Applied Acoustics, Chalmers

Introduction to Audio Technology & Acoustics

VTA 137

October 29, 2019, 8.30 – 13.30, Hörsalsvägen

Instructors: Astrid Pieringer, Jens Ahrens, Pontus Thorsson

Questions during the exam: Astrid Pieringer, Ph 2209 (will visit the examination room at 10.00 and 12.30)

Solutions will be posted on the department's bulletin board on Oct 30, 2019.

Preliminary exam results will be posted on the department's bulletin board latest Nov 15, 2019.

Questions on corrected exams can be discussed in the time slot announced together with the preliminary results.

Final results submitted to the university latest Nov 19, 2019.

Permitted material at the exam: Mathematical tables in books like the Physics Handbook, Tefyma, Beta, or similar books, acceptable calculators as defined below, the "Useful Formulae" - collection for Audio Technology and Acoustics, distributed at the course and available at the department's web site and the audio formula collection distributed at the course and available at the department's web site

An acceptable calculator is a calculator without (or cleared) text memory.

Grades: 12p = 3, 18p = 4, 24p = 5

Do not forget to specify the assumptions made in your solutions to the problems!

PROBLEM 1

a) Describe the frequency-dependent sensitivity of human hearing by using a diagram of equal loudness level contours. Discuss the concepts loudness level and phons. Explain why dBA-, dBB-, and dBC-weighting is used. (3p)

b) A large, outdoor electrical transformer emits a "hum"-like noise with its most significant frequency components at 125 Hz and 250 Hz. The 125-Hz component has a loudness level of 50 phons, while the 250-Hz component has a loudness level of 45 phons. The transformer's cover is then removed, and the sound pressure level for each component increases by 20 dB. Calculate the increase in phons for each of the two components, and determine the total A-weighted sound pressure level after removing the cover. (2p)

PROBLEM 2

a) What is the line level $L_{\mathrm{U}} = +4$ dBu expressed in Vrms? (1 p)

b) What is the line level $L_{\mathrm{V}} = -10$ dBV expressed in Vrms? (1 p)

c) Assume a microphone with a sensitivity of 15 mV/Pa. The microphone is connected to a microphone pre-amplifier with a gain of 30 dB. What is the maximum SPL that may occur at the microphone if the output from the mic pre should not exceed +24 dBu?

(3 p)

PROBLEM 3

After a renovation of an old auditorium, one discovers that the auditorium's reverberation time needs to be reduced in the 1 kHz band, from T_{old} = 2.45 s to T_{new} = 1.90 s. The dimensions of the auditorium are (20 x 30 x 13) m and one can assume that absorption of the floor, ceiling and wall is identical. Since the budget is limited, one decides to use second-hand absorbing panels. Unfortunately, the absorption coefficient of these panels is unknown. Therefore, 15 m^2 of the absorbing panels are placed on the floor in the auditorium and the reverberation time is measured again to T_{panel} = 2.40 s.

a) What is the absorption coefficient of the absorbing panels in the frequency band of interest? (3p)

b) How many m^2 of the absorbing panels should be placed in the auditorium to obtain the desired reverberation time? (2p)

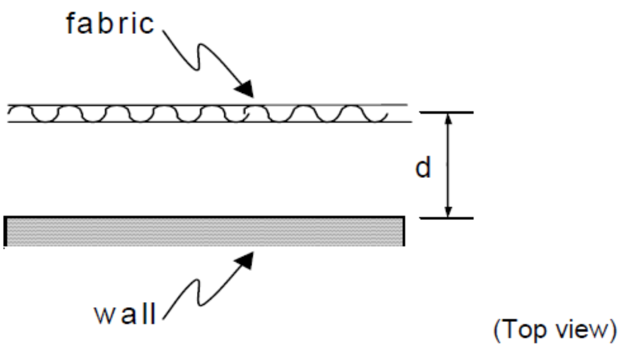
Sound absorption by air can be neglected.

(Speed of sound in air: c = 343 m/s)

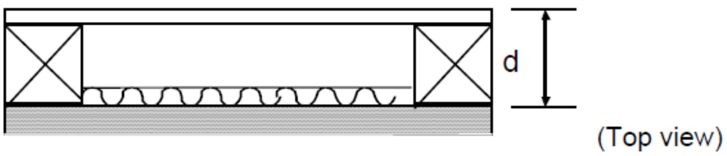
PROBLEM 4

In concert halls and other rooms intended for music performance, special "acoustic elements" are often incorporated in the room's design in order to improve the acoustics of the room. Below, three such "acoustic elements" are described. Explain how these elements work, how they affect the acoustics of a room and what should be considered regarding the dimensions of the elements.

