**Sound in Medicine**

A sound wave (or pressure or compression wave) results when a surface (layer of molecules) moves back and forth in a medium producing a sequence of compressions “C” and rarefactions “R”. Although individual molecules do not travel any appreciable distance, the disturbance travels outwards. The **compression** is a region where the molecules of the medium are very close to each other and the **pressure** is **higher** than normal pressure.

The **rarefaction** is a region where the molecules are farther away from each other and the **pressure** is **lower** than the normal pressure.





Sound propagates in the form of **longitudinal waves** through a medium. In such a wave, the particles of the disturbed medium move **parallel** to the wave velocity. The sound waves have the following categories:

i. **Audible** sound has a frequency from 20 Hz to 20,000 Hz.

ii. **Infrasonic** are the frequencies lower than 20 Hz.

Its produced by natural phenomena like earth quake waves and atmospheric pressure changes.

iii. **ultrasonic** are frequencies higher than 20,000 Hz

***General Properties of Sound***

1. They can travel through solids, liquids or gasses, but not vacuum.
2. The speed of sound is a constant for a given material at a given pressure and temperature. For example, the speed of sound in air, *v o* , at 1 atmospheric pressure and 0 oC is equal to 331 m/s.
3. Speed of sound in air ( *air v* ) < speed of sound in liquid ( *liquid v* ) < speed of sound in solid ( *solid v* ). This is mainly related to the intermolecular spaces in a substances.
4. When sound goes from low dense medium (e.g. air) into a higher dense medium (e.g. liquid) the frequency stays unchanged, the velocity

increases, and thus the wavelength must increases, recall the relation

*v* = *f*λ .

5. Speed of sound increases with increasing the temperature. Recall the

empirical formulae:

vt=v0+0.6T T is in 0C

**H.W1.** Calculate the speed of sound at 27 oC

1. Speed of sound in different media is expressed as:

is the Young's modulus, N/m2 =Pa,

B is the Bulk's modulus, = N /m2=Pa,

* The intensity I of a sound wave is the energy passing through lm2/sec or watts per square meter. The intensity can be expressed as:

I=P2/2Z

Where P is the maximum change, in pressure. Z is the acoustic impedance (Z=ρv where; ρ is the medium density and v is the velocity of sound in it)

* **Sound level:** (β), [β] = dB ≡ Decibel), is defined by:

Where I0 = 10-12 w/m2 is the lowest audible sound (the threshold of hearing).

**H.W.2**

1. Find the ratio of the intensities of two sound waves if the difference in

their sound levels is 7 dB.

1. If you loudest shout is 1000 times more intense than your normal speaking voice ,what is the dB difference between them?

* The most intense sound that the ear can tolerate without pain is about 120dB:.
* When a sound wave hits the body, part of the wave is reflected and part is transmitted into the body. The ratio of the reflected pressure amplitude R to the incident pressure amplitude A0 depends on the acoustic impedances of the two media Z1 and Z2. The relationship is:

**R/A0=(Z2-Z1)/(Z2+Z1)**

* The ratio of the transmitted pressure amplitude T to the incident wave amplitude A0is:

T/A0=2Z2/(Z2+Z1)

H.W.3 calculate the ratios of the pressure amplitudes and the intensities of the reflected and transmitted sound waves from air to muscle. Z1 of air = 430 kg /m2.sec, Z2 of muscle =1.64 ×106 kg /m2.sec.

* When a sound wave passes through tissue, there is some loss of energy due to frictional effects. The absorption of energy in the tissue causes a reduction in the amplitude of the sound wave. The amplitude A at a depth x cm in a medium is related to the initial amplitude Ao by the exponential equation.

A=A0e-αx

Where α (in cm-1) is the absorption coefficient for the medium at a particular frequency.

* Since the intensity is proportional to the square of the amplitude, its dependence with depth is:

I=I0e-2αx

Where I0 is the incident intensity and I is the intensity at a depth x in the absorber. Since the absorption coefficient is 2α, the intensity decrease more rapidly than the amplitude with depth.

* The half-value thickness (HVT) is the tissue thickness needed to decrease **I** to **I0/2**.

