

Energy characteristics



1. Acoustic impedance (Z)
2. Acoustic pressure (P)
3. Acoustic power (W)
4. Sound intensity (I)
5. Propagation of sound

Energy characteristics

1. Acoustic Impedance (Z)

- It characterizes the resistance of a medium to the propagation of sound

- Acoustic impedance, Z, is expressed in

$$\text{kg}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$$

Energy characteristics

1. Acoustic impedance (Z)

$$Z = \rho c$$

ρ : la masse volumique du matériau

c : la vitesse du son dans ce même matériau

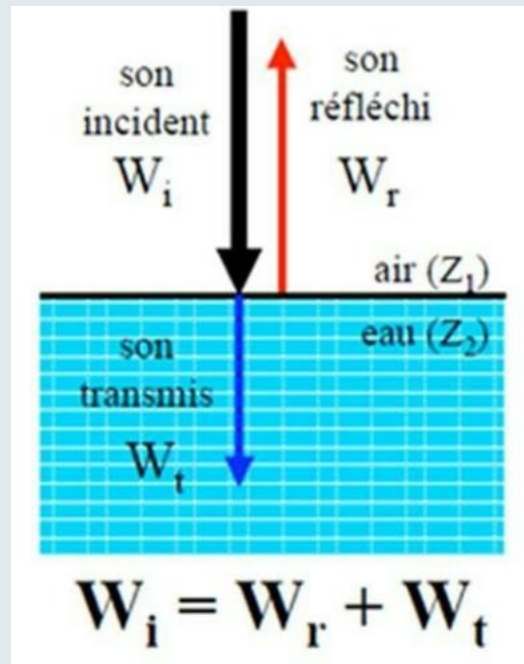
Energy characteristics

1. Acoustic impedance (Z)

Milieu	Masse Volumique ρ kg.m^{-3}	Célérité C m.s^{-1}	Impédance Z $\text{kg.m}^{-2}.\text{s}^{-2}$
Air	1,28	330	$4,25.10^2$
Poumons	788	330	$0,26.10^6$
Eau	1000	1480	$1,48.10^6$
Tissus mous	800-1000	1450-1700	$1,3-1,7.10^6$
Os	1400	3000-4000	$2,5-6,1.10^6$
Acier	7800	6100	47.10^6

Energy characteristics

5. Propagation of sound from one medium to another



$$R_n = \frac{W_r}{W_i} = \frac{(Z_2 - Z_1)^2}{(Z_1 + Z_2)^2}$$

pouvoir de réflexion

$$T_n = \frac{W_t}{W_i} = \frac{4 Z_1 Z_2}{(Z_1 + Z_2)^2}$$

pouvoir de transmission

Energy characteristics

● *Absorption*

In a homogeneous and unbounded medium, the sound energy from a source decreases as the inverse of the distance



Energy characteristics



- *Absorption*

But in reality, media are neither homogeneous nor unbounded. One must take into account sound absorption and its transformation into heat.

Energy characteristics

- *Absorption*

If there are obstacles or changes in the medium, new phenomena appear: reflection, refraction, and diffraction.

Energy characteristics

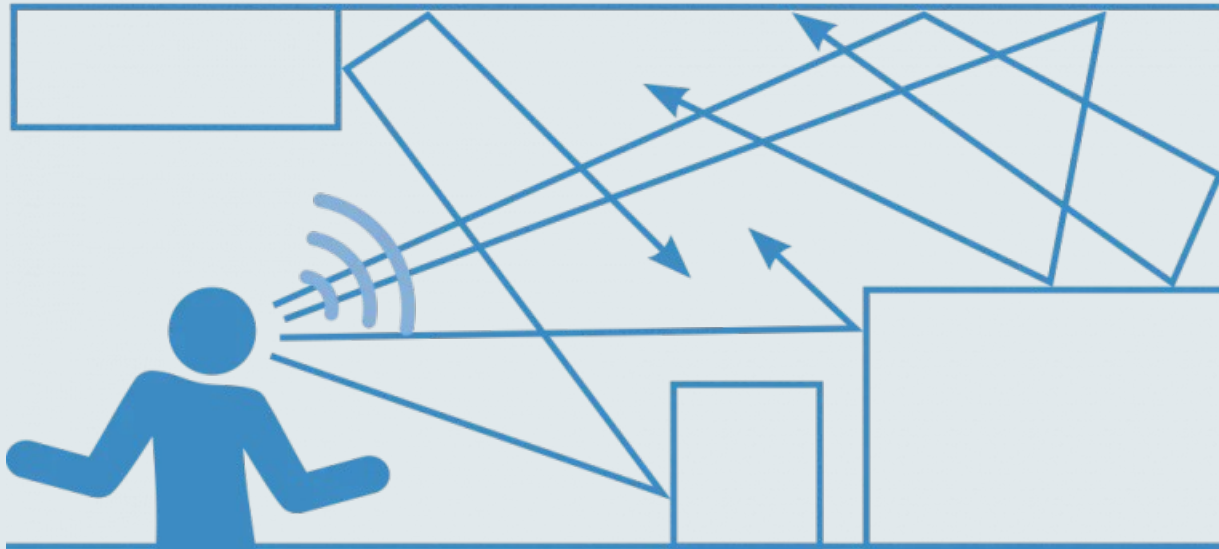
- *Reflection*

This is the well-known phenomenon of echo, which is perceptible when a short-duration sound is emitted in front of a sufficiently distant obstacle: after a certain time, a second sound is heard that appears to originate from a point symmetric to the sound source with respect to the obstacle. Reflections can be multiple and may present negative effects.

