FONDATION La main à la pâte
POUR L'ÉDUCATION À LA SCIENCE

Pure or complex sound
Scientific challenge

Physics / Sound

Middle School / High School

Duration of the challenge	30 minutes
Material	Smartphone or tablet with Fizziq application
Phenomena or concepts approached	Its pure and complex
Glossary	Sound, frequency, harmonic, music, timbre of a sound, Music education

Student Challenge

« Why does an untrained singer say that his "i's" are less rich than his "o's" when he sings vowels with the same intensity?

Try to find an explanation, then practice enriching the vowel "i" as much as possible when you sing it. »

Once the challenge has been launched, you can give the students about ten minutes to explore the app (individually or in groups, depending on the number of phones or tablets available) and choose the sensor they feel is appropriate to use. Depending on whether or not the "low or high-pitched sound" challenge has been done before, you can guide the students towards measuring the sound spectrum, by recording the spectrum of your voice for example.

You can also rephrase the challenge in a more "guided" form by adding the following question: "What is the difference between the sound spectra of two different vowels? ».

Possible prerequisites

The duration of this challenge will depend on the students' mastery of the application.

It seems useful to have previously completed one of the other proposed challenges: "sound volume" or "low or high-pitched sound" in order to have a better overall understanding of the FizziQ application and the phenomenon studied here (and not to add the conceptual difficulty to the technical difficulty of a first introduction).

Aids

These aids are intended for teachers or students.
You can consider different ways of using it:

- Read them out to the pupils (possibly rephrasing them).
- Print them, cut them out and distribute them as required (e.g. by group).

Links to some useful sites and instructions

- https://www.fondation-lamap.org/en/fizziq: Here you will find the various teaching documents available in relation to the use of the FizziQ application, including challenges for pupils that you can adapt to suit your objectives and your classes.

- https://en.fizziq.org: You will find protocols there, so you can get inspiration to create your own protocols.

- https://www.youtube.com/channel/UClEd0gCCnvvN4-oT037YV8A: You will find videos of less than 2 min each allowing a quick introduction to the application.

Below you will find information about the measurements that can be carried out in this challenge with the "microphone" sensor of tablets or telephones. The level of explanation you will find here is more suitable for adults who want to understand how the sensors work. For pupils, the choice may be to let them explore the different tools and measuring devices if you have the time. How quickly they can get to grips with it will depend on how familiar they are with the application (if Fizziq has already been used at another time in class).

Tool: Frequency spectrum (Microphone-spectrum)

Unlike the frequency meter, which gives only the fundamental frequency of a sound, the sound spectrum details all the frequencies that make it up. This tool thus makes it possible to precisely describe the characteristics of a sound.
The greater the number of frequencies that make up the note, the richer the sound is said to be. This contributes to the "timbre" of an instrument.

Remark

Frequencies are expressed in hertz, denoted Hz. Amplitude is expressed as a percentage of the maximum amplitude that the microphone is capable of detecting.

Accuracy

The data is updated every 0.5 seconds.
Displayed frequencies are limited between 50Hz and 5500Hz due to the sampling frequency of measurements with one display (20 Hz width histogram type).

Realization of the challenge

Before answering the challenge....

Pupils can be asked to find out where the microphone is that will be used to take the measurements and find a simple way to check that it is in the intended location (see the "noise level" challenge). It is certainly preferable to have completed the "sound level" and "bass or treble" challenges before this challenge.
This experiment can possibly be tested on a vowel (of your choice or different vowels for different groups of students...) at home before arriving in class. This will then allow you to see if the use of the application has been well understood.

Points of vigilance:

- Check that the volume of the sounds on the phone is turned on (it is the volume of the "media" that should be at maximum or fairly audible).
- Unlike the use of the frequency meter, which continuously measures and displays the value of the fundamental frequency (or the harmonic of higher intensity depending on the version of the application), the audio spectrum takes a single measurement of the sound at the moment the user presses "REC", so the vowel must be sung and the spectrum recorded during this "singing". The advantage of the application is that the students can repeat the experiments, the notes, the vowels, record different students... very quickly. Remind them that they can put titles to their recordings to remember "which vowel was sung" and "by which pupils" for example....

Working with microphones connected to smartphones or tablets can be considered: earphone microphones, for example, can improve the accuracy of measurements and avoid the problems associated with multiple measurements in the room.

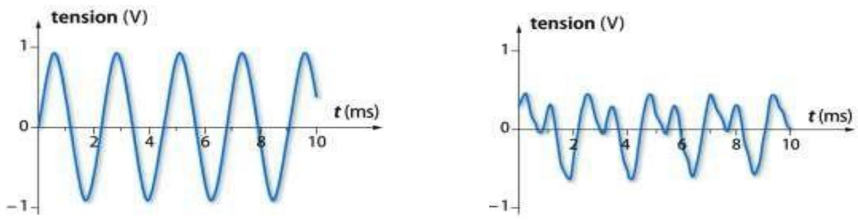
Use of the audio spectrum

Advantage

Very simple to implement.

