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).