Theme 2. Mechanical waves: quantitative and qualitative characteristics, classifications.

Problem
Ultrasound applications in diagnoses, therapy and surgery

Attendance prerequisite checklist. Note! Answer in writing to perform

1. Define or explain physics basics listed: simple harmonic motion; amplitude; cycle; frequency; hertz; period; spring motion; spring constant; restoring force; physical pendulum; simple pendulum; potential energy of a spring.

2. Complete statements

2.1. The time needed for one completed oscillation is the ___________; its reciprocal is the _________.

2.2. An object will undergo simple harmonic motion if its acceleration is proportional to __________.

2.3. The force needed to change the length of a spring is proportional to the ____________.

2.4. The characteristic frequency of oscillation of a mass on a spring decreases if the mass is ____________, and increases if the spring constant is ________________.

2.5. If the length of a simple pendulum is increased, its period ____________.

2.6. The kinetic energy of a simple harmonic oscillator is greatest when the displacement equals ___________, and least when the displacement equals ____________.

Information resources

1. https://www.ck12.org/physics/Mechanical-Wave/lesson/Mechanical-Wave-MS-PS/
2. http://www.phys.uconn.edu/~gibson/Notes/Section6_3/Sec6_3.htm

Introduction

Wave motion. A mechanical wave is a disturbance in matter that transfers energy through the matter. A mechanical wave starts when matter is disturbed. A source of energy is needed to disturb matter and start a mechanical wave.

The energy of a mechanical wave can travel only through matter. Physics nomenclature for matter a mechanical wave travels through is the **medium** (*plural*, media).

There are three types of mechanical waves: transverse, longitudinal, and surface waves. They differ in how particles of the medium move.

In a transverse wave, particles of the medium vibrate up and down perpendicular to the direction of the wave.

In a longitudinal wave, particles of the medium vibrate back and forth parallel to the direction of the wave.

In a surface wave, particles of the medium vibrate both up and down and back and forth, so they end up moving in a circle.

Periodic waves of any type are characterized by several quantities:

- the **frequency f** is a number of waves passing a point per second and is determined by the source of the waves;
- the **period T** is the time between successive wave crests, or the inverse of the frequency: $\mathbf{T = 1/f}$;
- the **velocity c** of a wave is the speed at which a wave peak travels;
- the **wavelength λ** of a periodic wave is the distance between successive wave peaks: $\boldsymbol{\lambda = c/f}$;
- the **amplitude a** is the maximum magnitude of the displacement; the displacement of a periodic wave varies back and forth between **+a** and **–a**.

Most of the periodic waves we consider are sinusoidal waves, and their graphs sine or cosine graphs: $\mathbf{y = a \cdot \sin(\omega t + \varphi_0)}$, $\mathbf{y = a \cdot \cos\omega t + \varphi_0)}$, where $\boldsymbol{\omega = 2\pi f}$.

There are three types of mechanical waves that can be classified as audible sound waves, infrasonic sound waves, and ultrasonic sound waves.

Infrasonic waves are inaudible to human ear and their frequency ranges are below 20 Hz. **Audible** waves are heard by human ear and their frequency ranges between 20 Hz and 20000 Hz. **Ultrasonic** waves are also inaudible to human ear and their frequency ranges are above 20000 Hz.

The nature and speed of sound. When a gas, liquid, or solid is mechanically disturbed, sound waves are often produced. In these waves the molecules of the substance vibrate and collide with one another but maintain the same average positions. However, since their motions are coordinated, a wave results and energy is transmitted, even though no net particle displacement occurs.

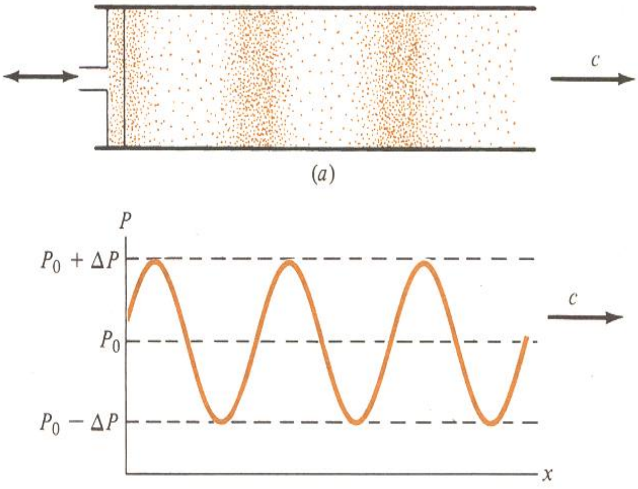

Figure 1

The figure 1 illustrates the production of a sound wave in a medium by a piston that oscillates back and forth at a frequency **f**. When it moves forward, it compresses the medium, and a compressional wave moves outward. When the piston moves backward, there is a region of reduced pressure, **rarefaction**. This disturbance also travels outward. Note that the individual molecules do not travel any appreciable distance but only oscillate about their average positions.

