1. Émission et propagation du son

1.1. Emission d’un signal sonore

Objet qui vibre

1.2. Propagation d’un signal sonore

Milieu matériel et vitesse

1.3. Caractéristique d’un signal périodique

2. Perception d’un son

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2.4 Exposition sonore (risques)

Today we are going to present the sound. The sound is everywhere and everyone uses the sound. The sound is used to communicate between us. Music is sound. Animals use sound to communicate with each other but humans don’t always hear the sound of some animals like elephants or dolphins using infrasound. Everyone knows what sound is but we will try to get a closer look to know how a sound is emitted, how it spreads, how we perceive it and which risks it can engender.

1. Sound emission and propagation

1.1. Emission

First, to understand how a sound can be produced, we can take a look at a quite simple instrument: the tuning fork. When someone hits this object, it produces a sound. Now, if we put the tip of the tuning fork in water, it will splash around. This proves that the tuning fork is somehow moving. But this motion is really fast. To understand what is happening here, we can record the scene using a high speed camera. In slow motion, it becomes clear that the tips of the instrument are oscillating, they vibrate. In fact, this is a very common way to produce a sound and we will remember from now that a vibrating object emits a sound. It is true for the tuning fork but it is how we are able to play music: the strings of a violin or a cello are vibrating, cymbals and drums are nothing more than vibrating membranes. Even our vocal cords are vibrating when we talk or sing.

But it is not enough. To emit a sound we can hear, all these instruments require a sounding board. We can see it underneath the tuning fork or on this acoustic guitar for example. Thanks to this box, the sound emitted by the vibrating object will be much louder.

Now let's see how the sound reaches our ears.

1.2. Propagation

To be able to propagate, the sound must evolve in a material medium. Thus, when a sound is produced in the air, its vibration causes the vibrations of the air molecules and, step by step, the other air molecules will vibrate and will then allow the sound to be propagated.

As we can see on the picture, some air molecules are compressed and some are not. The compression will propagate step by step to our ears.

In the air, sound travels at a speed of 340 meters per second. This speed is not the same depending on the material in which the sound propagates. In fact, the denser the material, the faster the speed of sound propagation. For example, the speed of sound propagation in water is around 1500 meters per second.This propagation is accompanied by a variation in pressure and density which propagates step by step. Thus, the greater the acoustic overpressure, the higher the sound volume.

1.3 Periodic characteristics of a sound

Oftentimes, a sound is associated with a periodic signal: that is to say a signal with a pattern that repeats itself after a fixed length of time, over and over again. On these graphs we can see two signals associated with different vibrations. We can see the amplitude of vibration on the y-axis as a function of time shown on the x-axis. Careful, in these examples the vibrations are quite fast so the time is given in milliseconds. On the left, the signal is not periodic: there is no pattern that repeats itself. However, the signal on the right figure repeats itself with identical pattern: it is periodic.

One important property of this signal is the minimum length of time after which the signal repeats itself. It is called the period and we use the letter T to refer to its value. For example, the signal depicted on the right figure has a period T = 2 ms. In this case, it is the time between two following peaks.

We often prefer to talk about frequency but it is closely linked to the signal’s period. Indeed the frequency f is defined as the inverse of the period: to determine the frequency of a signal we simply need to calculate one over T. Be careful with the unit here: the period is expressed in seconds and the frequency’s unit is the herz (Hz). For example, as we said, here the period is 2 ms, that is to say .002 s. The frequency is 1 divided by .002 which gives 500 hertz. So the frequency of this signal is 500 Hz. So, enough with the calculus, we can just keep in mind that the shorter the period the higher the frequency. Rather, a signal with a long period will have a low frequency.

Let’s now talk about how we, humans, perceive sounds.

2.1 Frequency domain

The human ear perceives the sound from 20 hertz to 20,000 hertz. When the frequency is less than 20 Hz, we speak about infrasound : they are not audible but are perceived by the body.

When the frequency is higher than 20000 Hz, we speak about ultrasound: they are also inaudible for humans but perceived by animals. For example, bats use ultrasound to locate and characterize elements of their environment as well as their prey: this technique is called "echolocation". These animals rely on the time it takes for the ultrasound to return : this allows them to determine a distance and a size.

The greater the frequency of the sound, the higher the pitch, whereas the smaller the frequency of the sound, the lower the pitch.

2.2 Pitch and timbre

Earlier, we said that in physics, we characterize a periodic signal by its frequency. When we talk about sound, it is common to use the term pitch to refer to this property. The higher the pitch, the greater the frequency. Rather, the lower the pitch, the smaller the frequency. In this example, we can see the signals associated with two sounds with different pitches. In both cases, the scale of the x-axis is the same. The period of the blue signal is longer than the orange one, so the frequency of the blue is smaller and his pitch is lower. Practically, the blue signal could be associated with the sound “laaaaa”. The orange one would sound more like “laaaa”. That’s for the pitch, but there is more.

With some practice, we can recognize someone as he or she speaks. We are able to tell which instrument is playing simply by listening to it. This is because even if two sounds have the same pitch, they have a different timbre. That’s what we can see here : these two signals have the same frequency but different shapes: the patterns are not the same. That’s what’s happening when a piano and a guitar are playing the same note: the pitch is the same but they sound different because the timbre is not the same.

Sound can be amazing but it also can be dangerous.

2.3 Sound intensity level and risks of noise exposures

The decibel is used to quantify the sound level. 0db is the threshold of audibility, that is, we cannot hear a sound of less than 0dB. There is a scale on which we find the indications of auditory safety for a certain level of sound intensity. Indeed, we observe a first threshold called the "danger threshold" around 80dB. Beyond 80 db, there is a risk of hearing impairment if prolonged exposure to such sounds. By example, we may be exposed to this risk when we are listening to loud music for too long in our headphones.

There is also a threshold called the "pain threshold" at 120 dB. Even at low levels of noise, we put our hearing at serious risk of hearing loss. It is therefore very important to protect oneself from sounds. Personal protective equipment is therefore used by persons working under such sound conditions in order to preserve their hearing.

We can see some examples of noise levels in common life : a conversation is at 50db, clubs are at 110db and take off from an aircraft at 130db.

Conclusion

So today, we saw how a vibrating object can produce a sound and how this sound reaches our ears. We saw that sounds can have different pitches depending on their frequency and different timbre that makes music so enjoyable. And remember, lower the volume and protect your hearing when it becomes too noisy and sounds will amaze you all your life.