INTRODUCTION TO ULTRASOUND & ECHOCARDIOGRAPHY

ECE 331 – INTRODUCTION TO BIOMEDICAL ENGINEERING

Monday, September 28, 2026

RECAP: PHYSICS OF ULTRASOUND

Common features:

- Transmit Energy
- Do not transmit matter

MECHANICAL WAVES

Medium: Requires Media to travel

Examples: Sound, Water waves, Seismic waves, Waves on ropes.

Mode of Travel: Longitudinal, Transverse or compression

ELECTROMAGNETIC WAVES

Medium: Can travel in vacuum.

Examples: Light, Radio waves, X-rays

Mode of Travel: Transverse



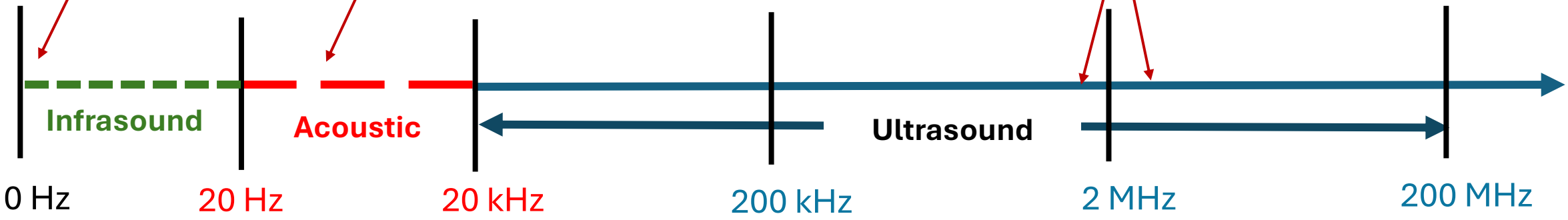


ULTRASOUND FREQUENCY SPECTRUM

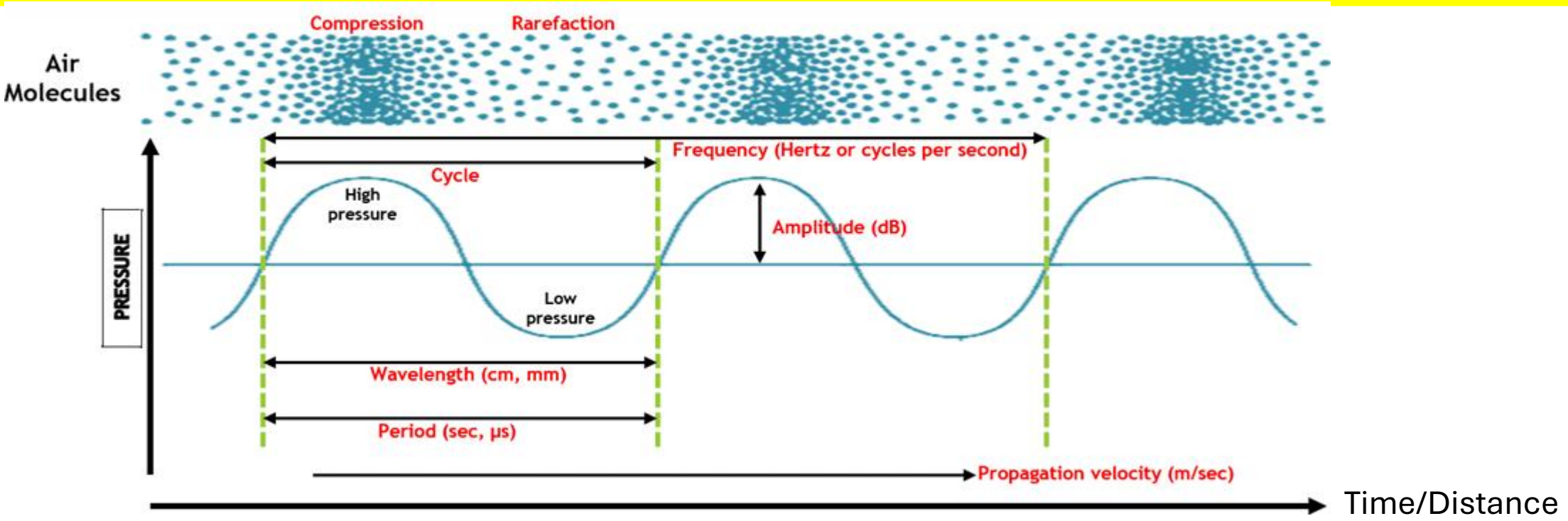
Infrasound:
Audible to:
Elephants,
Whales, Hippos

