Ministry of Higher Education and Scientific Research
Al-Mustaqbal University College
Radiology Techniques Department

Radiology Equipment Techniques

Al-Mustaqbal University College

2nd Class

Radiology Techniques Department

By

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MS.C. Theoretical Physics

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lecture 10: Ultrasound Imaging Physics

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Basic Acoustics

- Early, primitive display modes, such as A-mode and static B-mode, borrowed from metallurgical testing and radar technologies of the time, have given way to high-performance, real-time imaging.
- Modern ultrasound systems are able to make detailed measurements of blood movements in blood vessels and tissues, visualize moving structures in 3D, and make measurements related to the stiffness of tissues.
- Organ boundaries & complex tissues produce echoes(reflection or scattering) that return back to transducer after 'depth-dependent' time delays

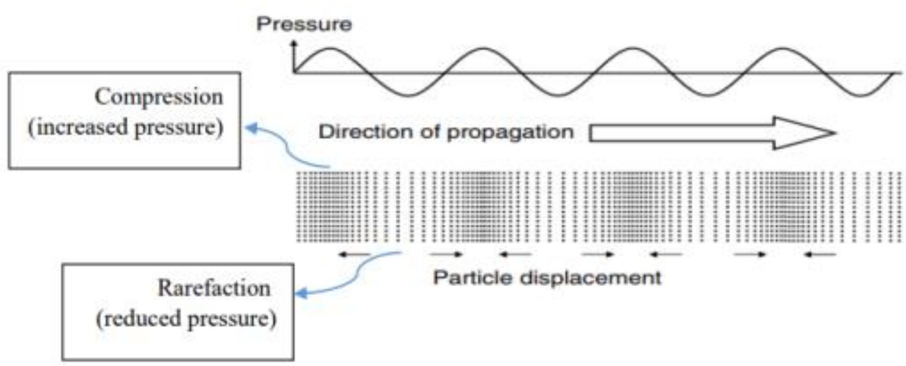
<u>The major advantages of ultrasound diagnostic methods over alternative procedures are its attributes of :</u>

1. No Radiation exposure, non-Invasiveness
2. Lack of any known side effects, either immediate or long-term ,
3. No associated discomfort to the patient
4. Fast(real-time)
5. Measure velocity of moving objects, e.g. blood flow (Doppler imaging)
6. Relative cheapness.
7. Safe in pregnancy
8. Portable

E.M Vs. US

Sound Waves (vibrations)	X-Ray
Mechanical wave	Electromagnetic radiation
longitudinal waves	Transverse waves
These vibrations, back and forth, occur along the line of travel of the sound wave	Electric and magnetic component perpendicular to each other
The speed of sound varies depending on the medium it is propagating through	Velocity is constant (the velocity of light 3×10^8 m/s

- Sound is the result of mechanical energy traveling through matter as a wave producing alternating compression and rarefaction.



The number of complete cycles in a unit of time is **the frequency**

Unit of frequency

Cycles per second = Hertz

1 Hz = 1 cycle/second

The wavelength (λ) of a wave is the distance between consecutive wave crests or other similar points on the wave, as illustrated, and the time (T) to complete a single cycle is called the **period.**

$$\lambda = c / \upsilon$$

$$\upsilon = 1/ T$$

Example: Calculate the wave length for 2 MHZ ultrasound beam in soft tissue assume the speed of sound is 1540 m/s

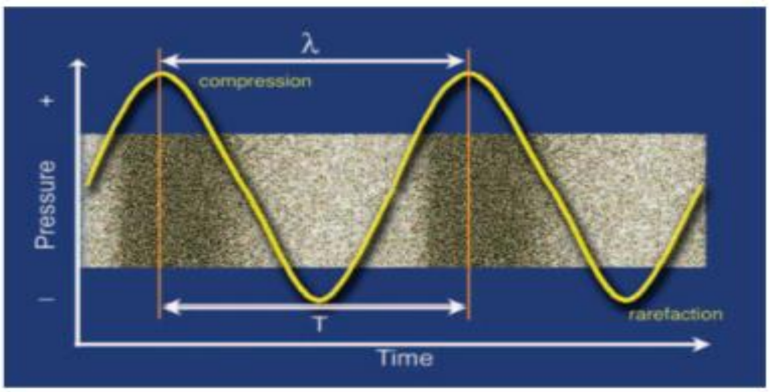
Answer:

