Physics of sound – basic phenomena

This guideline will provide an overview of the content and didactic context of the media in the media package entitled “Physics of sound – basic phenomena”.

1 Introduction to teaching this topic

1.1 Motivation for the topic

Students can identify strongly with the topic of sound in relation to their everyday life. For young people today the use of electroacoustic devices is second nature, and they are familiar with many everyday sound phenomena (for example, noise, echo, resonance) even if they might not know the explanation for them.

At **primary school** the topic of sound is usually addressed first and foremost from the phenomenological aspect in Personal, social and health education lessons. Students train their acoustic perception by focusing more specifically on the production and propagation of sound (in the same way that optical perception can be considered in terms of light propagation and mirror phenomena). At the same time, they also learn about parts of the ear in order to have a better understanding of the route taken by sound through the ear.

Students will generate tones, sounds and noises themselves, for example by means of vibrating bodies and objects. They will learn that there are high/low, loud/soft noises and that sound can propagate in air, solid bodies and fluids (for example water). They will become acquainted with methods of amplifying sound (bundling of sound, for example by means of a funnel or loudspeaker), as well as with measures for protecting against noise. The example of sound can also be used to create a link with the animal world. Bats find their way around by means of echo sounding and whales also communicate via sound signals through the water.

In physics and technology teaching at **middle schools / high schools** (M/HS), sound is dealt with principally in grades 7 – 9. Students will become acquainted with and understand the principles of sound generation, propagation and perception and learn the physics terms used in this connection such as frequency, vibration, amplitude and their parameters. There are also points of contact between the hearing process and the subject of biology.

The following table provides an overview of the topics of sound and the individual aspects that occur in them:

Topic (M/HS)	Aspects of this topic (M/HS)
Introduction to physics	Simple sounds Physical description of tones Speed of sound
Sound / acoustics	Creation, generation, source, reception, and propagation of sound Sound propagation in various media Frequency, vibration, amplitude, and their core parameters Sound receiver, forced vibration, resonance Hearing perception, Doppler effect Coding language and music
Noise	Noise avoidance, noise protection (noise as environment factor, noise-protection measures) Causes of noise

Topic (M/HS)	Aspects of this topic (M/HS)
Vibrations and waves	Comparability of phenomena in the propagation of mechanical and electromechanical waves Overview of the types of sound Sound waves and their properties Importance of sound in society, nature, and technology
The world of tones / sounds	Sound impressions and their physical description Perception of tone impressions Musical instruments High and low notes Making tones visible
Communication and understanding	Acoustic information takes a journey Language and music are electrically boosted and transmitted (tuning fork, musical instruments, microphone, loudspeaker) From sender to recipient (acoustic signals, telephone, radio, TV)

1.2 Media selection

The media portal of the Siemens Stiftung provides numerous media files relating to the basic phenomena of sound – both for primary school and for secondary schools. This media package only presents a small selection of these files.
Discovering physical or biological phenomena on one's own promotes better understanding than reading through an information sheet. This process of learning by discovery is reinforced especially through linking it to the students' own realm of experience and subsequently applying it to the natural law in question. Alternatively, of course, teacher-centered instruction on the subject of sound is also possible using the media in the media package.
For **primary school**, simple freehand experiments on the individual phenomena are presented. In addition to the experimentation instructions in each case, the media package also contains photos and graphics for the purpose of visualization.
For teaching in **secondary schools**, media are typically presented which transparently explain the physical principle behind each phenomenon, either in the form of simulations or theoretically in the form of information sheets.
The most important principles relating to the topic of "sound" are provided for teachers in a substantive guideline on the topic. This is also suitable for secondary school students for the purpose of further study.

Medium Guideline "Sound – basics"

1.3 Background information for teachers

This guideline relating to the media package explains the numerous facets of the individual topics and proposes various possible ways of using the material in context. The media files in the package can of course also be used individually and completely independently of each other strictly by subject. But it will surely make for more interesting teaching when components are used in context, as this creates an opportunity to stimulate students' interest in technical details.

To accomplish this, we recommend working through the topic in the following steps:

- How is sound produced?
- What is sound physically?
- How does sound propagate?
  - Sound propagates in the form of waves.
  - The sound wave has a speed.
- What happens when the sound wave strikes an obstacle?
- How do we perceive sound?

Note: Each step is divided into two sections:

- **Phenomenology** – the basic phenomenon is introduced using simple experiments or everyday situations. This introduction is suitable for dealing with the topic at primary school level as well as at secondary schools (unless explicitly stated otherwise).
- **Theory** – the basic phenomenon is explained scientifically at secondary school level.

2 How is sound produced?

2.1 Phenomenology

Students carry out simple experiments to produce sound, for example with a cup guitar. You can find a wide selection of simple experiments here:

Medium Experimentation instructions “Production of sound”

The media package also contains an illustration relating to one of these experiments:

Medium Graphic “Sound production with a cup guitar”

2.2 Theory

The production of sound can be explained graphically, for example, by the bursting of a balloon and a vibrating loudspeaker membrane.

Medium Information sheet “What is sound?”

3 What is sound physically?

3.1 Phenomenology

A simple experiment, for example, in which sound can be made “visible” is suitable for understanding what sound really is:
Sprinkle salt on a sheet of cling film stretched across a bowl. Make a humming noise against the film at the side. The louder you hum, the more vigorously the grains of salt will jump up and down.

Note: An oscilloscope is ideally suited for secondary schools for making sound “visible.” The media package offers a whole series of media for this purpose:

Media	Photo “Tuning fork – source of pure tones”
	Graphic “Tuning fork as ‘simple’ sound”
	Video “Tuning fork as ‘simple’ sound”
	Recording “Tuning fork as ‘simple’ sound”

It is also very easy to determine experimentally that noise can propagate in various materials.

