# Speech information systems

Basic Speech Acoustics I.

# Speech Information Systems - Basic Speech Acoustics I.

Laboratory of Speech Acoustics


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- What is this exercise about?
- Microsoft Form survey

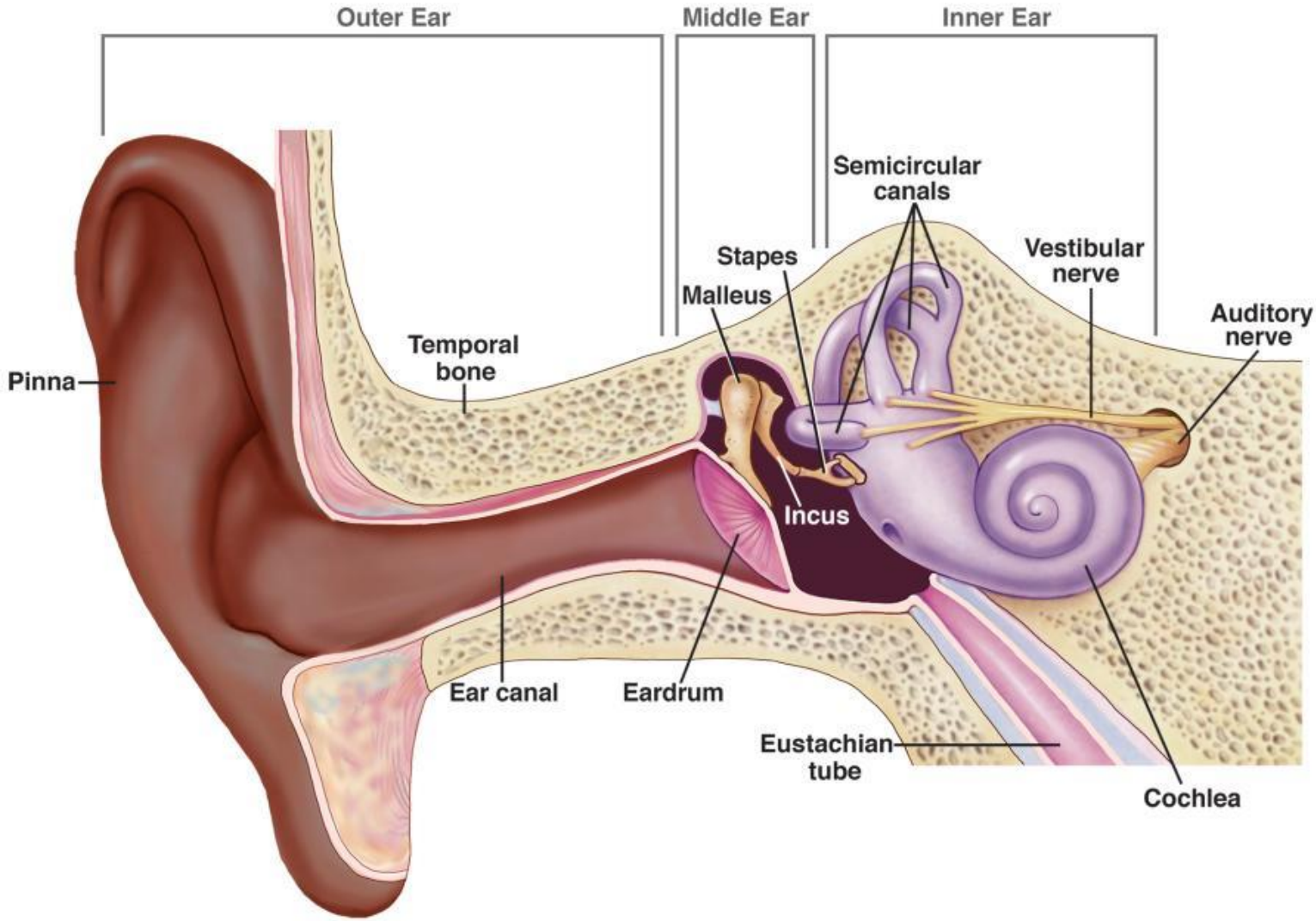
# Practice topics

- Concepts of hearing, sound intensity, dB scale
- Psychophysical factors
- More complex tasks
- Additional task

# Hearing

- How do we hear?

