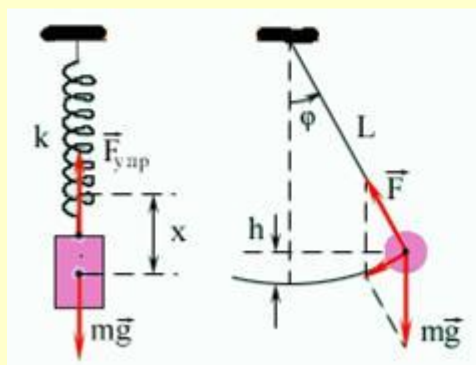
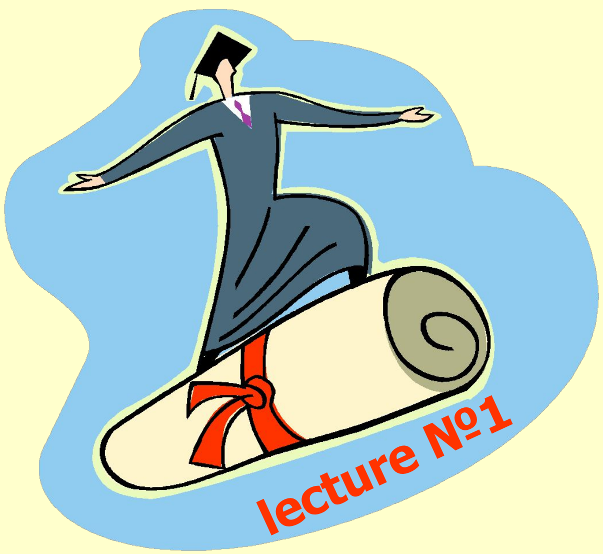
Mechanical oscillations and waves. Bioacoustics. Ultrasound



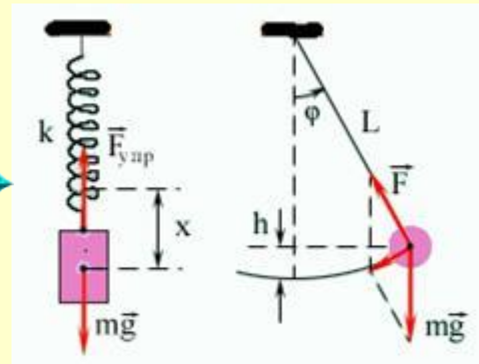


OSCILLATIONS

OSCILLATIONS – are movements or processes that repeat in time. Many biological objects and natural phenomena have oscillatory nature.

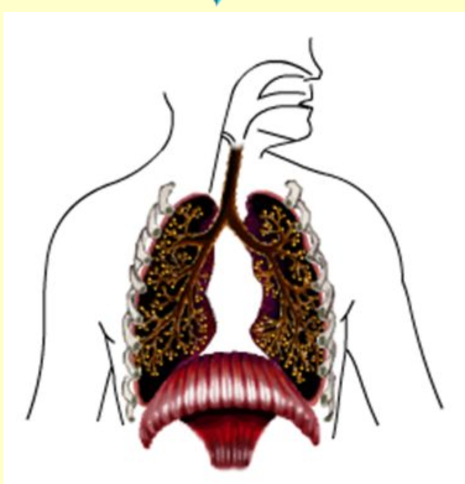
Examples:

spring pendulum

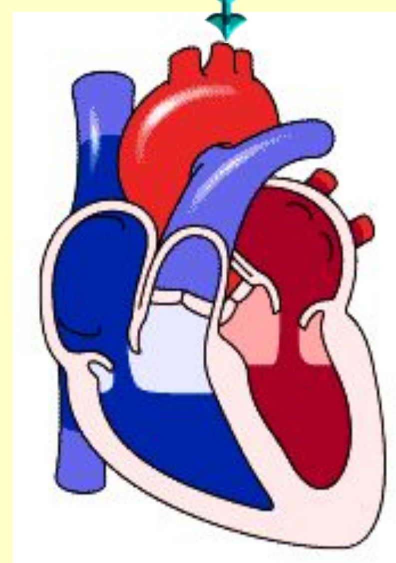


mathematical pendulum

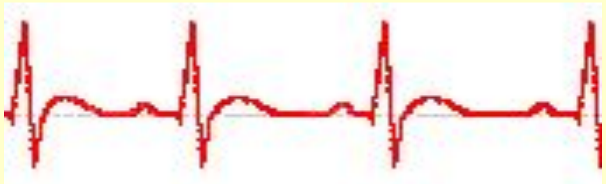
breath



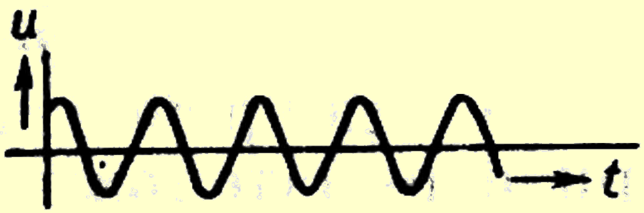
heartbeat



KINDS OF OSCILLATIONS

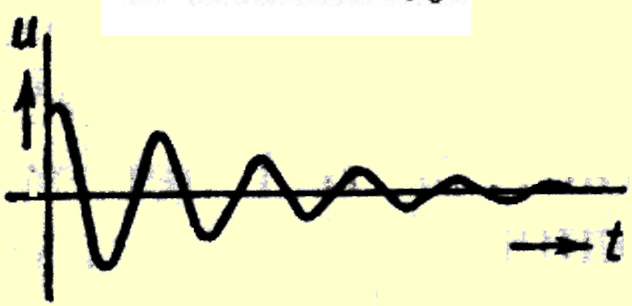


electrocardiogram



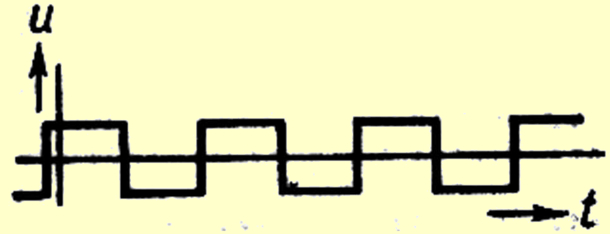
harmonic oscillations

$$S = A\cos(\omega t + \varphi_0)$$

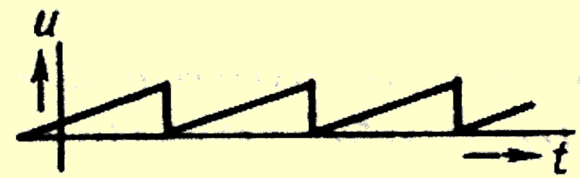


harmonic damped oscillations

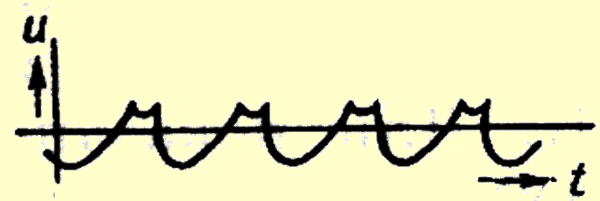
$$S = A_0 e^{-\beta t}\cos(\omega t + \alpha)$$



