Chapter III - Room acoustics
Corrections

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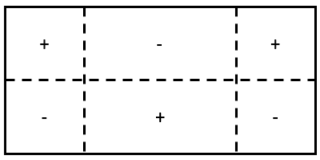
1 Exercise 1. Low frequency response of a room

1. $f_{m_x,m_y,m_z} = \frac{c}{2}\sqrt{\left(\frac{m_x}{L}\right)^2 + \left(\frac{m_y}{l}\right)^2 + \left(\frac{m_z}{h}\right)^2}$
   Peaks correspond to eigenfrequencies.
2. $f_{1,1,1} = 80\text{Hz}$: oblique mode
   $f_{2,1,0} = 83$ Hz : tangential mode.



3. The best location is a corner for both the microphone and the loudspeaker. It corresponds to the antinode position for each mode.
4. No, there is too much discrete resonances below 120 Hz (and probably also above).

Exercise 2. Standing waves in a tube (room modes in 1D)

1. $\dfrac{\partial p}{\partial x} = -\rho\dfrac{\partial v}{\partial t} = -j\omega\rho v$, and therefore
   $v(x,t) = -\dfrac{1}{j\omega\rho}(-jkp_{0+}e^{j(\omega t - kx)} + jkp_{0-}e^{j(\omega t + kx)}) = \dfrac{1}{\rho c}(p_{0+}e^{-jkx} - p_{0-}e^{jkx})e^{j\omega t}$
2. $v(0,t) = v_0 \rightarrow p_{0+} - p_{0-} = \rho c v_0$
3. $v(L,t) = 0 \rightarrow p_{0+}e^{-jkL} - p_{0-}e^{jkL} = 0$
4. $p_{0-} = \dfrac{\rho c v_0}{2j\sin kL}e^{-jkL}$ and $p_{0+} = \dfrac{\rho c v_0}{2j\sin kL}e^{+jkL}$
5. $p(x,t) = -j\rho c v_0 \dfrac{\cos k(L-x)}{\sin kL}e^{j\omega t}$ then the rms value is
   $\tilde{p}(x,t) = \dfrac{\rho c v_0}{\sqrt{2}}\left|\dfrac{\cos k(L-x)}{\sin kL}\right|$
   The resonance frequencies correspond to $kL = n\pi \rightarrow f = \dfrac{nc}{2L}$ where n is an integer.

Exercise 3. Measurement of the absorption coefficient in the reverberant chamber

The absorption coefficient can be derived through 2 succssive measurements :

— A first one with the empty room : $T_1 = 0.16\frac{V_0}{\alpha_0 S_0}$,
where $V_0 = 215.6\text{m}^3$ and $S_0 = 226.9\text{m}^2$ are the volume and the total surface of walls of the reverberant room, and α_0 is the (average) absorption coefficient of the walls (assuming $\alpha_0 << 1$ for the reverberant room) ;

— a second one with the material sample of volume $V_{mat} = 5\times(2.4\times1\times0.2) = 0.480\text{m}^3 << V_0$ and surface $S_{mat} = 5 \times (2.4 \times 1) = 12\text{m}^2$:
$T_2 = 0.16\frac{V_0 - V_{mat}}{\alpha_0(S_0 - S_{mat}) + \alpha_m at S_{mat}}$, where α_{mat} designates the (unknown) absorption coefficient of the material.

f (Hz)	125	250	500	1000	2000	4000
α_1	0.49	0.44	0.32	0.31	0.29	0.29
α_2	0.28	0.64	1.02	1.12	1.14	1.07
α_3	0.56	0.97	1.13	1.13	1.05	1.26

1. See Table 1 - α_1 : the absorption coefficients are rather low (<0.5) all over the whole frequency band of interest.
2. See Table 1 - α_2 : there's a significative increase of absorption above 500 Hz mainly due to the tissue, but still poorly absorbent in the lows.
3. See Table 1 - α_3 : the lower density of flakes does not degrade the high-frequency performance, and in the same time increase the low-frequency performance. It seems that filling with flakes at too high density does not favor absorption ; an optimal density might be investigated.
4. We can compute the effect of such temperature variation on the reverberation time measurement. Since $T_S = 55.4\frac{V}{c(\Theta)\alpha_s S}$ and the speed of sound $c(\Theta)$ depends almost linearly on temperature Θ inside the standard temperature ranges ($c(\Theta) \approx 331.6 + 0.607.\Theta$, for $\Theta \in [0 - 30°]$), we can write :
$$\frac{\Delta T_S}{T_S} = \frac{\Delta\Theta}{\Theta} = \pm1\%$$

Exercise 4. Rehearsal room of an orchestra

$T' = T/20 = 0.08$ s $\Longrightarrow$ impossible !!!

Exercise 5. Critical radius

$$A = 0.163 \cdot \frac{V}{T_{60}} \;\Big|\; r_h \simeq 0,14\sqrt{A} \;\Big|\; L_r = L_{Pa} - 10\log A + 6 \;\Big|\; L_d = L_{P_a} + L_\delta - 20\log r - 11$$

Given : $T_{60} = 1.6$ s, we can compute :

	$V(\text{m}^3)$	$A(\text{m}^2)$	r_h(m)	L_r(dB)	L_d(dB)
Room 1	500	50	0.98	109	109
Room 2	5000	500	3.13	99	109