



Acoustics

Acoustics

- Deals with the creation of sound waves, their transmission in space and with perception of sound
 - Physical Acoustics - observes the way of sound creation and transmission in space, reflection and absorption of different materials
 - Physiological acoustics – sound creation in the vocal cords and the perception of sound in the auditory system, the effect of noise

Sound

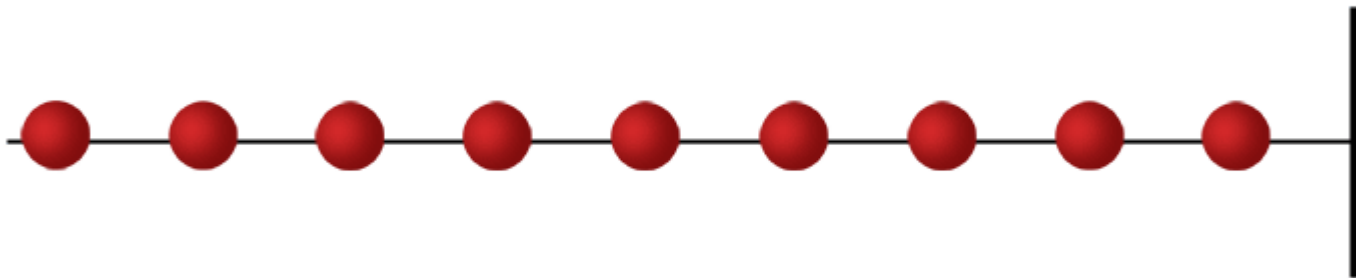
- The origin of the sound comes from an arranged oscillatory motion of a particle environment, which occurs when the particles are supplied with energy
- As a result of the interaction of particles, oscillating movement is transmitted to the neighboring particles = sound wave propagation

Sound wave propagation

- Propagation speed depends on:
 - Environment
 - Temperature, pressure
 - Humidity
- Sound waves propagation can happen by longitudinal or by transverse oscillation

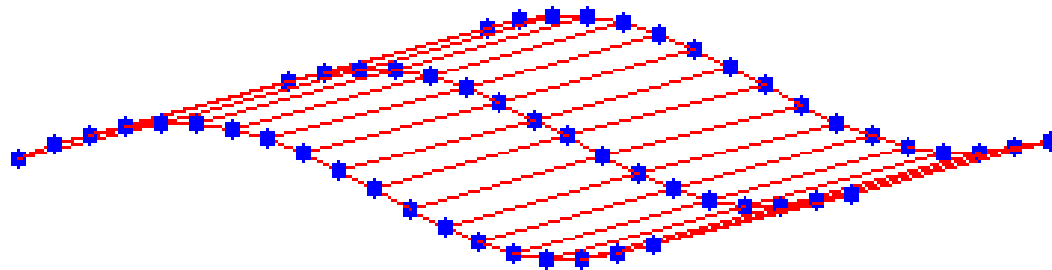
Sound wave propagation

- Longitudinal oscillation
 - Gaseous, liquid and solid environment
 - Thickening and thinning of particles



Sound wave propagation

- Transversal oscillation
 - Solid environment
 - Oscillation is perpendicular to the direction of the sound wave propagation



Basic quantities

- Frequency of oscillatory motion f (Hz)
- Period of oscillatory motion T (s)
- Propagation speed c (m.s⁻¹)
- Wave length λ (m)