# Hearing


Outer Ear
Middle Ear
Inner Ear
Semicircular canals
Stapes
Malleus
Vestibular nerve
Auditory nerve
Temporal bone
Pinna
Incus
Ear canal
Eardrum
Eustachian tube
Cochlea

# Hearing

- How do we hear?
- Which of the organs listed below play a fundamental role in the hearing process?
  - oval window
  - hammer, malleus
  - hair cells
  - saddle
  - stapes
  - horseshoe

# Hearing

- What is the role of the hunting horn, the bassoon, the auricle/earpiece/pinna, and the Eustachian tube in natural speech communication?
- What is the role of the sickle, hammer, anvil/incus, spurs, and stirrups/stapes in natural speech communication?
- Why do we feel a tightening sensation in our eardrums during a sudden climb or descent of an airplane?
- What should we do to make this tense feeling go away as soon as possible?

# Hearing

- You need to be aware of the structure of the ear to master the subject.
- It's worth knowing about it just for its sheer genius.
- Also, the ear is a fragile instrument, let's take care not to expose it to unnecessary damage.
- What do we hear? Over what range?

# The decibel scale

- What is decibel scale? What is the intuition of using it?
- „The **decibel** (**dB**) is the logarithm of ratio of two measures, which is widely used in acoustics, physics and electronics.”
- It has several advantages:
  - it allows the comparison of extremely large and small values,
  - simplifies operations with ratios to simple addition and subtraction, and
  - the logarithmic scale of the decibel corresponds to the functioning of the human auditory and visual system.
- (acoustic decibel)
  - L [dB] = 10 * lg($\frac{I}{I_0}$), $I_0 = 10^{-12}$ [$\frac{W}{m^2}$] or
  - L [dB] = 20 * lg($\frac{p}{p_0}$), $P_0 = 2*10^{-5}$ [$\frac{N}{m^2}$] = [Pa]

# Logarithm as a function

- Domain: positive numbers
- Value set: real numbers
- (The base can be a positive number greater than 1)
  - $\log_a xy = \log_a x + \log_a y$
  - $\log_a x^k = \mathrm{k} * \log_a x$
  - $lg\ x = \log_{10} x$
- How many times is log(1000) greater than log(10)?

# Calculating sound intensity and amplitude in dB

- One speaker produces sound with an **intensity level** of 60 dB. We duplicate the sound source. How many dB will be the combined intensity of the two sound sources?
- Solution:
  - Intensity level: 60 dB = 10 * lg(y) dB => $y = 10^6$
  - $L = 10 * \lg (2*10^6) = 10*(\lg(2) + \lg(10^6)) \Rightarrow \sim 63$ dB

- The **amplitude of a speech wave** is doubled by a factor of 2. How much increase in dB is this?
- Solution:
  - Sound pressure level => L = 20 * lg(2 * y) => 20 * (lg(2) + lg(y))
  - ~6 dB increase

# Calculating sound intensity and amplitude in dB

- What is the sound pressure level in acoustic dB of a sinusoidal sound at 80 Hz with an effective sound pressure of 0.02 N/$m^2$? Use the appropriate unit!
- Solution:
  - N/$m^2$ is Pa, sound pressure level (using "20" as the factor in the dB equation)
  - x dB = 20*lg($\frac{p}{p_0}$)
  - p = 0.02 N/$m^2$ => p = 2*$10^{-2}$ Pa
  - $p_0$=2*$10^{-5}$ Pa
  - 60 dB = 20*lg($\frac{2*10^{-2}}{2*10^{-5}}$)

# Calculating sound intensity and amplitude in dB

An engineer needs to understand the dB scale, it also plays an important role in electronics.

# Psychophysical factors

- Which sinusoidal sound has the highest sound pressure level ?