Possible reminder(s)

A sound can be pure or complex.
A microphone allows a sound wave to be faithfully transformed into an electrical signal and to give a temporal representation of it thanks to a computerised system.

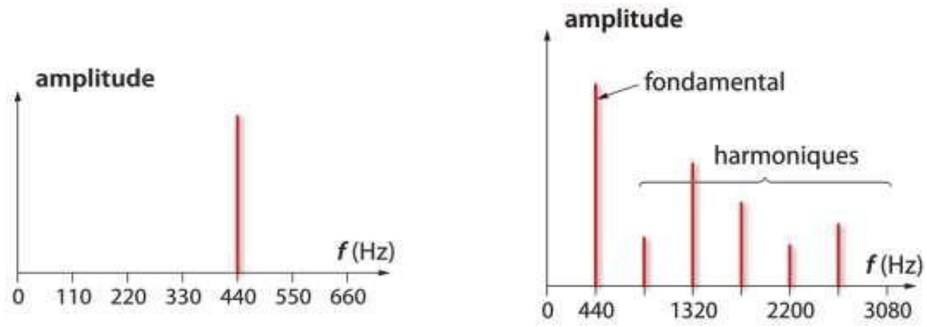


signal obtained with the A3 of a tuning fork ***signal obtained with the A3 of a piano***

The sound produced by the tuning fork is pure because the corresponding electrical signal is rigorously sinusoidal; the sound produced by the piano is complex (like most sounds).

In order to understand the constitution of a complex sound, its spectral analysis can be carried out (representation of the amplitude as a function of the frequency, etc.).

The sound spectrum obtained with the FizziQ application details all the frequencies that make up a sound. This tool therefore makes it possible to describe the perceived sound more precisely.



spectrum of the A3 of a tuning fork ***spectrum of the A3 of a piano***

It can be seen that the spectrum of a pure sound contains only one peak, whereas the spectrum of a complex sound contains several peaks (the fundamental and harmonics).

In 1822, Joseph Fourier showed that any periodic signal of frequency f1 (this is the frequency of the fundamental) can be decomposed into a sum of sinusoidal signals of frequency fn (these are the frequencies of the "harmonics") multiples of f1: $f_n = n \times f_1$

Physiologically, a sound is therefore characterised by:

- its sound level, linked to the amplitude of the wave ;
- its pitch (bass-treble) linked to the frequency of the wave (that of the fundamental for a complex sound);
- and its timbre, linked to the complexity of the wave (richness of harmonics).

Guidance for students as required:

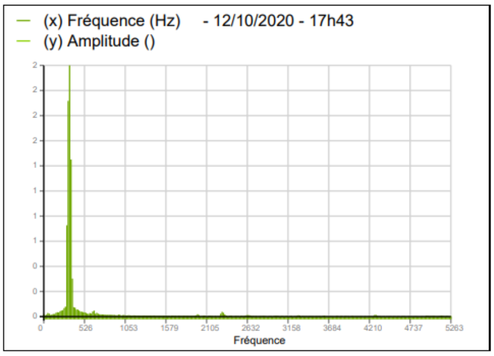
This "guidance" is not meant to be distributed to the students but rather to offer you leads when the students are stuck (which is unlikely because they are very comfortable with the application) or to help them observe the spectra obtained precisely in order to draw conclusions.

- In the "Instruments" menu, select the Audio Spectrum.

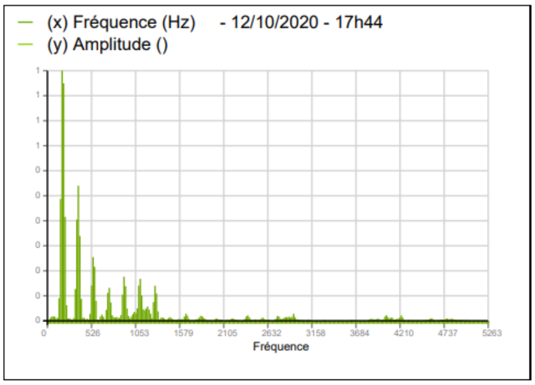
- Sing the vowel -i- for several seconds. Keep your voice steady so that the sound is "stable". While you sing, record the spectrum.
- Analyze the graph. What do you find? How many peaks appear on the graph? Can you find a mathematical relationship between the frequencies of the peaks?
- The lowest frequency peak is called the fundamental frequency. The other peaks are the harmonics. What is the fundamental frequency and how many harmonics do you find?
- Now sing the vowel -o- and record the sound spectrum. What do you find? How many harmonics does the vowel -o- consist of? What is the difference with the -i-?
- Ask a classmate to experiment and sing vowels, do you find the same result?
- Repeat the experience with the vowels a-u- and -e-.

