Experiment P-22
Sound Beats

Physics

Objectives

- To observe the beats of sound waves produced by two tuning forks on resonance boxes.
- To understand the concept of wave interference.

Modules and Sensors

- PC + NeuLog application
- USB-200 module
- NUL-212 Sound logger sensor

Equipment and Accessories

▪ B-480 Hz Tuning fork	1
▪ C-512 Hz Tuning fork	1
▪ Resonance box (wooden box)	2
▪ Hammer	1

- Please note that each tuning fork has imprinted on its base a musical note and its frequency in Hz.

- The items above are included in the NeuLog Sound kit, SND-KIT.

Introduction

Sound is a mechanical wave that results from the vibration of particles in a medium. Generally, sound waves are longitudinal so the motion of the particles is parallel (and anti-parallel) to the direction of the energy transport.

The particles of the medium vibrate at a given frequency (f). The frequency is the number of complete waves or cycles occurring in a unit of time, usually one second. The common units of frequency are Hertz (Hz); one Hz is equivalent to 1 cycle/second. The period (T) of a wave is the time it takes a particle to complete one cycle. It is usually measured in a fraction of a second.

1/T=f
1/Period=Frequency
1/(The time it takes to complete one cycle) = (Number of waves that pass in a period of time)

The wavelength (λ) of a sound wave is the distance the sound travels in order to complete one cycle. The common units for wavelength are m or mm.

The sound wave's velocity (v) refers to the distance that the disturbance travels per unit of time. Velocity of sound waves is often expressed in m/s.

The mathematical relationship between frequency, wavelength and velocity is given by the following equation:

v=f λ
Velocity=Frequency X Wavelength
(Speed of the waves) = (Number of waves that pass in a period of time) X (the length of each wave)

Tuning forks are used by musicians, physicists and by anyone who is involved with sound and hearing. Tuning forks have two rectangular tines. The length of the tines affects the frequency of the fork. The two tines are joined on a stem.

When hit by a hammer, the tines vibrate back and forth pushing the air molecules around them. When the tine moves forward the molecules are pushed together creating a compression (high

pressure region) and when the tine moves backward it creates a rarefaction (low pressure region). The compressions and rarefactions can be detected by a sound sensor (or a microphone).
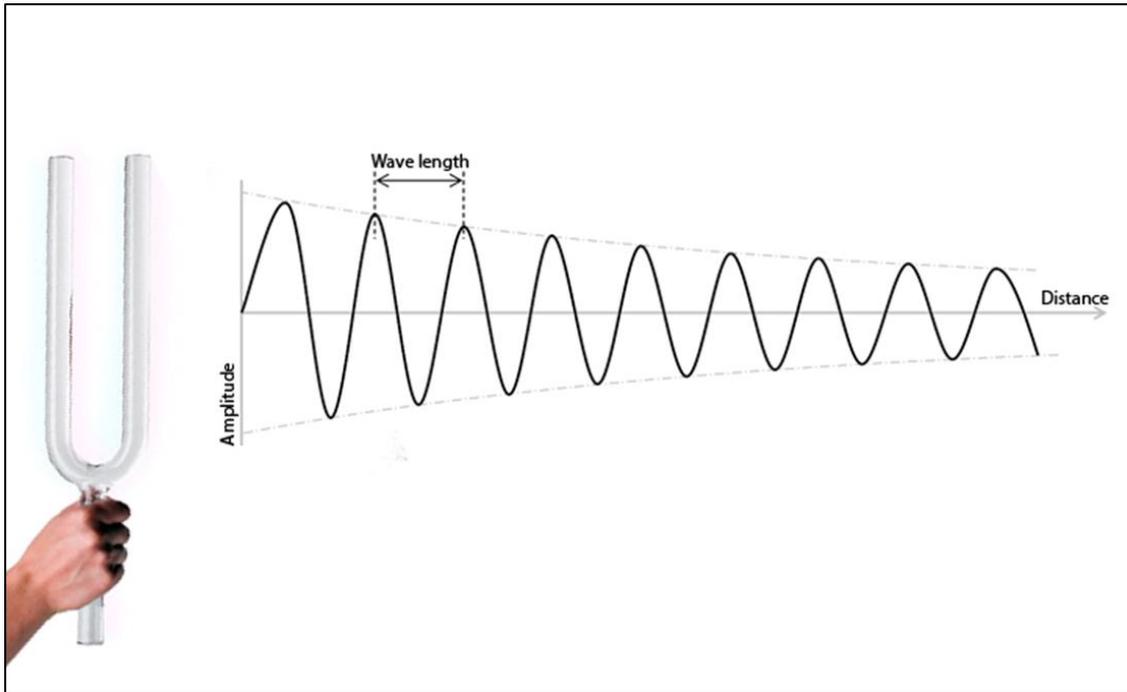
The image describes the way sound waves are propagated by the tuning fork motion. The waves decay over distance; therefore we should measure them close to the tuning fork. They also decay over time so the measurement should be started right after hitting it.

