<u>Solved Problems and Test Question on „Technical Acoustics and Noise Control”</u>

some example items

(Final modification: 22nd may 2015.)

1. One internal section of an infinite long tube is terminated with a vibrating piston. Due to this excitation a plane wave, traveling parallel with the tube axes, is generated. Determine the maximum velocity of the piston, when the sound pressure level inside the tube is 107dB! The inside air temperature is 30°C, and equilibrium pressure is 1bar.

$$p_{eff} = p_0\sqrt{10^{0,1\cdot L}} = 2\cdot 10^{-5}\sqrt{10^{10,7}} \approx 4{,}48\text{Pa}, \quad \hat{p} = p_{eff}\sqrt{2} \approx 4{,}48\sqrt{2} \approx 6{,}33\text{Pa}, \quad \rho_0 = p_0/RT_0 = 10^5/287\cdot 303 \approx 1{,}15\text{kg/m}^3,$$

$$a = \sqrt{\kappa R T_0} = \sqrt{1{,}4\cdot 287\cdot 303} \approx 348{,}9\text{m/s}, \quad \hat{v} = \hat{p}/\rho_0 a \approx 6{,}33/1{,}15\cdot 348{,}9 \approx 0{,}0158\text{m/s}$$

2. What is sound? List the occurrences related the wave nature, and shortly explain the features related the flow nature of the sound!

Details see in the lecture notes!

3. Let calculate the first and third natural frequency of a 4.5m long open ended tube! The inside air temperature is 35°C.

$$a = \sqrt{\kappa R T_0} = \sqrt{1{,}4\cdot 287\cdot 308} \approx 351{,}8\text{m/s}$$

The first natural frequency: Based on the boundary condition the particle velocity distribution is half sinus from a maximum to the next minimum: $\lambda_1 = 4\cdot l/2 = 2\cdot 4{,}5 = 9\text{m}$, $f_1 = a/\lambda_1 \approx 351{,}8/9 = 39{,}1\text{Hz}$

The third natural frequency: Based on the boundary condition the particle velocity distribution is a one and half sinus from a maximum to the second minimum: $\lambda_3 = 4\cdot l/6 = 4\cdot 4{,}5/6 = 3\text{m}$, $f_3 = a/\lambda_3 \approx 351{,}8/3 = 117{,}3\text{Hz}$

4. A point source operating in a free field that bounded with sound absorbing plane surface, is moved to a corner (intersection of 3 sound reflecting perpendicular planes), during the distance from the sound source is increased 4 times bigger and the radiated sound power is doubled. Calculate the resulted sound pressure level change!

$$\Delta L = L_2 - L_1 = L_{W2} - L_{W1} - 10lg\, r_2^2 + 10lg\, r_1^2 + 10lg\, D_2 - 10lg\, D_1 - 11 + 11 = 3 - 10lg(4r_1)^2 + 10lg\, r_1^2 + 10lg8 - 10lg1 = 0\text{dB}$$

5. What is the consequence on the sound spectra of a noise, when there is a characteristic difference between the linear (un-weighted) and A-weighted sound pressure levels.

Details see in the lecture notes! (The dominant components of the noise spectrum are in the less sensitive lower (about 20-500Hz), and higher (about 5k-20kHz) frequency range of the human ear.)

6. The stroke of a positive displacement vacuum pump, placed in free field, is doubled. Calculate the resultant sound pressure level change, if the other circumstances of the sound generation and propagation, do not change.

The dominant noise source mechanism of the pump is the fluctuating air flow rate, leaving the discharge section, which can take as a monopole. To double the stroke means double the characteristic speed of the flow. Based on the model low of the monopole, the sound pressure level change:

$$\Delta L = L_2 - L_1 = L_{W2} - L_{W1} = 10lg(P_2/P_0) - 10lg(P_1/P_0) = 10lg(P_2/P_1) = 10lg(\text{konst}\cdot v_2^4 l_2^2 \rho_2 a_1/\text{konst}\cdot v_1^4 l_1^2 \rho_1 a_2) =$$

$$= 10lg(v_2^4/v_1^4) = 40lg(2v_1/v_1) = 12\text{dB}$$

7. A harmonic wave of 0.001 sec time of period and 0.5 Pa sound pressure amplitude perfectly reverberated from a perpendicular positioned, plane surface. Give the name of the acoustic occurrence, calculate the characteristic frequency, length, the maximum sound pressure level of the resultant wave! The air temperature is 10°C.

