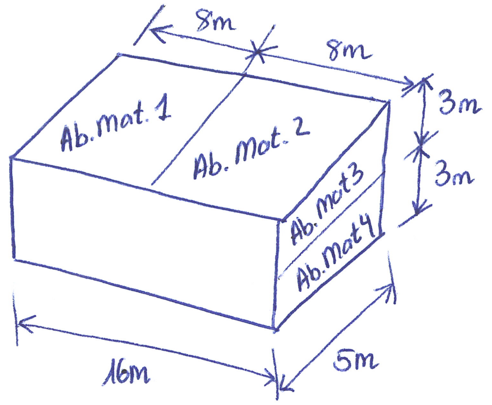
# EXAM VTAN01 - 12th JANUARY 2017

**1**




| Material | $\alpha$ |
|---|---|
| Ab. Mat 1 | 0'24 |
| Ab. Mat 2 | 0'37 |
| Ab. Mat 3 | 0'15 |
| Ab. Mat 4 | 0'22 |

NOTE: $\alpha$ is given for difusse field conditions (i.e. average for all freqs)

a) Reverberation time is the time required for the reflections of a direct sound to decay 60 dB. Two procedures to measure it were employed in Lab 2.

1) Interrupted noise: loudspeaker playing pink noise / all freq. excited with same energy
2) Impulse excitation: book banged or clap / some freqs. may not be excited

b) Sabine's formula: $T_{60} = 0'16 \cdot \frac{V}{A_{eff}}$; with $A_{eff} = \sum_i \alpha_i S_i$

We can first calculate the effective absorption area separately

$A_{eff\,longwalls} = A_{eff\,floor} = A_{eff\,frontwall} = 0$ (totally reflective; i.e. $\alpha = 0$)

$A_{eff\,ceiling} = \frac{S_{ceiling}}{2} \cdot \alpha_{Ab.mat1} + \frac{S_{ceiling}}{2} \cdot \alpha_{Ab.mat2} = (8 \cdot 5 \cdot 0'24) + (8 \cdot 5 \cdot 0'37) = 24'4\ m^2 Sab.$

$A_{rearwall} = \frac{S_{wall}}{2} \cdot \alpha_{Ab.mat3} + \frac{S_{wall}}{2} \cdot \alpha_{Ab.mat4} = (3 \cdot 5 \cdot 0'15) + (3 \cdot 5 \cdot 0'22) = 5'55\ m^2 Sab.$

- Thus, the total effective absorption area is: $A_{eff} = \sum_i \alpha_i S_i = 24'4 + 5'55 = 29'95\ m^2 Sab.$
- The volume of the room is: $V_{room} = 16 \cdot 5 \cdot 6 = 480\ m^3$

Hence, the reverberation time is: $T_{60} = 0'16 \cdot \frac{480}{29'95} \Rightarrow \boxed{T_{60} = 2'56\,sec}$

The value would be high or low depending on the room's use.

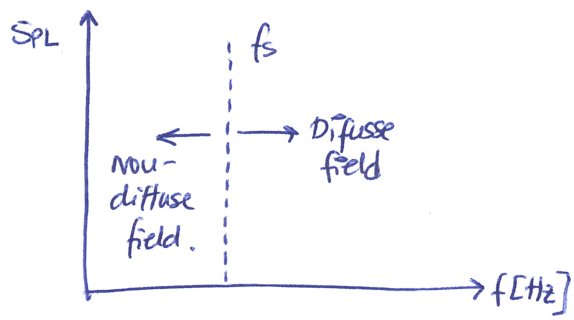
c) $T_{60}' = 0'95 \cdot T_{60} = 2'43$ sec, is to be obtained now to the stipulated reduction

- The new effective area will now be:

$A_{eff}' = A_{eff\,ceiling} + A_{rearwall} + A_{eff\,NEW\,wall} = 29'95 + 0'35 S_N$  $\boxed{S_{NEW} \approx 5 m^2}$

