Sound and Hearing

- Sound
  - vibrating medium
  - longitudinal wave
  - $v = \lambda \times f$

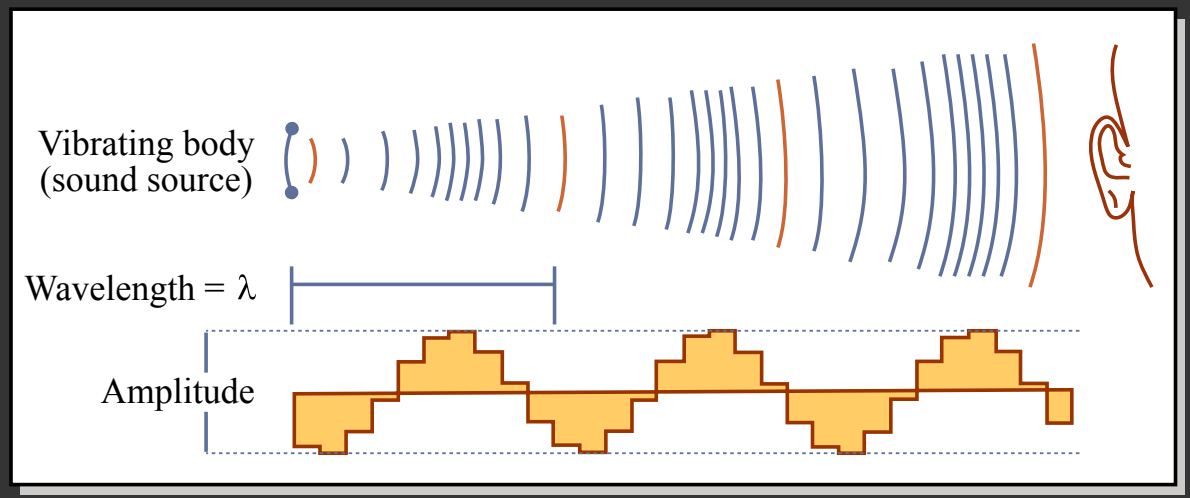
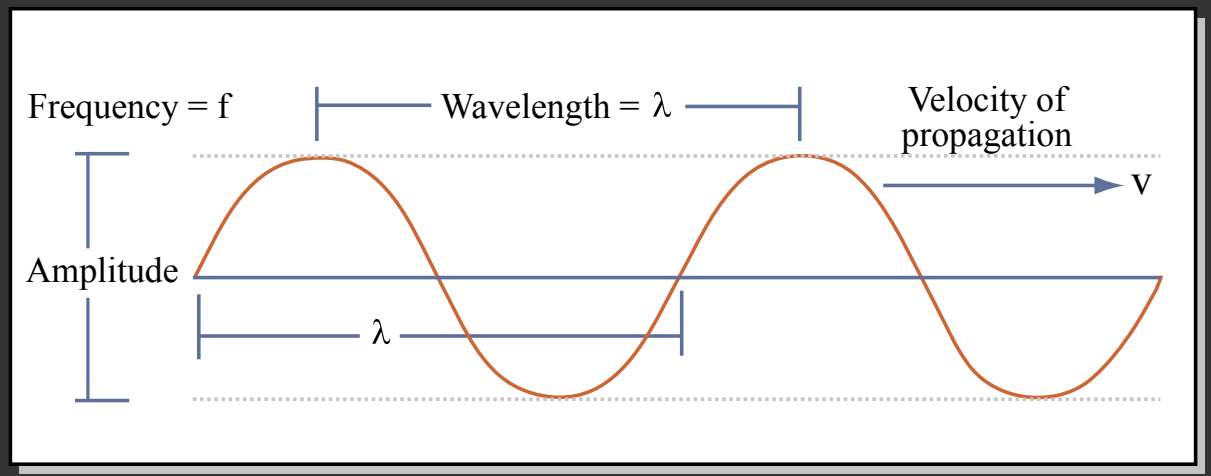


Image by MIT OCW.