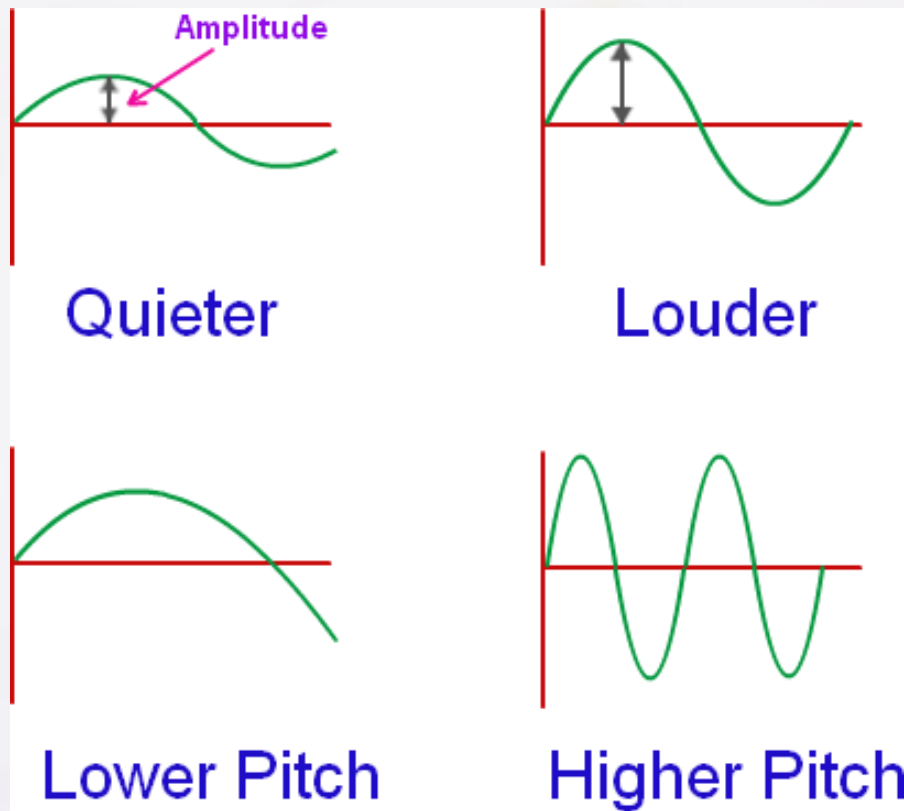
$$\lambda = \frac{c}{f}$$

$$\lambda = c.T$$

Sound

- Infrasound - low frequency (16-20 Hz), inaudible to human ears
- Audible sound area (20-20 000 Hz;)
- Ultrasound - Frequencies higher than 20,000 Hz

Sound



Sound

- Sound
 - Tones - Musical sound, tones – dependence of intensity on time is a periodical function (Vowels)
 - Simple
 - harmonical, sinus function (sine wave)
 - Compositied
 - Periodical; but not sine wave. Basic frequency + other hramonical frequencies
 - Noises - dependence of intensity on time is not a periodical function (consonant)
- Pitch – dependence on frequency
- Tone Timbre – dependence on partial tones intensity

Acoustic displacement

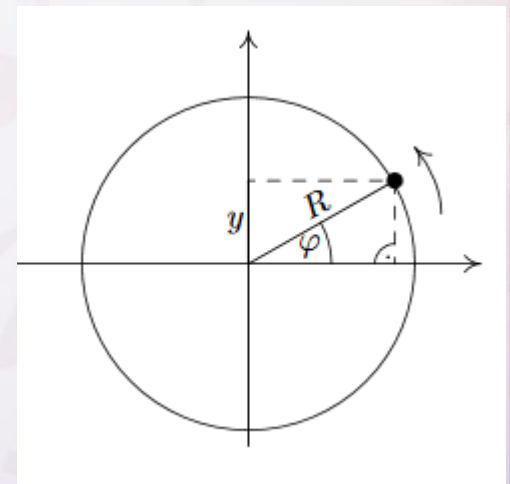
- Acoustic displacement is deflection of a particle from its equilibrium position, it is caused by acoustic wave
- If a displacement meets following requirements:

$$a = a_{\max} \cdot \sin(\omega \cdot t) = a_{\max} \cdot \sin(2\pi \cdot f \cdot t)$$

then the oscillation is harmonical

a_{\max} = amplitude

- $\Delta\varphi = \omega\Delta t$
- $\omega = 2\pi f$



Acoustic velocity of oscillatory motion

- Immediate speed of oscillating particle:

$$v = v_{\max} \cdot \cos(\omega.t) = v_{\max} \cdot \cos(2\pi.f.t)$$

$$v_{\max} = a_{\max} \cdot \omega = a_{\max} \cdot 2\pi.f$$

Acoustic pressure

- Movement of vibrating molecules is causing local pressure changes

$$p = p_{\max} \cdot \cos(2\pi \cdot f \cdot t)$$

$$p_{\max} = \rho \cdot c \cdot v_{\max}$$

Effective values

- at some calculations instantaneous values of acoustic velocity and sound pressure can be replaced with so called effective values
- For the harmonic pattern of oscillations effective pressure and speed can be determined by the relationship:

$$v_{ef} = \frac{v_{\max}}{\sqrt{2}}$$

$$p_{ef} = \frac{p_{\max}}{\sqrt{2}}$$

Acoustic impedance

- **Acoustic impedance** - describes the acoustic properties of the environment. It is calculated as the ratio of the effective values of sound pressure and acoustic velocity

$$Z = \frac{p_{ef}}{v_{ef}} \quad Z = c \cdot \rho \quad \text{Pa.s.m}^{-1}$$

- The impedance is characteristic for each environment; affects the size of the reflection at interfaces between environments
- By passing through the interface the propagation speed c is changed
- Passage through environment may result in partial absorption of energy (reduction in amplitude and acoustic velocity)

Intensity

- Intensity – the amount of energy that passes through an area perpendicular to the propagation direction of waves per time unit

$$I = \frac{P}{S} \qquad I = \frac{p_{ef}^2}{\rho \cdot c}$$

$$(W \cdot m^{-2})$$

Loudness

- Level of intensity

- Range of perceived intensity in $\text{W}\cdot\text{m}^{-2} = 10^{12}$

- Level of intensity creates more practical intensity description

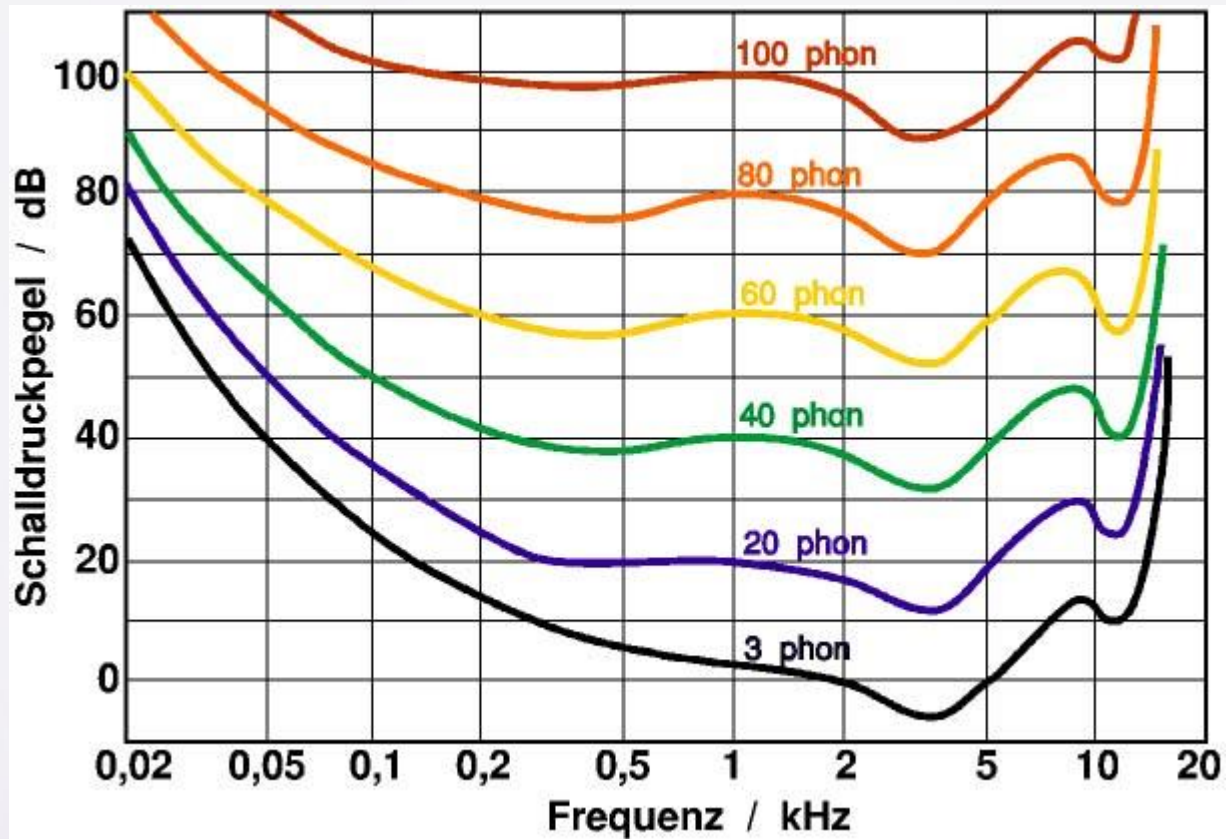
$$L_{(dB)} = 10 \log \frac{I}{I_0}$$

- Loudness perception is subjective;
Furthermore, the human ear differently sensitive to different frequencies