rectangular oscillations

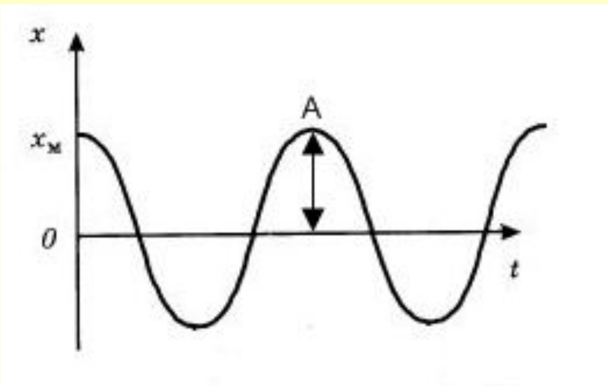


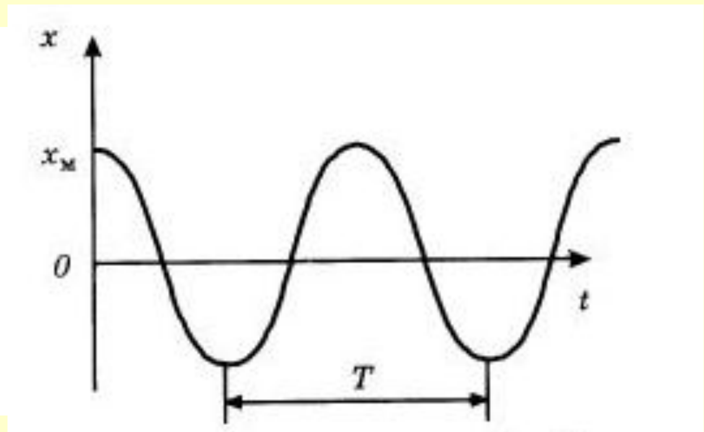
Sawtooth oscillations



complex form oscillations

PARAMETERS OF OSCILLATIONS



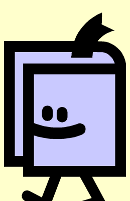


$$\nu = \frac{1}{T}$$

AMPLITUDE- maximal displacement from equilibrium

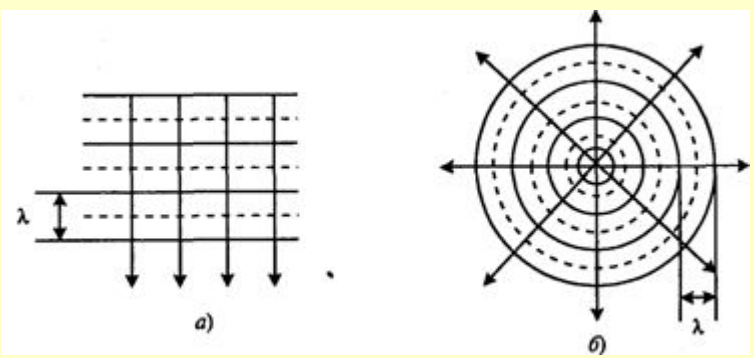
PERIOD- time of one full oscillation cycle

FREQUENCY – number of oscillations per unit of time



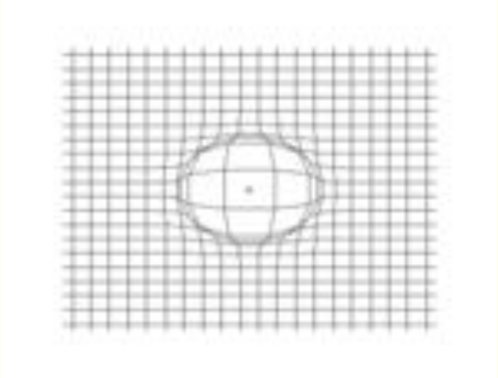
WAVE

Wave – is a disturbance of matter of medium, spreading in this medium and carrying energy

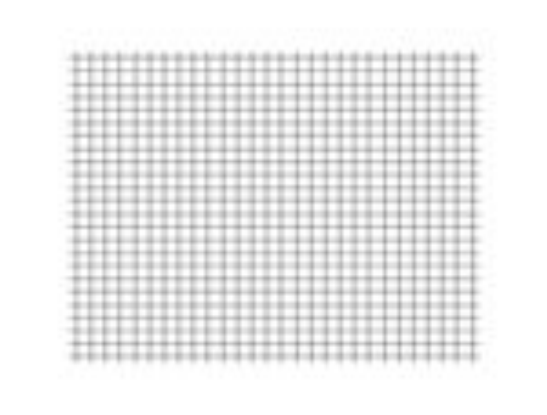


WAVEFRONT - is the locus (a line, or, in a wave propagating in 3 dimensions, a surface) of points having the same phase of oscillations.

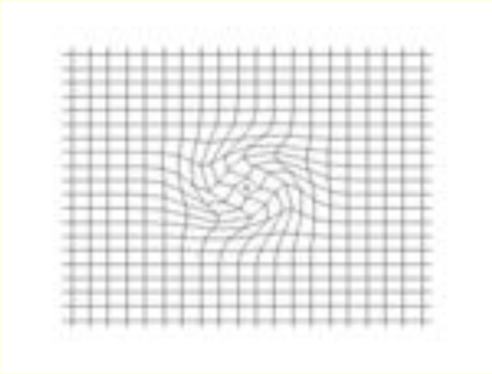
According the wavefront waves can be:

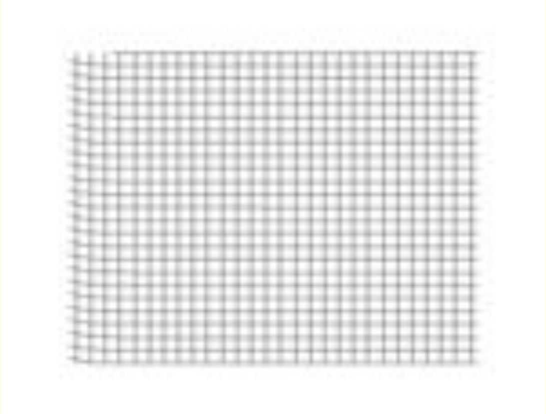


spherical



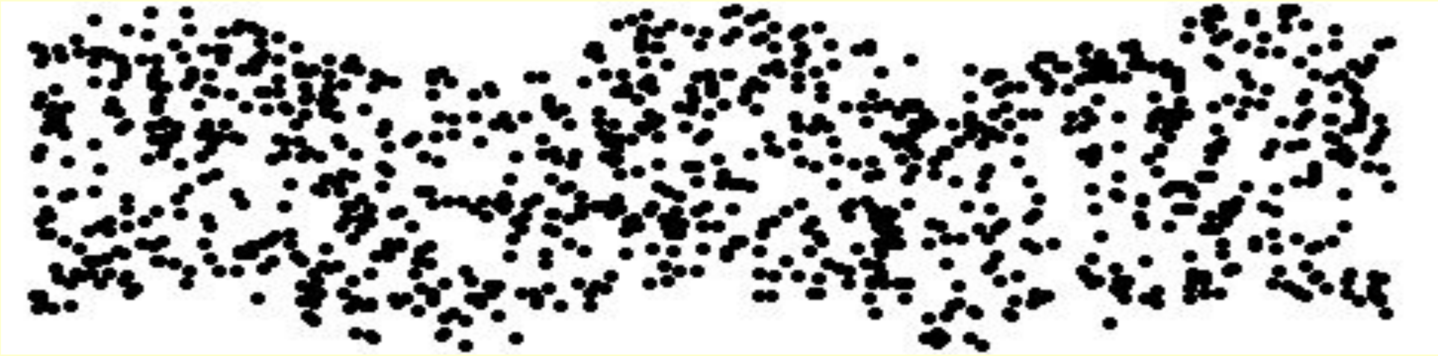
plane



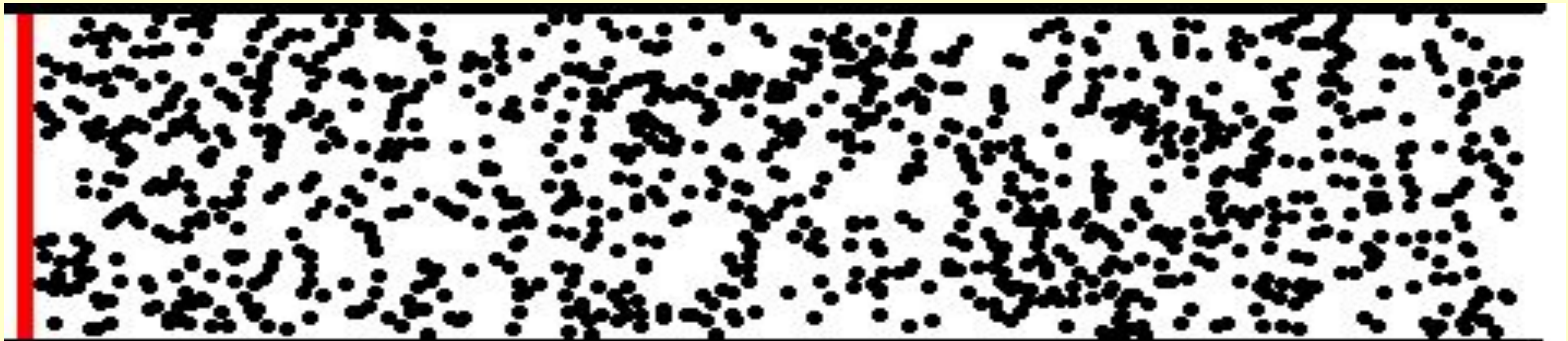


According to medium particles oscillation direction, waves can be:

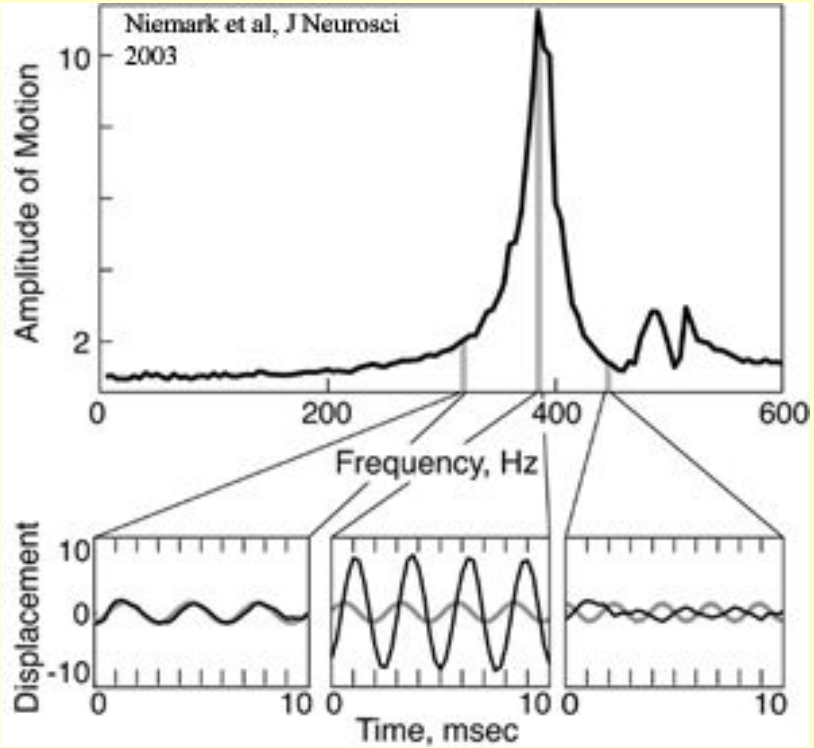
- transversal – particles of medium oscillate perpendiculary to the direction of wave spreading (electromagnetic waves, waves on the surface between two mediums);



- longitudinal – particles of medium oscillate along the direction of spreading of wave (sound waves);



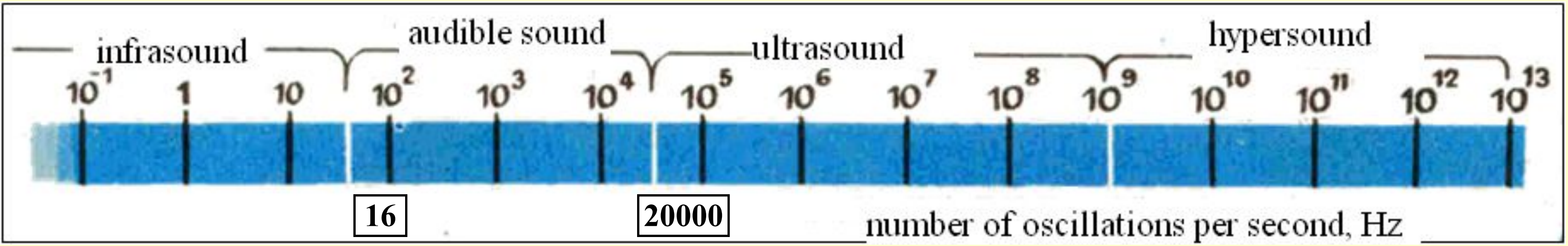
RESONANCE



Resonance (fr. resonance, from lat. resono - respond) - phenomenon of a sharp increase of the amplitude of forced oscillations, which occurs when the frequency of driving force coincides with the frequency of forced oscillations (resonance frequency).

SOUND WAVES

SOUND WAVES – are special case of elastic waves, which spread only in elastic media (gas, substances, solid)



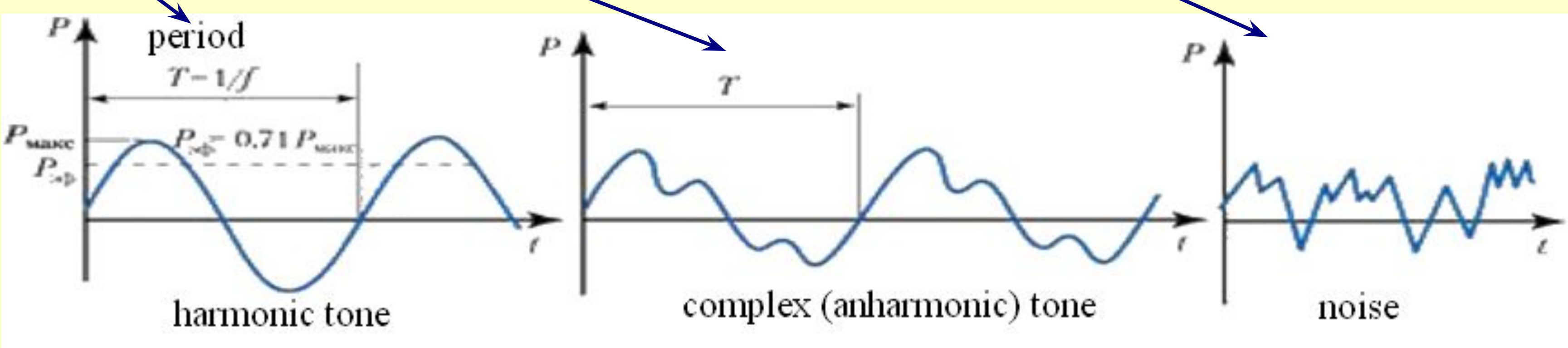
SOUNDS

TONES (periodical processes)

