Acoustics (VTAF 05) – Exam 18th December 2015 (08.00-13.00)

Maximum score is 60 p. For passing, 30 p are needed.

Grades:

Fail	3-	3+	4-	4+	5-	5+
0-29p	30-34p	35-39p	40-44p	45-49p	50-54p	55-60p

Allowed aids are calculator and formulae.
The tasks are not sorted after degree of difficulty.

The following task will be about sound transmission between two rooms. Here are some room and material data:

Room 1: $L \times B \times H$ = 4×5×2.5 m^3
Room 2: $L \times B \times H$ = 4×6×2.5 m^3

All walls are made of dense concrete, where *S* denotes the area between the two neighboring rooms: S=4×2.5 m^2. All five walls visible in Figure 1 are single leaf concrete walls with the same density and thickness and a weighted reduction index of R_w=45 dB. The flanking transmission can be neglected in tasks 1-2.

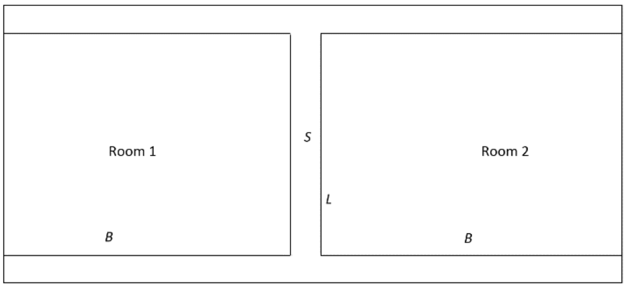


Figure 1. Room 1 and 2 from above.

1 & 2. Consider that the ceilings are the only partitions absorbing sound, covered with perforated metal panels whose absorption coefficient is α=0.5 in Room 1, that will act as the sending room, and α=0.6 in Room 2, that will be the receiving room. If pink noise (same energy in all frequency bands) is produced with the help of a loudspeaker and an amplifier in Room 1, with a sound pressure level of 85 dB, answer the following questions.

NOTE: Consider α to be constant and $R(f)=R_w$ for the whole spectrum (not realistic)

a) What is the sound pressure level in the receiving room? For simplicity, assume only direct transmission. *(3p)*

b) Sketch, in an approximate way, the shape of the sound reduction index curve obtained analytically/theoretically applying the exact method of the above mentioned wall, indicating the main features in it. What are the dips one can see in the curve? Explain the phenomena that causes them. *(3p)*

c) If a 1.5 m^2 window whose sound reduction index is $R(f)=R_w$=30 dB is now installed in the wall separating Rooms 1 and 2, what is the combined sound reduction index of the new building element consisting of the wall with the window? *(4p)*

d) After mounting the window in the wall, measurements are performed on site and one notices that the sound reduction index of the combined wall is 3 dB less than the one calculated in (c). We assume that this is due to a leakage that produces this decrease. Calculate the size (the area) of the leak. Describe in your own words possible practical solutions that can be taken on site so as to reduce such negative effects. *(3p)*

e) Calculate the reverberation time in the receiving room. What does the reverberation time indicate? *(3p)*

f) If the reverberation time is now to be set in the receiving room to 0.4 seconds (due to some regulations, for example), what is the absorption coefficient of the new material we would have to place in the ceiling and in one of the long walls? Consider that both surfaces will be covered by the same material and that the other surfaces are totally reflecting. *(4p)*

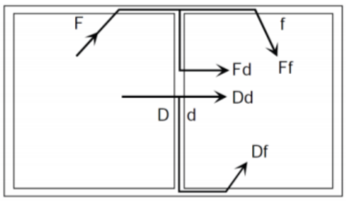
3. Calculate the sound pressure level in Room 2 given the same preconditions as in exercises 1-2 a), but now also taking flanking transmission into consideration. Some useful expressions and diagrams from the lecture notes are inserted in below. Consider just the flanking paths that you can "see" from Figure 1, i.e. the flanking transmission of the flooring system (and ceiling) can be neglected (i.e. only 7 paths). Assume all connections to be rigid. *(10 p)*

- Apparent sound reduction index (13 paths)

$$R'_w = -10\log\left[10^{\frac{-R_{Dd,w}}{10}} + \sum_{F=f=1}^{n} 10^{\frac{-R_{Ff,w}}{10}} + \sum_{f=1}^{n} 10^{\frac{-R_{Df,w}}{10}} + \sum_{F=1}^{n} 10^{\frac{-R_{Fd,w}}{10}}\right]$$

- If only *Ff* paths are assumed:

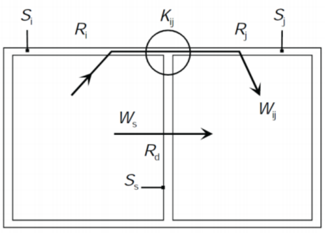
$$R'_w = -10\log\left[10^{\frac{-R_{d,w}}{10}} + \sum 10^{\frac{-R_{f,w}}{10}}\right]$$