- Loudness level Λ (Ph – phon)

- 1 phon corresponds to the intensity level of 1 dB for reference tone at a frequency of 1 kHz

Loudness



Physiological acoustics

- Voice

- Vocal cords: two ligaments stretched between the thyroid cartilage and vocal cord cartilage; during speaking, the vocal cords are stretched, thus changing the lumen
Exhaled air vibrates => vibrating vocal cords rhythmically interrupt the flow of air going out of the trachea

Physiological acoustics

- Voice
 - larynx, oral cavity and nasopharynx = **voice tube** = gives human color to laryngeal voice
 - Great influence on the final form of sound has **resonance**
 - The final formulation into syllables is also possible due to upper respiratory pathways, mouth, tongue, lips, and teeth
 - Vocal strength increases with increasing the airflow through the glottis

Physiological acoustics

- Area of hearing **16 Hz to 20,000 Hz**
 - we perceive 1000-5000 Hz best
- Below 16 Hz **infrasound**
- Over 20,000 Hz **ultrasound**
- **Outer ear** - captures and maintains signal; auricle (pinna) and external ear canal; most audible sounds are sounds that are coming in an angle of 15° to the axis of both ears, external ear canal = resonator (**2000-6000 Hz**)

Physiological acoustics

Middle ear

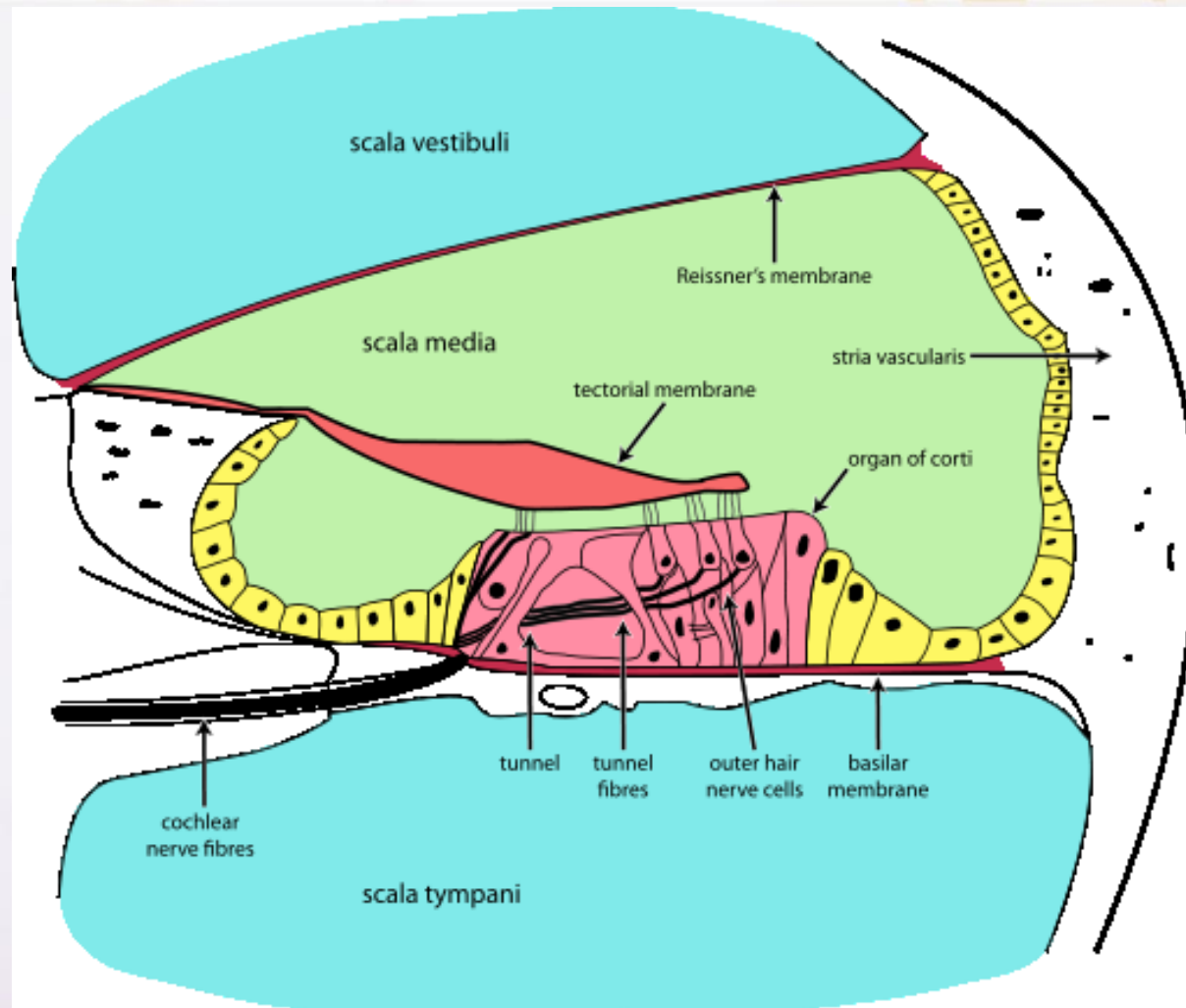
- Ear drum (connective pellicle) hammer, anvil, stirrup
- Transmission of the acoustic signal from the external environment to the inner ear fluid
- Transfer between environments means energy loss; compensation:
Drum with a large flat area => oval window (20x)
Hammer - Anvil: unequal lever; rotational motion

