Architectural Acoustics

Basics in room acoustics

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Agenda

- 15:45 - 16:30 Basics in Room Acoustics.
  - Sound propagation: Ray-like and wave-like propagation
  - Sound Wave Reflection, incident angle, reflected angle
  - Sound Wave Absorption
  - Sound Wave Diffusion
  - Scattering at edges

- 16:45 - 17:30 Discussion of assignments 1-3, focus on 3
- 17:45 - 18:00 Exercise 4
- 18:00 - 18:20 Acoustic walk on the campus
- 18:20 - 18:30 Wrap up

Sound Wave Propagation: Ray-like Propagation

Sound is specularly reflected when it bounces off a smooth and hard surface, following the law of reflection, much like light. Examples of surfaces that exhibit specular sound reflection include:

- Smooth walls in a tiled bathroom.
- Glass windows.
- Polished metal surfaces.
- Calm water surfaces, such as a still pond.

In these cases, sound waves bounce off the surface at an angle equal to the angle of incidence, creating distinct, predictable reflections.

[Parabolic reflections]

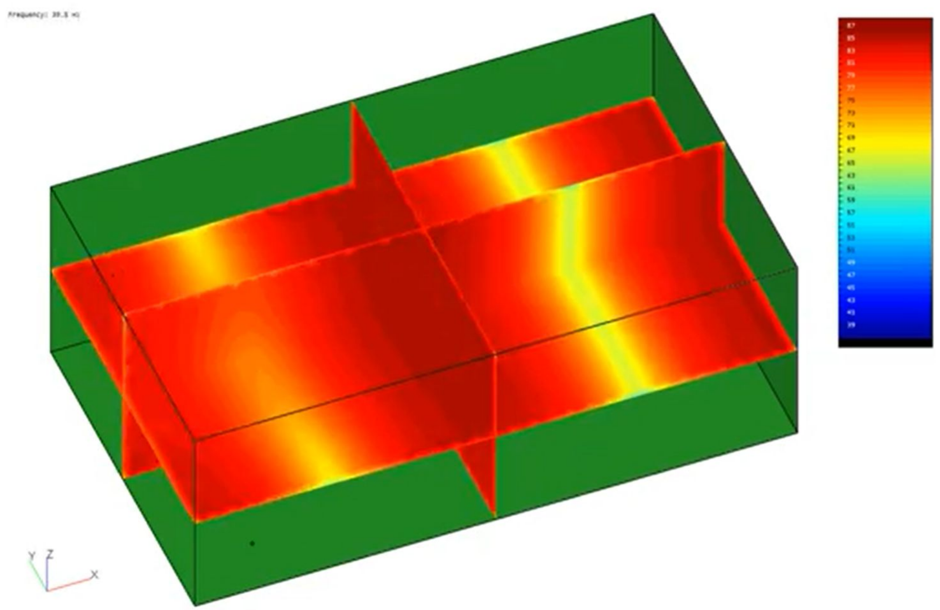
[Urban sound reflections]

[Specular reflections]

Sound Wave Propagation: Wave-like Propagation

Specially for low frequencies the following phenomena demonstrate the wave-like propagation type:

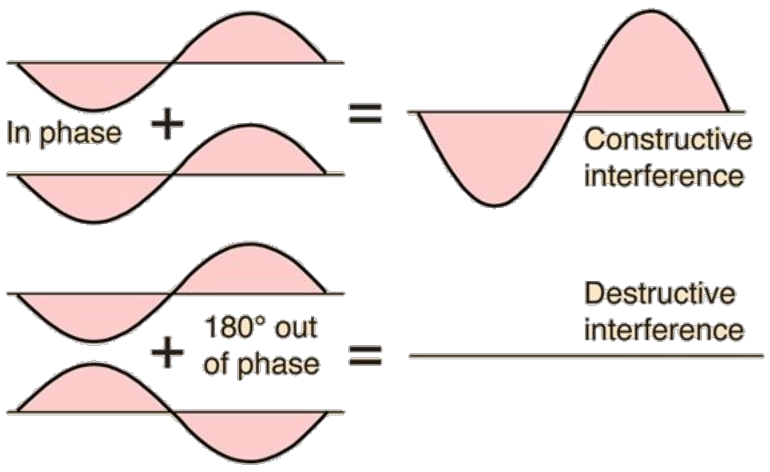
- Diffraction: Sound waves can bend around obstacles, allowing you to hear sounds from behind walls or around corners.
- Interference: When two sound waves overlap, they can either reinforce (constructive interference) or cancel each other out (destructive interference).
- Resonance: Objects can vibrate sympathetically when exposed to certain frequencies, leading to amplification of sound.
- Standing Waves: In enclosed spaces like rooms, standing waves can form due to sound wave reflections, creating areas with enhanced or reduced sound intensity.

