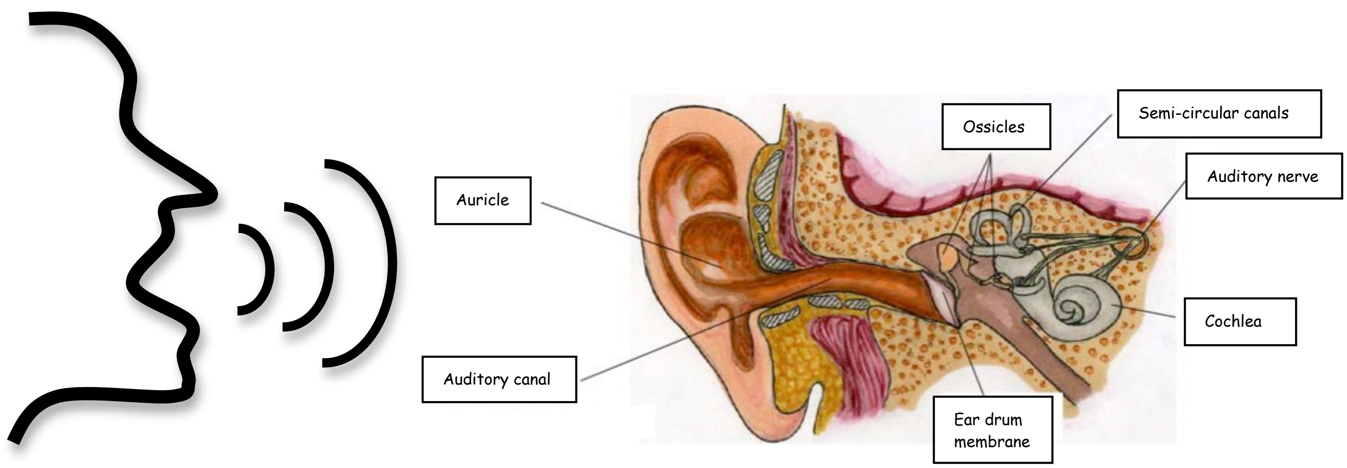
centre de
développement
pédagogique
pour la formation générale
en science et technologie

Working Document

"SOUNDS AND HEARING" TEACHING SEQUENCE

Guide for teaching and technical personnel



November 2014

Table of Contents

Notes:

- Linguistic review: February 2015
- In this document, the masculine is used to make the text more readable.

Introduction of the teaching sequence

This teaching sequence was developed to help understand the phenomena at issue when sounds are perceived by the human ear. The models presented in this guide allow teachers for secondary three (ST or AST) to make the function of the inner ear, specifically the function of the cochlea, more concrete. This sequence also allows the essential role of the basilar membrane in directing sounds with different frequencies to the corresponding cilia cells to be demonstrated. The sequence is spread over about two periods. It calls upon the scientific investigation process.

The sequence is divided into four parts. To begin, the student is presented with a model simulating the propagation of a sound using marbles. Next, a second model is presented, illustrating the vibration of a membrane similar to an ear drum. Then, the student activates and discovers the formation of sounds by wine glasses through a scientific investigation process. Finally, the student explores the phenomenon of resonance, using the model of the basilar membrane.

Overview of the teaching sequence

2nd cycle of secondary school (Secondary 3) ST or AST

Time required in class: 2 - 75 minute periods

Pedagogical intentions

- Understand the function of the human ear
- Help understand the phenomena at issue when sounds are perceived by the human ear (cochlea, basilar membrane and stereocilia or hair cells)
- Allow the student to acquire knowledge using the scientific investigation process.