- Harmonic tone
- Anharmonic tone

NOISES (sounds with non-repeating time dependence)

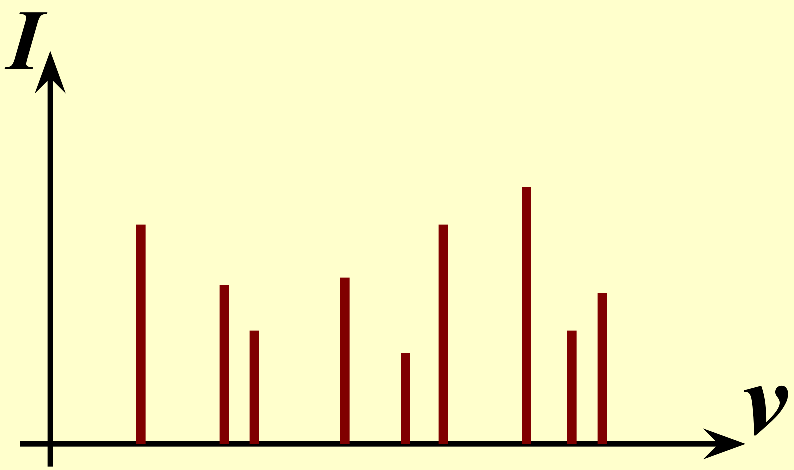
NOISE HITS (SHORT-TIME SOUND IMPACT)



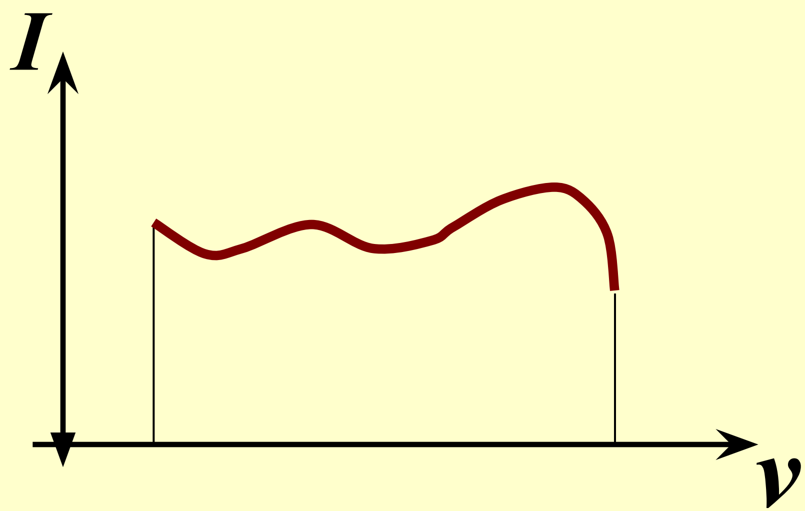
OBJECTIVE AND SUBJECTIVE SOUND CHARACTERICTICS

SOUND CHARACTERISTICS

PHYSICAL (objective)	PHYSIOLOGICAL (subjective)
FREQUENCY	PITCH
INTENSITY	VOLUME
ACOUSTIC SPECTRUM	TIMBRE

