Sound Beats
Experiment

Physics

Objectives

- Observe the beats of sound waves produced by two tuning forks on resonance boxes.
- Understand the concept of **wave interference** and its real-world applications.
- Learn how sound waves interact to create **constructive and destructive interference**.
- Gain hands-on experience in using a sound sensor to analyze sound patterns

Modules and Sensors

- PC + NeuLog application
- USB-200 USB module (or BLT-202 Bluetooth module)
- NUL-212 Sound logger sensor

Equipment and Accessories

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

- Each tuning fork has its frequency (in Hz) imprinted on its base.

Introduction

Sound is a **mechanical wave** that propagates through a medium by vibrating particles. Typically, sound waves are **longitudinal**, meaning that the motion of the particles is parallel (and anti-parallel) to the direction of the energy transport.

Key concepts:

- **Frequency (f):** Number of complete cycles per second, measured in **Hertz (Hz)**.
- **Period (T):** The time taken for one full cycle, measured in seconds.
- **Wave Interference:** The phenomenon that occurs when two waves meet while traveling along the same medium.

$$\frac{1}{T} = f$$

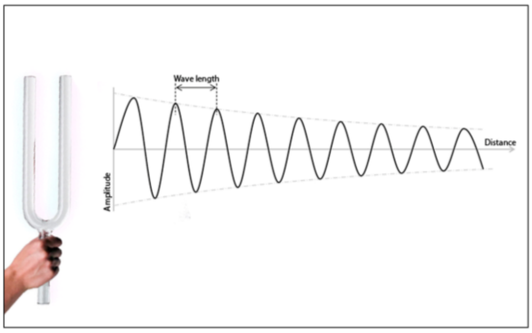
$$\frac{1}{\text{Period}} = \text{Frequency}$$

$$\frac{1}{\text{The time it takes to complete one cycle}} = \text{Number of waves that pass in a period of time}$$

Tuning Forks and Sound Propagation

Tuning forks are used by **musicians**, **physicists**, **and acoustics engineers** to study sound. They consist of two tines connected by a stem. The **tine length** determines the frequency of the tuning fork.

When a tuning fork is struck, the tines **vibrate**, causing surrounding air molecules to compress and expand, producing sound waves. If mounted on a **resonance box**, the vibrations are amplified, making the sound clearer and louder.



The image above illustrates how sound waves propagate from a vibrating tuning fork. The waves decay over distance; which is why measurements should be taken close to the tuning fork. They also decay over time, so measurements should start immediately after striking the fork.

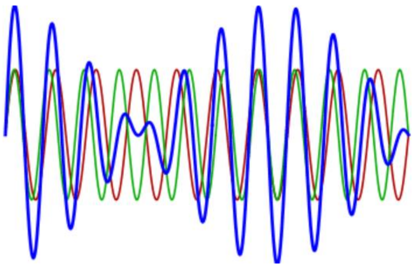
When the tuning fork is mounted on a **resonance (wooden) box**, its vibrations cause the air inside the box to oscillate at the same frequency, amplifying the sound intensity.

Wave Interference and Beats

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.

When **two sound waves of nearly identical frequencies** interact, they create a phenomenon called **beats**. Beats occur due to **superposition**, where two waves combine to form a new wave pattern.

- **Constructive interference** occurs when waves reinforce each other, increasing amplitude.
- **Destructive interference** occurs when waves cancel each other out, reducing amplitude.



This experiment explores how two tuning forks with slightly different frequencies produce beats. The frequency difference between the two forks determines the **beat frequency**, a concept used in **tuning instruments and medical ultrasound applications**.

Mathematical Foundation

A sound signal is **sine wave** represented by:

$$A\sin(2\pi ft)$$

Where:

- **A** = Amplitude
- **f** = Frequency

The following trigonometric formula converts a sum of two sine waves into a product of two waves:

$$\sin\alpha + \sin\beta = 2\cos((\alpha-\beta)/2)\sin((\alpha+\beta)/2)$$

Applying this formula to two sound waves:

$$A\sin(2\pi f1t) + A\sin(2\pi f2t) = 2A\cos(2\pi(f1 - f2)/2)t)\sin(2\pi(f1 + f2)/2)t)$$

We can look at the following product:

$$2A\cos(2\pi(f1 - f2)/2)t)\sin(2\pi(f1 + f2)/2)t)$$

This equation explains **modulated waves**, where:

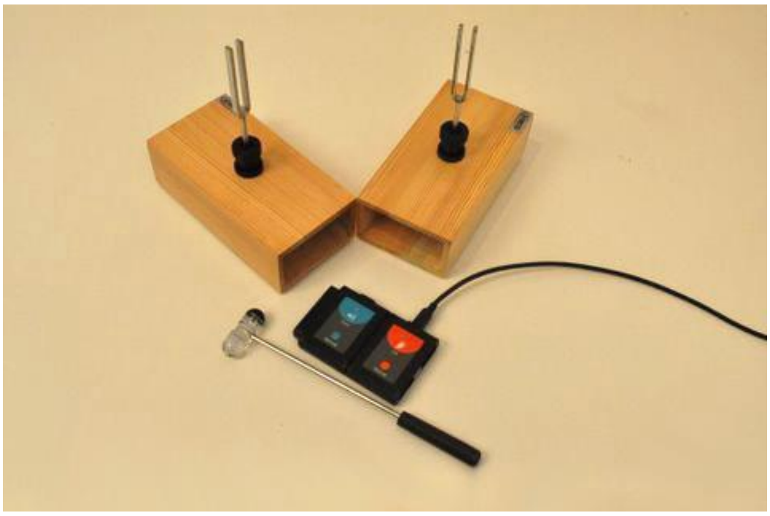
- $(f_1 + f_2)/2$ represents the **carrier frequency**.
- $(f_1 - f_2)/2$ represents the **modulation frequency (beat frequency)**.

The amplitude is changed according to the frequency $(f1 – f2)/2$.
This is what we call a modulated signal.

Procedure

Experiment setup

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



2. Place the 480Hz tuning fork in one resonance box and the 512Hz tuning fork in the second box.

3. Position the two boxes at an angle of approximately **120°**, ensuring the openings face the same direction.

4. Place the **sound sensor** in front of the openings to capture wave interactions.

5. Practice striking each tuning fork **one after the other** as quickly as possible to produce beats.

Sensor setup

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

7. Ensure the **sound sensor** is connected to the USB-200 module.

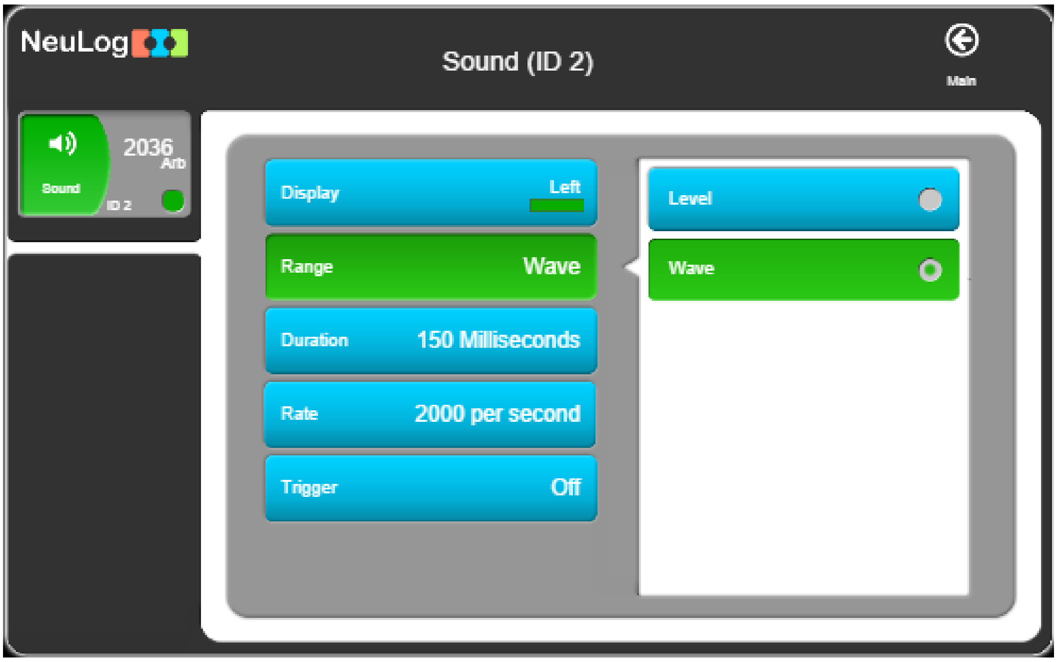
> **Note:**
>
> The following application functions are explained in short. It is recommended to practice the NeuLog application functions (as described in the user manual) beforehand.

8. Open the NeuLog application and verify sensor recognition.

Module and experiment setup

9. Click the **Sound Sensor Module** box.

10. Select **Wave Mode**.



11. Click on the  icon to go back to the graph.

12. Click on the **Run Experiment** icon  and set the:

Experiment duration to: **150 milliseconds**
Sampling rate to: **2000 per second**

Testing and measurements

> **Note:**
>
> This experiment works best with two participants: One strikes the tuning forks, and the other starts the measurement.