If the tuning fork is mounted on a resonance (wooden) box, when it vibrates it makes the air inside the box vibrate as well at the same frequency. This process increases the sound intensity of the tuning fork.

Wave interference is a phenomenon which occurs when two waves meet while traveling along the same medium. When two waves interfere, the resulting displacement of the medium at any location is the algebraic sum of the displacements of the individual waves at that same location.

Two sound waves of nearly the same frequency will create a variation of sound amplitude called beats. Beats are an example of superposition. In the figure below, the green and red waves are superposed (placed above each other), creating constructive and destructive interference.
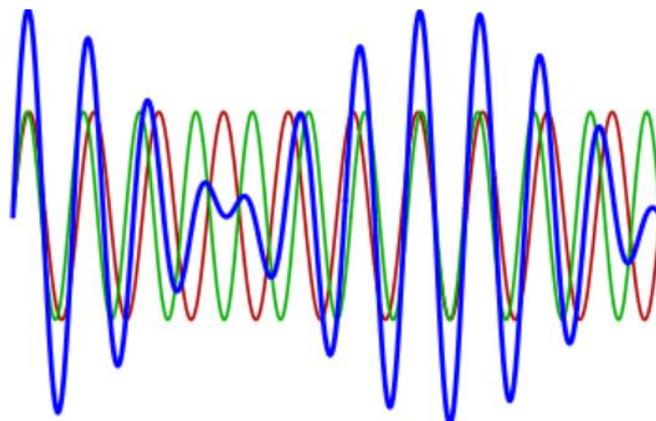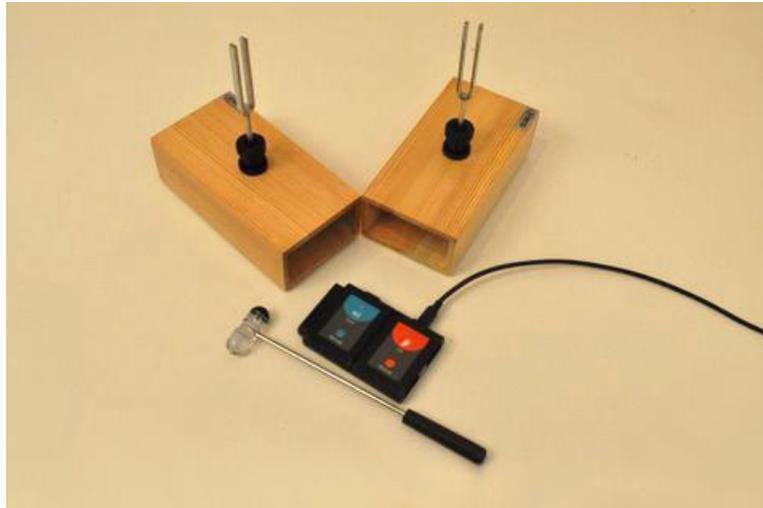

Figure by Adjwilley

In this activity, we will use a sound sensor to study the phenomenon of sound waves interference and sound beats; we will use tuning forks to create sound waves.

Procedure

Experiment setup

1.   Set up the experiment as shown in the picture below.

2.   Introduce the 480 Hz tuning fork in one of the resonance boxes and the 512 Hz tuning fork in the second.

3.   Place the two boxes on the table creating an angle of about 120⁰ as seen in the picture. The openings of the boxes should be directed to the same side.