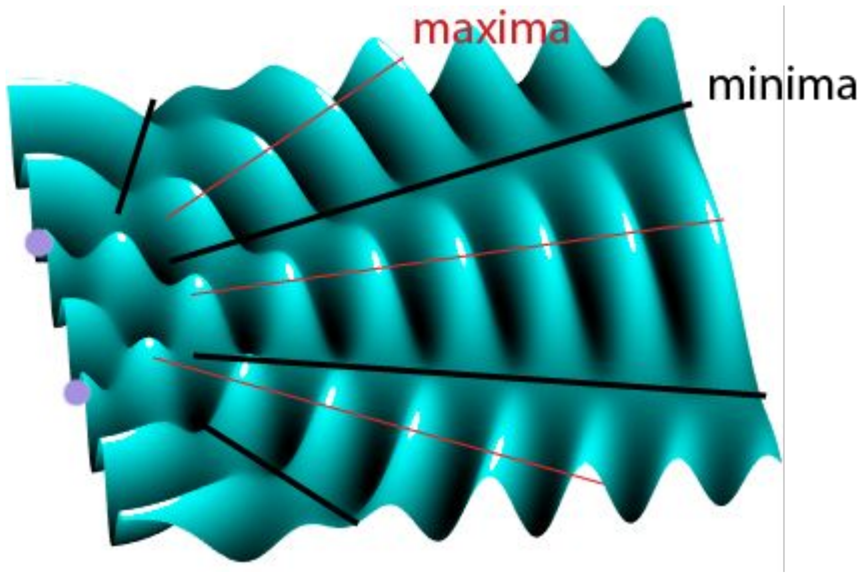


[Modes.avi]

[Two Sources]

Constructive and destructive interference

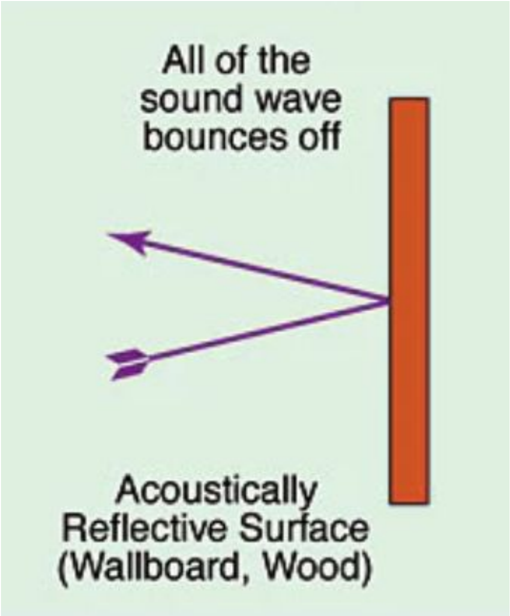




link

Specular Reflection of Sound

- Specular reflection with sound is when sound waves bounce off a smooth, flat surface like a mirror, often creating clear and organized echoes.
- The angle of incidence equals the angle of reflection.
- In contrast, diffuse reflection scatters sound waves in various directions, like from a rough wall, creating less organized and less distinct echoes.