Examples of measures

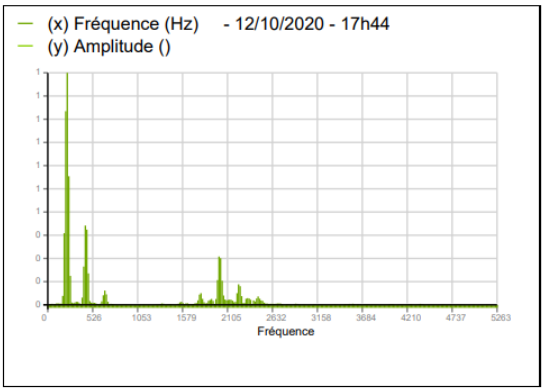
son voyelles



Example: The sung i is often an almost pure sound (or very little complex: very few overtones of significant amplitude), it can nevertheless depend on the people because different people have different "timbres" of voices. Singers also try to enrich the spectrum of their sung vowels in order to have a richer and more "pleasant" timbre for the listeners...



son a



son u

When you change the vowel (a, u, o, ...) the number of harmonics changes: the greater the number of harmonics, the richer the sound.

Remark:

Students with voices of varying pitch will surely notice that the richness of the vowel sung is also related to the "pitch" of the sound. You can then encourage them to repeat the experience by changing the tessitura (forcing them to sing the same vowels lower or higher).

Remind students to name each of their spectrums as they tend to multiply the measurements but do not always remember what they did!

To remember:

Sound propagates in material media: gases, liquids or solids.
Sound is a mechanical vibration of matter. The source of these vibrations (vocal cords, speaker membrane, guitar string, etc.) is a vibrating object.
The feeling of high or low pitch depends on the frequency of the sound, which is measured in hertz (Hz). This corresponds to the speed of the to-and-fro movement of the vibrating surface of the source.
An object that produces sound is called a **sound source**

Possible extensions:

- "The speech therapists explain that it is the cavities in your mouth that create more or less harmonics. Are you able to explain why some vowels produce more harmonics than others? "» . This type of questioning can be linked to the study of sound vibrations and therefore the superposition of vibrations. Indeed, the oral cavities can be compared to wind instruments. A documentary study can be carried out on the different wind instruments, with the pupils then having to explain in detail the origin of the creation of harmonics. These studies on the superimposition of mechanical waves can be approached succinctly in middle school but would seem more suitable for study in high school.
- "Is what is true for vowels also true for consonants? Try to sing the sound -grrrrr- of a dog growling. What do you notice? "This may allow the pupils to work on other types of sounds. Many harmonics appear on such complex sounds. This allows students who are comfortable with the concepts studied to perform other measures and to accentuate the mastery of the concepts studied.
- Possible extension with the Music Education teacher: "The analysis of the voice and the way sounds are pronounced is very useful for singers. Can you imagine applications of sound spectrum analysis to help them sing better? ». The link with music education can allow to set up a real project with the use of many tools and mobilization of many skills. By working on sounds the pupils can be led to record them and process them on computer + analysis of the sounds emitted + optimisation of the sounds to create the tool. Skills in music education, technology, mathematics and physics can be mobilised here.
- Based on the measurements and conclusions of these experiments, create a training tool for singers enabling them to perfect their singing technique by enriching, for example, the vowels sung (possible extension with the Music Education teacher for example).
- Documentary and practical work related to speech recognition methods. There are several possible areas of work in this theme, with teachers of French, technology, music education, etc.
- Possibility to perform a similar manipulation (spectral analysis) with different musical instruments and thus compare the timbre of the same note performed with the different instruments.

Official program

Music Education Middle School
Through the work of perception, that of listening to music, students develop their ability to perceive finer characteristics and more complex organisations of music; they learn to identify relationships, similarities and differences between several works. Manipulation of sound objects using appropriate digital tools.

Music Education Middle School
« Culture and artistic creation », « Science, technology and society », « Information, communication, citizenship »in relation to technology, physics-chemistry, mathematics, French, plastic arts. The impact of technology and digital technology on our relationship with art, sounds, music and information.

Physical Sciences Middle and High School
Sound signals: Notion of frequency: audible sounds, infrasounds and ultrasounds.
Crossover between teaching: In connection with music education, information and communication: sound signals (sound transmitters and receivers: microphones, etc.), light signals, electrical signals.

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