# ACOUSTICS & ULTRASONICS

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# ACOUSTICS

**Science of sound that deals with origin, propagation and auditory sensation of sound.**

Sound production
Propagation
Reception

by human beings/machines

## Classification of Sound waves

| Infrasonic | audible | ultrasonic |
|---|---|---|
| Inaudible | | Inaudible |
| < 20 Hz | 20 Hz to 20,000 Hz | >20,000 Hz |

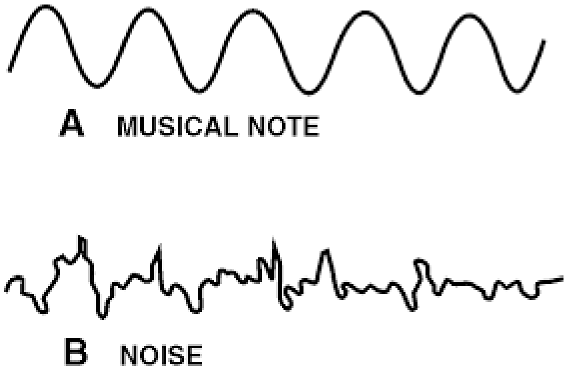
# Audible Sound

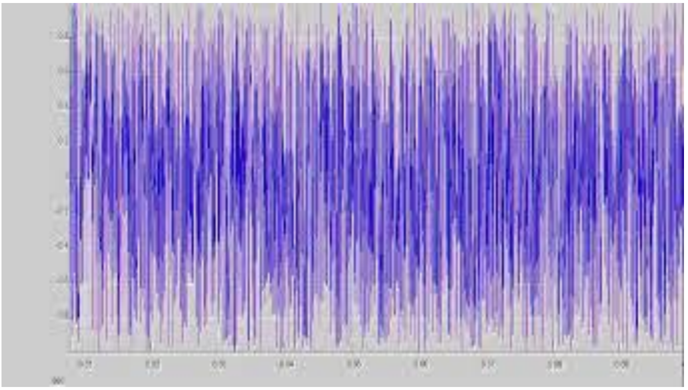
Music – The sound which produces rhythmic sensation on the ears

Noise-The sound which produces jarring & unpleasant effect

To differentiate sound & noise

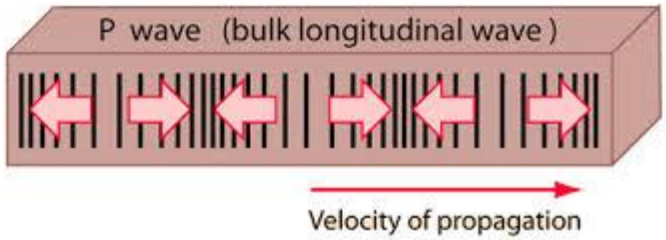
- Regularity of vibration
- Degree of damping
- Ability of ear to recognize the components

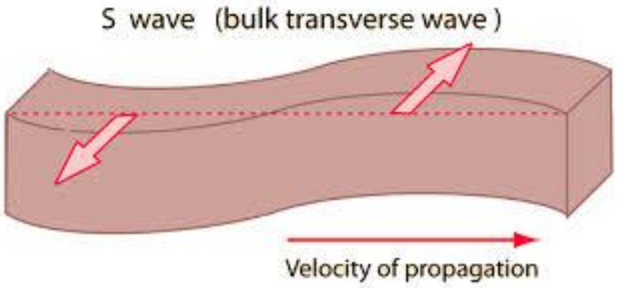


# Properties of Sound waves

- Sound is a form of energy
- Sound is produced by the vibration of the body
- Sound requires a material medium for its propagation.
- When sound is conveyed from one medium to another medium there is no bodily motion of the medium
- Sound can be transmitted through solids, liquids and gases. Velocity of sound is higher in solids and lower in gases.



- Sound travels with velocity less than the velocity of light. $c = 3 \times 10^{8}$ $V_0 = 330$ m/s at 0° degree
- Lightning comes first than thunder
- $V_T = V_0 + 0.6\ T$
- Sound may be reflected, refracted or scattered. It undergoes diffraction and interference.


# Characteristics of Sound waves:

- *Pitch or frequency*
- *Quality or timbre*
- *Intensity or Loudness*

**Pitch is defined as the no of vibrations/sec. Frequency is a physical quantity but pitch is a physiological quantity.**

Mosquito- high pitch

Lion- low pitch

**Quality or timbre** is the one which helps to distinguish between the musical notes emitted by the different instruments or voices even though they have the same pitch.

- **Intensity or loudness** It is the average rate of flow of acoustic energy (Q) per unit area(A) situated normally to the direction of propagation of sound waves.

$$\textbf{Intensity} = Q/A$$

$$I \propto (n^2 a^2 \rho v)/x^2$$

n=Frequency of the sound waves

a= amplitude of the wave

ρ= density of the medium

v= velocity of sound in that medium

x= distance from the source of sound to the receiving end.

# WEBER FECHNER LAW

The loudness of sound sensed by the ear is directly proportional to the logarithm value of intensity.

$L \propto \mathbf{Log\ I}$ $\mathbf{L=k\ Log\ I}$

**sensitiveness of ear**= $dL/dI$

Using the law $dL/dI=k/I$

Sensitiveness of ear decreases with increase in Intensity.