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Sound and Hearing

Sound

- pressure p in Pa
- intensity I in W/m^2

General relation: $I = p^2 / (\rho v)$

For standard conditions: $p = 20 \sqrt{(I)}$

- thresholds of audibility and pain (at 1000 Hz)

$I_o = 1\ pW/m^2$ (i.e. $10^{-12}\ W/m^2$)

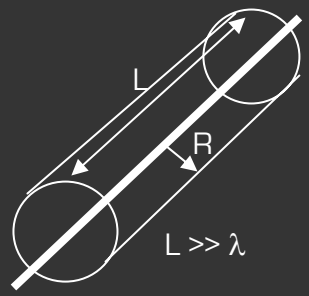
$p_o = 20\ \mu Pa = 2\ 10^{-5}\ Pa$

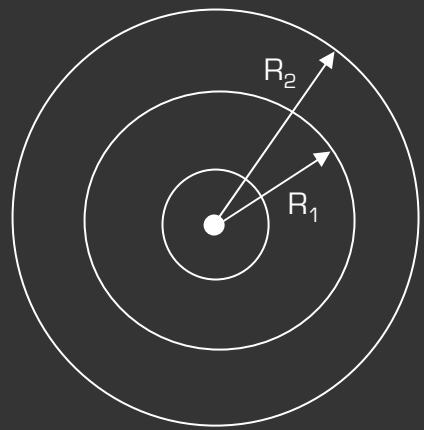
$I_{pain} = 1\ W/m^2$

$p_{pain} = 20\ Pa$

Sound and Hearing

- Sound field
  - Point source
  - Cylindrical source ⇒ attenuation with distance
  - Large source



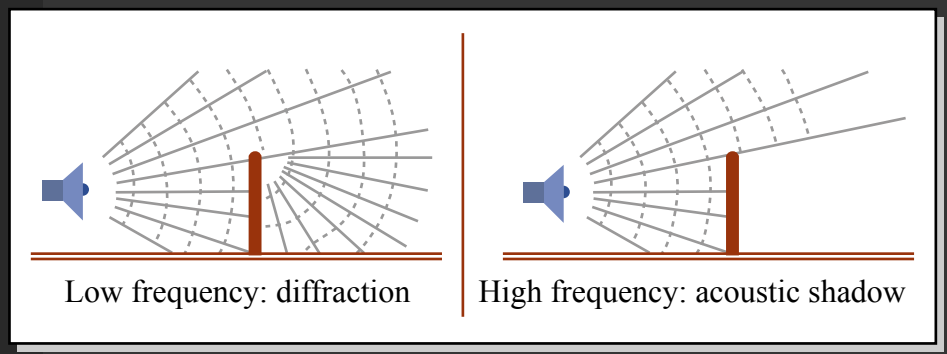


Sound and Hearing

Sound field

- Obstacles ⇒ calculation of characteristic frequency f_0

$$f_0 = d\, v / (2\, H^2)$$



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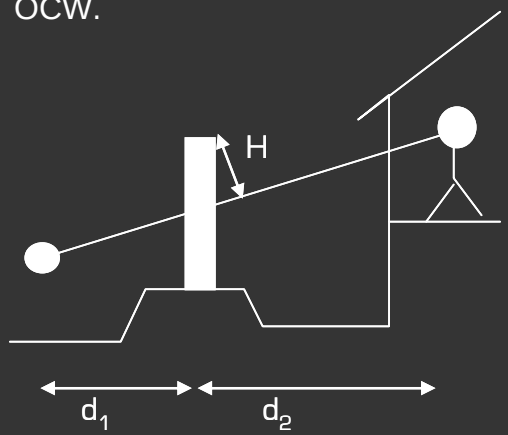
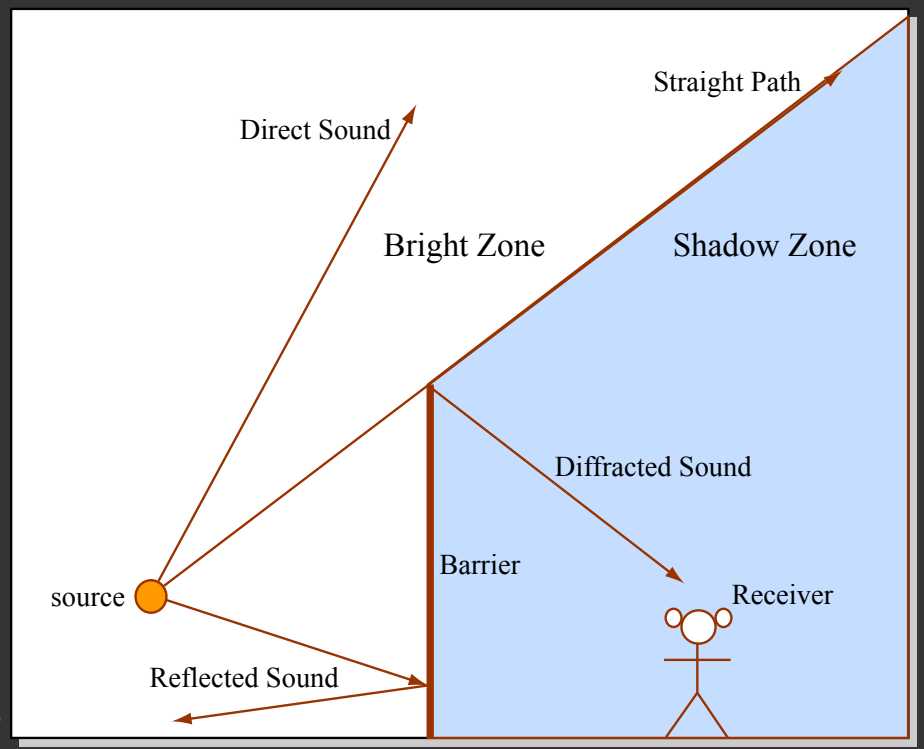


