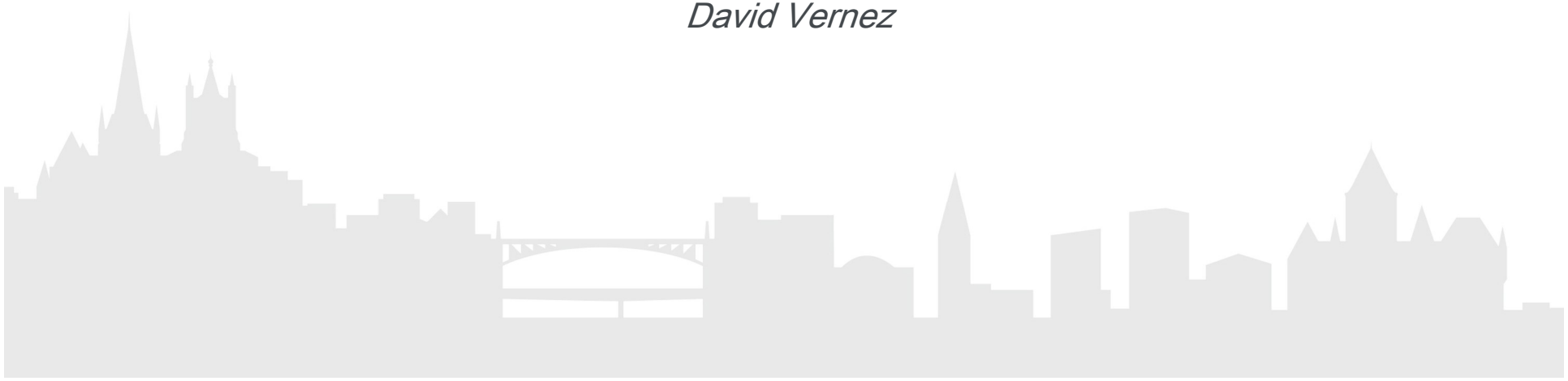
unisanté

Physical agents – Noise and vibrations

David Vernez



Noise

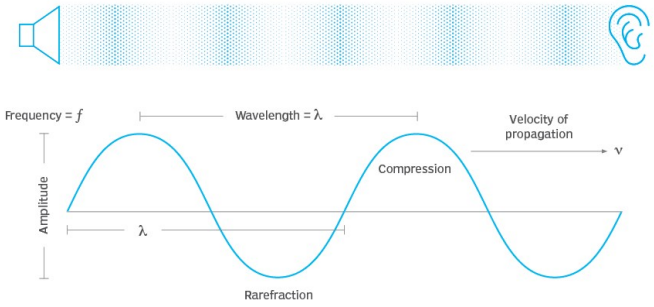
Course plan

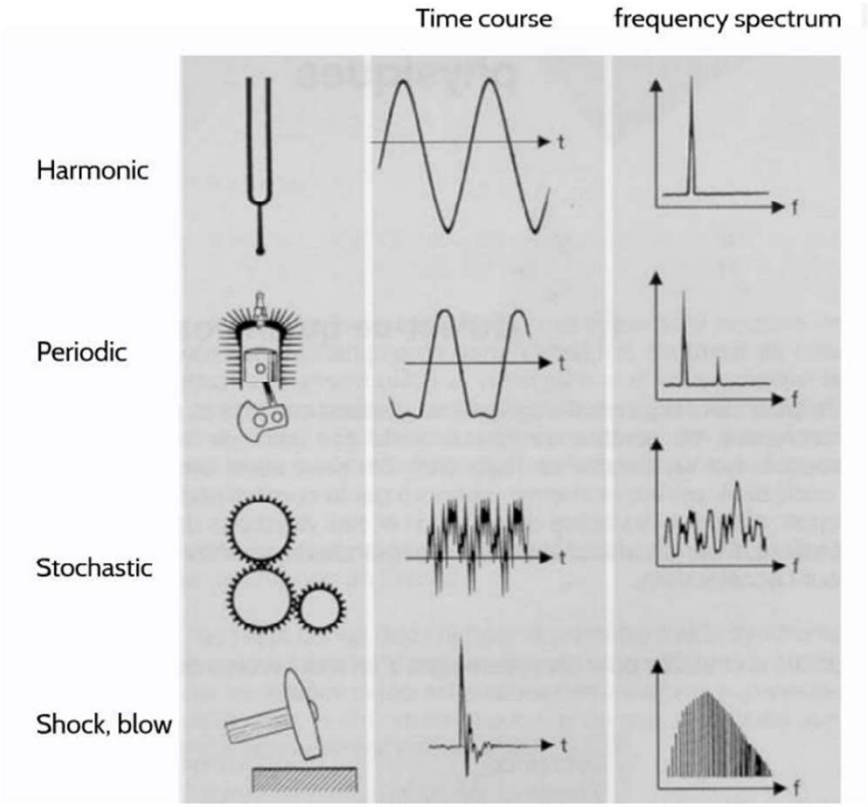
- Physics
- Audition
- Assessment and prevention

Noise

Definition

- The sound is produced by tiny oscillations in air pressure (alternating compressions and depressions)
- Frequency: number of periods per second (Hz)





Case study

The geothermal energy company

A geothermal energy company is drilling in urban areas. The drilling machines are noisy and often generate complaints from neighbors. A measurement taken near the construction site indicates a value of 78 dB(A).

