# Sound

## SPRAY-LINING MATERIALS FOR dealing with sound:

## 244 dB re 20 µPa = AVERAGE CAPACITY SOUND REDUCTION OR ELIMINATION

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*This article is about compression waves. For other uses, see Sound (disambiguation).*

**Sound** is a disturbance of mechanical energy that propagates through matter as a longitudinal wave. Sound is characterized by the properties of sound waves, which are frequency, wavelength, period, amplitude, and speed. The latter is sometimes referred to as 'sound velocity' but this is incorrect as it is not a vector quantity.

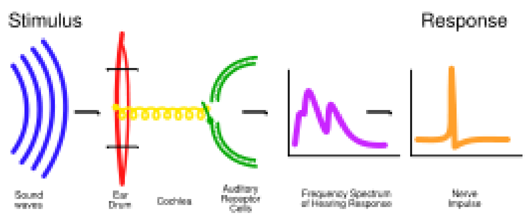
Humans perceive sound by the sense of hearing. By sound, we commonly mean the vibrations that travel through air and can be heard by humans. However, scientists and engineers use a wider definition of sound that includes low and high frequency vibrations in air that cannot be heard by humans, and vibrations that travel through all forms of matter, gases, liquids and solids. Sound can also be perceived by many other animals and is also used for echolocation.

The matter that supports the sound is called the medium. Sound propagates as waves of alternating pressure, causing local regions of compression and rarefaction. Particles in the medium are displaced by the wave and oscillate. The scientific study of sound is called acoustics while that underwater is called hydroacoustics.

Noise is often used to refer to an unwanted sound. In science and engineering, noise is an undesirable component that obscures a wanted signal. Sound is the movement of energy through a substance in longitudinal waves. Sound is produced when a force causes an object to vibrate.

# Content

### Perception of sound




A schematic representation of hearing. (Blue: sound waves. Red: eardrum. Yellow: cochlea. Green: auditory receptor cells. Purple: frequency spectrum of hearing response. Orange: nerve impulse)

Sound is perceived through the sense of hearing. Humans and many animals use their ears to hear sound, but loud sounds and low-frequency sounds can be perceived by other parts of the body through the sense of touch as vibrations. Sounds are used in several ways, notably for communication through speech and music. They can also be used to acquire information about properties of the surrounding environment such as spatial characteristics and presence of other animals or objects. For example, bats use echolocation, ships and submarines use sonar and humans can determine spatial information by the way in which they perceive sounds.

Humans can generally hear sounds with frequencies between 20 Hz and 20 kHz (the audio range) although this range varies significantly with age, occupational hearing damage, and gender; the majority of people can no longer hear 20,000 Hz by the time they are teenagers, and progressively lose the ability to hear higher frequencies as they get older. Most human speech communication

takes place between 200 and 8,000 Hz and the human ear is most sensitive to frequencies around 1000-3,500 Hz. Sound above the hearing range is known as ultrasound, and that below the hearing range as infrasound.
The amplitude of a sound wave is specified in terms of its pressure. The human ear can detect sounds with a very wide range of amplitudes and so a logarithmic decibel amplitude scale is used. The quietest sounds that humans can hear have an amplitude of approximately 20 μPa (micropascals) or a sound pressure level (SPL) of 0 dB re 20 μPa (often incorrectly abbreviated as 0 dB SPL). Prolonged exposure to a sound pressure level exceeding 85 dB can permanently damage the ear, resulting in tinnitus and hearing impairment. Sound levels in excess of 130 dB are more than the human ear can safely withstand and can result in serious pain and permanent damage. At very high amplitudes, sound waves exhibit nonlinear effects, including shock.

**Speed of sound**

The speed at which sound travels depends on the medium through which the waves are passing, and is often quoted as a fundamental property of the material. In general, the speed of sound is proportional to the square root of the ratio of the stiffness of the medium and its density. Those physical properties and the speed of sound change with ambient conditions. For example, the speed of sound in air and other gases depends on temperature. In air, the speed of sound is approximately 344 m/s, in water 1500 m/s and in a bar of steel 5000 m/s. The speed of sound is also slightly sensitive (to second order) to the sound amplitude, resulting in nonlinear propagation effects, such as the weak production of harmonics and the mixing of tones (see parametric array). Sound pressure

# Sound pressure

**Sound pressure** is the pressure deviation from the local ambient pressure caused by a **sound** wave. Sound pressure can be measured using a microphone in air and a hydrophone in water. The SI unit for sound pressure is the pascal (symbol: Pa). The instantaneous sound pressure is the deviation from the local ambient pressure caused by a sound wave at a given location and given instant in time. The effective sound pressure is the root mean square of the instantaneous sound pressure over a given interval of time. In a soundwave, the complementary variable to sound pressure is the acoustic particle velocity. For small amplitudes, sound pressure and particle velocity are linearly related and their ratio is the acoustic impedance. The acoustic impedance depends on both the characteristics of the wave and the medium. The local instantaneous sound intensity is the product of the sound pressure and the acoustic particle velocity and is, therefore, a vector quantity in time.

**Sound pressure level**

As the human ear can detect sounds with a very wide range of amplitudes, sound pressure is often measured as a level on a logarithmic decibel scale.
The **sound pressure level** (SPL) or $L_p$ is defined as

$$L_\mathrm{p} = 10\,\log_{10}\left(\frac{p^2}{{p_0}^2}\right) = 20\,\log_{10}\left(\frac{p}{p_0}\right)\ \mathrm{dB}$$

where $p$ is the root-mean-square sound pressure and $p_0$ is a reference sound pressure. (When using sound pressure levels, it may be important to quote the reference sound pressure used.) Commonly used reference sound pressures, defined in the standard ANSI S1.1-1994, are 20 µPa in air and 1 µPa in water.

Since the human ear does not have a flat spectral response, sound pressure levels are often frequency weighted so that the measured level will match perceived levels more closely. The International Electrotechnical Commission (IEC) has defined several weighting schemes. A-weighting attempts to match the response of the human ear to noise and A-weighted sound pressure levels are labeled dBA. C-weighting is used to measure peak levels.

**Examples of sound pressure and sound pressure levels**

| Source of sound | sound pressure<br>pascal | sound pressure level<br>dB re 20 µPa |
|---|---|---|
| threshold of pain | 100 | 134 |
| hearing damage during short-term effect | 20 | approx. 120 |
| jet, 100 m distant | 6 - 200 | 110 - 140 |
| jack hammer, 1 m distant / discotheque | 2 | approx. 100 |
| hearing damage during long-term effect | $6\times10^{-1}$ | approx. 90 |
| major road, 10 m distant | $2\times10^{-1}$ - $6\times10^{-1}$ | 80 - 90 |
| passenger car, 10 m distant | $2\times10^{-2}$ - $2\times10^{-1}$ | 60 - 80 |
| TV set at home level, 1 m distant | $2\times10^{-2}$ | ca. 60 |
| normal talking, 1 m distant | $2\times10^{-3}$ - $2\times10^{-2}$ | 40 - 60 |
| very calm room | $2\times10^{-4}$ - $6\times10^{-4}$ | 20 - 30 |
| leaves noise, calm breathing | $6\times10^{-5}$ | 10 |
| auditory threshold at 2 kHz | $2\times10^{-5}$ | 0 |

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