Exercise, week 1 – foundations of acoustics

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

2. 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 expressed in equation (1) with the amplitude $\hat{p}$ = 0.35 Pa and a fixed position ($x = x_0$).

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

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

5. Atmospheric pressure is p_{atm} = 101 300 Pa. A harmonically oscillating sound field can have this amplitude as a maximum. From this, calculate the maximal theoretical SPL.

6. Show from equation (3) that $L_p = 20\log\left(\frac{\tilde{p}}{p_{ref}}\right)$.

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 larger road is measured and logged during an entire day. Calculate the equivalent SPL $L_{eq,24h}$ and maximum SPL L_{max} for the following result:

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 6h and quiet the remaining 6 h.

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 making 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?

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 is producing noise with 30 dBA and 31 dBA, respectively, at a certain position.

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?

12. When measuring a sound you often have the problem of dealing with background noise, from different sources as well as from the instrument. How much lower SPL than the signal being measured can a background noise have without any affect on the result? The sum of the signal and the background noise must not be more than 0.1 dB of the signal itself.

13. Show that the complex displacement function

$$p(x,t) = \hat{p}e^{i(\omega t + kx)}$$

is a solution of, and therefore, satisfies the wave equation for a pressure wave in a fluid by inserting in

$$\frac{\partial^2 p}{\partial x^2} - \frac{1}{c^2}\frac{\partial^2 p}{\partial t^2} = 0$$

The relation between the angular velocity and wave number is

$$c = \frac{\omega}{k}$$

Answers

1. $\tilde{p}$ = 63 Pa

2. a) $\tilde{p}$ = $2 \cdot 10^{-5}$ Pa (= p_{ref})

   b) $L_p = -\infty$

3. $\tilde{p}$ = 0.25 Pa

4. L_p = 82 dB

5. $L_{p,max\text{-}theor}$ = 191 dB

7. L_A = 77 dBA

8. a) $L_{eq,24h}$ = 57.0 dBA

   b) $L_{eq,24h}$ = 54.0 dBA

   c) $L_{eq,24h}$ = 57.4 dBA

   d) $L_{eq,24h}$ = 55.5 dBA

L_{max} = 60 dBA in all cases

9. t = 15 min

10. a) $L_2 = L_A + 3.01$ dB $\approx L_A + 3$ dB

    b) $L_3 = L_A + 4.8$ dB

    c) $L_4 = L_A + 6$ dB

11. a) L_2 = 33.5 dBA

    b) L_p = 29.6 dBA

12. The background noise have to be at least 16.3 dB lower than the signal.