Question (4.1a)

What is the difference between a sound and a noise ?

What does the (A) in dB(A) means ?

Noise

Definition

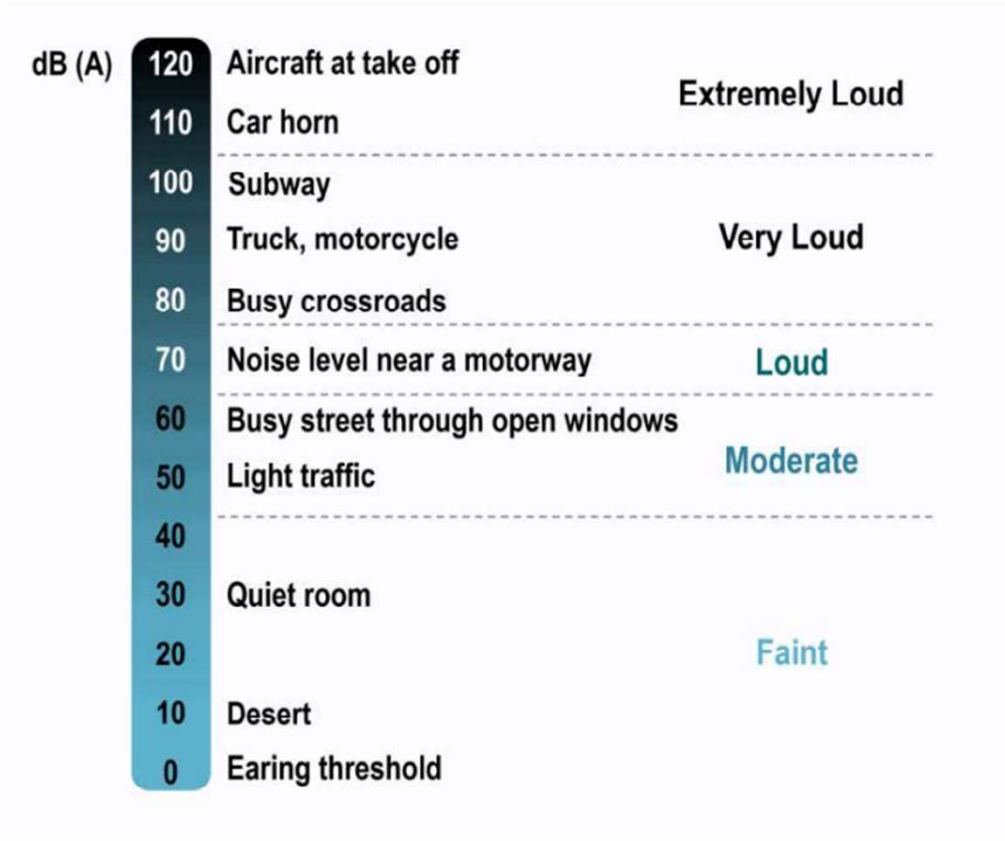
- Noise is measured in Decibels [dB] (logarithmic scale)

$$[\mathrm{dB}] = 20 \cdot \log \frac{P}{P_0}$$

P : measured acoustic pressure
P_0: reference acoustic pressure
$2 \cdot 10^{-5}$ Pa (hearing threshold)

$$[\mathrm{dB}] = 10 \cdot \log \frac{W}{W_0}$$

W : measured acoustic power
W_0: reference acoustic power
10^{-12} w



Noise

Addition of sources

- Addition of two sources of the same acoustic power leads to an increase of 3 dB
- The perceived difference is not proportional to the increase of sound power

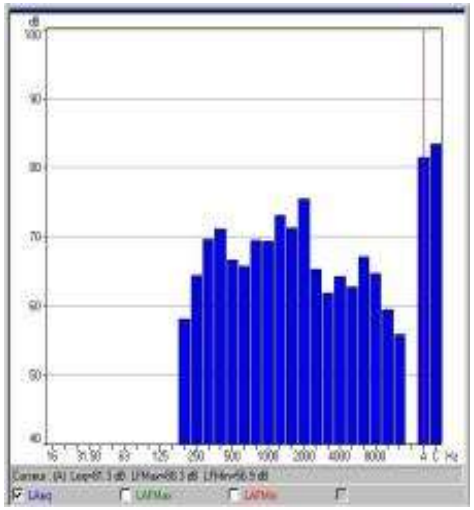
Increased perception	Noise level increase	Nbre of sources (noise power)
2 x louder	+ 10 dB	 x10
Significantly louder	+ 6 dB	 x4
Barely perceptible	+ 3 dB	 x2
Reference	+ 0 dB	 x1