4.   Place the sound sensor in front of the large openings of the resonance boxes with the tuning forks as shown in the picture. Its sensing aperture should be directed to the openings of the boxes.

5.   Practice producing sounds by hitting both tuning forks with the hammer, one after the other, as fast as possible.

NeuLog

Sensor setup

6.   Connect the USB-200 module to the PC.

7.   Check that the sound sensor is connected to the USB-200 module.

Note:

The following application functions are explained in short. It is recommended to practice the NeuLog application functions (as described in the user manual) beforehand.

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8.   Run the NeuLog application and check that the sound sensor is identified.

Module and experiment setup

9.   Click on the **On-line Experiment** icon [icon] in the NeuLog main icon bar.

10.   Click on the **Sensor's Module** box.

11.   Click on the **Range** button.

12.   Select the Wave button to set the sensor's mode.
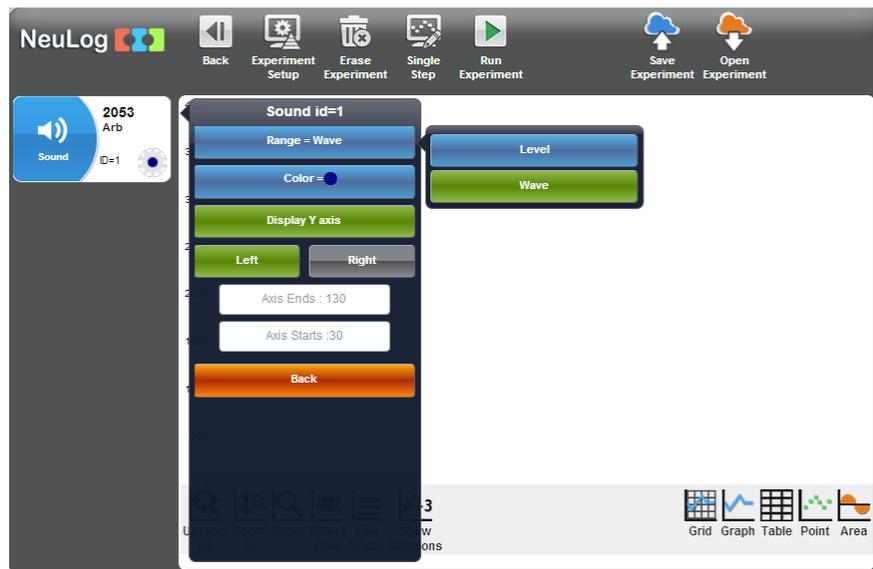
13.   Click on the **Experiment Setup** icon [icon] and set the:

Experiment duration to 150 milliseconds
Sampling rate to 2000 per second

Testing and measurements

Note:

In this activity, it is better to work in pairs. One student should hit the tuning forks and the second student should immediately start the measurement.

14. Produce sound waves: strike your tuning forks equally hard one after the other, as fast as possible.

15. Immediately, click on the **Run Experiment** icon to start the measurement.

16. Collect data while you can hear the two tones. You should see a change in the wave's amplitude over time.

17. Repeat the measurement a few times until you get two periodic waves (alternate between the 480 Hz and the 512 Hz tuning forks).