1kHz / 50dB

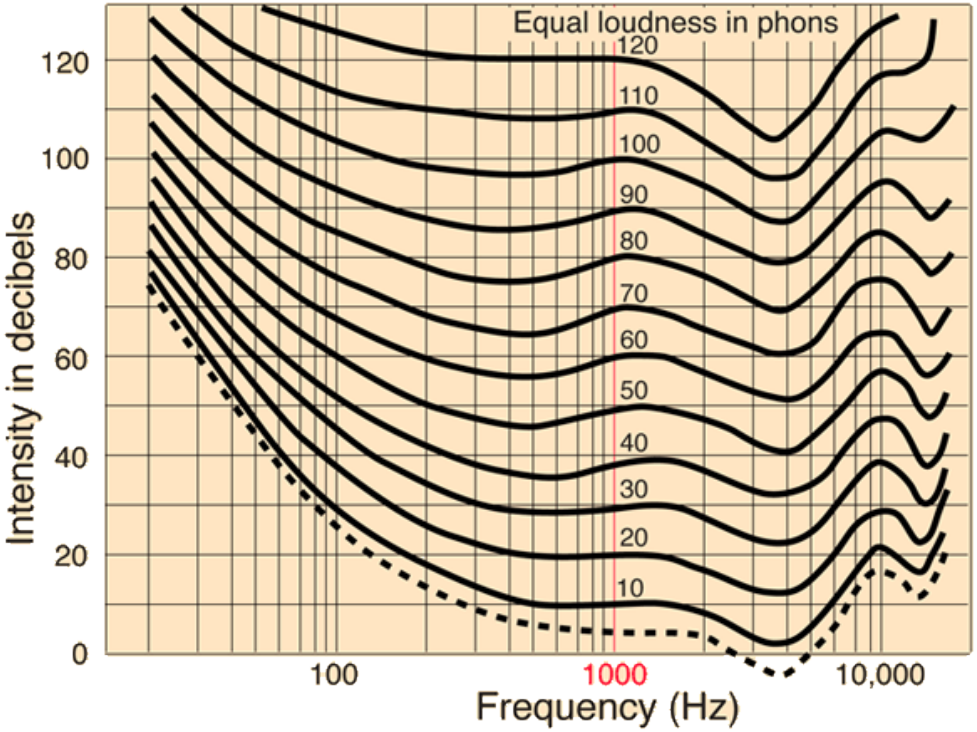
25Hz / 49phon

22kHz / 50dB

2kHz / 51phon

500Hz / 10dB

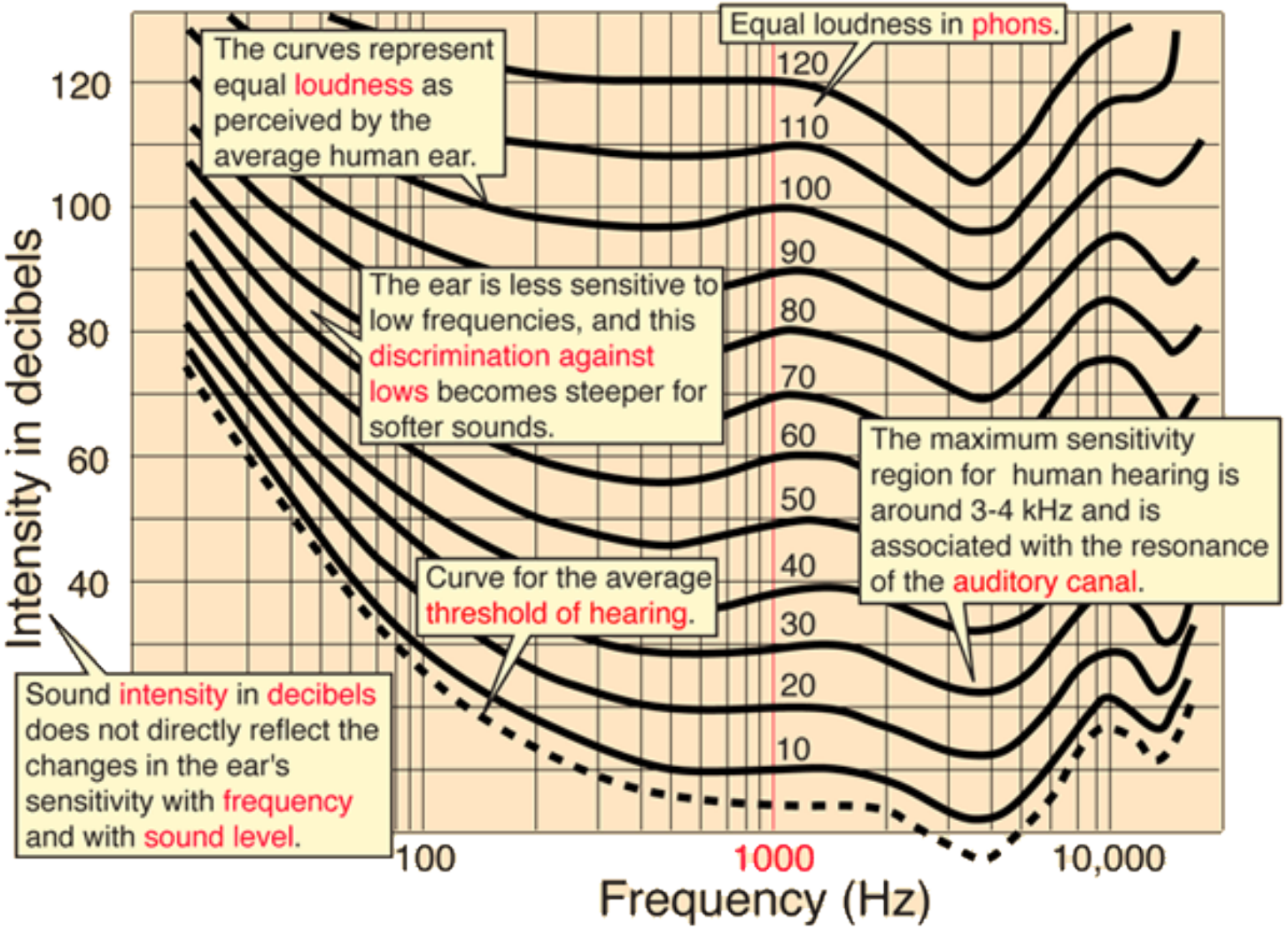
5kHz / 50 phons




- Phon curve : curve of equal loudness perception for sinusoidal sounds of different frequencies
  - X phon is as loud to an average person as X dB at 1 kHz.
- Solution:
  - They ask about intensity, so dB matters. Everything needs to be converted to dB.
  - That is, 50 dB = 50 dB > 10 dB; 2 kHz 51 phon = approx. 50 dB; 5 kHz 50 phon = approx. 44 dB
  - 25 Hz 49 phon is about 90 dB!!!

Reverse task: Which one gives the greatest sensation of loudness?

# Psychophysical factors



# Psychophysical factors

**We measured a sound pressure level of 120 dB. What could have been the source of the sound?**

- Petrol lawn mower \{from 1.5 m}
- Jet engine \{from 25 m}
- Whispered speech \{from 1 m}
- Normal speech \{from 1 m}
- Shouting \{from 15 m}
- Crying \{from 1 m}

**We measured a sound pressure level of 10 dB. What could have been the sound source?**

- Petrol lawn mower \{from 1.5 m}
- Mobile phone ringing \{from 2 m}
- Crying \{from 1 m}
- Normal speech \{from 1 m}
- Shouting \{from 5 m}
- Studio noise \{from 2 m}

| | | |
|---|---|---|
| **PAINFUL & DANGEROUS** | | |
| Use hearing protection or avoid | 140 | · Fireworks<br>· Gun shots<br>· Custom car stereos (at full volume) |
| | 130 | · Jackhammers<br>· Ambulances |
| **UNCOMFORTABLE** | | |
| Dangerous over 30 seconds | 120 | · Jet planes (during take off) |
| **VERY LOUD** | | |
| Dangerous over 30 minutes | 110 | · Concerts (any genre of music)<br>· Car horns<br>· Sporting events |
| | 100 | · Snowmobiles<br>· MP3 players (at full volume) |
| | 90 | · Lawnmowers<br>· Power tools<br>· Blenders<br>· Hair dryers |
| Over 85 dB for extended periods can cause permanent hearing loss. | | |
| **LOUD** | | |
| | 80 | · Alarm clocks |