The speed **c** with which a sound wave travels in a medium is determined by the strength of the forces among molecules. At microscopic level, these forces are characterized by the **bulk modulus K**. This quantity is a measure of how hard it is to compress a substance. When the pressure on an object is increased, its volume decreases; its density that is the mass-to-volume ratio, increases. The bulk modulus relates the fractional density change $\Delta\rho/\rho$ to the pressure change ΔP: $\Delta P = K\cdot\Delta\rho/\rho$.

A material such as air that is easy to compress has a small bulk modulus; stiff materials, such as steel, have large bulk moduli.

The velocity of sound **c** depends only on the bulk modulus and the density of the medium: $c = (K/\rho)^{1/2}$.

There is a resistance to the passage of a sound wave through a medium that is analogous to electrical resistance. This is called the **acoustic impedance Z**: $Z = \rho\cdot c$. This is an important quantity in determining how much sound is transmitted from one medium to another.

If the impedances of the two media are very different, then much of the sound will be reflected, not transmitted at the interface. The media are said to be **acoustically mismatched**. For **normal incidence** the reflectivity can be calculated via the relation:

$R = (\rho_1\cdot c_1 - \rho_2\cdot c_2)^2/(\rho_1\cdot c_1 + \rho_2\cdot c_2)^2$

The **intensity I** of a wave is defined as the power **P per unit area A of the wave front**: $I = P/A$.

It can be shown that the intensity is related to the amplitude **a**, and the impedance **Z**: $I = a^2/2Z$.

That is the intensity is proportional to the square of the amplitude, or the maximum change of pressure.

As a wave passes through a medium it will gradually lose intensity by **attenuation**. This is a result of a number of processes of interaction between the wave and the medium, including absorption, diffraction, scattering and other. As with any wave transmission, the intensity falls by

a constant fraction for each unit of distance traveled, which leads to an exponential fall of intensity with distance. Intensity at a distance **x** from original intensity $\mathbf{I_0}$ is given by:
$\mathbf{I_x = I_0 e^{-\mu x}}$, where μ is the **attenuation coefficient**.

The lowest intensity of sound that the ear can detect is called the **threshold**. It is typically about 10^{-12} W/m^2, corresponding to a pressure change of about $2{\cdot}10^{-5}$ Pa.

The highest intensity, beyond which the ear may be damaged, is reckoned to be about 100 W/m^2. This is an immense range, and it is observed that the ear's perception of a sound of intensity **I**, the **loudness L**, depends on the relationship between this intensity and the threshold intensity $\mathbf{I_0}$ according to the expression: $\mathbf{L \propto \log(I/I_0)}$.

Because of the enormous intensity range of the ear, it is common to measure intensities in logarithmic units or **decibels (dB)**. The **intensity level** is related to the intensity by:
$\mathbf{\beta = 10\lg(I/I_0)}$.

β is measured in **decibels**, **I** is the sound intensity, $\mathbf{I_0 = 10^{-12}}$ **W/m^2** is in arbitrary reference level roughly equal to the lowest intensity normally audible, and **lg** denotes the base 10. The decibel range of hearing at 1000 Hz is from near 0 dB up to about 120 dB.

Ultrasound generation: piezoelectric and magnetostrictive effects. Ultrasound can currently be produced at frequencies as high as somewhat more than 10^9 Hz. It is widely used as a diagnostic, therapeutic, and surgical tool in medicine.

The ultrasound generator is a device basically consists of a sine oscillator and a transducer. The sine oscillator generates high-frequency more than 20,000 Hz electric power, while the transducer unit converts the electric oscillations into mechanical ones. The electroacoustic transducers used in the ultrasound range operate on the basis of various phenomena.

Piezoelectric ultrasound generation. If pressure is applied to the surface of appropriately cut plates or discs of certain monocrystals, for example, quatz, electric changes are generated. This is the piezoelectric effect (fig. 2).

