Chapter II - Sound perception and noise

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Exercise 1.

1. $L_{Global} = 10\log(10^{\frac{L_1}{10}} + 10^{\frac{L_2}{10}} + 10^{\frac{L_3}{10}} + 10^{\frac{L_4}{10}} + 10^{\frac{L_5}{10}} + 10^{\frac{L_6}{10}})$
2. See table.
3. The A-weighting reflects the human ear sensitivity. (§ 2.3.15)
4. See table.
5. See table.

Bandes (Hz)	125	250	500	1000	2000	4000	Global
L_1 (dB)	84.3	80.5	77.3	72.0	69.3	68.0	86.7
L_2 (dB)	68.0	69.3	72.0	77.3	80.5	84.3	86.7
A-weighting (dB)	-16	-8.5	-3	0	+1	+1	
$L_{1,A}$ (dB(A))	68.3	72.0	74.3	72.0	70.3	69.0	79.2
$L_{2,A}$ (dB(A))	52.0	60.8	69.0	77.3	81.5	85.3	87.3

6. Remarks : here we can see the weight importance since two sounds with the same equivalent level in dB but with two different spectra give two A-weighted levels completely different. However these levels are more representative for ears.

Exercise 2.

1. Octave bands :

$$f_c = f_{min} \times \sqrt{2} = f_{max}/\sqrt{2}$$
$$f_{c_{sup}} = 2 f_{cinf}$$

Central frequencies (Hz)		125		250		500	
Min - Max frequencies (Hz)	88		177		354		707

Bandes (Hz)	125	250	500	Global
Niveau (dB)	84.0	87.0	80.0	89.3
Niveau (dB(A))	68.0	78.5	77.0	81.0

2. & 3.

4. Equivalent level in the engine shop :
   $L_{tot,A} = 10\log(4 \cdot 10^{\frac{L_{dB(A)}}{10}}) = 10\log(4 \cdot 10^{\frac{81.5}{10}}) = 87.0$ dB(A)
5. $$E_{A,T} = \int p_A^2(t)dt$$
   $$L_A = 10\log(\frac{p_A^2}{p_0^2}) \Longrightarrow p_A^2 = p_0^2 \cdot 10^{\frac{L_A}{10}}, \text{ with } p_0 = 2 \cdot 10^{-5} \text{ Pa}$$
   $$E_{tot,A} = p_A^2 \cdot t = p_0^2 \cdot 10^{\frac{L_{tot,A}}{10}} \cdot t = ((2 \cdot 10^{-5})^2 \cdot 10^{\frac{87}{10}})(8 \cdot 3600) \approx 5'774 \text{ Pa}^2\text{·s}$$
   The law is not respected.
6. $$E_{A,T} = p_{1,A}^2 \cdot t_1 + p_{2,A}^2 \cdot t_2 = p_0^2(10^{\frac{L_{1,A}}{10}} t_1 + 10^{\frac{L_{2,A}}{10}} t_2)$$
   $$= (2 \cdot 10^{-5})^2(10^{\frac{87.0}{10}}(7 \cdot 3600) + 10^{\frac{55}{10}}(1 \cdot 3600)) \approx 5'052 \text{ Pa}^2\text{·s}$$
   The law is respected now.

Exercise 3.

1. L(1000Hz) =90 dB → L_N(1000Hz) = 90 phones
   L(63Hz) =100 dB → L_N(63Hz) = 90 phones
   The two sounds are perceived at the same level.

   Calculation of the corresponding loudnesses :
   $N = 2^{(L_N - 40)/10}$
   L_N(63Hz) =90 phones → N(63Hz) =32 sones
2. New level :
   ΔL = $10\log(\frac{1}{10000})$= -40 dB
   L'(1000Hz) = 50 dB → L'_N(1000Hz) = 50 phones
   L'(63Hz) = 60 dB → L'_N(63Hz) = 40 phones

   1000 Hz is perceived louder than 63 Hz.

   Calculation of the new loudnesses :
   L'_N(1000Hz) =50 phones → N'(1000Hz) = 2 sones
   L'_N(63Hz) =40 phones → N'(63Hz) = 1 sones
   1000 Hz is perceived 2 times louder than 63 Hz.

Exercise 4.

An average level of $L_{limit,A}$ = 93 dB(A) during one hour (3'600 s) corresponds to the noise dose : $d_{limit} = p_A^2.\Delta t = (20.10^{-6})^2 10^{L_{limit,A}/10}.3600$ =2'873,2 Pa^2.s.

If the DJ already had 30 minutes with 97 dB(A), the corresponding noise dose is : $d = (20.10^{-6})^2 10^{97/10}.1800$ =3'608,5 Pa^2.s. The limit value is then already exceeded.

Exercise 5.

In one hour we have 450 times 5 sec with level 65 dB(A) + 50 times 5 seconds with level 75 dB(A). The remaining of the hour is considered silent (or at least sufficiently lower than 65 dB(A)).
The equivalent level $L_{eq,1h}$ corresponding to a measurement duration of 1 hour is then :
$L_{eq,1h} = 10log_{10}\frac{1}{3600}\left(450 \times 5 \times 10^{65/10} + 50 \times 5 \times 10^{75/10}\right) = 66{,}2$ dB(A)

Exercise 6.

The displayed value for a given integration time T can be derived as :
$L_{display} = 10log_{10}\left(\frac{1}{T}\int\limits_{t=0}^{T}\frac{\tilde{p}^2}{p_0^2}dt\right)$.
FAST setting : T= 125 ms
$\Longrightarrow$ Display : for signal durations of 1 s and 500 ms, $L_{display} = 100$ dB(A)
for signal durations of 100 ms, $L_{display} = 99$ dB(A)
for signal durations of 50 ms, $L_{display} = 96$ dB(A)

SLOW setting : T = 1s
$\Longrightarrow$ Display : for signal durations of 1 s = 100 dB(A)
for signal durations of 500 ms, $L_{display} = 97$ dB(A)
for signal durations of 100 ms, $L_{display} = 90$ dB(A)
for signal durations of 50 ms, $L_{display} = 87$ dB(A)