$d = \min(d_1, d_2)$



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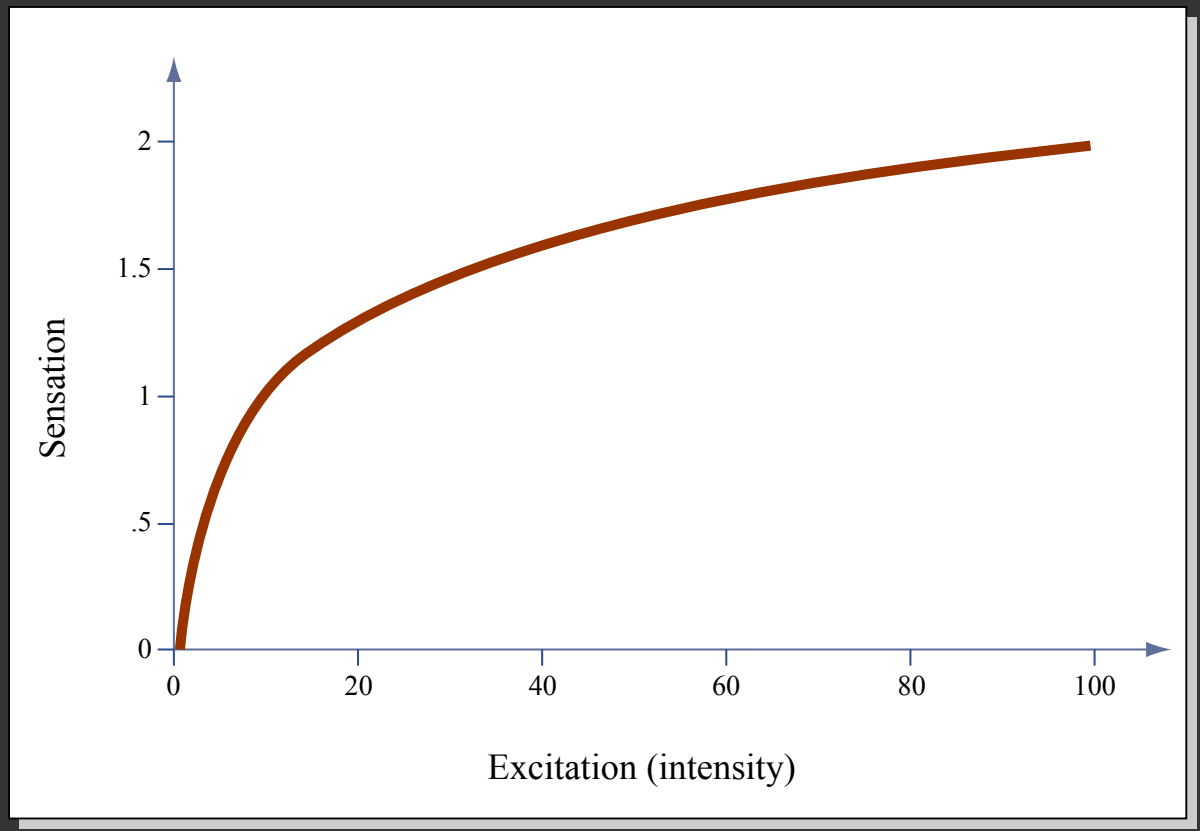
Sound and Hearing