Stethoscope

* It is a simple hearing aid permits physician or nurse to listen to sound made inside the body primarily in the heart and lungs.
* Auscultation: is the act of listening to those sound with stethoscope.
* The main parts of modern stethoscope are bell, which is either open or closed by a thin diaphragm, the tubing, and the earpieces.

Ultrasound generation

There are several methods of generating ultrasound, the most important for medical applications involves the piezoelectric effect. Many crystal can be cut so that an oscillating voltages across the crystal will produce a similar vibration of the crystal, thus generating a sound wave. The thinner the crystal, the higher the frequency at which it will oscillate. A device that converts electrical energy to mechanical energy or vice versa is called a transducer. Each transducer has a natural resonant frequency of vibration.

Ultrasound pictures of the body

* Typical frequencies for medical work are in the 1 to 5 MHz range. An average power level for diagnostic applications is a few milliwatts per square centimeter.
* Pulses of ultrasound are transmitted into the body by placing the vibrating crystal in close contact with the skin, using water or jelly paste to eliminate the air. This gives good coupling at the skin and greatly increases the transmission of the ultrasound into the body and of the reflected echoes back to the detector. Usually the same transducer that produce the pulse serves as the detector. The return signals are then amplified and displayed on an oscilloscope.

***A Scan***

To obtain diagnostic information about the depth of structures in the body, we send pulses of ultrasound into the body and measure the time required to receive the reflected sound from the various surfaces in it. This procedure is called the A scan method. The detected echo is converted to an electrical signal and is displayed as the vertical deflection on the cathode ray tube of an oscilloscope. The time required for the pulse to travel from the transducer to the far side and return to the transducer is indicated on the horizontal scale of the oscilloscope. This time can easily be converted to distance by knowing the velocity of sound to calibrate the scale.

Applications of A scan

1. Echoencephalography : used in the detection of brain tumors. ,
2. In ophthalmology : can be divided into two areas :
   1. One is concerned with obtaining information for use in the diagnosis of eye diseases.
   2. The second involves biometry or measurements of distances in the eye.

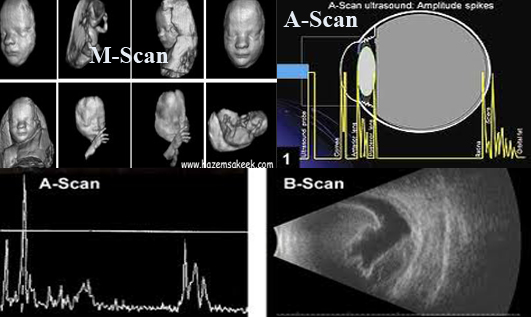
B Scan

The B scan method is used to obtain two dimensional views of parts of the body. The principles are the same as for the A scan except that the transducer is moved. As a result each echo produces a dot on the oscilloscope at a position corresponding to the location of the reflecting surface. The gray-scale display electronically changes the brightness on the oscilloscope so that large echoes appear brighter than weak echoes. B scans have been used in diagnostic studies of the eye, liver, breast, heart, and fetus.

M Scan

The M scan combines certain features of the A scan and the B scan. The transducer is held stationary as in the A scan and the echoes appear as dots as in the B scan. In M scan the oscilloscope trace is made to move vertically as a function of time displaying the motion of the interface.

M scans are used to obtain diagnostic information about the heart. Several heart conditions can be diagnosed with M scans such as mitral valves abnormalities and pericardial effusion.



Doppler Effect

The source of sound of frequency f0 has a higher pitch when it is moving toward a listener and a lower pitch when it is moving away from him. It also has a higher pitch when the listener is moving toward the source than when he is moving away from it. The frequency change is called the Doppler shift.

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When a continuous ultrasound beam is received by some red blood cell in an artery moving away from the source, the blood hears a slightly lower frequency than the original frequency f0. The blood sends back echoes of the sound it hears, but since it is now a source of sound moving away from the detector, there is another shift to a still lower frequency. The detector receive a signal that has undergone a double Doppler shift. When the blood is moving at an angle θ from the direction of the sound waves, the frequency change fd is:

fd=2f0Vbloodcos θ/vsound

Where:

**f0** is the frequency of the initial ultrasonic wave.

**V**bloodc is the velocity of the blood, vsound is the velocity of sound.

**θ** is the angle between Vs and vb

The Doppler effect is also used to detect motion of the fetal heart, umbilical Cord and placenta.