More sound in a room /hall the sound is not heard properly.

# Units to measure sound intensity

**Decibels db**

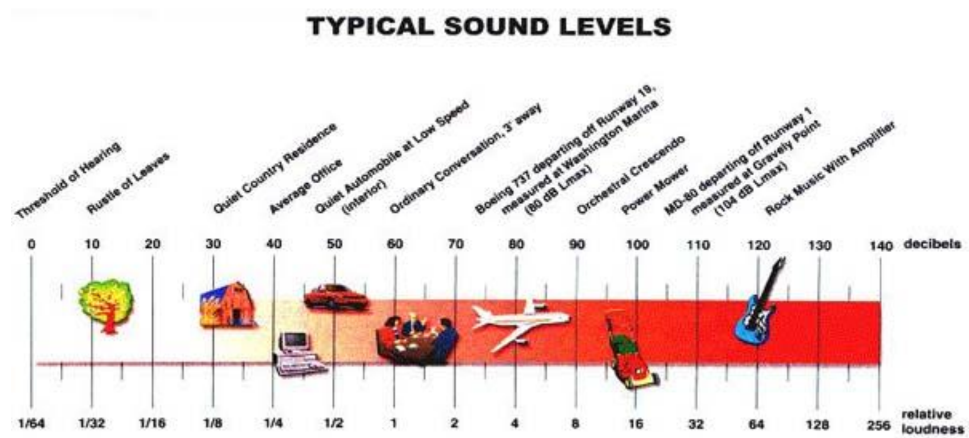
The maximum Intensity level

$I_L = 10 \log (1/10^{-12})$ dB Max level: 120 dB

**Phon**

$L_P = 10 \log I + 120$

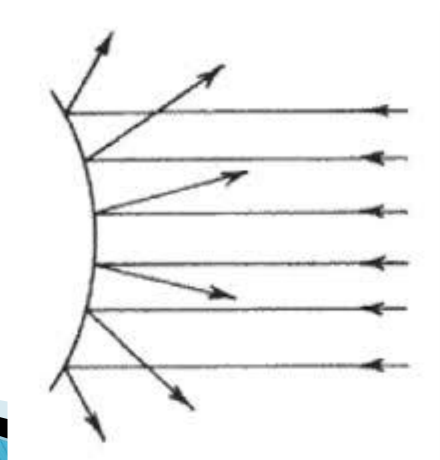
Here I= Intensity of sound in decibel

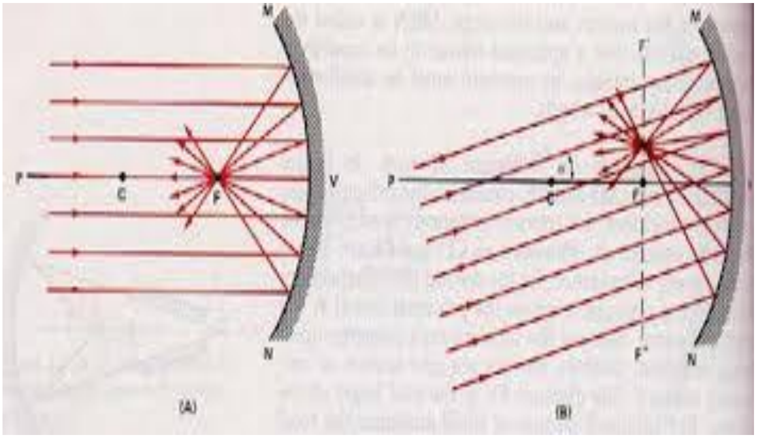




The **decibel (dB)** is a unit for describing sound pressure levels. A-weighted sound measurements (dBA) are filtered to reduce the effect of very low and very high frequencies, better representing human hearing. With A-weighting, sound monitoring equipment approximates the human ear's sensitivities to the different sounds of frequencies.

# Acoustic Reflectors and absorbers

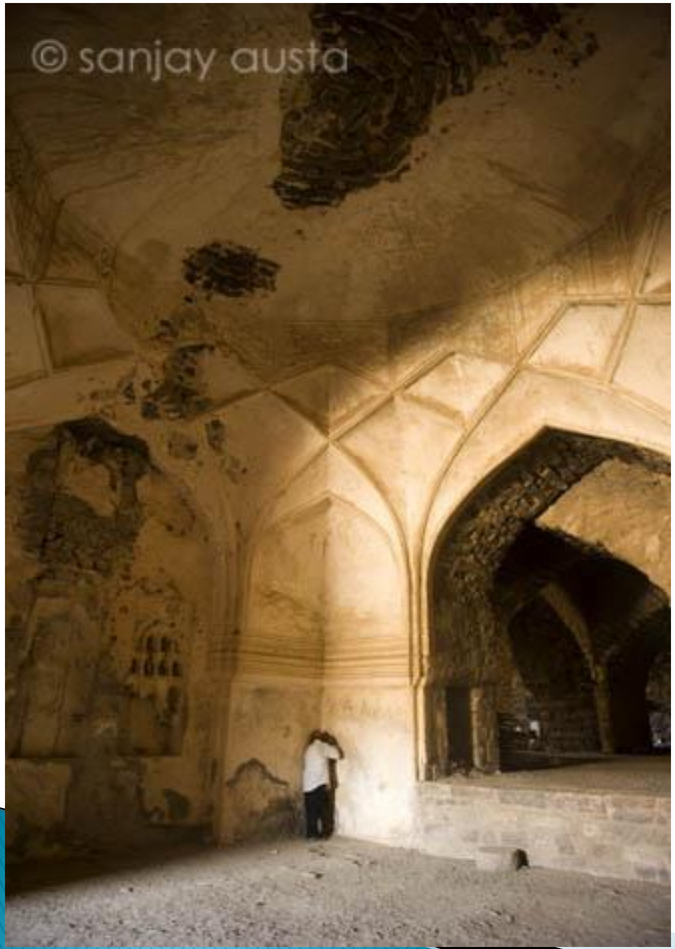
- Sound waves have freq 20 to 20,000 Hz means they have $\lambda$ from 15 µm ($3x10^8$ /20)to 15,000 m ($3x10^8$ /20,000).
- Sound waves undergo reflection & obey laws of reflection.
- Convex surface scatters sound.
- Concave surface focuses it.