General formula for noise addition

$$L_{tot} = 10 \log [10^{L1/10} + 10^{L2/10} + 10^{L3/10} + \ldots\ldots] \text{ dB}$$

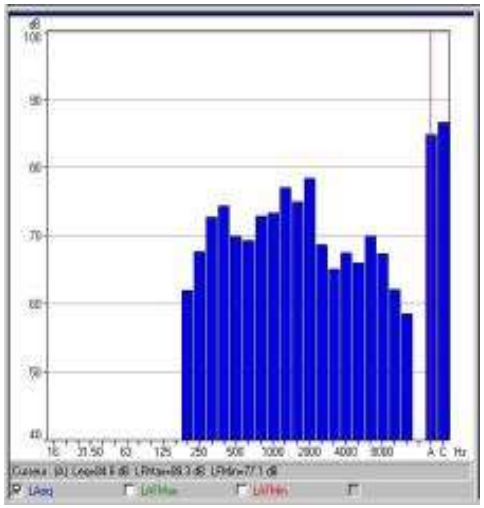
Noise

Adding of sources



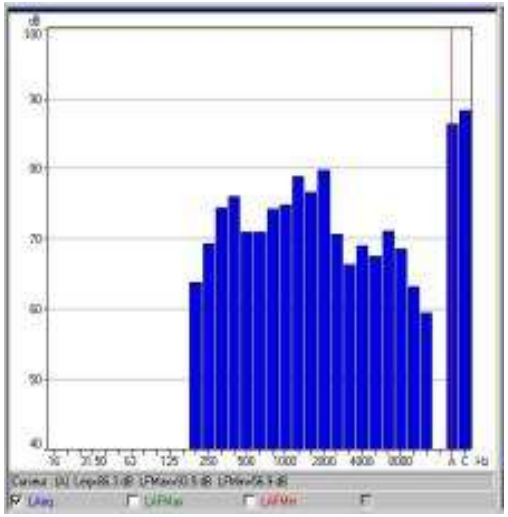
Slow punch press, 80 dB(A)

+



Fast punch press 85 dB(A)

=



Together

Noise

Assessment

- Sound level meters
  - Average sound level (Lm)
- Integrative sound level meters
  - Equivalent sound level (Leq)
- Dosimeter
  - Noise dose (%)
- Frequency analyzer
  - Spectral analysis

Noise

Average and equivalent noise

- Average level

  Integrated time measurement

$$L_m = 10 \cdot \log\left(\frac{1}{t_m} \cdot \int_0^{tm} \frac{p^2(t)}{p_0^2} dt\right) [dB]$$

  Average level over a reference time (often 8h) is a equivalent level (Leq)

- Equivalent level

  Integrated time measurement

$$L_{éq} = 10 \log_{10}\left(\frac{1}{100} \cdot \sum f_i \cdot 10^{\frac{Li}{10}}\right)$$

L_{eq} : equivalent sound level in dB(A)
F_i : time interval expressed in % of the reference period
L_i : sound level in dB(A)

Noise

Dose of noise

- Percentage of acoustic energy relative to the tolerated energy in workplaces (corresponding to **85 dB(A) during 8h**)

- A dose greater than 100% indicates that the permissible limit has been exceeded

$$ND = 100 \int_0^{T/8} \left| \frac{P(t)}{0.355} \right|^n dt$$

P(t) : sound pressure [Pa] weighted at time t
T : duration of exposure [hours]
0.355: pressure [Pa] corresponding to 85 dB(A)
N: 2 (ISO) or 1.2 (USA)

Case study

The geothermal energy company

Several machines must operate under the same roof. The site manager is concerned about the resulting noise.

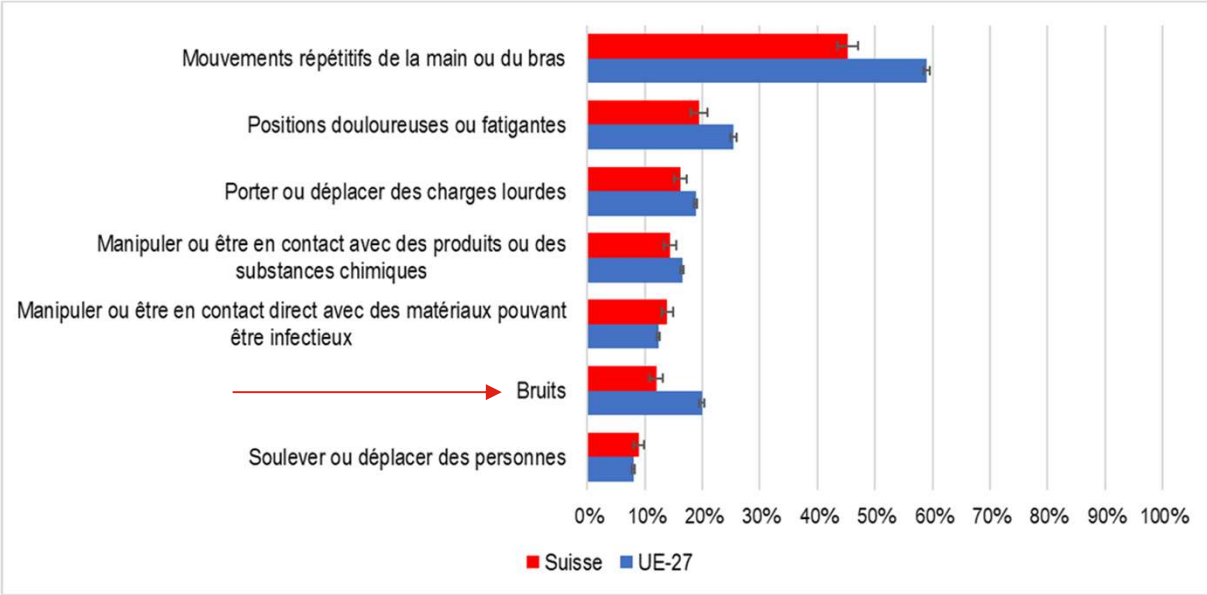
Question (4.1b)