- Hearing
  - logarithmic dependence of sensation on stimulus



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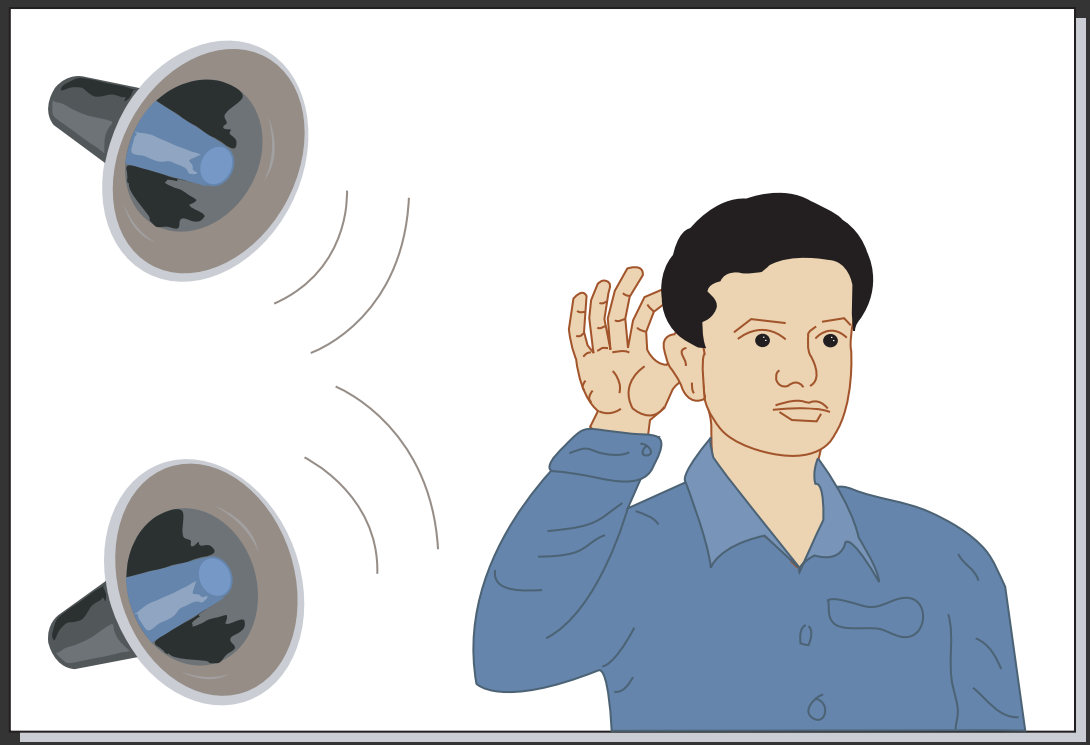
Sound and Hearing

- Hearing
  - sound level L in dB

$$L = 10 \log\left(\frac{I}{I_0}\right)$$

Sound and Hearing

- Hearing
  - sound level L in dB
  - contribution of two sounds to total sound level