[Specular reflections]

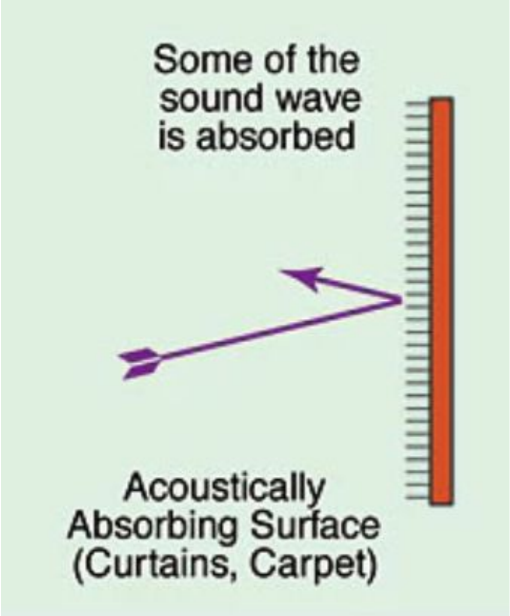
Sound Wave Absorption

Sound absorbers are materials or structures designed to reduce the reflection of sound waves.

They work by either being porous materials, which trap and dissipate sound energy through friction, or dampened resonators, which vibrate in response to sound and dissipate energy.

Sound absorbers are often engineered to be most effective at specific frequencies, addressing the need to control certain ranges of sound in different environments.

Porous materials absorb higher frequencies (only),
resonant materials absorb lower frequencies (not only).

