University of Al-Mustaqbal
College of Science
Department of Medical Physics

Name of material : Medical Physics II

Number stage : 3^{rd}

Lecture name :

Sound Waves

Lecture number : 4

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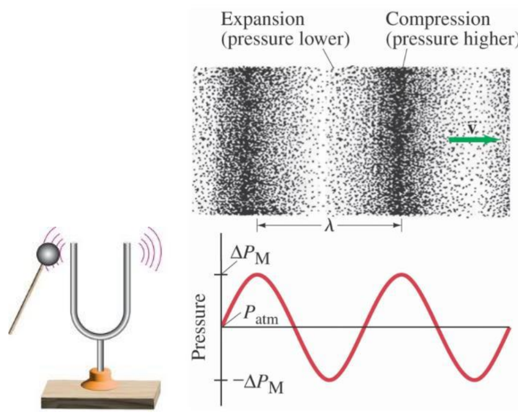
Properties of sound

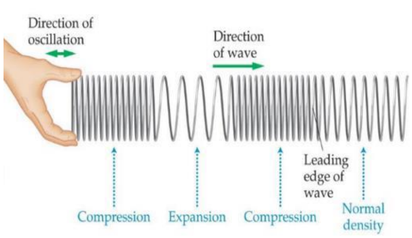
 A sound is a vibration that propagates through a medium in the form of a mechanical wave.

 Sound waves are longitudinal. Propagation of particle vibration is parallel to the direction of wave propagation.

 A sound wave is the pattern of disturbance caused by the energy traveling away from the source of the sound.



Propagation of sound wave



If you oscillate one end of a coiled spring back and forth, you will see a longitudinal wave moving away from you. Similarly, the figure below shows how a vibrating tuning fork produces sound waves oscillate back and forth. Just as spring, travels away from its source.

Compressions: (particles close together), the pressure is greater than the normal atmospheric pressure P_{atm} (positive pressure).

Rarefaction: (particles far apart), negative pressure the pressure is less than the normal atmospheric pressure P_{atm}.

The Frequency

The number of rarefactions and compressions that occur per unit time is known as the frequency of a sound wave. Mathematically, the frequency of a wave is denoted as follows:

$f = 1 / T$ Where f is the frequency and T is the time period.

The distance between the successive compression and rarefaction is known as the wavelength of a sound wave. The wavelength is mathematically represented as follows:

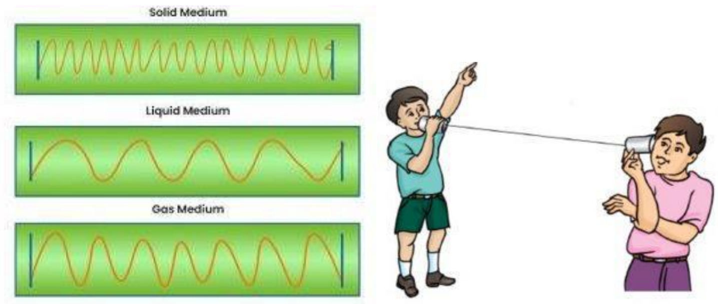
$\lambda = v_s / f$ Where v_s is the speed of sound

The Speed of Sound

The speed of sound depends on:

1. The medium (solid, liquid, or gas) through which it is moving, In general, the speed of sound depends on the "stiffness" of a material. That means the medium has been compressed and rarefied. Air is quite compressible and not very stiff, the speed of sound is relatively low in air compared to liquids and solids. Water is not very compressible, and the speed of sound in it is about 4 times greater than in air. Sound travels even faster in solids than in liquids.

$$v_{solid} > v_{liquid} > v_{gas}$$



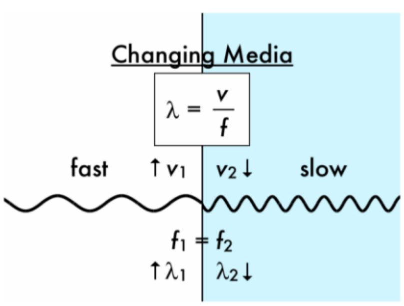
2. The temperature

As air is heated, the molecules move faster. As a result, the speed of sound also increases with temperature.

The speed of sound is the same in all directions of travel and for all frequencies. Thus, the speed v remains constant in the wave speed equation:

Speed = wavelength x frequency $\quad v_s = f\lambda$

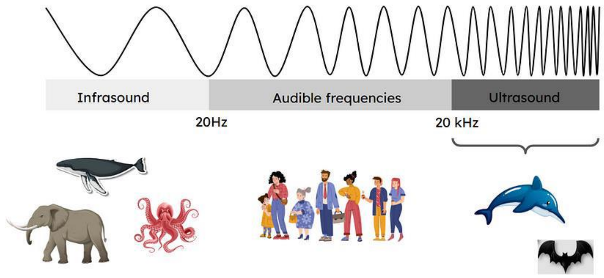
The fact that different frequencies travel with the same speed is evident when you listen to an orchestra in a large room. You hear the different frequencies produced by different instruments at the same time.



