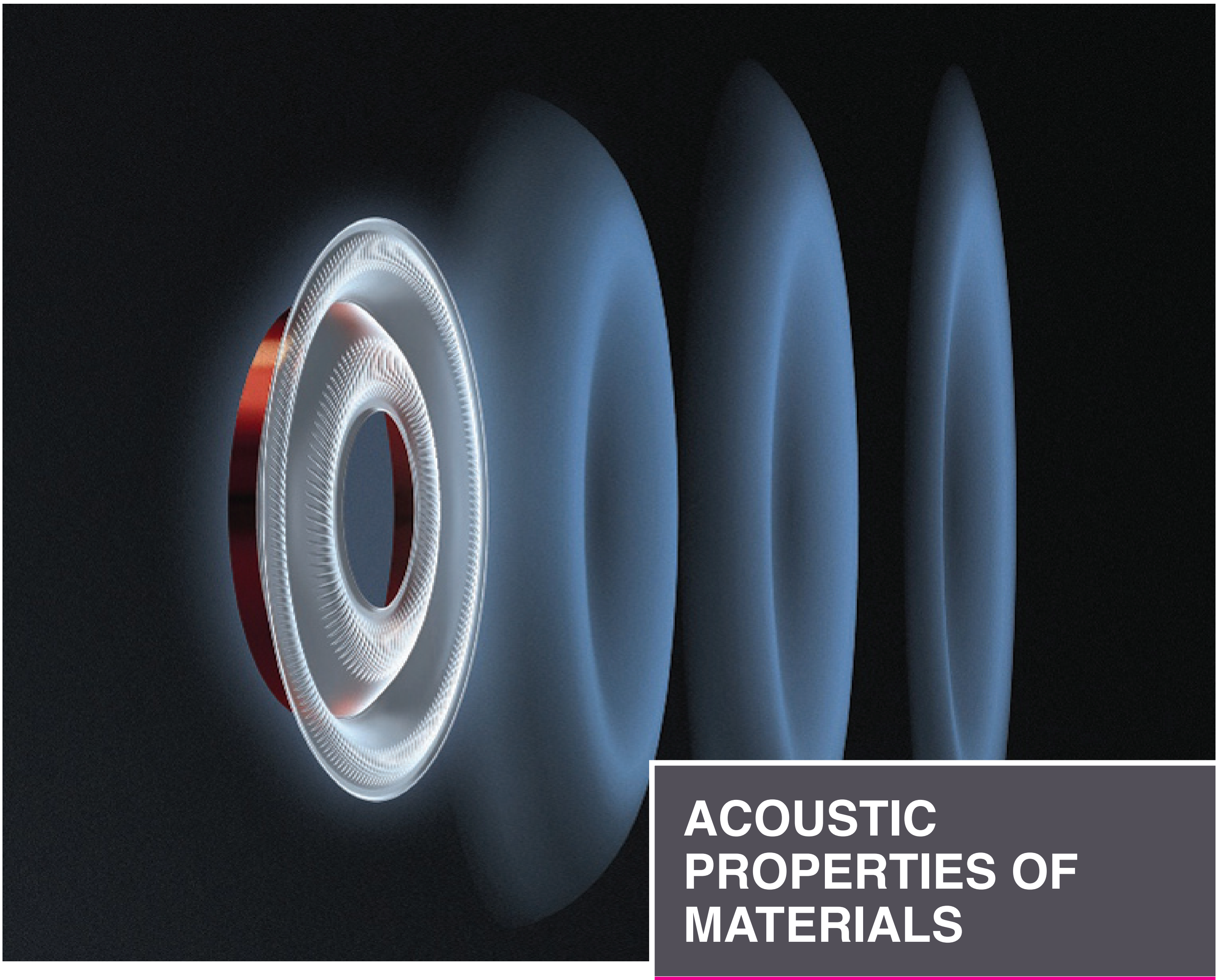

ACOUSTIC PROPERTIES OF MATERIALS

TEACHERS' MANUAL

ADAPTED VERSION

MATERIALS SCIENCE PROJECT

UNIVERSITY-SCHOOL PARTNERSHIPS FOR THE DESIGN AND IMPLEMENTATION OF RESEARCH-BASED ICT-ENHANCED MODULES ON MATERIAL PROPERTIES

SPECIFIC SUPPORT ACTIONS

FP6: SCIENCE AND SOCIETY: SCIENCE AND EDUCATION

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ACOUSTIC PROPERTIES OF MATERIALS

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A: DESCRIPTION AND ANALYSIS OF TEACHING AND LEARNING ACTIVITIES

A: DESCRIPTION AND ANALYSIS OF TEACHING AND LEARNING ACTIVITIES

The module “Acoustic Properties of Materials” has **been structured in three main units**, each with its own driving questions:

Unit 1: Sound wave - Material interaction (5h)
- *Acoustic problems of a disco: What happens to sound inside and outside a disco?*
- *Why can sound reach any corner of the dance floor?*
- *How can we manage to avoid hearing too much sound outside the disco?*

Unit 2: Properties and internal structure of sound reflectors and sound absorbers (5h)
- *Which characteristics does a good sound reflector have? And a good sound absorber?*
- *How can we explain that the properties of a material affect its acoustic behaviour?*

Unit 3: Acoustic conditioning and soundproofing (2h)
- *Comparing materials. Which one could be used to soundproof?*

Recommended settings and pedagogical approach

The whole module is **student-centred** and is intended to engage students in **group activities**, except those activities which require an individual reflection on one’s own learning or those that ask for a discussion within the whole class. The role of the teacher is to guide students, stating explicitly the aims of each task or reformulating and adapting new key questions in order to help them to find their own learning path. This **teacher’s role as a facilitator** is necessary to promote a gradual development of students’ autonomy when questioning, thinking, planning, reflecting, interacting, discussing, and gradually developing conceptual frameworks through the active participation in tasks, with or without an experimental component.