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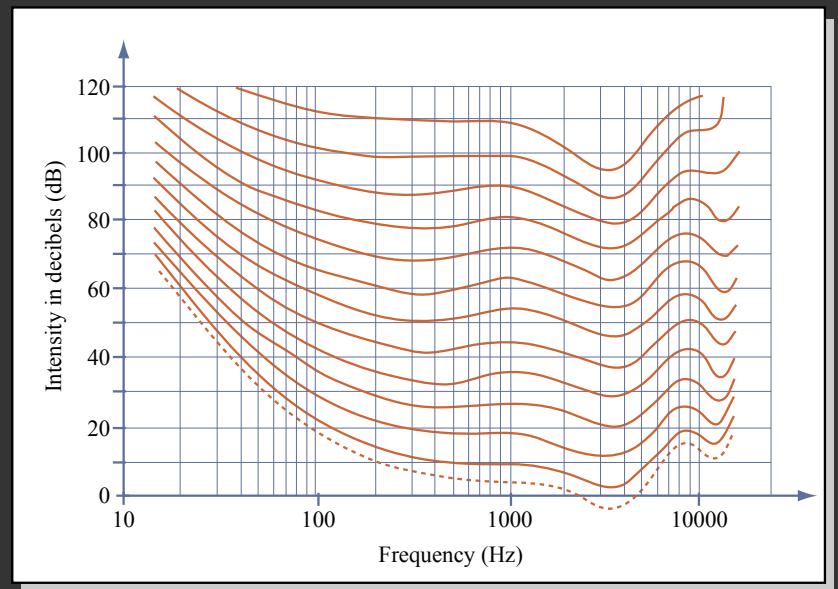
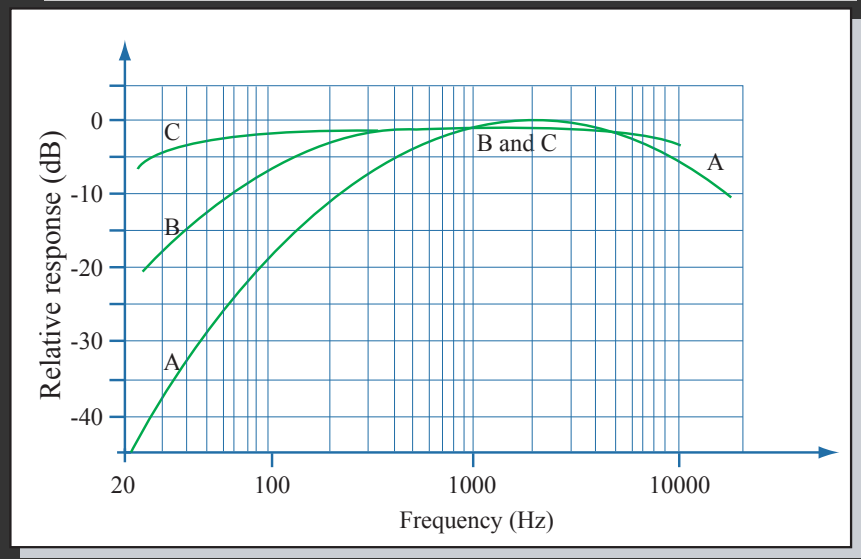
Sound and Hearing

