Ultrasonics

→ Ultrasonic wave:

- Sound waves having freq. > 20kHz (lies outside audible range)
- Wavelength is very small compared to sound waves.

↳ Applications of Ultrasonic waves:

1. Detection of flaws in metals:
   - Flaw in metal produces a change in the medium due to which reflection of ultrasonic waves take place.
   - Ultrasonic waves pass through a metal having some crack in it, an appreciable reflection occurs.
   - The reflected pulses are picked up by the receiver and amplified.

2. Depth of Sea:
   - Ultrasonic waves are highly energetic and show a little diffraction
   - Time interval b/w sending the wave and the reflected wave from the sea is recorded.
   - Velocity of the wave is known, hence depth can be calculated.

$$\text{Depth of Sea } (d) = \frac{vt}{2}$$

3. cleaning and clearing

4. Direction Signalling:
   - Ultrasonics waves can be concentrated into a sharp beam due to smaller wavelength and hence can be used for signalling.

5. Soldering and Metal Cutting:
   - Ultrasonic soldering uses high-freq. waves to enhance heating process.
   - The ultrasonic vibrations increase the efficiency of heat transfer.

6. Formation of alloys:
   - The constituents of alloys, having widely different densities can be kept mixed uniformly by ultrasonics.

7. SONAR: Sound Navigation and Ranging
   - In Sonar, an ultrasonic beam is directed in different directions in the sea.
   - In the absence of an obstacle, the beam travels undeviated.
   - In presence of any obstacle, pulses are reflected back.
   - Knowing the speed of the wave in water & time taken. Distance can be calculated.

↳ Production of ultrasonic waves :

→ Magnetostriction method :

· when a ferromagnetic rod is placed in a magnetic field parallel to its length, a small rod extension or contraction occurs.

- The change of length is independent of the sign of field. It depends only on magnitude of field and nature of material.

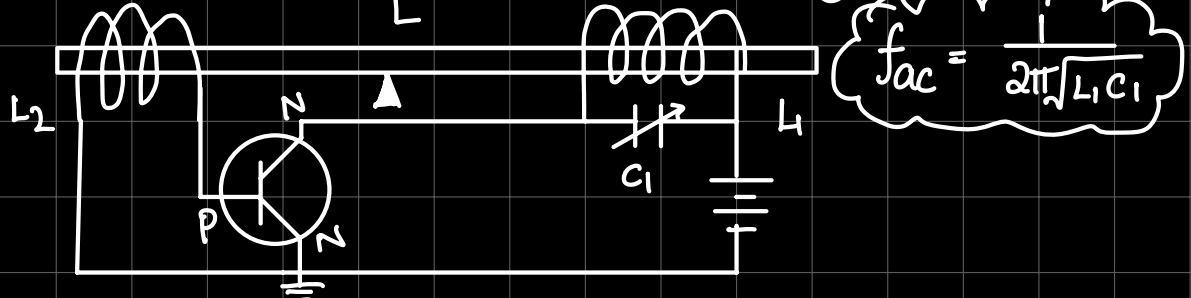
✱ Ultrasonic generator :

- Decide the freq. (f) of wave to be generated.
- Generate a magnetic field varying at freq. f.
- Choose a magnetostrictive material so that its resonance freq. matches f (Resonance ensures max. amplitude of oscillation.

$$f_{rod} = \frac{1}{2L}\sqrt{\frac{E}{\rho}}$$

(E → Young's Modulus, ρ → density)

- Place the magnetised magnetostrictive material in this field.
- Ultrasonic waves of freq. f will be generated.

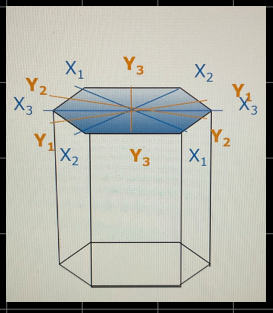


→ Piezo-Electric Effect:

- Refers to development of emf across opp. pair of faces of assymmetric crystals on application of mechanical stress. This emf appears perpendicular to the pair of faces. Eg: quartz.

