INTEGRATION OF SCIENCES IN THE STUDY OF THE THEORETICAL FOUNDATIONS OF ACOUSTICS

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***Abstract**. The article presents the theoretical foundations of sound phenomena and acoustic phenomena that exist in nature and regularly occur in our daily lives.*

***Keywords**: sound, sound waves, sound speed, sound height, wave amplitude, cyclic wave frequency, sound pressure, sound intensity, cavitation, infrasounds, sounds, ultrasounds, acoustic vibration system, radio loudspeakers.*

INTRODUCTION

It is important to suggets that at present time we regularly encounter sound phenomena and acoustic phenomena in our daily life. For example, the sounds that we hear every day, the sounds that we make, and the sounds that come from various things that we use in everyday life. All sounds that we hear, make and come from objects are based on the laws of physics. Our main goal is to study the theoretical basis of these phenomena and learn about them.

The science of sound is called acoustics. The reason for the perception of sound by humans and animals is the effect on the hearing organs of elastic waves propagating in the air or other elastic medium. The source of these elastic waves are oscillating bodies. An oscillating body creates thinning or thickening of the particles of the oscillating medium around it. Rarefaction and thickening of particles due to the elasticity of the medium spreads in it and creates sound waves.

Sound waves, like ordinary mechanical waves, can have a spherical or flat front. Sound waves can travel in gaseous, liquid and solid media. In gases and liquids, they take the form of longitudinal waves, in solids - in the form of longitudinal and transverse waves.

By sound we mean a physical phenomenon that affects our ears, that is, transverse waves. When studying sound, three main aspects can be seen. First, there must be a sound source; Like other waves, the source of sound waves is the vibration of bodies. Secondly, energy from the sound source is transmitted in the form of transverse waves. Third, sound is recorded by our ears or instruments. Chilirma, dutor, rubob and other musical instruments create sound waves in the air as a result of the vibration of stretched skin. In fact, sound travels through the air, the air comes into contact with the air membranes of our ears and causes them to vibrate. But sound waves can also propagate in other substances. When two rocks hit each other underwater, the vibration travels through the water and reaches our ears. In fact, sound waves do not propagate in the absence of any material medium. For example, you cannot hear the sound of a bell in a vacuum.

The speed of sound in different substances has different values. At a temperature of 0°C and a pressure of 1 atm, the speed of sound in air is 331.3 m/s. The speed depends on the elastic modulus and density of the substance. The speed of sound in air and other gaseous and liquid media is expressed as follows.

$$v = \sqrt{B/\rho}$$

where B is the elastic force or modulus of compression; r is the density of the medium. In helium, which has a significantly lower density than air, the speed of sound is almost three times greater, despite the fact that the compressibility modulus is the same in all directions. Sound is characterized by strength, pitch and timbre. The strength or speed of sound is determined by the amount of wave energy transmitted from a unit surface area perpendicular to the direction of wave propagation. Since the energy transmitted by a wave is proportional to the square of the amplitude and frequency of the wave, the sound power is proportional to these quantities.

$$I = \frac{1}{2} A^2 \omega^2 \rho v$$

where A is the wave amplitude; ω – cyclic frequency of the wave, r – density of the medium; v is the spatial velocity of wave propagation. For example, when the frequency does not change, the amplitude doubles and the sound intensity increase by one. In XBT, the unit of sound speed is measured in W/m^2, and in the SGS system - in Erg/ (〖cm〗 ^2 s).

The propagation of longitudinal sound waves in an elastic medium is associated with volumetric deformation of the medium. Therefore, the pressure at each point of the medium fluctuates continuously and is the equilibrium value of the medium pressure and ΔP

It is equal to the sum of additional pressures. Additional pressure ΔP is caused by deformation of the medium, called sound pressure. The sound pressure of a sinusoidal wave is equal to the product of the wave resistance (sw) of the medium and the particle oscillation speed ∂S/∂t.

$$\Delta P = \rho v \frac{\partial S}{\partial t}$$

The "bell" is perceived as a symbol of the height of sound pressure. Since "Bell" is a unit of measurement, one tenth of it is a decibel (dB). In physiological acoustics, the characteristics of sound perception are the height, timbre and hardness of sound. Loudness is the quality of almost periodic sound that depends on the frequency of vibration and the ability to hear. As the frequency decreases, the pitch of the sound decreases. Unlike power and speed of sound, loudness is a subjective assessment of the strength of auditory sensitivity, which depends on the density of the medium and the sensitivity of the ear. “Background” is taken as a unit of loudness and means that the pressure created by sound with a frequency of 10^3 Hz is equal to 1 dB.