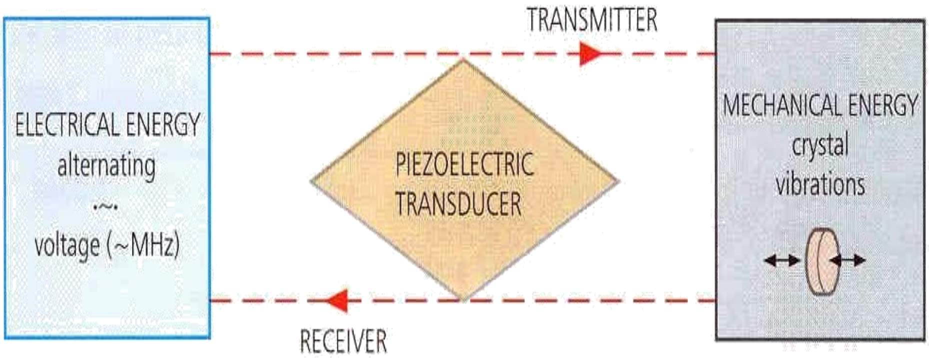

Figure 2

The piezoelectric effect is reversible, that is, if electrodes are placed on the crystal plate and the potential difference is applied to the electrodes, the plate will be deformed by the electric field.

In an alternating electric field the thickness of crystalline plate follows the variation of the electric field, that is, the crystalline vibrates, producing ultrasound.

Magnetostrictive materials. Magnetostrictive materials exhibit similar behavior in an applied magnetic field.

Both types of transducers also act as receivers, since the mechanical vibrations produce electric and magnetic fields that can be detected and used to monitor incoming sound waves.

The effects of ultrasound. In media irradiated with ultrasound complex processes take place. As a high frequency vibration of the body tissues it can produce physical and chemical changes. These depend on the intensity of the beam; in diagnostic use this is very low usually about 0.01 W/cm^2, much higher intensities up to 10^3 W/cm^2 are used for therapy.

Heat effect. Whenever ultrasound is passed through a medium, part of the vibrations energy is transformed into heat. Further, at the boundary surface of different media local heating too may occur. The reason for this effect is that the amplitudes of vibrations are different in the adjacent media, which undergo friction on each other. This explains the fact that thermometers kept in an ultrasound field show a higher temperature than that in the surroundings.

Cavitation. The varying compressive and tensile stresses produced in liquids by ultrasound may overcome the cohesive forces keeping the molecules together, so that cavities of microscopic dimensions are created. At an intensity of 35 W/cm^2 a wave of frequency 1 MHz can produce a change of 10 atmospheres in pressure over a distance of less than a millimeter (half a wavelength). This can cause dissolved gases, e.g. O_2 and CO_2 in blood to come out of solution and form bubbles. The lifetime of these cavities is less than 5 μs, and they soon collapse. Energy is released not only as heat, but also in the form of molecular excitation, ionization, and dissociation.

Chemical effect. As a result of ultrasound irradiation, similarly to high-energy corpuscular or electromagnetic radiation in aqueous solutions the water is activated following excitation or ionization of the molecules accompanied with cavitation. The presence of active ions and free-radicals such as OH', OH^{-1}, H', H^+ and H_2O_2 in the solution is indicated by oxidation processes. Free-radicals can result in oxidation reactions which disrupt the metabolism of that part of the body. These chemical effects are similar to those resulting from ionizing radiations.

Biological effect. Bacteria, viruses may be killed by ultrasound. The effect is rather a complex one, as all the mechanical, cavitational, chemical and heat effects of ultrasound must be taken into account.

Ultrasonic therapy. For **therapeutic purposes**, for example, in case of rheumatic complaints ultrasound with a frequency of (0.8 - 1.2) MHz and intensity of maximum a few W/cm^2 is usually applied. The therapeutic effect is mainly due to the mechanical pulsating effect (micro massage) and heat production.

Diathermy. Ultrasound is used to cause local heating of tissue deep inside the body in a similar way to that produced by microwave and electrical methods. The aim is to produce relief from pain, for example, in the joints of an arthritis sufferer. Typical treatments use intensity levels of several W/cm^2 for periods of a few minutes several times a week. A transducer is moved over the surface of the joint during treatment to avoid "hot spots" developing. Ultrasound is particularly useful as a "deep heat" source as it does not deposit much of its energy in the soft tissues near the surface of the body. It is not used in delicate organs such as the eye or the gonads.

Tissue destruction. At intensity levels of 10^3 W/cm^2 it is possible to selectively destroy tissue by focusing the beam on the required place. **Meniere's disease**, in which dizziness and hearing loss is caused by blockage in the middle ear, is treated very successfully by this method. In this case it is easy to locate the site. In treatment of Parkinson's disease in which there is a lack of muscle control due to the absence of dopamine, a neurotransmitting substance, it has proved more difficult to focus on the correct region of the brain and this method has been discontinued. Investigations have shown that ultrasound can destroy cancer cells, but that it may also stimulate growth. It has also been successful in breaking up gallstones which avoids the need of surgery.