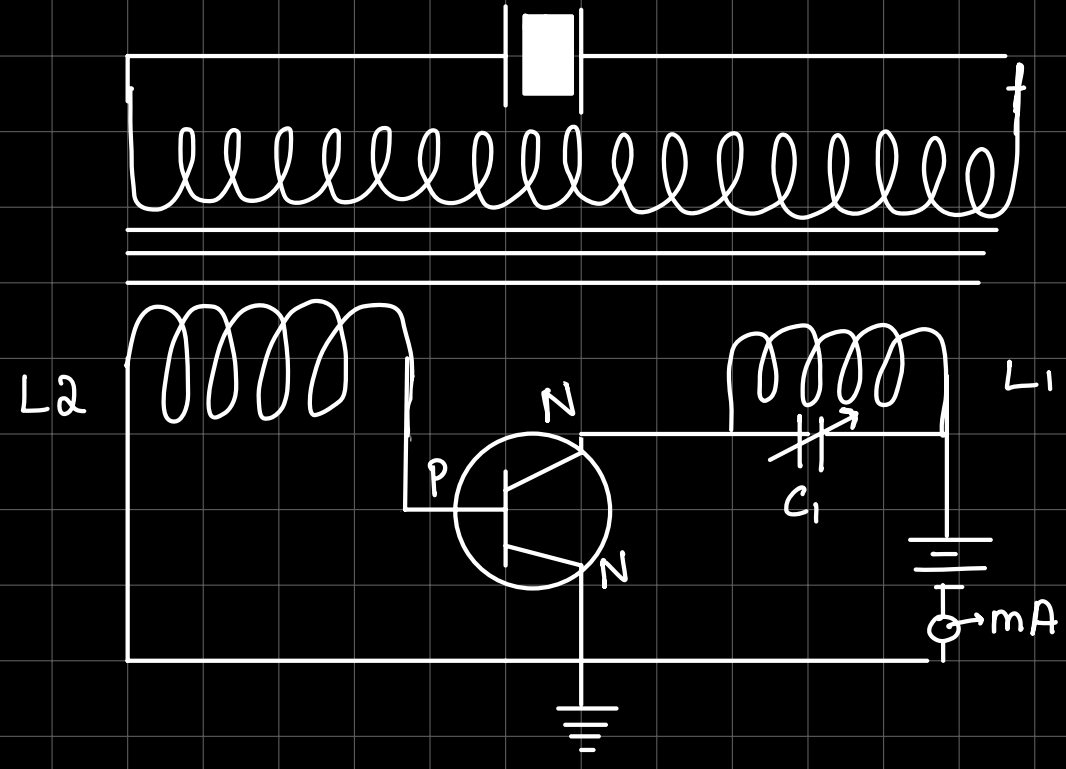
X axis – along opp corners of hexagon → Electrical axis

Y axis – along centre of opp. faces of hexagon. → Mechanical axis



$$f = \frac{n}{2l}\sqrt{\frac{E}{\rho}} = \frac{n}{2l}\sqrt{\frac{v^2\rho}{\rho}} = \frac{nv}{2l}$$ (v → velocity of sound)

* Piezo-Electric Generator:



Working:

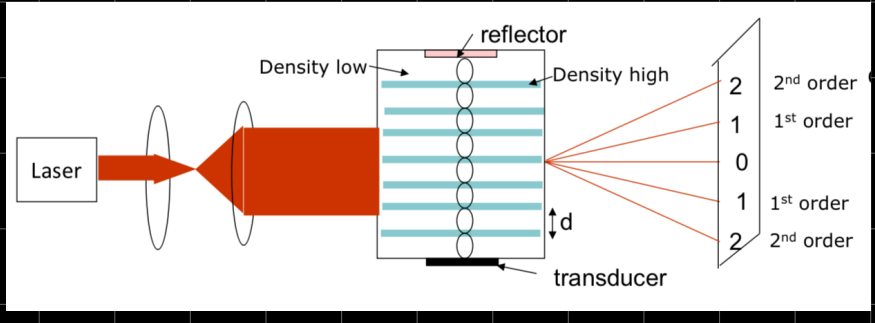
1. Oscillation Generation: When the circuit is powered, the tank circuit creates oscillations. The freq. of these oscillations can be adjusted by changing the capacitance in the circuit.

2. Resonance Condition: Freq. of oscillations is resonant with quartz crystal. Resonance allows the crystal to vibrate with max. amplitude.

3. Ultrasonic Wave Production: The oscillating electric field across the quartz crystal induces mechanical vibrations due to inverse piezoelectric effect, producing ultrasonic waves

→ Acoustic Grating:

Mechanism:



- When ultrasonic waves are generated in a liq. they create a standing wave pattern due to interference of direct and reflected waves.
- Nodes → max. density Antinodes → min. density.
- Due to variation in density, the liq. behaves as a diffraction grating.
- The antinodes act as slits allowing light to pass through at different refraction angles

The grating element (d) corresponds to wavelength of ultrasonic waves.