The learning targets and conceptual sequence for each block are described in detail below. The sequence of teaching and learning activities designed to promote the intended learning targets is also shown.

0. INTRODUCTION TO ACOUSTICS

The module is introduced by means of Unit 0, which poses the problem of noise pollution and emphasizes the role of science and technology in solving this kind of problem. This unit is also aimed at making students aware of the importance of using an accurate scientific language to allow us to communicate efficiently. For this reason, this unit revises the terminology associated to sound and summarizes the basic concepts related to sound nature and sound propagation that are required as a pre-requisite of the whole module.

Discussion of the experiments and exercises

At the beginning of this unit, it would be advisable that teachers encouraged students to begin discussing why the topic "Acoustic properties of materials" generates interest of study in order to wake up their own interest and feeling of usefulness of the contents which are dealt in the module.

0.1. Students should work in pairs and later, a whole class discussion would be fruitful. The main aim of this activity is to make students aware of the difficulty of describing sounds in a way that allows other people to reproduce exactly the described sounds. In consequence, the activity is aimed at making students aware of the necessity of describing sounds with a more accurate language, in terms of certain magnitudes.

0.2. In this exercise, students have to explore the relationships between scientific and everyday language related to acoustics.

After these two exercises, there is a text which summarizes and stresses the key concepts which are necessary as pre-requisites of the module.

0.3. The aim of these activities is to revise the basic concepts related to sound since the notions related to the nature of sound and sound propagation are dealt throughout the whole module. For instance, there are some interactive simulations (such as SimulaSON or the one developed within the PhET Project, see chapter 10 in section A) that could be very useful for this purpose. Other physical resources which are often used and experiments which turn out to be significant for students to learn about sound are:

- A slinky to teach/learn about the propagation of waves,
- An experiment which consists of placing a sound source inside a recipient to remove from there air molecules leaving behind a partial vacuum so that students can analyze the relationship between sound and the presence of a medium.
- It is also helpful to bring tuning forks with different frequencies to class to analyze the relation between frequency (and wavelength) and “speed of vibration”.

Equipment
No special equipment is required. It will depend on the needs of each class group.

UNIT 1: SOUND WAVE - MATERIAL INTERACTION

Sequence of contents
Phenomena related to sound wave – material interaction that affects to sound propagation: reflection, diffuse reflection, reverberation.

Phenomena related to sound wave – material interaction that affects to sound attenuation: reflection, absorption, attenuation.

Model of sound attenuation in terms of the distribution of energy associated to sound: energy of incident sound, energy of reflected sound, energy of transmitted sound, absorbed energy.

Principle of conservation of energy applied in sound attenuation phenomena.

Sound attenuating materials depending on their acoustic behaviour: sound reflectors, sound absorbers, sound insulators.

Learning targets
At the end of Unit 1, students should be able to…

1. Recognize the importance of using an appropriate scientific vocabulary to describe sounds.
2. Use scientific terminology to talk about sounds and sound phenomena.
3. Relate one’s own experiences related to sound and noise pollution with scientific knowledge.
4. Read and interpret images related to sound reflection.
5. Explain certain situations in terms of the sound reflection phenomenon.
6. Draw the direction of the reflected sound wave knowing the angle of the incident sound wave and using the law of the angles.
7. Explain certain situations in terms of reverberation of sound.
8. Interpret sound reflection on irregular surfaces in terms of sound diffusion.
9. Distinguish clearly between reverberation and echo phenomena.
10. Interpret sound attenuation in materials in terms of

energy distribution.

11. Apply the principle of conservation of energy when expressing that the energy of an incident sound in a closed space is distributed between the energy of the reflected sound, the energy of the transmitted sound and the absorbed energy within a material.
12. Express and apply in different contexts the diagram that describes that an incident sound on an interface is partly reflected, partly absorbed and partly transmitted through a material.
13. Relate the sound intensity level measured with the quantity of energy that is associated to the sound wave.
14. Associate the sound intensity level decrease through a wall or any other obstacle to sound attenuation.
15. Distinguish the meaning of sound absorber from the meaning of sound reflector according to their acoustic behaviour.
16. Design and carry out an experiment to measure the attenuation of sound caused by a material.
17. Relate the sound intensity level measured in a certain point of the space with the distance from that point to the sound source.
18. Control the variables of an experiment.
19. Measure the sound intensity level using a sound level meter.
20. Relate the intensity level of perceived sound with the respective values observed in a graph of sound intensity level vs. time.
21. Predict the evolution of a phenomenon and compare the prediction with the obtained result and with the conceptual model.
22. Interpret the meaning of graphs of sound intensity level vs. time.
23. Calculate sound attenuation as the subtraction between the incident sound and the transmitted sound through a material.