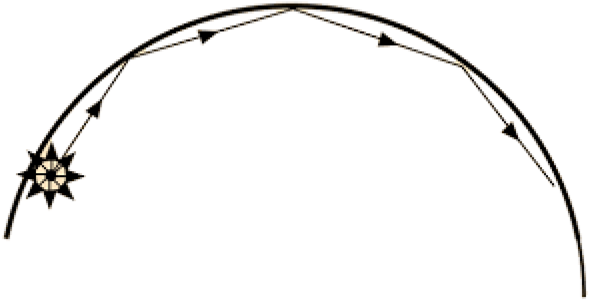




# Enclosed surfaces –effect of reflection is predominant

whispering galleries- Golgonda Fort



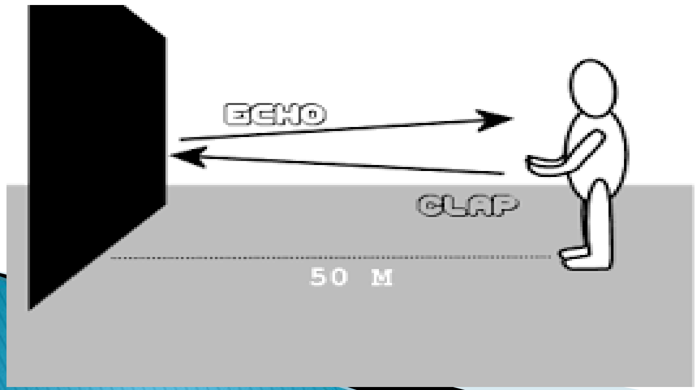



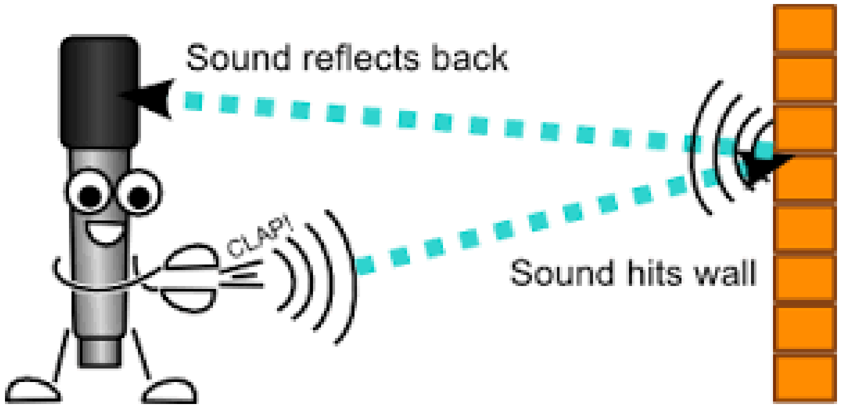
Reflection of sound causes two effects

1. Echoes
2. Reverberation

**Echo:** Reflection of sound when the time interval between the original sound & its reflection is long enough. Both( original & reflected)are heard distinctly.

Echo results when we have multiple reflective surfaces   Ex: Thunder  ( Mountains, clouds, buildings, land…)



# Reverberation & Reverberation time

- **Reverberation**

  Persistence of sound in a room due to multiple reflections, even when the source stops emitting the sound.

  Large no of echoes  which are closely spaced causes reverberation.

  Ex: large hall without furniture /audience ,New house
- **Reverberation time**

  The time taken by the sound in a room to fall from its average intensity to inaudibility

  The time interval during which the sound intensity falls from its steady state value to one millionth value after the source is shut off.