Acoustic:
Audible to: Humans

Ultrasound:
Applications: Medical Imaging, Non-Destructive Examination(NDE)
Frequency range: 1 – 20 MHz (medical Ultrasound Imaging)



PHYSICAL PROPERTIES OF SOUND



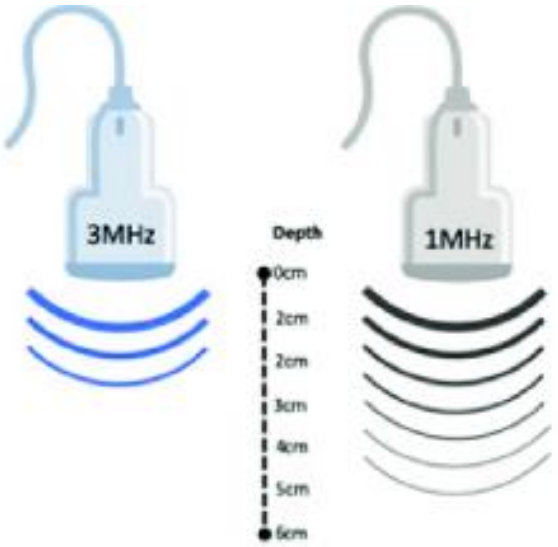
1. **Velocity (m/sec):** speed of sound propagation through a medium ($v = \lambda * f$)
2. **Frequency (Hz):** number of cycles per second
3. **Period/Cycle:** combination of one compression and rarefaction
4. **Wavelength (mm):** distance between two similar adjacent points on a wave
5. **Power (dB):** strength of the signal

SOUND PROPAGATION VELOCITY

MEDIUM	VELOCITY (M/Sec)
Air	330
Fat	1460
Water (20°C)	1480
Water (50°C)	1540
Human Soft Tissue	1540
Blood	1570
Liver	1559
Muscle	1580
Bone	3500

CHOICE OF DIAGNOSTIC FREQUENCY

- HIGHER FREQUENCIES → SHORTER WAVELENGTHS
- SHORTER WAVELENGTHS → BETTER AXIAL RESOLUTION
- BETTER AXIAL RESOLUTION → MORE DIAGNOSTIC INFORMATION



- HIGHER FREQUENCIES → LESSER PENETRATION

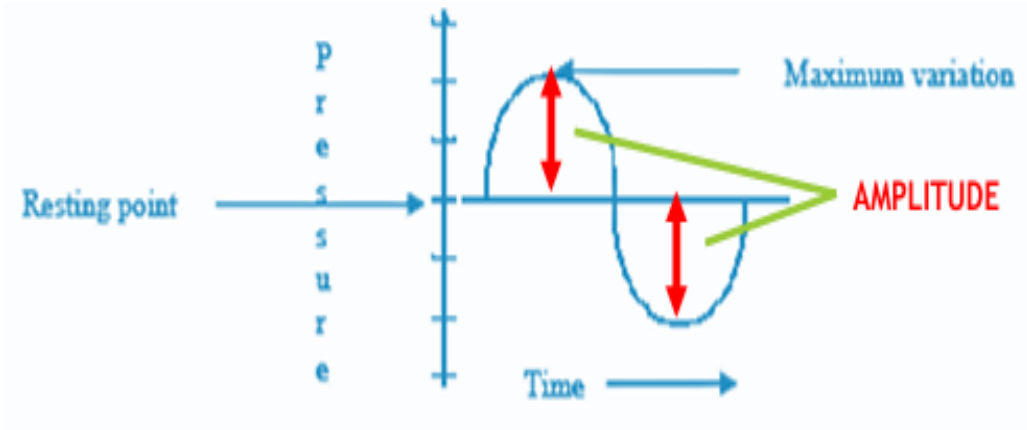
Transthoracic	1–8 MHz
Transoesophageal	3–10 MHz
Intracardiac	3–10 MHz
Epicardial	4–12 MHz
Intracoronary	10–20 MHz

↑ FREQUENCY ↓ WAVELENGTH ↑ AXIAL RESOLUTION ↑ DIAGNOSTIC INFORMATION ↓ PENETRATION

ULTRASOUND WAVE PARAMETERS /01

1. AMPLITUDE

- Height of the compression or depth of the rarefaction
- **Unit of Measurement:** Varies (cm or mm, grams/cc3, mmHg)
- **Determined by the sound source**, decreases as it travels through the tissue (attenuation)
- Can be used to calculate power
- **Operator adjustable**