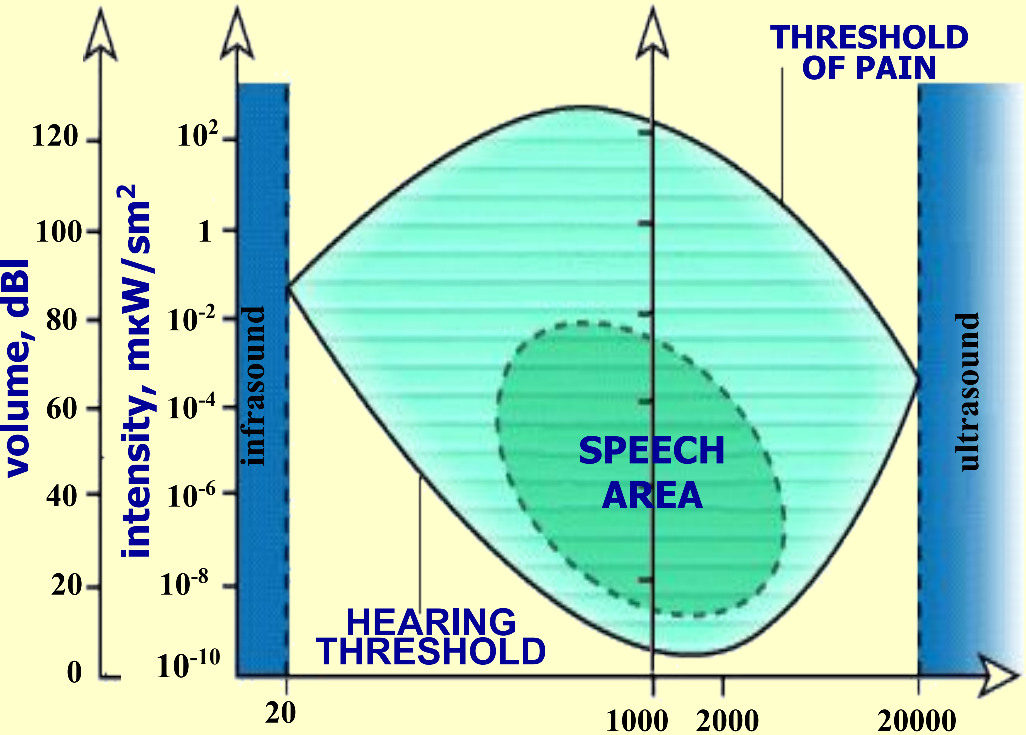


COMPLEX TONE SPECTRUM



NOISE SPECTRUM

SOUND PERCEPTION AREA

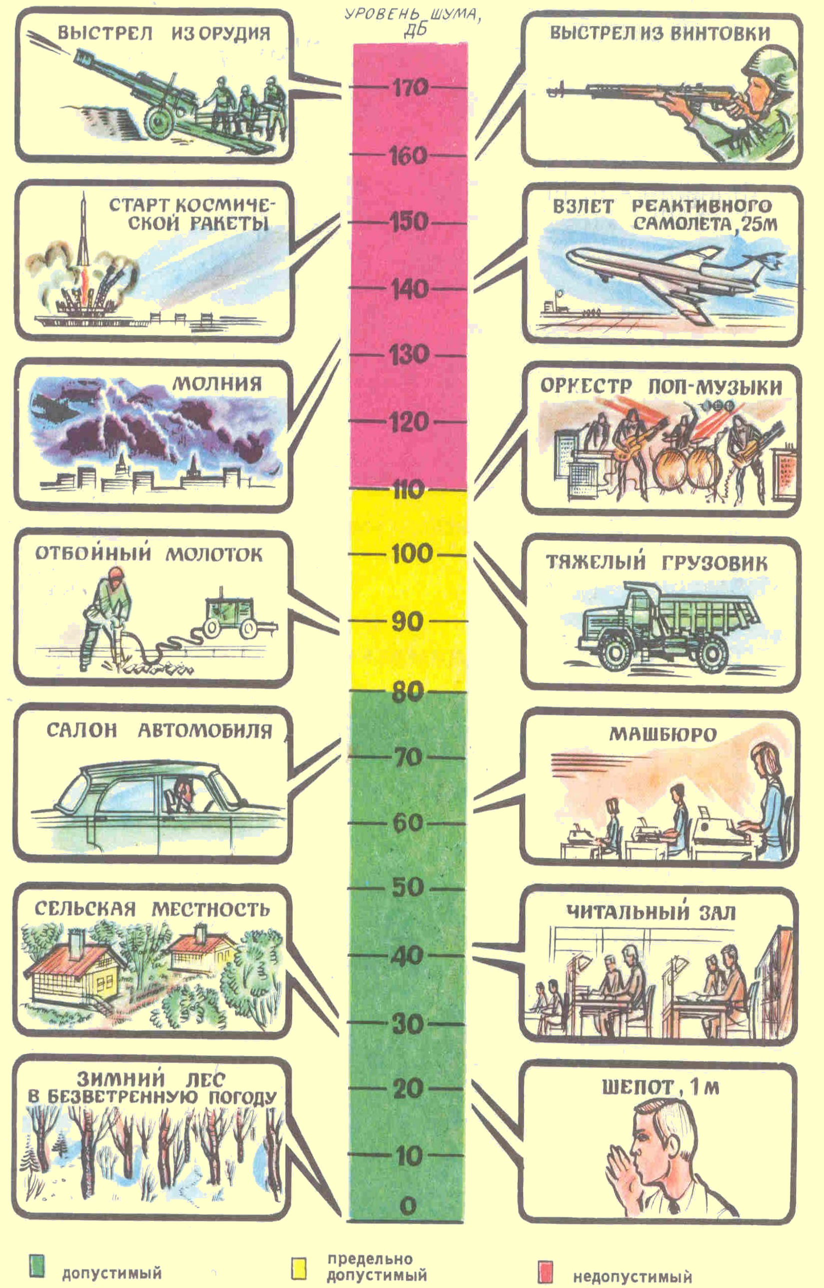


Weber–Fechner law

$$L = k \ln \frac{I}{I_0}$$

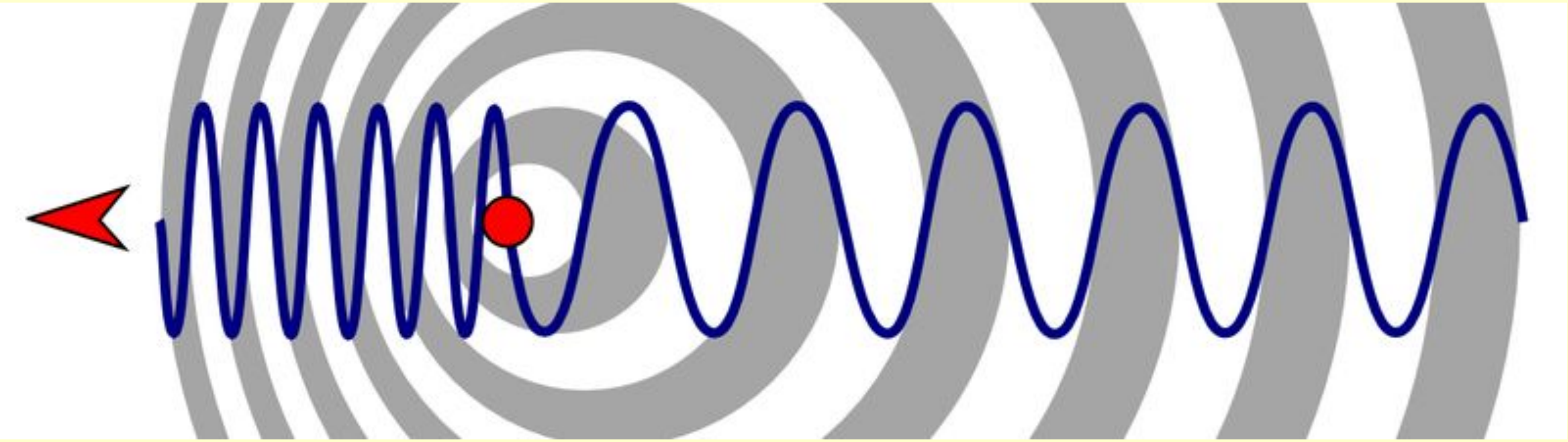
Where L – volume; I_0 – intensity on threshold of hearing; I – some intensity; k – coefficient, which depends on frequency of sound, for v=1000Hz, k=1

Volume scale



Doppler effect for sound waves

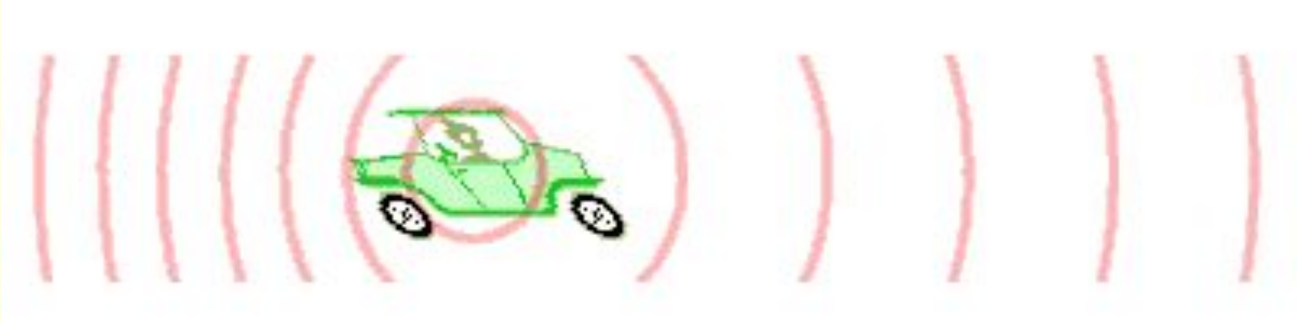
The Doppler effect (or Doppler shift), named after Austrian physicist Christian Doppler who proposed it in 1842 in Prague, is the change in frequency of a wave for an observer moving relative to the source of the wave. It is commonly heard when a vehicle sounding a siren or horn approaches, passes, and recedes from an observer. The received frequency is higher (compared to the emitted frequency) during the approach, it is identical at the instant of passing by, and it is lower during the recession.



$$\omega = \omega_0 \frac{\left(1 + \frac{u}{c}\right)}{\left(1 - \frac{v}{c}\right)}$$

u – velocity of receiver relative to the medium (positive, if it moves towards the source). ω_0 – frequency the source releases the waves, c – velocity of waves spreading in medium, *v* – velocity of source of waves relative to medium (positive, if source moves towards the receiver, negative if moves away from receiver).

