Exploring Sound
Experiment

Physics

Objectives

- Learn how to measure different intensities of sound.
- Understand the meaning of sound units (dB).
- Gain awareness of dangerous sound intensity levels.
- Understand the concept of sound isolation.

Modules and Sensors

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

Equipment and Accessories

▪ Audio device (or other steady sound source)
▪ Musical instrument
▪ Sound isolation sponge
▪ Felt
▪ Paper towels
▪ Sound isolation box
▪ Egg tray

Introduction

Sound is a travelling wave that propagates as an oscillation of pressure through solids, liquids, or gases. It consists of frequencies within the range of human hearing and of and at levels strong enough to be perceived.

Sound intensity is defined as the power per unit area. The basic units are watts/m^2 or watts/cm^2.

Sound intensity measurements are made relative to the standard threshold of human hearing intensity at 1000Hz, I_0:

$$\mathbf{I_0 = \frac{10^{-12}\ watts}{m^2} = \frac{10^{-16}\ watts}{cm^2}}$$

The sound levels we hear vary dramatically. For instance:

- Whispering is 1000 times louder than the hearing threshold.
- Speech in a restaurant is 10 million times louder than the hearing threshold.
- A rock concert is 10 billion times louder than the hearing threshold.

The amazing thing is that the human ear is able to distinguish speech at all different levels of intensity and on a logarithmic scale.

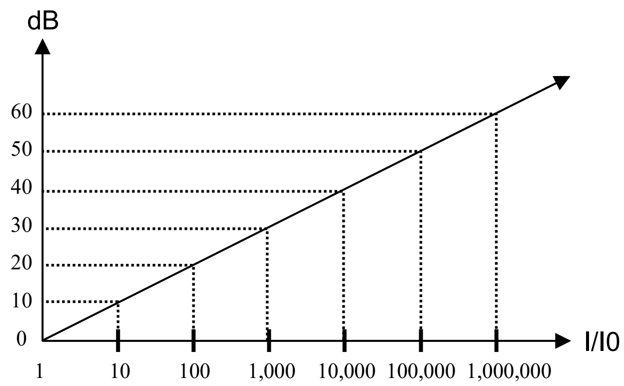
Sound intensity is commonly measured in decibels (dB). It is a logarithmic scale, meaning an increase of 10 dB represents a tenfold increase in intensity.

Decibels measure the ratio of a given intensity **I** to the threshold of hearing intensity, $\mathbf{I_0}$.

$$\mathbf{I(dB) = 10\log_{10}\left[\frac{I}{I_0}\right]}$$

When $\mathbf{I = I_0}$ the sound level is 0dB.

In a quiet room (what is called silence), the sound intensity is 10,000 times the threshold and produces 40dB ($10\log_{10}[10{,}000] = 40$).



The following table shows some typical sound levels in dB.

Sounds	dB
Rocket Launching	180
Jet Engine	140
Thunderclap, Air Raid Siren (1 meter)	130
Jet takeoff (200 ft)	120
Rock Concert, Discotheque	110
Firecrackers, Subway Train	100
Heavy Truck (15 meters), City Traffic	90
Alarm Clock (1 meter), Hair Dryer	80
Noisy Restaurant, Business Office	70
Air Conditioning Unit, Conversational Speech	60
Light Traffic (50 meters), Average Home	50
Living Room, Quiet Office	40
Library, Soft Whisper (5 meters)	30
Broadcasting Studio, Rustling Leaves	20
Hearing Threshold	0

The human ear is remarkably sensitive, capable of distinguishing sounds across vast intensity ranges while also having protective mechanisms to reduce exposure to excessive loudness.

Damage to hearing can occur instantly at sound levels above 130 dB or with prolonged exposure to sounds above 85 dB.

This incredible sensitivity is further enhanced by the effective amplification of sound signals through the structure of the ear. Additionally, protective mechanisms help reduce the ear's response to very loud sounds.

Another concept related to the decibel scale is -3dB, which represent a reduction to half the original sound intensity.

For example, if the initial intensity is 100,000, reducing it by half results in 50,000. Using logarithmic calculations:

$I = 10\log(100{,}000/2) = 10\log100{,}000 - 10\log2 = 50 - 3 = 47\text{dB}$

In this activity, we will generate sound using various sources (whistling, clapping, musical instrument, and an audio device) and measure the intensity levels with a sound sensor.

Sound isolation

In the second part of this activity, we will use a sound sensor to measure different sound levels and study which materials are better isolators.

Acoustic or sound isolation refers to technologies with materials and techniques developed to attenuate and/or isolate the level of sounds in a given space.

Isolation is the prevention of a sound from penetrating or leaving a media. Isolation is achieved by using both absorbent and isolating materials. When an acoustic wave influences a constructive element, part of the energy is reflected, another part is absorbed and the rest is transmitted to the other side. The element offers isolation which is the difference between the incident and the transmitted energy. In order to acquire a good acoustic isolation various basic factors must be involved:

- **Mass factor**. Acoustic isolation is acquired mainly by the mass of the constructive elements: the larger the mass, the greater resistance opposes the bumping of the sound waves and the greater the attenuation.