The human ear perceives sound of a certain intensity. The human ear does not perceive low or weak sounds. For each sound frequency there is a certain sound intensity, called the hearing threshold, that is, below it, the sound of this frequency cannot be heard. The human ear may not be able to hear even strong sounds, because this can only cause pain in the ear. The human ear can perceive sounds with an intensity from 10^(-12) W/m^2 (the lower limit of audibility) to 1 W/m^2 (the threshold for the perception of pain, but in this case it can be heard). he begins to feel pain in his ear. Since the range of audible sound frequencies is very large (10^12 times), the pitch of a sound is not directly proportional to frequency. As the speed increases, the volume increases, but to double the volume, you need to increase the speed of the sound wave by more than 10 times. For example, the average person hears a sound wave with a speed of 10^(-9) W/m^2 twice as loud as a sound wave with a speed of 10^(-10) W/m^2. A sound wave with a speed of 10^(-2) W/m^2 is twice as fast as a wave with a speed of 10^(-3) W/m^2 and four times faster than a wave with a speed of 10^(-4) W/m^2 will be high.

The structure of the human hearing organ.

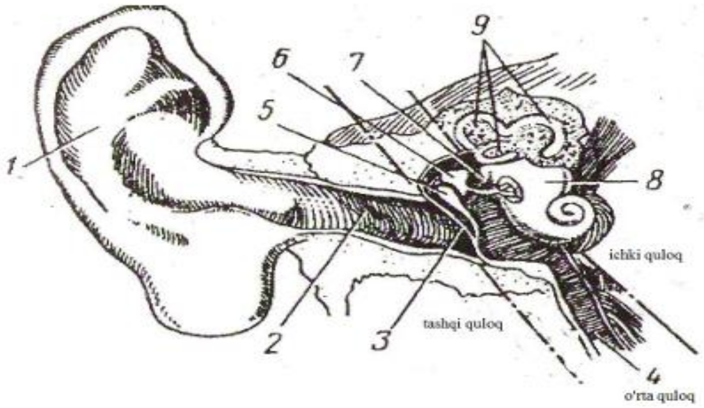

Figure 1.1. Hearing organ of a man.

The hearing organ consists of three parts: the outer, middle and inner ear. The outer ear consists of the auricle 1, from which the eardrum 3 and the ear canal 2 are separated. The eardrum is the first link in the process of auditory perception of sound. The eardrum vibrates in response to sound waves of different pressures reaching it. Its normal vibration is observed only when the atmospheric pressure is the same on both sides of the eardrum: the eardrum is the boundary of the outer and middle ear. Equalization of sound pressure on both sides of the eardrum is achieved by a special canal in the middle ear, called the Eustachiev tube 4, connecting the nose and throat. As a result of pressure imbalance in the ear, severe pain occurs. We all experience this feeling due to the increase in external atmospheric pressure when an airplane lands compared to the pressure during flight. The middle ear is made up of three small bones: the malleus 5, the inner ear 6, and the auditory ossicle 7. The bones are so named because of their resemblance to these things. The auditory ossicles form a special lever and transmit the vibration of the eardrum to the inner ear. The auditory ossicle is attached to the small, flat, oval window of the inner ear and transmits vibrations received by the eardrum. When the channel opens, the sound pressure on both sides of the eardrum is equalized. Normally, the eardrum is affected by changes in sound pressure on only one side.

The inner ear consists of several cavities of the temporal bone. All cavities are filled with viscous liquid. The 13 cavities located in the inner ear are filled with a viscous liquid that penetrates through 8 membranes. The membrane contains about 22,000 nerve fibers, which transmit vibrations of these fibers to the cerebral cortex. In the brain, sound vibrations become known sound, which we perceive with the mind.

The vestibular apparatus 9 in the form of semicircular canals is located in the middle ear. Although these semicircular canals are connected to the auditory organ, they do not have the sensation of sound, but serve only as an organ of balance.

Sound vibrations can also be transmitted to the inner ear through the bones of the skull surrounding the eardrum. It is known that its sound can be heard by biting the stem of a slowly vibrating tuning fork. The American inventor Edison, who suffered from dementia, said: “I hear with the help of my teeth and skull. All I have to do is put my head on the boards, and if I can’t understand the quiet sounds, I’ll bite the boards with my teeth, and then everything will become clear to me.”