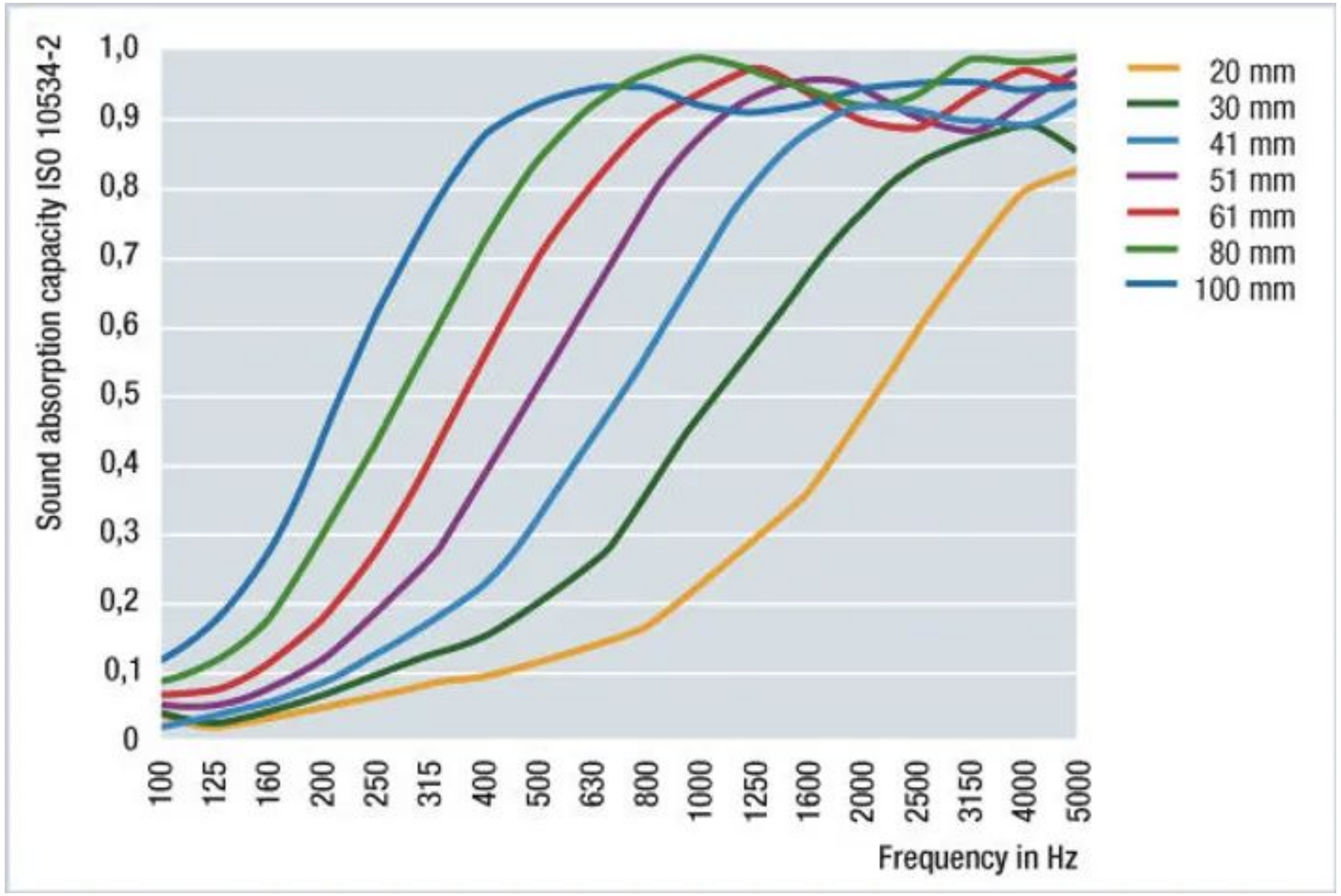


Sound Wave Absorption

- Porous materials absorb mainly higher frequencies (only),
- resonant materials absorb also lower frequencies (mainly).

Usually sound absorption is specified per octave or third octave.

Summing up all absorption-weighted surfaces yields the total absorbent surface for a particular frequency band and is the basis to calculate the reverberation time in that frequency range.



Sound absorption coefficients for Melamine foam.

Sound Wave Absorption: Porous Materials

Curtains

Textiles, fabrics

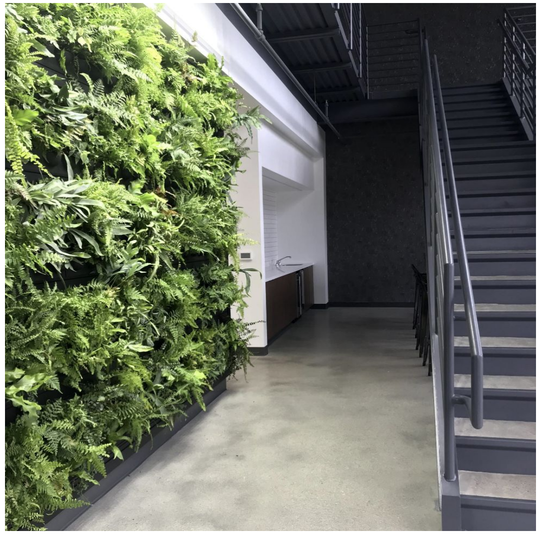
Acoustic ceilings

Fibrous materials

Desktop and wall absorbers

PET, textiles, open foams

Fancy stuff



Moss, dense plants

Sound Wave Absorption: Resonant Materials

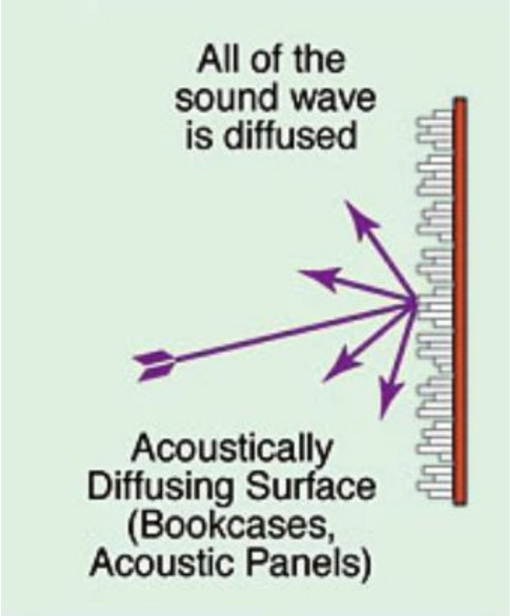
Corner Bass Traps	Slit and hole absorbers	Perforated ceiling absorbers	Fancy stuff
			
‘Box with slits, holes’	‘Box with slits, holes’	Wood/metal frame with infill	Perforated acrylic glass

Diffuse Scattering of Sound

An incident sound ‘ray / wave’ is scattered multiple in directions and not only reflected specularly.