- Hearing
  - sound level L in dB
  - dependence on frequency





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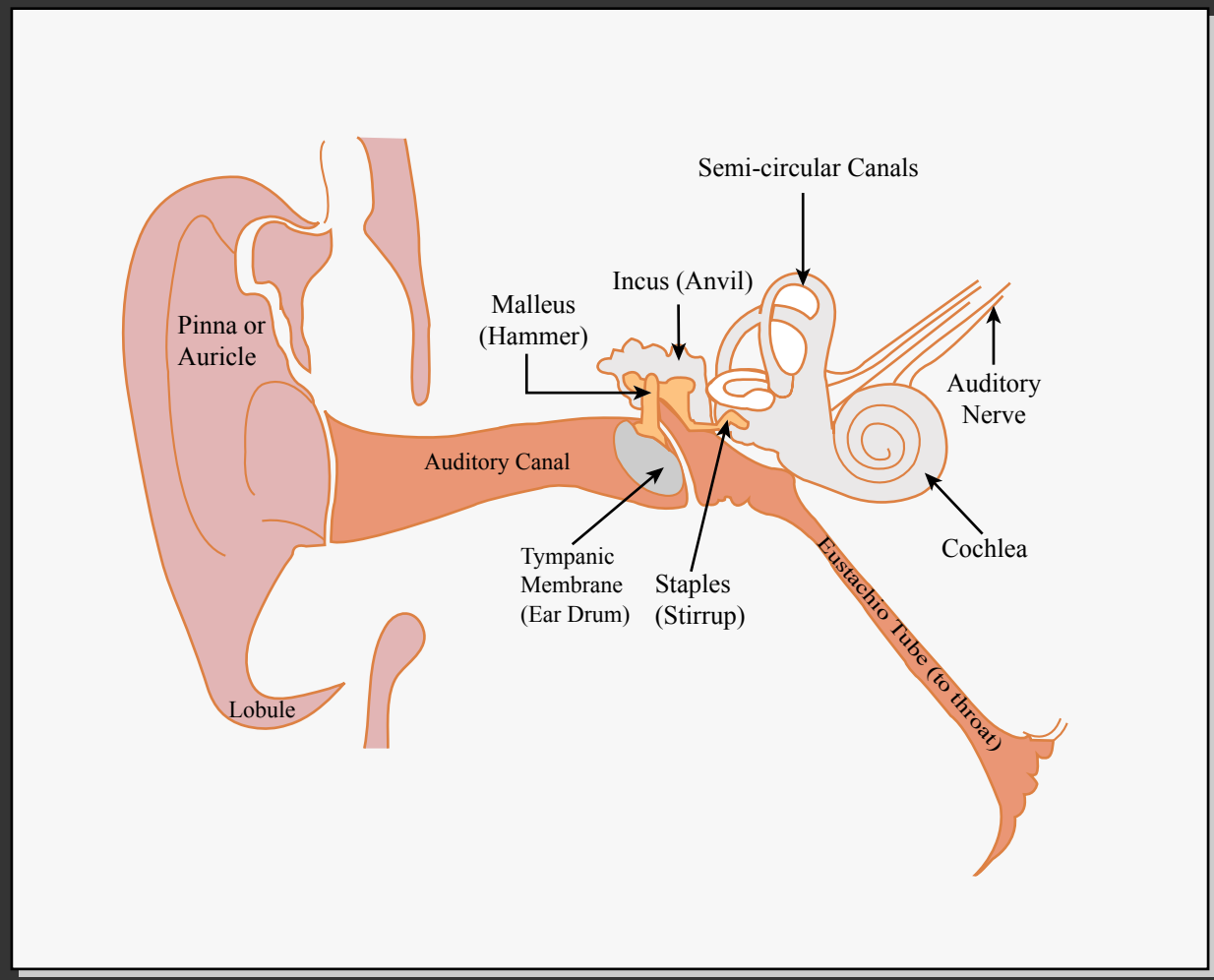
Sound and Hearing

- Hearing
  - Human ear



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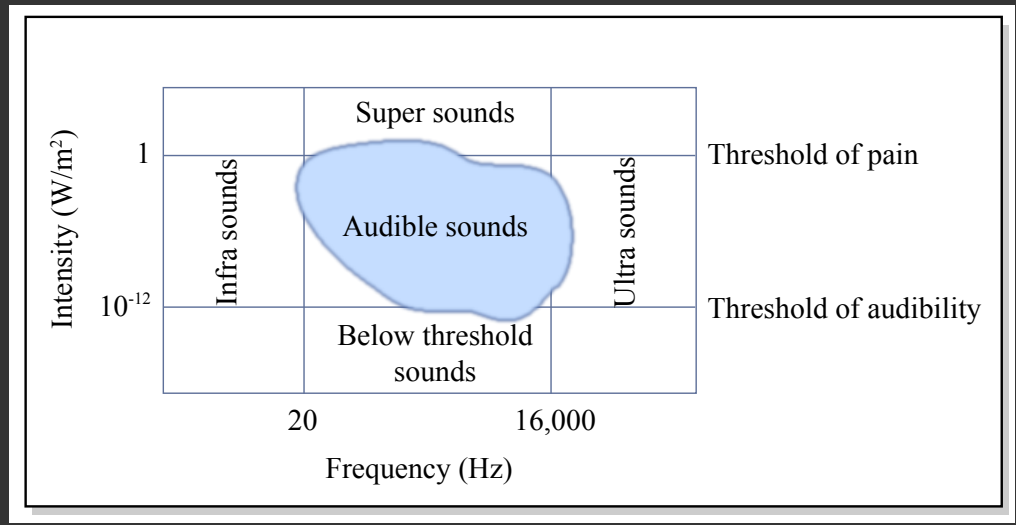
Sound and Hearing