Suggested context

The student experimentally discovers the concept of frequency of a sound wave using wine glasses. In addition, the presentation of three models allows the following phenomena to be illustrated:

- The propagation of a sound wave
- The function of the ear drum
- The function of the inner ear (cochlea, basilar membrane, stereocilia)

Broad area of learning

Health and Well-being
Focus of development: awareness of the consequences for health and well-being of his/her personal choices
The student becomes aware of the complexity and fragility of the inner ear. This leads him to think about sound levels that should not be exceeded (e.g. listening to music using earphones).

http://www.edp-audio.fr/actualites/recherche/4263-la-demyelinisation-du-nerf-auditif-en-cause-dans-la-perte-d-audition

(In French)

Targeted disciplinary competency:

- Seeks answers or solutions to scientific or technological problems (Scientific investigation process)
- Communicates in the languages used in science and technology

Statements from the Progression of Learning

Material World (D. Fluids)

↻ a Pressure

Material World (E. Waves)

✶ a.i Defines the frequency of a wave as the number of cycles per second (Hz)

✶ a.ii Associates the frequency of a sound wave with the pitch of the sound (e.g. a low-frequency wave produces a low-pitched sound)

✶ b.i Defines wavelength as the distance between two identical points on a wave at a given time (e.g. distance between crests)

✶ c.i Defines the amplitude of a sound wave as the loudness of the sound

Living Things: for ST (D. Systems) for AST (C. Systems) → Relationships

↻ b.i - Explains the role of the peripheral nervous system (transportation of nerve impulses from the senses to the brain and from the brain to the muscles)

↻ c.ii - Names the main parts of the ear involved in hearing (auditory canal, ear drum, ossicles, cochlea, semicircular canals)
- Describes the function of the main parts of the ear involved in hearing

Technological World (B. Mechanical engineering)

↻ 1.b.i Explains the effects of a force in a technical object (change in the motion of an object) (e.g.: model of the ear drum, model of the basilar membrane)

↻ 3.k.i Identifies motion transformation systems in technical objects (e.g.: model of the basilar membrane)

+ 3.l Function, components and use of motion transformation systems (e.g.: model of the basilar membrane)

Techniques (B. Science)

✶ d.vi Uses measuring instruments appropriately (e.g. frequency counter)

Legend
✶ : Element worked on in the LES
↻ : Element studied previously
+: If desired

Evaluation of learning

The evaluation criteria as well as elements fostering understanding of the criteria are integrated into the student notebook for the scientific investigative process. You will find them framed on the pages involved.

Suggested plan for the teaching sequence

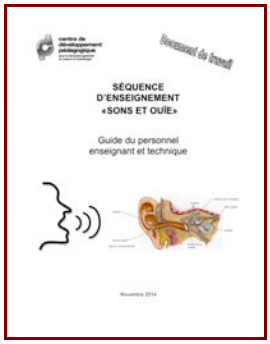
Class (75 min.)	**Description of each class**	**Documents**
Pre-requisites	• Pressure (relating to sound waves, since it is a compression wave) • Parts of the ear involved in hearing • Peripheral nervous system (auditory nerve)	
Class 1	**Model of the propagation of a sound (sound wave)** • Allows the illustration of sound propagation using marbles. Various phenomena are broached here: 1. The propagation of a sound wave between two points 2. The absorption of a sound wave 3. The energy transported by a sound wave 4. The reflection of a sound wave (the formation of an echo) 5. The speed of a sound wave	• To read: Theoretical capsule about sound propagation • Video presenting the model of marbles regarding sound propagation
	Model illustrating the ear drum using a laser • Allows the illustration of the vibration of a membrane similar to the ear drum when it is hit by sound waves. The reflection of a laser beam on a mirror attached to the membrane allows the phenomenon to be amplified.	• Document making the construction of the model of the ear drum easier.
	Scientific Investigation Process • Discover how to adjust the frequency of the resonance of a wine glass. (Allows the frequency of a sound wave to be associated to the pitch of the sound produced.) • Possibility of using the poster about the scientific investigative process to accompany the student during his experiment.	• Video introduction (suggestion: Michel Lauzière's video on the CDP web site.) • Student's notebook during the "Musical glasses" scientific investigation.
Class 2	**Large group discussion** • Frequency vs. the number of cycles per second • Frequency vs. the pitch of a sound • Wave length and amplitude • Resonance between two glasses tuned to the same note	• Based on material specific to each field
	Model of the basilar membrane of the cochlea • Allows the sound detection mechanism for various sounds of different tones by the basilar membrane to be made more concrete.	• To read: Theoretical capsule on the basilar membrane • Video of the basilar membrane model in action • Document making the fabrication of the basilar membrane model easier