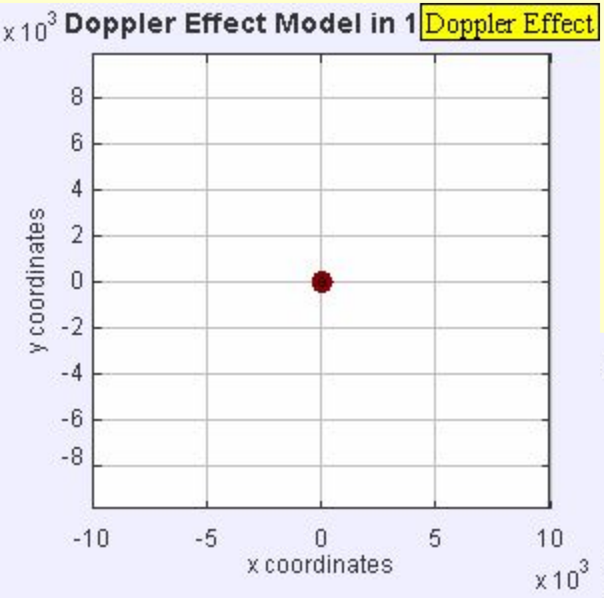
Doppler effect for sound waves

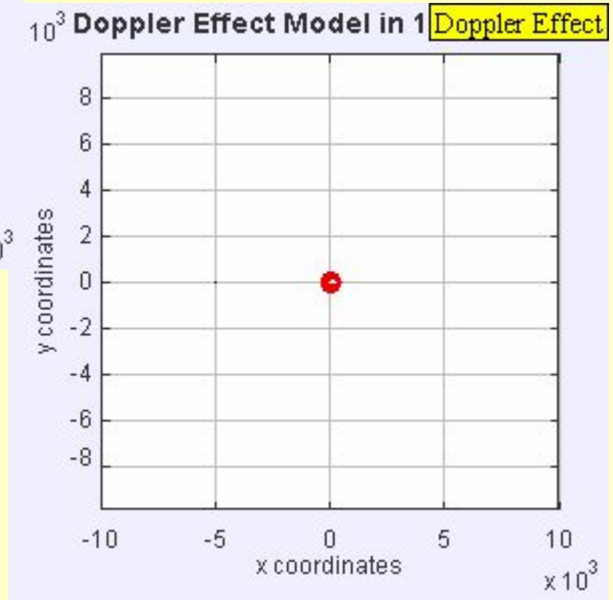


An animation illustrating how the Doppler effect causes a car engine or siren to sound higher in pitch when it is approaching than when it is receding. The pink circles are sound waves. When the car is moving to the left, each successive wave is emitted from a position further to the left than the previous wave. So for an observer in front *(left)* of the car, each wave takes slightly less time to reach him than the previous wave. The waves "bunch together", so the time between arrival of successive wavefronts is reduced, giving them a higher frequency. For an observer in back *(right)* of the car, each wave takes a slightly longer time to reach him than the previous wave. The waves "stretch apart", so the time between the arrival of successive wavefronts is increased slightly, giving them a lower frequency.

Doppler effect for sound waves

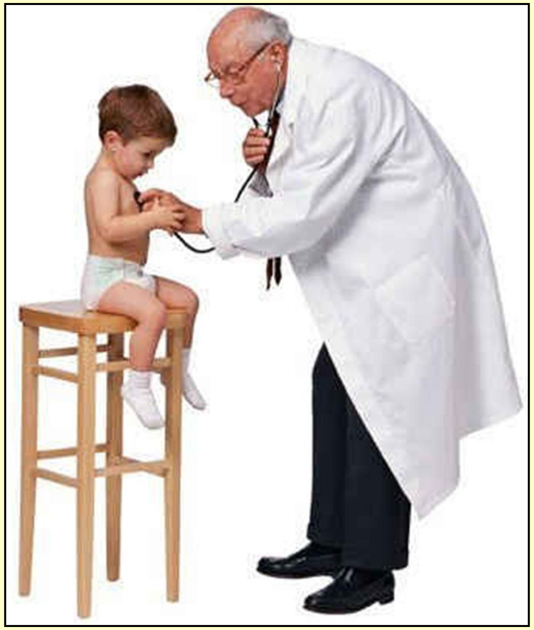
Stationary sound source produces sound waves at a constant frequency f, and the wave-fronts propagate symmetrically away from the source at a constant speed c (assuming speed of sound, c = 330 m/s), which is the speed of sound in the medium. The distance between wave-fronts is the wavelength. All observers will hear the same frequency, which will be equal to the actual frequency of the source where f = f0

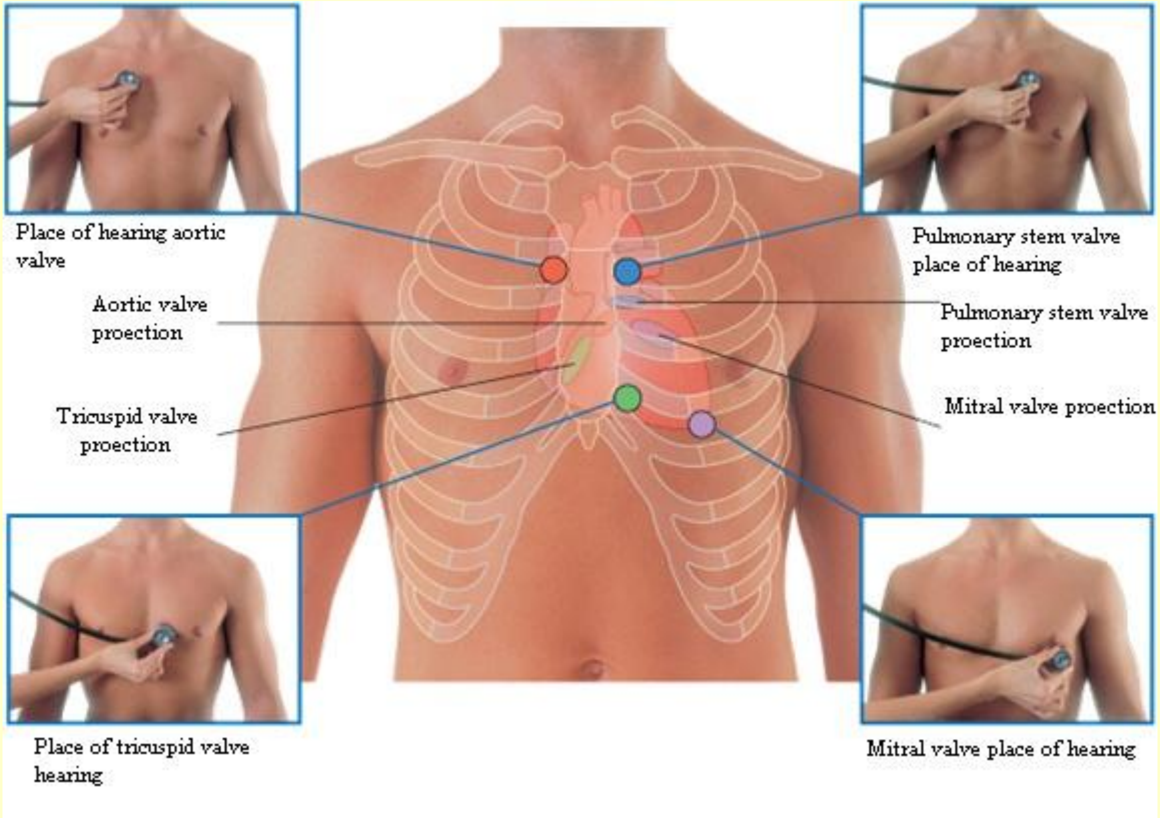




The same sound source is radiating sound waves at a constant frequency in the same medium. However, now the sound source is moving to the right with a speed vs = 0.7 c (Mach 0.7). The wave-fronts are produced with the same frequency as before. However, since the source is moving, the center of each new wavefront is now slightly displaced to the right. As a result, the wave-fronts begin to bunch up on the right side (in front of) and spread further apart on the left side (behind) of the source. An observer in front of the source will hear a higher frequency , and an observer behind the source will hear a lower frequency