- **Multilayer factor**. When dealing with constructive elements formed by many layers, a suitable arrangement of the layers can give a better acoustic isolation even to higher levels than the isolation that can be reached by the sum of each individual layer.

- **Dissipation factor**. Isolation is also better if an absorbent material is put between the two layers.

The Value of Experimentation

This experiment is crucial for understanding sound properties in a practical way. By measuring real-world sound levels and observing how different materials influence sound propagation and isolation, students can apply theoretical knowledge in an interactive setting. This hands-on experience allows for a deeper comprehension of sound physics and its practical implications.

Procedure

Experiment setup

1. Assemble a system as shown in the instructional image..

2. Place the sound sensor on a table in front of the sound sources.

3. Predict the sound level for each source before measurement.

Sensor setup

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

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

Note:

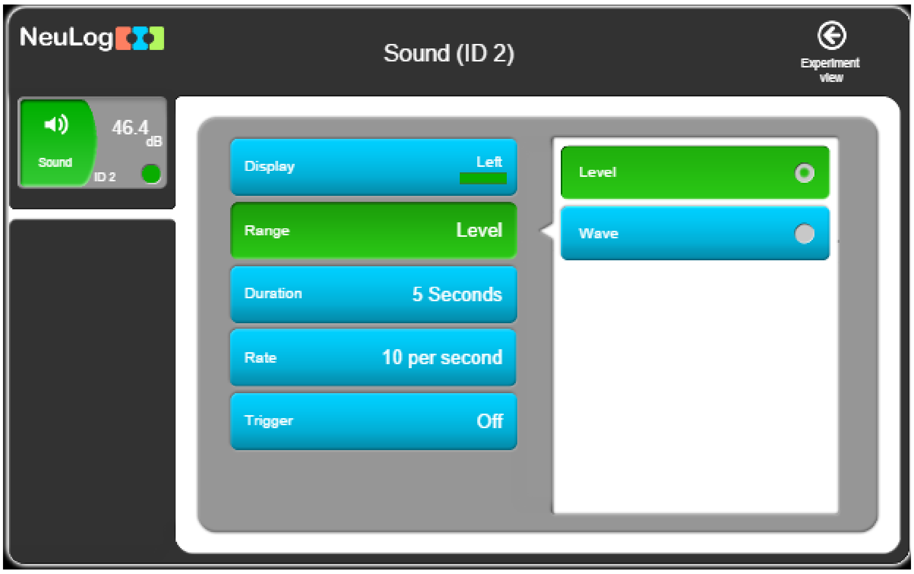
The following application functions are explained in short. It is recommended to practice the NeuLog application functions (as described in the user manual) beforehand.

6. Open the NeuLog application and verify sensor identification.

Settings

7. Click on the **Sensor's Module** icon on the left.

8. Select the **Level** button to set the sensor mode.



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

10. Click on the **Run experiment** icon  and configure:

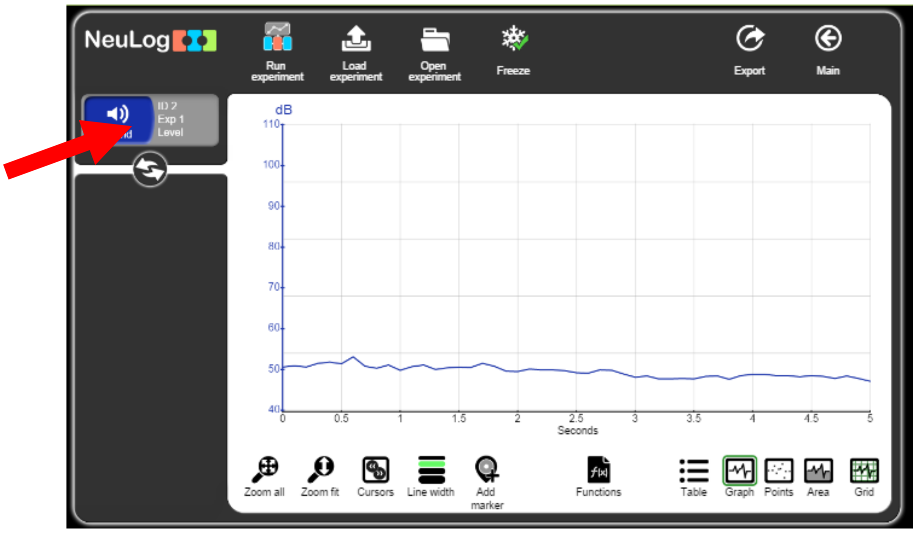
- Experiment duration: **5 seconds**
- Sampling rate: **10 per second**

Testing and measurements

We will generate sound using various sources (whistling, clapping, musical instrument, and an audio device) and measure the intensity levels with a sound sensor. We will start with the class being as possible.

11. Begin with a silent room and record the sound level.

Click on the **Record** icon  to start the measurement.



