Building Physics

LEVEL: **1 YEAR BACHELOR**

SPECIALTY: **COP**

COURS 04

ACOUSTICS

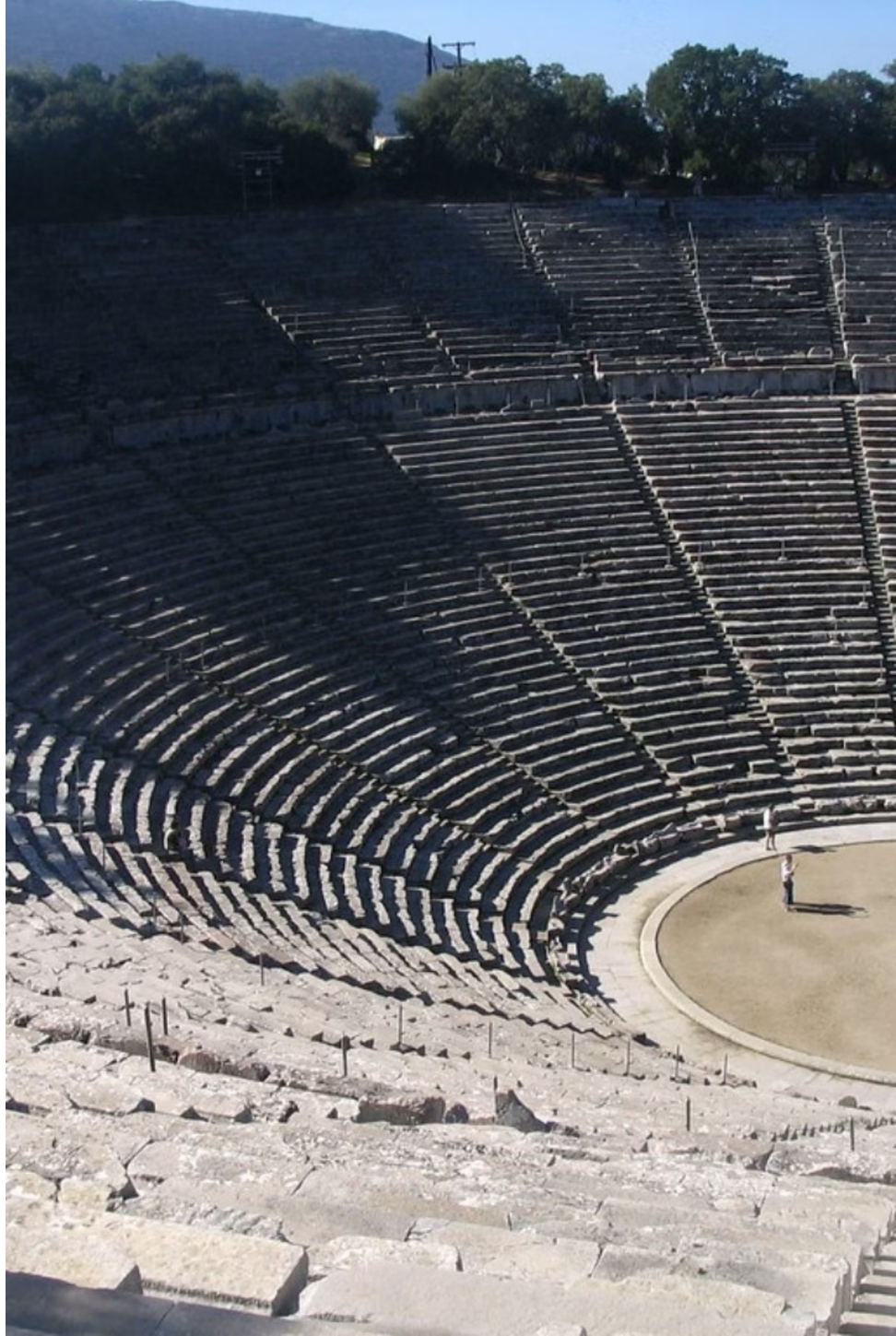
University of Biskra

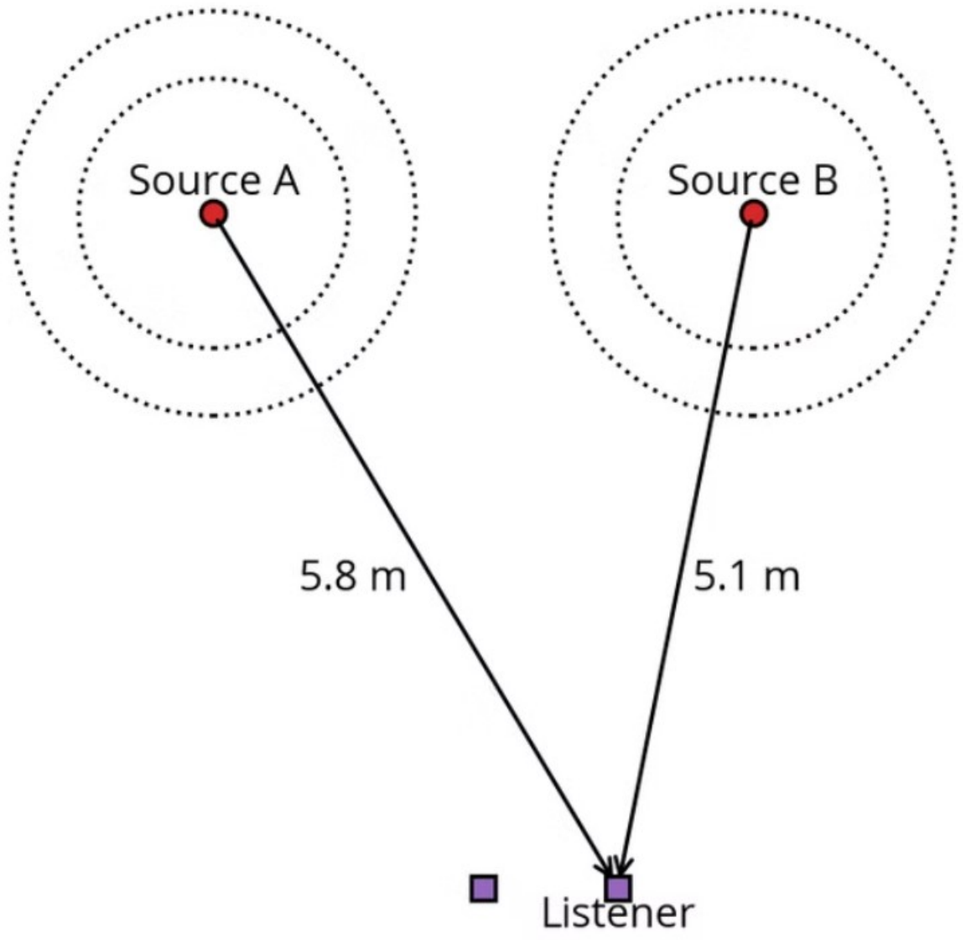
2024-2025

The Science of Acoustics

Acoustics, the science of sound, has been considered in construction since antiquity. The Theatre of Epidaurus, built in Greece in the 3rd century BC, demonstrates that acoustic concerns in buildings are not recent. Today, studies show that 54% of French people are disturbed by external noise and 85% by noise from within their own homes.

Acoustics comes from the Greek "acoustikos" meaning "for hearing." Originally focused on small pressure waves in air detectable by the human ear, its scope has expanded to include high and low frequencies: ultrasound and infrasound. It studies the mechanisms of sound production, propagation in air, and reception.





Understanding Sound

Psychological Perspective