- Hearing
  - Human ear



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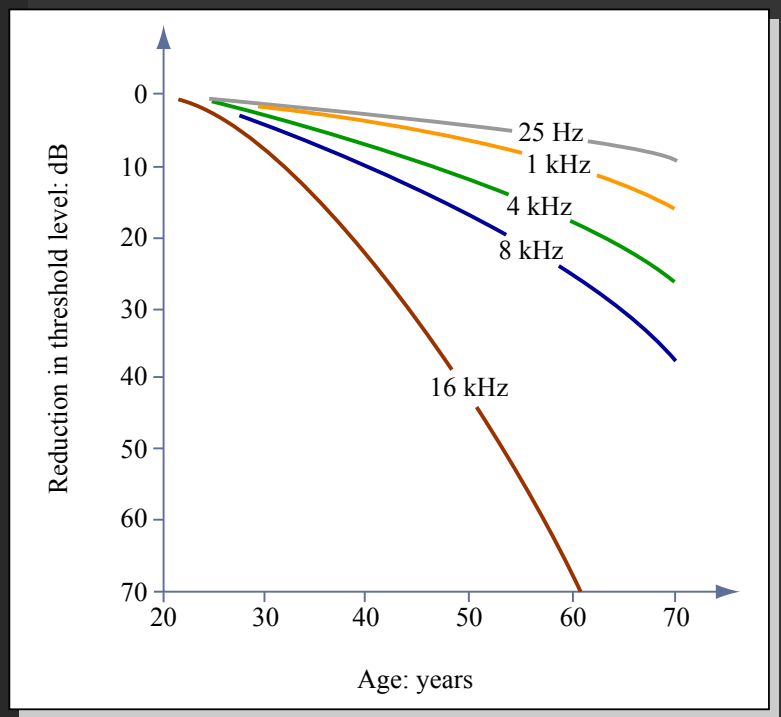

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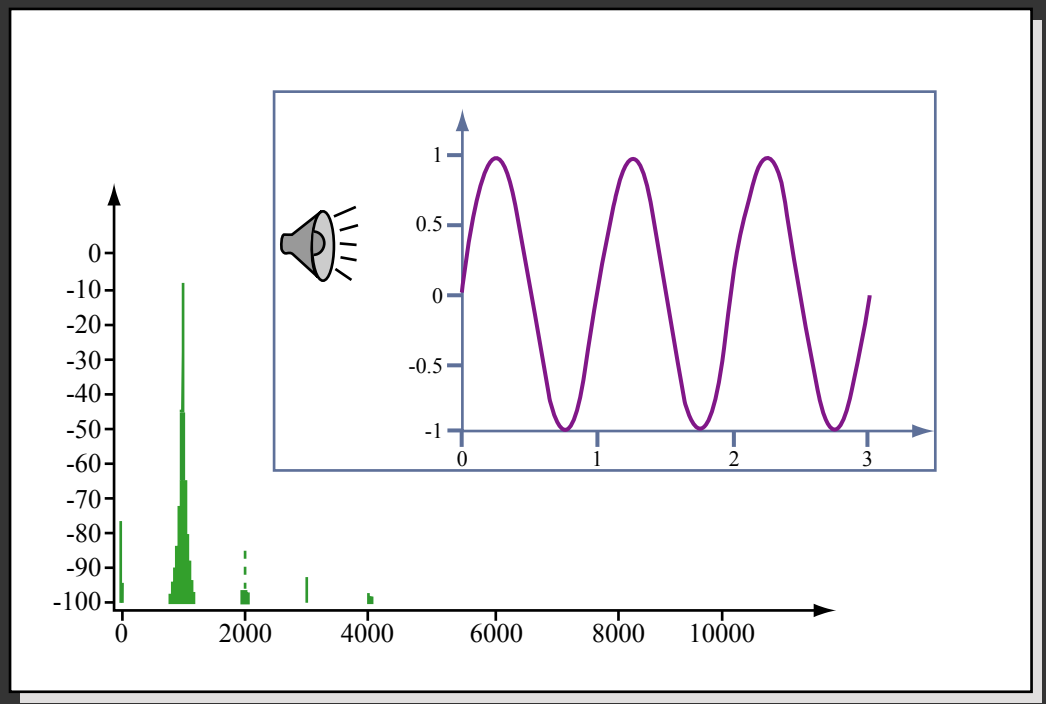
Sound and Hearing