Physiological acoustics

Inner ear

- the Labyrinth: Cochlea
- the vibrations are transmitted through the bones to the perilymph
- transmission of vibrations on the basilar membrane
- the sensory organ - the organ of Corti - hair sensillas

Physiological acoustics



Physiological acoustics

- Outer hair cells (20 000) – the amplifier
- Inner hair cells (4000) – main neural output
- Pathway to receptors
 - **Conduction through middle ear** – most effective
 - Bone conduction – skull bones

Hearing examination

Audiometry - examination of the hearing threshold in the entire spectrum of acoustic frequencies

Audiometer - low frequency oscillator

- generation of the acoustic signal
- the examination is conducted in each ear separately
- in acoustically shielded space
- recording levels of intensity for each frequency

Hearing examination

Tuner tests - used to distinguish perception disorder and conduct disorder

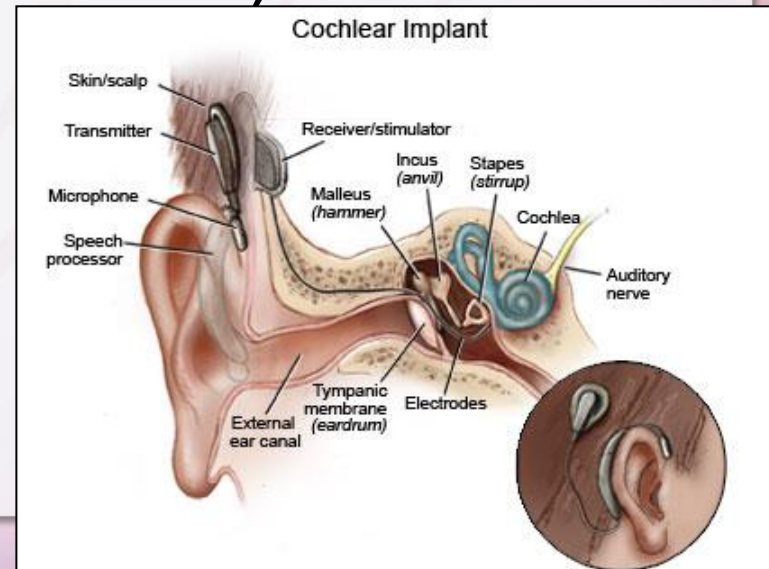
- Weber test - comparing the quality of audibility in each ear
- Rinne test - Comparison of middle ear and bone conduction
- Schwabach test - comparing the length of the bone hearings in patient and doctor (assuming that the doctor has a healthy sense of hearing)

Hearing examination

- Hearing disorders
 - **middle ear** sound conduction disorder (plug, mucus, inflammation); compensation by bone conduction
 - Perception disorders of the **inner ear**
fatigue - system noise exposure,
degeneration = bone conduction can not compensate for this type of disorder

Hearing examination

- Hearing aid – microphone, amplifier, speakers
- Cochlear implants– compensation for loss of or inadequacy of the inner ear (speech processor + receiver/stimulator)



The background of the slide is a light, warm-toned gradient with various musical notes and symbols scattered across it. The notes are in shades of yellow, orange, and pink, and include treble clefs, bass clefs, and various note heads and stems. The overall aesthetic is soft and artistic.