From a psychological viewpoint, sound is simply what we hear. This definition has intuitive appeal as it relates to our sensations and feelings associated with the myriad sounds we experience daily.

Physical Perspective

Physically, sound is a dynamic phenomenon involving oscillatory motion. It's the audible sensation caused by an acoustic wave propagating through a medium, creating small oscillations in atmospheric pressure capable of vibrating the eardrum.

Simple Yet Complex

Sound itself is a simple phenomenon–a very small movement of air–while acoustic isolation is a mechanical matter. However, human perception of sound is far more complex.

Sound Propagation

Propagation Speed

Acoustic vibrations propagate from point to point. The speed of this propagation is called the "celerity of sound," approximately 340 m/s in air, much greater than vibratory speed. This speed increases slightly with temperature.

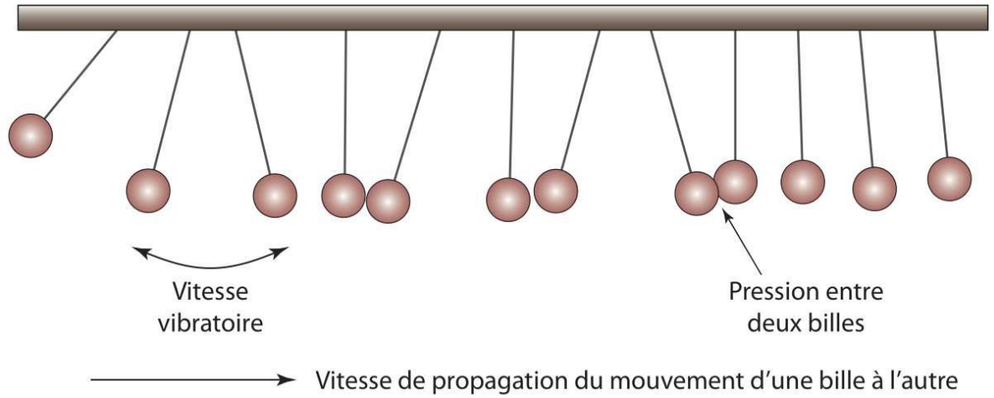
The speed (m/s) can be calculated based on temperature (◦C) using the formula:

$$C(\theta) = 331.4 + 0.607(\theta)$$

C: Speed of sound in m/s;
θ: Temperature in ◦C.