# Absorption

- The property of a surface by which the sound energy is converted into another form of energy.
- Absorption coefficient a= sound energy absorbed by the surface/ total energy incident on the surface
- A unit area of a open window transmits all the sound it absorbs.
- unit for measuring “a” is OPW or Sabine .

| Reverberation Time | Acoustics |
|---|---|
| 0.5-1.5 | Excellent |
| 1.5 -2.0 | Good |
| 2.0-3.0 | Satisfactory |
| 3.0- 5.0 | Bad |
| %.0 and above | Very bad |

| Optimum Reverberation Time | Activity in a hall |
|---|---|
| 1.0 - 1.5 | Conference hall |
| 1.2 - 1.3 | Theatre |
| 1.5 - 2.0 | Music concert hall |
| 1.8 - 3.0 | Church |

# Absorption Coefficient

| Material | Absorption coefficient / $m^2$ at 500 hz |
|---|---|
| Open window | 1.0 |
| Ventilators | 0.1 to 0.5 |
| Stage curtain | 0.2 |
| Carpet | 0.4 |
| Audience (one person) | 0.46 |
| Fiber board | 0.55 |

# Sabines law

- RT= Volume of hall/ Total absorption area

  $T=k\ V/A$

  $T= 0.161\ V/A$

  $T= 0.161\ V/\left(a_1S_1+a_2S_2+a_3S_3+\ldots+a_nS_n\right)$

$a_1, a_2, a_3\ldots$ = absorption coefficients of various materials

$S_1, S_2, S_3\ldots$ = Respective surface area of the materials

# Acoustical demands of a Hall – Conditions for good Acoustics:

- The sound from the source should be of adequate intensity.
- The sound should spread evenly and heard loud in any part of the hall.
- The sound of speech or music should be clear and words or musical notes must be distinctly audible.
- Any undesired or extraneous noise must be reduced so that it will not interfere with normal hearing of speech.
- The structure of the wall, ceiling and floor should be designed for uniform focusing of sound through the entire hall.
- The optional level of reverberation and echo should be measured and considered during the design of the hall.

# Methods of design for good acoustics:

- Proper site selection (Airport, rail track, industry…)
- Volume of the hall (Concert hall 4–5.5 $m^3$, Theatre 4–5 $m^3$, Public meeting 3.5– 4.5 $m^3$)
- Shape of the hall ( Curved surfaces- convex/concave, parallel walls –splayed side walls)
- Use of absorbers ( false ceiling, floor carpet, drilled fiber boards on side walls, perforated panels….)
- Reverberation( not too short or too large, check total absorption coefficient of the wall)
- Seating arrangement
- Echelon effect –reflection of sound from floor or stairs due to poor finishing–structural effects

# ULTRASONICS Ultra -beyond Sonic-sound

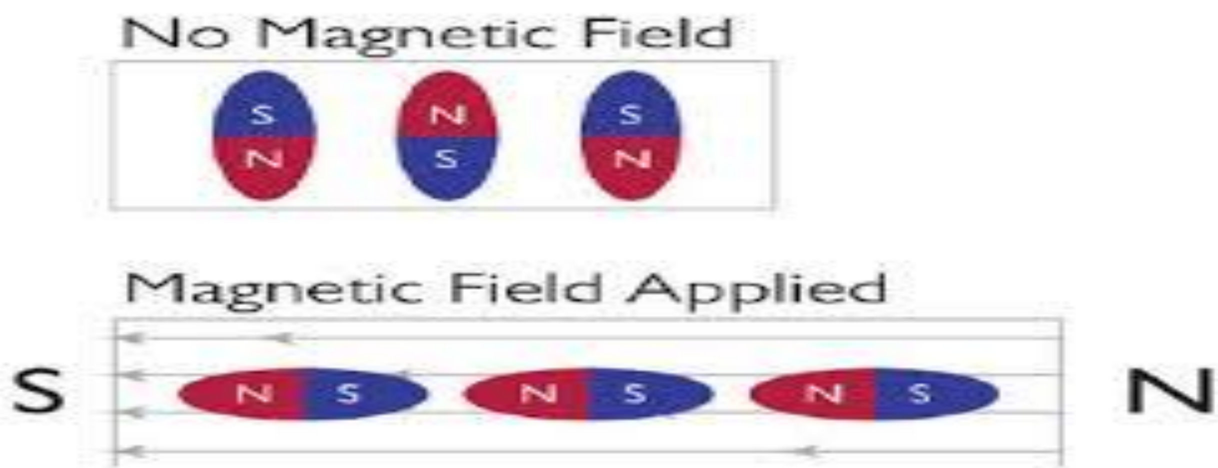
**Ultrasonics** deals with sound waves having frequency beyond audible range

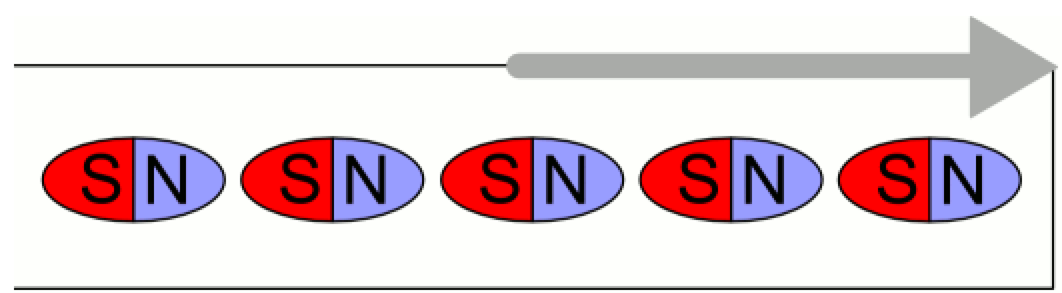
**Properties of Ultrasonic waves**:

- Highly energetic, Freq >20,000 Hz ,Intensity 10 $KW/m^{-2}$, ,
- Exhibit negligible diffraction effect due to smaller λ.
- Can be transmitted over long distances with min energy loss.
- Produce alternate compression and rarefaction like sound waves
- Can propagate through liquid and gaseous medium
- Velocity of US waves increases with increase in frequency. $v= n\lambda$
- When absorbed by a medium produce heating effect.
- US waves produce cavitations in liquids

# Production of Ultrasonic waves:

- Magnetostriction oscillator
- Principle:  magnetostriction effect

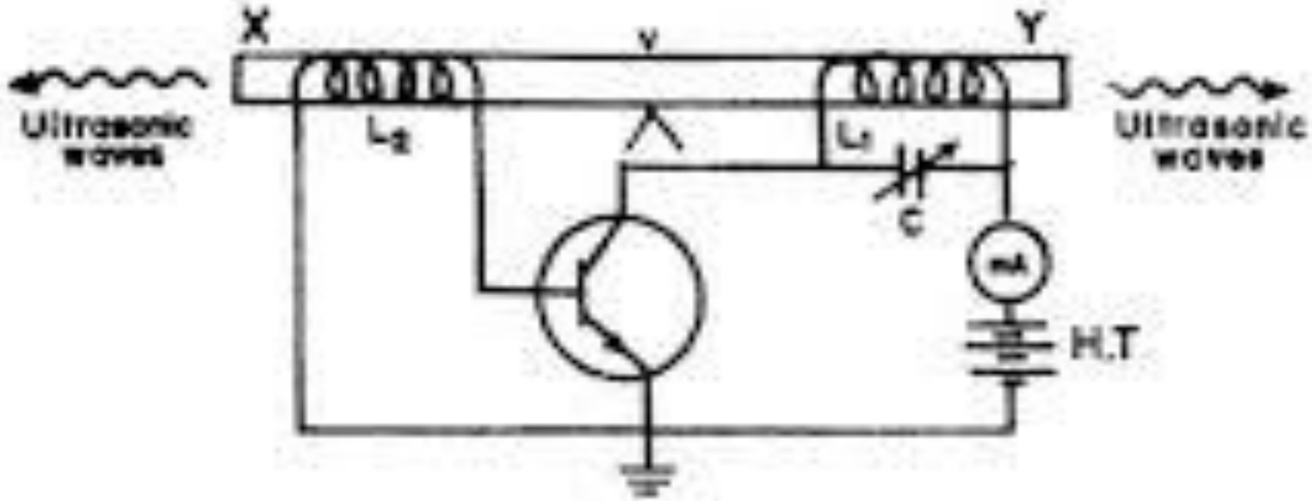


# Magnetostriction oscillator

## Construction

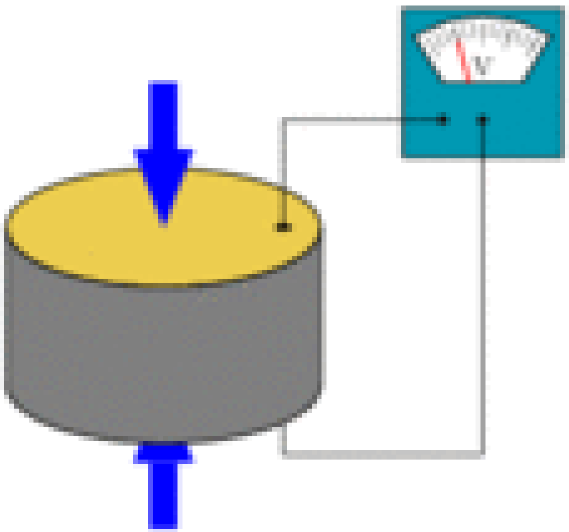
The experimental arrangement is shown in Figure




Magnetostriction oscillator

# Piezo electric oscillator

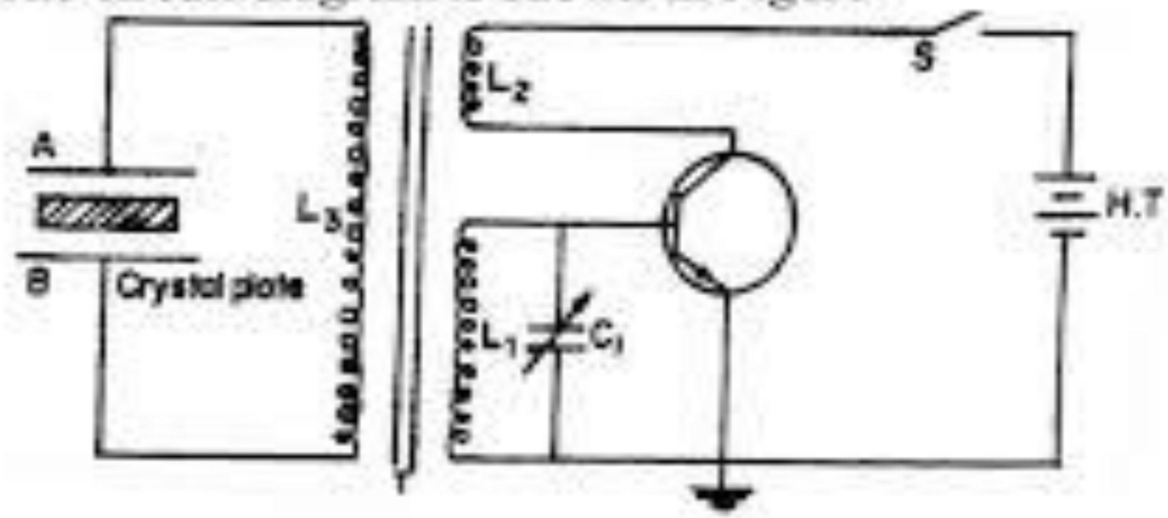
Principle: Inverse piezo electric effect
Diagrams: Piezo electric effect