Ultrasound and Ultrasound diagnostics

Ultrasound

- Ultrasound
- acoustic waves
- frequencies higher than 20000 Hz
- beyond hearing

Ultrasound

Creating ultrasound

- magnetostrictive generators
 - changing the volume of ferromagnetic materials due to the ambient magnetic field
 - the maximum frequency of 60 kHz
- piezoelectric generators
 - Indirect piezoelectric effect = material deformation due to voltage
 - Usually, 1-20 MHz

Ultrasound effects

- **Mechanical** - sound particle vibration = alternating pressures = material degradation
- **Dispersion** - the preparation of fine emulsions and suspensions
- **Heat** - friction of vibrating particles; a large amount of heat is generated at the interface tissue with different acoustic resistance
- **Physical, chemical** - energy supply => excitation, speeding up chemical reactions; depolymerization, radical formation in an aqueous environment

Biological effects of ultrasound

- Enhancing membrane permeability
- lowering the nerve fibers conduction of
- Increasing the pH of tissues
- Analgesic, spasmolytic effect

- Intensity of 1.5 W.cm^{-2} **positive** effect
- Intensity 3 W.cm^{-2} **negative** effect **reversible**
- Above intensity 3 W.cm^{-2} **irreversible** effect

Ultrasound diagnostics

- The ultrasonic detection devices use the piezoelectric effect
- The ability of crystal material deformation by a voltage (vibration source) and the ability of the crystal during its deformation to generate a voltage (detection)
- Ultrasonic transducer - silica crystals, ceramic materials

Ultrasound diagnostics

- At the interface of two environments that differ in acoustic impedance (resistance), there is a reflection of the ultrasonic waves
- The ratio of the former and the reflected intensity R

$$R = \left(\frac{Z_2 - Z_1}{Z_2 + Z_1} \right)^2$$

$R = 0$: Homogeneous environment

R close to 0: Tissue with similar impedance

R closer to 1: Bone and soft tissue

Ultrasound diagnostics

- Intensity decreases exponentially going through an environment:

$$I = I_0 \cdot e^{-\alpha d}$$

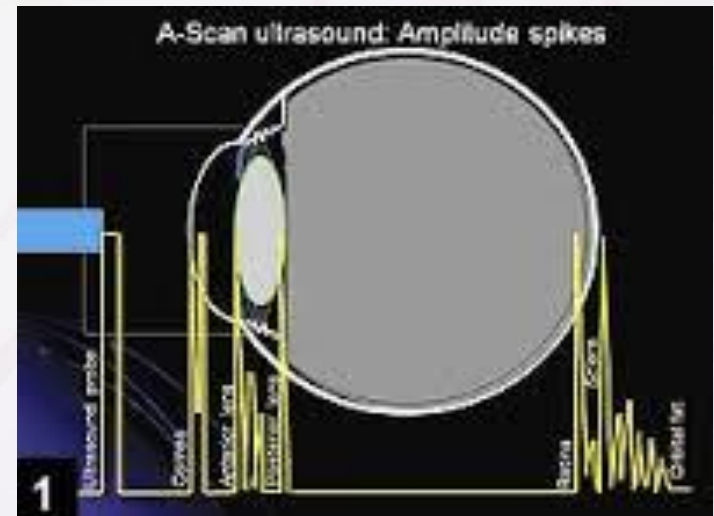
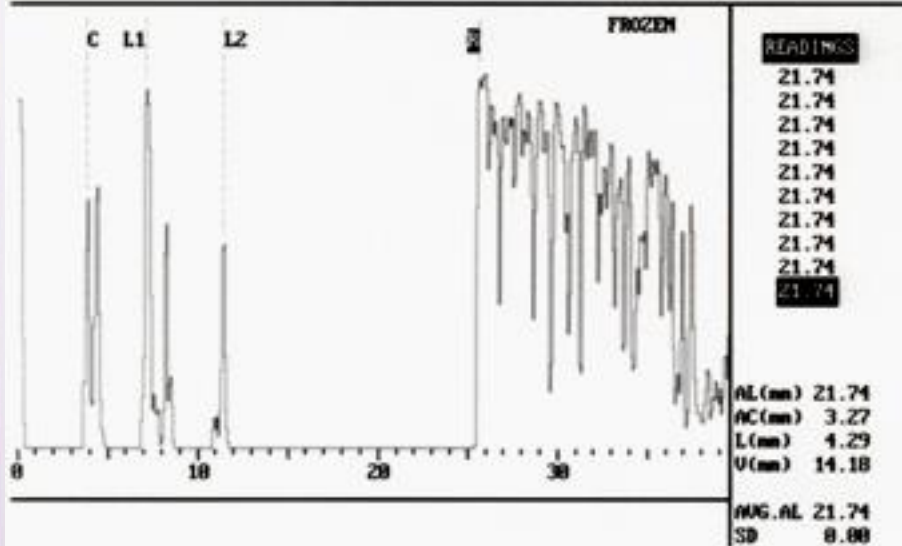
- d = length of the layer (m); α = absorption coefficient (m⁻¹)

