Ultrasound

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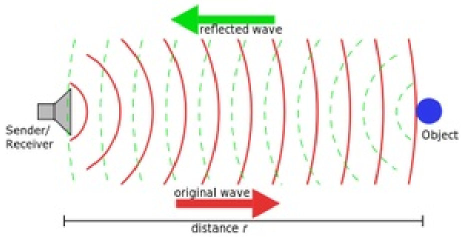
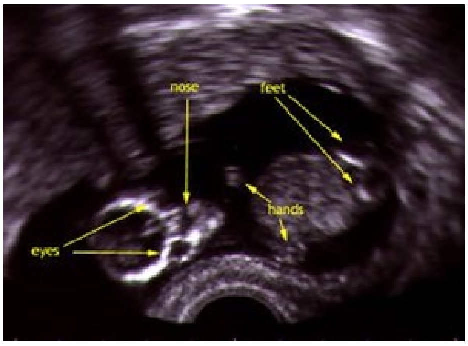


Ultrasound is sound waves with frequencies higher than the upper audible limit of human hearing. Ultrasound is a 'normal' sound in its physical properties, except that humans cannot hear it. This limit changes from person to person and is approximately 20 kilohertz (20,000 hertz) in healthy, young adults. Ultrasound devices operate with frequencies from 20 kHz up to several gigahertz.

Ultrasound is used in many different fields. Ultrasonic devices are used to detect objects and measure distances. Ultrasound imaging (sonography) is often used in medicine. In the nondestructive testing of products and structures, ultrasound is used to detect invisible flaws. Industrially, ultrasound is used for cleaning, mixing, and to accelerate chemical processes. Animals such as bats and porpoises use ultrasound for locating prey and obstacles. Scientist are also studying ultrasound using graphene diaphragms as a method of communication.

Human medicine



Ultrasound image of fetus (14 week)

Ultrasound sonography is a method that uses sound waves to produce pictures of the inside of the body. This method helps diagnose the causes of pain, swelling and infection in the body’s internal organs, also to examine a baby in pregnant women and the brain and hips in infants. It’s also used to help guide biopsies, diagnose heart conditions, and assess damage after a heart attack. Ultrasound is noninvasive method, and does not use ionizing radiation.

An instrument called a transducer emits high-frequency sound, unable to hear to human ears, and then records the echoes as the sound waves bounce back to determine the size, shape, and consistency of soft tissues and organs.

These informations are produced on a computer screen in a real time. Ultrasound technicians, or sonographers, have special training in how to perform the test. Then a radiologist will interpret the ultrasound images. This technology can help diagnose and treat certain conditions.

Physiotherapy


Sonograph for medical purposes

Ultrasound has been used since the 1940s by physical and occupational therapists for treating connective tissue: ligaments, tendons, and fascia (and also scar tissue).Conditions for which ultrasound may be used for treatment include the follow examples: ligament sprains, muscle strains, tendonitis, joint inflammation, plantar fasciitis, metatarsalgia, facet irritation, impingement syndrome, bursitis, rheumatoid arthritis, osteoarthritis, and scar tissue adhesion.

Biomedical applications

Ultrasound also has therapeutic applications, which can be highly beneficial when used with dosage precautions relatively high power ultrasound can break up stony deposits or tissue, accelerate the effect of drugs in a targeted area, assist in the measurement of the elastic properties of tissue, and can be used to sort cells or small particles for research.

This article has been translated from WikiSkripta; ready for the **editor's review**.

Technical properties

Ultrasound waves can be produced by three kinds of generator:

1. **mechanical** (small resonators, pipes: low frequency and output),
2. **magnetostrictive** (undulation around an iron pin in a magnetic field of an electromagnet that is supplied with alternating current: high output, but frequency only up to 100 kHz; utilized in dentistry and surgery),
3. **piezoelectrical** (a silicon shard is connected to electrodes with alternating voltage, therefore it vibrates with the same frequency as the voltage and changes the electric energy into mechanical energy, which causes the surroundings to vibrate: for use in both diagnostically and therapeutically).

High frequency causes the **very short wavelength** of the ultrasound waves, where pressure changes of the magnitude of **MPa** happen (danger of damage to cellular nuclei). On the borders between different tissues (with different speed of propagation of sound) a partial change of the direction of propagation happens, as well as their **reflection** (analogically to the law of refraction of light) → **use in diagnostics**.

$$R = \left(\frac{z_1 - z_2}{z_1 + z_2} \right) ^2 \cdot 100$$

. 100 R = percentage of the inbound wave's reflected energy z_1 and z_2 = acoustic impedance of two environments.

Effects

For more information see Effects of ultrasound.

- **Thermal effects** – energy of the wave is directly proportional to its f^2. There is substantial absorption on the borders between tissues with different acoustic impedance (soft tissue X bone = periosteal pain).
- **Mechanical** – the flow of the ultrasound wave through the environment results in local pressure changes (MPa/mm).
- **Physically-chemical** – ultrasound has dispersive effects, which means that using it we can prepare fine suspensions, emulsions, foams, etc., it also has **coagulating** effects – it is used e.g. for the purification of gasses.
- **Biological** – up to the intensity of 3 W/cm2 the ultrasound has rather **biopositive** effects: increase of metabolic exchange, etc., over 3 W/cm^2 they cause **irreversible morphological changes** – destruction of the cellular nucleus, thermal coagulation of protein.

Properties of diagnostic ultrasound

For more information see Diagnostic application of ultrasound.

Diagnostic ultrasound works with frequencies within **3–10 MHz** (subcutaneous probes around 7 MHz).

Ultrasound generates an **acoustic pulse** that propagates with the speed of sound in the proper environment and a part of its energy is **reflected** on impact. The crystal then **detects** the reflections of the signal and determines the size of the **echo**, then the **depth** of the reflection from the time delay, too.

- **A-image:** linear recording of the reflections depending on depth.

- **B-image:** A-image rotated 90°, the size of the echo in a certain depth is proportionate to the saturation of points in a row on the screen → composing a multitude of lines next to another creates a two-dimensional image, that is moving in relation to time.

- **M-image:** the saturation of points through time can be recorded *for example* on a running paper; important while determining the movement of heart's individual sections.

The higher the wave's frequency the **higher** the **definition**, but the **higher** the **absorption** as well (lower imaging depth).

Properties of therapeutic ultrasound

For more information see Therapeutic application of ultrasound.

In ultrasound therapy, machines with the frequency of 0,8–1 MHz, the intensity of 0,5–3 W/cm^2 and the exposition of 10 minutes are used most often.

Therapeutic effects: deep thermal effect, dampening of pain, release of prolonged local muscle tension, increase of local blood circulation, increase of metabolism. It is used mainly in joint and nerve inflammation.

In dentistry, vibrations with low amplitude (hundredths of mm) are used to remove tartar.

How ultrasound works in 60 sec: https://www.youtube.com/watch?v=I1Bdp2tMFsY

Ultrasonic cleaning

Ultrasonic cleaners, sometimes mistakenly called supersonic cleaners, are used at frequencies from 20 to 40 kHz for jewellery, lenses and other optical parts, watches, dental instruments, surgical instruments, diving regulators and industrial parts. An ultrasonic cleaner works mostly by energy released from the collapse of millions of microscopic cavitations near the dirty surface. The bubbles made by cavitation collapse forming tiny jets directed at the surface.

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