Humans

The upper frequency limit in humans (approximately 20 kHz) is due to limitations of the middle ear, children can hear some high-pitched sounds that older adults cannot hear, because in humans the upper limit pitch of hearing tends to decrease with age. Auditory sensation can occur if high-intensity ultrasound is fed directly into the human skull and reaches the cochlea through bone conduction, without passing through the middle ear.

What is the Ultrasound

- Humans can hear sound in the frequency range between 20 to 20,000 Hz (20 KHz).
- Sound is a mechanical, longitudinal pressure wave that travels through a medium such as air, water or metal.

What is the average speed of ultrasound waves in human tissue?

1540 m/s

What is the average speed of ultrasound waves in outer space?

Outer space has no medium for sound to travel through; it is a vacuum therefore: 0 m/s

Properties of ultrasound

Ultrasound is unlike light, X-rays and gamma rays. The sound requires a material medium for travelling. It can be reflected, refracted and focused, The velocity of ultrasound depends on the material it passes through. The denser material has lower velocity (i.e. the material with greater compressibility or smaller elastic modulus has lower velocity). Accordingly, velocity depends on the temperature.

Note that sound takes nearly (7 micro-second to travel each centimeter in average soft tissue. The table (1) lists the product of velocity and density, called the acoustic impedance .Air has a much lower density, but it is much more compressible than water or tissue, hence the low velocity. Because the frequency of a given transducer is fixed, wavelength is proportional to velocity. If a transducer is energized at a frequency of 3.5 MHz, the wavelength of the ultrasound changes as it travels from the transducer (1 mm) through soft tissue (0.4 mm) to bone (0.9 mm).

The intensity of ultrasound, measured in watts per square millimeter (W mm^{-2}), is proportional to the square of the wave amplitude and is under the operator's control.

Piezoelectric Effect

1- Piezoelectricity is the ability of certain materials to generate an electric potential in response to applied mechanical stress.

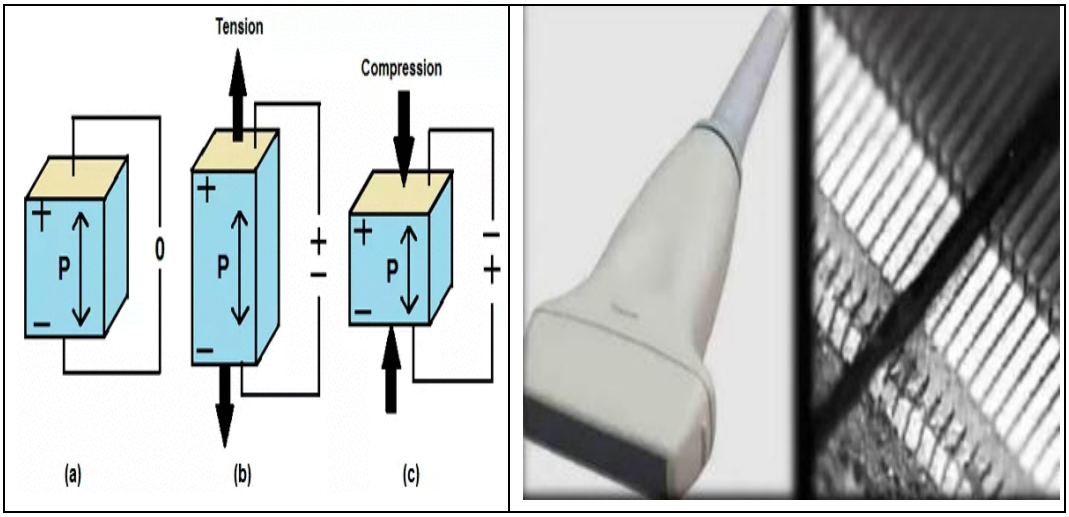
2- The word is derived from the Greek piezo or piezein, which means to squeeze or press.

3-The Curie brother discovered piezoelectricity on quartz crystals. This material is still in use today for precise and resonator applications. Quartz is a naturally occurring single-crystal material.

4-In 1954 the discovery of Lead Zirconate Titanate (PZT) ceramics led to a family of synthetic materials suitable for many applications. These materials are the most popular choice for ultrasound imaging transducers and arrays.

- Basically the ultrasound system is composed of a computer and a probe. The probe which is the essential part of the system contains piezoelectric crystals located on its anterior surface. The main property of these crystals is that they will have changes in shape and volume when they are exposed to electric

(produce mechanical vibrations with frequencies above 20 KHz).



