Rak-43.3415 Building Physics Design 2 – Acoustical Design
EXAM 4.3.2013

Permissible equipment: writing accessories, calculator.

Write on each exam paper: course code and name, date, your name, student number and department.

Please write your answers *in English*.

1.
Explain the following concepts or phenomena and their significance to acoustical design:

a) sound power level

b) resonance frequency of floating floor

c) Helmholtz resonator

d) dilatation resonance

2.
a)
Sketch the typical sound absorption behavior of *panel absorber* and *perforated panel absorber* in a figure (sound absorption coefficient as a function of frequency). Also present drawings of both structures, in which you illustrate and explain the factors that affect the sound absorption coefficient.

b)
Laboratory measurement results of two types of chipboard are presented in the table below. Your structural engineer colleague would like to use the boards in a partition structure, but he wonders how it can be possible that the decibel-values are equal although there is a notable difference in the mass of the boards. Explain to your colleague what acoustical phenomenon is the cause for the measurement results, what factors affect this phenomenon and in what way. Illustrate the phenomenon with an appropriate drawing.

Building board type	*m`* [kg/m2]	*E* [GPa]	R_w [dB]
Chipboard, thickness 11 mm	7,0	2,9	29
Chipboard, thickness 22 mm	13,9	3,4	29

3.
a)
Derive an equation from the Sabine formula, with which you can calculate the absorption coefficient of a material from the reverberation times measured in a reverberation room. The reverberation time of the empty reverberation room is T_1, the reverberation time of the room containing the material sample is T_2 and the surface

area of the sample is *S*. Calculate the absorption coefficient of a material with the following measurement results and present the result graphically in octave bands 125 – 4000 Hz. The volume of the reverberation room is 300 m^3 and the surface area of the material sample is 12 m^2.

[Hz]	125	250	500	1000	2000	4000
T_1 [s]	4,0	4,0	3,3	2,9	2,9	2,9
T_2 [s]	3,5	3,0	2,2	1,8	1,7	1,7

b)

Explain what type of absorption material is it in 3a) and why. Give an example of a practical material of this type. How can the absorption coefficient of such a material be improved at low frequencies?

4.

a)

Define what *reverberation time* means. Explain what type of equipment is needed in order to measure the reverberation time of a room.

b)

The air conditioning of a concert hall with 1200 seats is organized so that supply air is distributed to the hall via supply air terminal units situated below the seats (one terminal unit under each seat). According to Finnish building regulations D2-2010 the equivalent noise level caused by HVAC-equipment in a concert hall must not exceed 25 dB(A). What is the highest permitted A-weighted sound power level for a single supply air terminal unit in order to satisfy the regulation? The volume of the hall is 8000 m^3 and the reverberation time at mid frequencies is 2,0 s.

5.

a)

Derive an equation with which you can calculate the combined sound reduction index of a structure comprising of several building elements. Hint: use the definition of the sound reduction index and the connection between sound power and intensity $W = SI$.

b)

There is a machinery room next to an office room. The measured noise level in the machinery room is 82 dB(A). There is a 120 mm thick concrete wall between the rooms with dimensions 5 x 3 m. The wall contains a door (900 x 2100 mm), which has a sound reduction index of 35 dB, and a single-pane window (1 m^2, glass thickness 4 mm). The door has no doorstep, as a result of which there is a gap with a height of 4 mm under the whole width of the door. What is the A-weighted sound level in the office room, when the absorption area of the office room is 10 m^2-Sab at all frequencies? Calculate the needed sound reduction indexes using the mass law at frequency 1000 Hz. The density of concrete is 2400 kg/m^3 and that of window glass 2500 kg/m^3. Use the equation you have derived in 5a) in your solution.

Equations:

$$R = \begin{cases} 20\log_{10}(m`f) - 48, f < \frac{1}{2} f_c \\ 20\log_{10}(m`f) + 10\log_{10}\left[\eta\left(\frac{f}{f_c} - 1\right)\right] - 44, f \geq f_c \end{cases}$$

$$R = 10\log_{10}\left(\frac{W_i}{W_t}\right)$$