Angle of diffraction (θ), Order of diffraction (n), wavelength (λ)

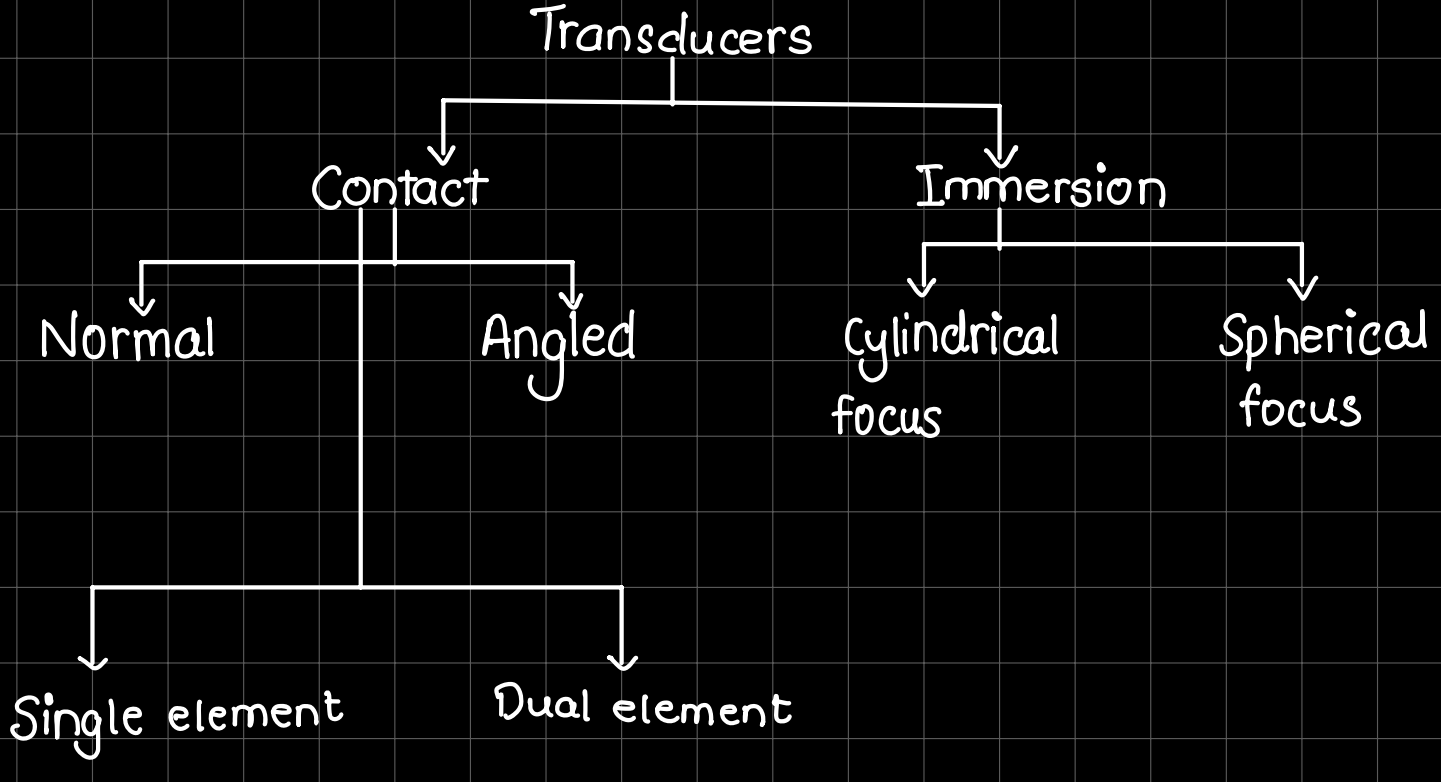
$d \sin\theta = n\lambda \Rightarrow d = \lambda_{Ac}/2 \Rightarrow \lambda_{ac} = \frac{2n\lambda_{laser}}{\sin\theta}$

$v = \frac{\nu n \lambda_{Ac}}{\sin\theta}$ → velocity of ultrasonic wave

freq.

