

Acoustics

Acoustics is the name given to that branch of science that deals with sound. The scientific study of sound attempts to characterise, quantify and describe sound. Acoustics originated with music, showing the close relationship that exists between art and science. At a simple level, 'sound' is what the ear receives via the air from someone's voice. Acoustics is based fundamentally on the study of motion: the movement of a source (e.g. the voice), the propagation of acoustic waves through a medium (e.g. the air) and the subsequent detection of the movement by a receiver (e.g. the ear).



the brain, which then processes this information and converts the received signal into something that we can understand. The sound is then perceived as loud or soft, as a high or a low note, or on a more general level, perhaps as noise, or as music.

Hearing

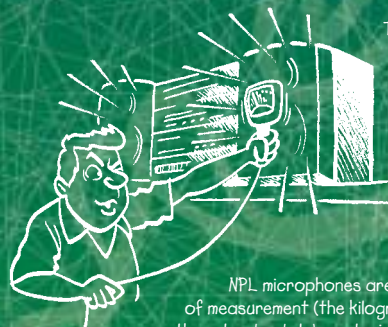
Of the five senses, hearing is one of the most important. Audible sounds enable communication, and they can tell us what and where things are. They certainly have a significant effect on how we feel. The human ear is an organ of complex design and function. The ear forms the receiver and transmission line to

Frequency

The pitch of a note is described by its frequency. Frequency is measured in hertz (Hz), or cycles per second. The general range of hearing for young people is 20 Hz to 20 kHz. The upper frequency limit decreases with age, and so the older a person gets, the less well they can hear high notes. Also, the male hearing range decreases more quickly than the female, and so women can generally hear higher pitch notes than men of similar age.

Measurement of Sound

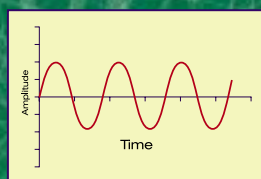
The measurement of sound determines how loud something is, whether it is too noisy, or even whether it is safe to be near. The National Physical Laboratory (NPL) measures airborne sound using microphones consisting of a sensitive element that converts the acoustic pressure into a proportional output voltage which can then be measured. The output of the microphone can be filtered to match the sensitivity of the human ear. In underwater acoustics, specially-adapted microphones, known as hydrophones, work in the same manner.



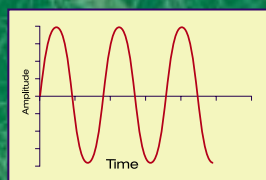
NPL microphones are calibrated against a source which is traceable to base units of measurement (the kilogram, metre, second). Through international comparisons with other standards laboratories, NPL's realisation of the acoustic pascal is checked on a regular basis. Using these calibrated microphones, other sound sources may then be characterised; these may themselves be used to calibrate other microphones. In this way, manufacturers and users of acoustic equipment can demonstrate that their equipment is traceable to national standards.

Sound Waves

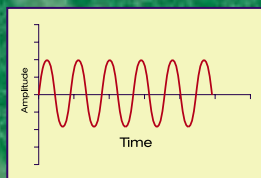
Sound is transmitted via the movement of the particles in a medium, such as air or water. Energy is transferred from one region to another via a series of compression and tension cycles: the motion of the particles is parallel to the propagation direction. The acoustic disturbance can be represented as a wave, with the x-axis representing time, and the y-axis the displacement of a given particle in the medium from its rest position.



Increasing the strength of the sound source extends the displacement of the particle, and so the acoustic pressure will also increase. This is heard as an increase in loudness.



Exciting the sound source more rapidly increases the frequency of the sound, and produces more cycles in a given period. This is heard as an increase in pitch.



Two basic quantities that can describe the nature of a sound are frequency and amplitude (of displacement or acoustic pressure). Sounds can be formed by a simple harmonic mixture of frequencies (as produced by a guitar string), an intentional mixture of frequencies and amplitude (music) or a seemingly random mixture of frequencies and amplitudes (noise).