Documents related to the teaching sequence

Here are the documents related to this teaching sequence:

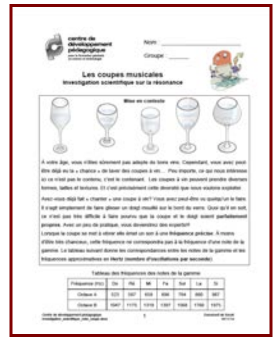
This guide on the "Sound and Hearing" teaching sequence

- Available in pdf format on the CDP web site
- Available in doc format on request



"Musical Glasses" scientific investigation

- Available in pdf format on the CDP web site
- Available in doc format on request



Theoretical capsule about the propagation of a sound

- Available in pdf format on the CDP web site
- Available in doc format on request

Video about the propagation of a sound (marbles model)

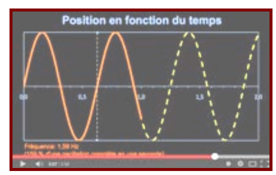
Produced by the CDP and available on YouTube:
https://www.youtube.com/watch?v=Pf6GBr6Kik8

Theoretical capsule about the model of the basilar membrane of the cochlea

- Available in pdf format on the CDP web site
- Available in doc format on request

Video about the model of the basilar membrane of the cochlea

Produced by the CDP and available on YouTube:
https://www.youtube.com/watch?v=7Jijp5GKLL4



Video about the model of the laser ear drum

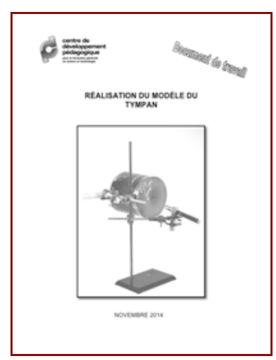
Produced by the CDP and available on YouTube:
https://www.youtube.com/watch?v=s6yW7Vz9aYk

Steps for producing the model of the basilar membrane of the cochlea

- Available in pdf format on the CDP web site
- Available in doc format on request

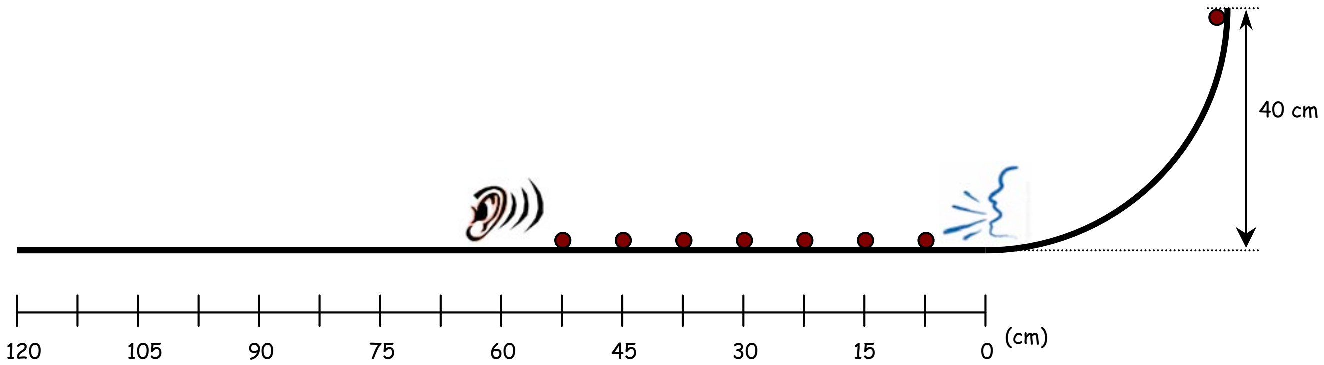
Production of the model of the ear drum

- Available in pdf format on the CDP web site
- Available in doc format on request



Propagation of a sound (marbles model)

This model allows the illustration of various phenomena related to sound propagation using marbles. A video presenting five demonstrations is available on YouTube.