Ultrasound diagnostics

- Display Type A – signal as shown on the timeline as pulses

●

Patient: Clinic: E VALLEY OPH 12/18/00
Patient ID: K7954 Setting: IMMERSION 1 Gain: 64 04:23:40 PM
Eye: OS/LEFT Operator: KATY Depth: 4.8
Type: Phakic Freeze: Automatic Vel AC: 1532 L: 1532 U: 1532
K1: --,-- Save: Manual
K2: --,-- Technique: Immersion



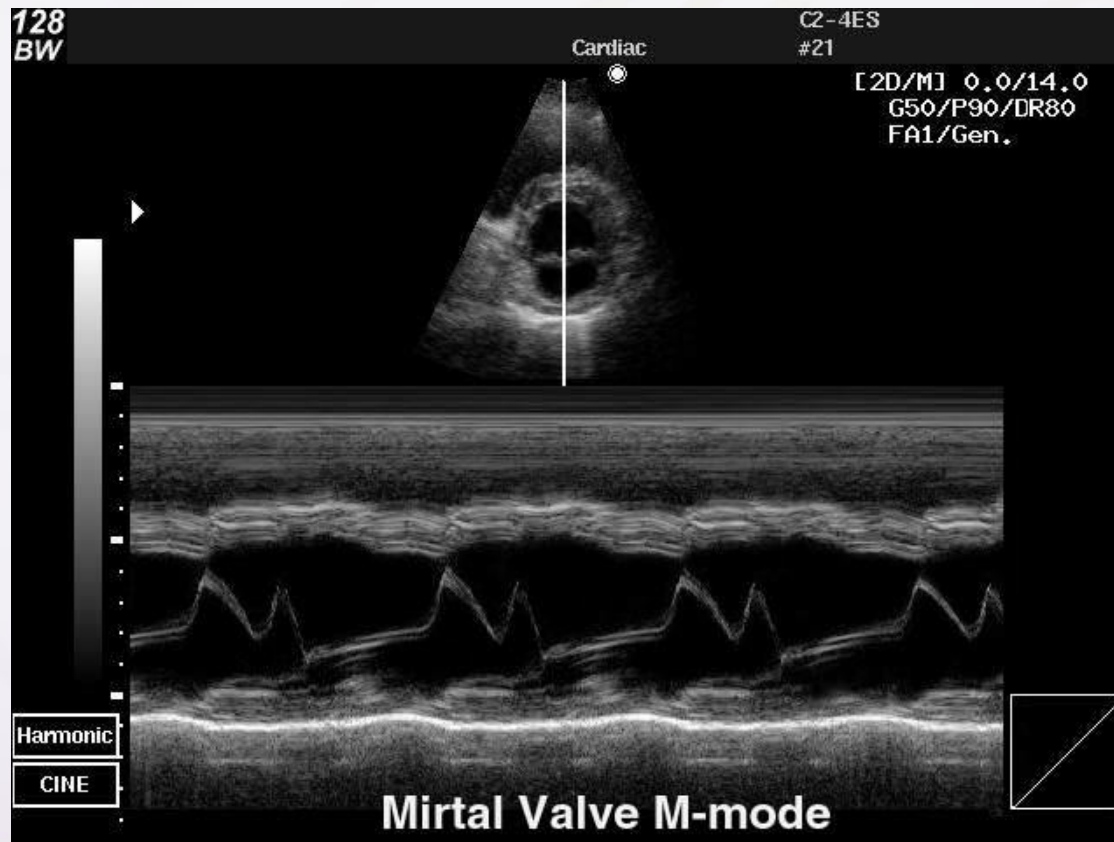
Ultrasound diagnostics

- Display Type B signal is displayed as dots on the screen with different brightness; tissues with higher levels of reflection are brighter (echogenic)



