7S3X0 Introduction Building Physics and Material Science

Exercises Acoustics
Answers

1) A sound source produces an effective sound pressure p_{eff} of 0.1 Pa at some distance from it.
   a) Compute the sound pressure level L_p.
   Using $L_p = 10log_{10}\left(\frac{p_{eff}^2}{p_0^2}\right)$*, and with* $p_0 = 2\ 10^{-5}$ *Pa, we can compute* L_p *= 74.0 dB.*

   b) Compute the sound pressure level when the source would produce an effective pressure twice as high ($2p_{eff}$), and ten times as high ($10p_{eff}$).
   $L_p = 10log_{10}\left(\frac{(2p_{eff})^2}{p_0^2}\right) = 80.0\ dB$
   $L_p = 10log_{10}\left(\frac{(10p_{eff})^2}{p_0^2}\right) = 94.0\ dB$

   c) Compute the sound pressure level L_p when a second sound source is turned on producing a p_{eff} of 0.2 Pa.

   We first add the total acoustic energy $p^2_{eff,1}$ *+* $p^2_{eff,2}$ from the first and second sound source in order to get the total acoustic energy $p^2_{eff,tot}$*. Again using* $L_p = 10log_{10}\left(\frac{p_{eff,tot}^2}{p_0^2}\right)$ *leads to* L_p *= 81.0 dB. The acoustics energy of the second source is 5 times as high as the energy of the first source, leading to an increase of almost 7 dB.*

2) What are the units of sound pressure *p* and sound power *W*? And what are the units of the sound pressure level L_p and the sound power level L_w?

   p in Pa and W in W. L_p *in dB and* L_W *in dB.*

3) What is the relation between the sound intensity *I* and the sound power *W*?

   The sound power W in W is equal to the intensity I in W/m^2 *multiplied by a surface area S in m*^{2}*.*

4) The 15-minute equivalent sound pressure level measured in a noisy environment is given in the Table below.

63 Hz	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz	8000 Hz
85.1 dB	81.4 dB	77.6 dB	73.2 dB	74.4 dB	78.8 dB	75.2 dB	71.2 dB

   a) What is the meaning of the equivalent sound pressure level?
   It is the time averaged sound pressure level over the given measurement time, where p^2 *is the quantitiy averaged.*

b) Compute the overall equivalent sound pressure level.

We compute the overall L_{eq} level as follows:

$$L_{eq} = 10log_{10}\left(\sum_{i=1}^{8} 10^{\frac{L_{p,i}}{10}}\right) = 88.4\ dB$$

c) Compute the overall A-weighted equivalent sound pressure level.

We compute the overall L_{Aeq} level as follows, where A_i are the weights of A-weighting that can be found in Table 2.1 of the course reader.

$$L_{A,eq} = 10log_{10}\left(\sum_{i=1}^{8} 10^{\frac{L_{p,i}+A_i}{10}}\right) = 83.0\ dB(A)$$

5) Due to industrial activity, the sound level at the facade of a nearby residential building has the following 10-minute period pattern: 1 minute 90 dB(A), 5 minutes 60 dB(A) and 4 minutes 70 dB(A), compute equivalent sound pressure level.

$$L_{A,eq} = 10log_{10}\left(\frac{1}{10}\left(1 \cdot 10^{\frac{90}{10}} + 5 \cdot 10^{\frac{60}{10}} + 4 \cdot 10^{\frac{70}{10}}\right)\right) = 80.2\ dB(A)$$

6) The sound pressure level in a room is 80 dB. The sound field can be considered as diffuse. Assume a speed of sound of 340 m/s and an air density of 1.2 kg/m^3.

a) What is the effective pressure *p* in this room?

Using $L_p = 10log_{10}\left(\frac{p_{eff}^2}{p_0^2}\right)$, *we find for p_{eff} = 0.2 Pa.*

b) What is the sound intensity *I* in the room?

The sound intensity in a diffuse room is $I = \frac{p_{eff}^2}{4\rho c}$, *thus I = 2.45 10^{-5} W/m^2.*

c) One wall construction of the room has a total surface area of S_{tot} = 10 m^2, of which a door area of S_{door} = 2 m^2 with a sound transmission coefficient of τ = 1*10^{-2}, and a brickwork area of 8 m^2 with a sound transmission coefficient of τ = 1*10^{-5}. What is the incident power on the construction (use an incident intensity *I* = 5*10^{-5} W/m^2 if b could not be solved).

The incident power can be computed from W = I S_{tot} = 2.45 10^{-4} W.

d) What is total transmitted power through this wall?

The total transmitted power can be computed with formula (3.5) from the course reader: $W_\tau = S_1 I \tau_1 + S_2 I \tau_2 = 2*1*10^{-2}*2.45\ 10^{-5} + 8*1*10^{-5}*2.45\ 10^{-5} = 4.9\ 10^{-7}$ *W.*

e) What is the sound transmission index *R* of this wall?

$R = 10 log_{10}\left(\frac{W_i}{W_\tau}\right)$ *=27.0 dB*

7) Laboratory measurements are conducted to measure *R* of a building element. The results for a certain octave band are: L_{source} = 80 dB, $L_{receiver}$ = 40 dB, *S* = 2 m^2 and A = 10 m^2. What is the sound transmission index *R* of this element. Is *R* larger or smaller than L_{source}-$L_{receiver}$ and why?

$R = L_s - L_r + 10 log_{10}\left(\frac{S}{A_r}\right)$ *= 33.0 dB. This is 7.0 dB lower than the level difference between the rooms. This means that the receiver room is actually causing a 7 dB lower sound pressure level in that room due to absorption of the boundaries.*

8) What is the difference in the meaning of *R* measured in laboratory conditions and D_{nt} measured in situ?

R can be assigned to a single partition wall or floor structure. D_{nt} *is a number that should be assigned to the whole structure, that means the level difference between rooms does not only depend on the separating wall or floor, but is also influenced by flanking paths.*

9) For $f < f_c$, the *R* for random wave incidence can be computed according to the mass law.

a) Compute f_c of a 0.1 m thick 2300 kg/m^3 concrete wall with a longitudinal sound velocity of c_L = 3300 m/s.

$f_c = \frac{64000}{c_L d}$ *= 193.9 Hz*

b) Compute *R* of the concrete wall with for *f* = 63 Hz and for *f* = 125 Hz.

Equation (3.33): $R = 20 log_{10}(m) + 20 log_{10}\left(\frac{f}{250}\right)$
leads to R_{63Hz} *=35.3 dB,* R_{63Hz} *=41.2 dB*

c) Compute R of the concrete wall for *f = 500 Hz,* assume an internal damping η *= 0.02.* What equation do you use and why?

We use equation (3.35) from the reader because this frequency is above the critical frequency.

$$R = R_{plateau} + 25 log_{10}\left(\frac{f}{f_c}\right)$$

$R_{plateau}$ is computed from equation (3.34):

$$R_{plateau} = 20log_{10}(mf_c) + 10log_{10}(\eta) - 44 = 32.0\ dB$$

Then we find R = 42.3 dB

10) In Figure 3.9 of the reader, explain the dips in *R* around 100 Hz and the 4 dips at the higher frequencies.

The first dip is due to the mass-spring resonance frequency, the last 4 dips are due to cavity resonances.

11) Draw possible flanking transmission paths in the cross section below (two rooms with source in left room). Consider only paths that cross one junction from one building element to another.