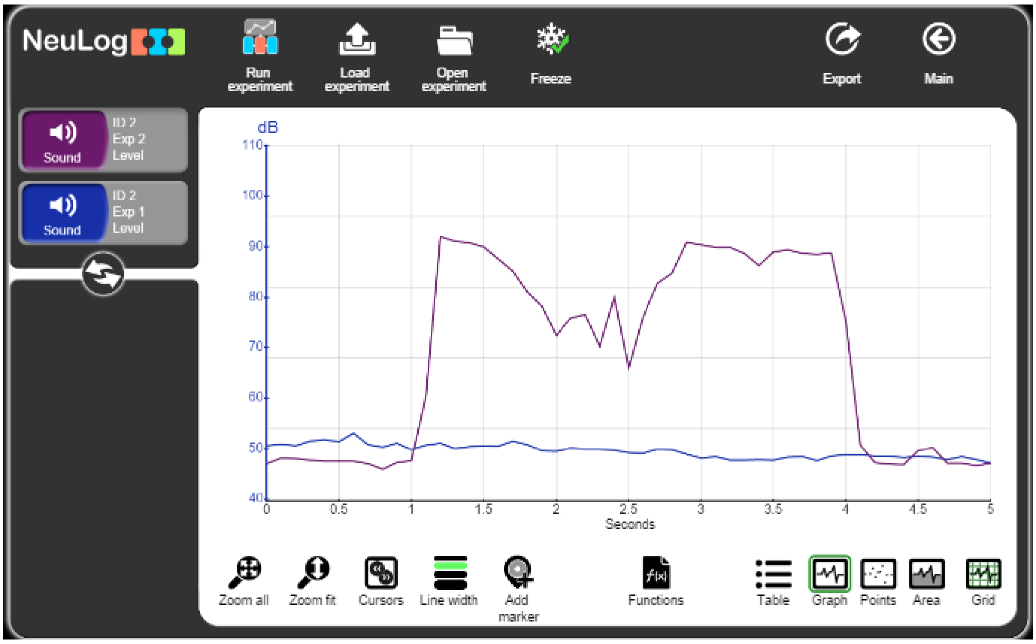
12. Click on the experiment's module box on the left of the screen. Look at the highest sample value.

Highest sample value: 53.1

The maximum level at silence is 53.1dB for the sample experiment.

13. Click on the **Freeze** icon .

14. Generate a second level of sound by whistling, then click on the **Record** icon  again.



15. Click on the experiment's module box on the left of the screen. Look at the highest sample value.

Highest sample value: 92

The maximum level of whistling is 92dB for the sample experiment.

16. Copy the following table and write the maximal sound level in it.

17. Generate different sounds and for each sound source, observe and record the highest sample value:

Action/sound source	Maximal sound level [dB]
Silence	53.1
Whistling	92
Clapping hands	
Note A by musical instrument	
Note D by musical instrument	
Audio device	

Summary questions

1. How did the sound sensor help quantify loudness?

2. Were you able to measure values close to 40dB?

3. Were you able to measure values close to 120dB?

4. Does playing different notes with the musical instrument affect the sound intensity?

Sound isolation

1. Assemble a system like the one in the picture bellow.

2. Put the sound sensor on the table in front of the sound source. Try to predict which materials will isolate sound better. Note that the sensor has an opening on the top through which sound is sensed.

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

   Experiment duration to: **10 seconds**
   Sampling rate to: **10 per second**

4. Turn on the audio device or other sound source without placing an isolating material.

5. Click on the **Record** icon to start the measurement.

6. Click on the **Experiment's module box** on the left of the screen. You will see the average and also the minimum and maximum values.

Highest sample value: 82.5
Lowest sample value: 66.6
Average value: 75.29

7. Copy the following table and write the average sound level in it.

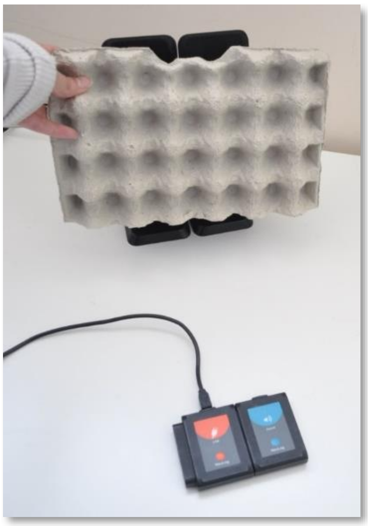
8. This measurement is different than the one in the previous section.

Isolating material	Average sound level [dB]
No isolating material	75.29
Sound isolation sponge	
Felt	
Egg tray	
Paper towels	
Sound isolation box	

9. Repeat the measurement placing an isolating material in front of the sound source and write the average sound level in the table.

   Try to predict which of the isolating material influences the most.

   Continue in the same way with other isolating materials.
   Which material influences the most on the sound level?



Challenge research

10. Place two materials together as two layers in front of the audio device.
    Try to predict the average sound level before the measurement.

Summary questions

1. How good were your predictions about the efficiency of the sound isolators?
2. Which material is a good isolator?
3. Which material is a bad isolator?
4. What combination of isolators was the best?
5. Can you explain why certain materials are better isolators than others?