1.1. ACOUSTIC PROBLEMS OF A DISCO

This unit is an introduction to the context of the module, which deals with the problems of a disco which is not well soundproof.

Discussion of the experiments and exercises

It is important to let students read and discuss the problems related to the context of the disco since it is the scenario in which problems are posed and questions are raised throughout the whole module.

1.1.1. This activity proposes the observation of a disco (by means of photographs) to encourage students to discuss and identify the acoustic necessities of each area of a certain disco.

1.1.2. This activity is intended to explore students' previous ideas about phenomena related to sound (reflection, diffraction, and attenuation) through questions contextualized in the disco scenario.

Equipment

No special equipment is required. Nevertheless, the images of the disco could be projected in a big screen to facilitate the observation of the different areas of the disco since the pictures shown in the students' worksheets are not very clear.

1.2. WHY CAN SOUND REACH ANY CORNER OF THE DANCE FLOOR?

This unit is intended to the study of sound reflection and other associated phenomena (such as reverberation and diffuse reflection) and different technological applications (such as surround sound systems).

Discussion of the experiments and exercises

1.2.1. This activity has the aim of promoting the exploration of previous ideas about sound reflection. Students are asked their ideas about reflection in smooth or uneven surfaces, and about the direction of propagation of reflected sound waves.

1.2.2. In this activity, students have to compare sound reflection with other phenomena involving reflection (such as light or mechanical rebounds after collisions). The purpose is to analyze the commonalities between these situations regarding the direction of propagation of the reflected waves or objects.

1.2.3. Students are provided with a set of experimental data about sound reflection in different directions and they have to reach a conclusion about the law of angles when sound is reflected on a surface.

1.2.4. Students are asked to summarize their conclusions on sound reflection: what reflection is and what angle the reflected sound waves form with the surface in relation to the incident sound waves.

1.2.5. Students are asked to apply their knowledge on sound reflection and directions of propagation of reflected sound in a practical situation: the use of sound diffusers in different rooms allocated to different uses.

1.2.6. This activity is intended to explore students' previous ideas about sound reverberation.

1.2.7. Two graphs that show the time of reverberation in a room before and after being acoustically conditioned are provided. Students have to interpret the meaning of these graphs in terms of the effects that a listener would perceive (more or less duration of sounds) due to the reverberation in the room.

1.2.8. Students are provided with some data about time of reverberation in a theatre and they have to interpret these data in order to reach a sound conclusion.

One of the most important tasks of the teachers is to promote that students confront the explanations that they elaborate with the scientific point of view. Therefore, it is advisable that teachers engage their students in reflecting and discussing what science tell us about the reflection phenomenon (in this case) regarding their previous ideas.

On the other side, students should learn that one's predictions do not need to be corrected but discussed and justified. Teachers should reinforce this view as a way of promoting an increasing students' reflection on their own explanations by discussing among peers and rising debates.

Equipment

No special equipment is required. Again the images in exercise 2.5 could be projected in a big screen to facilitate the observation of the rooms since the pictures shown in the students' worksheets are not very clear.

Some teachers have considered useful to use a ripple tank to generate waves and allow students to experience the reflection of waves in water when they reach an obstacle. The simulation developed within the PhET Project can be also used with the same purpose.

1.3. HOW CAN WE MANAGE TO AVOID HEARING TOO MUCH SOUND OUTSIDE THE DISCO?

This unit is devoted to the study of sound attenuation through a material object in terms of the energy associated to sound. Once the phenomena related to sound attenuation have been analyzed, the difference between sound insulators, absorbers and reflectors is stated in terms of their acoustic behaviour.

Discussion of the experiments and exercises

1.3.1. Students are asked some questions to allow teachers to explore students' previous ideas about sound attenuation.

1.3.2. This activity is the first time in the module that students have to use a data capture system and a sound level meter to measure the variations of sound intensity level. It would be necessary that students tried to understand and get familiar with the instruments, connections and setup as they will use the instrument in other experimental activities along the module. In order to interpret and predict appropriately graphs (sound intensity level vs. time) it is important to help students to identify the relevant aspects of a graph like the ones that are expected in this experiment (differences of sound intensity level of various sounds or values) and avoid the irrelevant ones (shape of the graph).

1.3.3. This experiment consists of the analysis of the empirical relation between sound intensity level and the distance from the sound source to the sound level meter. The graph that shows the relationship between sound intensity level and distance from the sound source can be obtained from the source up to a certain distance (2m approximately). Further than that distance, sound intensity level remains almost constant inside a closed room. The speed of separation of the sound level meter from the source can highly affect the form of the obtained graph. It is advisable to move away the sound level meter from the sound source at a constant speed.

1.3.4. Students have to apply what they understand by attenuation in order to calculate sound attenuation from provided data. If students have an appropriate conception of what attenuation is, they will calculate sound attenuation as the subtraction between the incident sound and the transmitted sound through a material.

1.3.5. From a visual representation of how two different materials behave in front of sound in terms of how they distribute the energy associated to sound when they interact, students have to interpret which material behaves as a sound reflector and which behaves as a sound absorber.

1.3.6. The last exercise of this part A consists of a self-assessment followed by a peer-assessment. Students are asked a general question so that they can reflect on and try to relate all the concepts that have been studied along this first part of the module. Furthermore, students have to contribute to help their classmates with each others' answers. It would be very beneficial for students that teachers also revised the answers that students elaborate in order to provide them some feedback and try to enrich their conceptual connections.