Calculate the sound level resulting from 3 machines each producing the following levels: 80 dB(A), 85 dB(A) and 90 dB(A).

Noise

Occupational exposure to noise

- Relatively high prevalence of exposure
- 45% of recognized occupational diseases in Switzerland are hearing impairments
- Approximately 1,000–1,200 cases per year



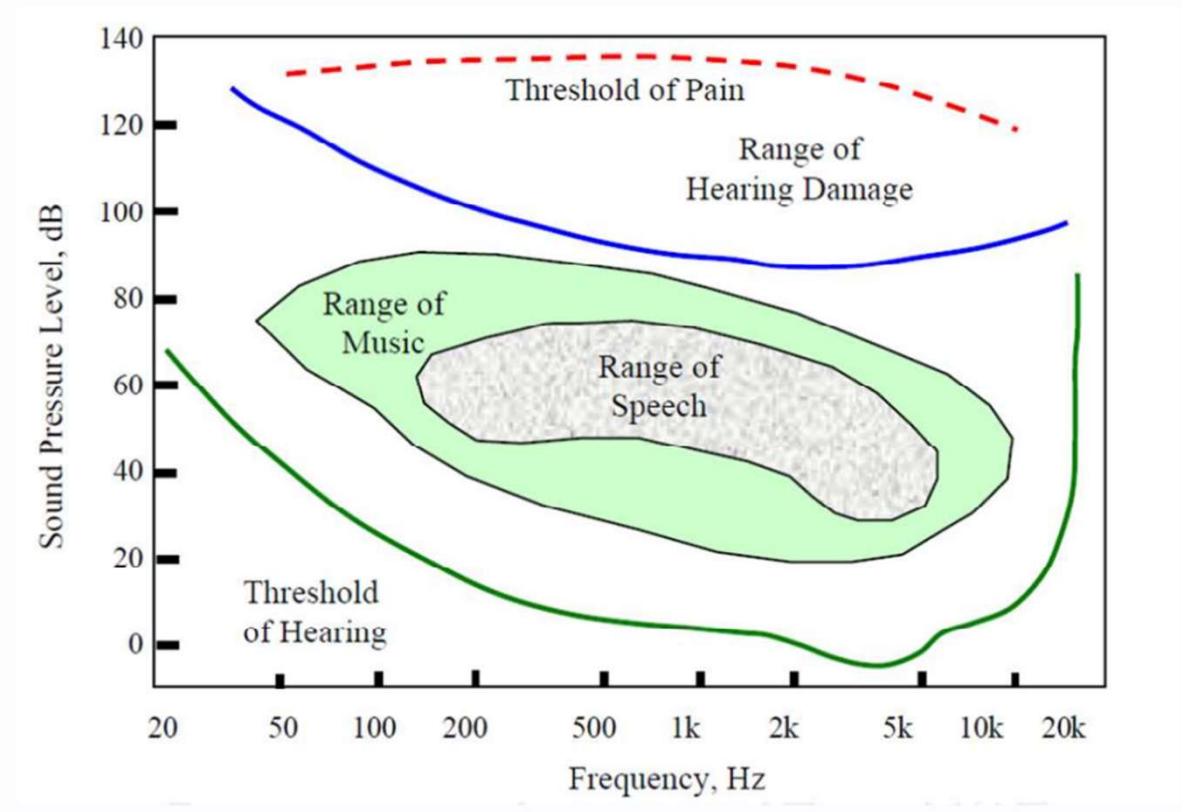
EWCTS 2021. How often does your main professional activity include the following elements? Answer: "Often" or "Always."