Here are the 5 themes broached:

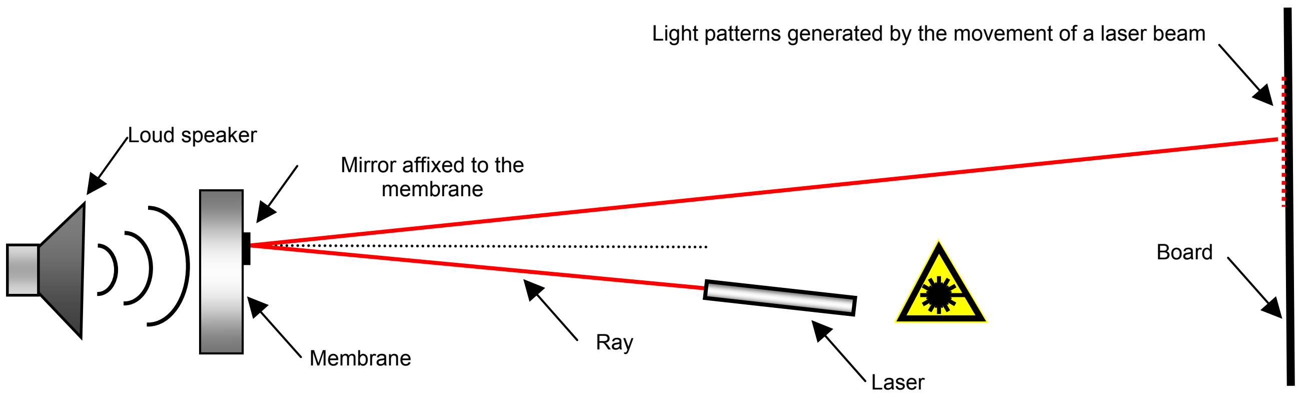
1. The propagation of a sound wave between two points
2. The absorption of a sound wave
3. The energy transported by a sound wave
4. The reflection of a sound wave (the formation of an echo)
5. The speed of a sound wave

For more information about this model, consult these two documents:

- Theoretical capsule about the propagation of a sound
- Video accompanying the theoretical capsule about the propagation of a sound (marbles model) (https://www.youtube.com/watch?v=Pf6GBr6Kik8)

Sound and vibration (model of the laser ear drum)

This model allows a membrane similar to the ear drum to be visualised when it is hit by sound waves. The reflection of a laser beam on a mirror attached to the membrane allows the phenomenon to be amplified.



Useful document

Document making the construction of the model of the ear drum easier.

Pertinent link

CDP video on youTube: Model of the laser ear drum
https://www.youtube.com/watch?v=s6yW7Vz9aYk

"Musical Glasses" Scientific investigative process

At a glance

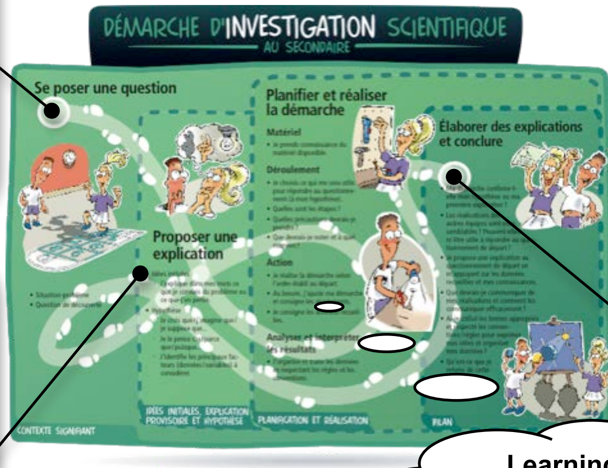
This activity was designed to illustrate a problem resolution process calling upon a scientific investigation process[1]. The proposed task allows teachers to explore teaching strategies to be put into place with 2nd cycle high school students.