Energy characteristics

- *Reflection*

Controlling reverberation is a classic problem in architectural acoustics

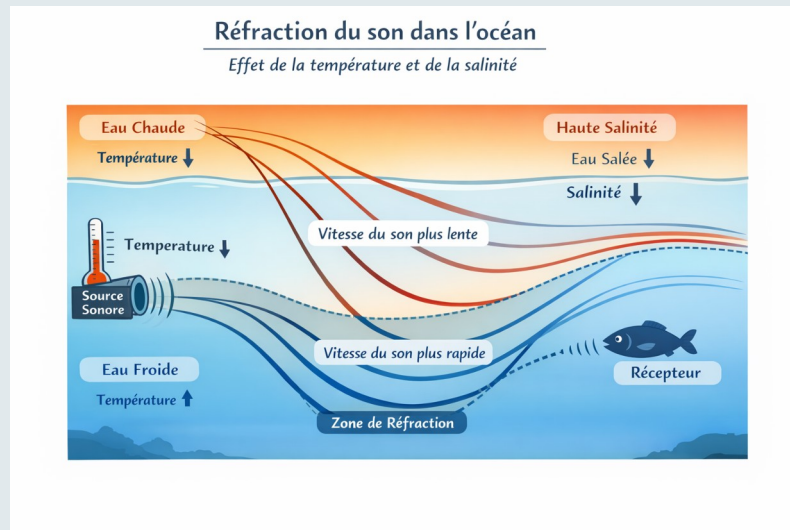


Energy characteristics

● Refraction

It is less obvious than reflection.

It occurs when there is a change of medium or during propagation in a non-homogeneous medium where a gradient of temperature or salinity exists.



Energy characteristics

- *Diffraction*

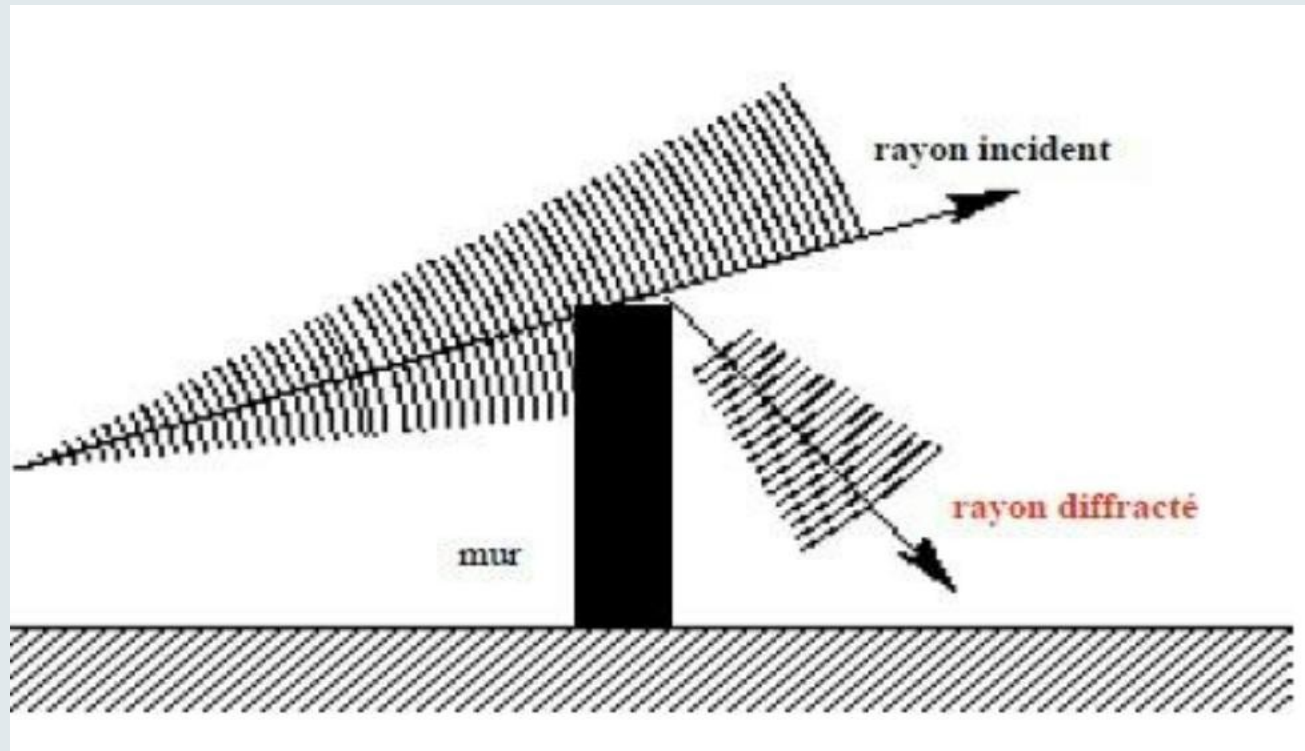
It is the behavior of waves when they encounter an obstacle. The obstacle causes part of the sound to be scattered.