Thus: $T_{60}' = 0'16 \cdot \frac{V_{room}}{A_{eff}'} \Rightarrow A_{eff} = 0'16 \cdot \frac{V_{room}}{T_{60}'} \Rightarrow 29'95 + 0'35 \cdot S_{new} = 0'16 \cdot \frac{480}{2'43} \Rightarrow \nearrow$

d) $f_s = 2000 \sqrt{\frac{T_{60}}{V_{room}}} = 2000 \cdot \sqrt{\frac{2'43}{480}} = \boxed{142'3\ Hz}$




Diffuse field: SPL $\approx$ constant in the room

Non-diffuse field: wave approach

**2** (a) 10 km far away (point 1): $L_{I_1} = 10\log\left(\frac{I_1}{I_0}\right) = 70\,dB$

1 km distance (point 2): $L_{I_2} = 10\log\left(\frac{I_2}{I_0}\right)$

The intensity of the sound wave at the deck is:

$$70 = 10\log\left(\frac{I_1}{10^{-12}}\right) \Rightarrow I_1 = 10^{-12}\cdot 10^{7} = 10^{-5}\,\frac{W}{m^2}$$

Due to spherical propagation being assumed: $\frac{I_2}{I_1} = \frac{r_1^2}{r_2^2} \Rightarrow I_2 = I_1\left(\frac{r_1^2}{r_2^2}\right) \Rightarrow$

$$\Rightarrow I_2 = 10^{-5}\cdot\left(\frac{10^2}{(10^3)^2}\right) \Rightarrow I_2 = 10^{-9}\,\frac{W}{m^2}$$

Thus, the sound intensity is: $L_{I_2} = 10\log\left(\frac{10^{-9}}{10^{-12}}\right) \Rightarrow \boxed{L_{I_2} = 30\,dB}$

(b) The distance at which the sound stops being audible is that at which the intensity equals the threshold value, $I_0 = 10^{-12}\,\frac{W}{m^2}$.

Due to spherical propagation: $\frac{I_1}{I_0} = \frac{r_0^2}{r_1^2} \Rightarrow r_0 = r_1\sqrt{\frac{I_1}{I_0}} = 10\sqrt{\frac{10^{-5}}{10^{-12}}} \Rightarrow \boxed{r_0 = 31600\,m}$

(c) $I = \frac{\tilde{p}^2}{\rho\cdot c} \Rightarrow \tilde{p} = \sqrt{\rho\cdot c\cdot I_0} = \sqrt{1'2\cdot 340\cdot 10^{-12}} \Rightarrow \boxed{\tilde{p} = 2\cdot 10^{-5}\,Pa}$

It does make sense; pressure threshold ($20\,\mu Pa$) $\approx$ Intensity threshold.

(d) $\boxed{L_p = 20\log\left(\frac{(20\,\mu Pa)^2}{(20\,\mu Pa)^2}\right) = 0\,dB}$

**3** (a) Pure tone $\Rightarrow$ Harmonic wave; $p(x,t) = \hat{p}\cos(Kx - \omega t + \varphi)$

We calculate the terms separately:

$\omega = 2\pi\cdot f = 2\cdot\pi\cdot 612 = 1224\pi\ Hz$

$K = \frac{\omega}{c} = \frac{1224\pi}{340} = 3'6\pi\ m^{-1}$

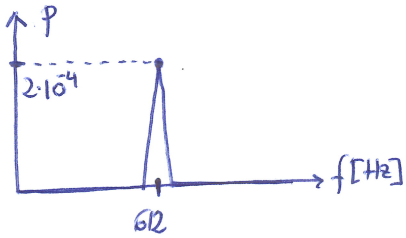
$\boxed{\lambda = \frac{2\pi}{K} = \frac{2\pi}{3'6\pi} = 0'555\ m}$

Considering $\varphi = 0$

$$\boxed{p(x,t) = (2\cdot 10^{-4})\cos(\underbrace{3'6\pi}_{11'3} x - \underbrace{1224\pi}_{3845'3} t)}$$

(b) $L_p = 20\log\left(\frac{\tilde{p}^2}{p_{ref}^2}\right) = 20\log\left(\frac{\left(\frac{2\cdot 10^{-4}}{\sqrt{2}}\right)^2}{(2\cdot 10^{-5})^2}\right) \Rightarrow \boxed{L_p = 40\,dB}$

(c)




The leap between the time and the frequency domain would be perform by means of Fourier Transform analyses.

