# ACOUSTICS

## 1. Definition

Acoustics is part of physics that studies the creation, propagation, reception and properties of sound.

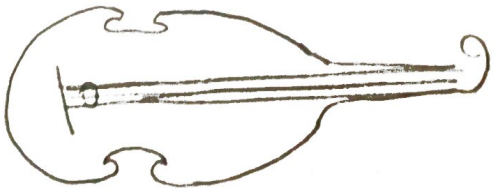
A mechanical wave capable to impress to human hearing organ is called sound.

## 2. Sound characteristics

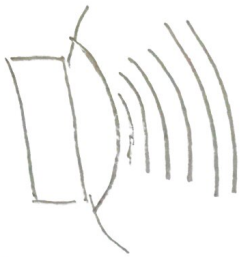
- to be produced by a sound source;
- the existence of an elastic mediumbetween source and receiver;
- the mechanical wave frequency should be larger than 16 Hz and smaller than 20kHz; $16\,Hz \leq \nu \leq 20\,kHz$.
- the power of mechanical wave should be high enough to produce an auditive sensation
- the sound intensity should be higher than the treshold $I = I_0 = 10^{-12}\,W/m^2$;
- the duration of a mechanical oscillation should be larger than 0.05 s; $t_s \geq 0.05\,s$.

## 3. Sound sources

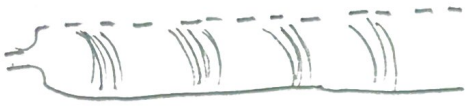
### 31. Vibrating cordes



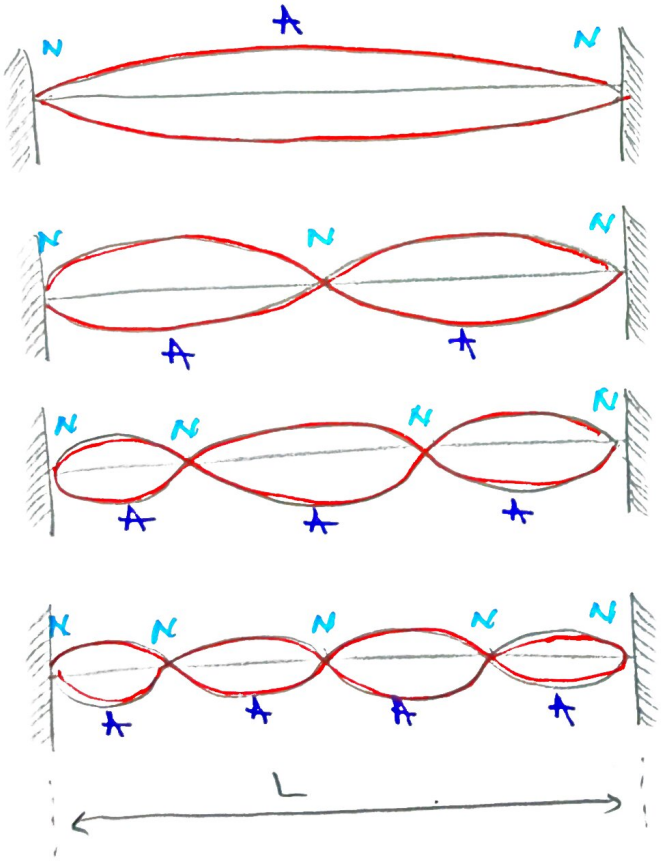