The name of this superposition is standing wave, the frequency is f=1/T=1kHz,

The distance between two neighbouring nodal point is the half wave length, $a = \sqrt{\kappa R T_0} = \sqrt{1{,}4\cdot 287\cdot 283} \approx 337{,}2\text{m/s}$,

$$\lambda = aT \approx 337{,}2\cdot 0{,}001 \approx 0{,}3372\text{m}, \quad \lambda/2 \approx 0{,}1686\text{m}$$

The resultant sound pressure amplitude at the anti-nodal (maximum) point is the simple sum of the amplitudes of the incident and reflected components, 1Pa. That expressed in sound pressure level:

$$L = 10lg(p_{eff}^2/p_0^2) = 10lg\left(1/\sqrt{2}/2\cdot 10^{-5}\right)^2 = 91\text{dB}$$

8. Based on the governing equation of the fluid mechanics derive the homogeneous acoustic wave equation. List the simplifications, explain the neglected terms in detail, and put down the general solution of the equation, and its applications.

Details see in the lecture notes!

9. Prove, that the resultant effective sound pressure square of the different frequency components is the simple sum of the components effective sound pressure square.

Details see in the lecture notes!

10. In a pure reverberant sound field, made by a sound source placed in a room, the sound pressure level is 84 dB. One third part of the internal surface of the room is changed to a sound absorbing material. After this the sound pressure level decreased to 78 dB. Calculate the sound absorption coefficient of the absorbing material, if the sound absorption coefficient of the room internal surface, α_{room} is 0.05 .

$$\Delta L = 6 = L_1 - L_2 = 10lg(4/R_{T1}) - 10lg(4/R_{T2}) = 10lg(R_{T2}/R_{T1}) = 10lg(\alpha_2 A(1-\alpha_1)/\alpha_1 A(1-\alpha_2)) =$$

$$= 10lg(\alpha_2(1-0{,}05)/0{,}05(1-\alpha_2)), \qquad \alpha_2 \approx 0{,}1732$$

$\alpha_2 = \alpha_{room} 2/3 + \alpha_{material} 1/3 = 0{,}05 \cdot 2/3 + \alpha_{material} 1/3 = 0{,}1732$ **$\alpha_{material} = 0{,}42$**

11. Two neighbouring axial flow fan transport air from a room, placed on the ground level and in the middle of a 320m long and 10 floor high concrete wall building, into the connected open air space. The observation point placed 55m from the fans, is on the sound absorbing surface in front of the building. Between the fan and the observation point there is an acoustically non-transparent object, with 14dB frequency independent insertion loss. Determine the A-weighted sound pressure level in the observation point. The sound power radiated by the fans outlet, and the relative levels of the A-weighting curve as a function of the octave-band frequencies can be found in the following tabulation. Please make a schematic drawing of the arrangement.

f_{okt} [Hz]	250	500	1k	2k	4k
P_{1oct} [W]	0.1	0.5	0.1	0.01	0.001
P_{2oct} [W]	0.5	0.1	0.05	0.01	0.005
ΔL_{Aoct} [dB]	-8.6	-3.2	0	1.2	1

Answer:

f_{oct} [Hz]	250	500	1k	2k	4k
$P_{1+2oct} = P_{1oct} + P_{2oct}$ [W]	0.6	0.6	0.15	0.02	0.006
$L_{W1+2oct} = 10lg(P_{1+2oct}/P_0)$ [dB]	117.8	117.8	111.8	103	97.8
$L_{oct} = L_{W1+2oct} - 10lgr^2 + 10lgD - 11 = L_{W1+2oct} - 10lg55^2 + 10lg2 - 11 =$ [dB]	75	75	69	60.2	55
$L_{okt} - \Delta L_{b\ garázs} = L_{okt} - 14$ [dB]	61	61	55	46.2	41
$L_{okt} - 14 + \Delta L_{Aokt}$ [dB]	52.4	57.8	55	47.4	42

$L_A = 10lg(10^{5,24} + 10^{5,78} + 10^{5,5} + 10^{4,74} + 10^{4,2}) \approx$ **60.7** [dB(A)]