| | 70 | · Traffic<br>· Vacuums |
| **MODERATE** | | |
| | 60 | · Normal conversation<br>· Dishwashers |
| | 50 | · Moderate rainfall |
| **SOFT** | | |
| | 40 | · Quiet library |
| | 30 | · Whisper |
| **FAINT** | | |
| | 20 | · Leaves rustling |

# Psychophysical factors

- Very interesting topic.
- These factors are important, for example mp3 encoding relies heavily on it.

# More complex tasks

- Sounds with fundamental frequencies of 500, 1000, 1500, 2000, 2500, 3000, 3500, 4000, 4500 and 5000 Hz and an intensity level of 60 dB are played simultaneously. What is the total intensity level of the complex sound consisting of these components?
- Solution:
  - 1 speaker has an intensity level of 60 dB
  - 10 speakers jointly is NOT equal with 10*60 dB!!! (120 dB is the pain threshold)
  - The multiplier of 10 can be moved outside the logarithm as a sum due to the rules of logarithm.
  - Total intensity level = 60 dB + 10*lg(10)dB = 70 dB

# More complex tasks

- How do we define the threshold of hearing using the acoustic dB and phon concepts? What is the characteristic frequency range of human hearing, human speech, and complex voiced speech?
- Solution:
  - Hearing threshold is 0 dB at 1 kHz (for a person with average hearing) => 0 phon curve corresponds to it
  - Human hearing: 20Hz-20kHz
  - Human speech: 60Hz-10kHz (8kHz)
  - Voiced sounds: 60Hz-4kHz

# Additional task

- Given a 1000 Hz sine wave with a sound pressure level of 80 dB in acoustic dB, how many times must the amplitude be changed to make the sound pressure level of 56 dB in acoustic dB while changing its frequency to 500 Hz?
- Solution:
  - Frequency doesn't matter
  - We want to achieve a 24 dB reduction, meaning the amplitude needs to be reduced.
  - 24 dB = 20*lg(x) => x is about 16, so the amplitude needs to be reduced to about 16-odd.

# Thank you for your attention!

Questions?

Test!