## 3.2 Vibrating membranes



## 3.3 Vibrating air columns



# 4. Fundamental sound and superior harmonics




$\lambda_1 = \frac{2L}{1}$

$\lambda_2 = \frac{2L}{2}$

$\lambda_3 = \frac{2L}{3}$

$\lambda_4 = \frac{2L}{4}$

$$\boxed{\lambda_n = \frac{2L}{n}}$$

$$\nu_n = \frac{v}{\lambda_n} \Rightarrow \nu_n = \frac{v}{2L} n$$

$$\boxed{\nu_1 = \frac{v}{2L}}$$

Fundamental frequency

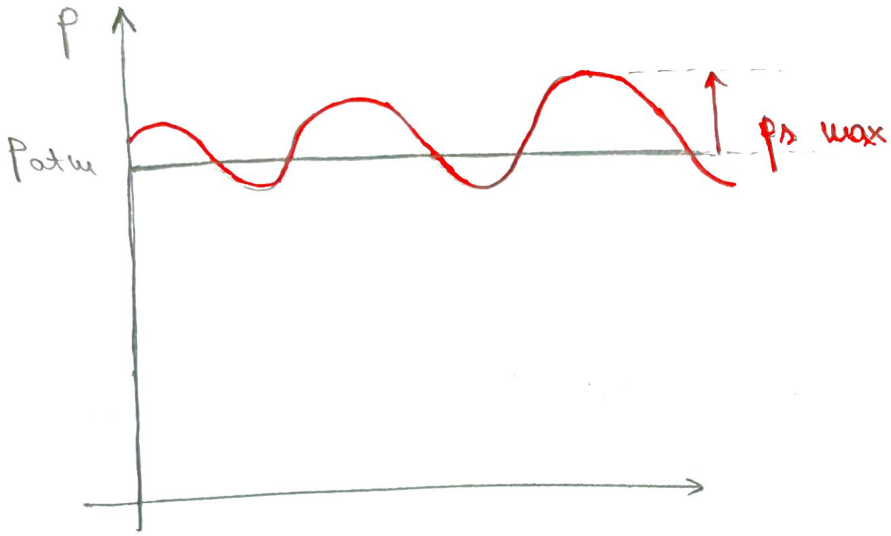
$$\nu_n = n \cdot \nu_1$$

superior harmonics

$n = 2, 3, 4 \ldots$

# 5. The sound properties

## 5.1 The sound pressure




$$p_s(t) = p_{s\ max} \sin(\omega t) ;$$

$$P_{s,max} = \rho \cdot v \cdot A \cdot \omega$$

$\rho$: the density, $v$: velocity — the elastic media

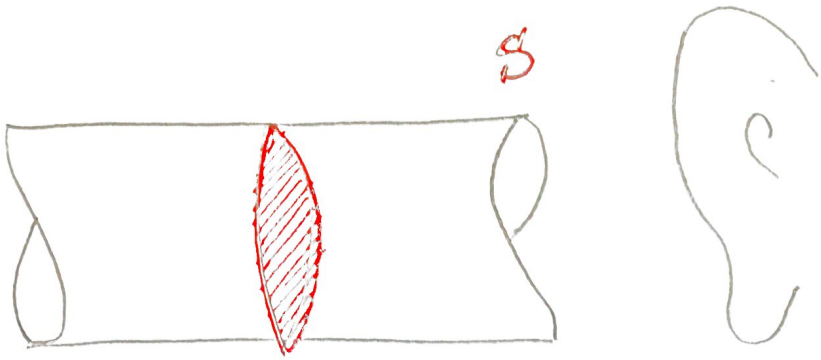
$A$: amplitude, $\omega$: pulsation — external perturbation (harmonic oscillation)

## 5.2 The sound intensity

$$I = \frac{1}{S}\left\langle \frac{dW}{dt} \right\rangle_t ; \quad [I]_{IS} = \frac{W}{m^2} \text{ watt}$$

