Exercise 1 – The foundations of acoustics

NOTE: Before start, please do first the exercises presented in the Annex *"Review of maths"* to refresh your knowledge about logarithms

1. The pain threshold is at 130 dB. Calculate the corresponding effective value for the sound pressure.

2. Answer the following questions:
   a. What is the effective value for the sound pressure corresponding to L_p = 0 dB?
   b. What is the sound pressure level that corresponds to absolute quiet ($\tilde{p} = 0$)?

3. Calculate the effective value of the sound pressure ($\tilde{p}$) from the sound field $p(x,t) = \hat{p}\cos(\omega t - kx + \varphi)$ with the amplitude $\hat{p}$ = 0.35 Pa and a fixed position ($x = x_0$).

   Hint 1: Let x and φ be 0 and sketch the oscillation of p and p^2 as a function of t in a diagram, and then take the mean of the curve over an integer number of periods.

   Hint 2: $\cos^2 x = \dfrac{1+\cos 2x}{2}$

4. Calculate the SPL for the sound field in the previous task.

5. The atmospheric pressure is p_{atm}=101300 Pa. A harmonically oscillating sound field can have this amplitude as a maximum. From this, calculate the maximal theoretical SPL.

6. Show, from $L_p = 10\log\left(\dfrac{\tilde{p}^2}{p_{ref}^{\ 2}}\right)$, that $L_p = 20\log\left(\dfrac{\tilde{p}}{p_{ref}}\right)$.

7. Calculate the A-weighed SPL L_A from the following frequency spectrum

f (Hz)	63	125	250	500	1000	2000	4000
L_n (dB)	75	77	82	75	67	60	55

8. Suppose that the SPL at a large road is measured and logged during an entire day. Calculate the equivalent SPL $L_{eq,24h}$ and maximum SPL L_{max} for the following situations:
   a. 60 dBA during 12 h and quiet the remaining 12 h.
   b. 60 dBA during 6 h and quiet the remaining 18 h.
   c. 60 dBA during 12 h and 50 dBA the remaining 12 h.
   d. 60 dBA during 6 h, 55 dBA during 6 h, 50 dBA during 6 h and quiet the rest.

9. How long can you have a constant SPL of 100 dBA (and quiet the rest of the time) if $L_{eq,8h}$ cannot exceed 85 dBA?

10. A sound source, e.g. a car, is producing noise with a certain SPL L_A.

a. How much does the SPL increase if another source is added, so you have two identical sources? (do it both analytically and proving it graphically).
b. How much does the SPL increase with three identical sources?
c. How much does the SPL increase with four identical sources?

11. Two machines placed at a certain position are, respectively, producing noise with 30 dBA and 31 dBA.

a. Calculate the total SPL at that position.
b. A third machine is to be purchased and placed next the other two. What is the maximum SPL this third machine can make if the total SPL cannot exceed 35 dBA?

Answers:

1. $\tilde{p} = 63\,\text{Pa}$
2. a) $\tilde{p} = \tilde{p}_{ref} = 2 \cdot 10^{-5}\,\text{Pa}$
   b) $L_p = -\infty$
3. $\tilde{p} = 0.25\,\text{Pa}$
4. $L_p = 82\ \text{dB}$
5. $L_{p,\max,theory} = 191\ \text{dB}$
6. Theoretical
7. $L_A = 77\ \text{dBA}$
8. a) $L_{eq,24h} = 57\,\text{dBA}$
   b) $L_{eq,24h} = 54\,\text{dBA}$
   c) $L_{eq,24h} = 57.4\ \text{dBA}$
   d) $L_{eq,24h} = 55.5\ \text{dBA}$
9. $t = 15\,\text{min}$
10. a) $L_2 = L_A + 3\ \text{dB}$
    b) $L_3 = L_A + 4.8\ \text{dB}$
    c) $L_4 = L_A + 6\,\text{dB}$
11. a) $L_2 = 33.5\,\text{dBA}$
    b) $L_P = 29.6\,\text{dBA}$