Hearing by frequency. From a physiological point of view, the organ of hearing is absolutely unique, but very subjective, that is, it is an instrument that introduces objective characteristics of existing sounds into the real auditory process. Especially when it comes to hearing, power and tone. The first feature of the hearing organ is the presence of a hearing threshold for different sounds. In the form of sound, the ear hears mechanical vibrations with a frequency of 16 to 20,000 Hz. We cannot hear vibrations below 16 gauss. Such sound vibrations are called infrasounds, and vibrations with a frequency above 20,000 Hz are called ultrasounds. We don't even hear such vibrations. Infra- and ultrasonic vibrations are clearly heard by animals. For example, earthquakes with a frequency of a few hertz are perceived by animals as disturbing, which indicates that they can hear such low-frequency vibrations. Sounds in the range of 16÷20000 Hz are not the same. The sensation of a loud sound disappears when its frequency is around 14,000 Hz. Sounds of higher frequencies are perceived by the hearing organ as sounds of equal height. Increasing the frequency from 14,000 Hz to the upper limit of 20,000 Hz causes the pitch to decrease. With age, the upper limit of a person's hearing decreases to 12,000 Hz, and the perception of sound volume also decreases. How does the hearing organ detect small changes in frequency? The sensitivity of the hearing organ to changes in sound frequency is called the sensitivity of the hearing organ. A sound vibration of 1000 Gauss has a noticeable change in frequency of 3 Gauss. It turned out that a relative frequency change of 0.3% in the range of 600÷4000 Hz is significant. To notice this change in low and high sounds, you need to change the frequency to a higher value. Musicians have two concepts for perceiving and assessing the pitch of music, dividing it into absolute and relative pitch. Absolute pitch is an ability found in rare people, that is, the ability to determine the pitch and note of a given sound. A person with perfect pitch can reproduce any note without comparing it with another sound. Few people naturally possess this absolute ability of hearing, and even many composers and performers - musicians do not possess this ability.

As you said above, under exposure to sound vibrations, the auditory bone moves the membrane of the oval window, which, in its ochered, causes lymphatic vibrations. Lymph kolebletsya naprotiv poverkhnosti osnovnoy membrany, to est poperechno ee voloknam. Lish opredelennye fibers vibrate and correspond to the frequency of oscillating lymph. Ryadom s helicotremoy located long fibers, resonating at low frequencies, and it is based on short fibers located at the hip, vibrating at high frequencies. A complex sound emits several groups of fibers. Takim obrazom, the membrane plays the role of a frequency analyzer. Resonance frequency depends on each fiber, whether it is a wave parameter fiber, or mass lymph, which moves along the fiber. Eta mass opredelyaetsya rasstoyaniem ot resonancenogo fiber do ovalnogo okna. A larger mass of lymph participates in low-frequency vibrations, while a small mass of lymph participates in high-frequency vibrations. Figure 1.2 shows the equivalent electrical circuit of the analyzer.

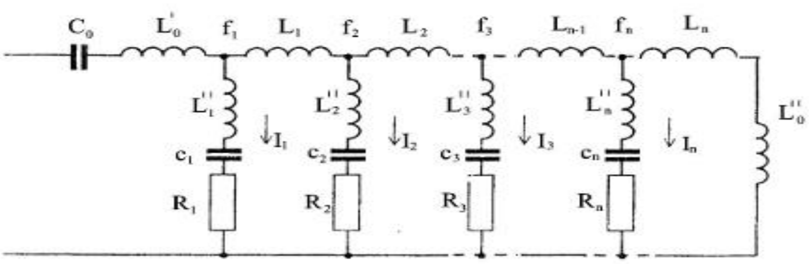

Figure. Equivalent electrical circuit of the tank.

Here C_0 is the equivalent of the oval and round window membranes; L - helicotrema equivalent; L_k - equivalent of lymph mass; I_k – fiber vibration speed. As can be seen from Figure 1.2, the equivalent electrical circuit of a shunt is similar to that of a bandpass filter. As we mentioned above, the limit of the frequency range of the hearing organ is 16÷20000 Hz. The frequency selectivity of an auditory analyzer is of great interest to us, since the demand for electroacoustic equipment largely depends on this parameter.