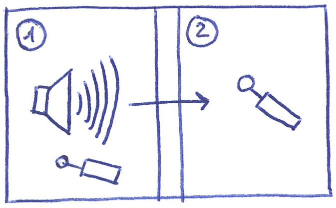
(d) Sampling frequency should be double as the highest freq. of interest

Thus: $\boxed{f_s > 2\cdot 612 = 1224\ Hz} \rightarrow$ Nyquist-Shannon criterion.

(e) $L_{p_T} = 10\log\left(\sum_i 10^{\frac{L_{p_i}}{10}}\right) = 10\log\left(4\cdot 10^{\frac{40}{10}}\right) \Rightarrow \boxed{L_{p_T} = 46\,dB}$

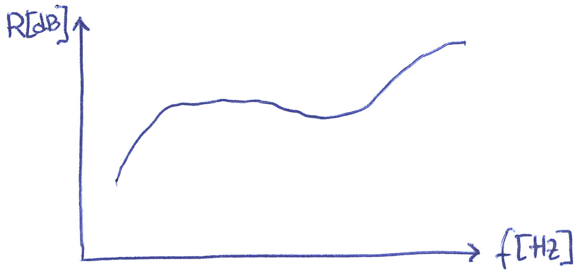
**(4)**

**(a)**




- Play sound (pink noise: equal energy in all frequencies) in sending room (room 1)
  - Measure SPL in both room 1 and 2
  Different number of microphone positions and loudspeaker positions should be considered → given in the standards).

$$R(f) = L_{send}(f) - L(f)_{rec} + 10\log\left(\frac{S}{A(f)}\right)$$




- measure the reverberation time in the receiving room in order to obtain the effective absorption area of the room. Two methods:
  - Interrupted noise
  - Impulse excitation

  } Explained in 1a

**(b)** Due to the fact that $V_2 = 50\,m^2$ and that $T_{2_{60}} = 0'8\,s.$ for all frequencies we have that:

$$A_{eff} = 0'16 \cdot \frac{V_2}{T_{60,2}} = 0'16 \cdot \frac{50}{0'8} = 10\,m^2\,Sab.$$

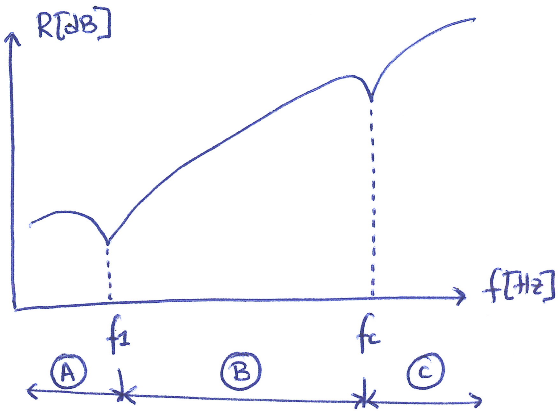
And since the surface of the wall is $10\,m^2$, the term $10\log\left(\frac{S}{A_{eff}}\right)$ vanishes. Thus

$$R(f) = L_{send}(f) - L_{rec}(f)$$

| f[Hz] | R(f) |
|---|---|
| 50 | 25 |
| 63 | 27 |
| 80 | 28 |
| 100 | 30 |
| 125 | 31 |
| 160 | 33 |
| 200 | 35 |
| 250 | 37 |
| ⋮ | ⋮ |
| 2500 | 53 |
| 3150 | 55 |
| 4000 | 57 |
| 5000 | 59 |

→ PLOT!

