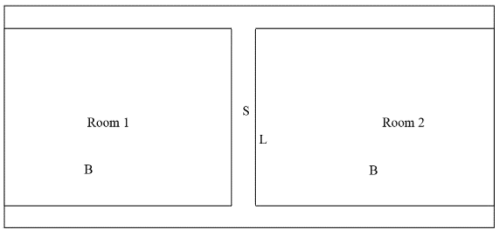
Exercises week 5 – Sound insulation

1. A glass window has a thickness of 8.3 mm. Using the “approximate” method, determine the sound reduction index as a function of frequency in octaves over the range from 63 Hz to 8000 Hz. Present the results in a table and as a graph of Transmission loss (i.e. R) vs. frequency (log scale).

2. Determine the sound reduction index, using the “exact” method, for a steel plate, 500 mm by 750 mm and 1.50 mm thick, for the frequencies: 125 Hz, 500 Hz and 16 kHz. Consider atmospheric air at 25 °C at both sides of the plate.

3. Here are some room and material data: Room 1 and Room 2: L×B×H = 4×5×2.4 m^3. The ceiling in Room 1 has an average absorption coefficient of α_1=0.5 and the ceiling of Room 2, α_2=0.6. All walls, ceilings and floors are made of dense concrete, where S=4×2.4 m^2 denotes the area between the two neighboring rooms. All wall thicknesses are h=35 mm, their density ρ=2280 kg/m^3 and their elastic modulus E=30 GPa. Suppose that the sound reduction index for all construction elements (R_w) equals 45 dB and that the reverberation time is 0.7 seconds. For simplicity, consider the reverberation time constant for all frequencies (not realistic). All connections between walls are rigid.



If sound with 85 dB is emitted in Room 1, estimate the sound pressure level in Room 2, accounting (when calculating the airborne sound reduction index) for the flanking transmission $R_{f,tot}$ (consider the 2D situation, i.e. neglecting ceiling and floor flanking transmission).

4. Assuming $f > f_c$ and σ =1 (radiation factor), a formula with the sound reduction index and the step sound level can be derived:

$$L_n + R \approx 30\log f + 38\text{dB}$$

Calculate the impact sound level for a concrete flooring if the reduction index is given by:

f [Hz]	125	250	500	1k	2k	4k
R [dB]	30	40	50	60	70	80

5. Critical frequency is the frequency for which the bending wave in a plate travels with the same velocity as sound in air, c_0 = 340 m/s. It be calculated using the coincidence number (K_h), which is a material dependent parameter, and the thickness of the structural element according to f_c=K_h/h.
   a) Express K_h in terms of other material parameters.
   b) Calculate the critical frequency f_c for a 13 mm thick gypsum wall (K_h = 32 m/s).
   c) In which direction does the sound radiate at $f = f_c$?
   d) In which direction does the sound radiate at $f = 2 f_c$.

6. A sound wave hits perpendicularly from the air (Z_{air}=415 Pa·s/m) against a very thick concrete wall ($\rho_{concrete}$=2300 kg/m^3 and $E_{concrete}$=26 GPa). The sound wave travels through the concrete and goes out again into the air on the other side. Calculate the transmission coefficient τ defined as the sound intensity that comes through the wall and out to the other side divided by the incident intensity on the wall, as well as the reflection coefficient ρ. Neglect the reflections inside the wall.

   Hint: $\tau_{ij}=(4Z_iZ_j)/(Z_i+Z_j)^2$

7. A plane sound wave in water at 20 °C has a sound pressure level for the incident wave of 105 dB and a frequency of 1000 Hz. The wave is normally incident on a very thick concrete wall. Determine:
   a) the transmission loss (i.e. sound reduction index)
   b) the intensity of the incident wave and the intensity of the transmitted wave
   c) the sound pressure level of the transmitted wave

Answers

1. 63Hz < f < 250Hz, Mass controlled region.

250Hz < f < 2500Hz, Damping controlled region.

2500Hz < f, Stiffness region.

2. f_{11} = 20 Hz, f_c = 8633 Hz

- for f = 125 Hz: R = 15.9 dB (mass law valid)

- for f = 500 Hz: R = 27.9 dB (mass law valid)

- for f = 16000 Hz: R = 32 dB (stiffness controlled region)

3. $L_{receiving}$ = 40 dB

4. Some values:
$L_n(250)$ = 70 dB,
$L_r(1000)$ = 68 dB

5. a) $K_h=(c_0^2/2\pi)\cdot \mathrm{sqrt}(12m''/Eh)$
b) f_c = 2.5 kHz
c) φ = 90°
d) φ = 45°

6. $\tau_{total}=4.62\cdot10^{-8}$ / $\rho\approx1$

7. a) R = 2.6 dB
b) I_{in} = $8.54\cdot10^{-6}$ W/m^2
I_{tr} = $4.73\cdot10^{-6}$ W/m^2
c) L_{ptr} = 109.4 dB