What is the Piezoelectric Effect?

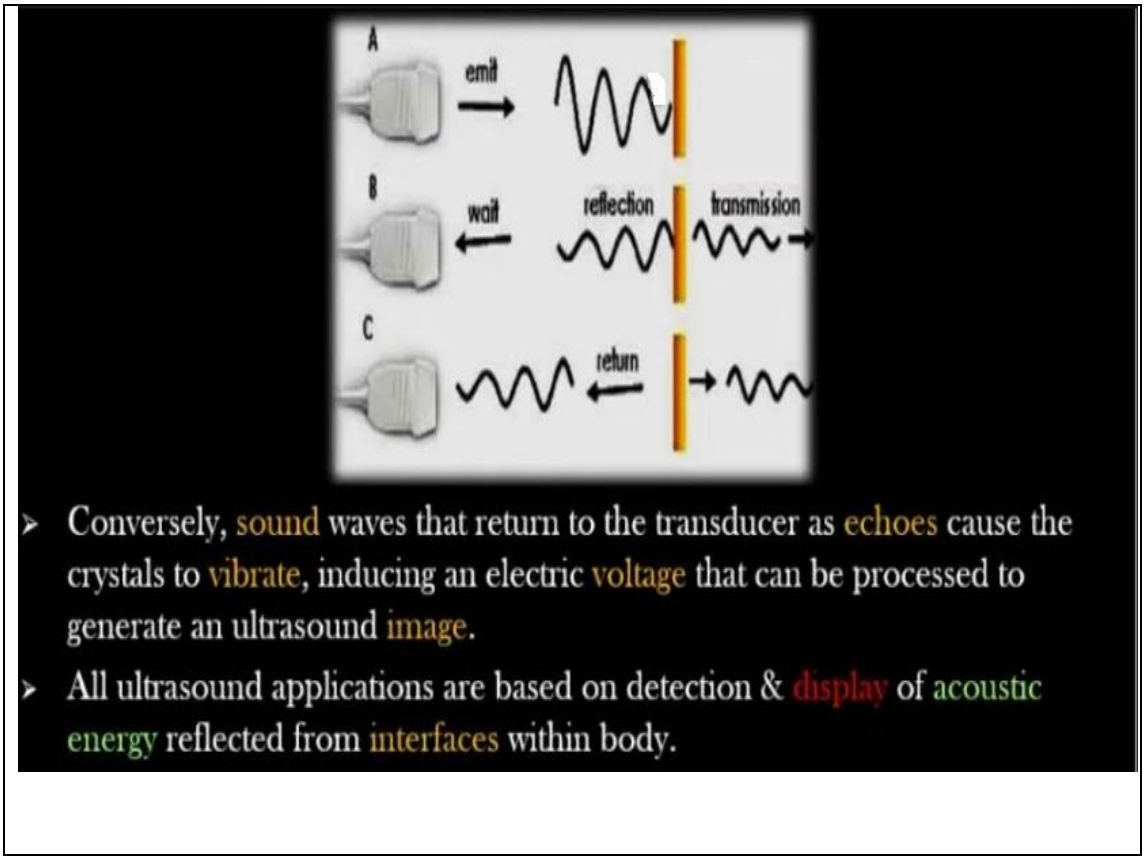
Is the most important property of a piezoelectric material its can convert electric energy to acoustic energy and vice versa