ULTRASOUND WAVE PARAMETERS /02

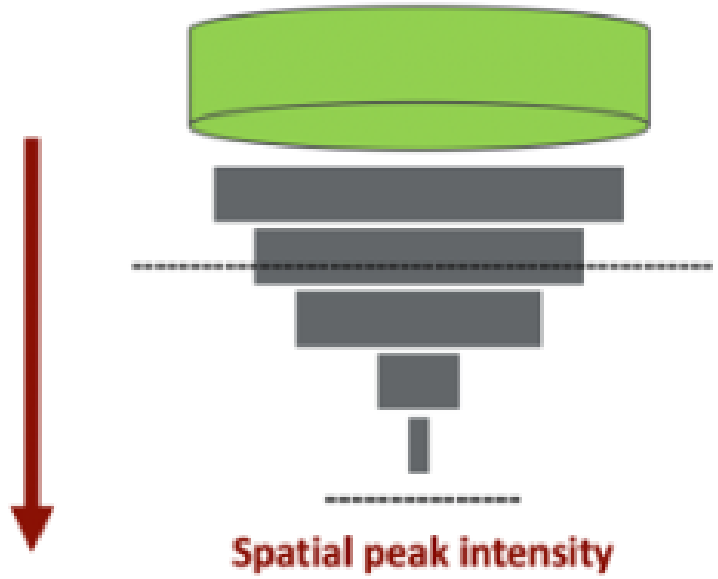
2. POWER

- Rate energy transmitted through tissue or the rate work is performed
- **Unit of Measurement:** Watts or mWatts
- Determine by the sound source
- **Operator adjustable**

ULTRASOUND WAVE PARAMETERS /03

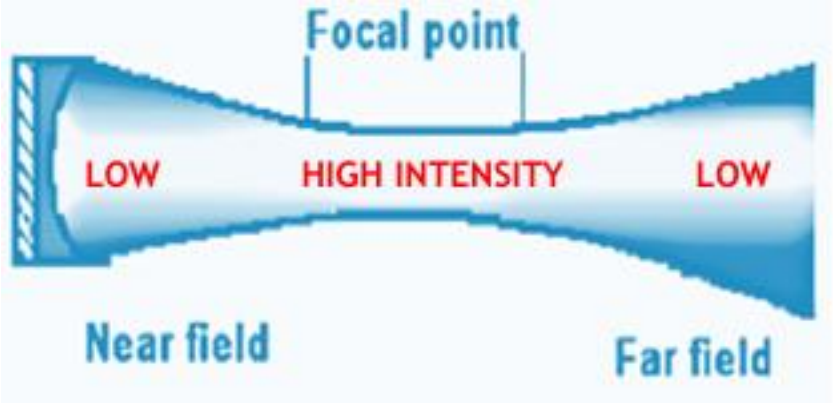
INTENSITY

1. **Unit of Measurement:** Watts/cm^2 or mWatts/ cm^2
2. Measure of ultrasound energy concentration present in human soft tissue
3. Rate ultrasound energy travels through tissue.
4. Measurement can be over a given area (**spatial)** or period of time (**temporal**)
5. **Operator adjustable**

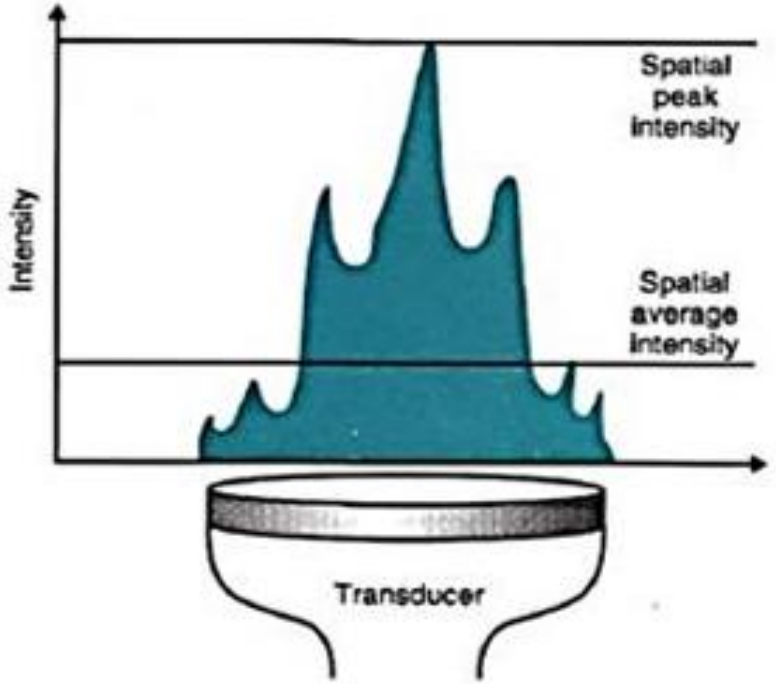


SPATIAL INTENSITY

- **Spatial Intensity** is exact measurement of energy dispersed over a given area-energy.
- **Spatial Intensity** is highest at the narrowest point along the central beam, than in the beginning and end.

