The Science of Music

Exercises for Chapter 6

6.1 In an impedance tube experiment like that described in Section 6.1.2, a sample is mounted in the tube and narrowband noise centered at 1000 Hz is played over the speaker. The microphone is moved back and forth along the tube and the maximum and minimum intensities are found to be 8×10^{-5} W/m and 1.2×10^{-7} W/m. What is the absorption coefficient of the sample at 1000 Hz?

6.2 In an impedance tube experiment like that described in Section 6.1.2, the maximum and minimum sound levels measured in the tube differ by 12 dB. What is the absorption coefficient of the sample?

6.3 In an impedance tube experiment like that described in Section 6.1.2, the microphone is moved back and forth along the tube to find the points of maximum and minimum sound volume. If the difference in decibels between the sound pressure level at the loudest and quietest points is ΔL, show that the absorption coefficient of the sample is given by

$$\alpha = \operatorname{sech}^2\left(\frac{\Delta L}{40 \log_{10} \mathrm{e}}\right),$$

where $\operatorname{sech} x$ is the hyperbolic secant of x and $\mathrm{e} = 2.718\ldots$ is the base of the natural logarithm.

6.4 Paris's Notre Dame cathedral has unusually long reverberation. It is found that it takes about one second for reverb to decay by just 10 dB. What is the value of T_{60}?

6.5 New York's Madison Square Garden arena, which is often used for music concerts, has a measured reverberation time of 7.65 seconds. About how long will it take for the intensity of the reverberation to decrease by a factor of ten?

6.6 A smaller music performance space has length 20 m, width 10 m, and ceiling height 8 m. The floor is covered with non-upholstered wooden seats for the audience, and the walls and ceiling are made of standard plasterboard.

a) What is the volume V of the room?
b) What is the area of the floor and roughly what is the absorption coefficient of the wooden seating at 1000 Hz if the room is unoccupied with nobody in the seats?
c) What is the total area covered in plasterboard and what roughly is its absorption coefficient?
d) Hence, what is the total absorption S of the room?
e) What is the reverberation time of the room? Is this an acceptable reverberation time for typical popular or classical music performance?
f) What will the reverberation time be when there is an audience in the space, with people in all the seats?

6.7 A large performance space is constructed with dimensions 20 m wide by 25 m long by 15 m high. After construction is finished the reverberation time is measured and found to be an uncomfortably long $T_{60} = 3$ seconds. It is resolved to reduce the reverberation time by placing fabric-covered acoustic panels on the walls.

a) What is the volume V of the space?
b) What is the total absorption S?
c) What is a typical absorption coefficient for acoustic panels?
d) The original walls had an absorption coefficient of 0.05. When we cover one square meter of this wall with acoustic paneling, by how much does the absorption coefficient of that square meter increase?
e) Hence, how much wall area, in square meters, will have to be covered with acoustic panels to reduce the reverberation time to a more reasonable 2 seconds?

6.8 A certain "reverberation room" used for acoustic measurements is rectangular with length 6 meters, width 4 meters, and height 3 meters. The walls, floor, and ceiling are made of smooth concrete.

a) What is the volume of the room?
b) What is the total area of the floor, ceiling, and all four walls put together?
c) What is their absorption coefficient at 1000 Hz?
d) What is the reverberation time at 1000 Hz?
e) A square baffle made of a sheet of plywood of size 2m × 2m is hung in the room, away from the walls and covered on both sides with fabric to make it absorbent. The reverberation time is now measured and found to be 1.5 seconds at 1000 Hz. What is the absorption coefficient of the fabric?

6.9 A new concert hall is being built with classical music performance in mind. We would like it to have a reverberation time of 1.8 seconds and a strength factor of 5 dB.

a) What should the volume V of the hall be in order to give the required strength factor?
b) The planned hall will be rectangular with width 25 m and length 35 m. How high should the ceiling be?
c) What should the value of the total absorption S be to give the required reverberation time?
d) The stage will occupy 200 m^2 of the floor space and the rest will be occupied by the audience, sitting in upholstered seating. What would be a typical absorption coefficient for this audience area of the hall at 1000 Hz when there is a full house?
e) Assuming the material used for the stage floor, walls, and ceiling has the same absorption coefficient everywhere, what should that absorption coefficient be in order to give the right value of the total absorption?

6.10 Based on the data in Table 6.4, what is the reverberation radius of Vienna's Grosser Musikvereinssaal? Hence how much louder in decibels is the reverberated sound than the direct sound for an audience member seated 20 meters from the performers?

6.11 The top five concert halls listed in Table 6.5 are Vienna, Boston, Beunos Aires, Berlin, and Amsterdam. Consulting Table 6.4 for data about these halls, comment in turn on the acoustic features of each hall, explaining why these features make for good sound in terms of reverberation, loudness, and clarity. Mention any possible weaknesses as well.