Ultrasound diagnostics

- M - display: subtype of type B display following the moving structure in relation to time



Ultrasound diagnostics

- 3D view – composed of high number 2D images



Ultrasound therapy

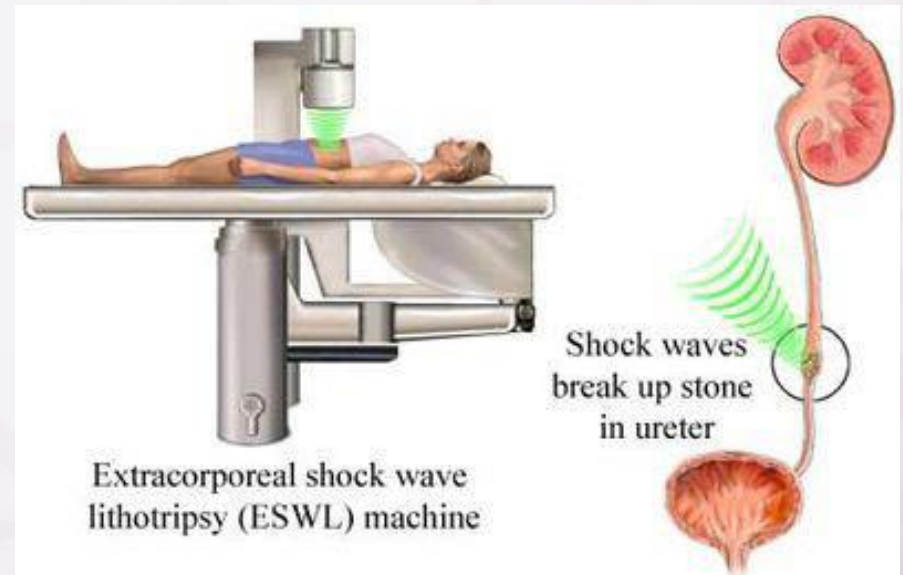
- Frequency 800 - 1000 kHz
 - Uses biological effects of ultrasound on the organism (increased permeability, increased pH, decreased neurotransmission)
- This increases blood circulation, metabolism
Spasm-analgetic effect

Ultrasound therapy

- Low-frequency ultrasound 20 to 30 kHz (magnetostrictive vibration source)
- Removal of tartar
- Uses the principle of cavitation

Ultrasound therapy

- Shockwaves
 - Unlike continuous ultrasound; here is just one wave (microseconds)
 - High sound pressure
 - Lithotripsy (ESWL)



Ultrasound therapy

- Shockwaves
 - 100-1000 shock waves to break the stone
- The need to ensure minimal damage to the surrounding tissue
 - Maximizing energy absorption at a given location
 - Focusing waves up to the point of stone position

Ultrasound use in lab

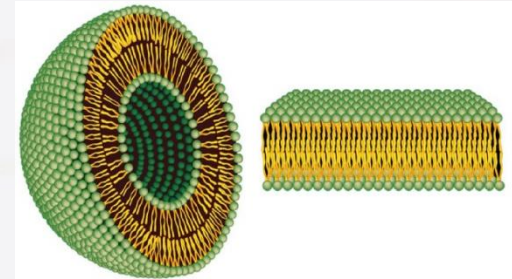


- Ultrasonic baths
Ultrasonic homogenizers
- cleaning
 - degassing
 - dissolvement
 - homogenization
 - emulsification



Liposomes preparation

- Composed of polar lipids - phospholipids (phosphoglycerides, sphingolipids) and cholesterol
- Size 25 - 2.500 nm



- Preparation

1. Drying the lipid solution in an organic solvent
2. **Dispersing lipids in an aqueous medium**
3. Purification
4. Analysis

