in the folder "\Ressourcen\Sounds". Load these files via the menu item "File -> Open".
Activate the diagram "Spectrum ... (microphone)" (see Help 2).

- Start the playback of the audio file with "Play".
- Freeze the frequency spectrum during the playback (see Help 2).
- Note down the frequencies that you can see in the frequency spectrum of the instrument together with their respective relative amplitudes (under "Result - Observations 2").

Part 3: Simulation of an instrument

- Try to simulate the sound of an instrument by generating a sequence of eight tones maximum with the tone generator.
- Select one of the instruments that you have examined in part 2 of the experiment. A piano or a wind instrument would provide the best results. String instruments are more difficult to simulate.
- Look at your observations in part 2 concerning this instrument. Select eight frequencies that are typical of the sound of the instrument. If you have observed more than eight frequencies in the spectrum in part 2, then select the frequencies with the highest relative amplitudes.
- Generate up to eight tones with the frequencies and relative amplitudes of part 2 in the menu of the tone generator (right-click the diagram -> menu "Tone generator").
- Set a a fade-out time and a playing time of 3 seconds each for all of the tones.
- Accept all of the settings and start the playback of the sequence of tones.
- Listen to the output several times. If necessary, modify the fade-out times of the higher frequencies. In a real instrument, these frequencies usually decay more quickly than the lower frequencies.

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Report: Fundamental, overtone and tone colour

Result - Table 1

Part 1: Frequency spectrum of your voice

Frequencies in the spectrum of your voice:

Tone	Frequency in Hz		Relative amplitude in %	
1	436	1	40	1
2	880	1	15	1
3	1321	1	18	1
4	1766	1	10	1
5	2215	1	8	1
6	2661	1	3	
7	3123	1	4	1

Result - Table 2

Part 2: Tone colour of instruments

Frequencies in the spectrum of two instruments

Tone	Frequency in Hz		Amplitude in %	
1	436	1	40	1
2	880	1	15	1
3	1321	1	18	1
4	1766	1	10	1
5	2215	1	8	1
6	2661	1	3	1
7	3123	1	4	1

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Result - Observations 1

Part 1: Frequency spectrum of your voice

Frequencies in the spectrum of your voice: See Table 1

Result - Observations 2

Part 2: Tone colour of instruments

Frequencies in the spectrum of two instruments: See Table 1

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Evaluation - Question 1

Compare the frequencies in the spectrum of your voice. How are the higher frequencies (overtones) connected to the lowest frequency (fundamental tone)?

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Evaluation - Question 2

What do the frequency spectra of the two instruments have in common and in what respect do they differ from each other?

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Evaluation - Question 3

Explain why the concert pitch tone A (440 Hz) has the same pitch on both instruments and why the tone colour differs.

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Evaluation - Question 4

Why does neither your voice nor the instruments produce pure (sinusoidal) tones, i.e. tones with only one frequency?

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