Ultrasonic scanning and imaging. The background of the **diagnostic application** of ultrasound is its reflection from the boundary media of different **acoustic impedance**, and the fact that the time interval between the emission of the ultrasound and the return of its echo is proportional to the distance of the reflecting surface (fig. 3). This permeates non-invasive insight into the structure of the tissues. The average ultrasound intensities of 10 mW/cm^2 order are required for the examination and physiological effects can be neglected.

Ultrasonic offers a method of investigating objects internally without causing any damage. It is widely used in medicine. An ultrasound beam is directed into the body. The reflections or echoes, from different structures are then detected and analysed, yielding information about their locations. There are several different modes of display: **A-scan, B-scan, Doppler methods**.

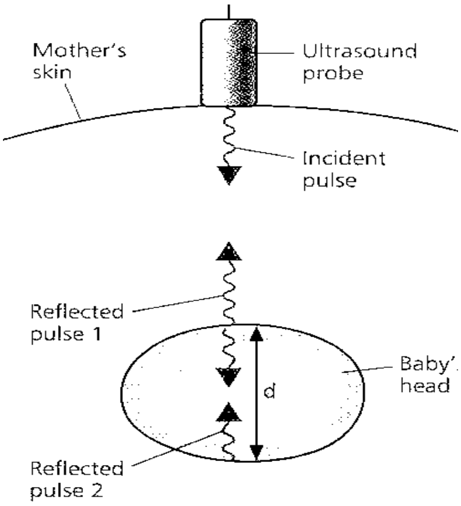

Figure 3

Ultrasound imaging relies on the reflection of ultrasound at body interfaces.

The strength of the echo depends on the **intensity reflection coefficient, k,** across the boundary

$\mathbf{k = (Z_2 - Z_1)^2/(Z_2 + Z_1)^2}$, where $\mathbf{Z = (\rho \cdot c)}$ is specific acoustic impedance, ρ is the density of the medium, **c** is the velocity of sound into it.

The A-scan. The A- or amplitude-scan (fig.3) operates by recording the time **t** taken for an ultrasonic pulse to travel to an interface in the body and be reflected back. The time-measuring instrument is the cathode ray oscilloscope, which must therefore be synchronised with the transmitter/receiver system. The A-scan is used to estimate the depth or/and linear dimensions of a structure: $\mathbf{d = c \cdot t/2}$.

Lab test. Test of sound physiological effects on human ear via audiometry

Problem

People hearing diagnoses and monitoring

Equipment

Audiometer AA-02

Attendance prerequisite checklist. Note! Answer in writing to perform

1. Complete statements

1.1. The minimum intensity that is just audible at a given frequency is termed ________________________________.

1.2. The human ear is most sensitive to the frequencies range (____ - _____) Hz.

1.3. The threshold of hearing at 3,000 Hz corresponds to the intensity level of ___ dB.

1.4. The threshold of hearing at 3,000 Hz corresponds to the intensity of ____ W/m^2.

2. Answer to the questions

2.1. Does the base of a basilar membrane respond better to high or to low frequencies?

2.2. In hearing tests, a tone of a given frequency is gradually reduced in intensity until it becomes inaudible. Why are tones of different frequencies used during the test?

2.3. Bone is a better conductor of low-frequency vibrations than air is. Why does a person feel that his or her voice is richer and lower pitched than do listeners?

2.4. Why do sinus infections in which the Eustachian tubes are infected often impair hearing?

Information resources

1. https://www.britannica.com/science/ear/media/175622/530

2. https://courses.physics.illinois.edu/phys406/sp2017/ Lecture_Notes/P406POM_Lecture_Notes/P406POM_Lect5.pdf

3. https://vula.uct.ac.za/access/content/group/27b5cb1b-1b65-4280-9437-a9898ddd4c40/Theory%20and%20practice%20of%20pure%20tone%20audiometry%20_PTA_.pdf

Introduction

Structure and function of the ear. The ear (fig. 4) is designed to convert weak mechanical vibrations of air into electrical pulses that can be sent to the brain. It consists of a mechanical collection and amplification system, in **outer** and **middle ear** and transducers to produce electrical potentials in nerves in **inner ear**. The auditory nerves lead to the auditory cortex, the part of the brain which interprets the signals.