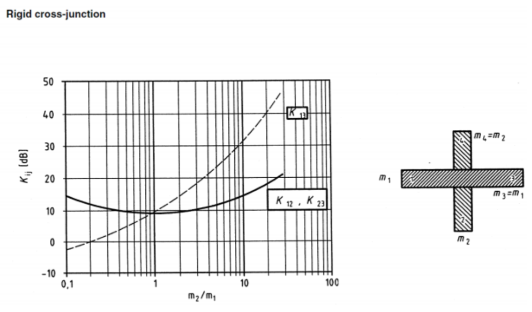
- Flanking sound reduction index R_{ij} (approximation given in the standard SS-EN 12354:2000)

$$\left(R_f\right)_{ij,w} = R_{ij,w} = \frac{R_{i,w} + R_{j,w}}{2} + K_{ij} + 10\log\left(\frac{S_s}{l_0 \cdot l_{ij}}\right)$$

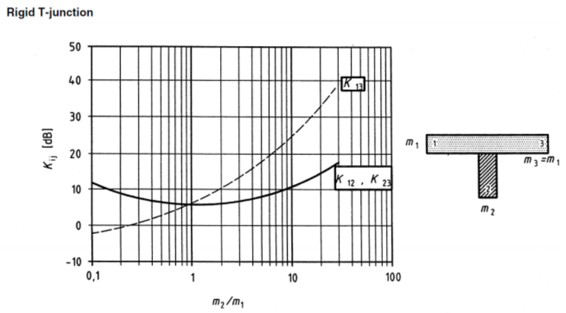
R_i & R_j : sound reduction index of flanking element *i* and *j*
K_{ij} : vibration reduction index (junction dependent)
S_s: floor / wall surface
l_0 = 1m
l_{ij} : junction common length



- Vibration reduction indexes K_{ij}
  – SS-EN 12354-1:2000 (Annex E)



$K_{13} = 8{,}7 + 17{,}1\,M + 5{,}7\,M^2$ dB ; 0 dB / octave
$K_{12} = 8{,}7 + 5{,}7\,M^2$ ($= K_{23}$) dB ; 0 dB / octave



$K_{13} = 5{,}7 + 14{,}1\,M + 5{,}7M^2$ dB ; 0 dB / octave
$K_{12} = 5{,}7 + 5{,}7\,M^2$ ($= K_{23}$) dB ; 0 dB / octave

4. Answer the following questions:

a) From equation $\int_{t_0}^{t_0+\Delta t} p_1(t)p_2(t)dt$ and $L_p = 10\log\left(\frac{\tilde{p}^2}{p_{ref}^2}\right)$ derive for 2 uncorrelated sources the equation: *(3p)*

$$L_{p,tot} = 10\log\left(\sum_{n=1}^{N} 10^{\frac{L_{p,n}}{10}}\right)$$

b) If the noise level by a road is measured and logged during a whole day (i.e. 24 hours), calculate the equivalent sound level $L_{eq,24h}$ if the measurements yield a value of 60 dBA during 6 hours, 65 dBA during 5 hours, 55 dBA during 10 hours and total silent the rest of the time. Express the result both in dB and dBA and explain the reason why the A-weighting is often used. *(4 p)*

c) What is the sound pressure level of total silence? Justify your answer. *(1.5 p)*

d) A step engine creates a theoretically harmonic excitation which excites the air (also harmonically) with a pressure peak amplitude of 55 Pa. What is the sound pressure level, in dB, emitted by the engine? *(1.5 p)*

5. A solution to the wave equation in air is $p(x,t) = \hat{p}e^{i(\omega t - kx)}$, where $\omega = 2\pi/T$ and $k = 2\pi/\lambda$. If T=1 ms and $\hat{p}$=0.1 Pa.

a) Show that $p(x,t)$ satisfies the longitudinal wave propagating in air.

b) Plot the solution to the wave equation $p(x,t)$ with x=0. Likewise, give an example, i.e. a physical interpretation of what plot represents and how/where can be measured.

c) Plot the solution to the wave equation with t=0. Likewise, give an example, i.e. a physical interpretation of what plot represents and how/where can be measured/seen.

d) Calculate the effective value of the sound pressure.

e) Calculate the sound pressure level created by the sound wave.

(10 p)

6. The sound in a bedroom (4×4×2.5 m^3) is dominated by a frequency of 340 Hz (with a constant value of 36 dBA at all times).

a) Where do you not want to place your head when sleeping?

b) At what distance from the wall should a thin absorber be placed in order to get maximum sound reduction? *(10 p)*