$\langle \ \rangle_t$ - the time average

$W$: energy




$$I = \frac{1}{2} \rho v A^2 \omega^2$$

$$I = \frac{\rho^2 v^2 A^2 \omega^2}{2 \rho v}$$

$$I = \frac{(\rho v A \omega)^2}{2 \rho v}$$

$$\boxed{I = \frac{P_{s,max}^2}{2 \rho v}}$$

Note: $Z = \rho v$ – the acoustic impedance

$$\boxed{I = \frac{P_{s,max}^2}{2 Z}}$$

$$\boxed{P_{s,eff} = \frac{P_{s,max}}{\sqrt{2}}}$$

$P_{s,eff}$ – (effective quantity) major value

$$P_{s,eff}^2 = \frac{P_{s,max}^2}{2}$$

$$\boxed{I = \frac{P_{s,eff}^2}{Z}}$$

## 5.3 The sound level

$$I_0 = 10^{-12} \frac{W}{m^2} \leq I \leq 10^{4} \frac{W}{m^2}$$

$$\log_{10}\left(\frac{I}{I_0}\right) = 14 \ldots$$

$$N_0 = 10 \log_{10}\left(\frac{I}{I_0}\right) \quad (dB)$$

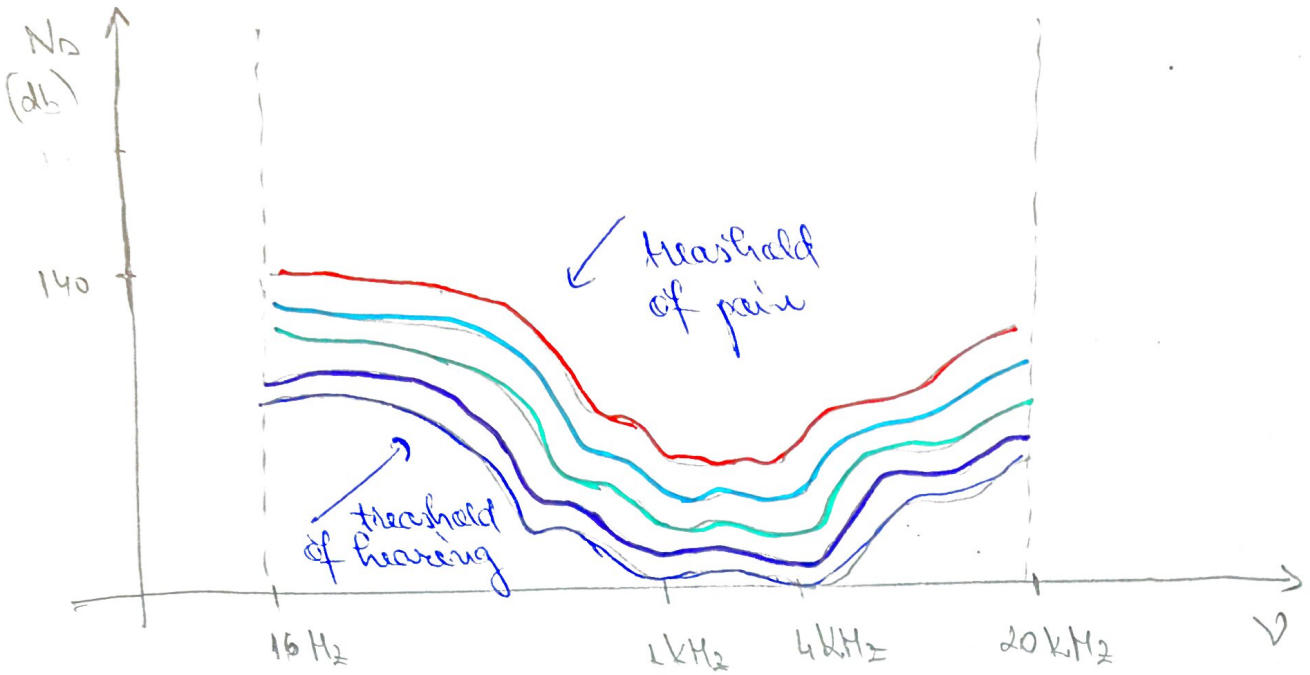
## 5.4. The acoustic level

$$N_a = 10 \lg\left(\frac{I_a}{I_0}\right)$$


# 6. The sound parameters

## 6.1. The loudness

↳ The physiological parameter of a sound related to its intensity.




## 6.2. The Pitch

↳ highness or lowness of a musical tone related to the sound frequency

## 6.3. The timbre

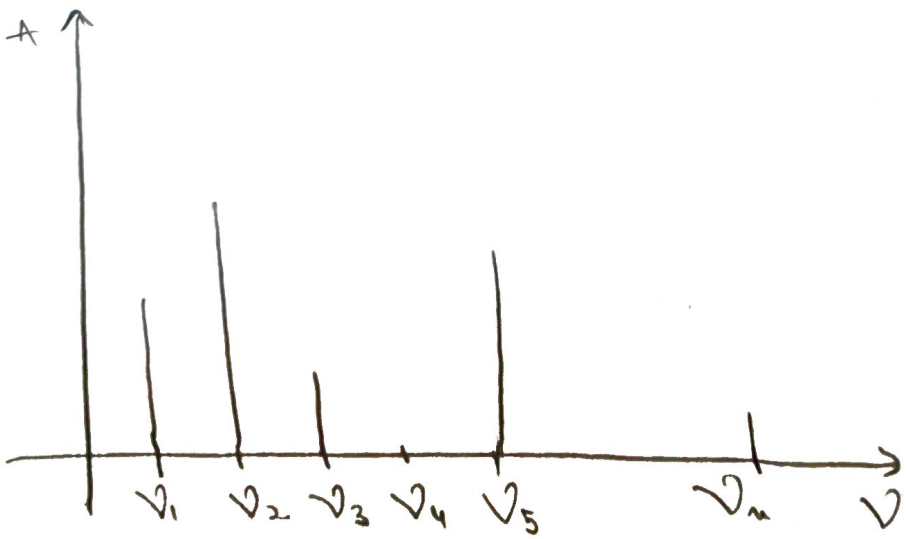
$$S(t) = A_1 \sin(\omega_1 t) + A_2 \sin(\omega_2 t) + A_3 \sin(\omega_3 t) + \dots$$