Complex task proposed to students

Set the frequency of the sound generated by a glass so it corresponds to a note on the scale.

Erroneous concept targeted by the teaching sequence

Presuming that the stereocilia of the cochlea are responsible for discriminating sounds of different frequencies.



Main targeted learning

- Use the scientific investigation process
- Discover the relationship between the frequency of a sound wave and the pitch of the sound produced.
- Be initiated to the phenomenon of resonance, which is at the base of human hearing.

Learning activity

Use of the "Frequency Analyzer" application

Introduction to the process

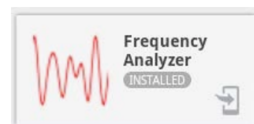
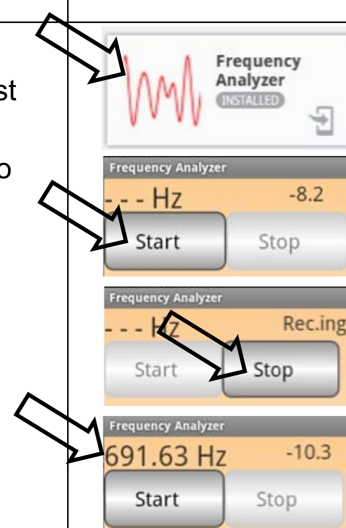
The process we propose is first and foremost a problem resolution or discovery process. This is the reason we give the student a notebook, rather than a booklet reproducing a complete laboratory report. This approach allows the process to come closer to what actually happens daily in research laboratories. It also brings a little spontaneity and passion to the experimental process.

Pedagogical intentions

- Allows the student to discover the relationship between the frequency of a sound wave the pitch of the sound produced.
- Allows the student to better understand the phenomenon of resonance, which is at the base of human hearing.

Notes for animation	Documents
• For this experiment to work, the glass and the finger used to make it sing must be perfectly clean. If this is not the case, the finger will simply slide without adhering to the edge. We must generate a "clean sound". A sort of squeaking similar to the squeal of a tire on pavement.	• "Musical glasses" investigative process notebook on

[1] The poster for this process is available on the CDP website at the following address: http://www2.cslaval.qc.ca/cdp/UserFiles/File/downloads/affiches_sec/invest_ang_sec_8x11.pdf

• The selected glass need not be of excellent quality, a dollar store glass will do just fine. It cannot have too thick a wall however (less than 2 mm). • We suggest you form teams of four students. This should limit the number of teams to eight per class. This way, the sounds generated by the other teams should not interfere with measurement taking. • It would be interesting to supply the same model of glass to more than one team. This way, an interesting demonstration could be made following the scientific investigation (see next page).	resonance, p. 1
• The student must not touch the equipment before formulating his hypothesis (otherwise, he will seek the "correct answer"). • The formulation of the hypothesis may be presented more or less formally, since the aim is informative. • The teacher could feed the thought process during the formulation of the hypothesis by invoking the use of various musical instruments.	• "Musical glasses" investigative process notebook on resonance, p. 2
• The measurement of the frequency of the sound is carried out by an "Android" application called "Frequency Analyzer". First, the application carries out a sampling of the sounds present around the device. Then, it purifies the sample, retaining only the sound with the greatest amplitude. Finally, the application determines the frequency of this sound and displays the frequency and a graph of the amplitude of the sound relative to time.	
This application is very easy to use. Here are the steps to follow: 1. Start the application by touching the icon (the small image the first arrow points to). 2. If possible, reduce the ambient sounds to a minimum. Namely, do not speak, make noise with objects, etc. 3. Bring the glass as close as possible to the device's microphone. 4. Make the glass sing with one finger. 5. Start the sampling by pressing "Start". 6. Continue making the glass sing for about 5 seconds. 7. Stop the sampling process by pressing "Stop". 8. Stop making the glass sing. 9. Wait for the display of the frequency in hertz (see the last arrow).	
• In the event that no "Android" tablets or telephones are available, it is possible to use the "BlueStacks" program to simulate an "Android" environment. This application works on PC or Mac and is free online. To be able to download applications, you will need to pair "BlueStacks" to a "Google Play Store" account.	BlueStacks