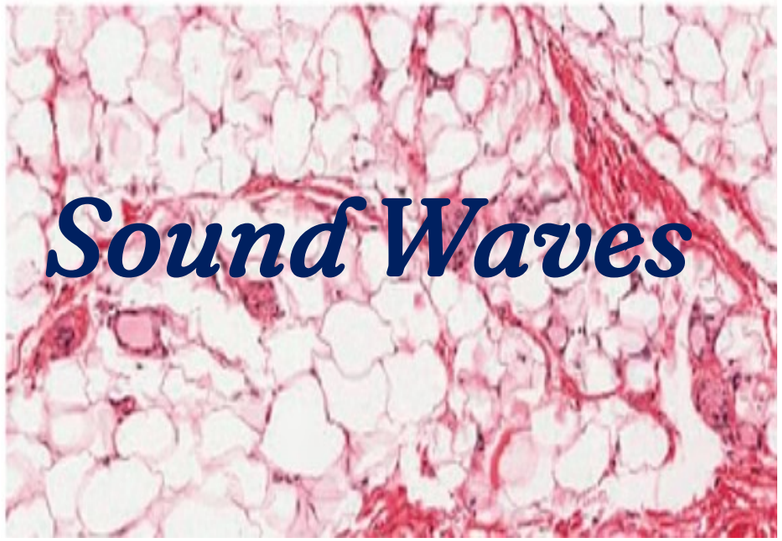
Particle Movement

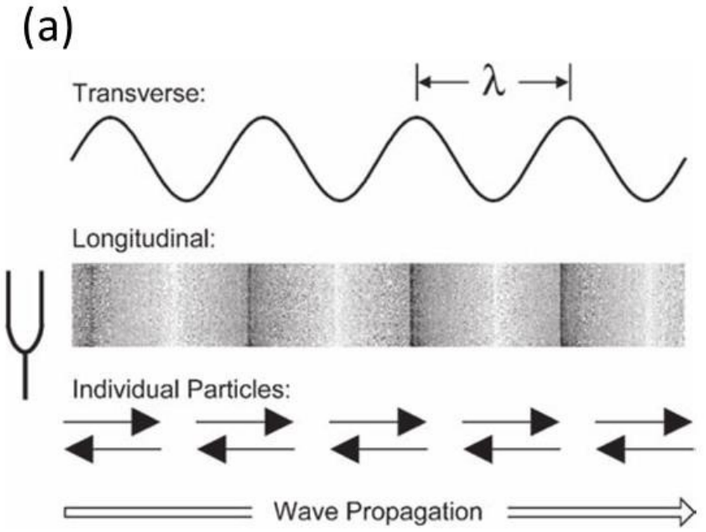
When a particle is excited, it communicates its movement to neighboring particles, which begin moving with a time delay related to the propagation medium's characteristics (density, compressibility coefficient, etc.).

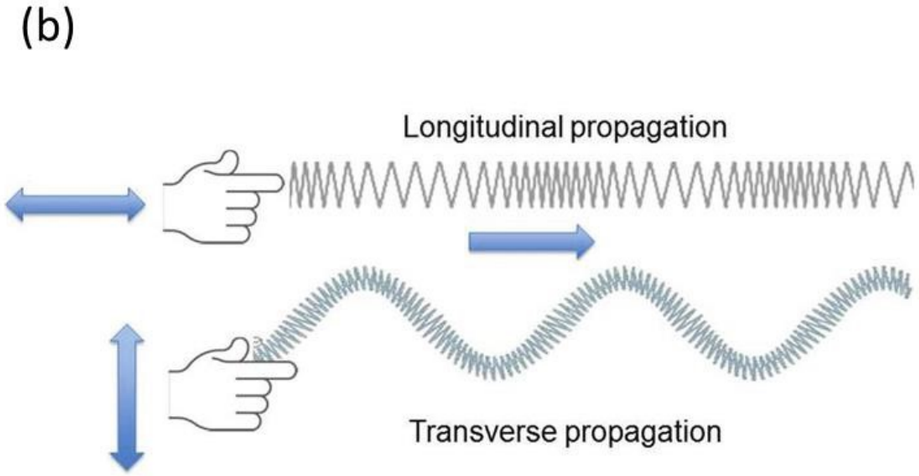


This creates a disturbance that propagates from particle to particle–an acoustic wave. The time delay between visual perception and acoustic signal arrival increases with distance.

Sound Waves







Wave Definition

A sound wave is a disturbance in motion that transports energy without transporting matter. This small mechanical disturbance propagates within matter, requiring a material medium (no sound in vacuum).

Transverse Waves

In transverse propagation, the direction of particle displacement is perpendicular to the wave propagation direction. These occur primarily in solids, not in air.

Longitudinal Waves

In longitudinal propagation, the direction of particle displacement is parallel to the wave propagation direction. Sound waves are longitudinal waves.

