Hearing – A Physical Phenomenon

VANITHA DANIEL
Lecturer
DIET, Kurukkathi
Nagapattanam, Tamilnadu

V.S. SURESH KUMAR
Lecturer in Physics (S.G.)
T.B.M.L. College
Porayar 609 307
Tamilnadu

EVEN IN THE quietest country side, there are still sounds, such as wind, singing birds and buzzing insects. Sound waves, a physical phenomenon, are sure to occur when a falling tree hits the ground. The human auditory system enables us to hear not only the sound produced by a falling tree, but also the birds singing in the trees and the wind blowing through their leaves. Our auditory systems are amazingly well adapted for detecting and interpreting an enormous variety of information.

Properties of Sound Waves

Sound waves are characterised by their amplitude, their wave length and their purity. These physical properties affect mainly the perceived qualities and sound like its loudness, pitch and timbre. Varying wavelengths of sound are described in terms of their frequency, which is measured in cycles per second or hertz (Hz).

Frequency

The frequency of a sound is the number of compressions per second, measured in hertz (Hz-cycles per second). Pitch is a perception closely related to frequency. As a rule, the higher the frequency of a sound, the higher is its pitch. The maximum displacement of the wave corresponds to amplitude and the number of waves per second corresponds to frequency (Fig. 1).

Higher frequencies are perceived as having higher ptich. Humans can hear sounds ranging in frequency from a low of 20 Hz upto a high of about 20,000 Hz. Sounds of either end of this range are harder to hear. At the other extremes, bats and porpoises can hear frequencies well above 20,000 Hz. Low frequency sounds under 10 Hz are audible to homing pigeons.

Amplitude

In general, the greater the amplitude of sound waves, the louder the sound perceived (Fig. 1). The amplitude is measured in decibels (dB). Even brief exposure to sounds over 120 decibels can be painful and affects auditory system.

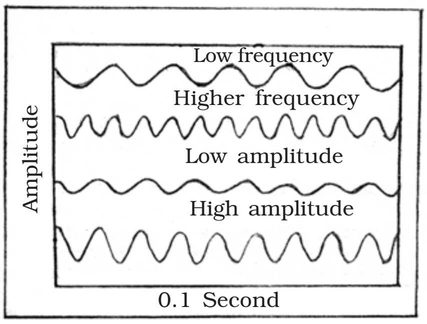

Fig. 1: Four Sound Waves of different frequencies and amplitude

The following table gives the relative intensities of a few sounds. The threshold intensity is taken as zero decibel.

Soft music	–	40 decibels
Telephone	–	60-70 decibels
Busy traffic	–	70-85 decibels
Alarm clock	–	80 decibels
Jet aircraft	–	115-120 decibels

According to WHO Noise affects health and prolonged exposure to sound above 140 decibels may produce insanity.

Perception of high frequency decreses with age. Preschool children are better than adults at hearing frequencies of 2,000 Hz and above (B.A. Schneider Trehub, Morron giello & Thorpe 1986). For middle aged adults, the upper limit for hearing decreases by about 80 Hz every six months (Von Bekery 1987). The upper limit drops even faster for those exposed to loud noises.

Loudness

The loudness of a note depends upon the intensity of sound or the rate of flow of energy to the ear. But it is not proportional to it since the sensitiveness of the ear varies with the pitch. Near the middle of the audible range of frequencies, the ear is mot sensitive to changes of intensity which it interprets as loudness.

Sensory Processing in the Ear

Our ears are specially designed to detect sound waves, turn them into nerve signals and send these nerve signals to the brain which analyses them and identifies the sound. Sound waves are periodic compression of air, water or other media. When a source emits sound it basically sets up vibration in the surrounding medium. The vibrating source sets up tiny disturbances in the surrounding medium. These disturbances in air cause rise and fall of air pressure relative to the normal ambient pressure. As the sound waves travel through the medium, the sound energy is passed on by the air molecules via vibration. The sound waves reach the listener from the source in this manner. The sound wave simply impinges upon a funnel (the pinna) in the human ear, which acts to feed the sound wave down a natural tube (the ear canal) to a terminating membrane (Jympanic membrane) to make it vibrate in response to the sound pressure variation and hence 'pass on' the sound energy via mechanical vibration. The sound wave is enhanced on arrival at the ear drum. This is a result of head baffle and ear cancel resonance. Figure 2 shows different regions of the pasilar