13. Strike both tuning forks **equally hard** in succession.

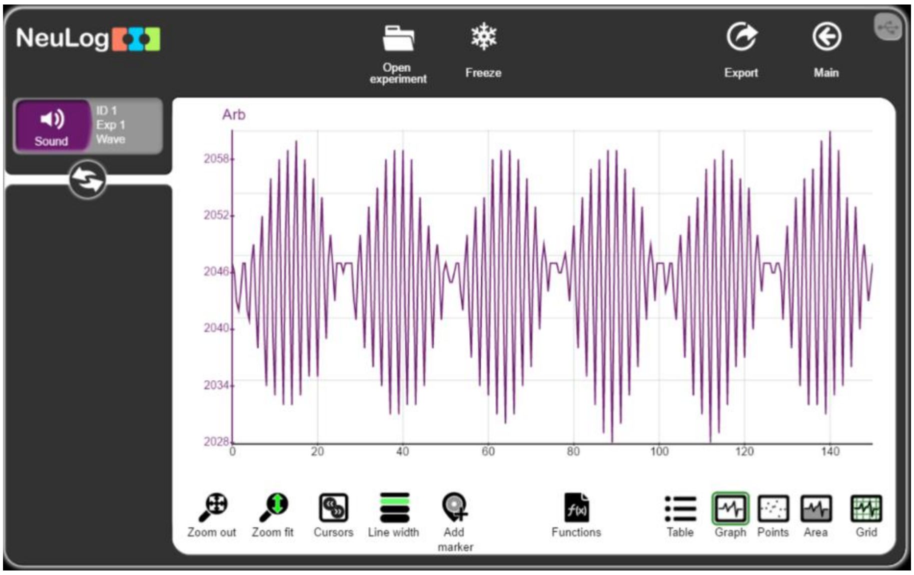
14. Immediately, press **Record**  to capture the wave pattern.

15. Observe changes in amplitude over time, indicating beat formation

16. Repeat the process until you obtain two periodic waves (alternate between the 480Hz and the 512Hz tuning forks).

17. Click **Zoom fit**  to properly visualize the graph.

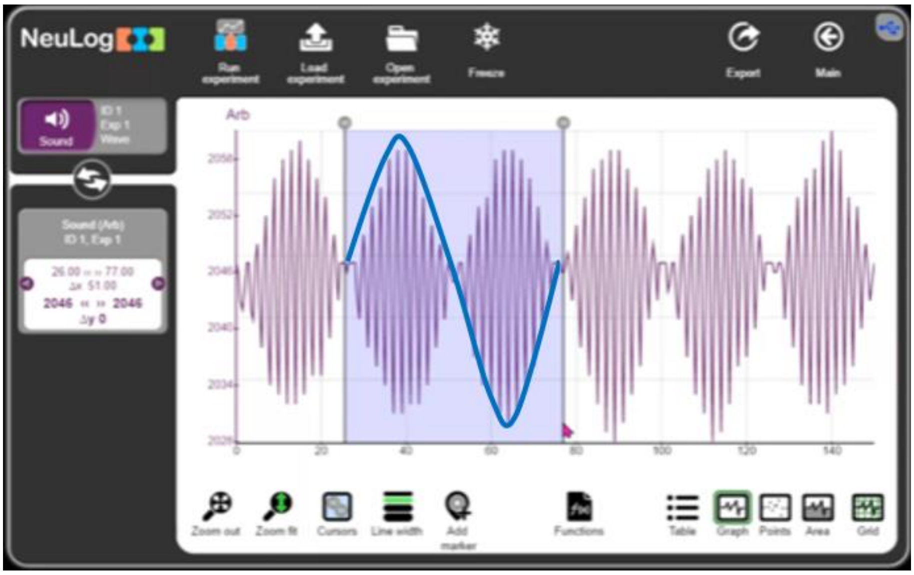
18. Your graph should show alternating **constructive and destructive interference**, forming a **beat pattern**.



19. Save your graph.

Analysis

20. Click the **Cursors** icon  and highlight a complete envelope wave.



On the left you can see **dx**, the time difference between two cursors on the graph. In this experiment, **dx = 50 milliseconds**.

The wave frequency is calculated as: $f = \frac{1}{T}$

The envelope frequency is therefore **20 Hz**.

The amplitude frequency is given by (f1 – f2) / 2.

21. Between the two cursors, we count 25 complete waves.
So, the wave period is 2 milliseconds and the wave frequency is 500Hz
f signal = (f1 + f2) / 2.