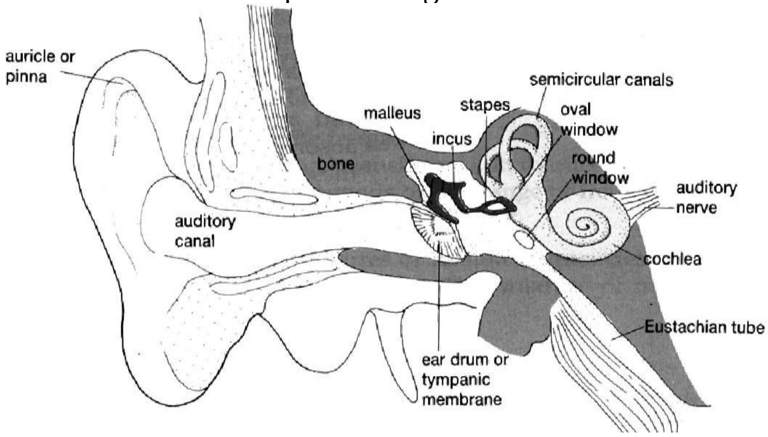

Figure 4

The outer ear. A **pinna** that is visible part of the ear is not strictly part of the outer ear as it plays very little part in the process. In some animals it has a role in collecting the sound vibrations, but in humans it can be removed without noticeable loss of hearing. This is because of the small size. Hearing can be improved by cupping your hands behind your ears, or by use of an ear trumpet, to make up deficiency.

The outer ear consists of the **external auditory canal**, which leads from the pinna to the **ear drum** or **timpanic membrane**. It is about 2.4 cm long and about 7 mm in diameter. It acts as an organ pipe closed at one end, so that the air in it can vibrate. This vibration is passed to the tympanic membrane, which is paper thin (≈ 0.1 mm), with an area of about 65 mm^2. This behaves, as its name indicates, like a drum, though the size of the vibrations can be as small as 10^{-11} m. Although its fibrous structure is relatively strong, it can be ruptured by loud sounds, or pencil poking.

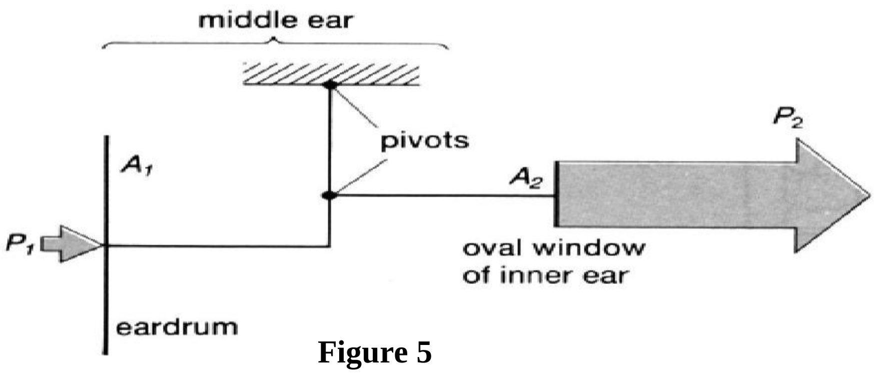

Figure 5

The middle ear. There is a mechanical linkage of three **ossicles** that are small bones between the ear drum and the oval window membrane. The **malleus, incus, and stapes** ossicles act as combined lever and pistons in the air-filled cavity between the membranes (fig. 5).

The lever has a mechanical advantage of about 1.5 and the ratio of the areas of the eardrum and the oval window is about 15 to 1. This results in the pressure applied to the oval window being increased by a factor of more than 20.

When sound is transmitted into a different medium a proportion of the sound is reflected, depending on a property of a medium called the impedance. If the impedance is similar, or matched then this avoids the loss of energy by reflection. The middle ear is designed to produce good matching.

The ossicles also help to protect the ear from damage by loud sounds, by a movement sideways which is not transmitted to the inner ear. This is too slow a reaction for a sudden increase in intensity. Another type of protection is by the **Eustachian tube**, which connects the middle ear to the mouth. This enables the pressures on each side of the eardrum to be kept equal. Differences in pressure impair the hearing and can cause pain. The tube is usually closed and is opened by swallowing, yawning or chewing. You will have experienced the relief this brings when you are subjected to a sudden change in air pressure, perhaps in a plane, lift or car in hilly country.

The inner ear. This where things get rather complicated! The inner ear is a cavity deep within the skull which contains two organs. The semicircular canals are narrow fluid-filled tubes that are not for hearing but for sense of balance and body movement.

The ear frequency response. Sound waves are produced by vibrating objects which cause alternating phases of compression and rarefaction in the medium surrounding the object. The compressions and rarefactions spread out as a sound wave. Human hearing frequencies range is of (20 – 20,000) Hz. The speaking voice is of frequencies range (2,000 – 5,000) Hz.