- Bookshelves: A bookshelves creates an irregular surfaces that break up sound waves and reduce the (flutter) echo in the room.
- Textured Ceilings: Ceilings with textured or stucco finishes can scatter sound diffusely.
- Wall Decorations and furniture with hard surfaces: Items like wooden tables, glass shelves, or metal cabinets can scatter sound without much absorption.

The dimensions of the structures of objects must be in the range of the wavelength of sound.



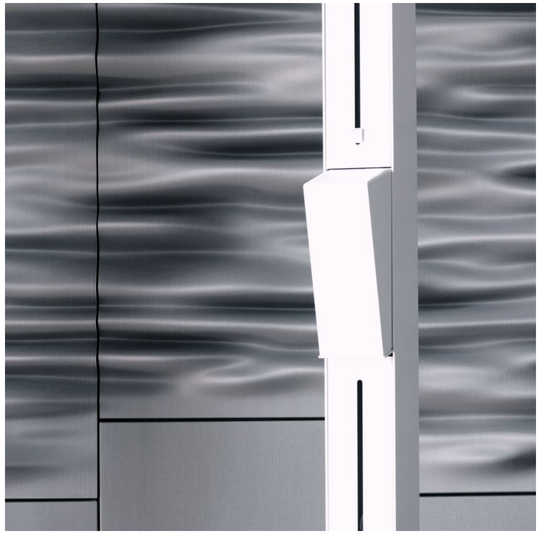
Diffuse Scattering

Sound Wave Diffusion: Structured Surfaces

Architecture 1

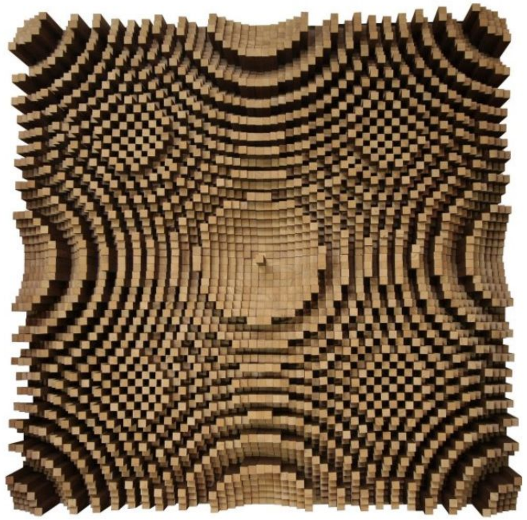
Ancient buildings, structures in all sizes

Architecture 2



3D printed, customizable plastic panels

Diffusors



Wooden mathematical structures

Rough surfaces

Irregular stone walls

Sound Wave Edge Diffraction

Edge diffraction in acoustics refers to the phenomenon where sound waves encounter an obstacle, such as the edge of a building or a wall, and undergo diffraction as they bend around the obstacle.

This bending of sound is dependent on the frequency and waves occurs mainly for low frequencies when the obstacle's dimensions are on the order of the wavelength of the sound or smaller than the wavelength.

Useful web pages to toy around with…

By Paul Falstad:

- Related to room modes: https://www.falstad.com/membrane/
- Related to wave propagation: https://www.falstad.com/ripple/

By amcoustics.com:

- Room mode calculator for box shaped rooms: https://amcoustics.com/tools/amroc
- Ray tracing sketch pad: https://amcoustics.com/tools/amray
- Reverberation time guessing tool: https://amcoustics.com/tools/amrev/#/room

Various RT60 calculators:

- http://www.csgnetwork.com/acousticreverbdelaycalc.html
- https://www.10log.com/public/rt
- https://www.soprema.co.uk/en/acoustic-reverberation-calculator

Wrap up and Feedback