Exercises week 4 –
Wave propagation / Building Acoustics / Room acoustics

1) Maximum sound absorption and energy loss is achieved in the locations where the air has the largest movements, i.e. where the particle velocity is maximal. Suppose that we place a thin absorbent at the distance x = 0.25 m from a hard wall.
    a) For which wavelengths can we expect a high sound absorption for normal incidence to the wall?
    b) For which frequencies can we expect a high sound absorption for normal incidence to the wall?

2) What is the influence of a crack in a wall whose dimensions are 1 mm in width and 1 m in length in a wall of 2.40 m height and 4 m length? The sound reduction index of the wall without leakage is 50 dB. How much the combined sound reduction index would be if the sound reduction index of the wall would increase up to 60 dB?

3) A wall having dimensions of 2 m by 5 m has a sound reduction index of 50 dB. If a glass window, 1 m by 2 m with a transmission loss of 45 dB is placed in the wall, determine the combined transmission loss for the wall with the window installed.

4) Pink noise with sound level 60 dB per 1/3 octave band is emitted in a room. Calculate the sound level as a function of frequency in a room on the other side of a gypsum 2×2 m^2 wall. Consider the following properties of the wall: ρ = 900 kg/m^3, E=2 GPa, h=13 mm, f_c=2.5 kHz. Assume also that the reverberation time in the receiving room is T_{60} = 0.5 s (which corresponds to $A = S$) and that the mass law applies.

5) A person living in an old apartment has a bedroom located directly above the boiler room. The noise from the boiler is very disturbing and its fundamental frequency at 30 Hz coincides with the lowest eigenfrequency of the bedroom. The eigenmode at this frequency completely dominates the sound field in the bedroom.

   The bedroom pillow is located at coordinate $(x_1,y_1,z_1)=(0.3,0.3,0.3)$. When the local health inspector measures the sound level, this is done using a microphone located approximately at the center of the room, i.e. at coordinate $(x_2,y_2,z_2)=(2.5,1.5,1.5)$. The sound pressure level L_{pA} at this point was measured, its value being 35 dBA which was considered acceptable. Calculate the actual sound level at the pillow location, assuming that the mode theory for an undamped rectangular room can be applied to the problem.

6) Impact sound insulation measurements were performed between two adjacent apartments according to the corresponding ISO standard. For the sake of "secureness" a person who is not used to this type of measurements measured "a bit of everything", as shown in the table, where L_s and L_r are the SPL measured in the sending (V_s=60 m^3) and the receiving (V_r=65 m^3) room respectively. $T_{60,s}$ and $T_{60,r}$ indicate the reverberation times in both rooms. The floor surface area is S=20 m^2. Plot the impact sound level in the receiving room in 1/3-octave band and calculate $L_{n,w}$ together with $C_{I,50\text{-}2500}$.

f (Hz)	50	63	80	100	12	160	200	250	315	400	500	630	800	1k	1.25k	1.6k	2k	2.5k	3.15k
L_s (dB)	90	85	70	72	75	77	79	82	83	85	86	87	89	90	87	83	80	84	88
L_r (dB)	70	69	55	52	53	55	56	58	58	59	59	59	60	60	57	53	50	54	58
$T_{60,s}$ (s)	2	2,1	2,2	1,5	2	2,1	1,3	1,5	1,6	1,2	1,4	1,6	1,2	1,2	1,4	1,7	1,8	1,1	1
$T_{60,r}$ (s)	1,6	1,9	2,7	2	1,3	1,1	1,1	1,1	1,2	1,3	1,3	1,4	1	1,3	1,2	1,3	1,2	1,1	1,1

7) Calculate the sound level outside an infinitely large wall that oscillates with particle velocity amplitude 2.5 mm/s.

8) A room with only hard surfaces has a floor area of 1.65 x 2.8 m^2. Calculate the five lowest eigenfrequencies of the room and give the corresponding eigenmodes. For this task you can assume that the ceiling is totally absorbing, hence only horizontal oscillations being considered. Where in the room can we find maximum sound pressure level?

Answers:

1. a) $\lambda = x/(1/4+n/2)$ =1 m, 0.3 m, 0.2 m...
   b) $f = c/x \cdot (1/4+n/2)$= 340, 1020, … Hz
2. R=39.4 dB / R=39.8 dB
3. R=48.7 dB
4. R(f=100 Hz)=13 dB,
   R(f=1000 Hz)=33 dB
5. L_{pillow}=35+14.6=49.6 dBA
6. $L_{n,w}$ ($C_{I,50\text{-}2500}$)=61(-2) dB
7. L_p=91 dB
8. f_{10}=60.7 Hz
   f_{01}=103 Hz
   f_{11}=120 Hz
   f_{20}=121 Hz
   f_{21}=159 Hz
   Corners