What to take away from this process?

1. High sounds are generated by a higher frequency than low sounds.
2. Under certain conditions, the glass resonates at a given frequency.

Evaluation

The evaluation criteria as well as elements fostering understanding of the criteria are presented in the framed sections. The greyed out elements cannot be evaluated.

Large group discussion

- Frequency vs. the number of cycles per second
- Frequency vs. the pitch of a sound (low and high)
- Wave length in time (the expression "period" is not in the program)
- Amplitude of a wave

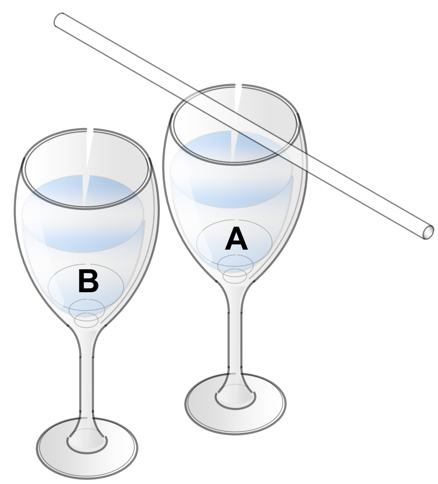
Note: The following demonstration would be pertinent at this time.

Pertinent demonstration about the resonance of two glasses

This demonstration could be carried out by the students themselves. To do so, you need to pair two teams with the same model of glass, tuned to the same note on the scale.
If the glasses generate the same note, they should interrelate. In other words, the first glass that is made to sing should enter into resonance with the second and make it vibrate.

Here is what to do:

1. Place the two glasses (tuned to the same note) as close as possible to one another without touching.
2. Put a plastic drinking straw on glass "A" (see drawing).
3. Make glass "B" sing the same way as in the previous scientific investigation.
4. Observe the straw...



Interesting links

A glass entering into resonance and breaking:
https://www.youtube.com/watch?v=17tqXgvCN0E
https://www.youtube.com/watch?v=BE827gwnnk4

Resonance and hearing (model of the basilar membrane)

This model enables the relationship to be made between the phenomenon of resonance and the sound detection mechanism of different tonalities by the inner ear. The stereocilia of the cochlea transform the sound waves into nerve impulses, but are not directly responsible for the differentiation of sounds of different frequencies. Indeed to affirm that "the difference in the length of the hairs allows low sounds to be distinguished from high sounds" is an erroneous concept. Rather, it is the basilar membrane, by its morphology, that effects this distinction. The model enables the phenomenon of resonance, which is at the base of the sound perception mechanism by the inner ear, to be demonstrated.

Among other things, the model answers these questions:

- How can the inner ear distinguish between low and high sounds?
- Why do the stereocilia not vibrate all at once?
- What role do the stereocilia play?
- What role does the basilar membrane play?
- How does a guitar string produce the desired sound?

For more information about this model, consult these three documents:

- Theoretical capsule about the model of the basilar membrane of the cochlea
- Video accompanying the theoretical capsule about the model of the basilar membrane of the cochlea (https://www.youtube.com/watch?v=7Jijp5GKLL4)
- Steps for producing the model of the basilar membrane of the cochlea