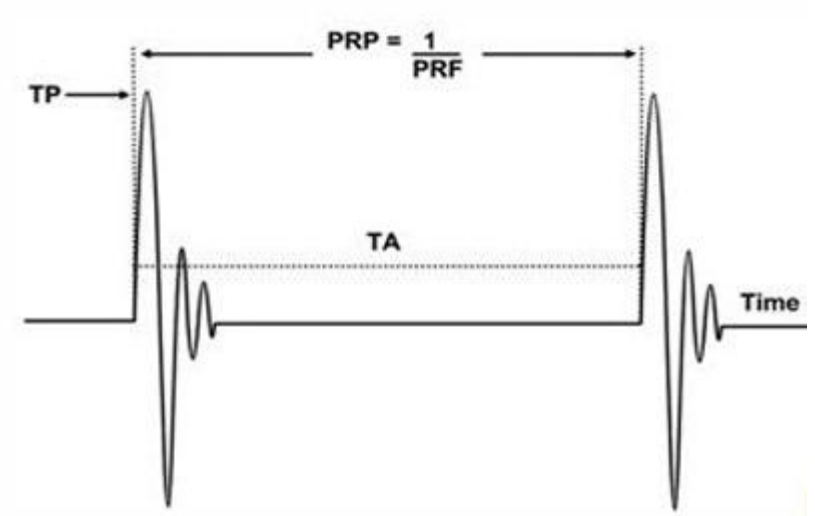


- **Spatial Peak intensity** –measured along the central beam at the narrowest point.
- **Spatial average intensity** in the sound beam and is usually measured at the transducer face.
- $Spatial\ Intensity,\ I = \frac{Power}{Area}$ mW/cm²

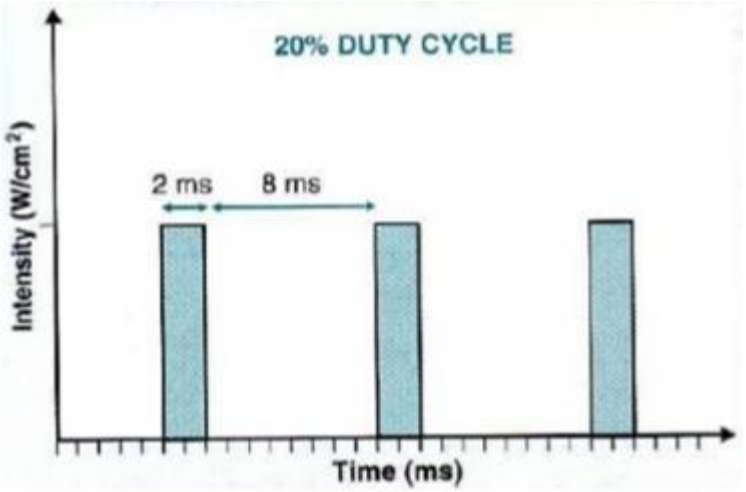


TEMPORAL INTENSITY

1. **Temporal Intensity** is the measurement of energy dispersed over a given time.
2. **Energy** is usually less in the beginning and end of a pulse, than in the middle



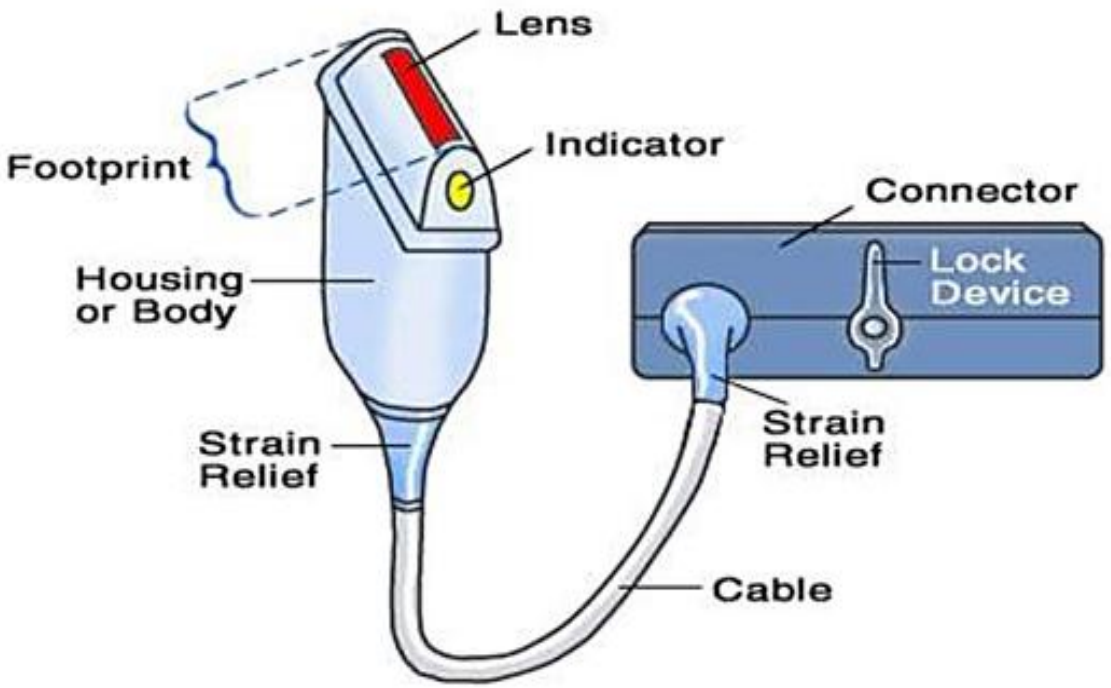
3. **Temporal Peak** – the point in time when intensity reaches its maximum
4. **Temporal Average** – average of all occurring pulses, only "ON" time is included
5. **Duty Factor**– proportion of time that sound energy is actually produced, "ON" time