When sound pass from one medium to another: v_s and λ are change, while f stay the same.

Sonic Spectrum

Sonic spectrum can be classified (depending on the frequency of the wave) into three frequency ranges: **infrasound, audible sound and ultrasound**.



Humans can hear sounds between 20 Hz on the low-frequency end and 20,000 Hz on the high-frequency end are referred to audible sound. Sounds with a frequency of less than 20 Hz are referred to infrasonic or infrasound. Sounds with a frequency greater than 20,000 Hz are called ultrasonic or ultrasound.

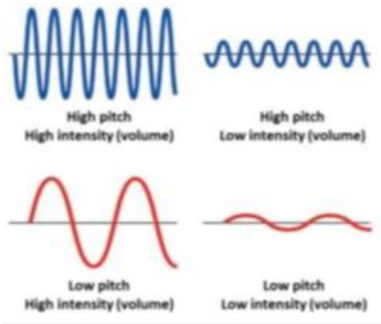
Infrasonic effect on human body

It can travel long distances without losing much power due to its low absorption and large wavelength and also, it can travel through most media, making its effects difficult to minimize.

- Intense infrasonic noise is observed to produce clear symptoms including: Respiratory impairment and aural pain and also, Fear, chills.

- Infrasonic may also be used in the study of heart mechanical function, revealed by the seism car diagram is the measure of the micro vibrations which are signals in the infrasonic range produced by the heart contraction and blood

ejection into the vascular).



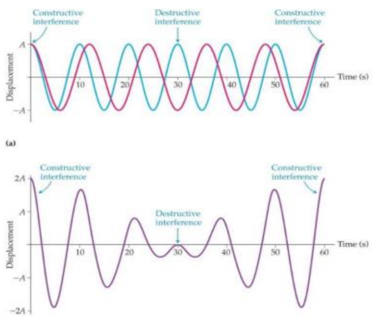
Some Properties of sound

The nature of sound: The human ear can distinguish two characteristics of sound. These are the **loudness** and **pitch**, and each refers to a sensation in the consciousness of the listener. **Loudness: (or volume)** is the degree of sensation of sound produced in the ear. It depends on its intensity. **Pitch:** refers to whether it is high (sharp), like the sound of a bird, or low, like the sound of a lion. It depends on its frequency.

If you pluck two guitar strings that have slightly different frequencies, you'll notice that the sound produced by the two strings changes in time. In fact, the loudness increases then decreases, increases then decreases, over and over. The changes in loudness produced by sounds of different frequency are referred to as **beats**.

- **The two waves interfere constructively, giving a large amplitude. The sound we *hear at this time is loud*.**

- **A short time later, the two waves interfere destructively, giving zero amplitude *and no sound*.**



A beat is its repeating pattern of loud and soft sounds. The frequency at which a beat repeats itself is known as the beat frequency. If one wave has the frequency f_1 and the other has a frequency f_2, the beat frequency is as follows:

$$f_{beat} = |f_1 - f_2|$$

Example, suppose two guitar strings have the frequencies 438 Hz and 442 Hz. what the beat frequency?

Sol: $f_{beat} = |f1 - f2| = |438 - 442| = 4$ Hz

The sound wave intensity:

The intensity of a sound wave *I* is the energy carried by the wave per unit area and per unit time (The sound intensity I in units of W/m^2). $I = E/At$

Power is energy per time, $P = E/t$, we can express the intensity as power per area:

$$I = P/A$$

The intensity can also be expressed as: $I = P^2/2Z$

Where: P: pressure, Z: acoustic impedance of the medium.

Acoustic impedance is total reaction of a medium to the transmission of sound through it, expressed as the ratio of sound pressure to particle velocity at a given point in the medium, $Z = \rho v_s$ where; ρ= density of the medium

The frequency of a sound wave determines its pitch. So what determines its intensity?

Solution :: The property of a sound wave that determines the intensity is the amplitude, the amplitude is the maximum difference in pressure between areas of compression and areas of expansion in the wave. The greater the difference in pressure, the louder the sound you hear.

Exercises

1- The velocity of sound in solids is --------------- its velocity in air

(a) Greater than (b) Lower than (c) Same as (d) half (e) None of them

2- The speed of sound equals;

(a) Intensity x frequency (b) Wavelength x Intensity (c) Wavelength x frequency

(d) Intensity x frequency (e) Power x Pressure

3- When sound travels from one medium to another, its --------------- remain constant

(a) Speed (b) Wavelength (c) Wavenumber (d) Frequency (e) None of them

4- -------------is the degree of sensation of sound produced in the ear

(a) Pitch (b) Loudness (c) Frequency (d) Wavelength (e) None of them

5- The property of a sound wave that determines the intensity is the-----------

(a) Energy (b) Area (c) Speed (d) Frequency (e) Amplitude