# Exercises week 6 – Miscellaneous

**1.** A sound wave with pressure function $p(x,t) = \hat{p}e^{i(\omega t+kx)}$ and sound pressure level $L_p$=50 dB impinges on a hard wall at $x$ = 0 where full reflection occurs, thus creating a standing wave. Calculate the sound pressure level of the resulting wave and give the amplitude at the following locations:

a) $x$=0
b) $x$=λ/2
c) $x$=λ/4
d) $x$=λ
e) $x$=λ/6

Hint: Full reflection implies $\widehat{p_{inc}} = \widehat{p_{refl}}$

**2.** Consider two rooms separated by a wall. Room 1 has a size of L×B×H = 6×5×3 m³, whereas Room 2's dimensions are L×B×H = 6×5×3 m³. Suppose that the sound reduction index for the separating wall is R=30 dB (consider it constant for all frequencies, which is not really realistic). One sound level meter is places on each room.

Consider that the ceilings are the only parts of the rooms absorbing sound. The ceiling in Room 1 has an average absorption coefficient of $\alpha_1$=0.5 and the ceiling of Room 2, $\alpha_2$=0.6 (again, consider it constant for all frequencies).

Pink noise is now played in Room 1 towards the separating wall. Measurements are taken in the middle of both the sending and the receiving room. Answer the following questions:

(a) Obviously, it takes some time for the sound to stabilise itself at a certain level, but how is the time it takes from the moment the loudspeaker is turned on until the microphone in Room 1 registers a sound? What about the microphone in Room 2? For this last case, consider that the sound propagates at the same speed in the room and through the wall.
(b) If one would plot the sound pressure level in Room 1 as function of frequency in narrow band (i.e. not in 1/3 octave band but rather for each single frequency), it would be seen that the sound pressure level is much higher for some frequencies that for others. Which ones (give just the first 4) and why? Explain the phenomena involved.
(c) If the sound pressure level in Room 1 is 70 dB for all frequencies, what would be the sound pressure level when measured in Room 2?
(d) What is the reverberation time in Room 2? How big difference in decibels would we get in the sound reduction index if we sink $T_{60}$ in the room to a value of 0.5 seconds instead?
(e) The relation between the surface of the partition wall and the effective absorption area in the Room 2 becomes pretty convenient in the latter case (i.e. if $T_{60}$ is 0.5 s). Suppose a cubic room (L=B=H); which average absorption coefficient (for all surfaces) would be needed so that $R=L_1-L_2$?
(f) If the sound energy transmits constantly through the wall between Room 1 and Room 2, how can it be then that one has a constant sound level in Room 2?
(g) What happens with the sound present in Room 1 that impinges the wall and does not get transmitted to Room 2?
(h) In both rooms one can experience a flutter echo. This goes hand in hand with the fact that sometimes measurements of reverberation time are not really trustworthy. How can this flutter echo be fixed?

**3.** A 0.1 g needle falls from 1 m height. Assuming that just the 0.05% of its potential energy turns into a sound impulse of duration 0.1 s, estimate the maximum distance from which one could hear the impact of the needle against the floor. Consider the minimum audible intensity as $10^{-8}$ W/m² and spherical propagation.

Hint: Power is energy by unit time, i.e. P=E/Δt.

**4.** Answer and justify the following questions:

a. The sound level of the waves emitted by an omnidirectional source, in the free-field, far away from any reflecting surface:

i. Decreases 6 dB each wavelength, true or false?
ii. Decreases 6dB with doubling the distance, true or false?
iii. Decreases 3 dB with doubling the distance, true or false?

b. If the difference between two sound levels is 6 dB, the intensity of the loudest one is:
   i. 3 times the quietest one, true or false?
   ii. 4 times the quietest one, true or false?
   iii. 6 times the quietest one, true or false?
   iv. Half the quietest one, true or false?

5. 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:

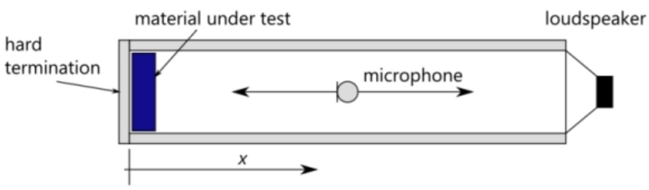
$$L_{p,tot} = 10\log\left(\sum_{n=1}^{N} 10^{\frac{L_{p,n}}{10}}\right)$$

   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. Explain the reason why the A-weighting is often used.
   c. What is the sound pressure level of total silence? Justify your answer.
   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?

6. As seen in the guest lecture of room acoustics, absorption coefficient of materials can be measured by use of a Kundt's tube (see Figure) by applying the following formulae:

$$F = \frac{\widehat{p_i} - \widehat{p_r}}{\widehat{p_i} + \widehat{p_r}} = 10^{\frac{(L_{max} - L_{min})}{20}} \quad \text{and} \quad \alpha = \frac{4F}{(1+F)^2}$$

where F is the ratio between the mazimum and the minimum of the standing wave in the tube and and are amplitudes of the incoming and reflected wave, respectively. Show that these expressions are correct by assuming an incoming and a reflected wave.




7. Answer the following questions regarding wave propagation in a guitar string (hint: think how mode shapes of a string look like)
   a. The speed of waves in the guitar string is 425 m/s. Determine the fundamental frequency (1st harmonic) of the string if its length is 76.5 cm.
   b. Determine the length of guitar string required to produce a fundamental frequency (1st harmonic) of 256 Hz. The speed of waves in a particular guitar string is known to be 405 m/s.
   c. A guitar string with a length of 80.0 cm is plucked. The speed of a wave in the string is 400 m/sec. Calculate the frequency of the first, second, and third harmonics

<u>**Answers:**</u>

1. a) $2\hat{p}$ and 56 dB
   b) $2\hat{p}$ and 56 dB

c) 0 and -∞ dB
d) $2\hat{p}$ and 56 dB
e) $\hat{p}$ and 50 dB
2. a) $t_1$=5.88 ms / $t_2$=20.59 ms
b) Eigenfrequencies (calculate them as in Lab2)
c) $L_2$=40 dB
d) $T_{60}$=0.96 s / ΔR=-2.83 dB
e) α=0.17
f/g/h) Theoretical
3. r=6.25m
4. a) F/T/F
b) F/T/F/F
5. a) Theoretical
b) 60.2 dBA
c) $L_{psilence}$= -∞
d)125 dB
6. Theoretical
7. a) 278 Hz
b) 0.79 m
c) 250 Hz / 500 Hz / 750 Hz