SOUND IN MEDICINE

Sound: is a mechanical wave produced by vibrating bodies.

	Infra sound	Audible sound	Ultrasound
Frequency	Sound frequency below the 20 Hz	Range is usually between 20Hz – 20 kHz	Frequency range above 20kHz (Ultrasonic imaging)

General properties of sound

- A sound wave is the pattern of disturbance caused by the energy traveling away from the source of the sound (waves transfer energy without transferring matter).

- Sound waves are longitudinal waves. This means that the propagation of particle vibration is parallel to the direction of the energy wave propagation.

- A sound is a vibration that propagates through a medium in the form of a mechanical wave. The medium in which it propagates can either be a solid, a liquid or a gas. Sound travels fastest in solids, relatively slower in liquids and slowest in gases.

- The **human ear** is sensitive to sound wave with frequencies between (***20Hz – 20 kHz***).
- Sound waves with frequencies below 20Hz are said to be infrasound, while those

with frequencies above 20 kHz are referred to as ultrasound. Rhinoceroses use infrasonic frequencies as low as 5 Hz to call one another. while bats use ultrasonic frequencies up to 100 kHz for locating their food sources and navigating.

- The most common sounds heard from common dolphins are tonal whistles (maximum frequency below 50 kHz) and high frequency echolocation (above 100 kHz).

● The relationship between **the frequency of vibration *f*** of the sound wave, **the wavelength λ**, and the velocity v of the sound wave is

***v*= λ *f*……. (1)**

The speed of sound depends on the medium the waves pass through:

In solid > in liquids > in gas

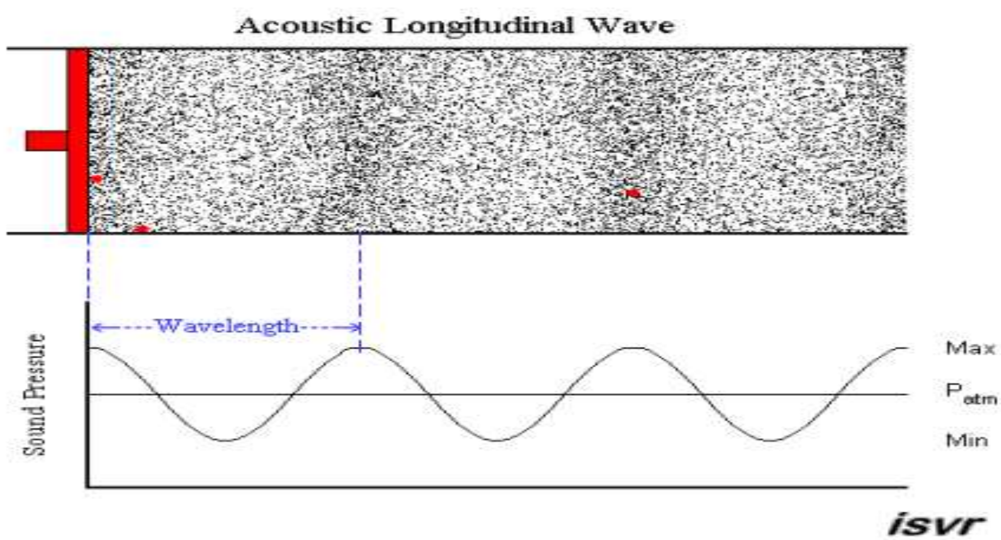
The Intensity of a Sound Wave

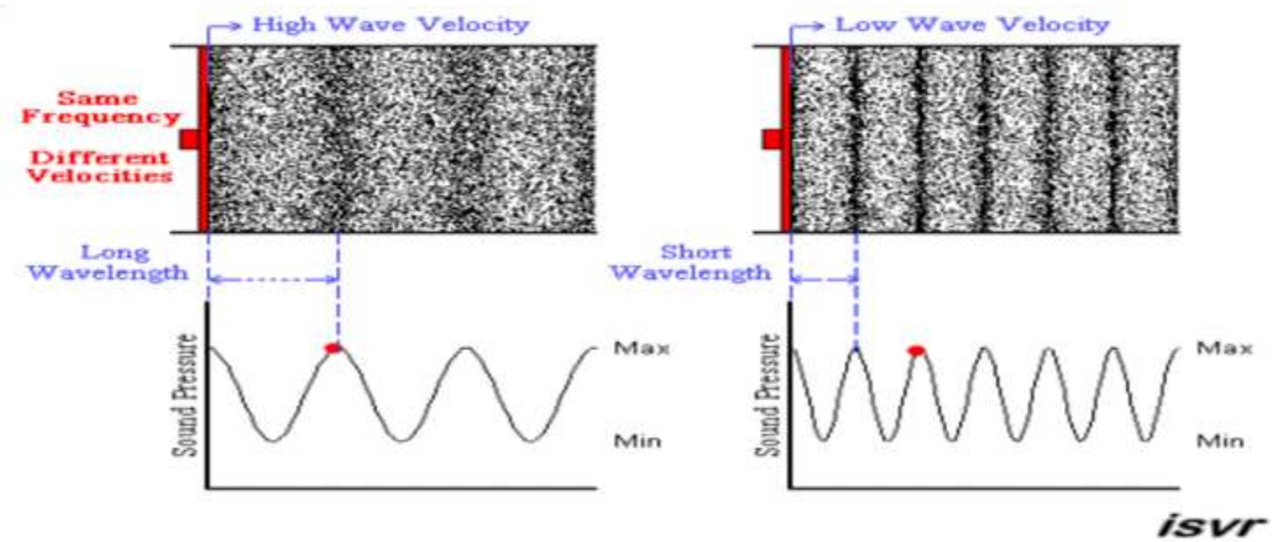
- The ***intensity* (I)** of the sound wave is the energy passing through 1 m2/ sec or watts per square meters, where I is measured in Bel or decibel (dB).
- The decibel: The common unit of sound pressure or intensity (dB).
- 1bel = 10 dB
- For hearing test, It is convenient to use a reference sound intensity (or sound pressure) to which other sound intensities can be compared.
- The reference sound intensity Io is 10^-16 w\cm^2.
- The most intense sound that ear can tolerate without pain is about 120 dB.
- Sound intensities above 160 dB can cause eardrum rapture.

● The ***intensity* (I)** of the sound wave is the energy passing through 1 m2/ sec or watts per square meters, where I is measured in Bel or decibel (dB),1 Bel = 10 dB. For hearing tests, it is convenient to use a reference sound intensity to which other sound intensities can be compared, the reference sound intensity I◦ is 10-16W/cm2. The most intense sound that the ear can tolerate without pain is 160dB, sound intensities above 160dB can cause eardrum rapture.

Propagation of sound wave

Let us consider air particles set in motion by a vibrating piston. We can see that the particles (the black dots in the animation; three of these have been colored red) move back and forth about their equilibrium position, thus creating alternating zones of **compression** and **rarefaction**. In the rarefied region (negative pressure),
the pressure is less than the normal atmospheric pressure, denoted Patm, and in the compressed region, the pressure is greater than the normal atmospheric pressure (positive pressure), as shown in the figure.





The Ultrasound

What is Ultrasound

- **Ultrasound is simply sound that has a very high frequency.**
- **Humans are not able to hear Ultrasound, though some animals can hear them.**
- **Sounds with frequencies above 20 kHz are called Ultrasounds.**

Ultrasound physical effects in tissues:

Hence, ultrasound waves differ from electromagnetic waves, they interact with tissues primarily by microscopic motion of the tissue's particles.
Ultrasound can be used to shatter gallstones or pulverize cancerous tissue in surgical procedures.
The sound waves that propagate into the liquid media result in alternating high-pressure **(compression)** and low-pressure **(rarefaction)** cycles, with rates depending on the frequency. The negative pressure in tissues during rarefaction can cause dissolved gas to come out from solution creating bubbles. The forming bubbles is called cavitation. When the bubbles attain a volume at which they can no longer absorb energy, they collaEpse violently during a high pressure cycle. This process release energy that can do both physical damage and chemical changes.

frequency of a sound wave: The number of rarefactions and compressions that occur per unit time, Mathematically, the frequency of a wave is denoted as follows:
f=1/T
Where f is the frequency of a sound wave and T is the time period

wavelength of a sound wave: The distance between the successive compression and rarefaction, the wavelength is mathematically represented as
follows
$\lambda = \boldsymbol{c / f}$

Example: find wavelength for a sound wave with a frequency of 1000Hz and velocity v=344 m/s in air at 200c?
$\lambda = v f$=344 m/s 1000Hz = 0.344m

Example: The velocity of sound in air is ***330 m/s***. Find the wavelength of sound waves if its frequency is ***10 K****Hz*.

v =330 ***m/s*** , f =10000Hz

$v = \lambda \times f$

330= λ ×1000

330/1000= λ

0.033= λ

so, the wavelength=0.033

Applications of audible sound in medicine (Stethoscope)

Stethoscopes A stethoscope is a medical device that is used, generally, by doctors, nurses and other medical professionals.
Modern stethoscope consists of, bell which closed by a thin diaphragm, tubing and earpieces.

Bell: The bell of a stethoscope is the cup shaped part at the end of the tubing, usually opposite to the diaphragm. Not all stethoscopes have a bell. The bell is used to listen to low pitched sounds.