The physical response of the ear to sound is essentially one of the resonances. That is sound vibrations match the natural frequencies of vibration of parts of the ear. The outer ear is the tube of length about 2.5 cm with one end closed. Its natural frequency is for a standing wave of length 10 cm to be produced. Since c = f·λ, f = 330 m/s/0.1 m = 3300 Hz.

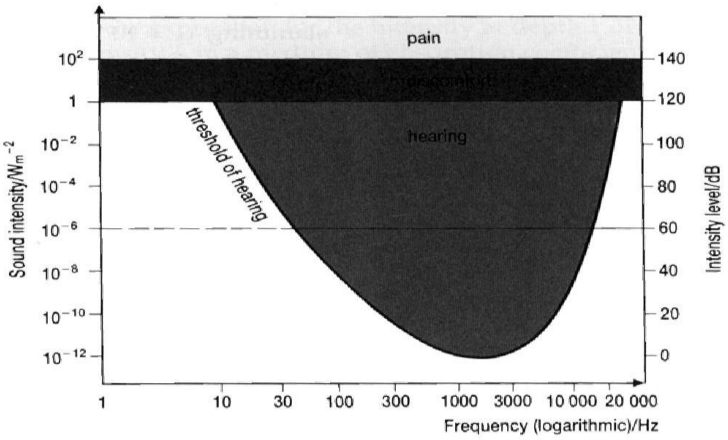

Figure 6

The middle ear displays a broader range of resonance (700 – 1500) Hz.

Within the inner ear the pressure variation becomes a traveling within the fluid. The amplitude of the wave decays as it travels and this depends on the frequency of the wave. High frequencies are absorbed in a short distance, low frequencies in a longer distance. This causes different parts of the basilar membrane to be affected by particular frequencies. Thus the short fibers of the organ of Corti, near the oval window respond to high frequencies, while the longer fibers at the narrow end detect the low frequencies. Below 20 Hz, there is no stimulation of the hairs.

The brain discriminates frequencies by distinguishing the places from that the impulses come. The combination of these various resonances gives the ear its **frequency range** (fig.3). The high frequency limit is about 20 kHz, though this falls with age.

The ear intensity response. Loudness. The human ear can comfortably respond to intensities range (10^{-12} – 1.0 W/ m^2).

Measurements of auditory response are somewhat subjective characteristics, but two objective characteristics have been fairly well established. One is the **threshold of hearing** the minimum intensity that is just audible at a given frequency. From the figure 6 it is obvious that the human ear is most sensitive to frequencies near 3,000 Hz.

The second objective characteristic is the **threshold of feeling**. At this high intensity, a tickling sensation is experienced when the ossicles vibrate so strongly that they strike the middle ear wall. The threshold of feeling is frequency dependent as the threshold of hearing. Its largest magnitude corresponds to frequencies near 3,000 Hz.

The sound intensity increase results in the inner ear:

- a greater movement of the basilar membrane, producing more stimulation of the nerve endings by the hair cells;
- additional hair cells are activated to stimulate nerve endings, in the particular location for that frequency of sound;
- nerves are stimulated beyond that part of the membrane as a result of its greater movement.

Each of these effects increases the extent of the nerve impulse that is sent to the brain. This increase is perceived as an increase in **loudness L**.

Thus loudness is dependent on intensity but is also a result of the energy transfer characteristics of the ear. It is measured in **phon**, and like the threshold of hearing, is strongly frequency dependent for a given intensity (fig. 7).

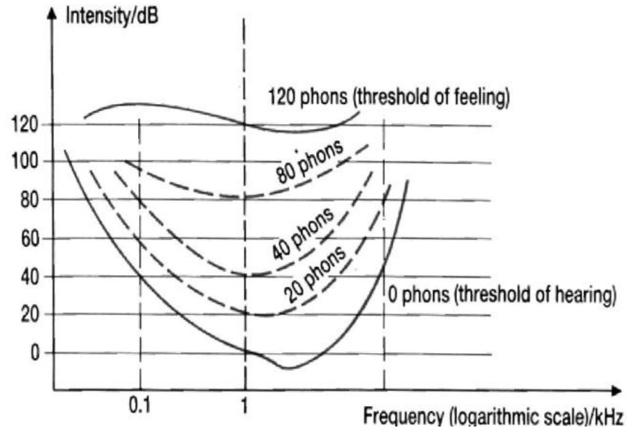

Figure 7

The perception of changes in loudness does not correspond directly to the changes in intensity (fig. 4). Equal increases in loudness result from equal proportional changes in intensity. For example, if the intensity is doubled, say from 10^{-6} to $2{\cdot}10^{-6}$, and from $2{\cdot}10^{-6}$ to $4{\cdot}10^{-6}$, the loudness will be heard to increase by the same amount each time. This can be expressed as