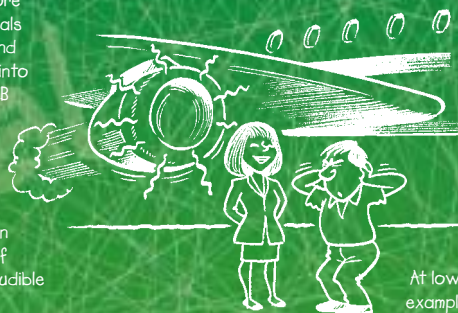
The Decibel

The decibel scale is a logarithmic scale applicable to any parameter used to make quantities with a wide range of values more manageable. In the measurement of sound, we are concerned with the amplitude of the acoustic pressure, measured in pascals (Pa). The range of acoustic pressures that the human ear can detect is very wide - from the lower limit of hearing at around 20 μPa (2×10^{-5} Pa) to the threshold of pain at around 20 Pa. This very wide range of values is unwieldy, so it is converted into a logarithmic scale. This changes the range of values shown above to the more manageable range of 0 dB to 140 dB. Thus 0 dB is roughly the lowest level a normal person can hear, but it is not the lowest level possible!

Animal Acoustics

Like humans, animals communicate by sound. In some species, the frequency of sound used is far above the limit of human hearing - and is hence ultrasonic. Bats can fly and navigate in darkness by echolocation, whereby they produce short bursts of sound. Insects also communicate via sounds, with crickets using their wings to produce audible frequencies, sometimes at acoustic pressure levels as high as 80 dB.

The ocean is awash with sound, as dolphins, whales and even snapping shrimp all join in the chorus. Bottlenose dolphins are among the most interesting species, with their characteristic "clicks" of sound at frequencies up to 150 kHz which are used in echolocation when feeding. Dolphins also produce whistles with each individual having a unique "signature" consisting of sound in the range 4 kHz to 20 kHz lasting for a few seconds. In this way they can communicate with other dolphins, vital for a social animal in an environment of limited visibility.



Underwater Acoustics

Underwater acoustics covers a wide range of applications, from sea-bed imaging to submarine detection, from whale-tracking to diver communication, from mine-hunting to oil exploration. But why use sound underwater? Electromagnetic waves are used in space and through the atmosphere for communication via radar, microwaves and of course visible light. In the turbid, saline environment of the sea, electromagnetic waves are rapidly attenuated, having a range of only a few tens of metres. However, sound signals can travel for thousands of kilometres underwater, and with techniques such as sonar, shipwrecks can be found and fish stocks counted - all using underwater sound.

Ultrasound

Sound that is beyond the upper limit of human hearing is termed ultrasound and generally refers to frequencies above 20 kHz. Ultrasound has been used for many years to communicate information: early remote controls for televisions used ultrasonic frequencies.

Many people are familiar with ultrasound as a way of looking inside the human body: specifically, for imaging unborn babies. This is in fact another form of echolocation. Measurement of ultrasound fields is carried out at NPL using hydrophones, which are simply microphones designed to operate under water. NPL is involved in developing standards in this area, to ensure that the safe track record of medical ultrasound is maintained. However, there are many other applications of ultrasound, such as cleaning, industrial processing and testing in the aircraft industry.



Courtesy of ATL Medical Systems

Noise

Noise is an important form of pollution caused by unwanted sound. At low levels noise can be a nuisance, but exposure to sustained high levels, for example in a noisy workplace, can cause hearing loss. Impulsive noise, such as the sound of a pneumatic tool, or tonal noise, such as the whine of a machine, can be particularly irritating. But what some people consider as noise, others can tolerate, or may even like, and so the study of noise has to recognise these different subjective responses.

How Noisy is...

Plane
125 dB



Pneumatic Drill
105 dB



Heavy Traffic
90 dB



Business Office
65 dB



Library
35 dB



Quiet Forest
15 dB



Threshold of Hearing
0 dB

NPL
National Physical Laboratory



If you have a measurement related scientific question contact us on: telephone 020 8943 6880 email: enquiry@npl.co.uk or visit our web site which has lots of measurement related information at <http://www.npl.co.uk>