$v = \frac{2\nu n \lambda_{laser}}{\sin\theta}$

→ Utrasonic Transducers:

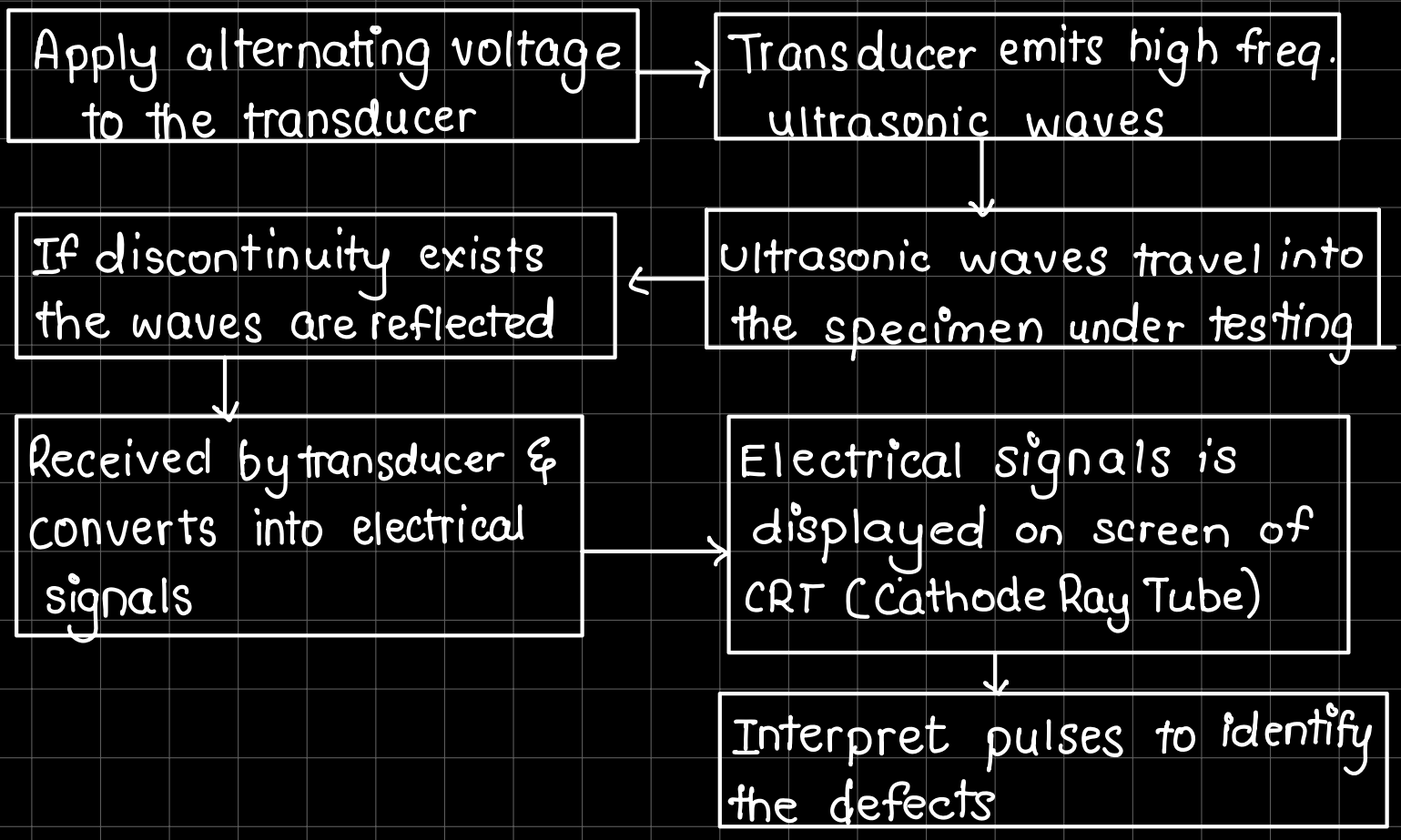


→ Properties of ultrasonic waves:

- Speed of ultrasonic waves ∝ frequency
- wavelength of waves is very small and the waves exhibit negligible diffraction effects
- They can travel long distances without much loss of energy.
- Highly energetic
- Produce cavitation effects in liquids.

→ Cavitations: The phenomenon where microscopic bubbles or cavities form and collapse in a liq. medium when subjected to high freq. sound waves. When ultrasonic waves propagate through liq. medium, they induce alternate regions of rarefaction and compression.