Equipment

According to the designers' proposal, activities 1.3.2 and 1.3.3 require a sound level meter connected to a computer which has previously installed software to collect and analyze data. In the design context, it was used MBL technology (sensor + interface). In these activities, it was decided to use the sensor (sound level meter) connected to a computer because this equipment facilitates the visualization of a graph which illustrates all the variations of sound intensity level that correspond to the perceived sounds. On the contrary, the sound level meter by itself only shows the changing values of sound intensity level at each moment but it can not save data.

UNIT 2: PROPERTIES AND INTERNAL STRUCTURE OF SOUND REFLECTORS AND SOUND ABSORBERS

Sequence of contents

Model of sound absorber in terms of its physical properties (little rigid, little dense, porous).

Model of sound reflector in terms of its physical properties (rigid, dense, non porous).

Model of sound absorber and sound reflector in terms of their internal structure.
Model to explain the mechanisms of sound attenuation (by reflection and by absorption) of sound absorbers and reflectors in terms of their physical properties (rigidity, density and porosity) and their internal structure.

Learning targets

At the end of Unit 2, students should be able to…

1. Prepare an experimental setting to measure and collect data of sound intensity level.
2. Compare numerical values obtained empirically in order to come to some conclusions.
3. Distinguish the meaning of sound absorber from the meaning of sound reflector depending on the sound intensity level that is measured inside a box covered with these materials.
4. Compare their preconceptions about acoustic properties of materials with the elaborated conceptual models and distinguish the differences.
5. Design an experiment to determine whether a material is a sound reflector or a sound absorber, controlling the dependent variables.
6. Use the properties of a material to predict whether a material will behave as a sound absorber or a sound reflector.
7. Relate the fact that a material is sound reflector or sound absorber with the combination of certain properties: numerical value of its density, degree of stiffness noticed by direct manipulation, its porosity observed with a binocular microscope.
8. Use a conceptual model of the microstructure to represent a dense material.
9. Use a conceptual model that allows relating the density of a material with its acoustic behaviour.
10. Use a conceptual model of the microstructure to represent a rigid material.
11. Use a conceptual model that allows relating the rigidity of a material with its acoustic behaviour.
12. Represent a porous material in terms of its internal structure.
13. Use a conceptual model that allows relating the porosity of a material with its acoustic behaviour.
14. Use a conceptual model to interpret mechanisms of sound attenuation in materials in terms of energy transfer or energy dissipation.

2.1. WHICH CHARACTERISTICS DOES A GOOD SOUND REFLECTOR HAVE? AND A GOOD SOUND ABSORBER?

This unit consists of a guided inquiry-oriented activity sequence that promotes the elaboration of a model of sound reflector and sound absorber in terms of their physical properties.

Discussion of the experiments and exercises

2.1.1. This exercise is an open-ended question that is intended to explore students' previous ideas about the characteristics or physical properties that sound attenuating materials have.

2.1.2. This activity is also an exploratory question about the properties that students associate to sound attenuating materials. Nevertheless, in this activity students have to justify why the assign certain characteristics to sound reflectors and sound absorbers. The main aim of this activity is to formulate a preliminary model of sound absorber and sound reflector in terms of their physical properties that allows them to predict and to test it after some experiments.

2.1.3. Students are asked to predict the acoustic behaviour of certain materials according to the preliminary model of their properties. It would be advisable that students could observe and manipulate a piece of each material before predicting their acoustic behaviour.

2.1.4. Students have to design an experiment to test at which level a material reduces the transparency of sound through it.

2.1.5. Students carry out the designed experiment

2.1.6. Students have to design an experiment to test if a material behaves as a sound reflector or as a sound absorber. A key question for triggering students' thinking on the experimental design is: "If you covered the walls of the disco (or the walls of your classroom) with pieces of a sound reflecting material (or sound absorbing material), what you would hear inside the closed space?" (In relation with the ordinary walls).

2.1.7. Students have to carry out the designed experiment using boxes covered inside with different materials. For doing so, they have to take into account that they need a reference value to which compare their measurements of sound intensity level. The reference value corresponds to the measurement of the sound intensity level inside a cardboard box without being covered by any material. Based on the experimental results, students are asked to classify the tested materials in two categories: sound reflectors and absorbers. If the sound intensity level that students measure inside the box covered by a certain material increases in relation to the reference value, it means that the material which covers the box is a sound reflector. On the contrary, if the sound intensity level decreases, it means that the material that has been used for covering the box is a sound absorber. At the end of this activity, it would be advisable that the whole class group shared their results in order to compare their experimental results and come to appropriate conclusions about the acoustic behaviour of each material.

2.1.8. Once students have classified the tested materials distinguishing sound reflectors from sound absorbers, they have to identify which properties are common to all the sound reflectors used in the previous experiment and which properties are common to all the sound absorbers. Students are asked to generalize the properties of sound absorbers and sound reflectors. The main aim is to make students aware that some properties of materials are related to their acoustic behaviour and other properties are not.

After the classification of properties, students are asked to distinguish properties which are specific of materials from those which are general for objects. This module is aimed at acoustic properties of materials but it does not deal with the influence of other properties of objects, such as thickness or surface of pieces of material. In order to avoid communicating the idea that these factors do not affect the acoustic behaviour of materials (because they do so), teachers should emphasize that properties of objects can also affect the acoustic behaviour of a piece of material and this influence could be also analyzed but it is not addressed in the module.