# Piezo electric oscillator

**Construction**

The circuit diagram is shown in Figure




**Piezo electric oscillator**

# Detection of US waves

- Sensitive flame method
- Thermal detector method
- Quartz crystal method
- Acoustic grating method

**Sensitive flame method:**

When a sensitive flame is moved in the path of the US waves the flame will flicker when it crosses the node & no change in the flame when it crosses the anti nodes.

- **Thermal detector method**

  A Pt wire in a Calender & Garrifihs bridge is moved in the path of US waves. Due to compressions & rarefactions temperature changes occur & in turn R of the wire changes.

  Anti nodes-no temp change

  Nodes-temperature changes

- **Quartz crystal method**

  One pair of opposite faces of a quartz crystal is exposed to US waves in the other pair of opposite faces charges of varying polarity developed

# Acoustic grating method

When us waves are passed through a liquid, the density of the liquid varies layer by layer due to variation in pressure and the liquid acts as a diffraction grating.

When light from a monochromatic source is passed through this liquid column, diffraction takes place. Using condition for diffraction the velocity of US waves can be determined.

$v = n\lambda$

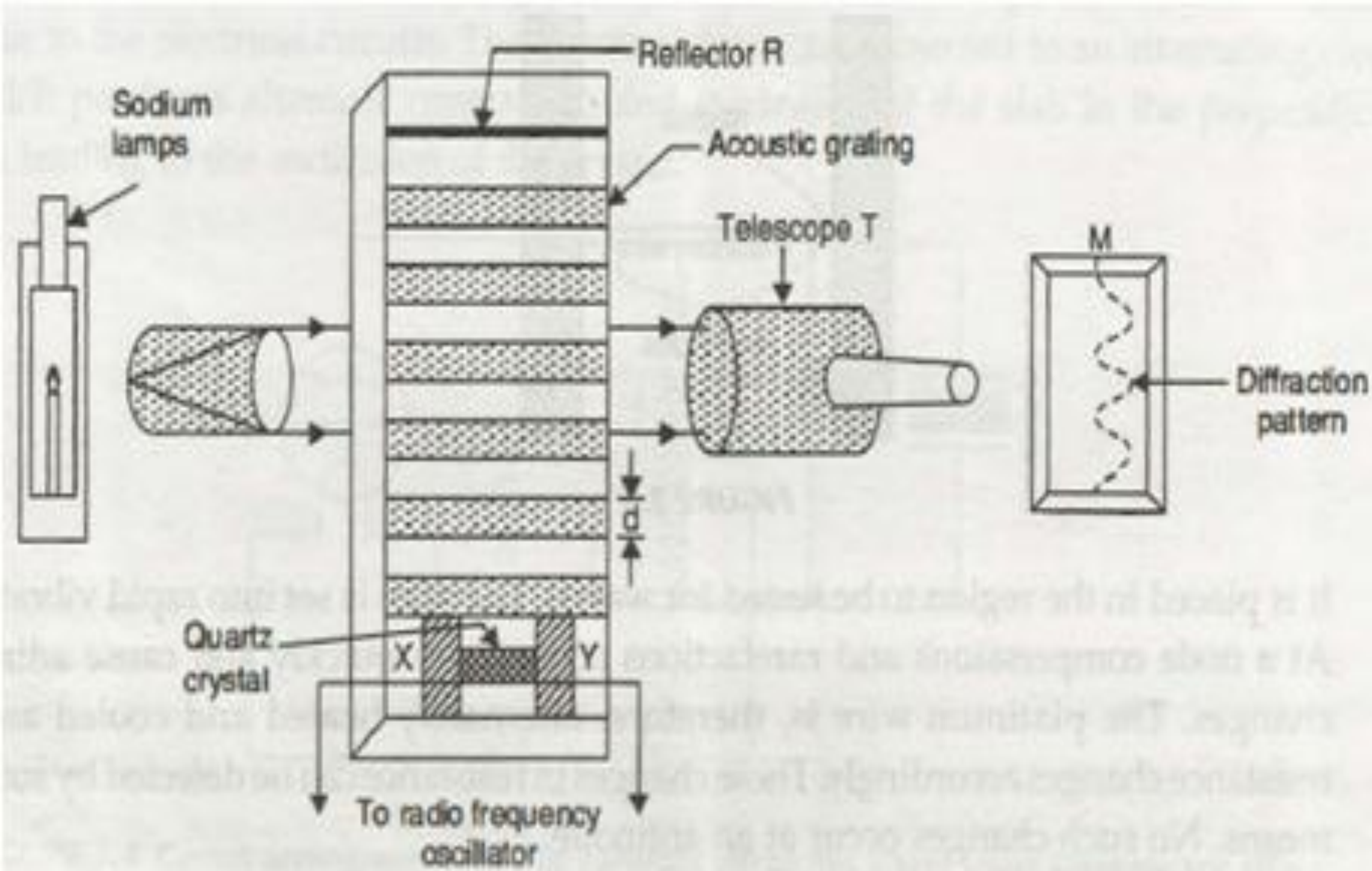
$\lambda = 2d$

$v = 2Nd$

N= resonant frequency of the piezo electric oscillator

d= distance between two adjacent nodes or anti nodes

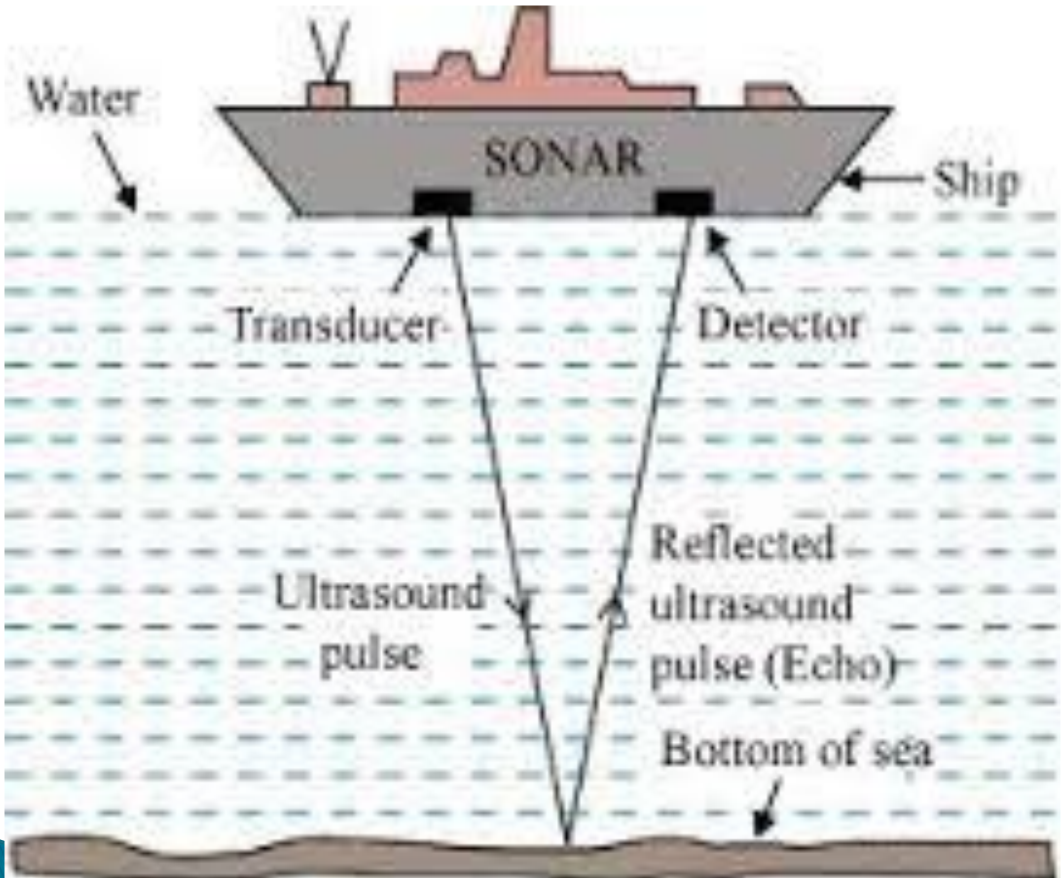
# Acoustic grating method – Detection of US waves