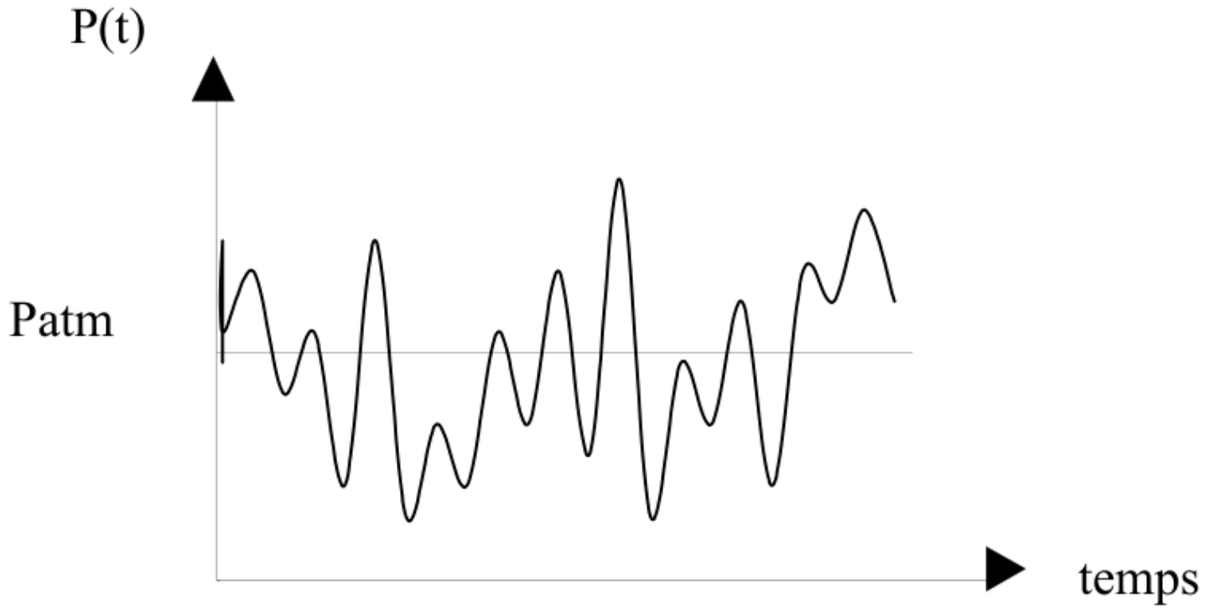
Propagation Direction

Sound waves propagate in all directions from the source. A wave surface is one where all points are in the same vibratory state.

Acoustic Pressure and Sound Level

Acoustic Pressure

Acoustic pressure P(t) is the fluctuating part of total pressure around a constant average value (atmospheric pressure). It's measured in Pascals (Pa) or N/m². An audible sound corresponds to a maximum variation of ±20 Pa.



Acoustic pressure P(t) (Kuznik et al., 2009).

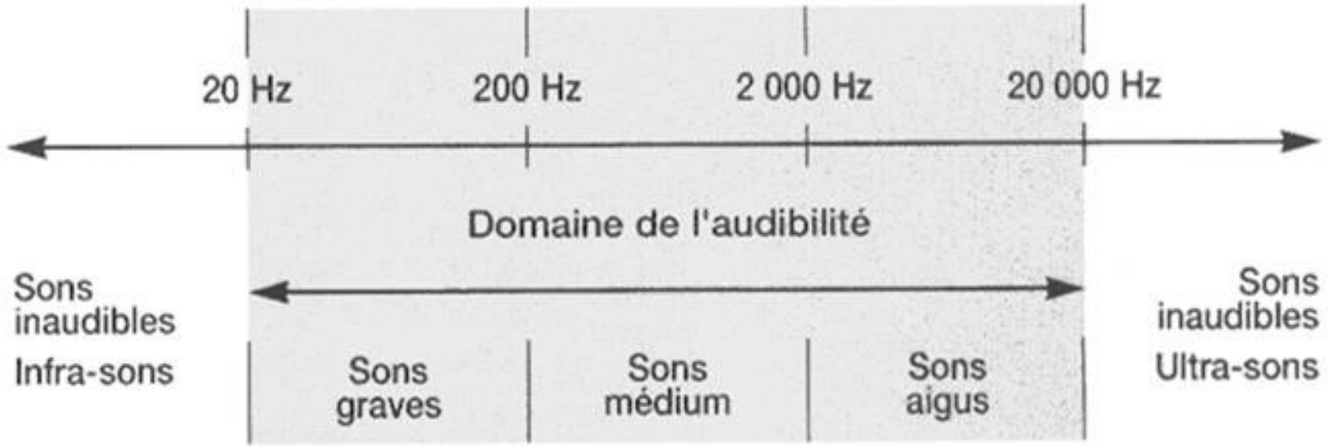
Acoustic Pressure and Sound Level

Sound Level

Sound level (Lp) characterizes sound amplitude. Since the human ear's perception scale is vast, a logarithmic scale expressed in decibels (dB) is used. Sound level is often measured with an A-filter and expressed as dB(A), noted as LpA.

Example of a sound level meter (Google image).