- Hearing
  - Human ear
  - Sound spectrum



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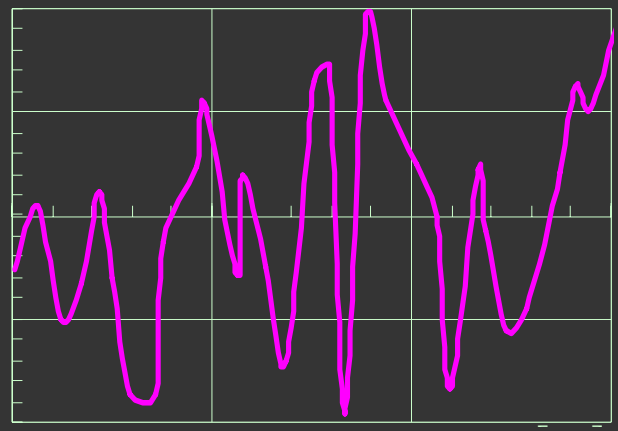
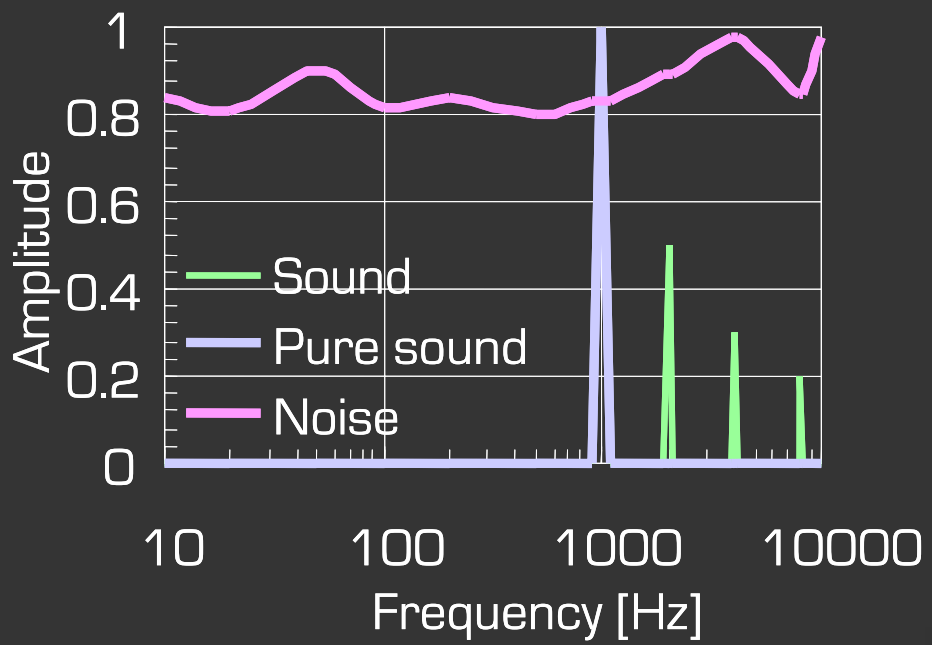
Sound and Hearing

- Hearing
  - Human ear
  - Sound spectrum





Sound and Hearing

- Noise level

Noise Level	Effect
150 dB	cause instant loss of hearing.
120 dB	is physically painful and should be avoided.
100 dB	short periods of exposure cause a temporary loss of acuity (threshold shift) with prolonged exposure likely to cause irreparable damage to auditory organs.
90 dB	long term exposure at this level normally causes permanent hearing loss.
65 dB	long periods of exposure cause both mental and bodily fatigue.

Image by MIT OCW.

Sound and Hearing

- Noise level

In a bedroom	30 - 40 dBA
For intellectual work	50 - 70 dBA
For manual work	80 dBA

Sound and Hearing

- Noise level

Perceived as:	Variation	Factor
Inaudible variation	1 dB	1,25
Barely audible	3 dB	2
Convincing	5 dB	3
Twice as strong	10 dB	10

Sound and Hearing

- Reading assignment from Textbook:
  - “Introduction to Architectural Science” by Szokolay: § 3.1 - 3.2
- Additional readings relevant to lecture topics:
  - "How Buildings Work" by Allen: pp. 124-129 in Chap 14