INTRO TO ULTRASOUND TRANSDUCER

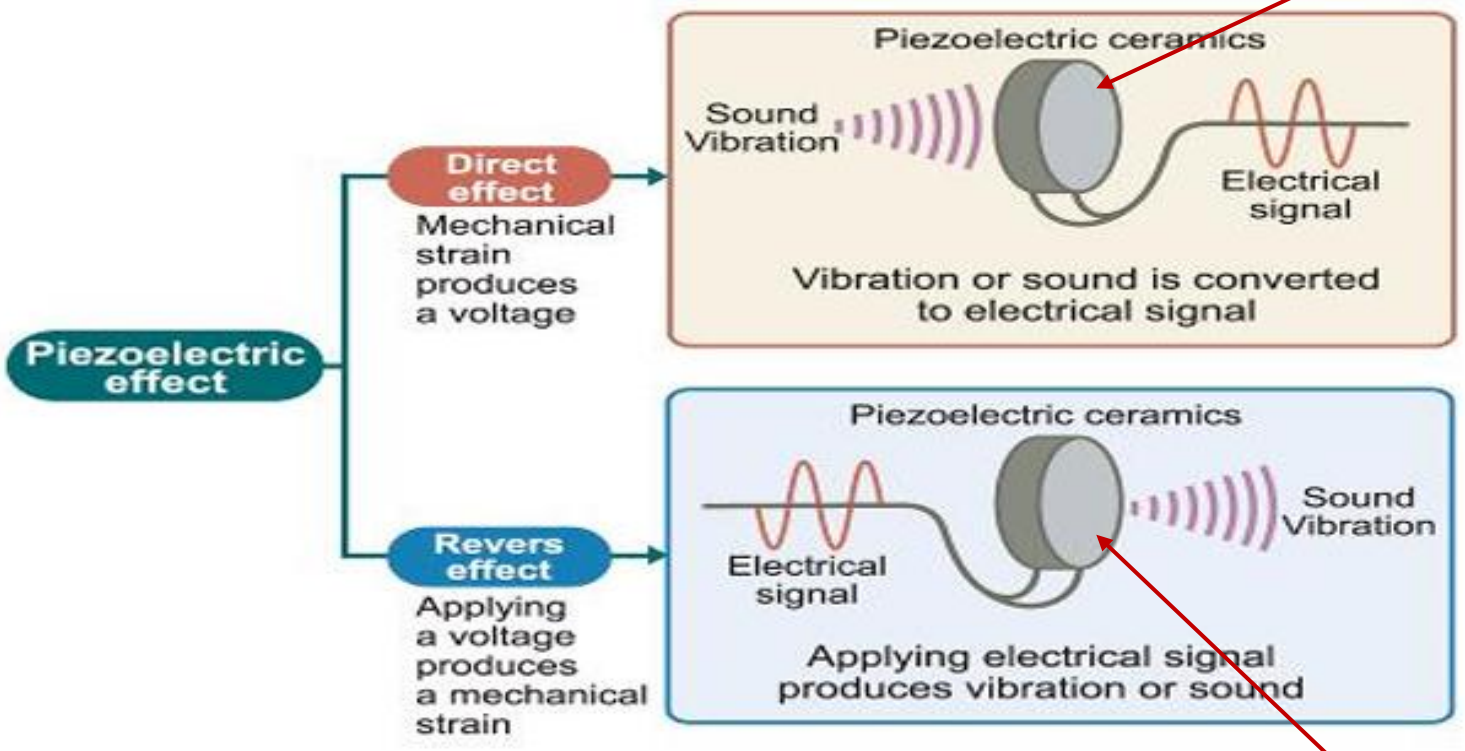
- **Ultrasound probe** is also known as a transducer and is a device used with ultrasound to create sound waves that bounce off body tissues, and to collect echoes.
- There are many **different models** of ultrasound probe with various purposes. Popular models include: Philips, Samsung, Siemens, Sonosite, Toshiba