Acoustic Pressure and Sound Level



Frequency scale. *https://eprofu.ro/ssm/modulul-6-i/*

Human Hearing

The "normal" ear is sensitive to audible frequencies between 20 Hz and 15,000 Hz, varying by individual and age. Sounds above 1,500 Hz are "high-pitched," below 300 Hz are "low-pitched," below 20 Hz are "infrasounds," and above 20 kHz are "ultrasounds."

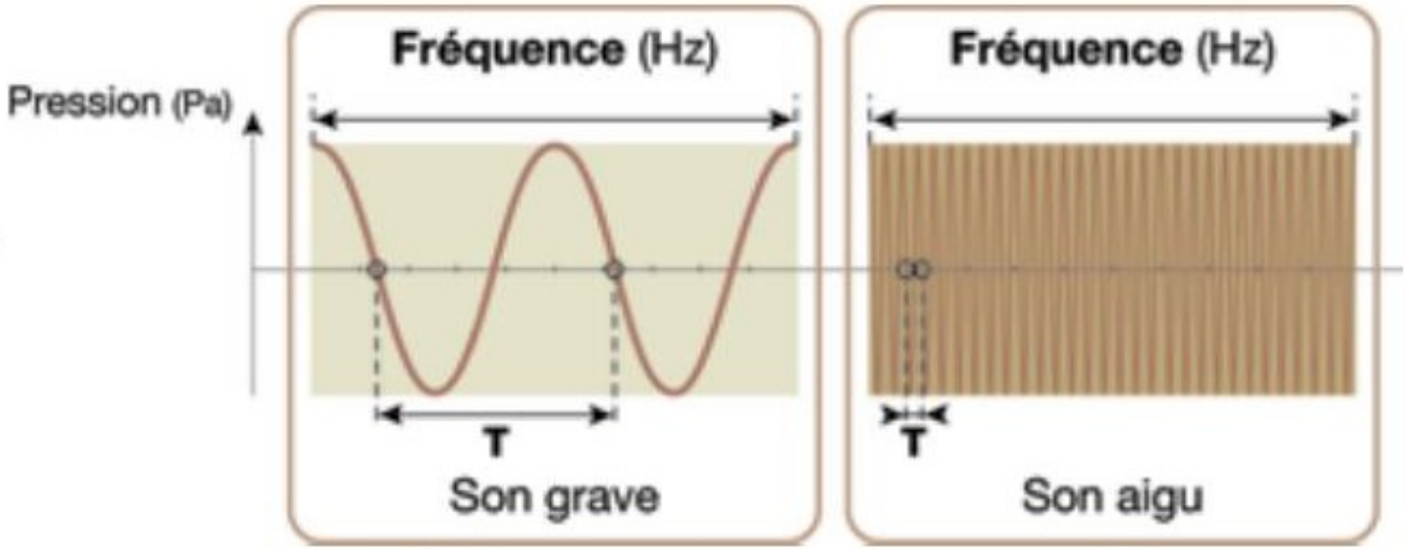
Frequency and Wavelength

Frequency Definition

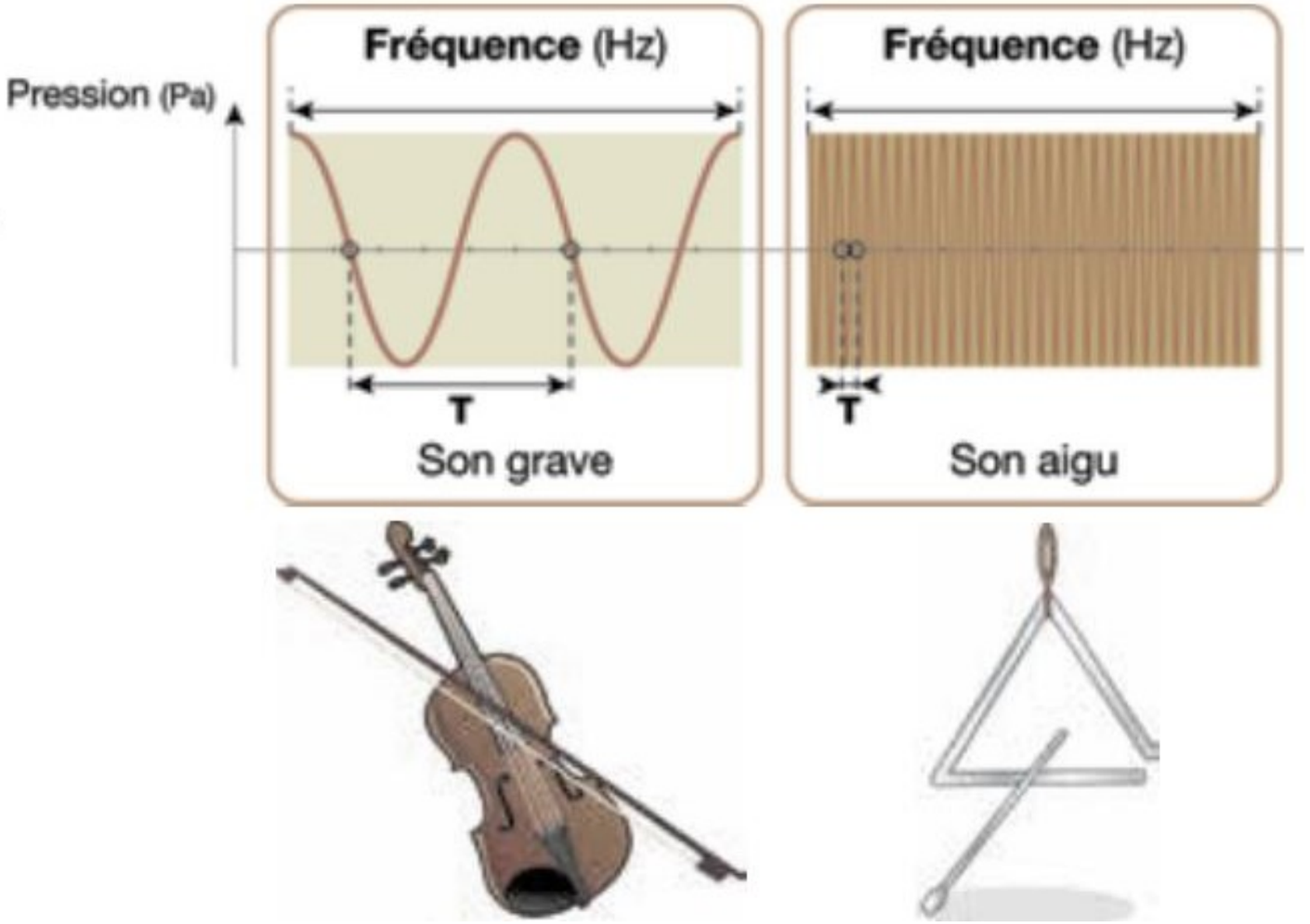
Within a sound wave, pressure fluctuates around atmospheric pressure. The number of fluctuations per second defines the sound's frequency in Hertz (Hz).

