

# ARCHITECTURAL ACOUSTICS REVIEWER

## 1. Objectives of Architectural Acoustics

- **Clear speech and good audibility**
- **Uniform sound distribution** across the space
- **Control of noise and echoes**
- **Acoustic privacy** between spaces

### Importance

- Architectural acoustics is not just controlling sound — it's about how humans perceive it.
- Considerations:
  - Hearing mechanism
  - Human perception
  - Comfort and health impacts
  - Noise control standards

## 2. How We Hear

### A. Anatomy of the Ear

Part	Function
<b>Pinna (External ear)</b>	Collects sound
<b>Ear canal</b>	Channels & amplifies sound
<b>Eardrum</b>	Converts sound waves to vibration
<b>Ossicles</b>	Amplify vibration
<b>Cochlea</b>	Converts vibration to nerve impulses
<b>Auditory nerve</b>	Sends signals to brain

### B. Hearing Process

1. Sound enters ear canal
2. Eardrum vibrates
3. Ossicles amplify vibration
4. Cochlea converts vibration to nerve impulses
5. Brain interprets sound

## 3. Sensitivity of the Ear

- **Frequency Range:** 20 Hz – 20,000 Hz
- **Most Sensitive Range:** 2,000 – 5,000 Hz
- **Thresholds:**
  - Hearing: 0 dB
  - Pain: 120–130 dB
- **Equal Loudness Curves:** Less sensitive to very low and very high frequencies

## 4. Sound Pressure Level (SPL)

- **Definition:** Measures intensity of sound in decibels (dB)
- **Formula:**

$$L_p = 20 \log_{10} \left( \frac{p}{p_0} \right) \quad L_p = 20 \log_{10} \left( \frac{p}{p_0} \right)$$

- $p$  = measured sound pressure
- $p_0$  = reference pressure (20  $\mu$ Pa)

## Typical SPL Levels

Sound	dB
Whisper	30
Conversation	60
Traffic	85
Jet engine	120

## 5. Loudness Level – Phon & Sone

- **Phon:** Based on 1 kHz tone reference
- **Sone:** Represents perceived loudness

$$\text{Sones} = 2^{(Phon - 40)/10} \quad \text{Sones} = 2^{\{(Phon - 40)/10\}}$$

- 40 phons = 1 sone
- Doubling sones  $\approx$  doubling perceived loudness

## 6. Sound in Enclosed Spaces

- **Components:**
  1. Direct sound – straight from source
  2. Reverberant sound – multiple reflections
- **Critical Distance:** Point where direct = reverberant sound

## 7. Sound Power & Pressure in Free Space

- **Sound Power (L<sub>w</sub>):** Property of source, independent of environment
- **Sound Pressure (L<sub>p</sub>):** Depends on distance and environment

### In Free Field:

$$L_p = L_w - 20 \log_{10} r - 11 \quad L_p = L_w - 20 \log_{10} r - 11$$

- Doubling distance  $\rightarrow$  SPL drops 6 dB

## 8. Other Factors in Hearing

- Age (e.g., presbycusis)
- Duration of exposure
- Psychological factors
- Directionality
- Masking & fatigue

**Architectural implication:** Accommodate elderly and sensitive users

## 9. Effects of Noise on Hearing

- **Temporary Threshold Shift (TTS):** Temporary hearing loss
- **Permanent Threshold Shift (PTS):** Irreversible hearing loss
- **Non-Auditory Effects:** Stress, sleep disturbance, reduced productivity, hypertension

- **Safe exposure:** ≤85 dB for 8 hours

## 10. Masking & Loudness in Rooms

- **Masking:** One sound makes another less audible
- Steps: Compare signal to masking threshold
- **Room Noise Example:** Convert SPL → phons → sones → total loudness

## 11. Directionality of Sound Sources

- **Omnidirectional:** Sound spreads equally in all directions (e.g., human voice at low frequencies)
- **Directional:** High frequencies are directional (e.g., loudspeakers, trumpets)
- **Design Implications:** Speaker placement, auditorium geometry, classroom layout

## 12. Speech, Music, and Noise

Sound Type	Key Points	Frequency
Speech	Most important for buildings; clarity depends on noise, reverberation, distance, absorption	250–4,000 Hz
Music	Covers 20–20,000 Hz; requires careful hall shaping for timbre and loudness	20–20,000 Hz
Noise	Unwanted sound (continuous, intermittent, impact, impulsive)	Variable

## 13. Room Effects on Sound

- **Reflection:** Hard surfaces (concrete, glass)
- **Absorption:** Soft materials (curtains, carpets, acoustic panels)
- **Reverberation:**
  - Too much → speech unclear
  - Too little → music dry
- **Design Tip:**
  - Short RT for speech
  - Moderate RT for music

## 14. Noise Criteria (NC)

Space	NC Value
Recording studio	15–20
Hospital	25–30
Classroom	30–35
Office	35–40
Factory	40–50

**Noise Reduction Methods:** Double glazing, acoustic ceiling tiles, duct silencers, vibration isolation

## 15. Sound Fundamentals

- Sound = mechanical energy from vibrating objects
- Needs a medium (air, liquid, solid)

- Cannot travel in vacuum
- Key properties: **Frequency, Wavelength, Velocity, Waveform**

## Velocity of Sound:

- Air (20°C) ~343 m/s
- Water ~1500 m/s
- Concrete ~3200 m/s
- Steel ~5000 m/s

## Frequency → Pitch:

- Infrasonic <20 Hz
- Audible 20–20,000 Hz
- Ultrasonic >20,000 Hz

## Wavelength: $\lambda = c/f$ = $c / f$ $\lambda = c/f$

- Low frequency → long wavelength → penetrates walls easily

**Timbre (Waveform):** Distinguishes instruments at same pitch

## 16. Sound Magnitude & Intensity

- **Sound pressure:** Pascal (Pa)
- **Threshold of hearing:** 20 μPa
- **Threshold of pain:** ~20 Pa
- **Inverse Square Law:** Intensity decreases with distance
- **Decibel scale:** Logarithmic, reflects human perception

## 17. Architectural Significance

- Fundamentals essential before designing:
  - Reverberation time
  - Sound absorption
  - Noise control
  - Auditorium/classroom design
- Good acoustic design = understanding sound behavior, not just adding materials