THE PIEZOELECTRIC EFFECT

Generation of Piezoelectric signals:
Ultrasound interacts with piezoelectric crystals and generates electric signal

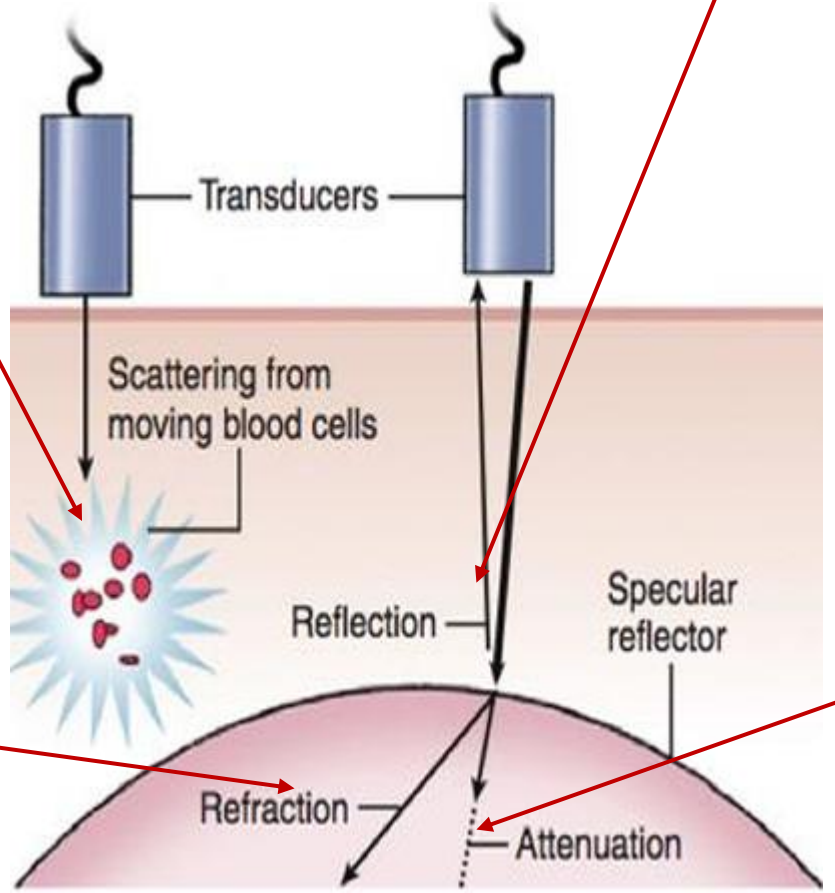


<u>Generation of Ultrasound:</u>
Electrical signal interacts with piezoelectric crystals and generates Ultrasound

INTERACTION OF ULTRASOUND WITH BODY TISSUES

Scattering:
Ultrasound hits blood cells and goes in different directions.

Reflection:
Ultrasound hits body tissues e.g. bones and gets reflected back to the piezoelectric transducer.



Refraction:
Ultrasound waves bend due to refraction at the interface of two body tissues with different refractive indices (Snell's Law).

Attenuation:
Ultrasound waves pass through body tissue with part of it being absorbed by the tissue leading to attenuation.

SPECTACULAR & REIGHLEIGH SCATTERERS

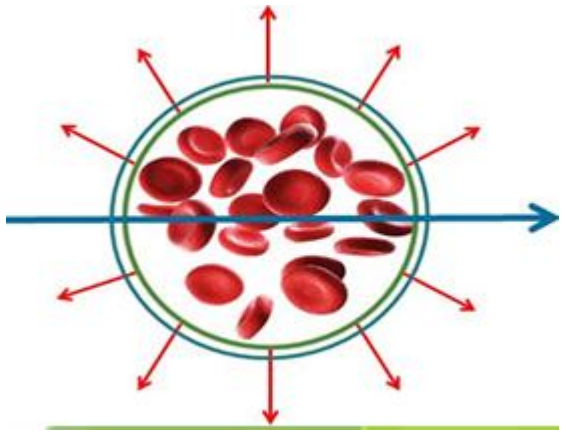
Spectacular scatterers are large tissue objects relative to the wavelength, e.g bones or smooth tissue walls.