unisanté

Noise

Audition

- The human ear (intact) can hear sounds from 20-20’000 Hz

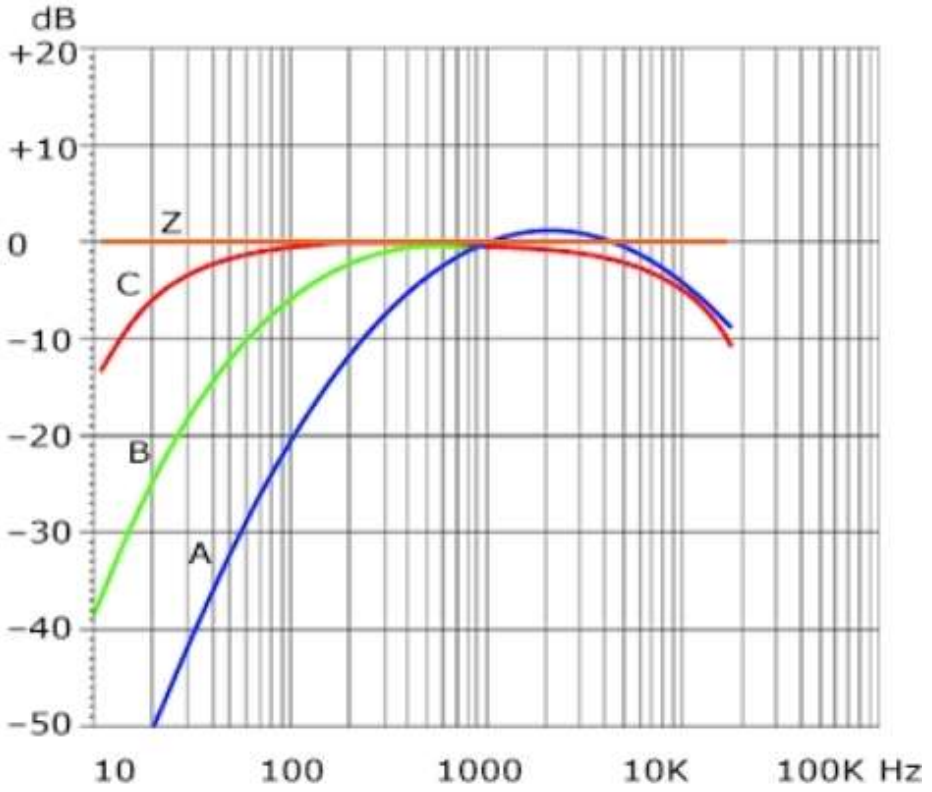


Noise

Acoustic weighting

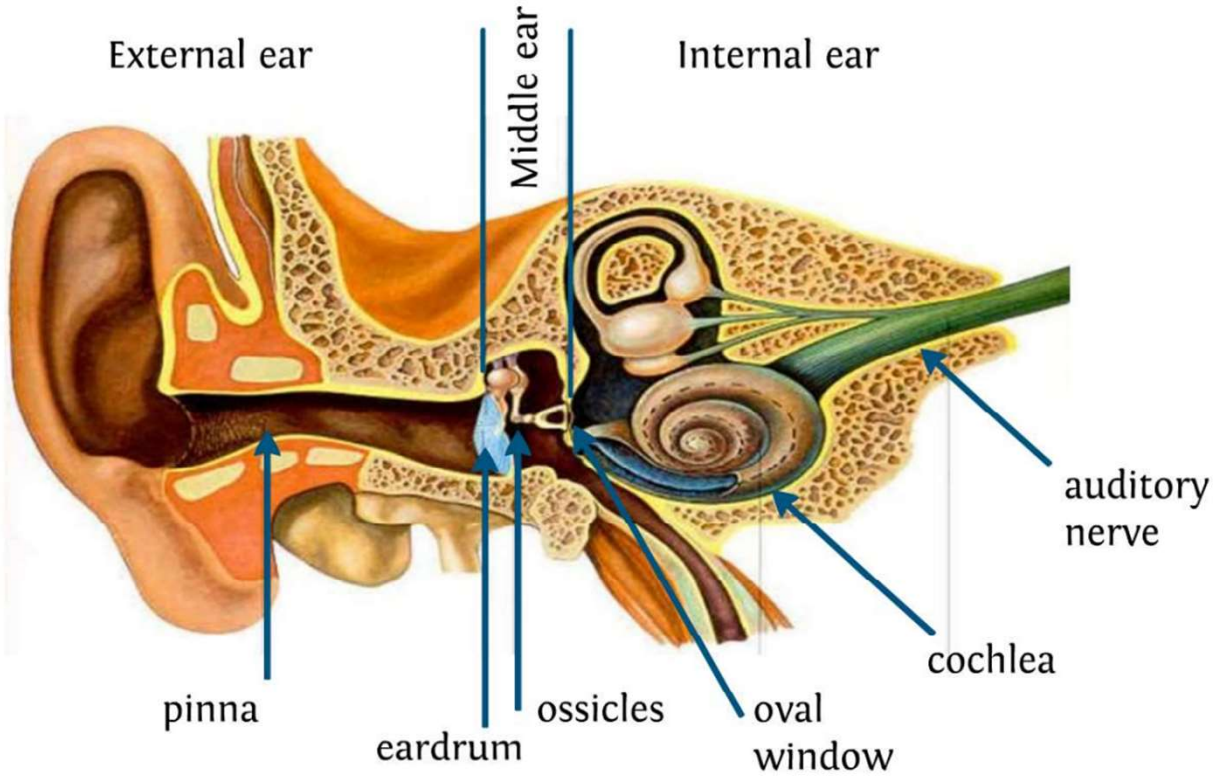
- Filters A-C, sensitivity of human ear
  - A: Usual filter
  - B: Moderate noise (old)
  - C: High intensity sounds

