Education in Acoustics

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Module #1: Sound – what it is, and how it affects comfort

Sound is one of the 5 senses (in addition to *touch, sight, smell* and *feel*). Sound is caused by a molecular chain-reaction, where there is a source that emits vibrations in the air which then stimulate air molecules to move. These air molecules are pushed away from the source (technically, this causes decompression of the air on the other side of the source, which in turn pulls the molecules forward). As these vibrational air waves move, they travel with a certain frequency, affecting their height and distance.

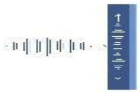
As the sound waves move, they either dissipate or they find their way to ones' eardrum, where the vibrations are processed and the signal transmits to the brain, enabling the sound to be 'heard'. The louder the source (ie: the stronger the oscillating vibrations to the air), the louder the sound will be, and all other things equal, the farther it will travel.

Frequency - refers to the number of waves of sound that pass a point in one second and is measured in Hertz (Hz). A higher frequency sound has more wave cycles per second, resulting in a higher pitch sound. A lower frequency sound has fewer wave cycles per second, resulting in a lower pitch sound.

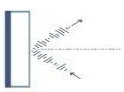
Sounds are everywhere- in nature, voices, and in mechanical noises. It is a force that moves in all directions. In enclosed spaces sound waves react differently based upon the obstacles in their way.

Sound waves typically encounter these processes in their journey indoors:

Absorption, Reflection, Diffusion, Diffraction, Refraction, and Transmission.

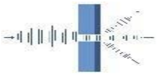


Absorption – a sound wave gets absorbed by the material it bounces into. As the sound wave hits the surface, the sound absorbed turns into heat energy inside the material or object.

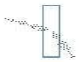


Reflection – a sound wave hits an object or wall surface, and it reflects off it at the same angle it came in on. If there is too much reflection in a space, it can amplify the sound, create echoes, or reverberation.

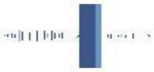
Diffusion – a sound wave scatters in different directions when it hits an obstacle, object, or material.



Diffraction – a sound wave either bends around the edge of a material or object it encounters, or the wave passes through an opening and then spreads out.



Refraction – a sound wave bends as it goes from material or object to another. The sound wave both changes direction and speed when refraction occurs.

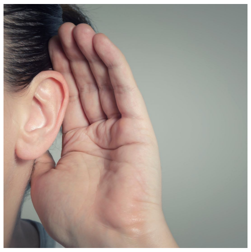


Transmission – a sound wave hits a material or object and a certain amount of it physically travels out of that material through the other side.

An acoustic environment refers to the physical space and the materials within it that affect the behavior of sound waves, which in turn can affect ones' comfort and their sense of physical well-being. The acoustic environment can include the size, shape, and materials of the room, as well as the presence of furniture, people, and other objects. The acoustic environment influences the characteristics of sound, including its frequency response, volume, and clarity. A well-designed acoustic environment can enhance the quality of sound, while a poor acoustic environment can produce unwanted reflections, echoes, and background noise that can affect speech intelligibility and music quality.

Poor acoustic spaces: environments that have characteristics that negatively impact the quality of sound. Not only can these spaces make it difficult to hear speech, music, or other sounds clearly, it can also lead to listener fatigue and discomfort. Some examples of poor acoustic spaces include:

- Rooms with hard surfaces, such as concrete or glass, which reflect sound waves and create echoes.
- Rooms with low ceilings and flat walls, which can produce a "boxy" sound with little natural reverb.
- Rooms with irregular shapes or asymmetrical surfaces, which can produce unpredictable reflections and dead spots.
- Rooms with excessive background noise, such as air conditioning or traffic, which can make it difficult to hear speech or music.
- Rooms with insufficient sound absorption, such as those with bare walls and floors, which can lead to excessive reverb and a lack of clarity.



Excessive high levels of noise have been shown to contribute to a wide range of psychological issues, from anxiety and depression to heart disease. In work environments, it has been shown that once a person is distracted by noise, it can take up to 25 minutes to recover to a level of full concentration. These noises affect focus, productivity, work accuracy, and ultimately occupant happiness and comfort. In educational environments, as studies have shown, a reduction in acoustic reverberation leads to greater information retention by students, higher levels of engagement, and improved behavior.

Good acoustic spaces: environments that enhance the quality of sound by controlling reflections, reverb, and background noise. A well-designed acoustic space can enhance speech intelligibility, music quality, and overall listening comfort. Here are some characteristics of good acoustic spaces:

- ***Appropriate size and shape***: A room with moderate dimensions and a balanced ratio of width to length to height can help control reflections and produce a natural reverb.
- ***Absorptive materials***: Materials with high sound absorption coefficients, such as thick curtains, carpet, and upholstered or acoustic furniture, can help control reflections and reduce reverb.
- ***Diffusive materials***: Materials with random surface profiles, such as perforated metal or acoustical tiles, can scatter sound and produce a more even sound field.
- ***Appropriate background noise***: Low levels of background noise, such as white noise or room tone, can help mask unwanted sounds and create a more pleasant listening environment.
- ***Sound-isolating construction***: Construction techniques that isolate the room from external sounds, such as double walls and floor/ceiling assemblies, can reduce background noise and improve speech intelligibility.

To summarize, sound is a dynamic science because it involves the study of constantly changing and complex processes. Sound waves can interact with the environment, reflecting off surfaces, bending as they move through different materials, and being absorbed by soft materials. These interactions produce changes in the sound wave's frequency, amplitude, and direction, making it a constantly changing and complex phenomenon.

In the next Module, we will delve into measuring sound and why it matters.