18.   Click on the **Zoom fit** icon .

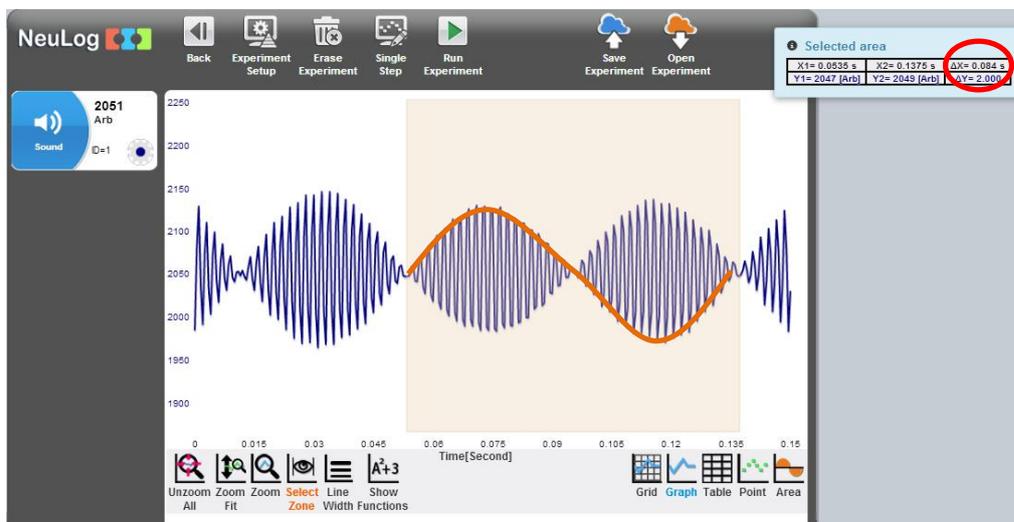19.   Your graph should be similar to the following:
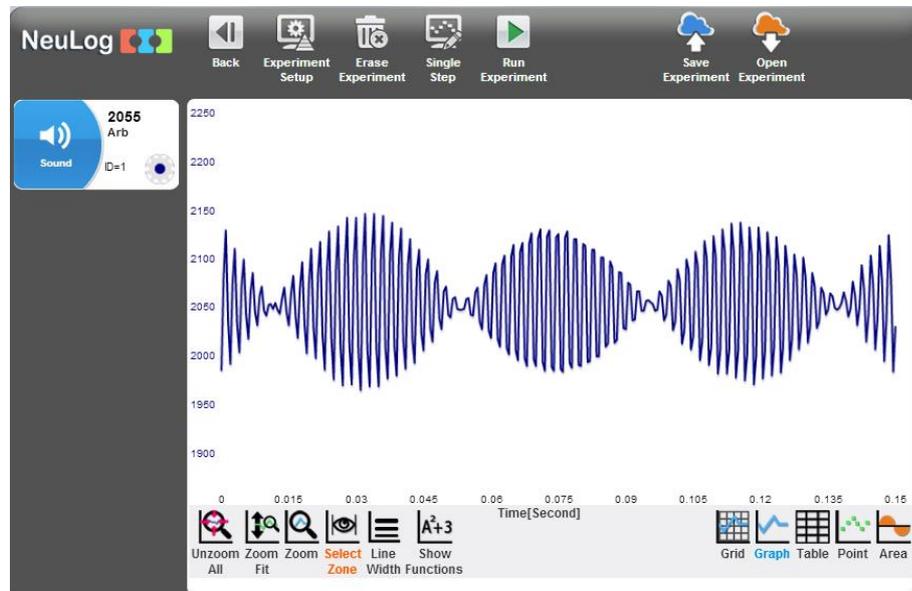
20.   Save your graph.

21.   We can see how the waves alternate between constructive and destructive interference, creating a beats pattern.

Challenge research

22. Click on the **Select Zone** icon ⬚ and choose a part that includes a complete envelope wave.

23. Look at the ΔX part in the table. Divide 1 by this number and you will get the frequency of the envelope wave. Insert this frequency in the table below.

Measured envelope wave frequency [Hz]	Measured high frequency inside the envelop [Hz]	Measured frequency of the 480 Hz tuning fork	Measured frequency of the 512 Hz tuning fork	Calculated envelope wave frequency $(f_1-f_2)/2$ [Hz]	Calculated high frequency inside the envelop $(f_1+f_2)/2$ [Hz]

