**ULTRASOUND**

**Theory**

ULTRASOUND IN MEDICINE

Ultrasonic methods gained in medicine a wide distribution, including the following areas:

*pharmacology*; apply the ability of ultrasonic waves to create emulsions of substances that are not mixed under normal conditions;

*physiotherapy*; use mechanical and thermal action to improve metabolic processes in tissues, increase the permeability of cell membranes when drugs are administered (phonophoresis);

*diagnostics*; widely used methods for basis:

a) Doppler effect (to determine speed of blood through the vessels, structures of the heart muscle in the cuts and etc.),

b) echolocation (to estimate the location of the tumor in the brain, determining the retinal detachment, as well as obtaining directly image the internal organs on the screen device for ultrasound – ultrasound);

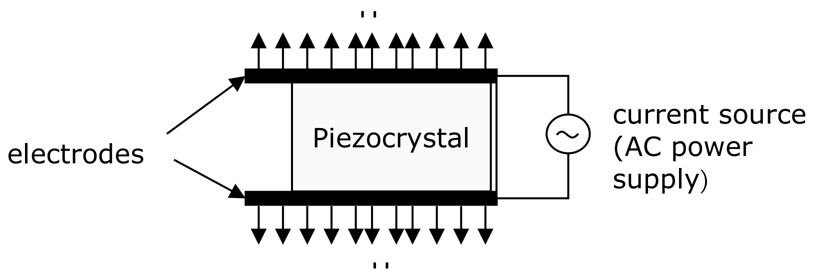
*surgery*; ultrasonic scalpel allows you to perform surgery with minimal blood loss, causing coagulation blood place tissue dissection and ultrasonic saw increases the level of processing bone tissue. Remove stones occur when kidney stones, with the use of ultrasonic equipment are easily portable operation. Under the action focused ultrasonic waves the stones crumble directly the body to the particles, which can easily bring out.

Called **ultrasound** mechanical waves whose frequency exceeds 20 kHz.

The human ear does not perceive ultrasound. Nevertheless, some representatives of the animal world (insects, bats, dolphins, etc.) have the ability to emit and perceive low-frequency ultrasound.

To artificially produce ultrasound, devices called ultrasonic emitters (generators) are used. Such emitters use the phenomena of ***magnetostriction*** (low-frequency ultrasound up to 100 kHz) and ***reverse piezoelectric effect*** (high-frequency ultrasound). Magnetostriction consists of vibrations (elongation and shortening) of the length of the ferromagnetic core under the action of an alternating magnetic field (Fig. 1b). The reverse piezoelectric effect consists in changes in the linear size of the piezoelectric plate under the action of an alternating electric field (Fig.1a). In both cases, fluctuations in the size of the working body of the radiator cause a longitudinal ultrasonic wave in the medium bordering the body.

When longitudinal ultrasonic waves propagate, as well as with sound waves, alternating areas of thickening and rarefaction of medium particles occur in the substance.



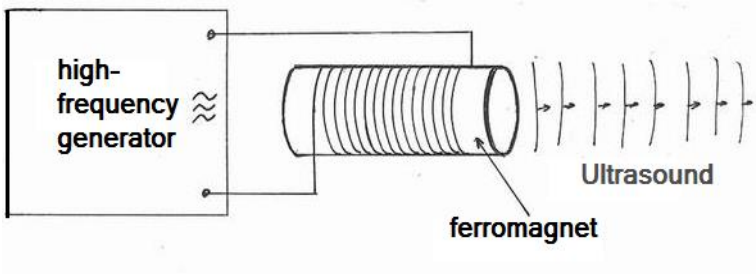



Fig. 1. generation of mechanical waves using reverse piezoelectric effect (a) and magnetostriction (b) (arrows show the direction of propagation of ultrasonic waves).

The speed of ultrasound propagation depends on the properties of the medium. As the density of the medium increases, the speed increases. So, in bones, it is about 3500 m/s, and in water and soft tissues – about 1500 m/s.

The ***absorption*** of ultrasonic waves in the medium occurs according to the exponential law:

$$I_d = I_0 e^{-\mu d}, \qquad (1)$$

where $I_0$ - is the intensity of the waves incident on the substance,

$I_d$ - the intensity of waves that have passed through a layer of substance with thickness d,

$\mu$ - the absorption coefficient, depending on the properties of the substance,

d - the thickness of the layer of substance.

From formula (1), the absorption coefficient $\mu$ can be determined as follows:

$$\frac{I_d}{I_0} = e^{-\mu d}, \qquad (2)$$

$$\ln\frac{I_d}{I_0} = -\mu d, \qquad (3)$$

$$\mu = \frac{1}{d}\ln\frac{I_0}{I_d}. \qquad (4)$$

**Acoustic impedance** - is the different ability of tissues to reflect and transmit an ultrasound pulse, it is determined by the characteristics of tissues and underlies the formation of an image on the ultrasound device screen. Acoustic resistance can be determined by the following measurements:

Acoustic resistance (Z) = velocity (v) × tissue density (ρ):

$$Z = v \cdot \rho$$

**The propagation of ultrasonic waves has some features:**

1. Ultrasound is strongly absorbed by gases (since its wavelengths are small) and weaker by liquids. For example, the absorption coefficient of ultrasound in air is about 1000 times greater than in

water. For this reason, as well as due to the reflection of ultrasound at the boundaries of two different media, the contact between the emitter and the irradiated object should not contain an air layer.

2. Ultrasound is emitted in the form of narrow directed beams and can be focused like light streams.

3. Reflection and refraction of ultrasonic waves at the interface of two media occurs according to the laws of geometric optics and depends on their wave resistances. The ultrasound is well reflected on the boundaries of muscle-periosteum-bone, on the surface of hollow organs, etc., which allows you to determine the localization of inhomogeneous inclusions in the human body (ultrasound location).

4. At high power ultrasonic waves in the form liquid media micro-cavities that occur in areas of rarefaction of the medium. They intensively enter gases from the surrounding liquid. Falling into the region of the wave front, micro-cavities are compressed, "collapse" under high pressure. In this case, a large amount of energy is released and the medium molecules are ionized. This phenomenon is called cavitation. Externally, the effect of cavitation resembles the boiling of a liquid.

5. Ultrasound has a complex mechanical, physico-chemical, and thermal effect on the substance.

The mechanical effect of ultrasound is associated with deformation microstructure of a substance that occurs due to the alternate convergence and rarefaction of its particles caused by an ultrasonic wave. In a liquid, this leads to the phenomenon of cavitation.

The complex action of these factors is based on the biological effect of ultrasound, which is accompanied by the following effects:

- micro-vibration at the cellular and subcellular level,
- the increased permeability of the membrane,
- the destruction of biomacromolecule,
- damage to biological membranes,
- heating effect,
- the destruction of cells and microorganisms.

## Control questions on the topic of the lesson:

1. What is called ultrasound?
2. What are the ways to obtain ultrasound?
3. Specify the features of ultrasound propagation.
4. Explain the principle of operation of the echoencephaloscope.
5. What is the method of ultrasonic echolocation?
6. Specify the main directions of ultrasound application in medicine.
7. Tell us about the impact of infrasound on biological objects.
8. What effect does ultrasound have on a substance?
9. What is the biological effect of ultrasound?

10. What is the mechanical effect of ultrasound?
11. Why calibrate ultrasonic medical device the echoencephaloscope is calibrated by water?
12. Indicate the main areas of application of ultrasound in medicine.
13. What is called the specific acoustic impedance (wave resistance)?