Diaphragm: The diaphragm of a stethoscope is the flat part at the end of the tubing, with the thin plastic "drum-like" covering. The diaphragm is used to listen to high pitched sounds. Some stethoscopes have a diaphragm but no bell.

Tubing: The stethoscope tubing transmits sound from the bell or diaphragm to the earpieces. Some stethoscopes have single tubes, some have double tubes. Double tubes are more sensitive, but may rub against one another causing "squeaks" to be heard.

Earpieces: Earpieces (gasp!) fit into the ears. They should angle slightly forward for the best fit. Earpieces made of soft rubber are more comfortable and may prevent outside sounds from interfering with your listening.

What is the stethoscope for?

Stethoscopes are used to hear sounds generated from within the body.
They are used to listen to the heart, lungs and intestinal tract. They are also used for measuring blood pressure.

Types of Ultrasound

1. A-Mode (1D)

It is used to obtain diagnostic information about the depth of structure (image with 1-dimention).
In this mode an US waves send into the body and measure the time required to receive the reflected sound (echoes) from the interface between the different tissues. In A-mode the transducer is held stationary without movement. A-mode is used to detect the brain tumors and eye diseases.

2. B-Mode (2D)

It is used to obtain 2D images of the body. The principle is the same as in A-mode except that transducer is moving. A storage oscilloscope is usually used to form the image.
B-mode is providing information about the internal structure of the body, such as size, location and change with time of the eye, liver, breast, heart, and fetus.

3. M-Mode (2D +motion)

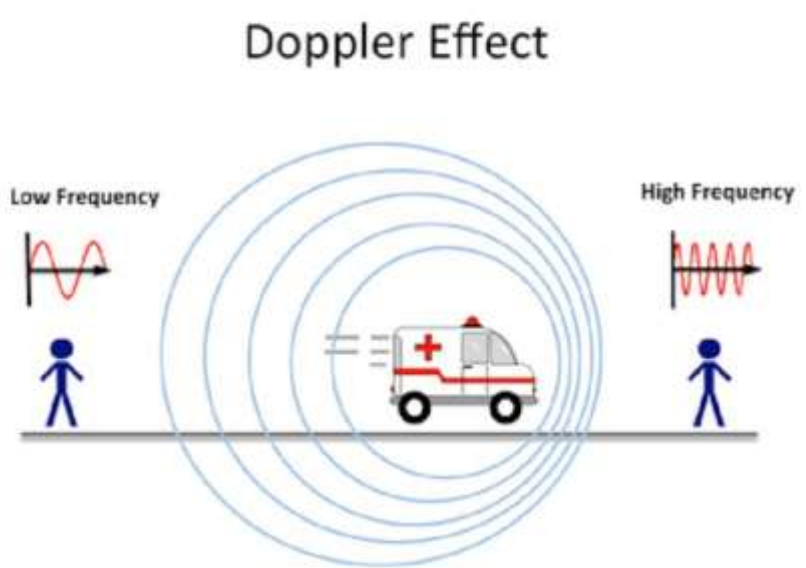
It is used to study motion such as that of heart and heart valves (image with 2D + motion). M-mode combines between features of A- and B-mode. The transducer is held stationary as in A-mode and the echoes appear as dots as in B-mode. It is used in diagnostic information about the heart (mitral valve) and detection of pericardial

4. Doppler Effect (4D)

The Doppler Effect is the perceived frequency of sound emitted by a moving source. The doppler technique is used for:

a. Study the blood motion in the circulatory system.

b. The doppler technique is also used to locate the point of the entry of the umbilical cord into the placenta to detect if there is bleeding due to misplaced placenta or if there is an intrauterine transfusion for Rh incompatibility



Physiological effects of ultrasound in therapy

Various physical and chemical effects occur when ultrasonic waves pass through the body, and they can cause physiological effects.

The magnitude of physiological effects depends on the frequency and amplitude of sound.:

1. **Low intensity US (~ 0.01 W/cm2)** → no harmful effects are observed → used for diagnostic work (as in the sonar).

2. **Continues US (~1 W/cm2)** → deep heating effect (diathermy) → temperature raise due to the absorption of acoustic energy in the tissue →.

3. **Continues US (1-10 W/cm2)** → sound moves through tissues → region of compression and rarefactions → pressure differences in adjacent regions of tissues (micromassage).

4. **Continues US (~ 35 W/cm2)** → tissue destroying effect. 35 W/cm2 → 10 atm over a very short distance → molecules cannot disperse the energy to its surrounding by vibration → breakage of chemical bonds → rupture DNA molecules.

5. **Continues and focused US** (~ 103 W/cm2) → selective destroying of deep tissue using a focused ultrasound beam.