Wavelength

Wavelength is related to frequency and sound speed. Low-frequency sounds (like a cello) have longer wavelengths than high-frequency sounds (like a triangle).



Frequency and Wavelength



Period

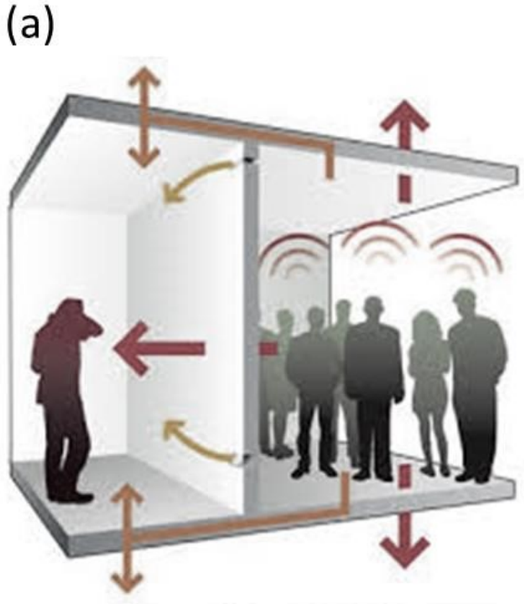
The period (t) is the time between two fluctuations in seconds. The longer the period, the lower the frequency, resulting in a deeper sound.

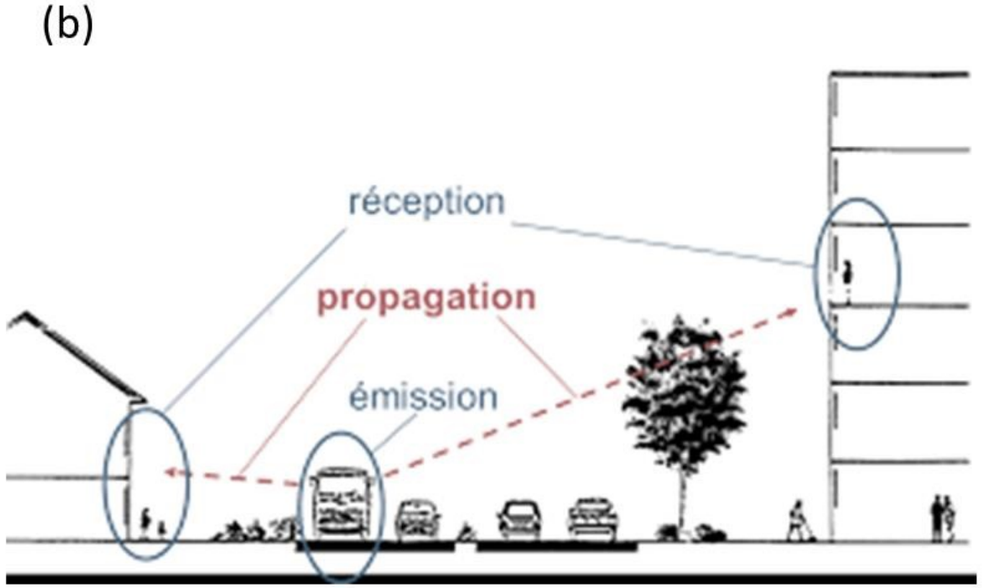
Pitch Perception

If the period is short, the frequency is high, producing a high-pitched sound. Different instruments produce different wavelengths.