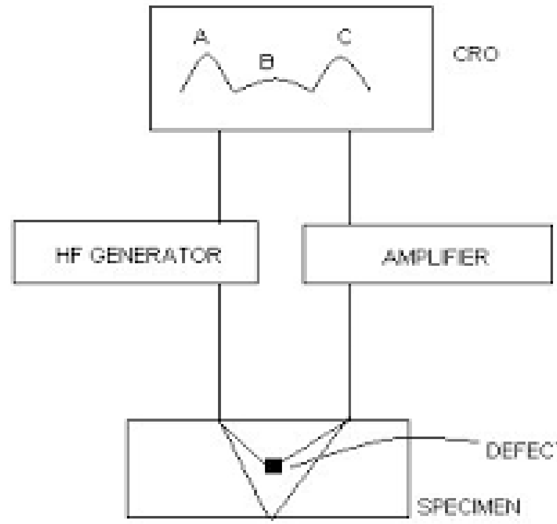


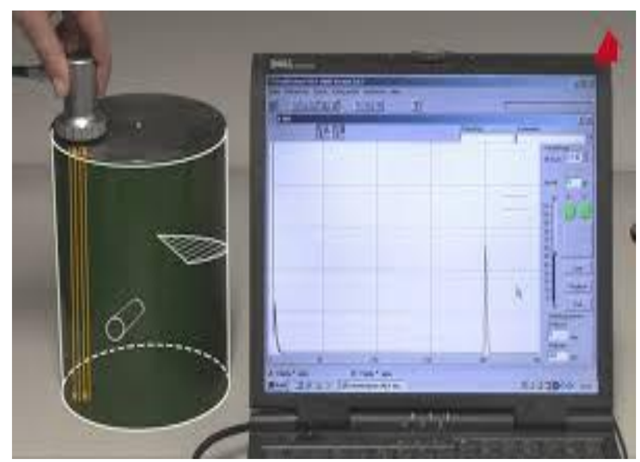
# Applications of Ultrasonic waves

- Depth of sea
- SONAR
- NDT-Non Destructive Testing
- US welding/cutting drilling
- US cleaning
- US soldering

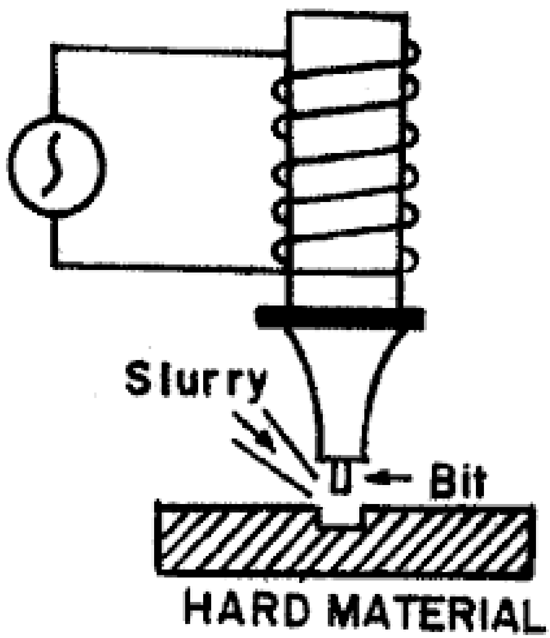
# Applications of Ultrasonic waves–
## SONAR & NDT

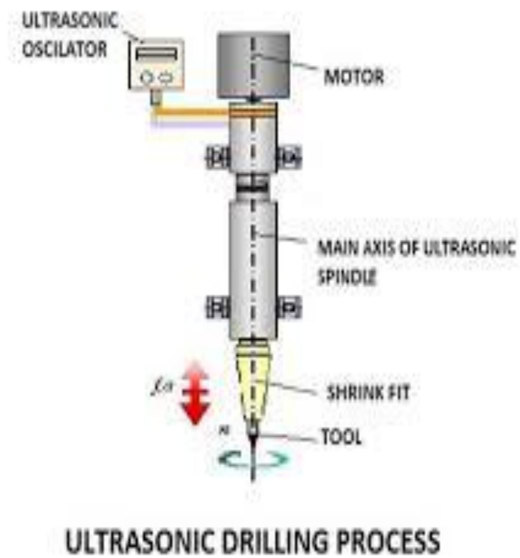


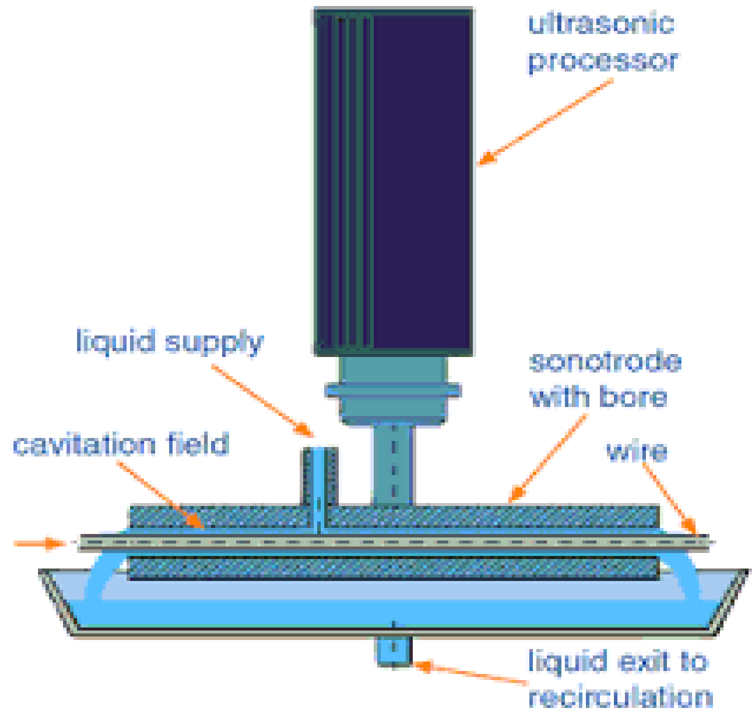
# US waves in the field of Industry:
## Cutting, drilling, welding,coining,grinding…



# Ultrasonic cavitation

Ultrasonic cleaning is an environmentally friendly alternative for the cleaning of continuous materials, such as wire and cable, tape or tubes.



US waves in the field of Medicine:

- Diagnostic sonography
- Ultrasound cardiograph
- Obstetric ultrasound
- Ultrasound therapeutic
- Ultrasonic guidance for blind

# THANK YOU