Finally, based on these new evidences, students are asked to revise the preliminary model elaborated in activity 4.2 which relates the acoustic behaviour of materials to their physical properties.

2.1.9. Students are provided with some empirical data (such as the measurement of density of the tested materials) and they also have to observe and manipulate the previous sound reflectors and sound absorbers to obtain accurate data about their physical properties.

2.1.10. Finally, students should come to a conclusion about the physical properties of sound absorbers and sound reflectors.

2.1.11. This exercise is aimed at applying the previous refined conceptual model which relates acoustic behaviour of materials to their physical properties. Students are asked to predict how different materials would behave in front of sound according to the physical properties they can identify from the pictures of these materials.

Equipment

In activity 2.1.3, it would be advisable to provide students with some samples or pieces of materials that students can observe and manipulate in order to predict their acoustic behaviour.

In activity 2.1.7, six cardboard boxes are used. Five of them are covered inside with different materials (aluminium foil, felt, polyurethane, chipboard with Formica and glass wool). The remaining box does not need to be covered by any material because it is used to measure the reference value to which the rest of the measurements should be compared.

In activity 2.1.11, students are provided with technical sheets (photos) of each material (see Annex 1) to allow them to observe the internal structure of each tested material. The students are also asked to describe the materials so they should have again some samples of the materials.

2.2. HOW CAN WE EXPLAIN THAT THE PROPERTIES OF A MATERIAL AFFECT ITS ACOUSTIC BEHAVIOUR?

This unit is aimed at promoting the elaboration of a model of the internal structure of sound reflectors and absorbers that allows interpreting their acoustic behaviour according to their properties.

Discussion of the experiments and exercises

2.2.1. Students are asked some questions to guide them to use the particular model of matter when conceptualizing density as a property of materials at a microscopic level. An analogy is introduced in the module: particles that form the materials or any other medium are depicted as balls placed one by the other in 3 dimensions. It is necessary that teachers explain the potential of this analogy and help them to make a sketch of a less dense material by placing the balls not so close the one by the other. Then, students are supposed to transfer the language and reasoning used with the previous analogy and focus on particles to explain how density of materials can be conceptualized at the level of their internal structure and how density of materials affects their acoustic behaviour.

2.2.2. Students have to use a similar analogy (balls connected with strings) to interpret how to conceptualize rigidity as a property of materials at a microscopic level. In this exercise, the students are supposed to transfer the language and reasoning used with the analogy and focus on particles to explain how rigidity of materials can be conceptualized at the level of their internal structure and how rigidity of materials affects their acoustic behaviour.

After these two activities, it would be necessary to discuss the limitations of the analogy used (e.g., it is important to clarify that density and rigidity are not independent properties but they are related. More density means higher atomic weight in some cases and/or a different arrangement of particles, but it also means different bonds among particles. The model used for explaining density is only useful for homogeneous materials but does not account for the differences between amorphous materials. Regarding the model for rigidity, the students should understand that the bonds among particles are not physical, as it is represented with springs).

2.2.3. Students have to interpret how porosity of a material affects its acoustic behaviour.

2.2.4. Students are asked to summarize the physical properties that sound reflectors usually have and to apply the model that relates physical properties to internal structure of materials to account for how sound is attenuated when reaches a sound reflector.

2.2.5. Students are asked to interpret some experimental results based on the model which relates acoustic behaviour of materials to their internal structure.

2.2.6. The last exercise of this chapter consists of a self-assessment followed by a peer-assessment. Students try to relate all the concepts that have been studied along this 2nd part of the module. Furthermore, students have to contribute to help their classmates with each others' answers. It would be very beneficial for students that teachers also revised the answers that students elaborate in order to provide them some feedback and try to enrich their conceptual connections.

Equipment

No special equipment is required.

UNIT 3: ACOUSTIC CONDITIONING AND SOUNDPROOFING

Sequence of contents

Applications of sound reflectors, absorbers and insulators:

- Acoustic conditioning
- Soundproofing

Learning targets

At the end of Unit 3, students should be able to…

1. Apply the conceptual model which relates the physical properties of materials to their acoustic behaviour in order to predict how new materials would behave with regard to sound attenuation.
2. Describe materials.
3. Design autonomously an experiment, using a sound level meter, to test empirically the acoustic behaviour of a material.
4. Distinguish empirically between a sound absorber and a sound reflector.
5. Determine empirically how much sound intensity a certain material attenuates.
6. Justify, using acoustic and non-acoustic criteria, their decisions about which materials are appropriate to use in order to achieve the acoustic conditions that a certain space requires.
7. Propose solutions to solve a problem related to soundproofing.
8. Summarize information and establish conclusions relating acoustic behaviour of some materials to their physical properties.

3.1. COMPARING MATERIALS. WHICH ONE COULD BE USED TO SOUNDPROOF?

This unit was conceived as an open inquiry-oriented sequence of activities which is driven by the question: which material would be the best sound absorber to be used for soundproofing a disco? This sequence of activities is proposed as a group project in which the students have to put into practice their knowledge on acoustic properties of materials and their skills to propose particular solutions to soundproof the disco (original problem).