Loudness increase ∝ intensity increase/initial intensity

$$dL \propto dI/I \quad \text{or} \quad dL = k{\cdot}dI/I$$

where **k** is constant. Integrating this gives

$$L = k{\cdot}\ln I + C$$

where **C** is also constant. It may be determined as follows: at the threshold intensity when $I = I_0$, the loudness is zero, $L = 0$, so

$$C = -k{\cdot}\ln I_0$$

Therefore, $L = k{\cdot}\ln I - k{\cdot}\ln I_0 = k{\cdot}\ln(I/I_0)$, or $L \propto \ln(I/I_0)$.

This relationship the **Weber-Fechner law** that states that **the change in human perceived property is proportional to the fractional change in the stimulus.** It is common to a number of stimuli including weight and brightness.

The **sensitivity** of the ear is its ability to detect the smallest fractional change in intensity **dI/I**. It is defined as

$$S = \lg(I/dI)$$

Sensitivity, as you would expect, is strongly dependent on frequency and intensity, being a maximum for low intensities at about 2 kHz. The minimum change in intensity that can be detected is about 0.5 dB. This corresponds to a ratio of sound intensities I_1/I_2 of 12 per cent or one eighth, given by equation $0.5 = 10{\cdot}\lg(I_1/I_2)$ $\quad I_1/I_2 = \text{antilog}_{10}(1/20) = 1.12$

This is comparable with the sense of weight change at ~ 10 per cent but is considerably poorer than the sense of brightness change at ~ 1 per cent.

As previously described the intensity level scale is defined to be similar to the ear response that is logarithmic. This describes a physical quantity that can be calculated from the amplitude or intensity of the wave. Loudness is a subjective sensation and so has to be measured subjectively. Since loudness is frequency dependent, measurement must take this into account. There are two ways in which this is done.

In **phon measurements** all sounds are referred to a standard frequency of 1 kHz. In order to measure the loudness of an unknown source the following procedure is followed. The source to be measured is placed near the standard source, whose intensity is adjusted until the two sources have equal loudness. If a standard source has an intensity level of l dB, then the loudness of the unknown source is l phons. This is not a very practical procedure in many situations so there is a more common method.

The **dBA scale** is an adaptation to the intensity level scale to take account of frequency dependence. Measurements are made with a **sound level meter** which is a microphone calibrated to register a “weighted decibel” reading. This is done by means of circuits which suppress the contributions of high and low frequencies, so that the response is similar to the ear. This scale is now used almost universally in the measurement of noise, since it maintains the relationship between perceived loudness and measured value of “weighted intensity”, for example, an increase of 10 dBA doubles the loudness.

The damage that sounds can cause depends on the time the ears are exposed as well as the intensity. Sounds or noise rarely continue for a long at the same intensity, so a further quantity is defined to enable comparisons to be made of the effects of varying levels. The **equivalent continuous sound level L_{eq}** is that sound level which is constant for a defined period, would give an exposure to sound energy equivalent to that received. The defined period is usually 8 hours, as that is the nominal length of the working day. The quantity is thus called **L_{eq}[8 h]**. It is measured in dBA.

Defects of hearing. Hearing losses are usually divided into two categories. **Conductive loss** in which the sound vibrations do not reach the inner ear, and **nerve loss** where the cochlea does not pass impulses to the brain. The main causes are accident or trauma, disease, age and exposure to excessive noise. Young children are susceptible to temporary deafness as a result of cold-type infections in which fluid fills the middle ear. The eardrum can be ruptured by a sudden shock wave, the inner ear can be damaged by a blow of the head. Disease and age can reduce the ability of the bones of the middle ear or the oval window to respond to the pressure variations. Conductive hearing loss can be sometimes corrected by surgery, such as the replacement of solidified ossicles with plastic ones. An alternative is use of a hearing aid which transmits the vibrations through the bones of the skull to inner ear.

