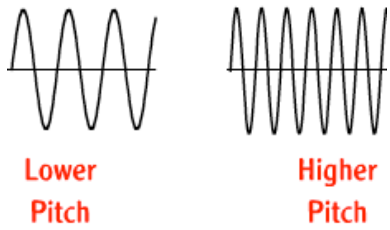
Practical Session n°3: MUSICAL ACOUSTICS

1- DOCUMENTARY PART ABOUT ACOUSTICS

Document 1: Pitch and Frequency

An important measurement of sound is the frequency. This is how fast the sound wave is oscillating. This is different than how fast the wave travels through the medium. Frequency is measured in hertz. The faster the sound wave oscillates the higher pitch it will have. For example, on a guitar a big heavy string will vibrate slowly and create a low sound or pitch. A thinner lighter string will vibrate faster and create a high sound or pitch.



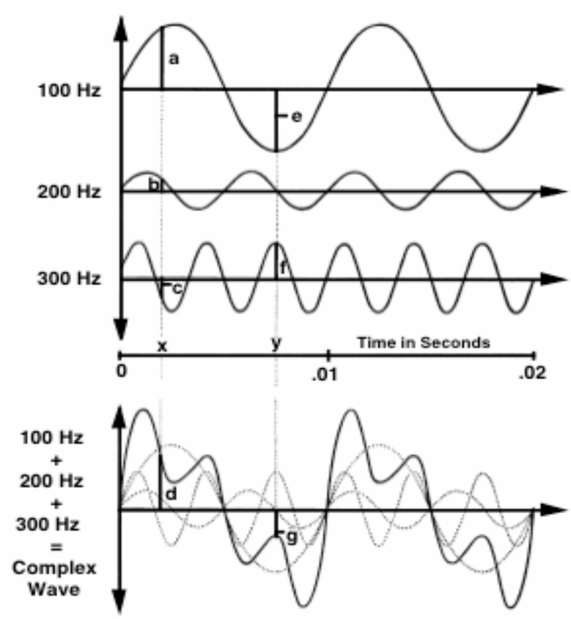
http://www.ducksters.com/science/sound102.php

Document 2: Timbre

Timbre is what makes a particular musical sound different from another, even when they have the same pitch and loudness. For instance, it is the difference between a guitar and a piano playing the same note at the same loudness. Experienced musicians are able to distinguish between different instruments based on their varied timbres, even if those instruments are playing notes at the same pitch and loudness.

http://en.wikipedia.org/wiki/Timbre

Document 3: Spectral analysis



In 1822, Joseph Fourier, a French mathematician, showed that any periodic signal of frequency f_1 can be decomposed into a sum of sinusoidal signals.

A musical tone of frequency f_1 is generally a **complex wave**. Therefore, it can be decomposed into a sum of sinusoidal signals.

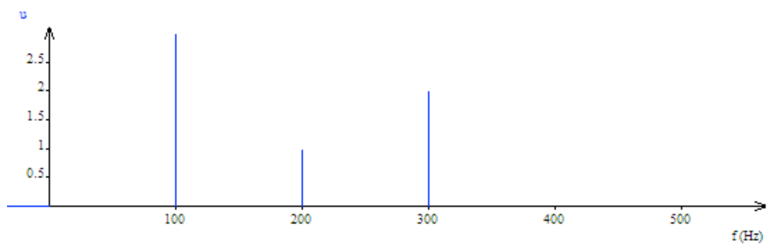
Its **fundamental** has a frequency f_1.

The frequencies of its **harmonics** are equal to $f_n = n \times f_1$ (n being an integer except 1).

For example, the opposite complex wave has for fundamental f_1 = 100 Hz and for harmonics f_2 = 200 Hz and f_3 = 300 Hz.

Image: http://hearinghealthmatters.org/waynesworld/2012/fourier-analysis-and-its-role-in-hearing-aids/

The **spectral analysis** of a sound is a graph representing the amplitude of its sinusoidal components as a function of frequency.



2- OBJECTIVES

The first objective is to illustrate the concepts of pitch, timbre, spectral analysis, fundamental and harmonics.
The second objective is to hear beats and check, by a spectral analysis, the validity of the beats method.