We use the concept of loudness, which is its main characteristic, while assessing the selectivity of the human auditory organ. This property is of great importance in the accurate equalization and classification of environmental sounds; this property of hearing is based in terms of musical intonation, that is, tones and harmonies. According to the international standard ANSI-994, “Ritch” is a characteristic of auditory hearing in which sounds can range from low to high on a frequency scale. The pitch of a sound mainly depends on the frequency of its stimulation, as well as on the sound pressure and waveform. In general, the sound vibration of air particles is complex. Their appearance and disappearance develops over time and represents a certain function of time a(t) (Fig. 1.3a). Normally, the oscillatory process has the shape of a sinusoid. It can be expressed by the following function of time: a(t) = amax sinōt, where amax is the vibration amplitude; ω – angular frequency ($\omega = 2\pi f$); f - vibration frequency. This change in sound over time is called tone. Thus, pitch is a linear classification of sound signals, different from pitch, which can be called more or less, so it is a relative classification.

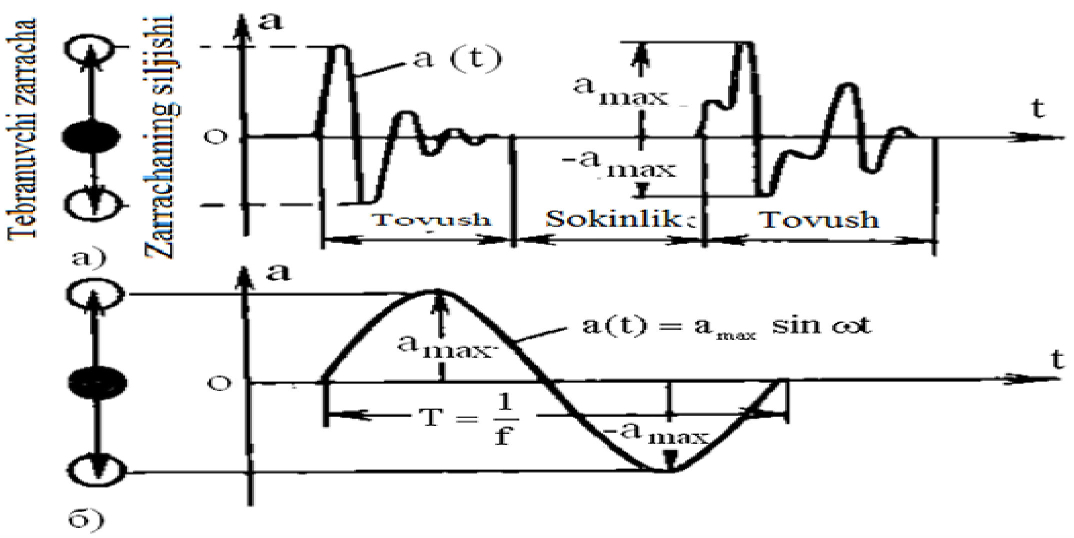

Figure 1.3. Vibration of air particles.
a – Complex oscillations; b – simple sinusoidal oscillation.

First of all, it should be noted that the auditory system determines the pitch of periodic signals, so the frequency of the signal is the main parameter for distinguishing pitch. If there is a complex sound, then the auditory system determines the pitch of the sound by its fundamental tone, that is, its spectrum consists of harmonics (overtones whose frequencies are an integer). If this condition is not met, the hearing organ cannot determine the pitch of the sound. For example, cymbals, bongs, etc. do not have a specific pitch. A graph of pitch versus frequency is shown in Figure 1.4.

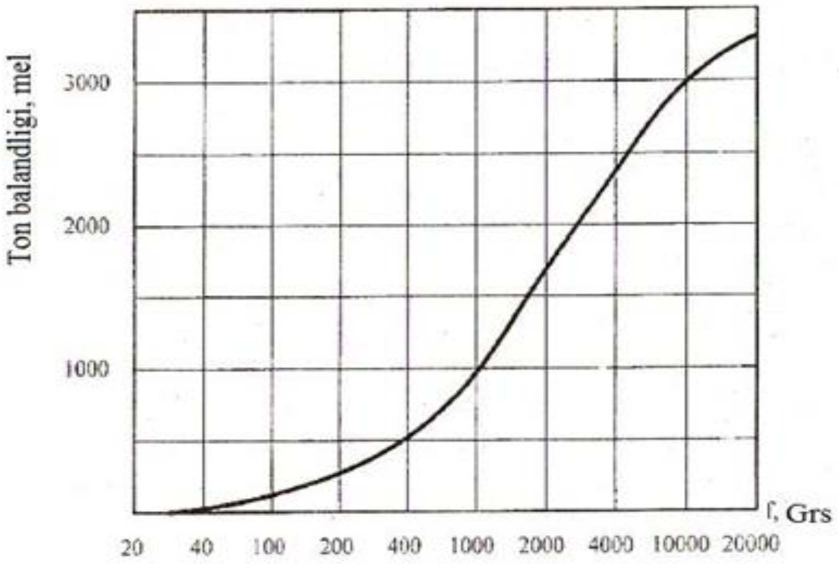

Figure 1.4 Dependence of sound pitch on frequency.