**(c)**




$f_1$ ≡ resonance frequency

$f_c$ ≡ coincidence frequency

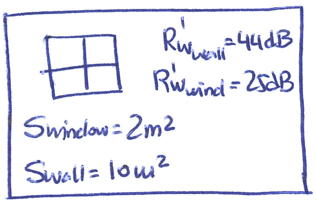
(A) Stiffness-controlled region

(B) Mass-controlled region

(C) Damping-controlled region.

**(d)** No, one cannot say anything, since impact sound insulation measurements are performed using a tapping machine as excitation source, and not a loudspeaker.

**(e)**



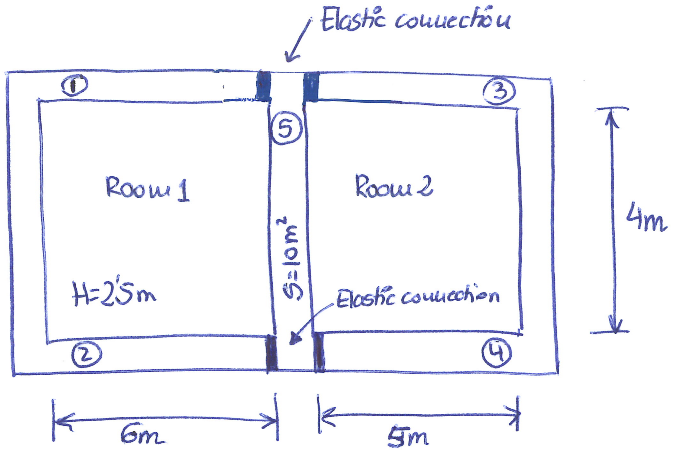

$$R'_{w,Total} = 10\log\left[\frac{1}{S}\sum_{i=1}^{n} S_i\, 10^{-\frac{R_i}{10}}\right];\quad \text{Then:}$$

$$R'_{w,total} = 10\log\left[\frac{1}{10}\left(8\cdot 10^{\frac{44}{10}} + 2\cdot 10^{\frac{25}{10}}\right)\right] \Rightarrow \boxed{R'_{w_{total}} = 43\,dB}$$

43-4=39dB

**(f)** $R'_{w_{leak}} = -10\log\left(10^{-\frac{R_w}{10}} + \frac{S_l}{S_{TOT}}\right) \Rightarrow S_{leak} = S_{TOT}\left(10^{-\frac{R'_{w_{leak}}}{10}} - 10^{-\frac{R'_{w_{TOT}}}{10}}\right) \Rightarrow \boxed{S_{leak} = 7'5\cdot 10^{-4}\,m^2}$

## 5




$R_{w,1} = R_{w,2} = R_{w,3} = R_{w,4} = 48\,dB$

$R_{w,5} = 52\,dB$

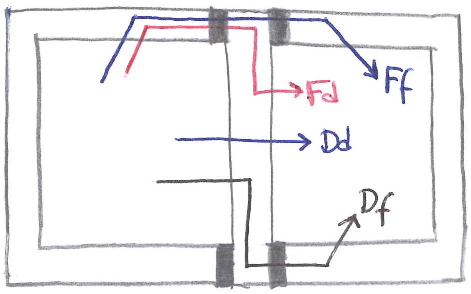
For task (b):

$\alpha_{Room1,\,ceiling} = 0'4$

$\alpha_{Room2,\,ceiling} = 0'7$

$L_{sending} = 90\,dB$

### a




$$R'_w = -10\log\left[10^{\frac{-R_{Dd,w}}{10}} + \sum_{F=f=1}^{n} 10^{\frac{-R_{Ff,w}}{10}} + \sum_{F=1}^{n} 10^{\frac{-R_{Fd,w}}{10}} + \sum_{f=1}^{n} 10^{\frac{-R_{Df,w}}{10}}\right]$$

