UNIT-III

ULTRASOUND IN MEDICINE

3.1 Ultrasonic Waves: Production, Properties, and Propagation

1. Production of Ultrasonic Waves

Ultrasonic waves are sound waves with frequencies higher than the audible range for humans (>20 kHz). They are typically produced using the following methods:

- **Piezoelectric Effect:**
  - Certain materials (like quartz or Rochelle salt) generate ultrasonic waves when subjected to an alternating electric field.
  - **Working Principle:** Applying an AC voltage causes the piezoelectric material to oscillate at ultrasonic frequencies.
  - **Applications:** Ultrasonic transducers in medical imaging (ultrasound) and industrial non-destructive testing (NDT).
- **Magnetostrictive Effect:**
  - Ferromagnetic materials (like nickel) change shape when exposed to a magnetic field, producing ultrasonic vibrations.
  - **Working Principle:** An alternating magnetic field causes oscillations in the material, emitting ultrasonic waves.
  - **Applications:** Used in sonar systems and certain industrial applications.
- **Mechanical Methods:**
  - High-frequency mechanical devices, such as whistles or tuning forks, can generate ultrasonic waves.
  - **Applications:** Limited use due to inefficiency compared to piezoelectric and magnetostrictive methods.

2. Properties of Ultrasonic Waves

- **High Frequency:**
  - Frequencies above 20 kHz, extending up to gigahertz (GHz) in specialized applications.
- **Short Wavelength:**
  - Due to their high frequency, they have very short wavelengths, allowing for detailed resolution in imaging applications.
- **High Energy:**
  - Ultrasonic waves carry significant energy, making them effective for cleaning, cutting, and welding applications.
- **Directional Propagation:**

- They can be highly focused into narrow beams, useful in applications like sonar and medical imaging.

- **Reflection and Refraction:**
  - They reflect off boundaries between different materials, which is crucial for imaging and flaw detection.
- **Non-audibility:**
  - Cannot be heard by humans, making them useful in applications where silent operation is required.

- **Cavitation Effect:**

  In liquids, ultrasonic waves can cause the formation of microscopic bubbles that implode, releasing en ergy. This is used in cleaning and certain chemical processes.

3. Propagation of Ultrasonic Waves

- **Medium Dependence:**
  - Ultrasonic waves require a medium to propagate and cannot travel through a vacuum.
  - **Solids:** Fastest propagation due to closely packed molecules.
  - **Liquids:** Slower than in solids but faster than in gases.
  - **Gases:** Slowest propagation due to large molecular spacing.
- **Attenuation:**
  - Energy loss occurs due to absorption and scattering, especially in heterogeneous or soft materials.
- **Reflection and Transmission:**
  - When encountering a boundary between two materials, part of the wave is reflected, and part is transmitted. This behavior is used in imaging and testing.
- **Diffraction and Interference:**
  - Like all waves, ultrasonic waves exhibit diffraction and interference, which can affect the precision of measurements.
- **Mode of Propagation:**
  - **Longitudinal Waves:** Particle motion is parallel to wave propagation, common in fluids and solids.
  - **Transverse Waves:** Particle motion is perpendicular to wave propagation, primarily in solids.

Applications of Ultrasonic Waves

- **Medical Imaging:**

- Ultrasound for prenatal imaging, organ examination, and therapeutic treatments.

- **Industrial Non-Destructive Testing (NDT):**
  - Detecting flaws in materials without causing damage.
- **Cleaning:**
  - Ultrasonic cleaners use cavitation to remove dirt from delicate objects like jewelry and electronic parts.
- **Sonar and Navigation:**
  - Used in submarines and ships for detecting underwater objects and measuring depth.
- **Welding and Cutting:**
  - Ultrasonic energy is used for precision welding and cutting, especially in plastics.
- **Chemical Processing:**
  - Enhancing reaction rates through ultrasonic agitation (sonochemistry).

3.2 BIOACOUSTICS CHARACTERISTICS OF HUMAN BODY

Bioacoustics, the study of sound production, transmission, and reception in biological organisms, can be applied to understand various acoustic characteristics of the human body. Here are some key aspects:

1. Vocalization and Speech Production

- **Vocal Folds (Cords):** Located in the larynx, they vibrate to produce sound when air is expelled from the lungs. The tension, length, and mass of the vocal folds determine pitch and tone.
- **Resonance:** The vocal tract (throat, mouth, nasal cavities) acts as a resonating chamber, amplifying certain frequencies to shape individual voice characteristics.
- **Formants:** Peaks in the sound spectrum that define vowel sounds. Different configurations of the vocal tract shape these formants, contributing to speech clarity and uniqueness.

2. Heart Sounds

- **Phonocardiogram (PCG):** Captures the acoustic signals produced by the heart, such as the "lub-dub" sounds corresponding to valve closures.
- **Murmurs and Gallops:** Abnormal sounds detected through auscultation can indicate various heart conditions.

3. Respiratory Sounds

- **Breath Sounds:** Normal sounds include vesicular breathing, while abnormal sounds like wheezes, crackles, or stridor can signal respiratory issues.
- **Lung Auscultation:** Using stethoscopes to detect variations in sound that could indicate diseases like asthma, pneumonia, or COPD.

4. Bone Conduction

- **Transmission of Sound Through Bones:** The skull can transmit sound vibrations directly to the inner ear, bypassing the outer and middle ear. This is used in hearing aids and bone-conduction headphones.

5. Gastrointestinal Sounds

- **Borborygmi:** Sounds produced by the movement of gas and fluids in the intestines, often heard with a stethoscope.
- **Acoustic Monitoring:** Can detect motility issues or obstructions in the digestive tract.

6. Joint and Musculoskeletal Sounds

- **Crepitus:** Crackling or popping sounds from joints, often associated with arthritis or cartilage issues.

- **Acoustic Emission Monitoring:** Used to study joint health and the integrity of musculoskeletal structures.

7. Hearing and Auditory Perception

- **Otoacoustic Emissions (OAEs):** Sounds generated by the inner ear in response to auditory stimuli, used in hearing tests.
- **Binaural Hearing:** The ability to perceive spatial information from sound using both ears.

8. Brain Activity

- **Sonification of Neural Activity:** While primarily electrical, some experimental techniques convert brain waves into audible sound for research purposes.

Applications:

- **Medical Diagnostics:** Using acoustic signals for non-invasive diagnosis (e.g., ultrasound imaging, heart sound analysis).
- **Speech Therapy:** Understanding vocal acoustics to aid in therapy and rehabilitation.
- **Wearable Technology:** Bioacoustic sensors for health monitoring, such as detecting heart rate or respiratory patterns.