$$\omega = 2\pi\nu$$

$$\nu_n = n \cdot \nu_1$$

$$S(t) = \sum_{n=1}^{N} A_n \sin(2\pi n \nu_1 t)$$

Fourier transformation →

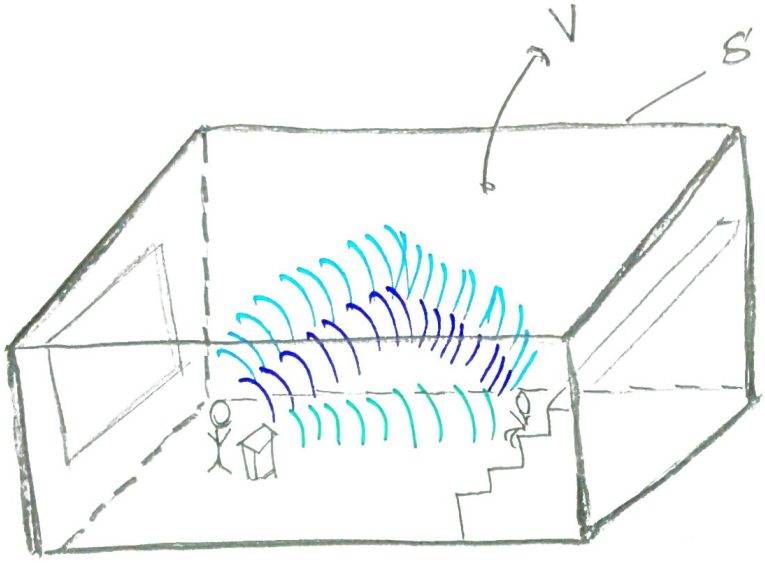


## 6.4. The noise

**Def.** A sound which contains too many components is called a noise.

## 7. The Reverberation

Ⓐ




**Def:** The collection of reflected sounds into an inclosure like an auditorium room is called reverberation.

Ⓑ The reverberation time, $t_R$

**Def:** The reverberation time is the time in which the sound level decreases with 60 dB or the intensity increases with $10^6$.

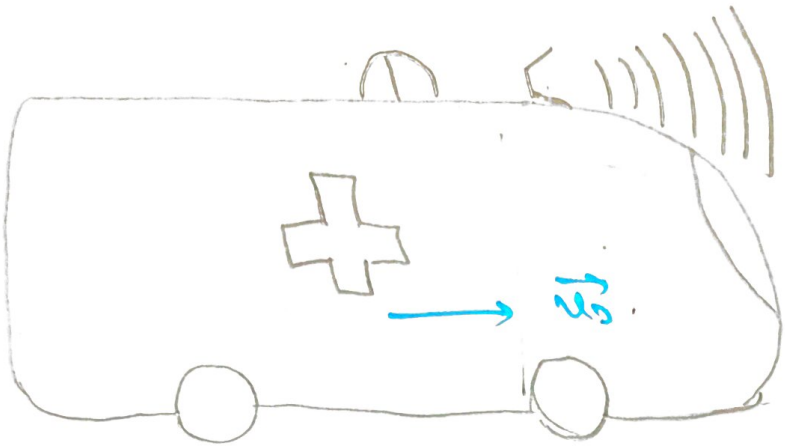
$$t_R = 0.16 \frac{V}{L \cdot S}$$

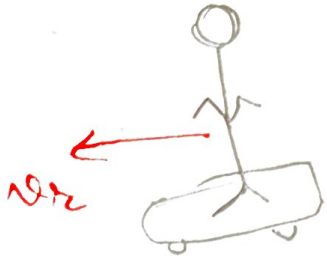
V - volume, S - surface (area of the surface);

L - the absobtion coefficient;

If $t_R > 0.1s \Rightarrow$ BAD ACOUSTICS

## 8. The Doppler effect




$v_s$: velocity of the sound source

C: the sound velocity

$v_r$: - receiver velocity

$$V = V_0 \frac{C \overset{+}{-} v_r}{C \underset{+}{-} v_s}$$

The upper sign should be used if the distance between the source and receiver decreases.

The lower sign should be used if the distance between the source and receiver decreases.