Exercise A1-6: Acoustical measurements

1. a) The measurement of an acoustical event yields unfiltered 67 dB, with the A-filter inserted 68 dB. What can be concluded regarding the spectral content of the signal?
   b) The measurement of an acoustical event yields 90 dB(C) with C-weighting and 70 dB(A) with A-weighting. What can be concluded regarding the spectral content of the signal?

2. At the end of a measurement the sound level meter indicates 50 dB $L_{eq}$ and 70 dB $L_E$ or $SEL$. How long did the measurement last?

3. A single impulse of height 1 Pa (RMS) and duration 10 ms is investigated. Calculate the maximum value of the momentary sound pressure level with the time constants FAST and SLOW and the event level $L_E$ or $SEL$.

4. An octave band analysis of a broadband stochastic signal is performed with help of a sound level meter with adjustable octave band filter. Thus at a time only one octave can be evaluated. How long does it take to get all octaves from 125 Hz to 4 kHz analyzed with an accuracy of ± 1 dB (90% probability)?

5. A pistonphone mounted on a microphone produces a sound pressure level of 124 dB under reference ambient pressure at sea level (1013 hPa). The enclosed cavity $V$ has a volume of 20 cm$^3$, the diameter of each of the two oscillating pistons that generate the pressure variation is 3 mm. Calculate the maximum excursion (amplitude of the oscillation) of the pistons and calculate the produced sound pressure under reference conditions but at a height of 500 m above sea level.
Solutions to Exercise A1-6

1. a) the dominating frequency range is 1.8 kHz. b) there are strong low frequency components.

2. \[ 10 \log \left( \frac{T}{T_0} \right) = -20 \text{ dB} \rightarrow T = 100 \text{ s} \]

3. the continuous sound pressure level after 10 ms is found as:

\[
L(10\text{ms}) = 10 \log \left( \frac{1}{RC} \int_0^{10\text{ms}} \frac{1\text{Pa}^2}{p_0^2} e^{-\frac{t}{RC}} \, dt \right)\\
= 10 \log \left( \frac{1}{RC} \int_0^{0.01} e^{-\frac{t}{RC}} \, dt \right) = 10 \log \left( \frac{1 - e^{-0.01}}{p_0^2} \right)
\]

Alternatively the algorithm for the evaluation of the moving square average may be used:

\[
x_{\text{rms}}^2(t + \Delta t) \approx x_{\text{rms}}^2(t) + \frac{x^2(t + \Delta t) - x_{\text{rms}}^2(t)}{\frac{RC}{\Delta t}}
\]

As the length of the impulse is much smaller than the two time constants 125 ms and 1000 ms, the sampling interval can be chosen as \( \Delta t = 10 \text{ ms} \). With this:

\[
x_{\text{rms}}^2(10\text{ms}) \approx \frac{1\text{Pa}^2}{10\text{ms}}
\]

With FAST the maximum level reaches 83 dB, with SLOW the maximum is 74 dB.

4. The specified accuracy makes a value for the degrees of freedom of \( n = 2BT = 100 \) necessary.

| B [Hz] \(125 \text{ Hz} \) 250 Hz 500 Hz 1 kHz 2 kHz 4 kHz | T [s] 0.6 0.3 0.1 0.1 0.0 0.0 |
|---------------------------------------------------------|

The total analyzing time sums up to 1.1 sec.

5. It is:

\[
PV^\kappa = \text{constant} \quad \rightarrow \quad \frac{\Delta P}{P} \approx -\kappa \frac{\Delta V}{V} \quad \text{for} \quad \Delta P \ll P
\]

\[
\rightarrow p_{\text{rms}} \approx \kappa \frac{\Delta V}{V} \cdot \frac{1}{\sqrt{2}} P
\]

\[
\Delta V = 2 \cdot \text{piston area} \cdot \text{max. excursion} \quad (1)
\]

with \( p_{\text{rms}} = 31.7 \text{ Pa} \) (124 dB), \( \kappa = 1.4 \), \( V = 2 \times 10^{-5} \text{ m}^3 \) and \( P = 101300 \text{ Pa} \) follows \( \Delta V = 6.3 \times 10^{-9} \text{ m}^3 \). With the area of the piston = 7.1E-6 m\(^2\), the maximum excursion is = 0.44 mm. Normal pressure at a height of 500 m above sea level may be estimated by 1013000-500\times12 = 95300 Pa. The sound pressure generated by the pistonphone is proportional to the absolute pressure. With \( \frac{P_{\text{rms}}}{P_{\text{max}}} = 0.941 \) follows a value of the sound pressure level of 123.5 dB.