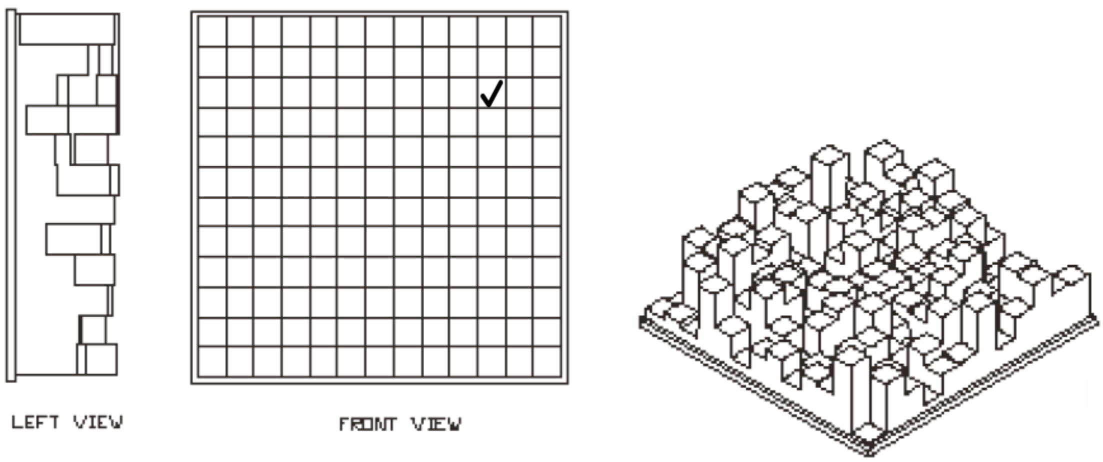
a) A cotton fabric suspended from the ceiling in front of a wall: (2p)



b) A gypsum board mounted on wooden studs: (1.5p)



c) The panel made of solid wood shown below. (1.5p)



PROBLEM 5

Daniel sits in his room (=room 1) and plays his electric guitar through a guitar amplifier/loudspeaker. The loudspeaker produces a sound power level of L_W=85 dB re 10^{-12} W (in the octave bands 250 Hz, 1 kHz). Vincent, quite annoyed by the sound asks Daniel if he can't play in the adjoining room (=room 2) instead. Daniel, unwilling to move his 50 kg tube amplifier, tells Vincent that it would be much better if he had moved into the adjoining room. Is this true, i.e. will the total A-weighted sound pressure level be lower in room 2 if Daniel is playing in room 1 compared to the total A-weighted sound pressure level in room 1 if Daniel is playing in room 2? Assume that Daniel would adjust the volume knob on his amplifier if he moved to room 2, so that the sound pressure level would be equal to what it was in room 1.

Volume, room 1 = 40 m^3 Reverberation time, room 1 = 0.5 s

Volume, room 2 = 50 m^3 Reverberation time, room 2 = 1.1 s

The wall between the rooms has a door (area 2 m^2). The wall area without door is 10 m^2. Reduction indices of the wall parts are shown in the following table:

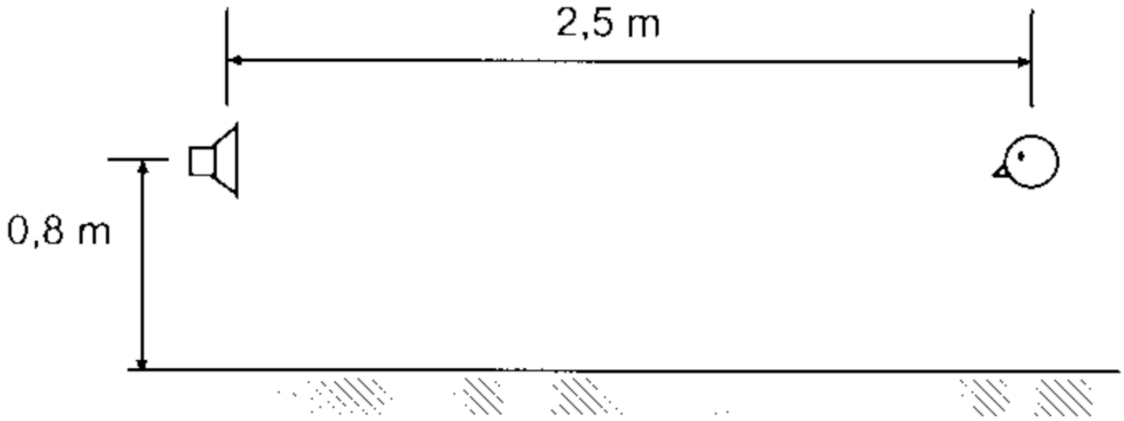
	250 Hz	1 kHz
R_{door} [dB]	20	31
R_{wall} [dB]	32	44

Assume diffuse fields in both rooms, that the loudspeaker radiates as a point source and that both persons are located in the reverberant field.

(Speed of sound in air: c=343 m/s) (5p)

PROBLEM 6

Assume that we have a loudspeaker mounted on a stand 80 cm above the floor. The listening position is 2.5 m away from the loudspeaker and on the same height as the loudspeaker. The sound reaching the listening position consists of direct sound from the loudspeaker plus reflected sound from the floor.



a) What are the maximum deviations from free field response (in dB) in the listening position? Assume that the floor is perfectly reflecting, that the loudspeaker is omnidirectional and has a flat frequency response in the range 100 Hz – 20 kHz. (2p)

b) Determine the frequencies of the first two minima in the frequency response. (1p)

c) We would like to decrease the interferences by putting an absorber on the floor. If a maximum of ±2 dB deviation from flat frequency response is required, what absorption coefficient α is needed? Make the simplified assumption that α is the same for all angles of incidence. Additionally, assume that the reflection coefficient r is real. (2p)

(Speed of sound in air: c=343 m/s)