Diffraction is significant when the size of the obstacle is very small relative to the wavelength.

Diffraction is important at low frequencies

Energy characteristics

- *Diffraction*



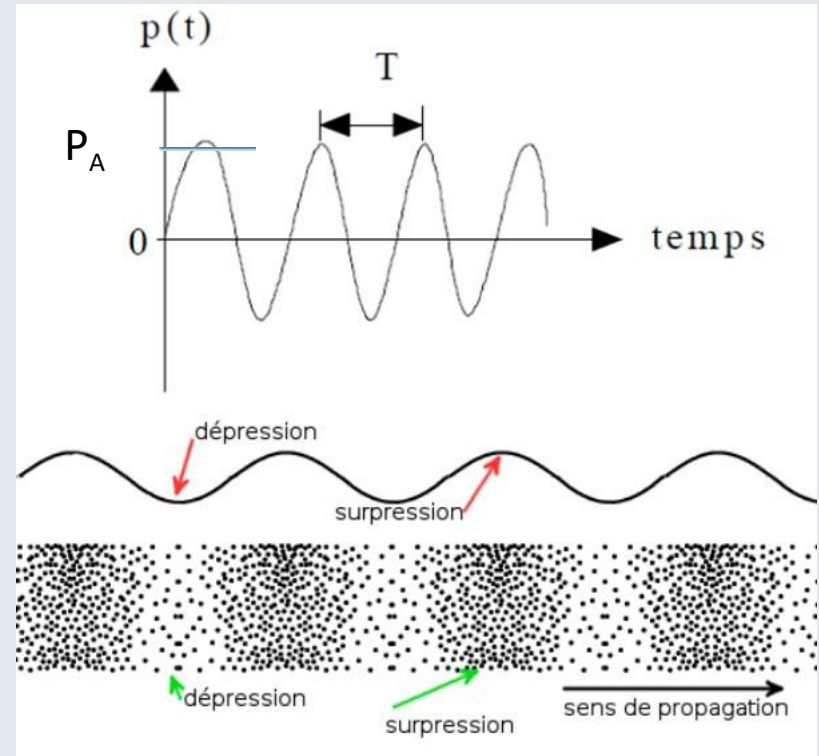
Energy characteristics

2. Acoustic pressure

$$P(t) = P_A \sin \omega t$$

- P_A : Maximum acoustic pressure
- ω : Angular frequency (or angular velocity) defined by

$$\omega = 2\pi f$$



Energy characteristics

2. Root mean square (RMS) acoustic pressure (P_{eff})

$$P_{\text{eff}} = \frac{1}{\sqrt{2}} P_A = 0,71 P_A$$

P_A : the maximum value of the pressure in Pa or N/m²

The acoustic pressure of an ordinary conversation ranges from 0.1 to 1 N/m² at a distance of 1 m from the mouth.

The weakest acoustic pressure perceptible by the human ear (the threshold of hearing) is 2×10^{-5} N/m², while the threshold of pain is reached at a pressure of 20 N/m².

Energy characteristics

3 Acoustic power (W)

- A sound wave corresponds to a transfer of energy.
- Acoustic power is the amount of energy per unit of time.

$$P = I \cdot S = \frac{p_{\text{eff}}^2}{\rho c} \cdot S$$

- Its unit is the Watt. (W)

Energy characteristics

4. Sound intensity (I)

It is the energy transported by the wave per unit of time and area; thus, it is the effective value of acoustic power per unit area.

$$I = \frac{P}{S} = \frac{p_{\text{eff}}^2}{\rho c}$$

- I = intensité sonore (W/m^2)
- P = puissance acoustique (W)
- S = surface de propagation (m^2)
- p_{eff} = pression acoustique efficace (Pa)
- ρ = masse volumique du milieu (kg/m^3)
- c = vitesse du son dans le milieu (m/s)

Example 1

- Deduce the percentage of energy transmitted when ultrasound passes from air into water.
- Given: $C_{\text{water}} = 1480 \text{ m/s}$, $\rho = 1000 \text{ kg/m}^3$

Example 2

An ultrasound wave propagates in water. The effective (RMS) acoustic pressure is:

$$p_{\text{rms}} = 2 \text{ Pa}$$

The properties of water are:

$$\rho = 1000 \text{ kg/m}^3, \quad c = 1480 \text{ m/s}$$

Questions:

1. Calculate the **acoustic intensity** I .
2. If the ultrasound beam has a cross-sectional area of $A = 1 \text{ cm}^2$, calculate the **acoustic power** P .