Sources of Noise

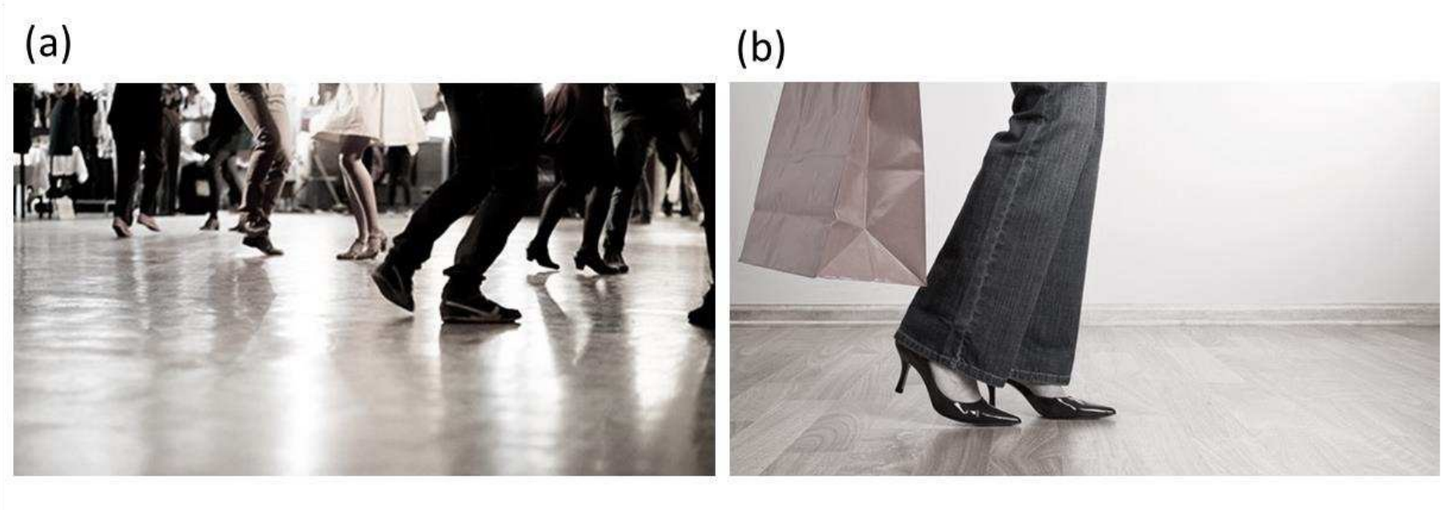
Airborne Noise





Airborne noise propagates through ambient air. There are two categories: interior airborne noise (pink noise) such as conversation, and exterior airborne noise (road noise) such as railway traffic. These sounds travel through the air before reaching walls and other structures.