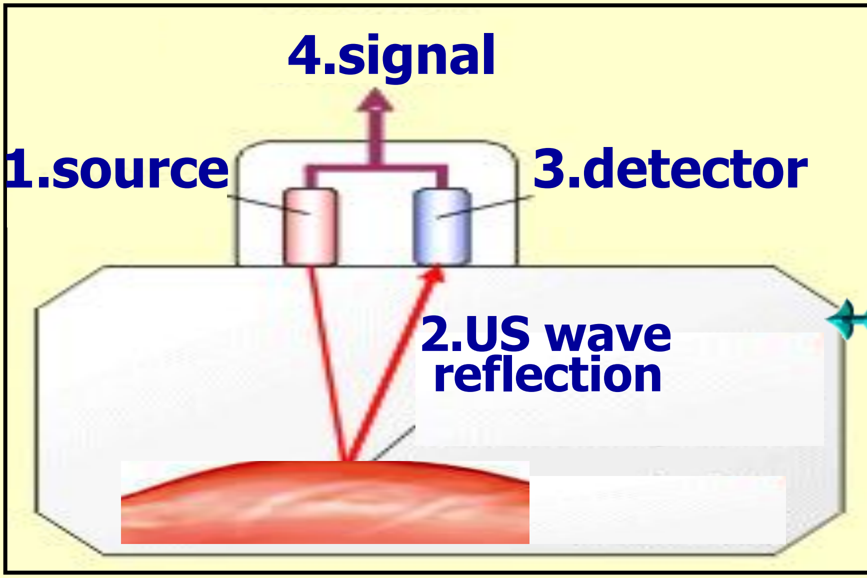
SOUND DIAGNOSTIC METHODS





Auscultation is the term for listening to the external sounds of the body, usually using a stethoscope; based on the Latin verb auscultare "to listen". Auscultation is performed for the purposes of examining the circulatory system and respiratory system (heart sounds and breath sounds), as well as the gastrointestinal system(bowel sounds).

ULTRASOUND IN MEDICINE



IN DIAGNOSTICS

IN CURING

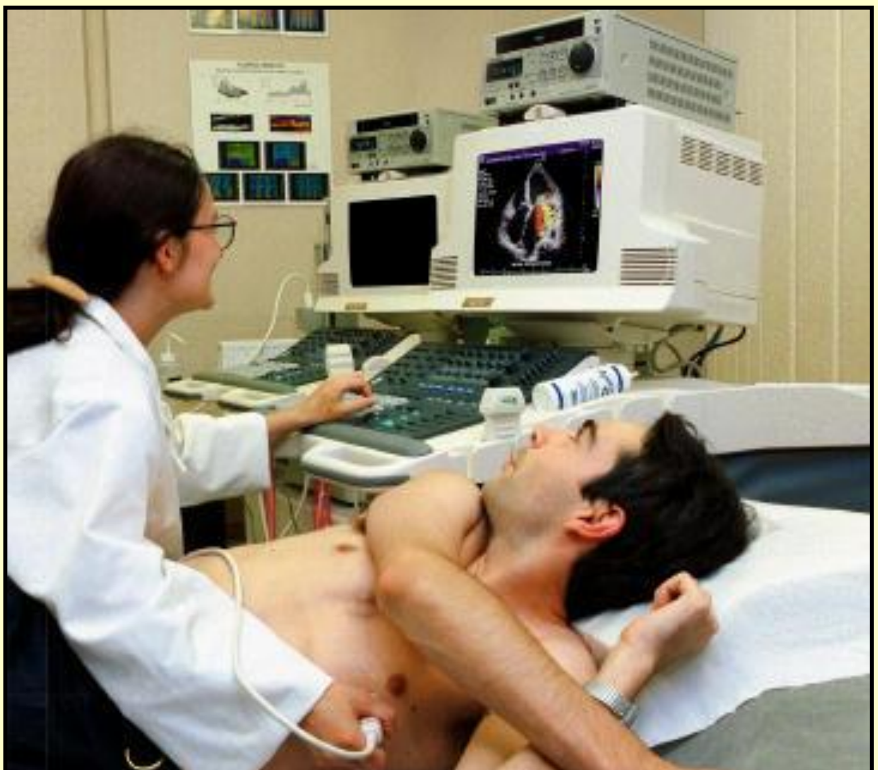
ULTRASOUND DIAGNOSTICS

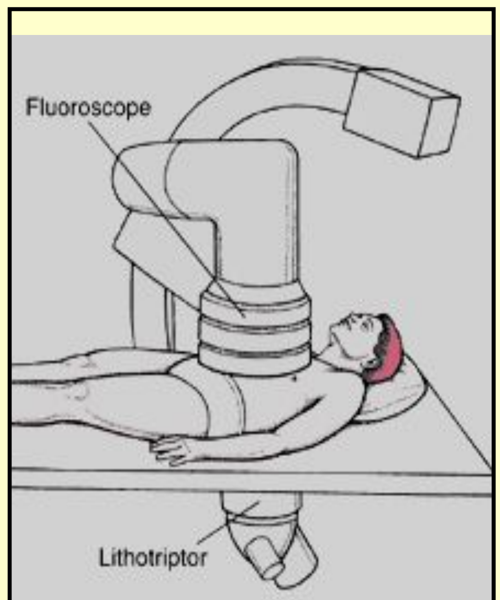
Ultrasound physiotherapy

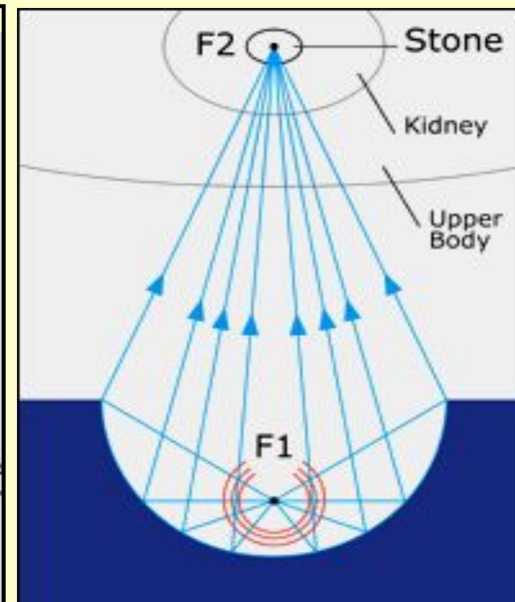
Ultrasound surgery

Mechanical impact (cavitation)

Thermal impact (mechanical work transforms into heat)







Principle of kidney stones destruction with ultrasound

ULTRASOUND IMAGING

Modern USI apparatus

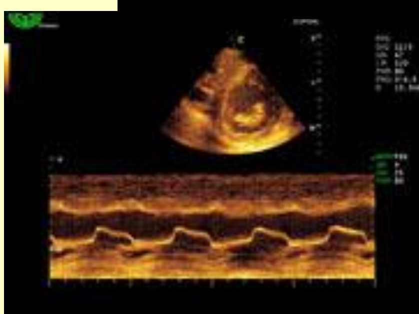
Ultrasound imaging (syn: USD, echography, ultrasonography) — diagnostics method which gives the possibility to obtain the image of patient’s inner structures. This method is based on sound waves with frequency above the human range of hearing application.