Diffuse scatterers are large tissue objects with rough tissue walls relative to the wavelength

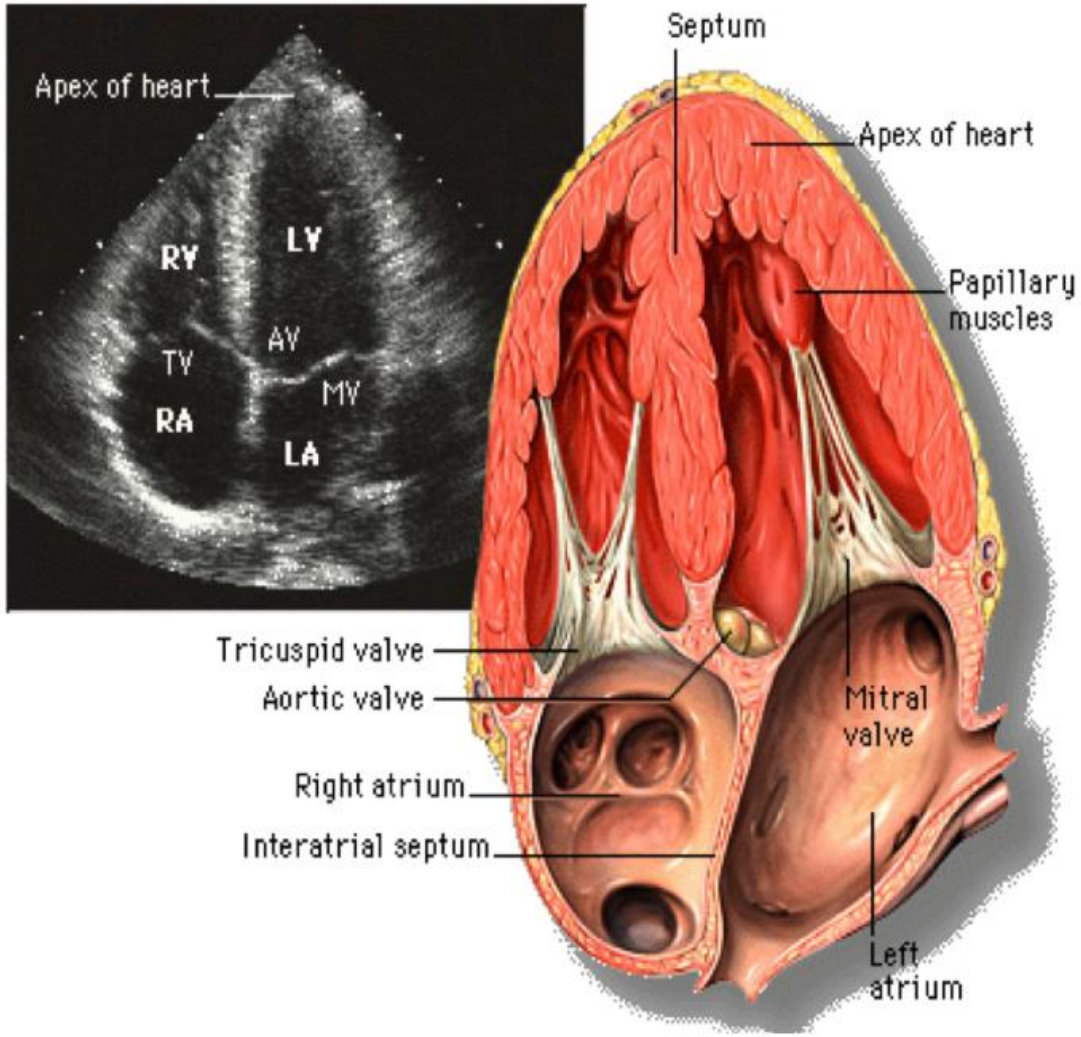


Reighleigh scatterers are small tissue such as blood cells whose dimensions are much smaller than the ultrasound wavelength. Reflections from Reighleigh scatterers are used in Doppler imaging



ECHOCADIOGRAPHY & ECHOCARDIOGRAM

1. **Echocardiography (also known as cardiac ultrasound)**, is the use of ultrasound to examine the heart.
2. **Echocardiography** uses standard ultrasound or Doppler ultrasound.
3. The visual image formed using this technique is called an **echocardiogram.**
4. **The main difference between ECG and Echocardiogram:**
   a) **ECG** detects abnormalities in the electrical impulses of the heart, whereas
   b) **Echocardiogram** uses ultrasound to check for anomalies in the heart's structure.