$$\lambda = 1540 / 2 * 10^6$$

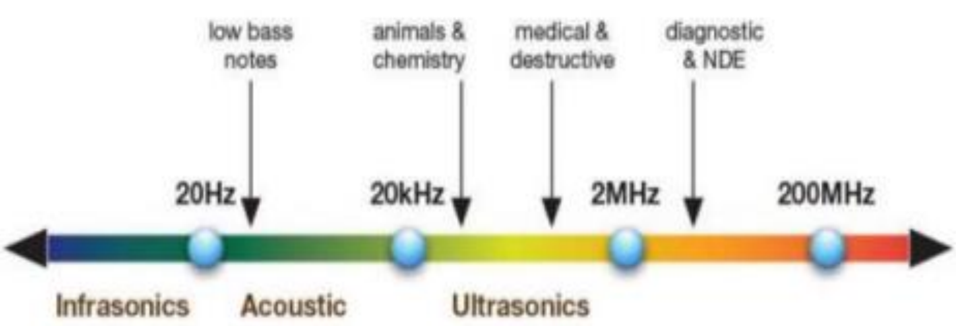
$$= 0.00077 \text{ m}$$

$$=0.77 \text{ mm}$$

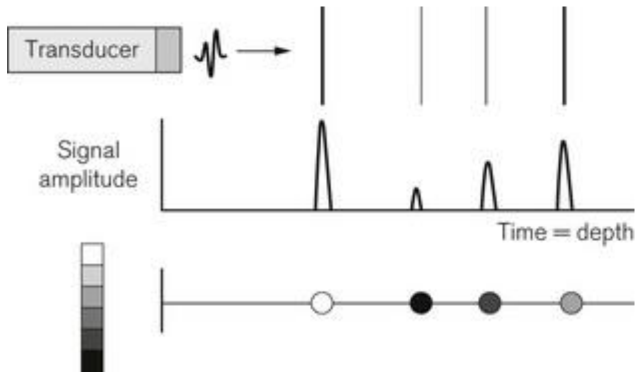
(H.W) If the frequency of a vibrating particle is 400 hertz, and the speed of sound in air is 320 m/s. Find the distance traveled by the sound produced by the particle's vibration when the particle has completed only 30 vibrations?



- Humans can hear sound waves with frequencies between 20 Hz and 20 KHz
- Ultrasound: > 20 KHz
- Diagnostic medical ultrasound typically uses transducers with a frequency



Pulse-Echo Ultrasound



Speed of sound

The speed of sound is the speed a sound wave travels or propagates in a medium along a specified direction.

$$C = \frac{1}{\sqrt{\rho\, K}}$$

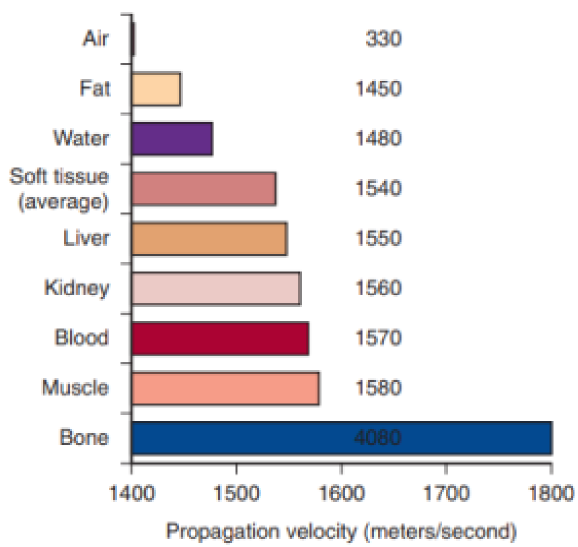
The material properties which determine the speed of sound are density and stiffness

Density is a measure of the weight of a material for a given volume

Stiffness (compressibility) is a measure of how well a material resists being deformed when it is squeezed.

The propagation velocity of sound (c) is related to frequency and wavelength by the following simple equation:

$$c = \upsilon\, \lambda$$



Acoustic Impedance

Acoustic impedance is the opposition of a tissue to the passage of ultrasound waves.

$$Z = \rho c$$

Acoustic impedance Z has units of $kg.m^{-2}\ s^{-1}$, but the term rayl (after Lord Rayleigh) is often used to express this unit.

The amount of reflection or backscatter is determined by the difference in the acoustic impedances of the materials forming the interface

- Determines the amplitude of the reflected / transmitted waves at interface.
- Complex scattering properties of tissues are due to acoustic impedance interfaces in microstructure of tissues.

Table: Values of acoustic impedance.

Material	$z\ (kg\ m^{-2}\ s^{-1})$
Liver	1.66×10^6
Kidney	1.64×10^6
Blood	1.67×10^6
Fat	1.33×10^6
Water	1.48×10^6
Air	430
Bone	6.47×10^6

For example, ultrasound beams are reflected strongly at air–tissue and air–water interfaces because the impedance of air is much less than that of tissue or water