- Filter Z, no weighting



Noise

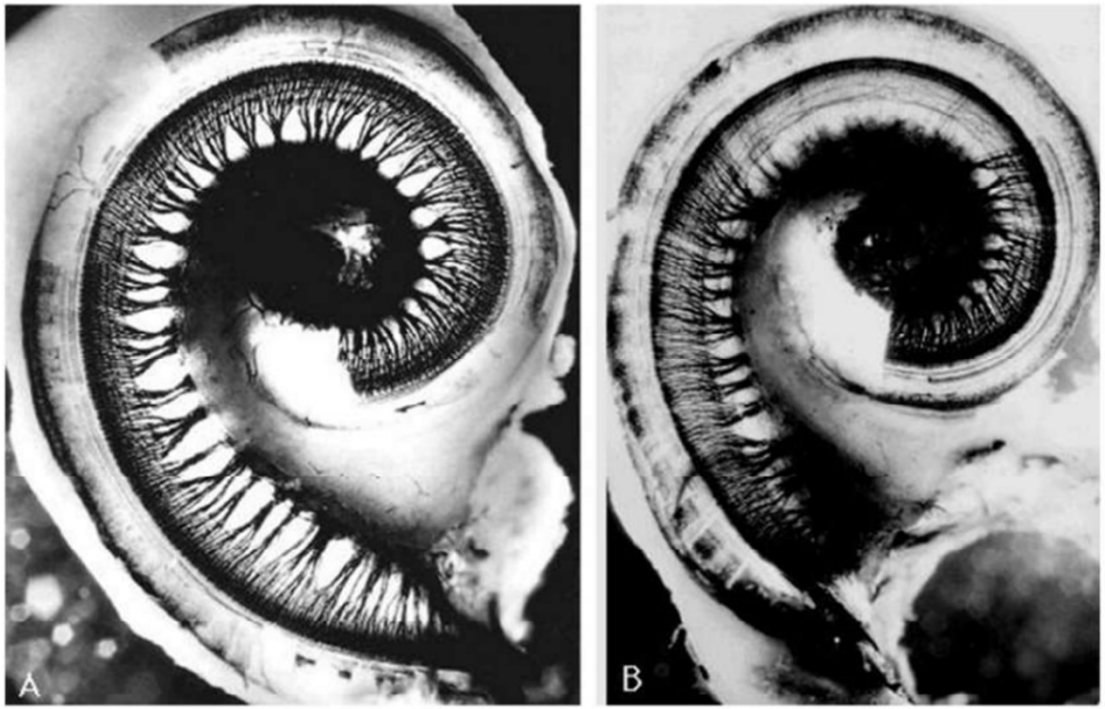
Ear physiology



Noise

Damage to the inner ear

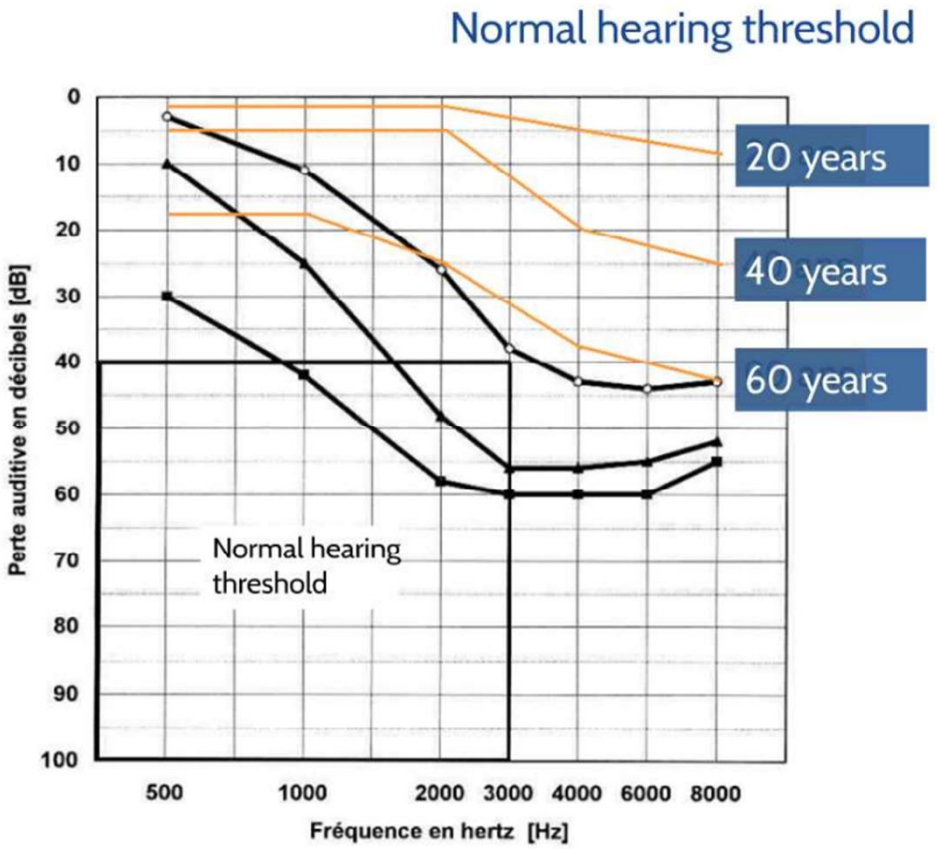
- Excessive noise exposure leads to premature damage
- Destruction of the cilia lining the cochlea
- Loss of hearing in certain frequency ranges



