MEASUREMENT OF HEARING THRESHOLD USING AN AUDIOMETER

Theoretical introduction:

A precise assessment of hearing function is a frequently performed procedure in otorhinolaryngology. It is part of the entrance medical evaluation for professions in which normal hearing function essential. It is also frequently performed when assessing work-related health damages.

The audiometric examination is the most precise available assessment of hearing function. Audiometers are devices that generate audible tones with specified pitch and intensity level. The intensity level $L$ is measured in the units of decibel (dB), with the following relation to the intensity $I$ (measured in units of W/m$^2$):

$$L = 10 \log \frac{I}{I_0},$$

Here $I_0 = 10^{-12}$ W/m$^2$, which is the lowest audible intensity (for a healthy young subject) of a tone with frequency 1 000 Hz.

Audiometry determines the hearing threshold (i.e., the lowest audible intensity level) for pure tones of frequency between 125 Hz and 8 000 Hz (in octave increments). Audiometers are standard equipment at ORL clinics and audiometric centers. They are used in the so-called quiet chambers with good sound insulation from the surroundings. The left and right ear is examined separately. To prevent the non-examined ear from detecting the tone played to the examined ear, the audiometer outputs a masking noise to the non-examined ear. This is necessary when the examined ear has a strong hearing deficit compared to the non-examined ear. The masking noise is generated by mixing a range of frequencies.

During the audiometric measurement, we fix the frequency and gradually increase the intensity from very low (inaudible) values. When the examined subject can first hear the tone, he/she signals this by pressing the response button. This determines the threshold intensity for the given frequency. The intensity level is calibrated in decibels, and can be increased in increments of 2 or 5 dB. The norm (for a young healthy subject) corresponds to 0 dB. If the examined subject has better hearing than the norm, it is necessary to start with intensities below 0 dB (most audiometers permit to set the intensity as low as -20 dB).

The sound wave is transmitted to the subject either by a headphone (air conduction) or by a vibrating bar placed on the processus mastoideus (bone conduction). The bone conduction stimulation bypasses the outer and the middle ear, and directly activates the inner ear.
The audiogram is a graphical representation of the measured threshold values for air conduction, or for both air and bone conduction. In the graph below, the left panel shows the audiogram for a subject with hearing deficit, while the right panel is for a subject with normal hearing.

**Audiogram interpretation:**

**Types of hearing loss:**

- normal hearing – thresholds below 15 dB, hearing loss – above 15 dB
- sensorineural hearing loss - when the loss is equal for air and bone conduction
- conductive hearing loss – the loss is seen in air conduction but not in bone conduction

**Degree of hearing loss:**

1. Slight hearing loss = 25–40 dB,
2. Moderate hearing loss = 41–65 dB,
3. Heavy hearing loss = 66–90 dB,
4. Heavy loss with deafness = over 90 dB.
Description of apparatus used in the lab:

The audiometer Maico MA 50 generates pure tones for either air or bone conduction. The pitch of the tone is selected by choosing the frequency in the range 125 Hz - 8 kHz, with the following selectable frequencies: 125 Hz, 250 Hz, 500 Hz, 750 Hz, 1 kHz, 1.5 kHz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, 8 kHz. The intensity level is regulated in the range of -10 to 110 dB in 5 dB increments.

![Audiometer and a soundproofed chamber for audiometric examination.](image)

Fig.1 Audiometer and a soundproofed chamber for audiometric examination.

Equipment:

1) Audiometer MA 50
2) Headphones
3) Bone vibrator
4) Response button
5) Blank audiogram
Task:

Determine the hearing thresholds for air conduction and for bone conduction, in the frequency range 125 Hz – 8 000 Hz.

Procedure:

Please be careful when handling the audiometer. In particular, do not pull on the cables connected to the earphones and the bone vibrator, and do not drop the equipment.

1) Divide into groups of 2 or 3 students. Each group performs separate measurements.
2) 1 or 2 students manipulate the audiometer and record into the provided blank audiogram the values of the hearing thresholds of the examined student.
3) Use separate symbols for the left and right ear. The legend for symbols is shown in the right margin of the provided audiogram.
4) Switch on the audiometer by pressing the button on the right side.
5) The default setting after switching on is: air conduction, frequency 1000 Hz, 30 dB tone on right ear, -10 dB noise on left ear.
6) Press the button **STIM MODE** (uninterrupted unmodulated tone) and set the noise level to 15 dB. Then press **TRACK** (the noise level will then be automatically adjusted when the tone intensity level is changed).
7) The examined student, sitting about 1 m from the audiometer, puts on the headphones – red on right ear, blue on left ear. He/she holds the response button (when pressed, the light in the upper middle part of the audiometer is activated). The light signals to the examiner that the examined subject has just heard the lowest audible intensity level.
8) On the right ear, measure the threshold intensity levels (set by the wheel on your right) for the frequencies 1000 Hz, 750 Hz, 500 Hz, 250 Hz, 125 Hz and then 1500 Hz, 2 kHz, 3 kHz, 4 kHz, 6 kHz, 8 kHz (set by the buttons +/- Hz on the left under display). Draw the measured values in the audiogram. Proceed similarly for the left ear (after switching the button at bottom left to L).
9) Next, determine the hearing loss for bone conduction. Press the button with **symbol BC**. Press R (right ear). Place the vibrator on the **processus mastoideus** of the temporal bone of the right ear (see Fig. 3). Do not remove the headphones; on the left side keep the earphone on the ear, on the right side place the earphone on the cheekbone. Switch off TRACK, set noise level to 15 dB, then switch **TRACK** back on. Keep **STIM MODE** on.
10) Determine the hearing threshold for frequencies 1000 Hz, 500 Hz, 250 Hz and then 1500 Hz, 2 kHz, 3 kHz, 4 kHz, 6 kHz. Plot the obtained values in the
audiogram. Press L, switch sides for the vibrator and headphones, record the values for left ear and plot in audiogram.

11) Record the results of all measurements into the lab protocol.

Test questions:

1. What is the audible field?
2. Describe the sound conduction and detection in the human ear.
3. What is the range of frequencies audible to humans?
4. What is the loudness (measured in units of phon)? How would you determine the loudness in phons of a tone of given frequency and intensity level?