Media	Experimentation instructions “Sound propagation experiments”
	Photo “Sound propagation in solid bodies”

3.2 Theory

The molecules in elastic media can be excited to vibrate mechanically around their position of equilibrium through the application of an external force. These vibrations are known as “sound.” Sound propagates differently depending on the nature of the medium (solid, liquid, gaseous). The basic understanding of sound is therefore based partly on the knowledge of the physical properties of **vibrations**. An information sheet provides an insight into the most important properties:

Medium	Information sheet “Wave, Frequency, Amplitude”

Notes:

- For students in higher grades, it is worthwhile comparing sound and light waves at this point. In the case of sound the frequency defines the pitch and in the case of light the color, while the amplitude defines the volume of the sound or the intensity of the light.
- In practice, sound is classified according to its frequency. What frequency range does ultrasound comprise, for example, and what range does infrasound cover, etc?
- Sound is also classified in practice according to how the vibrations are composed: What, for instance, distinguishes the tone from the sound?

Understanding of sound also calls for knowledge of the **structure of matter**. Sound propagates in air, for example, in the form of compression or thinning of the air. One speaks of longitudinal waves. What happens in water?

Note: The terms airborne sound structure-borne sound and fluid-borne sound should be introduced in this context.

4 How does sound propagate?

4.1 Sound propagates in the form of waves

4.1.1 Phenomenology

The experiment “Tambourine blows out candle” provides an impressive demonstration that sound waves propagate and that this is associated with the movement of air particles. The following photo series can be used for follow-up or instead of the actual experiment:

Media	Photo “Sound propagation: tambourine & candle 1”
	Photo “Sound propagation: tambourine & candle 2”
	Photo “Sound propagation: tambourine & candle 3”

The example of ripples on water is well suited for an initial demonstration of how exactly sound waves propagate.

Medium	Video “Water as wave model”

4.1.2 Theory

An explanation of the propagation of sound in the experiment with the tambourine is provided by an information sheet:

Medium	Information sheet “Sound propagation”

The physical properties of waves and the differences compared with vibrations must be clear to students for a basic understanding of sound propagation:

Medium	Overview graphic “Vibrations and waves”

Note: At this point it is again worth drawing an analogy with the propagation of light.
It is also important to know that sound propagates in a circular form from its source. One speaks of the “sound field”.

Medium	Schematic diagram “Sound field and sound absorption”

4.2 The sound wave has a speed

4.2.1 Phenomenology

Many students will already know the old rule of thumb that you can calculate how far away a thunderstorm is by measuring the time between seeing the flash of lighting and hearing the thunder (sound!). However, to do this you need to know that it takes about 3 seconds for sound to cover a distance of one kilometer through air.
The fact that the speed of propagation depends on the medium is demonstrated by the “knocking” experiment in the following medium:

Medium	Experimentation instructions “Sound propagation”

4.2.2 Theory

Sound propagates faster in solid bodies than in fluids, and faster again in fluids than in air. A simulation graphically demonstrates this fact. Why this is so is explained in an information sheet.

Media	Information sheet “Speed of sound” Simulation “Sound propagation velocity in different materials”

5 What happens when the sound wave strikes an obstacle?

5.1 Phenomenology

If sound strikes an obstacle, various effects can occur depending on the nature of the obstacle.

- The direction of propagation of the sound changes.
  Effects: Reflection, diffraction, refraction
- The sound is amplified.
  Effects: Bundling of sound, resonance
- The sound becomes weaker (it is attenuated).
  Effect: Absorption

Students can reproduce these effects by means of some simple experiments, for example:
Reflection

Medium	Experimentation instructions “Sound reflection – experiments”

Bundling of sound

Medium	Experimentation instructions “Experiments on bundling of sound”

Absorption
Simple experiment: Wrapping a ringing alarm clock in a blanket.

Note: Students name other acoustic effects that they know from their own experience (for example, echoes in the mountains or reverberation in a concert hall) and allocate them to the three categories mentioned (change of direction, amplification, attenuation).

5.2 Theory

A detailed information sheet explains all possible phenomena:

Media	Information sheet “Sound propagation and obstacles”

Note: Here again it is worthwhile drawing an analogy with the light wave.

6 How do we perceive sound?

6.1 Phenomenology

Since sound is based on the mechanical movement of matter it can be perceived physically. Anyone who has ever attended a rock concert and stood near the bass loudspeaker will know this. However, in order to perceive sound acoustically (i.e. hear it) or transport it over long distances (by telephone for instance) it is necessary to convert or transduce it.
The following simple experiment, for example, can be carried out in order to illustrate the transduction of sound in the ear:

Medium Animation “Construct eardrum – experiment”

Instructions for carrying out this experiment and other experiments related to the topic of hearing can be found in these experimentation instructions:

Medium Experimentation instructions “Experiments on hearing”

6.2 Theory

Sound transduction in the ear (conversion of fluid-borne sound into electric pulses) takes place in the cochlea. A detailed explanation can be found in the following information sheet:

Medium Information sheet “The route of sound through the cochlea”

The hearing process is particularly well suited for observing the interaction of other sound effects apart from sound transduction (bundling, amplification). A microphone also functions in a similar fashion.

Medium Animation “Sound transduction physiological vs. electronic”

Teaching ideas: The animation clearly illustrates the fact that technical devices usually follow natural models. Students are encouraged to think of other examples that occur to them. For example, how does a telephone work?

Note: On the topic of sound there are many other media files available at the media portal of the Siemens Stiftung that can be found by making a full text search under the keyword “Sound (basic phenomenon)”.