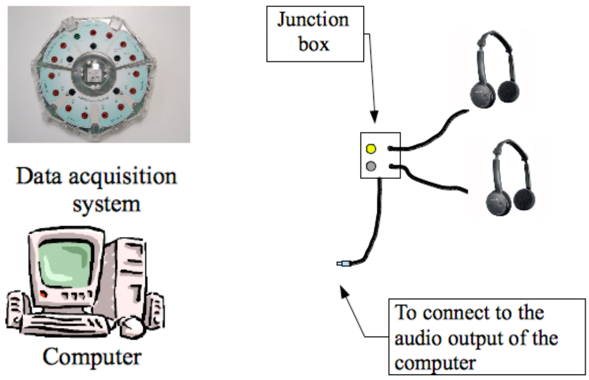
3- Equipment

Music files obtained by recording different musical notes emitted by several musical instruments are available.

File 1	Guitar, E_4 (string 2 - 5^{th} fret) (note 1) - it is **tuned**
File 2	Guitar, E_4 (open string 1) (note 2)
File 3	Guitar, E_4 (open string 1) (note 3)
File 4	note 1 + note 2 played together
File 5	note 1 + note 3 played together
File 6	Tuning fork
File 7	Guitar, A_4
File 8	Piano, A_4
File 9	Sax, A_4
File 10	Guitar, B_4

Equipment

- a computer with the Latis Pro software that can make the acquisition and the spectral analysis of a signal
- a data acquisition system
- a junction box to connect the audio output of the computer to the data acquisition system
- headphones



4- Work that should be done

Your report: *Start by creating a sheet in OpenOffice that will be your report (one per group).*

Each acquired curve and its spectral analysis will be copied and pasted into OpenOffice (see help card) before making the next acquisition.

4.1- Simulation of musical tones

Open the simulation software at Usager sur serhugo/Espace Physique Eleves/TS/TP/Physique/TP3/fourier_fr.jnlp
You can observe that a pure sound is simulated.

Change the settings to get time in abscissa. *What can you measure?*

You can add a harmonic (for instance on A2). *What can you observe? What's the difference between a pure sound and a complex one?*

Add two other harmonics (on A3 and A4).

Measure T_1 (the temporal period of the A1 sound). Calculate f_1, its frequency.

Measure T_2 (the temporal period of the A2 sound). Calculate f_2, its frequency. What can you notice?

Check this observation on A3 and A4.

Then, measure T (the temporal period of the complex sound). Calculate f, its frequency. What can you notice?

Which musical tone is it?

Musical note (English name)	**Musical note** (French name)	**Frequency** **(in Hz)**
A_2	La_1	110.0
A_4	La_3	440.0
A_6	La_5	1,760
B_2	Si_1	123.5
B_4	Si_3	493.8
B_6	Si_5	1,975.5

Document 4:
Frequencies and musical tones

4.2- Illustrating the concepts of spectral analysis, fundamental and harmonics

Open the Latis Pro software in "Logiciels Physique Chimie".

The music files are recorded in the web site of our school at "La vie du lycée/Physique/TP TS/TP3". You just have to click on the guitar to get them.

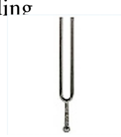
Caution: **Disconnect the headphones before each acquisition!**

Number of the string	Musical note (English name)	Musical note (French name)	Frequency (in Hz)
6	E_2	Mi_1	82.4
5	A_2	La_1	110.0
4	D_3	$Ré_2$	146.8
3	G_3	Sol_2	196.0
2	B_3	Si_2	246.9
1	E_4	Mi_3	329.6

Document 7: Frequencies of the open strings notes played by a guitar

Document 6: The guitar strings

- E – the thickest or lowest sounding string is the 6th string
- A – is the 5th
- D – is the 4th
- G – is the 3rd
- B – is the 2nd
- E – the thinnest or highest sounding the 1st



uration: 500 ms, Triggering: EA0, 200 mV).

ning fork, press F10. Then listen to File 6.

ted by the tuning fork.