24. Click on the **Select Zone** icon and choose the part inside the envelope wave.
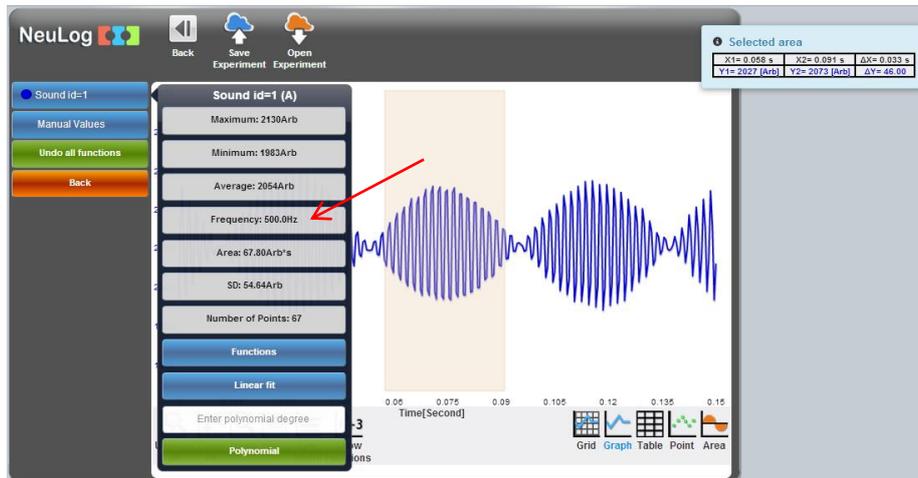
25. Click on the **Show Functions** icon , and then click on the sound sensor button on the left of the screen.
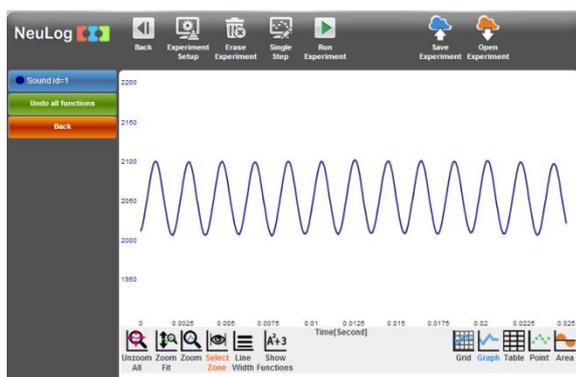
26. Look at the frequency and insert it in the table on the previous page.

27. Click on the **Erase Experiment** icon .

28. Change the experiment duration to 25 milliseconds and the rate to 10,000 per second by clicking on the **Experiment Setup** icon .

29. Strike one of the tuning forks.

30. Immediately, click on the **Run Experiment** icon to start the measurement.
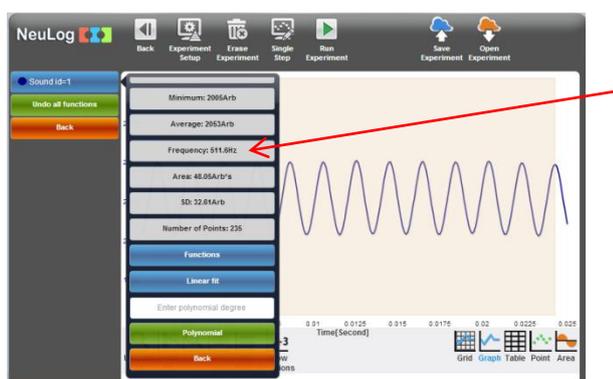
31. Click on the **Select Zone** icon and choose the largest part that includes a round number of waves (start and end your selection at the same point of a wave) like in the graph below.
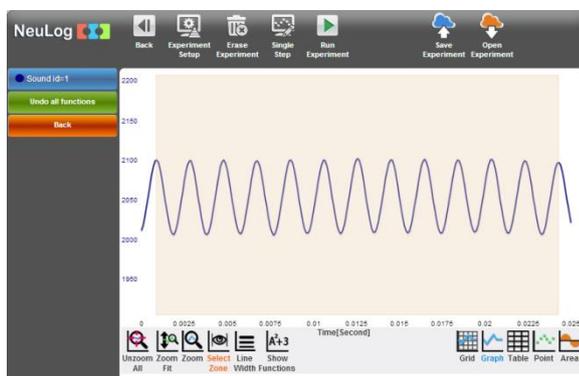
32. Click on the **Show Functions** icon , and then click on the sound sensor button on the left of the screen.

33. Look at the frequency and insert it in the previous table.

34. Repeat this procedure with the other tuning fork and write the measured frequency in the table on section 23.

Summary questions

1. Explain the meaning of constructive and destructive interference.

2. The envelope frequency should be equal to $(f_1-f_2)/2$; f_1 and f_2 are the original tuning fork frequencies you measured. Calculate the envelope frequency and insert the value in the table in section 23. Are the two envelope frequency values similar to each other?

3. The high frequency inside the envelope should be the average of the two original frequencies $(f_1+f_2)/2$. Calculate the high frequency and insert the value in the table in section 23. Are the two high frequency values similar to each other?