Sources of Noise



Impact Noise

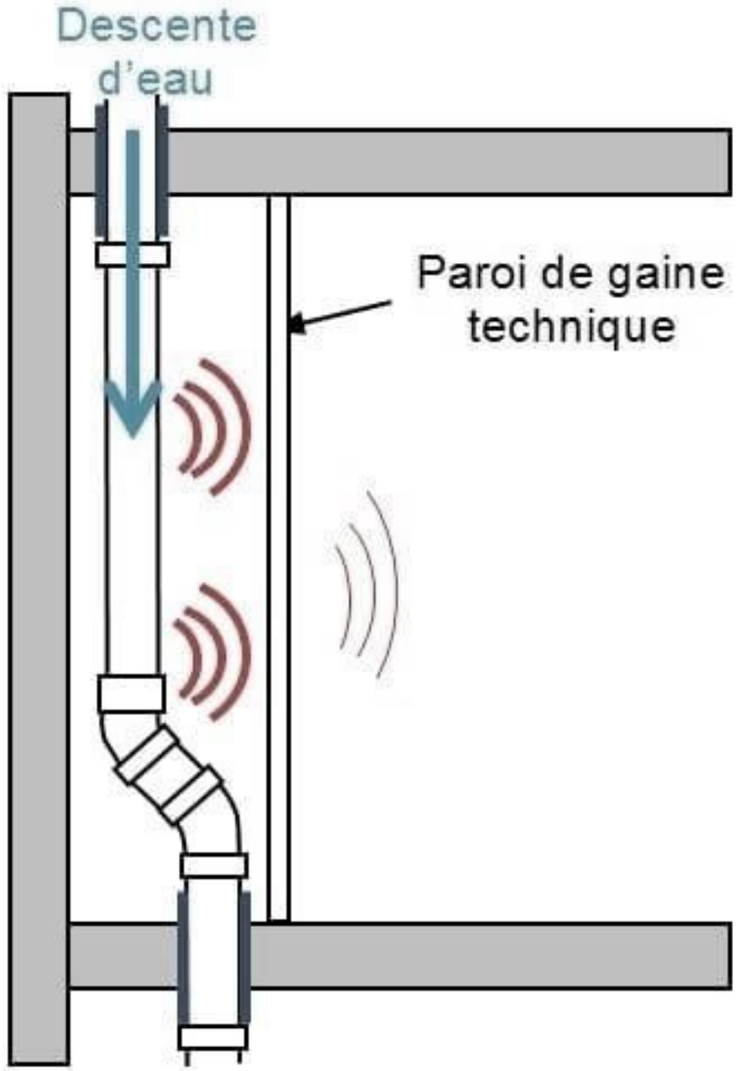
Impact Noise

Impact noise (or structure-borne noise) is transmitted through the vibration of walls and structures. These include footsteps, falling objects, and other physical impacts that cause vibrations to travel through solid materials.

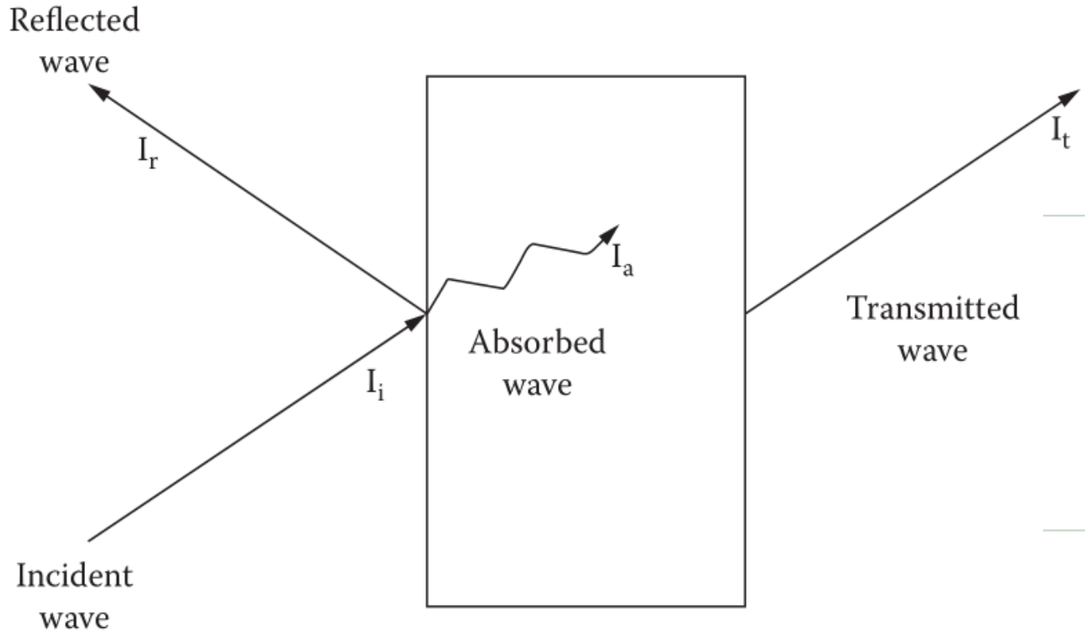
Sources of Noise

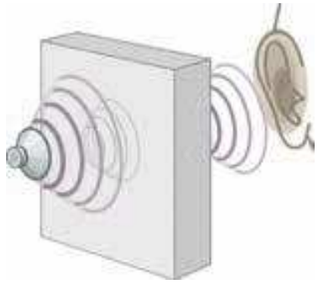
Equipment Noise

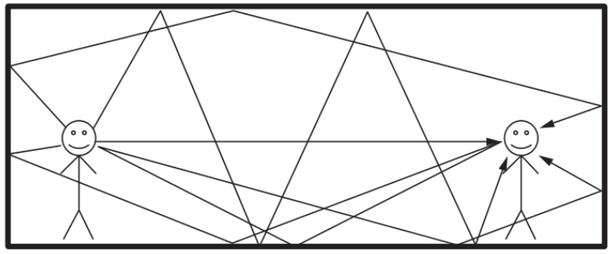
Equipment noise can be transmitted both through ambient air and through vibrations. This includes elevators, ventilation ducts, and hydraulic networks that create both airborne and structure-borne noise.



Acoustic Phenomena in Buildings







Transmission

Sound transmission through walls is governed by partial differential equations of plate deformation. The transmission coefficient (τ) is the ratio of transmitted to incident intensities.

Reflection

Most surfaces act as perfect mirrors for sound, potentially causing reverberation in interior spaces. Each reflection produces an "image source" whose acoustic pressure adds to the original.

Absorption

The absorption coefficient (α) represents the portion of sound energy not reflected by a surface. It ranges from 0 (perfect reflector) to 1 (perfect absorber) and varies with frequency.

Diffraction

Diffraction is a phenomenon where acoustic waves deviate when encountering an obstacle, allowing sound to bend around edges and corners.

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Merci pour votre Attention