Discussion of the experiments and exercises

3.1.1. Students are asked to suggest solutions for the acoustic insulation of the different sections of the disco.

3.1.2. In order to do so they have to look for information for the materials included in the given table, or for some more that they consider as appropriate for such use.

3.1.3. Students should present on a poster their suggestions for each section of the disco along with a model disco in which certain materials are used for acoustic insulation.

Equipment

In activity 3.1.1, students are provided with technical sheets of each material (see Annex 1) to allow them to observe the internal structure of each tested material. The students are also asked to describe the materials, so they should have some samples of the materials to manipulate and observe them.

In activity 3.1.3, students should be provided with some of the materials that they will ask for in order to construct their model disco.

B: EVALUATION TASKS

B: EVALUATION TASKS

A broad range of strategies and instruments has been proposed to assess students' learning outcomes.

The assessment tasks include:

- Certain activities selected from the students' activity sequence (formative assessment).
- A final test that assesses most of the learning targets which were intended for this sequence (summative assessment).

Formative assessment

Some activities of the module have been designed to make students express their **previous ideas** on certain concepts or phenomena. Therefore, teachers can use them as a way of exploring students' starting point. For instance:

1.1.1: It deals with sound-material interaction (sound reflection, sound transmission, sound diffraction, and sound attenuation)

1.2.1: It deals with sound reflection on different surfaces and direction of propagation of reflected sound.

1.2.6: It deals with the phenomenon of reverberation.

1.3.1: It deals with sound transmission and sound attenuation.

2.1.1: It deals with physical properties of sound reflectors and sound absorbers.

2.1.2: It deals with the relationship between acoustic behaviour of materials and their physical properties and internal structure.

Some activities of the module have been designed to promote that students elaborate their **conclusions** after a set of activities. Therefore, teachers can use them as a way of exploring students' learning progress along the module. For instance:

1.2.4: It deals with reflection.

1.3.6: It deals with sound attenuation and acoustic behaviour of materials. This activity consists of a self-assessment activity followed by a peer-assessment.

2.1.10: It deals with the conceptual model which relates physical properties of materials to acoustic behaviour.

2.2.6: It deals with the conceptual model which relates internal structure of materials to acoustic behaviour.

3.1.3: It was conceived as an application project. Students are asked to use the previous conceptual models to explore the acoustic behaviour of some materials and decide how to use them for constructing a model disco. This project also involves assessing some procedural skills (such as, designing process with specific purposes or using experimental data to interpret evidence and suggest applications).

Summative assessment

The established partnership designed a final test, as an instrument that allows teachers (and researchers too) to assess most of the students' learning outcomes that were stated when designing the sequence. Questions 1-3 could be also used in a pre-test at the beginning of the activity sequence and questions 4-6 in a pre-test before Unit 2. The questions are shown below:

QUESTION 1

The aim of the following question is to assess students' understanding about the nature of sound as a mechanical wave that needs matter to propagate through it.

Is it possible for the sound produced from the explosions on the surface of the sun to arrive on earth? Explain your answer.

Categorization of responses:

	CATEGORY OF STUDENT'S RESPONSE	TYPICAL ANSWER
1	No answer.	
2	Distance and/or velocity are mentioned indicating understanding that sound is transmitted.	*"Sound cannot arrive at Earth because the distance from the Sun is too long."*
3	Identify the need for material means for the propagation of sound without explaining why.	*"I believe no because there is empty space between Earth and Sun."*
4	Identify the need for material means for the propagation of sound reasoning why.	*"Sound is a mechanic wave. That is the molecules of the mean which it propagates through are oscillating. So it cannot arrive to Earth because there is empty space between Earth and Sun."*

QUESTION 2

The next exercise examines students' understanding on sound phenomena like reflection and reverberation.

The images show two different perspectives of the same office. Two persons work there being separated by a screen. The problem they have is that despite of the screen, they disturb each other when the talk on the phone. They want to know how sound emitted by the person on the left reaches the person on the right.

(a) *Represent the path that sound waves travel from one person to the other, using both the wavefront and "sound ray" representations. Mention one of the phenomena which make possible that these two people can hear to each other. Describe this phenomenon.*

(b) *How this office would be if there was reverberation? What would the employees hear?*

(c) *An expert on acoustics tells them that a possible solution to avoid hearing to much sound is placing sound diffusers and sound absorbers. How do you account for the fact that these materials can be a solution?*

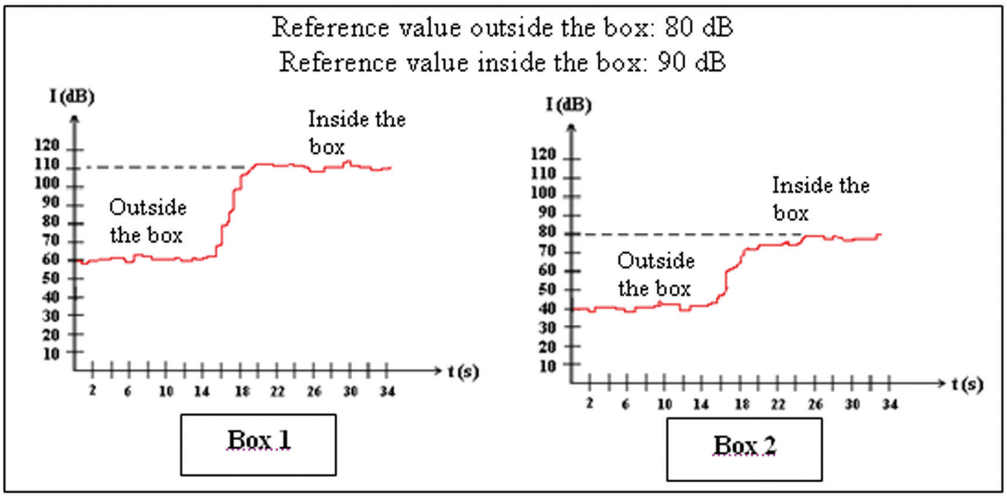
Categorization of responses:

	CATEGORY OF STUDENT'S RESPONSE	TYPICAL ANSWER
1	No answer.	
2	Sound is transmitted everywhere despite any hitch.	*"Sound is a wave and travels everywhere."*
3	Propagation over the wall without explanation.	*"Sound passes through the gap over the wall."*
4	Propagation through the wall.	*"The material of the wall is not a sound insulator so sound passes through it."*
5	Reflection on the ceiling.	*"The ceiling reflects the sound and it arrives at the other person."*
6	Reflection on the ceiling and propagation through the wall.	*"Sound is reaching the other office because is reflected on the ceiling and propagates through the wall."*

QUESTION 3

The following exercise focuses on the ability of students to interpret data from graphic representation.

A group of students have performed the same experiment that you made during the module. They have used two boxes, each of them covered inside with a different material, to cover the sound source, and have measured the sound intensity level inside the box and outside the box. Look at their results and interpret them, answering the following questions.



(a) *What box attenuates sound better? How much sound does each box attenuate?*

(b) *Which of the two boxes is covered inside with a sound absorber? Which box is covered inside with a sound reflector? Justify your answer.*

(c) *When these students measured the sound intensity level outside the box, they put the sound level meter at a certain distance from the box. What would happen if they measured the sound intensity level at a bigger distance?*

Categorization of responses:

	CATEGORY OF STUDENT'S RESPONSE	TYPICAL ANSWER
1	No answer.	
2	Random or without explanation answer.	*"The 1st is sound-reflector and the 2nd is sound-absorber."*
3	The sound-reflecting material increases the intensity of sound inside the box while the sound-absorbing material reduces the intensity of sound (no explanation).	*"The 1st is sound-reflector because sound is louder inside than the initial sound while the 2nd is sound-absorber because the sound is lower inside."*
4	The sound-reflecting material increases the intensity of sound inside the box because of reverberation while the sound-absorbing material reduces the intensity of sound because of absorption.	*"The 1st is sound-reflector because the measurement inside is higher than the initial, because of reverberation. The 2nd is sound-absorber because the measurement is lower inside, so sound is absorbed."*

QUESTION 4

The aim of the following activities is to examine students' ability to relate physical properties of materials with their acoustical properties.

The company DSR is working in a project of soundproofing and acoustic conditioning of the local multi-purpose building of the drawing.

In the ground floor there is a library and a conference room (equipped with a good loudspeakers system) and in the first floor there is a dance room and a playing room for children. The entrance to the building is located at the library.

(a) Which acoustic conditions do you think the library should have to allow addressing an ordinary activity inside?

(b) In the previous image there are some points that could be problematic regarding noise inside the library. These are marked with a red circle. Explain why each of those points is problematic regarding the soundproofing (1- Entrance from the street, 2- Structure that separates the ground and the first floor, 3- Dividing wall between the library and the conference room).

(c) To solve these problems, the company DSR proposes using different materials so that the sound intensity level inside the library is adequate to allow reading and studying.
The following table includes the data and description of the properties of such materials:

MATERIAL	DENSITY (g/cc)	RIGIDITY	POROSITY
A	0,02	Rigid	No
B	0,07	Flexible	Yes
C	3,00	Rigid	No

According to their properties, which of these three materials do you think that would be appropriate for the marked surfaces?
Which of these materials would be the best sound absorber?
Justify your answer.

Categorization of responses:

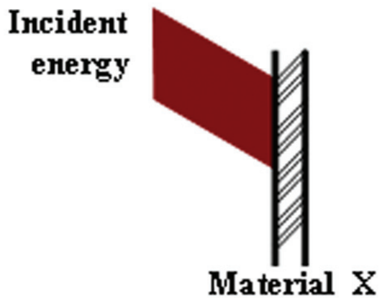
Categorization of responses:

	CATEGORY OF STUDENT'S RESPONSE	TYPICAL ANSWER
1	No answer.	
2	Identify the problems in some of the points but do not relate them with sound insulation or with the acoustic condition of a room.	*" The problem is that the conference room is under the disco so they will have a difficulty to discuss. Also the playroom is over the library so people won't be able to study. The arrangement of the rooms should change."*
3	Identify the problems but relate them inappropriately with sound insulation or with the acoustic condition of a room, suggesting materials without reasoning.	*" I would use B in all rooms because is sound-absorbing and, as came out from our experiments, these material are the best for attenuating sound."*
4	Identify the problems but relate them only with sound insulation, suggesting materials and reasoning their choices.	*"At all the 4 points the problem is that sound is transmitted through the walls. The appropriate material should be placed. At points 1, 3 and 4 material B, which is sound-absorbing, should be placed in order to attenuate the transmitted sound. At point 2, material C which is sound-reflecting should be placed."*
5	Identify the problems and relate them with sound insulation or with the acoustic condition of a room. Suggest the correct combination of materials in order to achieve the proper acoustic conditions in every room.	*"At point 1 the problem is the sound coming from the road into the library. Material C should be placed to the outer side of the wall and B on the inner. At point 2 the problem is the noise from playroom transmitted into the library so material B should be used. At point 3 the problem is the reflection of sound in the conference room and at point 4 the noise coming from disco. Material C should be used at the side of the disco and b at the side of the conference room."*

