Room Acoustics

Prof. Unruh told us:
- ***sound drops with distance squared***
- ***lower frequency can "bend" around walls***
- ***sound waves are additive***
- ***large build-up of pressure near walls → sound is 3db louder at walls***
- ***sound wavelength > walls "wiggle size" causes sound to scatter in different directions***
- ***so walls are oriented in direction and material to control reflections***

Terms:
- **long wavelength→low frequency**
- **short wavelength→high frequency**
- **reflection → wave bounces off object**
- **diffraction → edges used to spread in non-linear directions**
- **absorption → objects turn waves to heat**

Reverberation Time

- reverberation: prolonged sound if incident and secondary/reflected waves are separated by <1ms
- sound continues to reverberate around a room until it's energy has been fully absorbed by air and objects
- RT_{60} →time for amplitude to decay by 60dB
- RT_{60} AND number of modes is proportional to the size of room, inversely prop to absorption in room
- complex frequency spectra ring longer → more possibility of survival
- trick is to design a room where all frequencies have same RT_{60}
- If the RT_{60} s *too short*, all sounds very dry and hard to hear
  - ie: outdoor arenas, where the sound never reflects
- speech audibility = 1s
- <1s broadcasting/recording studio
- 1.5s-2s in opera/concert halls
- 10s old stone cathedrals
  - good for a slow organ music; as long as there are very slow changes of pitch
  - but terrible for fast music/speech

Reflection – Echoes

- perceiver in a room will hear sound which is a combo of the original sound and echoes from the walls, ceiling, and floors

- low frequencies (long wavelengths, up to 17m)
    - "bend" around walls via diffraction, using the edges to aid in propogation
    - less easily absorbed by air than high frequencies (think of thunder)
    - ear is less sensitive to them
    - tend to be diffracted and travel in different directions easier than low frequency
    - strong uniform echoes for simple uncluttered rooms

- high frequencies (small wavelength as small as 20mm)
    - short wavelengths have nice predictable reflections (forward)
    - reflections can be inconsistent and garbled

- an initial wave that hits someone's ear may still be dying out as the reflected wave arrives, resulting in distorted sounds (think about loud music in a gym)

Different materials absorb different frequencies to different degrees

- reflection off flat walls preserves sounds
    - concrete can reflect everything

- fibrous material absorb high frequencies well, but have troubles with low

- people, seats, furniture can absorb waves of most freq, depending on positions (node/antinode, later)
    - cause selective frequencies absorption/reflection depending on substance

- Clothing-- fur coats vs bare skin changes absorption

Architectural Acoustics

- specialized materials and shape employed to control sound propogations
- Chan centre
    - a adjustable-height chandelier/acoustic canopy over the stage made of steel and cork reflects sound as desired
    - sound-absorbent fabric banners acoustically mask walls
    - cello-like shape of the hall allows for an even distribution of sound
    - concrete walls are convex, with a stippled surface which helps to break down sound and prevent reverb
    - wood seen in the concert hall has been sealed to the concrete in order to prevent

any sympathetic vibrations

- other specialized reflection:
    - sound reflecting off a curved surface (parabola) will bounce out in a straight line (stage)
    - sound in an ellipse emitted at one focus will only converge at the other focus, due to standing wave interference…

Standing Waves – Interference

- waves flying through the room overlap, additive process or original/reflective waves causes interference
- “standing waves” develop due to
    - natural acoustic resonance of room (plucking string or striking drum response depends on where you strike it)
    - locations of nodes and antinodes remaining after inference of the modes of the sound
- some points end up strong, others weak
- If ONE ear is at node of a standing pressure wave, very quiet.
- both listener and instrument must be at relative max of a mode if a listener is to hear it well

EXPERIMENT: Modes in room

- Use loudspeaker w/ Fcn Generator at 1KHz (wavelength about 30cm)
- Have people close one ear and move head around
- Find nodes in room by moving head around.
- **problem:** not a simple source - many modes are being oscillated