Noise

Audiogram

- Hearing acuity decreases with age (persbiacusia)
- Regular exposure to noise > 80 dB(A) also cause a decrease in acuity
- Measured by audiometry



Noise

Ototoxicity

- Agents that are toxic to the sensory organ of hearing or potentiate the effects of noise exposure

Effects

- Poisoning of the outer hair cells
- Symptoms identical to noise exposure, no specific tests
- Epidemiological and animal evidence

Substances

Aromatics:

Toluene, styrene, ethylbenzene

Carbon monoxide, hydrocyanic acid [P]

Antibiotics

Diuretics, salycilates, anti-tumor agents [R]

[P] potentiating
[R] reversible

Noise

Permissible limits

- Noise disturbances (Suva and OLTr 3) recommendations

Activities	normal requirement Leq [dB(A)]	increased requirement Leq [dB(A)]
industrial activities, arts and crafts	< 85	< 75
office work and similar activities	< 65	< 55
intellectual activities requiring great concentration or creativity	< 50	< 40

Immediate and temporary effects

- Cardiovascular disorders, decreased attention, decreased memory capacity, agitation, reduced visual field, gastrointestinal disorders

Long term effects

- Physical and nervous fatigue, insomnia, bulimia, chronic high blood pressure , anxiety, depressive and aggressive behavior

Case study

The geothermal energy company

The operator's exposure to noise from a small drill is measured over a period of 4 hours. The noise measured over this period is 67%. Calculate the average noise level in dB(A) during this period.

Question (4.1 c)

What is the average noise level during this period ?

What preventive measures would be appropriate?

Noise

Control (STOP strategy)

- Reduce emission
  - Noiseless machines
  - Change processes e
  - Eliminate the hazard

- Reduce transmission
  - Insulation against vibrations
  - Damping
  - Hooding

Noise

Control (STOP strategy)

- Limit exposed area and population
  - Subdivide the premises
  - Concentrate sources
  - Acoustic dampening of ceiling and walls
- Work organization
  - Limit exposure duration
  - Job rotation
- Individual protection
  - Information, training
  - Protective equipment
  - Medical prophylaxis

Physical agents – Noise and vibrations

Vibrations

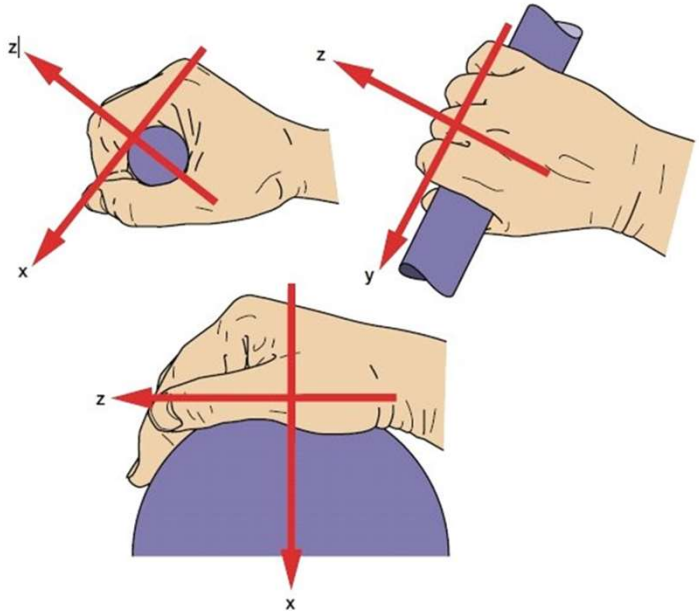
Vibrations

Definition

- Three possibilities to express a vibration
  - Displacement [m]
  - Velocity [m/s]
  - Acceleration [m/s^2]

- Similar than noise in terms of frequency and intensity integration, but:

- Vibrations must be measured along the three conventional axis
  - X: horizontal “front- back”
  - y: horizontal “left - right”
  - Z: vertical



Vibrations

Exposure situations

- Whole body
  - Construction machinery, tractors, etc.
  - Low frequencies (2-8 Hz)