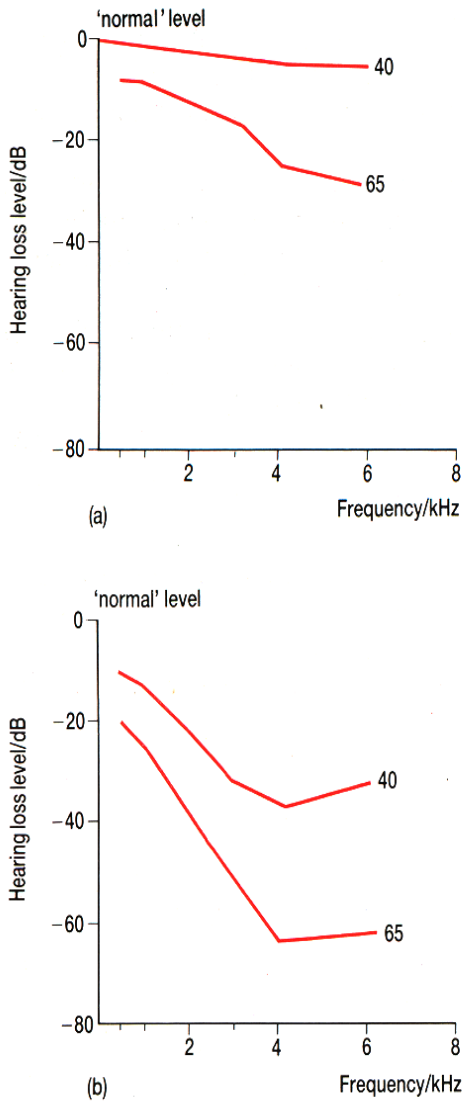

Figure 8

Any hearing aid cannot of course replace the sensation. At present there is no cure for nerve hearing loss, because of the nature of the nerve conduction process. Electronic aids (and ear trumpets) amplify the vibrations to compensate for the loss of sensitivity of the ear. Usually the frequency range is very limited, for conversation (2,000 – 5,000) Hz is adequate. This compares with the telephone's range of (3,000 – 3,400) Hz.

Measuring hearing. Ears are tested in a soundproofed room, usually with sound supplied by headphones to each ear in turn. The intensity is gradually increased until the subject indicates that it is heard. The procedure is repeated for selected frequencies to cover the normal range. These hearing thresholds are plotted on audiogram on which normal hearing is taken to be 0 dB. Figure 5a shows typical results for people aged 40 and 65, whose loss is due only to ageing (**presbycusis**). Figure 5b shows the results for similar age groups who have been exposed to noise with a L_{eq} of 96 dBA for eight hours a day, five days a week since their eighteenth birthday. Note how the higher frequencies are most severely affected.

Lab test. Pure tone audiometry

What is pure tone audiometry?

Pure tone audiometry is a test is to get a qualitative and quantitative analysis of the patients hearing. The frequency range tested is 125 Hz to 8000 Hz.

What are the aims of pure tone audiometry?

Analysis of the patients hearing loss (conductive, sensorineural or mixed loss)

1. For pre-operative and post operative evaluations
2. Medico-legal purposes
3. For prescription of hearing aid
4. In malingering patients

How is pure tone audiometry done?

Pure tone audiometry is carried out in a sound proof room. Air conduction thresholds for frequencies upto 125, 250, 500, 1000, 2000, 4000 and 8000 Hz, and bone conduction thresholds for 250, 500, 1000, 2000 and 4000 Hz are done. The patient is told to raise his finger or give a signal when he appreciates the slightest sound.

Inference: The intensity of the sound raised above the normal level is directly proportional to the degree of hearing loss. The bone conduction hearing is indicative of the cochlear function. The difference between the thresholds of air and bone conduction is a measure of the conductive hearing loss. The audiometer is calibrated such that a normal person would have an air bone gap within 20db with bone conduction higher than air conduction. Sensorineural hearing loss shows reduction in threshold of both bone conduction and air conduction.

Recording of results. Results are recorded in tabular and graphic form. Separate forms to represent each ear is used.

Audiogram form. When the graphic form is used, the test frequencies shall be recorded on the abscissa, indicating frequency on a logarithmic scale, and hearing levels shall be recorded on the ordinate, using a linear scale to include the units of decibels. The aspect ratio of the audiogram is important for standardization. The correct aspect ratio is realized when a square is formed between any given octave pair on the abscissa and any 20 dB increment on the ordinate. For conventional audiometry, the vertical scale is to be designated hearing level in decibels; the horizontal scale is to be labeled frequency in hertz. By convention, frequency is recorded in ascending order from left to right, and hearing level is recorded in ascending order from top to bottom, ranging from a minimum value of −10 dB to the maximum output limits of the audiometer (usually 110 or 120 dB HL). It is advisable when reporting extended high-frequency audiometric results to use a separate graph that incorporates the appropriate decibel scale (HL vs. SPL) and frequency range measured.