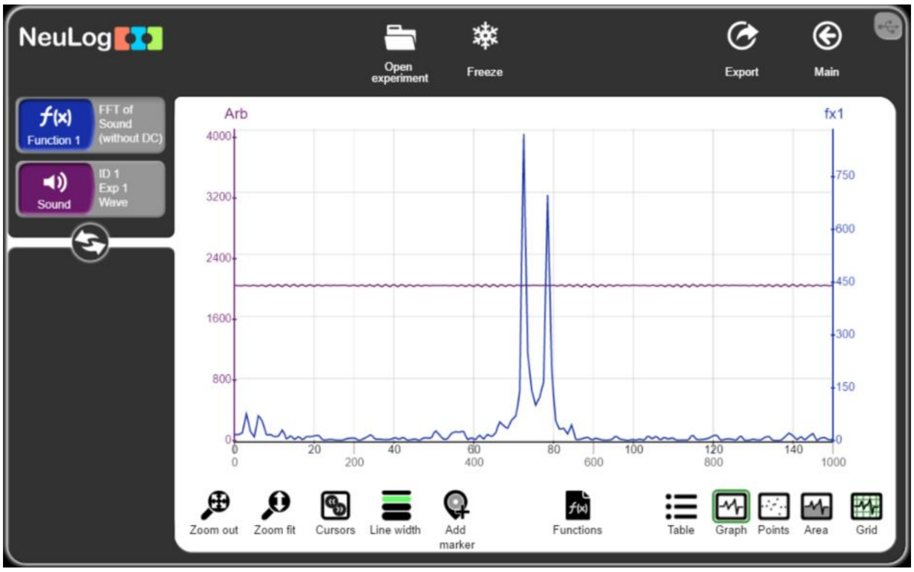
22. Clear the cursors on the screen

23. Observe how many complete waves appear between two beats.

Confirm the modulated wave frequencies using FFT analysis:

24. * Click on the 'FFT of A (without DC) and create a function 1 graph to generate a frequency spectrum.

25. * Identify two peaks corresponding to the tuning fork frequencies.



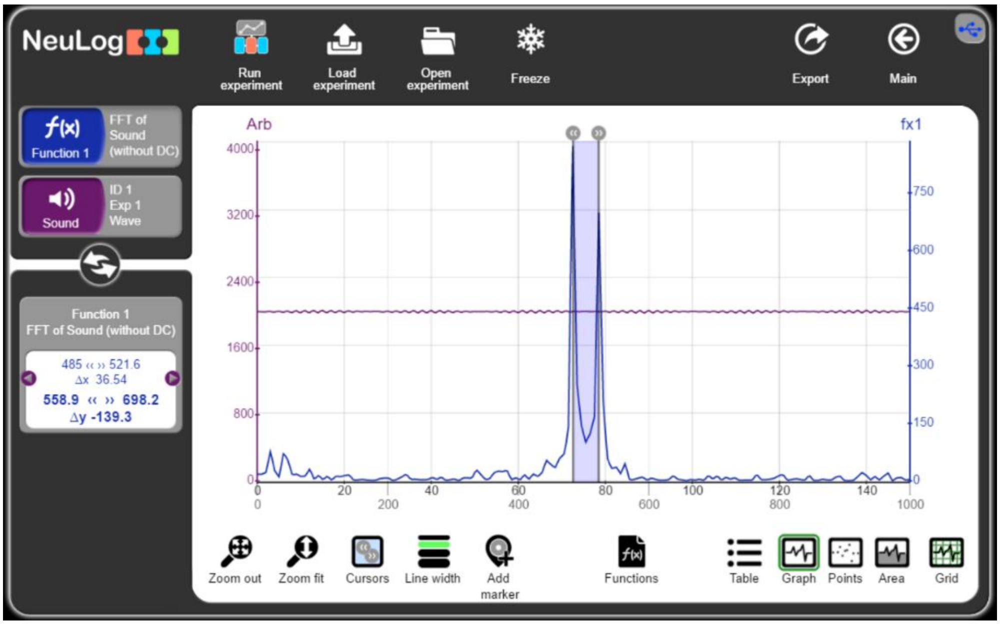
The FFT (Fast Fourier Transform) function displays the constituent frequencies and their amplitudes of the measured signal.

Function 1 graph displays the two waves that construct the modulated wave

26. Add cursors and move the left cursor to the peak on the left

27. Move the right cursor to the peak on the right

28. Change the display on the left to show the frequencies of function 1 graph



The frequency displayed on the left is 485 Hz
The frequency displayed on the right is 522 Hz

Challenge research:

A string instrument add to the string sound over tones and harmonies as describe in the video 'Sound waves and musical instruments'

Repeat this experiment by playing two stings at a time on a string instrument

Summary questions

1. Explain constructive and destructive interference. How do they influence sound perception?

2. If you use tuning forks of 1100Hz and 1200Hz, what would the beat frequency be?

3. What is the high-frequency wave inside the envelope for the 1100Hz and 1200Hz tuning forks?