- Hand-arm vibrations
  - Jackhammer, sander, grinder, router, etc.
  - Medium-high frequencies (4-800 Hz)

bulldozer

Using a router

Vibrations

Effects on target organs

Frequency	Effect
Low: 0.5-16 Hz	motion sickness, spinal injuries, neurovegetative disorders
Medium: 10-80 Hz	osteoarticular lesions of the upper limbs
High: 80-1000 Hz	peripheral vascular lesions (Raynaud's syndrome or dead fingers), neuromuscular lesions

Vibrations

Pathologies related to hand-arm vibrations

- Vascular diseases
  - Vibration syndrome (Raynaud's disease)
- Neurological disorders
  - Vibration neuropathy, loss of sensitivity
- Osteoarticular disorders
  - Joint pain, loss of mobility

Vibrations

Permissible limits

- European directive 2002/44/EC
  - Hands-arms and whole body
  - Occupational exposure: 8h/d and 5 f/wk

	action values	exposure limit values
manubrachial	2.5 m s^{-2}	5.0 m s^{-2}
total body	0.5 m s^{-2}	0.8 m s^{-2}

Vibrations

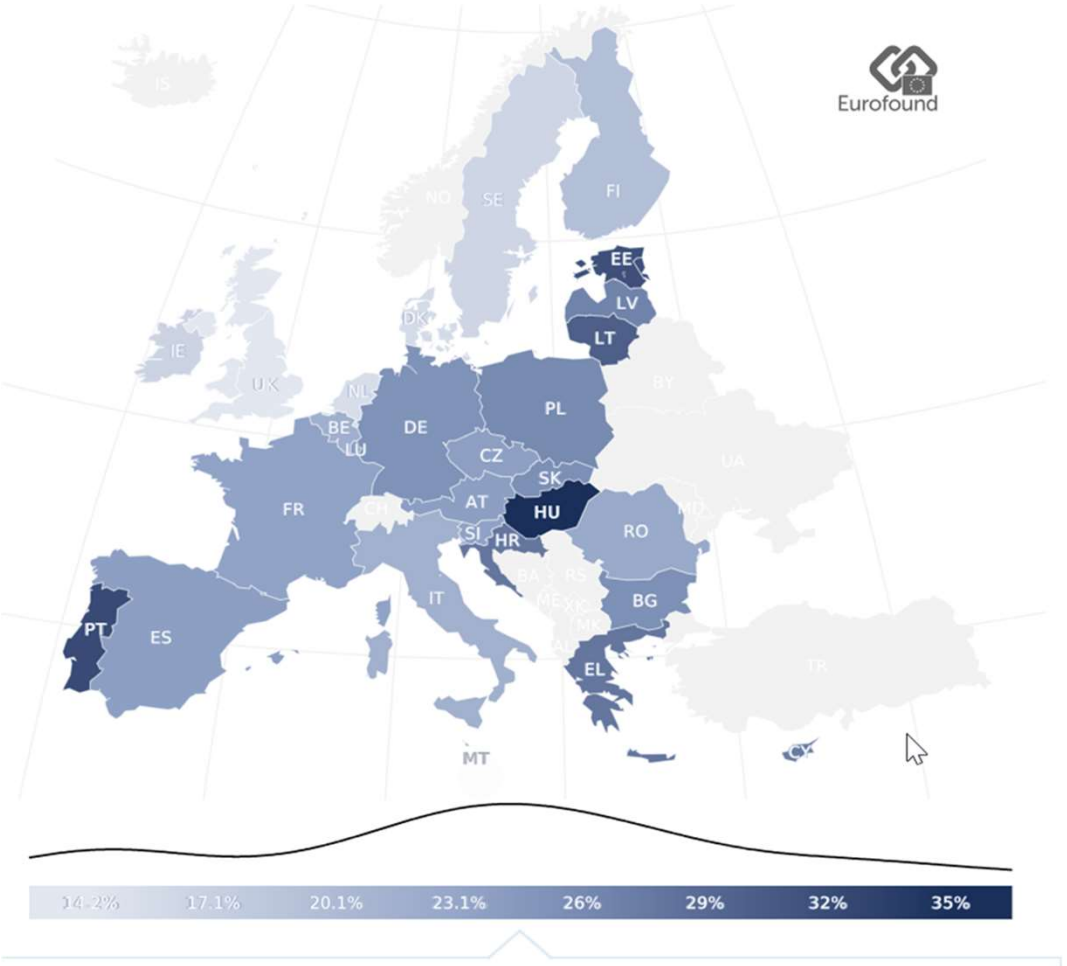
Prevention, control

- Process, less polluting machines
- **Dampening**
- Exposure time, rotation, information
- Personal protection

Vibrations

Definition

- Relatively high prevalence
- 23% of EU workers report being exposed to vibrations >25% of their time (2010)
- Between 1-20 cases recognized per year as occupational diseases
- Contribution to low back pain



Case study

The geothermal energy company

In spite of hearing protections, the operator of a large drill complains of hearing annoyance and sleep disorders. A noise measurement showed a noise level of 92 dB(A). Impact noise measurement was also measured and showed 96 dB(C), which turns out to be lower than the legal threshold.

Question (4.1 d)

What hypothesis(es) can you formulate to explain the problem, what do you recommend?