Ultrasound transducer

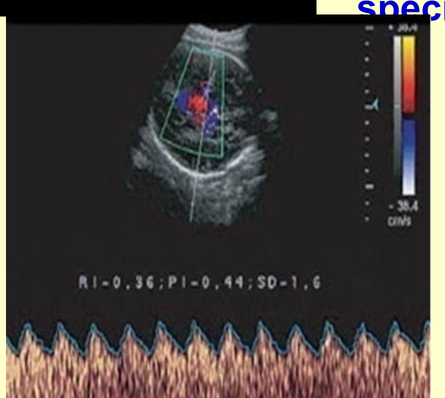
US scanning modes

A-mode or “Amplitude mode” - A single transducer scans a line through the body with the echoes plotted on screen as a function of depth. Therapeutic ultrasound aimed at a specific tumor or calculus is also A-mode, to allow for pinpoint accurate focus of the destructive wave energy.

B-mode or “brightness mode” - In B-mode ultrasound, a linear array of transducers simultaneously scans a plane through the body that can be viewed as a two-dimensional image on screen.



M-mode “motion mode” - M stands for motion. Ultrasound pulses are emitted in quick succession - each time, either an A-mode or B-mode image is taken. Over time, this is analogous to recording a video in ultrasound. As the organ boundaries that produce reflections move relative to the probe, this can be used to determine the velocity of specific organ structures.



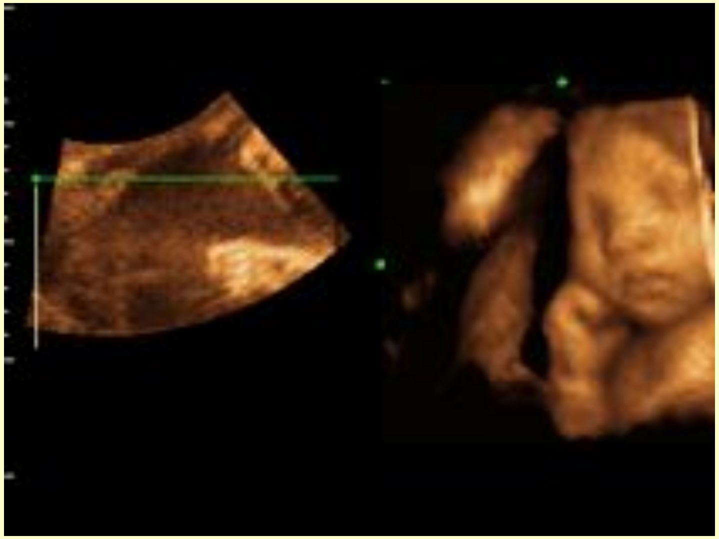
D –mode or “doppler mode" - this mode makes use of the Doppler effect in measuring and visualizing blood flow

3D USI

3D USI gives a three dimensional image. USI transducer gets a number of images of investigated area of a body. Computer forms a 3d picture from these images.
3d image makes possible to examine the structures or processes from different sides. It makes the diagnostics more accurate and reliable.

3D USI of a fetus and a child born

4D USI

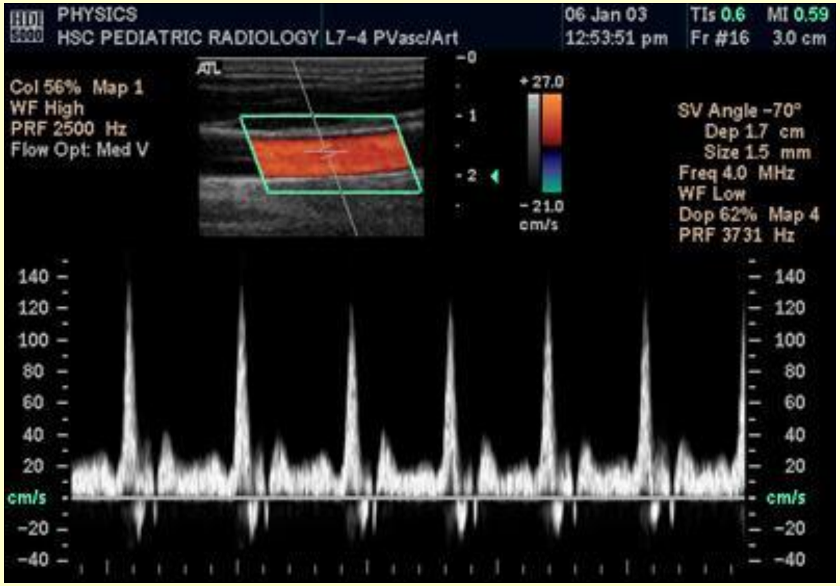


4D - four dimensions USI. The fourth dimension is time. Modern technologies allow to reconstruct the 3d image in real time regime so it looks like a movie.

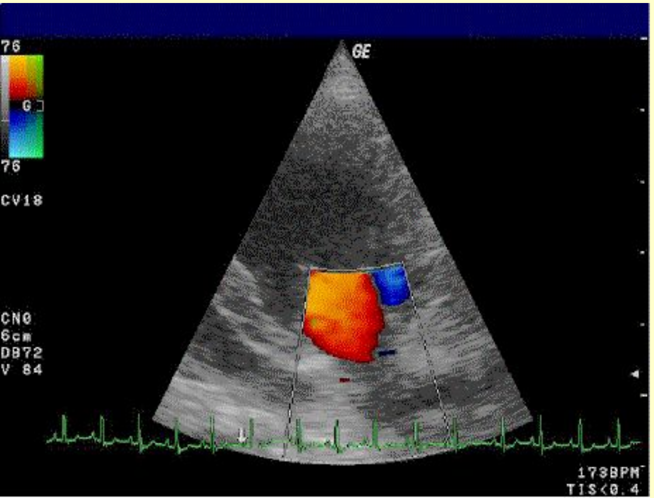
Dopplerography

Transcranial doppler.

Spectral doppler common carotid artery



Color doppler mapping



The method is based on encoding the doppler shift of frequency in colors. The method shows the flows of blood in large vessels and in heart. Red color shows the flow going towards the transducer? Blue color shows the flow going away from transducer. Dark shades of these colors correspond to low speed, light shades - high. Disadvantages: unable to obtain an image of small blood vessels with a small velocity of blood flow. Advantages: Allows you to examine both morphological state of vessels and blood flow rate.

ECHOCARDIOSCOPY