USES OF ECHOCARDIOGRAM

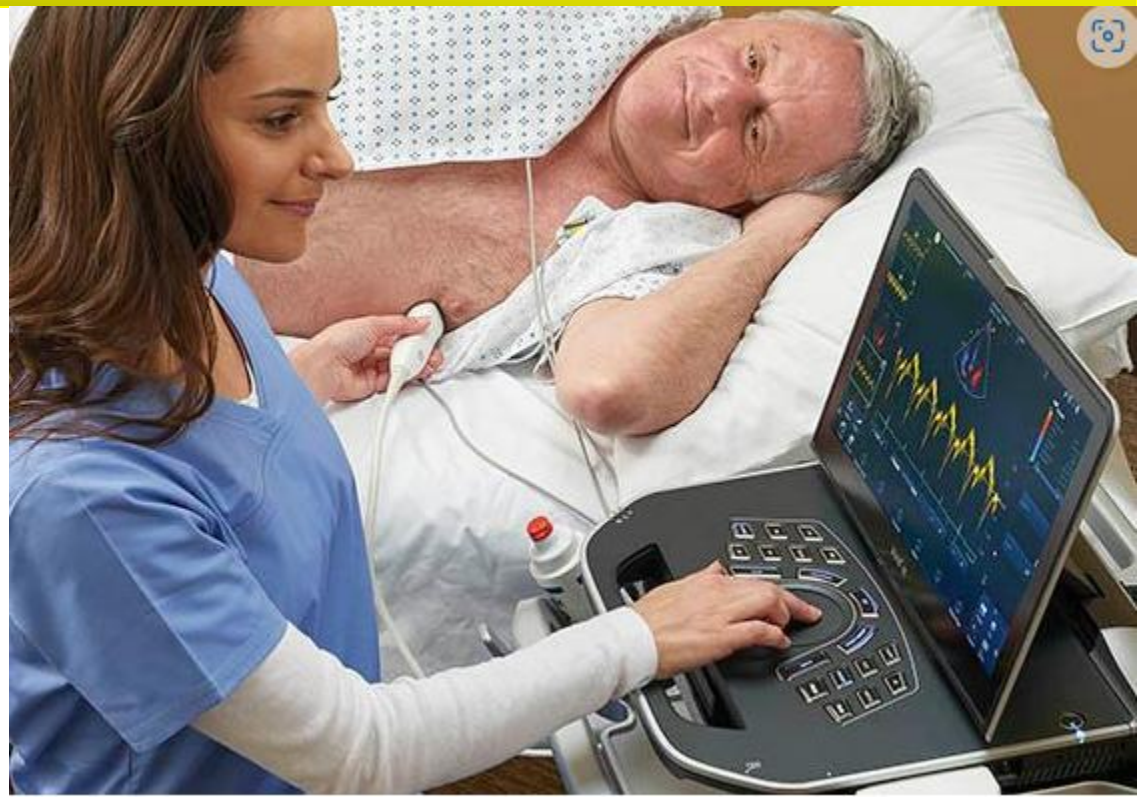
Echocardiogram helps doctors get the following information:

1. **Size of the heart**, for instance, if there is any change in the chamber size, dilation, or thickening
2. **Blood clots** in the heart chambers
3. **Presence of fluid in the sac** around the heart
4. **Problems with the aorta**.
5. **Problems with the pumping function** or relaxing function of the heart
6. Problems with the function of **heart valves**
7. **Pressure in the heart**



HOW MUCH CAN ECHOCARDIOGRAPH MACHINE COST? /01

1. Cost of a cardiac ultrasound machine varies greatly based on the type of machine you choose.
2. Several factors can impact their cost, including:
    1. Brand and model
    2. The age of the unit
    3. Features and functionality
    4. Purchase or lease



(a) A sonographer performing a cardiac ultrasound examination.

Further Reading:

How Much is a Cardiac Ultrasound Machine? (ultrasoundportables.com)

HOW MUCH CAN ECHOCARDIOGRAPH MACHINE COST? /02



Ge Healthcare Voluson E8 Expert Ultrasound...

Ksh 1,224,9...

US$9,500.00...

Absolute Me...

Ultrasound



Portable Color Doppler System NEUCU38

Ksh 2,443,4...

US$18,950.0...

neuvar.com



Siemens Acuson SC2000 Ultrasound...

Ksh 451,290...

US$3,500.00...

Zantek Medical

Ultrasound Machine



Siemens/Acuso S3000 Ultrasound System

Ksh 1,898,6...

US$14,725.0...

Absolute Me...

Ultrasound



Ge VOLUSON E8 Ultrasound Machine

Ksh 2,326,7...

US$18,045.3...

Absolute Me...

Ultrasound Machine



Ge Voluson S8 BT15 Ultrasound System (Year...

Ksh 1,674,9...

US$12,990.0...

Zantek Medica

Ultrasound