→ Ultrasonic Testing:



↳ Normal beam pulse echo testing:

- An ultrasonic pulse propagating perpendicular to the surface to the surface of the test object is reflected at the boundaries of object and surface of defects.
- The reflected pulses → echoes

↳ Normal beam pulse through transmission testing

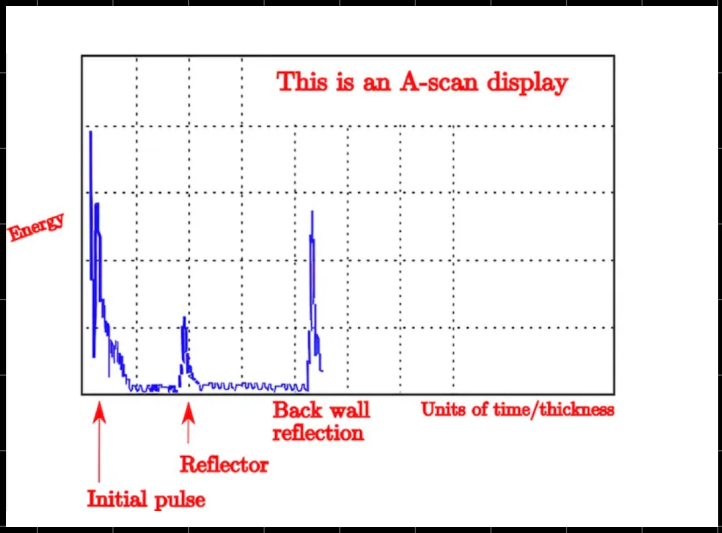
- Two ultrasonic transducers
- Transducer held at front of object emits ultrasonic wave ⊥ to the surface.
- The transmitted pulses are detected by 2nd transducer held at opp. side.

→ Modes of Display:

↳ A-scan:

X axis → time taken

Y axis → Amplitude of echoes



- Location of defect is estimated by position of echo on X axis
- Size of defect is estimated by the amplitude of echo.
- 1-D representation

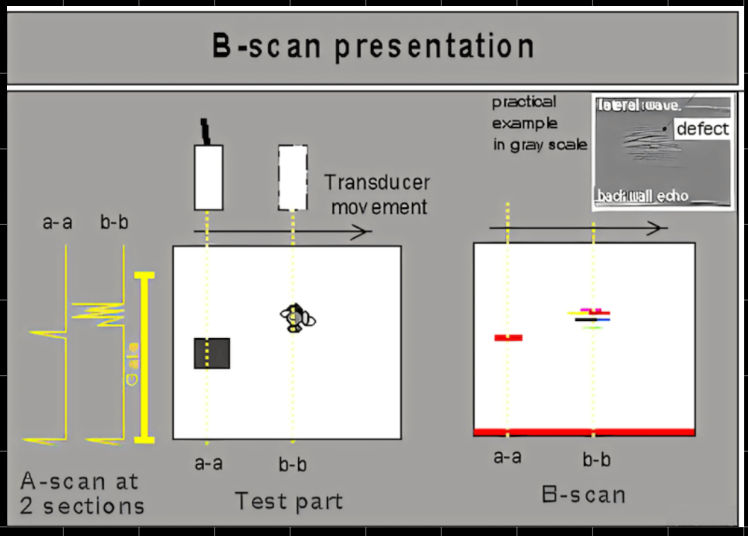
↳ B-scan:

- Shows position, orientation & depth of defect

Y axis → time elapsed

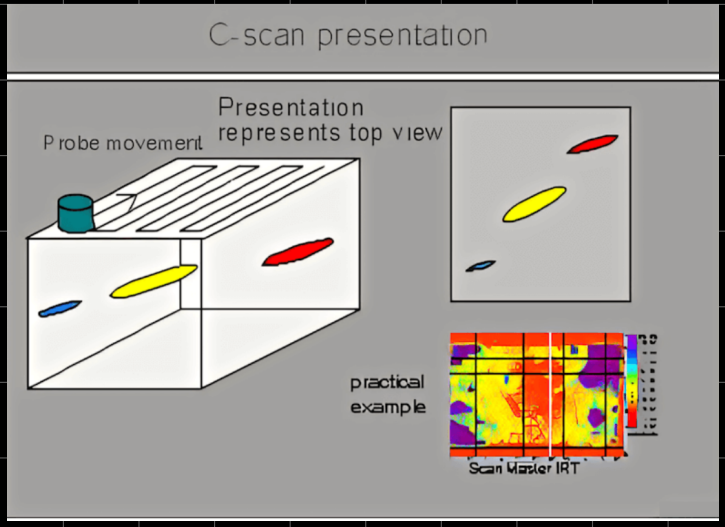
X axis → Position

- Echo amplitude is indicated by the relative brightness of echo indications.



↳ C-scan:

- The transducer is moved over surface of test piece & echo intensity is recorded as a variation in line shading.



→ Sonography: (Ultrasound imaging)

- Exposing parts of body to high freq sound waves to produce pictures of internal organs.
- This provides information of size, location, displacement of tumors & other regions of organs which differ in density from the surrounding tissues.