QUESTION 5

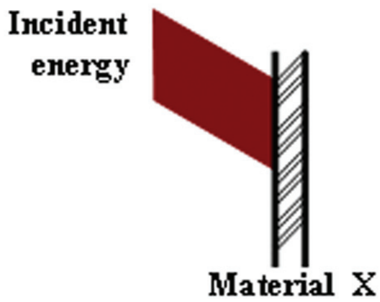
The following question assesses students' ability to describe and represent what happens to sound in terms of energy after its incidence on various materials.

(a) *Represent the energy of the reflected sound wave, the absorbed energy and the energy of the transmitted sound wave in a material X which attenuates very little sound, **(bad sound absorber and bad sound reflector)**.*



If you were outside the disco and the walls were made of this material X, what would you hear? What level of sound intensity could be measured?

(b) *Represent the energy of the reflected sound wave, the absorbed energy and the energy of the transmitted sound wave in a material X which **is very good sound absorber**.*



If you were outside the disco and the walls were made of this material X, what would you hear? What level of sound intensity could be measured?

Categorization of responses:

	CATEGORY OF STUDENT'S RESPONSE		TYPICAL ANSWER
	SOUND-ABSORBING	SOUND-REFLECTING	
1	A small part of the energy is reflected / transmitted and the rest is absorbed.	A small part of the energy is absorbed / transmitted and the rest is reflected.	*"The sound-absorbing material absorbs a large part of sound energy, but some sound is reflected or transmitted through while the sound-reflecting material reflects the most of the energy"*
2	A part of the energy is transmitted and the rest is absorbed.	A small part of the energy is transmitted and the rest is reflected.	*"The sound-absorbing material absorbs the sound so only a small part is transmitted through, while the sound-reflecting material."*
3	Absorbs all the energy.	Reflects all the energy	*"Sound is absorbed from the sound-absorbing material ... sound rebounds when meets sound-reflecting materiall."*
4	Lets all the energy to pass through.		*"Sound passes through sound-absorbing material."*

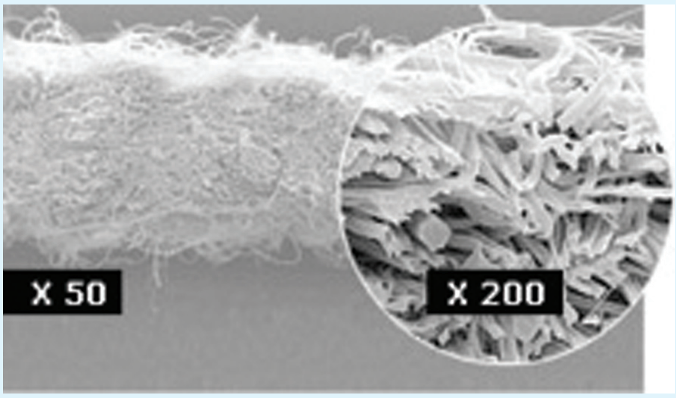
QUESTION 6

This exercise examines students' ability to interpret given data and to explain how the physical properties of the materials affect their acoustical properties using the corresponding conceptual model.

A building company has developed a new generation of sound absorbers. The advertisement of this company says:

Absorbson is a textile that offers very good sound absorbing properties. Its structure, made of fibres or microfilaments is very compact. It is very enduring. This material is permeable to air and has a density of 0,2 g/cc.

Up to now, the materials used were very thick and heavy, but the structure of microfilaments of Absorson guarantees an efficient sound absorption with minimal thickness (approximately 0,5 mm) and a density 10 or 30 times lower. In addition, it is very flexible and it can be used in many different fields such as building or car industry. For instance, the installation of this material in a big restaurant reduced the sound intensity level up to 10 dB.



(a) *Identify in the text only the physical properties that influence the acoustic behaviour of the material and make it a good sound absorber.*

(b) *How would you explain the fact that these properties make this material a good sound absorber? Reason your answer in terms of the internal structure of this material, and so, in terms of the particles that form the material.*

Categorization of responses:

	CATEGORY OF STUDENT'S RESPONSE	TYPICAL ANSWER
1	No answer.	
2	Identify some of the properties of the material but give wrong explanation about how these properties affect its acoustic properties.	*"It is sound-absorbing because fibers are very close to each other."*
3	Identify some of the properties of the material and give explanation about how these properties affect its acoustic properties but without using conceptual models for each property.	*"The material consists of fibers and strands which absorb the sound. Its density (0,2gr/cm3) and its thickness (0.5cm)should be larger ."*
4	Identify some of the properties of the material and give explanation about how these properties affect its acoustic properties using conceptual models for each property.	*"The low density of the material does not allow sound to be easily transmitted from particle to particle. Moreover the rough surface of the fibers causes multiple reflections trapping the sound inside the material."*

MATERIALS
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