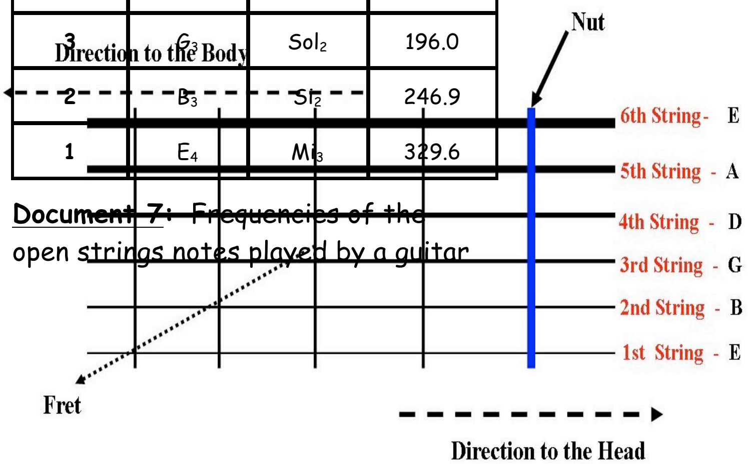
nd justify the obtained spectrum.

7).

m it the frequency of the studied sound.

e 9) and the guitar B_4 (file 10).

define the characteristics of two notes that have
ent timbres.



http://bradwaltersblog.com/photobpyd/guitar-strings-layout

Step 1: Finding a reference note

You should start tuning the A string (5th string) as accurately as you can. Its musical note will be your reference. By chance, it is often in tune anyways as it is one of the thickest strings. But, if you want to check that it is not detuned, here is the procedure to follow.

To tune the 5th string, you can use a tuning fork. When you hit it on a hard surface (but not on your guitar, of course!), it produces a steady sound at 440 Hz (tone A). Then, stretch the 5th open string and hear the two sounds simultaneously. Both tones should be the same. Otherwise, turn the tuning peg of the 5th string until the note you hear and that emitted by the tuning fork are the same.

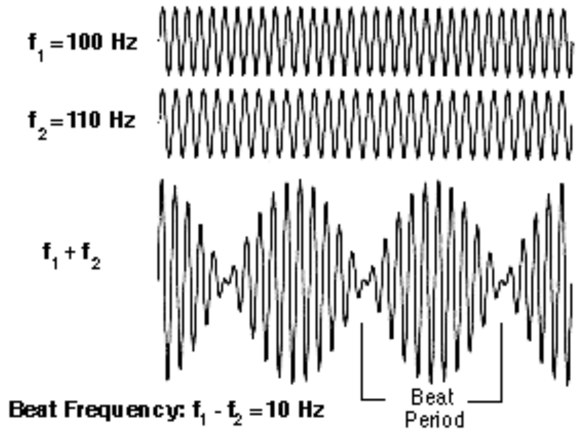
Then, thanks to this reference musical note, you can tune all the five other strings.

<u>Step 2</u>: Tuning the five other strings – Beats method

You can tune the 4th string with the 5th one, then the 3rd string with the 4th one, then the 2nd string with the 3rd one, and so on.

For example, to tune the 1rst string (Mi or tone E), you ne the 2nd one. You should place the first finger of your le hand just behind the 5th fret on the 2nd string. You ke your finger on that fret. Then, you pick the 2nd string a the open 1rst string simultaneaously. If you get the sensati of hearing beats (slight "waves" in the sound, intens varying over time), turn the tuning peg of the 1rst string, ur the beats disappear. When there are no more beats, the musical sounds are identical.

two sounds of slightly different frequencies, perceived as periodic variations in volume. The beats frequency is the difference between the two sounds frequencies.
From http://en.wikipedia.org/wiki/Beat_%28acoustics%29



5.1- Tuning the guitar by ear

The objective is to tune the 1rst string with the 2nd one (which has been previously tuned).

Listen to files 1, 2 and 3.

Only one note among files 2 and 3 is tuned with the note played in file 1.
Can you hear which one is tuned? Record your answer.

Listen to files 4 and 5.
Use the beats method to check if your answer is correct. Don't hesitate to correct yourself if necessary.

5.2 – Tuning the guitar from a spectral analysis

Make the acquisition of the sound files 4 and 5.

Perform their spectral analyses.

Interpret the results and compare them with those obtained by ear (question 4.1).