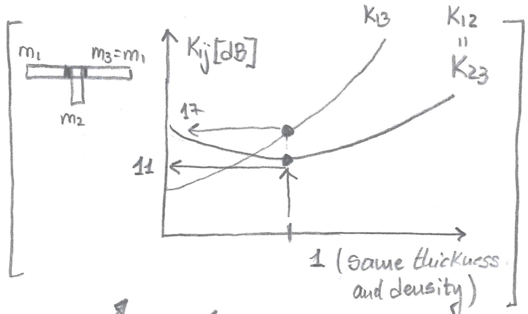
with the $R_{ij}$ paths defined as:

$$(R_f)_{ij,w} = R_{ij,w} = \frac{R_{i,w} + R_{j,w}}{2} + K_{ij} + 10\log\left(\frac{S_s}{l_0 \cdot l_{ij}}\right)$$

In our case (neglecting floor and ceiling flanking transmission), we have:

2 Df paths
2 Fd paths
2 Ff paths
1 Dd path

$\Rightarrow$ In total, there are 7 reduction indeces to take into account.




⊛ We first calculate the Df paths, black in the figure

$$R_{Df,w} = \frac{52+48}{2} + 11 + 10\log\left(\frac{10}{1 \cdot 2'5}\right) = 67\,dB$$

⊛ The Fd paths (red colour in the figure) are calculated as:

$$R_{Fd,w} = \frac{48+52}{2} + 11 + 10\log\left(\frac{10}{1 \cdot 2'5}\right) = 67\,dB$$

⊛ The Ff paths are:

$$R_{Ff,w} = \frac{48+48}{2} + 17 + 10\log\left(\frac{10}{1 \cdot 2'5}\right) = 71\,dB$$

Thus, we have: $R'_w = -10\log\left[10^{-\frac{52}{10}} + 4 \cdot 10^{\frac{-67}{10}} + 2 \cdot 10^{\frac{-71}{10}}\right] \Rightarrow \boxed{R'_w = 51'4\,dB}$

### b

The sound pressure level in the receiving room is calculated as:

$$R'_w = L_{sending} - L_{receiving} + 10\log\left(\frac{S}{A_2}\right) \Rightarrow L_{receiving} = L_{sending} - R'_w + 10\log\left(\frac{S}{A_2}\right) \Rightarrow$$

$$\Rightarrow L_{receiving} = 90 - 51'4 + 10\log\left(\frac{10}{(5 \cdot 4 \cdot 0'7)}\right) \Rightarrow \boxed{L_{receiving} = 37'1\,dB}$$

6

a) Theoretical (see lecture notes)

b) Theoretical (see lecture notes)

c) Theoretical (see lecture notes)

d) • 60dBA for 12h and completely silent the rest

$$\boxed{L_{peq,24h}} = 10\log\left(\frac{1}{T}\int_0^T 10^{\frac{L_p(t)}{10}}dt\right) = 10\log\left(\frac{1}{24}\int_0^{\frac{24}{2}} 10^{\frac{60}{10}}dt + 0\right) = \boxed{57dBA}$$

• $$\boxed{L_{peq,24h}} = 10\log\left(\frac{1}{24}\int_0^{0'25} 10^{\frac{95}{10}}dt + \int_0^{0'5} 10^{\frac{101}{10}}dt + 0\right) = \boxed{84'70dB}$$

e) • $L_p = 20\log\left(\frac{\tilde{p}}{p_{ref}}\right) \Rightarrow 0 = 20\log\left(\frac{\tilde{p}}{p_{ref}}\right) \Rightarrow \boxed{\tilde{p} = p_{ref} = 20\,\mu Pa}$

• $L_p = 20\log\left(\frac{\tilde{p}}{p_{ref}}\right) \Rightarrow L_p = 20\log\left(\frac{0}{p_{ref}}\right) \Rightarrow \boxed{L_p = -\infty}$