The unit of tone is chalk. One chalk is equal to 40 dB of perceived sound level at 1000 Hz. As can be seen from the figure, this dependence is not linear - for example, when the frequency increases three times (from 1000 to 3000 Hz), the volume only increases twice (from 1000 to 2000 Hz). The nonlinear dependence is clearly visible at low and high frequencies. In the middle part of the frequency range, the change in pitch is proportional to the logarithm of frequency. When sound is heard, the intervals of pitch are called intervals or musical intervals. Normal ranges accepted for hearing aids:

¬Unison – 1:1 (two sounds of the same frequency);

Octave – 1:2;

Kinta – 2:3;

Quarta – 3:4;

Senior third – 4:5;

Minor third – 5:6 or 6:7;

Major second (tone) – 7:8 or 8:9;

Minor second (semitone) – 15:16;

Acoustic vibration system. In addition to mechanical vibration systems, electroacoustic transducers use systems called acoustic vibration systems. Some elements in them consist of a gaseous medium. Acoustic systems take the form of cavities, channels, volumetric resonators and together form complex devices that have resonant motion circuits, filters, etc. looks like. As a simple example of an acoustic oscillatory system, we can mention a tubular Helmholtz resonator (Fig. 1.5). The resonator parameters represent a distributed system. However, when the size of the resonator is smaller than the wavelength affecting it, then such a system can be considered as an embodied system.

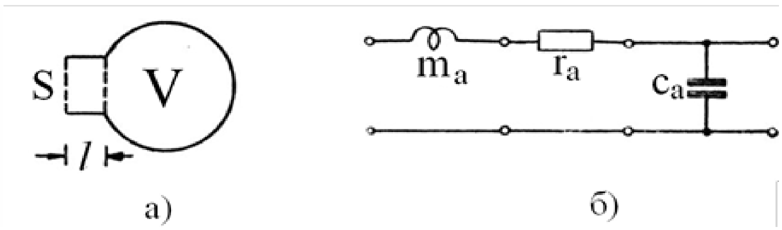

Figure. Helmholtz resonator

The resonator consists of a tubular container with volume V, cross section S, and neck length l. It is assumed that the air in the flask is conventionally divided into two parts: one part is at the bottom of the container, the other part is at the neck of the resonator. The entire air mass m of the resonator is located in the neck of the tube, and its elasticity is contained in its bottom; we will assume that the air mass in the neck of the tube is practically incompressible and moves like a solid piston. When such a piston moves, friction r occurs between its wall and air particles. The air located at the bottom of the resonator has the property of elasticity, that is, it plays the role of elasticity $C_в$. This distribution is only approximate, since part of the air at the bottom of the resonator has inertial resistance. However, this assumption is satisfactory only when the S/S_1 ratio is large, since the main part of the kinetic energy of vibration is located in the neck of the resonator. Consequently, the previously obtained results are also valid for acoustic-oscillatory systems. For example, the mechanical resonant frequency of the resonator is $\omega=1/\sqrt{(m_a C_v)}$. Resonators are widely used in practice. Its use may vary depending on the value and nature of the resistance of the asset. If you do not take into account the active resistance, the resonator acts as a sound amplifier. If the friction resistance is artificially increased, the resonators will have sound-absorbing properties; the friction in them will increase due to the fabric covering the neck of the resonator. This principle is the basis for the operation of resonant silencers, which are widely used in radio and television studios, architectural and construction sites, and concert halls.

Radio speakers are a transducer-motor that converts electrical vibrations into acoustic ones. In many types of radio speakers, electrical energy is converted into acoustic energy. There is a type of radio speakers based on the relay principle (for example, pneumatic radio speakers), in which, under the influence of acoustic or mechanical vibrations, the constant energy of the air flow is converted into acoustic energy. The performance of radio speakers is assessed according to the following technical indicators.

DISCUSSION.

In order to consolidate the knowledge gained during the study of the topic, the following questions were asked.

1. List the main characteristics of sound?
2. In what cases does a person perceive sound and in what cases does it not?
3. Explain Helmholtz resonators?
4. What are radio speakers and how are they made?

CONCLUSION

Summerising it should be suggested about how sound is produced and in what cases a person hears it and in what cases he does not, information about how it works, how it receives sounds, about acoustic vibration systems and radio speakers. The primary purpose of providing this and similar information is to increase your and our knowledge on this topic.

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