Behavior of a beam at an interface between different materials

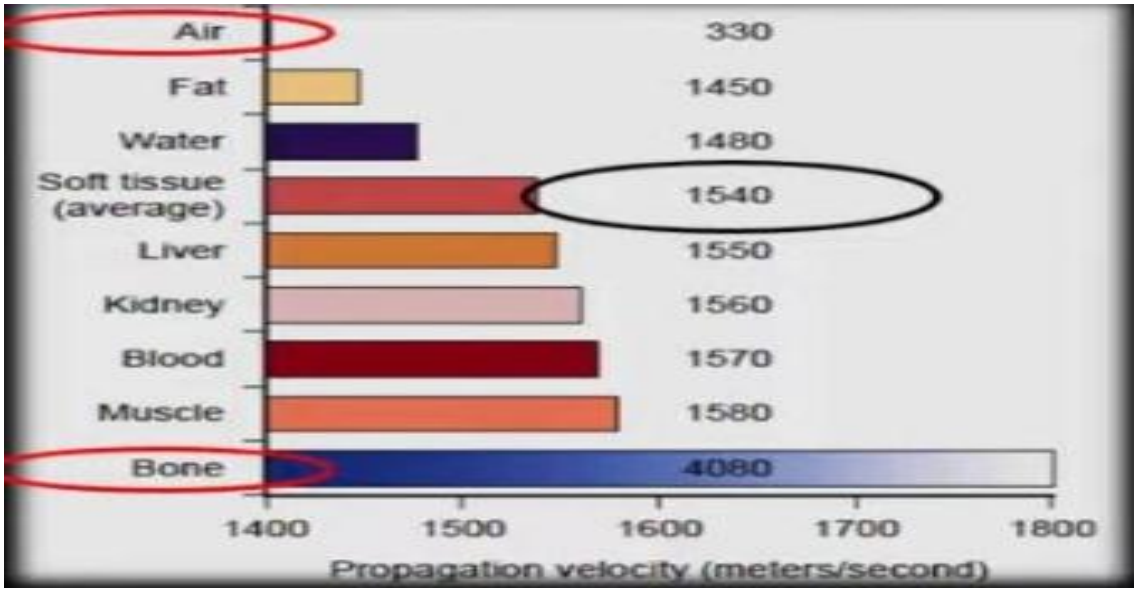
If abeam strikes the boundary between two materials (transducer-skin, tissue, bone, tissue-air, etc.) at right angle, some of energy is reflected as in (echo) and some is transmitted.

The sound waves has several interactions when transmitted through organs of living tissues. It well known that the speed of sound is about 330m/s in air at

20◦C. the speed of sound increases with the decrease in density of medium through it passes.

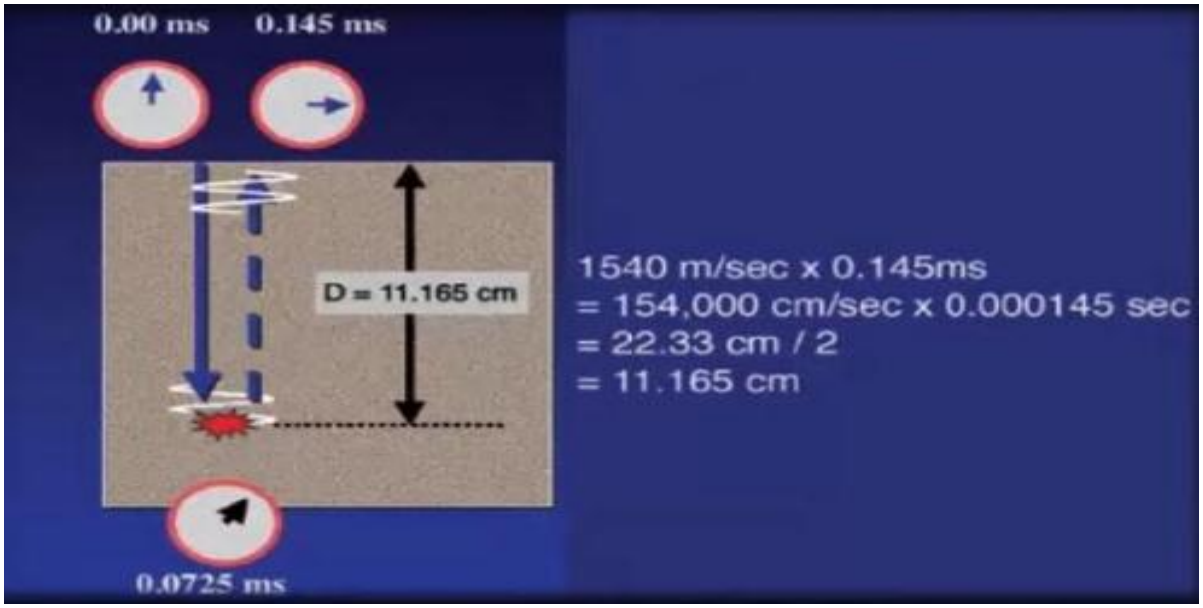


Propagation of Ultrasound



- Ultrasound wave moves through in tissues & fluid by certain speed.
- Propagation velocity is constant for a given tissue (influenced by its density) & is not affected by frequency or wavelength of ultrasound.

Distance Measurement:



- If an ultrasound pulse is transmitted into the body and time until echo returns is measured, it is simple to calculate the depth of the interface that generated the echo, provided the propagation velocity of sound for the tissue is known.

- Average propagation velocity of sound in the body is 1540 m/s.
- When ultrasound travels within tissues with propagation values significantly different from the average value, this leads to measurement errors (artifacts).