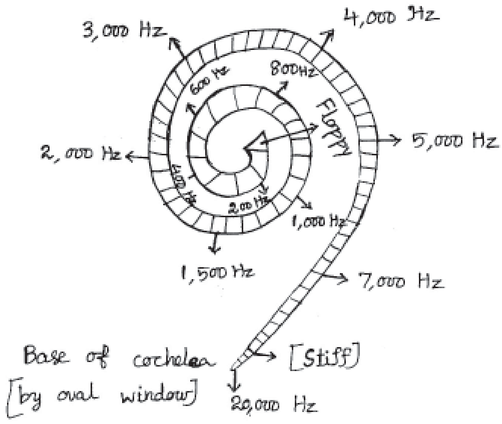

Fig. 2: The Basilar Membrane of the Human Cochlea

membrane of the ear that are sensitive to different range of frequencies.

If a person is to perceive a stimulus, it will be necessary to translate the molecular sound energy to fluid vibratory energy in the cochlea, which will in turn produce the electrical potentials of the auditory nerve fibres. This can be achieved effectively in human by means of conducive pathway of the ear, which facilitates the efficient transfer of acoustic vibratory energy into fluid vibratory energy, with the resultant generation of electrical potentials in the auditory nerve (Fig. 3).

of sound energy transfer from tympanic membrane to stapes foot plate being achieved via mechanical vibration of the ear ossicles. The sound pressure at the stapes foot plate is therefore enhanced by a factor of ~18 relative to that at the tympanum membrane.

The ossicles may be considered as a series of levers. Since the length of the manubrium and nech of the malleus is longer than the long process of the incus, a mechanical advantage of 1.3 results. Overall boost to sound pressure at the stapes foot plate is approximately a factor of 23 (i.e. 18 × 1.3).

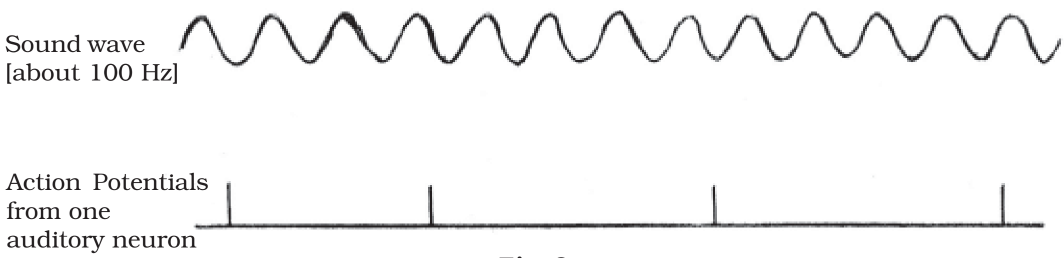

Fig. 3

Air molecules are very light, inelastic particles while the perilymph molecules are much denser and highly elastic. It is necessary to boost the incoming sound wave, so that an effective transfer of energy to the fluid medium is achieved. The sound pressure at the tympanic membrane is enhanced to that at the entrance to the pinna by the resonance effects of cochlea and ear canal. This sound pressure acts upon the tympanic membrane and causes vibration. Two-thirds of membrane area is involved in sound pressure transfer to the manubrium of the mallius — a passage

The inner ear consists largely of the cochlea a fluid filled coiled-tunnel that contains the receptors for hearing. The basilar membrane, which runs the entire length of the spiraled cochlea, holds the authority receptors called hair cells.

Vibrations that are transmitted to cochlea through the oval window by the foot plate of the stapes set up vibrations in the perilymph which surrounds the membranous labyrinth containing the end organs of hearing and balance. At last the vibration of the basilar membrane cause a pull or shearing force on the hair cells attached to the tectorial membrane. This action transform the fluid vibratory energy into electrical impulses that stimulate the fibres of the acoustic nerve (eighth cranial nerve). These signals then travel along the acoustic nerve to the brain where they are translated into sound, whether it is the sound of rustling leaves or chirping birds or cars backfiring.

REFERENCES

SAIHGAL, B.L. *A textbook of Sound.*
TUCKER, IVAN AND NOLAN, MICHAEL, *Educational Audiology.*
WEITEN, WAYNE. *Psychology Themes and Variation.*